ECE 3317
Applied Electromagnetic Waves

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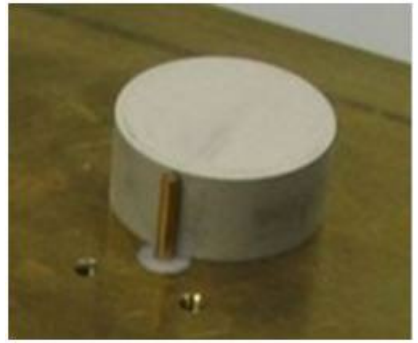
Fall 2024

Notes 20

Introduction to Antennas



Introduction to Antennas

An antenna is a device that is used to transmit and/or receive an electromagnetic wave.

The antenna itself can always transmit or receive, but it may be used for only one of these functions in a particular application.

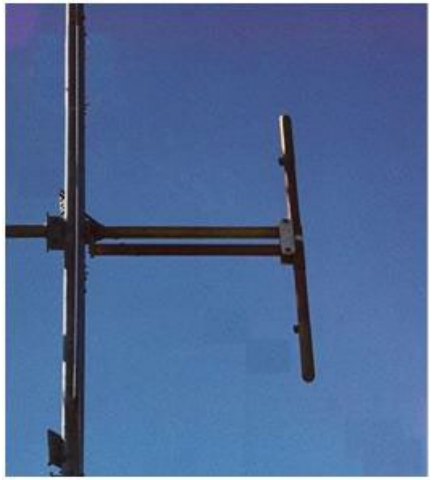
Examples:

- Cell-phone antenna (transmit and receive)
- TV antenna in your home (receive only)
- Wireless LAN antenna (transmit and receive)
- FM radio antenna (receive only)
- Satellite dish antenna (receive only)
- AM radio broadcast tower (transmit only)
- GPS position location unit (receive only)

Advantages of Antennas

Antennas are often used for a variety of reasons:

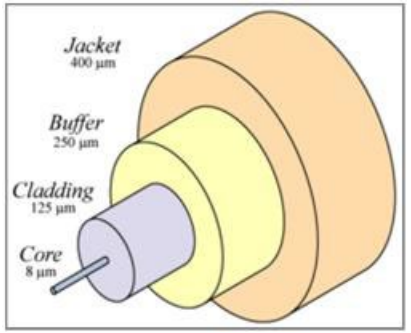
- For communication over long distances, to have lower loss.
- Where transmission lines or fiber optic cables are impractical or inconvenient.
- When it is desired to communicate with many users at once.



Antenna

Coax

Twisted pair (CAT 5 cable)



Fiber optic cable

Main Properties of Antennas

Main properties of antennas:

- Radiation pattern
- Beamwidth and directivity (how directional the beam is)
- Sidelobe level
- Efficiency (power radiated relative to total input power)
- Polarization (linear, CP)
- Input Impedance
- Bandwidth (the useable frequency range)

Types of Antennas

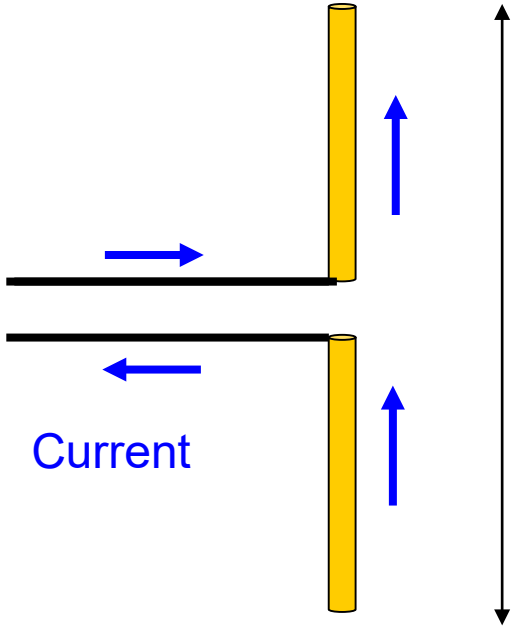
Reflector (dish) antenna

Ideally, the dish is parabolic in shape.

- Very high bandwidth
- High directivity (directivity is determined by the size / wavelength)
- Linear or CP polarization (depending on how it is fed)
- Works by focusing the incoming wave to a collection (feed) point

Types of Antennas (cont.)

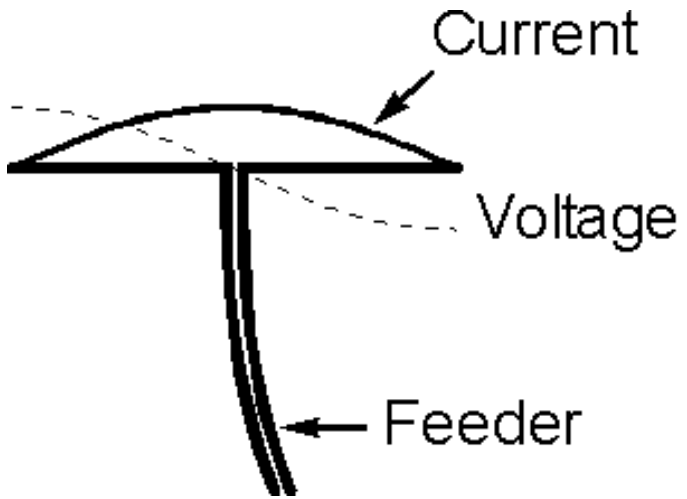
Dipole Wire Antenna



$$L \approx \lambda_0 / 2$$

(resonant)

$$\lambda_0 = c / f$$

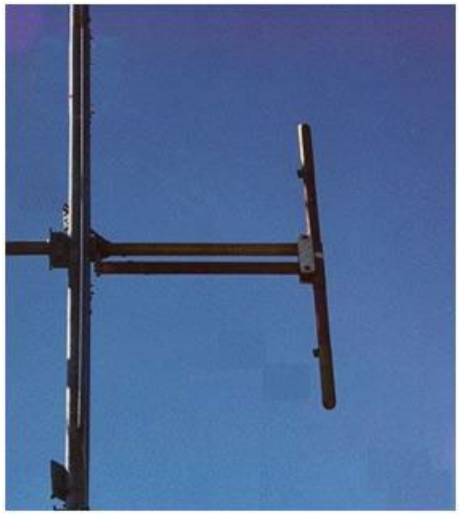


$$Z_{\text{in}} = 73 \ [\Omega]$$

- Very simple
- Moderate bandwidth
- Low directivity
- Omnidirectional in azimuth
- Most commonly fed by a “twin-lead” transmission line
- Linear polarization (E_θ, assuming wire is along z axis)
- The antenna is resonant when the length is about one-half free-space wavelength

Types of Antennas (cont.)

Dipole Wire Antenna (cont.)



"Bow-tie" variation (for higher bandwidth)

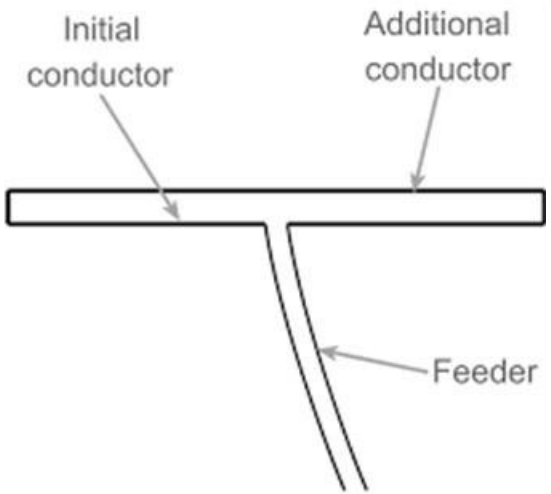
"Rabbit ears"

Types of Antennas (cont.)

Folded Dipole Antenna

The folded dipole is a variation of the dipole antenna. It has an input impedance that is 4 times higher than that of the regular dipole antenna.

At resonance : $Z_{in} = 292\ [\Omega]$



Compatible with TV twin lead

$Z_0 = 300\ [\Omega]$

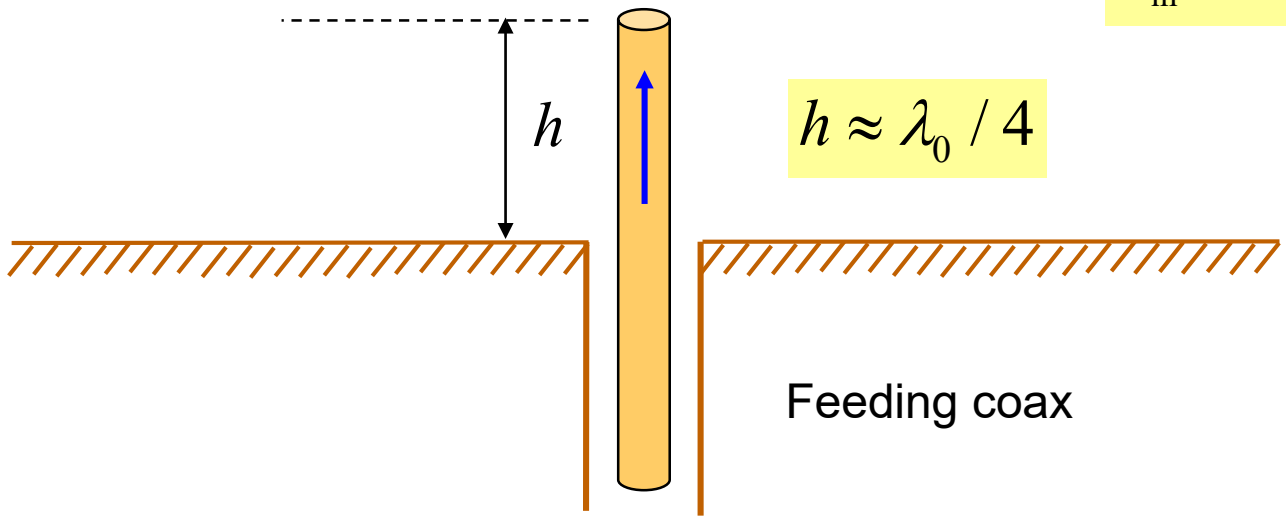
Matched system:

$Z_{in} = Z_0$

Types of Antennas (cont.)

Monopole Wire Antenna

$$Z_{in} = 36.5 \ [\Omega]$$



$$h \approx \lambda_0 / 4$$

This is a variation of the dipole, using a ground plane and feeding with a coax.

- Similar properties as the dipole
- Mainly used when the antenna is mounted on a conducing object or platform
- Usually fed with a coaxial cable feed

Types of Antennas (cont.)

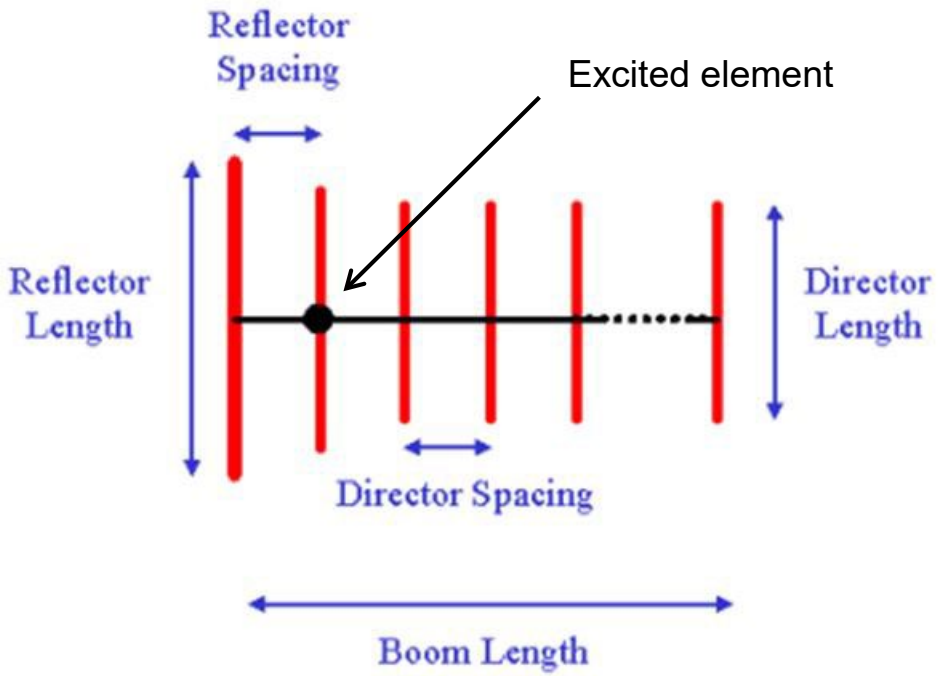
Monopole Wire Antenna (cont.)

$$h \approx \lambda_0 / 4$$

$$\lambda_0 = c / f$$

Types of Antennas (cont.)

Yagi Antenna



Prof. Yagi

This is a variation of the dipole, using multiple passive wires (with one “reflector” and one or more “directors” (acting as a lens).

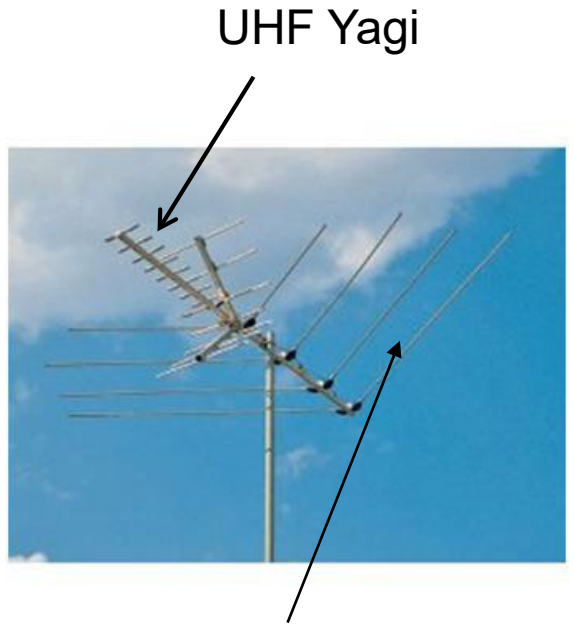
- Low bandwidth
- Moderate directivity
- Commonly used as a UHF TV antenna

Types of Antennas (cont.)

Yagi Antenna (cont.)

UHF Yagi

UHF Yagi



VHF Log-periodic

Types of Antennas (cont.)

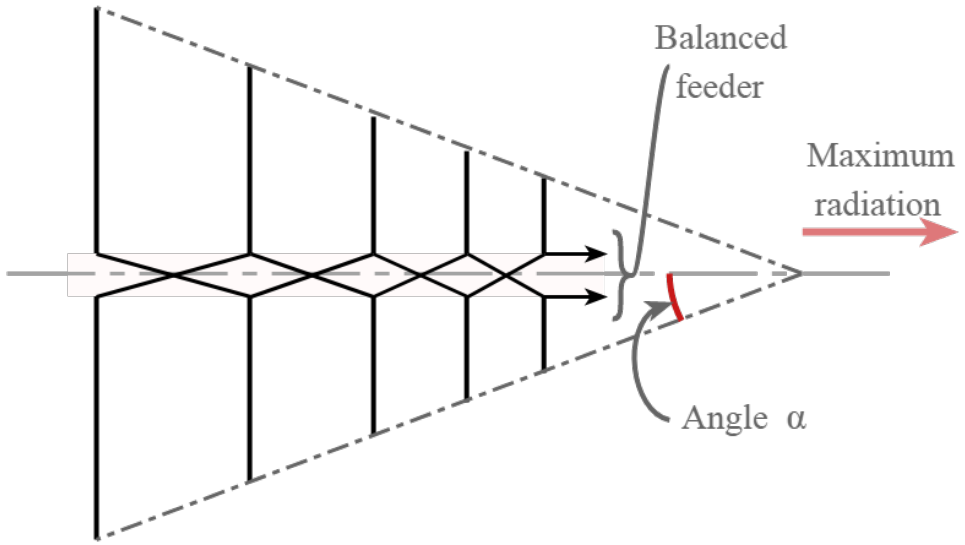
Yagi of CP Elements

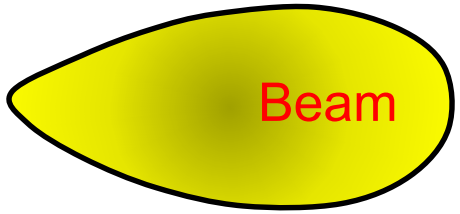
Two perpendicular dipoles fed 90^{o} out of phase.

- Used for circular polarization

Types of Antennas (cont.)

Log-Periodic Antenna





This consists of multiple dipole antennas of varying lengths, connected together.

- High bandwidth
- Moderate directivity
- Commonly used as a VHF TV antenna

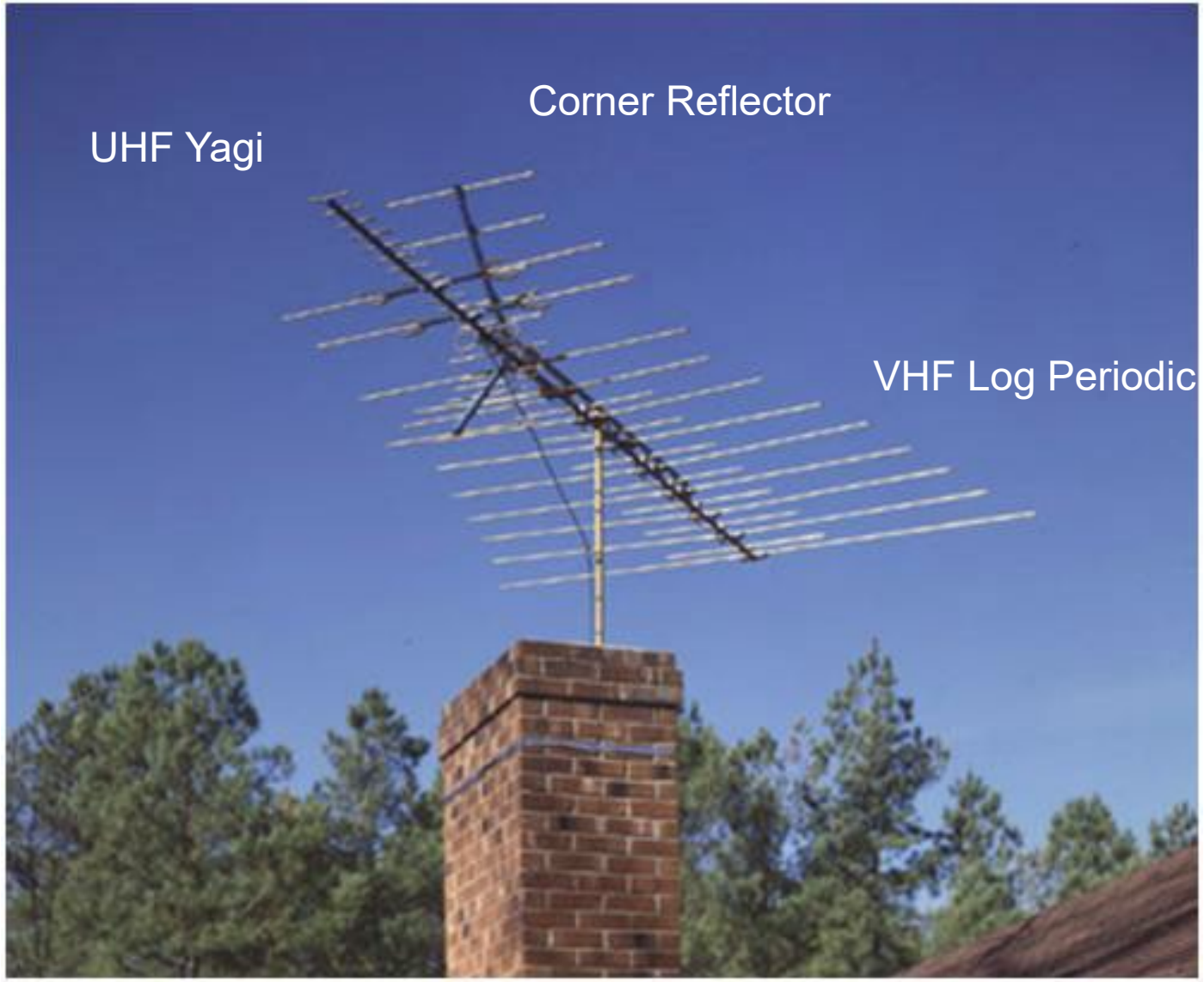
The input impedance repeats periodically when plotted vs. the log of the frequency.

Types of Antennas (cont.)

Log Periodic Antenna (cont.)

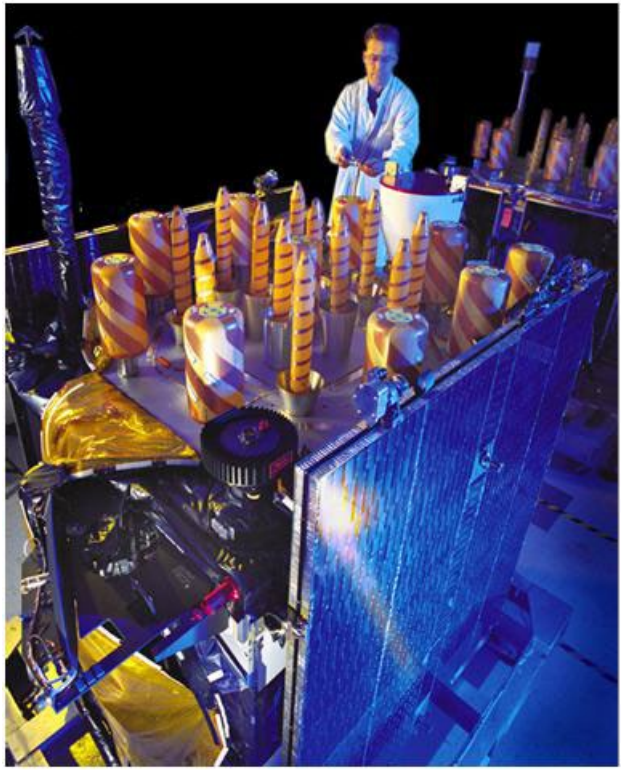
Types of Antennas (cont.)

Typical Outdoor TV Antenna



Types of Antennas (cont.)

CP Helical Antenna

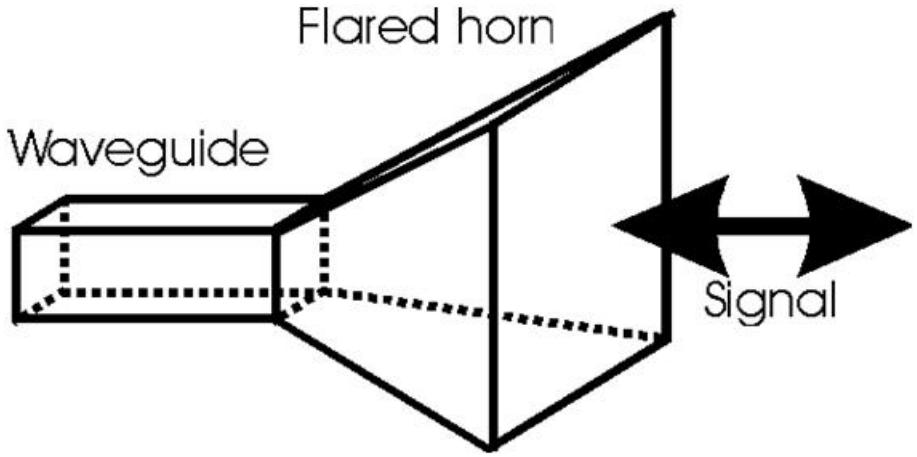


GPS satellite

- Helical antennas are often used for circular polarization.

Types of Antennas (cont.)

Horn Antenna

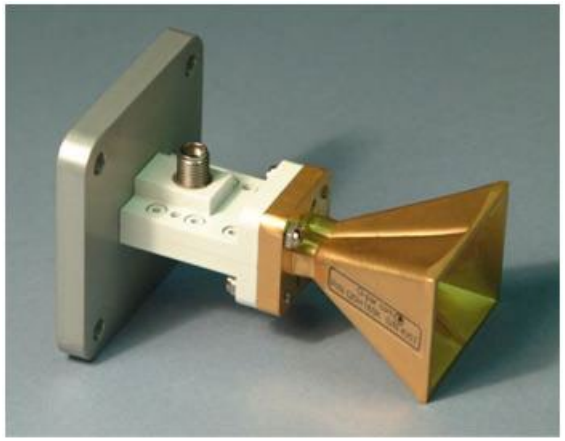


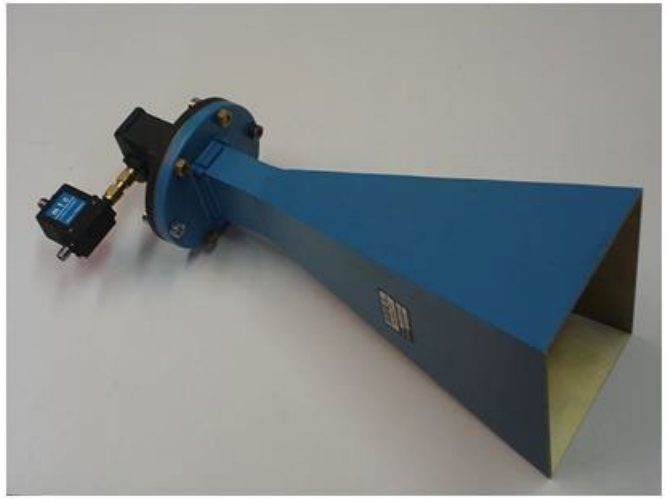
It acts like a “loudspeaker” for electromagnetic waves.

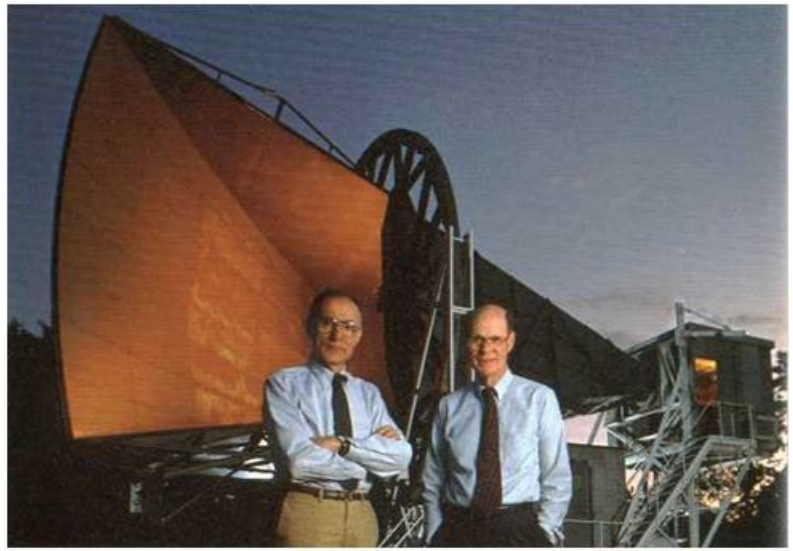
- High bandwidth
- Moderate to high directivity (directivity is determined by the size / wavelength)
- Commonly used at microwave frequencies and above
- Often used as a feed for a reflector antenna

Types of Antennas (cont.)

Horn Antenna (cont.)



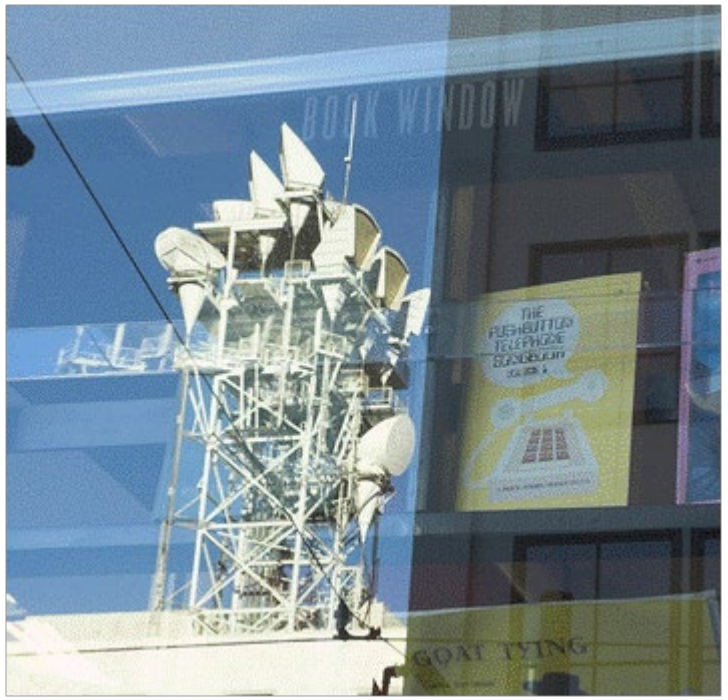




Arno A. Penzias and Robert W. Wilson used a large horn antenna to detect microwave signals from the "big bang" (Nobel Prize, 1978).

Types of Antennas (cont.)

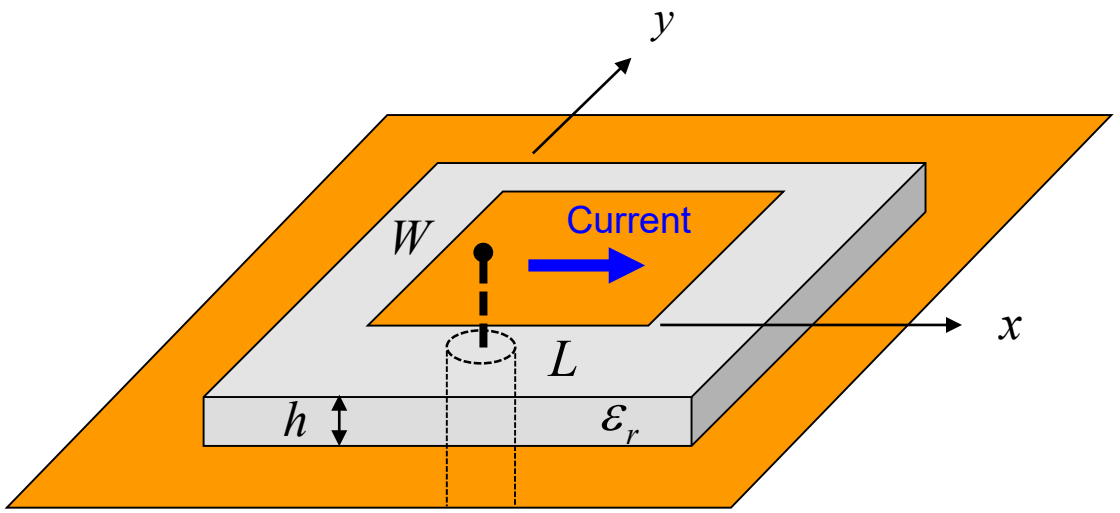
Horn Antenna (cont.)



This is a variation called the “hoghorn” antenna (a combination of horn+reflector).

Types of Antennas (cont.)

Microstrip (Patch) Antenna



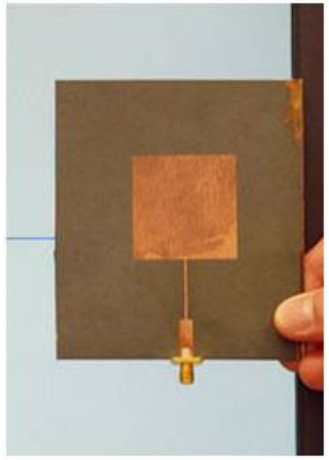
$$L \approx \lambda_d / 2 = \frac{1}{2}\frac{\lambda_0}{\sqrt{\varepsilon_r}}$$

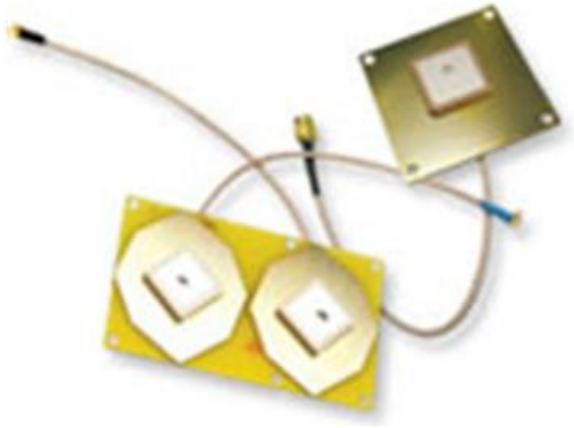
It consists of a printed “patch” of metal on top of a grounded dielectric substrate.

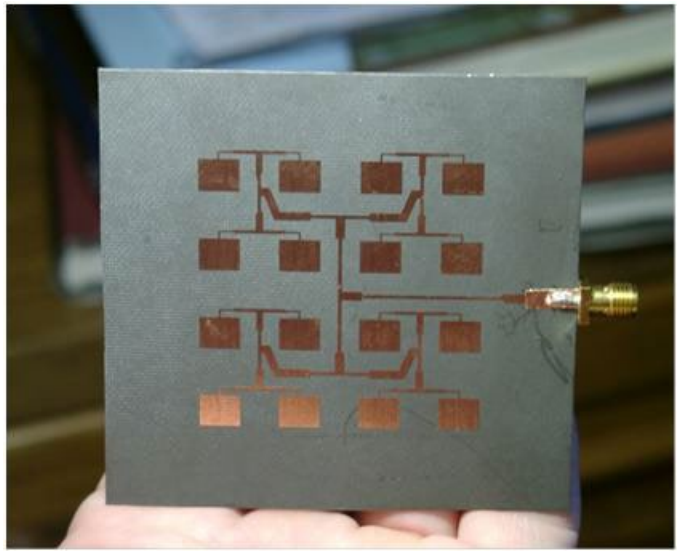
- Acts as a *radiating resonant cavity*
- Easily fed by microstrip line or coaxial cable
- Low to moderate bandwidth (usually a few percent)
- Low directivity (unless used in an array)
- Low-profile (h can be made very small, but at the expense of bandwidth)
- Can be easily made by etching or machining
- Can be made conformable (flexible and mounted on a curved surface)
- Commonly used at microwave frequencies and above

Types of Antennas (cont.)

Microstrip (Patch) Antenna (cont.)

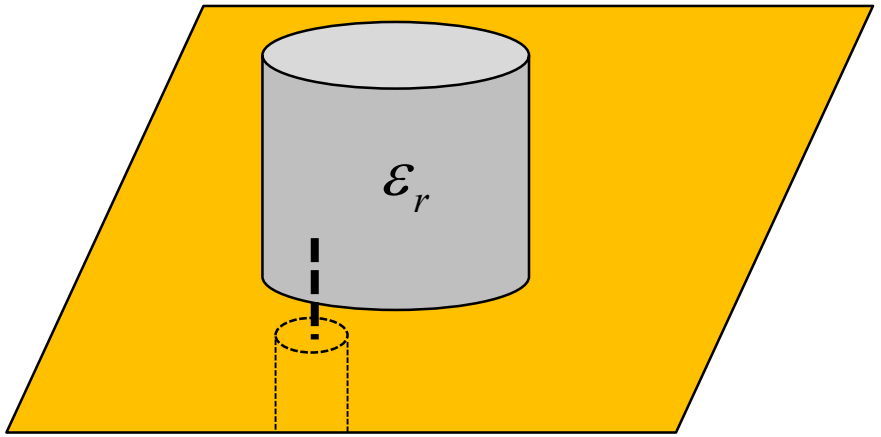






Types of Antennas (cont.)

Dielectric Resonator Antenna (DRA)



Cylindrical DRA

The dielectric resonator antenna was invented by our very own Prof. Long in the Dept. of ECE!

It consists of a dielectric material (such as ceramic) on top of a grounded dielectric substrate.

- Acts as a *resonating dielectric object*
- Moderate to large bandwidth
- Low directivity (unless used in an array)
- Commonly used at microwave frequencies and above
- Usually more difficult to fabricate than a patch antenna

Types of Antennas (cont.)

Dielectric Resonator Antenna (cont.)