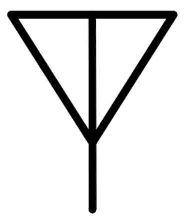
Antennas Reference Guide

Definition - An antenna is a passive metal structure that captures or emits electromagnetic waves



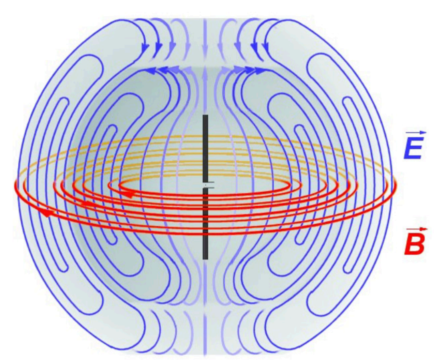
Transmission: When an electrical signal is applied to the antenna, it creates a changing electromagnetic field around it, propagating through space as an electromagnetic wave.

Reception: When the antenna encounters an electromagnetic wave, it induces an electrical signal, which can be detected and amplified by electronic circuits.

The antenna design determines its efficiency, radiation pattern, and ability to transmit and receive signals in different directions and frequencies. Matching the antenna size and shape to the wavelength of radio waves is essential for optimal performance. Antennas obey the reciprocity theorem, i.e. the same radiation pattern applies to transmission as well as reception of radio waves.

Omnidirectional Antenna	Directional Antenna
Radiates energy approximately equally in all horizontal directions. Extreme: The hypothetical isotropic radiator.	Radio waves are concentrated in some directions. Extreme: The unidirectional beam antenna, designed for maximum response in the direction of the other station.

Most antenna designs are based on the **Dipole Antenna**. A dipole antenna oriented horizontally sends no energy in the direction of the conductor (**antenna null**), but is usable in most other directions.



The electric fields (blue) and magnetic fields (red) radiated by a **dipole antenna** (black rods) during transmission.

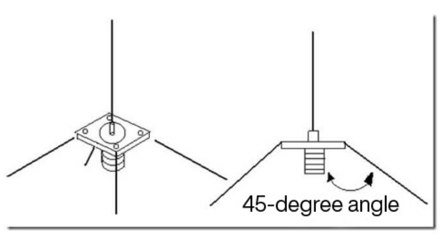
The **half-wave dipole** is probably the most widely used antenna design. This consists of two 1/4-wavelength elements arranged end-to-end, and lying along essentially the same axis (or collinear), each feeding one side of a two-conductor transmission wire. The physical arrangement of the two elements places them 180 degrees out of phase, meaning that at any given instant, one of the elements is driving current into the transmission line while the other pulls it out.

The **monopole antenna** is essentially one half of the half-wave dipole, a single 1/4-wavelength element with the other side connected to ground or an equivalent ground plane (or counterpoise). Monopoles, which are one-half the size of a dipole, are common for long-wavelength radio signals where a dipole would be impractically large. Another common design is the folded dipole which consists of two (or more) half-wave dipoles placed side by side and connected at their ends but only one of which is driven.

Electrically short antennas: It is possible to use simple impedance matching techniques to allow the use of monopole or dipole antennas substantially shorter than the 1/4 or 1/2 wave, respectively, at which they are resonant. As these antennas are made shorter (for a given frequency) their impedance becomes dominated by a series capacitive (negative) reactance; by adding an appropriate size 'loading coil' – a series inductance with equal and opposite (positive) reactance – the antenna's capacitive reactance may be cancelled leaving only a pure resistance.

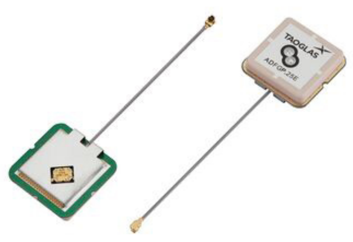
Sometimes the resulting (lower) electrical resonant frequency of such a system (antenna plus matching network) is described using the concept of electrical length, so an antenna used at a lower frequency than its resonant frequency is called an electrically short antenna.

Basic antenna types



1/4 wave: The simplest form of a vertical antenna with an omnidirectional radiation pattern. A single radiating element approximately 1/4 wavelength long.

1/2 wave antenna: A single radiating element 1/2 wavelength long.



GPS: Active GPS antennas include an amplifier circuit in order to provide better reception of the satellite signal.

Dipole: An antenna - usually 1/2 wavelength long - split at the exact center for connection to a feed line.

Embedded omni: Embedded omni antennas are generally integrated on a base for applications such as access points. This structure could be externally mounted or directly integrated on the PC board of the system.

Yagi: A directional gain antenna utilizing one or more parasitic elements. A yagi consists of a boom supporting a series of elements, typically aluminium rods.

Omni ceiling mount: Omni ceiling mount antennas are used for the propagation of data in an in-building environment. In order to provide good coverage, these antennas are vertically polarized and present an omnidirectional pattern in the horizontal plane and a dipolar pattern in the vertical plane.

Parabolic: An antenna consisting of a parabolic reflector and a radiating or receiving element at or near its focus. Solid Parabolics utilize a dish-like reflector to focus radio energy of a specific range of frequencies on a tuned element.

Key antenna characteristics

Bandwidth: The frequency range or bandwidth over which an antenna functions well can be very wide (as in a log-periodic antenna) or narrow (as in a small loop antenna); outside this range, the antenna impedance becomes a poor match to the transmission line and transmitter (or receiver). The bandwidth characteristics of a resonant antenna element can be characterized according to its quality factor Q taking into account the radiation resistance, which represents the emission of energy from the resonant antenna to free space.

Gain: G measures the degree of directivity of the antenna's radiation pattern. A high-gain antenna will radiate most of its power in a particular direction, while a low-gain antenna will radiate over a wide angle. The antenna gain, or power gain of an antenna is defined as the ratio of the intensity (power per unit surface area) I radiated by the antenna in the direction of its maximum output, at an arbitrary distance, divided by the intensity I^{iso} radiated at the same distance by a hypothetical isotropic antenna which radiates equal power in all directions. This dimensionless ratio is usually expressed logarithmically in decibels, these units are called decibels-isotropic (dBi). A second unit used to measure gain is the ratio of the power radiated by the antenna to the power radiated by a half-wave dipole antenna Idipole , called decibels-dipole (dBd).

$$G_{dBI}=10log\frac{I}{I_{iso}}$$

$$G_{dBd}=10log\frac{I}{I_{dipole}}$$

Effective area/effective aperture: A describes the portion of the power of a passing electromagnetic wave which the antenna delivers to its terminals, expressed in terms of an equivalent area.

$$A_{eff}=G\,\frac{\lambda^2}{4\pi}$$

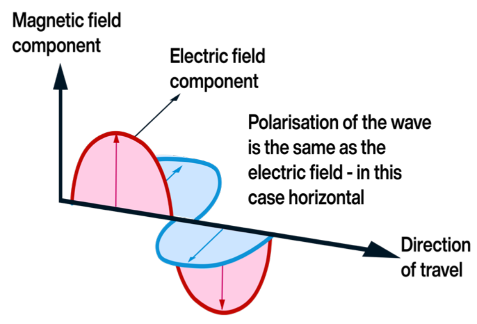
Efficiency: The ratio of power actually radiated (in all directions) to the power absorbed by the antenna terminals. The loss resistance will generally affect the feedpoint impedance, adding to its resistive component. That resistance will consist of the sum of the radiation resistance R_{rad} and the loss resistance R_{loss}. If a current I is delivered to the terminals of an antenna, then a power of I^2*R_{rad} will be radiated and a power of I^2*R_{loss} will be lost as heat. Therefore, the efficiency of an antenna is equal to

$$\frac{R_{rad}}{R_{rad}+R_{loss}}$$

Only the total resistance $R_{rad}+R_{loss}$ can be measured directly.

Polarization: An antenna's orientation and physical structure determines the polarization of the electric field of its radio wave.

For instance, an antenna composed of a linear conductor (such as a dipole or whip antenna) oriented vertically will result in vertical polarization; if turned on its side, the same antenna's polarization will be horizontal.



An electromagnetic wave

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