Antennas

Course Coordinator:

Prof. Girish Kumar
Electrical Engineering Department, IIT Bombay

gkumar@ee.iitb.ac.in
(022) 2576 7436

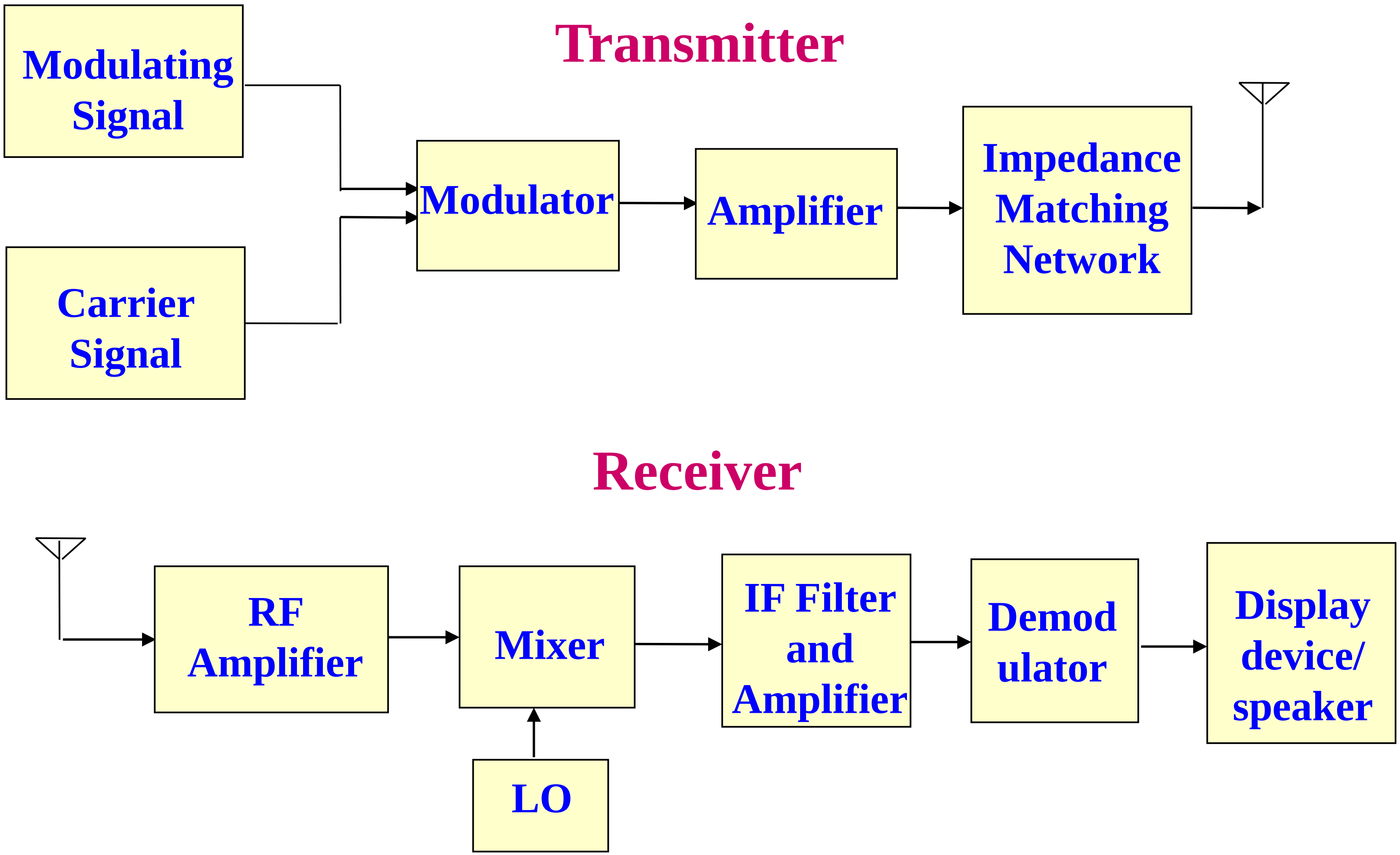
Course Outline

- Introduction to Antennas
- Dipole, Monopole, Loop and Slot Antennas
- Linear and Planar Arrays
- Microstrip Antennas
- Helical Antennas
- Horn Antennas
- Reflector Antennas
- Yagi-Uda and Log-Periodic Antennas

Reference Books

1. C.A. Balanis, *Antenna Theory – Analysis and Design*, John Wiley, 2005
2. J.D. Kraus and R.J. Marhefka, *Antennas*, McGraw Hill, 2003
3. G. Kumar and K.P. Ray, *Broadband Microstrip Antennas*, Artech House, 2003
4. J.R. James and P.S. Hall, *Handbook of Microstrip Antennas*, Peter Peregrinus, 1989
5. W.L. Stutzman and G.A. Thiele, *Antenna Theory and Design*, John Wiley, 2012
6. R.C. Johnson, *Antenna Engineering Handbook*, McGraw Hill,1993

Antennas in Wireless Communication Systems



Antennas for Various Applications

- MW Radio – Frequency: 530 to 1620 kHz (use $\lambda/4$ monopole antenna)
- Cell Phones – CDMA, GSM900, GSM1800, 3G, 4G, Wi-Fi/Bluetooth (use monopole, normal mode helical, microstrip antenna, etc.)
- Cell Towers (use monopole, dipole, microstrip antenna arrays, etc.)
- Satellite and Defense Communications (use microstrip, horn, spiral, helical, reflector, Yagi-Uda, log-periodic antennas, etc.)

Antenna Radiation Pattern

Radiation Pattern:

Isotropic

Omni-directional

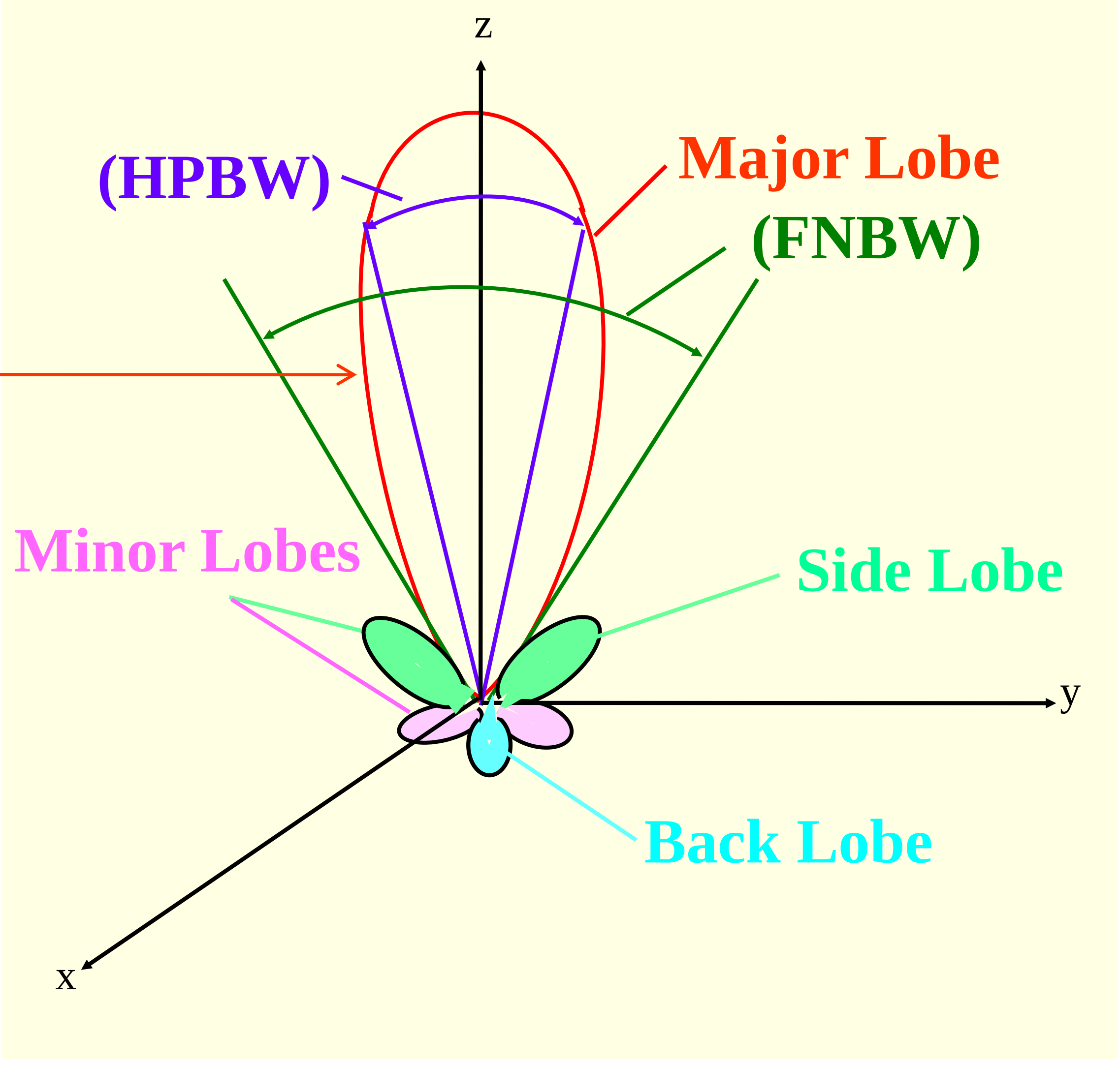
Directional

Polarization:

Linear (H or V)

Elliptical

Circular



Antenna Fundamentals

Gain and Directivity of the Antenna

$$D = \frac{41253}{\theta_E \theta_H}$$ $= 4\pi A / \lambda^2$

Gain = η D

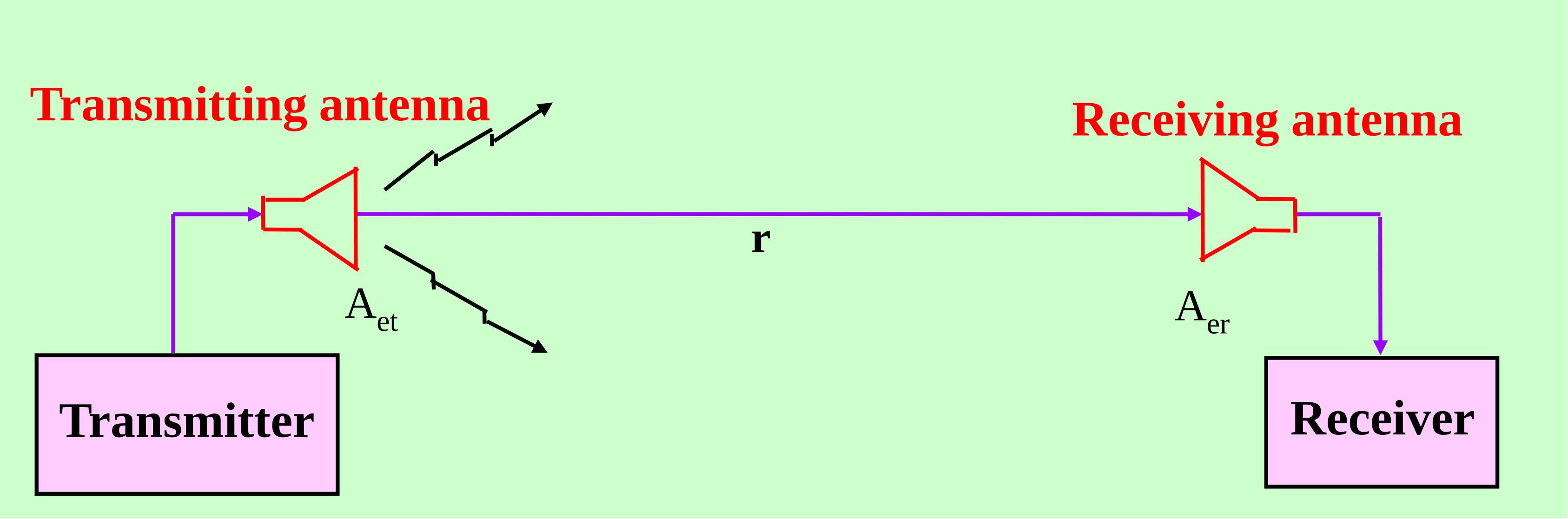
Reflection Coefficient and VSWR

$$\Gamma = \frac{Z_A - Z_0}{Z_A + Z_0}$$

$$\mathrm{VSWR} = \frac{V_{max}}{V_{min}} = \frac{1+|\Gamma|}{1-|\Gamma|}$$

Bandwidth of the Antenna: Frequency range over which VSWR $\leq$ 2 (corresponds to $|\Gamma| = 1/3$, $P_r = 1/9 = 11.1\%$)

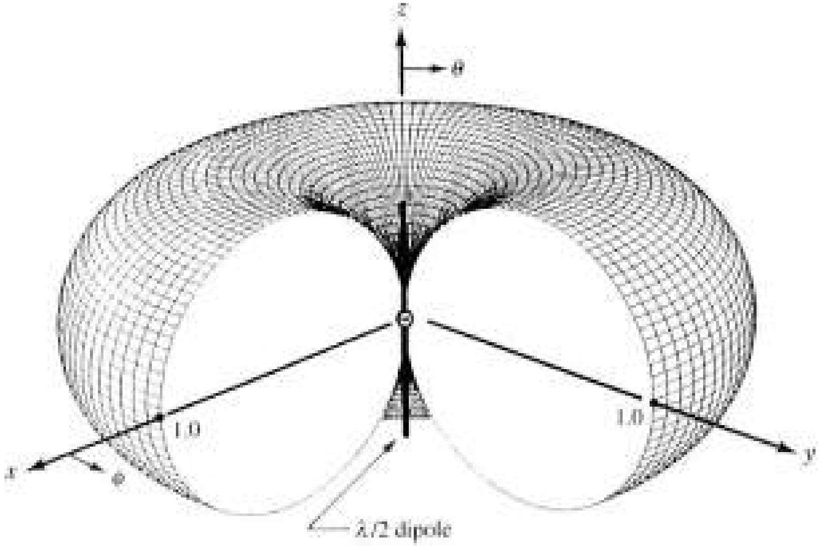
Link Budget



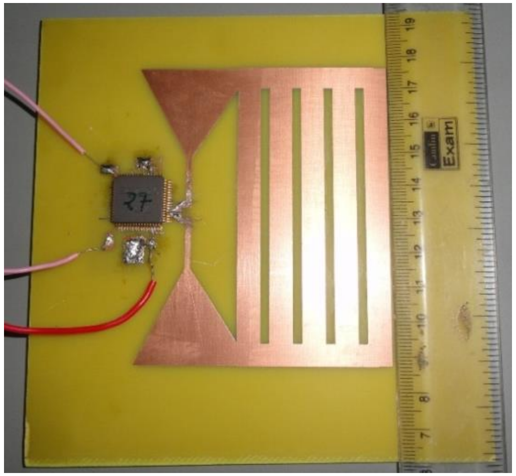
Friis Transmission Equation

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi r} \right)^2 (\text{Watt})$$

Dipole Antennas



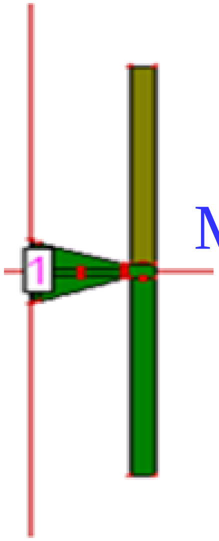
Radiation Pattern of a Dipole Antenna



Folded Broadband Dipole Antenna for RF Harvesting

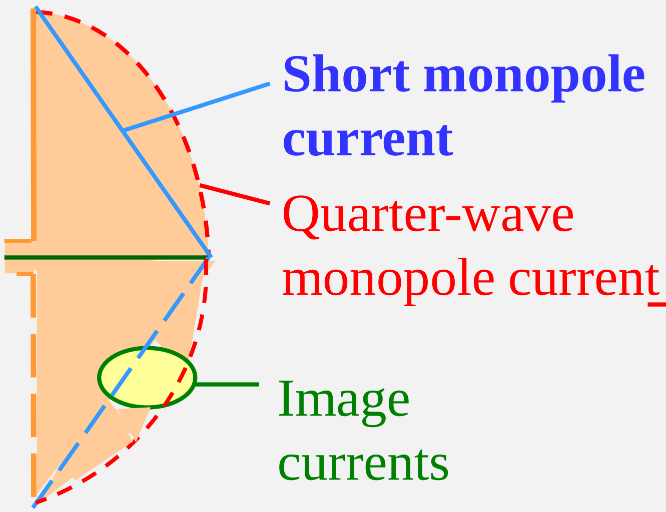
Chip

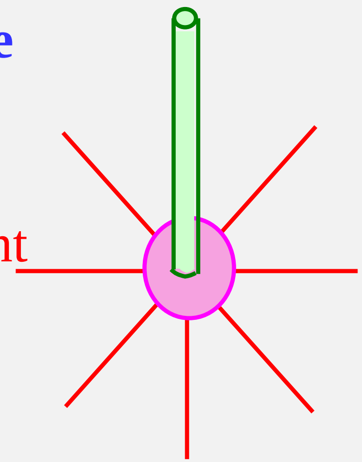
Dipole Antenna for RFID

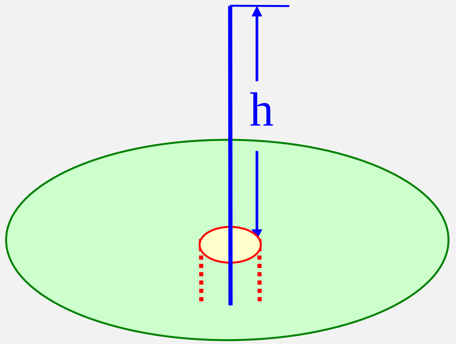


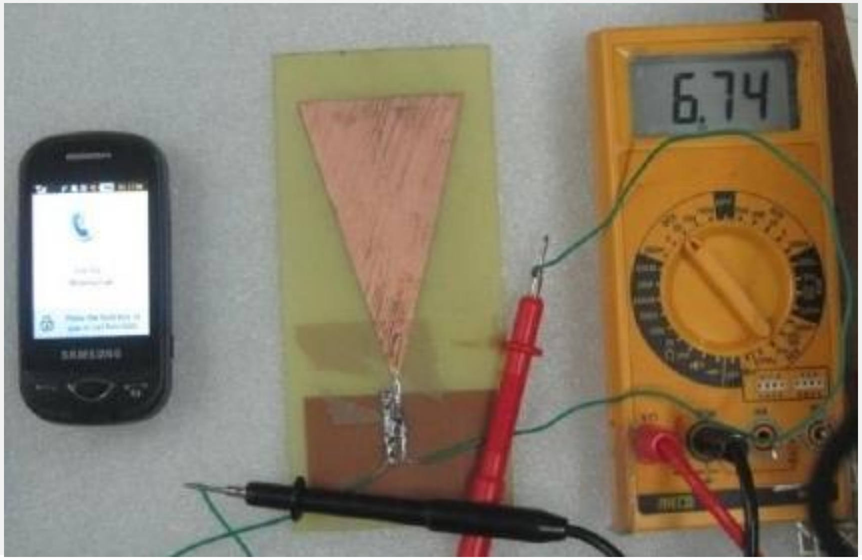
Microstrip line fed Dipole Antenna

Monopole Antennas



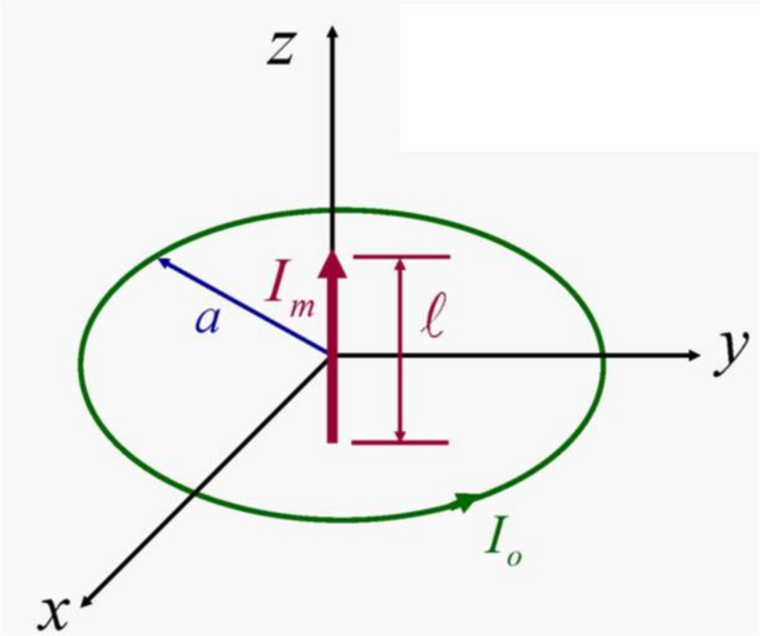




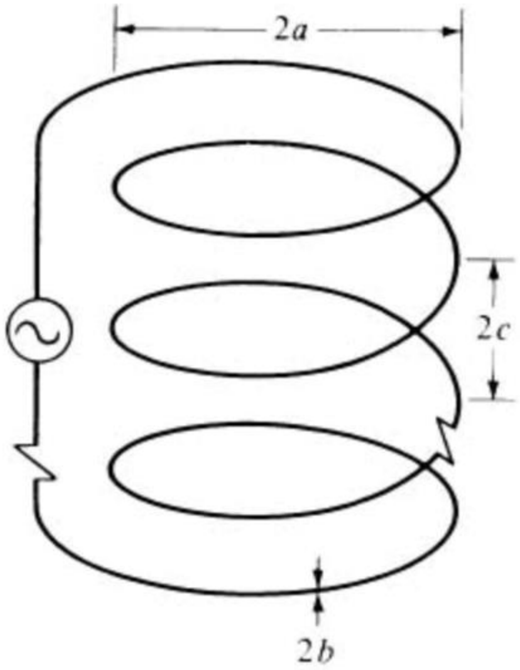


Broadband Triangular Monopole Antenna used for RF Harvesting from Cell Phone

Loop Antennas



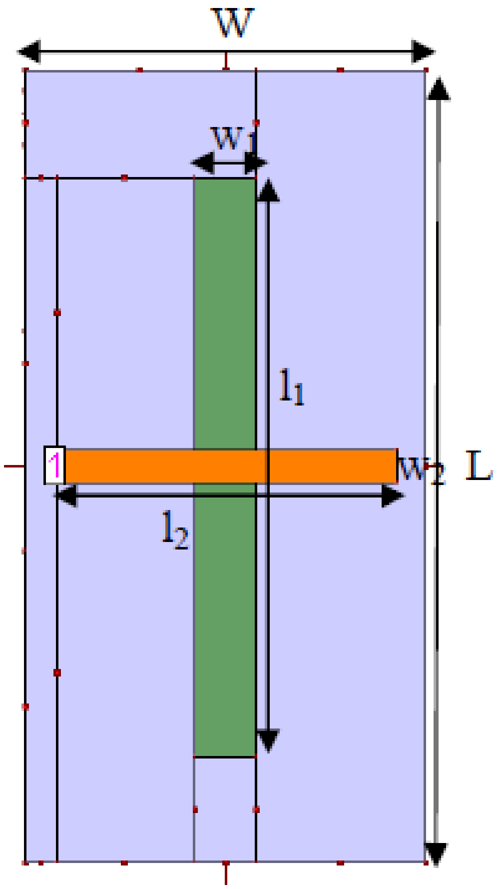
Small Circular Loop Antenna equivalent to Magnetic Dipole



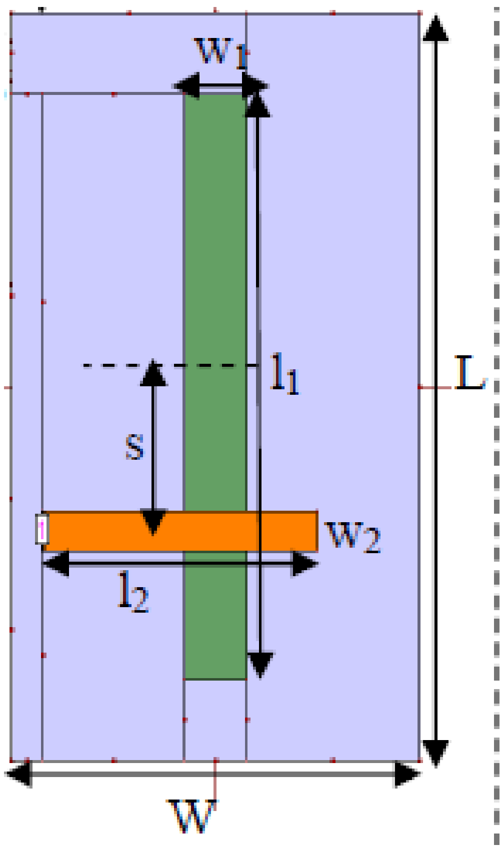
Multi-turn Loop Antenna

[C.A. Balanis, *Antenna Theory – Analysis and Design*, John Wiley, 2005]

Slot Antennas

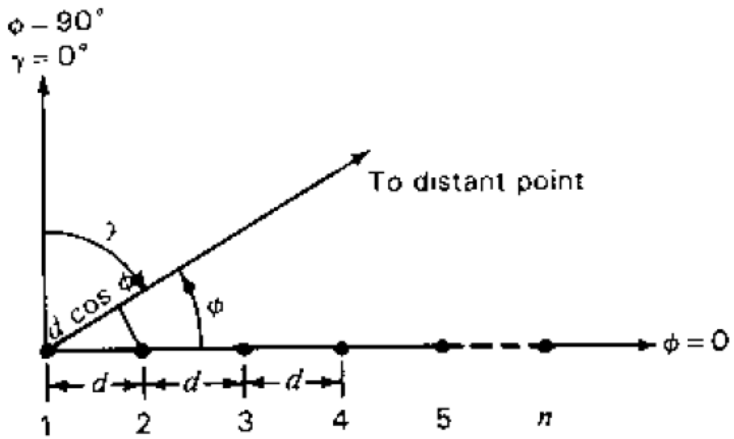


Centre-fed Slot Antenna

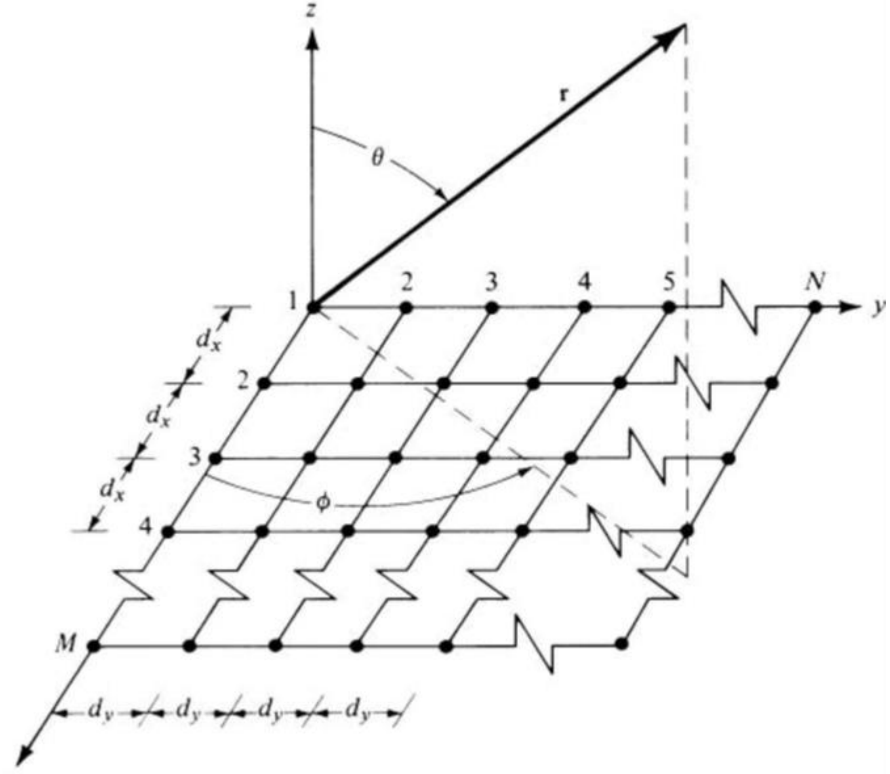


Off-centre-fed Slot Antenna

Linear and Planar Antenna Arrays



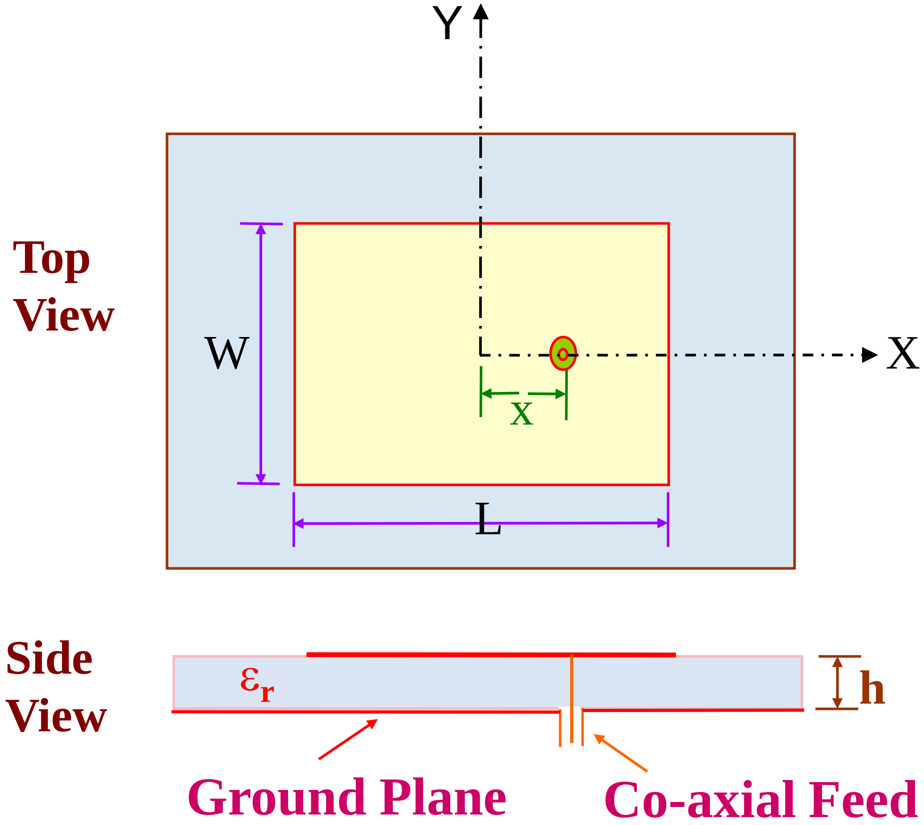
Linear Antenna Array



Planar Antenna Array

Type of element, amplitude and phase of each element, spacing between the elements, and feed network determine performance of the antenna array

Microstrip Antennas (MSA)

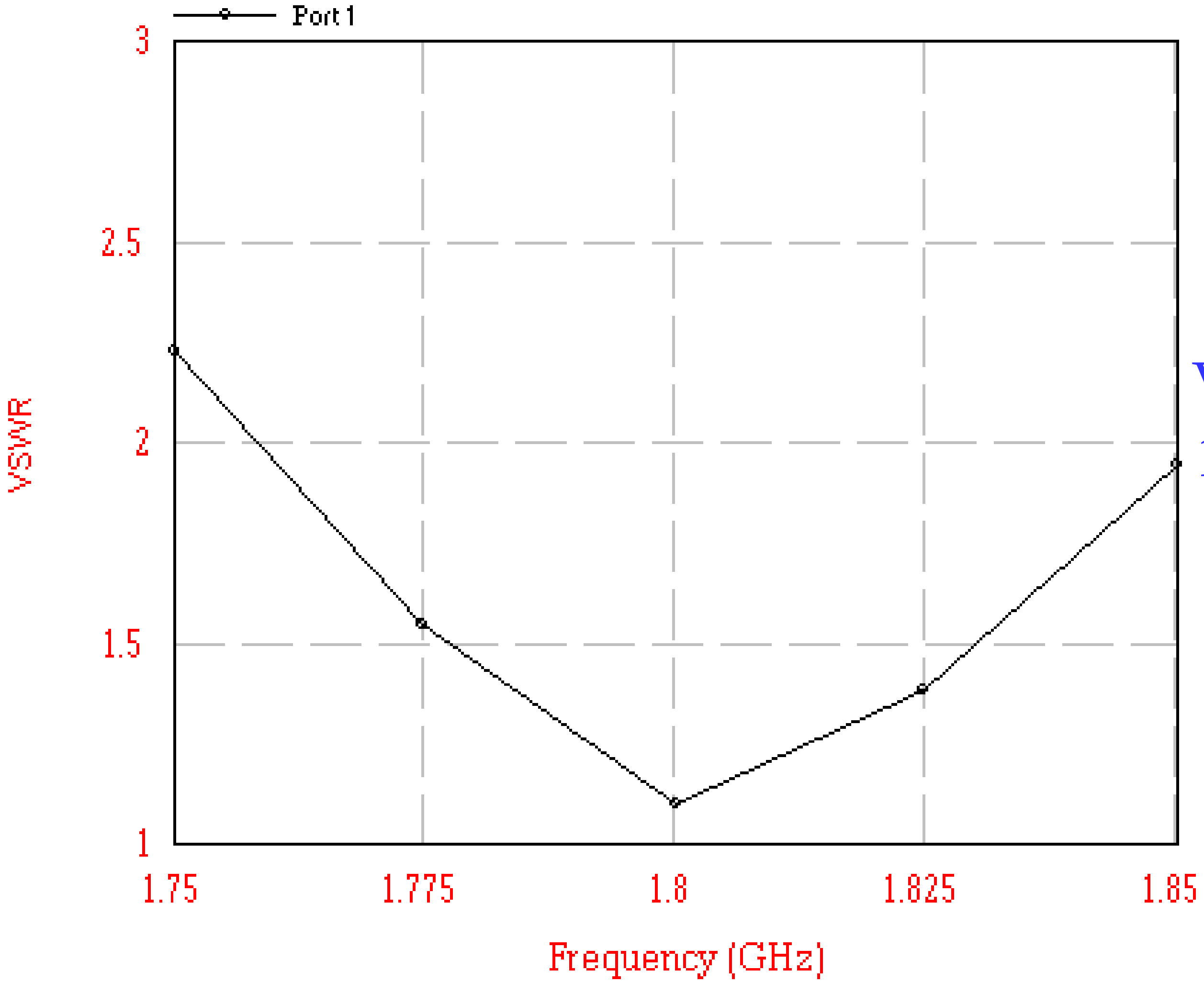


Rectangular Microstrip Antenna on Finite Ground Plane

Microstrip Antennas:

- Different Shapes
- Broadband
- Compact
- Multi-band
- Dual polarization
- Circular Polarization
- Linear and Planar Arrays (series and parallel feeds)

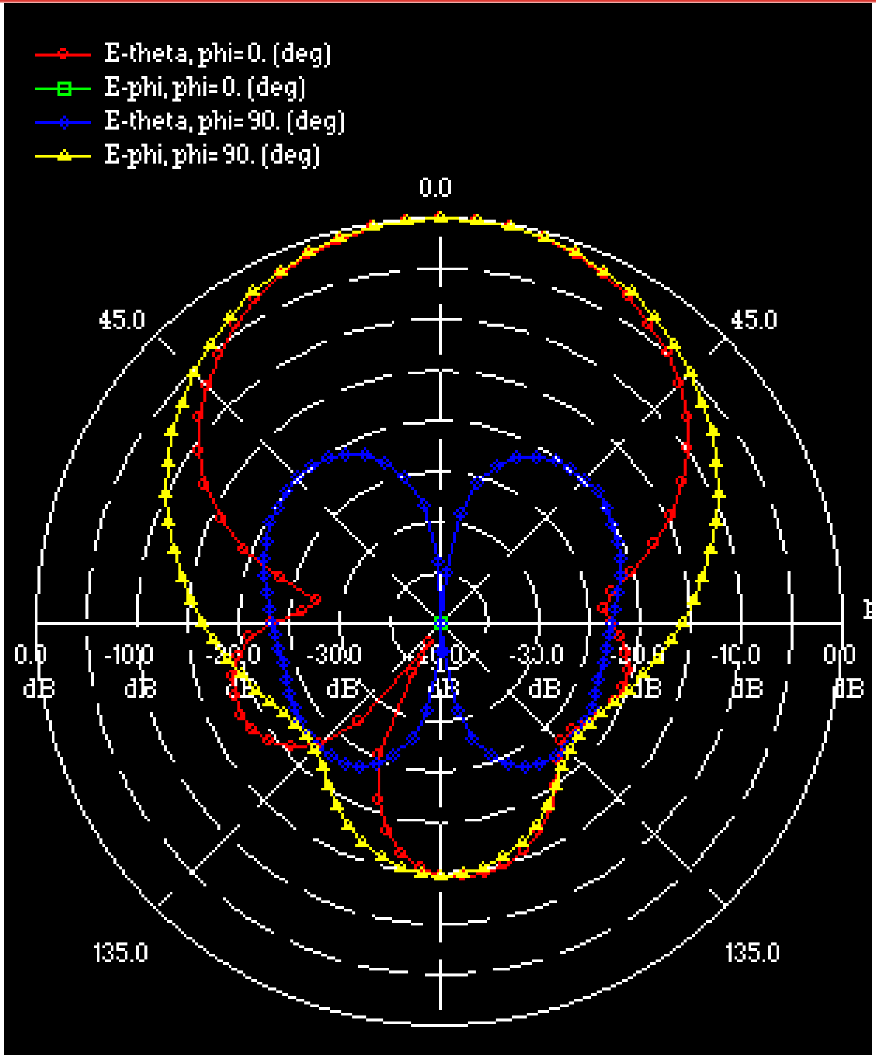
Microstrip Antenna – VSWR Plot



Bandwidth for VSWR $\leq$ 2 is from 1.76 to 1.855 GHz (95 MHz)

% BW $\simeq$ 5%

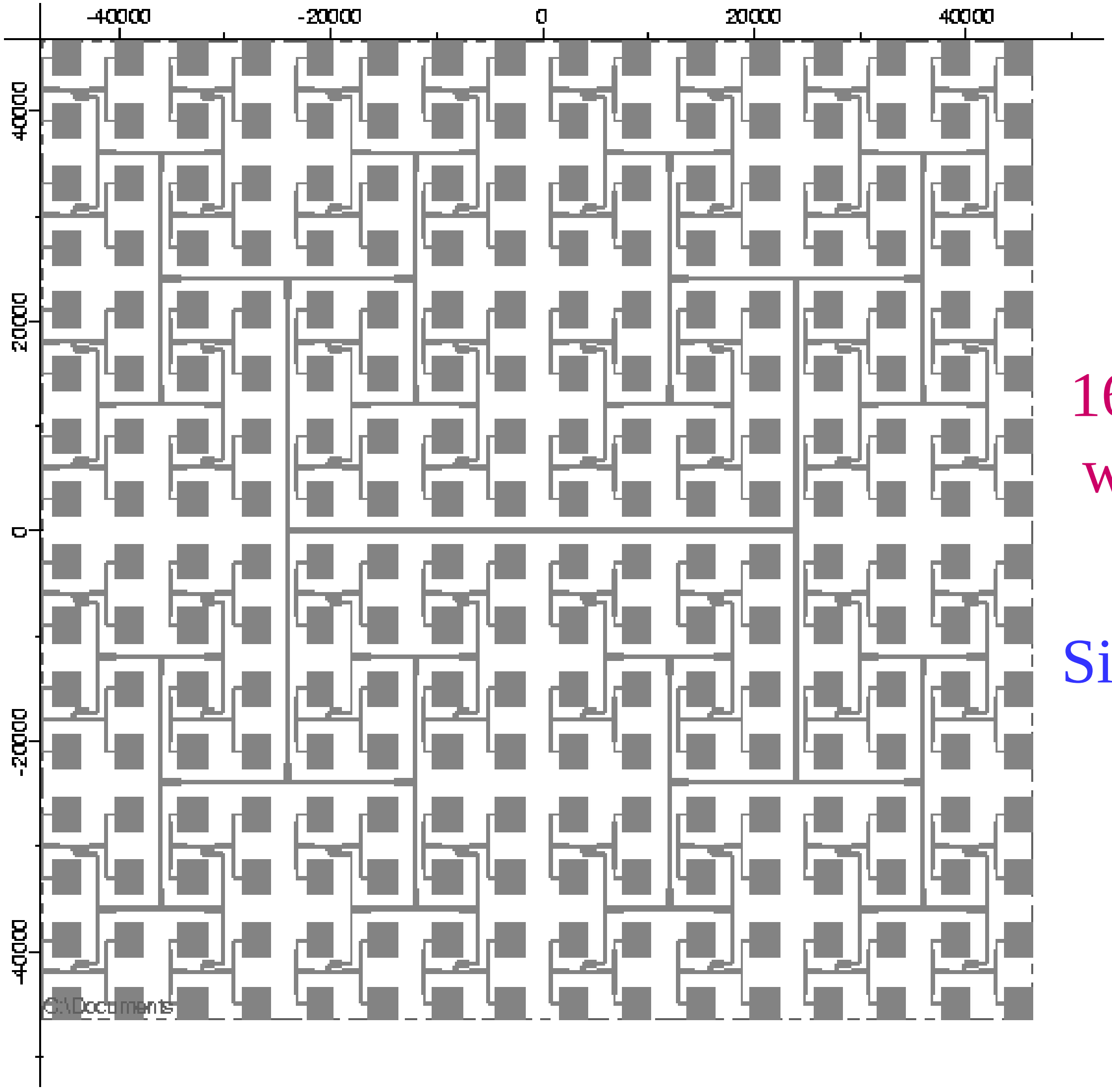
Microstrip Antenna – Radiation Pattern



Radiation Pattern
at 1.8 GHz

Front to Back Ratio
F/B = 15 dB

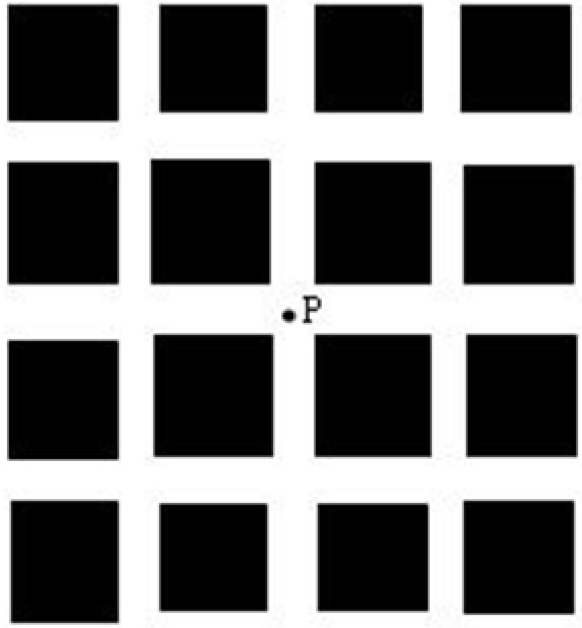
Microstrip Antenna Array



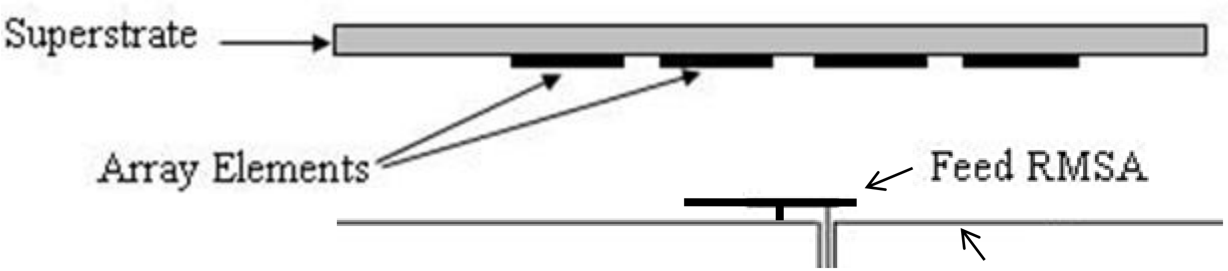
16 x 16 MSA array with feed network at 35 GHz

Size: 10cm x 10 cm

Space Fed MSA Array



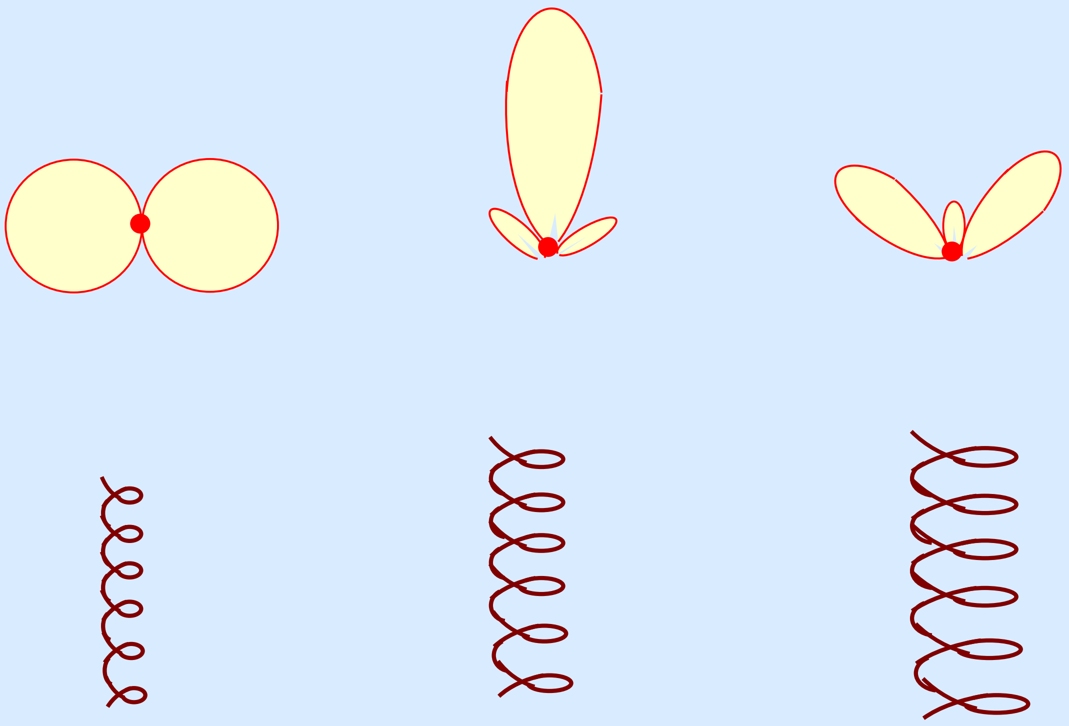
Top View



Ground Plane

Side View

Helical Antennas



NORMAL MODE

$C = \pi D << \lambda$

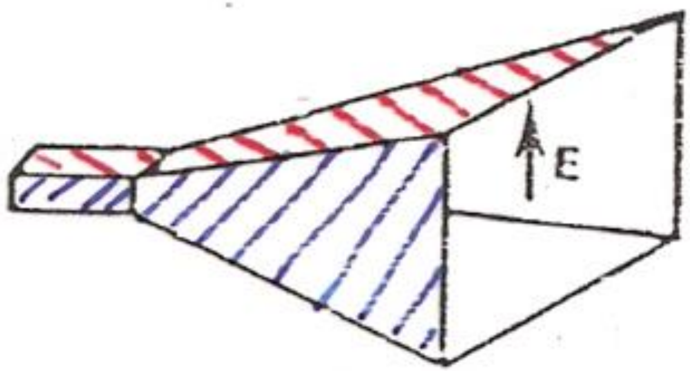
AXIAL MODE

$C = \pi D = \lambda$

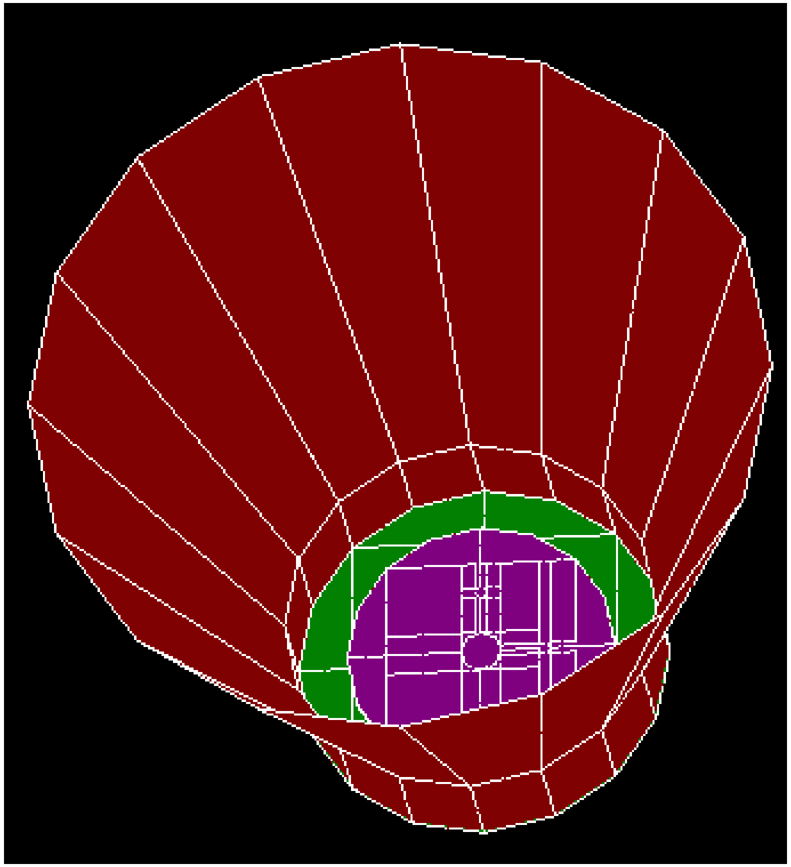
CONICAL MODE

$C = \pi D = n\lambda$

Pyramidal and Conical Horn Antennas



Pyramidal Horn Antenna



Microstrip Antenna Integrated with Conical Horn Antenna

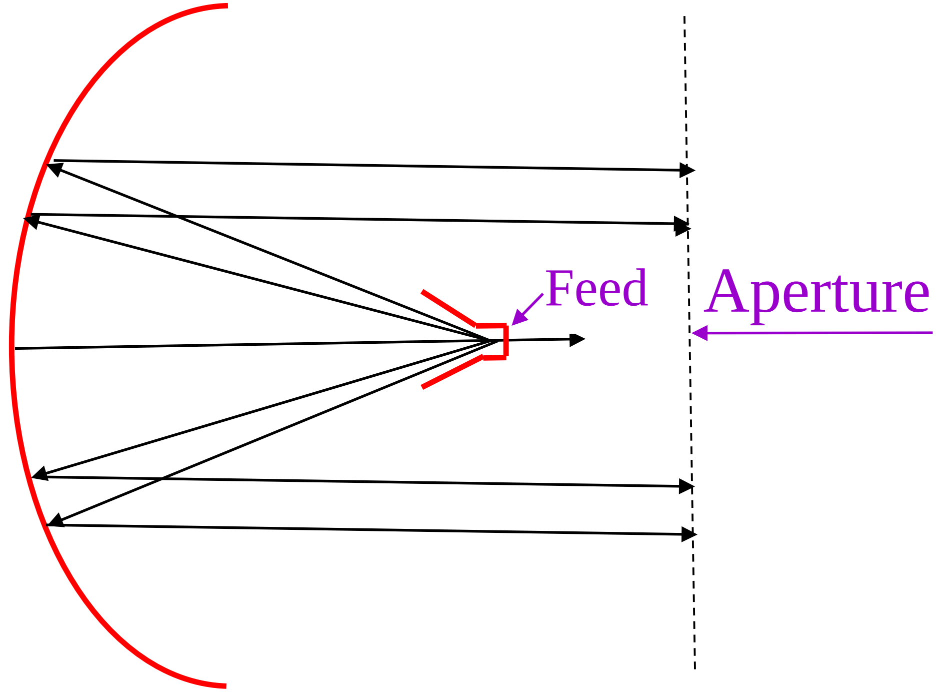
Reflector Antennas

Reflector Antennas:

Planar

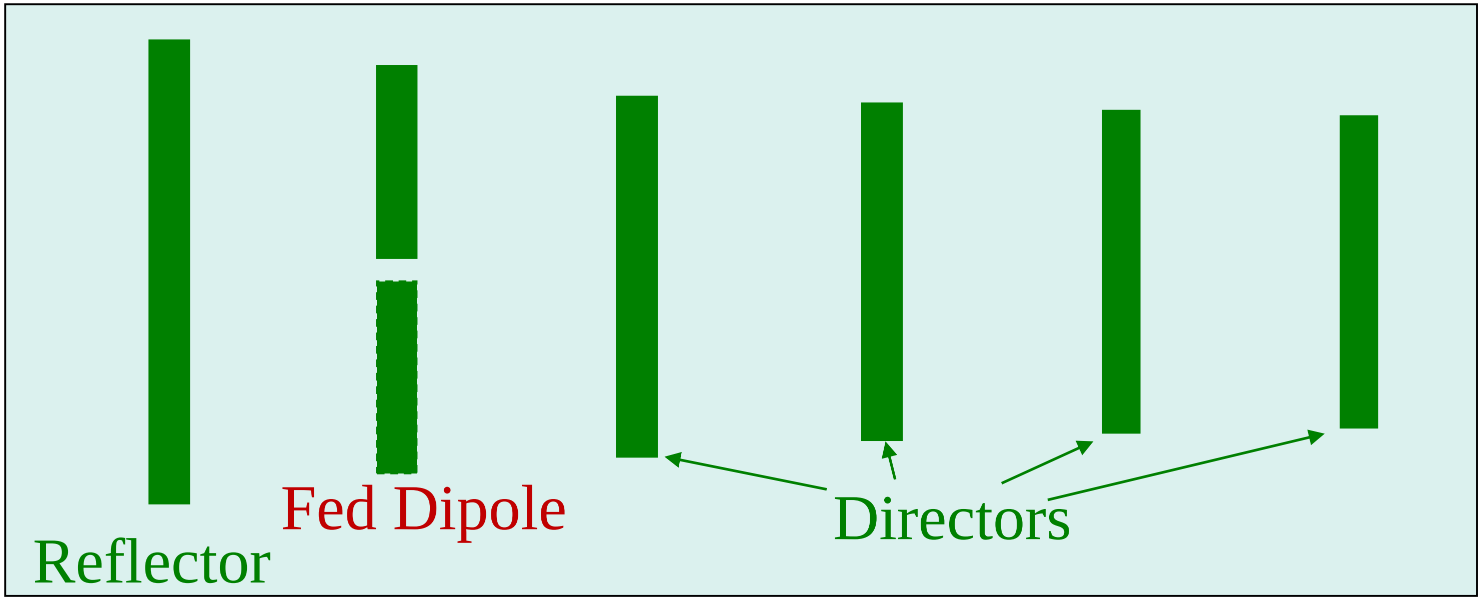
Corner

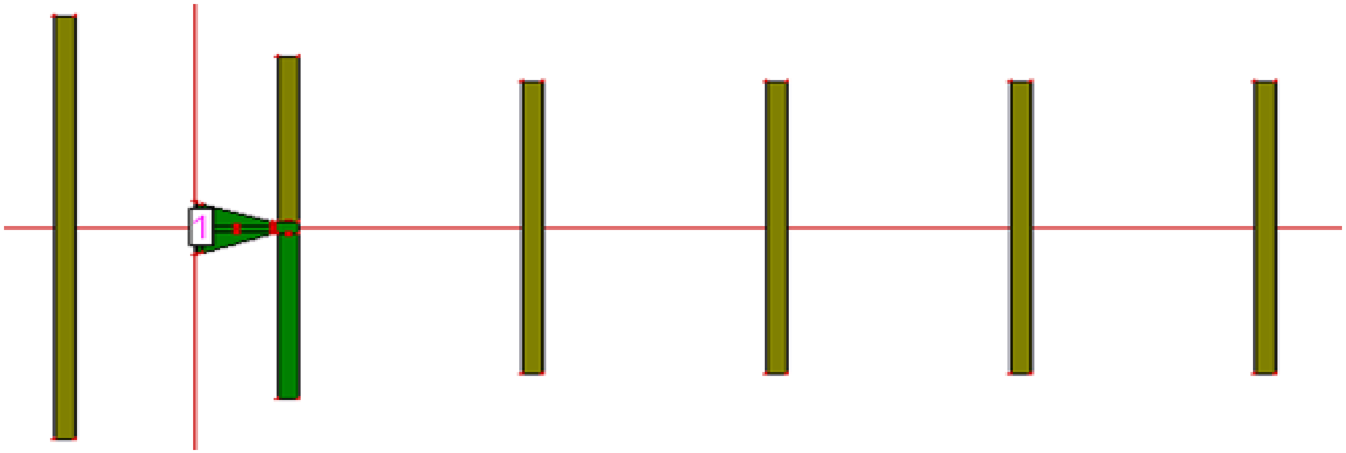
Parabolic



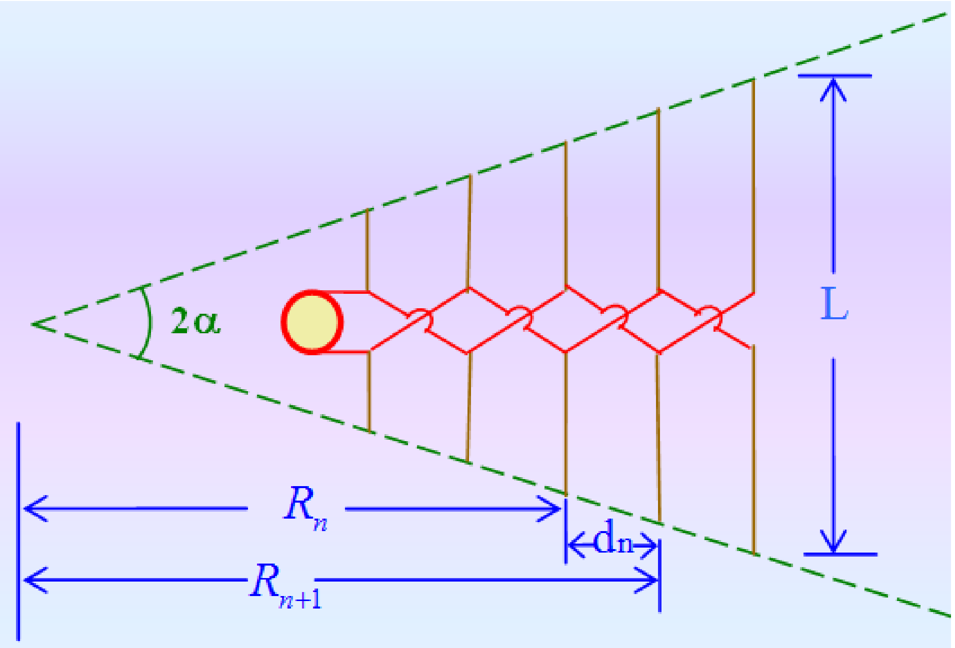
Higher gain but occupies large space

Yagi – Uda Antennas





Log-Periodic Antenna



$$\frac{1}{\tau}=\frac{\ell_2}{\ell_1}=\frac{\ell_{n+1}}{\ell_n}=\frac{R_2}{R_1}=\frac{R_{n+1}}{R_n}$$

$$=\frac{d_2}{d_1}=\frac{d_{n+1}}{d_n}=\frac{s_2}{s_1}=\frac{s_{n+1}}{s_n}$$

CONCLUSIONS

- Antenna technology is rapidly changing.
- Requirement for innovative thinking to meet the challenges – broad-band, multi-band, compact, high efficiency, multi-polarization, MIMO, smart antennas, etc.
- Design is the most important thing.
- Requires precision manufacturing.
- Low cost without sacrifice in performance.