Antenna Basicss

A Simplified Perspective for Hams and SWLs

Disclaimer

I am not an antenna expert!

Information presented here has been assembled from many different sources.

Why Understand Antennas?

The antenna is arguably the most important component in most radio systems.

Let’s use a sound system analogy to help reinforce this notion.

With a home audio system, you can have a $10,000 amplifier with small, cheap loudspeakers and it will sound awful.

Conversely, with a basic cheap audio amp and some really good speakers it can sound fabulous.

The speakers make all the difference; they contribute the most to what we hear.

Why Understand Antennas?

The same goes for an amateur radio station. Here we can have the nicest transceiver you can buy paired with a lousy antenna and we won't hear much or be heard well.

But take a cheap radio with a good antenna and we can do wonders.

The antenna makes the most impact on a radio communications system.

Whether transmitting or receiving, a weak signal isn't sometimes due to poor band conditions or lack of power, it's caused by a bad antenna.

Definition

An antenna is simply defined as an arrangement of conductors used to radiate electromagnetic energy into space or, conversely, collect it from space.

Sounds simple, right? In reality, functional antennas are a bit more complicated. There are many factors to consider in practical antenna design & installation.

Definition

It may also be helpful to think of an antenna as a transducer which converts alternating current (AC) into radio waves, and, conversely, radio waves into AC.

You may be unfamiliar with the word transducer – it's a device which changes one form of energy into another.

We are all familiar with: Speakers, microphones, temperature and pressure sensors, room lighting of all sorts, and indicators. They are all transducers.

We control the electrical side of things in our radios and the antenna converts that AC into useful radio waves, and vice-versa.

Common Characteristics

Antennas come in a myriad of sizes, shapes and configurations.

These vary greatly based on the nature of the application (mainly frequency and performance).

Regardless of these differences, all antennas share three common characteristics:

- Reciprocity
- Directivity & Gain
- Polarization

Reciprocity

Reciprocity means it works both ways.

The electro-magnetic characteristics of an antenna make it work equally well for transmitting and receiving.

This means that for both transmission and reception, antennas are equally directive, have equal gain and bandwidth, and have the same polarity.

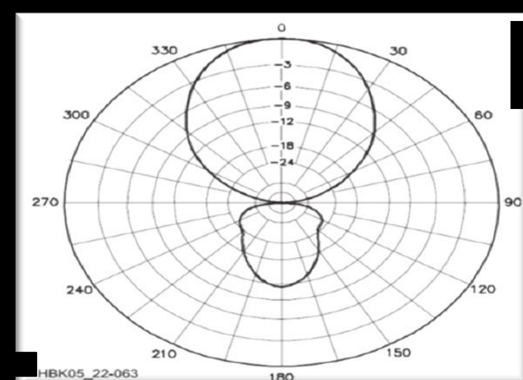
Directivity & Gain

Directivity is an antenna’s ability to focus the energy to - or from - one or more directions.

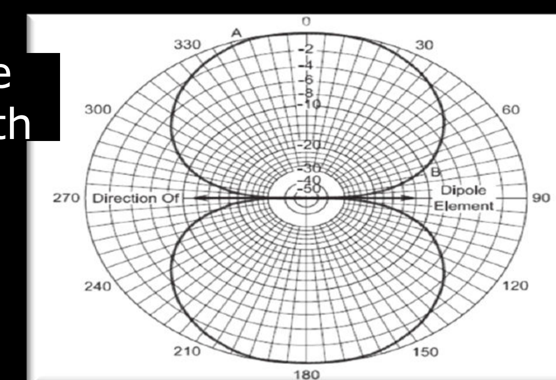
All practical antennas have some degree of directivity, some slightly directive (verticals), some semi-directional (dipole), and others very directional (beam).

Directivity & Gain

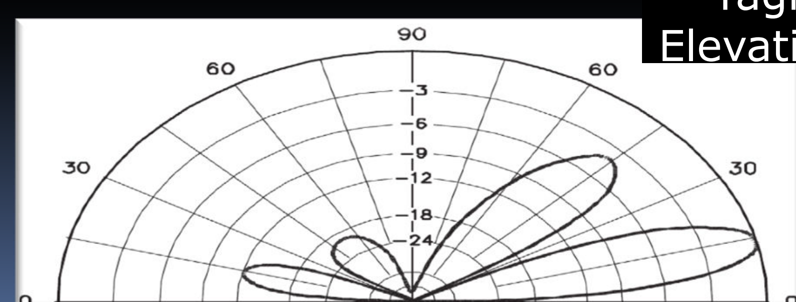
Antenna radiation Patterns



Yagi Azimuth

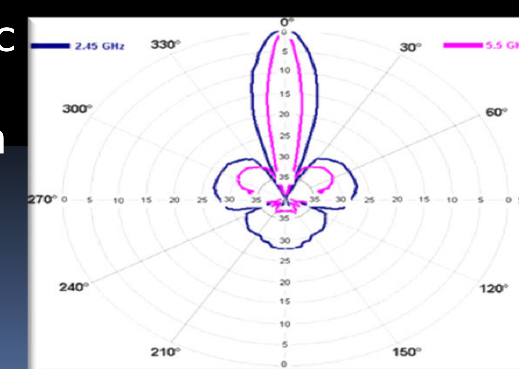


Dipole Azimuth



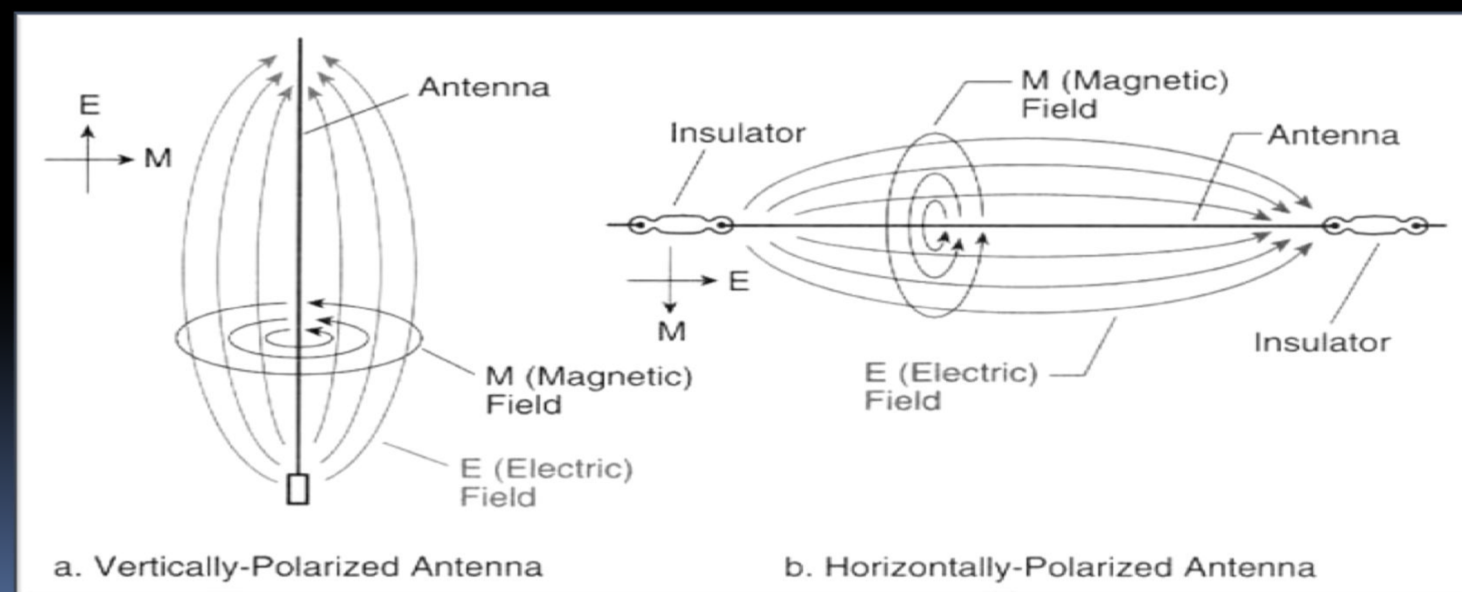
Yagi Elevation

Parabolic (Dish) Azimuth



Polarization

Antenna polarization is determined by the orientation of the electric field with respect to the earth.



Polarization

For line-of-sight communications in the VHF and UHF spectrum, antenna polarization is important.

All repeater antennas and mobile antennas are (or should be) vertically polarized.

Handheld transceivers (HTs) work best when held with the antenna up and down. You would see about 3dB signal loss (half power) at a 45º tilt.

For short distances in open space polarization is a non-issue due to relative signal strength.

Polarization

At lower frequencies in the HF spectrum antenna orientation is less important because ionospheric propagation randomizes polarization.

This blended E-field orientation is sometimes referred to as elliptical polarization.

As a result, you can use either vertical or horizontal antennas on HF bands.

Other Factors

Yet there are other factors important to antenna theory.

Primary among these are:

Impedance

Capacitance

Impedance

Can be thought of as “AC Resistance”

All antennas have impedance at a given frequency.

Antenna impedance varies with conductor arrangement, signal frequency, height above ground, conductor diameter, nearby objects, and connecting wires (feedline), among other things.

For maximum power transfer of a source to a load, the impedance of the source, load and transmission line must be the same (matched).

Impedance

In an antenna system these three impedances are matched as closely as possible over a specified range of frequencies.

When there is an impedance mismatch, some of the signal is reflected back to the source. Of course, the impedance there doesn't match so part of the reflected signal is reflected back again.

And so on: back and forth until the signal is attenuated into oblivion, losing part of its energy all the way.

Impedance

Matching antenna impedance seems obvious when transmitting, since you want all of your transmitter power to be radiated from the antenna.

But it also works in reverse. When receiving, signal strength is also maximized by properly matched impedances.

Impedance

A common way for hams to quantify impedance matching is with the term Standing Wave Ratio (SWR).

SWR is a generalized measurement of how well matched the radio is to the antenna and feedline.

SWR is quite a topic in and of itself, because the antenna is only one contributor to SWR. We'll take a simple look at SWR in a moment.

Capacitance

Capacitance is a measure of how easily an object can store electric charge.
The capacitance of an object is the ratio of the amount of charge to the potential difference between conductors.

The capacitance of a capacitor is the ratio of the maximum charge that can be stored to the applied voltage across its plates.

The use of a capacitor can have a big impact on the physical size of an antenna. For example, a capacitance "top hat" on a Planar Inverted F antenna can reduce the antenna size by 30% or more.

RX vs TX

The antenna’s impedance determines how much incident RF power will be converted into current flow in the antenna and how much will be reflected back off it.

This is a much more significant issue if the antenna is being used to transmit RF power rather than receive it. For the case of a transmitting antenna, the antenna designer has to get an impedance match between the antenna, the feed line, and the transmitter at the frequency being produced by the transmitter.

A good match may require the addition of small amounts of capacitance or inductance to the antenna structure in order to *tune* it…(Demo)

Real-World Antennas

All this theoretical study of antennas is fine and necessary but in the real world a practical antenna is imperfect.

A real antenna system is always a compromise or tradeoff between two or more competing interests:

- Bands/Frequencies
- Directivity & Gain
- Bandwidth
- Space Available
- Practical Height
- Cost
- Stealthiness/Visibility
- Spousal Approval…

Real-World Antennas

Many hams live in urban or suburban areas with little or no space to install antennas, or have restrictions on what is allowed.

Types & Configurations

Let's look at some common antenna types and configurations.

We're going to present only the basics today.

The advantages, disadvantages and other details of these types will be covered in a separate presentation.

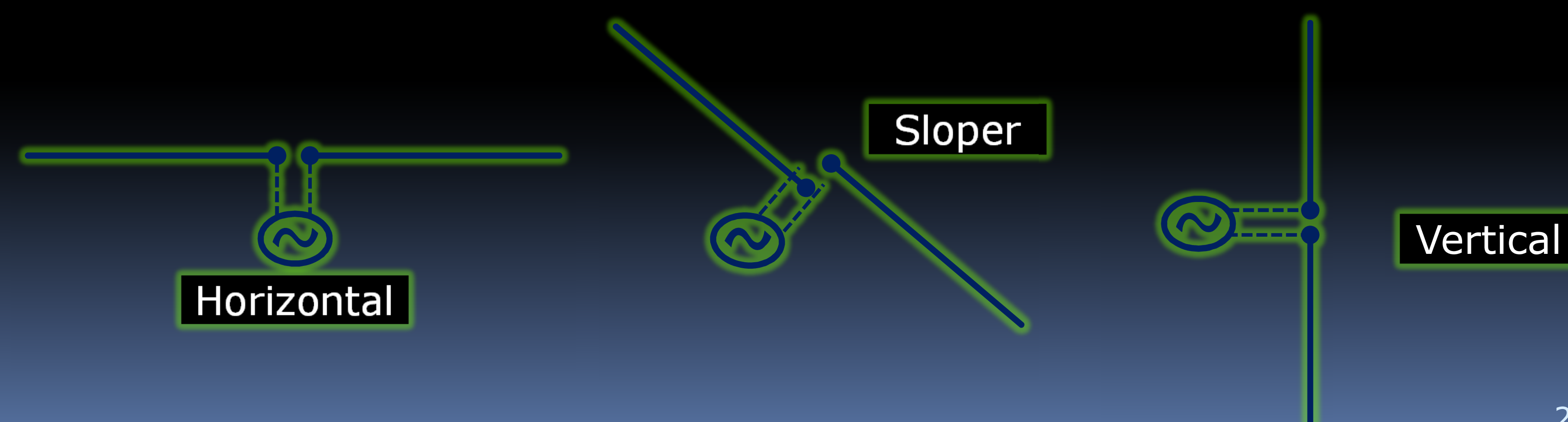
Types & Configurations

Standard Dipole

Typically half-wave center-fed antenna with two quarter-wave symmetrical elements.

Resonant at one frequency (single-band).

Three common orientations: horizontal, vertical, and sloping.



Types & Configurations

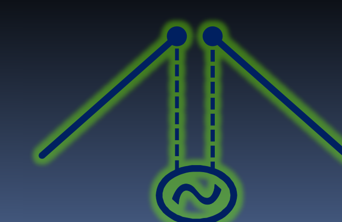
Inverted Vee

Common variant to the standard 1/2-wave dipole.

The name derives from the orientation of the dipole elements that are supported in the middle and angled down.

This dipole occupies less horizontal space and requires only a single center support, which makes it popular for field use on HF bands.

Inverted Vee



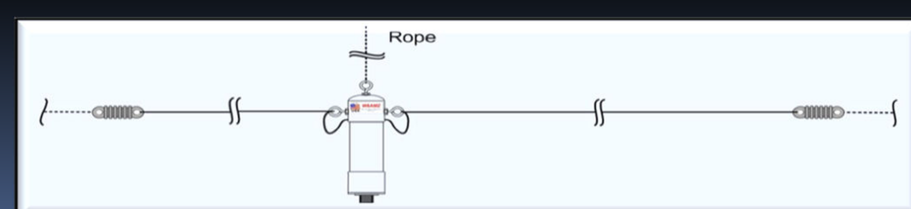
Types & Configurations
OCF Dipole

Half-wave antenna with asymmetrical elements.

Feed point is off-center (OCF=off-center fed). Also known as a Windom antenna.

Proper design permits multi-band operation.

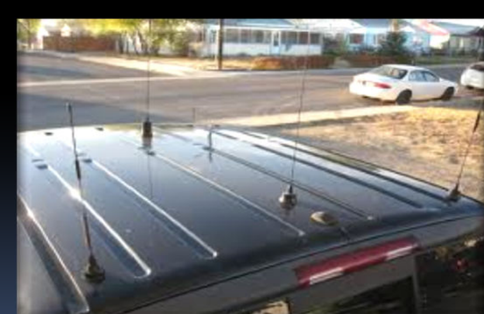
Horizontal, sloping, or inverted vee orientation.

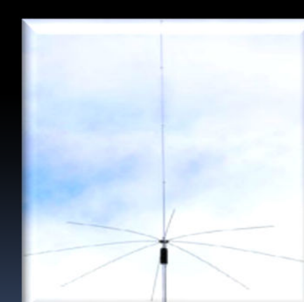


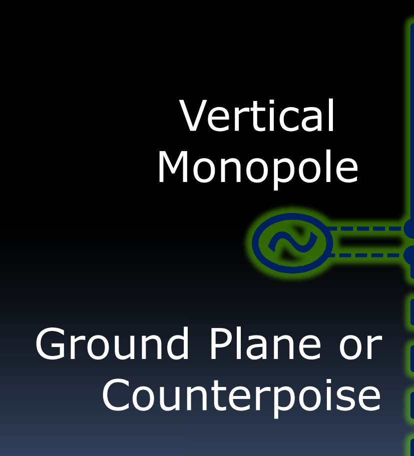
Types & Configurations

Vertical Monopole

Instead the vertical monopole replaces the lower element by the earth (ground) or a substitute called a counterpoise or ground plane.







Types & Configurations

J-Pole

Half-wave (λ/2) end-fed antenna also known as the Zepp (originally developed for use on airships with the antenna trailing behind).

Features a λ/4 parallel tuning stub (for impedance matching) that forms a J-shape.

Slim-Jim version folds over longer element for greater gain.

J-pole

VHF J-pole

Slim-Jim Variant

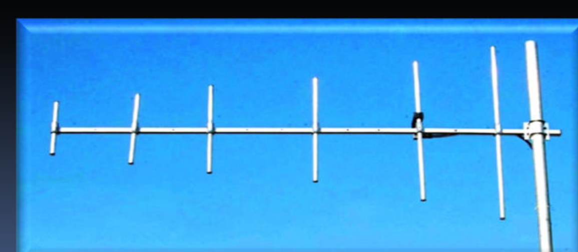
Types & Configurations

Yagi

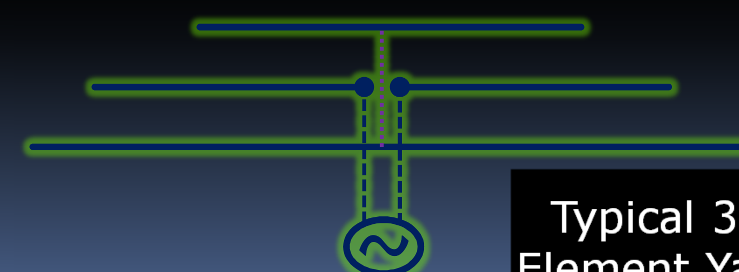
Directional (beam) half-wave center-fed antenna with two quarter-wave symmetrical elements.

Essentially a dipole with extra elements to provide directivity. Officially termed Yagi-Uda (inventors).

More commonly oriented horizontally but may be vertical for local VHF/UHF use.



6-Element Vertical Yagi



Typical 3-Element Yagi

Types & Configurations

Loops

Loops are generally grouped into two classes.

Types & Configurations

Small Loop

The **small** (AKA magnetic) **loop** is a fractional wavelength antenna with poor efficiency.

This magnetic loop has superior directional qualities and is often used in radio direction finding. Small loops also have excellent electrical noise immunity.

Matching requires fine tuning with a large variable capacitor. For this reason it is not often a ham's primary HF antenna. However, it is well-suited for low-power (QRP) portable use.

Types & Configurations

Large Loop

The **large** (AKA resonant) **loop** is simply a single full wavelength element, λ in circumference.

The loop shape is generally round but it does not have to be circular. It can be oval, hexagonal, square or even triangular. Acute angles should be avoided.

Types & Configurations

Large Loop

Due to the long lengths required for full-wave antennas, resonant loops need a lot of space.

For the 80m band, the loop would be around 270ft long. On 40m the circumference would be 140ft. On 20m you need a 70ft loop.

Although multiple turns may be used to reduce the diameter, performance improves with greater loop area. Lower-frequency HF band loops are often relatively low to the ground and horizontally oriented.

Types & Configurations

Quads & Deltas

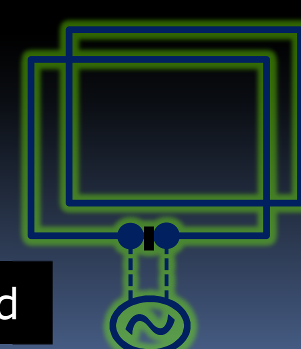
Directional (beam) antennas derived from the loop.

Usually two-element antennas with parasitic reflector slightly longer than λ.

Gain comparable to a 3-element Yagi.

Polarization depends on orientation of feedpoint.

Quad



Delta

Types & Configurations

VHF/UHF Mobile

Vertical monopole with the vehicle body/chassis acting as the ground plane (counterpoise).

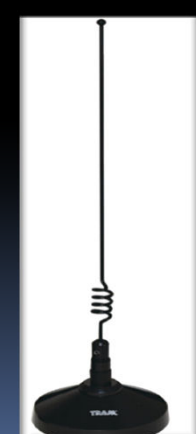
Nominally λ/4 whip for general omni-directional radiation pattern.

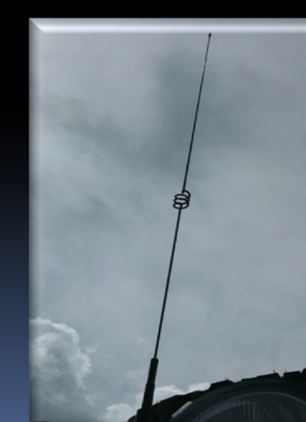
5/8-wave mobile antennas are more popular because they have radiation lobes closer to horizontal with relative gain over 1/4-wave.

Types & Configurations

VHF/UHF Mobile

With the 5/8-wave whip an inductor (loading coil) is added for impedance matching and is usually located in the middle but sometimes at the base.





Types & Configurations

VHF/UHF Mobile

Most VHF mobile antennas work well on UHF so are often called dual-band antennas.

This is unique to the 2m and 70cm amateur bands where the UHF band is 3x the frequency of the VHF band.

Antennas are resonant on odd multiples of the wavelength. 70cm (435MHz) is conveniently close to the third harmonic of 2m (146MHz).

Radiation patterns are a little different but a 2m antenna generally works for 70cm.

Other Types & Configurations

There are many other antennas out there with some really interesting names: Bazooka, Discone, Parabolic, Log-Periodic, Beverage, Nord, Isotropic, Helical, Cloverleaf, Bowtie, and others.

We could spend hours discussing antenna types but have presented the most common ones that an ordinary ham is likely to see or use.

Antenna Safety

RF exposure by contact means: ***Do not touch the antenna elements when transmitting***. It also means never install an antenna where people or animals might contact it.

RF exposure by radiation must also be considered. Be aware of power levels and frequencies where this becomes a safety concern. Understand Maximum Permissible Exposure (MPE) and the FCC regulations associated with it.

THANK YOU!