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Training Manual  
(TRAMAN)



# Electronics Technician

## Volume 4—Radar Systems

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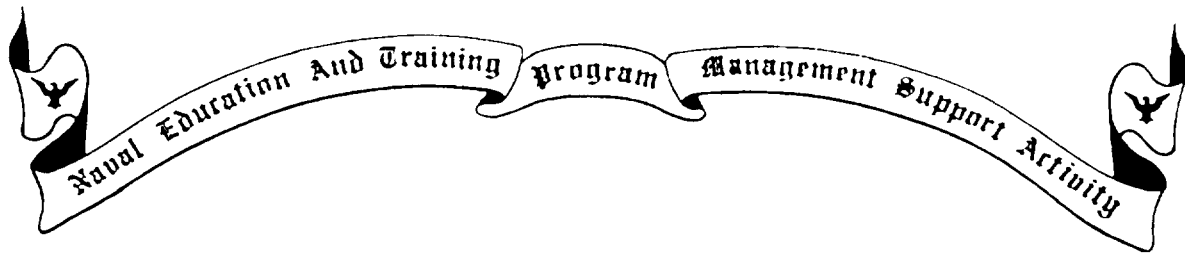


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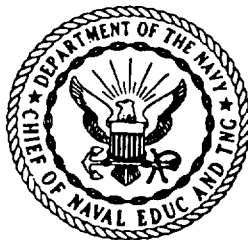
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# **ELECTRONICS TECHNICIAN**

## **VOLUME 4 RADAR SYSTEMS**

**NAVEDTRA 12414**



*1993 Edition Prepared by  
ETCS(SW) Linda Villareal*





# PREFACE

This training manual (TRAMAN), *Electronics Technician, Volume 4, Radar Systems*, NAVEDTRA 12414, and its companion nonresident training course (NRTC), NAVEDTRA 82414, are part of a planned 9-part series of TRAMANs intended to provide Navy enlisted personnel with information pertinent to their assignments and necessary for advancement to the Electronics Technician Second Class rate. The nine volumes planned for the series areas follows: Volume 1, *Safety*; Volume 2, *Administration*; Volume 3, *Communications Systems*; Volume 4, *Radar Systems*; Volume 5, *Navigation Systems*; Volume 6, *Digital Data Systems*; Volume 7, *Antennas and Wave Propagation*; Volume 8, *System Concepts*; Volume 9, *Electro-Optics*.

Designed for individual study instead of formal classroom instruction, the TRAMANs provide subject matter that relates directly to the Occupational Standards for the Electronics Technician Second Class. The Navy Electricity and Electronics Training Series (NEETS) modules provide information that is basic to your understanding of the material presented in these volumes. To avoid repeating such basic information, these volumes refer you to the appropriate NEETS modules and EIMB handbook. You may also be directed to review or study additional references commonly found in ET workspaces or used by Electronics Technicians. You should study the referenced publications as thoroughly as you would if they were repeated as part of the ET2 TRAMAN. The NRTCs, printed under separate cover, consist of supporting questions designed to help you study the associated TRAMAN and referenced publications and to satisfy part of the requirements for advancement.

This training manual and the nonresident training course were prepared by the Naval Education and Training Program Management Support Activity for the Chief of Naval Education and Training.

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# **THE UNITED STATES NAVY**

## **GUARDIAN OF OUR COUNTRY**

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

## **WE SERVE WITH HONOR**

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations as we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

## **THE FUTURE OF THE NAVY**

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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# SUMMARY OF THE ELECTRONICS TECHNICIAN TRAINING SERIES

This series of training manuals was developed to replace the *Electronics Technician 3 & 2 TRAMAN*. The content is directed toward personnel working toward advancement to Electronics Technician Second Class.

The nine volumes in the series are based on major topic areas with which the ET2 should be familiar. Volume 1, *Safety*, provides an introduction to general safety as it relates to the ET rating. It also provides both general and specific information on electronic tag-out procedures, man-aloft procedures, hazardous materials (i.e., solvents, batteries, and vacuum tubes), and radiation hazards. Volume 2, *Administration*, discusses COSAL updates, 3-M documentation, supply paperwork, and other associated administrative topics. Volume 3, *Communications Systems*, provides a basic introduction to shipboard and shore-based communication systems. Systems covered include man-pac radios (i.e., PRC-104, PSC-3) in the hf, vhf, uhf, SATCOM, and shf ranges. Also provided is an introduction to the Communications Link Interoperability System (CLIPS). Volume 4, *Radar Systems*, is a basic introduction to air search, surface search, ground controlled approach, and carrier controlled approach radar systems. Volume 5, *Navigation Systems*, is a basic introduction to navigation systems, such as OMEGA, SATNAV, TACAN, and man-pac systems. Volume 6, *Digital Data System*, is a basic introduction to digital data systems and includes discussions about SNAP II, laptop computers, and desktop computers. Volume 7, *Antennas and Wave Propagation*, is an introduction to wave propagation, as it pertains to Electronics Technicians, and shipboard and shore-based antennas. Volume 8, *System Concepts*, discusses system interfaces, troubleshooting, sub-systems, dry air, cooling, and power systems. Volume 9, *Electro-Optics*, is an introduction to night vision equipment, lasers, thermal imaging, and fiber optics.



# CHAPTER 1

## INTRODUCTION TO BASIC RADAR

The Navy Electricity and Electronics Training Series (NEETS) modules, especially module 18, *Radar Principles*, provide information that is basic to your understanding of this volume. This volume will discuss radar and radar systems as you may encounter them as an Electronics Technician at your command. You should refer to NEETS module 18 and Electronics Installation and Maintenance Book (EIMB), *Radar and Electronic Circuits*, on a regular basis to ensure that you have a complete understanding of the subject matter covered in this volume.

As an Electronics Technician, Second Class, and possible work center supervisor, you must understand the basic radar principles and safety requirements for radar maintenance. However, due to luck of the draw, your first assignment may not afford you exposure to radar systems. Our intention with this volume is NOT to teach you every radar system the Navy uses, but simply to familiarize you with the radars and their general maintenance principles.

You will be able to identify the equipment requirements and general operation of the three basic radar systems covered in chapter 1. You'll become familiar with the nomenclature of specific radars used in the Navy today as we discuss them in chapter 2. Then, armed with all that knowledge you will easily grasp the system concepts addressed in chapter 3. And before you go out to tackle the radar world, chapter 4 will give you necessary safety information specific to radar maintenance.

When you arrive at your next command as a second class with work center responsibilities for a radar maintenance shop, you will be ready.

### BASIC RADAR CONCEPTS

The term *radar* is an acronym made up of the words *radio*, *detection*, and *ranging*. It refers to electronic equipment that detects the presence, direction, height, and distance of objects by using reflected electromagnetic energy. The frequency of electromagnetic energy used for radar is unaffected by darkness and also penetrates weather. This permits radar systems to determine the position of ships, planes,

and land masses that are invisible to the naked eye because of distance, darkness, or weather.

Radar systems provide only a limited field of view and require reference coordinate systems to define the positions of the detected objects. Radar surface angular measurements are normally made in a clockwise direction from **TRUE NORTH**, as shown in figure 1-1, or from the heading line of a ship or aircraft. The actual radar location is the center of this coordinate system.

Figure 1-1 contains the basic terms that you need to know to understand the coordinate system. Those terms are defined in the following paragraph.

The surface of the earth is represented by an imaginary flat plane, known as the **HORIZONTAL PLANE**, which is tangent (or parallel) to the earth's surface at that location. All angles in the up direction are measured in a secondary imaginary plane, known as the **VERTICAL PLANE**, which is perpendicular to the horizontal plane. The line from the radar set directly to the object is referred to as the **LINE OF SIGHT (LOS)**. The length of this line is called **RANGE**. The angle

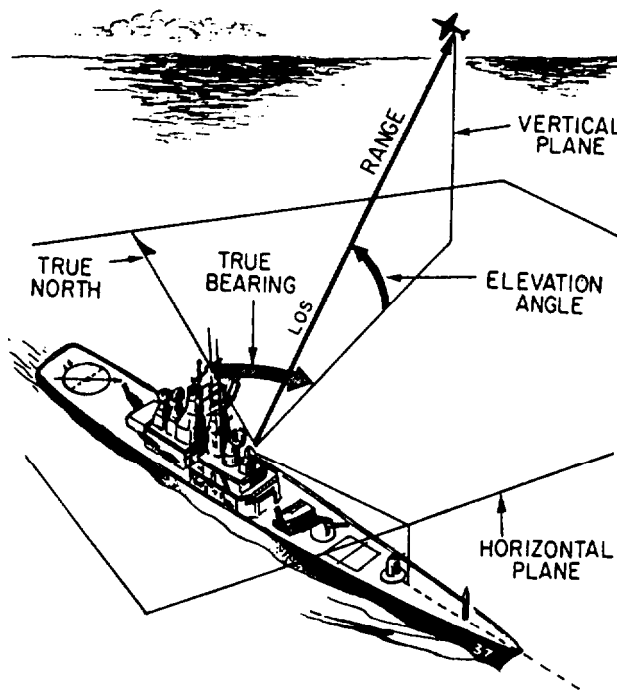


Figure 1-1.—Radar reference coordinates.

between the horizontal plane and the LOS is the **ELEVATION ANGLE**. The angle measured clockwise from true north in the horizontal plane is called the **TRUE BEARING** or **AZIMUTH** angle. Information based on these terms describes the location of an object with respect to the antenna, giving the operator data on range, bearing, and altitude.

### **RANGE/BEARING/ALTITUDE**

Using the coordinate system discussed above, radar systems provide early detection of surface or air objects, giving extremely accurate information on distance, direction, height, and speed of the objects. The visual radar data required to determine a target's position and to track the target is usually displayed on a specially designed cathode-ray tube (crt) installed in a unit known as a planned position indicator (ppi).

Radar is also used to guide missiles to targets and to direct the firing of gun systems. Other types of radar provide long-distance surveillance and navigation information.

Bearing and range (and in the case of aircraft, altitude) are necessary to determine target movement. It is very important that you understand the limitations of your radar system in the areas of range, bearing, and altitude.

### **Range**

Radar measurement of range (or distance) is made possible because of the properties of radiated electromagnetic energy. This energy normally travels through space in a straight line, at a constant speed, and will vary only slightly because of atmospheric and weather conditions. The range to an object, in nautical miles, can be determined by measuring the elapsed time (in microseconds) during the round trip of a radar pulse and dividing this quantity by the number of microseconds required for a radar pulse to travel 2 nautical miles (12.36). In equation form this is:

$$\text{range (nautical miles)} = \frac{\text{elapsed time}}{12.36}$$

**MINIMUM RANGE.**— Radar duplexers alternately switch the antenna between the transmitter and receiver so that one antenna can be used for both functions. The timing of this switching is critical to the operation of the radar and directly affects the minimum range of the radar system. A reflected pulse will not be received during the transmit pulse and subsequent receiver recovery time. Therefore, any reflected pulses

from close targets that return before the receiver is connected to the antenna will be undetected.

**MAXIMUM RANGE.**— The maximum range of a pulse radar system depends upon carrier frequency peak power of the transmitted pulse, pulse repetition frequency (prf), or pulse repetition rate (pr), and receiver sensitivity.

The peak power of the pulse determines what maximum range the pulse can travel to a target and still return a usable echo. A usable echo is the smallest signal detectable by a receiver that can be processed and presented on an indicator.

The prr will determine the frequency that the indicator is reset to the zero range. With the leading edge of each transmitted pulse, the indicator time base used to measure the returned echoes is reset, and a new sweep appears on the screen. If the transmitted pulse is shorter than the time required for an echo to return, that target will be indicated at a false range in a different sweep. For example, the interval between pulses is 610 sec with a repetition rate of 1640 pulses per second. Within this time the radar pulse can go out and come back a distance equal to 610 sec ' 164 yards per sec, or 100,000 yards, which becomes the scope's sweep limit. Echoes from targets beyond this distance appear at a false range. Whether an echo is a true target or a false target can be determined by simply changing the prr.

**RANGE ACCURACY.**— The shape and width of the rf pulse influences minimum range, range accuracy, and maximum range. The ideal pulse shape is a square wave that has vertical leading and trailing edges. A sloping trailing edge lengthens the pulse width. A sloping leading edge provides no definite point from which to measure elapsed time on the indicator time base.

Other factors affecting range are the antenna height, antenna beam width, and antenna rotation rate. A higher antenna will create a longer radar horizon, which allows a greater range of detection. Likewise, a more concentrated beam has a greater range capability since it provides higher energy density per unit area. Also, because the energy beam would strike each target more times, a slower antenna rotation provides stronger echo returns and a greater detection range for the radar.

Given the range information, the operator knows the distance to an object, but information on bearing is still required to determine in which direction from the ship the target lies.

## Bearing

Radar bearing is determined by the echo signal strength as the radiated energy lobe moves past the target. Since search radar antennas move continuously, the point of maximum echo return is determined either by the detection circuitry as the beam passes the target or visually by the operator. Weapons control and guidance radar systems are positioned to the point of maximum signal return and maintained at that position either manually or by automatic tracking circuits.

**TRUE BEARING.**— The angle between true north and a line pointed directly at a target is called the *true bearing* (referenced to true north) of a radar target. This angle is measured in the horizontal plane and in a clockwise direction from true north.

**RELATIVE BEARING.**— The angle between the centerline of your own ship or aircraft and a line pointed directly at a target is called the *relative bearing* of the radar target. This angle is measured in a clockwise direction from the centerline.

Both true and relative bearing angles are illustrated in figure 1-2.

Most surface search radars will provide only range and bearing information. If the operator had a need to direct air traffic or to track incoming missiles, the radar would also have to provide altitude.

## Altitude

An operator can determine the altitude of a target by adjusting a movable height line on a height indicator to

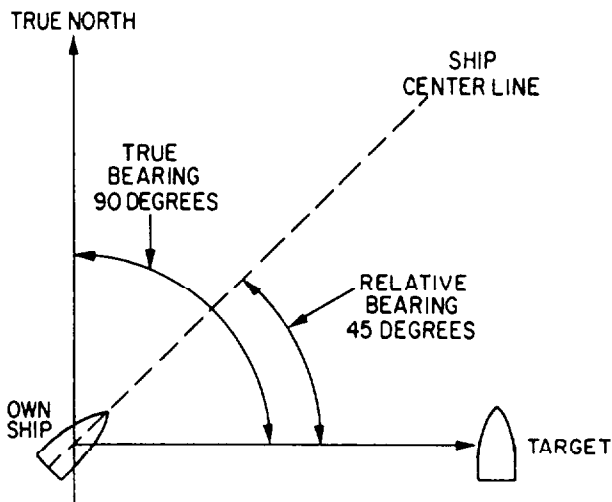


Figure 1-2.—True and relative bearings.

the point where it bisects the center of the target. The altitude is then displayed by an altitude dial or digital readout. A search radar system that detects altitude as well as range and bearing is called a three-dimensional (3D) radar.

Altitude or height-finding radars use a very narrow beam in the vertical plane. This beam is scanned in elevation, either mechanically or electronically, to pinpoint targets. Tracking and weapons-control radar systems commonly use mechanical elevation scanning techniques. This requires moving the antenna or radiation source mechanically. Most air search radars use electronic elevation scanning techniques. Some older air search radar systems use a mechanical elevation scanning device; however, these are being replaced by electronically-scanned radar systems.

## RADAR DETECTING METHODS

Radar systems are normally divided into operational categories based on energy transmission methods. Although the pulse method is the most common method of transmitting radar energy, two other methods are sometimes used in special applications. These are the continuous wave (cw) method and the frequency modulation (fm) method.

### Continuous Wave

The continuous wave (cw) method uses the Doppler effect to detect the presence and speed of an object moving toward or away from the radar. The system is unable to determine the range of the object or to differentiate between objects that lie in the same direction and are traveling at the same speed. It is usually used by fire control systems to track fast moving targets at close range.

### Frequency Modulation

With the frequency modulation (fm) method, energy is transmitted as radio frequency (rf) waves that continuously vary, increasing and decreasing, from a fixed reference frequency. Measuring the difference between the frequency of the returned signal and the frequency of the radiated signal will give an indication of range. This system works well with stationary or slowly-moving targets, but it is not satisfactory for locating moving objects. It is used in aircraft altimeters that give a continuous reading of how high the aircraft is above the earth.

## Pulse Modulation

With the pulse modulation method, depending on the type of radar, energy is transmitted in pulses that vary from less than 1 microsecond to 200 microseconds. The time interval between transmission and reception is computed and converted into a visual indication of range in miles or yards. Pulse radar systems can also be modified to use the Doppler effect to detect a moving object. The Navy uses pulse modulation radars to a great extent.

## FACTORS AFFECTING RADAR PERFORMANCE

Radar accuracy is a measure of the ability of a radar system to determine the correct range, bearing, and in some cases, altitude of an object. The degree of accuracy is primarily determined by the resolution of the radar system and atmospheric conditions.

### Range Resolution

Range resolution is the ability of a radar to resolve between two targets on the same bearing, but at slightly different ranges. The degree of range resolution depends on the width of the transmitted pulse, the types and sizes of targets, and the efficiency of the receiver and indicator.

### Bearing Resolution

Bearing, or azimuth, resolution is the ability of a radar system to separate objects at the same range but at slightly different bearings. The degree of bearing resolution depends on radar beamwidth and the range of the targets. The physical size and shape of the antenna determines beamwidth. Two targets at the same range must be separated by at least one beamwidth to be distinguished as two objects.

Earlier in this chapter, we talked about other internal characteristics of radar equipment that affect range performance. But there are also external factors that effect radar performance. Some of those are the skill of the operator; size, composition, angle, and altitude of the target; possible electronic-countermeasure (ECM) activity; readiness of equipment (completed PMS requirements); and weather conditions

### Atmospheric Conditions

Several conditions within the atmosphere can have an adverse effect on radar performance. A few of these

are temperature inversion, moisture lapse, water droplets, and dust particles.

Either temperature inversion or moisture lapse, alone or in combination, can cause a huge change in the refraction index of the lowest few-hundred feet of atmosphere. The result is a greater bending of the radar waves passing through the abnormal condition. The increased bending in such a situation is referred to as **DUCTING**, and may greatly affect radar performance. The radar horizon may be extended or reduced, depending on the direction in which the radar waves are bent. The effect of ducting is illustrated in figure 1-3.

Water droplets and dust particles diffuse radar energy through absorption, reflection, and scattering. This leaves less energy to strike the target so the return echo is smaller. The overall effect is a reduction in usable range. Usable range varies widely with weather conditions. The higher the frequency of the radar system, the more it is affected by weather conditions such as rain or clouds.

All radar systems perform the same basic functions of detection, so, logically, they all have the same basic equipment requirements. Next, we will talk about that basic radar system.

## BASIC RADAR SYSTEMS

Radar systems, like other complex electronics systems, are composed of several major subsystems and many individual circuits. Although modern radar systems are quite complicated, you can easily understand their operation by using a basic block diagram of a pulsed radar system.

## FUNDAMENTAL RADAR SYSTEM

Since most radars used today are some variation of the pulse radar system, the units we discuss in this section will be those used in a pulse radar. All other

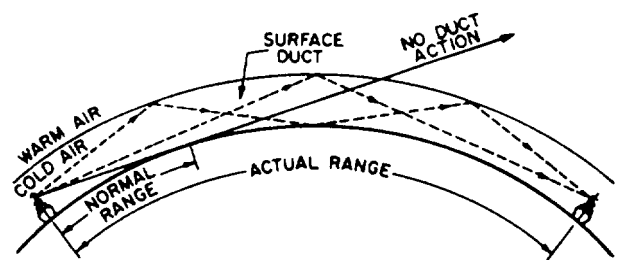


Figure 1-3.—Ducting effect on the radar wave.

types of radars use some variations of these units, and we will explain those variations, as necessary in the next chapter. For now, let's look at the block diagram in figure 1-4.

### Modulator

You can see on the block diagram that the heart of the radar system is the modulator. It generates all the necessary timing pulses (triggers) for use in the radar and associated systems. Its function is to ensure that all subsystems making up the radar system operate in a definite time relationship with each other and that the intervals between pulses, as well as the pulses themselves, are of the proper length.

### Transmitter

The transmitter generates powerful pulses of electromagnetic energy at precise intervals. The required power is obtained by using a high-power microwave oscillator, such as a magnetron, or a microwave amplifier, such as a klystron, that is supplied by a low-power rf source. (You can review the

construction and operation of microwave components in NEETS module 11, *Microwave Principles*.)

### Duplexer

The duplexer is essentially an electronic switch that permits a radar system to use a single antenna to both transmit and receive. The duplexer must connect the antenna to the transmitter and disconnect the antenna from the receiver for the duration of the transmitted pulse. As we mentioned previously, the switching time is called *receiver recovery time*, and must be very fast if close-in targets are to be detected.

### Antenna System

The antenna system routes the pulse from the transmitter, radiates it in a directional beam, picks up the returning echo and passes it to the receiver with a minimum of loss. The antenna system includes the antenna, transmission lines, and waveguide from the transmitter to the antenna, and transmission lines and waveguide from the antenna to the receiver.

### Receiver

The receiver accepts the weak rf echoes from the antenna system and routes them to the indicator as discernible video signals. Because the radar frequencies are very high and difficult to amplify, a superheterodyne receiver is used to convert the echoes to a lower frequency, called the intermediate frequency (IF), which is easier to amplify.

### Indicator

The indicator uses the video output of the receiver to produce a visual indication of target information including range and bearing (or in the case of height-finding indicators, range and height).

## TYPES OF RADAR SYSTEMS

Because of different design parameters, no single radar set can perform all the many radar functions required for military use. The large number of radar systems used by the military has forced the development of a joint-services classification system for accurate identification of radars.

Radar systems are usually classified according to their specific function and installation vehicle. The joint-service standardized classification system divides these broad categories for more precise identification.

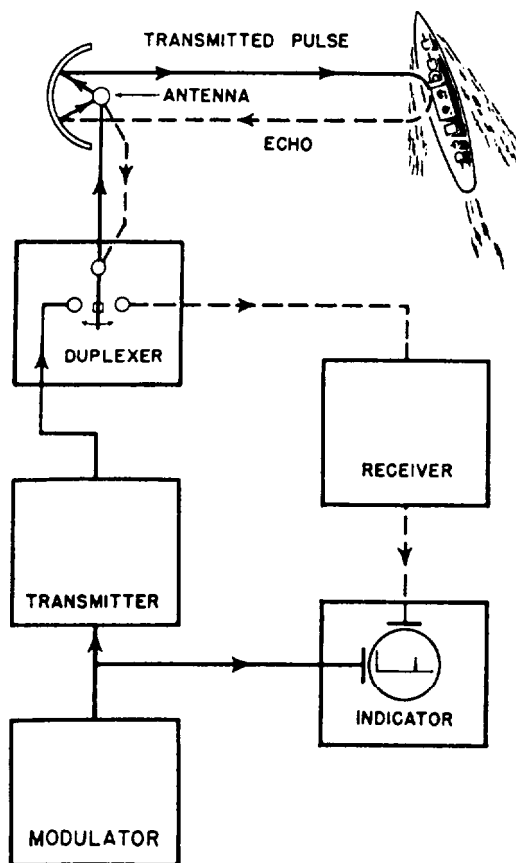


Figure 1-4.—Block diagram of fundamental radar system.

Table 1-1 is a listing of equipment identification indicators. You can use this table and the radar nomenclature to identify the parameters of a particular radar set.

If you use the table to find the parameters of an AN/FPS-35, you will see that it is a fixed (F) radar (P) for detecting and search (S). The AN indicates Army/Navy and the 35 is the model number.

Since no single radar system can fulfill all of the requirements of modern warfare, most modern

warships, aircraft, and shore installations have several radar sets, each performing a specific function. A shipboard radar installation may include surface search and navigation radars, an air search radar, a height-finding radar, and various fire control radars.

### Surface Search and Navigation

The primary function of a surface search radar is to maintain a 360-degree search for all targets within line-of-sight distance from the radar and to detect and

Table 1-1.—Table of Equipment Indicators

Installation (1st letter)	Type of Equipment (2nd letter)	Purpose (3rd letter)	Miscellaneous Identification
A—Piloted aircraft	A—Invisible light, heat radiation	B—Bombing	X,Y,Z—Changes in voltage, phase, or frequency
B—Underwater mobile, submarine	C—Carrier	C—Communications (receiving and transmitting)	T—Training
D—Pilotless carrier	D—Radic	D—Direction finder reconnaissance and/or surveillance	(V)—Variable grouping
F—Fixed ground	G—Telegraph or teletype	E—Ejection and/or release	
G—General ground use	I—Interphone and public address	G—Fire control, or searchlight directing	
K—Amphibious	J—Electromechanical or inertial wire covered	H—Recording and/or reproducing (graphic meteorological and sound)	
M—Ground, mobile	K—Telemetry	K—Computing	
P—Portable	L—Countermeasures	M—Maintenance and/or test assemblies (including tools)	
S—Water	M—Meteorological	N—Navigational aids (including altimeters, beacons, depth sounding, approach and landing)	
T—Ground, transportable	N—Sound in air	Q—Special, or combination of purposes	
U—General utility	P—Radar	R—Receiving, passive detecting	
V—Ground, vehicular	Q—Sonar and underwater sound	S—Detecting and/or range and bearing, search	
W—Water surface and under water combination	R—Radio	T—Transmitting	
Z—Piloted and pilotless airborne vehicle combination	S—Special types, magnetic, etc., or combinations of types	W—Automatic flight or remote control	
	T—Telephone (wire)	X—Identification and recognition	
	V—Visual and visible light	Y—Surveillance (search detect, and multiple target tracking) and control (both fire control and air control)	
	W—Armament (peculiar to armament, not otherwise covered)		
	X—Facsimile or television		
	Y—Data processing		

determine the accurate ranges and bearing of surface targets and low-flying aircraft.

The following are some applications of surface search radars:

- Indicate the presence of surface craft and aid in determining their course and speed
- Coach fire control radar onto a surface target
- Provide security against attack at night, during conditions of poor visibility, or from behind a smoke screen
- Aid in scouting
- Obtain range and bearing on prominent landmarks and buoys as an aid to piloting, especially at night and in conditions of poor visibility
- Facilitate station keeping
- Detect low-flying aircraft
- Detect certain weather phenomena
- Detect submarine periscopes
- Aid in the control of small craft during boat and amphibious operations

Navigation radars fall into the same general category as surface search radars. As the name implies, navigation radars are used primarily as an aid to navigate or pilot the ship. This type of radar has a shorter operating range and higher resolution than most surface search radars. Because the navigation and surface search radars share the same general operating characteristics, both radar types can be used simultaneously with one covering longer ranges, while the other covers distances closer to the ship. The use of radars for navigation is discussed further in *Electronics Technician, Volume 5—Navigation*.

So now, with surface search and navigation radars on line, the ship is aware of all surface targets, land masses, and low-flying aircraft. But, to protect itself from fighter planes, incoming missiles, and other targets in the upper skies, the ship requires a different type of radar.

### **Air Search**

The primary function of an air search radar is to maintain a 360-degree surveillance from the surface to

high altitudes and to detect and determine ranges and bearings of aircraft targets over relatively large areas.

The following are some applications of air search radar:

- Early warning of approaching aircraft and missiles, providing the direction from which an attack could come. This allows time to bring anti-aircraft defenses to the proper degree of readiness and to launch fighters if an air attack is imminent.
- Constant observation of movement of enemy aircraft, once detected, to guide combat air patrol (CAP) aircraft to a position suitable for an intercept
- Provide security against attacks at night and during times of poor visibility
- Provide information used for aircraft control during operations requiring a specific geographic track (such as an anti-submarine barrier or search and rescue pattern)

Together, surface and air search radars provide a good early warning system. However, the ship must be able to determine altitude to effectively intercept any air target. This requires still another type of radar.

### **Height Finding**

The primary function of a height-finding radar (sometimes referred to as a 3D or three-coordinate radar) is to compute accurate ranges, bearings, and altitudes of targets detected by air search radar. This information is used to direct fighter aircraft during interception of air targets.

The height-finding radar is different from the air search radar in that it has a higher transmitting frequency, higher output power, a much narrower vertical beamwidth, and requires a stabilized antenna for altitude accuracy.

The following are some applications of height-finding radar:

- Obtain range, bearing, and altitude data on enemy aircraft and missiles to assist in the guidance of CAP aircraft
- Provide precise range, bearing, and height information for fast and accurate initial positioning of fire control tracking radars
- Detect low-flying aircraft

- Determine range to distant land masses
- Track aircraft over land
- Detect certain weather phenomena
- Track weather balloons

As we stated previously, the modern warship has several radars. Each radar is designed to fulfill a particular need, but may be capable of performing other functions. For example, most height-finding radars can be used as secondary air search radars; in emergencies, fire control radars have served as surface search radars.

In this chapter we looked at general radar operation and the three types of radars most frequently maintained by ETs. Tracking radars, missile-guidance radars, and airborne radars are also critical to Navy readiness; however, they are not normally maintained by ETs and will not be covered in this TRAMAN.

Because there are so many different models of radar equipment, the radars and accessories we describe in this volume are limited to those common to a large number of ships or shore stations. In our discussion of specific equipments in the next chapter, we will purposely leave out older equipment currently installed in the fleet, but scheduled for replacement.



## CHAPTER 2

# RADAR SYSTEMS EQUIPMENT CONFIGURATIONS



In chapter 1, we discussed the configuration of a basic pulse radar system and the three basic types of radar sets. We cannot cover in one chapter every radar used by the Navy or every application of radars at the various units. Therefore, this chapter will present only a general overview of commonly used radars. We will not teach you specific equipment, but *will* help you identify and understand the operation of surface search/navigation radars, air search radars, 3D radars, CCA/GCA radars, and various repeaters used in the Navy today. For each type of radar, we will provide a basic system description, followed by its “theory of operation” and a brief explanation of the maintenance concept.

Most of the radar equipment discussed in this chapter has specific maintenance training available. However, except for certain crypto equipment, you do not need *specific* training to work on the gear. By combining the information in the appropriate technical manual with your extensive basic electronics background from “A” school and the general knowledge you get through training manuals and on-the-job

training, you can become an expert maintainer of ANY electronic equipment.

You’ll be surprised at how much you can figure out on your own. And if you ever get stumped, there are ways to get help. You may request maintenance assistance from tenders, repair ships, Mobile Technical Units (MOTUs), or NAVSEA field activities. In addition, Direct Fleet Support (DFS) will resolve maintenance repair problems beyond the capability of ship’s force, Ship Repair Facilities (SRFs), Intermediate Maintenance Activities (IMAs), and MOTU personnel. If you need DFS assistance, submit a request to the applicable NAVSEACEN via your type commander, as prescribed in NAVSEAINST 4350.6.

The first radars we’ll talk about are the surface search and navigation radars.

### **SURFACE SEARCH AND NAVIGATION RADARS**

Recall from chapter 1 that the two main functions of surface search and navigation radars are to (1) detect

surface targets and low-flying aircraft and (2) determine their range and bearing. Some of the more commonly used surface search and navigation radars in the Navy are the AN/SPS-10, AN/SPS-67(V), AN/SPS-64(V)9, and AN/SPS-55. Since the AN/SPS-10 will soon be replaced by the similar AN/SPS-67(V), we will not discuss the AN/SPS-10 in this chapter.

**AN/SPS-67**

The AN/SPS-67(V) radar is a two-dimensional (azimuth and range) pulsed radar set primarily designed for surface operations. It can also detect antiship-missiles (ASM) and low-flying aircraft. The AN/SPS-67(V)1 is the primary surface search and navigation radar, with limited air search capability, for the following types of ships:

AO	CG	DDG	LHD
AOE	CGN	FF	LPH
AOR	CV	LCC	LSD
BB	CVN	LHA	TAH

On DDG51 class ships, the AN/SPS-67(V)3 radar performs navigation, station keeping and general surface search duties. Additionally, the AN/SPS-67(V)3 supports the combat systems as shown below:

- Primary combat mission (ASUW)—provides a quick reaction, automated target detection and track capability
- Secondary combat mission (AAW)—detects low elevation (conventional) threats.

**General Theory of Operation**

The AN/SPS-67(V) radar set operates in the 5450- to 5825-MHz frequency range, using a coaxial magnetron as the transmitter output tube. To enhance radar performance for specific operational or tactical situations, the receiver-transmitter can operate in a long (1.0 %sec), medium (0.25 %sec), or short (0.10 %sec) pulse mode. The corresponding pulse repetition frequencies (prf) are 750, 1200, and 2400.

The AN/SPS-67(V)3 version has a new, high data rate, nuclear survivable, low-profile antenna and pedestal assembly that replaces the AN/SPS-10 antenna and pedestal assembly. In addition, the synchro signal amplifier function is integrated into the radar.

Some special operating features included in the AN/SPS-67(V) radars areas follows:

- Automatic Frequency Control (AFC)
- Automatic tuning
- Fast Time Constant (FTC)
- Interference Suppression (IS)
- Anti-log circuit (Target Enhance)
- Sensitivity Time Control (STC)
- Video Clutter Suppression (VCS)
- Built-In-Test (BIT) Equipment
- Sector Radiate (SR)
- Ships Heading Marker (SHM)
- Jitter mode
- Stagger mode

The following additional special operating functions are included in the AN/SPS-67(V)3 model:

- Synthesized Channel Frequency Selection
- RF Sensitivity Time Control (RFSTC)
- Antenna bearing squint correction
- Digital relative to true bearing conversion
- Full-time relative and true bearing synchro output at the ante ma controller
- Relative or true bearing synchro output selectable at the Radar Set Control (RSC) for the video processor unit
- Digital Moving Target Indicator (DMTI)
- Selectable environmental sector
- Constant False Alarm Rate (CFAR) threshold gating by external control
- Centroid function
- Track function
- Coherent EMI suppression in the DMTI channel
- Jam strobe detection
- Wraparound test by external control
- Target selectable threshold gating by external or internal control

## Configuration

The major units of the AN/SPS-67(V)1 and (V)3 radar sets are shown in figure 2-1 and figure 2-2 respectively. As you can see, there is only a slight difference between the AN/SPS-67(V)1 and the AWSPS-67(V)3 versions. Think back to the basic block diagram of a pulse radar in chapter 1 (fig. 1-4). Relate the function blocks in figure 1-4 to the basic units shown in figure 2-1. If you understand the basics, you'll find that no matter how many special operating functions a radar has, the basic system is still the same.

The receiver-transmitter and video processor components of the AWSPS-67(V) bolt to the same bulkhead foundations used for the AN/SPS-10 series components. The remaining components mount in the same area of the units they replace, although they may or may not have the same shape as the AN/SPS-10 components. The dummy load mounts on the output of the receiver-transmitter unit.

**SIGNIFICANT INTERFACES.**— Although radar systems provide valuable information by themselves, the interface of that information with other warfare systems is critical.

The AN/SPS-67(V)1 meets interface requirements of the following equipment:

- Electronic Synchronizer, AN/SPA-42 or AN/SPG-55B
- Blanker-Video Mixer Group, AN/SLA-10( )
- IFF Equipment
- Indicator Group, AN/SPA-25( ) or equivalent
- Synchro Signal Amplifier, Mk 31 Mod 8A or equivalent

The AN/SPS-67(V)3 meets interface requirements for the following additional equipment:

- Shipboard Emission Monitor-Control Set, AN/SSQ-82(V) (MUTE)
- Data Multiplex System, AN/USQ-82(V)
- Signal Processor Converter Group, OL-191(V)5/UYQ-21(V)
- Command and Decision System, Mk-2
- Gyro Digital Converter, P/O Mk-38/39 and ACTS Mk-29
- Surveillance and Control System, AN/SPY-1

**FOR THE MAINTAINER.**— The AF/SPS-67(V) is a solid-state replacement for the AN/SPS-10 radar system. Miniature and micro-miniature technologies are used throughout the radar set. It is more reliable and has better logistical support, with 92 percent of its construction being Standard Electronic Modules (SEM).

The Built-in-Test (BIT) microprocessor sub-assembly uses on-line performance sensors to decrease the chance of operating the radar with an undetected fault. Using BIT circuitry during normal operation will not degrade system performance, nor will faulty BIT circuitry affect system performance. When system failures *do* occur, you can use BIT to isolate 95 percent of the possible faults to a maximum of four modules within the receiver-transmitter or video processor.

BIT circuitry uses light-emitting diodes (index indicators) at certain test points to indicate the locations of faults. The condition of the system at each test point is displayed on readout indicators as GO, MARGINAL, or NO-GO. In addition, the BIT subsystem provides an interactive test mode that permits you to monitor certain test points while making level or timing event adjustments. Power and voltage standing wave ratio (vswr) are monitored on an on-line basis. The BIT subsystem also automatically tests itself periodically by going into a self-check mode.

## Maintenance

The AN/SPS-67(V) radar set operates continuously during the ship's deployment. The responsibility for the organizational level maintenance falls on the ship's Electronics Technicians, (NEC ET-1507.)

Organizational level maintenance consists of preventive maintenance (PM) and corrective maintenance (CM). PM is performed according to maintenance requirement cards (MRCs) developed for the AN/SPS-67(V) system. PM at this level includes checks of operational status and filter/equipment cleaning. CM is performed according to the AN/SPS-67(V) technical manual procedures, and includes removing and replacing chassis-mounted piece parts, modules, assemblies, and sub-assemblies.

Repairable modules, assemblies, and sub-assemblies are returned to the depot according to Navy supply procedures.

## AN/SPS-64(V)9

The AN/SPS-64(V)9 radar is a two-dimensional (2D) navigation/surface search radar used as a primary radar on small combatants and various non-combatant

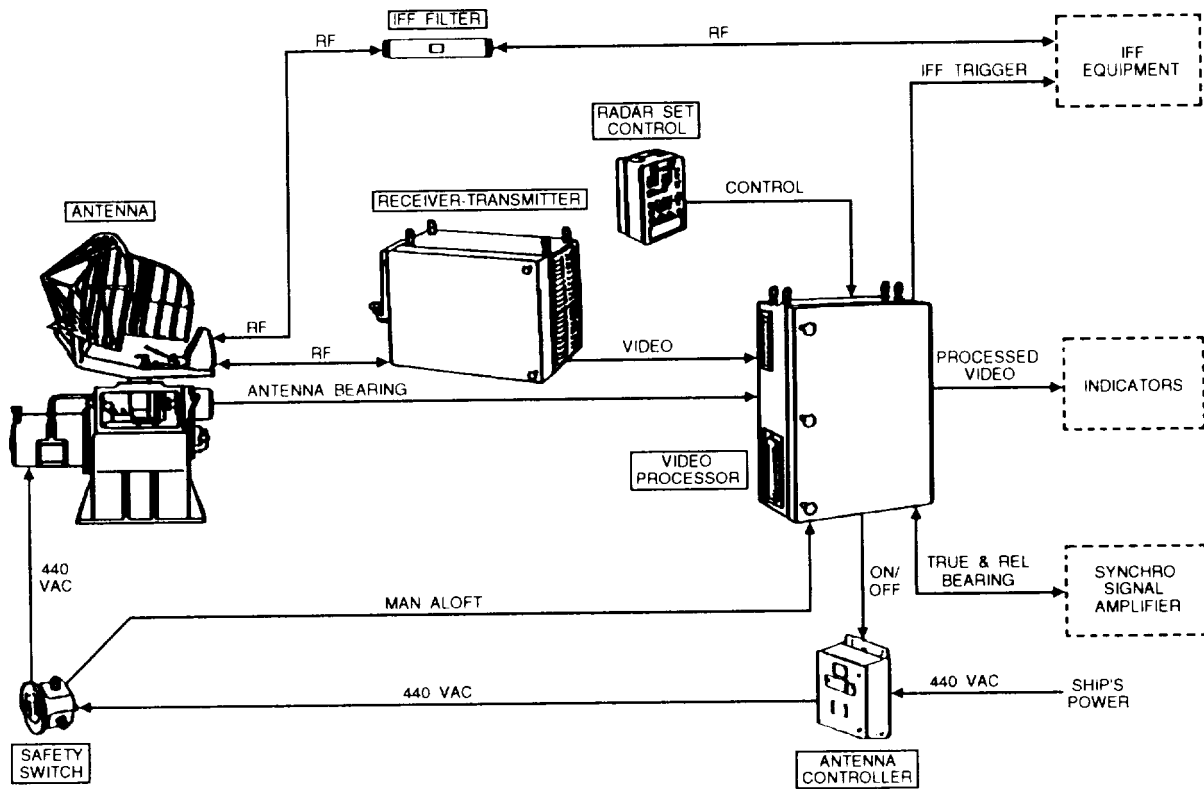


Figure 2-1.—AN/SPS-67(V)1 radar.

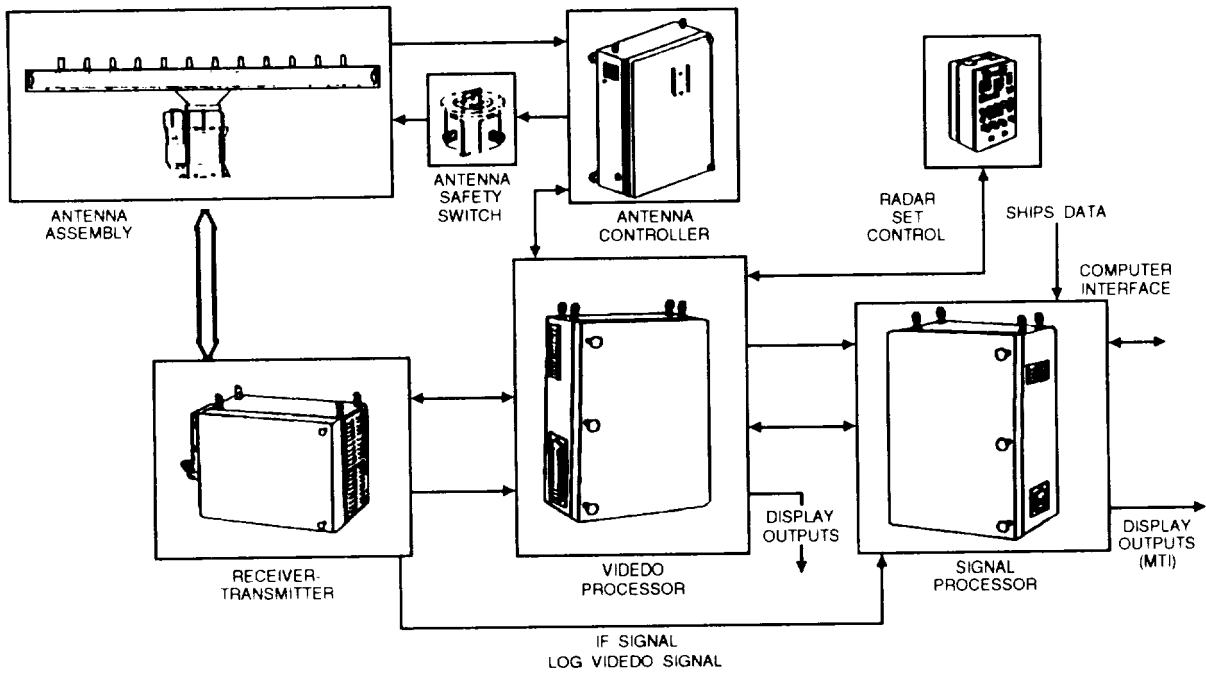


Figure 2-2.—AN/SPS-67(V)3 radar.

ships. It is also used as a back-up radar on large combatants. It provides a true bearing display for coastal piloting and a capability for radar navigation and station keeping.

The AN/SPS replaces a variety of small commercial radars on the following types of ships:

AE	ASR	CGN	FFG	LPH
AGDS	ATS	CV	LCC	LST
AOE	AVT	CVN	LHA	MHC
ARL	BB	DDG	LHD	MSO
ARS	CG	FF	LPD	PHM

### General Theory of Operation

The AN/SPS-64(V)9 has a minimum detection range of 20 yards on a radar cross-sectional target of 10 square meters, 3 feet above the surface of the water. It can operate in either true or relative bearing when used with Navy gyrocompasses.

Some special operating features of the radar include:

- Ship line voltage protection
- Ship Heading Marker (SHM)
- Variable range marker

### Configuration

Figure 2-3 provides a general overview of how this radar operates. Unlike the AN/SPS-67 radars, this off-the-shelf radar system was not designed to use existing antennas and indicators. All the components, including the indicator and the antenna system, are unique to the AN/SPS-64(V)9.

**SIGNIFICANT INTERFACES.**— Information from the AN/SPS-64(V)9 interfaces with the following Navy equipment:

- Blanker/Video Mixer Group, AN/SLA-10
- Indicator Group, AN/SPA-25( ) or equivalent
- Synchro Signal Amplifier, Mk 27 or equivalent
- Mk 19 gyrocompass or equivalent

**FOR THE MAINTAINER.**— The AN/SPS-64(V)9 is designed and constructed according to the best

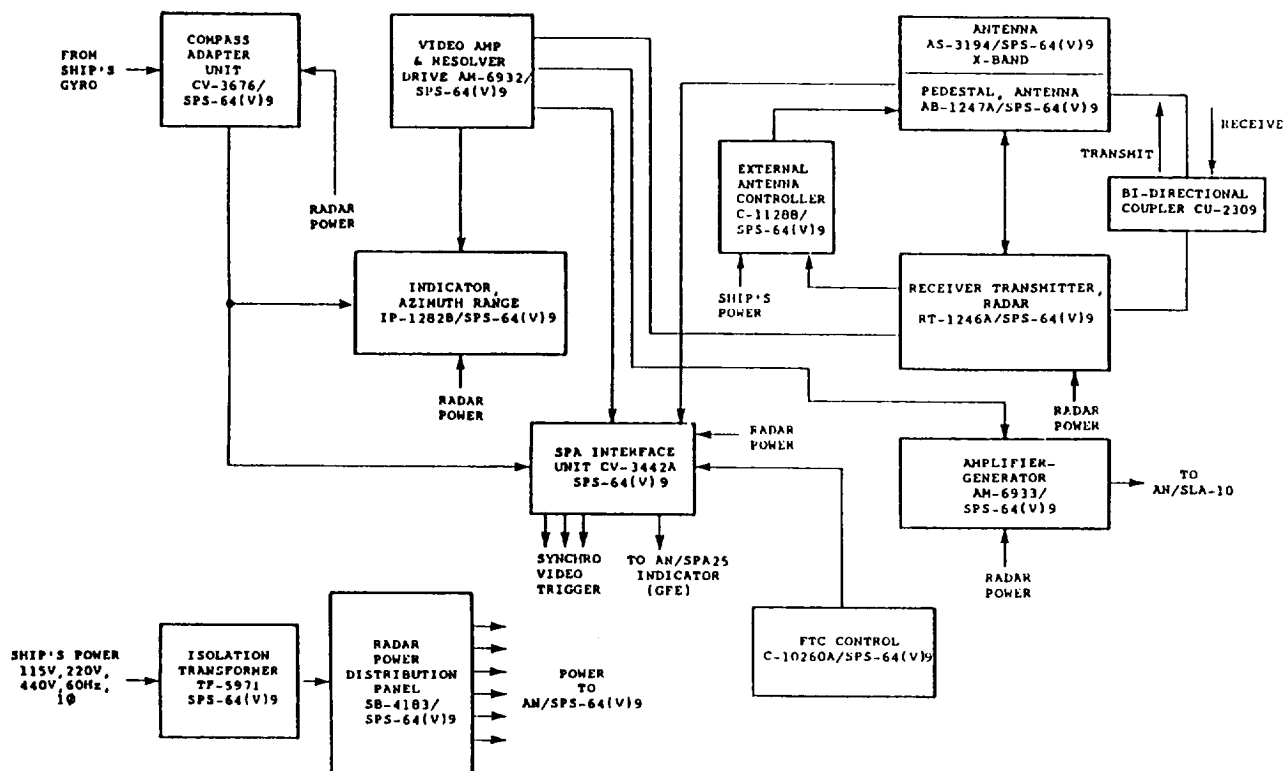


Figure 2-3.—AN/SPS-64(V)9 radar block diagram.

commercial practices. For example, there are safety interlocks on the antenna pedestal, the receiver/transmitter (R/T) unit, and the azimuth range indicator. All the other units include ON/OFF switches and indicator lights.

## Maintenance

The AN/SPS-64(V)9 was purchased as the single, commercially available, off-the-shelf radar for the Navy's Class B1 radar program. Maintenance support, including documentation, spares, and levels of maintenance is also an off-the-shelf concept.

Maintenance responsibilities are assigned to an existing billet and performed by an Electronics Technician (no specific NEC assigned). Organizational level maintenance consists of preventive maintenance (PM) and corrective maintenance (CM). PM is done according to the maintenance requirement cards (MRCs). CM consists of (1) adjustments, alignments, and tests, as described in the technical manual and (2) replacement of the lowest replaceable unit (LRU) required to correct radar discrepancies.

The Miniature/Microminiature (2-M) Electronic Repair Program and the Support and Test Equipment Engineering Program (STEEP) are not used for the AN/SPS-64(V)9 radar, since the Navy has no data rights for the equipment.

Major overhaul and restoration of the AN/SPS-64(V)9 radar and LRU repair are performed at the depot level, in the prime contractor's facility. Technical Repair Standards (TRSs) are not available since the Navy does not make depot-level repairs.

## AN/SPS-55

The AN/SPS-55 is a solid-state, Class A surface search and navigation radar. It is used to detect small surface targets and for navigation and pilotage. The AN/SPS-55 radar detects targets from as close as 50 yards to as far as 50 nautical miles. It was specifically designed for installation in the following new-construction ship classes:

AO-177	CGN-38	DDG-993	MCM-1
CG-47	DD-963	FFG-7	PBC-1

A radar video converter (RVC) modification was developed for AN/SPS-55s used on the FFG-61 class.

The AN/SPS-55 radar supports several mission areas including Antisurface Warfare (ASUW), Antisubmarine Warfare (ASW), Amphibious Warfare (AMW), Special Warfare (SPW), Mobility (MOB), and Command and Control (CAC).

## General Theory of Operation

The radar set operates from 9.05 GHz to 10 GHz, and can tune over the entire bandwidth within 60 seconds. Tuning can be controlled from either the remote radar set control (RSC) or the receiver-transmitter (R/T) unit. The transmitter uses a magnetron with a minimum peak power of 130 KW. The receiver can operate in a long-pulse mode (1.0 %sec) or short-pulse mode (.12 %sec) with minimum ranges of 200 yards and 50 yards respectively. The antenna consists of two back-to-back end-fed, slotted waveguide arrays with a scan rate of 16 rotations per minute (rpm).

Some special operating features of the AN/SPS-55 radar set include:

- Squint compensation
- Variable sensitivity time control
- Fast time constant (FTC)
- Log/linear-log intermediate frequency (IF) amplifier
- Video blanking circuit
- Sector radiate capability
- Automatic and manual frequency control (AFC/MFC)

The RVC modification provides these additional features:

- Analog/digital (A/D) conversion
- Digital integration with beam time interval
- Noncoherent DMTI
- Moving window constant false alarm rate (CFAR) thresholding
- Segmented CFAR

## Configuration

As shown in figure 2-4, the major components of the AN/SPS-55 radar include the antenna, the

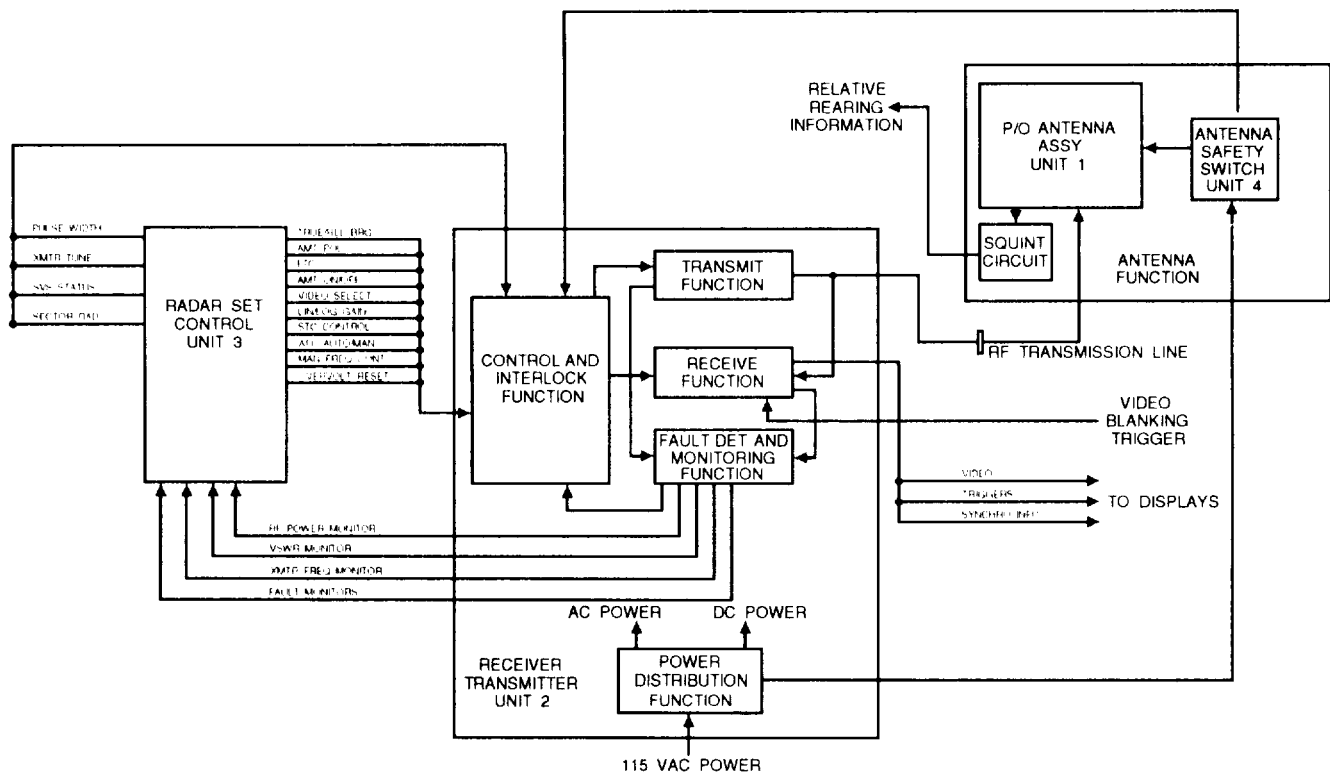


Figure 2-4.—AN/SPS-55 block diagram.

receiver-transmitter (R/T), the radar set control (RSC), and the antenna safety switch.

Although the AN/SPS-55 radar is electronically reliable, the antenna pedestal has been a source of mechanical maintenance problems. A field change kit, developed in FY89, provided an improved antenna pedestal. Delivery and installation of the pedestal modification are coordinated by the Restoration Program Manager.

**SIGNIFICANT INTERFACES.**— The AN/SPS-55, like all radars, has an impact on other systems, subsystems, and equipment. The RVC modification developed for the FFG-61 and the antenna pedestal modification not only improved the radar set, but improved the interface capabilities. The RVC enables the FFG-61 Integrated Automatic Detection and Tracking System (IADT) to use the AN/SPS-55 data. The pedestal modification allows interface with IFF.

The AN/SPS-55 interfaces with the following equipment:

- Blanker/Video Mixer Group, AN/SLA-10
- Indicator Group, AN/SPA-25( ) or equivalent
- Mk 27 synchro signal amplifier or equivalent

- Mk XII IFF (pedestal mod only)
- AN/SYS-2(V)2 IADT (FFG-61 RVC mod only)

**FOR THE MAINTAINER.**— The AN/SPS-55 radar has various built-in features to protect the maintainer and the equipment. The transmitter has a voltage standing wave ratio (vswr) alarm. Fault detection indicators, located on both the transmitter and the RSC unit, show when the high-voltage power supply, modulator, or magnetron exceeds predetermined safe limits. A low-power condition in the radar automatically places the radar in the standby mode and activates an indicator at the RSC when low power exists.

The antenna safety switch, when activated, opens the radiate interlock, removing power from the drive motor. It also activates a “Man Aloft” indicator on both the R/T and the RSC unit to ensure that no one tries to operate the radar during maintenance.

## Maintenance

Maintenance of the AN/SPS-55 consists primarily of module replacement, with limited repair or replacement of certain individual components. The equipment is designed for rapid fault isolation to the

lowest replaceable unit (LRU). The technical manual lists the assemblies and components that can be replaced during organizational level maintenance.

Electronics Technicians (NEC ET-1491 for FFG-7 Class ships or ET-1504 for all other ships) are responsible for organizational level maintenance of the AN/SPS-55. Preventive maintenance (PM) and corrective maintenance (CM) include:

- electrical and mechanical alignments;
- adjustments, and calibration;
- fault detection, isolation, and module or major part repair/replacement; and
- all correction and verification necessary to restore the radar set to an operating condition.

Disposition and repair of failed components is specified by the Source, Maintenance, and Recoverability (SM&R) codes in the applicable Allowance Parts List (APL). Send your repairable modules to the Designated Overhaul Point (DOP) for repair or condemnation.

## **AIR SEARCH (2D) RADARS**

The two primary functions of air search radar are to (1) detect aircraft targets at long ranges and (2) determine their range and bearing. Some of the most widely used two-dimensional (2D) air search radars in the Navy are the AN/SPS-37A, AN/SPS-43, AN/SPS-43A, AN/SPS-49(V), AN/SPS-40B/C/D/E, and AN/SPS-65(V) aboard ships and the AN/GPN-27 (ASR) at shore installations.

We will not discuss the AN/SPS-29, AN/SPS-37, and AN/SPS-43 radars, since the AN/SPS-49(V) radar replaces them.

### **AN/SPS-49(V)**

The AN/SPS-49(V) radar is the primary U.S. Navy early warning air search 2D radar. It is a very-long-range radar, and provides long-range air surveillance in severe clutter and jamming environments. It primarily supports the anti air warfare (AAW) mission on surface ships, but also provides backup to the 3D weapon system radar. The AN/SPS-49(V) radar is also used for air traffic control (ATC), air intercept control (AIC), and antisubmarine aircraft control (ASAC).

The AN/SPS-49(V) radar replaces the AN/SPS-29, AN/SPS-37, AN/SPS-40, and AN/SPS-43 radars in some ships, including the following ship types:

CG	CV	DDG	LHD
CGN	CVN	FFG	LSD

Current planning calls for installation of the AN/SPS-49(V) radar in 160 U.S. Navy ships, plus various shore installations.

### **General Theory of Operation**

The AN/SPS-49(V) is a narrow-fan beam radar developed from a Specific Operational Requirement. It provides the capability to conduct air search operations on a previously unused radar frequency. This minimizes electronic interference between ships and increases the difficulty for hostile electronic countermeasures (ECM). The AN/SPS-49(V) provides good bearing measurements to backup the 3D radar weapons system. Its narrow beamwidth substantially improves resistance to jamming.

The coherent side lobe canceler (CSLC) cancels jamming and interference signals, providing the AN/SPS-49(V) radar further resistance to jamming and interference. The DMTI capability enhances detection of low-flying, high-speed targets.

The AN/SPS-49(V)5 version, which has automatic target detection (ATD) capability, has even more sophisticated antijamming features. This version offers improved clutter suppression and a digital interface to the AN/SYS-2(V) IADT system. The AN/SPS-49(V)5, does not cancel non-moving targets as with MTI, instead it uses the newest development in doppler processing, Finite Impulse Response (FIR) filters. These filters separate radar echo returns into fixed and moving channels according to their doppler characteristics. The moving channels contain moving targets only. The fixed channels contain fixed clutter and blind speed targets. Rejection of non-moving targets recurs at a later point in time in the clutter maps.

The "AEGIS Tracker" modification consists of a PCB card set integrated into the signal data processor. It adds an embedded tracker, with direct digital interface with the AEGIS combat system, to the AN/SPS-49(V)7 radar (installed on AEGIS cruisers). With this modification incorporated, the AN/SPS-49(V)7 nomenclature changes to AN/SPS-49(V)8.

The digital coherent side lobe canceler (DCSC) is part of the Medium PRF Upgrade (MPU) modification.



It improves performance against small targets when subjected to stand-off jamming. The modification primarily replaces the receiver's *sensitivity time control* (STC) with a *sensitivity velocity control* (SVC). SVC uses radial velocity and target size information to "filter" out birds and near-in clutter. It suppresses these unwanted targets while retaining detection performance throughout the volume of coverage. The MPU also aids in reducing reaction time to only two scans by providing very high-quality velocity estimates for radar targets.

**Configuration**

The AN/SPS49(V) radar set contains 47 major units in nine variant configurations, (V)1 through (V)9. Figure 2-5 shows the physical configuration of the AN/SPS-49(V) radar system.

The nine variant configurations are:

- (V)1 Baseline radar
- (V)2 AN/SPS49(V)1 radar without the coherent side lobe cancellation feature
- (V)3 AN/SPS-49(V)1 radar with the radar video processor (RVP) interface (FC-1)
- (V)4 AN/SPS49(V)2 with the RVP interface
- (V)5 AN/SPS-49(V)1 with automatic target detection (ATD)
- (V)6 AN/SPS-49(V)3 without the cooling system
- (V)7 AN/SPS-49(V)5 without the cooling system
- (V)8 AN/SPS-49(V)7 with automatic detection and tracking (ADT)
- (V)9 AN/SPS-49(V)5 with medium PRF upgrade (MPU)

**SIGNIFICANT INTERFACES.**— The AN/SPS-49(V) radar interfaces with shipboard display systems via conventional radar switchboards and NTDS switchboards. Field Change 1 provides an optional interface through the Dual Channel RVP and associated equipment. In addition, the AN/SPS-49(V)5 version interfaces with the AN/SYS-2(V) MDT system.

**FOR THE MAINTAINER.**— Solid-state technology with modular construction is used throughout the radar, except for the klystron power amplifier and high-power modulator tubes. Digital processing

techniques are used extensively in the AN/SPS-49(V)5, 7 and 8.

The radar has comprehensive BIT features, such as performance monitors, automatic fault detectors, and built-in-test equipment (BITE). The AN/SPS-49(V)5, 7, and 8 include automatic, on-line, self-test features. Each major unit has test panels with fault indicators and test points. There is also a test meter to monitor system power supply voltage.

**Maintenance**

The AN/SPS-49(V) radar operates continuously during deployment. Radar maintenance is a responsibility of the ET rating (NEC ET-1503 for (V)1, 2, 3, 4, and 6 or ET-1510 for (V)5, 7, 8 and 9). Basic maintenance involves module replacement and planned maintenance (PM) and follows the policies set forth in NAVSEAINST 4700.1 and NAVMATINST 4700.4B.

Organizational maintenance consists of PM and CM, performed on the radar in place, while the ship is underway. CM is limited to (1) fault isolation, (2) removal and replacement of modules or cabinet-mounted piece parts, and (3) the adjustment, alignment, and testing required to correct the radar degradations. All repairable modules are shipped to DOP for repair as directed by SPCC Mechanicsburg.

Removing and replacing the radar antenna and various major antenna subassemblies require intermediate-level maintenance. These tasks are conducted as directed by the NAVSEASYS COM Restoration Program.

**AN/SPS-40B/C/D/E**

The AN/SPS-40B/C/D/E is the primary shipboard long-range, high-powered, two-dimensional (2D), air search radar. It provides 10-channel operation, moving target indicator (mti), pulse compression, and high data short range mode (SRM) for detecting small, low-altitude, close-in targets. Designed for use aboard frigate-size or larger ships, the AN/SPS-40B/C/D radar is used on the following types of ships:

AVT    FF    CC    CGN    DDG

Field Change 11, which changes the nomenclature to AN/SPS-40E, replaces the tube-type power amplifier with a solid-state transmitter (SSTX) and provides a substantial improvement in operational availability. The AN/SPS-40E radar is used on the following types of ships:

AGF    DD    LHA    LPH  
 AOE    LCC    LPD    LSD

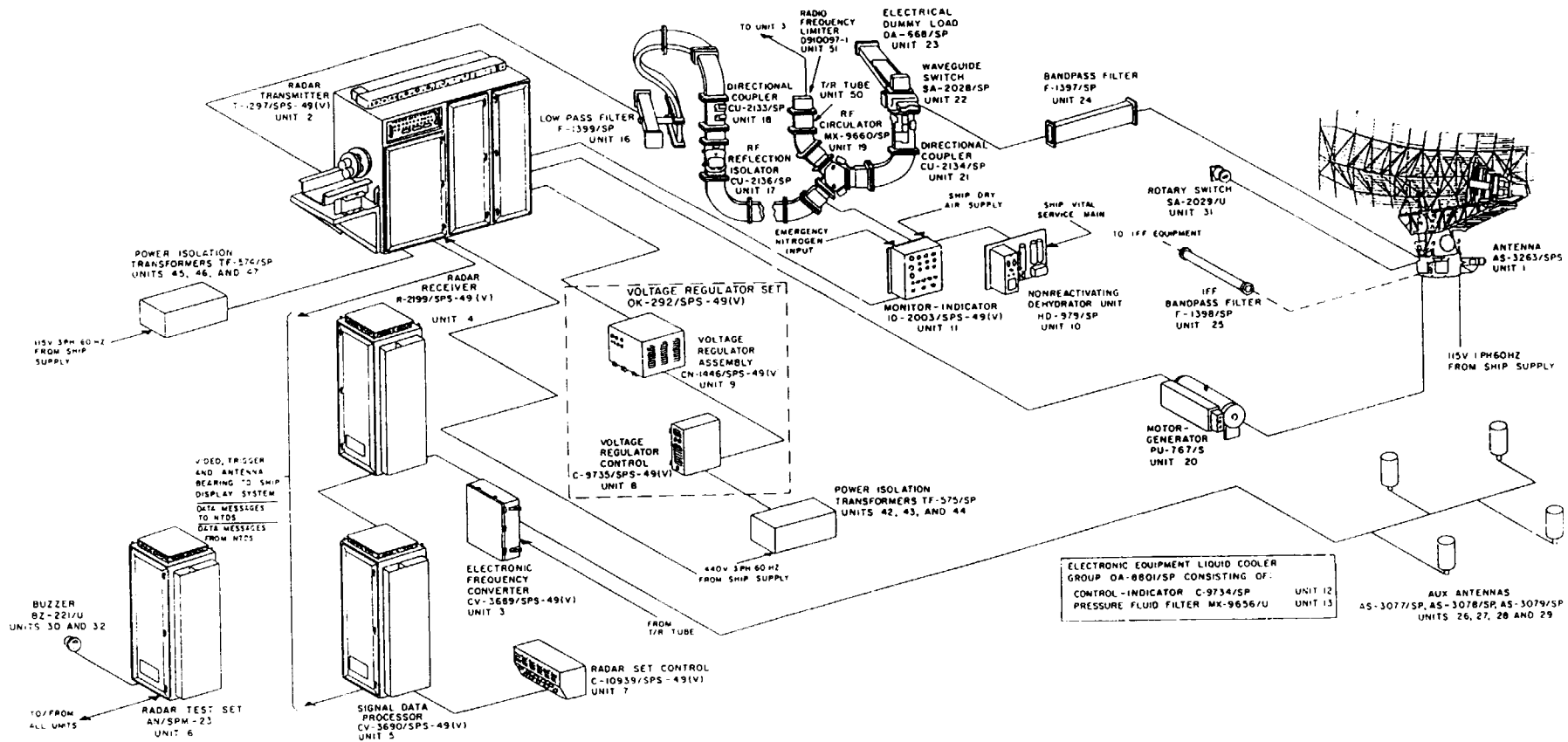


Figure 2-5.—AN/SPS-49(V) radar system.

The many changes to this radar set have improved its minimum range capability, as well as made it more reliable and easier to maintain.

### General Theory of Operation

The AN/SPS-40 radar set, with the automation module, is better able to detect targets over land and water and to generate clutter-free target data. It has a two-speed drive motor, which increases the antenna rate to 15 rpm for high-data rate capabilities and operates at a normal 7.5 rpm speed in the long-range mode (LRM).

Some special operating features of the AN/SPS-40B/C/D/E include the following:

- DMTI
- Long-range, long-range/chaff, and short-range modes
- Automatic target detection (ATD)
- Built-in-test (BIT) equipment
- Analog/digital conversion
- Four-pulse staggered pulse repetition frequency (prf)
- Operator selectable antenna scan rate
- Sensitivity time control (STC)

### Configuration

Figure 2-6 illustrates the AN/SPS-40B/C/D DMTI/RVC radar system. The DMTI field change replaces the analog moving target indicator with more reliable and more easily maintained digital circuitry. It also provides a new radar set control (RSC) and replaces the duplexer with a solid-state unit. The RVC field change allows the radar to interface with the AN/SYS-1 IADT system.

Installation of the solid-state transmitter, field change (FC-11), replaces 11 shipboard units (units 2, 3, 4, 6, 16, 17, 18, 19, 21, 23, and 25) with five units (units 28 through 32) as shown in figure 2-7.

**SIGNIFICANT FIELD CHANGES.**— As we mentioned before, this radar set has had many changes. Some of the more significant field changes are:

- Digital moving target indicator (DMTI)—solid-state upgrade
- Radar video converter (RVC)—interface with AN/SYS-1

- Solid-state transmitter (SSTX)—changes the number of units in the configuration and the nomenclature of the system
- AN/SPS-40E Field Change 2—changes the two-cabinet PA configuration to a single cabinet PA
- AN/SPS-40E Field Change 3—replaces the DMTI with a new coherent receiver processor

**SIGNIFICANT INTERFACES.**— The AN/SPS-40B/C/D/E interfaces with shipboard display systems via conventional radar switchboards and NTDS switchboards. The AN/SPS-40B/C/D/E radar with DMTI/RVC interfaces with the AN/SYS-1 Integrated Automatic Detection and Tracking System (IADT).

**FOR THE MAINTAINER.**— The increased use of solid-state design and modular construction in the AN/SPS-40 radar results in a longer mean time between failures (MTBF) and a shorter mean time to repair (MTTR). The new receiver and mti both use built-in-test equipment to help in alignment and troubleshooting.

### Maintenance

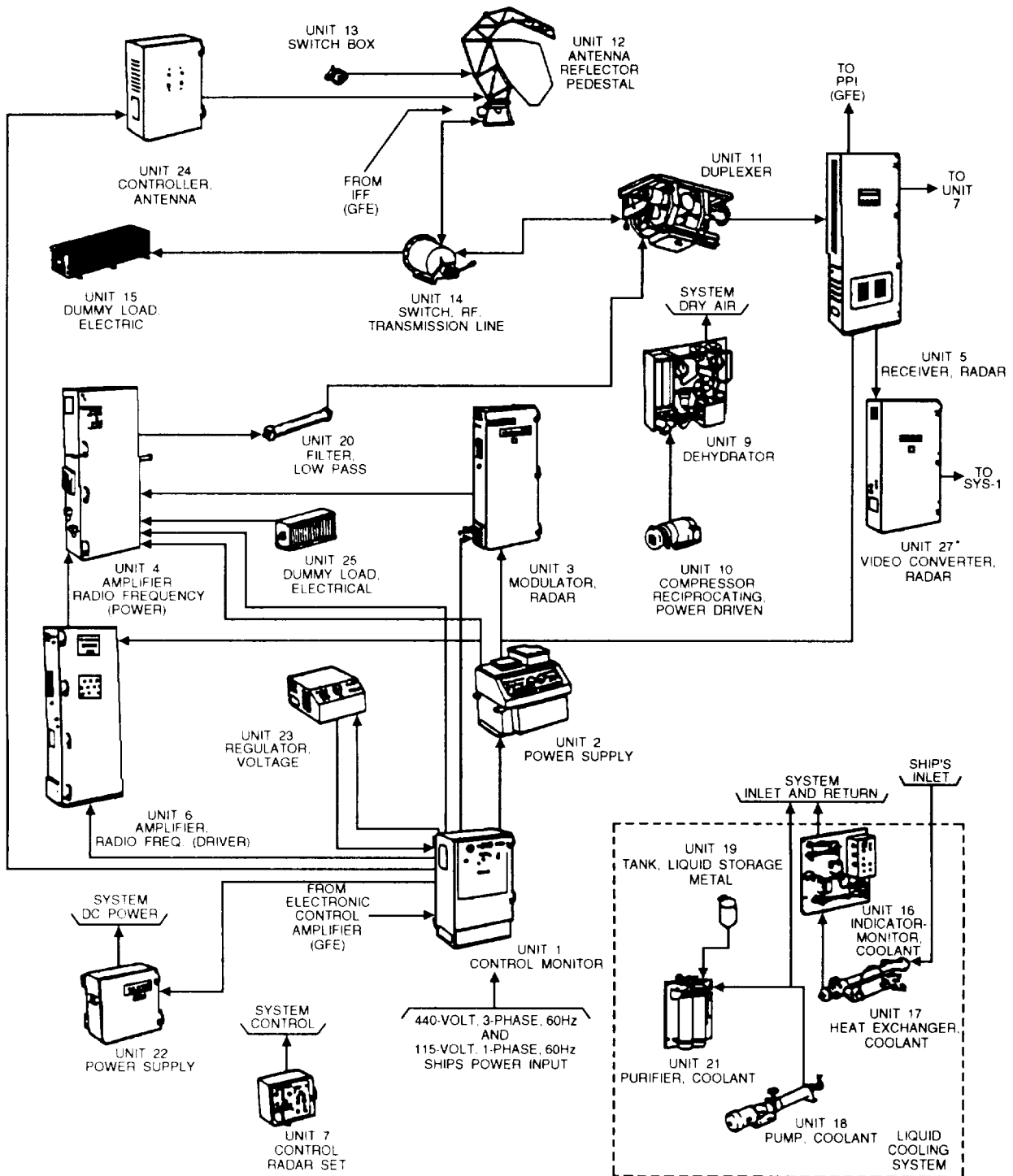
The AN/SPS-40B/C/D/E radar is designed for continuous operation during deployment. The maintenance responsibilities are assigned to the ET rating (NEC ET-1516, ET-1508 (with DMTI), and ET-1511 (with FC-11)). The SPS-40's modular design minimizes maintenance actions at the organizational level.

Organizational maintenance includes preventive and corrective maintenance. PM is performed according to technical manuals and maintenance requirement cards (MRCs).

CM is performed according to the corrective maintenance section of the technical manuals and by the Source Maintainability and Recovery (SM&R) code assigned in the APL. You may be required to perform any of the following actions:

- Remove and replace cabinet-mounted piece parts, modules, assemblies or sub-assemblies.
- Repair modules, assemblies, or sub-assemblies designated as shipboard repairable.
- Turn in depot repairable items using prescribed supply procedures.

# AN/SPS-40B/C/D RADAR WITH F.C. 1.3 THROUGH 10



\*USED WITH AN/SYS-1 ONLY

Figure 2-6.—AN/SPS-40B/C/D DMT/RVC radar system.

# AN/SPS-40B/C/D RADAR WITH F.C. 1,3 THROUGH 11 AND 14

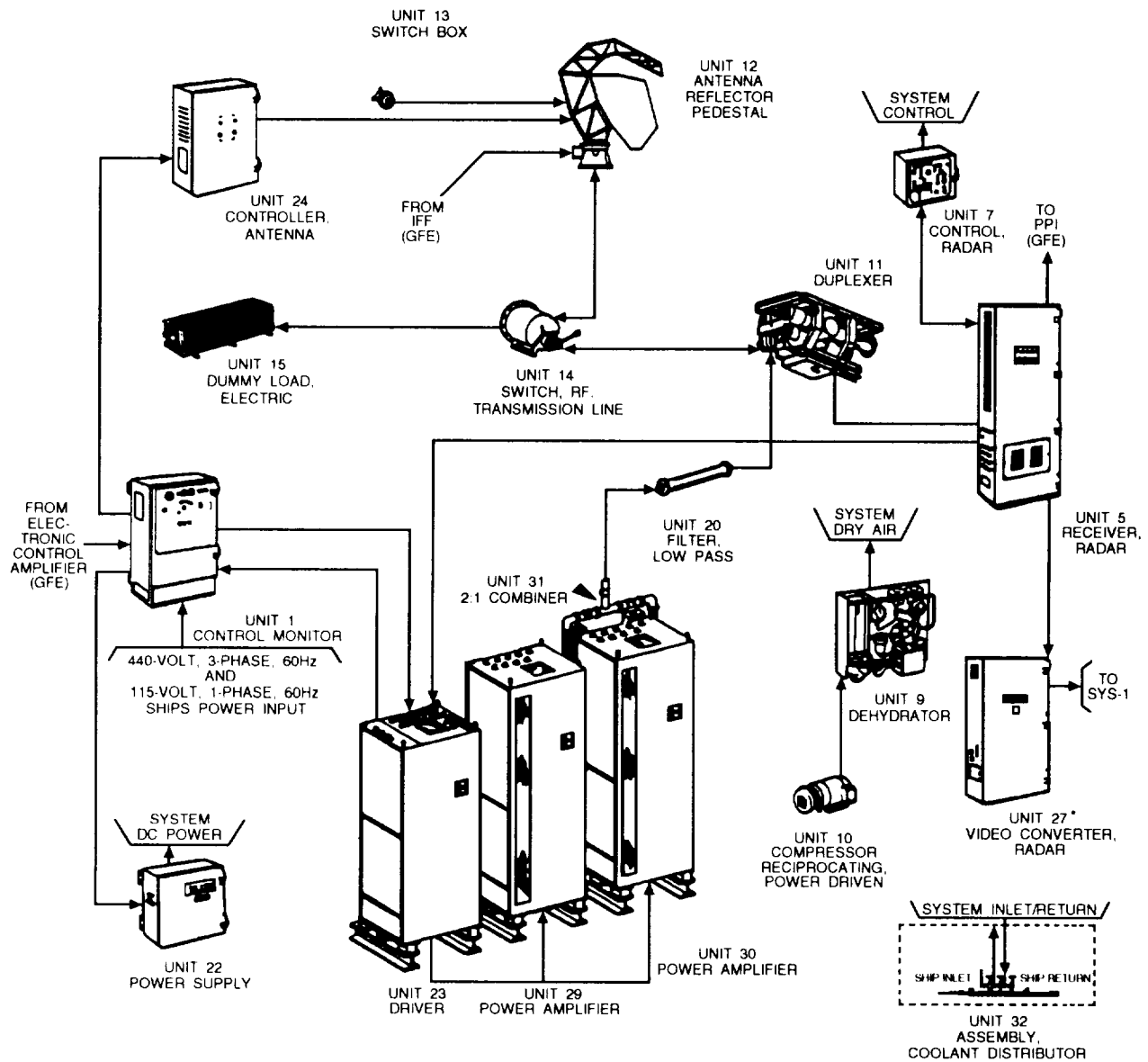


Figure 2-7.—AN/SPS-40E radar system.

System overhaul and restoration are performed on a turn-around basis every 10-15 years by naval shipyards or private contractors as directed by NAVSEA. Antenna and pedestal restoration is done on a turn-around basis, with the assembly aboard ship replaced about every 3 years.

## AN/GPN-27 (ASR-8)

The Airport Surveillance Radar AN/GPN-27 is used at naval air stations (NAS) and Marine Corps air stations (MCAS) to detect aircraft within 60 nautical miles of the station and to generate plan position indicator (PPI) information for aircraft control.

## General Theory of Operation

The AN/GPN-27 is a modular, solid-state, dual-channel, dual-beam/frequency diversity, S-band, surveillance radar used for safe, efficient movement of air traffic within the naval or Marine Corps Air Station National Airspace System area.

Some of the operating features include:

- Stable local oscillator (STALO)
- MTI with 10-bit design
- Clutter rejection
- Circular polarization
- Reduced side lobes
- Field-programmable range azimuth gate

## Configuration

The AN/GPN-27 radar includes three major groups: an antenna group, a transmitter building group, and a display site group.

The *antenna group* consists of a reflector, dual-feed assembly, rotary joint, pedestal, and a dual-drive train assembly. It is a dual-beam design with normal and passive channels, including switchable linear and circular polarization. The cosecant-squared elevation pattern provides constant radiation altitude coverage up to 30 degrees above peak of beam. The passive, receiver-only feed horn is tilted upward from the normal beam to reduce interference from ground clutter at short ranges.

In the *transmitter building group*, the transmitter has an air-cooled klystron, a solid-state modularized modulator, and a solid-state, high-voltage power supply. The receiver provides normal video, log video, and moving target indicator (mti) video signals to the processor unit. The digital processor processes the receiver video for the radar tuning and control circuits, the range/azimuth gate generator, the azimuth pulse generator (APG), and the video cable-line drivers. The system control interface and distribution unit features a solid-state control system for radar command and status indications. A 16-inch maintenance plan position indicator (MPPI) aids in system alignment and maintenance. The transmitter building group also has two of the five stations (1 master and 1 slave) of the intercommunication system.

The *display site group* at the indicator site or air traffic control (ATC) room consists of a display site remote unit, two system control panels, a display site cable junction box, and an intercommunications system with three stations (2 master and 1 slave).

**SIGNIFICANT INTERFACES.**— The only interfacing is within the system itself. The control system contains control boxes that have release and take-control circuitry to ensure that radar command is available only at the selected control box. Operators scan the radar screen for incoming and outgoing aircraft, vector aircraft to the airfield, and work with other controllers to coordinate precision approach radars (PAR) and land aircraft.

**FOR THE MAINTAINER.**— The AN/GPN-27 uses state-of-the-art design and technology. All radar command and status signals stay in power-protected solid-state memory, isolating the control system from short-term power outages. The MPPI at the transmitter building aids in system alignment and other maintenance.

## Maintenance

Maintenance of the AN/GPN-27 is performed on demand or as scheduled and is done by Electronics Technicians (NEC ET-1580). Organizational level maintenance includes fault isolation, performance testing, and alignment. Corrective maintenance consists of the removal and replacement of sub-assemblies, modules, and printed circuit boards (PCBs). Those items not repairable at the organizational level are returned to the depot facility through normal Navy supply channels.

## THREE COORDINATE (3D) AIR SEARCH RADARS

Fire Control Technicians (FCs) usually maintain the height-finding radars installed aboard Navy ships. So, rather than cover specific equipment, we will cover general information to help you understand the overall radar capabilities of your ship.

The 3D radar functions much like the 2D system, but also provides elevation information. To do this, the height-finding radar uses a beam that is very narrow, both vertically and horizontally. Azimuth is provided as the antenna rotates continuously at speeds varying up to 15 rpm. Although the antenna usually operates in the automatic mode, the operator may

control it manually for searching in a specific target sector.

As we mentioned in chapter 1, the air search 3D radars determine altitude by scanning the vertical plane in discrete increments (steps). Although this may be done mechanically, most frequently, it is done electronically. Figure 2-8 shows the radar beam radiated at different elevation angles as electronic scanning changes the radiated frequency in discrete steps. Each elevation angle or step has its own particular scan frequency.

A computer electronically synchronizes each radiated frequency with its associated scan angle to produce the vertical height of a given target.

The 3D radars also use a range-height indicator (RHI) in addition to the PPI used with 2D radars. We will discuss both indicators in further detail in the section on radar indicators.

### **CARRIER-CONTROLLED APPROACH (CCA) AND GROUND-CONTROLLED APPROACH (GCA) RADARS**

Carrier-controlled approach (CCA) and ground-controlled approach (GCA) systems guide aircraft to safe landings, even under conditions approaching zero visibility. Radar is used to detect aircraft and to observe them during their final approach and landing. Guidance information is supplied to the pilot in the form of verbal radio instructions, or to the automatic pilot (autopilot) in the form of pulsed control signals.

The primary approach systems in the Navy are the AN/SPS-46(V) Precision Approach Landing System (PALS) for CCA and the AN/FPN-63 Precision Approach Radar (PAR) for CGA.

#### **AN/SPN-46(V) PALS**

The AN/SPN-46(V)1 system provides safe and reliable final approach and landing for PALS-equipped

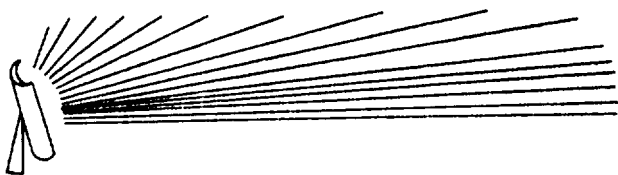


Figure 2-8.—Electronic elevation scan.

carrier-based aircraft, during daylight or darkness. It is rarely affected by severe weather and sea state conditions, and is not affected by low ceiling and visibility problems.

The AN/SPN-46(V)2 system is installed at selected naval air stations (NAS). It is used for the PALS training of flight crews, operator and maintenance personnel, and the PALS certification of aircraft.

The AN/SPN-46(V)1 system replaces the AN/SPN-42A Automatic Carrier Landing System (ACLS) on CV/CVN class ships. The AN/SPN-46(V)2 system replaces the AN/SPN-42T1/3/4 at various naval air stations.

#### **General Theory of Operation**

The AN/SPN-46(V) PALS allows simultaneous and automatic control of two aircraft during the final approach and landing phase of carrier recovery operations. Designed primarily as an “automatic” landing system, it also has manual control capabilities. The AN/SPN-46(V) has three modes of operation that are identified, based on the type of control (automatic or manual) and the source of information (display or voice).

**Mode I** (automatic control).—The Central Computer Subsystem (CCS) processes flight information from the radar/ship motion sensor (SMS), wind speed and direction equipment, and other ancillary equipment. It then transmits command and error signals to each aircraft via the Link 4A. The aircraft receives these command and error signals and translates them into control actions that maintain the aircraft within a narrowly prescribed flight envelope.

**Mode II** (manual control with display).—The aircraft cockpit display receives command and error signals that direct the pilot to take proper actions.

**Mode III** (manual control with voice).—The air traffic controller, using the processed flight data transmitted to the operator control console (OCC), provides the pilot with voice communications for a manual approach.

#### **Configuration**

The AN/SPN-46(V)1 system consists of 26 units categorized into four major subsystems: display (units 1 and 2), ancillary equipment (units 3-11), central computer (units 12- 16), and radar/SMS (units 17-26). A pictorial flow diagram of the system is

shown in figure 2-9. The AN/SPN-46(V)2 functions the same as the AN/SPS-46(V)1, except that it does NOT use the MK 16 Mod 12 stable elements (units 17 and 18). Also, the (V)2 uses a 7-foot diameter antenna instead of the 4-foot antenna used for the (V)1.

The *display* subsystem consists of two identical operator control consoles (OCC) (units 1 and 2), one for each channel of the system. The OCCs allow the final controllers to control and monitor the AN/SPN-46(V) system. The OCC includes a radar display, a data generator, and an embedded computer. The OJ-314 system installed in the OCC provides operator communications.

The *ancillary equipment* subsystem includes aircraft control indicators (units 4, 6, and 7) for the Carrier Air Traffic Control Center (CATCC) and Primary Flight (PRI-FLI) areas. The PRI-FLI indicators (units 6 and 7) display the flight information and system status required for each OCC. The recorder-converter (unit 8) records selected system data. The landing signal officer (LSO) waveoff light (unit 10) provides the LSO with a visual indication of the system waveoff on the nearest aircraft under control.

The *central computer* subsystem (CCS), consisting of two identical AN/AYK-14(V) computer sets, receives data from the radar/SMS and OCCs. It computes aircraft command and error signals and transmits them to controlled aircraft via Link 4A.

The *radar/ships motion sensor (SMS)* subsystem consists of two radar channels, each with an X-band receiver, a K<sub>a</sub>-band transmitter, and an antenna. It consists of several units, including the receiver and antenna (units 24 and 25), Mk 16 stabilization elements (units 17 and 18), and embedded computer processors (unit 19). Aircraft tracking information (from the radar) combines with ship's stabilization data (from the Mk 16 gyros) and goes to the CCS for processing.

**SIGNIFICANT INTERFACES.**— The digital data switchboard (unit 14) provides an automatic switching interface between the master-slave computers in the central computer group (unit 12) and all external system peripherals required for PALS operation. The AN/TPX-42A(V)8 CATCC DAIR, AN/SSW-1C/D, and OA-7984(U)/UYK Input/Output (I/O) Control Console (unit 16) can all operate as the master computer of the CCS. Electrically operated switches automatically switch these equipment into a master or slave configuration in the central computer group. The AN/SPN-46(V) also interfaces with the

AN/TPX-42(V)8 system through the power distribution panel (unit 3).

Other radars, such as the AN/SPN-35, the AN/SPN-43, and the AN/SPN-44, are also used in conjunction with the precession carrier controlled approach (CCA) system for landing operations.

**AN/SPN-35.**— The AN/SPN-35 radar set provides both azimuth and elevation data for precision approaches to aircraft carriers during adverse weather conditions. Using the radar display, the operator directs pilots along a predetermined glide path and azimuth course to a point one mile from the ship.

**AN/SPN-43.**— The AN/SPN-43 is a surveillance and air traffic control radar used on carriers and amphibious-type ships. It operates in a 2-4 GHz frequency band (S-Band) and provides air navigational data for control and identification of aircraft in the area of the ship. With a range of 50 nautical miles, it tracks low-flying aircraft to a minimum of 250 yards and covers 360° at altitudes from radar horizon to 30,000 feet. The radar displays azimuth and range which the operator uses to direct control of the aircraft to the CCA transfer point. An IFF system, synchronized with the radar, provides positive identification of the aircraft.

**AN/SPN-44.**— The AN/SPN-44 is a range-rate radar set that computes, indicates, and records the speed of aircraft making a landing approach to the carrier. Both true and relative air speed are indicated. Supplied with this accurate information on the speed of the approaching aircraft, the LSO can wave off those attempting to land at an unsafe speed.

**FOR THE MAINTAINER.**— The AN/SPN-46(V) is a modernized PALS system that provides improved reliability, maintainability, and performance. It uses standard electronic modules (SEMs), an AN/USH-26 Magnetic Tape Unit (MTU) and standard computers (AN/AYK-14) to provide reliability and improved supply support.

The AN/SPN-46(V) has a self-monitor capability to prevent the transmission of erroneous control and error signals in Mode I and Mode II operation. It also displays the deck status.

The power distribution panel (unit 3) provides circuit breaker protection and acts as a junction box for all stabilization source inputs and outputs, and anemometer inputs. The PRI-FLI indicator control (unit 5) contains circuit breaker protection for PRI-FLI indicators (units 6 and 7) and a maintenance intercom for troubleshooting purposes. The recorder-converter



AUTOMATIC CARRIER LANDING SYSTEM AN/SPN-46(V) 1  
PICTORIAL FLOW DIAGRAM

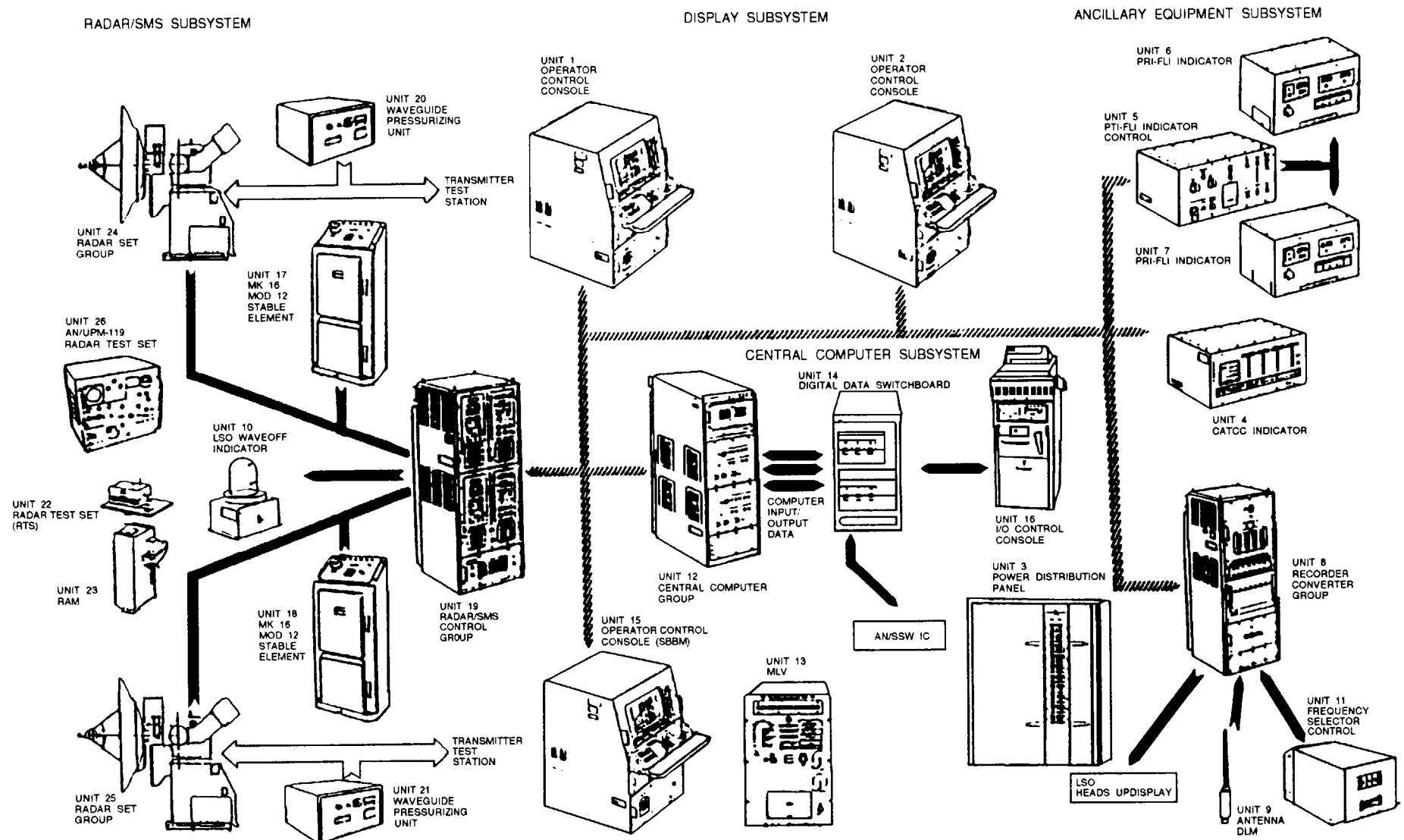


Figure 2-9.—AN/SPN-46(V)1 pictorial flow diagram.

group (unit 8) has a synchro test point panel to monitor input synchro voltages.

The OCC installed in the equipment room (unit 15) is a system/bootstrap bus monitor (SBBM) that performs on-line system testing and troubleshooting, and computer bootstrap program loading. The memory loader/verifier (MLV) (unit 13), stored in the equipment room, is used for the following purposes:

- Load and verify operational programs from cassettes
- Initiate AN/AYK-14 self-test and display results
- Load diagnostics and provide maintenance interface and control
- Write cassette memory with received data
- Display and change register and memory locations

The SPN radar test set (RTS) (unit 22) is used to align, calibrate, and maintain the radar/SMS subsystem. The retractable alignment mast (unit 23) elevates the SPN RTS and a collocated corner reflector to a minimum of 19 feet above the carrier flight deck for system calibration. The UPM radar test set (unit 26) is also used to test and calibrate the radar/SMS subsystem. This test set combines the functions of a spectrum analyzer and synchroscope to provide pulse or CW test signals and visual spectrum indication. It also has a direct reading cavity frequency meter, and a power level meter.

## **Maintenance**

Organizational maintenance is performed by ET personnel (NEC ET-1524). It consists of removal and replacement of plug-in assemblies and chassis-mounted parts. You can isolate faults using the built-in-test (BIT), built-in-test equipment (BITE), general-purpose electronics test equipment (GPETE), special-purpose test equipment (SPETE), and maintenance assist modules (MAM).

Depot level maintenance includes repair of failed printed circuit boards (PCBs) or modules and major repairs, such as overhaul, refurbishment, and calibration.

## **AN/FPN-63 PAR**

The AN/FPN-63(V) Precision Approach Radar (PAR) is used at naval air stations (NAS) and Marine Corps air stations (MCAS) for air traffic control

operations. It replaces the PAR portion of the AN/CPN-4 family of equipment. The AN/MPN-23 is a version of the same equipment mounted on a trailer.

## **General Theory of Operation**

Although the AN/FPN-63(V) is functionally and operationally similar to the PAR portion of the AN/CPN-4, it uses a modified version of the AN/CPN-4A PAR antenna system. The antenna modifications reduce signal side lobes and minimize ground and precipitation clutter. The AN/FPN-63(V) is based on solid-state circuitry and includes a digital moving target indicator (mti). The modification also includes a remote control subsystem that provides complete operational use of the PAR up to 10,000 feet from the radar van.

The solid-state AZ-EL range indicator generates its own internal map, sweeps, range marks, and cursors. A single cursor adjustment allows alignment of each cursor with the runway centerline.

Independent transmitters and receivers provide one operational channel and one "hot standby" channel. This allows the operator to use one set of equipment, while a technician performs maintenance on the other set. Thus, service is never interrupted.

## **Configuration**

A remote control turntable unit and the associated remote control panels allow positioning of the radar for multiple runway operation. Stations not requiring multiple runway operation use a fixed-mounted AN/FPN-63.

All radar components are in racks and enclosures of the radar sets, with empty spaces covered by blank front panels. The number of indicators varies by site.

## **Maintenance**

Organizational maintenance is performed by ET personnel (NEC ET-1579) and includes performance verification, testing, alignment, and fault isolation. Repair of equipment consists of the replacement of discrete chassis components and piece parts.

The prime contractor performs all depot-level maintenance. If you have any modules or PCBs that your organization cannot repair, return them to the depot facility.

## RADAR INDICATORS (REPEATERS)

The purpose of a radar indicator (repeater) is to analyze radar system echo return video and to display that information at various remote locations. For the repeater to present correct target position data, it must have three specific inputs from the radar selected: video input, trigger (timing) pulses, and antenna information.

A *video input* from the radar via a video amplifier for each returning echo enables the repeater to display detected **targets**.

*Trigger (timing) pulses* from the radar ensure that the sweep on the repeater starts from its point of origin each time the radar transmits. This allows repeaters to display the target at actual **range** from the radar based on the time lapse between the instant of transmission and the instant of target echo receipt.

*Antenna information* from the radar allows the angular sweep position of the repeater to be synchronized with the angular position of the radar antenna. This will produce and display the target at its actual **bearing** (azimuth) from the radar.

The three most common types of displays are the A scope (range-only indicator), the PPI scope (range-azimuth indicator), and the RHI scope (range-height indicator). The A scope, limited by its range-only capability, is normally considered an auxiliary display rather than a radar repeater. The PPI scope is by far the most used radar repeater.

## PLANNED POSITION INDICATOR (PPI)

The PPI is a polar-coordinate display of the surrounding area with the origin of the sweep (normally located at the center of the screen) representing your radar. The PPI uses a radial sweep pivoting about the center of the presentation, resulting in a maplike picture of the area covered by the radar beam. A relatively long-persistence screen is used so targets will remain visible until the sweep passes again.

Bearing is indicated by the target's angular position in relation to an imaginary line extending vertically from the sweep origin to the top of the scope. The top of the scope represents either true north (when the radar is operating in true bearing), or ship's head (when the radar is operating in relative bearing).

To allow a single operator to monitor several tactical data inputs from one location, many radar repeaters are being replaced with multipurpose consoles on Naval Tactical Data Systems (NTDS) equipped ships. However, radar repeaters still serve as a back-up to the

consoles used on NTDS ships and are irreplaceable on non-NTDS ships.

The most common radar indicator group used in the Navy is the AN/SPA-25G. This Radar Display and Distribution System usually includes the AN/SPA-25G Indicator, the CV-3989/SP Signal Data Converter, and the SB-4229/SP Switchboard.

## AN/SPA-25G Indicator Group

The AN/SPA-25G Indicator Group is found on 90 percent of all Navy ships. It meets the diverse mission requirements of anti-air warfare, anti-surface warfare, anti-submarine warfare, electronic warfare, strike and amphibious warfare, as well as navigation and bridge requirements such as piloting and station keeping. The AN/SPA-25G will replace the AN/SPA-4, SPA-8, SPA-25, SPA-33, SPA-34, SPA-40, SPA-41, and SPA-66. The AN/SPA-50 and SPA-74 radar display system/indicator groups are also potential candidates for replacement by the AN/SPA-25G.

The AN/SPA-25G is an advanced, solid-state (except the CRT display) radar indicator for both Combat Information Center (CIC) and bridge environments. It can receive multiple data inputs, including three radar video signals from the same radar, radar triggers, antenna synchro data, external course and speed, off-centering inputs, and dead reckoning analyzer (DRA) inputs.

The various radar inputs, except video that is in analog form, are in the Radar Display and Distribution Systems (RADDS) serial 64-bit data stream format. The data is continually processed through five megabits of digital memory. By correlating the radar data with internally generated graphic symbols, the operator can fully interact with the displayed information on the CRT. Figure 2-10, the AN/SPA-25G top panel layout, shows all of the operational controls and indicators.

Some of the significant design features of the AN/SPA-25G include:

- High Definition Raster Scan Display—enables the AN/SPA-25G to perform at maximum capacity, without a hood, in either the subdued lighting of CIC or the bright daylight on the ship's bridge.
- Flicker Reduction—provides an effective display refresh rate that suppresses flicker in any lighting environment.

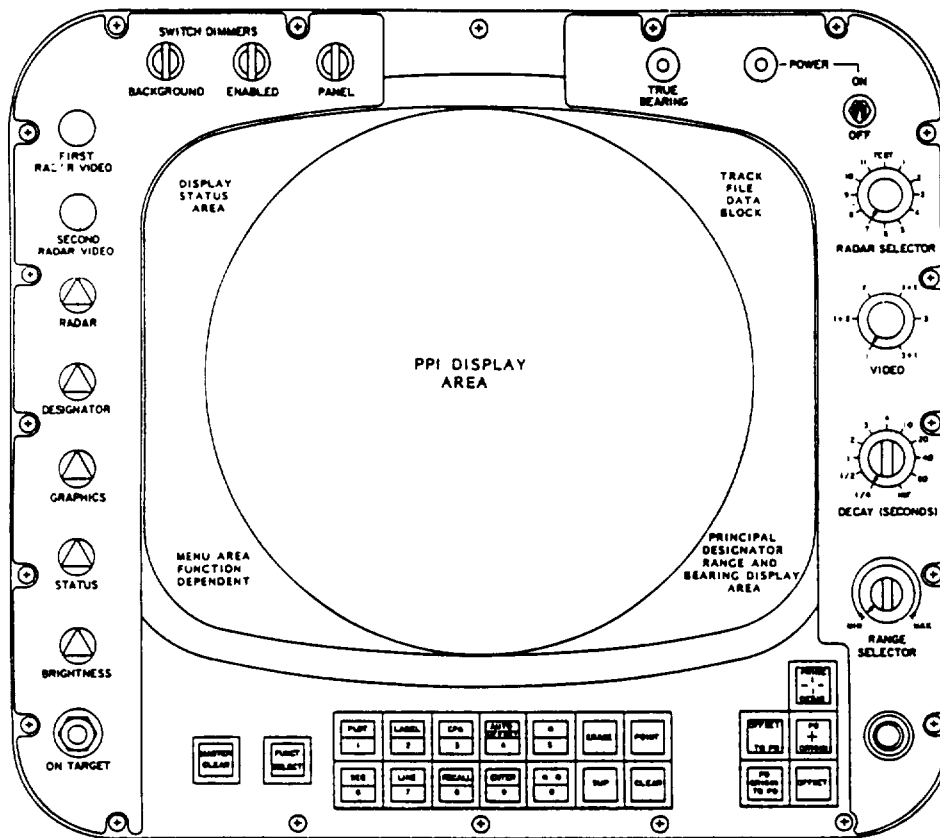


Figure 2-10.—AN/SPA-25G radar indicator, top panel controls and indicators.

- Azimuth Fill process—prevents voids, gaps, and holes in the radar video that occur when translating from rhotheta to X-Y format.

- Electronic Bearing Circle—around the perimeter of the radar video display, has bearing markers displayed every 5°, and is numerically labeled every 10°.

- Electronic Plotting Aid—provides a continuous display of ship's speed and course, offset settings, principal designator range and bearing, and BIT message.

Figure 2-11 shows the physical configuration of the AN/SPA-25G. It has the same form and fit as previous indicator group models in the AN/SPA-25 series. It will pass through a 25-inch diameter hatch without disassembly. If a tilted panel or sit-down console is required, a 60° insert section and an attachable front shelf are available (fig. 2-12).

The AN/SPA-25G has unlimited operational capabilities, since it will interface with any Navy conventional search radar system. The CV-3989/SP

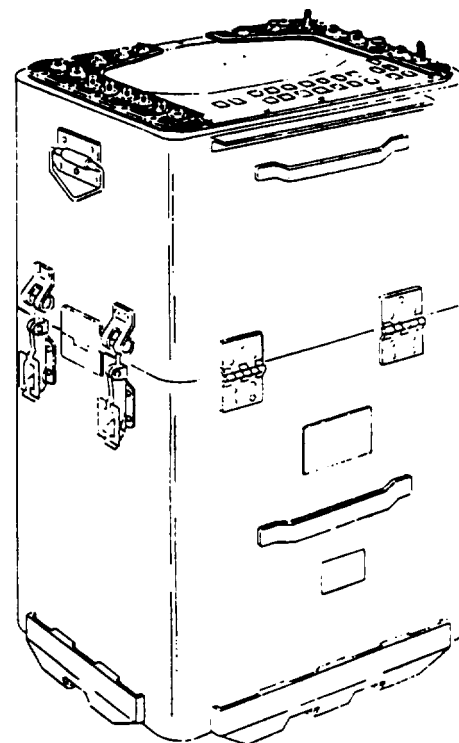


Figure 2-11.—AN/SPA-25G stand-up configuration.

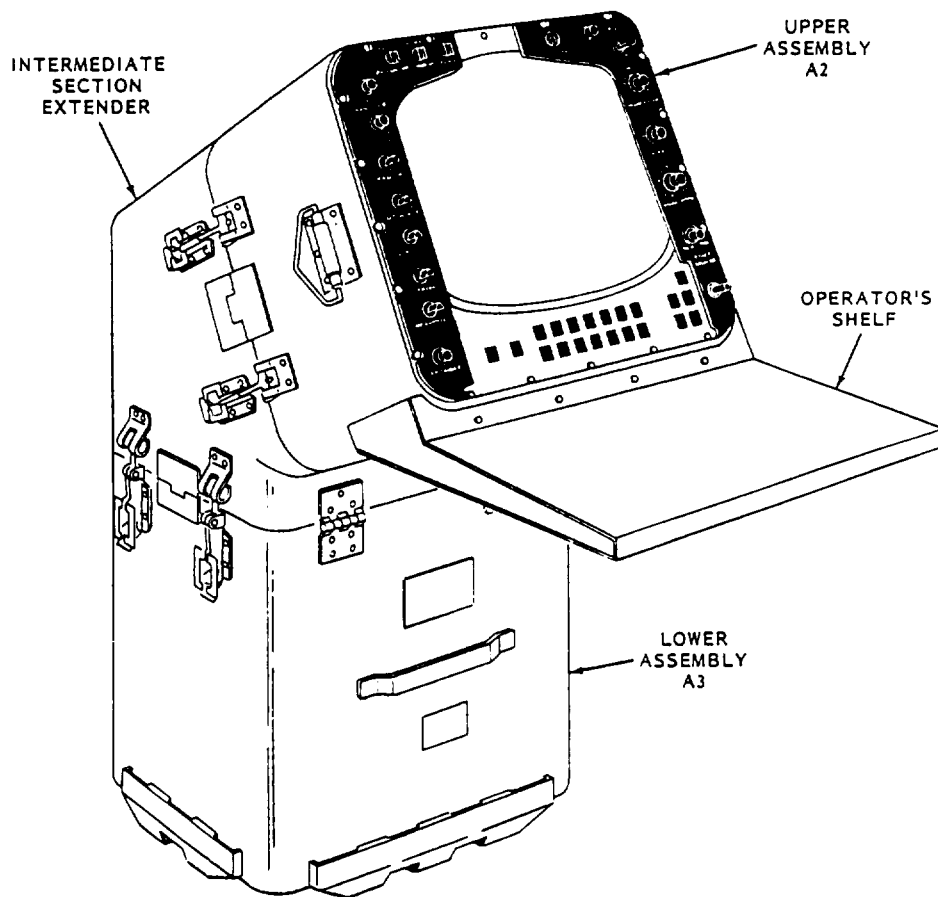


Figure 2-12.—AN/SPA-25G with insert section.

Signal Data Converter provides the primary interface between conventional equipment by multiplexing analog information into a single digital data stream for use by the AN/SPA-25G.

The AN/SPA-25G allows the maintainer to localize faults quickly by using built-in-test (BIT) and test messages for circuit and module checkout.

#### CV-3989/SP Signal Data Converter

The Signal Data Converter CV-3989/SP (SDC), shown in figure 2-13, is designed for installation inside the shipboard radar room. It is mated to the radar (triggers), antenna azimuth, ship's gyro-heading, and ship's speed or distance (ship's pit log).

The SDC conditions and multiplexes the various data inputs into a single digital data (RADDs) stream. This permits a single cable to distribute RADDs stream data throughout the ship. Previous distribution of radar and navigation data required multiple cables. The SDC accepts radar and navigation inputs and converts them into five independent serial digital data (RADDs stream) outputs. Over a single coaxial cable, the following data is provided by the SDC RADDs data stream:

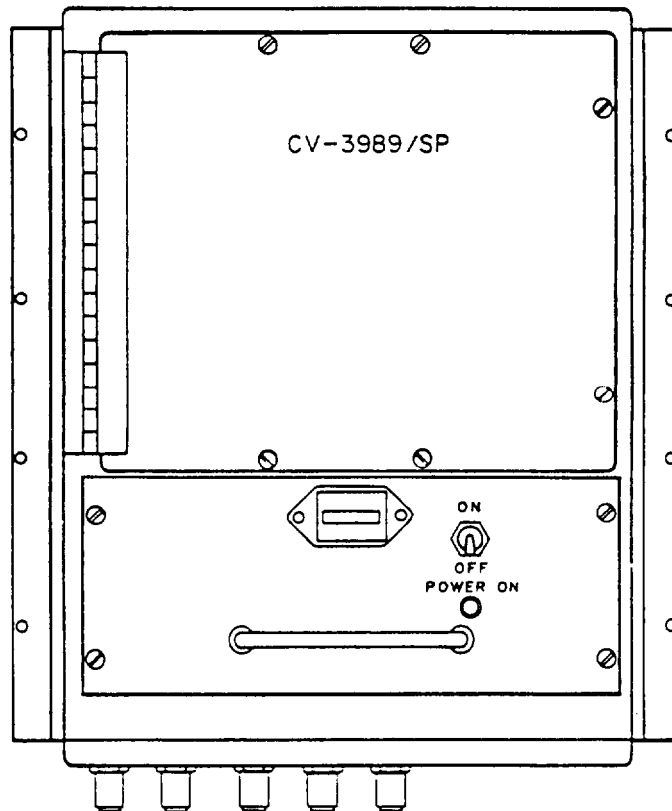


Figure 2-13.—Signal Data Converter, CV-3989/SP.

- Radar trigger(s)
- Radar antenna azimuth (stabilized and unstabilized)
- Dead reckoning information
- Ship's heading
- Radar set sensor ID

The SDC also contains the necessary circuitry for future growth and expanded use in data distribution. A compatible switchboard is required to interface the data from various radar sets with other systems.

### SB-4229/SP Switchboard

The SB-4229/SP switchboard, shown in figure 2-14, replaces all SB-440, SB-1109, and SB-1505 switchboards. It provides selectable distribution of data from any Navy conventional search radar set. The CPU-controlled switchboard can accept signals from 16 radar sets and five IFF interrogator sets, then distribute them to nine individual radar indicators and nine IFF decoders. It can also accept mode control from any IFF decoder associated with any of the radar indicators and switch the mode control of the IFF interrogator associated with the radar set being viewed on that indicator. This process is explained in more detail in chapter 3.

The SB-4229/SP switchboard allows radar and IFF signals from ship's radar and RADDs data stream inputs to be selected from up to 16 signal data converters. It provides up to nine selectable outputs to the AN/SPA series radar indicators. So, up to nine different operators can select one of 16 input sensors to display at their indicator. Each of the 16 input sensors can consist of three radar videos, RADDs data stream, and IFF control with its associated videos. The more significant design features include:

- Local or remote selection of input sensors
- Conversion of RADDs data stream back to analog (for older indicators)
- Distribution of any of the 16 input sensors to any of up to nine separate radar indicators
- Detection of improper operation by self-test (BIT)

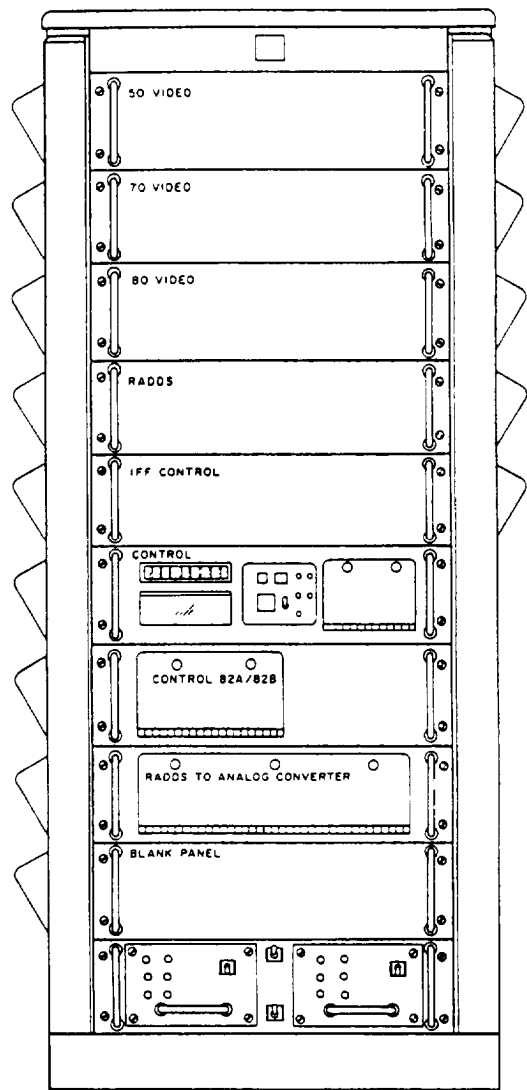


Figure 2-14.—Radar Distribution switchboard, SB4229/SP.

### Maintenance

The maintenance of the AN/SPA-25G, CV-3989/SP, and the SB-4229/SP is performed by the Electronics Technician (ET) assigned maintenance responsibilities for the surface search radar or conventional radar display and distribution systems.

Organizational maintenance consists of corrective and preventive maintenance actions. Preventive maintenance is performed according to the maintenance requirement cards (MRCs).

Shipboard personnel perform corrective maintenance according to the corrective maintenance sections of the applicable technical manuals and as reflected by the maintenance code assigned in the equipment APL. CM may require (1) removal or replacement of cabinet mounted piece parts, (2)

replacement of components, assemblies, or sub-assemblies, or (3) repair of certain units, assemblies or sub-assemblies designated as "shipboard repairable." It may then require "turn in" of depot repairable assemblies or sub-assemblies through prescribed supply procedures.

All replaceable modules, assemblies or printed circuit boards with a replacement value of \$500 or more (except the CRT and high-voltage power supplies) are designed and constructed to be repairable by component replacement at the depot maintenance level.

### RANGE-HEIGHT INDICATOR (RHI)

The range-height indicator (RHI) scopes used with height-finding radars obtain and display altitude information. The RHI is a two-dimensional presentation showing target range and altitude. An example of a RHI presentation is shown in figure 2-15.

The sweep of a RHI starts in the lower left side of the scope and moves across the scope to the right at an angle that is the same as the angle of transmission of the height-finding radar. The line of sight to the horizon is indicated by the bottom horizontal line. The point

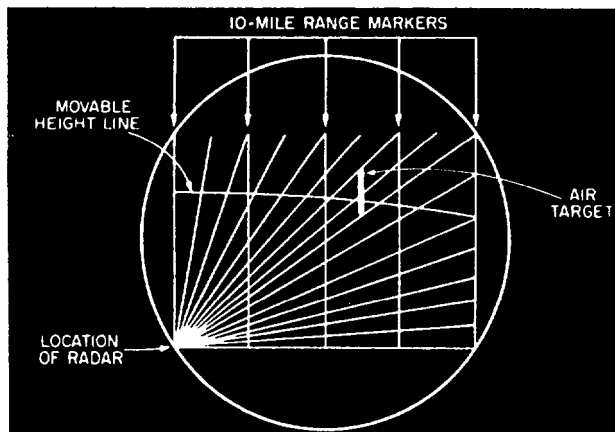
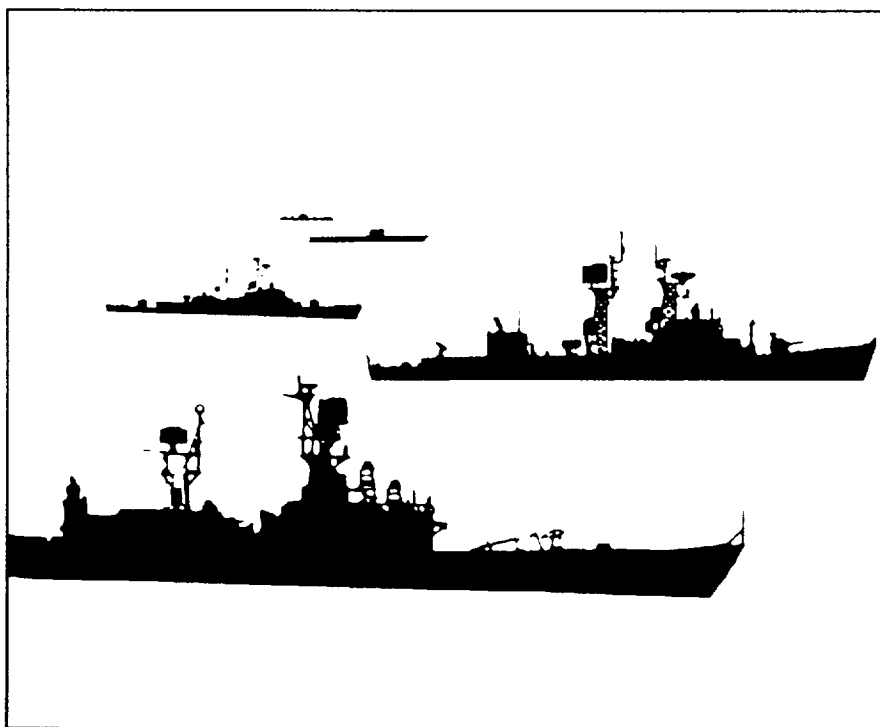


Figure 2-15.—RHI presentation.

directly overhead in the sky (the zenith) is straight up the left side of the scope. Targets are displayed as vertical blips. Vertical range markers are provided to estimate target range.

The operator determines altitude by adjusting the moveable height line to the point where it bisects the center of the target blip. Target height is then read directly from altitude dials (counters).



## SUMMARY

In chapter 1, you reviewed the basics of the theory of radar operation. In this chapter, you learned some basics about specific equipment used in the fleet.

You now know which missions, on what types of ships, are supported by surface search and navigation radars, such as the AN/SPS-67(V), the AN/SPS-64(V)9, and the AN/SPS-55. You are aware of some of the special operating, maintenance, and safety features of these radars. You can identify, during troubleshooting, which systems they interface with.

You learned the same types of things about the 2D air search radars used by the Navy, such as the AN/SPS-49(V), the AN/SPS-40B/C/D/E, and the AN/SPS-65(V) aboard ships and the AN/GPN-27 (ASR) at shore installations. These are air search radars that you will maintain.

Although the FCs will usually maintain the 3D radars aboard your ship, you must understand how they operate in the scheme of the overall radar mission.

Knowledge of carrier controlled approach and ground controlled approach radar systems such as the AN/SPN-46(V) and the AN/FPN-63 is essential in the high-tech warfare we use today. Successful air strikes and air cover are the key to any military victory.

Multipurpose consoles are replacing many of the radar repeaters on Naval Tactical Data Systems (NTDS) equipped ships. But, radar repeaters still serve as a back-up to the consoles used on NTDS ships and are

irreplaceable on non-NTDS ships. So, it is still necessary that you know radar information is provided by displays such as radar indicators. The A scope (range-only indicator) is used primarily by the maintenance personnel to evaluate the operation of the radar. The PPI scope (range-azimuth indicator) is the most common usually consisting of a Radar Display and Distribution System, including the AN/SPA-25G Indicator, the CV-3989/SP Signal Data Converter, and the SB-4229/SP switchboard. The RHI scope (range-height indicator) is used with height-finding radars to obtain and display altitude information.

The *Handbook for Shipboard Surveillance Radars*, NAVSEA SE 200-AA-HBK-010, provides information on radar fundamentals and “rules of thumb” to the level that will allow you to interpret technical specifications and performance statements with respect to radar performance requirements. This is a good publication to review if you want to make a suggestion for improvement or modification to a radar system. This handbook provides technical support and back-up data for shipboard radar systems engineers. However, it also provides fundamental and descriptive information for Navy radar users, including radar principles and shipboard surveillance radar characteristics.

In chapter 3, we will discuss some of the systems that use radar information. We'll discuss the equipment involved with IFF and DAIR, and also look at some of the unique maintenance concepts of the Navy Tactical Data System (NTDS).



## CHAPTER 3

# RADAR SYSTEM INTERFACING

In the previous chapters, we discussed a basic pulse radar system, basic types of radar sets and specific radar equipment used in the fleet. Most every radar we've mentioned can interface with other systems. In this chapter we'll look at some of the systems that use that radar information, such as Identification Friend or Foe (IFF) systems, Direct Altitude and Identity Readout (DAIR) systems, and Navy Tactical Data Systems (NTDS). We will not teach you specific equipment, but *will* help you identify and understand the interface of radar information with the various systems used in the Navy today.

Most of the equipment discussed in this chapter has specific maintenance training available. However, except for certain crypto equipment, you do not need *specific* training to work on the gear. Remember, as an ET, you can become an expert maintainer of ANY electronic equipment.

The first system we'll talk about is Identification Friend or Foe (IFF) equipment, specifically, the AIMS Mark XII IFF system, used by aircraft and surface vessels.

### IDENTIFICATION FRIEND OR FOE (IFF) SYSTEMS

IFF equipment, used with search radars, permits automatic identification of targets before they are near enough to threaten the security of a friendly craft. In addition to friendly identification, modern IFF systems also provide other information such as type of craft, squadron, side number, mission, and aircraft altitude.

#### GENERAL THEORY OF OPERATION

IFF completes the identification process in three basic steps: (1) challenge, (2) reply, and (3) recognition.

#### Challenge

The IFF interrogator sends a coded *challenge* in the form of pulse pairs. The selected mode of operation determines the spacing between the pulses.

#### Reply

A friendly target's IFF transponder will automatically *reply* to the coded challenge with an omnidirectional transmission. It sends a different set of pulses at a slightly different frequency than the interrogator frequency. A suppression (blanking) signal keeps your ship's transponder from replying to its own interrogator.

#### Recognition

The IFF interrogator receives the coded reply and processes it for display on an indicator. *Recognition* of the target is based on the ppi display. The coded reply from a friendly craft normally appears as a dashed line just beyond the target blip, as shown in figure 3-1.

The identification process uses two sets of IFF equipment, the interrogator set and the transponder set. A ship may have one or more interrogator sets, but will have only one transponder set. Normally, interrogators and transponders aboard ships function independently.

#### Interrogator

The IFF interrogator operates like a radar transmitter and receiver. It uses a small directional antenna either attached to or rotated in synchronization with the air search radar antenna. The modulator of the search radar set provides synchronization triggers for the IFF interrogator.

When processing replies for display, the IFF interrogator uses the time lapse between the transmission of a challenge and the reception of a reply to determine range. The synchronized antenna information provides the correct bearing.

A high output power is not required for the one-way trip to the target taken by the transmitted pulses, so the IFF interrogator can operate at low peak power (1 to 2 kilowatts).

#### Transponder

The IFF transponder is a receiver-transmitter combination that automatically replies to a coded

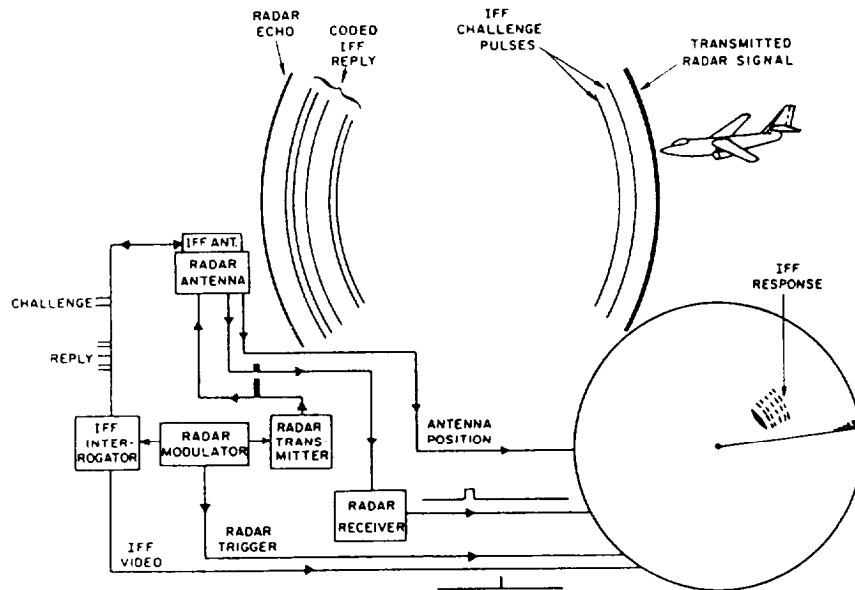


Figure 3-1.—Fundamentals of IFF operation.

challenge. The receiver section receives and amplifies signals within its bandpass and decodes the challenge signals. Reception of correctly coded challenge signals will automatically key the transmitter section to send prearranged reply signals on a different frequency.

In times of hostility, safe or unsafe transit through a particular area could depend on how well your IFF is operating. It's not very safe to approach another ship in a hostile area without being able to identify yourself as a friendly target. Also, being without an IFF that can identify the targets on your radar screen puts your Tactical Action Officer (TAO) at a disadvantage. Therefore, your understanding of IFF operation and maintenance is extremely important.

### AIMS MARK XII IFF SYSTEM

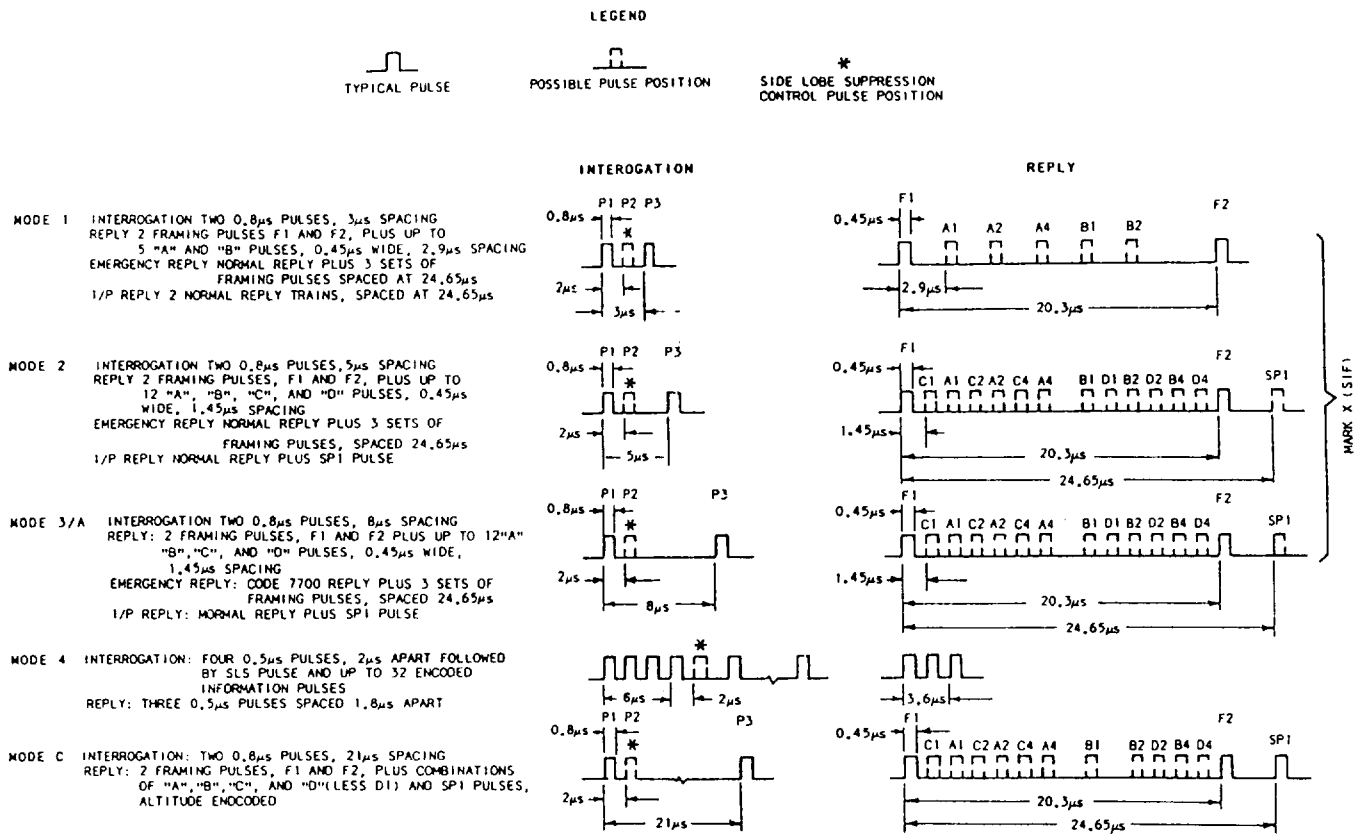
AIMS is an acronym for an *air traffic control radar beacon system (ATCRBS), identification friend or foe (IFF), Mark XII system*. ATCRBS designates the civilian air traffic control system used for air control worldwide. IFF identifies military systems. The AIMS system includes equipment such as interrogators, transponders, decoders, interrogator side lobe suppression (ISLS) switches and drivers, defruiters, and crypt computers.

### Modes of Operation

The Mark XII system can challenge in five different modes (1, 2, 3/A, 4, and C), each with a specific function. The video decoder unit, associated with a specific indicator, provides control signals that the interrogator uses to send challenges and decode replies in the various modes. As we mentioned in chapter 2, when the operator has multi-radar inputs available, the radar distribution switchboard routes the control signals to the correct interrogator unit.

**SIF MODES.**— Air traffic control and code monitoring for friendly aircraft and surface craft use selective identification feature (SIF) modes (modes 1, 2, and 3/A). Challenges in these modes consist of two pulses spaced at a characteristic interval for each pulse, with a third pulse added for ISLS operation, as shown in figure 3-2.

For SIF modes, the transponder reply is a binary code contained between two bracket (framing) pulses. Framing pulses are present in every reply, regardless of code content. Each reply code corresponds to a unique 4-digit decimal code. For each mode, the user dials the desired reply code into the transponder using thumbwheel switches. Mode 1, 2, 3/A, and C replies, by themselves, cannot be separated according to mode. The interrogator, knowing in which mode it has challenged, separates and identifies the replies with the proper mode.



**Figure 3-2.—AIMS Mark XII IFF interrogations and replies.**

When desired, a transponder may send an identification of position (I/P) reply to mode 1, 2, or 3/A interrogations. This reply, when decoded, marks on the indicator a particular aircraft with which the system operator has voice communications.

A pilotless aircraft containing a transponder transmits an X-pulse reply when responding to SIF mode interrogations. This is a normal mode reply with an additional pulse occupying the center position of the reply train.

**Mode 1.**— Mode 1 operation, set at the control box C-6280, is for military use only. The first digit of the reply code must be a number from 0 to 7. The second digit must be a number from 0 to 3. The remaining two digits will normally be 0. Military emergency replies (called 4X or four train emergencies) include the normal reply plus 3 sets of framing pulses for both modes 1 and 2.

**Mode 2.**— Mode 2 operation, set in at the transponder unit, is also for military use only. In mode 2 and 3/A reply codes, each of the four reply digits can have any value from 0 to 7.

**Mode 3/A.**— Mode 3/A operation, also set at the control box, is available for military or civilian use. Mode 3/A military emergency replies consist of a combination of 4X and 7700 codes. Civilian emergency replies use just the 7700 code. A 7600 reply code, for both military and civilian use, indicates a failure in radio communications. A 7777 reply code is assigned to interceptors on active air defense missions. Any transponder sending replies to mode 3/A with codes of 7500, 7600, 7700, or 7777 will trigger an alarm at nearby FAA towers.

The FAA's nationwide computer network tracks all assigned mode 3/A codes. The Department of Defense is assigned four mode 3/A code blocks (50XX, 54XX, 61XX, 64XX) for use within U.S. national air space.

A conflicting signal from your ship could cause havoc for both local and national air control functions. The mode 3/A code assigned to your unit during an operation is probably not a code authorized for military use in national airspace. It may even be the same as one assigned to a commercial flight. To avoid problems with air control, keep mode 3/A off the air when your ship is in port or coastal waters.

**MODE 4.**— Mode 4 operation is for military use only and allows for secure identification of friendly aircraft and surface vessels. IFF automatically generates a reply code according to a preset crypto key list. As shown in figure 3-2, mode 4 interrogations use encoded, multipulse trains with 4 (sync) pulses and an ISLS pulse, followed by up to 32 information pulses.

When the transponder receives and processes a valid mode 4 interrogation, it sends out a time-coded, three-pulse reply. The interrogator converts the valid mode 4 reply back to one pulse. The reply is then time decoded before it is presented on the indicator. There are no emergency replies for mode 4 or mode C.

**MODE C.**— Mode C replies used by civilian and military aircraft indicate aircraft altitude and are taken automatically from the aircraft's barometric altimeter. Mode C interrogations are the same as those for SIF modes. Replies are binary codes contained between bracket pulses similar to those for SIF modes.

The reply, derived from an encoder linked to the aircraft altimeter, may represent any altitude from -1,000 feet to +126,700 feet in 100-foot increments. Shipboard transponders are wired to reply to mode C interrogations with bracket pulses only (code 0000).

Commercial aviation has implemented the Traffic Alert and Collision Avoidance System (TCAS), which uses a low-power mode C interrogator-processor. Using mode C altitude reports, it computes the closest point of approach (CPA) to other aircraft and displays the information as an overlay on the weather radar indicator. General aviation aircraft flying below 12,500 feet reply to mode C with empty brackets (code 0000), the same code used by Navy ships.

TCAS cannot distinguish between replies sent by your ship and those sent by small aircraft. It assumes that a mode C target is at the same altitude as itself if no altitude is reported. Therefore, your ship's mode C reply can set off a projected collision alarm in the cockpit of an arriving or departing airliner, causing the pilot to make unnecessary and dangerous maneuvers. Since this situation is a great threat to air safety, your transponder's mode C should always be secured in or near port, unless you are testing the unit, with the antenna disconnected.

**Equipment Components**

As we mentioned earlier, the interrogator and transponder sections of the AIMS Mark XII IFF operate independently of each other. In the following

paragraphs, we'll discuss each section, beginning with the interrogator section.

**INTERROGATOR SECTION.**—The major units of the interrogator section (except the video decoder group) are usually mounted in a rack located in the radar equipment room, as shown in figure 3-3.

A simplified block diagram of the interrogator section is shown in figure 3-4. The **Interrogator Set AN/UPX-23**, provides rf challenges for the various modes. It also receives transponder replies and processes them into proper video signals for application to the decoders and indicators.

The **pulse generator** provides IFF system pretriggers that initiate challenges for the enabled modes. In a "slaved IFF system," associated with a specific radar, the pulse generator synchronizes the interrogations with the radar. In a "black IFF system," not associated with a radar, it produces triggers internally.

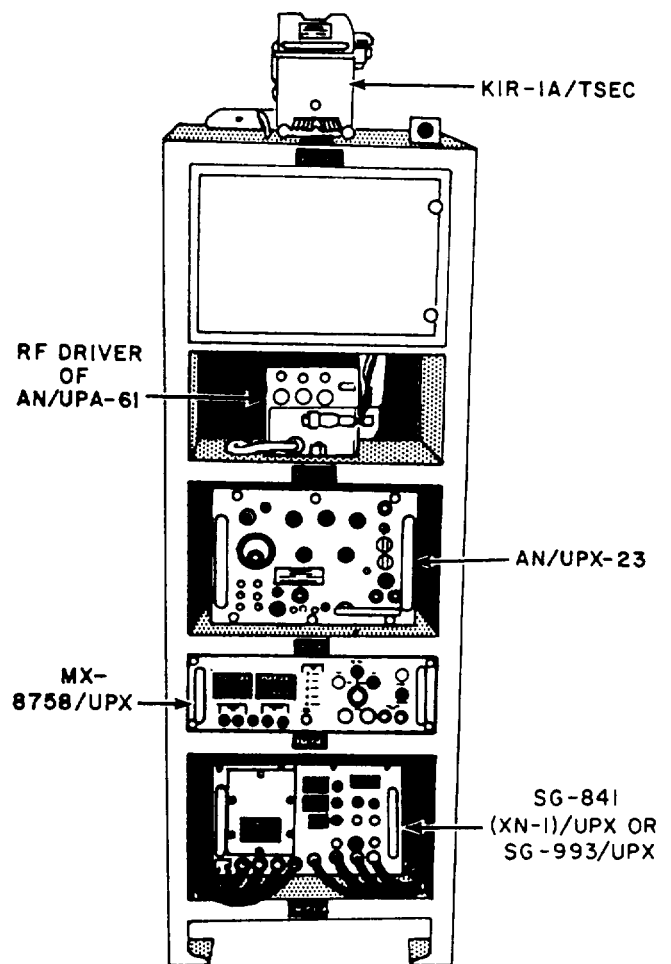


Figure 3-3.—Mark XII IFF interrogator equipment.

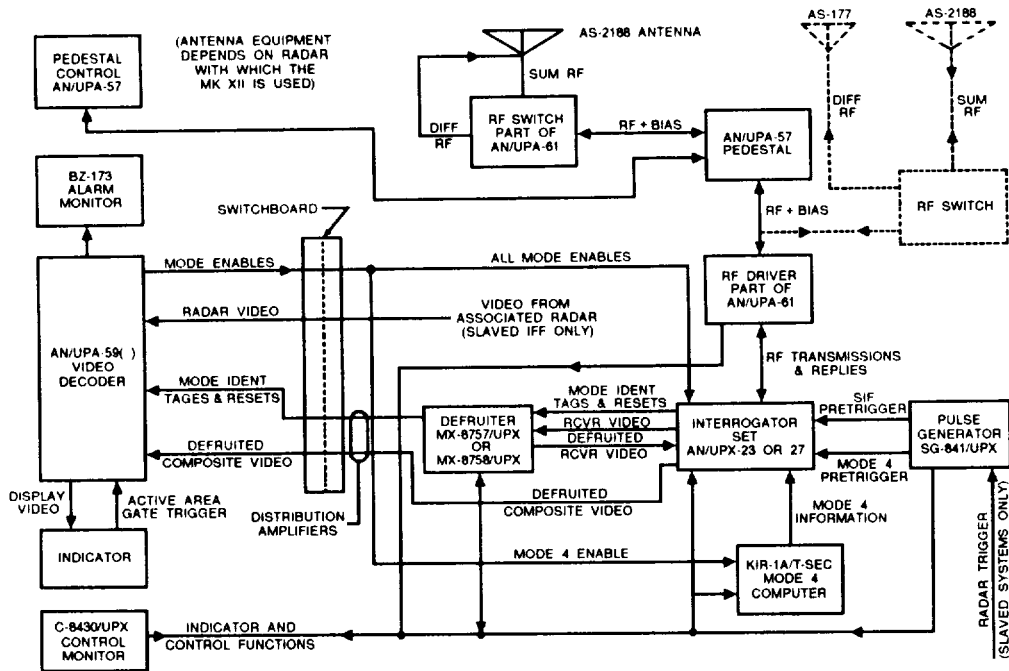


Figure 3-4.—Mark XII IFF system interrogator station.

The **Computer, KIR-1A/TSEC**, encodes mode 4 challenges for transmission by the interrogator. It also decodes the received mode 4 transponder replies. The code changer key, TSEC/KIK-18, inserts the mode 4 code into the computer.

The **Video Decoder, AN/UPA-590**, has various configurations. The most common configuration uses a video decoder, an intra-target data indicator, and an alarm monitor.

The *video decoder* provides control signals that the interrogator uses to display challenges in the various modes. It also decodes and processes reply video (mode 4 video goes directly through without processing) and provides video output to the indicator. The video decoder will accept radar video from an associated radar and route it, with or without IFF video, to the indicator for display. An *intratarget data indicator* plugs into a receptacle in the decoder's front panel. It provides readouts of reply codes for modes 1, 2, and 3/A and direct altitude readouts for mode C. The *alarm monitor* contains a loud speaker and indicator lights to provide audible and visual alarms when IFF emergency signals are decoded.

The **defruiter** can be one of two types of interference blankers. The MX-8757/UPX is a four-channel type, using one channel per mode for modes 1, 2, 3/A, and C. The MX-8758/UPX is a one-channel type, using one channel for all modes.

Both units remove nonsynchronous transponder replies (fruit) and receiver noise from IFF video.

The **control monitor** functions as a remote control and remote monitor for the interrogator section. The front panel of the control monitor is shown in figure 3-5.

The **Switch and Driver, AN/UPA-61**, provides ISLS operation for the Mark XII system. Targets at close range may reply to side and back lobes, as well as to the main antenna beam. This could cause a target to appear for nearly 360 degrees close to the origin of the display, a phenomenon known as "ring-around." ISLS prevents ring-around by inhibiting transponder replies to side lobes.

The **Antenna Pedestal Group, AN/UPA-57**, can operate in any of three modes: slaved to a radar system, self-synchronous, or manually. It consists of a manual pedestal control unit, a control power supply unit, an antenna pedestal assembly, and a pedestal disconnect mast switch.

The *manual pedestal control* is usually located at the ppi. The front panel controls allow the selection of free run, slave, or manual operation. The *control power supply unit*, located below decks, develops all power required for the antenna pedestal group. In the free run operation mode, the power supply unit can rotate the pedestal assembly at up to 15 rpm. When slaved to a

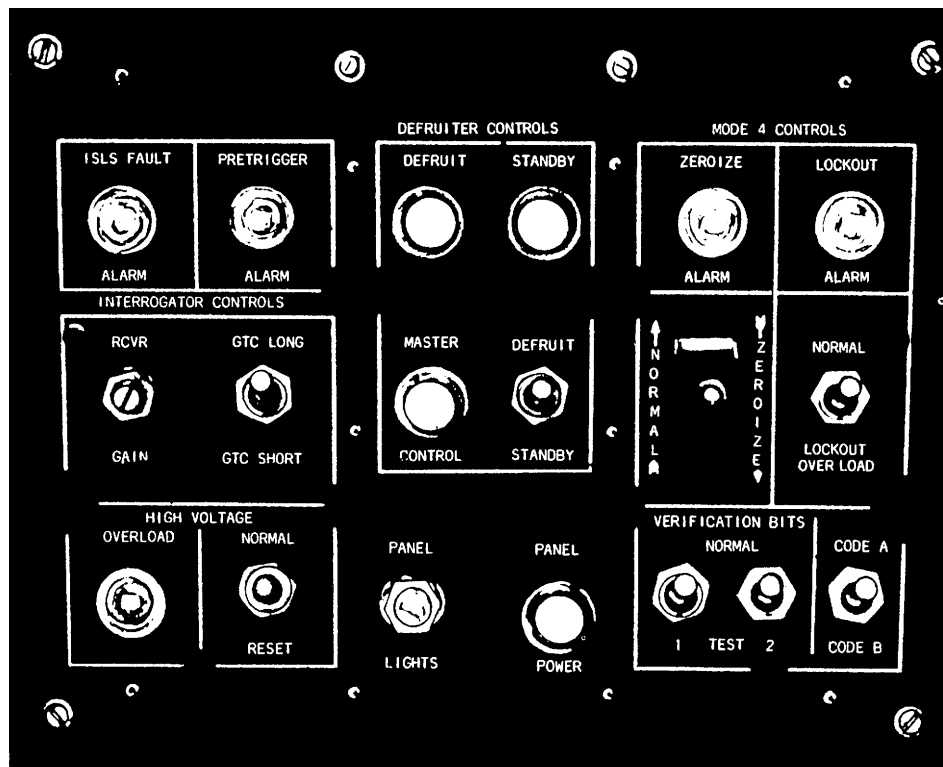


Figure 3-5.—Control monitor front panel.

radar, it can accommodate rotation rates from 2 to 30 rpm, receiving radar synchro information via the radar switchboard. In the manual mode, it can position the antenna to any azimuth directed from a remote position. The *antenna pedestal assembly* can mount the AS-2188( )/UPX or any other 10-foot antenna designed to mount on the same platform. The *pedestal disconnect mast switch*, located above decks, removes all power from the pedestal assembly.

The selection of system antenna equipment depends on which radar is using the Mark XII system. For installations where the rotary joint will not pass the switching bias, the AS-2188( )/UPX will transmit a sum pattern only, with a separate AS-177( )/UPX omnidirectional antenna transmitting the difference rf. Some installations use an integral antenna to transmit and receive both radar and IFF signals, with difference rf transmitted on a separate AS-177( )/UPX antenna.

**TRANSPONDER SECTION.**—The transponder receives interrogation pulses and, in turn, generates the proper reply pulses. A simplified block diagram of a typical shipboard transponder section is shown in figure 3-6. As we discussed before, desired reply codes are set by thumbwheel switches for modes 1, 2, and 3/A; ships are wired for code 0000 mode C replies. Mode 4 replies are coded automatically according to the crypto key installed in the TSEC/KIT-1A.

The organizational-level maintenance of the Mark XII IFF system is performed by ETs (NEC ET-1572). You must have formal training or written permission from your commanding officer to work on the TSEC/KIR-1, TSEC/KIT-1, or TSEC/KIK-18 crypto units.

The *AIMS Newsletter*, published by Naval Electronic Systems Engineering Activity (NESEA) St. Inigoes, Maryland, provides information to shipboard technicians and operators on AIMS systems, primarily Mk XII IFF and its related subsystems. It keeps you up to date on any equipment modifications, PMS changes, and significant interface problems. It also gives you an AIMS hotline number to use if you have any questions or problems concerning maintenance or operation of Mk XII IFF equipment. You can find more information on this publication in ET, Volume 2, *Administration*.

Agreements between the Navy, Air Force, and FAA, under the AIMS program, required the development of a system to present ATRCBS data instantly, in symbolic and numeric form, directly on the indicator, and superimposed over live radar video. The AIMS Mark XII IFF system does this for ships. Under the AIMS

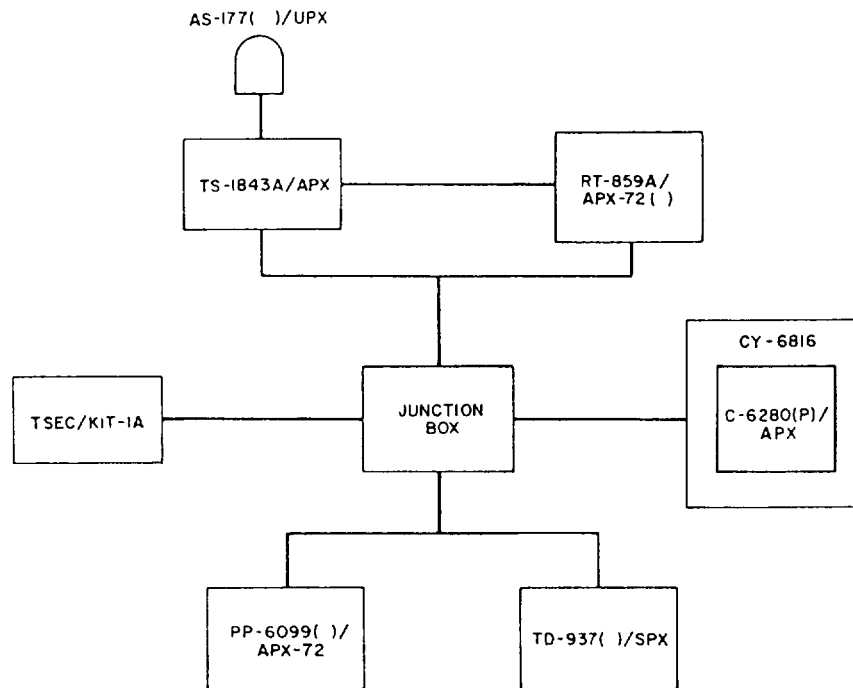


Figure 3-6.—Typical shipboard Mark XII transponder section.

program, the Navy, Air Force, and FAA further agreed on specifications for a ground/shore-based configuration called the DAIR system.

### DIRECT ALTITUDE AND IDENTITY READOUT (DAIR) SYSTEM

The DAIR air traffic control system provides several different types of configurations for different user requirements. They are as follows:

- Type 5, DAIR
- Type 10, Radar Air Traffic Control Facility (RATCF) DAIR
- Type 8, Carrier Air Traffic Control Center (CATCC) DAIR
- Type 12, Amphibious Air Traffic Control (AATC) DAIR
- Type 13, Shipboard DAIR.

The Navy Training Plan (NTP) for the Type 13 system is currently being reviewed for approval. This shipboard DAIR system is scheduled to replace all Type 8 and Type 12 systems in the fleet; however, there is currently no confirmed time for the conversions. We will include the specifics of this system in the first revision of this volume after the NTP is approved and

an installation schedule is set. In the meantime, if you would like to find out more about the Type 13 system, contact the instructors who teach the DAIR systems at the Naval Air Technical Training Center, NAS Memphis, Millington, TN.

All the types of DAIR systems use an operator (or a team of operators) to control air traffic via display devices. Each operator gathers and assembles information by monitoring and operating display devices. The operators use this information to control air traffic within a given area.

### DAIR (AN/TPX-42A(V)5)

AN/TPX-42A(V)5 gives the air traffic controller rapid, positive identification and altitude data on transponder-equipped aircraft. It is used for ground-controlled approach at shore installations, such as Naval and Marine Corps air stations (NAS, MCAS), radar operational facilities (ROF), and radar air traffic control facilities (RATCF). At expeditory airfields, the AN/TPX-42(V)5, in a transportable shelter with ASR, is used by Marine Air Traffic Control Squadrons (MATCS). This system operates with a primary radar. The radar supplies synchronizing triggers and azimuth data to the system. The DAIR information is superimposed on the primary radar video.

All the equipment for the DAIR system, except antennas, is installed in remote shelters, vans, control rooms, and equipment buildings. Depending on the requirements of the site, a variety of configurations could be used.

### **RATCF DAIR (AN/TPX-42A(V)10)**

RATCF DAIR is used at major shore installations to increase the capability of the AN/TPX-42A(V)5 interrogator system. This programmable system retains all the features of the DAIR system and modifies the signal-processing chain. The use of computer-processed data increases controller efficiency and traffic handling capability. Some of the RATCF DAIR new capabilities include:

- Automatic tracking of emergency targets
- Audible and visual alarm when an aircraft descends below a preselected minimum altitude
- Altitude monitoring with an alarm when targets stray 300 feet from controller-assigned altitude
- Semi-automatic handoff and exchange of flight data between operators and facilities

RATCF DAIR offers an expanded display and aircraft tracking capability and impacts other radar systems in the same way as DAIR. The RATCF DAIR interfaces with FAA enroute centers, ARTS facilities, Air Force PIDP facilities, and other RATCF DAIR facilities.

### **CATCC DAIR (AN/TPX-42A(V)8)**

The AN/TPX-42A(V)8 is designed for air traffic control aboard aircraft carriers. Its radius of coverage can extend to 200 nautical miles, although air traffic controllers are responsible only out to 50 nautical miles. Controllers cover their area of responsibility using the alphanumeric display of flight identity, altitude, and other pertinent information provided by this system and superimposed over primary radar video.

The CATCC DAIR system accepts trigger and azimuth data from several shipboard radars. It also accepts ship's data such as speed, heading, position, clock time, and barometric pressure and displays them in a tabular list on the controller's indicator. The system automatically computes the final bearing and displays it as a vector on the indicators.

A controller can put flight information into the system, via a keyboard, up to 24 hours before aircraft take-off or recovery. The system automatically tracks

aircraft (using beacon response), matching each aircraft with the proper identification data from the flight data tabular list. As each aircraft leaves the controller's area of responsibility, its track is passed to another CATCC control position, CIC, or ACLS/PALS as appropriate.

Some of the significant operating capabilities of the CATCC DAIR system include:

- Automatic tracking and alphanumeric identity of selected aircraft by aircraft side numbers
- Independent radar selection by position
- The ability to accept NTDS map or to draw anew or modified map from a keyboard
- Independent maintenance modes for displays with computer-driven maintenance patterns
- Built-in Test Equipment (BITE) with computer-assisted diagnostics

Figure 3-7 shows a typical CATCC DAIR system interface diagram. CATCC DAIR interfaces with many systems including:

- NTDS
- Keypad Central Multiplexer (KCMX)
- ACLS/PALS
- IFF
- RD-379 recorders
- Radar switchboards

CATCC DAIR equipment is installed in the CY-7567 electrical cabinet and the MT-4939 and MT-4940 electrical equipment racks located in the auxiliary radar room. The CATCC operations room has 5 indicator-control groups and 5 keyboard controllers, including the emergency IFF/radar switch.

### **AATC DAIR (AN/TPX-42A(V)12)**

The AATC DAIR system is designed for air traffic control aboard LHA, LPH, and LHD amphibious ships. Display capabilities are similar to those of CATCC DAIR, but new equipment and software programs provide capabilities needed for amphibious operations. The controller is provided the identity, altitude, and status of IFF-equipped aircraft within the amphibious objective area (AOA). Information such as Air Plan Lists and ship's data are also available for display on the controller's console. AATC DAIR uses the IFF beacon as a primary means of target detection and tracking, but



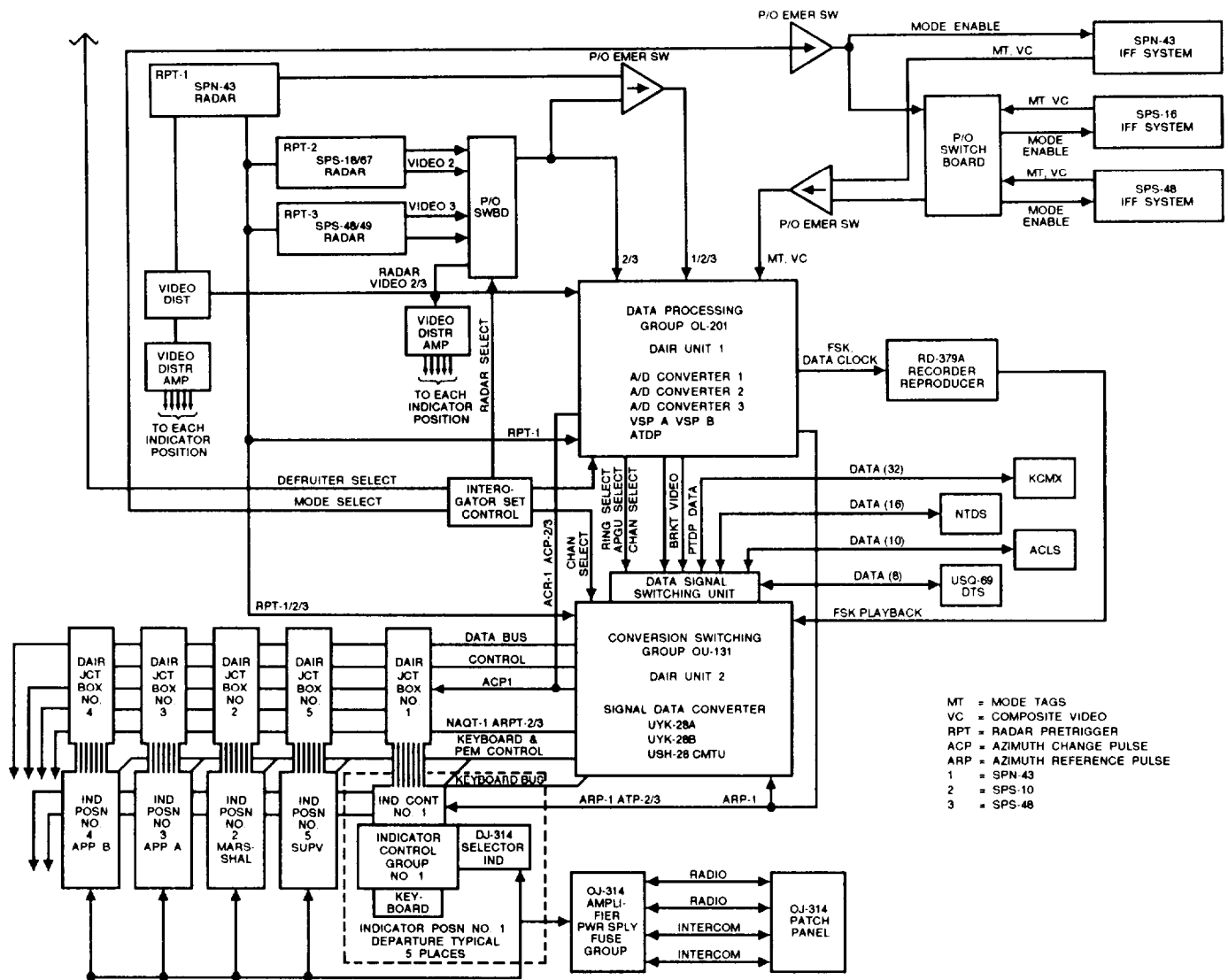


Figure 3-7.—CATCC DAIR system interlace block diagram.

also incorporates primary radar track processing as a backup.

The AN/TPX-42A(V) 12 does not replace any existing system. On amphibious-type ships, 4 indicator control groups (consoles) are located in the Helicopter Direction Center (HDC). Additional consoles are located in the Tactical Air Control Center (TACC) on LHA- and LHD-type ships. To accommodate the installation, some existing consoles may be removed from these locations, but no system is replaced. Field change kits will update currently installed CATCC DAIR systems on CV- and CVN-type ships to the (V)12 configuration.

The AATC DAIR interfaces with the same systems as CATCC DAIR, with the following additional interface capabilities:

- Integrated Tactical Amphibious Warfare Data System (ITAWDS)
- Shipboard Data Multiplex System (SDMS)

### MAINTENANCE

The organizational maintenance for the DAIR systems is done by ETs (NEC ET-1574 for DAIR, ET-1576 for CATCC DAIR, ET-1576 with 2 weeks of difference training for AATC DAIR, and ET-1578 for RATCF DAIR). You will perform both on-line and off-line tests and alignment, system operational checks and adjustments for CATCC and AATC DAIR, and periodic inspection, verification and cleaning of certain equipments in RATCF DAIR. By using BITE for on-line fault isolation, you will be able to isolate faults

to discrete components and, in some cases, to a set of several digital cards. You'll complete most repairs by removing and replacing discrete chassis components, modules, or digital circuit cards.

The Air Force performs depot-level maintenance on DAIR equipment under a joint maintenance task agreement; however, the contractor will repair all CATCC- and AATC DAIR-unique items at the depot level. Return the items that you can't repair to supply. They'll know where to send them.

All the systems we've discussed so far are the maintenance responsibility of the ET rating. The next system, NTDS, is maintained by several ratings. As we explained in ET, Volume 3, *Communications Systems*, the only way to ensure optimum operation of the NTDS system is to work closely with the other ratings involved.

### NAVAL TACTICAL DATA SYSTEM (NTDS)

ET, Volume 3, addresses the NTDS tactical communications data system. In this volume, we will address the tactical radar section. The NTDS computer-centered control system coordinates the collection of data from various sources. It accepts data from ship's sensors, such as radar, sonar, and navigation inputs, and from external (off-ship) sources via communications links. It also processes and correlates this data for tactical use.

### GENERAL THEORY OF OPERATION

NTDS accomplishes its objectives in real time; the system receives data from various sensing devices that are in continuous contact with the outside environment. It uses this data to evaluate an event as it happens. How often the system requires an update will determine the rate of sampling for each sensing device. The concept of standard computers operating in conjunction with each other to increase capacity and functional capability is known as the "unit computer concept." It is basic to the design philosophy of NTDS. A diagram of a typical NTDS equipment grouping is shown in figure 3-8.

NTDS integrates all systems and subsystems for performing the basic combat system functions including:

- Detection and entry
- Tracking and identification
- Threat evaluation and weapon assignment
- Engagement and engagement assessment

The NTDS system accomplishes its varied tasks by receiving, storing, and processing the data inputs from the other systems and subsystems. The operational program then distributes the processed data as usable inputs for other systems and subsystems. The data display also allows the operator to interact with the system.

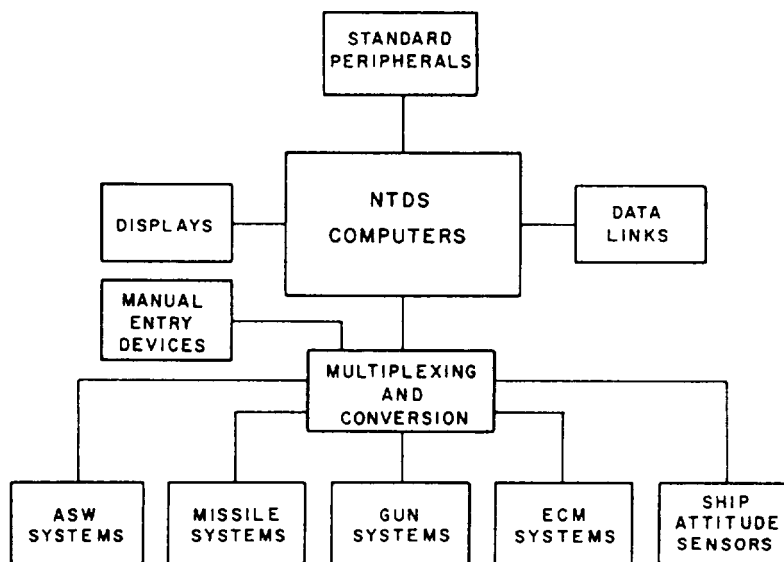


Figure 3-8.—NTDS equipment grouping.

## MAINTENANCE

As an ET, you are responsible for maintaining the radar, antenna, video and sync amps, and radar switchboard, plus any associated equipment directly connected to this group.

All ships with NTDS have a *Combat Systems Technical Operations Manual* (CSTOM). The CSTOM documents the total integrated combat systems concept; you will find it a useful guide regarding communications, radar, and NTDS as a whole integrated system.

The CSTOM organizes the technical data associated with the integrated combat system, providing information required to both operate and maintain the system. It defines significant capabilities and limitations of the system, and even outlines requirements for maintaining material and personnel readiness for the system. The publication is structured as follows:

### VOLUME 1—COMBAT SYSTEMS DESCRIPTION

### VOLUME 2—OPERATIONAL SEQUENCES

### VOLUME 3—COMBAT SYSTEM READINESS

### VOLUME 4—CAPABILITIES AND LIMITATIONS

As you may imagine, with such an all-encompassing system, troubleshooting may take you beyond ET lines of maintenance responsibility. If the system has a problem, you should be aware of what the FCs, or DSs, or ICs are doing. Your expertise on the radar or the radar distribution switchboard may help prevent them from wasting their time. Being aware of what other ratings are doing also will allow you to become more familiar with other equipment and more knowledgeable about what could affect your equipment.

Regardless of your technical knowledge on a piece of gear, you must know the safety requirements associated with that gear before you work on it. In the next chapter, we will discuss safety aspects that are specific to radar maintenance.



## CHAPTER 4

# RADAR SAFETY

You are now a radar systems technical expert. As an Electronics Technician, Second Class, and possible work center supervisor, you also must understand the basic safety requirements for radar maintenance and operation.

In ET Volume 1, *Safety*, we discussed the following safety items that apply to radar: (1) the proper handling of cathode-ray tubes (CRTs), (2) measuring voltage on energized equipment, (3) the use of protective equipment, (4) tag-out procedures, (5) working aloft, and (6) RF hazards.

We will not cover that material in this volume. However, we will test your understanding of that material in the NRTC for this volume. Therefore, if you have not completed Volume 1, you may want to do so before proceeding with this course.

### RADIATION HAZARDS

Much of your radar gear (if labeled correctly) will have radiation hazard (RADHAZ) warnings attached. These labels indicate a radiation hazard producing RF electromagnetic fields intense enough to actuate electro-explosive devices, cause spark ignition of volatile combustibles, or produce harmful biological effects in humans. You will probably not be able to eliminate the hazards caused by normal operation of your radar equipment. Therefore, you will need to minimize them during certain evolutions.

The most effective way to reduce radiation hazards is to shut down equipment when possible or to locate equipment so that radar main beams do not illuminate ordnance, personnel, or fuels.

NAVSEA OP 3565 requires each commanding officer to establish procedures for maintaining positive control of RF transmitting equipment and to coordinate the actions of personnel working near emitters or handling ordnance. By instruction, no one may turn on any transmitting equipment without proper authorization from the supervisor in charge of operations. That means that you need permission to operate, test operate, rotate, or radiate electronic gear.

Each command has an Emissions Control (EMCON) Bill that establishes the level of EMCON

required during certain types of operations. The EMCON bill identifies the equipment to be secured while each EMCON level is set. Label your radar equipment according to your EMCON bill to make identification easy and to provide for timely shut down.

The following paragraphs discuss the primary adverse affects of electromagnetic radiation on material and personnel and the programs designed to minimize those effects.

### HERO—HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE

During on-loading or off-loading of ammunition, there is a danger that RF electromagnetic fields could accidentally activate electro-explosive devices (EEDs) or electrically-initiated ordnance. This is a very real hazard to the ordnance, the ship, and the crew. The HERO program was developed to control these types of situations.

When HERO is set, it usually requires that radars be secured. When you are in port and must conduct any radar maintenance requiring rotating the antenna or radiating, always coordinate your actions with Base Operations via the CDO. HERO conditions anywhere in the area could be affected by your radar. Even if you just want to radiate a short period for an operational test, check with the OOD or CDO first.

Table 4-1 identifies ordnance hazards associated with common electronic equipment. This is an example of tables found in NAVSEA OP 3565 Volume II, part 1.

### HERF—HAZARDS OF ELECTROMAGNETIC RADIATION TO FUELS

The HERF program was developed to protect fueling operations. During fueling operations, RF electromagnetic fields with a large enough intensity could produce a spark that could ignite the volatile combustibles. Therefore, certain radars may need to be shut down during fueling operations. Check your HERF publications for specific details.

Table 4-1.—NAVSEA OP 3565 Volume II, Table 2-4, Safe Separation Distances for Radar, EW, and NAVAIDS Equipment

SYSTEM	GAIN (dbi)	HERO SUSCEPTIBLE (METERS/FEET)	HERO UNSAFE/HERO UNRELIABLE (METERS/FEET)
AN/SPS-10	32	37/121	52/171
AN/SPS-10 (Beacon Mode)	32	34/112	49/161
AN/SPS-10B	30	48/157	67/220
AN/SPS-10B (Beacon Mode)	30	43/141	61/200
AN/SPS-10C, 10E, 10F	30	36/118	51/167
AN/SPS-10C (Beacon Mode), 10E (Beacon Mode)	30	33/108	47/154
AN/SPS-10D	31	40/131	57/187
AN/SPS-10D (Beacon Mode)	31	38/125	53/174
AN/SPS-10F (Beacon Mode)	30	34/112	48/157
AN/SPS-12	28.2	3170/10400	5799/19025
AN/SPS-29A, 29B, 29C, 29D, 29E	18	157/515	609/1998
AN/SPS-30	40.4	1070/3510	1509/4951
AN/SPS-32	22	426/1398	1644/5394
AN/SPS-33	44	1532/5026	2160/7087
AN/SPS-35 LR, 35 SR	31	3/10	3/10
AN/SPS-37	18.5	111/364	429/1407
AN/SPS-37A	23	186/610	719/2359
AN/SPS-39A	39.5	593/1946	836/2743
AN/SPS-40, 40A	21	203/666	610/2001
AN/SPS-40B (LFDM), 40C (LFDM), 40D (LFDM)	21	143/469	432/1417
AN/SPS-40B (LRM), 40C (LRM), 40D (LRM)	21	216/709	652/2139
AN/SPS-43	18.5	114/374	449/1473
AN/SPS-43A	23	191/627	755/2477

**HERP—HAZARDS OF ELECTROMAGNETIC RADIATION TO PERSONNEL**

The HERP program was developed to protect personnel from RF electromagnetic radiation. Anywhere a radar or transmitter is operating, there is a danger that the RF electromagnetic fields may produce harmful biological effects in humans exposed to them. The following paragraphs identify the typical hazards and the steps you can take to minimize them.

**Hazards**

RF hazards to personnel are based on overexposure to RF energy. The biological hazard level for exposure to RF radiation is established by the Bureau of Medicine and Surgery and is included in NAVSEA OP 3565 Volume I.

**SAFE LIMITS.**— Safe limits are based on the power density of the radiation beam and the exposure time of the human body. Table 4-2 identifies safe limits associated with common electronics equipment. It is an

example of tables found in NAVSEA OP 3565 Volume I.

**RF BURNS.**— As we mentioned in ET Volume 1, voltages of enough potential to cause a burn injury can be induced on metallic items from nearby transmitting antennas. However, there has to be actual physical contact for the burn to occur. You can help prevent contact by ensuring that warning signs are placed properly and obeyed.

**Precautions**

During normal operations, personnel can easily avoid most hazards if the hazards are labeled properly. However, during maintenance, some hazards must be eliminated by specific, planned actions, such as those listed below. Using all safety precautions is the personal responsibility of the technician.

**TAG-OUT.**— Tag-out procedures are covered in depth in ET Volume 1. Hanging a proper tag can save your life. Using tags improperly or not at all will eventually put you, maybe your best buddy, maybe your

Table 4-2.—NAVSEA OP 3565, Volume I, Table 2-1, Personnel Hazards from Continuous or Intermittent Exposure to Main Beam Radiation

TRANSMITTER	MODE	FIXED BEAM HAZARD			MOVING BEAM		
		DISTANCE		MAX. EXP. TIME <sup>(a)</sup>	PERSONNEL HAZARD	DISTANCE	
		METERS	FEET			METERS	FEET
SHIPBOARD AND SHORE STATION EQUIPMENT (Continued)							
AN/SPS-37A		14	45	0	NO	-	-
AN/SPS-38		15	50	0	NO	-	-
AN/SPS-39, A		120	400	1	NO	-	-
AN/SPS-40, A, B		18	60	1	NO	-	-
AN/SPS-41		NO HAZARD		6	NO	-	-
AN/SPS-42		55	180	1	NO	-	-
AN/SPS-43		21	70	0	NO	-	-
AN/SPS-43A		14	45	0	NO	-	-
AN/SPS-45		14	45	0	NO	-	-
AN/SPS-46		NO HAZARD		6	NO	-	-
AN/SPS-48**		250	840	0	NO	-	-
AN/SPS-49		61	200	1	NO	-	-
AN/SPS-51		NO HAZARD		6	NO	-	-
AN/SPS-52		130	440	0	NO	-	-
AN/SPS-53, A, E		NO HAZARD		6	NO	-	-
AN/SPS-55		8	25	0	NO	-	-
AN/SPS-57		NO HAZARD		6	NO	-	-
AN/SPS-58		NO HAZARD		6	NO	-	-
AN/SPS-58A		NO HAZARD		6	NO	-	-

whole crew, in a Navy mishap report. Ensure that required tags are installed properly and observed fully.

**MAN-ALOFT CHITS.**— Man-Aloft chits protect you from RF hazards when you are working on radar antennas. If the chit is run properly, the operations on your ship and any ship next to you are modified to keep you safe. Heed the requirements and follow the procedures.

**EQUIPMENT SAFETY DEVICES.**— Devices built into equipment, such as cut-off switches on antennas, are for your safety. A cut-off switch, when set, will keep you out of danger. It will prevent someone from rotating the antenna from a remote location. But, you, the technician, have to set the cut-off switch for it to be of any use. Equipment safety devices are there for your protection. Use them!

Everywhere you go in the Navy, there will be communications and radar equipment that produces an Electromagnetic Radiation Environment (EME). And, there will always be electromagnetic radiation hazards introduced by operating this equipment. To be safe,

become familiar with the hazards associated with your equipment. If you install new equipment, update your EMCON bill. Use NAVSEA OP 3565 Volume I or Volume II to determine the hazards associated with the equipment.

**OTHER RADAR HAZARDS**

You cannot always avoid hazards when working on radars. In these instances, take what precautions you can and at least be prepared for an emergency. As we discussed in ET Volume 1, there are various safety concerns associated with working on energized equipment, going aloft, or handling CRTs.

**ENERGIZED EQUIPMENT**

You may have to work on energized equipment on a hectic bridge, in a crowded CIC, or in a cramped radar equipment room. These are not ideal safety environments. As these spaces are maintained by various people, always check the rubber matting around your equipment. Also check other protective

equipment, such as rubber gloves and shorting probes before using them.



**SHOCK  
HERTZ!**

**WARNING!**

**NEVER WORK ALONE ON ENERGIZED EQUIPMENT.**

On ships with minimum manning, you may not have the option of using another ET as a safety observer. Make sure that whoever is going to observe you is CPR qualified. Brief your observer on what you will be doing. Physically show him or her where the cut-off switch is located. Have him or her stand by at a safe distance with a rope or wooden cane to pull you from the equipment, should you get hung up. Follow procedures outlined in ET Volume 1 for voltage checks.

**MAN-ALOFT**

As we mentioned earlier, when you work aloft on radar antennas, your man-aloft chit protects you from the RF radiation hazards. But, you also need to be protected from falling. Do the required PMS for safety harnesses every time you use the harness. And remember, even a good harness can't save you unless you use it right. When you go up the mast attach your harness properly so you can't free fall to the deck. Attach a line to any tools you carry up, so they are unable to fall freely. Set the cut-off switches for any antennas along your way.

**WARNING!**

**NEVER WORK ALOFT WITHOUT A SAFETY OBSERVER.**



It's your life; pick good safety observers. Your safety observers should be aware of what type of maintenance you're going to do. They also need to know whom to contact if you run into technical problems.

Safety Observers are responsible for the safety of those walking underneath you as well as for your safety. They should position themselves so you can communicate with them without having to come down. The safety observer will pass your information to everyone else. If something is falling, communicate quickly.

**CATHODE-RAY TUBES (CRT'S)**

Cathode-ray tubes are part of radar scopes. You will definitely have to work around them. You will probably, at one time or another, pack or unpack, install, repair, or dispose of one. There are some very real dangers associated with handling a CRT. Always take the precautions discussed in ET Volume 1 whenever you handle a CRT.

Never think about electronics without thinking about safety. Learn from the safety information you get from the Ship's Safety Bulletins, Navy mishap reports, and personal experience. Follow established procedures and all safety instructions. Live longer.

We've discussed many aspects of radar in this volume. In ET Volume 7, *Antennas and Wave Propagation*, we will provide specific information about radar antennas, waveguides, and transmission lines. Then in ET Volume 8, *System Concepts*, we will discuss specifics on radar cooling systems.



## APPENDIX I

# GLOSSARY

- 2-M**— Microminiature electronic repair.
- 2D RADAR**— Two dimensional; the radar provides information on two separate coordinates (usually range and azimuth).
- 3D RADAR**— Three dimensional; the radar provides information on three separate coordinates (usually range, azimuth, and altitude).
- A/D**— Analog/digital.
- AATC DAIR**— Amphibious air traffic control DAIR uses an AN/TPX-42A(V)12 and is known as a type 12 system.
- AAW**— Antiair Warfare.
- ACLS**— Autostatic Carrier Landing System.
- ADT**— Automatic detection and tracking.
- AFC**— Automatic frequency control.
- AIC**— Air intercept control.
- AMW**— Amphibious warfare.
- AOA**— Amphibious objective area.
- APG**— Azimuth pulse generator.
- APL**— Allowance parts list.
- ASAC**— Antisubmarine aircraft control.
- ASM**— Antiship missile.
- ASUW**— Antisurface warfare.
- ASW**— Antisubmarine warfare.
- ATC**— Air traffic control.
- ATCRBS**— Air Traffic Control Radar Beacon System.
- ATD**— Automatic target detection.
- BIT**— Built-in-test.
- BITE**— Built-in-test equipment.
- CAC**— Command and control.
- CAP**— Combat Air Patrol.
- CATCC**— Carrier Air Traffic Control Center.
- CATCC DAIR**— Carrier Air Traffic Control Center DAIR system uses a AN/TPX-42A(V)8 and is known as a type 8 system.
- CCA**— Carrier controlled approach.
- CCS**— Central computer subsystem.
- CDO**— Command duty officer.
- CFAR**— Constant false alarm rate.
- CIC**— Combat information center.
- CM**— Corrective maintenance.
- CPA**— Closest point of approach to other surface craft or aircraft.
- CPR**— Cardiopulmonary resuscitation.
- CRT**— Cathode ray tube.
- CSLC**— Coherent sidelobe canceler.
- CSTOM**— Combat Systems Technical Operations Manual.
- CW**— Continuous wave.
- DAIR**— Direct Altitude and Identity Readout. The standard DAIR system uses an AN/TPX-42A(V)5 and is known as a type 5 system.
- DCSC**— Digital coherent sidelobe canceler.
- DFS**— Direct fleet support.
- DMTI**— Digital moving target indicator.
- DOP**— Designated overhaul point.
- DRA**— Dead reckoning analyzer.
- DUCTING**— The increased bending of radar waves as they pass through abnormal atmospheric conditions.
- ECM**— Electronic countermeasures.
- EED**— Electro-explosive devices.
- EIMB**— Electronics Installation and Maintenance Book.
- EMCON**— Emissions control.
- EME**— Electromagnetic radiation environment.
- EMI**— Electromagnetic interference.
- ET**— Electronics Technician.
- FC**— Fire Control Technician.

**FM**— Frequency modulation.

**FRUIT**— Nonsynchronous transponder replies that interfere with IFF video.

**FTC**— Fast time constant.

**GCA**— Ground controlled approach.

**GPETE**— General-purpose electronic test equipment.

**HDC**— Helicopter direction center.

**HERF**— Hazards of electromagnetic radiation to fuel.

**HERO**— Hazards of electromagnetic radiation to ordnance.

**HERP**— Hazards of electromagnetic radiation to personnel.

**I/O**— Input/output.

**IADT**— Integrated Automatic Detection and Tracking System.

**IF**— Intermediate frequency.

**IFF**— Identification friend or foe.

**IMA**— Intermediate maintenance activity.

**IS**— Interference suppression.

**LSLS**— Intemogator side lobe suppression.

**ITAWDS**— Integrated Tactical Amphibious Warfare Data System.

**KCMX**— Keyset central multiplexer.

**LED**— Light-emitting diodes.

**LOS**— Line of sight.

**LRM**— Long range mode.

**LRU**— Lowest replaceable unit.

**LSO**— Landing signal officer.

**MAM**— Maintenance assist module.

**MATCS**— Marine air traffic control squadrons.

**MCAS**— Marine Corps air station.

**MFC**— Manual frequency control.

**MLV**— Memory loader/verifier.

**MOB**— Mobility.

**MOISTURE LAPSE**— A falling away from the standard moisture content of the air.

**MOTU**— Mobile technical unit.

**MPPI**— Maintenance planned position indicator.

**MPU**— Medium PRF upgrade.

**MRC**— Maintenance requirement card.

**MTBF**— Mean time between failures.

**MTI**— Moving target indicator.

**MTTR**— Mean time to repair.

**MTU**— Magnetic tape unit.

**MUTE**— Shipboard Emission Monitor-Control Set, AN/SSQ-82(V).

**NAS**— Naval air station.

**NAVSEA**— Naval Systems Engineering Activity.

**NAVSEACEN**— Naval Systems Engineering Activity Center.

**NEC**— Navy Enlisted Classifications.

**NEETS**— Navy Electricity and Electronics Training Series.

**NTDS**— Navy Tactical Data System.

**OCC**— Operator control console.

**OOD**— Officer of the deck.

**PA**— Power amplifier.

**PALS**— Precision Approach Landing System.

**PAR**— Precision approach radar.

**PCB**— Printed circuit board.

**PM**— Planned/preventive maintenance.

**PMS**— Planned Maintenance System.

**PPI**— Planned position indicator.

**PRF**— Pulse repetition frequency, also referred to as pulse repetition rate (PRR).

**PRI-FLI**— Primary flight.

**PRR**— Pulse repetition rate, also referred to as pulse repetition frequency (PRF).

**R/T**— Receiver/transmitter.

**RADDS**— Radar Display and Distribution Systems.

**RADHAZ**— Radiation hazard.

**RATCF DAIR**— Radar Air Traffic Control Facility DAIR system uses the AN/TPX-42A(V)10 and is known as a type 10 system.

**RF**— Radio Frequency.

**RFI**— Radio frequency interference.

**RFSTC**— RF sensitivity time control.

**RHI**— Range-height indicator.

**RING-AROUND**— The appearance of a target close to the origin of the display screen that extends nearly 360 degrees. Usually a result of close-in targets responding to side lobe IFF interrogations.

**ROF**— Radar operational facilities.

**RPM**— Rotation per minute.

**RSC**— Radar set control.

**RTS**— Radar test set.

**RVC**— Radar video converter.

**RVP**— Radar video processor.

**SBBM**— System/bootstrap bus monitor.

**SDC**— Signal data converter.

**SDMS**— Shipboard data multiplex system.

**SEM**— Standard electronic modules.

**SHM**— Ships heading marker.

**SIF MODES**— Selective identification feature modes of IFF (modes 1, 2, and 3/A) used by friendly aircraft and surface craft.

**SM&R CODE**— Source, maintenance, and recoverability code.

**SMS**— Ships motion sensor.

**SPETE**— Special-purpose electronic test equipment.

**SPW**— Special warfare.

**SR**— Sector radiate.

**SRF**— Ship repair facility.

**SRM**— Short range mode.

**SSTX**— Solid-state transmitter.

**STALO**— Stable local oscillator.

**STC**— Sensitivity time control.

**STEEP**— Support and Test Equipment Engineering Program.

**SVC**— Sensitivity velocity control.

**TACC**— Tactical Air Control Center on LHA and LHD type ships.

**TAO**— Tactical action officer.

**TCAS**— Traffic Alert and Collision Avoidance System.

**TEMPERATURE INVERSION**— An atmospheric condition in which the normal properties of the layers of the air are reversed.

**TRS**— Technical repair standards.

**VCS**— Video clutter suppression.

**VSWR**— Vohage standing wave ratio.



## APPENDIX II

# REFERENCES USED TO DEVELOP THE TRAMAN

**NOTE:** Although the following references were current when this TRAMAN was published, their continued currency cannot be assured. You, therefore, need to ensure that you are studying the latest revision.

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*Navy Training Plan, AN/SPS-55 Surface Search Radar*, NTP S-30-7512E, Chief of Naval Operations, Washington, DC, June 1989.

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*Navy Training Plan, AN/SPS-64(V) 9 Radar*, NTP S-30-8106C, Chief of Naval Operations, Washington, DC, May 1989.

*Navy Training Plan, AN/SPS-67(V) Radar*, NTP S-30-7716F, Chief of Naval Operations, Washington, DC, August 1990.

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