

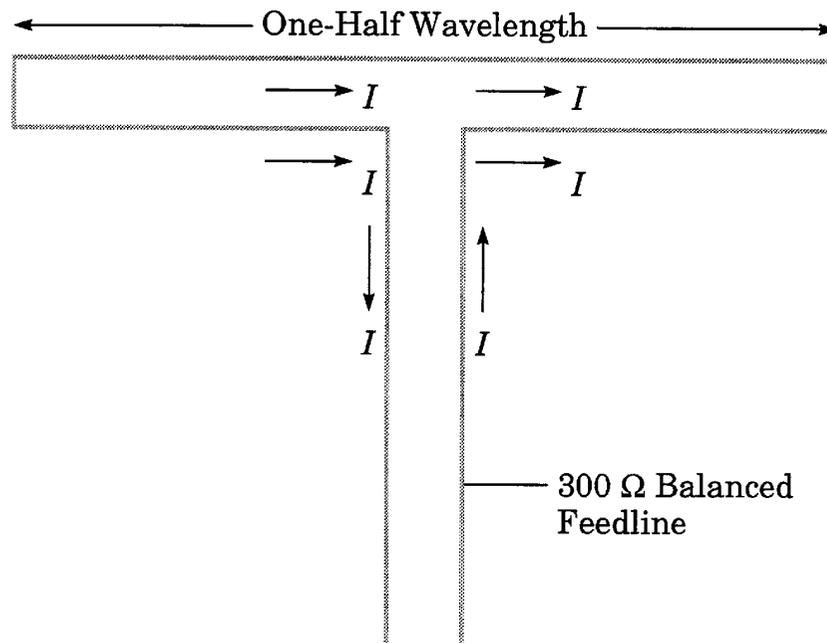
Antenna Types

- Dipole
- Folded Dipole
- Monopole
- ARRAYS: Yagi-Uda (parasitic arrays)
- Phased Arrays
- Loop *Ground Plane
- Helical *Discone
- Turnstile
- Microstrip Patch
- Dish

Monopole Antenna

- $\frac{1}{4}$ wavelength fed at one end
- Fed with unbalanced feedline with ground conductor connected to earth ground.
- In practice it usually requires an array of radials to develop a better ground plane. (Marconi antenna)
- When used at low frequencies the field should be vertically polarized and antenna could be a tower.
- The tower is ground insulated and fed at a point above ground with a Gamma match. Z increases upward.

Folded Dipole



Folded Dipole Antenna

- Same length as $1/2$ wave dipole
- Parallel conductors joined at each end separated by an appropriate spacing.
- 300 ohm radiation resistance: Even though current is same magnitude but out of phase with respect to the wire, in SPACE the currents are actually in the same direction due to FOLDING of antenna.
- Given the same conditions a dipole and folded dipole radiate the same amount of power.
- The current at the feedpoint of the folded dipole is only half the total current.

If the power is the same as the 1/2 wave dipole and current is reduced by half due to folding then feedpoint voltage must be doubled.

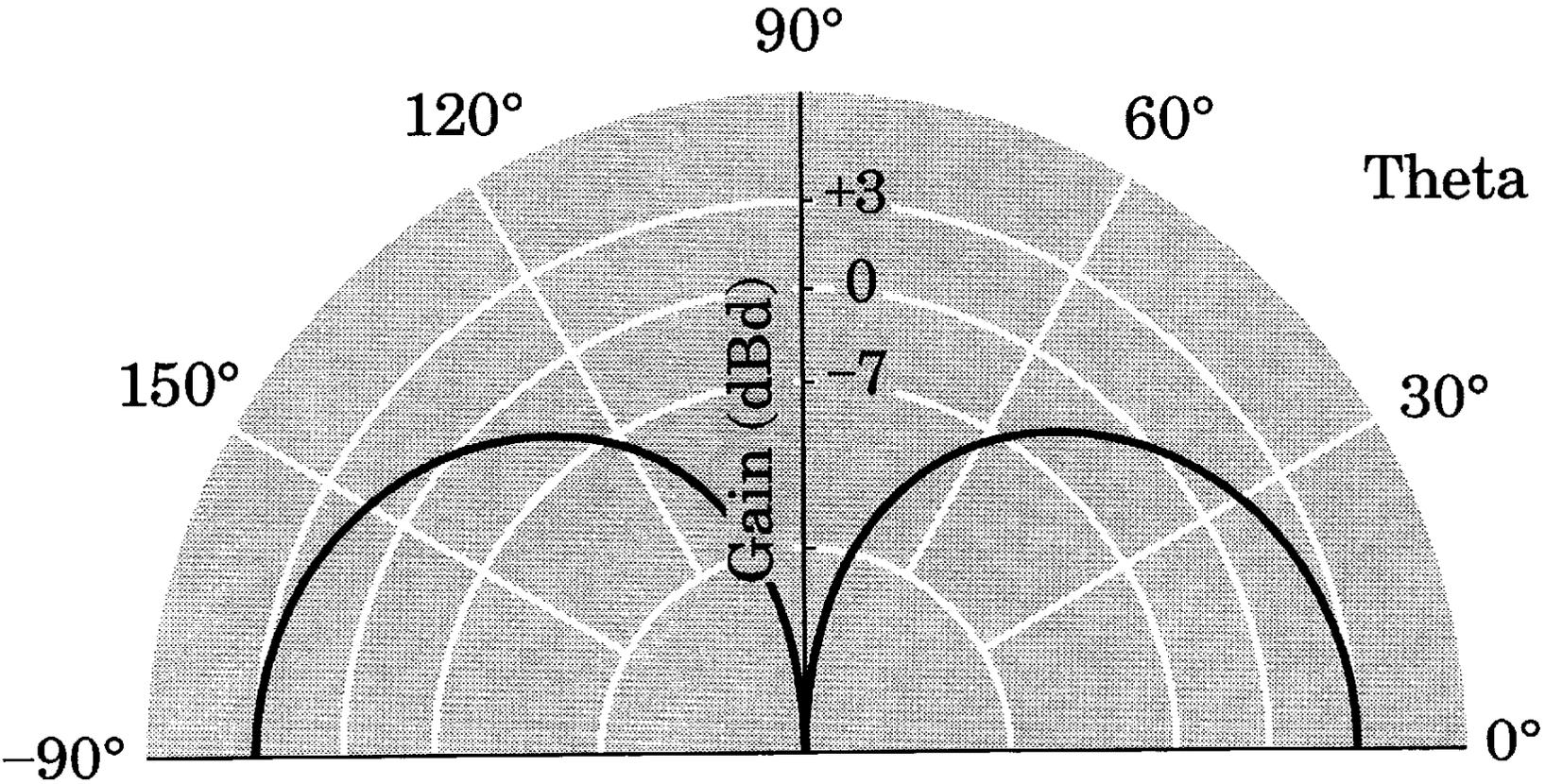
$$P = VI = 2V \left(\frac{I}{2} \right)$$

$$R = V / I$$

$$R' = \frac{2V}{I/2} = \frac{4V}{I} = 4R$$

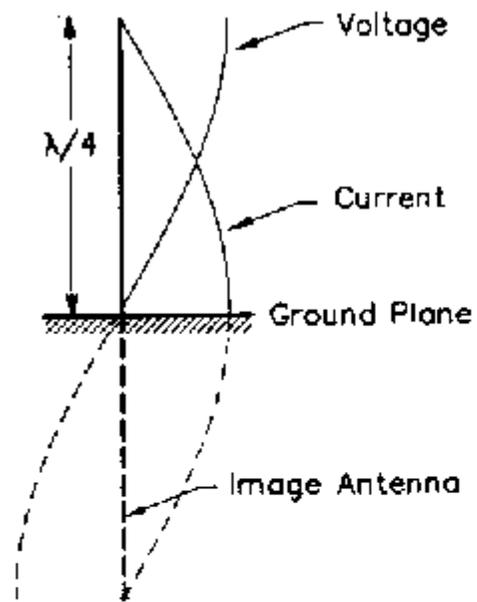
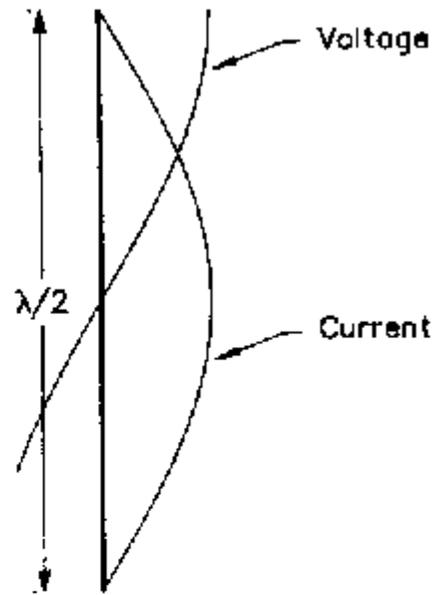
The result of twice the voltage and half the current is a feedpoint impedance that is four times that of a dipole.

Vertical Monopole



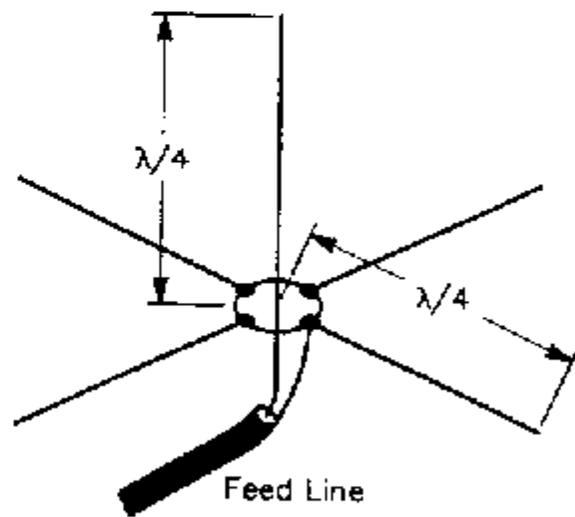
Monopole Antenna

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- Fed with unbalanced feedline with ground conductor connected to earth ground.
- In practice it usually requires an array of radials to develop a better ground plane. (Marconi antenna)
- When used at low frequencies the field should be vertically polarized and antenna could be a tower.
- The tower is ground insulated and fed at a point above ground with a Gamma match. Z increases upward.



Ground Plane Antenna

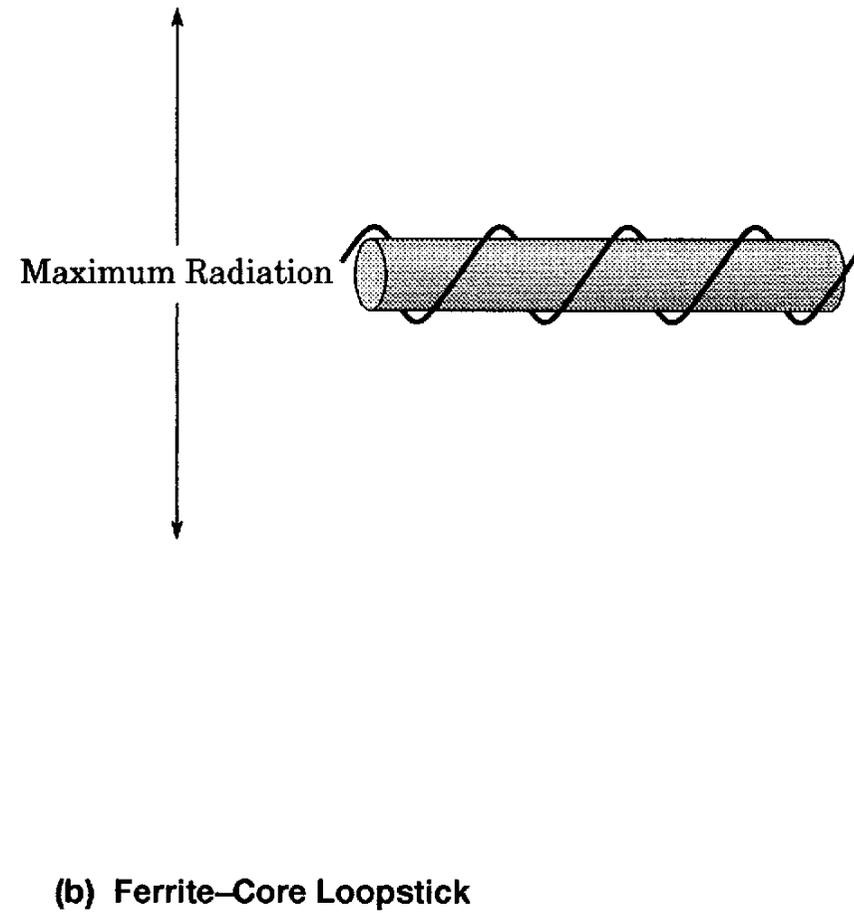
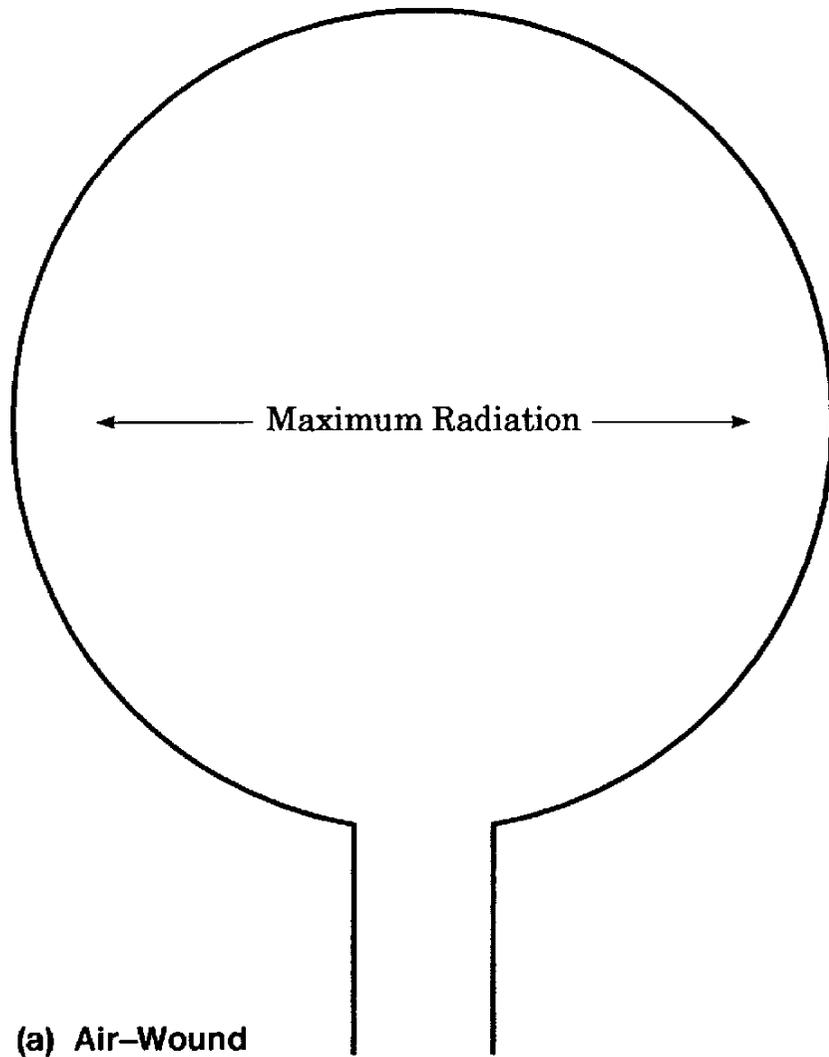
- Can use a COUNTERPOISE system of radials cut to $\frac{1}{4}$ wavelength to develop ground plane elevated above earth.
- If used in a mobile application the roof of the vehicle can serve as a ground plane.
- At low frequencies a whip antenna can be used with a loading coil.



Loop Antenna

- Typically a receiving antenna.
- Uses an air core with radiation in the plane of the loop.
- A ferrite core loopstick is also used typically in A.M receivers.
- Radiation is in same plane as the loop but broadside to the loopstick
- Can also be used as a coil in the R.F. tuned circuit.

Loop Antennas



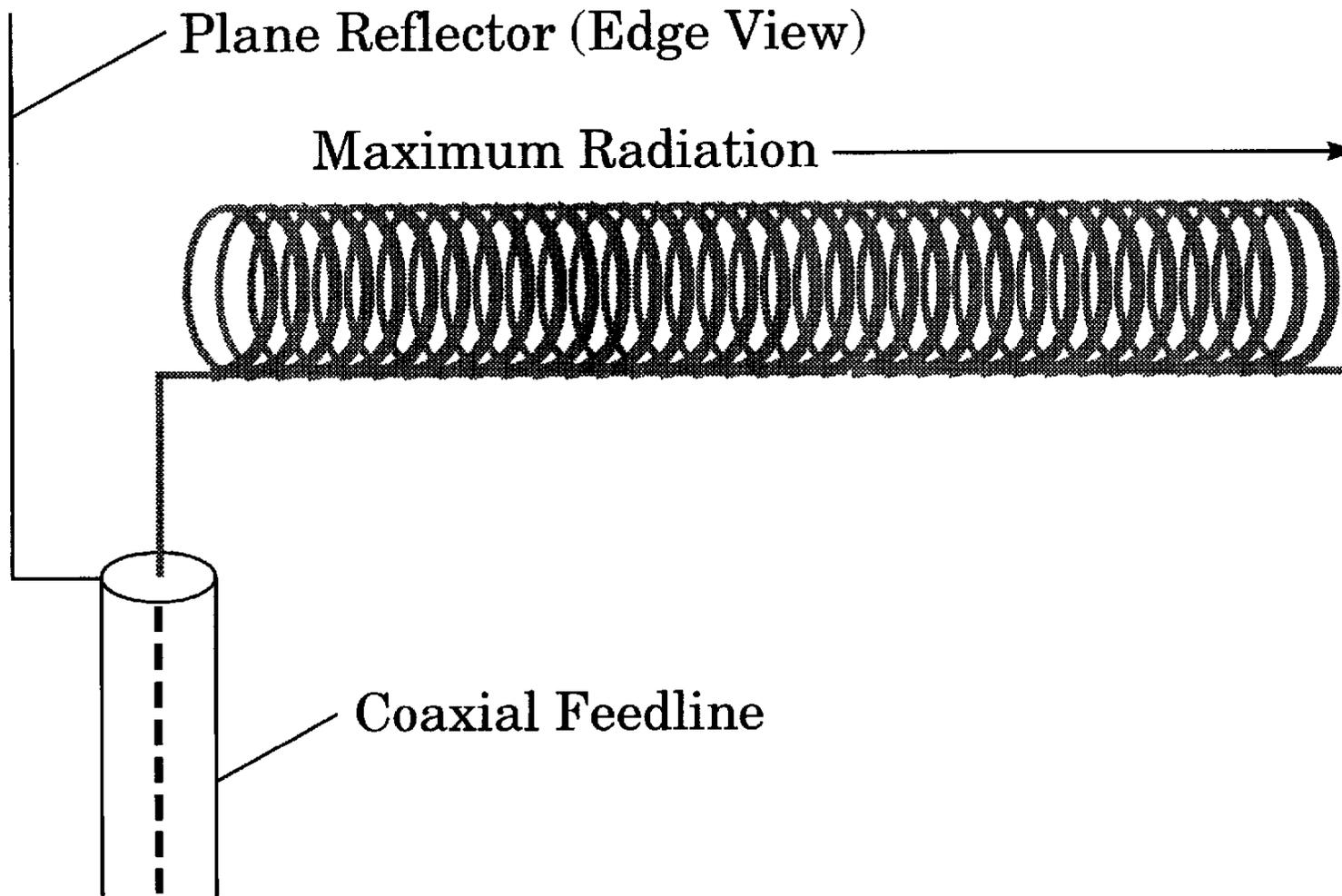
$5/8^{\text{th}}$ wavelength Antenna

- Application as a mobile or base station antenna..
- Omnidirectional response in horizontal plane.
- Advantage is realized in the concentration of low angle radiation in horizontal direction.
- Does not require as good a ground plane because feedpoint Z at $5/8^{\text{th}}$ wavelength is higher therefore lower current.
- Z is lowered to match 50 ohm feedline by matching section.

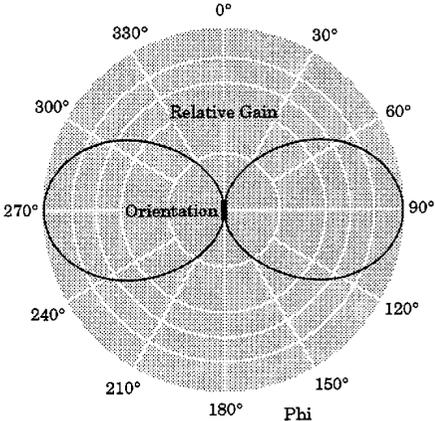
Helical Antenna

- Helix is spiral
- An example: $\frac{1}{4}$ wavelength dipole shortened into helix (rubber ducky) for handheld transceivers.
- Typically several wavelengths long and used with a ground plane.
- Circumference is $\frac{1}{2}$ wavelength and the turns are $\frac{1}{4}$ wavelength apart.
- Application: VHF satellite transmission. (cross polarization)

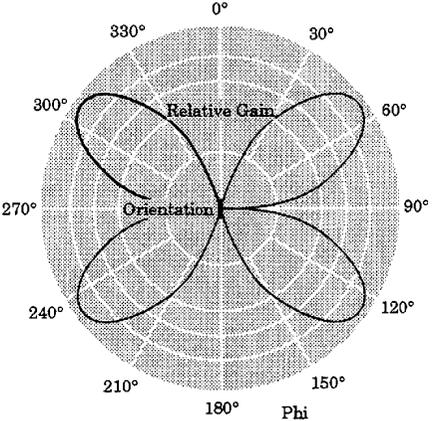
Helical Antenna



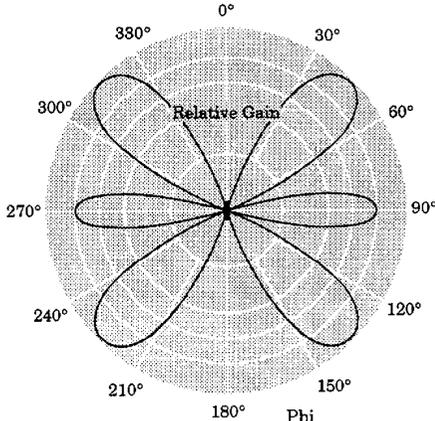
Long-Wire Antennas



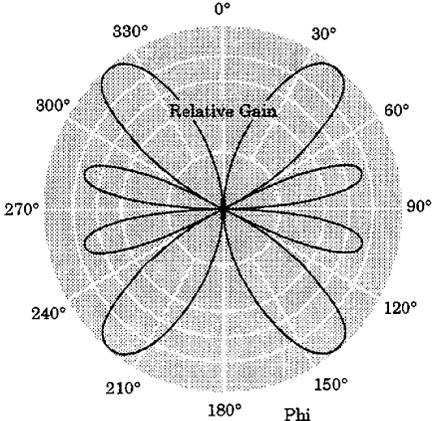
(a) One-Wavelength Antenna



(b) Two-Wavelength Antenna



(c) Three-Wavelength Antenna



(d) Four-Wavelength Antenna

Discone Antenna

- Widebandth – 10:1 range.
- Omnidirectiional in horizontal plane.
- Vertically polarized.
- Gain is similar to a dipole. Z approaches 50 ohms.
- Application: RX scanner antenna for VHF and UHF.
- Can also be used for TX.

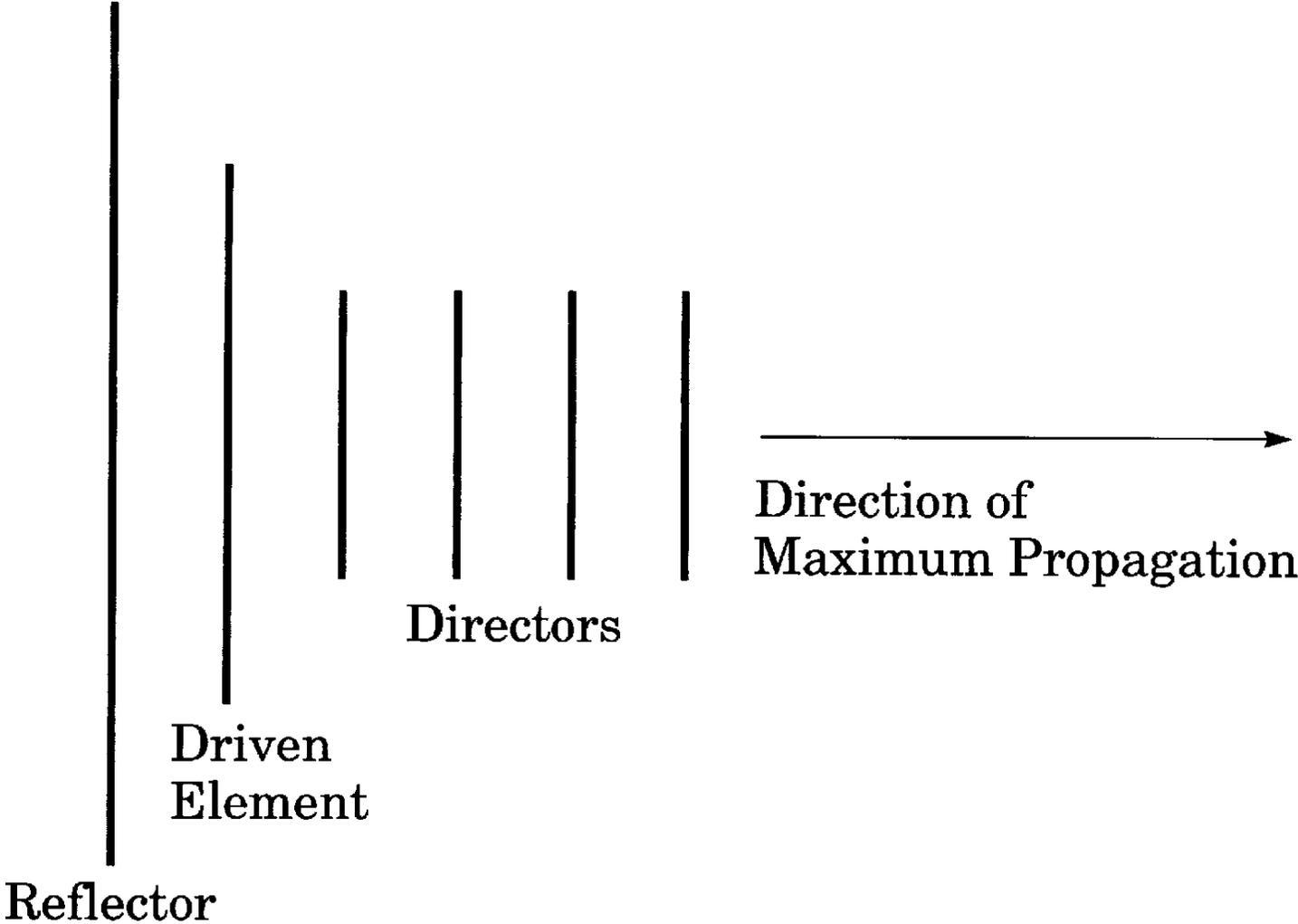
Parasitic Array – Yagi-Uda

- Array antennas can be used to increase directivity.
- Parasitic array does not require a direct connection to each element by a feed network.
- The parasite elements acquire their excitation from near field coupling by the driven element.
- A Yagi-Uda antenna is a linear array of parallel dipoles.
- The basic Yagi unit consists of three elements:
 - 1. Driver or driven element
 - 2. Reflector
 - 3. Director

Yagi-Uda Antenna

- Develops an endfire radiation pattern.
- Optimum spacing for gain of a reflector and driven element is 0.15 to 0.25 wavelengths
- Director to director spacings are 0.2 to 0.35 wavelengths apart.
- Reflector length is typically 0.5 wavelengths or 1.05 that of the driven element.
- The driven element is calculated at resonance without the presence of parasitic elements.
- The directors are usually 10 to 20% shorter than at resonance.

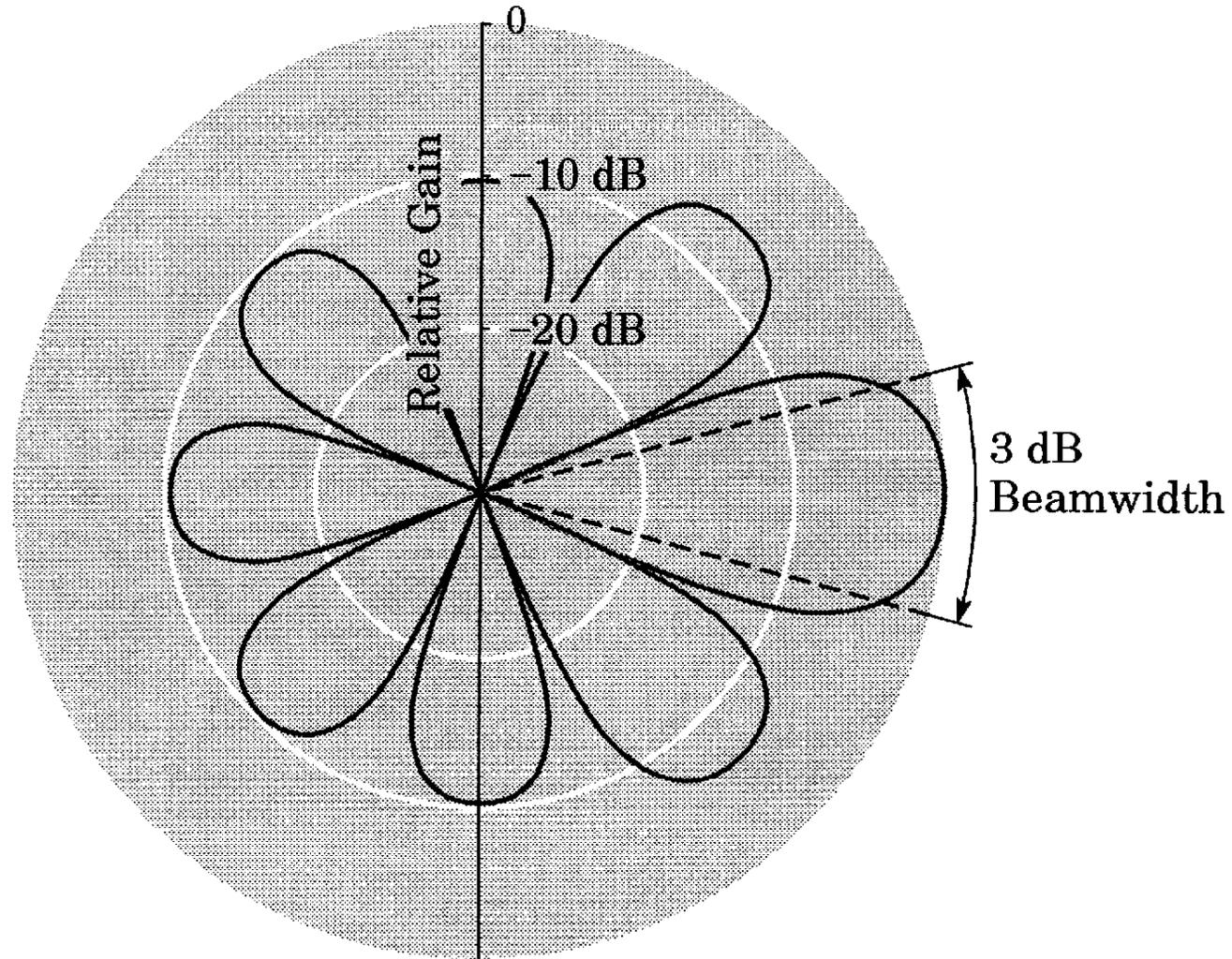
Yagi Array



Yagi-Uda antennas

- Gain is related to boom length and number of directors.
- Max directivity of a 3 element Yagi is 9 dBi or 7dBd.
- Addition of directors up to 5 or 6 provides significant increase in gain. Addition of more directors has much less impact on gain.
- Increasing N from 3 to 4 results in 1 dB increase.
- Adding a director to go from 9 to 10 presents a 0.2 dB gain improvement.
- Adding more reflectors has minimal impact on gain however does impact on feedpoint Z and the backlobe.

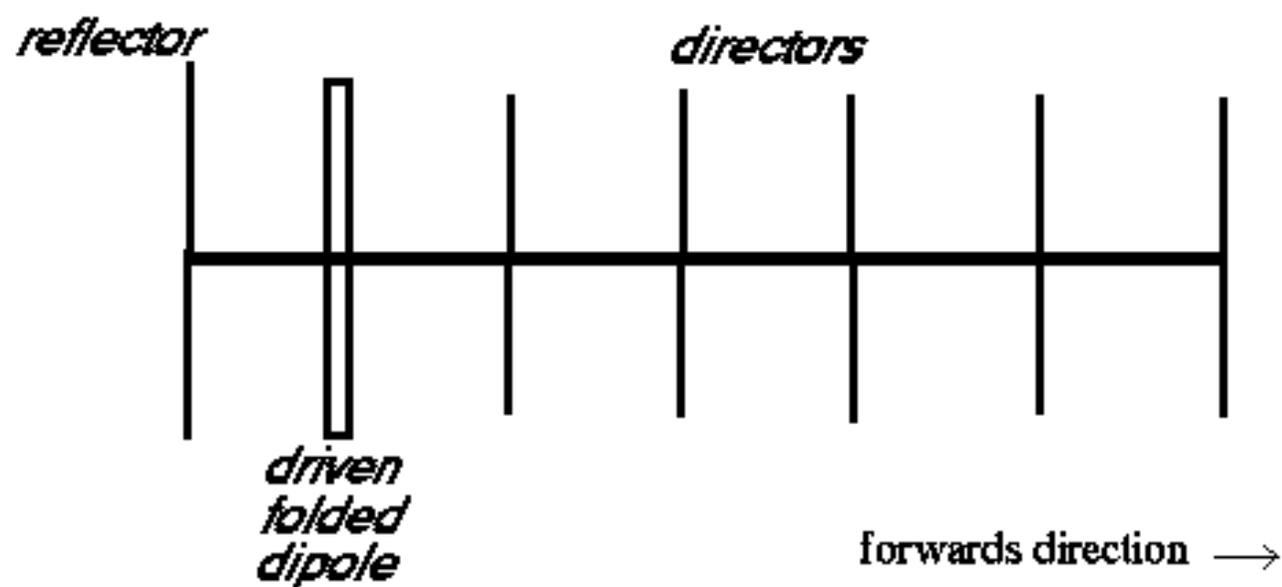
Radiation Pattern for Eight-Element Yagi

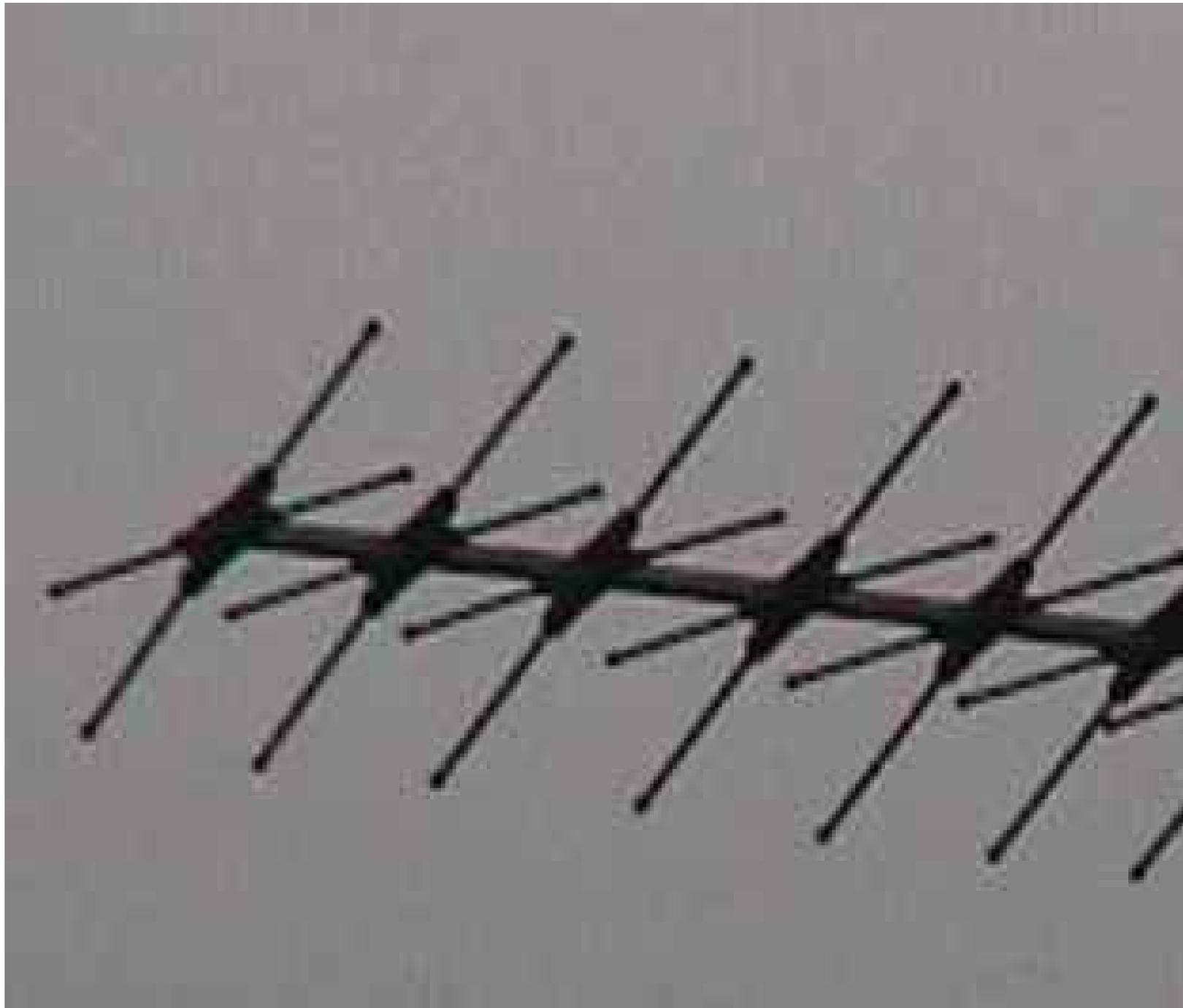


Yagi-Uda

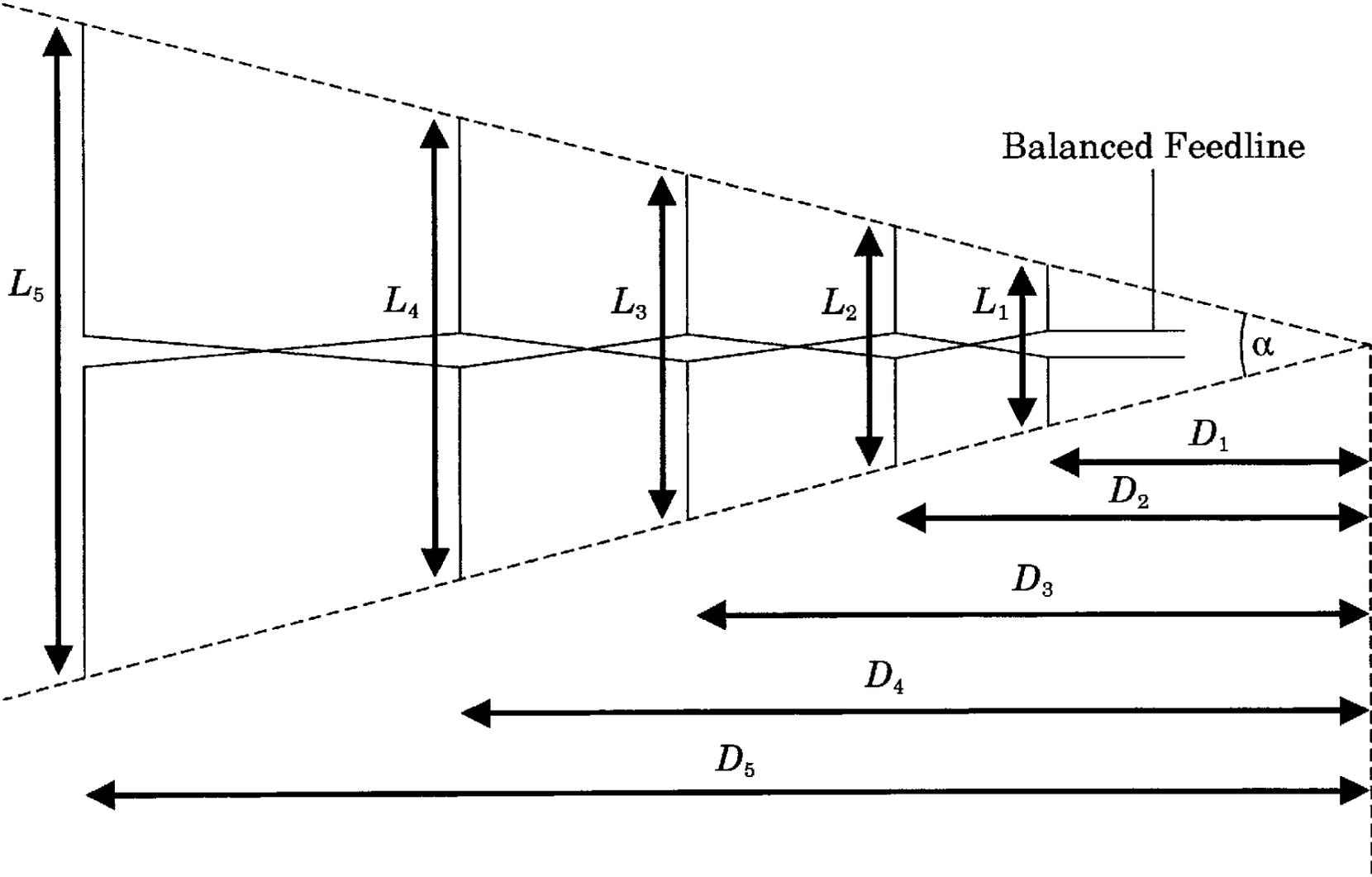
- Metal booms can be implemented because voltage is at zero midway through the element.
- Other factors that effect resonant lengths:
 - 1. A comparatively large boom will require parasitic elements to increase their length.
 - 2. Length to diameter ratio of the elements.

Seven element Yagi-Uda





Log-Periodic Dipole Array



$$\tau = \frac{L_1}{L_2} = \frac{L_2}{L_3} = \frac{L_3}{L_4} = \dots\dots$$

where L is respective element lengths

$$\tau = \frac{D_1}{D_2} = \frac{D_2}{D_3} = \frac{D_3}{D_4} = \dots\dots$$

*where D represents spacings between elements
and apex of angle closing them.*

D₁ is shortest.

$$\frac{L_1}{2D_1} = \tan \frac{\alpha}{2}$$

Alpha is the angle of the apex of tapered elements and is typically 30 degrees.

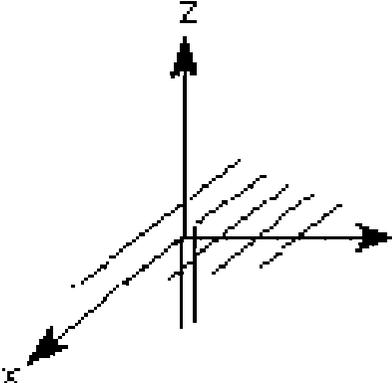
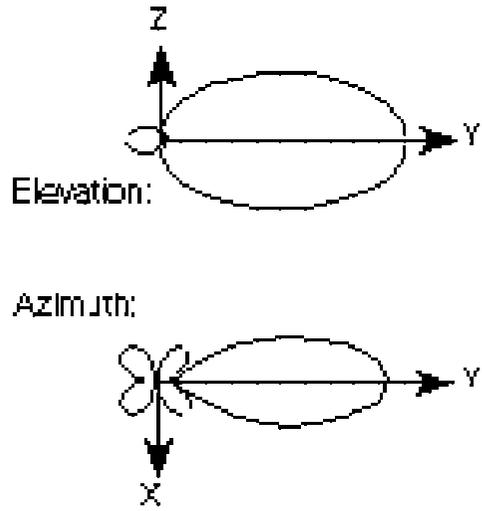
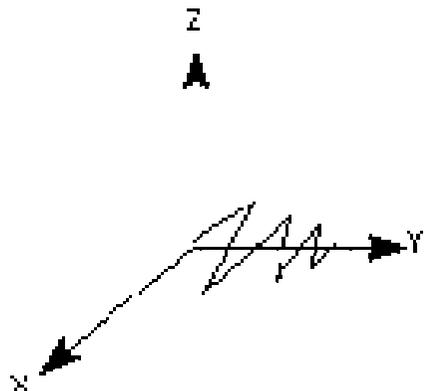
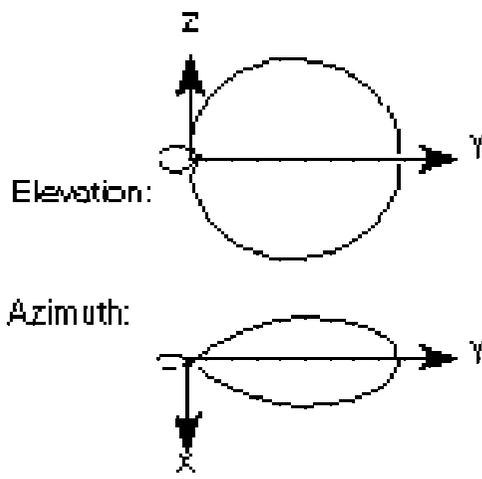
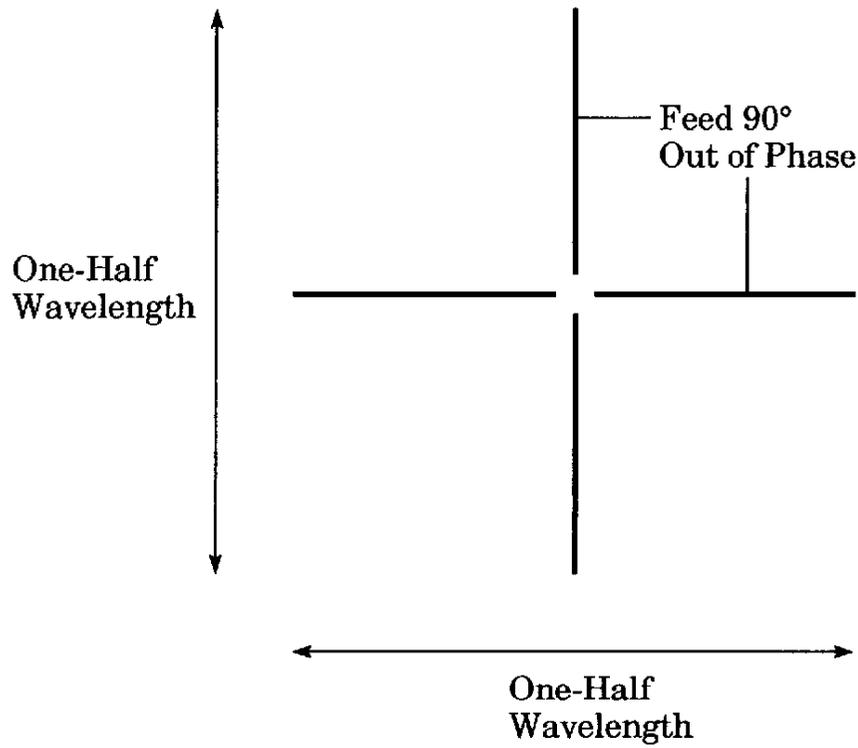
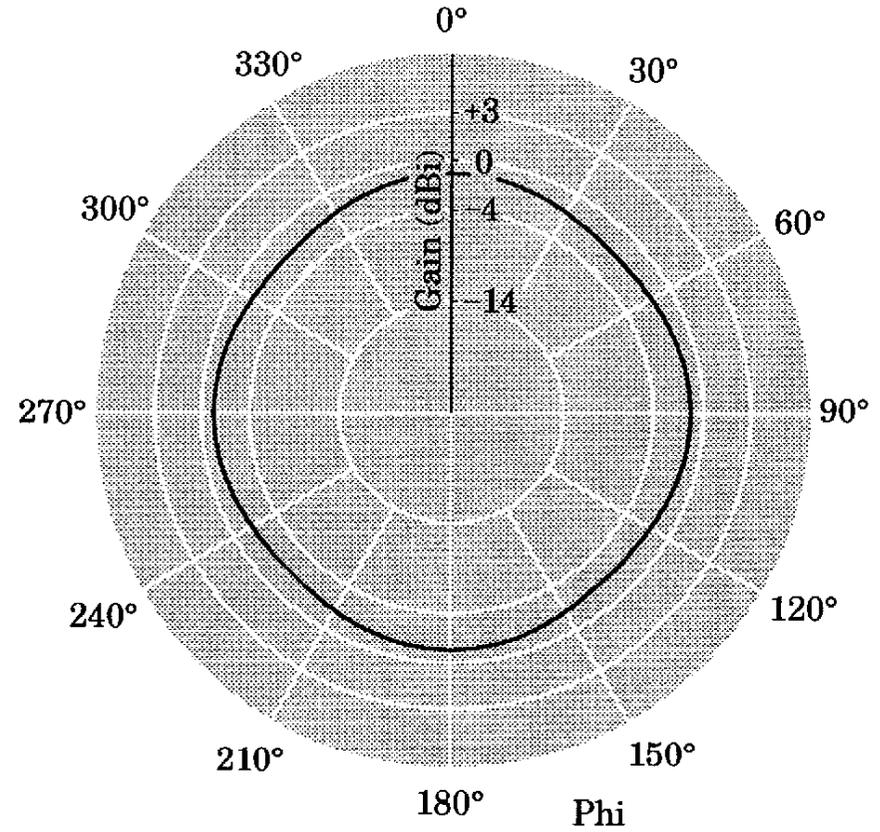
| Antenna Type | Radiation Pattern | Characteristics |
|--|---|--|
| <p>YAGI</p>  |  <p>Elevation:</p> <p>Azimuth:</p> | <p>Polarization: Linear Horizontal as shown</p> <p>Typical Half-Power Beamwidth: 50 deg X 50 deg</p> <p>Typical Gain: 5 to 15 dB</p> <p>Bandwidth: 5% or 1.05:1</p> <p>Frequency Limit: Lower: 50 MHz Upper: 2 GHz</p> |
| <p>LOG PERIODIC</p>  |  <p>Elevation:</p> <p>Azimuth:</p> | <p>Polarization: Linear</p> <p>Typical Half-Power Beamwidth: 60 deg x 80 deg</p> <p>Typical Gain: 6 to 8 dB</p> <p>Bandwidth: 163% or 10:1</p> <p>Frequency Limit: Lower: 3 MHz Upper: 18 GHz</p> <p>Remarks: This array may be formed with many shapes including dipoles or toothed arrays.</p> |

Figure 11

Turnstile Antenna



(a) Geometry

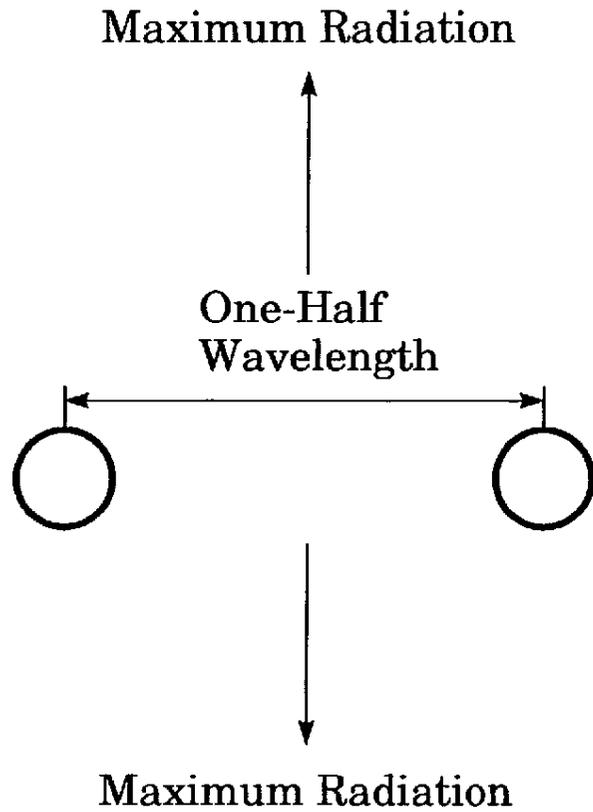


(b) Radiation Pattern

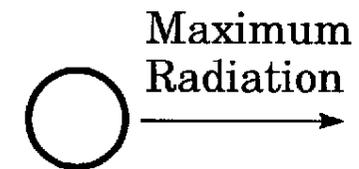
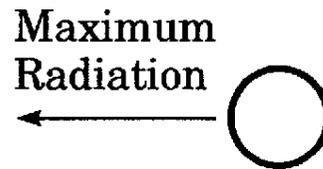
Phased Array Antennas

- To be discussed: Monopole Array
- Collinear Array
- Broadside Array
- Endfire Array

Monopole Array

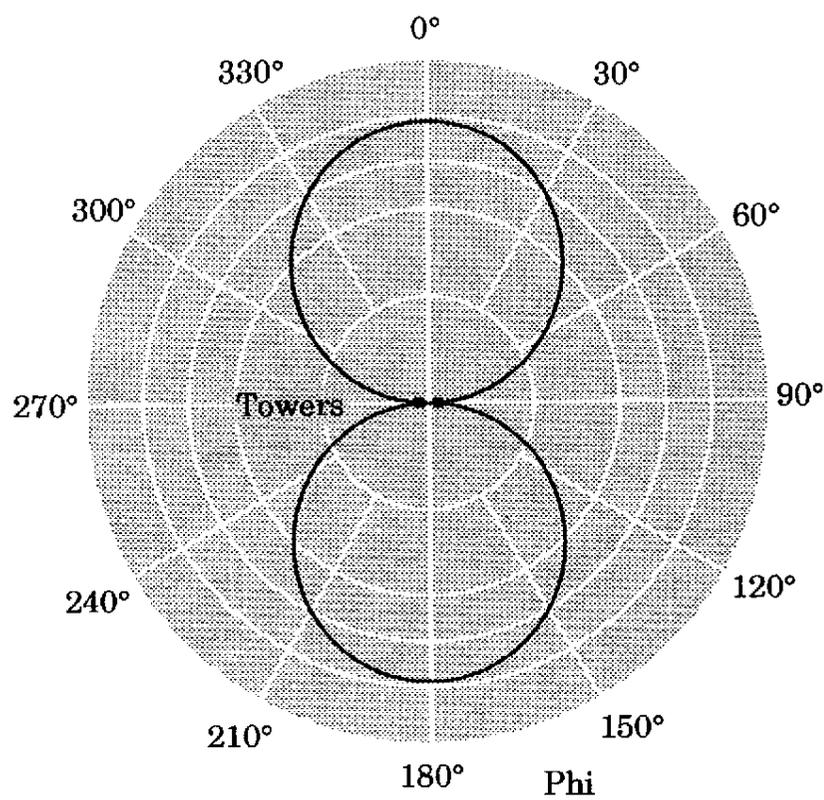


(a) Towers Fed in Phase

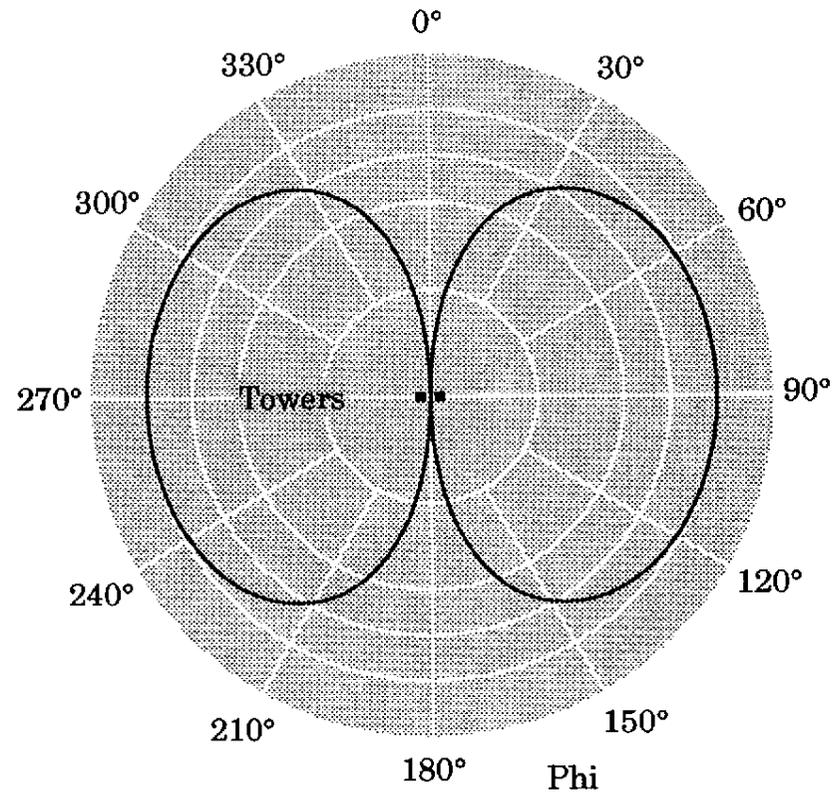


(b) 180° Out of Phase

Radiation Patterns for Monopole Arrays



(a) Two Monopoles in Phase

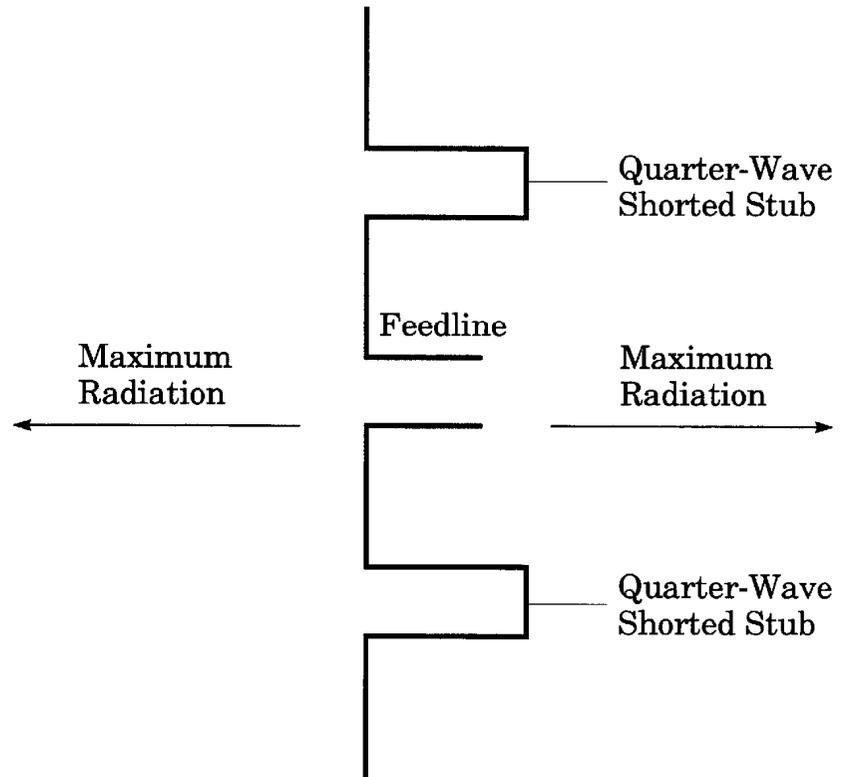


(b) Two Monopoles Out of Phase

Collinear Array

- Two or more half wavelength sections.
- A broadside array because the axes of the elements are along same line.
- Half wave sections are linked by $\frac{1}{4}$ wave transmission lines. They develop a phase reversal to keep all dipoles in phase.
- Usually vertical with an omnidirectional pattern in the horizontal plane with a narrow angle of radiation in the vertical.
- What would be a good application for this system?

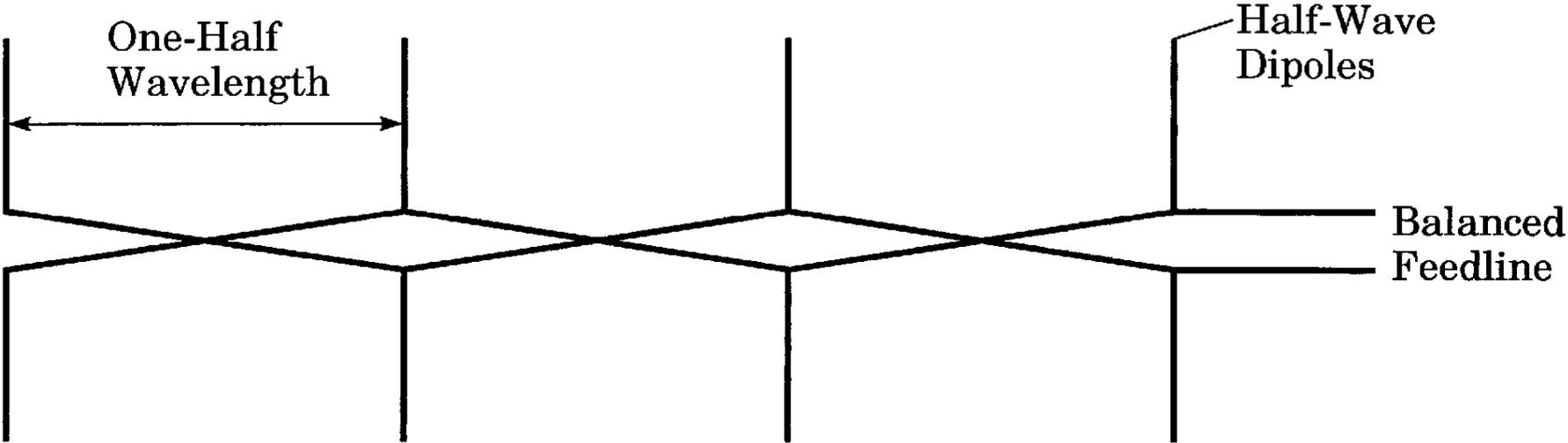
Collinear Array



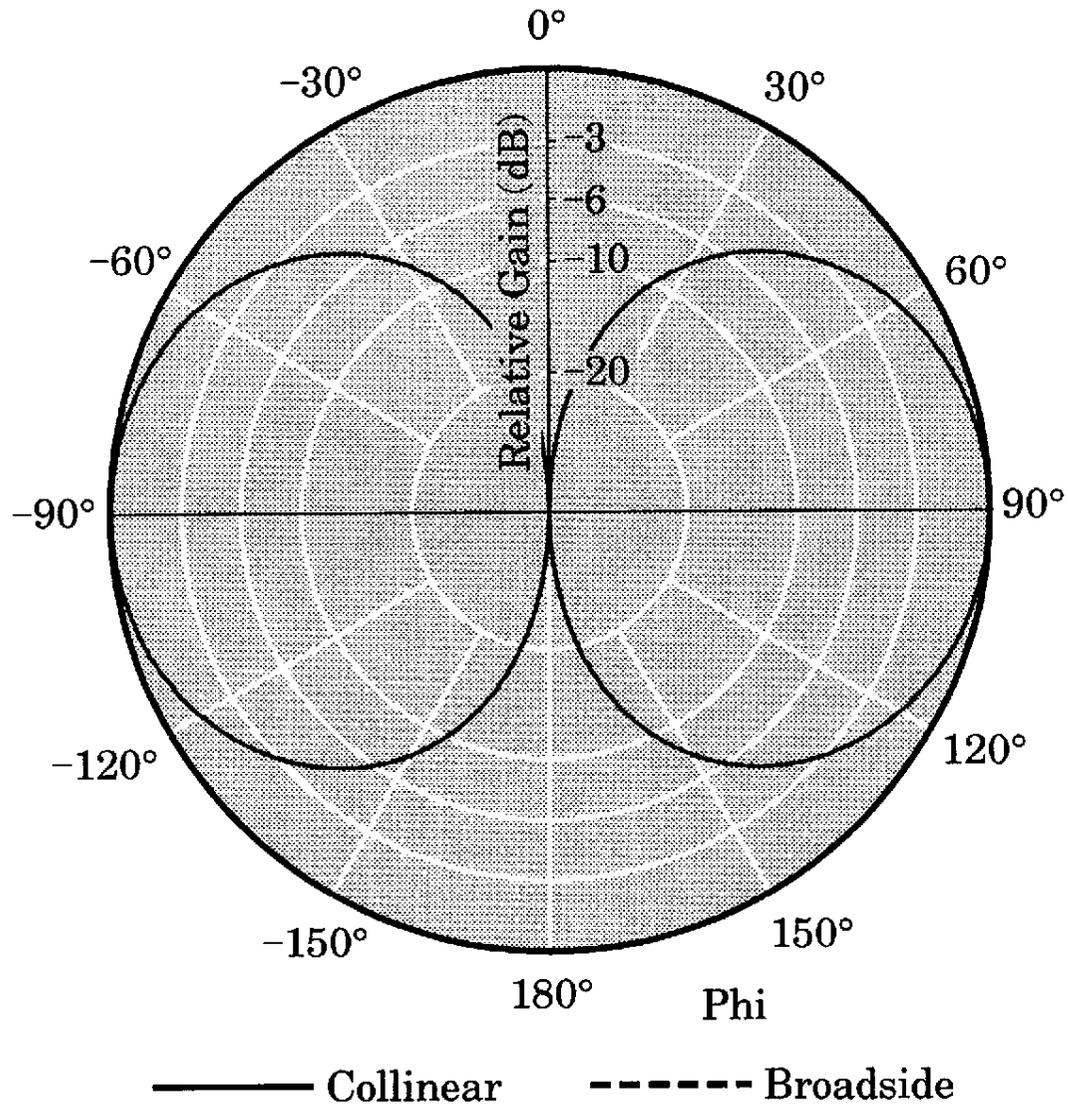
Multi-Element Broadside and Endfire Arrays

- BROADSIDE elements are spaced $\frac{1}{2}$ wavelength apart.(180 degree phase shift.
- In order to maintain a broadside presentation of the field the elements are fed out of phase.
- ENDFIRE elements are also $\frac{1}{2}$ wavelength apart
Elements are fed in phase.
- Radiation from all elements sum of the end.

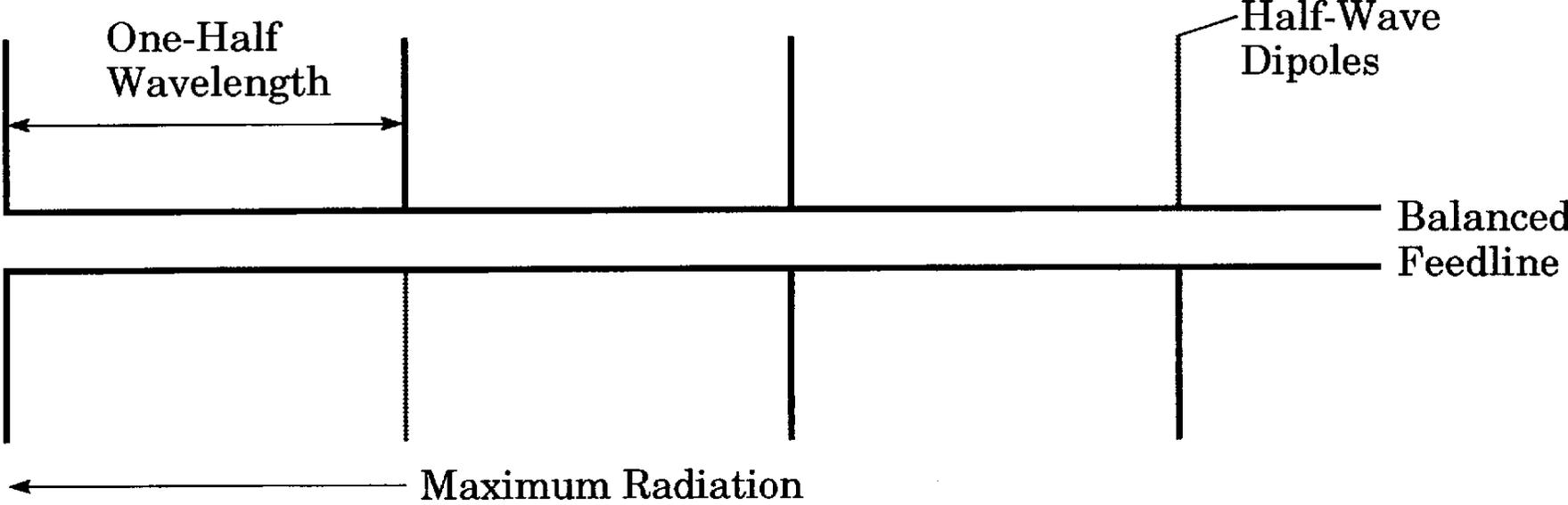
Broadside Array



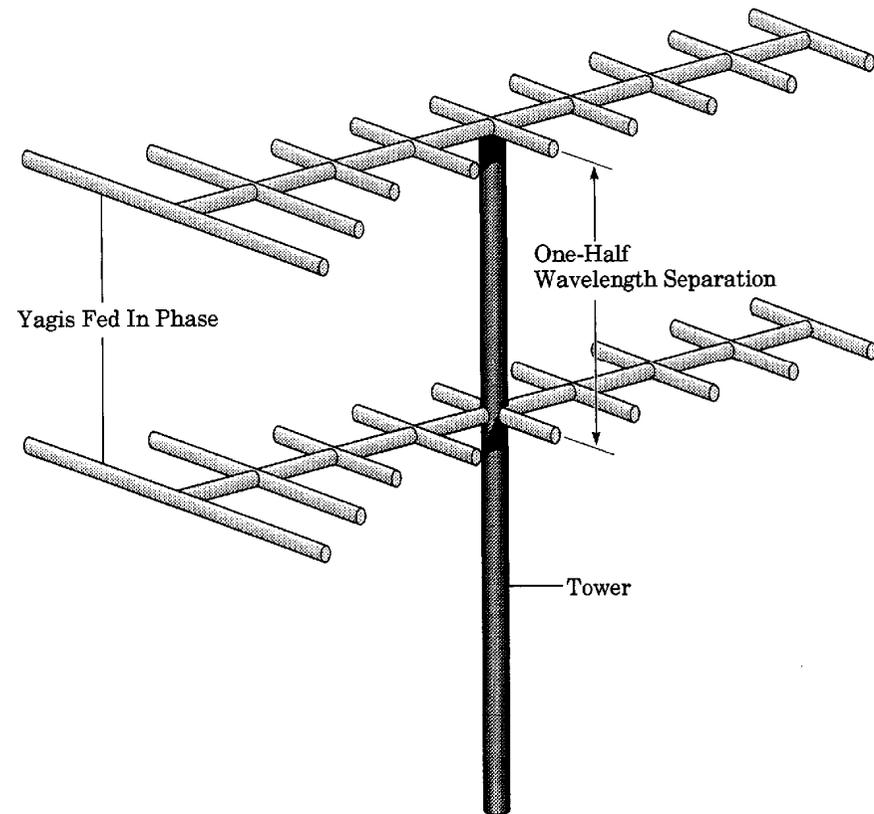
Collinear/Broadside Comparison



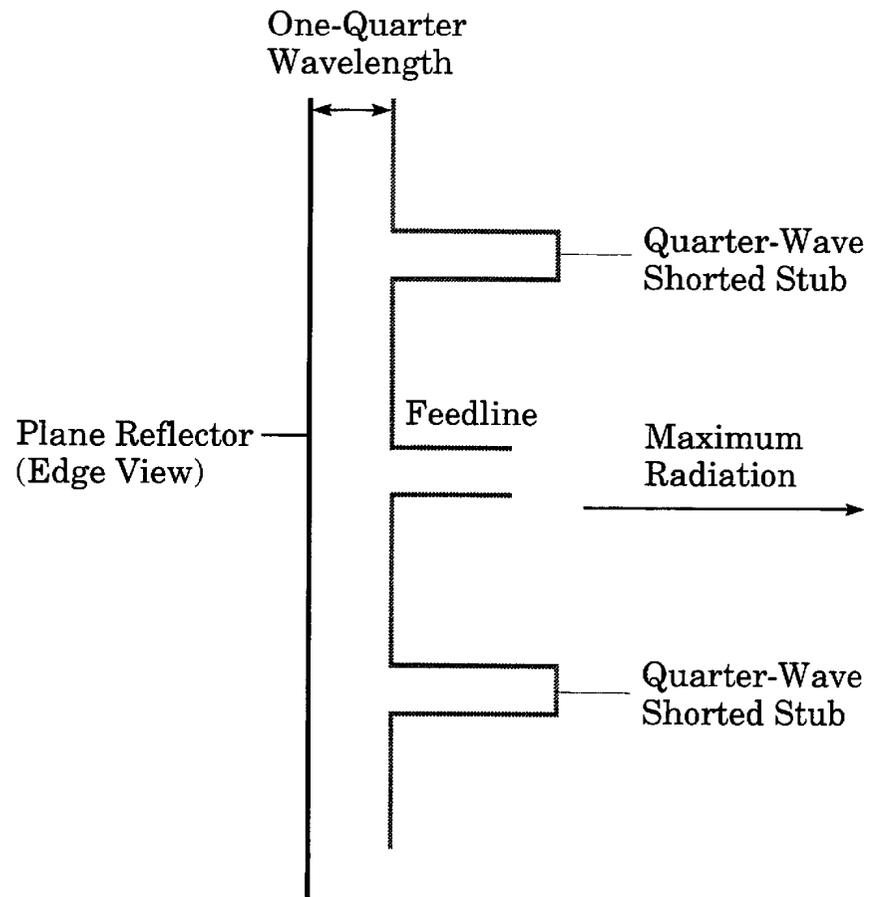
End-Fire Array



Stacked Yagis



Collinear Array with Plane Reflector



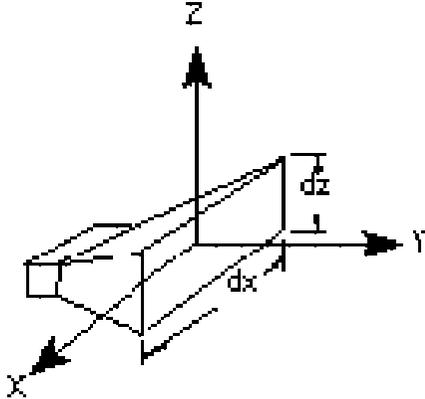
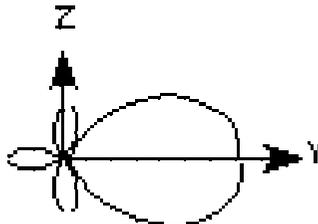
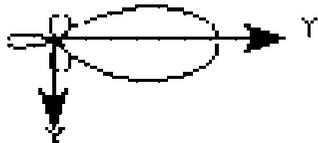
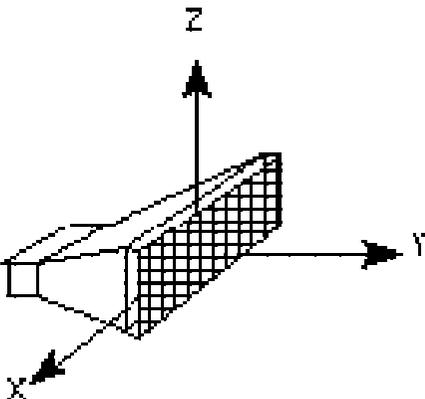
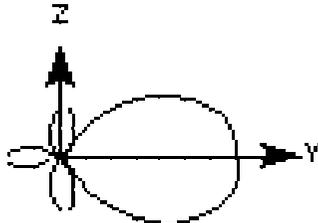
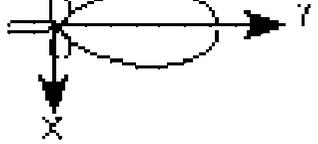
| Antenna Type | Radiation Pattern | Characteristics |
|---|---|---|
| <p>HORN</p>  | <p>Elevation:</p>  <p>3 dB beamwidth = $56 \lambda / dz$</p> <p>Azimuth:</p>  <p>3 dB beamwidth = $70 \lambda / dx$</p> | <p>Polarization: Linear</p> <p>Typical Half-Power Beamwidth: 40 deg x 40 deg</p> <p>Typical Gain: 5 to 20 dD</p> <p>Bandwidth: If ridged: 120% or 4:1 If not ridged: 67% or 2:1</p> <p>Frequency Limit Lower: 50 MHz Upper: 40 GHz</p> |
| <p>HORN W/ POLARIZER</p>  | <p>Elevation:</p>  <p>Azimuth:</p>  | <p>Polarization: Circular, Depends on polarizer</p> <p>Typical Half-Power Beamwidth: 40 deg x 40 deg</p> <p>Typical Gain: 5 to 10 dB</p> <p>Bandwidth: 60% or 2:1</p> <p>Frequency Limit Lower: 2 GHz Upper: 18 GHz</p> |

Figure 9

Parabolic Reflector

- Gain is a function of parabolic reflector diameter, surface accuracy and illumination of the reflector by the feed mechanism.(focal point)
- Optimum illumination occurs when the power at the reflector edge is 10 dB less than at the centre.
- F/D ratios of 0.4 to 0.6 will deliver maximum gains.
- A collimated beam of radiation will be produced.

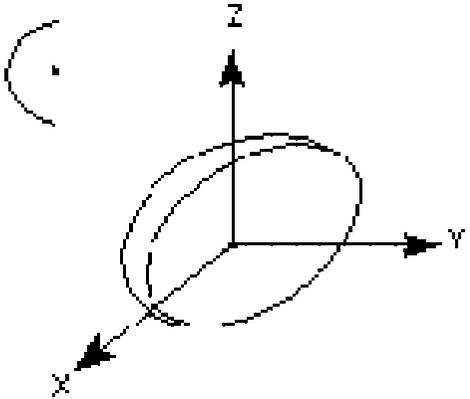
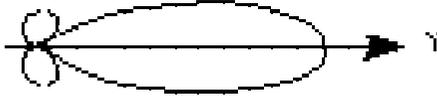
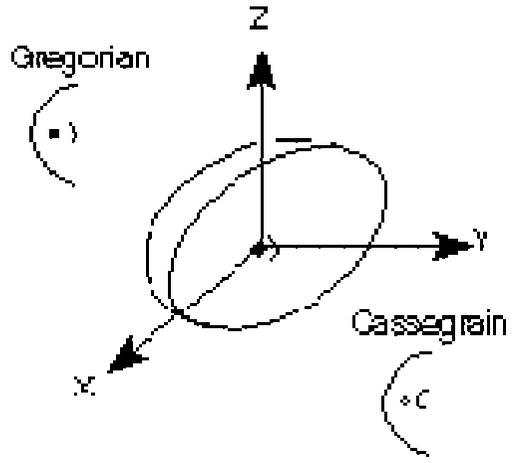
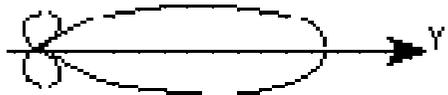
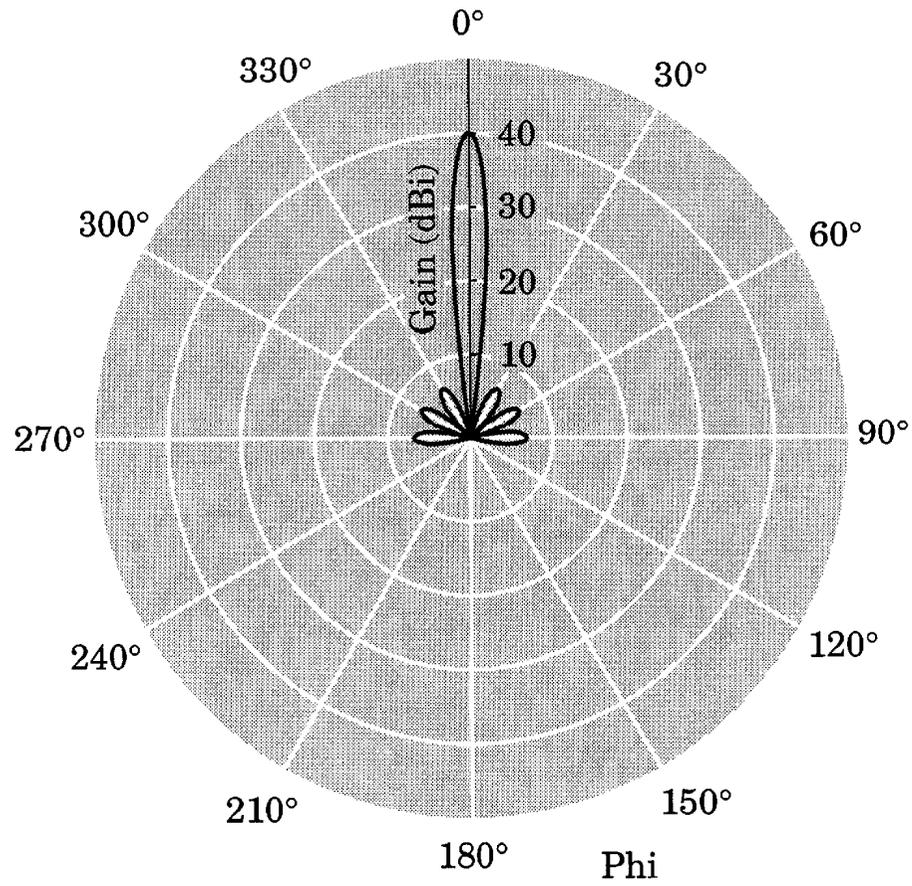
| Antenna Type | Radiation Pattern | Characteristics |
|--|---|--|
| <p>PARABOLIC (Prime)</p>  | <p>Elevation & Azimuth</p>  | <p>Polarization: Takes polarization of feed</p> <p>Typical Half-Power Beamwidth: 1 to 10 deg</p> <p>Typical Gain: 20 to 30 dB</p> <p>Bandwidth: 33% or 1.4:1 limited mostly by feed</p> <p>Frequency Limit: Lower: 400 MHz Upper: 13+ GHz</p> |
| <p>PARABOLIC</p>  | <p>Elevation & Azimuth</p>  | <p>Polarization: Takes polarization of feed</p> <p>Typical Half-Power Beamwidth: 1 to 10 deg</p> <p>Typical Gain: 20 to 30 dB</p> <p>Bandwidth: 33% or 1.4:1</p> <p>Frequency Limit: Lower: 400 MHz Upper: 13+ GHz</p> |

Figure 10



Polar Pattern for Typical Parabolic Antenna



$$G = \frac{\eta \pi^2 D^2}{\lambda^2}$$

where G is the *power RATIO* with respect to isotropic radiator

η = efficiency

λ = free space wavelength

$$\theta = \frac{70\lambda}{D} \quad \text{Beamwidth}$$

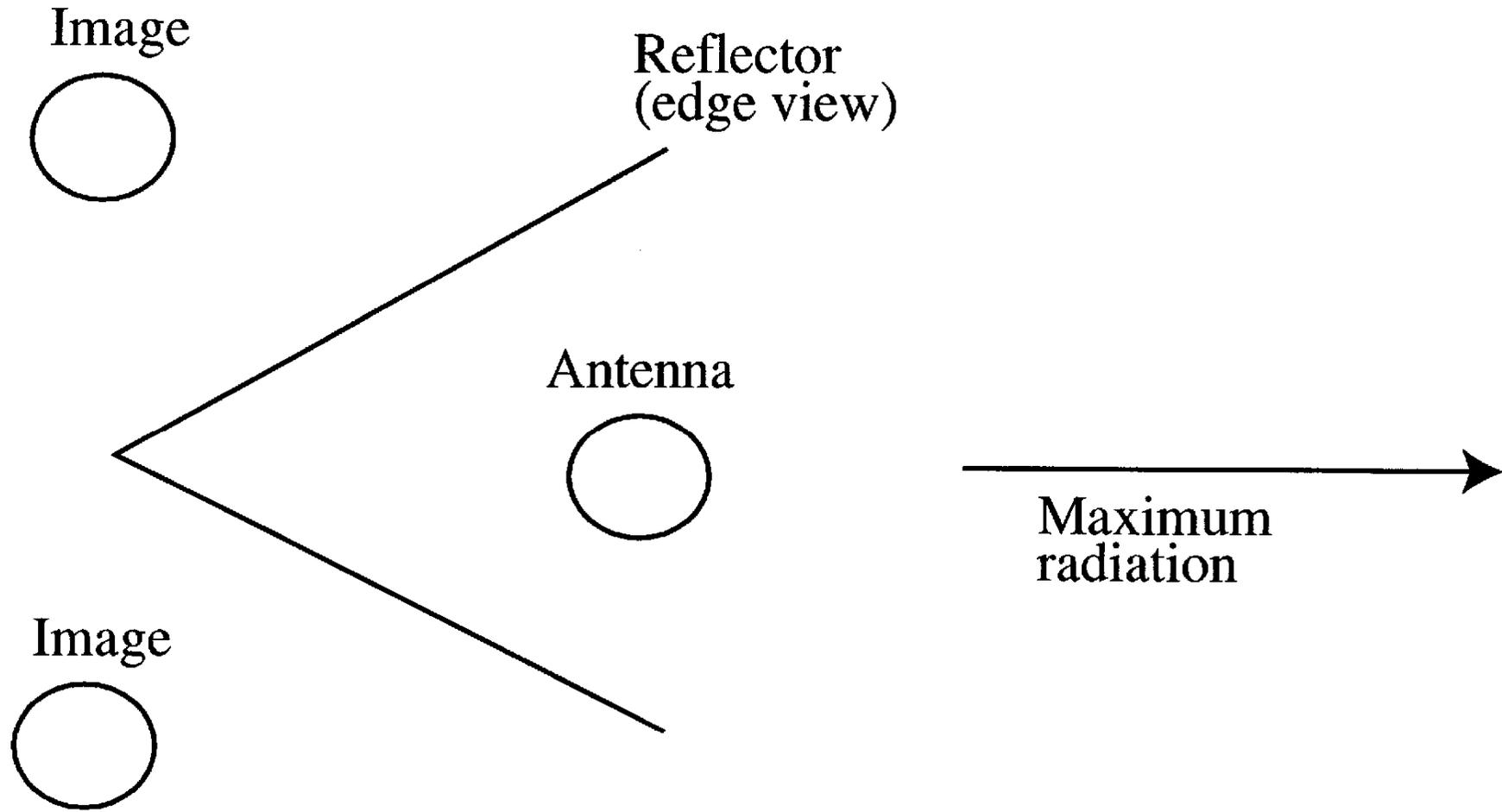
$$f = \frac{D^2}{16d}$$

f = focal point

D = dish diameter

D = depth from plane at mouth of dish to vertex.

Corner Reflector and Images



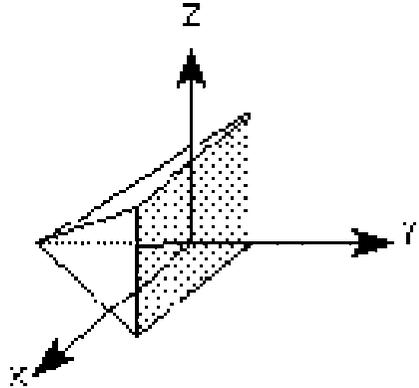
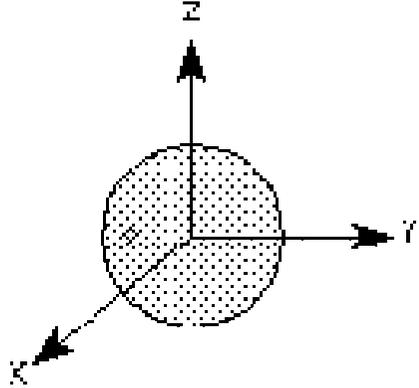
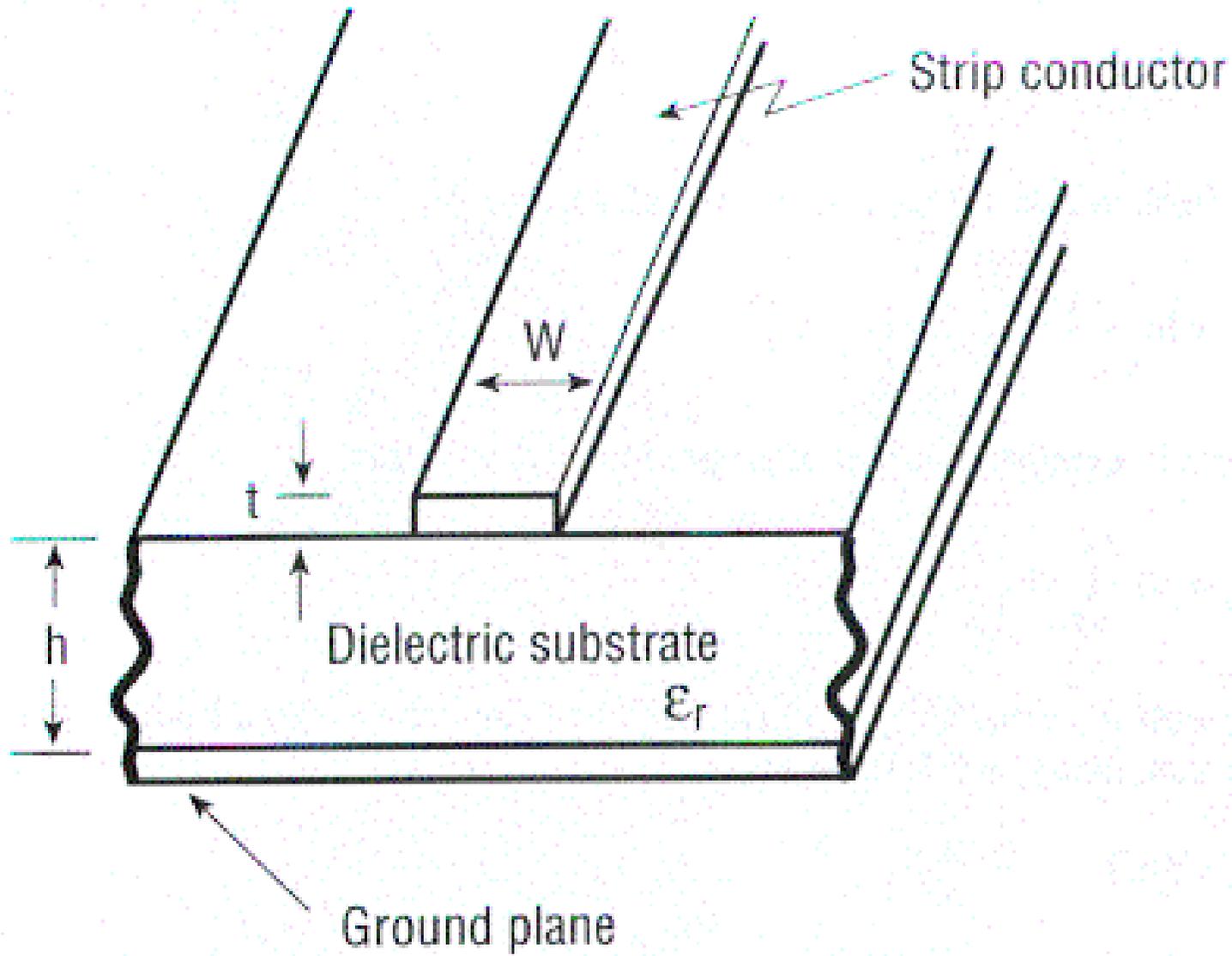
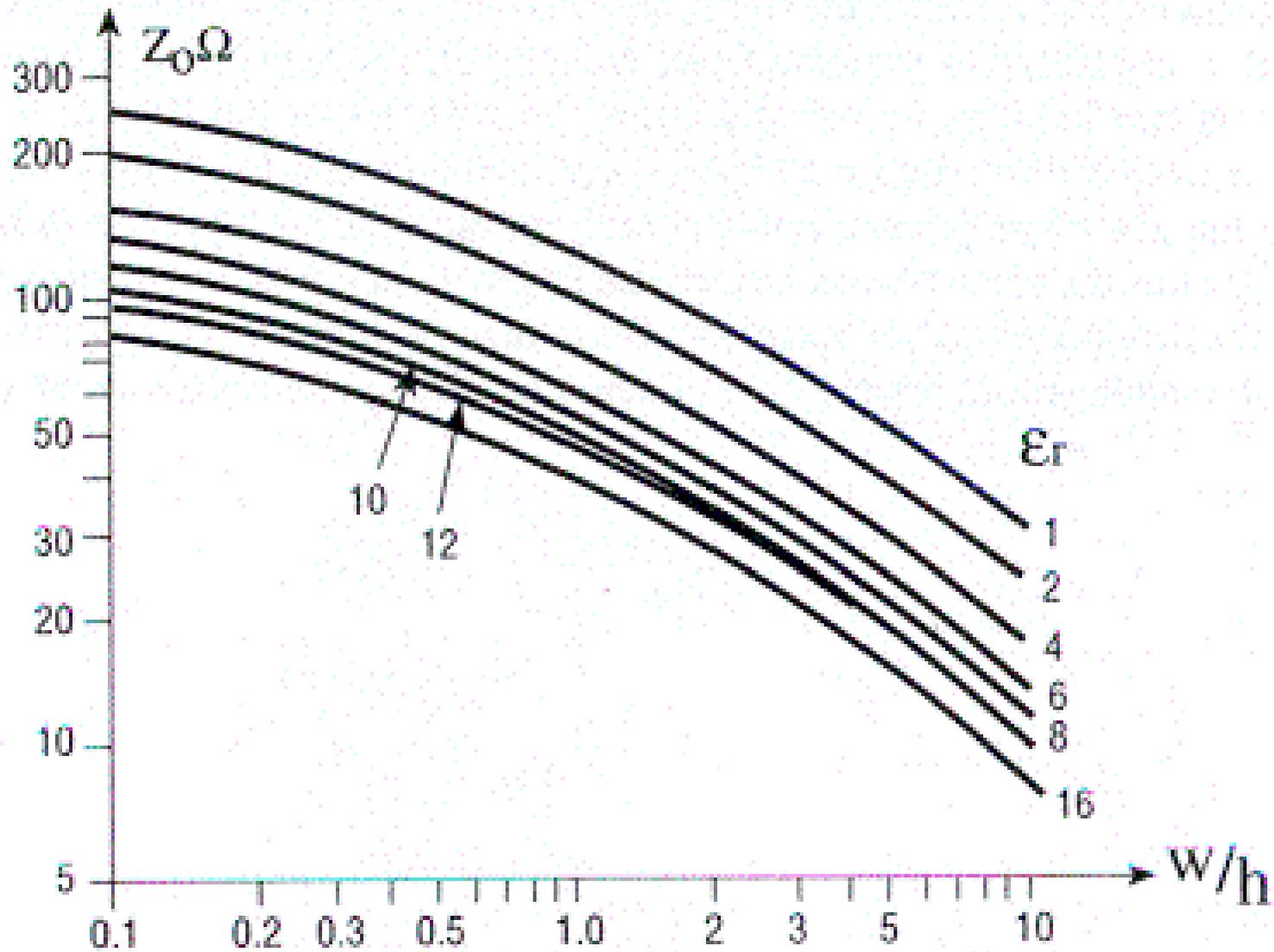
| Antenna Type | Radiation Pattern | Characteristics |
|---|---|---|
| <p data-bbox="277 268 658 308">CORNER REFLECTOR</p>  | <p data-bbox="837 448 1061 517">Elevation: $\{Z-Y\}$ Azimuth: $\{X-Y\}$</p> <p data-bbox="913 563 1323 595">Dependent upon feed emitter</p> | <p data-bbox="1406 240 1637 308">Polarization: Feed dependent</p> <p data-bbox="1406 344 1854 411">Typical Half-Power Beamwidth: 40 deg x variable</p> <p data-bbox="1406 448 1854 480">Typical Gain: 10 dB above feed</p> <p data-bbox="1406 517 1697 549">Bandwidth: Narrow</p> <p data-bbox="1406 585 1653 684">Frequency Limit Lower: 1 GHz Upper: 40 GHz</p> <p data-bbox="1406 721 1928 788">Remarks: Typically fed with a dipole or collinear array.</p> |
| <p data-bbox="286 863 595 903">LUNEBURG LENS</p>  | <p data-bbox="846 1031 1010 1098">Elevation & Azimuth</p>  | <p data-bbox="1406 855 1653 922">Polarization: Feed dependent</p> <p data-bbox="1406 959 1877 1026">Typical Half-Power Beamwidth: System dependent</p> <p data-bbox="1406 1062 1899 1094">Typical Gain: System dependent</p> <p data-bbox="1406 1131 1704 1163">Bandwidth: Narrow</p> <p data-bbox="1406 1200 1659 1299">Frequency Limit Lower: 1 GHz Upper: 40 GHz</p> <p data-bbox="1406 1335 1906 1402">Remarks: Variable index dielectric sphere.</p> |

Figure 14

MICROSTRIP LINE



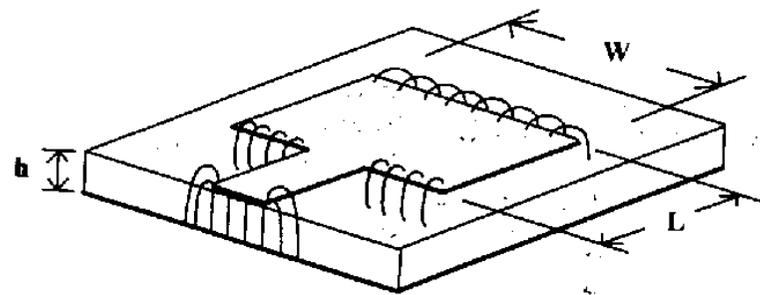
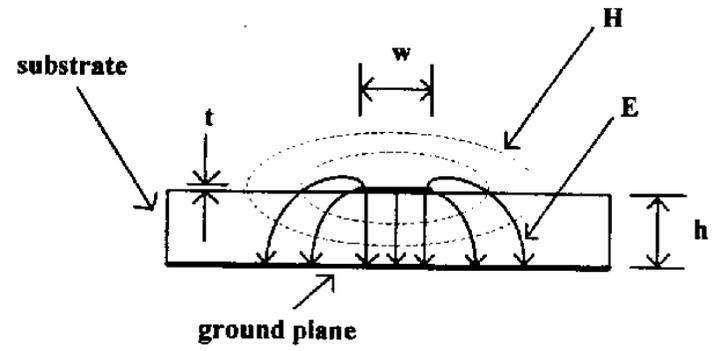
Microstrip Dimensions



Variation of Z_0 for Different Dielectric Constants and Aspect Ratio

Microstrip Antennas

- MICROSTRIP LINE:
- In a microstrip line most of the electric field lines are concentrated underneath the microstrip.
- Because all fields do not exist between microstrip and ground plane we have a different dielectric constant than that of the substrate. It is less, depending on geometry.
- The electric field underneath the microstrip line is uniform across the line. It is possible to excite an undesired transverse resonant mode if the frequency or line width increases. It now behaves like a resonator consuming power.
- A standing wave develops across its width as it acts as a resonator. The electric field is at a maximum at both edges and goes to zero in the centre.



Microstrip antennas

- Microstrip discontinuities can be used to advantage.
- Abrupt truncation of microstrip lines develop fringing fields storing energy and acting like a capacitor because changes in electric field distribution are greater than that for magnetic field distribution.
- The line is electrically longer than its physical length due to capacitance.
- For a microstrip patch the width is much larger than that of the line the fringing fields also radiate.
- An equivalent circuit for a microstrip patch illustrates a parallel combination of conductance and capacitance at each edge.
- Radiation from the patch is linearly polarized with the E field lying in the same direction as path length.

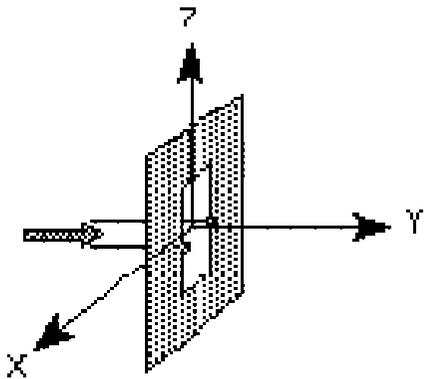
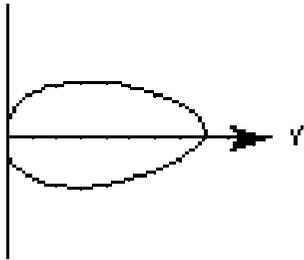
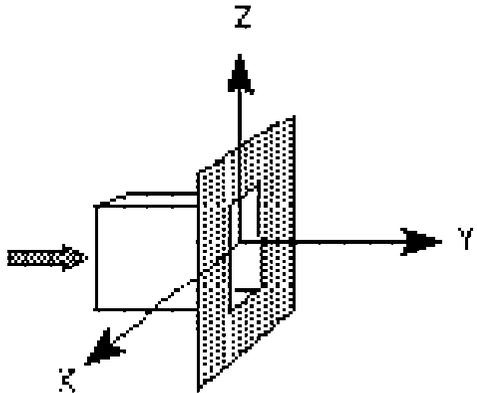
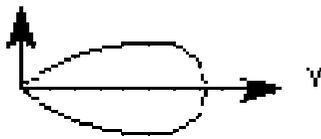
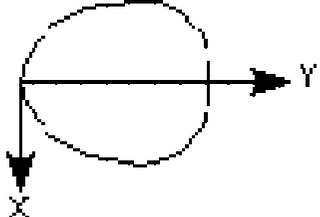
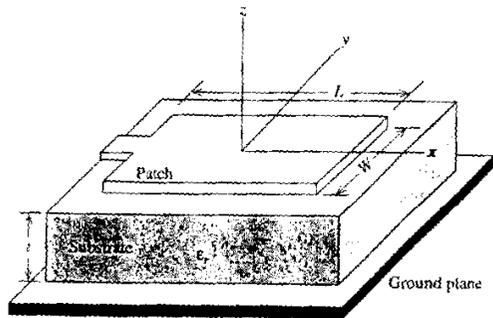
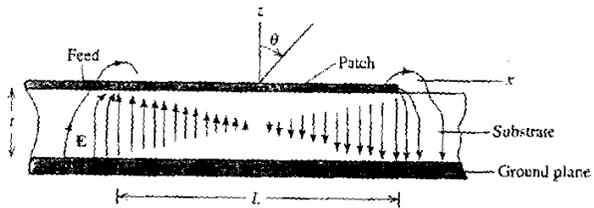
| Antenna Type | Radiation Pattern | Characteristics |
|--|--|---|
| <p>CAVITY BACKED CIRCUIT FED SLOT (and Microstrip Patch)</p>  | <p>Elevation & Azimuth</p>  | <p>Polarization: Linear, vertical as shown</p> <p>Typical Half Power Beamwidth: 80 deg x 80 deg</p> <p>Typical Gain: 6 dB</p> <p>Bandwidth: Narrow</p> <p>Frequency Limit Lower: 50 MHz Upper: 18 GHz</p> <p>Remarks: The feed line is sometimes separated from the radiator by a dielectric & uses capacitive coupling. Large conformal phased arrays can be made this way.</p> |
| <p>GUIDE FED SLOT</p>  | <p>Elevation:</p>  <p>Azimuth:</p>  | <p>Polarization: Linear,</p> <p>Typical Half-Power Beamwidth Elevation: 45-50° Azimuth: 80°</p> <p>Typical Gain: 0 dB</p> <p>Bandwidth: Narrow</p> <p>Frequency Limit Lower: 2 GHz Upper: 40 GHz</p> <p>Remarks: Open FF Waveguide</p> |

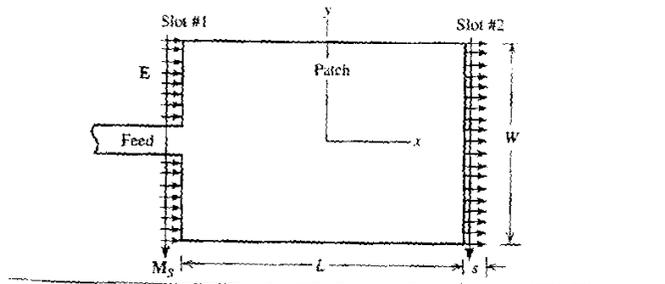
Figure 13

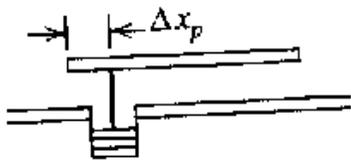


(a) Geometry for analyzing the edge-fed microstrip patch antenna.

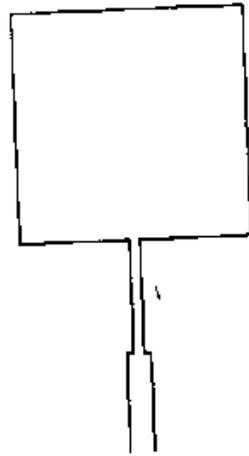


(b) Side view showing the electric fields.

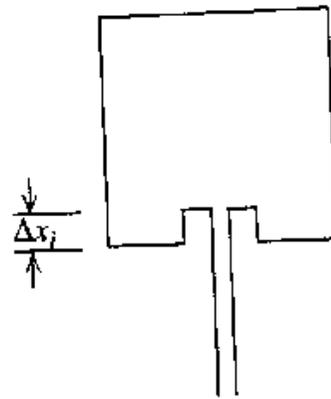




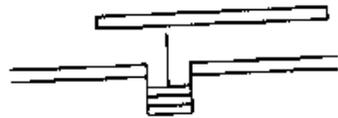
(a) Probe feed.



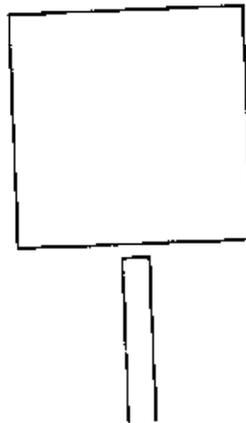
(b) Microstrip edge feed with quarter-wave transformer.



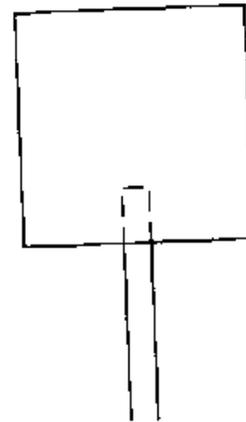
(c) Microstrip edge feed with inset.



(d) Probe feed with a gap.



(e) Microstrip edge feed with gap.



(f) Two-layer feed.

$$\lambda = \frac{\lambda_o}{\sqrt{\epsilon_{re}}}$$

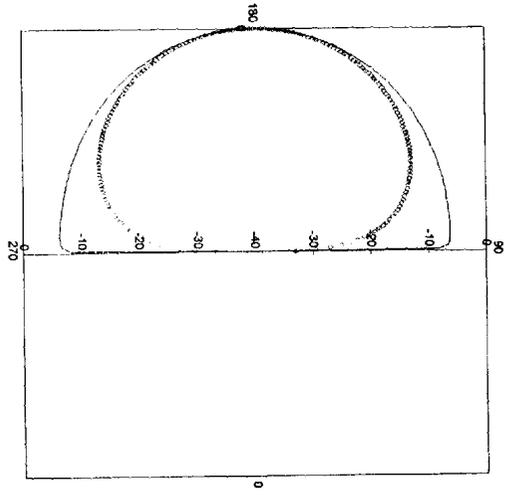
where λ_o is free space wavelength

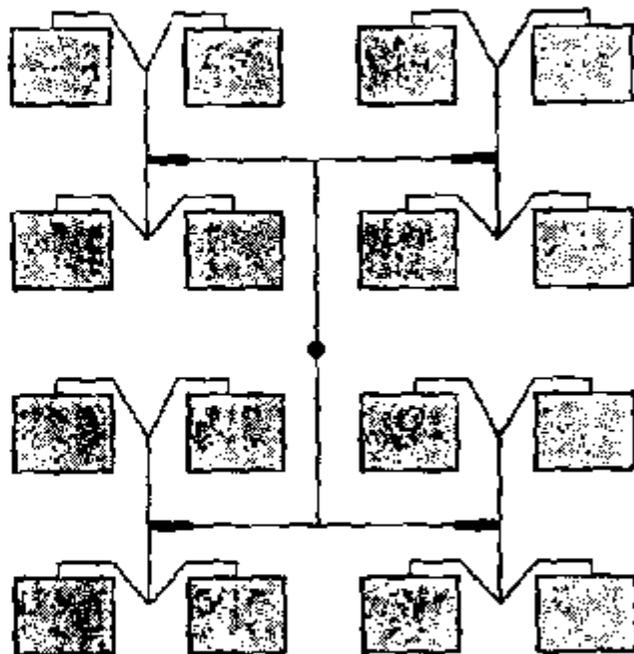
ϵ_{re} = relative dielectric constant

$$L = 0.5 \lambda_o / \sqrt{\epsilon_{re}}$$

$$\epsilon_{effr} = 0.5 \left[(\epsilon_r + 1) + (\epsilon_r - 1) \left(1 + \frac{12H}{W} \right)^{-1/2} \right]$$

$$W = 0.5 \text{ to } 2 \times L$$

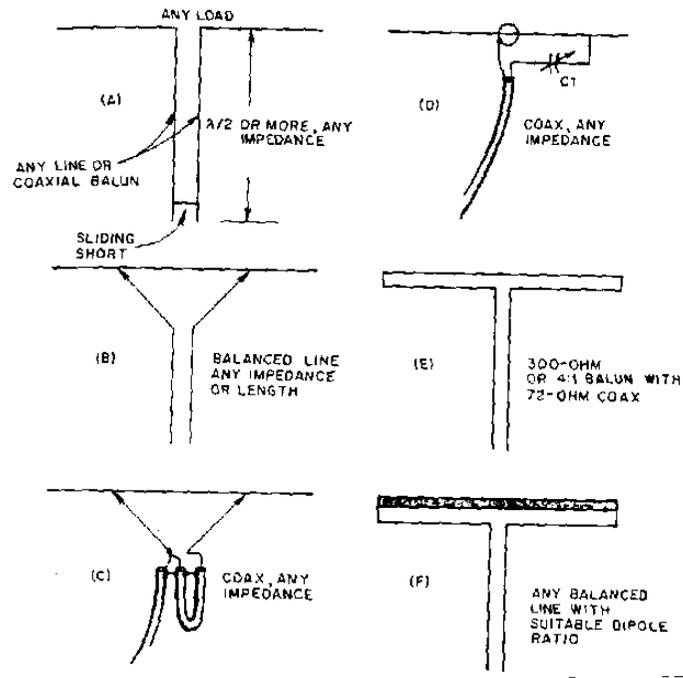




A 16-element array formed from subarrays.

Matching Techniques

- Balun
- Lumped components
- Gamma Match
- Delta Match
- Loading Coil
- Capacitive Hat



Essential Antenna Performance Specifications

- Gain and Directivity
- Bandwidth
- Field Patterns
- Beamwidth
- Impedance
- Front to Back Ratio
- Polarization