CHAPTER 2

ANTENNAS

As an Electronics Technician, you are responsible for maintaining systems that both radiate and receive electromagnetic energy. Each of these systems requires some type of antenna to make use of this electromagnetic energy. In this chapter we will discuss antenna characteristics, different antenna types, antenna tuning, and antenna safety.

ANTENNA CHARACTERISTICS

An antenna may be defined as a conductor or group of conductors used either for radiating electromagnetic energy into space or for collecting it from space. Electrical energy from the transmitter is converted into electromagnetic energy by the antenna and radiated into space. On the receiving end, electromagnetic energy is converted into electrical energy by the antenna and fed into the receiver.

The electromagnetic radiation from an antenna is made up of two components, the E field and the H field. The total energy in the radiated wave remains constant in space except for some absorption of energy by the earth. However, as the wave advances, the energy spreads out over a greater area. This causes the amount of energy in a given area to decrease as distance from the source increases.

The design of the antenna system is very important in a transmitting station. The antenna must be able to radiate efficiently so the power supplied by the transmitter is not wasted. An efficient transmitting antenna must have exact dimensions, determined by the frequency being transmitted. The dimensions of the receiving antenna are not critical for relatively low frequencies, but their importance increases drastically as the transmitted frequency increases.

Most practical transmitting antennas are divided into two basic classifications, HERTZ ANTENNAS (half-wave) and MARCONI (quarter-wave) ANTENNAS. Hertz antennas are generally installed some distance above the ground and are positioned to radiate either vertically or horizontally. Marconi antennas operate with one end grounded and are mounted perpendicular to the earth or a surface acting as a ground. The Hertz antenna, also referred to as a dipole, is the basis for some of the more complex antenna systems used today. Hertz antennas are generally used for operating frequencies of 2 MHz and above, while Marconi antennas are used for operating frequencies below 2 MHz.

All antennas, regardless of their shape or size, have four basic characteristics: reciprocity, directivity, gain, and polarization.

RECIPROCITY

RECIPROCITY is the ability to use the same antenna for both transmitting and receiving. The electrical characteristics of an antenna apply equally, regardless of whether you use the antenna for transmitting or receiving. The more efficient an antenna is for transmitting a certain frequency, the more efficient it will be as a receiving antenna for the same frequency. This is illustrated by figure 2-1, view A. When the antenna is used for transmitting, maximum radiation occurs at right angles to its axis. When the same antenna is used for receiving (view B), its best reception is along the same path; that is, at right angles to the axis of the antenna.

DIRECTIVITY

The DIRECTIVITY of an antenna or array is a measure of the antenna's ability to focus the energy in one or more specific directions. You can determine an antenna's directivity by looking at its radiation pattern. In an array propagating a given amount of energy, more radiation takes place in certain directions than in others. The elements in the array can be arranged so they change the pattern and distribute the energy more evenly in all directions. The opposite is also possible. The elements can be arranged so the radiated energy is *focused* in one direction. The

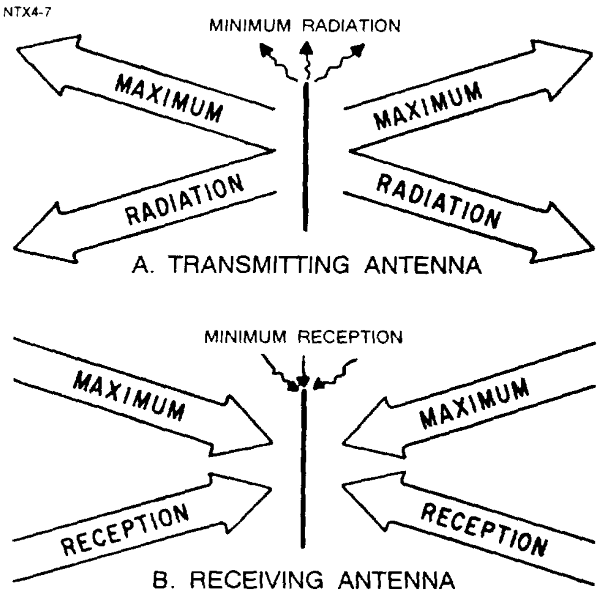


Figure 2-1.—Reciprocity of antennas.

elements can be considered as a group of antennas fed from a common source.

GAIN

As we mentioned earlier, some antennas are highly directional. That is, they propagate more energy in certain directions than in others. The ratio between the amount of energy propagated in these directions and the energy that would be propagated if the antenna were not directional is known as antenna GAIN. The gain of an antenna is constant. whether the antenna is used for transmitting or receiving.

POLARIZATION

Energy from an antenna is radiated in the form of an expanding sphere. A small section of this sphere is called a wavefront. positioned perpendicular to the direction of the radiation field (fig. 2-2). Within this wavefront. all energy is in phase. Usually, all points on the wavefront are an equal distance from the antenna. The farther from the antenna the wave is, the less curved it appears. At a considerable distance, the wavefront can be considered as a plane surface at right angles to the direction of propagation.

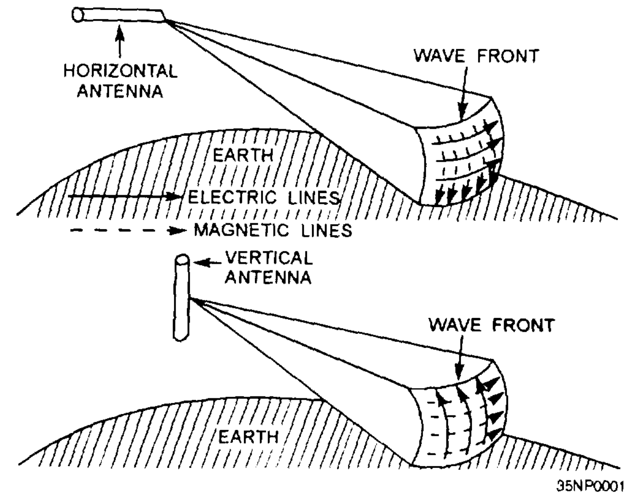


Figure 2-2.—Horizontal and vertical polarization.

The radiation field is made up of magnetic and electric lines of force that are always at right angles to each other. Most electromagnetic fields in space are said to be linearly polarized. The direction of polarization is the direction of the electric vector. That is, if the electric lines of force (E lines) are horizontal, the wave is said to be horizontally polarized (fig. 2-2), and if the E lines are vertical, the wave is said to be vertically polarized. Since the electric field is parallel to the axis of the dipole, the antenna is in the plane of polarization.

A horizontally placed antenna produces a horizontally polarized wave, and a vertically placed antenna produces a vertically polarized wave.

In general, the polarization of a wave does not change over short distances. Therefore, transmitting and receiving antennas are oriented alike, especially if they are separated by short distances.

Over long distances, polarization changes. The change is usually small at low frequencies, but quite drastic at high frequencies. (For radar transmissions, a received signal is actually a wave reflected from an object. Since signal polarization varies with the type of object, no set position of the receiving antenna is correct for all returning signals). Where separate antennas are used for transmitting and receiving, the receiving antenna is generally polarized in the same direction as the transmitting antenna.

When the transmitting antenna is close to the ground, it should be polarized vertically, because vertically polarized waves produce a greater signal strength along the earth's surface. On the other hand, when the transmitting antenna is high above the ground, it should be horizontally polarized to get the greatest signal strength possible to the earth's surface.

RADIATION OF ELECTROMAGNETIC ENERGY

Various factors in the antenna circuit affect the radiation of electromagnetic energy. In figure 2-3, for example, if an alternating current is applied to the A end of wire antenna AB, the wave will travel along the wire until it reaches the B end. Since the B end is free, an open circuit exists and the wave cannot travel further. This is a point of high impedance. The wave bounces back (reflects) from this point of high impedance and travels toward the starting point, where it is again reflected. Theoretically, the energy of the wave should be gradually dissipated by the resistance of the wire during this back-and-forth motion (oscillation). However, each time the wave reaches the starting point, it is reinforced by an impulse of energy sufficient to replace the energy lost during its travel along the wire. This results in continuous oscillations of energy along the wire and a high voltage at the A end of the wire. These oscillations move along the antenna at a rate equal to the frequency of the rf voltage and are sustained by properly timed impulses at point A.

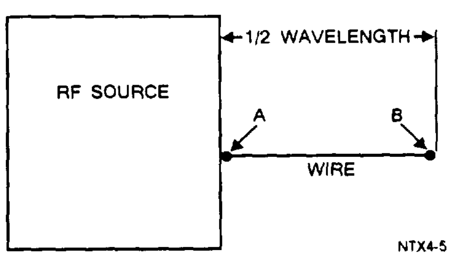


Figure 2-3.—Antenna and rf source.

The rate at which the wave travels along the wire is constant at approximately 300,000,000 meters per second. The length of the antenna must be such that a wave will travel from one end to the other and back again during the period of 1 cycle of the rf voltage. The distance the wave travels during the period of 1 cycle is known as the wavelength. It is found by dividing the rate of travel by the frequency.

Look at the current and voltage distribution on the antenna in figure 2-4. A maximum movement of electrons is in the center of the antenna at all times; therefore, the center of the antenna is at a low impedance.

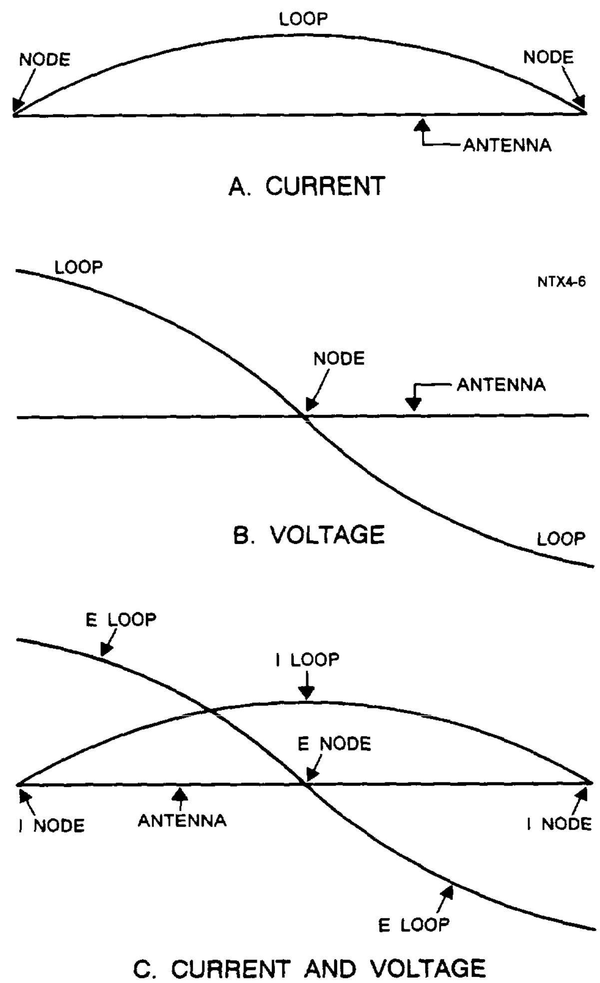


Figure 2-4.—Standing waves of current and voltage on an antenna.

This condition is called a STANDING WAVE of current. The points of high current and high voltage are known as current and voltage LOOPS. The points of minimum current and minimum voltage are known as current and voltage NODES. View A shows a current loop and two current nodes. View B shows two voltage loops and a voltage node. View C shows the resultant voltage and current loops and nodes. The presence of standing waves describes the condition of resonance in an antenna. At resonance, the waves travel back and forth in the antenna, reinforcing each other, and are transmitted into space at maximum radiation. When the antenna is not at resonance, the waves tend to cancel each other and energy is lost in the form of heat.

RADIATION TYPES AND PATTERNS

A logical assumption is that energy leaving an antenna radiates equally over 360 degrees. This is not the case for every antenna.

The energy radiated from an antenna forms a field having a definite RADIATION PATTERN. The radiation pattern for any given antenna is determined by measuring the radiated energy at various angles at constant distances from the antenna and then plotting the energy values on a graph. The shape of this pattern depends on the type of antenna being used.

Some antennas radiate energy equally in all directions. Radiation of this type is known as ISOTROPIC RADIATION. The sun is a good example of an isotropic radiator. If you were to measure the amount of radiated energy around the sun's circumference, the readings would all be fairly equal (fig. 2-5).

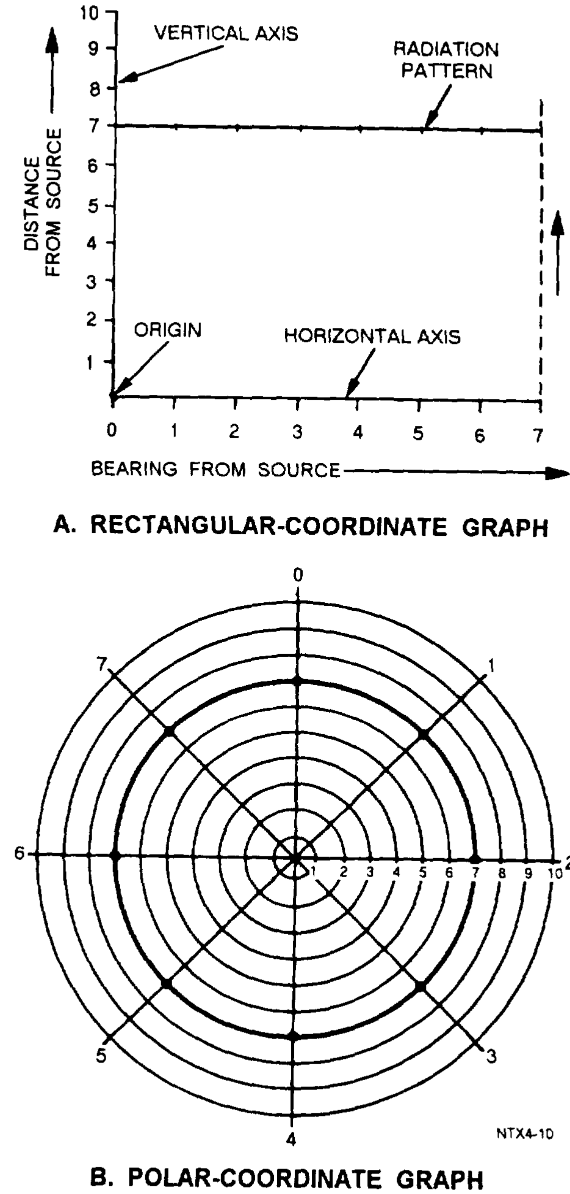


Figure 2-5.—Isotropic radiation graphs.

Most radiators emit (radiate) energy more strongly in one direction than in another. These radiators are referred to as ANISOTROPIC radiators. A flashlight is a good example of an anisotropic radiator (fig. 2-6). The beam of the flashlight lights only a portion of the space surrounding it. The area behind the flashlight remains unlit, while the area in front and to either side is illuminated.

MAJOR AND MINOR LOBES

The pattern shown in figure 2-7, view B, has radiation concentrated in two lobes. The radiation intensity in one lobe is considerably stronger than in the other. The lobe toward point X is called a MAJOR LOBE; the other is a MINOR LOBE. Since the complex radiation patterns associated with antennas frequently contain several lobes of varying intensity, you should learn to use the appropriate terminology, In general, major lobes are those in which the greatest amount of radiation occurs. Minor lobes are those in which the least amount of radiation occurs.

ANTENNA LOADING

There will be times when you may want to use one antenna system to transmit on several different frequencies. Since the antenna must always be in resonance with the applied frequency, you must either lengthen it or shorten it to produce the required

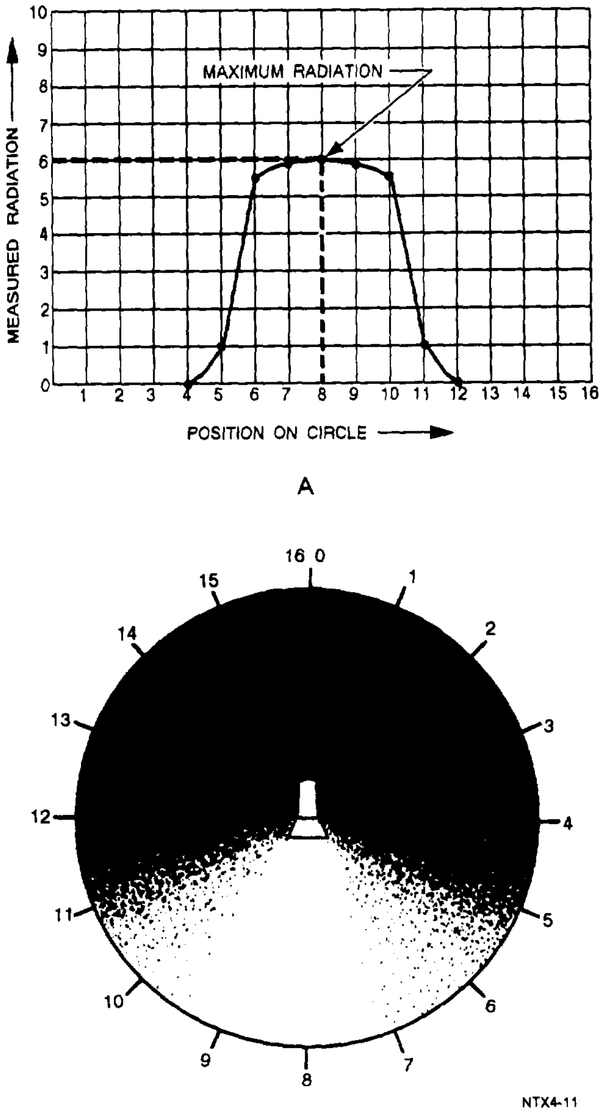


Figure 2-6.—Anisotropic radiator.

resonance. Changing the antenna dimensions physically is impractical, but changing them electrically is relatively simple. To change the electrical length of an antenna, you can insert either an inductor or a capacitor in series with the antenna. This is shown in figure 2-8, views A and B. Changing the electrical length by this method is known as LUMPED-IMPEDANCE TUNING or LOADING. If the antenna is too short for the wavelength being used, it will be resonant at a higher frequency. Therefore, it offers a capacitive reactance at the excitation frequency. This capacitive reactance can be compensated for by introducing a lumped inductive reactance, as shown in view A. Similarly, if the

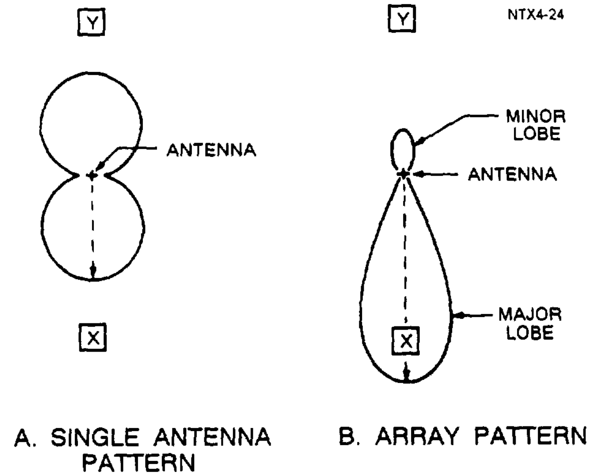


Figure 2-7.—Major and minor lobes.

antenna is too long for the transmitting frequency, it will be resonant at a lower frequency and offers an inductive reactance. Inductive reactance can be compensated for by introducing a lumped capacitive reactance, as shown in view B. An antenna with normal loading is represented in view C.

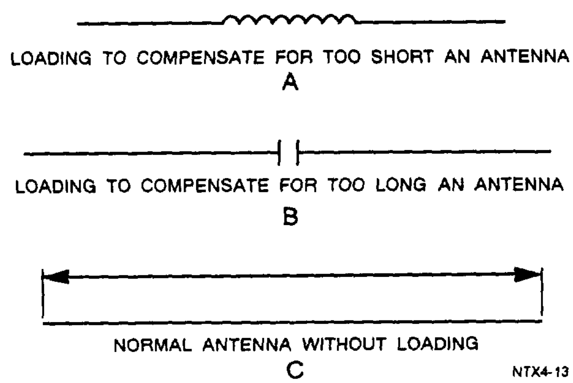


Figure 2-8.—Electrical antenna loading.

GROUND EFFECTS

As we discussed earlier, ground losses affect radiation patterns and cause high signal losses for some frequencies. Such losses can be greatly reduced if a good conducting ground is provided in the vicinity of the antenna. This is the purpose of the GROUND SCREEN (fig. 2-9, view A) and COUNTERPOISE (fig. 2-9, view B).

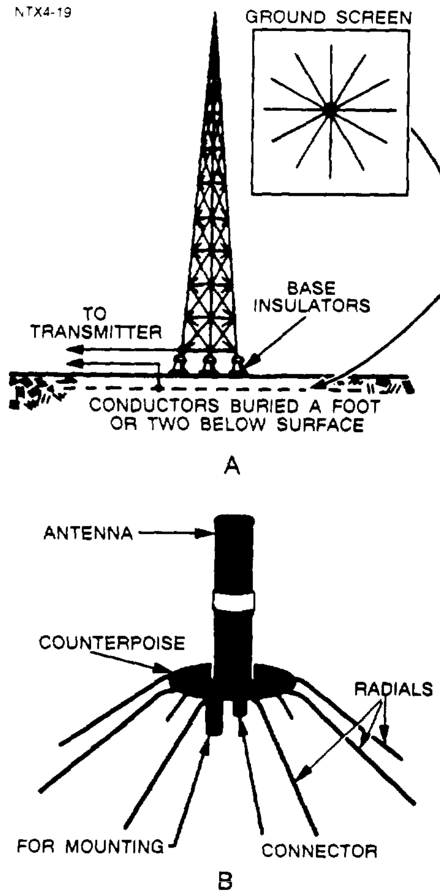


Figure 2-9.—Ground screen and counterpoise.

The ground screen in view A is composed of a series of conductors arranged in a radial pattern and buried 1 or 2 feet below the surface of the earth. These conductors, each usually 1/2 wavelength long, reduce ground absorption losses in the vicinity of the antenna.

A counterpoise (view B) is used when easy access to the base of the antenna is necessary. It is also used when the area below the antenna is not a good conducting surface, such as solid rock or ground that is sandy. The counterpoise serves the same purpose as the ground screen but is usually elevated above the earth. No specific dimensions are necessary for a counterpoise, nor is the number of wires particularly critical. The primary requirement is that the counterpoise be insulated from ground and form a grid of reflector elements for the antenna system.

COMMUNICATIONS ANTENNAS

Some antennas can be used in both shore-based and ship-based applications. Others, however, are designed to be used primarily in one application or the other. The following paragraphs discuss, by frequency range, antennas used for shore-based communications.

VERY LOW FREQUENCY (VLF)

The main difficulty in vlf and lf antenna design is the physical disparity between the maximum practical size of the antenna and the wavelength of the frequency it must propagate. These antennas must be large to compensate for wavelength and power handling requirements (0.25 to 2 MW), Transmitting antennas for vlf have multiple towers 600 to 1500 feet high, an extensive flat top for capacitive loading, and a copper ground system for reducing ground losses. Capacitive top-loading increases the bandwidth characteristics, while the ground plane improves radiation efficiency.

Representative antenna configurations are shown in figures 2-10 through 2-12. Variations of these basic antennas are used at the majority of the Navy vlf sites.

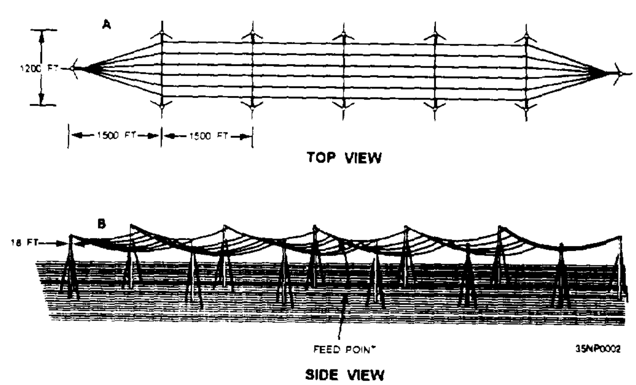


Figure 2-10.—Triatic-type antenna.

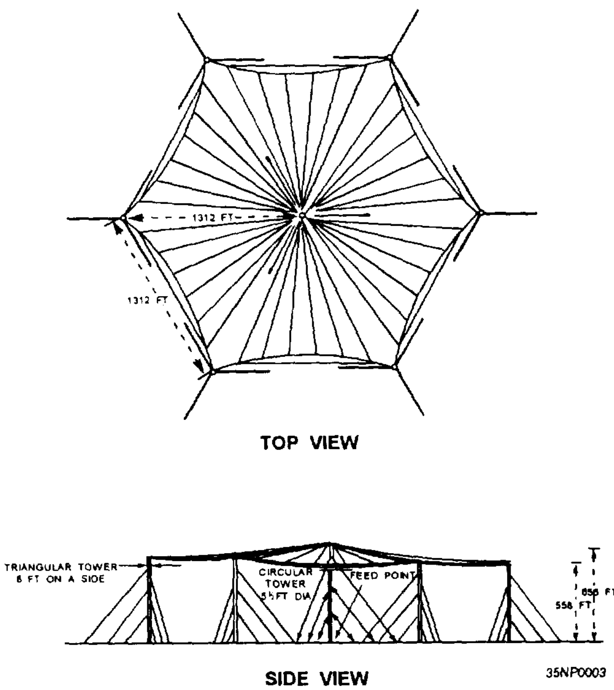


Figure 2-11.—Goliath-type antenna.

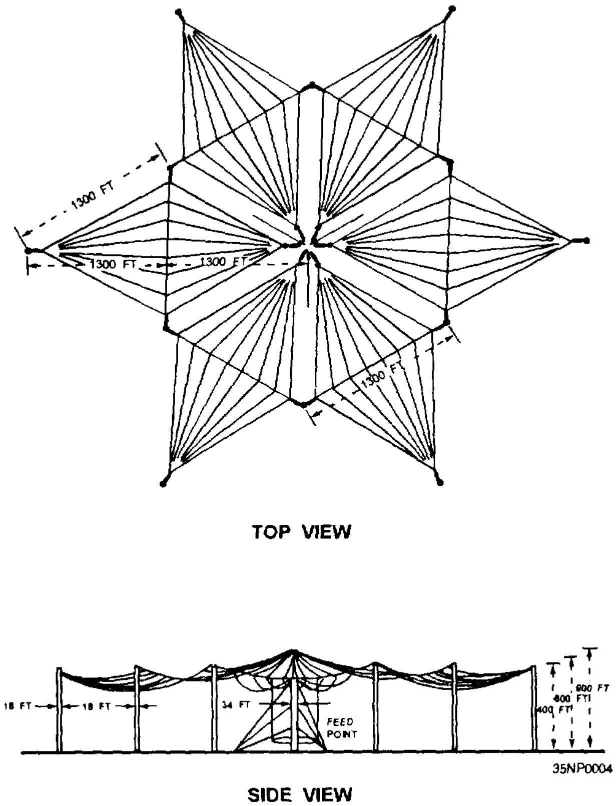


Figure 2-12.—Trideco-type antenna.

LOW FREQUENCY (LF)

Antennas for lf are not quite as large as antennas for vlf, but they still occupy a large surface area. Two examples of If antenna design are shown in figures 2-13 and 2-14. The Pan polar antenna (fig. 2-1 3) is an umbrella top-loaded monopole. It has three loading loops spaced 120 degrees apart, interconnected between the tower guy cables. Two of the loops terminate at ground, while the other is used as a feed. The NORD antenna (fig. 2-14), based on the the folded-unipole principle, is a vertical tower radiator grounded at the base and fed by one or more wires connected to the top of the tower. The three top loading wires extend from the top of the antenna at 120-degree intervals to three terminating towers. Each loading wire has a length approximately equal to the height of the main tower plus 100 feet. The top loading wires are insulated from ground and their tower supports are one-third the height of the transmitting antenna.

HIGH FREQUENCY (HF)

High-frequency (hf) radio antenna systems are used to support many different types of circuits, including ship-to-shore, point-to-point, and ground-to-air broadcast. These diverse applications require the use of various numbers and types of antennas that we will review on the following pages.

Yagi

The Yagi antenna is an end-fired parasitic array. It is constructed of parallel and coplaner dipole elements arranged along a line perpendicular to the axis of the dipoles, as illustrated in figure 2-15. The most limiting characteristic of the Yagi antenna is its extremely narrow bandwidth. Three percent of the center frequency is considered to be an acceptable bandwidth ratio for a Yagi antenna. The width of the array is determined by the lengths of the elements. The length of each element is approximately one-half

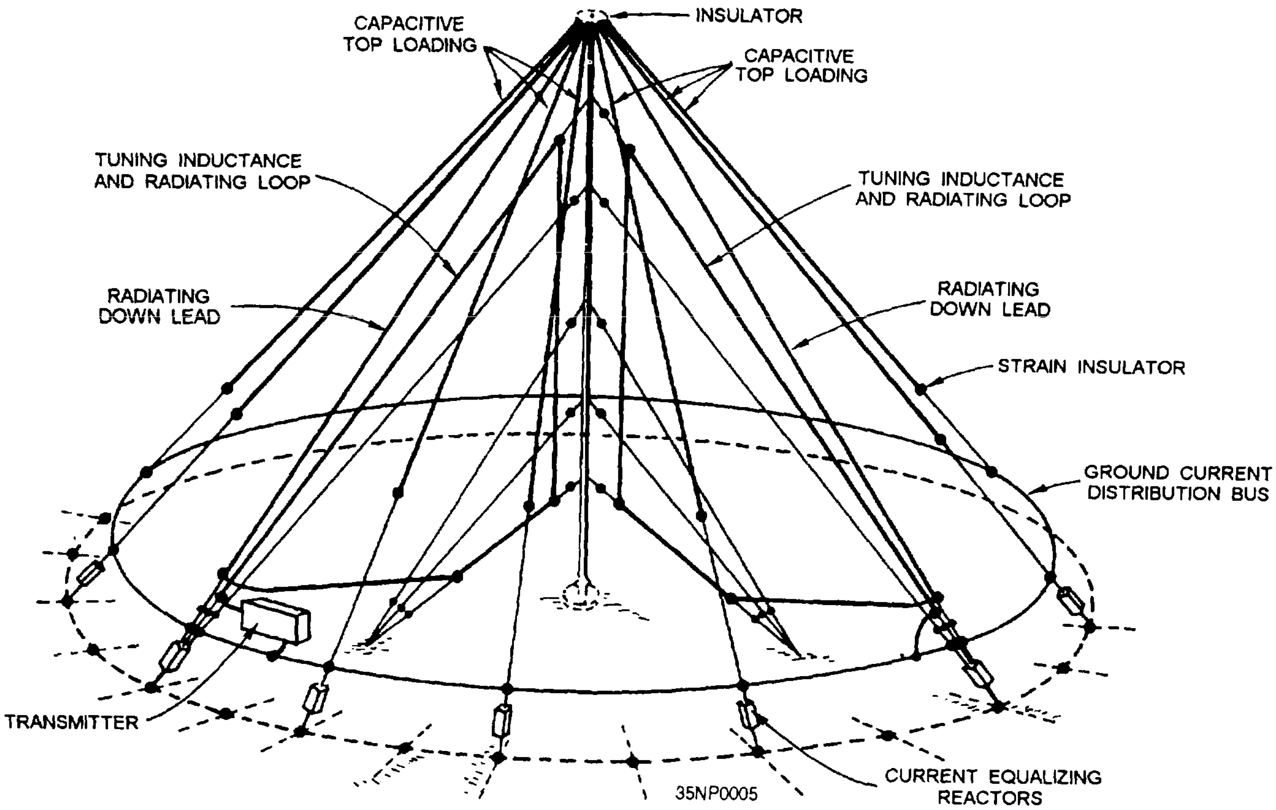


Figure 2-13.—Pan polar antenna.

wavelength, depending on its intended use (driver, reflector, or director). The required length of the array depends on the desired gain and directivity. Typically, the length will vary from 0.3 wavelength for three-element arrays, to 3 wavelengths for arrays with numerous elements. For hf applications, the maximum practical array length is 2 wavelengths. The array's height above ground will determine its vertical radiation angle. Normally, array heights vary from 0.25 to 2.5 wavelengths. The dipole elements are usually constructed from tubing, which provides for better gain and bandwidth characteristics and provides sufficient mechanical rigidity for self-support. Yagi arrays of four elements or less are not structurally complicated. Longer arrays and arrays for lower frequencies, where the width of the array exceeds 40 feet, require elaborate booms and supporting structures. Yagi arrays may be either fixed-position or rotatable.

LOG-PERIODIC ANTENNAS (LPAs)

An antenna arranged so the electrical length and spacing between successive elements causes the input impedance and pattern characteristics to be repeated periodically with the logarithm of the driving frequency is called a LOG-PERIODIC ANTENNA (LPA). The LPA, in general, is a medium-power, high-gain, moderately-directive antenna of extremely broad bandwidth. Bandwidths of up to 15:1 are possible, with up to 15 dB power gain. LPAs are rather complex antenna systems and are relatively expensive. The installation of LPAs is normally more difficult than for other hf antennas because of the tower heights involved and the complexity of suspending the radiating elements and feedlines from the towers.

Vertical Monopole LPA

The log-periodic vertical monopole antenna (fig. 2-16) has the plane containing the radiating elements in a vertical field. The longest element is approximately one-quarter wavelength at the lower cutoff frequency. The ground system for the monopole arrangement provides the image equivalent of the other quarter wavelength for the half-dipole radiating elements. A typical vertical monopole designed to

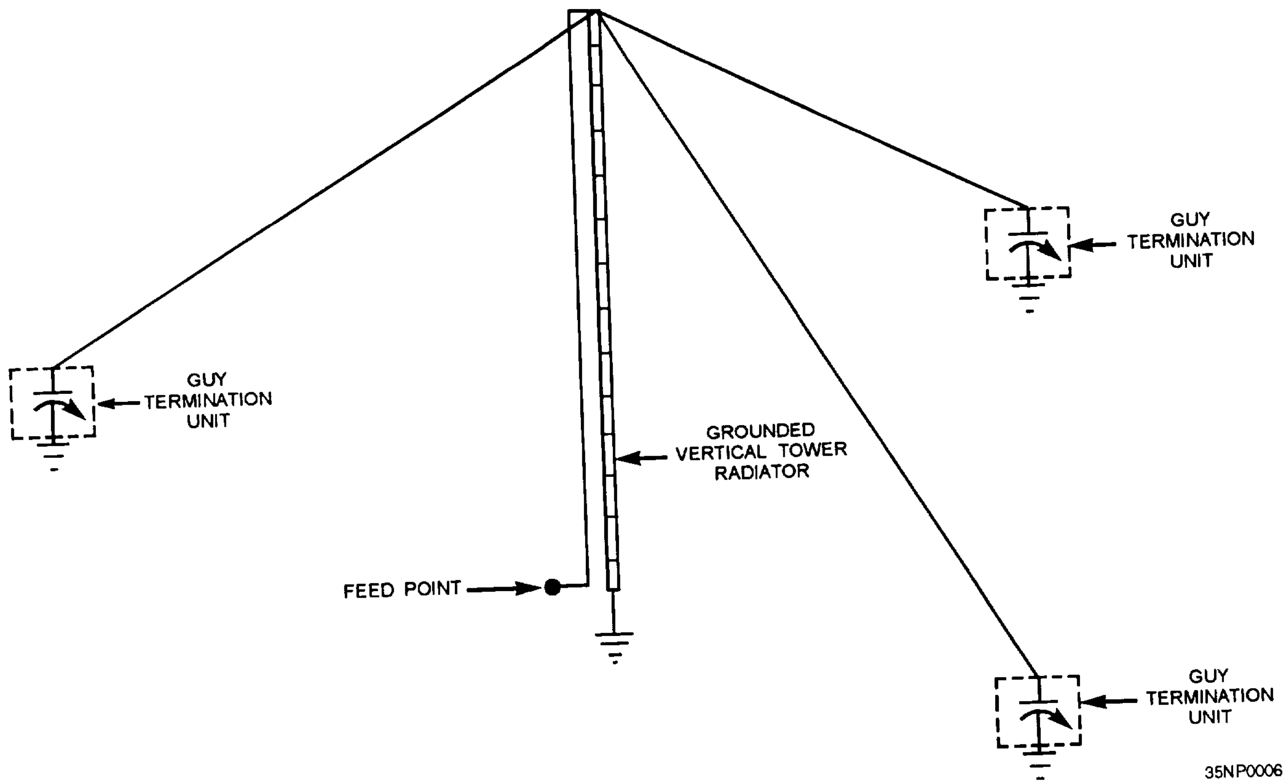


Figure 2-14.—NORD antenna.

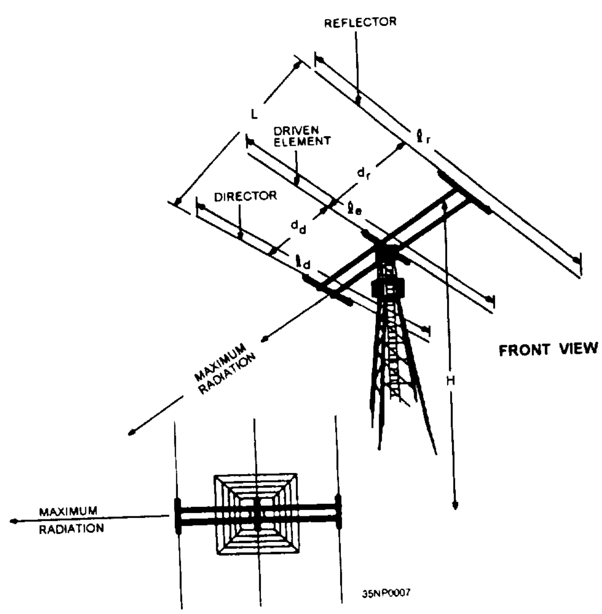


Figure 2-15.—Yagi antenna.

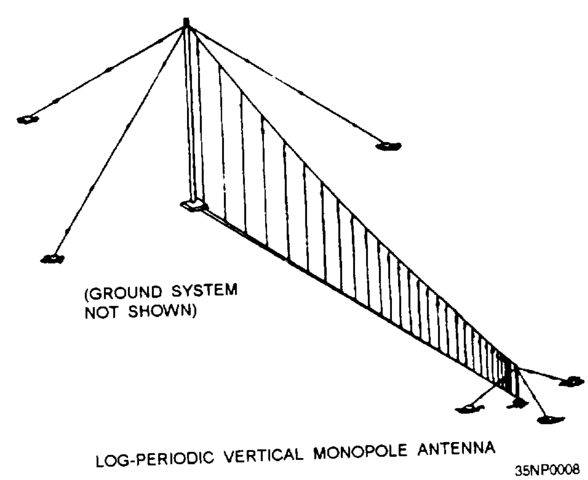


Figure 2-16.—Log-periodic vertical monopole antenna.

cover a frequency range of 2 to 30 MHz requires one tower approximately 140 feet high and an antenna length of around 500 feet, with a ground system that covers approximately 3 acres of land in the immediate vicinity of the antenna.

Sector Log-Periodic Array

This version of a vertically polarized fixed-azimuth LPA consists of four separate curtains supported by a common central tower, as shown in figure 2-17. Each of the four curtains operates independently, providing antennas for a minimum of four transmit or receive systems. and a choice of sector coverage. The four curtains are also capable of radiating a rosette pattern of overlapping sectors for full coverage, as shown by the radiation pattern in figure 2-17. The central supporting tower is constructed of steel and may range to approximately 250 feet in height, with the length of each curtain reaching 250 feet, depending on its designed operating frequencies. A sector antenna that uses a ground plane designed to cover the entire hf spectrum takes up 4 to 6 acres of land area.

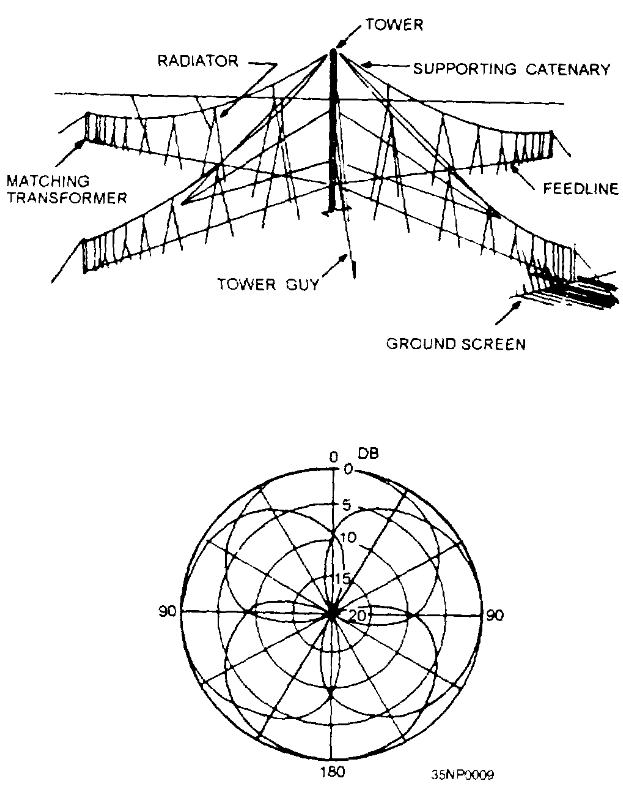


Figure 2-17.—Sector LPA and its horizontal radiation pattern.

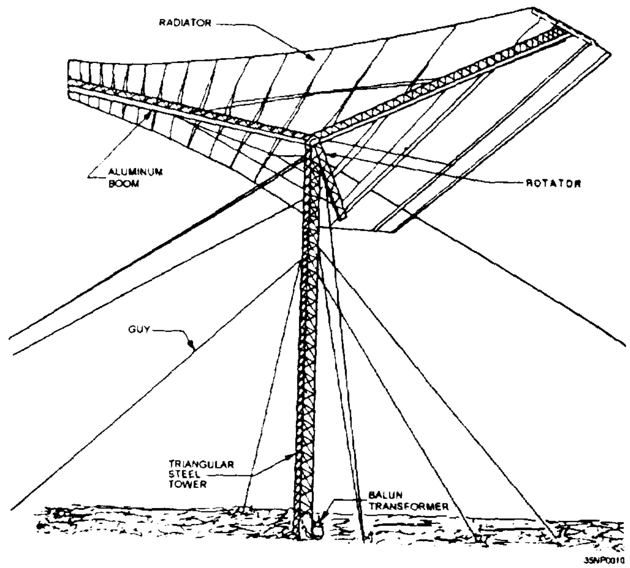


Figure 2-18.—Rotatable log-periodic antenna.

Rotatable LPA (RLPA)

RLPAs (fig. 2-18) are commonly used in ship-to-shore-to-ship and in point-to-point ecm-u-nunica-tions. Their distinct advantage is their ability to rotate 360 degrees. RLPAs are usually constructed with either tubular or wire antenna elements. The RLPA in figure 2-18 has wire elements strung on three aluminum booms of equal length, spaced equally and arranged radially about a central rotator on top of a steel tower approximately 100 feet high. The frequency range of this antema is 6 to 32 MHz. The gain is 12 dB with respect to isotropic antennas. Power handling capability is 20 kw average, and vswr is 2:1 over the frequency range.

INVERTED CONE ANTENNA

Inverted cone antennas are vertically polarized, omnidirectional, and have an extremely broad bandwidth. They are widely used for ship-to-shore and ground-to-air communications. Inverted cone antennas are installed over a radial ground plane system and are supported by poles, as shown in figure 2-19. The equally-spaced vertical radiator wires terminate in a feed ring assembly located at the bottom center, where a 50-ohm coaxial transmission line feeds the antenna. Inverted cones usually have gains of 1 to 5 dB above isotropic antennas, with a vswr not

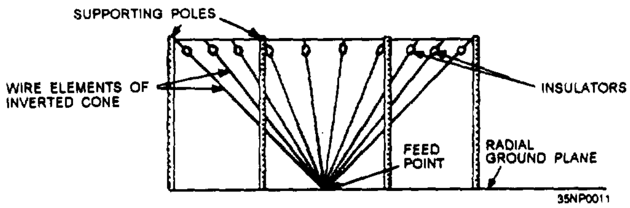


Figure 2-19.—Inverted cone antenna.

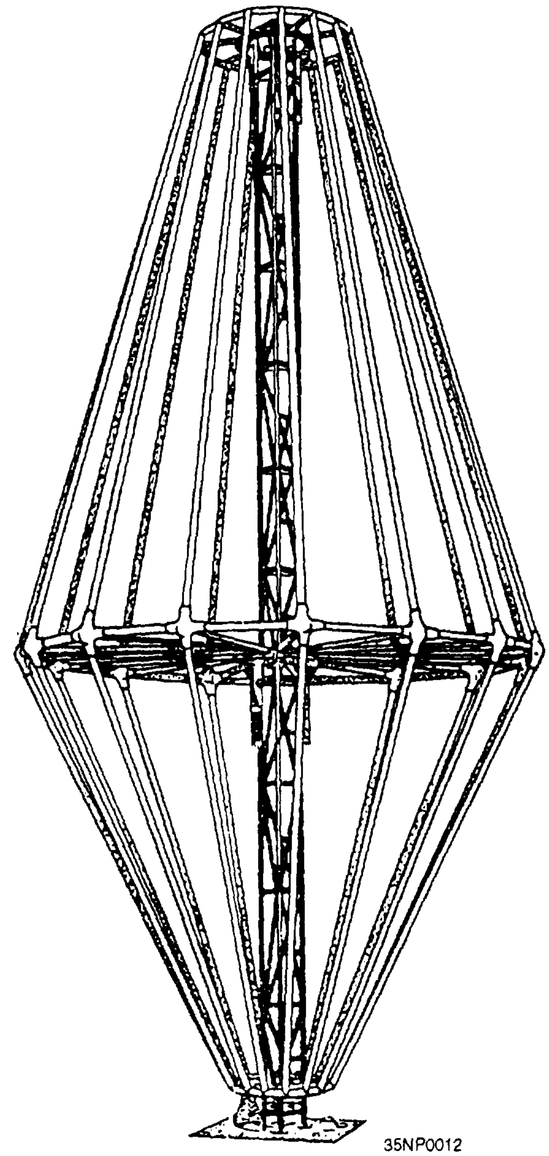


Figure 2-20.—Conical monopole antenna.

greater than 2:1. They are considered medium- to high-power radiators, with power handling capabilities of 40 kW average power.

CONICAL MONOPOLE ANTENNA

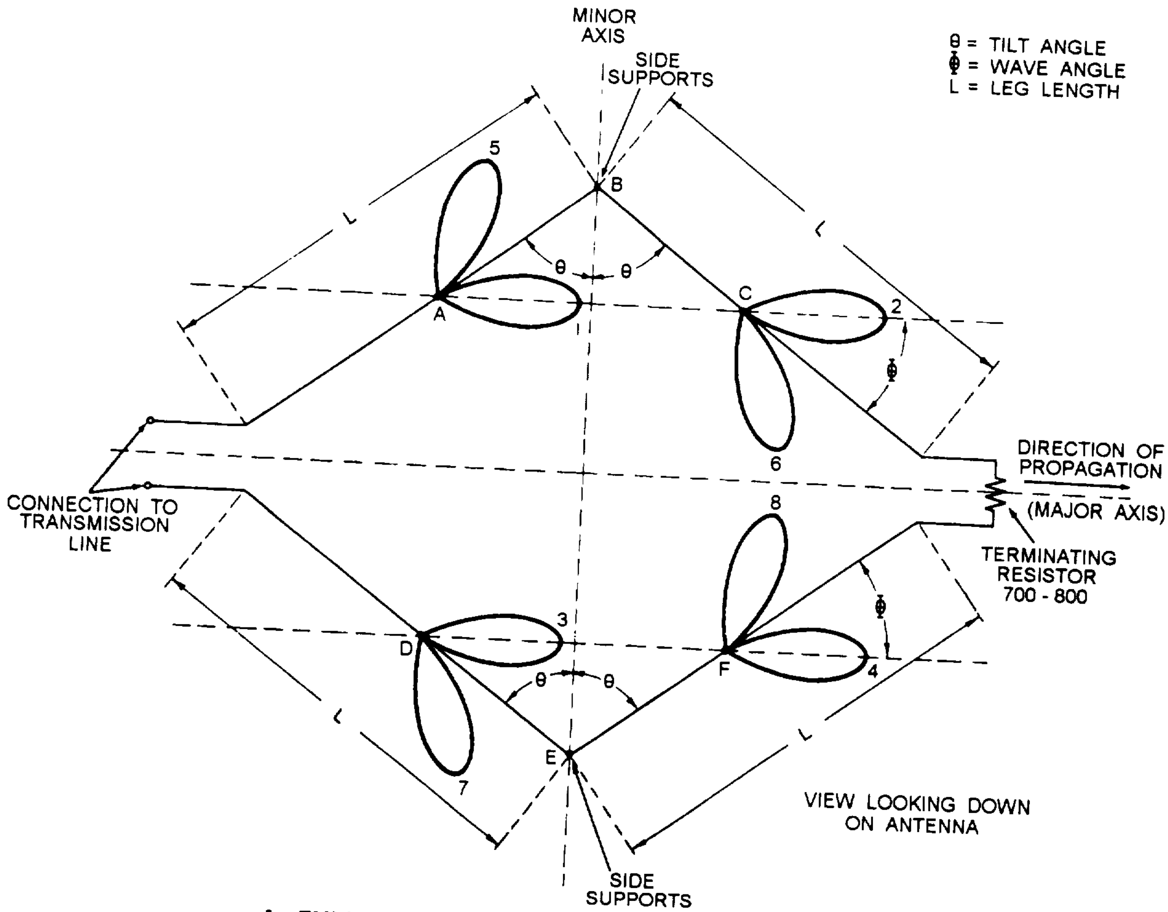
Conical monopoles are used extensively in hf communications. A conical monopole is an efficient broadband, vertically polarized, omnidirectional antenna in a compact size. Conical monopoles are shaped like two truncated cones connected base-to-base. The basic conical monopole configuration, shown in figure 2-20, is composed of equally-spaced wire radiating elements arranged in a circle around an aluminum center tower. Usually, the radiating elements are connected to the top and bottom discs, but on some versions, there is a center waist disc where the top and bottom radiators are connected. The conical monopole can handle up to 40 kW of average power. Typical gain is -2 to +2 dB, with a vswr of up to 2.5:1.

RHOMBIC ANTENNA

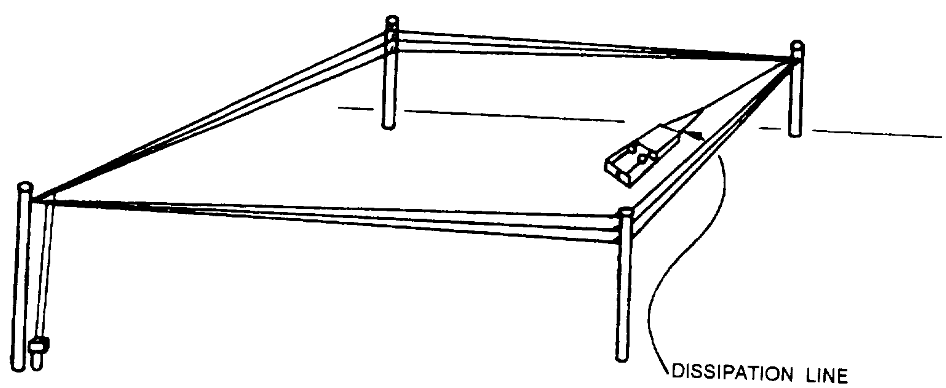
Rhombic antennas can be characterized as high-power, low-angle, high-gain, horizontally-polarized, highly-directive, broadband antennas of simple, inexpensive construction. The rhombic antenna (fig. 2-21) is a system of long-wire radiators that depends on radiated wave interaction for its gain and directivity. A properly designed rhombic antenna presents to the transmission line an input impedance insensitive to frequency variations up to 5:1. It maintains a power gain above 9 dB anywhere within a 2:1 frequency variation. At the design-center frequency, a gain of 17 dB is typical. The radiation pattern produced by the four radiating legs of a rhombic antenna is modified by reflections from the earth under, and immediately in front of, the antenna. Because of the importance of these ground reflections in the proper formation of the main lobe, the rhombic should be installed over reasonably smooth and level ground. The main disadvantage of the rhombic antenna is the requirement for a large land area, usually 5 to 15 acres.

QUADRANT ANTENNA

The hf quadrant antenna (fig. 2-22) is a special-purpose receiving antenna used in ground-to-air-to-ground communications. It is unique among horizontally-polarized antennas because its



A. FULL - RHOMBIC TRANSMITTING ANTENNA



B. NON - RESONANT HORIZONTAL THREE - WIRE RHOMBIC

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Figure 2-21.—Three-wire rhombic antenna.

element arrangement makes possible a radiation pattern resembling that of a vertically-polarized, omnidirectional antenna. Construction and installation of this antenna is complex because of the physical relationships between the individual elements and the requirement for a separate transmission line for each dipole. Approximately 2.2 acres of land are required to accommodate the quadrant antenna.

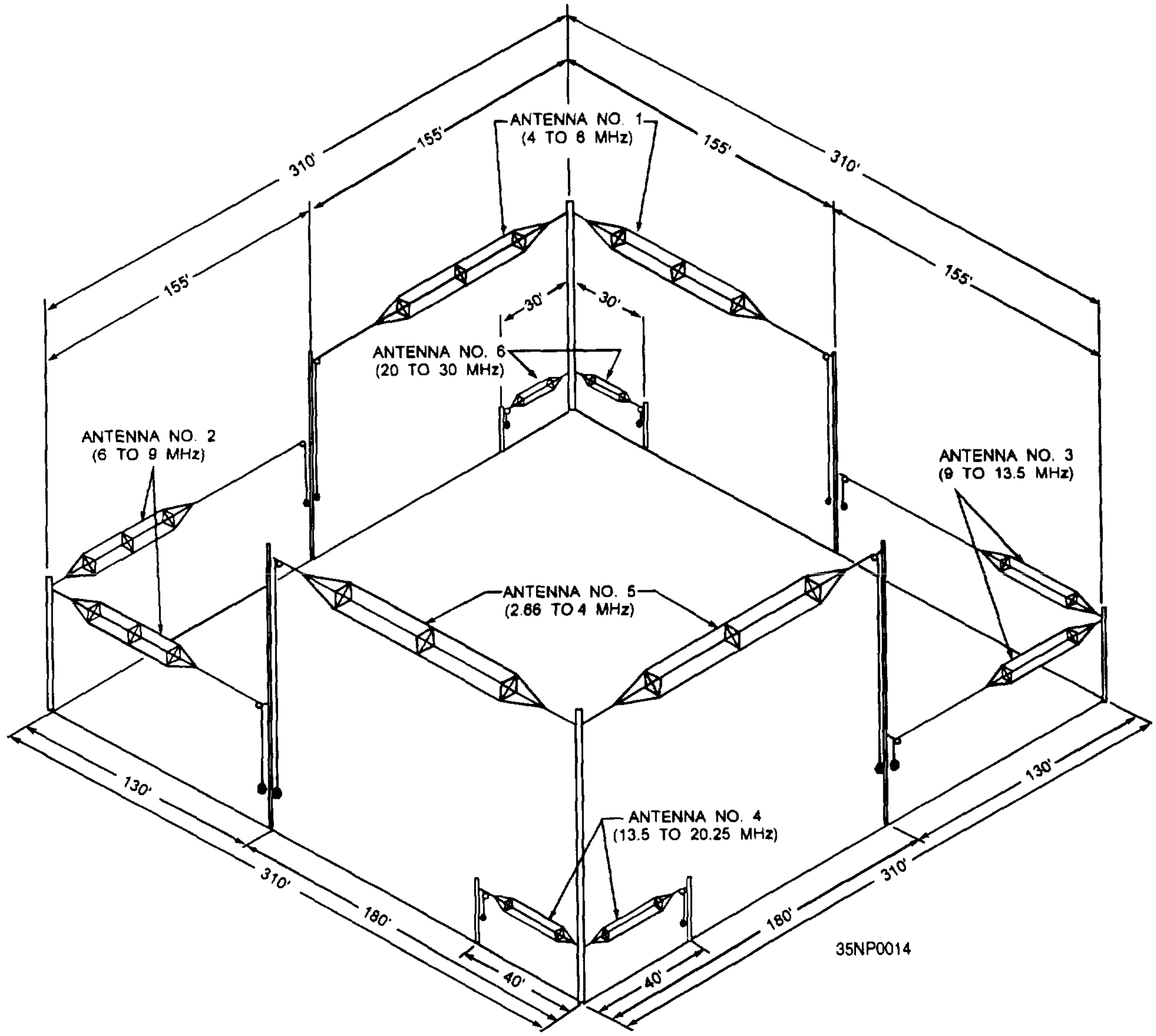

Figure 2-22.—Quadrant antenna.

WHIP ANTENNAS

Hf whip antennas (fig. 2-23) are vertically-polarized omnidirectional monopoles that are used for short-range, ship-to-shore and transportable communications systems. Whip antennas are made of tubular metal or fiberglass, and vary in length from 12 feet to 35 feet, with the latter being the most prevalent. Although whips are not considered as highly efficient antennas, their ease of installation and low cost provide a compromise for receiving and low-to-medium power transmitting installations.

The self-supporting feature of the whip makes it particularly useful where space is limited. Whips can be tilted, a design feature that makes them suited for use along the edges of aircraft carrier flight decks. Aboard submarines, they can be retracted into the sail structure.

Most whip antennas require some sort of tuning system and a ground plane to improve their radiation efficiency throughout the hf spectrum. Without an antenna tuning system, whips generally have a narrow bandwidth and are limited in their power handling

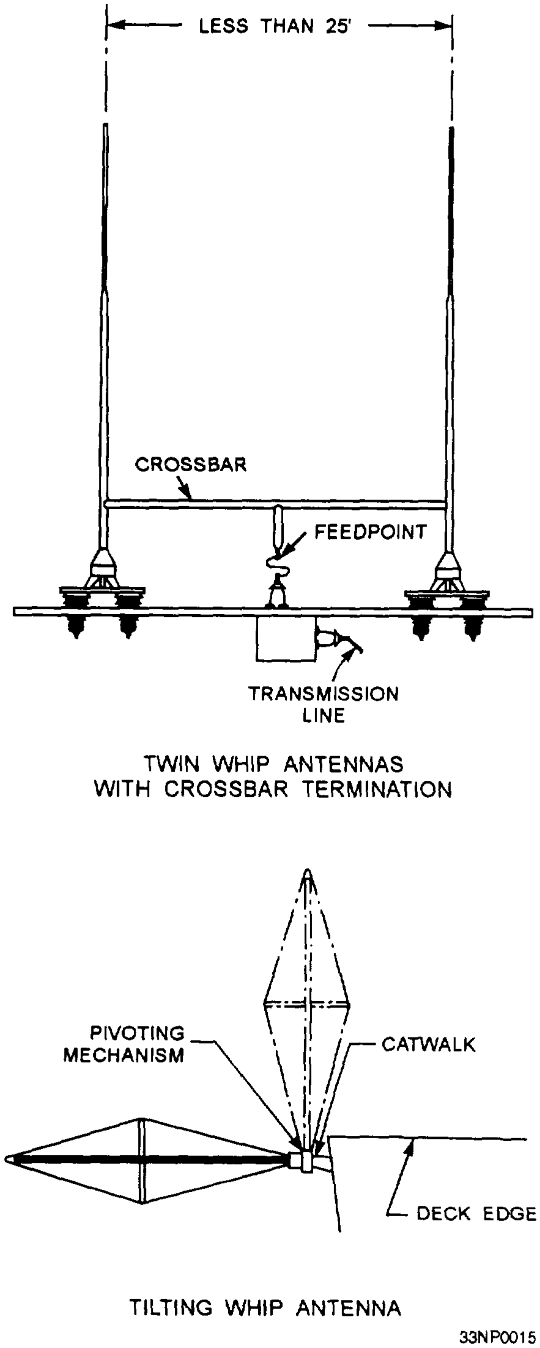

Figure 2-23.—Whip antennas.

capabilities. Power ratings for most whips range from 1 to 5 kW PEP.

WIRE-ROPE FAN ANTENNAS

Figure 2-24 shows a five-wire vertical fan antenna. This is a broadband antenna composed of five wires,

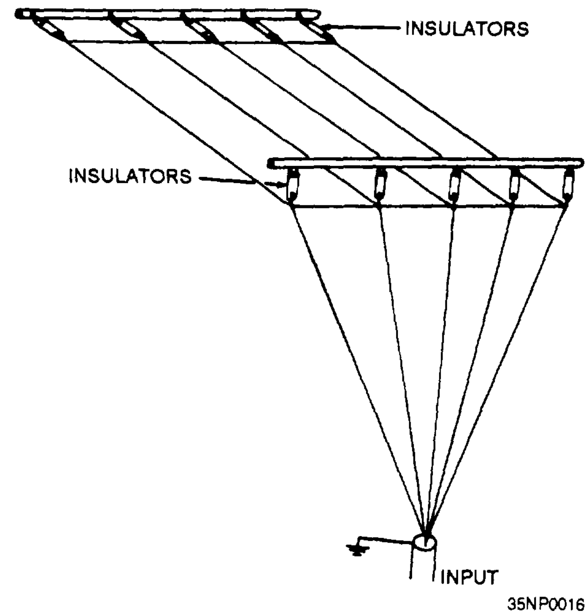

Figure 2-24.—Vertical fan antenna.

each cut for one-quarter wavelength at the lowest frequency to be used. The wires are fanned 30 degrees between adjacent wires. The fan antenna provides satisfactory performance and is designed for use as a random shipboard antenna in the hf range (2-30 MHz).

DISCAGE ANTENNA

The discage antenna (fig. 2-25) is a broadband omnidirectional antenna. The diseage structure consists of two truncated wire rope cones attached base-to-base and supported by a central mast. The lower portion of the structure operates as a cage monopole for the 4- to 12-MHz frequency range. The upper portion operates as a discone radiator in the 10- to 30-MHz frequency range. Matching networks limit the vswr to not greater than 3:1 at each feed point. Vinyl-covered phosphor bronze wire rope is used for the wire portions. The support mast and other portions are aluminum.

VHF/UHF

At vhf and uhf frequencies, the shorter wavelength makes the physical size of the antenna relatively small. Aboard ship these antennas are installed as high as

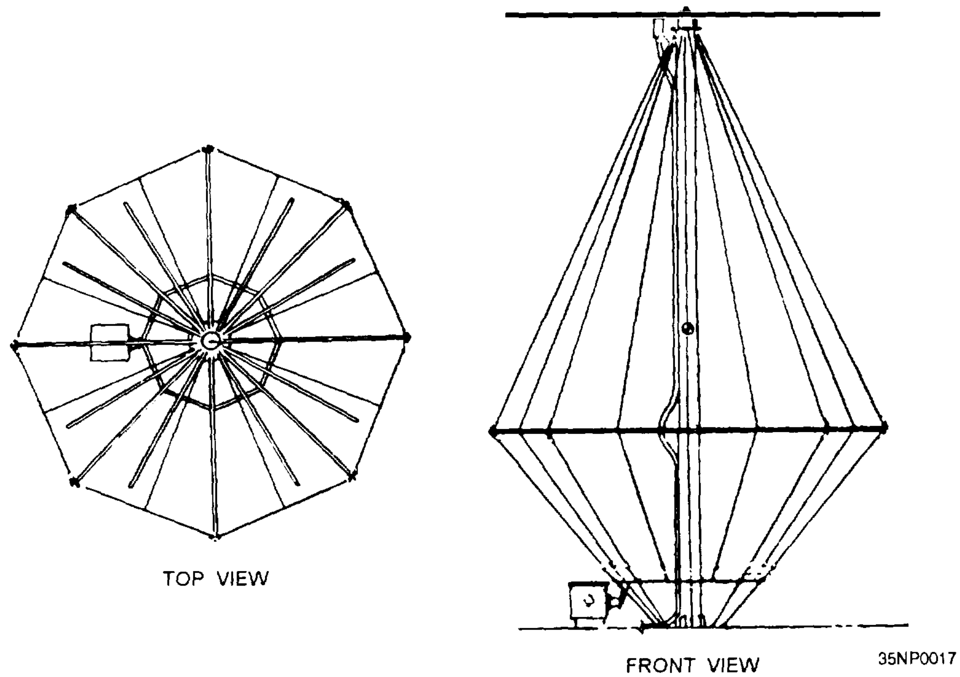

Figure 2-25.—AS-2802/SCR discage antenna.

possible and away from any obstructions. The reason for the high installation is that vertical conductors, such as masts, rigging, and cables in the vicinity, cause unwanted directivity in the radiation pattern.

For best results in the vhf and uhf ranges, both transmitting and receiving antennas must have the same polarization. Vertically polarized antennas (primarily dipoles) are used for all ship-to-ship, ship-to-shore, and air-to-ground vhf and uhf communications.

The following paragraphs describe the most common uhf/vhf dipole antennas. All the examples are vertically-polarized, omnidirectional, broadband antennas.

Biconical Dipole

The biconical dipole antenna (fig. 2-26) is designed for use at a normal rf power rating of around 250 watts, with a vswr not greater than 2:1. All major components of the radiating and support structures are aluminum. The central feed section is protected and waterproofed by a laminated fiberglass cover.

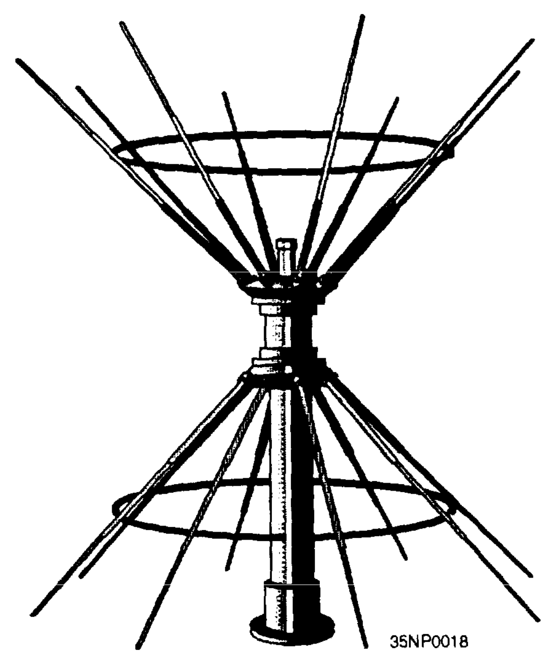

Figure 2-26.—AS-2811/SCR biconical dipole antenna.

Center-Fed Dipole

The center-fed dipole (fig. 2-27) is designed for use at an average power rating of 100 watts. All major components of the radiating and support structures are aluminum. The central feed section and radiating elements are protected by a laminated fiberglass cover. Center-fed dipole antennas range from 29 to 47 inches in height and have a radiator diameter of up to 3 inches.

Coaxial Dipole

Figure 2-28 shows two types of coaxial dipoles. The coaxial dipole antenna is designed for use in the uhf range, with an rf power rating of 200 watts. The AT-150/SRC (fig. 2-28, view A) has vertical radiating elements and a balun arrangement that electrically balances the antenna to ground.

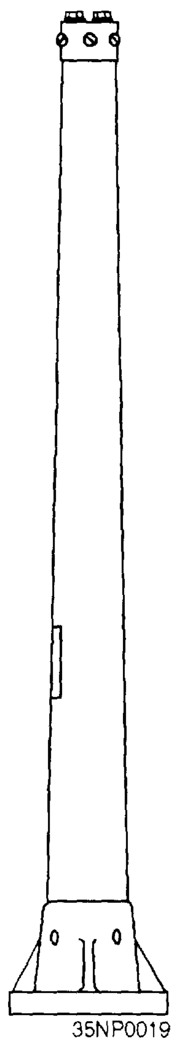

Figure 2-27.—AS-2809/RC center-fed dipole antenna.

Figure 2-28, view B, shows an AS-390/SRC antenna assembly. This antenna is an unbalanced broadband coaxial stub antenna. It consists of a radiator and a ground plane. The ground plane (or counterpoise) consists of eight elements bent downward 37 degrees from horizontal. The lower ends of the elements form points of a circle 23 inches in diameter. The lower section of the radiator assembly contains a stub for adjusting the input impedance of the antenna. The antenna is vertically polarized, with an rf power rating of 200 watts, and a vswr not greater than 2:1.

SATELLITE SYSTEMS

The Navy Satellite Communication System (SATCOM) provides communications links, via satellites, between designated mobile units and shore sites. These links supply worldwide communications coverage. The following paragraphs describe some of the more common SATCOM antenna systems to which you will be exposed.

AS-2815/SRR-1

The AS-2815/SSR-1 fleet broadcast receiving antenna (fig. 2-29) has a fixed 360-degree horizontal pattern with a maximum gain of 4 dB at 90 degrees from the antenna's horizontal plane. The maximum loss in the antenna's vertical pattern sector is 2 dB. The vswr is less than 1.5:1, referenced to 50 ohms. This antenna should be positioned to protect it from interference and possible front end burnout from radar and uhf transmitters.

ANTENNA GROUPS OE-82B/WSC-1(V) AND OE-82C/WSC-1(V)

Designed primarily for shipboard installations, these antenna groups interface with the AN/WSC-3 transceiver. The complete installation consists of an antenna, bandpass amplifier-filter, switching unit, and antenna control (figs. 2-30 and 2-31), Depending on requirements, one or two antennas may be installed to provide a view of the satellite at all times. The antenna assembly is attached to a pedestal that permits

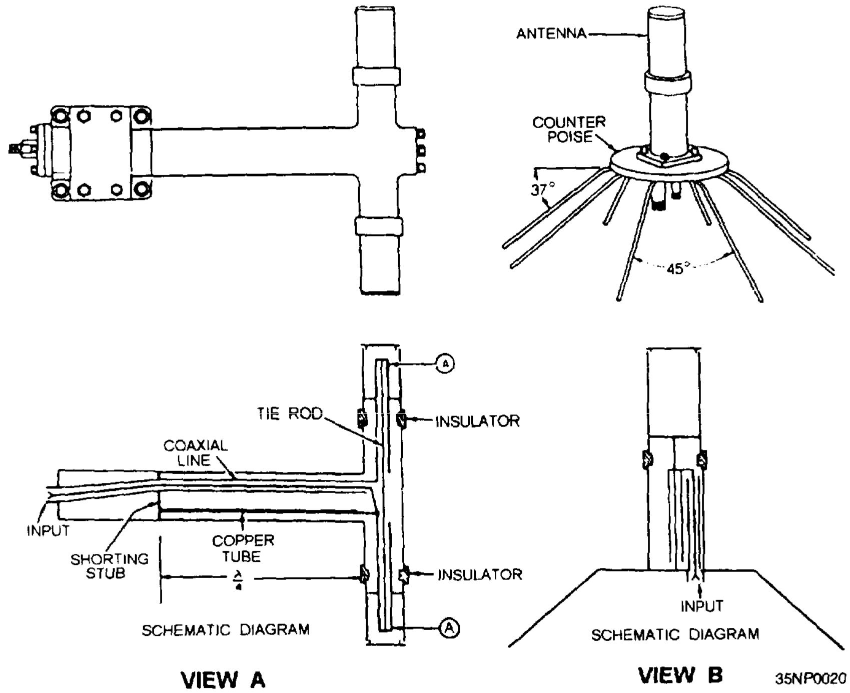

Figure 2-28.—Coaxial dipole.

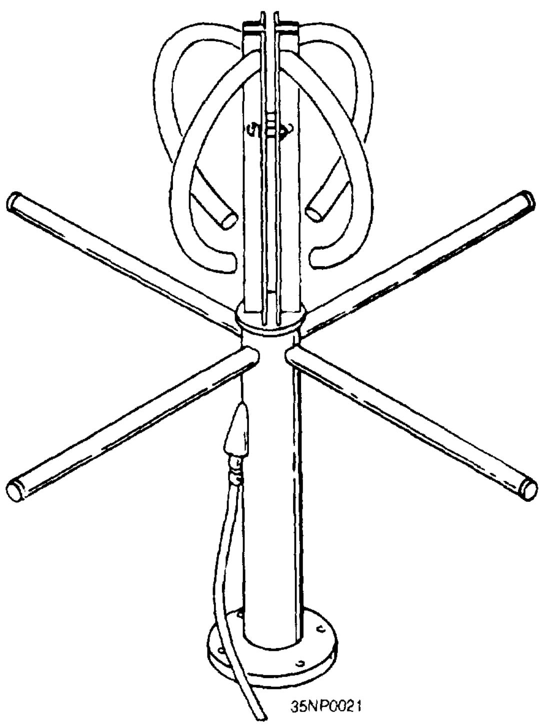

Figure 2-29.—AS-2815/SSR-1 fleet broadcast satellite receiving antenna.

it to rotate 360 degrees and to elevate from near horizontal to approximately 20 degrees beyond zenith (elevation angles from +2 to +110 degrees). The antenna tracks automatically in azimuth and manually in elevation. Frequency bands are 248-272 MHz for receive and 292-312 MHz for transmit. Polarization is right-hand circular for both transmit and receive. Antenna gain characteristics are nominally 12 dB in transmit and 11 dB in receive.

AN/WSC-5(V) SHORE STATION ANTENNA

The AN/WSC-5(V) shore station antenna (fig. 2-32) consists of four OE-82A/WSC-1(V) backplane assemblies installed on a pedestal. This antenna is intended for use with the AN/WSC-5(V) transceiver at major shore stations. The antenna is oriented manually and can be locked in position to receive maximum signal strength upon capture of the satellite signal. Hemispherical coverage is 0 to 110 degrees above the horizon. Polarization is right-hand circular in both transmit and receive. The antenna's operating frequency range is 240 to 318 MHz. With its mount,

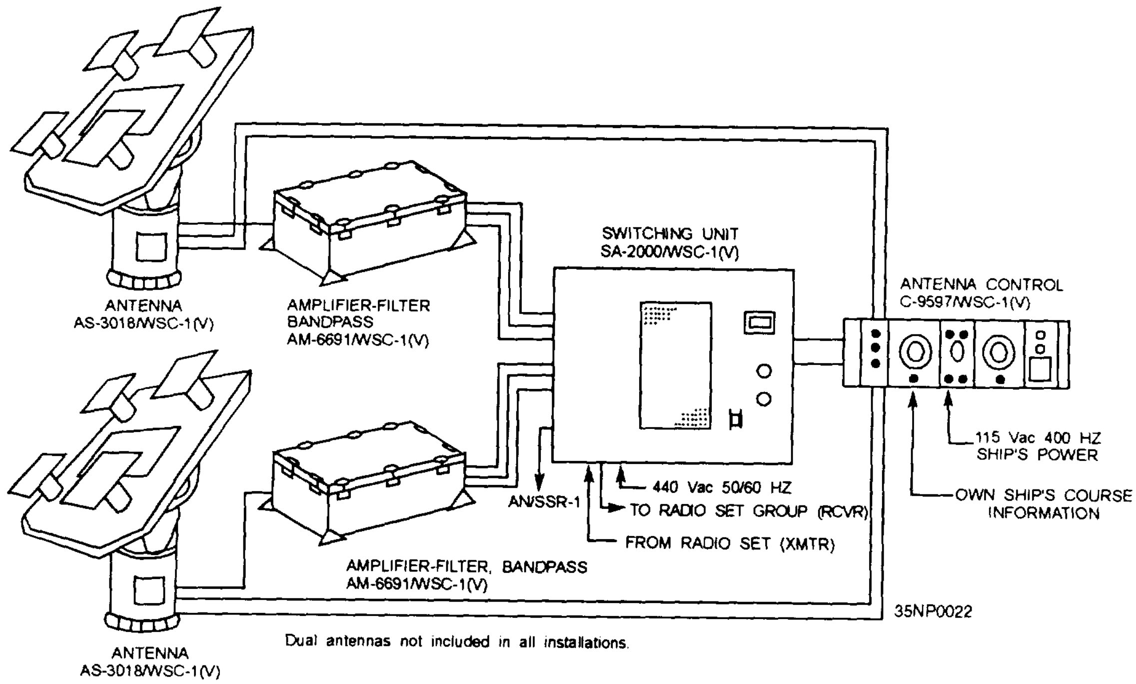

Figure 2-30.—OE-82/WSC-1(V) antenna group.

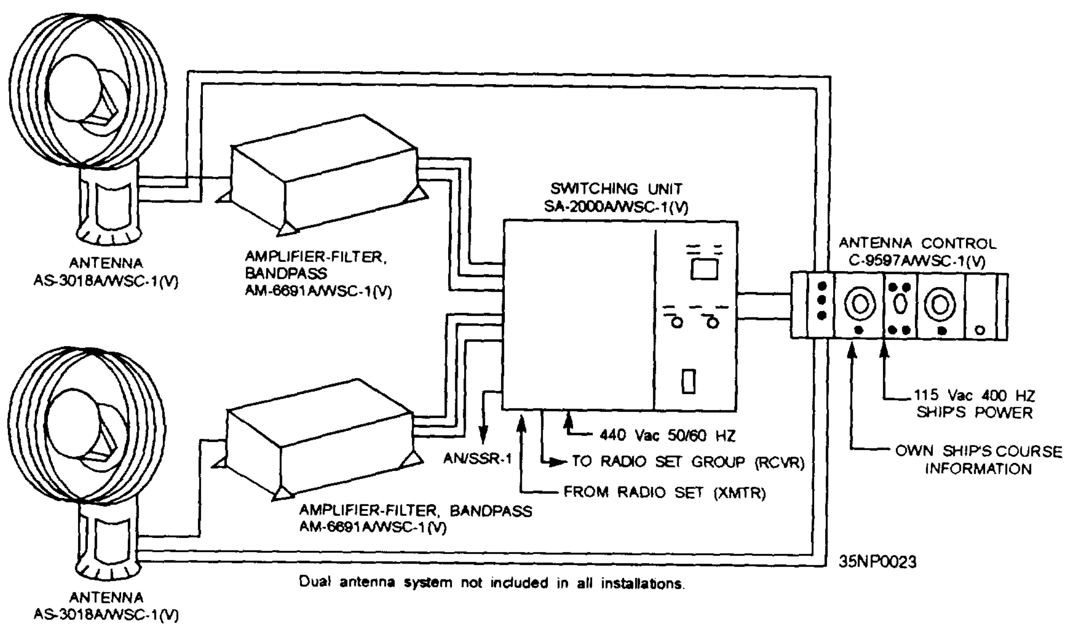

Figure 2-31.—OE-82C/WSC-1(V) antenna group.

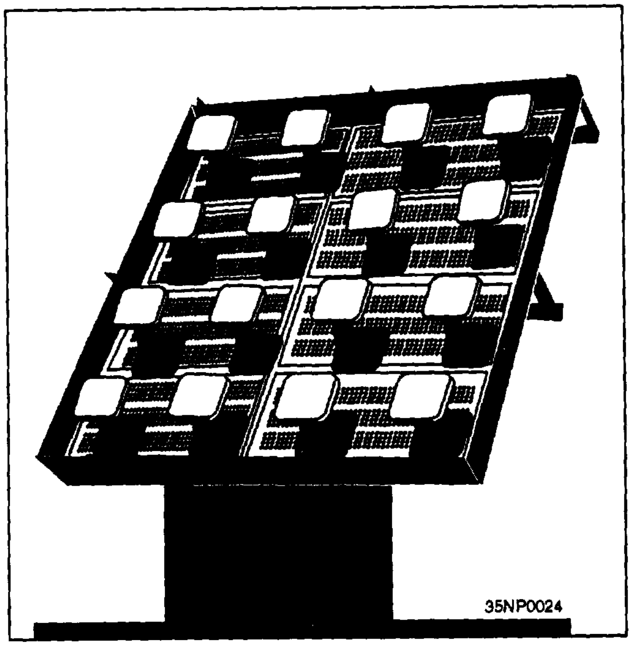

Figure 2-32.—OE-82A/WSC-1(V)/AN/WSC-5(V) shore station antenna.

the antenna weighs 2500 pounds and is 15 feet high, 10 feet wide, and 10 feet deep. The gain characteristics of this antenna are nominally 15 dB in transmit and 18 dB in receive.

ANDREW 58622 SHORE ANTENNA

The Andrew 58622 antenna (fig. 2-33) is a bifilar, 16-turn helical antenna right-hand circularly polarized, with gain varying between 11.2 and 13.2 dB in the 240-315 MKz frequency band. It has a 39-inch ground plate and is about 9 feet, 7 inches long. It can be adjusted manually in azimuth and elevation. This antenna is used at various shore installations, other than NCTAMS, for transmit and receive operations.

AN/WSC-6(V) SHF SATCOM ANTENNA

The antennas used on current shf SATCOM shipboard terminals are parabolic reflectors with casseegrain feeds. These antennas provide for LPI (low probability of intercept), with beamwidths less than 2.5 degrees (fig. 2-34). The reflectors are mounted on three-axis pedestals and provide autotracking of a beacon or communication signal by conical scanning techniques. The antennas are radome enclosed and include various electronic components. Both a 7-foot model (fig. 2-35) and a 4-foot model (fig. 2-36) are operational in the fleet.

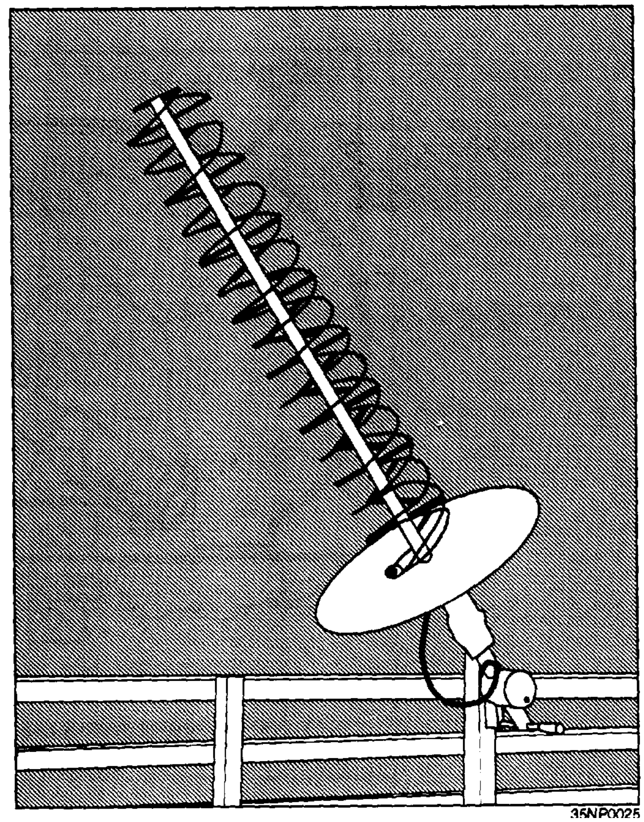

Figure 2-33.—Andrew 58622 shore antenna.

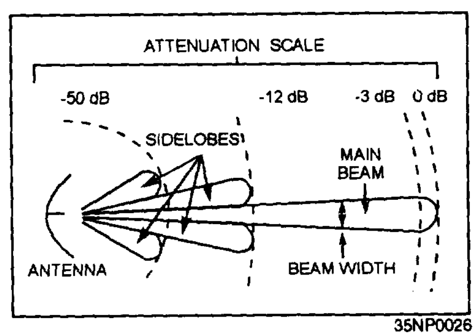

Figure 2-34.—AN/WSC-6(V) attenuation scale.

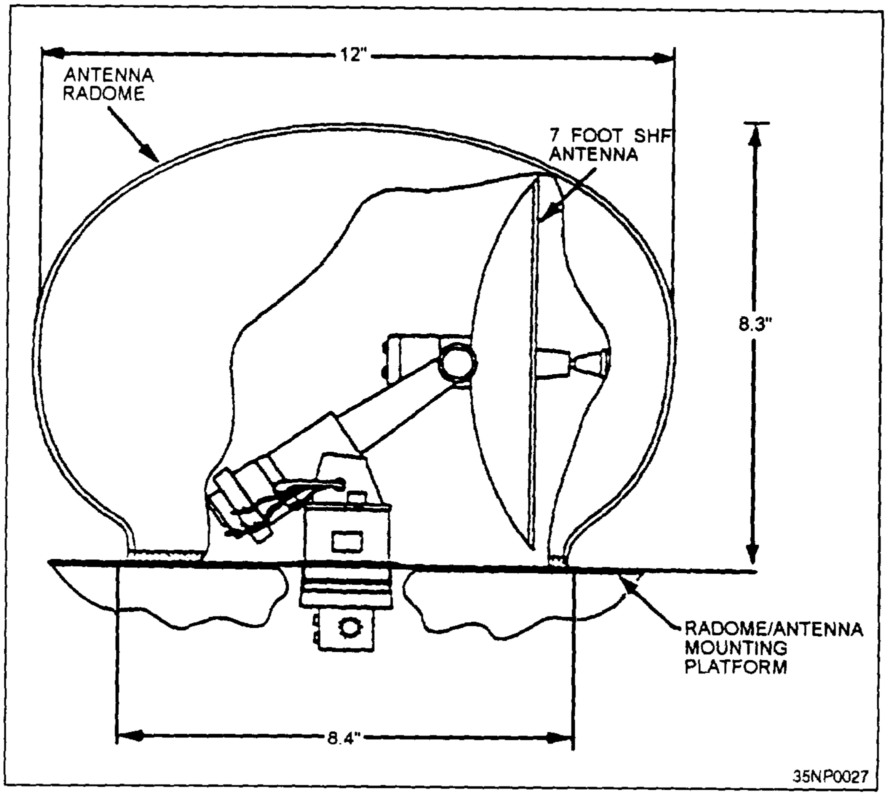

Figure 2-35.—Seven-foot shf SATCOM antenna.

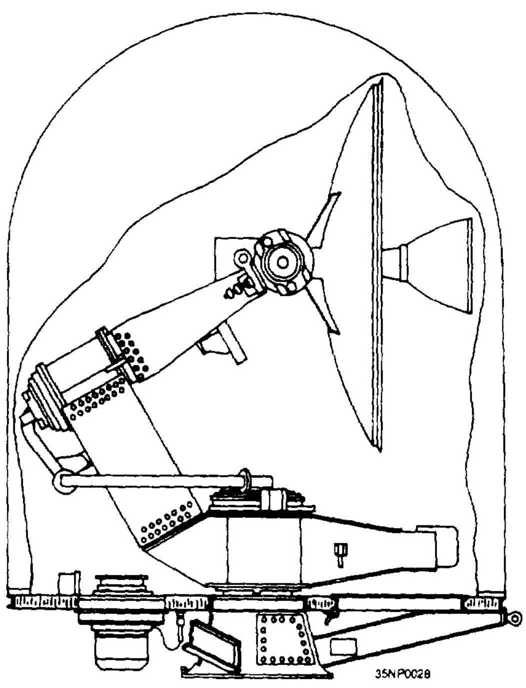

Figure 2-36.—Four-foot shf SATCOM antenna.

MATCHING NETWORKS

An antenna matching network consists of one or more parts (such as coils, capacitors, and lengths of transmission line) connected in series or parallel with the transmission line to reduce the standing wave ratio on the line. Matching networks are usually adjusted when they are installed and require no further adjustment for proper operation. Figure 2-37 shows a matching network outside of the antenna feedbox, with a sample matching network schematic.

Matching networks can also be built with variable components so they can be used for impedance matching over a range of frequencies. These networks are called antenna tuners.

Antenna tuners are usually adjusted automatically or manually each time the operating frequency is changed. Standard tuners are made with integral enclosures. Installation consists simply of mounting

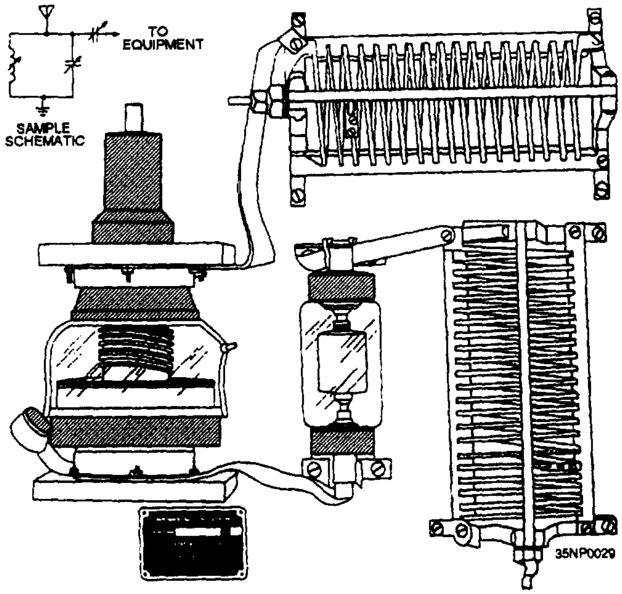

Figure 2-37.—Matching network.

the tuner, assembling the connections with the antenna and transmission line, and pressurizing the tuner, if necessary. Access must be provided to the pressure gauge and pressurizing and purging connections.

ANTENNA TUNING

For every frequency in the frequency spectrum, there is an antenna that is perfect for radiating at that frequency. By that we mean that all of the power being transmitted from the transmitter to the antenna will be radiated into space. Unfortunately, this is the ideal and not the rule. Normally, some power is lost between the transmitter and the antenna. This power loss is the result of the antenna not having the perfect dimensions and size to radiate perfectly all of the power delivered to it from the transmitter. Naturally, it would be unrealistic to carry a separate antenna for every frequency that a communications center is capable of radiating; a ship would have to have millions of antennas on board, and that would be impossible.

To overcome this problem, we use ANTENNA TUNING to lengthen and shorten antennas electrically to better match the frequency on which we want to transmit. The rf tuner is connected electrically to the antenna and is used to adjust the apparent physical length of the antenna by electrical means. This simply means that the antenna does not physically change length; instead, it is adapted electrically to the output frequency of the transmitter and "appears" to change its physical length. Antenna tuning is done by using antenna couplers, tuners, and multicouplers.

Antenna couplers and tuners are used to match a single transmitter or receiver to one antenna whereas antenna multicouplers are used to match more than one transmitter or receiver to one antenna for simultaneous operation. Some of the many antenna couplers that are in present use are addressed in the following paragraphs. For specific information on a particular coupler, refer to the appropriate equipment technical manual.

Antenna Coupler Group AN/URA-38

Antenna Coupler Group AN/URA-38 is an automatic antenna tuning system intended primarily for use with the AN/URT-23(V) operating in the high-frequency range. The equipment also includes provisions for manual and semiautomatic tuning, making the system readily adaptable for use with other radio transmitters. The manual tuning feature is useful when a failure occurs in the automatic tuning circuitry. Tuning can also be done without the use of rf power (silent tuning). This method is useful in installations where radio silence must be maintained except for brief transmission periods.

The antenna coupler matches the impedance of a 15-, 25-, 28-, or 35-foot whip antenna to a 50-ohm transmission line, at any frequency in the 2-to 30-MHz range. When the coupler is used with the AN/URT-23(V), control signals from the associated antenna coupler control unit automatically tune the coupler's matching network in less than 5 seconds. During manual and silent operation, the operator uses the controls mounted on the antenna coupler control unit to tune the antenna. A low-power (less than 250 watts) cw signal is required for tuning. Once tuned, the CU 938A/URA-38 is capable of handling 1000 watts PEP.

Antenna Coupler Groups AN/SRA-56, -57, and -58

Antenna coupler groups AN/SRA-56, -57, and -58 are designed primarily for shipboard use. Each coupler group permits several transmitters to operate simultaneously into a single, associated, broadband antenna, thus reducing the total number of antennas required in the limited space aboard ship.

These antenna coupler groups provide a coupling path of prescribed efficiency between each transmitter and the associated antenna. They also provide isolation between transmitters, tunable bandpass filters to suppress harmonic and spurious transmitter outputs, and matching networks to reduce antenna impedances.

The three antenna coupler groups (AN/SRA-56, -57, -58) are similar in appearance and function, but they differ in frequency ranges. Antenna coupler group AN/SRA-56 operates in the 2- to 6-MHz frequency range. The AN/SRA-57 operates from 4 to 12 MHz, and the AN/SRA-58 operates from 10 to 30 MHz. When more than one coupler is used in the same frequency range, a 15 percent frequency separation must be maintained to avoid any interference.

Antenna Coupler Group AN/SRA-33

Antenna coupler group AN/SRA-33 operates in the uhf (225-400 Mhz) frequency range. It provides isolation between as many as four transmitter and receiver combinations operating simultaneously into a common uhf antenna without degrading operation. The AN/SRA-33 is designed for operation with shipboard radio set AN/WSC-3. The AN/SRA-33 consists of four antenna couplers (CU-1131/SRA-33 through CU-1134/SRA-33), a control power supply C-4586/SRA-33, an electronic equipment cabinet CY-3852/SRA-33, and a set of special-purpose cables.

OA-9123/SRC

The OA-9123/SRC multicoupler enables up to four uhf transceivers, transmitters, or receivers to operate on a common antenna. The multicoupler provides low insertion loss and highly selective filtering in each of the four ports. The unit is interface compatible with the channel select control signals from radio sets AN/WSC-3(V) (except (V)1). The unit is self-contained and is configured to fit into a standard 19-inch open equipment rack.

The OA-9123/SRC consists of a cabinet assembly, control power supply assembly, and four identical filter assemblies. This multicoupler is a state-of-the-art replacement for the AN/SRA-33 and only requires about half of the space.

RECEIVING ANTENNA DISTRIBUTION SYSTEMS

Receiving antenna distribution systems operate at low power levels and are designed to prevent multiple signals from being received. The basic distribution system has several antenna transmission lines and several receivers, as shown in figure 2-38. The system includes two basic patch panels, one that terminates the antenna transmission lines, and the other that terminates the lines leading to the receivers. Thus, any antenna can be patched to any receiver via patch cords.

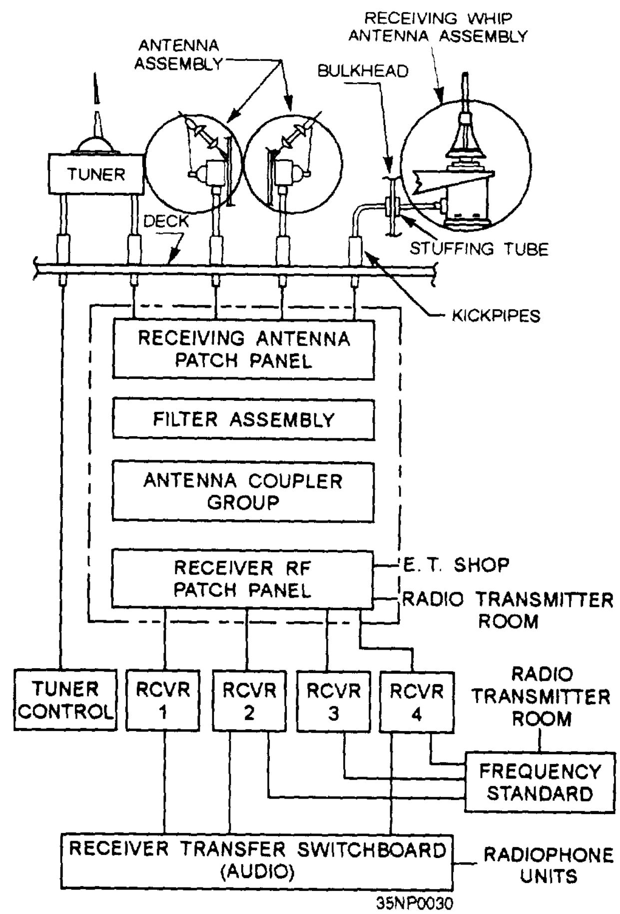

Figure 2-38.—Receive signal distribution system.

Some distribution systems will be more complex. That is, four antennas can be patched to four receivers, or one antenna can be patched to more than one receiver via the multicouplers.

RECEIVING MULTICOUPLER AN/SRA-12

The AN/SRA-12 filter assembly multicoupler provides seven radio frequency channels in the 14-kHz to 32-MHz frequency range. Any of these channels may be used independently of the other channels, or they may operate simultaneously. Connections to the receiver are made by coaxial patch cords, which are short lengths of cable with a plug attached to each end.

ANTENNA COUPLER GROUPS AN/SRA-38, AN/SRA-39, AN/SRA-40, AN/SRA-49, AN/SRA-49A, and AN/SRA-50

These groups are designed to connect up to 20 mf and hf receivers to a single antenna, with a highly selective degree of frequency isolation. Each of the six coupler groups consists of 14 to 20 individual antenna couplers and a single-power supply module, all are slide-mounted in a special electronic equipment rack. An antenna input distribution line termination (dummy load) is also supplied. In addition, there are provisions for patching the outputs from the various antenna couplers to external receivers.

RADAR ANTENNAS

Radar antennas are usually directional antennas that radiate energy in one lobe or beam. The two most important characteristics of directional antennas are directivity and power gain. Most radar systems use parabolic antennas. These antennas use parabolic reflectors in different variations to focus the radiated energy into a desired beam pattern.

While most radar antennas are parabolic, other types such as the corner reflector, the broadside array, and horn radiators may also be used.

PARABOLIC REFLECTORS

To understand why parabolic reflectors are used for most radar antennas, you need to understand how radio waves behave. A point source, such as an omnidirectional antenna produces a spherical radiation pattern, or spherical wavefront. As the sphere expands, the energy contained in a given surface area decreases rapidly. At a relatively short distance from the antenna, the energy level is so small that its reflection from a target would be useless in a radar system.

A solution to this problem is to form the energy into a PLANE wavefront, In a plane wavefront, all of the energy travels in the same direction, thus providing more energy to reflect off of a target. To concentrate the energy even further, a parabolic reflector is used to shape the plane wavefront's energy into a beam of energy. This concentration of energy provides a maximum amount of energy to be reflected off of a target, making detection of the target much more probable.

How does the parabolic reflector focus the radio waves? Radio waves behave much as light waves do. Microwaves travel in straight lines as do light rays. They may be focused or reflected, just as light rays may be. In figure 2-39, a point-radiation source is placed at the focal point F. The field leaves this antema with a spherical wavefront. As each part of the wavefront moving toward the reflector reaches the reflecting surface, it is shifted 180 degrees in phase and sent outward at angles that cause all parts of the field to travel in parallel paths. Because of the shape of a parabolic surface, all paths from F to the reflector and back to line XY are the same length. Therefore, all parts of the field arrive at line XY at the same time after reflection.

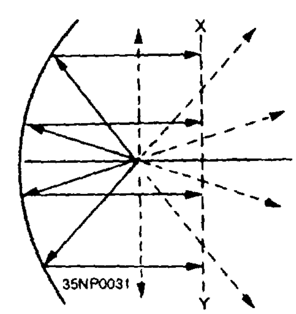

Figure 2-39.—Parabolic reflector radiation.

Energy that is not directed toward the paraboloid (dotted lines in fig. 2-39) has a wide-beam characteristic that would destroy the narrow pattern from the parabolic reflector. This destruction is prevented by the use of a hemispherical shield (not shown) that directs most of what would otherwise be spherical radiation toward the parabolic surface. Without the shield, some of the radiated field would leave the radiator directly, would not be reflected, and would serve no useful purpose. The shield makes the beamsharper, and concentrates the majority of the power in the beam. The same results can be obtained by using either a parasitic array to direct the radiated field back to the reflector, or a feed horn pointed at the paraboloid.

The radiation pattern of the paraboloid contains a major lobe, which is directed along the axis of the paraboloid, and several minor lobes, as shown in figure 2-40. Very narrow beams are possible with this type of reflector. View A of figure 2-41 illustrates the parabolic reflector.

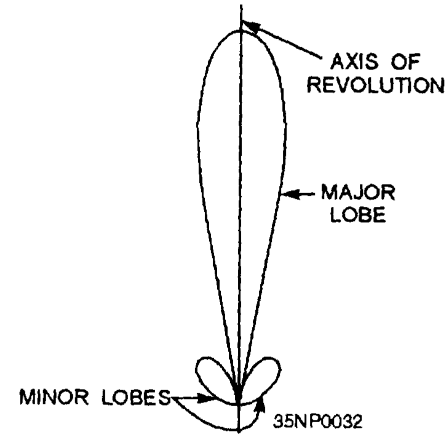

Figure 2-40.—Parabolic radiation pattern.

Truncated Paraboloid

While the complete parabolic reflector produces a pencil-shaped beam, partial parabolic reflectors produce differently shaped beams. View B of figure 2-41 shows a horizontally truncated, or vertically shortened, paraboloid. This type of reflector is designed to produce a beam that is narrow horizontally but wide vertically. Since the beam is wide vertically, it will detect aircraft at different altitudes without changing the tilt of the antenna. It also works well for surface search radars to overcome the pitch and roll of the ship.

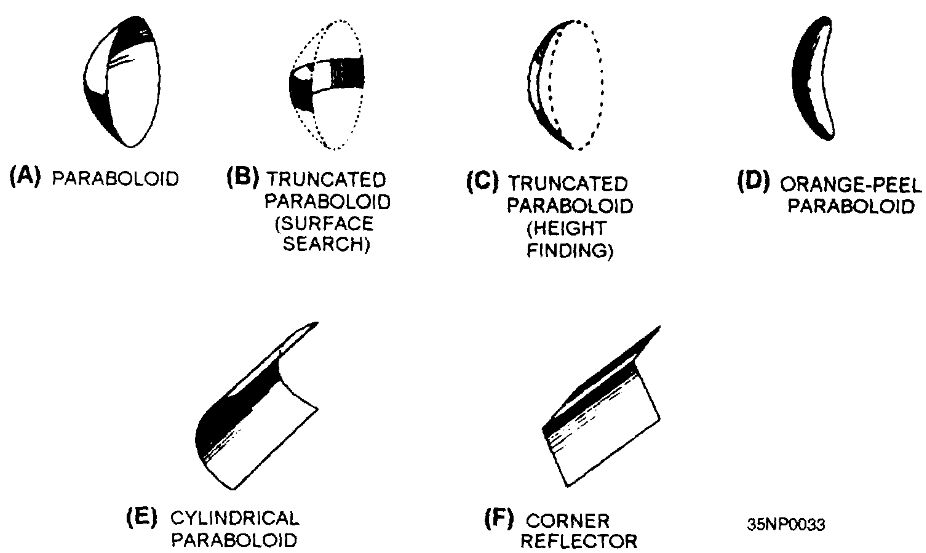

Figure 2-41.—Reflector shapes.

The truncated paraboloid reflector may be used in height-finding systems if the reflector is rotated 90 degrees, as shown in view C of figure 2-41. This type of reflector produces a beam that is wide horizontally but narrow vertically. The beam pattern is spread like a horizontal fan. Such a fan-shaped beam can be used to determine elevation very accurately.

Orange-Peel Paraboloid

A section of a complete circular paraboloid, often called an ORANGE-PEEL REFLECTOR because of its shape, is shown in view D of figure 2-41. Since the reflector is narrow in the horizontal plane and wide in the vertical, it produces a beam that is wide in the horizontal plane and narrow in the vertical. In shape, the beam resembles a huge beaver tail. This type of antenna system is generally used in height-finding equipment.

Cylindrical Paraboloid

When a beam of radiated energy noticeably wider in one cross-sectional dimension than in the other is desired, a cylindrical paraboloid section approximating a rectangle can be used. View E of figure 2-41 illustrates this antenna. A parabolic cross section is in one dimension only; therefore, the reflector is directive in one plane only. The cylindrical paraboloid reflector is either fed by a linear array of dipoles, a slit in the side of a waveguide, or by a thin waveguide radiator. Rather than a single focal point, this type of reflector has a series of focal points forming a straight line. Placing the radiator, or radiators, along this focal line produces a directed beam of energy. As the width of the parabolic section is changed, different beam shapes are produced. This type of antenna system is used in search systems and in ground control approach (gca) systems.

CORNER REFLECTOR

The corner-reflector antenna consists of two flat conducting sheets that meet at an angle to form a corner, as shown in view F of figure 2-41. This reflector is normally driven by a half-wave radiator located on a line that bisects the angle formed by the sheet reflectors.

BROADSIDE ARRAY

Desired beam widths are provided for some vhf radars by a broadside array, such as the one shown in figure 2-42. The broadside array consists of two or more half-wave dipole elements and a flat reflector. The elements are placed one-half wavelength apart and parallel to each other. Because they are excited in phase, most of the radiation is perpendicular or broadside to the plane of the elements. The flat reflector is located approximately one-eighth wavelength behind the dipole elements and makes possible the unidirectional characteristics of the antenna system.

HORN RADIATORS

Horn radiators, like parabolic reflectors, may be used to obtain directive radiation at microwave frequencies. Because they do not involve resonant elements, horns have the advantage of being usable over a wide frequency band.

The operation of a horn as an electromagnetic directing device is analogous to that of acoustic horns. However, the throat of an acoustic horn usually has dimensions much smaller than the sound wavelengths for which it is used, while the throat of the electromagnetic horn has dimensions that are comparable to the wavelength being used.

Horn radiators are readily adaptable for use with waveguides because they serve both as an impedance-

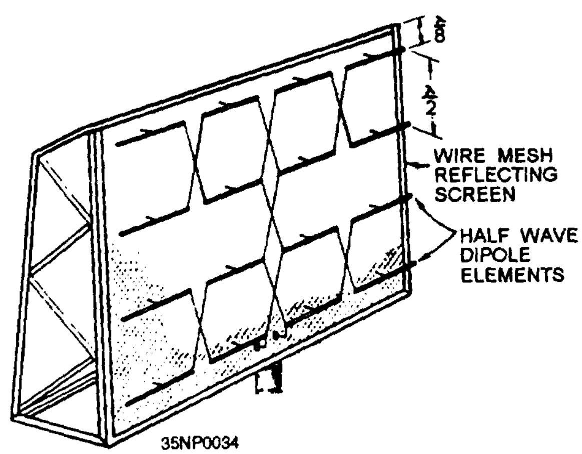

Figure 2-42.—Broadside array.

matching device and as a directional radiator. Horn radiators may be fed by coaxial or other types of lines.

Horns are constructed in a variety of shapes as illustrated in figure 2-43. The shape of the horn and the dimensions of the length and mouth largely determine the field-pattern shape. The ratio of the horn length to mouth opening size determines the beam angle and, thus, the directivity. In general, the larger the opening of the horn, the more directive is the resulting field pattern.

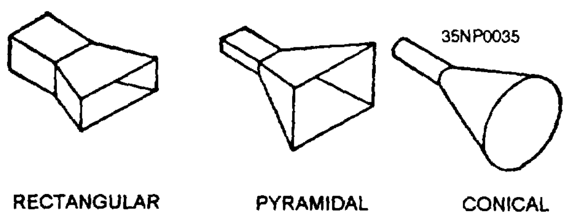

Figure 2-43.—Horn radiators.

FEEDHORNS

A waveguide horn, called a FEEDHORN, may be used to feed energy into a parabolic dish. The directivity of this feedhorn is added to that of the parabolic dish. The resulting pattern is a very narrow and concentrated beam. In most radars, the feedhorn is covered with a window of polystyrene fiberglass to prevent moisture and dirt from entering the open end of the waveguide.

One problem associated with feedhorns is the SHADOW introduced by the feedhorn if it is in the path of the beam. (The shadow is a dead spot directly in front of the feedhorn.) To solve this problem the feedhorn can be offset from center. This location change takes the feedhorn out of the path of the rf beam and eliminates the shadow. An offset feedhorn is shown in figure 2-44.

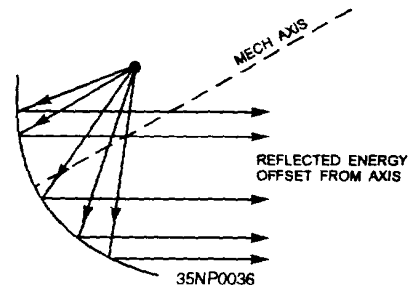

Figure 2-44.—Offset feedhorn.

RADAR SYSTEMS

Now that you have a basic understanding of how radar antennas operate, we will introduce you to a few of the radar systems currently in use.

AN/GPN-27(ASR-8) AIR SURVEILLANCE RADAR

The AN/GPN-27(ASR-8) (fig. 2-45) antenna radiates a beam 1.5 degrees in azimuth and shaped in elevation to produce coverage of up to approximately 32 degrees above the horizon. This provides a maplike presentation of aircraft within 55 nautical miles of an airport terminal. The antenna azimuth

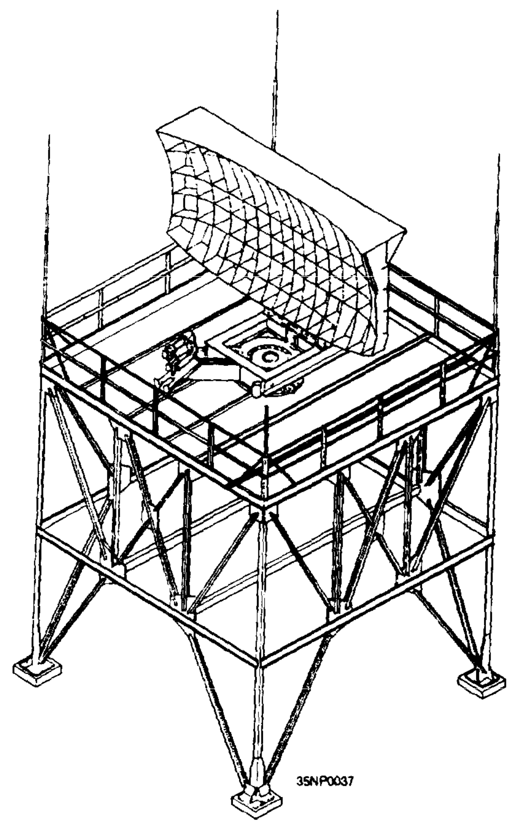

Figure 2-45.—AN/GPN-27(ASR-8) air surveillance radar.

pulse generator (APG), located in the rotary joint, transmits to the radar indicator azimuth information corresponding to beam direction. Polarization of the radiated energy can be remotely switched to either linear or circular polarization. The reflector has a modified parabolic shape designed to produce an approximately cosecant squared beam in the elevation plane. The reflector surface, covered with expanded aluminum screen, is 16.1 feet wide and 9 feet high. The antenna feedhorn, which mounts on the polarizer, provides impedance matching between the waveguide system and free space, and produces the desired feed pattern to illuminate the reflector. A radome over the horn aperture excludes moisture and foreign matter, and provides a pressure seal.

AS-3263/SPS-49(V)

The AS-3263/SPS-49(V) antenna (fig. 2-46) consists of three major sections: the antenna base and pedestal assembly, the feedhorn and feedhorn support boom, and the reflector assembly.

The base assembly provides a surface for mounting the antenna to the ship. It also contains the azimuth drive gearbox. The gearbox is driven by the azimuth drive motor, which drives the pedestal in azimuth through a pinion gear mated to a ring gear located at the bottom of the cone-shaped pedestal assembly, The azimuth drive circuits rotate the antenna through 360 degrees at speeds of 6 rpm and 12 rpm.

The reflector and the feedhorn support boom are mounted on a trunnion, allowing the elevation angle of the rf beam to be controlled by a jackscrew located behind the reflector. The jackscrew is rotated by the elevation drive gearbox, which is connected to two dc motors. The rf energy to the feedhorn is routed through elevation and azimuth rotary joints located within the pedestal.

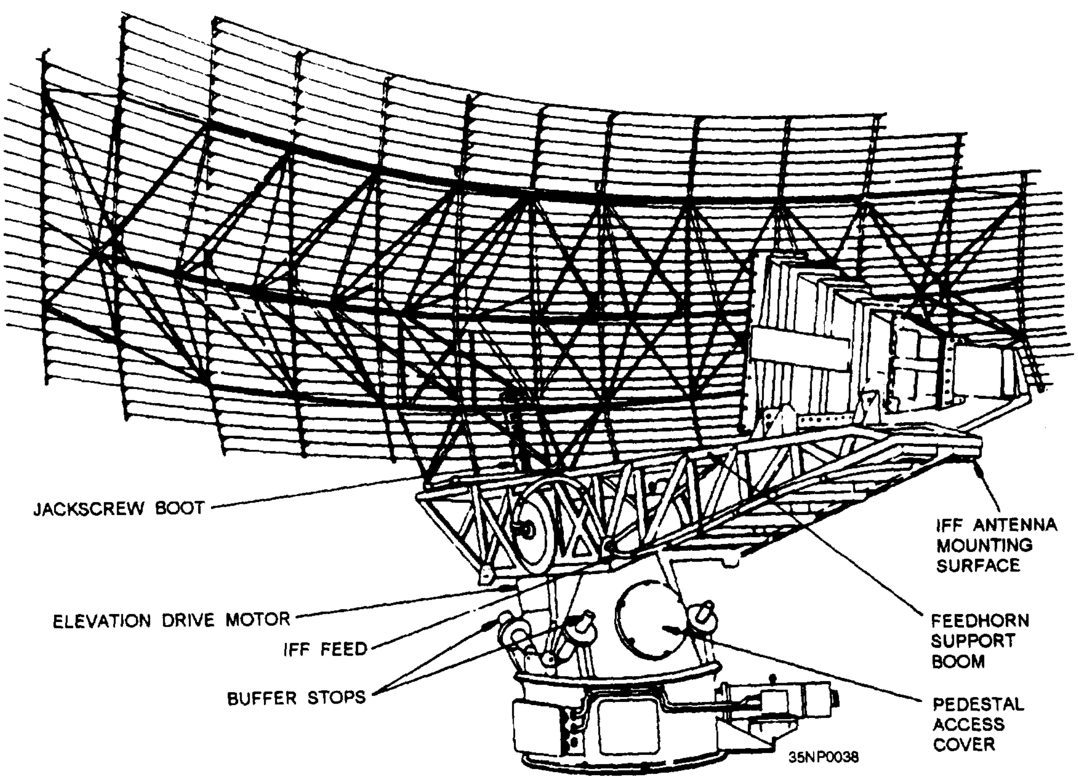

Figure 2-46.—AS-3263/SPS-49(V) antenna.

The reflector is 24 feet wide and has a double-curved surface composed of a series of horizontal members that form a reflecting surface for the horizontally polarized C-band energy. The antenna has a 28-dB gain, with a beamwidth of 9 degrees minimum vertically and approximately 3.3 degrees horizontally. Antenna roll and pitch stabilization limits are plus or minus 25 degrees, Stabilization accuracy is plus or minus 1 degree with the horizontal plane.

The antenna is equipped with a safety switch located near the antenna pedestal area. The safety switch disables the azimuth and elevation functions in the antenna and the radiate function in the transmitter to provide protection for personnel working on the antenna.

OE-172/SPS-55

The OE-172/SPS-55 antenna group consists of the antenna and the antenna pedestal. The antenna group is mast-mounted by means of four bolt holes on the base of the pedestal.

The antenna consists of two waveguide slotted arrays mounted back-to-back. One array provides linear polarization, while the other provides circular polarization. The array used is selected by means of a remotely controlled waveguide switch located on the pedestal. Linear polarization is used for most conditions. Circular polarization is used to reduce return echoes from precipitation. Each antenna forms a fan beam that is narrow in the azimuth plane and moderately broad in the elevation plane.

Figure 2-47 shows a cross-section of the SPS-55 antenna. During transmission, the rf signal enters the antenna through a feed waveguide and then enters a feed manifold region of 80 periodic narrow-wall slots. The slots are skewed in angle and alternated in direction of skew. They are separated by approximately one-half wavelength, resulting in broadside radiation into the sectoral horn region of the antenna. The horizontally polarized radiation from the manifold travels in the horn region toward the aperture, where it encounters an array of vertical sheet metal slats.

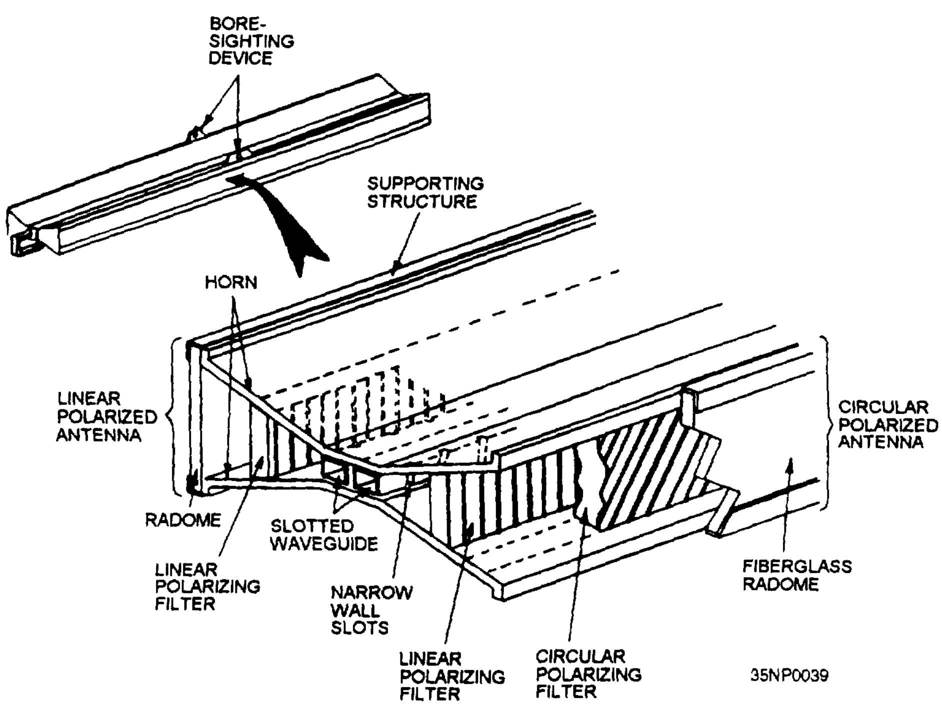

Figure 2-47.—SPS-55 antenna cross section.

This array is a polarizing filter, which ensures that only horizontally polarized energy travels from the horn region. The antenna scans at a rate of 16 rpm and produces an absolute gain of 31 dB at midband.

AN/SPN-35A AIRCRAFT CONTROL APPROACH RADAR

The AN/SPN-35A (fig 2-48) is a carrier-controlled-approach (CCA) radar set used for precision landing approaches during adverse weather conditions. The radar displays both azimuth and elevation data, which enables the radar operator to direct aircraft along a predetermined glide path and azimuth course line to a transition point approximately 2 miles from the ramp of the flight deck.

The azimuth antenna, AS-1292/TPN-8, functions in the azimuth rf line for radiation and reception of X-band rf pulses. The azimuth antenna comprises a truncated paraboloid-type reflector with an offset feedhorn and a polarizer assembly that provides remote-controlled selection of either horizontal or circular polarization. The antenna is located above the azimuth drive assembly on the stabilized yoke. The azimuth drive can rotate the antenna in either 360 degrees or in limited-sector modes of operation in the horizontal plane.

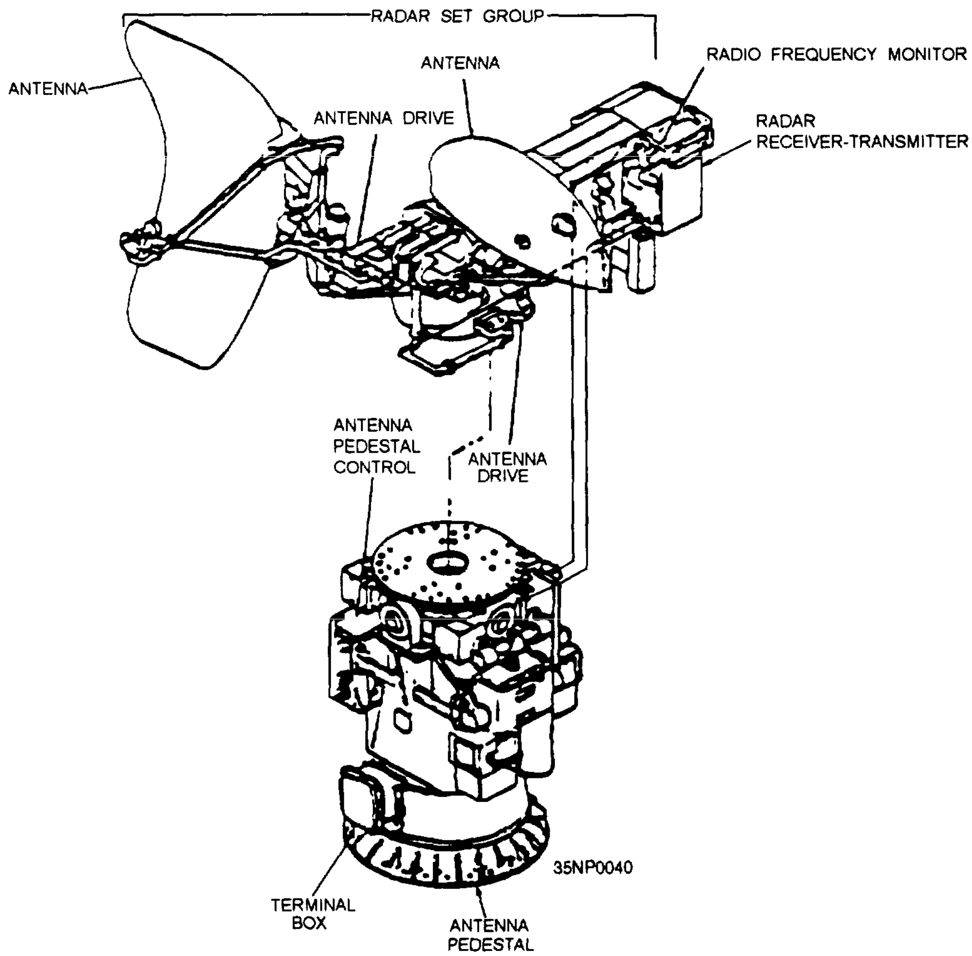

Figure 2-48.—AN/SPN-3SA aircraft control approach radar.

The elevation antenna, AS-1669/SPN-35, is a truncated paraboloid-type reflector with a dual-channel feedhorn and a polarizer assembly providing monopulse-type radiation and reception of X-band rf pulses. The horizontal shape of the laminated fiberglass reflector is cosecanted. The dual-channel feedhorn and polarizer are fixed in circular polarization by an external grid device. The elevation antenna is stabilized-yoke mounted on the elevation drive assembly adjacent to the azimuth antenna. The elevation drive provides the required motion for the elevation antenna and locks electrically with the search drive when the radar set operates in the precision mode.

The radar operates in three modes, final, surveillance, and simultaneous, with each antenna acting independently. In the final (precision) mode, the azimuth antenna scans a 30-degree sector (60-degree sector optional) while the elevation antenna scans a 10-degree sector (35-degree sector optional). In the surveillance mode the azimuth antenna rotates through the full 360-degree search pattern at 16 rpm while the elevation antenna scans a 10-degree sector. In the simultaneous mode, the azimuth antenna rotates through the full 360-degrees search pattern in 60-degree increments while the elevation antenna scans a 10-degree sector. The data rate in this mode is approximately 16 azimuth sweeps and 24 elevation sweeps every 60 seconds.

The antenna pedestal control stabilizes the azimuth and elevation antennas for plus or minus 3 degrees of pitch and plus or minus 10 degrees of roll.

RF SAFETY PRECAUTIONS

Although radio frequency emissions are usually harmless, there are still certain safety precautions you should follow whenever you are near high-power rf sources. Normally, electromagnetic radiation from transmission lines and antennas isn't strong enough to electrocute personnel. However, it may lead to other accidents and can compound injuries. Voltages may be induced into metal objects both above and below ground, such as wire guys, wire cable, hand rails, and ladders. If you come into contact with these objects, you may receive a shock or an rf burn. The shock can cause you to jump involuntarily, to fall into nearby equipment, or, when working aloft, to fall from the elevated work area. Take care to ensure that all transmission lines or antennas are de-energized before working on or near them.

When working aloft aboard ship, be sure to use a working aloft chit. This will ensure that all radiators, not only those on your own ship but also those nearby are secured while you are aloft.

ALWAYS obey rf radiation warning signs and keep a safe distance from radiating antennas. The six types of warning signs for rf radiation hazards are shown in figure 2-49.

The two primary safety concerns associated with rf fields are rf burns and injuries caused by dielectric heating.

RF BURNS

Close or direct contact with rf transmission lines or antennas may result in rf burns caused by induced voltages. These burns are usually deep, penetrating, third-degree burns. To heal properly, rf burns must heal from the inside toward the skin's surface. Do **NOT** take rf burns lightly. To prevent infection, you must give proper attention to **ALL** rf burns, including the small pinhole burns. **ALWAYS** seek treatment for any rf burn or shock and report the incident to your supervisor so appropriate action can be taken to correct the hazard.

DIELECTRIC HEATING

While the severity of rf burns may vary from minor to major, burns or other damage done by DIELECTRIC HEATING may result in long-term injury, or even death. Dielectric heating is the heating of an insulating material caused by placing it in a high-frequency electric field. The heat results from the rapid reversal of molecular polarization dielectric material.

When a human is in an rf field, the body acts as the dielectric. If the power in the rf field exceeds 10 milliwatts per centimeter, the individual will have a noticeable rise in body temperature. Basically, the body is "cooking" in the rf field. The vital organs

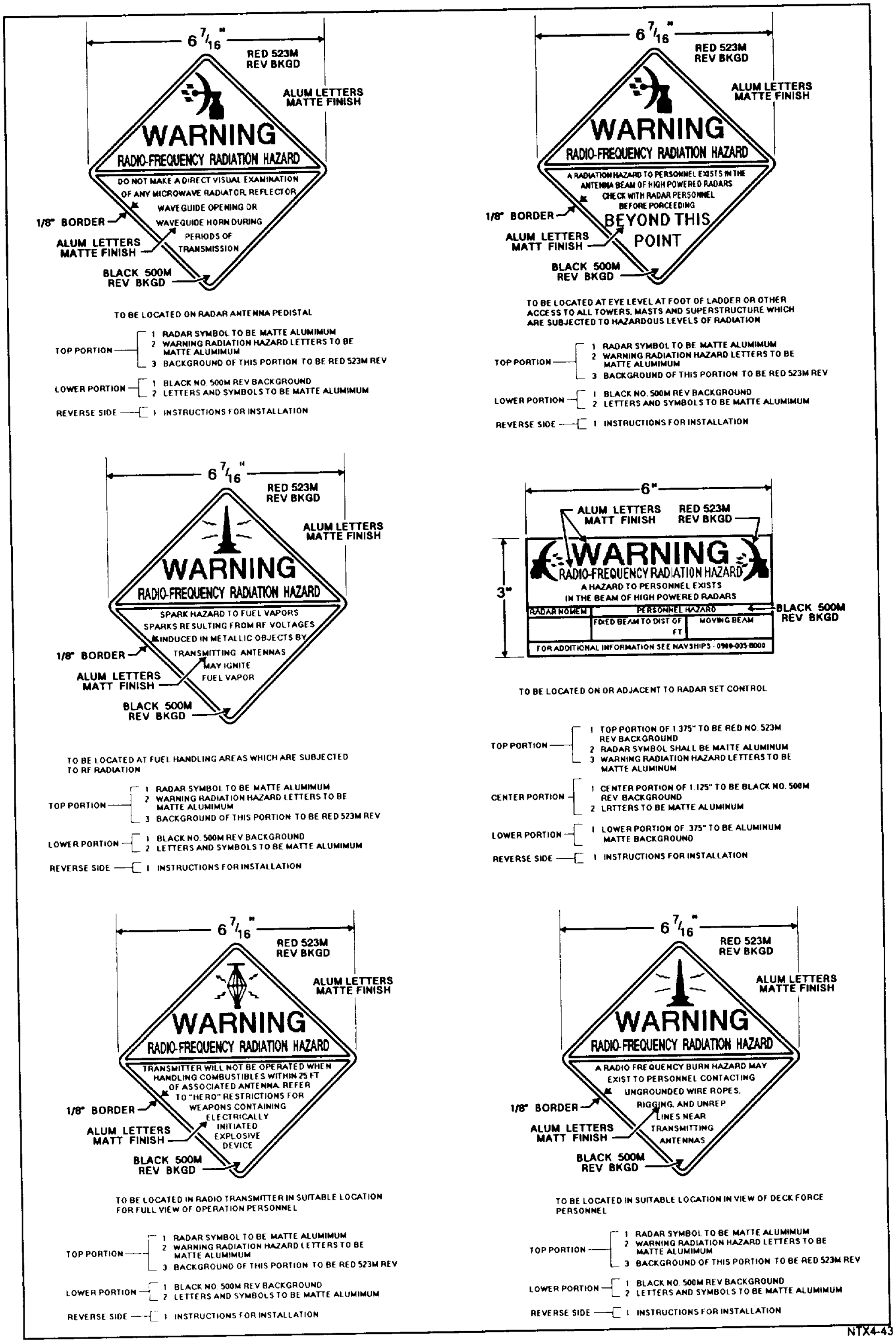

Figure 2-49.—Rf radiation warning signs

of the body are highly susceptible to dielectric heating. The eyes are also highly susceptible to dielectric heating. Do NOT look directly into devices radiating rf energy. Remember, rf radiation can be dangerous. For your own safety, you must NOT stand directly in the path of rf radiating devices.

PRECAUTIONS WHEN WORKING ALOFT

As we mentioned earlier, it is extremely important to follow all safety precautions when working aloft. Before you work on an antenna, ensure that it is tagged out properly at the switchboard to prevent it from becoming operational. Always be sure to secure the motor safety switches for rotating antennas. Have the switches tagged and locked open before you begin working on or near the antenna.

When working near a stack, draw and wear the recommended oxygen breathing apparatus. Among other toxic substances, stack gas contains carbon monoxide. Carbon monoxide is too unstable to build up to a high concentration in the open, but prolonged exposure to even small quantities is dangerous.

For more detailed information concerning the dangers and hazards of rf radiation, refer to the NAVELEX technical manual, *Electromagnetic Radiation Hazards.* NAVELEX 0967-LP-624-6010.

This completes chapter 2. In chapter 3, we will discuss transmission lines and waveguides.