CHAPTER 2

TRANSMISSION LINES, MULTICOUPLING DEVICES, AND ANTENNAS

The propagation and reception of RF energy not only requires a wide variety of transmitting and receiving equipments, but also many different types of transmission lines, antennas, and coupling devices. In many cases it is the responsibility of the radio operator to select the most suitable antenna for the task at hand. In order to make the proper selection, it is essential that the operator have a solid understanding of the basic types of antennas and their capabilities. Since the changing of antennas may also involve making or changing antenna connections, a knowledge of coupling devices is also necessary as they may mean the difference between efficient and inefficient operations. Further, a general knowledge of antennas and related devices will assist the operator in determining (1) whether or not the equipment is properly connected to the antenna best suited for the assigned circuit, and (2) whether or not the antenna and connecting devices are operating properly.

The two basic elements in every receiving system are the antenna and the receiver; however, the antenna and the receiver are seldom located together. A third element, the transmission line—is necessary to carry the energy from the antenna to the receiver.

TRANSMISSION LINES

There are many different types of transmission lines. Generally speaking, just about any type of wire is capable of carrying RF energy from an antenna to a receiver. The type of line that is used depends mainly upon the antenna used and the frequency of the signal being transmitted or received. In order to minimize the loss of energy associated with the transmission line, the one selected must be the most efficient available. The most commonly used transmission lines are the PARALLEL PAIR, TWISTED PAIR, SHIELDED PAIR, COAXIAL CABLE, and WAVEGUIDES.

PARALLEL PAIR

Parallel Pair are so named because they consist of a pair of conductors kept parallel to one another over the entire length of the line.

The open two-wire line, shown in figure 2-1A, uses insulating bars called "spacers" to separate the wires and has an air dielectric. (A dielectric is a material characterized by its relatively poor electrical conductivity.)

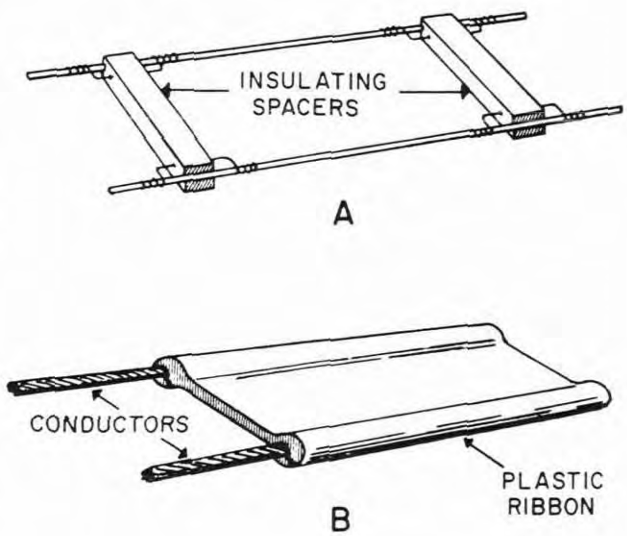

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Figure 2-1.—Parallel pair transmission lines.

The insulated two-wire line, shown in figure 2-1B, uses a solid plastic dielectric to separate the two wires and maintain a set distance between them. This is the type of transmission line commonly used to connect a television receiving antenna to a television set.

A parallel pair transmission line has the advantages of low cost, ease of installation, and good operating efficiency up into the mid-UHF range. At higher frequencies, however, a parallel pair may suffer high radiation losses, particularly when placed in the vicinity of metal objects.

TWISTED PAIR

The twisted pair, as the name implies, consists of two insulated wires twisted to form a flexible line. As can be seen in figure 2-2, the twisted pair does not use spacers. This type of transmission line is limited to low frequency applications below 15 MHz, and over very short distances. At frequencies above 15 MHz high energy losses are incurred. Its advantages are that it is easy to construct, it is economical, and it may be used where more efficient lines would not be feasible because of mechanical considerations.

SHIELDED PAIR

A shielded pair (figure 2-3) consists of two parallel conductors, separated from each other and surrounded by an insulating dielectric material. The conductors and dielectric material are contained within a metal braid tubing which acts as a shield. The entire assembly is then contained within a weatherproof coating made of rubber or some other flexible composition. This type of line is normally used for applications in the HF band and below. The principal advantage of the shielded pair over other types of two-wire lines is its low radiation loss. It also prevents interference from undesired radiations.

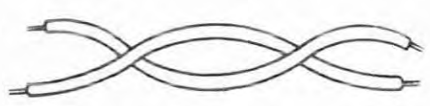

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Figure 2-2.—Twisted pair transmission line.

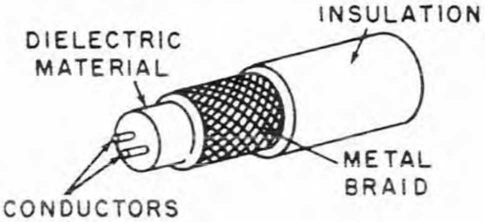

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Figure 2-3.—Shielded pair transmission line.

COAXIAL LINES

It is possible to place one conductor INSIDE another conductor to form a transmission line. Such a line is called a COAXIAL line. There are two types of coaxial lines: AIR COAXIAL and SOLID COAXIAL.

AIR COAXIAL.—The air coaxial, shown in figure 2-4A, consists of a wire inner conductor

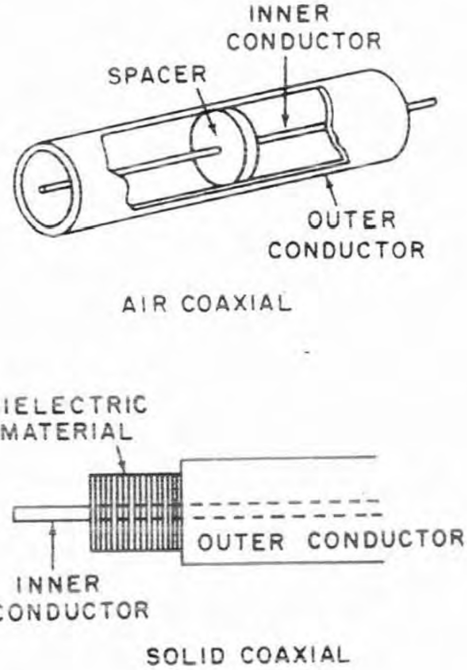

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Figure 2-4.—Coaxial transmission lines.

placed within a metal tube which serves as the outer conductor. The inner conductor is separated from the outer conductor by insulating spacers placed at regular intervals.

Air coaxial lines are very efficient for operation up to the mid-UHF band.

The principle advantage of air coaxial line is its ability to minimize radiation losses. The outer conductor provides perfect shielding–there is no radiation from the line and no noise is picked up from external sources. The major disadvantage is its high expense. The area between the inner and outer conductors must be kept pressurized to keep out moisture, thereby preventing power losses and supressing RF energy arcs between conductors.

SOLID COAXIAL.–The solid coaxial line (figure 2-4B) is probably the most commonly used type of transmission line. It consists of a wire inner conductor surrounded by a solid dielectric material, and an outer conductor of metal braid. One disadvantage in the solid coaxial line is that some of the energy transmitted through the inner conductor is absorbed by the dielectric material and, therefore, is lost. The amount of energy lost in this manner increases with frequency. Therefore the suitability of solid coaxial lines is limited to frequencies up to the lower portion of the UHF band.

Waveguides

Because of their extremely short wavelengths, frequencies above 1000 MHz are referred to as MICROWAVE frequencies. Excessive energy losses from radiation occur whenever standard transmission lines are used at microwave frequencies. Therefore, a special type of transmission line known as a WAVEGUIDE is used.

Waveguides are round or rectangular metal tubes (figure 2-5). They channel the signal from the input end with a much lower energy loss than that which would occur through the use of other types of transmission lines. Since waveguides can also effectively handle high power transmissions, they are ideal for radar applications where high levels of power are transmitted at microwave frequencies. The frequency range for waveguides is in the UHF band and above.

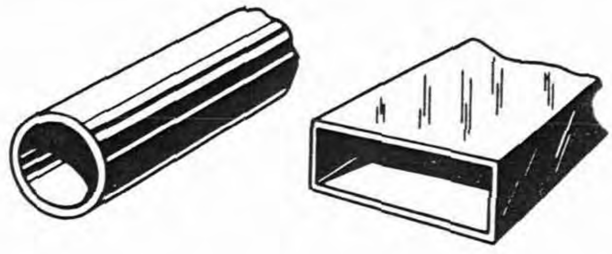

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Figure 2-5.–Cylindrical and rectangular waveguides.

MULTICOUPLERS

Multicouplers are devices that permit several receivers to operate simultaneously from one antenna. They are designed to provide the best possible coupling between antennas and receivers while isolating the receivers from each other. Unfortunately, some loss of signal quality will occur when multicouplers are used. Multicouplers are designed to operate efficiently over a fixed frequency spectrum only. A sha drop in efficiency will occur for frequenc outside the spectrum of the multicouplers. In order to use multicouplers efficiently, it is extremely important for the operator to ensure that the receiving frequency is within the range for which the multicoupler was designed.

ANTENNAS

An antenna is a device which either radiates (transmits) or receives energy in the form of electromagnetic waves. In its most elementary form, an antenna may be simply a single length of wire to which a transmission line is connected.

When such an antenna is used to transmit, waves of RF energy travel from the transmitter, through the transmission line, and on out toward the end of the antenna. An electromagnetic field expands around the antenna wire and then collapses with each alternation of the waves. During the first half of the alternation, (while the current is swinging from zero to its maximum positive or negative value), the electromagnetic field expands outward from the antenna. During the last half of the alternation, (while the current is swinging from its maximum positive or negative value back to zero) that portion of the electromagnetic field that is still near the antenna collapses and returns to the antenna, while that portion that is away from the antenna continues to travel outward into space.

If a receiving antenna is placed in the path of an electromagnetic wave that is traveling through space, RF (signal) current will be induced in the antenna. This induced current is then transported to the receiving system via a transmission line.

CT T, R, & I personnel may seldom have an occasion to work with transmitting antennas. However, operators should become familiar with the characteristics of transmitting antennas so that they can better select a receiving antenna, should the need arise.

WAVELENGTH

The physical length of an antenna is often referred to in wavelengths. Such terms as quarter-wave, half-wave, and full-wave are used extensively. Wavelength is usually expressed in meters and is defined as the velocity of a radio wave in free space divided by the frequency of the wave. The symbol for wavelength is λ (lambda).

Since the velocity of an electromagnetic wave in free space is considered to be 300 million meters per second, the formula for computing wavelength is expressed as:

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For example, to compute the length of a full wave antenna for use on 10,000 kHz proceed as follows:

$$\frac{300{,}000{,}000}{10{,}000{,}000} = 30 \text{ meters, or, since } 1 \text{ meter} = 3.28 \text{ feet}$$
$$30 \times 3.28 = 98.4 \text{ feet}$$

In half-wave or quarter-wave antenna values are desired, simply divide the result by 2 or 4.

ANTENNA POLARIZATION

The polarization of radio waves is dependent upon the position of the transmitting antenna with respect to the plane of the earth. An antenna that is mounted in a horizontal position radiates horizontally polarized waves, whereas a vertically mounted antenna will radiate vertically polarized waves.

Accordingly, a receiving antenna will generally receive radio waves most efficiently if it is configured in the SAME polarization as that of the transmitting antenna. A compromise of sorts may be achieved with receiving antennas by mounting them at 45° with respect to the earth's plane. Thus, both horizontally and vertically polarized signals can be received with acceptable efficiency. A receiving antenna with its polarity opposite to that of the transmitting antenna may be used for reception, however a substantial loss of signal energy will occur.

FIELD INTENSITY

The field intensity of a radiated radio wave is the strength of the wave at any given distance from the transmitting antenna. Field intensity is usually expressed in MICROVOLTS-PER-METER and is measured by special instruments after the antenna is installed and while it is being test-operated. On the basis of these measurements, changes may be made in the design or installation of the antenna in order to improve its radiation pattern.

ANTENNA RADIATION PATTERNS

The total radiation from an antenna is, in effect, comprised of two components: one component is radiated directly from the antenna into space; the other component is a ground reflection that appears to originate a mirror image of the antenna, as shown in figure 2-6.

The amount of energy reflected by the ground may vary greatly. Some terrains reflect virtually all of the energy that strikes it, while others reflect very little. Therefore, the ground reflection may be uniform or patchy, depending upon the composition of the terrain near the antenna.

Depending upon their amplitude and phase relationships, the direct and reflected components may reinforce or cancel one another. If the terrain near the antenna is a good conductor, with very little absorption of energy occurring during the reflection process, the reflected wave has the same amplitude as the direct wave. If two equal amplitude waves arrive at the receiving site in phase, the signal strength is much greater than that from the direct wave alone. On the other hand, if the direct and reflected waves arrive 180° out of phase, the signal strength will be zero. Intermediate values of signal strength occur with intermediate amplitude and phase relationships between the direct and reflected waves.

Because of ground reflections, the radiation pattern of an antenna is broken up into a series of gaps and lobes as shown in figure 2-7. A gap in the radiation pattern occurs in any direction wherein the two components cancel each other.

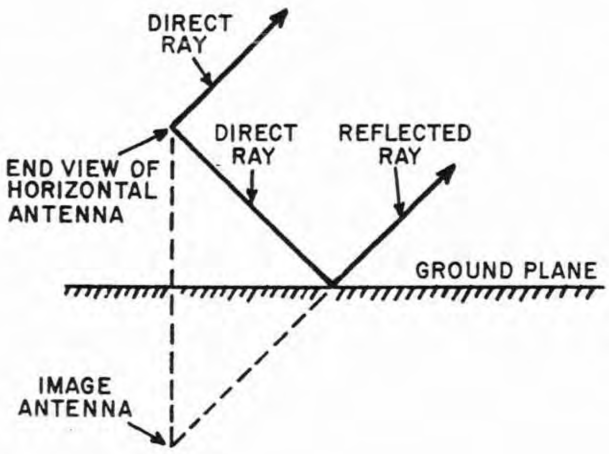

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Figure 2-6.—Direct and ground reflected rays.

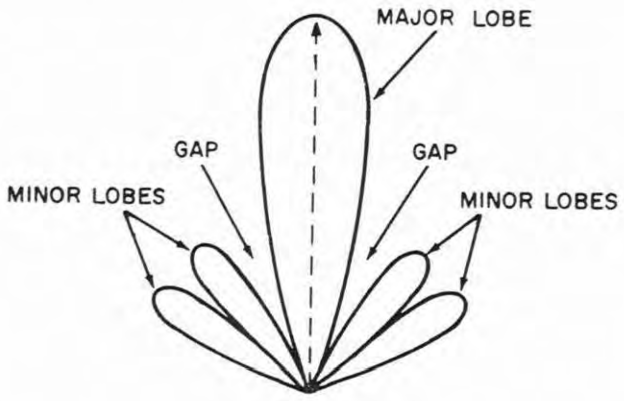

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Figure 2-7.—Radiation lobes and gaps.

A MINOR LOBE of radiation is formed where they partially cancel, and a MAJOR LOBE of radiation is formed where they reinforce each other.

RADIATION ANGLE

The angle between the horizontal plane of the earth and the axis of the antenna lobe is called the RADIATION ANGLE (figure 2-8). The radiation angle of an antenna can v greatly and is dependent upon several factors: the type of antenna; the height of the antenna above ground; the length of the antenna in number of wavelengths; and; the frequency at which the antenna is operated.

Antennas made up of long wires radiate at a low angle when the height or size of the antenna is large in terms of wavelength. These are design considerations that do not change once the antenna is installed. Of more importance in day-to-day operations, since it is a factor that can be controlled, is the frequency at which the antenna is operated—the higher the frequency, the lower the radiation angle.

Neither highly directional beam forming antennas, nor antenna arrays made of tubing, exhibit the changes in radiation angle that characterize wire antennas.

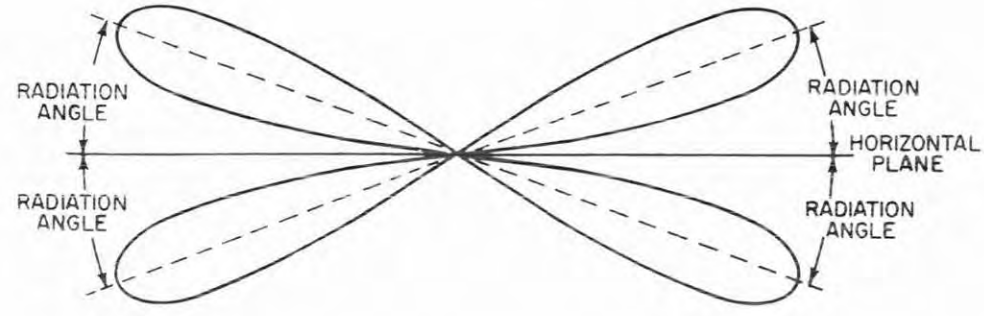

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Figure 2-8.—Antenna radiation angle.

ANTENNA BEAMWIDTH

A lobe of energy radiated from an antenna is referred to as a "beam". The width of a beam is expressed in degrees and, not too surprisingly, is referred to as the antenna BEAMWIDTH.

Narrow beamwidths are used extensively at microwave frequencies, particularly for radar systems. Radars may have beamwidths as narrow as one or two degrees, depending upon their application.

ANTENNA DIRECTIVITY

Most practical antennas are directional to some extent. This means that an antenna used for transmitting will radiate most of its energy in certain directions. The more an antenna concentrates its energy in a particular direction, the greater will be the field intensity produced in that direction for a given amount of total radiated power. Likewise, an antenna that is used for receiving will receive best if it is oriented in the direction of the radiation.

The directional characteristics of an antenna are determined to a great extent by its design and the position in which it is installed. Thus, certain directional qualities are associated with each type of antenna. The following terms are used to describe general directional qualities of an antenna:

OMNIDIRECTIONAL.—Receives or radiates approximately equal amounts of energy throughout a full 360 degree pattern.

DIRECTIONAL.—Receives or radiates energy only in certain directions. Directional antennas can be further classified as follows:

Bidirectional.—Receives or radiates efficiently in two directions: for example, North and South or East and West.

Unidirectional.—Receives or radiates efficiently in only one direction.

BASIC TYPES OF ANTENNAS

In the following discussion of basic types of antennas, reception rather than transmission of radio waves will be emphasized. Generally speaking, any antenna designed to transmit radio waves on a particular frequency can receive radio waves of the same frequency equally well. The greatest differences between transmitting and receiving antennas are the greater power-handling capability of transmitting antennas and the types of transmission lines that are used.

HALF-WAVE ANTENNA

The most basic type of antenna is a one-half wavelength antenna known as DIPOLE or HERTZ antenna. It consists of two one quarter wavelength conductors placed end to end. Normally, the transmission line is connected to placed within a metal tube which serves as the outer conductor. The inner conductor is separated from the outer conductor by insulating spacers placed at regular intervals.

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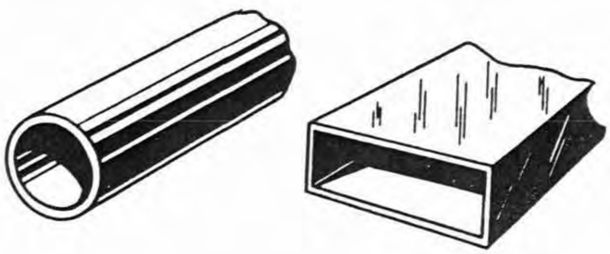

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ANTENNA RADIATION PATTERNS

The total radiation from an antenna is, in effect, comprised of two components: one component is radiated directly from the antenna the inside ends of the conductor as shown in figure 2-9.

Maximum efficiency is obtained from a dipole antenna only when it is operated at the frequency for which it is designed, or a multiple of that frequency. As we move away from the design frequency, efficiency drops off, becoming unacceptable at frequencies approximately five percent higher or lower than the design frequency. Therefore, this antenna is not suitable when a wide range of frequencies is to be used.

A dipole antenna is more or less omnidirectional, radiating energy in all directions from the surface of its conductors, but little, if any, from their ends. However, the effective radiation pattern of a dipole depends upon whether it is mounted in a horizontal or in a vertical position. A vertical dipole radiates in a full 360 degrees pattern resembling a doughnut lying on its side, as shown in figure 2-10. A dipole mounted horizontally also radiates in a doughnut-shaped pattern, but since energy radiated from the underside of the antenna is either absorbed or reflected by the ground, the effective radiation pattern is shaped more like a half-doughnut in the upright position. Figure 2-11 shows the radiation pattern of a horizontal dipole.

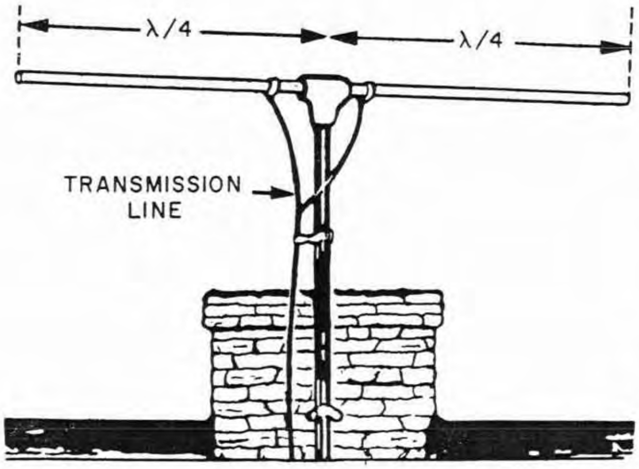

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Figure 2-9.—Dipole antenna.

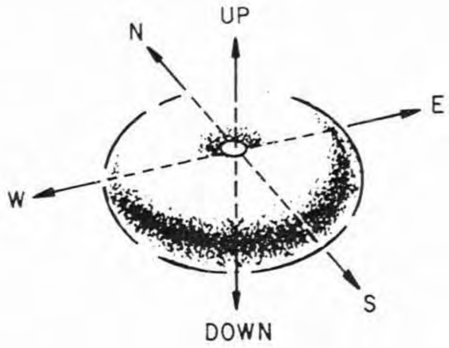

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Figure 2-10.—Radiation pattern of a vertical dipole antenna.

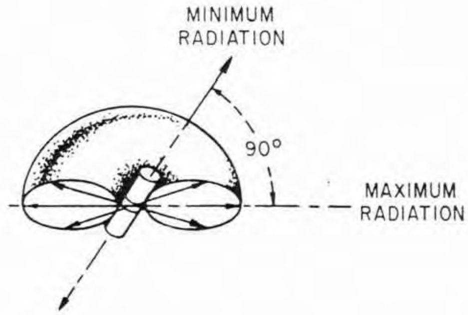

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Figure 2-11.—Radiation pattern of a horizontal dipole antenna.

QUARTER-WAVE ANTENNA

If the ground plane of an antenna is a fairly good conductor, it will act as a mirror for the reflection of energy that is radiated downward from an antenna. Using this characteristic, an antenna that is only a quarter-wavelength long can be made into the equivalent of a half-wave antenna. The antenna itself provides one quarter-wavelength, and the ground reflection serves as another quarter-wavelength antenna, known as the image antenna, as shown in figure 2-12.

The quarter-wave antenna (also known as the MARCONI or "grounded antenna") is widely used where available space is limited,

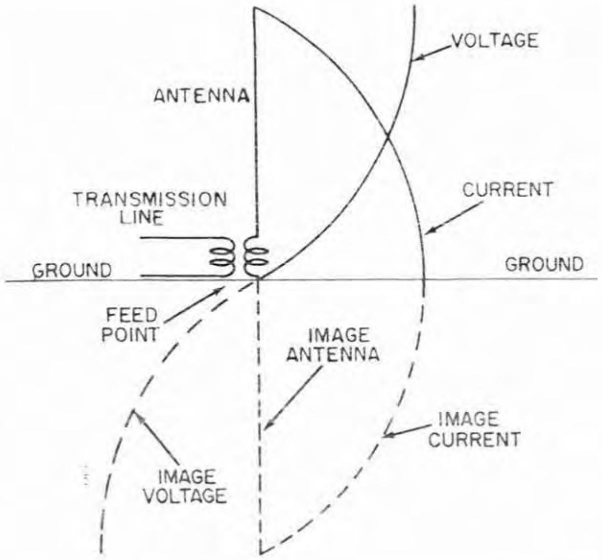

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Figure 2-12.—Quarter-wave antenna concept.

such as on ships and planes. Normally mounted in the vertical position, the quarter-wave antenna is electrically grounded to the ship's hull or plane's fuselage which serves as the ground to provide the image antenna. The transmission line is connected between the bottom of the antenna and the ground surface as illustrated in figure 2-12.

LONG WIRE ANTENNA

For some applications, especially in the VLF and LF spectrum, it is practical to use an antenna that is simply a long wire stretched horizontally between two poles, as shown in figure 2-13.

The long-wire antenna will radiate and receive better in certain directions than in others; however, it does not acquire appreciable directivity until it is several wavelengths long. As the number of wavelengths is increased, the more directional its radiation pattern becomes. Unfortunately, the benefit of increased directivity is offset by increased real estate requirements. In some cases in the VLF band, the antenna may be several miles long.

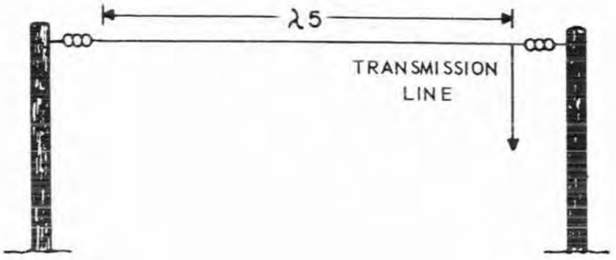

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Figure 2-13.—Long-wire antenna.

HORIZONTAL VEE ANTENNA

The horizontal Vee antenna is widely used in military and commercial applications. It consists of two horizontal long-wire antennas arranged in the shape of a V, with the apex of the Vee connected to the transmission line. The energy radiated from each of the long-wire antennas combine in such a way as to give the Vee antenna a bidirectional pattern as shown in figure 2-14.

RHOMBIC

One of the commonly used antennas for Security Group applications is the horizontal

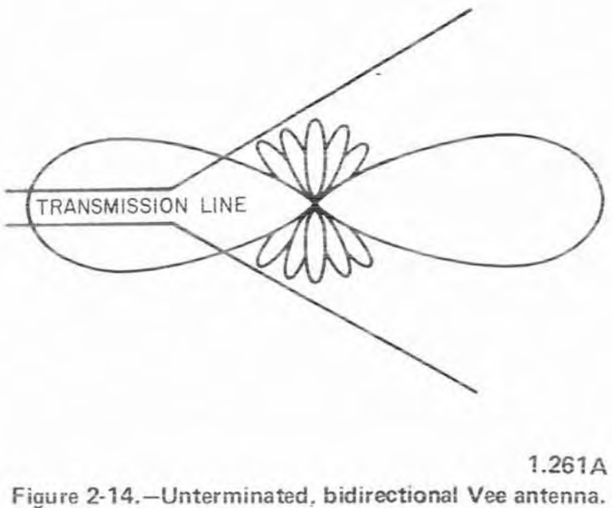

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Figure 2-14.—Unterminated, bidirectional Vee antenna.

RHOMBIC antenna. It consists of four long-wire antennas connected in the shape of a rhombus (or diamond), with a transmission line attached to one end as shown in figure 2-15.

Two advantages of the rhombic antenna are that it has a broad frequency range and it is easy and inexpensive to construct.

The rhombic antenna is not without its disadvantages, the principal one being that a fairly large antenna site is required for its erection. Each leg must be at least two wavelengths long at the lowest operating frequency, and when increased gain and directivity are required, legs of from 8 to 12 wavelengths are used.

A rhombic antenna that is designed primarily for reception will receive best when oriented toward the transmitting terminal. An operator, in selecting one of several rhombic antennas to receive a desired signal, or to attenuate an interfering signal, must often experiment with several antennas. The best method for choosing the proper antenna is to listen to the received signal while changing antennas, and use the one with the best signal quality.

MULTI-WIRE RHOMBIC

A rhombic antenna will improve in performance if more than a single wire is used form each leg. By using three wires to form ea... leg and connecting all of them at both ends to a common point, but spacing them vertically 5 to 7 feet apart at the side poles, an improved antenna known as a multi-wire or curtain rhombic is formed.

Advantages of the multi-wire rhombic include an improved signal-to-noise ratio, a slight increase in signal gain, and a reduction in interference caused by rain (precipitation static).

BROADBAND ANTENNAS

Concial Monopole

The Conical monopole antenna was developed to fulfill a need for a broad-band antenna in the HF range. It is omnidirectional in radiation and may be operated over a frequency range ratio of approximately 3 to 1, i.e., 5-20 MHz.

Conical monopoles are in the shape of two cones with the ends cut off and connected base to base as shown in figure 2-16. The bas...

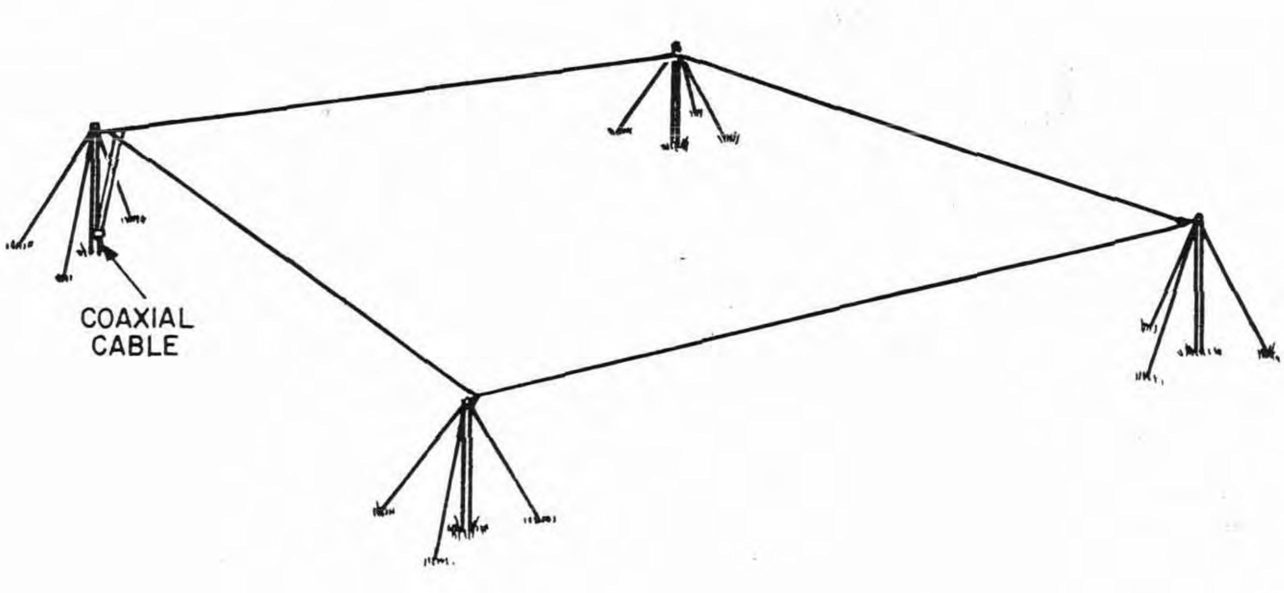

Figure 2-15.—A rhombic antenna.

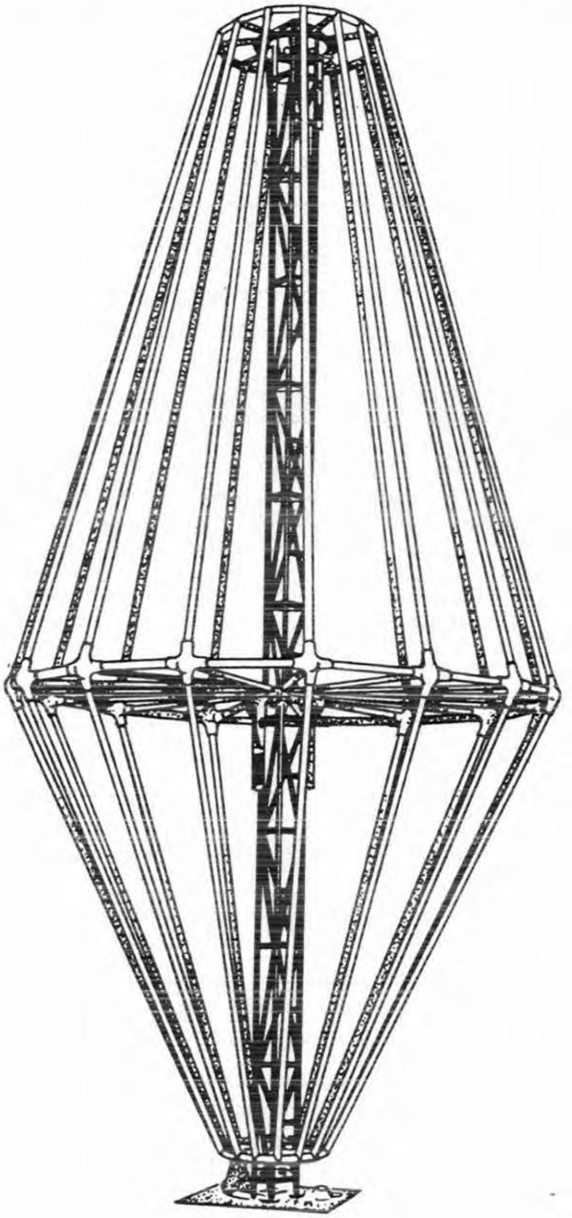

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Figure 2-16.—Conical monopole antenna.

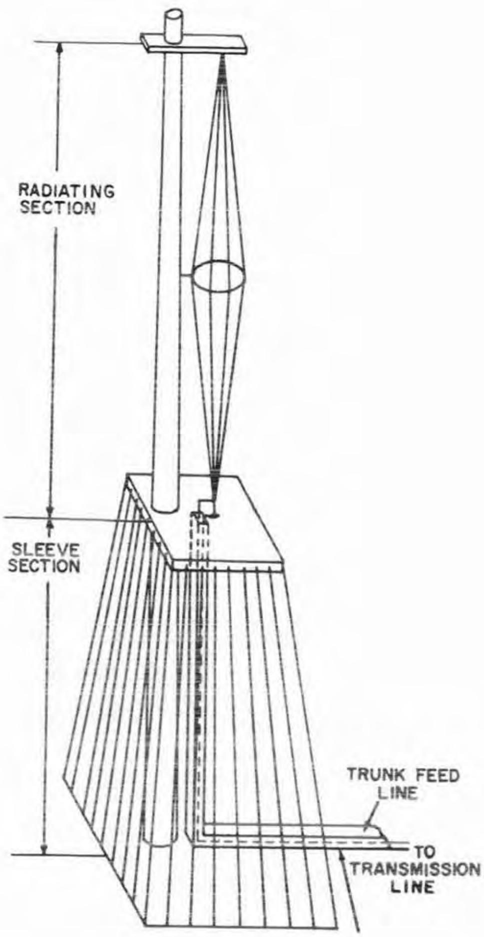
configuration is composed of equally spaced wire radiating elements arranged in a circle around an aluminum center tower and terminated at the top and bottom discs.

The conical monopole's compactness is a definite advantage along with its excellent power handling capabilities and broad bandwidth. It is readily adaptable to ship/shore/ship, ground/air/ground, and broadcast service.

Broadband Sleeve Antenna

Broadband sleeve antennas are also used for ship/shore/ship, ground/air/ground, and broadcast service. Originally, it was developed to fill a need for a versatile HF antenna at shore stations, but it has since been modified to shipboard use also. Figure 2-17 shows a simplified sketch of a shore station sleeve antenna.

Broadband sleeve antennas are omnidirectional, have a low radiation angle and operate over a 3:1 frequency range ratio.



13.40
Figure 2-17.—Shore station sleeve antenna.

HF Whip Antenna

HF Whip antennas, widely used by CB (Citizen Band) radio operators, are used by the Navy for ship/shore/ship communications, for transportable systems, and for laboratory and shop installations.

HF whip antennas are vertically polarized and are omnidirectional. They are normally made of sections of tubular metal or fiberglass-covered metal. Electrical tuning devices are used to alter the effective wavelength of the whip antenna and enable it to operate over a broad band of frequencies.

Of all commonly used vertical antennas, whips are the least efficient. The reasons that they are so widely used are that they are inexpensive; require minimal space, and; they are simple to install. (They may be installed on poles, tops or sides of buildings, on decks or superstructures of ships, or on vehicles of most any type.)

Log Periodic Antenna

The LOG PERIODIC ANTENNA (LPA) is a unidirectional broadband antenna with up to a 10 to 1 frequency range ratio. A typical frequency range for an LPA would be 30 to 300 MHz. As shown in figure 2-18, it consists of a long piece of tubing bent in such a manner as to form a series of progressively longer parallel cross elements, each connected to the cross element next to it. Only these cross elements radiate or receive energy; the tubing in between them serves only to connect the cross elements and space them the correct distance apart.

For some applications, ROTATABLE LOG PERIODIC ANTENNAS (RLPA's) are used. Regardless of type, however, size limitations restrict the use of LPA's to the upper portion of the HF band and above.

PARASITIC ARRAYS

PARASITIC ARRAYS represent another method of achieving high antenna gains. They are made up of tubular aluminum elements mounted parallel to each other as shown in figure 2-19. The DRIVEN ELEMENT is referred to as the RADIATOR and is connected directly to the transmission line. The remaining elements consist of a REFLECTOR, which is located directly behind the driven element, and one more DIRECTORS, located in front of the driven element. The reflector and director elements are called PARASITIC elements because they are not connected to the transmission line, but derive their energy from the driven element. The complete antenna assembly, because it has these parasitic elements, is known as a PARASITIC ARRAY.

The two main advantages of a parasitic array are increased gain and unidirectivity. There is a reduction of transmitted energy in all but the desired direction. This makes the parasitic array particularly useful in antenna systems that can be rotated to a given direction. The disadvantages of these arrays are that their adjustment is critical and they do not operate over a wide frequency range.

When three or more nondriven elements are used in conjunction with a driven element, the parasitic array is commonly known as a YAGI array or YAGI antenna.

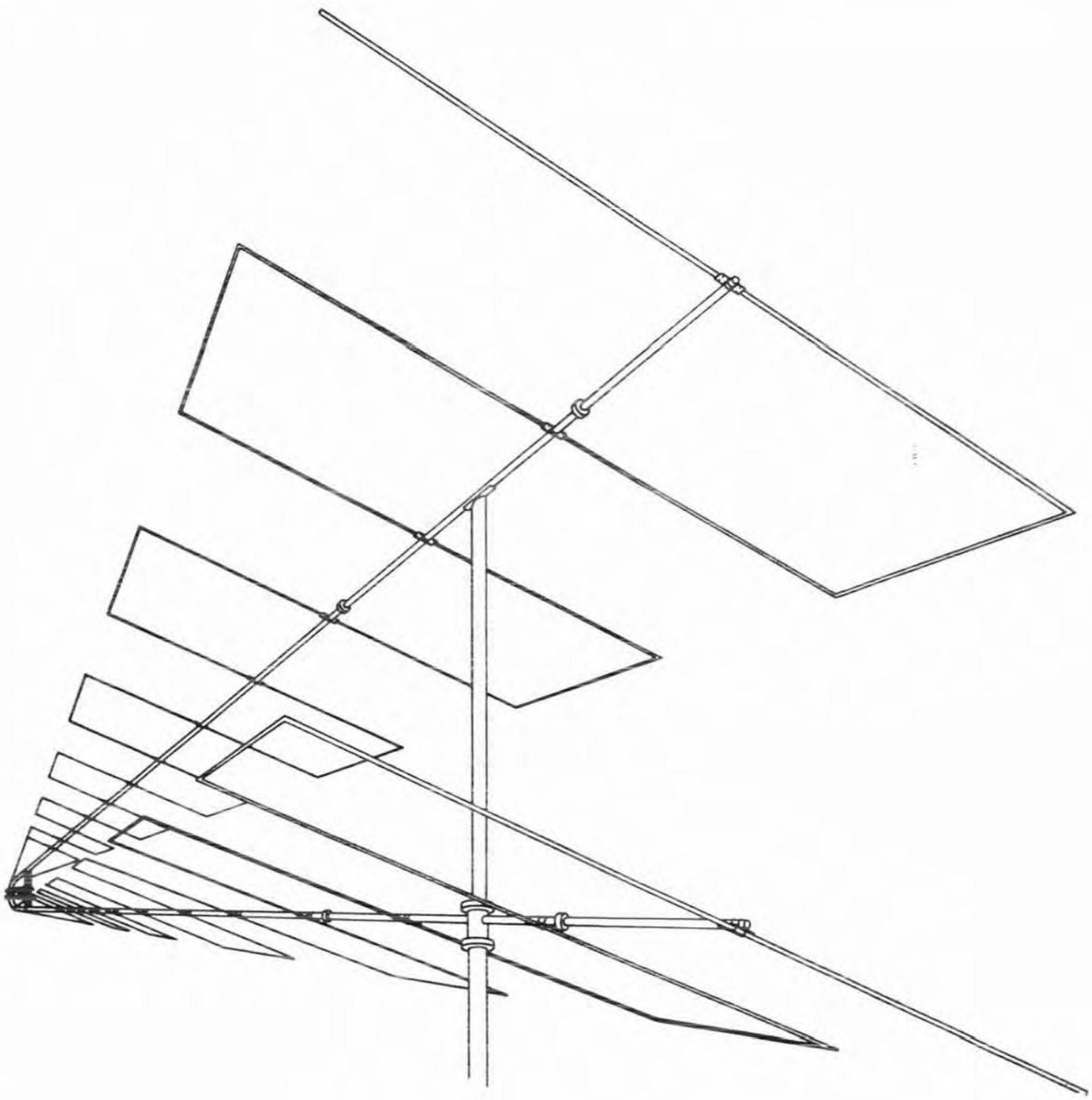
MICROWAVE ANTENNAS

The basic principles of antennas operating in the microwave region (1000-30,000 MHz) are the same as those of antennas operating at the lower frequencies. However, because of the short wavelength involved at these frequencies, microwave antennas can be more readily designed to have higher gain and directivity. The properties of microwaves approach those of light waves. They may be beamed or brought to a focus by the use of parabolic reflectors; likewise, their direction can be readily changed by placing a suitable reflecting surface in their path.

Horn Radiators

Horn radiators are used to obtain directive radiation at microwave frequencies. They are constructed in a variety of shapes, as shown in figure 2-20.

The operation of a horn radiator as a directing device can be compared to an acoustic horn. However, the throat of an acoustic horn is



93.26

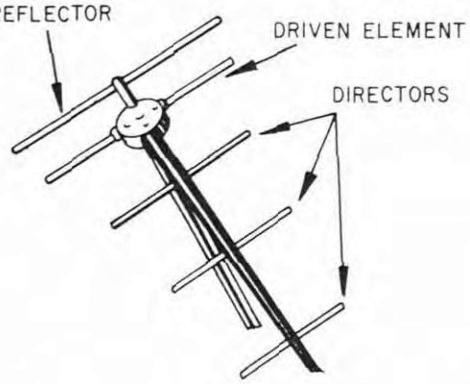
Figure 2-18.—Log-periodic antenna.

much smaller than the wavelengths of audio frequencies, while the throat size of a horn used for electromagnetic radiation is compatible with the wavelength of the operating frequency.

Even though they may be fed by other types of transmission lines, horns are most readily adaptable for use with waveguides because they serve as impedance matching devices as well as directive radiators of energy.

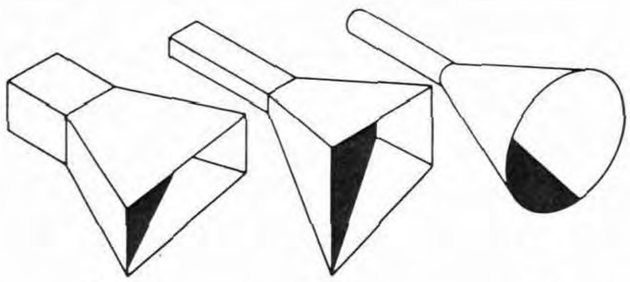
Parabolic Reflectors

Parabolic reflectors, commonly referred to as "Dish Antennas" (figure 2-21) are highly directional antennas that are widely used for microwave communications and radar applications. Basically, parabolic reflectors focus the radiated energy into a narrow beam, much like the light beam from a searchlight.



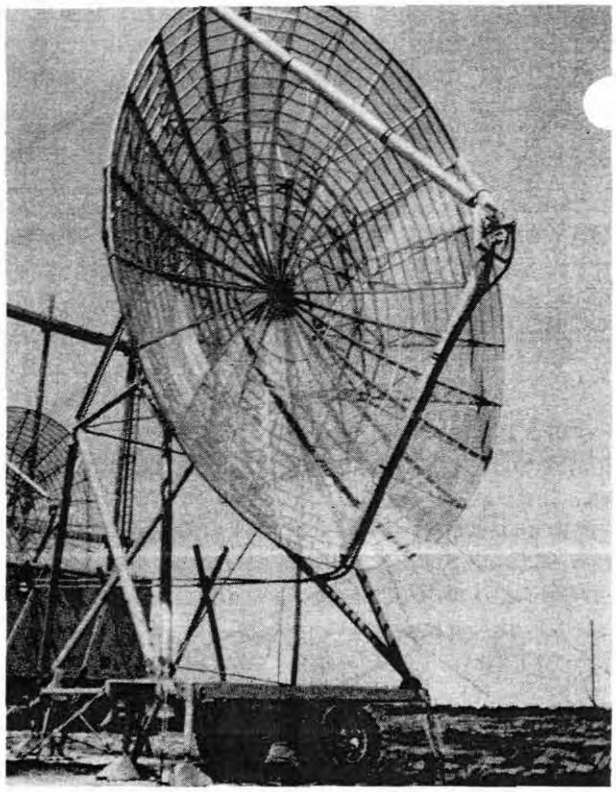
264.14

Figure 2-19.—Parasitic array.



13.41

Figure 2-20.—Horn antennas.



76.58

Figure 2-21.—Mobile parabolic reflector 30-foot scatter antenna.

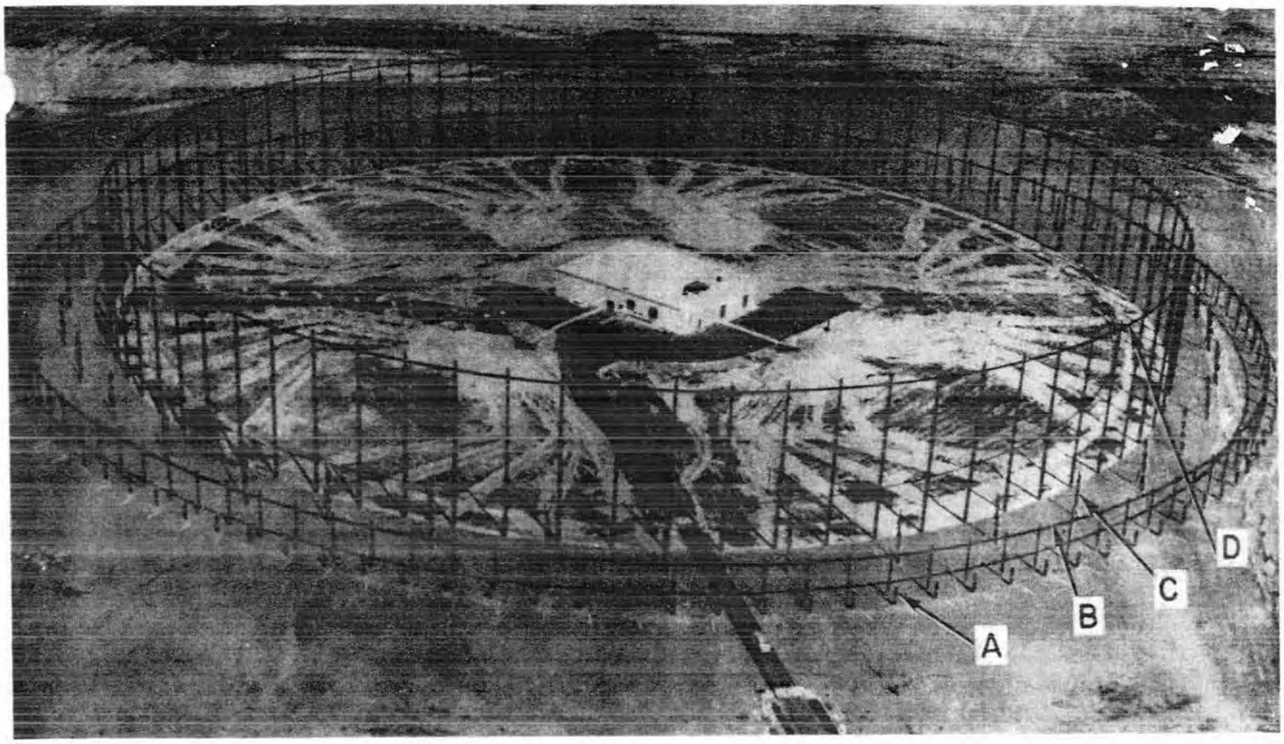
WULLENWEBER ANTENNA ARRAY

The WULLENWEBER ANTENNA ARRAY, named after its designer, is a receiving system capable of providing coverage from 2 to 30 MHz. This is accomplished through the use of two separate arrays of antenna elements, one of which provides coverage from 2 to 8 MHz (low band), the other from 8 to 30 MHz (high band). The system is capable of providing omnidirectional coverage, coverage of a given sector of rather broad bandwidth, or highly directional beams.

The Wullenweber was initially developed for high frequency direction finding applications; however, it has been accepted for service in the Navy's HF point-to-point communications. It is widely used within the Naval Security Group as both a receiving antenna and a direction finding antenna.

A typical Wullenweber array, also commonly known as a Circularly Disposed Antenna Array (CDAA), is shown in figure 2-22. It consists of two arrays of receiving antenna elements and two reflecting screens, arranged in four concentric circles. The extreme outer circle is the high band antenna array (figure 2-22A). It is approximately 875 feet in diameter and consists of 120 equally spaced antenna elements, one for each 3 degrees of azimuth. Each of these elements is a sleeve monopole of the proper length to permit reception of signals in the 8 to 30 MHz range.

The next circle is the high band reflector screen (figure 2-22B) composed of vertical wires



(A) High-band receiving elements.
(B) High-band reflector screen.
(C) Low-band receiving elements.
(D) Low-band reflector screen.

25.117

Figure 2-22.—Wullenweber antenna array.

which are suspended from pole supported horizontal braces. The reflector screen does not receive signals but does contribute to the directional characteristics of the CDAA by shielding the receiving elements from those signals arriving from any direction other than the outer perimeter of the array.

Inside the high band reflector screen, lies the third circle which is the low band receiving array (figure 2-22C). It consists of 40 equally spaced folded monopoles; one for each 9 degrees of azimuth. These elements are longer than those of the high band since the frequencies received (2 to 8 MHz) by the low band elements have longer wavelengths.

The low band reflector screen (figure 2-22D) comprises the inner most circle. It is similar in operation to the high band screen, but the vertical wires are longer and correspond to the lengths of the low band receiving elements.

The high band and low band antenna elements are connected to buried coaxial transmission lines that terminate inside the operations building which is normally located at the center of the array. The transmission lines are electrically equal in length to ensure that the time delay in each line is the same. That is, the time required for a signal to travel from the input end of a line to its output end is exactly equal for all lines. This makes it possible for an electronic sampling device to determine which receiving element was the first to be struck by an incoming signal. That, in turn, indicates from which direction the signal arrived, since the first receiving element to be struck by a signal is the one nearest the transmitting station.

ANTENNA PATCH PANELS

In addition to antennas, transmission lines, and coupling devices, an operator will also be concerned with antenna patch panels. This is the point at which the equipment is actually connected to the desired antenna. Because there are various types of patch boards in use, it is not practical to provide detailed operating procedures herein. It is well to remember that connections should be made with care and that connecting cords (usually solid coaxial lines) should be handled very carefully. Caution should also be taken not to bend or b connecting plugs or damage the insulation on connecting cords.

If there are indications of poor communication signals, one of the first procedures should be to check the antenna patch panel and associated connections.