

The "IEEE Standard Definitions of Terms for Antennas" (IEEE STD-145) represents a consistent and comprehensive vocabulary suited for the effective communication and understanding of antenna theory. General use of these definitions of terms would eliminate much of the wide-spread inconsistency concerning antenna characteristics, particularly with regard to the basic parameters of gain, beamwidth, polarization and efficiency. For convenience, IEEE antenna terms of general interest are listed here. Wherever these terms appear in this catalog, the definitions given below apply. Other commonly used terms, not covered by the IEEE standard, are shown with an "\*".

**ANTENNA APERTURE.** 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:** The aperture is often taken as that portion of a plane surface near the antenna, perpendicular to the direction of maximum radiation, through which the major part of the radiation passes.

**ANTENNA EFFICIENCY OF 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 FACTOR.** That quantity by which the voltage developed across the output of an antenna is related to the incident field strength in which the antenna is immersed. **Note:** Applicable to low frequency antennas and usually refers to a 50 ohm output.

$$AFE \text{ (dB m}^{-1}\text{)} = E \text{ (dB V / m)} - V \text{ (dB V)}$$

AFE = Electric Field Antenna Factor  
E = Electric Field Strength at antenna  
V = Voltage at terminals of antenna

$$AFH \text{ (dB AV}^{-1}\text{ m}^{-1}\text{)} = H \text{ (dB A / m)} - V \text{ (dB V)}$$

AFH = Magnetic Field Antenna Factor  
H = Magnetic Field Strength at antenna  
V = Voltage at terminals of antenna

$$AFE \text{ (dB m}^{-1}\text{)} = AFH \text{ (dB AV}^{-1}\text{ m}^{-1}\text{)} + 51.53$$

for a plane wave in free space.

$$AFB \text{ (dB } \frac{\text{pT}}{\mu\text{V}}\text{)} = B \text{ (dBpT)} - V_0 \text{ (dB}\mu\text{V)}$$

AFB = Magnetic flux Antenna Factor  
B = Magnetic flux at the antenna  
pT: picoTesla units  
V = Voltage at the terminals of the antenna

$$AFB \text{ (dB } \frac{\text{pT}}{\mu\text{V}}\text{)} = AFH \text{ (dB } \frac{\text{A}}{\text{Vm}}\text{)} + 2$$

**APERTURE ILLUMINATION.** The field over the aperture as described by amplitude, phase, and polarization distributions.

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

**BEAM.** The major lobe of the radiation pattern.

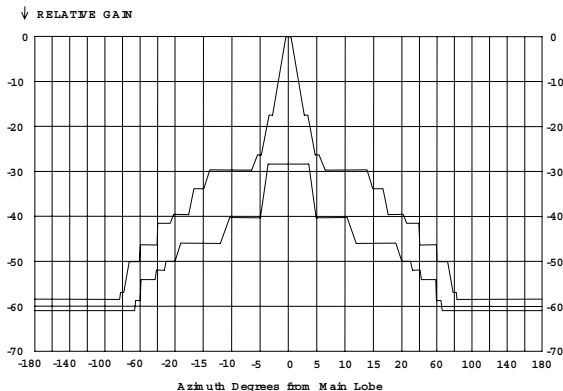
**CIRCULAR POLARIZATION.** It may be either right hand circular polarization (RHCP) or left hand circular polarization (LHCP). The sense of polarization is determined by observation of the direction of rotation of the electric field vector from a point behind the source, RHCP and LHCP correspond to clockwise and counter-clockwise respectively. **Note:** RHCP transmit requires a like polarization to receive.

**CO-POLARIZED.** The polarization which the antenna is intended to radiate or receive. Also "like polarization".

\* **CROSS POLARIZATION DISCRIMINATION (XPD).** Cross polarization discrimination is the measure of the antenna's ability to differentiate between the vertical and the horizontal polarization of an antenna. This difference, shown in relative signal level, is indicated on directional pattern envelopes (DPE's).

# STANDARD ANTENNA TERMS AND RELATED FORMULAS

\* **DIRECTIONAL PATTERN ENVELOPES (DPE'S).** In accordance with standard practice, radiation characteristics in any given plane of polarization are measured and plotted using 360-degree polar coordinate systems. The resultant Directional Pattern Envelope is the smoothed composite of all these measurements. The purpose of these DPE's is to emphasize the worst composite condition.



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

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

**EFFECTIVE AREA OF AN ANTENNA.** In a given direction, the ratio of power available at the terminals of a receiving 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.

**FAR FIELD REGION.** That region of the field of an antenna where the angular field distribution is essentially independent of the distance from a specified point in the antenna region.

\* **FRONT-TO-BACK RATIO.** The ratio of the maximum directivity of an antenna to its directivity in a specified rearward direction.

\* **Gain, dBi.** The gain expressed in decibels relative to an isotropic radiator that is linearly polarized.

$$G(\text{dBi}) = 10 \log(G) \quad G = 10^{\frac{G(\text{dBi})}{10}}$$

\* **GAIN, dBic.** The gain expressed in decibels relative to an isotropic radiator that is circularly polarized.

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

**HALF-WAVE DIPOLE.** A half wavelength antenna, center fed so as to have equal current distribution in both halves. Mounted vertically, it has a doughnut shaped pattern, circular in the horizontal plane. It is an antenna that can be constructed. It has some inherent losses. When used as a gain reference, the half-wave dipole has a power gain of about 1.7 dBi.

\* **ISOLATION.** Refers to the ability of one port of a dual polarized feed to discriminate against a signal fed into the other port.

**ISOTROPIC RADIATOR.** A hypothetical antenna having equal radiation intensity in all directions. Note: An isotropic radiator represents a convenient reference for expressing the directive properties of actual antennas.

**NEAR-FIELD REGION.** The spherical region of space between the antenna and the far field region.

**NULL.** The region of a radiation pattern, either computed or measured, where the amplitude goes through a minimum value. Note: (1) It represents the angular position where the phase or the far field pattern crosses the zero axis if the pattern is plotted as a phasor instead of a scalar value. Note: (2) The region outside the main beam of a directive antenna pattern consists of a series of minor lobes separated by nulls.

**PARALLEL POLARIZATION.** The condition where the electric vector is parallel to the local conducting surface. Note: Over the earth, this is usually referred to as being horizontal polarization.

**PHASE CENTER.** The location of a point associated with an antenna such that, if it is taken as the center of a sphere whose radius extends into the far-field, the phase of a given component over the surface of that radiation sphere is essentially constant, at least over the portion of the sphere where the radiation is significant.

# STANDARD ANTENNA TERMS AND RELATED FORMULAS

**POLARIZATION.** The polarization of an antenna is defined as the polarization of the electromagnetic wave as described by the shape and orientation of an ellipse, which is the locus of the extremity of the field vector, and the sense in which the ellipse is traversed with time. The elliptical locus is called the polarization ellipse and the wave is said to elliptically polarized. Circular polarization and linear polarization are degenerate cases of elliptical polarization.

## POWER DENSITY AT A POINT

$$S_{av} = \frac{GP_t}{4\pi r^2}$$

$S_{av}$  = Time average power density in W/m<sup>2</sup>

$P_t$  = Power transmitted in watts

$G$  = Antenna gain relative to an isotrope

$r$  = Distance from antenna to point in meters

## POWER DENSITY TO VOLTS/METER IN FREE SPACE

$$E^2 \text{ (V / m)} = 377 S_{av} \text{ (W / m}^2\text{)}$$

$$S_{av} \text{ (W / m}^2\text{)} = E^2 \text{ (V / m)} / 377$$

$$1 \text{ V / m} = 2.65 \text{ mW / m}^2$$

**POWER GAIN.** In a given direction, 4 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. (2) Power gain does not include reflection losses arising from mismatch of impedance.

**POWER GAIN IN PHYSICAL MEDIA.** In a given direction and at a given point in the far field the ratio of the power flux per unit area from an antenna to the power flux per unit area from an isotropic radiator at a specified location with the same power input as the subject antenna.

**Note:** The isotropic radiator must be within the smallest sphere containing the antenna. Suggested locations are antenna terminals and points of symmetry, if such exist.

**POWER GAIN REFERRED TO A SPECIFIED POLARIZATION.** The power gain of an antenna, reduced by the ratio of that portion of the radiation intensity corresponding to the specified polarization to the radiation intensity.

## POWER TRANSMISSION FORMULAS

$$P_r = P_t \frac{G_t G_r \lambda^2}{(4\pi r)^2}$$

$$P_r \text{ (dB W)} = P_t \text{ (dB W)} + G_t \text{ (dBi)} + G_r \text{ (dBi)} - 20 \log r - 20 \log f + 27.56$$

$$P_r \text{ (dB W)} = P_t \text{ (dB W)} - AFE_t \text{ (dB m}^{-1}\text{)} - AFE_r \text{ (dB m}^{-1}\text{)} - 20 \log r + 20 \log f - 32$$

$P_r$  = Power received

$P_t$  = Power transmitted

$G_r$  = Gain of receiving antenna

$G_t$  = Gain of transmitting antenna

$f$  = Frequency in MHz,  $\lambda$  = Wavelength

$r$  = distance between antennas in meters

$AFE_r$  = AFE of receiving antenna

$AFE_t$  = AFE of transmitting antenna

**RADIATOR.** Any antenna or radiation element that is a discrete physical and functional entity.

**RADIATION, ELECTROMAGNETIC.** The emission of energy in the form of electromagnetic waves.

**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 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. (2) Radiation properties include power flux density, field strength, phase, and polarization.

## NOTES:

\* **RADIATION RESISTANCE OF AN ELECTRICALLY SMALL LOOP ANTENNA.** The resistive component of an antenna's input impedance that results from the coupling of the antenna to its environment. This resistance dissipates the power that is actually radiated from the antenna.

$$R_r = 20 (2\pi/\lambda)^4 n^2 A^2 \text{ ohms}$$

n = number of turns

A = area of the loop

**REALIZED GAIN.** The power gain of an antenna in its environment, reduced by the losses due to the mismatch of the antenna input impedance to a specified impedance.

\* **REALIZED RADIATOR EFFICIENCY.** The efficiency of an antenna in its environment reduced by all losses suffered by it, including: ohmic losses, mismatch losses, feedline transmission losses, and radome losses.

**RELATIVE POWER GAIN.** 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.

**RETURN LOSS.** The reflection coefficient of a mismatch expressed in decibels. **Note:** Modern swept VSWR techniques actually sense the reflected component which is normalized to the forward component to yield return loss. A 2:1 VSWR is equivalent to 9.5 dB return loss.

**VSWR.** The voltage standing wave ratio of a component such as an antenna. It is referred to the characteristic impedance of the transmission line being used. **Note:** The most common characteristic impedance is 50 ohms, but 75 and 300 ohms are frequently used in coaxial or twin lines for VHF, UHF applications.