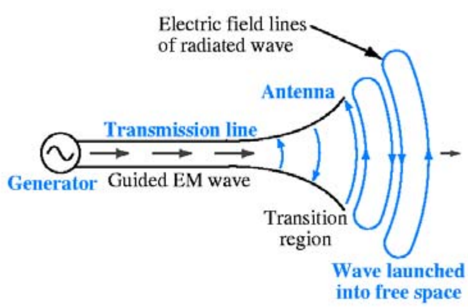
EE302 Lesson 13: Antenna Fundamentals

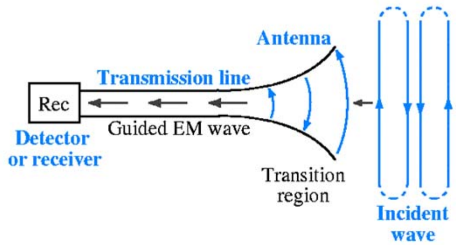
Antennas

- An **antenna** is a device that provides a transition between guided electromagnetic waves in wires and electromagnetic waves in free space.



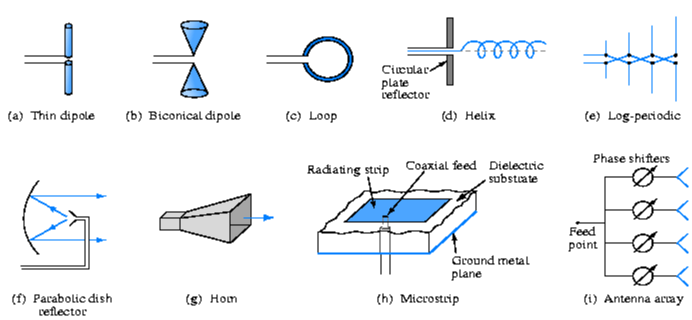
Reciprocity

- Antennas can usually handle this transition in both directions (transmitting and receiving EM waves). This property is called **reciprocity**.



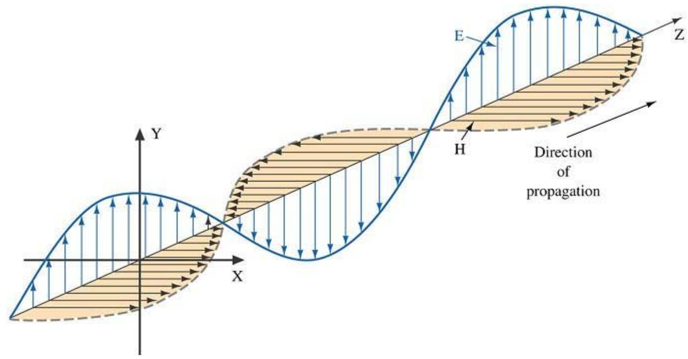
Antenna physical characteristics

- The antenna's size and shape largely determines the frequencies it can handle and how it radiates electromagnetic waves.



Antenna polarization

- The polarization of an antenna refers to the orientation of the **electric field** it produces.
- Polarization is important because the receiving antenna should have the same polarization as the transmitting antenna to maximize received power.



Antenna polarization

- Horizontal Polarization
- Vertical Polarization
- Circular Polarization
  - Electric and magnetic field rotate at the frequency of the transmitter
  - Used when the orientation of the receiving antenna is unknown
    - Will work for both vertical and horizontal antennas
  - Right Hand Circular Polarization (RHCP)
  - Left Hand Circular Polarization (LHCP)
    - Both antennas must be the same orientation (RHCP or LHCP)

Wavelength (λ)

- You may recall from physics that wavelength (λ) and frequency (f) of an electromagnetic wave in free space are related by the speed of light (c)

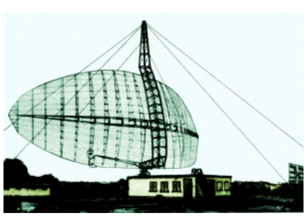
$$c = f\lambda \quad \text{or} \quad \lambda = \frac{c}{f}$$

- Therefore, if a radio station is broadcasting at a frequency of 100 MHz, the wavelength of its signal is given

$$\lambda = \frac{c}{f} = \frac{3.0 \times 10^8 \text{ m/s}}{100 \times 10^6 \text{ cycle/s}} = 3 \text{ m}$$

Wavelength and antennas

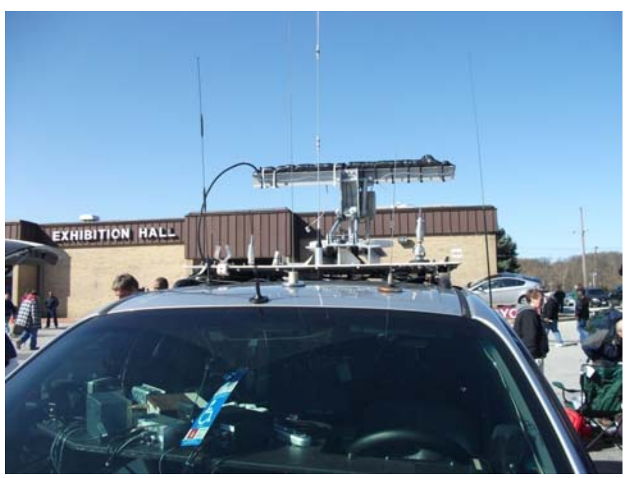
- The dimensions of an antenna are usually expressed in terms of **wavelength** (λ).
- Low frequencies imply long wavelengths, hence low frequency antennas are very large.
- High frequencies imply short wavelengths, hence high frequency antennas are usually small.



ANTENNAS

As much an art as it is a science.

Everyone's Dream Car



What to look for in Antennas

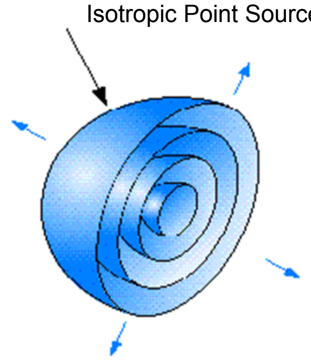
- Freq/Wavelength
- Beam Pattern
- Bandwidth
- Gain

Basic Antenna

- An antenna can be a length of wire, a metal rod, or a piece of metal tubing.
- Antennas radiate most effectively when their length is directly related to the wavelength of the transmitted signal.
- Most antennas have a length that is some fraction of a wavelength.
- One-half and one-quarter wavelengths are most common.

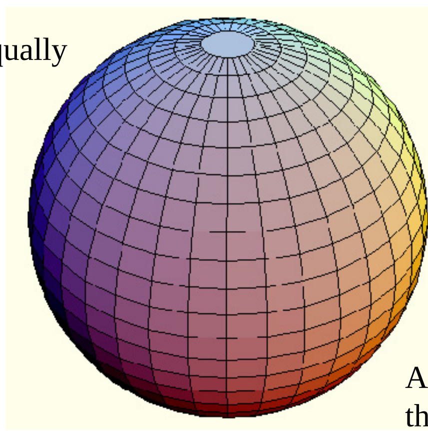
Basic Antenna

- Let's start by looking at the radiation pattern of an **isotropic point source**.
- Power from an isotropic point source is equally distributed in all directions
- It is completely **unfocused**.



Radiation Pattern for Isotropic Point Source

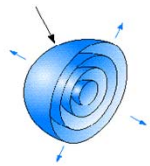
Antenna radiates equally in all directions



Antenna only exists theoretically

Antenna gain (G)

- Because an antenna is a passive device, the power radiated can not be greater than the input power.
- The ability of an antenna to focus electro-magnetic energy is defined by its **gain**.
- Antenna gain is expressed as a ratio of the effective radiated output power (P_{out}) to the input power (P_{in})
- The **gain** of an antenna is a measure of power transmitted **relative** to that transmitted by an isotropic source.



- Antenna gain relative to an isotropic source is expressed in decibels as **dBi**.

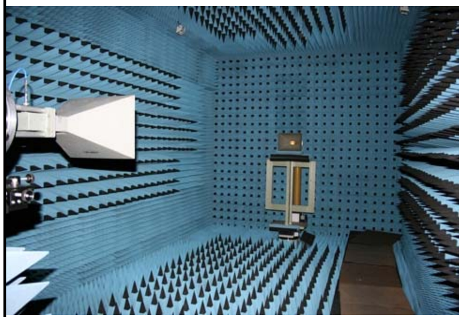
Effective Radiated Power

- The **effective radiated power** (ERP or EIRP) is the gain of an antenna (with respect to an isotropic radiator) multiplied by its input power.

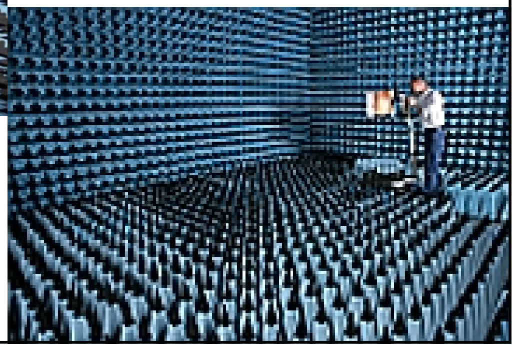
$$\text{ERP} = \text{input power} \times \text{ antenna gain}$$

- For example, a highly directional antenna with a gain of 7 has an input power of 1-kW. Its ERP is therefore 7 kW.

Measuring Antenna Radiation Patterns



Antenna is rotated in an Anechoic Chamber to measure radiation pattern



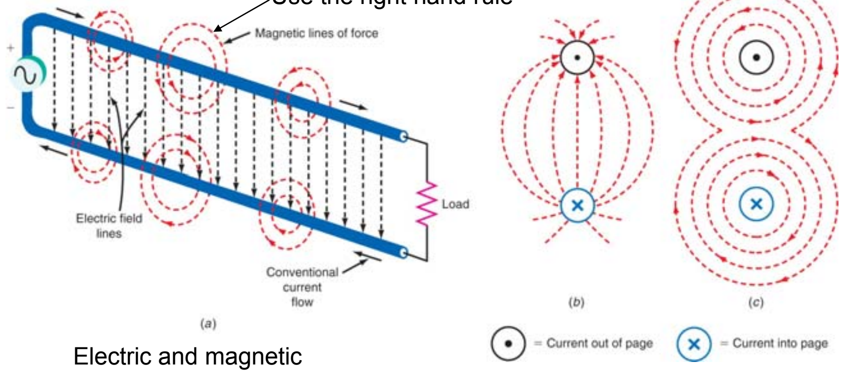
Radiation pattern of any antenna
Is the shape of the
Electro-magnetic field radiated or
Received by the antenna

Dipole Antenna

- One of the most widely used antenna types is the half-wave dipole.
- The half-wave dipole, also called a doublet, is formally known as the Hertz antenna.
- A dipole antenna is two pieces of wire, rod, or tubing that are one-quarter wavelength long at the operating resonant frequency.

Electric and Magnetic Fields around a Transmission Line

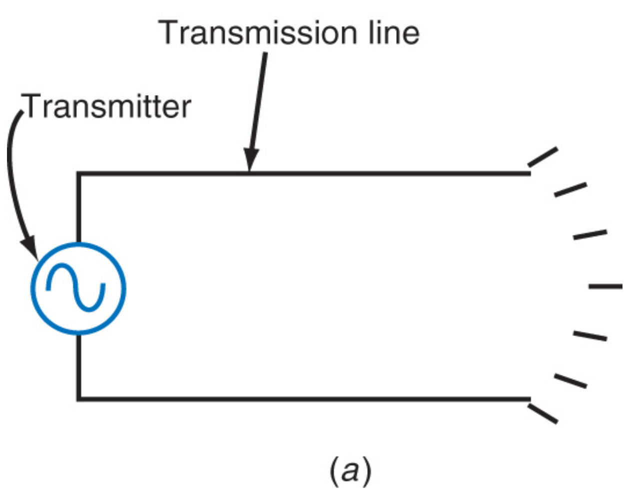
Use the right hand rule



Electric and magnetic field lines around a conductor

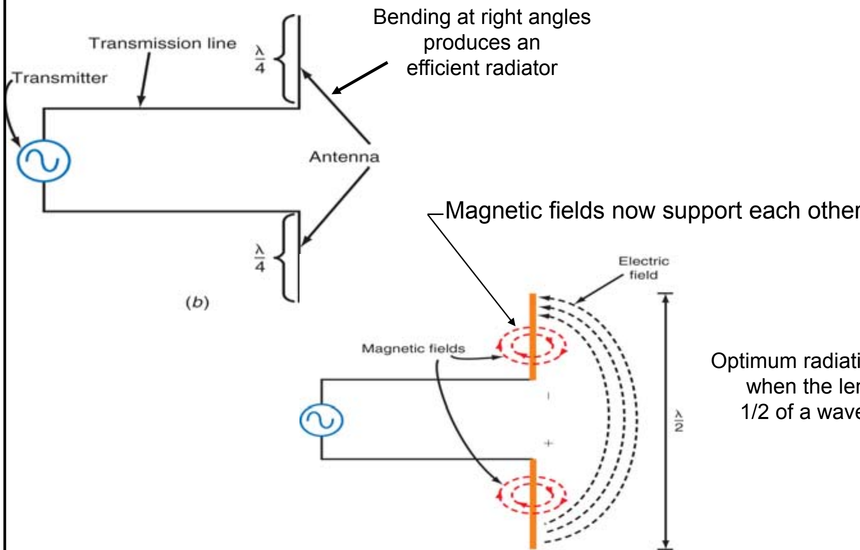
Between the conductor, magnetic field lines add.
Beyond the conductor, the field lines cancel each other

Converting a Transmission Line into an Antenna



Inefficient radiation

Converting a Transmission Line into an Antenna



Optimum radiation occurs when the length is 1/2 of a wavelength

The Dipole Antenna

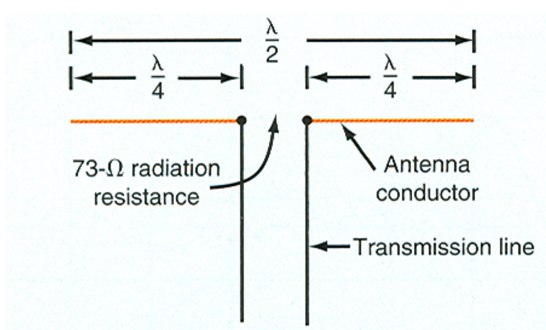
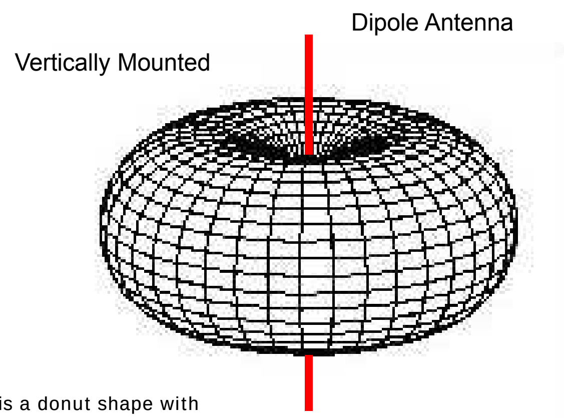


Fig. 14-10

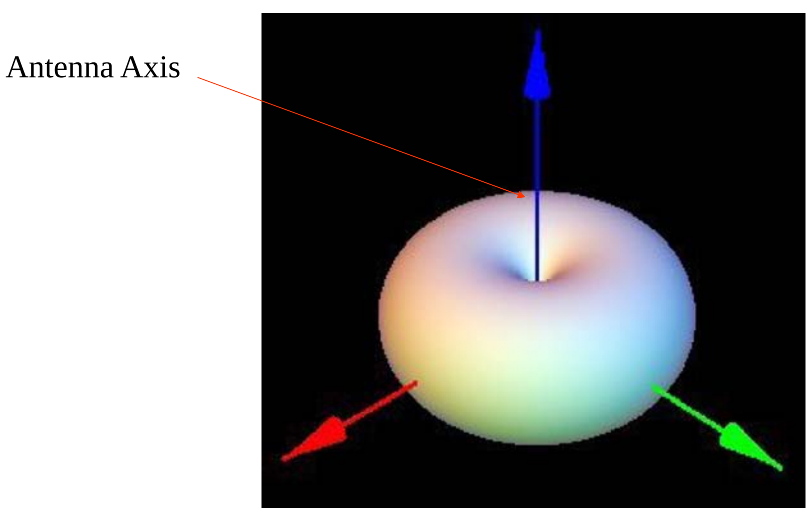
Three-dimensional radiation pattern for a dipole.



This pattern is a donut shape with
the antenna passing thru the center.

There is no radiation from the end of the antenna.

Dipole Radiation Pattern



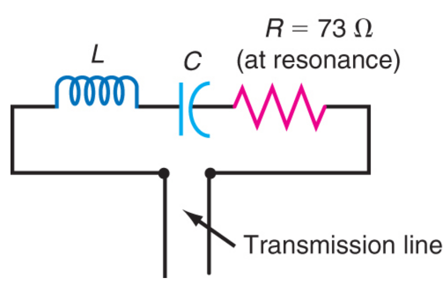
Antenna Losses

- Radiation Loss
  - Caused by radiation resistance
  - Results in radiated RF energy
- Resistive Loss
  - Results in heat due to resistance of conductor

By Definition…

- The dipole has an impedance of 73 Ω at its center, which is the radiation resistance.
  - An antenna ideally appears as a resistor to the transmitter. This "radiation resistance" does not dissipate power in the form of heat; the power is dissipated as radiated electromagnetic energy.
- An antenna is a frequency-sensitive device, and a particular antenna can be operated over a range of frequencies (BW).
- At the resonant frequency, the antenna appears to be a pure resistance of 73 Ω

Equivalent circuit of a dipole



Antenna gain (G)

- A dipole antenna gain is 1.64

$$10\log_{10}(1.64) = 2.15 \text{ dBi}$$

- A half-wave dipole antenna has a power gain of 1.64 (or 2.15 dB) over an isotropic source.
- Antenna gain relative to a dipole antenna can be expressed in decibels as **dBd**.
- Thus, an antenna with a gain of 3 dBd would have a gain of 5.15 dBi (3 dB + 2.15 dB)

Actual Antenna Lengths

- A dipole resonates best when it is approx. 95% of the actual "half-wavelength length"
- Shortcut:

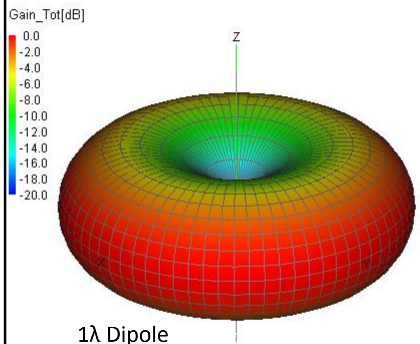
$$L_{feet} = 468/f_{MHz} \text{ (This is in Feet)}$$

- 1 ft = .3048 m
- Dipole hung vertically is closest to an isotropic radiator
- Bottom of dipole antenna should be at least ½ a wavelength off the ground
  - May make total structure height unreasonable

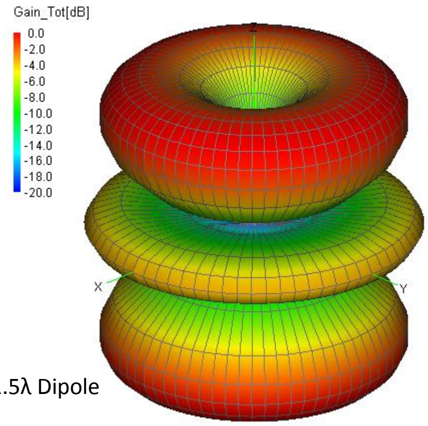
Example

- How long would a dipole antenna be for AM 1100?
  - Calculate using wavelength and shortcut

Effect of Antenna Length on Radiation Pattern



1λ Dipole



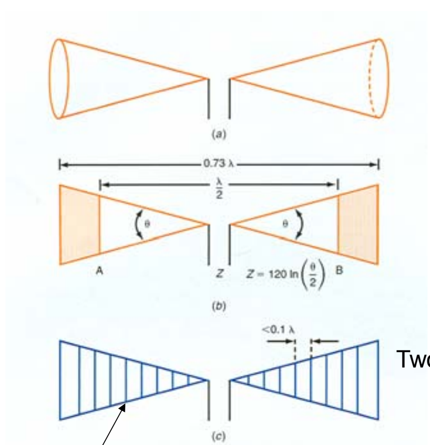
1.5λ Dipole

We will look at this more later.

Conical Antenna

- A common way to increase bandwidth is to use a version of the dipole antenna known as the conical antenna.
- The center radiation resistance of a conical antenna is much higher than the 73 Ω usually found when straight-wire or tubing conductors are used.
- The primary advantage of conical antennas is their tremendous bandwidth.
- They can maintain a constant impedance and gain over a 4:1 frequency range.

Conical Antenna and Variation



Conical
(expensive)

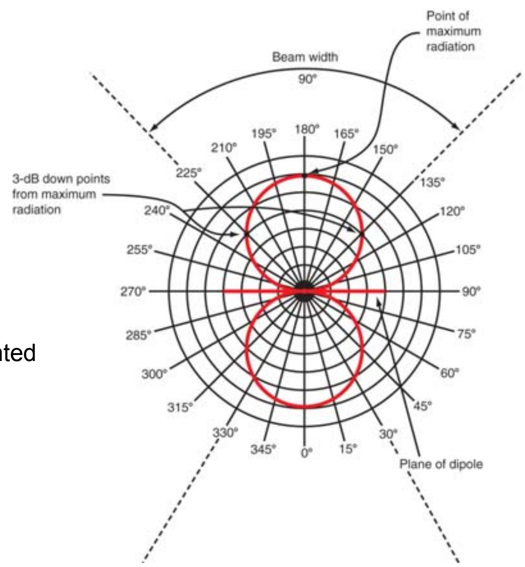
Bow-tie
(flat)

Two-dimensional cone,
Equally effective

grid, or flat plate

Fig. 14-14

Antenna Beam Width



Dipole is
horizontally oriented

Marconi or Ground-Plane Vertical Antenna

- The quarter-wavelength vertical antenna, also called a Marconi antenna is widely used.
- It is similar in operation to a vertically mounted dipole antenna.
- The Marconi antenna is half the length of a dipole antenna.

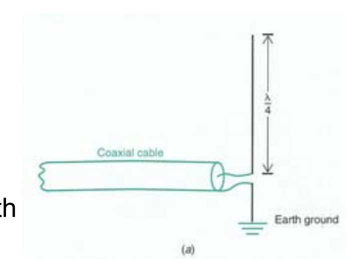
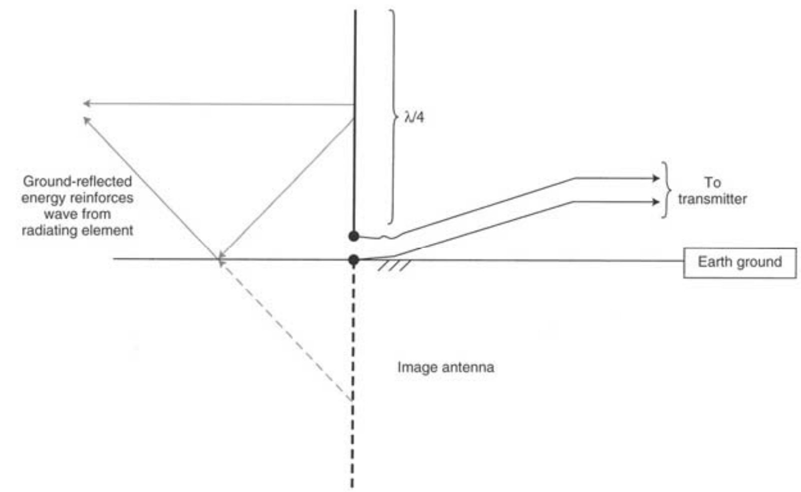


Fig. 14-20a

- The earth acts as a type of electrical "mirror," effectively providing the other quarter wavelength making it equivalent to a vertical dipole.

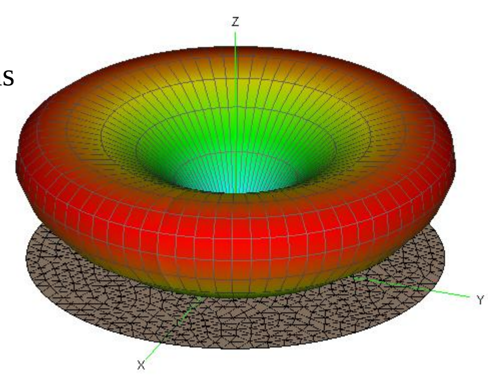
Figure 12–6 A Marconi antenna



Tom Wheeler
Electronic Communications for Technicians, 2e

Monopole Radiation Pattern

Ground plane reflections lift pattern up



Monopole showing effects of ground plane

Advantages

- Half the length of a dipole
- Can be located at earth level without degrading performance
- Has omni-directional radiation pattern similar to dipole

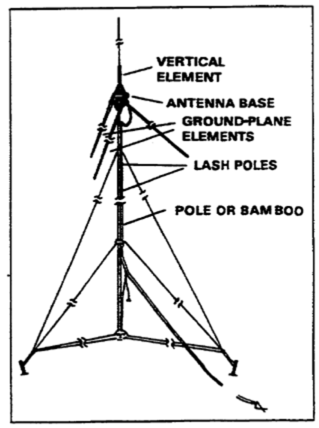
Disadvantages

- Gain is slightly lower than a dipole (about 1 dB less), but for our purposes we will consider them the same
- Antenna is extremely dependent on conductivity of the earth
- Using a counterpoise will improve conductivity

Counterpoise

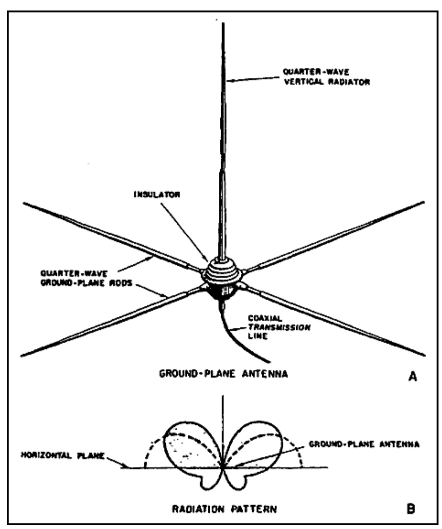
- Sometimes connecting a monopole antenna to the ground is not feasible. Create a ground.
  - Antennas mounted on buildings or towers
  - Soil is highly resistive (dry)

Ground material	Relative conductivity
Sea water....................	4,500
Flat, rich soil..............	15
Average flat soil............	7
Fresh water lakes............	6
Rocky hills..................	2
Dry, sandy, flat soil........	2
City residential area........	2
City industrial area.........	1



Counterpoise

- A **counterpoise** is a flat structure of wire or screen that forms an artificial reflecting surface for the monopole antenna if the actual earth cannot be used.



Counterpoise

- Counterpoise requirements
  - Must be at least equal to or larger than the antenna.
  - Should extend in equal distances from the antenna.
  - Must be insulated from the ground.
- The performance of a quarter-wave antenna (either well-grounded or using a counterpoise) is essentially the same as a half-wave dipole antenna.

Counterpoise

Adjusting Antenna Impedance

"Drooping" radials is one way to adjust antenna impedance