

CHAPTER 15

MICROWAVE INSTALLATION CRITERIA

This chapter covers the development and preparation of detailed installation plans for microwave radio communication stations. Constraints placed upon the installation due to the system design requirements will also be discussed.

Information and data are provided as facility design criteria in accordance with current Navy regulations, and updated on a continuing basis until finalized. A&E drawings, utilized for the station implementation phase, become the station "plant-in-place" records upon completion of the installation.

Facility design criteria, supplied by the communications system engineering activity, include site location and layout information, building location and layout information, site leveling and grading requirements, AC power requirements, utilities, water and sewage requirements, proposed manning, and, when appropriate, plans for future station expansion.

When a station is to be installed in existing buildings, the physical dimensions and layout of the buildings are supplied to the Navy planners who determine if modifications are needed. Orientation of the equipment and buildings must be considered to provide the optimum antenna arrangement. Distribution of AC power in the building must be investigated to assure ample power for the equipment. The equipment layout must be reviewed to verify the availability of sufficient floor space and overhead for equipment installation.

The detailed installation drawings prepared by the system engineering activity will contain all information required to accomplish not only the entire inside plant installation but also that portion of the outside plant under cognizance of the system engineering activity. Engineering information affecting the A&E design contained in these drawings is provided to the Navy planners prior to generation of the A&E drawings. Installation drawings specify where and how to install cable trays, cables, distribution frames, equipment, system grounds, and AC power distribution. Each drawing also includes a List or Bill-of-Material (LOM or BOM) required to accomplish the installation.

The engineering activity, engaged in development of a communication system, is responsible for providing the Navy planners with definitive facility design criteria, covering the scope of development work involved. The extent of plans and specifications required for this development work, depends upon the individual station and system requirements. The categories of activity required for total development and construction of a communication station are as follows:

- o Site Layout and Plot Plan, RADHAZ Clearances
- o Access Roads and Parking Areas
- o Site Preparation, Clearing and Grading (maximum slope of 5%)
- o Building Design
- o Water Supply and Sanitation System
- o Antenna Footings and/or Structures
- o Prime and Auxiliary Power
- o Heating and Air Conditioning (Environmental Control)
- o Site Security Fencing and Lighting

General information, relative to a proposed station, needed by the Navy planners for the development of facilities, plans and specifications includes:

- o Expected life of station
- o Location of station
- o Elevation of station
- o Meteorological conditions
- o Personnel housing requirements
- o Total assigned personnel
- o Number and functions of "on-duty" personnel

15.1 SITE LAYOUT REQUIREMENTS AND RESTRICTIONS

Development of site plans requires close coordination of all aspects of civil and communications system engineering to determine the optimum site configuration. Site plans are developed by the system engineering activity and provided to the Navy planners as guidance. This compatibility is based on various factors that affect or control the logical arrangement of system components with respect to activity and operational requirements. These factors include:

- o Site topography
- o Available area
- o Size, number, and types of buildings

- o Direction and number of transmission paths
- o Size, number, and height of antennas and supporting structures
- o Obstructions to radio paths.

15.1.1 Antenna Spacing

A typical site layout, prepared by the Navy planners is based on making the equipment building the center of site operations, with the antenna structures as close to this building as practicable to minimize the transmission line lengths required between equipment and antennas. Diversity antennas require vertical separation from each other by a distance, h , determined as follows: In a space diversity system, only one signal is transmitted but it is received by two (or more) receivers connected to separate antennas. The antennas are widely spaced in elevation, so that propagation effects or path reflections are not likely to be the same at the different elevations. An approximation of the spacing required is given by the following formula:

$$h = \frac{1.3 \times 10^6 d}{f \times h_t} \quad (15-1)$$

where:

h = diversity spacing in feet

d = distance between stations, in miles

f = operating frequency, in megacycles

h_t = height of transmitting antenna, in feet, above a reflecting plane tangent to the earth at the point of geometrical reflection.

Figure 15-1 illustrates a space diversity antenna arrangement. Figure 15-2 is a block diagram of a typical space diversity system.

15.1.2 Buildings

The number and direction of transmission paths specified normally determine orientation of the equipment building with respect to the site. Power generator buildings require separation from the equipment building, but are located sufficiently close to minimize power cable voltage drops between generators and equipment. Fuel storage areas should be located where the RF power density is less than 5.0 watts per square centimeter. Living quarters are to be located sufficiently remote from equipment and power buildings to assure isolation of living and work areas.

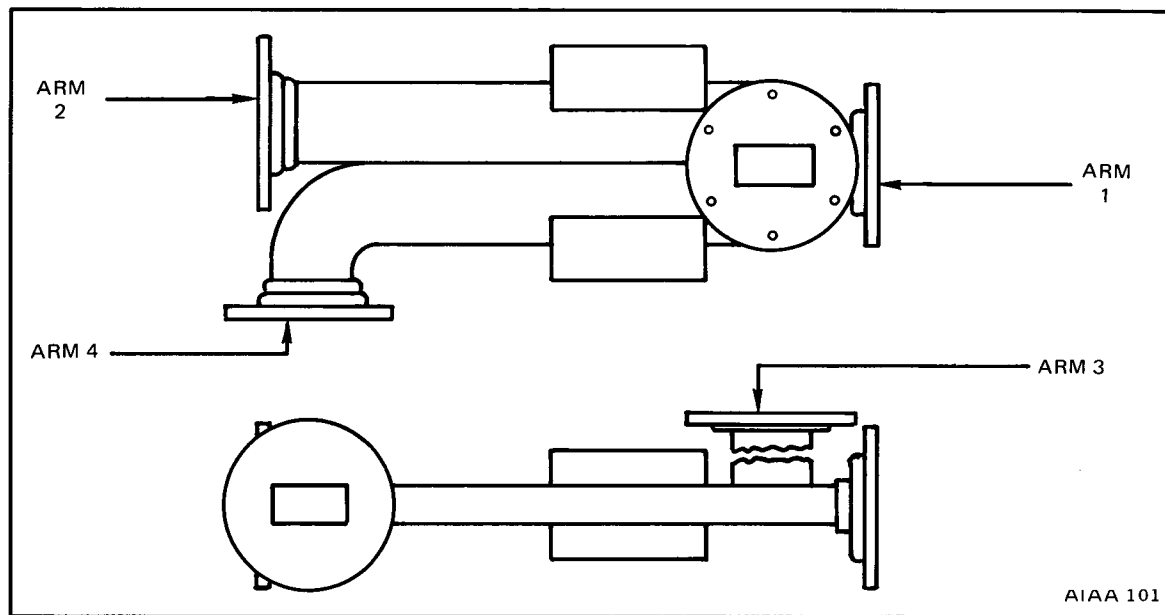


Figure 15-1. Space Diversity Antenna Arrangement

15.1.3 Topography

The topography of the site area has an important effect upon the site layout. When necessary, compromises in site layout are effected to keep site preparation and grading within reasonable limits.

15.1.4 RADHAZ Clearances

Since microwave line-of-sight transmitters presently operate with relatively low output powers (one to five watts are typical values) the radiation levels which are considered hazardous to personnel (0.01 watts per square centimeter) are not present. The equation used to determine the radiation intensity at the center of a beam in the near field is:

$$W = \frac{4P}{A} \quad (15-2)$$

W = Power density in watts per square centimeter

P = Transmitter output power in watts

A = Antenna area in square centimeters

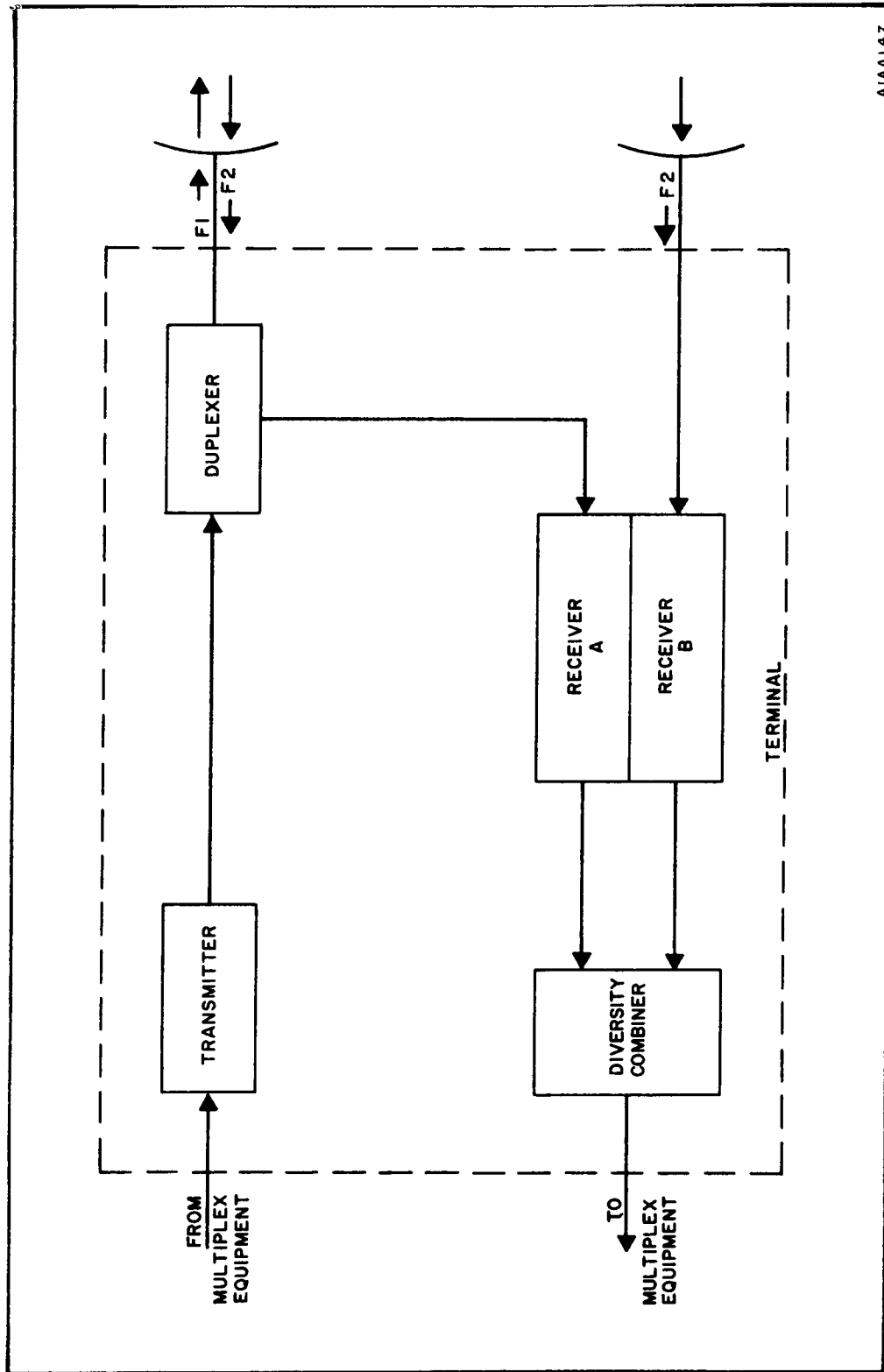


Figure 15-2. Typical Space Diversity Operation

This subject is covered in detail in Volume II, Tropospheric Radio Communication Systems, since the radiated energy for tropo-scatter systems does create significant hazards to personnel, fuel, and explosive storage.

15.1.5 Final Site Plan

A final site plan is prepared by the Navy planners using the preliminary site layout prepared by the communications system engineering activity, site survey information, and the criteria discussed above. The final site plan includes the following data in addition to the physical positioning of various site components:

- o Site boundary and property lines
- o Base line and benchmarks
- o Access roads and parking areas
- o Elevation, azimuth, and coordinates for the center of each antenna
- o Underground utilities
- o Underground services
- o Existing buildings and facilities.

A typical site plan is illustrated in figure 15-3.

15.2 ACCESS ROADS

The design of access roads to a communications station is accomplished by the Navy planners. A preliminary engineering study, prior to the development of site access roads and parking areas, should take into account vehicular traffic demands. Although the final access road position will depend primarily on site location, layout, and topography, the final design should offer direct routing, adequate right of way visibility, good foundation, proper drainage, and degrees of curvature and grade consistent with good highway engineering practice.

15.3 SITE PREPARATION

Site preparation includes clearing and grubbing, roadway excavation, structure excavation, burrow and fill excavation, site grading, and drainage operations. Site topographical information and other survey data provided by the systems engineering activity, form the basis for site clearing and grading drawings.

15.4 BUILDING DESIGN-CONSTRUCTION CRITERIA

The size of a building used to house microwave equipment depends upon the station function. In particular the following factors must be considered:

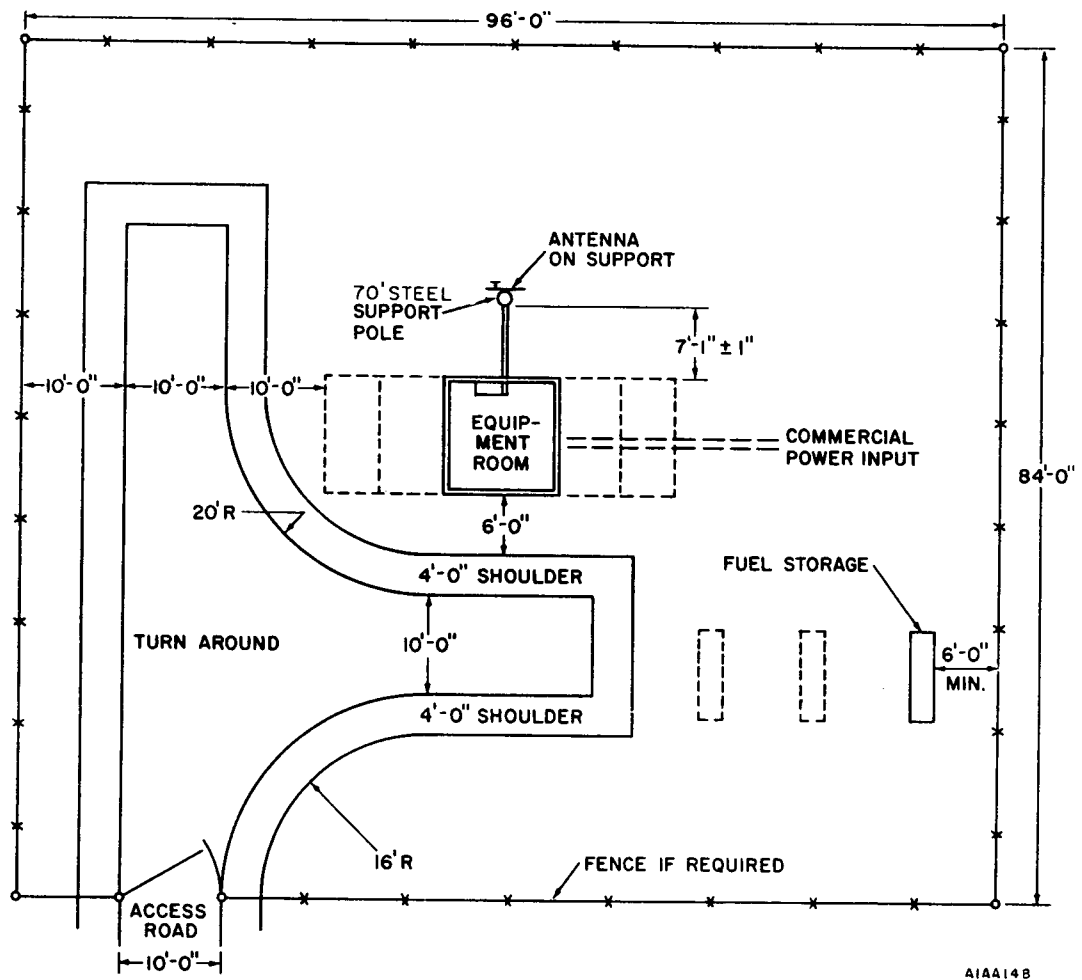


Figure 15-3. Typical Site Plan

- o Size and quantity of required equipment and possible future equipment
- o Necessary working space around equipment
- o Required space for maintenance purposes
- o Personnel requirements (desk space, sanitary facilities)
- o Housing of power equipment.

At some sites, contemplated use of existing buildings necessitates investigation of load bearing capabilities of the floor. The need for heavy antenna mounts on the building may require building reinforcement.

At remote sites new buildings must be erected, the type of construction depending upon physical conditions peculiar to the locality, and availability and relative cost of construction materials. Other considerations include the required strength and durability of the building, and necessary maintenance. Additional factors affecting the type and strength of a structure are: climatic conditions, temperature range, wind velocities, and amount of rainfall and/or snowfall. Transportation and handling costs and site accessibility affect the selection of construction materials. Local codes governing the use of certain materials and methods of construction must be investigated. The availability of skilled labor may be a deciding factor. For small stations the above requirements can be met by using either sheet metal or masonry construction. Sheet metal buildings can be prefabricated, easily erected, and readily enlarged. Masonry buildings have greater durability. For each building, the Navy planners prepare an A&E drawing package that includes the following categories of plans:

- o Architectural Plans. Floor plans, elevations, details, schedules
- o Structural Plans. Foundations, section, construction details
- o Electrical Plans. Power distribution, control panels, lighting, schematics
- o Mechanical Plans. Heating, ventilation, air conditioning
- o Plumbing. Water supply and sanitation facilities and systems.

Actual building design is accomplished by the Navy planners using the space requirements, room configurations, and other facilities design criteria provided by the communications system engineering activity. The design includes a future station expansion capability of 25 percent. Various architectural standards and specifications are utilized. Specific building design criteria associated with communications station requirements are discussed in the following paragraphs. In new facilities a 100 percent equipment expansion should be anticipated.

Buildings of single story, rectangular construction are most desirable for microwave radio communications equipment installation. Normally, equipment buildings are physically separated from other site buildings such as power generator buildings and living quarters. When a single building is employed, use of one end as the equipment room minimizes interference by off-duty personnel, and power generators. The center of the building is then utilized for maintenance and storage, the opposite end for administrative functions at the station.

To determine the space requirements and layout of the building, floor plans are developed showing the location of all equipments in the operations and maintenance areas. Requirements for spare parts storage space are determined by the types of equipment, and level of maintenance to be performed at the station. Consideration is given to the reduction of spare parts storage requirements resulting from improved equipments, and streamlines maintenance and supply techniques now being employed. Space requirements for administrative and sanitation facilities are determined from the number of personnel programmed for normal operation and maintenance duty at the station.

At least one outside door to the equipment room, capable of passing the largest single component that may be moved into the station, is required. A loading ramp must be provided immediately outside this door to facilitate loading and unloading heavy equipment from trucks.

Ceilings in the equipment area should be at least 10 feet above the floor level for adequate ventilation of standard eight-foot equipment racks. This height also provides proper diffusion of light throughout the equipment area from ceiling luminaires.

The building floor must be designed to support the heaviest equipment likely to be placed upon it. Overall, the floor should support the entire weight of all equipment, and provide a 50 percent overload factor to accommodate any expansion of facilities. A minimum floor loading of 200 pounds per square foot is considered desirable. Provisions must be made in the walls, ceiling and roof of the equipment building for installation of transmission lines running to the outside of the building. These exit ports require "tailoring" to the installation at each station, and may include RF shielding.

Incandescent lights will be used in electronic equipment areas to preclude fluorescent light radiation interference. A minimum of 30 foot-candles of light will be provided at a distance of 26 inches above the floor. A battery-powered emergency lighting system is required during power failures, pending activation of auxiliary power plants.

The building must be provided with a good station ground system in accordance with NAVELEX 0101, 102, Naval Communication Station Design.

15.5 ELECTROMAGNETIC COMPATIBILITY (EMC)

Although many specifications and standards exist which may be applied against individual electronic equipments for the purpose of interference control, these documents do not necessarily insure electromagnetic compatibility when a multiplicity of equipments are located in a common electromagnetic environment. Many cases have been recorded where a well-designed piece of equipment failed to perform its intended function because of electromagnetic incompatibility with another equipment at the intended location. The application of interference control measures to individual equipment, without regard for those measures already applied at interfacing equipment, can also result in redundancy, with associated increased cost, weight, and design time.

The system design approach avoids problems because system design for EMC means approaching the problem at the very beginning of project activity, wherein a detailed functional design study is made of the overall system, its constituent subsystems and equipments, and the intended operational environment. At that time, the EMC problem is defined, possible contributory factors are analyzed, and necessary goals are established. In general, the desired goals in the achievement of optimum compatibility are:

- o Minimization of electromagnetic emissions which may affect other equipment (effects of the system upon external elements - inter-system)

- o Minimization of susceptibility to emissions (e.g., effects of external elements upon the system inter-system)
- o Minimization of emissions and susceptibility between equipments within a system (internal effects - intra-system).

System designs also mean that EMC must be integrated into all project activities throughout the project life to assure the accomplishment of these goals from a preventive-measures approach rather than the use of inefficient, costly, after-the-fact remedies.

The implementation of EMC, therefore, calls for the establishment of a formal program having well-defined objectives and controls. Such a program is discussed in the following paragraphs. A summary of the salient features of EMC programs and their objectives follows.

The establishment of an EMC program within the framework of an overall project must include a clear statement of the objectives of such a program. In general, a formal program will have the following objectives:

- o Gathering of information and data, including spectrum signature measurement data on the equipment or system and on the intended operational electromagnetic environment
- o Selection, interpretation and application of EMC specifications and standards, engineering methods, and testing procedures which may be applied toward the selection or design of equipments
- o Selection and application of methods of prediction of both interference and radiation hazards in the intended environment, based on information gathered
- o Dissemination of gathered information to all personnel concerned with the planning, design, or installation of the equipment or system
- o Generation of an EMC program plan when required, which states the specific practices, procedures, design criteria, etc., to be used (and to be avoided) to achieve EMC throughout all phases of a program.

15.6 ANTENNA FOOTINGS AND/OR STRUCTURES

Supporting structures, foundations, lighting system, and antenna interfaces are designed by the Navy planners. Design factors include: height of structure, size and type of antennas, obstruction lighting regulations, path azimuths, and wind and ice loading. Foundation design is based on results of a soil analysis performed during the site survey. The Navy planners prepare specifications for the supporting structures and foundation design, and construction drawings for installation of structures at the Station. Erection drawings and procedures for the structures and antenna interfaces with the towers, are normally supplied by the antenna component manufacturer.

15.7 PRIMARY AND AUXILIARY POWER (TECHNICAL POWER)

DCS requirements for power systems are contained in paragraph 3.6 of DCA Standard 300-172. Primary power requirements for a communications facility are determined by the system configuration, and include equipment loads (technical power), utility and domestic loads, and provisions for future expansion. The A&E design agency is responsible for design of the site primary power system and its distribution. One of the most economical and convenient sources of auxiliary power is the diesel engine-generator. However, an engine-driven-generator requires time to start and warmup, causing a delay before taking the load after a power failure. NAVELEX practice is to use storage batteries to provide power instantly and economically. They are kept fully charged by the primary power source during normal operation and, when a failure occurs, the batteries assume the load instantly without interruption to service. Batteries lack the capacity to supply power for a long period of time and it is necessary to have available an auxiliary generator. Figure 15-4 illustrates the arrangement of a typical DC power plant, containing the 24-volt and 48-volt system, required to satisfy the demands of current transistorized equipments. The figure also shows the "standby" generator input to the distribution panel. The "end cells" are employed in battery systems to offset the effect of dropping voltage as the batteries discharge. End cells are switched into the regular battery circuit one cell at a time, as needed, to raise the battery voltage to a proper level.

15.8 ENVIRONMENTAL CONTROL (HEATING AND AIR CONDITIONING)

Design of the environmental control system is accomplished by the Navy planners. The communications system design activity is responsible for specifying the required environmental limits for equipment operating conditions, and personnel requirements. This includes detailed information concerning the heat dissipation figures for all equipments.

The heating system will vary as to type of fuel employed and method of heat distribution. Oil is usually the best fuel choice. If the microwave station is located on or near an existing Government facility, it may be possible to obtain piped steam heat from the facility central heating plant. Forced hot air is the preferred method of distribution and has the following advantages:

- o The ducts, blower, and outlets may also be used for the air conditioning system. Compactness and economy are realized by this approach
- o Dust control is maintained by means of filters
- o The Navy planners determine the capacity of the heating system.

Heating evaluations include personnel comfort provisions under regional extremes of humidity, high wind, and low temperature. Individual controls for each room should be specified where required to achieve proper temperature control, especially for equipment rooms which require less heat when the equipment is operating.

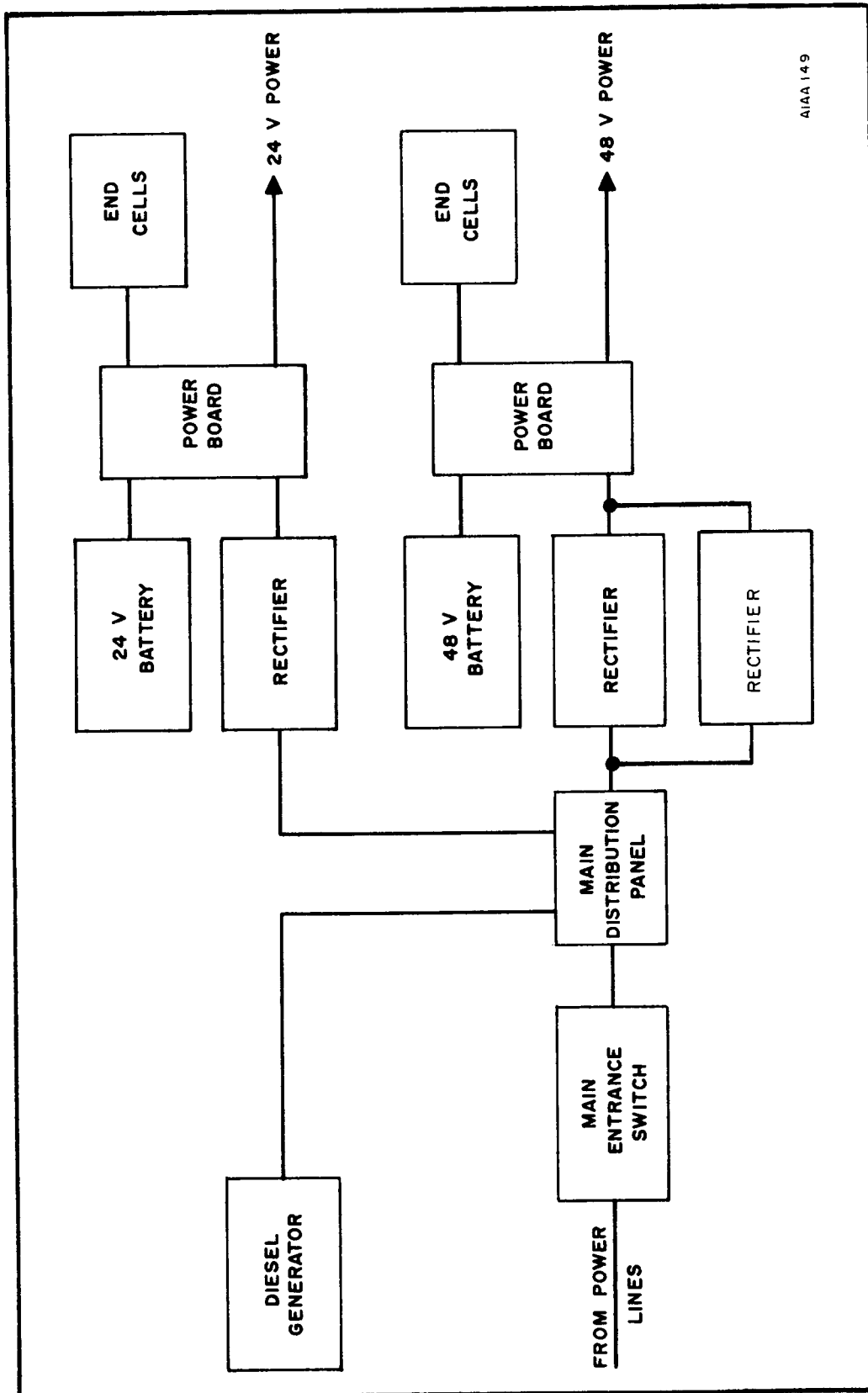


Figure 15-4. Typical DC Power Plant

Air conditioning must be provided to remove sufficient heat from the building to bring the temperature within an acceptable range for equipment and personnel, and condense sufficient water vapor from the air to bring the relative humidity within acceptable limits. Air conditioning units employing the compressor-condenser-evaporator cycle are preferred. The compressor is driven by an electric motor.

15.9 SITE SECURITY AND PROTECTION

The extent of site security and protection required depends upon the nature, size, and location of the communications facility. The A&E design agency is responsible for the design and implementation of security facilities, and protective devices required by the system design agency. This may include site security fencing, security lighting, fire detection and alarm systems, fire-fighting equipment, and personnel safety and protection features.

15.10 INSTALLATION PLANS

Installation drawings contain all the information required to accomplish the "inside plant" installation, and that portion of the "outside plant" installation under the cognizance of the system engineering agency.

15.10.1 Installation Plan (Inside-Plant) Installation Drawings

Drawings provide complete information to make the station or system installation as planned and in accordance with approved installation practices; a listing of the specific types and quantities of installation materials and hardware required for installation of the individual equipments; a complete "as-installed" record of the installation including the following drawings:

- o Floor Plans
- o Cable Rack Installation Drawings
- o Cable Termination Lists
- o Cross-connect Lists
- o Power Distribution Drawings
- o Grounding and Bonding Plans.

15.10.2 Floor Plans

Floor plans are prepared to provide a pictorial representation of equipment placement. Equipment racks are usually arranged side by side in a row (or rows). Microwave transmitter and receiver racks are arranged to provide short waveguide runs to the antenna(s). All racks are arranged to minimize inter-rack cabling. Minimum

requirements for front and rear clearance are obtained by consulting the equipment handbooks. Equipment lineups require a break at least every 20 feet.

Exceptions to these procedures are equipments subject to mutual interference. These are physically separated. Equipment is arranged to minimize interconnecting cable lengths. Attended equipment should be arranged for operating convenience and minimum personnel requirements.

Auxiliary equipment, such as voltage regulators, are often wall-mounted and arranged to simplify power distribution wiring. Other items or furnishings that should be shown on a floor plan are: workbenches, storage racks for test equipment and spare parts, desks, ventilating fans, air conditioners, and space heaters. A separate, ventilated room should be provided for battery storage and use. When the station is confined to one large building, rooms will be provided to accommodate the attendant personnel.

All required dimensions must be specified on the floor plan. Sufficient details are included, relative to obstructions, to preclude interference with equipment placement. Notes should be included to clarify the drawings and installation requirements for installation personnel.

15.10.3 Cable Rack Layouts

Cables for interconnecting and terminating equipments are distributed by one or a combination of two methods: overhead open rack, or floor trenches in order of preference. The advantages and disadvantages of each method are compared in Table 15-1.

Selection of one or a combination of the above cable distribution methods is dictated by individual station environment. Layout drawings are prepared for cable rack distribution. The A&E drawings of the building include floor trenches so no additional layout drawings are generated for this type of distribution. Information provided on the rack layout includes:

- o Overhead view of rack layout superimposed on floor plan
- o Detailed two-dimensional and perspective three-dimensional views of rack arrangements such as elbows, splits, tee sections, reducing sections, and dropouts
- o Equipment distribution frames and AC branching panel access details
- o Rack and hardware bill of materials keyed to layout and details
- o Notes required to assure that the drawing is completely self-explanatory.

15.10.4 Cable Termination Lists

Terminating information for multipair cables on a distribution frame is provided by these lists. The base and mate of each individual pair are given specific punching assignments on a specific distribution frame termination block.

Table 15-1. Distribution Comparison

Type Distribution	Advantages	Disadvantages
Overhead Open Rack	<p>Flexibility in arrangement and rearrangement of cables</p> <p>Rapid economical installation of racks and cable</p> <p>Cable expansion accommodated readily</p>	<p>Time consuming for cable installation</p> <p>Difficult to maintain clean, neat appearance</p> <p>Separate racks required for separation of signal and power cables</p>
Floor Trench	<p>Rapid, economical installation of cable</p> <p>Provides neat, clean appearance</p>	<p>Equipment arrangement dictated by trench layout</p> <p>Cable expansion limited by trench size</p> <p>Extremely difficult to separate power and signal cables</p>

15.10.5 Cross-Connect Lists

The jumpers required on a distribution frame are specified on a cross-connect list. Separate lists are prepared for each distribution frame, so lists vary in length from a single wire to several pairs. Cross-connects are used to describe the connection of a particular equipment group in a prescribed manner. Typical Cross-Connect lists are shown in Table 15-2.

15.10.6 Power Distribution Drawings

Power wiring from the power distribution panel to each equipment is completely described by the power distribution drawings, including the method to be used by the installer in wiring individual electronic equipments to the AC power source. They specify:

Table 15-2. Station Cross-Connect List

ITEM NO.	FROM				TO				CKT
	EQUIPMENT	CKT	PIN STENCIL	BLOCK ROW	PIN	BLOCK ROW	PIN	PIN STENCIL	
1	SBC-1 (NORMAL)	REC #1	A	20	A	1	A	1	AP PATCH & MON.
2			B		B	2	B	2	
3	AP PATCH & MON.	REC #1	A	3P	A	1	A	1	REC #1
4			B		B	2	B	2	
5			A		A	1	A	1	DEMUX INPUT
6	DEMUX OUTPUT	REC #1	A1	20	A	13	K	13	AP PATCH & MON.
7			A2		B	14	P	14	
8			B1		F	20	D	20	
9			B2		A	25	A	25	
10					B	26	B	26	
11	AP PATCH & MON.	REC #1	A1	3B	G	12	A	12	REC
12			A2		H	12	B	12	
13			B1		E	3	A	3	1ST DETAIL M
14			B2		F	3	B	3	
15					C	1	E	1	
16	1ST DETAIL M	RAY 11	2	40	D	4	F	4	4WR
17			5		A	1	E	1	
18			8		B	4	F	4	
19									
20									

- o Type and size of wire to be used
- o Routing of wires
- o Specific circuit breakers associated with each equipment
- o Diagrams of each panel board, indicating equipment connected to each circuit breaker, rating of the breaker and the load connected to each breaker
- o Tabulation of total loads on each phase of the panel feeder and the total load on all phases
- o Itemized list of materials required to accomplish the installation.

Most electronics equipment in a microwave radio system requires a source of single phase, 115-volt, 50 to 60-cycle AC power. The non-technical load equipments require three-phase power. Since most commercial power units furnish three-phase power, the station load must be evenly divided between the three legs. With modern solid-state equipments, a 24-volt DC or 48-volt DC (optional) requirement exists for an auxiliary power source in event of prime power failure.

Power distribution from a panel board is protected by means of automatic circuit breakers. Individual equipments are connected to the panel boards by running the wiring in cable racks or conduits, or a combination of both.

Insure that power wiring and signal wiring are run in separate ducts. Any conduit used must be of sufficient size to permit ready installation or withdrawal of the conductors. Consideration should be given to dissipation of the heat generated in wire "bundles" without injury to insulation.

The wiring to each equipment will be sized to carry the load current with no noticeable voltage drop. Circuit breakers must be rated in accordance with the current carrying capacity of the conductor. Signal leads will consist of individually shielded pairs of a size consistent with good commercial practice.

Convenience outlets will be provided in the base of equipments in sufficient number to provide maintenance personnel ready access to power for test equipment or tools. Power distribution systems will be designed in complete conformance with the requirements of the National Electric Code (NEC) of the National Board of Fire Underwriters.

15.10.7 Grounding Drawings

The station grounding system is shown by a grounding diagram that specified ground system routing, cable sizes, type and position of all ground connectors and an itemized list of materials required to install the grounding system. The station ground shall be in accordance with NAVELEX 0101, 102 Naval Communication Station Design.

15.10.8 Equipment Installation Drawings

All necessary information to accomplish installation of an equipment is provided by the equipment installation drawing. It contains installation details peculiar to a specific equipment and illustrates the planned procedures for accomplishing each portion of the installation effort. When several different equipments require identical basic installation information, a common installation drawing may be submitted for individual equipment drawings. In either case, the drawing provides the list of materials required to accomplish the individual equipment installation efforts.

15.10.9 Transmission Line Layout

Details for the RF transmission line installation are provided by a transmission line layout. This drawing shows transmission line routing. The layout shows what size "pieces" to use at each point along the route and where bends and flexible sections are to be located. The location of gas barriers and the arrangement of the pressurizing system are also included on this drawing. The major consideration in planning coaxial transmission line runs is to keep them as short as possible. Waveguide planning is subject to certain restrictions. Some general rules for planning the layout of waveguide systems follows:

- o Waveguide runs should be made as short as possible to achieve minimum line loss
- o Waveguide clamps should be spaced every four feet to support waveguide runs
- o Allowance must be made for the expansion and contraction of waveguide. For a change in temperature of 100 degrees Fahrenheit, the change in length is approximately 1-1/2 inches per 100 feet. Under the same conditions, the change in length of the waveguide relative to the change in height of a steel tower is approximately 1/2 inch per 100 feet.

When sections of waveguide are joined, the rectangular openings must be made to coincide and a choke flange should be mated with a plain flange. In vertical runs, the choke flange should be uppermost so that moisture cannot collect in the slot of the choke.

Sharp bends in flexible waveguide sections should be avoided.

Flexible waveguide sections should be used only where freedom of motion is required. A typical installation has the rigid waveguide attached to the midpoint of the tower; waveguide clamps above and below this point permit the waveguide to expand or contract; a flexible section at the antenna not only permits the waveguide to change length, but also permits antenna alignment; a flexible section at the base of the tower has two functions - to permit changes in length and to provide for any motion of the tower with respect to the equipment building. Inside the building, a flexible section(s) may be used to relieve strain between the microwave equipment and the building, and also to serve as an odd length of waveguide.

Pressurizers and automatic dehydrators should be used where the total waveguide length to a single equipment exceeds fifty feet. This figure should be adjusted according to prevailing humidity conditions. Pressure windows are available to isolate pressurized and unpressurized portions of the waveguide.

15.11 TOWER REQUIREMENTS

In addition to the calculation of tower heights, it is necessary to consider the types of towers (or similar structures) available, the structural requirements of the towers, government regulations concerning such structures, and the preparation of installation specifications. These matters are important in that they have a significant effect upon the cost, performance, and reliability of the entire microwave radio-relay system. Fortunately, many of the engineering problems have been simplified by industry-wide acceptance of EIA (Electronic Industries Association) standards, and as a result, standard towers are readily available to suit most needs. For special problems, technical assistance can be obtained from the engineering departments of tower manufacturers.

15.11.1 Types of Towers

Any structure that is sufficiently high to meet the clearance requirements of the microwave signal path, and that provides a stable mounting place for an antenna or plane reflector, may be used as, or in place of, a tower. The antenna or plane reflector must remain rigid within a specified tolerance to assure maximum directivity of the radiated beam. Grain elevators, office buildings, mountains, wooden poles, and steel structures have been successfully used to provide the required elevation and to maintain the necessary rigidity.

For lower tower height requirements (30 to 60 feet), wooden poles of good quality, properly preserved, may be used if they are available in the required lengths. Consideration must be given to guying arrangements in order to obtain the required rigidity. It is often necessary to use H-frame or other special construction techniques to attain this rigidity.

Generally, a hot-dipped galvanized-steel tower is the most desirable support for an antenna or plane reflector. This type of tower is easily shipped in sections 10 or 20 feet in length, it is durable, it can be easily climbed, and it can be procured to meet the exact height requirements. Both the guyed and self-supporting types of towers may be obtained to support the antenna or plane reflector in increments of height up to several hundred feet. In general, it is not economically advisable to go above 300 feet because of the rapidly increasing cost of suitable towers. Guyed towers are generally preferred over the self-supporting type because they are more economical and because they can be installed more easily (foldout 15-1). The guyed tower can usually be placed closer to a shelter; this is advantageous when a roof-mounted antenna and a tower-mounted plane reflector are to be used. Of course, the guyed tower requires a larger site because of the need for installing guy anchors to which the guy wires can be attached. It can be seen that self-supporting towers are more likely to be required where real estate is at a premium or where the tower is to be placed on a roof of limited area.

15.11.2 Physical Factors and Design Considerations

The specifications for antenna towers will depend somewhat upon the terrain features (soil bearing pressure) of the location chosen, but they are mainly dependent upon the size, physical arrangement, and beam width of the paraboloidal antenna or passive reflector to be mounted at the top of the tower and upon the meteorological conditions to be expected.

15.11.3 Foundations and Soil Bearing Capacity

Tower installation specifications usually include a statement of the minimum allowable value of bearing pressure for the soil upon which the foundation will be placed. Table 15-3 may be used as a guide in determining whether the intended location has sufficient bearing capacity to support a tower of standard design, or whether a special base design is needed. Because of the arbitrary nature of soil designations, an adequate safety margin should be allowed when using the table. As an example, assume that the tower to be used is designed for 4000 pounds per square foot soil-bearing pressure and that the soil at the site will withstand a maximum of only 3000 pounds per square foot. To be conservative, the design bearing pressure of the soil would be taken as 2000 pounds per square foot. These values indicate that the area of the base should be slightly more than doubled in order to reduce the design pressure by one-half. (The additional concrete added to the base in enlarging it keeps the variation between area and pressure from being exactly inverse.) A good approximation is obtained by a factor of 1.6. Whenever possible, expert advice should be obtained to substantiate such findings. Standard foundations should be of reinforced concrete, with anchor bolts firmly embedded, and should be of such dimensions as not to exceed a soil pressure of 4000 pounds per square foot under the specific loading area of the tower. A typical example of a concrete base for a microwave tower is illustrated in foldout 15-1. The relative dimensions of the foundation shown are typical for a 250-foot tower; these dimensions will vary, depending on the tower height, design load, and soil conditions. The height of the foundation above the ground line will be governed by ground-water conditions, but in any event should be not less than 6 inches. In warm climates, where frost is not a problem, the depth of the foundation will be governed only by tower-load and soil-bearing characteristics, but in colder climates it will be necessary to extend the depth of the foundation below the frost line or to firm ground.

15.11.4 Wind Loading

Towers are generally designed for a wind load of 30 pounds per square foot of flat surfaces without ice coatings. For areas subject to tornadoes or hurricanes, or where ice loads may be excessive, heavier towers are necessary. Wind loads are defined as the maximum forces and torques produced by a specified unit horizontal wind pressure acting on the tower, antenna assemblies, reflectors, and other members (additional radio antennas, etc.), which may be attached to the tower. Meteorological wind data is usually given in terms of wind velocity in miles per hour. If the wind velocity is known, the wind pressure that is exerted on a tower can be calculated by means of the following formula:

Table 15-3. Maximum Soil Bearing Capacity

MATERIAL	MAXIMUM ALLOWABLE BEARING VALUE (LB PER SQ FT)
Bedrock (sound) without laminations	200, 000
Slate (sound)	70, 000
Shale (sound)	20, 000
Residual deposits of broken bedrock	20, 000
Hardpan	20, 000
Gravel (compact)	10, 000
Gravel (loose)	8, 000
Sand, coarse (compact)	8, 000
Sand, coarse (loose)	6, 000
Sand, fine (compact)	6, 000
Sand, fine (loose)	2, 000
Hard clay	12, 000
Medium clay	8, 000
Soft clay	2, 000

$$P = KV^2$$

(15-3)

where:

P = the wind pressure in pounds per square foot

K = the wind conversion factor (considered to be 0.004 for flat surfaces, and 2/3 of 0.004 for cylindrical surfaces)

V = the wind velocity in miles per hour.

Table 15-4 indicates the wind loading that can be expected for several wind velocities. The expected wind velocity is taken from meteorological records. The projected area for towers having a triangular cross section is generally assumed to be 1.5 times the area of one face, and the projected area for towers having a square cross section is generally assumed to be 1.75 times the area of one face.

Table 15-4. Wind Loading Values for Flat Surfaces

WIND (MPH)	LOADING (LB PER SQ FT)
25	2.5
50	10.0
80	25.6
88.6	30.0
100	40.0

Meteorological data, which is representative of peak and average wind velocities and icing conditions for areas throughout the world, can be obtained from prepared charts and graphs. An example can be found in EIA Standard RS-222, which includes a map of the United States and related data showing wind-loading zones and values.

15.11.5 Twist and Deflection

The twist and deflection tolerances of the tower structure depend upon the characteristics of the antenna system. The maximum value of these tolerances is also determined by the required reliability of the overall communications system. Tower twist at any specified elevation is defined as the horizontal angular displacement of the tower from its no-wind-load position at that elevation is defined as the angular displacement of a tangent to the tower axis at that elevation from its no-wind-load position at that elevation.

The importance of twist and deflection tolerances can easily be understood when the antenna beam width is considered. Experience indicates that it is satisfactory to provide sufficient tower stability to limit the decrease in signal strength caused by deflection of the antenna to 3 dB for winds up to 50 mph, and to 10 dB for winds up to 80 mph. The resulting occasional decrease in signal strength does not impair system performance because a good system will be designed for a fading margin of approximately 30 dB. Tropospheric fading and the decrease in signal strength caused by tower motion do not occur simultaneously; during periods of severe tower motion, therefore, the fading margin is available to compensate for the deflection of the antenna beam from the norm.

For antenna systems, the twist and deflection specifications must conform with the limitations dictated by the beam width, which is inversely proportional to the size of the antenna or reflector. The specifications for 4-, 6-, and 8-foot systems are given in Table 15-5.

For systems using directly beamed paraboloids without plane reflectors, the deflection tolerance may be reduced to the same value as the twist tolerance. In general, towers designed to meet required wind-load and ice-load specifications are sufficiently rigid to meet twist and deflection tolerances. For increased rigidity, it is advisable

to use rigid torque braces in the guying system, and six guy wires at the top of the tower instead of three guy wires. When cross-connected, these guys will maintain a high degree of rigidity. The guy anchors should be capable of withstanding the maximum load imposed by the guy wires, with an adequate margin of safety. Furthermore, the guys must be evenly tensioned and the turnbuckles securely locked, to prevent turning and resultant loosening of the guys. A typical guyed microwave tower is illustrated in foldout 15-1. Note the guying arrangement for maximum stability, and the requirements set forth for proper installation of the guy anchor section.

Table 15-5. Antenna-Tower Twist and Deflection Specifications for Antenna Systems Using Plane Reflectors

PARABOLOID DIAMETER (FT)	WIND VELOCITY (MPH)	PERMISSIBLE TWIST (DEGREES \pm)	PERMISSIBLE DEFLECTION (DEGREES \pm)
4	50	1.5	0.75
	80	2.5	1.25
6	50	1.0	0.50
	80	1.7	0.80
8	50	0.75	0.40
	80	1.25	0.60

15.11.6 Lightning Protection

Lightning protection must be considered as part of each tower installation. Tower grounding procedures establish an electrical connection between the tower and the earth to provide proper lightning protection. In the case of directly beamed paraboloidal antenna systems, the waveguide path down the tower cannot be considered as a reliable path to ground. Steel tower installations should be protected by the use of a low-resistance ground connection at the base of the tower. When wooden poles are used for towers, copper wire should be connected from the top of the pole to a low-resistance ground arrangement at the base of the pole. The steel tower should be grounded in the following manner: Install ground rods on opposite sides of each tower foundation at a distance not greater than 12 inches from the foundation. Use 5/8-inch-diameter ground rods, or equivalent, and drive them not less than 8 feet into the ground. Bond each leg or the common base of the tower to the ground rods by means of No. 6 AWG or larger copper wire. Using the same size wire, connect the tower ground system to the station ground system. Specifications for the station ground system are in NAVELEX 0101, 102. Install ground rod in the same manner at each concrete guy anchor; the metal portion of the guy anchor should be bonded to the ground rod. Where steel or other metallic anchors are in direct contact with the earth, no additional ground rods are required.

Any and all equipment mounted on a tower shall be so fastened that it is effectively grounded through the tower. On structures provided with obstruction lights, it may be desirable to place suitable lightning arresters on the wires supplying these lights, at least between the lower portion of the tower and the power-supply source, and in some cases also at the top of the tower.

The above-mentioned standards as set forth by the EIA, through the mutual cooperation of electronics equipment manufacturers, are the minimum requirements for such installations. These standards, in addition to sound engineering judgment, will determine the specific requirements for any tower installation.

As a general rule, the maximum resistance that is permissible between any two ground rods prior to connection to the tower is 2 ohms. If the resistance between rods is found to be greater than 2 ohms, it will be necessary to increase the conductivity of the soil. One method of lowering the resistance path between ground rods is as follows: Dig a tapered trench around each ground rod. (The trench should be approximately 2 feet deep, with a bottom radius of 1 foot and a top radius of 2 feet). Then place approximately 40 pounds of rock salt in the trench and backfill the trench.

15.11.7 Painting and Lighting Requirements

In order to prevent excessive hazards to air commerce, antenna towers and similar structures must be marked in such a way as to make them conspicuous when viewed from aircraft. The type of marking to be used depends, in part, on the height of the structure, its location with respect to other nearby objects, and its proximity to aircraft traffic routes near landing areas.

Requirements and specifications for the marking and lighting of potential hazards to air navigation have been established through the joint cooperation of the Federal Aviation Agency (FAA), the Federal Communications Commission (FCC), the Department of Defense (DOD), and appropriate branches of the broadcasting and aviation industries. The specifications determined by these groups aid in the final decisions as to whether or not a structure constitutes an obstruction to air navigation.

In the conduct of the preliminary survey of main and alternate routes for microwave sites, it is advisable to determine the prevailing ordinances concerning such structures, and perhaps to discuss them with local government and building authorities. When dealing with locations within the continental limits of the United States, the latest copies of Government Rules and Regulations (FCC FORM 715 and FCC Rules Part 17, and FAA Standards for Marking and lighting Obstructions to Air Navigation), with all revisions, should be consulted. These rules not only apply to specifications for antenna structures, but also set forth the forms which must be submitted to the FCC, FAA, and U. S. Coast and Geodetic Survey (FCC Form 4-1A Revised, FAA Form 117, FAA Form ACA-114, and C & G. S. Form 844).

a. Day Marking. In order to warn airmen of the presence of obstructions during daylight hours in good weather conditions, all structures that may present a hazard to air commerce should be painted from top to bottom with alternate bands of orange

and white aviation surface paints, terminating in orange bands at both top and bottom. The width of the orange bands should be approximately one-seventh the height of the tower structure, provided, however, that the bands shall be not more than 40 feet nor less than 1-1/2 feet in width. If the height of the tower causes the width of the color bands to fall outside these limits, a larger or smaller number of bands should be used, depending on whether the structure is greater than 280 feet or less than 35 feet in height. The surface coatings used should be selected in accordance with the applicable specifications and existing approved aviation surface paints.

b. Night Marking. The purpose of lighting a structure that is a hazard to aircraft operations is quite obvious. Both the FCC and FAA lighting specifications are set forth in terms of the heights of the antenna structures. Figure 15-5 illustrates the requirements for the placement of obstruction lights on towers up to 600 feet in height. The specifications further stipulate that the placement of the lights on either square or rectangular towers shall be such that at least one top or side light be visible from any angle of approach. When a flashing beacon is required, it shall be equipped with a flashing mechanism capable of producing not more than 40 nor less than 12 flashes per minute, with a period of darkness equal to one-half the luminous period.

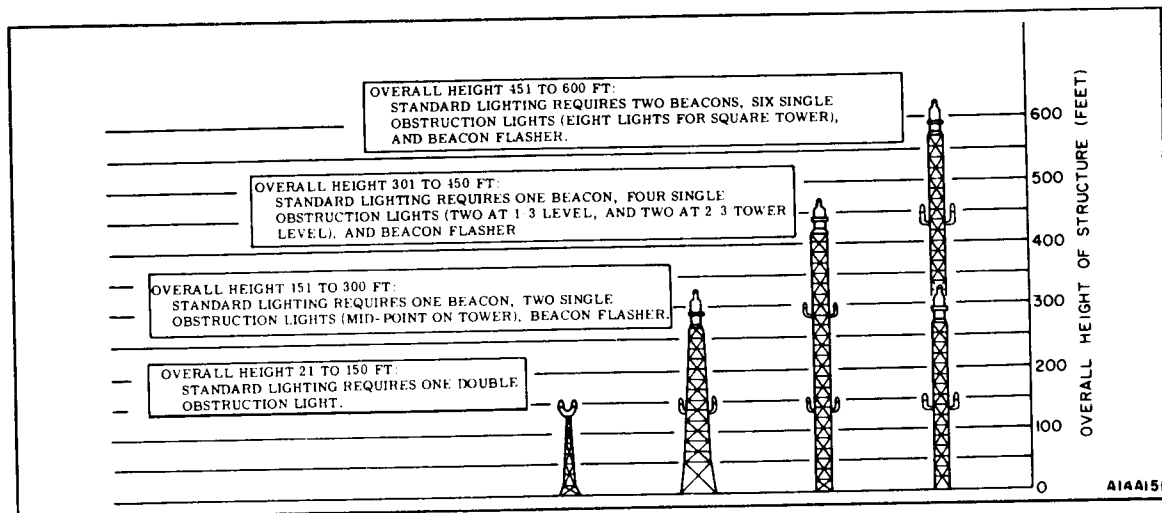


Figure 15-5. Tower Lighting Specifications

When the tower structure is in the process of construction, the FCC and FAA require that temporary lights, consisting of at least two 100-watt lamps enclosed in aviation red globes, be displayed at the top of the structure from sunset to sunrise. Lights must also be installed at intermediate heights, if necessary, in accordance with the general specifications indicated in figure 15-5.

(1) Lamp Requirements. The lamps most commonly used for tower lighting have a rated operating voltage of 115 volts. The specifications state that the maximum voltage variation at the lamps should not exceed 5 percent, i. e., the regulation above and below the rated voltage should not exceed 2.5 percent. It is quite possible that the regulation of the primary voltage source will not fall within these limits; however, these values are useful in determining the allowable voltage drop in the wiring to be selected for lighting a particular obstruction. The stated requirements for obstruction lights and beacons are 111 and 620 watts, respectively; special lamps are designed to meet specifications for reliability and long life expectancy (3000 hours). The lamps should be encased in a beacon assembly or obstruction light assembly which uses approved aviation-red globes in ruggedized, watertight housings.

(2) Light Control. The FCC requires that the tower lighting be exhibited during the period from sunset to sunrise unless otherwise specified. At unattended microwave installations, a dependable automatic obstruction-lighting control device must be provided. A light-sensitive control device or an astronomic dial clock and time switch may be used to control the obstruction lighting in lieu of manual control. This requirement can be met in microwave installations by employing a photoelectric control unit that applies power to the lights when the north skylight intensity is less than approximately 35 foot-candles, and that disconnects the power when the north skylight intensity is greater than approximately 58 foot-candles.

(3) Fault Indication. To insure the proper operation of tower lights, the FCC specifies that the lights be inspected at least once every 24 hours; the inspection can be performed either by direct observation or by observation of an automatic and properly maintained indicator designed to register failure of such lights. Where obstruction lighting is not readily accessible for periodic inspection, the rules permit the use of electric signaling devices to indicate lamp failure. Should the fault alarm system register a failure in obstruction or beacon lighting, the failure must be reported to the nearest Airways Communication Station of the Federal Aviation Agency. The FAA must be notified of any code beacon, rotating beacon, or top light failure if not corrected within 30 minutes after failure.

(4) Tower-Lighting Control Circuits. The block diagram of a typical tower-lighting control circuit is shown in figure 15-6. The operation of the circuit is as follows: When the photoelectric control unit senses a light intensity of less than 35 foot-candles, a relay within the unit applies AC power to the coil of an obstruction lamp relay and to the motor of a flashing mechanism. As a result, the relay is energized and its contacts apply power to the obstruction lamps. Also, the motor of the flashing mechanism causes power to be applied intermittently to the beacon lamps by way of the fault relay, and the beacon lamps flash on and off. If the flashing mechanism fails to function or the beacon lamps burn out, the fault relay signals the failure to the fault alarm system, which sounds an alarm at a remote control center. Should any problem arise concerning the proper procedure to be followed in the marking or lighting of tower structures, the FAA will provide professional guidance for obstruction marking. Since the FCC specifications for tower marking and lighting are, in general, more rigid than those of the FAA, and the proposed lighting must be approved by the FCC before that agency will issue a construction permit, it may be expected

that the FCC specifications will apply in those cases where FAA and FCC specifications differ. In overseas installations, regulations imposed by cognizant military and/or governmental agencies must be studied.

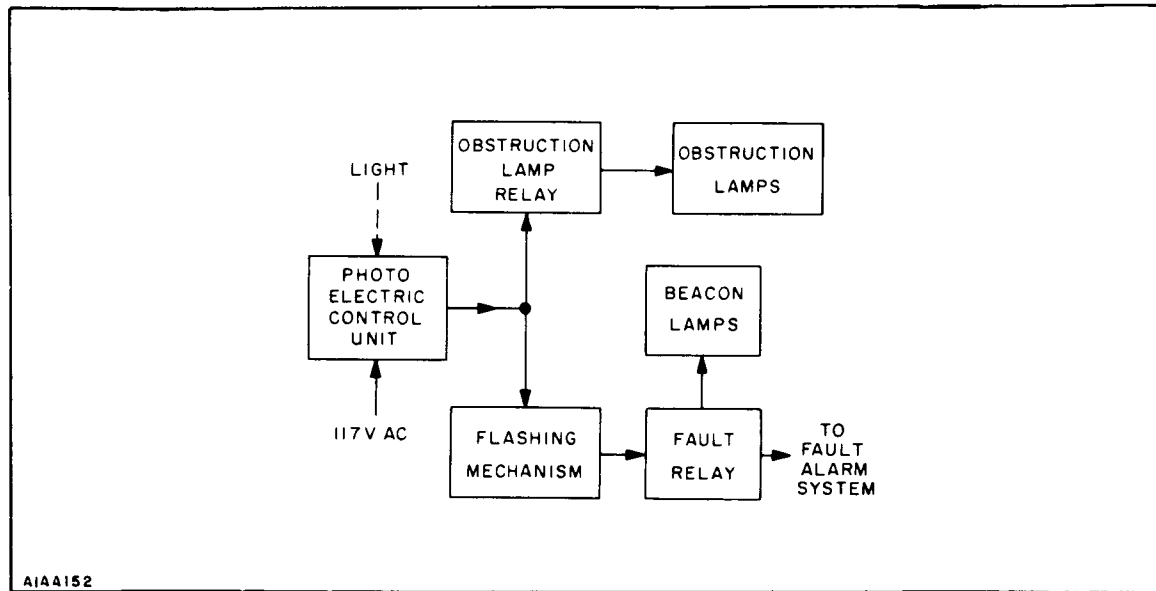


Figure 15-6. Tower Lighting Control Diagram

15.11.8 Tower Specifications

If a tower is to be furnished and/or installed by an outside contractor, specifications must be prepared to define the extent of the work and to establish responsibility. Written specifications such as those given in the following paragraphs, and any applicable drawings, can be said to constitute the tower specifications, provided, of course, that they are presented in the proper format as given in NAVFAC DM-2.

The tower shall be a guyed, steel, non-insulated structure of uniform cross section. A pivoted base type tower shall be considered preferable but not mandatory. The tower shall be supplied with guys, anchors, and all necessary hardware for erection. When erection is specified the tower shall be erected at sites specified by the purchaser, and the contractor shall provide all material, labor and tools necessary to install the complete tower, plan reflectors and accessories, such as tower lighting equipment and VHF antenna as required by the purchase order.

15.11.9 Design Specifications

In general, all material, loading, unit stresses, manufacture, workmanship, finish, plans, markings, foundations and installation shall conform with EIA standard RS-222 as amended to date. For towers in excess of 300 feet in height, the requirements of NAVPAC DM-2 shall apply.

Loading shall be based on the coaxial VHF antenna and transmission line, obstruction lighting equipment including wiring, and two plane reflectors.

With the tower fully equipped but with a wind load of 20 pounds per square foot on flat surfaces and 13.3 pounds per square foot on cylindrical surfaces, the tower shall not exceed the following limits of twist and deflection at the elevation of reflector attachment.

- o Twist - 1.25 degrees
- o Deflection - 0.60 degrees.

The angle of twist shall be defined as the horizontal angular displacement of the tower from its no wind load position at the specified elevation. The angle of deflection shall be defined as the angular displacement of a tangent to the tower axis at the specified elevation from its no wind load position.

The path from paraboloidal antennas (located near base of tower) to plane reflectors must be unobstructed by any member of the tower structure but may be obstructed by guy wires.

The two passive reflectors shall be mounted at the top of the tower at any angle of approximately 45 degrees from the vertical. The mounting for the two reflectors shall be designed to permit orientation of the reflectors in azimuth so that the included angle with respect to each other covers a range of 90 degrees to 180 degrees. Each reflector shall be capable of rotating through a range of 90 degrees in azimuth about its own pivot point.

- a. Tower Height. Shall be specified by purchase order.
- b. Plans. One complete set of prints shall be submitted to the purchaser for approval prior to fabrication. Complete bill of material, plans, and erection drawings, including guy tension data, shall be supplied showing all necessary details for installation. One set of prints or reproduced tracings shall be supplied to the purchaser.

NOTE

When tower manufacturer does not install tower, one complete set of erection prints shall be shipped with each tower.

c. Calculations. The tower manufacturer shall submit stress calculations and twist and deflection calculations which must be approved by the purchaser prior to fabrication.

Sample approval by the purchaser is required but this approval does not release the manufacturer of responsibility for failure under conditions covered by the specifications.

d. Tower. The tower manufacturer shall specify the warranty life of tower and necessary maintenance procedures.

The tower manufacturer shall supply foundation and guy anchor design specifications, calculations, and drawings for each height of tower for approval by the purchaser. All towers shall provide suitable climbing facilities to the top of the tower, including access to any beacons or antennas mounted thereon.

e. Grounding. The tower manufacturer shall supply the following as a minimum amount of grounding material for each tower:

- o Two 8-foot long, 5/8 inch diameter copper covered ground rods or equivalent for each tower base
- o One 8-foot long, 5/8 inch diameter copper covered ground rod or equivalent for each guy anchor
- o Grounding wire, No. 6 AWG copper wire as required (minimum length 30 feet)
- o Two grounding clamps per ground rod for attaching the grounding wire from the ground rod to the guy anchor or tower mast.

f. Installation. Erection of tower when specified by the purchase order shall be in accordance with the following specifications:

- o The foundation and guy anchors shall be installed in accordance with approved drawings as furnished under paragraph 3-544, and shall conform to EIA standard RS-222.
- o Prior to installation, soil conditions shall be reviewed and determined through data submitted on the site plan and/or by contractor's survey. Where actual soil conditions are not normal, the contractor shall supply complete information of soil conditions and the remedial measures that are to be taken. When construction has been started and abnormal soil conditions are encountered, the contractor shall immediately notify the purchaser and modify the construction to suit conditions, after obtaining permission from the purchaser
- o The tower shall be erected in accordance with best modern practices for similar structures and shall conform to the erection drawings

- o The ground rods shall be driven into the ground at 12 in. minimum distance from each side of the foundation and approximately 6 ft. to 8 ft. apart. Ground rods shall be connected to each of two tower legs and form a good electrical and mechanical contact

- o Tower lights, when specified, shall be installed in accordance with EIA specifications

- o VHF antenna and coaxial transmission line, when specified, shall be installed in accordance with the specifications

- o Painting of tower, when specified, shall conform with latest CAA and FCC regulations

- o Passive reflectors shall be installed in accordance with the site plan and as specified on the purchase order.

15.12 SAFETY

15.12.1 Safety Measures

Safety implies the absence and/or control of conditions that can cause personal injury or death or damage to or loss of equipment or property. Within the system safety is concerned with the elimination or control of those factors affecting the safe and efficient operation of personnel, equipment and facilities organized to attain a common goal. The criteria established in the safety engineering portions of MIL-STD-1472, MIL-STD-882, MIL-STD-454 followed in the test, checkout and operation of the equipment.

15.12.2 Safety Plan

The objective of safety is to assure maximum freedom from inadvertent and possibly destructive mishaps resulting from facilities, equipment, procedural or personnel deficiencies during all phases of system operation.

15.12.3 Electrical Safety

Provisions are normally incorporated in the equipment to protect personnel from accidental contact with dangerous voltages while operating the equipment or performing maintenance. Some of the features provided for this assurance are:

- o Each equipment cabinet grounded
- o Convenience outlets will be the 3 wire type to automatically ground the case or frame of any tools and equipment
- o AC power plugs equipped with safety ground

- o All subsystem drawers equipped with circuit breakers. The AC input terminals appropriately covered for protection during maintenance periods
- o Voltages greater than 70 volts are protected by barriers that are labeled with the highest voltage encountered upon removal
- o Voltages greater than 500 volts marked with danger labels and completely inaccessible to personnel
- o Interlocks provided, when voltages in excess of 70 will be exposed to personnel. Interlocks are two piece type and when bypass devices are required, returning the door or cover to its operating position automatically opens the bypass switch and leaves the interlock in its normal functioning position
- o Provision for capacitor discharge devices
- o No voltages will be exposed when equipment connectors are removed from cabinets
- o Utilization of step down circuitry for measuring high voltages
- o Maintenance telephone system provided to allow coordination of activity during servicing.

15.12.4 Mechanical Safety

A number of simple features should be provided to protect personnel from mechanical hazards. Equipment cabinets are designed without sharp corners. Slide mounted drawers are provided with automatic stops to prevent accidental disengagement of the slides. Some additional mechanical safety measure deals with lighting, provision of fire extinguishers, adequate exits in case of emergency, environmental control, use of non-slip mats in front of equipment cabinets.

15.13 PERSONNEL REQUIREMENTS

Personnel should be selected whose background and basic skills lend a high degree of assurance that all the qualifications can be met after training, thus meeting the functional organizations minimum requirements. Some job descriptions and qualifications for microwave communication systems personnel deployed at active terminals would be the following:

15.13.1 Operations Section Head

The Operations Section Head is responsible for effective operations and maintenance of the continuous communication service. This includes directing continuous shift operations; enforcing maintenance methods and procedures; and utilizing personnel in an efficient manner. In the absence of the Assistant Station Manager he will assume those duties.

In addition, he has parallel responsibilities to the Support Section Head, which include, but are not limited to:

- o Gives direction and assists in the calibration, check-out and test trouble analysis, adjustment and alignment of the basic equipment
- o Establishes and supervises maintenance and operations activities
- o Analyzes system operating trends based on operations records
- o Evaluates system and subsystem discrepancies and/or failures and takes appropriate action for changes
- o Reviews and makes changes to operating and maintenance procedures
- o Evaluates technical logistic problems
- o Enforces and recommends quality control procedures
- o Evaluates and makes changes in supporting documentation of the communications equipment and support equipment
- o Coordinates all maintenance activities in both sections.

15.13.2 Support Section Head

The Support Section Head, through three or four Maintenance Leaders:

- o Establishes and supervises the more complex maintenance work areas
- o He directs and assists with the in-depth maintenance routines
- o Analyzes system operating trends based on operating records
- o Responsible for the maintenance of all equipment histories, test data collection, and data documentation
- o Reviews and recommends changes to operating and maintenance procedures
- o Evaluates technical logistics problems
- o Recommends quality control procedures
- o Evaluates and makes changes in supporting documentation on the communications equipment and support equipment
- o Responsible for spares inventory, teletype repair, and test equipment maintenance/calibration.

In addition to this function devoted to the basic equipment, he must be capable of directing the maintenance of facilities through the Facilities Leader. This requires giving direction in the maintenance of all heavy equipment as follows: continuous duty power generating equipment; heating, air-conditioning and ventilating units; and heat exchangers.

15.13.3 Maintenance Leader

The Maintenance Leader is responsible for the performance of in-depth preventive maintenance routines on the equipment that requires specialized knowledge not possessed by the Operations Section personnel. He is responsible for specifically assigned communications equipments requiring complex alignment, adjustment, and calibration procedures. He performs preventive maintenance routines himself; and he has Communications Shift Supervisors and Communication Technicians assigned to him for the performance of routine tasks. These are the tasks that can be assumed by the shift personnel after procedures are learned. He must cross-train these personnel in the more complex maintenance tasks in which he is knowledgeable, and monitor the performance of the various routine maintenance he has given them. He directs work which may involve disassembly of significant portions of the communications equipment. He provides back-up to the Communications Shift personnel when communications problems occur.

15.13.4 Facilities Leader

The Facilities Leader supports his Section Head through independent maintenance activities performed on heat, ventilation, and air-conditioning equipment. He is responsible for the all-important maintenance of uninterrupted power. This includes the care, repair and overhaul of the diesel engines. He is provided help in this by having the Electrician-Machinist assigned full time to him. Cross-support is given by four shift Electrician-Technicians. In addition, he directs the housekeeping and groundskeeping personnel required for the maintenance of buildings, structures, water, sanitation, and lighting, as well as fire-fighting, roads, and grounds, when required.

15.13.5 Communications Shift Supervisor

The Communications Shift Supervisors are responsible for continuous operation of the station, including all communications circuits and the equipments supporting communications, including Message Center. He directs activities from the control center. In order to accomplish this, he performs calibration, checkout, trouble-shooting, testing, and operations of the communications equipment himself and with the aid of the Communications Technicians. He sets up new communications channels as traffic routing changes, and provides the basic quick-reaction fault location and correction leadership. He is responsible for the station log and careful documentation of significant events on his shift.

Typically, he monitors communications circuits using idle channel noise measurements. He makes deviation and level adjustments. He monitors the spectral display of all transmit and receive sub-carriers to detect intermodulation anomalies produced

by saturation effects. He monitors television transmissions, establishing routing for it and adjusting its baseband parameters.

Additionally, he performs preventive maintenance work assigned to him by the Operations and/or Support Section Head.

15.13.6 Communications Technician

The Communications Technician performs routine calibration, troubleshooting, testing and operation of the communications equipment, and the message center equipment. He is able to quickly analyze and isolate communication faults and equipment anomalies independently. He has detailed knowledge in the total variety of patching and use of replaceable modules. Typically, he performs tasks parallel to those of the Communications Shift Supervisor, and provides cross-support to the Support Section by doing routine maintenance himself and giving hands-on assistance to Maintenance Leaders in the more complex and/or time consuming routines.

15.13.7 Electrician-Technician

The Electrician-Technician is required to directly monitor the operation of the diesel-driven power generating plant in the power building. He performs generator phasing and cutover operations as required by preventive and corrective maintenance schedules. He is necessary for quick-reaction failure correction in the power generating plant. He detects faults beyond the capability of monitoring devices supplied with the diesel-driven power generating equipment. He provides cross-support, hands-on repair and overhaul of heavy equipment, and maintains power building logs and records.

15.13.8 Electrician-Machinist

The Electrician-Machinist is assigned full time to the Facilities Leader to accomplish preventive maintenance of the support facilities. In addition, he fabricates semi-precision special parts and assemblies and makes repairs using the shop power tools available to him. He provides hands-on repair and overhaul of the diesel driven power generating plant including the diesel engines.

15.13.9 Spareskeeper

The Spareskeeper is directly responsible for the maintenance of the spares inventory and attendant record keeping. In addition, he provides hands-on maintenance, repair, and on-site calibration of all electronic test equipment. He takes care of all the necessary arrangements for off-site maintenance and coordinates factory repair and returned goods activity. He does the repair and maintenance of teletype equipment.