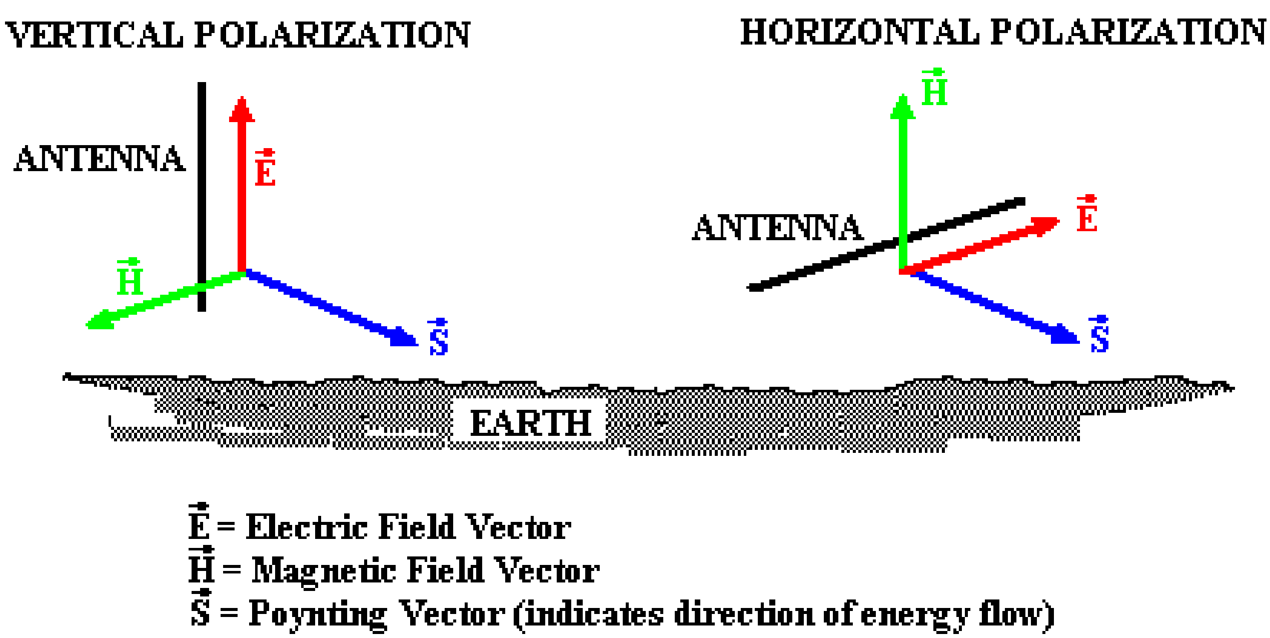
BASIC ANTENNA THEORY

An antenna is a device that provides a transition between electric currents on a conductor and electromagnetic waves in space. A transmitting antenna transforms electric currents into radio waves and a receiving antenna transforms an electromagnetic field back into electric current.

There are several basic properties that are common to all antennas:

Reciprocity: an antenna's electrical characteristics are the same whether it is used for transmitting or receiving. Because this is always true, throughout this lecture, we will consider antennas as transmitting antennas.

Polarization: polarization is the orientation of the electric field vector of the electromagnetic wave produced by the antenna. For most antennas, the orientation of the antenna conductor determines the polarization. Polarization may be vertical, horizontal or elliptical.

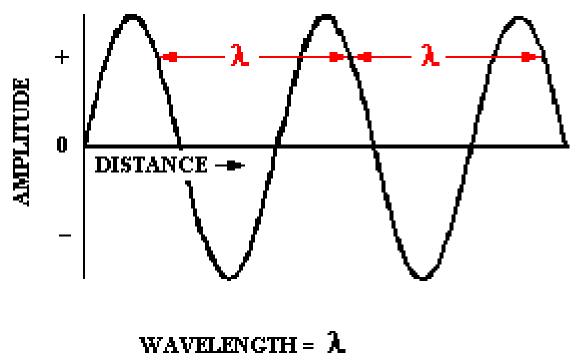


The diagram above shows vertical and horizontal polarization. If the radio wave's electric field vector points in some other direction, it is said to be obliquely polarized.

If the electric field rotates in space, such that its tip follows an elliptical path, it is elliptically polarized.

Wavelength: this is the length of one RF wave. It can be computed by either of the following formulas, depending on the units required:

λ(in m) = 300/f(in MHz) or λ(in ft) = 984/f(in MHz)



For more information on wavelength, click here.

Gain (directivity): This is a measure of the degree to which an antenna focuses power in a given direction, relative to the power radiated by a reference antenna in the same direction. Units of measure are dBi (isotopic antenna reference) or dBd (half-wave dipole reference). The two gain measurements can be converted using the following formula:

dBi = dBd + 2.1

If the directivity of the transmitting and receiving antennas is known, it is possible to compute the power received by the receiving antenna using either of the formulas below:

When using dB:

$$P_{RECEIVED} = P_{TRANSMITTER} + G_T + G_R + 20\log(\lambda) - 20\log(d) - 21.98$$

Antenna gain should be expressed in dBi, wavelength and distances in m and powers in dBm or dBW.

When using gain ratios and powers in W:

$$P_{RECEIVED} = \frac{P_{TRANSMITTER} G_T G_R \lambda^2}{16\pi^2 d^2}$$

Antenna gains should be expressed as a number, distances and wavelengths in m and powers in W.

Here is an example:

Two dipole antennas 100 km apart are aligned and one transmits a 1 kW signal. The frequency is 222 MHz. What is the received power?

Solution A using dB

Convert 1 kW to dbm P_T = 10log(1kW/1mW) = 10 log(1,000,000) = 60 dBm
Find the wavelength: λ = 300/f = 300/222 MHz = 1.35 m

$$P_{RECEIVED} = 60dBm + 2.15dBi + 2.15dBi + 20\log(1.35) - 20\log(100{,}000) - 21.98$$

$$P_{RECEIVED} = 64.3 + 2.6 - 100 - 21.98 = -60.3dBm$$

This is the same as $9.4 \cdot 10^{-10}$ W

Beamwidth: the angular separation between the half-point (-3dB) points in an antenna's radiation pattern. In general, the beamwidth of the main lobe of the radiation pattern decreases as the directivity increases.

Near field (induction field): electromagnetic field created by an antenna that is only significant at distances of less than 2D/λ from the antenna, where D is the longest dimension of the antenna.

Near field region: A spherical region of radius 2D/λ centered on the antenna.

Far field (radiation field): electromagnetic field created by the antenna that extends throughout all space. At distances greater than 2D/λ from the antenna, it is the only field. It is the field used for communications.

Far field region: The region outside the near field region, at distances greater than 2D/λ.

Input Impedance: This is the impedance measured at the antenna input terminals. In general it is complex and has two real parts and one imaginary part:

Radiation resistance: - represents conversion of power into RF waves (real)
Loss resistance – represents conductor losses, ground losses, etc. (real)
reactance – represents power stored in the near field (imaginary)

Efficiency: this is the ratio of radiation resistance to total antenna input resistance:

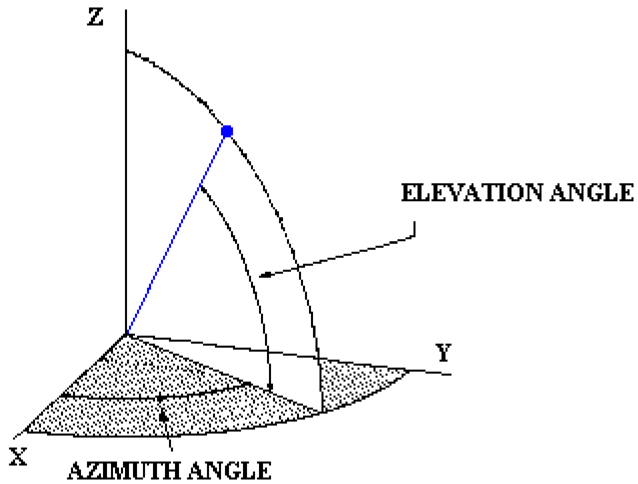
$$\eta = \frac{P_{RADIATED}}{P_{INPUT}} = \frac{R_{RADIATION}}{R_{LOSS} + R_{RADIATION}}$$

The loss resistances come from conductor losses and losses in the ground (the near field of the antenna can interact with the ground and other objects near the antenna). The efficiency of practical antennas varies from less than 1% for certain types of low frequency antennas to 99% for some types of wire antennas.

Electrical length. This came up in the section on transmission lines. It is the length or distance expressed in terms of wavelengths.

Bandwidth: generally the range of frequencies over which the antenna system's SWR remains below a maximum value, typically 2.0

Azimuth and Elevation: These are angles used to describe a specific position in an antenna's radiation pattern. Azimuth is a horizontal angle, generally measured from true north. The elevation angle is a vertical angle, ranging from 0 degrees (horizon) to 90 degrees (zenith).



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