APPENDIX A

MATCHING AND TUNING DOUBLETS

A.1 GENERAL CONSIDERATIONS

When a resonant two-wire doublet, or half-wave antenna, is connected to a 600-ohm transmission line, standing waves will exist along the transmission line between the antenna and the transmitter. These standing waves are objectionable because (1) they cause radiation losses, (2) they make transmitters unstable or difficult to tune, and (3) they cause intermodualtion problems due to radiation from the line.

The simplest way to reduce these standing waves to a minimum is to connect a short-circuited transmission line stub to the main transmission line at an appropriate point near the antenna. Techniques for determining the length of such a stub and its proper location on the transmission line are discussed here for certain doublet antenna configurations. Since both the location and length of any stub are frequency dependent, the work involves conversions between linear dimensions in feet and the same dimensions expressed in terms of wavelength or electrical degrees. The conversion relationships used in the following discussions are:

$$\text{Wavelength (in feet)} = \frac{984}{\text{Frequency (in MHz)}} \qquad \text{(A-1)}$$

$$\text{Feet per degree} = \frac{2.73}{\text{Frequency (in MHz)}} \qquad \text{(A-2)}$$

Although an RF milliammeter may be inductively coupled to the transmission line to determine the standing wave ratio, the use of such an instrument may lead to false readings in antenna fields where other nearby antennas induce strong currents into the line. Since most Navy shore installations have an AN/PRM-25 or equivalent receiver available, a shielded loop may be used with such an instrument for this type of measurement. Since the AN/PRM-25 is frequency discriminative, and the loop itself is shielded against extraneous pickup, relatively accurate readings may be obtained in fields of strong off-frequency RF. Details of a shielded probe and pad to adapt the AN/PRM-25 for this service are shown in figure A-1.

A.2 SINGLE-STUB METHOD FOR MATCHING A FOLDED DOUBLET ANTENNA

a. The shielded loop is moved along the transmission line near the antenna to detect the locations of current minima and to measure the standing wave ratio. To ascertain that correct null locations are found, several consecutive null points along the transmission line should be located and the distances between null points should be measured to verify that the nulls are equally spaced along the line.

b. The standing wave ratio (SWR), calculated from measurements of current maxima and minima, is used as the entry into the graph of figure A-2 to determine the length of the stub and its proper distance from the current null nearest the antenna. Formula (A-1) is used to convert the length and distance from fractions of a wavelength to feet.

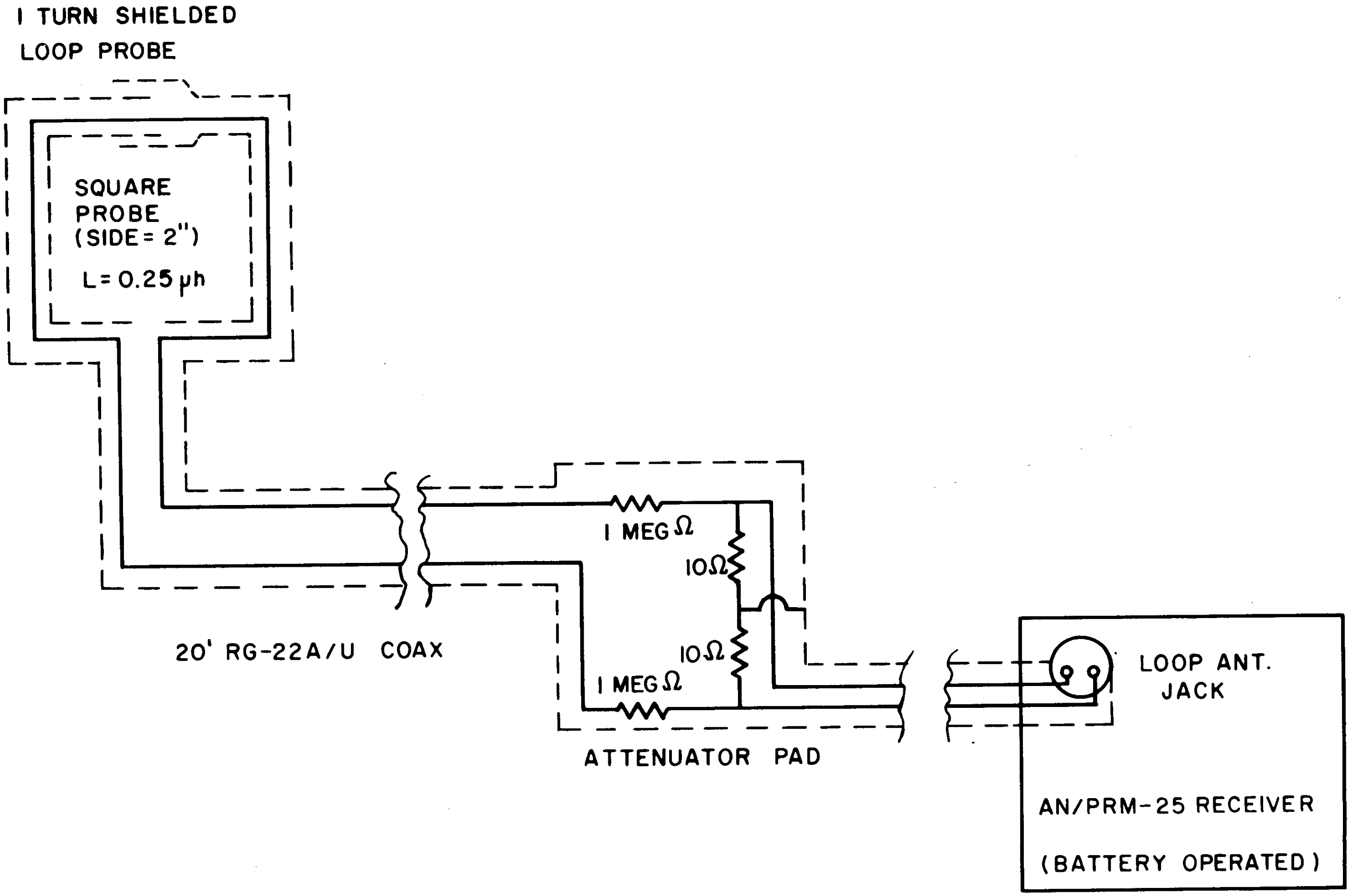


Figure A-1. Details of Shielded Probe and Pad

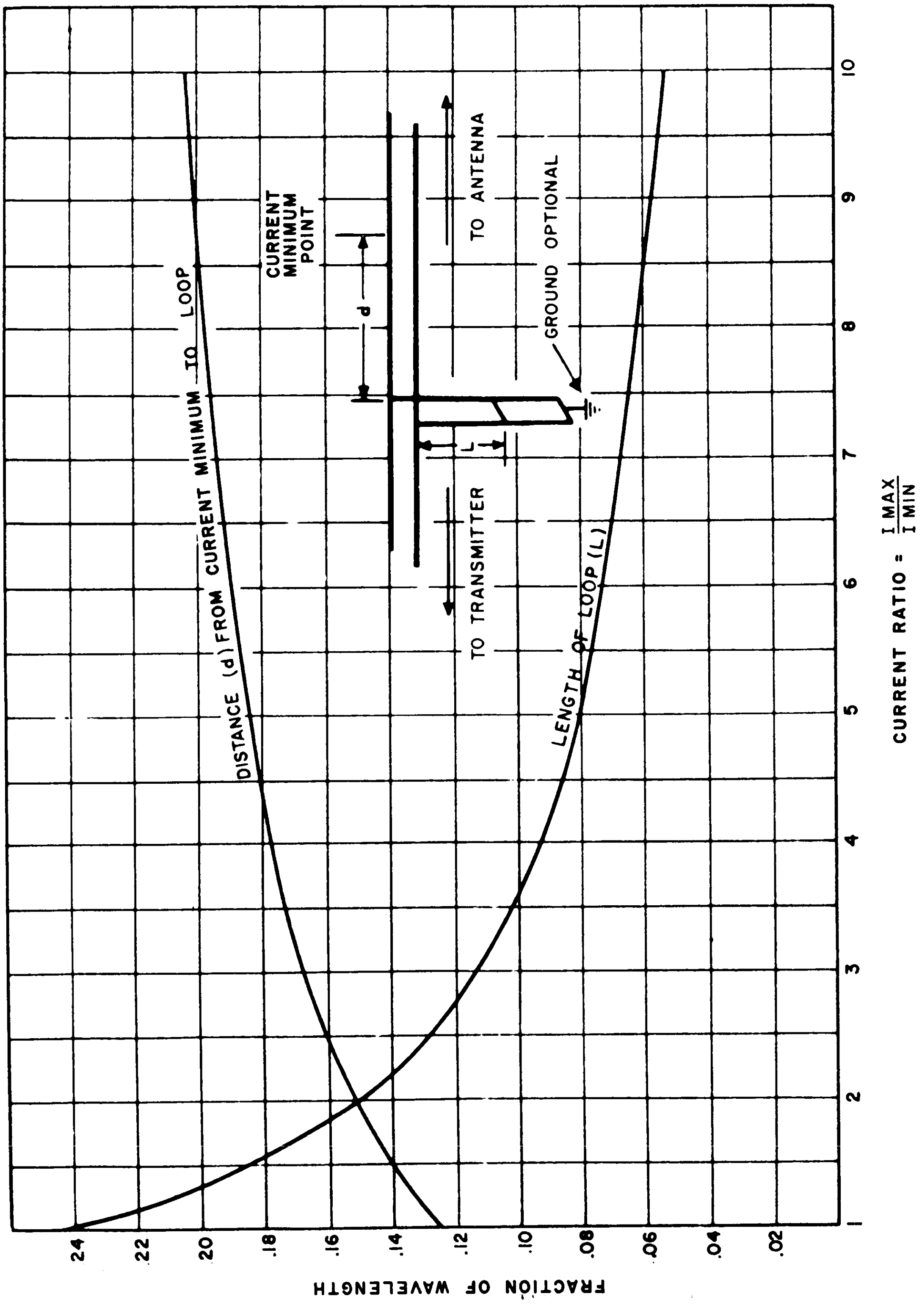


Figure A-2. Doublet Stubbing Chart

c. For adjustment purposes the stub should be cut somewhat longer than the length indicated by the graph. The stub is attached to the transmission line at the point indicated by the graph, and the positions of the stub and shorting wire on the stub are marked to establish reference points for later adjustments.

d. Next, the transmitter tuning is readjusted to compensate for attaching the stub to the line, and the resultant standing wave ratio is obtained and recorded.

e. To further reduce the standing wave ratio, adjustments are made in the positions of the stub and the shorting wire. An organized record of the positions of the stub and shorting wire, together with the SWR for each adjustment, should be kept as the stub and shorting wire are moved in small increments away from their starting positions. For example:

Stub Pos.	Short Pos.	I Max	I Min	I Ratio
Start	Start	120	80	1.50
3" to Antenna	3" down	100	80	1.25
3" from Antenna	3" up	100	90	1.11

Measurement of the standing wave ratio after each adjustment will indicate whether the change was in the right direction. Adjustments should be continued by this trial-and-error process until the standing wave ratio is minimum.

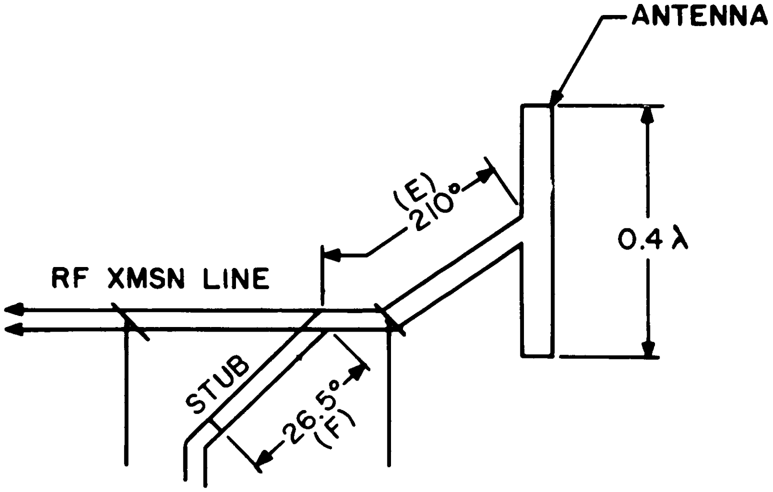
f. The time involved in this trial-and-error process can be reduced somewhat by making adjustments in the following sequence:

(1) Adjust the shorting wire on the stub to get equal line currents at one-eighth and three-eighths wavelength positions away from the stub toward the transmitter. This resonates the antenna and the stub. Record the stub adjustment and the corresponding standing wave ratio.

(2) Take a series of readings with the shorting wire moved up and the stub connection moved away from the antenna by exactly the same amount (a few inches). Record the distances and current readings. If the SWR increases consistently as a result of these adjustments, return to the adjustment in step (1) above. Then make a series of adjustments in the opposite directions, that is, by moving the shorting wire down and the stub connection toward the antenna by exactly the same amounts. Record the data as before.

(3) By roughly graphing the data in the field, the best positions for the stub and shorting wire will be indicated.

An alternate method of establishing the initial positions of the stub and shorting wire is to use data compiled from a number of actual installations. Analysis of the results of stubbing 19 vertical doublet antennas shows that, on the average, a good starting point is to connect a stub 26.5 degrees long at a point 210 degrees from the antenna terminals as illustrated in figure A-3. (Formula A-2 gives the relationship between degrees and linear dimensions.) With these values as a guide, it is possible to specify the stub length and location on the installation plans, and, thereby minimize the time and effort spent on final tuning of the antenna. This method of determining the approximate stub length and location is particularly advantageous during the construction and installation of antennas since it may be awkward, or impossible, to set up a test transmitter to excite the antenna during the construction period.



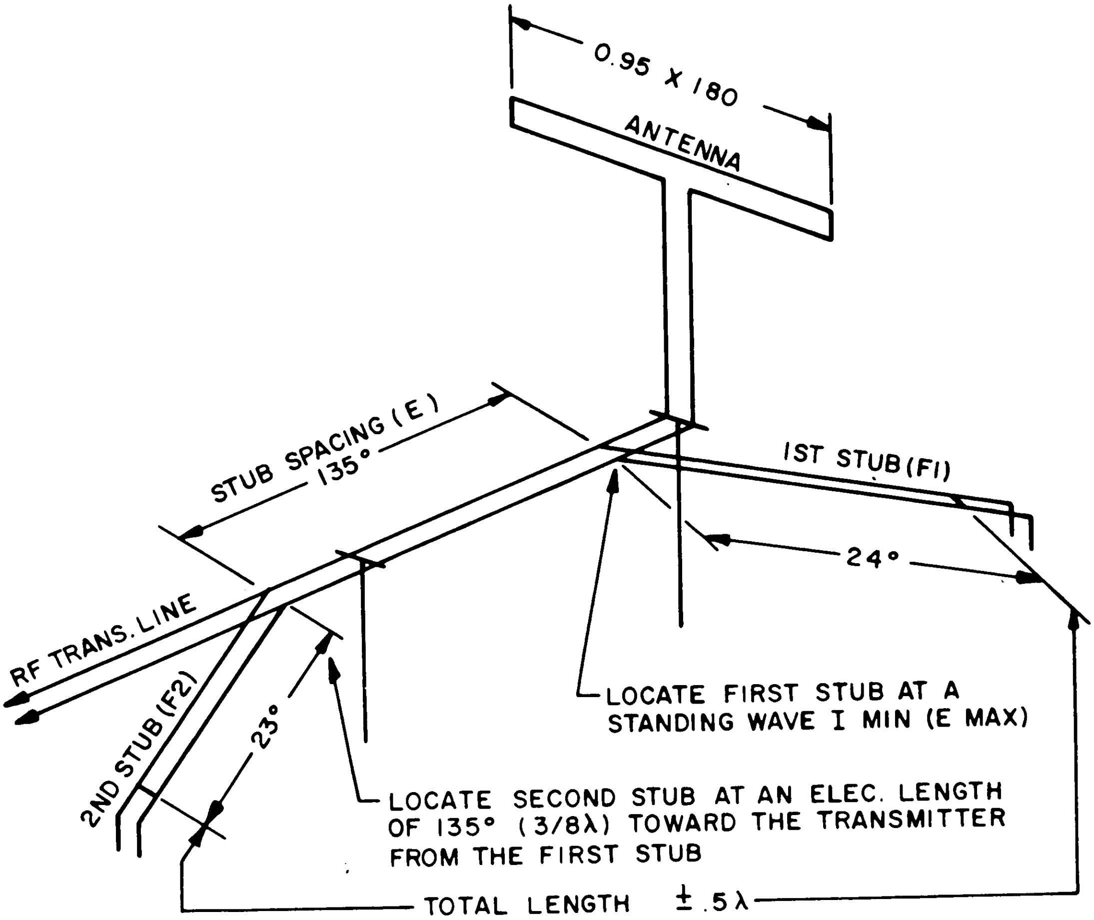
ADJUST STUB ATTACHMENT POINT &
STUB SHORTING BAR FOR LOWEST VSWR.

Figure A-3. Approximate Method of Determining Stub Length and Location

A.3 DOUBLE-STUB METHOD FOR MATCHING A FOLDED DOUBLET ANTENNA

Although the single-stub method for matching a folded doublet antenna to its transmission line is simple and effective, the length required for the matching stub becomes greater as the design frequency for the antenna is lowered. For doublet antennas in the 2- to 5-MHz frequency range it is convenient to use two matching stubs, as illustrated in figure A-4, to reduce the effective length of the stubs required. Double stubs are also more convenient to adjust, since matching is accomplished by moving the location of the stub shorting bars without changing the point of stub attachment at the transmission line.

a. The double-stub impedance match may be considered to be a half-wave transformer extending from closed stub to closed stub. On a balanced system a current loop will exist in the shorting bar of each stub. The length of stub nearest the antenna may be adjusted to tune out antenna reactance while the other stub is adjusted to provide the transmission line "match." The two stubs cannot, however, be adjusted independently; when one stub is lengthened the other must be shortened to maintain an approximate half-wavelength of transmission line between the two shorting bars.



LOCATE FIRST STUB AT A STANDING WAVE I MIN (E MAX)

LOCATE SECOND STUB AT AN ELEC. LENGTH OF 135° (3/8λ) TOWARD THE TRANSMITTER FROM THE FIRST STUB

ADJUST THE STUB SHORTING BARS FOR LOWEST VSWR (STUB LENGTHS SPECIFIED ARE MEDIAN VALUES)

$$\text{LENGTH IN FEET} = \frac{2.73\,D}{\text{FREQUENCY IN MHz}}$$

WHERE D = THE ELECTRICAL LENGTH IN DEGREES

DOUBLE STUB METHOD FOR 2 TO 5.5 MHz

HORIZONTAL AND TILTED FOLDED DOUBLETS

Figure A-4. Double Stub Method

b. Spacing between the two stubs, (F1 and F2 in figure A-4), determines the range of impedance that can be matched by the double-stub transformer. At a spacing (E) of 90 degrees (one-quarter wavelength), a 600-ohm transmission line can be matched to any antenna load in the range of 600 ohms to infinity. With a spacing of 135 degrees (three-eighths wavelength), a 600-ohm transmission line can be matched to any antenna load in the range of 300 ohms to infinity. Half-wave (180 degree) spacing is not useful, since all transformer action is lost. Therefore, double-stub spacing of 135 electrical degrees (three-eighths wavelength) is most useful in matching two-wire folded doublets to a 600-ohm transmission line.

c. The location of the first stub, F1, in relation to the standing wave pattern of the unstubbed transmission line, determines the amount of reactance which must be tuned out by the double-stub transformer. The best range of adjustment is obtained by attaching stub F1 at a standing current minimum (voltage peak). Calculation of the stub length is greatly simplified for this stub location, because antenna reactance is zero at a current minimum.

d. The active lengths for double-stubs spaced three-eighths wavelength apart and located in accordance with subparagraph c, above, may be calculated from the following formulas:

$$\text{Cot F1} = 1 \pm \sqrt{\frac{2R-1}{R}} \qquad \text{(A-3)}$$

$$\text{Cot F2} = 1 \pm \sqrt{2R1} \qquad \text{(A-4)}$$

where F1 and F2 are the electrical lengths in degrees for stubs F1 and F2, and where R is the measured standing wave ratio of the unstubbed transmission line connected to its antenna. For example, if the measured VSWR is 2.0, the calculated stub lengths are 24 and 20 degrees.

e. The active lengths for double-stubs spaced one-quarter wavelength apart and located in accordance with subparagraph c, may be calculated from the following formulas:

$$\text{Cot F1} = \sqrt{\frac{R-1}{R}} \qquad \text{(A-5)}$$

$$\text{Cot F2} = \sqrt{R-1} \qquad \text{(A-6)}$$

A.4 TUNING PROCEDURE FOR HIGH FREQUENCY TWO-ELEMENT VERTICAL DIRECTIONAL ANTENNA ARRAY

The vertical directional array, also known as a driven, or phased array, consists of two half-wave vertical doublets spaced at 90 degrees (as shown in figure A-5). The feeders to each doublet branch off the main transmission line at points 90 degrees (one-quarter wavelength) apart. Therefore, the current in the front doublet leads that of the rear doublet by 90 degrees. As the two doublets radiate, these currents add, giving the array a 3 dB gain over a single doublet in a cardioid pattern.

To bring about this 90-degree phase shift between the two doublets, a quarter-wave point on the transmission line must be found and the rear doublet feeders must be connected at this point. This is done as follows:

NOTE

> The branch feeders to the individual doublets must be electrically equal in length. Mechanical requirements might require that one feeder be physically longer than the other. The additional length, disregarding velocity factors, should be a multiple of a half-wavelength.

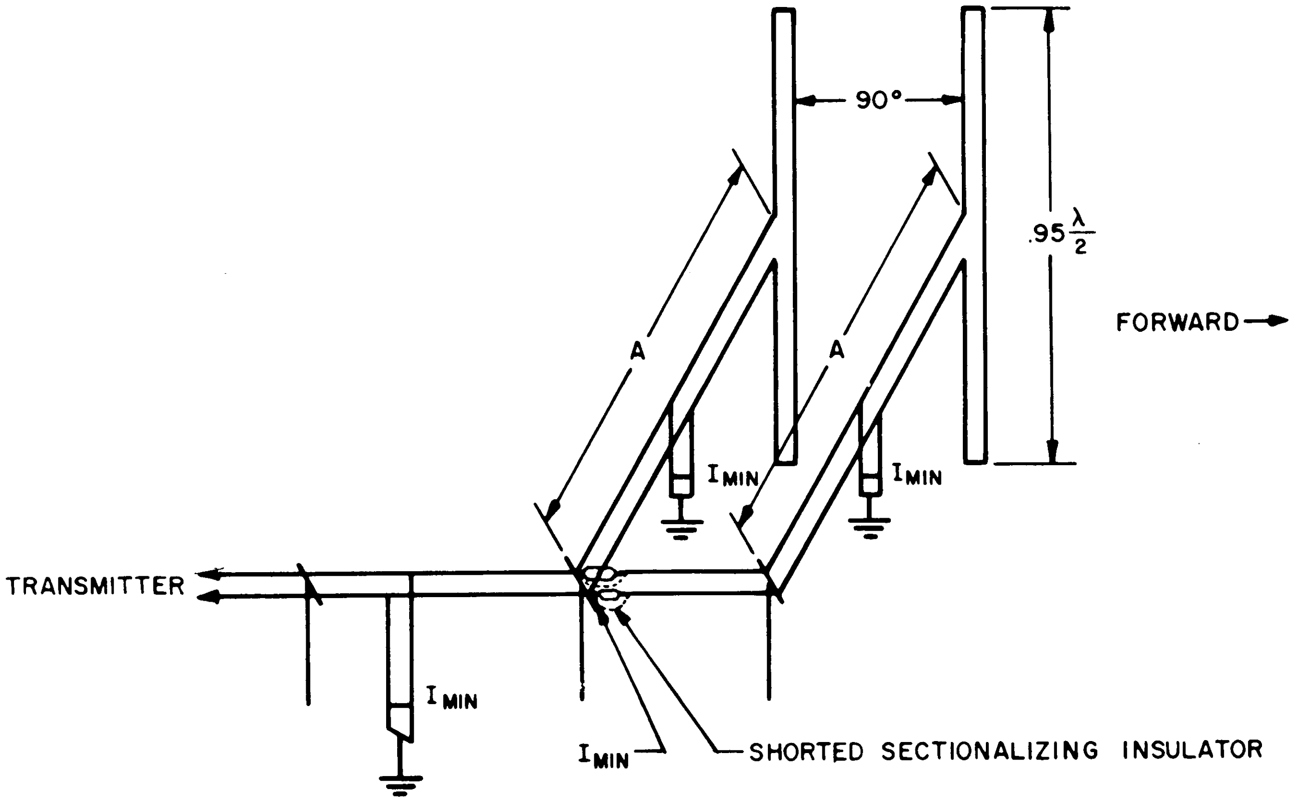


Figure A-5. Driven or Phased Array

a. Disconnect both branch feeders from the main transmission line and short the end of the main transmission line.

b. Feed the main transmission line with low power (50 to 100 watts) at the desired frequency.

c. Locate the current null nearest the antenna end of the transmission line with an RF milliammeter or a field intensity meter inductively coupled to the line, as previously described in paragraph A.2.

d. Install a twelve-inch bar insulator (NT 61374 or equivalent) in series with each wire of the main transmission line so that the shackle nearest the transmitter end of the line will lie at the minimum current point determined in subparagraph c above. Remove the short at the end of the main transmission line.

e. Short-circuit and ground the front doublet and its transmission line at two or three points to minimize intercoupling with the rear doublet. The feeders to the rear (away from the desired direction of transmission) doublet can now be temporarily installed on the transmission line at the current minimum point determined in subparagraphs c and d above.

f. Stub the rear doublet feeder and adjust for the minimum VSWR, using the stubbing methods outlined in paragraph A.2

g. Disconnect the rear doublet feeders from the main transmission line and short out the rear doublet as described in subparagraph e.

h. Permanently strap out the insulators previously installed in the transmission line by paralleling them with No. 6 wire, wrapped and secured at each end, in accordance with standard installation practices.

i. Remove short circuits and grounds from the front doublet (in the direction of desired transmission) and permanently connect the feeders to the end of the transmission line.

j. Match the front doublet to the transmission line with the stub as was done with the rear doublet in subparagraph f above.

k. Remove shorts and grounds from the rear doublet and make permanent connections to the transmission line as described for the temporary installation in subparagraph e above.

l. Measure from the stub shorting bar of one of the antennas up the stub and up the feeder a few feet toward the antenna, and mark this point. Take identical measurements on the other doublet feed line. These are <u>physical</u> measurements.

m. Apply power to the array and use two RF milliammeters, or two AN/PRM-25 field intensity meters, to measure the current (using the techniques described in paragraph A.2) as follows:

(1) Place one meter at each marked point on the two branch feeders, and note the readings. The front doublet current should initially read somewhat lower than that of the rear doublet. Therefore, it is necessary to equalize these currents.

(2) Equalize the two currents by readjusting the stubs to each antenna. In every case the matching stub's point of connection to the feed line, and the position of its shorting bar, are changed by measured distances to keep the distance from the stub shorting bar to the doublet the same. Otherwise the system will be detuned and further adjustments will be complicated. Currents should be equalized by <u>decreasing</u> the load resistancies; i.e., <u>raise</u> both shorting bars, and move both stubs <u>toward</u> the main transmission line in small increments. In all cases, RF milliammeters should not be moved on lines because any movement will cause erroneous indications.

n. After completing the previous steps, standing wave ratios up to 4:1 may be expected on the main transmission line. To remove or minimize these standing waves, consider the sectionalizing insulator point, described in subparagraph d above, as the load. Follow normal stubbing procedures and place the stub on the main transmission line at the nearest current minimum point towards the transmitter and adjust for minimum SWR.

A.5 ADJUSTMENT OF A FOLDED DOUBLET WITH TUNED PARASITIC ELEMENT

Two-element directional parasitic arrays consist of a folded doublet driven element and a parasitic element, also a folded doublet. The latter is called either a reflector or director depending on the electrical length of the element. With spacings between the two doublets of approximately 90 degrees (one-quarter wavelength), the parasitic element is preferably tuned as a reflector and the following tuning procedure applies. See figure A-6.

a. Set the shorting bar on the parasitic element tuning line to approximately 225 degrees (five-eighths wavelength) from the parasitic doublet.

b. Follow the stubbing procedure given in paragraph A.2, to match the driven element to the transmission line with a minimum SWR. Since readjustment will be necessary later, this may be set roughly. A SWR of approximately 2:1 is satisfactory at this point.

c. If two AN/PRM-25 or similar field intensity meters are available, set up one 500 feet or more in line with and in the forward direction of the array and set up the second a similar distance in the opposite direction. These positions should be well clear of other antennas and transmission lines in the field, and the other antennas in the field should not be radiating. The loop antenna should be used with the AN/PRM-25 to insure that direct bearing readings are obtained. If only one field intensity meter is available, the two positions should be marked with stakes, and readings should be taken at both positions for each change in array adjustment.

d. Adjust the shorting bar on the parasitic element tuning line for a minimum reading in the back (parasitic element) direction and a maximum reading in the forward (driven element) direction. The final ratio of readings should be in the order of 3:1 or better.

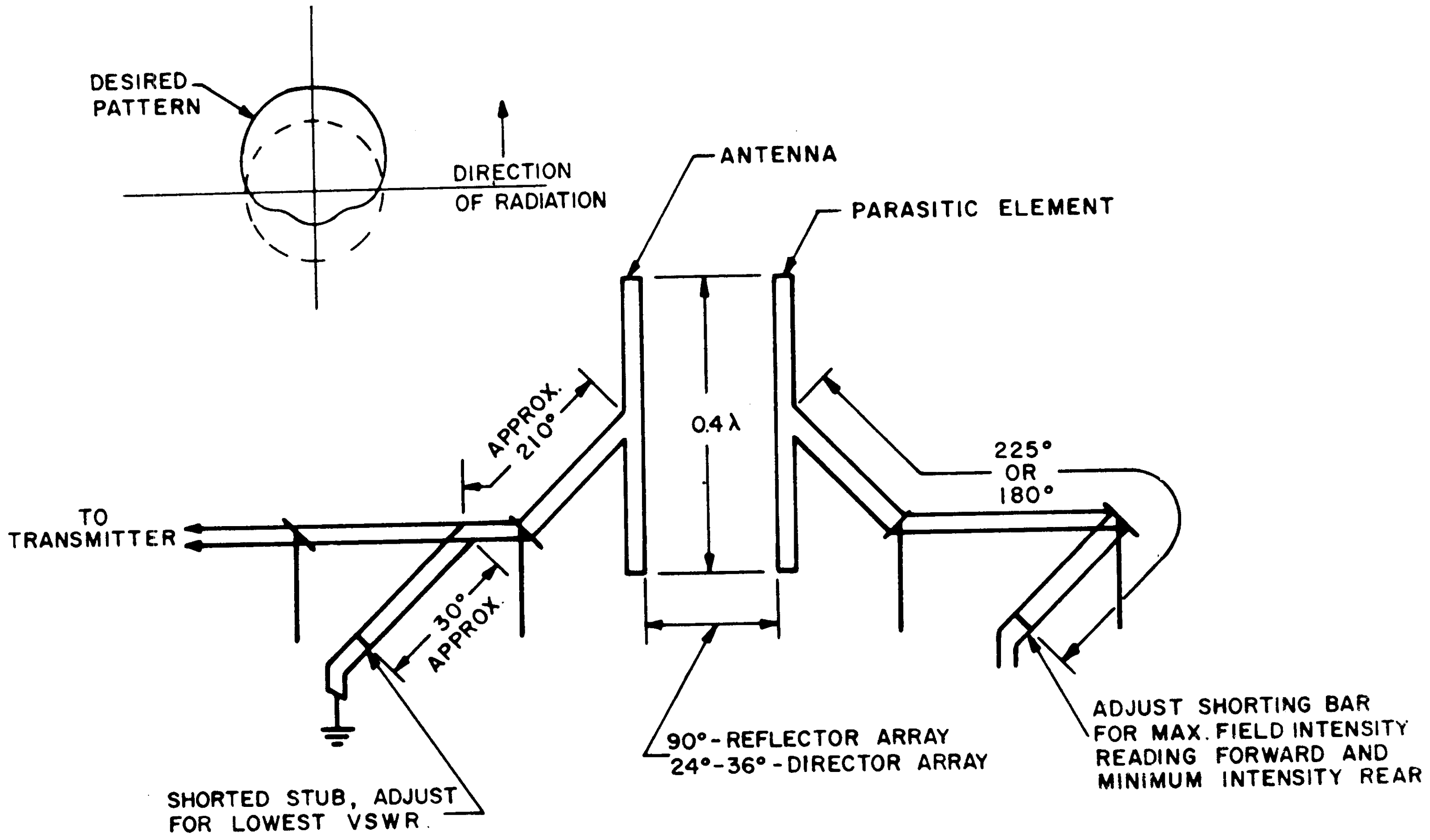


Figure A-6. Stubbing Adjustment of Parasitic Arrays

e. Readjust the stub on the driven element transmission line for a minimum SWR and recheck the field strength. Some readjustment of the shorting bar on the parasistic tuning line may be required to attain an optimum pattern.

f. Field strength should be checked next in a radius around the array to roughly determine the horizontal pattern. Some readjustment may be required if the radiation lobe does not meet required sector coverage. Uniform gain in a sector approximating 180 degrees with attenuated radiation to the rear is usually the most serviceable pattern. The pattern shown in figure A-6 is typical of that normally desired. However, this ideal pattern may be very difficult to achieve because of electrical obstructions in the field, stray couplings, and compromises in measurement techniques. Therefore, arrays should be tuned to best meet local requirements.

g. It may be necessary from a clearance or physical location requirement to reduce the spacing between the driven element and the parasitic element. In such cases, spacings of from .1 wavelength to .15 wavelength are recommended and the parasitic element may be tuned as a director, i.e., electrically short with respect to the driven element.

h. In using the parasitic element as a director, the distance to the initial position of the shorting bar on the tuning line should be set at approximately 180 degrees (one-half wavelength) and tuning should then proceed as outlined above, except that field intensity readings should indicate maximum current in the direction of the parasitic element and minimum current in the direction of the driven element.

APPENDIX B

DEFINITIONS

The following definitions have been taken from "Transactions on Antennas and Propagation," published by the Institute of Electrical and Electronics Engineers (IEEE), May 1969.

Adaptive Antenna System.

An antenna system having circuit elements associated with its radiating elements such that some of the antenna properties are controlled by the received signal.

Adcock Antenna.

A pair of vertical antennas separated by a distance of one-half wavelength or less and connected in phase opposition to produce a radiation pattern having the shape of the figure eight.

Antenna (Aerial).

A means for radiating or receiving radio waves.

Antenna Effect.

In a loop antenna, any spurious radiation effect resulting from the capacitance of the loop to ground.

Antenna Efficiency, of an Aperture-Type Antenna.

For an antenna with a specified planar aperture, the ratio of the maximum effective area of the antenna to the aperture area.

Antenna Pattern.

See Radiation Pattern.

Antenna Resistance.

The real part of the input impedance of an antenna.

Aperture, of an Antenna.

A surface, near or on an antenna, on which it is convenient to make assumptions regarding the field values for the purpose of computing fields at external points.

Note: In the case of a unidirectional antenna, the aperture is often taken as that portion of a plane surface near the antenna, perpendicular to the direction radiation, through which the major part of the radiation passes.

Aperture Illumination (Excitation).

The amplitude, phase, and polarization of the field distribution over the aperture.

Aperture Illumination Efficiency.

For a planar antenna aperture, the ratio of its directivity to the directivity obtained when the aperture illumination is uniform.

Area.

See Effective Area, of an Antenna; Equivalent Flat-Plate Area, of a Scattering Object; Back-Scattering Cross Section (Target Echoing Area).

Array Antenna.

An antenna comprising a number of radiating elements, generally similar, which are arranged and excited to obtain directional radiation patterns.

Array Element.

In an array antenna, a single radiating element or a convenient grouping of radiating elements that have a fixed relative excitation.

Average Noise Temperature, of an Antenna.

The noise temperature of an antenna averaged over a specified frequency band.

Back-Scattering Cross Section (Monostatic Cross Section, Target Echoing Area).

The scattering cross section in the direction toward the source. (cf. Radar Cross Section.)

Bandwidth, of an Antenna.

The range of frequencies within which its performance, in respect to some characteristic, conforms to a specified standard.

Beam, of an Antenna.

The major lobe of the radiation pattern of an antenna.

Beam Steering.

Changing the direction of the major lobe of a radiation pattern.

Beamwidth.

See Half-Power Beamwidth.

Beverage Antenna (Wave Antenna).

A directional antenna composed of a system of parallel horizontal conductors from one-half to several wavelengths long, terminated to ground at the far end in its characteristic impedance.

Boresight.

See Electrical Boresight, Reference Boresight.

Boresight Error.

The angular deviation of the electrical boresight of an antenna from its reference boresight.

Broadside Array.

A linear or planar array antenna whose direction of maximum radiation is perpendicular to the line or plane of the array.

Cheese Antenna.

A reflector antenna having a cylindrical reflector enclosed by two parallel conducting plates perpendicular to the cylinder, spaced more than one wavelength apart. (cf. Pillbox Antenna.)

Collinear Array.

A linear array of radiating elements, usually dipoles, with their axes lying in a straight line.

Conical Scanning.

A form of sequential lobing in which the direction of maximum radiation generates a cone whose vertex angle is of the order of the antenna half-power beamwidth. Such scanning may be either rotating or nutating according to whether the direction of polarization rotates or remains unchanged, respectively.

Corner Reflector.

A reflecting object consisting of two or three mutually intersecting conducting flat surfaces.

Note: Dihedral forms of corner reflectors are frequency used in antennas; trihedral forms with mutually perpendicular surfaces are more often used as radar targets.

Corner Reflector Antenna.

An antenna consisting of a feed and a corner reflector.

Counterpoise.

A system of conductors, elevated above and insulated from the ground, forming a lower system of conductors of an antenna.

Cross Polarization.

The polarization orthogonal to a reference polarization.

Note: If the reference polarization is right-handed circular, the cross polarization is left-handed, and vice versa.

Cross Section.

See Back-Scattering Cross Section, Radar Cross Section, Scattering Cross Section.

Cylindrical Reflector.

A reflector which is a portion of a cylinder. This cylinder is usually parabolic, although other shapes may be used.

Dielectric Rod Antenna.

An antenna that employs a shaped dielectric rod as the significant part of a radiating element.

Dipole.

See Dipole Antenna, Electric Dipole, Folded Dipole Antenna, Magnetic Dipole.

Dipole Antenna (Doublet Antenna).

Any one of a class of antennas producing a radiation pattern approximating that of an elementary electric dipole.

Note: Common usage considers the dipole antenna to be a metal radiating structure which supports a line current distribution similar to that of a thin straight wire so energized that the current has a node only at each end.

Directional Antenna.

An antenna having the property of radiating or receiving electromagnetic waves more effectively in some directions than in others.

Directive Gain, of an Antenna.

In a given direction, 4π times the ratio of the radiation intensity in that direction to the total power radiated by the antenna.

Note: The directive gain is fully realized on reception only when the incident polarization is the same as the polarization of the antenna on transmission.

Directivity.

The value of the directive gain in the direction of its maximum value.

Director Element.

A parasitic element located forward of the driven element of an antenna to increase the directive gain of the antenna in the forward direction.

Doublet Antenna.

See Dipole Antenna.

Driven Element.

A radiating element coupled directly to the feed line of an antenna (cf. Parasitic Element.)

E Plane, Principal.

For a linearly polarized antenna, the plane containing the electric field vector and the direction of maximum radiation.

Effective Area, of an Antenna.

In a given direction, the ratio of the power available at the terminals of an antenna to the power per unit area of a plane wave incident on the antenna from that direction, polarized coincident with the polarization that the antenna would radiate.

Effective Height, of an Antenna (high-frequency usage).

The height of the antenna center of radiation above the ground level.

Note: For an antenna with symmetrical current distribution, the center of radiation is the center of distribution. For an antenna with asymmetrical current distribution, the center of radiation is the center of current moments when viewed from directions near the direction of maximum radiation.

Effective Height, of an Antenna (low-frequency usage).

See Effective Length, of an Antenna.

Effective Length, of an Antenna.

For an antenna radiating linearly polarized waves, the length of a thin straight conductor oriented perpendicular to the direction of maximum radiation, having a uniform current equal to that at the antenna terminals and producing the same far-field strength as the antenna. Alternatively, for the same antenna receiving linearly polarized waves from the same direction, the ratio of the open-circuit voltage developed at the terminals of the antenna to the component of the electric field strength in the direction of antenna polarization.

Note 1: The two definitions yield equal effective lengths.

Note 2: In low-frequency usage the effective length of a ground-based antenna is taken in the vertical direction and is frequently referred to as effective height. Such usage should not be confused with Effective Height, of an Antenna (high-frequency usage).

Efficiency.

See Antenna Efficiency, of an Aperture-Type Antenna; Aperture Illumination Efficiency; Radiation Efficiency.

Electric Dipole.

An elementary radiator consisting of a pair of equal and opposite oscillating electric charges an infinitesimal distance apart.

Note: It is equivalent to a linear current element.

Electrical Boresight.

The tracking axis as determined by an electric indication, such as the null direction of a conical-scanning or monopulse antenna system, or the beam-maximum direction of a highly directive antenna. (cf. Reference Boresight.)

Electronic Scanning (Inertialess Scanning).

Scanning an antenna beam by electronic or electric means without moving parts.

Element.

See Array Element, Director Element, Driven Element, Parasitic Element, Radiating Element, Reflector Element.

End-Fire Array.

A linear or planar array antenna whose direction of maximum radiation lies along the line or the plane of the array.

Equivalent Flat-Plate Area, of a Scattering Object.

The area of a flat, perfectly reflecting plate, large compared to the wavelength and parallel to the incident wavefront, which has the same back-scattering cross section as the object.

Note: The equivalent flat-plate area is equal to the wavelength times the square root of the ratio of the back-scattering cross section to 4π.

Excitation.

See Aperture Illumination.

Excitation Coefficients (Feeding Coefficients).

The relative values of the excitation currents of the radiating elements of an array antenna.

Far-Field Region.

That region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna.

Note 1: If the antenna has a maximum overall dimension D which is large compared to the wavelength, the far-field region is commonly taken to exist at distances greater than $2D^2/\lambda$ from the antenna, λ being the wavelength.

Note 2: For an antenna focused at infinity, the far-field region is sometimes referred to as the Fraunhofer region on the basis of analogy to optical terminology.

Feed, of an Antenna.

That portion of an antenna coupled to the terminals which functions to produce the aperture illumination.

Note: A feed may consist of a distribution network or a primary radiator.

Feeding Coefficients.

See Excitation Coefficients.

Folded Dipole Antenna.

An antenna composed of two or more parallel, closely spaced dipole antennas connected together at their ends with one of the dipole antennas fed at its center.

Fraunhofer Pattern, of an Antenna.

A radiation pattern obtained in the Fraunhofer region.

Fraunhofer Region.

The region in which the field of an antenna is focused. (See Note 2 of Far-Field Region for a more restricted usage.)

Fresnel Pattern, of an Antenna.

A radiation pattern obtained in the Fresnel region.

Fresnel Region.

The region (or regions) adjacent to the region in which the field of an antenna is focused, i.e., just outside the Fraunhofer region. (See Note 2 of Near-Field Region, Radiating, for a more restricted usage.)

Front-to-Back Ratio.

The ratio of the directivity of an antenna to its directive gain in a specified direction toward the back.

Gain.

See Directive Gain, Directivity, Power Gain, Relative Gain, Superdirectivity.

H Plane Principal.

For a linearly polarized antenna, the plane containing the magnetic-field vector and the direction of maximum radiation.

Half-Power Beamwidth.

In a plane containing the direction of the maximum of a beam, the angle between the two directions in which the radiation intensity is one-half the maximum value of the beam.

Height.

See Effective Height.

Helical Antenna.

An antenna whose configuration is that of a helix.

Note: The diameter, pitch, and number of turns in relation to the wavelength provide control of the polarization state and directivity of helical antennas.

Horn Antenna.

A radiating element having the shape of a horn.

Horn Reflector Antenna.

An antenna consisting of a section of a paraboloidal reflector fed with an offset horn which intersects the reflector surface.

Note: The horn is usually pyramidal or conical.

Illumination.

See Aperture Illumination.

Impedance.

See Input Impedance, Intrinsic Impedance, Mutual Impedance, Self-Impedance.

Inertialess Scanning.

See Electronic Scanning.

Input Impedance, of an Antenna.

The impedance presented by an antenna at its terminals.

Intrinsic Impedance, of an Antenna.

The theoretical input impedance of an antenna for the basic radiating structure when idealized.

Note: The idealized basic radiating structure usually consists of a uniform cross-section radiating element, perfectly conducting ground or imaging planes, zero base capacitance (in the case of vertical radiators), and no internal losses.

Isolation, between Antennas.

A measure of power transfer from one antenna to another.

Note: The isolation between antennas is the ratio of power input to one antenna to the power received by the other, usually expressed in decibels.

Isotropic Radiator.

A hypothetical antenna having equal radiation intensity in all directions. (cf. Omnidirectional Antenna.)

Note: An isotropic radiator represents a convenient reference for expressing the directive properties of actual antennas.

Length.

See Effective Length.

Lens Antenna.

An antenna consisting of a feed and an electromagnetic lens.

Lens, Electromagnetic.

A three-dimensional structure propagating electromagnetic waves, with an effective index of refraction differing from unity, employed to control the aperture illumination.

Line Source.

A continuous distribution of current lying along a line segment.

Linear Array Antenna.

An array antenna having the centers of the radiating elements lying along a straight line.

Loading, of an Antenna.

The modification of a basic antenna, such as a dipole or monopole, by adding conductors or circuit elements that change the current distribution or input impedance.

Lobe.

See Beam, of an Antenna; Major Lobe; Minor Lobe; Radiation Lobe; Side Lobe.

Lobe Switching.

A form of scanning in which the direction of maximum radiation is discretely changed by switching. (cf. Sequential Lobing.)

Log-Periodic Antenna.

Any one of a class of antennas having a structural geometry such that its electrical characteristics repeat periodically as the logarithm of frequency.

Long-Wire Antenna.

A wire antenna that, by virture of its considerable length in comparison with the operating wavelength, provides a directional radiation pattern.

Loop Antenna.

An antenna whose configuration is that of a loop.

Note: If the current in the loop, or in multiple parallel turns of the loop, is essentially uniform and the loop circumference is small compared with the wavelength, the radiation pattern approximates that of a magnetic dipole.

Luneburg Lens Antenna.

A lens antenna with a circular cross section having an index of refraction varying only in the radial direction such that a feed located on or near a surface or edge of the lens produces a major lobe diametrically opposite the feed.

Magnetic Dipole.

An elementary radiator consisting of an infinitesimally small current loop.

Main Lobe.

See Major Lobe.

Major Lobe (Main Lobe).

The radiation lobe containing the direction of maximum radiation.

Note: In certain antennas, such as multilobed or split-beam antennas, there may exist more than one major lobe.

Minor Lobe.

Any lobe except a major lobe.

Monopole.

Any one of a class of antennas constructed normal to an imaging plane to produce a radiation pattern approximating that of an electric dipole in the half-space above the imaging plane.

Monopulse.

In radar, simultaneous lobing whereby direction-finding information is obtainable from a single pulse.

Monostatic Cross Section.

See Back-Scattering Cross Section.

Mutual Impedance.

The mutual impedance between any two terminal pairs in a multielement array antenna is equal to the open-circuit voltage produced at the first terminal pair divided by the current supplied to the second when all other terminal pairs are open-circuited.

Near-Field Region, Radiating.

That region of the field of an antenna between the reactive near-field region and the far-field region wherein radiation fields predominate and wherein the angular field distribution is dependent upon distance from the antenna.

Note 1: If the antenna has a maximum overall dimension which is not large compared to the wavelength, this field region may not exist.

Note 2: For an antenna focused at infinity, the radiating near-field region is sometimes referred to as the Fresnel region on the basis of analogy to optical terminology.

Near-Field Region, Reactive.

That region of the field immediately surrounding the antenna wherein the reactive field predominates.

Note: For most antennas the outer boundary of the region is commonly taken to exist at a distance $\lambda 2\pi$ from the antenna surface, where λ is the wavelength.

Noise Temperature, of an Antenna.

The temperature of a resistor having an available thermal noise power per unit bandwidth equal to that at the antenna output at a specified frequency.

Note: Noise temperature of an antenna depends on its coupling to all noise sources in its environment as well as noise generated within the antenna.

Omnidirectional Antenna.

An antenna having an essentially nondirectional pattern in azimuth and a directional pattern in elevation. (cf. Isotropic Radiator.)

Paraboloidal Reflector.

A reflector which is a portion of a paraboloid of revolution.

Parasitic Element.

A radiating element which is not coupled directly to the feed lines of an antenna and which materially affects the radiation pattern and/or impedance of an antenna. (cf. Driven Element.)

Pattern.

See Radiation Pattern.

Pencil-Beam Antenna.

A unidirectional antenna having a narrow major lobe with approximately circular contours of equal radiation intensity in the region of the major lobe.

Phase Center.

In a given direction, the center of curvature of the wavefront of the radiation from an antenna in a given plane.

Phased Array Antenna.

An array antenna whose beam direction or radiation pattern is controlled primarily by the relative phase of the excitation coefficients of the radiating elements.

Pillbox Antenna.

A reflector antenna having a cylindrical reflector enclosed by two parallel conducting plates perpendicular to the cylinder, spaced less than one wavelength apart. (cf. Cheese Antenna.)

Planar Array Antenna.

An array antenna having the centers of the radiating elements lying in a plane.

Polarization, of an Antenna.

In a given direction, the polarization of the radiated wave, when the antenna is excited. Alternatively, the polarization of an incident wave from the given direction which results in maximum available power at the antenna terminals.

Note: When the direction is not stated, the polarization is taken to be the polarization in the direction of maximum gain.

Polarization, of a Radiated Wave.

That property of a radiated electromagnetic wave describing the time-varying direction and relative magnitude of the electric-field vector; specifically, the figure traced as a function of time by the extremity of the vector at a fixed location in space, and the sense in which it is traced, as observed along the direction of propagation.

Note: In general, the figure is elliptical and it is traced in a clockwise or counter-clockwise-sense. The commonly referenced circular and linear polarizations are obtained when the ellipse becomes a circle or a straight line, respectively. Clockwise-sense rotation of the electrical vector is designated "right-hand polarization" and counterclock wise-sense rotation is designated "left-hand polarization."

Power Gain, of an Antenna.

In a given direction, 4π times the ratio of the radiation intensity in that direction to the net power accepted by the antenna from the connected transmitter.

Note 1 : When the direction is not stated, the power gain is usually taken to be the power gain in the direction of its maximum value.

Note 2: Power gain does not include reflection losses arising from mismatch of impedance.

Note 3: Power gain is fully realized on reception only when the incident polarization is the same as the polarization of the antenna on transmission.

Primary Radiator.

A feed which illuminates a secondary radiator.

Pyramidal Horn Antenna.

A horn antenna, the sides of which form a pyramid.

Radar Cross Section.

That portion of the back-scattering cross section of a target associated with a specified polarization component of the scattered wave.

Radiating Element.

A basic subdivision of an antenna which in itself is capable of effectively radiating or receiving radio waves.

Note: Typical examples of a radiating element are a slot, horn, or dipole antenna.

Radiation Efficiency.

The ratio of the total power radiated by an antenna to the net power accepted by the antenna from the connected transmitter.

Radiation Intensity.

In a given direction, the power radiated from an antenna per unit solid angle.

Radiation Lobe.

A portion of the radiation pattern bounded by regions of relatively weak radiation intensity.

Radiation Pattern (Antenna Pattern).

A graphical representation of the radiation properties of the antenna as a function of space coordinates.

Note 1: In the usual case the radiation pattern is determined in the far-field region and is represented as a function of directional coordinates.

Note 2: Radiation properties include radiation intensity, field strength, phase or polarization.

Radiation Resistance.

The ratio of the power radiated by an antenna to the square of the root-mean-square antenna current referred to a specified point.

Radiator.

Any antenna or radiating element that is a discrete physical and functional entity.

Radome.

An enclosure for protecting an antenna from the harmful effects of its physical environment, generally intended to leave the electric performance of the antenna unaffected.

Reactive Field.

Electric and magnetic fields surrounding an antenna and resulting in storage of electromagnetic energy.

Reference Boresight.

A direction defined by an optical, mechanical, or electrical axis of an antenna established as a reference for the purpose of beam-direction or tracking-axis alignment. (cf. Electrical Boresight.)

Reflector.

See Corner Reflector Antenna, Cylindrical Reflector, Horn Reflector Antenna, Paraboloidal Reflector, Reflector Antenna, Spherical Reflector.

Reflector Antenna.

An antenna consisting of a reflecting surface and a feed.

Reflector Element.

A parasitic element located in a direction other than forward of the driven element of an antenna intended to increase the directive gain of the antenna in the forward direction.

Relative Gain, of an Antenna.

The ratio of the power gain in a given direction to the power gain of a reference antenna in its reference direction.

Note: Common reference antennas are half-wave dipoles, electric dipoles, magnetic dipoles, monopoles, and calibrated horn antennas.

Resistance.

See Antenna Resistance, Radiation Resistance.

Rhombic Antenna.

An antenna composed of long-wire radiators comprising the sides of a rhombus. The antenna usually is terminated in a resistance. The side of the rhombus, the angle between the sides, the elevation, and the termination are proportioned to give the desired radiation properties.

Scanning, of an Antenna Beam.

A repetitive motion given to the major lobe of an antenna.

Scattering Cross Section.

The scattering cross section of an object in a given orientation is 4π times the ratio of the radiation intensity of the scattered wave in a specified direction to the power per unit area in an incident plane wave of a specified polarization from a given direction.

Note: The term "bistatic cross section" denotes the scattering cross section in any specified direction other than back towards the source.

Secondary Radiator.

That portion of an antenna having the largest radiating aperture, consisting of a reflecting surface or a lens, as distinguished from its feed.

Sectoral Horn Antenna.

A horn antenna; two opposite sides of the horn are parallel and the two remaining sides diverge.

Self-Impedance, of a Radiating Element.

The input impedance of a radiating element of an array antenna with all other elements in the array open-circuited.

Note: In general, the self-impedance of a radiating element in an array is not the same as the input impedance of the same element with the other elements absent.

Sequential Lobing.

A direction-determining technique utilizing the signals of partially overlapping lobes occurring in sequence. (cf. Lobe Switching.)

Side Lobe.

A radiation lobe in any direction other than that of the intended lobe.

Side-Lobe Level, Maximum Relative.

The relative level of the highest side lobe.

Side Lobe, Relative Level of.

The ratio of the radiation intensity of a side lobe in the direction of its maximum value to that of the intended lobe, usually expressed in decibels.

Signal-Processing Antenna System.

An antenna system having circuit elements associated with its radiating element(s) which perform functions such as multiplication, storage, correlation, and time modulation of the input signals.

Simultaneous Lobing.

A direction-determining technique utilizing the signals of overlapping lobes existing at the same time.

Sleeve-Dipole Antenna.

A dipole antenna surrounded in its central portion by a coaxial conducting sleeve.

Slot Antenna.

A radiating element formed by a slot in a metal surface.

Spherical Reflector.

A reflector which is a portion of a spherical surface.

Spillover.

That part of the power radiated by a feed not intercepted by the secondary radiator.

Squint Angle.

A small difference in pointing angle between a reference beam direction and the direction of maximum radiation.

Superdirectivity.

The directivity of an antenna when its value exceeds the value which could be expected from the antenna on the basis of its dimensions and the excitation that would have yielded in-phase addition in the direction of maximum radiation intensity.

Note: Superdirectivity is obtained only at the cost of a sharp increase in the ratio of average stored energy to power radiated per hertz.

Surface Wave Antenna.

An antenna which radiates power from discontinuities in the structure that interrupt a bound wave on the antenna surface.

Target Echoing Area.

See Back-Scattering Cross Section.

Turnstile Antenna.

An antenna composed of two dipole antennas, perpendicular to each other, with their axes intersecting at their midpoints. Usually, the currents on the two dipole antennas are equal and in phase quadrature.

Uniform Linear Array.

A linear array of identically oriented and equally spaced radiating elements having equal current amplitudes and equal phase increments between excitation currents.

V Antenna.

An antenna that has a V-shaped arrangement of conductors, balanced-fed at the apex and with included angle, length, and elevation proportioned to give the desired directive properties.

Wave Antenna.

See Beverage Antenna.

APPENDIX C

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Antenna Types Listed by Azimuthal Patterns and Polarization	Useful Frequency Range (MHz) (Note 1)	Power Gain (Referred to Isotropic)(dB) (Note 2)	Usable Radiation Angles (degrees) (Note 3)	Approximate Land Required (acres)	Power Handling Capability (KW PEP) (Note 4)	Approximate Material Cost (thousands) (Note 5)	Nominal Bandwidth Ratio (Note 6)	Nominal Bandwidth Limited by	Horizontal Beamwidth (-3dB) (degrees)	Horizontal Beamwidth (-10dB) (degrees)	Sidelobe Suppression (dB)	Transmit Maximum VSWR (Note 7)	Nominal Input Impedance (ohms) (Note 8)
UNIDIRECTIONAL PATTERNS													
Horizontal Rhombic	2-30	8 to 23	3-35	5-15	Limited by Termination	5-10	≥2:1	Pattern	6°-26°	11°-46°	≥ 6	2:1	50/600
Horizontal Terminated V	2-30	4 to 17	5-30	3-7		3-6	≥2:1	Pattern	8°-36°	11°-48°	≥ 6	2:1	50/600
Horizontal Log-Periodic	2-30	10 to 17	5-45	2-4	40	15-25	≥8:1	VSWR	55°-75°	75°-120°	≥ 12	2:1	50/300
Horizontal Log-Periodic (Rotatable)	6-32	10 to 12	5-35	< 1	40	12-18	≥6:1	VSWR			≥12	2:1	50
Vertical Log-Periodic (Dipole)	2-30	6 to 10	3-25	3-5	40	10-20	≥8:1	VSWR	90°-140°	150°-180°	≥12	2:1	50
Yagi	6-30	6 to 19	5-30	< 1	20	5-10	≥3%	VSWR	28°-50°	38°-80°	≥ 9	1.5:1	50
Vertical Log-Periodic (Monopole)	2-30	4 to 8	3-25	.3-5	20	10-20	≥8:1	VSWR	90°-140°	150°-180°	≥12	2:1	50
Horizontal Half-Wave Dipole	2-30	5 to 7	5-80	<1	20	1-2	≥5%	VSWR	80°-180°/ lobe	180°/lobe	NA	1.5:1	50
OMNIDIRECTIONAL PATTERNS (VERTICAL)													
Conical Monopole	2-30	-2 to +2	3-45	2-4	40	3-8	≥4:1	Pattern	NA	NA	NA	2.5:1	50
Discone	6-30	2 to 5	4-40	<1	40	5-10	≥4:1	Pattern	NA	NA	NA	2:1	50
Inverted Cone	2-30	1 to 5	5-45	2-4	40	5-10	≥10:1	Pattern	NA	NA	NA	2:1	50
Vertical Sleeve	4-27	-1 to +3	4-40	2-4	10	5-10	≥3:1	VSWR	NA	NA	NA	3:1	50
SECTOR PATTERNS (VERTICAL)													
90° Corner Reflector Sleeve	4-27	5 to 8	4-40	2-4	10	5-10	≥3:1	VSWR	56°-118°		NA	3:1	50
180° Sector Sleeve	4-27	2 to 5	4-40	2-4	10	5-10	≥3:1	VSWR	148°-180°		NA	3:1	50
Sector Log-Periodic	2-32	8 to 11	5-40	4-6	40	15-30	≥8:1	VSWR	4 Sectors 90° apart		NA	2:1	50
SELECTIVE PATTERNS (VERTICAL)													
Selectively Directional Monopole (Transmit only)	4-30	4.5 to 9.5	5-40	5-8	1200	Cost figures not available	≥7:1 (Note 9)	VSWR	360°, 180°, or 45°, as selected		NA	2:1	50
Wullenweber (Receive only)	2-30			32-38	NA	Cost figures not available	≥10:1	NA	360° and various sectors as selected		NA	NA	50
Transportable Wullenweber (Receive only)	3-30	Directive Gain 14 to 19	3-45	10-14	NA	Cost figures not available	≥10:1	NA	360°, 120° sector, 36 narrow beam as selected		NA	NA	50

Note 1 - The useful frequency range is the range of the antenna type, not necessarily the bandwidth of an individual antenna.

Note 2 - Typical power gains are gains of antennas over good earth for vertical polarization and poor earth for horizontal polarization.

Note 3 - Usable radiation angles are typical radiation angles over good earth for vertical polarization and poor earth for horizontal polarization; lower angles may be possible for vertical antennas over better earth, e.g., sea water.

Note 4 - The power limitation criteria apply to the antenna only. The use of certain baluns may result in a lower power limitation. These criteria should be used as a basis of comparison only, since any antenna can be engineered at increased cost, to provide increased power-handling capability.

Note 5 - Approximate material costs include steel towers, guys, and installation hardware. Costs are established only to provide a relative basis of comparison of one antenna against another.

Note 6 - Nominal bandwidth is the ratio of the two frequencies within which the stated VSWR will not be exceeded or within which the desired pattern will not suffer more than 3 dB degradation.

Note 7 - Maximum VSWR for receiving antennas shall not exceed 3:1.

Note 8 - Includes any impedance matching device.

Note 9 - Overall combined bandwidth of low and high band monopoles.

Foldout 5-1. Antenna Characteristic Chart