# Miscellaneous Topics

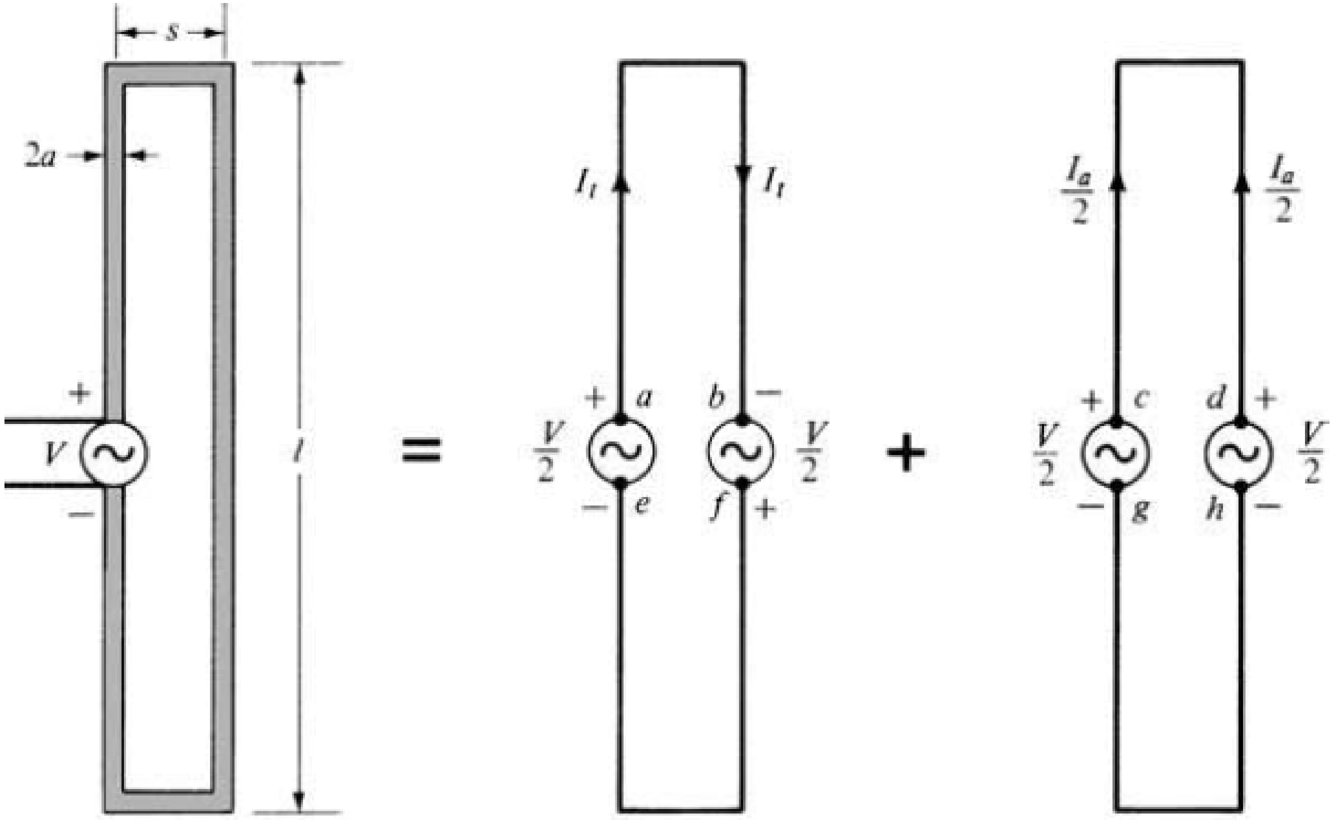
- **Folded dipole antenna**
- **Special antennas**
  - Yagi-Uda antenna
  - Broadband antenna
  - Log-periodic antenna
- **Other antennas**
- **Feed Lines**

# Folded Dipole

- Half-wavelength dipoles have impedance 73+j42.5 Ω
- Typical transmission line : 50 or 75 Ω
- Twin-lead transmission line has impedance 300 Ω
- Folded dipole is one way to match 300 Ω




# Folded Dipole (2)




(a) Folded dipole (b) Transmission-line mode (c) Antenna mode

# Folded Dipole (3)

- **Transmission line mode:**

$$Z_t = Z_0\left[\frac{Z_L + jZ_0\tan(kl')}{Z_0 + jZ_L\tan(kl')}\right]_{l'=l/2, Z_L=0} = jZ_0\tan\left(\frac{kl}{2}\right)$$

$$Z_0 = \frac{\eta}{\pi}\cosh^{-1}\left(\frac{s/2}{a}\right) = \frac{\eta}{\pi}\ln\left[\frac{s/2+\sqrt{(s/2)^2-a^2}}{a}\right]$$

$$\xrightarrow{s/2>>a} \cong \frac{\eta}{\pi}\ln\left(\frac{s}{a}\right) = 0.733\eta\log_{10}\left(\frac{s}{a}\right)$$

$$I_t = \frac{V/2}{Z_t}$$

# Folded Dipole (4)

- **Antenna mode:**

$$I_a = \frac{V/2}{Z_d}$$

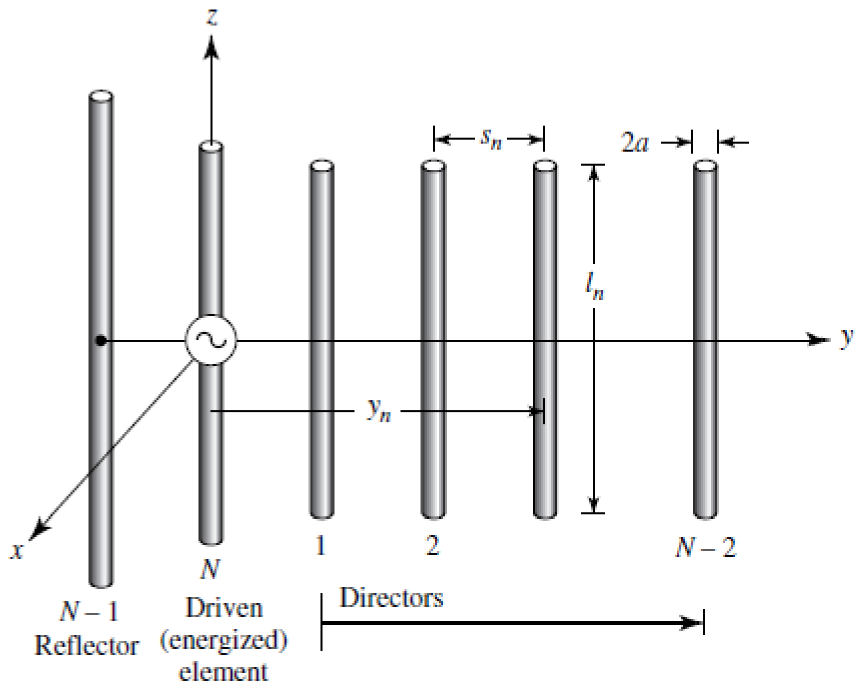
**$Z_d$ : input impedance of dipole**

$$I_{in} = I_t + \frac{I_a}{2} = \frac{V}{2Z_t} + \frac{V}{4Z_d} = \frac{V(2Z_d + Z_t)}{4Z_t Z_d}$$

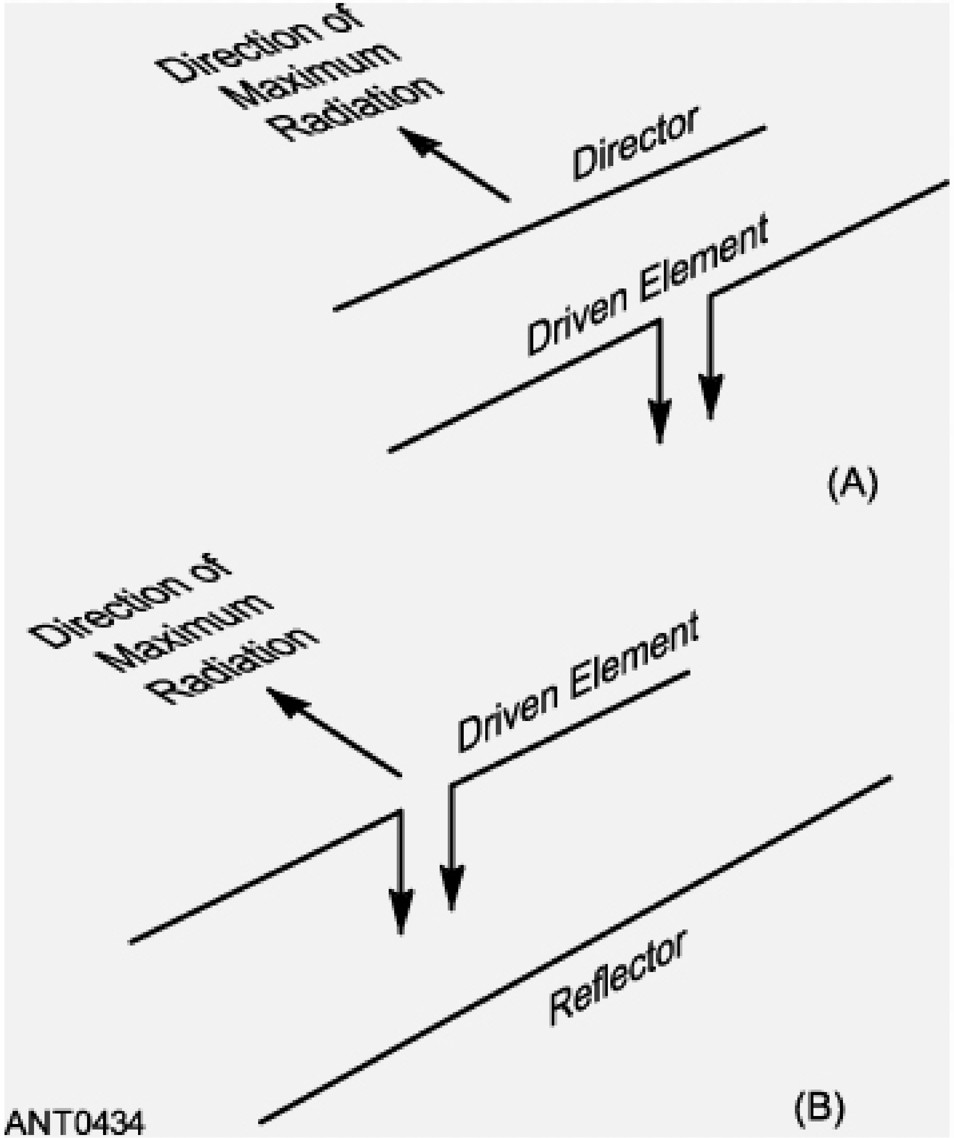
$$Z_{in} = \frac{V}{I_{in}} = \frac{4Z_t Z_d}{2Z_d + Z_t} \xrightarrow{l=\lambda/2} 4Z_d$$

# Yagi-Uda Antenna

- Yagi-Uda antennas are directional antennas with good front-to-side and front-to-back ratios to minimize interference.
- Common configuration



- **A Yagi is a parasitic array antenna made up of two or more elements. The main lobe is in the forward direction of the Yagi.**
  - The driven element is an approximately ½ wave dipole or folded dipole.
  - The reflector is a parasitic element behind the driven element (opposite the direction of the main lobe), and is a bit longer than the driven element.
  - The director is a parasitic element in front of the driven element, and is a bit shorter than the driven element.
  - A three element Yagi has a theoretical gain of 9.7 dBi and front-to-back ratio of 30 to 35 dB.


Direction of Maximum Radiation
Director
Driven Element
(A)
Direction of Maximum Radiation
Driven Element
Reflector
ANT0434
(B)

- Reflector spacing and size have

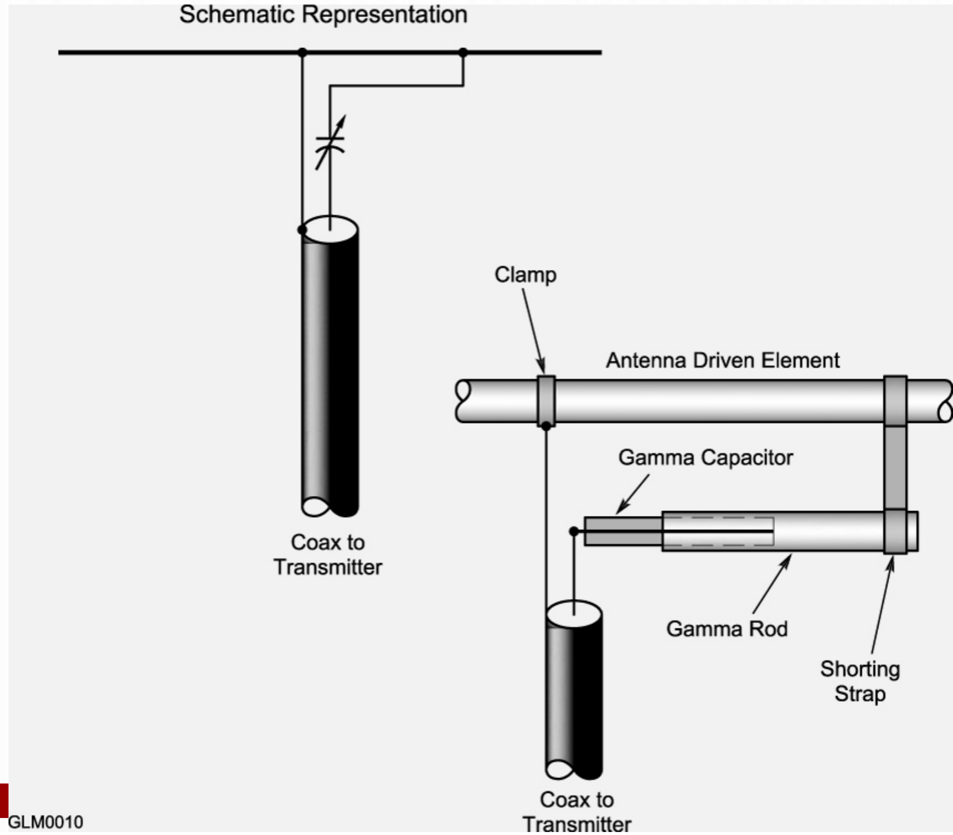
1. Negligible effects on forward gain
2. Large effects on backward gain (Front-to-back ratio) and input impedance.

- Feeder size and radius control input impedance, which is usually made real (resonant element)
- Director spacing and size have large effects on forward gain, backward gain and input impedance.

- A Yagi can have additional directors to increase gain, but the gain is limited.
- Larger diameter elements improves the bandwidth of at Yagi.  This is also true for other antennas.
- Element spacing, boom length, and the number of elements all affect the SWR and performance of a Yagi.
- Yagi antennas have a feed point impedance of around 20 to 25 ohms.

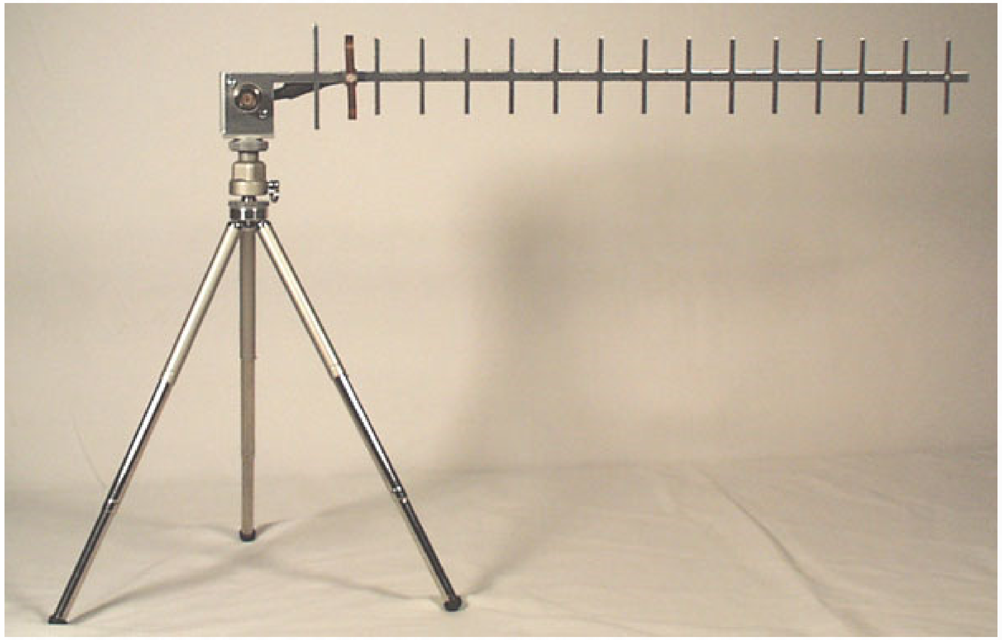
➢ Need impedance matching.

- A gamma match is used to match the Yagi's feed point impedance to 50 Ω. The driven element can be electrically connected to the boom which makes construction easier.



# 2.4 GHz Yagi with 15dBi Gain

- G ≈ 1.66 * N (not dB)
- N = number of elements
- G ≈ 1.66 *3 = 5 = 7 dB
- G ≈ 1.66 * 16 = 27 = 16 dB



# Broadband Antennas

- **Typical antennas are designed for a specific narrow band of operation**
- **Sometimes called *frequency-independent antennas*.**
- **Broadband antennas are designed to operate effectively over a wide range of frequencies**
  - Public two-way-radio VHF covers 130-174Mhz
  - Public two-way-radio UHF 406-512Mhz
  - The challenge is to create an antenna which can operate in both the VHF and UHF bands
- **Also crucial for astronomical radio observations.**

# Bandwidth

- Definition for center frequency: $f_C = \dfrac{f_U - f_L}{2}$

- Bandwidth can be expressed as a percentage of the center frequency or as a ratio
  - The percentage is commonly used for small bandwidth antennas:

$$B_R = \frac{f_U - f_L}{f_C} \times 100\%$$

  - The ratio is commonly used for large bandwidth antennas:

$$B_R = \frac{f_U}{f_L}$$

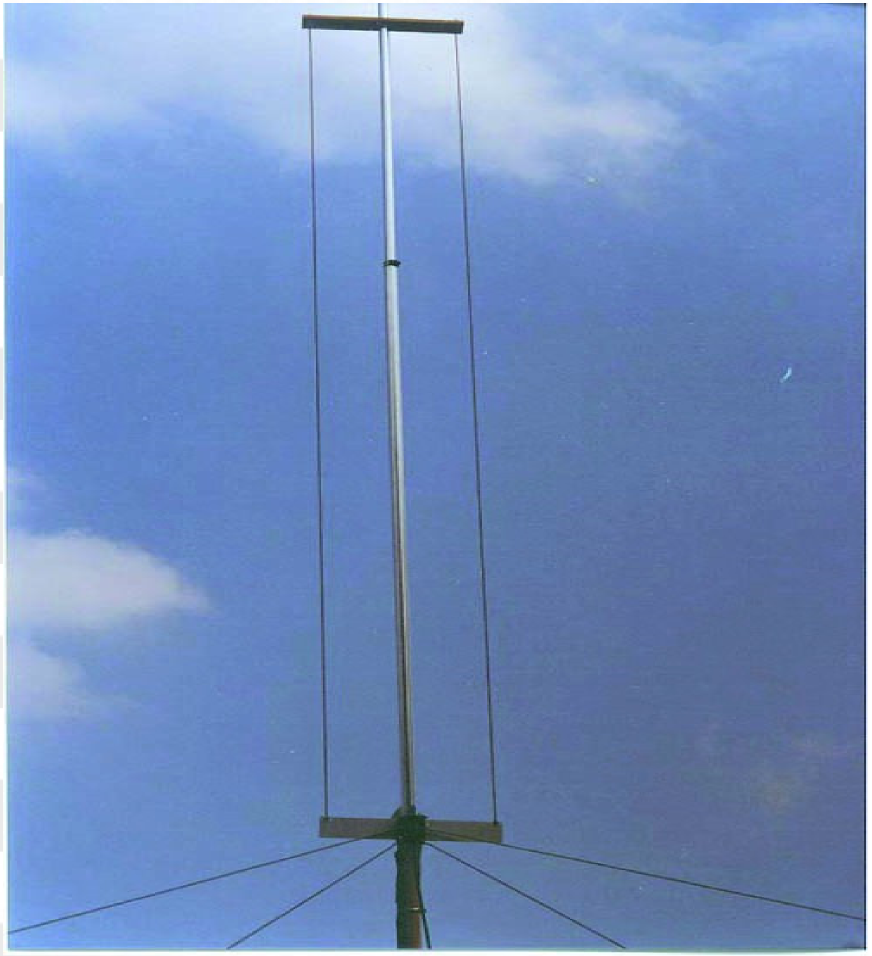
# Broad Spectrum of Types

- Log Periodic
- Helical
- Biconical
- Sleeve
- Spiral

# Biconical Antenna


- **Types of Biconical**
  - Infinite Biconical
  - Finite Biconical
  - Discone
- **http://www.ik8uif.it/biconical-10ghz.htm**

# Sleeve Antenna



- The sleeve antenna is used primarily as a receiving antenna. It is a broadband, vertically polarized, omnidirectional antenna. Its primary uses are in broadcast, ship-to-shore, and ground-to-air communications. Although originally developed for shore stations, there is a modified version for shipboard use.

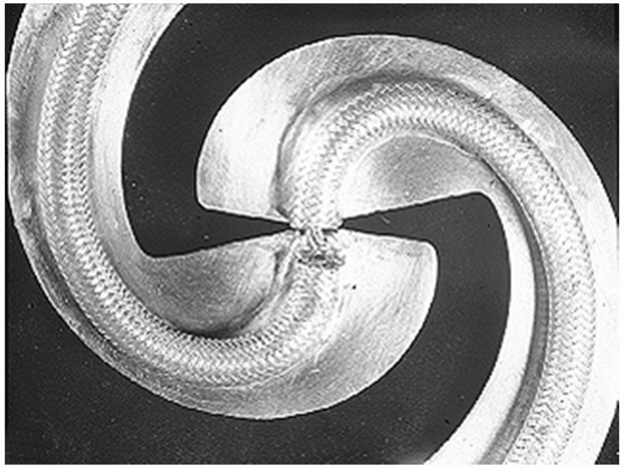
- http://www.tpub.com/inch/32.htm
- http://www.emartin.it/it9vky/Risorse/opensleeve.htm

# Spiral Antenna

http://www.emi.dtu.dk/research/afg/research/gpr/spiral_antenna.html

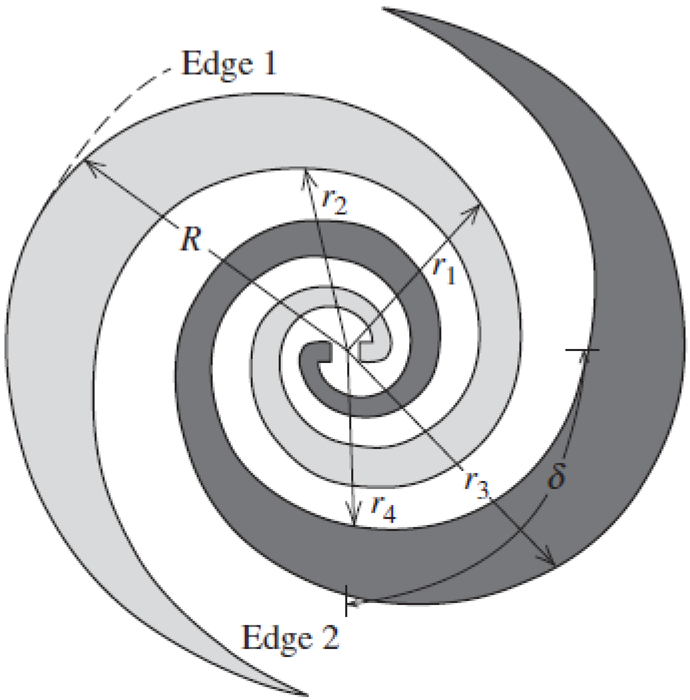
http://www.naapo.org/Argus/docs/990702.htm

- **The spiral antenna is used primarily as a receiving antenna**
- **Vertically polarized**
- **Self-complementary structure**
- **Frequency Independent**
  - Designed to minimize finite lengths and maximize angular dependence

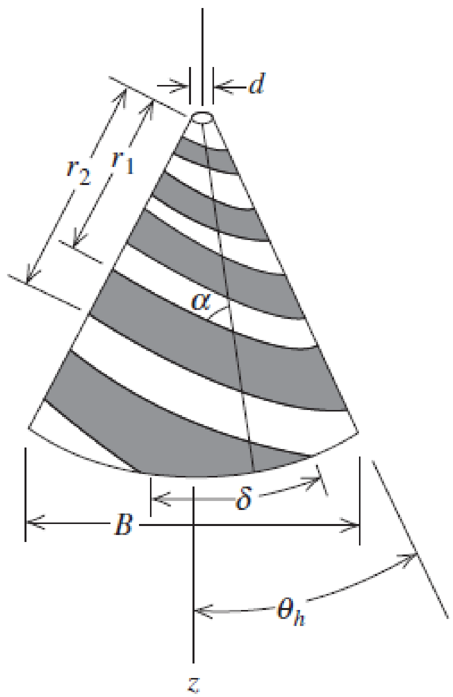


http://www.ece.uiuc.edu/pubs/antenna/slide03.html

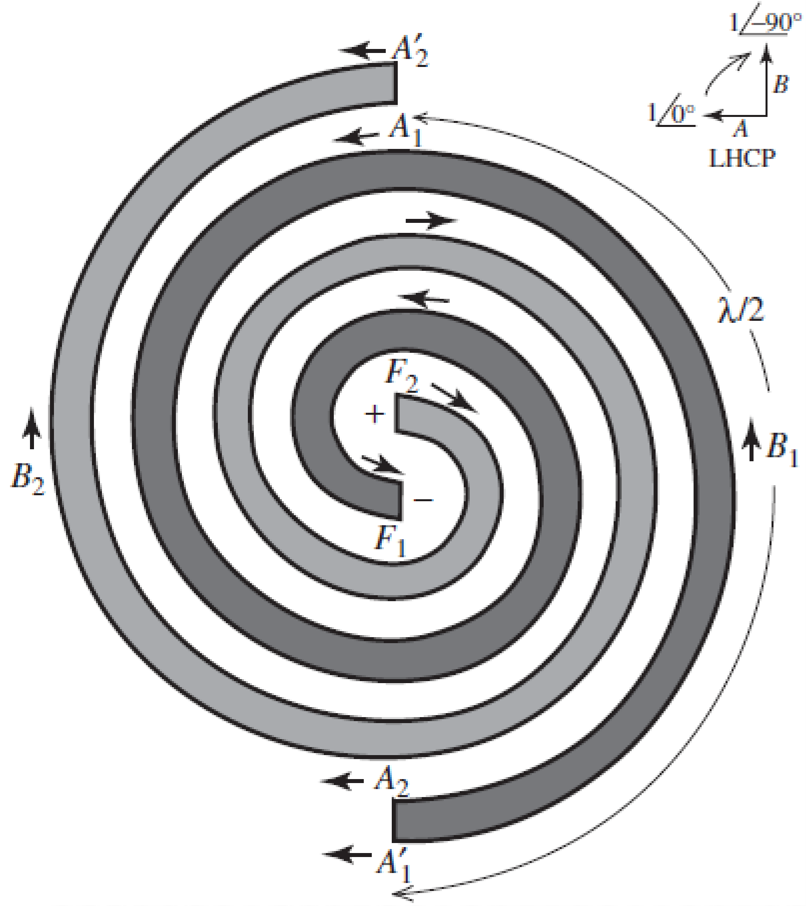
# Spiral Antenna (2)




Planar Equiangular



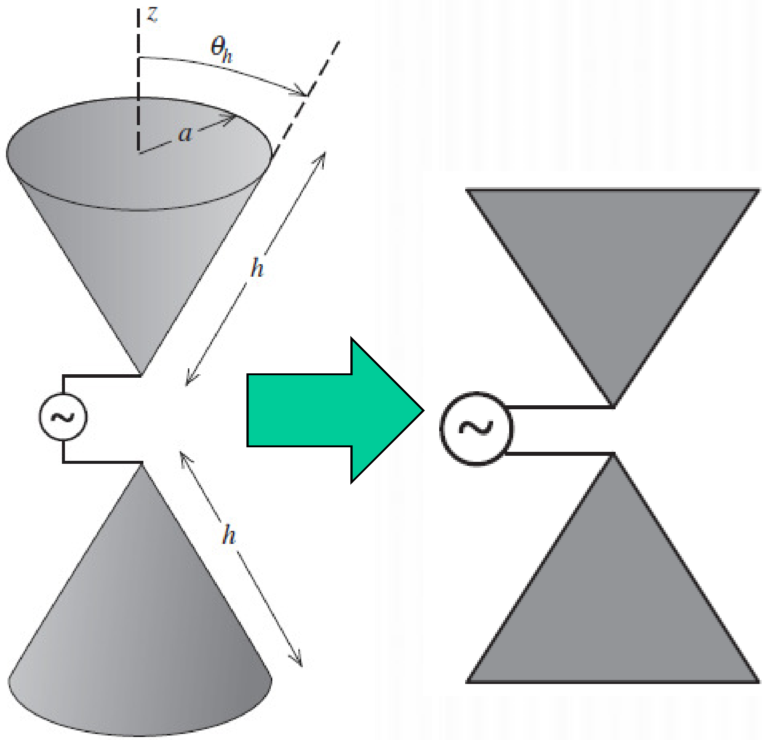

Conical Equiangular




Planar Archemedean

# Bow-tie antenna

- Also called *bifin antenna*.
- Developed from finite biconical antenna.
- Biconical antenna is a broadband version of dipole.

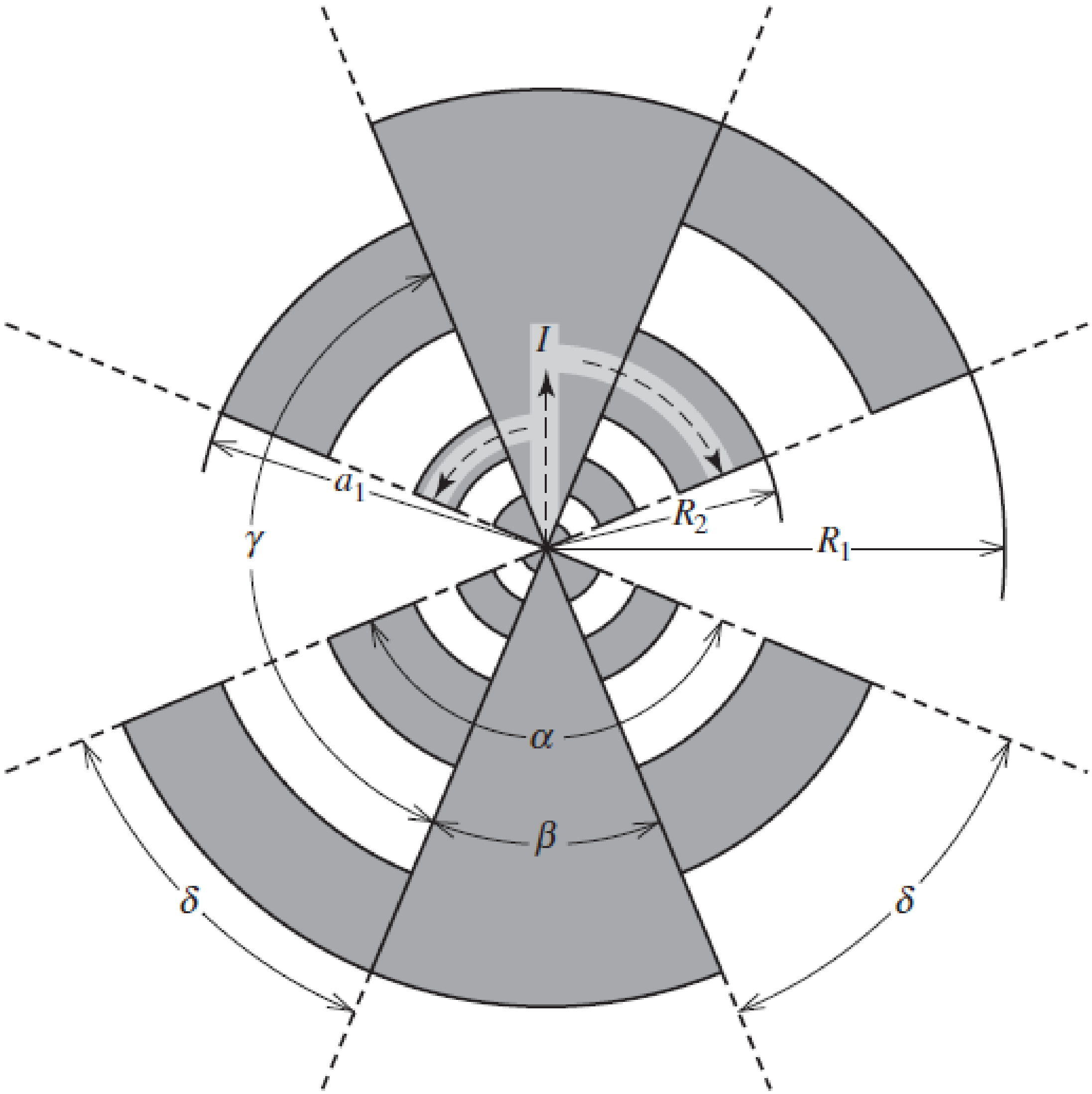



- Bow-tie antenna is the planar version of biconical.
- Used as a receiving antenna for UHF TV.
- Has limited bandwidth due to abrupt termination.

# Log-Periodic Antenna

- Modifying the simple bow-tie antenna can make the current die off more rapidly with distance from the feed point.
- Thus, introduction of periodically positioned teeth. -> *Log-periodic antenna*
- Log-periodic antenna is an antenna having a structural geometry such that its impedance and radiation characteristics repeat periodically as the logarithm of frequency.

# Log-Periodic Toothed Planar Antenna




- **Teeth disturb current flow.**
- **Current flow out along the teeth, except at the frequency limits; insignificant at the ends.**

# Log-Periodic Toothed Planar Antenna (2)

$$r_n = r(\phi + 2n\pi) = r_0 e^{a(\phi+2n\pi)}$$

$$\frac{r_{n+1}}{r_n} = \frac{r_0 e^{a(\phi+2(n+1)\pi)}}{r_0 e^{a(\phi+2n\pi)}} = e^{2a\pi} = \varepsilon$$

**Expansion Ratio**

$$\tau = \frac{R_{n+1}}{R_n} < 1$$

**Scale Factor**

$$\sigma = \frac{a_n}{R_n} < 1$$

**Slot Width**

$$\frac{f_n}{f_{n+1}} = \tau, f_n < f_{n+1} \Rightarrow \log f_{n+1} = \log f_n - \log \tau$$

# Self-Complementary

**Since** $\gamma + \beta = 180° \text{ and } \beta + 2\delta = \alpha$

**for self-complementary**

$$\alpha = \gamma \text{ and } \beta = \delta$$

**Solving this yields**

$$\boxed{\alpha = 135° \text{ and } \beta = 45°}$$

**Self-complementary has $Z_{in}$=188.5 Ω.**

**Furthermore, if** $\sigma = a_n / R_n = R_{n+1} / a_n$

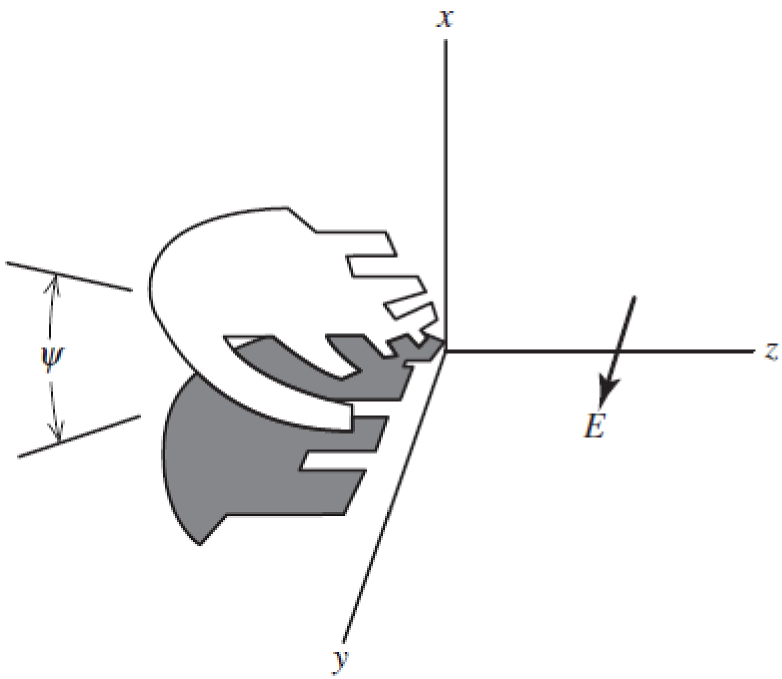
**then** $\boxed{\sigma = \sqrt{\tau}}$

# Log-Periodic Toothed Planar Antenna Properties

- Depend on $\tau$.
- HPBW increases with increasing , from 30°@$\tau$=0.2 to 75°@$\tau$=0.9
- Two main lobes at normal directions
- Linear polarization parallel to the teeth edge, perpendicular to that of bow-tie antenna ($\delta$= 0).
- Most of the currents appears on teeth that are about ¼ wavelength long. (active region)

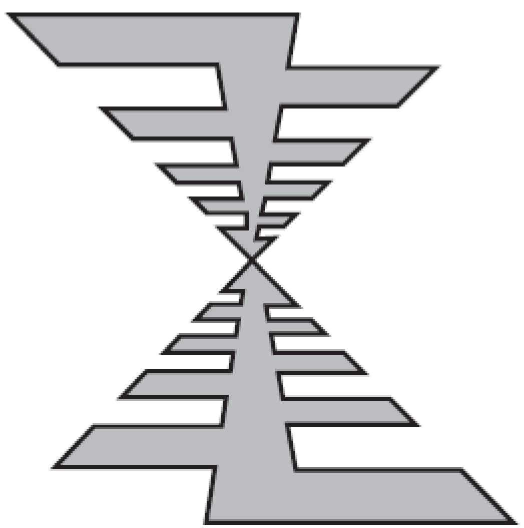
# Log-Periodic Toothed Wedge Antenna

- **Broad main beam exists in the +*z* direction.**
- **Patterns nearly frequency-independent for $30° < \psi < 60°$.**
- **Linear polarization, *y*-directed.**
- **Small cross-polarized component (18dB down)**
- **Same bandwidth but reduced $Z_{in}$ with decreasing $\psi$. (e.g., 70 Ω @ $\psi$=30°.**

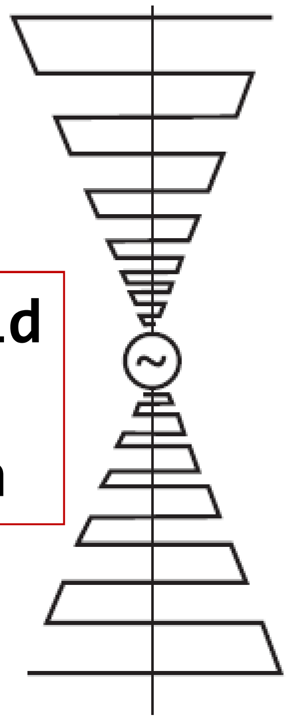


# Other Variations of LP antennas

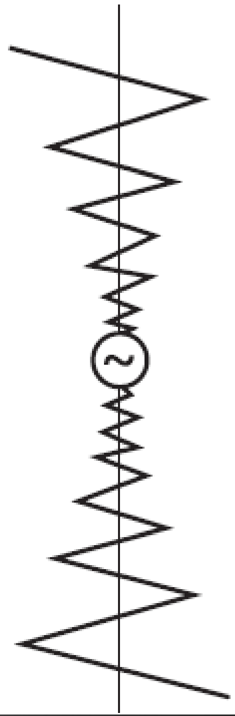
- **LP toothed trapezoid antennas use straight edges instead of curved ones.**
- **LP trapezoid wire antennas use wires instead of plates as do zig-zag version.**



Trapezoid

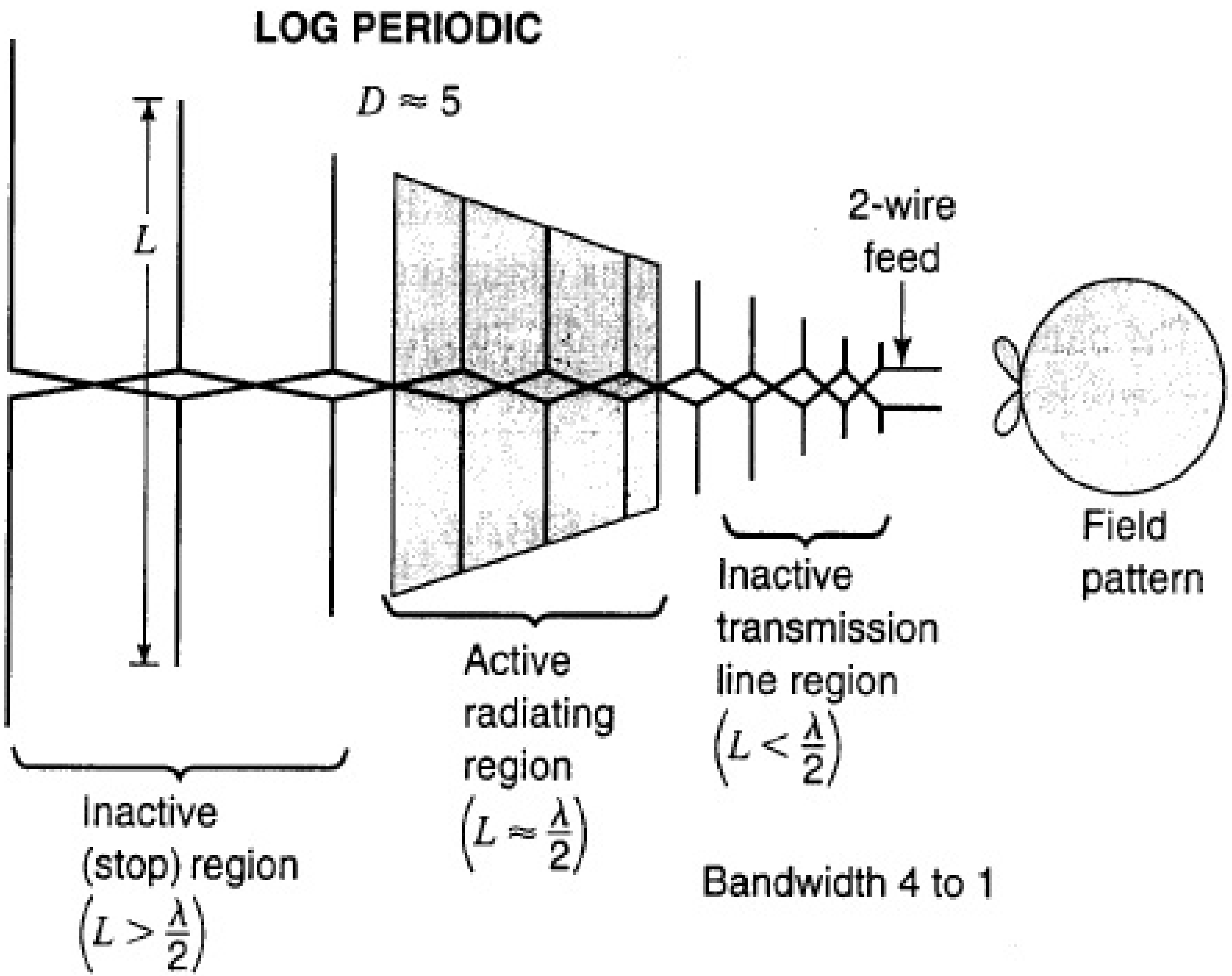


Trapezoid : Wire version



Zig-zag

# Log-Periodic Dipole Array (LPDA)



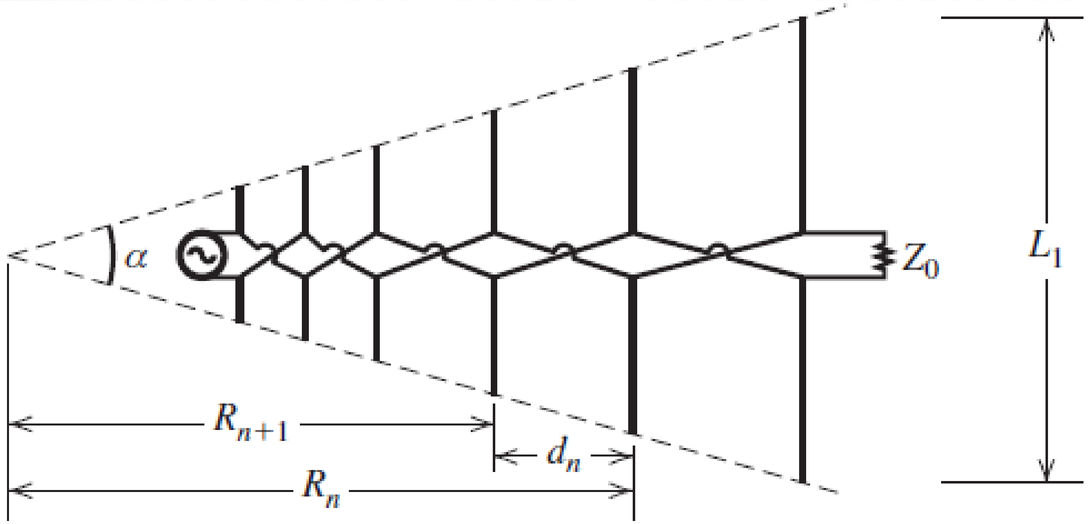
# LPDA Geometry

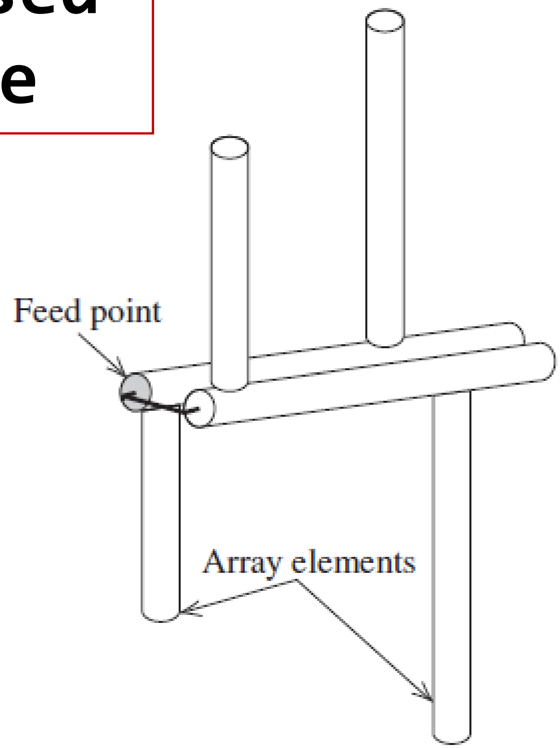
$$\tau = \frac{R_{n+1}}{R_n} < 1$$

Scale Factor

$$\tan\frac{\alpha}{2} = \frac{L_n/2}{R_n} = \frac{L_{n+1}/2}{R_{n+1}}$$

Enclosed Angle



# LPDA (2)

**Thus**

$$\frac{L_1}{R_1} = \cdots = \frac{L_n}{R_n} = \frac{L_{n+1}}{R_{n+1}} = \cdots \frac{L_N}{R_N}$$

**It follows that :**

$$\tau = \frac{R_{n+1}}{R_n} = \frac{L_{n+1}}{L_n}$$

**Spacing Factor**

$$\sigma = \frac{d_n}{2L_n}; d_n = R_n - R_{n+1}$$

**But** $\tau R_n = R_{n+1}$ ⇨ $d_n = R_n - \tau R_n = (1-\tau)R_n$

**Also,** $R_n = L_n / 2\tan(\alpha/2)$ ⇨

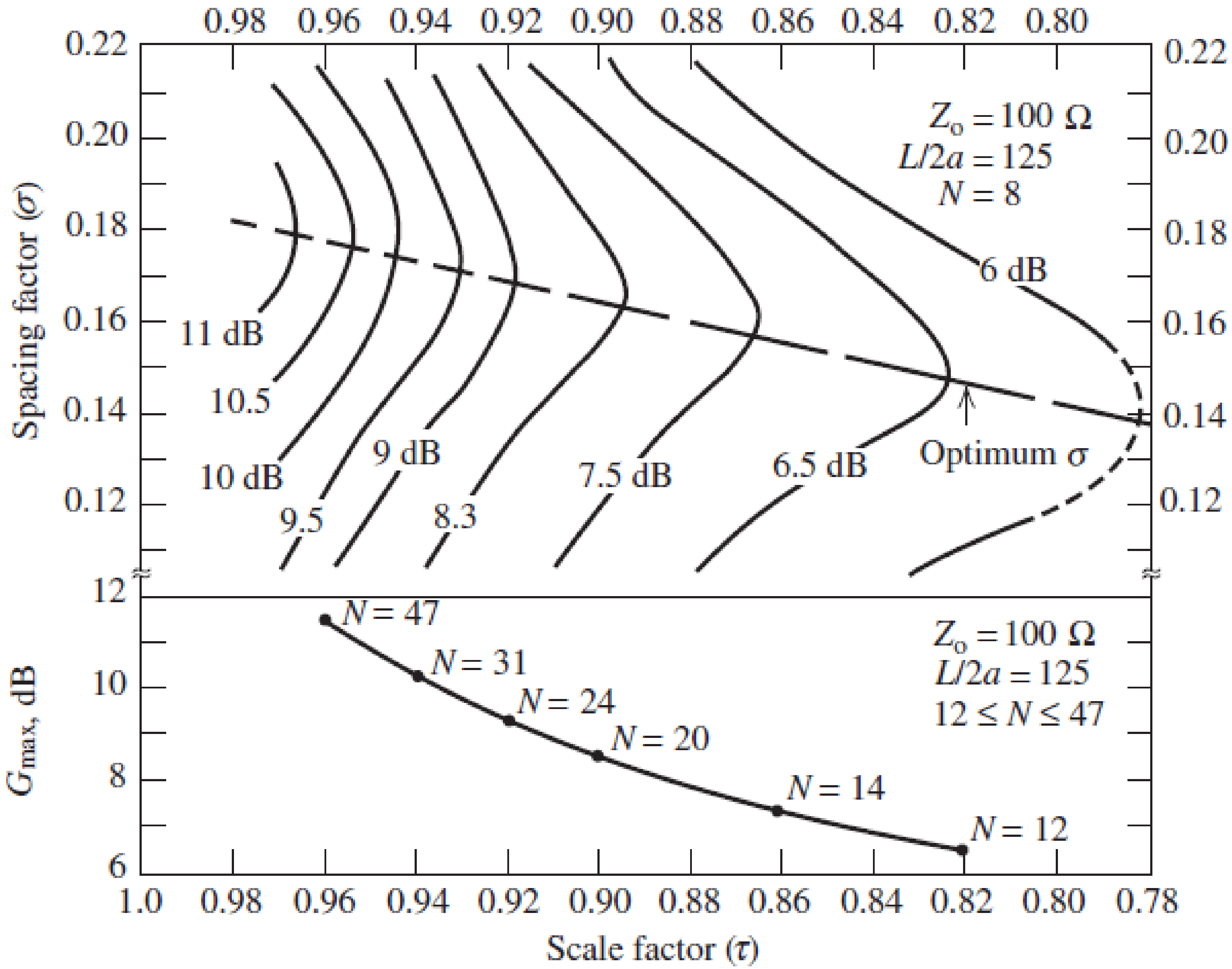
$$d_n = (1-\tau)\frac{L_n}{2\tan(\alpha/2)}$$

# LPDA (3)

$$\sigma = \frac{d_n}{2L_n} = \frac{1-\tau}{4\tan(\alpha/2)} \text{ or } \alpha = 2\tan^{-1}\left(\frac{1-\tau}{4\sigma}\right)$$

- **Note that** $\tau = \frac{R_{n+1}}{R_n} = \frac{L_{n+1}}{L_n} = \frac{d_{n+1}}{d_n}$
- **Active region = dipoles near $\lambda/2$**
- **Long dipole=reflector, short dipole=director**
- **Operational band limits** $L_1 \approx \lambda_L/2; L_N \approx \lambda_U/2$
- **$\lambda_L$, $\lambda_U$ : Lower, Upper frequency limits**

# LPDA Gain



0.98 0.96 0.94 0.92 0.90 0.88 0.86 0.84 0.82 0.80
0.22
0.20
0.18
0.16
0.14
0.12
Spacing factor (σ)
Z_o = 100 Ω
L/2a = 125
N = 8
6 dB
11 dB
10.5
10 dB
9.5
9 dB
8.3
7.5 dB
6.5 dB
Optimum σ
12
10
8
6
G_max, dB
N = 47
N = 31
N = 24
N = 20
N = 14
N = 12
Z_o = 100 Ω
L/2a = 125
12 ≤ N ≤ 47
1.0 0.98 0.96 0.94 0.92 0.90 0.88 0.86 0.84 0.82 0.80 0.78
Scale factor (τ)

# Design of 54 to 216 MHz LPDA

**SPEC : 4:1 bandwidth, 6.5 dB Gain**

**From graph : $\tau = 0.822$, $\sigma = 0.149$**

**Then** $$\alpha = 2\tan^{-1}\left(\frac{1-0.822}{4(0.149)}\right) = 33.3^\circ$$

**Next $L_1 = .5\lambda_L = .5(5.55) = 2.78$m ($.5\lambda_U = .694$m)**

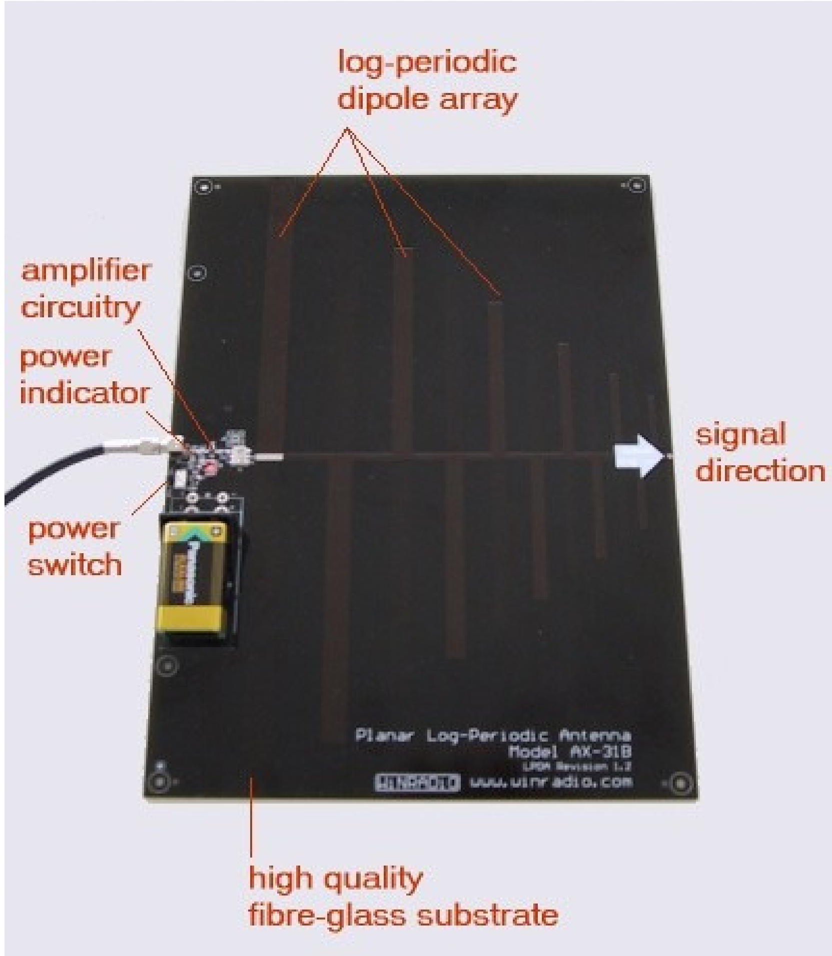
**$L_2 = \tau L_1 = 2.29$m, $L_3 = 1.88$m, $L_4 = 1.54$m, $L_5 = 1.27$m, $L_6 = 1.04$m, $L_7 = 0.858$m, $L_8 = 0.705$m, $L_9 = 0.579$m**

**Element spacing $d_n = 2\sigma L_n = 0.298 L_n$**

**$d_1, d_2, \ldots, d_8$ = .828, .682, .560, .459, .378, .310, .256, .210, respectively.**

# Log Periodic Antenna Example

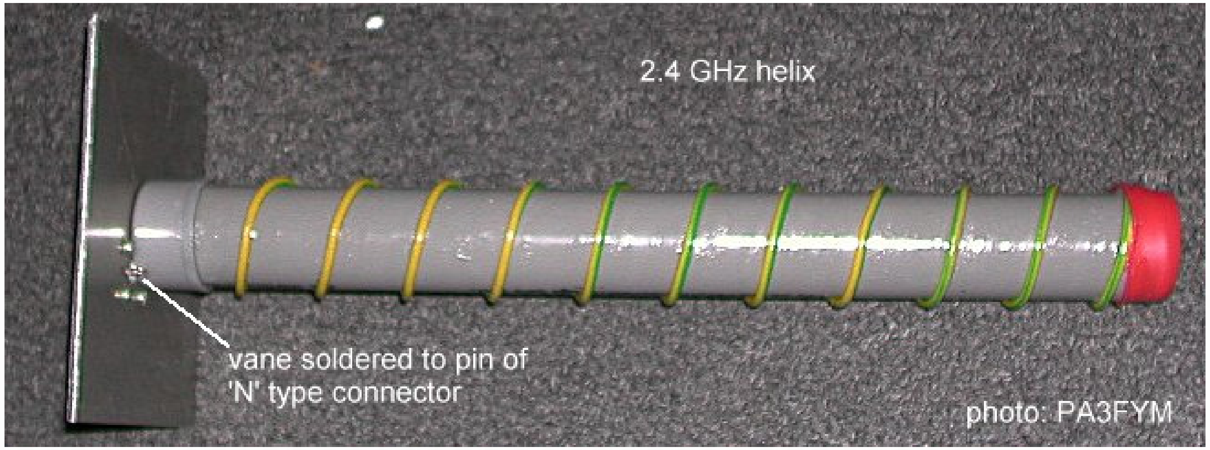
- The antenna is ideally suited for reception of VHF/UHF point-to-point communication where its directional characteristics can significantly improve rejection of interfering signals.
- In professional applications, this antenna is ideally suited for EMC pre-testing, surveillance and monitoring.
- The antenna covers a frequency range of 230 to 1600 MHz (a much wider frequency range can be received with reduced gain).



# Helical Antenna

- **Directional**
- **Circularly Polarized**
  - Polarization changes with time
- **Both high gain and wide band**

http://www.wireless.org.au/~jhecker/helix/helical.html




http://helix.remco.tk/

# Geometry

D= diameter of helix

C= circumference of helix

Lo= length of one turn

α= pitch angle

S= spacing between turns

N= number of turns

Lw= length of helix

d= diameter of conductor

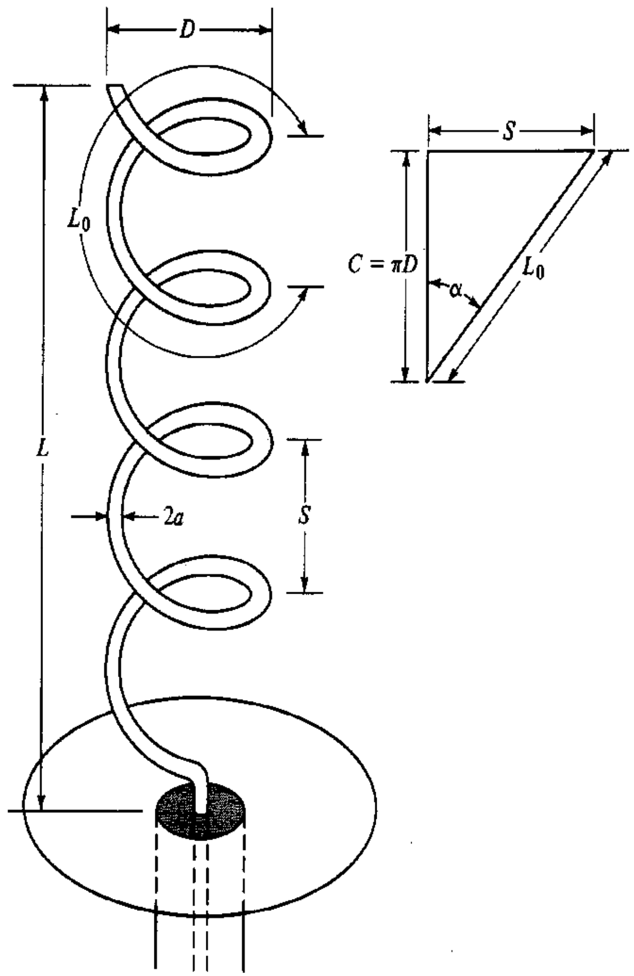
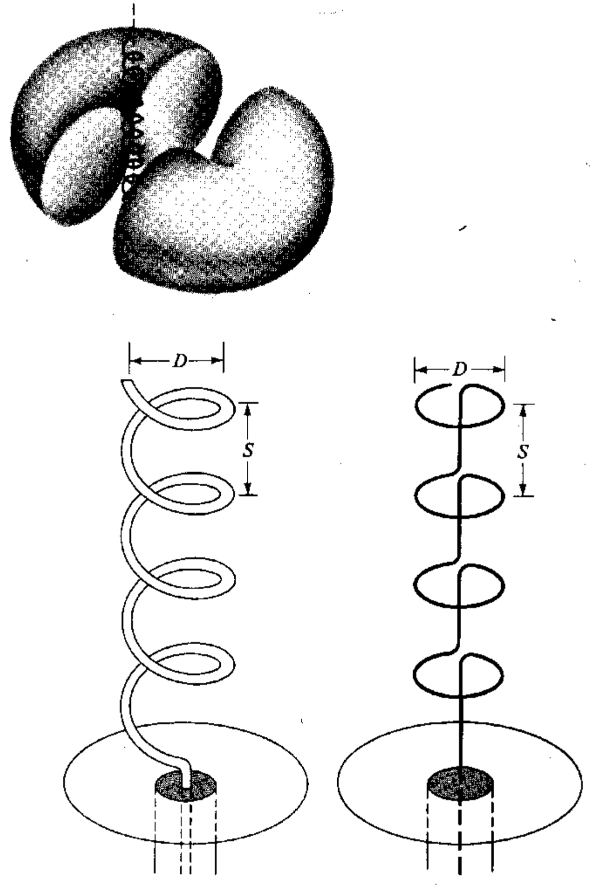



Figure 9.9 Helical antenna with ground plane.

# Normal Mode

- Radiation pattern similar to linear dipole
- The dimensions of the helix are small compared to the wavelength
- Narrow in bandwidth
- Radiation efficiency is small
- Rarely used




(a) Normal mode (b) Equivalent

Antenna Theory, Constantine A. Balanis

# Axial Mode

- **Circular Polarization**
  - 3/4<C/λ<4/3
  - C/λ=1:near optimum
  - S ~ λ/4
  - Axial ratio ~ (2*N*+1)/2*N*
- **Typical Gain: 10-15 dB**
- **Bandwidth: ~ 2:1**
- **Frequency limit: 100MHZ to 3GHz**
- **Input resistance ~ 140($C/\lambda_0$)**

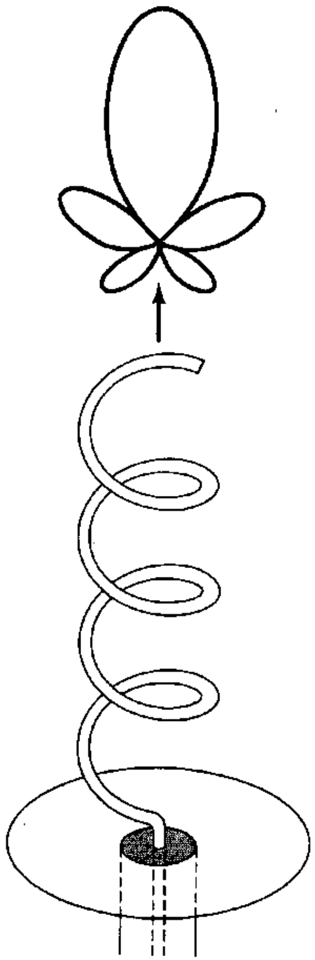
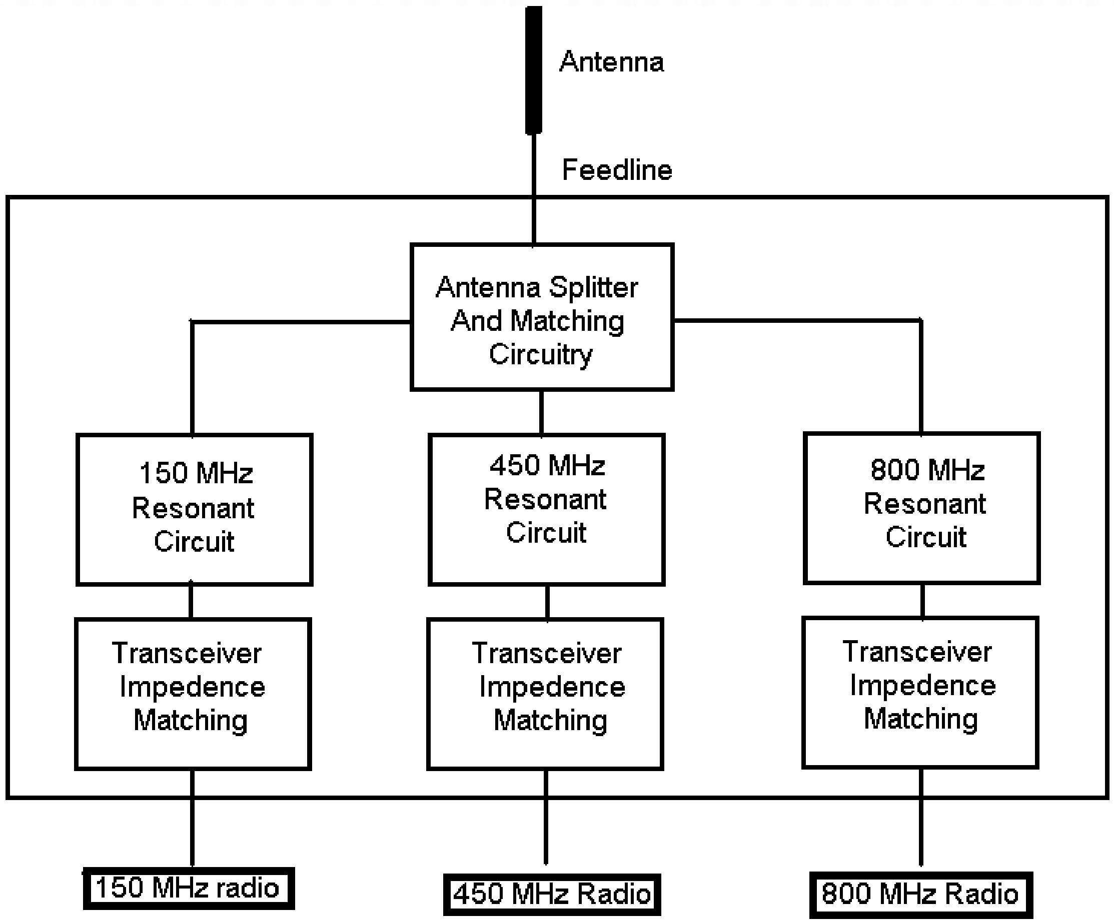


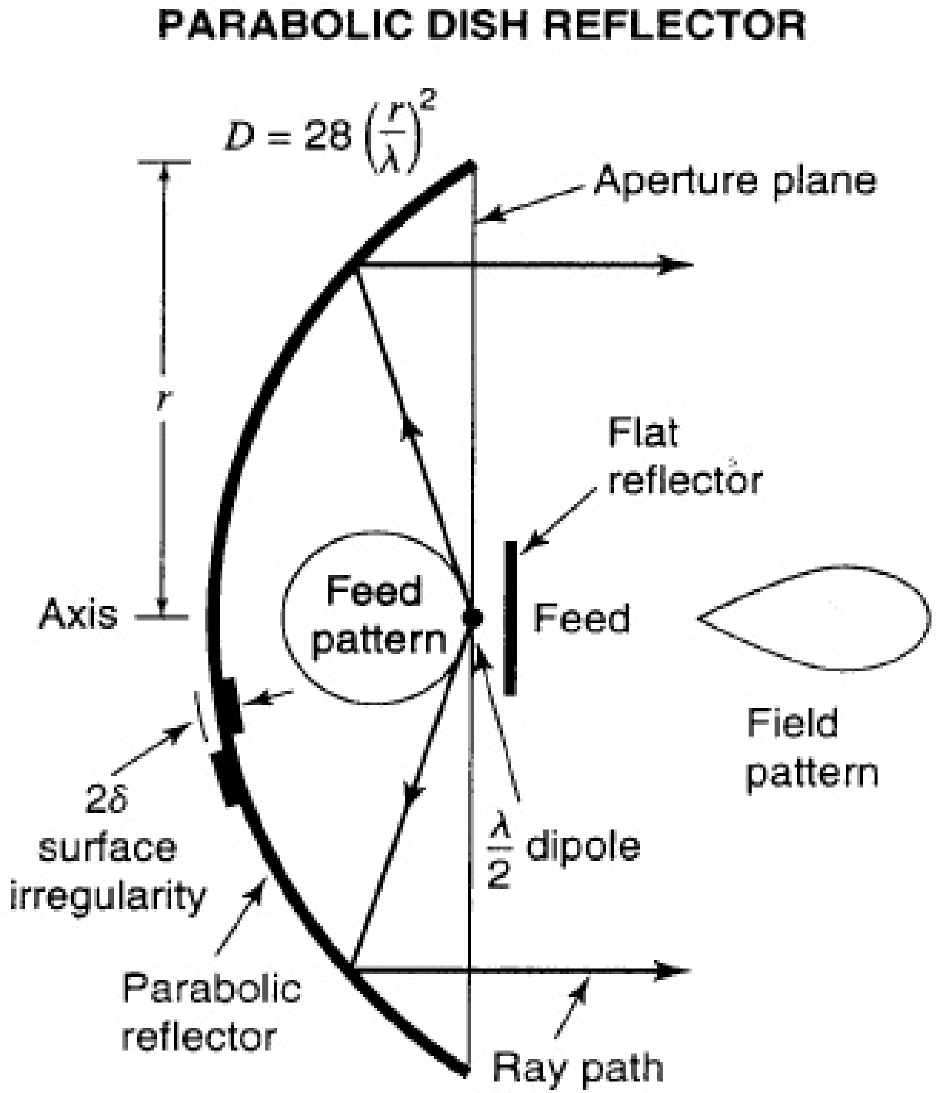
Figure 9.11 Axial (endfire) mode of helix.

# Adaptation of Single Antenna for Multi-band Use.



# Parabolic Reflectors

- A parabolic reflector operates much the same way a reflecting telescope does
- Reflections of rays from the feed point all contribute in phase to a plane wave leaving the antenna along the antenna bore sight (axis)
- Typically used at UHF and higher frequencies

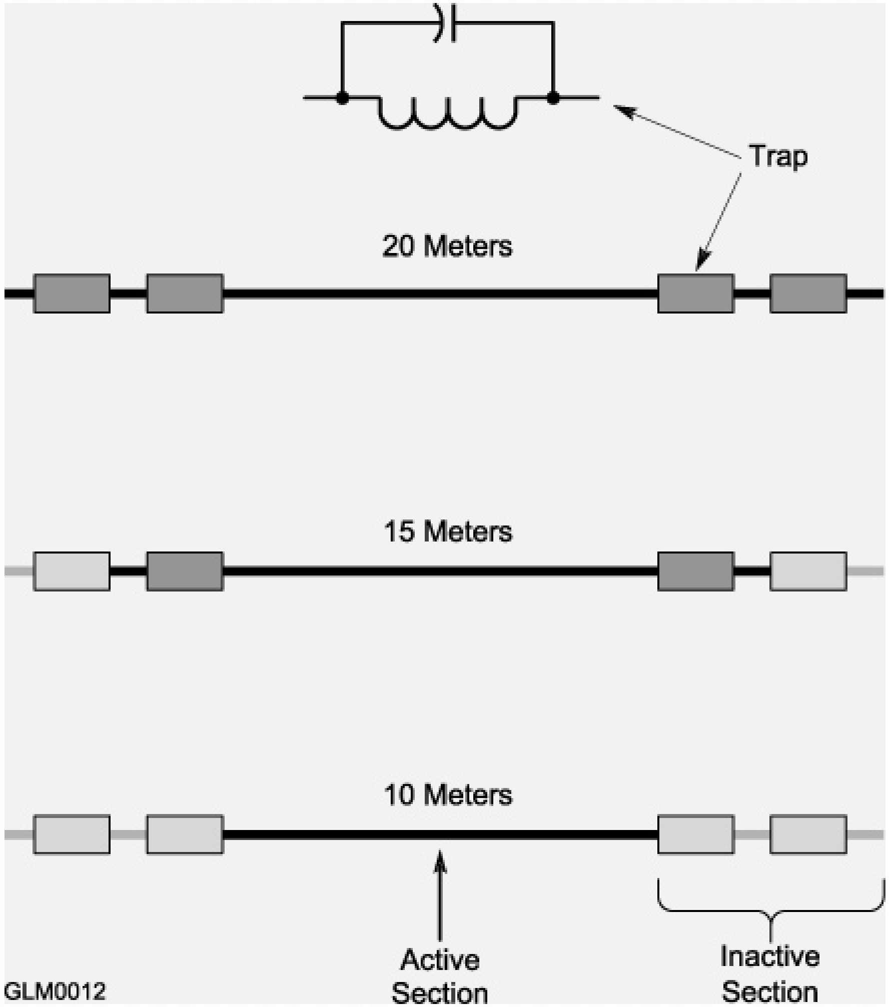


# Stanford's Big Dish

- 150 ft diameter dish on alt-azimuth mount made from parts of naval gun turrets
- Gain ≈ 4 π εA/λ$^2$ ≈ 2 x 10$^5$ ≈ 53 dB for S-band (l ≈15 cm)

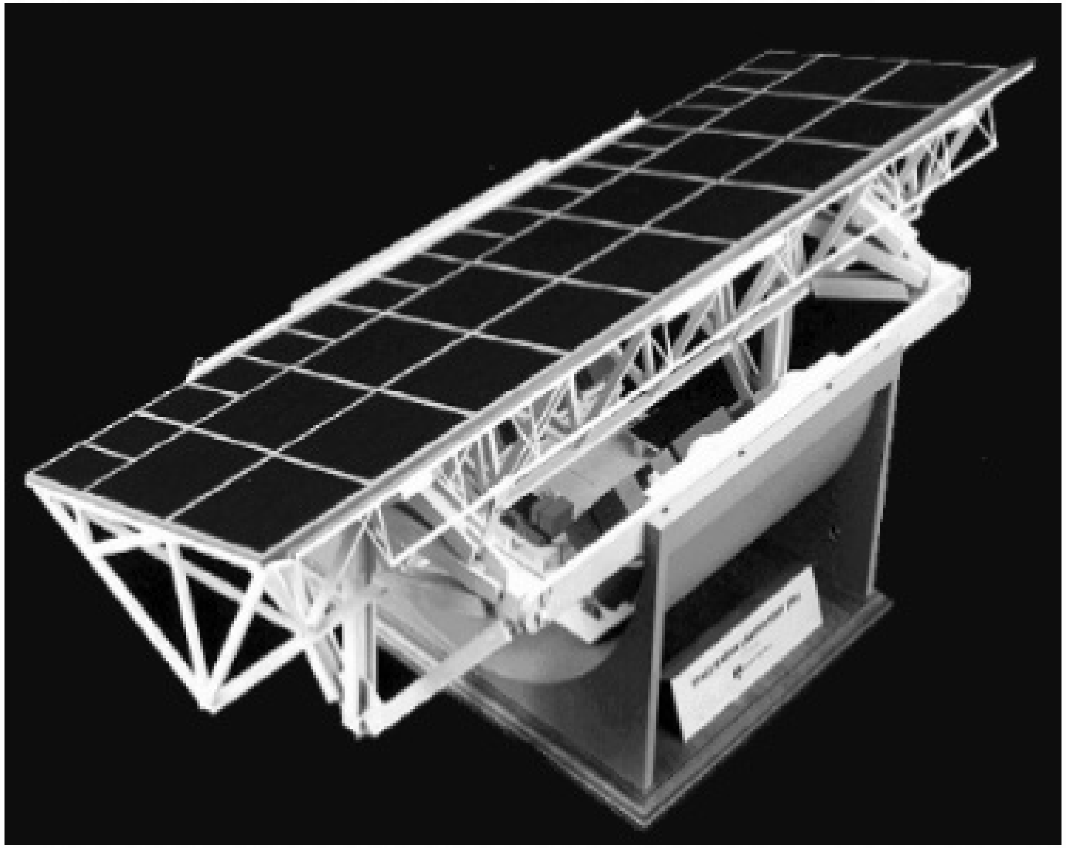
# Multiband Antennas

- A trap dipole uses LC traps so that the dipole looks resonant for more than one band.
  - At their resonant frequency the trap looks like an open circuit and cuts off the rest of the antenna.
  - At lower frequencies the trap adds inductance making the antenna look electrically longer
  - At higher frequencies the trap adds capacitance making the antenna look electrically shorter.



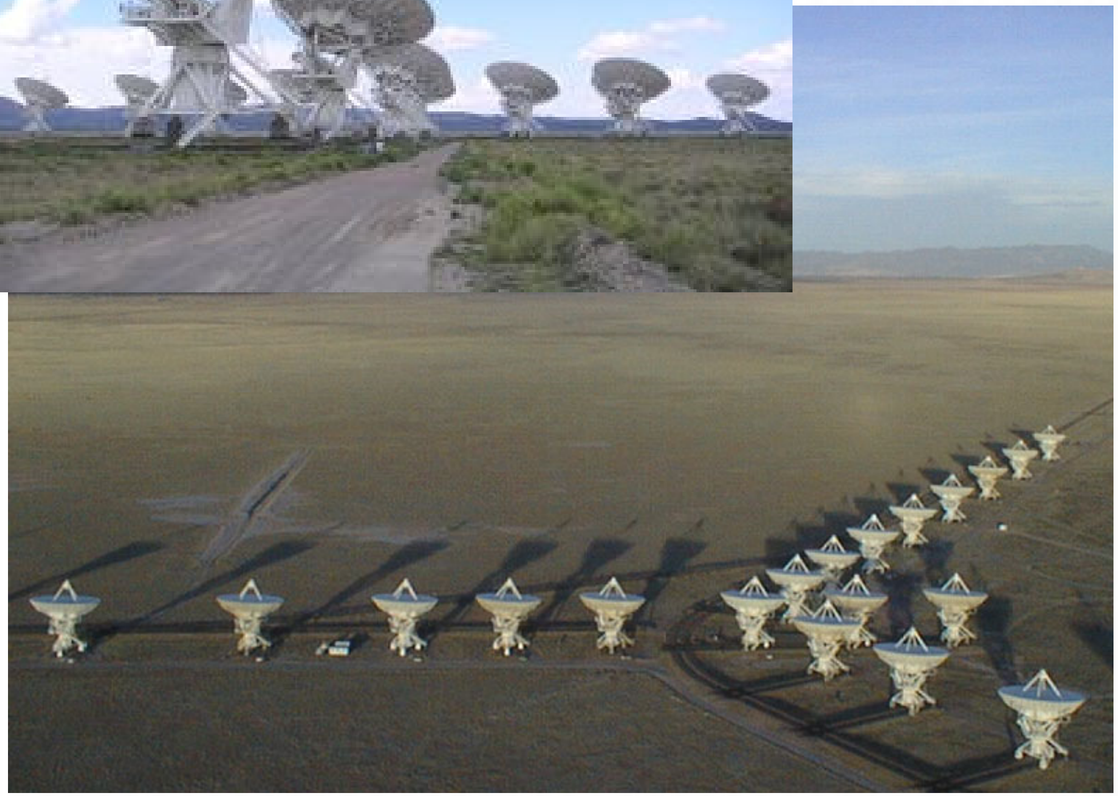
# Patch Antenna Array for Space Craft

- **The antenna is composed of two planar arrays, one for L-band and one for C-band.**
- **Each array is composed of a uniform grid of dual-polarized microstrip antenna radiators, with each polarization port fed by a separate corporate feed network.**
- **The overall size of the SIR-C antenna is 12.0 x 3.7 meters**
- **Used for synthetic aperture radar**



# Very Large Array

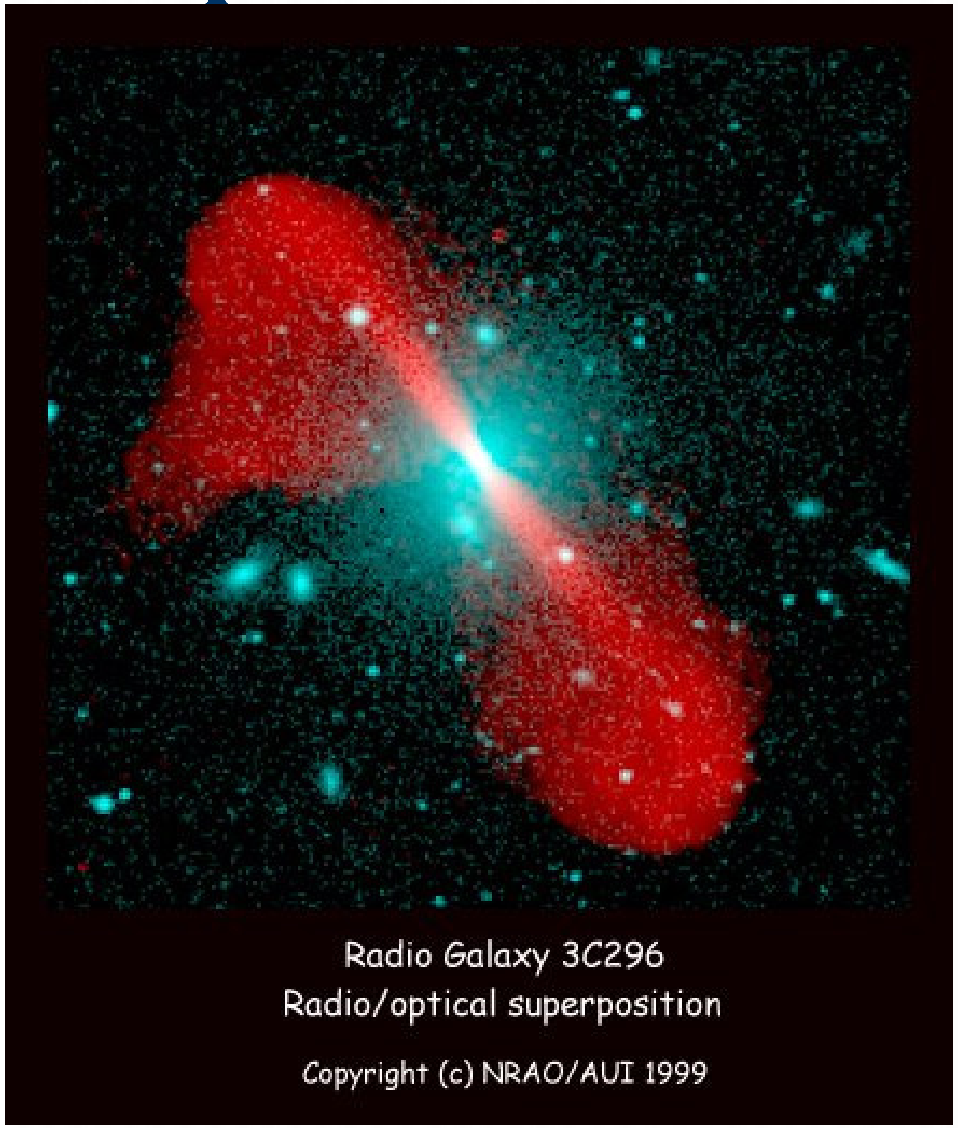
**Organization: National Radio Astronomy Observatory**
**Location:Socorro NM**
**Wavelength:**
radio 7 mm and larger
**Number & Diameter**
27 x 25 m
**Angular resolution:**
0.05 (7mm) to 700 arcsec



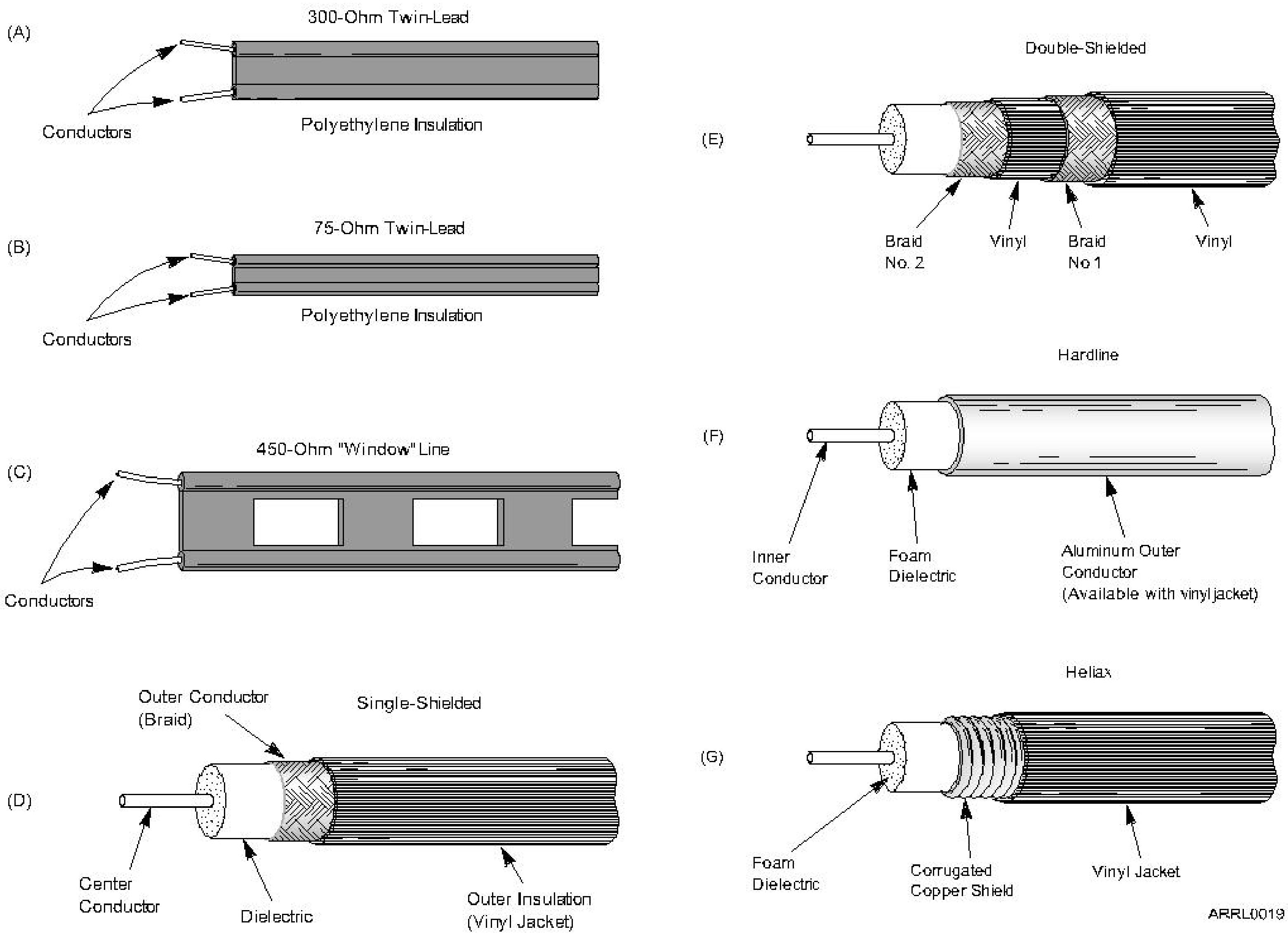
http://www.vla.nrao.edu/

# Radio Telescope Results

- **This is a false-color image of the radio galaxy 3C296, associated with the elliptical galaxy NGC5532. Blue colors show the distribution of stars, made from an image from the Digitized Second Palomar Sky Survey, and red colors show the radio radiation as imaged by the VLA, measured at a wavelength of 20cm. Several other galaxies are seen in this image, but are not directly related to the radio source. The radio emission is from relativistic streams of high energy particles generated by the radio source in the center of the radio galaxy. Astronomers believe that the jets are fueled by material accreting onto a super-massive black hole. The high energy particles are confined to remarkably well collimated jets, and are shot into extragalactic space at speeds approaching the speed of light, where they eventually balloon into massive radio lobes. The plumes in 3C296 measure 150 kpc or 480,000 light years edge-to-edge diameter (for a Hubble constant of 100 km/s/Mpc).**
- **Investigator(s):ハ J.P. Leahy & R.A. Perley. Optical/Radio superposition by Alan Bridle**



# Feed Lines



(A)
300-Ohm Twin-Lead
Conductors
Polyethylene Insulation
(B)
75-Ohm Twin-Lead
Conductors
Polyethylene Insulation
(C)
450-Ohm "Window" Line
Conductors
(D)
Outer Conductor (Braid)
Single-Shielded
Center Conductor
Dielectric
Outer Insulation (Vinyl Jacket)
(E)
Double-Shielded
Braid No. 2
Vinyl
Braid No 1
Vinyl
(F)
Hardline
Inner Conductor
Foam Dielectric
Aluminum Outer Conductor (Available with vinyl jacket)
(G)
Heliax
Foam Dielectric
Corrugated Copper Shield
Vinyl Jacket
ARRL0019

- **All feed lines have two conductors**
- **All feed lines have a characteristic impedance ($Z_0$).**
- **The characteristic impedance of parallel feed lines (balanced feed lines) is determined by the radius of the conductors and the distance between them.**
  - TV type twin lead has an impedance of 300 Ω.
  - Open wire or ladder line has impedances from 300 to 600 Ω.

- **The characteristic impedance of coaxial transmission lines is determined by the diameter of the inner and outer conductors, and their spacing.**
  - The insulating material between the inner and outer conductors affects the feed line loss and velocity factor (how fast a wave travels down the cable).
  - 50 Ω and 75 Ω cables are the most common.

## Forward and Reflected Power

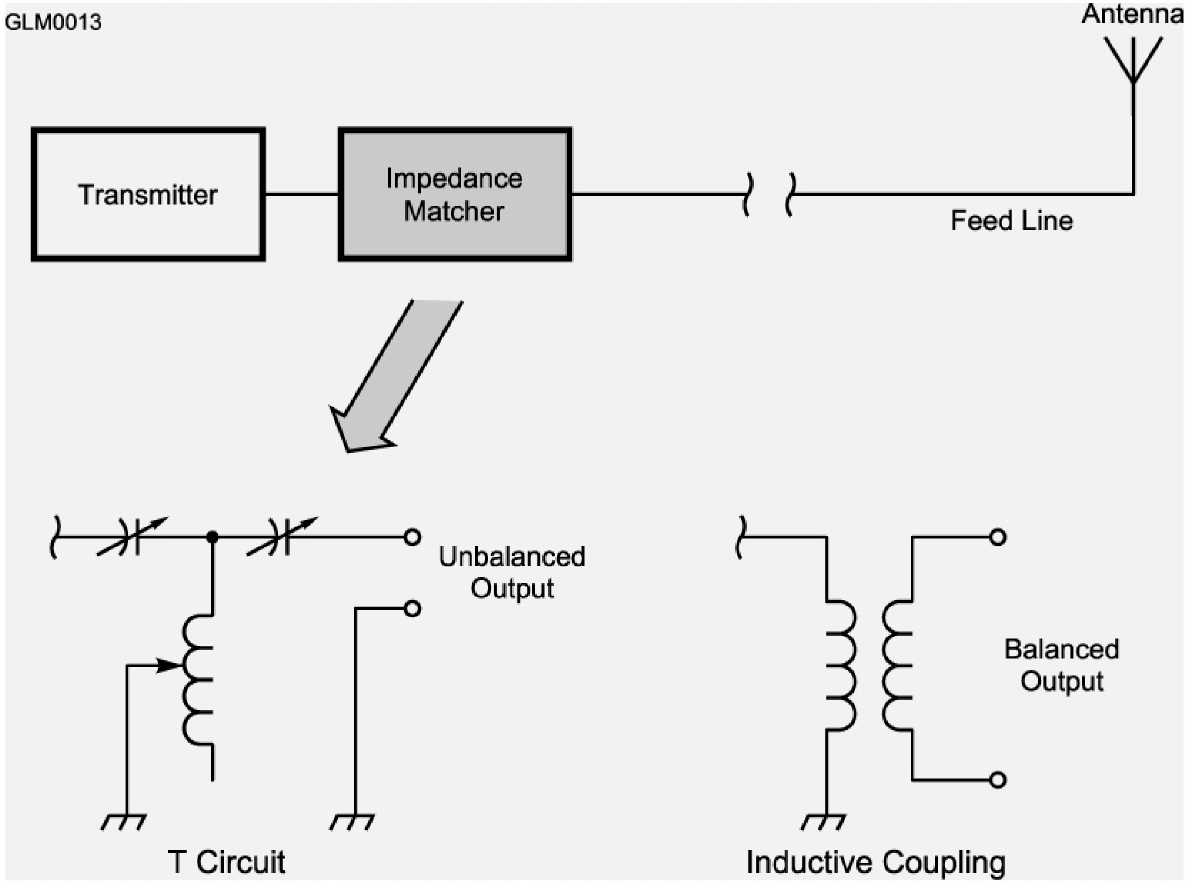
- A feed line delivers all the power to the antenna when the antenna's feed point impedance and the feed line's characteristic impedance are the same.
- A reflection occurs when the impedances don't match. Forward power is power traveling toward the antenna and reflected power is power reflected back due to the impedance mismatch.
- The forward and reflected power create standing waves on the transmission line.

- **A standing wave ratio (SWR) of 1:1 represents a perfect match (no reflected power). A higher SWR means more reflected power.**
- **SWR is the ratio of the antenna impedance to the feed line characteristic impedance, and is always greater than 1.**
  - Example: What is the SWR in a 50 Ω transmission line when connected to an antenna with a feed point impedance of 25 Ω?
    - SWR = 50/25 = 2:1

- Example: What is the SWR in a 50 Ω transmission line when connected to an antenna with a feed point impedance of 250 Ω?
  - SWR = 250/50 = 5:1

- **A high SWR can damage a transmitter because of the reflected power returning the transistors (or tubes) in the final power amplifier.**
- **Matching the antenna to the feed line will maximize the power delivered from the transmitter to the antenna.**

- **A device to match the feed line to the antenna is called an impedance matcher, transmatch, antenna coupler, or antenna tuner.**



- A section of transmission line connected in parallel, called a stub, can be used to match impedances.
- Impedance matching does not change the SWR in the feed line from the matching device to the antenna.  Only the SWR between the transmitter and the impedance matching device will be low.

## Feed Line Loss

- All feed lines will dissipate some energy as heat.  This loss effects both receive and transmit.
- Air insulated transmission lines tend to have the lowest loss.
- Loss is measured in dB/100 feet.
- Loss increases with frequency for all transmission lines.
  - Example: RG-8 has a loss of 1.08 dB/100 ft at 30 MHz and 2.53 dB/100 ft at 150 MHz.