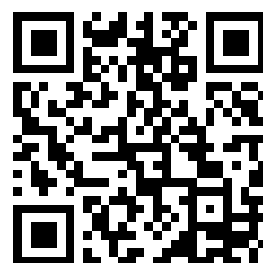

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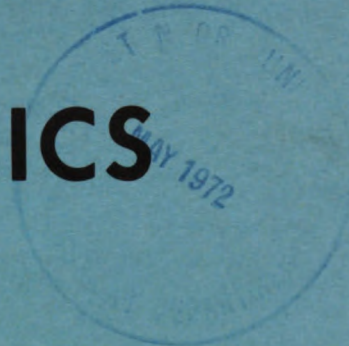
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WASHINGTON, D.C. 20360



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RECORD OF CHANGES

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FOREWORD

This handbook presents engineering data and information concerning Naval Air Station Aeronautical Facilities. Material contained in this handbook is intended to present the basis for standardization of practices and to identify a common baseline to be used as a guide during the planning of a new installation or in the addition of equipments or systems to existing facilities. To facilitate usage of this handbook, the contents are presented in two basic related categories: Functional Electronic Systems and Base Systems Engineering. In order to permit a ready cross-reference between each category, the following major topics are common to each category:

- o Air Navigational Systems
- o Radar
- o Communication
- o Meteorology
- o Air Traffic Control
- o Special Activities

The initial category, Functional Electronic Systems, presented in the first six chapters is devoted to narrative, descriptions of the various systems used on Naval Air Stations. The intent is to provide to personnel concerned with planning, design, construction, and operation an understanding of the equipment, systems, and facilities required.

The remaining eight chapters devoted to Base Systems Engineering, contain data of primary importance to the senior planners and design engineers, and provide engineering criteria required for design, installation, and operation of a compatible and integrated Naval Air Station base electronic systems.

Source data and material used in the preparation of this handbook include current Navy directives, technical manuals, field studies and observations, and reports of research and development which promote standardization and provide optimum performance of installed electronic systems.

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CHAPTER 1

FUNCTIONAL ELECTRONIC SYSTEMS

Descriptive information of functional electronic systems used on Naval Air Stations (NAS) is given in chapters 2 through 6. These systems include:

- o Air navigation systems - VHF omnidirectional range (VOR), tactical air control air navigation (TACAN), VHF omnidirectional range tactical air control (VORTAC), radio beacons, and radio direction finders (RDF).
- o Air traffic control (ATC) systems - control towers, radar, identification friend or foe (IFF), radar ancillary equipment, and communication systems.
- o Aircraft landing systems - ground control approach (GCA), instrument landing systems (ILS), and automatic landing systems (ALS).
- o Special activities - Atlantic Fleet Weapons Range (AFWR), Fleet Air Control and Surveillance Facility (FACSFAC), and Pacific Missile Range (PMR).
- o Meteorological systems and facilities - measurement systems, dissemination systems, and weather activities.

Planners, engineers, installation supervisors, and newly arrived station personnel will find chapters 2 through 6 useful for understanding the how, why, and what of each system: how the system works; why it is used; and what equipment it contains. In brief, each of the above cited systems is discussed in terms of system operational concepts, configuration, and application. Every attempt has been exercised to present useful and factual data without elaborate mathematical derivations and expressions. In order to present a generic overview of the various systems, direct description and/or reference to existing nomenclatured equipments has been avoided whenever possible. In addition, by including either established standards of current proven field practices, topics pertinent to the integration of several functional systems (base subsystems) into the larger overall base systems are treated as comprehensively as possible.

CHAPTER 2

AIR NAVIGATION SYSTEMS

2.1 GENERAL

Air Navigation is the science of determining the location of an aircraft in motion. Principal methods of air navigation are pilotage, dead reckoning, and celestial navigation. Of these methods, only pilotage systems are found installed in Naval Air Stations.

Dead reckoning is the determination of position by advancement of a previous position for the direction and distance the aircraft is believed to have moved.

Celestial navigation is the determination of position with the aid of celestial bodies, a method used principally on long overwater flights and in polar regions.

Pilotage was originally performed by visually noting various landmarks passed, and comparing them with information given on aeronautical charts. Modern pilotage, however, is performed by means of electronic aids to navigation which include VOR, TACAN, VORTAC, radio beacons, and radio direction finders. In this chapter, the theory of operation, description of components, and specific applications of these systems are presented as they pertain to the ground based equipment, and where applicable, the airborne equipments will be highlighted.

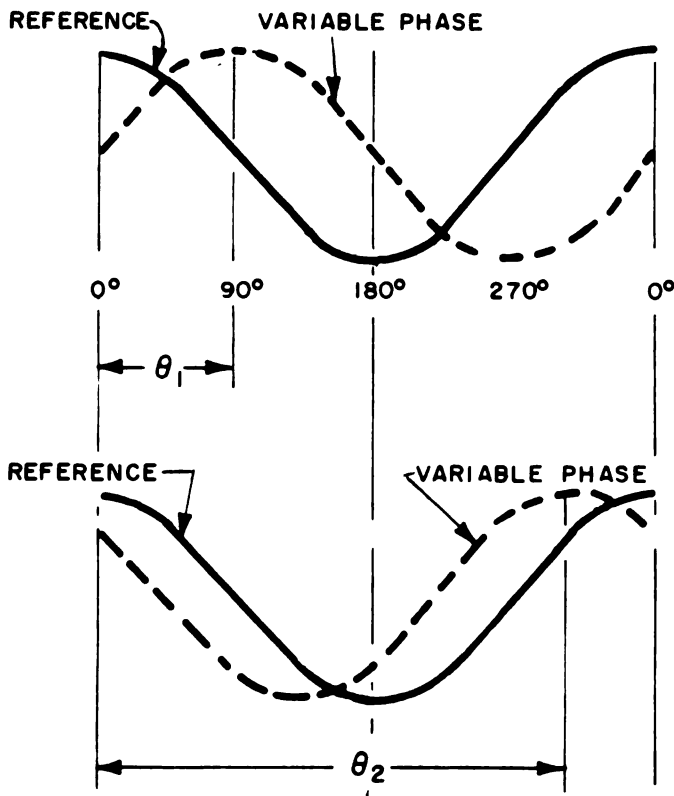
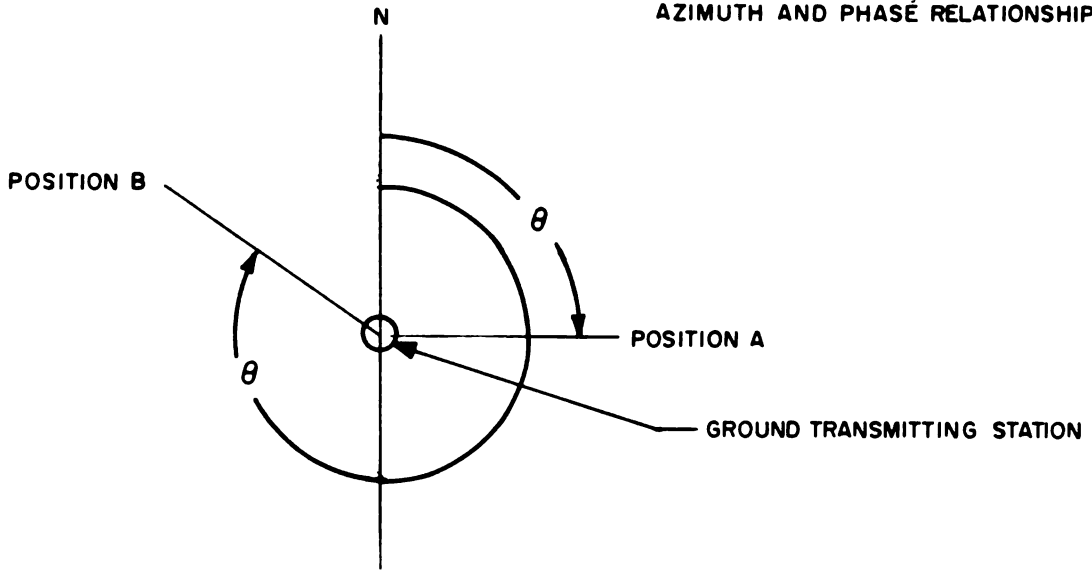
2.2 VHF OMNIDIRECTIONAL RANGE

The VOR system is a navigational aid to aircraft, providing bearing information from a fixed ground station. Although used exclusively by civilian aircraft, the Navy supports the national system by operating and maintaining VOR facilities. A basic VOR system consists of a fixed ground transmitting station and an aircraft receiver. The ground station provides directional guidance signals which can be supplemented by voice and tone signals for identification or other information. The assigned frequency band for the system is 108-118 MHz. Ground stations are assigned frequencies within this band in progressive 0.1-MHz steps. The maximum range of a VOR transmitted signal is 100 miles with a bearing accuracy of ± 2 degrees.

2.2.1 Principles of Operation

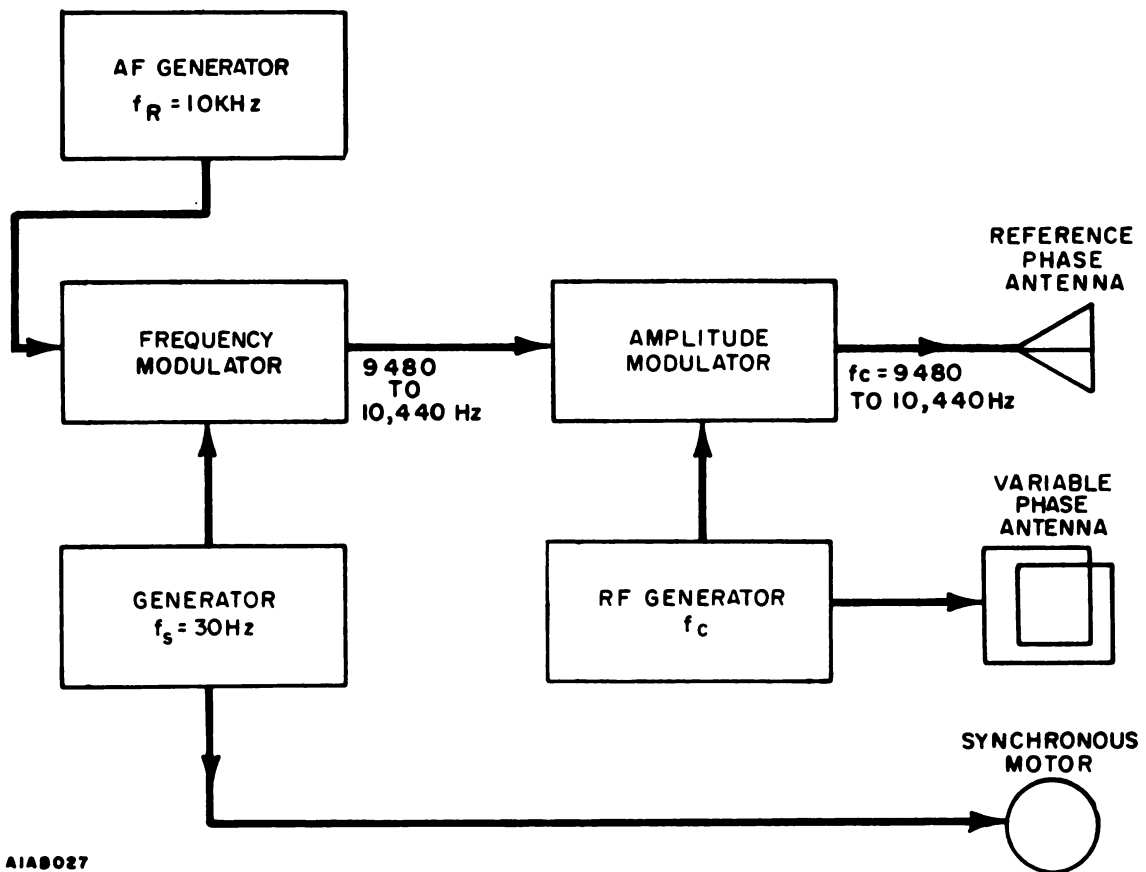
a. Ground Station System. VOR operation is based on the principle that the phase difference between two signals can be used to determine azimuth. One signal maintains a fixed-phase reference through 360 degrees of azimuth, and the phase of the other signal is made to vary as a direct function of azimuth. The phase difference between the two signals thus indicates the azimuth of the aircraft receiver with respect to the transmitting station as shown in figure 2-1. In practice, 30-Hz reference-phase and variable-phase signals are used. In the VOR system, the reference-phase signal frequency-modulates a subcarrier signal having a mean frequency of 9960 Hz. The frequency swing of the modulated subcarrier is ± 480 Hz, providing a deviation ratio of 16. The subcarrier FM signal amplitude-modulates an RF carrier which is radiated omnidirectionally. The variable-phase signal has a figure-eight propagation pattern, and consists of 30-Hz RF carrier sideband energy. The figure-eight pattern is made to rotate clockwise at 1800 r/min (equivalent to 30 Hz). Station identification codes or audio information is mixed with the FM signal enabling the pilot to determine the identity of the transmitting VOR station. The signal flow of a VOR ground station is shown in the simplified block diagram of figure 2-2. A single carrier frequency is used to produce both the variable and the reference-phase signals. The unmodulated carrier frequency is applied directly to the variable-phase antenna. It is also applied to the reference-phase antenna after it is amplitude-modulated by a 10-kHz tone that is frequency-modulated at a 30-Hz rate.

AZIMUTH AND PHASÉ RELATIONSHIP



A1AB026

Figure 2 - 1. VOR Bearing Information



AIAB027

Figure 2 - 2. VOR Ground Station, Simplified Block Diagram

(1) Ground Station Signal Flow Analysis. A detailed look into VOR signal flow (illustrated in figure 2-2) begins with an RF source connected to an antenna that radiates the variable phase. For convenience, the variable-phase antenna is depicted as a loop. For a position lying in a direction that makes an angle θ from the center of the loop with respect to a reference direction, the field strength (E_v) will be:

$$E_v = E_m \cos \theta \quad (2-1)$$

In equation 2-1, E_m is the maximum value that the field will attain at any position about the antenna. The RF voltage, E_m , is equal to:

$$E_m = ME_m \sin \omega_c t \quad (2-2)$$

In equation 2-1, $\omega_c t = 2\pi f_c t$ where f_c is the carrier frequency in hertz. E_m is the peak value of the reference-phase antenna RF field, and M is a constant representing the ratio of maximum value of E_m to the variable-phase antenna peak RF field. In the system used by the Federal Aviation Administration (FAA), the

value of M is 0.3. Figure 2-2 shows that the loop antenna may be rotated by the synchronous motor; therefore the field will vary as a function of time. If the speed is s revolutions per second, the complete equation of the loop antenna field strength at any instant will be:

$$E_v = ME_m \sin \omega_c t \cos (\theta + \omega_s t) \quad (2-3)$$

In this example, it is assumed that the loop antenna is being rotated by a synchronous motor that is driven by an audio frequency (AF) generator having an output frequency of f_s . The same audio frequency (30 Hz in this design) is used to frequency-modulate a higher frequency tone f_r (9960 Hz in this design). The frequency-modulator output will be:

$$E_r = E_a \sin (\omega_r t + (\Delta f_r / f_s) \sin \omega_s t) \quad (2-4)$$

In equation 2-4, E_a is the maximum value of voltage at any time during the cycle, $\omega_r = 2\pi f_r$, and Δf_r is the frequency deviation (480 Hz in this design). The frequency-modulator output is applied to an amplitude modulator that serves to modulate the carrier frequency.

If the frequency-modulator output is expressed as $\alpha t = \omega_r t + [(\Delta f_r / f_s) \sin \omega_s t]$ then the amplitude-modulator output which is radiated from a nondirectional antenna and received at an observation point will be:

$$E_r = E_m \sin \omega_c t (1 + k \sin \alpha t). \quad (2-5)$$

Equation 2-5 expresses the output of any amplitude-modulated transmitter; k is the modulation index (0.3 in this system).

After the signal reaches the antenna located at the observation point, the outputs of the reference-phase and variable-phase antennas combine and modulate each other. Neglecting distortion and other quantities not pertinent to this discussion, the output (E_o) of the normal receiver detector will be:

$$E_o = E_m^2 \cos (\theta + \omega_s t) + k E_m^2 \sin \alpha t. \quad (2-6)$$

The two distinct frequencies represented by the two terms of equation 2-6 are easily separated by filters, since the variable-phase frequency is 30 Hz and the frequency contained in α is between 9480 and 10,440 Hz. The frequency represented by the second term of equation 2-6 is passed through a frequency discriminator where it is differentiated with respect to time, therefore the output $d\omega_r/dt$ is:

$$d\omega_r/dt = \omega_r + \omega_s B \cos \omega_s t \quad (2-7)$$

In equation 2-7, constant B is equal to f_r/f_s . In the circuits associated with the frequency detector, the frequency f_r is suppressed and the output E_{o1} is:

$$E_{o1} = \omega_s B \cos \omega_s t. \quad (2-8)$$

The frequency expressed by equation 2-8 is applied to a phase meter for comparison with the frequency expressed by the first term of equation 2-6. Note that the frequency given by the first term of equation 2-6 is identical to that given by equation 2-8, since they both originated in the same AF generator. The phase meter therefore indicates a value proportional to θ , which is the bearing of a line of position relative to a north-south reference line passing through the center of the antenna array.

(2) Antenna Signal Transmission Analysis. The discussion thus far has been concerned with illustrating the principle of VHF phase-comparison omnidirectional range. The hypothetical antennas considered have been vertical loops and vertical nondirectional radiators because the radiation characteristics of these antennas are well known. Operational VOR utilizes horizontal polarization, and the special form of radiators required includes the Alford loop as an element. The loop is shown diagrammatically in figure 2-3. This antenna consists of four

elements arranged to form a square. The sides of the loop have lengths up to 0.2 wavelength. The elements forming the antenna have appreciable width, and at the two corners, the conductors fold toward the center to form capacitors. The value of the capacitance formed by the elements at the corners of the loop is adjusted so that the current maximum will occur at the center of each element. The current along each element, therefore, rises from a lower value at the corners to a maximum value at the center. Ideally, the current would have an unvarying value around the entire periphery of the loop. By maintaining a quasi-constant value of current, the radiated vertical field is minimized.

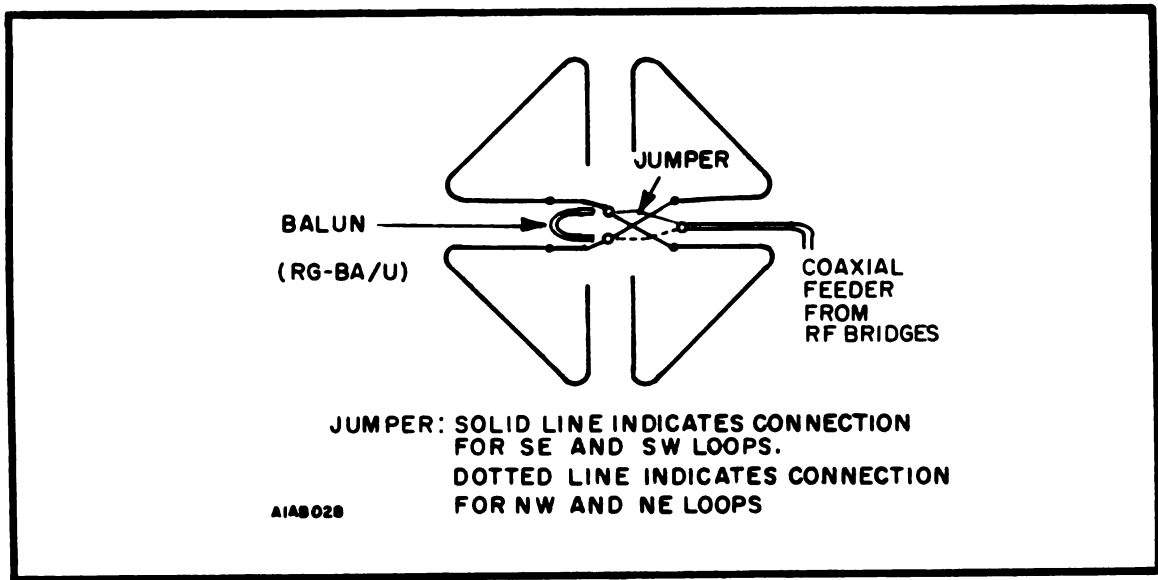


Figure 2 - 3. VOR Antenna Loop, Simplified Schematic Diagram

A four-loop antenna array is used to radiate the VOR energy. The antennas, arranged in a square on top of the VOR counterpoise are excited by two RF bridge networks as shown in figure 2-4. The bridges are such that the RF carrier, modulated by the FM signal and the identification signal, energizes the four loops in phase, producing a circular reference-phase pattern. Simultaneously, two 30-Hz sidebands from the rotating goniometer capacitor are applied through the bridges in such a manner that two figure-eight patterns are produced. Combining the rotary figure-eight patterns and the circular reference-phase pattern will result in the actual field pattern as seen by the airborne receiver. Due to the phase relationship of the patterns, obtained from the mechanical and electrical construction of the goniometer, loop antennas, RF bridges, and connection lines, a rotating cardioid pattern results.

A tone wheel and a magnetic pick up, located in the goniometer assembly, are used to produce the FM signal, which is amplified in the carrier modulator driver and used to modulate the RF power developed in the transmitter. The goniometer rotates at 1800 r/min, thus producing two 30-Hz sideband signals. The station identification pulses, consisting of keyed 1020-Hz oscillations, or a voice message, are mixed with the FM signal in the driver to produce a modulated carrier. The modulated carrier is applied to the antenna array via the antenna changeover and phasing unit, as shown in figure 2-4.

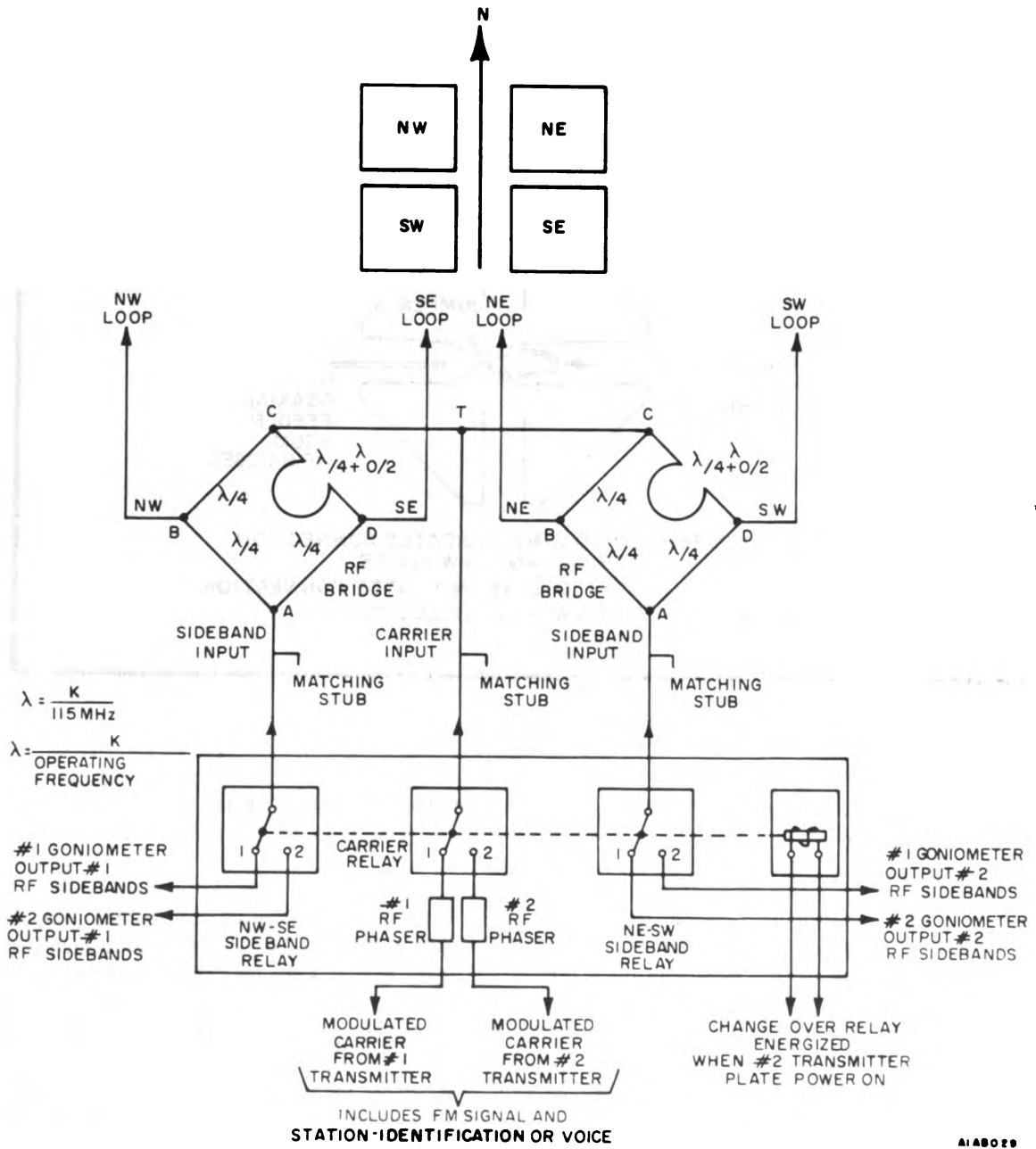


Figure 2 - 4. VOR RF Output Circuits, Schematic Diagram

b. Airborne Operation. To complete discussion of the VOR principles of operation, a simplified theory of airborne reception is presented. As the cardioid pattern passes through a single point in space, three distinct signal components may be derived from the combined waveforms modulating the RF carrier. These will enable an aircraft pilot at this point to determine his azimuth with respect to north. First, all audio information between 300 and 4000 Hz (which includes the 1020-Hz keyed identification) is detected and amplified so that the pilot will know to which VOR station his receiver is tuned.

Second, at this same point in space, the FM component is changing in frequency, at the rate of 30 Hz between 9480 (9960 - 480) and 10,440 (9960 + 480) Hz. In the aircraft receiver reference-phase channel, all frequencies except those between 9480 and 10,440 Hz are filtered out, providing only the FM subcarrier from which the 30-Hz modulating signal component is derived. This 30-Hz signal is applied to the phase comparison circuits as the reference-phase signal. It must be remembered that VOR equipment at any point in space will receive the FM component in the same phase as that received at any other point in space, since this signal is radiated omnidirectionally. For example, an aircraft at due north would receive a subcarrier (FM signal) frequency of 10,440 Hz at exactly the same time (for all practical purposes) as would an aircraft at due south (or any other azimuth).

Thus, the aircraft's azimuth is determined by comparing the phase of the variable-phase signal at any one point with the constant phase of the reference signal. The phase-comparison circuits in the airborne receiver perform this operation instantaneously and continuously to provide bearing information to the pilot.

Therefore, a pilot flying an airplane equipped with a VOR receiver can navigate to or from a VOR ground station by flying the indicated azimuth reading. Aircraft location in space (obtaining a fix) can be determined by taking two independent readings (from two VOR stations) and finding the point where the two azimuth lines cross.

2.2.2 Ground Station System Configuration

a. Basic Equipment Groups. A VOR system has four basic groups of equipment: transmitter group, antenna group, voice and control circuits, and the power supplies. In order to provide reliable information, VOR transmission must be uninterrupted. Therefore, the system is built with a certain amount of redundant equipment. One half of the duplicate equipment operates, while the other half is on hot-standby ready for cutover, should the first half fail. A block diagram of a typical VOR ground station is shown in foldout 2-1. A list of components comprising a typical VOR ground station is presented in table 2-1.

b. Subsystem Descriptions. The VHF radio transmitter is crystal controlled, operating in the frequency range of 108-118 MHz with an output of 200 watts. The RF carrier output is normally modulated 30 percent by the 10-kHz subcarrier and 10 percent by the 1020-Hz identification signal. Voice modulation of about 30 percent may be used simultaneously with the 10-kHz modulation. The 1020-Hz identification signal is automatically interrupted when the voice-broadcast feature is in use. The total audio distortion in the modulation output envelope is less than 5 percent.

Each omnirange VHF goniometer consists of a synchronous motor, a reference-phase signal generator, a capacitive goniometer, and an RF transformer. The generator consists of a pickup coil wound over a permanent magnet whose lines of flux pass through a toothed disc called a tone wheel. The capacitive goniometer receives the unmodulated RF power from the transmitter via the modulation eliminator and delivers two RF outputs; the amplitude of one output being proportional to the sine, and the amplitude of the other output being proportional to the cosine of the rotational angle of the goniometer rotor. These outputs contain only 30-Hz sideband energy caused by rotation of the goniometer at 1800 r/min. The synchronous motor is used to rotate the tone wheel and the capacitive goniometer rotor; therefore, the rotational speed of these components is directly dependent upon the speed of the motor, which in turn is dependent upon the frequency of the voltage applied to the motor. The motor rotor will rotate at 1800 r/min when the commercial line-frequency is 60 Hz. The RF transformer is used to convert from unbalanced RF coaxial cable to balanced RF cable used in the goniometer circuits.

Table 2-1. Typical VOR Ground Station Components

EQUIPMENT GROUP	ITEM	QUANTITY
Transmitter	VHF radio transmitter	2
	VHF goniometer	2
	Carrier modulator	2
	Carrier modulator driver	2
	Oscillator keyer	2
	Modulation eliminator	2
	Oscillator, 1020 hertz	2
Voice and control	Voice operated relay	1
	Audio amplifier, regulated output	1
	Line equalizer	1
	Control unit	1
	Automatic transfer unit	1
	Monitor amplifier	1
	Monitor equipment	
	VOR monitor	1
	Monitor power supply	1
VOR field detector	1	
Antenna	Antenna changeover and phasing unit	1
	VOR antenna loops and pedestals	4
	Antenna polarizer and pedestal	1
	RF bridge (cut to frequency)	2
Power supplies	Rectifier power supply	1
	Voltage regulator, 7500 VA	1
	Frequency stabilizer power supply	2

The carrier modulator driver provides facilities for combining three low-level audio-frequency input signals and amplifying the resultant composite signal to a power level sufficient to drive the modulator. Three 600-ohm balanced input circuits with separate level controls are provided for voice, 10-kHz subcarrier, and 1020-Hz identification. Input levels to any channel of -2 dBm or greater can be amplified to drive the carrier modulator to full output.

The carrier modulator when used in conjunction with the carrier modulator driver, comprises a complete audio channel. This combination of equipment is capable of amplifying low level inputs and developing sufficient audio power to produce the modulation necessary for the 200-watt VHF transmitter.

The oscillator keyer is a plug-in assembly consisting of a motor-driven cam wheel containing adjustable cam segments which actuate a cam follower and contact assembly, and a TACAN follower and contact assembly. The keyer, preset with adjustable cams, interrupts the output of the 1020-Hz oscillator tone in a repetitious sequence of dots and dashes for station identification. The TACAN follower provides identity-keying of any TACAN ground station that may be associated with the VOR.

The voice operated relay unit provides voice modulation. Amplified voice frequencies actuate the relay and are then applied to the modulation circuits. When the voice signal ends, the relay will open in about 0.4 seconds.

Omnirange modulation eliminators remove the amplitude modulation from that portion of the carrier RF energy delivered to the VHF goniometer. Power-divider circuits within these units proportion the power delivered to the sideband antennas and the carrier antenna for proper space modulation.

Antenna changeover and phasing unit provides a means of transferring the antenna array to either of the two transmitter-goniometer combinations, and permits rapid equipment changeover. Through the use of three coaxial relays, the antenna array is automatically connected to the equipment being used. System phasing is also accomplished by means of this unit. Phasing is initially obtained by cutting the RF transmission lines to the correct lengths and by properly adjusting the RF phasers.

A four-loop antenna array, providing a very narrow cone of silence above, and negligible vertical-polarization errors, is used to radiate the VOR RF energy. The array is placed within a plastic dome which protects the antennas from the elements. The four radiators are horizontal plane. Each loop is placed at the corner of a square, 56.1 electrical degrees (at 115 MHz) from the center of the array and 48 inches above the counterpoise which forms the 35-foot diameter roof of the VOR station. The counterpoise surface is terneplate, a lead-clad material having good conductivity. The counterpoise is an antenna element which aids in the formation of desired cone characteristics. Each diagonal pair of antenna loops, driven by goniometer output, propagates a figure-eight pattern. All four loops are simultaneously driven with modulated carrier-frequency energy of the same phase, resulting in a quasi-circular radiation pattern. Vertically polarized radiation is reduced by means of a vertical antenna array (polarizer) consisting of four vertical radiating elements equally spaced around a center pedestal, and parasitically excited by the loops. The length of these elements, as well as their height above the loops, is adjustable to facilitate minimizing the vertically polarized energy from the four-loop pedestals.

The control unit provides VOR control from either a remote point or from the transmitter location.

The monitor equipment is used to check course alignment, and radiated reference-phase and variable-phase signal levels. Associated with the monitor are its power supply and the counterpoise-mounted field-detector which samples the radiated RF field and provides the monitor unit with the information necessary to accomplish its functions. Monitoring alarm levels are set to prescribed values by means of front panel controls. The reference and variable amplitude alarms are adjusted to detect decreases in signal level in the range of 5 to 30 percent. The phase alarm circuit may be set to detect course shifts in the range of 0.3 to 3.0 degrees. The field detector output, which passes through the alarm detection channels in the monitor, contains the 30-Hz variable-phase signal, the keyed 1020-Hz identification tone or aural information, and the 10-kHz subcarrier which is frequency-modulated at 30 Hz.

The automatic transfer unit automatically transfers standby equipment to the operational status in the event of an equipment malfunction.

2.2.3 System Application

a. Basic System Application. The basic function of a VOR facility is to provide bearing information to aircraft. Output power of VOR stations range from 50 to 200 watts. The normal operating field starts at the radio horizon and encompasses an elevation angle of not less than 60 degrees. The FAA specifies the maximum VOR operating range to be 130 nautical miles (NMI) and a height of 45,000 feet mean sea level (MSL); some VOR equipments operate only up to 12,000 feet MSL within a 25-NMI range.

The radial-signal error, associated with the ground components only, excluding all other error factors, has been found to be ± 1.9 degrees. The aggregate system error, including the airborne component error (± 3.0 degrees) is equal to ± 3.5 degrees. But airway routes and terminal area procedures in the United States are designed on the

basis of a system use accuracy of ± 4.5 degrees. The tolerance difference allows a factor for pilot-error in utilization of the information. This utilization error (an independent variable), is attributable to the fact that a pilot cannot keep the aircraft precisely centered on the bearing presented.

Both the Navy and the FAA have added ground-to-air communication to the VOR system. Station identification signals may be transmitted by International Morse Code and/or voice. Voice broadcasts are generally limited to providing local weather conditions, but airfield VOR stations may add local landing and takeoff information.

b. Types of VOR. There are three basic types of VOR facilities: en route, terminal, and test. The latter two are low-power facilities usually located on or near the airfield. A test facility VOR is used by a pilot to check the operation of his equipment prior to departure. Terminal VOR, with a range of 15 to 25 NMI, is used by the pilot to line up his aircraft with the active runway during final approach. A second application for a terminal VOR is as a navigational guide around the airspace above an airport during aircraft stacking. A VOR may be located near an airfield for use by a pilot primarily as a navigational aid over congested or restricted areas during an airfield approach; for final approach, the pilot would switch to the terminal VOR, visual approach slope indicator (VASI), or other terminal systems as directed by the local controller.

There are over 400 en-route VOR facilities in the United States, distributed in an overlapping pattern along the many air routes. These stations, transmitting at high output power, provide ground-to-air communications and bearing information to civil aircraft flying above 5000 feet MSL within a range of 40 to 100 NMI. A single VOR facility provides bearing information relative to one fixed point. Using transmitted signals from two adjacent VOR facilities, a pilot can determine his position and by continuing this procedure, his geographic location can be determined anywhere as he traverses the United States.

c. Doppler VOR. Terminal VOR facilities near large cities have bearing information errors induced by signal-reflections from large structures. To overcome this problem, doppler VOR was developed. Doppler VOR is highly accurate and relatively free of the errors that result from unfavorable sitings. The doppler mode of operation is considerably changed from that of the regular FAA-VOR, but it provides the same information to conventional VOR aircraft receivers. The ground-installation for the doppler system includes the addition of a second transmitter and of 50 antennas mounted 7.2 degrees apart on the counterpoise at a 22-foot radius. The original transmitter and antenna provides the reference signal, and the second transmitter provides the variable-phase signal by sequentially switching its output from one to another of the 50 antennas, at a switching rate of 1500 times per second; thus simulating an antenna rotation of 30 revolutions per second to produce the 30-Hz variable-phase signal.

2.3 TACTICAL AIR CONTROL AIR NAVIGATION

Tactical Air Control Air Navigation (TACAN) is an air navigational aid which provides aircraft with azimuth and distance information with respect to a ground reference point. TACAN is a polar-coordinate system similar to that provided by VOR when combined with distance-measuring equipment (DME). TACAN utilizes the coordinated-system principle that a single emission may provide both bearing and distance information. The airborne equipment consists of a transmitter-receiver (interrogator); the ground station consists of a ground beacon (transmitter-receiver-antenna) and control equipment. The range of TACAN is 200 NMI, while its accuracy is ± 0.2 mile in distance and one degree in bearing.

2.3.1 System Principles

a. Objectives. The objective of a TACAN facility is to provide safe navigation for user aircraft. Whether a facility is categorized either as "special," for military temporary tactical purposes or "published," for routine operations, safety of flight and effective navigation must be preserved at all times. Both situations necessitate that the facility be reliable, and that it perform within the tolerances specified in the United States Interagency Ground Inspection Manual, OPNAVINST 3721.18.

The TACAN system provides polar-coordinate bearing and distance information from a known reference point which enables a pilot to fix his position as illustrated in figure 2-5. The system does not, however, measure or provide aircraft heading. As shown in figure 2-5, the TACAN ground beacon antenna must be accurately aligned with magnetic north since bearing information is derived from magnetic north and is displayed on an indicator which is calibrated in degrees. On a typical azimuth indicator, the dial is fixed and the pointer arrowhead indicates bearing to the beacon.

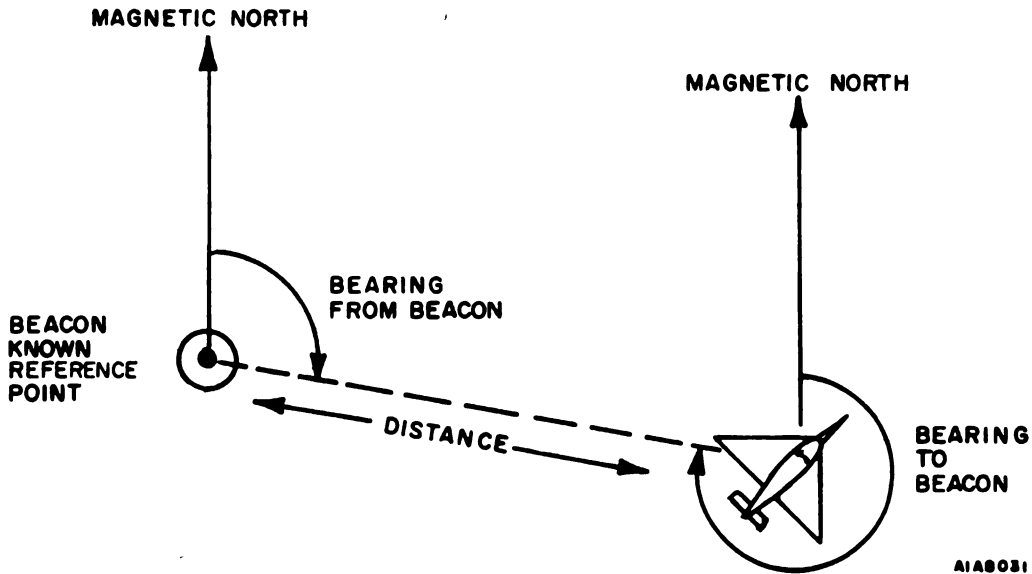
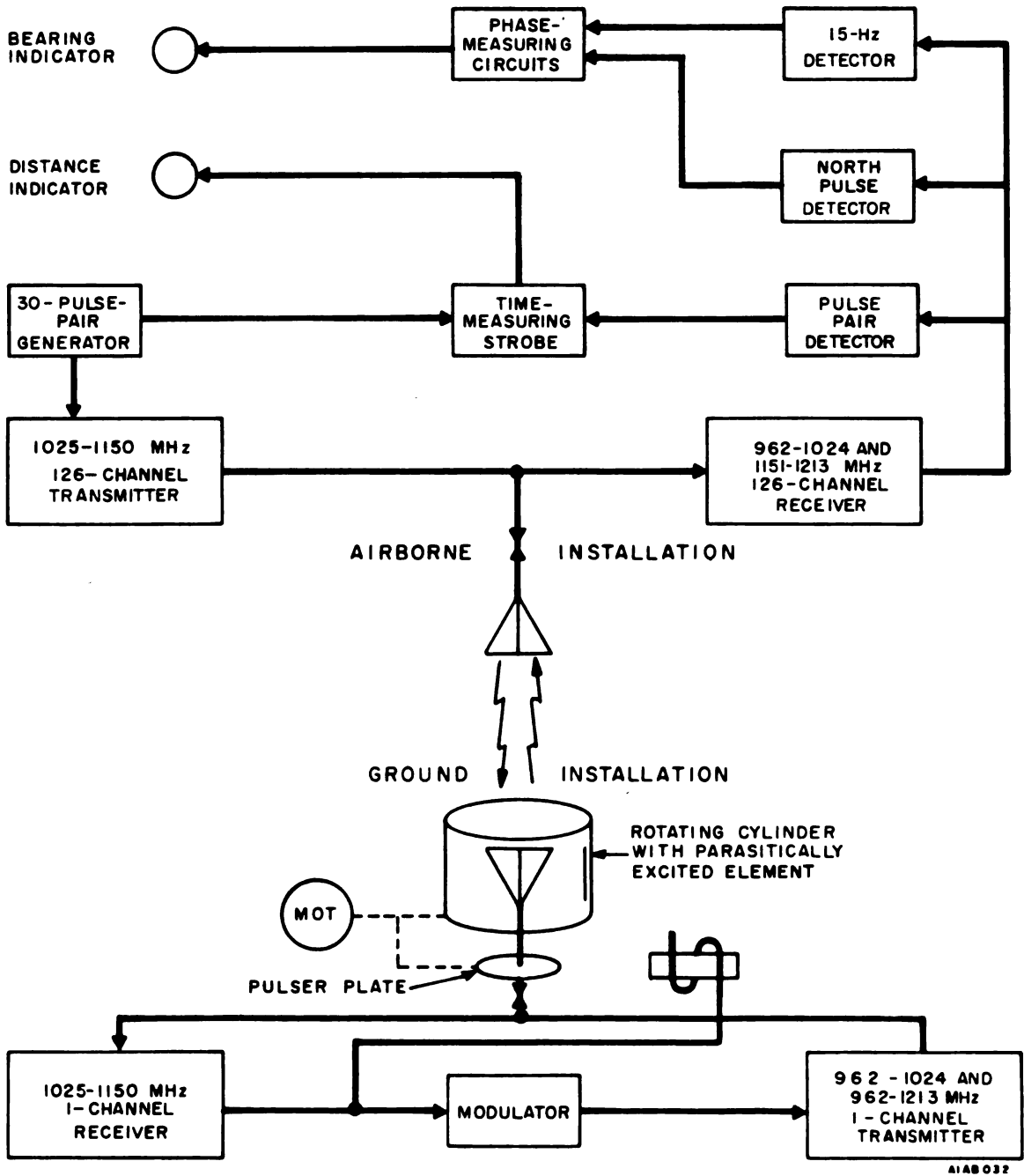


Figure 2 - 5. Principles of TACAN

The distance measured to the beacon source is presented in nautical miles. It should be noted, that distance as measured by TACAN is slant distance or line-of-sight distance from the beacon antenna to the airplane (not geographical distance on the earth's surfaces) and will be designated as beacon distance. The typical beacon-distance-indicator is a drum-type meter with a three-digit display.

The third important TACAN beacon output is the identification call which is transmitted periodically in International Morse Code, thus enabling the aircraft to determine which facility it is contacting.

b. Distance Measurement. Operation of a TACAN system starts with the airborne transmitter or interrogator sending out a continuous train of pulse-pairs at a rate of 30 pair per second at a frequency in the 1025 to 1150 MHz band (figure 2-6). Transmission may be on any one of 126 channels spaced 1 MHz apart. The pulses have a duration of 3.5 microseconds with a spacing of 12 microseconds. Airborne transmissions (interrogations) are received in the ground equipment (transponder) and are retransmitted on a channel in either the 962 to 1024 or 1151 to 1213-MHz band. Transmission is on one of 126 channels in these bands, with the receiver and transmitter frequencies 63 MHz apart. The transmission from the ground transponder goes to the airborne receiver and the difference in time between the original airborne and ground equipments display on the azimuth indicator. Except for the frequencies and pulse characteristics specified, the foregoing description illustrates any pulse distance-measuring system. Beginning from this fundamental basis, TACAN employs special equipment so that bearing, as well as distance, is furnished.



AIAB032

Figure 2 - 6. TACAN System, Simplified Block Diagram

In the foregoing description, the transmitter of the distance-measuring ground beacon is required to send out pulses only in reply to interrogations. In such a system, the number of transmitted pulse pairs would be 30 per second per airborne equipment. Thus, none would be sent out if there were no aircraft interrogations and 3000 if there were 100 aircraft interrogating the beacon. There is a serious problem in maintaining the receiver sensitivity of the ground beacon at maximum level throughout the range of the interrogations. At low interrogation rates, random noise may trigger the transmitter. Therefore, TACAN ground beacons are operated with a constant-duty cycle. In this method of operation, the beacon receiver is provided with an automatic gain-control system that maintains the number of pulses out of the receiver at an almost constant 2700 pulse-pairs per second. When only a few interrogations are being received, receiver gain is very high and the noise generates filler pulses. These pulses are counted, and receiver gain adjusted for the 2700 pulse-pairs. When additional interrogations are received, the gain is reduced proportionally and the noise-generated pulses are replaced by replies to the interrogations. If more than 100 aircraft interrogate the beacon, replies are made to the 100 strongest interrogations.

The relation between the gain and the number of pulses is such that only a 3-dB change in sensitivity occurs between reception from 1 aircraft and from 100 aircraft. An added advantage of the constant-duty-cycle beacon is that overall transmitter-circuit drain remains constant. Such operation permits use of simple power supplies, minimizes tuned-circuit drift, and makes for more predictable component life and maintenance-cycle requirements.

c. **Bearing Information.** The TACAN emission is used to generate a cardioid pattern very similar to that of the VOR. This pattern is generated by rotating about the normally nondirectional ground-beacon antenna a parasitic element that serves either to absorb or to reflect the energy along a line containing the element and the antenna. The pattern may be rotated in azimuth by mechanically rotating the parasitic element about the vertical antenna. To signify when some characteristic of the cardioid is passing through north, it would be possible to attach a contact to the rotating mechanism so that a special series of pulses would be sent out at the appropriate time. Bearing would then be determined by measuring the phase between the special pulse burst and the signal generated by the modulated pattern. TACAN employs two sets of rotating elements: one element produces a cardioid that resolves the direction ambiguity produced by the pattern generated by a second set of elements; the second set of elements generates a nine-lobed pattern that produces finer bearing information. The single element of the TACAN beacon is rotated about the antenna at 900 r/min; thereby producing a 15-Hz signal in the receiver output. The nine elements also rotate at the same speed, thereby producing a 135-Hz output signal.

The TACAN ground beacon supplies to its antenna 2700 pairs of pulses per second at all times. All pulses are of equal amplitude, but the energy radiated from the antenna has a definite directional pattern.

In the directional antenna shown in figure 2-7 only the central fixed element is energized by the transmitter. Outside of the central element there are two cylinders made of nonconductive materials and tied together by disks at top and bottom. These cylinders rotate together at 900 r/min. Imbedded in the outer cylinder are nine similarly excited elements. Assume that the outer cylinder is removed; the remaining parasitic element reflects energy in one direction and attenuates the energy in the exactly opposite direction. If the rotation of the cylinder were stopped and the amplitude of the signal were measured around the antenna and plotted in polar coordinates, the result would be a cardioid pattern as shown in figure 2-8A. With this antenna the airborne equipment would receive a series of amplitude-modulated-pulse-pairs represented by the vertical lines in figure 2-8B. The envelope of these pulses, indicated by the dashed line, is a 15-Hz sine wave. Modulation is maintained below 100 percent to ensure that the pulses will always have sufficient strength to supply distance-measurement service.

Before considering the effect of the outer cylinder, note should be taken of the closely spaced reference pulses shown in figure 2-8B. These pulses, which furnish a reference for the measurement of phase (bearing), are sent out at each instant that the cardioid-pattern maximum is pointing due east. They are distinguished from the distance-measuring signals by their coding. The distance replies (filler pulses) occur in pairs with 12-microsecond spacing. The 15-Hz reference signal, on the other hand, is a precisely arranged regular group consisting of 12 pulse pairs with exactly 30 microseconds between pairs, as shown in figure 2-9.

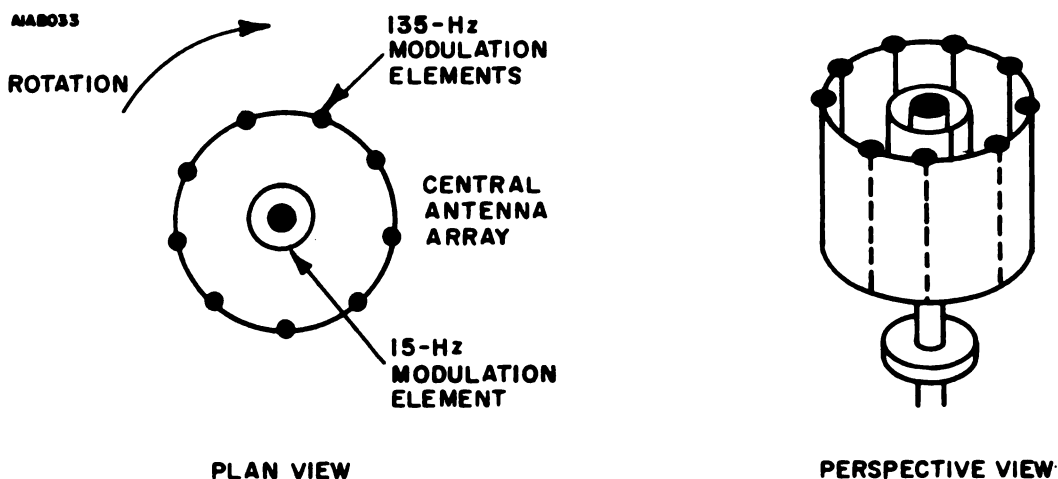


Figure 2 - 7. TACAN Antenna, Pictorial Diagram

Consider the effect of the outer cylinder, which has nine parasitically excited elements uniformly spaced at 40-degree intervals; these elements cause an increase in the radiated field in one direction and a corresponding decrease in the exactly opposite direction. If the outer cylinder existed alone, the resulting field pattern would take the shape of a gear with nine teeth. Since there is an inner cylinder, which already has produced a distorted pattern, the result is a cardioid with nine perturbations as shown in figure 2-10. The resulting sinusoid has a frequency of 15 Hz with a pronounced ninth harmonic, i.e., a frequency of 135 Hz. Reference pulses are also sent out for the ninth harmonic. These reference pulses, transmitted every 40 degrees, consist of 6 pulse-pairs spaced 24 microseconds apart. Eight of these reference groups are transmitted for every antenna rotation. The ninth position in the transmission cycle is occupied by the 15-Hz reference signal as shown in figure 2-10.

A solid-surface representation of the antenna radiation pattern is illustrated in figure 2-11. The field pattern E_ϕ of the TACAN ground beacon, expressed as a continuous wave, is given by:

$$E_\phi = E_{\max} [1 + k_1 \cos (\omega_m t - \phi) + k_2 \cos (9 \omega_m t - 9 \phi)] \tag{2-9}$$

where:

ω_m = angular rate of rotation of the space pattern

ϕ = bearing of the beacon from the receiver

k_1 and k_2 = constants determining percentages of modulation

Following the detector, the 15- and 135-Hz components of the wave given by equation 2-9 are separated and become, respectively:

$$E_{\phi_1} = E_{\max} [1 + k_1 \cos (\omega_m t - \phi)] \tag{2-10}$$

$$E_{\phi_2} = E_{\max} [1 + k_2 \cos (9\omega_m t - 9\phi)] \tag{2-11}$$

The 15-Hz reference signals could control the phase of a local oscillator so that its output, E_{r_1} , would be given by:

$$E_{r_1} = E_{\max} \cos \omega_m t \tag{2-12}$$

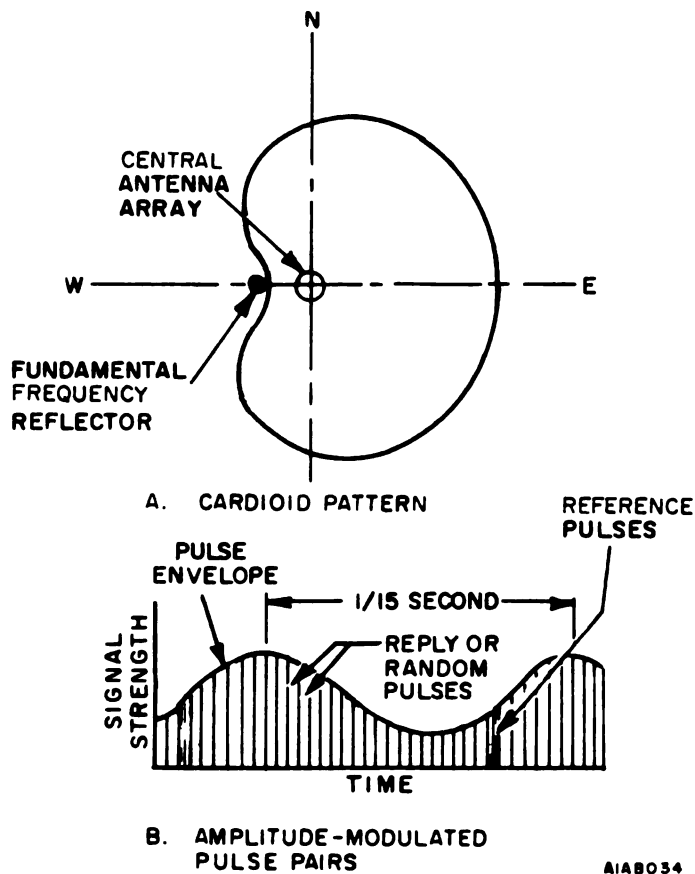


Figure 2 - 8. TACAN Radiation Pattern

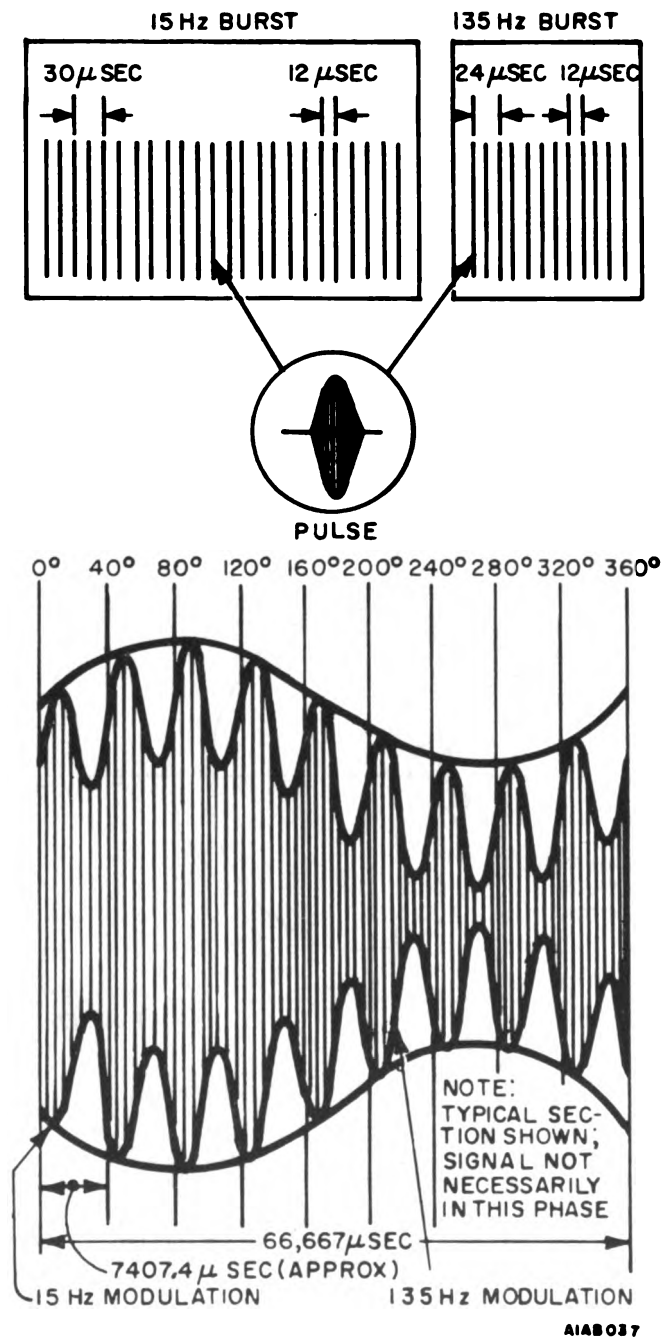


Figure 2 - 9. Radio-Beacon Signals, Synthesis of

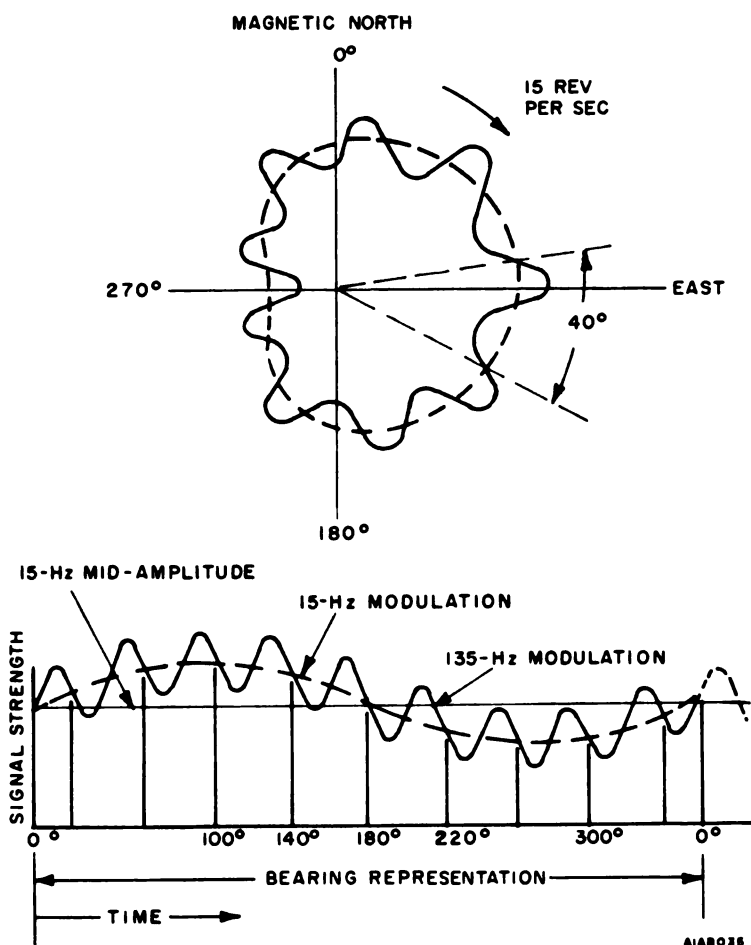


Figure 2 - 10. TACAN Modulation Envelope

A phase-measuring circuit is used to compare the local oscillator output with the 15-Hz signal from the detector by subtracting the voltage given by equation 2-12 from that given by equation 2-10 to yield ϕ , the bearing of the aircraft from the beacon. This process is identical with that employed in the VOR and would produce bearings with no greater accuracy.

The 135-Hz reference signals could control the phase of a local oscillator so that its output E_{r_2} is given by:

$$E_{r_2} = E_{\max} \cos 9\omega_m t \tag{2-13}$$

A phase comparison of the waves given by equations 2-13 and 2-10 yields the measurement of an angle θ , which is:

$$\theta = 9\phi \tag{2-14}$$

An error in the measurement of angle ϕ through comparison of equations 2-12 and 2-10 should be of the same order of magnitude as a similar measurement of angle θ obtained by comparing the voltages given by equations

2-13 and 2-12. In the latter measurement, however, ϕ equals only 1/9th of θ ; therefore it should yield a result 9 times more accurate than the former. Consequently, the 15-Hz phase measurement is employed initially to move the bearing-indicator pointer to within the correct 40-degree bearing sector. The exact positioning of the pointer within the sector is under control of the 135-Hz phase measurement, which is geared down by a 9-to-1 ratio.

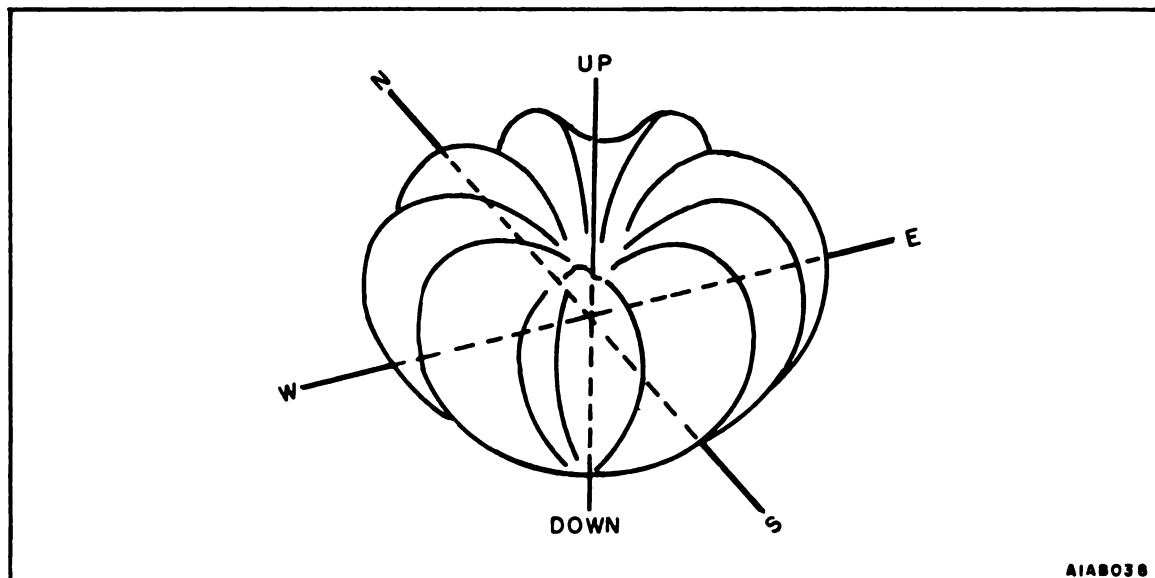


Figure 2 - 11. TACAN Solid Surface Radiation Pattern

An observer within the aircraft receiving the radiated signals cannot determine his bearing from the modulated signals alone. A reference system must be superimposed on the modulated signals to enable determination of bearing with respect to transmitter location. In order to establish this reference, the TACAN beacon is made to transmit reference signals, spaced at specific intervals. These reference signals are initiated by a reference pulse generator (pulse plate). This plate is mechanically linked to the rotating reflectors and mounted horizontally below the central array. Machined on the lower edge are eight slots, and machined on the upper edge is one slot. Fitted in the slots are soft iron slugs. As the antenna reflectors rotate, the pulser plate also rotates. The upper and lower slugs on the edge of the pulser plate each pass through the air gaps of magnetic circuits which are separately excited. As each of the slugs passes through the air gap the net reluctances of the magnetic circuits are changed and pulses are induced in the coil windings. These trigger pulses are sent into the video circuits of the coder-indicator where they initiate the pulse patterns peculiar to the 15- and 135-Hz reference bursts.

Generation of a 15-Hz reference trigger pulse occurs each time the 15-Hz component is at zero phase, going positive. The coder-indicator uses this 15-Hz reference trigger pulse to generate the 15-Hz reference burst, which are video, not RF pulses. The video pulse becomes the envelope of the waves shown in figure 2-11 which are transmitted by the TACAN beacon antenna as north (15 Hz) bearing marker signals. Thus, for a coarse bearing reading, an aircraft receiver measures the phase shift between the 15-Hz modulator bearing signal and the 15-Hz north marker signal. This reference signal establishes the time reference for all directions from the beacon and is independent of the location of the interrogating aircraft.

Similarly, 135-Hz reference trigger pulses are generated by the slugs on the lower edge of the pulser plate. Thus, every 40 degrees of rotation from north, a 135-Hz trigger pulse is sent to the coder-indicator for generation of 135-Hz reference bursts. These bursts are used by the aircraft receiver as 40-degree reference markers. Transmission of a 135-Hz reference burst occurs at phase-coincidence of the 135-Hz component of the beacon output; the 0-degree (north) reference occurs when the mid-amplitude point on the positive slope of the 135-Hz sinusoid crosses the mid-amplitude line of the 15-Hz sinusoid positive slope. Thus, the 135-Hz reference bursts (also called auxiliary reference pulses) are associated with the 135-Hz modulation and the phase difference between the two signals, as measured by an aircraft receiver, is the fine azimuth reading.

d. Airborne Operation. The airborne TACAN receiver (figure 2-12) develops bearing information by comparing the amplitude modulation and the reference pulse burst components of the received signal. The 15- and 135-Hz modulations are isolated by filters and fed to individual phase shifters where the phase of each signal is automatically adjusted to its respective reference pulses by a servo motor. The mechanical linkage of the "coarse" and "fine" systems are common to the servo motor; because of this common link, any discrepancy in the "coarse" system will affect the performance of the "fine" system or vice versa. Also, when the azimuth control circuit is in the search position, the servo motor slews counterclockwise until the north reference burst coincides with the "coarse" crossover point. With this coincidence, the relay is energized and the contact switch to the track position. The servo motor is then controlled by the "fine" system and seeks to maintain the auxiliary reference pulses in alignment with the crossover points of the 135-Hz modulation.

The "coarse" system selects and maintains the sector within ± 20 degrees of correct azimuth; it does not track small bearing angles. The "fine" system performs the incremental tracking and if azimuth error exceeds 20 degrees, the search-track relay opens and the coarse system slews the motor counterclockwise to again seek a new correct coarse sector.

Figure 2-13 illustrates how the aircraft receiver interprets the bearing reference signals. While the 135-Hz modulator pattern and the 135-Hz reference bursts are employed as verniers to obtain greater accuracy, they have been omitted for the sake of simplicity. Actually they are interpreted automatically by the aircraft receiver to provide a continuous, accurate meter reading.

2.3.2 System Configuration

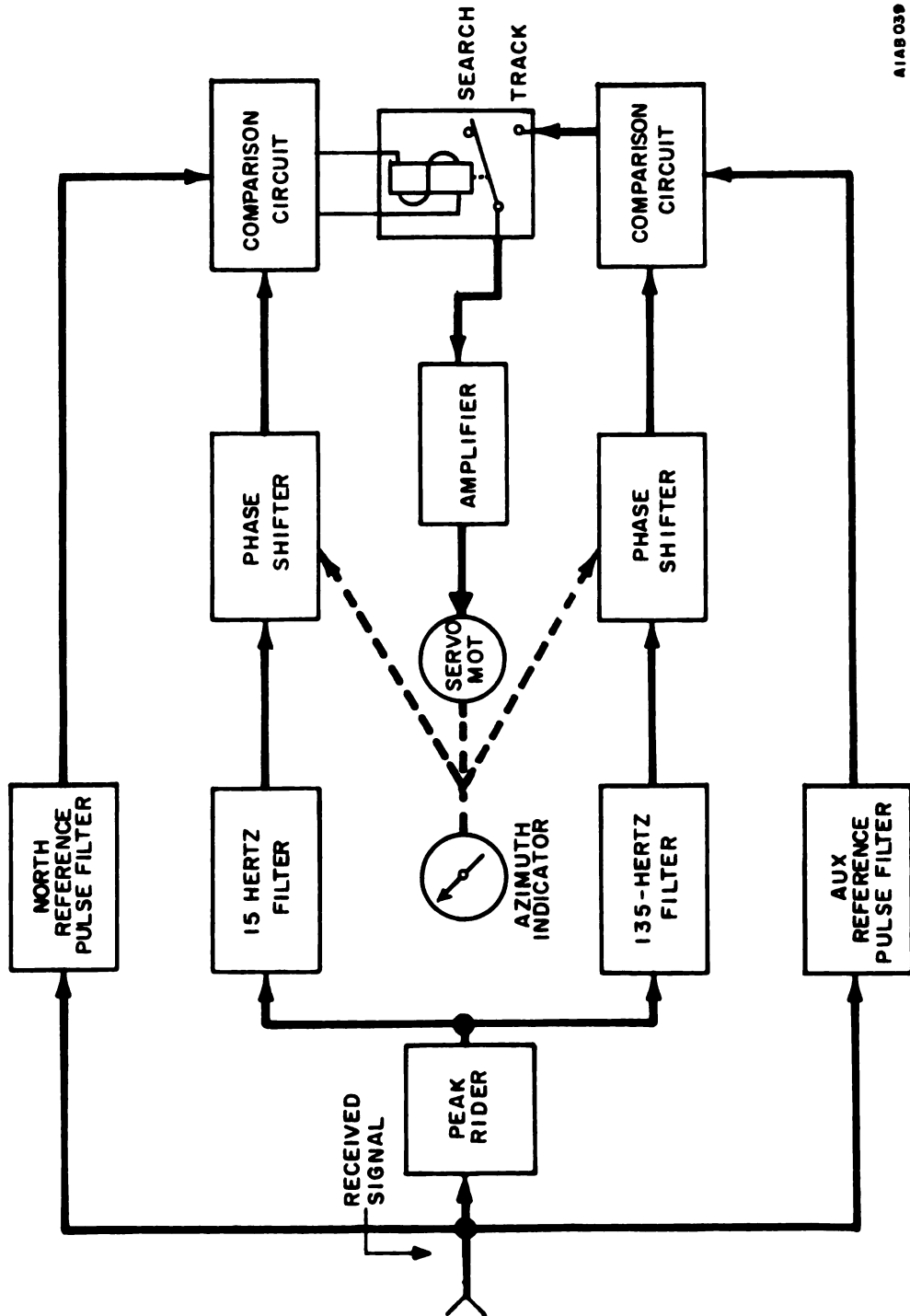
a. System Description. A TACAN system consists of three groups; a receiver-transmitter group, a power supply test set assembly, and an antenna group. A simplified block diagram of a typical (AN/URN-3) TACAN system is shown in figure 2-14.

A tabulation of the component parts of a typical TACAN system ground equipment (AN/URN-3A) is presented in table 2-2. The functional block diagram is shown in foldout 2-2.

b. Component Functions. The receiver-transmitter group comprises an electrical equipment cabinet which houses the radio receiver, coder indicator, frequency multiplier oscillator, amplifier-modulator and control duplexer.

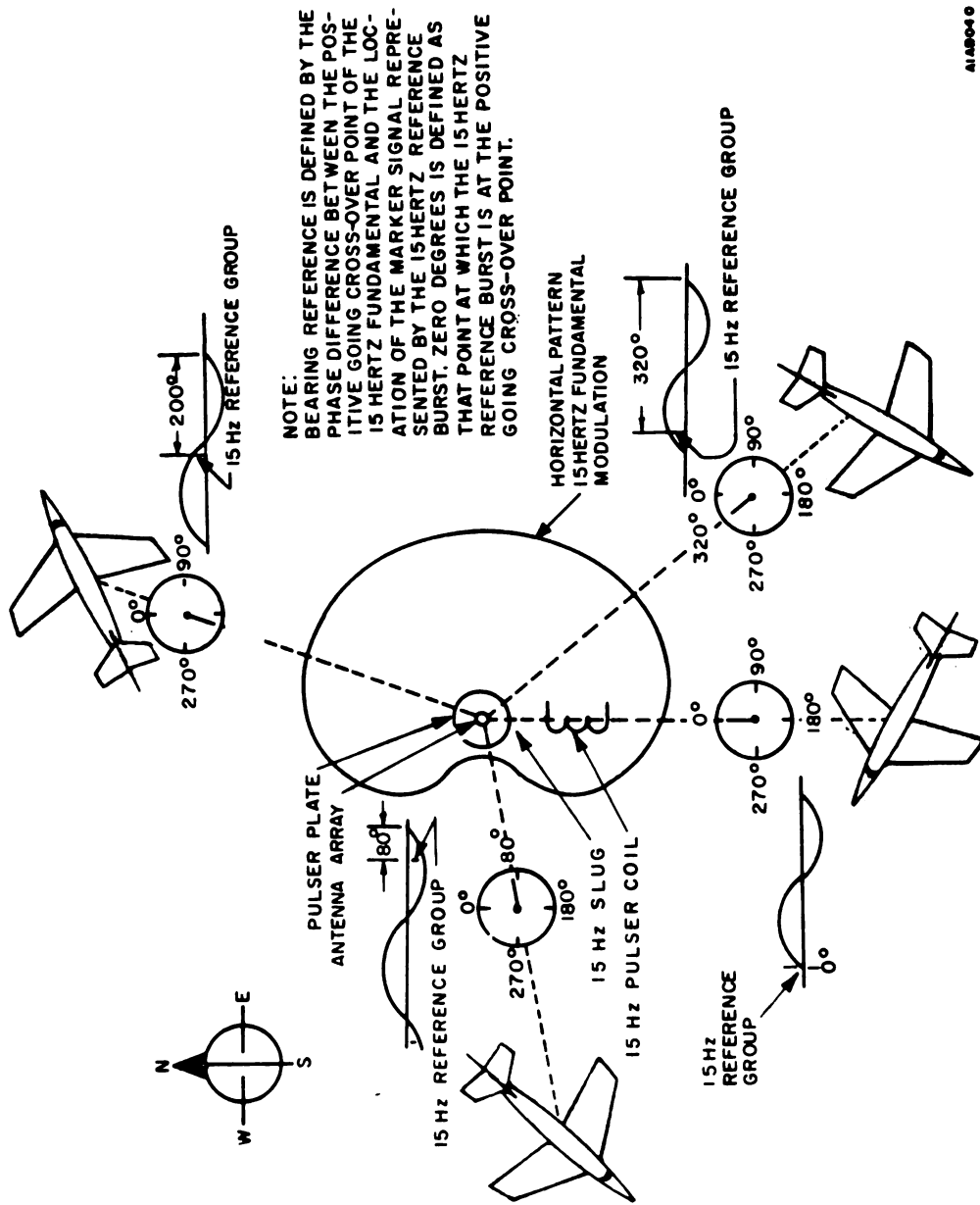
The radio receiver performs the following functions sequentially:

- o Receives from the control-duplexer the aircraft distance-interrogation pulse-pairs
- o Converts the distance interrogation pulse-pairs, along with random noise generated in the receiver crystal mixers and first preamplifier stage, to an intermediate frequency of 63 MHz and then amplifies and demodulates them
- o Produces a single pulse for each decoded pulse-pair by means of a coincidence decoding circuit. This circuit decodes noise and interrogation pulse-pairs having pulses separated by 12 microseconds



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Figure 2 - 12. TACAN Airborne Receiver Azimuth Circuits, Block Diagram



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Figure 2 - 13. TACAN, Avionics Signal Interpretation

- o Assures, by means of a blanking circuit, a separation of 40 microseconds between decoded pulses by cancelling all pulses which occur less than 40 microseconds after a preceding pulse for echo suppression
- o Maintains a constant output at 2700 ± 90 pulses per second, regardless of the interrogation rate.

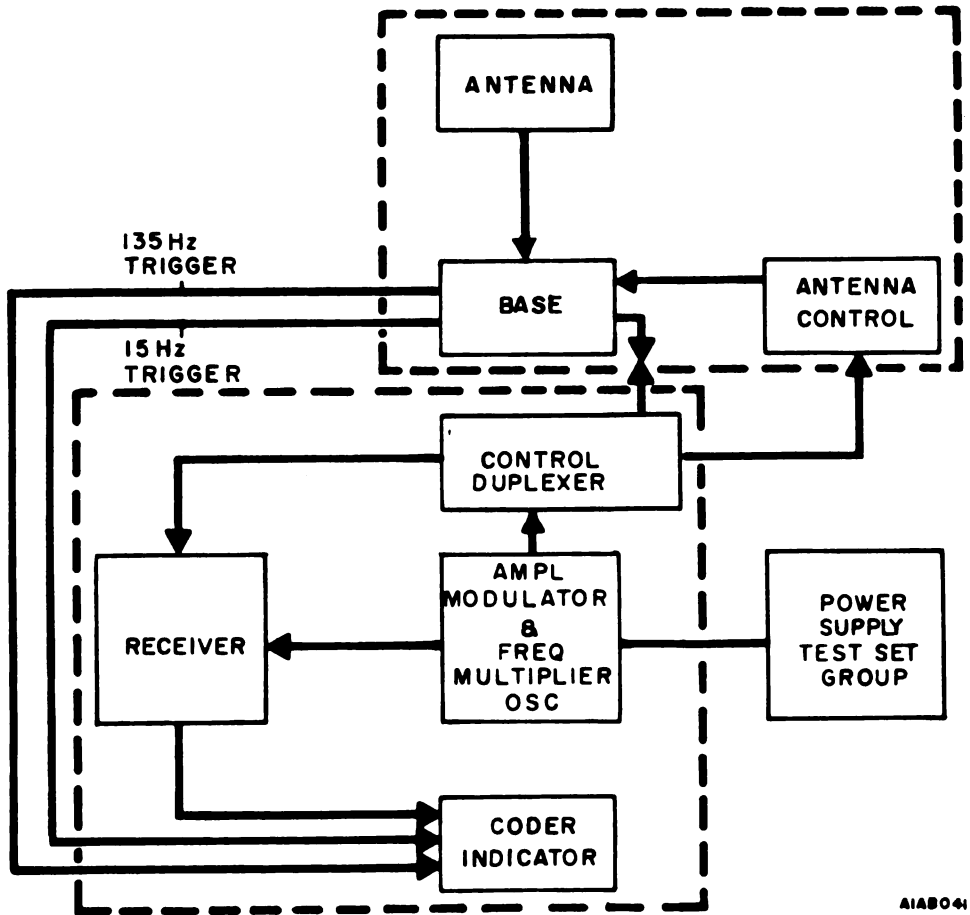


Figure 2 - 14. TACAN, Simplified Block Diagram

The coder-indicator performs the following functions as required:

- o Generates a 15-Hz reference burst each time a 15-Hz trigger video pulse is generated in the antenna
- o Generates a 135-Hz reference burst each time a 135-Hz trigger video pulse is generated in the antenna
- o Generates a radio beacon identification call of 1350-Hz and applies International Morse Code keying to the transmitter at specific intervals

Table 2-2. Typical TACAN Equipment List

QUANTITY PER EQUIP.	NAME	NAVY TYPE DESIGNATION	DESCRIPTION	OVERALL DIMENSIONS			WEIGHT (POUNDS)
				HEIGHT (INCHES)	WIDTH (INCHES)	DEPTH (INCHES)	
1	Radio set consisting of: (A) Receiver transmitter group consisting of: (1) Coder-indicator (2) Radio receiver (3) Radio set control (4) Amplifier-modulator (5) Frequency multiplier-oscillator (6) Electrical equipment cabinet (7) Duplexer	AN/URN-3A OA-2570/URN-3A	Receiver-transmitter group	72	25	34 ¹ / ₈	1173
		KY-101/URN-3 R-971/URN-3A C-3150/URN-3A AM-1701A/URN CV-1012/URN CY-2755/URN-3A CU-787/URN	Coder-indicator Radio receiver Radio set control Amplifier-modulator Frequency multiplier oscillator Receiver-transmitter cabinet Duplexer	32.3	13	21.5	80
1	(B) Power supply assembly consisting of: (1) Power supply (2) Power supply (3) Power supply (4) Electrical equipment cabinet	OA-2571/URN-3A	Power supply assembly	72	25	34 ¹ / ₈	1031
		PP-2501/URN-3A PP-2502/URN-3A PP-2503/URN-3A CY-2756/URN-3A	Low voltage power supply Medium voltage power supply High voltage power supply Power supply cabinet				
1	Antenna group consisting of: (A) Antenna (B) Antenna base (C) Antenna Control OR Antenna group consisting of: (A) Antenna (B) Antenna base (C) Antenna control	OA-592/URN-3 AS-685/URN-3 AB-361/URN-3 C-1349/URN-3	Low band antenna group Low band antenna Antenna base Shore antenna control unit	78 ¹ / ₂	45 dia 30 ⁷ / ₈	72.3 12 ¹ / ₂	410 443
		OA-591/URN-3 AS-686/URN-3 AB-361/URN-3 C-1349/URN-3	High band antenna group High band antenna Antenna base Shore antenna control unit	70 ³ / ₄ 70	45 dia 30 ⁷ / ₈	65.2 15.6	410 443

- o Processes the distance interrogation pulses and, in combination with time delays in the receiver, transmitter, and RF cable, adjusts net transit time to exactly 50 microseconds

- o Assigns priorities of transmission to the components of the signal, which consists of the bearing reference bursts, the radio beacon identification call, and the replies to distance interrogations and random noise pulses

- o Combines the various components of the signals

- o Produces, through a tapped delay line and double-coding circuit, for each component pulse a pulse-pair, the pulses of which are separated by 12 microseconds. (This action makes the 15-Hz reference burst a train of 12 video pulse-pairs spaced 30 microseconds apart, and the 135-Hz reference burst a train of 6 pulse-pairs spaced 24 microseconds apart.)

The frequency multiplier-oscillator chronologically functions to:

- o Generate the initial frequency by means of its crystal oscillator
- o Provide the radio receiver with output-oscillator frequency
- o Modulate the RF provided for the klystron drive in a carefully shaped fashion
- o Provide RF drive power to the klystron.

The principal functions of the amplifier-modulator as required are:

- o The application of beam pulses to the cathode of the klystron in the unit. (When applied to the klystron, these pulses key-on the beam coincident with the application of RF power to the klystron, thereby permitting amplification and transmission of the RF to the antenna.)

- o The application of pulses of the correct magnitude and delay, with respect to the modulator pulse input, to the pulse-widener stage of the sharper network.

- o The application of pulses of the correct magnitude, shape, and delay, with respect to the modulator pulse input, to the control grid of the first double stage of the oscillator.

- o The provision of a variable time-delay for the modulator input pulses. (A compensating adjustment of the variable time delay is made every time the channel frequency of the transmitter output is changed to maintain the overall delay to distance-interrogation and reply signals through the radio beacon constant, at 50 microseconds.)

The control-duplexer performs the following functions:

- o Incorporates the major portion of the control circuits which, by governing power distribution to the other circuits of the radio beacon, determine to a large extent proper functioning of the equipment

- o Permits simultaneous connection of the transmitter units and the radio receiver to a single antenna.

The power supply-test set group consists of an electrical equipment cabinet which contains the low voltage power supply, medium voltage power supply, high voltage power supply, and a transformer and blower. The upper portion of the cabinet is divided into four compartments for housing test equipment, including a peak power meter, oscilloscope, and pulse analyzer signal generator, which provide the capability of monitoring system operational performance and of malfunction detection.

Two type of TACAN antennas are used for required frequency coverage. Each antenna can operate on 63 channels, either in the low band (962 to 1087 MHz) or in the high band (1088 to 1213 MHz). Separate frequencies are used in each channel for receiving and for transmitting. The low-band receiving frequency is 63 MHz above the transmitting frequency; the high-band receiving frequency is 63 MHz below the transmitting frequency. A cutaway view of a typical TACAN antenna is shown in figure 2-15.

Whichever antenna group is used, the following functions are performed as required:

- o Receive distance interrogation pulse-pairs from the aircraft
- o Radiate replies which the aircraft receive and process to obtain distance and bearing information
- o Provide bearing reference pulses to trigger the coder-indicator at specific intervals
- o Modulate the pulse envelope with 15- and 135-Hz frequencies used for bearing information

c. Typical Installation. Flight safety rules for TACAN operation require that the system be continuously operative. To increase system reliability, each TACAN facility has dual transmitter-receiver groups and power supply test assemblies (see figure 2-16). The control monitor group monitors the radiated TACAN signal for proper operation. Utilization of the monitor antenna for continuous sampling of the radiated output permits the monitoring circuit to constantly check significant radio-set characteristics such as peak power, receiver sensitivity, reply delay, pulse spacing, identity, squitter count, antenna speed and azimuth error. Any failure or out-of-tolerance reading will cause automatic switching of the antenna group from one transmitter set to the other.

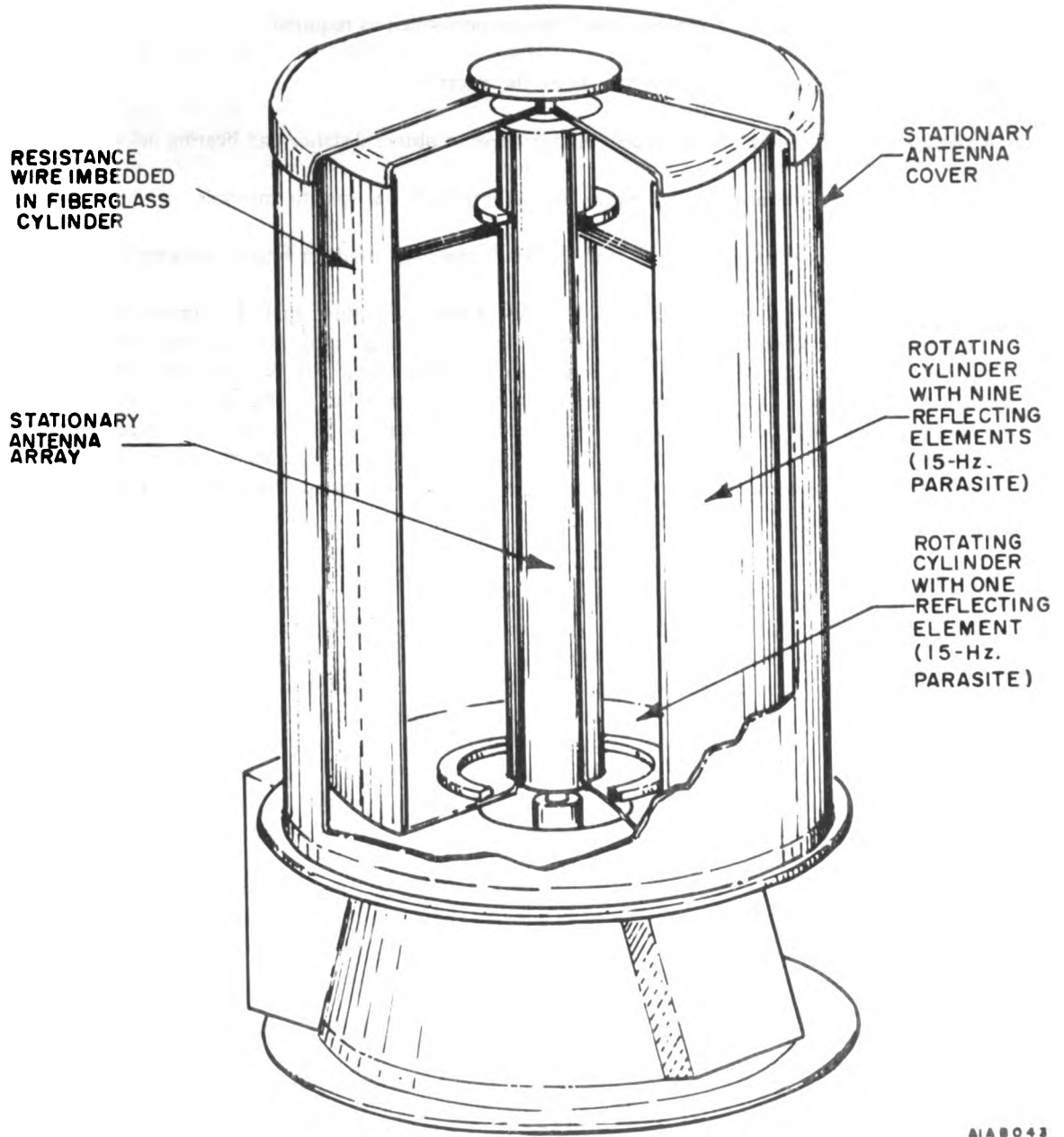
2.3.3 Applications

TACAN is used at shore activities to provide the radio beacon or "ground" portion of an air navigation system. The principal outputs of the beacon are the distance information signals, bearing information signals, and the station identification call. Thus, an aircraft with TACAN equipment (such as Radio Set AN/ARN-21) can accurately determine its position. The airborne equipment transmits distance-interrogation signals to the radio beacon and receives from it a composite signal which is translated into distance from the beacon, the bearing of the TACAN site from the aircraft relative to magnetic north, and radio beacon station-identification. Using this information, the geographical location of an aircraft can be established, and as many as one hundred aircraft may simultaneously obtain navigational information from a single TACAN ground installation.

With an operating range of approximately 200 NMI, TACAN is considered an en-route, short-distance, navigational aid. A single beacon may be used as a guide when flying a short distance or, by changing frequencies as they pass from the operating range of one TACAN station to the next, an aircraft could fly from coast to coast, or border to border, in the continental United States without requesting or receiving verbal navigational instructions. As an aircraft approaches a station and the pilot selects it on his receiver, the bearing and slant distance to the beacon will be displayed on the azimuth and range indicators. The indicators will continue to display updated information throughout the beacons' operating range.

2.4 VHF OMNIDIRECTIONAL RANGE TACTICAL AIR CONTROL

VORTAC is the designator for co-located VOR and TACAN systems at one navigational facility. The two systems operate independently except for transmission of the station-identification call. The VORTAC theory of operation is covered separately under VOR and TACAN in this handbook.



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Figure 2 - 15. TACAN Antenna, Cutaway View

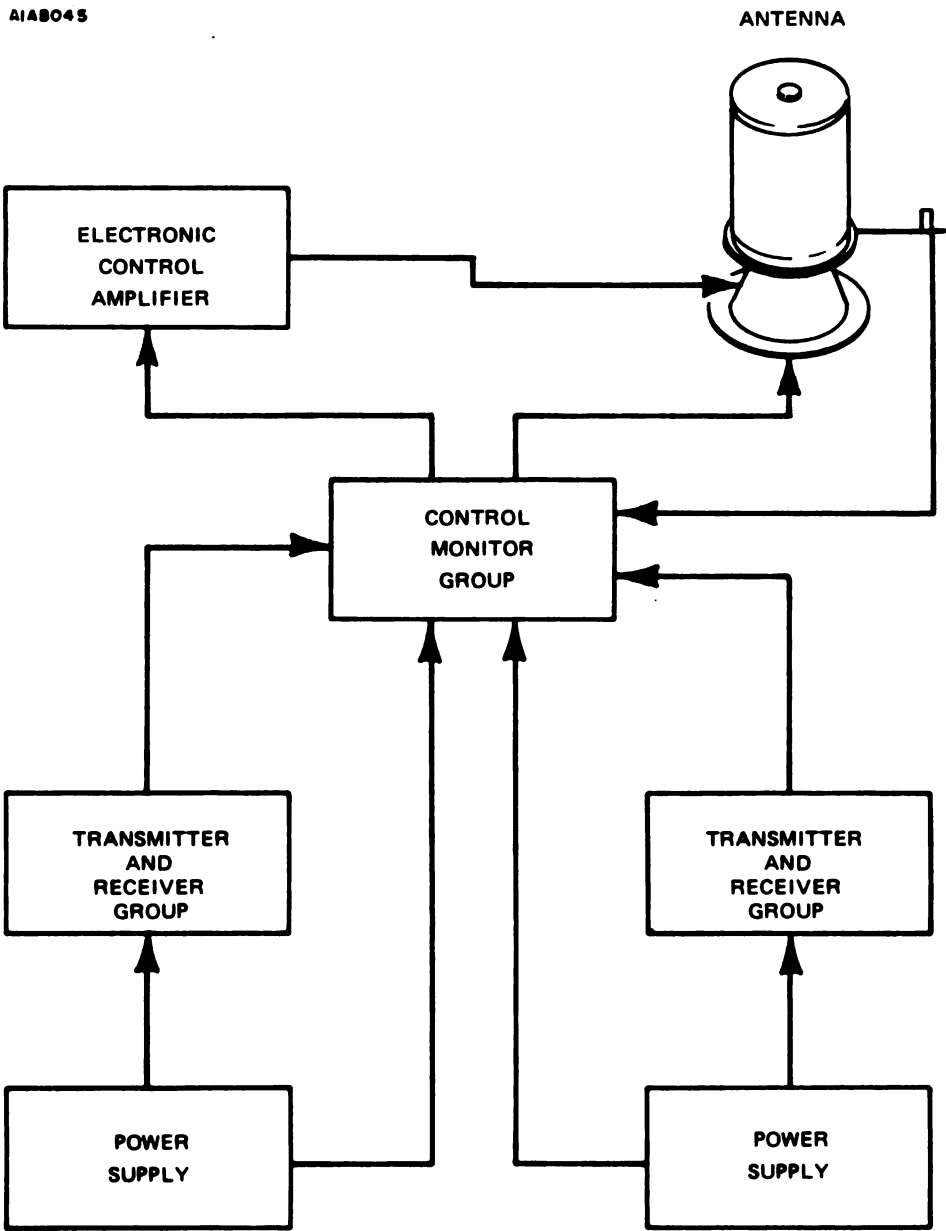


Figure 2 - 16. TACAN Ground System, Block Diagram

2.4.1 System Principles

The assigned channel of transmission for each VORTAC facility is assigned by the Chief of Naval Operations. The VOR components operate in the 108.00 to 117.90 MHz band, presently with a 0.10-MHz channel separation. TACAN components presently operate in two 63-channel bands from 962 to 1213 MHz. A low-band ground installation is interrogated by 1025- to 1087-MHz signals and responds at 962 to 1024 MHz; a high-band ground installation is interrogated by 1088- to 1150-MHz signals and responds at 1151 to 1213 MHz. TACAN channel separation is 1.0 MHz, while the interrogate-reply frequency separation is 63 MHz.

All 100 VOR channels are paired with 100 selected TACAN channels for VORTAC operation as defined in FAA Advisory Circular AC NO: 00-31, dated 10 June 1970, "U.S. National Aviation Standard for the VORTAC System." TACAN channels 1 through 16 and 60 through 69 are allocated for independent military TACAN operation.

2.4.2 System Configuration

A VORTAC facility contains two systems: the VOR portion includes a main and a standby transmitter group, main and standby goniometer and amplifier circuit, one antenna group, and one set of control and monitoring circuits; the TACAN portion includes dual receiver-transmitter units, dual power supply-test monitor assemblies, and one antenna group. All power used by the electronic equipment in a VORTAC facility is separately regulated for VOR and for TACAN. In the event of a commercial power failure, there is available a 37.5 kVA autostart engine generator. The autostart feature is sensitive to both voltage and frequency variation; if either exceeds preset limits the engine-generator will start and be switched in.

The TACAN antenna is positioned directly above the VOR antenna, under the same fiberglass dome. The antenna assembly is mounted above the counterpoise roof of the building; the counterpoise is approximately 52 feet in diameter and the TACAN antenna is at a height of approximately 30 feet.

The VOR and TACAN systems are individually self-monitoring, and will automatically switch operating components upon intolerable performance degradation. Operating-status indications from the monitors are continuously and simultaneously remoted to the local control tower and the FAA flight service station to indicate proper operation, transfer of equipment, or shutdown of each system.

2.4.3 System Application

VORTAC facilities are installed by the FAA as en-route stations to service both civil and military aviation. Most en-route VOR stations have been converted to VORTAC. Civil aircraft use VOR for bearing information and use TACAN for distance measuring information; TACAN is used by military aircraft for both bearing and distance information.

By using the available matrix of VORTAC stations, a pilot may determine his geographic location anywhere in the United States.

Of the 100 VOR channels, 20 are allocated for instrument landing system (ILS) channels used exclusively by civil air carriers and general aviation. Terminal VOR and ILS facilities are located at most commercial airports. The heavy increase in aviation traffic has resulted in the need for augmented en-route and terminal navigational facilities. The resulting radio frequency congestion has become an acute problem in several sections of the country; it is no longer possible to provide dedicated frequencies for all proposed navigational aids. Since the VOR and ILS frequency band is constrained by the FM commercial broadcast and the aeronautical mobile communication bands, an adequate frequency spectrum to provide additional frequencies is not available. The next logical step is implementation of 50 kHz separation of VOR and ILS channels to double the channel availability. To increase the number of TACAN channels for pairing, the same frequency band will be used for both interrogating and reply signals. The original allocations are referred to as X channels and the new channels as Y. Table 2-3 illustrates the paired X and Y VOR-TACAN channel frequencies, which are definitized in FAA Advisory Circular AC NO: 170-12, dated 7 October 1970, entitled "Implementation of 50 kHz/Y Channels for ILS/VOR/DME."

Table 2-3. VOR-TACAN Channel Frequencies

VOR CHANNEL FREQUENCY MHz	CHANNEL NUMBER	TACAN	
		INTER FREQUENCY MHZ	REPLY FREQUENCY MHz
108.40	21X	1045	982
108.45	21Y	1045	1108
112.20	59X	1083	1020
112.25	59Y	1083	1146
113.70	84X	1108	1171
113.75	84Y	1108	1045
116.30	110X	1134	1197
116.35	110Y	1134	1071
117.50	122X	1146	1209
117.55	122Y	1146	1083

Figure 2-17 shows the relationship of the interrogating-reply frequencies with respect to the paired X and Y channels. These new channels are scheduled for implementation by 1 January 1973 with only minor modifications required for both civilian and military equipment.

2.5 RADIO BEACONS

A radio beacon in its fundamental form is a nondirectional radio station in a fixed geographical location, emitting a characteristic signal from which an aircraft can obtain bearing information. Some beacons operate continuously, while others transmit only in response to an interrogation signal.

Marker beacons are widely used navigational aids. Radio beacons are located along airways to supplement radio navigation systems, and along airport approaches to supplement aircraft landing systems. Radio beacons operate in three frequency bands: LF, VHF, and UHF.

2.5.1 LF Marker Beacons

Nondirectional ground stations, called radiophares, used as a source of radio transmission is the simplest form of radio beacon that can be installed as an aid to navigation. These stations transmit an omnidirectional signal pattern modulated by a 1020-Hz identification tone which can be used for long- or short-range homing by aircraft equipped with radio direction finders. The low-frequency tone is also used to intermittently transmit the station identification in International Morse Code. LF radio beacons operate in the 200 to 800 kHz band with a power output up to 400 watts.

A typical LF radio beacon communication set (figure 2-18) consists of radio transmitter, antenna coupler, modulator power supply, and transmitter control equipment.

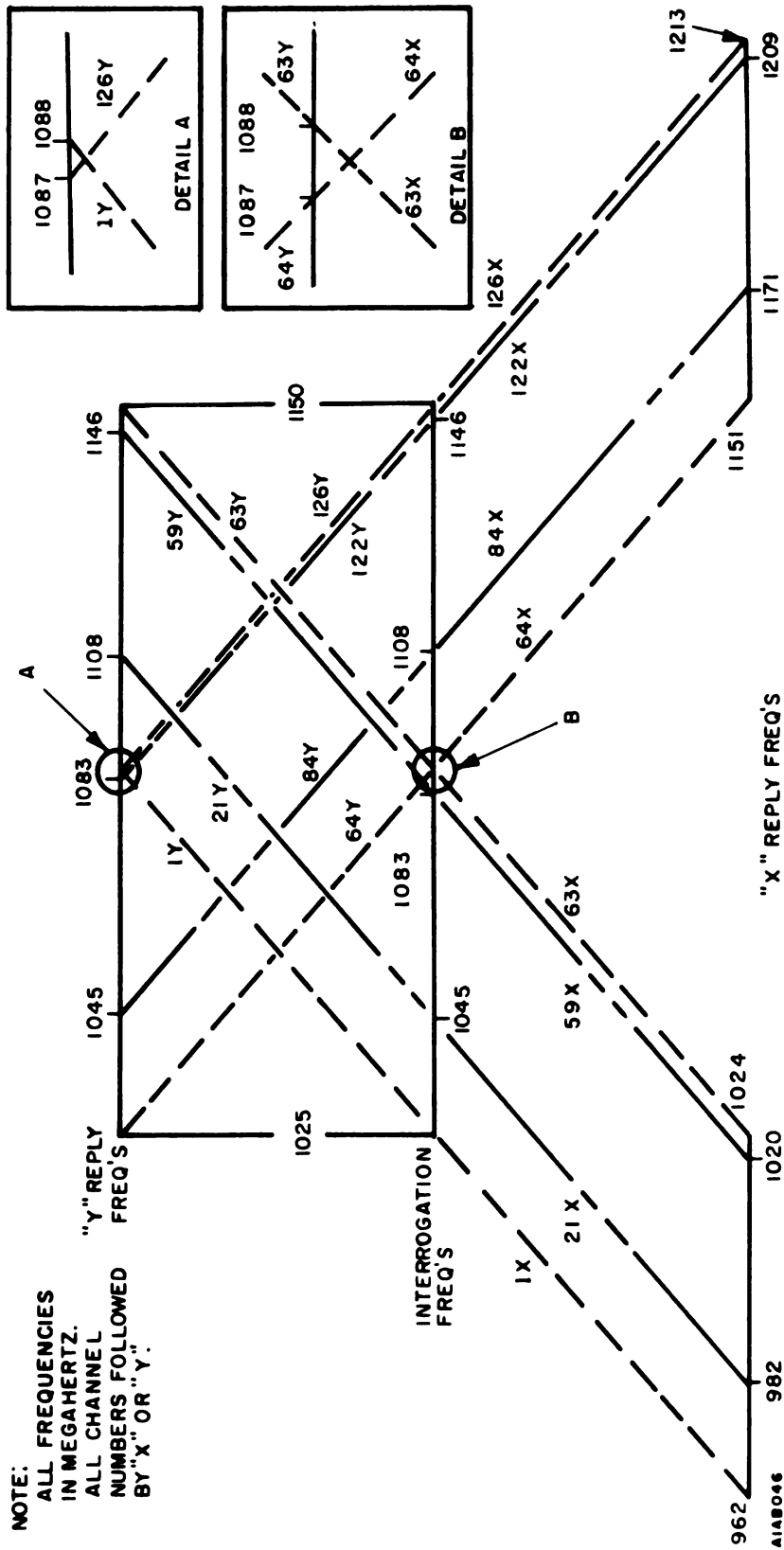


Figure 2 - 17. TACAN X and Y Channels, Paired Relationship

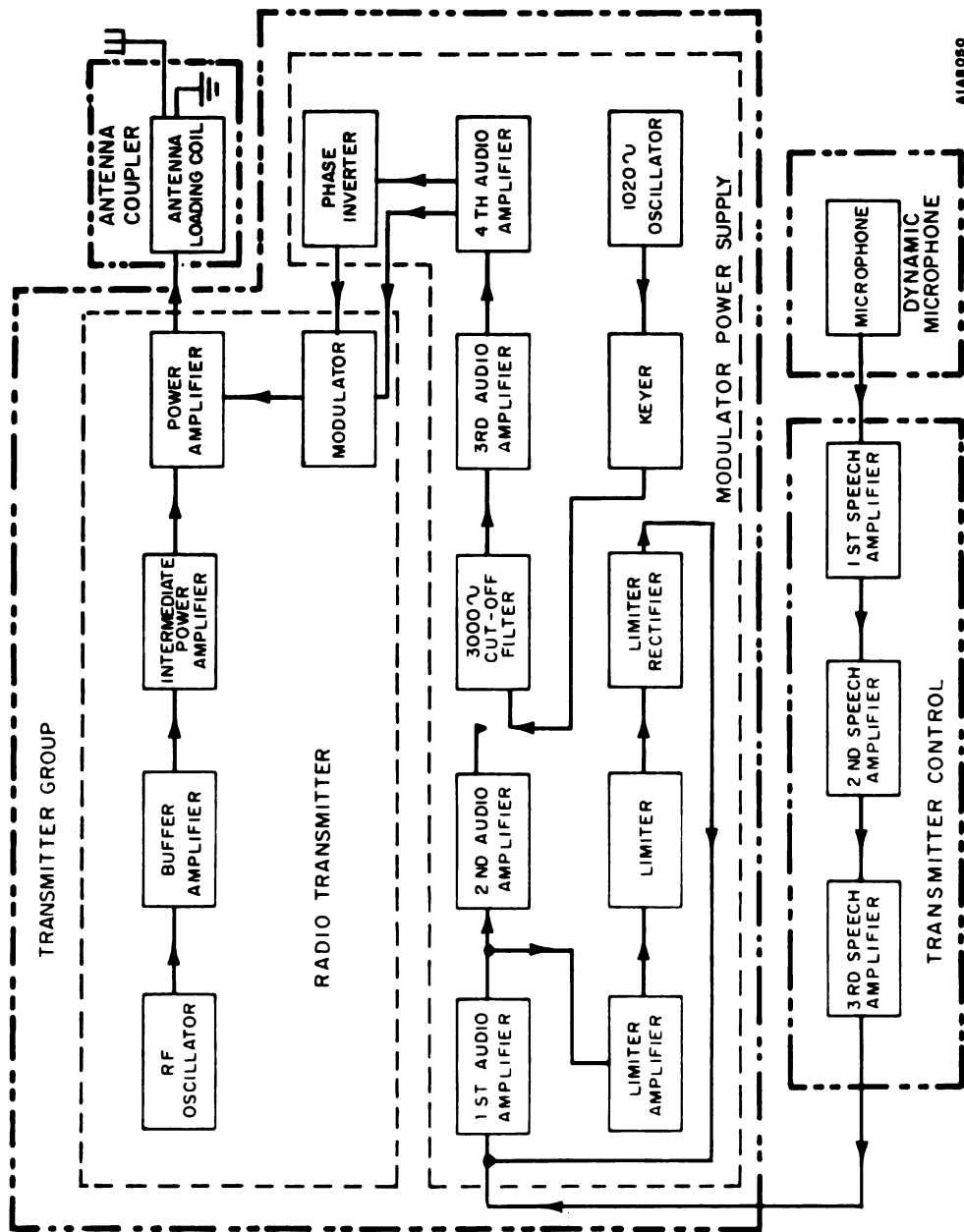


Figure 2-18. L.F. Radio Beacon Communication Set, System Block Diagram

The transmitter group generates an RF carrier. The group contains an oscillator, a buffer amplifier, intermediate power amplifier, and power amplifier.

The antenna coupler is a loading coil assembly for resonating the antenna to the operating frequency and coupling the antenna to the transmitter. Taps are provided so that the coil can be adjusted at any frequency in the operating range.

The modulator-power supply consists of four audio amplifier stages, with a 3-stage limiter circuit, a 1020-Hz phase-shift oscillator circuit, a low-voltage power supply, and a bias supply. The unit also contains a voice control relay, which is energized by the DC signal received from the remote control unit.

The transmitter control (remote control) unit applies primary power to the transmitter and selects the type of intelligence transmitted (voice or 1020-Hz keyed oscillation). When voice transmission is used, a three-stage microphone amplifier in the remote control unit amplifies the input signal for the audio stages in the transmitter.

LF radio beacons, with power output up to 400 watts, are classified as long-range radio-compass locator stations. For this type of operation LF radio beacons are installed along the coast and on weather-station vessels, to aid air navigation over established ocean routes. Some stations also have voice communication capability.

Most LF radio beacons are employed as long-range homing beacons, but are also used for short-range homing to an airfield approach course. For this application, the facility operates with a power output of less than 10 watts and is generally co-located with the airfield outer marker beacon. This short-range compass-locator allows aircraft within a radius of 10 NMI to "home" into a transmitter and antenna, which have a certain relationship with the airfield approach course.

The Navy classification of LF transmitters is as follows:

Type H - Power output greater than 50 watts, operates continuously

Type MH - Power output less than 50 watts, operates on request

Type K - Power output 25 watts; operates continuously, generally complements landing system boundary markers.

2.5.2 VHF Marker Beacons

VHF marker beacons, used to identify geographic locations, are classified in three categories:

- o Station Location Marker - To locate the range station with which it operates

- o Fan Marker - to furnish aircraft with a check as to progress along airways, to mark the junction of two radio-range courses, to designate a hold-point for aircraft within 10 to 20 miles from an airfield or to mark obstructions

- o Low Power Fan Markers - for special purposes such as "let-down" along a radio-range course. (The lower power is required for installations closer than eight miles to an airport to reduce interference with the station location markers.)

All VHF marker beacons operate at 75 MHz but are distinguishable by their modulating tone and pulse rate. The low-power fan markers used for airport boundary markers are modulated at 400, 1300, or 3000 Hz with a pulse rate of 2, 6, or 12 pulses per second (PPS) respectively. If an airport approach has three boundary markers, the outer marker is modulated at 400 Hz with a pulse rate of 2 PPS, the middle marker is modulated at 1300 Hz

with a pulse rate of 6 PPS and the inner marker is modulated at 3000 Hz with a pulse rate of 12 PPS. The FAA now uses only two markers with the runway approach system. The outer marker, located approximately five miles from the end of the runway is modulated by 400 Hz with 2 PPS. The second (middle) marker, located 3500 feet from the end of the runway, is modulated at 1300 Hz with 6 PPS. The output power from these beacons is only 2 watts, and the radiating pattern is such that if an aircraft is not within the runway approach pattern (in both altitude and azimuth) the beacon signal will not be received.

With the advent of VOR and TACAN, the FAA has eliminated most other VHF fan and station location markers, but usually two low-power boundary-marker beacons are located at each end of each instrumented civilian runway.

2.5.3 UHF Marker Beacons

UHF radio-beacon equipment installed on or near Naval Air Stations provides an identifiable modulated continuous wave signal for station location and voice-modulation for ground-to-air communication. Operating in the 225 to 400 MHz frequency range, with nominal carrier output of 22 to 25 watts, a UHF homer beacon is limited in range to line-of-sight coverage. The facility is usually located 3 to 10 miles from the air station, on the centerline of the instrument runway if feasible. The UHF radio beacon equipment is designed for remote, unattended, continuous operation. Continuous operation is accomplished by employing one transmitter in hot-standby for automatic transfer in the event of master-transmitter failure. Transfer of transmitters can also be accomplished manually either locally or remote, by means of a telephone dial system. A typical UHF radio beacon set is illustrated in figure 2-19. Included also is the voice communication capability which is usually a recorded transmission of local weather conditions and landing/departure instructions. This recorded message, known as Automatic Terminal Instruction Service, is controlled by the operations personnel with the weather information obtained from the local weather facility. These recordings which are updated as conditions warrant, tremendously reduce ground-to-air communications.

2.5.4 Automatic Direction Finder Transmitters

The automatic direction finders (ADF) transmitter is usually a high powered transmitter located near an air station to aid aircraft equipped with automatic direction finders. For military operations those facilities located near the coast are operated in the LF/MF (200 to 800 Hz) range, while homer beacons near air stations not close to the coast operate in the UHF (200 to 400 MHz) range. Navy facilities operate in the UHF band, but joint FAA-Navy activities may have transmitters operating in both the VHF and UHF bands (VHF band ranges from 120 to 200 MHz).

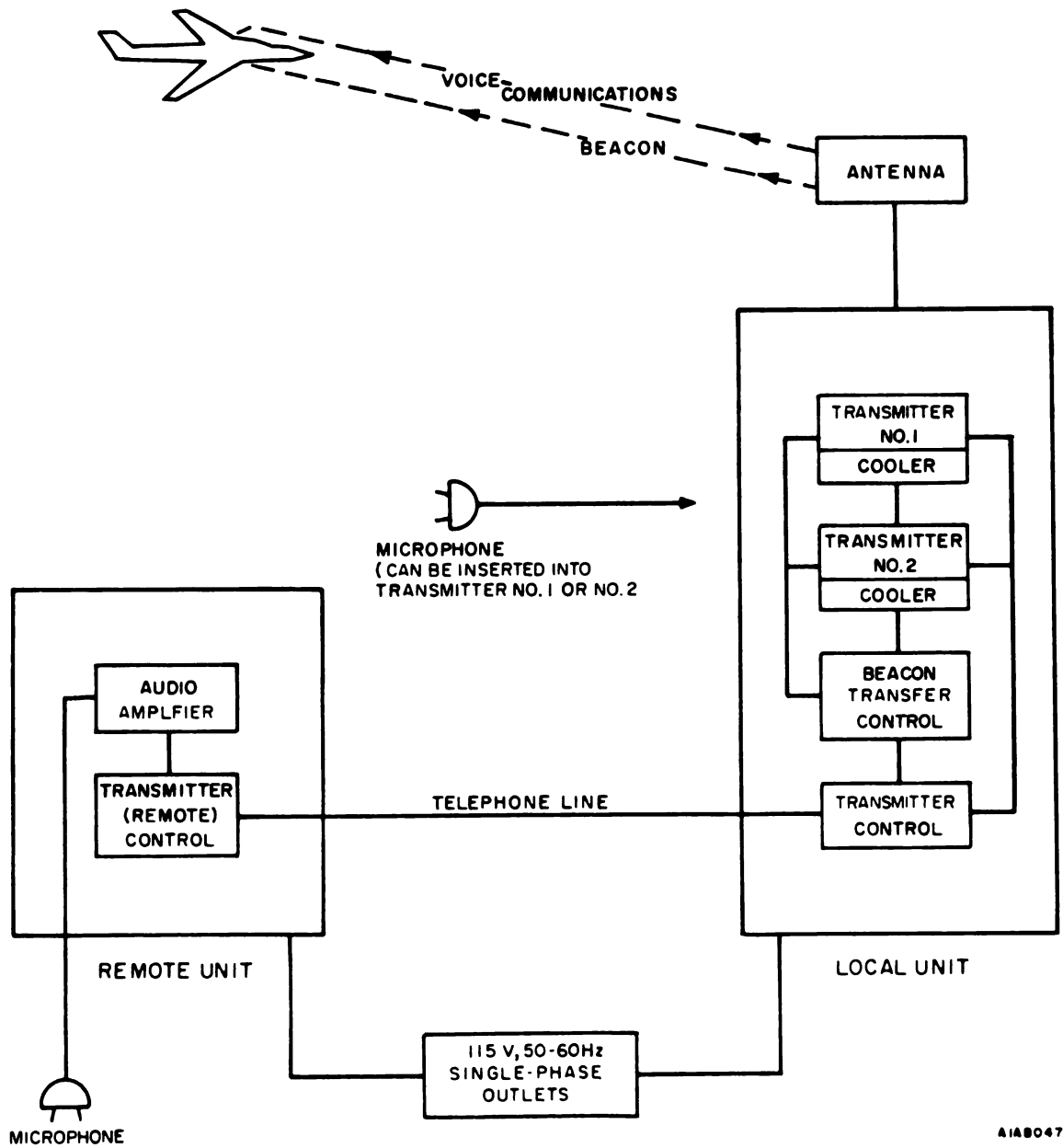
Homer facilities are operated at up to 400 watts power output maximum, thus providing high flying aircraft, many hundreds of miles away, another navigational aid.

2.6 RADIO DIRECTION FINDERS

Radio direction finders (RDF), installed on Naval Air Stations, provide course-guidance for aircraft unable to use other navigational aids. The primary purpose of RDF is to determine the exact bearing of any transmitted radio signal. Two RDF ground stations may be used to determine the location of a radio transmitter.

2.6.1 System Principles

The radio direction finder (hereafter referred to as direction finder (DF)) provides a means of rapidly determining on the ground the direction of fixed or mobile sources of radio transmissions. Received-signal bearing is displayed on the face of cathode-ray tube (CRT). If the received signal is amplitude-modulated with voice or tone, the audio portion of the signal is made available for monitoring.



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Figure 2 - 19. UHF Radio Beacon Set, Block Diagram

Present radar air traffic control centers are configured with both direction finder equipment and radar. Although the two systems are deriving aircraft position information, they have heretofore remained independent of each other. Paragraph 2.6.1b will detail the integration of DF and radar.

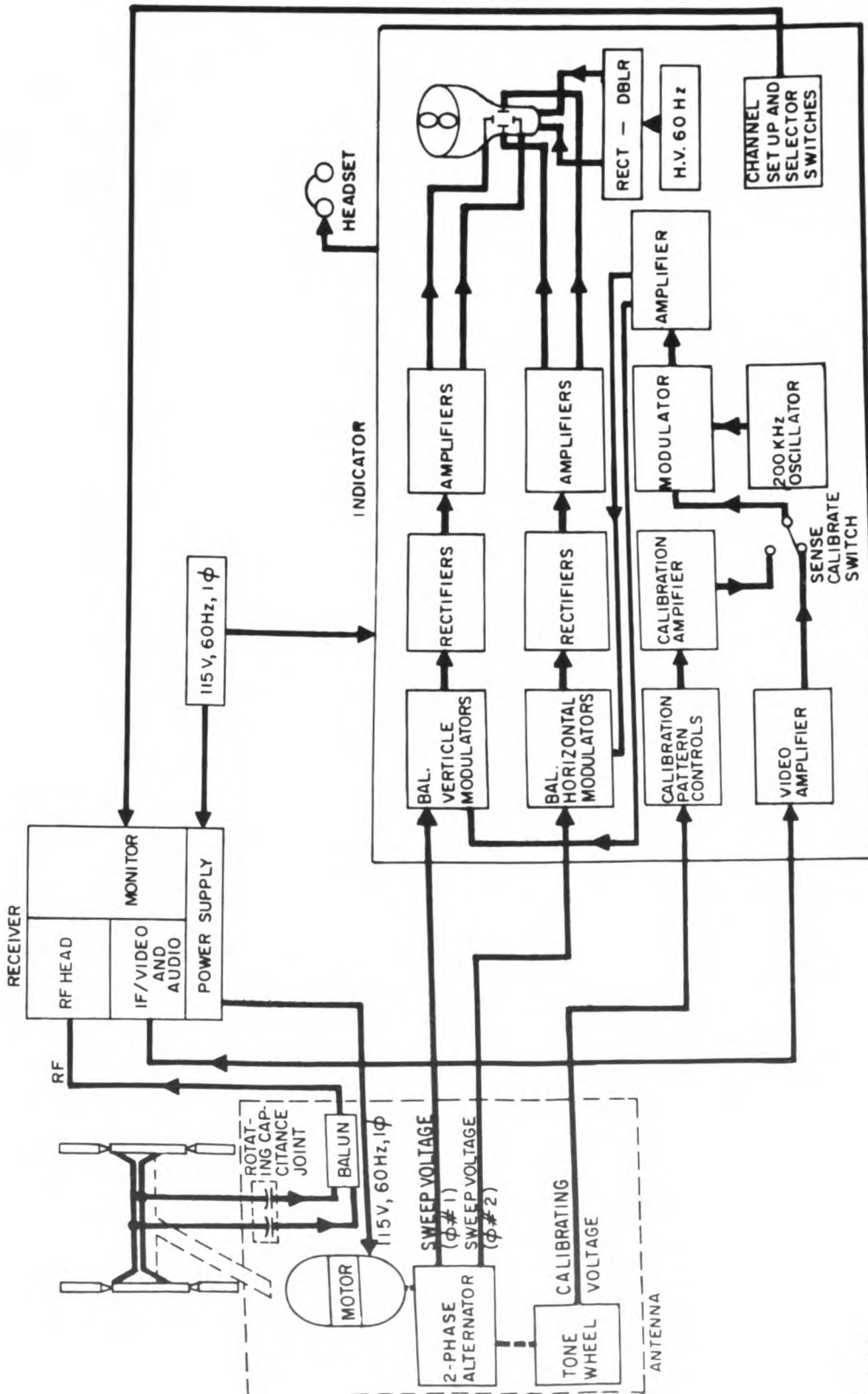
a. Direction Finder. A direction finder set has three major subassemblies: a rotating Adcock antenna array, a double superheterodyne radio receiver, and an azimuth indicator (see figure 2-20). The receiver operates in either the VHF (116 to 150 MHz) or UHF (225 to 400 MHz) range. Signals present at the antenna are fed to the receiver by means of coaxial cable. At the receiver the signal is amplified and mixed with the output of a monitor-controlled variable-frequency oscillator (VFO) to produce the first IF signal. The IF signal is amplified and mixed with output of a crystal controlled fixed-frequency oscillator to produce a second, lower-frequency IF signal. The second IF signal is amplified and applied to a signal rectifier for detection. If the received signal has been amplitude-modulated there will be two rectifier-stage outputs: a video signal and an audio signal. These signals are applied through their respective amplifying stages to the indicator. The audio signal is fed to headphones through a jack on the indicator cabinet front panel. The video signal is amplified and applied to a modulator stage where it is superimposed on the carrier oscillator output. The modulated carrier is fed simultaneously to the suppressor grids of two balanced modulators. From this point on, there are two signals involved in this discussion; one for application to the CRT horizontal deflection plates and the other for application to the vertical deflection plates.

The horizontal and vertical sweep signals, generated at the antenna, are applied to the control grids of the balanced modulators. The resultant balanced modulator outputs are fed to a pair of detector stages for demodulation and removal of the carrier signals. The detector output signals are composite signals composed of video signals and the sweep signals. The detected signals are amplified and applied to the CRT vertical and horizontal deflection plates. The resultant pattern on the CRT face is a figure eight, indicating reception of a signal of the frequency to which the receiver is tuned. Around the perimeter of the CRT face is a compass scale from which signal-bearing is read. Encircling the compass scale is an alidade ring which permits rotation of a cursor screen positioned over the CRT face. When the figure-eight pattern is present on the CRT face, the cursor screen is rotated so that its centerline coincides with the principal axis of the figure eight. This condition indicates two possible bearings, one at each end of the cursor screen centerline. To overcome this ambiguity, a CALIBRATE-SENSE switch is provided on the indicator front panel. When this switch is set to SENSE, the figure eight is resolved into a V pattern, the apex of which indicates signal bearing to an accuracy of ± 5 degrees. When no signal is being received, the pattern on the CRT face is a circle. When the CALIBRATE-SENSE switch is set to CALIBRATE, the pattern appearing at the indicator is a 36-lobe daisy pattern.

The DF antenna is an Adcock array consisting of two vertically positioned dipoles, rotated by an 840-r/min motor. The major factors contributing to the received signal strength are the polarization and directional properties of the dipole. Although the antenna is most receptive to vertically polarized signals, it will respond satisfactorily to signals polarized at angles up to 45 degrees from the vertical. Also, maximum voltage is induced in the antenna when the signal being received is parallel to the axis of the dipoles. Conversely, minimum induction occurs when the axis of the dipole is perpendicular to the direction of the signal travel. The result of this varying response, as the antenna rotates, is an amplitude-modulated (AM) signal output from the antenna. The envelope of this modulated signal becomes the video signal, after demodulation in the receiver, that is applied in combination with sweep signals, to the CRT deflection plates.

The system is responsive to amplitude-modulated, frequency-modulated, and unmodulated signals. Voice reception is possible with AM signals only. The antenna motor also drives a two-phase alternator which generates the CRT horizontal and vertical sweep voltages and a tone wheel used to generate a CRT calibration signal.

b. Direction Finding Coordination System. For rapid control of air traffic it is desirable that the DF and radar be automatically coordinated, particularly for use in the event of an emergency. In such an integration the DF bearing information of the target provides an immediate identification of the calling aircraft on the radar



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Figure 2 - 20. Direction Finder Set, Block Diagram

monitor. The direction finding coordination system (DFCS) applies the output of a direction finder to one or more radar indicators. The coordination system is controlled by the DF operator such that bearing data on the target of interest is immediately transferred to the selected radar indicator and displayed in a method that designates the target.

Initially the direction finder operator receives a target of interest on his display. If it is determined that this target should be coordinated with the radar, the normal procedure of depressing the DF SENSE switch will determine which is the true target. As long as video information is available, the DFCS azimuth readout will present a readout corresponding to the aircraft bearing. However, since the same ambiguity of target position exists in the DFCS panel, the readout advance may have to be depressed until the true bearing is obtained. Once the correct azimuth is determined the DFCS will continue to track the aircraft unless transmission ceases or excessive noise masks the signal. After correct target determination, the SYSTEM SELECT switch can be placed in the DFCS enable position, thereby transferring the azimuth information to the radar azimuth cursor.

To obtain the desired accuracy, an improvement must be made in the ability to locate target aircraft more precisely than that seen on the cathode-ray tube of the direction finder. The DF system determines the aircraft position by using the null of the antenna pattern which is more definite than the relatively broad peak.

If a single DF video pulse (equivalent to 180 degrees of antenna rotation) is examined, as in figure 2-21A, the symmetry of the signal about the peak is evident. The aircraft azimuth is the point of peak symmetry. Integration of the falling 90 degrees of this signal (area 1) will yield a value equal to that obtained by integration of the rising 90 degrees (area 2). If the integrated values are subtracted the result is zero.

The system application of this principle involves sampling two adjacent 90-degree portions of the video pulse train. Only every other video pulse is sampled because two video pulses are equivalent to one rotation of the antenna (360 degrees). Figure 2-21B illustrates the results if sampled integration areas are not at the line of symmetry. Area 1 does not equal area 2; subtraction of the two areas gives a resultant value which is the error signal used to drive a servo motor and resolver in the proper direction to make the integrated samples coincide with the line of symmetry. When a reference point obtained from the antenna position alternator is established, the angle through which the resolver rotates is an indication of the azimuth of the aircraft. The antenna-position signals from the horizontal and vertical alternator windings mounted on the DF antenna pedestal are 14-Hz sine waves 90 degrees out of phase. After processing in the DFCS, these signals are applied to a resolver. Any rotation of the resolver rotor by the servo motor will result in an equal phase shift of both 14-Hz signals. With proper feedback loops the servo motor rotates the resolver until the areas of integration of the video signal are equal. As equality is obtained, the system is nulled and the resolver angle is aligned with the line of symmetry of either the true or the ambiguous position of the aircraft. This possibility of false indication is removed when the DF operator observes the azimuth readout and corrects the ambiguous position by depressing the readout advance until the readout indicator is within ± 60 degrees of the true position. The DFCS will then null to the correct azimuth. A second resolver, driven from the same servo motor and synchronized with the first, replaces the cursor azimuth resolver within the radar to provide a signal to the radar relative to aircraft heading. The radar or DFCS resolver is selected from the system control panel with the SYSTEM SELECT switch.

System accuracy depends on several factors, most important is the clarity of the 90 degree phase-reference signals obtained from the DF that controls the DFCS integrator. Another is the small dead band inherent in the servo loop which accounts for slight target heading changes without apparent changes in indication. Also of great importance is the problem of signal reflections causing the antenna pattern null to deviate from its true position.

2.6.2 System Configuration

a. Direction Finder. This set consists of three major components: an azimuth indicator, a superheterodyne radio receiver, and a rotating Adcock antenna array. Figure 2-22 illustrates the relationship of the units as connected in a shore installation.

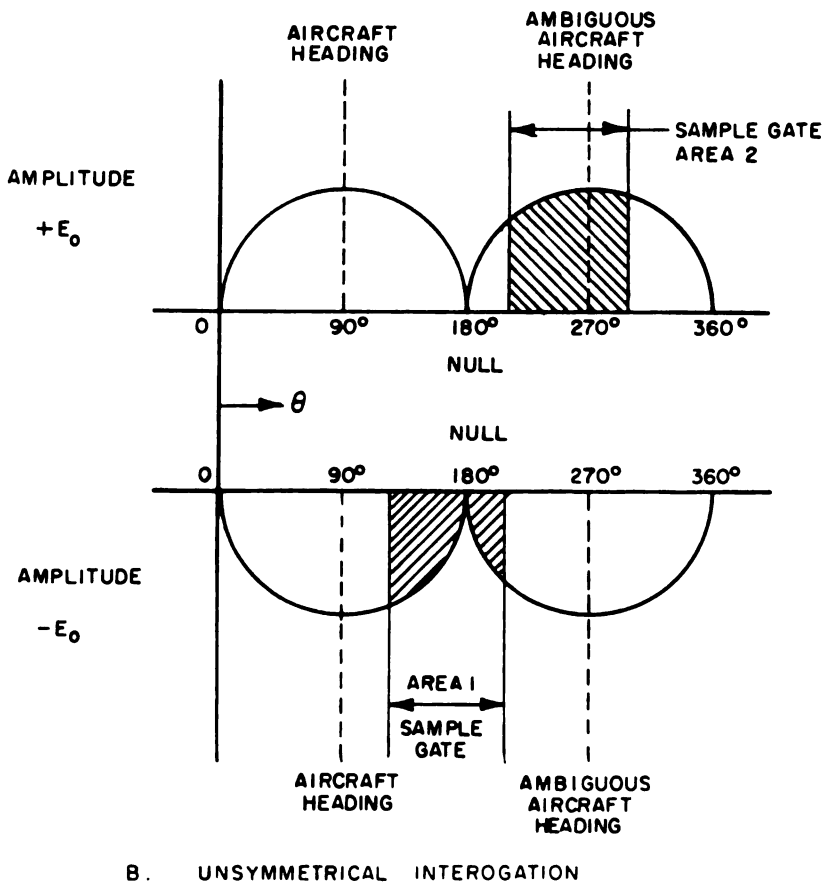
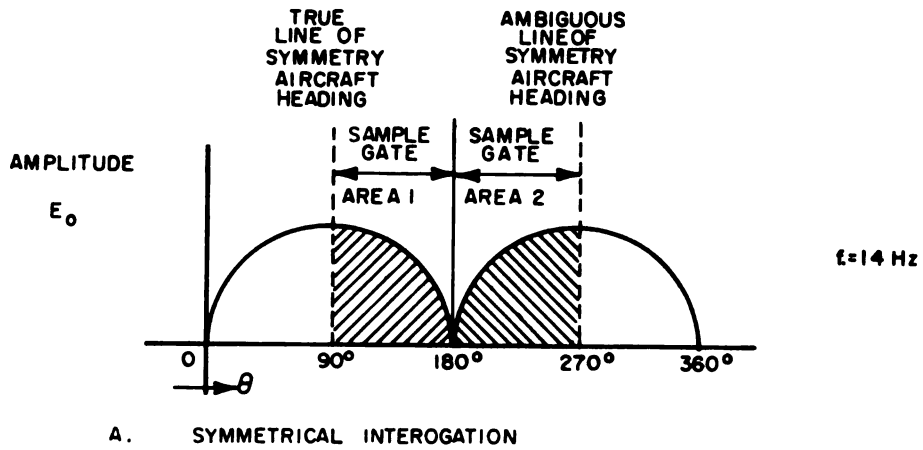


Figure 2 - 21. Direction Finding Coordination System, Video Pulse Train Presentation

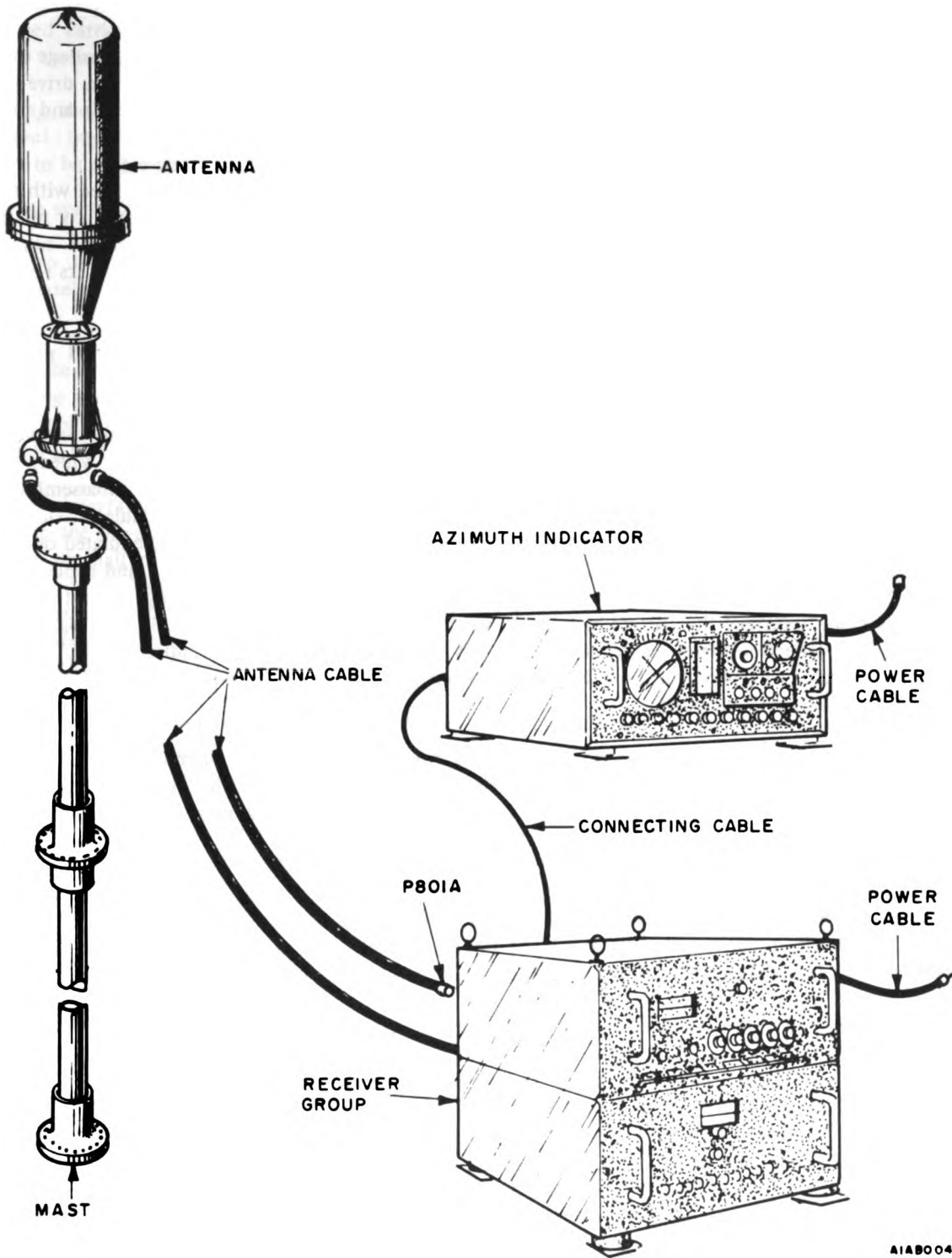


Figure 2 - 22. Direction Finder Set, Shore Installation Configuration

The antenna array employing two vertically positioned dipoles with a sense relay, is located in the upper antenna housing and enclosed in a plastic radome.

The lower antenna housing encloses the drive motor, balun, tone wheel, and alternator. Actuation voltage for the sense relay is applied, through brushes, to sliprings at the base of the antenna shaft. Antenna drive-motor operation is controlled by a switch on the azimuth indicator front panel. The antenna control cable and the RF cable are connected to the antenna assembly through jacks at the base of the antenna housing.

The receiver group contains a receiver and a power supply mounted in individual cabinets equipped with safety interlock switches. The receiver is comprised of three separate plug-in subassemblies designed to minimize maintenance downtime: the RF head, the monitor, and the IF video-audio chassis. Receiver tuning is accomplished from the azimuth indicator front panel. The receiver can be tuned to any channel in its range; 20 channels can be preset to expedite tuning.

The power supply operates from a single-phase 115-V, 50-60 Hz source, and provides regulated plate and filament voltages for the tuning motor, clutch control, and frequency-control circuits.

The azimuth indicator subassemblies contain antenna and receiver remote controls, video- and sweep-circuit amplifiers, a power supply, and the CRT indicator which provides a visual readout of bearing. Video, audio, sweep, and calibration signals from the receiver are further processed in the azimuth indicator subassembly. The video signals are amplified, modulated, and applied to the suppressor grids of a balanced modulator. Horizontal and vertical sweep signals are applied to the control grids of the balanced modulator. The demodulated output of the balanced modulator contains the composite video and sweep signals which are amplified and applied to the CRT vertical and horizontal deflection plates. The resultant pattern on the CRT face is a figure eight indicating that a signal is being received; the pattern is a circle when no signal is present. The calibration signal, when applied to the CRT deflection plates, causes a 36-lobe daisy pattern to appear on the indicator face. The audio signal is applied directly to a phone jack on the indicator front panel. All controls required for system operation are located on the indicator front panel.

b. Direction Finding Coordination System. To incorporate the DFCS requires a minimum of modification to existing equipment, as it has been designed to be adaptable to any type of DF and radar. A block diagram of the direction finding coordination system is presented in foldout 2-3. The complete system is contained in a 7-inch high, 19-inch panel, 21 inches deep.

Connections with the direction finder are from the horizontal and vertical winding of the two-phase alternator mounted on the DF pedestal. These are fed into the DFCS amplifiers A1 and A2 which are high impedance (one million ohms) field effect amplifiers with a gain of 0.6 that isolate the 14-Hz signals from the DF. These amplifiers drive modulators M1 and M2 required to improve the resolver response.

Since the 14-Hz signal is low frequency compared to the 400 Hz, the output is 400 Hz suppressed carrier modulated at 14 Hz. This process is exactly reversible; that is, if suppressed carrier signal is applied into the output terminals, a demodulated signal will appear at the input terminals.

Amplifiers A3 and A4 have 9,100 ohm summing resistors at the input to give an overall gain of 0.5. These amplifiers accept the signal from the modulator and drive resolver No. 1. The resolver used in this application has six windings. Two stator windings are at right angles to each other to prevent a signal from one inducing a signal in the other. Two compensation windings are wound so that one will pick up the signal from one stator while the other picks up from the second stator winding. These compensation windings are used to provide the feedback signal that is applied to the driving amplifiers A3 or A4. This corrects any non-linearity within the stator winding by using the amplifier gain. The two remaining windings are rotor windings at right angles to each other. The signal phase shift induced on each of these rotor windings is a function of their angle with respect to the stator winding.

The rotor output is fed into amplifiers A5 and A6 which are connected as follower amplifiers and present a high impedance output to the resolver. The amplifiers drive the demodulators demod-1 and demod-2 where the suppressed carrier signal is demodulated and fed into the low pass filters. The output from the filters will be equal to the original 14-Hz input signal, but phase shifted by the angle of rotation, θ , of Resolver No. 1.

Following the filters are two stages of amplification. A7 and A8 amplify with a gain of four and present a high-input impedance to the filters. Squaring amplifiers A9 and A10 have no feedback resistors causing their outputs to be square wave, and to drive the diode-transistor logic gates (figure 2-23).

The servo system consists of a video amplifier, gated integrator, servo amplifier and servo motor.

The video output, as received from the direction finder, is a full wave 14-Hz signal superimposed on approximately +80 VDC. For the DF to work in a linear region, the majority of the DC voltage must be removed.

Signal processing amplifier A-11 (foldout 2-3) removes the DC, amplifies the signal level, eliminates some noise by filtering and provides an automatic voltage control feedback loop for maintaining a more nearly constant output amplitude. If the carrier is unmodulated the output of A-11 will be very similar to that described in paragraph 2.6.1b (figure 2-21B). This signal is the input to the gated integrator circuit.

The gated integrator is controlled by gates G1 and G2. If both gates are closed, then no input signal will be present to the integrator. Gate G1 opens first and remains open for 90 degrees of the 14-Hz video signal. This integrates one-half of an inverted lobe of the video signal. Gate G1 closes and gate G2 opens. Gate G2 allows integration of one-half video lobe. If the average integrated value of the video signal equals the average integrated value of the inverted signal, the net result of the integration is zero. If the two integrated values are not equal, then the sampled value is amplified to drive the servo motor. A schematic presentation of the case where the system null has a sample error of zero is shown in figure 2-24.

After integration is accomplished, G1 and G2 are off and G5 is closed. The integrated remainder of the integrator is fed into the servo amplifier. If a remainder is present the servo will be driven towards a null. Gate G3 discharges the integrator capacitor in preparation for integrating the next signal period.

The servo motor has two resolvers geared to the output shaft. One supplies the feedback signal to close the DFCS loop. The second provides a signal to the radar by replacing the cursor azimuth resolver with the radar. The entire servo loop (figure 2-25) contains the integrator, servo amplifier, servo motor, resolvers, and gate outputs.

The servo system, over a long period time, can be represented by a single position loop in which the resolver is rotated to feedback a resulting null into the servo amplifier. The short-term operation actually differs in the following manner:

The integrator integrates for one-half cycle of the 14-Hz period. An error voltage is obtained if the system is not aligned. In the next half cycle of the 14-Hz signal, the servo operates open loop without feedback to null the input signal. The integrator monitors the error signal and if it exists, the servo is again operated for one-half cycle. Thus if the servo drives through the null, the next half cycle the integrator will give a signal to drive in the opposite direction. With this system, a high-accuracy stable servo is obtained.

The digital display system is a redundant indication of aircraft bearing as measured from the DF antenna. The display consists of a voltage controlled oscillator, decade and binary counters, driver units, and three "sample and hold" Burroughs 8404 display assemblies.

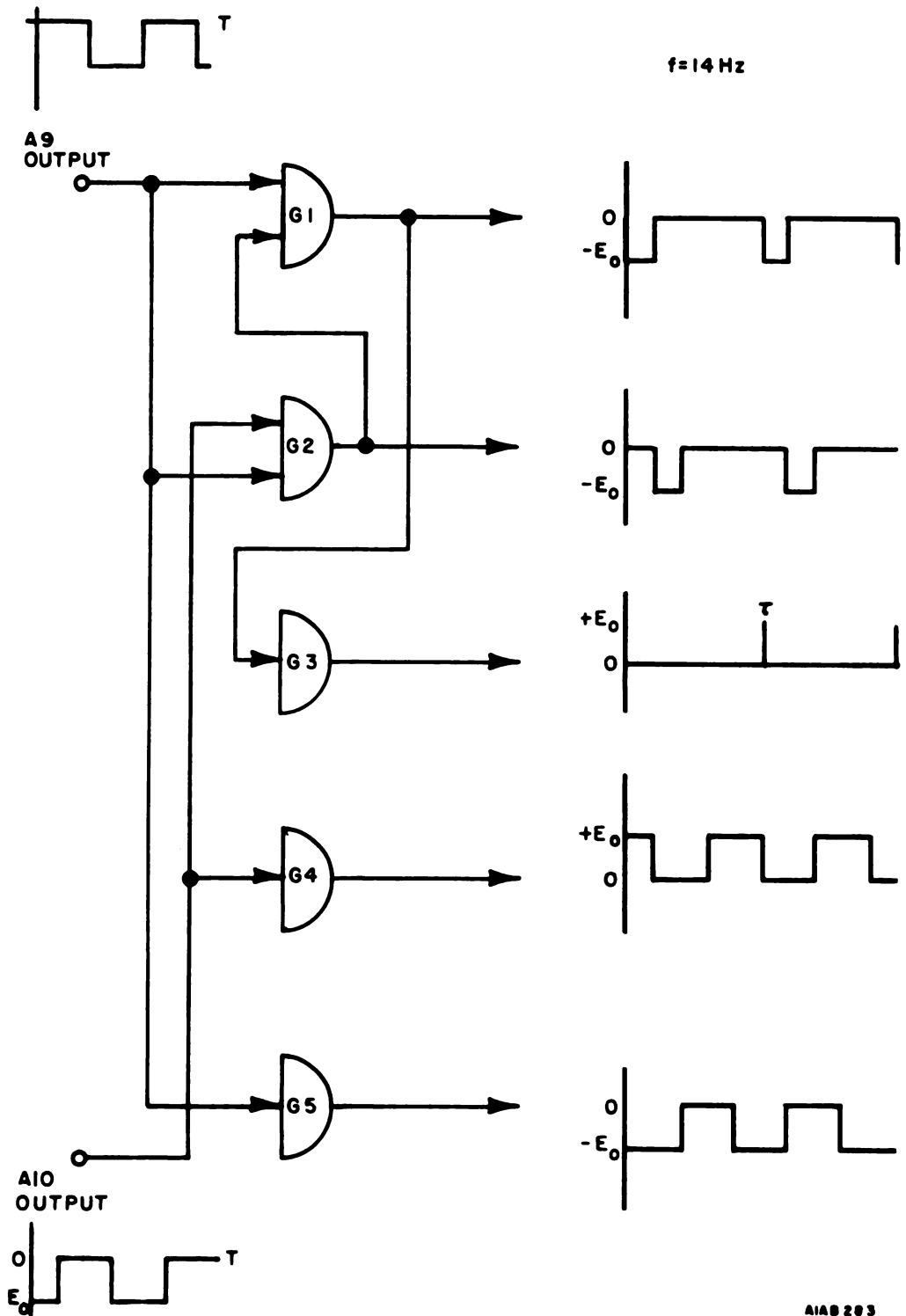
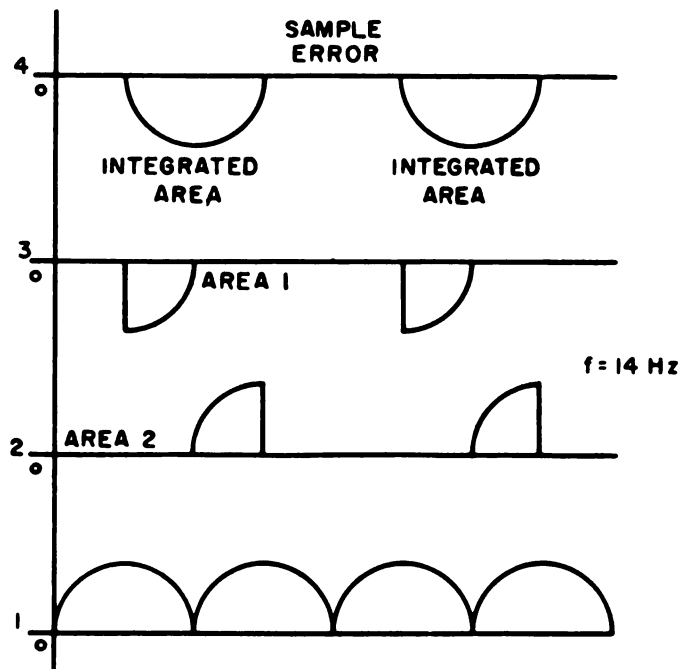
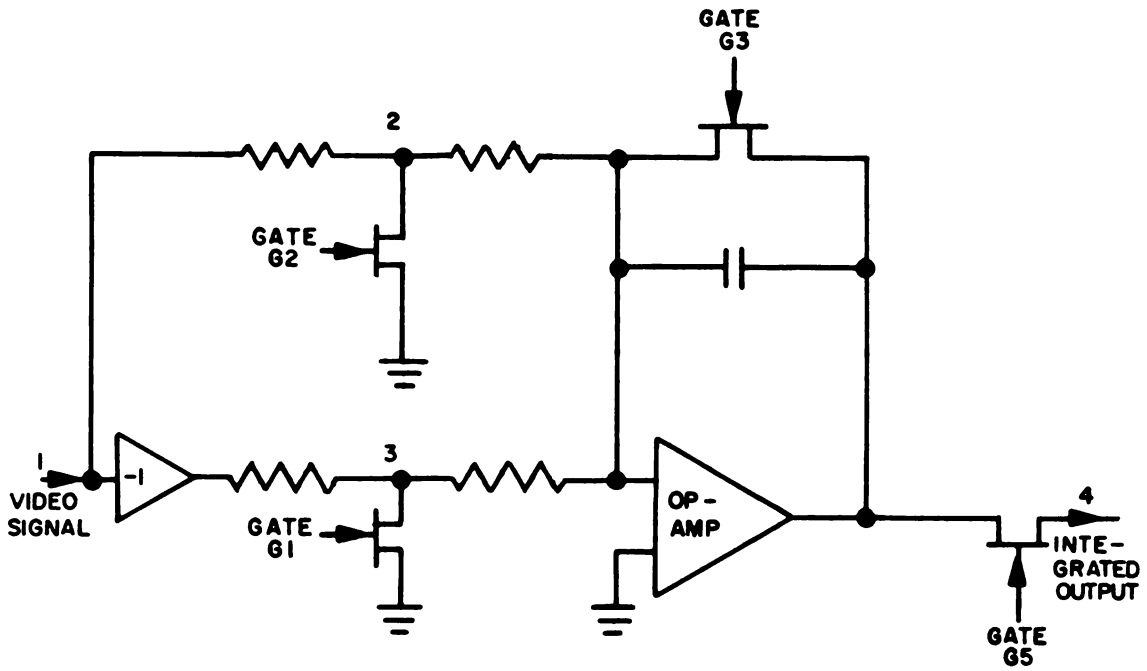


Figure 2 - 23. Direction Finding Coordination System, Logic Gate Schematic Diagrams



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Figure 2 - 24. Direction Finding Coordination System, Gate Integrator Schematic Diagram

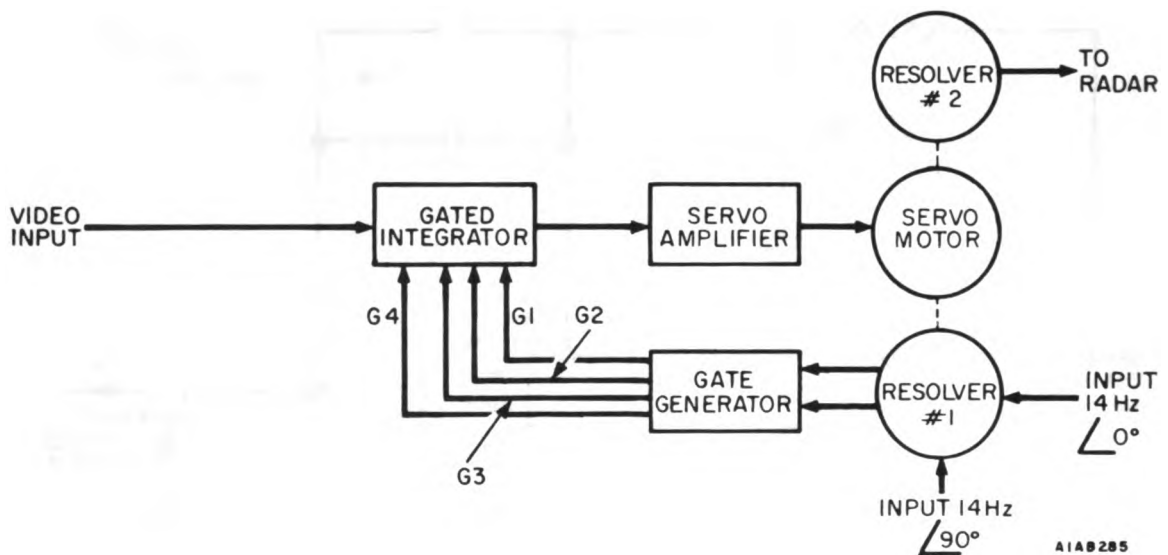


Figure 2 - 25. Direction Finding Coordination System, Servo Loop Schematic Diagram

The voltage controlled oscillator (a relaxation oscillator) drives the counters, and in turn the drivers. The sample and hold circuit samples the $\sin \omega t$ signal each time the counters are reset. The number in the counter is transferred to the digital readout units each time the "clear and transfer" signal is generated. Approximately every half second the display is updated. This number is θ degrees, which represents the relationship of the target with respect to true north of the antenna.

2.6.3 System Applications

A radio direction finder set on an air station is important, as its primary mission is to determine the exact bearing of any transmitted radio signal. Though aircraft-originated radio signals are of prime importance, an NAS-located DF in conjunction with a second DF may be highly effective in search and rescue efforts, antisubmarine warfare, and location of unfriendly transmitters. The range of the equipment is approximately 20 miles for surface-to-surface operation and approximately 90 to 125 miles for aircraft-to-surface operation.

The DF was originally used to supply course-guidance to direct aircraft into the range of GCA control with the advent of search radar, VOR, and TACAN, the DF set has been relegated to the roll of an emergency navigational aid. When an aircraft cannot use VOR or TACAN, and search-radar monitoring is not available, a controller may use the DF to guide that aircraft into the landing area.

If the search radar is available, and is combined with the DFCS, the DF becomes extremely useful as an aid in monitoring the movement of aircraft. Incorporation of the DFCS in the ATC system has the following advantages:

- o Does not affect normal operation of either the DF or radar
- o Adaptable to other equipment types
- o Requires only minor modification to existing equipment
- o Simple to install, operate, and maintain.

The direction finder is also used periodically to maintain controller-proficiency in its utilization.

CHAPTER 3

AIR TRAFFIC CONTROL SYSTEMS

Navy Air Traffic Control System's mission is to provide safe, efficient, and orderly movement of aircraft arriving at and departing from Naval Air Stations, aircraft movement control over larger areas as required to effectively carry out the missions assigned to a given station; and station and area control coordination with civil airways en-route control. The system is closely related to each station's operations department and has two major components: the tower cab, which is basically responsible for air traffic control at each station and which provides complete control when in visual contact, and the instrument flight rules (IFR) room, which supports the tower by providing control through radar contact at distances beyond visual range and under other than visual conditions. The IFR room employs medium-range and short-range radars for area control and precision radars for control of instrument landings. Both the tower cab and the IFR room employ a large number of communication links to effect control over aircraft, and to coordinate their activities with other parts of the station's operations department as well as with civilian aviation agencies. Navy air traffic control systems may operate independently but in coordination with civilian agencies, or they may operate jointly, sharing facilities with the civilian agencies.

In fulfilling its mission, the Navy Air Traffic Control System is organized to perform two basic functions:

- o Preparation and dissemination of flight plans and clearances.
- o Control aircraft on the ground and in the air during arrival and departure and en route.

To perform these functions, the Navy Air Traffic Control System consists of a number of individual systems: control tower, radar and communication systems and subsystems. A description of these systems and subsystems will be found in this chapter.

3.1 NAVAL AIR STATION CONTROL TOWERS

The nerve center of a Naval Air Station is considered to be the control tower of which the primary function is the housing of the visual flight rules (VFR) room at the most advantageous position and elevation with respect to the airfield.

3.1.1 System Principles

A standard component of all air stations is the control tower. Whether integral with the operations building or as an independent structure, the control tower is the nerve center of an air station. Its functions are to centralize control over aircraft activities, both on the ground and in the air; to promote safe and orderly movement of air traffic; and to facilitate control of all aircraft within the general area designated as being under control tower jurisdiction. The control system provides taxiing instructions, takeoff clearances, designations of landing priorities, approvals to deviate from prescribed traffic patterns, collision course warnings, reports of emergencies, directions for air and rescue, required information on aircraft traffic, airfield surface conditions, weather, and other pertinent conditions.

Aircraft control is exercised by voice communication on designated channels, by visual means (light gun), and is supported by air navigational aids (VOR, TACAN and beacons), radar, and radio direction finders.

In controlling aircraft movements, the control tower personnel perform three major functions: ground control, air control, and the accumulation of flight data on all aircraft traffic in the area. The required number of operating personnel required in a tower varies from two to six, according to station traffic.

Control of aircraft in the air, taking off, and landing is the prime responsibility of the local controller. His additional responsibilities are as follows:

- o Establishing landing and takeoff intervals, and controlling the separation of aircraft in the traffic pattern during VFR operating conditions.
- o Monitoring weather (wind, altimeter settings), NAVAIDS, and field condition displays, and communicating this information to approaching aircraft.
- o Monitoring all assigned radio frequencies and providing local traffic information to the pilot either on request, or when necessary, in the interest of safety.
- o Responding to landing clearance requests from the precision controller and coordinating traffic movement with the approach and radar surveillance controllers during IFR conditions.
- o Relaying messages to the Officer-of-Day regarding VIP's aboard arriving aircraft, and informing cognizant personnel when aircraft emergencies occur.
- o Dispatching fire, crash, and rescue equipment for emergency landings, crashes, and accidents.

Control of aircraft on the ground and vehicles on taxi-ways and runways is the responsibility of the ground controller. His specific duties include:

- o Providing taxi instructions to arriving and departing aircraft.
- o Relaying flight clearances and performing radio checks.
- o Making time checks, providing wind, data, altimeter settings, and information concerning field conditions to departing aircraft.
- o Routing terminal traffic to desired airfield destinations.
- o Controlling the movement of motor vehicles operating on active portions of the airfield.
- o Operating airport lighting facilities and utilizing the mobile air traffic control light (light gun) to communicate with ground traffic not equipped with radio, or whose radio equipment has malfunctioned.

Accumulating, maintaining and disseminating flight data is the prime responsibility of the flight data controller. His duties include the following:

- o Receiving, copying, and posting on data strips all flight data pertaining to arriving and departing aircraft.
- o Passing the data strips to the appropriate ground or local controller.
- o Recording all traffic control messages, NOTAMS, weather information, flight plans, progress reports, and departure and arrival times on appropriate forms and either posting or disseminating this information to cognizant personnel.
- o Maintaining airport traffic control operating forms and filing flight data information and terminated flight progress strips.

- o Providing assistance to the other controllers during emergency and unusual situations, or as directed by the tower watch supervisor.

The tower watch supervisor is responsible for control tower operation in accordance with applicable directives and standard procedures. His specific duties include:

- o Supervising the checking of all communications and other tower equipments.
- o Maintaining proper coordination between the tower and IFR room.
- o Organizing, training, and assigning controllers to function as a smooth-working team.
- o Providing instruction in evaluating and processing flight information, communication techniques, and standard operating procedures.
- o Notifying cognizant personnel of emergencies and other unusual situations involving the control of aircraft.

Usually there are three controllers (local, ground, and flight data) on duty in a control tower. On a small airfield with very light air traffic, two controllers may be adequate to safely control the air and ground traffic.

During periods of high traffic density and at air stations having more than one active runway, it may be necessary to double-up on one or more of the controller positions. Flight data and ground controller operations may require one each to control arriving and departing aircraft. The local controller position may also require one for arriving and one for departing aircraft, or one for each runway. But the important point is that a good working team can greatly increase the safe, efficient, and orderly flow of aircraft in, out, and around an airfield.

3.1.2 System Description

The control tower is often constructed as a part of the operations building for the sake of convenience, since offices and facilities for aerology, operations, and communications are also located in this building. The tower should be located as near the geometrical center of the runway system as practicable, taking into consideration any future expansion of runways.

The standard air station control tower, as shown in foldout 3-1, is designed to provide for:

- o Control room (control cab)
- o Electronic equipment rooms
- o Electronic equipment
- o Emergency communication system
- o Emergency generator equipment
- o Air-conditioning equipment
- o Sanitary facilities

3.1.3 Description of Control Tower Cab

The control tower cab or VFR room, is the focal point of the air traffic control system. The cab operation is basically responsible for ATC at each station, and provides complete control of aircraft under VFR conditions. During conditions of limited visibility, cab personnel coordinate all air traffic movements with the IFR

controllers. In order for the cab personnel to be able to exercise maximum overview of airfield runways, taxi-ways, and parking aprons, the control cab is located at the top of the control tower.

To perform the ATC function, the cab is provided with standard controller consoles and required ancillary equipment. A standard cab contains three controller consoles or controller positions which are referred to by the function each performs; local controller position, ground controller position, and flight data position. The local and ground controller positions are practically mirror images of each other, so as to provide the flexibility of shifting these functions from one side of the cab to the other as required by traffic condition. The overall view of a modern cab is shown in figure 3-1.

A standard modern control tower cab equipment arrangement is shown in foldout 3-2. Positions A and C are quite similar in equipment allocation and layout, so that either one may be the local controller position while the other acts as the ground controller, according to the air traffic pattern prevailing. Position B is the flight data controller's position and is typically located between the aircraft controllers to whom they provide data and assistance.

Examination of each controller position indicates that all three positions (refer to foldout 3-2 and figures 3-2, 3-3, and 3-4) contain complete communication circuit control equipment (items 1-6), weather and time indicators (items 8-10), and flight data strip holders (item 14). The two controller positions also contain parallel operated visual communication (VISCOP) units (item 27), details of which are presented in paragraph 3.1.5. Position A also contains the emergency communication control (ESC) panel (item 7), and the emergency panel (item 15) which controls the perimeter road lights and emergency flares. The order wire control (item 20) is an intercom type system for communicating with the maintenance sections and other pertinent areas in the station. Details on the communication equipment are presented in paragraph 3.5.

Additional equipment located at the flight data controller's position (B) includes the red crash phone (item 18) and control panel (item 21), and the original wind indicator unit (item 19), and traffic counters (item 24) to record the different flights in and out of the field. Between positions B and C is the general airport lighting switch panel (item 16) for control of field installed equipment and area obstruction lights and taxi-apron lights. To the right of this panel is the field lighting panel (item 17) which controls the taxi-way and runway lights, including their intensity. The location of these lighting control panels as shown is necessary for a smooth, efficient, ATC operation.

The weather vision monitor (item 13) is located at position C to provide the aircraft controllers with the latest weather information available directly from the aerology office. The runway visual range indicator (item 11), located below the weather vision monitor provides a direct reading of the visibility in the area of touchdown of the instrument runway. The landlines amplifier (item 22) is located next to the runway visual range indicator and is used in conjunction with the landline circuits operating in and out of the control cab.

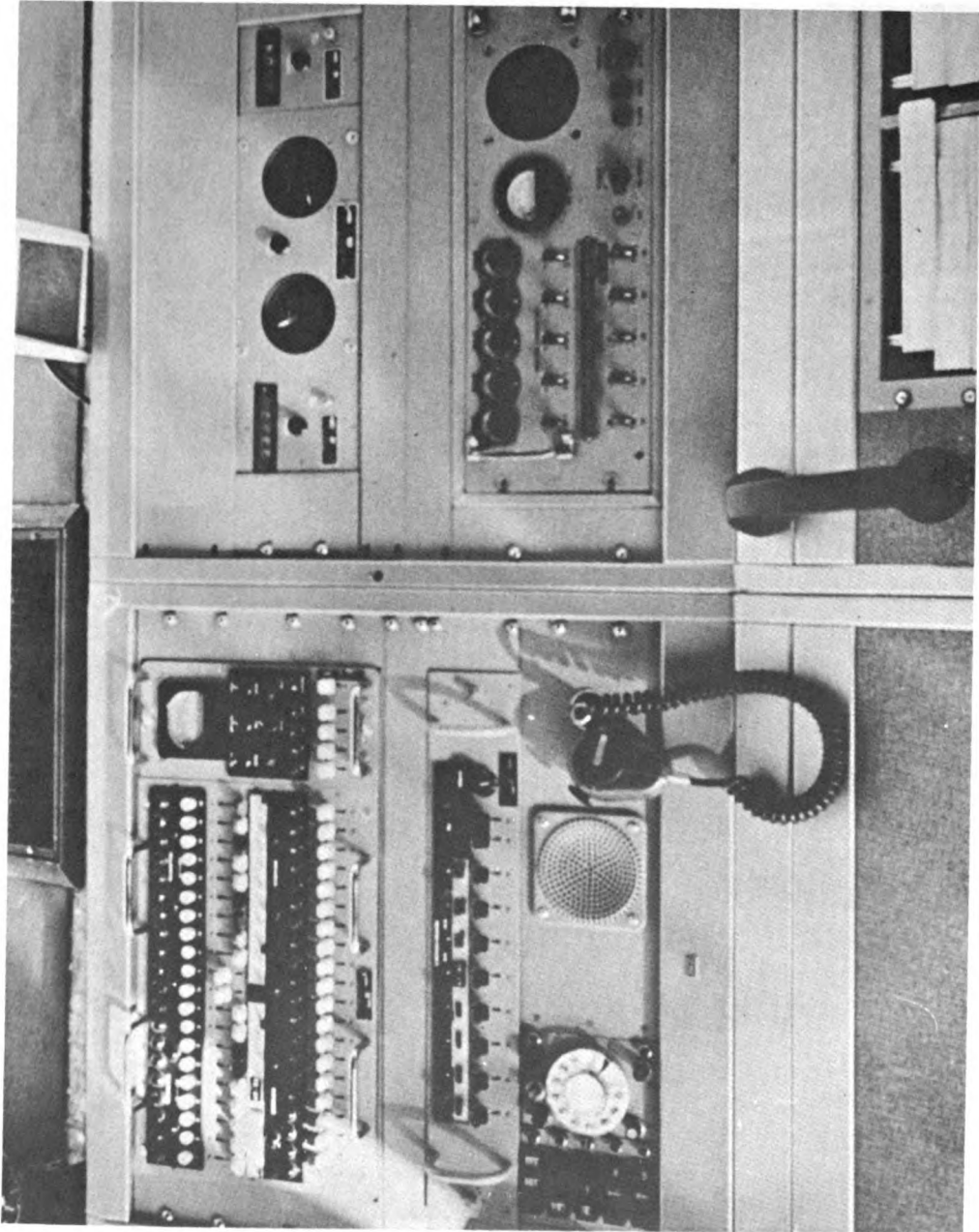
Next to position A is located the ATIS microphone (item 25), on top of the desk, with the recorder placed below. Also on top of the desk is the telewriter (item 28). This unit is used at some stations for incoming weather information where they do not have weather vision, and some stations use it for incoming flight data information from the flight planning office on the station or the area en-route center. The final item shown is BRITE-2 (item 26), which is a radar repeater for use in the control tower and is further described in paragraph 3.4.3.

The control tower cab described is typical for all sizes of air stations, including the largest facility with high air traffic density. If the control tower cab is physically larger than the one illustrated in foldout 3-2, the equipment may be arranged differently and may even include additional equipment for doubling up on operating positions. For instance, NAS Lemoore sometimes operates as two separate airports, in which case there are two local controllers and, if necessary, two ground and flight data controllers. The layout of the cab and the additional equipment is such as to allow this type of operation.



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Figure 3 - 1. VFR Room, Overall View



AIAB 274

Figure 3 - 2. VFR Room, Controller Position A

AIAB275

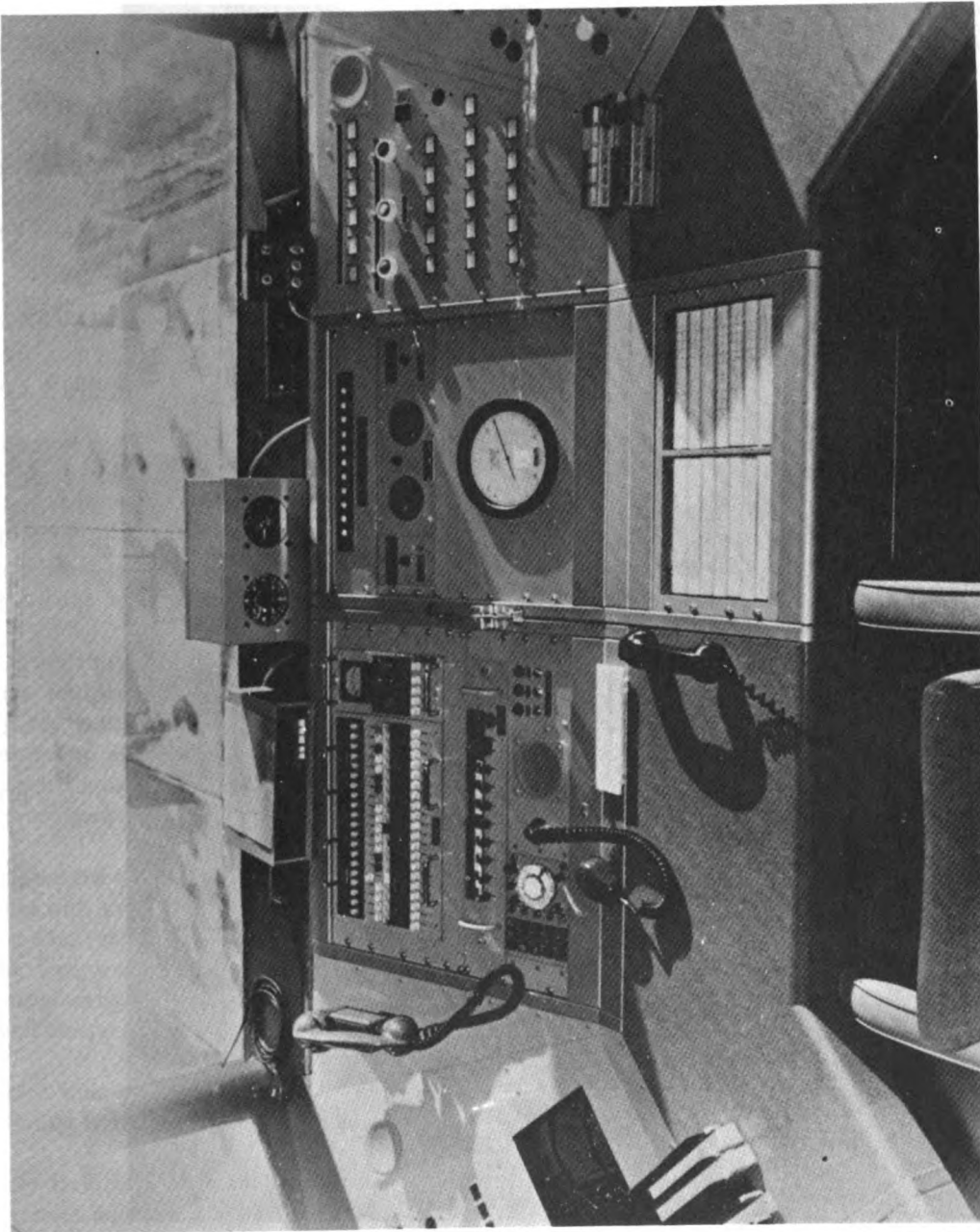
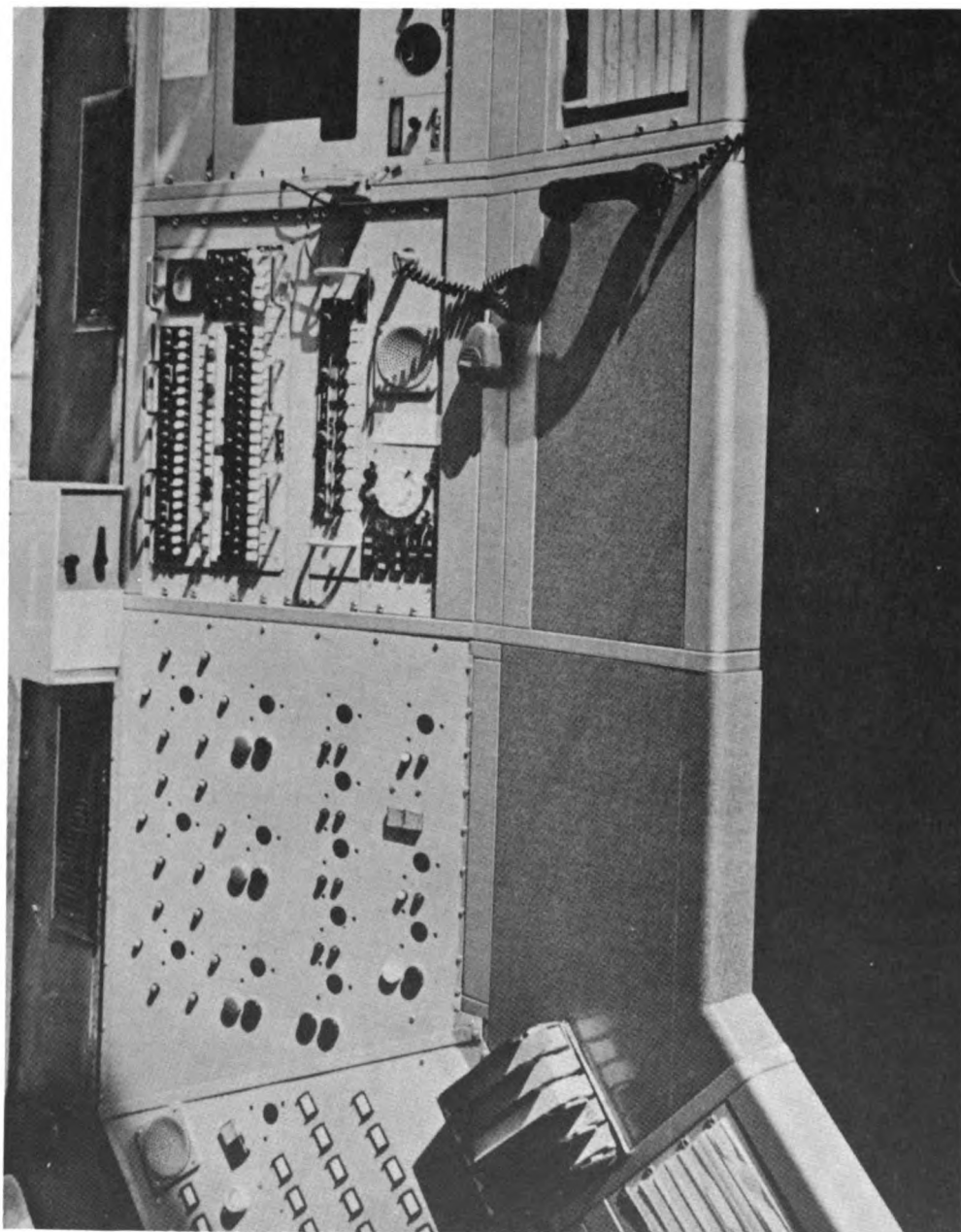


Figure 3 - 3. VRF Room, Controller Position B



AIAB275

Figure 3 - 4. VRF Room, Controller Position C

Additional items that are important parts of the control cab include:

- o Light gun - usually suspended from the ceiling
- o Radio direction finder - at small facilities having no IFR room
- o Floor covering and acoustical ceiling tile - for noise abatement
- o Window shades - dark, for use on sunny days, to prevent wash-out of indicators and monitors
- o Air conditioner
- o Cockpit lights - on top of consoles for nighttime operation, with a minimum of window reflections
- o Floor lighting - under consoles for nighttime operation to allow safe movement about cab without reflections
- o NAVAIDS display and control - to monitor operation of navigational aids in the area of the station.

3.1.4 Control Tower Configuration

The control tower is normally a five-floor structure located on relatively flat terrain of the air station. A height of 43 feet, from the ground to the floor of the control cab, is considered as the minimum acceptable elevation (foldout 3-1). Where necessary, control towers are built as high as 10 floors in order to provide adequate visibility to all runways, taxi-ways and parking aprons. The standard air station control tower is usually erected as an integral part of the operations building. If built as a separate unit, it should be designed in such a way as to permit the possible future addition on the standard operation building.

It is mandatory that emergency communication equipment be installed in the control tower to function as backup equipment to the normal complement of electronic equipment installed in remote facilities. An emergency generator with automatic start and switchover capabilities is included as part of the control tower equipment to assure continuous communication equipment operations. Control of the emergency communication equipment must be completely independent of normal console control facilities. Unless an automatic-start emergency generator is immediately available, battery-operated equipment is required.

During normal operating conditions, control tower equipment utilizes the station prime power. However, in order to cope with primary power failures and emergencies, a 60 kilowatt emergency generator is provided and located on the first (ground) floor. The ground floor area should be large enough to permit easy repair and maintenance of the emergency generator. In addition, the room must be well ventilated and equipped with intake and motorized exhaust louvers. At those station locations where air conditioning of the cab is not required, a 30 kilowatt emergency generator is sufficient to meet the power requirements of the control tower equipment.

The electronic equipment room contains the emergency communication equipment, voice recorders, the main distribution frame, and other equipment.

Sanitary facilities should be located on the floor immediately below the control cab. Fixtures should include a water closet and a lavatory supplied with hot and cold running water. A cold water drinking fountain should be provided in the control tower cab.

The previous description is in reference to the fixed control tower type and may vary in size from small, to medium, to large, as required. Another control tower type is the mobile or transportable tower. This type of control tower is used during emergencies, during construction of a fixed tower, and for interim use during rework of a fixed tower. The size and shape of the mobile-transportable control tower varies from a small utility van containing a few transceivers with batteries or portable engine-generator, to a larger van containing a

complete complement of communication and meteorological equipment, controller's operating position including windows, air conditioning and portable engine-generator, and finally to an erector-set type control tower which is constructed on the site with a tower, a completely equipped cab, total complement of communication and meteorological equipment, air conditioning and portable engine-generator.

The small utility van, after arrival at a site, could be set up and be ready for operation in a matter of minutes. This type of control tower would be used during an emergency at an air station or an emergency at an outlying airfield for aircraft training sessions. The van usually is a completely enclosed vehicle which is operated from the outside with possibly a door open for access to the equipment. A slightly larger van with no more equipment, but additional room for the controller, is used at some activities. In this unit there are plexiglass windows on all four sides, so that the controller may sit inside and still have good visual contact with the air traffic. The portable engine-generator is mounted on the outside of this cab.

A transportable control tower, known as Air Traffic Control Group, which is constructed or assembled on the site is shown in figure 3-5. This air traffic control facility can be placed into service rapidly, and in case of emergency, can be relocated without delay.

This configuration is designed as a complete airfield control system, and consists of a console-shelter group, an electrical equipment shelter, and the tower (a sectionalized mounting structure). All three subsystems are transportable by truck or cargo-type aircraft.

The ATC Group contains adequate equipment to provide complete control of aircraft traffic. In the control cab there are two operating positions provided for controlling up to 10 transmitting and 10 receiving circuits, and 4 telephone circuits. The controllers also have available a VHF and a UHF radio direction finder, a UHF and a VHF radio set for emergency communications, wind direction and velocity indicators, a portable signal light, and a clock. An exterior view of the cab is presented in figure 3-6, showing the many antennas, siren, wind transmitter, and the obstruction light mounted on top. The floor of the cab is 24 feet above the ground, providing the controllers a good view of airfield operations.

The electrical equipment shelter provides rack mounting for the remotely controlled receivers and transmitters, sound recorder-reproducers, and power control and distribution panels; an external power source is required for this system capable of supplying 120/208 volt, 60 Hz, 3-phase 4-wire AC power at 16 kW minimum. Interior views of a typical equipment shelter is shown in figure 3-7. If additional communication equipment is required a second equipment shelter may be used. Some antennas may be mounted on top of the shelter.

The tower is installed in sections with each section assembled on the ground and then raised into position. The cab is mounted on top of the tower with the use of a crane or a helicopter. The assembled tower occupies only a ground area of approximately 6 feet x 4 feet but additional space for installing the guy wires requires a cleared area of approximately 80 feet x 80 feet. Details for assembling the tower and operating the equipment therein are thoroughly described in the manual provided with each ATC Group.

3.1.5 Air Traffic Control Subsystems

A number of air traffic control subsystems not detailed elsewhere in this handbook are described in this paragraph.

a. Visual Communication Monitor Group. The Visual Communication-Monitor Group (VISCOM), a modular communication system, provides visual display of operational information/instructions transmitted between two separately located controllers (see figure 3-8).

Much information normally transmitted on voice circuits between two control points is of a stereotyped nature, and may be represented by simple codes or single words. VISCOM uses lighted pushbuttons labeled with standard phrases to pass such messages between two controllers. Thus voice circuits which parallel VISCOM are not used for routine messages and are reserved for unique messages resulting in the following advantages: significant reduction in voice communications; voice traffic may concentrate on other communications without interruption; and pushbuttons provide a reliable memory display while other tasks are being accomplished.

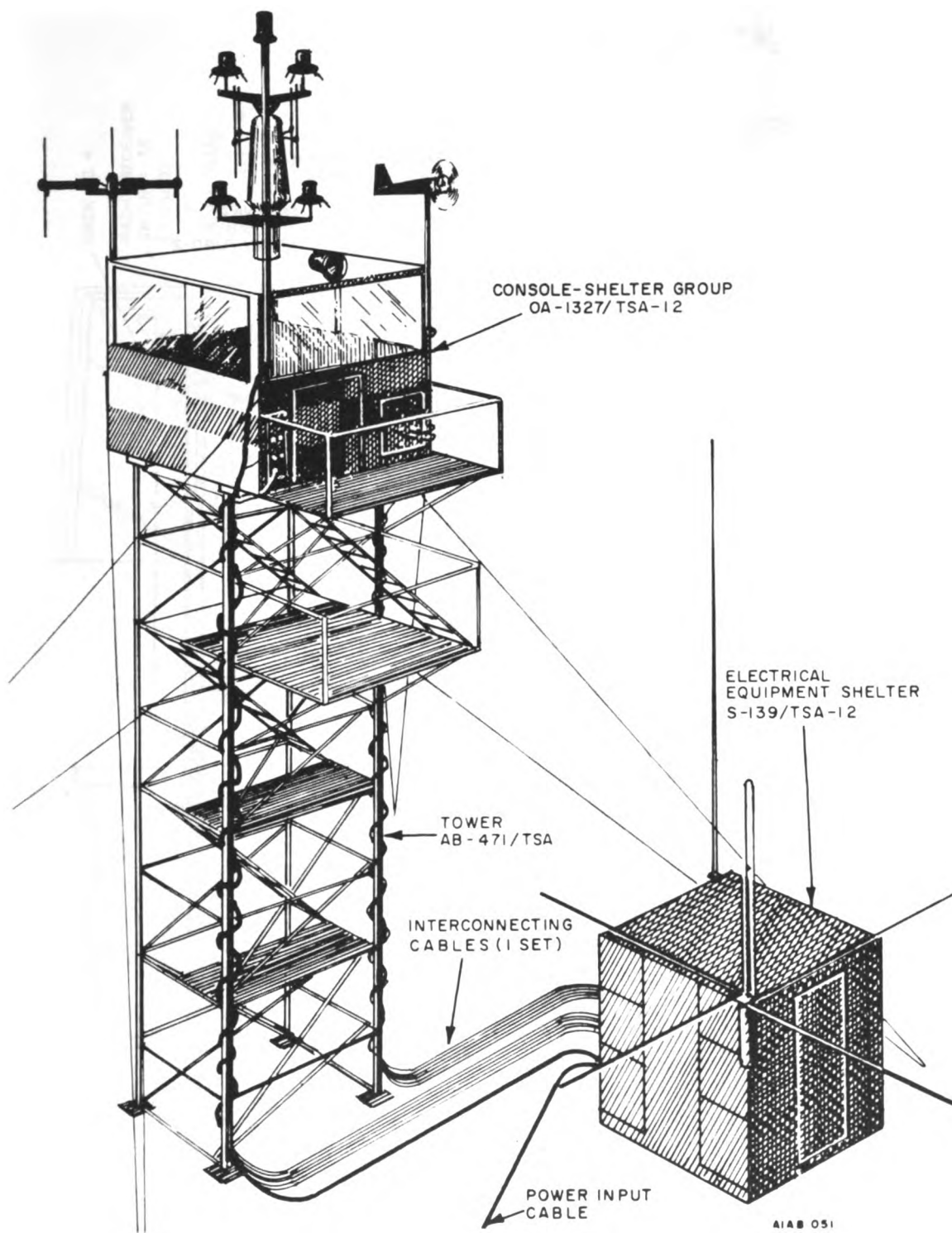


Figure 3 - 5. Air Traffic Control Group, TSA-12

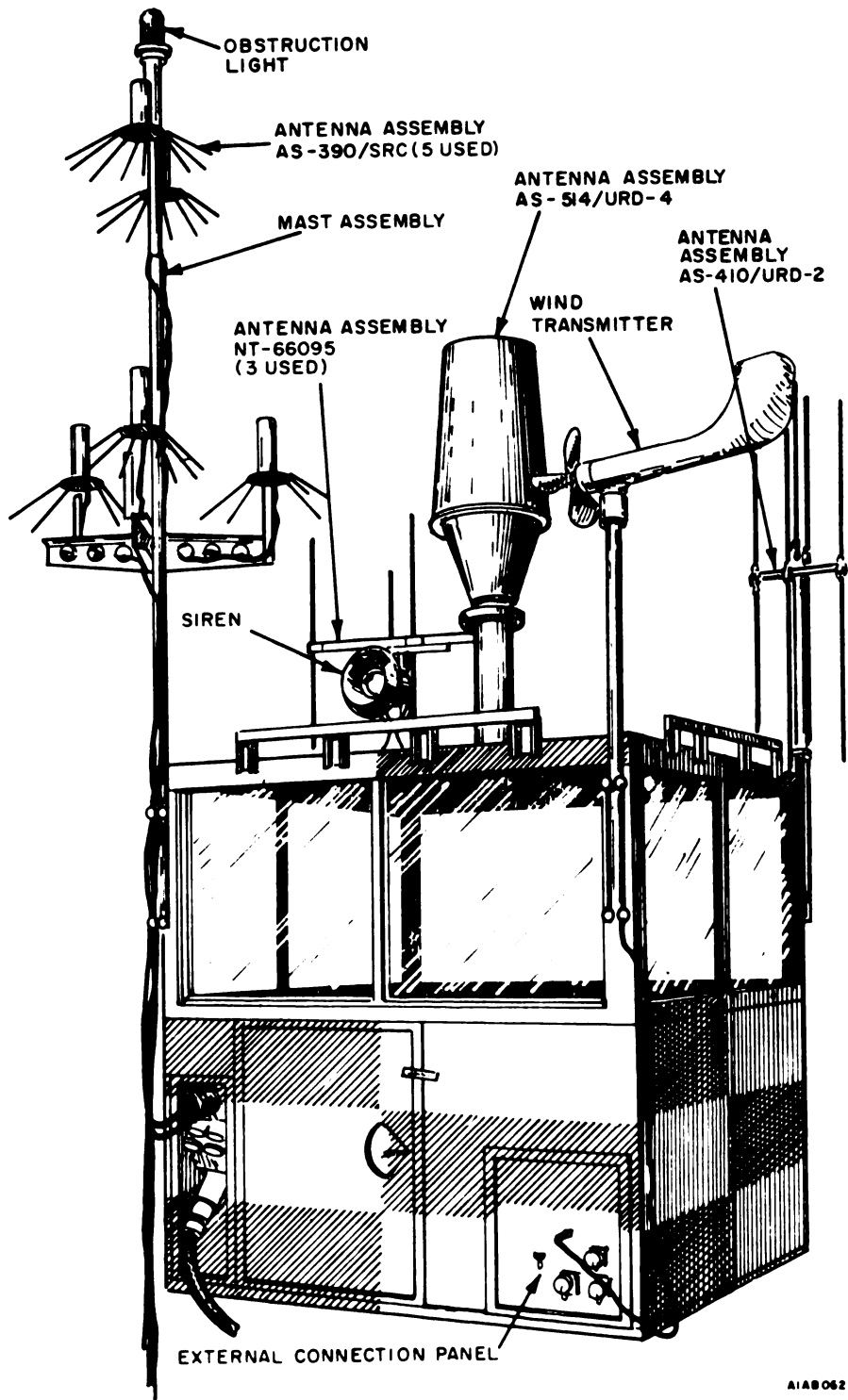


Figure 3 - 6. Air Traffic Control Console-Shelter Group, TSA-12

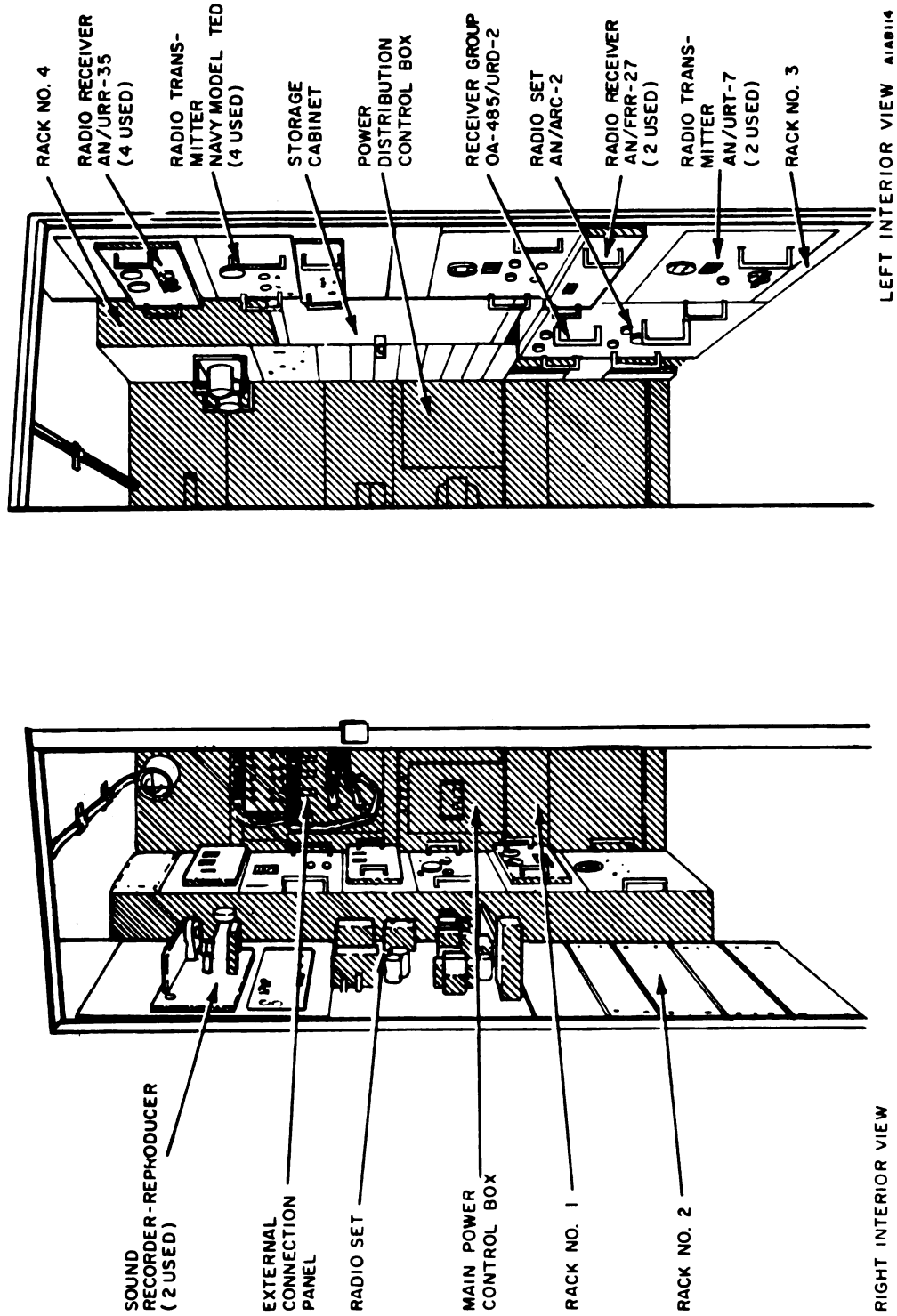
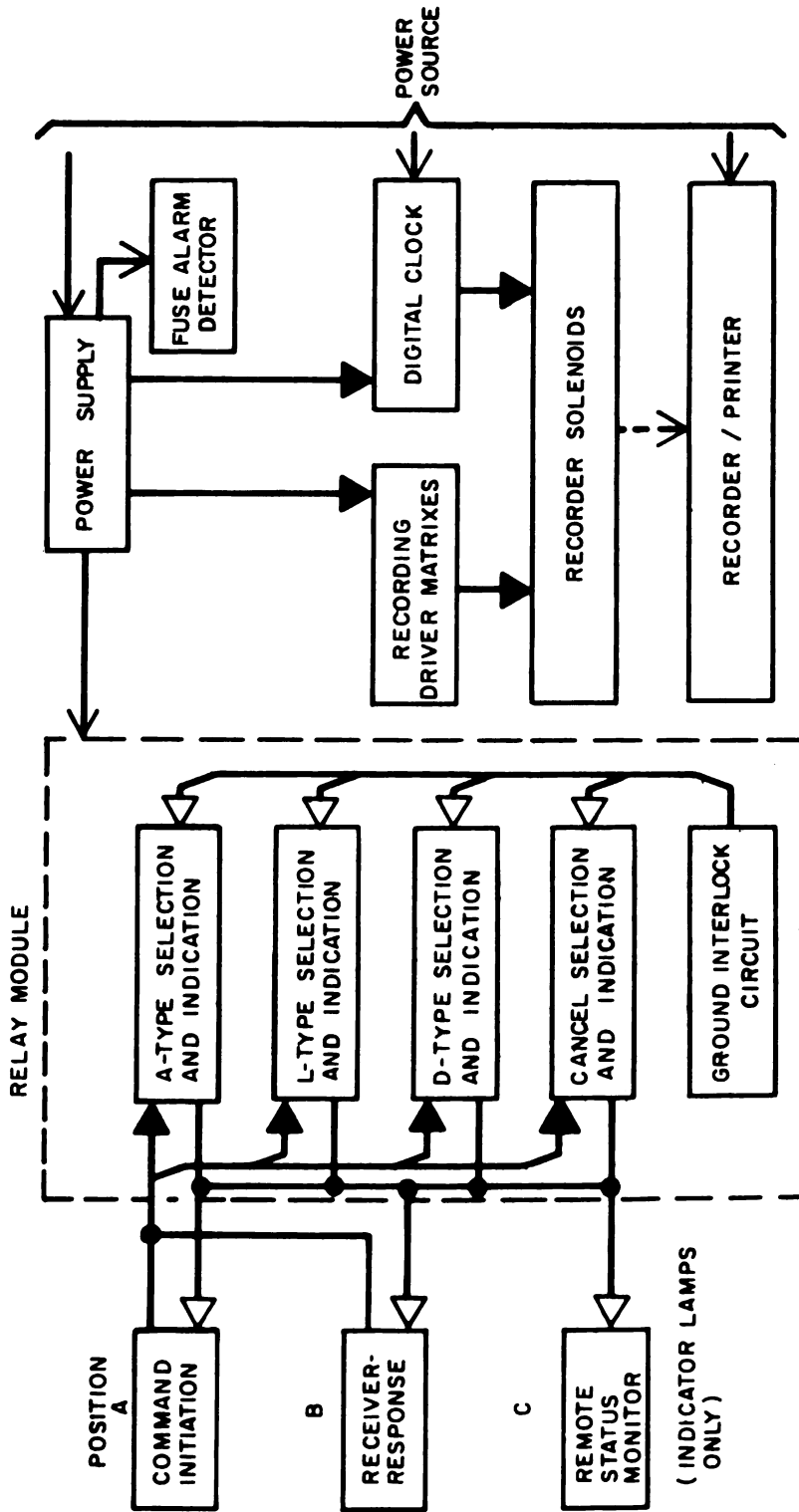


Figure 3-7. Air Traffic Control Electrical Equipment Shelter, TSA-12, Interior View



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Figure 3 - 8. VISCOM Functional Block Diagram

The prime application of this system is its use for ground-based communication between the precision approach radar (PAR) controller in the IFR room and the local controller in the tower cab.

VISCOM provides up to five independent information channels, each with 16 individual messages. Each channel has two active switching panels (A-COMMAND-INITIATION, and B-RECEIVER-RESPONSE), and one passive panel (C-REMOTE STATUS-MONITOR). Each channel is subdivided into three message groups: A, L, and D. A CANCEL pushbutton clears and resets the channel.

- o A Type. An information/definition-type message group that must be originated by the A position and acknowledged by the B position. Five pushbuttons provide selection of discrete messages. When one message is chosen, the other four are locked out.

- o L Type. A request or permission-type message group that must be originated by the A position and acknowledged by the B position either by an acceptance or by initiation of an alternative message that must then be acknowledged by the A position. Four pushbuttons provide a selection of this type message with a fifth pushbutton reserved for a request for emergency action. This request may be originated by either A or B position. Once chosen, the other four messages are locked out.

- o D Type. A sequential operation type message group for progressive instructions that must be originated by the A position and acknowledged by the B position. Five pushbuttons provide for unidirectional progression of changing messages. Any button of this group may be skipped to accelerate the progression. Once chosen, all buttons to the left are locked out.

- o Cancel and Reset. A CANCEL pushbutton entry, when acknowledged, clears and resets the channel for new message entries. Cancellation may be originated by either A or B position.

Additional features of VISCOM are:

- o Incoming messages are announced by both a flashing light and a pulsating audible tone. Acknowledgment stabilizes the light and mutes the tone.

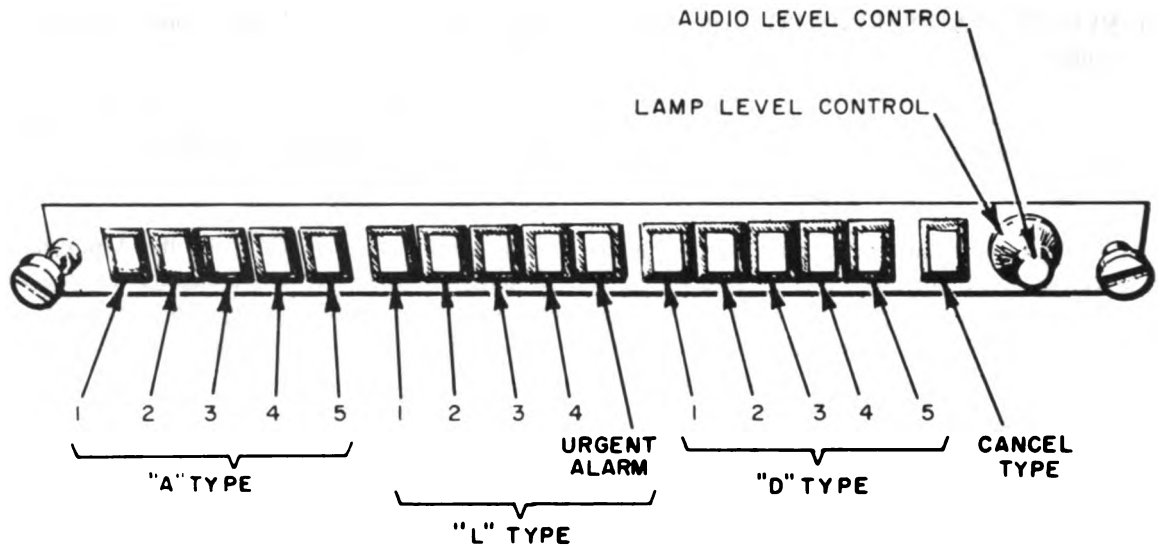
- o A permanent recording of all messages passed between the two positions, including time of transmission to within a tenth of a minute, is provided.

- o The system is adaptable to operation in either light or dark environments.

A typical VISCOM installation at an air station has one switching panel unit, as shown in figure 3-9, installed in each IFR room PAR controller's console. The responding switching panels will be clustered in the control tower cab, at the local controller's position. If the local and ground controller's positions are reversed according to air traffic flow, parallel clusters of switching panels should be installed, as illustrated in foldout 3-2 (item 27).

The legend of titles used on each pushbutton-indicator (figure 3-9) illustrates the type of communication required between the IFR room and the control tower. Normal operation would be for the PAR controller to inform the local controller of the type of aircraft and its intentions when the aircraft is approaching the start of PAR control. Thus the PAR controller would press one A type and one L type switch and D-1 switch. With this procedure, the PAR controller is also requesting permission for the aircraft to land. The local controller's response to the flashing lights and pulsating tone may be affirmative or negative. If permission is granted for the aircraft to proceed in the landing pattern, the local controller will press the flashing buttons to stabilize the lights and mute the tone. A negative reply would be indicated by depression of the wave-off button and acknowledgment by the PAR controller, who would so inform the pilot.

As the plane proceeds to follow the PAR controller's guidance toward touchdown, the VISCOM is used to inform the local controller of the aircraft's progress. At each mile-post indicated, the appropriate button is depressed. A tower response in the affirmative or negative must be indicated at each checkpoint. After touchdown or passage of the aircraft, the local controller will depress the cancel button to clear and reset the channel. The PAR controller will respond by depressing his cancel button, thus resetting his panel.



LEGEND OF TITLES

- "A"
1. JET
 2. PROP
 3. JET TRANS
 4. PROP TRANS
 5. HELOC

- "L"
- FULL STOP
 - TOUCH & GO
 - LOW PASS
 - EMERG
 - WAVE OFF

- "D"
- 7
 - 5
 - 3
 - 1
 - CONT

AIAB055

Figure 3 - 9. VISCOM Switching Panel Unit

b. Environmental Display System. Time, wind speed and direction, and altimeter setting are four important facts required by all controllers in the tower and in the IFR room. To allow each controller to have this information at his finger tips, a standard 5-1/4 inch x 19-inch panel has been designed and installed in modern ATC facilities. The panel consists of two 3-inch servo repeaters and two digital displays (see figure 3-2, upper right side).

The servo repeaters are used to display the wind speed and direction. The transmitter for this servo system is located in the weather vane. Further details on the system are presented in chapter 6.

The two digital displays, one on each side of the wind indicators, present the time and altimeter settings with projection type light readouts. Control for the 4-digit altimeter setting is located in the meteorology office. It consists of four 10-position switches mounted in a cabinet along with a power supply. The aerographer on duty determines the altimeter setting and manually sets the four digits.

The second display presents Zulu Time (Greenwich mean time) to a tenth of a minute. This 2400.0-hour readout is part of the master clock system installed to assure that all controllers will have exactly the same time indication. The systems central equipment uses the 60-Hz power source to generate pulses which are used to step a set of relays. These relays control the digits displayed at the controller's position. The system can be calibrated or reset in case of a power failure at the systems central equipment location. At this position, provision must be made for installation of a radio receiver capable of tuning to WWV, or a telephone line, for obtaining time checks.

c. Field Lighting Control. For safe and efficient ATC operation, the field lighting control panels should be located convenient to the local controller, as shown in figure 3-1 and foldout 3-2. Any other location would be inconvenient and detrimental to the air station air traffic control operation. During nighttime arrivals and departures it is sometimes necessary to quickly adjust the runway or taxi-way lights to accommodate a pilot in a fast moving aircraft. A delay in adjusting the lights could be dangerous and costly.

d. Ancillary Equipment. Additional equipment used in the control tower include:

o Light gun. Located in the tower cab, the portable traffic control light gun is utilized to control the movement of vehicles and aircraft on the runways and taxi-ways, that are not equipped with radio or have had radio failure. The light is usually mounted overhead, suspended from the ceiling with a retractable chain and cable. A selector handle allows the controller to select red, green, or a clear light; a spring-loaded switch in a pistol type grip, enables the controller to flash or to hold steady the selected color. The light emits a narrow beam which has a range of approximately 10 miles during daylight and 15 miles at night.

o Telewriter (Teleautograph telecriber). The telecriber is an electromechanical system which transmits handwritten messages simultaneously to multiple receiver stations. This system is used as a supplement for weather dissemination on an air station not equipped with Weathervision. The telewriter may also be used to pass flight data information between the tower, IFR room, and the flight planning office.

3.2 RADAR

The acronym RADAR, formed from the capitalized letters in RAdio Detection And Ranging, signifies a means of employing radio waves to detect and locate material objects. Location of an object is accomplished by determining the distance and direction from the radar equipment to the object and requires, in general, the measurement of three coordinates; usually range, angle of azimuth, and elevation.

Applied first in wartime, radar searched the sea for enemy ships and surfaced submarines and kept watch in the sky for aircraft. Radar aided air and sea navigation and directed fighter and bomber aircraft. Radar information was used to aim large guns and anti-aircraft weapons, and airborne radar controlled the dropping of bombs. In peacetime, radar and allied techniques contribute greatly to the safety of air and sea travel. Radar-equipped ships move through fog without danger of colliding with other ships or with ice floes. Despite weather conditions or poor visibility, aircraft can be prevented from colliding in mid-air, and the capacity of airfields can be greatly increased by radar traffic-control and landing systems.

To meet the requirements of the many different applications, radar sets having a wide variety of characteristics have been manufactured. Some are designed, for example, to detect objects at the greatest possible distance. This type of equipment is referred to as search radar. In others, range is sacrificed in order that accuracy and resolution may be as high as possible. Precision radar fits this description.

3.2.1 RADAR Functional Categories

Radar equipment may be classified in two categories according to their function:

o Search-Type Radar Sets may be further classed in two groups when part of air traffic control, medium range and short range. Medium-range air traffic control (Air-Search) radar is capable of detecting aircraft with a target area of one square meter or more, to line-of-sight ranges of approximately 100 miles and at altitudes of

40,000 to 50,000 feet. This equipment may be installed on or off the air station and may be located to serve more than one activity. Intercommunication between activities is required and remote display at any operating center may be provided as necessary and feasible. Short-range Airport Surveillance Radar (ASR) is an integrated part of a traffic control system and is located so as to have an unobstructed view of the approaches to all runways to be serviced, especially the instrument runway. This equipment is capable of detecting aircraft with a one square meter or larger target area, to line-of-sight ranges of approximately 20 to 50 miles, and altitudes of 10,000 to 25,000 feet. For technical reasons, its location should be no closer than one-half mile to the nearest touchdown point. This radar supplies information to remote indicating devices located in the traffic control center, and is remotely controlled from that center. The ASR is used to direct aircraft to a position 6 to 10 miles from the airfield so that it will be aligned for final approach to the active runway.

o Precision Approach Radar (PAR) is capable of providing information required by a controller for the safe approach guidance of single or multiple aircraft to within a height of 50 feet above the active runway touchdown point. Though this equipment is used for all types of aircraft, en route or in training, and during all weather conditions, it is especially important during minimum ceilings of 50-foot ceiling and one-quarter mile visibility. This radar set is housed in a trailer, located on a hardstand adjacent to the runway(s) to be serviced. The trailer is usually mounted on a turntable to expedite alignment of the radar when weather conditions require a change in the active runway approach pattern. The PAR operation begins when an arriving aircraft is approximately 6 to 10 miles from the approach end of the active runway. Another term for the combination of ATC, ASR, and PAR is Ground Control Approach (GCA) system. The term GCA is applicable where the facilities of a medium-range radar is not available or required. Additional information pertaining to fixed and mobile GCA equipment and installations are provided in both volumes of this handbook.

3.2.2 Airport Surveillance Radar

a. System Principles. The basic radar set comprises a transmitter and antenna arranged to send out radio waves in a series of short pulses, an antenna and receiver for detecting the echo pulses that return, and an indicator. The indicator includes a cathode-ray tube (CRT). Distances on the CRT screen are proportional to the time interval between transmitted and echo pulses and thus to the range of the object.

The transmitter supplies RF energy in pulses of high power but brief duration to the transmitting antenna. The waveform of the transmitter output voltage is therefore as indicated in figure 3-10A. During a short time interval, the transmitter produces a sinusoidal voltage wave of extremely high frequency (e.g., 3,000 MHz) indicated by the closely spaced lines in figure 3-10A. During the remainder of the time, the transmitter is quiescent. The time of operation of the transmitter, called the pulse duration T , varies from one radar set to another, but a typical value is one microsecond or one-millionth of a second. The total time required for the completion of a cycle of events in the radar system (the pulse duration plus the time between pulses, during which echoes may be received) is called the repetition period, T_r . The reciprocal of T_r is the repetition frequency f_r , or number of repetitions of the cycle of events that occurs in one second. A typical value of T_r is 1,111 microseconds and the corresponding value of f_r is 900 Hz. Note that the transmitted pulse duration is such a tiny fraction of the repetition period that it is impossible to illustrate the pulse with respect to the time-scale in figure 3-10. The ratio of pulse duration to repetition period is called the transmitter duty ratio. For typical ASR values of T and T_r , the duty ratio is 0.001.

The transmitter is required to produce a tremendous burst of power during its brief period of operation. The transmitted pulse energy must be large so that the minute part contained in the echo return may be detectable. Because of the short pulse duration, extremely high transmitter power is required to produce a pulse of sufficient energy. A typical ASR value of power produced during the pulse, called the peak power of the transmitter, is 425 kW. Because the duty ratio is small, the average power output of the transmitter is not high, despite the high peak power.

Because:

$$\frac{\text{Average power}}{\text{Peak power}} = \frac{T}{T_r} = \text{Duty ratio} \quad (3-1)$$

The average power corresponding to the assumed values is $0.001 \times 425 \text{ kW}$ or 425 watts.

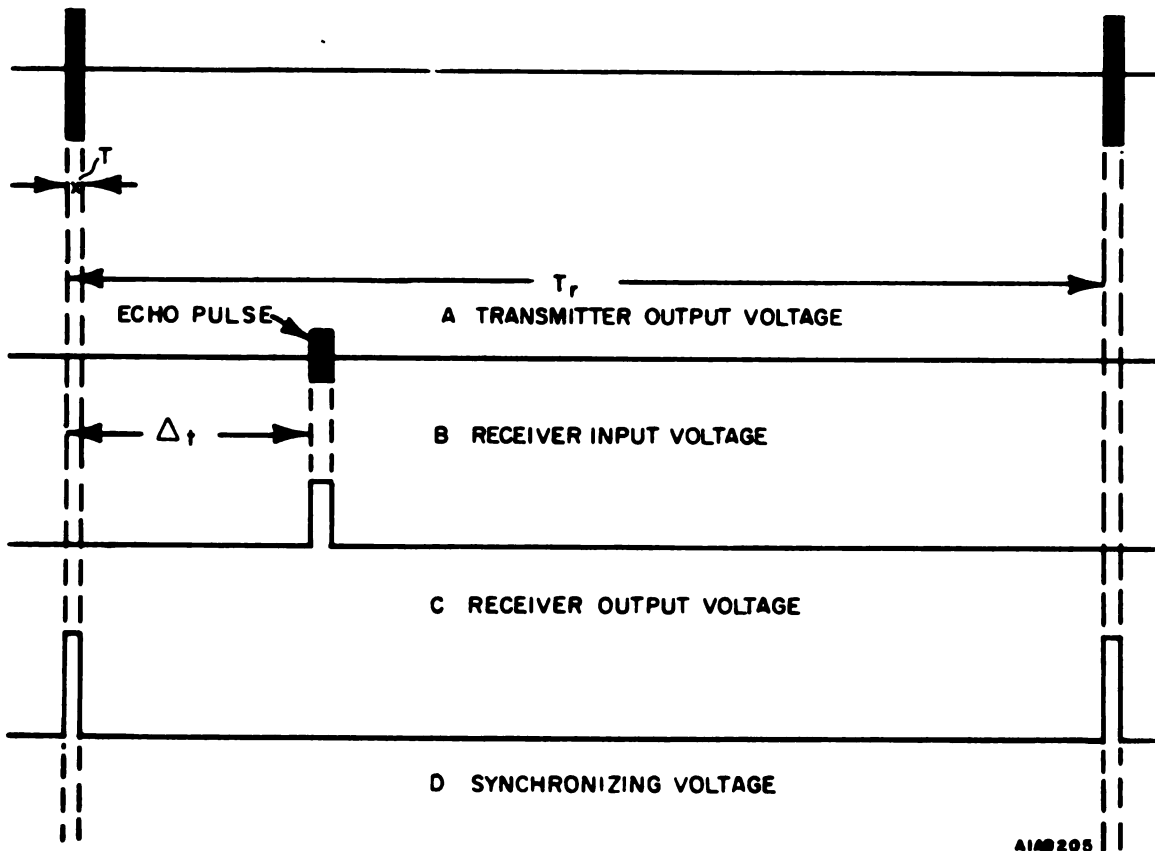


Figure 3 - 10. Waveforms Showing Time Relations in Elementary Radar Set

Radio waves that travel from the transmitting antenna to the reflecting object and back to the radar set generate a RF voltage in the receiving antenna. If only a single small object reflects the waves, the waveform of receiver input voltage is shown in figure 3-10B. The time required for the two-way trip of the waves is called Δt . Voltage amplitudes in figure 3-10 (A and B) should not be compared because the echo pulse would be completely invisible if the two figures were drawn to the same scale. The transmitted-pulse power is of the order of 425 kW, but the peak power of the echo pulse may be less than $1 \mu\mu\text{W}$ (0.000,000,000,001 watt). The function of the receiver is to amplify this tiny pulse to usable size and to detect it, that is, to produce a direct voltage that varies in magnitude in accordance with the envelope of the RF echo pulse. The receiver output is therefore a pulse of direct voltage, called a video pulse, as indicated in figure 3-10C.

The time interval Δt in figure 3-10 is equal to the time required for a radio wave to travel from the radar set to the object detected and back. If r denotes the distance from set to object and c the speed of light (which, for practical purposes, equals the speed of propagation of radio waves in air), the time required for the two-way trip is $\Delta t = 2r/c$ and the range is:

$$r = \frac{c}{2} \Delta t \quad (3-2)$$

This fixed proportional relation between range and the delay time of the echo pulse is the basis of range measurement by radar.

Conversions between time intervals and ranges are so frequently required in the study of radar that a list of values of $2/c$ and $c/2$ for several convenient units of length is useful. From the value of c , $2,998 \times 10$ mi/s, or 186,000 mi/s, the constants in table 3-1 are calculated. Persons working constantly with radar find it convenient to remember the underscored numbers in this table.

Table 3-1. Radar, Range-Time Conversion Factors

$c/2$	$2/c$
0.0310 nautical miles/ μ s	<u>12.36</u> μ s/nautical mile
0.0931 statute miles/ μ s	<u>10.74</u> μ s/statute mile
0.1640 thousand yards/ μ s	<u>6.10</u> μ s/thousand yards
<u>492</u> feet/ μ s	0.002035 μ s/feet

Though long relative to the pulse duration, the time interval Δt is much too short to be measured by mechanical means. If, for example, the range of an object is 50 statute miles, Δt is only $50.00 \times 10.74 = 537.0$ millionths of a second. To measure this short time, the radar indicator employs electronic circuits, and the results of the measurement are presented on the screen of a cathode-ray tube. In one system, the receiver output voltage is applied to one pair of deflecting plates in the cathode-ray tube to cause a vertical motion of the spot on the screen, and a sawtooth sweep voltage is applied to the other pair of plates to cause horizontal motion of the spot. This display is known as a type A indicator.

Measurement of direction angles by radar depends upon the use of highly directional antennas, i.e., transmitting antennas that send out radio waves in a narrow beam and receiving antennas that respond most strongly to waves arriving from one particular direction.

If both antennas are directional, and if the two antennas are turned as a unit so that the direction of maximum radiation is always the same as the direction of best reception, then the orientation of the two-antenna unit becomes an indicator of direction. Use of two directional antennas in this way improves the accuracy of angle measurement, because a slight shift of the antennas from the correct position has a double effect in reducing the amplitude of the pulse observed; the antennas can therefore be positioned more accurately.

In order to obtain the greatest accuracy in determining direction angles, radar sets commonly employ directional antennas for both transmission and reception. To avoid the serious mechanical problems associated with using two large antennas and rotating them so that axes remain accurately aligned, means have been developed for employing only one antenna and using it for both transmission and reception. The directivity of the antenna is thus used twice, and the axes of maximum radiation and maximum sensitivity of reception are automatically aligned, provided the antenna is not moved appreciably during the time interval between transmission of a pulse and reception of the echoes (an interval usually less than 1/500 second).

The narrowness of the antenna beam is important because it determines the accuracy with which the radar set can measure azimuth and elevation angles. It is important also because it determines the angular resolution of the radar set, exactly as pulse duration determines the range resolution. The apparent angular extent of any object is increased by the width of the antenna beam, and objects separated by less than the width of the beam appear to the radar operator as a single object.

When both direction and range information is required, several methods of data presentation are possible. However, the standard presentation of ASR is the Plan Position Indicator (PPI), in which radial displacement of the spot from the center of the screen indicates range and the direction of the radial displacement indicates azimuth angle. PPI presentations are given in figure 3-11B and 3-11C which are the illustration of figure 3-11A under two conditions, antenna stationary at 60° and antenna rotating about a vertical axis.

Video signals from the receiver circuits are processed by indicator circuits and displayed on a cathode-ray tube in a PPI. The PPI sweep is synchronized with the transmitted pulse by a pretrigger from the receiver, and a servomechanism synchronizes the PPI sweep with antenna azimuth range marks, which are calibrated in radar nautical miles, are displayed on the sweep with target video. The relative position of a target echo and a range mark indicates the range of a detected object. A cursor sweep with a range strobe can be selected and displayed on the PPI. The cursor control assembly, operated by the radar operator, controls the cursor origin, cursor azimuth, and the position of an intensified range strobe along the cursor sweep. The operator can position the cursor sweep through any indicated target, position the range strobe over the target, and then read target range and azimuth from strobe range and cursor bearing indicators on the front panel of the console cabinet. The strobe range is calibrated in nautical miles and the cursor bearing indicators on the front panel of the console cabinet. The strobe range is calibrated in nautical miles and the cursor bearing in degrees. The range and bearing of one target can be determined relative to another target or relative to the position of the radar site.

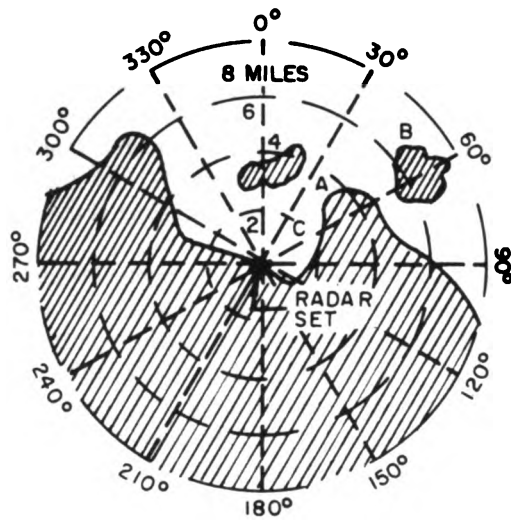
The ASR system may incorporate the capability of processing and displaying either normal video or moving target indicator (MTI) video, or a combination of each on the same display. The normal receiver provides the capability for detection and display of all reflected signals within system range. However, fast-time constant (FTC), sensitivity time control (STC), integrated normal video, and range gated normal video circuits are provided for use at the option of the radar operator.

The MTI receiver reduces ground clutter return and stationary target echoes to system noise level and enhances moving target echoes on the PPI display. This is accomplished by MTI circuits that make use of the phase difference between the transmitted pulse and the reflected pulse from a moving object. Echoes from fixed objects produce the same outputs on each pulse, but echoes from moving targets vary in phase from pulse to pulse to provide differences in amplitude and/or polarity. The phase detection circuitry cancels signals with identical phase and amplitude characteristics, but signals with varying phase and amplitude characteristics are allowed to continue to the indicator and leave a residue that represents moving target echoes.

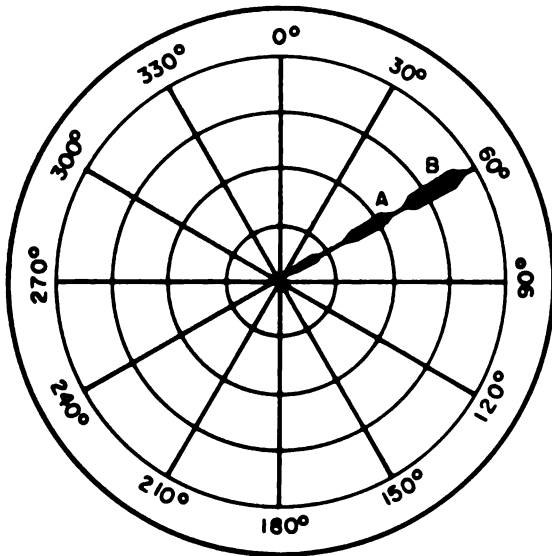
b. System Configuration. Airport Surveillance Radar systems are designed for maximum reliability and ease of servicing. With the exception of the antenna, major assemblies are duplicated to provide dual-channel operation. If the operational channel fails, the radar supervisor can switch the standby channel into operation and maintenance may be performed on the faulty channel.

The ASR system consists of two main groups of equipment, referred to by their location; Radar Site Group and Remote Site Group. The antenna, transmitting and receiving equipment, video line driving equipment and associated auxiliary equipment are located at the radar site consisting of a transmitter building and a tower for the antenna. All equipment at the radar site except the antenna is located in the building. The master PPI consoles and remote control circuitry are installed in the air station IFR room, and the associated equipment and video mapper are located in the equipment room near the IFR room.

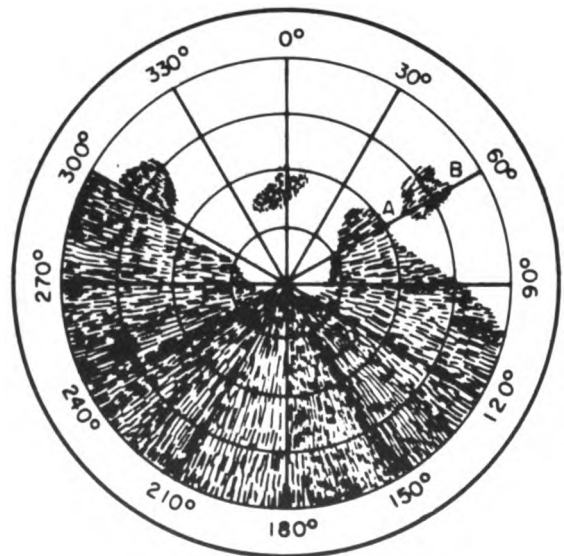
A block diagram of the ASR system is shown in figure 3-12. A brief description of the major assemblies and the components is presented to identify the ASR equipment complement.



A. LOCATION OF RADAR SET

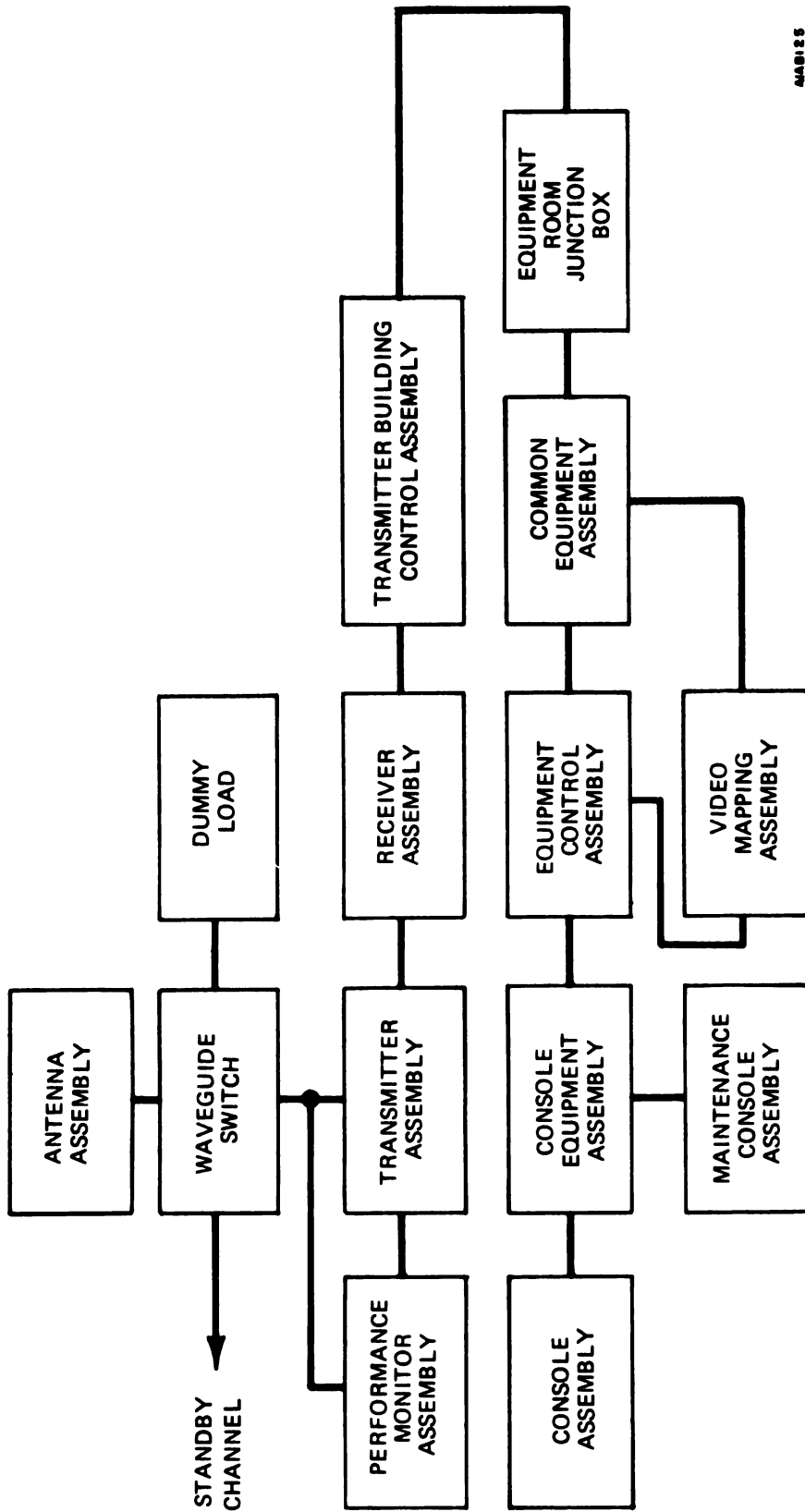


B. APPEARANCE OF PPI ANTENNA STATIONARY AT 60°



C. APPEARANCE OF PPI-ANTENNA ROTATING

Figure 3 - 11. Relation of Plan Position Presentation to Map of Region Surrounding Radar Set



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Figure 3 - 12. ASR Block Diagram

The antenna assembly consists of the following:

- o Antenna pedestal
- o Reflector assembly
- o Antenna feedhorn
- o RF rotary joint
- o Polarizer
- o Reflector support
- o Feed system support

The antenna assembly radiates a beam of RF energy, either linearly or circularly polarized, from 2700 to 2900 MHz; scans a 360-degree azimuth pattern; receives reflected energy from targets; and transmits, by a two-speed synchro data system, azimuth information corresponding to beam location.

Channel A and channel B transmitters are in the transmitter building at the local site. Each transmitter is connected to the waveguide switch. This switch connects the selected operating channel to the antenna and the standby channel to the RF dummy loads.

The transmitter assembly consists of the following:

- o Transmitter cabinet
- o High voltage power supply
- o Modulator
- o Magnetron
- o Cable connections for the panels
- o Panels inside the cabinet are as follows:
 - Fault AFC
 - Preamp filament transformer panel
 - Automatic frequency control
 - Transmitter fault indicator and meter panel
 - Transmitter control panel
 - Modulator driver power supply
 - Transmitter fault relay panel
- o Preamplifier
- o Modulator driver
- o TR tube meter panel
- o STALO power supply
- o Miscellaneous transmitter waveguide components

The performance monitor assembly is located at the radar building between the transmitter and receiver assemblies, and consists of the following:

- o Performance monitor cabinet
- o RF power monitor
- o Relative tuning monitor
- o Crystal tester
- o Noise figure IF amplifier
- o Noise figure monitor
- o Normal video line driver
- o MTI or map video line driver
- o Monitor PPI connection panel 280 V power supply
- o 150 V power supply
- o Six 120 V power supplies
- o Power supply metering panel

All ASR receiving equipment is located in the radar building. Except for the automatic frequency control (AFC) and the preamplifier, all receiver panels are mounted in the receiver cabinet. The AFC and preamplifier are mounted in the transmitter cabinet. The panels in the receiver cabinet are:

- o Normal IF amplifier
- o MTI IF amplifier
- o Normal video realignment unit
- o MTI video realignment unit
- o COHO
- o Sensitivity time control
- o Video selector and mixer
- o Cancellor No. 1 delay line driver
- o Cancellor No. 2 and video integrator delay line drivers
- o Video integrator
- o PRF stagger unit
- o Lock test pulse generator

- o Video test pulse generator
- o Synchronizer and canceller No. 1 carrier amplifiers
- o Cancellor video unit
- o Swept frequency test generator
- o Cancellor No. 2 carrier amplifiers
- o Dummy delay line
- o COHO filament supply
- o Monitor synchroscope

Except for the monitor synchroscope and COHO, all panels are vertically mounted.

The transmitter building control assembly contains the following five panels that provide control and switching functions for the radar system:

- o Metering and video selection panel
- o Two control voltage power supplies
- o Two transmitter building radar control panels

Since circuits must be provided to allow each console independent selection of sweep range, cursor, and video display, part of the individual circuitry is installed in separate cabinets, so that the PPI console size can be held to a minimum. A separate console equipment assembly is provided for each console assembly.

The console equipment assembly panels are vertically mounted on both sides in the console equipment cabinets, which are 72 inches high, 27 inches wide, and 26 inches deep. All operational panels and a filament power supply are mounted on swing-out panels in the front. All other power supplies and a metering panel are mounted in the rear. The panels are:

- o Console video mixer
- o Unblanking gate generator
- o PPI gate generator
- o Resolver amplifier
- o Equipment filament supply
- o Console equipment metering panel
- o Two 280 V power supplies (500 MA - 1% REG)
- o Two 150 V power supplies (500 MA - 0.1% REG)
- o Two 280 V power supplies (500 MA - 0.1% REG)

The console assembly receives time-shared sweeps, video, and unblanking gates from the console equipment assembly and displays this information on a 16-inch CRT plan position indicator. The console assembly includes:

- o Deflection yoke drivers
- o Video amplifiers
- o Intensifying and unblanking circuits
- o A CRT high voltage power supply
- o Cursor sweep generator
- o Sweep and cursor decenter time-share circuits
- o Triple-function cursor control assembly that controls the origin and bearing of an electronic cursor and the position of a range strobe along the cursor sweep
- o In addition, various controls mounted on the console cabinet establish limit and operating levels in the video and sweep circuits.

The common equipment assembly consists of all circuitry that can be used simultaneously by all indicator consoles. Included in this equipment are:

- o Range-mark generator
- o Sweep generator
- o Servo amplifier
- o Gate generating functions

One common equipment assembly drives four console equipment assemblies. However, one operating and one standby common equipment assembly is provided with each radar system.

The equipment control assembly contains subassemblies that provide control and switching functions for equipment room assemblies. These subassemblies include:

- o Control panel to control power on-off and local-remote operation
- o Switch panel to control distribution of all video and pulse outputs of the common equipment and video mapping equipment
- o 28 VDC power supply and monitoring panel
- o Monitor synchroscope

The video mapper provides each PPI console with selected navigational references and fixes. An outline map is presented as video information synchronized in plan position with the radar signal video display. The video mapper is composed as follows:

- o Map scanner
- o Servo amplifier
- o Video mapping high voltage power supply

- o Tektronix monitor synchroscope
- o Two 280 V power supplies
- o One 150 V power supply

c. System Application. Short-range ASR equipment is used to detect aircraft within 40 NMI of its ground-based location. The radar video is conducted to the indicator group for display on plan position indicators in the air station IFR room. There may be only two or three ASR displays or as many as ten, according to the air traffic density and the size of the ATC facility. The IFR room positions requiring the ASR display are the approach, arrival, final, and departure controllers. This may require three positions, or possibly a minimum of two for low density air traffic and doubling-up of operating tasks. At larger air stations, having two runways operating as separate airfields, the IFR room operation may have six or more ASR displays for two separate sets of controllers, plus spare positions. The spare units may also be used for observation or training of new controllers.

An ASR installation may also be used as the common surveillance radar for more than one airfield in the area. Some air stations are located near other airfields, military or civilian. If the adjacent airfield is a military activity, the radar video signal is generally remoted to both activities for individual control of their air traffic. If the neighboring airfields are operated by civilian personnel, there may be a joint Navy-FAA IFR room located on the Navy facility. Under this condition, the FAA will handle the approach, arrivals, and departure controller positions for all airfields. Navy personnel will man the final controller's position for NAS air traffic. Also under joint operations, the FAA usually maintains the ASR equipment and installation facility, and maintenance in the IFR room is shared by FAA and Navy personnel.

3.2.3 Ground Control Approach - Search and Height Finder

Ground controlled approach radar equipment may be operated in one of three modes: search, height finder or as precision approach radar. Information pertaining to search and height finder modes of operation are included here and data relating to the GCA-PAR mode will be detailed in a subsequent paragraph. GCA equipment is also capable of operating as taxi-radar.

a. System Principles. The four major groups of a GCA radar system (radar set group, indicator group, remoting group and power supply group) are divided into the following basic system blocks as shown in figure 3-13. The basic system signal flow through the radar system block is shown in figure 3-13.

The synchronizer (part of the receiving group) develops a positive pulse output at a rate of 1500 pulses per second (PPS). These pulses, known as the system trigger (or as the A-trigger), are applied to three groups as shown in figure 3-13. Using the system trigger as a reference, the transmitting group produces pulses of RF energy at a rate of 1500 PPS. This energy is routed through the RF switch in the antenna group to the azimuth and/or elevation antennas, as required by the mode of operation selected. During surveillance operation, energy is fed to the azimuth antenna; during height finder mode, the energy is fed to the elevation antenna; during PAR mode, energy is fed alternately to the azimuth and elevation antennas. The received energy (echo) is routed from the antenna through the RF switch to the receiving group. In the receiver, this energy is converted to an intermediate frequency and amplified. The receiver then produces detected video signals and from the detector, the video signals are routed through the remoting system to the indicating system. When in the remoting group, the video signals and the system trigger pulses are combined and amplified in the remote line driver and transmitted over a single coaxial cable to the remote site. The remote line amplifier receives the mixed signal from the remote cable and separates the video signals from the trigger pulses; both are amplified and restored to proper form and applied to the indicating group. The range marks and cursor pulses are mixed with the receiver video in the indicating group and applied to the indicator CRT sweep. Centering voltages are developed in the marker generator and applied to the deflection coils of the indicator CRT to provide the proper relation of antenna scan mode to indicator sweep deflection.

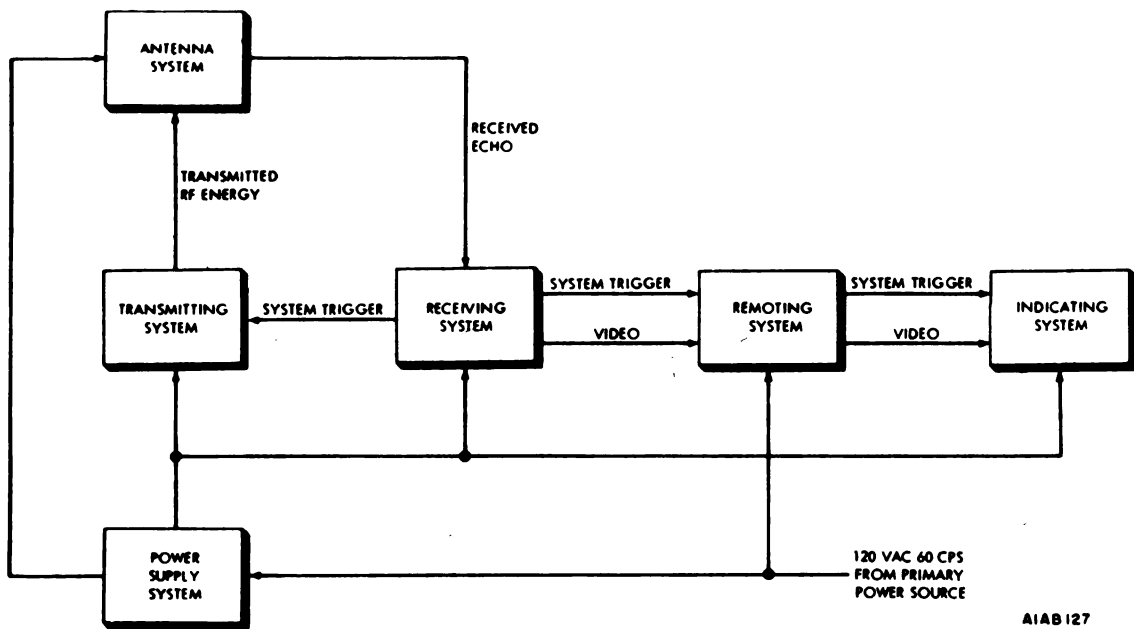


Figure 3 - 13. GCA System Block Diagram

The antenna group of the GCA radar set has two antennas which makes this set different than the ASR radar previously described. A block diagram of the antenna group is shown in figure 3-14. As in other radar systems, the antenna system receives the RF energy from the transmitting group and applies it to the duplexer. The duplexer connects the transmitting group to the antenna line and disconnects the receiving group whenever the magnetron is oscillating. The RF energy from the duplexer is applied to the crossguide coupler which provides a testpoint for measuring, transmitting, and receiving system performance. From the crossguide coupler, the RF energy is routed through waveguide to the RF switch blades. The remaining assemblies of the antenna group are common only to GCA radar sets. The RF switch blades connect the output of the transmitting system and the input of the receiving group between the azimuth and elevation antennas as required by the mode of operation selected. From the RF switch blades, the energy is fed to the polarizers. When operating in clear weather, the polarizers provide linear polarization of the radiated energy. During periods of rain or snow, circular polarization may be selected to reduce precipitation returns. After passing through the polarizers, the RF energy is radiated from the antenna horns to the parabolic reflectors which shape the radiated beam to the desired proportions.

GCA radar equipment operates in the X-band (3 cm band) at a frequency of 9000 to 9160 MHz. Other general operating characteristics of this equipment are:

- o Pulse width - 0.18 to 0.6 μ sec at 50 percent peak pulse amplitude
- o Pulse repetition frequency - 1500 pulses per second
- o Peak power output - 150 kW
- o Receiver bandwidth - 4 MHz minimum at half power point
- o Range accuracy - ± 1.0 percent or true range
- o Azimuth accuracy - ± 0.35 degrees

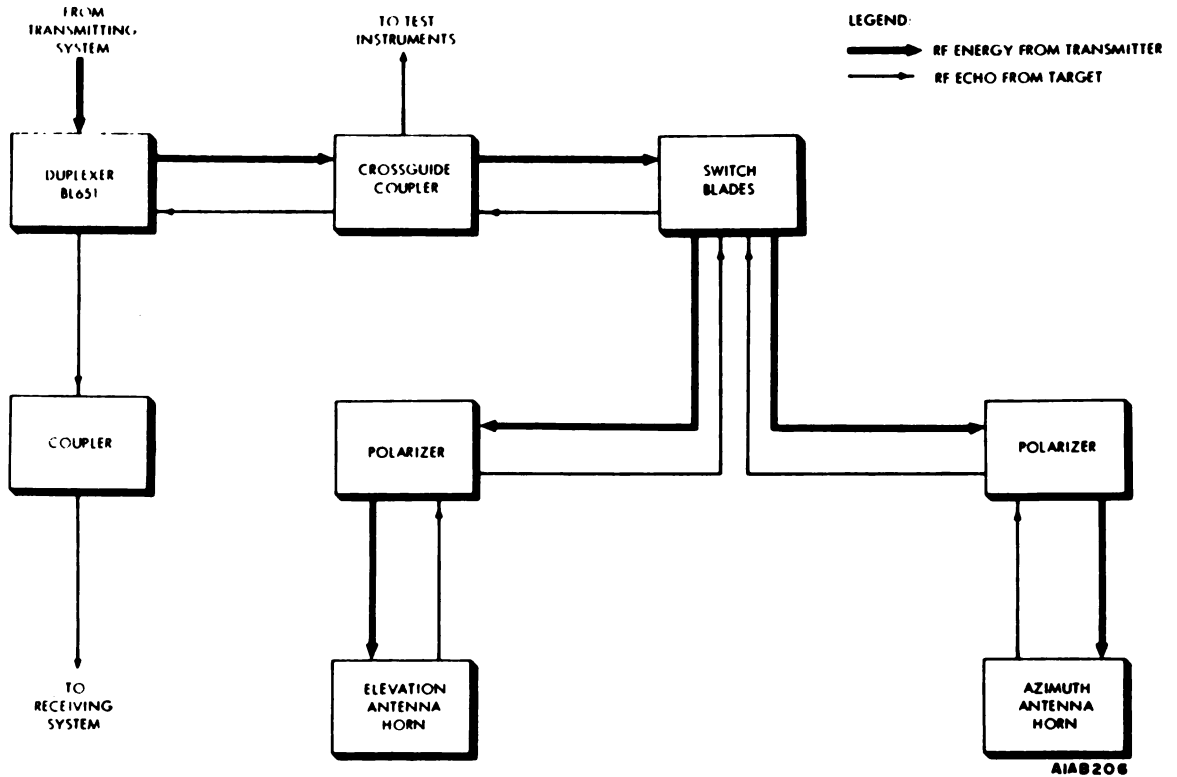


Figure 3 - 14. GCA Radar Antenna Group, Block Diagram

Functioning as a search radar, additional characteristics include:

- o Ranges - 5, 10, 20, and 40 NMI
- o Offset ranges - 10, 20, and 40 NMI
- o Range markers - 1 mile spacing on 5- and 10-mile ranges; 5 mile spacing on 20- and 40-mile ranges
- o Display - PPI
- o Deflection - rotating deflection coil
- o Antenna coverage - 360 degrees

Functioning as a height-finder radar, and using only the elevation antenna, additional characteristics include:

- o Range - 40 mile slant range at a 30 degree angle
- o Range marks - 1-mile spacing on the 1- to 20-mile ranges; 5-mile spacing on the 40-mile range
- o Display - beta scan
- o Deflection - horizontal sweep, linear (exponential on 10-mile range)
- o Azimuth presentation - any 30 degree sector of 360 degrees
- o Elevation presentation - -1 degree to +30 degrees

b. System Configuration. The GCA radar system consists of four major groups: the radar set group (receiver-transmitter group and antenna group), the indicating group, power supply group and the remoting group. The radar set group is located on the landing field (next to the active runway) and contains components necessary to transmit and receive radar information. The remoting group, which provides remote site flexibility, consists of a remote line driver installed with the receiver-transmitter group at the site of the radar set, a remote line amplifier installed in a remoting case located near the indicator group, and interconnecting cables. The indicator group contains components necessary for the operator to control the radar system and interpret the radar information received. The power supply group supplies the necessary power to components of the indicator group.

Location of the indicator group is determined by the actual system used and the overall ATC configuration provided at the NAS. One system has separate and portable subsystems for each group. Thus the indicator and power supply groups may be located in an IFR room, a control tower, or a building or shelter on or near the landing field, as locally required.

A second GCA system configuration has the radar set and remoting equipment installed in a van which is mounted on an airfield hardstand turntable. As the first system, the indicator and power supply group will be located as required. A third GCA system, having both short-range search and PAR capability, is housed in two large trailer vans. With all components of the system located in or on the vans, ATC radar operations are performed in the GCA van. This configuration is generally referred to as a mobile and transportable GCA system.

The radar set group consists of the transmitter-receiver group and the antenna group. Radiating pulsed energy from the transmitter and routing the received energy (echoes) to the receiver is performed by the antenna group. There is one antenna for scanning 360 degrees in the horizontal plane during surveillance operations. This antenna is known as the azimuth antenna. A second antenna for scanning the vertical plane (the vertical antenna) is used during height finder operations. This antenna will scan up to 31 degrees in the vertical plane. To support these antennas the antenna group also contains:

- o Azimuth and vertical antenna pedestals, which support and drive their respective antennas
- o Antenna drive and mount which support both azimuth and elevation pedestals and contains drive mechanisms and waveguide assemblies
- o Two polarizers for selecting either linear or circular polarization of the radiated energy
- o RF switch blades for connecting the transmitter-receiver group to the appropriate antenna
- o A crossguide coupler which provides a test point for measuring transmitter-receiver performance
- o Duplexer-coupler which connects the transmitter and receiver alternately to the antenna (see figure 3-14).

The transmitter-receiver group develops pulses of RF energy for transmission, and receives, amplifies, and detects returning RF signals from the antenna group and routes them to the remoting group. To perform these tasks the group contains a transmitter-modulator, receiver, high voltage transmitter power supply, receiver power supply, and a control and test panel.

The remoting group consists of two assemblies, remote line driver and the remote line amplifier. The remote line driver combines and amplifies signals from the receiver for transmission to the indicator group through remote cabling. At the remote site, the remote line amplifier receives, amplifies, and detects the RF signals and routes them to the indicator group.

The indicator group provides a visual display of the azimuth, elevation and range information received from the radar set group. To aid in interpreting the radar information, the indicator group consists of two control panels, and a marker generator for controlling all power and signal flow, as well as generating the range markers, gates, sweeps, and centering voltages used in the indicator; a computer for generation of reference markers, gates and strobes necessary for accurate alignment of the indicator PPI and beta scan displays; a 10-kV power supply which supplies the anode voltage to the indicator cathode-ray tube; and the indicator which contains the components necessary to display the radar information and data generated by the other components of the indicator group. The indicator power supply group provides the required operating voltages to the components of the indicator group.

c. System Application. The Naval ATC system requires that ground controlled approach radar equipment be installed at all NAS. The type of GCA equipment used will depend on the density of air traffic and the mission of the airfield. If ASR equipment is installed on the station or available in the area for monitoring by the Naval ATC personnel, then the GCA equipment would be used only as PAR control. Therefore, only in case of an emergency, such as the ASR becoming inoperative or to assist in the direction finder location of an aircraft, would the GCA radar be used in the search and/or height finder modes of operation.

In the search mode, the GCA radar equipment functions the same as ASR, with approximately the same range 40 NMI versus 60 NMI for ASR. Though the antenna group contains two separate antennas, for scanning both the horizontal and vertical planes, only the azimuth antenna is used in the search mode. Also in this mode the detected targets are displayed on a PPI display which indicates their range and azimuth bearing.

During ATC search operations it may become necessary to determine the altitude of an aircraft. Then the GCA equipment will be switched to the height finder mode when the aircraft is within 30 miles of the airfield. If the plane is flying between altitudes of 500 and 50,000 feet, it may be detected on the beta display of the indicator, and the indicator control panel (No. 1) will present a direct readout of the aircraft altitude in feet. This is accomplished by the operator rotating the height finder control until the cursor on the elevation portion of the display intersects the target. The altitude of the aircraft is then indicated on the control panel height finder counter. The counter reading may be referenced either to the altitude of the airfield or to mean sea level.

3.3 RADAR BEACONS

The basic principle of operation of the ATC radar beacon (Radar Recognition Set) is that of transmitting a coded challenge and receiving a coded reply from a friendly aircraft. The wartime name for this system was Identification Friend or Foe. As a carry-over, present day radar beacon systems used as an ATC informational input are referred to as IFF systems, or the common military/civil Mark X SIF/IFF System (SIF - selection identification feature). To permit these replies to be presented on a radar display, the challenge signals are synchronized with the radar transmission as shown in figure 3-15, the radar system provides a trigger signal to the radar beacon system.

3.3.1 Principles

A discussion of the theory of operation of the basic IFF system will be followed by an analysis of the principles of the AIMS program.

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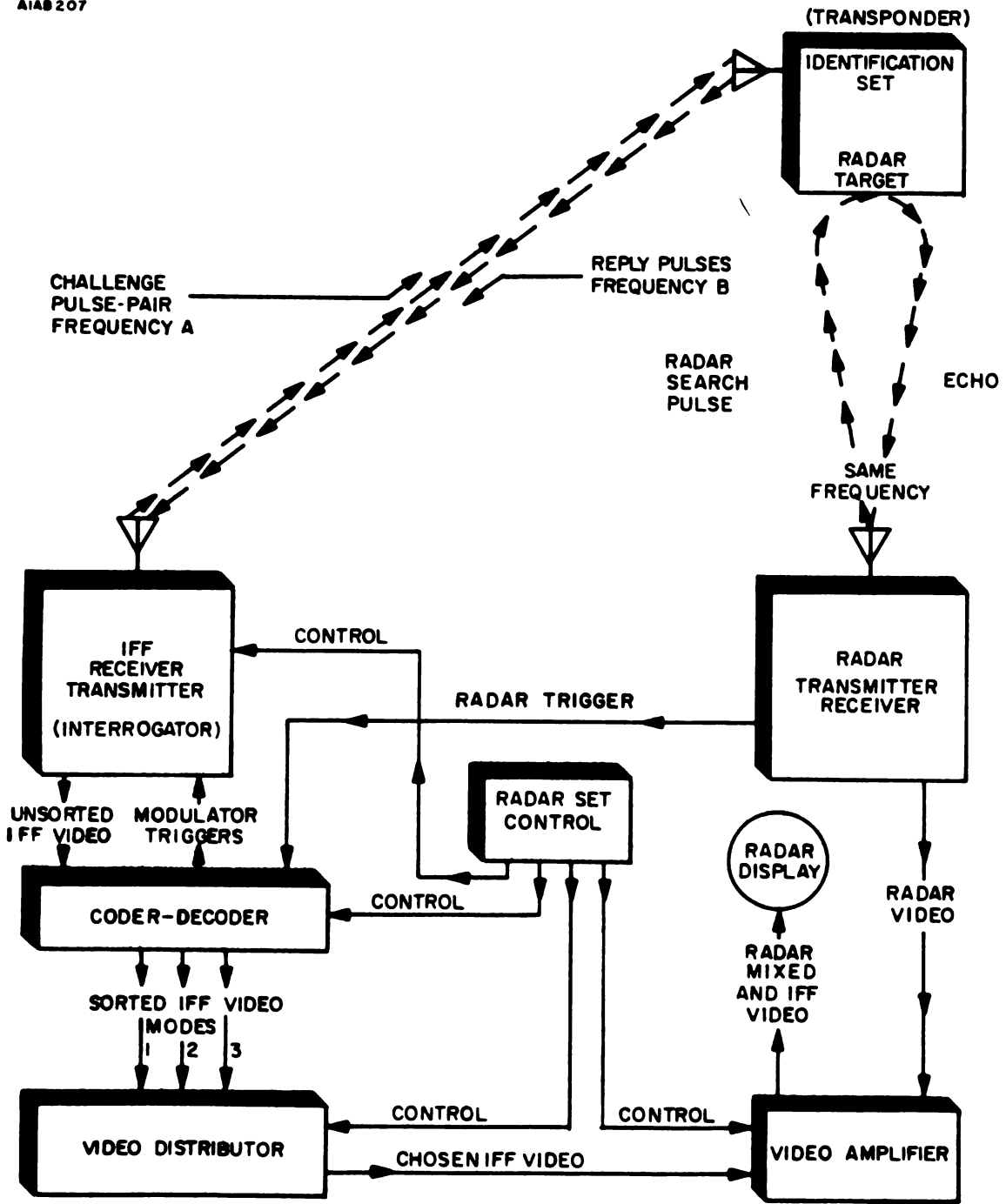


Figure 3 - 15. Radar Recognition Set, Operation Block Diagram

a. **Basic IFF System.** The basic system consists of four major units as shown in figure 3-15; an interrogator, antenna coder-decoder, radar set control, and video distributor. Certain installations require the use of additional units such as additional video amplifiers, selector switches, and different radar set control units.

Radar pulses are produced in the form of pulse-pairs, with each pulse one microsecond long. The spacing between the pulses is determined by the mode of operation selected. There are three modes, or forms of code, available for general or specific identification; mode 1 spaces the pulses three microseconds apart, mode 2 produces a five microsecond spacing, and there is eight-microsecond spacing with mode 3 (see figure 3-16).

The IFF transmitter operates between 1010 to 1030 MHz (Frequency A) during the one-microsecond interval of each radar pulse. The transmitter has a peak power output of 1 kW minimum and a duty cycle of 0.01 percent maximum. The transmitter and receiver use a common antenna (figure 3-15). The returning IFF signal, after passing through the T/R switch, enters the superheterodyne receiver between 1090 and 1110 MHz (Frequency B). After detection, the signal is amplified and converted to (unsorted) video pulses. Gating and gain-time circuits modify the action of the IF amplifier to attenuate returns from nearby targets. The decoder accepts the unsorted video signals from the receiver and sorts them by modes. A gating function turns on the IFF receiver for the period when IFF returns are desired. In order to reduce the effects of antenna side lobes and back radiation a modification of the gate is introduced. This is accomplished by the gain-time control (GTC) which controls the rise-time of the gain so that the earliest returns, from nearby targets, are partially attenuated. The gain slowly increases until normal gain is established, permitting weak, distant targets to be received. GTC may be chosen "long" or "short", and is adjustable. Optimum values for GTC recovery and GTC amplitude depend upon the operating conditions and on the antenna-gain characteristics at individual installations. Figure 3-17 shows the resulting difference of target display before and after GTC is used.

The distribution and amplification of the IFF video signal, between the radar building and the radar control center, is accomplished by the AN/GPA-106 and -107 Radar Distribution Groups.

The IFF reply signals appear on a radar PPI display scope as broken, illuminated arcs at the bearing but at slightly greater range than the radar echoes received from the target (see figure 3-18). Replies to mode 1 and mode 3 interrogations show as a single broken arc; this duplication causes no confusion in identification, because only the replies to the mode selected are displayed. Replies to mode 2 interrogations show as two broken arcs, one at a greater range than the other. In each mode the arc is broken in several places, the breaks representing the time during which the modes could be shown on other displays. There is a third type reply, "Emergency"; here the transponder answers modes except "c" with a four-pulse reply that appears as four broken arcs, each at a slightly greater range than the preceding one.

b. **AIMS.** The AIMS system is based on the U.S. National Standard for Common System Component Characteristics for the IFF Mark X (SIF)/Air Traffic Control Radar Beacon Systems SIF/ATCRBS. The National Standard contains the technical details of future equipments, systems, and operational techniques.

The AIMS program is the first major equipment/subsystem program involving tri-service implementation which is managed by a single department. The Air Force has been designated as the DOD AIMS executive agent. The acronym AIMS is derived as follows:

- A - ATCRBS (Air Traffic Control Radar Beacon System)
- I - IFF (Identification, Friend or Foe)
- M - Mark XII Identification System
- S - Systems (reflecting the many AIMS configurations)

The original Mark X IFF System differed from the basic IFF System, previously described, by the fact that only one interrogation frequency (1,030 MHz) and one reply frequency (1,090 MHz) was employed. But, with the advent of the jet, and the need to control these high-speed aircraft adequately, especially in dense traffic areas, it is necessary to determine at any given moment the location of each aircraft with respect to all others. The ground controller must be able to distinguish one friendly aircraft from another according to its designation or

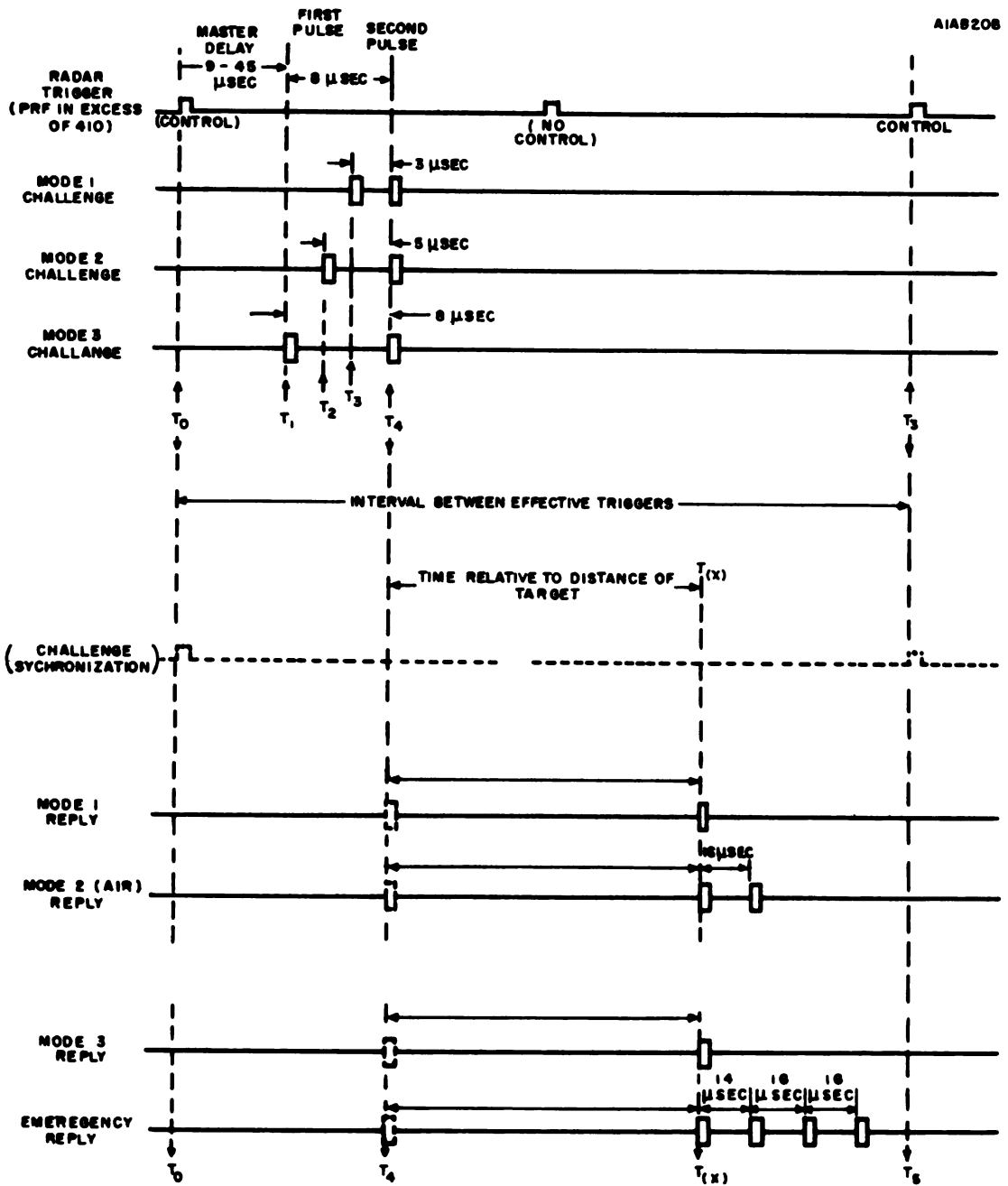


Figure 3 - 16. Basic IFF, Pulse Spacing Diagram

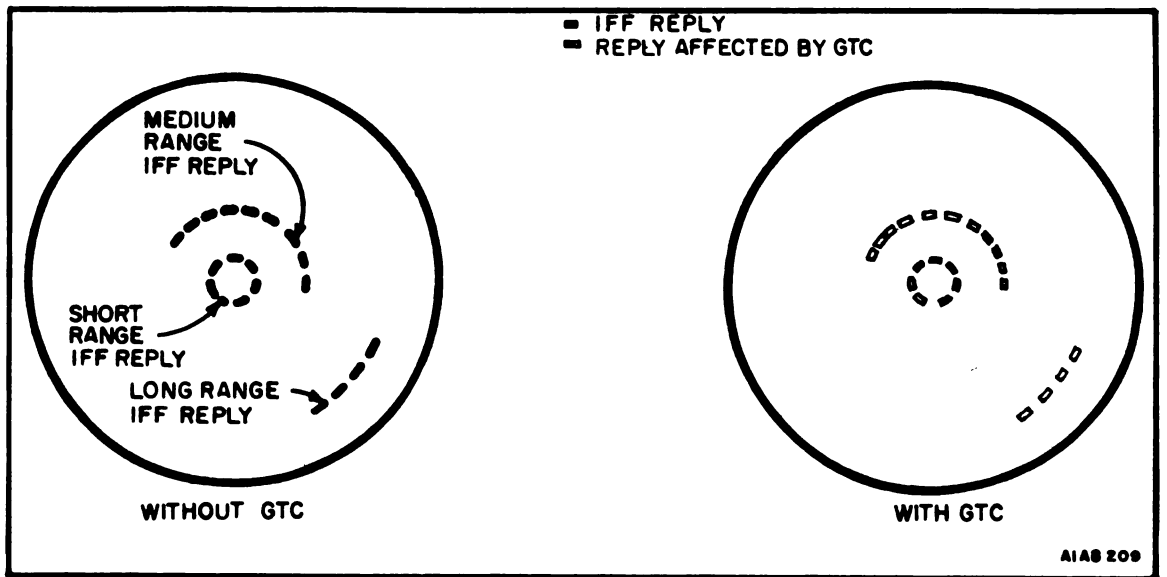


Figure 3 - 17. Effect of GTC on PPI Scope Display

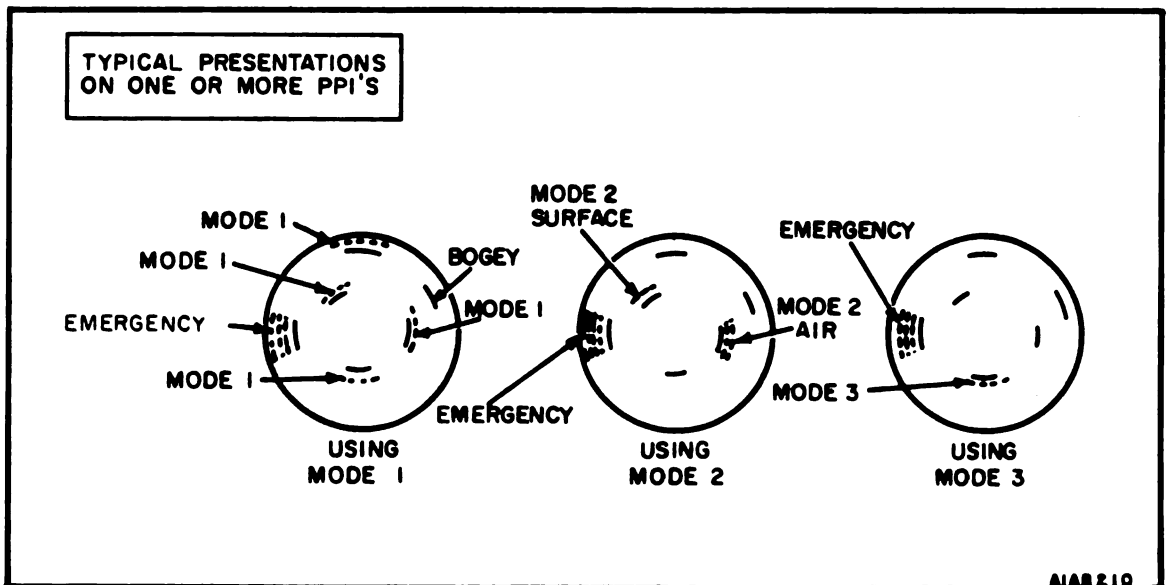


Figure 3 - 18. IFF and Radar Displays

function. Because of this traffic control problem and because the basic Mark X system lacked any real security aspects, a coder unit was added to the IFF system. The coder unit enabled the IFF system to generate many variably-coded replies, and this coding capability was termed the selective identification feature. The Mark X with the SIF added was designated Mark X SIF/IFF System and since 1959 has been used in most military aircraft. This combination of equipment essentially permits discrete replies to be selected by means of dials from among 32 possibilities for mode 1; 64 for Navy, and 4,096 for Air Force in mode 2; 64 in mode 3. The ability of this system to label the replies of particular aircraft or types of aircraft led to the adoption of this IFF system as an aid to aircraft traffic control by both the civil and DOD agencies. Under civil usage, the system became known as the Air Traffic Control Radar Beacon System.

Basically, the AIMS program is an equipment and subsystem acquisition effort which will provide specific capabilities to selected airborne and ground/surface systems. These specific capabilities include:

- o An increase to 4,096 from 64 codes on the common military/civil mode 3/A of the present Mark X SIF/IFF System.
- o Implementation of mode C which will provide automatic reporting of aircraft altitude in 500- or 100-foot increments.
- o Incorporation of a sidelobe suppression technique to minimize clutter (fruit) on the display unit associated with the interrogating equipment.
- o An improved military IFF system. The majority of data applicable to this system is classified and therefore is not presented in this handbook.

The National Standard details the intended capabilities of the ATCRBS, which is equally applicable to the AIMS program. Two important system features presented in the National Standard are the system coverage and accuracy.

The ATCRBS is intended to provide the air traffic controller with continuous, reliable, and accurate information concerning the plan-position (rho-theta) altitude and identity of any and all equipped aircraft in the airspace under his control. With a properly sited Air Traffic Control Beacon Interrogator and other units having characteristics as stated in the National Standard the ATCRBS will provide spatial line-of-sight coverage equal to, or greater than, the following limits:

- o Range. 1 to 200 NMI. Interrogators having limited range may be employed at many locations. While it is necessary to establish specific standards for the airborne components of the system and to define the characteristics of the radiated signals from both the interrogator and transponder, the power and sensitivity requirements for the interrogator may be determined on the basis of the intended usage.
- o Elevation. 1/2 to 45 degrees above the horizontal plane.
- o Altitude. Limited only by service ceiling of aircraft. The transponder automatic pressure-altitude range is -1000 feet to 126,700 feet, in 100-foot increments.

The system accuracy is determined by the characteristics of the ATC beacon interrogator, (including its antenna), transponder, altimeter and transducer, video processing equipment, and the associated display. With equipment meeting the characteristics stated in the National Standard, the system will be capable of providing accuracy in excess of the following:

- o Azimuth. + 1.5 degrees depending on quality of radar indicator used.
- o Range. + The root-sum-square of 500 feet and up to 3 percent of display range; the latter depending on quality of radar indicator used.
- o Altitude. +100 feet.

This accuracy includes the sum of the incremental error and the digitizer error and does not include the pressure-altitude data source errors.

Additional examples of the type of information contained in the National Standard follow:

- o Interrogation frequency, 1030 + 0.2 MHz
- o Transponder frequency, 1090 + 3 MHz
- o System transmission polarization, vertical
- o Interrogation pulses designated, P₁ and P₃
- o Control pulse designated, P₂
- o Interval between P₁ and P₂ shall be 2.0 + 0.15 μs
- o P₁, P₂ and P₃ pulse width at half voltage points, is 0.8 + 0.1 μs
- o P₂ radiated amplitude shall be 9 dB below the radiated amplitude of P₁ within the desired arc of interrogation
- o P₃ radiated amplitude shall not be more than 1 dB below radiated amplitude of P₁
- o Framing pulses (brackets) must be 20.3 μs apart
- o Code 77 (or 7700) on mode 3/A for aircraft emergency
- o Code 76 (or 7600) on mode 3/A for aircraft communications failure
- o Interrogation limited to a maximum of 450 PPS

Also contained in the National Standard are the mode designations for both the interrogator and the transponder's response, as follows:

MODE DESIGNATION (INTERROGATIONS)

Military	Civil	Pulse Spacing
1 (As required)		3 ±0.2 μs
2 (Personal ident)		5 ±0.2 μs
*3 (Common ATC)	A (Common ATC)	8 ±0.2 μs
	B (Civil ATC)	17 ±0.2 μs
	C (Altitude)	21 ±0.2 μs
	D (Unassigned)	25 ±0.2 μs

*Designated mode 3/A

MODE DESIGNATION (REPLIES)

Mode 1 - 32 Codes

Mode 2 - 64 Codes (Navy)

4096 Codes (AF)

Mode 3 - 64 Codes (Navy, AF: old)

Mode 3A - 4096 Codes (civil, military)

Mode C - Altitude in 100 foot increments from -1000 feet to 126,500 feet.

Mode B is used for air traffic control purposes in the United Kingdom. Mode C will be used for automatic altitude reporting by both civil and military transponder-equipped aircraft. Mode D is not currently in operational use but is reserved for possible future use in civil aviation.

In operation, an interrogation pulse-group (figure 3-19A), i.e., the modes 1, 2, 3/A, or C, is transmitted from the interrogator via a directional antenna assembly. These interrogation signals trigger each airborne transponder located in the direction of the antenna main beam, causing a pulse-coded reply group to be transmitted from each transponder. These replies are received by the ground interrogator-receiver and, after video processing (decoding, etc.), are displayed to the operator. Measurement of the round-trip transit time determines the range to the replying aircraft while the mean direction of the main beam of the interrogator antenna determines the azimuth.

o Coding. The coding of the multiple-pulse reply provides the individualized information pertaining to the responding aircraft. The reply group is derived from the pulse-position coding scheme shown in figure 3-19B. In addition to the framing or bracket pulses, (BR_1 and BR_2) there are 12 information pulses various combinations of which are selectable by manually operated dials. Each information pulse position is assigned a letter and a number subscript. A specific binary code is determined by adding the numbers corresponding to each letter. For example, the code 3712 would utilize information pulses A_1 , A_2 , (3); B_1 , B_2 , B_4 , (7); C_1 , (1); and D_2 , (2). Since for each letter the sum of subscripts can represent the numbers 1 through 7, and since 0 can be represented by the absence of all pulses of a letter group, there are 8^4 , or 4,096 discrete codes available on modes 2 and 3/A and also mode C. On mode 1, the B_4 and C and D pulses are not used; thus, mode 1 code selection is limited to the 32 codes from 0000 to 7300. Mode 2 and 3/A code selections range from 0000 to 7777. Mode C is described later.

There are two special reply code configurations known as EMERGENCY and IDENT (Identification of Position). EMERGENCY can be selected, when appropriate, by pilot, in which cases the emergency situation is reported on mode 1 or 2 as the code of the day and on 3/A as code 7700, each followed by a three-time repeat of the bracket pulses. The IDENT function, when selected by the pilot on request from the ground controller, causes modes 2 and 3/A replies to be followed by the special position identification (SPI) or "caboose" pulse. The mode 1 reply will be a double repeat of the code of the day as it is at present. This IDENT function provides a marker for the controller to identify the position of a particular aircraft, on demand. The identification reply will continue for a period of approximately 20 seconds after initiation in the aircraft.

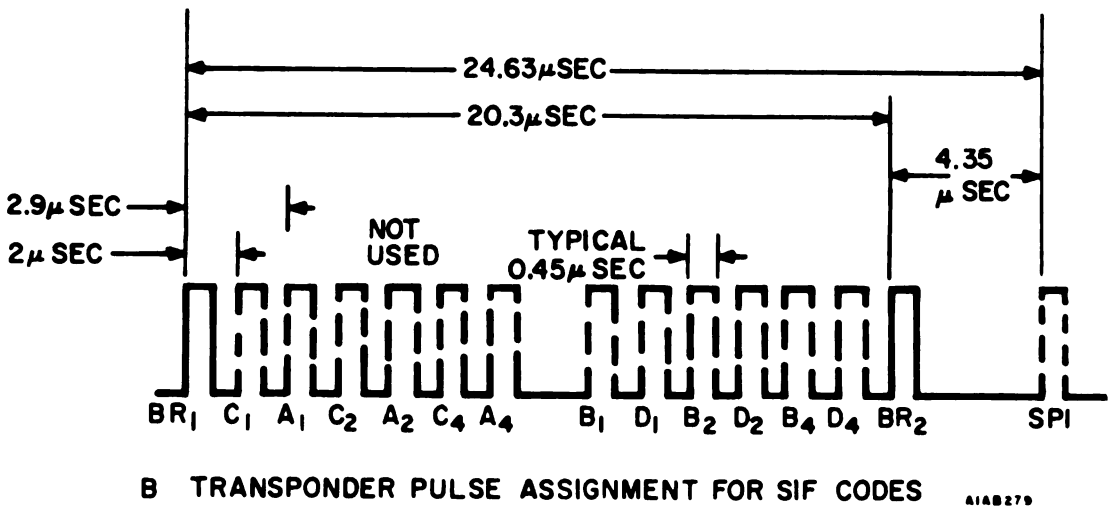
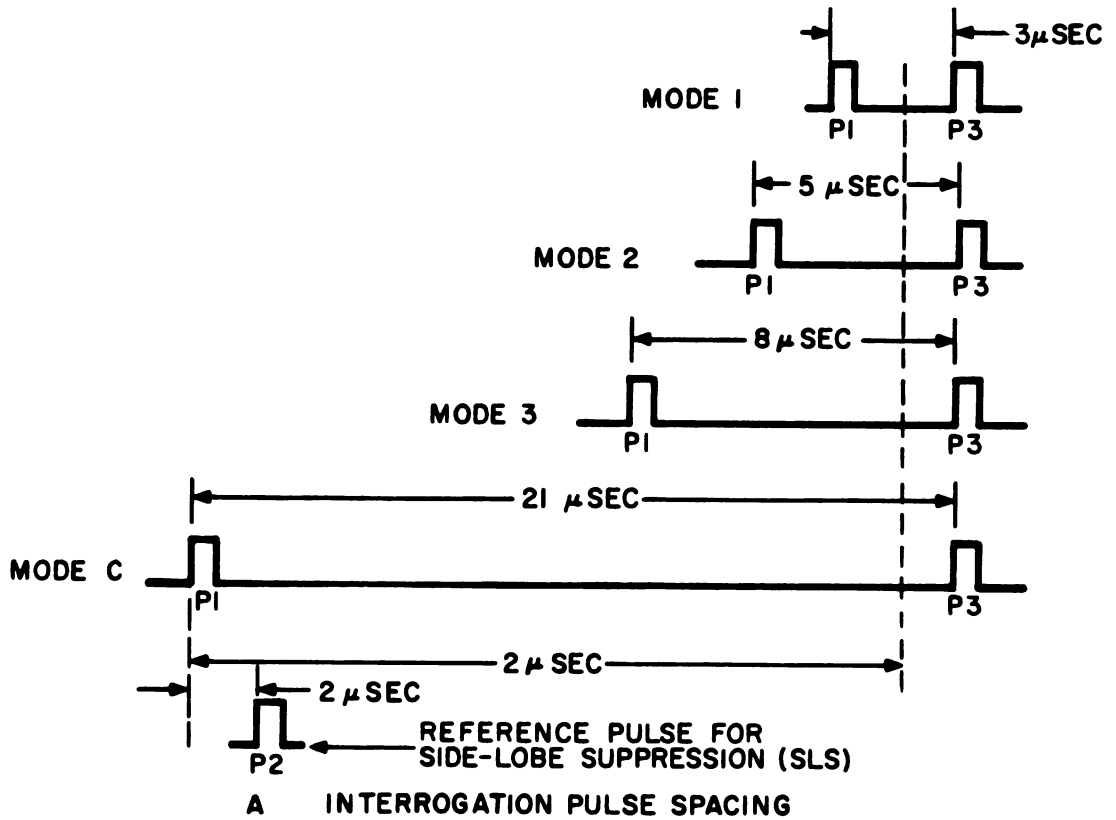


Figure 3 - 19. IFF Coding Pulses

o **Sidelobe Suppression Capability.** The interrogating system normally employs a directional antenna for transmitting the interrogation pulse-pair. However, an aircraft not within the mainlobe can be within a sidelobe pattern, and the transponder is committed to respond to the interrogation. Replies generated by sidelobe interrogation are undesirable because on a PPI-type display they do not represent the bearing of the replying aircraft. They also can result in the IFF "paint" being split in two, which results in a confusing display. Furthermore, in high-traffic areas, where several interrogators may be in operation simultaneously, these replies merely add clutter to the already busy display unit. Efforts to minimize this problem have led to a technique known as 3-pulse, interrogator sidelobe suppression (ISLS).

Basically, the ISLS technique consists of transmitting a control pulse, P_2 in addition to the normal interrogation pulse-pair, P_1 and P_3 . Control pulse P_2 occurs two microseconds after P_1 and is radiated in a nondirectional pattern.

As illustrated in the simplified diagram of figure 3-20 the omnidirectional antenna is powered to exceed the sidelobe-radiation from the directional antenna but to be less than the mainlobe. The transponder compares the level of P_2 with P_1 and P_3 (see figure 3-20) and responds accordingly. In practice, there is a gray area; if P_1 is greater than the control pulse by less than 9 dB, the transponder may or may not reply.

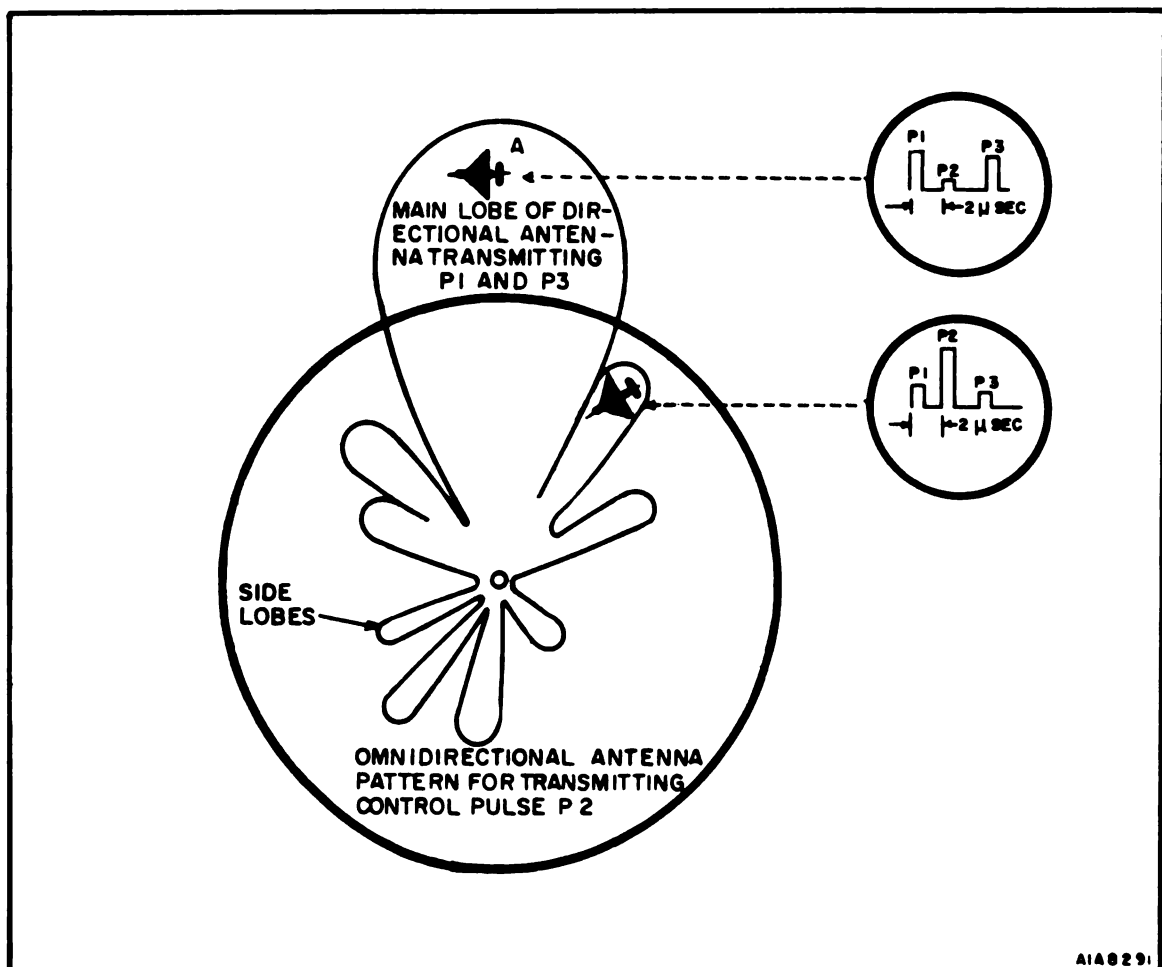


Figure 3 - 20. Simplified Illustration of the Concept of ISLS

Another problem associated with the identification system is the problem of nonsynchronous replies which occur when a particular interrogator receives replies from transponders which have been triggered into replying by other interrogators. These extraneous replies are termed "fruit". Defruiting, or, eliminating the nonsynchronous replies, is normally accomplished by storing incoming replies for one or more periods of interrogator transmission time, and then comparing the stored reply with subsequent replies. Only those pulses which are repetitive or synchronous are passed on for decoding. It is expected that most ground and surface interrogating equipment will contain defruiters.

- o Altitude Reporting. When fully implemented, mode C will provide the capability of automatic altitude reporting in 100- or 500-foot increments. ATCRBS ground-processing equipment will provide the IFF or beacon-derived altitude information on controller displays as numeric data adjacent to the aircraft target.

For the airborne portion of the system, altitude information is automatically furnished the transponder from the altimeter within the aircraft. The altitude information is encoded in accordance with a special coding scheme set forth in the U. S. National Standard. The system uses 11 information pulses and the special position identification pulse. Examples of the codes assigned to various altitudes are shown in table 3-2. Nine of the available pulses are used to encode altitude in 500-foot increments (from -1,000 feet to 126,500 feet referenced to the standard pressure setting of 29.92 in. Hg). Up to two of the three remaining pulses are used to report 100-foot increments.

In a typical airborne system (figure 3-21), an altitude computer-encoder subsystem senses static pressure and provides the necessary corrections for static pressure error. The corrected pressure altitude is encoded into the required format for transmission by the transponder. Additionally, the computer-encoder provides analog altitude outputs which position a servoed altimeter indicator. Thus, the pilot has at hand a display of the corrected altitude being transmitted to the ground station.

3.3.2 System Configuration

The basic radar beacon system consists of four major units as shown in figure 3-15. A brief description of each unit follows.

a. Basic Equipment

- o The receiver-transmitter consists of a panel and chassis on which are mounted power supplies, meter circuits, and the following subassemblies: modulator, RF head, IF amplifier, video amplifier, and GTC generator. The receiver-transmitter circuits perform two major functions: they generate the RF pulses in accordance with the modulator triggers supplied by the coder-decoder, and they accept the identifying replies and convert them into video signals. All connections to the receiver-transmitter, except the RF cable from antenna, are made through cables attached to terminal strips located in the cabinet. In the new equipments all cables are connected to connectors. Heaters are provided that automatically turn off when the temperature within the cabinet reaches 25° C (77° F). A blower, in conjunction with an inlet and an outlet air filter, provides ventilation. The two main AC input power line fuses are mounted on the front panel with four spare fuses nearby. A meter, a selector switch, and a momentary-ON pushbutton switch are used in monitoring the voltage and current in various circuits.

- o The coder-decoder consists of a panel and chassis on which are mounted a power supply and the circuits necessary to perform the following major functions. It sorts the IFF video from the receiver-transmitter into three channels and it provides the specially coded trigger pulses for the modulator of the receiver-transmitter. All connections to the coder-decoder are made through cables attached to terminal strips located in the cabinet.

- o The video distributor and video amplifier, shown in figure 3-15, are part of the AN/GPA-106 and -107 Radar Distribution Group. Details on this equipment are presented in a subsequent paragraph. The radar set control master control unit provides all the controls necessary for operation of the IFF system. Three accessory radar set control boxes are used in conjunction with the master control unit, but provide fewer controls.

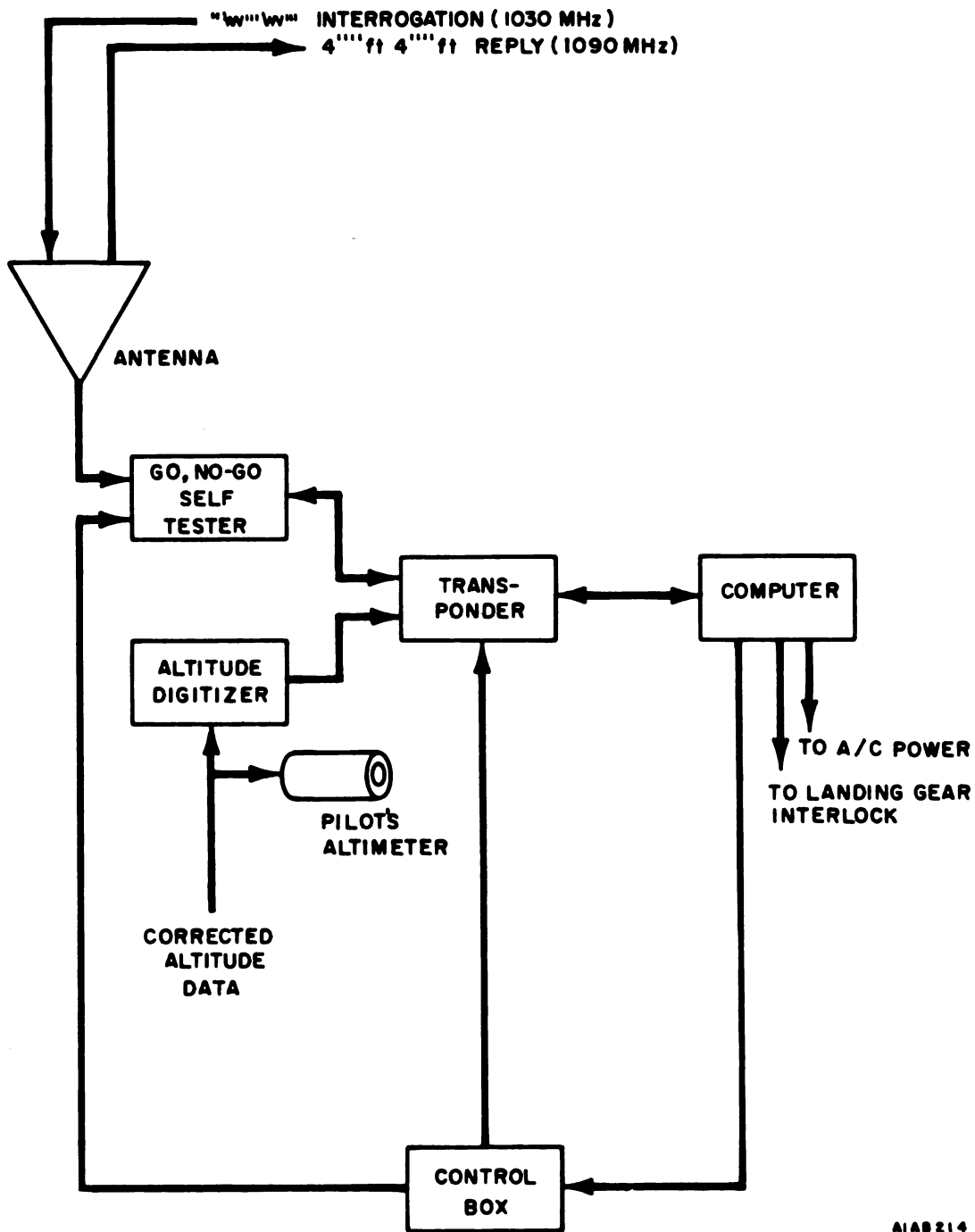
Table 3-2. A Portion of the Assigned Codes for Mode C Altitude Reporting

LARGE INCREMENTS (500 FEET)	SMALL INCREMENTS (100 FEET)	D ₄										
		D ₂ and SP ₁	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄	
11,750 to 12,250	11,750 to 11,850	0	0	0	1	0	1	1	1	0	0	1
	11,850 to 11,950	0	0	0	1	0	1	1	1	0	1	1
	11,950 to 12,050	0	0	0	1	0	1	1	1	0	1	0
	12,050 to 12,150	0	0	0	1	0	1	1	1	1	1	0
	12,150 to 12,250	0	0	0	1	0	1	1	1	1	0	0
12,250 to 12,750	12,250 to 12,350	0	0	0	1	0	1	1	0	1	0	0
	12,350 to 12,450	0	0	0	1	0	1	1	0	1	1	0
	12,450 to 12,550	0	0	0	1	0	1	1	0	0	1	0
	12,550 to 12,650	0	0	0	1	0	1	1	0	0	1	1
	12,650 to 12,750	0	0	0	1	0	1	1	0	0	0	1
12,750 to 13,250	12,750 to 12,850	0	0	0	1	0	0	1	0	0	0	1
	12,850 to 12,950	0	0	0	1	0	0	1	0	0	1	1
	12,950 to 13,050	0	0	0	1	0	0	1	0	0	1	0
	13,050 to 13,150	0	0	0	1	0	0	1	0	1	1	0
	13,150 to 13,250	0	0	0	1	0	0	1	0	1	0	0

o An important element in an IFF system is the antenna used to transmit and receive the interrogating signals. It may be a slaved antenna, that is an independent antenna that rotates in synchronism with another or master antenna. The most common is an integral antenna, an antenna that is built into or becomes a mechanical part of an existing radar antenna and that has no independent mechanical operation.

b. AIMS. The AIMS system consists of the basic transponders and interrogators previously described, with the addition of computers, transducers, servoed altimeters, altimeter-encoder sets, and video processors. As illustrated in figure 3-22, the interrogators perform a "question" function and are included in all AIMS-equipped ground and surface sites, in tactical ground and surface systems, and in certain special-task airborne vehicles. Interrogators as in the basic IFF system are usually associated with or slaved to, a primary radar. The transponders (figure 3-21) are utilized primarily on aircraft and perform the "answer" function.

The AN/UPX-23 Interrogator, designed for use in the AIMS system, provides the three RF pulses outputs, P₁ and P₃ mode pulses, and the control pulse P₂. The peak power output may be 500, 1000, or 2000 watts. The maximum allowable interrogation repetition rate is 450 interrogations per second. The Regional Federal Aviation Administration Frequency Management Office assigns the exact pulse repetition frequency (PRF), so that no two IFF systems are operated with less than a 20.3 μ s pulse recurrence time, thus preventing mode overlap. To minimize unnecessary transponder triggering and the resulting high fruit density, the interrogator will use the lowest possible PRF that is consistent with the display characteristics, interrogator antenna beamwidth and antenna rotational speed employed. If the primary radar used to trigger the beacon system has a PRF greater than 450 PPS, it must be counted down by an even divisor so that the IFF interrogations are less than 450 PPS.



AIAB 214

Figure 3 - 21. AIMS Airborne Portion, Block Diagram

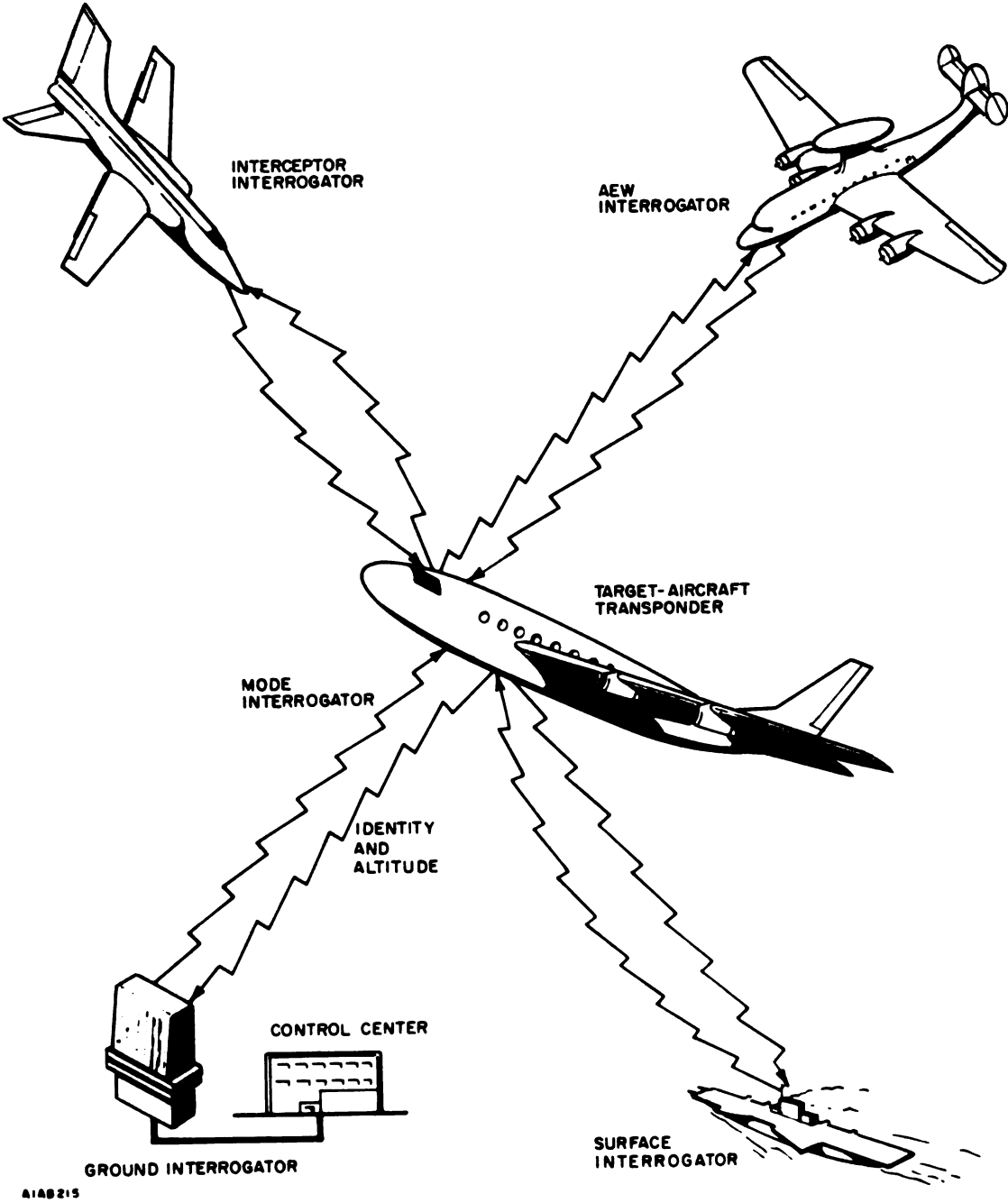


Figure 3 - 22. AIMS Environments

The AN/UPX-23 uses a long gain time control for shore installations, and a short gain time control is used only on ship-to-ship IFF systems. With this interrogator the mode interlace is established by a front panel control or by an external control box such as an AN/UPA-59 Decoder. The dwell time on the individual mode interlace is adjustable via a control on the AN/UPX-23. Samples of this adjustment are as follows:

- 1, 2, 3/A and C, repeated, or
- 1, 1, 2, 2, 3/A, 3/A, C and C, repeated, or
- 1, 1, 1, 2, 2, 2, 3/A, 3/A, 3/A, C, C, and C, repeated.

The interference blanker MX8757/UPX used to remove non-synchronous reply interference from the IFF system is known as the defruiter. The defruiter uses a memory device for storage comparison on a pulse-to-pulse basis to establish valid synchronized IFF returns. The MX-8757/UPX is a defruiter consisting of four video channels, pulse-to-pulse comparison using 0.5 μ s bits, with a range of 200 NMI (expandable to 350NMI). If a pulse of a reply compares in range with a stored pulse within +0.2 μ sec, the defruiter will pass the pulse. If it changes position by more than + 0.9 μ sec, the defruiter will reject the pulse.

3.3.3 System Application

The radar recognition set or IFF System is used primarily for the recognition of radar targets. A supplementary use of the equipment is to provide a more detailed recognition of radar targets for additional security and tactical information. The IFF system is designed to operate in conjunction with shipboard and ground radar equipments. It normally uses the radar display for presentation of its IFF data and its antenna is either integral to or "slaved" with the associated radar antenna.

The IFF system on an air station is an integral part of the ATC search or surveillance radar system. The system is used by the air-traffic controllers to help identify aircraft in the area. If an aircraft has developed an emergency condition, the pilot will so inform the controller and at the same time he sets (or is told to set) his transponder to EMERGENCY. The IFF emergency response (four broken arcs beyond the target blip for the basic system or the 7700 code for AIMS) will enable the controller to quickly locate the plane's echo on his radar display.

3.3.4 AIMS Processing and Display Systems

A new system called Direct Altitude Identity Readout (DAIR) is replacing the broadcast IFF system. The equipment which performs this function is identified as the AN/TPX-42A. The AN/TPX-42A is basically a digital processing system which accepts the AIMS video from the AN/UPX-23 Interrogator, through the MX-8757/UPX defruiter, and obtains bearing signals from the antenna synchro transmitter. The system processes this data to produce digital target messages containing all the valid information (i.e., position, code, altitude) for each target. The digital data is stored in the processor until required to provide a flicker free symbolic/numeric display on a PPI. The symbolic/numeric data from the AIMS system and radar video are simultaneously displayed on the PPI. The system also provides bracket video for display with the radar readings. Display of the symbolic/numeric data is an option of the radar controller via a specially provided control box. The control box permits the controller to display all codes and altitudes, and to select targets for display by codes, code blocks, altitudes or by any combination thereof.

3.4 RADAR ANCILLARY EQUIPMENT

Radar Ancillary Equipment are those equipments which are necessary for an efficient presentation and dissemination of radar video data. These equipments (not supplied as part of the basic radar equipment) include the following: Video Mapping, Data Distribution Group, Communication Transmission Systems, Common Digitizer, and BRITE 2.

3.4.1 Video Mapping Equipment

a. System Principles. The video mapping group, figure 3-23, is designed for use with search and tracking radar systems.

The primary function of the video mapper is to provide an electronic map which may be superimposed on the radar PPI displays. The desired map details originate as transparent lines, symbols, and lettering on a circular film negative (figure 3-24). The radar antenna site is located at the center of the map which rotates in synchronism with the antenna. A CRT, centered under a radius of the map, is swept by a straight-line constant-intensity beam. Its sweep is initiated by the system trigger during operation. The sweep rate is set for the correct map scale factor so that map range marks and PPI range marks coincide. Light generated by the CRT passes through transparent portions of the map, thus carrying map information which is synchronized with the instantaneous azimuth and range position of the PPI spot deflection. A photomultiplier tube converts the instantaneous light energy passing through the map to an electrical signal. After modification by various shaping and amplifying circuits, the resulting video pulses are coupled to the radar system where they modulate the beam of the PPI. The PPI thus reproduces transparent portions of the map which appear correctly oriented in azimuth and range on its screen.

Electronic reproduction allows simultaneous reproduction on several PPI screens regardless of sweep or type of presentation. The map retains the correct scale factor even when different range scales are expanded and offset presentations are used. The map presentation may be attenuated or eliminated at will by manipulation of the PPI controls. Changing of map areas is simple.

b. System Configuration. The video mapper (figure 3-25) consists of the following eight principal subassemblies. The electrical equipment cabinet houses the other subassemblies and incorporates the interconnecting cables, primary terminal board, and connectors. The subassemblies are the electrical synchronizer which contains the map driving mechanism, the power distribution panel, the electronic control amplifier which controls map azimuth synchronization, the sweep generator which generates the sawtooth current pulse for map scanning, the video amplifier which picks up the light signal from the scanned map and produces a suitable electronic map signal, the oscilloscope used for periodic checks of the mapping function of the mapper, and the power supply which supplies DC power for all units except the oscilloscope. A functional description of the principal subassemblies follows.

o Synchronizer. The map drive assembly includes map drive motor, a one speed synchro control transformer, 36-speed synchro control transformer, and associated gearing. The IX control transformer for coarse error correction is geared one-to-one to the map drive ring. The 36X control transformer for fine correction when fine correction is geared thirty-six-to-one to the map drive ring. The whole mechanism is geared to the map drive motor.

o Primary Power Distribution Section. The primary power distribution panel controls the switched 120-volt primary power from the radar set which is filtered and available for accessory and test equipment.

The main power switch and circuit breaker applies power to the balance of the equipment when in ON position. Operation of the oscilloscope is controlled secondarily through the power switch.

o Electronic Control Amplifier. During normal operation the electronic control amplifier relay circuits select error signals for precise bearing position control. The selected error signals are stabilized, amplified, and returned to the electrical synchronizer to drive the map. A low speed error signal is supplied so that the map will follow the correct high speed null and aid in initial synchronization when the equipment is first turned on.

o Sweep Generator. The sweep generator provides the sawtooth current for the deflection coil, a gating pulse for the cathode-ray tube, and a sawtooth voltage for operation of the focus compensation circuits, and the electrical synchronizer.

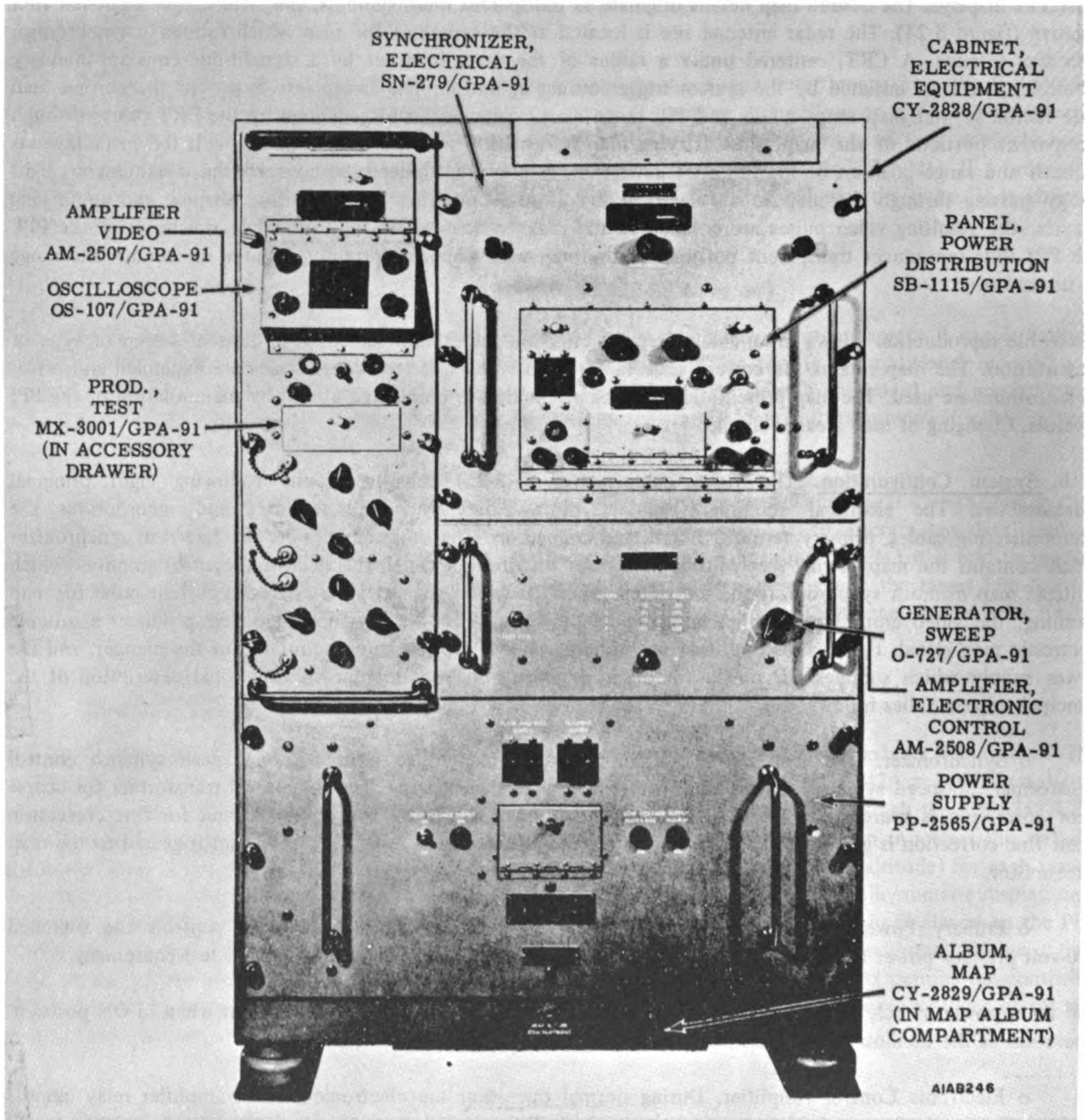


Figure 3 - 23. Video Mapping Group, AN/GPA-91

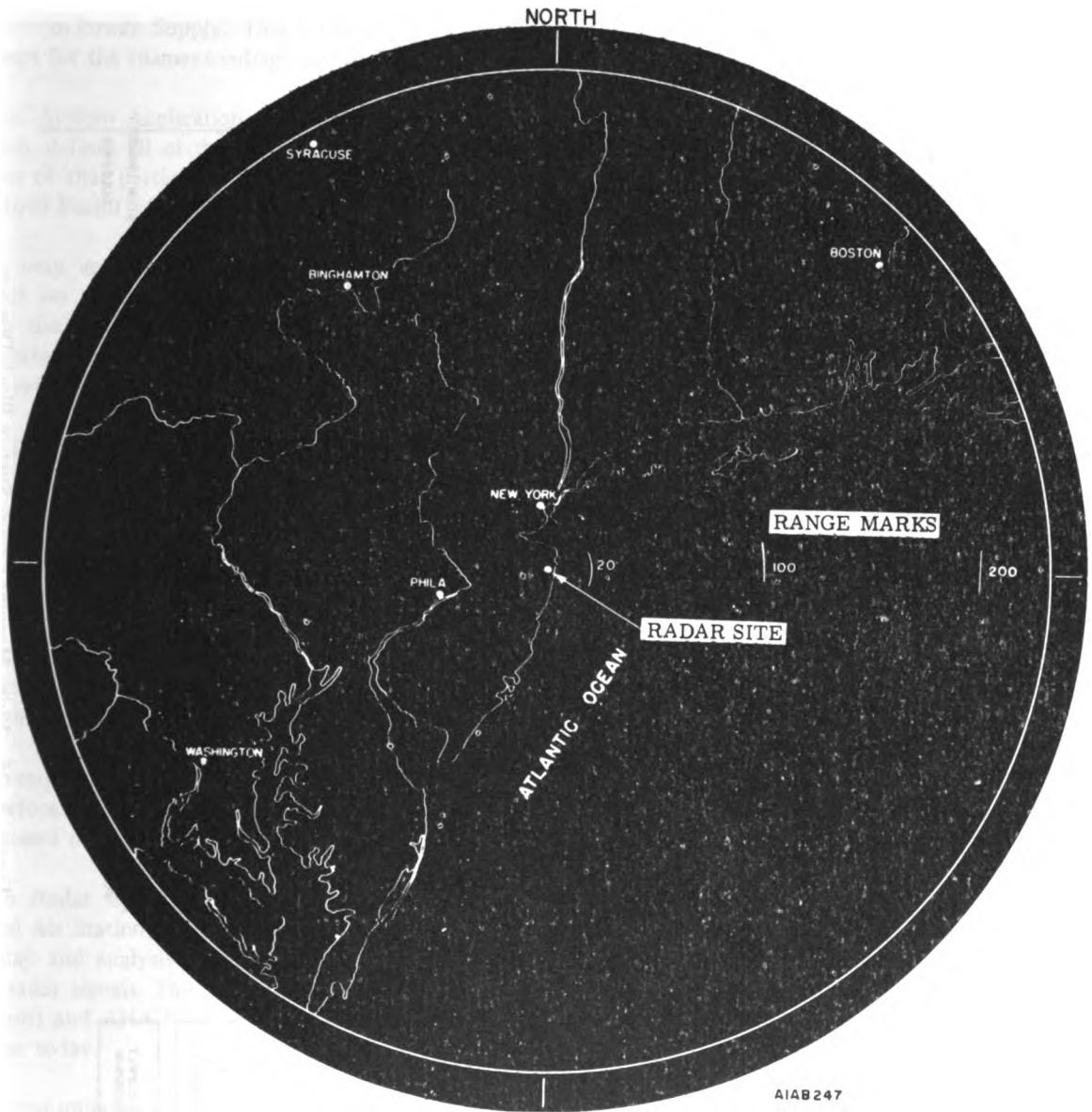


Figure 3 - 24. Video Mapping Presentation

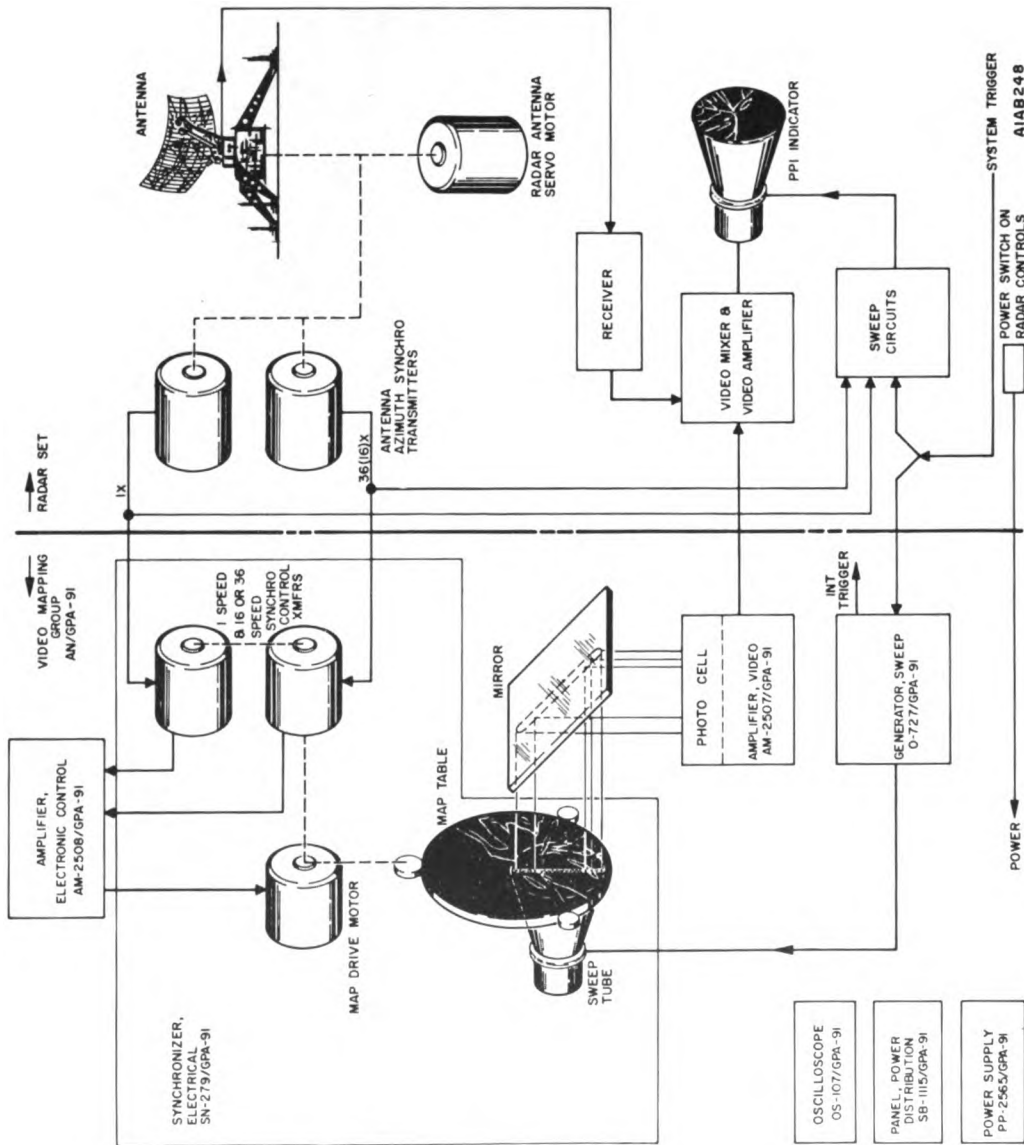


Figure 3 - 25. Video Mapping Group, System Block Diagram

- o **Video Amplifier.** The video amplifier converts the modulated light map data produced in the electrical synchronizer into electrical signals. It amplifies, shapes, and further amplifies this map information to generate a video signal suitable for display on the associated radar PPI.

- o **Oscilloscope Section.** The oscilloscope is included in the video mapper to facilitate adjustments and periodic checking of the performance of the video mapping sections. It is also used for trouble-shooting sections of the unit when so required. In addition, it may be readily used as a general purpose synchroscope/oscilloscope when the equipment to be tested can be brought reasonably close.

- o **Power Supply.** This furnishes all filament and operating voltages required by the video mapping unit except for the filament voltage and high voltage in the oscilloscope.

c. **System Application.** The video mapper provides a plan position indicator with a presentation on the scope which defines all of the primary landmarks, obstructions, runway locations, and layouts within a range of 350 miles of that particular station. It may also be used to define an area under the control of a Radar Air Traffic Control Facility (RATCF) with more than one airport, airfield, or emergency landing strip under its control.

The map area may be expanded or contracted by changing the individual PPI range scale without having any effect on other PPI's receiving the same map data. The data is electronically generated and, after being mixed with the PPI video, is controlled by the local operator. The operator has complete control of the map on his indicator. He has the capability of varying the intensity from very high to the entire elimination of the map but still retaining the target information.

3.4.2 Methods of Remoting Video Data

The remoting of video data on a Naval Air Station is usually associated with one or two types of signals. These signals are either radar or television video. The transmission of these signals can be accomplished in a number of ways depending on the signal type, strength, and distance between transmitter and receiver. First, consider the two signals and their usages.

- o **Television signals** are usually transmitted for purposes of station weather briefings and may be remoted either by coaxial cable or microwave link for distribution to the remote locations which require the information. The basic requirements for coaxial cable transmission of video signals are applicable to radar and television.

The requirements for microwave transmission of video signals are not identical for both television and radar, therefore each configuration will be presented separately. The television microwave configuration will be discussed in chapter 6.

- o **Radar signals** are used for purposes of identifying, tracking, and controlling aircraft in the vicinity of a Naval Air Station. The relative signal strength of the radar returns is usually weak but is amplified sufficiently for display and analysis at the local site. Remote IFR room operations require some processing and conditioning of the radar signals. This is accomplished by use of the Radar Data Distribution Groups AN/GPA 106(V) (radar site system) and AN/GPA 107(V) (operations site system). These systems are designed to operate with any radar set in use today.

The transmission system by which the signals will be remoted is determined primarily by distance. Sites located less than 10,000 feet apart will generally utilize a coaxial cable. If unique conditions exist, like the inability of acquiring a right-of-way through private property, or a natural obstacle exists, i.e., a lake or river which cannot be crossed, the video signals will be transmitted by microwave link. The use of coaxial cable beyond a distance of 10,000 feet encounters both physical and economic problems.

Medium and long distance video remoting is usually accomplished by radio microwave links. They are capable of good quality wideband signal transmission from a few hundred yards to distances approaching hundreds of miles providing line-of-sight contact is maintained between stations.

The microwave link used between stations for medium range remoting would be greater than 2 miles but less than 30 miles. At these distances line-of-sight and good signal reliability are easily maintained.

Long distance video remoting is presently accomplished by the use of microwave links with relay stations located every 20 to 30 miles apart.

The equipment and maintenance costs of the relay stations required for long distance video remoting systems rise rapidly with increases in terminal separation. Therefore another method of long distance remoting which should be considered is the common digitizer system. This equipment processes the video data (analog) at the radar site and transmits digital data on standard telephone lines. This could prove to be a more economical transmission method than a number of microwave relay stations if the distance covered between stations exceeds 100 miles.

a. Radar Data Distribution Groups. There are two separate radar data distribution groups each configured to perform its required function. The (radar site) radar data distribution group will be discussed first, followed by a discussion on the (operations site) radar data distribution group.

(1) Radar Site. The radar data distribution group (foldout 3-3) is designed to perform the following functions at a remote radar site:

Accepts data from two radar and IFF systems.

Distributes video data from both radar channels to the radar common control unit for selection of channel to be transmitted.

Performs remotely-controlled selection of IFF data and makes the data available to landline or microwave terminal equipment for transmission to a radar operations site.

Distributes radar pretrigger to the IFF system and provides transfer switching of the IFF antenna and dummy load when IFF channels are switched.

Provides for selection of radar and IFF video data to be displayed on a local radar indicator.

Provides a means for allowing IFF mode and code selection within the dual-channel IFF system.

o Configuration. The radar data distribution group is composed of the following main components: the electrical equipment cabinet, the electrical equipment base and the required interconnecting boxes as shown in foldout 3-3.

The electrical equipment cabinet is divided into horizontal enclosures that house most of the individual units. These units are arranged in the cabinet from top to bottom as follows:

The relay assembly which contains 21 identical plug-in relays. Its function is to adapt status indication signals received from the radar system and to dry-contact signals for use by both the microwave link terminal and landlines which are transmitted directly by cable.

The sweep generator unit is used for testing and maintenance and its main use is in checking video response in the data distribution group.

The switching unit receives radar and IFF data from both radar channels and both IFF channels. It distributes these data to selected destinations such as the radar common control unit, the IFF sets, the transmission terminal equipment, and electronic gate amplifier. The channels of radar and IFF data that have been selected at the radar common control unit can be selected by front-panel controls on the switching unit for display on the local radar indicator. The switching unit contains the following types of plug-in assemblies:

- o Isolation amplifiers which isolate the distribution circuits from the active video signal circuits.
- o Trigger control and unseparated video control relay assemblies which have a primary function of circuit switching. The two 28-VDC power supplies which are the primary source of DC power.
- o Signal distribution panel which consists of four sections of video patch panel.

Within the electronic gate amplifier assembly provision is made for adjustable time-sequenced video gates within one radar trigger interval for three individually synchronized video inputs with remote control of gate length and video levels. This assembly contains the four following plug-in subassemblies:

- o Range gate generators, and the normal operation of range gate controls provides video from (approximately) 5 to 50 miles, 50 to 120 miles, and 120 to 228 miles.
- o Video switch plug-in relay assembly is a functional part of the switching unit and performs switching of dual-channel radar and IFF data as determined by selection at the switching unit.

The following assemblies are also associated with the electronic gate amplifier:

- o The range gate mixer control provides the operator with independent control of the indicator gating section which, in turn, controls the video display on the individual indicator.
- o The interconnecting box serves as a junction for video, trigger and antenna azimuth synchro data circuits between the local radar indicator and the distribution group. It is also a junction for IFF mode and code select voltages between radar set control and video decoder.

The electrical equipment base provides a mounting base for two IFF sets consisting of two receiver-transmitters and two coder/decoders. The following units of the distribution group mounted within the base enclosure are:

- o The relay assembly which removes pretrigger from the inputs to the two IFF sets while the antenna and dummy load are being switched and controls the operation of radio frequency transmission line switch.
- o The radio frequency transmission line switch assembly transfers the antenna and a dummy load between the outputs of IFF sets A and B.
- o The interconnecting box which serves as the cable termination unit in the landline system when required.
- o System Application. Radar data distribution group (radar site) is an integral part of a complete radar data distribution system, as shown in figure 3-26. A typical data distribution system, using the equipment, is the Radar Air Traffic Control Facility (RATCF) system of the U. S. Navy. The system was designed to operate with specific medium range search radars and IFF systems but is also compatible to other radar and IFF systems.

(2) Operations Site. The operations site or terminal equipment room radar data distribution group will now be discussed noting modifications which provide variations on the basic capabilities of the system. These variations include the ability to provide synchro information to 20 additional display indicators although this involves the loss of remote radar and IFF information. The capability also exists to increase the number of indicator groups to fifteen when the data is transmitted via landlines only. This modification is not possible when a microwave link is employed.

The radar data distribution group figure 3-27 is used at a radar operations site or terminal equipment room of the control center to perform the following functions:

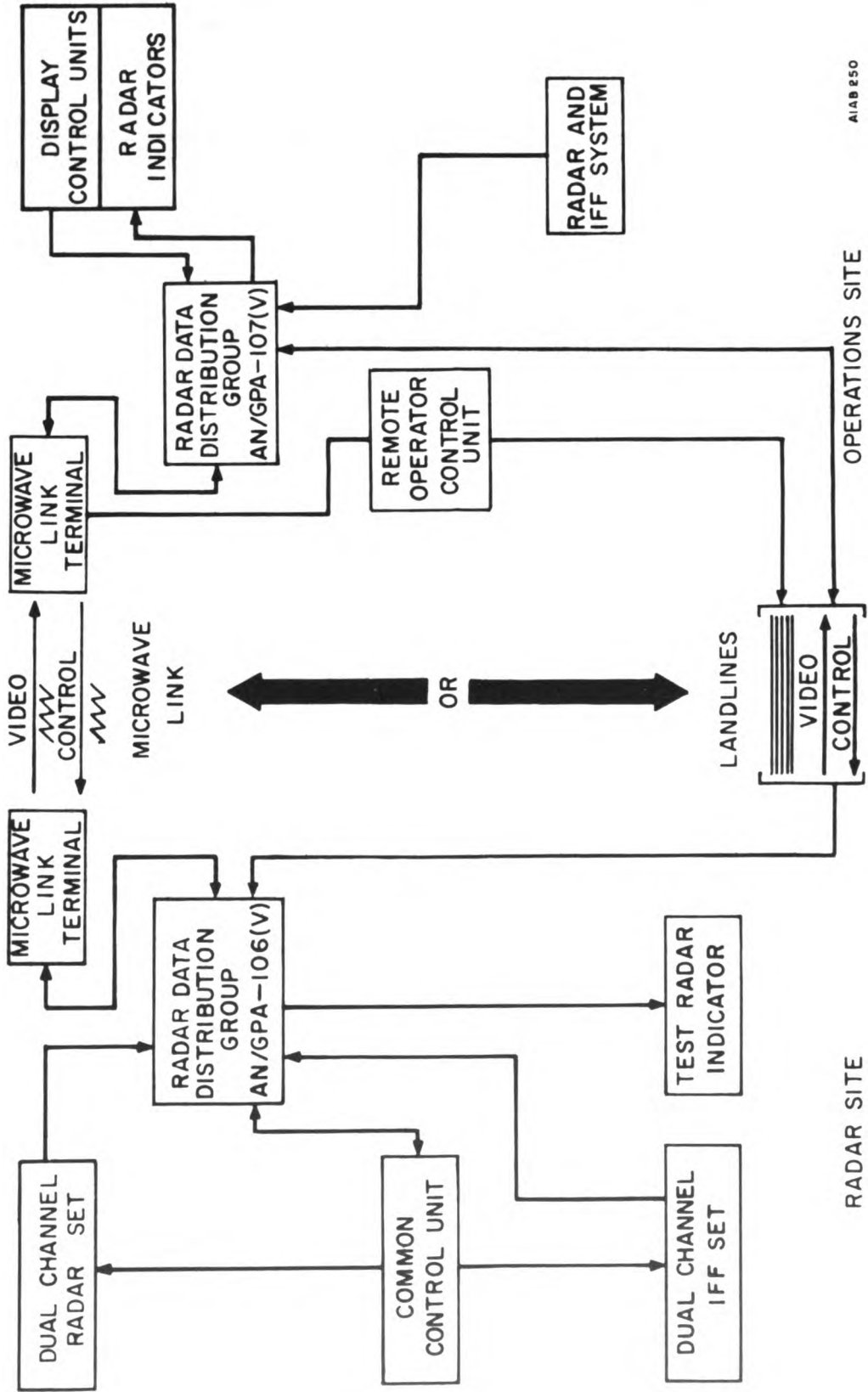


Figure 3 - 26. Radar Data Distribution System, Block Diagram

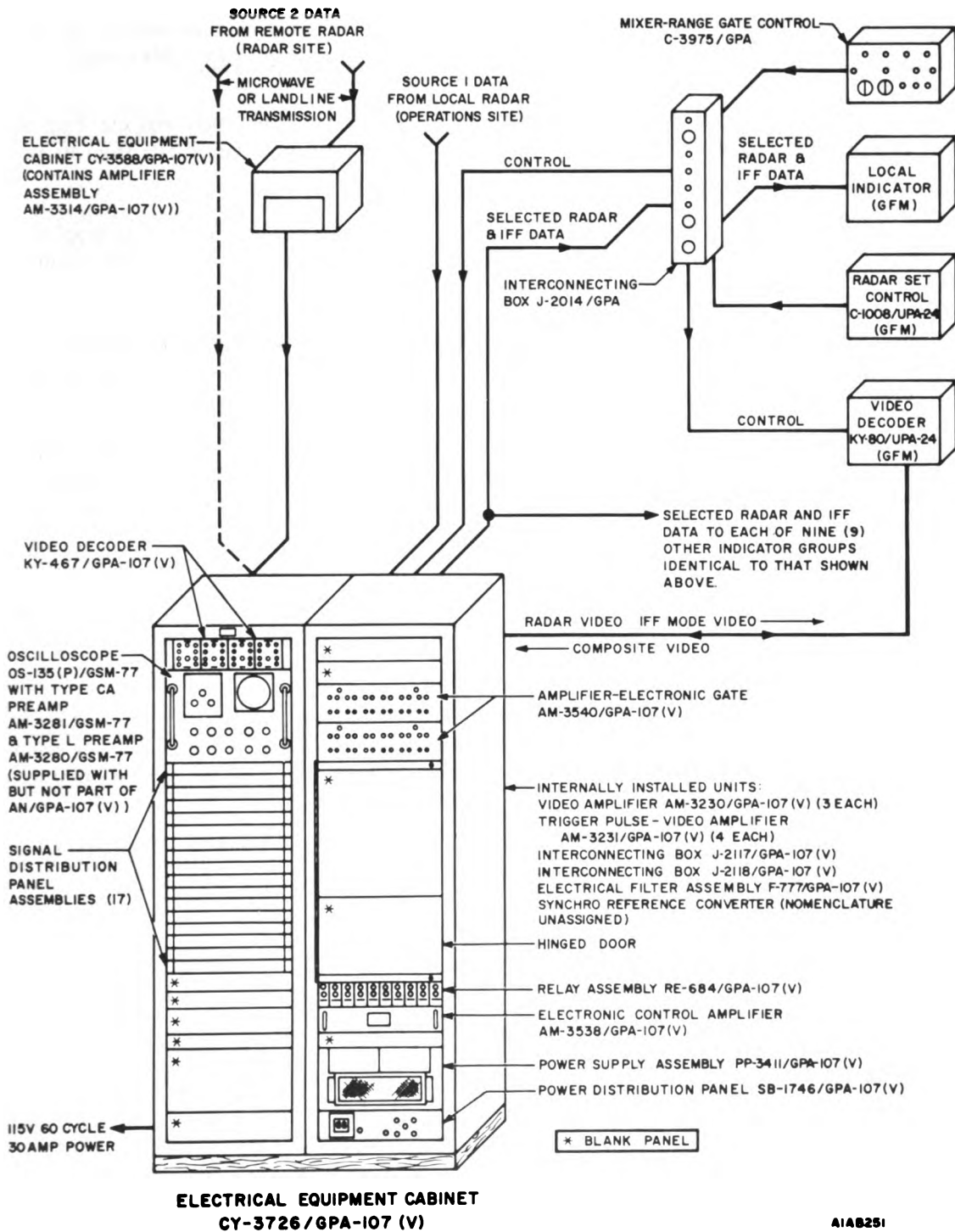


Figure 3 - 27. Radar Data Distribution Group, AN/GPA-107 (V), Relationship of Units

- o Terminate and equalize landline cables (when used) which supply radar and IFF video data from a remote radar site.
- o Distribute radar and IFF data transmitted from a radar site when either microwave link or landlines are used for data transmission.
- o Distribute radar and IFF data from radar equipment located at the operations site.
- o Distribute video mapping data from two mapping equipments located at the operations site. Each mapping equipment provides mapping data for display on the radar indicators along with target data from its associated radar set.
- o Define data supplied from the local radar equipment as source 1 data, while the data supplied from a remote radar equipment is referred to as source 2 data. All data from both sources are prepared and distributed to a maximum of 10 radar indicators capable of presenting PPI displays.
- o Provide each indicator operator position with facilities for selecting and controlling display data from either source 1 or source 2. Each operator may select data from either source without impairing the displays of other indicating equipments at the operations site.
- o Provide mixing and gating of normal, MTI, and integrated radar signals supplied by the selected radar equipment and mapping video supplied by the selected mapping equipment. The amplitudes and gating intervals of each signal can be controlled by the individual indicator operators without affecting the presentation on other indicators in the system.
- o The equipment receives unseparated mode video data from Mark X IFF equipment at both sources. The unseparated mode video data is then separated (decoded) and distributed to a maximum of ten IFF decoding equipments. The operator of each indicator may select any mode of interrogation without impairing the operation of other decoding equipments in the system.
- o The mixed video data and separated IFF data supplied by the distributor group are supplied to the IFF decoding equipments at the respective indicator positions. The video mixing circuits of the decoding equipments are utilized for final mixing of radar and IFF video data before application through the signal distribution panel to an indicator for display.

When the operator of an indicator selects a source of data for display, the active IFF transmitter of the selected source is automatically connected into the selected circuit. Each operator may enable mode 1, mode 2, or mode 3 of the IFF transmitter selected.

o Configuration. The radar data distribution group is composed of the following units, as shown in figure 3-27. The main equipment cabinet is divided into two vertical sections which house the individual units of the cabinet. These units are arranged as follows:

The video decoder units are located at the top of the left-hand section. Each unit contains two identical plug-in decoding assemblies which provide separation, or decoding, of unseparated IFF mode data. Only one plug-in assembly in each of the decoder units is active.

The 17 individual signal distribution panel assemblies provide the input and output connections of all video distribution circuits.

Behind the signal distribution panel assemblies are located one or two synchro reference converter units. One is always used to provide reference conversion for local radar synchro signals. A second unit is used for remote radar synchro signals when landline transmission is employed.

Four trigger pulse-video amplifier units are located behind the hinged door. Two units are active and are used to process local and remote radar pretrigger data.

Pretrigger signals from local and remote radar are applied to the active units where they are delayed to become synchronized with the main trigger signals of the respective radar equipments. Each delayed signal is then distributed to 12 channels: ten channels feed into one indicating equipment to initiate indicator sweep; one channel to trigger a video mapping unit; the twelfth channel is a spare.

The three units (located behind the door) are video amplifier units and each unit contains 12 five-channel amplifier plug-in assemblies.

A total of 14 radar and IFF signals are processed by the video amplifier units. Each of the fourteen signals is distributed into 10 channels for presentation to the indicators of the system. Each signal utilizes two five-channel amplifier plug-in assemblies.

The signals processed include:

- NORMAL VIDEO
- MTI VIDEO
- INTEGRATED VIDEO
- MAPPING VIDEO
- MODE 1 IFF (SIF)
- MODE 2 IFF (SIF)
- MODE 3 IFF (SIF)

The two top units in the right-hand section are electronic gate amplifier units. Each unit houses six groups of four printed circuit plug-in assemblies. Each of five active groups of plug-in assemblies performs the video gating, mixing, and switching for one radar indicator.

The gated video outputs of the electronic gate amplifier units are supplied to the video mixing circuits of the IFF decoding equipment (used at the indicator positions) where the gated radar video is mixed with IFF video for presentation on indicating equipment.

The relay assembly contains ten switching assemblies, one for each radar indicator.

When an operator selects one radar source for presentation, the corresponding switching assembly of the unit is operated to select the proper synchro data from the selected source.

IFF mode enabling is also accomplished by this unit. When the operator selects a mode of interrogation, the circuitry of the corresponding switching assembly connects the mode enabling circuit of the selected IFF transmitter.

The electronic control amplifier contains 10 plug-in amplifier assemblies.

Eight of the assemblies are active and process synchro data from local and remote radar equipments.

The second unit from the bottom is the power supply assembly and the bottom unit is the power distribution panel.

Each indicator position is furnished with an interconnecting box and a mixer-range gate control contains all connections between the indicator group, associated IFF decoding equipment, and other main components of the distribution group. The control unit provides the operator of each indicator with a means of selecting a source of radar data for presentation and of controlling the functions of the electronic gate amplifier units described earlier.

The electrical equipment cabinet houses the landline cable termination assembly and amplifier assembly. The unit contains equalization amplifier assemblies which compensate for the high-frequency attenuation caused by landline transmission. If the radar site is linked with the operations site by a microwave transmission system, this cabinet is not supplied.

o Application. The radar data distribution group (operations site or terminal equipment room) is designed to be an integral part of a complete radar distribution system as shown in figure 3-26. The equipment is not limited to any definite type of installation, but can be used in a wide variety of applications where distribution of radar data is required. The equipment is capable of providing system synchro information to 20 additional indicators by the addition of one more electronic control amplifier, a system interconnecting box, and 20 individual interconnecting boxes at each additional indicator unit. This capability is possible although it involves the loss of the remote radar and IFF capabilities.

b. Remoting Video Data Via Coaxial Cable. The selection of the right coaxial cable for a given application requires consideration of the physical and electrical characteristics of the cable, such as the materials, impedance, attenuation, and voltage rating of the cable. A discussion of the properties of coaxial cables follows. Cables should be chosen with impedances that match other circuit elements and no cable should be selected that would reduce the signal to an unusable level for the application.

(1) Cable Configurations. There are basically two types of coaxial cables in use by the Navy at Naval Air Stations. These are the solid dielectric types RG 59 and RG 11A/U (figure 3-28) and the semiflexible air dielectric type (figure 3-29).

The solid dielectric RG 59 cable is primarily used within a building with a controlled environment to interconnect equipments in a console or short-distance interconsole configurations. The RG 11A/U is also a solid dielectric cable and is used under conditions of controlled environment to interface equipments and initial signal entry points up to distances of 50 feet. When a coaxial cable is required that will run in excess of 50 feet to some external location in a normal atmospheric environment or underground, a semiflexible air dielectric cable must be used.

(2) Coaxial Cables Application. Coaxial cables are used as RF and video transmission lines to provide minimum loss and distortion of both signal intelligence and power. The application of transmitting radar video from a radar site to an IFR room for air traffic control presents a condition which is not easily satisfied. This condition is the selection of a coaxial configuration which is capable of transmitting broadband radar video signals with minimum signal loss and distortion. The coaxial configuration which best satisfies this need is the semiflexible, air dielectric type. This cable type exhibits low dielectric loss due to its helically wound polystyrene tape construction which results in a low tape to air ratio which reduces the level of signal attenuation as compared to a solid dielectric construction. Other cable types have been tested in an attempt to reduce the relatively high cost of the air dielectric type, but their higher signal attenuation levels and lower bandwidth capabilities indicated that these cables were not acceptable for the task required. The cable exhibits the flexibility of a lead sheathed cable, yet has an extremely high crush strength (1200 PSI) which is capable of being pressurized. The cable emits no electromagnetic radiation.

c. Remoting Video Data Via Radio Microwave Links. A microwave system is a means of transmitting and receiving information as are other radio systems. In its most basic arrangement a microwave system consists of two terminal stations. Each station is equipped with an FM transmitter and receiver and employs duplex operation. In cases where the terminal stations are separated by a distance greater than 20 to 30 miles communications become unreliable, and one or more repeater stations are added (foldout 3-4). The number and location of repeater stations depend upon several factors including terrain, path length for each hop, antenna size, transmitter power output, receiver sensitivity, and maximum allowable fade margin.

The intelligence transmitted by a microwave system may take almost any form, from video signals and trigger pulses to audio tones. For detailed information regarding microwave systems, see NAVELEX 0101.112, Microwave and Tropospheric Communication Systems.

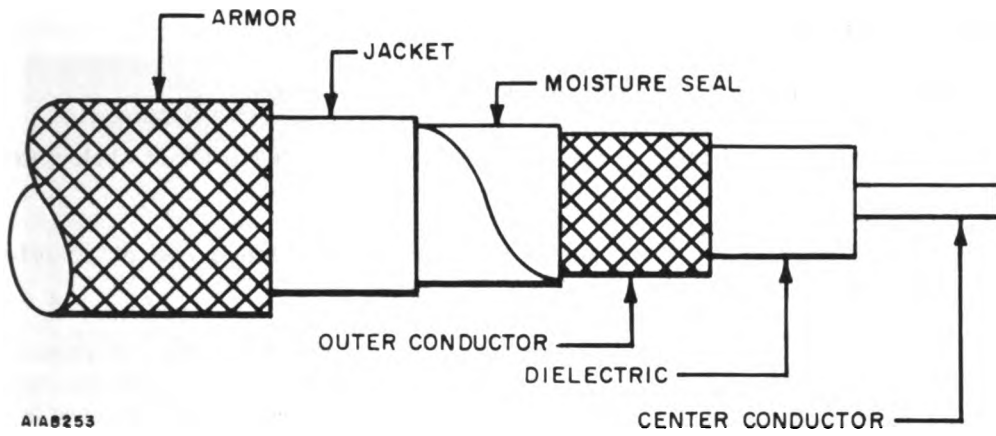


Figure 3 - 28. Flexible RF Coaxial Cable

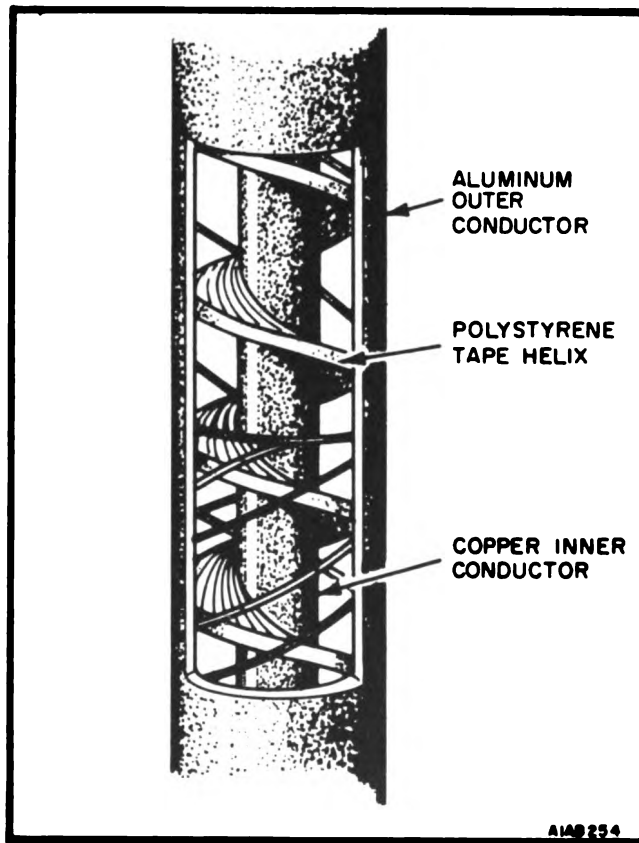


Figure 3 - 29. Styroflex SGM Coaxial Cable

(1) System Configuration. The equipment is configured for modular construction wherever possible. Maintenance is greatly simplified since a defective module is easily replaced and then repaired on the bench with the least amount of downtime for the system.

- o Modules provide maximum flexibility and uniformity of design.
- o Spare provisioning is more economical since only spare modules and not whole systems need be stocked.
- o Modular construction also conserves space and weight through use of printed-board type construction. An additional dividend of printed circuits is uniform performance.

This type construction allows the RF units to be stacked one above the other and utilize a common waveguide. It also simplifies the physical installation and electrical phasing for maximum power transfer, therefore maximum transmitter and receiver efficiency is realized. A rack of microwave link circuit modules is shown in figure 3-30.

Transmission of all forms of information requires several types of equipment which may be grouped as follows: RF equipment, radar data transmission equipment, voice and tone transmission equipment, control system equipment, fault alarm and switchover equipment, and power supplies.

The RF equipment produces and transmits FM RF channels in the microwave band (7125 to 7650 MHz). The exact frequency allocation for any one system is determined by the initial system survey. Three RF channels relay information from the radar site to the IFR room, one other channel operates in the IFR room-to-radar direction. The IFR room and radar sites may be located several miles apart. Repeater sites are used to maintain line-of-sight transmission paths. Each repeater station receives, amplifies and retransmits the signals.

The signal applied to the RF equipment is known as the baseband signal. At a terminal station the baseband signal is routed to other components of the radio microwave link for further separation.

The voice signal transmission is accomplished by multiplex techniques (see chapter 11) using single-sideband transmission. Eight voice channels are available. The received composite signal is demodulated by the receiver and applied to channel demodulators. These channel demodulators extract the voice signal and apply it to audio termination units. The audio is then coupled to the headset or speaker. Two additional voice channels are utilized to transmit control information which has been converted to tone form.

The control signal equipment allows transmission of the following:

- o One instantaneous variable function-IFR room to radar site:

The instantaneous variable function is transmitted in the form of a variable amplitude tone which modulates a low-frequency subcarrier transmitted in the microwave baseband.

- o Six instantaneous on-off functions-IFR room to radar site:

The instantaneous on-off subsystem consists of six tone oscillators at the IFR room and six tone detectors at the radar site. When a switch controlling an instantaneous on-off function is thrown by the operator, the transmitted tone causes a relay to operate in a tone detector and the relay contacts perform the control function.

- o One instantaneous on-off-on (increase-off-decrease) function-IFR room to radar site;

The output contacts of the instantaneous on-off-on (increase-off-decrease) control are switched by noninstantaneous on-off controls to six different control motors in the radar equipment. Each motor controls the

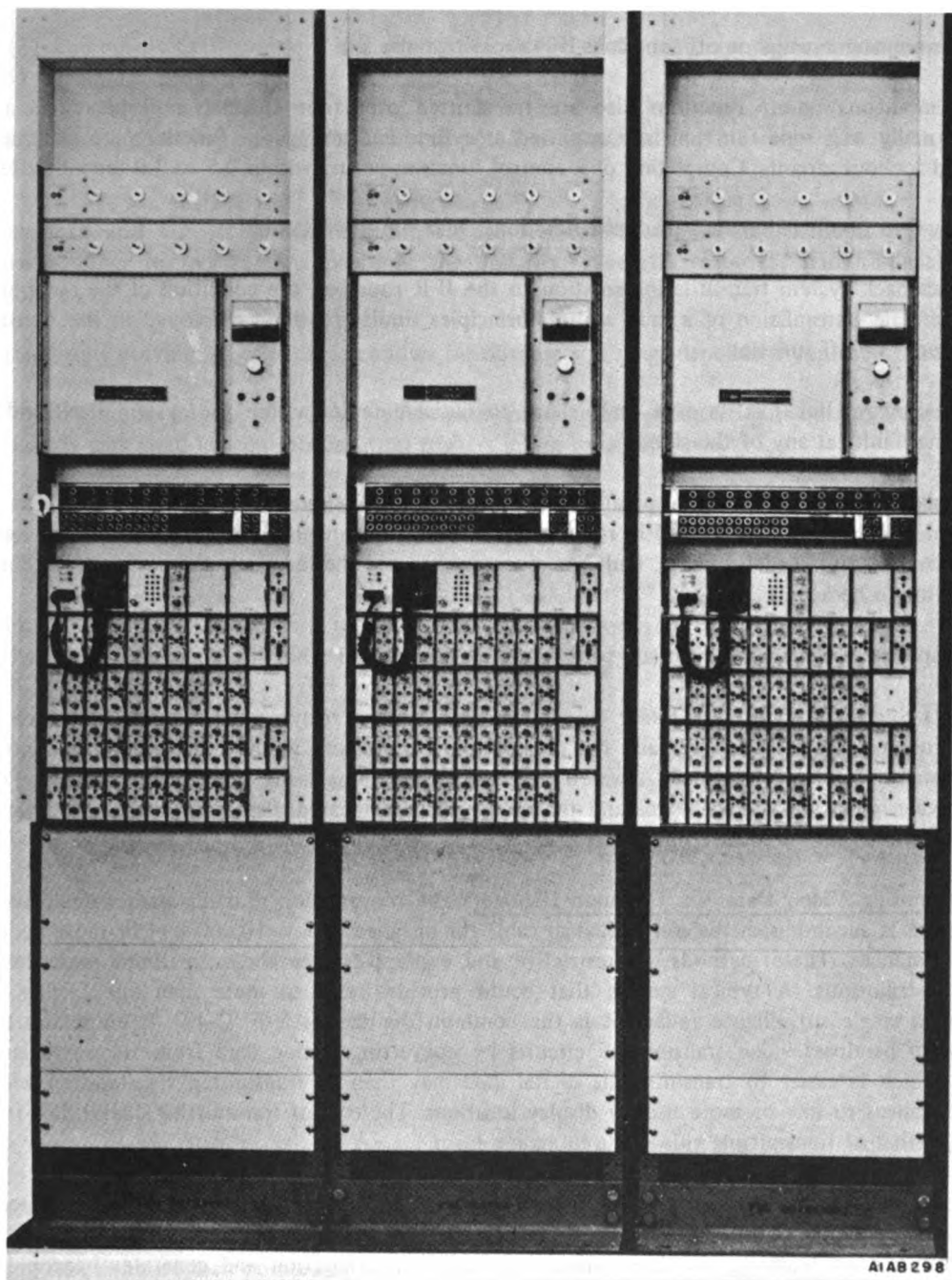


Figure 3 - 30. Typical Microwave Link, Rack Mounted Modules

position of a potentiometer and is controlled in forward or reverse direction by two tone channels. Control is instantaneous after the function has been selected. Readback indicating the position of the variable function is transmitted to the IFR room through a telemetering channel.

- o Forty noninstantaneous on-off functions-IFR room to radar site

The noninstantaneous on-off functions also are transmitted over tone channels multiplexed in a microwave channel. Normally only one function is transmitted at a time and ambiguous functions are eliminated through readback and lockout circuits. Completion of a control function occurs within 0.5 to 3.0 seconds after initiation.

- o Twenty-four noninstantaneous readback functions-radar site to IFR room

A fault or readback system transmits information to the IFR room on the condition of the radar equipment at the radar site. The transmission of a fault utilizes principles similar to those employed in the transmission of a noninstantaneous on-off function.

The radio microwave link has its own fault alarm to indicate faults within the system itself and to indicate certain external faults at any of the sites.

Loss of signal is detected and causes operation of a relay. The relay causes a system alarm lamp to light on the remote channel selector unit at the IFR room. Concurrently a channel alarm lamp on the channel selector is extinguished to identify the channel at fault. At repeater sites and the radar site failure of an RF channel causes a tone oscillator to be keyed.

The power supplies are located at each site to provide the necessary B+, biasing, relay, and filament voltages.

(2) System Application. Radar microwave link system relays radar data and control information between the radar transmitter/receiver and the radar display equipment in the radar air traffic control center of the ATC system. This path has been covered in many installations using underground cables. The distances involved between most of the radar sites and the more centrally located display sites does not always allow the use of cables. Therefore, microwave link systems are used in these situations.

d. Remoting Video Data Via Common Digitizer. The transmission of radar data from detection site to display location is accomplished by either coaxial cable for distances below 10,000 feet, or radio microwave links for greater distances. These methods are restrictive and expensive since these are direct point-to-point single destination distributions. A typical system that could provide usage to more than one facility of the data generated by a single surveillance radar set is the common digitizer (AN/FYQ-49). It eliminates the need for extremely wide bandpass video transmission circuits by converting analog data from the surveillance radar to digital data which is easier to transmit. The digital data may then be transmitted via standard telephone lines over great distances to one or more user or display locations. The cost of transmitting digital data is very low in comparison to that of transmitting video data in analog form.

The common digitizer also can provide the basic video data processing required plus many special features including statistical detection and transfer of aircraft target data for both surveillance radar and beacon systems. It derives information from up to three modes of beacon interrogation and generates beacon interrogation triggers. It can also reduce weather clutter on displays and provide dual detection thresholds to match specific operating requirements of two users, or transfers messages according to predetermined priorities. The system can transmit data at the rate of 2400 bits per second to operate with standard data modems.

These features could represent a substantial saving if it were possible to display the digitized data directly on the PPI, but since the common digitizer is designed to operate with a computer or with a random access plan position indicator (RAPPI), the system is advantageous for a station handling heavy air traffic such as an area

control facility which requires the computer for traffic control and data distribution to other control centers. A small, light traffic station could not justify the need for a common digitizer due to the auxiliary equipment required.

(1) Equipment Configuration. The component groups of the common digitizer systems electronic unit (foldout 3-5) will be discussed briefly.

The azimuth, range, and timing group (ARTG) is composed of an azimuth unit, a range unit, and a beacon mode interrogator.

- o The azimuth unit accepts antenna azimuth change and reference pulse and converts them into a digital number corresponding to the antenna position; the unit also generates real-time, azimuth-dependent control signals.

- o The range unit provides parallel range counter bit outputs and range-dependent control signals.

- o The beacon mode interrogator generates beacon mode interrogation triggers in the internal mode and decodes externally-generated beacon interrogation triggers in the external mode.

The radar quantizer group (RQG) provides amplitude and range quantization of video from search radars. The quantizer output, a binary representation of the incoming video, is clock synchronized to eliminate video replies less than 1/32 NMI wide.

The RQG provides the following outputs to the performance monitor group (PMG) for display in the PPI display mode:

- o Raw video 1
- o Raw video 2
- o Amplitude quantized video 1
- o Amplitude quantized video 2
- o Amplitude quantized gated video
- o RQG output
- o Video crossover outline

The beacon reply group (BRG) extracts beacon reply information from the beacon video signal. For each detected reply, range synchronous pulses are generated for statistical detection and PPI display. The code data with flags are then made available for further processing.

The following functions are incorporated in the BRG:

- o Beacon video quantization
- o Bracket detection
- o Data code
- o Garble sensing

- o Beacon radar line-up delay
- o In-process address control
- o Military emergency decoding
- o Double pulse generation for display.

The memory control group (MCG) fulfills the storage requirements of the target detection group (TDG), the target processing group (TPG), and the output buffer group (OBG). The MCG also controls memory accesses on the basis of system requirement priorities.

The MCG is divided into two functional sections, the core memory system and the memory access controls. These sections are discussed in the following paragraphs.

- o The core memory system (CMS) contains a random access, coincident current, word-organized, ferrite core memory and the associated electronics.
- o The MCG controls all accesses to the core memory system.

The six groups in the electronics unit requiring access to the memory are:

Target Detection Group

Beacon Reply Group

Target Processing Group

Output Buffer Group

Map Outline Generator (MOG)

Performance Monitor Group (PMG)

The TDG performs the following functions:

- o Search statistical detection and automatic clutter elimination (ACE).
- o Beacon statistical detection is similar to search detection. Basic operation is the same, although beacon detection is simpler than search for the following reasons:

The window size is smaller.

Beacon has no ACE.

Only a single detector is used.

Beacon detection occurs only on mode 3/A bracket returns.

- o Target status and record keeping.
- o Range accuracy determination and hit sync.

As each search hit and beacon bracket enters the target detection section, a range accuracy indicator is associated with the return. The indicator is derived from the memory timing signals that divide the range cell.

- o Run length discrimination criteria generation.

The minimum run length discrimination criteria depends on the range of the target and the MTI/normal crossover point.

- o AIMS processing - (Classified functions - not described in this handbook).
- o Search and beacon strobe elimination and report generation.

The target detection group contains logic to detect, report, and eliminate strobe conditions.

- o RTQC target detection.

Target detection for the beacon and search RTQC targets is performed in a manner similar to detection for any other target except for the introduction of some fixed processing criteria.

- o Self checking and maintainability features.

To ensure correct operation of the TDG, the detector alarms, the target detection memory stop condition, and the target detection test are provided.

The target processing group collects data on each target detected in the target detection group and performs the operations of beacon code data processing, beamsplitting, run length processing, and mode C conversion.

The major functions of the output buffer group are message buffering, output message selection, and formatting. The OBG uses 512 words of memory which are divided into a 493-word message area and a 19-word description area. All data from the CD are transmitted from the OBG. The message area accepts target messages from the TPG and the auxiliary data for other messages such as status, map outline and strobe.

A radar and beacon test target generator (TTG) provides inputs for the testing, calibration, and maintenance of CD target detection, processing, reporting, and alarm functions. The TTG also provides test target triggers to the external radar and beacon equipment. The test patterns and adjustment capabilities of the TTG are designed to provide the flexibility needed for maintenance.

The map outline generator supplies messages that define the areas where target processing is either inhibited or restricted due to automatic, sector, or fixed mapping.

The MOG consists of three sections: sector map, fixed map, and outline message.

The Performance Monitor Group provides two functions, alarm monitoring and status message generation.

- o Critical signals and functions are monitored in various parts of the CD and its associated (external) equipment.

- o Status messages provide the direction center with a running check of the sensory and processing equipments.

The radar console unit (foldout 3-6) will be discussed in the following paragraphs.

The common digitizer radar console unit (RCU) is the monitor display, called the RAPPI/PPI (Random Access Plan Position Indicator/Plan Position Indicator), and provides a radar-type presentation that includes symbol generation.

The RAPPI mode provides visual monitoring of processed radar data (range and azimuth) including beacon, search targets, and map outlines selected by message label and displayed as unique symbols.

In the PPI mode, the display uses a rotating sweep oriented to antenna direction and synchronized with the various antenna speeds. Displayed target information includes MTI, normal and gated search video, beacon video, target in process and target processing completed.

(2) System Application. The common digitizer is fed raw radar video data (analog information) which it samples, analyzes, and converts to digital data. This data may be transmitted serially over inexpensive (narrow band) telephone lines instead of expensive broadband video lines or microwave links. The data is routed to stations equipped with compatible terminal systems. The transmitted digital data must be terminated into a data receiving group (DRG) where it is converted from serial to parallel data for insertion into a computer. The computer then processes the data for display in the local IFR room or control center. The common digitizer can be used to digitize radar data to input a computer directly without use of a transmission system.

This system is presently in use at both the Atlantic Fleet Weapons Range Operations Control Center (AFWROCC), Pacific Missile Range (PMR) and the Fleet Air Control and Surveillance Facility (FACSFAC). At these stations the data receiving group is fed into the (NTDS) Navy Tactical Data System computers.

3.4.3 Bright Radar Indicator Tower Equipment (BRITE 2)

The BRITE-2 system (figure 3-31) is intended to be installed in an air traffic control tower to provide various air traffic control functions from the control tower cab. The display is a television type display designed with sufficient brightness, contrast, and resolution for the extremely high and variable ambient light levels normally encountered in the tower cab. The equipment is designed to operate with the station surveillance type radar and has a maximum range of 60 miles. The system includes a remote control unit which provides the local controller with range selection switching, video gains, range marks intensity control, setting of radar sweep origins for decentering, MTI/normal gating, background for MTI, erasure of displayed data, and the TV display brightness, and contrast control. The system is intended to be operated on a continuous basis at an attended site.

a. System Configuration. The BRITE-2 system as shown in simplified block diagram figure 3-32 is comprised of a plan position indicator unit, a television camera, a remote control unit, and a television display. The PPI unit and TV camera are mounted and aligned on the support structure for optical coupling between the two units and must be mounted either horizontally on a bench or vertically in a relay rack.

The PPI unit is an enclosed assembly, mounted and aligned upon the base of the support structure.

The TV camera is an assembly mounted and aligned to the base of the support structure.

The front end of the TV camera contains a Wollensak 2-inch (50 mm), $f/1.5$ Raptor lens with a standard 16 mm C mount.

The TV display is a self-contained 945 line closed-circuit television monitor. The display is presented on a .6-inch round CRT. The useful diameter of the CRT is a minimum of 14-1/2 inches. A detachable sunshield is used to prevent direct sunlight from falling on the face of the CRT.

The power ON-OFF switch, and the focus, bright, and contrast maintenance controls are mounted on the CRT bezel at the front of the TV display. The rear contains a local-remote switch. The power connector supplies the AC power input and the brightness and contrast control is transferred to the remote control unit (via the remote control unit connector) by the local-remote switch.

The RCU is designed to be operated either on a desk top or from a recess in a control console.

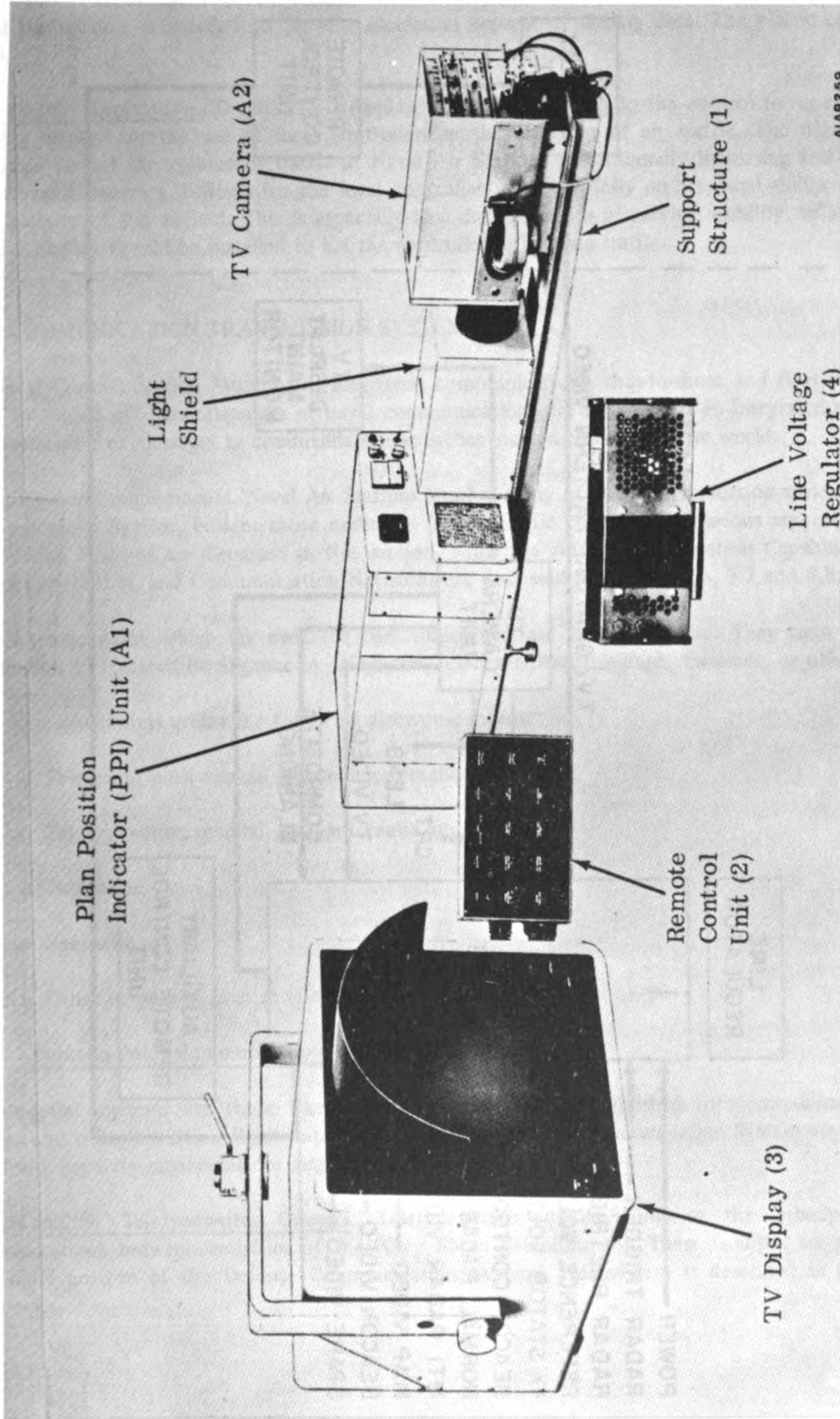


Figure 3 - 31. Bright Radar Indicator Tower Equipment

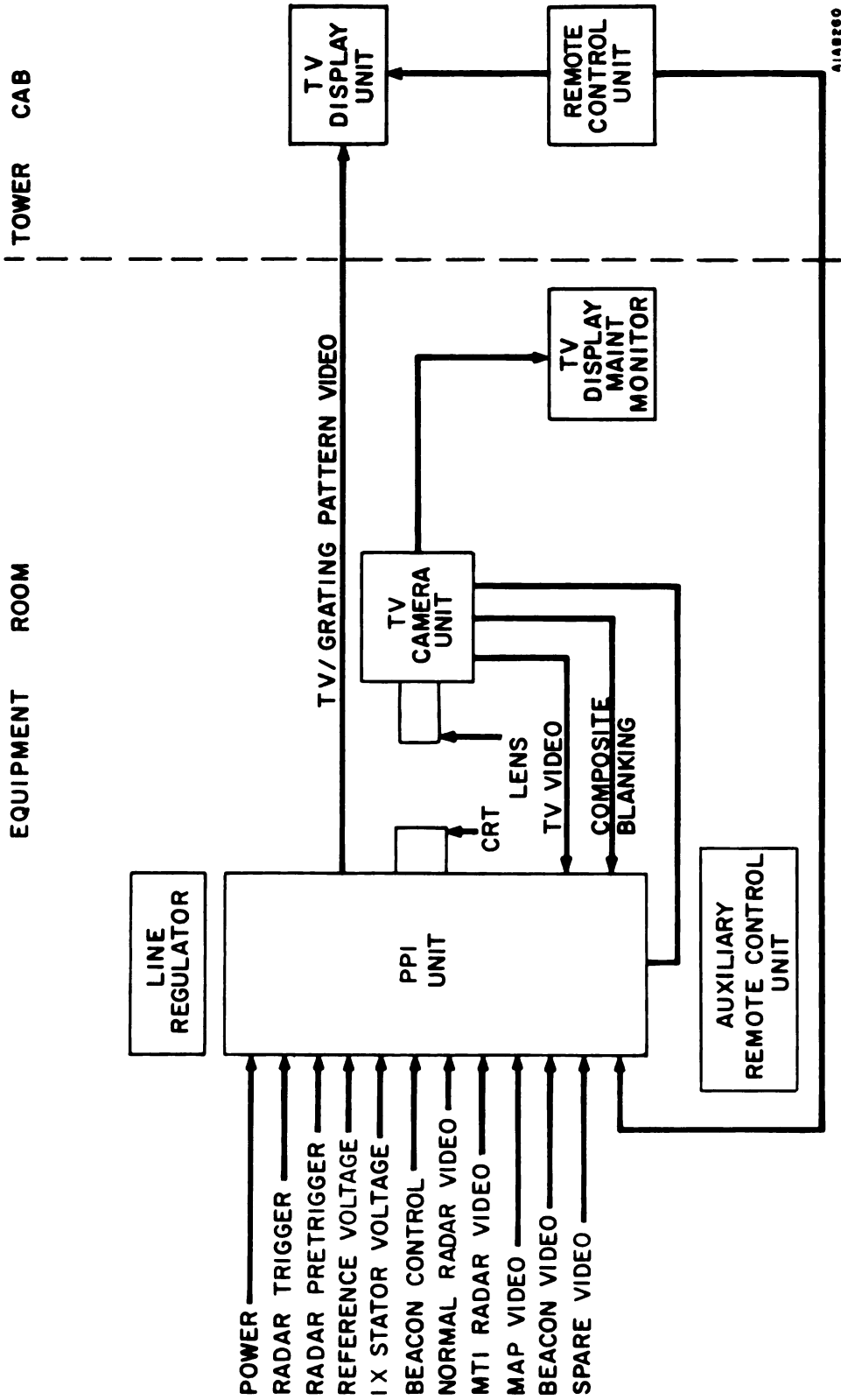


Figure 3 - 32. Brite-2, System Block Diagram

The RCU contains an illuminated control panel and two connectors for the PPI unit-TV camera assembly. The unit contains all the controls required for the operation of the BRITE-2 system. The controls are divided into four groups: PPI unit controls, TV camera erase control, TV display controls, and panel light control. The erase control pushbutton is guarded to prevent accidental erasure of display data. The plastic control panel is edge lighted.

b. System Application. The BRITE-2 display is intended for use in the control tower cab as a continuously operating display for the use of local controllers in the direction of air traffic. The necessity of having this installation is that the volume of traffic at Naval Air Stations is continually increasing and ultimately reaches a point when it becomes difficult for the local controller to rely strictly on his visual ability to control air traffic in the vicinity of the airfield. This is especially true during periods of varying visibility, to assist the controller a BRITE-2 display should be installed to aid the controller in locating traffic.

3.5 COMMUNICATION TRANSMISSION SYSTEMS

The Naval Communication System provides fixed communications, ship-to-shore and fleet broadcasts, and is the means by which all other elements of naval communications are linked. It is an integrated network required for the transmission of messages to commands and activities located throughout the world.

Depending upon requirements, Naval Air Stations employ many of the communication systems used by the Naval Communication System, besides those necessary for air traffic control. The various aspects of Communications Transmission Systems are discussed in this section, while the ATC Communication Capabilities, Communication Control Capabilities, and Communication Networks are discussed in sections 3.6, 3.7 and 3.8.

The electronic paths which are used for communications are radio and wire. They may be used singly or in combination to transmit intelligence by telephone, teletypewriter, telegraph, facsimile, or other emissions.

Naval communications utilize the following electronic means:

- o Telegraph; both manual and semi-automatic.
- o Teletypewriter; manual, semi-automatic and automatic.
- o Telephone
- o Facsimile
- o Other emissions, such as television and data impulses.

3.5.1 Point-to-Point Communications Systems

Point-to-point systems are those fixed radio or wire circuits established for communications between shore stations and other facilities. Point-to-point circuits of the Naval Communication System are usually multichannel with trunk capacity engineered for large traffic loads.

a. Landline Teletypewriter Circuits. Teletypewriter circuits comprise the principal means of rapid communications between activities of the Navy Shore Establishment. These facilities are provided through the AUTODIN portion of the Defense Communication System. This system is described in paragraph 3.8 of this handbook.

The use of the AUTODIN network for automatic switching and high-speed teletypewriter circuits permits the rapid exchange of message traffic between naval activities without the attendant delays that may be encountered in a manual or semi-automatic system. Once a properly prepared message has been entered into the AUTODIN system, its routing and delivery to its destination is accomplished without manual handling and with very little loss of time.

b. Radio Teletypewriter Circuits. Point-to-point, multichannel radio teletypewriter circuits are provided to furnish communications between domestic communication stations and shore stations located overseas.

(1) Major Trunks. There are six primary communication centers located throughout the world to furnish complete radio coverage of the major portions of the world's ocean areas. These six (located at Washington, San Francisco, Honolulu, Guam, Balboa and Port Lyautey) are linked together by multichannel radio teletypewriter trunk circuits and form the nuclei of the Naval Communication System's radio teletypewriter network. In addition, each of these primary centers maintains and operates multichannel radio teletypewriter circuits to major or minor communication centers throughout the world.

Point-to-point teletypewriter circuits, provided by Naval Radio Stations, make use of high frequency radio circuits using single sideband modulation that is capable of multichannel operation. For optimum performance, directional antennas oriented in the direction of the radio station with which communication is desired are used.

(2) Tributaries. Tributary circuits are used to provide radio teletypewriter communication service from primary communication centers to major and minor centers, or to individual activities. Depending on the operational requirements, they may be trunk circuits capable of multichannel operation or they may be single channel circuits.

c. Radio Voice Circuits. Radio voice channels are usually included in all multichannel, single sideband radio circuits. These channels may be used as "order wires" to permit radio station personnel to exchange information on circuit operation or routing. Voice circuits also permit direct, person-to-person communications between overseas commanders and commands in the United States. By the use of telephone patch equipment it is possible to connect radio voice circuits directly into the landline telephone system.

3.5.2 Ship-to-Shore

Ship-to-shore circuits are the principal means of transmitting messages from individual ships to shore stations. Radio stations of the Naval Communication System have been strategically located to provide the necessary ship-to-shore support on a world-wide basis. The Primary Ship-to-Shore Circuit uses multiple high frequencies to permit selection of the optimum frequency for best reception. Navy radio stations listen simultaneously to several ship-to-shore frequencies in order to assure reception. A ship may transmit to any Naval shore radio station that can receive it. Transmission may be by CW telegraph, radioteletypewriter, or facsimile. The Secondary Ship-to-Shore and Harbor Common Circuit is used for short range or local ship-to-shore communications. Medium or UHF frequencies may be employed using CW, RATT or voice transmissions.

In addition to the Primary and Secondary ship-to-shore circuits the following specialized ship-to-shore circuits are also available to meet operational requirements: Fleet/Force Commanders (CW-RATT-MUX), Fleet Marine Force Commanders, Facsimile, Atlantic and Pacific Barrier, Oceanographic Net, Pacific Missile Range, Guided Missile Evaluation Data Coordination, Merchant Fleet, Fleet Intership, Ship-to-Shore Net and Fleet-Airwing Operations.

3.5.3 Ground-to-Air Communication System

Ground-to-air (or air-to-ground) communication circuits may be considered as analogous to ship-to-shore circuits in that they provide a means of communication between a mobile station (aircraft) and a fixed shore station (air

station). Ground-to-air circuits may be broadly classified as of two types: short range VHF/UHF Air Traffic Control (ATC) circuits, and longer range HF tactical circuits. Voice radio circuits are the principal means of communication with aircraft for ATC, and RATT is the primary (voice secondary) means for communication with long range, multi-engine patrol and transport aircraft.

Typical of short-range approach and landing circuits are those used for control tower operations, radar air traffic control, and ground controlled approach. Communications are generally maintained over a multiplicity of VHF/UHF voice radio channels. Highly efficient, reliable and noise-free communications are mandatory in the approach and landing zone of an air station.

En-route communications, an FAA function, are usually accomplished by VHF/UHF transmissions. The requirements of en-route communications are reliability, flexibility and speed. Loss of communications can cause the institution of lost-aircraft procedures. Flexibility requires the ability to shift transmitters and frequencies rapidly to meet operating conditions or doctrine. Speed of communication is necessary to permit short transmission in order to avoid hampering the operation of other aircraft.

a. Reliability of Service. It is important, especially in air traffic control service, to provide great reliability in the communication system used to communicate with aircraft. For sets in normal use on the various required channels, the controllers must be able instantly to turn to alternate sets when normal sets fail. Emergency requirements to deal with failure of both normal and alternate sets must also be faced. The following categories of equipment readiness are therefore recognized:

(1) Normal Communication System. This consists of the radio equipment normally available at the controller's operating position, as required by the air station to perform its operational mission. This includes any communications control console equipment, and ancillary equipment, and also any standby or back-up equipment.

o Standby Equipment. Sometimes called Hot Standby, this consists of the radio equipment which is kept tuned to the frequency of a normal set, and with any filaments "hot", so that it can be put into operation without any delay. Upon failure of the normal equipment, transfer to the standby equipment is instantly made by depressing a button on a console. Depending upon the local installation, the controller using the set may have such a transfer button. In other cases, it may be necessary for the supervisor to make the transfer.

o Back-up Equipment. Back-up equipment may be of the same type as the normal and standby equipment, but it is not necessarily tuned to the desired frequency, and is not kept "hot". Upon failure of the normal equipment, the back-up equipment may be activated and patched into the circuit so as to be ready to be put into service instantly. It should be noted that the terms "Standby" and "Back-up" apply to equipment only, and do not relate to system.

(2) Emergency Communications System. This is a minimum capability system used only when the normal system, including its standby and back-up equipment, is completely inoperative, for instance when the control cable is cut by a bulldozer. It is a system used in a last effort to keep the station in limited operation to divert air traffic, and land only those aircraft that cannot be diverted to another airfield. This system is completely independent of the normal system. Its antennas are normally located above the tower cab room.

3.5.4 Landline Communication Systems

Landline communication systems serving local purposes for operation of the Naval Air Station are discussed here. Point-to-point landlines have been discussed under that heading.

Shore station communication departments furnish local communications essential to the accomplishment of the shore station's mission. The communication departments maintain and operate various communication facilities

to provide local (intra-activity and/or intra-area) communications for activities of the Shore Establishment and, when required, units of the fleet. These communication department facilities usually connect with the world-wide arterial network of the Naval Communication System.

Normally, the local communication department provides for a small communication center consisting of a message center and cryptocenter. However, when required, it may also provide for a relay station, wire and/or radio center, control center, radio transmitting and receiving facilities and a visual signal station.

Where radio transmitting and receiving facilities are required, it is the policy, where practicable, to install the transmitting and receiving equipments in regularly established radio transmitter and receiver stations of the Naval Communication System and remotely control these facilities from the communication center of the activity concerned.

a. Landline Teletypewriter Circuits. Local communication centers are provided automatic teletypewriter service by leased tributary lines from the automatic switching center serving the area in which they are located. The local message center may serve only one command, or in the case of a large activity, may provide communication service for other commands that may be tenants of a large activity, or may provide message service to adjacent activities. This service may be accomplished by 'over-the-counter' delivery service whereby user activities employ messengers to pick-up and deliver messages to the message center. If the volume of traffic warrants, user activities may receive, and deliver, message center by direct teletypewriter circuits. These circuits are called "local loops" and connect teletypewriter stations to other teletypewriter stations in the same local area. Local loops consist of wire facilities that provide channels needed by the teletypewriter stations. A loop may provide a single channel operated as a one-way circuit or on a half-duplex basis, or it may provide for full-duplex operation.

One-way operation may be provided. In this type of installation, a teletypewriter transmitter in the message center would be connected to a receive-only printer at the user activity. This allows the user activity to receive messages by wire. Messages originated by the user activity, however, must be delivered to the message center by messenger or other means. Half-duplex operation allows both stations to transmit and receive alternately. Full-duplex service requires two-wire circuits, one for each direction, and allows both stations to send to the other one at the same time. Full-duplex operation is generally used only when expected service is heavy. Local loops may utilize Navy-owned circuits and equipment, or the circuits and equipment may be leased from commercial carriers.

b. Telephone. Switched telephone service requires provisions of a switchboard, which not only handles local calls, but also serves as access to and from the public long distance network. The private branch exchange (PBX) may be provided by the telephone company, or may be Navy-owned. Besides handling the usual business of the station, some operating positions are also provided with service. In that case, a landline selecting panel and equipment is provided, for the appearance of the PBX line and for appearance of various other lines not served by the PBX switchboard.

c. Communication Control Links. These may use local landline facilities, and as such are discussed in the following paragraph.

3.5.5 Communication Control Links

In a Naval Air Station, communication control links (CCL) are mainly used as part of the ATC system to interconnect the controller positions with the VHF and UHF radio transmitters and receivers, which are generally located at a distance from the control tower.

a. Choice of Communication Facility. These circuits may be telephone-type cable pairs (either leased or Government-owned), or special short-range (from 25 to 30 miles) radio equipment commonly known CCL. The choice of which facility to use is a command responsibility based on physical security, cost, and importance of such control circuits.

In general, control cables are preferred if the entire cable route is through government-owned or controlled property, and such cables should be government owned, separate from commercial telephone circuits where such telephone service exists. When the control line route is outside of direct control, and physical security is questionable (cables subject to pilferage or tampering), the radio link is preferred.

b. Cable CCL. Cable CCL may be leased from the telephone company or they may be Navy-owned. Generally channels serving radio receivers may require only a pair for the received audio signals; on the other hand, two pairs may be required for transmitters, unless the keying channel is superimposed on the audio channel. Communication cables should always be kept from close association with cables carrying power.

c. Microwave CCL. Microwave links properly engineered and installed are as reliable as cable, are preferred to cables from the engineering standpoint, and do not require cable backup. VHF links have not been sufficiently reliable to be used as primary control circuits and, therefore, have been installed as secondary circuits with cables performing primary service.

Economic factors such as tower heights, and whether or not relay stations are required, will influence the choice between leased wire service and radio links.

For practical reasons, no new major installation will be made in the VHF range except, possibly, at overseas locations in isolated areas. VHF equipment now installed is being replaced wherever possible, on a planned basis, with microwave equipment operating in the 1,700 to 2,400 MHz and 7.125 to 8.400 GHz range. Radio frequencies above 300 MHz are called microwaves.

3.6 AIR TRAFFIC CONTROL COMMUNICATION CAPABILITIES

Radio communications at a Naval Air Station include facilities for ground-to-air communication with tactical and transient aircraft, for control of aircraft departures and landings, and for communication with other air stations. It is often the case that civilian aircraft operations take place in or near the area of the NAS so that the FAA operations are involved. In some cases, communication facilities are shared between the Naval Air Station and the FAA. Since most FAA ATC uses the VHF band, while the Navy ATC is mostly UHF, it is often necessary to provide both UHF and VHF equipment at a Naval Air Station. Both visual and radar controllers are provided with radio communications with which they control aircraft operations.

3.6.1 System Capabilities

The overall capabilities of ATC communication control systems are described herewith, while in the following paragraphs more detail is given with respect to the location of the equipment, e.g. IFR room, terminal room, transmitter site, etc. The capabilities of typical available communication systems are described, without type numbers, etc.

a. Communication Control Console Group. A Communication Control Console Group is a communications control system used by Naval Air Stations and other activities engaged in air traffic control, surveillance, and similar missions where many controllers are used to operate multi-channel radio communications while at the same time maintain interphone contact with each other. This system provides communication control consoles for 23 controllers and one supervisor for the control of 60 radio transmitters and receivers. Fifteen additional channels are available when a Transfer Control Group is connected to the equipment. The system has the following general capabilities:

- o Control of a maximum 60 radiophone channels.
- o Control of a maximum 60 4-wire telephone channels.

- o Access to 24 interphone channels.
- o Programing of a maximum of 5 party line channels.
- o Operation in either dark or light environment.
- o Patchboard programing of radiophone and telephone channels.
- o Solid state plug-in electronic components throughout.
- o Instantaneous and automatic fault indications.
- o Transfer control (by controller personnel) to standby radiophone equipment- 15 channels provided.
- o Recording of all incoming and outgoing conversations for each position on a separate recorder channel.

The system is controlled by:

- o One supervisor's console with all of the general capabilities under his full control and observation plus certain special features.
- o 23 controllers' consoles with a programed selection at each of 20 radiophone or telephone channels, 23 interphone channels and one party line channel.

b. Landline Selector Control Group. A landline Selector Control Group is the communication control system used by Naval shore facilities and other activities engaged in air traffic control, surveillance, and similar missions where many controllers are used to operate multi-channel landline communications in conjunction with multi-channel radio communication operations. Although this system provides complete integration of landline communications functions into the operational modes of the communications control console system described above, it can be used alone, or in conjunction with other communication systems whenever it is necessary to interface landlines with communications at multiple operator positions.

It is a terminal system that provides termination for private landline circuits (point-to-point communications). The system is designed to provide many operators with selection capability of many private landline circuits. This system works in conjunction with the Communications Control Console Group which provides for control of the radio and interphone modes of operation. All positions are functionally alike and no one position has more or less "priority control" over other positions. The system allows only one channel to be selected at a time by any one operator, whereby the channel selection will not interfere with another operator selecting a different channel. In the event two operators require the use of the same line at the same time, one of the operators must request the other operator to remain off the line until the remaining operator completes the ring-down or dial signalling procedure. The direct line private interphone features of a Communication Control Console system provides a convenient means for effecting this coordination.

The system is designed so that there is no limit to the number of landlines or of operator positions. The landline arrangement is flexible at each console, allowing the addition or deletion of lines on any console, and 2-wire or 4-wire landlines can be used. Each position has its own tape recording circuit. Voice call-up, ring-down or dial calling can be used, as required for the individual landline. A conference capability is provided, so that after any operator signals a called party, any number of other operators may select the same channel to form a conference network. All operators will hear both sides of the conversation.

c. Emergency Communication System. The normal, standby and back-up radio equipment is usually located in separate transmitter and receiver buildings which must be located at some distance from the control tower for

various reasons. In case access to one or another of these installations is cut off, by an air accident or public works operations cutting the control cable, it is very important that the controller working with an aircraft be able to resume contact by some separate means. This is provided by the Emergency Communication System. The equipment consists of UHF and VHF radio sets located within the control tower, with antennas above the control cab. Controls are located in the IFR and VFR rooms for the sets serving each of them. Normally only a supervisor can activate the emergency radio sets, but controls are provided for all positions requiring them.

Sufficient emergency equipment shall be installed to provide simultaneous transmission or reception on the following Navy tower channels: (1) UHF primary, (2) UHF emergency, (3) VHF primary, and (4) VHF emergency. Standard AC and DC operated, fixed-frequency equipment such as the new AN/GRT-21, -22, and AN/GRR-23, -24, shall be provided for new installations; older type equipment will continue to be used at existing facilities. They are connected to permit selected operation from either the normal or emergency AC power source or batteries for a minimum period of eight hours in case power fails. Control of the emergency communication equipment shall be completely independent of normal console control facilities.

3.6.2 IFR Room

This facility is required in all Radar Air Traffic Control Facilities (RATCF). There are a number of PAR and ASR positions, and at least one DF position. The operators at these positions are provided with radio and landline communication controls. The capabilities of these several systems that appear at the IFR positions are as follows. There is also a supervisor, for whom a number of additional capabilities are provided.

a. Communication Control Console Group. The Controller Operational Functions and Capabilities are divided into three sections, Radiophone (or telephone), Private Line Interphone, and Party Line. The functions and capabilities for each follow:

(1) Radiophone (or telephone)

- o **Programing.** A combination of 20 of the 60 radiophone or telephone channels at each console.
- o **Channel Selection.** Through lever switch operation. A channel selected by a controller is "locked out" to other controllers. Only the supervisor may pre-empt a selected channel.
- o **Channel Status.** Indicated by green lamps above each channel switch. Half lamp brilliance indicates the channel has been selected by another controller or the supervisor. A busy signal sounds in the headset of a controller who attempts to select a busy channel. Also, the green lamp will glow at full brilliance.
- o **Channel Identification.** By means of illuminated channel numbers and by frequency marked on removable plastic notation tabs.
- o **Channel Monitoring.** Provided by channel selector switch. A pushbutton switch programs the audio to either headset or position speaker.
- o **Visual Receiver Signal.** Yellow lights, inside the pushbutton monitoring switch, flicker on amplified voice signals picked up by the corresponding receiver. This allows the controller quickly to identify the receiver corresponding to an audible signal on his position speaker. In the IFR room, this feature is especially useful to the DF operator.
- o **Transmitter Keying.** Through foot-operated switch at each console.
- o **Speaker Muting.** Automatic muting of keyed channels in position speaker when transmitting.

o **Transmitter Sidetone and Indication.** Immediate audible indication in controller's headset that microphone output is being radiated and picked up by the channel receiver. In addition, the yellow lamps for each channel indicate presence of a received signal in the receiver circuit. This feature provides a complete automatic radio system-check with each transmission.

o **Simultaneous Transmission.** May be made on any combination of radiophone or interphone channels.

o **Headset Transfer Feature.** Removal of headset from jackbox automatically transfers headphone audio to speaker.

o **Jackbox Telephone Input.** Additional isolated telephone line input provided to jackbox at some installations. Channel headphone monitoring is automatically transferred to the speaker when the jackbox is switched to telephone line(s) (abbreviated as TEL-CO).

o **Telephone Line Selection.** Provision is made for pushbutton selection of telephone lines by selective signalling, by integrating with the Landline Selector Control Group.

(2) Private Line Interphone

o **Selection.** By lever switch operation to monitor or to call each controller and the supervisor individually, or in any combination.

o **Indication.** By means of red lamps over each selector switch. When lit, indicates the recipient is being called by another controller or the supervisor.

o **Private Line.** Between each console without any indication or distraction at any other console.

o **Call Up.** Does not remove called position from radiophone keying of transmitters nor does it interfere with their modulation.

(3) Party Line

o **Programming.** By rotary switch selection at Control Central.

o **Communication.** Without any control action between pre-programmed controllers.

o **Indication.** Audio only. Sidetone is provided.

o **Transmitter Keying.** Automatic removal of microphone audio from party line system.

o **Private Line Call.** Removes called and calling console from party line.

o **Party Line Cut-off.** By lever switch operation, removing controller's headphone from party line system.

Figure 3-33 shows typical equipment at the controller position.

b. Supervisor Operational Functions and Capabilities. The Supervisor's Console has all of the features of the Controller's Consoles as listed above with the following additional capabilities:

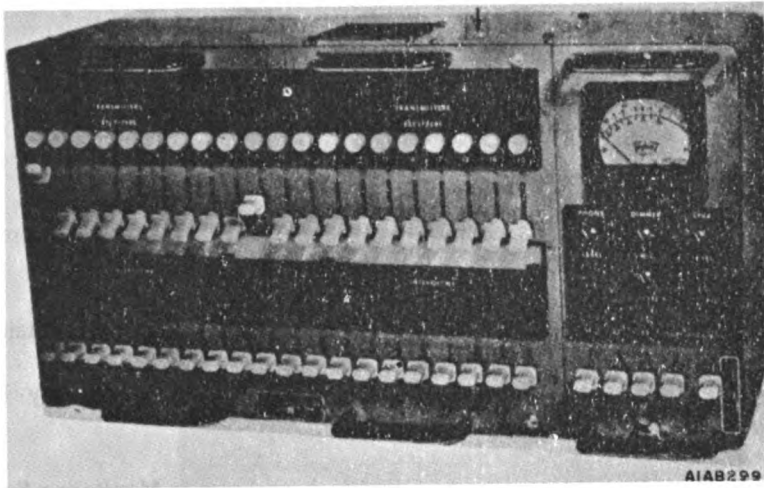


Figure 3 - 33. Controller Position Equipment-Communication Control Console Group

(1) Radiophone or Telephone

- o **Programing.** All 60 channels available at the console.
- o **Selection.** By lever switch operation.
- o **Indication.** As on controller's consoles.
- o **Channel Override.** By channel selector switch. When supervisor selects a channel, he automatically pre-empts any controller on the selected channel.
- o **Monitoring.** Both ends of any selected channel.
- o **Channel Selection Status.** By rotary switch operation indicating on a numeric display panel, specific controller who has selected a particular transmitter.
- o **Channel In-Use Status.** On program indicator green lights, a simultaneous display of all transmitters which are "in use".
- o **Channel Program Status.** On above lights indicating all channels which are programed to a specific controller.

(2) Private Line

- o Selection and Indication. As on controller's consoles.
- o All Interphone. By single switch communicates simultaneously with all controllers.

(3) Party Line

- o Programing. By party channel selector switch on supervisor's console.
- o Selection. Direct entry to any of the five party line channels.

(4) System Power Supply Status. By visual and audible alarm of any fuse failure or power supply transfer in the system.

(5) Maintenance Interphone. Between supervisor's console and Control Central maintenance position.

c. Optional Operational Functions and Capabilities. The following equipment may be added at some installations:

(1) Overhead Speaker Monitoring. Installation of an Overhead Speaker Monitoring System as an integral part of the console system provides overhead speaker monitoring of all incoming and outgoing communications for Airport Control Tower consoles.

(2) Radiophone External Channel Transfer Equipment. Installation of this system as an integral part of the console system provides controller operated MAIN-STANDBY radiophone channel switching for 15 transmitters and receivers.

(3) Telephone Selection and Signaling. Integration of telephone line selection and signalling is provided with the Landline Selector Control Group using the headset and console amplifier of the communication control console group.

Figure 3-34 shows a typical supervisor console. The other equipment is the same as illustrated in figure 3-33, for a controller.

d. Landline Selector Control Group. Each operator position consists of a Dial Unit, a Line Select Module, and a Speaker Amplifier Unit as shown in figure 3-35. Also, this position has a Jackbox, Headset/Handset, Distribution Block, and Jackbox Cable.

- o Dial Unit. The Dial Unit contains the common functional controls for all landline channels. Every operator's position requiring telephone lines will require one Dial Unit.

- o Line Select Module. The Line Select Module contains the pushbutton selector switches for telephone line selection. Every operator's position requiring landline channels will require a minimum of one Landline Selector Unit. Each Landline Selector Unit has a fifteen channel selection capability.

- o Speaker-Amplifier Unit. The Speaker-Amplifier Unit allows the operator to monitor all "voice call-up" landline channels programed to his position. The Loudspeaker Unit is only required at positions not having a Communication Control Console.

- o Jackbox. A jackbox is required at each operator's position. A single jackbox is utilized for both radiophone communication wherever a Radio Control Console is provided.

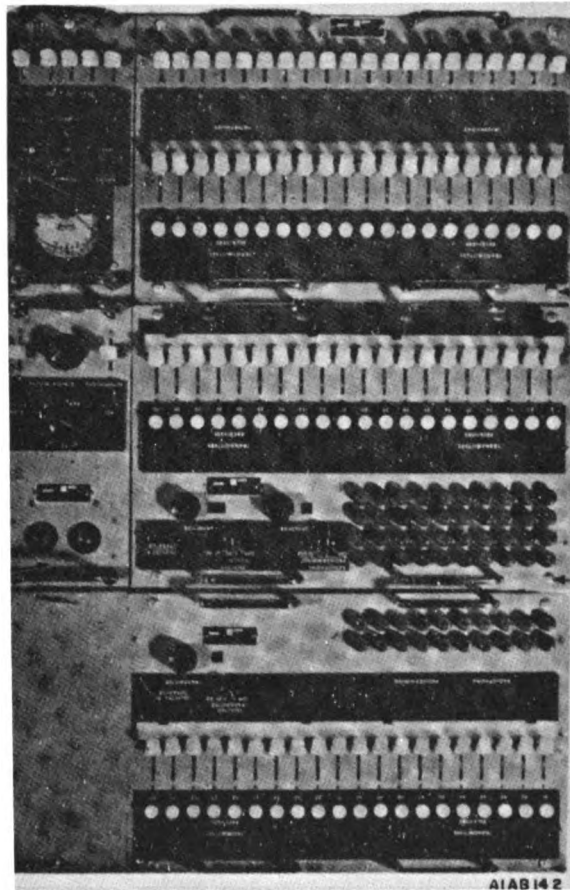


Figure 3 - 34. Communication Control Console Group, Supervisor Position Equipment

o **Headset/Handset.** A headset or handset is required for each operator position. The headsets are furnished as part of the Communication Control Console group. At positions not utilizing a Radio Control Console, Handset may be utilized. The "headset" is equipped with a carbon microphone and an earphone, both of which are mounted in an adjustable head strap. This headset has a lock-type switch in the cord which is used to close the microphone circuit. The "handset" is electrically identical to the headset; however, the earphone, the microphone, and the "push-to-talk" switch are all mounted in a standard plastic telephone case.

e. **Emergency Communication System.** In the event both normal and standby radio channels fail, emergency radio equipment is typically provided for the IFR room. It may consist of a UHF radio set and a VHF radio set. Control boxes for these sets are installed in the supervisor's position, and at each of the controller positions, a

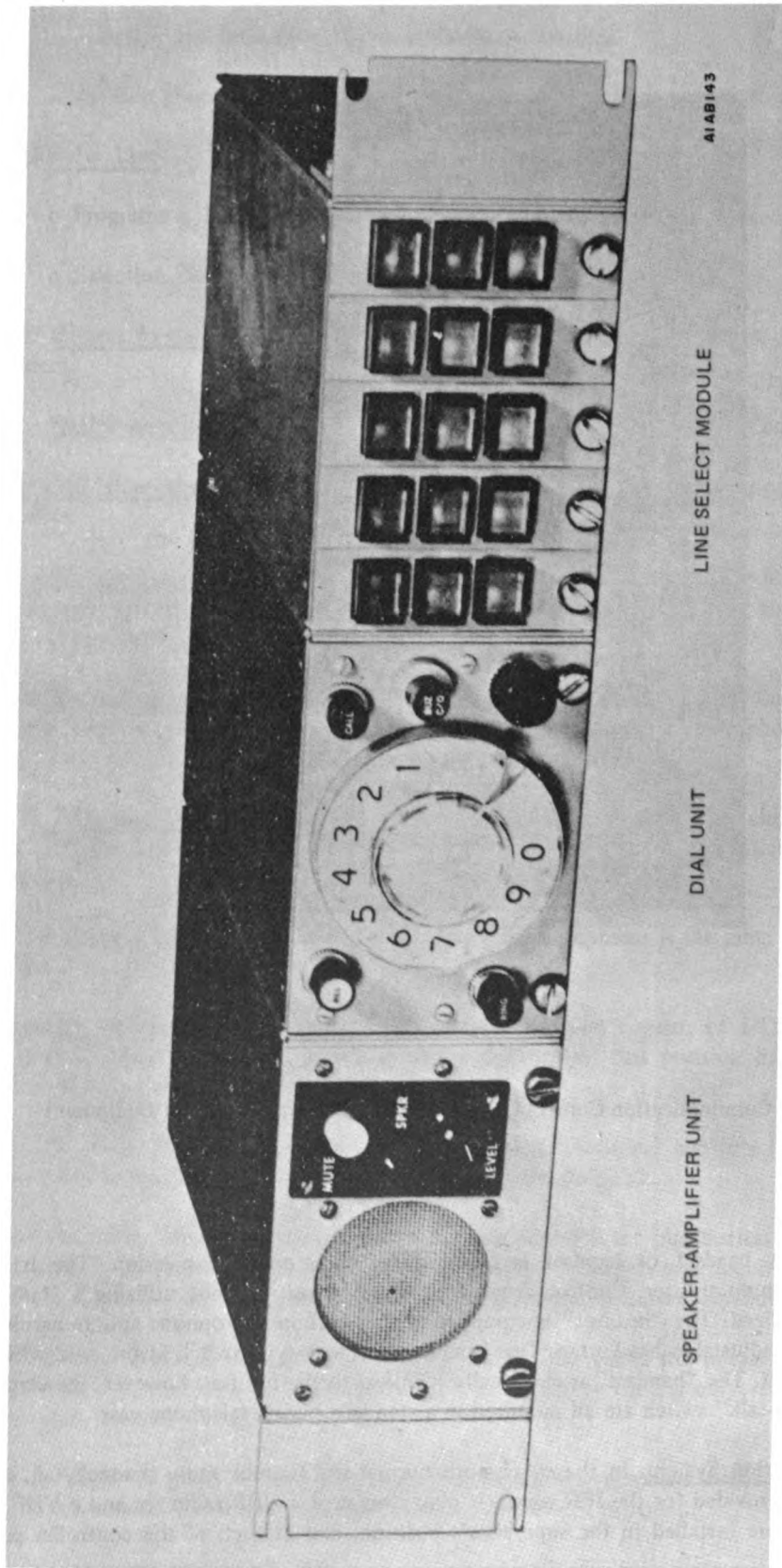


Figure 3 - 35. Landline Selector Control Unit - Operator's Position

normal/emergency transfer panel is installed. These panels contain a headset jack into which the operator's headset is plugged, and a three-position switch with positions for OFF-NORMAL, VHF and UHF. Normally only the supervisor can activate the emergency radio sets and select the channels.

3.6.3 VFR Room

The VFR Room, or Control Cab, is used to control aircraft operating under Visual Flight Rules. Operating positions are provided for at least one each of the following: Local Controller, Ground Controller and Data man. The operators at these positions are provided with radio and landline communication controls. The capabilities of these several systems that appear at the VFR positions are described below. The communications equipment is normally the same in each operating position, with the exception that one also has controls for emergency radio sets.

a. Communication Control Console Group. Each of the operating positions in the VFR room is provided with the same type of communication control console as described for the IFR room, and provides the same operating capabilities. (See figure 3-36). In addition, the VFR room is normally equipped with a set of eight overhead speakers, and amplifier-mixer-muter equipment, to handle up to 20 communication channels as follows. Figure 3-37 is a typical overall functional block diagram. Only the loudspeakers and the one or more "Hi-Lo" switching panels are in the VFR room.

(1) Amplification and Mixing. This equipment provides amplification and mixing of audio signals from 20 low level (0 dBm) communications channels to a power level high enough to drive eight overhead speakers in a control tower. Fifteen of the 20 channels are mixed in three groups of five channels each. Each group of five channels is fed to a separate power amplifier and speaker. The remaining five channels are each fed through separate amplifiers to individual speakers.

(2) Selective Control. Selective muting of any of the 20 channels is provided. When the equipment is operated from the outputs of receivers, it is necessary to mute the receiver audio on a channel whenever an operator in the same room with the speakers transmits on that channel. The "feedback" from the speaker to the operator's microphone would otherwise cause a "squeal" on the channel. By connecting the muting control lines to the operator's transmit control switches, receiver audio is muted for the channel on which he is transmitting. Since this muting action is "local" in nature, the operator's transmission may be monitored at other locations, e.g., by an operator in another room. The operator can also monitor any other transmission which does not originate in the vicinity of the speaker.

When an operator hears an incoming voice signal on one of the overhead loudspeakers, he can readily identify the channel receiving it by observing the communication control console, where there will be a flickering yellow light for the channel, operating from amplified voice as described previously.

(3) Remote Control. Remote control of speaker level is provided. Each operator in the room may have a remote control unit (Switching or "Hi-Lo" Panel) which provides an individual switch for each speaker (figure 3-38).

Depressing one or more of these spring loaded switches drops the audio level on the corresponding speakers as long as the operator holds the switch down. A separate switch (ALL) reduces the level of all speakers simultaneously. However, if any one is depressed while the "ALL" switch is depressed, the output of that channel will return to normal volume level; e.g., if channel 5 switch and "ALL" switch are depressed at the same time, levels of all channels except channel 5 will be reduced.

b. Landline Selector Control Group. The capabilities of the landline selector control provided to the operators in the VFR room are identical with those described for the IFR room.

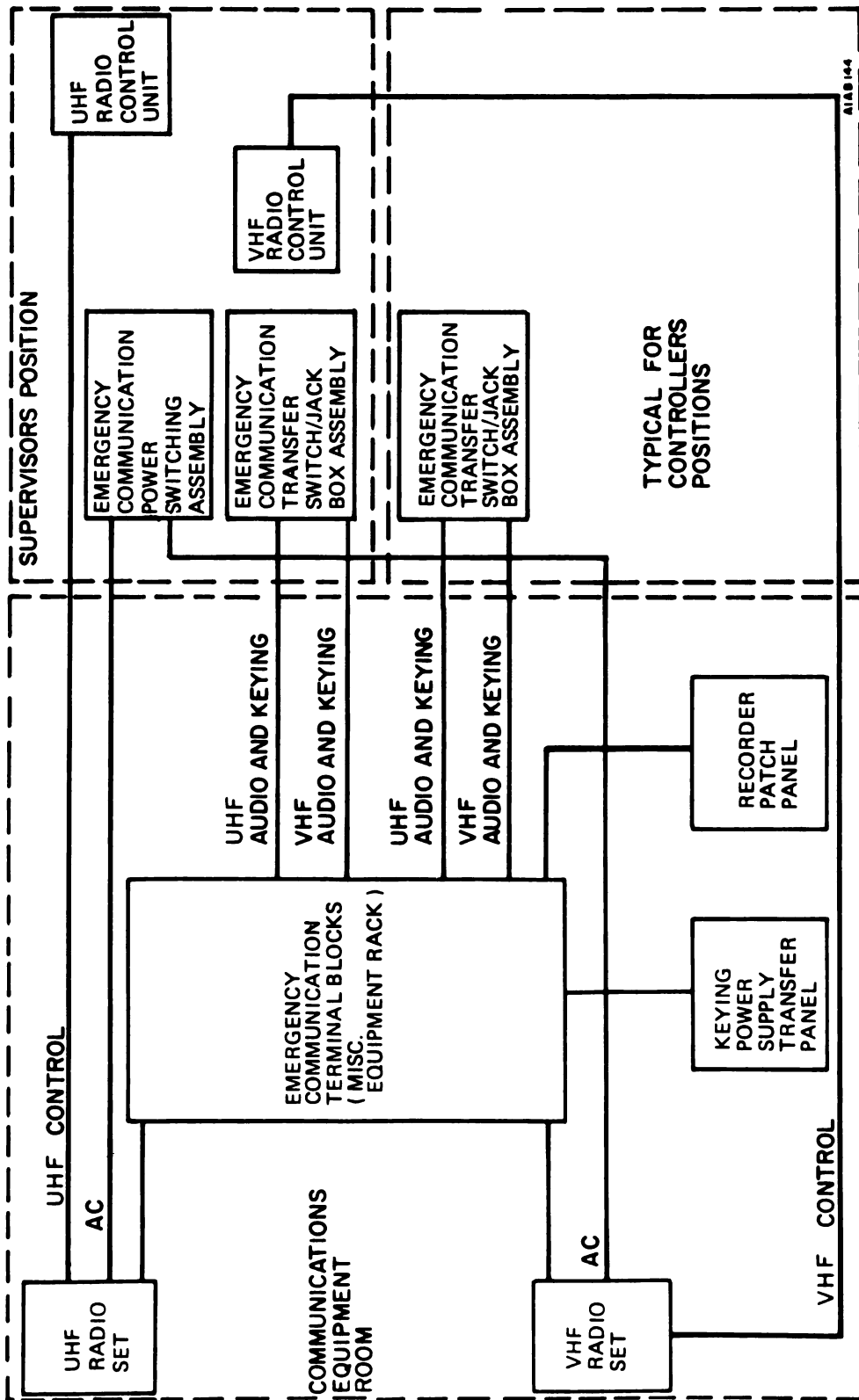


Figure 3 - 36. IFR Room Emergency Communications System, Block Diagram

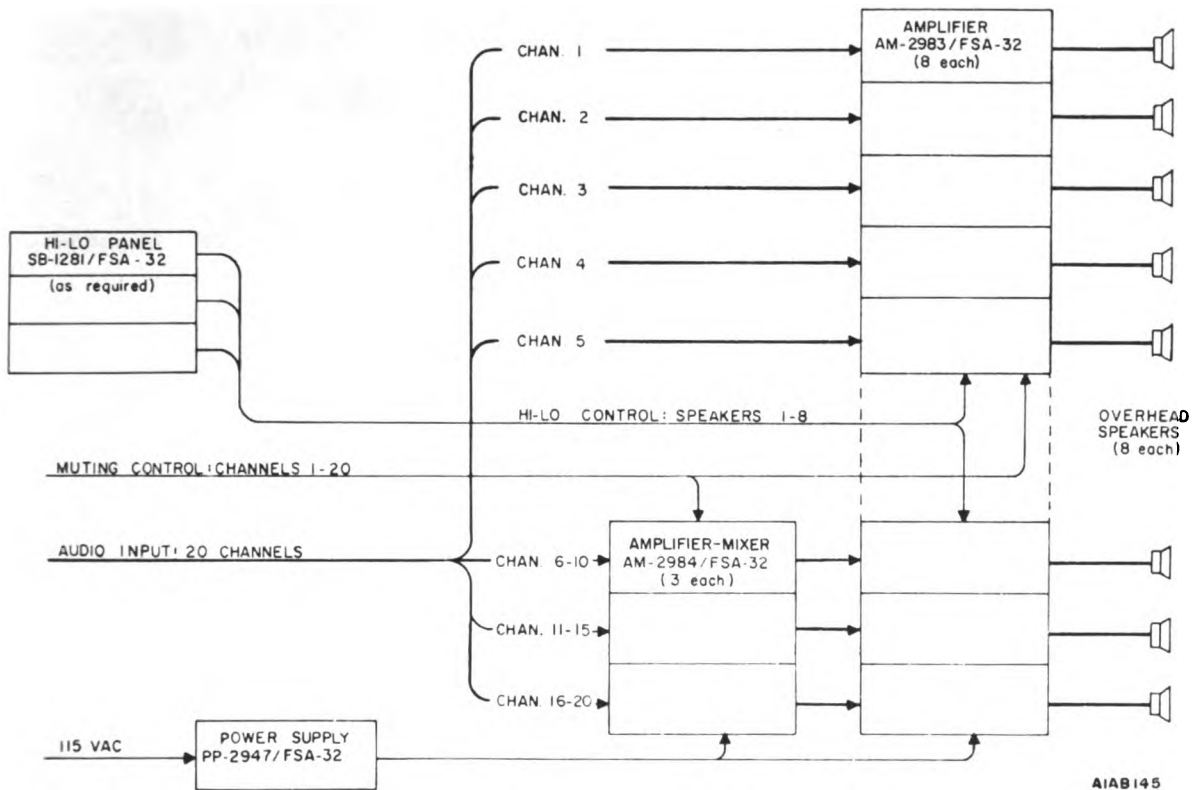


Figure 3 - 37. Amplifier-Mixer-Muter Group, Block Diagram

c. Emergency Communication System. If both the normal and standby radio sets should become inoperative, emergency radio equipment is provided for the VFR room. The emergency radio equipment consists of enough UHF and VHF radio sets required by the location as described in paragraph 3.6.1. An emergency radio control console is provided at one of the VFR operating positions, as described in paragraph 3.1.3 and foldout 3-2.

3.6.4 Terminal Room Facilities

The "Terminal Room" refers to the one or more rooms in which the equipment serving the IFR and VFR rooms, etc., is located. The rooms in an actual installation may be called "Radar Equipment Room", "Communications Equipment Room", etc. The following description refers only to the communications equipment.

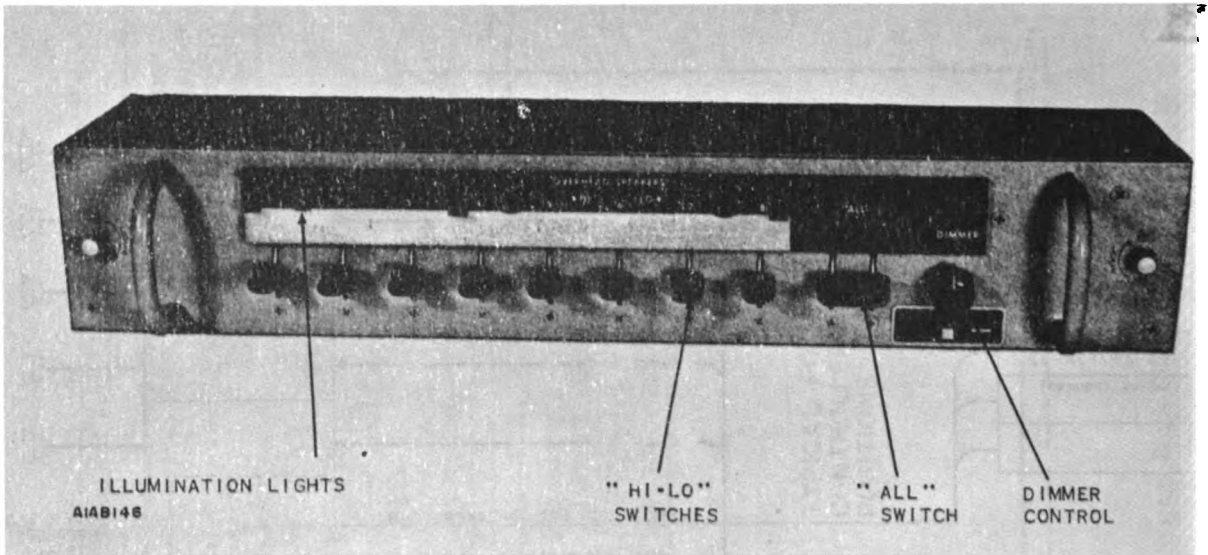


Figure 3 - 38. Switching or Hi-Lo Panel

a. Communication Control Console Group. The equipment located in the terminal room is rack-mounted on a number of racks.

(1) Transmitter Rack. This mounts 60 plug-in operator transmit selectors allowing any one of 23 controllers to obtain exclusive control of a transmitter (with supervisor over-ride), using 24-point rotary selectors. This rack also provides ten 2-wire/4-wire hybrid circuits, one per 2-wire landline, and a fuse panel with alarm features.

(2) Receiver Rack. This rack mounts the following:

- o 60 receiver amplifiers, each with 2 amplifiers. (One handles the received voice signal to the headset; the other amplifies the voice to operate a yellow light at the console, to indicate which channel is receiving the signal.)

- o 1 party line programming panel, with 23 6-position rotary switches (one per controller) and 6 party line amplifiers.

- o One monitor panel, with VU meter, etc., for maintenance.

- o A transfer control group, with maintenance switching panels, with modules of 5 circuits to switch between normal and standby channels, maximum number of channels: 25.

o Up to 80 line amplifiers for landlines. Delivers 0 dBm with adjustable input to receive -20 to 0 dBm.

o Fuse panel, with alarm features.

(3) Patch Rack. This rack may be equipped with the following:

o 23 Communication patching panels (one for each controller, to program his position to any 20 of the possible 60 channels, using patch cords.)

o One supervisor's transmit selector, to show him which controller has control of a particular transmitter, using his "Nixie" 2-digit display, before over-riding it.

(4) Power Rack. This rack has three power supplies, one of which is available as instant back up for either normal supply, a power transfer switch to make the interchange automatically, and a fuse panel, with various alarms. Figure 3-39 shows the four racks of Communication Control Console Group as mounted in a typical installation. Starting with the right-hand rack, these are the power rack, receiver rack, patch rack and transmitter rack. The latter is equipped with 40 out of the possible 60 operator transmit selectors.

b. Landline Selector Control Group. The control central part of this group is mounted in the terminal room, typically on three racks. Because of the variable requirements at different locations, not all of the modular units may be installed at any given station. Figure 3-40 illustrates the three landline selector control group racks at a typical installation.

(1) Line Equipment Rack. The left rack shows the following units:

o Line Amplifier/Terminator Units. One is required for each landline circuit. It provides line amplification and a 2-wire/4-wire hybrid circuit. Eight out of the possible 15 units are equipped, in the top three panel positions.

o Two Ringdown Decoders occupy the left two positions on the panel in the 4th space. One is required for each ring-down landline circuit. It responds to the normal 20-Hz ringing signals, and gives audible and visual indications to the operator's consoles.

o One Automatic Signaling Unit in the 3rd space on the same panel. These units are provided on the basis of one per local 2-wire line. The unit provides talking battery and signaling to a remote telephone station, and gives visual and audible signals to the programed operator positions.

o Four Interposition Amplifier/Signaling Units appear below the previous panel. Each unit provides interphone communications between positions not equipped with consoles of the radio selector system.

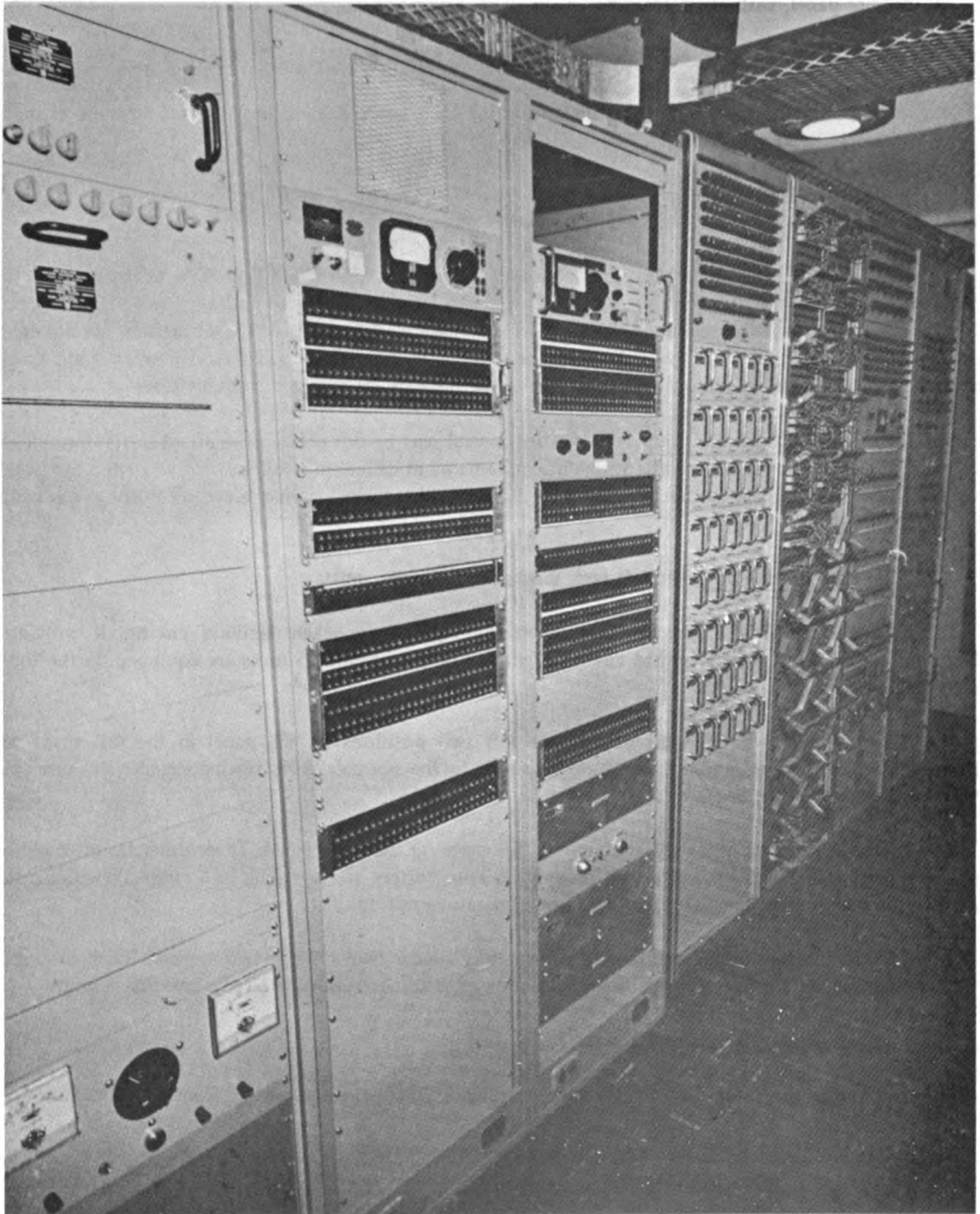
o A fuse panel with alarm features.

o A ringer generator (Sub-Cycle) which produces 20-Hz ringing current from a 60-Hz power source.

(2) Relay and Patch Rack

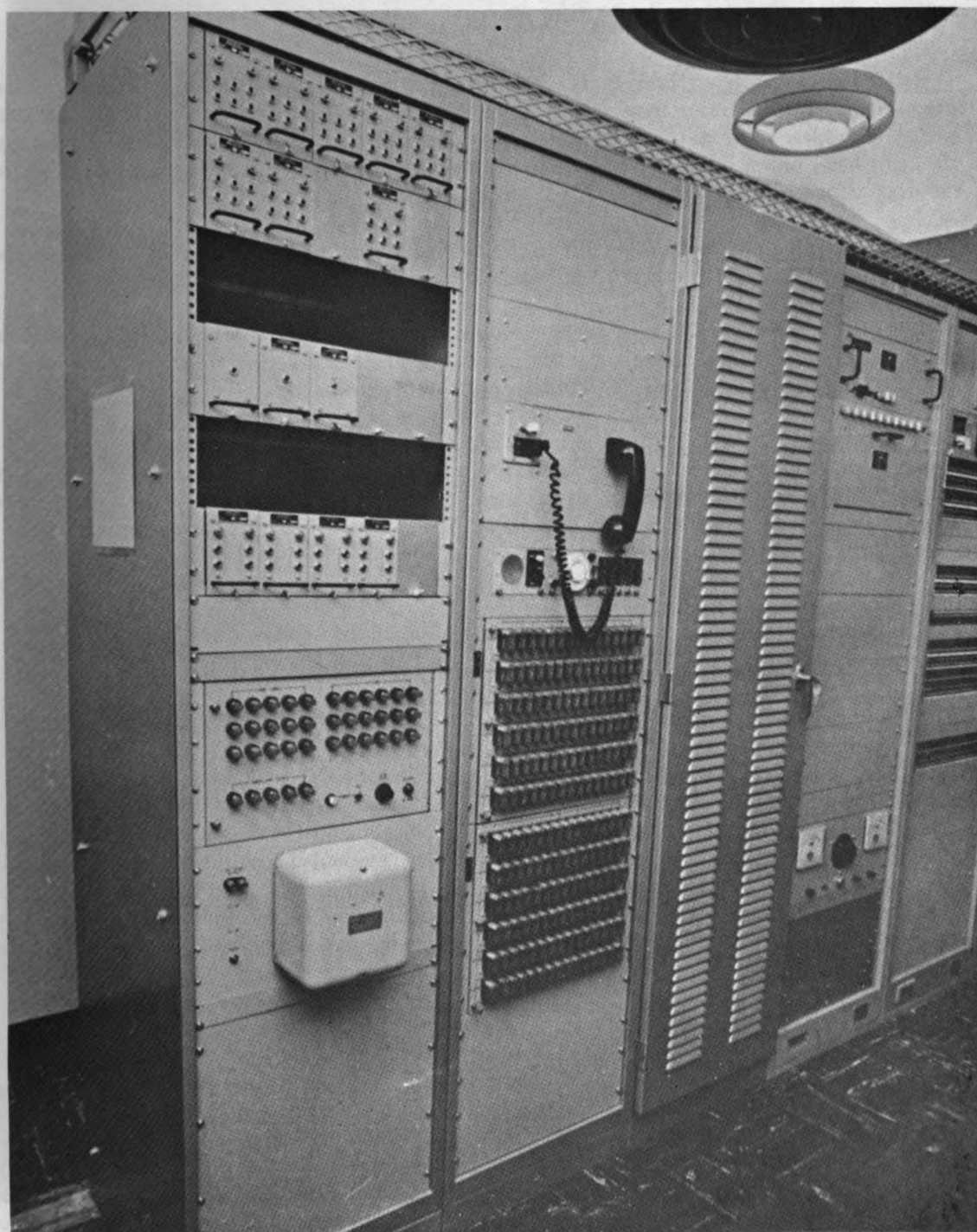
o A maintenance position, the same as the position operators is provided, consisting of a Dial Unit, Line Select Module, Speak-Amplifier Unit, a headset/handset and jack box.

o Two Relay and Patch Assemblies. Each provides, for six operator positions, line select relays and programing facilities. The patching facilities for the programing are located on the rear side of the panels shown.



AIAB 147

Figure 3 - 39. Communications Equipment Room - Communications Control Group



AIAB 148

Figure 3 - 40. Communications Equipment Room, Landline Selector Control Group

(3) Power Rack. Behind the louvered panel on the third rack from the left, are the following:

- o Distribution fuse panel for associated circuits, with alarm features.
- o Rectifier/Charger Unit (Nominal 24 volts) and batteries.

c. Typical Patch Cabinets. (Figure 3-41). Patch cabinets are used for temporary patching of test and maintenance equipment. The radio transmitter audio and keying circuits, the radio receiver audio circuits, and recorder channels appear on these jacks. Associated test equipment is also provided. Of the two similar-appearing racks, the right hand one is for transmitter audio and keying circuits, while the left hand rack is for receiver audio and recorder channels.

d. Emergency Radio Equipment. The UHF and VHF radio sets used for emergency communications are located in the tower structure. The exact "room" used for them depends on local conditions.

e. Recorders. All communications on radio channels are individually recorded, as well as all controller positions. In some cases, multiple channel recorders are used. Single track recorders may also be used as required. Figure 3-42 shows a recorder with 30 tracks for recording 30 different channels.

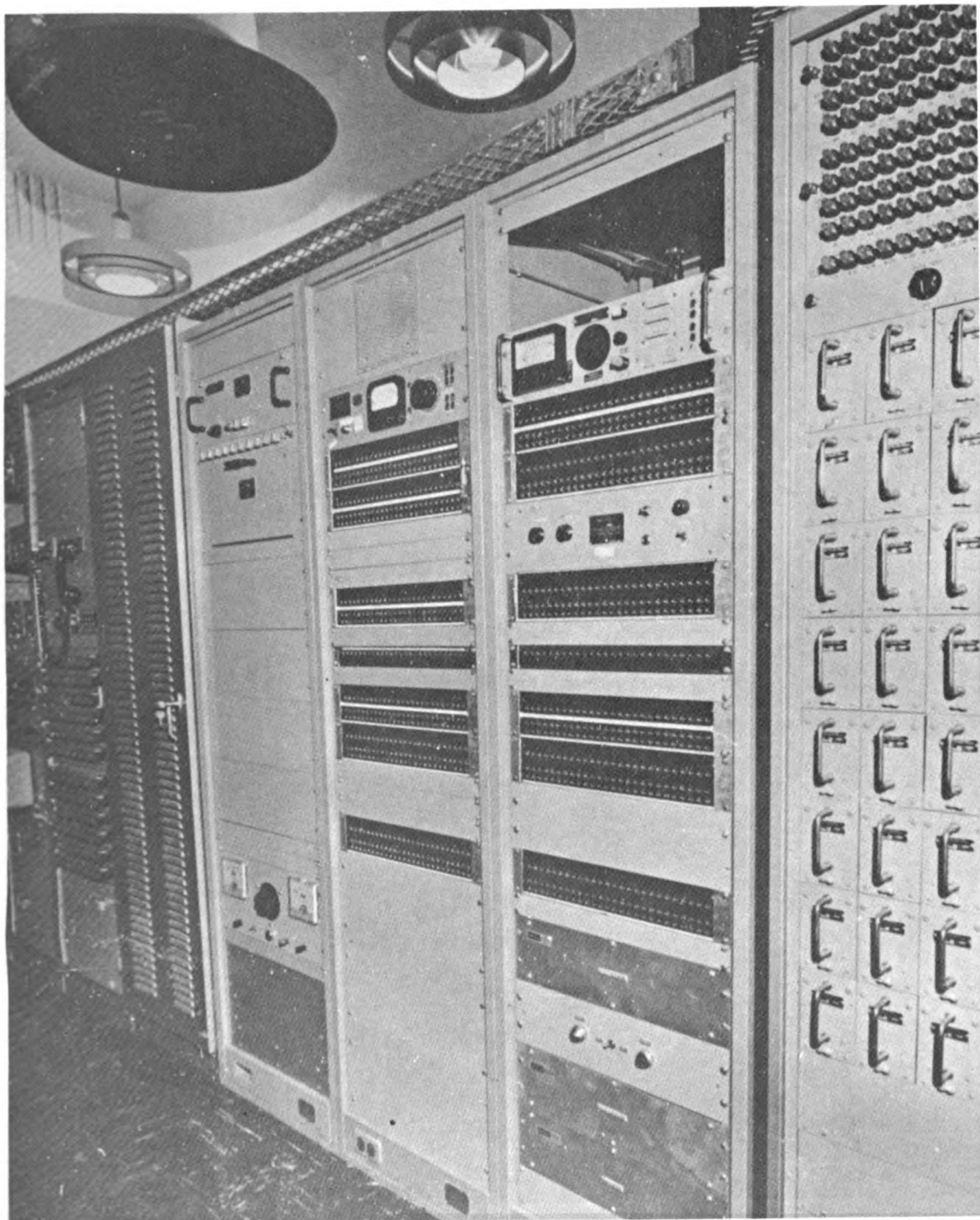
f. Main Distribution Frame (MDF). All wires or cables entering the control building are terminated at the MDF. Lightning and overload protection is applied permanently to each wire or pair. Equipment to be connected to the outside facilities is wired to a set of separate terminal strips. The equipment and the lines are connected using jumpers running through the guide rings in the frame. These soldered connections can be changed to reflect changes in assignments of equipment or facilities. A typical MDF installed in a control tower is shown in figure 3-43. The outside facilities enter the building through a "cable vault" beneath the MDF room, and can be seen where they come up through a number of large conduits.

3.6.5 Remote VHF/UHF Transmitter Building

The VHF/UHF transmitter equipment is located in a building which should be placed to satisfy specific geographical requirements stated in chapter 11. The transmitting antennas will be mounted on various poles surrounding the building. Cabling from the control building carrying the audio and control (keying) circuits terminates at an intermediate distributing frame usually located on the patch cabinet. This cabinet provides patch facilities and test equipment. The transmitting equipment includes the VHF and UHF transmitters, and antenna multicouplers as required. Coaxial cable is used for all RF wiring, and buried coaxial cable is generally used from the transmitter building out to the antenna poles. Emergency power may be provided within the transmitter building, preferably in a separate room. Switchover equipment is provided to change from normal power to emergency, and the reverse. Other equipment may also be housed in the transmitter building, for example, a crash communication set or a homer beacon. The maintenance orderwire includes a station here.

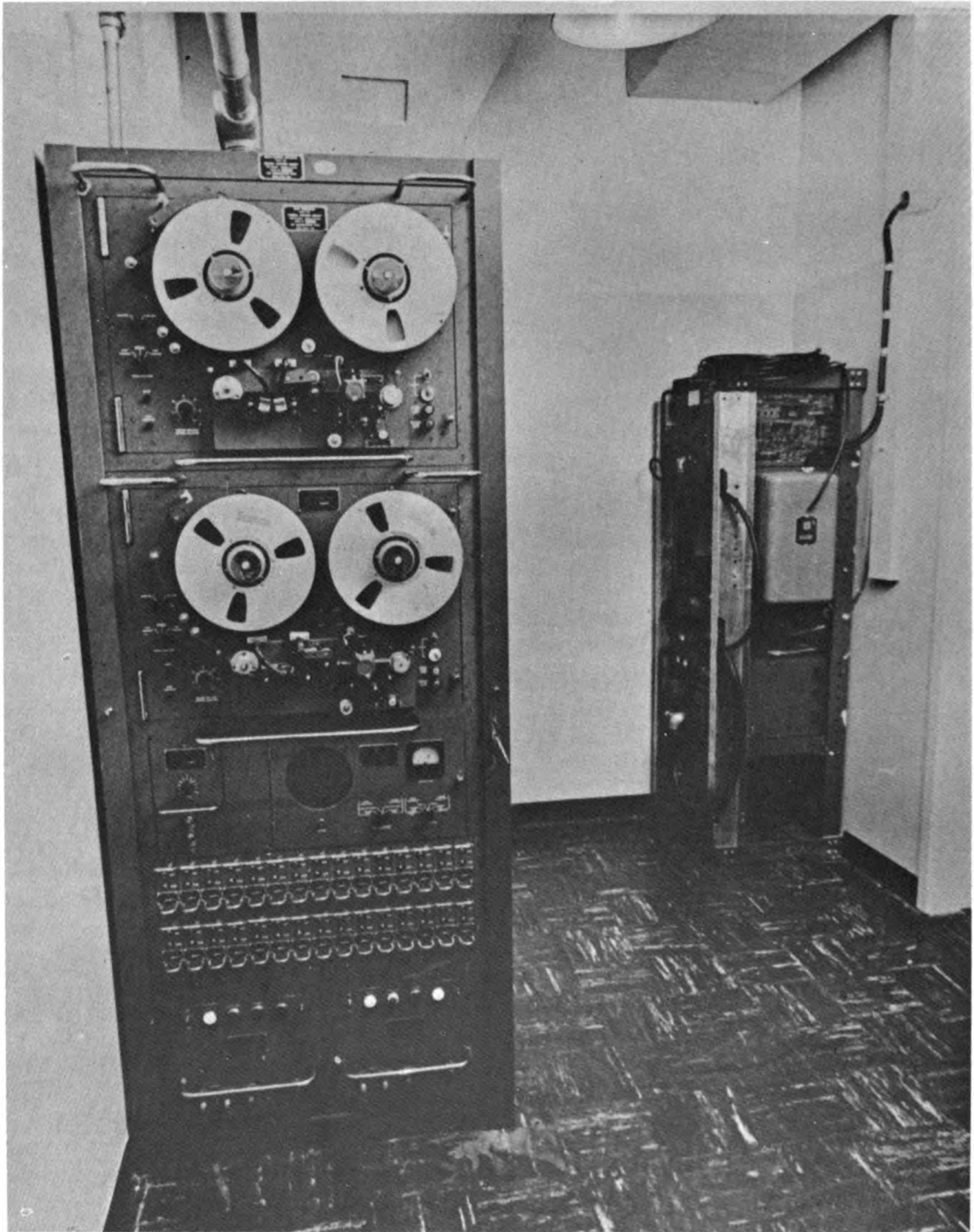
3.6.6 Remote VHF/UHF Receiver Building

VHF/UHF receiver equipment is located in a separate building, generally nearer the control tower than the transmitter building. Geographical factors are covered in chapter 11. The receiving antennas will be mounted on poles surrounding the building. All RF wiring is by coaxial cable, with the cables from the antenna poles to the building preferably buried. The receiving equipment will include antenna multicouplers as required, VHF and UHF receivers, and audio frequency amplifiers for each receiver output. The patch cabinet provides intermediate distribution frame and patching jack field. The audio lines then run through the control cable to the control building. Emergency power may be supplied by equipment at the receiver building, but the distance may make it more practical to supply emergency power from sources in the control building. A station of the maintenance orderwire should be located in the receiver building to alert the maintenance force to problems as they arise.



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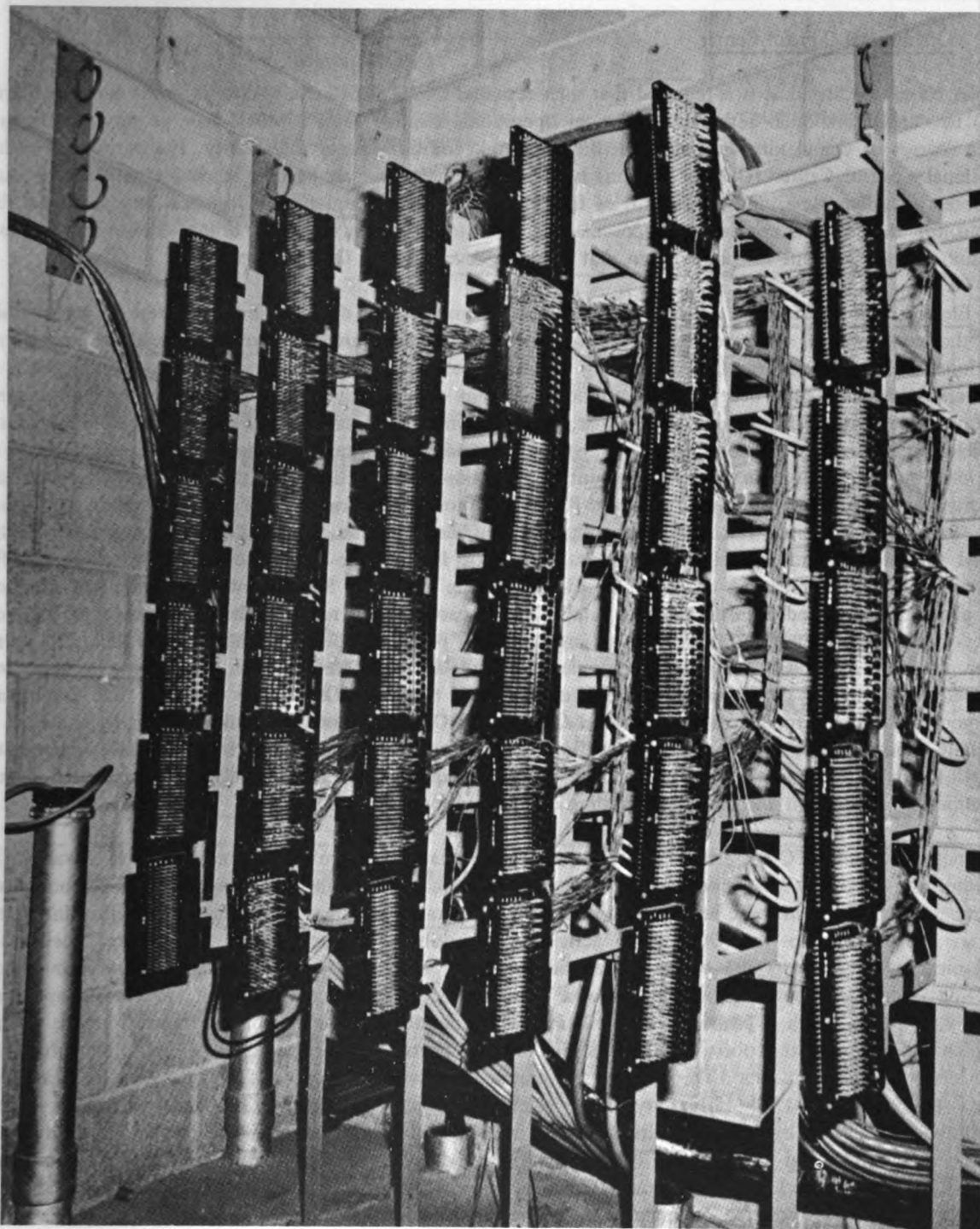
Figure 3 - 41. Communications Equipment Room, Patch Cabinets



AIAB 15,

Figure 3 - 42. Communications Equipment Room, 30-Channel Recorder and UHF Radio Set

Communication Control Capabilities located at Naval Air Station are Operational Control Centers and Communication Control Centers. The functions of these centers are described in the following paragraphs.



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Figure 3 - 43. Main Distribution Frame

3.7 COMMUNICATION CONTROL CAPABILITIES

Communication Control Capabilities located at Naval Air Stations are Operational Control Centers and Communication Control Centers. The functions of these centers are described in the following paragraphs.

3.7.1 Operational Control Center

At some Naval Air Stations, it is required that such activities as Air-Sea Rescue (ASR) or Antisubmarine Warfare (ASW) be carried on. Such activities require an operational control center, which may be very simple, or of varying degrees of complexity depending on the magnitude and duration of the activity. The purpose of such an Operational Control Center (OCC or OpCon) is to provide the person or persons in charge with the necessary data about location, type, and movement, of friendly and unfriendly units; with logistical and personnel data, required for the analysis of the situation, and decision to issue any required orders. Following is a brief discussion of the electronic instrumentation that has been developed for OCC purposes.

a. Electronic Equipment for OCC Purposes. Effective employment of naval units can best be accomplished when the commanders who are responsible for such employment are provided with accurate and current operational and tactical information concerning the various elements of the existing situations. During WWII and the Korean conflict, newly developed electronic equipment was employed as a primary method of obtaining operational and tactical data. Radar, IFF, sonar, direction finding and navigational equipments were foremost in this field. Radio communications were employed as the primary means of transmission of information, and operational and tactical orders. The vast amount of operational and tactical data thus obtained was required to be plotted and analyzed by manual methods. Radar plan position indicators, and plotting boards, navigational charts, maneuvering boards and other manually attended devices were employed for this purpose. The time required for plotting and analyzing of such data left little if any time for full consideration prior to a final decision and subsequent issuing of orders by the responsible authority. Subsequent development of supersonic speed aircraft, high speed ballistic missiles, satellites and space vehicles required the development of electronic means for speeding up the acquisition, analysis and display of pertinent operational and tactical data. The parallel development of electronic computing equipment offered an adequate solution. Computing systems were developed suited to the particular operating requirements of the Navy. One of the results of this development was equipment suitable for Operational Control Centers. An OCC is a shore installation, generally located in the immediate vicinity of the headquarters of the fleet or area commander which it serves. Major electronic systems installed in an OCC consist of electronic data processing equipment, electronic display equipment, adequate communication equipment and facilities including on-line cryptographic equipment.

The function of an OCC may be broadly stated to be that of control and coordination of naval surface, subsurface, and air operations; surveillance and control of merchant shipping when required, and performance of effective evaluations of strategic and tactical intelligence. Operational data and strategic and tactical intelligence data are transmitted to the OCC from activities responsible for such action via selected methods of communication. These data are entered into the computer which has been programed to perform selected processing operations, and to issue complete or selective reports after completing the processing operations. Generally, the data which is processed in ship, aircraft, and unknown movement of any nature which is reported to the OCC by movement reports, flight plans, or contact reports. Also logistic personnel and other information of concern to the commander is processed as required. Provisions for display of the processed data are made through the employment of various types of electronic display equipment. This presentation is made in recognizable visual form by means of direct view cathode-ray tubes, film projection or printed information. The type of presentation and the amount of information provided is selected and controlled by the computer program. The use of this kind of equipment obviates the need for manual plotting and record keeping, while its speed and accuracy provide the commander with the complete information which he needs to enable him to render proper command and control decisions.

Representative Data Processing and Display Systems for OCC are shown in figure 3-44 which shows the relationship of the various parts of the data processing and display systems for an electronically equipped OCC. The data processing system consists of the Electronic Digital Computer, and Peripheral Output Equipment.

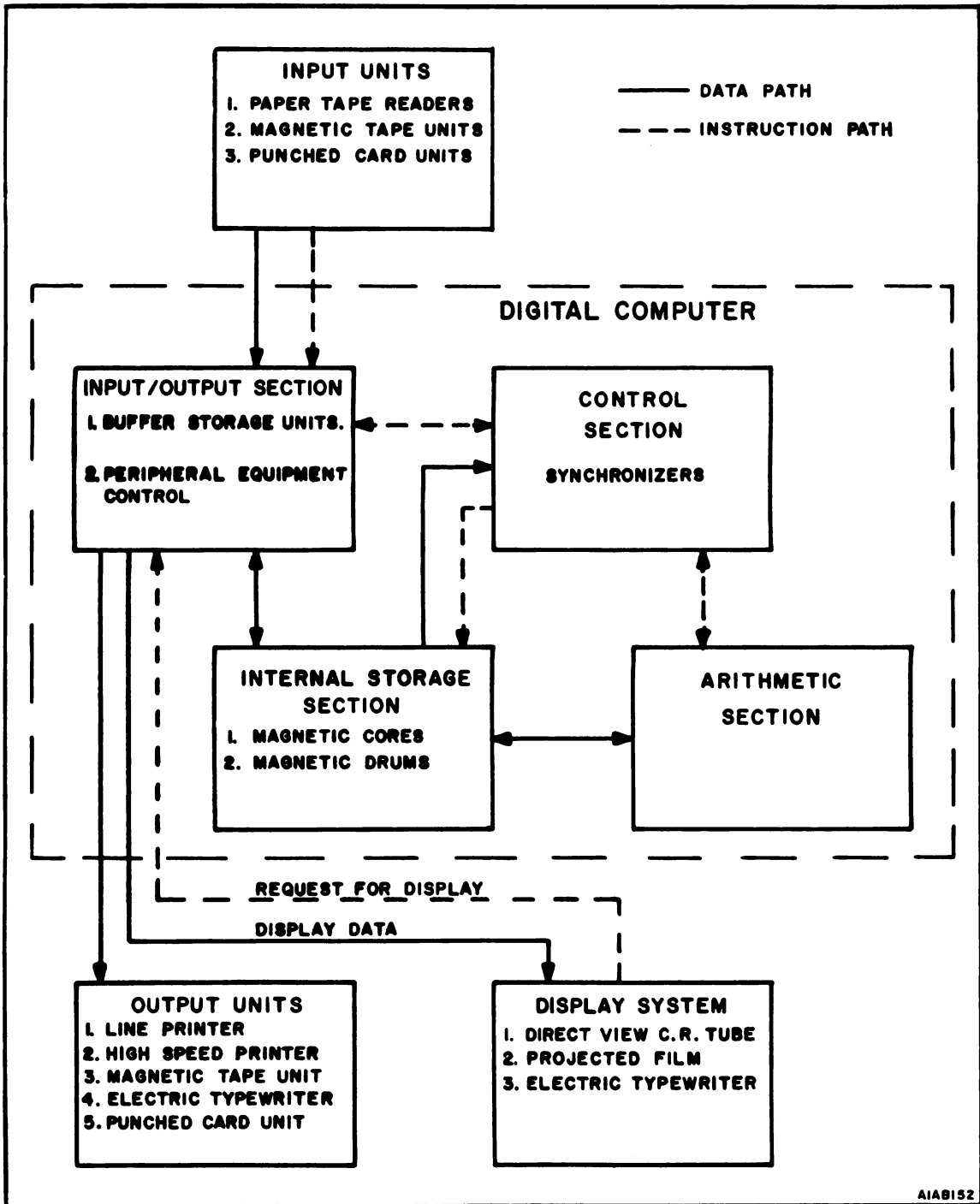


Figure 3 - 44. Data Processing and Display Systems Flow Chart

(1) Digital Computer Equipment. This is the primary unit of the data processing system. It is comprised of several inter-related sections, which, functioning together, perform the required data processing tasks. These sections will be briefly described.

- o Input-Output Section. All data entering and leaving the computer must pass through this section. It contains buffer storage registers for temporarily storing coded signals going in or out of the computer (the computer proper can accept and send information much faster than the input and output devices). It also contains peripheral equipment control circuits, including means to synchronize operation of the peripheral equipment and the computer.

- o Internal Storage Section. This is the "memory" section. It is directly controlled by the Control Section and includes all the storage that is automatically accessible to the computer. It includes fast access storage (e.g. magnetic core) and slow access storage (e.g. magnetic drum or disc). The fast access storage carries the program currently in use and mathematical constants employed in problem solution. Programs and data are shifted between slow and fast access storage as required, automatically.

- o Control Section. This aligns and interprets each instruction, and provides signals to cause the arithmetic section and other parts of the computer to operate in accordance with the instructions. Data and instructions are "read in" from the input units and placed in specified locations in the internal storage section under guidance of the control section. It also calls for, and interprets, the instructions in the internal storage unit. Data to be processed goes from the storage unit to the arithmetic unit where, under guidance of the control unit, arithmetical and certain logical operations are carried out. The processed results are returned to storage or "read out", again under guidance of the control unit.

- o Arithmetic Section. This performs the mathematical computations for the system. It includes several storage registers, including an accumulator register, and a multiplier-quotient register.

- o Power Supply Section supplies electric power to sections of the computer. It rectifies and regulates all direct currents used.

- o Cooling Section. This provides temperature and humidity control for the system. The transistorization of computers has greatly reduced the cooling needed in comparison to that required by vacuum tube equipment.

(2) Peripheral Equipment. The peripheral equipment consists of the equipment that is required for proper functioning of the system, but which is not part of the digital computer. Some units are connected to and controlled by the computer, these are also shown in figure 3-44. Others are used "off-line", such as tape preparation and conversion equipment. Representative units of peripheral equipment are mentioned below.

- o Paper Tape Reader. It uses a photoelectric cell to read paper tape at relatively high speed. It is used as an input device, for priority data.

- o Magnetic Tape Unit. This is used as an input or an output device. It has a specially designed magnetic clutch and brake which allows very rapid starting and stopping of the tape drive mechanism without tape breakage. Similar units are also used for off-line purposes.

- o Electric Typewriter. One make used is called "Flexowriter". It can produce a typed copy and punched paper tape simultaneously. On-line, it is mainly used to monitor computations and for output. Off-line, it can be used for paper tape preparation.

- o Output Printer, or Line Printer. Different types exist, printing from 90 to 150 lines per minute, with 100 to 150 characters per line. It is used as an output device in the on-line system.

o **High Speed Printer.** Of varying designs, such printers can print from 600 to 2000 lines per minute, with up to 160 characters per line. On-line, it can take data directly from the computer. Off-line, it requires a separate magnetic tape unit and storage register operating with it.

o **Paper Tape Punch.** This is an on-line output device. It is slower than a magnetic tape unit (about 60 tape frames per second) but this is a high speed for paper tape.

o **Tape Preparation Equipment.** This is needed for off-line preparation of both magnetic and paper tapes.

o **Tape Conversion Equipment.** This converts paper tape in teletypewriter code form to magnetic tape data in binary code. It is used off-line.

o **Transrecording Equipment.** This allows transmission of data between like units over radio or wire communication circuits. It uses magnetic tape prepared by tape preparation equipment.

(3) Display Component. There are four primary display methods.

(a) **Electronic Display.** Electronic display is used in connection with electronic data processing equipment. The number and types of electronic display equipment will vary with the requirements of the activity. The electronic display equipment is equipped with manually operated special control panels for the selection of the data desired for display. The data selected is transmitted through electronic circuits to the display unit from the computer. Figure 3-44 shows the relationship of the display equipment and the data processing equipment. Normally, the following three types of electronic display are available for the OCC.

o **Direct View Cathode-Ray Tube.** With associated circuitry is mounted in a console sometimes called "Situation Display" unit. It will display selected segments of data available in the computer. It can also display maps and charts if so equipped.

o **Typewritten Display.** Controlled from the Situation Display console, gives amplifying data on items displayed on the Situation Display.

o **Projection Type Display.** Film from film processing equipment (prepared in about 10 seconds) is projected from a projection booth onto a large screen.

(b) **Television Display.** This is provided by a closed circuit television system within the OCC. The number of camera and monitors depends on the operational requirements of the OCC. It provides simultaneous visual presentation of all pertinent plots to strategically located television monitors.

(c) **Graphic Display.** This consists of the projection of slides, strip or motion-picture film by various means. The material is generally prepared in the OCC photographic laboratory.

(d) **Manual Display.** Older manual displays used large plotting boards on which special attendants marked information in chalk. Sometimes the boards were transparent, in which case the information was chalked in reverse on the back side of the board. Later display boards are made of sheet steel, to which magnetic symbols are manually attached. Often the boards are on track-equipped racks, which allow a number of plotting boards to be shown selectively.

(4) Manual (Back-Up) Equipment. An electronic malfunction might disable both the electronic data processing system and the electronic display system. It is desirable, therefore to maintain manual back-up of unit location and movement. This involves independent data processing and display equipment.

b. Air-Sea Rescue (ASR). In many cases, the installation of electronic data processing and display equipment is not justified. Manual plotting boards can readily be kept current with changing situations, reported by HF or VHF/UHF radio circuits. Liaison with other interested stations can be made using HF or microwave circuits, or landline circuits.

c. Anti-Submarine Warfare (ASW). It is possible that a situation might develop requiring use of electronic data processing and display equipment. However due to the relatively low speed operation of underwater vehicles, it is likely that manual plotting boards will be entirely adequate. The use of communication facilities will be similar to the ASR case, except that use of cryptographic procedures will be mandatory, on account of the nature of the intelligence handled.

d. Aircraft Carrier-Shore Communication. This is sometimes known as the "Raspberry Circuit". This is required for communication between the carrier personnel and shore-based personnel of the same organization. The requirements are simple: a small operating room with controls for HF and possibly UHF radio equipment, plus landline connections to squadron areas. This "circuit" is entirely separate from ATC communications and personnel.

3.7.2 Communication Center

A Naval Air Station may require some or all of the facilities of a Naval Communication Station. The functional components of a communication center are outlined in figure 3-45 and are defined as follows:

a. Message Center. The message center is the hub of operations. Here the ship locators and routing information is currently maintained for proper routing of traffic in the system. Traffic originating locally, or for local delivery, or interchanged between ship-to-shore and the relay system, is routed via the message center for checking and routing. Radio broadcast and ship-to-shore circuits, both RATT and C.W., wire line teletype circuits, other than tape relay, and crypto processing are considered an integral part of the message center operations, and are conveniently located to facilitate the passing of messages.

b. Technical Control Center. The technical control center provides for technical control of the circuits in the communication center. Patchboards terminate lines to remote transmitters and from remote receivers as well as drops to the equipment located within the center. This provides flexibility so the control supervisor can make substitutions by patching, in case of circuit outage, to restore service, and maintain operation. Due to the relationship to the on-line crypto equipment in operations, OPNAV has directed that this facility be located in the on-line crypto spaces. CSPM 1, 1-34 (REV) 1 November 1959 must be complied with.

c. Relay Center. The relay center exchanges teletype traffic between other relay centers, its tributaries, and all the elements comprising the communication center. This process utilizes perforated tape for receiving and re-transmitting. "Hard copies" are not required except as monitor copies on receive point-to-point radio circuits as a circuit supervisory device. The relay functions may be accomplished by the use of automatic switching equipment, in which the traffic is routed automatically according to the routing indicators, or by torn tape equipment in which all traffic must be processed manually for re-transmission. Equipment and maintenance services for the automatic switching system will normally be leased, with the Navy furnishing operating personnel. Provisions are to be made in the relay center for the future installations of single channel on-line cryptographic equipment on individual channels.

d. HF Radio Facilities. A communication center generally employs HF radio channels in addition to other communication methods. Because of the characteristics of HF radio, it is almost always necessary to locate the transmitters and receivers at separate sites, and both are normally separated from the communication center, (figure 3-46). The geographical spacing between transmitter site and receiver site is necessary because of the high power often used in the HF transmitters. Each should have a "protective corridor" about one mile wide around it. The communication center location is governed by different considerations, such as location of other establishments. Control links between the communication center and the radio transmitter and radio receiver locations can be either by landlines or microwave links. Further details on HF Radio Facilities may be found in NAVELEX 0101,103, HF Radio Propagation Facilities.

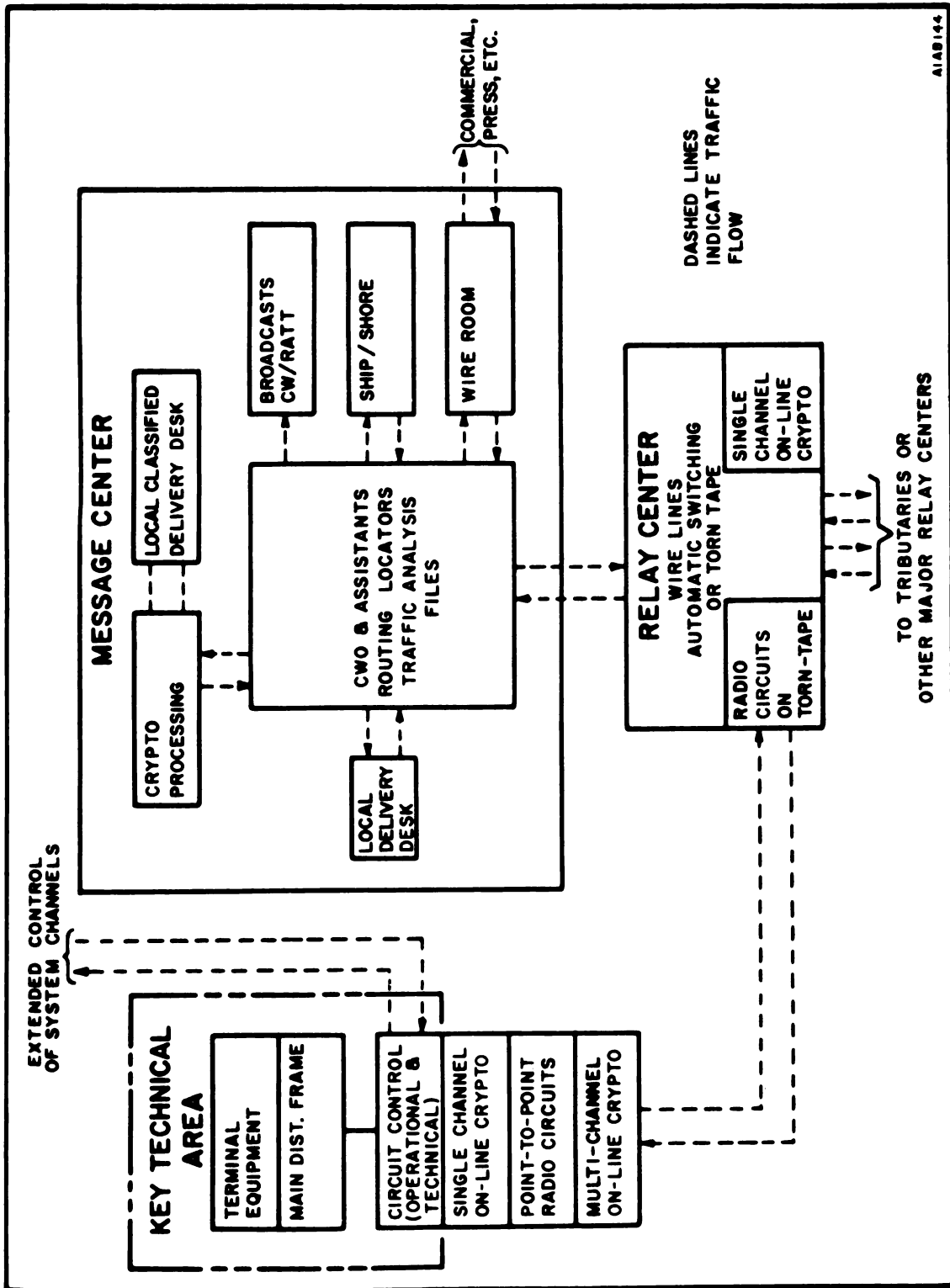


Figure 3 - 45. Communication Center - Functional Layout

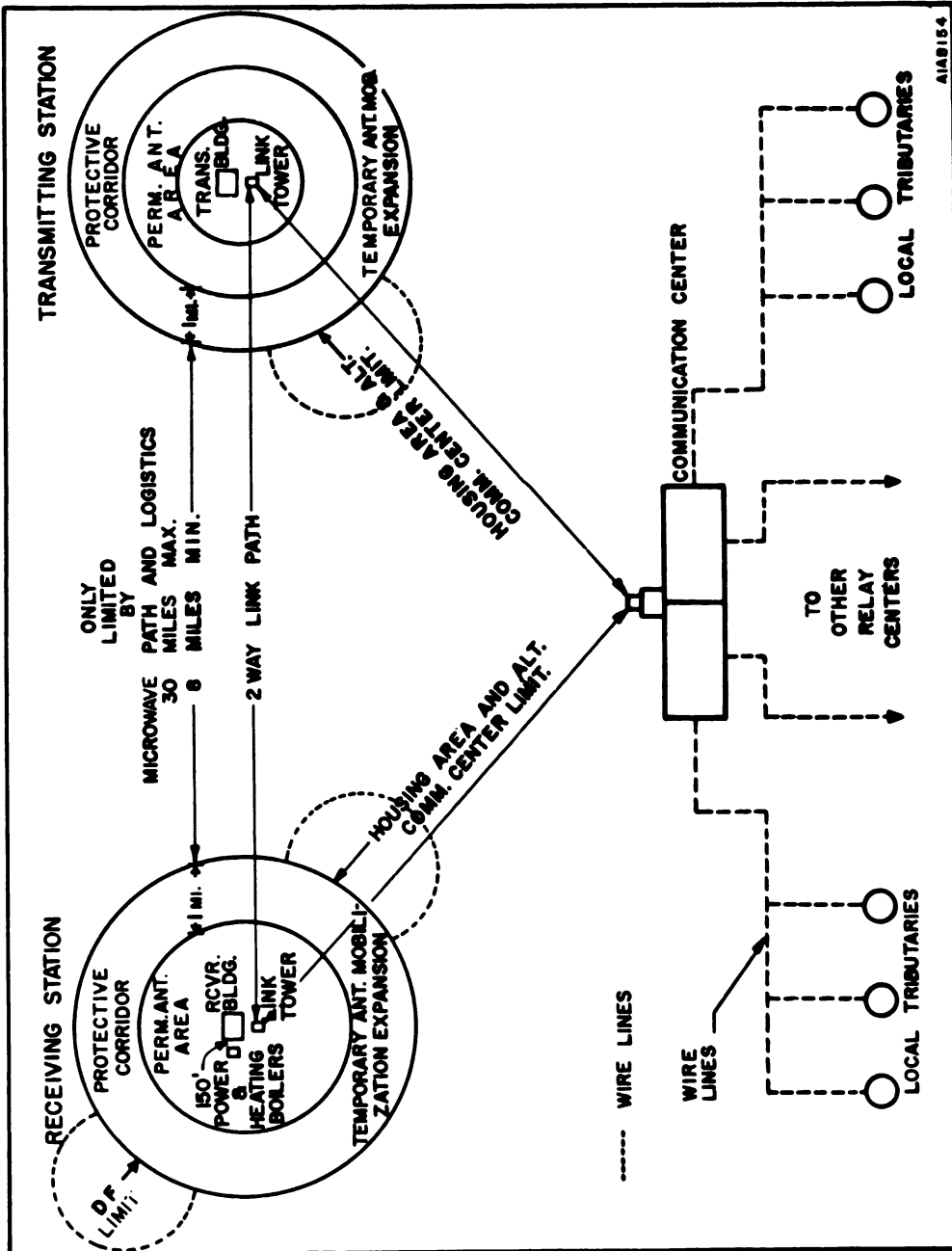


Figure 3 - 46. HF Radio Facilities, Station Configuration

3.8 COMMUNICATION NETWORKS

Major communication networks utilized by NAS facilities are the AUTOVON and AUTODIN, a brief description of which follows.

3.8.1 AUTOVON

AUTOVON, which means AUTOMATIC VOICE Network, is the single, world-wide communications system for handling end-to-end circuit-switched communications for the Department of Defense and certain non-Department of Defense users. These communications include voice, graphics, and data. It is one of two major switching networks provided as a part of the Defense Communications System (DCS). The other is AUTODIN, the AUTOMATIC DIGITAL Network.

AUTOVON consists of automatic switching equipment, transmission facilities and terminal equipment. The network handles command and control, operational, administrative, logistical and intelligence traffic. Because the network is world-wide in scope, and many links may be used in tandem to span great distances, high transmission standards are required. For this reason AUTOVON is a 4-wire network.

AUTOVON is divided into two major areas: CONUS AUTOVON (CONTinental United States), primarily leased, includes that portion of the network in CONUS, plus Alaska, Greenland, Iceland, Bermuda, and Canada. Overseas AUTOVON is primarily Government-owned and includes all of the network outside CONUS, except Alaska, Greenland, Iceland, and Bermuda. Hawaii and Puerto Rico are a part of the overseas portion.

Since the network is automatically switched, it offers several advantages over the many point-to-point circuits formerly used within the military departments. Among the advantages are survivability, economy and efficiency. It is also designed to provide many special features such as: five levels of precedence and four levels of pre-emption; automatic and random conferencing; off-hook service, which provides instantaneous connection between two pre-determined subscribers; direct connection to 4-wire switches for priority subscribers; automatic alternate routing; abbreviated keying and special, or dedicated, service within the network for selected groups of users.

a. Switching Centers. AUTOVON switching centers include automatic switching equipment and Dial Service Assistance (DSA) operators' positions, together with the necessary technical-control facilities required to control both the switching equipment and the primary transmission media. Most switching machines in the network are 4-wire, stored program, automatic switches. In some cases, manual switchboards may be designated as AUTOVON switchboards where limited transmission facilities or transmission media unsuited for automatic switching do not warrant the cost of an automatic switching machine.

There are at present, more than 50 operational AUTOVON switching centers in the Continental United States, 9 in Canada, and more than 15 in overseas locations. Centers in the United States are common-carrier owned and operated, and the Government leases service on a line-by-line basis under tariffs filed with cognizant regulatory agencies (see foldout 3-7 and 3-8).

b. AUTOVON Circuits. AUTOVON circuits used for interconnection of switching centers and for provision of subscriber access lines are derived from DCS transmission facilities, either military or leased. In overseas areas, AUTOVON circuits may occupy the full capacity of an interconnecting transmission link or only a part. The transmission link may be microwave, cable, tropospheric scatter or in some instances may be high frequency radio or communication satellites.

Because of the long distances spanned by AUTOVON (12,000 to 15,000 miles), transmission facilities must conform to the highest technical standards. AUTOVON is designed for the interconnection of up to seven voice grade trunks in tandem; therefore, network transmission facilities will be 4-wire except at main PBX's where 2-wire connections to station equipment will normally be employed.

Up to four data grade trunks may be connected in tandem. Transmission standards for data grade trunks are similar to those for voice grade trunks, with the addition of more stringent attenuation versus frequency, and envelope delay distortion limits.

c. Terminal Equipment. Since AUTOVON is a 4-wire system, its terminal equipment must be 4-wire. In cases where such terminal equipment as 2-wire local switchboards are to be interconnected, a 4-wire/2-wire conversion is required as a part of the system. In the case of 4-wire subscriber devices these devices are included as a part of AUTOVON. In the case of 2-wire devices, the conversion terminal device is considered to be the interface point. Terminal equipment which can employ AUTOVON for service include 4-wire telephones, 2-wire and 4-wire local switchboards, special purpose consoles, facsimile machines and data subsets. Any terminal equipment employing on-line cryptographic devices must establish the connection before the cryptographic device is placed on-line. AUTOVON may be used to provide low volume data services where it proves economically more advantageous than connection to AUTODIN.

d. Services Provided. A wide range of communication services is provided on a world-wide basis by AUTOVON for the use of its various subscribers and users.

AUTOVON provides a Direct Distance Dialing (DDD) telephone capability to connect selected subscribers with other subscribers at any location in the world. This capability is available to subscribers in one of three ways:

(1) 4-Wire Service. Selected subscribers are provided with special 4-wire terminal equipment, having direct access to the AUTOVON Network. The equipment may be a telephone instrument, or any other subset that can employ a nominal 4-kHz circuit. Data subscribers, requiring specially treated circuits, are provided access to those AUTOVON circuits which are specially conditioned. AUTODIN circuits connected to AUTOVON switches fall in this category. Signaling from 4-wire subscribers is on a dual-tone, multifrequency basis, or an M-lead off-hook condition.

4-wire subscribers can be provided with up to four levels of precedence with a fifth level reserved for National Command Authority use in accordance with the Joint Uniform Telephone Priority System.

Any level of precedence employed, if required, will pre-empt any lower level with which it is in contention. A 4-wire subscriber may employ any level of precedence he desires up to, and including, the highest level he is authorized. Assignment of precedence levels to subsets is accomplished at the serving switching center(s) and is reprogrammable.

(2) "Off-Hook" Service. "Off-Hook" service ("hot lines") can be provided through the network. An off-hook subscriber, upon lifting the handset of his telephone, will immediately be connected with the pre-designated subscriber. An off-hook instrument cannot be employed as a normal instrument in the network (4-wire service to off-hook subscribers must be provided by a separate instrument or as one circuit in a multi-line switch).

(3) Service through PABX. At some locations where PABX facilities exist, 2-wire to 4-wire conversion equipment may be installed at the local switchboard to allow direct dialing by authorized users through the PABX into the AUTOVON system. The user, however, will not be able to automatically pre-empt a circuit directly from his telephone instrument if he should require to do so, but he can avail himself of operator assistance in this regard from a DSA position.

e. Conference and Broadcast Services. Conferences may be preset, that is, previously programed, or random, on an operator-assisted basis, or on a "meet me" basis. Broadcasts, during which only the originator can speak, may have up to 100 participants.

f. Dial Service Assistance. Dial Service Assistance (DSA) operators are provided at selected locations in AUTOVON. These operators provide information assistance, establish conferences, can place precedence calls for AUTOVON users whose telephones are not equipped for pre-emption and assist maintenance personnel in their routines.

g. Responsibilities. The DCA is responsible for overall policy and management direction of the program. DCA, through its Communications Services Division, performs day-to-day management and supervision of the trunk or backbone portion of the network.

The Military Departments (Army, Navy, Air Force) are responsible for all Government-owned plant and terminal facilities and for determining their requirements for AUTOVON services, including access and subscriber lines.

3.8.2 AUTODIN

AUTODIN is the Department of Defense world-wide AUTOMATIC DIGITAL Network. It is an automatic, fully electronic, transistorized, high-speed data communications system. It comprises a complex of message switches that accept and relay world-wide traffic for graphics, computers, teletypewriters and other connected digital end devices. Each AUTODIN switching terminal will perform modulation rate conversion as required to communicate with message switches in other terminals, and will provide code conversion within itself to permit end-to-end message-switched connections between digital users having incompatible end devices. In addition to the present store-and-forward service, plans call for circuit switching service between like subscriber terminals. Like AUTOVON, the AUTODIN system is divided into two major areas: CONUS AUTODIN and Overseas AUTODIN.

The CONUS portion is presently operational with five Automatic Electronic Switching Centers (AESC) providing card, teletypewriter, magnetic tape and on-line computer service to over 300 Army, Navy, Air Force and other authorized agency locations. The operational CONUS AESC's are located at Norton AFB, Cal.; McClellan AFB, Cal.; Tinker AFB, Okla.; Gentile AFB, Ohio; and Andrews AFB, Md. See figure 3-47 which shows the locations of both CONUS and Overseas AUTODIN switching centers, and which military department has operational and maintenance responsibility. It is noted that the Navy is listed for four of the centers, at Albany, Ga.; Hancock Field, N. Y.; Finegayan, Guam; and Wahiawa, Hawaii. Data originating at overseas locations flows through manual data relay centers into automatic terminal facilities directly connected to Gateway AESC's at Andrews, Gentile, Tinker, and McClellan AFB's.

a. Switching Centers. The basic function of AESC equipment is to accept, store and re-transmit digital messages from one location to another, accomplishing code and speed conversion, automatic error detection and correction, and alternate routing when necessary. Plans call for providing automatic circuit switching (direct user-to-user) service for those locations requiring either real-time service or whose traffic volumes are such as not to require full-time, immediate access to the system, or which need to exchange lengthy messages.

b. AUTODIN Circuits. Connections between AUTODIN switching centers are established through AUTOVON on a call-up basis or via nonswitched (dedicated) circuits, depending upon traffic requirements.

c. Terminal Equipment. Present tributary subscriber terminals use 5-unit punched paper tape, 80 column punched cards, and magnetic tape as input and output media. The existing terminals are the Compound Terminal (CT), High Speed Card Teletypewriter Terminal (HSCTT), and Magnetic Tape Terminal (MTT). The compound terminal, and high-speed card teletypewriter terminal use punched paper tape and punched-card input-output media. The magnetic tape terminal uses magnetic tape input and output. Other terminals may be used provided that the line coordination procedures and message formats are adhered to.

d. Modulation Rates. For synchronous operation the system processes traffic at modulation rates of 75×2^m bauds, where m is any positive integer between 1 and 6, that is, 150, 300, 600, 1200, 2400 and 4800 bauds. (At digital interfaces, the signals are binary (2-level), and in synchronous operation, the rate in bits per second is equal to the modulation rate in bauds). Synchronous operation is employed on trunks between switching centers and on tributary circuits when equipped with appropriate terminal equipment. Start-stop ("asynchronous") circuits accommodate modulation rates of 45.45 and 74.2 bauds in addition to the 75×2^m standard. Start-stop operation is employed only on tributary circuits and interchange circuits to other teletypewriter networks.

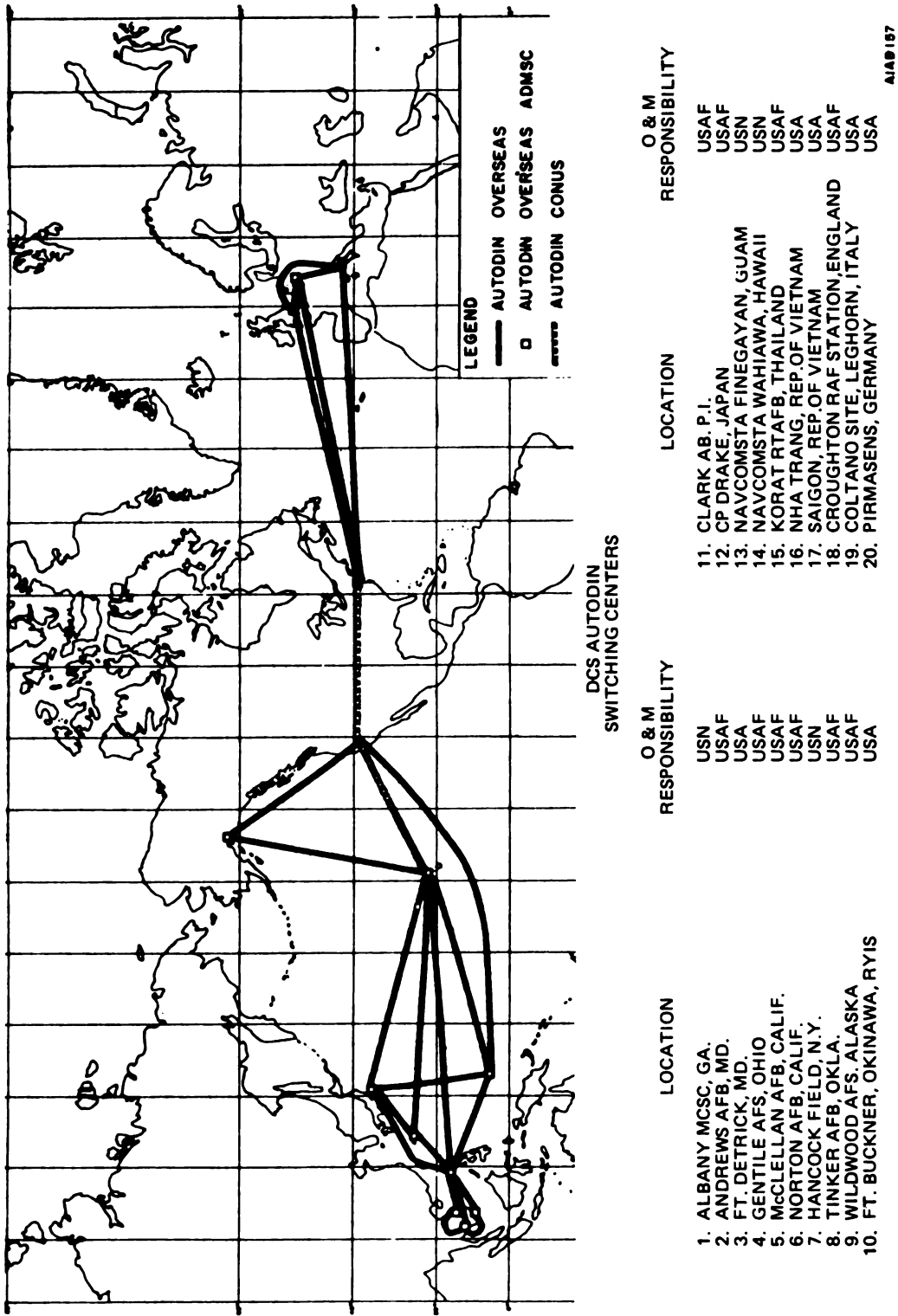


Figure 3 - 47. AUTODIN Switching Centers, CONUS and Overseas

e. Codes. Synchronous operation on trunks between switching centers and on subscriber circuits uses the American Standard Code for Information Interchange (ASCII). Start-stop operation uses either ASCII or the American Variation of International Telegraph Alphabet Number Two (ITA No. 2), the 5-unit code widely used before the development of ASCII or the American Variation of International Telegraph Alphabet Number Two (ITA No. 2), the 5-unit code widely used before the development of ASCII.

f. Format. Message formats shall be as described in JANAP-128 for synchronous operation, and as described in JANAP-128 and ACP 127(c) and U. S. Supplement (A)-1 thereto, for start-stop (asynchronous) operation.

g. Responsibilities. The responsibilities are divided between the DCA and the Military Departments, as described in connection with AUTOVON.

3.8.3 Maintenance Orderwire

This is a local system giving instant access to maintenance personnel for the visual and radar controllers. It may differ in details according to local requirements, but in general it consists of a number of cabinets or consoles, with keys or switches to activate a talking circuit between two or more points. A simple type provides a single audio channel, usable by any one station to speak to one or more other stations, and signaling is entirely by voice calling. More elaborate systems have one or more "master" stations, with one or more "remote" stations. Various degrees of selectivity can be provided, depending on the local requirements.

3.8.4 Base Communication Networks

Fixed Base Station and mobile FM communication networks which need to be provided at a Naval Air Station include the following:

a. Crash Communications. This provides communications required in connection with rescue and salvage operations in the event of an airplane crash at or near an air station. This involves the control cab, various vehicles and other fixed locations depending on the local situation.

b. Internal Security. This provides for the communication requirements of the police, fire department, ambulance, and shore patrol. This network also serves as a Disaster Control Network.

c. Industrial Control. This network provides for the control of station taxicabs, motor pool, busses, large movable cranes, trucks, and other mobile industrial equipment.

CHAPTER 4

AIRCRAFT LANDING SYSTEMS

4.1 SYSTEM BACKGROUND

Landing approach control is the last segment to receive an aircraft in the chain of an air traffic control system. From the time an aircraft leaves the ground until it lands again, it is tracked by many radar systems. The most critical period of an aircraft flight is the final approach and landing. The dangers are minimized when weather conditions are good, but are tremendously increased during poor weather.

The fact that the atmosphere is in a state of constant flux makes it impossible for aircraft to fly only during ideal visual flight rules (VFR) weather conditions. This condition has led to the realization that some system, or group of systems, must be designed to allow for safe air traffic control during weather conditions considered much less than favorable for aircraft approach and landing operations.

Today's air traffic control system is constantly seeking ways of operating and controlling aircraft under all weather conditions with the maximum degree of safety humanly and electronically possible. The ultimate goal of air traffic control is the ability to land aircraft under conditions of absolute zero visibility and ceiling. The pilot would function solely as an observer from the point at which he transfers control of the aircraft to an automatic control system until it has landed on the runway.

A system which is intended to perform this feat of total hands-off landing is the Navy Automatic Carrier Landing System (ACLS). When fully operational, this system will enable a pilot to acquire a lock-on signal from the ACLS system which will control the aircraft autopilot and fly the aircraft to the carrier deck or landing strip unaided by the pilot.

The levels of remote control are classified as Mode I, IA, II and III.

- o A Mode III landing control is a standard ground controlled approach (GCA) which is a system that utilizes both the GCA controller and the aircraft pilot. The controller provides verbal directions which allow the pilot to align his aircraft with the runway and approach at the proper glidepath angle and on the runway centerline.

- o The Mode II landing control system is the Aircraft Approach Control System (AACS). This system requires the pilot to fly a crosspointer on an indicator. The crosspointer provides the pilot with an indication of his position relative to that which he should be flying for a proper landing.

- o The Mode IA landing control system is an Automatic Carrier Landing System approach which the pilot terminates at an altitude of approximately 200 feet, and one-half mile from touchdown.

- o The Mode I landing control system is the Automatic Carrier Landing System which is designed to provide the ultimate automatic landing system. With this system, the pilot's only function is that of monitoring the crosspointer indicator of the AACS. This indicator is monitored to give the pilot the opportunity to assume control of the aircraft should a major equipment failure occur either in the aircraft or at the ground station. This provides a thinking back-up for the electronic units in the system. If the system is operating under conditions of zero ceiling and zero visibility, it is required that the Mode I and II systems be operating simultaneously.

4.2 GROUND CONTROLLED APPROACH

4.2.1 System Principles

Precision approach radar (PAR) is a radar system used in guiding aircraft in final landing approaches, but it is primarily designed as an integral part of a complete Air Traffic Control (ATC) facility. PAR is provided as an independent radar system or as part of a GCA installation having both search and PAR capability (refer to paragraph 3.2). As part of a complete ATC facility, the purpose of the precision radar set is to monitor aircraft altitude, range, and flight course information so that the controllers can accurately direct the approach and landing of aircraft during bad weather and training flights. The radar set tracks the approaching aircraft down the glidepath and along the course line during the final critical phase of ground controlled approach. In order to track both the course and the glidepath (line of descent) of the aircraft, the antenna system of the radar set alternately scans or looks in both the vertical and horizontal planes. The two scans are shown on the map face of the Az-El azimuth position and elevation position indicator, as presented in figure 4-1. Also shown is the antenna propagation pattern as seen from the aircraft.

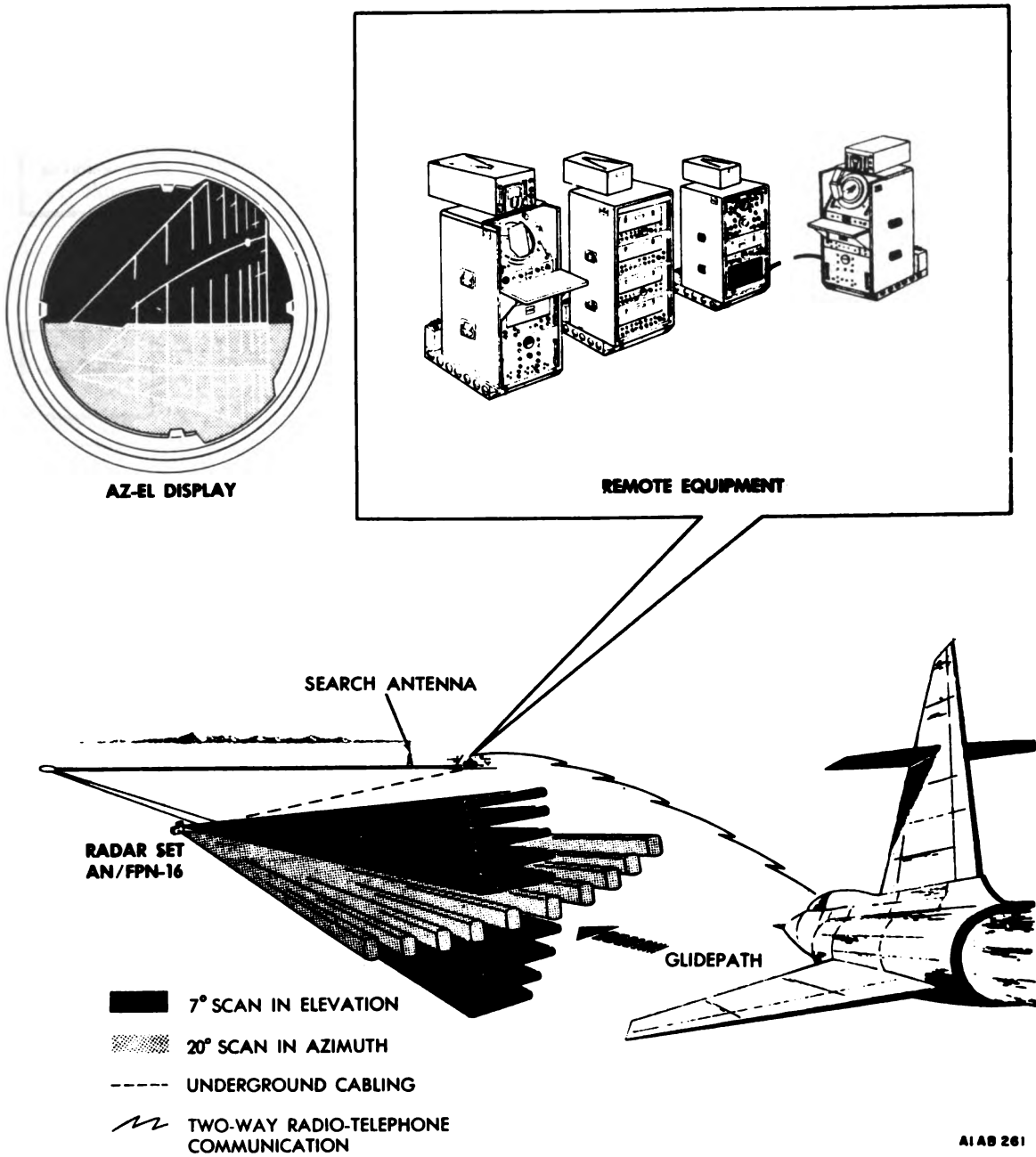
Two special features of PAR are the moving target indication (MTI) receiving system (previously described in chapter 3) and the novel indicating system. The indicating system utilizes a unique dual expanded plan position indicator (EPI) which, in effect, divides the display on the cathode-ray tube (CRT) into two sections. The upper section displays signals received by the elevation antenna, while the lower section displays the signals received by the azimuth antenna. This unique display is referred to as an Az-El indicator.

The basic block diagram for the PAR is similar to that presented in figure 3-13. A PAR signal flow diagram is shown in figure 4-2, and a brief description of operation follows.

The system MTI triggers (A and B) are generated in the system timing unit (STU) in the canceller. These triggers are sent to the synchronizer where they are routed to all components requiring synchronization. B1 triggers from the synchronizer are used to start generation of the RF pulses in the trans-mod. These RF pulses enter the duplexer in the converter and continue through the waveguide transmission line to the RF switch blades. The RF switch blades alternately apply the transmitted RF pulses to the azimuth and elevation antennas. These antennas radiate the pulses in narrow wedgeshaped beams. The azimuth antenna scans its beam back and forth over a 20-degree sector and the elevation antenna scans its beam up and down over a 7-degree area. Coupled to each antenna is a data take-off circuit or angle voltage generator which delivers a voltage to the indicating system that represents the instantaneous scan angle of the radiated beams.

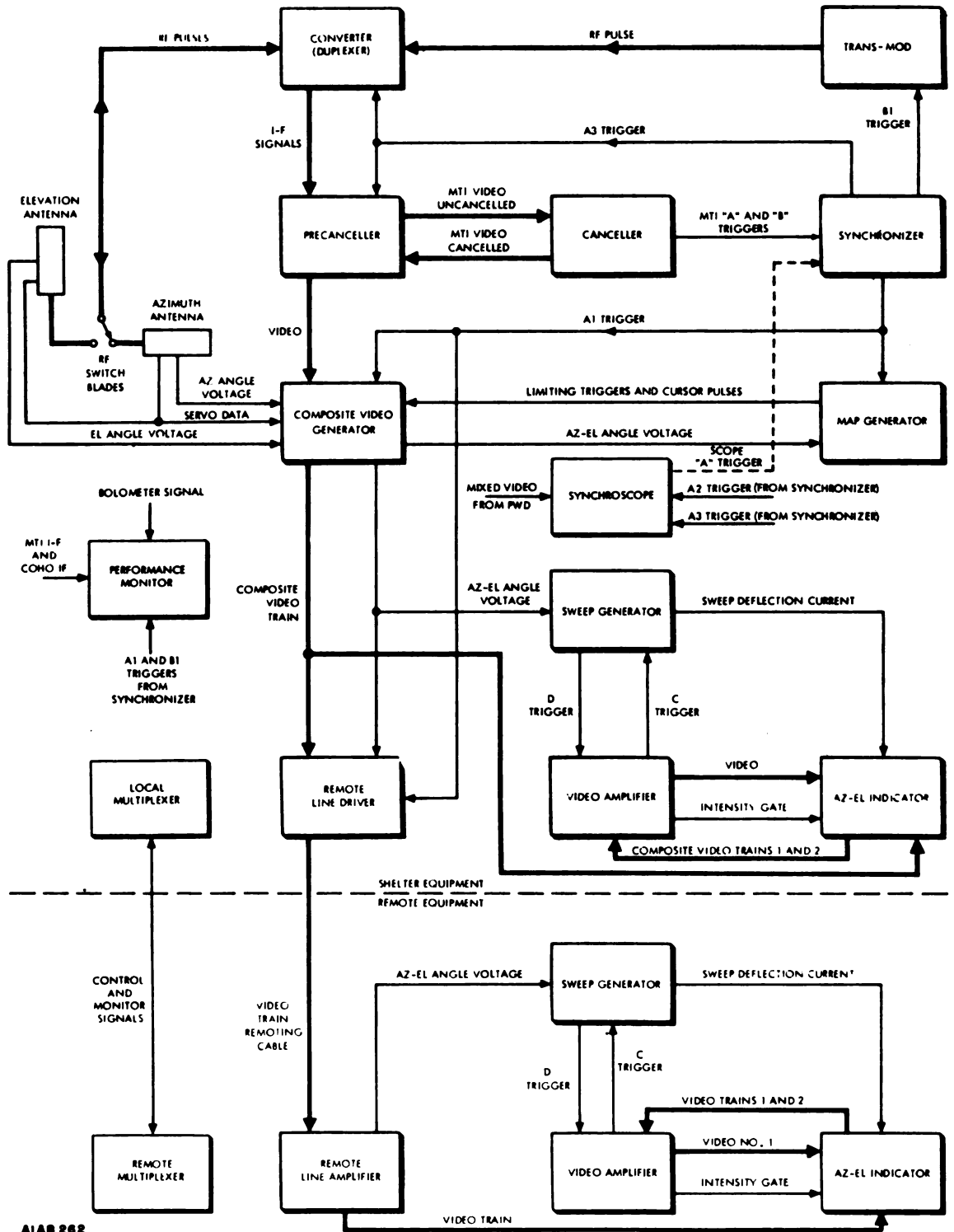
The return signals are received by antennas, routed through the RF switch, and then sent to the converter. The converter mixes the received RF signals with RF from the local oscillator. The resulting IF signal is amplified and routed to normal and MTI components in the precanceller. The MTI circuits in the precanceller convert IF signals into phase-detected video. The amplitude and polarity of the phase-detected video changes with target movement with successive interpulse periods. This sensitive phase detection causes the canceller to be extremely responsive to target motion, reducing the attenuation of slow-moving targets. The MTI video output of the canceller is routed back to the video switch. It can be mixed with the normal video by clutter-gating which displays MTI video where clutter exists on normal video. The MTI video can also be displayed by range-gating which allows MTI video to be present for a preset range. The video output of the video switch is routed to the composite video generator where it is mixed with cursors, limit triggers, and rangemarks. This composite video signal is routed to the Az-El indicator assemblies.

The Az-El indicator assemblies, which include the sweep generator and the video amplifier, depend on the map generator and the composite video generator to supply the required information. In the Az-El indicator, the composite video train is routed to the remote line driver which sends the basic signal information to the remote equipment installation. The remote line driver receives a composite video train from the composite video generator and the angle voltage from the antenna system. The angle voltage information is converted into triggers. These triggers are mixed with the video train, and the resulting remote video train containing all of the basic signal information is routed to the remote installation through a single coaxial cable.



AIAB 261

Figure 4 - 1. Radar Set AN/FPN-16 Functions



AIAB 262

Figure 4 - 2. Radar System Basic Signal Flow Diagram

The remote line amplifier, located at the remote installation, amplifies and extracts the information contained in the remote video train. The information is separated, converted into the proper form, and sent to the remote Az-El indicator assemblies. The remote Az-El indicator assemblies receive the same information from the remote line amplifier that the shelter indicator receives from the shelter systems. The operation of the remote sweep generator and video amplifier of the Az-El indicator is identical to that of the shelter Az-El components.

4.2.2 System Configuration

The system configuration of PAR equipment has several variations. One design was described under GCA search and height finders equipment (paragraph 3.2); that system has antennas which physically scan in elevation and azimuth. A second system which electronically scans is herein described.

Figure 4-3 illustrates a complete PAR set, including the shelter equipment (items 1 thru 33) which is located near the air station active runway, and the remoted equipment (items 34 thru 41). Functionally, this PAR system consists of the following subsystems:

Antenna

Transmitter

Receiving

Remoting

Indicating

Power Supply

Performance Monitoring

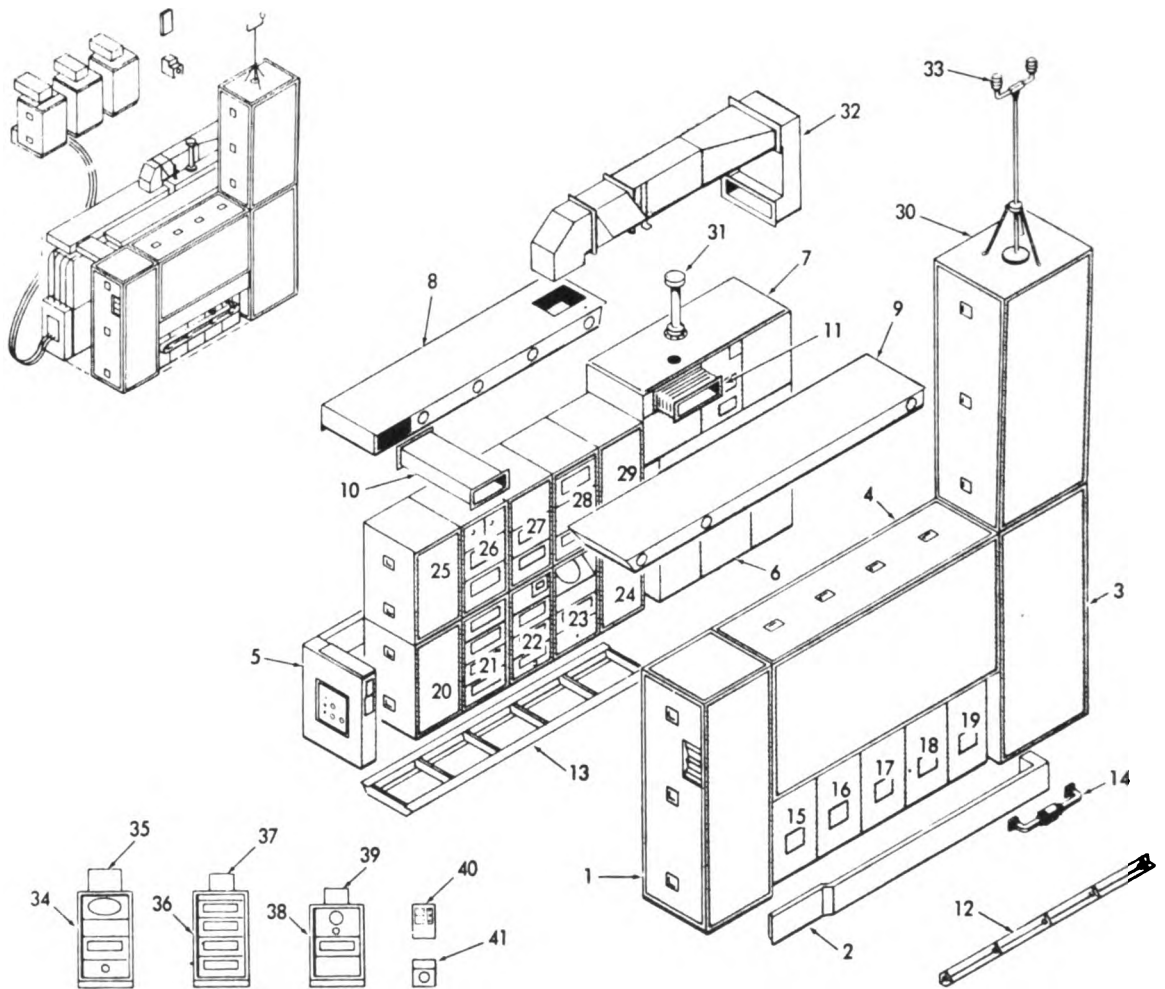
Each of these subsystems is composed of several components and a brief description of these components and their function in the overall system follows.

The antenna subsystem contains six major components:

- o Azimuth and Elevation Antennas - Radiate pulsed RF energy from the transmitter and receives RF echoes. Scans in their respective plane by means of a variable-width waveguide.
- o Angle Voltage Generator and Servo Data Potentiometers - Develops voltage proportional to scan angles for the purpose of indicating and recording.
- o RF Switch - Directs transmitter energy to azimuth and elevation antennas alternately.
- o Antenna Servos - Provide a means of operator control over the azimuth position of the elevation scan and the elevation position of the azimuth scan.

The transmitter subsystem develops pulses of RF energy for transmission to the azimuth and elevation antennas. The major components of this subsystem are:

- o System Timing Unit - Generates triggers for the transmitting system and controls timing sequence of all system functions.
- o Trigger Shaper - Converts STU triggers into narrow, high amplitude pulses for the modulator circuits.
- o Modulator - Consists of a pulse forming network and a thyratron discharge tube which provides a high voltage pulse of the proper amplitude, duration, and shape to the transmitter.



- | | |
|---|---|
| <ul style="list-style-type: none"> 1. POWER DISTRIBUTION ASSEMBLY 3. LOWER ELEVATION ANTENNA ASSEMBLY 4. AZIMUTH ANTENNA ASSEMBLY 15. SYNCHRONIZER ASSEMBLY 16. TEST ASSEMBLY 17. SYSTEM TEST ASSEMBLY 18. TRANSMITTER ASSEMBLY 19. MTI ASSEMBLY 20. STORAGE AND TEST ASSEMBLY NO. 1 21. SPARE UNIT STORAGE NO. 2 22. COMPOSITE VIDEO ASSEMBLY 23. AZ-EL INDICATOR ASSEMBLY 24. TRANSMITTER ASSEMBLY (SPARE) | <ul style="list-style-type: none"> 25. STORAGE AND TEST ASSEMBLY NO. 2 26. TRANSMITTER REMOTING ASSEMBLY 27. INDICATOR SWITCHING ASSEMBLY 28. SPARE UNIT STORAGE NO. 3 29. STORAGE AND TEST ASSEMBLY NO. 3 30. UPPER ELEVATION ANTENNA ASSEMBLY 33. OBSTRUCTION LIGHT ASSEMBLY 34. AZ-EL INDICATOR ASSEMBLY (REMOTE) 35. TEST AND VENTILATION ADAPTER 36. INDICATOR REMOTING ASSEMBLY 38. SYSTEM TEST ASSEMBLY 40. VOLTAGE REGULATOR CONTROL PANEL 41. VOLTAGE REGULATOR |
|---|---|

NO. 2, 5-14, 31, 32, 37 AND 39 ARE MECHANICAL SUPPORTS OR DUCTS

AI AB 263

Figure 4 - 3. Radar Set AN/FPN-16, Equipment Configuration

- o Radar Transmitter - Has two components, the magnetron transformer and the magnetron. The magnetron is energized by the high voltage negative pulse from the magnetron transformer which is a result of the discharge of the pulse forming network. The magnetron oscillates at a frequency of 9080 MHz.

- o AFC Tuning Assembly - Tunes the transmitter frequency to maintain the proper IF frequency of 30 MHz thus eliminating receiver detuning due to transmitter frequency drift.

The receiver subsystem converts the returning echo signals into video signals with the aid of three major components.

- o Converter - Amplifies and converts RF energy into IF. Provides local oscillator signal that is stabilized to prevent drift and consequent deterioration of MTI system performance.

- o Precanceller - Amplifies and converts IF energy into unipolar normal video and bipolar MTI video. Determines polarity and amplitude of MTI video to permit detection of moving targets by the canceller. Mixes normal and cancelled MTI video.

- o Cancellor - Alternates video signals from stationary targets.

Remoting video signals and controlling circuitry at both the shelter and remote sites is the function of the remoting subsystem. The three major components of this subsystem are:

- o Remote Line Driver - Transmits the signal from the composite video generator over a coaxial cable to the remote installation.

- o Remote Line Amplifier - Modifies the remote composite video signal from the remote line driver and applies the required information to the remote Az-El indicator.

- o Local and Remote Multiplexer - Switches control of various functions between the shelter and remote installations.

The indicating subsystem provides a means of determining visually the distance bearing and elevation angle of a target with respect to the location of the radar set and a predetermined geographical point on the runway. The major components of this subsystem are as follows:

- o Map Generator - Produces limiting triggers used to form the outline of the Az-El display and cursor pulses which portray the glidepath, courseline, and maximum permissible downward deviation from glidepath on the Az-El display.

- o Composite Video Generator - Mixes map generator information and internally generated range marks with video signals which are routed to the Az-El indicator.

- o Video Amplifier - Amplifies the composite video signals applied to the Az-El indicator.

- o Az-El Indicator - Top portion of display presents information on range and height of targets within the area scanned by the elevation antenna; lower portion of display presents information on range and height of targets within the area scanned by the elevation antenna; lower portion of display presents information on range and azimuth bearing of targets within area scanned by azimuth antenna.

- o Sweep Generator - Produces time-base (horizontal) and expansion (vertical) sweep deflection currents which are applied to Az-El indicator.

The PAR equipment in the main shelter requires three-phase, 4-wire, 60 Hz, 120/208 volt power from an external source. The remote installation on three-phase power or single phase 117 volt power. The power supply subsystem consists of four major components.

- o Voltage Regulator - There are three motor-driven induction type voltage regulators (one for each phase of primary power) which maintain the regulated AC voltage at 117 + 1 V. A single voltage regulator is supplied for the equipment at the remote installation when single phase power is used at that location.

- o Power Distribution Panel - All AC power, regulated and unregulated, and all DC power supplied to the shelter is controlled by circuit breaker type switches on the power distribution panel.

- o 28 VDC Power Supply - A 28 VDC power supply, powered by the regulated AC source, provides DC voltage for operating the antenna servo motors as well as various control circuits and relays in the shelter equipment.

- o Regulated Power Supplies - Electronically regulated rectifier type power supplies are included in the radar set to provide stable operating voltages for the various components. Each of these power supplies is protected by a bias interlock circuit which removes AC power from the positive voltage supplies if the negative bias voltage fails.

The performance monitor, a part of the shelter equipment, consists of three basic circuits: a power monitor, a relative tuning monitor, and a noise figure monitor. Each of these circuits has a meter and three indicating lights on the front panel of the performance monitor which indicate the power, relative tuning, and noise figure as being good, poor, or unsatisfactory. The condition of each characteristic is routed to the remote installation where similar lights indicate equipment performance.

4.2.3 System Application

As part of a complete ATC facility, the PAR equipment is used to provide the final approach controller a visual indication of an approaching aircraft's relative altitude, range, and flight course information. With the shelter equipment properly installed adjacent to the active runway and the remotod equipment located in the IFR room of the Naval Air Station, the controller is able to track and guide approaching aircraft down the glidepath and along the courseline to final touchdown on the runway.

On Naval Air Stations the landing of aircraft requires coordinated team work. The controller, with the aid of his PAR equipment, and the pilot in an approaching aircraft work as a team to land the plane. As with any team, practice of the routines will insure that the team works smoothly. Because pilots move from one field to another, it is important that landing procedures remain similar. Another important factor of any PAR run is the trust of the pilot. In an effort to keep the pilot's confidence throughout the approach, the controller's voice procedure, tone, and rate of speaking should be firm, clear, and steady. This voice is the pilot's guidance and all data should be clear and to the point.

The final approach sequence begins at the point when the final controller is notified by the search radar approach control operator that an aircraft is on final approach for a precision landing. At this time the aircraft is ususally 6-10 NMI from touchdown. Throughout the final approach, the aircraft is tracked by means of the antenna servo control which servos the azimuth antenna up and down and the elevation antenna right and left. When an aircraft enters the range of the indicator display, the echo is sighted in two places near the right-hand edge of the display, in the elevation (upper) sector, and in the azimuth (lower) sector. Throughout this operation the pilot of the aircraft is advised by means of two-way radio-telephone communication of his range to touchdown and his position on the glidepath and courseline. If required, the pilot is directed to correct his approach as necessary to keep the aircraft on optimum approach paths.

Two important facts about the PAR display of which the controller must be aware are:

- o The elevation portion of the Az-El map is expanded to approximately eight times the actual elevation scan. The indicated angle of glide is therefore approximately eight times as steep as the actual glidepath of the aircraft. Any deviation from the glidepath by the aircraft will be proportionately magnified on the display.

- o The azimuth portion of the Az-El map is extended to approximately triple the actual width of the azimuth scan. Any deviation from the runway courseline by the aircraft will be proportionately magnified on the display.

Therefore, the controller may readily determine if the flight path of the aircraft deviates in either azimuth or elevation so as to make a safe approach questionable. If so, the pilot is ordered to execute a missed-approach procedure. The limits set for a wave-off are 1/2 degree or more deviation from the published elevation glidepath, and/or a rapid or radical deviation from the courseline within a mile of touchdown.

4.3 TRANSMITTED RADIO NAVIGATION SYSTEM (AN/TRN-28)

4.3.1 System Principles

The Aircraft Approach Control System is an all weather aircraft approach guidance system which consists of ground or shipboard and airborne equipment. The receiving-decoding group is the airborne portion of the AACS. This equipment receives coded microwave transmissions from ground or carrier based azimuth and elevation transmitters and decodes these signals for display on a crosspointer indicator in the aircraft cockpit (see figure 4-4). A centerline display of both elevation and azimuth on the crosspointer indicator depicts the flight path the pilot must follow to line up accurately with the airport runway or carrier deck. By consecutively scanning through azimuth and elevation, the system provides continuous measurement of the lateral and vertical aircraft deviations from the optimum approach line in space.

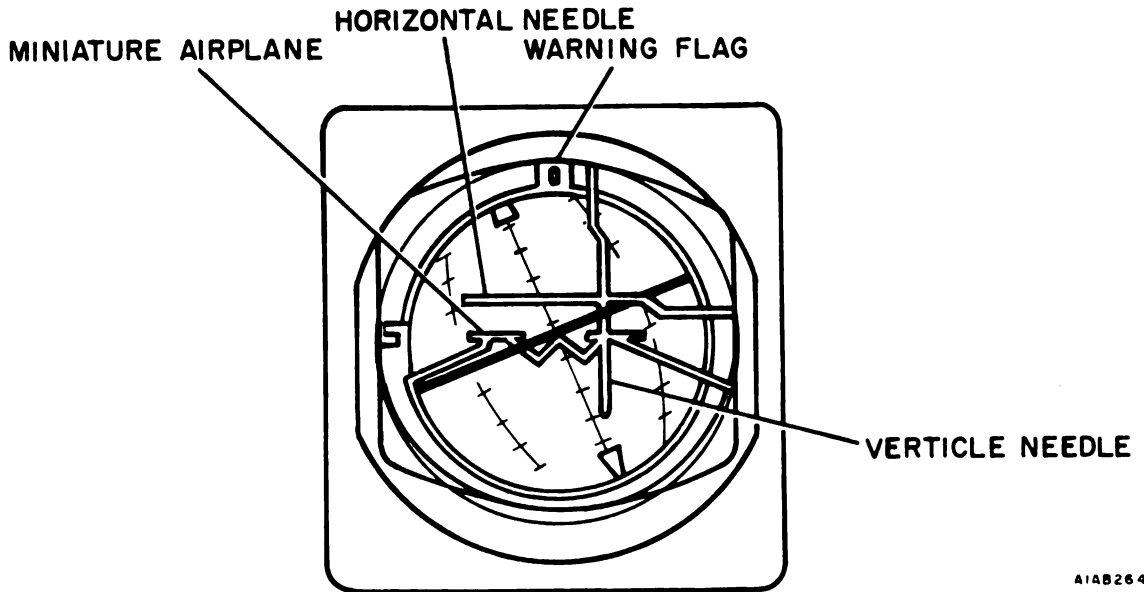
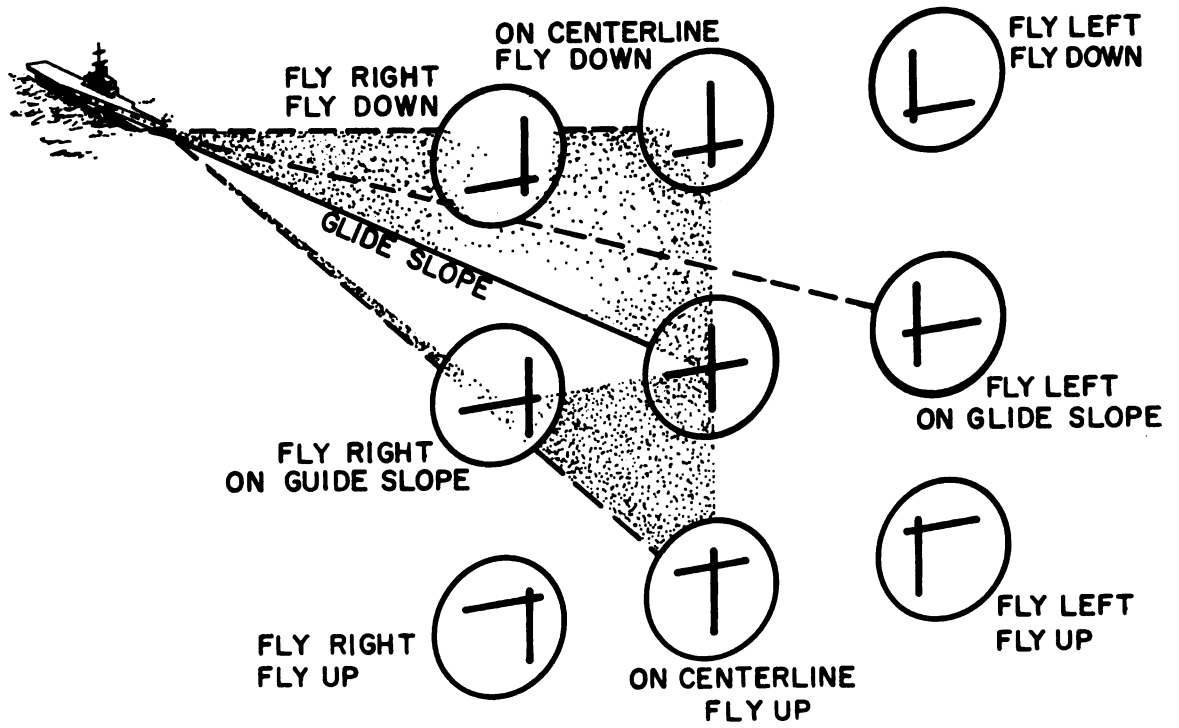
The AACS uses only ground-to-air transmissions and does not depend on radar principles. It operates at microwave frequencies (Ku-band, 15.4 to 15.7 GHz) and generates relatively narrow beams (2 degrees in azimuth and 1.3 degrees in elevation) utilizing antennas with 2-foot (azimuth) and 3-foot (elevation) apertures.

System coverage is obtained by consecutively scanning two narrow fan-shaped beams through the required coverage volume in azimuth and elevation (see figure 4-5). The beams are narrow so that the aircraft receives signals only when each transmitting antenna is pointing directly at the aircraft. Modulation on each beam continuously represents its pointing angle which is decoded by the airborne equipment. The angle coverage of the transmitting beam is 40 degrees in azimuth (20 degrees each side of the centerline) and 20 degrees in elevation (from the horizon to 20 degrees above the horizon).

The transmitters transmit a complete series of elevation and azimuth signals five times per second using sector scanners operating in simple harmonic motion. Since the mechanical scan rate is 2.5 Hz (period 400 ms), the 5-Hz signal rate is achieved by transmitting during a portion of the left-to-right azimuth scanning time and transmitting again during a portion of right-to-left scanning time. A similar, but interlaced two-way scan, is used for elevation. The azimuth and elevation transmitters share time on the same frequency; the on and off periods are governed by the synchronized scans of the azimuth and elevation antennas.

Each transmission consists of a series of paired pulses which is encoded with either azimuth or elevation identification and with angle information. The time between the two pulses in each pair identifies the data as being from the elevation or azimuth transmitter. The time between pulse pairs represents a value of angle data, as shown in figure 4-6 for the elevation transmitter.

Station identification data is multiplexed with the azimuth transmissions and obstacle clearance data with the elevation transmissions.



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Figure 4 - 4. Crosspointer Indicator

AN/SPN-41 SCAN COVERAGE

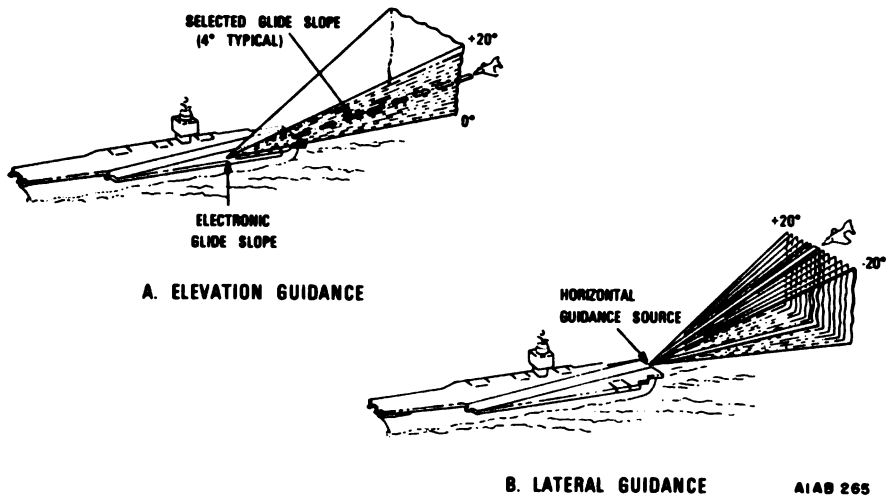


Figure 4 - 5. AN/SPN-41 Scan Coverage

VERTICAL SCANNING BEAM

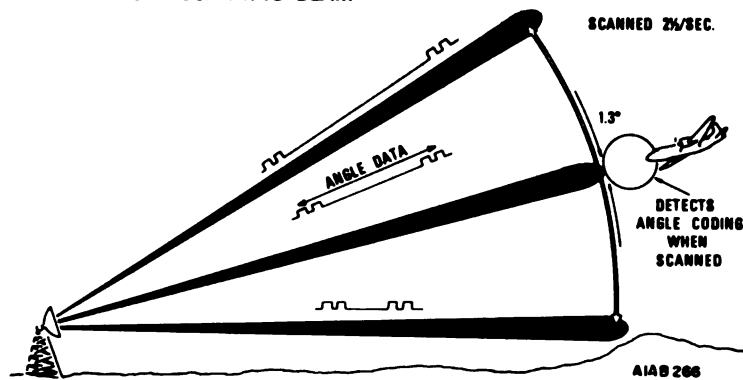


Figure 4 - 6. Vertical Scanning Beam Angle Data Signal Waveforms

4.3.2 System Configuration

The system may be used either on shore as the Transmitted Radio Navigation System (AN/TRN-28) or aboard an aircraft carrier as the Aircraft Approach Control Set (AN/SPN-41). Both equipments are similar and perform the same functions and, are configured to operate in their primary environment. The simplified functional block diagram figure 4-7, reflects the shipboard configuration. Since an aircraft carrier is constantly in motion there exists the need to provide stabilization for the system. This is accomplished by the addition of units such as platform stabilizers, a selector control unit, programable oscilloscope, and for the azimuth antenna, a yaw smoothing computer. These components are not required for the AN/TRN-28 system since it operates from a fixed point on a Naval Air Station and therefore does not require any stabilization. Figure 4-8 is a block diagram of the system with all stabilization units removed and represents the AN/TRN-28.

The two transmitting groups and the two cabinets are similar in many respects. However, they differ in detail as noted.

The elevation transmitting group transmits the microwave beam carrying vertical-angle identification. Because the antenna is the most prominent feature of the unit, the entire group is commonly called the elevation antenna. The azimuth transmitting group transmits the microwave beam carrying azimuth identification.

a. The elevation and azimuth units each contain an antenna scan and synchronization system, a photoelectric angle-data pulse pickoff for the elevation or azimuth encoder, a pulse modulator, magnetron transmitter, and a monitor to check the signal for proper operation. The radiating portion of the antenna is an end-fed slotted waveguide supported by a torsion bar.

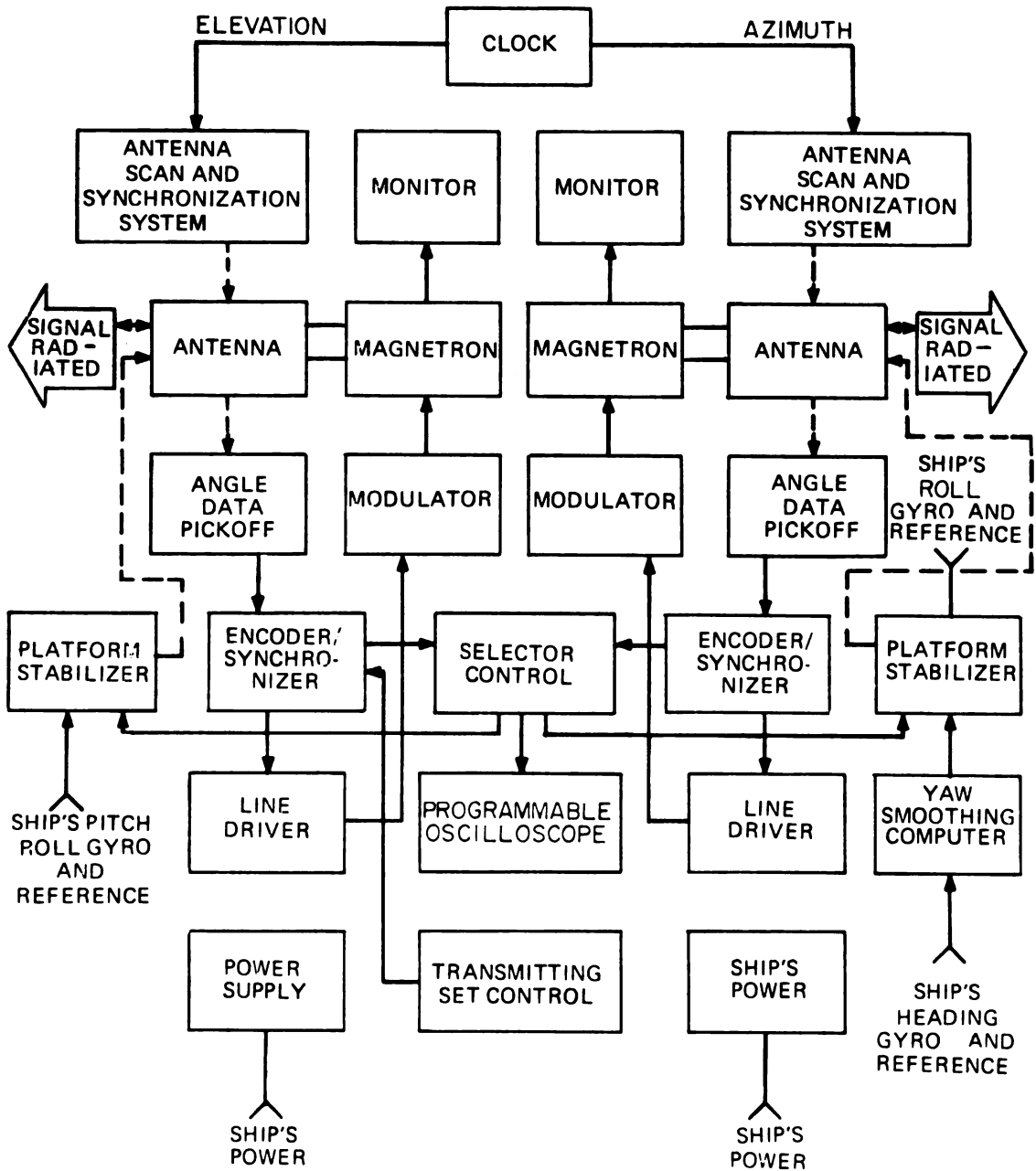
b. The elevation encoder synchronizer contains the 3-1/3 Hz clock from which is derived the signal that normally maintains the scan of the elevation and azimuth antennas in synchronization. The azimuth encoder/synchronizer contains the 3-1/3 clock from which is derived the signal that maintains the scan of the elevation and azimuth antennas in synchronism when control has been transferred from the elevation master timer. For checking encoder operation with the transmitters and antennas turned off, a built-in test-generator oscillator simulates the antenna angle-data pickoff pulses while a decoder provides test-point output for oscilloscope observation.

c. The elevation and azimuth power supplies are identical and each operates from 115-volt, 400-Hz, single-phase power, with outputs of +28, -28, +6 and -12 volts DC. Outputs are measured by a voltmeter and ammeter on the front panel controlled by a six-position selector switch.

d. The elevation and azimuth control/monitors control transmitting-set power and synchronization voltages panel circuit breakers, and switches turn main power on and off to the elevation and azimuth cabinets and antenna, start the encoder and modulator, start the antenna scanning, and turn on the transmitter. Another switch provides for selecting normal operation or testing of the angle encoding circuits by reference to an oscillator simulating antenna-angle signals. Another switch permits selection of local or remote operation by the transmitting set control.

o Secondary operation of the elevation control/monitor is the ability with proper switch settings on the azimuth-cabinet control/monitor, to control the azimuth transmission in addition to elevation, and to transfer synchronization control of antenna scan to the azimuth clock.

o Secondary operation of the azimuth control/monitor is the ability to turn antenna scan synchronization over to the elevation cabinet clock, and to turn on-off control over to the elevation control/monitor.



CONNECTIONS
 MECHANICAL - - - - ->
 ELECTRICAL - - - - ->

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Figure 4 - 7. Simplified Functional Block Diagram (AN/SPN-41)

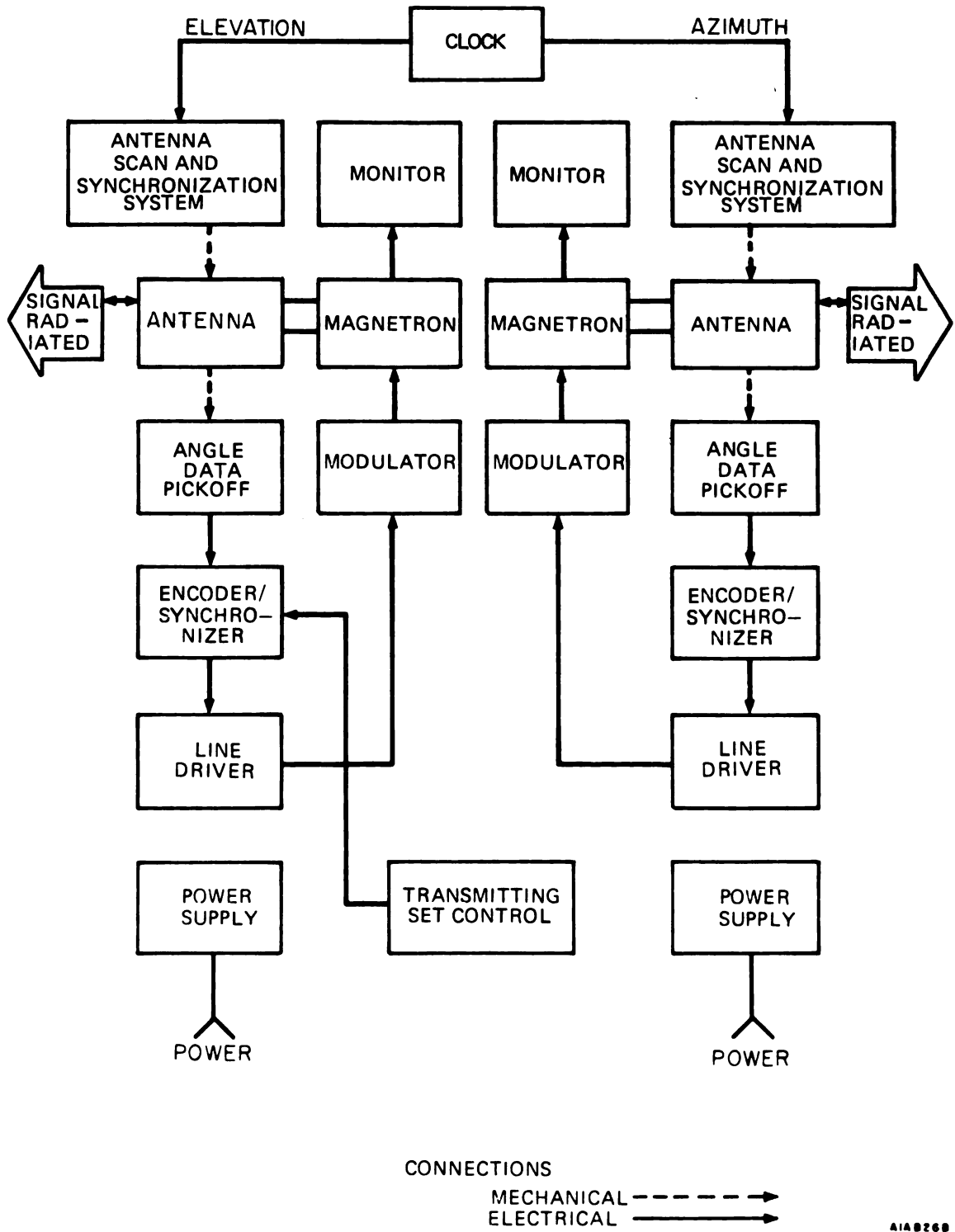


Figure 4 - 8. Simplified Functional Block Diagram (AN/TRN-28)

- o Lamp indicators show the operation or nonoperation of the different unit circuits under control.

- o The antenna scan circuit is interlocked through a latching power-shutoff relay to prevent the accidental transmission of signals if the antenna is not synchronized properly.

The transmitting set control provides turn-on, monitor, and turn-off functions of the aircraft approach control transmitting set at a location remote from the equipment cabinets. It permits an operator at the RATCF to apply power to the entire transmitting set, to start the antennas. It also shows that the transmitters are operating.

4.3.3 System Application

The AN/TRN-28 is the ground subsystem of the Navy aircraft approach control system which is used to provide cockpit indications to the pilot showing his relative position with respect to the runway glideslope and courseline. This is accomplished in the aircraft by a radar receiver and pulse decoder which provide signals to a set of crosspointers on an indicator as shown in figure 4-4. The crosspointers move to positions relative to that of the aircraft with respect to the proper courseline and provide the pilot with an indication of how he must maneuver his aircraft to achieve the proper angle of descent and alignment with the runway for a good landing. Properly aligned crosspointers will bring the plane down at a predetermined glideslope angle on the runway centerline under any weather conditions.

The AACS (AN/TRN-28) is a totally independent mode II landing system capable of controlling an aircraft to final approach. It is also used as a feeder system for the (mode I) Automatic Carrier Landing System. In addition it provides a monitor for the pilot to determine the accuracy of the automatic control system.

4.4 AIRCRAFT CARRIER LANDING SYSTEM TRAINER AN/SPN-42-T1

4.4.1 System Principles

The Landing Control Center Trainer (LCCT), AN/SPN-42-T1 operating in conjunction with other units of the Navy All-Weather Return to Base System and a suitably equipped aircraft, may be considered a part of a closed-loop servo system (foldout 4-1). Two control channels, A and B, are provided. Each is capable of controlling the approach and landing sequence of one aircraft at a rate of one landing per minute. These two channels, one of which is shown in foldout 4-1, are identical but independent, providing a system landing rate of two aircraft per minute. For descriptive purposes, only one channel will be discussed. However, some items of equipment are shared by the two channels and will be noted.

Major units of the landing system are grouped functionally into subsystems. These units comprise the radar, buffer, and computer subsystems. Other major units provide display and manual control facilities and also record the landing operations.

The Landing Control Central (LCC) AN/SPN-42 is designed for integrated operation with the Navy Tactical Data System (NTDA). However, it is capable of performing its mission of automatically landing aircraft with any suitable communication data link. The two configurations, referred to as integrated system operation (foldout 4-2) and non-integrated system operation (foldout 4-3) will be described separately.

The equipment provides four modes of landing operation: automatic (mode I), automatic 200 feet (mode IA), semiautomatic (mode II), and manual or GCA-type talkdown (mode III). In the automatic mode, the landing aircraft is controlled by its autopilot in response to LCC command signals, without pilot assistance, except for throttle control. The mode IA operation is an automatic approach to an altitude of 200 feet, at a range of one-half mile, at which point the pilot breaks the automatic control and lands the aircraft manually. For

semi-automatic landings, the flight path errors determined by LCC are displayed in the landing aircraft cockpit and the pilot maneuvers his aircraft to reduce the displayed errors to zero. During manual or GCA-type operation, flight path correction commands are issued verbally by the equipment operator and the pilot is talked down to GCA minimums. The aircraft pilot selects the mode of operation and may, at his discretion, terminate the landing sequence at any time.

Aircraft position data are compared in the computer with the optimum glideslope for the particular aircraft and the landing area centerline extension to determine flight path error. Correction commands developed from these error signals are then transmitted to the landing aircraft to correct or maintain its approach path.

The LCC provides preset landing programs for up to ten different aircraft types. These programs are based on the flight characteristics of the aircraft. Glideslope and corner reflector height program data may be manually set into the equipment by the operator to provide landing capabilities for additional types of aircraft.

Functionally, Landing Control Central Trainer AN/SPN-42-T1 provides the same landing capabilities and modes of operation as AN/SPN-42 when operating with any suitable data link. In addition, the trainer provides all equipment necessary for voice communications between the operators and the pilot or air traffic control personnel during landing operations.

4.4.2 System Configuration

The aircraft carrier landing system trainer consists of an AN/SPN-42 LCC housed in a pair of semitrailers which are equipped as follows:

The Radar and Operations Semitrailers V-263 and V-262/MPN-T1, figure 4-9, are van-type bodies incorporating all features necessary for long distance highway travel or short distance movement across airfield terrains. The two-compartment radar semitrailer provides a rigid, horizontal base for the two automatic tracking, precision radar antennas, located in the rear compartment, and an air conditioned environment for the electronic equipment located in the forward compartment. The air conditioned, three-compartment operations semitrailer provides an enclosure for two aircraft landing control consoles and the operating personnel in the forward compartment and electronic equipment in the center and aft compartments.

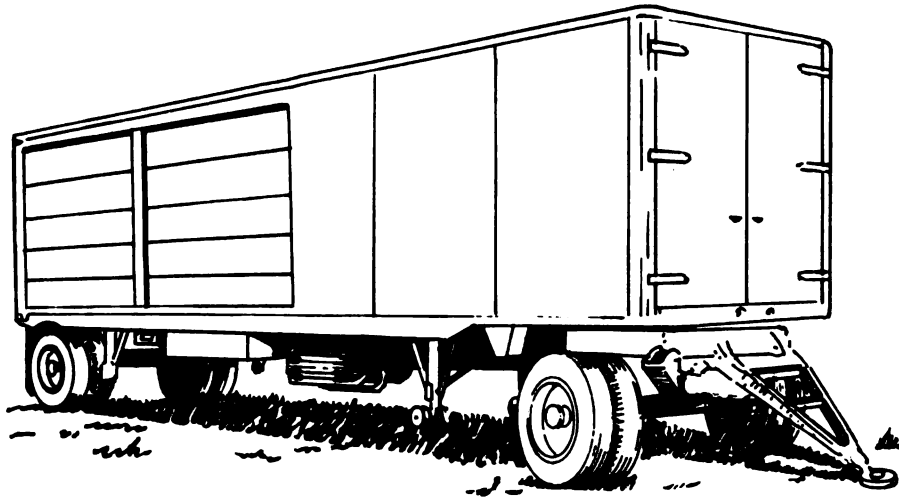
The radar semitrailer, (figure 4-10) contains rack-mounted electronic equipment and houses the two floor-mounted radar antenna units.

The system A and B units installed in the forward compartment are the Radar Transmitter Groups OT3/SPN-42, Control Monitor Groups OK-18/SPN-42, Waveguide Pressurization Units HD-514/SPN-10, Motor Generators PU-491, and Motor Generator Controllers C-3414/USQ-20. The only equipments located in the aft compartment are the Antenna-Receiver Groups OE-29/SPN-42.

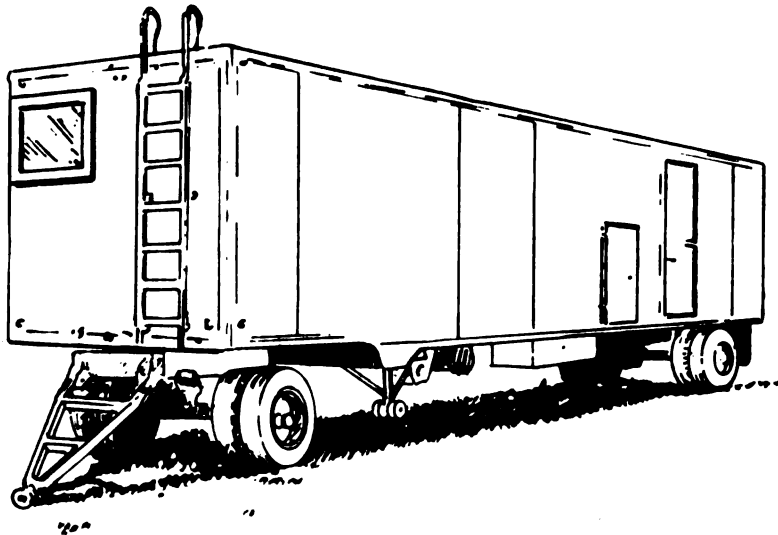
The operations semitrailer (figure 4-11) is divided into three compartments. Each compartment is separated by partitions, and is cooled or heated as required by the air conditioner mounted at the rear of the semitrailer. Electronic equipment in the three compartments is mounted along the sidewalls. Racks and consoles containing electronic equipment are protected during transportation by shock-mount bases and wall-supported stabilizers.

The forward compartment or operating compartment contains equipment used in the operation of the landing control system trainer. Auxiliary equipment in the form of chairs, a clock, first aid kit, and 117-volt power outlets is furnished for the operator's convenience.

The operating equipment includes the following electronic units and consoles: Aircraft Landing Control Consoles OJ-21/SPN-42; Signal Data Recorder RO-319/SPN-42; Aircraft Landing Control Indicator ID-1417/SPN-42, the control indicator digital data; the digital data indicator panels; and the wind direction and speed indicator.



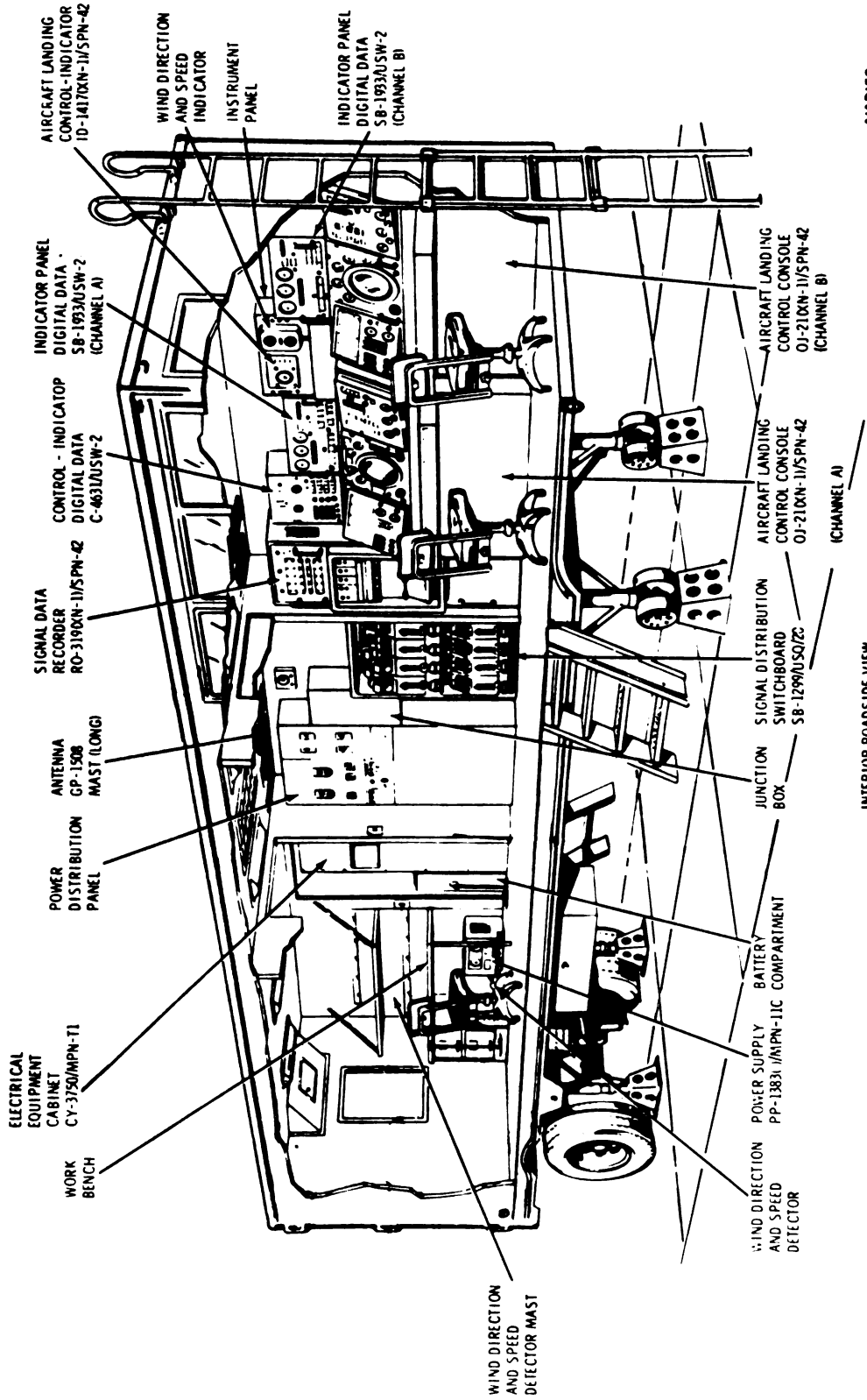
RADAR SEMITRAILER V-263/MPN-T1 WITH
SEMITRAILER CONVERTING DOLLY



OPERATIONS SEMITRAILER V-262/MPN-T1 WITH
SEMITRAILER CONVERTING DOLLY

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Figure 4 - 9. Landing Control Central Trainer AN/SPN-42-T1



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INTERIOR ROADSIDE VIEW

Figure 4 - 10. Radar Semitrailer V-263/MPN-T1, Interior (Sheet 1 of 2)

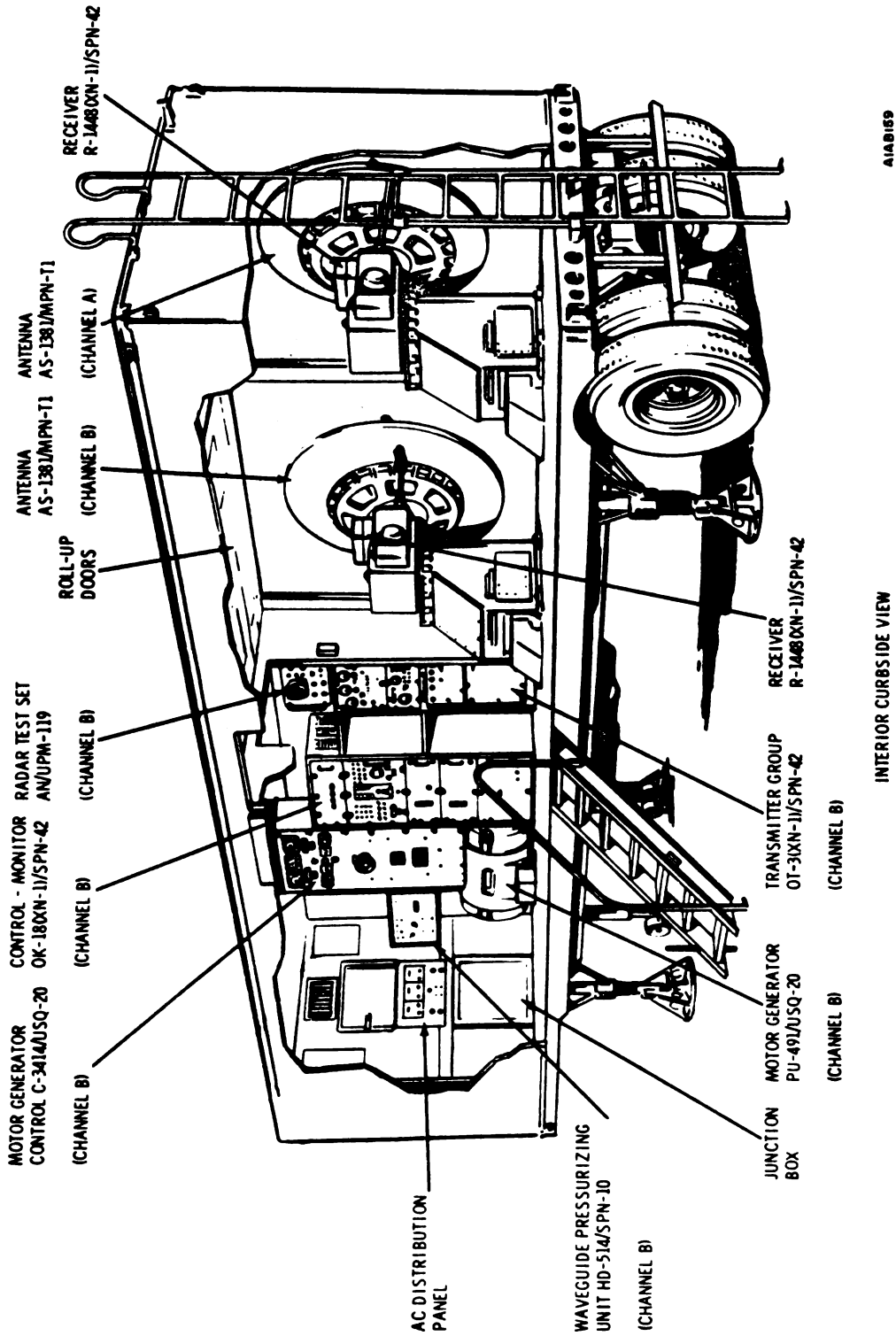


Figure 4 - 10. Radar Semitrailer V-263/MPN-T1, Interior (Sheet 2 of 2)

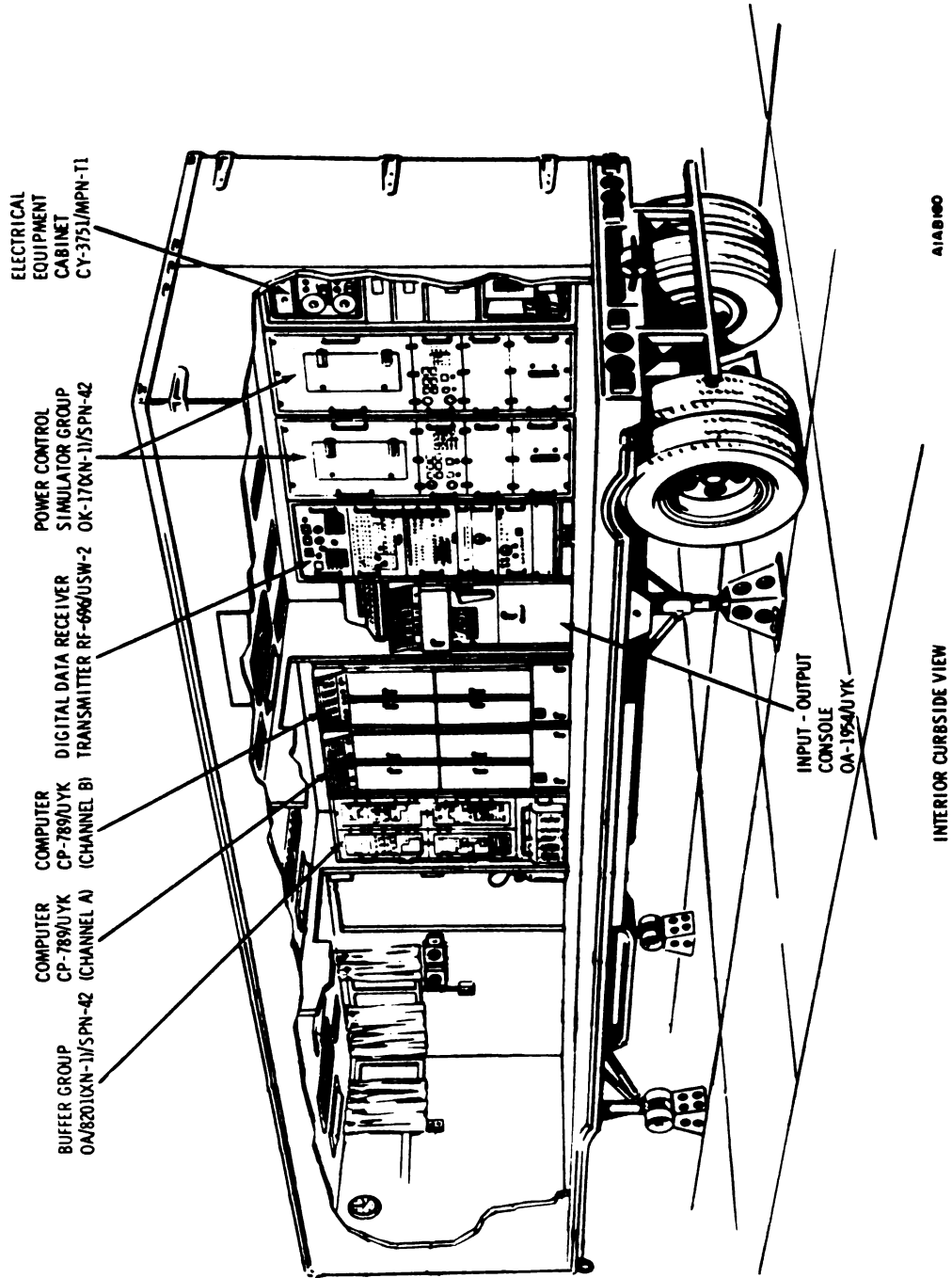


Figure 4 - 11. Operations Semitrailer V-262/MPN-T1, Interior (Sheet 1 of 2)

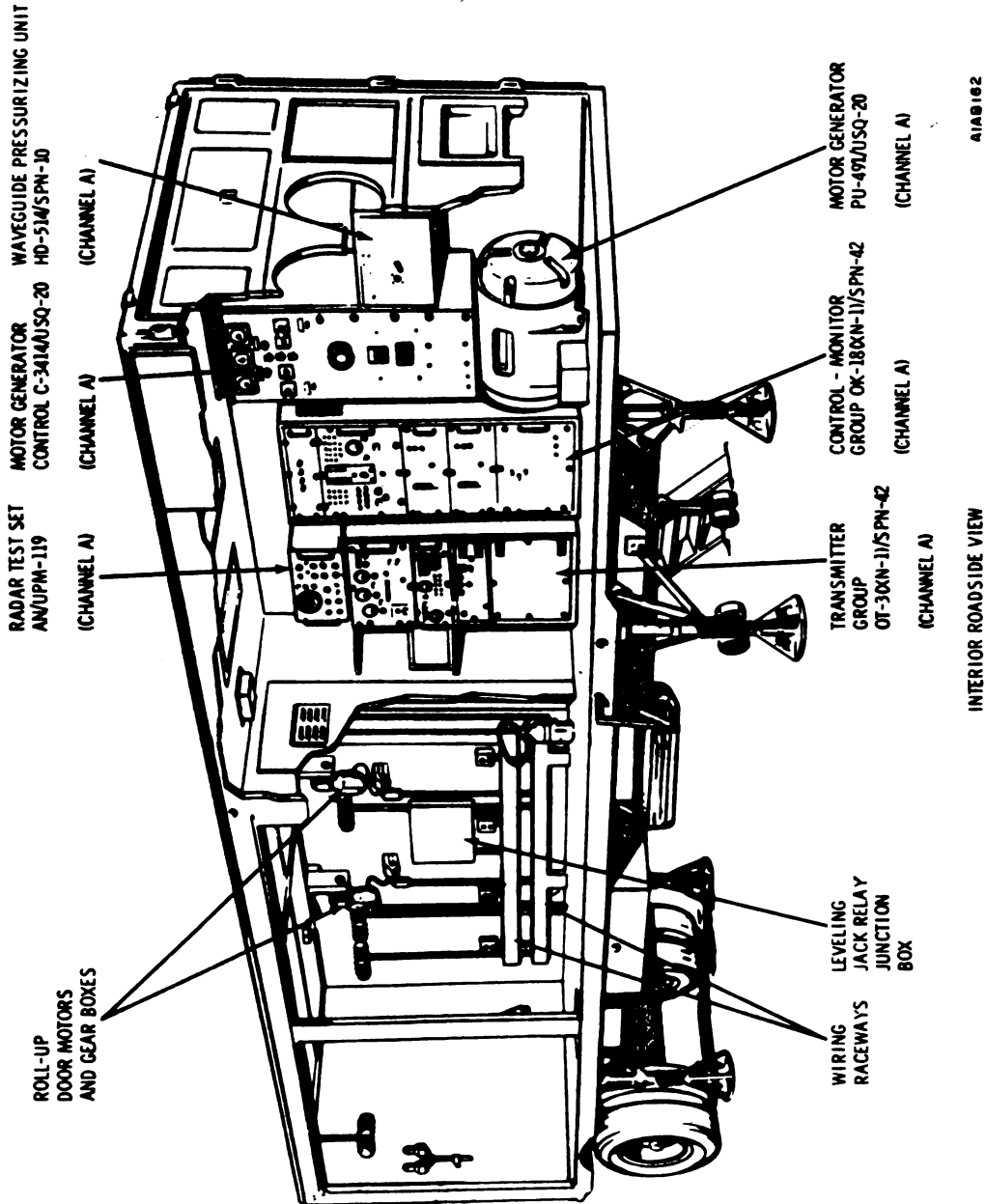


Figure 4 - 11. Operations Semitrailer V-262/MPN-T1, Interior (Sheet 2 of 2)

The center compartment contains the two Computers CP-789/UYK, Buffer Group OA/8201/SPN-42, Signal Distribution Switchboard SB-1299/USQ/20, and a power distribution panel and junction box.

The aft compartment contains the Input-Output Console OA-1954/UYK, Power Control Simulator Group OK-17/SPN-42, the digital data receiver transmitter, Electrical Equipment Cabinet CY-3751/MPN-T1, Electrical Equipment Cabinet CY-3750/MPN-T1, Power Supply PP-1383()/MPN-11C, the wind speed and direction detector, and a battery compartment.

Accurate aircraft position information required in the operation of Landing Control Center Trainer AN/SPN-42-T1 is supplied by the radar subsystem. Operating in the K-band, the subsystem utilizes a narrow-beam, high-definition, automatic tracking radar and antenna to locate and continuously track the assigned aircraft. Radar slant range, and antenna azimuth and elevation angle information is developed and used by the computer subsystem to compute the aircraft position in deck coordinates.

The radar subsystem is divided into radar transmitting and receiving loops and the antenna servo system. Built-in test features and controls are provided to facilitate checking and maintaining the subsystem.

Major components of the radar transmission path, in addition to Antenna-Receiver Group OE-29/SPN-42, are located in Transmitter Group OT-3/SPN-42. The radar transmitter group provides mounting and interconnection between the electrical synchronizer, radar set control, and radar transmitter.

The major components of the radar receiver loop are mounted on the antenna-receiver group to reduce waveguide losses. Radar return signals from targets within the antenna scan area are received by the antenna. The signals are routed to the duplexer (ferrite circulator) which directs them through sensitivity time control (STC) to the variable ferrite attenuators and automatic gain control (AGC) to the variable ferrite attenuator and to the receiver balanced mixer. The detected video, with antenna-generated amplitude modulation, is then directed to the radar synchronizer. The radar target simulator also mounted on the antenna-receiver group provides simulated radar return signals for testing the receiver and synchronizing circuits.

Precision tracking of the assigned aircraft is essential for landing control. This is accomplished by the antenna servo system operating in conjunction with other components of LCC. These components consist of the electrical synchronizer, buffer group, and computer unit. The servo system consists of the antenna control located in the control-monitor group and subassemblies in the electrical synchronizer located in transmitter group and antenna-receiver group.

The servo system operates in two basic modes: search and track. The search mode is either manual or automatic depending upon the method by which the center of search is established. A third mode of operation is available to enable the operator to manipulate antenna hand controls to manually locate, acquire, and track aircraft.

- o Search Mode. The antenna servo system is basically a position servo. In the search mode of operation, desired antenna position signals are compared (summed) with a signal corresponding to the actual antenna position. The resultant error signal is then amplified and used to correct the antenna heading.

- o Track Mode. Operation of the antenna servo system in the track mode is similar to that of the search mode. The basic difference between the two modes is the manner in which the position error signal is obtained. In addition, the stabilizing networks and the tachometer feedbacks are altered in the azimuth and elevation networks. In this mode, position command signals and search signals are disabled and the servo error signal detector provides the servo system tracking error signals.

The display and control subsystem consists of:

- o The Aircraft Landing Control Console OJ-21/SPN-42 which provides all of the controls and indicators required for normal operation or test of an individual channel of the landing system. Major subassemblies of the

console include a position indicator, aircraft parameter panel, aircraft acquisition panel, the necessary power supplies, and the subsystem test panels located on control console shelf. The light intensity control panel provides controls for console indicator illumination.

- o The Aircraft Landing Control Indicator ID-1417/SPN-42 provides a direct reading, visual display of true or closing airspeed, and four indicator lights to monitor the landing sequence for the aircraft nearest to touchdown. During normal shipboard operation of the LCC, two aircraft landing control indicators are in operation. One is located in the primary flight control area and the other is in the air traffic control center.

- o The Signal Data Recorder RO-319/SPN-42 operating in conjunction with the other subsystems of the LCC consists of an electrical test panel, signal data recorder set, and X-Y plotter recorder set. Output flight characteristic data and aircraft position data is extended through the signal data recorder to the aircraft landing control indicator. These data may also be recorded on the recorders located in the signal data recorder.

The computer subsystem comprising Computer CP-789/UYK, Input-Output Console OA-1954/UYK, and Signal Distribution Switchboard SB-1299/USQ-20 are GFE units and are described in their applicable technical manuals.

The buffer subsystem is the same as the shipboard system. The trainer configuration does not utilize the NTDS buffer since there is no NTDS operating with the trainer. The Buffer Group OA-8201/SPN-42 includes an output buffer, input buffers, NTDS buffer and buffer power supply. Although the first four subassemblies have the common function of interface, isolation, and adaptation, only the input buffers operate in parallel on inputs which are processed to the LCC computer unit. The output buffer processes data from the computer unit to the other units of the LCC system. Each buffer is treated as an entire subassembly.

The Control-Monitor Group OK-18/SPN-42 provides the housing and interconnections for several of the antenna servo system components, namely: antenna control and control-monitor and power supply assemblies. The control monitor is utilized during equipment checkout and troubleshooting of the system.

The antenna control provides antenna limit and pullout circuits, azimuth and elevation gimbal disable relays, limit indicate relays, and clutch solenoid relays. It also houses the pedestal control power amplifiers.

The control monitor provides power control of the operating channel at the equipment during test. It also provides controls and indicators for metering and monitoring of the various subsystem functions.

The two power supply assemblies provide operating voltages for the output buffer, aircraft flight characteristics simulator, and the radar subsystem.

The data link system consists of the digital data receiver-transmitter located in the forward compartment.

The digital data control indicator is mounted on the left hand side of the aircraft landing control console. Next to this unit is one of the two digital data indicator panels.

The following are the support subsystems required to fulfill the mission of the LCC trainer which are housed in the electrical equipment cabinets.

One electrical equipment cabinet contains two Tape Recorder-Reproducers RD-217/UNH mounted one above the other. These are used to record voice communications between AN/SPN-42-T1 and the landing aircraft. The wind direction and speed transmitter is mounted in the lower section of this unit behind an access panel.

Radar-derived slant range and angular position data are then applied through the buffer group to the computer to establish the range, lateral, and altitude (X, Y, and Z) coordinates of aircraft position. This data is scaled and compared with the optimum flight path established for the assigned aircraft. Deviations from the optimum flight path are established for the assigned aircraft. Deviations from the optimum flight path are used to generate pitch and bank command signals. Range to touchdown information is also generated. They are also addressed for transmission to the aircraft under control of the channel (A or B).

In addition to the flight path commands and range data, an automatic waveoff discrete command may be generated in the computer subsystem at any time up to five seconds before touchdown (committed). This is done whenever the aircraft under control cannot complete a safe landing.

Progress of the automatic landing sequence is monitored by the controlling channel operator at his indicator. In addition to the automatic waveoff generated in the computer subsystem, the aircraft landing control console operator may initiate a waveoff command during landing operation.

o The semi-automatic landing sequence operation of the LCC is essentially the same as for automatic operations.

Two Radio Sets AN/ARC-27 and two Radio Sets AN/ARC-1, used for UHF and VHF radio communication, are contained in the electrical equipment cabinet located in the compartment adjacent to the front partition. Control boxes for both AN/ARC-1 and AN/ARC-27 and five detector amplifiers supply the signal to energize the UHF, VHF, and data link monitor lights located in the instrument panel over the aircraft landing control consoles.

4.4.3 System Applications

The integrated landing control central (foldout 4-2) is designed to function with an air traffic control computer and provide automatic and semi-automatic landings. The non-integrated system is designed to operate via a voice communications data link instead of an air traffic control computer. A brief description of the fully automatic, semi-automatic, and talkdown sequences follows:

o The automatic landing sequence is initiated when aircraft are assigned to the LCC through the operation of air traffic control computer for final approach and landing control.

In the normal sequence of events, the LCC automatically requests an aircraft assignment from the air traffic control computer. In answer to this request, an aircraft prospectus is returned and assigned to the first available control channel. Data received includes the aircraft type and acquisition window data. This information is then forwarded to the computer and radar subsystems. In the computer subsystem an optimum glidepath and landing sequence are programed according to aircraft type.

o Operating as a manual or GCA-type talkdown sequence, aircraft are assigned to the first available control channel in the same manner as for both of the other modes of operation. However, the pilot receives verbal flight path correction information from the controlling operator via voice channel communications. Optimum glideslope and landing program are established in the computer subsystem according to aircraft type and are displayed on the azimuth and elevation position indicator of the aircraft landing control console. Radar-derived aircraft position is also displayed on the azimuth and elevation position indicator as intensified dots with reference to the optimum glideslope and landing area centerline extension traces. These data are also compared in the computer subsystem and the flight path errors are displayed on meters to enable the operator to transmit precise correction commands.

When the LCC is operated in the non-integrated configuration (foldout 4-3) the controlling channel operator receives a landing assignment and aircraft data from the air traffic control center via voice communications rather than from the air traffic control computer. Utilizing the various controls and selector pushbutton switches located on the aircraft landing control console, the operator manually establishes the position of the acquisition window and selects the appropriate landing program according to aircraft type. As in the integrated system, automatic, semi-automatic, and manual or GCA modes of operation are available. After the operator establishes the program, the landing is accomplished as described for integrated system operation with flight path correction commands being transmitted over a suitable data link.

Landing Control Central Trainer AN/SPN-42-T1 (foldout 4-1) is a land-based, automatic aircraft landing system designed for the training of Navy personnel in the operation and maintenance of the carrier-based Landing

Control Central AN/SPN-42. The trainer operates in an identical manner to LCC and will automatically acquire, control, and land a suitably equipped aircraft on a field carrier landing practice runway, which simulates the deck of a stationary aircraft carrier in all weather conditions. Although LCCT is primarily a training device for pilots, operators, and maintenance technicians, it will augment the all-weather return to base capabilities of any Naval Air Station by providing precise control of aircraft during the final approach and landing sequence.

Primary power for trainer operation may be from commercial-type service or Government-furnished power units.

The AN/SPN-42-T1 is a self-contained automatic carrier landing system. It is designed to provide semi-automatic and automatic landings on carriers in foul weather and in cases of pilot incapacity. This system is in use in the fleet. Trailer mounted versions of the equipment are in use for the training pilot/operator teams. These trailers are installed at major air stations to provide the training while fleet squadrons are based ashore.

Positive radar control of all aircraft existing, or terminating, at the station and other aircraft in the area is maintained when required. The design of the AN/SPN-42-T1 is such that it must be installed near the touchdown point on the main instrument runway. If such an equipment is planned for use at an air station, it is obvious that there will be three or more operators at three or more areas on the air station all individually charged with the control and landing of aircraft. This is by no means an ideal situation. The obvious solution to the problem is to incorporate the operational functions of the AN/SPN-42-T1 into the existing radar environment and to integrate the subsystems so as to provide for unified handling of aircraft.

The AN/SPN-42-T1 is a closed system in which the radar positioning data is used to maintain the aircraft on a predetermined path to touchdown. In order to conform to a remote manual air traffic control environment, system reconfiguration is necessary. However, upon completion of the change, the system must still operate as a closed loop. As a minimum, this closed loop must be expanded to include the geographical and electrical distance from the radar equipment near the touchdown point in the control facility of the operations building. This distance could be about two miles.

CHAPTER 5

SPECIAL ACTIVITIES

5.1 GENERAL

The Navy has established a number of activities which may be considered as one-of-a-kind. The basic mission of these activities may be training, surveillance and tracking, search and rescue, research and development, or any combination of these functions. Operations at these facilities may involve aircraft, ships, submarines, and/or missiles. As these operations may directly or indirectly affect Naval Air Stations in their areas, the mission, configuration, and operation of three special activities are detailed in this chapter. The NAVELEX responsibility to these activities is in the development and procurement of new and improved electronic equipment to assure that their system configuration fulfills the mission efficiently, effectively and economically, and that new equipment contains state-of-the-art designs.

Typical systems (equipment) found at Special Activities include the following:

Sensors

- o Surveillance Radar (2D and 3D) and IFF
- o Tracking Radar
- o Telemetry
- o Underwater Tracking Systems

Radio Communications

- o HF Radio Facilities
- o HF Data Links
- o Air-Ground VHF/UHF Radio Facilities

Signal Remoting, Storage and Displays

- o Computers and Peripheral Equipment
- o Recorders (voice and data)
- o Microwave Remoting Systems
- o Video Digitizer
- o Individual Large Screens
- o X-Y Plotters

Operation Controls

- o Radio, telephone and intercom control circuits
- o Switching Facilities (audio and data)
- o Drone Control

In general the Special Activities operation/equipment area is housed in a building specifically designed for the required mission. This building contains the operation controls, signal remoting, storage, and display equipment and receives the remoted sensor signals and radio communications via cable or microwave data links. Computer data, to and from ships and aircraft operating in the area, is transmitted and received in Naval Tactical Data System (NTDS) format via data links. In the operations area, the computer driven displays may present various combinations of stored and real time data for display, range reaction, and/or recorded for later playback or critique. Drone planes and missiles used in many operations may be controlled via radio link by aircraft or ships in the area, or from the operation center.

A simplified block diagram of a typical data link used at two Special Activities (FACSFAC and AFWR) is shown in figure 5-1. This diagram illustrates one of the many complex circuits used at the various ranges. The three activities to be detailed are:

Atlantic Fleet Weapons Range (AFWR)
Fleet Air Control and Surveillance Facility (FACSFAC)
Pacific Missile Range (PMR)

5.2 ATLANTIC FLEET WEAPONS RANGE

5.2.1 Mission

The primary missions of Atlantic Fleet Weapons Range are Fleet Training and Weapons Systems Evaluation. To accomplish these missions the AFWR System, including the Range Operations Control Center (ROCC) and radar tracking stations, have been designed and structured to provide direct support to the AFWR personnel in achieving the primary missions. This system, a complex interface of man and machine, is a combination of many subsystems each of which contributes to the total systems capability.

The AFWR consist of two ranges located in sea areas near Puerto Rico. Operation of the dual facilities is centralized in a primary operations control center located at Roosevelt Roads, Puerto Rico. Radar and radio facilities are located on a mountain, Pico del Este, within microwave range of Roosevelt Roads.

The current advanced state of Navy Weapons Systems technology and the capability of modern instrumentation, communication and data processing systems yield a challenging environment for the Fleet Training and Weapons Systems Evaluation missions of AFWR.

The primary missions of AFWR, together with the physical, operational and technical environment, dictate two fundamental requirements for the Range Operations Control Center and other AFWR Subsystems.

- a. The AFWR system must provide the capability for effective and efficient surveillance, detection, identification, and tracking of all surface and air tracks within the AFWR operational area.
- b. The AFWR system must provide the capability for exercising efficient and effective Command and Control over all Fleet and AFWR units involved in training or weapons systems evaluation exercises.

Thus, the two basic functions, Surveillance and Tracking, and Command and Control are fundamental to the Atlantic Fleet Weapons Range System.

5.2.2 System Configuration

A block diagram of the AFWR system is shown in foldout 5-1. The four primary subsystems which provide fundamental sensing, man/machine/radar interface, display and computational capability to support a modern Atlantic Fleet Weapons Range System are:

- o Digital Computer Subsystem
- o Naval Tactical Data Subsystem
- o Large Screen Display (LSD) Subsystem
- o Surveillance and Tracking Radar Subsystems

There are two other subsystems which augment the capability of the AFWR system, namely: the Remote Data and Drone Control System (RDDCS) and the Profile Tracking System (PTS). However, these systems do not dictate the AFWR system structure to the same extent as do the four primary subsystems specified.

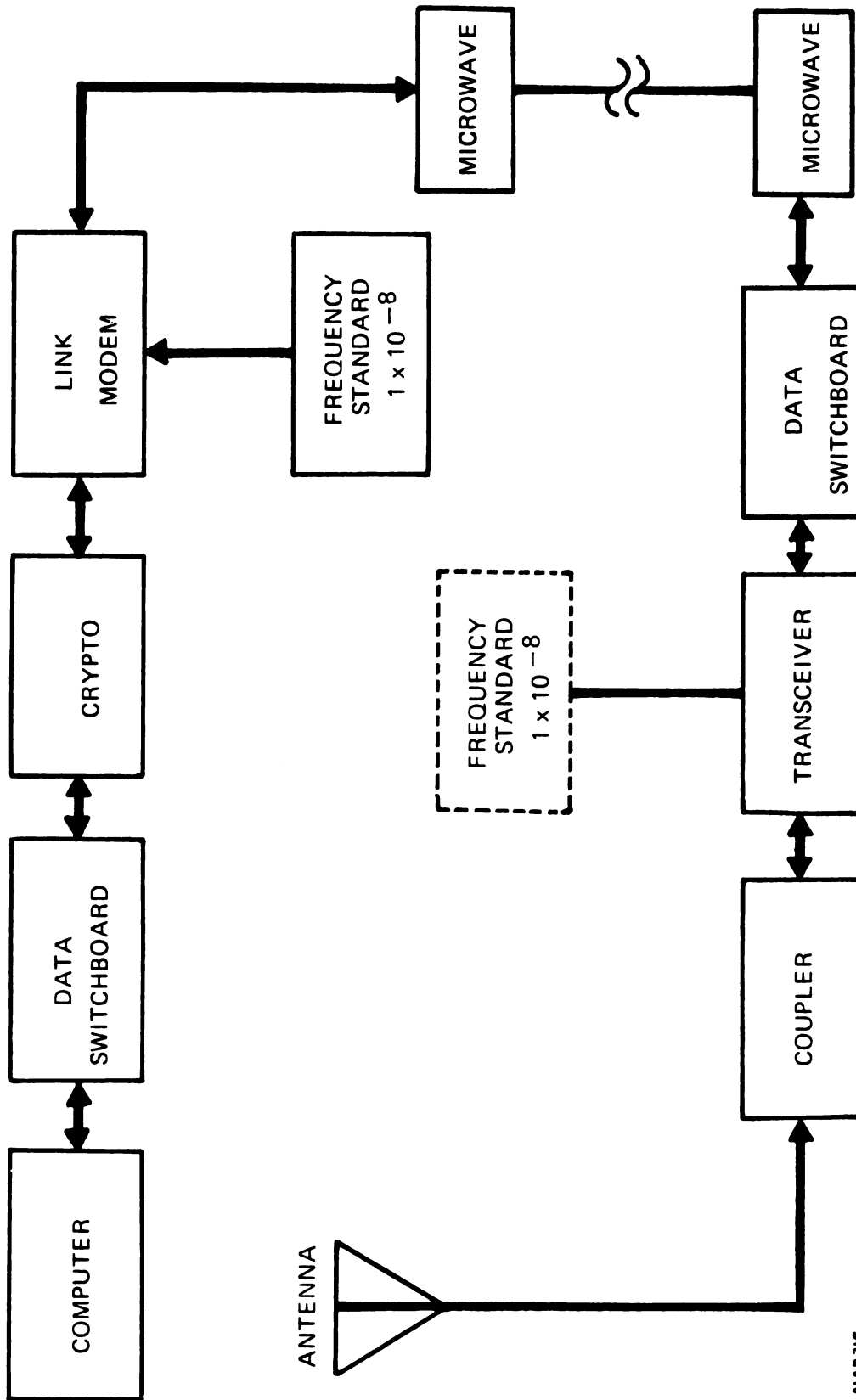


Figure 5 - 1. HF Speed Data Link, FACSAC and AFWR

There is another AFWR subsystem, the Data Transmission and Communications System (DTCS) which provides data transmission and communication links which are vital to the AFWR system functions.

From a human factor/man/machine interface point of view, the Navy Tactical Data Subsystem is the heart of the ROCC system. The basic element of the NTDS subsystem is the Data Display Console (OA-7979/UYA-4) which is a combination plan position indicator (PPI) surveillance radar display, sophisticated input/output console to the computer and a cathode-ray tube and alphanumeric readout device. The Data Display Console provides an efficient combination man/radar and man/computer interface which is specifically designed to provide a desirable human factors environment for the performance of Command and Control and Surveillance and Tracking functions in the computer based AFWR system.

a. Navy Tactical Data System Data Display. The Navy Tactical Data System hardware currently being utilized as a primary subsystem for the AFWR, is a third generation of surveillance radar distribution, conversion, and display equipment. The equipment, designated as the UYA-4 system, is specifically designed for use in a computer-based surveillance, tracking, data display, and command and control environment. The basic equipment complement includes hardware for surveillance radar distribution and switching, radar azimuth conversion (from standard analog format to a digital format), symbol generation and pulse amplification/distribution, surveillance radar video display (PPI display on the data display console) and an input/output console (built into the display console) to the digital computer.

The AFWR Operations Controller mode is designed and mechanized strictly to meet the functional/operational requirements of the Command and Control function of the Atlantic Fleet Weapons Range and does not necessarily have any relation to previously mechanized NTDS modes.

b. Large Screen Display (LSD) Subsystem. The Large Screen Display System capability and functional utilization is fundamental to the Command, Control, and Surveillance process of AFWR. As a primary subsystem to the AFWR, the Large Screen Display capabilities and characteristics have significant impact on the system/operational configuration and organizational structure of the AFWR.

There are three independent displays which are generated on separate 7 x 7 foot projection screens. All displays are identical in content and capability. Each is developed by a separate array of seven Vigicon plotting projectors and a Vigicon rotating spotting projector. In regular operation, one of the plotting projectors is used as a reference projector to display prepared background material. The Large Screen Display System can receive instructions from three sources. In normal automatic operation, instructions will come from the system digital computer. Graphic and alphanumeric data can be entered manually from the Graphic Tracing Table and its associated Manual Data Entry Panel. Projector functions, such as lamp, slide, and color can also be controlled from the manual control panels which are mounted in the LSD control console.

c. Radar Subsystem Surveillance and Tracking. Presently, the AFWR has four radar systems which are used for range surveillance. They are FPS-67A (the primary surveillance radar); the MSQ-51 on N. S. Roads (the secondary surveillance radar and one of the surveillance/tracker radars); the MSQ-51 (surveillance/tracker) on St. Thomas, V.I.; and the MSQ-51 (surveillance/tracker) on St. Croix, V.I.

d. Remote Data and Drone Control System (RDDCS). The Remote Data and Drone Control System (RDDCS) will provide AFWR with the capability to control one QF-9 or two BQM-34 drones from each of two Drone Control Consoles (DCC) located at the Range Operation Control Center (ROCC). These consoles will display telemetry, remote-site status, and command-verify signals while X-Y plot boards will display drone position, allowing operators to monitor drone and site performance and to guide the drone along the required flight path. A block diagram of the RDDCS and its basic relation to the AFWR is shown in foldout 5-1.

e. Data Transmission and Communication System (DTCS). The DTCS, as a subsystem to the AFWR, provides a twelve station microwave radio system capable of handling multiple toll quality (4-kHz bandwidth) channels of voice or data communications for the Atlantic Fleet Weapons Range. In addition to the voice communication capability between stations, the DTCS is used to provide the following specific capability to the AFWR:

- o Transmission of the tracking and drone status data from the target control centers to the ROCC.
- o Transmission of the tracking and status data from the ROCC to and from the Profile Tracker Site.

5.3 FLEET AIR CONTROL AND SURVEILLANCE FACILITY

5.3.1 Mission

In the late 1950's, it became evident that the advent of sonic and supersonic aircraft would have an ever-increasing impact on the use of available airspace. With the widespread use, both civilian and military, of aircraft capable of sonic and supersonic speeds, it became immediately necessary to impose new requirements on use of airspace for safety. At the same time, in the interest of national defense, military requirements and the world military situation created an urgent need for better offshore monitoring of airspace and surface and subsurface shipping. Today's sophisticated weapons systems demand a continuing training schedule to ensure operational readiness at any time. To provide an adequate training schedule and environment, offshore areas have of necessity been used more and more for training exercises by the various military agencies. Congestion in these areas has brought about a sharp increase in the possibility of mid-air collision, and inadvertent flight through areas being used for gunnery practice, missile firings, and other potentially hazardous operations.

Thus, after several years of study, the West Coast Offshore Tactical Control and Surveillance System (WTCSS) was established. The name has since been changed to the Fleet Air Control and Surveillance Facility. FACSFAC mission was to provide through communications and radar surveillance, effective control of that offshore area, air and surface, so designated, in order to promote overall safety, maintain efficient utilization, and to supplement tactical operations by providing command and control facilities for such military commanders as may be directed by competent authority, in order to assist them in the effective discharge of their command responsibilities.

For the purpose of implementation the mission has been divided into five major functional areas:

(1) Area Assignment and Air Surveillance - to provide area assignments and advisory control of aircraft in the assigned airspace, and maintain surveillance and a plot of all aircraft movement; provide flight assistance through "hot areas" created by nearby Pacific Missile Range (PMR) and by other offshore users conducting operations that affect flight safety.

(2) Anti-Submarine Operations - to provide assistance during anti-submarine warfare (ASW) operations through control of air ASW units, and by coordinating efforts of all participating ASW units.

(3) Surface and Subsurface Surveillance - to maintain surveillance of and a plot of the movement of all surface and subsurface units in the assigned area.

(4) Search and Rescue - to provide assistance to the U.S. Coast Guard and USAF and serve as naval coordinator during search and rescue operations.

(5) NORAD Assistance - to provide air defense assistance to the NORAD sector commander as requested.

5.3.2 Operational Concept

To fulfill any of the five major mission assignments, it becomes immediately apparent that certain operational requirements must be satisfied. These functional requirements are:

- o Detection
- o Identification

- o Communication
- o Coordination

a. Detection. Requirements for detection are those of providing aircraft tracking at a minimum distance of 200 miles radius from San Clemente Island, with altitude coverage in all directions from sea level to 80,000 feet. Surface detection requirements are approximately the same, although practical implementation is impossible because of earth curvature.

b. Identification. The identification requirement is not only one of identification as friend or foe, but also one of identification of each aircraft and ship within the system on an individual basis. It follows that if complete identification of an aircraft can be established, then it can also be ascertained the class of aircraft to which it belongs, ADC Interceptor, ASW, etc. This identification by class is an important requirement of the system.

For control of air operations positive identification of all aircraft is necessary. The most useful tool for preventing air collision is the utilization of computers to extrapolate the velocity vector of an aircraft and determine if the predicted vector for any aircraft intersects the predicted vector for any other aircraft on a time-space basis. That is, in addition to course and speed, altitude must be considered in the computation. When such an intersection of predicted vectors occurs, a collision is imminent. When presented with this situation, the air controller does not have time then to initiate identification procedures and ascertain the communications frequencies used by each aircraft. To provide the control measures desired of the system, it is imperative that each air controller be able to establish immediate contact with any aircraft in the area, and thus he must have positive, continuous identification of all aircraft and their operating radio frequencies. To provide this identification capability, standardization of required information is necessary. Each air controller must have the capability to provide identification inputs to the system, and must also in turn be able to have access to any identification data already available in the system.

c. Communications. Communications capabilities required in the Tactical Control Center (TCC) include:

- o Two-way communications with aircraft in offshore operating areas.
- o Two way communications with ships in operating areas.
- o Communications with other system centers, Air Defense Command centers, Air Route Traffic Control centers, U.S. Coast Guard Search and Rescue centers, as well as airport operations centers and other services.
- o Administrative communications.

Operationally the majority of aircraft operating offshore are limited to monitoring two radio channels: the operational frequency, and the guard or emergency channel. Aircraft working together must communicate with each other and with other participating units, and the Tactical Control Center must likewise be able to communicate on the same frequency. With many varied operations being conducted simultaneously, it is necessary for the Tactical Control Center to be able to communicate on several operational frequencies. Present day interceptor aircraft are equipped with ultra high frequency radio gear, with no capability in the very high frequency range. The characteristics of these frequencies impose limitations on range of two-way communications, because of their line-of-sight versus altitude restrictions. A maximum range of 250 miles for VHF and UHF communications, ground to air, has been established as a system requirement.

Aircraft operating beyond the 250 mile range limit or below line-of-sight horizon must, of necessity, depend on radio communications in the high frequency spectrum. The use of digital data, voice transmission, both AM and SSB, as well as CW modes will result in reliable communications at ranges of up to several hundred miles.

The combined requirements for radio communications result in a radio communication system requirement encompassing the HF, VHF, and UHF frequencies, with capabilities in both voice data and CW modes of operation.

d. Coordination. Coordination is necessary to tie together the other functions of detection, identification, and communication. These functions must be available to the air controllers for them to properly carry out their assignments. Primary requirement for the coordination function is the logical display of all available information, and ready access to communication links necessary to the function. Since it is possible for any air controller to require access to only limited information, means must be provided to permit the individual operator to determine the extent of his individual information display. It is also essential that any data inputs to the system that may be initiated by any single operator be made available to the other air controllers. This necessitates a system whereby each air controller must be able to initiate data inputs and monitor all other data inputs also.

5.3.3 Organization

To implement the functional requirements described under Operational Concept, consideration was given to various methods of providing the best overall performance capability at the lowest overall cost. The facility plan was based upon using existing installations, where possible, but only if performance would be adequate for the assigned mission. Figure 5-2 shows an overall geographic plan of the system.

a. Detection. Primary system detection functions are performed by radar, with manual supplementation where necessary. Radar data from Miramar Naval Air Station and Fleet Anti-Air Warfare Training Center (FAAWTC), are used. Manual entry of detection information beyond the range of radar surveillance will continue to be accomplished. At the present time, the only method of entering sub-surface crafts into the display is by manual means. This is expected to be the normal method for an indefinite period.

b. Identification. Identification requirements are presently met by techniques using a combination of IFF/SIF equipments and voice position reporting. Since identification for the specific system use is not one of just friend or foe, the use of IFF/SIF systems is only an expedient for use in conjunction with voice contact with the target. The controller can identify a contact by requesting selection of a specific IFF/SIF coded response, or by verification of voice commands with observed target track maneuvers. Through use of the emergency mode of IFF, the Tactical Control Center is able to identify craft in distress for immediate action.

c. Communications. VHF and UHF radio communications problems are similar, and the criteria for both are essentially the same. Communications in the VHF/UHF range are limited to line-of-sight versus altitude parameters. To achieve the 250 mile range, a relatively high location for both receiving and transmitting antennas is required. The installation of both receiver and transmitter facilities at Mt. Thirst, on San Clemente Island, accomplished several things. Elevation of the site is approximately 1965 feet above mean sea level. The geographical location of the island is as near as practical to the center of the assigned area of control.

The antenna installations at Naval Radio Station (R), Imperial Beach, satisfy the requirements for directivity for direction finding purposes, and use of these existing facilities decreases initial installation costs. Existing transmitter antennas at Naval Air Station, Miramar, are adequate for transmitting purposes. The separation between Imperial Beach, and Miramar, approximately 30 miles, is more than adequate to ensure required performance capability both in transmitting and in receiving.

Because of the optimum receiving conditions at San Clemente Island, an HF receiver section was included in the Mt. Vista installation. This equipment is now used as the primary HF receiving facility for SSB, with Imperial Beach facilities used when directivity is a factor, or as a backup for the San Clemente Island equipment.

Communications to be provided between the various remote sites and the Tactical Control Center include those for control and operation of the remote receivers and transmitters as well as voice links for coordination and maintenance purposes. Microwave links between the various sites and channelling into the Tactical Control Center

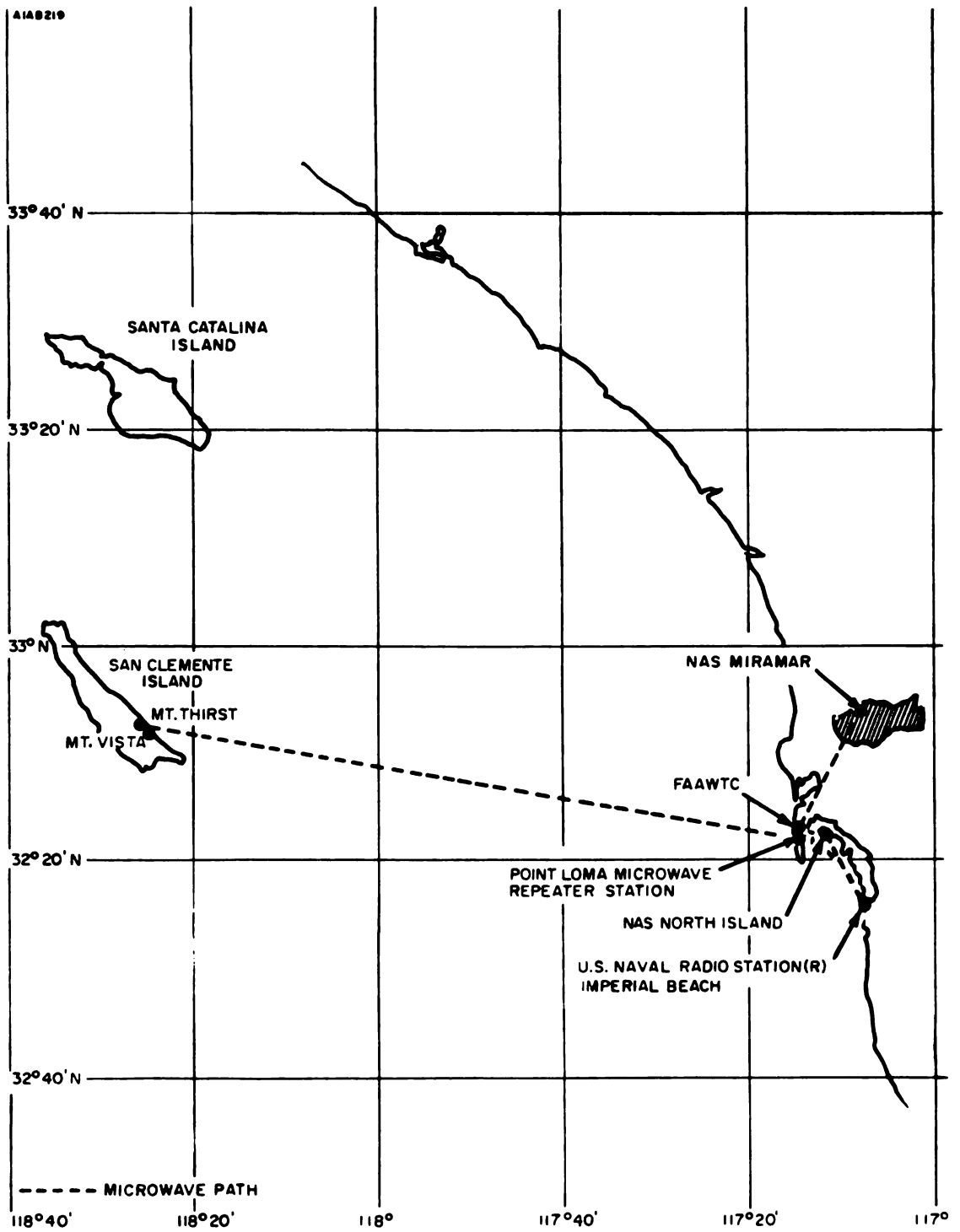


Figure 5 - 2. Overall FACS FAC Geographic Plan

provide a capability of control of the off-site equipment, as well as the routing to audio signals to and from the Tactical Control Center and the receivers and transmitters. A microwave system capable of the number of channels required for this system was not in existence, and therefore one was built expressly for the purpose. The microwave link consists of frequency division multiplex equipment for transmission of voice data and control tones, and RF links for transmission of video and azimuth information for the radar data. The link between San Clemente Island and North Island includes a repeater station on Point Loma which feeds into the link between FAAWTC and North Island. The Miramar to North Island link includes a relay at FAAWTC. Thus, there are only two microwave links at the Tactical Control Center, one directly from Imperial Beach, and the other from FAAWTC, which includes Miramar, San Clemente Island, and FAAWTC inputs.

Direct landline links are used between the Tactical Control Center and other shore installations. These links include commercial telephone service, leased telephone lines, and teletype facilities.

d. Coordination. Coordination of the surveillance, control, and communications functions for the entire system is concentrated at the Tactical Control Center. The heart of the system is the digital computer system comprising three CP-642/USQ-20 digital computers. These are large, general purpose stored-program machines capable of rapidly processing a large quantity of complex data. They are programed to perform the functions required of the system, such as:

- o Data Processing
- o Data Storage
- o Transmission of programed electronic commands
- o Track and other function computations
- o Drive and large screen display equipment

Inputs to the computer can be made through manual means from each NTDS console or by manual or programed means through the universal keyset. Manual inputs from the air controllers are continually being provided during operations. Programed inputs from the keyset are used to provide position data and track information pertinent to a specific surveillance problem, and include such information as may be obtained from OPORDERS, Notice to Airmen (NOTAMS), sailing plans, movement reports, and cancellations.

The computers provide display symbols to the data consoles, continuously update all tracks being held, provide computed range and bearing or course and speed of targets, initiate conflict probes, and alert the console operator when the tactical situation demands immediate attention.

The Tactical Control Center is required to process a great volume of information, and only through computer techniques can this processing be handled in the required reaction time and in the quantities necessary. The speed of processing this information through the computer permits a real-time display of all data in the system. This display is accessible to eight NTDS consoles in the Tactical Control Center. As a companion unit to the console, each position is provided with a data readout console which provides alphanumeric readouts of auxiliary information from the computer pertaining to any specific track. Upon interrogation by the console operator, the computer provides specific information regarding the designated target by sending sequential readout words to the data readout console. The extent of this readout is limited only by the specific program. Typical information computed, stored, and available in alphanumeric form includes:

- o Aircraft identification numerals
- o Primary radio frequency used
- o SIF code

- o Altitude limits
- o Number of aircraft in flight
- o Conflict track numbers, if any
- o Range and bearing from specific references
- o Latitude and longitude
- o Any other information regarding a specific track.

The large screen display provides an expanded presentation of the data appearing on the NTDS console screens. The large screen display utilizes a photographic-electronic wet film process which requires approximately 13 seconds for each sequence. The large screen display, therefore, may reflect a time lag from real-time of as much as 26 seconds. Although this delay is unacceptable for control purposes, it is completely acceptable for tactical decision making purposes. The large screen is visible from the lounge area immediately above the decision making area in the Tactical Control Center. The film is retained for historical purposes and later recall and playback.

Lighted status boards are visible from all controller, evaluator, and supervisor console positions, as well as from the tactical viewing area. These boards show aircraft call signs, ship hull numbers, frequencies, and other pertinent information which might be needed at any moment. Additionally, a status board showing airfield conditions at all major military and civilian airfields in the area is maintained on a current basis. A closed circuit television system also provides instantaneous updated weather at all airfields in the area.

Radio communications capability is provided at 21 points in the Tactical Control Center. Each station provides selection of up to 20 radiotelephone channels, 21 intercommunication channels, and five party lines for use in either internal or external communications. Pre-programmed selection of the 20 radiotelephone channels from any of the 60 radiotelephone channels available in the system is made through a master patch panel. The master control post in the decision making area provides for control of all 60 radiotelephone channels. All channels are continuously recorded on a 24-hour basis, and tapes of all communications are kept on file for a period of 10 days.

5.3.4 System and Facility Description

A functional block diagram of the FACSFAC system is shown in figure 5-3. All functions originate or terminate in the Tactical Control Center, which is the operation and coordination center of the system. Using the subsystems which are peculiar to the Tactical Control Center, such as the computer and AN/SYA-4 data display system, the personnel in the Tactical Control Center coordinate all functions of the facility. Communications systems, such as radio, telephone, teletype, and hot lines, allow controllers at the NTDS consoles to maintain effective communications with the agencies utilizing the FACSFAC services.

The Tactical Control Center is located at NAS North Island, California. All data and communications links with other sites terminate in the microwave terminal equipment at the TCC. Radar video, IFF/SIF data, and azimuth data are also routed to the radar distribution switchboard, thence to the NTDS display consoles in the operational area. Data generated by the controllers are fed to the computer system, which is programed to provide the basic characteristic functions of data processing, data storage, track and other function computations, transmitting programed electronic commands, and driving the large screen display.

The computer processed data are then fed back to the NTDS display consoles as required either by programing, in the case of track data, or by specific interrogation by the controllers at the various consoles.

Audio signals coming from the off-site receiver locations, or going to the transmitters, are routed to and from the microwave link through the Communication Control and Interphone System. In addition to radio transmitter voice and keying signals, control tones for control of the remote control receiving equipments are also routed to the microwave link for transmission to the off-site locations.

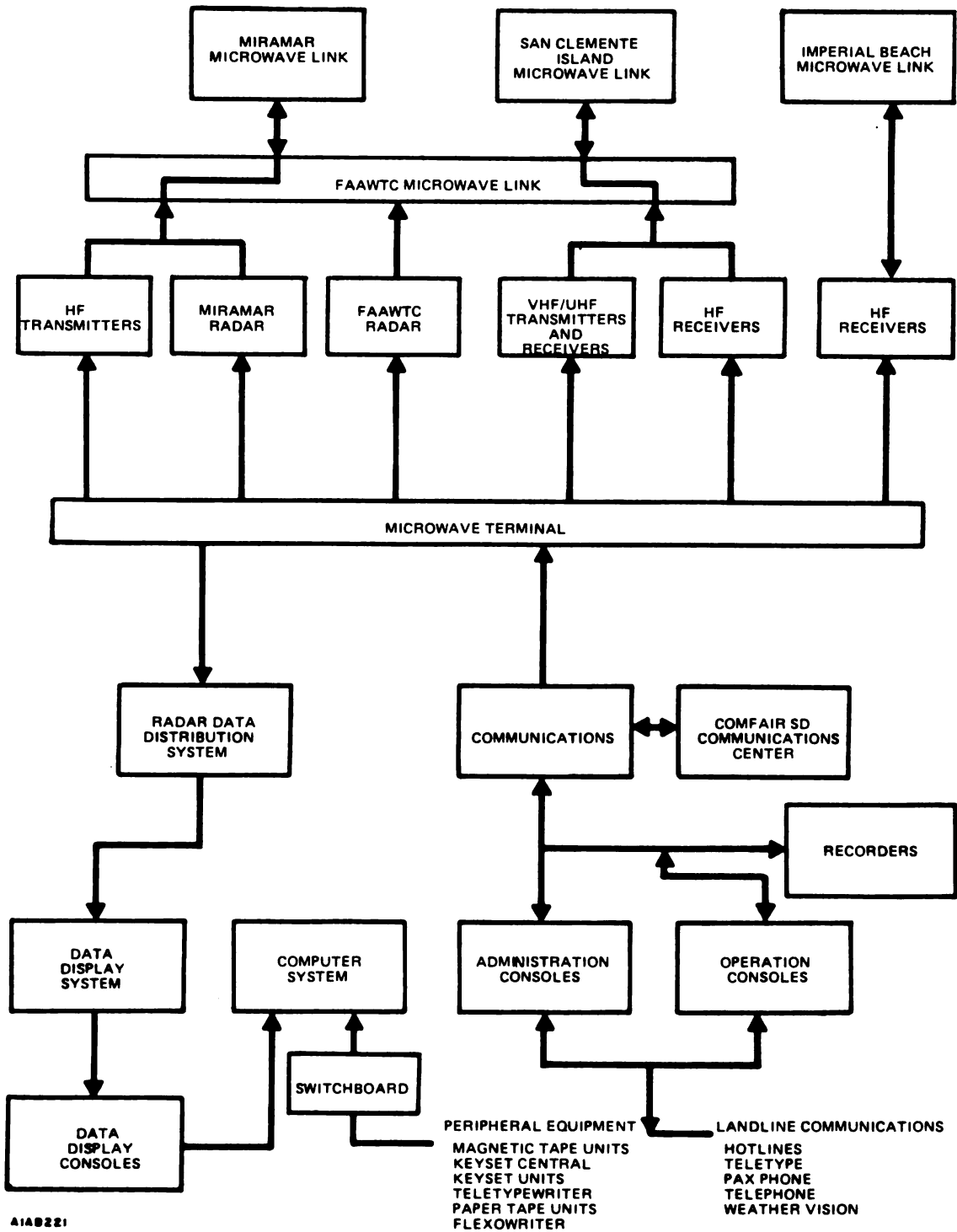


Figure 5 - 3. FACSFAC Electronic Systems, Functional Block Diagram

The Peripheral equipment used with the computer system includes the magnetic tape unit, the keyset equipment, teletypewriter, paper tape unit, and a flexowriter for use in preparing paper tapes. Computer/peripheral interchange is provided by a computer switchboard.

The NTDS data display equipment is used to coordinate various inputs to provide a logical display of data. The immense data processing and storage capability of the computer frees the command personnel from routine bookkeeping chores and leaves them free for concentrating on the primary functions of control and surveillance.

The computer stores descriptive data on as many as 184 separate tracks. The computer automatically sends track data on each tracked target to all consoles at a rate of up to 20 times per second for the purpose of displaying track markers. Additional data on particular tracks are routed to any console which requests data on a particular track.

The computer performs calculations for the manual tracking process, such as determining target speed and course from successive position entries and extrapolating future target positions based on the target velocity. The computer calculates a conflict probe for each given target and all other targets. This computation is a straight line extension of velocity and aircraft altitude, and will indicate any probable conflict situations.

The Communications Control and Interphone System provides the means of controlling and routing radiophone audio and control signals from the NTDS display consoles and other administrative communication stations to the microwave link. The AN/FSA-52 Communication Control Console Group provides capability of controlling up to 60 radiotelephone channels, both receive and transmit, 24 private line intercommunication channels and 5 party line intercommunication channels, with a high degree of isolation. As used in FACSAC, the AN/FSA-52 equipment routes audio signals from the various radio receiving facilities as they arrive from the microwave terminal, and provides transmitter control and microphone audio out to the microwave link to control radio transmitters used with the particular receiving systems.

The communications control system includes a model AN/FSA-47 Transfer Control Group mounted in the receiver rack of the AN/FSA-52(V) Control Center. This equipment permits selection of "hot-standby" radio receivers and transmitters in the event of malfunction of any of the primary equipments. In the FACSAC installation, this capability is wired for transfer of any of the first 15 channels. The supervisor's communication console provides control and monitoring of all 60 radiophone channels, as well as indication of the particular controller's console that is using a given transmitter. The supervisor can override any controller's transmitter selection.

A group of 60 line amplifiers is included in the system to compensate for individual line losses between the output of the radiophone receivers and the inputs to the AN/FSA-52(V) system so that all input levels will be equal. A VU meter is included in each console to allow setting of amplifier gain.

Landline communications facilities at Building 93 include twelve hot lines, four on-line teletype nets and one off-line net, off-base commercial and on-base closed PAX telephone systems, and the closed circuit television weather vision system. Landlines and "hot lines" as used at the operator's position terminate in Telephone Co. "call-director" type instruments or special key panels.

The television display provides weather information regarding most of the airfields in the Southern California area, and is updated on an hourly basis. Once each hour, and whenever changes occur, the information is taken from the weather vision screen, transcribed onto individual cards, and delivered to the controllers' consoles.

Ground electronics installations at the Tactical Control Center include the microwave terminal equipment in the microwave room, the control equipment for the HF, VHF, and UHF receivers and transmitters at San Clemente Island, and the NTDS display equipment and computer which are used wholly within the Tactical Control Center.

The microwave terminal equipment consists of two complete systems, one for the link to Imperial Beach and the other for the link to FAAWTC. The Collins Model MW-508C Transmitter-Receiver equipment installed contains 4 transmitters and 14 receivers. Two transmitters are used on each link to provide frequency diversity operation. Two of the receivers are used on the Imperial Beach link and the remaining twelve are used on the FAAWTC link.

Video and radar conditioning equipments installed in the TCC include the Radar Data Distribution Group, the IFF Decoder Group, and the video distribution panel in the microwave room. The Radar Data Distribution Group accepts the data from the two radar sets through the microwave link. This group functions as the radar data distribution system, and operates in conjunction with the decoder unit to provide each of eight operator or supervisor consoles with facilities for selecting and controlling the display data from either radar without impairing the displays of other consoles in the system. The equipment provides mixing and gating of the normal video from both radars, and the MTI from Miramar, and receives unseparated mode video data from the IFF/SIF equipment at both radar sources. The unseparated video is separated (decoded) and distributed to the eight IFF decoding equipments. The operator at each console may select any mode of interrogation without impairing the operation of any of the other decoding equipments in the system. The video mixing circuits of the decoding equipments are utilized for final mixing of radar and IFF video data before application through the signal distribution panel to the consoles.

The TCC has two important functional areas, the decision area and the operational viewing section. The decision area is immediately adjacent to the operational viewing area, and is afforded an overall view of the display facilities available in the operational viewing area. Along the walls of the decision area are a series of vertical display boards showing manually inserted ship information along the entire coastal area of the Southern Sector, as well as areas to the north. The decision area is equipped with a supervisor's communications console capable of monitoring all of the 60 radio channels available, as well as the intercom channels and party lines. A ceiling-mounted speaker, controlled from communications position 20 in the operational viewing area, provides communications monitoring capabilities for any radio or intercom channels.

The operational viewing area includes the supervisor's position and the FACSFAC evaluator's position, each of which are equipped with NTDS consoles with data user readout consoles. Each position is similar to the display consoles in the operations control and display area, with the exception that these consoles are data user consoles rather than data input consoles. The large U-shaped console in the middle of the area contains a supervisor's communications console, capable of operation on any of the 60 radio channels, as well as the intercom and party line system. In addition, auxiliary equipments for control of status board lighting, and the large screen projector, are mounted within this panel. Figure 5-4 shows a plan and elevation view of the large console.

The large screen display is located along the south wall of the operational viewing area. This display is visible from any point in the area, as well as from the decision area, and the balcony lounge. The balcony lounge is provided for staff personnel and local commanders, and is located immediately above the decision area. It is equipped with a ceiling speaker controlled from the supervisor's position, and affords an unobstructed view of the large screen display, the vertical status boards, and all other displays in the operational viewing area. Figure 5-5 is an elevation view of the decision area and balcony lounge.

5.4 PACIFIC MISSILE RANGE

5.4.1 Mission

The Pacific Missile Range has as its mission to provide range support for the Department of Defense and other designated Government agencies for launching, tracking, and collecting data in guided missile, satellite, and space vehicle development, evaluation, and training programs; to conduct test and evaluation of Naval Guided Missile weapons systems and their components; and to provide supporting base service. PMR is a national range supporting all range users, including Department of Defense agencies, NASA, AEC and other Government agencies.

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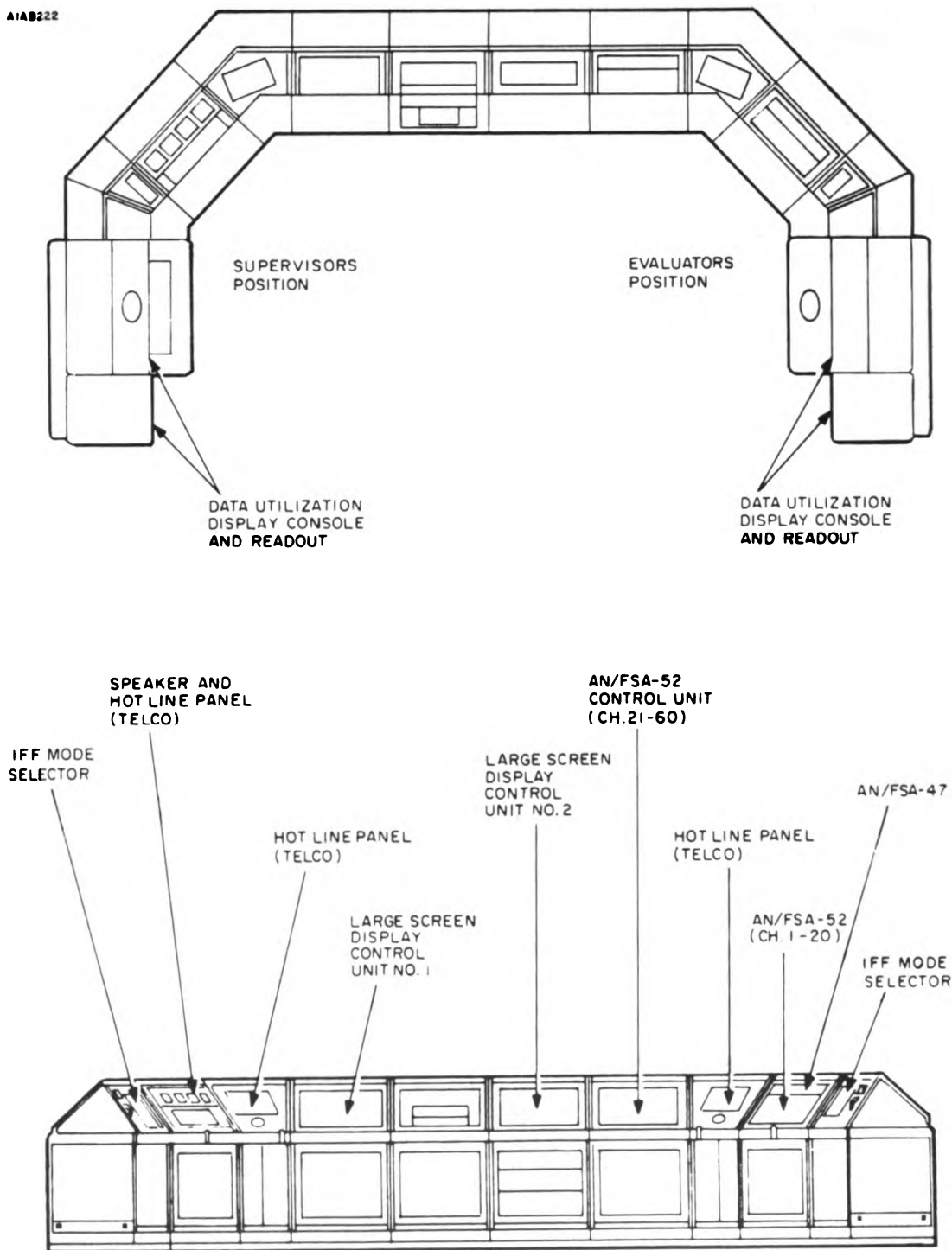


Figure 5 - 4. Supervisor and Evaluator Console, Plan and Evaluation View

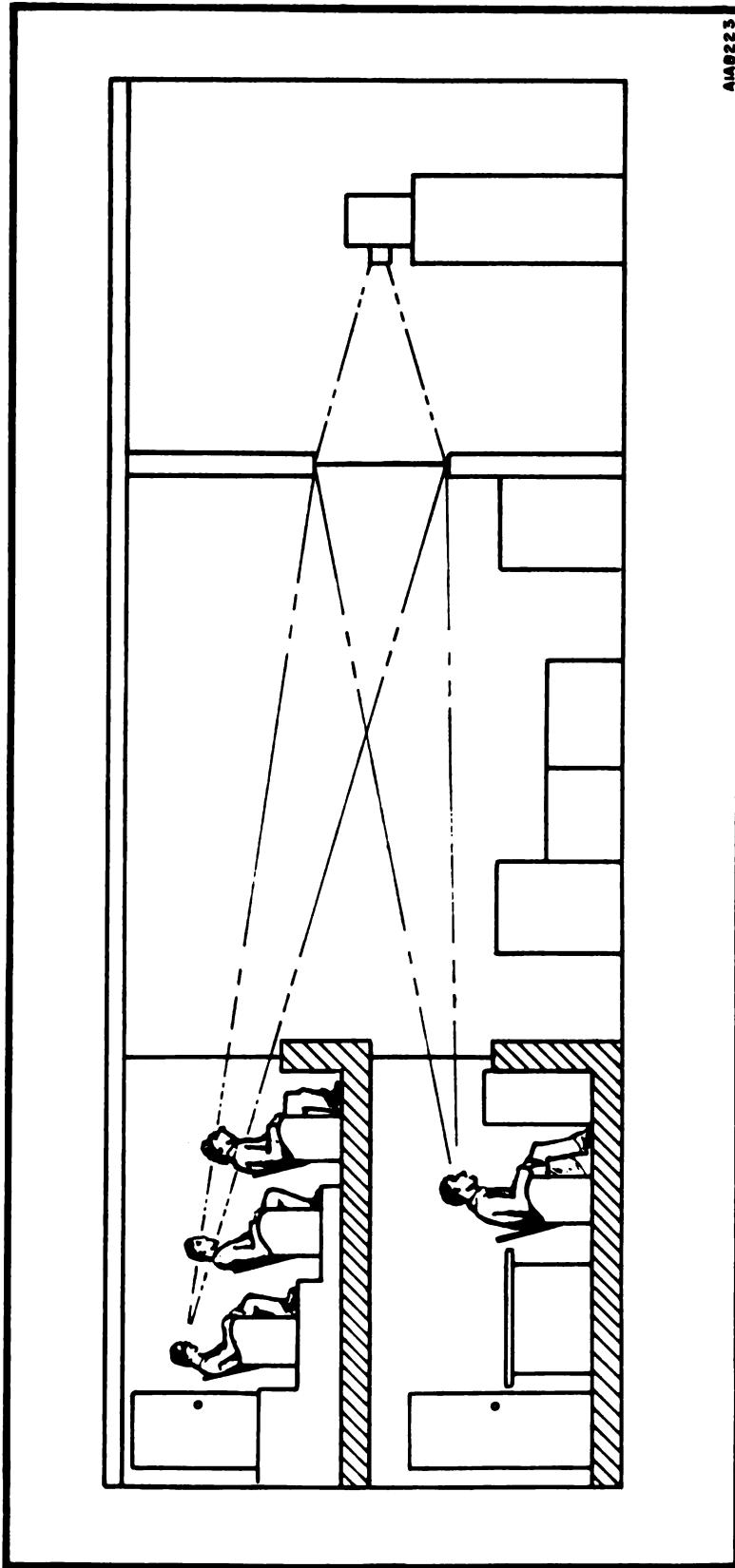


Figure 5 - 5. Decision Area and Balcony Lounge

The Pacific Missile Range originally started with the testing of missiles at Point Mugu, California. As the range of missiles increased, so did the length of the range. Then Naval ships became involved for short range and long range operations. Thus the requirement for further development and expansion of the PMR shore facilities increased. The basic purpose in utilizing a shore station in support of fleet exercises is to provide a fixed station from which the path of all units participating in the exercise, including missiles, can be tracked with extreme accuracy. The data collected during the operation can then be evaluated and presented to the fleet units so that their performance can be improved. Also problems of Range Safety involving fleet units and missiles can be accurately observed in real time displays and thus, through destruct capability and direct communications many accidents which can be costly in lives and money are avoided.

To allow for expanded operations in areas other than off the west coast of California, a facility in Hawaii was authorized. In accordance with Sec Nav Notice 5450 serial 554PO9B2 of 20 March 1961, the following mission is prescribed for the Pacific Missile Range Facility (PMRF), Hawaiian Area: To maintain and operate facilities and provide services to support operation of the Pacific Missile Range and other activities and units in prescribed areas and as designated by the Commander, Pacific Missile Range. The PMRF at Barking Sands is continually expanding because of increased responsibilities in the area of Fleet support. Continually increasing requirements in support of Mid-Pacific (MIDPAC) fleet operations will be further augmented by the new Pacific Fleet Tactical Range (PFTR) which will require extensive underwater instrumentation as well as surface and air tracking and telemetry systems.

The discussion of PMR facilities in this handbook will be limited to the west coast activities and the new Hawaii facility.

5.4.2 System Configuration

The PMR surveillance system consists of five radar tracking stations as shown in figure 5-6. The microwave links from Santa Cruz Island to San Nicolas Island and the Air Force Western Test Range (AFWTR) are approximately 55 and 70 miles respectively. The Santa Cruz link to Point Mugu is approximately 40 miles. A block diagram of the surveillance radar system presented in figure 5-7, shows that the Navy's west coast PRM control center is located at Point Mugu, California. This figure also provides a partial list of the vast equipment employed.

A map of the area, showing the coverage of aircraft above 5,000 feet, is illustrated in figure 5-8.

The MIDPAC operations are in two sections, one for the launching of targets for fleet units at sea to locate and intercept, and the other involves the evaluation of Anti-Submarine Warfare readiness of air, surface, and underwater units. To support the launching operation, the Barking Sands facility has the following capabilities:

- o Communication equipment for HF, VHF, UHF, and local exchange.
- o Frequency interference control monitoring equipment.
- o Surveillance radars and area clearance craft for area control.
- o Land based C-band instrumentation radar for launch ship positioning determination and ships missile trajectory determination (including position, velocity and acceleration).
- o Telemetry automatic tracking antenna for acquisition aid for C-Band land based instrumentation radar.
- o Land based C-Band or S-Band instrumentation radar for target flight path determination (including position, velocity, and acceleration).
- o Analog plotting boards located in Operations Control Center for real time simultaneous plot of launch ship, target and missile.

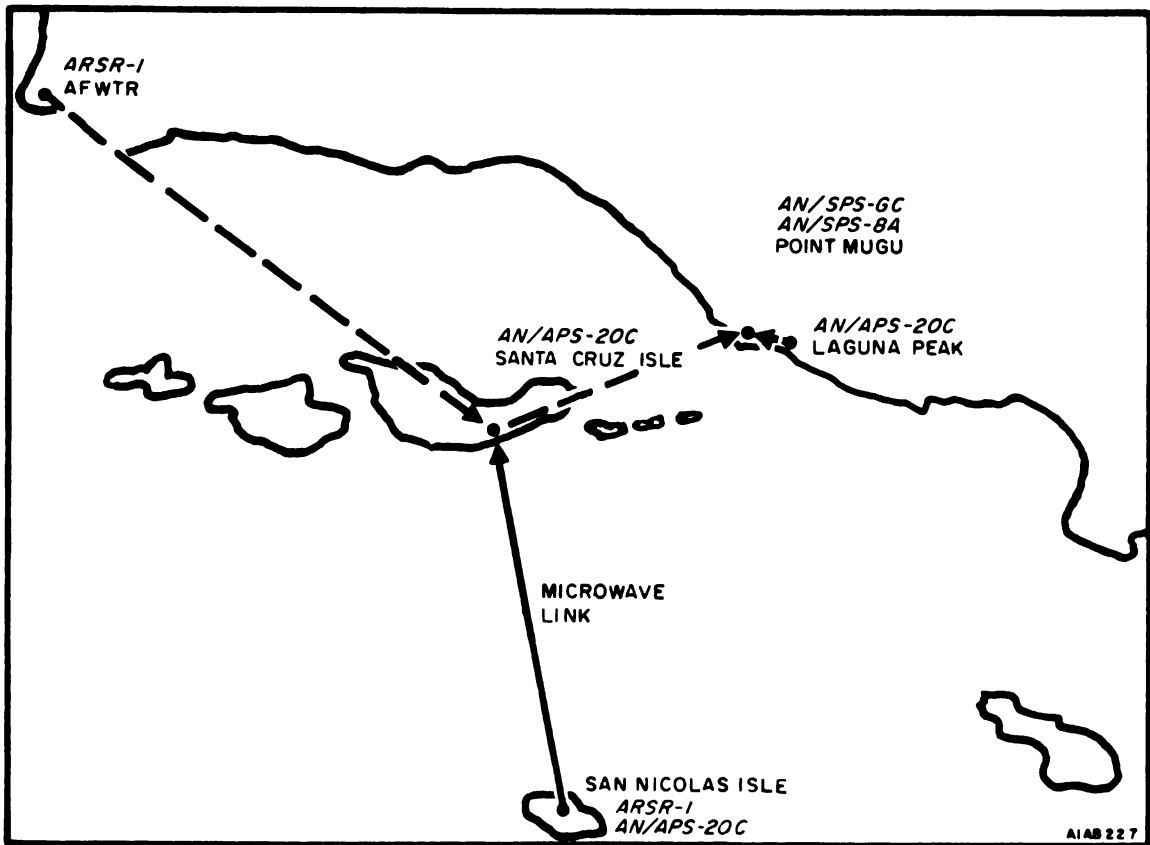


Figure 5 - 6. PMR Surveillance Radar Locations

- o Command control destruct transmitters for target control and destruct.
- o Digital data units and recording equipment for digital data recording of radar tracking data (azimuth, elevation, range and timing).
- o Telemetry receive and record equipment for receive/record of missile functions (acceleration, chamber pressure, gyro rates etc.).
- o Miss distance indication equipment (missile and target).
- o Data processing equipment for telemetry, metric, and miss distance.
- o Meteorological equipment for observations and forecasts (temperature, pressure, sea state, wind etc.).
- o Time code generator for timing.

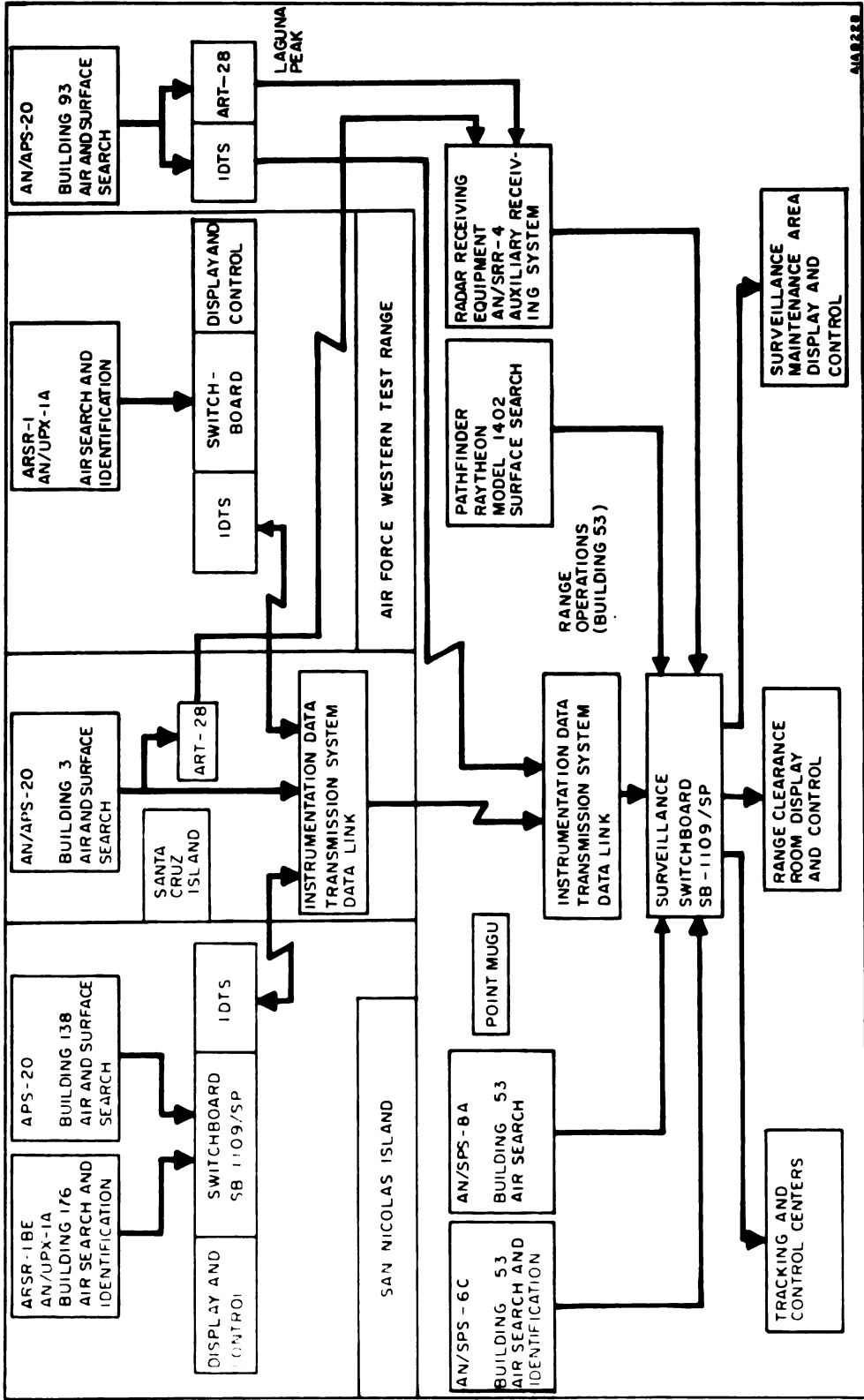


Figure 5 - 7. Surveillance Radar System Block Diagram

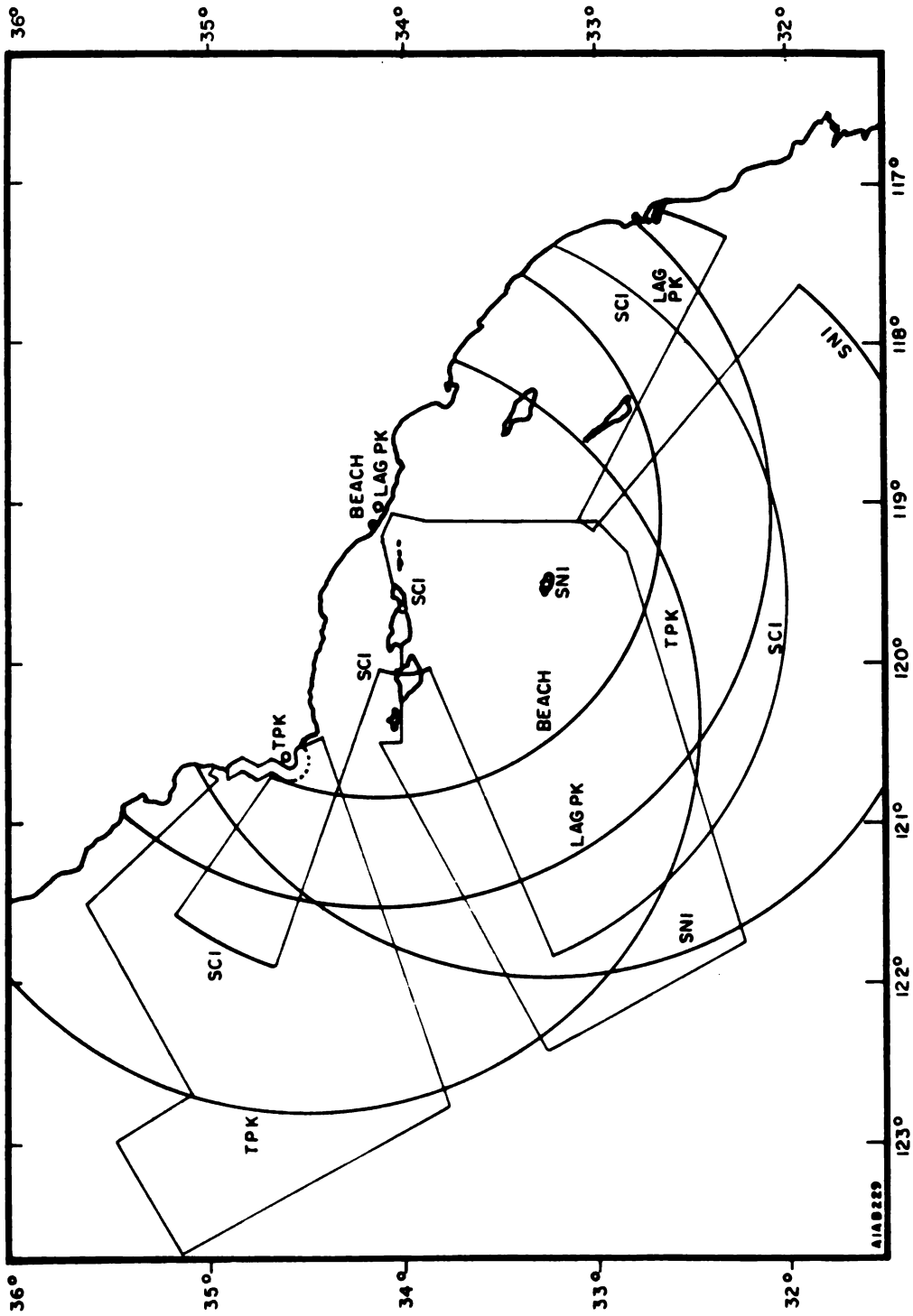


Figure 5 - 8. Coverage of Aircraft Above 5000 Feet Over the Sea Test Range

- o Launch facilities for ground handling, launching and recovery of targets.
- o Photographic documentation.

For evaluation of ASW readiness, the Hawaii facility has the equipment and capabilities as follows:

- o Underwater tracking system (hydrophone network) for tracking underwater fleet units and weapons.
- o An increased capability for tracking additional surface and airborne fleet units is required over that needed for MIDPAC operations.
- o Underwater communication system for the underwater range.
- o Recovery of torpedoes.
- o Additional control center area and other support facilities as required.

5.4.3 System Operation

For long range missile firings from Point Mugu into the Pacific Ocean, the west coast PMR facilities and the Hawaiian facility both function as tracking stations with the Point Mugu control center functioning as the coordination center. This same center is also the principal control for all operations in the PMR off the coast of California.

In the mid-pacific PMR area, the Barking Sands facility controls, directs, and monitors the launching of target drones. The PMRF controls the launching of the targets, and directs them into a predetermined area. In these sea areas the fleet units, aircraft, ships, and submarines are required to locate and intercept these targets with their own weapons systems. The PMRF will monitor the complete operation and evaluate the results.

The Pacific Fleet Tactical Range was established in the Barking Sands area to provide the capability to test the ASW readiness of air, surface, and underwater units. To perform this function the facility evaluates:

- o ASW sensors and weapon system performance.
- o Weapon delivery and fleet ASW tactics.

The range sensors provide position versus time data for underwater, surface, and airborne objects with real time display provided only for range surveillance, control, and safety purposes. Complete position versus time data records are available after each operation for analysis at other locations.

Another continuing function performed at the Barking Sands station is the mid-range support, including tracking and data reduction, of ICBM's fired into the western pacific area from the continental United States. The continuation of this specific function could depend on the disposition and use of instrumentation in the Kokee Park area and the possible procurement of similar instrumentation to support MIDPAC and AFTR. In any event, some support would still be required in the area of communication and data reduction.

CHAPTER 6

METEOROLOGICAL SYSTEMS AND FACILITIES

6.1 INTRODUCTION

Meteorology is the science concerned with the atmosphere and its phenomena. It is an observational science since the meteorologist observes the atmosphere, its temperature, density, winds, clouds, precipitation, and other characteristics and aims to account for its observed structure in terms of external influences and the basic laws of physics. Empirical relationships between observed variables, as those between wind patterns and resultant weather, are developed to present the problems requiring explanations and essential material for the application of this science.

The meteorological and related oceanographic programs of the Navy are worldwide in scope. They utilize not only the capabilities of the Naval Weather Service Command, but also the environmental observation and collection efforts of other Navy units, Army and Air Force, other agencies of the U. S. Government, and foreign countries. International cooperation and coordination for the exchange of meteorological and oceanographic information are achieved primarily by the efforts of member countries of such organizations as the World Meteorological Organization of the United Nations, the International Oceanographic Commission, and NATO.

The purpose of the Navy programs is to meet military worldwide operational requirements for environmental information and forecasts, and to provide climatological information (i.e., historical studies and statistics) for planning purposes and for research. The scope includes environmental conditions on and under the sea and in the atmosphere. The very large and nearly continuous flow required data necessitates the use of high-speed data links, other rapid communications, and centralized computer processing. The highly perishable nature of operational environmental information requires real-time handling and processing from the time of observation to ultimate delivery of the analyzed data to the user activity. It is toward the effective prosecution of these programs, which provide for Navy and DOD environmental requirements, that the efforts of the Naval Weather Service Command are directed.

The meteorologist uses special apparatus and equipment to obtain quantitative information about the weather. This information includes the state of the atmosphere in such aspects as motion, energy exchange, electrical activity and other factors, as well as their composite effect in combinations. The measurements of air temperature and pressure which describe the state of the atmosphere are obtained with simple instruments such as thermometers and barometers. However, visibility and other meteorological parameters require more complex instruments. These instruments assist the meteorologist in making four types of observations: climatological, synoptic, operational, and research. The operational type observations are of primary interest to Naval Air Stations since they are used to support the safe operation of high performance aircraft by providing such parameters as the measurement of wind, temperature, visibility, and cloud ceiling over and around the station. Climatological observations (the accumulation of local weather data as indicated by temperature, wind velocity and precipitation) are performed at all Naval facilities to provide records of the local climate. Synoptic and research observations include the assembly and analysis of observation taken in various places over wide areas at the same time and are the primary responsibility of such facilities as the Fleet Numerical Weather Center, the Monterey and Norfolk distribution centers of the Navy Environmental Data Network, and the Weather Satellites.

6.2 MEASUREMENT SYSTEMS

Equipment which is used at Naval Air Stations includes Semiautomatic Meteorological Weather Station, Transmissometer Set, Cloud-Height Set, and Wind Measuring Set. Other systems which are found at a Naval Air Station but not as directly related to aircraft control include Weather Radar, Rawinsonde, Facsimile, Weather Television, and Telemetric Data Receiving System.

Each system mentioned will be discussed in sufficient depth to enable the reader to understand its value and to determine if the need exists for the equipment or systems at the station.

6.2.1 Weather Radar Systems

a. System Principles. The ability to study and analyze areas of precipitation and associated disturbances is provided by meteorological radar systems. The necessity of having range and azimuth information and the ability to observe a large volume of the atmosphere with great accuracy is made possible by the use of radar. The basic requirements for a weather radar system are a relatively high-power transmitter (to generate short bursts of RF electrical energy), an antenna to form this energy, and a sensitive receiver, plus a means of displaying the information. Figure 6-1 is a simplified block diagram of a meteorological radar set.

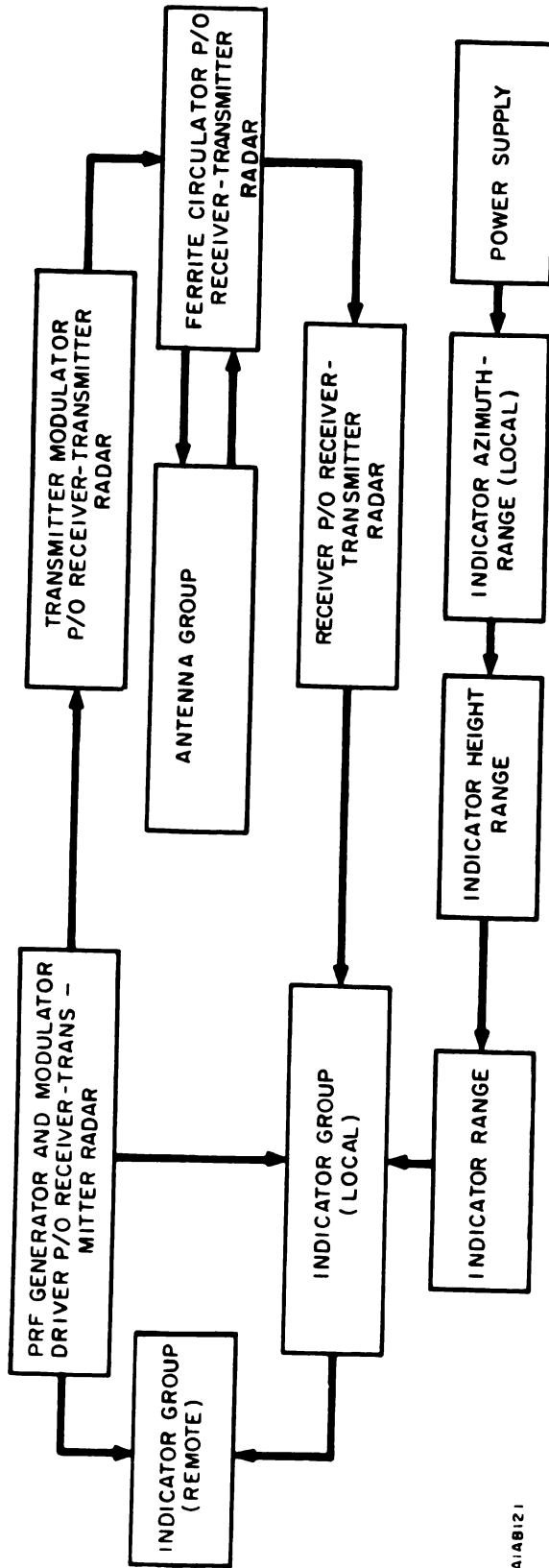
The meteorological radar sets used by the Navy today are of the pulse modulated type and operate in "C and S" band of the electromagnetic spectrum since it more closely approximates the size-wavelength ratio of the target for good responses.

Factors to be considered when selecting a meteorological radar system are: pulse length, which determines targets detection and resolution capabilities; pulse repetition frequency, which determines maximum measurable range of the system; and beamwidth, which determines the possibilities of detecting a target. A wide beamwidth will better enable the detection of a target but will decrease the accuracy of determining its azimuth and elevation responses.

b. System Configuration. A typical Meteorological Radar Set AN/FPS-81 (figure 6-2) is a radar system used for detecting, ranging, and plotting movements of storms and other meteorological phenomena. The radar set consists of an antenna group, receiver-transmitter, local control indicator group, and remote indicator group. Operating range is from 1 to 200 NMI with an azimuth scan of 360 degrees and an elevation scan from -2 to +60 degrees. Operating frequency is from 5450 to 5650 MHz, pulse-modulated at 324 pulses per second. Power output is variable from 250 to 350 kW at a duty cycle of 0.00065 nominal.

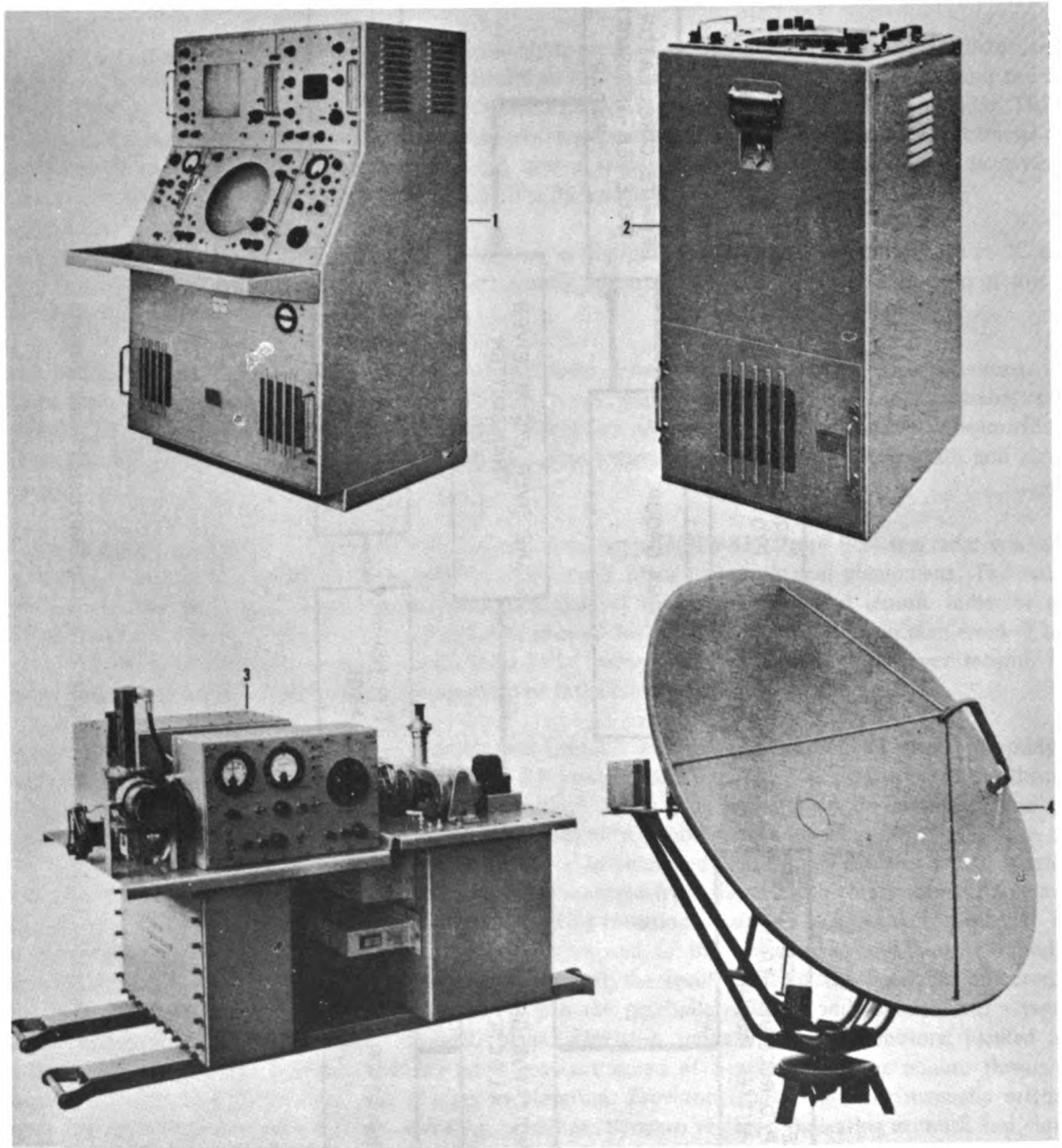
The antenna group (figure 6-2D) consists of an antenna assembly mounted to an antenna pedestal assembly. The antenna group is tower- or roof-mounted, receiving RF energy from the radar receiver-transmitter through a waveguide. This waveguide is attached, at the underside of the antenna pedestal, to the stationary end of the azimuth rotary joint waveguide. The antenna and yoke assembly is bolted to a rotating platform at the top of the pedestal. The azimuth rotary joint at the top of the antenna pedestal, allows the antenna to rotate 360 degrees about a vertical axis. A section of waveguide is connected from the azimuth rotary joint to an elevation rotary joint on an outer edge of the parabolic reflector. This elevation rotary joint allows the reflector to rotate from -2 to +60 degrees about a horizontal axis. The inner end of the elevation rotary joint is bolted to a waveguide section that terminates in the feedhorn located at the focal point of the parabolic reflector, 35.8 inches from the exact center. RF energy is directed into the parabolic reflector and focused into a vertically polarized beam, nominally 1.58 degrees in each plane. Elevation and azimuth servo motors, located in the antenna pedestal rotate the antenna assembly at a constant speed of .5 revolutions per minute through 360 degrees in azimuth, and from -2 to +60 degrees in elevation. Provision is also made for manually setting the antenna assembly to desired azimuth and elevation positions. Synchro voltages, indicating azimuth and elevation positions, are supplied to the indicator group and remote indicator group for display references.

The radar receiver-transmitter, (figure 6-2C) consists of a superheterodyne receiver, and externally-excited pulse-modulated transmitter-modulator, and a pulse-repetition-frequency (PRF) generator. The receiver section receives RF signals from the antenna group. The receiver intermediate frequency (IF) is 30 MHz supplied by the interaction of the received signals and a local oscillator. Automatic frequency control (AFC) is provided by sampling the transmitted RF energy and supplying this sample to the receiver AFC circuits. A calibrated noise source is incorporated in the receiver station so that receiver noise figure can be monitored periodically. Receiver IF output is applied to a post-IF amplifier and then to a video amplifier for indicator display.



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Figure 6 - 1. Meteorological Radar Simplified Functional Block Diagram



- 1. Indicator Group OA-3871/FPS-81 or OA-3871A/FPS-81
- 2. Indicator Group OA-3872/FPS-81

- 3. Receiver-Transmitter, Radar RT-658/FPS-81
- 4. Antenna Group OA-3870/FPS-81

Figure 6 - 2. Meteorological Radar Set AN/FPS-81

The transmitter-modulator section generates pulse-modulated RF energy at a PRF of 324 pulses per second. The pulse repetition frequency is established by a means of a separate PRF chassis that supplies the PRF trigger to the modulator. This same PRF trigger signal is used to synchronize the two indicator groups with the transmitted signal. After being triggered, the modulator supplies a high-voltage pulse to a mechanically tuned magnetron-oscillator transmitter. The pulse-modulated RF output, at a power level 250 to 350 kW, is applied to the antenna through a ferrite duplexer and waveguide. The duplexer acts as a transmit-receive (TR) switch, disconnecting the receiver from the antenna during transmission and disconnecting the transmitter from the antenna during reception.

The control and indicator group (figure 6-3) consists of a cabinet amplifier power supply, range indicator, range-height indicator, and azimuth-range indicator. The indicator group displays received signals in the form of azimuth, range, and elevation information. All operating controls for the radar set are located on the front panel of the cabinet while iron-core components for the indicator power supplies are mounted within the cabinet.

Receiver signals are applied to the post-IF amplifier that detects the video signals and applies them to the video amplifiers of each indicator. An output also is supplied to an auxiliary video amplifier located in the amplifier-power supply. The output of this auxiliary video amplifier is applied to the remote indicator group. Synchronizing pulses for the indicator group originate in the pulse forming circuits in the transmitter-modulator section of radar receiver-transmitter.

The range indicator display shows range of the target on a horizontal sweep (figure 6-4). Receiver echoes cause a vertical deflection on this horizontal sweep, with vertical amplitude approximately proportional to the received signal strength. Horizontal distance along this sweep to the vertical deflection of the echo indicates target range. It is possible to obtain a rough estimation of direction by rotating the antenna until a maximum echo of amplitude is indicated. Sweep ranges are 30, 60, 120, and 200 nautical miles. Range markers are used for range measurement. This indicator also contains the range strobe circuitry. This range strobe is presented on all indicators in the cabinet and is used for vernier range measurement up to 150 miles.

The range-height indicator display indicates range of a target on a horizontal sweep and elevation on a vertical sweep. Refer to figure 6-5 for a typical display. Horizontal sweep ranges are 15, 30, 60 and 120 NMI. Range markers at 5, 10, 25, or 50 miles are used for range measurement. Vertical sweep ranges are 40,000 and 80,000 feet. The horizontal sweep is triggered by the PRF circuits in the transmitter-modulator section of the radar receiver-transmitter. The sweep deflects vertically in the same manner as the elevation scan pattern of the antenna. The combination of the two sweeps produces a "windshield wiper" effect on the indicator face. A received echo is represented by a bright spot on the tube face. This bright spot fades but persists sufficiently until the sweep recrosses the spot to reinforce it.

The azimuth-range indicator display indicates range and azimuth of a target in a plan view utilizing polar coordinates (plan position indicator or PPI). Refer to figure 6-6 for a typified display. The sweep on the indicator face rotates synchronously with the antenna, indicating antenna azimuth. A received echo is presented as a bright spot along the sweep and remains at this point after the sweep has passed. Sweep ranges are 30, 60, 120, and 200 nautical miles. Range markers at 5, 10, 25, or 50 nautical miles are used for range measurement while range strobe is used for vernier measurements. This indicator also contains the range-marker circuitry and controls for selection of range markers for the other two indicators. The azimuth-range indicator in the remote indicator group (figure 6-4) performs the same functions as does the azimuth-range indicator in the local indicator group. In addition, the remote indicator provides a camera trigger pulse for photographic recording of the visual display.

c. System Applications. The systems are used to detect and track the movements of electrical storms, hurricanes, general precipitation including snow, cloud structures, formations of frontal wave patterns, and squall lines.

The "C band" meteorological radar systems are the AN/FPS-68 and FPS-81, with a nominal peak power of 350 kW. They are pulse modulated and have a maximum range of 200 NMI and a minimum range of about one NMI. They also have the iso-echo contouring capability for pinpointing severe cells within a general storm area.

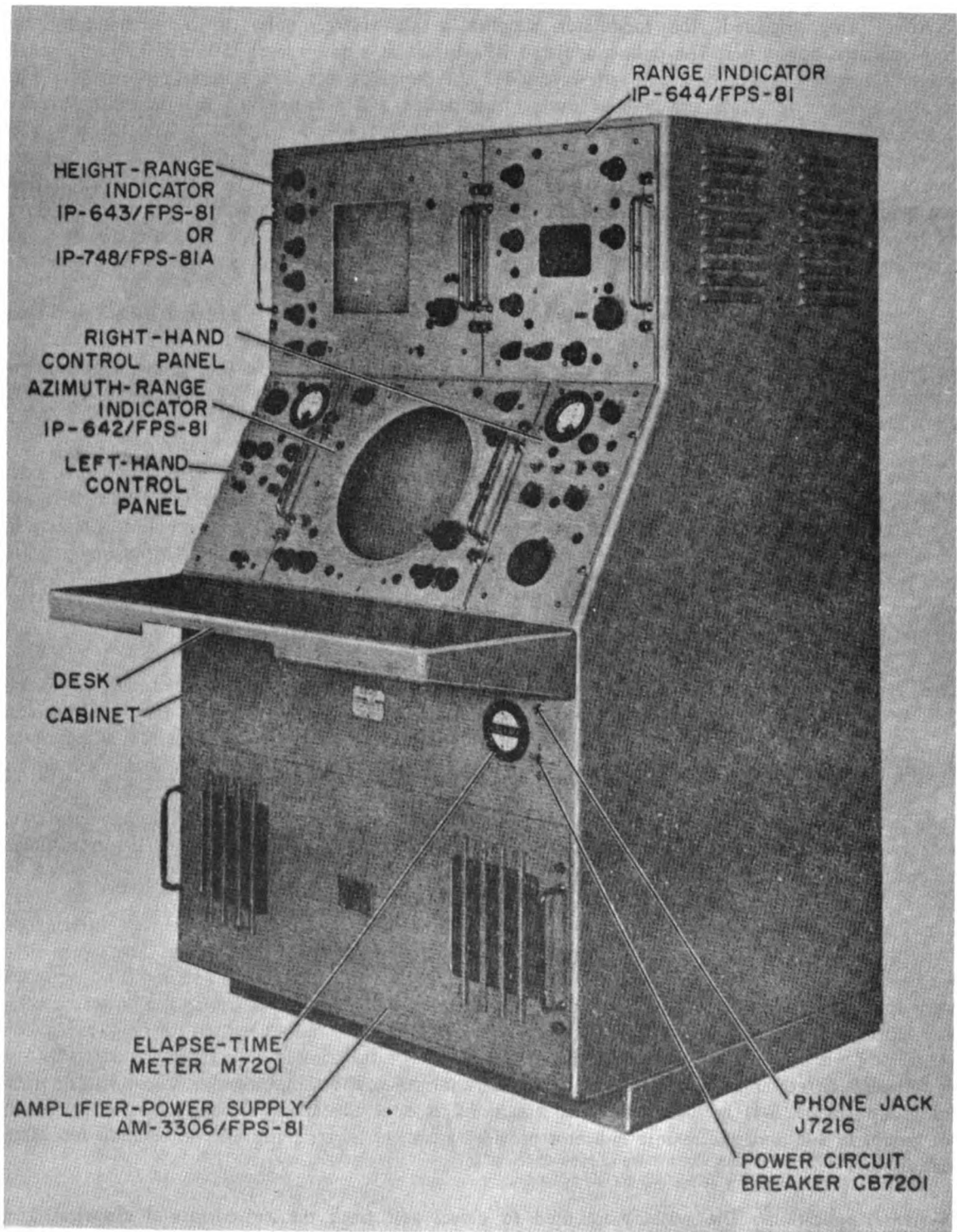


Figure 6 - 3. Control and Indicator Group

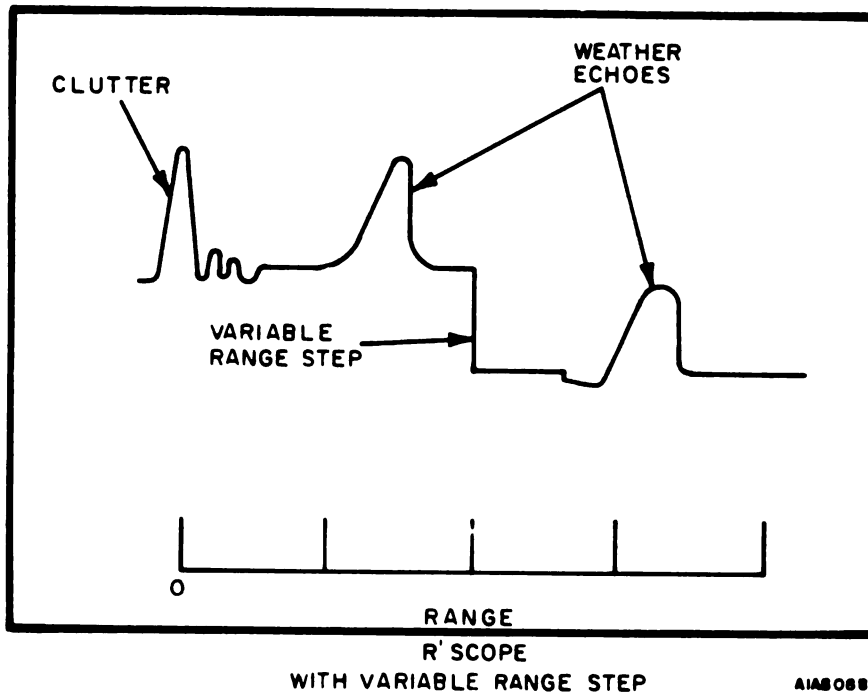
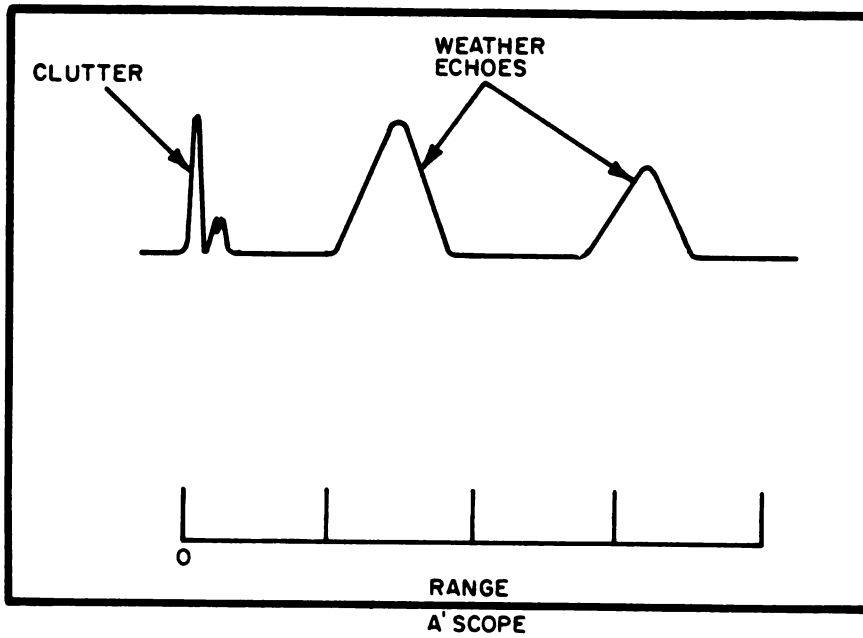


Figure 6 - 4. Range Indicator-Scope Displays

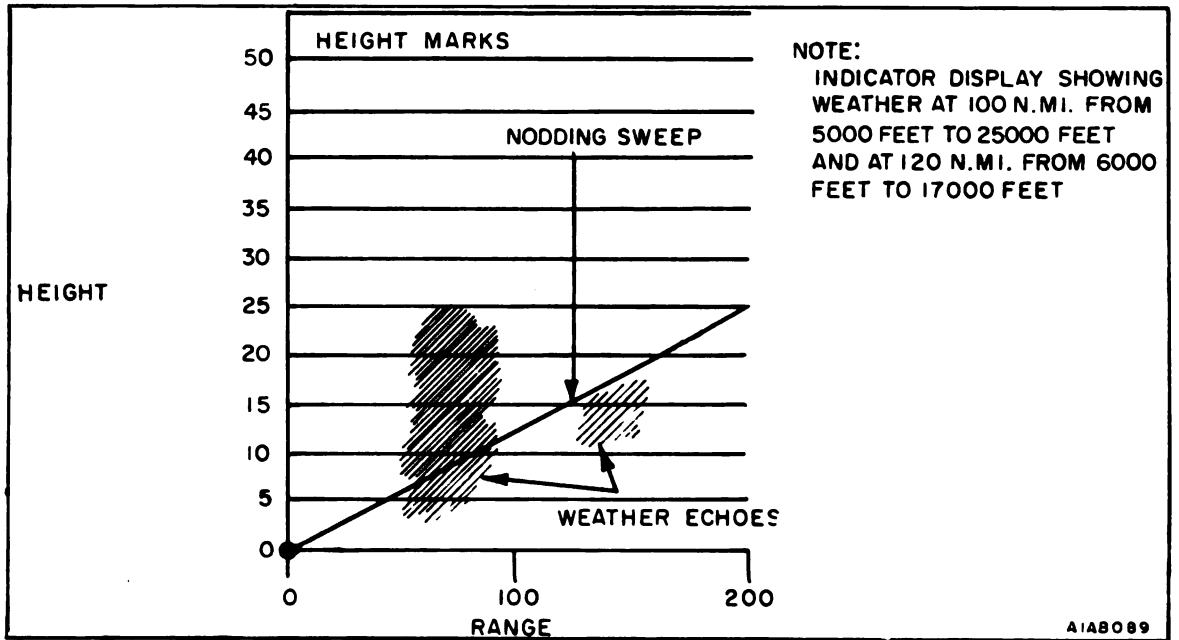


Figure 6 - 5. Range-Height Indicator Typical Display

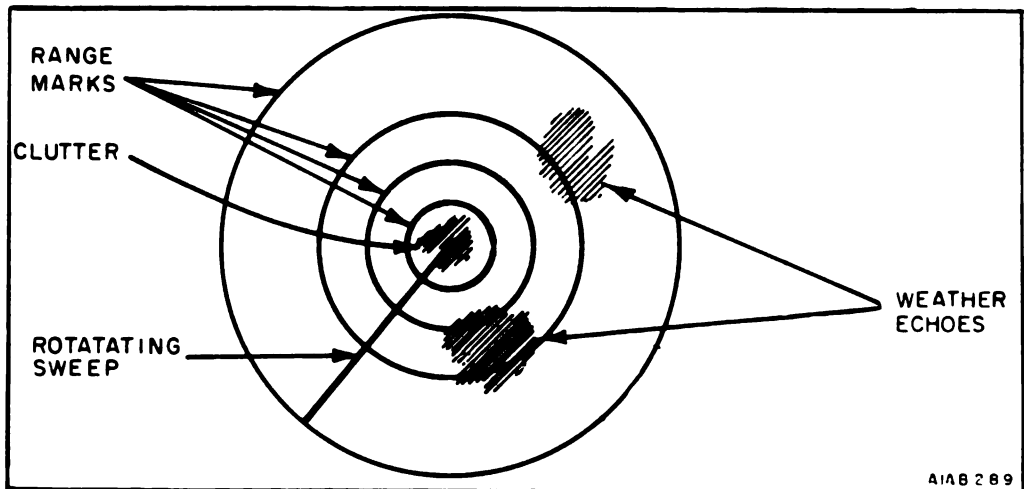


Figure 6 - 6. Azimuth-Range Indicator Typical Display

The "S band" system AN/FPS-41, radiates at a nominal peak power output of 500 kW. Its maximum range is approximately 250 NMI and a minimum range is about one-half NMI. It is capable of displaying off-center presentations of the PPI which permits the enlarging of a selected area for detailed study and the capability for separate PPI to be utilized for photographic purposes.

The systems in the field today operate in the C and S band. When new systems are developed, they will probably operate in the X band.

6.2.2 Transmissometer

The Transmissometer Set AN/GMQ-10, figure 6-7 is an electro-optical system developed by the National Bureau of Standards for measuring continuously the atmospheric transmission of a horizontal path between two fixed points and providing an indication of visibility at remote locations. The remote locations which receive the transmissometer signals are the meteorology office, where an ID-353/GMQ-10 recorder is housed and the air traffic control IFR room and control tower cab where Converter Indicator Group OA-7900/GMQ-10 is used to display the runway visual range. This unit provides a direct reading digital display which updated once every minute, thereby providing the radar controllers in the IFR room and the aircraft controller in the tower cab with visibility indications at the aircraft touchdown point. The discussions on both the transmissometer and converter indicator group (runway visual range indicator) will follow.

a. System Principles. The operating principle of the transmissometer is as follows: The projector emits a light beam of constant intensity. The receiver telescope picks up light energy from the projector inversely proportional to path attenuations due to fog, haze, snow or rain along the path of the beam. Light energy from the telescope impinges upon the cathode coating. The conductivity of the photocell establishes the pulse rate of the pulse-generating or trigger tube. The pulses are amplified and integrated at the indicator. The output of the indicator amplifier is a DC voltage proportional to the pulse rate generated at the trigger tube. The DC voltage is therefore proportional to the light energy entering the phototube, which in turn is a measure of visibility or the ability of visible light energy to penetrate the atmosphere between the projector and the receiver. The DC output is applied to the pen of a recorder which graphs the visibility with respect to time on a calibrated chart. Examples of transmissometer recordings are shown in figure 6-8. These charts show the visibility levels during periods of clear and variable weather, and moderate and heavy fog. The clear weather chart shows only the sensitivity level line across the top and the hourly shutdown spikes which indicate proper system operation. The variable weather chart shows the wide variations in visibility and the heavy fog shows the relatively consistent low readings.

b. System Configuration. The transmissometer set may be conveniently divided into two main subsystems: the receiving station and the transmitting station. The transmitting station consists of an optical projector, power supply, and a cable terminal chamber. The receiving station consists of an optical receiver, amplifier power supply cable terminal chamber, and an indicator.

It should be noted that there is a physical connection between the receiving station and the transmitting station consisting of a cable run connecting the cable terminal chambers of the two stations. The configuration of the transmissometer is shown in the block diagram, figure 6-9.

A brief description of the various transmissometer components is as follows:

The projector consists of an alignment system and a sealed-reflector lamp operated at a constant intensity. The projector directs the constant-intensity light-beam (about 140,000 candlepower) toward the receiver. The amount of light reaching the receiver varies with the density of the fog or haze in the path between the two units.

The projector power supply furnishes regulated lamp-filament voltage to the projector. Facilities are provided for making checks by turning the power off automatically at fixed intervals, and off manually from the indicator.

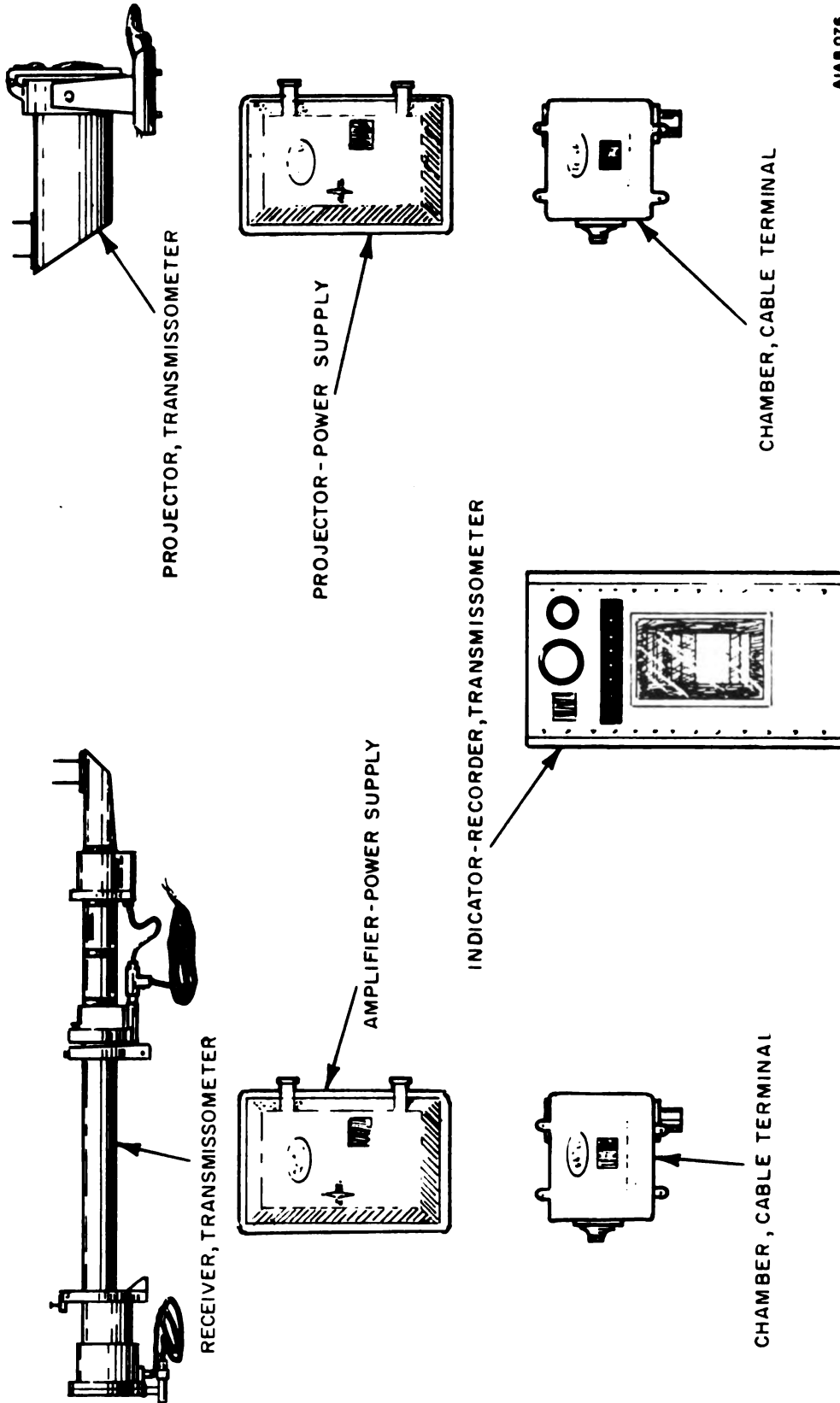


Figure 6 - 7. Component Parts of Transmissometer Set, AN/GMQ-10

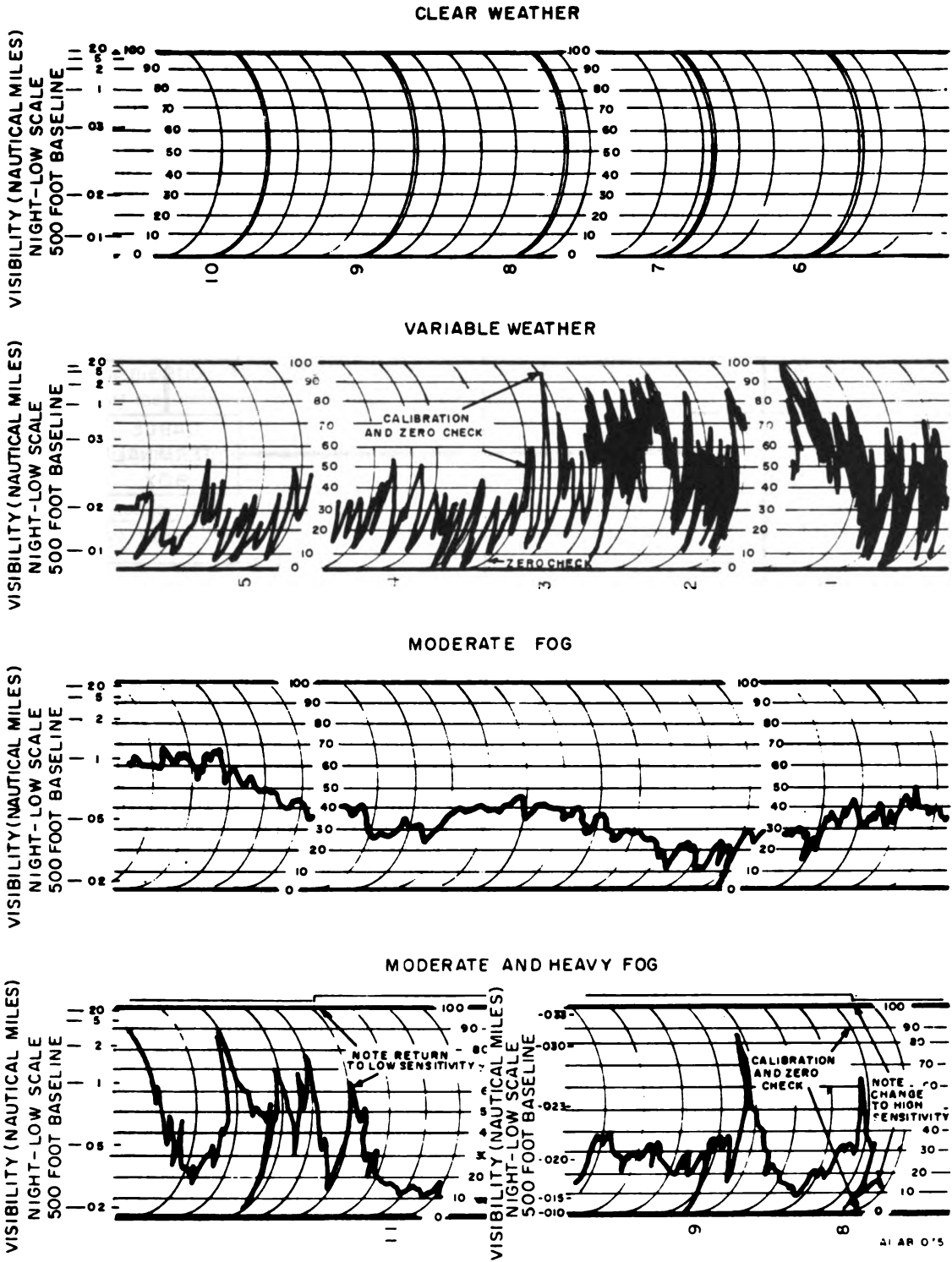


Figure 6 - 8. Examples of Transmissometer Records

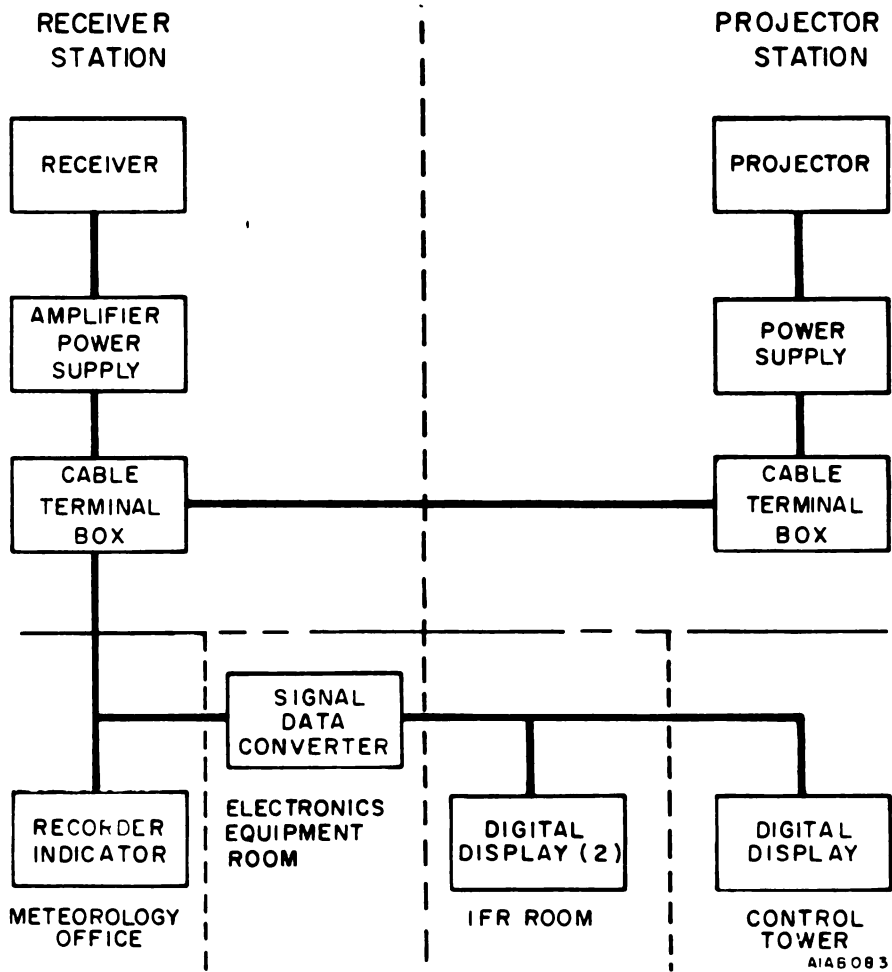


Figure 6 - 9. Transmissometer Configuration

The receiver consists of a telescope to collect light from the projector, and a photo-electric detector within the telescope, which converts received light intensity to a pulse modulated signal. At the same time the receiver excludes most background light. The pulse rate is proportional to the amount of light falling on the receiver. An iris diaphragm behind the objective lens of the telescope permits initial adjustment of the light falling on the photoelectric cell and hence the pulse rate. Adjustment screws at the rear of the telescope facilitate system collimation.

The amplifier-power supply unit provides regulated voltage for the photoelectric receiver and amplifies the pulse signal of the receiver for transmission to the indicator. A metering circuit which measures the pulse rate of the receiver is also provided to facilitate field adjustment.

The indicator is essentially a frequency meter which converts the pulse signal repetition rate to a proportional direct current which is a function of the light transmission. The scale of the indicator assembly meter is calibrated in visibility units between 0 and 100. A direct reading footage value is not shown.

The recorder provides a continuous record upon a strip chart of the indicator output. An auxiliary pen indicates the sensitivity range on which the indicator is operating.

In all models of transmissometer, the indicator and recorder are housed in a single unit which is known as the indicator-recorder.

The cable terminal chambers, two with each set, act as a housing and a junction for all cabling used in the set. One cable terminal chamber is mounted on the projector stand, and the other is mounted on the receiver stand.

c. System Application. Experience has shown that during periods of low visibility the actual visibility observations made at airfield weather stations by human observers are often not representative of the visibility conditions of the approach and touchdown areas. By using transmissometers it is possible to obtain measurements of visibility without stationing observers in these areas. The set also provides a more sensitive measurement of changes and a better indication of trends than is possible with periodic visual observations.

The transmissometer provides visibility measurements in the range of 0.05 to 2.0 miles in the daytime, and 0.1 to 2.0 miles in the nighttime when a 500-foot baseline is used. For visibilities greater than these, the indication is generally good, but measurement-accuracy decreases with increasing visibility.

6.2.3 Converter Indicator Group

a. System Principles. The Converter Indicator Group OA-7900/GMQ-10, shown in figure 6-10, is also referred to as the Runway Visual Range (RVR) indicator. It consists of a signal data converter and a digital display indicator.

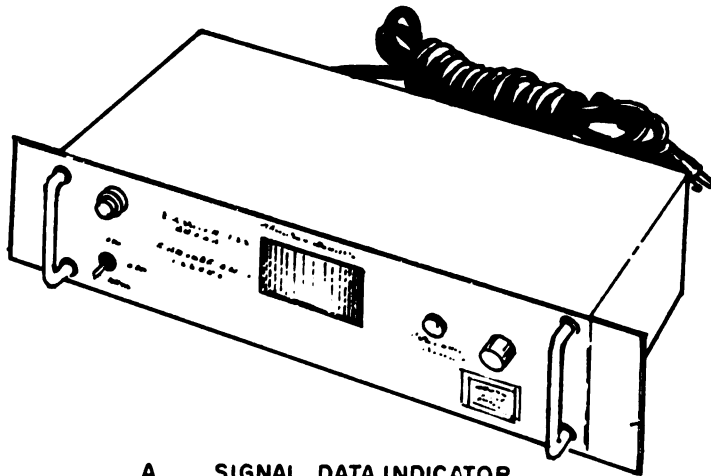
The converter-indicator group is designed to operate in conjunction with the Transmissometer Set AN/GMQ-10, and provide air traffic control personnel with direct reading runway visibility information. The existing indicator (ID-353) is not scaled for direct readout and is located in the meteorology office. The indicator is housed in the same cabinet with the recording unit. The transmissometer supplies light transmittance signals in the form of pulse repetition rates. These pulse rates are transmitted to the visual range converter where they are correlated with the empirically obtained visibility data encoded therein. The corresponding runway visual range value is then displayed by the displays once every minute.

The visual range values are displayed digitally in increments of 200 feet ranging from 1000 to 6000 feet. Values less than 1000 and greater than 6000 feet are displayed as 800 feet and 6200 feet respectively. Actually, the runway visual range values are displayed as two digit numbers which should be multiplied by a factor of 100 in order to obtain the correct reading in feet.

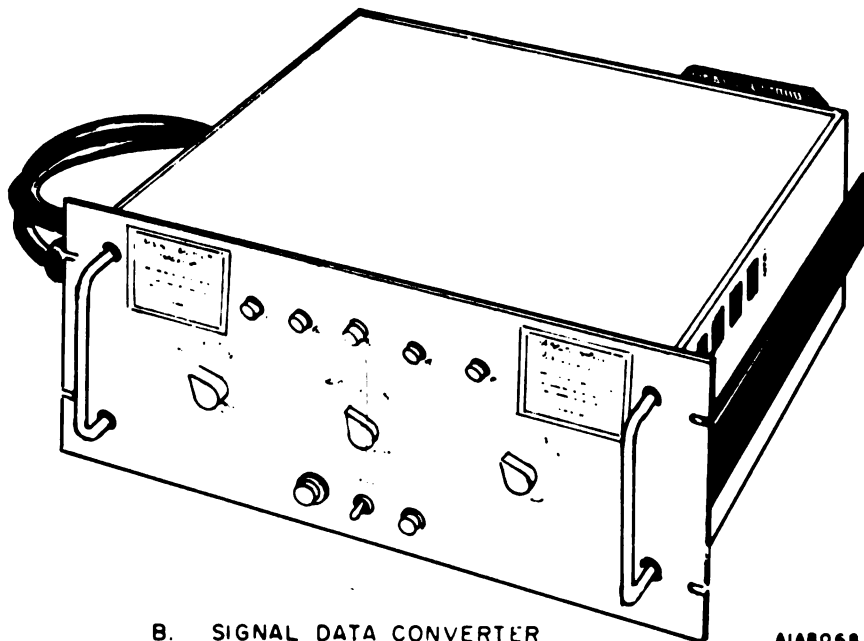
The system is designed to convert the transmittance pulse rates to their corresponding visual range values. Transition rates, i.e., pulse rates within one or two pulses per minute of the next lower or higher value, may be converted with an accuracy of +1, -0 increments (200 feet). Pulse rates and corresponding runway visual range values are available in tables. These values are based on the baseline distance between the transmissometer projector and receiver. For each different baseline length new runway visual range values must be computed and encoded on the encoder disc. The converter indicator group will convert pulse rates from transmissometer sets of any baseline length provided the visual range values to be displayed are properly related to the pulse rates, and encoded on the encoder disc.

The conversion and display process is completely digital. In fact, the system may be considered as being a "table look-up digital converter" with the capability of displaying its contents on remote displays. The equipment consists of digital circuits (flip-flips, counters, gates, drivers, etc.) and one electromechanical encoder unit.

b. System Configuration. The system is composed of a Signal Data Converter and a Digital Display Indicator each of which will be discussed briefly.



A. SIGNAL DATA INDICATOR



B. SIGNAL DATA CONVERTER

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Figure 6 - 10. Converter-Indicator Group, OA-7900/GMQ-10

The Signal Data Converter is comprised of six major circuits which include an encoder, time base generator, data and display control, data counter, signal coil drivers, and a power supply. These circuits perform specific functions of data conversion, selection, correlation, control, and display.

The encoder consists of an encoder disc, motor and brushes. The encoder disc is composed of eight tracks, six of runway visual range (3 day, 3 night), a start pulse, and ground. The runway visual range curves are sets of discrete pulse rate values encoded on concentric tracks of the disc, one for each of the six conditions. Each track consists of 27 segments each of which represents 200 feet of runway visual range.

The encoded disc is driven by the synchronous motor at 2 r/min. This results in two complete sets of data pulses generated every minute, only one set of data per minute is used, and the other is inhibited.

The Time Base Generator converts the incoming pulse rates into equivalent time intervals which are directly proportional to the pulse rates. This means that for higher pulse rates there will be longer time intervals and vice versa. These time intervals, are established with reference to an arbitrarily assumed zero point such as the start pulse. The correct time interval is then observed to be the time required for the time base counter to have a positive output every minute. The maximum and minimum time interval is one and zero minutes respectively.

The Data and Display Control circuit performs the function of controlling data pulses to the data counter, triggering the display set coils, clearing and presetting the data counter, and gating the difference pulses to the time base counter.

The Data Counter and Signal Coil Driver circuits consist of two binary counters and drivers. One binary counter is for the least significant digit and the other is for the most significant digit. Data pulses are applied to the first stage of the least significant digit counter. This divide-by-5 counter has an output which is applied to the most significant digit counter. Since there are but five numerals to be displayed in the least significant digit, only three binary bits are used for the binary coded decimal digit. The most significant digit uses four bits because of the counter configuration. The outputs of these counters are applied to the signal coil drivers for the display units. The drivers maintain the proper levels for the signal coils to sense and decode. Thus, at the end of the one-minute intervals, these coils will have been energized for "ones" and remained de-energized for "zeroes". Since the drivers invert their inputs, complementary outputs from the counters are used.

The display unit consists of two digital readouts, set coil drivers, filament transformer and switching relay. The readout units are of the 4-2-2-1 code requiring four bits per decimal digit. However, since the least significant digit displays only even numbers, the least significant bit is always zero and, therefore, not used.

c. System Application. The Converter Indicator Group OA-7900/GMQ-10 provides a digital display of visual range values for the Transmissometer Set AN/GMQ-12. The Indicator Group uses the transmissometer output to compute the visual range automatically and presents this information on a direct reading display. These digital display units are usually located in the control tower cab, and in the meteorology office. Each data converter is capable of driving three separate digital displays.

6.2.4 Semiautomatic Meteorological Station

The Semiautomatic Meteorological Station AN/GMQ-14 (figure 6-11) is an electromechanical instrument complex containing individual equipment systems with facilities to sense and record temperature, dewpoint, precipitation, pressure, wind speed, and wind direction. The station, as issued, includes a rain gage; a dewcel (dewpoint sensing element) housed in a shelter; a dewcel power supply; a dewpoint transmitter; an air temperature bulb; an air temperature transmitter; an equipment rack containing a combined rainfall, dewpoint, and temperature recorder; a 24-hour clock; a junction box; and a test cord. The barometer barograph, and wind recorder are added to the station and are separately issued.

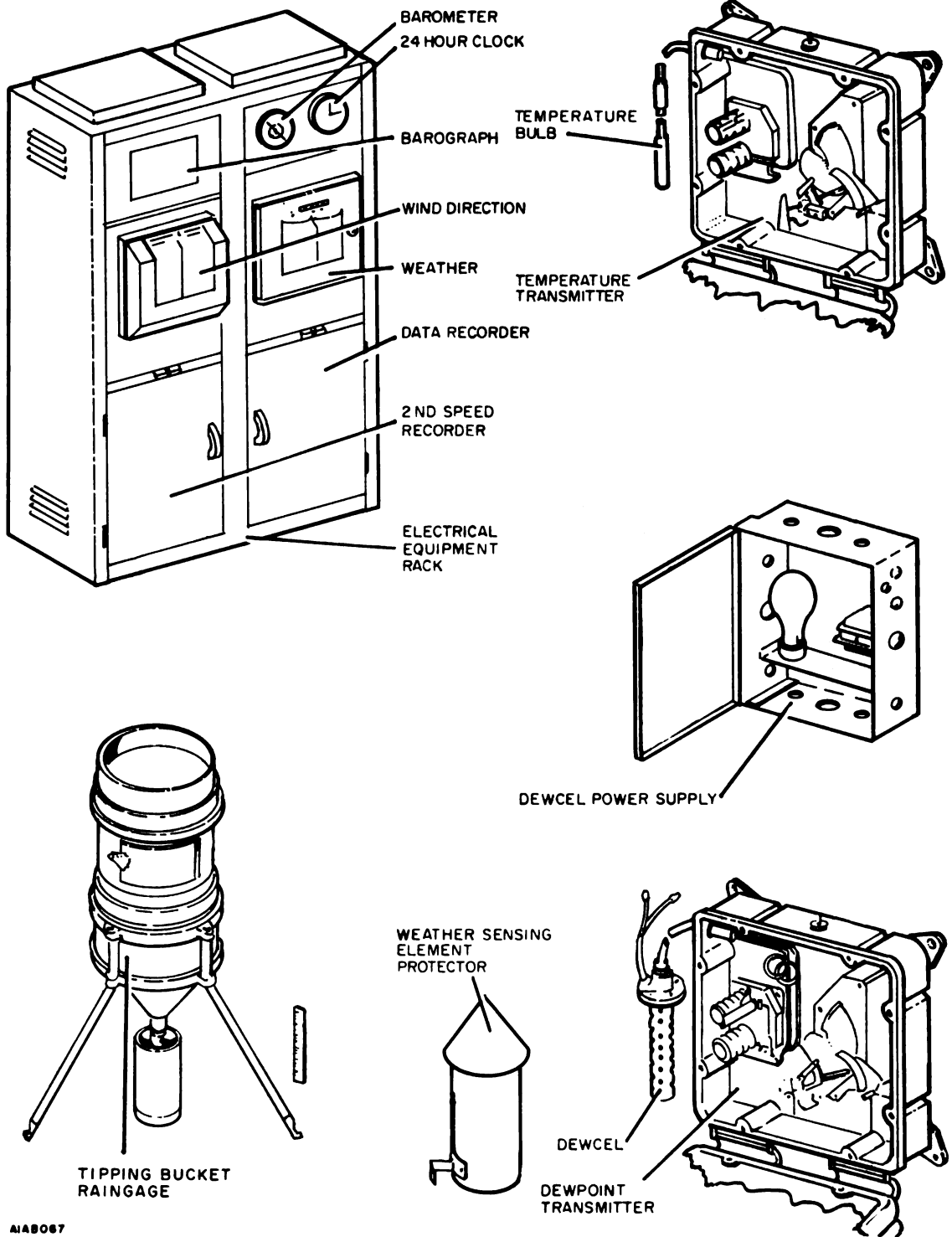


Figure 6 - 11. Semiautomatic Meteorological Station, AN/GMQ-14

a. System Principles. The Semiautomatic Meteorological station is a grouping of many independent electromechanical instruments (see figures 6-11 and 6-12). Principles of these instruments and their function will be discussed individually where applicable in the following text.

b. System Configuration. Three systems of the semiautomatic meteorological station discussed are the rainfall gaging and recording system, the dewpoint measuring and recording system, and the air temperature measuring and recording system. In addition the barometer and barograph which are purely mechanical systems are briefly described. For a detailed description of these instruments see handbooks NAVAER 50-30 ML448 -501, and NAVAER 50-30 FR-519.

(1) Open-Scale Barograph. A barograph is a pressure instrument that is used to obtain a continuous graphic picture of atmospheric pressure. The standard barograph used in the Navy today is the 4-day open-scale barograph, ML-3. It makes a continuous autographic record of the variations in barometric pressure.

The open-scale barograph (figure 6-13) is an instrument for the visible recording of minute changes in barometric pressure. Two Sylphon elements (aneroid cells) mounted one above the other in tandem are enclosed in a cylindrical case with a thumbscrew adjustment knob at the top controlling the setting or adjustment of the pressure element and hence, the pen setting. The tandem element magnifies the motion resulting from the expansion or contraction of the Sylphon cells with atmospheric pressure changes. The lever linkage system further magnifies the scale value of the pressure element movement that is transmitted to the pen arm which carries the pen. A continuous record of the pressure is made on a chart which is graduated for every 1-millibar change in pressure and can be read fairly accurately to one-tenth of a millibar. The chart is mounted on a drum operated by a high-grade, 8-day clock, geared to produce one chart revolution in 4 days.

The open-scale barograph is sensitive to jars and shocks. To minimize the effects of jars insofar as possible, dashpots are used.

The dashpots are two oil-filled cylinders in which a piston in each moves to retard or dampen sudden movements of the pen arm due to shock. The dashpot pistons do not affect the normal variations and changes in the pen arm setting produced by changes in atmospheric pressure.

The microbarograph has a range from 965 to 1,050 millibars, and an accuracy to within 0.68 millibar (mb).

(2) The Precision Aneroid Barometer (ML-448/UM). Used aboard ship and in the Semi-Automatic Meteorological Station AN/GMQ-14 is constructed to accurately indicate atmospheric pressure in millibars.

The pressure element of the precision aneroid is a Sylphon cell. This element is sensitive to minute variations in atmospheric pressure. The Sylphon cell is connected to an indicating pointer or index by means of a quadrant gear and lever system in such a manner that the movement of the cell, for a given change in atmospheric pressure, is greatly magnified by the linkage and is transmitted to the index hand or pointer with a minimum of friction in the moving parts.

The precision aneroid barometer is compensated for temperature changes; therefore, the indicated readings require no temperature corrections as are required for the mercurial barometer.

Aneroid barometers utilize spring pressure to balance the effect of the air pressure on the Sylphon cell. Therefore, no corrections for effect of latitude (gravity) need be applied. The only authorized field adjustment to be made on this instrument is the current pressure adjustment. Before each reading, tap the case slightly to remove the drag effects of linkage friction. The ML-448/UM has a range of pressure from 910 to 1,060 mb and in the normal range of sea level pressures is accurate to within 0.67 mb. Outside the normal sea level pressure range it is still accurate to within 1.0 mb. This barometer is normally installed in the AN/GMQ-14. (See figure 6-14).

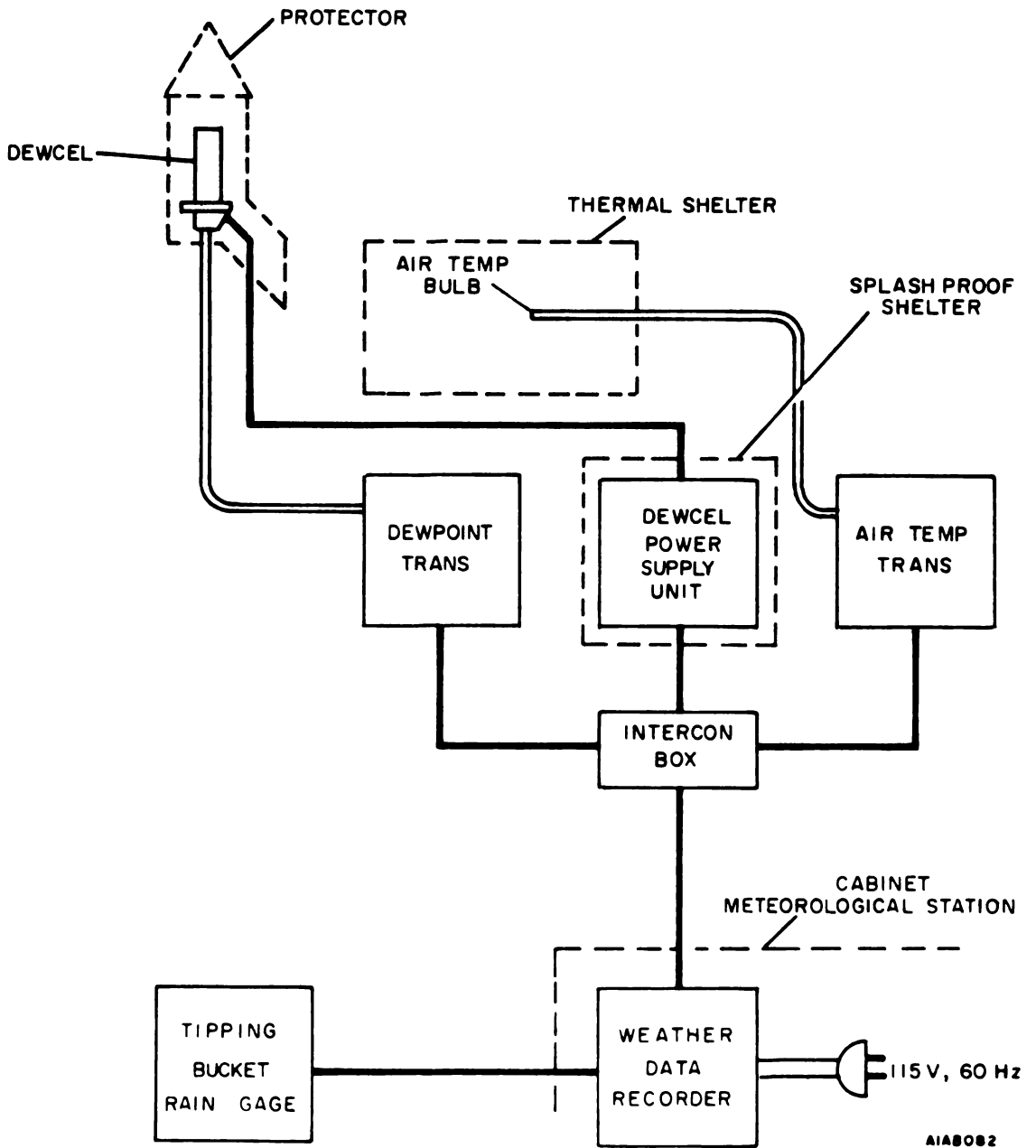


Figure 6 - 12. Semiautomatic Meteorological Station, AN/GMQ-14, Block Diagram

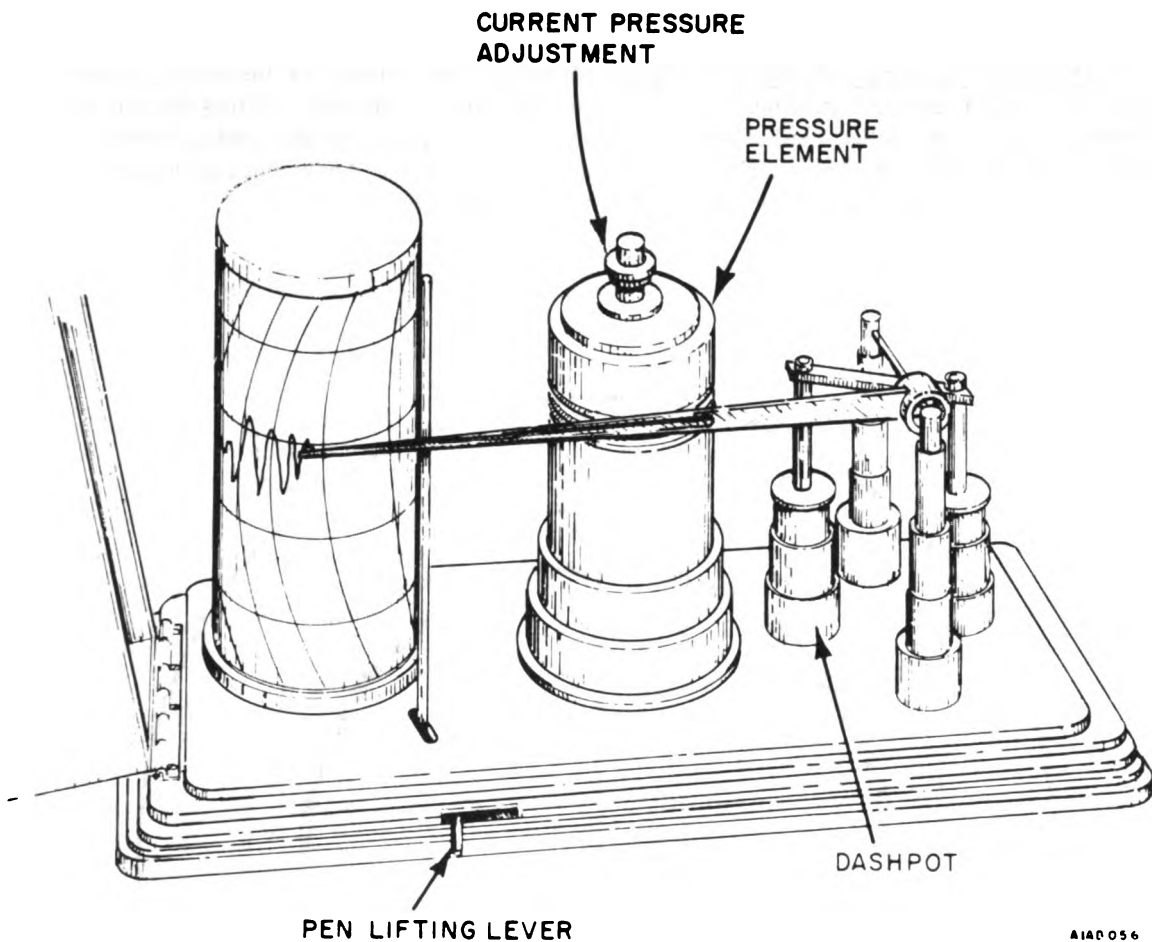


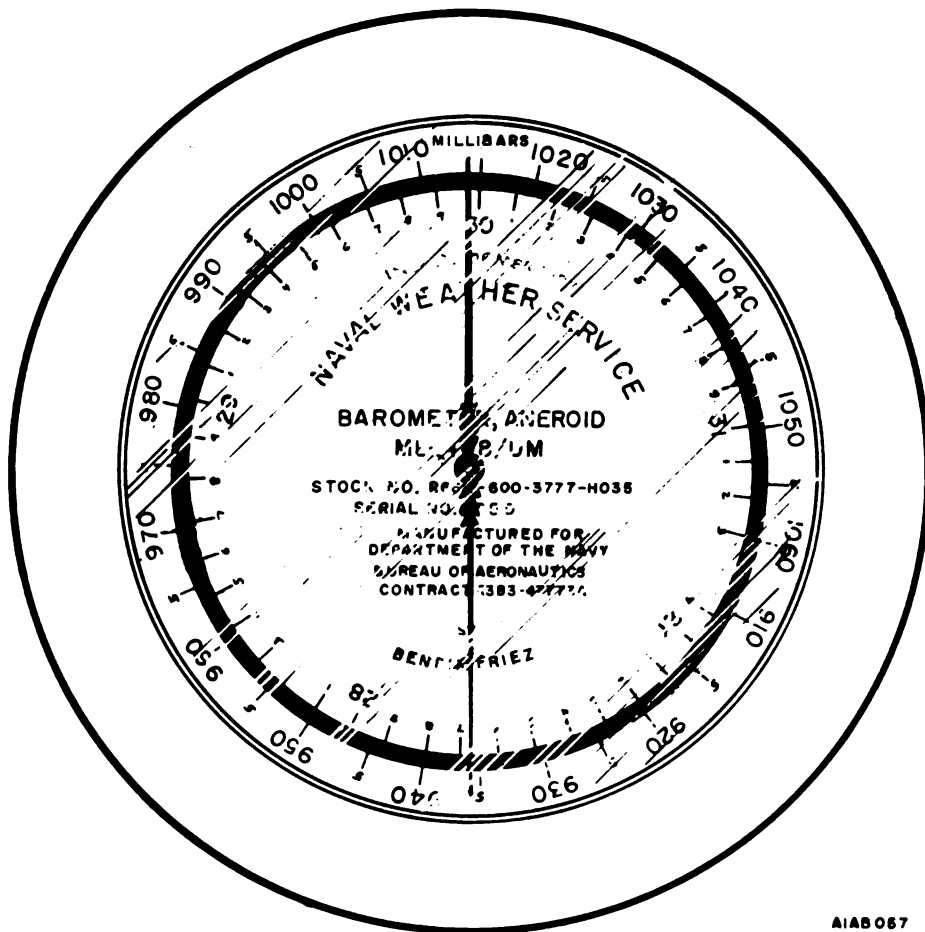
Figure 6 - 13. Open-Scale Barograph

(3) **Rainfall Gaging and Recording System.** A tipping bucket rain gage is mounted in a housing which permits rain to fall directly on the gage. The tipping bucket is a two-compartment container which pivots within a casting. Rainfall enters through the upper funnel in the housing into one compartment of the bucket until 0.01 inch of rainfall has accumulated. The weight of this amount of rain unbalances the bucket, causing the unit to tip on its pivots, dumping the accumulated rainwater, and moving the other compartment directly under the funnel.

When the bucket tips, its rainfall content falls into a funnel beneath the bucket. At the base of the funnel is a cock, which in its closed position permits the rain to collect so that it may be drained into the cylinder below the funnel at the time of measurement. If no purpose in measuring the rainfall at a given time exists, the cock may be left open and the collector removed; the run-off water will be evaporated and absorbed along with the rainfall.

The tipping motion of the bucket actuates a mercury switch in the casting. Momentary contact is established within the switch, causing an electrical impulse to be sent to the recorder, thereby tripping a relay. Each time the signal is received, the rainfall counter registers the 0.01 inch of rain, and the rainfall recording pen moves laterally one step. The pen has a range limit of five steps before reversing its direction of motion.

(4) Dewpoint Measuring and Recording System. Moisture determination by the dewcel is based on the fact that water vapor pressure in contact with a saturated lithium chloride solution has an equilibrium temperature at which this solution neither absorbs nor gives up moisture to the surrounding atmosphere. Below this equilibrium temperature the lithium chloride solution absorbs moisture. Above this equilibrium temperature the saturated lithium chloride solution dries out until only dry crystals are left.



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Figure 6 - 14. Barometer AN/GMQ-14

The dewcel (figure 6-11), covered with woven glass tape impregnated with lithium chloride and wrapped with gold or silver wires, measures the dewpoint temperature. If the temperature of the dewcel is below the equilibrium temperature, the lithium chloride absorbs moisture from the atmosphere, the conductivity of the solution on the tape increases and the dewcel is raised to equilibrium temperature.

The current for the dewcel passes through the dewcel power supply (figure 6-11) which actuates the temperature element in the transmitter assembly, causing it to position a cam follower, the cam for which is driven by a synchronous motor. The telemeter transmitter converts the position of this cam follower into a signal to the recorder having a time duration proportional to the dewpoint temperature. This signal drives a cam in the recorder assembly which operates a pen which records the data on the left side of the chart.

(5) Air Temperature Measuring and Recording System. The temperature measuring and recording system operates similarly to the dewpoint measuring and recording system. Instead of the dewcel, a temperature bulb (figure 6-12) is used and no separate power supply is required. The temperature bulb is similar to the dewcel minus the glass tape and wire wrappings. The signal is recorded on the right half of the chart.

(6) Recorder and Case Assembly. The recorder and case assembly housed in the electrical equipment rack (figures 6-11 and 6-15) is a convenient means of combining in a single assembly the receivers, recorders, and power controls for the three systems. The receivers for the dewpoint and temperature systems each contain a synchronous motor, both of which are at the back of the recorder. Another synchronous motor drives the chart. One ink reservoir supplies the air temperature and dewpoint recording pens. The rainfall recording pen has an independent ink reservoir. The power input for all three systems as well as for the recorder is in the recorder case assembly and is designed for 115-volt, 60-Hz alternating current. The power switch for the three systems, the recorder lights switch, and the chart drive speed switch are also in the recorder case.

c. System Application. The semiautomatic meteorological station performs all of the basic meteorological observations necessary for local forecasting and local climatological historical records.

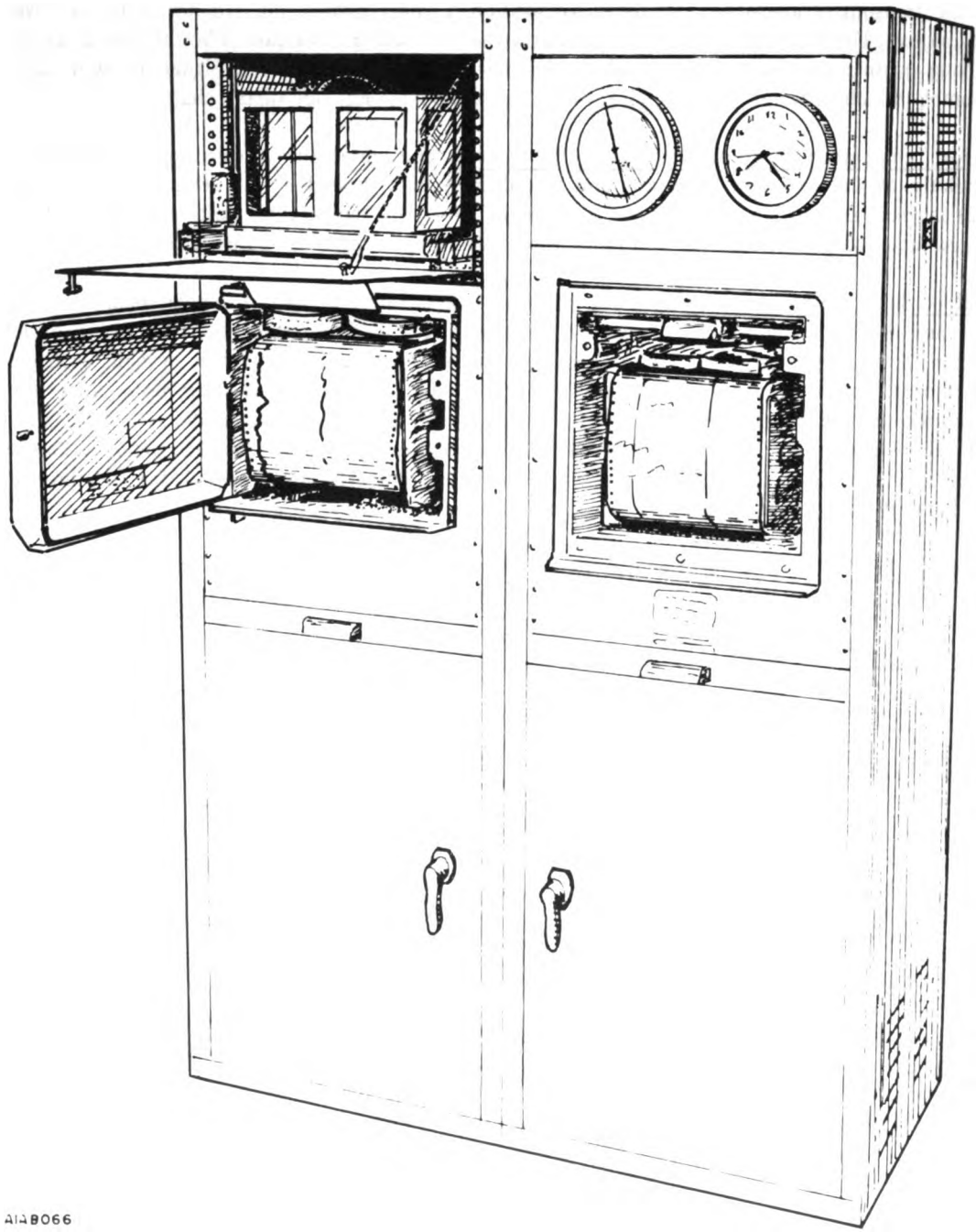
6.2.5 Cloud-Height Set

a. System Principles. Cloud-height set is a fixed ground electronic meteorological device capable of measuring cloud heights up to 5,000 feet when an optimum baseline of 400 feet is used. This equipment is capable of measuring cloud heights during daylight hours as well as at night.

The projector and detector, two of the major components of the cloud-height set, use the basic principle of triangulation to measure cloud heights (figure 6-16). The projector directs a beam of light to the clouds at a measurable angle. Light signals reflected from the clouds or other objects within the vertical sector over the detector are detected and amplified by that unit. The known angle of projection and the known fixed distance between projector and detector furnish the basis for accurate measurement of cloud heights over the detector unit. These data are transmitted over landlines to a recorder in the weather station.

The accuracy of the cloud-height measurements are affected by many factors, some of which are fixed and some variable. The variable factors which affect the accuracy of the data are changes in the sensitivity of the detector photocell and background light reflections. Fixed factors affecting cloud-height measurements are reduced gain of the detector amplifier, alignment of the system, cleanliness, and the aging of the projector high intensity lamps. Assuming that all previously mentioned conditions remain unchanged, the length of the system baseline is the most important single factor in determining the accuracy of the system. Thus the baseline and the angle at which the light beam subtends the cloud base determines the height of the clouds.

It may be readily noted that at an angle of 30 degrees the difference in cloud height for a change of one degree is nine feet on a 400-foot baseline as compared to a 14- and 18-foot change for baselines of 600 and 800 feet respectively. This change in height varies rapidly with increasing angles, as may be noted in table 6-1, which shows the effect of varying baseline and angle of interception of the projected light beam.



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Figure 6 - 15. Electrical Equipment Rack

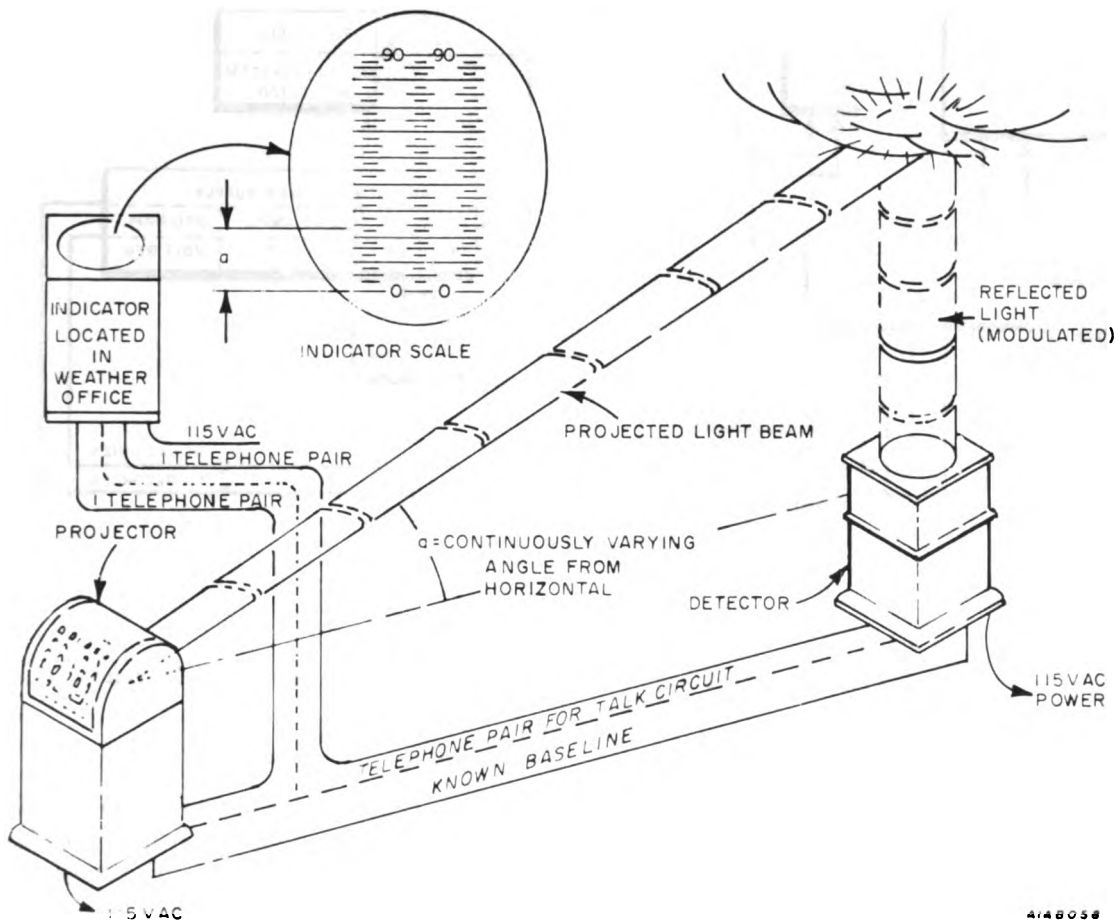


Figure 6 - 16. Cloud-Height Set, AN/GMQ-13, Typical Installation

b. **System Configuration.** The Cloud-Height Set AN/GMQ-13 or rotating beam ceilometer is composed of a detector, a projector, a recorder, and in some instances, an indicator, as shown in figure 6-17. The system is powered by 115-volt, 60-Hz AC.

The detector is located at a known fixed distance (usually 400 feet) from the projector and the detector field of view is directed vertically upward.

On installation the detector optical system is directed to the zenith. As the projector beam sweeps the cloud base, the light reflected from the cloud base in the detector field of view is received by the detector optical system (a parabolic reflector and photo-electric cell) and amplified by the detector amplifier. The detector-amplifier output is fed by cables or radio link to the recorder and/or indicator. Figure 6-18 shows a cloud-height detector.

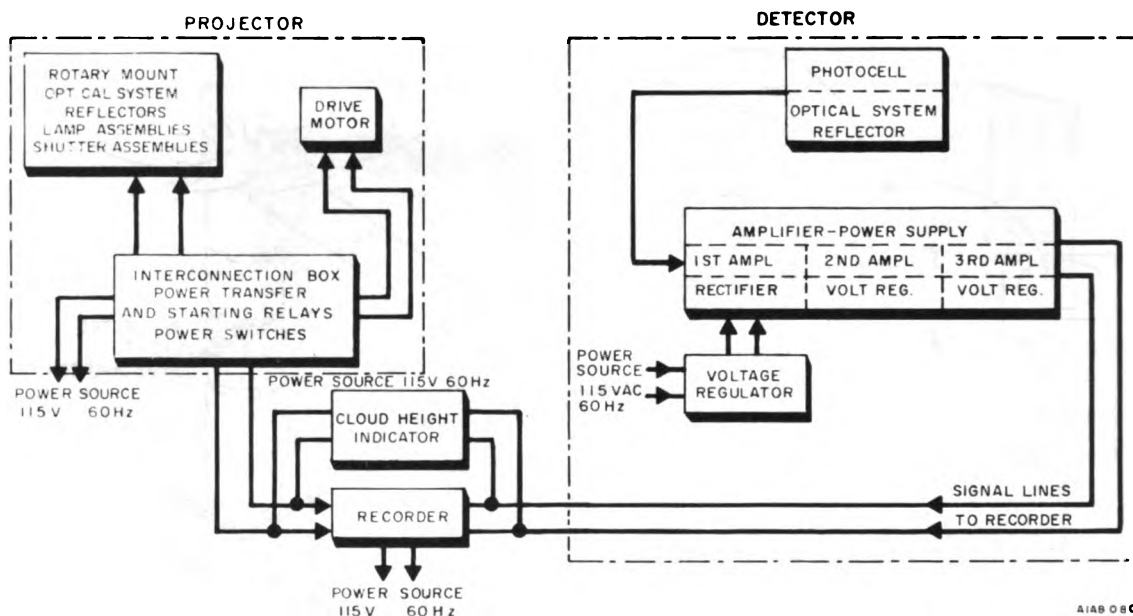


Figure 6 - 17. Cloud Height Set, AN/GMQ-13, Simplified Block Diagram

c. System Application. The cloud-height set is used on relatively short baselines of 400 to 900 feet with the result that the highest usable value of cloud height measurement is approximately 5,000 feet. The standard baseline is 400 feet. Cloud heights can be quite accurately measured in the height range of interest to pilots during final approach.

The Cloud Height-Set System, designed to give frequent measurements from a remote location, is used primarily at the end of an instrument runway. Since the equipment does not involve synchros or other devices requiring multiconductor cables, it is relatively easy to install a remote site.

Field site selection is influenced by: suitability of site location for equipment operation, site observational desirability, ready access for maintenance, and installation costs.

Equipment operational efficiency is influenced by EMI, vibrations, strong induction field, or proximity to high intensity lamps. The detector should be located in the sight of and the same elevation as the projector to facilitate alignment and maintenance. From an observational standpoint, it is desirable to install the equipment near the middle marker of the most commonly used instrument runway approach zone.

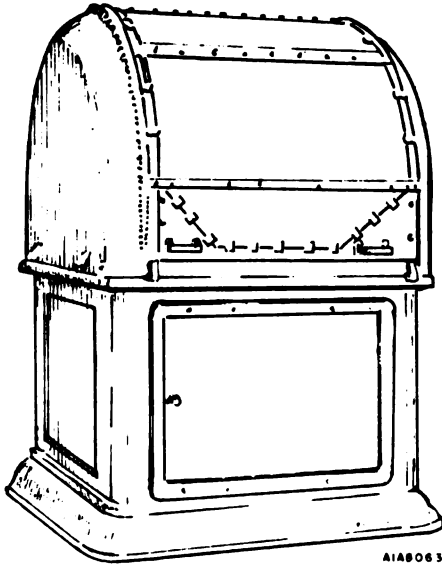


Figure 6 - 18. Cloud Height Detector

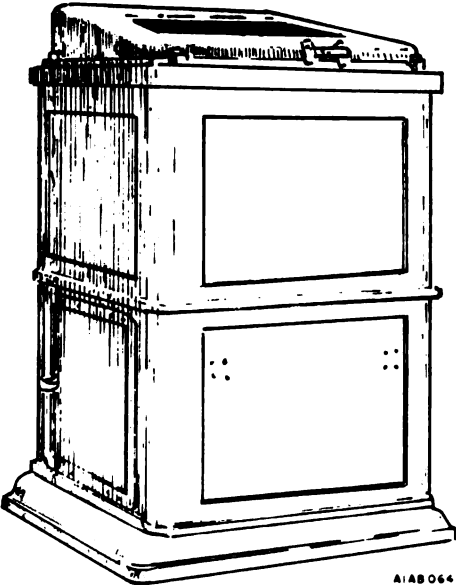
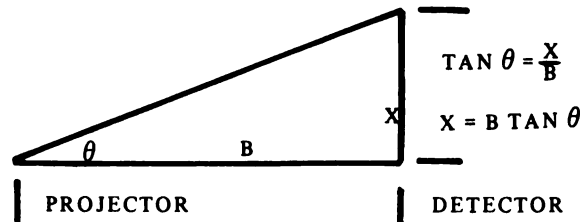


Figure 6 - 19. Cloud Height Projector

Table 6-1. Height Measurement Baseline Distance Versus Projection Angle



θ	15°	30°	45°	60°	75°
B					
400'	107 ^{+7'} _{-8'}	231 ^{+9'} _{-10'}	400 ±14'	693 ^{+28'} _{-27'}	1493 ^{+111'} _{-99'}
600'	161 ±11'	346 ±14'	600 ±21'	1039 ^{+43'} _{-41'}	2239 ^{+167'} _{-147'}
800'	214 ±15'	462 ^{+18'} _{-19'}	800 ±28'	1385 ^{+58'} _{-54'}	2982 ^{+226'} _{-193'}

Note: Cloud height differences for a ±1° change in projection indicated by equivalent ± values.

The projector comprises two identical optical systems mounted back-to-back on a rotary mount such that modulated light beams which they project are continuously rotated in the plane of the detector's field of view. The light beams are produced by lamps mounted at the focal point of a parabolic reflector and they produce up to 3,000 candlepower. At some point in the rotation each portion of the detector field of view from the top of the detector to the zenith is illuminated. Any cloud or other reflective obstruction will cause a light spot to occur as the light beams pass. The detector photocell and amplifier produce a signal voltage corresponding to the intensity of the spot on the clouds. Two light beams are used to increase the rate of measurement and to provide a safety factor in case of failure on one optical system.

The rotary mount, which carries the two back-to-back optical systems, rotates at 5 r/min, i.e., the rotary mount makes a complete revolution in 12 seconds and the optical system projects a beam every 6 seconds. However, since each optical system is blocked off for one-half of the revolution through the upper semicircle, the actual sweep of each optical system is 3 seconds in duration. Each measuring sweep, therefore, lasts 3 seconds, and a measuring sweep is provided every 6 seconds. Figure 6-19 shows a cloud-height projector.

The indicator consists of a long-persistence cathode-ray tube (CRT) with the appropriate electronic and mechanical circuits and is housed in the weather office. The electron beam of the CRT moves up the vertical axis of the tube in synchronism with the rotation of the projector.

Light reflected from a cloud results in a signal from the detector and is fed to the CRT indicator. There it causes the electron beam to widen. As the beam moves up the face of the CRT, the point at which the electron beam widens corresponds to the angle of the projector at which the light beam strikes the cloud over the detector. The face of the CRT is calibrated in degrees (corresponding to the angle of projector rotation), and this angular measurement can readily be converted into height by reference to precomputed tables (figure 6-20).

One recorder which has been developed for use with this equipment is of the facsimile type. The horizontal motion of the stylus is synchronized with the rotation of the projector, and the density of the record varies directly with signal strength.

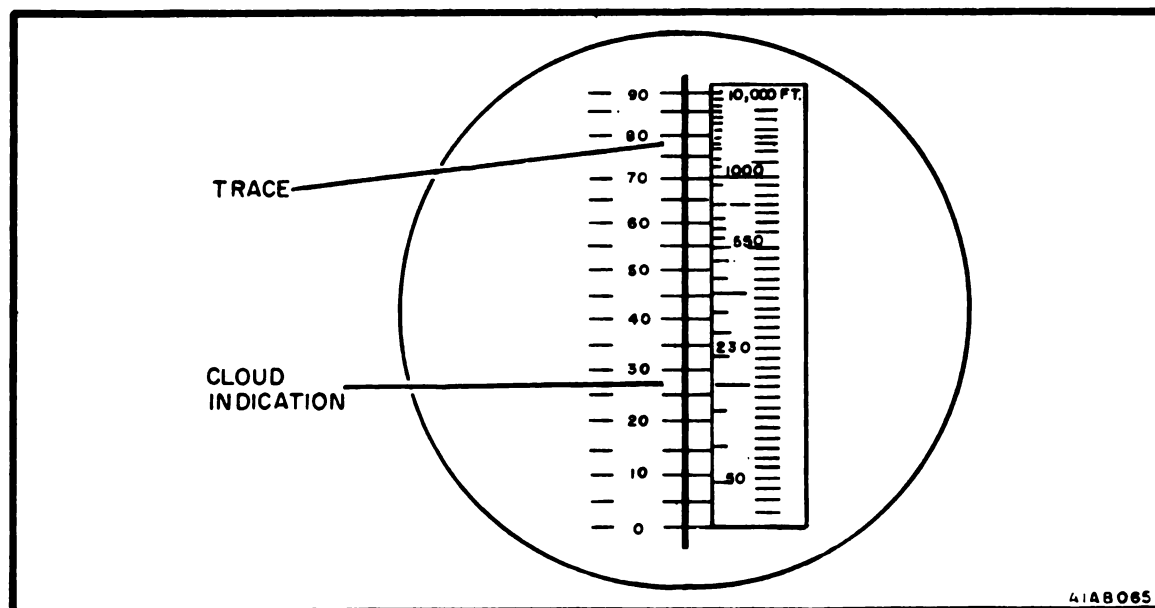


Figure 6 - 20. Cathode-Ray Tube Display With Gradations

6.2.6 Wind Measuring Systems

a. System Principles. The system in use today for wind measurement, both velocity and direction, is an anemometer and vane combination. The vane tracks the directional changes and the anemometer converts wind speed to rotation. The system block diagram is shown in figure 6-21.

b. System Configuration. The Wind Measuring Set AN/UMQ-5 (figure 6-22) is the standard equipment designed to provide a visual indication and/or a printed record of wind direction and speed values. Various options of the system are provided to permit continuous recording of wind direction and speed values at several measuring sites.

A set includes a minimum of one transmitter, one support, and one recorder or indicator. The basic system is capable of operating a maximum of 6 indicators or recorders as designed. It is possible to use one of the six indicator outputs to connect an Electronic Control Amplifier AM-6181/UM and to drive an additional 24 ID-1649/UM wind direction and speed indicators from this same transmitter. The AM-6118/UM and ID-1649/UM are auxiliary equipment and not part of UMQ-5 set.

The Transmitter ML-400() (figure 6-22) is a vane mounted on a vertical support. The tail of the vane brings the nose into wind. The nose consists primarily of a screw-type impeller directly coupled to a tachometer-magneto. The magneto voltage output is directly proportional to the wind speed and is connected to the plug in the transmitter-vertical support through brushes and sliprings, then down to the indicator or recorder where the voltmeter automatically indicates or records the voltage in knots. Rotational motion of the vane is transmitted mechanically to a synchro located inside the enlarged section of the vertical support.

The synchro transmitter is placed on top of a connector housing. The electrical cable leading from the housing through the support then goes to any one or all of any combination of six repeaters, all indicators or all recorders, or a combination of them. A synchro receiver converts the electrical energy into wind direction indication or recording. The transmitter is designed to carry the six repeaters.

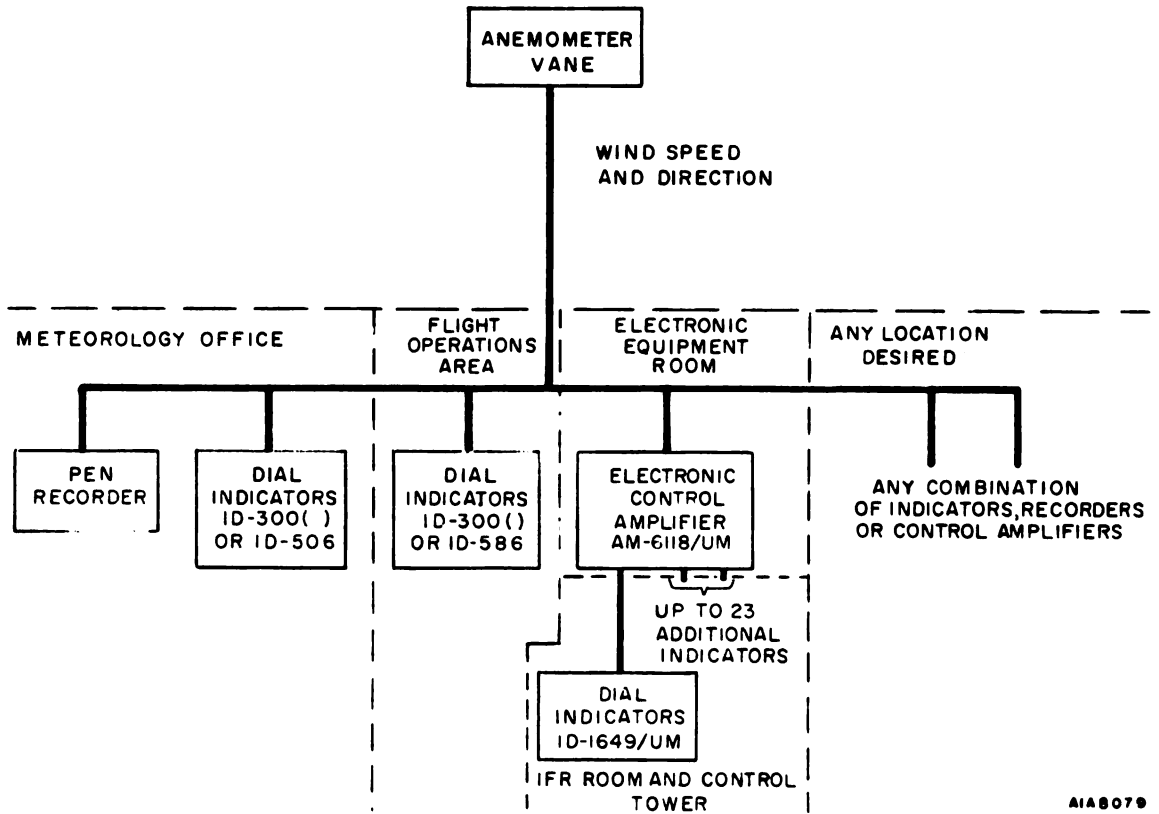
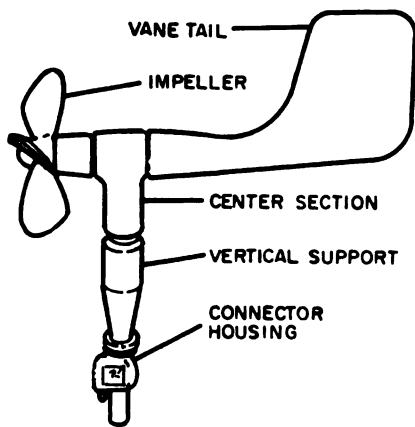


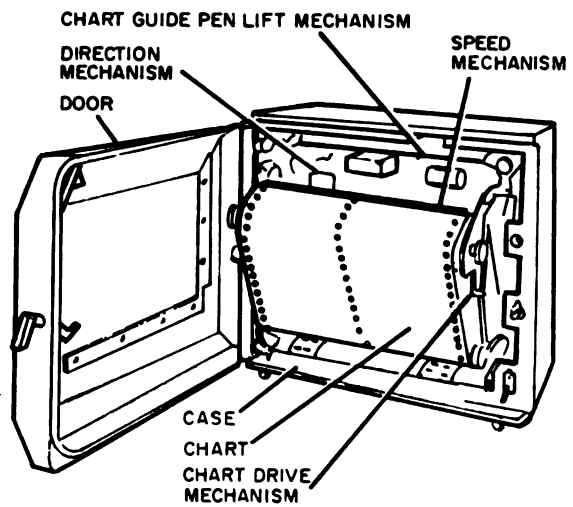
Figure 6 - 21. Wind Measuring Set, AN/UMQ-5, and Optional Indicating Equipment, Simplified Block Diagram

The transmitter vane aligns itself to within 3 degrees of the true wind direction when displaced 8 degrees from the true direction of a 4.4-knot wind. The wind speed is accurate to within ± 1.5 knots for winds of 3 knots to 40 knots and 3 knots for winds of 40 to 120 knots.

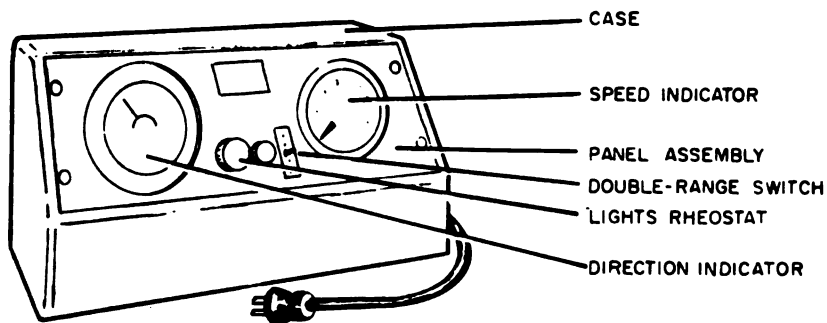
The Indicator ID-300() (figure 6-22) consists of two units: the panel assembly and the mounting case which holds the panel assembly. The panel assembly contains the wind direction indicator and the wind speed indicator positioned in two 4-inch dials, the lighting circuits, and the double-range switch for the speed section. The wind-direction indicator consists of a synchro follower on whose rotor shaft is mounted a pointer that indicates wind direction values on a 360 degree circular scale. The dial is graduated at the cardinal and intercardinal compass points as well as every 5 degrees from north. The wind speed indicator is a precision voltmeter whose pointer indicates wind speed in knots on a 270 degree scale whose ranges are 0 to 60 knots or 0 to 120 knots. Selection of ranges is accomplished by the use of the double-range switch to change range from 0 to 60 knots to 0 to 120 knots. A tapped dummy load resistor is mounted on a rear of the panel assembly for use in establishing the proper load conditions on the magneto in the transmitter. The lighting circuit of a rheostat, transformer, and seven 6-volt dial lights.



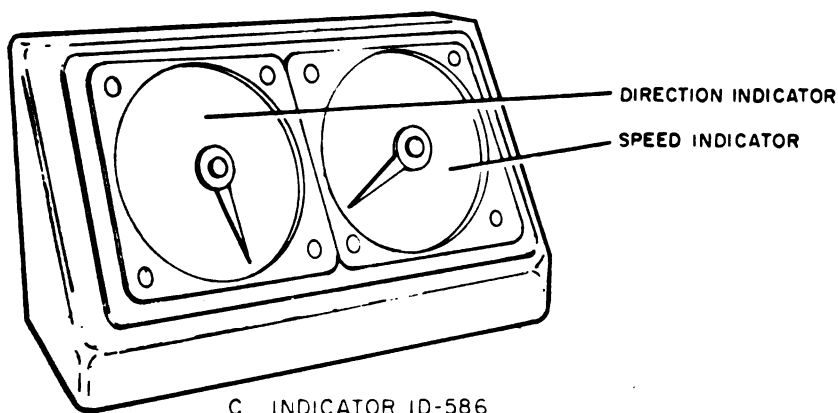
A TRANSMITTER



D RECORDER



B INDICATOR ID-300



C INDICATOR ID-586

AIAB117

Figure 6 - 22. Wind Measuring Set, AN/UMQ-S ()

This indicator is accurate to within ± 2 degrees in wind direction and ± 1.2 knots on the 0- to 120-knot wind speed range.

The Indicator ID-586 (figure 6-22) consists of a speed indicator (voltmeter) and a direction indicator (synchro) mounted on a panel which is inserted in a case. The two indicators position their pointers on 8-inch dials. A dummy-load resistor is attached to the terminal board mounted in the bottom of the case. No panel lighting or dual-range circuits are installed in this indicator. Each of the indicating assemblies (speed and direction) is removable and may be installed individually.

The indicator is accurate to within ± 2 degrees in wind direction and ± 1.2 knots in wind speed.

The Recorder RD-108 (figure 6-22) basically consists of a direction mechanism, speed mechanism, chart drive mechanism, chart guidepen lift mechanisms, chart, and case. A description of each is given in the following paragraphs.

The recorder is accurate to within ± 4 degrees in wind direction and ± 1.2 knots in wind speed.

The wind direction mechanism consists of a synchro follower which positions the pen through a gear train which converts 540 wind degrees of synchro rotation to approximately 62 degrees of pen rotation corresponding to 540 wind degrees of the chart. Whenever wind conditions are such that the pen would run off the chart in recording wind direction, a repositioning mechanism is energized. This mechanism removes power from the synchro, drives the pen to the approximate center of the chart, and then returns power to the synchro so that recording is continued after the pen is displaced 360 wind degrees toward the middle of the chart.

The wind speed mechanism consists of a voltmeter mechanism which drives the wind speed pen across the speed section of the chart. Also included in the speed section is a dummy-load resistor connected across a terminal board. The pen and inking system of the speed is identical to that of the direction section.

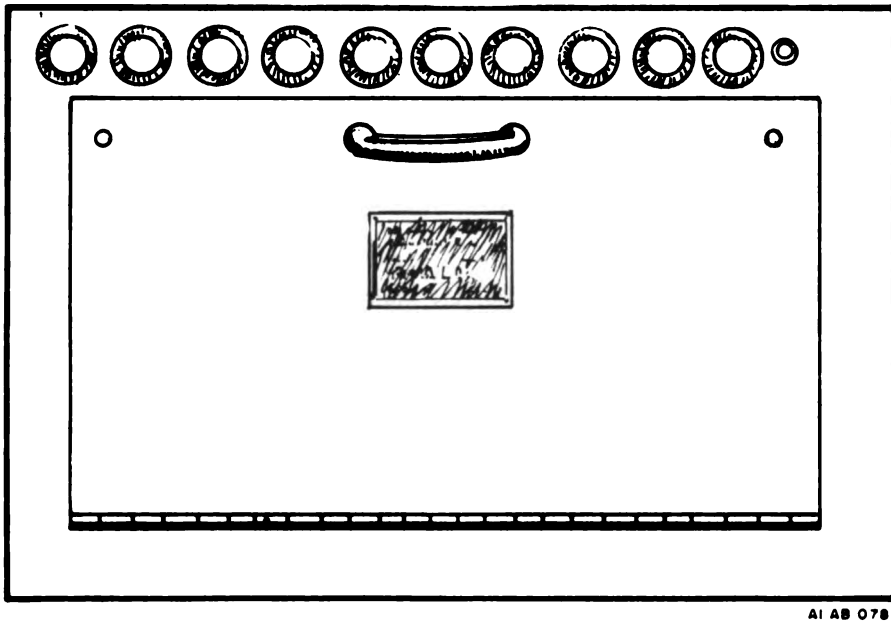
The chart drive mechanism is a removable, self-contained assembly consisting of a frame and various mounted parts. The assembly contains the chart drive motor, drive gear train, drive roll, idler roll, chart trough, removable take-up reel, take-up motor, and hinged panel. Also mounted on the assembly are the speed change gears, chart drive ON-OFF switch, take-up motor microswitch, and the plug through which power is introduced to the mechanism.

The Electronic Control Amplifier, AM-6181/UM (figure 6-23) provides amplified wind speed and wind direction information to operate up to 24 remote readout units. It is used with wind indicators type ID-1649/UM. The amplifier requires the same input drive levels as a single ID-586/UMQ-5 which it receives from the existing wind speed and direction sensing equipment at the station.

Typically, the AM-6181/UM is installed at air traffic control centers to provide drive for remote indicators at each operator's position.

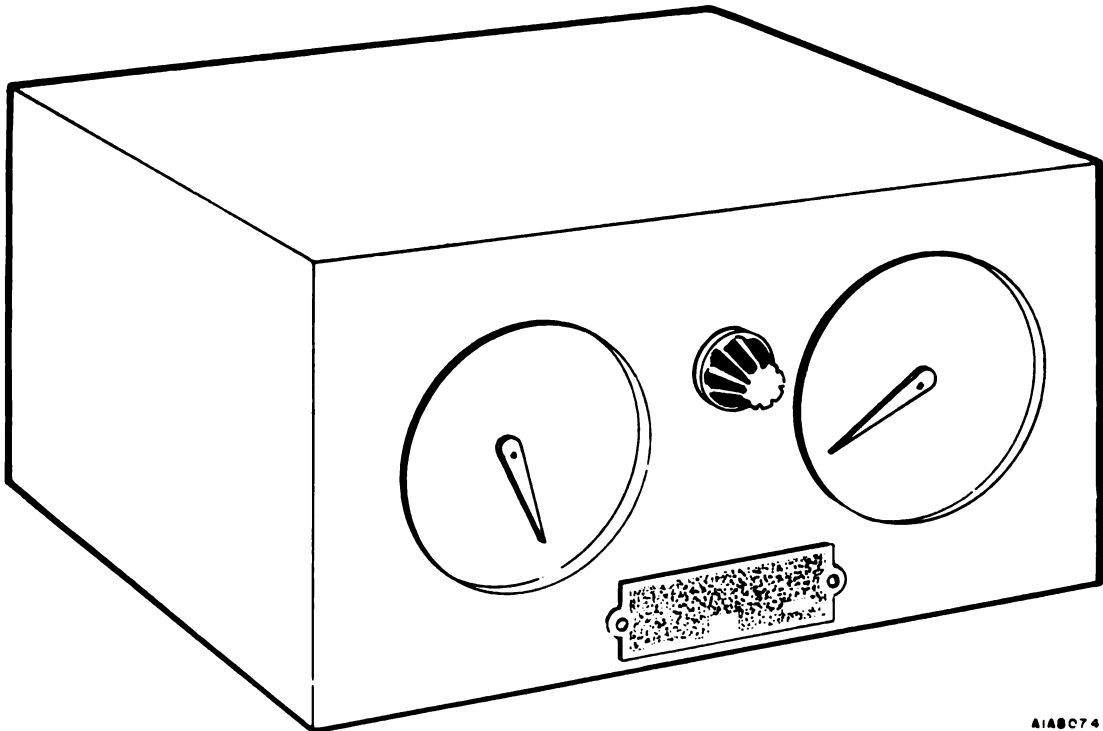
The Wind Direction and Speed Indicator ID-1649/UM (figure 6-24) provides a visual readout of wind velocity by presenting the wind direction and speed information. It is used with an electronic control amplifier, which supplies signals for up to 24 indicators in parallel. The ID-1649/UM indicator is installed in air traffic control towers and IFR rooms to provide one unit at each operator's position.

Each indicator contains a synchro driven wind direction dial calibrated in fifteen degree increments for 360 degrees and also calibrated at eight compass points. It also contains a voltmeter, calibrated from zero to 100 knots, to display the wind speed. Internal lights illuminate the dials and their intensity may be controlled by a front panel dimmer control.



AI AB 078

Figure 6 - 23. Electronic Control Amplifier, AM-6181/UM, Operating Controls and Indicators



AIAB074

Figure 6 - 24. Wind Direction and Speed Indicator, ID-1649/UM

It has become evident that there is a difference in requirements of the Fleet Weather Service and Air Traffic Control. The Weather Service requires that its wind direction data be related to true north and Air Traffic Control requires that magnetic north be indicated. The situation is being remedied by the installation of a synchro box. The box is used to shift the true north indication from the transmitter the few degrees required to read magnetic north for the Air Traffic Control operational areas.

The necessity of having wind speed and direction information at each aircraft controller's position in both the IFR room and control tower cab is satisfied by the use of the AM-6181/UM Electronic Control Amplifier. The amplifier is capable of driving 24 ID-1649/UM indicator sets utilizing only one normal UMQ-5 indicator output. This eliminates the necessity of providing either an additional transmitter or line amplifier to provide more than 6 indicator or recorder positions at an air station.

A tapped dummy-load resistor is located in each of the indicators and recorders of the indicators and recorders of the UMQ-5 to establish the proper load for the magneto in the transmitter. This allows any unit to operate independently and still to provide the proper impedance for the magneto.

c. System Application. This system is used at Naval Air Stations to provide normal forecasting and observational information to meteorology sections, and to provide wind direction and velocity information to the Air Traffic Control operations of the base. The transmitters are usually placed at or near the threshold of the most active runway to get the most accurate indications at that location to aid the pilots.

6.2.7 Rawinsonde System

a. System Principles. The rawinsonde is an electronic system used for making atmospheric sounding consisting of measurements of wind speed and direction, pressure temperature, and humidity. This system in reality is a combination of the rawin set, radiosonde set, and additional transmitting equipment. In this configuration, the rawin set and the additional transmitting equipment constitute the ground station, whereby the radiosonde set constitutes the free-flight balloon station. An artist's presentation of the rawinsonde system is shown in figure 6-25.

Wind data are obtained from slant range and angular information between the ground and balloon-borne stations. A measurement of phase difference between transmitted intelligence and that received provides information as to the range. For ease of understanding, the system description is given in terms of the rawinsonde system.

(1) Rawin Set. Essentially, the rawin set is an electronic theodolite and radiosonde receiver. The directional antenna will track a balloon-borne radiosonde to altitudes of approximately 100,000 feet, and over a horizontal distance up to approximately 125 miles. The angles of azimuth, the elevation of the antenna, and the height of the balloon (as determined from a radiosonde recorder) determine the position of the balloon. Changes in the computed position of the balloon over a given time are indicative of the wind speed and direction. The rawin set receives and amplifies the signal from the radiosonde and passes this signal to a radiosonde recorder. This recorder, in turn, translates the modulated signal into graphical functions of pressure, temperature, and humidity.

(2) Radiosonde Set. The radiosonde set attached to a free balloon is sent aloft to transmit temperature, humidity, and reference in sequence under control of a clock-driven commutator.

The operation of radiosonde involves two different signals whose basis signal is the 1680 MHz carrier wave transmitted by the radiosonde transmitter. This signal is frequency modulated by the radiosonde's radio receiver. The repetition rate of the pulses in an 74.95 kHz subcarrier is a function of the meteorological element being measured.

A 403-MHz signal is generated by the ground equipment transmitter and directed by a Yagi antenna toward the radiosonde. This 403-MHz signal is amplitude modulated by the ground equipment signal comparator, which generates a signal of 74.95 kHz.

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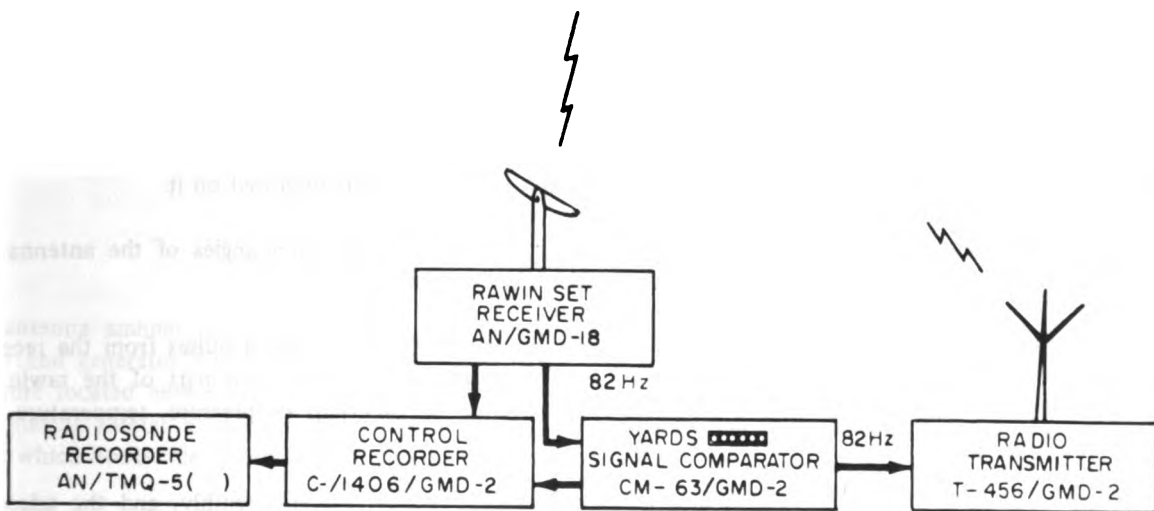
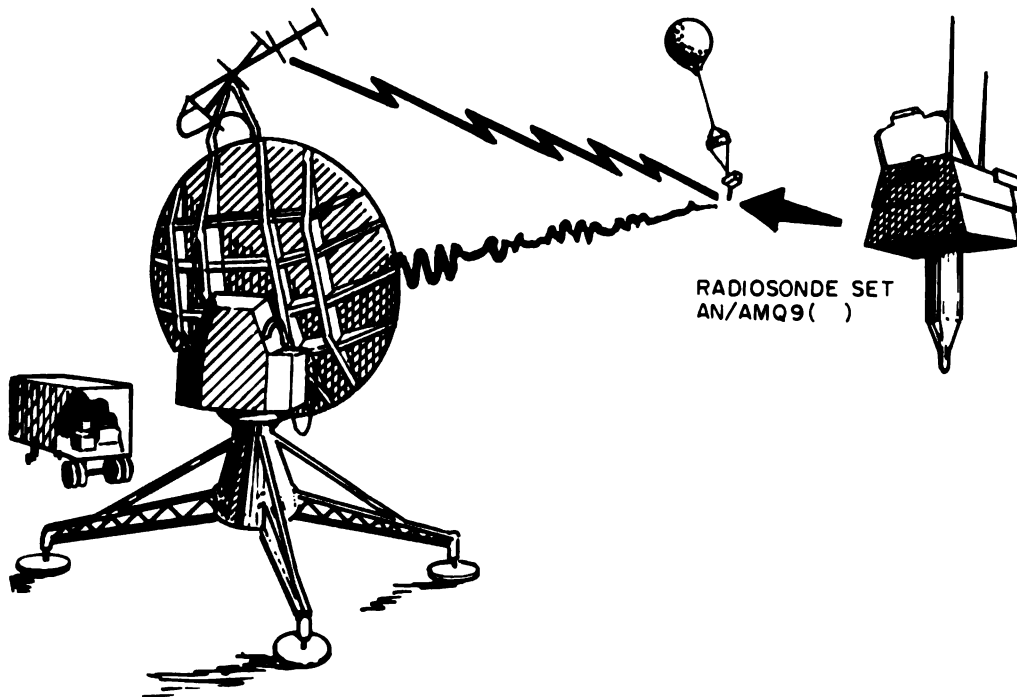


Figure 6 - 25. Rawinsonde System AN/GMD-2

The radiosonde radio receiver detects, receives, and amplifies this signal and re-transmits the 74.95-kHz sideband of the 403 MHz signal as a frequency modulation of the 1680-MHz carrier wave, which is generated by the radiosonde. The 1680-MHz signal is received and FM demodulated by the rawin set receiver, and the 74.95-kHz modulation is fed into the signal comparator. This incoming signal is compared with the internally generated 74.95-kHz signal, and the phase difference is translated into slant range in meters. The output of the signal comparator (slant range) is fed to the control recorder where altitude, corrected for the curvature of the earth, is computed from slant range and elevation angle data. The meteorological information is sent to the radiosonde recorder. These signals received by Rawinsonde System AN/GMD-2 are recorded by the radiosonde recorder. The basic rawin set is capable of automatically tracking the radiosonde in azimuth and elevation but could not determine slant range.

(3) Additional Ground Equipment. The addition of a radio transmitter, signal comparator, and distance indicator and control-recorder to the rawin set result in the added capability of determining range.

b. System Configuration. The configuration of this system is that of the rawin set, radiosonde set, plus the ground-additional equipment. A simplified block diagram is shown in figure 6-26. Because of this, the system description will be given in terms of its major subsystems.

(1) Rawin Set, AN/GMD-B (figure 6-26), is divided into five systems. These systems are the RF system, the receiving system, the antenna positioning system, the position indicating and recording system, and the meteorological data transmission system.

The RF system receives energy radiated by a radiosonde and modulates the received energy by a conical scanning method. The RF energy is reflected to a stationary dipole antenna, which feeds the energy to a mixer assembly. The mixer output, an intermediate-frequency (IF) signal, is fed to the receiver.

The receiving system amplifies the IF signal and divides it into two outputs. One output is the meteorological information, which is connected through the control-recorder to the meteorological recorder. The other receiver output is an error signal, proportional to the deviation of the balloon-borne transmitter from the axis of the antenna reflector. The error signal forms one input to the antenna control unit, which determines the angles of azimuth and elevation through which the axis of the antenna reflector must move to be in line with the balloon-borne transmitter.

A further function of the antenna positioning system is the feeding of the elevation angle signal to the elevation drive in the elevation unit, thus positioning the antenna in elevation. The azimuth angle signal is fed to the azimuth drive in the azimuth unit, which rotates the turntable and all the units mounted on it.

The position indicating and recording system indicates the azimuth and elevation angles of the antenna and produces a printed record of these angles coordinated with a time recording.

The meteorological data transmission system receives and amplifies the meteorological pulses from the receiver, and passes them on to the meteorological recorder. The meteorological recorder (not part of the rawin set) converts the meteorological pulses into a graphical representation of functions of pressure, temperature, and humidity.

The antenna consists of the reflector antenna scanner assembly, receiver mixer assembly, and the telescope assembly.

The spun aluminum reflector is perforated to reduce the weight and wind resistance and is made in three sections to facilitate shipping. The back of each section is reinforced by aluminum stiffeners which serve as bolting surfaces when assembling. The elbow telescope is mounted in back of the reflector by three mounting screws. The hole located in the lower right-hand portion of the reflector is used as a window for the telescope.

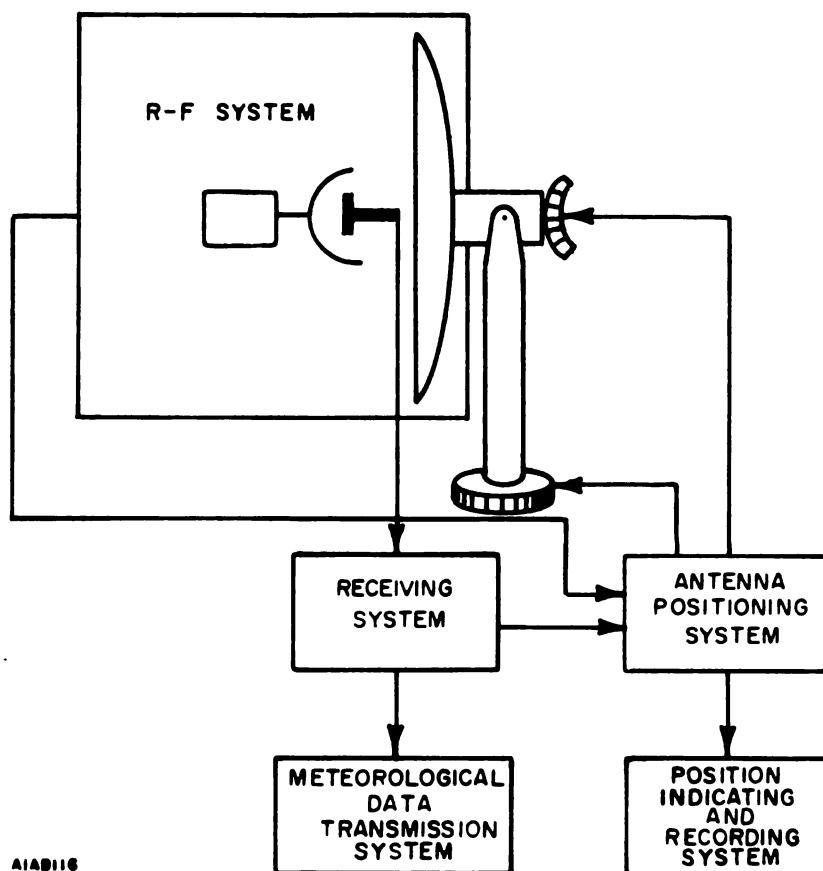


Figure 6 - 26. Rawin Set AN/GMD-1 () Systems Block Diagram

The antenna scanner assembly consists of the motor and generator assembly, the pylon, and the radome. The motor and generator assembly contains the drive motor and the drive motor gear. The pylon is a conical metal structure located between the motor and generator assembly and the radome. When the set is in operation, the drive motor rotates at a constant speed (approximately 1,760 r/min). The radome is a two-section Fiberglas dome which houses the eccentric cup, rotating joint, and dipole.

The mixer assembly is a rigid coaxial transmission line with a coupling at one end and two arms located one-fourth of a wavelength from the outer end. The arms are mounted in a line and are at 90 degrees to the main body of the mixer. The mixer crystal is located at the base of the IF arm.

The elbow telescope is an 9-power prism type telescope secured to a mounting bracket assembly. The eye-piece of the telescope is equipped with a focusing ring, and the reticle has calibrated markings for accurate sighting. A selector knob on the body of the telescope allows a choice of clear, neutral amber, or red filters. The mounting bracket assembly permits movement of the telescope independently of the reflector. Two knobs lock the telescope in azimuth and in elevation.

The elevation unit assembly consists of the yoke and the elevation unit.

The U-shaped yoke is secured to the top of the receiver and antenna control housing. Two trunnions extend through the holes in the arms of the yoke and into the sides of the elevation unit housing. A bushing at the top of the left arm of the yoke receives the stow-lock shaft when the elevation unit is in the 0-degree elevation position.

The elevation unit consists of a housing and cover, and elevation drive assembly, an elevation indicator, a stow-lock assembly, and the counterbalance spring assemblies.

The elevation unit houses the elevation drive assembly, the counterbalance spring assemblies, and the elevation indicator. The stow-lock assembly is mounted on the left side of the case. Rotation of the stow-lock handwheel causes a shaft in the stow-lock case to extend outward. If the axis of the antenna reflector is at the 0-degree or 90-degree position, the stow-lock shaft enters one of the bushings in the stationary yoke assembly and prevents movement of the antenna in elevation. When the stow-lock shaft extends outside the case, it operates a microswitch in the stow lock case which shuts off the power supply to the elevation drive motor.

The elevation drive assembly consists of the elevation drive motor, elevation synchro transmitter, elevation anti-hunt generator, two microswitches, gears, and drive shaft. Rotation of the elevation drive motor causes rotation of the output pinion, and the entire elevation unit tilts upward or downward, depending on the direction of rotation of the motor. The antenna assembly is bolted to the elevation unit housing and tilts in elevation when the elevation drive motor rotates.

The counterbalance spring assemblies and the elevation drive motor aid in positioning the antenna by exerting a force in a direction opposite to the weight of the antenna assembly. When the axis of the antenna reflector is vertical, the entire weight of the antenna assembly is on the top of the trunnions and the coil springs are completely unwound. As the elevation angle of the elevation unit housing and antenna assembly decreases, the two spring assembly gears rotate and both coil springs wind up. When the axis of the reflector is horizontal, the coil springs are fully wound, and their combined tension exerts a force which is opposite and nearly equal to the weight of the antenna assembly. Because the springs unwind as the antenna assembly is raised in elevation, the required torque of the elevation motor is small.

The receiver and antenna control housing supports the yoke of the elevation unit assembly, houses the receiver and antenna control, and interconnects the various units of the main assembly. The base of the housing is secured to the azimuth unit mounting shelf. The two potentiometers on the panel on the left side of the housing are used for manual control (elevation and azimuth) of the rawin set. The location of these controls facilitates orientation of the rawin set and manual tracking of the balloon when sighting through the telescope. Two levels mounted at right angles on the right side of the housing are used for levelling the main assembly.

The rawin receiver is located in the top compartment of the housing. The frequency megahertz meter is visible through a window in the control panel. The service meter and meter selector switches are on the left-hand side of the control panel.

The antenna control unit is located in the bottom compartment of the housing and includes the azimuth drive assembly and turntable assembly, which are electromechanical devices used to support and transmit electrical signals by use of sliprings.

(2) Radioonde Set, AN/AMQ-9. The radioonde set (figure 6-27) consists of the following: A superregenerative detector, and 74.95-kHz amplifier, and a 600-kHz oscillator contained in one tube, a clock-driven commutator, and mountings for the temperature and humidity elements. The R-610 radio receiver and clock-driven commutator are mounted on top of a housing and are completely enclosed by a hinged cover. Metal clips are hinged to this cover and used to mount the temperature element. The humidity element mounting

clips are located underneath a white plastic shield. The clock and commutator assembly make up the clock-driven commutator. The time for one revolution of the wiper arm around the commutator is approximately 52 seconds. The various circuits are introduced in the following sequence:

Temperature - OFF

Humidity - OFF

Unknown - OFF

Temperature - OFF

Reference - OFF

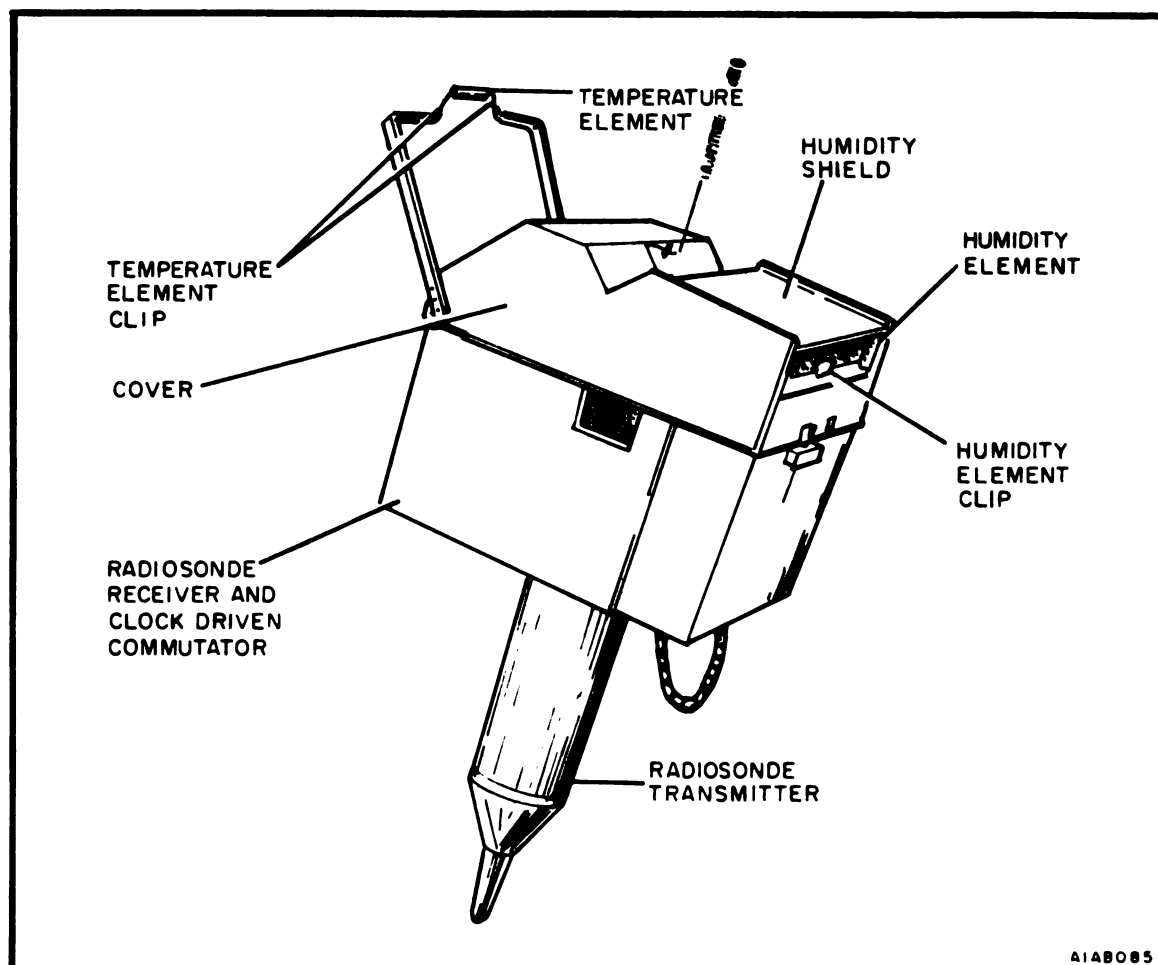


Figure 6 - 27. Radiosonde Set AN/AMQ-9

Each of the circuits is introduced twice in one revolution. Two metal spring clips on plastic support arms are hinged to the cover of the plastic housing and used to connect the temperature element to the circuit. When not in use, the arms are swung down to rest against the side of the plastic container.

Two metal spring clips, spaced approximately 2 inches apart, are attached to the top cover of the plastic housing and hold the humidity element. A white plastic shield protects the humidity element from direct rainfall and sunlight.

The transmitter is mounted in an opaque plastic shell and is attached to the bottom of the battery-compartment door. A temperature element and a humidity element, packed in a metal container, are also provided.

The temperature element is a negative temperature-coefficient resistor whose ceramic body is covered with a waterproof lead-carbonate coating that is reflective to solar radiation.

The humidity element consists of a strip of polystyrene with electrodes along its two long edges. The polystyrene strip is covered with a film containing carbon whose resistance varies with both humidity and temperature. Each element is packed in a sealed container.

(3) Rawinsonde Radio Transmitter T-456/GMD-2. The rawinsonde radio transmitter generates a crystal-controlled signal of at least 15 watts at frequencies selectable in 1-MHz increments from 401 MHz through 405 MHz. The 403-MHz carrier is amplitude modulated by a 74.95-kHz signal.

The radio-transmitter output is connected to a Yagi antenna that radiates in the direction of the balloon-borne radiosonde. The transmitter consists of the following sections; RF exciter, final-output stage, 74.95-kHz modulator, metering circuit, and power supply.

The transmitter is mounted by means of two hangers secured to the left side of the transmitter case. The operator attaches these hangers to the antenna-control and receiver-housing handles on the right side of the rawin set.

(4) Signal Comparator CM-63/GMD-2. The signal comparator measures the phase difference between the transmitted and received 74.95-kHz signals and indicates on a counter the corresponding phase difference in meters. The comparator is divided into the following components: timing-base generator, phase-shifting network, AGC amplifier, phase discriminator, servosystem, and power supply.

The signal comparator is mounted by means of two hangers located on the right side of the comparator case. The operator attaches these hangers to the antenna-control and receiver-housing handles on the left side of the rawin set.

(5) Distance Indicator ID-112. This component is being furnished to provide readout in meters instead of yards/feet. An inverter amplifier and switch are provided to permit response to either positive or negative course range return signals. A course range adjustment permits the setting of initial slant range in 200 meter increments.

(6) Control-Recorder C-1406/GMD-2. The control-recorder is a remote control station for the rawin set. The control-recorder remotely tunes the rawin receiver, remotely orients the antenna position, computes altitude, corrected for the earth's curvature, and records the position data as well as the time.

(7) Radiosonde Recorder AN/TMQ-5. (Figure 6-28) - This unit records weather information in graphic form that is transmitted from a balloon-borne radiosonde. This recorder is normally used when taking an upper air sounding with AN/GMD-2() equipment which employs a 1680-MHz radiosonde.

c. System Application. The rawinsonde system is used to make atmospheric soundings which comprise measurements of wind speed and direction, pressure and humidity, and given the parameter of height and temperature, is used to find pressure.

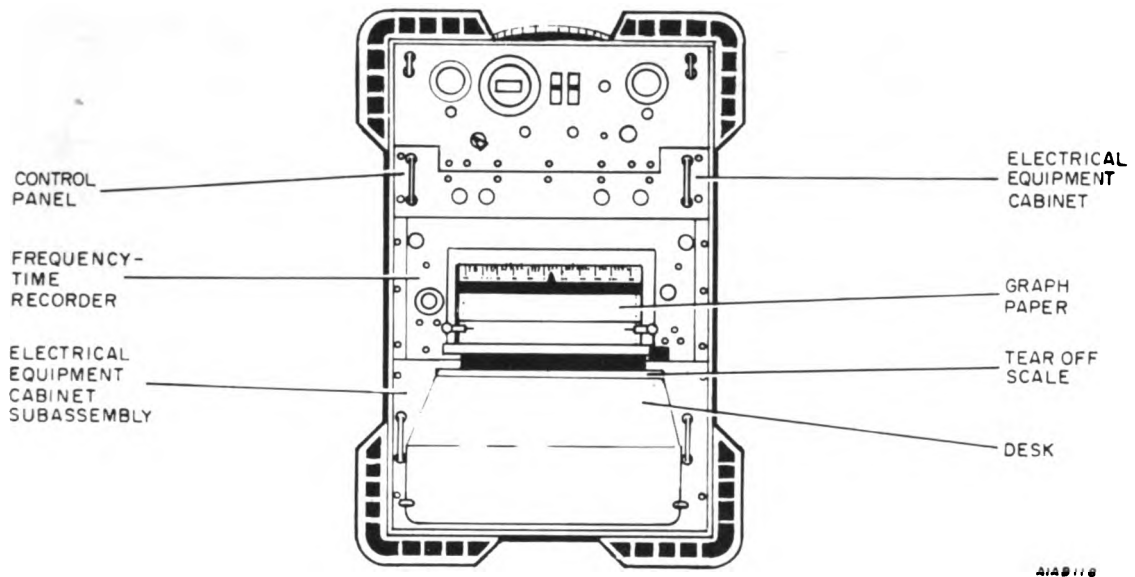


Figure 6 - 28. Radiosonde Recorder AN/TMQ-5 ()

The radiosonde system is designed to measure temperature in the range of $+60^{\circ}$ C to -90° C, relative humidity from 15 percent to 100 percent, slant range from 0 to 225,000 meters, and altitude from 0 to 120,000 feet above the station. The present frequency is 1680 MHz plus or minus 4 MHz. The signal is frequency modulated at 74.95 kHz.

6.2.8 Weather Television System

The Weather Television System AN/GMQ-19 was designed for the transmission of weather and weather briefing information and combines a closed-circuit television system and a two-way audio system. It provides for transmission of transparent and opaque weather charts, maps, drawings, and other data from a central weather facility to a maximum of up to 20 remoter receiver sites. The system installation should be such that it may also handle other television communications requirements of the future.

a. System Principles. Weather television is a closed-circuit television system which provides a TV camera, the required video and audio (amplifying, shaping and controlling) circuits, lighting and distribution system, in a single console. The remote monitors and a tape recorder complete the system. An AN/GMQ-19(V) Weather Television System is shown in figure 6-29. The latest procurement of Weather Television Equipment is the AN/GMQ-27(V). It is similar to the AN/GMQ-19(V).

The weather television is intended for use as a cable-distributed system although the capability exists for its use with a microwave radio link for remote or inaccessible sites requiring weather television information as shown in the simplified system block diagram figure 6-30. The principles of operation of a radio microwave link have been described briefly in chapter 3.

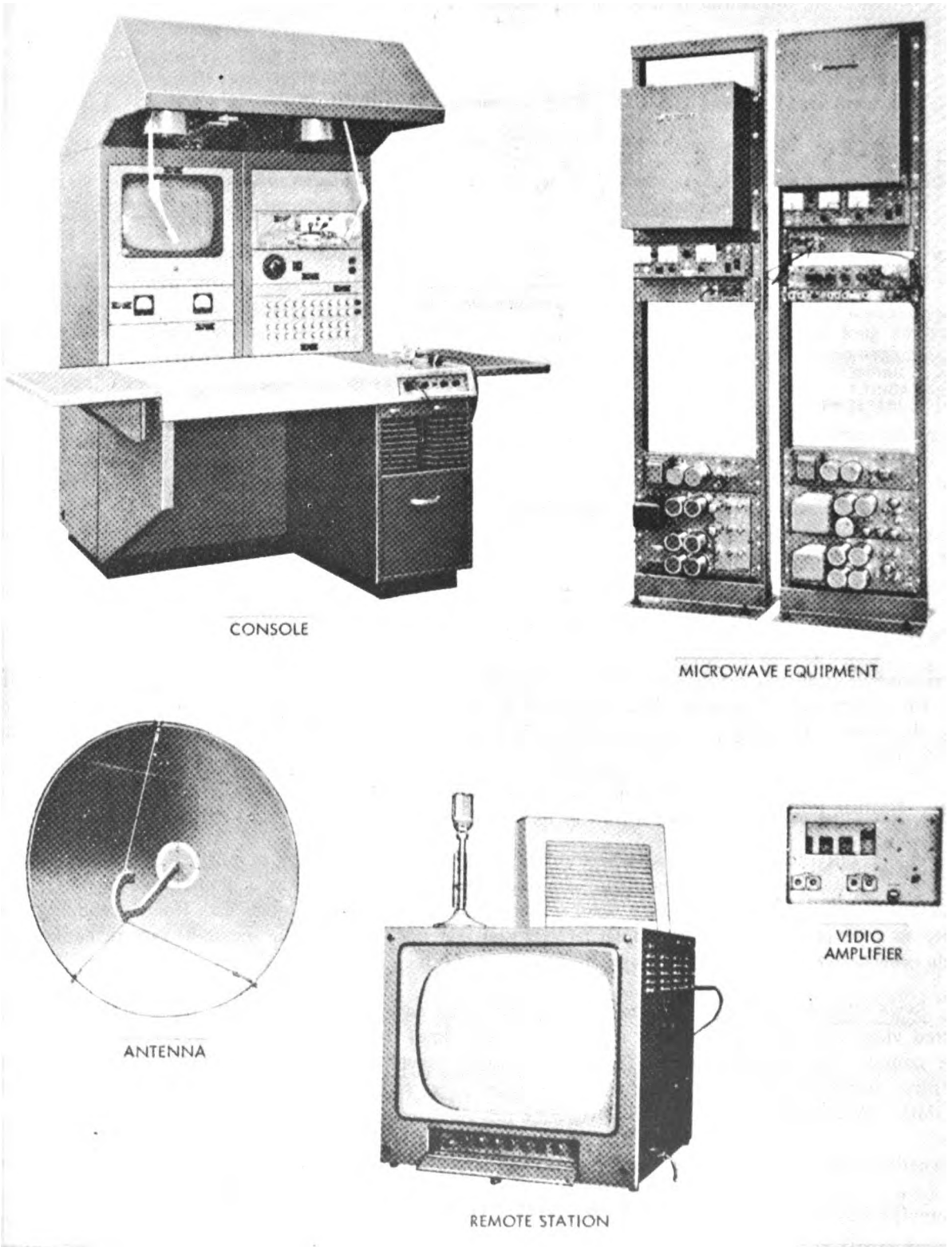


Figure 6 - 29. Weather Television System, AN/GMQ-19 (V)

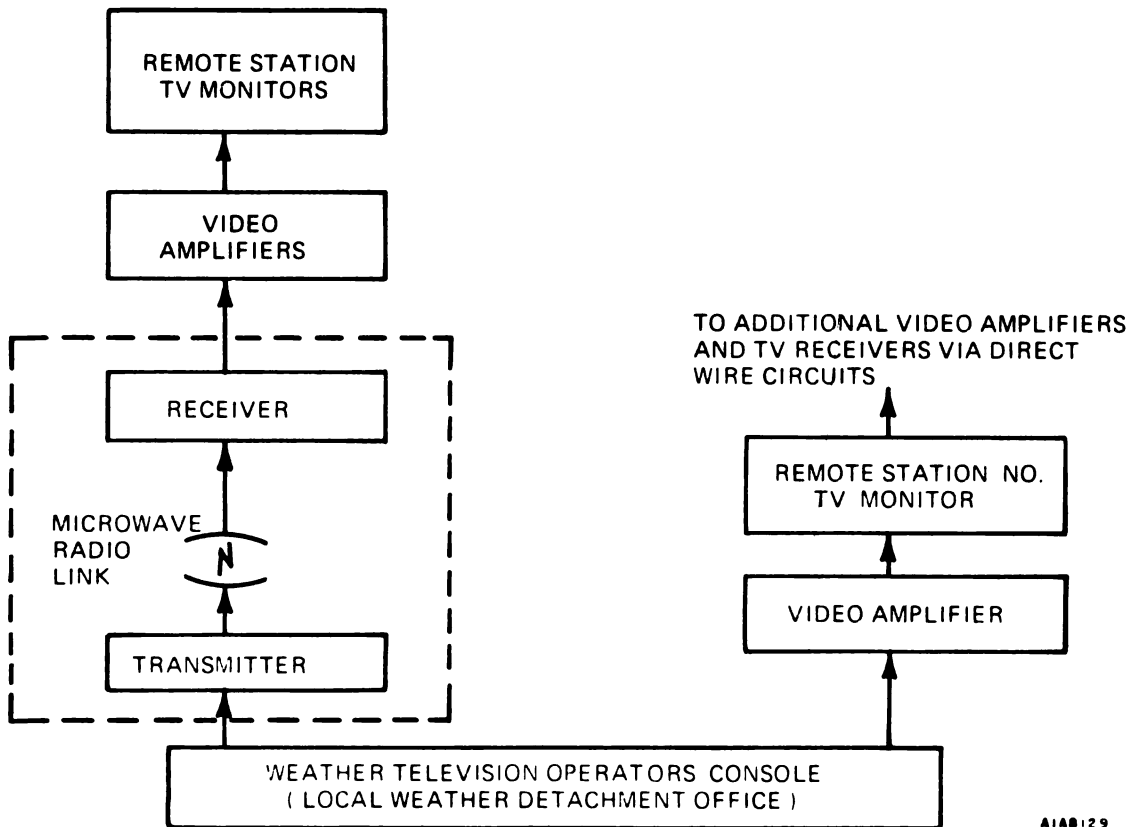


Figure 6 - 30. Weather Television Simplified Block Diagram

b. System Configuration. The basic weather television system consists of the following component parts:

The console consists of two cabinet racks fastened together. Units within the console are mounted with swing-out hinges for easy accessibility. The briefing table is partially illuminated and is provided with drop-leaf sections. The slot-type chart file provides storage space. A file drawer provides additional space for filing records, or may be used for the storage of spare parts.

The camera and overhead lamps are mounted on the cabinet racks and are situated so that any information placed on the illuminated portion of the briefing table will be viewed by the camera.

The video portion of the console is switched ON and OFF as a system with the exception of the remote monitors which have individual ON-OFF switches. Video output levels are displayed on a VIDEO LEVEL meter (on the speaker panel). Video displayed on the console monitor is received by the video monitors at the remote stations.

The camera is designed to produce a composite video television signal of 0.2 volt minimum peak-to-peak (depending on light level). A mounting plate is fixed to the bottom, while a camera cable receptacle and two fuse cases are located on the back.

The camera contains a vidicon pickup tube, its deflection components, and a subchassis containing a video preamplifier, target control, and blanking amplifier. Deflection focus and alignment are accomplished electromagnetically. The video preamplifier uses a series cascade amplifier for a good noise figure. Complete correction for the output circuits of the vidicon tube is accomplished within the camera. The blanking amplifier supplies a 40-volt peak-to-peak mixed blanking signal to the camera through the camera cable.

The control unit is frame mounted in the rear of the console. Each individual chassis of the unit is mounted to the frame for ease of maintenance. The circuits of the control unit are divided functionally into a sweep chassis, a video chassis, and a power supply chassis and are readily accessible for servicing.

The sweep chassis generates horizontal and vertical deflection signals which are fed through the camera cable to the vidicon deflection yoke. The horizontal drive signal is integrated, clipped, amplified, and mixed with vertical drive to produce blanking for the camera. Amplified and integrated horizontal drive is also used to actuate the video clamp circuit in the video chassis. A single-tube constant-current focus regulator is included to hold vidicon focus current constant. The sweep chassis also contains an electronic sweep failure protection circuit which extinguishes the vidicon beam if either the horizontal or vertical sweep circuits should fail, thus preventing damage to the vidicon.

The video chassis amplifies the video signal. The video is then clamped and combined with blanking and sync pulses. Aperture correction is provided which may be switched in or out with a three-position switch.

The power supply is divided, basically, between a regulator chassis and a rectifier chassis. Outputs of the power supply are all regulated.

The sync generator utilizes transistorized circuits, printed wire boards, self-contained power supplies, and vacuum-tube amplifiers on each of four outputs.

The monitor is a complete self-contained 17-inch picture monitor which is operated from a line containing video and sync.

The audio system allows the console operator to select one or all of the remote stations to be called by depressing pushbutton microswitches on the call panel, operating the PUSH-TO-TALK button, and talking into the microphone. The appropriate microswitch lights when the remote station calls in. All remote stations may be called by depressing the AUDIO and VIDEO ALL CALL red pushbuttons.

When a remote station calls the console, its corresponding microswitch on the call panel lights, indicating to the console operator that a remote station is calling. The light remains on until the operator answers the call. A busy light at all other remote stations lights when the console operator is being called, and remains on until the remote station operator calling the console releases the microphone PUSH-TO-TALK button.

Remote stations may call the console, or interrupt a briefing by voice, at any time to request transmission repeats, briefing, or clarification. The remote station speaker is muted when the operator presses the microphone PUSH-TO-TALK button.

Audio amplifier is a high-gain, completely self-contained, self-powered unit built for heavy-duty continuous operation at low operating temperatures. The amplifier, incorporating both microphone and phone inputs, can be quickly converted to low impedance by the addition of a transformer for which there are built-in-provisions. The amplifier is designed to handle a wide range of input levels without distortion.

The tape recorder automatically monitors all audio communications between the console and any or all of the remote stations. It is a 24-hour, single-channel magnetic tape recorder-reproducer.

The remote monitor is a complete self-contained 21-inch picture monitor which is operated from a line containing video and sync. A microphone and speaker are provided for audio communication with the console operator. The speaker has a power handling capacity of 10 watts.

The video amplifier has a high-impedance bridging input which may be looped or terminated with a 75-ohm termination plug. The dual video outputs are source terminated in 75 ohms. A gain control allows the video amplifier to be operated at any gain setting from 0 to 20 dB. The amplifier and its regulated power supply are enclosed in a weatherproof housing.

The Microwave Relay System Configuration as indicated on equipment block diagram figure 6-31 will be described as follows:

The transmitter consists of the components necessary to generate and modulate a microwave carrier.

The transmitter RF assembly is composed of three units, the transmitter RF plumbing, the video modulation amplifier and the transmitter RF panel.

The microwave carrier is generated by a reflex klystron mounted in the waveguide plumbing assembly. The reflex klystron is a velocity-modulation type oscillator which is tuned by varying the spacing of its resonator gap and is modulated by varying the voltage on its repeller electrode.

The operation of the transmitting klystron is monitored both for frequency and for power output. The DC output of the detector meter on the transmitter control panel gives a peak indication when the transmitting klystron is tuned to the correct frequency.

The DC output of the power monitor circuit meter on the transmitter control panel gives an indication proportional to the amplitude of the microwave energy in the waveguide.

The nominal output of the transmitter is 1 watt. Maximum power output of the transmitter is 2.5 watts. The transmitter equipment is designed to operate at 7200 MHz.

All frequency sensitive components of the waveguide assembly (including particularly the klystron and the frequency monitor cavity) are enclosed in a heated, thermostatically controlled box, thereby assuring an accuracy of +0.025 percent for the frequency monitor cavity and a frequency stability for the transmitter of +0.05 percent of the assigned frequency.

The video modulation amplifier, amplifies the incoming video signal and uses the amplified signal to vary the voltage on the klystron repeller, thereby frequency-modulating the microwave carrier. A total gain of 35 dB (± 10 percent) is provided by the modulation amplifier which uses degenerative feedback to reduce distortion and provide a wide response bandwidth.

Two 75-ohm, unbalanced inputs are provided on the video modulation amplifier. Either of these inputs may be selected for the signal input, depending upon the desired polarity of the signal output. A dummy cable can be connected to the second input, providing hum and noise pickup which may then be used to cancel the same pickup in the input cable.

The transmitter RF panel provides space for mounting the transmitter RF plumbing and the video modulation amplifier, and provides the wiring connections to operate these two units. The panel contains a regulating transformer which supplies the filament voltages to the transmitter klystron and to the modulation amplifier.

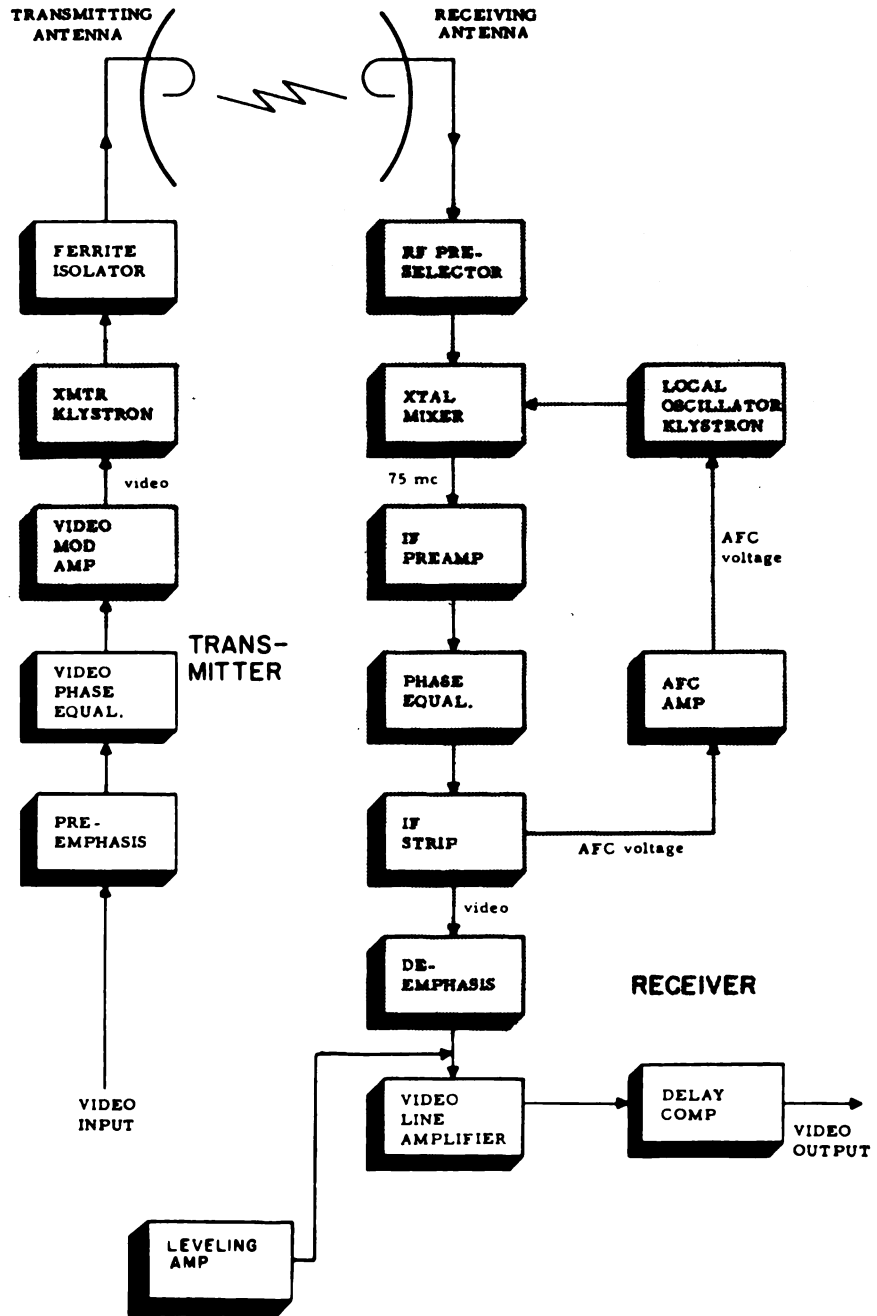


Figure 6 - 31. Microwave Relay Equipment, Block Diagram

The ferrite isolator is a unilateral waveguide transmission device which isolates the transmitter klystron from the antenna system, thus preventing distortion of the modulation characteristic of the klystron due to reflected energy from mismatches. It allows the transmitted energy to pass with less than 1 dB of attenuation, but attenuates energy in the reverse direction by more than 40 dB.

The transmitter control panel is used for control and metering of the transmitter. For convenience and operational clarity, the components of the panel are grouped according to their function.

The transmitter control panel also contains a remote control feature which, when the Local-Remote switch is in the Remote position, may be used to turn off either the klystron beam voltage or the main AC power. The local indicator lamp is on when the transmitter is controlled locally.

The frequency meter is used in tuning the transmitter to the assigned operating frequency. The current from the frequency monitor crystal in the transmitter RF plumbing is fed to the 0-50 microammeter.

The beam-off switch is connected in series with the power to the klystron cathode, and is turned off when operation of the klystron is not desired.

The video panel is an open frame which mounts on the rack beneath the transmitter control panel. The video panel provides a common juncture point for the video cabling. All video circuits may be monitored at the video panel without affecting the operation of the system, or the system may be interrupted for a minimum of time at any point for testing or adjustment.

The receiver consists of the units necessary to receive and demodulate the microwave carrier.

The receiver RF assembly is composed of five units: The receiver RF plumbing, the IF preamplifier, the IF phase equalizer, the IF strip, and the receiver RF panel.

Contained within the receiver RF plumbing are the components which fulfill the following functions:

- o Accept the incoming microwave signal from the antenna system.
- o Reject adjacent channel and image frequencies.
- o Generate the local oscillator signal.
- o Mix the incoming signal with the local oscillator signal to provide a 75-MHz IF signal.

The local oscillator signal is generated by a reflex klystron. The reflex klystron is a velocity-modulation type oscillator which is tuned by varying the spacing of its resonator gap. The gap spacing is manually adjusted by means of a tuning control located at the bottom of the receiver RF panel.

The entire receiver RF plumbing mounts on the receiver RF panel.

The IF preamplifier is a high-gain, low-noise, 75-MHz amplifier inserted between the mixer and the IF strip. It is used to amplify the signal output of the mixer with a minimum introduction of noise, thereby establishing a satisfactory signal-to-noise ratio for the system. To achieve the low-noise figure, the preamplifier is designed with a cascade input stage.

The input impedance to the IF preamplifier is 300 ohms, and the output impedance of the phase equalizer is 75 ohms. The total gain of the amplifier-equalizer combination is 26 dB, and the response between half power points is 15 to 16 MHz.

The purpose of the IF strip is the amplification and demodulation of the intermediate-frequency signal. To achieve this purpose, the IF strip contains seven IF amplifiers, two limiters, and a discriminator stage. Sufficient amplification is provided to obtain limiting with no signal, thus improving the signal-to-noise ratio, plus reserve

gain sufficient to allow for normal aging of tubes. Facilities are provided for monitoring several of the important functions of the IF strip. An automatic frequency control voltage is obtained from the discriminator for ultimate application to the local oscillator klystron.

Also mounted on the receiver RF panel are a 60-cycle notch and lowpass filter which removes AC hum pickup and RF interference above 50 MHz (such as TV pickup in strong signal areas) from the line supplying the negative DC voltage to the local oscillator klystron repeller, a video cable and connector for the output of the IF preamplifier, a dummy line connector with a 75-ohm termination, and a plug-in filter unit for the mixer crystal monitor jack of the IF preamplifier.

The receiver control panel is used to accomplish control and metering of the receiver. For convenience and operational clarity, the components of the panel are grouped according to their function.

The panel contains a remote control feature which, when the Local-Remote switch is in the Remote position, may be used to turn off either the main AC power or the AFC voltage. An indicator lamp is on when the receiver is controlled locally.

The frequency meter is used to monitor four important functions of the receiver. These are, the discriminator stage in the IF strip, the limiter which monitors the grid of the first limiter in the IF strip, the frequency monitor crystal in the receiver RF plumbing, and Meter Adj to adjust the sensitivity of the meter.

The video panel is an open frame which mounts on the rack beneath the terminal panel. This panel provides a common juncture point for the video cabling. All video circuits may be monitored at the video panel without affecting the operation of the system, or the system can be interrupted for a minimum of time at any point for testing or adjustment.

The pre-emphasis is used in conjunction with the transmitter in applications where the modulation consists of high-level, low-frequency energy intermixed with low-level, high-frequency energy. With the pre-emphasis network inserted in the video input line which feeds the transmitter modulation amplifier, the high-level synchronizing pulses are attenuated by approximately 6 dB. Thus, the peak voltage swings in the amplifier and peak deviation of the transmitter are effectively reduced. By restricting the dynamic range over which the circuits in the transmitter or receiver must operate to accommodate the synchronizing pulses, it is possible to reduce distortion and still maintain a relatively high modulation index and signal-to-noise ratio.

The pre-emphasis network is used at terminal transmitter stations. It is not necessary to provide the pre-emphasis at a straight-through repeater station, since the video output from the microwave receiver is already pre-emphasized.

The de-emphasis network is employed at any point in the system where it is necessary or desirable to restore the pre-emphasized video signal to its original form. Thus, de-emphasis is used at the receiving terminal and at repeater stations having a video drop for testing or distribution purposes.

The pre- and de-emphasis networks are adjusted to be complementary. The overall insertion loss of the two units is 6 dB. The characteristic impedance of each network is 75 ohms and each must be used in 75-ohm, unbalanced video circuits. If the video system is to operate in conjunction with 124-ohm, balanced circuits, it will be necessary to convert to a 75-ohm unbalanced line by means of suitable impedance transformers or amplifiers.

The line amplifier is a wide-band video amplifier used primarily at the receiving terminal of a microwave system to amplify the demodulated signal to those levels normally required by television studio and broadcast equipment. It has a minimum gain of 25 dB and a maximum output level of +6 dBV.

The line amplifier is used in many diversified applications. Its primary uses are described:

o The video signal level at the output of the receiver is approximately -20 dBV if the video channel is relayed alone, and approximately -25 dBV if both video and audio channels are carried over the system. (0 dBV is 1 volt peak-to-peak across 75 ohms.) In either case, it will be necessary to use the line amplifier to increase the video signal level to 0 dBV or higher to conform to the television station equipment operating requirements.

o The polarity of the signal at the output of the receiver assembly is reversed from that at the input to the transmitter. If an odd number of relay links are used in the system, the signal polarity of the output will be reversed in respect to the input. If the system contains an even number of links, the polarity will be the same as the input. By applying the video signal to the correct input receptacle on the line amplifier, it is possible to obtain either polarity at its output.

The video phase equalizer is inserted in series with the video line at the input to the modulation amplifier of the transmitter. The equalizer introduces a phase delay complementary to the phase delay of a combined transmitter and receiver. As a result, the phase delay envelope of one hop is held to ± 0.025 microseconds from 300 kHz to 3.58 MHz, and 0.05 microseconds at 4.3 MHz. One video phase equalizer is used at each transmitter, so that phase delay is corrected for every hop in a system.

The leveling amplifier is used when random-low frequency variations cause the relayed signal to bounce or bobble. The application of the leveling amplifier can be compared to that of a clamper, except that sine wave signals can be passed along the video bus without adverse action by the leveling amplifier.

The improvement ratio (amplitude reduction of the disturbance frequency) of the leveling amplifier is 18 dB minimum from 2 Hz to 20 Hz, and 10 dB minimum from 1 Hz to 60 Hz.

The directional coupler and attenuator can be permanently inserted into the waveguide transmission line to facilitate performance measurements and maintenance tests on the RF equipment.

The two-channel diplexer is used to connect two microwave RF units to a common antenna. Using the two-channel diplexer in conjunction with the additional channel multiplexer, as many as five RF units may be connected to a single antenna. The RF units may be either transmitter assemblies, receiver assemblies, or a combination of both. Thus it is possible to obtain either parallel or duplex operation with only one antenna. Four different power supplies provide the filament and plate power for the equipment mounted on the transmitter and receiver racks.

The circuits of these supplies are similar. All use semiconductor rectifiers which feed electronic regulators circuits. Series regulator, difference amplifier, and reference voltage tubes form the regulating circuits. Each transformer primary and each high-voltage secondary is protected from over-load by fuses. A potentiometer is included in each regulator circuit to permit adjustment to the rated DC output voltage.

The microwave antenna radiates and intercepts a narrow beam of microwave energy. The signal from the transmitter is directed through the waveguide to the antenna feedhorn, then to the paraboloid reflector. The reflector concentrates the energy it intercepts at the antenna feedhorn. This energy is then directed to the receiver through the waveguide. The microwave relay equipment used with the AN/GMQ-19 is shown in figure 6-32.

c. System Application. At most Naval weather activities, the duty forecaster is required to prepare weather data displays for weather television presentation. These displays vary at different weather units. They may include current/prognostic surface and/or upper air charts, significant weather charts, and airways and upper wind data for selected stations. For an example of a weather data display, see figure 6-33.

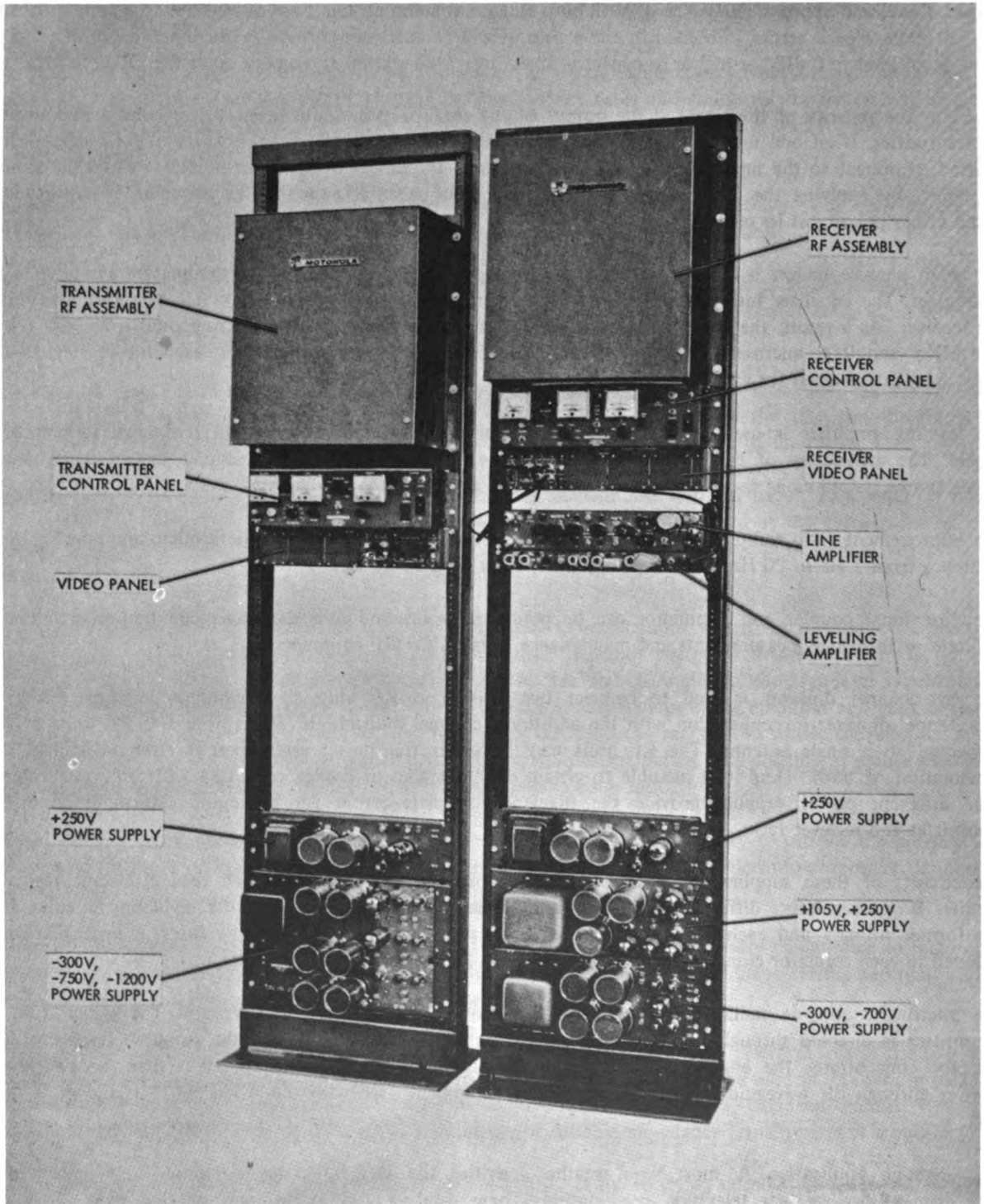


Figure 6 - 32. Microwave Relay Equipment

UPPER AIR - VT 01/06-12Z				
	5 M	10 M	20 M	30 M
NIP	160/10	270/30	310/40	300/50
NAS	310/20	320/35	310/45	300/45
NMM	320/20	320/35	300/40	290/40
NQA	330/25	330/35	290/40	280/35

Figure 6 - 33. Weathervision Weather Data Display Example

Some weather television systems have the capability of transmitting the radar weather presentation from the station radar.

The use of a microwave relay system as a possible weather television component part is a necessity. This need exists because there may be sites which require weather television information but are isolated and cannot be included in the normal coaxial cable routing.

6.3 DISSEMINATION SYSTEMS

6.3.1 Meteorological Satellite Systems

a. Background. The weather reporting networks over densely populated areas provide a large amount of meteorological information. There are, however, many areas of the earth with an acute scarcity of meteorological reporting stations. These areas include the vast ocean areas, the uninhabited regions, and those regions which, although densely populated, do not operate with enough reliability for sociological or technological reasons. The advent of the meteorological satellite has provided a tremendously effective means of receiving meteorological data, not only over these areas but over the entire globe. It is one of the greatest forward strides in the acquisition of data in many years. This in turn provides us with the means for a great increase in our operational forecasting accuracy.

The number and nomenclature of the various satellites launched under the many and varied satellite programs such as TIROS, NIMBUS, ATS, etc., are too numerous and complex to attempt a detailed coverage here. The intent is simply to provide the reader with a brief description of the meteorological data available through the use of satellites, and the means of extracting this information.

The first standard weather satellite, TIROS I, was launched April 1960. Subsequently, nine more TIROS satellites were launched, gradually leading to the development of the TIROS Operational Satellite (TOS), also known as the Environmental Survey Satellite (ESSA). The first of these was launched in early 1966.

b. Space Subsystem Configuration. The TOS Satellite System is composed of the spacecraft, the advanced vidicon camera system (AVCS) and automatic picture transmission (APT) camera systems in the spacecraft, Direct Readout Infrared (DRIR) sensors, and the APT ground station equipment.

The AVCS which has proven successful in operational service on the TOS and Nimbus spacecraft will also be used with slight modification on the ITOS series. The AVCS provides cloud cover pictures of the sunlit side of the earth and consists of three 1-inch 800-line raster vidicon cameras. Two cameras are tilted 35 degrees to the vertical in the plane normal to the velocity vector. From a distance of 600 NMI the 3-array picture covers 450 NMI of longitude by 1,450 NMI of latitude. The pictures are spaced at time intervals of 108 seconds. This allows about 10 percent latitudinal and longitudinal overlap. There may be some variation in this overlapping of pictures due to changes in altitude of the satellite in orbit. The picture resolution is from 1/2 to 1-1/2 miles. There are 33 pictures taken per orbit. Sufficient tape is provided for recording 64 pictures (two orbits) which can be played back in ten minutes. Fewer frames require less readback time, allowing the control center to use passes with less receiving time.

These video data are recorded on magnetic tape and, later, played back to command and data acquisition (CDA) stations for relay to global weather analysis centers.

The spacecraft APT camera system utilizes two fully redundant APT cameras for direct local readout at an APT ground station. The present type of TOS camera takes pictures as long as it is in the sunlight. Each picture may cover an area of approximately 1,700 NMI to a side. The camera takes eight pictures on each orbit or one picture every 35 seconds while the satellite is over illuminated areas of the earth.

The DRIR relies on temperature instead of daylight in determining cloud layers and amounts. Therefore, nighttime pictures are available. This allows complete global coverage throughout the entire orbit, over the dark areas of the earth as well as the daylight areas.

The high resolution infrared radiometer (HRIR) which maps the earth's cloud cover during the day and night, and measures the radiative temperature of cloud tops and terrain features at night, is mounted on the satellite in a manner to afford an unobstructed view of the earth from horizon to horizon. The HRIR sensory data are normally recorded on tape and stored in the satellite until command to playback by the data acquisition facilities. However, the HRIR data can be transmitted in a real-time mode whereby the data can be acquired by local APT ground stations simultaneously with the data being fed in parallel to the satellite recorder. This real-time mode of HRIR data transmission from the satellite is known as the Direct Readout Infrared.

c. Ground Subsystem Principles. The automatic picture transmission ground station provides facsimile reproductions of pictures transmitted by meteorological satellites. The various equipments required to receive and print these weather pictures include a console unit, an antenna system unit, and a signal source unit.

The Telemetric Meteorological Data Received System (TMDRS), AN/GKR-4 or AN/MKR-9, is a ground receiving station (figure 6-34) which may be used to acquire signals from a weather satellite. The station receives daily APT predict messages which provide necessary information required to acquire and track the satellite, and to locate, orient, and grid the facsimile picture to extract the data. To acquire the satellite it must be more than 10 degrees above the horizon with the station directional helical antenna manually oriented to the satellite's position. The satellite's transmitted signals will be received by the TMDRS helical antenna. These signals are filtered, preamplified, and sent to a VHF receiver which extracts an AM subcarrier from the FM carrier, which will be utilized by the facsimile recorder. The facsimile will reconstitute the picture data transmitted by the satellite and print out the picture for station usage. The proper utilization of these pictures requires that they be properly oriented geographically in relation to picture center and aspect. Prior to operation, each station is provided with a work package that includes tables, charts, maps, overlays, and other required information to properly extract the data presented on the picture.

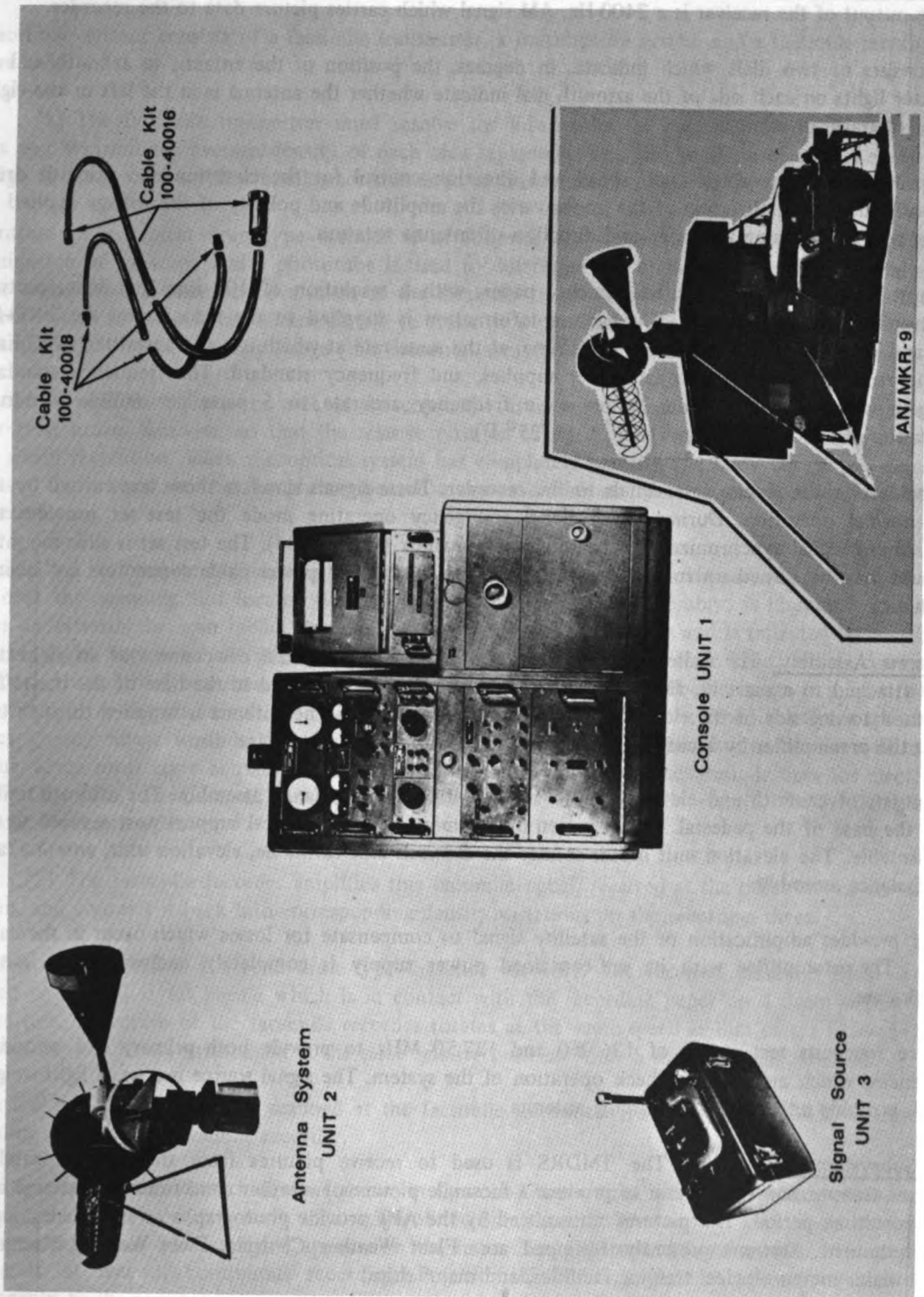


Figure 6 - 34. Telemetric Meteorological Data Receiving Set (TMDRS) AN/GKR-4

d. Ground Subsystem Configuration. The system configuration of the equipment is shown in figure 6-34 are the console (unit 1), which consists of the receiver, indicator, controller, recorder, and test set; the antenna system (unit 2), which includes the antenna, the pedestal, and preamplifier; and the signal source (unit 3).

(1) Console Components. The receiver amplifies and demodulates the 136.950-MHz, FM signal from the preamplifier. The output of the receiver is a 2400-Hz, AM signal which carries picture data to the recorder.

The indicator consists of two dials which indicate, in degrees, the position of the antenna in azimuth and in elevation. Indicator lights on each side of the azimuth dial indicate whether the antenna is in the left or the right 180-degree sector of travel in azimuth.

The controller provides separate single-knob speed and direction control for the elevation and azimuth drive motors in the positioner units. Rotation of the knobs varies the amplitude and polarity of the voltage applied to the drive motors, thus determining the speed and direction of antenna rotation.

The recorder reproduces, on electrosensitive catechol paper, with a resolution of 100 lines per inch, picture information transmitted by the satellite. The picture information is supplied to the recorder by the 2400-Hz receiver output and is reproduced line-by-line in real-time, at the same rate at which it was transmitted (240 lines per minute). The recorder contains its own power supplies, and frequency standard. The frequency standard provides driving power for the recorder motor at a frequency accurate to 5 parts per million within a temperature variation of 0° C (32° F) to 51.65° C (+125° F).

The test set provides various precise test signals to the recorder. These signals simulate those transmitted by the satellite during normal operation. During the TMDRS emergency operating mode the test set provides the recorder with a timing signal synchronized to the satellite frequency (figure 6-34). The test set is slide-mounted in the console and may be turned up for maintenance purposes. Signal and power cable connectors are located on top of the chassis.

(2) Antenna Assembly. The helical antenna with a minimum gain of 12.5 dB consists of an eight-turn aluminum helix attached to a mast by fiber rods and a ground-plane disc attached to the base of the mast. The antenna is mounted to one side of the elevation unit. The signal received by the antenna is supplied through two coaxial relays to the preamplifier by a coaxial transformer in the antenna ground-plane disc.

The pedestal consists of azimuth and elevation units, and windfin counterbalance assembly. The azimuth unit is incorporated in the base of the pedestal. The elevation unit is mounted on a vertical support post secured to the azimuth unit turntable. The elevation unit motor rotates the azimuth unit turntable, elevation unit, antenna, and windfin counterbalance assembly.

The preamplifier provides amplification of the satellite signal to compensate for losses which occur in the cable to the console. The preamplifier with its self-contained power supply is completely enclosed in a finned, pressurized, black case.

The signal source transmits test signals of 136.950 and 137.50 MHz to provide both primary and secondary operating frequencies which are used to check operation of the system. The signal source is a small light-weight, battery-operated, portable unit with a telescoping antenna.

e. Ground Subsystem Application. The TMDRS is used to receive pictures from the weather satellite automatic pictures transmission system and to produce a facsimile picture of weather conditions over a large area in a relatively short time period. The pictures transmitted by the APT provide photographs to stations equipped with TMDRS equipment. Stations presently equipped are: Fleet Weather Centrals, Fleet Weather Facilities, isolated stations, major meteorological training facilities, and major ships.

6.3.2 Facsimile

a. System Principles. Facsimile equipment is used to transmit fixed images over an electrical communication system, such as wire or radio telephone circuits. These images may be pictures, maps, sketches, typewritten and printed text, or handwriting.

A facsimile system consists of a facsimile transmitter, a transmission system and a facsimile recorder as shown in figure 6-35.

(1) The facsimile transmitter must resolve the information to be transmitted into very small elemental areas and transmit the average density of each area separately. The size of these elemental areas must be small enough to resolve the smallest intelligence that is to be transmitted.

Operation of a typical drum-type scanner is as follows: An exciter lamp is used as a source of uniform illumination of the copy and a phototube is used to determine the brightness of each elemental area. The copy to be transmitted is clamped on a drum at the facsimile transmitter. An image of the copy is focused upon an aperture plate which is located immediately in front of a phototube. The size of the hole in the aperture plate determines the area of the copy image (the elemental area) which passes through to the phototube.

In order to scan each elemental area of the copy, the drum upon which the copy is clamped rotates and at the same time moves sidewise, so that the relative position of the optical system shifts by one elemental area for each drum revolution. When the optical system has completely scanned the copy, all of the elemental areas on the copy have been seen by the phototube and a corresponding amplitude signal has been transmitted for each elemental area.

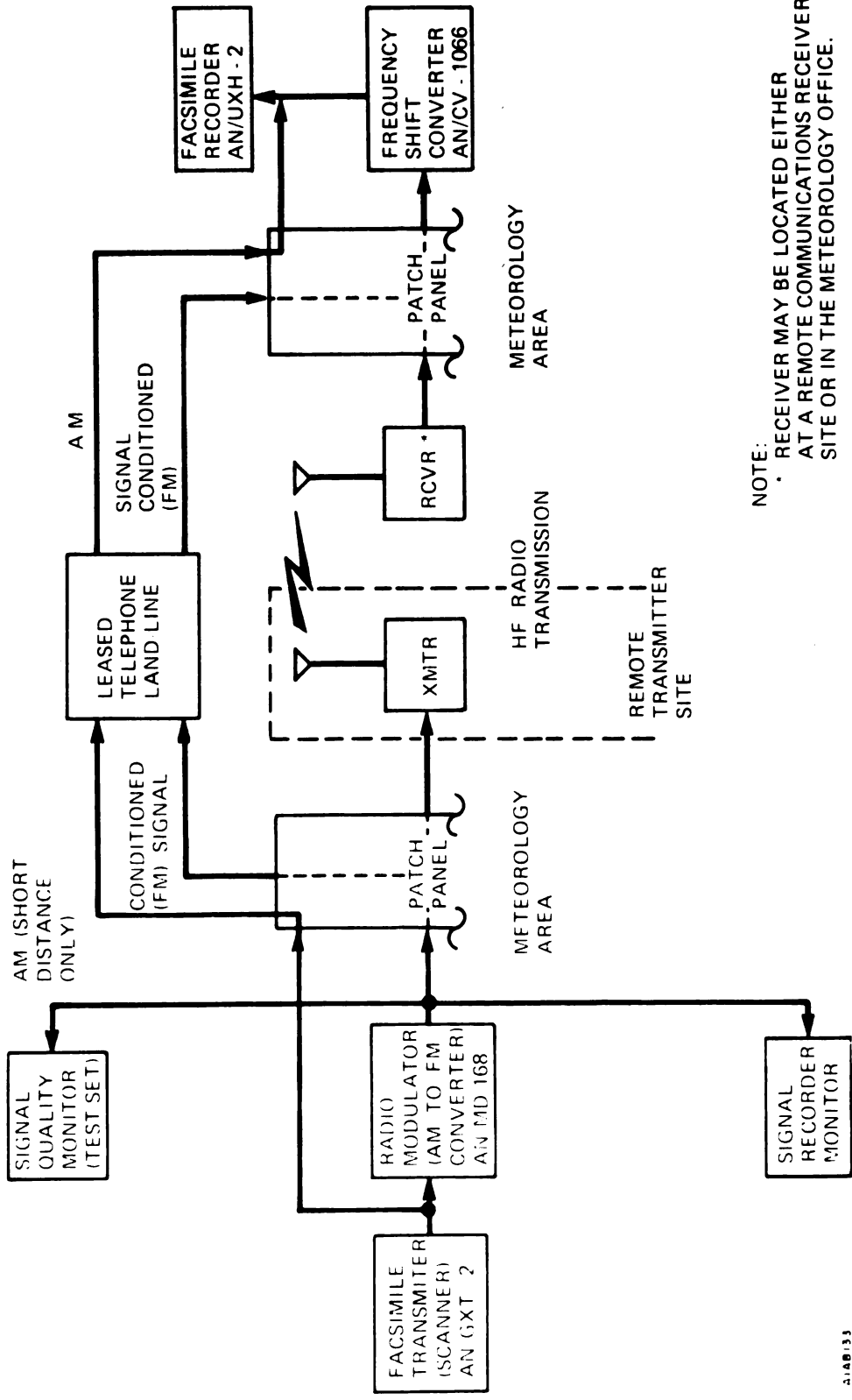
The flat bed scanning technique uses the "flying spot" principle. The document, when placed on the scan table and over the scanning slot located directly beneath the copy feed assembly, is illuminated by a set of flood lamps underneath the scan table. This light is absorbed by the dark areas and is reflected by the light areas. The resultant light variations are passed through the focus lens to the scanner head, which converts these light variations to electrical impulses. When the flying spot is scanning the reflected image in a light (white) area, the reflected light to the photomultiplier will result in a negative voltage output. When the flying spot is scanning the reflected copy image in a dark (black) area, the absence of light to the photomultiplier will result in a zero output. Since most copy contains dark information on light or white background, then the electrical output of the PE Cell (also referred to as photomultiplier) for any one scan line will resemble the PE Cell electrical output as shown in figure 6-36.

(2) The facsimile recorder amplifies this facsimile signal, received at the other end of the communication system, and converts it back into corresponding density variations on the recording sheet.

The following describes a typical drum-type facsimile recorder. The received facsimile signal is amplified and applied to a small stylus needle which is in contact with the recording paper on a drum similar to that of the transmitter. The drum of the facsimile recorder rotates at the same speed as that of the facsimile transmitter so that the two drums are maintained in the same relative position while a signal is being received.

When the entire copy has been scanned at the facsimile transmitter, the same copy has been reproduced on the recording paper at the facsimile recorder.

The flying spot recording technique as shown in figure 6-37 uses a resilient helix which provided low inertia and constant electrode pressure over a wide range of recording speeds. The endless loop electrode deposits ions on the recording paper when a signal appears on the helix. The electrode "blade" moves continuously to provide thousands of feet of continuous recording. Precision blade stops maintain precise, straight-line electrode relationship to the resilient helix.



NOTE:
 * RECEIVER MAY BE LOCATED EITHER AT A REMOTE COMMUNICATIONS RECEIVER SITE OR IN THE METEOROLOGY OFFICE.

Figure 6 - 35. Facsimile System, Simplified Block Diagram

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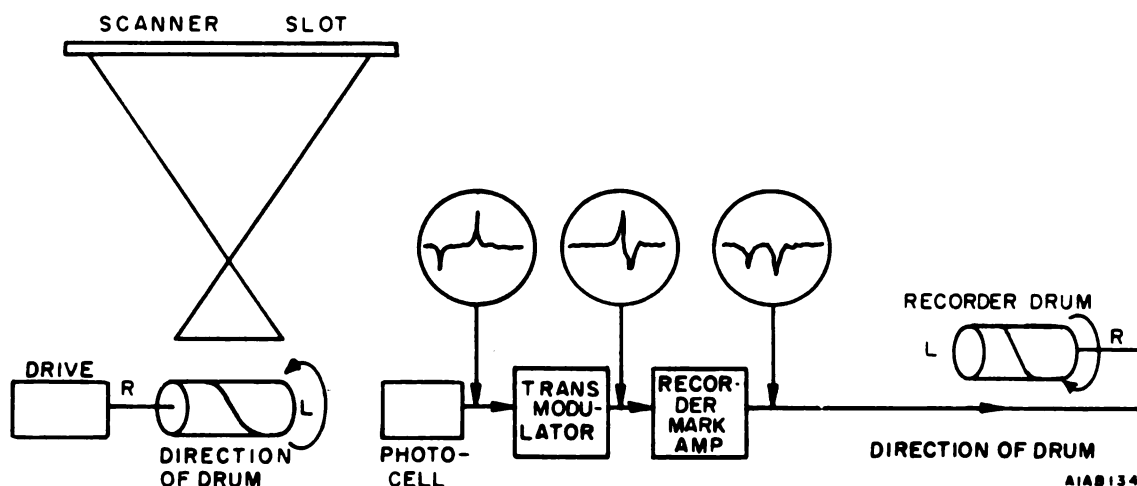


Figure 6 - 36. Flying Spot Scanner Block Diagram and Signal Waveforms

The moving endless loop electrode provides a linear writing edge for the length of the scan line. With the loop rotating, this writing edge is continuously “freshened” with a new writing surface, thus affording equally distributed wear along its circumference. Should the bottom writing edge be damaged the loop can be turned over; the top edge then provides a new writing surface.

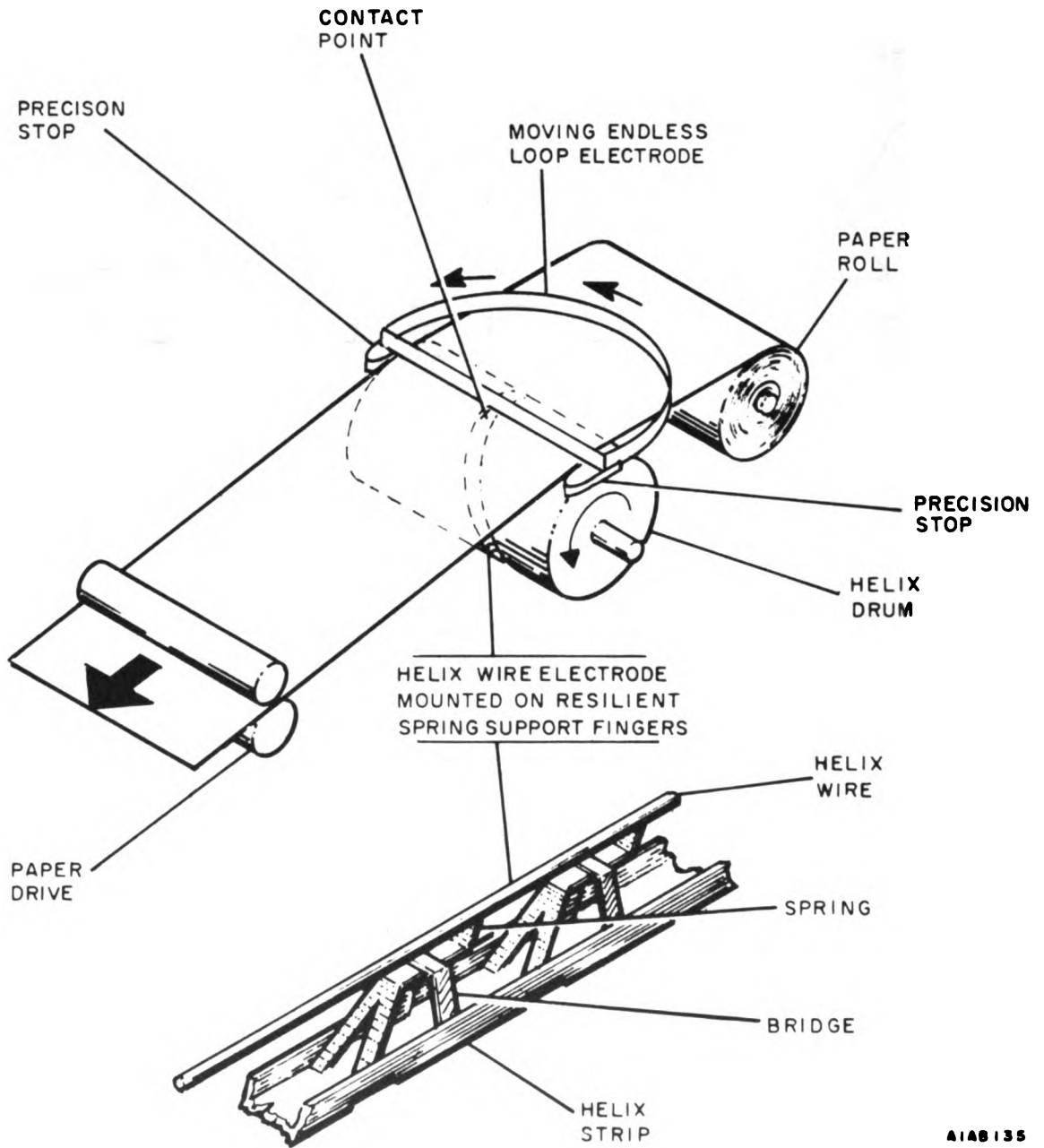
Mounted on the helix drum, the helix wire “crosses” the endless loop electrode at an angle, generating an intersection or “contact point” between the two. The helix wire serves to conduct signal data to this “contact point” and ultimately through the paper to the endless loop electrode.

The “intersection” between the helix wire and endless loop electrode forms a writing point having a very small cross-sectional area. When the helix drum is rotating, this “writing point” becomes a “flying spot” as the entire length of the helix wire is exposed to the writing surface of the endless loop electrode. When negative signal data (ground reference) is applied to the helix wire, current may pass from the helix wire to the endless loop electrode. With electrosensitive recording paper between these two electrodes, ferrous ions are deposited from the loop electrode into the paper. These positive ions cause the paper to be marked instantly at the writing point. The density of this mark is determined by the magnitude and duration of current passing through the paper at the writing point.

The helix drum provides a cylindrical mounting surface and drive for the helix.

The paper drive provides friction drive for the paper to generate a “Y axis”. Actual feed rate depends upon external drive to this assembly.

Facsimile signals are transmitted either by direct wire circuits of point-to-point cable networks or for greater distances by radio transmission. The radio system and most long distance landline circuits require auxiliary equipment to synchronize and condition the facsimile signals.



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Figure 6 - 37. Flying Spot Helix Recording Technique

Auxiliary equipment used for radio and most direct wire transmission of facsimile signals are radio modulators at the transmitting location and frequency shift converters at the receiving recording location.

o The radio modulator converts the AM facsimile signals to audio-frequency-shift modulation since this form of modulation when demodulated at the receiving station will be independent of changes in signal level and other forms of transmission distortion common in HF radio transmissions. These signal variations could cause variations and streaks in the received copy of the information transmitted.

o The Frequency Shift Converter (CV-1066A/U) is designed to convert 1500 and 2300 Hz audio frequency shift facsimile signals to amplitude-modulated signals for a facsimile recorder. Provisions are made for audible monitoring of the incoming signal and for visual checking of frequency limits.

b. System Configuration. The Navy Weather Service uses facsimile transmitters and recorders to disseminate weather data from Fleet Weather Centrals to all operating levels as far down as the lowest organizational level which is the Weather Service Environmental Detachments found on Naval Air Stations and a few other activities.

The standard Navy facsimile transmitter today is the flat copy scanner transmitter, AN/GTX-2 (figure 6-38) which is composed of the following major assemblies.

(1) The scanner optics which convert the copy information to electrical impulses was previously described in system principles.

(2) The scanner mechanics which are:

The copy feed which advances the copy over the scan slot at the proper rate corresponding to three variables: helix sweep speed, the lens 18 inch or 11 inch active scan slot; the recorder to which copy is being transmitted 18- or 11-inch paper.

The helix drive motor which rotates the scanner drum at sweep speeds of 60 or 120 r/min.

(3) The scanner electronics which include:

The power supply which provides +250 VDC for the flood lights and as a B+ supply for other scanner circuits.

The motor amplifier chassis provides a precision 60-Hz drive signal for the helix motor drive system.

The high voltage chassis provides high voltage for the photoelectric cell tube and the output signal monitor scope CRT and also filament voltage for the modulator chassis, the constant frequency chassis, and signal control chassis.

The signal control unit which automatically sends out start, phasing, and information signals when initiated by the START pushbutton and a stop signal when initiated by the STOP pushbutton, or automatic stop circuit.

The constant frequency chassis is the source of the 300-Hz start control signal and the 1800-Hz carrier frequency used in the modulator and signal control chassis.

The modulator chassis modulates (AM or FM as applicable) the control signals (FM) and the photomultiplier output (AM and FM).

The output signal monitor scope provides visual display of all output control and information signals (AM mode only) and allows operator to adjust for proper signal to background ratio prior to transmission.

The dB meter provides a visual indication of the relative power output during transmission.

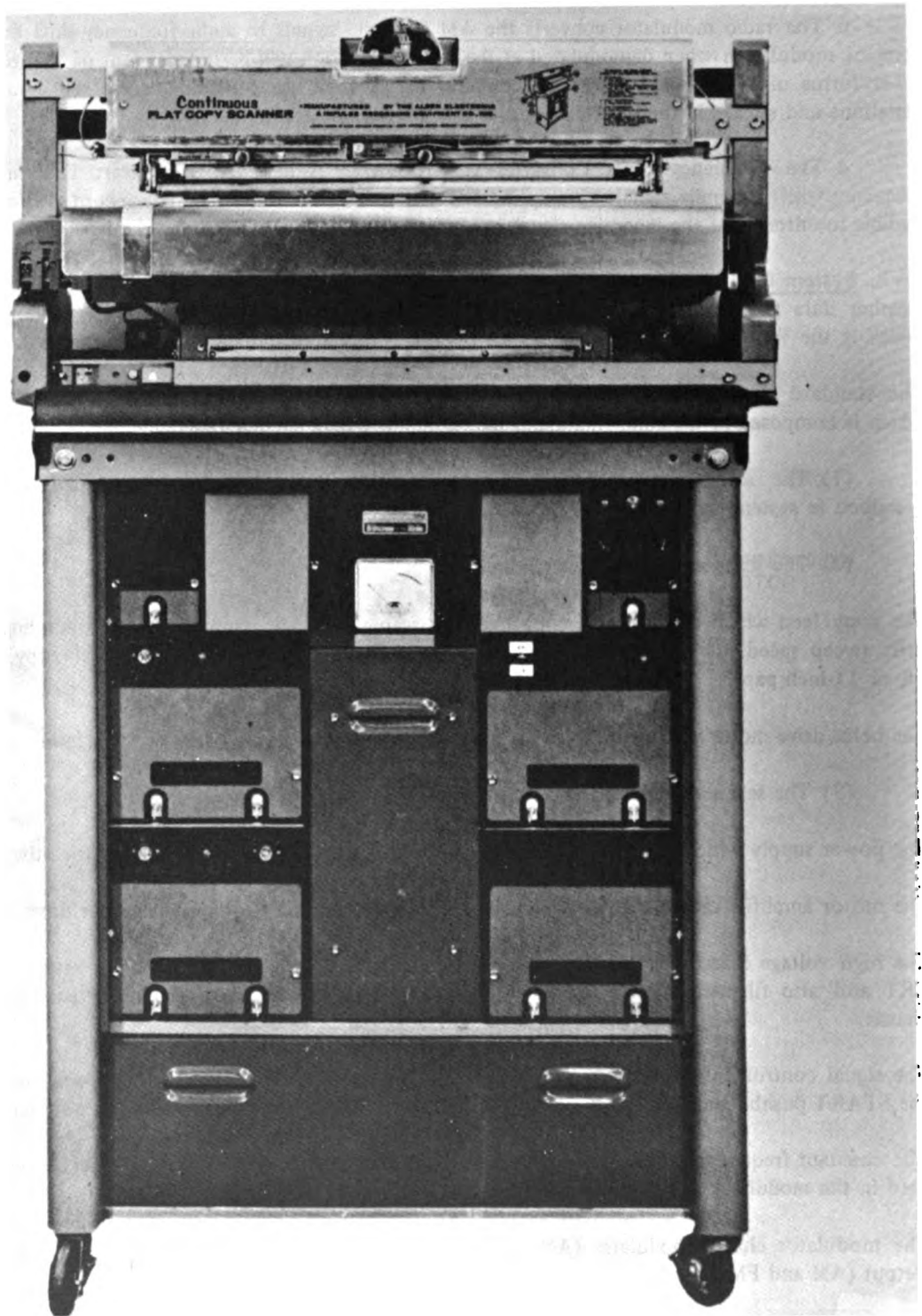


Figure 6 - 38. Flat Copy Scanner Alden Model 9165ND-TL

(4) The console provides the means of mounting and interconnecting all the major assemblies of the scanner. It includes extension supports, allowing the accommodation of copy up to 60 inches wide in 18 inch segments, and a copy guide, which can be used to set the left edge of the copy over the scan slot at the same location for repeated transmission of like documents.

The primary facsimile set presently being used by the Navy is the Facsimile Recorder Set, AN/UXH-2 (figure 6-39). This unit receives and reproduces the transmitted facsimile signals and is composed of the following major subassemblies as shown in the simplified block diagram, figure 6-40.

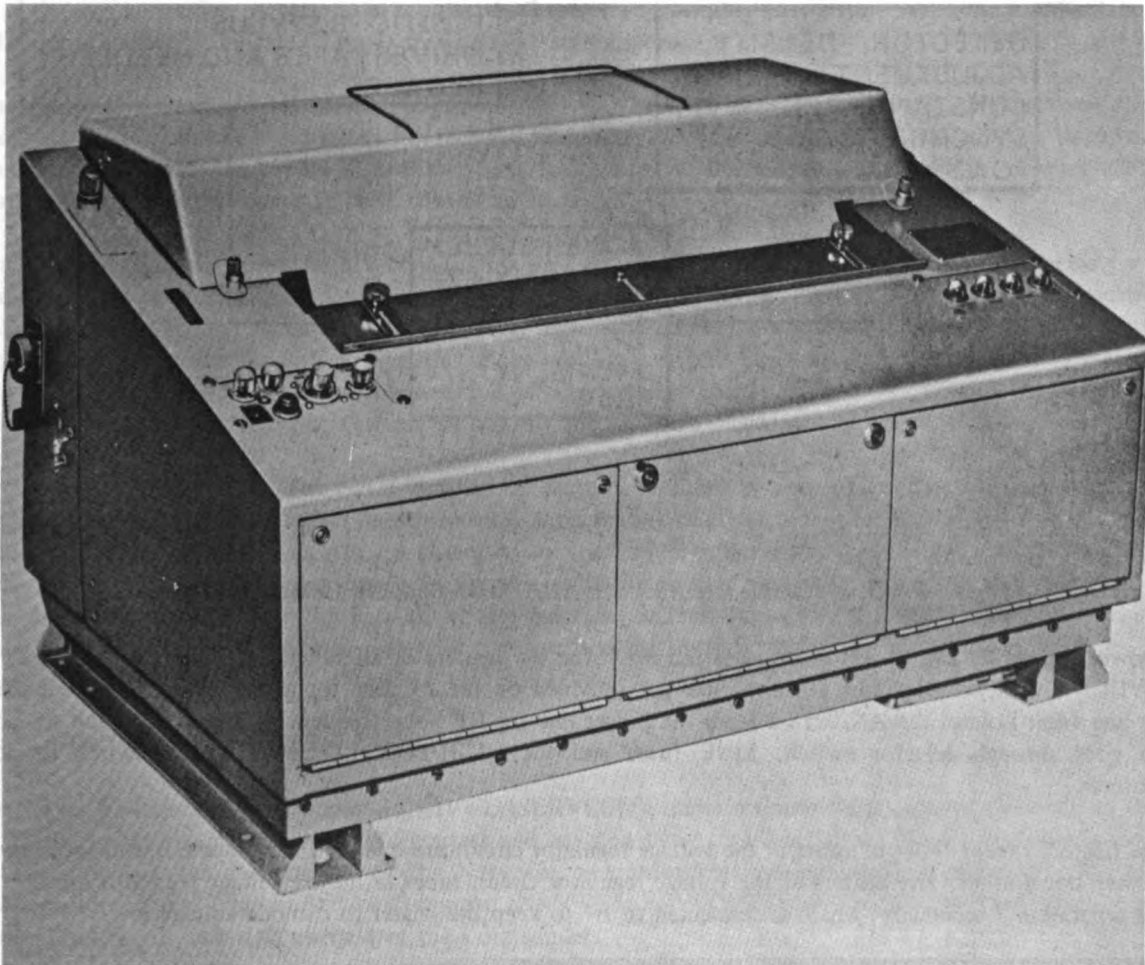


Figure 6 - 39. Facsimile Recorder Set, AN/UXH-2

The circuitry sections of the electrical control amplifier, AM-1845/UXH-2, are the signal amplifier, automatic level control and print circuits; the automatic control circuits; the fork oscillator and sync motor drive circuits; the speaker amplifier and the test signal circuits. The speaker amplifier is connected directly to the secondary of the input transformer and is independent of the other circuits; it is used to monitor the incoming signal. The signal amplifiers and automatic level control circuits amplify and adjust the signal on to the recording stylus needles. The control circuits amplify the incoming signal and control tones to control various relay circuits which

start, phase and stop the recording mechanism in response to the received signals. The fork oscillator provides a constant frequency source of 3600 Hz which is divided down to provide the correct sync motor frequency.

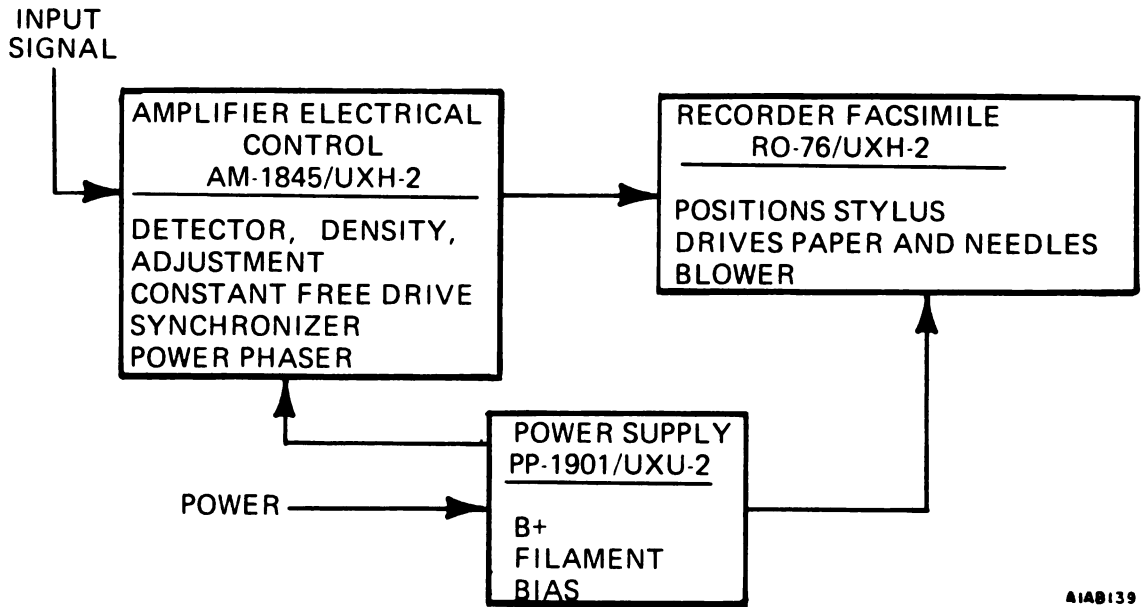


Figure 6 - 40. Facsimile Recorder Set, AN/UXH-2, Simplified Block Diagram

The power supply PP-1901/UXH-2 furnishes 6.3 VAC for the heaters of all tubes, 400 VDC for the HI B+ and -105 VDC. A utility outlet and 10 amp fuse are provided on the AC line for utility or auxiliary equipment. Power line filter isolates the AN/UHX-2 from the power line for RF noise frequencies. Input from the AC power source goes through selector switch, LINE fuses and the HIGH/LOW LINE VOLTAGE switch to power transformer.

All the heaters except those of tubes in the voltage regulator circuit are operated from one 6.3 volt secondary of the power transformer. The heaters of the voltage regulator circuit tubes in the B+ voltage regulator are operated from a separate 6.3 secondary, which is connected to B+ to keep the heater to cathode voltage low.

The Facsimile Recorder RO-76/UXH-2 records by means of three stylus needles on a band carried by two pulleys. As the pulleys turn, the stylus needles (one at a time and at synchronous speed) move across the recording paper while the paper feeds from a roll in a direction perpendicular to the stylus movement. The recording mechanism consists of four assemblies: the sync system, the run system, the stylus and base assembly, and the paper feed assembly.

The sync system, on the left end of the base casting, acts as a governor to control the speed of the stylus needles. It is coupled to the band through a unidirectional drive assembly which allows the sync motor to rotate even when the band is stationary.

The run mechanism, mounted on the right end of the base casting, drives the band above sync speed until it catches up with the unidirectional drive assembly in the sync system. The stylus needles are then maintained at sync speed by the sync motor.

The base casting, part of the stylus and base assembly, is the main structural support for the other mech unit assemblies. The two wheels mounted on the front face serve as pulleys for the flat stainless steel band that conveys the stylus needles across the recording paper. The run motor drives the band through the right run (or drive) wheel. The left wheel is an idler wheel, serving merely as a support for the band at the left side.

The sync arm mounted behind the idler wheel catches each lug on the band to restrain the band to synchronous speed.

The paper feed assembly, mounted on the top of the base casting, holds the roll of recording paper and feeds it past the stylus needles. A gear train couples the paper feed assembly to the run motor to maintain the proper relationship between the rate of paper feed and the stylus speed.

The Radio Modulator, MD-168A/UX, (figure 6-41), consists of an amplifier and a variable-frequency phase-shift oscillator. The amplifier increases the received facsimile signal to the proper level needed to operate the phase-shift oscillator and plug-in headset. The frequency of the phase-shift oscillator is controlled by a variable-resistance tube circuit in the feedback network.

The Frequency Shift Converter CV-1066A/U is used as part of terminal equipment at the receiving end of a direct wire or radio facsimile circuit of the audio frequency shift type. The signal from the radio receiver is an audio frequency shifted signal in which 1500 Hz represents maximum signal and 2300 Hz represents minimum signal output from the facsimile transmitter at the sending terminal. The amplitude of the signal to the converter may vary as much as 50 dB due to transmission effects of the radio circuit. The CV-1066A/U converts this signal from the radio receiver into one that can be used by the facsimile recorder.

c. System Application. The Naval Weather Service uses facsimile systems to transmit and receive graphic data such as weather maps and other meteorological information that defines both surface and upper atmospheric conditions. These maps and charts are generated by the U.S. Weather Bureau and Fleet Weather Centrals which gather, process, and disseminate weather forecasts, atmospheric data, sea state and other meteorological data all over the world to user facilities. Satellite photos may also be reproduced on facsimile recorders when the proper auxiliary equipment is provided to receive and process the transmitted satellite signals.

6.4 WEATHER ACTIVITIES

The Naval Weather Service Command (NAVWEASERVCOM), under a Commander reporting directly to the Chief of Naval Operations, comprises a Headquarters and assigned shore (field) activities. The Commander is the central authority within the Department of the Navy for meteorological and associated oceanographic matters. The Headquarters, Naval Weather Service Command (NAVWEASERVCOMHQ), located at the Washington Navy Yard, Washington, D. C., is a staff element of the Commander.

6.4.1 Fleet Weather Centrals and Facilities

Fleet Weather Centrals (FLEWEACEN), the Fleet Numerical Weather Central (FLENUMWEACEN), and Fleet Weather Facilities (FLEWEAFAC) are line elements of the Naval Weather Service Command.

FLEWEACEN's are assigned geographic areas of responsibility in which they perform the functions of data collection, centralized computer processing, and the dissemination of analyses, forecasts, warnings, and ship routing information. As an exception of this policy, FLEWEAFAC Suitland is also assigned a geographical area of responsibility in conjunction with assigned Arctic ice forecasting functions.

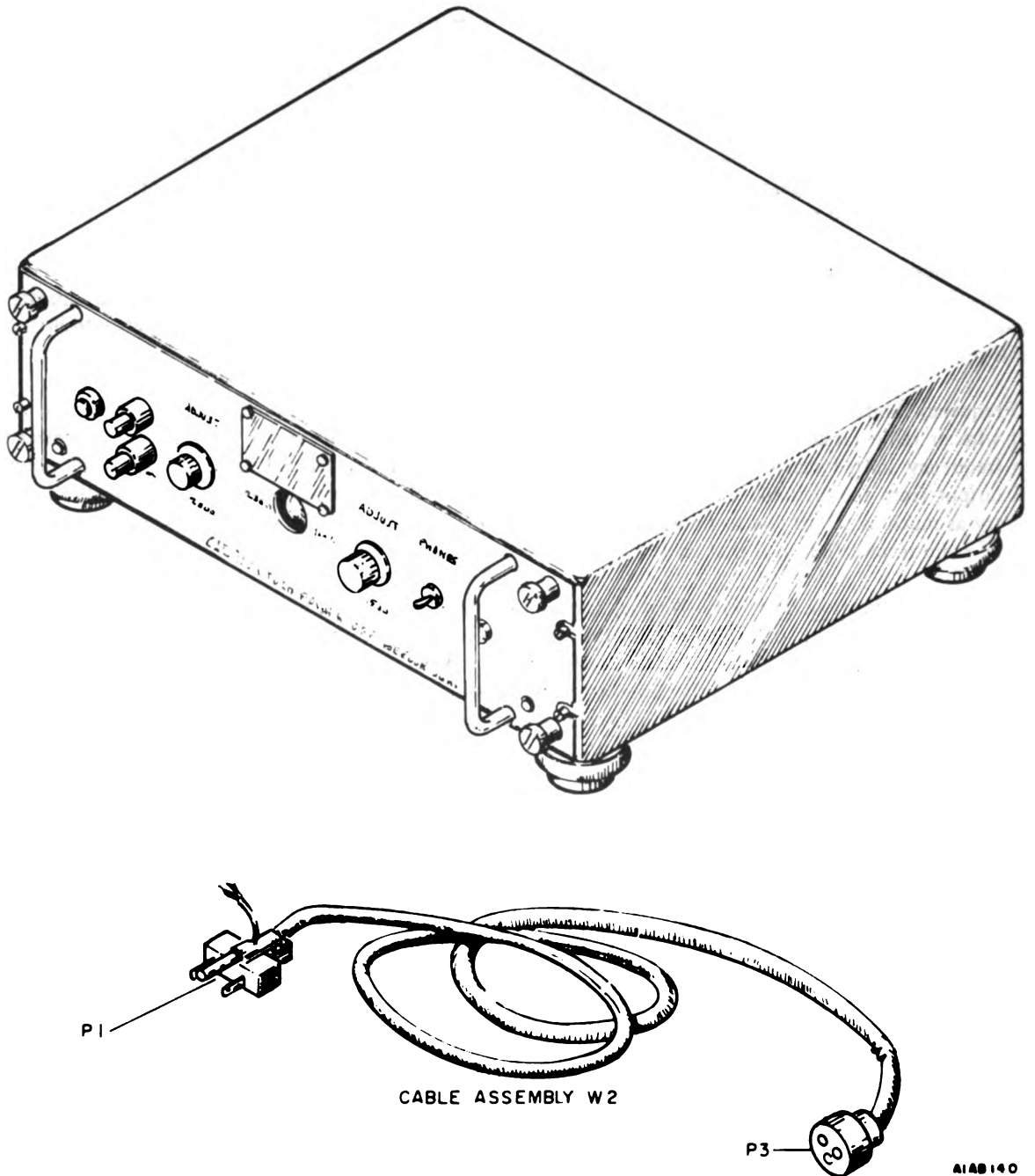


Figure 6 - 41. Radio Modulator, MD-168A/UX

FLEWEAFAC's provide assistance in the performance of assigned functions to the FLEWEACEN in their geographic areas. In addition, they are assigned specialized functional tasks such as hurricane forecasting, ASWEPS support, surf and swell forecasting, and ice reconnaissance coordination and forecasting.

6.4.2 Fleet Numerical Weather Control

The Fleet Numerical Weather Central (FLENUMWEACEN), located at Monterey, California, coordinates the NAVWEASERVCOM electronic computer effort and operation of the Navy Environmental Data Network (NEDN). It is linked with the data collection networks of the U. S. Air Force and the Environmental Science Services Administration (ESSA), and provides world coverage.

a. Development of the Fleet Numerical Weather Central. The activity started in 1958 as a Navy Numerical Weather Problems Group by personnel attached to the Fleet Weather Central, Suitland, Maryland. Relocation to Monterey occurred in 1959. In recognition of its increasing importance in the Naval Weather Service, and its related Fleet Weather Central System, the facility was designated Fleet Numerical Weather Central (FNWC) in 1968.

FNWC has become a vital part of the oceanographic community in the ensuing decade. The officers and civilian scientists and technicians are leaders in the use of environmental parameters for operational forecasts using numerical methods and high-speed computers. Many of those assigned to FNWC duty have advanced degrees in both meteorology and oceanography.

b. The Missions and Functions of FNWC. Fleet Numerical Weather Central has been assigned the missions to provide, on an operational basis, numerical meteorological and oceanographic products peculiar to the needs of the Department of the Navy; and to develop and test numerical techniques in meteorology and oceanography applicable to the Naval Weather Service Command analytical and forecasting problems.

The following functions are assigned to Fleet Numerical Weather Central:

- o Provide operational environmental support to the Department of the Navy, and to other government agencies or activities, as assigned.
- o Conduct studies leading to development of operational numerical models and techniques for improved weather and oceanographic analysis and prediction. Submit progress reports to Naval Air Systems Command with a copy to the Commander, Naval Weather Service Command (COMNAVWEASERV) in accordance with AIRTASK/WORK UNIT ASSIGNMENTS:
- o Investigate environmental effects on oceanographic sound propagation and develop computer techniques for forecasting propagation conditions.
- o Act as system/network coordinator of the Naval Environmental Data Network (NEDN) in accordance with NAVWEASERVCOMINST 2309.1-series, and establish necessary network control procedures to ensure efficient and timely product distribution throughout the network, referring any significant conflict in priorities to higher authority.
- o Develop and maintain a climatological and oceanographic data bank of sufficient size to support validated environmental product requirements.
- o Provide environmental inputs to the Fleet ASW Analysis Program (FADAP) data bank as requested.
- o Assist operational commanders, as requested, in the evaluation of environmental effects on naval operations.
- o Conduct liaison with the academic community and research activities in connection with the development of computer programs and techniques for naval applications.

- o Conduct formal liaison with the Environmental Science Services Administration and the U. S. Air Force computer centers as required to ensure maximum use of common products and avoid undesirable duplication of effort.

- o Maintain a library of all operational and management programs and routines written for the various NEDN computers in use, and distribute properly documented programs to computer-equipped activities within the NAVWEASERVCOM.

- o Prepare, submit or distribute, as appropriate, technical memoranda and notes on technical developments of the FLENUMWEACEN, indicating the appropriate distribution of the document.

- o Act as technical advisor to the COMNAVWEASERV on computer techniques, utilization, and maintenance matters, and provide assistance to component activities throughout NAVWEASERVCOM.

- o Investigate methods, evaluate, and develop prototype equipment for the rapid and economical dissemination of numerical environmental products to the Department of the Navy and other agencies as separately authorized.

- o Investigate computer and associated equipment developments and recommend procurement plans for the NAVWEASERVCOM. Procure, when authorized, the computers, and other computer equipment for the NEDN. Coordinate, in conjunction with the NAVWEASERVCOM receiving activity, delivery and installation arrangements for the computers procured. In addition, maintain plant property accounts in accordance with NAVCOMPT Manual Volume 3, Chapter 6, for all NEDN equipment less such equipment as may be plant accountable by the Naval Communications Command.

- o Provide systems design and prototype equipment development for interfacing environmental measurements, as obtained from weather observation systems with high speed data transmission systems. Transmitted data must be computer compatible. Test and evaluate system developed.

- o Prepare and distribute, as appropriate, the NEDN System Preventive Maintenance Manual with standards for all equipment plant accounted to the NEDN.

- o Solicit, evaluate, and implement, as appropriate, suggested modifications and/or changes in configuration of NEDN equipment from NEDN equipment users.

c. Concept of Operations. Consistent with the missions and functions listed earlier, FNWC produces and transmits a complete set of environmental products and services to support the whole spectrum of Naval operations and planning. Products are available in any form, scale, or map projection. In fact, the availability of these tailored products has led both to increased requirements and to formulation of a "numerical philosophy" wherein field specialists learn to devote their time and talents to matters of interpretation and judgement, and to critical analysis and feedback, rather than engage in wasteful manual efforts.

The concept of operations of FNWC pertains to, and delineates, the manner in which each step of the environmental "data cycle" is executed. There are eight steps in this cycle. The cycle is repeated twice daily for upper air and oceanographic variables; and four times daily for hemispheric surface variables. The steps are: observation, collection, input processing, analysis, prediction, output processing, distribution, and display. By means of a fully automated, computerized operation, FNWC minimizes the time lag between the collection of data and the distribution of the final products. The job cannot be done by hand in the time allowed.

In each cycle FNWC performs hemispheric scale analyses and prognoses of all the meteorological and oceanographic parameters necessary to accomplish the support function. Very often the success or failure of a Naval operation is determined by the availability and validity of products which specify the state of the operating environment. The Navy's environment extends from the ocean floor to "near" space. By "adequate support" is meant accurate future descriptions of all pertinent oceanographic and meteorological parameters and phenomena as required for operations and planning.

These environmental analyses and predictions are transmitted, on high speed digital-data communications links, to the NEDN's primary computer sites at the Navy's Fleet Weather Centrals around the world (Guam; Pearl Harbor; Norfolk, Virginia; and Rota, Spain).

At these sites the received hemispheric data "fields" are used as inputs for other computer programs which tailor the output to specifications of the user (maps, messages, or computer graphics). These products are transmitted to the operating forces via Navy radio-telegraph and radio-facsimile. These are also used as the basis for rather lengthy verbal descriptions of significant weather, wind, and sea conditions for the vast ocean areas around the Northern Hemisphere. These messages are relayed both to Navy vessels and to commercial shipping.

For shore-based installations in the United States, environmental products reach recipients by means of the East Coast Tieline and West Coast Tieline, another innovation of the NEDN. Tieline stations are equipped with map plotting and teletype playback equipment. In addition to Navy stations, the tielines also service such users as the oceanographic institutions (SCRIPPS, WOODS HOLE), and the Bureau of Commerical Fisheries.

Aside from using a fully computerized operation, FNWC also adheres to a set of postulates which contribute both to validity and reliability of the entire support system. Among these are:

- o Single Environment. Realistic solutions are obtained for environmental prediction problems, if and only if, the atmosphere and the oceans are treated as a single, coupled system. The atmosphere is considered as the principal "driving force" for the oceans. Most Naval operations take place at or near the air-ocean interface where interactions are very complex.

- o Engineering Approach. Since dynamic models suffer from poor initialization (due to sparse, inaccurate, or non-representative observations), incompleteness of the physics, and a lack of knowledge about the physics of small-scale processes and phenomena; logic leads one to attempt to "tune" or optimize the mathematical models to better resemble the real environment. Any consistent "manual" improvement is assumed to be programable. Extensive comparisons between the forecasts and the observed distributions of variables are in order until such time as more of the universal truth about the environment is known.

6.4.3 Navy Environmental Data Network (NEDN) System Principle

The Naval Weather Service/Navy Environmental Data Network (NWS/NEDN) (figure 6-42) is based upon the timely collection and assembly of worldwide environmental data at one location, where it can be quickly processed and accurately analyzed for immediate worldwide dissemination to Navy and other authorized users. The central processing and analysis location is FNWC Monterey, and the worldwide communications network by which this data is collected and disseminated is the NEDN.

The flow of data, both atmospheric and oceanographic, into the NWS/NEDN system originates with many different sources of information. These include the USAF Automated Weather NET (AWN), U. S. Navy Fleet units and shore activities, the U. S. Weather Bureau and various other sources, such as the worldwide merchant fleets of many countries, which contribute periodic weather observations. Oceanographic facilities such as the Bureau of Commercial Fisheries and Woods Hole Oceanographic Office contribute sea temperature, current flow, and other oceanographic data.

The overriding constraint on almost every aspect of NWS/NEDN operations is time. Environmental data is a highly perishable commodity whose value decreases rapidly towards zero, often after only a few hours. Operational decisions and military mission planning, as well as the protection of life and property, frequently depend upon the timely receipt of accurate environmental analyses. The whole NWS system can be rendered valueless and its purpose thwarted by a failure of the data communications to operate in an acceptable and realistic time frame.

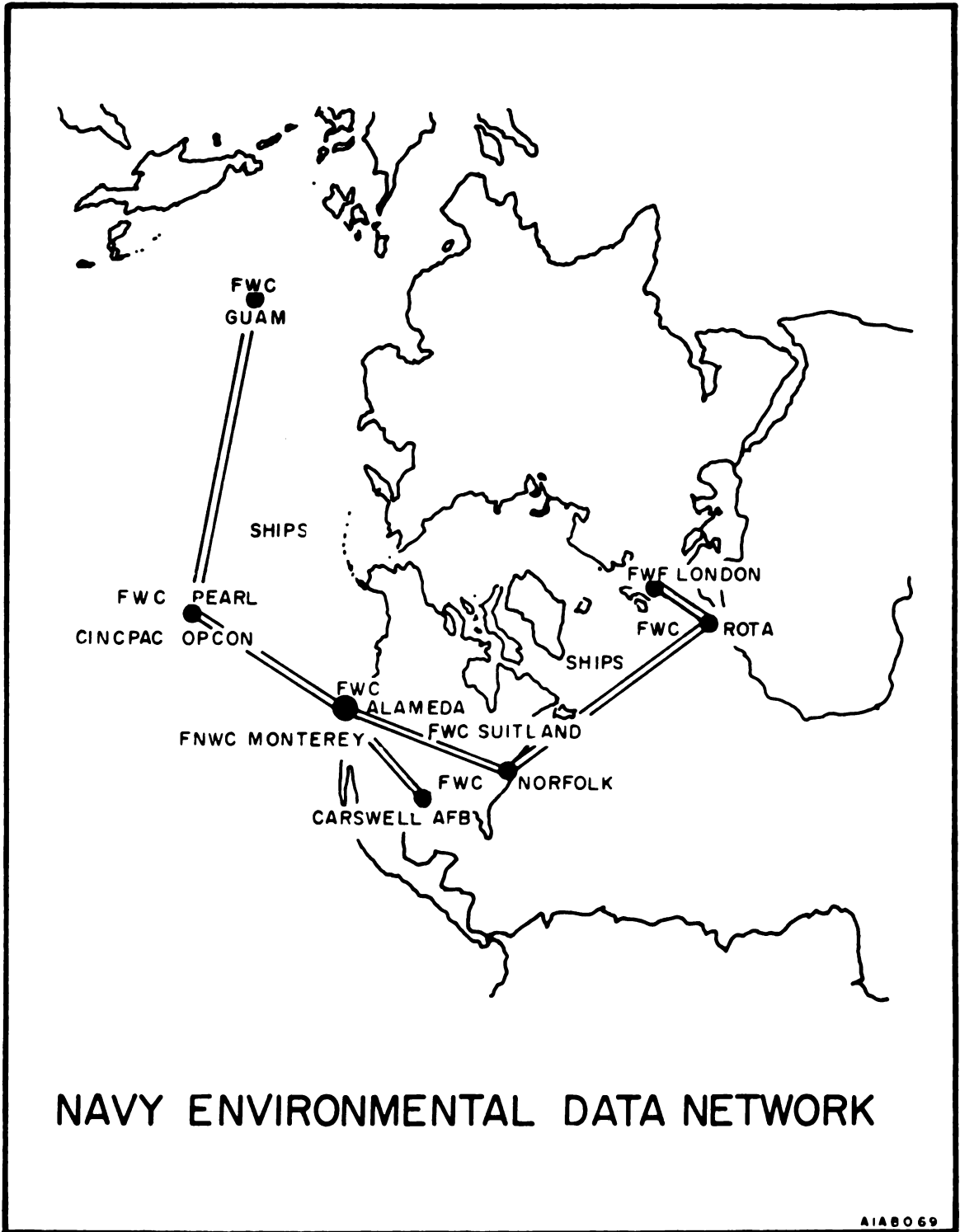


Figure 6 - 42. Navy Environmental Data Network

a. System Configuration. The NEDN is distributed by the use of dedicated landline circuits which are broken down into two primary distribution systems. These circuits are the mainline and tieline circuits. The NEDN mainline system (figure 6-43) consisting of point-to-point circuits linking Monterey to Norfolk to Rota, and Monterey to Pearl to Guam, with additional links from Monterey to Carswell AFB, Monterey to Alameda, Norfolk to Suitland, and Rota to London. FNBC Monterey is the NEDN mainline network controller and the primary distributor for the NEDN system.

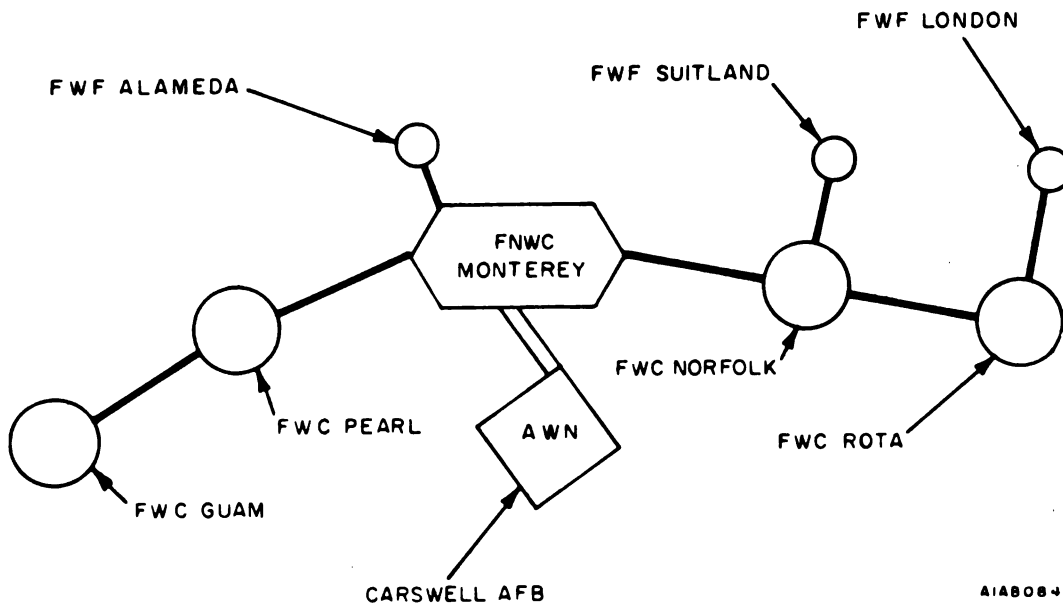


Figure 6 - 43. NEDN Mainline Circuits

The tieline circuits are designed to service each coast with the proper data required by each area or station. The east and west coast NEDN tielines (figure 6-44) operate quite differently from the NEDN mainline net. The tielines are not physically linked to the mainline circuits. Instead, data from ENWC Monterey addressed to the East Coast tieline stations are sent directly to Norfolk on the mainline where it is captured on a tape drive, peripheral to the on-line computer. Tieline data is discretely addressed to the station or stations for which the data is intended. The tieline net control coordinators, Monterey and Norfolk, take the data tapes for their tieline stations and broadcast them on the tieline.

FNBC Monterey and FWC Norfolk deliver computer-formatted meteorological data to subscriber stations on the NEDN east and west coast tieline networks. NEDN data to be delivered to the tieline stations will include general products, such as hemispheric maps which are scheduled for all tieline stations, regional information which will be scheduled for a number of stations, and single addressee information which need be sent only to one tieline addressee.

b. System Application. The intent of the NEDN system is to gather meteorological data from all over the world and to distribute the end result of previously gathered data which has been analysed and prepared for transmission to user stations. This information will be used to prepare forecasts, or maintain local meteorological records.

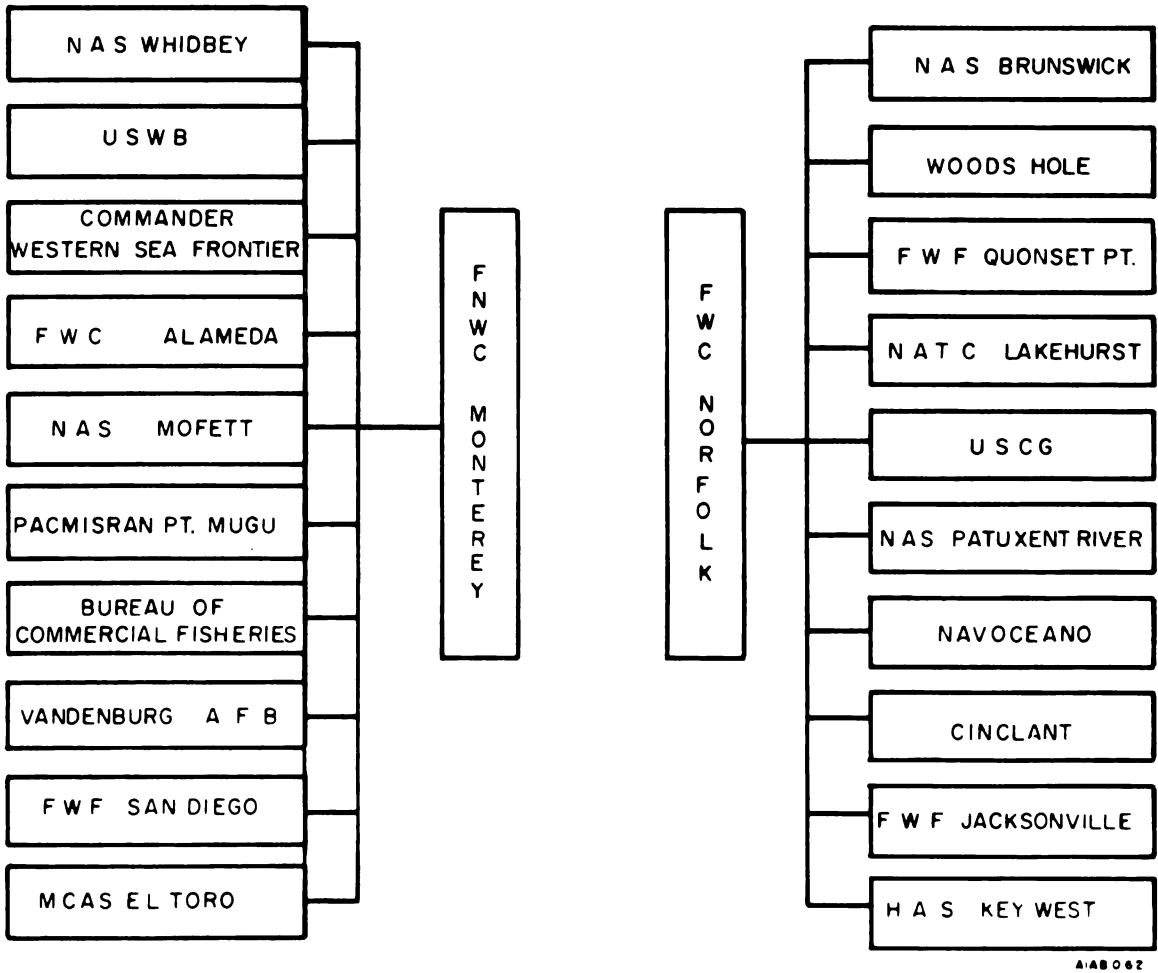


Figure 6 - 44. NEDN East and West Coast Tieline Circuits

The mainline circuits transmit high speed data which must be computer analysed and formatted prior to redistribution to user stations. The tieline stations receive only properly formatted data which has been addressed to specific stations for their immediate use. The NEDN is a service function of the Naval Weather Service.

6.4.4 Naval Air Station Weather Facilities

The meteorological equipments located on a Naval Air Station are operated and controlled by a Naval Weather Service Environmental Detachment which provides specific local support services to the station. They are organized under officers-in-charge who report to designated Fleet Weather Centrals or Fleet Weather Facilities which are comprised of trained meteorological personnel. There are certain equipments which are unique to Naval Air Stations such as the transmissometer and runway visual range indicator, the cloud-height set, wind measuring system, and the weather television system. These systems have been discussed in this chapter, their installation criteria will be discussed in chapter 13.

CHAPTER 7

BASE SYSTEMS ENGINEERING

Base system engineering is concerned with the proper operation of the complete station, including the functional electronic systems, buildings, and grounds. This handbook is mainly concerned with presenting engineering and installation criteria on Naval Air Station electronic systems and associated equipment. The latter will encompass special buildings, rooms, structures, and conditioned terrain. The criteria required by planners, engineers, and supervisors responsible for the installation and operation of the following electronic systems are presented in chapters 8 through 14.

- o Air navigational systems
- o Radar systems
- o Communications systems
- o Air traffic control facilities
- o Meteorological facilities and systems.

The material of these chapters is intended to present the most acceptable practices and procedures for use in electronic system design, installation and operation. It should be used to establish a basis for standardization of Naval Air Station Systems. However, no handbook can substitute for detailed planning and sound engineering judgement in the design of each project. The individual systems are detailed as follows:

- o Operational requirements - Why the system is needed, and a brief description of how it works.
- o System configuration - Overall configuration in light of installation and location, and a brief description of the subsystems.
- o Site and structural criteria - All pertinent facts required to prepare for the installation of an electronic system.
- o Installation criteria - All specifications and procedures to be observed for an efficient, reliable, and qualified electronic system installation.
- o Operational and maintenance procedures.

CHAPTER 8

ELECTRONIC FACILITIES

In planning a new Naval Air Station or alteration of existing electronics facilities, it is realized that in certain cases compromises will be necessary because of limited available land areas or similar contingencies. However, the following requirements shall be adhered to wherever possible, and all budgetary estimating for new construction projects shall be based on these criteria.

8.1 SITE FACTORS AND STRUCTURAL CRITERIA

Site selection criteria for all electronic facilities are based on technical requirements for the avoidance of mutual interference and for maximum utility. The specified minimum separations therefore will be maintained insofar as possible. Except as herein modified, the specifications for site selection for the Radio Transmitter Station and the Receiver Station, as described in other NAVELEX publications (e.g. 0101,102/0101,103/0101,104) shall apply.

8.1.1 Siting of Components for Electronic Considerations

Although not always obtainable, the following site areas and component separations are highly desirable minima:

- o Remote transmitter (HF), site area 60 acres, from:
 - Operations building and control tower: one mile
 - Remote receiver building (HF): three miles
 - Remote VHF/UHF receiver building: 1500 feet
- o Remote receiver building (HF), site area 250 acres, from:
 - Operations building and control tower: one mile
 - Radar installation (depending on type): 1500 feet (See Note.)
 - Highways and industrial and housing areas: one mile
 - Open-wire power lines and station roadways: 1000 feet
- o Remote VHF/UHF transmitter building, site area 1 acre, from:
 - Operations building and control tower: 1000 feet
 - Remote VHF/UHF receiver building: 1500 feet
- o Remote VHF/UHF receiver building, site area 102 acres, from:
 - VHF/UHF transmitters: 1500 feet
 - Highways, industrial and housing areas: 1000 feet
 - Radar installations: 1500 feet (See Note.)

NOTE

The 1500-foot separation is based on interference to communication facilities by some of the older radar types. Later radar models have been engineered to minimize such interference to the extent that a lesser separation may be acceptable.

8.1.2 Siting of Components for Other Considerations

All electronic facilities should be located as far from salt water and as high above sea level as possible to avoid corrosion of metal parts and requirement for special filtering of outside air supply to air condition equipment. See paragraph 8.1.8, Environmental Control, where it is necessary to place buildings closer than 1/2 mile of salt water.

8.1.3 Aircraft Clearance

Sites shall be in conformance with Naval Air Systems Command requirements for aircraft clearance. Sites shall be so located as to anticipate possible expansion of the runway system without relocation of electronic facilities. See U.S. Naval Weapons Shore Facilities Planning Standard, NAVWEPS (Formerly NAVAER) 00-100-505.

8.1.4 Ammunition and Fuel Storage Areas

If the radio facility requirements that are listed in paragraph 8.2.1 can be met in these areas, there is no technical (electronics) objection to locating them in ammunition and fuel storage areas. Any decision to so locate them shall take into consideration the risks involved, and requires full approval of the appropriate technical bureaus and cognizant commands. If a waiver requirement exists, it should be initiated at activity level in accordance with established procedures. It should be noted that ammunition or explosives containing electro-explosive devices must have a separation of at least 1000 feet from all radio and radar antenna, and other high energy RF fields. Further precautions are to be found in chapter 7 (7.7.3 and 7.7.4) of NAVELEX 0101,106.

8.1.5 Buildings

The Bureau of Yards and Docks has definitive designs for standard structures, expandable in increments. Building space for electronic facilities and buildings designed for electronic equipment shall be of such size as to permit an increase of electronic equipment to 25 percent over and above current Chief of Naval Operations' operational requirements.

8.1.6 Fire Protection

"Normally, for protection of electronic equipment a carbon dioxide hose reel protection system will be required. This requirement is applicable to government owned electronic equipment installations in which the total equipment value is in excess of \$100,000 or the operating requirements of the installation are of strategic importance. Requirement for equipment to be protected by carbon dioxide hose reel system will be stipulated in the Physical Plant Section of the Project BESEP.

Specific design criteria for protection of electronic equipment and raised floor spaces containing exposed cables is found in NAVFAC Design Manual DM-8 and NAVFAC Design Technical Note No. 38."

8.1.7 Power

A standard medium generator building accommodates a generator power range of approximately 60 to 160 KW, at 0.85 power factor. A standard large generator building accommodates a generator power range of approximately 160 to 400 KW. Both buildings cover the estimated power range requirements for all electronic equipment. See Definitive Designs (BuDocks).

All buildings will require underground radio-frequency cable, communication cable (telephone type), and power cable. Control cables shall be as far removed as possible from the power-cable entrance.

The capacity of the primary source of power should be sufficient to provide the peak electric power demand during normal operations. Where provided, the station standby plant shall be considered adequate for auxiliary power if separate feeders are installed.

For emergency power at each site, an automatic start, switch-over plant, with manual features, shall be provided. It shall be capable of carrying 100 percent of the electronic load, plus the minimum utility requirements. Where economically feasible, 100 percent load emergency power should be provided which may also serve as standby power.

8.1.8 Environmental Control

Environmental control includes provisions for heating as well as cooling to suit climatic conditions and filtering air to suit local conditions. A general specification for spaces housing electronic equipment requires that the air conditioning be capable of conditioning the entire space either when all equipment is in operation, in standby or down. It should be designed to maintain a temperature not higher than 80°F during cooling season and not lower than 70°F during heating season. The relative humidity should not exceed 60%. For facility containing humidity sensitive equipment such as computers and paper tape devices the humidity should be controlled as detailed by equipment requirements and generally will be 50% ± 10%. These conditions should be stated in BESEP. The outside and recirculated air should be filtered with 20% efficiency filters per National Bureau of Standards Atmospheric Dust Spot Test. For stations located closer than 1/2 mile from salt water or other corrosive atmosphere, the outside air should be filtered with high efficiency filters. The rating should be approximately 80% efficiency (to suit electronic equipment requirements) per National Bureau of Standards Atmospheric Dust Spot Test.

8.1.9 Antenna Construction

All antenna construction must be accomplished with consideration given to the mission of the station which is to furnish control and guidance to aircraft. Clearance requirements must be met. Antenna mast lighting is required by flight safety criteria.

8.2 BASIC COMPONENTS

The basic functional electronic system requirements for a Naval Air Station include:

- o Air Navigational Aids (Chapter 9)
- o Air Surveillance - Radar (Chapter 10)
- o Communication (Chapter 11)
- o Air Traffic Control (Chapter 12)
- o Meteorology (Chapter 13)

The quantity of each type of equipment required, will depend on the station's mission. Thus, an important consideration in the development of the facility is the amount of traffic anticipated for the facility. Air traffic control (ATC) facility has been variously defined as anything from a flashlight and a hand set to a fully instrumented radar complex with a dozen or more indicators. The extent of the capability of the air traffic control system is predicated on the volume of traffic. The selection of a radar will oftentimes be dictated by the amount of traffic. A mobile GCA and a small remotod GCA facility have essentially the same radar capability. However, the mobile GCA facility can only handle a relatively few aircraft at any one time. Whereas a remotod

GCA with radar indicators added as necessary can handle a huge volume of traffic in the same period of time. Another important difference lies in communications. Mobile GCA communications are extremely limited, particularly from the point of view of area coordination. A remoted GCA facility on the other hand has a far greater landline capability, the extent of which is dictated by area requirements. The number of targets and the amount of traffic to be handled will in general dictate the expansion; for example, a mobile GCA facility into a full blown radar air traffic control facility (RATCF).

Many of these ATC innovations have been discussed in chapter 3, and additional systems and equipment are presented in the following chapters.

8.3 CONTROL AND TERMINAL SYSTEMS

The equipments required to provide linkage between end instruments and transmission facilities and/or between one transmission facility and another in a complex communication system are part of control and terminal systems. In elementary systems, for example, if the output of an end instrument, such as a microphone, is used to directly modulate a transmitter, or a headset at the output of a receiver is the end instrument, neither requires terminal equipment. However, as the complexity of the communication system goes beyond this, the landlines, microwave links, multichannel operation, and multiplexed systems are used for remote control and for rapid transfer of intelligence between end instruments, terminal equipment is required to perform complex conversions and for interlinkage of transmission facilities.

Remote control of the electronic equipment is usually accomplished by the use of buried telephone-type cables. Buried video cabling may be required. Microwave links may be desirable, especially for off-station components. Leased wire service is used where applicable. Cable or microwave closed-circuit TV service may be used for dissemination of weather information.

The radar equipment and navigational aids used for air traffic control are increasing in quantity and are required to be remoted from the control center. Therefore, control and terminal equipment for these systems must be included in the design and construction of modern air stations.

Many different types of terminal equipment are currently in use in military communication systems. For versatility and flexibility, many types have been designed to work interchangeably with existing transmission systems such as telephone, point-to-point, and broadcast radio circuits. Other types of terminal equipment have been designed to work with specific systems such as microwave link systems which have built-in terminal facilities. Equipment currently in use includes frequency shift keyers, telephone terminal equipment, time division multiplex teletypewriter systems and teletypewriter carrier terminal systems. Details on these and other equipments are presented in chapters 3 and 11.

8.4 OPERATIONS

The electronic facilities can be roughly divided into two categories: those which require attended operation, and those with design features which permit unattended operation. Both categories require facilities for monitoring and testing, and system engineering should provide facilities and set up procedures so that equipment will operate to meet the required performance standards prescribed for the system in which the equipment operates.

NAVELEX, through the local Field Technical Authority who has had technical responsibility toward selection and installation of the equipment, also has a firm interest in such techniques of operation and maintenance that will provide optimum performance. The Field Technical Authority, upon request, will provide engineering service toward the development of operating techniques, and maintenance procedures aimed at improved operation. The instruction book of an individual equipment may be adequate for that unit, but it may fail to provide operational techniques which will make it compatible with other units integrated into a system.

Criteria for the establishment of system tests and maintenance are contained in chapter 14. Such criteria are useful to the Ground Electronic Maintenance Officer (GEMO) in collaboration with the Field Technical Authority, toward the establishment of operating techniques for equipment and systems. Performance should conform to applicable portions of the current MIL-STD-188, and to such criteria on performance standards as are discussed in this handbook.

Precise line-level maintenance and the proper set-up of transmitters are particularly needed where numerous communication channels for the control of aircraft are in operation simultaneously. Crosstalk and the effects of over-modulation are frequently encountered through carelessness or lack of information concerning proper operating and maintenance techniques. When equipment does not contain automatic output level circuitry, the use of line amplifiers with a compression feature is specified by NAVELEX for use on multi-pair telephone-type cables to prevent high level signal crosstalk. Such an amplifier, if improperly adjusted or installed, may produce distortion, or raise the noise level to an unsatisfactory degree. Clipping circuits, used in the modulators of transmitters to prevent over-modulation, may also distort the audio output if improperly used. The newer VHF/UHF transmitters, receivers and associated control equipment do not require compressor amplifiers in normal installations.

Circuits used in the control of aircraft are continuously monitored with tape recorders to obtain a record of message traffic.

Audio amplifiers and speakers are arranged for continuous use, or for patching into audio lines when required.

Vu-meters such as the TS-629/U are mounted conveniently for use at all patch panels carrying audio signals.

Modulation measuring equipment is made available at transmitter facilities so that transmitters may be adjusted for optimum performance. At the VHF/UHF receiver building, if all IF outputs of the receivers are brought to a central patch panel, an HF receiver, tuned to the intermediate frequency of the VHF/UHF receivers, plus an oscilloscope, will permit critical examination of both incoming and outgoing transmissions.

All transmitting antenna feeders (coaxial lines) will have monitor-coupler assemblies so arranged that the measurement of the forward and reflected wave energy, and thus the VSWR, can be measured during operation. This applies to HF transmitters and with VHF/UHF additionally to those assemblies which are a part of the multicouplers. For operator convenience, the VSWR derived voltages are remoted to the control console area.

Navigational aids usually operate unattended, but equipment is provided in key locations for continuous monitoring of these systems.

Radar facilities are usually manned during the day shift and operate unattended at night. During the day, maintenance personnel conduct routine checks and are available for major repairs of inoperative or faulty equipment. At night the radar controllers monitor the radar equipment operation and call the duty maintenance personnel in case of failure.

Maintenance facilities and equipment required on a Naval Air Station are detailed in chapter 14.

CHAPTER 9

AIR NAVIGATIONAL AIDS FACILITIES

An air navigation aid is a device or system that provides a pilot (or navigator) with some or all of such navigation data as present position, heading, speed, location of fixed objects and moving objects, steering directions or automatic steering, and altitude.

Considerable progress has been made in recent years in the development of electronic equipment systems for the purpose of aiding navigation. These systems, when properly used, have proven to be of value in providing information in the navigation of aircraft.

This chapter sets forth some of the equipment and criteria established by the military and civil aviation authorities as standards for air navigational aids. This material is presented in limited detail, with reference documents mentioned for further in-depth study.

9.1 VHF/UHF DIRECTION FINDERS

9.1.1 Operational Requirements

A VHF/UHF direction finder (DF) is a ground-based radio direction finder capable of being used alone or in conjunction with airfield surveillance radar for ATC. In recognition of its ATC capabilities, a VHF/UHF DF is recommended, wherever surveillance radar is installed, to be used as a secondary means of identifying targets on the radar scope. As no specialized equipment beyond the normal VHF/UHF transceiver is required in an aircraft, the direction-finding operation is capable of providing navigational guidance to aircraft equipped with only a minimum of radio equipment.

For rapid control of air traffic it is desirable that the direction finder and radar be automatically coordinated, particularly for use in emergency. The Direction Finding Coordination System, when installed in an ATC facility, applies the output of the direction finder to one or more radar indicators. In such an integration the direction finder bearing information of the target provides an immediate identification of the calling aircraft on the radar monitor.

The VHF/UHF direction finder installations at naval air activities are engineered for use in the IFR room of large facilities, or the control tower of small air stations. A direction finder is also a standard component of a mobile GCA van. The range of this equipment is approximately 125 miles for detection of aircraft-originated radio signals.

9.1.2 System Configuration

The three major units of a VHF/UHF DF installation are the antenna, the receiver group, and the azimuth indicator. The rotatable antenna is designed for either the VHF or UHF range and is usually located on top or near the control tower. The receiver group may be located up to 150 feet from the antenna, thus is usually installed in the tower equipment room located below the control tower cab. The azimuth indicator may have up to a 1,000-foot (cable distance) separation from the receiver group. As the operating and control component of the radio direction finder, the indicator is located in either the IFR room or the control tower of a small activity.

A typical radio direction finder block diagram is shown in figure 2-20.

9.1.3 Site and Structural Criteria

There are specific factors and precautions that must be considered and exercised in the installation of a radio direction finder antenna that directly affect bearing accuracy and optimize gapless coverage of the area. In addition, factors which are considered for VHF/UHF air-to-ground communications are also applicable to radio direction finders at these frequencies. Factors which affect wave propagation are directly applicable to the needs of a direction finder site. For example, a resonant conductor will reradiate and its field, when added to the direct field, will cause a change in apparent bearing as well as the signal strength of the received signal. A slender conductor will be sharply resonant, so the effects will be apparent at one frequency, whereas a wide conductor, will be broadly resonant and the effects will be apparent over a rather wide range of frequencies. It is necessary to locate a DF antenna sufficiently distant from a possible reradiator in order to reduce these effects to an acceptable level. Similar reasoning will, for the most part, provide criteria for optimum siting of any DF array. The following criteria are based upon such considerations and upon actual measurements, and will provide a guide for the siting of a DF facility with minimum bearing errors. The total bearing error in the low- and medium-frequency ranges is the algebraic sum of the individual errors, but in the HF range, the RMS value will give correct data since the phases are random. In the VHF/UHF range however, a study of the individual site is required to determine the total bearing error. The individual error caused by each of the criterion listed will be less than one degree. Specific siting criteria applicable to VHF/UHF direction finders are as follows:

- o Elevated horizontal conductors. An elevated horizontal conductor, such as a receiving antenna, must not subtend a vertical angle greater than three degrees at the base of the direction finder. This means that a horizontal antenna or conductor of approximately one-half foot or larger in length should not be positioned above and within 10 feet from the DF antenna. If conducting towers are used, or if the elevated horizontal conductor is a receiving antenna, the tower or transmission lines will be of greater significance and the siting must consider a vertical conductor (as described in the following paragraphs), except that the distance must be doubled due to the loading effect of the horizontal conductor.

- o Vertical conductors. Vertical conductors should not subtend an angle greater than one and one-half degrees at the DF antenna. Therefore, a vertical conductor three inches in length or larger, should not be within 10 feet from the DF antenna (at its height or above).

- o Large conducting surfaces. A flat surface, one wavelength (λ) long and one wavelength high should be at least 50 wavelengths from the DF antenna; the distance is proportional to the area. For DF operation at approximately 280 MHz, the wavelength is 3.5 feet. Therefore, a building 35 feet high and 70 feet wide, facing the DF antenna, must be at least 3500 feet away; (10λ high x 20λ wide x 50λ distance = 1000λ ; $1000 \times 3.5 = 3500$ feet).

- o Trees and woods. Single trees should be 500 feet from the base of the antenna and woods should be 1200 feet away.

9.1.4 Installation Criteria

The DF antenna should be mounted high enough to clear obstructions and reflecting surfaces in its immediate vicinity to minimize signal reflections and unequal signal pick-up. The radio direction finder has been designed to allow selection of a favorable antenna site far removed from the desired operating location. Maximum cable lengths between DF equipment groups are: antenna to receiver 150 feet, and receiver to indicator 1,000 feet.

When mounted on its mast, the antenna must be oriented so the reference arrow stamped on the antenna housing points in the direction of magnetic north (zero degrees), plus or minus 11 degrees. Fine alignment to magnetic north is accomplished after calibration of the indicator and with the aid of a signal generator and target antenna positioned due north of the DF antenna. With the signal generator in operation and a figure-eight pattern on the cathode-ray tube (CRT) of the indicator, the pattern is rotated so that the figure-eight tip falls at zero degrees on the azimuth scale of the indicator.

The antenna is enclosed in a watertight radome, thus temperature variations tend to cause unequal pressure between the antenna's interior and the atmosphere. The vent hole in the antenna drain plug allows pressure equalization and permits accumulated water due to rain and condensation, to drain. A preferable installation can be made by replacing the drain plug with a standard 1/8 inch AN hydraulic fitting and attaching an air-pressure line. With air pressure maintained at approximately 1/2 to 1 pound per square inch, both entrance of water and condensation within the antenna housing will be avoided.

The receiver group and the azimuth indicator require a 115 VAC, 60 Hz single-phase power source. Adequate ventilation is required for both the receiver group and the indicator, to avoid breakdown due to overheating of components.

9.1.5 Operation and Maintenance Procedures

Operation and maintenance procedures to be observed are found in the technical manual accompanying the RDF, and therefore, will not be discussed in this handbook.

9.2 VHF OMNIDIRECTIONAL RANGE

9.2.1 Operational Requirements

VOR is a navigational aid to aircraft, providing bearing information from a fixed ground station and consists of a fixed ground transmitting station and an aircraft receiver. The ground station provides directional guidance signals which can be supplemented by voice and tone signals for identification or other information. A special receiver mounted in the aircraft compares the phase difference of the two signals transmitted from the ground station; the fixed reference-phase and the variable-phase signals. The phase relationship of the two signals is translated by the receiver into bearing information, providing the pilot continuous track guidance to or from the ground station.

In order to provide uninterrupted transmission of navigational information, VOR station equipment operation must not be interrupted. Therefore, the VOR station is built in duplicate; one half of the station operates while the other half is held in standby status, ready to "takeover" station operation should the first half fail.

The assigned frequency band for VOR is 108-118 MHz, with a 0.1 MHz separation of channels. Power output varies from 50 watts for a terminal VOR, to 200 watts for an en-route VOR transmitter.

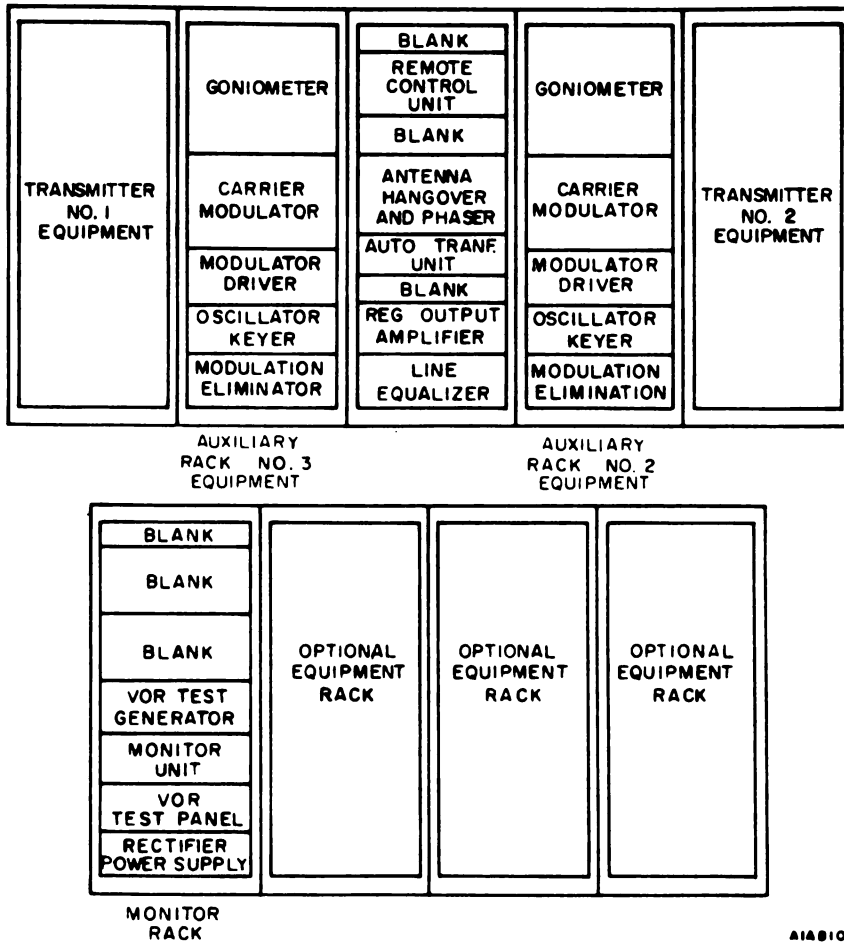
9.2.2 Ground Station Configuration

A VOR facility is designed for continuous operation and includes two complete signal-generating, modulating and transmitting sets; one set acting as a standby for the other. An equipment rack layout is presented in figure 9-1. For a block diagram and description of components, refer to chapter 2.

The four-loop antenna array used to radiate the VOR RF energy, is placed within a plastic dome-shaped enclosure which protects the antenna from the elements. The array is located 48 inches above the counterpoise which forms the 35-foot diameter roof of the VOR facility. The counterpoise surface consists of terneplate, a lead-clad material having good conducting properties. The counterpoise is an antenna element which aids in the formation of the proper radiating cone characteristics. A typical VOR facility is shown in figure 9-2.

9.2.3 Site and Structural Criteria

The quality of performance of a VOR system is dependent upon the terrain and obstructions in the immediate vicinity of the antenna as well as the terrain and obstructions within service range of the station. In other words, the most troublesome source of errors for VOR courses is propagational rather than instrumental. Reradiation or reflection of the energy reaching the aircraft can introduce an appreciable error in bearing.



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Figure 9 - 1. VOR Equipment Rack Layout

An ideal VOR site would have the following characteristics:

- o Location on the highest ground in the vicinity to provide maximum coverage.
- o Level terrain and cleared of all objects for a radius of at least 3,000 feet.
- o Within the service range of the station, no obstruction extending above the horizontal plane that contains the antenna.

In this case, since the ideal site does not contribute any errors, all errors are due to equipment. The maximum permissible deviations of the equipment, as established by ground check methods are described in FAA Handbook 6790.4 "Maintenance of VHF Omirange Equipment", dated 10/28/65.

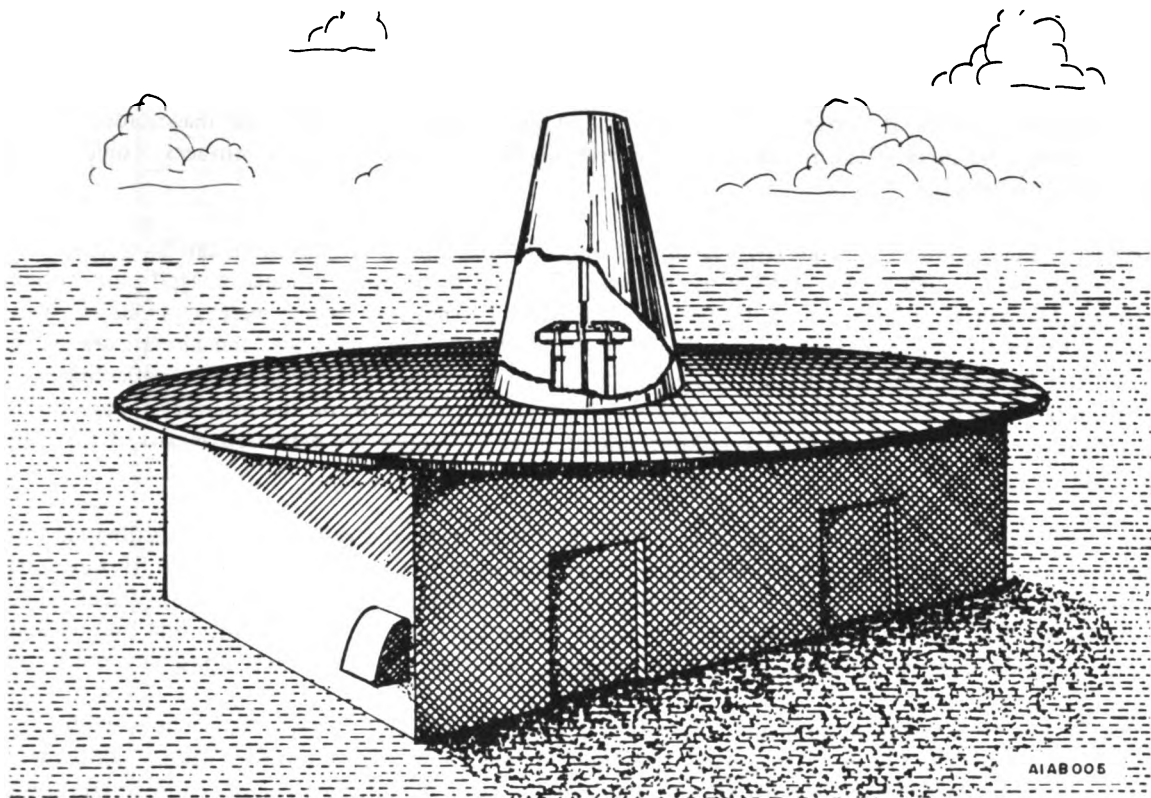


Figure 9 - 2. Typical VOR Installation

The practical or actual site generally will represent a compromise between the ideal site and what can be realistically obtained under the constraints of availability, economy of construction, legal and political, and other factors. Site selection consists of identifying potential sites and establishing the degree to which these sites can be modified to approach the ideal site. In view of the practical difficulty of obtaining an ideal site, terrain criteria are presented as an aid in the selection of a satisfactory location:

Terrain adjacent to the VOR antenna should be flat and lie in a plane parallel with and having a minimum of discontinuities visible to the antenna. The terrain should be level at the antenna for a radius of at least 200 feet. Beyond 200 feet and out to 1,000 feet, a downward slope of 4 feet per 100 foot radius may be tolerated. Terrain beyond the leveled area should be cleared and reasonably smooth.

Warped ground surfaces, either convex or concave, such as twisting ridges or hollows, will cause roughness or scalloping but may be tolerated if they do not exceed the values given in figures 9-3 and 9-4. On figure 9-4 it is shown that for an antenna 16-feet high transmitting at a frequency of 115 MHz, a 35-foot terrain deviation (H)

would be considered rough terrain up to 1,000 feet; beyond, it would be considered smooth terrain. A set of curves must be generated for each radiating frequency and antenna height. The curves depict Rayleigh's roughness criteria, establishing limits of the horizontal reflector (ground) which restricts the phase difference between the direct and corresponding indirect signals to 45 degrees causing negligible error in bearing. Terrain changes which present a smooth, vertical, reflecting surface visible from the antenna is a potential reason for course disturbance, even though the height of the change falls within the criterion for smooth terrain.

Although the quality of the VOR radiation pattern is largely determined by the terrain adjacent to the antenna, prominent terrain features at greater distances may cause disturbances of considerable magnitude. Thus, any terrain containing prominent features of landscape irregularities or large reflecting surfaces visible from the antenna, should be avoided.

The Rayleigh criteria shows that a greater degree of ground irregularities or rough terrain can be tolerated as the distance between the rough area and VOR is increased. Further, in order to produce a significant amount of interference, this area must be a substantial portion of the first Fresnel zone, which increases in size as it moves away from the VOR. The geometric relationships between VOR, first Fresnel zone, and aircraft are shown in figures 9-5 and 9-6 where the first Fresnel zone length ($x_1 + x_2$) and width W are given. For reflecting surfaces smaller than the length and width of the first Fresnel zone, the amplitude of the interfering wave decreases rapidly with size. Details on the first Fresnel zone, equations and examples are presented as part of the TACAN siting criteria paragraph.

A selected site should contain a minimum of ground irregularities, fixed and variable (such as taxiing aircraft) so the environment will conform to the permitted tolerances illustrated in figures 9-3 through 9-6. However, in the case of isolated irregularities that cannot be removed for practical reasons, guidance (as to the effect on-course error) can be obtained by establishing the size of the plane reflecting surfaces relative to the first Fresnel zone. If the reflecting surfaces are small relative to the first Fresnel zone, they are not likely to cause any course errors.

Trees close to the VOR antenna can cause severe scalloping of the radiated pattern. Single trees up to 35 feet may be tolerated beyond 750 feet, but no closer. There should be no groups of trees within 1,000 feet; and between 1,000 and 2,000 feet, all trees must subtend a vertical angle of 2 degrees or less. At mountain-top sites, no trees within 1,000 feet should be visible from the VOR antenna array.

Structures, such as hangars, buildings or towers, should not be within 750 feet, except those below the level of the counterpoise. All structures that are partly or entirely metallic shall subtend a vertical angle above the horizontal of 1.2 degrees or less, as measured from the antenna site.

Further details on the criteria presented and other VOR siting criteria is documented in VOR Siting Criteria, FAA Systems Research and Development Service, CSI-66-TR-2191 and VOR/VORTAC Siting Criteria, DOT-FAA-6700.11.

9.2.4 Installation Criteria

The VOR system equipment, including the electronic components and the antenna are installed in a building as shown in figure 9-2, along with a power distribution panel, an auxiliary power supply, and maintenance equipment. The antenna is mounted on top of the counterpoise roof with extreme care. Experience has proven that the antenna system must be installed as symmetrically as possible in order to attain a minimum radiation error and a facility that is stable and easy to maintain within low error limits. Details of the loop antenna spacing are presented in figure 9-7. The VOR monitor pickup is installed on the edge of the counterpoise or on the ground mounted detector positioner brackets at a magnetic azimuth of either 90 degrees or 270 degrees or sometimes in the primary approach radial.

Complete installation criteria for any VOR facility is documented in Section 3 of the instruction book, "VHF Omni-range Theory and Installation", originally prepared for Department of Commerce Civil Aeronautics Administration, September 1956.

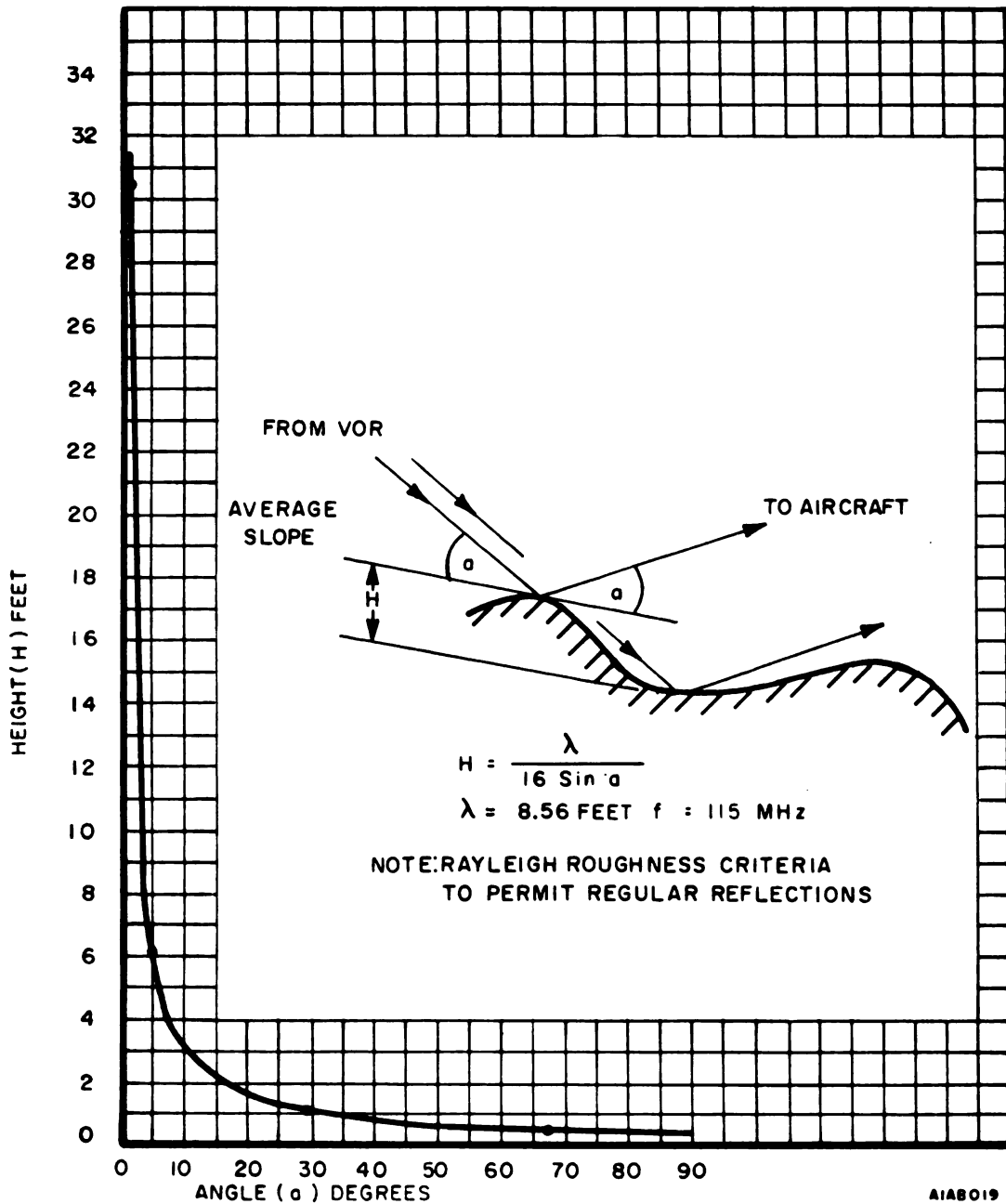


Figure 9 - 3. Terrain Roughness as Function of Average Slope

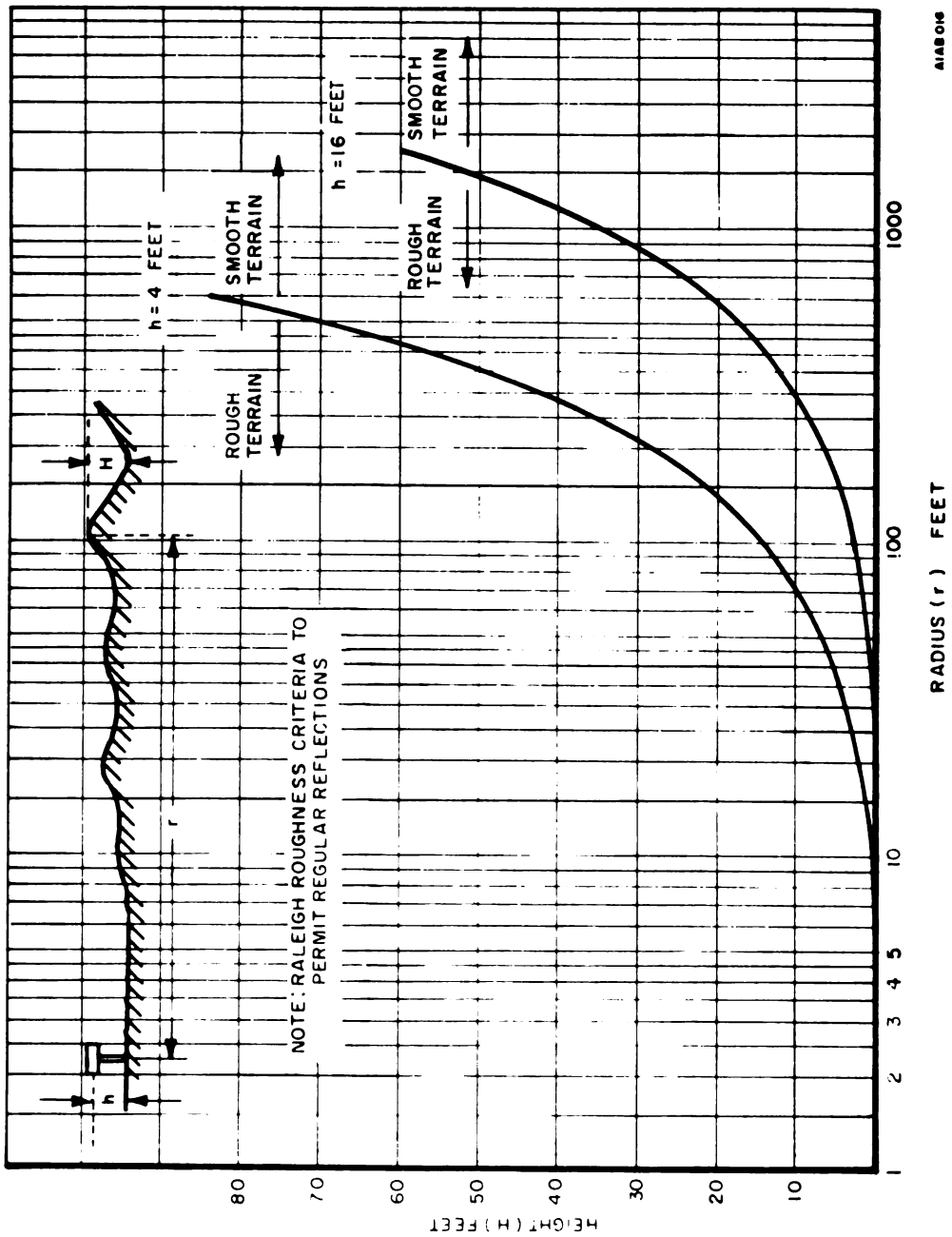


Figure 9 - 4. Terrain Roughness as Function of Distance From Antenna

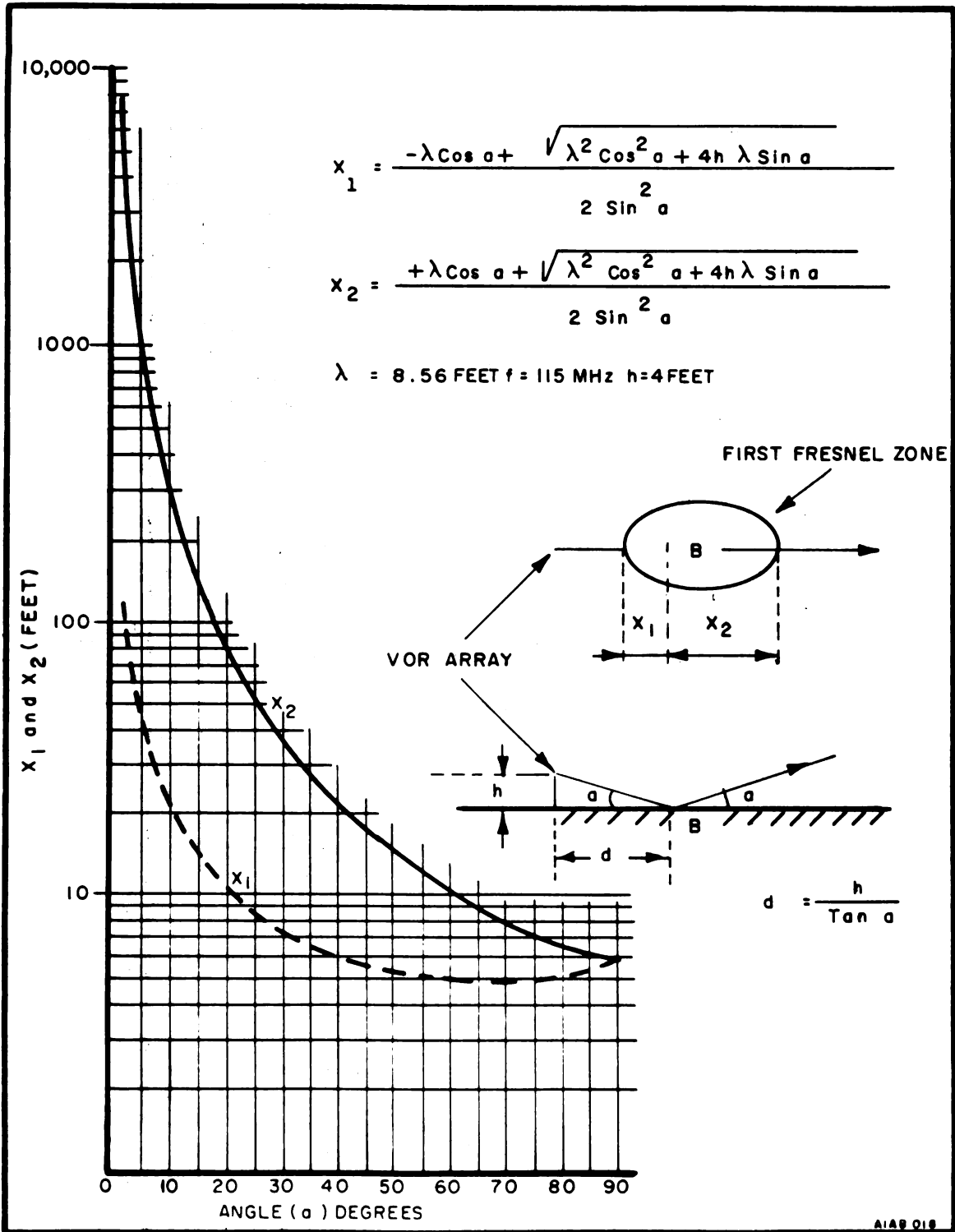


Figure 9 - 5. Length of First Fresnel Zone

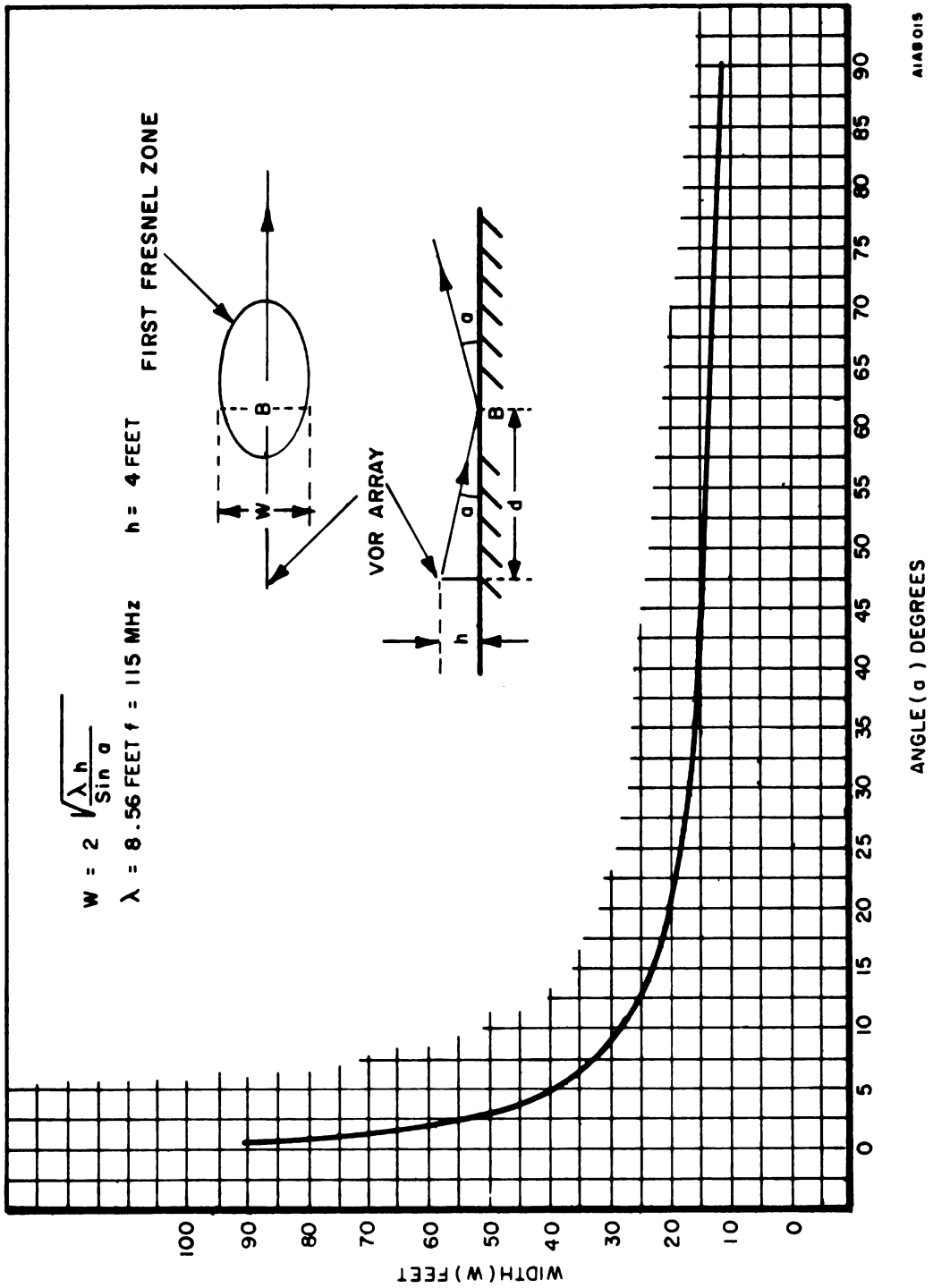


Figure 9 - 6. Width of First Fresnel Zone

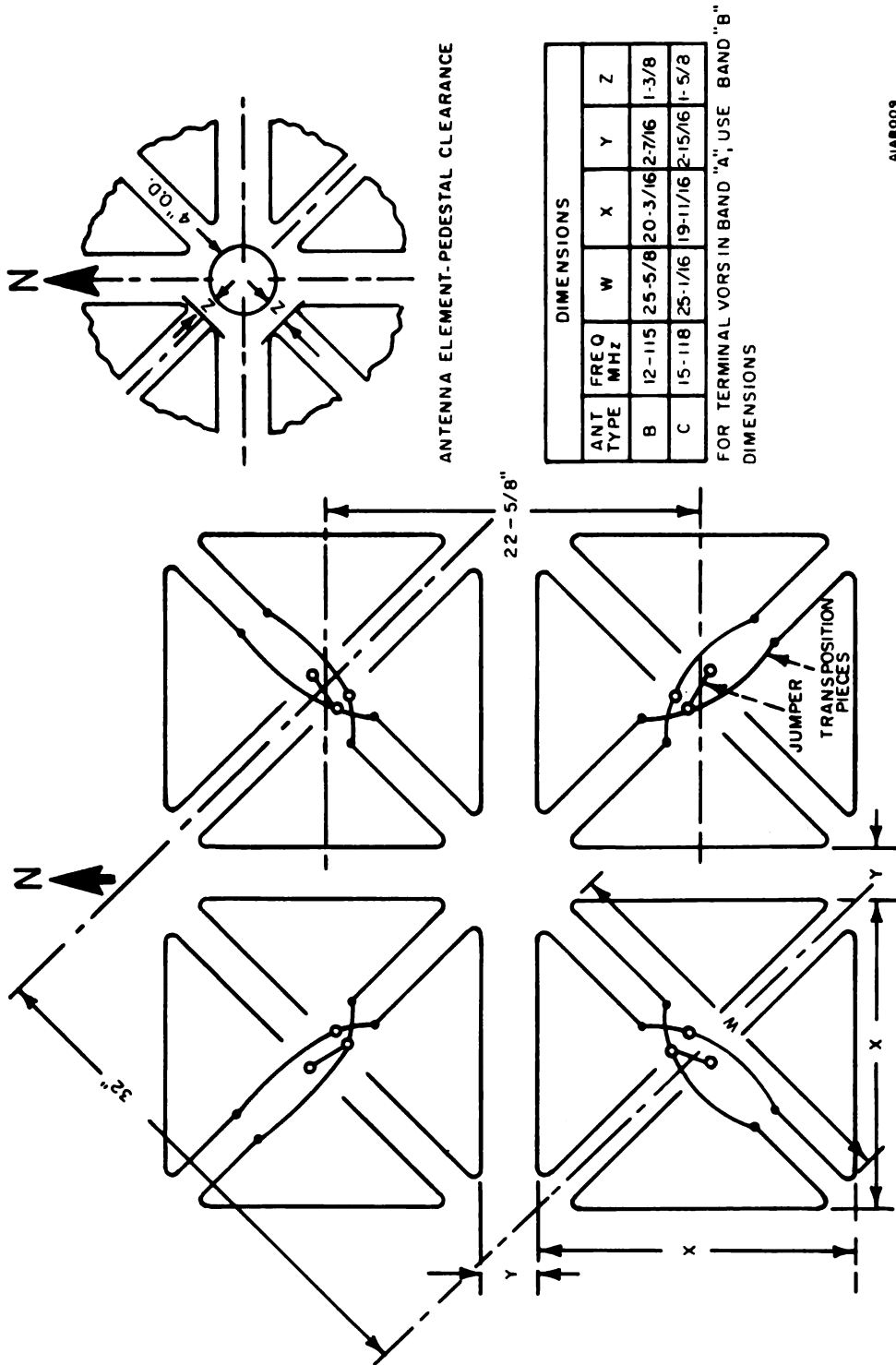


Figure 9 - 7. VOR Loop Antenna Spacing

9.2.5 Operation and Maintenance Procedures

VOR operational and maintenance procedures are thoroughly documented in Sections 4 and 5 of the instruction book referenced in the previous paragraph.

9.3 VHF MARKER BEACONS**9.3.1 Operational Requirements**

VHF marker beacons are used to identify a geographical location. With the advent of VOR and TACAN, VHF marker beacons have been relegated to use as low-powered boundary markers on airport runway approaches. To indicate progress along the approach path, use is made of marker beacons. They are transmitters that confine their radiation largely in the vertical plane and only over a small area in the horizontal plane. The transmitter operates at a frequency of 75 MHz with an output of 2 to 5 watts and is used to actuate a separate receiver in the airplane. The primary indication in the cockpit consists of a light that illuminates as the aircraft passes over the transmitting array, but an aural indication in the form of a continuous tone may be heard slightly before and after the light signal is observed. The frequency of the tone is dependent on the location of the marker beacon. Figure 9-8 shows location of marker beacons for both the two- and three-marker low-approach systems, with the individual tone signals indicated. For two-marker operation, the middle and outer markers only are used.

9.3.2 System Configuration

Dual transmitting equipment is employed for supplying the marker indications. The transmitters are arranged so that the antenna array is connected from one to the other if a failure occurs. They are crystal controlled and employ a 6.250 MHz crystal. Besides the oscillator, there are two stages of multiplication (to increase the crystal frequency to 75 MHz), a modulation oscillator and amplifier, and the output stage.

In the formation of the space pattern, the antenna array is all-important. The array developed consists of four horizontal half-wave elements. These elements are connected to the transmitter by means of a transmission line. The line connecting to one pair is a quarter wavelength longer than that connected to the other pair. In this manner essentially circular polarization results. The plan pattern resulting with this array is shown in figure 9-9. By varying the signal strength, the vertical pattern may be adjusted for maximum altitude and limited horizontal radiation, as shown in figure 9-10. This array is mounted a quarter wavelength above a counterpoise (wire screen) that serves to project the energy upward. This screen is mounted a half wavelength above the ground; thus the growth of vegetation, the accumulation of snow, et cetera, occur below the screen and do not affect the characteristics of the marker. This antenna is shown in figure 9-11.

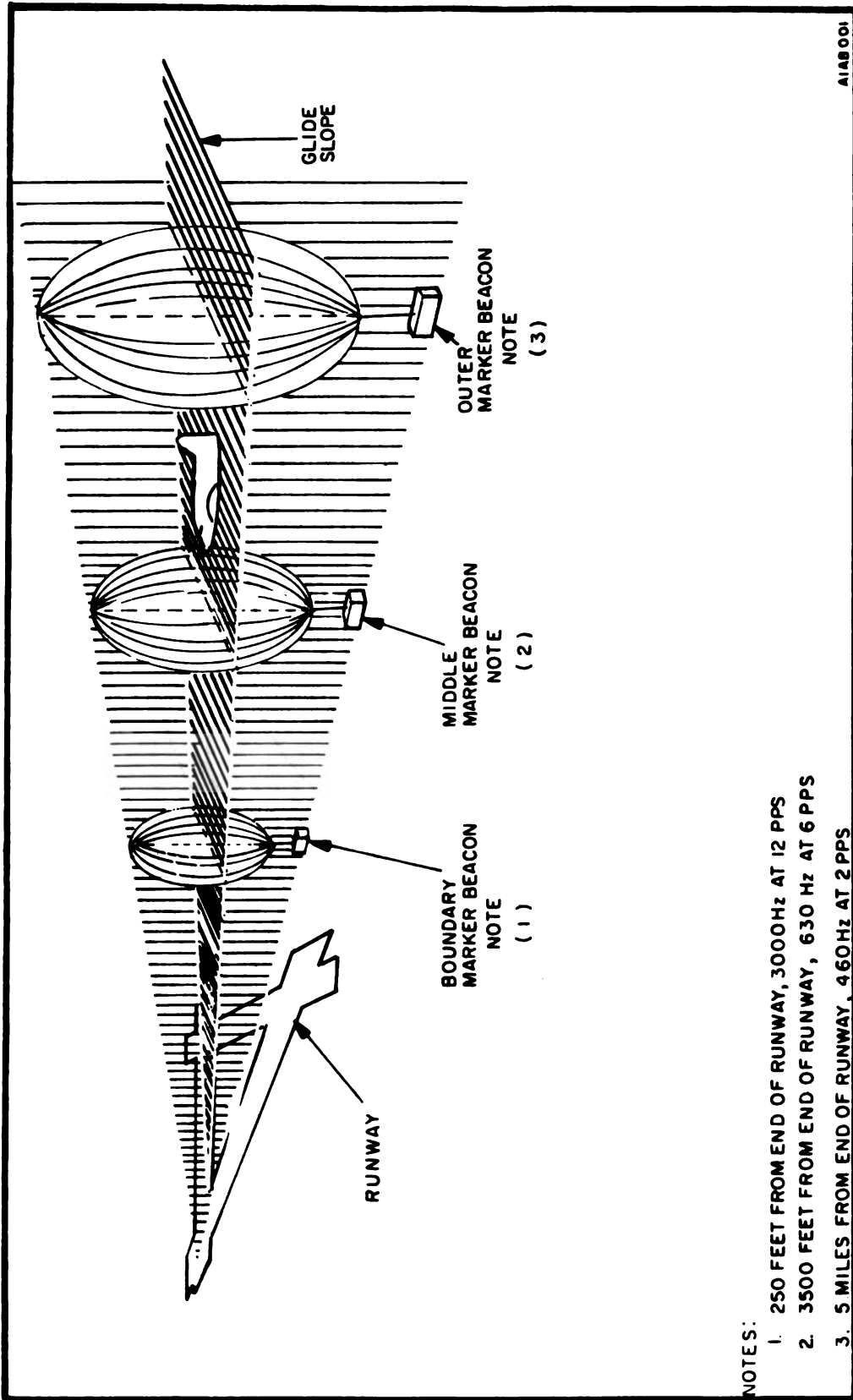
9.3.3 Site and Structural Criteria

Site selection is determined by the purpose of the marker beacon. As airway markers, the beacon facility will be located in line with the airport runway as shown in figure 9-8. The equipment is usually housed in a standard prefabricated structure with power supplied by power lines. The antenna with the counterpoise may be mounted on the roof of the equipment structure provided that the height of the counterpoise is not less than $1/2\lambda$ from the ground.

The area surrounding the transmitter building, about an acre in size, is kept clear of vegetation and completely fenced in to keep out unauthorized personnel.

9.3.4 Installation Criteria

The marker beacon electronic equipment is usually mounted in a single cabinet and located in the center of the small building. The facility is operated as an unmanned site, with remote control and monitoring circuitry located in the control tower cab.



NOTES:

1. 250 FEET FROM END OF RUNWAY, 3000Hz AT 12 PPS
2. 3500 FEET FROM END OF RUNWAY, 630 Hz AT 6 PPS
3. 5 MILES FROM END OF RUNWAY, 460Hz AT 2 PPS

Figure 9 - 8. Low Powered Marker Beacons

A new design is coming into use, called a pole-mounted solid-state marker. The electronics consisting of plug-in modular cards are installed in a watertight metal box which is mounted on a pole in the marker area, thus eliminating the need for a building. The counterpoise and antenna must still be mounted as mentioned, but without a building for support.

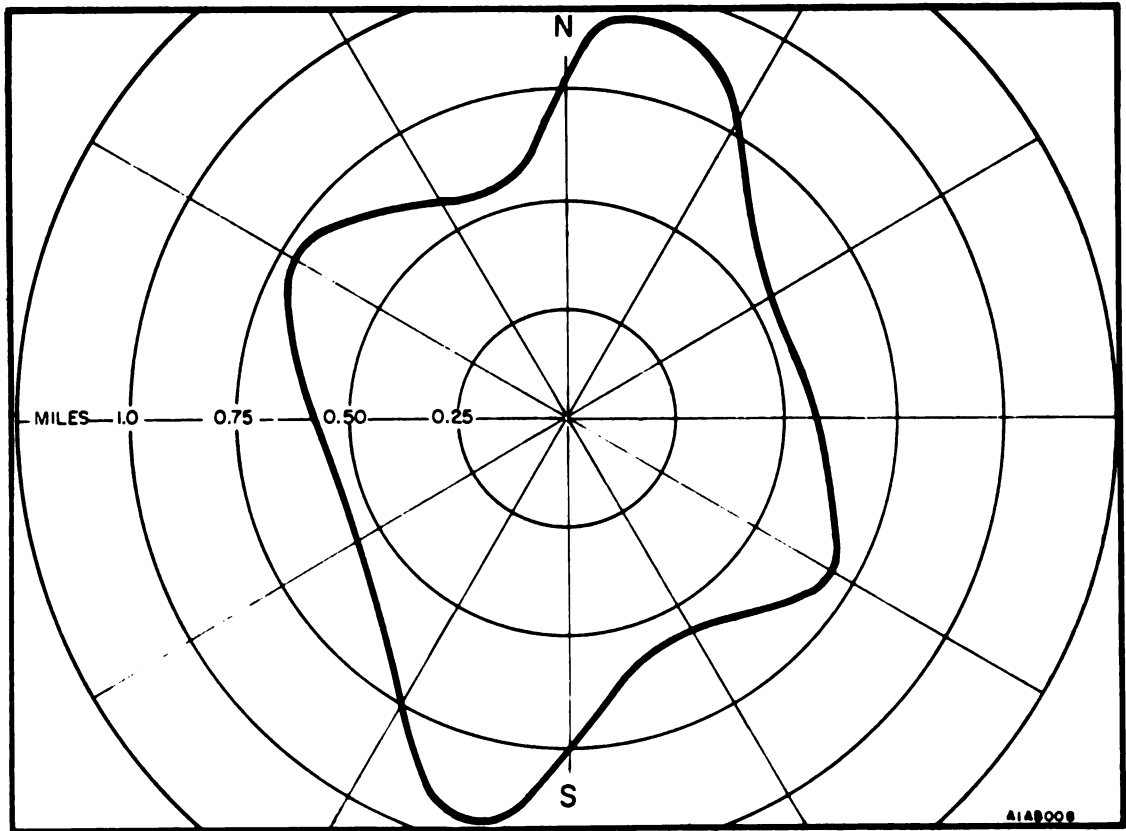
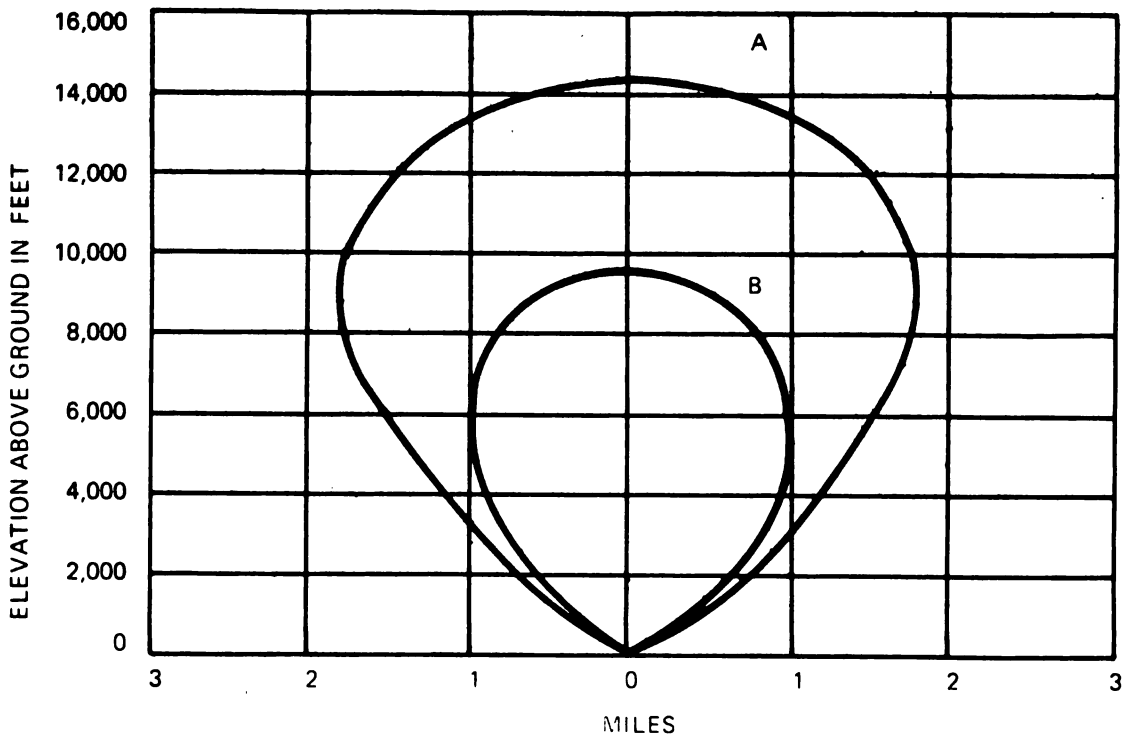


Figure 9 - 9. Plan Pattern of Boundary Marker

9.3.5 Operational and Maintenance Procedures

The beacon equipment is monitored and controlled remotely from the local airport control tower cab. Maintenance procedures are according to the radio beacon set technical manual. The new solid-state pole-mounted marker equipment with plug-in modular cards greatly reduces maintenance problems.



NOTE: PATTERN A REQUIRES 50 PERCENT MORE SIGNAL
THAN REQUIRED FOR PATTERN B

AIABOIO

Figure 9 - 10. Marker Beacon Vertical Radiation Pattern

9.4 UHF OMNIRANGE

9.4.1 Operational Requirements

TACAN is a short-range air navigational aid which supplies continuous and accurate azimuth and distance information relative to an aircraft's position from a selected ground station. Presented in direct readout indicators, the information is used directly by the pilot.

Operating in the 1,000 MHz band, the system is limited in range to line of sight; however, the equipments were designed to provide distance information to 100 aircraft simultaneously up to a maximum distance of 200 miles and azimuth information to an unlimited number of aircraft.

The TACAN system consists of a ground station transponder in association with a special directional antenna, and a receiver-transmitter (interrogator) in the aircraft (figure 9-12). The aircraft sends out an interrogating signal for distance measuring information (DMI). The ground station meanwhile is continuously transmitting bearing information, and upon being interrogated, replies with DMI for the requesting aircraft. Operating frequencies of the aircraft and the ground station are separated by 63 MHz. The actual frequencies used are dependent on the operating channel of the ground station in the geographical area of the aircraft.

TACAN facilities are used in terminal areas and en route on national airways. Terminal TACAN facilities are usually only a TACAN site, while en-route TACAN is usually incorporated in a VORTAC facility (collocation of a VOR and TACAN system).

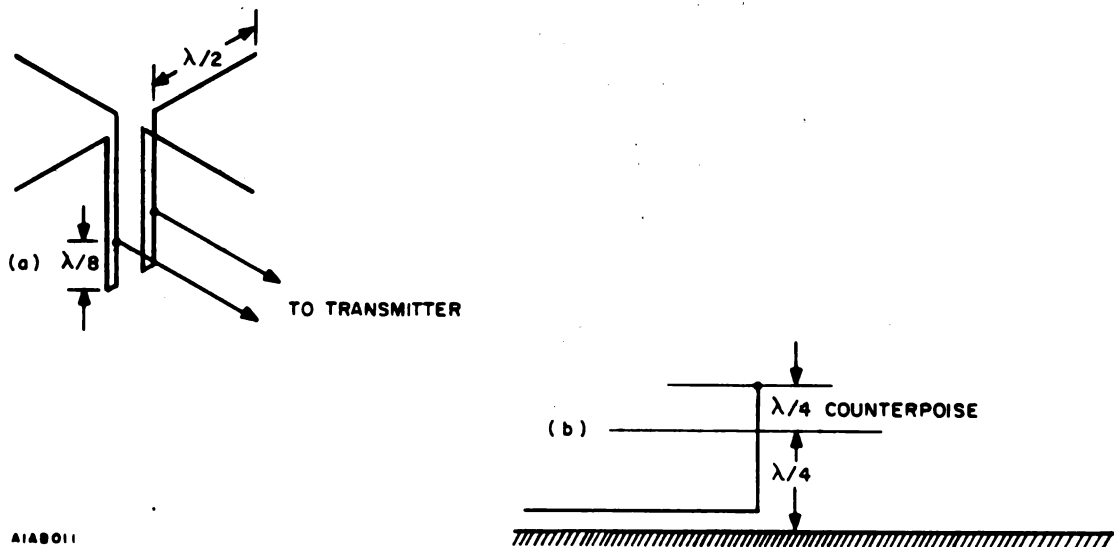


Figure 9 - 11. Boundary Marker Antenna Diagram

9.4.2 Ground Station Configuration

Flight safety rules for a TACAN ground station require that it be operative at all times. Therefore, to increase system reliability, every TACAN facility has built-in redundancy by having two complete TACAN radio sets; one half of the station operates while the other half is held in standby status, ready to takeover station operation should the first half fail. The block diagram of a typical TACAN installation is shown in figure 2-16. A standard TACAN building layout is shown in figure 9-13, along with external views of the building, and a list of the equipment installed. A larger equipment room is desirable so that equipment spacing could be increased for maintenance purpose and allow for a work area in the building.

The antenna is usually mounted on the roof of the TACAN building at a height of approximately 15 feet above ground (figure 9-13). At VORTAC sites, the TACAN antenna is usually installed directly above the VOR antenna at a height of approximately 16 feet above the counterpoise, which is mounted on the roof of the facility building. A standard VORTAC building specified by the FAA is 25 feet x 31 feet containing a dual VOR, a dual TACAN and the necessary monitoring equipment, plus an auxiliary engine generator.

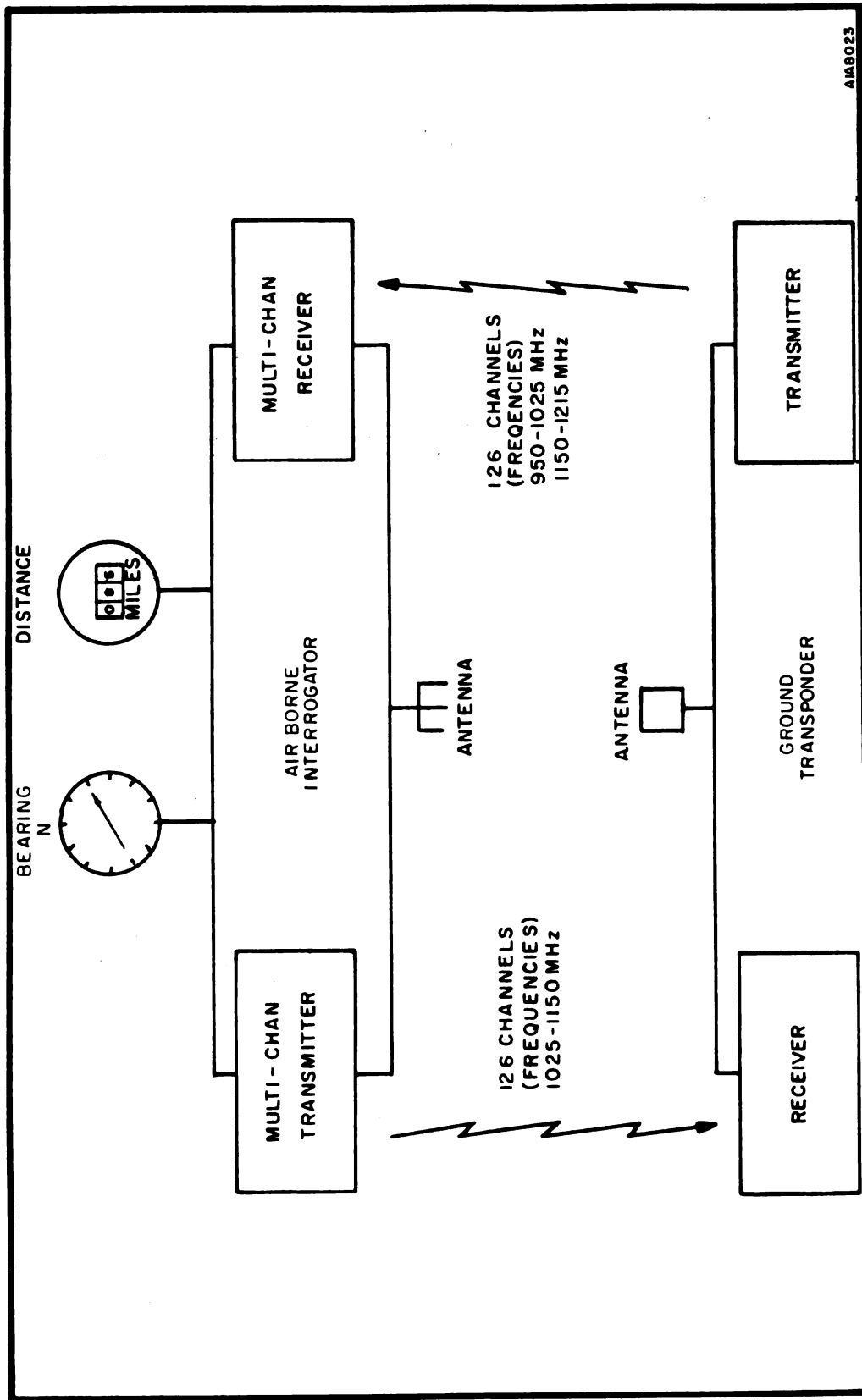


Figure 9 - 12. TACAN System Elements

EQUIPMENT SCHEDULE	
1	30KW DIESEL DRIVEN GEN
2	ENGINE CONTROL PANEL
3	AUTO POWER TRANSFER SWITCH
4	ANTENNA CONTROL UNIT
5	AUTO TRANSFER SWITCH
6	PWR-SPLY-TEST SET GROUP
7	RECEIVER-XMTR GROUP

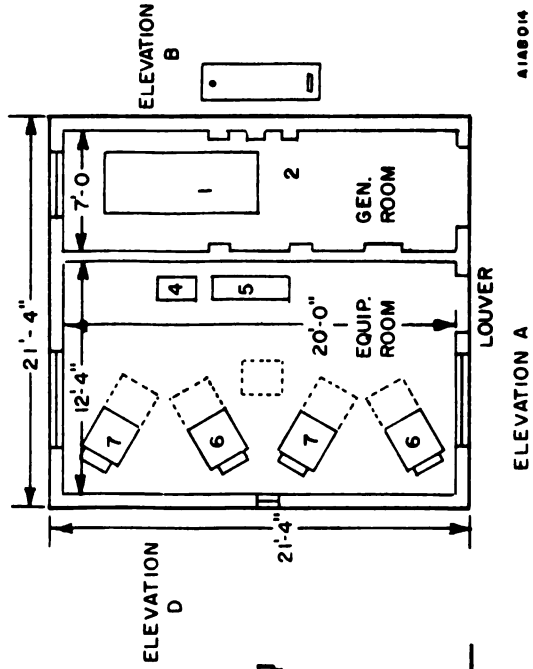
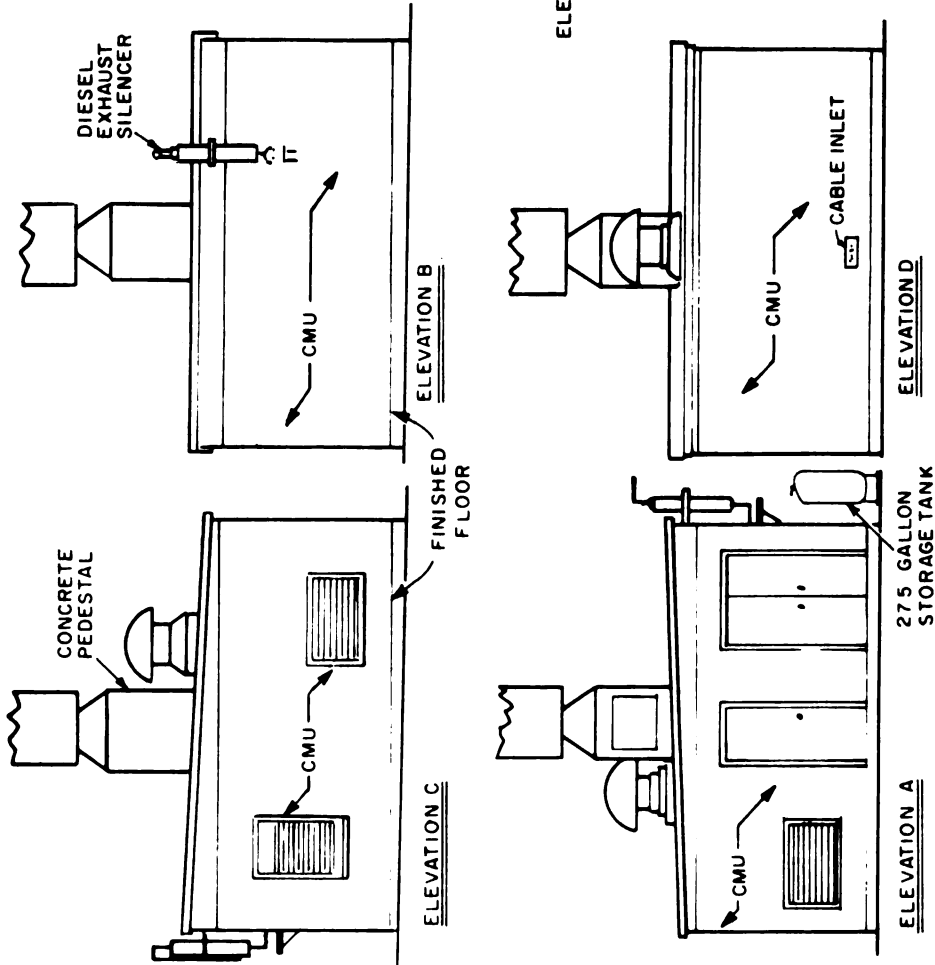


Figure 9 - 13. TACAN Building Layout

9.4.3 Site and Structural Criteria

The optimum location and actual height at which the TACAN ground equipment antenna should be installed is a compromise among the following factors:

- o Line-of-sight coverage
- o Availability of real estate
- o Obstruction and terrain clearance
- o Cost and installation difficulty
- o Gaps in solid navigational information coverage
- o Reliability and maintenance difficulty
- o Adherence to safety ordinances
- o Adherence to air traffic control rules.

Studies have found that the overall TACAN system errors include instrumental and propagational errors. The latter, generally caused by improper antenna siting, are the most troublesome and vary depending on location.

The aircraft receiver is sensitive to the composite energy received along all paths. Therefore, reflections and/or re-radiating objects such as large buildings, hills, or other prominences that may introduce loss of signal (nulls) or bearing errors depending on the amplitude and phase differences between the direct and indirect signals must be minimized. To minimize these unwanted multipath propagation effects, a site must be carefully chosen so that the surrounding terrain does not strongly reflect the TACAN signal. Since the site location is of paramount importance, guidelines used in determining site locations must present procedures for predicting specific ranges, bearings, and airplane altitudes at which reflections may affect TACAN performance.

A principal factor affecting multipath propagations is the first Fresnel zone. Radio waves radiating into this area will be reflected and cause partial or complete cancellation of transmitted signals in space. Location of the line in space indicating complete cancellation, the first signal null, is of prime importance. It is desirable, especially within the airport area, that approaching aircraft not be required to intersect with this area of signal null. Fresnel theory, equation, and illustrations are herein presented to demonstrate its effect on siting criteria.

The Fresnel-Kirchhoff theory was originally developed to account for the diffraction of light when obstructed by diaphragms, and when transmitting through apertures of various shapes and sizes. This theory may be applied to radio and sound waves and is based on the concept that any small element of space in the path of a wave may be considered as the source of a secondary wavelet, and that the radiated field can be built up by the superposition of all these wavelets (Huygens principle).

Consider a transparent vertical screen between a distant transmitter T and a receiver R, with the distance from screen to transmitter being at least 10 times the distance from screen to receiver, and with the plane of the screen perpendicular to the direction T-R. Concentric circles may be drawn on this screen, with the centers at the point where the line T-R intersects the screen at O, the radius of the first circle being such that the difference in length between the path O-R and the path from the circumference of this circle to R is $1/2$ wavelength (λ). The radii of the other circles are such that the corresponding path length differences are integral multiples of $1/2\lambda$. The radius of the first circle is $(d\lambda)$, where d is the distance from O to R, and the radius of the second circle is $(2d\lambda)$, of the third $(3d\lambda)$, etc. The area within the first circle is called the first Fresnel zone, and the other ring-shaped areas are the second, third, etc. Fresnel zones. The fields from the odd-number zones are in phase at R, and the fields from the even-number zones are also in phase at R but are opposite in phase to

the fields from the odd-number zones. It can be shown that the effect at R of each zone is nearly equal. If an infinitely absorbing screen is provided with an aperture of the same diameter as the first Fresnel zone, it will be found that the field at R is twice as great as the unobstructed or free-space field. If the aperture is increased to include the second zone, the field at R will then be nearly zero, since the fields from zones 1 and 2 are nearly equal in amplitude and opposite in phase. With a continued increase in the diameter of the aperture, further maxima and minima appear; the amplitude of these oscillations decreases very gradually until eventually the field at R approaches the free-space value, which is half that due to the first Fresnel zone.

If the distance from the screen to the transmitter is d_1 , and from the screen to the receiver is d_2 , then the general expression for the radius of the nth Fresnel zone is

$$\left\{ \eta \lambda [(d_1 \times d_2) / (d_1 + d_2)] \right\}^{1/2} \quad (9-1)$$

A criterion to determine whether the earth is sufficiently removed from the radio line-of-sight path to allow mean free-space propagation conditions to apply is to have the first Fresnel zone clear all obstacles in the path of the rays. This first zone is bounded by points for which the transmission path from transmitter to receiver is greater by one-half wavelength than the direct path. Let d be the distance from the antenna to the vertex of the first Fresnel zone (point B on figures 9-5, 9-6 and 9-14). Point A, refer to figure 9-14, is the antenna array and h is the height of the antenna. A cancellation of signals or a null will occur for a vertically polarized (TACAN) antenna when the ground reflected signal path is delayed by any whole number of wavelengths. The distance d from the antenna to point B and the angle of the first null may be calculated as shown on figure 9-14. AC is equal to the pathlength of the radiating signal, and AB is equal to the reflected signal path; thus a null is created when $AB - AC = \lambda$.

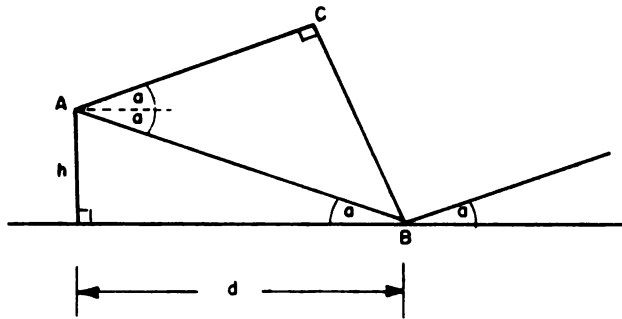
Equations required to locate the first Fresnel zone, determine its dimensions and calculate the angle of the first null are provided in table 9-1. Using these equations and four different antenna heights, a tabulation of the calculated parameters is presented. The resulting data reveals that the higher the antenna height, the larger the first Fresnel zone or area that may cause a radiating null. In terms of siting criteria, a larger area which must be flat with a minimum of terrain irregularities is required. The table also shows that the higher antenna places the first Fresnel zone further away from the antenna.

The effect of changing antenna height on the angle of the first signal null is shown in figure 9-15. The location of the four "first signal null" lines was determined by the value of "a" in table 9-1.

Two possible angles of descent to the selected airport runway and the relationship to the null angles produced by three different antenna heights are shown in figure 9-15. The graph also shows that an aircraft will descend through the 1.900 degrees null area at approximately 11 NMI for the high altitude approach and at approximately 5.2 NMI for the low altitude approach. For the 11.53 degrees null area, the points of intersection would be less than a half mile and for the 0.95 degree and 0.286 degree null areas there is no intersection (30 feet is the TACAN antenna height at most VORTAC facilities). The null lines plotted on a 4/3 earth profile chart and the altitude they reach as the range increases are shown in foldout 9-1. The graphs may be used to determine which antenna height will be selected, but the severity of the null in reduced signal strength can only be determined by an operational flight evaluation.

Similar to the VOR siting criteria, the ideal TACAN site, would have the following characteristics:

- o Location on the highest ground in the vicinity, to provide maximum coverage.
- o Terrain level, and cleared of all objects for a radius of at least 3,000 feet.
- o Within the service range of the station, no obstructions extending above the horizontal plane that contains the antenna.



$$\begin{aligned} \lambda &= AB - AC & AB &= \frac{h}{\sin \alpha} & AC &= AB \cos 2\alpha \\ &= AB - AB \cos 2\alpha \\ &= AB (1 - \cos 2\alpha) \\ &= \frac{h}{\sin \alpha} (1 - \cos 2\alpha) \\ &= \frac{h}{\sin \alpha} (2 \sin^2 \alpha) \\ \lambda &= 2h \sin \alpha \\ \therefore \text{ANGLE of first null; } \sin \alpha &= \frac{\lambda}{2h} \\ \text{and distance from antenna; } d &= \frac{h}{\tan \alpha} \end{aligned}$$

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Figure 9 - 14. Angle of First Null, Derivation

The selected site will represent a compromise between the ideal site characteristics and what can be realistically obtained under the constraints of availability, economy of construction, legal and political, and other factors. The technical factors are dependent on the surrounding terrain, and obstructions within the antenna line-of-sight. Siting criteria equations and formulas presented as applicable to VOR also apply to TACAN, though the UHF operation will increase the size of the Fresnel zone, move it further from the antenna, and decrease the elevation angle of the first signal null line.

The TACAN course structure is affected by reflections from objects in the horizontal, vertical, and oblique planes at VOR frequencies, they may be considered relatively poor reflectors, but may be efficient reflectors at TACAN frequencies (see figures 9-16 and 9-17). Hence, objects of any given size and shape are potentially more troublesome for TACAN than for VOR, due to the greater number of wavelengths at TACAN frequencies as well as the respective sizes of the first Fresnel zones.

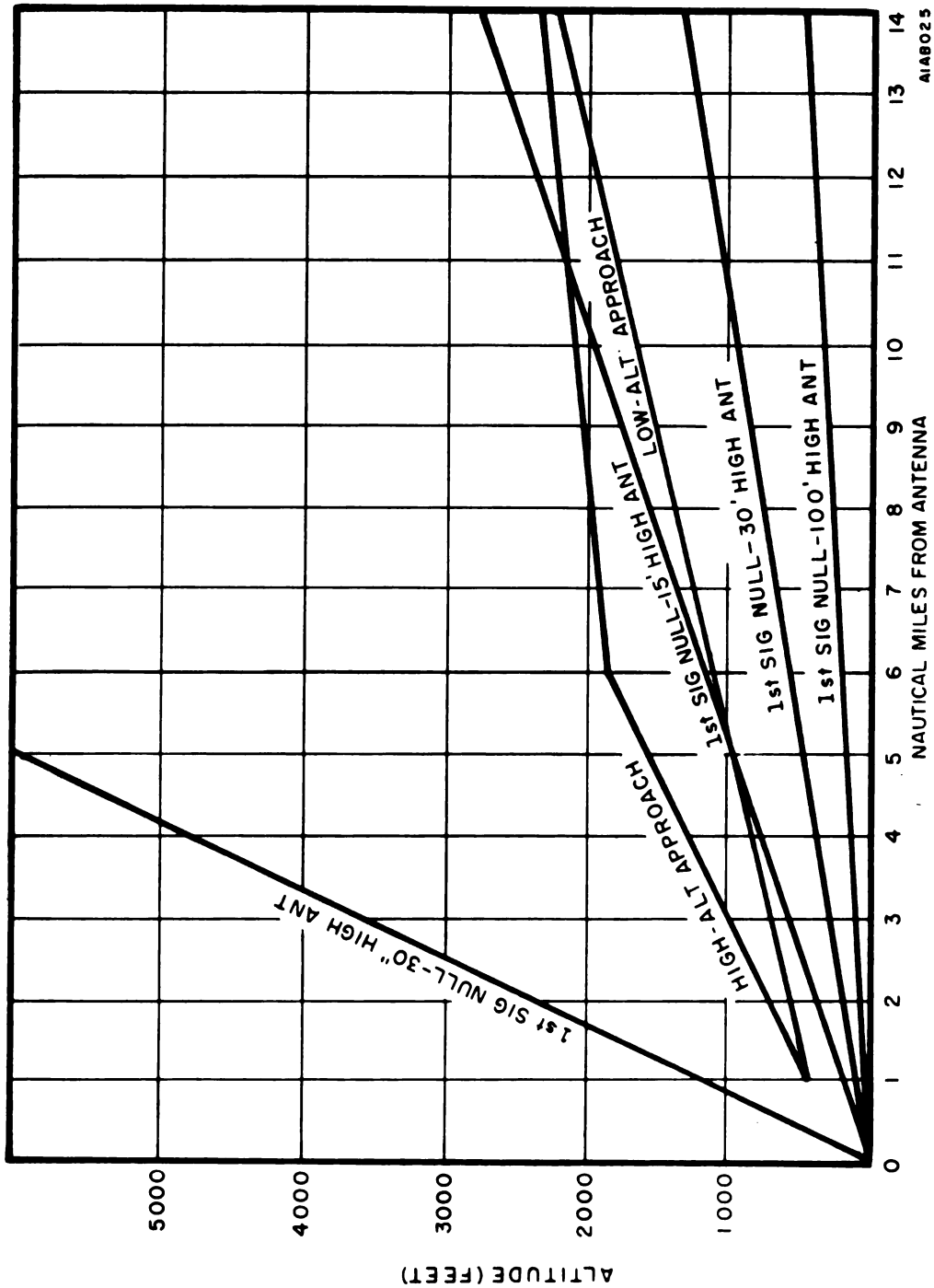


Figure 9 - 15. Relationship of Antenna Height and First Signal Null

Table 9-1. Application of Fresnel Zone Equations

Let $f = 984 \text{ MHz}$ $\therefore \lambda = 1 \text{ ft.}$

$h_1 = 2\text{-}1/2 \text{ ft. (30 in.)}$ $h_2 = 15 \text{ ft.}$ $h_3 = 30 \text{ ft.}$

$\sin a = \lambda/2h$ $d = h/\tan a$

$$w = 2 \frac{\lambda h}{\sin a}$$

$$x_1 = \frac{-\lambda \cos a + \lambda^2 \cos^2 a + 4h \lambda \sin a}{2 \sin^2 a}$$

$$x_2 = \frac{+\lambda \cos a + \lambda^2 \cos^2 a + 4h \lambda \sin a}{2 \sin^2 a}$$

	$h_1 = 2\text{-}1/2 \text{ ft.}$	$h_2 = 15 \text{ ft.}$	$h_3 = 30 \text{ ft.}$	$h_4 = 100 \text{ ft.}$
Sin a	= 0.2	= 0.0333	= 0.0167	= 0.005
a	11.53°	1.90°	0.95°	0.286
Cos a	0.9798	0.9995	0.9998	1.000
d	12.255 ft.	450 ft.	1800 ft.	20,000 ft.
w	7.07 ft.	42.4 ft.	84.7 ft.	282.8 ft.
x_1	9.26 ft.	330 ft.	1317 ft.	24,720 ft.
x_2	33.75 ft.	1231 ft.	4913 ft.	64,720 ft.

Signal reflections from adjacent terrain produce lobing in the vertical antenna pattern that is directly proportional to frequency and antenna height above ground. At TACAN frequencies there are a large number of signal minima within the intended vertical coverage angle. The elevation angles at which these minima occur with a given antenna depend not only upon the electrical height of the antenna above ground, but also on the complex dielectric constant of the ground and the angle of reflection. The vulnerability to signal reflections from vertical and oblique surfaces is higher in areas of vertical pattern minima than in the maxima.

In cases where satisfactory performance has been achieved for VOR but not TACAN, there is a good probability that TACAN performance can be improved by raising the TACAN antenna height.

The similarity of VOR and TACAN siting requirements has been such that acceptable performance for each component could usually be achieved through application of the VOR siting criteria alone when the TACAN antenna is coaxially mounted at a height of 30-feet-or-more above ground.

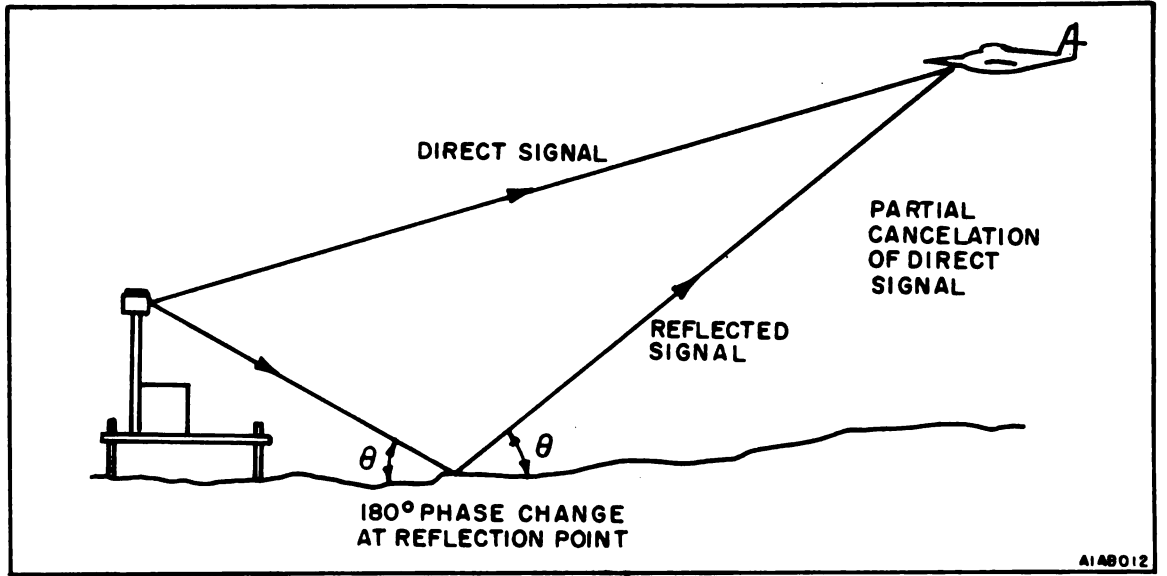


Figure 9 - 16. Reflection From Earth's Surface

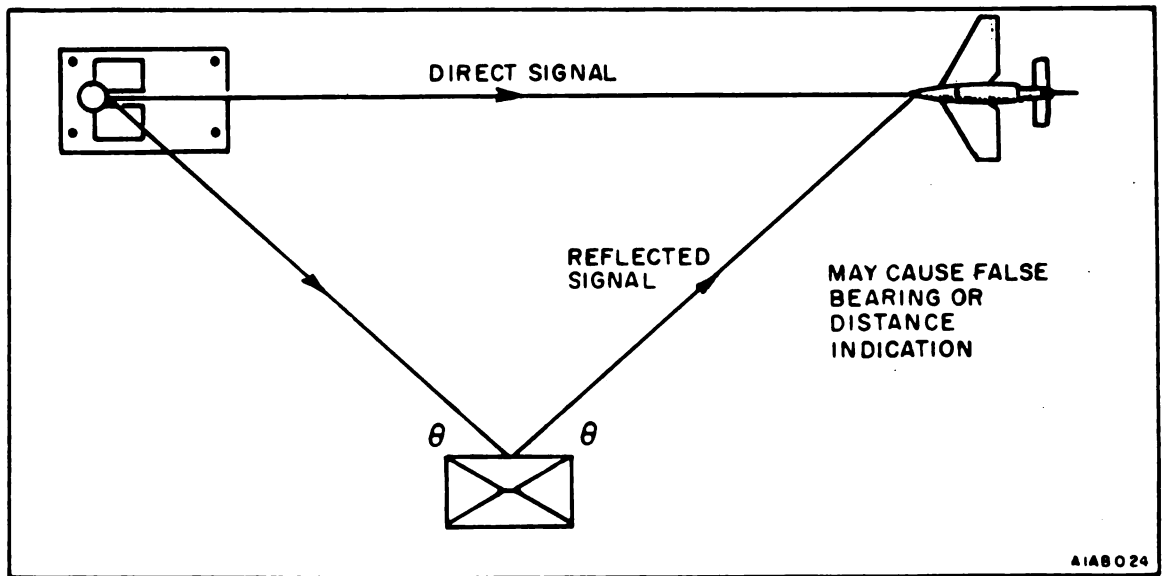


Figure 9 - 17. Reflection From Vertical Surface

A study (refer to Appendix B, item B.2.9) regarding the feasibility of elevating the TACAN antenna to heights compatible with elevated VOR antennas was conducted in 1966. The primary concern was the possibility of specular ground reflections giving rise to deep and frequent spatial fading. Theoretical considerations regarding the reflection of 1,000-MHz energy from the ground indicate that at high antenna heights much more terrain is involved in reflecting energy than at low heights. In rough terrain the possibility of specular reflection from a low antenna exists because there are likely to be small areas which are smooth and support strong reflections. At greater antenna heights these possible reflectors are a much less significant portion of the reflecting area and the possibility of specular reflection is much reduced.

Experimental data showed conclusively that markedly less spatial fading is evident at ground antenna heights above approximately 100 or 200 feet compared to that observed on antennas elevated 18 to 35 feet above average terrain. Thus, it appears from theoretical rough terrain propagation considerations that it is not only practical to elevate TACAN antennas to heights of 100 feet or more above terrain, but that some benefit of the system reliability may result due to the lower spatial fading ranges at these heights. There seems to be no upper height limit which can be used.

The procedure used to determine the proper location of the TACAN antenna and electronic equipment, starts with a study of station requirements. Included in this study must be the high-altitude and low-altitude aircraft approach paths, along with all other factors mentioned. Then one or more tentative sites are selected and a preliminary on-the-site survey is made. During the preliminary siting, photographs of the station are taken from each site so that a panoramic profile of objects extending above the horizon may be plotted. These pictures will show what the antenna radiation pattern will have in its path. The pictures are taken from the intended antenna height. If the approach radials are free of obstructions and most of the other factors are satisfied, a second or operational TACAN siting evaluation is made. This survey will include the set-up and operation of a TACAN field test van, with the antenna mounted above the van or on a mast.

A complete FAA flight evaluation of the site is made with an operating test van. The flight check will determine where the radiated signal nulls are located and whether the site will meet the station operational requirements.

9.4.4 Installation Criteria

The TACAN system equipment, is installed in a building as shown in figure 9-13, along with the auxiliary power supply, and the antenna mounted on the roof. With tower- or roof-mounted antenna, the monitor antenna will be mounted on the antenna base. Mounting details for the AT-592/URN-3 antenna are shown in figure 9-18. The mounting bracket shown is constructed and mounted in closed proximity to the AS-686/URN-3 TACAN Antenna. Mobile TACAN have the antenna mounted on the van or on a mast with the TACAN monitor pickups (2 each) installed on a metal pole set out a minimum distance of 60 feet from the center of the antenna. There is no specific azimuth required for TACAN monitoring, but the antenna must be accurately positioned with respect to true magnetic north for the radio set to transmit accurate bearing information.

Station power is used as the primary source, with an emergency automatic-switching power supply furnished as part of the TACAN equipment. A maintenance area is provided in the facility building and aids in reducing equipment downtime. Though the system operates unattended, remote monitoring capabilities are installed in the IFR and VFR rooms of the NAS. Remote en-route systems are monitored at the local FAA flight service station, as well as in the control tower of the nearest major airport.

Further installation criteria is documented in the equipment handbook section on Installation. Three such technical manuals are as follows:

- o NAVSHIPS 92348(A) for Radio Sets AN/URN-3 and AN/URN-3A
- o NAVSHIPS 0967-041-0010 for Radio Set AN/URN-20
- o NAVSHIPS 95753 for Radio Set AN/TRN-14.

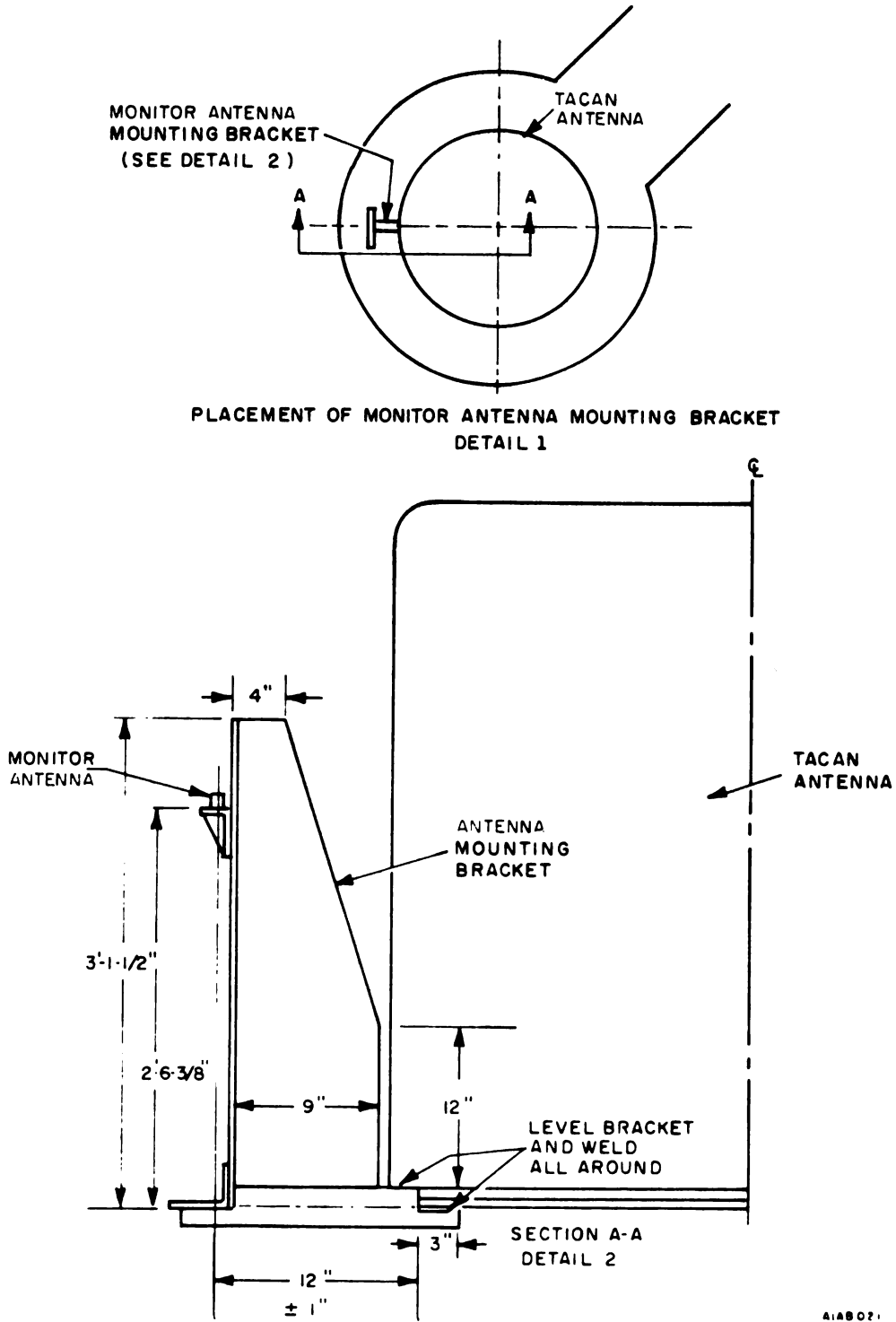


Figure 9 - 18. Antenna, AT-592/URN-3, Mounting Details

9.4.5 Operation and Maintenance Procedures

It is extremely important that a preventive maintenance program be followed because a TACAN system operates unattended. The manual for each system contains charts and tables for daily, weekly, and monthly checks. These checks must be adhered to for maximum operating efficiency and minimum equipment downtime. Frequent operational checks are also made on the equipment by aircraft operating in the area. The U. S. Standard Flight Inspection Manual requires that at least four flight inspections be conducted annually, with 90 to 120 days between checks.

a. Tolerances. All TACAN facilities will conform to these tolerances for an UNRESTRICTED classification of the facility based on flight check results. Classification is the responsibility of the Flight Inspector.

o Station identification will be correct, clear and readable to the coverage limits of the station. Course characteristics will not be affected by the identification.

o Sensing will be correct.

o Rotation will be correct.

o Course alignment must be within ± 2 degrees of the correct magnetic bearing.

o Polarization effect will not exceed ± 1 degree.

o Maximum distance error will be 0.2 mile or 2 percent of the distance, whichever is greater.

o The amplitude of a course bend must not exceed ± 2 degrees. The total course displacement resulting from misalignment and/or bends must be within ± 2 degrees alignment envelope.

o Coverage will be 40 miles for both azimuth and distance at minimum en-route altitude.

o Transmitter differential between transmitters will not exceed 2 degrees for course alignment and 0.2 mile for distance.

o Approach radials and procedure turn areas must meet all requirements for course characteristics: rotation, course alignment and polarization effect, as specified. In addition, a combination of various borderline characteristics should not cause a condition which would make the procedure unflyable for the average pilot.

Airborne receiver check points must meet all requirements as specified above for tolerance in polarization effect, distance errors, course bends, course roughness and scalloping and coverage. Alignment tolerances will be ± 1.5 degrees.

Ground receiver check points shall meet the following requirements:

o Course alignment shall be within ± 3.5 degrees of measured azimuth, and within ± 2 degrees of the published azimuth.

o Distance shall be within 0.2 mile of measured distance.

o Standby equipment will meet the same tolerances as the primary equipment. If standby equipment is installed, it will be operative.

o Standby power shall not produce deterioration in course alignment, quality, and distance indication when used by operation of standby power as a secondary source of energy for TACAN and VOR. If standby power is installed, it will be operative.

o Monitors shall alarm when course alignment shifts more than ± 1 degree from established alignment.

b. Adjustments. Any conditions found beyond the specified tolerances, if attributable to station adjustment, will immediately be brought to the attention of maintenance personnel, with a request for correction.

In the case of overall misalignment of the station, the flight inspector will determine the amount and direction of course shift required to balance the station error and keep all courses within alignment tolerances. He will then request a course shift of a specific number of degrees in the correct direction, and recheck the station alignment after the adjustment. When balancing station error, both transmitters must be shifted in approximately equal amounts so that they are matched at the monitor. This is necessary in order that course-shift alarm tolerances may be held to the required minimum.

Other malfunctions such as increased alignment error spread, excess transmitter differential at specific points, excess attitude effect, course bends, etc., should be described to the maintenance personnel, including all pertinent data, when requesting adjustments in order that the trouble may be more easily located and corrected.

9.5 HOMING FACILITY

9.5.1 Operational Requirements

A homing facility provides recognizable signals for aircraft homing-in to an airport runway or for guidance while in a holding-pattern. These facilities may be operated in either the LF/MF or UHF ranges. The LF/MF (200 to 400 kHz) facilities are generally located near the coast and operate as a long-range homing beacon with a 400 watt power output. When installed on a weather station vessel, it is used to aid air navigation over established ocean routes. The UHF (225 to 400 MHz) facilities are usually located on or near an airport and functions as a station locator. The UHF homer beacon with a power output of 22 to 25 watts is usually placed on the centerline of the active runway, and 3 to 10 miles from the end of the runway.

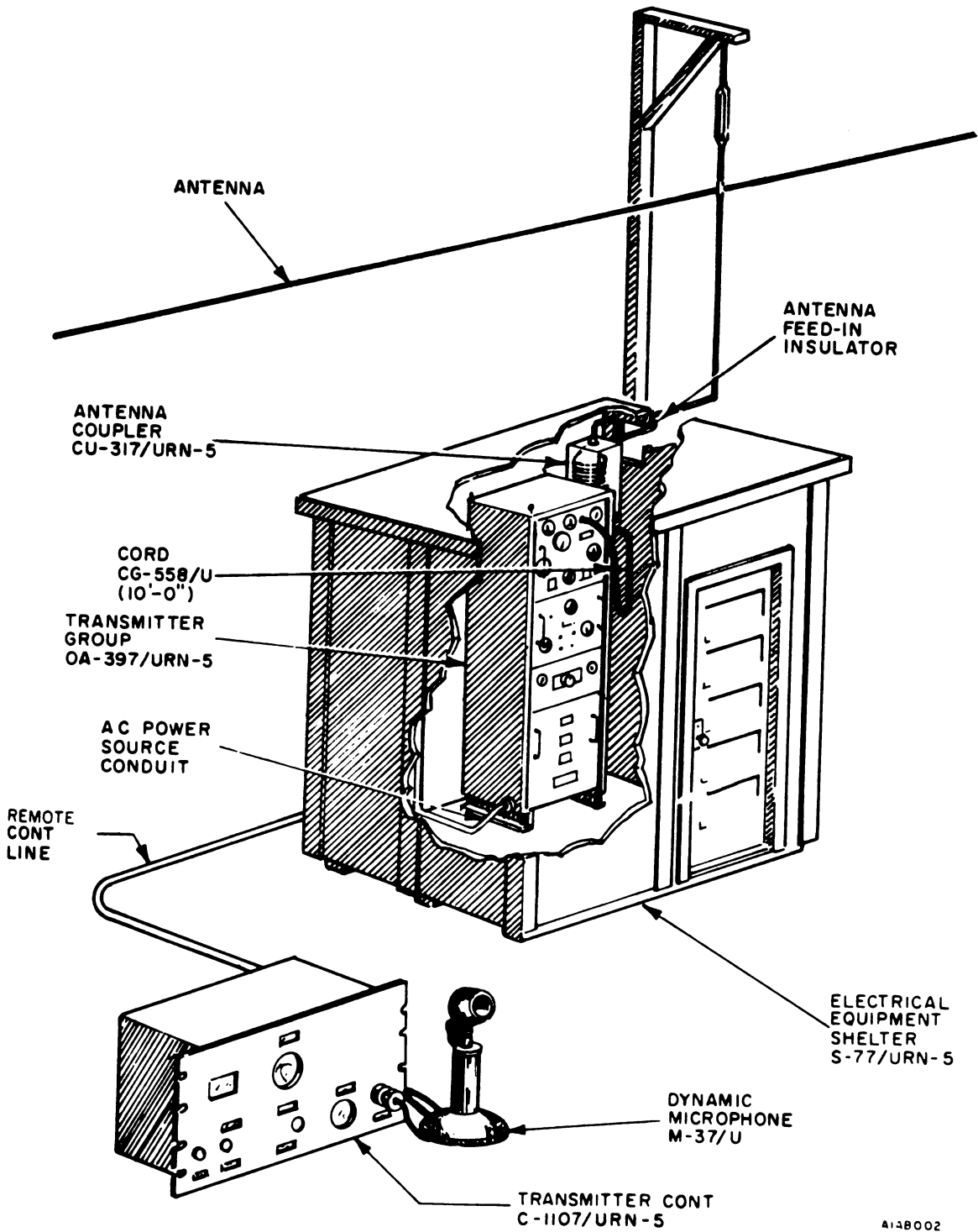
9.5.2 System Configuration

A typical LF/MF homing facility is shown in figure 9-19. The transmitter is shown in the typical shelter building provided for remote and unattended beacon operation with the transmitter control panel and the microphone used for voice communication usually located in the airport control tower cab. Thus the radio beacon communication set normally operates as a navigational aid by transmitting an omnidirectional signal pattern modulated by a 1020 Hz identification tone. Change over to voice transmission, for tower communication, is accomplished by pushing a press-to-talk switch on the microphone. A representative LF/MF transmitter console is shown in figure 9-20.

The UHF radio beacon set, found most frequently at or near an air station, is designed for continuous operation. The beacon set contains two transmitters and two keyer units, along with a transmitter control panel and a beacon transfer control panel (figure 9-21). Continuous operation of the beacon is accomplished by employing one transmitter in an alternate or standby status with provision for automatic transfer in event of a failure in the operating transmitter. The antenna shown in figure 9-22 is usually mounted on separate pole a few feet from the shelter building (same type as used for LF/MF beacon).

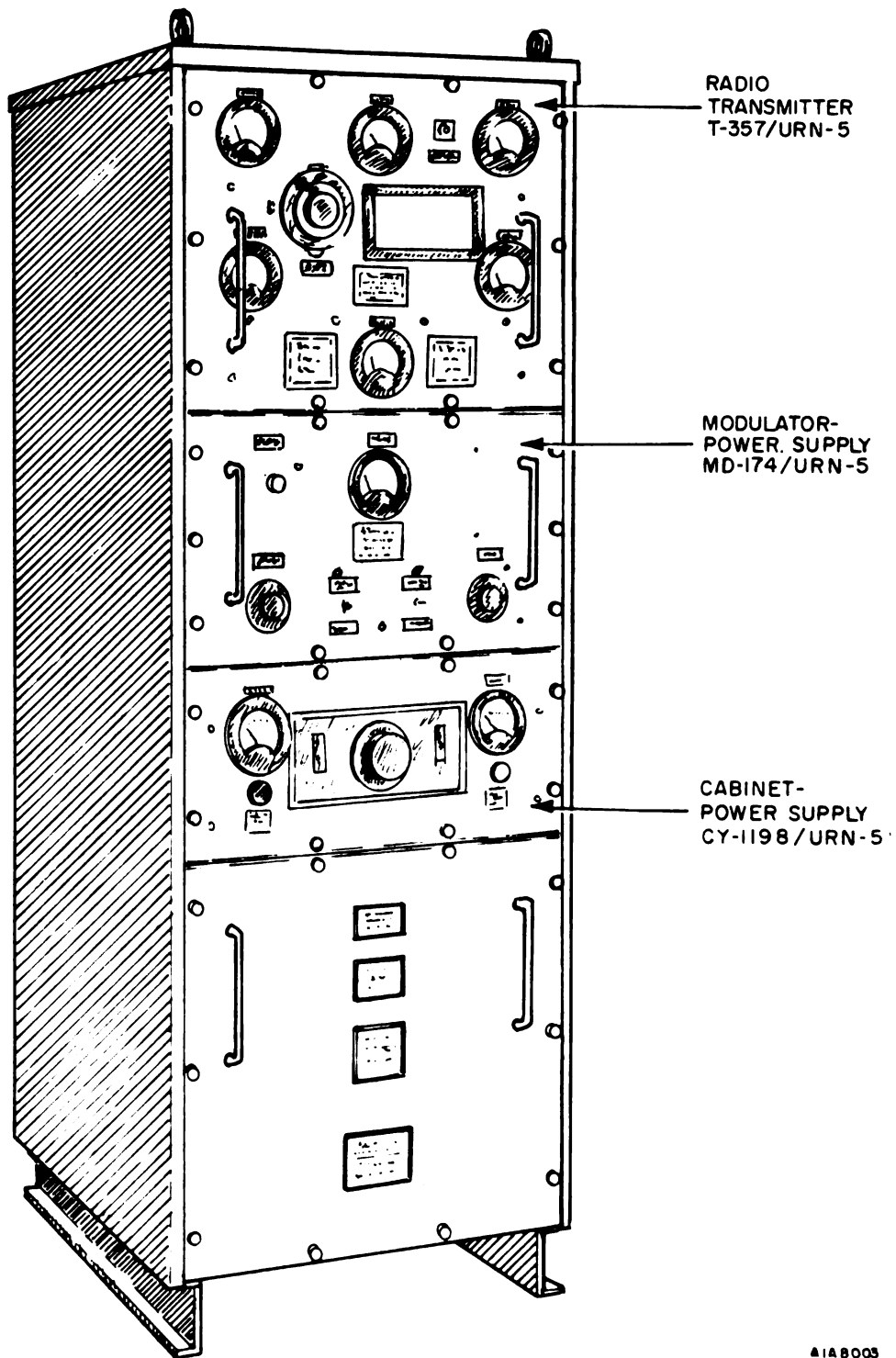
9.5.3 Site and Structural Criteria

Siting of a radio beacon set is determined by its function, but all precautions required for LF/MF and UHF communication antenna location must be observed at beacon facilities. The surrounding terrain should be as free as possible from mountains, hills or other obstructions which tend to shield or deflect low-angle electromagnetic waves. For LF/MF propagation, good ground conductivity is of great importance because the ground is part of the propagation mechanism. Meanwhile, good ground conductivity in the UHF propagation path may affect transmission effectiveness because of interfering ground reflection which tends to increase over areas of high conductivity. For UHF omnidirectional transmission, where a choice of sites is possible, it is better to choose a site which will provide a maximum propagation path over water. This is because propagation, even for short distances over land, attenuates the signals much more than an equivalent distance over sea water. Where sector coverage is required, each case must be considered separately, and specifically engineered. The criteria for UHF



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Figure 9 - 19. Radio Beacon Communication Set, AN/URN-5



41A 8003

Figure 9 - 20. Transmitter Group, OA-397/URN-5

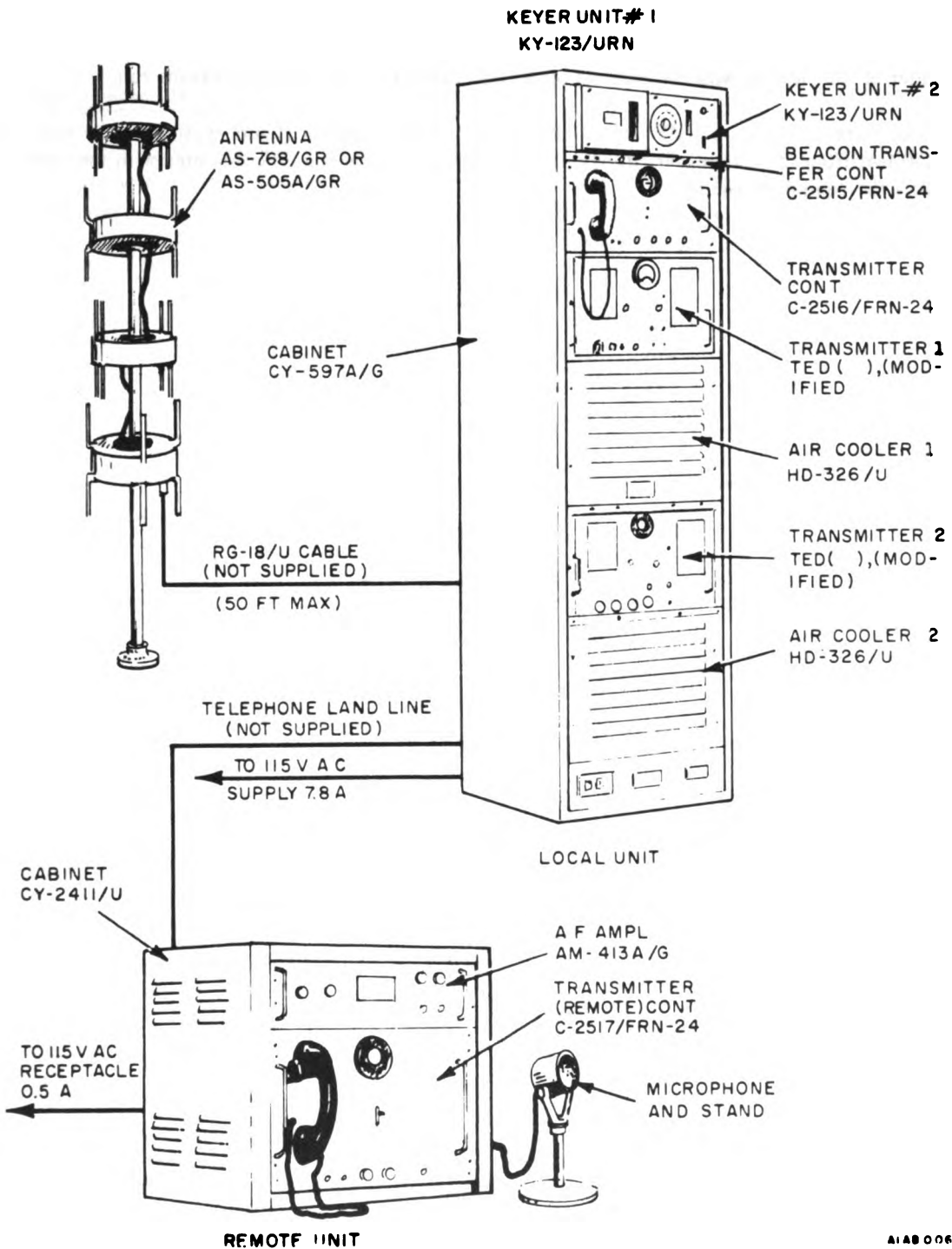


Figure 9 - 21. Radio Beacon Set, AN/FRN-24

communication installations at Naval Air Stations are to establish a vertical pattern lobe structure to achieve maximum gapless coverage. A compromise height for the antenna has been established at 35 feet above ground level, even for beacons when feasible.

For the LF/MF beacon, a minimal clearing of 200 feet by 200 feet must be available for the equipment shelter and for erection of the horizontal member of the antenna, as shown in figure 9-22. The shelter must be erected near the center of the clearing with the antenna outlet side parallel to the 200-foot antenna run.

A smaller area is required for a UHF beacon site and the antenna shown (figure 9-20) must be mounted not more than 50 feet from the transmitter site. The usual UHF beacon site is a fenced-in area with the antenna pole located behind the equipment shelter.

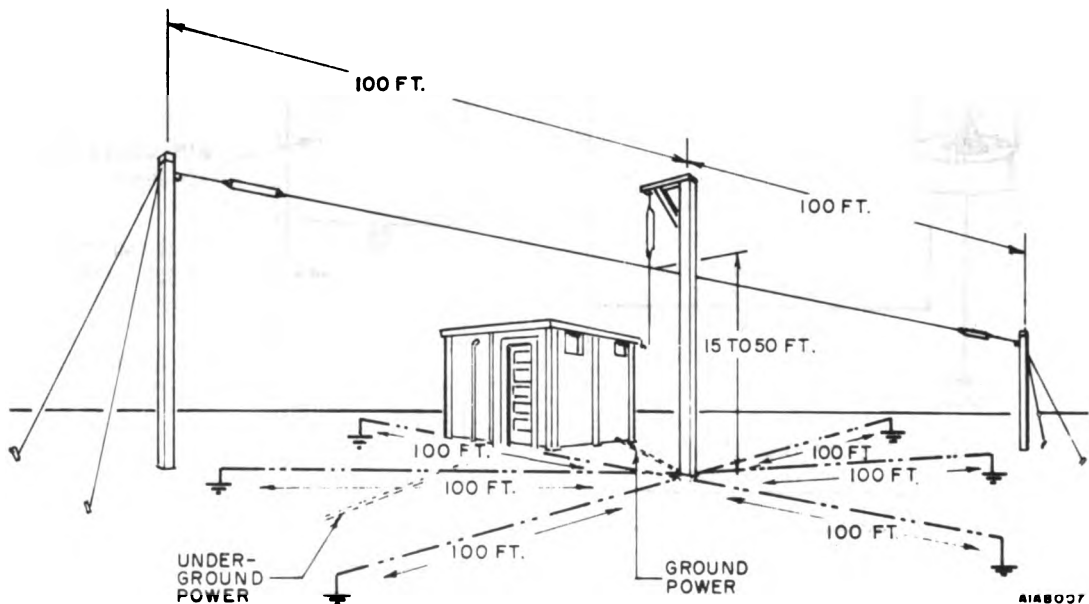


Figure 9 - 22. Antenna Used With Radio Beacon Communication Set, AN/URN-5

9.5.4 Installation Criteria

A primary power source capable of supplying 1 to 3 kVA at 115 V single phase, 50 to 60 Hz, must be available at the equipment site. Newer equipment of solid-state design requires less power than some of the older equipment still in use. Also, at least a single-pair telephone line is required to connect the transmitter to the remote control unit, usually located in the control tower cab.

Units comprising the local transmitter station are contained in a single cabinet located in the center of the equipment shelter. A circuit-breaker box and the antenna coupler are mounted on the shelter wall, along with an air conditioner. Thus, with the remote control unit connected via the telephone line and the antenna connected to the coupler, the transmitter console need only be connected to the power source to be ready for tuning and adjustment prior to being put into on-the-air operation.

Further details on installation criteria are documented in the following individual beacon equipment technical manuals.

- o NAVSHIPS 91766, for Radio Beacon AN/URN-5 (LF/MF)
- o NAVSHIPS 93291, for Radio Beacon AN/URN-24 (UHF).

9.5.5 Operation and Maintenance Procedures

Routine checks are made at the beginning of each watch in the control tower to ensure that the beacon set is transmitting. At the monitoring position the operator may listen for the modulated tone, the ATIS broadcast (if it is incorporated into the system), or press the push-to-talk switch on the microphone and observe the indications on the transmitter control unit, speech on, and output meter. Any faults discovered by these checks must be reported to the duty technician.

There are specific weekly and monthly preventive maintenance checks that are made by the technician in order to ensure continuous beacon operation. The weekly and monthly maintenance check lists are provided in the individual equipment technical manuals.

CHAPTER 10

RADAR SYSTEMS

All aircraft, military and civilian, flying over the continental United States are under control of the National Airspace System. This system is the common network of U.S. airspace, navaids, communications and air traffic control facilities and equipment. It also includes aeronautical information and weather information, FAA manpower and material and system components jointly shared with the military. It does not include the system operated by the military entirely for military purposes. Air traffic control services provided by the Navy and Marine Corps in the United States are for a specifically defined area arrived by mutual agreement with the FAA. Domestically, air traffic control facilities operated by the military are, in effect, extensions of the National Airspace System.

Radar facilities equal to, or superior to, the FAA minimum requirements are used at Navy air activities and weather Naval Air Station to function as air traffic control aids.

Radar equipment installed on an NAS will depend on its mission, location, and other radar facilities in the area. The types of radar found on or near a NAS will include Air Surveillance Radar (ASR), Precision Approach Radar (PAR), and Radar Identification Systems (IFF). Engineering criteria for these systems are included in this chapter.

10.1 AIR SURVEILLANCE RADAR

10.1.1 Operational Requirements

Surveillance type radar is required as part of an air traffic control operation at many naval air activities. Search or surveillance type radars are categorized long range, medium range and short range.

- o Long-range surveillance radar is capable of detecting a one square meter target in excess of 200 NMI and at altitudes up to 100,000 feet.

- o Medium-range air traffic control radar, similar to AN/FPS-37, is capable of detecting aircraft in line-of-sight ranges of approximately 100 NMI and at altitudes of 40,000 to 50,000 feet. This is a fixed facility, permanently housed, with antenna elevation sufficient for 360 degree coverage and maximum scanning radius. It is not remotely controlled but does supply remote indication devices located in the traffic control center. The medium-range radar may be installed on or off an NAS, to serve more than one activity, and may be operated by another station or agency. Normally this type of radar is procured, installed, operated, and maintained by the FAA.

- o Short-range air traffic control radar, similar or equal to the AN/FPN-47 is capable of detecting aircraft to line-of-sight ranges of approximately 20 to 60 miles and altitudes of 10,000 to 15,000 feet. This is a fixed facility, housed and located so as to have unobstructed view of the touchdown point of all runways to be serviced, particularly the instrument runway. This component supplies information to remote indicating devices located in the traffic control center and is also remotely controlled from the traffic control center. The AN/FPN-47 is a short-range terminal radar, procured by the FAA for the Navy. Therefore only short-range surveillance radar will be detailed in this handbook.

10.1.2 System Configuration

The AN/FPN-47 (or FAA ASR-4, -5) is a pulse-modulated radar system operating in the S-band from 2700 to 2900 MHz. This system is designed for maximum reliability and ease of servicing. Except for the antenna assembly, the radar system is dual-channeled and supplied as two separate and identical channels. The equipment is installed in two main groups separated by a maximum of two nautical miles. The antenna, transmitting and receiving equipment, video line driving equipment, and associated auxiliary equipment are located at the transmitter site consisting of a transmitter building and tower for the antenna (see foldout 10-1). All equipment at the transmitter site except the antenna assembly is located in the transmitter building. The master consoles and remote control circuitry are installed in or near the airport IFR room, and the associated indicating equipment and video mapper in an equipment room not more than 300 feet from the consoles. A block diagram of equipment location at a typical installation is shown in foldout 10-2. Details of the system components are presented in chapter 3.

10.1.3 Site and Structural Criteria

The location of an ASR transmitter site is determined by its mission. If the radar is to serve as an ATC aid for only one airfield, it should be located near the field, but no closer than one-half mile from the closest runway touchdown point. When a radar facility is to service more than one airfield, it should be located at a convenient and serviceable area between them. Thus, the first consideration is to select the site which will provide the desired area or sector coverage for radar line-of-sight operation.

Since the factors involved in radar siting are many and varied, two or more tentative locations are selected for each area of coverage. These sites are then studied and investigated on the basis of all information available, and a visit is made to the site. Siting reports are then prepared for each tentative site and an intelligent site selection is made based on a thorough analysis of all pertinent facts.

One of the many factors affecting radar coverage is weather. Radar wave propagation is affected by weather in many ways and only the most important factors will be considered. Almost all the atmospheric conditions and changes known as weather are contained within the 6 miles extending upward from the surface of the earth. At the higher frequencies used in radar (100-9000 MHz), wave propagation occurs principally through this region and is thereby affected by the existing conditions that exist there. The atmospheric conditions and changes regarded as weather refer to a standard set of atmospheric conditions. Standard atmosphere is one in which the air is constant in composition at any given altitude and the pressure and temperature vary uniformly with change in altitude.

Refraction of the radar wave causes it to bend or curve down, thus extending the radar range beyond the line-of-sight cutoff used by the curvature of the earth. Refraction occurs when the radar wave passes from an atmosphere of one density to that of another density. Density is dependent upon temperature, atmospheric pressure, and water vapor pressure of the air. This is usually referred to as the refractive index of the air which ordinarily decreases uniformly with elevation. The relationship between the radar horizon and the optical horizon is expressed mathematically by using a figure of $4/3$ times the true earth's radius for calculations of radar horizons. In a nonstandard atmosphere, refraction may occur to a lesser or greater degree than in a standard atmosphere. This, in turn, can cause the radar range and coverage to diminish or increase, depending upon the specific atmospheric condition.

Pronounced changes from the standard atmosphere may result in a condition known as ducting or trapping. This occurs when a large portion of the energy in a radar wave is confined in a narrow layer within the atmosphere. This layer guides the energy in the form of a duct following the curvature of the earth close to the earth's surface. In this manner, low-flying aircraft and surface vessels may be detected at unusually long ranges. Ducting particularly affects the rays leaving the antenna at low angles, less than 1 degree, such as are used for long-range search. Ducting has little effect on the coverage of high-angle radar operation.

The location of the antenna with respect to the duct layer has an important bearing on radar performance. Refer to figure 10-1. When the antenna is located entirely within a duct, the radar range is extended for targets located in the duct. If the antenna is located outside the duct, the coverage is variable and may be greater or smaller than normal. Conditions in a barometric high-pressure area, including calm and clear skies are particularly subject to ducting, especially during the night. Conditions in a barometric high-pressure area, with strong winds, turbulence in the lowest areas, and overcast skies are conducive to standard propagation.

Storms can cause a reduction in radar coverage because of the heavy concentration of rain or snow within the storm area. Storm areas can be detected at greater ranges than normal because of the large vertical spread of the storm. Storms, besides causing large blocks of clutter to appear on the radar indicator, can cause shielding of targets behind the storm front.

A storm decreases the radar coverage because of the attenuation of the radar wave by the water, principally rain, in the atmosphere. Attenuation is the result of absorption or scattering. Absorption occurs when the radiated energy striking a raindrop is trapped or absorbed by the drop and changed into heat. Scattering describes the effect of reradiation in many directions of energy striking a raindrop. The greater the density of rain and size of the raindrop, the greater the attenuation that can be expected.

Other forms of water, such as fog and snow, cause attenuation but to a lesser degree than rain. The density of water in fog and snow is much less than that of rain and does not affect radar coverage as much as rain. At frequencies above 1000 MHz, raindrops within a cloud cause reflections of the radiated signal to appear on the radar indicator and the amount of reflection increases with frequency.

Another factor which must be considered in radar installations at shore activities is imperfect performance caused by self-interference. This phenomenon may be caused by ground reflection which occurs when the beam radiated from the antenna strikes the surface of the earth and bounces upward. Vertical coverage of a radar can vary greatly because of ground reflections, as the reflected wave may arrive at the target in a manner that will either aid or oppose the direct wave. The reflected wave causes a decrease in the overall amount of power striking a target at certain altitudes and an increase in the amount of power striking the target at other altitudes. This effect of subtraction and addition between the reflected wave and direct wave creates a vertical pattern consisting of areas of minimum power called nulls and maximum power called lobes (shown in figure 10-2).

At the lower radar frequencies, the nulls and lobes are widely spaced and a target aircraft flying through this pattern will be seen to appear and disappear on the indicator. Thus, tracking of the target will become difficult. At the higher radar frequencies, the nulls and lobes become more closely spaced, so that the tracking of the target by the radar is improved.

Ground reflection is a variable factor, depending mainly on the type of terrain. Reflection is greatest when the reflecting surface is smooth, such as a calm sea. When the reflecting surface is uneven, such as encountered on land or choppy sea, it may absorb a large portion of the radiated energy or cause a scattering of the energy. This reduces the amount of reflected energy by adding to or subtracting from the direct wave.

Within the range of a radar set, there is an area in which a target may be present but remain undetected. This area is created by the screening effect of terrain features of the earth. When the earth is smooth, the curvature of the earth causes the area beyond the horizon to be invisible to the radar beam, as shown in figure 10-3. If there are hills or mountains in the radar path above the horizon, the screened area is increased and the radar coverage is reduced, as shown in figure 10-4.

The line from the radar antenna to the upper limit of the screening object, whether it be a hill or the horizon, is called the radar line-of-sight. The radar line-of-sight is considered a straight line when the radar energy travels through a standard atmosphere over a $4/3$ earth's radius, as illustrated in figure 10-3 and 10-4. The radar line-of-sight establishes the maximum theoretical range at any given altitude and is used in the preparation of preliminary coverage diagrams.

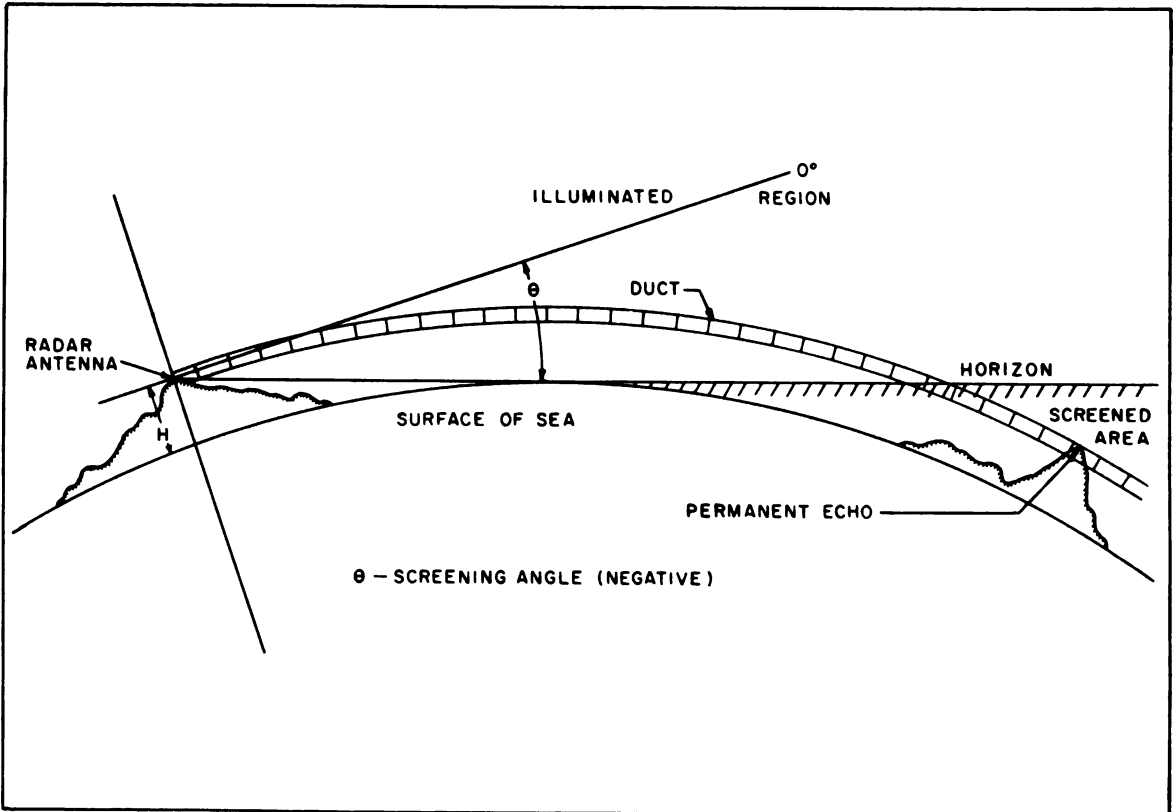


Figure 10 - 1. Ducting Versus Range

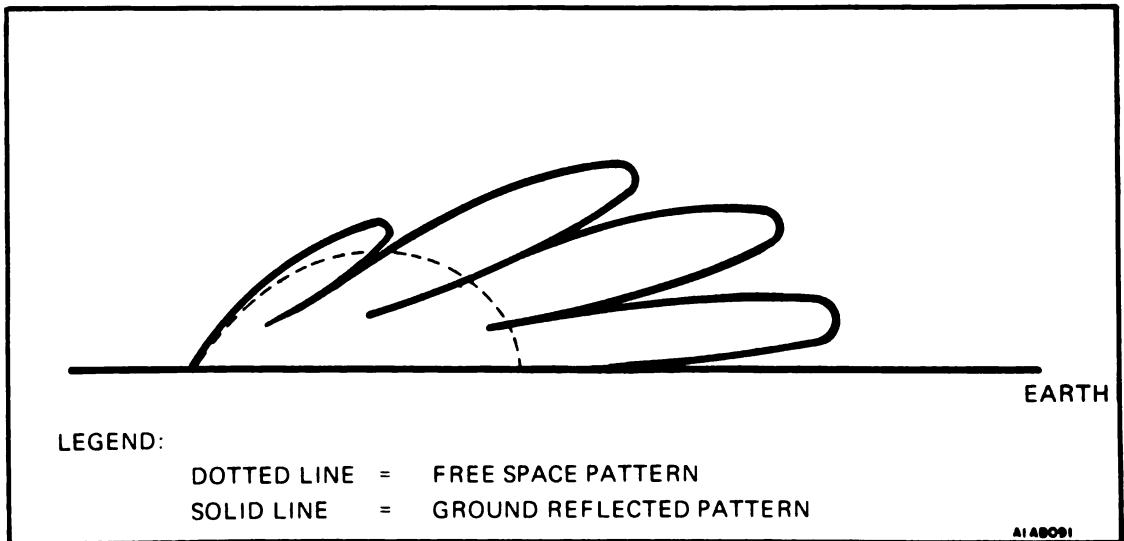


Figure 10 - 2. Typical Vertical Radiation Pattern With Ground Reflection

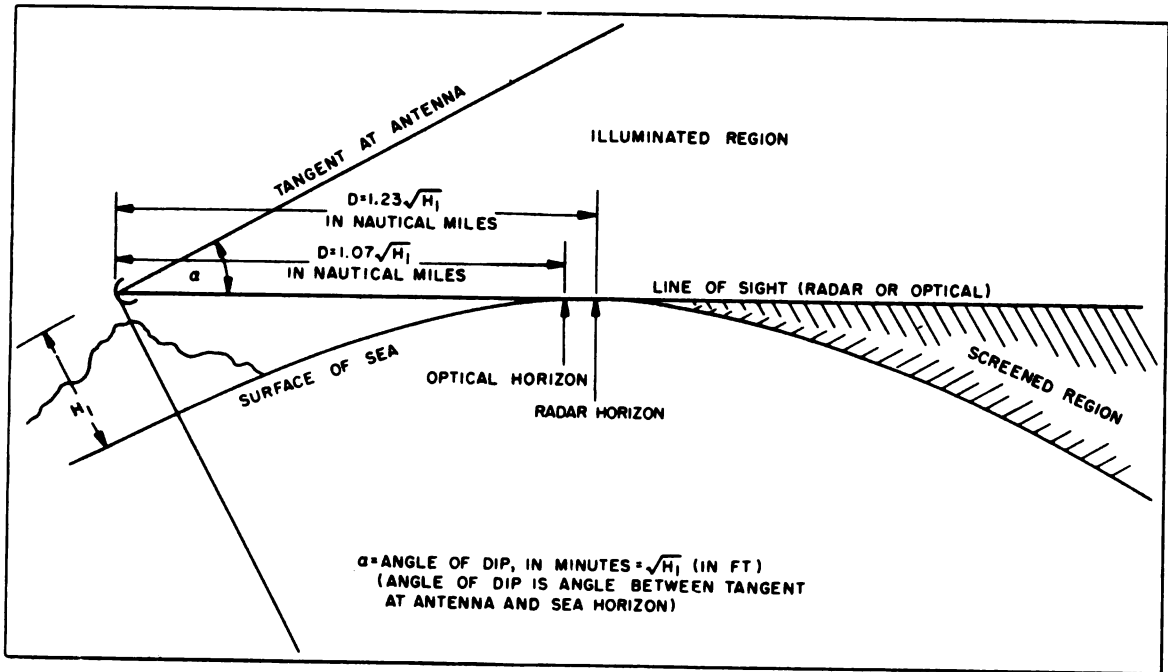


Figure 10 - 3. Curved Earth Screening

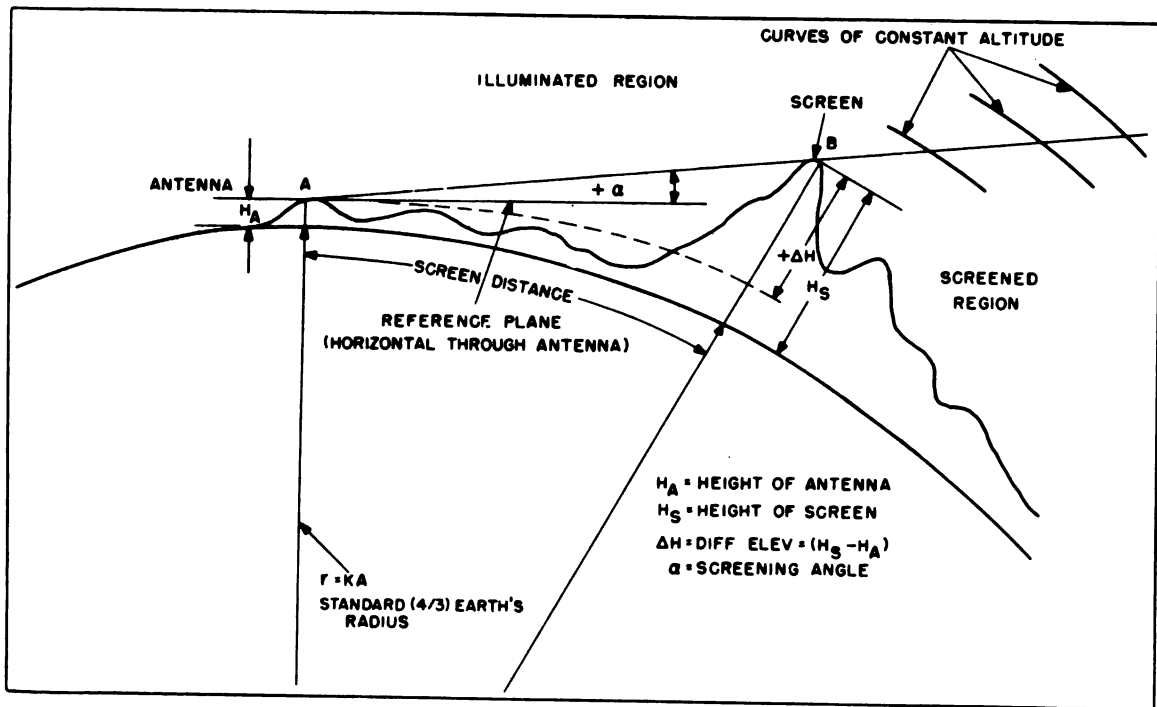


Figure 10 - 4. Obstacle Screening

The amount of screening associated with the radar site depends upon the screening angle (α). This is the angle formed by the intersection of the radar line-of-sight and the horizontal plane at the radar antenna. The angle may be positive or negative depending on the elevation of the site. The effect of screening is expressed as a relationship between screening angle and radar range at a given altitude.

The effect of elevating the radar line-of-sight is shown graphically in figure 10-5. In the figure the antenna site is at sea level and the radar line-of-sight range for a screening angle of 0 degrees at 10,000 feet is 123 nautical miles. If the radar line-of-sight limit for 10,000 feet is reduced to 67 nmi; a reduction in range of 56 NMI, or 46 percent results. If the maximum allowable reduction in range is arbitrarily fixed at 15 percent at the altitude of interest (10,000 feet), the reduction in range is 18 NMI and the maximum range is 105 NMI. The corresponding screening angle is 0.25 degree which is the maximum allowable screening angle for the conditions stated.

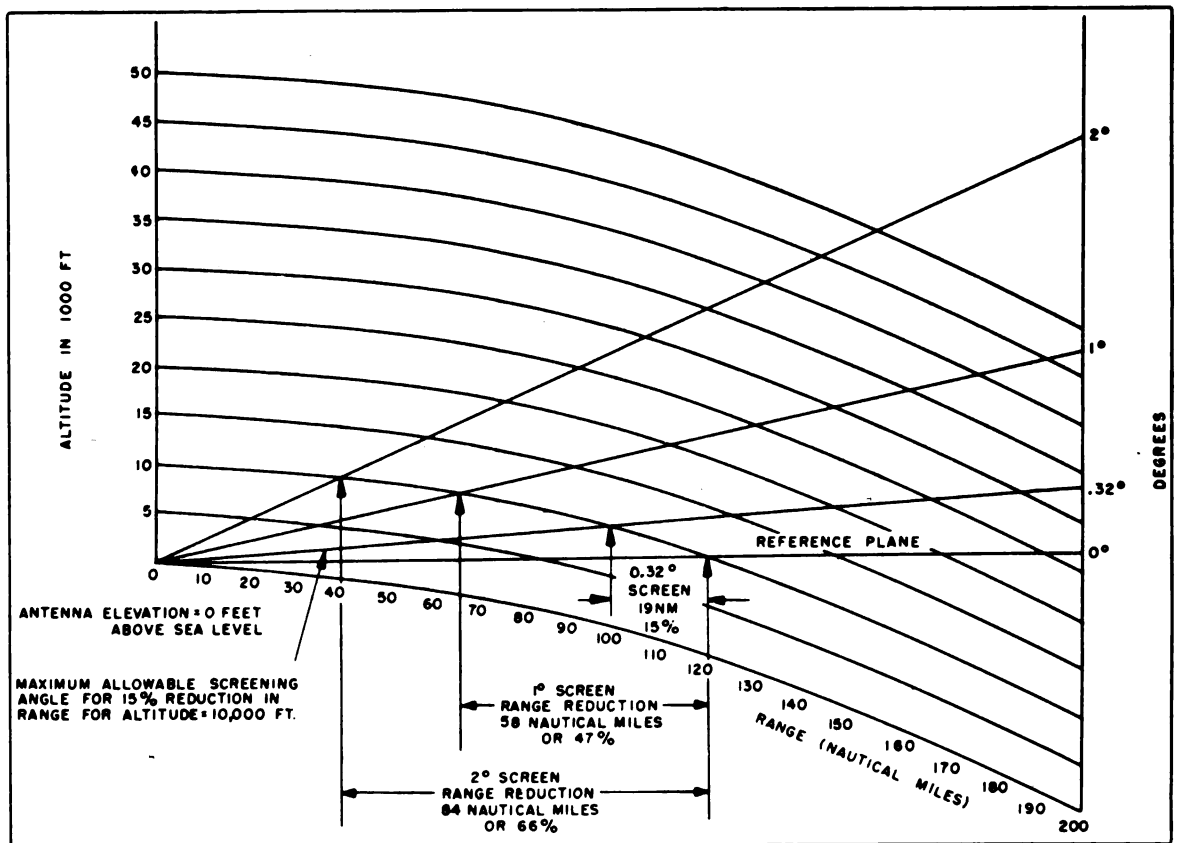


Figure 10 - 5. Screening Angle Versus Range

Radar performance is materially affected by the nature of the local terrain. The terrain in the immediate vicinity of the radar antenna can alter the radiation pattern in varying degrees depending on the surface roughness, presence of obstacles, and effective antenna height. The character of the surrounding terrain determines the low-angle coverage by controlling the amount of obstacle screening. Radar siting is concerned primarily with selecting a site from the available geographic locations that will provide the required radar coverage with the radar sets supplied or available. Therefore, a radar set with a fixed set of operating characteristics may or may not provide adequate coverage depending upon the choice of geographic location. The coverage diagrams in figures 10-6, 10-7, and 10-8 do not represent a specific radar set but are typical examples. The diagrams are intended for use only as an aid in understanding the factors involved.

The effect of site elevation on the radiation pattern and coverage of the radar antenna may be seen by comparing the diagrams in those figures. For ease of discussion, the range capability of a radar set is referred to as long-range and short-range. A distinction is also made between a high-sited or low-sited radar, referring to the difference of elevation between the radar antenna and the surrounding terrain. A comparison of radiation patterns between the high-sited radar in figure 10-6 and the low-sited radar in figure 10-7 shows that the high-sited radar has the greater low-angle coverage most useful for early-warning purposes. However, the extent of clutter (signal return from nearby land and sea surfaces) is increased and the high-altitude coverage is decreased.

The radiation patterns for both high-sited and low-sited short-range radars are illustrated in figure 10-8. The high-sited radar is designated "A" and the low-sited radar is designated "B". A study of these radiation patterns shows the effects of elevation on the performance of this type of radar.

The effective height of an antenna is a significant factor in calculating the effect of the earth on the radiation pattern. It may or may not correspond to the site elevation. The elevation of an antenna is fixed, once its location is fixed, and is given in feet above sea level. The effective height of an antenna, with the earth regarded as a smooth reflector, is its height above the local terrain or reflecting surface. Effective height can vary as the antenna rotates. This is especially true of a coastal cliff-sited antenna; its effective height is equal to its elevation on an over-water azimuth but is much less when the antenna looks inland, as shown in figure 10-9.

The factor of effective antenna height has significance only where reflections from the earth's surface materially affect the structure of the radiation pattern. Where the earth is smooth, relative to radar wavelength, ground reflections of the radar beam occur. Where the earth is rough, diffuse reflection (scattering) of the radar beam results. The radiation pattern is much less affected by ground reflection, and the factor of effective antenna height has much less significance.

In general, radar sites are divided into four geographic categories: coastal, overland, flat-earth, and mountains. Since the terrain varies considerably with locality, the discussion of each category is presented as background information for guidance in specific site selection.

- o Coastal Sites. When the area of primary search overlooks the sea, the site should be located to obtain a wide, unobstructed panorama of the sea. Low-angle long-range coverage is best obtained with the antenna site at the highest practical elevation. Lowering the height of the antenna raises the radar line-of-sight and results in a reduction in range at the lower altitudes. Therefore, if the detection of target aircraft at low angles is a criterion in meeting operational requirements, the sacrifice in low-angle coverage that results from decreasing the antenna height must be carefully considered.

The extent of sea clutter can be expected to diminish with decreased radar horizon distance as the elevation of the antenna is decreased. For the case of the long-range radar sited relatively low over the sea, the problem is one of intensity of clutter rather than of extent of clutter relative to the maximum range of the radar.

The radiation pattern for a lower antenna height, as shown in figure 10-7 is characterized by fewer lobes at higher elevation angles and greater spacing between the lobes. The consequent reduction in low-angle coverage is in addition to that imposed by changing the radar line-of-sight. Reduction of low-angle coverage and the greater gaps in vertical coverage are perhaps the most important characteristics of the low-sited coastal radar.

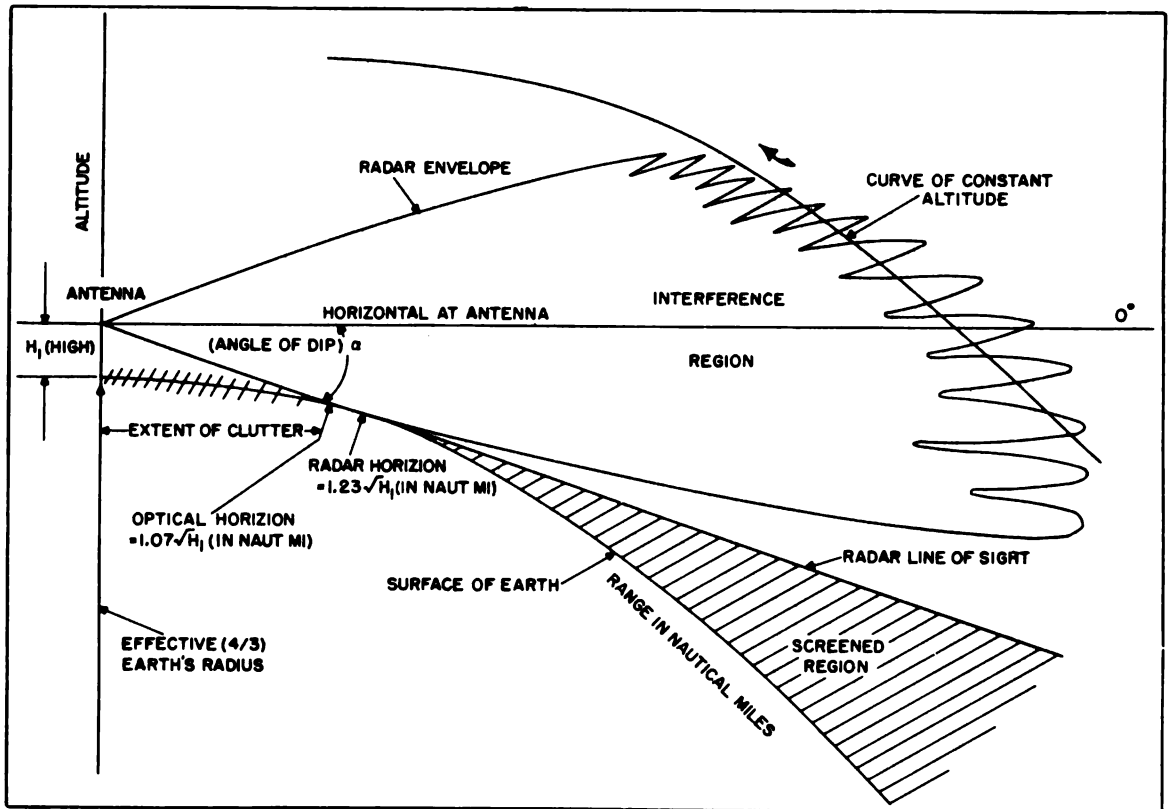


Figure 10 - 6. High-Sited, Long-Range Radar

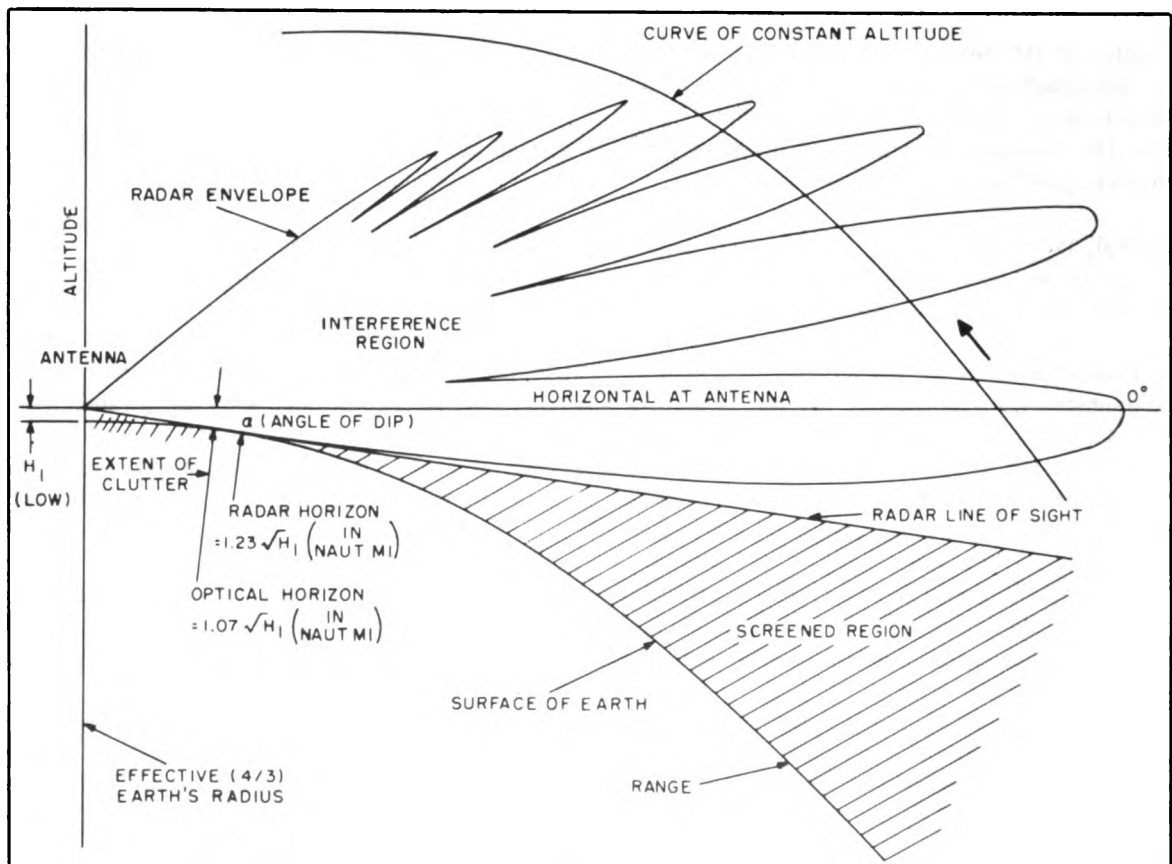


Figure 10 - 7. Low-Sited, Long-Range Radar

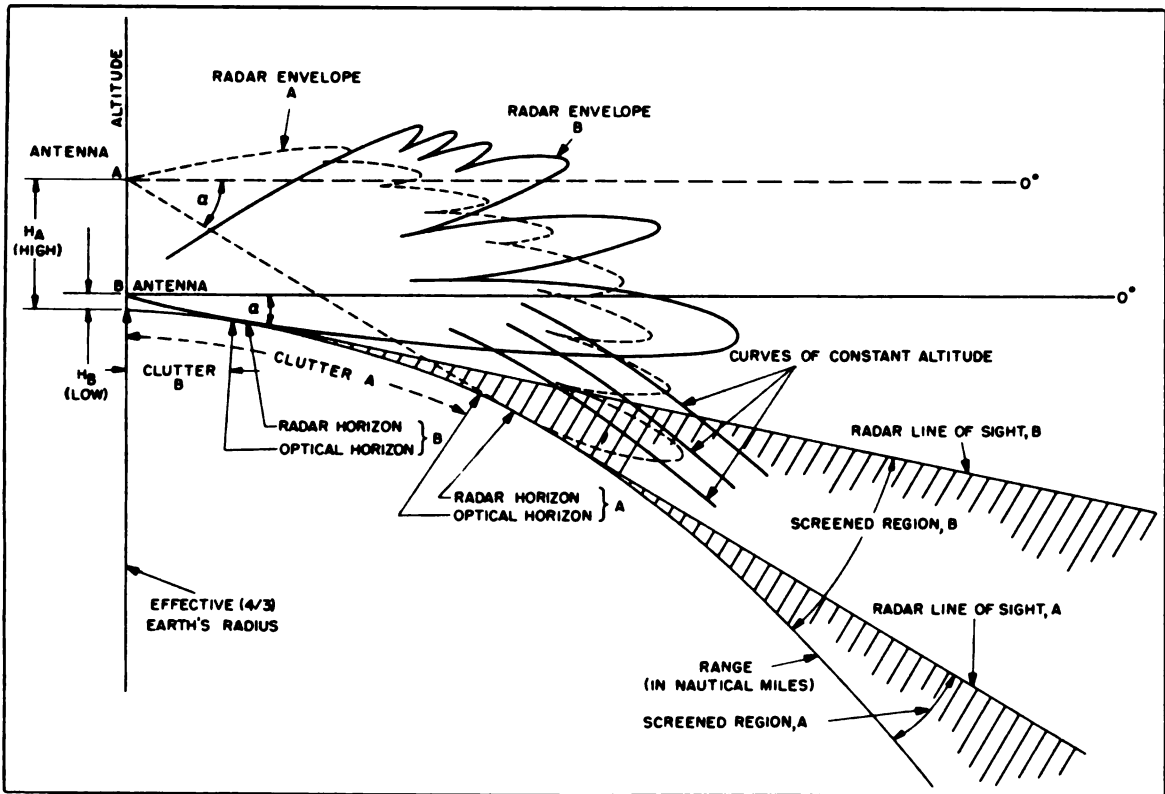
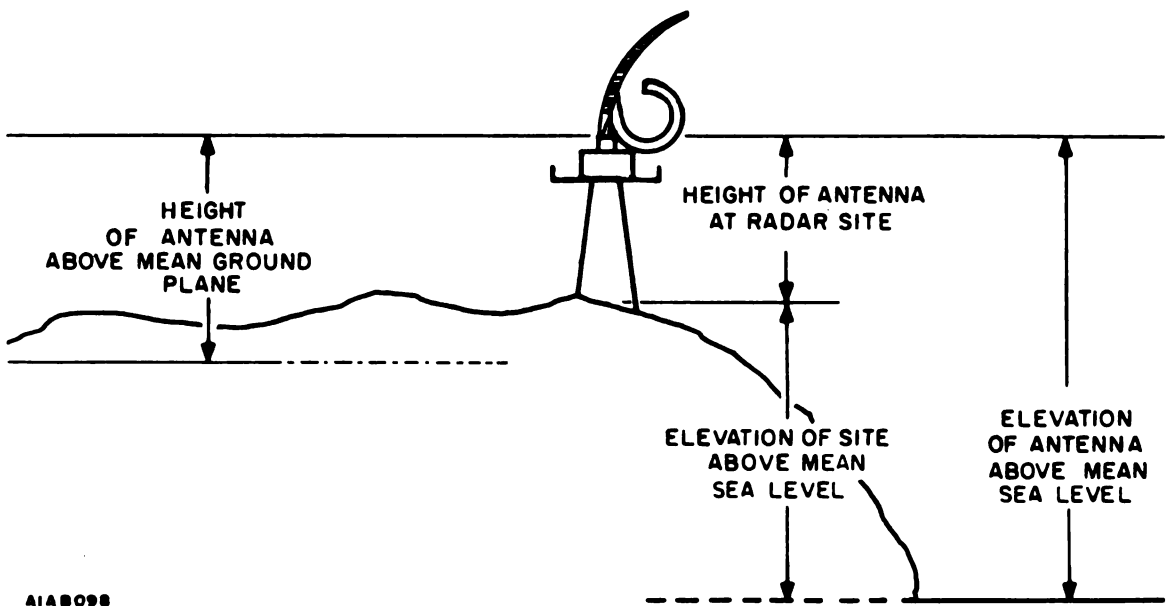


Figure 10 - 8. High-Sited, Low-Sited, Short-Range Radar



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Figure 10 - 9. Effective Antenna Height Versus Rotation

For short-range radar, the elevation of the antenna above the sea is more critical. A compromise is needed as for long-range radar, between the maximum range afforded by the radar and the extent of the sea return. Nothing is gained by locating the short-range search antenna at a high elevation if the extent of the sea return is comparable with the maximum range of the radar.

Radar range, as well as the extent of sea clutter, varies somewhat with the condition of the sea, that is, whether the sea is smooth or disturbed. When the sea is smooth, clutter is reduced, and the vertical radiation pattern is characterized by a large number of closely spaced lobes in the pattern. Under conditions of a disturbed sea, it may be expected that clutter will increase in extent and intensity and the radiation pattern will tend toward the free-space condition because of the effect of scattering. As a result, radar coverage or tracking beyond the range of clutter may be expected to be more "solid". However, because of the great intensity of the sea return, tracking within the range of clutter may be greatly diminished.

If there is a choice between a site overlooking the open sea and one overlooking a large expanse of relatively protected water of comparable azimuth sweep, the latter is to be preferred. This is due to the reduced sea clutter and, to some extent, the more nearly stable effect on the radiation pattern. Guiding factors in any case should be maximum unobstructed azimuthal sweep of the antenna and sufficient height for operational area coverage.

o Overland Sites. In overland azimuth sectors of search, particularly over rough terrain, ground clutter can be extensive up to the radar horizon. In addition, the permanent echo returns from terrain features located beyond the radar horizon are visible on the radar indicator because of their height and large reflecting areas. The primary difference, then, between a site overlooking the sea and one overlooking land is the extent and intensity of the ground clutter. Land search imposes more severe clutter limitations on a given radar. Antenna height above the ground will have to be a compromise between the maximum useful range of a radar and the amount of ground clutter that can reasonably be tolerated.

It is entirely possible, particularly in the case of a short-range radar, that the ground clutter can compare with, or even exceed, the practical maximum range of the radar. Tracking of targets in such a case may be extremely difficult, and the additional range gained by locating a short-range radar at a high elevation may be made useless by the increase of ground clutter.

o Flat-Earth Sites. In situations where the terrain in the general locality of a proposed radar site is relatively flat, particular regard should be given to the following factors:

(a) The distant horizon should be visible from the antenna location over as great an azimuth sector as possible for minimum screening particularly for the azimuth sector of interest.

(b) Ground in the vicinity of the antenna should be flat and clear of obstructions such as trees, undergrowth, buildings, and towers, to assure a good reflecting surface for the radar beam. This also reduces the amount of ground clutter or permanent echoes resulting from these obstructions.

In heavily wooded regions, or in the presence of natural or manmade obstructions to visibility, the radar antenna should be tower-mounted at a height sufficient to clear the obstructions and permit visibility of the distant horizon. If the range capability of a given radar set-target aircraft combination is comparable to the horizon distance, and therefore to that extent of clutter, it may be necessary to resort to some means of clutter reduction. This can usually be done only with some sacrifice of range capability.

Clutter may be reduced to some extent by adjusting the antenna tilt, using moving target indicator devices, or incorporating an allowable amount of local screening. The first two clutter-control measures are associated with the radar equipment. In the latter the screening obstacle may be a ridge, a succession of ridges, or a series of hills in the vicinity of the site. Location of the antenna with respect to the screening obstacle should be such that the clutter is reduced to allowable limits and that elevation of the line-of-sight does not exceed operational limits. In an idealized case, location of a radar antenna would be at the center of a large, shallow, saucer-shaped depression. However, such depressions are not commonly found.

o **Mountain Sites.** In mountainous regions, location of a search-radar antenna is generally determined by the amount of screening that may be tolerated from adjacent mountain ranges or ridges, the extent and intensity of the clutter and permanent echo return, the accessibility of the site, and economic limitations imposed by special problems incident to the topography of a locality. With the relatively high elevation of an antenna site located on a mountain top, the problem of clutter is correspondingly greater.

Principal factors to be considered in selecting a mountain-top location are: elevation of the tentative site in relation to that of adjacent screening terrain, distance between the site and the screening terrain, and range or performance capability of the radar compared with the extent of clutter. The first two combine to determine the angular elevation of the line-of-sight or screening angle. They should be such as to yield a maximum depression of the line-of-sight in the azimuth sectors of operational interest. The second, screen distance, affords an estimate of the extent of clutter to be expected (clutter generally extends to the visible sky line). The choice of a mountain-top location as a radar site thus involves a compromise between screening and clutter limitations and radar performance capability.

Consideration must also be given to factors other than coverage. A remote site may be selected which is ideal for propagation, but provision for power and utilities, as well as road building and other construction, may make the cost prohibitive. Mountain-top sites are especially susceptible to the problems of construction, as well as, protection against wind, snow and ice, and the availability of water and fuel.

In remote operation, the additional problem of maintenance must be considered. Unattended operation is usually impracticable and total personnel requirements for remote operation are generally increased. Voice communications between the control tower or control center and radar sites, or between a control center and radar sites, will be by either telephone, intercom, or radio channels. Remote displays are required at the control center necessitating use of video lines to supply information to the control center indicators for distances less than 10,000 feet. At greater distances, video amplifiers will be required to compensate for cable losses. Microwave relay equipment should be provided for this service.

The antenna tower and transmitter building are permanent installations and must have solid foundations. Standard building construction as determined by Public Works with reference to the (FAA) standard plan for an ASR transmitter building tower foundation, shall be observed. In practice, tower height is specified to be no higher than that necessary to obtain line-of-sight coverage over obstructions and to touchdown points on the Naval Air Station runways. The antenna tower for the AN/FPN-47 may vary from 17 to 77 feet in ten foot increments. The selected height will be determined after a survey of obstructions in the area of the proposed site.

10.1.4 Installation Criteria

The radar antenna is mounted on the tower located adjacent to the transmitter building and connects to the radar equipment inside the building through 10-centimeter waveguide. Extreme care must be maintained during the installation of the waveguide to prevent damage or misalignment which would interfere with the transmission of signals between the antenna and radar equipment. A typical radar transmitter building layout recommended with minimum variations is presented in foldout 10-1.

The remote equipment, that presents a visual display to air traffic controllers, and the necessary associated equipment is usually installed in two groups in the airfield control tower building and is termed the remote site. The remote site cannot be more than two nautical miles from the transmitter site if connected by cable. Operational PPI consoles and the radar equipment remote control assembly are usually installed in the IFR room (refer to foldout 10-2). Associated indicating equipment is installed in an equipment room that cannot be more than 300 feet from the three operational PPI consoles. The airfield control tower building will vary in size, construction, and layout from site to site, but an attempt will be made to standardize the remote area at all NAS.

10.1.5 Operation and Maintenance Procedures

Proper operation and maintenance of the ASR equipment is vital to an NAS air traffic control system as well as the National Airspace System. Therefore, the procedures thoroughly detailed in the ASR technical manual must be strictly observed.

10.2 PRECISION APPROACH RADAR

10.2.1 Operational Requirements

Precision approach radar (PAR) is required to enable the ATC final approach controller to safely guide single or multiple aircraft within a minimum height of 50 feet above the active runway. The controller guides the aircraft over the touchdown point until the pilot acquires visual contact with the runway. This service is required at all Naval Air Stations, under all conditions of weather, including conditions of 50-foot ceiling and one-fourth mile visibility.

As part of the ATC facility, the PAR provides on a visual display the relative altitude, range, and flight course of an approaching aircraft. This information is interpreted by the controller, who in turn directs the pilot during the final critical phase along the optimum glidepath and course line to the touchdown point.

10.2.2 System Configuration

The complete PAR set consists of:

- o Shelter equipment, consisting of the transmitter group, receiver group, indicator group, and accessory equipment.
- o Remote equipment, consisting of amplifying components, one or more sets of indicating equipment, and auxiliary items.
- o Interconnecting cabling, between shelter equipment and the remote equipment.

The shelter equipment is designed for installation in a shelter which is located on the airfield. Components of the Radar Set AN/FPN-16, similar to FPN-52, are shown in figure 4-3. Radar Set AN/FPN-36 has field installed equipment which does not require a shelter (see figure 10-10).

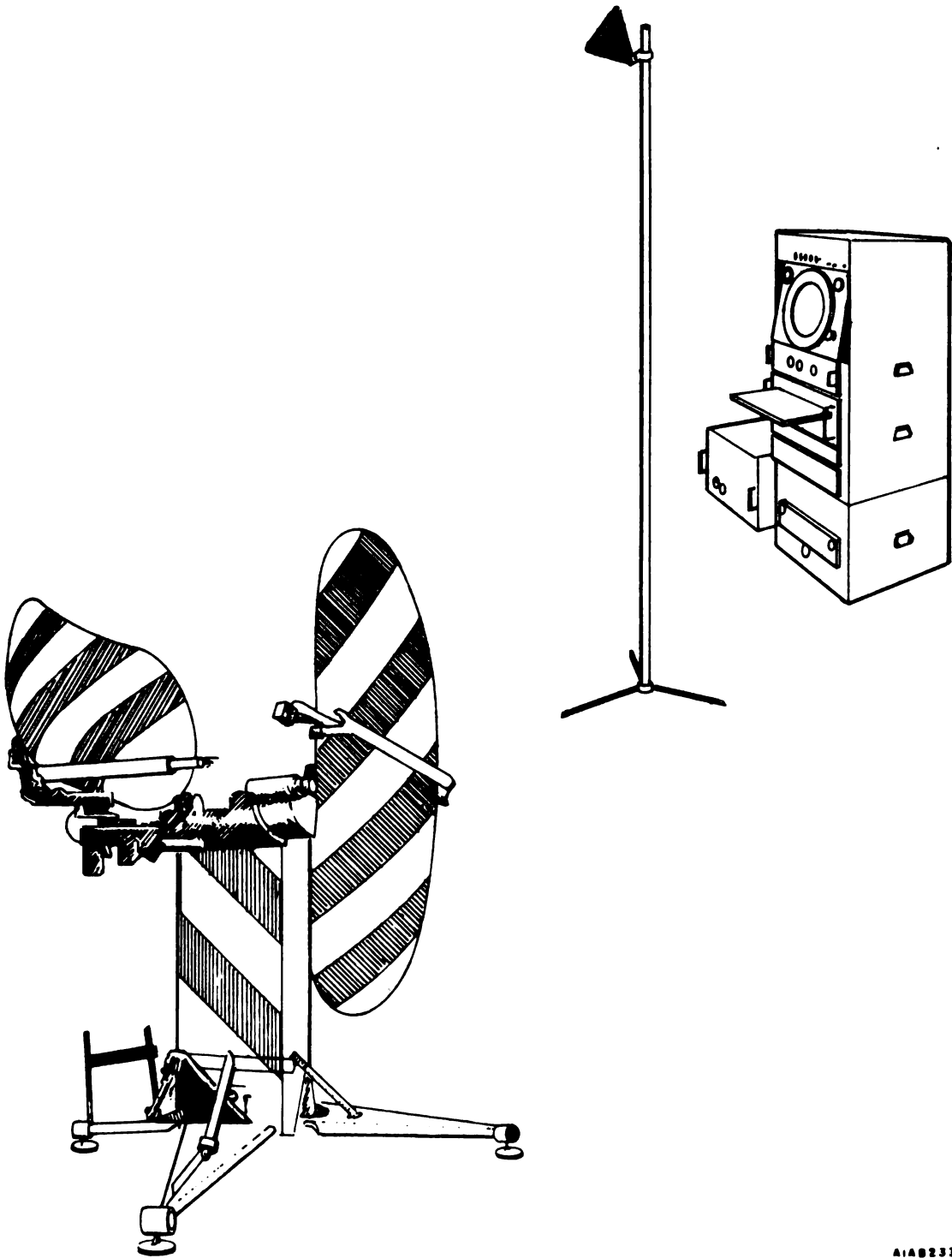
The remote equipment is usually installed in the IFR room of the ATC facility. The AN/FPN-16 and -52 are designed specifically for control center installation. The AN/FPN-36 remote indicator group and power supply group have been designed for installation in control tower cab, IFR room, or a shelter on or near the landing field.

Details on the components of AN/FPN-36 are presented in chapter 3. System configuration of AN/FPN-16 and -52 are presented in chapter 4.

10.2.3 Site and Structural Criteria

After the operational requirements of an airfield are determined, location of the field equipment (receiver-transmitter and antennas) is of prime importance in planning the installation and siting of GCA-PAR. Operational requirements include:

- o Selection of instrument runway
- o Direction of aircraft approach on the instrument runway



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Figure 10 - 10. Radar Set AN/FPN-36

- o Glide angle to be used
- o Exact location of touchdown.

It must be noted that it is the responsibility of the base commander to make the final decision on the operational considerations.

Runway lengths, distance between runways, and taxi strips are limiting factors in choosing the best position for the radar. For maximum operational efficiency, radar siting limits are 250 feet to 1500 feet from the centerline of the runway covered, and 2000 feet and 10,000 feet from the touchdown point. The minimum distance from touchdown that the radar set can be operated is governed by the requirement to extend the runway coverage at least 500 feet past the touchdown point. Because objects at the outer edge of the display may not always be completely visible, the usable limit of the azimuth scan is considered to be 14 degrees for left-of-runway operation and 9 degrees for right-of-runway operation. Figure 10-11 illustrates the 14-degree and 9-degree limit lines, including the 500-foot minimum coverage point, and the boundary lines of possible siting locations on a typical runway.

Regulations governing the airfield will determine the minimum distance from the end of the runway to touchdown. Assume a minimum distance of 500 feet, the runway must be 6000 feet long to permit the radar to cover approaches from both ends with normal siting. Parallel runways 1500 feet apart would have to be 8000 feet long to permit coverage for all approaches under normal siting conditions.

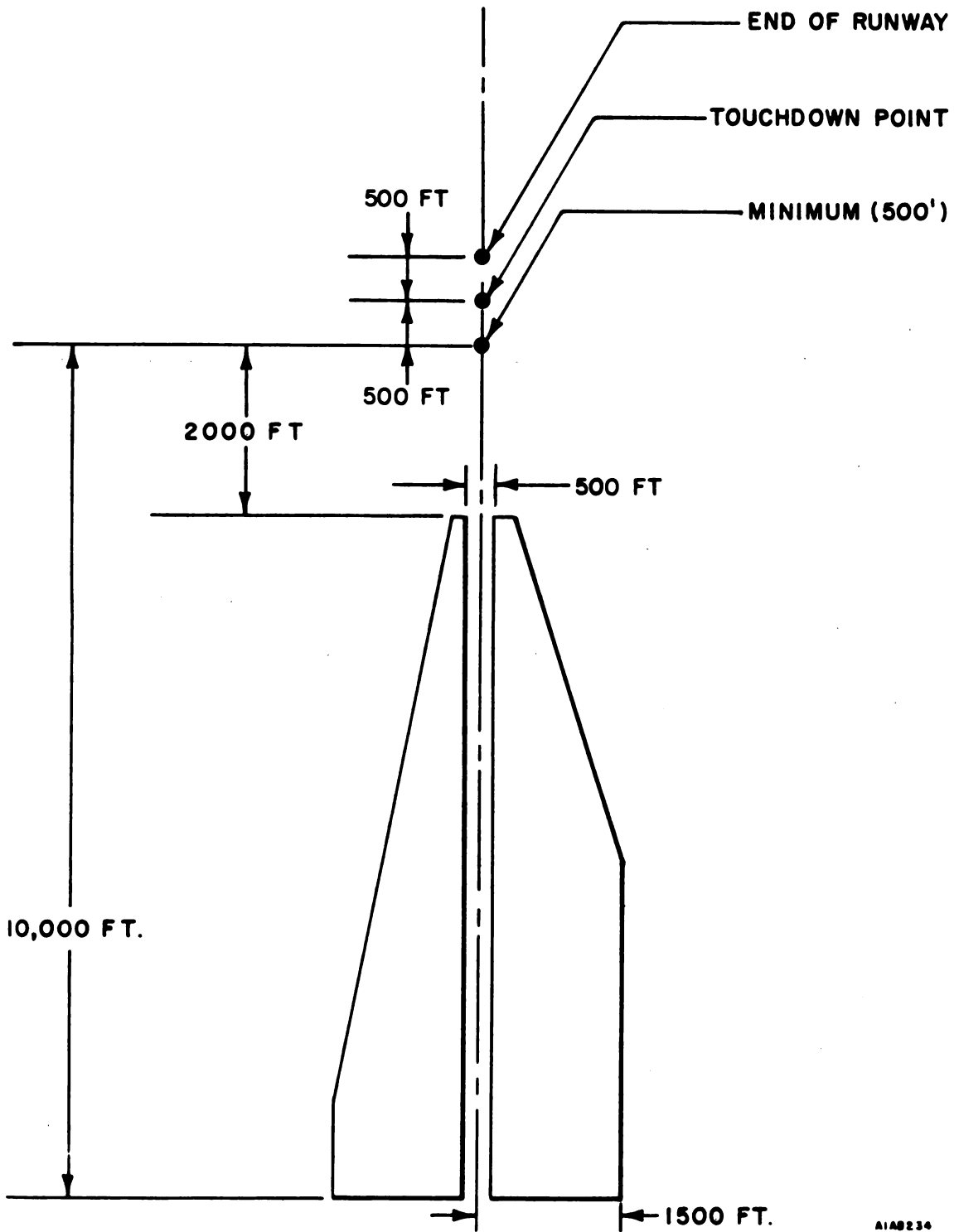
To choose the best possible site, the boundary lines of possible siting locations for each approach to be covered should be outlined on an airfield map. Shade all areas on the map common to the siting location of all approaches (up to a maximum of four) to be covered. Select a site within the shaded area after carefully surveying that no obstructions (such as hangars, wooded areas, or rises in the terrain) are blocking the precision scan area.

A deciding factor for determining the siting of the PAR is the location of the control tower. The radar is usually located on the opposite side of the runway from the tower so that the tower controllers will have a clear view of the runway.

Other factors which must be considered during a site survey and before finally locating the radar include:

- o Type of terrain and site topography
- o Proximity of other electronic facilities which may cause or receive interference
- o Site map drawn to scale showing the proposed location of the shelter and the standby power unit
- o Profile chart taken from estimated elevation of the shelter foundation to ensure that there is no obstruction to block the radar view
- o Availability of primary power and accessories to include location of existing power lines, transformer banks, or vaults; length and type of power line required; primary power reliability, phase frequency, and expected voltage and frequency stability; required ducts under runways and other facilities for installation of remote cabling
- o All-weather access road requirements
- o Determination of any special problems related to installation of lightning protection and grounding at the proposed site due to local soil conditions
- o Location and facilities available for installation of the remote indicators.

The limits of environmental conditions for the assigned radar set are specified in the technical manual.



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Figure 10 - 11. GCA-PAR Siting Area

For a permanent PAR installation, a hardstand is strongly recommended. The radar set AN/FPN-36, with its tripod-transmitter-antenna combination requires a good solid base to prevent the tripod feet from sinking into the earth. The radar set must remain level so that antenna tilt information and cursor alignment will remain accurate in any direction. AN/FPN-16, -52 and other trailer (shelter) mounted PAR equipment require a hardstand and a turntable (unless operation is limited to one runway and only one approach direction). The turntable will simplify the rotating procedure required when the approach direction, or in the event the active runway, is changed. Single and multiple runway operations with a single PAR is illustrated in figure 10-12. For single runway operation with approaches from both directions (figure 10-12) a site midway along the runway will provide the best coverage.

Assume that the radar set has been located as shown in figure 10-12A and that the azimuth antenna is covering the single runway. Also shown is an imaginary line parallel to the runway which passes through the center of the azimuth antenna; this line is called the runway parallel line (RPL). If this one radar is to cover another runway from the same physical location, the RPL must be rotated until it is parallel to the new runway. With the radar equipment mounted on a turntable it is an easy task to align the RPL to any runway desired. Consequently, the one radar set will cover a number of runways from the same physical location as illustrated in figure 10-12.

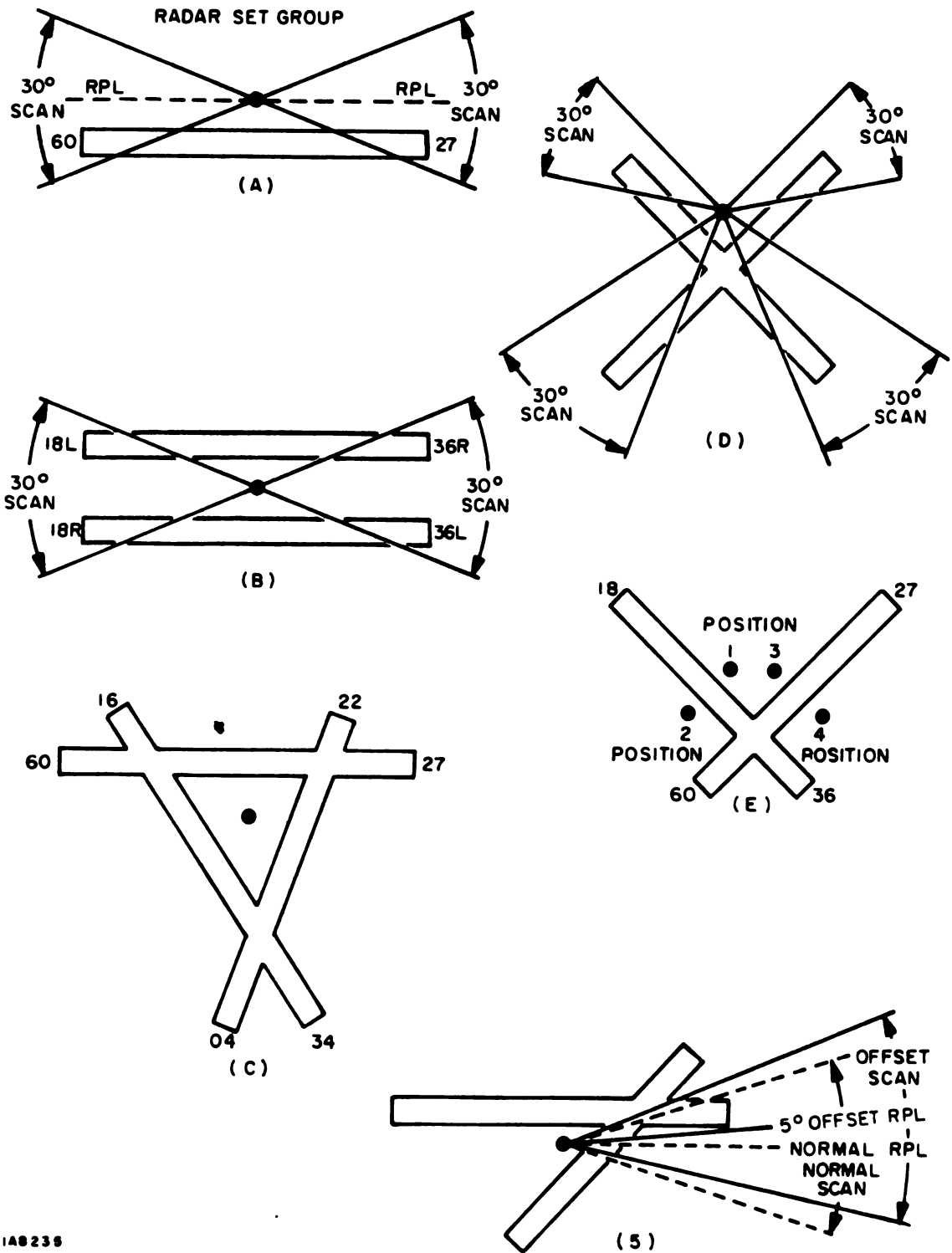
Traffic patterns and maximum traffic flow determine the location of the radar set for multiple runway coverage. If one runway is designed as the primary instrument runway, it should be given adequate coverage even at the expense of other approaches. Various combinations of multiple runway layouts are shown in figure 10-12. If the runway layout is in the shape of a cross, view D, the radar set can be located in any of the four quadrants. Access roads, power source, terrain, and other factors determine the actual siting position. For parallel runways, view B, the best location is directly between the runways and midway between the ends. If the location is moved toward the end of the runway in either direction, the location limits of the radar equipment (see figure 10-11) must be considered. It is difficult to cover all four approaches in the runway layout illustrated in figure 10-12E. Positions 1 and 2 readily cover runways 18, 27, and 36, but are too close to the end of runway 09 for proper coverage. The runway number usually, but not always, indicates the magnetic heading of the runway; thus, the number 18 indicates a magnetic heading of 180 degrees. Positions 3 and 4 will not cover runway 36. Siting positions which are close to touchdown are considered abnormal and are discussed in the following paragraph. One of the most common multiple runway layouts is shown in view C. However, the position shown is the only one that will give complete coverage of any four of the six approaches.

Abnormal siting problems can often be solved by offsetting the RPL. This means that the precision 30-degree scan area must be moved toward the runway so that the touchdown point will fall within the azimuth sector, view F. In nearly all cases where the radar set group is too close to the point of touchdown, a 5-degree offset will be sufficient. If RPL is offset 5 degrees towards the runway centerline, the radar set group can be sited 30 percent closer to touchdown. The RPL can be offset more than 5 degrees, but cursor accuracy decreases when large angles are involved.

10.2.4 Installation Criteria

Detailed installation procedures are included in the technical manual provided with each radar set, but a few of the critical installation specifications are presented.

Both the vertical and azimuth antennas must be level. Spirit levels are usually provided on the antenna mounts and they must indicate a level condition in all operating positions of the antenna. The portable PAR (AN/FPN-36) must be thoroughly checked for a level condition at all possible operating positions during initial installation. Turntable-mounted radar sets must also indicate a condition of level for all 360 degrees of rotation, therefore extreme care must be taken during installation of both the turntable and the radar equipment. As indicated, the radar antennas must be level to ensure that the information presented on the visual indicator will be true regardless of the azimuth direction being monitored.



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Figure 10 - 12. Locations for Multiple Runway Operation

For example, if the radar set is tilted so that the elevation antenna is 2 degrees down from level (in the direction of the approaching aircraft), the aircraft would appear on the display to be above its actual glidepath by 2 degrees or approximately 1650 feet at 8 miles, or 210 feet at 1 mile. To be told that he is above the glidepath during final runway approach, when he is actually on course, would cause a pilot to quickly lose faith in his controller. Thus, errors in antenna level adjustment are dangerous and can cause serious accidents.

Corner reflectors will be located at established points around the approach end of the runway. These target or corner reflectors, accurately positioned; will provide landing field reference points for calibration of the radar equipment and for making periodic checks of alignment accuracy. For normal installations, four target reflectors are used for each runway to be covered, though as many as twelve reflectors may be installed. If four reflectors are employed, two are used to bracket the end of the runway, one is placed at a fixed distance on the RPL, and the fourth reflector is placed on an imaginary line which runs from the radar antenna to a point on an extension of the runway centerline 6 NMI from touchdown. See figure 10-13.

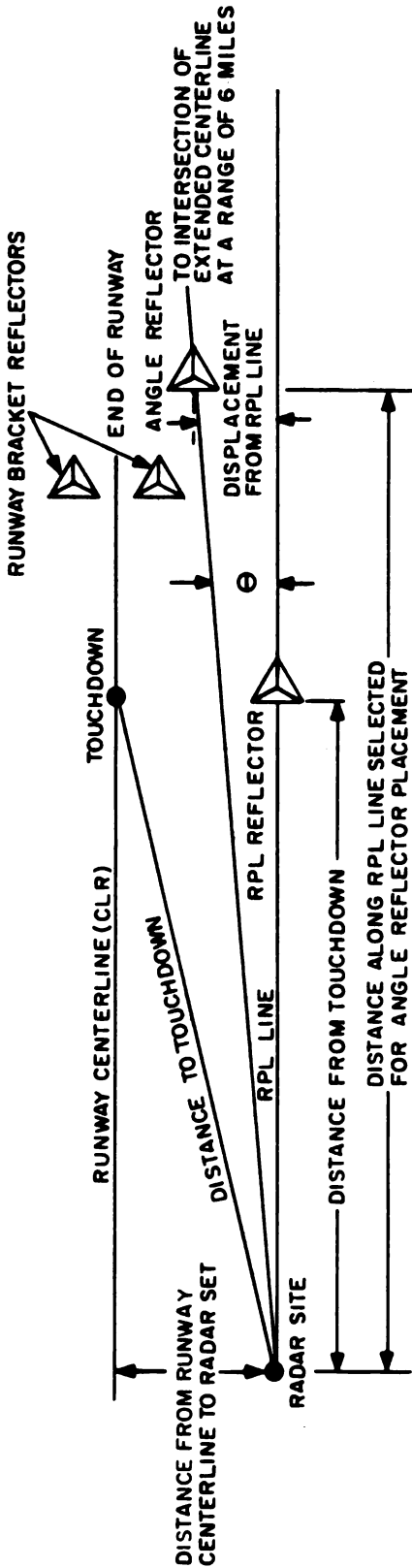
The reflectors are of either the frangible (breakable) or nonfrangible type, and the height of each reflector will be chosen so that it is in line of sight of the azimuth antenna. The height of the nonfrangible reflectors must comply with current NAS standards regarding obstructions in the vicinity of the runway. Table 10-1 lists the functions and uses of as many as twelve reflectors. Figure 10-14 shows type and possible corner reflector locations for left-of-runway and right-of-runway sites.

10.2.5 Maintenance Procedures

An effective preventive maintenance program, properly supervised, is essential for the efficient, reliable performance of this equipment. This program consists of checking the operation of the equipment utilizing the performance routines described in the technical manual. Also of importance is visual inspection, cleaning, and lubrication with the aid for servicing routines provided. The program should be carried out in accordance with a strict preventive maintenance schedule.

The following practices are generally recommended which will aid in improving the preventive maintenance program:

- o Review each routine prior to actual performance to ensure understanding of procedure and purpose.
- o Ensure that maintenance personnel are equipped with proper test equipment to accomplish the performance routines.
- o Ensure that test equipment is properly calibrated.
- o Doublecheck all procedures if desired results are not obtained.
- o Leave electronic components as they are when operating in accordance with performance standards. Do not be a knob twister; you may put in more trouble than you take out.
- o Ensure maximum cleanliness of all electronic circuitry to prevent maintenance problems.
- o Place special emphasis on lubrication practices to obtain maximum operating time of moving parts.
- o In the interest of safety, it is recommended that a servicing routine be performed on a component while it is in the status of a spare. If this is not possible, turn the equipment off. If routines interfere with scheduled radar operations, such routines should be performed during normal equipment shutdown periods.
- o Avoid bodily contact with exposed wires, terminals, and heat-generating equipment. Many electronic circuits retain sufficient charge (after equipment is turned off) to still be dangerous. In all high voltage circuits, discharge high voltage capacitors with the proper grounding tool. Serious burns can be inflicted by the glass envelopes of tubes, power transformers, and heavy-current-carrying resistors.



$$\tan \theta = \frac{\text{RADAR SITE DISPLACEMENT IN FEET TO LEFT OR RIGHT OF RUNWAY CENTER LINE}}{\text{DISTANCE ALONG RPL LINE TO A LINE PERPENDICULAR TO EXTENDED RUNWAY CENTERLINE AT SIX MILES FROM TOUCHDOWN (6 MILES = 36480 FEET)}}$$

$$\text{DISPLACEMENT OF ANGLE REFLECTOR} = \tan \theta \times \text{DISTANCE (IN FEET) ALONG RPL LINE TO POINT PERPENDICULAR TO AREA SELECTED FOR ANGLE REFLECTOR PLACEMENT}$$

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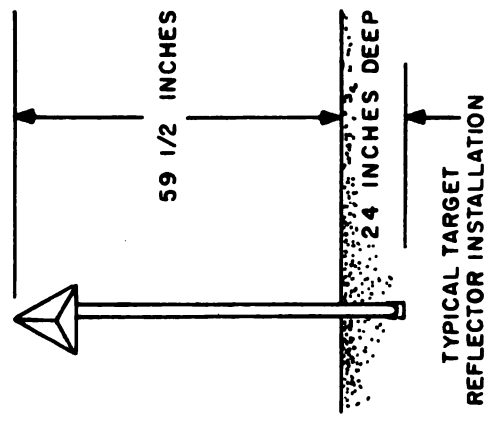
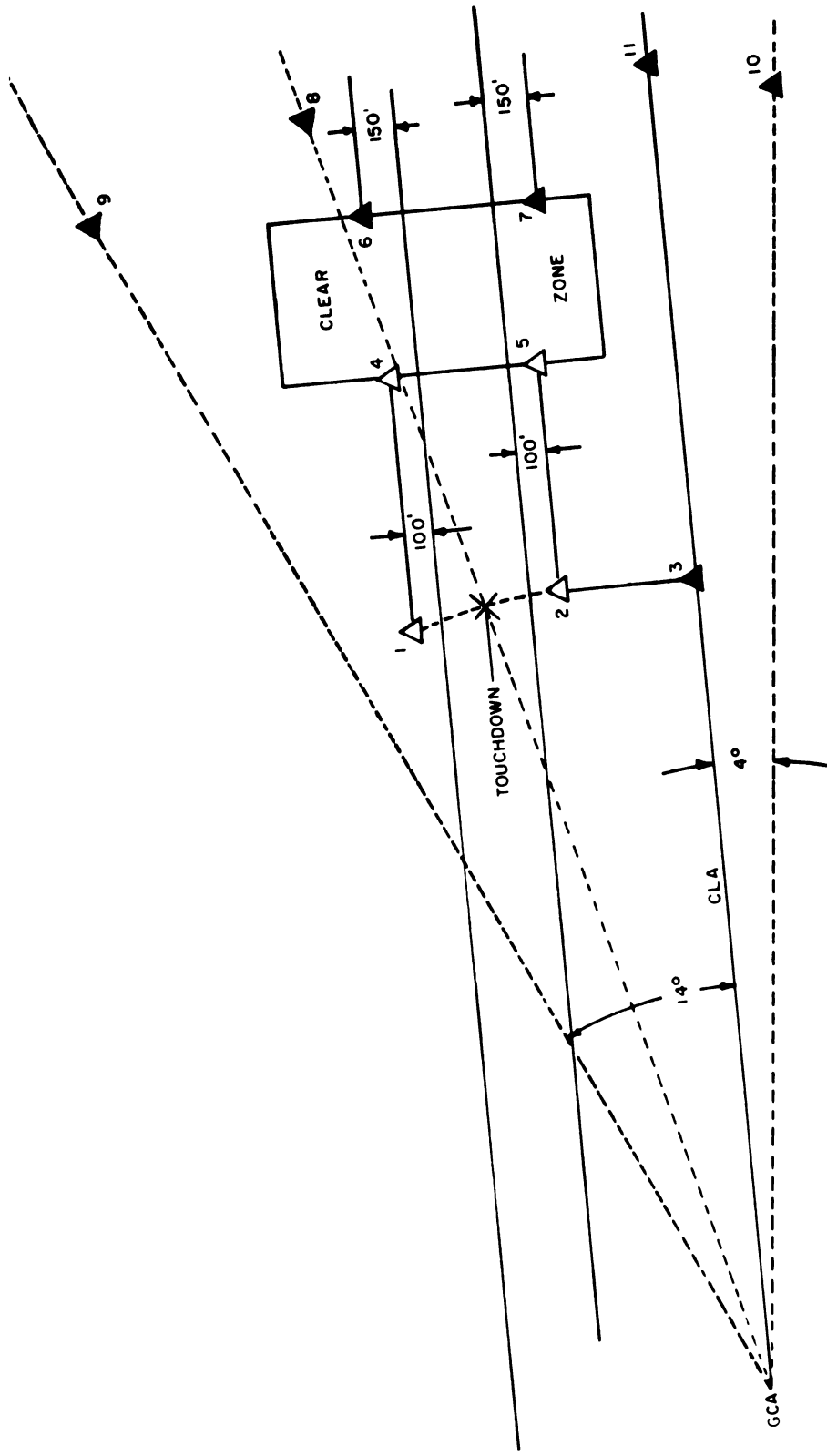


Figure 10 - 13. Siting Target Reflectors

Table 10-1. Reflector Designations and Utilization

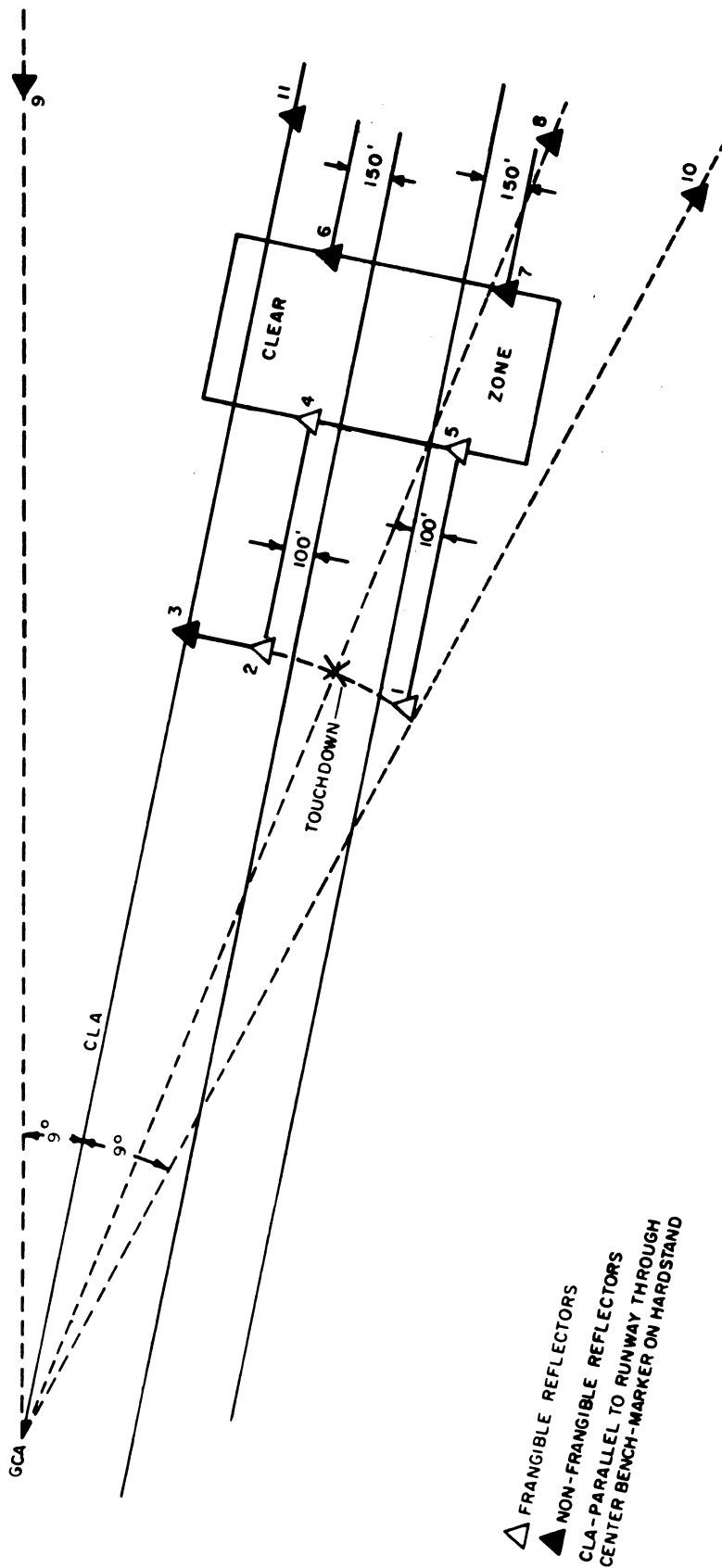
REFLECTOR NO.	DESCRIPTION AND PURPOSE	REMARKS
1, 2	Touchdown and runway bracketing reflectors (aid az cursor alignment)	May be used in place of no. 4, 5, 6, 7 or combination with no. 4, 5, 6, 7. Locate at same range (distance) as touchdown.
3	CLA and touchdown reflector	May be used in place of no. 1, 2. Locate anywhere along CLA (center line of amplification) if another reflector is used for touchdown.
4, 5	Runway bracketing reflectors (aids az cursor alignment)	May be used in place of no. 6, 7 and no. 1, 2 (if another reflector is used for touchdown reflector), or in combination with no. 1, 2, 6, 7.
6, 7	Runway bracketing reflectors	May be used in place of no. 4, 5 and no. 1, 2 (if another reflector is used for a touchdown reflector), or in combination with no. 1, 2, 4, 5.
8	Cursor alignment reflector (aids cursor alignment)	On projected line from GCA through touchdown. Locate at 6080-ft range from radar set.
9, 10	Edge-of-scan reflectors	May be used as range mark reflectors if unable to locate no. 1, 2, 3. Either no. 9 or no. 10 may be used as a touchdown reflector by placing at same range as touchdown.
11	Range mark and CLA reflector	Not required if any above reflectors are located on a range mark.
12	Horizontal reference line reflector (provides ground check for elevation scope alignment)	Position anywhere within the scan area bounded by reflectors no. 9 and 10 and at an elevation equal to the height of the center of the elevation antenna array. Not required if any of the above reflectors are positioned at this elevation: however, reflectors no. 1, 2, 4, 5, 6, and 7 should not be used in this application because of possible airfield clearance violation.



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- △ FRANGIBLE REFLECTORS
- ▲ NON-FRANGIBLE REFLECTORS
- CLA-PARALLEL TO RUNWAY THROUGH CENTER BENCH-MARKER ON HARDSTAND

Figure 10 - 14. Positioning Corner Reflectors (Sheet 1 of 2)



- △ FRANGIBLE REFLECTORS
- ▲ NON-FRANGIBLE REFLECTORS
- CLA - PARALLEL TO RUNWAY THROUGH CENTER BENCH-MARKER ON HARDSTAND

Figure 10 - 14. Positioning Corner Reflectors (Sheet 2 of 2)

o Following the performance of a routine, ensure that all components are restored to original positions with interlocks engaged.

o The preventive maintenance program should be monitored continuously by the maintenance supervisor to ensure that the routines are accurately and conscientiously being performed.

10.3 IFF SYSTEMS

10.3.1 Operational Requirements

To adequately control high-speed aircraft, especially when a large number are airborne in a given area, it is necessary to determine at any given moment the location of each aircraft with respect to all other. The ground controller must be able to distinguish one friendly aircraft from another according to its designation of function. Though the present Mark X SIF/IFF System is used in most military aircraft in conjunction with the surveillance radar, the new AIMS program will update the IFF system for all three military services, and coordinate with the FAA to ensure efficient and safe control of all traffic within the United States.

The Mark X SIF/IFF System, since 1959, has added a coder unit to the airborne transponder of the basic system. This unit permits the generation of many variably-coded replies, and this coding capability is termed the Selective Identification Feature (SIF). This combination of equipment essentially permits discrete replies to be selected by means of dials from among 32 possibilities for mode 1, 64 for mode 3, and 4096 for mode 2. The ability of this system to label the replies of particular aircraft or types of aircraft led to the adoption of this IFF system as an aid to aircraft traffic control by both the civil and DOD agencies. Under civil usage, the system is known as the Air Traffic Control Radar Beacon System (ATCRBS).

The AIMS program will increase the coding capability of mode 3A (to 4096 codes), and implement the automatic altitude reporting, thus, significantly improving the efficient use of airspace by providing timely aircraft flight data and reducing voice communication between controllers and pilots. A sidelobe suppression technique to minimize clutter, erroneous azimuth information on the display unit associated with the interrogating equipment, will also be incorporated. Details on the principles of both systems are presented in chapter 3.

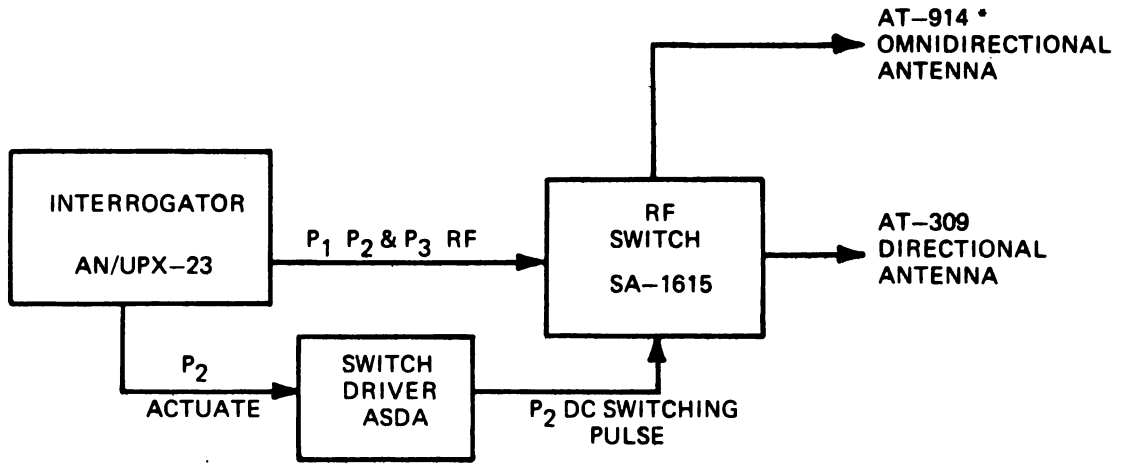
10.3.2 System Configuration

The basic IFF system consists of transponders, interrogators, and associated radar display equipment. The coder unit added to the transponder changes the configuration to a SIF/IFF system. Addition of servoed altimeters, altimeter-encoders, transducers and computers to the transponder equipment with a new coder-decoder, an omnidirectional antenna, and computers to the interrogator installation will update the system to the requirements of the AIMS program.

A block diagram of the basic IFF system was presented in figure 3-15. The AIMS conversion to the interrogator produces an output of three pulses, instead of two, to be radiated by two antennas. A simplified block diagram of AIMS switching system circuitry used in conjunction with the AN/FPN-47 and AN/FPS-37 radar sets is shown in figure 10-15. As shown, the pulse P_2 actuates the switch driver, which pulses the RF switch to allow the omnidirectional antenna to radiate P_2 . The normal position of unpulsed condition of the RF switch allows the pulses (P_1 and P_3) to be radiated by the directional antenna. Then the comparison circuits in the transponder will determine if the interrogating signal requires a reply or silence.

AIMS switching circuits used for other radar systems are presented in figures 10-16, 10-17, and 10-18.

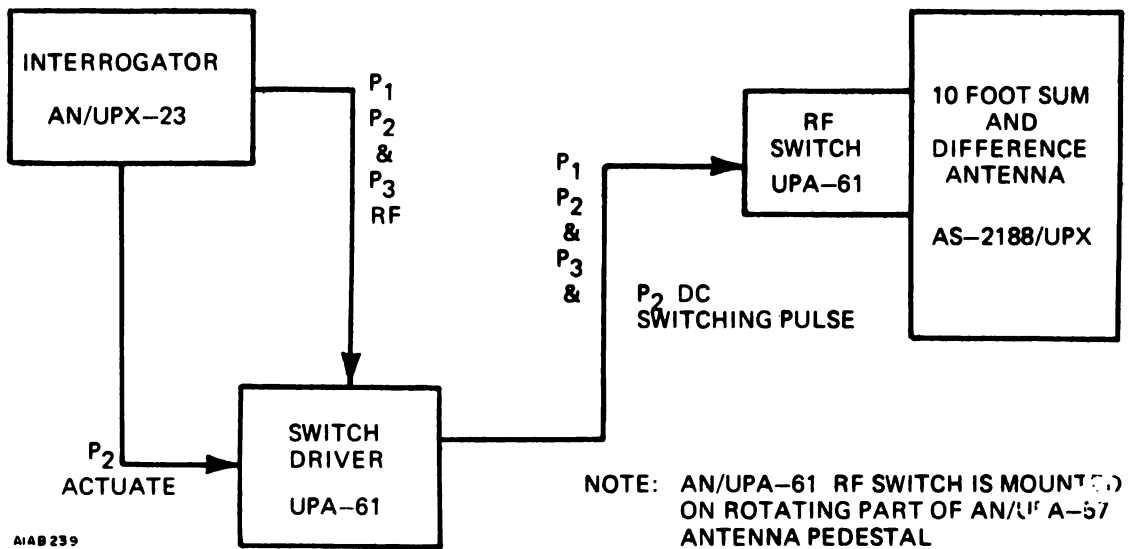
Military-operated ATC radar facilities will require new or modified ATCRBS ground/surface equipment to properly decode the standard AIMS emergency and identification-of-position reply-code configurations. The Navy



A1A0238

* SHIPS TYPE AT-177A CAN BE USED IF AT-914 IS NOT AVAILABLE

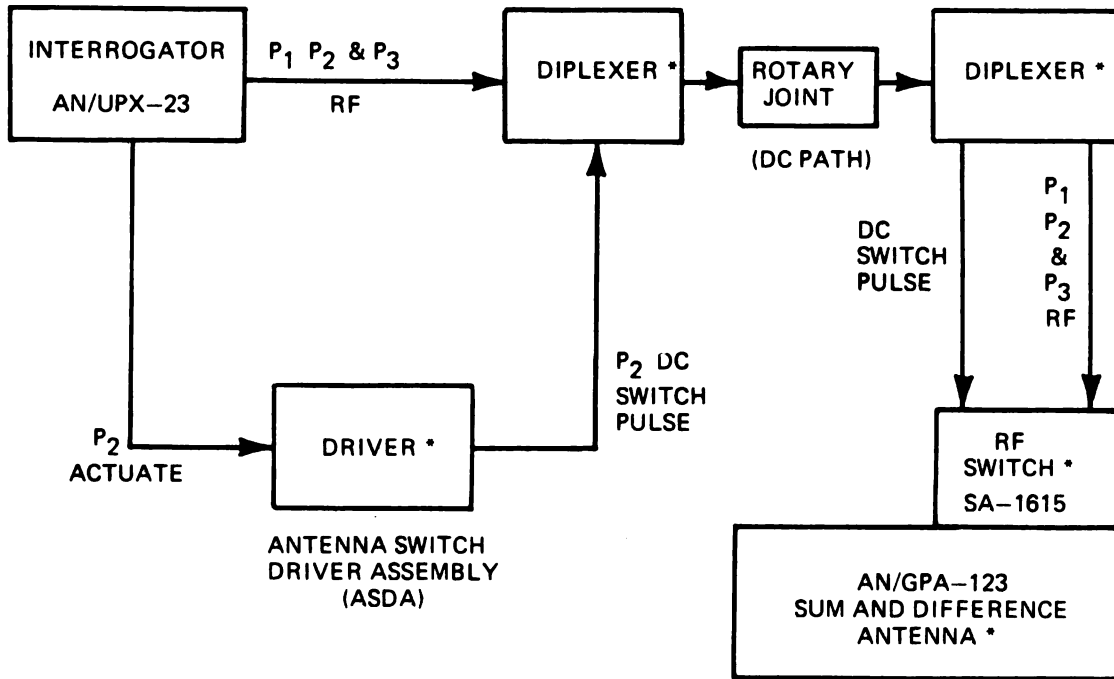
Figure 10 - 15. AIMS Switching Circuit, Block Diagram Used With AN/FPN-47 and AN/FPS-37 Radar



A1A0239

Figure 10 - 16. AIMS Switching Circuit, Block Diagram for AN/FPN-36 Radar

ATCRBS includes mobile and fixed GCA's Radar Air Traffic Control Centers (RATCC), Marine Air Traffic Control Units (MATCU) and mobile Radar Approach Controls (RAPCON), as well as the systems installed aboard ships.



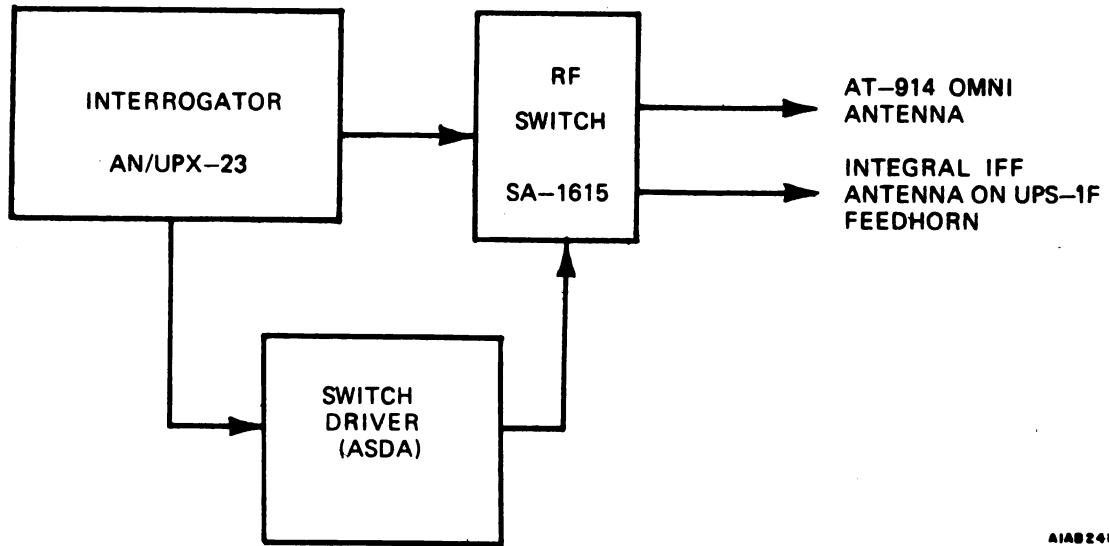
* AN/GPA-123 CONSISTS OF A DRIVER, TWO DIPLEXERS, RF SWITCH, AND SUM AND DIFFERENCE ANTENNA

AIA8240

Figure 10 - 17. AIMS Switching Circuit, Block Diagram for Other GCA Radar

10.3.3 Site and Structural Criteria

Operation of the basic Mark X SIF/IFF System (AN/UPX-1) is related to the operation of a radar set. Positive radar triggers are required by the coder-decoder to provide synchronization in range between the radar and IFF displays. The AN/UPX-1 equipment accepts positive triggers of 0.3 to 25 microseconds duration and 5 to 50 volts peak amplitude across 75 ohms. The operation of the AN/UPX-1 equipment requires the use of a directional antenna either integral with the radar antenna or a separate IFF antenna synchronized in bearing with the radar antenna. To properly display the IFF system responses on the radar PPI indicator, the AN/UPX-1 equipment has a control circuit to adjust the IFF video level to match the radar video signal.



AIAB241

Figure 10 - 18. AIMS Switching Circuit, Block Diagram for AN/TSQ-18A (MATCU) Radar

The IFF antenna is usually mounted above and aligned to within 0.5 degrees of the radar antenna. A major portion of the IFF electronics is located in the radar transmitter building across the aisle from the radar equipment. Radar set control units are usually incorporated in the surveillance radar controller's console. If the IFF antenna is mounted on a separate pedestal from the radar antenna, separation should be kept to a minimum with screening criteria taking priority.

For conversion to AIMS, additional criteria is important. Cable lengths between the RF switch and the omnidirectional antenna should be as near equal as the cable between the RF switch and the directional antenna.

Also the two antennas should be sited as close together as possible and as close to the same elevation as possible. (See figure 10-19.)

10.3.4 Installation Criteria

For convenience of maintenance and operation, the receiver-transmitter and coder-decoder of the basic IFF system should be installed adjacent to each other and in the same room as the radar transmitter-receiver consoles. Each radar set control unit must be installed in or adjacent to the controller's console, so that the controller can see and operate the controls without diverting his attention from the related display. The master control box is located at the radar master display. Video distributors and video amplifiers may be located with convenience of cabling in mind, unless special considerations arise in connection with length of coaxial leads and terminations. In order to prevent reflections, which may cause undesirable loss of power and distortion of waveforms, video cables must be terminated properly. Throughout the AN/UPX-1 system, correct termination consists of a 75-ohm resistor connected at the physical end of each video line and connections at intermediate points should be made by a high impedance (5000 ohms or more) circuit.

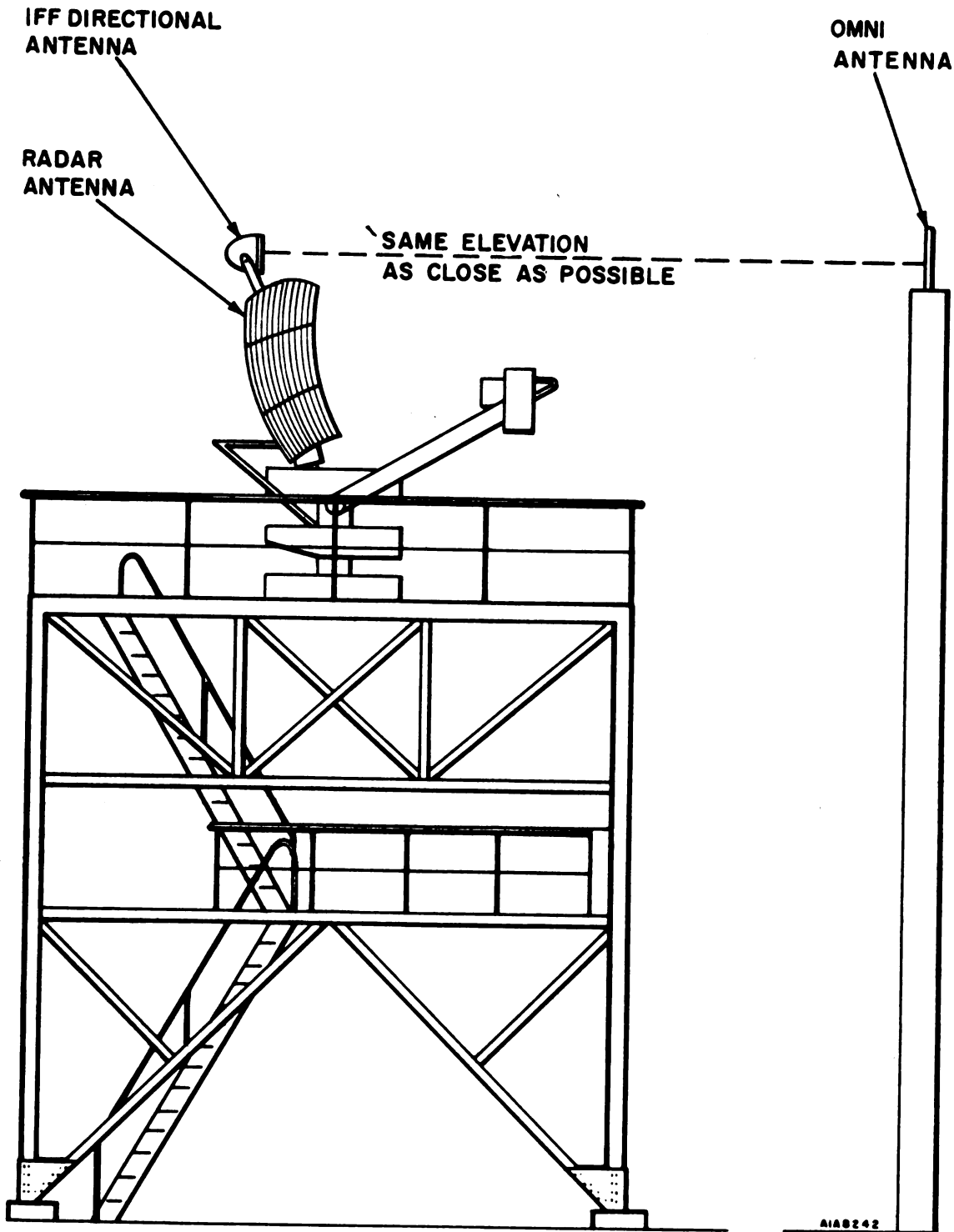


Figure 10 - 19. AIMS Antenna Configuration

Regardless of location, each unit must be installed with the following consideration:

- o Adequate ventilation
- o Sufficient room for servicing or removal of units from their cabinets
- o Access to air inlets for cooling
- o Cable runs must enter the cases without excessively sharp bends
- o Cable lengths should be kept to a minimum and in no case should any AN/UPX-1 equipment interconnections exceed 300 feet in length.

Further details on the installation of IFF equipment is presented in section 3 of NAVSHIPS 91343, Instruction Book for Radar Recognition Set AN/UPX-1.

The interrogator, AN/UPX-23, used for the AIMS program requires the video output be limited in travel to 200 feet, using RG-11/U type cable. The AN/TPX-42 Direct Altitude Processor also has limitations on its cable length. From the processor to the first indicator. There should be no more than 300 feet of cable from the processor to the first indicator and no more than 600 feet of cable to the last indicator of which there may be 12 indicators.

The RF Switch and Driver, AN/UPA-61, is normally installed in the transmitter building adjacent to the interrogator equipment. However, when used on the AN/FPN-36 Quad Radar Set, AN/FPN-36, the switch is mounted on the rotating part of the antenna pedestal as noted in figure 10-16.

Further details on the installation of the AIMS interrogator-evaluation equipment will be found in the applicable technical manuals.

10.3.5 Operation and Maintenance Procedures

For special purposes, Radar Recognition Set, AN/UPX-1, may be operated locally (partly from the receiver-transmitter and partly from the coder-decoder). However, it is normally intended that the set be operated from stations located at some distance from the set itself. When the LOCAL-REMOTE switch on the receiver-transmitter is in the LOCAL position, mode selection and challenging may be made either at the coder-decoder or remotely. However, GATE-GTC and IFF GAIN are controlled on the receiver-transmitter only. When the LOCAL-REMOTE switch is in the REMOTE position GATE-GTC and IFF GAIN are controlled at the master control box only. Also, mode selection and challenging can only be controlled remotely.

Further details on the operational procedures for the IFF system are included in the technical manual. Included in the manual are suggested preventive maintenance routines for daily, weekly, monthly, quarterly, and semi-annual checks of the system and its components. As IFF systems are improving in identification capability, it is imperative that an effective preventive maintenance program be instituted and maintained to ensure efficient and reliable performance of ATC systems.

CHAPTER 11

COMMUNICATION SYSTEMS

Communication systems at a Naval Air Station may include arrangements for ground-to-air communications with tactical and transient aircraft, for control of aircraft departures and landings, for communication with other air stations, for ship-to-shore, and for connection to the Naval Communication System. Systems engineering is concerned in the development of such facilities by prescribing the equipment, and establishing communication systems which will most effectively meet the operational requirements established by the Chief of Naval Operations for the Naval Air Station. In this chapter communication facilities and equipment will be discussed.

11.1 COMMUNICATION FACILITIES

The communication facilities of a NAS are categorized into administrative, visual control tower, IFR room, and radio/fleet-airways operations. A typical communication facilities layout with minimum separation distances is shown in figure 11-1. A typical block diagram of a NAS equipped with visual and radar control facilities is shown in figure 11-2.

11.1.1 Administrative Communications

a. Operational Requirements. This facility is set up for communication within the Naval Communication System, with various Navy establishments including other Naval Air Stations. Requirements for administrative communications are met by a communication center whose design may vary widely according to size, location with respect to other communication facilities, and the mission of the particular Naval Air Station.

b. System Configuration. The functional division of a Communication Center is shown in figure 11-3. There may be three main divisions: Message Center, Fleet Center, and Technical Control which performs the following functions:

(1) Message Center accepts messages via messenger mail, pneumatic tube, etc., for rapid transmission, prepares messages for transmission, receives messages via electrical means for local delivery or further relay, and operates room or tributary circuits to and from the relay station.

(2) Fleet Center terminates ship/shore record communications systems, processes and distributes record communications traffic, and provides ship/shore/ship traffic interface.

(3) Technical Control of the quality of all circuits is exercised in the technical control facility (TCF). However technical control functions are performed in three distinct areas:

technical control facility (supervisory area),

communications security equipment (CSE) area (patch and test, crypto), and

terminal equipment area (patch and test, terminals).

Technical Control actions are performed by using patch and test facilities that allow technical control personnel to monitor and substitute equipment. Although patch and test facilities are included in all three areas, the overall technical control function is managed from the TCF where all operational circuit patching is done.

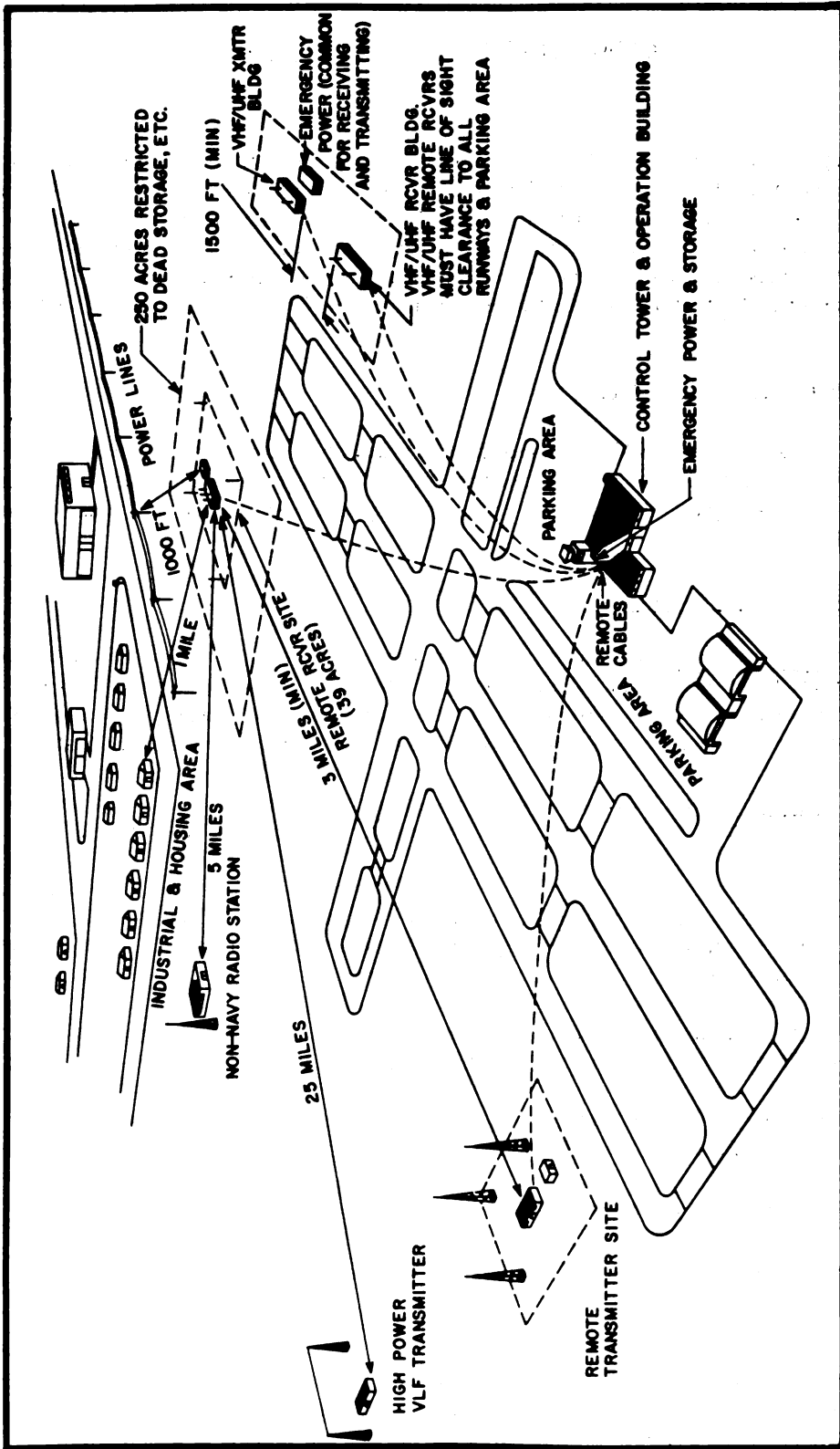


Figure 11 - 1. Typical Communications Facilities

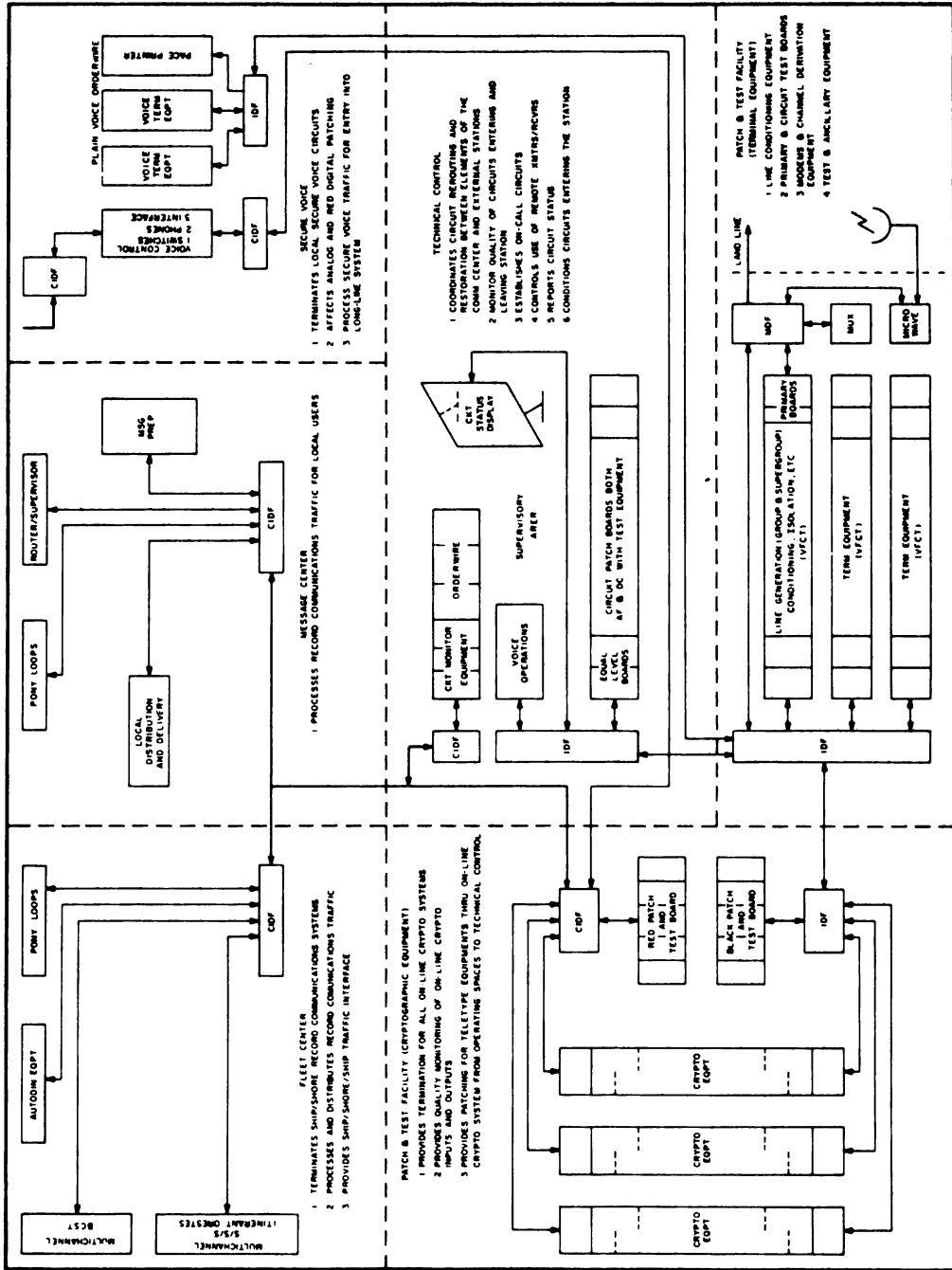


Figure 11 - 3. Communication Center Functional Division Concept

Definitions applicable to these functional areas are given in the following paragraphs.

(a) Technical Control Facility (TCF) or supervisory area contains the circuit and channel patchboards, test equipment, and monitoring facilities sufficient to permit a technical controller to:

- o Exercise technical coordination between the connecting external technical control the maintenance element, and the users
- o Exercise technical direction, coordination and supervision over, (1) transmission media at the supergroup, group, and channel level, (2) interface equipment appearing in the patch and test facilities, (3) remote transmitter and receiver sites, (4) relay sites and (5) those communications facilities at all directly connected user installations
- o Reroute and restore disrupted communications circuits at all levels of circuit capability in accordance with a pre-determined priority
- o Establish on-call circuits
- o Perform quality control tests on all circuits passing through the TCF.
- o Establish, activate or de-activate, re-arrange, and discontinue circuits that enter and leave the station
- o Report circuit status to proper management for record purposes
- o Operate the area as a limited-access area with the capability of being temporarily unclassified with a minimum effort in the event that personnel with a lesser clearance require access for maintenance or installation.

Facilities included are: covered orderwires; limited classified circuit monitoring and testing can be provided on a patch basis by the patch and test facility (Communications Security Equipment); circuit status display; unclassified voice control; transmitter and receiver control; equal level boards (DCA requirement); digital and analog testing facilities; supervisory alarm control display center; and supervisory control equipment for control of patch and test facilities DCS reporting capability.

(b) Communications Security Equipment (CSE) area contains on-line cryptographic equipment with sufficient patchboard, test, and monitoring equipment to permit personnel under the direction of the technical control supervisor to:

- o Isolate equipment troubles occurring in the CSE area
- o Substitute equipments, channels, and circuits within the CSE area
- o Perform back-to-back and loop-patching of cryptographic equipments, channels, and circuits for maintenance testing
- o Perform monitoring and testing
- o Perform crypto start and restart.

The CSE is an exclusion area. Facilities included are: black patchboards and test facilities to enable the back-to-back patching of crypto security equipment for maintenance; on-line crypto security equipment with associated ancillary units less remote control units normally associated with an operating position; red patchboards separated from the black boards physically and electrically to prevent interconnection by patching,

electrical induction, or accidental interconnections; test equipment for maintenance and repair of low-level devices, cryptographic equipment, and the lines to the red processing equipment; classified and unclassified digital test equipment; and narrative TTY monitors.

(c) Terminal Equipment Area contains line conditioning equipment, modems and channel derivation equipment, primary test boards, and circuit test boards to permit operating personnel under the direction of the technical control supervisor to:

- o Condition all lines to meet transmission criteria
- o Restore (repair) disrupted communications links
- o Replace and/or by-pass faulty terminal equipment.

This area is usually an unclassified space wherein the connecting landlines or microwave links are terminated. Facilities included are: all line conditioning equipment; all terminal equipment and channel derivation equipment; primary test boards; and circuit test boards.

(d) Patch and Test Facilities are located in each of the technical control areas to provide operational flexibility in the use of equipment and circuits. In general, these patch and test facilities allow equipment and circuit changes under the direction of the technical control supervisor as follows:

- o Patching of any circuit to any other compatible circuit
- o Patching of equipment to replace faulty equipment
- o Patching of test equipment to determine signal quality or circuit degradation.

A typical signal flow routed through the patch and test facilities of the three technical control areas is shown in figure 11-4. Standard plans provide the specific routing criteria for each type of circuit as it is distributed through the communications center (see NAVELEX 0101,102, chapter 2).

(e) Patchboard Equipment gives technical control personnel the flexibility to substitute and reconfigure the communications resources and they afford access for monitoring circuit quality. Patchboards are wired to attain the circuit flow prescribed by the NAVELEX standard plan for the system being implemented. In a patchboard, each circuit appears at a jack which permits rerouting of the circuit through the use of patch cords. However, design of the circuit requires that all jacks be the "normal through" type, so that patch cords are not required when the circuit is operating normally and without monitoring by general purpose test equipment.

Assignment of circuits and equipments to specific jacks in a patchboard is accomplished by cross connections at the distribution frame. All circuits that are accommodated by a particular patchboard are arranged in an order that closely fits the function for which the board is used. This arrangement permits quick location of a specific circuit or item of equipment for monitoring or troubleshooting.

Separate patchboards are provided for red and black information and are separated by a minimum of 3 feet. The purpose of this separation is to prevent an operator from inadvertently patching a red circuit to a black circuit.

There are three general types of patchboards with the following functional capabilities:

- o VFCT Patchboards. Voice-frequency carrier telegraph (VFCT) DC circuits are assigned to patchboards with a 104-circuit capability for a single equipment cabinet. When additional circuits are required, other equipment cabinets with patchboards are placed to the right and the system grouping is continued. VFCT DC patchboards are made up of the standard DC circuit patch modules which are provided only as needed to satisfy the circuit requirement.

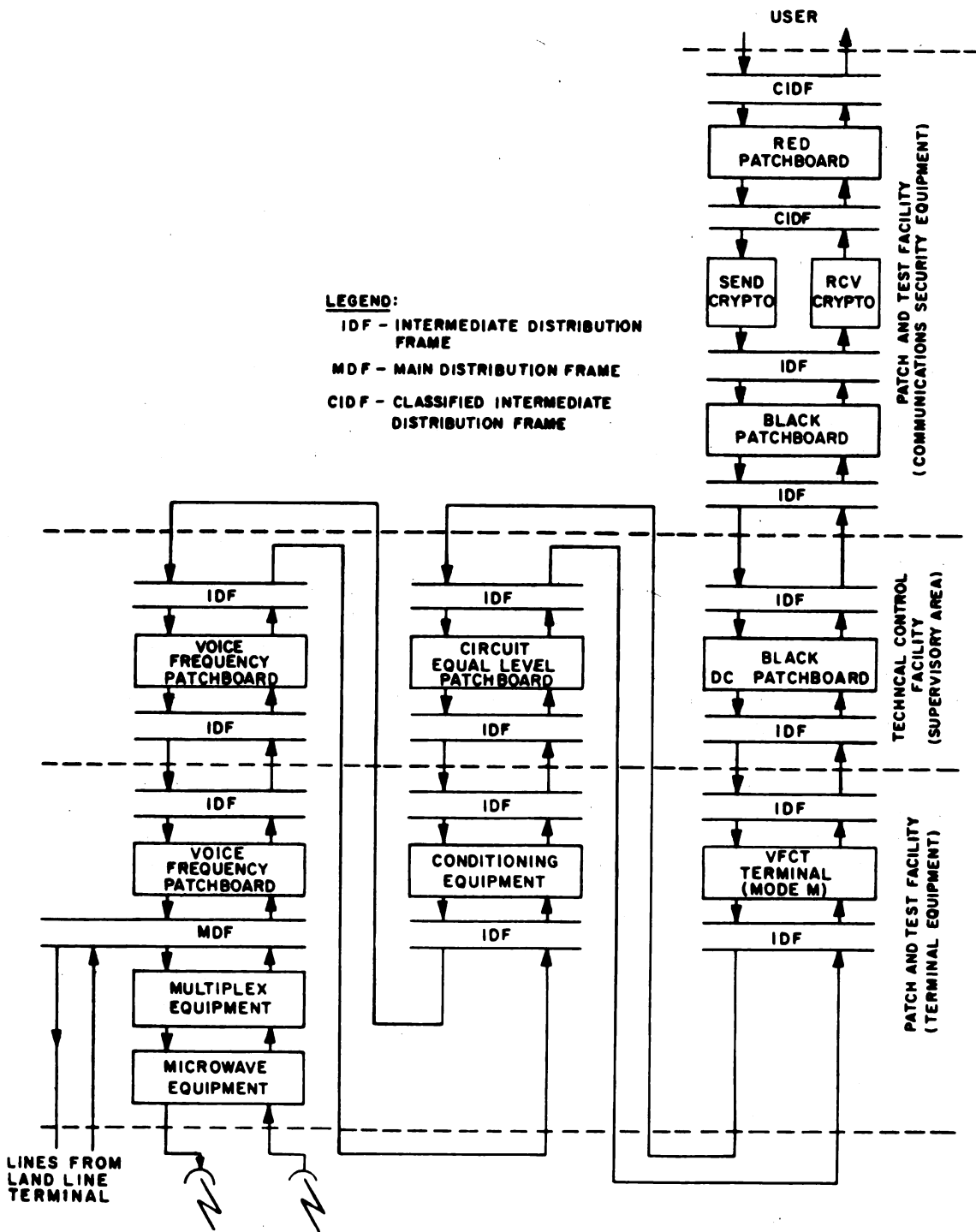


Figure 11 - 4. Typical Circuit Flow Through Communications Center Patching Facilities

o Hubber Unit Patchboards. The numerous inputs and its broad range of capabilities dictate a configuration in which each module of the hubber unit requires four sets of jacks and these sets appear on the patchboard consecutively from left to right.

o Audio Patchboards. The circuit layout of the audio-frequency patchboards is determined by their use. Where the patchboards are used to support intersite channels, the channels are grouped according to their receive or transmit function. Within a group the channels will appear in consecutive order from left-to-right and top-to-bottom.

(f) Orderwire equipment circuits are used for coordination of the communications resources of the Naval Air Station and for coordination of the communication circuits between stations. The terminal location for orderwire circuits is the technical control facility (supervisory area). The terminal device, telephone or teletypewriter, may be shared among several orderwire circuits provided that each circuit includes an alarm to indicate an incoming call.

(g) Communications Security (COMSEC) Equipment performs cryptographic functions to convert between red and black data. COMSEC equipment is installed in the communications security equipment area of the communications center and is arranged in racks by types. Operator access is a major consideration in placing the equipment. Since the COMSEC devices alert operators to alarm conditions by visual and audible means, the equipments should be visible from the red and black patchboards that are located with the COMSEC equipment. Teletypewriter equipment must be collated with the cryptographic devices to aid in restarting. One restart teletypewriter is usually provided for each group of 5 cryptographic equipments.

(h) Time and Frequency Standard. A central time and frequency standard for the various equipments used throughout the communications center is being planned. Some existing systems generate 10-MHz, 1-MHz, and 100 kHz frequencies which are distributed to the equipments to control timing and to stabilize the frequency of modulation and demodulation equipment. However, the requirements for redundancy in the event of failure and for isolation of red and black data have not yet been fully defined for the time and frequency standard. When approved, the time and frequency standard will be installed and operated as part of the technical control equipment. The output of the central time and frequency standard will be distributed through coaxial cables routed in the same trays with the signal cabling.

(i) Audio Frequency Interface Equipment. Most information sent from or received at the communication center is in the form of analog signals carried in a 300- to 3400-Hz band. The audio-frequency equipment provides interface between the communications center and all landline, line-of-sight, cable, or other transmission means. Such equipment provides equalization, attenuation, amplification, or other signal conditioning needed for interface between the transmission means and the equipments of the communication center. These equipments are contained within the patch and test (terminal equipment) area.

(j) Voice Frequency Carrier Telegraph (VFCT) Equipment combines up to 16 separate teletype and digital DC signals into complex tones for radio transmission using a 3-kHz bandwidth. The terminal also separates a received 3-kHz complex tone signal into its individual DC signals. VFCT is the primary means of transmission for large-volume, long-haul traffic in the Navy. The communications center may use VFCT equipment to interface with systems other than Navy tactical systems. In this case, VFCT channelization and frequency assignment would be determined on a special case basis.

The capability of monitoring the quality of the composite and individual signals may be incorporated within the equipment. In any case the monitoring equipment used operates in parallel with the functioning circuit, measures distortion content, and must be capable of operating at the 37.4 to 150 baud rate. When automated monitoring equipment is employed, the circuit status display is located within the TCF supervisory area.

(k) Digital-Data End-Instrument Equipment terminals consist of input and output equipments, modulation and demodulation devices, and manual or automatic supervisory controls. The digital signals are received from and sent to the equipment by one or more of the methods listed in table 11-1. A terminal may also perform temporary storage, code format, and band conversion functions. Conversion of data between serial and parallel form is also a function of the data terminal.

Table 11-1. Digital Data Input and Output Methods

INPUT	OUTPUT
Keyboard Punched paper tape Magnetic tape Direct computer input Punched card	Page printer Punched paper tape Magnetic tape Direct computer output Punched card

The ability of the transmission means to pass the required data at the required rate is important factor in planning the use of digital data equipment. Voice channels with a nominal 4-kHz bandwidth are used to interconnect data equipment. These voice channels are combined as required to provide a path of sufficient capacity to support the equipment data rate. Low speed, up to 150 bauds, requires only narrow-band channels. From 12 to 24 such narrow-band channels may be multiplexed over one voice channel. Medium speed, up to 2400 bauds, presently requires one voice channel. High speed, up to 5000 kilobits per second, requires a large number of voice channels. Voice channels are usually arranged in groups (12 voice channels) and supergroups (5 groups) for multiplexing over broadband transmission links within the telephone network. One group will accommodate 40.8 kilobits per second.

The modulation rate of about 2400 bauds is near the theoretical limit for sending binary (two signal-state) signals over a 4-kHz spaced channel such as those derived by telephone-type multiplex equipment. However, development continues at a rapid rate in this field. Sophisticated modems, using multiphase or multilevel, or vestigial sideband techniques, plus automatic equalizers, are giving up to 9600 bits per second over some telephone-type circuits. These equipments are expensive and their economic justification must be carefully studied versus the use of more of the 2400 baud modems of a type already in use.

Distribution of digital data throughout the communications center is accomplished via DC circuits using a low-level polar signal loop voltage. The nominal low-level voltage and current for a "mark" is +6 1.0 volt, 0.001 ampere (max), and for a "space" is -6 1.0 volt, 0.001 ampere (max). Low-level keying is specified for use within the communications center for both red and black circuitry. Red circuits carry classified plain-text traffic. Black circuits carry traffic protected by COMSEC equipment or unclassified, plain-text traffic. Black DC circuits are currently distributed using high level neutral or polar current loops. However, communications centers using high-level loops are to be converted to low level. In a neutral circuit the marking condition occurs when the signal loop is closed. The polar circuit reverses the current of the signal loop to differentiate between the marks and spaces. Positive voltage represents a mark and negative voltage a space. The current and voltage parameters for high level loops are listed in table 11-2. High level DC loops, usually neutral, may find continuing use at transmitting stations and for communications over small tributaries on a special case basis. Therefore, the advent of low level black systems may not entirely eliminate high level lines that must interface with other Navy or public carrier lines. Western Union may use 130-volt 20-milliampere polar keying, while phone lines frequently use both a positive and a negative 130-volt battery for the two sides of the line giving an effective voltage of 260 volts.

Table 11-2. High-Level Signal Loop Parameters

	POLAR*	NEUTRAL*
Loop current	20 mA +10%	60 mA or 20mA +3%
Loop voltage	+60 V +2%, -60 V +2%	130 V +2%
Termination impedance	150 ohms	150 ohms
*Peak voltage is limited to 150 volts		

(1) Automatic Digital Network (AUTODIN) digital subscriber terminal is installed within the communications center. In figure 11-3 it appears in the Fleet Center, but the physical location of this equipment will depend on local conditions.

The family of systems being supplied and their major components and capabilities is shown in figure 11-5. Standard plans are issued to insure standardization of installation and arrangement. These plans show the permissible equipment arrangements from which the best one for the location is selected. Plan RW 10 F 2262 is the standard plan for the AN/FYA-71 (V)2 system.

(m) Teletypewriter Equipment uses a five-unit code composed of marks and spaces. Different groupings of the units represent a specific printed character.

The Navy normally uses a 7.42 unit code with a signal length of 13.47 milliseconds for a 100 word-per-minute teletypewriter circuit. Slower speed circuits are also in existence for special purpose use.

(n) Automatic Secure Voice Communications (AUTOSEVOCOM) System is a worldwide voice network that provides 4-wire secure and non-secure voice quality communications between designated military commands (subscribers). AUTOSEVOCOM interconnects locations with either narrow-band or wide-band communications channels. A narrow-band channel will support communications at a rate of 2400 bits per second and can be transmitted over a 3-kHz HF radio circuit. The wide-band circuit supports communications at 50 kilobits per second and is transmitted by wire line or microwave means.

The Navy Communications Center supports the system by operating subscriber terminals that interface between the worldwide system and the local subscriber or HF radio circuit (Steam Valve) which in turn connects with the subscriber. The subscriber is homed to the worldwide system either on a secure voice switch or directly on an Automatic Voice Network (AUTOVON) switch or to a Joint Overseas Switchboard (JOSS). The AUTOSEVOCOM equipment provides for wide-band secure voice communications between local subscribers and enables local subscribers to establish long distance voice calls with other military commands. The AUTOVON switch provides narrow-band, long haul communications for subscribers that cannot be economically served by wide-band equipment. The majority of long-distance calls are routed via the AUTOVON system. Narrow-band and wide-band circuit parameters for AUTOSEVOCOM are prescribed by the latest issue of DCAC 130-130-1, "Processing of Telecommunications Service Requests."

SET NOMENCLATURE	CAPABILITY						INPUT/OUTPUT DEVICES SUPPLIED								
	ORIGINAL CONFIGURATION CODE	150 BAUD PAPER TAPE	1200 BAUD PAPER TAPE	300 BAUD PUNCHED CARD	1200 BAUD PUNCHED CARD	COMMON CONTROL UNIT C-8120(P)/G	READER, PUNCHED CARD C-7185/G	READER, PUNCHED TAPE RP-152/G	PAGE PRINTER RP-157/G	CARD PUNCH, LOW SPEED RO-313/G (ON LINE)	CARD PUNCH, LOW SPEED RO-313/G (OFF LINE)	CARD PUNCH, HIGH SPEED RO-312/G	PAPER TAPE PUNCH, LOW SPEED RO-315/G (ON LINE)	PAPER TAPE PUNCH, LOW SPEED RO-315/G (OFF LINE)	PAPER TAPE PUNCH, HIGH SPEED RO-314/G
AN/FYA-71(V)1	AA	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
AN/FYA-71(V)2	AB	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
AN/FYA-71(V)3	AE		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					<input type="checkbox"/>		<input type="checkbox"/>	
AN/FYA-71(V)4	BB				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>								<input type="checkbox"/>
AN/FYA-71(V)5	BC				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>							<input type="checkbox"/>
AN/FYA-71(V)6	BE				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>								<input type="checkbox"/>

Figure 11 - 5. DSTE Set Capabilities and Concepts

Simplified typical single-line circuit flow diagrams for the AUTOSEVOCOM system within the communications center are shown in figures 11-6 and 11-7. AUTOSEVOCOM minor relay interface (figure 11-6) is the system used when narrow-band capabilities will satisfy the operational requirement. When a major relay with both narrow-band and wideband capabilities is required, a system shown in figure 11-7 is used. Typical floor plans for AUTOSEVOCOM systems are contained in the latest issues of DCAC 300-S175-3 through 6. Controlling criteria for the overall system are contained in the latest issues of the following publications:

- o DCAC 300-S-175-3 through 7
- o DCAC 310-S70-12
- o DCAC 310-130-1
- o DCAC 370-S185-9
- o DCAC 370-S185-10

(o) Microwave Radio Relay Links terminal equipment area (figure 11-3) indicates that microwave equipment may be used. Depending upon the distances to the remote HF transmitter site and the HF receiver site, and upon the Communication Center, microwave links may be used for that purpose. Additional information is provided in another paragraph of this chapter.

c. Site and Structural Criteria. Permanent communications center buildings are constructed of masonry and concrete and may consist of more than one floor. The primary consideration in building construction is maximum operational efficiency. The general building requirements for communications stations are discussed in NAVELEX 0101,102. Specific communication center building criteria and considerations are identified in the following material.

(1) Building Features.

- o Spaces containing computers will normally have raised flooring and shall not contain provisions for cable trays.
- o Cable vaults are not normally included in communications center buildings.
- o A separate room is required for microwave system battery power supplies.
- o A shielded maintenance room is not normally required and is provided only on a special case basis.
- o Physical security requirements applicable to building construction are stated in the latest NAVELEX Instruction 011120.1.

(2) Grounding. The communications center building does not require special grounding or bonding for its structural members. One grounding system is required for personnel and equipment protection and a second grounding system is required to ground the signal circuits.

The personnel and equipment protective ground system is the AC protective ground distribution, described in chapter 12, NAVELEX 0101,102. The earth ground connection point for the AC ground connection point for the AC ground distribution system must comply with the provisions of article 250-84 of the National Electrical Code and therefore, must not present more than 25 ohms to ground.

The governing criteria for the grounding system to be used as the signal ground are contained in NAVELEX Instruction 011120.1. The following general requirements must be met when engineering a signal ground system.

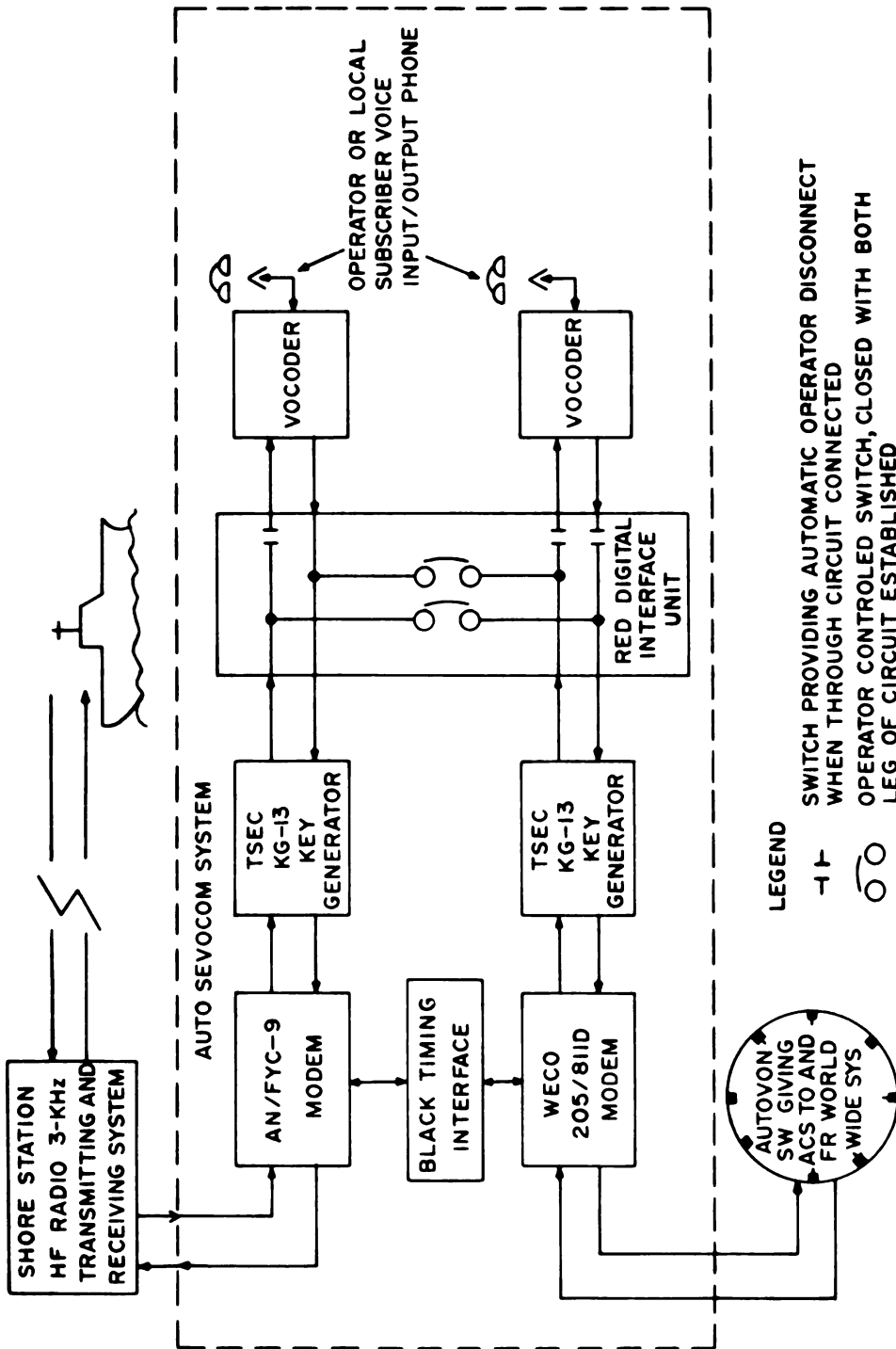


Figure 11 - 6. AUTOSEVOCOM Minor Relay Narrow-Band Interface

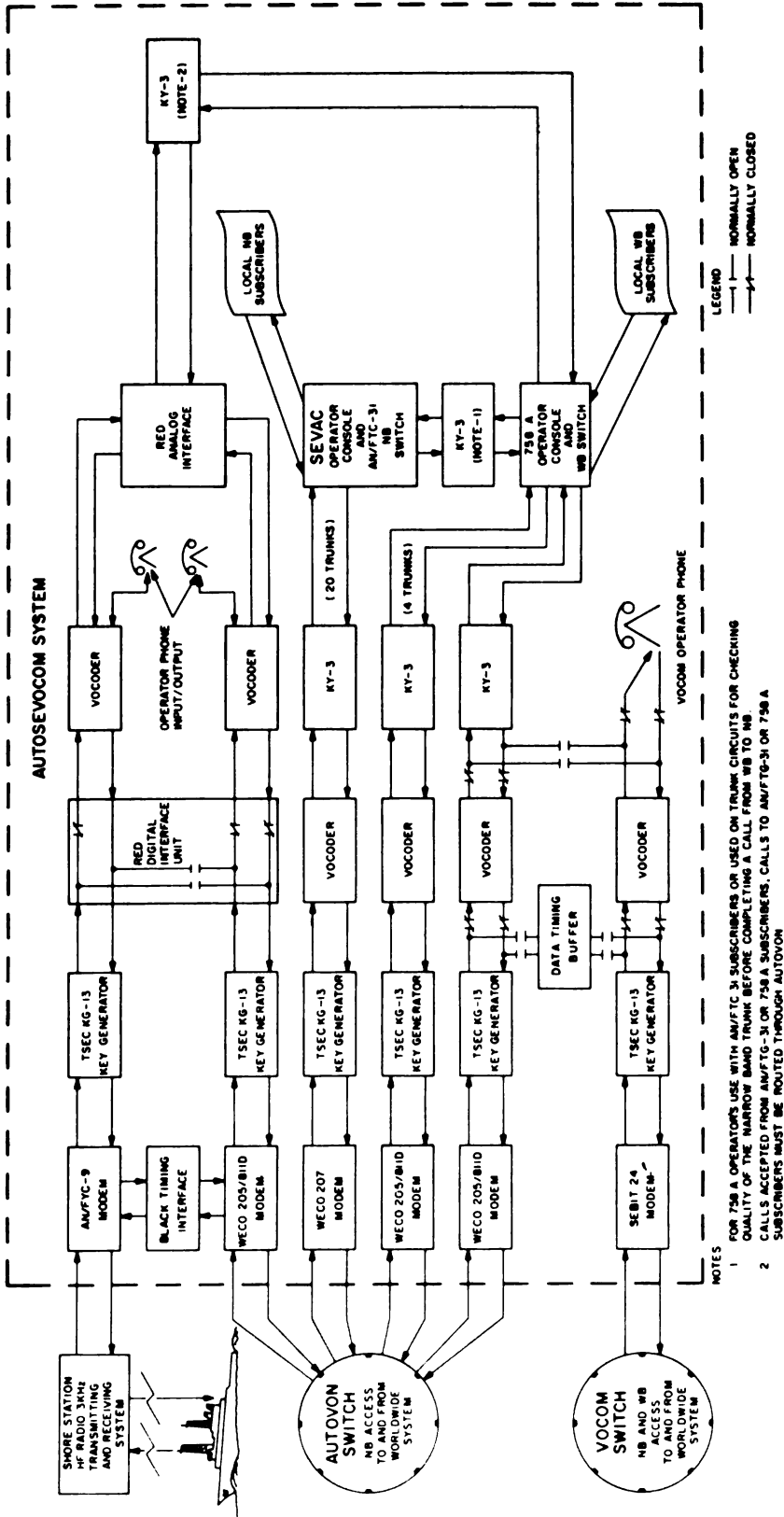


Figure 11 - 7. AUTOSEVOCOM Major Relay Interface

o The signal ground system may have its own ground connection point. NAVELEX Instruction 011120.1 specifies the type of ground connection to be used for both large and small systems.

o Separate ground distribution systems are required for red and black signal grounds. NAVELEX Instruction 011120.1 specifies when and where these two systems are to be interconnected.

(3) Building Electrical Power. The primary power for the communications center is usually supplied by a commercial power company. An emergency power source may be provided to satisfy operational reliability requirements. Electrical power requirement for additional capabilities or for a new facility is stated in the BESEP for the use of the Naval Facilities Engineering Command (NAVFAC) Engineering Field Division (EFD). The following factors are applicable to the communications center power system:

o No-break power (Class D) is provided for designated equipments. These equipments usually include the synchronous communications security equipments.

o All communications equipment not connected to no-break power will be fed from the technical load bus.

o The technical load bus may be subdivided into a critical technical load and a non-critical technical load. This will permit orderly restoration of power in the event of failure and will make load shedding possible in the event of power shortages. Separate circuit breakers are required at the power distribution panel for each equipment rack or cabinet.

(4) Equipment Arrangement. Efficiency is the primary consideration for locating equipment in the operations area. The general rule is that equipments used to perform the same or similar function are grouped together.

(5) Siting. The communications center building is physically separated from other station buildings such as power generating plants and living quarters. Also, to reduce to a minimum the possibility of mutual interference, the communications center is separated from other portions of the communications station as shown in table 11-3.

d. Installation Criteria. The controlling criterion for the planning and installation of cabling and distribution frames in the communications center is the separation of circuits carrying red information from those carrying black information. Refer to the latest issue of NAVELEX Instruction 011120.1, "Shore Electronics Engineering Installation Guidance for Equipments and Systems Processing Classified Information."

(1) Distribution Frames. Distribution frames are used to terminate cabling from equipments, patchboards, and battery sources. A distribution frame is also used to serve as a central point for the exit and entrance of all communications circuits concerned with the mission of the communications center. The general types of frames and their wiring criteria are discussed in chapter 9 of NAVELEX 0101,102. As a general rule distribution frames are located near the patchboards they terminate to minimize the length of cable runs.

(2) Cabling. Cabling within the communications center is to be routed between equipments in a manner that presents a neat appearance and is compatible with the operational use of the system. Conduit and duct systems have been used in the past; however, such systems are not specifically required. Systems supported for the overhead are preferred. Systems within raised flooring are authorized on a special case basis only.

Table 11-3. Communications Center Siting Separations

FACILITY	SOURCE OF INTERFERENCE	MINIMUM DISTANCE
<p>Communications Center</p>	<p>VLF transmitters</p>	<p>25 miles</p>
	<p>LF, HF transmitters</p>	<p>15 miles</p>
	<p>Transmitters not under Navy control</p>	<p>5 miles*</p>
	<p>Main highways</p>	<p>1000 feet</p>
	<p>Areas capable of industrialization</p>	<p>1 mile</p>
	<p>Radar installation</p>	<p>1500 feet</p>
	<p>Primary HF receiver building and antenna field</p>	<p>2 miles from nearest antenna</p>
	<p>Primary power plant</p>	<p>1500 feet</p>
<p>*Signal from non-Navy station may not exceed 10 millivolts per meter (field intensity) at the location of the building.</p>		

The following general criteria apply to the cabling within the communication center:

- o One overall non-ferrous shield protected by an insulating sheath is the minimum shielding requirement for cables carrying red information.

- o Individual non-ferrous shielded pairs of wire within a cable which is protected by an overall non-ferrous shield is required only on a special case basis as determined by the system engineering design requirements.

- o Non-ferrous shields on cables should be broken by termination at a distribution frame before the cable leaves a red information area.
- o Low-level signal and control cables need not be encapsulated within a ferrous duct or distribution system.
- o High-level signal and control cables carrying red information should be encapsulated within a ferrous duct or distribution system.
- o Spare conductors within a cable are to be grounded at the appropriate distribution frame serving the particular cable.

11.1.2 Visual Control Tower Communications

a. Operational Requirements. The control tower cab is used for visual control of aircraft landings and departures. This involves visibility to all landing strips, taxi-ways, and parking aprons.

b. System Configuration. Equipment is provided for at least three operating positions, for a local controller, a ground controller, and a data man. These are all provided with consoles giving control of VHF/UHF radio channels and selection of landline and interphone connections. Common to the controllers is a set of overhead speakers for monitoring radio channels. The operating positions have a panel of "hi-lo" switches to control the level of the overhead speakers. Equipment controlled by the console equipment is mounted within the control tower, in equipment or terminal rooms. The tower equipment controls VHF/UHF radio equipment which is located two separate buildings, the remote VHF/UHF transmitter building, and the remote VHF/UHF receiver building. The capabilities of equipment located in these two buildings were described in chapter 3 and criteria for them are discussed in these paragraphs. Typical equipment for the systems mentioned above is discussed in the following paragraphs.

(1) Console Group, Communication Control AN/FSA-52(V). Figure 11-8 shows the relationship of the units comprising this equipment. The four equipment cabinets are located in the terminal room. The VFR operating positions are each provided with the smaller communication control consoles and associated loudspeaker, jack box, foot switch, and headset-microphone. The large console is provided only to the supervisor in the IFR room. A test area is provided for use by the maintenance personnel. This equipment is covered in detail in the Technical Manual for Control Group, Communication Control AN/FSA-52(V), NAVSHIPS 94975.

(2) Transfer Control Group, AN/FSA-47(V). The Transfer Control Group is used to give controllers the ability to switch from a radio set that has failed to a standby set by merely depressing a button. The relationship between units comprising this equipment is shown in figure 11-9. Each module will control 5 channels, and 5 modules may be stacked for a total control of 25 channels. When used with the AN/FSA-52(V) equipment, the AN/FSA-47(V) is commonly used to give access to 15 standby radio sets. The Transfer Control Group equipment may be located at a controller's console, but is usually installed in the communication room. Complete information on this equipment is given in Technical Manual for Transfer Control Group, AN/FSA-47(V), NAVSHIPS 95725.

(3) Amplifier Group, A-4391&FSA-17. The Amplifier Group consists of a power supply and one to five amplifier modules, designed for modular 19" rack assembly. The amplifier modules contain 20 plug-in amplifiers, thus a system with 5 modules is capable of 100 channel operation. Figure 11-10 shows the relationship of the systems units. These amplifiers are used on the incoming receiver lines to bring them individually up to the desired power level at the control consoles. For further details, see the Technical Manual for OA-4391/FSA-17, NAVSHIPS 0967-052-4011.

COMMUNICATION CONTROL GROUP OA-6765(V)/FSA-52(V)

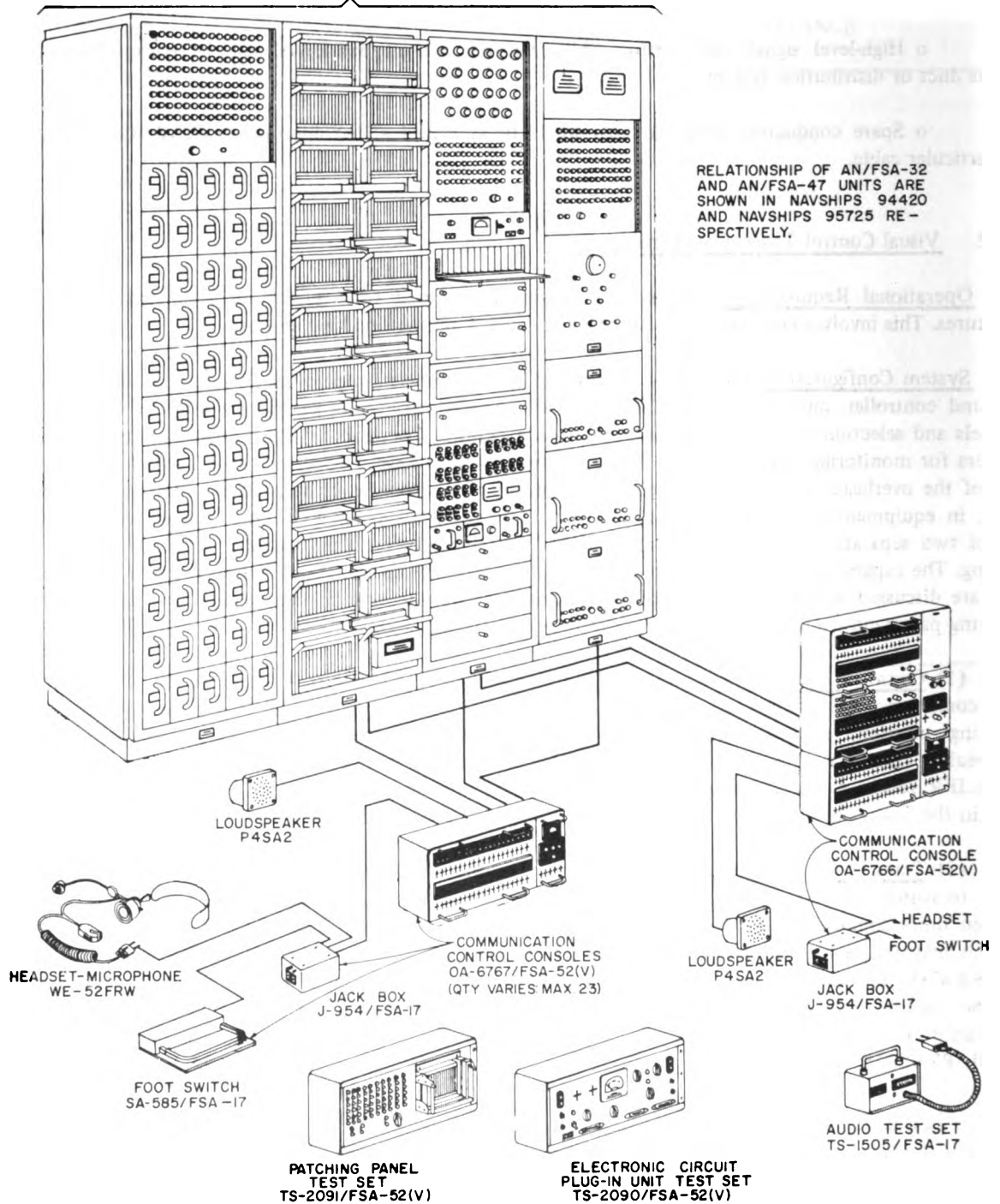


Figure 11 - 8. Console Group, Communications Control AN/FSA-52 (V)

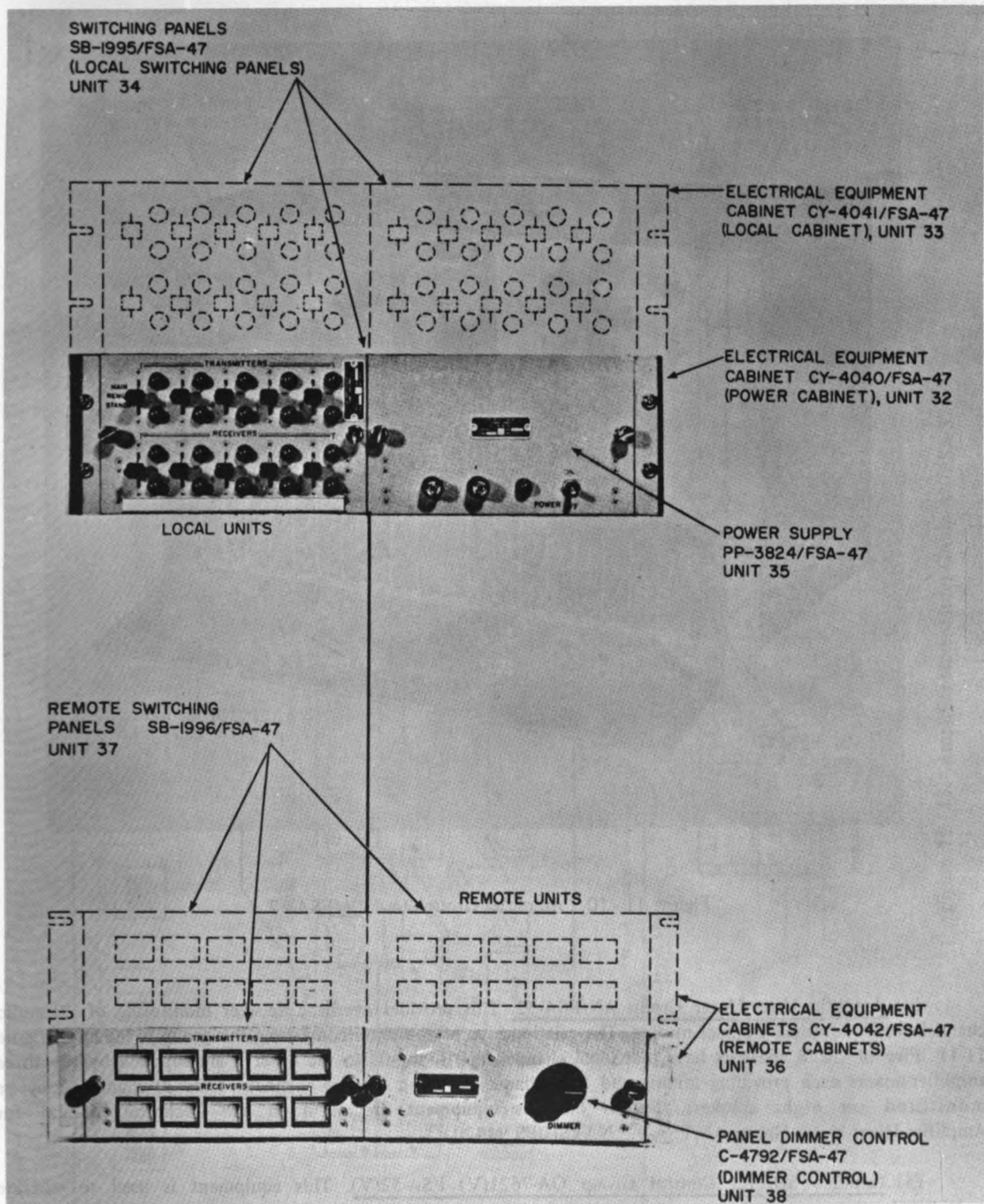


Figure 11 - 9. Transfer Control Group AN/FSA-47 (V)

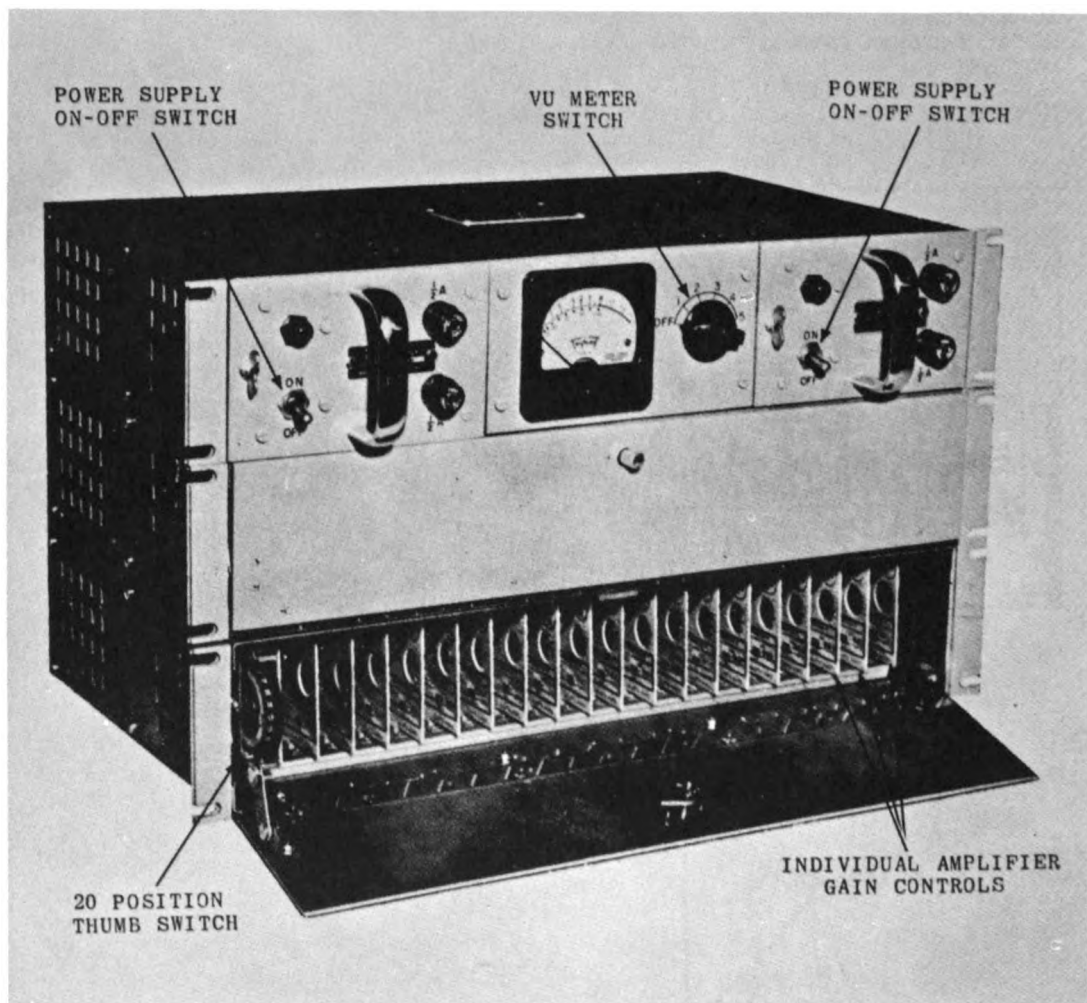


Figure 11 - 10. Amplifier Group OA-4391/FSA-17

(4) Amplifier-Mixer-Muter Group AN/FSA-32. This provides overhead speaker monitoring of 20 audio channels with individual channel muting. The relationships of the units comprising this group is shown in figure 11-11. Five of the 8 speakers have individual channel inputs. Inputs to the other 3 are supplied by the three amplifier-mixers each providing mixing and inter-channel isolation for five channels. Thus 20 channels may be monitored on eight speakers. Details on this equipment are given in the Technical Manual for Amplifier-Mixer-Muter Group AN/FSA-32, NAVSHIPS 94420.

(5) Landline Selector Control Group OA-7621(V) FSA-52(V). This equipment is used to operate multi-line landline communications in conjunction with the multi-channel radio communication provided by the Console Group, Communication Control AN/FSA-52(V) described above. The relationship of its various parts is presented in foldout 11-1. For efficient operation the three equipment cabinets are installed in close proximity to the cabinets of the radio channel Console Group AN/FSA-52(V) in the terminal room. This equipment is described in detail in the Technical Manual for Landline Selector Control Group OA-7621(V)/FSA-52(V), NAVSHIPS 0967-005-9000.

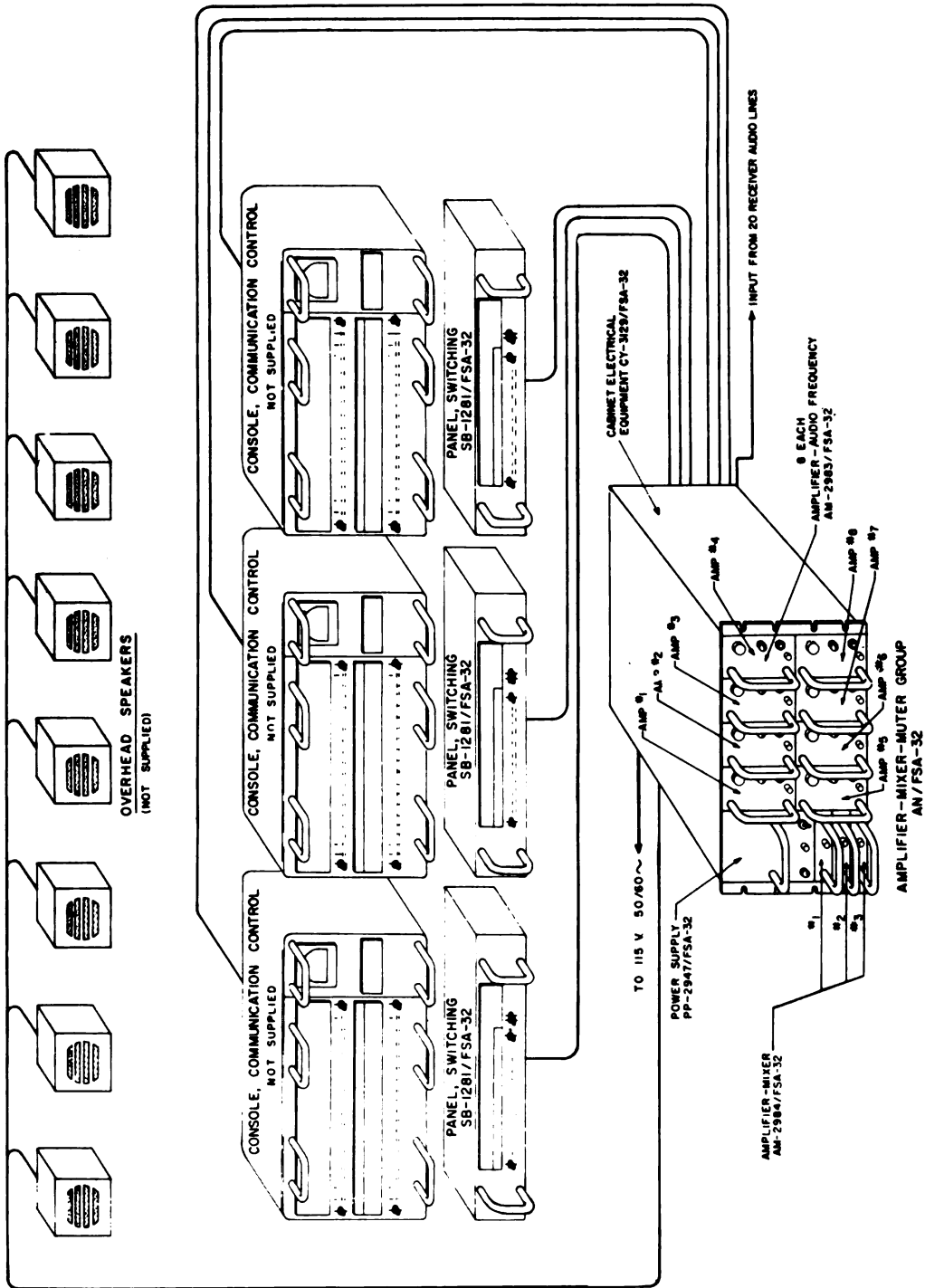


Figure 11 - 11. Amplifier-Mixer-Muter Group AN/FSA-32

(6) Emergency Communication System. One of the controller positions includes an emergency control console. Sufficient emergency equipment shall be installed to provide simultaneous transmission or reception on the following Navy tower channels: UHF primary, UHF emergency, VHF primary, and VHF emergency. The new standard fixed-frequency equipment AN/GRT-21, -22 and AN/GRR-23, -24 shall be provided. Unless an automatic-start emergency generator is immediately available the new equipment types shall be installed to use their battery-operated capability. Control of this emergency communication equipment shall be independent of normal control console control facilities. The VHF and UHF antennas of the emergency system are mounted on the roof of the visual control tower.

c. Site and Structural Criteria. The site shall provide visibility to all landing strips, taxi-ways, and parking aprons. The control tower is normally five stories high and in relatively flat terrain. A height of 43 feet from the ground to the floor of the control room (control cab) is considered the minimum acceptable elevation.

Arrangement in the control cab is made to provide adequate space for the location of a standard operator's communication control console, direction finder equipment, and emergency communication equipment. Suitable foundations and supports shall be provided on the tower roof for obstruction-clear VHF/UHF antennas of the emergency communication system. Adequate cable raceways shall be provided for all equipment locations. The tower provides space for the installation of electronic equipment in the first, third, and fourth floors in addition to facilities within the control cab for control and operation of the equipment.

Station power is normally used. Standby (emergency) automatic-start, gasoline or diesel power-generating equipment is generally provided, or battery-operated equipment must be immediately available. The arrangement of equipment for the control group provides a normal and an emergency control system which operates on 115 volt, single phase 60 Hz power sources. The normal system requires 1600 watts, and the emergency system requires a separate 55-watt supply. Further details on the control towers are presented in chapters 3 and 12.

d. Installation Criteria. The operator control equipment shall be installed in the VFR control tower room as required. The equipment cabinets shall be mounted in the terminal room. The antennas for the emergency radio equipment shall be mounted above all obstructions on the cab roof.

e. Operation and Maintenance Procedures. Operation and maintenance procedures are covered in the appropriate technical manuals. Shop and storage space is available in the operations building.

11.1.3 IFR/Control Tower Facilities

a. Operational Requirements. Under Visual Flight Rules (VFR) and Instrument Flight Rules (IFR) and at stations designated Radar Air Traffic Control Facilities (RATCF), close coordination is required between IFR room and Control Tower operators. It is essential that the tower consoles and interphone capability are an integral part of the RATCC communications control system even though RATCC is normally located in the operations building. Since a greater number of radiophone channels, operating positions, and IFR traffic operations are controlled by this RATCC system, it is incumbent that the system design include greater emphasis on features to provide:

- o Close coordination between operators.
- o Positive radio channel control.
- o Fast position re-programming.
- o Actual broadcast indication with each transmission.
- o Capability at each position to monitor both ends of communication.
- o Low environmental noise level.
- o Low cross-talk level (-80 dB).

- o System status information position.
- o Fast replacement of defective electronic assembly units.
- o Automatic fault alarm detector circuits.
- o Types of electronic assembly units which occupy minimum space.
- o Maximum use of cable conductors.
- o Low heat generating components and minimum power.

The operational requirements of the IFR room/Control Tower complex are described as follows:

(1) Normal or Operational Communications Systems (OCS) consist of any number of control operator positions controlling varying number of radiophone channels, selective interphone and party line circuits and contains a quick transfer to selective telephone landline circuit. The number of control positions and controlling capability is determined by the individual station requirements. Speaker and headphone monitoring is required in the control tower and headphone monitoring only in the IFR room except for the preselected one or two operator positions that are permitted speaker monitoring during the late watch.

(2) Emergency Communications System (ECS) is the communications system required by an ATC facility to provide a capability to conduct limited operations or to divert air traffic safely in case of total or partial failure of the OCS. The transmitters and receivers, or transceivers provided for this purpose are to be installed in the immediate vicinity of the operating spaces. The control system for the ECS shall be completely independent and separate from the OCS and provide the following standard capability at all ATC Facilities that have remoted OCS:

- o At tower only activities, one fixed tuned VHF transmitter/receiver and two fixed tuned UHF transmitters/receivers are to be provided. Circuit allocations are VHF Emergency, UHF Tower Primary and UHF Emergency.

- o At activities having tower and radar operating rooms, one fixed tuned VHF transmitter/receiver, two fixed tuned UHF transmitters/receivers and two multi-channel UHF transmitters/receivers or transceivers are to be provided. Circuit allocations are UHF Tower Primary to tower only, VHF and UHF Emergency to both tower and Radar Operating Room, and two multi-channel UHF to the Radar Operating Room only. At ATC Facilities jointly shared with FAA or where a significant amount of civil air traffic is controlled by the approach controller, an additional multi-channel VHF transmitter/receiver or transceiver shall be provided.

- o A modular control system electrically independent of the operational control system modules shall be provided. One ECS control module shall be provided in the tower in a location convenient to the local controller. In the Radar Operating Room, control modules with the capability to use any or all of the four channels, i.e., one VHF and three UHF shall be located at the supervisor's position, between each adjacent surveillance/precision radar position and at the approach control position. The frequencies on the two multi-channel UHF equipment shall be selectable at the supervisor's position. Additionally, at ATC Facilities jointly shared with FAA or where a significant amount of civil aircraft are controlled the VHF multi-channel equipment, with frequency selectability, shall be provided at the supervisor's position. In this case, the approach control position will have control of two VHF and three UHF channels.

- o Selective interphone, speaker and headphone capability at all positions, and dedicated ECS position recording shall be provided independently of the OCS.

- o Immediate (on-line) availability of an ECS power source for up to four hours of continuous operation shall be provided in the event of failure of the OCS power source.

b. System Configuration. The communication equipment provided for the IFR controller positions for radio channel and landline operation is the same as provided for the visual control tower positions. The supervisor position has all the capabilities of an IFR controller position, plus some others discussed in chapter 3 and is illustrated in figure 11-8.

c. Site and Structural Criteria. Space for IFR room is generally provided in the operations building. Proximity to the VFR control tower is essential.

For the IFR room standard planning requires provision for overhead wireways with adequate space for the assigned equipment and for possible expansion of facilities. Incandescent, non noise-producing fluorescent lighting, is specified. Station power is normally used, in an amount determined by equipment requirements, with an automatic quick-shift emergency source immediately available.

Adequate air conditioning and dehumidification facilities of the control center are of special importance. Heating may be required in the temperate or frigid zones. Standard practice dictates that the temperature be maintained within the range of 65^o to 80^o F, with a 20 percent air discharge and an equal intake of filtered fresh air.

The IFR room requires a quiet environment for operating personnel. The room is built to eliminate outside noise sources. Sound absorbent materials are used on the walls, ceiling and floor.

The room is constructed with unobstructed views for the operators. Structural members, such as columns, are not placed in the interior of the room. Indirect lighting is provided to prevent glare from reflecting surfaces or direct entrance into an operator's eyes.

Structural members are not placed in an IFR room from the standpoint of flexibility of arrangement of operating positions. Rearrangement of IFR rooms is commonplace due to changing requirements and technical advances in air traffic control systems.

Back-up/standby radio communications and radar/radio microwave systems require antennas in close proximity to the IFR room. Buildings housing the IFR room are constructed so that antennas can be mounted on the roofs and so that RF transmission lines can be installed between the equipment rooms and the antennas on the roof.

d. Operation and Maintenance Procedures. Operation and maintenance procedures are covered in the various technical manuals referenced in the paragraph Visual Control Tower Communications.

11.1.4 Radio/Fleet-Airwing Operations

a. Operational Requirements. These two facilities may be operated separately or combined in one area. Operational requirements dictate that these ground facilities provide communication with tactical and transient aircraft.

b. System Configuration. Local operating positions will contain receivers and/or remote receiver control facilities, and transmitter control facilities for local (emergency) and remote transmitter operation. Figure 11-2 is a block diagram of a Naval Air Station including a fleet airwing facility.

c. Site and Structural Criteria. Space is provided in the Operations Building for these facilities. The standard Operations Building (plans selected from BUDOCKS' "Definitive Designs") provides facilities for four major functional electronic systems: operations, communications, meteorology, and air traffic control. Additional space must be provided where fleet airwing staffs are assigned. The standard structure will permit expansion, when required, for additional operating facilities. The location shall conform to current planning standards concerning clearance and line of sight to aircraft operating areas.

Communication facilities provided in the Operations Building (which may or may not be attached to the control tower structure), shall include the Operations or Base Radio, and the Fleet Airwing Command, as required. Systems engineering will provide teletypewriter equipment, positions, and patching facilities as required, to meet the local operational requirements. (see figure 11-4). Space for the fleet airwing is provided as necessary, with consideration given to the integration of fleet and operations radio facilities.

Station power is normally used, but standby (emergency) automatic-start gasoline or diesel power-generating equipment is also provided to restore power within 5 seconds.

The building is designed for roof-mounted antennas as required. Poles may be erected for additional antennas and must meet aircraft clearance requirements.

d. Installation Criteria. Telephone-type control cables are used for remote control of receivers and transmitters. The station TTY loop, operations intercom, and order-wire facilities are installed. Standard patching and monitoring facilities are made available in local cabinets.

e. Operation and Maintenance Procedures. Attended operation with facilities for record keeping of system performance by the application of monitoring and system test procedures is standard practice for these facilities.

The operations building will contain space assignment for a shop-repair facility capable of caring for all the electronic equipment in the building or control tower.

11.2 COMMUNICATIONS EQUIPMENT

Types of communication equipment discussed are:

- o HF Transmitters/Receivers
- o VHF/UHF Transmitters/Receivers
- o Microwave Links
- o Mobile/Transportable ATC Equipment

11.2.1 HF Radio Transmission

a. General. For radio communication beyond the line-of-sight range of VHF/UHF radio systems and for worldwide operations high frequency (nominally 3 MHz to 30 MHz), HF radio operation is the most widely used. Systems are now coming into use employing space communication satellites. These have a great potential capacity in terms of channels and may eventually be used for routing communications with surface vessels and aircraft. However, the advantages of HF communication, especially with respect to cost, will probably insure the use of HF radio systems for a considerable period.

In spite of some difficulties posed by the propagating medium, the technical simplicity and low cost of HF systems relative to LF and MF communication systems quickly led to rapid exploitation of the HF band. In this band, ionospheric refraction makes long-distance communication possible with considerably less power and much cheaper antenna system than are required in the LF and MF bands.

b. Propagation Difficulties. One of the salient features of HF long-distance communication is the variable nature of the propagation medium. Successful transmission of HF signals over long distances is dependent upon refraction (apparent reflection) of radio waves by layers of the ionosphere. The height and density of these layers, formed primarily by ultra-violet radiation from the sun, varies significantly with the time of day, season of the year, and the eleven-year cycle (approximately) of sunspot activity. Because of these variations, it is generally necessary to use more than a single frequency, sometimes up to four or five, to maintain communications on a circuit.

Changes in the characteristics of the ionosphere during the eleven-year solar cycle cause a variation of approximately 2:1 in the portion of the HF band usable for long-distance communication. During periods of high solar activity the entire HF spectrum is usable, but during periods of low solar activity only the lower portion up to approximately 15 MHz can be relied upon for long-distance communication by ionospheric refraction.

At relatively short distances within approximately 300 miles of a minimum range for sky-wave propagation is beyond the receiving point while the signal strength of a ground wave may be inadequate for suitable quality reception. HF radio circuits are prone to fading, and, in particular, to a selective type of fading which results from multiple reflections from the ionosphere or multipath transmission. They are subject also to interference from atmospheric disturbances, other natural causes, and interruption from magnetic storms caused by solar flares.

Because high frequencies can be used effectively with relatively low power for long-distance communications, the range of potential interference between stations is also large, and the number of stations that can use the same frequency without mutual interference is limited.

As a result of many years of intensive study, these disturbing effects are not understood well enough so that HF communications can be conducted with a high degree of reliability under all but the most extreme ionospheric conditions.

c. Spectrum Congestion. In spite of the difficulties encountered with HF propagation, the economic and technical advantages of using high frequencies have led to rapid expansion of the use of the HF band. Ultimately, as the number of users increased, use of the HF spectrum approached saturation. In 1950 President Truman cited crowding of the HF band as being the most pressing communication problem of the times. In 1964 the Joint Technical Advisory Committee of the IEEE and the Electronic Industries Association suggested that this band appears to be heading toward chaos as world requirements are expected to continue to exceed, at an increasing rate, the limited supply of usable frequencies. The HF band is shared by many users, both foreign and domestic, and only portions scattered throughout the band are allocated to the military services. In common with other agencies, Navy requirements have grown so as to severely tax the capacity of the Navy's assigned portion of the HF spectrum. The use of single-sideband equipment and the application of independent sideband techniques have increased the capacity, but not enough to catch up with the demand. Some predict that satellite communication will eventually relieve congestion in the HF band and that, for some types of service, it will replace HF for long-distance communications. Nevertheless, it appears the HF spectrum will continue to be in high demand for some time to come.

d. Typical Navy HF Communication Systems. Naval communications within the HF band can be grouped into four general types of services: point-to-point, ship-to-shore, ground-to-air, and fleet broadcast. Some of these services involve ships and aircraft which present special problems because of their physical characteristics and mobility. Generally, the less than optimum HF performance of these mobile terminals is at least partially offset by powerful transmitters and sensitive receiving systems at the shore terminals.

(1) Point-to-Point Communications. Point-to-point systems are those established to communicate over long-distance trunks or links between fixed terminals. Generally, sufficient real estate is acquired at the terminals to permit the use of large, high-gain antennas aimed at opposite terminals of each link. This increases the effective radiated power and the sensitivity of the receiving system and it also reduces susceptibility of a circuit to interference. With the path length and direction fixed, accommodation of the other propagation variables is simplified and highly reliable communications can be achieved.

Within the Defense Communications System (DCS), the standard bandwidth 12 kHz for each operating frequency is divided into four 3-kHz channels so that each channel can contain information different from the others. One is generally used as a voice frequency carrier telegraph channel (VFCT) which can accommodate sixteen teletype circuits. The others can be used for facsimile, voice, orderwire, or other forms of data transmission. Navy point-to-point circuits that do not interface with the DCS are not constrained to the DCS standard bandwidth and channel alignment. Therefore, the bandwidths indicated in the emission designations given in JANAP 195 are used for these Navy circuits. A table of these emission designators is contained in NAVSHIPS 0967-308-0010, "U. S. Navy Emissions and Bandwidths Handbook," November 1968.

(2) Ship-to-Shore Communications. This application of the HF band is more difficult than the point-to-point case since one terminal, the ship, is mobile. In this case the path length and direction are variable. At the ship terminal, limited space and other restrictions prohibit installation of large, efficient HF antennas. Because of the mobility of ships, shipboard antennas are designed to be as nearly omnidirectional as possible.

The constraints are not as severe at the shore terminal where there is sufficient space for more efficient omnidirectional antennas or arrays designed for area coverage. Moreover, at the shore terminal, a rotatable, high-gain antenna, or one of the fixed point-to-point antennas may be used under appropriate circumstances. For example, a rhombic antenna may serve long-haul ship-to-shore communications when the ship is at a distance such that its operating area is within the coverage of the antenna at that distance.

Several frequencies are usually assigned for each circuit so that the best frequency can be chosen for the propagation path conditions between the shore terminal and the ship's location. The length of the path determines whether skywave or ground-wave propagation will be effective for the link. Ships relatively close to shore usually depend upon the ground wave for communication with the shore terminal. Alternatively, high-angle sky-wave propagation can be used for communications within the skip distance; however, the probability of ionospheric support at high angles is relatively low.

(3) Ground-to-Air Communications. The application of HF radio communications between the ground and airborne aircraft is similar to the ship-to-shore case except the aircraft terminal changes position much more rapidly than does a ship. Transmitter power and antenna restrictions imposed by the airframe design limit the effectiveness of the airborne HF radio terminal so that all major circuit improvements must be made by the application of suitable techniques at the ground terminal. For example, higher-powered transmitters, lower-noise receiving installations, and more efficient antennas can be used on the ground. HF antenna considerations for ground-to-air communications are discussed in NAVELEX 0101,104, "HF Radio Antenna Systems."

(4) Fleet Broadcasts. As the name implies, this type of service involves broadcast area coverage from shore-based transmitters to ships at sea. Messages addressed to a ship in a designated broadcast area are delivered by various means to the appropriate fleet broadcast station where they are broadcast for pickup by the ships. To overcome the propagation difficulties discussed earlier, the same information is broadcast simultaneously on several frequencies. This gives flexibility for the receiving terminal to choose the best frequency for the path considerations at the time.

e. Planning Criteria. Most Navy point-to-point circuits are included in the DCS and, therefore, must be designed to satisfy the requirements imposed by the Defense Communications Agency (DCA) which prescribes engineering standards for the point-to-point circuits of the DCS. Since the DCA standards apply principally to circuit quality requirements over which control can be exercised only within the terminals of a circuit, these standards are discussed in NAVELEX 0101,102 Naval Communications Station Design. Other than to prescribe a signal-to-noise ratio of 32 dB (for all types of service) and to specify the use of certain sunspot numbers for making propagation predictions, the DCA standards do not state circuit quality standards for the propagation path.

The Navy's ship-to-shore, ground-to-air, and fleet broadcast applications of HF radio are not directly controlled by the DCA standards since these circuits are not a part of the DCS. The interface between these services and the DCS does, however, come under control of the DCA, as does any circuit entering the DCS.

Although some HF system components aboard a mobile terminal, such as a ship or aircraft, may be comparable in performance to those ashore, other limitations force acceptance of mobile terminal performance that often is marginal at best. For effective two-way communications between a shore terminal and a mobile terminal, both the transmitting and receiving systems ashore should be superior to those aboard ships and aircraft. Generally, overall circuit performance can be improved by installing efficient antennas at low-noise-level sites ashore.

The subject of HF Radio Propagation and Facility Site Selection, NAVELEX 0101,103 is described in considerable detail in this document.

f. DCS HF Radio Circuit. The DCS HF radio circuits provide for long-haul, point-to-point composite transmissions that carry a large portion of today's high-volume traffic load. The basic publications that prescribe the DCS radio circuit requirements are: DCAC 330-185-1, DCS Engineering Installation Standards Manual, and DCAC 370-185-1, DCS Applications Engineering Manual. The basic circuit is shown by figure 11-12. This circuit is composed of one to four channels, each with a bandwidth of 3 kHz. The independent sideband (ISB) technique is used to transmit up to four of these channels within the authorized 12-kHz bandwidth. When ISB techniques are used, the sideband channel allocations are as shown in figure 11-13.

11.2.2 HF Transmitters

a. Operational Requirements. This facility will provide HF transmitters for remote control by all other operating centers of the Naval Air Station. These centers include the administrative communication center, operations radio, and the fleet airwing.

b. System Configuration. Information for transmission is routed from the communications center via intersite links. Reliability may require the provision of alternate links routed over separate paths between the communications center and the transmitter site.

(1) HF Transmitting Equipment. NAVELEX supplies general purpose independent sideband (ISB) transmitters to achieve operational flexibility. Present generation transmitters are capable of the classes of emissions shown in table 11-4. They are designed for matched loading into 50-ohm coaxial transmission lines and they may be tuned and placed into operation by operators at the equipment or by remote control from circuit operator positions. Spare transmitters and associated equipment are provided for maintenance and backup on a basis of one spare for every five active units. Transmitters are rated by their output power and are classified in accordance with the designations listed in table 11-5 .

General purpose ISB transmitters provided by NAVELEX are rated at either 1kW, 10 kW, or 200 kW PEP output.

(2) Transmitter Control. A centralized area for control, monitoring and testing of transmitting systems is provided at each transmitter building on the station. This center includes provisions for all elements of transmitter control other than the switching of RF output and the initial turn-on of the transmitters. The station orderwire and telephone is installed to augment transmitter control.

(3) Channelization and Routing. Signal flow with a minimum of processing is preferred. It is desirable to transmit 3-kHz bandwidth audio signals in the same form as received from the communications center. When the signal at the output of the link demultiplexing equipment is routed directly to the transmitter, the resultant transmission is more likely to be error free and reliable. In order to approach this objective, the following design criteria are established for the links and for the information received:

- o All links to the transmitter site carry information on 4000-Hz nominal bandwidth link channels.
- o The information for each designation is received on a dedicated link channel (3-kHz bandwidth audio channel) or a voice frequency carrier telegraph (VFCT) channel which may be part of a 3-kHz bandwidth audio channel.
- o All signals received via the links are routed via patchboards to provide the flexibility to use any signal to modulate (or key) any transmitter.

Information that is to be transmitted by on-off keying (CW emission) or frequency shift keying (FSK emission) is received in the form of VFCT tones. The station VFCT terminal separates the tones into channels and converts the tones into DC keying signals that are routed through patchboards to the appropriate transmitter keyer or keyers.

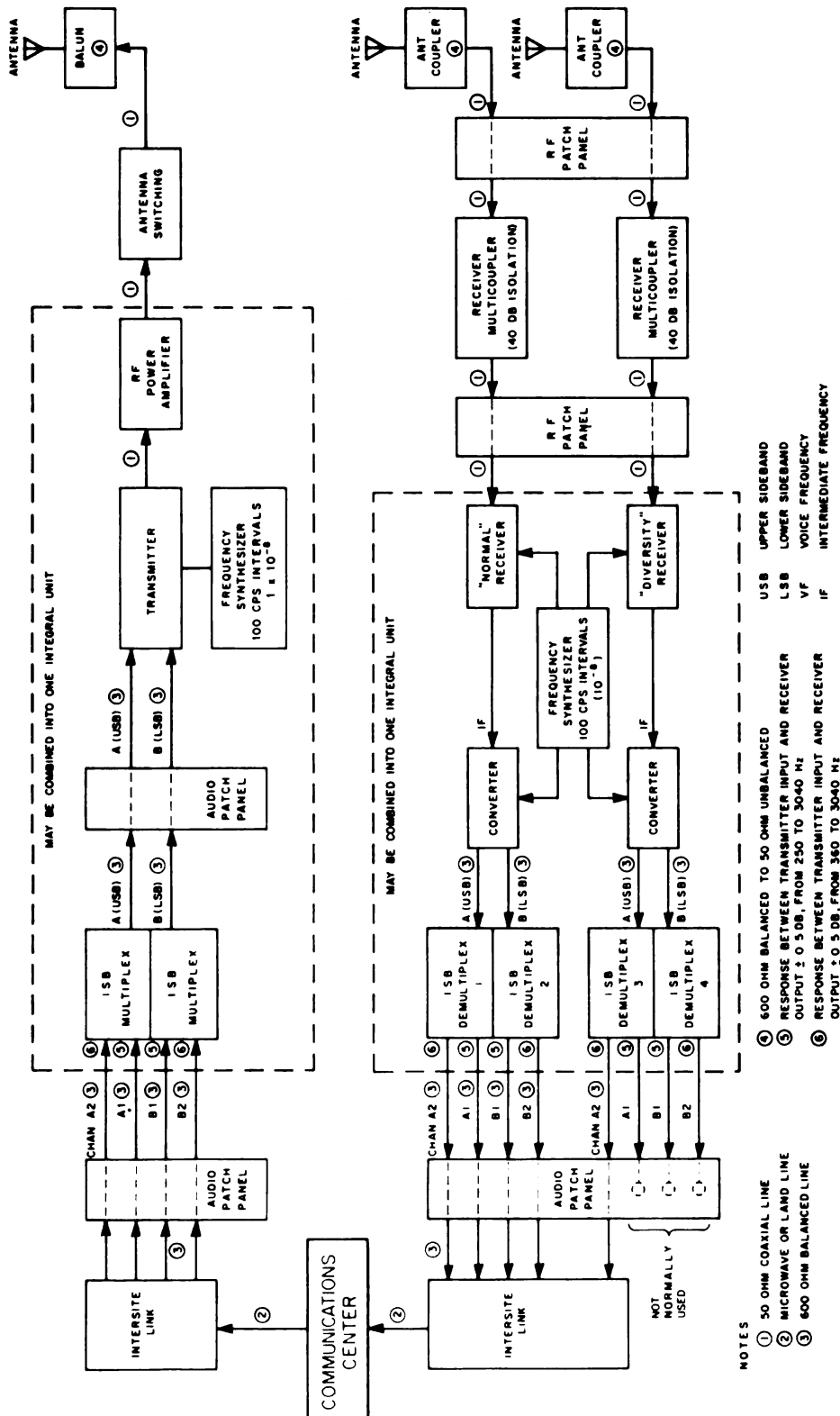


Figure 11 - 12. DCS HF Radio Circuit Basic Block Diagram

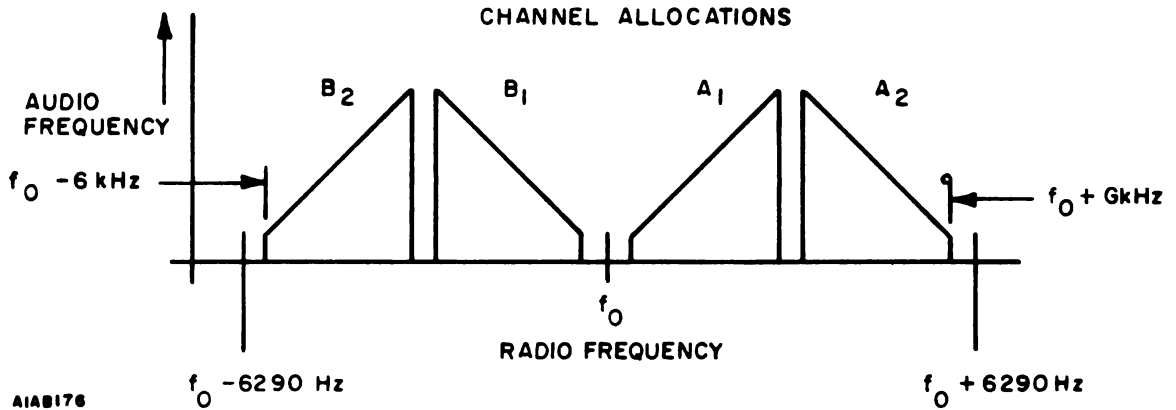


Figure 11 - 13. Independent Sideband Allocation

Information for use within the station such as orderwire traffic and DC control signals is received in the form of VFCT tones via the intersite links. The DC signals are in turn routed via distribution frames and patchboards to teletype equipment or to the applicable transmitter. In-band control signals are also received at the transmitter station. In-band signaling incorporates control information with the information to be transmitted. Separation of the in-band control signals from the information straight-through type of transmission is possible because separate distribution of the control signal is not required.

All in-house signal and control information (both audio and DC) is distributed by shielded-pair cabling. In general, the in-house circuit flow is from the link terminal equipment to a distribution frame, to a patchboard, back to a distribution frame, and then to the transmitter, orderwire terminal, or other electronic equipment. The link channels between the communications center and the station are terminated on the transmitter station main distribution frame (MDF) and then routed to an intermediate distribution frame (IDF). The MDF and the IDF may be combined as long as distinctly separate areas are maintained within the frame.

(4) Antennas. The HF transmitting antennas surround the transmitter building. Detailed discussion of HF antenna systems is given in NAVELEX 0101,104, HF Radio Antenna Systems.

c. Siting Criteria. The transmitter building is located in the center of the antenna park to minimize the length of the antenna transmission lines. The following planning distances have been established for separating the transmitter station from other facilities.

- o Overhead high-tension power lines, 1000 feet from the nearest antenna.
- o Main highways, 1000 feet.
- o Other transmitter stations, 3 miles.

Table 11-4. Emission Designation

DESIGNATION	DESCRIPTION
0.1A1	Continuous wave, on-off keying telegraphy, 100 Hz bandwidth (CW Telegraph at 25 wpm)
1.7A7J	Amplitude modulated, multichannel, voice-frequency telegraphy, suppressed carrier, single sideband, 1700-Hz bandwidth (100 wpm, 8 channel)
3A3J	Amplitude modulated, telephony, suppressed carrier, single sideband, 3000-Hz bandwidth
3A7J	Amplitude modulated, multichannel voice-frequency telegraphy, reduced carrier, single sideband, 3000-Hz bandwidth
3A9A	Amplitude modulated, combination telegraphy and telephony, reduced carrier, single sideband, 3000-Hz bandwidth
3A9J	Amplitude modulated, combination telegraphy and telephony, suppressed carrier, single sideband, 3000-Hz bandwidth. A single sideband, suppressed carrier, amplitude modulated emission occupying 3 kHz of spectrum and which does not fall into any of the preceding categories. Examples of emissions properly classified as 3A9J include data, simultaneous voice and tone telegraphy, simultaneous voice and data, or simultaneous data and telegraphy.
6A3	Amplitude modulated, telephony, double sideband full carrier, 6000-Hz bandwidth
6A3B	Two independent 3-kHz intelligence channels authorized for voice transmission. The suppressed carrier frequency is the same as the assigned frequency.
6A7B	Two independent 3-kHz intelligence channels for multichannel telegraph transmission. The suppressed carrier frequency is the same as the assigned frequency.
6A9B*	Amplitude modulated, combination telegraphy and telephony, two independent sidebands, 6000-Hz bandwidth
9A3B, 9A7B 9A9B*	Amplitude modulated, combination telegraphy and telephony, three independent sidebands, 9000-Hz bandwidth
12A3B, 12A7B 12A9B*	Four independent 3-kHz intelligence channels for voice, multichannel telegraphy, or composite transmissions respectively. Suppressed carrier frequency is the same as the assigned frequency
1.24F1	Frequency modulated, one of any two frequencies being emitted at any one instant, 1240-Hz bandwidth (100 wpm RATT)
4F4	Frequency modulated, facsimile transmission, 4000-Hz bandwidth
*Note that for 6A9B, or 12A9B emissions, one 3-kHz intelligence channel may carry only voice and another only telegraphy and still fall within the definition of composite transmission.	

- o Airfields and glidepaths, 3 miles when the station is used for general purpose communications.
- o Airfields and glidepaths, 1500 feet when the station is used in conjunction with air operations.
- o Receiver buildings and associated antenna fields, 25 miles when VLF transmitters are installed.
- o Receiver buildings and associated antenna fields, 3 miles when HF transmitters are installed.

The transmitter station is sited on reasonably flat or rolling terrain in accordance with the factors discussed in NAVELEX 0101,103, HF Radio Propagation and Facility Site Selection. The principal concern in selecting a transmitter site is its potential for creating RF interference with other operations such as receiving stations and local commercial broadcast reception. This, and the large area needed for the antenna park forces the choice of a site remote from populated and industrial areas. An extensive noise survey is not required. Siting transmitters in an area where interference will not cause adverse effects is more important than choosing a site with a low ambient noise level.

d. Structural and Installation Criteria

(1) Structural Factors. The transmitter building located in the center of the antenna field is designed to satisfy the operational requirements and to promote operational efficiency. At small stations, transmitters are located in a transmitter room and a control and monitoring facility is installed in an area central to the transmitters. The width of a typical transmitter room is 20 feet, which permits placement of two rows of transmitters facing front to front with an 8-foot-wide center aisle and with approximately 4 feet of space behind the transmitters. This concept is illustrated in figure 11-14. Space is also provided for a repair shop and storage of spare parts.

Transmitter buildings are usually permanent structures; however, present DOD instructions state that new communications facilities in overseas areas on foreign soil are to be transportable. These transportable stations are discussed in Naval Communication Station Design, NAVELEX 0101,102.

When new and permanent building construction is required, the Naval Facilities Engineering Command (NAVFAC) designs and constructs the building in accordance with the specific BESEP requirements. In addition, the following criteria apply specifically to the transmitter building:

- o The transmitter room (wings) and rooms for other electronic equipment will be windowless and free from obstructions and columns.
- o A control area is required for transmitter control, monitoring, and testing. Preferably, this area should be chosen so that operators will be able to see all the transmitters.
- o The floor will be concrete and will be designed to support a loading of 200 pounds per square foot.
- o A truck loading platform is required at the end of each transmitter wing. Access doors must be large enough to accommodate large equipment shipments.
- o An electronic maintenance shop is required. This shop will contain a shielded room that provides 60 dB attenuation of electromagnetic radiation from 100 kHz to 100 MHz.
- o Cable vaults are normally installed to serve as entrance for all RF and signal cables.
- o The building must include features that isolate transmitter acoustic noise from the operating and control areas.

Table 11-5. Transmitter Output Power Versus Type

POWER	DESIGNATION	POWER RATING
Low	LP	Under 1 kW
Medium	MP	1 - 5 kW
Medium High	MHP	5 - 20 kW
High	HP	20 - 50 kW
Very High	VHP	Above 50 kW

The equipment required for ventilating air and cooling the building are based upon the climatic conditions and heat generated within the building by personnel, lighting, and equipment. The preferred method of cooling transmitters is one using ventilating air. Heat is transferred directly to the air by passing the ventilating air directly over the parts to be cooled or indirectly by passing air through heat exchangers that are integral parts of the transmitters.

(2) Installation Factors. Maximum operational flexibility is achieved by installing circuit patchboards and distribution frames. The patchboards provide access for equipment maintenance, signal monitoring, and for rerouting of signals as required by operations in the event of an equipment failure. All circuit patchboards are wired "normal through" so that no patch cord connection are required when the system is operating as planned. Wiring criteria concerning frames and patchboards are discussed in chapter 9 of NAVELEX 0101,102.

RF switches provide signal flexibility by permitting transmitters to operate into selected antennas or into a dummy load to satisfy various frequency, directivity, and maintenance requirements. Crossbar switching matrices are the latest approved switching devices.

At the present time studies are planned which will result in establishing new criteria for the grounding and bonding of the transmitter building. When completed, these new criteria will be incorporated in a NAVELEX Manual on EMC/RADHAZ. Meanwhile, NAVFAC DM-23, Communications, Navigational Aids and Airfield Lighting should be used as the source of criteria for bonding and grounding of transmitter buildings.

Electrical power requirements for electronic equipment are specified in the BESEP for use by NAVFAC or the NAVFAC Engineering Field Division in designing the station electrical power system. The demand load for the transmitter building electronic equipment is 100 percent of the connected technical load. For new facilities the primary power should include design for 25 percent growth of the total electrical load. The primary power source for a transmitter facility is usually a commercial power company unless the commercial power is inadequate, in which case a class A power plant is installed. Factors that determine the adequacy of a commercial power company are contained in DM-4, "Electrical Engineering." The following criteria are applicable to the transmitter building power system:

New facilities are to be designed around a 480-volt, 3-phase, either 50- or 60-hertz system and are to have separate buses for the technical and non-technical loads.

At new facilities, transmitters will require power as follows:

- o Power amplifier 480-volt, 3-phase, 3-wire from the technical bus.
- o Exciter: 120-volt, single-phase from the technical bus.

o Transmitter utility outlets: 120-volt, single-phase from the non-technical bus. Class D, no-break power is not provided for a transmitter building.

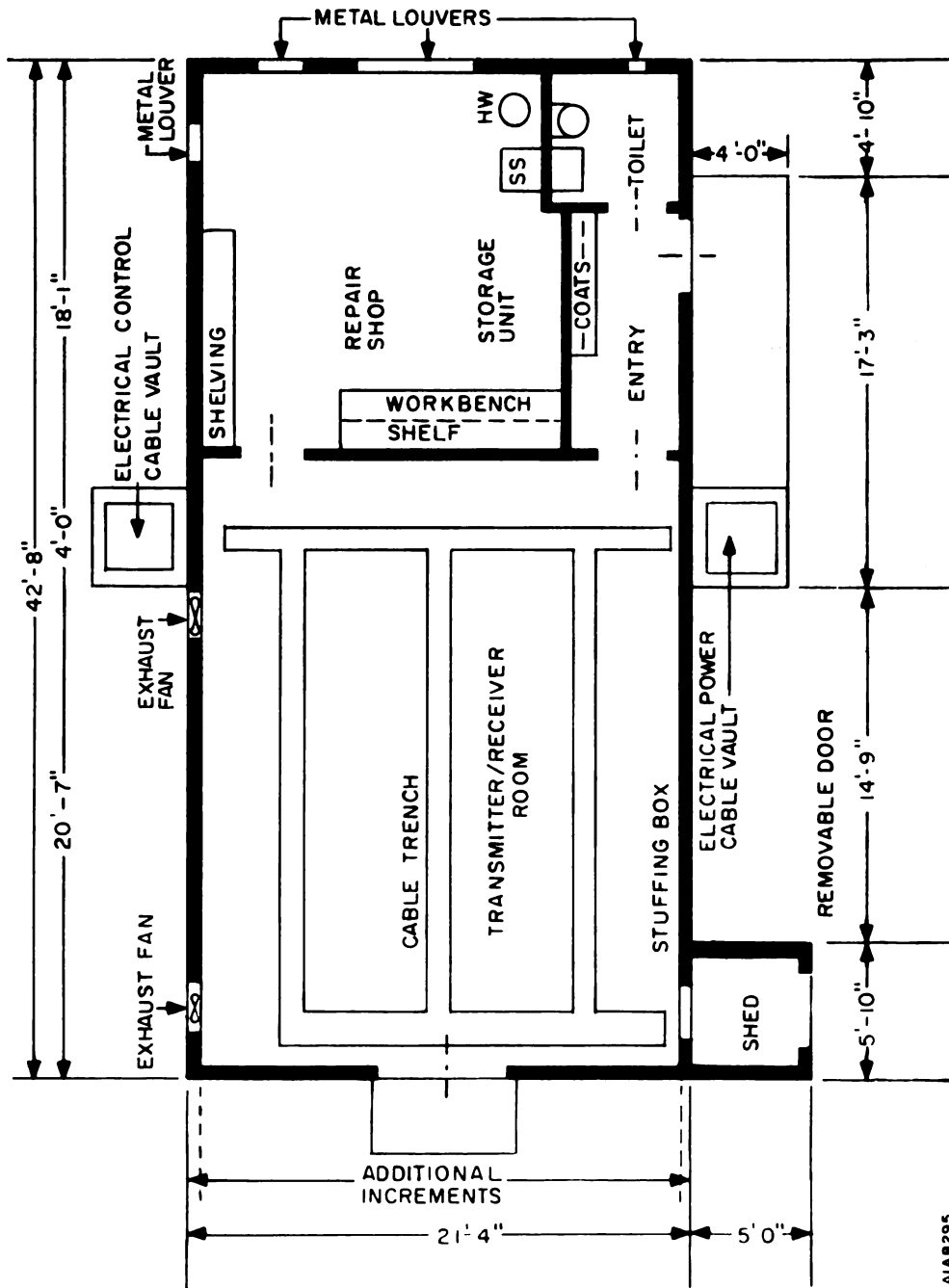


Figure 11 - 14. Typical Floor Plan for a Transmitter/Receiver Building

e. Operation and Maintenance Procedures. Attended operation is standard practice. Operator training programs should aim toward a thorough indoctrination and the development of skill in the following aspects of operation:

Accurate Output Adjustment
 Frequency and Channel Shifting
 Patching (RF and AF)
 VSWR Measurement and Maintenance
 Modulation Measurement and Control
 System Test Procedures
 Line Level Maintenance

Space is provided in the transmitter building for repair facilities and parts storage. A preventive maintenance program is required.

11.2.3 HF Receivers

a. Operational Requirements. This facility will provide HF receivers for local control or for remote control by operating centers. These centers include the administrative communication center, operations radio, fleet air wing or tactical communication centers. When the facilities of a naval communication station are available, HF receivers, other than tower and emergency will be installed at the naval communication station and maintained for NAS requirements.

b. System Configuration

(1) HF Receiving Equipment. Each station or facility is comprised of an antenna and building housing electronic equipment to receive transmitted radio signals and/or data from remote locations. Antennas receive this transmitted data which is then translated and converted by the receiving equipment into information for use and processing by the communication center. The specific number and types of HF receiving equipment installed at each station or facility is determined by the particular function and operational requirements. Where necessary, additional receiver sections are included as part of the overall installed equipment. This redundancy provides the necessary backup for continuous operation and facilitate maintenance. A list of typical receiver equipment to be found at a station is identified in Navy document NAVELEX 0101,102. However, particular equipments required to implement a specific receive function are identified by the applicable NAVELEX standard plan.

Reception of desired radio signals is the controlling factor when a radio receiver station is designed and constructed. Any other consideration, such as the need for survivability against bomb damage or a natural disaster, must not be permitted to degrade the ability of the station to function as a radio receiving station. The principal factors entering into the general arrangement and construction of the station are:

- o Fundamental suitability for conducting efficient communications.
- o Adaptability to meet normal expansion requirements and emergencies.
- o Total cost.

One of the methods of integrating the above factors into the design is to provide for maximum flexibility in the use of antennas and receivers. An accepted method for accomplishing this is to include (1) multicouplers to supply multiple outputs from a single antenna, (2) RF switches and patchboards to feed any receiver with any RF input, and (3) audio and DC circuit patchboards to distribute the receiver and ancillary equipment outputs.

HF receivers capable of processing the various types of emissions listed in table 11-4 are preferred. Use of multipurpose receivers provides operational flexibility and allows equipment substitution for maintenance and for equipment failure.

HF receivers in use at shore stations vary from those that receive only a single channel 3-kHz sideband to those that receive an independent sideband (ISB) modulated RF carrier consisting of an upper and a lower sideband each 6 kHz wide. Usually receivers are controlled manually at the front of the unit, but some later model receivers may be controlled remotely from a distant operator position. Remote control from the distant operator position is usually accomplished by sending teletype or digital instructions to a receiver control unit which automatically makes the proper adjustment. The ISB receiver itself may demultiplex each of the 6-kHz sidebands into two 3-kHz audio channels. Receivers that include all necessary demultiplexing and converting equipment are preferred over those with separate demultiplexers. HF receivers capable of receiving single-channel frequency shift keying or on-off keying signals are also required at various receiver stations. Outputs of these receivers are converted into audio tones for further distribution and processing. Preferred receivers are those that perform this conversion as an integral function without the use of auxiliary devices.

(2) Signal Processing and Distribution. A minimum of signal processing is accomplished at the receiver building. Most 3-kHz circuits are relayed to the communications center where the signal is processed to extract the intelligence. Information received on CW circuits is relayed via teletype to the communications center for distribution or retransmission; however, the CW circuit is usually operated from within the receiver building. From the operational standpoint, the converter/comparator equipment associated with diversity reception of single-channel FSK performs best when located in the receiver building. The resulting DC signal is routed to a processing room in the receiver building or relayed to the intersite communications center for processing. Experience has shown that better operation of the Ship/Shore Itinerant Orestes circuit is obtained when all processing is accomplished within the receiver building. Therefore, a receiver building usually contains a ship/shore room for signal processing.

Signals are distributed within the receiver building in accordance with the NAVELEX standard plan for the particular circuit being implemented. The NAVELEX standard plan for the circuit specifies whether the information is to be processed within the receiver building or relayed to the communications center for processing. The location specified is the one that has been found to be most operationally and technically efficient.

(3) Channelization and Routing. All receiver radio outputs, except those in the ship/shore room are routed to the receiver control area. There, they are monitored for proper level adjustment and quality before transmission to the communications center or processing in the ship/shore room. Each receiver output is distributed through shielded, twisted-pair cabling to distribution frames and patchboards. Wiring criteria for such distribution are described in NAVELEX 0101,102. When an intersite communications center link is required, the main distribution frame is the point of interface. All information passed over this intersite link, which may be from a telephone cable system or a microwave system, must be in audio form and be capable of being passed over a 4-kHz bandwidth circuit. Some telephone cable and all microwave intersite link systems cannot directly pass DC signals. These DC signals are converted by VFCT prior to transmission over the intersite link. DC signaling may be permitted where the intersite cable link characteristics allow such operation.

(4) Antennas of all types may be required. A park having a rosette antenna arrangement provides the shortest possible transmission lines to the receiver building constructed in the center of the park. The antennas occupy concentric circles around the receiver building. Rhombics or other directional antenna types are on the outer circle, while omnidirectional and sector coverage antennas are placed on the inner circles with the highest frequencies nearest the building. (Refer to Navy document) NAVELEX 0101,104, for additional information.

(5) Receiver and Circuit Control. Receiver and circuit control is accomplished through the use of equipment in the supervisor area. Receivers are connected to antennas through coaxial patchboards or switching matrices to permit rapid substitution of equipment, monitoring without circuit interruption, and testing of lines and equipment. Orderwire circuits between the receiver supervisory area and the communications center are used to exchange information concerning circuit and equipment usage.

(6) Tranceivers. These are separate transmitters and operating in the frequency ranges of 132-152 and 225-400 MHz, and may be located within the receiver building if the power output is less than 100 watts. This type of equipment is normally used for administrative purposes in communicating with maintenance, fire

protection, and security forces located in remote areas of the station. However, some receiver stations use this equipment for short range (line-of-sight) and point-to-point communications services in support of the mission of the station.

(7) Emergency Communications. For emergency communications, HF transmitters may be installed in a receiver building. Transmitters for this purpose are normally of less than 100 watts power output and usually radiate from a whip antenna on the roof of the building. Dummy loads must be provided for testing these transmitters since on-the-air testing is seldom permitted. Any such transmitters are normally located in a room other than a receiver room.

c. Siting Criteria.

(1) General. The general geographic site for the HF receiver facility selected is based upon the operational requirements and the adaptability of the site for receiver purposes as discussed in NAVELEX 101,103. When a station is erected, the reasons for selection and initial background noise measurements must be recorded for future reference. This information provides a baseline for future evaluation of request to permit other facilities to encroach upon the receiver location and for determination of the seriousness of any noise pollution problems. To protect an HF receiver facility from encroachment, a protective circular corridor and legally restricted area must be established, each one mile wide, as shown in figure 11-15. The protective corridor is located within the facility boundary and can be used for installation of temporary antennas. The legal restricted area is a land area surrounding the boundary of the facility in which it is illegal to develop the land in any way that would be detrimental to the mission of the receiver facility. Constant vigilance is required to maintain the status quo once the legal restricted area is established.

(2) Interference. One of the most important factors to consider when siting or installing receiver systems is to minimize the effects of interference. This applies to self-generation of radio interference as well as provision against external interference. Poor installation and poor maintenance practice can result in the existence of high levels of radio interference even though the original installation was not located in an area of high radio interference levels. This condition is caused by the subsequent installation and operation of radio interference sources in proximity to a receiving activity without taking corrective action.

The best time to minimize future sources of interference is in the initial planning stages. Periodic checks of local activity near the receiving facility should be performed to verify that separation distances originally specified have not changed. Often, if local authorities can be convinced of the need for restriction, potential interference can be averted.

Man-made noise appears to be increasing on an exponential curve. Therefore, at all existing sites periodic noise measurements should be made and recorded for future reference. A record of noise intensities could aid in solving encroachment problems and may help in isolating sources of new man-made interference problems.

d. Structural and Installation Criteria.

(1) Structural Factors. Receivers and their associated equipments are adaptable for installation in most existing structures. The controlling criteria for the structure is that it must provide an acceptable environment for the equipment and personnel. Receiver buildings are usually permanent structures, however, current DOD instructions state that communication facilities when overseas on foreign soil, be transportable rather than permanent structures. When new construction is contemplated, the criteria of NAVELEX 0101,102 applies.

- o The building must be a rectangular single floor structure.
- o The receiver room and rooms for other electronic equipment must be windowless and free from obstructions.
- o The floor may be concrete, and it must be designed to support a loading of 150 pounds per square foot.

- o The equipment rooms must have a 10-foot clearance between floor and ceiling. This clearance must be maintained when raised floors and suspended ceilings are installed.

- o The electronics maintenance shop must contain a screen room, measuring about 10 by 15 feet, that provides 60 dB attenuation in the frequency range of 10 kHz to 100 kHz.

- o Cable vaults are required to serve as the entrance for all antenna transmission lines.

- o Fluorescent lighting may be used in the receiver building and in the receiver room when the fixtures are equipped with power line filters and are grounded with the green, third wire of the power line feeder.

(2) Installation Factors. Receiver are terminated at audio patchboards in the receiver control areas. These outputs are arranged in a logical sequence usually starting from the upper left-hand portion of the board. ISB receiver outputs are labeled as to sideband and channel.

When receivers have separate outputs for FSK or CW signals, they are terminated on the audio patchboard. All FSK outputs are grouped together and arranged in numerical order according to the receiver number. Separate outputs for CW signals are terminated and arranged in a similar manner.

Present day antennas, receivers, and intermediate equipments are designed for RF 50-ohm impedance matching. Therefore, when new systems are being planned, all RF signal distribution is to be accomplished using 50-ohm coaxial cables.

Switching matrices, or patchboards provide flexibility in the RF distribution system by terminating:

- o Each antenna output
- o Each multicoupler input and output
- o Each receiver RF input.

These switching matrices, or patchboards, are used by operators to test, substitute, and bypass equipment.

Receiver multicouplers permit use of a single antenna as the signal source for more than one receiver by providing several outputs identical to the input. Although passive multicouplers are used occasionally, most multicouplers are active devices with amplification limited to that which is necessary to raise the output of each channel to the level of the input. Multicouplers can be cascaded to provide additional multiple outputs.

It is an accepted practice to install multicouplers in a cascaded "normal-through" arrangement when operations require more than 8 outputs of a single antenna. Up to 5 multicouplers have been successfully cascaded without degrading the signal below acceptable limits. When the multicoupler is installed cascaded, the input to the cascaded multicoupler does not appear on the RF patchboard.

Multicouplers are installed in groups by antenna types in CY-597A/G or CY-2675 standard equipment cabinets and each multicoupler is identified with the antenna to which it is normally connected. The patching equipment and RF multicouplers are normally collocated within the receiver building. All antenna transmission lines enter the receiver building through the cable vault where any necessary reduction in cable size or change of cable type takes place. RF distribution within the receiver building is usually accomplished with a smaller diameter cable than that used from the antenna to the building.

Equipment is placed to promote operator efficiency and ensure sufficient space for maintenance accessibility. A standard layout has not been established because station operational requirements differ greatly. A layout with the operating equipment surrounding the supervisor's control area is the most desirable arrangement. At small stations, all receiving and associated equipment can be observed from the supervisory area. Figure 11-14

illustrates a typical station layout. In this example the station is in one of a building and space required for support services is also shown. At larger stations the quantity of equipment installed precludes such a simple layout, but the general principle should be followed as far as possible. For further details refer to Naval Communication Station Design, NAVELEX 0101,102 and the site restrictions shown in figure 11-15.

The grounding criteria for the receiver building, provided red and black processing (exclusive of order wire traffic), will not be required. When red and black circuit processing is to be accomplished within the receiver building, the signal grounding system must be in accordance with the latest issue of NAVELEX Instruction 011120.1. A discussion of red and black signal grounding is included in NAVELEX 0101,102 and NAVELEX 0101,106.

A good earth ground connection can be established by referring to the National Electrical Code Handbook which states that an underground water piping system, either local or one that supplies a community, is preferred as the ground point. This handbook permits other ground point possibilities such as the metal frame of a building, other underground pipe or tank systems (exclusive of gas service piping), and electrodes installed in the ground. A general discussion of installed electrodes, together with recommended test methods, is found in NAVELEX 0101,102. The ground distribution system in the receiver building emanates from a ground bus that is connected to the selected earth ground connection point. All ground systems must be terminated on this common ground bus.

e. Operation and Maintenance Procedures. Attended operation is standard practice. Operator training programs should emphasize the following aspects of receiver operation:

- o Accurate Receiver Adjustment
- o Frequency Measuring Techniques
- o Modulation Measuring Techniques
- o Line-Level Maintenance
- o Patching (AF and RF)
- o Line Amplifier-Limiter Operation
- o System Test Procedures

The standard building has space assignment for shop facilities. A preventive maintenance program shall be established.

11.2.4 VHF/UHF Transmitters/Receivers.

The VHF/UHF propagation characteristics over the frequency band from about 100 MHz to 450 MHz are so similar that only minor differences in antenna siting are required.

a. Operational Requirements. The purpose of these facilities is to provide VHF/UHF communications for the control of aircraft landings and departures and other VHF/UHF communication as required for air station operation.

b. System Configuration. For normal and standby service, transmitters are usually located in a building some distance away from the control tower building. Receivers are usually located in another building which may be somewhat closer to the control building. Controls and audio signals are interchanged over a communication control link, usually buried cable, but under certain conditions it may be a microwave radio link. The radio sets are normally under the control of the controllers in the VFR and IFR rooms, but other personnel requiring their use may also be given to some channels. However, the antennas for the emergency communication system of the control tower are to be mounted directly on the roof of the tower above all obstructions.

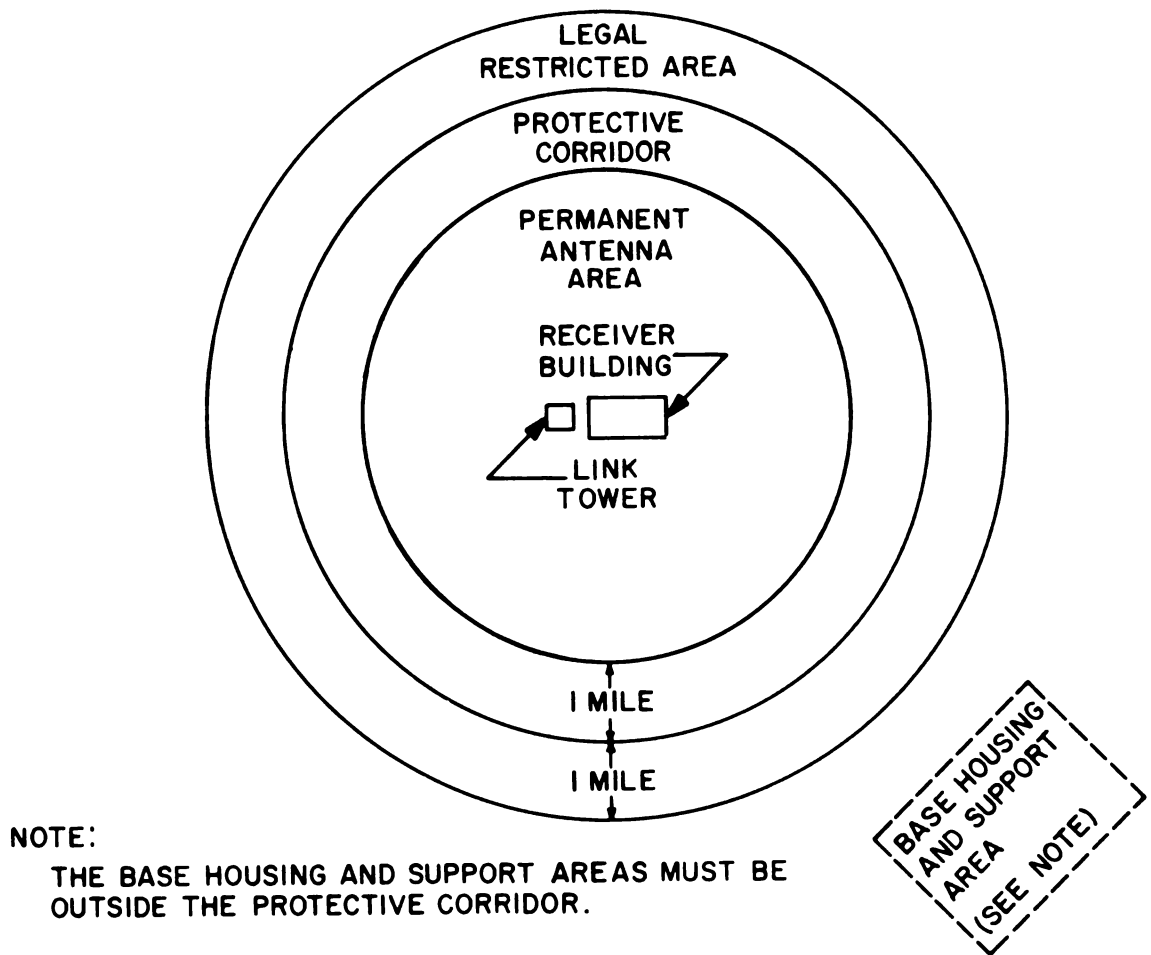


Figure 11 - 15. Receiver Station Site Plan

(1) VHF/UHF Transmitters and Receivers. Table 11-6 shows some available transmitters in the range of 115-400 MHz, while Table 11-7 lists receivers in this range. Standard receiver and transmitter assemblies to be installed in new facilities are presented in figures 11-16 and 11-17. The number of receiver transmitter units employed will depend on the station's communication requirements, but usually there is only one set of RF patch, audio monitor and test bays (units 7 and 8, or units 9 and 10) in a receiver or transmitter building.

(2) Multicouplers. Multicouplers allow multiple connection of either transmitters or receivers to the same antenna. Their use is mandatory in multichannel operation at shore installations such as for visual control tower and RATCC (IFR) control of aircraft. This not only cuts down on antenna requirements, but also provides higher quality operation.

Table 11-6. Shore Station Radio Transmitters

TYPE	FREQ. MHz	EMIS- SION	MAX POWER OUTPUT kW	AN- TENNA Z	POWER REQUIREMENTS			REFERENCE OR LITERATURE	MAJOR COMPONENTS ITEM	REMARKS	
					kW	VOLTS	PHASE				FREQ. MHz
AN/URT-7	115-156	A2,A3	.03	50	.75	115/230	1	50-60	NAVSHIPS 9168X Std Plan Re-52-F-2185	Transmitter	
AN/GRC-27	225-399.9	A2,A3	.1	52	2.3	115/220	1	50-60	T031R2-2 GRC-27 -64 Std Plans Re-52-F-2181 Re-52-F-2182	Transmitter/ Receiver with Rack	
AN/GRT-3	225-400	A3	.1	52	.750	105/125 210/250	1	60	Std Plan Re-52-F-2183	Transmitter Mod/Power Supply	
TED	225-400	A2,A3	.015	50	.75	115/230	1	50-60	NAVSHIPS 91357 Std Plan Re-52-F-1285	Transmitter	
AN/GRT-20	225-400	A3	.05	50	.60 max .125 min	120/208 230 V	1	50-60		Transmitter	New std equipment (2)
AN/GRT-21	116-149.9	A3	.01	50	(1) +	(1) +	1	50-400 Hz/DC	T1108/GRT-21	Exciter	New std equipment (2)
			.05		24 VDC	(1)					
AN/GRT-22	225-399.9	A3	.01	50	(1) +	(1) +	1	50-400 Hz/DC	T1109/GRT-22	Exciter	New std equipment (2)
			.05		24 VDC	(1)					

Legend: A2 Emission - Tone Modulated Telegraph (MGW). Notes: (1) 105/120/210/240 VAC ±10%
A3 Emission - Voice, double sideband, full carrier. (2) For exciter operation only, if AC power fails, battery is switched in automatically.

Table 11-7. Shore Station Radio Receivers

TYPE	FREQ. MHz	EMIS- SION TYPE	SENSI- TIVE uV	AN- TENNA Z	OUTPUT Z	POWER REQUIREMENTS				REMARKS
						WATTS	VOLTS	PHASE	FREQ. MHz	
AN/FRR-27	100-156	A2,A3	1	50	200/600 600	54	105/115/ 125	1	50-60	Single Chan Xtal Control.
AN/URR-27A	105-190	A2,A3	10	50	600 50 Video	112	115	1	60	Xtal Control or Continuous Tuning Single Channel.
AN/URR-21	115-156	A2,A3	5	50	600	106	115	1	55-65	4 Preset Xtal Control Chan- nels to R-432/URR and RCK.
AN/URR-9	225-400	A2,A3	10	50	600	150	115	1	50-60	10 Manually Preset Channels Similar to RDZ.
AN/URR-13	225-400	A2,A3	8	50	600	125	115	1	50-60	Single Channel.
AN/URR-28	225-400	A2,A3	8	50	600	197	115	1	50-60	10 Preselected Xtal Con- trolled Channels. Similar to RDZ.
AN/URR-35	225-400	A2,A3	8	50	600 50 Video	98	115	1	50-60	Preset or Manual Xtal Con- trol Channel.
AN/GRR-23	116-149.9	A3	3	50	600	≈70 WAC (1) 30 WDC 24 VDC	(1)	1	(2)	New standard equipment(3)
AN/GRR-24	225-399.9	A3	3	50	600	≈70 WAC (1) 30 WDC 24 VDC	(1)	1	(2)	New standard equipment(3)

Legend: A2 Emission - Tone Modulated Telegraph (MCW). Notes: (1) 150/120/210/240 VAC ±10%.
 A3 Emission - Voice, double sideband, full carrier. (2) 50-400 Hz ±5%.
 (3) If AC power fails, battery is automatically switched in.

The following description of one UHF multicoupler type will illustrate its application.

Antenna Coupler CU-691/U provides isolation between four transmitter and/or receiver combinations operating simultaneously with a common antenna. Isolation is achieved with four highly selective tandem filters and a combining network. The high selectivity reduces intermodulation interference, cross modulation interference, and spurious responses. Harmonic radiation from the transmitter(s) is also attenuated.

Inside the coupler are eight silver-plated aluminum tunable cavities. When properly tuned, each cavity is a 1/4-wavelength, shorted coaxial element. The cavities are aperture-coupled in groups of two forming four dual-cavity tunable tandem filters. Adjustable tuning slugs in the cavity side-walls permit compensation for minor irregularities in the cavity resonance curve. The outputs of the four filters are coupled to a common junction at the input of a combining network and is the output connector for the antenna transmission line.

VHF multicouplers are available commercially and provide high selectivity by use of cavity resonators. UHF multicouplers are standard Navy equipment and operational facilities are augmented in such multicoupler arrangements as the CU-691/U. This equipment has a monitor-coupler assembly inserted in each input type N coaxial connector and the input to the tandem filter. The coupler assembly develops direct-current (DC) voltages proportional to the forward and reflected wave components existing on each line. The DC voltages are supplied to the meter circuit via the function selector switch. Calibrating resistors, selected by the switch, derive meter readings from the developed DC voltages which indicate forward power and standing wave. (SWR) The meter readings are useful for tuning the filters and for monitoring line conditions during operation.

(3) Antennas. VHF/UHF antennas may be of several available types and figures 11-18 and 11-19 illustrate several of these antennas. In figure 11-18, the large cylindrical housing is the weatherproof cover of the AS-1018/URC antenna used in the frequency range of 225-400 MHz. It is vertically polarized with a gain of 5 dB above an isotropic source. It has an input impedance of 50 ohms with a minimum VSWR of 2.0:1.0. Its horizontal radiation pattern is omnidirectional to within ± 1.0 dB throughout its 225-400 MHz frequency range. The antenna beam is tilted upward to place the lower half-power point on or below the horizon.

The second antenna in the figure operating in the frequency range of 225-400 MHz is the vertically stacked antenna array, AS-768/GR. It has a circular radiation pattern in the horizontal plane with the point of maximum radiation four degrees above the optical line of sight. It consists of 16 center-fed dipoles mounted vertically, with four dipoles at each level. The four dipoles are mounted on circular antenna plates and are 90 degrees apart. Each set of four dipoles is displaced 45 degrees in order to give complete antenna coverage for 360 degrees. The RF power supplied to the antenna is fed through impedance-matching coaxial transformers and feed lines and antenna plate feeds to the dipoles. The input impedance is nominally 50 ohms at 300 MHz with a maximum VSWR of 2.1:1.0.

Both the AS-1018/URC and AS-768/GR are used for long range gapless coverage of aircraft communication. Characteristics of these two antennas are realized when there is a separation of approximately 40 feet between them and other vertical metal objects.

The third antenna, NT-66095, in figure 11-20 is the small vertical rod suspended below and to the right of the AS-1018/URC antenna. The antenna broad band dipole antenna used for transmitting or receiving in the frequency band of 100-156 MHz. It is unbalanced with respect to ground. The characteristic impedance of the basic dipole is 72 ohms, but due to the use of a stepped feedline inside the horizontal support housing, the impedance presented to the coaxial cable is a nominal 52 ohms.

Figure 11-19 presents two antennas used for transmitting or receiving vertically polarized radio waves at frequencies from 220 to 400 MHz. They are the AT-150/GRC and the AS-390/SRC, which are primarily used for local circuits out to 25 miles. The AT-150/SRC is a broad band, coaxial dipole antenna, balanced with respect to ground and has a nominal input impedance of 52 ohms. The AS-390/SRC is a broad band coaxial stub antenna with a nominal input impedance of 52 ohms and is unbalanced with respect to ground. The radiation pattern of both antennas is similar to that of a conventional dipole.

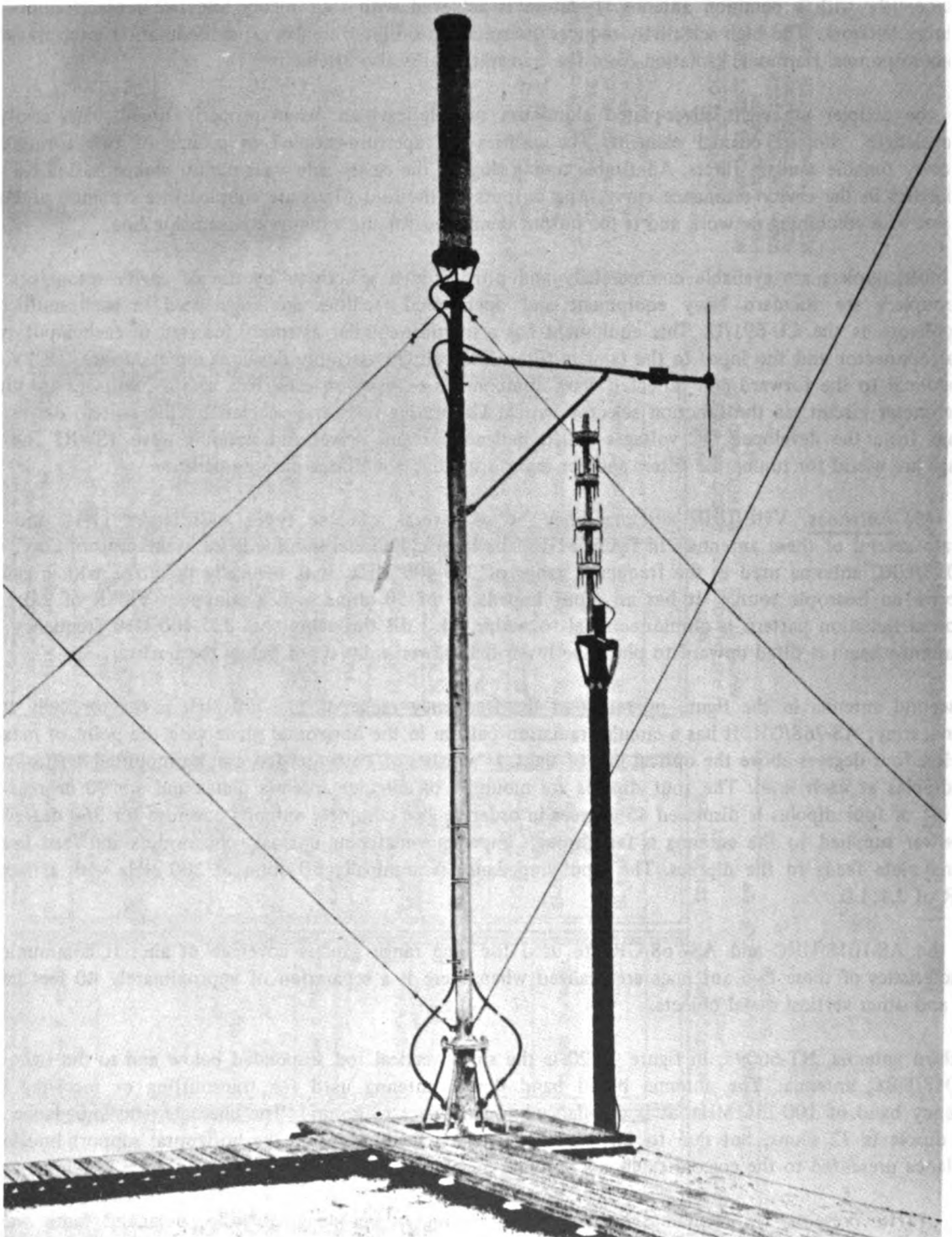


Figure 11 - 18. Typical VHF/UHF Antennas

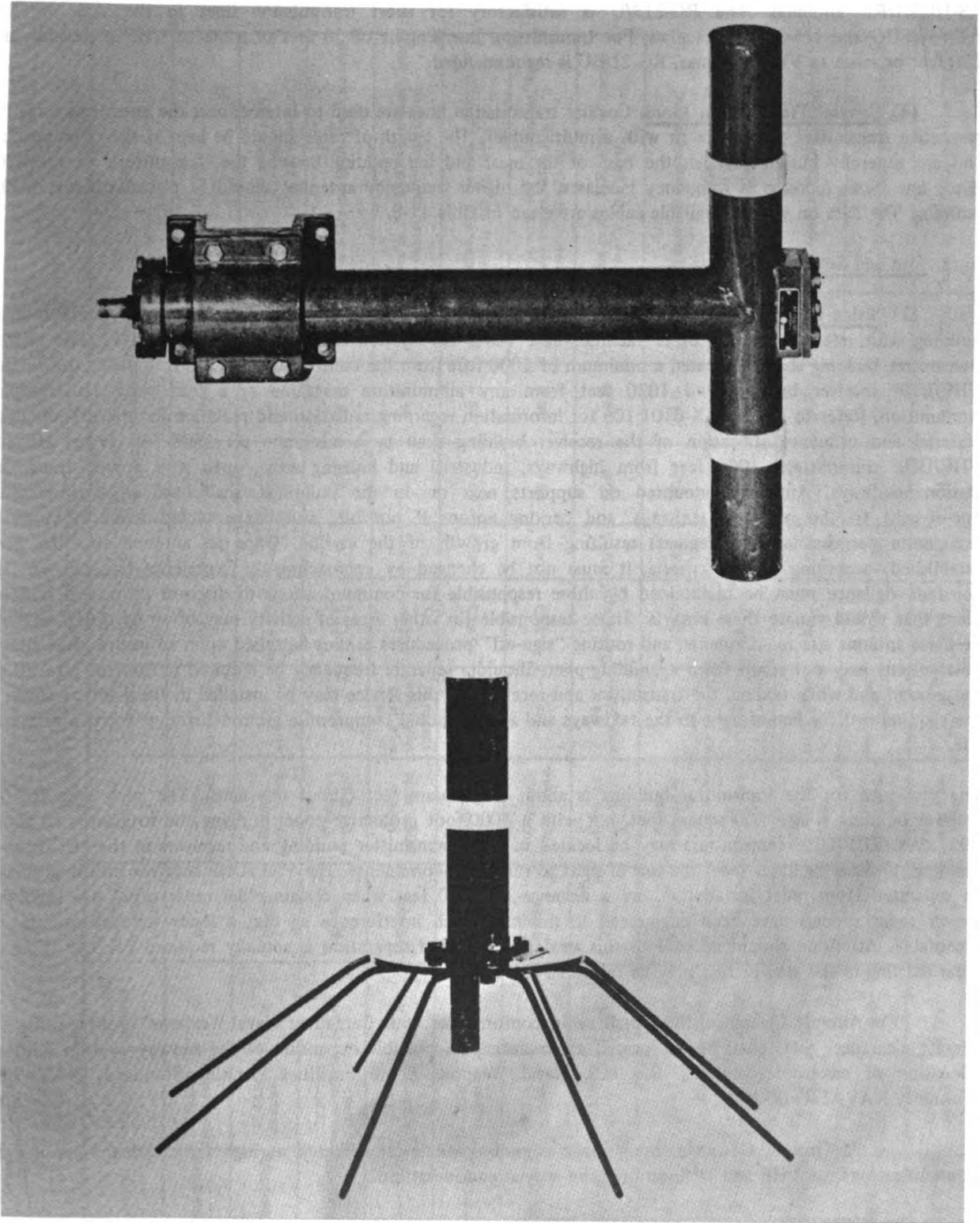


Figure 11 - 19. Typical UHF Antennas

All of these antennas are designed to operate with a coaxial cable transmission line having a nominal impedance of 50 ohms, such as RG-213/U and RG-218/U. The RG-218/U is recommended for use with the AS-768/GR and AS-1018/URC antennas. The RG-213/U is satisfactory for short transmission lines to the AS-390/SRC, AT-150/SRC and NT-66095 antennas. For transmission line lengths of 50 feet or more to UHF antennas, and 100 feet or more to VHF antennas, RG-218/U is recommended.

(4) Coaxial Transmission Lines. Coaxial transmission lines are used to interconnect the antennas with the respective transmitter or receiver or with a multicoupler. The length of cable should be kept as short as possible and are generally buried between the base of the mast and the building housing the transmitters or receivers. Since line losses increase as frequency increases, the higher frequency antennas should be placed closest to the building. The data on various available cables are given in table 11-8.

c. Site and Structural Criteria.

(1) Siting Factors. Criteria for location of the VHF/UHF transmitter building and the VHF/UHF receiver building with reference to the other facilities at a Naval Air Station is illustrated in figure 11-1. The remote transmitter building shall be located a minimum of 1000 feet from the control tower, 1500 feet from the remote VHF/UHF receiver building and 1000 feet from any ammunition magazine or a road used to transport ammunition. Refer to NAVELEX 0101,106 for information regarding radiation and radiation hazard effects upon material and ordnance. Location of the receiver building shall be a minimum of: 1500 feet from HF and VHF/UHF transmitters; 1000 feet from highways, industrial and housing areas, open wire power lines, and station roadways. Antennas, mounted on supports near or on the buildings, shall have an unobstructed line-of-sight to the runways, taxiways, and parking aprons if possible, and be protected from obstruction (maximum permissible: two degrees) resulting from growth of the station. Once an antenna site has been established, according to this criteria, it must not be changed by encroachment. Experience has shown that constant vigilance must be maintained by those responsible for communications to discover proposed building plans that would violate these criteria. Those responsible for other areas of activity may often be quite unaware of these antenna site requirements, and routine "sign-off" procedures cannot be relied upon to insure that sizable obstructions may not result from a building plan. Should a separate frequency be required to control aircraft on the ground and while taxiing, the transmitter and receiver for this service may be installed in the control tower if the requirement for line-of-sight to the taxiways and aprons should compromise ground coverage from a common site.

The plot area for the transmitter building is about 200 square feet (about one acre). The plot area for the receiver building is also 200 square feet, but with a 1000-foot protective zone, bringing the total area to about 102 acres. VHF/UHF transmitters may be located in a HF transmitter building and receivers in the HF receiver building, if these facilities meet the line-of-sight to runway requirements. The VHF/UHF receiver building should be separated from radar installations by a distance of 1500 feet when certain older radar types are involved. Newer radar models have been engineered to minimize such interference so that a lesser separation may be acceptable. Attention should be paid to this to determine what separation is actually required for the types of radar existing in the area or that may be relocated there.

o Aircraft Clearance. Sites shall be in conformance with Bureau of Naval Weapons' requirements for aircraft clearance. Sites shall be so located as to anticipate possible expansion of the runway system without relocation of electronic facilities. See U.S. Naval Weapons Shore Facilities Planning Standard, NAVWEPS (Formerly NAVAER) 00-100-505.

o Air-Ground Coverage. Long range communications are effected at high frequencies. Line-of-sight communications use VHF and UHF and require special consideration.

Criteria for VHF/UHF communication installations at air stations are to establish a vertical pattern lobe structure to achieve maximum gapless coverage suitable for air-ground communications. A compromise height for UHF antennas has been established at 35 feet above average ground level. The height of VHF antennas above average ground level should not exceed 90 feet. These installation criteria apply to receiving as well as transmitting antennas; both for roof-top and pole mounting.

Table 11 - 8. RF Cable Data Tabulation

JAN type	Inner conductor	Dielectric material γ	Nominal diameter of dielectric (inch)	Shielding braid	Protective covering γ	Nominal over-all diameter (inch)	Weight (lb/ft)	Approximate impedance (ohms)	Nominal capacitance (uuf/ft)	Maximum operating voltage volts(rms)	Remarks
RG-12A/U	7/26 AWG tinned copper	A	0.285	Copper, single braid	IIa with armor	0.475	---	75.0	20.5	5,000	Similar to RG-11A/U but with armor.
RG-35B/U	.1045 in. copper	A	0.680	Copper, single braid	IIa with armor	0.945 (max)	0.480	75.0	21.5	10,000	Large size, high power, low attenuation, video and communication cable.
RG-59B/U	0.230 in. copper-covered steel	A	0.146	Copper, single braid	IIa	0.242	---	75.0	21.0	2,300	General purpose, small size, video cable.
RG-65A/U	.1045 in. copper	A	0.680	Copper, single braid	IIa with lead sheath and special ar.	1.565 (max)	2.910	75.0	21.5	10,000	Same as RG-94A/U with special armor for subterranean installation.
RG-213/U	7/.0296 in. copper	A	0.285	Copper, single braid	IIa	0.405	0.120	50.0	29.5	5,000	Medium size, flexible cable. Formerly RG-8A/U.
RG-218/U	.195 in. copper	A	0.680	Copper, single braid	IIa	0.870	0.491	50.0	29.5	11,000	Large size, low attenuation, high power transmission line. Formerly RG-17A/U.
RG-219/U	.195 in. copper	A	0.680	Copper, single braid	IIa with armor	0.945 (max)	0.603	50.0	29.5	11,000	Same as RG-218/U but with armor. Formerly RG-18A/U.
RG-284/U	.220 in.	A & air	0.795	Copper corrugated tube	NA	1.005	0.41	75.±2.	15.0	1480	7/8 Nominal flexible cable.
RG-286/U	4.30 O.D. .360 I.D.	A & air	1.57	Copper corrugated tube	NA	1.830	0.72	75.±2.	15.1	2,720	1 5/8 Nominal flexible cable.
RG-289/U	.82 O.D. .74 I.D.	A & air	2.96	Copper corrugated tube	Vinyl jacket	3.75	3.0	75.±2.	14.7	4,700	3 1/8 Nominal flexible cable.
RG-290/U	4.3 O.D. .36 I.D.	A & air	1.57	Copper corrugated tube	Polyethylene jacket	1.99	0.8	75.±2.	15.1	2,720	Same as RG-286/U except jacketed.
RG-305/U	.430 O.D. .36 I.D.	F & air	1.57	Copper corrugated tube	Polyethylene jacket	1.99	0.8	75.±2.	14.4	2,720	Same as RG-290/U except Teflon

A - Polyethylene F - Teflon IIa - Noncontaminating synthetic resin.

Antennas mounted in close proximity, such as on a yardarm, shall be spaced at a minimum of 10 wavelengths, horizontally and vertically, from other antennas.

There is an optimum ground station antenna height for use in typical air-to-ground VHF/UHF communication systems. When antennas lower than this optimum are used, the maximum distance range is reduced at all aircraft altitudes. When antennas higher than this optimum are used, the interference between the direct and ground-reflected waves causes gaps to occur in the coverage with increasing frequency and this in turn reduces the maximum distance range for satisfactory communication.

Figure 11-20 is provided to show the maximum ground station antenna height, h_{1m} , for gapless over land air-to-ground communications up to the aircraft altitude, H_m . These curves are based on compiled data contained in a report of the Department of Commerce concerning Gapless Coverage in Air-to-Ground Communications at Frequencies Above 50 MC, (GRPL-6-4, 28 March 1951).

In the use of this graph, it is assumed that a six dB communication system attenuation which includes that caused by the length of the propagation path within the confines of the radio horizon will provide satisfactory communications. Calculations are also made for 12 dB attenuation. From the graph, it can be determined that at 200 MHz, the maximum tower height for gapless coverage within the range of normal 12 dB attenuation, is approximately 30 feet for altitudes up to 40,000 feet. At 300 MHz, to obtain the same coverage, a tower height of 15 feet or less is indicated.

Considering the fact that solid coverage at the shorter ranges is usually more important operationally than an increase in the maximum distance range, calculations have been made of the maximum ground station antenna height, h_{1m} . These calculations will ensure gapless communications out to the maximum distance range at all altitudes less than a specified value, $H_m = 10,000$ feet, 25,000 feet, and 40,000 feet. Figure 11-20 shows these values of h_{1m} as a function of the radio frequency throughout the range of 100 to 1000 MHz. It is interesting to note that there should be no gaps in communications at frequencies below 118 MHz regardless of the height of the ground station antenna.

Additional information on this subject may be obtained by referring to Proceedings of the I.R.E., May 1952, concerning Service Range for Air-to-Ground Communications at Frequencies above 50 MC, by R. S. Kirby, J. W. Herbstreit, and K. A. Norton.

(2) Structural Factors

(a) Buildings. A standard building is shown in figure 11-21. It is to be used for either transmitters or receivers. The prescribed 1500-foot separation between the transmitter and receiver buildings provides a location for a common emergency power supply housed in a building near the transmitter building. Figure 11-22 shows the interior of a typical transmitter building, and figure 11-23 shows the interior of a typical receiver building.

“General Criteria for Buildings” are given in a chapter with that title, in NAVELEX 0101,102. This document also includes lists of Navy publications dealing with all phases of building construction. That chapter deals with building features applicable particularly to communication buildings, such as ceilings, floors, cable ways, fire protection, lighting, battery room, and environmental control.

(b) Antennas. Antennas may be mounted directly upon the building roof or placed on top of masts erected to provide unrestricted coverage. Height limitation for UHF antennas is 35 feet above the coverage area. VHF antenna height limitation is 90 feet with consideration being given to aircraft clearance requirements. Refer to chapter 1 for criteria concerning air-ground coverage.

d. Installation Criteria

(1) Equipment Mounting. The transmitters, receivers, amplifiers, and multicoupler are mounted on racks, generally in two facing rows, with adequate spacing being provided both between the rows and behind them (see figures 11-21, 22, and 23).

CALCULATED FOR A SMOOTH SPHERICAL EARTH & THE AVERAGE
 ATMOSPHERE AT WASHINGTON, D.C.
 AIRCRAFT TRANSMITTER POWER 6 WATTS; GROUND STATION RECEIVER
 SENSITIVITY $0.18 \mu\mu$ WATTS; AIRCRAFT & GROUND STATION ANTENNAS
 HALF-WAVE VERTICAL DIPOLES

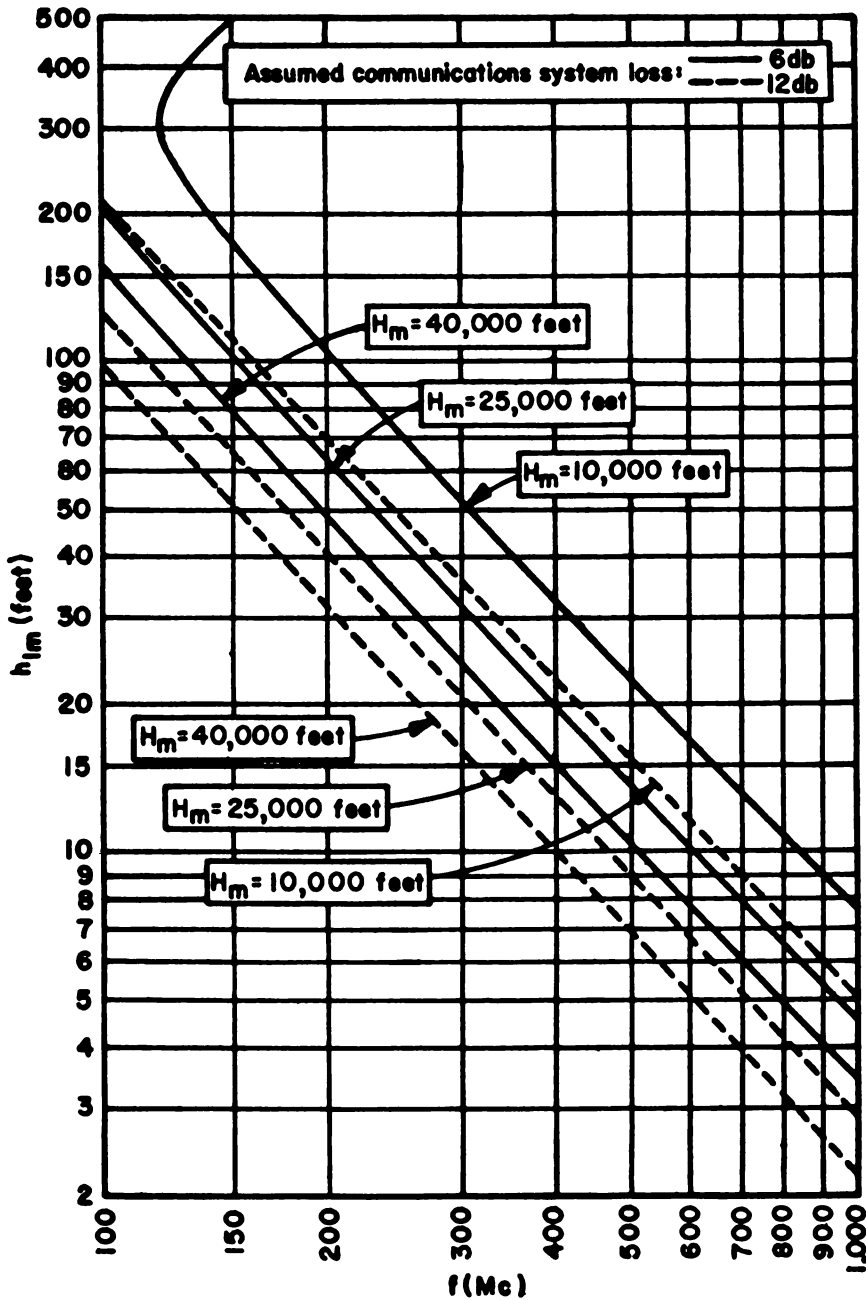
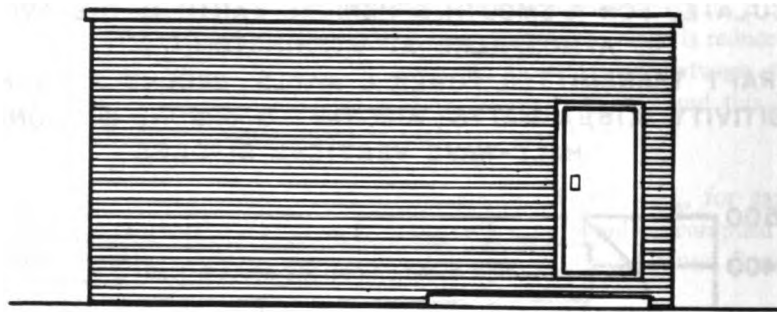


Figure 11 - 20. Antenna Height, Air Ground Propagation



ELEVATION VIEW

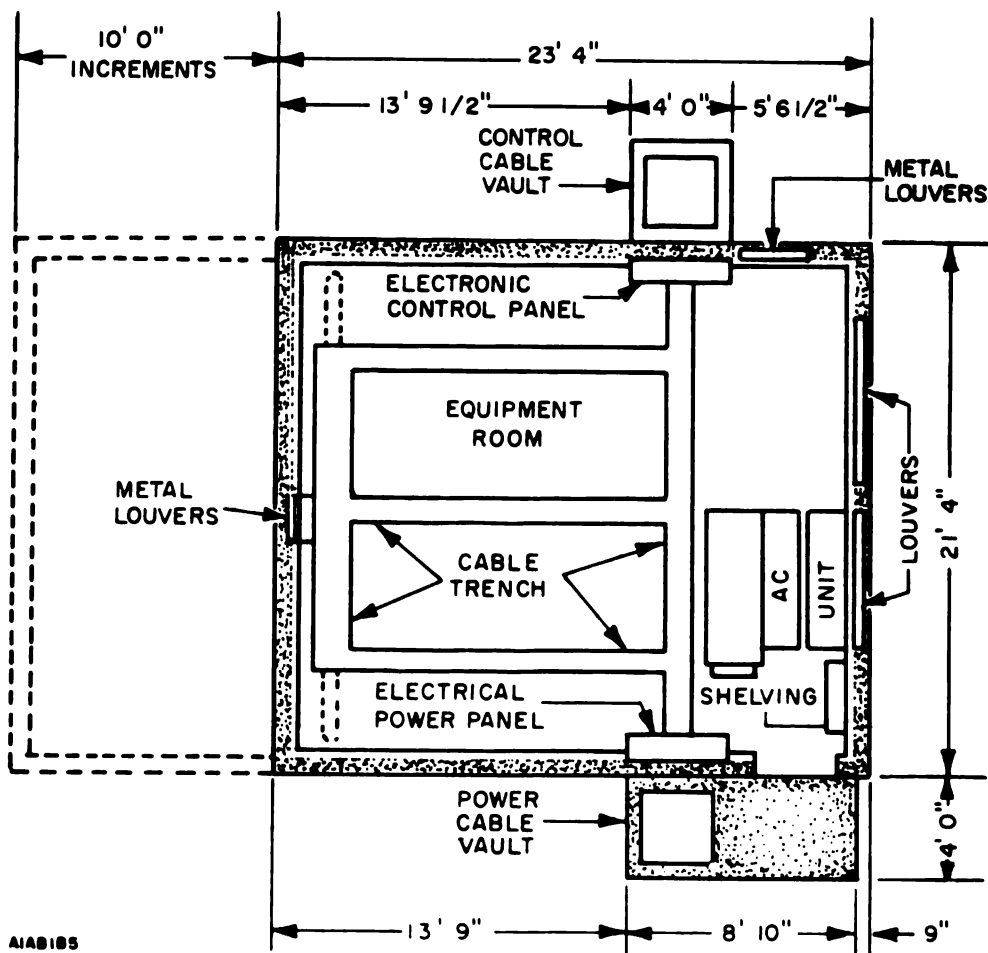


Figure 11 - 21. Floor Plan VHF/UHF Communication Building, NAS

(2) Audio and Control Wiring. If a cable is used to interconnect the control tower and the VHF/UHF transmitter or receiver buildings, it will

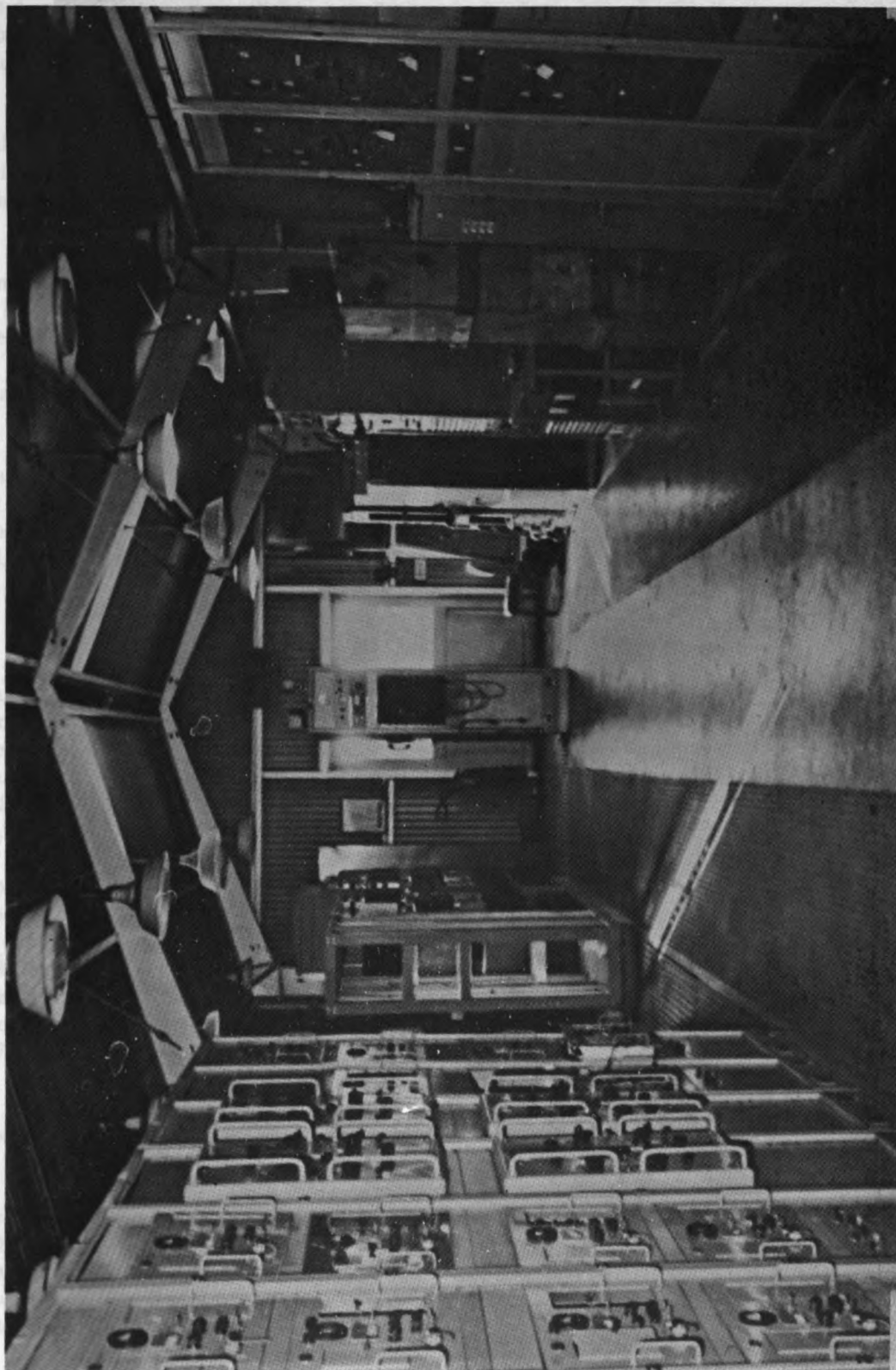


Figure 11 - 22. Interior, Typical VHF/UHF Transmitter Building

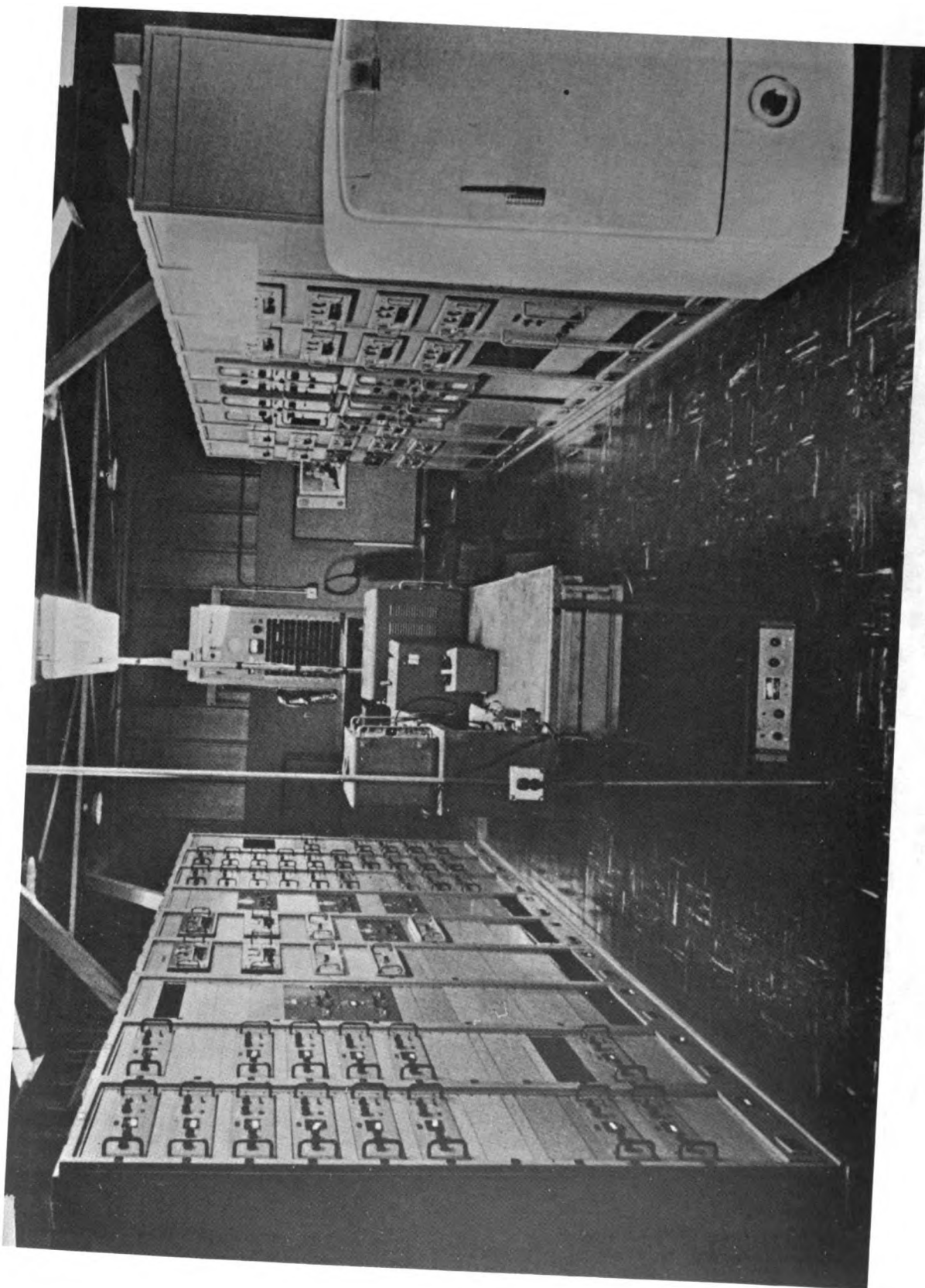


Figure 11 - 23. Interior, Typical VHF/UHF Receiver Building

(2) Audio and Control Wiring. If a cable is used to interconnect the control tower and the VHF/UHF transmitter or receiver buildings, it will terminate at an intermediate distribution frame (IDF). This may be mounted on the patch cabinet which also provides test equipment. Full details on distribution frames, patchboards, and wiring methods are provided in NAVELEX 0101,102. In case that a microwave radio communications control link is used, the link equipment will terminate on the IDF in a similar manner.

(3) RF Wiring. VHF/UHF transmitting or receiving equipment is interconnected with the antennas using coaxial cable, with a 50 ohms nominal impedance. Table 11-8 gives data on various types of coaxial cable. In most installations the cable shall be buried from 12 to 36 inches underground. Figure 11-24 shows a typical receiving antenna field, with buried coaxial cable between the receiver building and the various antennas.

(4) Antennas. VHF/UHF antennas are generally mounted on poles around the transmitter or receiver building. The UHF antennas are usually mounted closer to the building than the VHF antennas, to keep the cable lengths shorter for the higher frequencies. Figure 11-24 shows a typical arrangement for a VHF/UHF receiver layout.

Installation procedures are covered in detail in the appropriate technical manuals.

e. Operation and Maintenance Procedures. Attended operation is the standard practice for the VHF/UHF transmitter and receiver facilities. A preventive maintenance program is required. Maintenance procedures shall follow those specified in the appropriate technical manuals. If space is not available in the building, equipment may be removed to a station central repair facility. It is desirable to provide such repair facilities at both the VHF/UHF transmitter and receiver facilities.

11.2.5 Microwave Links

a. Operational Requirements. Microwave communications channels are sometimes required to link the NAS communications center with the receiver building, transmitter building, and any other locations that may be two miles or more from the communications center. Microwave communication links provide the necessary channels between locations. All information carried over the links is in unclassified form and primary flow is from the communications center to the transmitter building and from the receiver building to the communications center. In addition, two-way traffic is carried between locations for control and coordination of the communications resources.

Information is carried over the links in standard 4-kHz bandwidth audio circuits when the distance between locations exceeds two miles or when the transmission of DC signals is not reliable due to high RF radiation or background noise. DC signals are transmitted as VFCT tone groupings on 4-kHz audio circuits. The 4-kHz audio circuits may be provided by a local telephone company or by a Navy-owned microwave system. Except at overseas locations on foreign soil, a military-owned telephone system must be used rather than the local telephone company. The DCS transmission standards for the 4-kHz audio circuit are contained in DCAC 330-175-1.

b. System Configuration. Navy-owned microwave intersite links are wideband, line-of-sight, transmission systems. Frequency division multiplexing methods are used for the simultaneous transmission of information on 4-kHz bandwidth channels in either or both directions.

Microwave systems currently in use operate in the frequency bands of 1700 to 1850 MHz, 2200 to 2300 MHz, and 7125 to 8400 MHz and can accommodate up to 600 4-kHz channels. To ensure link reliability, most Navy installations have two continuously radiating transmitters and two operating receivers at each terminal. At a given microwave terminal either of the operating transmitters is fully capable of maintaining circuit continuity to the distant terminal, and either receiver is fully capable of receiving all information from the distant terminal.

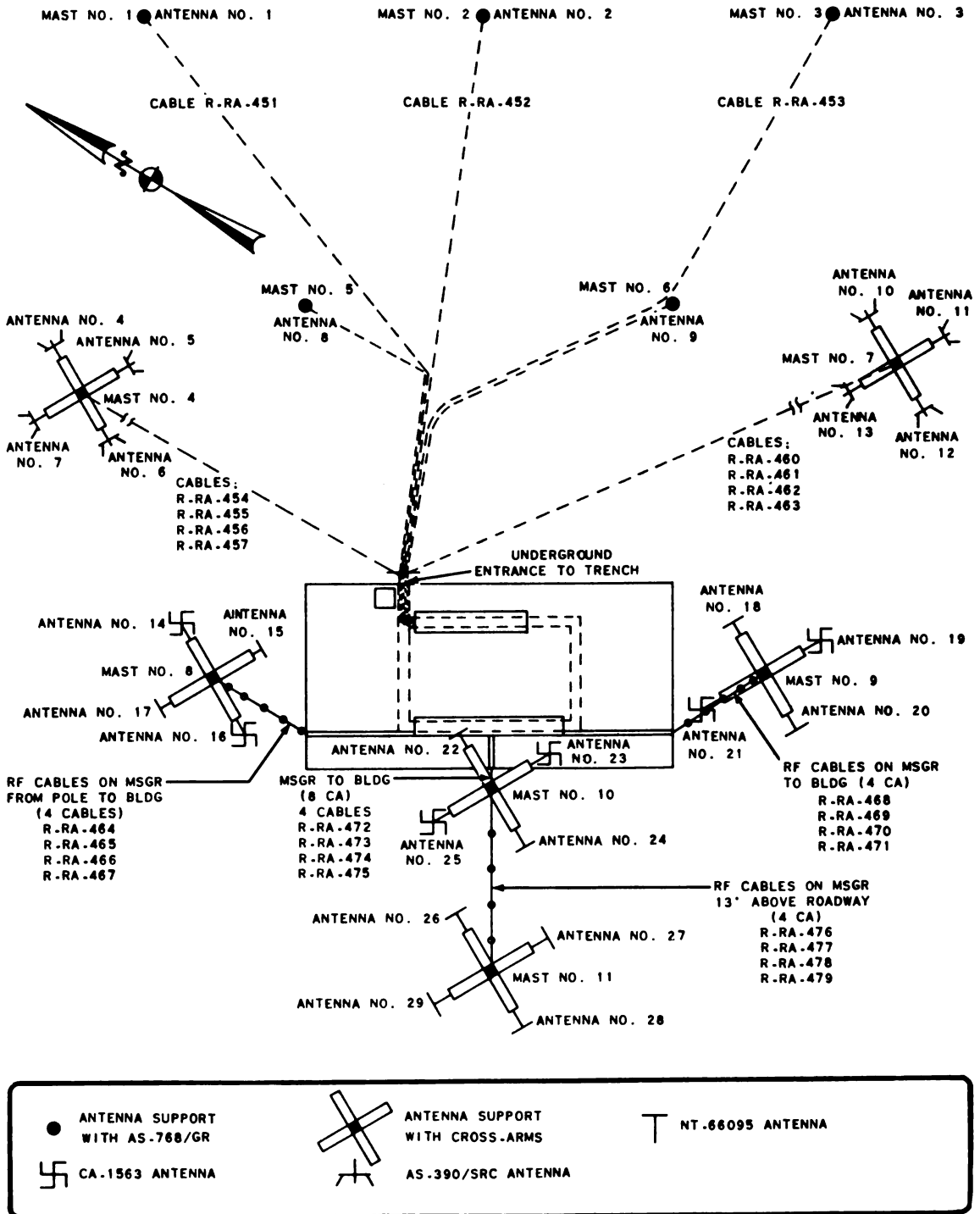


Figure 11 - 24. Receiving Antenna Field, Plot Plan

Frequency division multiplexing is used with microwave transmission links. Multiplex equipment combines 4-kHz voice-frequency channels into discrete portions of the microwave link baseband. The current standard multiplex set is the AN/UCC-4(V) which uses a lower-sideband modulation plan requiring 12 channel-carrier frequencies and each channel uses a different carrier. The lower sideband is selected from the channel modulator (see figure 11-25). The frequency and transmission level of the AN/UCC-4(V) group is 104.08 kHz at -20 dBmO. The AN/UCC-4(V) is adaptable to station expansion since the equipment supports from 12 to 60 communications channels and occupies four standard equipment racks. For each 60-channel expansion, two additional racks of equipment are required. The system can be expanded in this manner to reach a total system capacity of 600 channels.

c. Site and Structural Criteria. Microwave RF energy travels in a direct path from the transmitting antenna to the receiving antenna, however, it can be reflected from the surface of the earth or any other reflecting surface. The reflected energy often arrives out of phase with respect to the direct wave and may cause cancellation and serious fading of the received signal. Earth-reflected energy is particularly bothersome at operating frequencies between 1000 and 3000 MHz. Above 3000 MHz earth reflections become less serious since the small irregularities of the earth's surface such as rocks, become an appreciable part of the wavelength and scatter the energy instead of reflecting it. Because of this scattering, a strong reflected signal does not arrive at the receiving antenna. At frequencies above 10,000 MHz, raindrops or snowflakes can cause high attenuation of the signal since their diameters may be one-half of a wavelength or more at the frequency of the transmitted RF energy. The drops or flakes thus short-circuit the electric field and the energy is dissipated as heat. A water surface between transmitting and receiving antennas forms a poor microwave path because the smooth surface is an excellent reflector. Rough terrain makes a better microwave path than does a smooth surface since the surface irregularities refract and scatter the reflected energy. A high-low antenna siting technique is one method of causing the refracted energy to be reflected away from the receiving antenna when propagation is over water or smooth earth. Figure 11-26 illustrates this technique for both water and smooth earth.

When a direct line-of-sight cannot be selected, it is possible to use passive reflectors or back-to-back parabolas to alter the direction of transmission. A change of transmissions direction might be dictated to avoid interference with other services or to avoid an obstacle in the path between stations. A plane reflector can be used when the stations are located so that the signal will bounce off the reflector onto the receiving antenna. Plane reflectors arranged as shown in figure 11-27 may be used to provide a double bounce, but plant reflectors may not suffice when a very high ridge intercepts the beam. In this latter case, back-to-back parabolic antennas interconnected by a short length of waveguide or coaxial cable can be used. One antenna faces each station.

Due to the fact that microwave energy propagates like light energy, a clear line-of-sight path must exist between the transmitting and receiving antennas of a microwave system. Although the problem appears simple, it must be appreciated that over a path of 20 to 30 miles it is difficult for an observer to determine the relative elevations along the path. Several methods are available for obtaining a path profile, one way is to consult topographic maps published by the United States Department of the Interior Geological Survey.

Further path study will be required because the topographic maps do not show tall buildings or heavy timber growth or other factors that might influence the propagation of microwave energy. A path survey may also disclose that a large flat area shown on the topographic map becomes flooded during spring rains, creating a large water surface along the transmission path. Other methods of obtaining a path profile include surveying with normal surveying instruments or plotting the readings of a radio altimeter from a helicopter. An aneroid altimeter is used to maintain the helicopter at a fixed altitude while it is being flown over the proposed path. One relatively easy test technique is to transmit along the desired path and suspend receiving equipment below a helicopter in the proposed receiving antenna location. The height of the tower required to support the receiving antenna can be determined by locating the strongest signal. A detailed procedure for selecting the most desirable microwave propagation path and determining specific antenna height is part of the subject matter of a handbook planned for future publication.

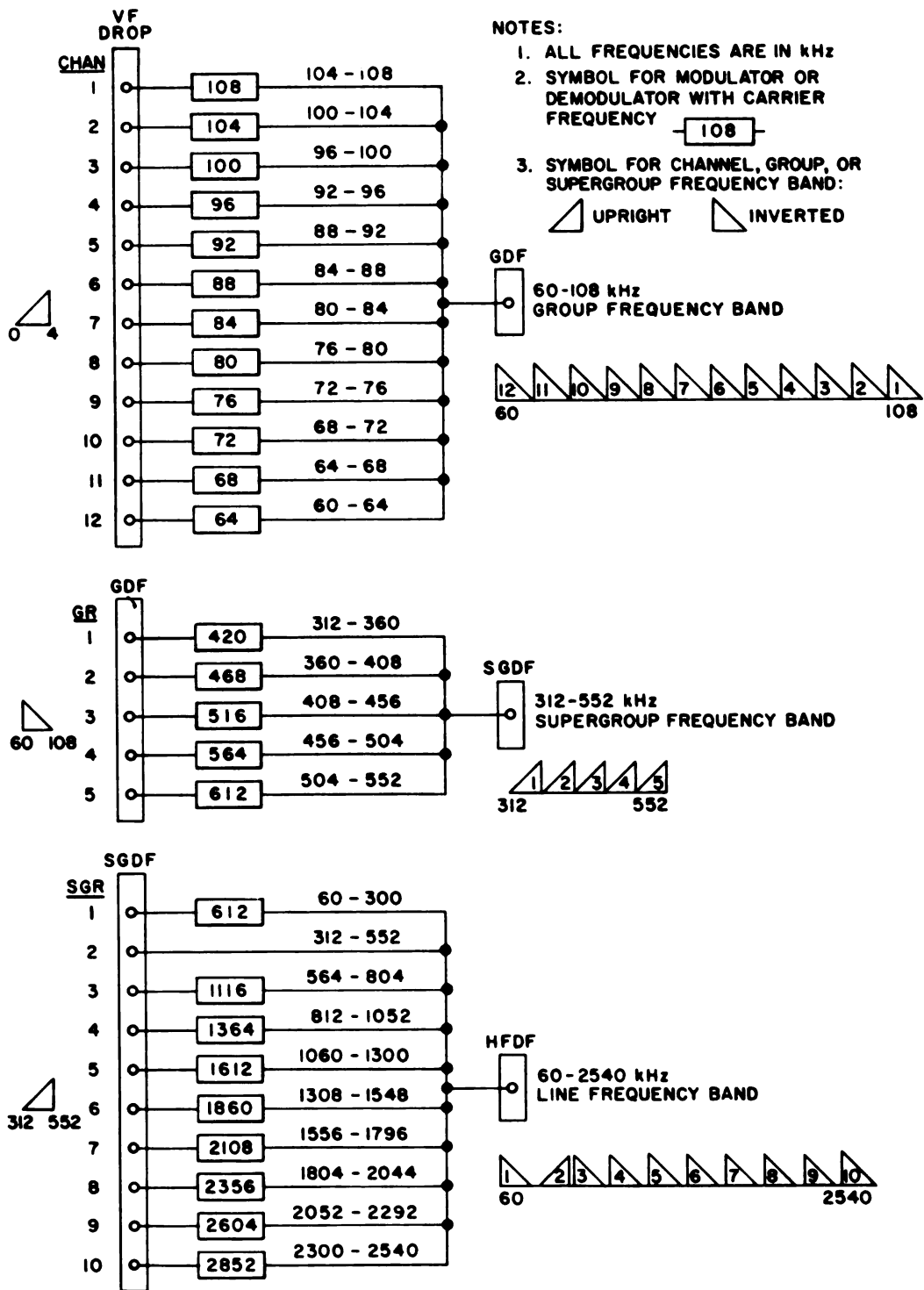


Figure 11 - 25. AN/UCC-4(V) Frequency Translation Plan

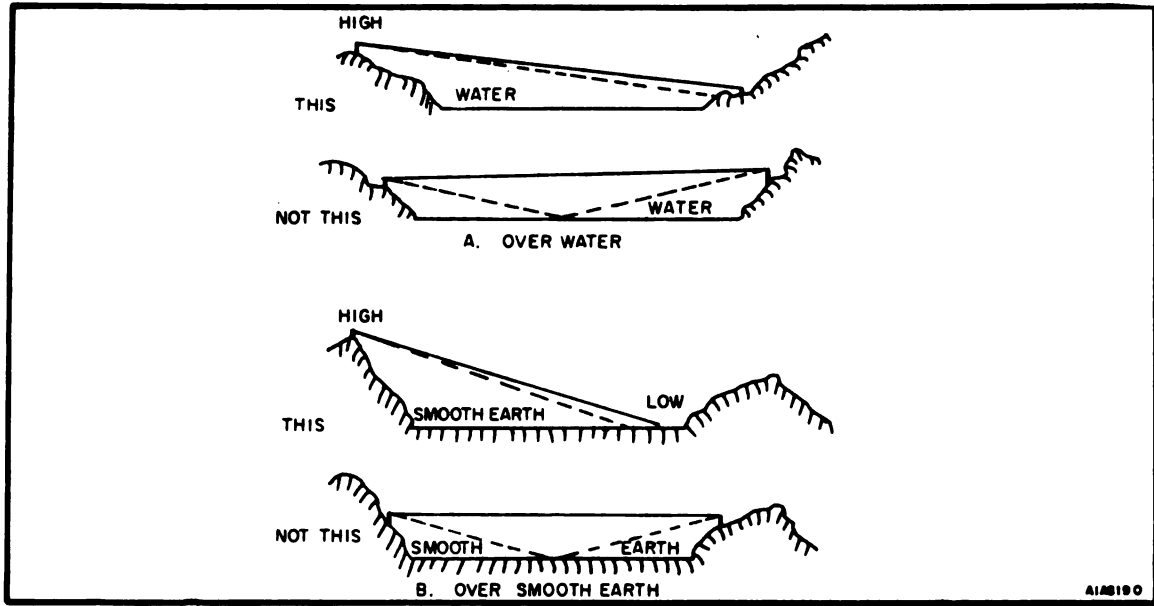


Figure 11 - 26. High-Low Antenna Siting Technique

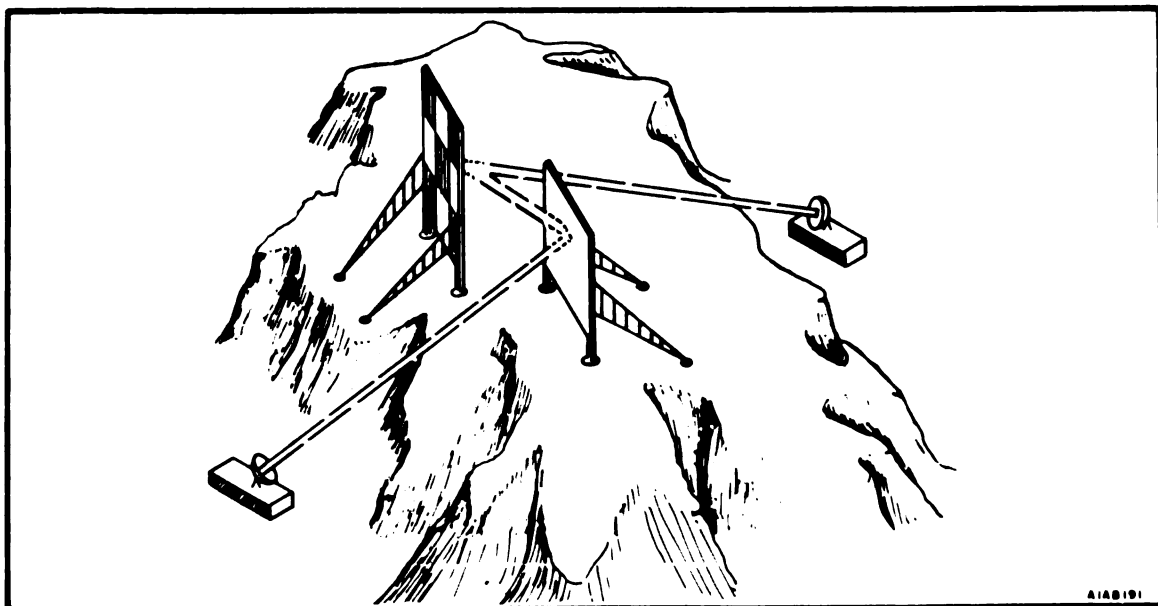


Figure 11 - 27. Passive Double Reflector

d. Installation Criteria. The following installation requirements have been established for microwave communication equipment including the AN/UCC-4(V) Multiplexing Set:

- o Batteries are to be installed in a separate room from all other equipment.

NOTE

Present day microwave systems used by shore stations are furnished a 48-volt DC rectifier charger unit with a floating lead-calcium battery plant connected across the power leads. The batteries will carry the system for 8 hours under full load during AC power failure and the charger unit will restore the batteries to full charge within 24 hours. During normal operation the batteries float on the line with the charger unit serving as the primary power source.

- o The battery room is to be supplied with its own ventilation intake and exhaust ports.
- o The central ventilation system supplying air to and exhausting air from the building may be used to service the battery room.
- o A ceiling height of 10 feet and floor space of 10 square feet should be programmed for each rack of equipment to ensure a sufficient maintenance and operational area.

NOTE

Most racks measure 90 x 23-1/4 x 20-1/8 inches and require a minimum height clearance of 8 feet and a front clearance of 48 inches.

- o The room temperature should be maintained at 77°F ±18° and the relative humidity should not exceed 80%.
- o The set may require RF shielding if it is located near high power radio transmitting equipment. However, the presence of radiated electromagnetic fields up to the following limits are permissible.

14 kHz to 2.6 MHz:	0.1 volt/meter
2.6 MHz to 100 MHz:	0.3 volt/meter
100 MHz to 10,000 MHz	1.0 volt/meter

- o The soil at any site under consideration should be analyzed carefully before a tower is installed. Since the antenna beam is narrow, tower movement due to soil deformation could decrease system reliability. Tower footings for fixed installations can be very costly in marshy or rocky soils.

e. Maintenance Procedures. Microwave systems are a highly reliable means of communication when properly designed and installed. Many factors enter into system reliability besides the power supply and equipment considerations. The most important of these is site selection. Since microwave propagation is essentially "line of sight" transmission, the path must be maintained clear of obstacles to obtain reliable operation.

Maintenance instructions for the electronic equipment including operational test procedures, trouble shooting, alignment and adjustment, and removal and replacement procedures are thoroughly covered in the technical manual. To assure dependable service, it is recommended that regular check-ups and routine servicing should be provided to maintain the equipment in good working condition.

11.2.6 Mobile/Transportable ATC Radio Equipment

a. General. Over a period of time, the Navy has provided a number of radio equipments for ATC use. These vary from a complete automotive vehicle with radio equipments for 6 channels and 2 controllers, to a trailer with 3 or 4 radio channels, to a single portable/mobile VHF/UHF radio set. These may be used as auxiliary systems to equip certain activities outside the control tower of an established NAS (such as LSO, etc.) or may be used as the principal means of ground/aircraft communications for a temporary operation. These radio equipments will be described in the order mentioned.

b. Mobile ATC Communications Central, AN/MRC-131(V)

(1) System Principles. This set provides a modified panel truck equipped with up to six radio channels for ground control of aircraft take-off and landings, or for other related purposes. It can be operated by two controllers (operators). A remote control enables one controller to operate at a moderate distance from the vehicle. Provision is also made to operate over 2-wire or 4-wire telephone system.

(2) System Configuration. This Mobile ATC Communications Central consists of a modified panel body truck configured to accommodate the radio sets listed:

1-AN/URC-35, a HF, SSB Set, 3-30 MHz frequency band, nominal output: 100 watts.

1-AN/URC-68 or -77, VHF-FM Set, 30-42 MHz or 132-150.8 MHz, 25 watts.

2-AN/ARC-101, VHF, AM Set, 116-149.5 KHz, nominal output 20 watts.

2-AN/ARC-51AX, UHF, AM Set, 225-399.0 MHz, nominal output 20 watts.

The mobile communication vehicle with various antennas supported by the truck is illustrated in figure 11-28. The interior view of the vehicle controls and meters and the ATC equipment for the two operators is shown in figure 11-29. They control only six channels. In figure 11-30, the rear view of the vehicle, with tailgate down, shows the radio equipment. Figure 11-31 shows a remote operator control set up on a tripod outside the truck. It is exactly like the two control units shown inside the truck in figure 11-29. In figure 11-32, the local control unit is shown. It controls only frequency on the two UHF sets and two VHF sets. This local control panel also includes a telephone control panel, a telephone dial, voltmeter, and a power control panel.

(3) System Operation. The Operator Control Unit (figure 11-33) allows the controller to operate up to six radio channels in a manner similar to that of a console of the Console Group, Communication Control AN/FSA-52(V). The six white circles represent switches to switch from loudspeaker (out) to headset (in). Each switch has a light which glows or flickers whenever the related receiver is receiving a signal. This serves as a monitor on outgoing transmissions as well as indicating to the controller that someone is calling on that channel. If the operator of the particular control unit has the transmitter of a certain channel in transmitting condition, his lamp for that channel will glow brightly while corresponding lamp(s) on other panels will glow at half brilliancy. The latter indicates to that operator that he is locked out, that is, he cannot assume control of that channel. However, he can hear everything on that channel. Next is a marking panel for temporary identification of the channels available to that controller. The six switches have three positions. In the down position the channel is OFF so far as that control panel is concerned. In the middle position, MONITOR, any operator can listen on that channel. To transmit and receive, the upper position of a switch is used. This places the transmitter under control of the controller's press-to-talk switch. The operator can monitor two or more channels simultaneously on his panel loudspeaker by placing the top "push-push" switches in the out position. He can readily identify the channel heard on the speaker by observing the receiver lights behind the top line of switches by noting one(s) producing a flickering light on the incoming speech. A dimmer control is provided by use of which the operator can control the brightness of the panel lights.

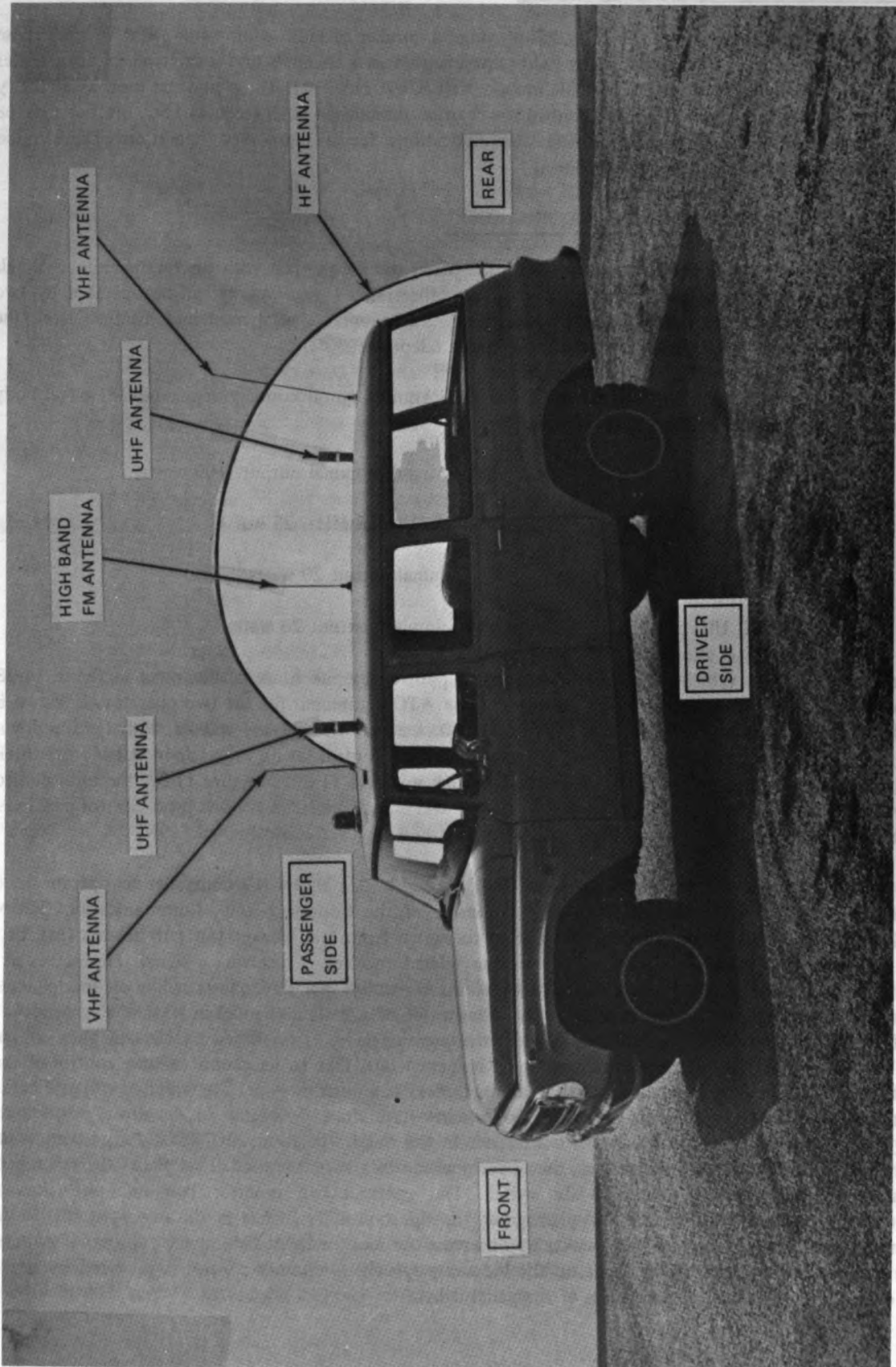


Figure 11 - 28. Mobile Air Traffic Control Communication Central, AN/MRC-131(V)

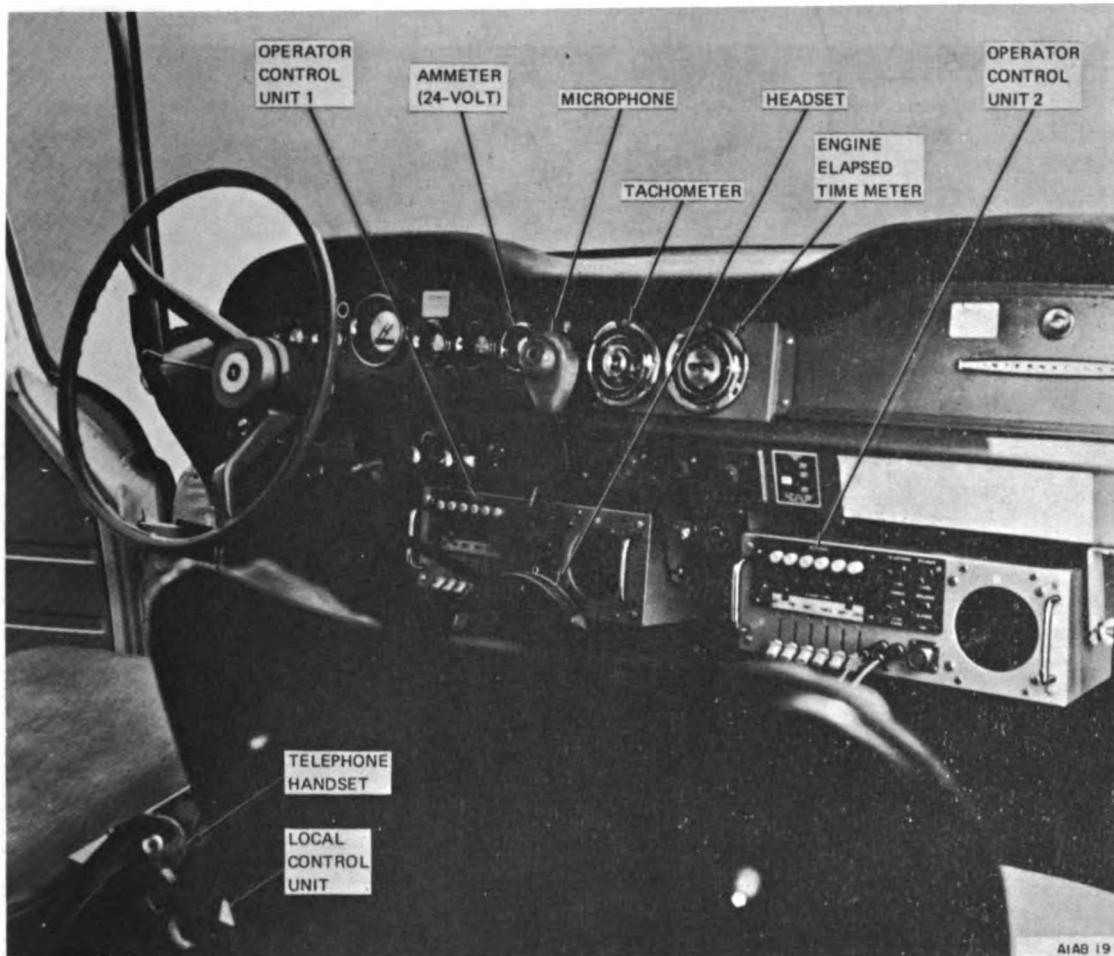


Figure 11 - 29. Front Interior View of AN/MRC-131(V)

The level of signals on loudspeaker and headset can be controlled independently by the two level controls. The speaker silence control allows the operator to silence quickly all signals that may be coming in on the speaker. The panel also mounts jacks for the headset and headphone and the microphone connector.

The site for the AN/MRC-131(V) should provide a 360 radius for radio transmission without shielding from any structural installation. If required, the set should be within reasonable distance of 115 or 230 volts alternating current input power and telephone communication wires.

c. Radio Set AN/GRC-164

(1) System Principles. The Radio Set AN/GRC-164 is a lightweight UHF AM portable/mobile transceiver capable of operating on three preset channels within the frequency range of 225 to 400 MHz. The radio set provides a power output of one watt for ground-to-ground or ground-to-air voice communication and is powered by 115 volt, 60 Hz, single phase, or 11 to 29 volt DC from external sources, or by internal re-chargeable

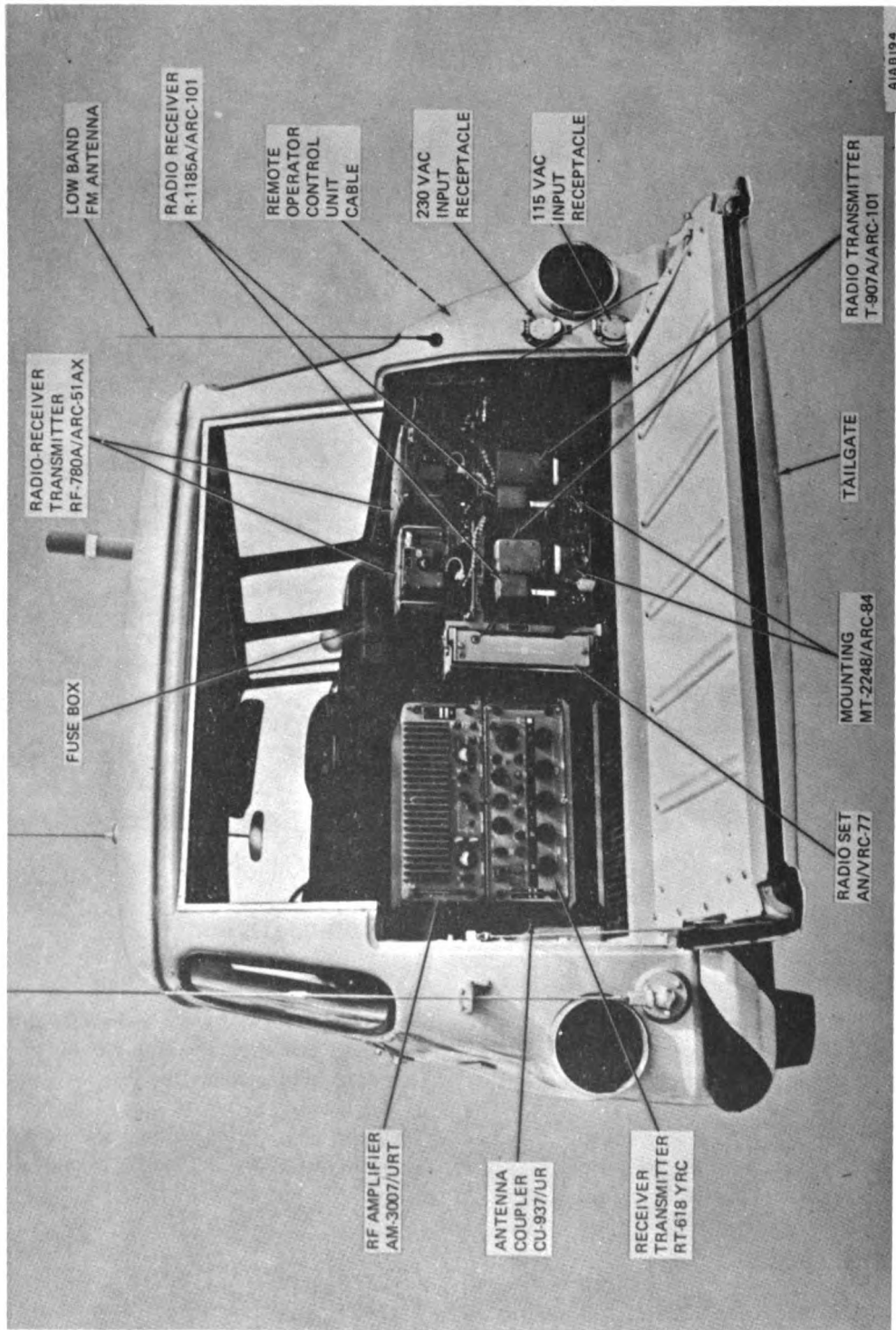


Figure 11 - 30. Rear Exterior View of AN/MRC-131(V)



Figure 11 - 31. Remote Operator Control Unit Installation

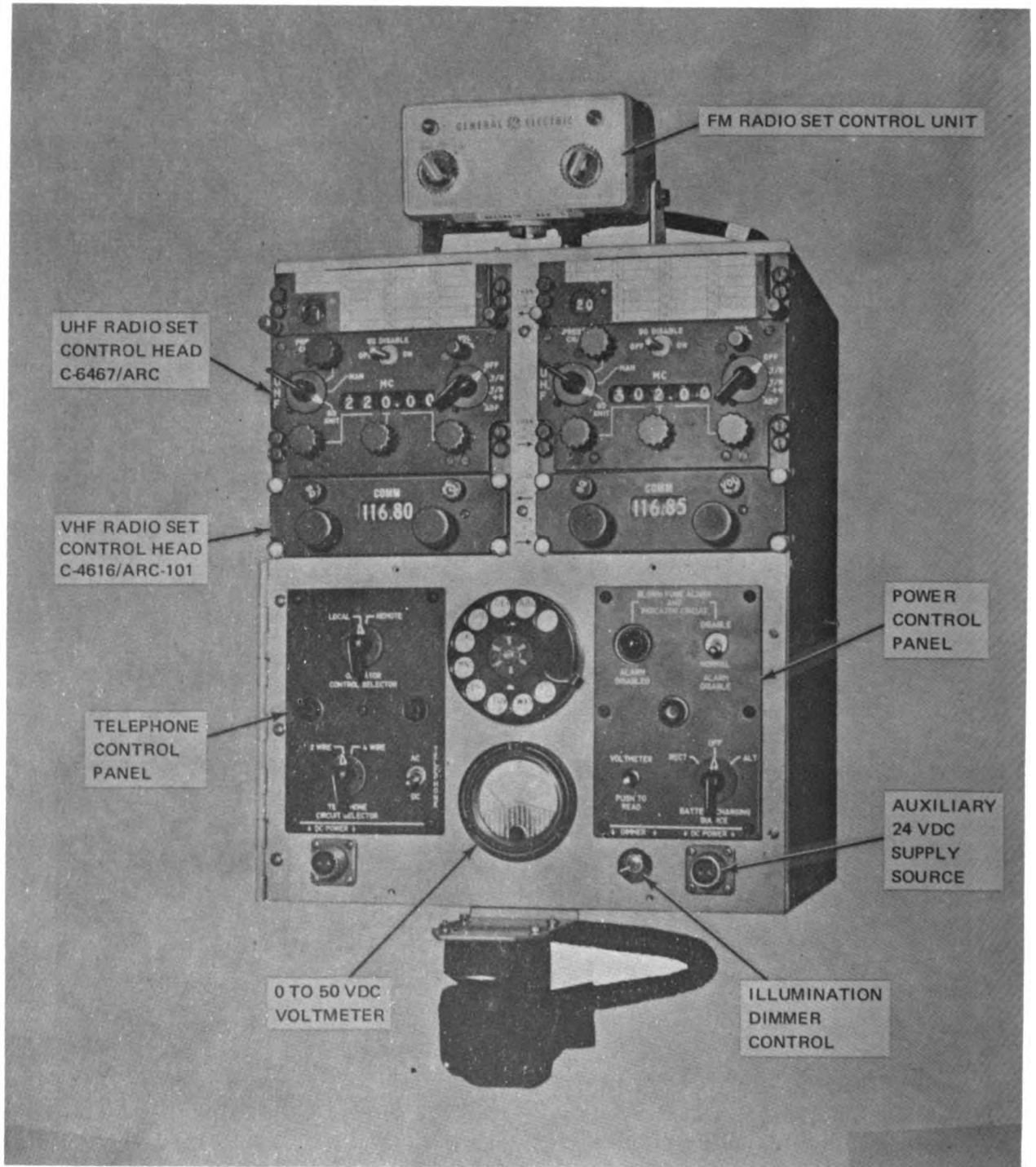


Figure 11 - 32. Local Control Unit Indicators and Controls

batteries. This set contains a mounting fixture which permits quick conversion from a portable operation to a vehicular or fixed base installation. This set is small enough to easily fit under the dashboard of most military vehicles.

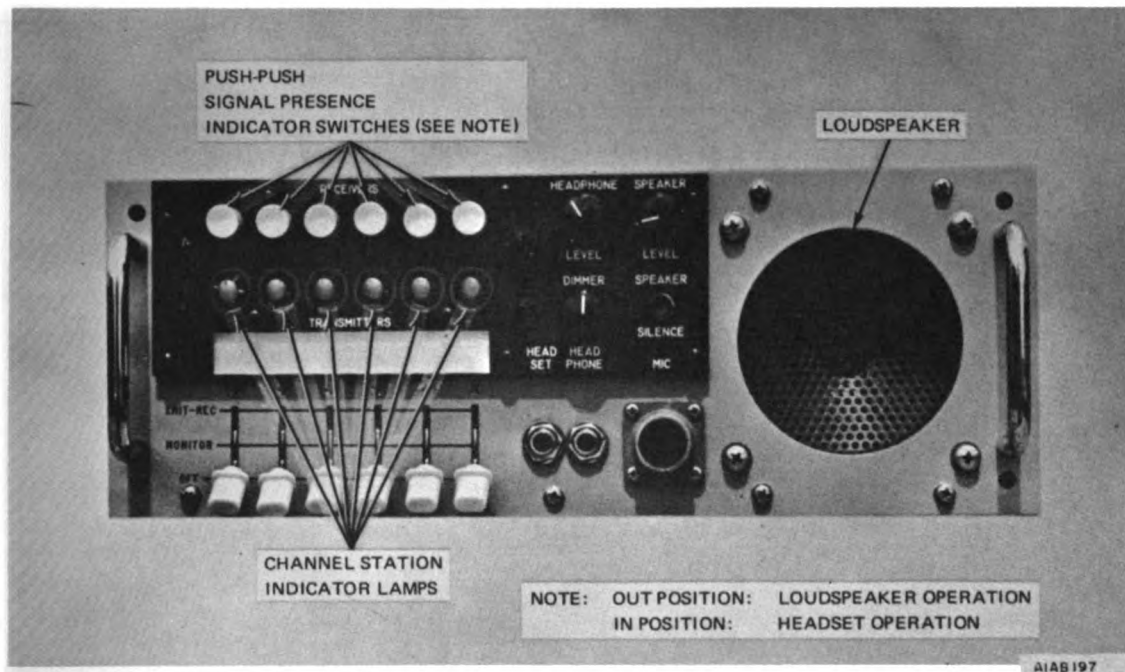


Figure 11 - 33. Operator Control Unit Controls and Indicators

(2) System Configuration. Figure 11-34 shows the radio set assembly at the top, the accessories kit below. The name of each item shown in this figure is listed below.

- Item 1. Tranceiver
- Item 2. Battery Assembly
- Item 3. Mounting Fixture
- Item 4. Accessory (Kit) Bag
- Item 5. Antenna
- Item 6. Microphone
- Item 7. Antenna Cable
- Item 8. AC Power Cable
- Item 9. DC Power Cable
- Item 10. Connector, Right Angle Coaxial

With the exception of an available power source and the selection and installation of six crystals, the radio set is a self-contained unit and no additional equipment items are required for operation.

The radio set requires a total of six crystals for operation. Three each are required for the transmit and receive mode of operation. Crystals are selected from the CR-83/U series.

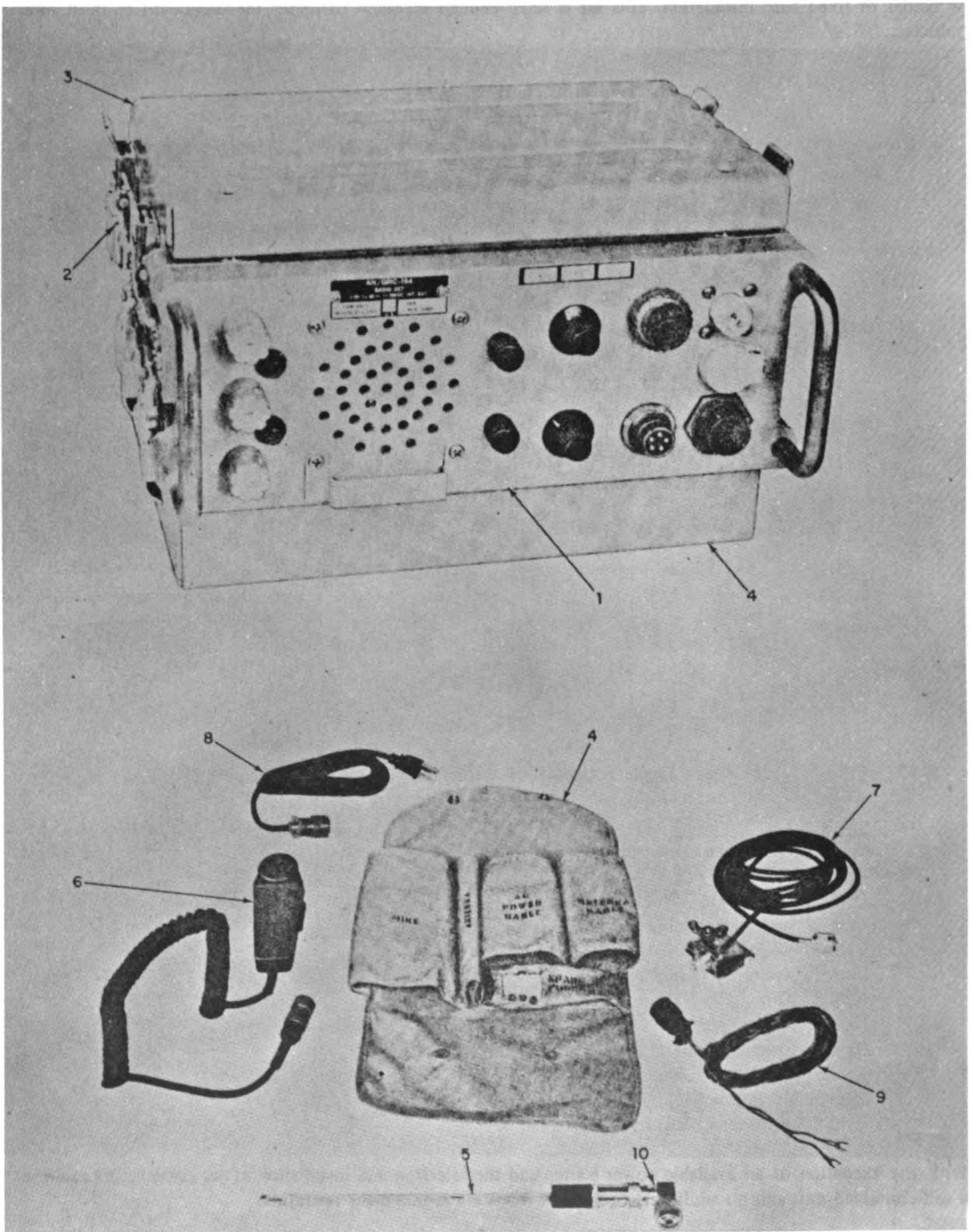


Figure 11 - 34. Radio Set AN/GRC-164 and Accessories Kit

(3) System Operation. All operating controls and indicators are located on the front panel of the radio set. After proper installation of the radio set, as per TM (NAVSHIPS 0967-376-0010), the frequency of operation is determined by the operator. Six crystals are required for three-channel operation; the six crystals are used on three pairs, each pair consisting of one transmit crystal and one receive crystal. To determine the crystal frequency the transmit crystal is chosen so that it is equal to one quarter the desired channel frequency and the receive crystal selected is 17.000 MHz above the transmit crystal frequency. In equation form, the calculation is as follows:

$$\text{Transmit Crystal Frequency} = \frac{\text{UHF channel frequency}}{4}$$

$$\text{Receiver Crystal Frequency} = \frac{\text{Transmit crystal frequency}}{+ 17.000 \text{ MHz}}$$

With the required crystals selected and installed, the sequence of operation consists of turning the equipment on, turning squelch to maximum (clockwise), and then adjusting squelch (counterclockwise) so that the receiver is just quieted with no signal, and adjusting the volume to the desired level. To transmit, the microphone push-to-talk switch is depressed; as the operator speaks into the microphone.

(4) Maintenance. Maintenance instructions, including performance test procedures, troubleshooting, alignment and adjustment, and removal and replacement procedures are covered fully in the Radio Set Technical Manual, NAVSHIPS 0967-376-0010.

CHAPTER 12

AIR TRAFFIC CONTROL FACILITIES

"In those volumes of air where the combination of air vehicle density, speed, visibility, or maneuvering rate is such that pilot applied rules and procedures cannot insure an appropriate level of safety, active ground-based control of air vehicle movement will be instituted." With the utterance of these words by the CAA (now FAA) and passage of the Federal Aviation Act in 1958 the air traffic control system in the United States was established.

The Federal Aviation Act of 1958 assigns responsibility for control of the navigable airspace of the United States to the Administrator, Federal Aviation Administration. The administrator in turn exercises this control through the National Airspace System which is the common network of the U.S. airspace, navaids, communications and air traffic control facilities and equipment. It also includes aeronautical information and charts, weather information, FAA manpower and material, and system components jointly shared with the military. It does not include the system operated by the military entirely for military purposes. Domestically, air traffic control facilities operated by the military are, in effect, extensions of the National Airspace System. Air traffic control services provided by the Navy and Marine Corps in the United States are for a specifically defined area arrived at by mutual agreement with the FAA. In foreign countries, similar arrangements for authority to control air traffic within sovereign airspace is a matter of formal agreement with the appropriate military or foreign government officials of the country involved.

The mission of Navy and Marine Corps air traffic control facilities is to provide for the safe, orderly and expeditious movement of air traffic. It includes aircraft movements on the airport surface, to and from the airport, within airspace where control jurisdiction has been delegated, to and from operating areas, and into and from the airways and jet routes. The complex of functions, equipment and personnel to provide this service comprises an Air Traffic Control (ATC) facility and is authorized by the Chief of Naval Operations to provide a required operational capability.

The airspace in which control jurisdiction is assigned to an ATC facility is specifically delineated in Letters of Agreement executed locally with FAA in accordance with OPNAVINST 3710.7E, dated 24 April 1970. Normally, this area of responsibility is for the terminal area in the immediate vicinity of the airport being served. However, in some cases air traffic control service may be provided for air operations in restricted, warning or other designated operating areas.

References 1 through 15 of Appendix B.5 should be used to supplement the information provided in this handbook on the subjects of operations, procedures, and equipment maintenance and inspection pertinent to the proper functioning of an ATC facility.

The type and amount of active ground-based control will vary with the nature of the problem in particular volumes of airspace, but will be primarily concerned with safety, and secondarily, with efficient movement of air traffic. To accomplish its mission at Naval Air Stations, the Navy ATC system has listed a number of ATC elements and navigational aids as standard NAS components. Most NAS will have one or more of these systems aboard, depending upon operational requirements.

Radar Air Traffic Control Center (RATCC)

Fixed GCA

Mobile GCA

VHF/UHF direction finders

Communication equipment

VHF omnirange (VOR)

Air surveillance radar installations

Radar beacons

VHF fan marker beacons

UHF omnirange (TACAN)

“H” omnirange facility, LF/MF homing, UHF homing

Instrument landing system

Ground-to-air communication equipments are provided on all air station facilities regardless of size. The quantity of receivers and transmitters and respective antenna size is determined by the station mission and air traffic density.

VHF omnirange (VOR) facilities are only included on naval activities upon the request of the FAA and with the approval of the CNO. This equipment would then be operated and maintained by Navy personnel, even though it is used only by civilian aircraft.

VHF fan marker beacons are generally used on large commercial airfields by civilian aircraft. Therefore, this equipment would only be installed at joint civilian-Navy airfields or large Naval Air Stations also serving as a commercial aircraft terminal. Operation and maintenance of the electronic equipment at a joint activity would be determined locally.

The following paragraphs detail four ATC facilities, ranging from the smallest to the largest, and will indicate which of the systems previously listed is required. The four ATC facility classifications, with their radar control capability are as follows:

- o Low density facility - for a traffic density of a few aircraft landings and takeoffs per hour.
- o Mobile GCA facility - for a traffic density of approximately 10-25 aircraft per hour.
- o Remoted GCA facility - for a traffic density of approximately 25-60 aircraft per hour.
- o Fixed maximum facility - for a traffic density of 60 or more aircraft per hour.

A summary of the aircraft landing systems used on NAS to train aircraft carrier pilots is also included.

12.1 RADAR CONTROLLERS

Each of the four ATC facilities to be described have different operational requirements, specific quantities of radar and communication equipment, and a variable number of radar controllers. The number of personnel required may vary from two to ten, or more, depending on the station traffic, the quantity of radar indicators available, and local task assignments. Five major functions are performed by the radar controllers; namely, approach control, arrival control, final or precision control, departure control, and accumulating and disseminating flight data. At low density air stations or during the late watch, some controllers may perform more than one function.

The Approach Controller has the responsibility of coordinating and controlling the movement of all instrument traffic within the ATC facility jurisdiction. He shall possess a facility rating and his general duties, in addition to such supplementary duties as may be assigned, are:

- o Monitor approach frequencies, communicate with aircraft arriving at a fix, verify aircraft position by means of his radar indicator, and hand-off aircraft to assigned arrival or vector controllers.
- o Issue air traffic control clearances and advisory information to aircraft under approach control jurisdiction.
- o When radar approach control is utilized, maintain radar surveillance of assigned area, provide radar separation between aircraft under approach control jurisdiction and other radar targets, monitor approaches and departures and provide radar assistance to air traffic as required.
- o Determine the interval to be used between successive approaches taking into consideration all aspects of the air traffic control situation, including weather, runway in use, reliability of navaids and other approach aids, reliability and adequacy of communication, types of aircraft under control, runway acceptance rate and any other factors which may affect operations.
- o Provide assistance and priority of services to aircraft in emergency situations, and initiate search for aircraft overdue.
- o Utilize any or all other operating positions necessary to assist in the control of air traffic.
- o Work closely with the arrival and departure controllers, precision controllers, tower personnel, and keep the supervisor or coordinator informed of air traffic conditions.

The Surveillance Controller is responsible for monitoring the ASR indicator at the arrival or departure position. In addition to possessing the basic FAA certification, he shall be a graduate of the GCA controller school and be qualified in the performance of his duties in accordance with local ATC facility operating instructions. His general duties are as follows:

- o Accept control of aircraft from the approach control and assume responsibility for the proper identification, control and separation of the aircraft until they have reached surveillance minimums or until they are turned over to the final controller.
- o Provide radar vectors to arriving and departing aircraft to ensure safe and expeditious movement of air traffic.
- o Monitor instrument approaches made on other facility navaids and advise pilots of deviation from normal approach paths, when required.
- o Provide radar assistance to aircraft in emergency situations.

The Final or Precision Controller is responsible for providing aircraft on final approach with aircraft position information regarding glidepath, runway centerline and distance from touchdown. The final controller, in addition to possessing the basic FAA certification, shall be a graduate of the GCA controller school and be qualified in accordance with local ATC facility operating instructions. His general duties are as follows:

- o Coordinate with arrival controller in identifying aircraft and accepting hand-overs assigned by the coordinator or supervisor.
- o Provide range, azimuth, and elevation data to assist the pilot in low visibility approach to the instrument runway in use.

- o Obtain and transmit wind conditions and weather information, and provide procedures for a missed approach.
- o Inform the approach controller of aircraft taking a wave-off and re-entering the holding pattern.
- o Monitor communications with the visual observer, and communicate with the control tower to obtain landing clearance information at specified distances from the end of the runway for aircraft in final approach.
- o Log time of aircraft release aircraft to ground control, log corrected altimeter setting when required, and monitor nav aids and weather displays.
- o Keep informed of traffic in the pattern by occasionally monitoring the search radar.
- o Monitor approaches made on other facility nav aids to runways served with precision radar and advise pilots of any deviation from normal approach paths, when required.

The general duties of the Flight Data Position Controller are as follows:

- o Receive and disseminate flight data information on all inbound and outbound traffic by means of appropriate interfacility communications.
- o Copy, post, and relay flight clearances, weather information, NOTAMS, control messages, reports, and other information received on appropriate communication channels.
- o Post flight data on flight progress strips, maintain them in an orderly manner, and remove and store them when the aircraft has terminated its flight.
- o Maintain traffic control operating forms and assist at other operating positions as required.

The position of Assistant Approach Controller may be used in the IFR room. The assistant approach controller shall possess the minimum qualifications of basic FAA certification and be qualified in his duties in accordance with local ATC facility operating instructions. In order to provide the maximum flexibility of operations, the ATC Facility Officer is authorized to modify the duties of this position as the local situations dictate. His general duties are as follows:

- o Assist the approach controller in the control and coordination of instrument air traffic within the ATC facility area of responsibility.
- o Collect and post flight data for the approach controller.
- o Assist the other controller positions as required.

Each ATC facility will have a coordinator or watch supervisor on duty at all times of operation. He will normally be the senior enlisted (or civilian, where appropriate) air traffic controller on duty possessing a facility rating and will be specifically designated by the commanding officer. The watch supervisor has the responsibility for the overall efficiency of the air traffic control services provided by the facility. Thus he will:

- o Supervise the conduct of all operating positions in the IFR room and provide the coordination necessary to move traffic expeditiously and with safety.
- o Coordinate between the radar control positions and assign aircraft to the precision controllers.
- o Receive and record flight data information from dispatch and use this data for planning purposes.

- o Monitor weather, wind, and nav aids displays and relay this information, when required, to appropriate positions in the radar room.
- o Monitor communications with the visual observer and coordinate activities between the radar room and the visual tower.
- o Ensure that all equipment is operating properly by performing the necessary tests and checks and contact maintenance personnel when malfunctions occur.
- o Provide on-the-job training and maintain personnel record forms of training progress.
- o Render operating decisions and keep cognizant personnel informed of emergency situations and any other unusual situations that involve the control of aircraft.
- o Provide technical assistance to the ATC facility duty officer.

Finally, the ATC facility duty officer shall be available at all times of operation. He shall be a graduate of the ATCO course, possess the minimum qualification of basic FAA certification, and shall be designated as qualified by the commanding officer, based on the recommendation of the ATC facility officer. The ATC facility duty officer shall be on duty at the facility whenever operations are being conducted during instrument conditions prescribed for that facility. If not directly monitoring instrument operations, he must be available to all operating positions through a direct inter-communication system. The duty officer must be available to man the ATC facility within 15 minutes after being alerted on pending operations under instrument conditions. His duties while on watch include:

- o Responsibility for the overall operation of the ATC facility.
- o Active supervision of personnel on watch including military and administrative matters.
- o Keeping cognizant parties informed of all emergencies and unusual situations concerning the control of aircraft.
- o Consulting with the operations duty officer to provide technical assistance in flight clearance and ATC procedures.

12.2 LOW DENSITY ATC FACILITY

12.2.1 Operational Requirements

A small Naval Air Station (NAS), Naval Auxiliary Landing Field (NALF), or Naval Outlying Landing Field (NOLF) having a normal aircraft traffic density of only a few landings and takeoffs per hour, will require a low density ATC facility. The design of this facility would provide a minimum of ATC aids, but allow for future expansion, should there be an increase in traffic.

Operation of this type of air station is closely analogous to the original small civilian airfield, having only ground-to-air communication equipment, landing lights, a wind sock, and a signal gun for emergencies. The low density ATC facility has improved the tower controllers working conditions and capabilities with a modern control tower, up-to-date communication equipment, and two navigational aids (radio direction finder and homer beacon). In addition to this basic equipment a portable radar equipment consisting of two AN/FPN-36 Radar Sets is included. This equipment has four operational modes (search, height finder, precision approach and surface detection or taxi-radar), but it is primarily used in the precision approach and search modes. With two sets installed, one may be used in the search mode and the other as a precision approach radar (PAR), or the equipment may be switched from search to PAR mode as an aircraft approaches the air station.

Aircraft destined for a low density ATC facility will be guided to within either 6 to 10 miles or 20 to 40 miles of the air station by an approach control, according to the station radar operational procedure. Normally, one radar set is used in the search mode and the other in the PAR mode. When the search mode is employed, the approach controller may hand-off the arriving aircraft when it is as far away as 40 miles. Then the arrival controller would guide the aircraft to the approach end of the active runway, ready for hand-off to the PAR controller for final approach and landing guidance or the same operator may switch to the radar operation mode and perform both search and PAR controller functions (under emergency conditions or during late watch operation). If station procedure requires using the radar for final approach guidance only, the aircraft would be guided to within 6 to 10 miles of the approach end of the air station's active runway by the area's approach control.

The precision controller, after receiving landing clearance from the local controller in the tower, uses visual display information and his communication equipment to guide the aircraft along the approach glidepath and courseline to the touchdown point. Upon landing, the pilot switches to the control tower ground controller frequency for taxiing instructions, and the radar operator is ready to guide another aircraft.

12.2.2 System Configuration

A low density air traffic control facility shall contain a standard tower and cab, with the basic equipment described in chapter 3 of this handbook. The number of radio and landline communication channels installed may be reduced, but the cab layout should be standard. Remoted VHF/UHF transmitter and receiver buildings, as described in chapter 11 will be included in the ATC system and only the quantity of equipment will be reduced as required.

The basic radar set (refer to figure 10-10), AN/FPN-36, is incorporated in a two radar-two controller system as shown in figure 12-1. The transmitter-receiver-antenna equipment is installed off the active runway and positioned to monitor aircraft approaching from either direction. The AIMS equipment building and ISLS antenna is located a minimum of 20 feet from the radar set used in the search mode, and the two antennas are synchronized in rotation. The IFF responses are displayed on the radar monitoring console during the search mode operation. When the radar mode of operation is switched out of the search mode, the AIMS information is removed from the display. The indicator site containing the monitor and control consoles, and IFF master control and alarm panels is usually located in the operation building. It may be located in a shelter near the runway, if the distance to the operation building and tower is greater than 10,000 feet. Adequate communication links between the radar controllers and tower controllers must be provided with the required ground-to-air communication equipment.

A UHF homer beacon shall be provided to directly aid arriving aircraft to locate the air station. If the area is available, the beacon installation should be on the centerline of the active runway and 3-10 miles from the approach end of the airfield.

The second navigational aid provided on a low density ATC facility is a radio direction finder. The control tower shall contain a VHF/UHF radio direction finder with the indicator conveniently located in the cab and the receiver installed in a tower equipment room. The antenna would be located either on the cab room or adjacent to and at the level of the tower cab.

12.2.3 Site and Structural Criteria

The control tower site is determined by competent authority and will provide obstruction-free visibility to all runways, taxiways, and aircraft parking aprons. The tower is normally five stories high, as shown in foldout 3-1, and described in that chapter. Further details on the tower structural criteria is provided in the Bureau of Yards and Docks Definitive Drawings series on Control towers, starting with Y&D Drawing No. 817248 (revised July 1962).

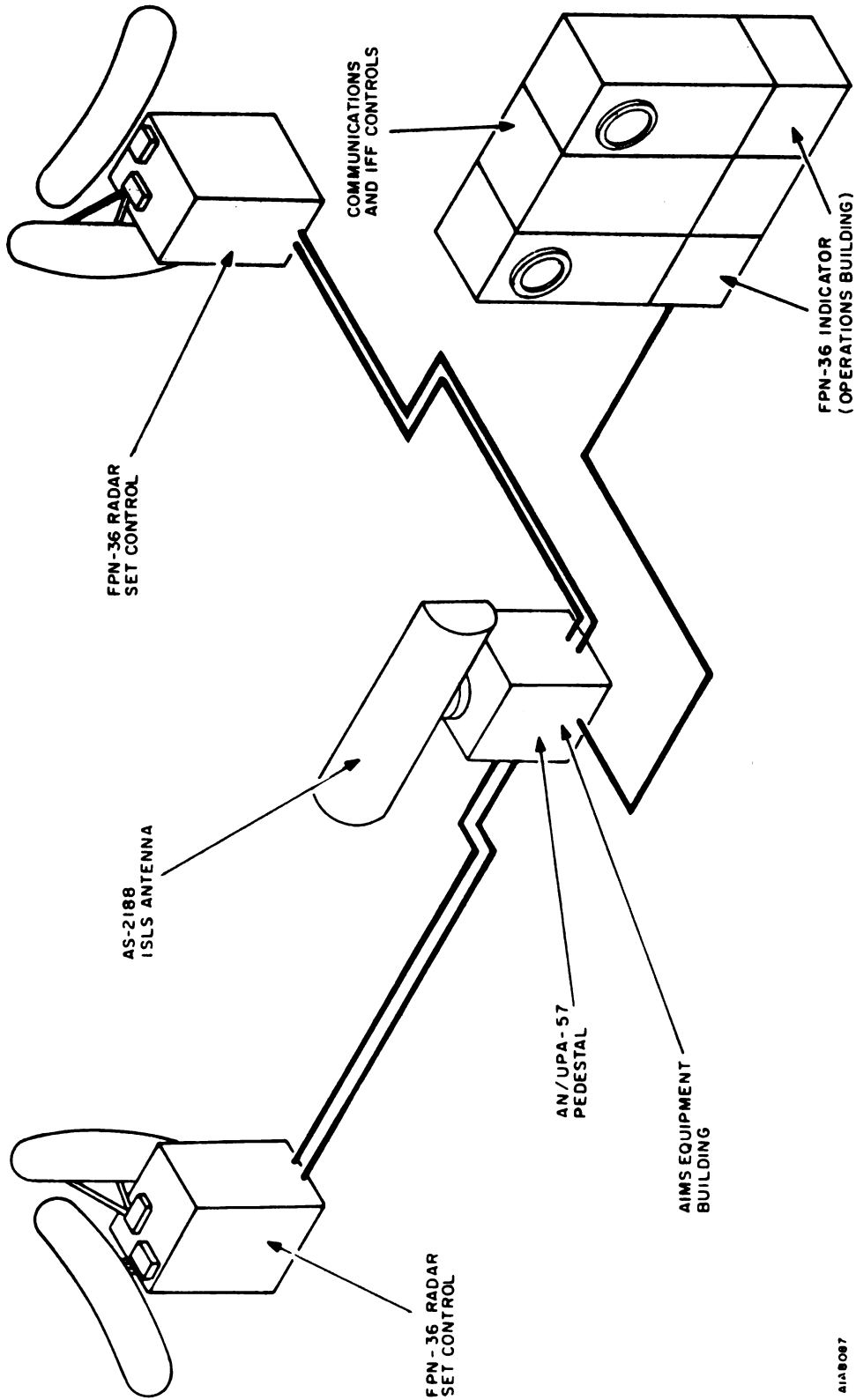


Figure 12 - 1. Low-Density Radar Configuration Using Two AIMS Radar Sets

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The AN/FPN-36 Radar Sets are bolted to a solid, flat and level foundation. Therefore, an approximate 4 foot square concrete foundation should be provided at the appropriate off-runway sites selected for each radar set. Cable trenches must be provided between these sites and the AIMS building, and the operation building. Site and structural criteria for the AIMS building and the ISLS antenna will be provided in NAVELEX Standard Plans.

12.2.4 Installation Criteria

Control tower cab equipment installation should be similar to the layout illustrated in foldout 3-2 for standardization and efficient operation. In a low density ATC facility, blank panels would be installed in place of equipment not required.

The tower includes space for the installation of electronic equipment in the first, third, and fourth floors, in addition to facilities within the cab for control and operation of the equipment. Standard cellular floor construction provides space for cable runs, and permits standard installation practices.

Radar set installation criteria is included in technical manuals provided with the equipment. Location of the indicators should be within 1200 feet of the control tower cab, in a miniature IFR room. Only one indicator is used with each field installed radar set. A second indicator, if connected, could only be operated as a slave or parallel monitor. Therefore the room required would house the two indicator consoles, IFF master control and alarm panels, intercom to the tower cab, and ground-to-air communication control equipment. A second adjacent room would be required as a terminal equipment room and would contain the radar and communication terminal equipment, including power panels, video amplifiers, voice recorders, VHF/UHF transmitters and receivers, junction boxes and test equipment.

12.2.5 Operation and Maintenance Procedures

The tower watch of a minimum ATC facility usually consists of two controllers. One controller will function as both the local (air) and ground controller; the other will operate the flight data console and assist as ground controller if air traffic increases. The responsibilities of the controllers have been described previously and apply for all Naval Air Stations towers, regardless of size or air traffic density.

The search mode of operation, depending on location, will provide the controller the capability of performing two basic functions:

- o Coordinate local air traffic which may or may not come through the area's approach control.
- o Monitor and identify approaching aircraft via the AIMS equipment capability and display, in coordination with the approach control, wherever it is located.

Standard maintenance procedures, including routine inspections and operational checks, many of which are listed in the equipment technical manuals, must be initiated and maintained to ensure proper operation of the station's air traffic control system.

12.3 MOBILE GCA FACILITY

12.3.1 Operational Requirements

A Naval Air Station having a normal aircraft traffic density of approximately 10 to 25 landings and takeoffs per hour will require the combination of a low density ATC facility and a mobile GCA radar installation (replacing the quad-radar, AN/FPN-36). The mobile GCA contains two separate radars: ASR and PAR which operate independently and have separate displays.

Utilization of this radar equipment permits the air station controllers to see more of the surrounding airspace. Therefore, approaching aircraft may be guided to the active runway touchdown point more efficiently and from greater distances.

The principal van of a mobile GCA contains three operator positions each having separate search and precision monitors with independent radar and communication controls. This enables each operator to perform the function of either an arrival or a final controller, and handle required flight data. Usually one position is for the supervisor who assigns the arriving aircraft to the two controllers.

Normal operation of a mobile GCA is to use the full capability of both the ASR and PAR equipment. Therefore, an airfield containing a mobile GCA would normally have the area approach controller hand-off arriving aircraft at distances up to 40 miles from the air station. Then, the arrivals controller using the GCA search radar and VHF/UHF communication equipment will guide the aircraft to within 6 to 10 of the approach end of the active runway. At that point, the controller will either hand-off the aircraft to the PAR controller or start observing the precision indicator, located below and in the same console as the ASR monitor, and function as the PAR controller. In either case, the PAR controller, after receiving landing clearance from the local controller in the tower, uses the visual display information and his communication equipment to guide the aircraft along the approach glidepath and courseline to the touchdown point. Upon landing, the pilot switches to control tower ground controllers frequency for taxiing instructions and the controller is ready to guide another aircraft.

12.3.2 System Configuration

A complete GCA mobile facility is contained in three vans parked on a hardstand adjacent to the runway served. One van contains the radar and communication equipment and operating consoles for the controllers; the second van contains the emergency power generating equipment to be used in case of a local power failure and when prime mover is used to position the GCA for a new active runway approach. The third van houses maintenance parts and facilities and additional equipment required for mobile GCA operation. This equipment includes:

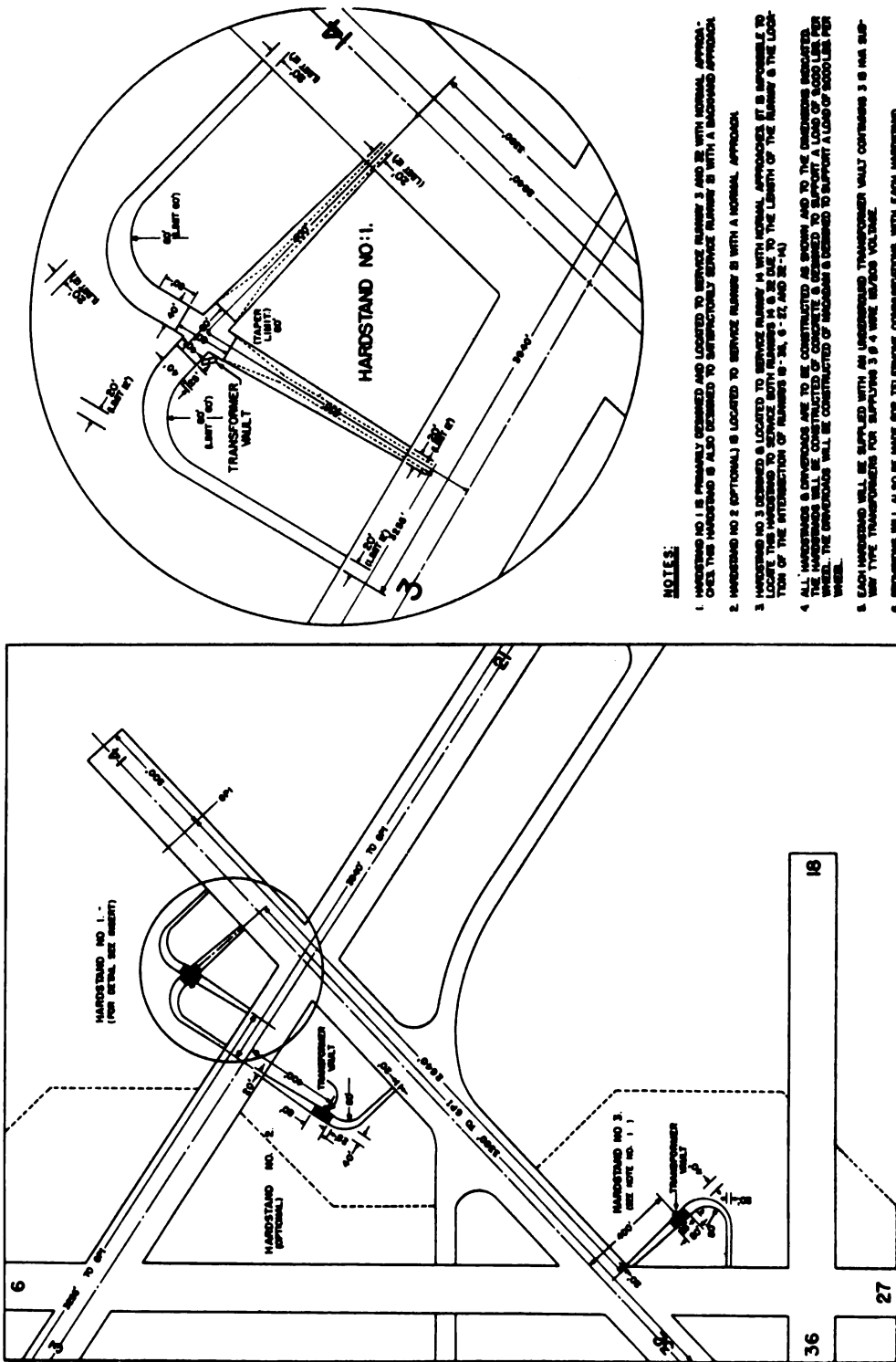
- o Main power switches and control panels for AC input power
- o Amplifiers and power supplies
- o Tape recorders for each radio channel operating from the van
- o Air conditioners for equipment and personnel comfort.

The operation van layout has the three identical controller consoles, with all necessary radar and communication controls on one side, and radar transmitters, receivers, and antennas on the other side. Also included in the van are VHF/UHF communication facilities, IFF/SIF equipment, and a completely selective intercommunication system. Thus, the controllers have all the equipment necessary to efficiently perform their ATC function.

12.3.3 Site and Structural Criteria

The GCA unit must be accurately sited by use of a transit and precise measurements, to ensure that the distance to the touchdown point and actual off-set angle from the runway centerline may be computed. These off-set calculations must be incorporated in the controller's visual display, such that he sees the aircraft on the true glidepath and courseline.

In planning a new air station or modifying an existing one, hardstands must be included in the design and constructed for mobile GCA use. GCA hardstand locations at a typical airfield, with notes which indicate provisions made to meet operational requirements are shown in figure 12-2.



NOTES:

1. HARDSTAND NO. 1 IS PRIMARILY DESIGNED AND LOCATED TO SERVICE BATTERY 3 AND IS WITH NORMAL APPROACH. OVER THE HARDSTAND IS ALSO DESIGNED TO SERVICIALLY SERVICE BATTERY 8 WITH A BACKWARD APPROACH.
2. HARDSTAND NO. 2 (OPTIONAL) IS LOCATED TO SERVICE BATTERY 8 WITH A NORMAL APPROACH.
3. HARDSTAND NO. 3 DESIGNED AND LOCATED TO SERVICE BATTERY 14 WITH NORMAL APPROACHES. IT IS DESIGNED TO LOCATE THE HARDSTAND TO SERVICE BATTERY 14 AS IS DUE TO THE LENGTH OF THE NUMBER 8 THE LOCATION OF THE INTERSECTION OF NUMBERS 18, 27, AND 36-A.)
4. ALL HARDSTANDS & APPROACHES ARE TO BE CONSTRUCTED AS SHOWN AND TO THE DIMENSIONS INDICATED. ALL HARDSTANDS & APPROACHES TO BE CONSTRUCTED TO SUPPORT A LOAD OF 3000 LBS PER SQUARE FOOT.
5. EACH HARDSTAND WILL BE SUPPLIED WITH AN UNDERGROUND TRANSFORMER VAULT CONTAINING 3 8 HVA SUPPLY TYPE TRANSFORMERS FOR SUPPLYING 3 8 WIRE SUPPLY VOLUME.
6. PROVISIONS WILL ALSO BE MADE FOR TELEPHONE COMMUNICATIONS WITH EACH HARDSTAND.

Figure 12 - 2. Typical GCA Hardstand Layout

General siting criteria for mobile GCA hardstand construction and positioning are:

- o One or more hardstands, 40 feet by 80 feet, are constructed with the long dimension 90 degrees from the runways to be served.
- o Hardstands are to be located at a minimum of 2500 feet from the end of the runway touchdown point (3000 feet or more is preferable), and at a minimum distance of 250 feet (400 feet or more is preferable) from the runway centerline.
- o Hardstands should be positioned on the left side of the runway as viewed from the aircraft making an approach to the instrument runway. Right-hand positioning is acceptable in cases where the same hardstand can serve more than one runway, or where left-handed positioning is impracticable.
- o Refer to figure 12-2 for typical hardstand details. Specifications prescribe that access roads to the hardstand should be a minimum of 12 feet wide, with a turning radius of not less than 60 feet. The taper from the end of the 12-foot width should extend for at least 80 feet to permit alignment of the equipment on the hardstand.
- o Hardstand construction should be capable of withstanding trailer wheel loads of 9000 pounds per wheel minimum.
- o The hardstand will be supplied with 60 KVA, 60 cycle, three-phase, four-wire 120/208 V, commercial/station power. Transformers are usually housed in an underground vault.
- o All hardstands are furnished with a standard 26-pair communication cable terminating in the control tower for communication between tower and other hardstands.
- o A turntable mounted GCA should be used to service more than one runway approach. Power cables are ducted to surface in the center of the turntable. The GCA van may then be manually rotated for a new runway approach with power on all equipment, thus reducing turning time to less than 5 minutes. The average time, in good weather, for reorienting a mobile GCA on a hardstand is 25 to 50 minutes. The ultimate objective is to have a motor driven turntable for automatic position control of the GCA equipment.

Although the foregoing hardstand specifications apply particularly to mobile GCA, the same hardstand could be used for the remote GCA equipment and the PAR component of a fixed maximum ATC facility if provision is made for cable ducts and integration with the control center.

Siting and structural criteria pertinent to a fixed minimum ATC facility is also applicable to an air station with a mobile GCA installation.

12.3.4 Installation Criteria

Installation criteria for the mobile GCA equipment is provided in the technical manual included in the vans. Criteria for installation of remaining ATC equipment is the same as specified for a minimum ATC facility.

12.3.5 Operation and Maintenance Procedures

ATC personnel required to operate a mobile GCA installation will consist of a tower watch and a GCA watch. Operation in the control tower is basically the same as a minimum ATC facility. If air traffic density at the station has periods of reduced air traffic, the GCA crew may be on standby until alerted by the tower controllers. Responsibilities of the GCA controllers is similar to those of the controllers described previously.

Operational procedures for the GCA equipment may be locally established to have a supervisor position, one air-surveillance position, and one precision approach controller. This arrangement would require a 6 to 10 mile separation between arriving aircraft. If the two controllers functioned as PAR controllers, and the supervisor functions as the arrival controller (or receives the aircraft from an area ASR), two aircraft may be guided down the approaching glidepath at the same time with the minimum three-mile separation.

Maintenance of the mobile GCA equipment is usually performed in the van work area. All routine inspection and operational checks as suggested in the technical manuals should be made on schedule, to assure continuous operation of the GCA system. All maintenance procedures pertinent to the remaining ATC facility should also be systematically performed to ensure proper operation of the air station's air traffic control system.

12.4 REMOTED GCA FACILITY

12.4.1 Operational Requirements

A Naval Air Station having a normal aircraft traffic density of approximately 25-60 landings and takeoffs per hour will require more electronic equipment than is contained on a mobile GCA facility. To control the additional air traffic, a larger ATC activity, referred to as a remoted GCA facility, would be required to coordinate and control a larger air space. Therefore, this facility differs from a mobile GCA facility in several ways:

- o Air Surveillance Radar (ASR) is used for terminal area coverage (360 degrees, up to 40 nautical miles). This equipment is van installed.
- o Controllers for both the ASR and PAR equipment would be located in a common Instrument Flight Rules (IFR) room, usually located in the operations building.
- o Additional radar monitors, ground-to-air communication links, and landline circuits are mandatory.
- o The remoted receiver and transmitter sites contain additional ground-to-air communication equipment, including larger antenna fields.
- o Operational control of the remoted ATC facility would be extended up to a 40 mile radius, if required, depending on the local area control center of the National Airspace System.

Arriving aircraft are handed-off from the en-route center, to the surveillance radar controller when they are 20-40 miles from the airfield. The ASR or approach controller, in the air station's IFR room, will have received arrival data on the aircraft before the time of hand-off.

Upon first radio contact with the arriving aircraft, the approach controller will transmit altimeter setting, wind direction and velocity, and runway information or the pilot may have received this information via the ATIS broadcast. The approach controller will provide pilot with descent information until the aircraft is cleared to leave the holding pattern and enter the landing pattern. At this time, the aircraft is released to the arrival controller and the pilot is instructed to switch to an approach frequency.

Upon leaving the holding pattern, the pilot will contact the arrival controller. Having properly identified the aircraft on radar, the arrival controller will then provide vectoring information until the aircraft is turned on final approach. At this time, he will hand-off the aircraft to the final or precision controller.

The aircraft, having turned on final approach, is accepted by the final controller who contacts the air traffic controller in the tower directly, or through the coordinator, to obtain permission for the aircraft to land. When radio contact is made, the precision controller transmits emergency procedures in the event of a missed approach. He will continue to monitor the radar and advise the pilot when the aircraft is approaching glidepath interception. When this point is reached, the pilot will be advised to begin descent. Thereafter, the controller will give position information related to the glidepath and runway centerline, and distances from touchdown. At the

3 or the 4 mile marker, he will transmit wind and weather conditions and a clearance to land. At the 1 mile marker, he will announce that the aircraft is approaching minimums. The final controller continues to control until the aircraft is over the end of the runway after having advised the pilot to take over visually on reaching visibility minimums. When the aircraft is over touchdown, the precision controller will release the aircraft and inform the pilot to contact ground control after roll-out.

The flight data controller in the tower will record the time the aircraft is on the ground and transmit the information to the center concerned. The controller will then file the flight data strips.

After roll-out, the pilot will contact ground control for taxi instructions to the desired location on the airfield.

12.4.2 System Configuration

A remoted GCA facility is a complete air traffic control system for terminal area coverage. The remoted GCA field installation may contain the same type of equipment found on a mobile GCA facility (ASR and PAR in two GCA vans), or a separate ASR transmitter building and tower installation (reference chapter 10), and a single PAR shelter mounted on a turntable (see figure 12-3). The facility may also contain a TACAN (or VORTAC) site and a homing beacon, usually at opposite ends, and a few miles beyond the ends, of the runway. The remoted receiver and transmitter buildings, with an increased amount of electronic equipment, provide the greater communication capability required.

The air traffic control center of a remoted GCA requires more operational space than a tower alone. Therefore, the tower and the ATC center are usually part of the station's operations building (see FO 12-1, foldout 12-1 and 12-2) or the ATC center may be in a separate building close to the visual control tower. Besides the control tower the ATC complexity will consist of three areas, the IFR room, radar equipment and communication equipment rooms. A typical layout of these areas is shown in foldout 12-2, FO 12-3. This arrangement may be used as a guide, but the quantity of equipment and its actual position in these rooms will vary from station to station, and system engineering of a facility must be governed by local operational requirements.

The IFR room contains remote radar indicators for each of the radar systems, as well as a VHF/DF, UHF/DF, and control for the IFF equipment. Selective communication and intercommunication systems, described in chapter 4, are provided for control of the transmitters and receivers shared with the control tower.

Additional monitoring and control equipment installed in the IFR room include:

- o Digital clocks and altimeter readouts
- o Visual communication system (Viscom)
- o NAVAID Monitoring Panel (AN/GSA-35)
- o Weather Vision Monitor (AN/GMQ-19)
- o Wind direction and speed indicators

A typical front panel layout of the IFR room consoles is presented in foldout 12-3, FO 12-4. Only the flight data console is not shown, but it will be similar to the control tower flight data console, refer to figure 3-3.

The radar equipment room contains the radar terminal and maintenance consoles, ancillary equipment and power distribution panels. The radar transmitter-receiver installations are remotely located from the control center, therefore, their video signals must be relayed to the IFR room indicators, via the equipment room. The signals may be transmitted over cables, or by a microwave link if the distance or terrain between the center and field installation deem it necessary. If a microwave link is installed, the antenna installed on the outside of the

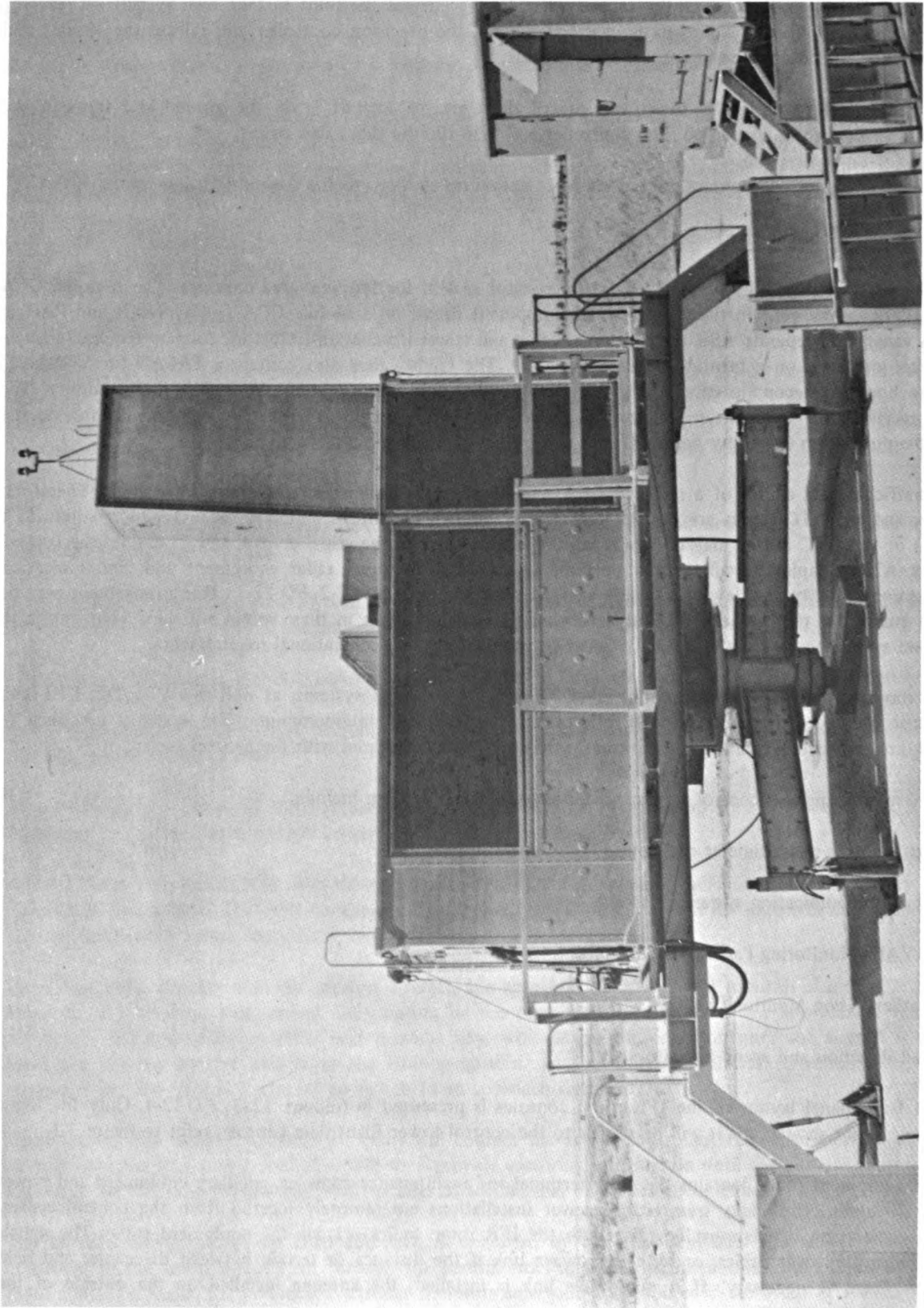


Figure 12 - 3. Precision Approach Radar (PAR) Site

building would receive and relay information to and from the radar site. In the radar equipment room will be located the necessary microwave equipment including an RF receiver, mux-servo and power supply racks. Additional components of the equipment room usually include:

- o Radar data distribution group AN/GPA-107(V)
- o ASR maintenance position and terminal equipment
- o PAR maintenance position and terminal equipment
- o Video Mapper
- o Decoder Groups AN/UPS-51 (Emergency Alarm), -54 (IFF mode)
- o NAVAID remote controls (TACAN, VOR and UHF HOMER)
- o BRITE-2 PPI-TV Camera Cabinet
- o Miscellaneous test equipment and work area.

The communication equipment room serves as the terminal for both the IFR and VFR rooms. The equipment contained in the room includes:

- o Landline Selector Control Group, OA-7621/FSA-52(V)
- o Communication Control Group, OA-6765/FSA-52(V)
- o Transmitter patch panels
- o Receiver and Recorder patch panels
- o Voice channel recorders
- o Digital Clock Master Control
- o Emergency VHF and UHF Radio Sets
- o Power distribution panel
- o Miscellaneous test equipment and work area.

12.4.3 Site and Structural Criteria

The siting and structural criteria pertinent to a low density ATC facility and a mobile GCA facility, is also applicable to the remoted GCA facility. Refer to other chapters in this handbook for applicable details.

As previously mentioned, a remoted GCA facility requires additional equipment, thus greater space. Addition of the radar air traffic control center (IFR room) and its equipment rooms in close proximity to the control tower will require careful engineering planning. If the control tower stands alone on the airfield, a building will have to be constructed, adjacent to the tower, to house all the center's equipment. Usually the operations building and the control tower are attached (see foldout 12-1, pages FO 12-1 and 12-2), thus the ATC center may be located on the upper floor of the operations building. The IFR room should be located close to the tower structure to simplify the IFR room-control tower interconnection installation and maintenance. The horseshoe shaped IFR room arrangement, shown in foldout 12-2, page FO 12-3, should be the guide for standardization, efficient operation, and ease of maintenance. All operations would be inside the horseshoe, with the equipment paneling extended to the ceiling. The area is illuminated with subdued lighting to allow efficient and comfortable

operation by the controllers monitoring the radar indicators. For maintenance and repair purposes, the space on the outside of the horseshoe is left clear enabling technicians to service the IFR room consoles. All indicators should be mounted on rollers allowing easy transfer into the work area for maintenance and repair. NAVELEX standard plans for the horseshoe construction include modular framing, cable troughs and easy access to the rear of the panel mounted equipment.

12.4.4 Installation Criteria

Adequate air conditioning and dehumidification facilities of the ATC areas are of special importance. There is a considerable concentration of heat-producing equipment in a small area, and with the number of personnel required to operate this equipment, it is imperative that the proper environment be provided. This is important not only from the human engineering point of view, but to assure that the equipment will operate satisfactorily.

The radar equipment and communication equipment rooms are in close proximity to the IFR room and the cables are usually run overhead between the areas. The equipment rooms must also be arranged to facilitate access to both front and rear of the consoles and cabinets.

The control tower structure will be capable of providing adequate space for the additional ATC equipment and passageways for the interconnecting cables.

12.4.5 Operation and Maintenance Procedures

ATC personnel necessary to operate a Naval Air Station with a remoted GCA installation will consist of a tower watch, an IFR room watch, and a maintenance watch. With the increase in air traffic, the number of personnel and the quantity of electronic equipment will be increased, and the operational procedures will become more involved, but the basic tower controller functions will remain the same as described in chapter 3. The tower watch will consist of three controllers: local (air), ground, and flight data. During peak periods there may be need for a supervisor or relief controller. If the air traffic density is extremely high, it may be necessary to increase the number of personnel by assigning arrival and departure air and/or ground controllers, operating on separate communication channels.

The IFR room operational procedures are determined by the ATC area of coverage, air traffic density and the quantity of radar indicators. A normal IFR watch will consist of; an approach controller at an ASR indicator, an arrival controller at a ASR indicator, a final or precision controller at a PAR indicator, a flight data controller, and a supervisor. If the approach controller is located at another center, then the arrival controller will be the first to contact aircraft entering the air station airspace. Most IFR rooms will have two or three PAR positions, with at least two controllers alternately handling arriving aircraft. If necessary, a third PAR position may be operative, but a minimum three mile separation of landing aircraft is usually maintained. The function of each controller has been previously described.

An ATC facility, having a remoted GCA installation, will contain a large amount of electronic equipment which must be kept in good operating condition. The technical manual for each type of equipment details prescribed preventive maintenance procedures. These procedures should be incorporated into an overall ATC maintenance program which would include periodic checks on all equipment in all areas. Routine checks will help reduce downtime of both individual electronic equipment and the services of the ATC facility.

12.5 HIGH DENSITY ATC FACILITY

12.5.1 Operational Requirements

A Naval Air Station having a normal aircraft traffic density of approximately 60 or more landings and takeoffs per hour will require a high density ATC facility. This facility differs from a remoted GCA installation in several areas. The most important of which are its increased service volume, communication requirements, area of coordination, and local traffic.

Planning an airfield capable of handling 60 or more aircraft per hour would be more involved than merely updating or increasing air traffic handling capability of an existing airfield with the installation of GCA equipment. The overall plan would include more permanent installations, except where mobile equipment is required. Radar sites, including the PAR equipment, would be installed in standard enclosures rather than mobile vans.

If the required area coverage of the facility extends to 100 miles from the station, a medium-range radar will be installed. Three types of Navy medium-range radar used for ATC surveillance are the AN/FPS-20, -37 and -67. This component of the maximum ATC facility may be located on the station or at another site. Information concerning en-route aircraft obtainable by this radar is made available in the IFR room, either directly on radar indicating consoles, or indirectly on communication channels between the radar site and the IFR room. Compared to a remoted GCA facility, the size of the IFR room on this station is usually larger as it must contain more equipment and more personnel.

With the addition of a fixed terminal radar or a medium-range radar, this facility would have approach control capability and may function as an area air traffic control unit and receive aircraft directly from the en-route center. But the usual high density ATC facility will function as its own station approach control and provide approach control for adjacent airfields. Therefore, the procedure for handling aircraft will be the same as for a remoted GCA facility, except the aircraft may be handed-off as far away as 100 miles. Also the additional radar will be extremely helpful during search and rescue operations.

12.5.2 System Configuration

A high density ATC facility is a complete system capable of controlling the airspace for extended terminal area coverage. This facility will have the same type of equipment as found on a remoted GCA facility with the possible addition of a terminal radar and additional communication equipment to enable the facility to control the increased air traffic. The radar antenna and transmitter-receiver building located on or off the station, and the additional air search controller consoles in the IFR room, would be the only basic difference in system configuration.

The IFR room would be larger to contain at least three or more air search controller positions and possibly additional ASR positions for guiding aircraft to adjacent airfields. Standard plans are available for ATC operation and equipment areas, though the dimensions may change according to the quantity of equipment to be installed.

12.5.3 Site and Structural Criteria

The medium-range air traffic control radar is a fixed facility, permanently housed, with the antenna elevation sufficient for 360-degree coverage and maximum scanning radius of approximately 100 miles for detecting aircraft up to altitudes of 60,000 feet. Terminal radar installations having a scanning radius of approximately 40 miles and capable of detecting aircraft up to altitudes of 25,000 feet are also permanently housed. Therefore, the first consideration is to select a site to give the desired area or sector coverage for line-of-sight operation.

When the general requirement for radar coverage has been determined, tentative site locations can be chosen. These locations, in addition to providing proper radar coverage, must also satisfy such other factors as logistic support, budgetary limitations on engineering and construction costs, and communications requirements.

If the radar is located on the station, the transfer of video information to the indicators of the ATC center may be accomplished by cable or by microwave control link. Video cabling is generally preferred. Cable equalizers and video amplification will permit this type of operation to be extended beyond 10,000 feet to a practical limit determined by economic factors. Microwave link operation is required when the radar is located off the station, or when cable burial is impractical because of construction difficulties of public or private properties. System engineering is therefore confronted with the problem of providing the information to the IFR room by whatever method is applicable to local requirements.

A higher control tower may also be required to gain height above the terrain or adjacent buildings and hangars and to contain the additional ATC equipment. A control tower cab (foldout 12-4, FO 12-5) above a six-story structure which includes an elevator. Shown in the figure are recommendations for use of each floor. This control tower diagram may be used as a guide for future construction, including taller towers. Further details on control towers are available in the Bureau of Yards and Docks Definitive Drawings. All other siting and structural criteria pertinent to a remoted GCA facility, is applicable to a high density ATC facility.

12.5.4 Installation Criteria

The same general IFR and equipment room installation criteria applicable to a remoted GCA facility will apply to high density ATC facility. The only difference would be that this facility would be larger in size and contain more equipment. Thus, the installation planning is more involved. Layout of the controller consoles in the horseshoe arrangement should be maintained though it will be larger. Additional space required for the equipment rooms must be provided in close proximity to the IFR room, the tower, and the remoted cable entrance. Spacing of all consoles and cabinets in the equipment and IFR rooms must be maintained to allow easy access by the technician for repair and maintenance. Adequate work areas should also be provided in the equipment rooms.

Regardless of tower height, the VFR control room or cab is approximately the same size. Therefore, for standardization and efficient operation, the equipment layout of the control tower cab should be similar to the arrangement presented in foldout 3-2. The control tower floor plan utilization, as presented in foldout 12-4 page FO 12 - 5, has been found to be an excellent arrangement for the support equipment, and is highly recommended as a guide for future installations.

12.5.5 Operation and Maintenance Procedures

The controllers operational procedures presented previously apply in a high density ATC IFR room. With the additional equipment and airspace responsibility, there will be a greater number of controllers in the IFR room, therefore, strict adherence to all ATC operational procedures should be maintained.

The additional airspace responsibility and equipment will also require strict adherence to an efficient maintenance program. The technical manuals are a source of prescribed preventive maintenance procedures. The overall ATC maintenance program will schedule periodic checks on all equipment in all areas. This procedure will minimize reduction of ATC services due to electronic equipment downtime.

12.6 AIRCRAFT LANDING SYSTEMS

The ability to land all aircraft launched from an aircraft carrier is a major concern of the Navy since there are no alternate landing fields at sea. A carrier cannot cease operations or refuse to land an aircraft due to poor weather conditions or darkness therefore systems must be designed which will allow landing operations during unfavorable weather conditions or reduced visibility due to darkness. Systems such as the Automatic Carrier Landing System (ACLS) AN/SPN-42 and the Aircraft Approach Control System (AACS) AN/SPN-41 and AN/TRN-28 have been developed to satisfy this requirement. The proper utilization of these systems is only attained when pilots, operators, and maintenance personnel are properly trained.

The mission of Naval Air Stations is the training of aircraft carrier crews (pilots, equipment operators, and maintenance personnel) in the operation of these systems. The pilots are introduced to the systems under favorable conditions with greater safety factors than exist during carrier operations and thereby build confidence in the capabilities of the system. The ACLS is capable of operation in any of three basic landing modes:

- o Mode I. Fully automatic hands-off landing. The aircraft is acquired by a radar tracker which is computer controlled and by use of a data link flies the aircraft's autopilot to a landing on the carrier deck.
- o Mode Ia. Automatic landing approach from acquisition down to an altitude of 200 feet at a distance of one quarter mile at which point the pilot disengages the automatic control and lands the aircraft.

o Mode II. Semi-automatic aircraft landing which requires the pilot to fly the crosspointer of his altitude director indicator (ADI) as "fly to" indications until the crosspointers are centered. This indicates the aircraft is aligned with the runway centerline and on the proper glideslope.

o Mode III. A ground controlled approach which is a talkdown system with a precision approach radar operator directing the pilot of the course corrections required for a successful landing. The pilot and radar operator both are actively engaged in this landing mode.

The AACS operates as a Mode II landing system which provides a crosspointer indication for the pilot and functions as previously described.

12.6.1 Aircraft Approach Control System Justification

The AN/TRN-28 and AN/SPN-41 are microwave scanning beam landing systems which operate on any of 20 channels in the Ku-band between 15.4 and 15.7 GHz. The system has two transmitters, one for azimuth and the other for elevation, which are synchronized to time-share the same frequency.

The system transmits flat fan beams which are scanned to illuminate an approach aperture which at a distance of 20 miles from the base is 8 miles and 4 miles high. The precise angle at which the antenna is pointing at the instant of transmission is encoded on the radiated beam. Flying into the approach window a pilot whose aircraft is equipped with the proper receiver/decoder begins to read "fly-to" data. This is shown on a crosspointer display indicator, i.e., if the crosspointer is located in the upper right hand quadrant, the pilot would fly to the right and up until the crosspointers moved toward the center of the indicator. Once the aircraft is lined up on the correct approach path and glideslope, the pilot is only required to maintain that line-up for the remainder of the approach.

o Configuration. The Aircraft Approach Control System AN/TRN-28 consists of an elevation transmitter, azimuth transmitter, and an equipment and control group for each function.

o Site Selection and Construction. The elevation antenna assembly should be located parallel to the instrument runway approximately at the touchdown point at the side of the runway. The area should be free of obstructions that may cause distortion or reflection of the transmitter signals. The elevation antenna will require a mounting base facing the approach direction. The base will contain mounting bolts as indicated in standard installation drawings. Local construction and building ordinances, where applicable, shall be observed for depth of base and material requirements.

The azimuth antenna should ideally be located 300 feet forward of the touchdown point on the centerline of the runway extended to provide a true carrier approach indication. This location is impractical at most Naval Air Stations, therefore other locations are being evaluated. The closest approximation to the carrier location is the opposite end of the runway although other aircraft in the approach pattern could cause distortions or reflections leading to erroneous indications. The determination of a preferred site for the azimuth antenna will be provided at a later date.

The azimuth antenna assembly will also require a mounting pad similar to that required for the elevation antenna which will provide an unobstructed transmission path.

The system requires two 115 V, 400 Hz power lines, one for power voltage, the other for reference voltage at each site.

o Installation. The installation of the system requires that the sites for the two antenna assemblies are prepared and have power available (either commercial or an emergency power unit).

12.6.2 Landing Control Central Trainer AN/SPN-42-T1 Facility Justification

The Landing Control Central Trainer (LCCT) AN/SPN-42-T1 is a land based automatic aircraft landing control system designed to train Navy pilots, system operators, and maintenance personnel in the operation and maintenance of the carrier-based AN/SPN-42. The system operates in an identical manner to the AN/SPN-42 and will automatically acquire, control and land a suitably equipped aircraft on a field carrier landing practice runway. This training is intended to increase the confidence of the pilots in the system and operational mode. The system, when fully operational, provides the station with an all-weather landing capability beyond the required training function.

The design criteria for the Automatic Carrier Landing System Trainer is presently being developed and will be presented in a later revision of this handbook.

CHAPTER 13

METEOROLOGICAL FACILITIES

The Meteorological Facilities available at Naval Air Stations are categorized as Meteorological Equipment and Weather Dissemination Systems. Functional descriptions of these facilities are given in chapter 6, whereby their base system engineering aspects are discussed in this chapter.

13.1 METEOROLOGICAL EQUIPMENT

Meteorological equipment utilized on Naval Air Stations are normally one of a kind and these are: Meteorological Radar Systems, Transmissometer Set, Runway Visual Range Indicator, Semi-Automatic Meteorological Station, Cloud Height Set, Wind Measuring System, Rawinsonde Set, and Weather Television System.

13.1.1 Meteorological Radar Systems

a. System Justification. The need for detection and tracking of tropical storms, associated disturbances, and other meteorological phenomena has been satisfied by use of meteorological radar sets. A typical weather radar set is shown in figure 13-1. These sets are operated at frequencies which produce good target returns from these various phenomena. Because hurricanes are capable of causing extensive damage to Naval Air Stations, it is essential that the stations receive early warning in order to prepare for the storm.

Meteorological radars are generally capable of determining range, azimuth, and height of weather phenomena. The radar antenna must be able to view 360 degrees in azimuth and position to an elevation angle of plus 40 degrees.

b. System Configuration. A meteorological radar consists of the following units: an antenna system, transmitter, receiver, processor, and displays. The displays are equipped for photography.

c. Site Considerations. The configuration of the system poses certain conditions which must be considered. The transmitter/receiver should be located close to the antenna but the console/displays may be located remotely from the transmitter/receiver. These conditions can create greater flexibility or unacceptable restrictions, as determined by the selected site. Since site selection is usually a compromise, all of these factors warrant consideration during site selection studies. The siting criteria for a meteorological radar is very similar to that for a surveillance radar.

d. Installation Criteria. The ideal installation would have the antenna and transmitter receiver on a tower with the modulator located in a nearby building. The console and remote indicator are located in or near the operations area. Primary considerations for this installation are the tower and foundations, floor loading, availability of sufficient space to allow the performance of all required maintenance, and availability of sufficient operating power.

Various installation criteria to be considered are presented in the following documents; Naval Shore Electronics Criteria, NAVELEX 0101,106 Electromagnetic Compatibility and Electromagnetic Radiation, and the CNM Electromagnetic Radiation Hazards Manual. These documents present criteria and data applicable to:

- o RF hazards to ordance
- o Radiation hazards to personnel
- o Radio frequency interference to/from other radars/communications

- o Hazards to fuels
- o Grounding criteria.

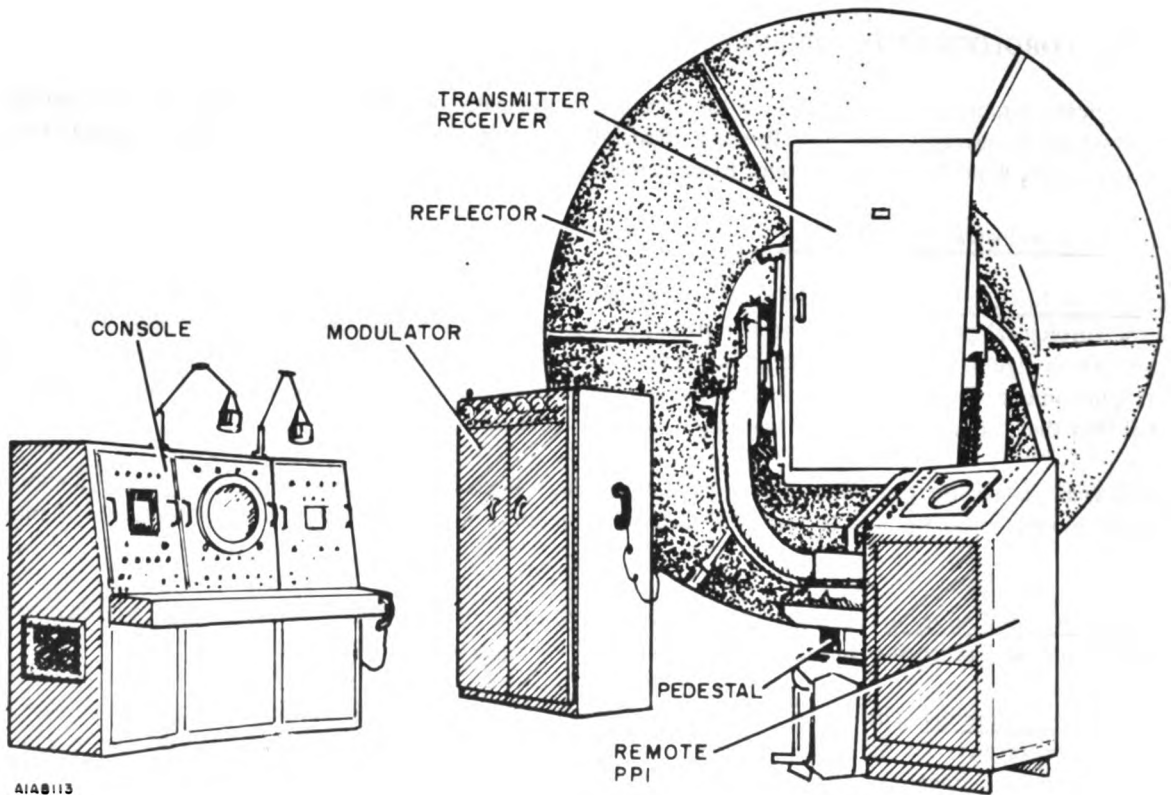


Figure 13 - 1. Typical Meteorological Radar

The following considerations are provided by or require the approval of NAVFAC:

- o Structures and foundations
- o Tower structural design considerations
- o Power availability
- o Lighting.

The following are primarily equipment-associated criteria such as:

- o Radome requirements
- o Emergency power requirements
- o Maintainability
- o Accessibility
- o Use of optional general purpose indicators
- o Video mapping requirements
- o Cable type vs. distance and routing
- o Underground duct internal-spacing of power, control, and coaxial cables
- o Remoting techniques - cable, line amplifiers, microwave
- o Distances from tower, transmitters and console.

13.1.2 Transmissometer Set

a. Operational Requirements. The Transmissometer Set, AN/GMQ-10, is an electro-optical instrument system used to measure the visibility between two points (the projector and receiver) and to determine the vapor density (fog) of the atmosphere. The result of this measurement is transmitted by cable to an indicator-recorder at an observer site.

This observer site may be located in the weather office, control tower, or other appropriate locations. The system, generally located near the touchdown point on the instrument runway ensures that the visibility in that area will be known with the greatest possible accuracy. The transmissometer was developed because control tower operators were unable to accurately inform pilots of the visibility at the end of the runway.

The system operates on the principle that the intensity of the light which falls on the receiver is determined by the clarity or vapor density of the atmosphere in the area. Variations in the light intensity will vary the frequency of these pulses and these changes are recorded on the recorder strip chart and are used to determine visibility in the runway touchdown zone.

b. System Configuration. The projector directs a beam of light of constant intensity from a sealed beam lamp whose filament voltage is regulated to ensure that the lamp will maintain a constant intensity. The projector unit housing is capable of adjustment in both the vertical and horizontal planes to ensure proper aiming at the receiver.

The receiver consists of the optical sub system and the electrical sub system. The optical sub system consists of a 4-inch objective lens with a 31.5-inch focal length and an iris diaphragm to control the light flux incident on the photoelectric cell. There is a secondary lens which forms the image of the large lens on the sensitive surface of the photoelectric cell. This lens also provides a heat seal between the pulse-amplifier and telescope tube. The electrical sub system consists of the electronic circuitry for the pulse amplifier and three heater circuits. The pulse amplifier circuitry includes the phototube, a trigger tube, and pulse-generator electronic circuitry.

The remaining components have been described in chapter 6.

c. Site and Structural Factors. The current Naval Weather Service Regulations covering procedures for fixed meteorological facilities states "the transmissometer projector and receiver will be located in an area which will be representative of the visibility encountered over the greatest portion of the airfield during low visibility periods when the airfield is without a precision-instrument approach". Airfields with precision instrument approaches may have one transmissometer per precision instrument runway located adjacent to the touchdown zone. In general, locations near local air contamination such as vents and smoke stacks should be avoided unless these stacks cause a general contamination over the entire field of interest. Locations near bluffs, sharp grade changes, or reflective background areas should be avoided as these will have an undesirable effect on the accuracy of the visibility indications. A typical site location for a transmissometer set showing both preferred and alternate locations for the installations is shown in figure 13-2.

The "background" is what can be seen from the receiver when looking toward the projector. Trees, hills, etc., make better backgrounds than the sky, sunlighted buildings, etc. When the amount of light that is reflected from the background is low, the receiver may be oriented to look in any direction so long as the system line-of-sight is within 45 degrees of the north-south line. Never orient the line-of-sight within 25 degrees of the east or west line.

The preferred location of the projector and receiver is in the approach zone of the instrument runway and situated so that the nearest piece of equipment to the (extended) runway centerline shall be 850 feet and the farthest piece approximately 2,000 feet from the approach end of the runway. The projector and receiver shall be placed 500 feet apart and a minimum of 100 feet outboard from a system like a ceilometer, whether the system is located in either the preferred or alternate location. The projector and receiver shall be mounted by means of frangible coupling to reduce the damage inflicted on aircraft or other objects which might collide with either of these units.

A typical preferred type transmissometer stand is shown in figure 13-3. The height of the stand will be determined by the local terrain since a minimum of 6 feet above the ground must be maintained with the minimum height of the units at 10 feet and oriented 5 degrees to 30 degrees from the centerline of the runway.

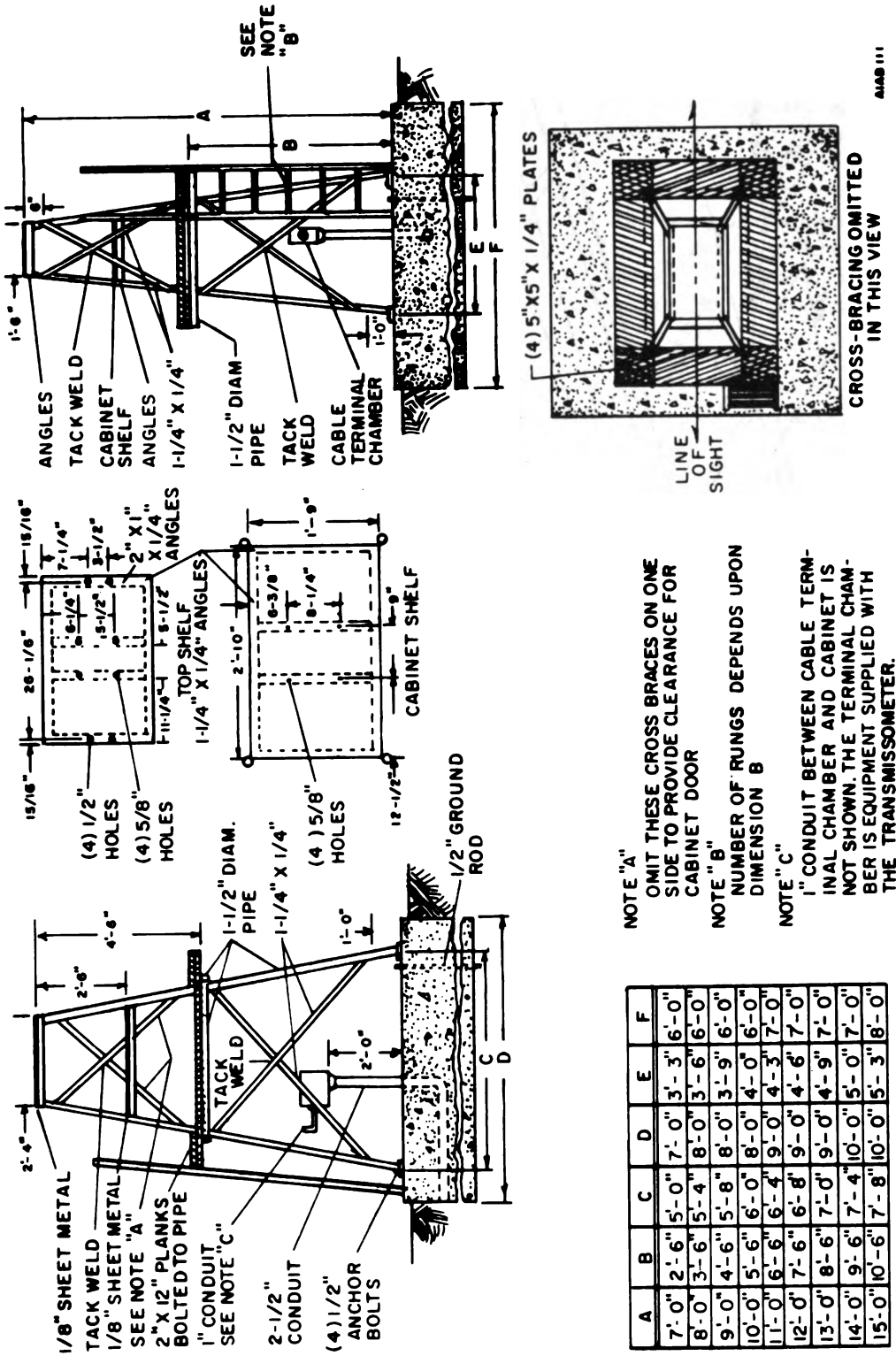
Site and structural factors are detailed in NAVAER 00-100-503, Technical Planning Manual and NAVAER 00-100-505, Definitive Drawings.

d. Installation Criteria. The preparations required to install a transmissometer set including the definition of size and type of foundations necessary, tower heights and construction details may be found in NAVWEPS 50-30GMQ10-2 section III.

The system requires approximately 1.25 kVA of single-phase 115 ± 10 V $60 \pm$ Hz power. Power may be applied at the nearest terminal chamber to reduce the length of cable runs thereby reducing excessive voltage drops due to wire loss. It is essential that provisions be made for the availability of power during local failures to maintain constant operation of the system.

The cable terminal chambers are designed to allow the data signal to be acquired at either the projector or receiver thereby reducing the length of cable required between the field units and the indicator unit. The maximum cable length from field to indicator is 15,000 feet or approximately 3 miles. Figure 13-4 shows the simplified interconnection wiring of the system including grounding requirements.

e. Operational Procedures. The system is usually operated continuously after it has been installed. On initial start-up, power switches on the amplifier and projector power supplies, and circuit breakers in the cable terminal chambers must be placed in the ON position. After initial start-up, control of the system is provided from the indicator panel at the remote observer point.



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Figure 13 - 3. Preferred Type of Transmitter Stand Drawings

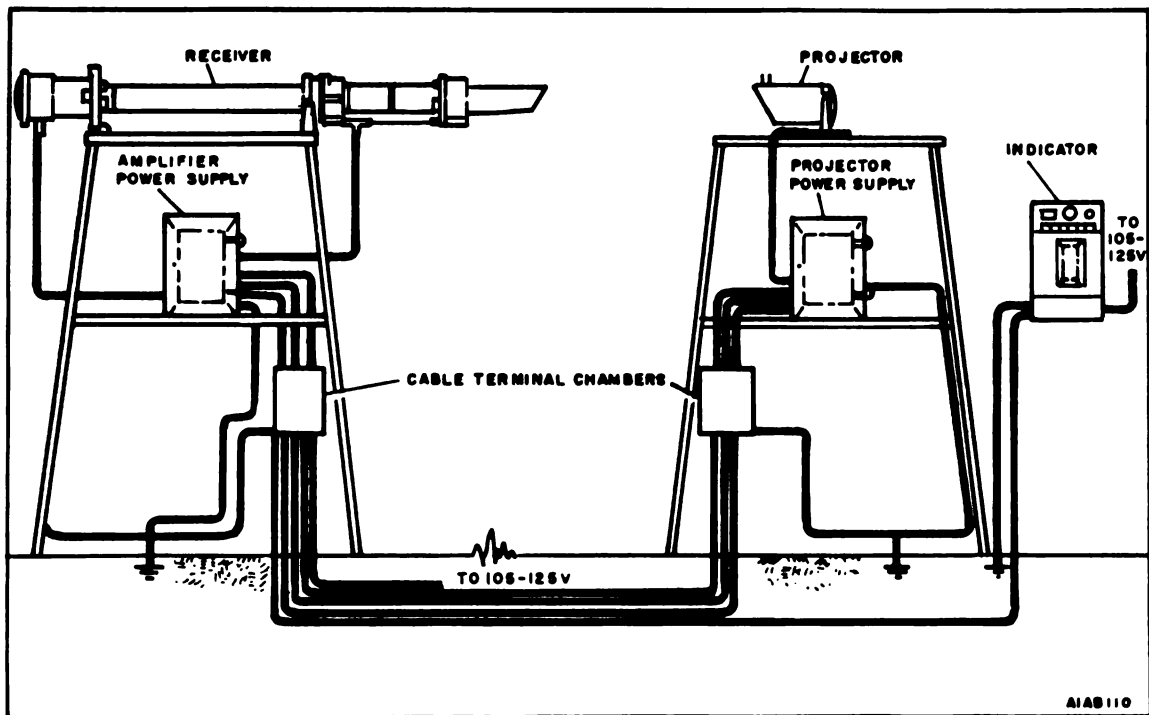


Figure 13 - 4. Simplified Interconnection Diagram, Transmissometer Sets AN/GMQ-10 ()

13.1.3 Runway Visual Range Indicator

a. **Functional Description.** The Converter Indicator Group 0A-7900/GMQ-10 Runway Visual Range Indicator is a digital converter which converts the output of the transmissometer receiver into a direct reading digital display. This display provides control tower personnel with very accurate indications of the true visibility at the end of a runway. The system provides a two-digit display which must be multiplied by one hundred when providing the information to inbound aircraft. The unit automatically updates once every minute for visibilities between 1,000 feet and 6,000 feet. Readings below 1,000 feet or above 6,000 feet will be indicated by 800 and 6,200 feet respectively.

b. **System Configuration.** The system consists of a Signal Data Converter (CV-2062/GMQ-10) and a Digital Display Indicator (ID-1348/GMQ-10). The signal converter receives the pulsed signal from the transmissometer and converts it into a digital signal which is presented on the display unit. These units have been discussed in more detail with brief functional descriptions of the units in chapter 6.

c. Siting and Installation Criteria. The siting and installation requirements are simply that the equipment be accessible for maintenance, visible for operators, and mounted on or in a structurally sound cabinet or surface (table, console or shelf) with sufficient space to connect the required power and signal cables (shown in system interconnection diagram figure 13-5). The system requires 1.2 amperes of 115 V 60 Hz power for proper operation.

d. Operation and Maintenance Procedures. The operation of the system is dependent on all units being interconnected properly and turned on with all indicators reading correctly the proper selection of encoder tracks for accurate conversion of transmissometer pulse rates.

Maintenance procedures are outlined in technical manuals for specific equipments.

13.1.4 Semi-Automatic Meteorological Station

a. Operational Requirements. The Semi-Automatic Meteorological Station, AN/GMQ-14, is used to provide station-weather record information and the determination of local climatological conditions. It provides precipitation quantity, air temperature, dewpoint temperature (humidity), barometric pressure, wind speed, and wind direction data.

b. System Configuration. The system consists of a tipping-bucket rain gage; a dewcel sensor, transmitter, and power supply; an air temperature sensor, transmitter, and power supply; the recorder cabinet, which houses the wind direction and speed recorder, and weather data recorder; an aneroid barometer, and a barograph to record the barometric changes. Detailed discussions of these subsystems have been presented in chapter 6.

c. Site and Structural Factors. The field site selected for the station is primarily concerned with the location of the tipping-bucket rain gage, the dewcel, and the temperature bulb. The site selected for the rain gage should be level, reasonably free of wind swirls, updraughts, or other conditions which might impair the accuracy of the precipitation measurements. The dewcel and air temperature bulb location should allow the free flow of air about the sensors, yet protect them from precipitation and splashing.

The recorder cabinet is usually located in the base meteorological office where data may be extracted and recorders serviced whenever necessary. This includes changing strip charts on the recorders, and routine maintenance.

d. Installation Criteria. The rain gage should be secured to the ground with standard hardware appropriate to the mounting surface.

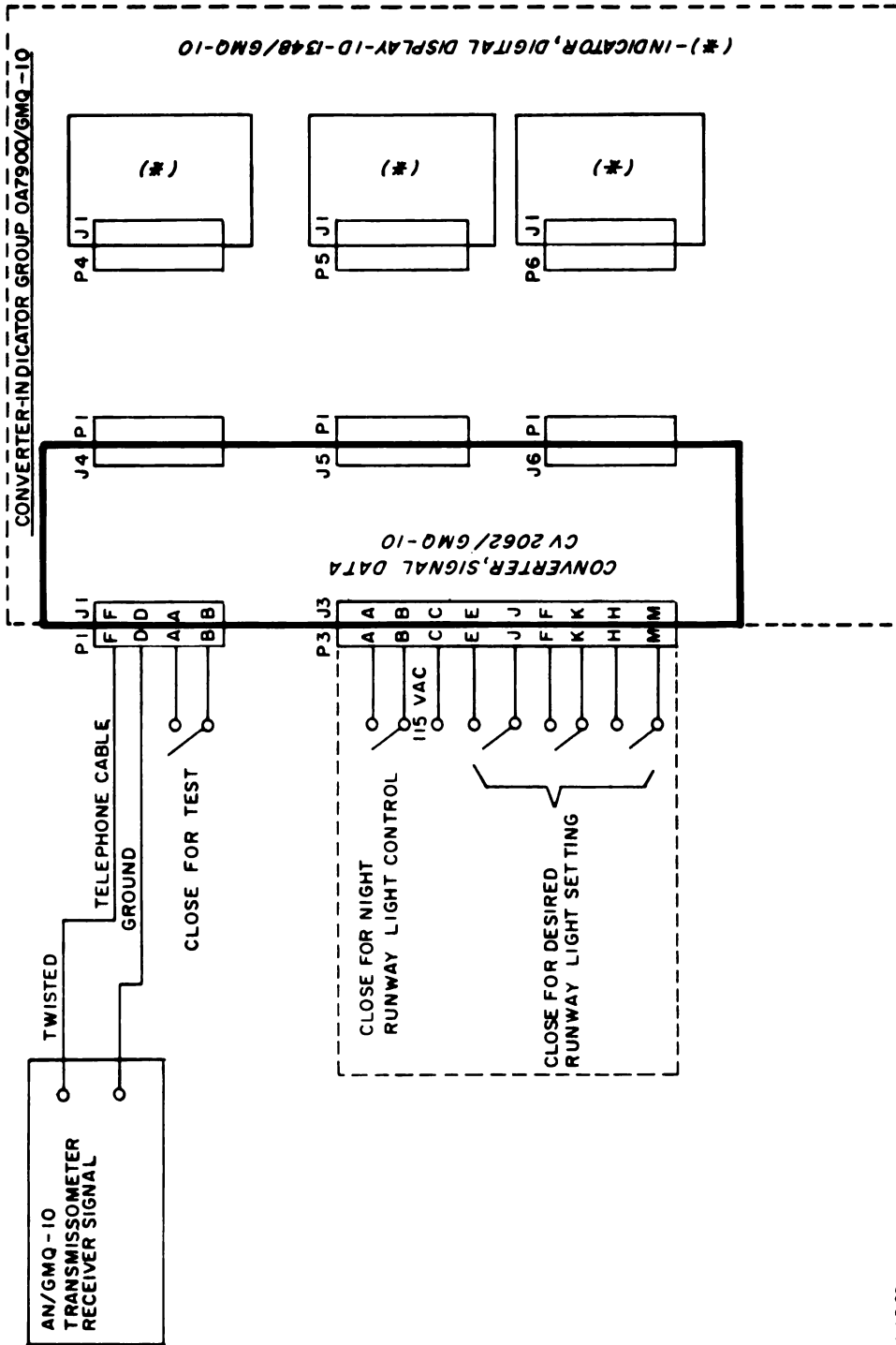
The dewcel power supply requires a splashproof shelter and be relatively close to the transmitter but at sufficient distance not to affect the dewcel by the heat emitted from these units. Location of the dewcel should be such that the capillary tube will not be required to make any sharp bends. The capillary tube should be handled very carefully to avoid damage. The air temperature measuring system installation requirements are the same as those for the dewcel regarding location and cautions with respect to the capillary tubing.

The meteorological cabinet houses the barograph, wind recorder, weather data recorder, wind indicator, and clock.

e. Operational Procedures. Operation of the system is controlled from the recorder cabinet. Application of power at this location actuates the rain gage, the dewcel and the temperature sensor power supplies and transmitters. They are operational immediately.

13.1.5 Cloud-Height Set

a. Operational Requirements. The Cloud-Height Set (AN/GMQ-13) or rotating beam ceilometer is an optical system which is utilized at Naval Air Stations. It is a relatively accurate and rapid method of measuring the height of clouds in the area. It is usually operated in the vicinity of the instrument runway. The height data is



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Figure 13 - 5. Converter-Indicator Group, OA-7900/GMQ-10 Interconnection Diagram

used in meteorology to provide information to air traffic control personnel who determine whether the station is to operate under Visual Flight Rules (VFR), Instrument Flight Rules (IFR), or be closed to all air traffic.

The cloud-height set operates on the principle that the lowest cloud layer will reflect a beam of light from the projector unit onto the surface of the detector unit which will transduce the change in light level to an electrical signal. This signal is passed through a high-gain audio amplifier to either the recorder, cathode-ray tube (CRT) display or both. These instruments are calibrated either in angular intervals from which height may be determined, or the calibrated scale of the CRT tube which indicates the height directly. A 400-foot baseline allows cloud heights up to 5,000 feet maximum to be measured.

b. System Configuration. The Cloud-Height Set (figure 13-6) consists of three major components which are the projector, detector, and either a recorder or a CRT display. Each unit will be described briefly. Details of these units may be found in chapter 6.

The projector consists of an optical system drive assembly, power and control relays in a glass-domed cabinet. The unit employs two identical optical systems to increase the repetition rate of the measurements and obtain two measurements per revolution. Each source is modulated by a barrel-type shutter driven by a synchronous motor. This modulation ensures that the detector will be able to identify the projector signal from other light sources in the area.

The detector consists of an optical system, a photoelectric cell, an amplifier power supply, and a voltage regulator all housed in an aluminum housing with a glass-windowed cover. The optical system is comprised of a parabolic mirror with a 10-inch focal length. The photoelectric cell is located above the reflector at the focal point. The photoelectric cell is fitted with an infrared cover glass to eliminate saturation of the cell and changes to input parameters due to high ambient light levels.

The recorder provides a permanent chart-type record which utilizes an electrolytic effect on chemically treated paper. Cloud heights are recorded in terms of elevation angles. The horizontal motion of the stylus is synchronized to the rotation of the projector, and the density of the record varies directly with the signal strength from the detector.

The CRT indicator provides visual indications of cloud height. The electron beam moves up the tube in synchronism with the sweep of the projector beam and widens at a point corresponding to the angle at which the projector light beam strikes the cloud over the detector. The tube face is calibrated in degrees and a conversion scale calibrated in height gives an instant reading of the indicated cloud height.

c. Site and Structural Factors. The preferred site for a rotating beam ceilometer set is in the approach zone of the instrument runway. The projector and detector are located 400 feet apart, parallel to the runway centerline (extended) at a minimum of 750 feet from the centerline. The most distant piece of equipment should not be located more than 2,000 feet from the approach end of the instrument runway. If these conditions are not satisfactory to a station then alternate locations should be considered. The projector and detector must be parallel to the instrument runway centerline but no closer than 500 feet from any runway centerline, 150 feet from taxiway centerline, and 100 feet from parking aprons. A typical layout showing both preferred and alternate equipment locations is shown in figure 13-2. The systems requires 115 V, 60 Hz power from a single source for projector and detector. The site selected should be convenient to maintenance personnel. The location should not be hazardous to either personnel or equipment, nor cause the light to shine into operational areas during night operations.

Structural considerations for equipment foundations should be vibration and drift free. Spacing between foundations should be at intervals of 100 feet plus or minus five feet. The optimum baseline is 400 feet although any baseline length up to 900 feet is allowable.

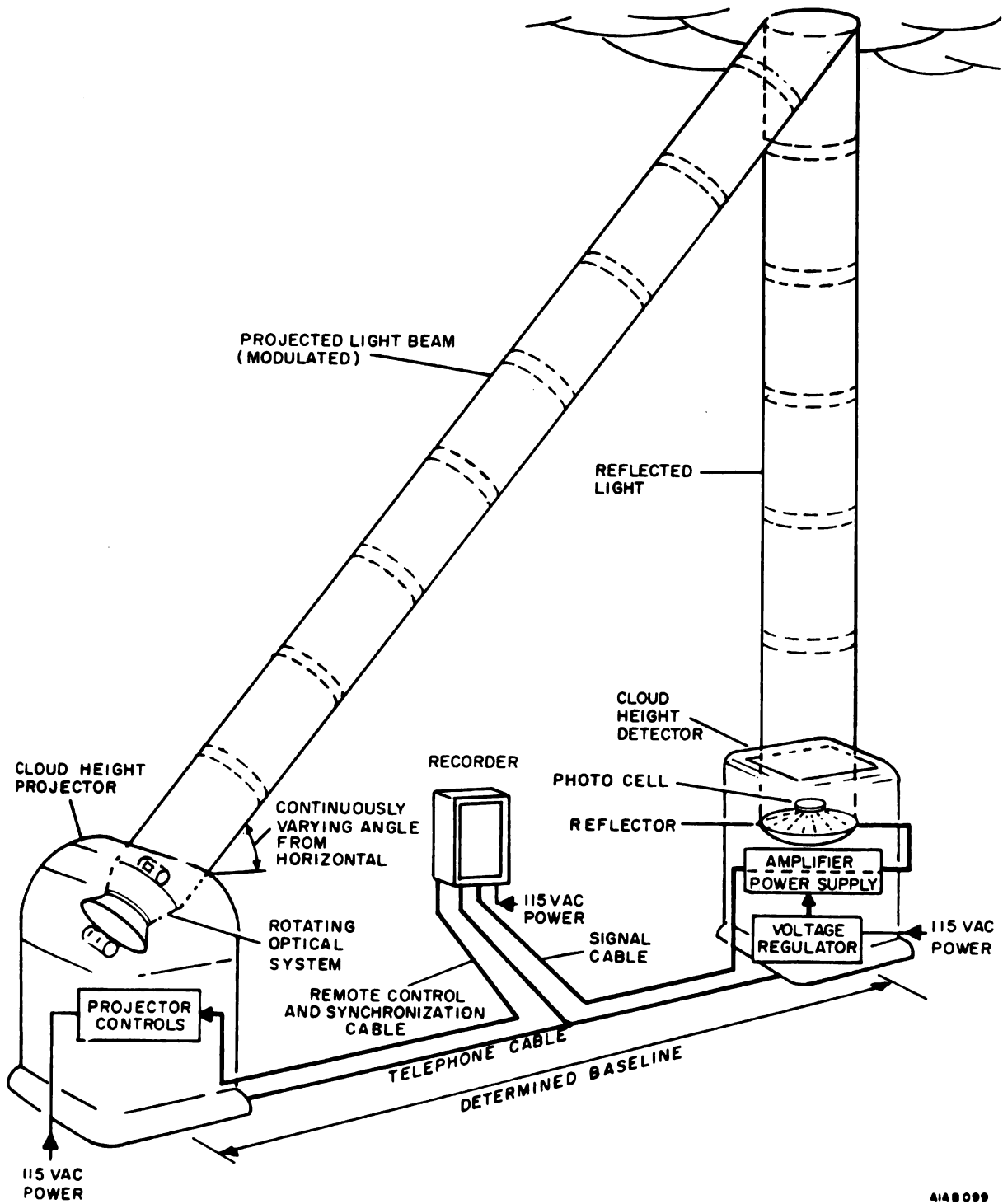


Figure 13 - 6. Cloud-Height Set

The normal installation is at ground level on concrete foundations although there are occasions when this type installation cannot be accomplished. Then, an above-ground installation must be made. The requirements for a proper foundation are still a primary consideration, although the materials used may be steel, concrete, or timber properly treated with creosote. The minimum thickness of wood or concrete shall be 4 inches in all cases.

d. Installation Criteria. Installation of the cloud-height set starts with the proper positioning of the foundations and accurate location of the base mounting hardware and electrical conduits (see figure 13-7). This operation is facilitated by the construction of a foundation alignment template which locates the hardware, conduits and sighting bar to align the two foundations as shown in figure 13-8.

Proper synchronization between the projector and detector can only be attained when both units are powered from a common source. The cables which provide signal, control, telephone service, and power to the projector and detector are A6 conductor AWG No. 16 cable, run from the recorder site to the nearest unit (either the projector or detector for the signal, control and telephone lines). A2 conductor AWG No. 6 cable is also run from the power source to the same unit where it is paralleled to the other unit. The cable should be properly layed out and buried in a trench wide enough to allow separation to avoid signal interference, and deep enough to fall below the frost line. The trench should have good drainage, be properly marked, and be as short as practicable. Power at northern locations will normally require 1000 watts for deicing both projector and detector. For severe icing, use 2000 watts. At southern locations provide 1000 watts for projector and 200 watts for detector since no heat is required for deicing.

Details of the physical alignment of the projector and detector may be found in NAVWEPS HDBK 50-30GMQ13-1.

e. Operational Procedures. The operational status for this system are basically start, stop, and standby. The system can be controlled either on-site or remotely from the recorder location. The detector is always ready as long as field alternating current power is present. The projector may be started and stopped either locally or remotely.

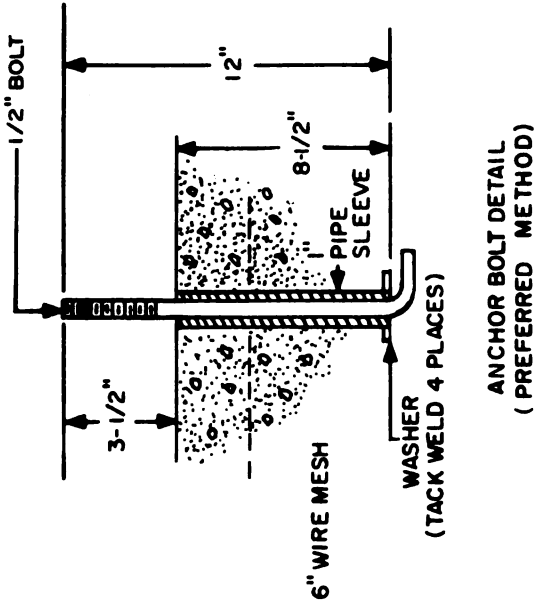
13.1.6 Wind-Measuring System

a. Facility Description. The Wind-Measuring Set (AN/UMQ-5) is a fixed unit that can provide visual and/or recorded indications of wind speed and wind direction to the meteorology department, flight operations desk, IFR room, control tower, or any other required location.

b. System Configuration. The system consists of a direction-velocity transmitter, a dial indicator set available with either 4-inch or 8-inch dials, for wind speed and wind direction and/or a chart recorder for permanent records of local wind conditions. Each of these units have been described in detail in chapter 6.

c. Site Criteria. Primary site consideration for this system is the location of the transmitter unit. The area should provide unobstructed wind flow from all directions, yet be located not less than 500 feet from the runway centerline and not less than 400 feet away from aircraft engine blasts. Do not select a location where the transmitter will be subjected to eddies of wind from any nearby objects or may be struck by flue gases or other contaminants which could impair unit accuracy in a short period of time. The transmitter should be located no closer than 500 feet from any obstruction which would restrict the free flow of air or 150 feet from taxiway centerline and not less than 100 feet from the edge of a parking apron.

d. Installation Criteria. The mast for the transmitter should be properly mounted on a wooden or concrete base providing enough strength so that the support mast will be able to support the weight of maintenance personnel, sustain high-wind conditions and be properly guyed. The wind-measuring set shall be mounted by means of frangible coupling. The system requires 115 VAC, 50 Hz single-phase power to the transmitter sight. To maintain accuracy at the indicators, it is essential that the line resistance not exceed 3.2 ohms. The maximum length and conductor gage of cable between recorders and/or indicators and transmitter are indicated in table 13-1.



1. DEPTH OF BASE SHALL BE AT LEAST 24 INCHES AND SHALL EXCEED THIS MINIMUM IN CERTAIN SOFT WET OR SANDY LOCATIONS, OR WHEN IT IS NECESSARY TO EXTEND TO A POINT BELOW THE FROST LEVEL. LOCAL BUILDING ORDINANCES, WHEN APPLICABLE, SHALL BE OBSERVED.
2. CONCRETE SHALL BE WELL MIXED, CAREFULLY PLACED, AND SMOOTHLY TROWELED, EDGES SHALL BE SLIGHTLY ROUNDED OR 45° BEVELED.

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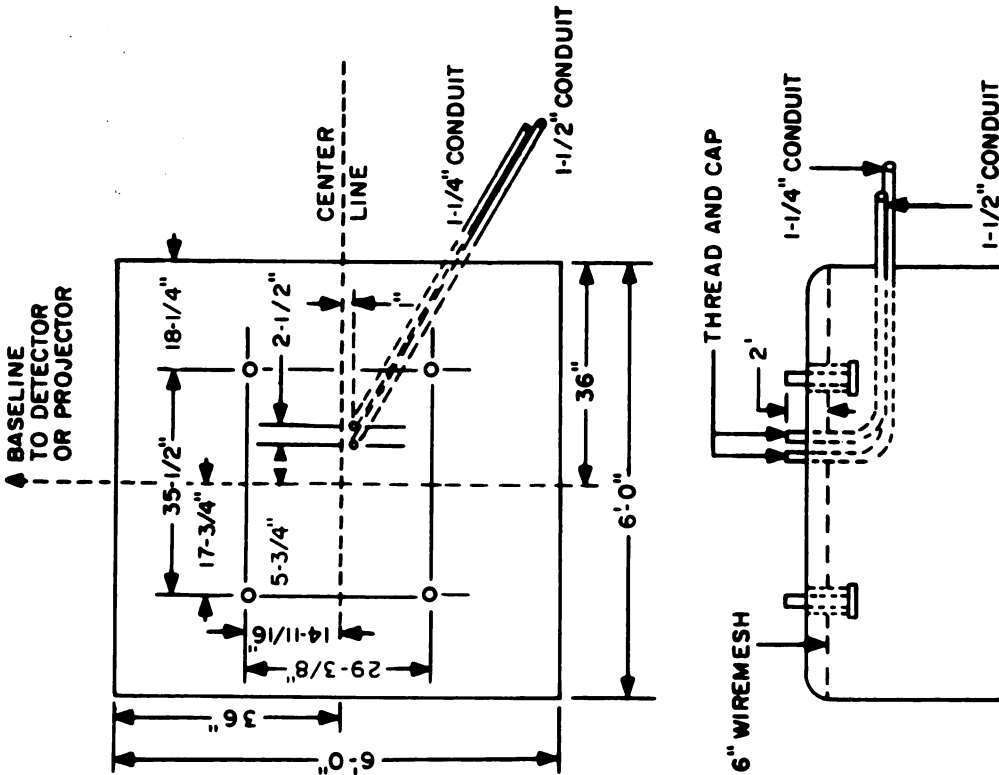


Figure 13 - 7. Projector and Detector Foundation Construction Detail Diagram

The indicators may be table-top, shelf- or rack-mounted. Table and shelf-mounted indicators should allow sufficient space for the performance of routine maintenance through the removal panel at the rear of the housing.

The recorder may be table or rack-mounted but requires ample room for the connection of cable in the recess at the bottom of the cabinet.

13.1.7 Rawinsonde Set

a. Facility Description. Rawinsonde Set consists of a Rawin Set (AN/GMD-2) and a Radiosonde Recorder (AN/TMQ-5) that are used with a balloon-borne Radiosonde Set (AN/AMQ-9) to determine upper-air temperature, relative humidity, wind speed, wind direction, and vertical pressure-height distribution. This data is used in weather analysis, aircraft navigation, and ballistic trajectory computations.

b. System Configuration. The rawin set (figure 13-9) transmits an amplitude-modulated signal that is received and detected by the radiosonde receiver which operates on two different signals.

The basic signal is the 1680-MHz carrier wave, which is transmitted by the radiosonde transmitter. This signal is frequency modulated by the radiosonde's radio receiver. The repetition rate of the pulses in a 74.95 kHz subcarrier is a function of the meteorological element being measured. The temperature and humidity data is received and recorded (or processed) by the ground equipment.

The second signal is the 403-MHz signal which is generated by the rawinsonde transmitter and directed by a Yagi antenna toward the radiosonde. This 403-MHz signal is amplitude modulated by the rawinsonde signal comparator, which generates a signal of 74.95 kHz.

The radiosonde's radio receiver detects, and amplifies the signal and retransmits the 74.95 kHz signal as frequency modulation on the 1680 MHz carrier wave generated by the radiosonde. The 1680 MHz carrier wave is demodulated by the rawinsonde receiver, and the 74.95 kHz signal is fed into the signal comparator. This incoming signal is compared with the internally generated signal and the phase difference is translated into slant range in meters. The output of the signal comparator (slant range) is fed to the control recorder where altitude (corrected for earth curvature) is computed from slant range and elevation angle data. This gives the winds-aloft information. The meteorological information is sent to Radiosonde Recorder AN/TMQ-5().

c. Site Structure and Installation. The ideal site for the operation of a rawinsonde set is the center of a large open area with no natural or artificial objects within 200 yards and no obstructions, at any distance, that extend above 3 degrees from the horizon. However, ideal conditions seldom exist and the selection of an operational site often must be a compromise. The major considerations for the external siting of the main assembly are as follows:

(1) The distance from the operating location of the control-recorder to the main assembly must not exceed 200 feet, the length of the main cable.

(2) The horizon from the main assembly should be unobstructed above 3 degrees, at least in the direction toward which the balloon-borne radiosonde set is carried by the prevailing winds. The prevailing winds at both low and high levels must be considered.

(3) The main assembly must be installed on a level and firm site so that proper leveling and orientation can be obtained.

(4) Adequate clear areas must be available for the release of balloons.

(5) Nearby structures and elevated terrain must be avoided since they may intercept or reflect the radio signal from the radiosonde set and give erroneous bearings.

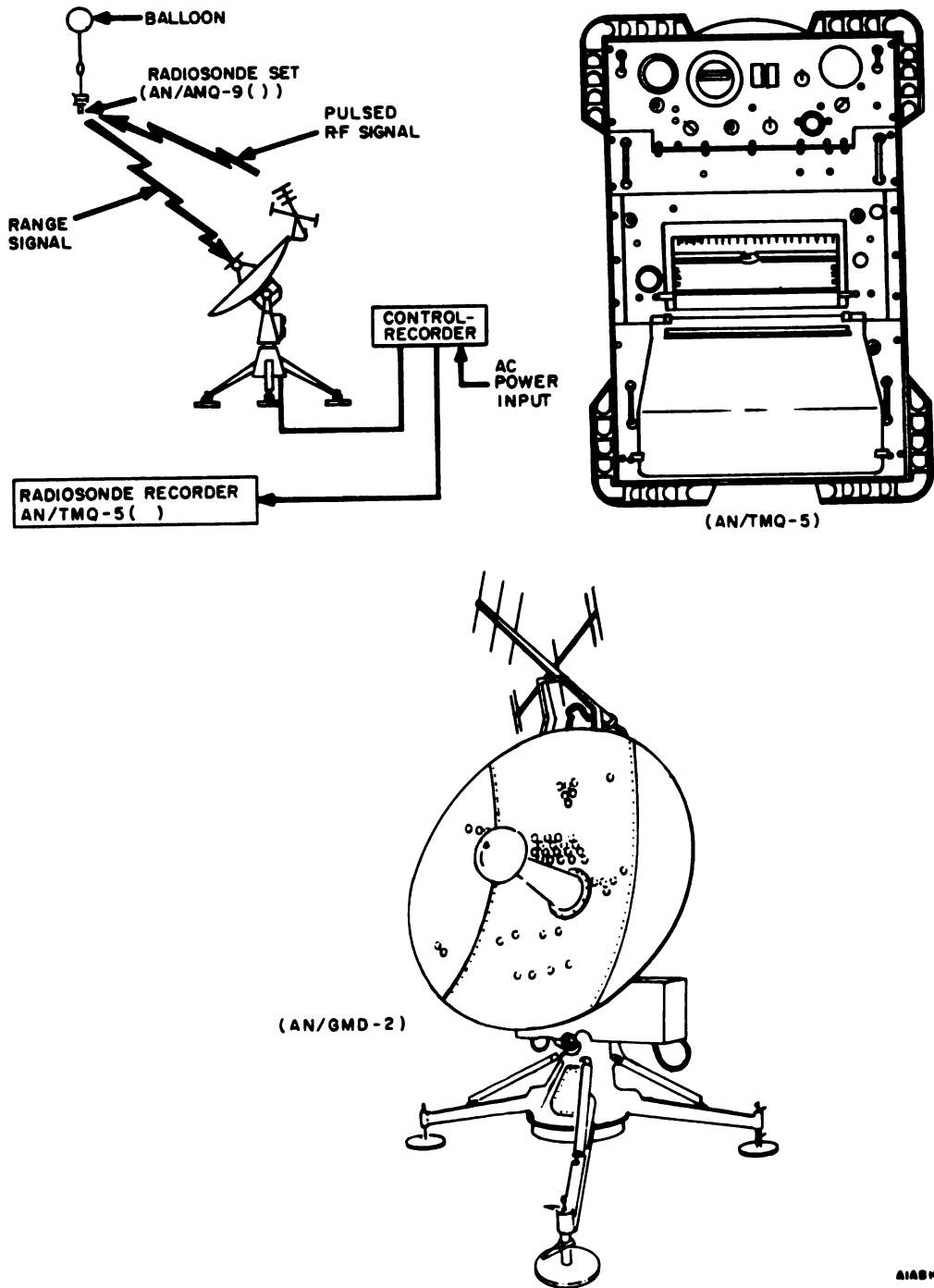


Figure 13 - 9. Rawinsonde Simplified System Block Diagram

(6) Distant landmarks, suitable for orientation references should be visible from the site.

(7) Installation of the main assembly on the roof of a solidly constructed building is often desirable. The control-recorder and radiosonde recorder then can be installed on a lower floor of the same or an adjacent building.

(8) Receiver radio interference to the radiosonde receiver may be encountered in some locations with high electronics activity and possibly from certain older types of radar equipment.

13.1.8 Weather Television System

a. Facility Description. The Weather Television System (AN/GMQ-19(V)) is a closed-circuit (wire transmission) television network used to transmit weather data to remote locations on the station. It provides a means of conveying visual information from charts, maps, or other materials, accompanied by verbal description, to any or all stations on the network. The transmitting equipment of the weather television system is contained in a console. This provides either overhead lights for opaque briefing material, or an illuminated light table for transparent material. The briefing material, placed on the table, is reflected in a mirror, where the image is scanned by a television camera. An eight-hour audio tape recorder is provided as part of the equipment, recording four hours on one side of the tape and four hours on the other. The chassis of the console are, individual components, easily accessible for maintenance and testing procedures. Each chassis, except the camera and the monitor, lends itself to a bench check independent of any other chassis.

b. System Configuration. The weather television set consists of an operator's console which houses the television camera, illuminated briefing table, local monitor set, remote station selection console for selection of remote sites to receive briefings, and the necessary amplifiers, signal generators, and power supplies to transmit the video signals from the camera to these remote locations. The component parts of this system have been described in greater detail in chapter 6.

Each remote site is equipped with a remote video viewer, amplifier, microphone and speaker. This equipment provides the site with the ability to receive briefings, question or interrupt a briefing in progress, or request a briefing.

c. Site and Structural Factors. The selection of a site for the weather television console is limited to a location convenient to the meteorology office. The floor must be capable of supporting the console. Sufficient space must be provided to allow free access for maintenance and proper ventilation of the equipment. The console heat load must be considered in determining if the existing heat exchange system is able to accommodate the added load. Remote video viewers and amplifiers should also be considered in the heat exchange system of the building in which they will be located. Remote stations require sufficient space and structural ability to support a TV monitor and video amplifier.

The most commonly used method of video distribution is by video cable, although microwave data transmission is sometimes employed. In most applications the direct video signal is distributed, however carrier systems might be chosen for special applications. Two types of video cables are typically employed: single conductor unbalanced (75 ohm) coaxial line, and two conductor balanced coaxial line with a common shield. A network of video amplifiers are required to compensate for the video transmission line loss where the direct video signal is distributed. Care must be taken to avoid induction field pickup from power lines. Minimum allowable spacing between power lines and video cables should be observed, and power and video lines should be crossed at right angles if possible. Consideration of cable and distribution amplifier frequency response and signal-to-noise ratio must be given to the transmission line system. A total of 400 W of 115 V 60Hz single-phase power is required by the system.

The AN/GMQ-27() is another weather television system available in the Navy system. Operating characteristics and installation criteria requirements are similar to those of the AN/GMQ-19 system.

13.2 WEATHER DISSEMINATION SYSTEMS

Weather Dissemination Systems available at Naval Air Stations are the Telemetered Meteorological Data Receiving Set (TDMRS) and the facsimile equipment. Other such dissemination systems are common communication facilities and therefore not discussed in this chapter.

13.2.1 Telemetered Meteorological Data Receiving Set

a. Facility Description. The TMDRS, AN/GKR-4, consists of a receiving ground station which is used with an orbiting satellite containing a TV camera and telemeter transmitter to provide a facsimile picture of cloud cover. It is available as either a fixed installation or a mobile unit.

b. Operational Description. The ground station (figure 13-10) provides facsimile reproductions of pictures transmitted from an orbiting meteorological satellite. The pictures, in the form of video signals, are received from the camera subsystem in the satellite while the satellite is orbiting the earth at a nominal distance of 600 nautical miles. The area covered in each picture is 1150 feet with only slight degradation of performance characteristics.

The antenna-to-console distance applies only to fixed location equipment. This condition does not exist with the mobile station (AN/MKR-9) installation since the console is located within the van on which the antenna is mounted.

The system requires the availability of a maximum of 5,565 115-volt 60 Hz single-phase power, including power required for convenience outlets. The console installation requires a minimum space of 12 inches behind the console for cool air circulation and cable runs, and should be located 6 inches to the right of the facsimile recorder.

Site selection for a mobile van configuration requires that no obstructions exist above 10 degrees elevation and 360 degrees in azimuth. The site should be as level as possible on hard, well-drained ground. Site selection criteria should not be sacrificed for the availability of commercial power.

If lightning protection is necessary, considerations should include distance from antenna to lighting rod support, height of pole above antenna, and proper grounding of antenna pedestal.

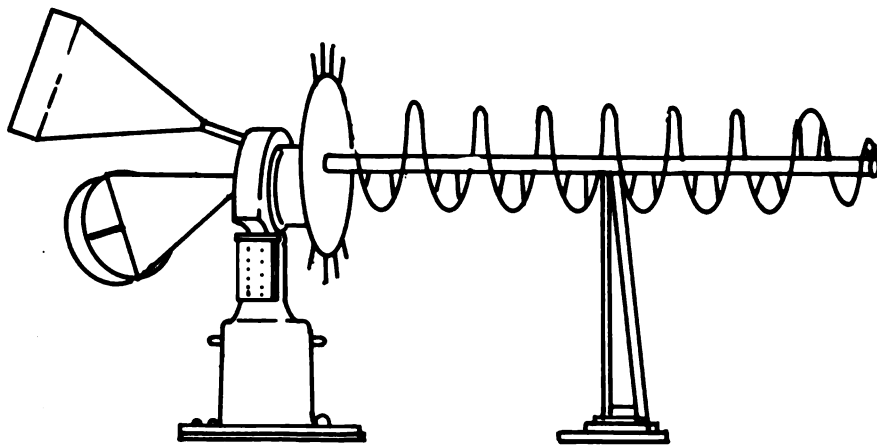
d. Operation and Maintenance Procedures. Operational procedures outlined in the Installation, Operation and Maintenance Manual, TO 31M7-2GKR4-2, should provide good operation when properly used.

13.2.2 Facsimile Transmitters and Recorders

a. System Principles. Facsimile systems consist of a transmitter used to convert printed matter to electrical impulses thereby allowing the transmission of maps, diagrams, drawings etc., to remotely located recorders (see block diagram 13-11). The recorders receive these electrical impulses and reproduce a copy of the transmitted original. These signals are transmitted either by direct wire or radio communications circuits and may be utilized in connection with the following type circuits:

o Wire Circuits. A facsimile transmitter may be operated directly into landline wire circuits, when good quality lines are available and may be used by the recorder without any further processing. Most signals are preconditioned in a radio modulator which converts the amplitude-modulated facsimile signal to a frequency-modulated signal prior to transmission. The remote station will then require a frequency shift converter to convert back to an amplitude-modulated signal for use by the facsimile recorder.

o Radio Circuits. When the facsimile transmission system to be used is a radio circuit there is generally a need for auxiliary equipment to condition the signals prior to transmission. An exception involves the use of short-range circuits providing amplitude-modulated signals to a recorder. These circuits generally do not require special auxiliary equipment unless the receiver does not have a 500-ohm signal output. This situation would require the use of a matching transformer to condition the signals for the recorder. Usually radio circuits are long



ANTENNA SYSTEM UNIT
A. ANTENNA UNIT

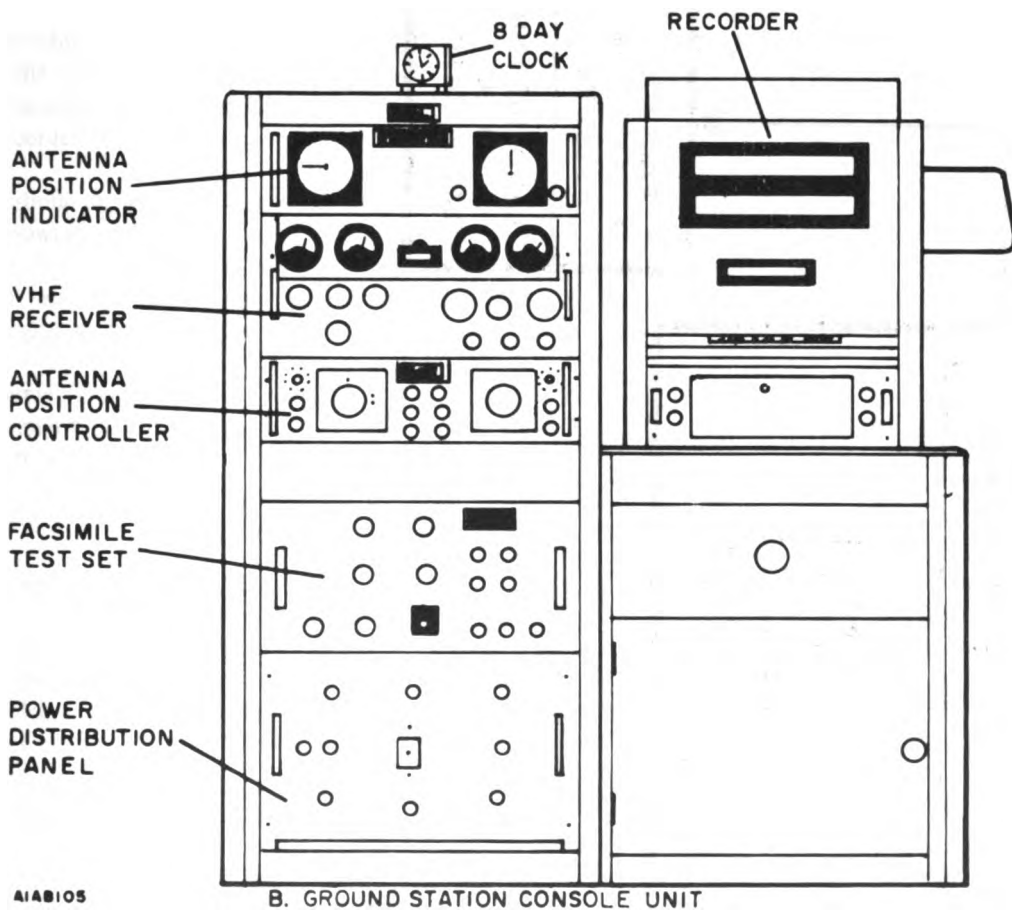
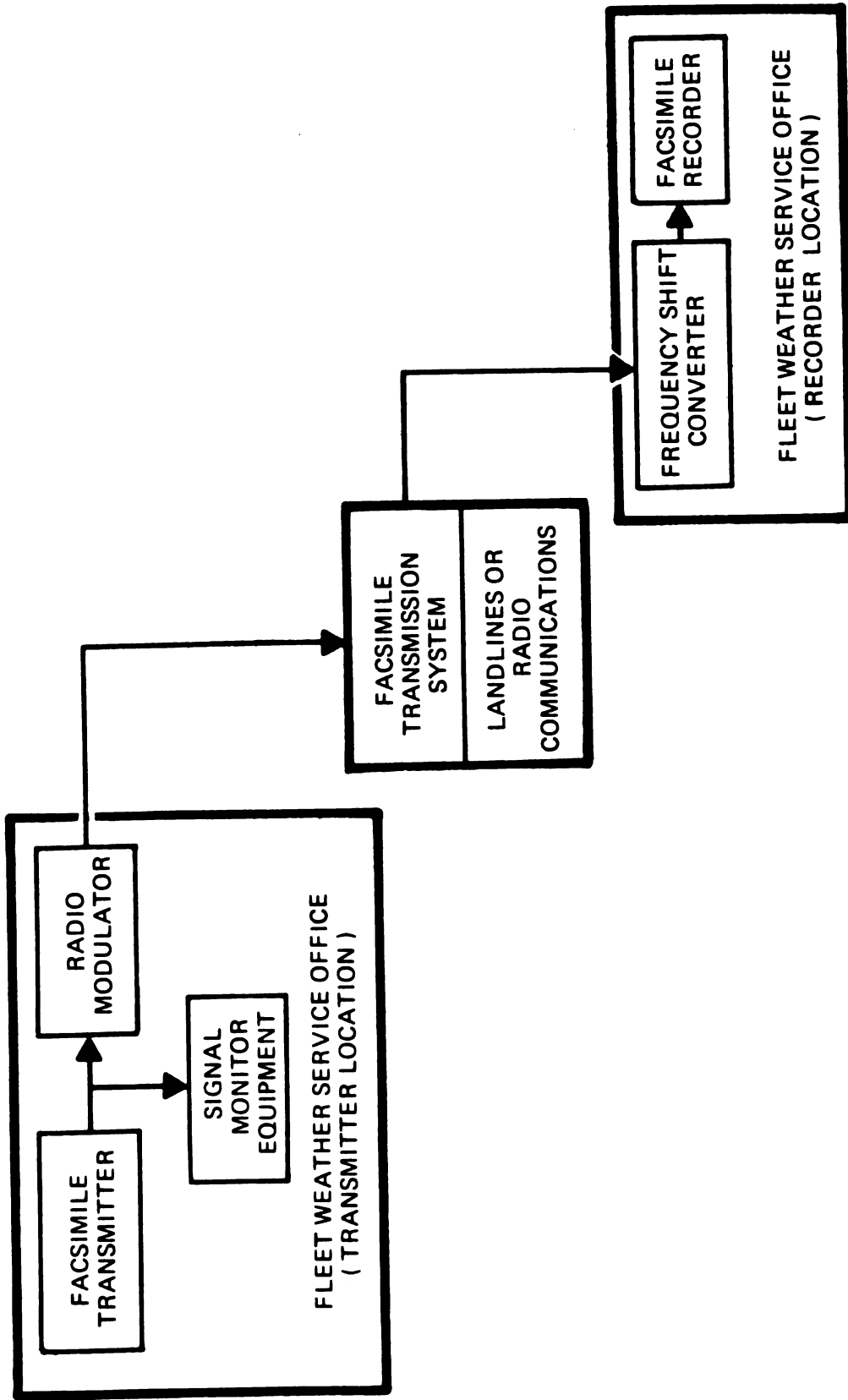


Figure 13 - 10. Ground Station Console and Antenna Unit



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Figure 13 - 11. Simplified Block Diagram of a Facsimile Transmission System

range and can be affected by a variety of signal-distorting conditions, therefore the facsimile signal is remodulated, transmitted and reconditioned by a signal converter at the recorder to ensure good quality reproduction of the original transmitted data.

b. **System Configuration.** A facsimile system is composed of the transmitter, transmission media, and the recorder subsystems. Equipment used in each subsystem and type of transmission media are shown in figure 13-11. These subsystems are described in chapter 6.

c. **Site and Installation Criteria.** The site selected should have ready access to voice quality transmission circuits as a minimum. The circuits available should have a frequency response which is flat to within +2 dB between the frequency limits of 900 and 2700 Hz, and the total delay distortion over this band should not exceed 500 microseconds. These conditions hold true for both transmitter and recorder locations. The transmission circuits may be either wire lines or radio circuits:

o **Wire Lines.** The wire line circuit used should be free of amplitude variations and reflections. If wire line facilities are ordered from the telephone company, it is recommended that a schedule 1 or 2 facsimile circuit be used. For distances of less than 100 miles it is often possible to use a conventional voice circuit instead of a special facsimile circuit. The telephone pair is connected directly to the line terminals which are located on the top of the signal amplifier box at the rear of the facsimile recorder.

o **Radio Circuit.** A radio circuit should be selected which will be free from interference and multipath transmission. Radio circuits require radio modulators (AM to FM) at the facsimile transmitter location and a frequency shift converter (FM to AM) at the recorder location. The transmitter signal is passed through the radio modulator which may be located at either the facsimile or radio transmitter site. The preferred location is as close to the facsimile transmitter as possible. The frequency shift converter should also be located at the facsimile recorder location to eliminate the pickup of any interference after the signals have been reconditioned for the recorder.

If the facsimile signals are being received from an FM radio circuit, a short haul AM radio circuit with no fading or a microwave radio relay, it is not necessary to use a converter. In this case the radio circuit output is connected directly to the line terminals of the facsimile recorder. If the output is coming directly from a radio receiver, it may not be necessary to connect a resistance pad between the radio receiver output and the facsimile recorder input so that the signal level at the recorder input is not more than 0.7 volts.

The Facsimile Transmitter Set, AN/GTX-2 (figure 13-12), is a free standing unit which should be located in an area convenient to both alternating current power and outgoing signal lines. It has provisions for shock mounting of the unit when necessary. The operating area should provide sufficient space to allow adequate ventilation and space for the performance of any required maintenance. The transmitter requires 500 watts of 115 V 60 Hz power.

The Facsimile Recorder Set, AN/UXH-2 (figure 13-13), should be mounted on a table or platform convenient to the power outlet and the incoming signal lines. The table or platform surface should be capable of supporting the recorder's weight. Allow sufficient clearance for equipment operation and maintenance. Adequate space should exist between the equipment and the rear wall to ensure adequate ventilation. Recorders with roll-type paper supply which may run unattended for extended periods of time should allow space for unremoved recordings to collect, yet not inhibit the operation of the recorder. The recorder requires 275 watts of 115 V 60 Hz power.

d. **Operation and Maintenance.** The Facsimile Transmitter requires that the operator apply primary power, determine flood light polarity which should be changed each day, select scanner rotation speed, set copy feed to correspond to the scanner rotation speed, set automatic stop switch (OFF for manual stop mode, or ON for automatic stop at end of copy), prepare documents for transmission, and adjust both black and white level controls for proper modulation ratio on output signal monitor scope. Upon completion of this setup sequence, the start button is pressed to transmit the copy. When the last of the desired information has passed the copy slot, the transmitter will return to standby in auto-stop or operator must push the stop switch in manual which sets the transmitter in a setup or standby mode.

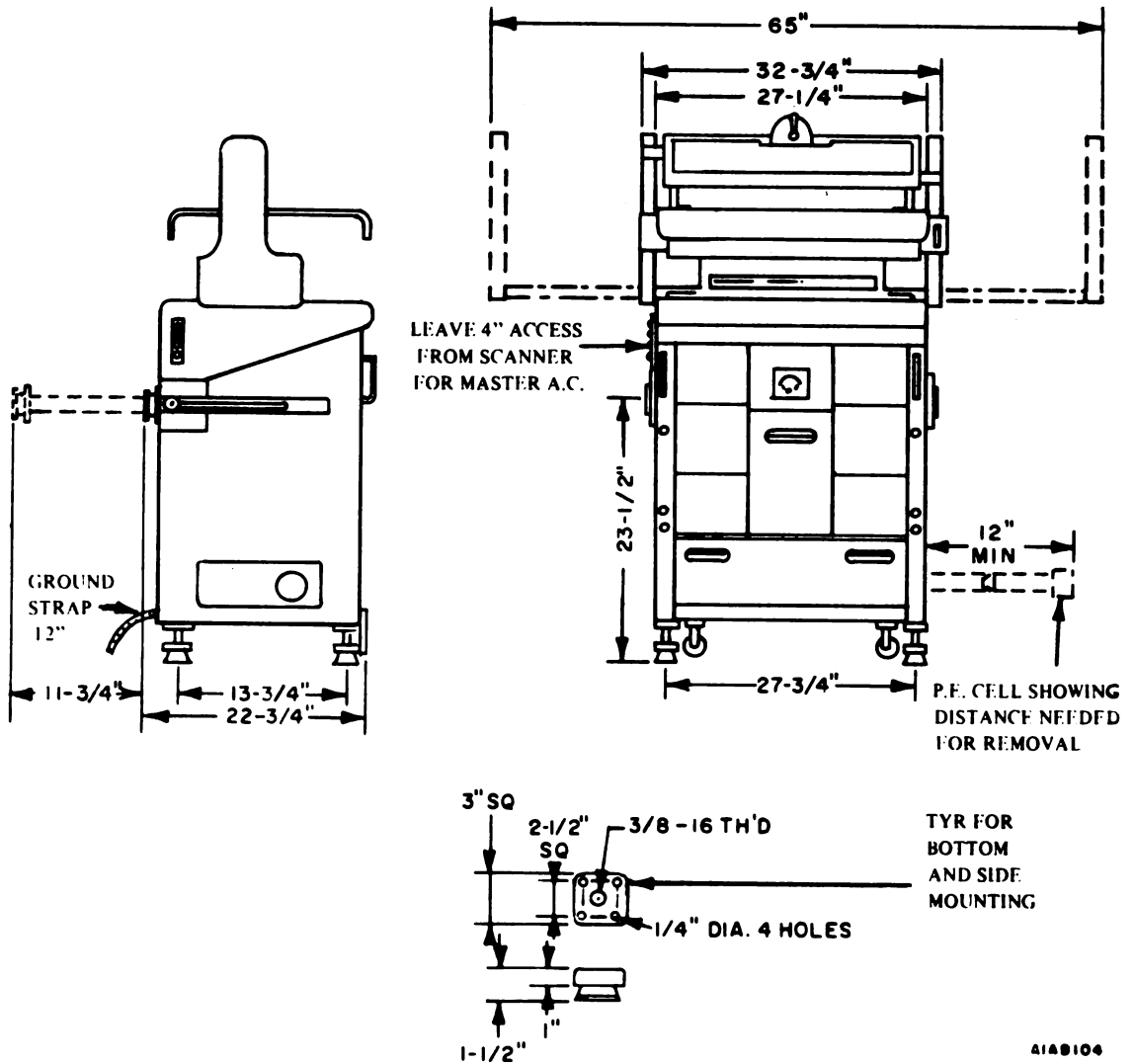


Figure 13 - 12. Facsimile Transmitter Set AN/GTX-2 Outline Drawing

The recorder can be operated either manually or automatically. Manual operation requires that an operator prepare the unit and start it every time a picture transmission is scheduled. Automatic operation can be accomplished by the use of an adapter unit if the recorder is not designed to operate automatically on receipt of control signals from the transmitter.

Maintenance of the transmitter and recorder units is described in the individual equipment technical manuals.

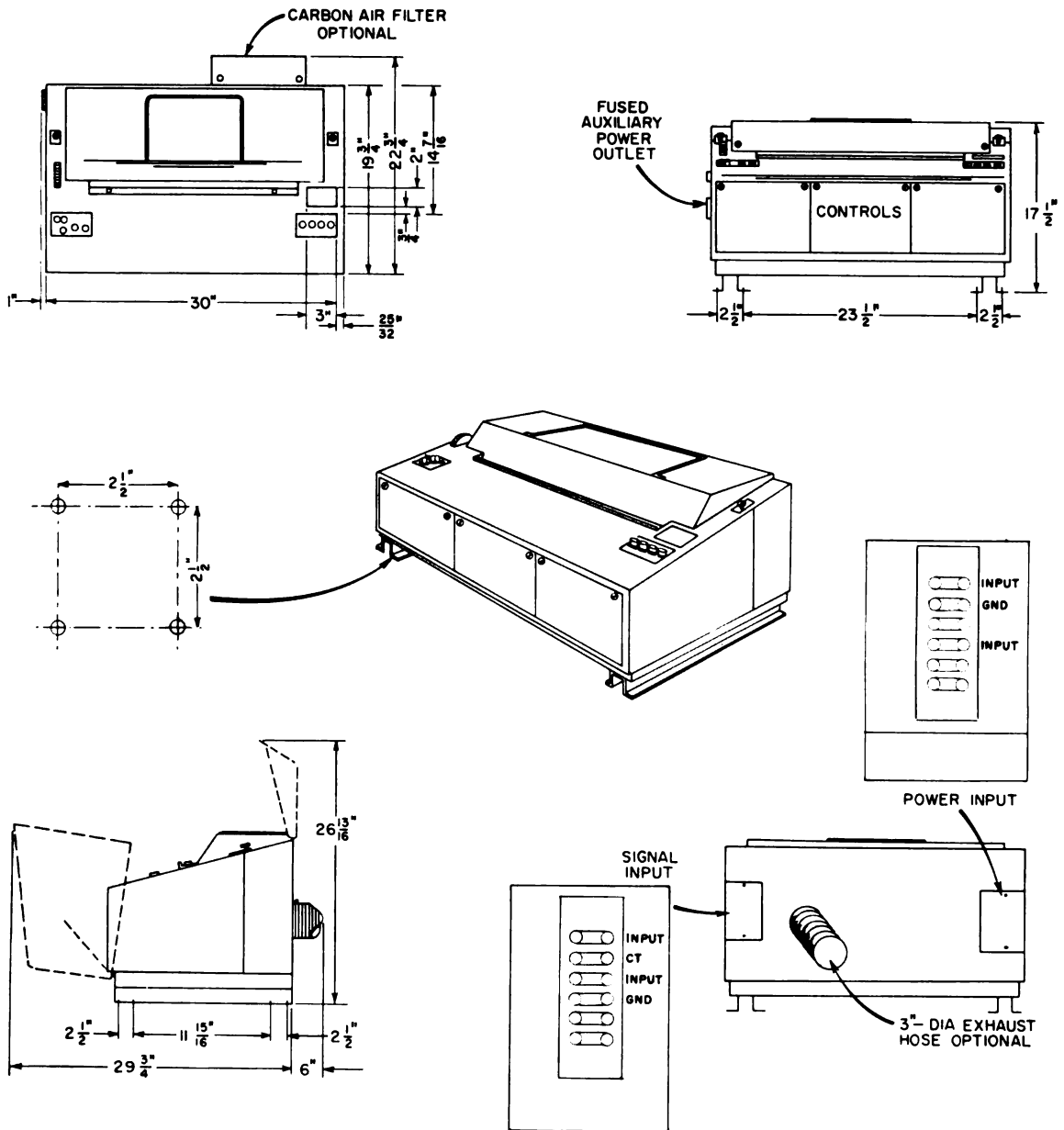


Figure 13 - 13. Facsimile Recorder Set, AN/UXH-2, Outline Drawing

CHAPTER 14

MAINTENANCE FACILITIES AND SYSTEM TEST CRITERIA

The Naval Electronic Systems Commands Technical Policies and Procedures Manual states in part that maintenance of electronic equipment, both corrective and preventive, is the responsibility of the commanding officer of the activity. The commanding officer shall have a preventive maintenance program. The degree of emphasis required on preventive maintenance due to equipment complexity can be determined by reference to the technical manuals provided with the equipment. Most repairs can be accomplished by proper use of the information supplied therein, and the judicious expenditures of repair parts carried aboard. Equipment abuse arises from lack of adequate preventive maintenance and from failure to follow proper operational procedures. The major factors involved in reducing these problems are set forth in the technical manuals for specific equipment and various maintenance manuals and publications. The field activity shall assist in formulating the program on request of the commanding officer, or spontaneously on a program-wide basis as deemed necessary.

14.1 PROGRAM

The goal of optimum operational reliability of electronic equipment cannot be approached without the implementation of a good effective program of preventive maintenance. Preventive maintenance is the systematic accomplishment of items deemed necessary to reduce or eliminate failures and to prolong the useful life of electronic equipment. Electronic equipment instruction books supplied with each equipment ensure that information is always available on which to base a preventive maintenance schedule.

A preventive maintenance program may be implemented by: following procedures outlined in the equipment instruction books, application of system test procedures, and employment of performance and maintenance standards of electronic equipment publications where applicable.

14.2 PERFORMANCE AND MAINTENANCE STANDARDS

NAVELEX promulgates performance standards and standardized test procedures for electronic equipment. The program may also serve as the basis for recommended preventive maintenance procedures for combined ship and shore types of electronic equipment used at Naval Air Stations. In the implementation of this program, NAVELEX is the monitoring authority in the preparation and procurement of manuals and publications. A description of the manuals and publications making a complete package for an equipment follows:

14.2.1 Performance Standard Sheets

The sheets provide the operational data and basic technical measurements indicative of the minimum acceptable level of performance for electronic equipment.

14.2.2 Maintenance Standard Books

These books provide standard methods for determining measurements affecting the performance of a specific equipment, space to record measurements, and a preventive maintenance schedule for the equipment. The Maintenance Standards Books include: Part I - Test Procedures and Maintenance Reference (originally published as Performance Standards Book), and Part II - Preventive Maintenance Check-Off (originally published as Maintenance Check-Off Book).

14.2.3 Operating Instruction Charts

These charts provide a summary of the procedures to be followed in starting, operating, and stopping the equipment. This information is prepared in chart form, on laminated plastic sheets, for posting on or nearby each respective equipment. One chart should be convenient to each operating position. Operating instruction charts are not produced for all types of electronic equipment, but are produced generally for those types having a complex operating nature, or having high power output.

Field activity personnel are available, upon request, to assist station forces in establishing the initial equipment performance standard. It will be necessary to first peak the equipment concerned, before running through the complete check-out procedure, as prescribed in the applicable publication.

14.3 SYSTEM TESTING

14.3.1 Definitions

A system (electrical-electronic) is a combination of two or more sets, generally physically separated when in operation, and such other assemblies, subassemblies, and parts necessary to perform an operational function or functions. (Examples: AEW electronic system, telephone carrier system, GCA electronic system, fire control system including the tracking radar, computer and gun mount).

Another example of a system is a complete air surveillance radar (ASR) system which includes the transmitter-receiver site and the remoted monitoring site (IFR and equipment room). The site interconnection may be by cable or a microwave link, as required by location.

A system test is defined as a procedure whereby system performance is measured. This measurement shall indicate quickly and effectively just how well a system is performing its specific functions. When malfunctioning is apparent, test measurements will provide information which will permit localizing the cause. Where possible, it is preferred that system testing will permit measurement of performance during operating periods without interruption to continuous normal function.

14.3.2 Application

System tests are applied to any one point, or at a number of points, where system performance can be effectively measured. A complete system, such as an ASR installation is extensively complex and may include the propagation path as a component of the system. No single measuring device at one point may be used to measure the overall system performance. Instead a complete system test requires a separation of the overall system into smaller segments, with performance standards specified for each segment. Measurement of the performance of component segments serves to pinpoint causes of system performance degradation, when such is indicated by the alarm mechanism of the overall measuring device.

The establishment of standard System Test Procedures applies particularly to a communication systems or segments of complete systems. System test procedures are also applicable to other electronic systems such as air surveillance radar system and radar air traffic control systems having remote presentation. Since many Navy electronic facilities contain duplicate systems, a standard test procedure should be established for each system.

14.3.3 System Test Procedure

A system test procedure is written instruction prepared for each electronic system of the Naval Air Station. Each system test procedure bears a number for identification. Each of these numbered tests is complete in itself and contains all required information and directions for conducting the system test.

The Naval Shore Electronics System Test Manual will contain all current system test procedures and shall be prepared in accordance with the military specifications for technical manuals, MIL-M-15071 (SHIPS) as modified for this particular type of technical manual. As new system tests are developed, or changes are made to current tests, the publication will be revised.

Optimum employment of illustration and test shall be used to present the test in the simplest most readily understood form. The object of all system tests is to provide checks which may be performed by non-technical personnel whenever possible. Tests may be divided into two parts: an operator test with partial use of the system; and a technician test utilizing the full system, to be performed upon operator call or on a routine, scheduled basis. A System Test Procedure for any particular system will contain the following items:

- o Components. The components of the system shall be listed and system boundaries clearly defined.

- o Test Equipment. The test equipment required for the measurement of system performance is often included in the composition of the system, or as part of individual components. Additional general purpose portable test equipment may be required. Certain systems may require special test equipment to be fabricated, installed in the system, or otherwise made available. When such equipment is fabricated for a special system, or procured for a specific application, the applicable portions of MIL-T-945 "Test Equipment, For Use With Electronic Equipment; General Specifications" shall be followed in the design of such equipment when practicable and economically feasible. In all cases, the prescribed equipment required to perform the system test shall be listed and made available.

- o Procedures. The system test procedure shall contain precise instructions for conducting the system test. These instructions shall include the times for applications of the tests. In some systems, measuring techniques may be applied continuously, while other systems require only periodic measurement and examination to ensure optimum performance.

The instructions shall describe test points, and any special conditions which may be required when applying test procedures. Typical meter readings and tolerances shall be specified. Where oscilloscope examination is part of a system test, a typical presentation shall be illustrated.

- o Recorded Data. In order to detect gradual performance degradation, a written record of testing shall be maintained where applicable. Forms shall be made available for such purpose. The design of the forms shall be such as to provide medium utility combined with simplicity, so that maintenance of records will not be excessively burdensome.

- o Performance Standards. The preparation of a system test procedure shall contain a discussion of the performance standards applicable to that system. Reference shall be made to the appropriate paragraphs of this publication, to military specifications, and to design specifications of components of the system, as needed in the preparation of the discussion. The discussion shall be based upon performance standards applicable to each component and upon the effects that integration into a system has on their performance.

NOTE

Each component of a system has the capability to perform individually to meet a specified operational requirement. A transmitter is designed for a certain frequency range, power output, frequency stability, type of emission, and for specified limits as to harmonic output and extraneous emission. A receiver has a certain sensitivity, bandwidth, and other features which are characteristic. A landline has a special transmission characteristic, with a limit to permissible attenuation. When such components have been integrated into a system, the design of the system has considered the maximum capabilities as well as the limitations of each component.

The preparation of a standard System Test Procedure is under the direction of NAVELEX. The contractor, or other designated authority, shall be furnished with the following facilities to be used in the preparation of a System Test Procedure:

- o Instruction Books Equipment test data and pertinent publications shall be furnished by the Government.

- o System Availability. The Government shall either provide the prime equipments which comprise the system to the contractor, or shall provide access to an existing Government system for measurements, and demonstration of the proposed system test. Prior to acceptance of a system test, and final preparation of the system test instructions, the contractor shall provide the Government opportunity for evaluation of the system test and shall incorporate such modifications to the test procedures as may be requested by the Government.

- o Test Equipment. Test equipment specified by the contractor for the systems tests shall be selected from NAVSHIPS 3791 (4-60). Recommended, or permanent substitute type equipment, shall be used wherever such equipment will perform the required function. If the contractor considers that other test equipment is required, he shall request Government authorization before proceeding with its procurement of development.

System test procedures should be incorporated into routine station operation and integrated with prescribed maintenance procedures. Operating personnel should be given a thorough indoctrination into the application of system test procedures so that the burden of system testing does not rest entirely upon maintenance personnel.

In new installations the Field Technical Authority shall apply system tests to obtain assurance that operation of the equipment and systems will meet prescribed performance standards. Upon request, the Field Technical Authority will provide engineering assistance toward the integration of appropriate system test procedures into routine station maintenance.

Available system tests shall be performed during the annual inspection of an activity.

14.4 MAINTENANCE FACILITIES

Electronics repair facilities must be provided and be equipped with workbenches, power, and tools of sufficient quantity and proper type to effect routing and emergency maintenance and repair of installed equipment. The Ground Electronics Maintenance Office should have a centrally located facility for take-out equipment, as well as on-site work areas for routine checks and minor repairs. Standard and special test equipment as required must be included in the up-dated allowance list and should be supplied. Repair parts must be integrated into the supply system. A maintenance parts system requires the installation of standard storage bin units for parts "peculiar" and parts "common" normally carried on board, and requires establishing a standard plant accounting system in accordance with current directives.

For radar, navigational aids, communication and all other electronic systems equipment, a maintenance program must be established on an equipment rotational basis.

Performance and maintenance procedures as appropriate shall be applied. System test procedures integrated with the maintenance program should be scheduled and records shall be established and maintained to facilitate early detection of performance degradation.

The maintenance program for special systems, such as data handling equipment, must be tailored to the overall system. The technical manuals supplied with the equipment will contain maintenance recommendations. Marginal and diagnostic routines must be prepared for the computer and each unit of peripheral equipment. Diagnostic routines must be prepared for the display system. An overall system maintenance routine must be prepared with emphasis placed on known or suspected weak areas. Special test equipment peculiar to these systems must be included in the allowance as required.

The Ground Electronics Maintenance Office should maintain an updated technical library. Technical manuals for every electronic system and equipment used on the Naval Air Station, along with a broad assortment of general technical textbooks should be available. Specific books concerning the theory of operation, installation, and maintenance of the more complex systems, such as data processing and display equipment, should also be considered a prime requirement.

A special maintenance training program should be established to train technical personnel in the many systems. For many of the technicians, this program will be a review, but for others it will be a new experience. To assure a competent maintenance team, training sessions should be periodically scheduled. For the more sophisticated systems, the program should place initial emphasis upon the evaluation of personnel as to their adaptability for such training, before they become too involved in the complexities of these systems.

APPENDIX A

BASE ELECTRONIC SYSTEM ENGINEERING PLAN

Planning is an activity carried on by each individual in every walk of life, either on a personal basis, or at the corporate level. It is a process which results ultimately in decision. The extent of planning is dictated by the complexity of the problem at hand. Such questions as which grade of gasoline to put in the tank, or where to have lunch often require only a few moments of reflection. A question of where to locate a new plant, or which defense system to employ, requires more extensive and detailed documented planning. For decades, management has been growing from the "proprietor-owner-do-it-all" concept to the presently accepted "scientific management." In recent years, the terms "systems engineering" and "operations research" have represented improvements in areas of technical management. Mathematics has become the right arm of management. These improvements in management have as a common base a well defined sequence of events leading to ultimate problem solution. These events are the definition of the problem; a statement of objective; the synthesis of a solution; the analysis of the synthesized solution, and various alternatives thereto; and finally the selection of the best solution.

The familiar 3-Ms of management; men, money, and material, are as important in the Navy as any other organization. Effective utilization of these resources is of primary concern. Some of the Navy's resources are allocated to the Naval Shore Establishment which has as its sole purpose support of the fleet. The Shore Electronic Facilities, which are a vital part of the Naval Shore Establishment, are constantly changing in response to changes in requirements. Improvements are made in keeping with the state of the art. In some cases, improvements advance the state of the art. There are thousands of men and women in shore electronics. There are billions of dollars of material currently in use, and millions of dollars are required every year to support electronic activities. Obviously, a change in a facility is therefore a complex problem, the solution of which requires far more effort than a moment's reflection. On the other hand, the change is very seldom of such a major nature as to require rigorous mathematical planning. At some point in between, lies a level of technical planning which is adequate for the needs of the moment and is economically justifiable. This loosely defined level of planning is outlined for implementation by the Base Electronic System Engineering Plan (BESEP).

A-1 THE BESEP

Shore electronic projects, by their very nature, involve electronics and construction. Within the Naval Material Command, electronic engineering capabilities are concentrated in the Naval Electronic Systems Command. Construction capabilities are assigned to the Naval Facilities Engineering Command. Each of these commands has a headquarters organization supported by field activities established on a regional basis. Essentially parallel operations are carried on at the respective levels down through the command. The BESEP provides the mechanics for chain of command review and cross-command coordination at various levels for each project. By this means, all responsible activities from the user to the sponsor are accorded the opportunity of contributing to project development and planning. This ensures that compatible and integrated shore electronics systems and facilities are provided which are adequate in all respects to meet the needs of the user. The BESEP is normally prepared by the Naval Electronic Systems Command Electronic Field Activity in concert with the Facilities Engineering Command Engineering Field Division. The field activity assumes the responsibility and proceeds automatically unless specifically directed to the contrary by headquarters. Changes to the BESEP will often be introduced during the review procedure. These changes are incorporated in the approved draft of the BESEP by the field activity. The BESEP is an engineering document which is developed at the moment of project conception and is maintained current throughout the project until completion. The BESEP translates operational requirements into statements of resource requirements and system concepts, and remains as the basic technical reference governing electronics and the related basis of facilities/installation project planning and implementation. The BESEP equates a sponsor/user statement of operational need with appropriate shore electronic systems and facilities concepts

which will meet this need. It provides information on electronic systems, equipment and devices to be used, their pertinent technical parameters, the physical characteristics, environmental requirements, and complete system performance objectives.

The BESEP is primarily a technical document and, although it is a vital management tool, it normally does not treat matters pertaining to project management such as cost estimating and scheduling. As the basic technical reference governing electronics and allied phases of project planning and implementation, the approved BESEP serves in effect as a user/producer contract. It therefore becomes a vital instrument in meeting the following project needs:

- o A means of obtaining sponsor approval of the plan developed to fulfill stated operational needs.
- o The central availability of a complete and authoritative engineering plan and major material requirements list for use as a project program management tool.
- o A formally approved technical basis for preliminary and final design specifications.
- o A basis for evaluating performance of systems, or increments thereof, acquired under a project, in terms of the degree to which approved design objectives are actually achieved.
- o A record document for use by operating, support, and management agencies after the project has been completed.

The objective of the BESEP is to provide all the background information and technical data necessary for project planning and implementation but to avoid detail and redundancy which may serve no real need or useful purpose. It is expected, for instance, that small project preliminary BESEPs will often consist of a minimum narrative and tabular requirement supported by single-line diagrams and sketches. For very small projects, this depth of treatment may be adequate as a final BESEP. Larger, complex projects require and warrant more detailed and comprehensive treatment.

Experience has shown that timely preparation and approval of the BESEP as a complete package is not always possible. For this reason a format was developed which permits some degree of incremental development and approval to fulfill first needs first.

The content of the BESEP is as follows:

A-1.1 General Requirements

This section establishes a basis for the engineering and development of a project. It includes information and guidance such as:

- o Historical data leading to the establishment of the project.
- o Reference to, and appropriate paraphrasing of, operational requirements and other guidance documents.
- o Overall objectives of the systems to be provided.
- o Identification of existing or other proposed system/facilities which are affected or with which compatibility is required.
- o Requirements or provisions for incremental implementation.
- o Special requirements for operational continuity of existing facilities during project execution.
- o Special clearance considerations due to flight safety, radiation hazards, and security.

- o General plan for selection of sites, or identification and description of sites already selected.
- o System packaging guidance (i.e., transportable or fixed plant).
- o Special requirements of operational flexibility and convenience.

A-1.2 Scope

This section describes that portion of the overall system/facility requirements to be fulfilled, and, if appropriate, designated phases of long-range projects or programs. It defines the limits of planned construction, alteration, disestablishment and demolition of facilities as well as design, procurement, alteration, installation or disestablishment of electronic equipment and systems. This information is derived from the general requirements outlined in A-1.1, program data provided by the sponsor, and other materials used in describing and justifying the project.

A-1.3 Electronic System Design and Installation

This section outlines the operational and technical concepts and philosophy underlying the selection of electronic equipments, their integration into required electronic systems, and the discrete designs developed and adopted to meet the stated operational requirements. It provides, or refers to, appropriate technical criteria and standards, including siting, and describes all significant technical and operational features to be incorporated. Single-line flow diagrams, typical equipment cabinet loadings, and panel layouts are provided, as required, for clarity. Additionally, this section details the electronic characteristics of the site and describes the influence of these characteristics on the system design and the predicted operational performance.

A-1.4 Electronic Equipment

This section lists the types and quantities of required electronic equipment and test equipment tabulated by site location. It includes tabular information such as equipment nomenclature, height, weight, power required, water cooling requirements, heat load, special equipment cooling, maintenance, and operational access space required.

A-1.5 System Checkout and Acceptance

This section contains the electronic equipment standards and system checkout procedures integrated into an overall system test plan. Reference is made to those applicable procedures for the test and checkout of equipments and systems which have been published previously. Appraisal and acceptance standards must be established in terms of the operational requirements, within the scope of the project. Any special software or documentation required for test, checkout, acceptance, and turnover would be a part of this section of the BESEP initially, or should be provided as it is developed.

A-1.6 Physical Plant

This section contains information on the electronic equipment and systems which affect the design of the supporting structures and buildings which have not been covered in preceding sections. To be especially noted are those special features, relating to the architectural, structural, mechanical and electrical portions of the plant design, including clearances, siting, and access requirements. Single-line drawings showing planned layouts of equipment and antennas are prepared to assist in defining the technical approach. Where appropriate, tabulations of personnel loadings, movements, occupancy, consumption, and other such support requirements are provided.

A-2 TYPES OF BESEPS

Several types of BESEP's are prepared depending upon the phase of project planning. Material content and degree of detail contained in a BESEP allows ready identification with one of the following categorical types:

- o GUIDANCE
- o PRELIMINARY
- o FINAL

A one-of-a-kind facility is rather an infrequent occurrence in the Navy. The majority of projects by far, are the multistation type. Obviously, if there is a requirement for a change in one portion of the operating system, this same change should be made at similar facilities throughout the shore establishment. At any given time, therefore, there will be underway, a number of projects for the installation of a system, or for the development of projects at a number of activities. The BESEPs developed for these projects, would differ only by the name of the activity and by certain site adaptation factors. Such parallel development is an unnecessary expenditure of manpower. The solution to this problem is the development of a guidance BESEP. The guidance BESEP contains 70 to 90 percent of the information that is required for each of the individual BESEPs. An activity is assigned the task of developing the guidance BESEP. Upon completion, this document is provided to all field activities which are involved in project development. Each of the field activities then uses the guidance BESEP as the basis for the individual project. To this document is added all of the information necessary to support the installation design at a specific location.

The guidance BESEP is a logical extrapolation of a procedure which has been in use in the Navy for many years. This procedure is based on the use of "Standard System Plans." The content of the guidance BESEP is similar to that of a preliminary BESEP except that the information is given in general terms rather than specifics. Much of the data contained in the General Requirements Section and the Scope Section is provided to establish an adequate base for conversion into a station preliminary BESEP.

In a guidance BESEP, the bulk of the material is contained in the section entitled "Electronic System Design and Installation," in the form of standard system plans. These plans are complete except for such adaptation information as cable lengths and site locations. A complete list of new electronic equipment is provided together with a list of on-board equipment that must be relocated or reinstalled in accordance with the standard plans. Information on the physical plant requirements is provided in order to permit the respective field activities to tailor the standard plans to the specific station.

The principal purpose of the guidance BESEPs, with the associated standard system plans, is to accomplish the following:

- o Reduction in planning time with consequent reduction in planning cost.
- o Standardization of electronic facilities throughout the Naval Shore Establishment.
- o Standardization of installation materials to reduce supply and logistic problems.
- o Improvement in utilization of engineering personnel.
- o Reduction in training time for operating personnel.
- o Increase in system reliability.

The preliminary BESEP is aimed at providing the technical basis for, and support of, the operating command's initial project submission and for use in preparing the project cost estimate. It is therefore necessary that initial planning by the field activity and/or operating command be assembled into appropriate BESEP format at the earliest practicable time.

Among the principal factors affecting depth and detail are the following:

- o Intended use as a programming/budgetary justification and management tool. Personnel using the BESEP for this purpose do not require intricate technical detail. They do require concise factual information regarding the operating requirement to be fulfilled, new equipment requirements of the project, real estate and siting, floor space, environmental control, gross power, and similar basic information.

- o Use as a basis for project definition and preliminary cost estimates.

- o The status of planning, programming and initial technical development of the project as a result of previously expedited actions. In other words, the extent to which the preliminary BESEP purpose has already been fulfilled.

- o The size and complexity of the project.

With the exception of checkout and acceptance procedures, the general areas of coverage in the preliminary BESEP are the same as in the final version. Emphasis, however, is placed on conceptual planning decisions and engineering estimates rather than precise and binding detail. The goal is to provide only those data required for electronics and facilities budgetary planning and technical justification, establishment of project feasibility, and an adequate base for development of the cost estimate where required. The general requirements and scope are in sufficient detail to describe the basic need for, and objectives of the project and to provide a firm delineation of project boundaries. Electronic systems design and installation material is developed only to the extent necessary to define in broad terms the kinds of electronic systems planned, interfacing and compatibility considerations, siting requirements, and similar basic information. Illustrating sketches are provided as necessary. The electronic equipment list includes a first estimate of total equipment requirements. The estimate is based on information developed in concert with the user activity in the field plus any timely information provided by headquarters. Material on physical plant is included to provide basic data such as floor space requirements in feasible arrangements, feasible antenna types and layouts, proposed general siting of technical facilities within site boundaries, gross power and air conditioning requirements, typical floor loadings, and similar vital feasibility and cost determining facilities data.

In the majority of cases, the final BESEP will be a logical development based on the preliminary plan. Updated requirements and scope data keyed to headquarters level planning developments will be provided. Time normally will have enabled the field activities and operating command to pursue any special technical and operational studies earlier determined to be required. Based on the foregoing planning information, development of the final BESEP should proceed on a schedule compatible with that of the project final design phase. In certain cases, due to compressed time schedules or abrupt changes in system planning concepts, the final BESEP will be developed without prior benefit of a preliminary plan.

The principal factors affecting depth and detail of the final BESEP are:

- o Intended use as user/producer material support "Contract." Sufficient detail is required for review by the sponsor and operating command.

- o Adequacy as a technical basis for project A&E design effort.

- o Planned method of accomplishing electronic installation design, whether in-house, or by contract. The BESEP should be adequate for use as the technical requirement portion of the design contract specifications or work statement.

- o Extent to which previously expedited project actions have already fulfilled the BESEP purpose. "Over-the-shoulder" direction due to emergency project scheduling is an example.

- o Size and complexity of the project.

The Electronic Field Activity having responsibility for preparing and updating a particular BESEP, assumes prime responsibility for coordination of changes, identification and issuance of approved change sheets, and maintenance of the master record of action taken on all change proposals. Change proposals may be originated by project planning principals either at the headquarters level or in the field, and appropriate procedures are in effect to ensure overall coordination.

A-3 INTEGRATION OF THE SYSTEM WITH THE BASE

There are specific factors that have direct impact upon integration of the system with the base and require consideration. They are:

- o Site survey
- o Radio frequency interference
- o Radiation hazards
- o Compatibility with other station projects

In order to provide a satisfactory electronic system, it is also necessary to take into account the environment within which the system must operate. That is, the system design must be integrated with the base. This environment includes both the physical aspects, such as existing facilities and terrain features, as well as the environment which is determined by the other electronic systems in the vicinity of the proposed location for the new facility.

As the density and complexity of electronic systems increase, the probability of radio frequency interference also increases. It is therefore important to consider this in the system design, because the solution of compatibility problems after the facility is completed is costly, if a feasible solution is possible. In many instances, it is not feasible to solve the problem completely and the system must operate with restrictions and/or reduced capability.

Proper siting of the system is another part of base system planning. The physical terrain at, or adjacent to, the location of electronic systems such as communication, radar and navigational aids, which send and/or receive radio energy can significantly affect the performance of the system. Therefore, the BESEPs involving these systems either specify a general plan for the selection of the site or the identification and description of sites, if the site survey has been completed.

Compatibility is considered in the development of the BESEP. Each BESEP includes the identification of existing or proposed systems/facilities affected, with which compatibility is required. This is very important because conflicting projects can be under the direction of different groups with the conflict going unnoticed until late in the system design. To overcome this, the BESEP is required to include evidence that the Five-Year Plan for the station has been reviewed to ensure that these conflicts will not arise or are resolved before proceeding with the project.

There are several other special aspects affecting base compatibility covered in the BESEP. In projects involving facilities located near or at air station facilities, consideration is given to height of structures and other criteria required to ensure the safety of aircraft using the facility. In projects involving radio transmitters, the preparation of the BESEP includes consideration of and certification that no radiation hazards will be caused by the project. The hazards considered are those associated with electrically activated ordnance refueling of aircraft and vehicles, and the effects of RF radiation on personnel. In many projects, various portions of the criteria cannot be met. However, by identifying the matter early in the project, an acceptable compromise can be obtained without delay or re-engineering of the system.

In conclusion, the BESEP provides an all-inclusive method of subsystem integration and integration with the base environment. Additionally, the BESEP provides technical planning for the system design and equipment requirements. Timely development of the BESEP can result in cost savings through the orderly execution of the associated project.

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GLOSSARY

The following terms used in this handbook are based on information in the Bureau of Ships Joint Instruction 5430.38. Where required, technical terms used in the text are refined in the Military Standard Technical Terms and Definitions (Navy).

BASE ELECTRONIC SYSTEM - The integrated combination of all electronic sets (equipment) and parts of electronic systems installed within a base (air station, communication station, etc.). Examples are: Air Station Electronic System, Communication Station Electronic System, Sound Surveillance Station Electronic System.

BASE ELECTRONIC SYSTEM INSTALLATION ENGINEERING - The engineering processes required for electronics design of a compatible and integrated base electronic system which includes:

- o Development of engineering standards, criteria, and instructions for planning, design, installation, maintenance, and utilization of base electronic systems.

- o For new facilities and for changes to existing facilities: electronics engineering surveys for site selection; cost estimating for electronics installation and planning; establishment of design criteria and approval of plans for structures affecting electronics installation or performance; antenna field layout; development preparation, coordination, and approval of electronics installation plans; and the establishment of technical performance criteria of the base electronics system designed.

- o Engineering supervision, inspection, and acceptance of installation work and the determination and recording of performance characteristics of base electronic systems.

- o Technical cognizance of electronic installation accessories and ancillary devices used for installation ashore and not specifically assigned to the technical cognizance of another naval agency.

- o Engineering consultation in the development of requirements and functional systems designs for shore electronics facilities.

BASE (SHORE STATION) SYSTEM - The complete entity of a shore station, or base, including the devices, equipment, buildings, and grounds required to make the station operational.

COMPATIBILITY - The quality which insures that the various equipments which make up an electronic system are so selected and located that no malfunction results from frequency spread, radiation, or interconnection and that they operate in harmony. The term "compatibility" also entails insuring that functional electronic systems will operate in harmony in their operational environment.

COORDINATION - To bring into common action. It implies that activities concerned with a problem or proposed action are advised of the situation and provided an opportunity to indicate capability and problem areas.

ELECTRONIC EQUIPMENT AND MATERIAL - In general, those devices basically actuated by circuits using electromagnetic wave motion, particularly those associated with electron tubes (or successor developments for the same general function, such as transistors or molecular electronic devices) and the radio frequency transmission

systems in support thereof, and employing propagation of energy through space, water, ground, or the atmosphere. Electronic equipment also includes special cabling; terminal equipment; interconnecting equipment; calibration; test and repair equipment; special power generating equipment; radac equipment, and vans or trucks associated with the equipment.

ELECTRONIC SYSTEM - A combination of two or more electronic equipments (sets) generally physically separated when in operation and such other assemblies, subassemblies, and parts which are complementary and interdependent for performance or overall operational functions. Examples: AEW electronic system, fire control system, communication electronic system (a combination of radio transmitter, receiver, antennas and transmission lines is the simplest form of this system).

NOTE

This is the generic term and will be further modified or qualified when used by one of two basic means:

(1) A function or use term, i.e., communication, command and control, weapon control, detection, etc.

(2) A vehicle or base term, i.e., ship, aircraft base (air station, communication station, etc.). The use of (1) clarifies and specifies a particular type of functional system. However, the use of (2) introduces a different concept of system from an electronics standpoint and a different problem from the functional electronic system. It implies the integration and coordination of sets and parts of electronic systems which are basically incompatible in many cases. They are brought together to carry out the mission of the vehicle or base and must operate together but not necessarily with each other as in the functional electronic system. The radio transmitter is not communicating with a receiver on its own vehicle but rather with one elsewhere. Moreover the receiver on this vehicle, which operates as part of another communication electronic system, presents a problem of interference and coordination because of its location in the vehicle with other sets; hence, the term "vehicle or base electronic system."

EQUIPMENT (SET) - A unit or units and necessary assemblies, subassemblies, and parts connected or associated together to perform an operational function. Examples: radio receiving set; sound measuring set, which includes such parts, assemblies, and units as cable, microphone and measuring instruments; radar homing set.

FUNCTIONAL ELECTRONIC SYSTEMS - Systems designed primarily to perform a specific function, but not necessarily limited thereto. The following are typical of functional electronic systems:

o Command and Control Electronic System - A combination of equipments required to collect, analyze, process, display, and relay data received from sensors for purposes of command and control during an engagement.

o Surveillance Electronic System - A combination of equipment or sensors used to detect the presence of objects or materials, usually over a wide area.

o Navigation Electronic System - A combination of equipment used to determine the position, course, and speed of a vehicle.

o Air Control System - A combination of equipment used to control the course, speed, and altitude of an aircraft or astronautic vehicle.

o **Communications System** - A combination of equipment used to convey intelligence in all forms from one point to another.

GENERAL PURPOSE ELECTRONIC TEST EQUIPMENT - That test equipment which measures a range of parameters of electronic functions common to two or more equipments or systems of basically different design.

INTEGRATION - The achievement of maximum compatibility, interchangeability, and sharing of equipments, assemblies, techniques, all with minimum interference.

INTERFERENCE - Any disturbance which causes undesirable response or malfunctioning of electronic equipments.

NAVAL COMMUNICATION SYSTEM - The worldwide network of communication stations designed and built to provide worldwide and local communication service to the Navy ashore and afloat; provides common user facilities and facilities for special communication requirements.

OPERATIONAL REQUIREMENTS - A statement which outlines in broad terms the operational capability needed to solve, wholly or in part, an operational problem. An operational requirement generally includes general functional requirements phased in time, desired development work, completion date, present equipment affected, and material under development.

PART - One or more pieces joined together which are not normally subject to disassembly without destruction of designed use. Examples: electron tube, composition resistor, screw, gear, mica capacitor, audio transformer.

REQUIREMENT - A statement of the need to be met, the purpose to be served, the problem to be solved or the end to be achieved, by what date and for what reason.

SPECIAL PURPOSE TEST EQUIPMENT - That test equipment which is built into or associated with a major equipment or system and is used to measure specific unique parameters of electronic functions of the equipment or system. This equipment is usually for the purpose of determining operational readiness of the major equipment or system.

STANDARDIZATION - The process of establishing by common agreement engineering criteria, terms, principles, practices, materials, items, processes, equipments, parts, subassemblies, and assemblies to achieve the greatest practicable uniformity of items of supply and engineering practices; to insure the minimum feasible variety of such items, and practices, and to effect optimum interchangeability of equipment parts and components.

SYSTEM - A combination of two or more interrelated equipments (sets) arranged in a functional package to perform an operational function or to satisfy a requirements; e.g., ship system, communication system, navigation system, etc.

NOTE

A system usually consists of various size components, items, or subdivisions. The order of level from the most complex to the simplest (their definitions or cross-reference) follows:

o **System** - See **BASE ELECTRONIC SYSTEM**, **BASE (SHORE STATION) SYSTEM**, **ELECTRONIC SYSTEM**, **FUNCTIONAL ELECTRONIC SYSTEM**, **NAVAL COMMUNICATION SYSTEM**, and **SYSTEM**.

o **Subsystem** - A combination of sets, groups, etc., which performs an operational function within a system and is a major subdivision of the system. (Examples: data processing subsystem, guidance subsystem.)

o Set - See EQUIPMENT

o Group - A collection of units, assemblies, or subassemblies which is not capable of performing a complete operational function. A group may be a subdivision of a set or may be designed to be added to, or used in conjunction with, a set to extend the function or the utility of the set. (Example: antenna group.)

o Unit - An assembly or any combination of parts, subassemblies and assemblies mounted together, normally capable of independent operation in a variety of situation. (Examples: electric motor, power supply, electric generator, radio receiver.) This term replaces the term "Component." Note: The size of an item is a consideration in some cases. An electric motor for a clock may be considered as a part inasmuch as it is not normally subject to disassembly.

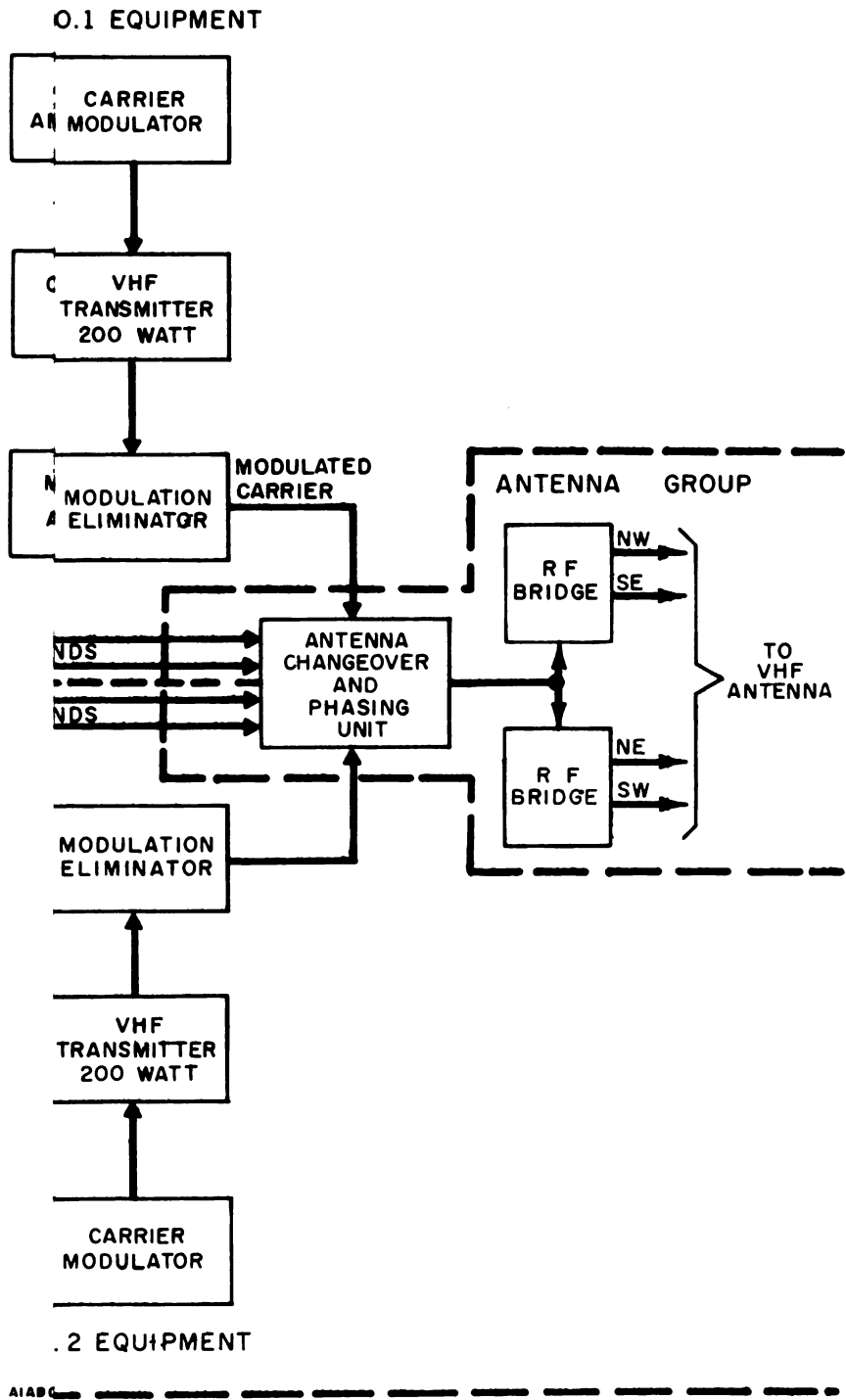
o Assembly - A number of parts or subassemblies or any combination thereof joined together to perform a specific function and capable of disassembly. (Example: audio frequency amplifier.) The distinction between an assembly and subassembly is determined by the individual application. An assembly in one instance may be a subassembly in another where it forms a portion of an assembly.

o Subassembly - Two or more parts which form a portion of an assembly or a unit replaceable as a whole, but having a part or parts which are individually replaceable. (examples: gun mount stand, window recoil mechanism, floating piston, telephone dial, IF strip, mounting board with mounted parts, power shovel dipper stick.

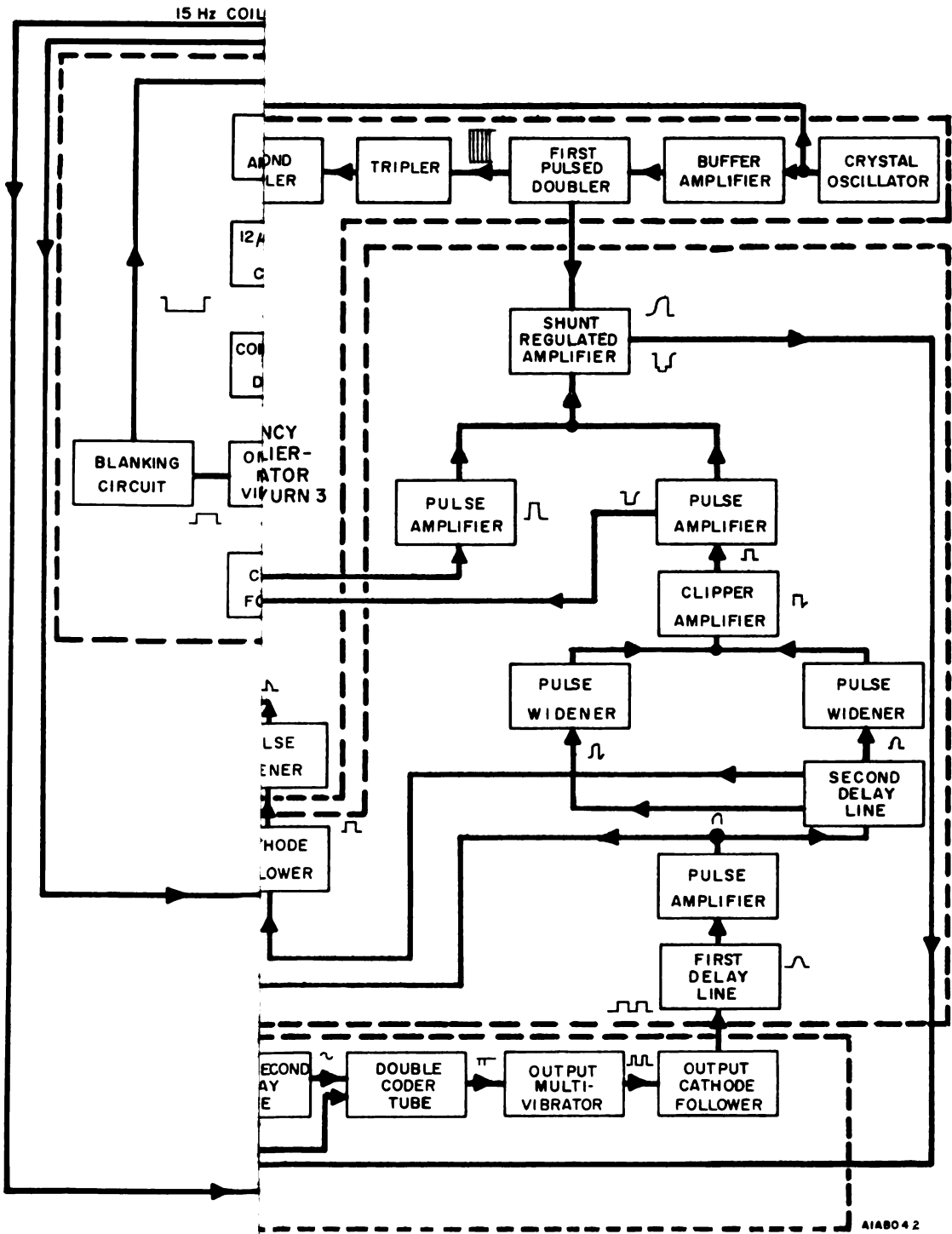
o Part - See PART

TECHNICAL COGNIZANCE - The responsibility for research, design, development test, technical evaluation, and production or construction of equipment, assemblies and parts. It includes responsibility for providing engineering services in speciality areas and criteria for installation, alteration, maintenance, repair, overhaul, and material effectiveness of material and equipment. It also includes the responsibility for applied technical direction.

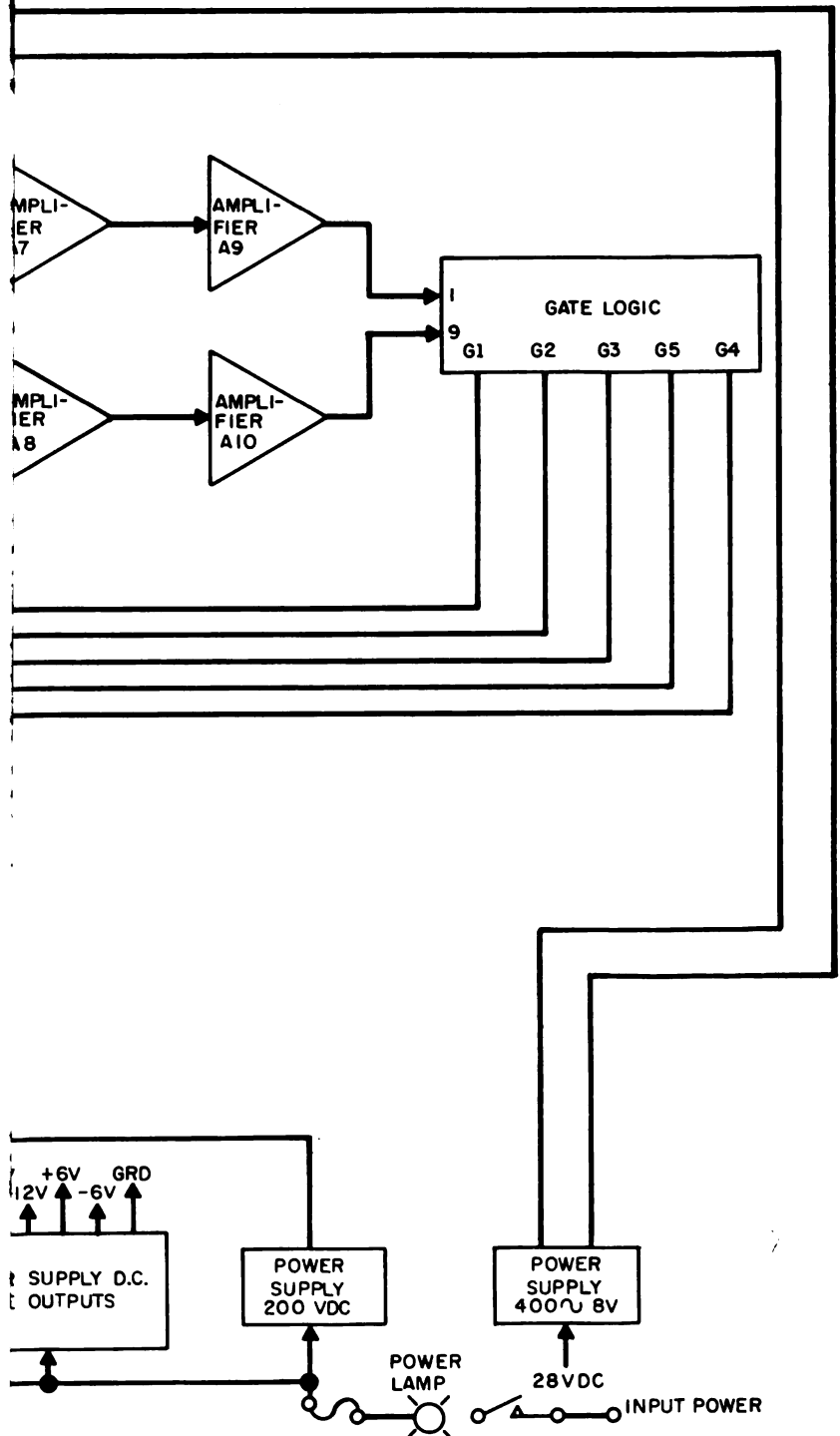
TECHNICAL DIRECTION - Generally the specialized or professional service performed, or professional guidance or direction exercised through promulgation of policies and procedures in technical matters by an organization in accordance with its assigned mission.



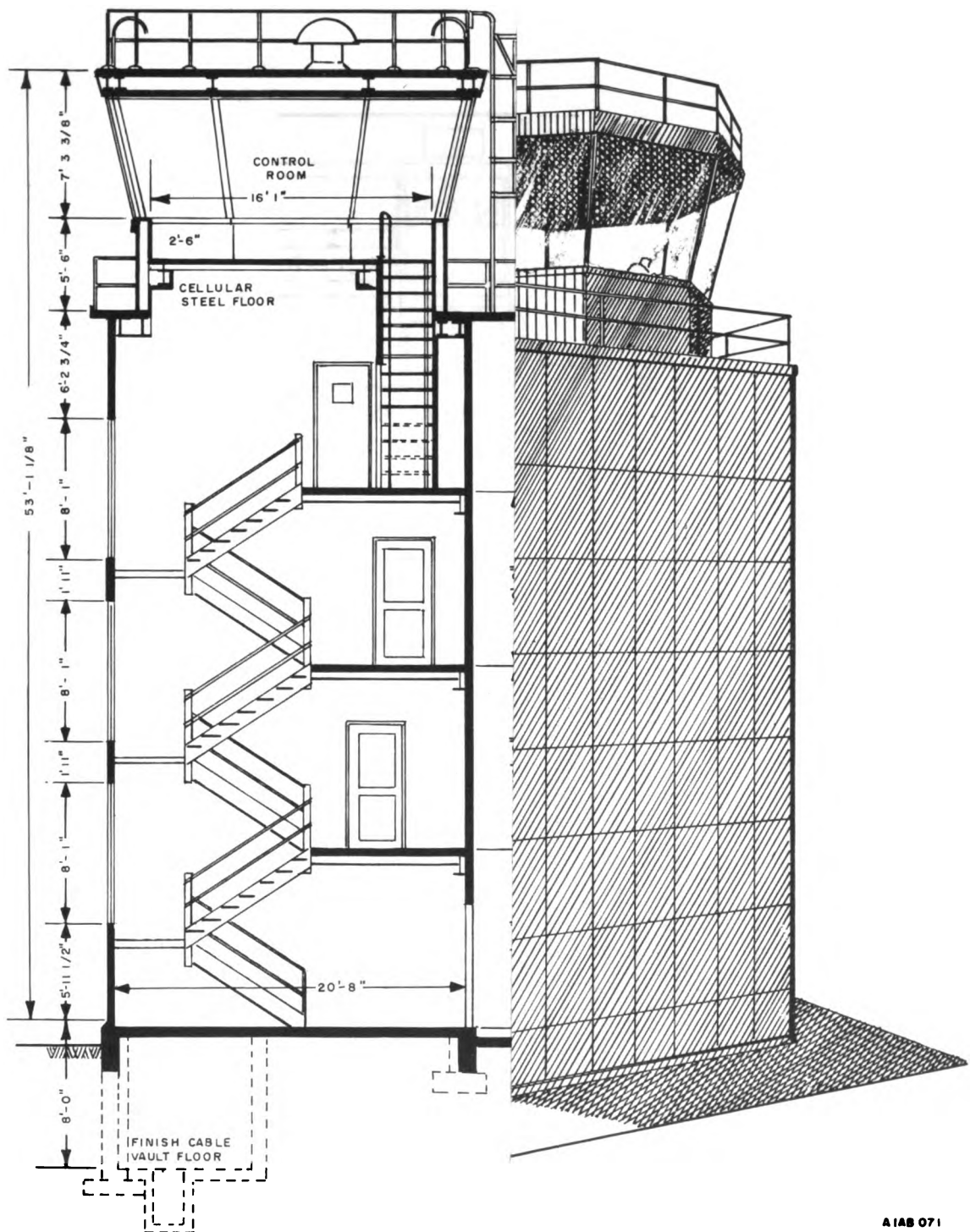
Foldout 2 - 1. VOR Ground Station, Block Diagram



Foldout 2 - 2. Typical Radio Beacon, Functional Block Diagram

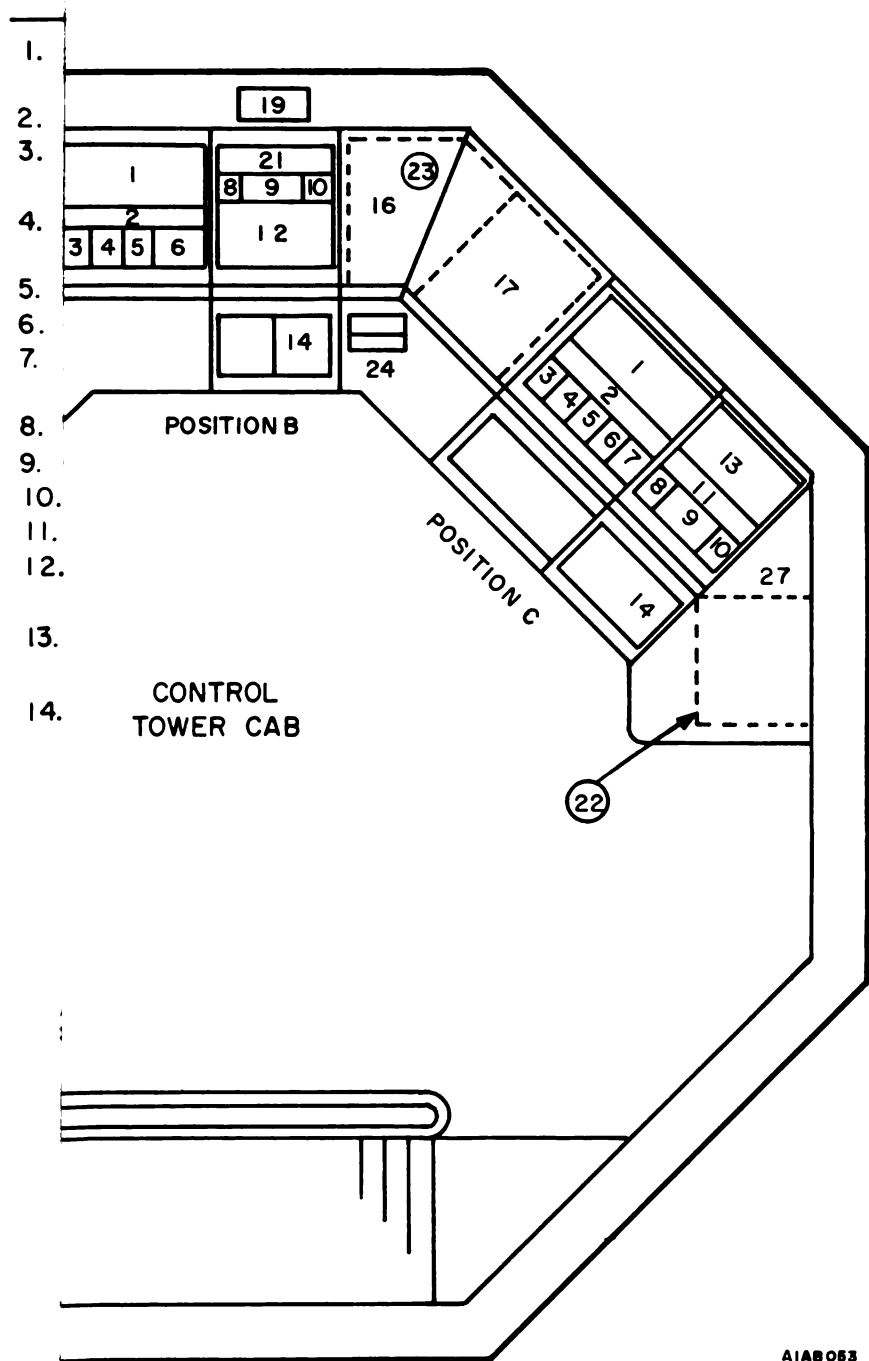


Foldout 2 - 3. Direction Finding Coordination System, Block Diagram



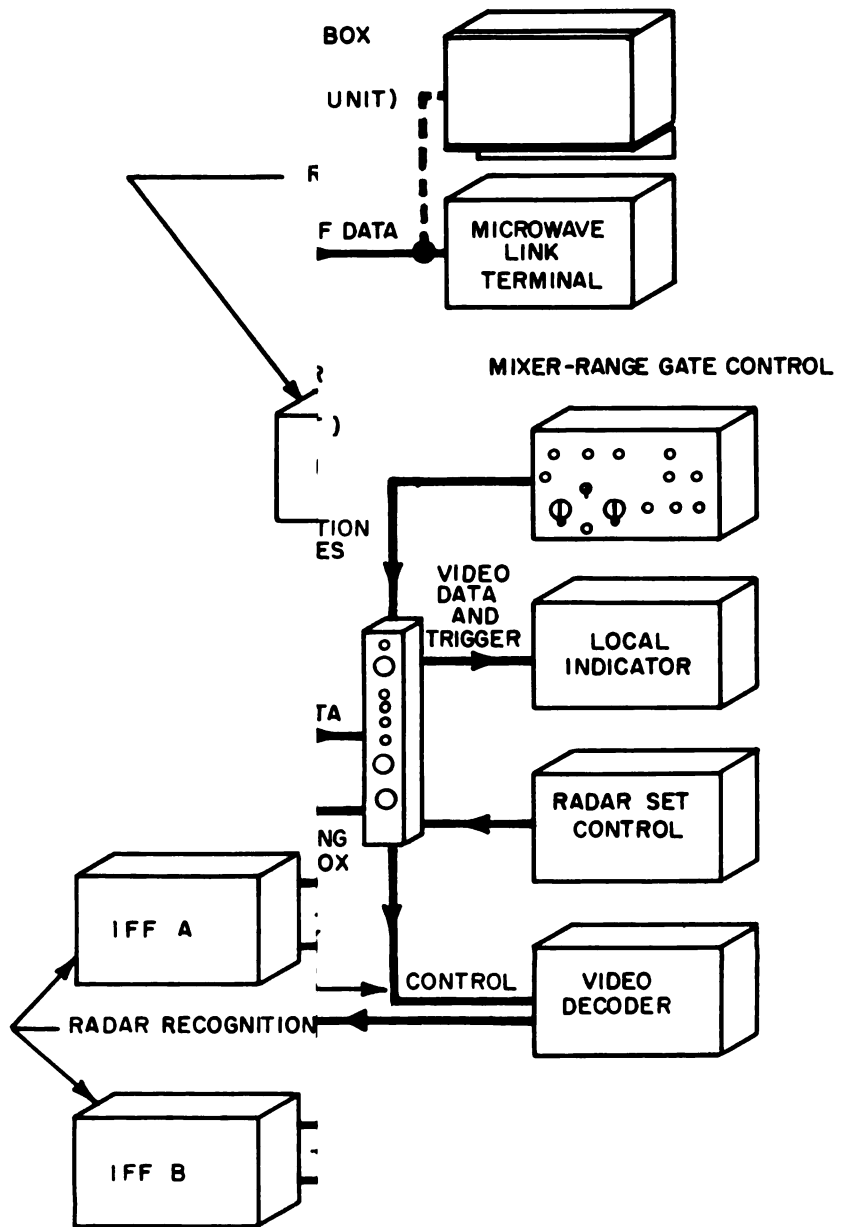
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ut 3 - 1. Standard Naval Air Station Control Tower



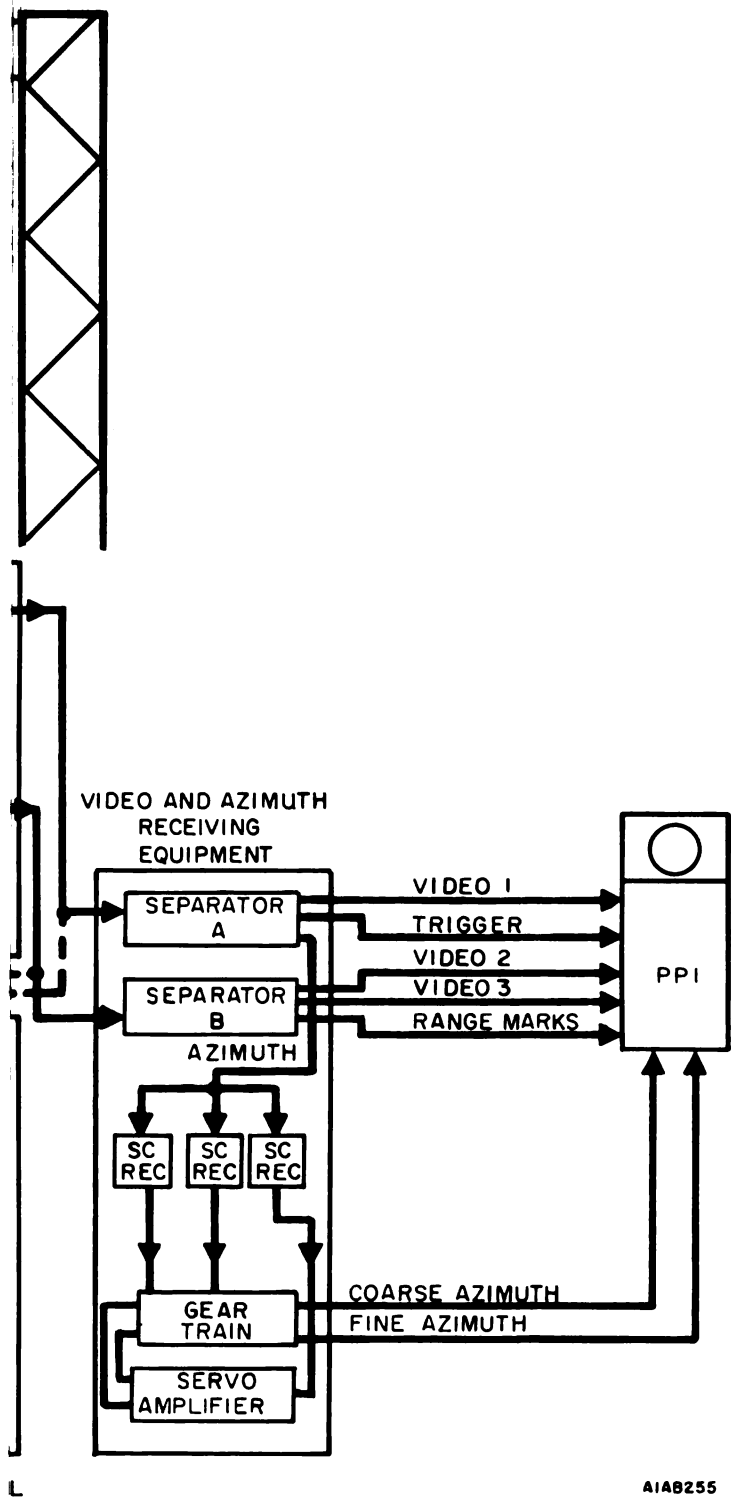
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Foldout 3 - 2. Control Tower Cab Equipment Arrangement



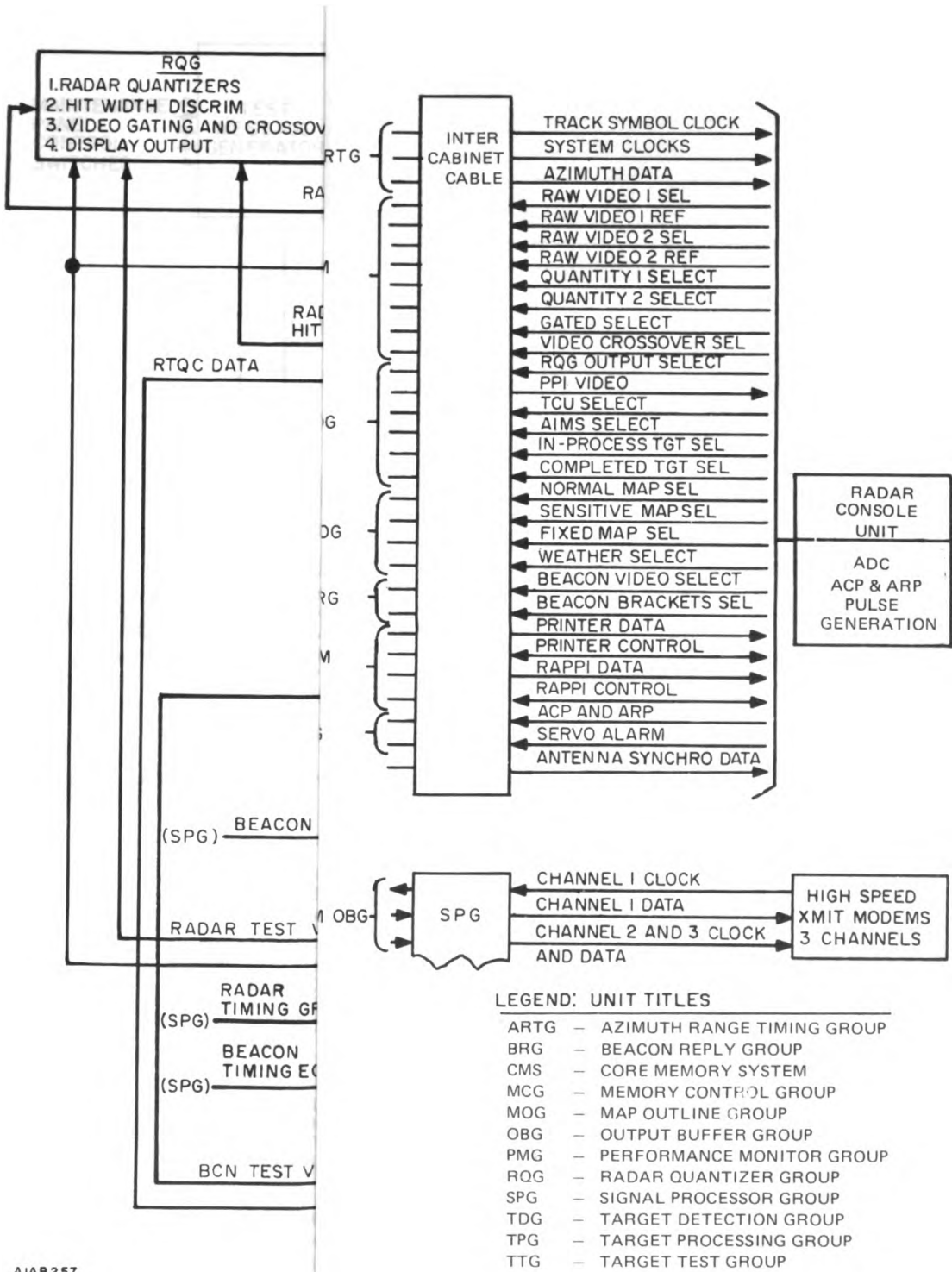
AIAB 249

Figure 3-3. Radar Data Distribution Group, AN/GPA-106(V), Relationship of Units



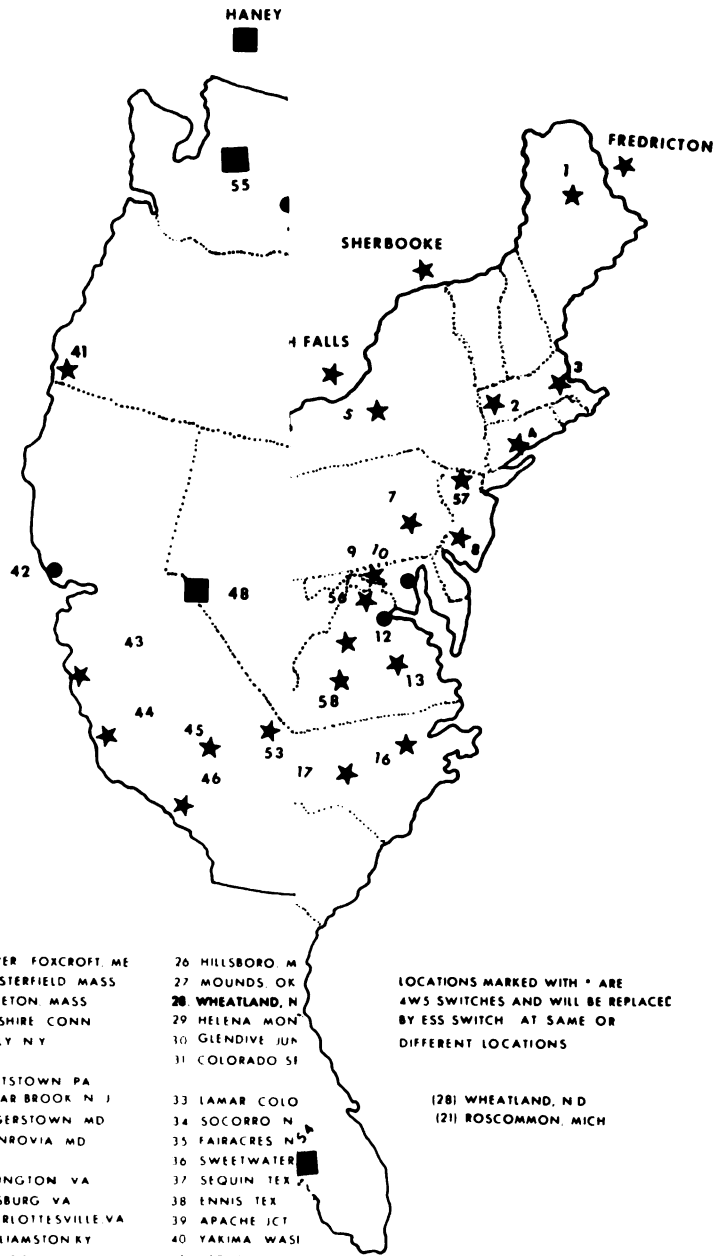
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Foldout 3 - 4. Radar Microwave Relay, Simplified Block Diagram



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Foldout 3 - 5. Electronics Unit, Block Diagram



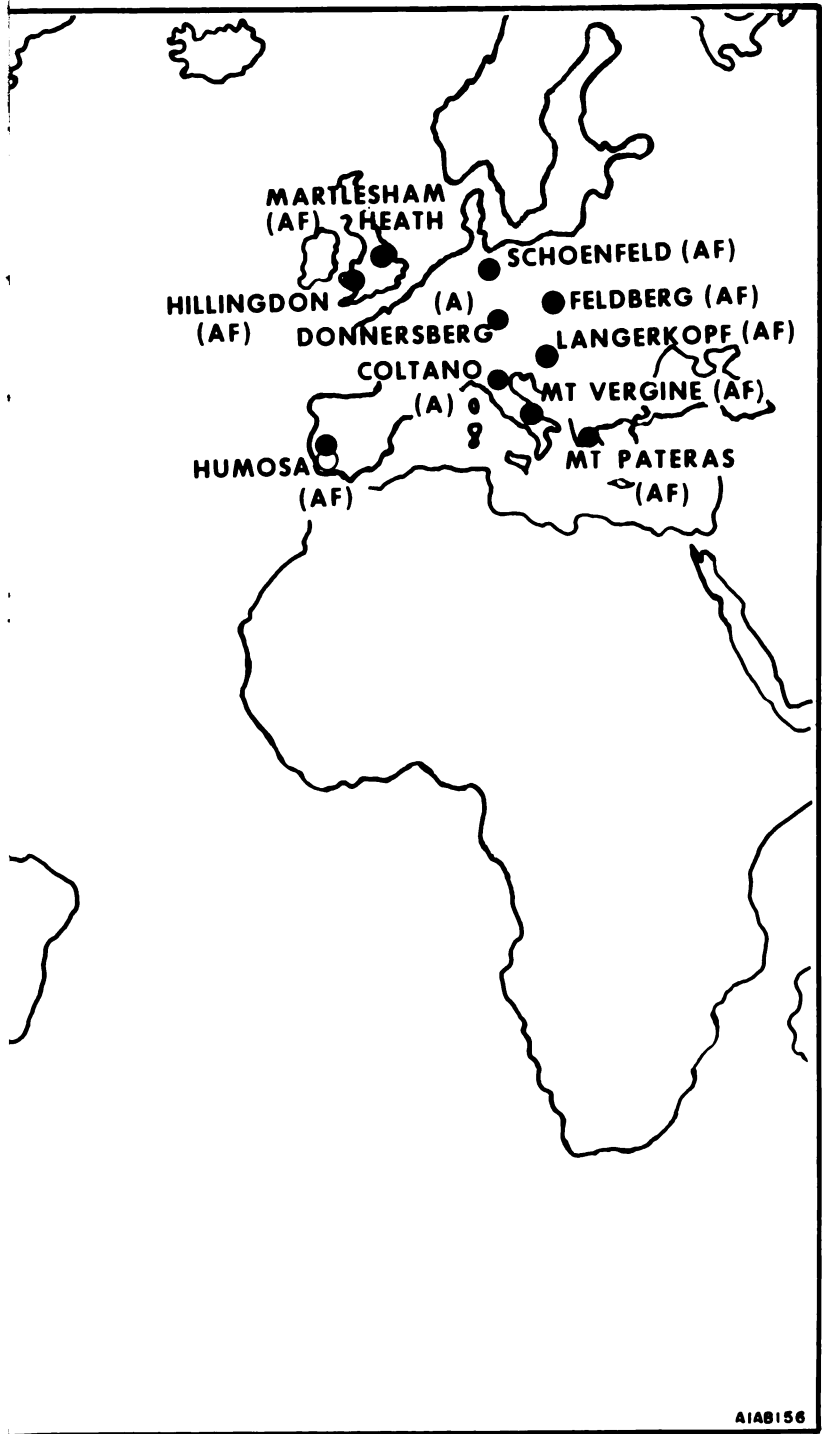
- | | |
|-----------------------|------------------------|
| 1 DOVER FOXCROFT ME | 26 HILLSBORO M |
| 2 CHESTERFIELD MASS | 27 MOUNDS OK |
| 3 LITTLETON MASS | 28 WHEATLAND, N |
| 4 CHESHIRE CONN | 29 HELENA MON |
| 5 TULLY NY | 30 GLENDIVE IOW |
| | 31 COLORADO SI |
| 7 POTTSTOWN PA | 33 LAMAR COLO |
| 8 CEDAR BROOK N J | 34 SOCORRO N |
| 9 HAGERSTOWN MD | 35 FAIRACRES N |
| 10 MONROVIA MD | 36 SWEETWATER |
| 12 ARLINGTON VA | 37 SEQUIN TEX |
| 13 LEESBURG VA | 38 ENNIS TEX |
| 14 CHARLOTTESVILLE VA | 39 APACHE JCT |
| 15 WILLIAMSTON KY | 40 YAKIMA WASH |
| 16 STANFIELD NC | 41 MEDFORD OR |
| 17 CHATHAM N C | 42 SANTA ROSA |
| 18 ROCKDALE GA | 43 LODI CALIF |
| 19 JASPER ALA | 44 SAN LUIS OBIS |
| 20 BREWTON ALA | 45 MOJAVE CALIF |
| *21 ROSCOMMON MICH | 46 JULIAN CALIF |
| 22 IRON MT MICH | 47 DELTA, UTAH |
| 23 WYOMING MINN | 48 TOPAZ LAKE N |
| 24 STEVENS PT WISC | 49 BOONE IOWA |
| 25 NORWAY ILL | 50 PICKENS MISS |

LOCATIONS MARKED WITH * ARE
4WS SWITCHES AND WILL BE REPLACED
BY ESS SWITCH AT SAME OR
DIFFERENT LOCATIONS

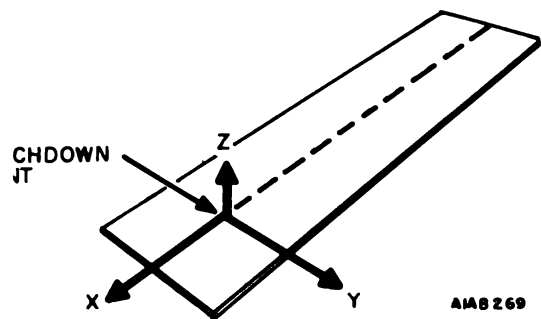
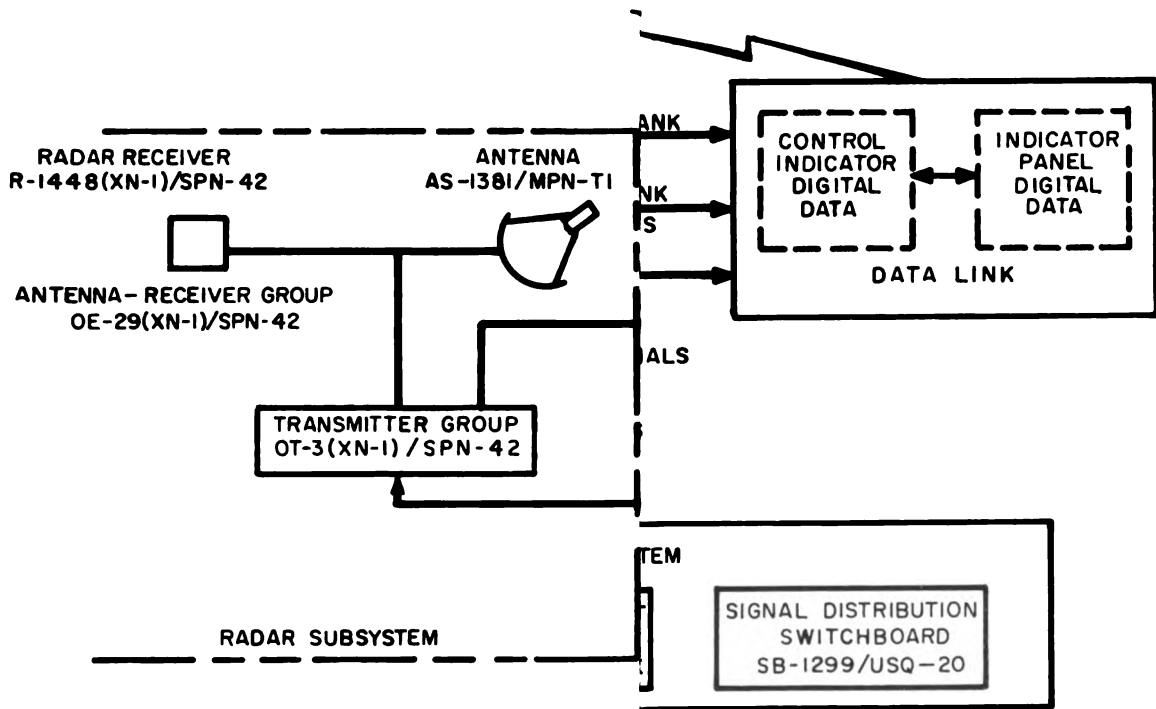
(28) WHEATLAND, ND
(21) ROSCOMMON, MICH

AIAB 155

i - 7. AUTOVON Switching Centers,
CONUS and Canada

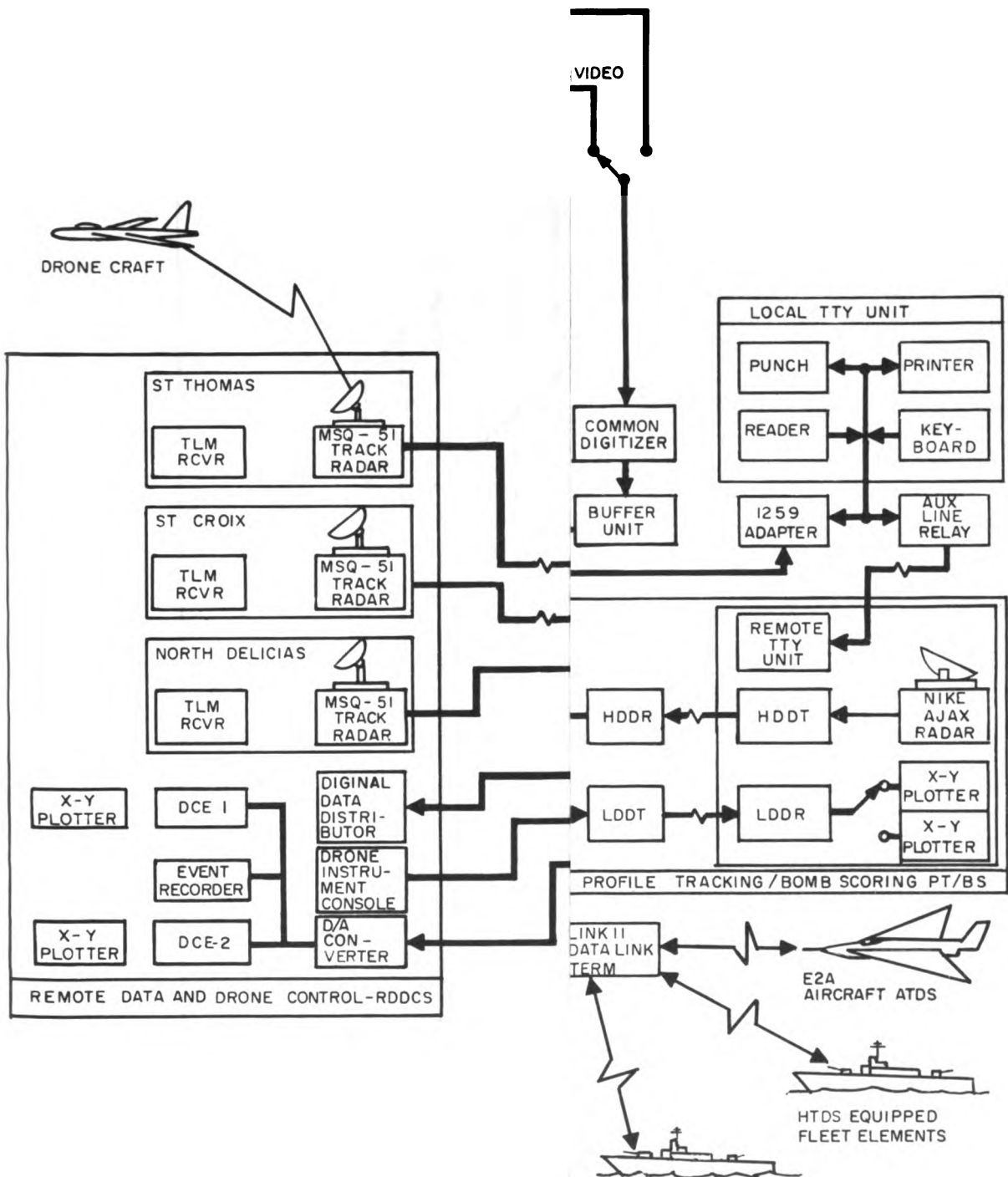


Foldout 3 - 8. AUTOVON Overseas Switching Centers



AMB 269

Idout 4 - 1. Landing Control Trainer System, AN/SPN-42-T1, System Functional Block Diagram



A1AB 220

ut 5 - 1. AFWR System Block Diagram

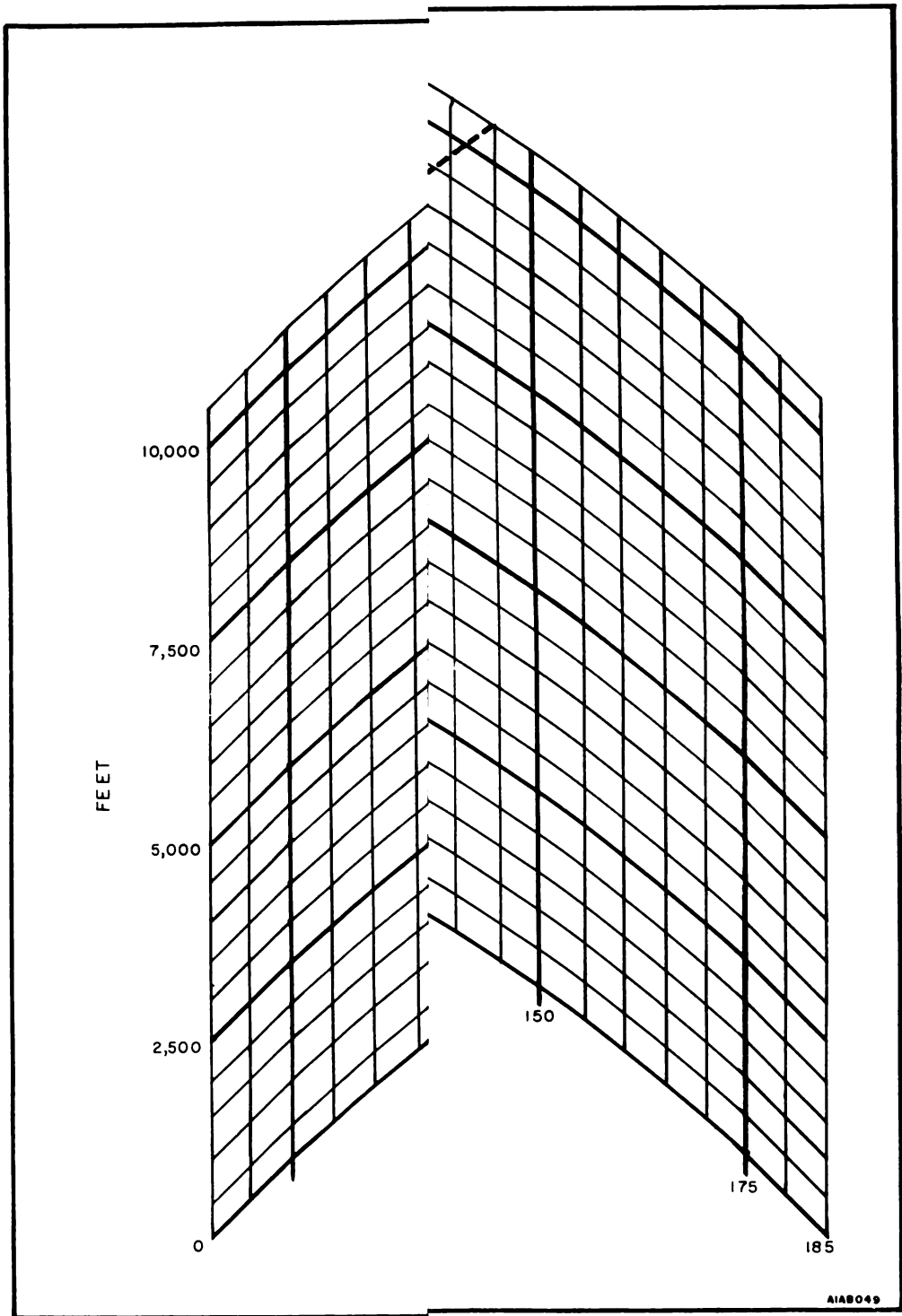
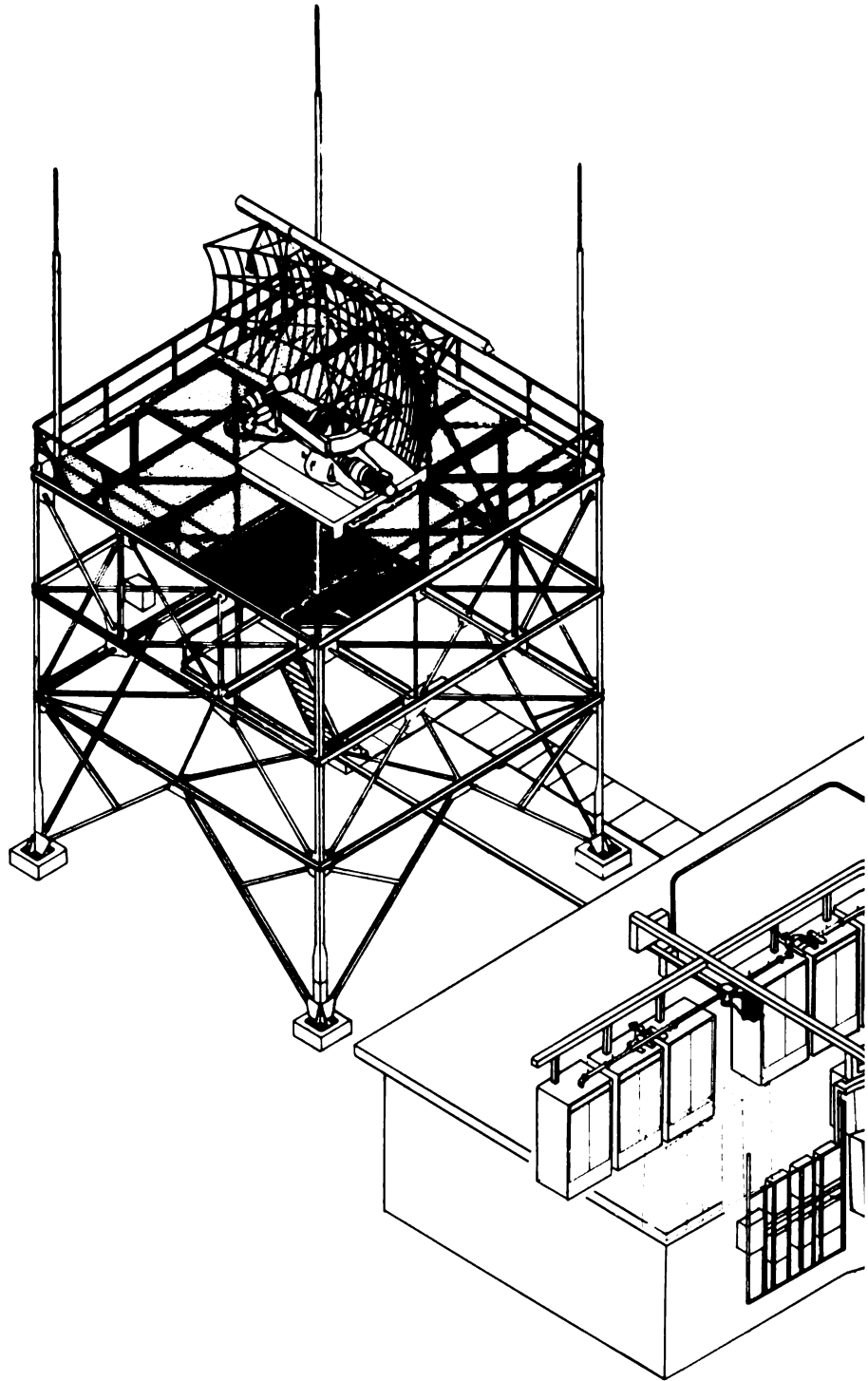
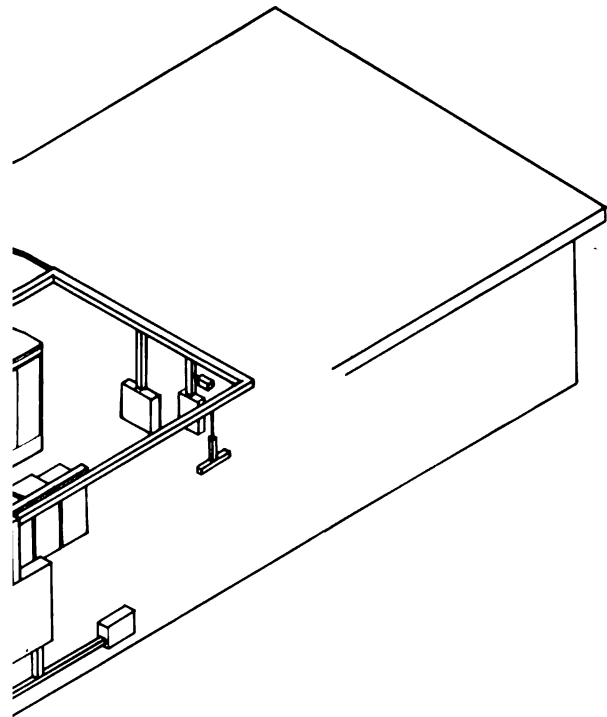


Figure 9 - 1. First Signal Null on 4/3 Earth Profile





AI AB231

Foldout 10 - 1. Radar Transmitter Site, Typical Site Configuration

FA-4721
TRANSMITTER
ASSEMBLY

FA-4742
PERFORMANCE
MONITOR
ASSEMBLY

FA-4751
RECEIVER
ASSEMBLY

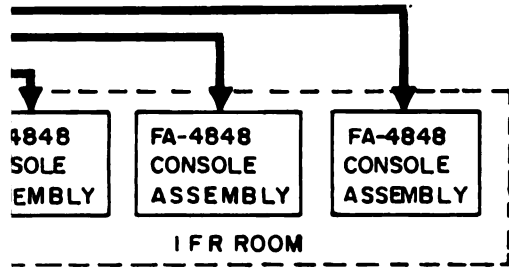
FA-4'NG
FA-4 UNIT
BUILI

3KVA
VOLTAGE
REGULATOR CONTROL

FA-4715
THREE PHASE
AC REGULATOR CONTROL
UNIT

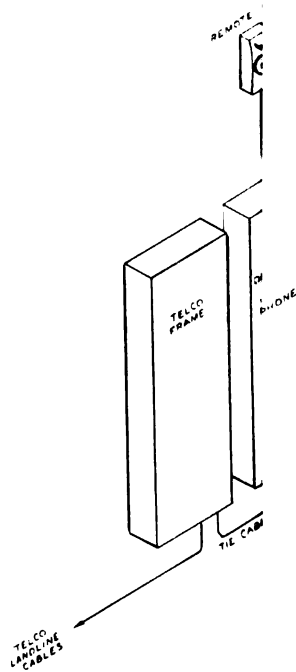
3KVA
VOLTAGE
REGULATOR

TRANSMITTER BUILDING



A1A8278

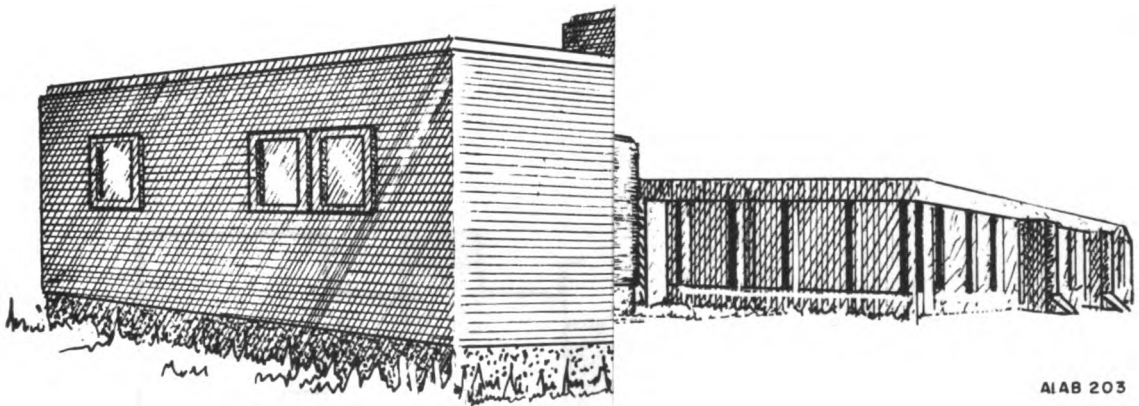
t 10 - 2. Transmitter and Remote Site, Typical Equipment Location



SUBSTITUTE "NAVAL ELECTRONIC SYSTEMS COMMAND,
SOUTHEAST DIVISION," FOR ALL REFERENCES HEREIN
TO INDMAN 6ND.

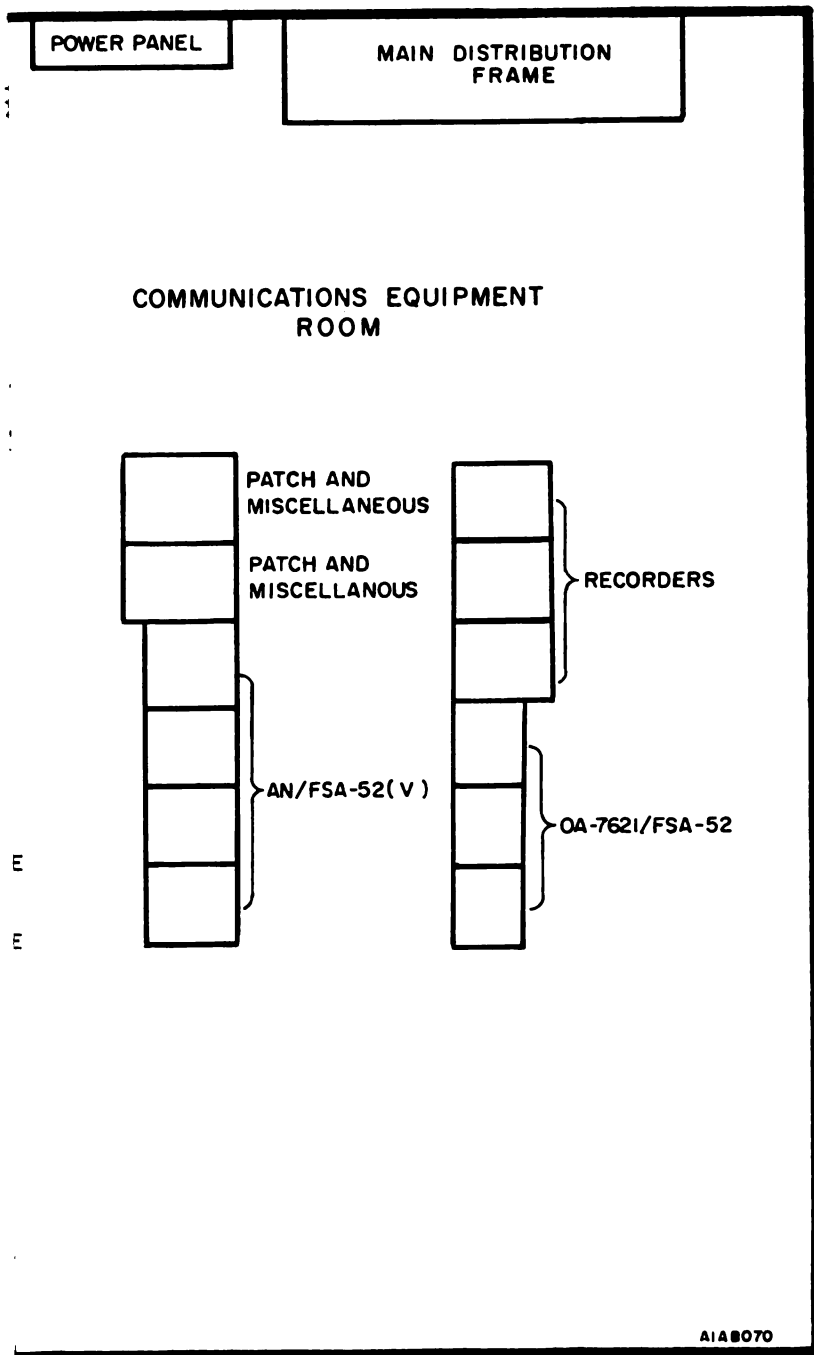
A1A8174

11 - 1. Landline Selector Control Group,
OA-7621(V)/FSA-52(V), Unit
Relationships

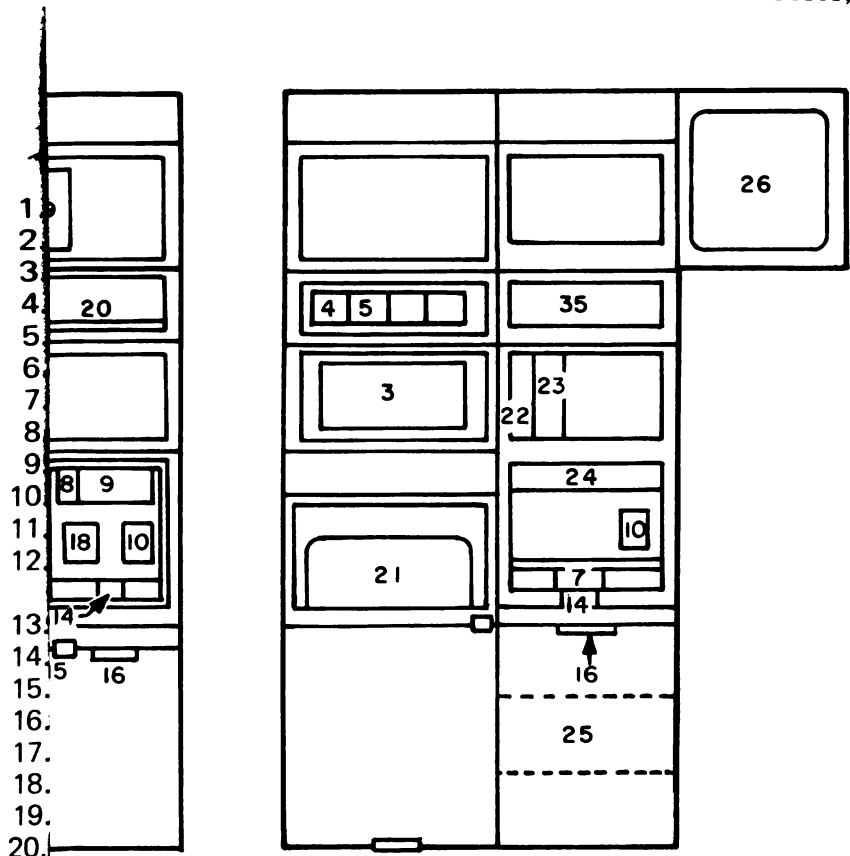


AIAB 203

Oldout 12 - 1. Air Station Operations Building,
Profile View (Sheet 1 of 2)

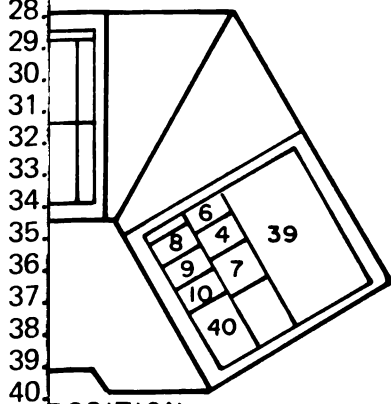


Foldout 12 - 2. Air Traffic Control Center, Typical Equipment Layout



21. N

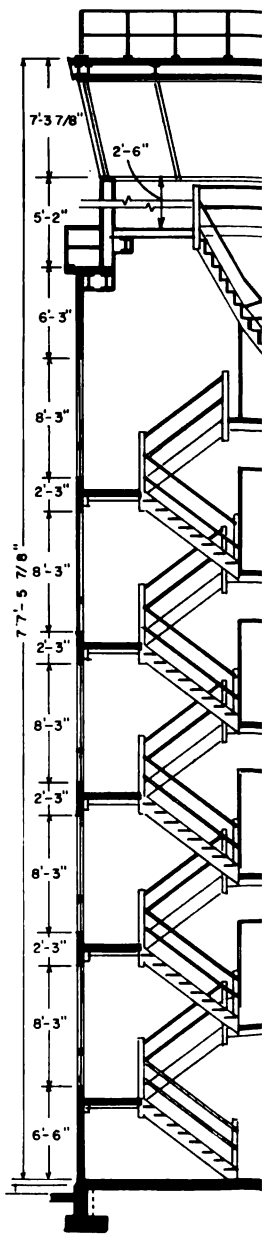
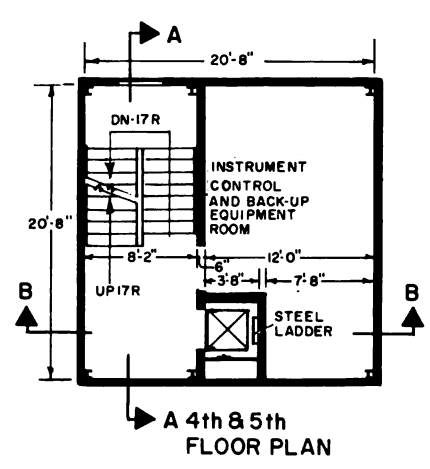
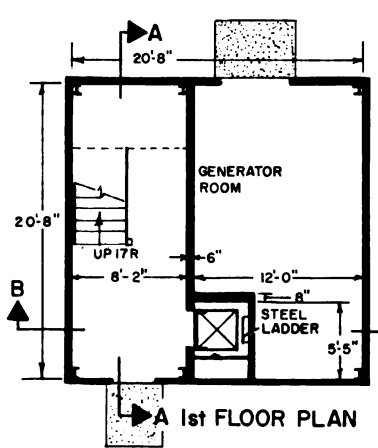
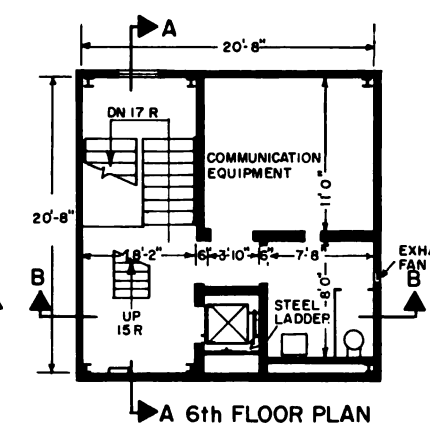
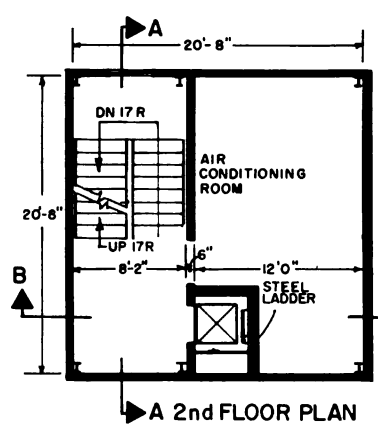
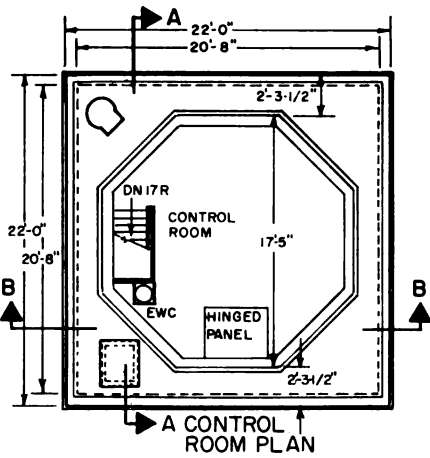
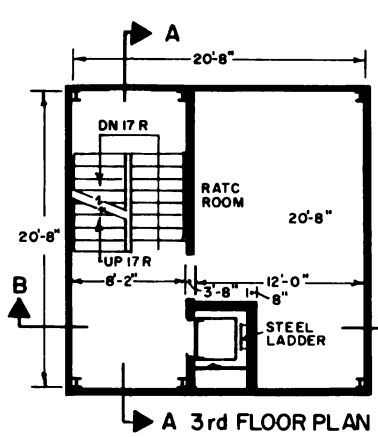
DIRECTION CODER
POSITION

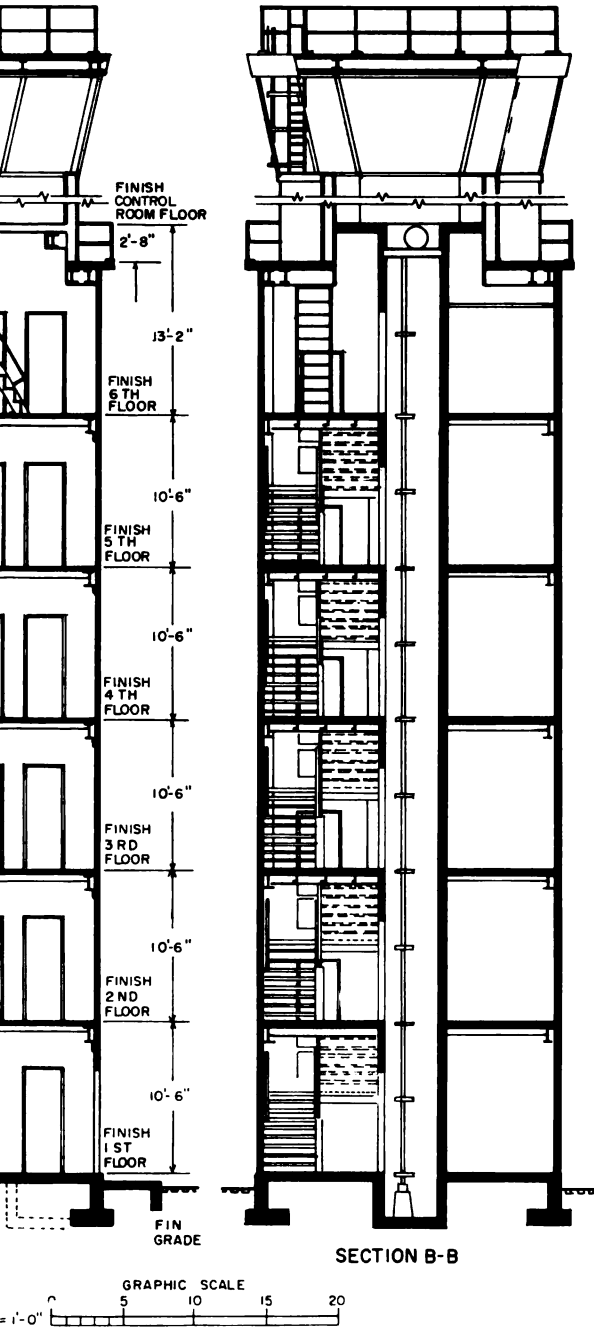


40. POSITION

AIAB072

Foldout 12 - 3. IFR Room, Console Front Panel Layout





A1A8073

Foldout 12-4. Control Tower, Floor Plan Utilization and Elevator

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