TE 372: Antennas and Propagation

Examiner: M. S. Ellis, PhD
smellis.coe@knust.edu.gh
057 904 7591

January 17th , 2017

Syllabus

- Introduction to Antennas
- Fundamental Parameters of Antennas and Antenna arrays
- Wire antenna
- Travelling wave and broadband antennas
- Mobile phone and microstrip antennas
- Challenges in antenna design
- Radio wave propagation

Reference material

- C. Balanis, *Antenna Theory Analysis and Design*, 3rd Edition, John Wiley, 2005

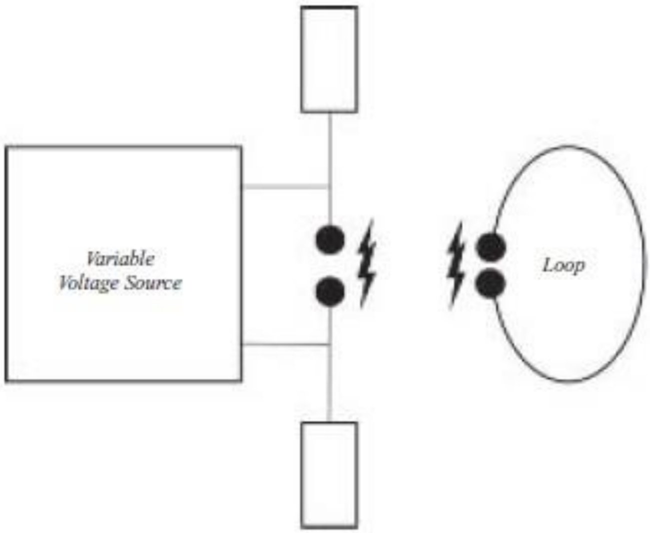
- Yi Huang and Kevin Boyle, *Antenna from theory to practice*, John Wiley, 2008

- Per-Simon Kildal, *Foundations of Antennas*, Chalmers University, 2009

Introduction to antennas: ***History & Background***

- The first well-known antenna experiment was conducted by German physicist Heinrich Rudolf Hertz (1857-1894). The SI unit for frequency is named after him, i.e., Hertz
- The intent of the experiment was to demonstrate the existence of electromagnetic radiation
- In the setup, a variable voltage source was connected to a pair of wires (dipole) with conducting balls at each end of the wire
- The gap between the balls could be adjusted for circuit resonance and generation of sparks
- A spark or discharge was produced when the voltage was increased to a certain value
- The receiver was made up of a loop with two conducting balls. The gap between the balls was tuned to receive the spark from the transmitter clearly
- The setup was placed in a dark box in order to see the spark clearly. A spark generated at the transmitter was also noticed at the receiver at almost the same time
- This showed that the information from the transmitter was reaching the receiver by electromagnetic waves

Heinrich Rudolf Hertz



Hertz's experimental setup

- This is sometimes considered as the first very digital wireless system (on-off tuning of sparks)

- Till date, the dipole and loop antennas are one of the best known antennas

- The dipole antenna is also called the Hertz antenna

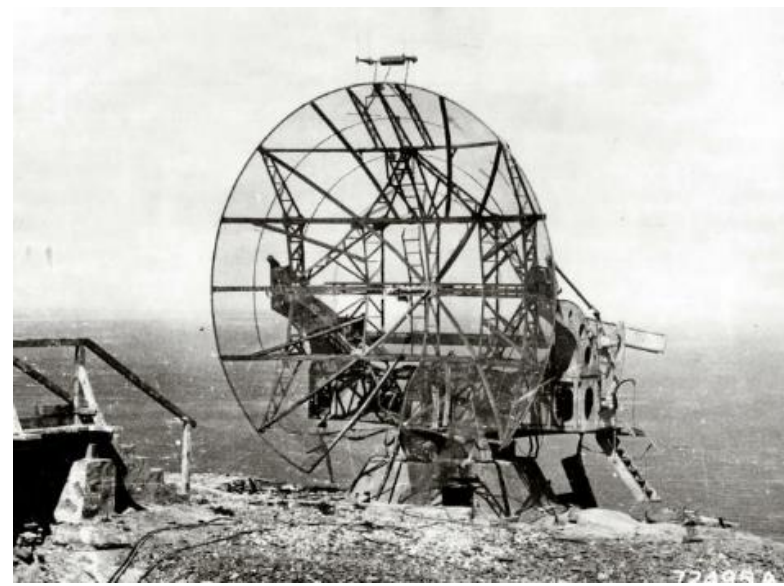
- In 1874 – 1937, Guglielmo Marconi, an Italian inventor, commercially developed wireless technology by introducing a radiotelegraph system. He won the Nobel prize for this invention

- In his experiment, he widely used monopole antennas (quarter-wavelength)

- Thus vertical monopole antennas are called Marconi antennas

Guglielmo Marconi

- During World War II (1939 – 1945), battles were won by armies that could spot enemy airplanes, ships or submarines
- Scientist developed radar technology that could see targets from several miles away
- This resulted in research in high-frequency radar antennas, and no longer simple wire antennas
- Some reflector antennas and horn antennas were developed then
- Broadband, circularly polarized antennas, ultrawideband antennas and other types of antennas were developed for various applications
- Recently, one of the main challenges of antennas is to make them broadband and small enough for portable or mobile wireless communications



Radar systems designed for World War 2

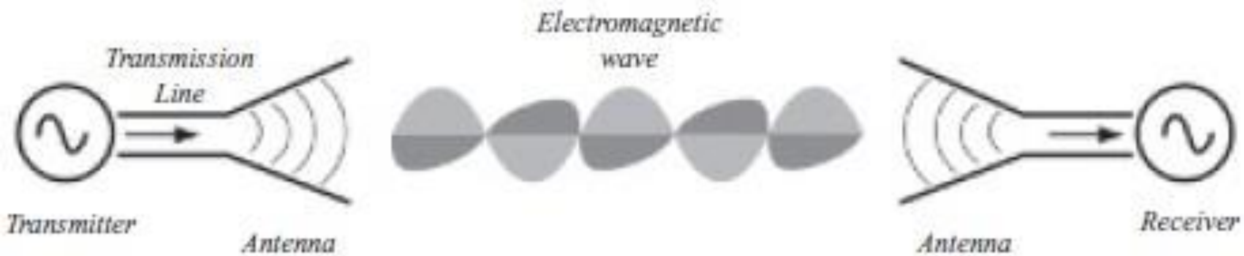
- **An antenna** is an essential part of a ***radio system*** since it transmits and receives the electromagnetic waves in a *desired* manner

- A radio system is essentially an electronic system which utilizes radio waves

- Several things can radiate or receive EM energy but cannot be viewed as antennas because the EM energy is not transmitted or received in an efficient and desired manner, e.g. power leads

- Since radio systems possess some unique advantages over wired systems, numerous radio systems have been developed: TV, radar, mobile radio communication, etc

- Advantages of radio systems include mobility, and good coverage



A typical radio system

- The antenna can be viewed as a *transformer* that transforms electrical signals (voltages and currents) to electromagnetic waves (electric and magnetic fields) or vice versa

- Aside being a transformer, it can also be considered as a bridge between the radio wave and the transmission line

- An antenna system is defined as the combination of the antenna and its *feed line*

- Since the antenna is always connected a feed line (transmission line), how best to design this feed line to efficient carry the signal to the antenna for radiation is very important

- To understand antenna theory, one has to understand radio waves and transmission lines

- In some cases, the antenna and its feed line are integrated (e.g. portable devices) and in other cases, they may be far apart (TV broadcasting/reception antenna)

Lumped and distributed element systems (recap)

- A circuit or system is usually separated into lumped element system or distributed element system

- In most countries the electrical power supply operates at 50 Hz, which is approximately 6000 km wavelength

- This wavelength is much longer than an transmission line in use, therefore the currents and voltages may remain constant on the transmission line

- Such a system is considered as a lumped element system. Lumped systems can be analyzed by *circuit theory* ($V=IR$, $P = V^2/R$ *etc*)

- When frequency increases, the wavelength decreases and it may be comparable to the length of the transmission line linking the source and the load

- In this case, the voltage and currents are functions of distance on the line, i.e., they may change as one moves along the line

- Such a system is a distributed element system. Distributed systems are analyzed by *transmission line theory*

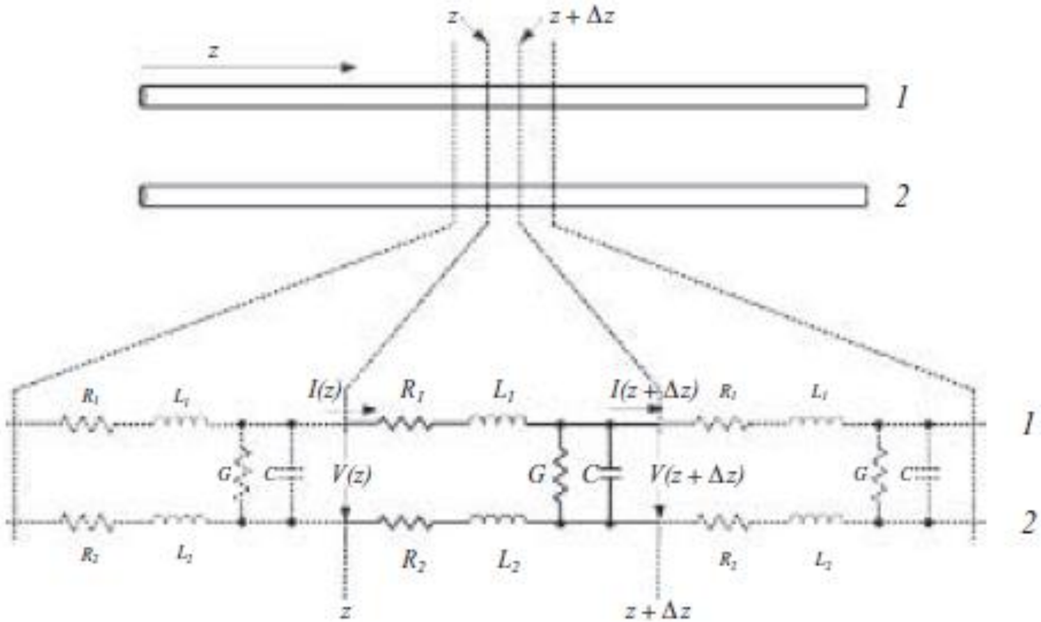
Transmission Line theory (recap)

- A transmission line is the structure that is a part or forms the entire path for energy transmission (electric power, optical waves) from one place to another

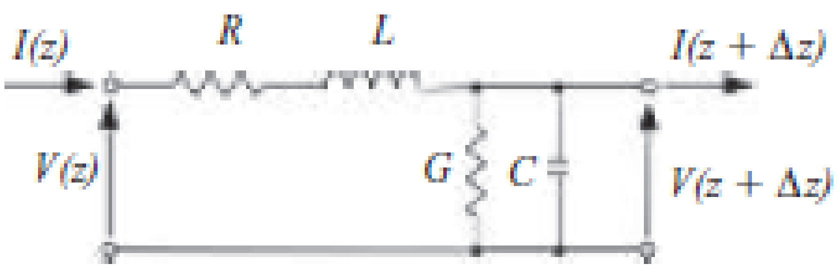
- Examples of transmission lines include conducting wires, electrical power lines, coaxial cables, dielectric slabs, optical fibers and waveguides

- The simplest transmission line is a two-wire conducting transmission line

- It is widely used for electrical power supply and also for radio and TV systems



A two-wire transmission line model



A section (elementary component) of a transmission line

- R = resistance per unit length Ω/m
- L = inductance per unit length H/m
- C = capacitance per unit length F/m
- G = conductance per unit length S/m
- R represents the conductive loss of the t-line
- L is the self inductance of the t-line
- C is the capacitance between the two conductors of the t-line
- G is the conductance of the dielectric material separating the two conductors

The following equations for a transmission line can be obtained:

$\gamma = \alpha + j\beta$ **Propagation constant = attenuation constant + j phase constant**

$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$ **Attenuation constant**

$Z_0 = \frac{V_+(z)}{I_+(z)} = \frac{R + j\omega L}{\gamma} = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$ **Characteristic impedance**

$\beta = \frac{\omega}{v} = \frac{2\pi f}{v} = \frac{2\pi}{\lambda}$ **Phase constant**

$v = \frac{dz}{dt} = \frac{\omega}{\beta}$

Phase velocity

Terminated Transmission Line (recap)

Unlike voltage and currents, the characteristic impedance is not a function of position z. It is a constant. When the line is terminated with a load with impedance Z_L. The input impedance is given as follows:

$$Z_{in}(l) = Z_0 \frac{Z_L + jZ_0 \tan(\beta l)}{Z_0 + jZ_L \tan(\beta l)}$$

Where l = length of the t-line away from the load, Z_0 is the characteristic impedance, β is the phase constant

- ***Matched case**: $Z_L = Z_0$* $Z_{in}(l) = Z_0.$

  the input impedance is the same as the characteristic impedance and its not a function of length

- ***Open circuit:** $Z_L = \infty$* $Z_{in}(l) = Z_0 \frac{1}{j\tan(\beta l)}$

The input impedance has no resistance, just reactance

- ***Short circuit:** $Z_L = 0$* $Z_{in}(l) = jZ_0 \tan(\beta l)$

The input impedance has no resistance, just reactance

- ***Quarter-wavelength case:** $l = \lambda / 4$* $Z_{in}(l) = \frac{Z_0^2}{Z_L}$
- This is called a quarter wave transformer

Reflection coefficient,return loss, and VSWR (recap)

A general expression of the reflection coefficient of a t-line is given by:

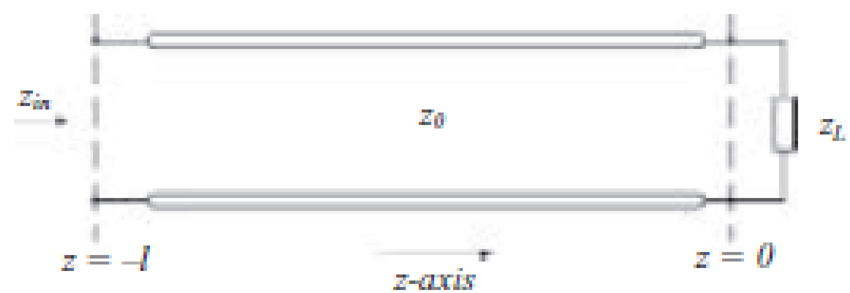
$$\Gamma(l) = \frac{Z_L - Z_0}{Z_L + Z_0} e^{-2\gamma l} = \Gamma_0 e^{-2\gamma l}$$

- Reflection coefficient gives a measure of how much signal is reflected back from its terminal

$$L_{RT}(l) = -20 \log_{10}(|\Gamma(l)|)$$

- The return loss is given by:

- When the characteristic impedance of the line is same as the load impedance, reflection coefficient is zero, known as the matched case



- Voltage standing wave ratio (VSWR) is the ratio of the magnitude of the maximum voltage on the line to the magnitude of the minimum voltage on the line. Mathematically,

$$VSWR(l) = \frac{|V|_{max}}{|V|_{min}} = \frac{|V_+| + |V_-|}{|V_+| - |V_-|} = \frac{1 + |\Gamma(l)|}{1 - |\Gamma(l)|}$$

2. ANTENNA BASICS

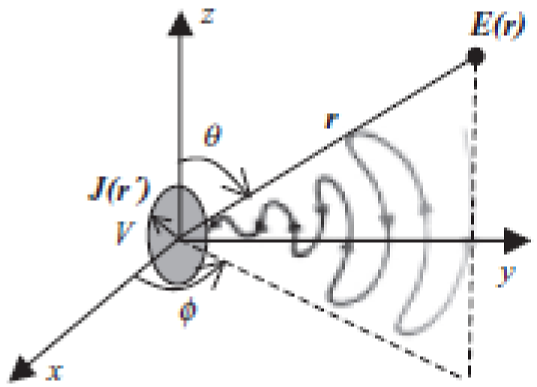


Fig. 1. Coordinates and radio waves generated by a time-varying source

$$\nabla \times \boldsymbol{E} = -j\omega\mu \boldsymbol{H}$$

$$\nabla \times \boldsymbol{H} = \boldsymbol{J} + j\omega\varepsilon \boldsymbol{E}$$

$$\nabla \bullet \boldsymbol{E} = \rho/\varepsilon$$

$$\nabla \bullet \boldsymbol{H} = 0$$

Maxwell's equations

$$\boldsymbol{E}(\boldsymbol{r}) = -j\omega\mu \int_V \boldsymbol{J}(\boldsymbol{r}') \frac{e^{-j\beta\cdot|\boldsymbol{r}-\boldsymbol{r}'|}}{4\pi\,|\boldsymbol{r}-\boldsymbol{r}'|} dv' + \frac{1}{j\omega\varepsilon} \nabla \left(\nabla \bullet \int_V \boldsymbol{J}(\boldsymbol{r}') \frac{e^{-j\beta\cdot|\boldsymbol{r}-\boldsymbol{r}'|}}{4\pi\,|\boldsymbol{r}-\boldsymbol{r}'|} dv' \right)$$

Wave equation in an unbounded region as shown in Fig. 1

- Wave equation gives the radiated electric field from a time-varying current ***J***. This is the foundation of antenna theory – it reveals how the antenna is related to radio waves
- It proves that only a time-varying current can generate a radio wave – not static charges or DC current
- Antenna design is basically how to control the current distribution ***J*** and hence to obtain the desired radiated field ***E. Note that this expression can be simplified for different cases as will be described next***

Near field and far field

- The field equation can be made easy for very simple cases. Consider an ideal current element with length ***Δl*** and current value ***I***, the current density vector ***J*** can be expressed as: $\boldsymbol{J} = \hat{z} I \, \Delta l$
- The field equations (E and H) can be simplified to:

$$E_r = 2\frac{I\,\Delta l}{4\pi}\eta\beta^2\cos\theta\left(\frac{1}{\beta^2 r^2} - \frac{j}{\beta^3 r^3}\right)e^{-j\beta r}$$

$$E_\theta = \frac{I\,\Delta l}{4\pi}\eta\beta^2\sin\theta\left(\frac{j}{\beta r} + \frac{1}{\beta^2 r^2} - \frac{j}{\beta^3 r^3}\right)e^{-j\beta r}$$

$$H_\phi = \frac{I\,\Delta l}{4\pi}\beta^2\sin\theta\left(\frac{j}{\beta r} + \frac{1}{\beta^2 r^2}\right)e^{-j\beta r}$$

$$H_r = 0; \; H_\theta = 0$$

- In the ***far field (Fraunhofer region), βr >> 1, i.e. r >> λ / 2π***, then the E field and H field components become:

$$E_\theta = \frac{jI\,\Delta l}{4\pi r}\eta\beta\sin\theta e^{-j\beta r}$$

$$E_r \approx 0; \qquad E_\phi = 0$$

$$H_\phi = \frac{jI\,\Delta l}{4\pi r}\beta\sin\theta e^{-j\beta r}$$

$$H_r = 0; \qquad H_\theta = 0$$

$$\boldsymbol{S} = \boldsymbol{E}\times\boldsymbol{H}^* = \hat{r}\left(\frac{I\,\Delta l}{4\pi r}\beta\sin\theta\right)^2\eta$$

It can be said from the equations that:

- There is one electric field and one magnetic field component, both inversely proportional to distance ***r***
- The E field and H field are orthogonal to each other and the cross product is **the power density** function, which is inversely proportional to the distance squared r^2
- The fields are proportional to sin ϴ. They are zero at 0^0 & 180^0 and maximum at ϴ = 90^0

S is known as ***Poynting Vector***, named after John Henry Poynting who introduced it in 1884

- The far field equation is basically the same as a plane wave equation. Thus the far field is considered a *plane wave*

- For electrically small antennas, the far field is given by $r >> \lambda/2\pi$ (function of frequency only, not antenna dimensions)

- When the antenna is electrically large *D* ($D>\lambda$), the far field is commonly defined as $r > 2D^2/\lambda$ (function of both freq and antenna dimensions). The latter is the *common definition for far-field condition*

- If the antenna cant be considered electrically large, then $r > 3\lambda >> \lambda/2\pi$

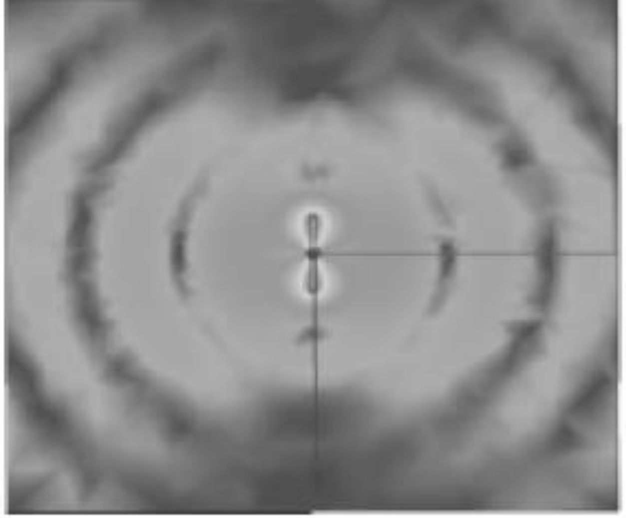
- In antenna measurements, the separation between transmitting and receiving antennas should be greater than the far-field distance, else significant errors could be generated

- When the far field conditions are not met, the field is considered ***near field* (βr < 1, i.e., r < λ/2π).** Here, E_θ is maximum at $\Theta = 90^0$ and E_r peaks at $\Theta = 0, 180^0$

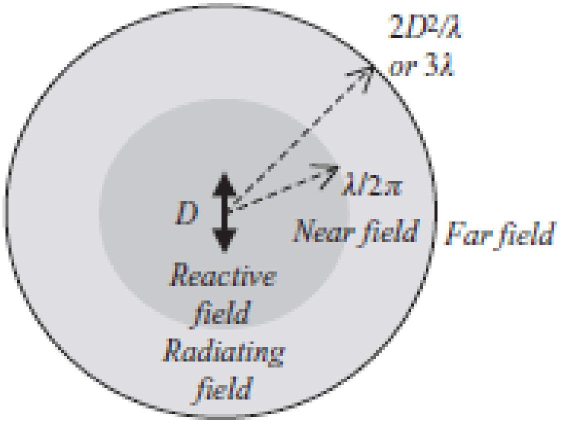
- The **near field region** $r < \lambda/2\pi$, is called *reactive near field* . Here the field changes rapidly with distance. Hence from the power density function $S = E \times H^*$, we can see that:

1. It contains both a real part (radiating energy) and an imaginary part (reactive energy) which does not dissipate energy – imaginary part dominates in this region

2. It has components in both r and ϕ directions. Former is radiating away from source and latter is reactive



Near field electric field around a dipole antenna



radiated field regions of antenna with maximum dimension D

NB: The region between the reactive near field and far-field is a transition region known as *radiating near field (Fresnel region).* Here, the radiative fields dominate

Radiation Pattern

- Radiation pattern of an antenna is a plot of the radiated field/power (at the far field distance) as a function of distance

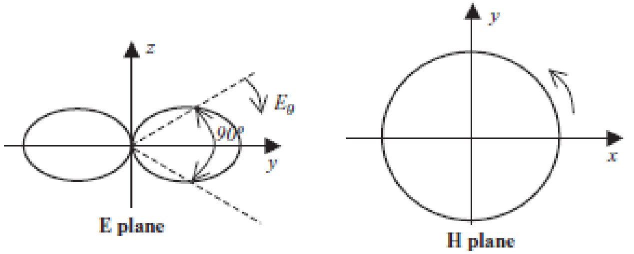
- Radiation pattern is usually plotted in 3D since its an excellent illustration of the radiated field distribution as a function of the angles *Θ* and *Φ* in space

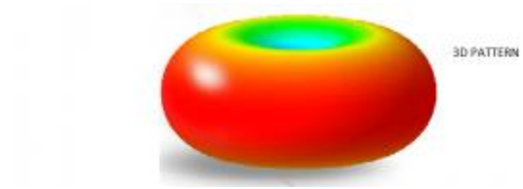
- Radiation patterns in the E–plane and the H-plane are the important patterns *Θ*

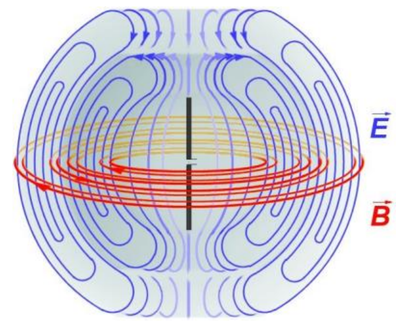
- The E-plane is the plane that the electric field E lies on, and the H-plane is the plane the magnetic field H is on

- For example, the short current element as shown, the E-plane is *Eɵ* and the magnetic field is *Hɸ* , hence the E plane pattern is the field Eɵ measured as a function of ϴ when the angle ɸ and the distance are fixed, while the H-plane pattern is the field Eɵ measured a function of ɸ when the angle ϴ and the distance is fixed

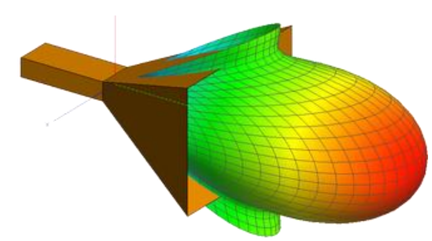
- The H-plane has an ***omnidirectional*** pattern. This is a desirable feature for mobile antennas since the antenna wouldn't be sensitive to orientation. If the antenna has the same radiation power at all angles, it is called an ***isotropic antenna***



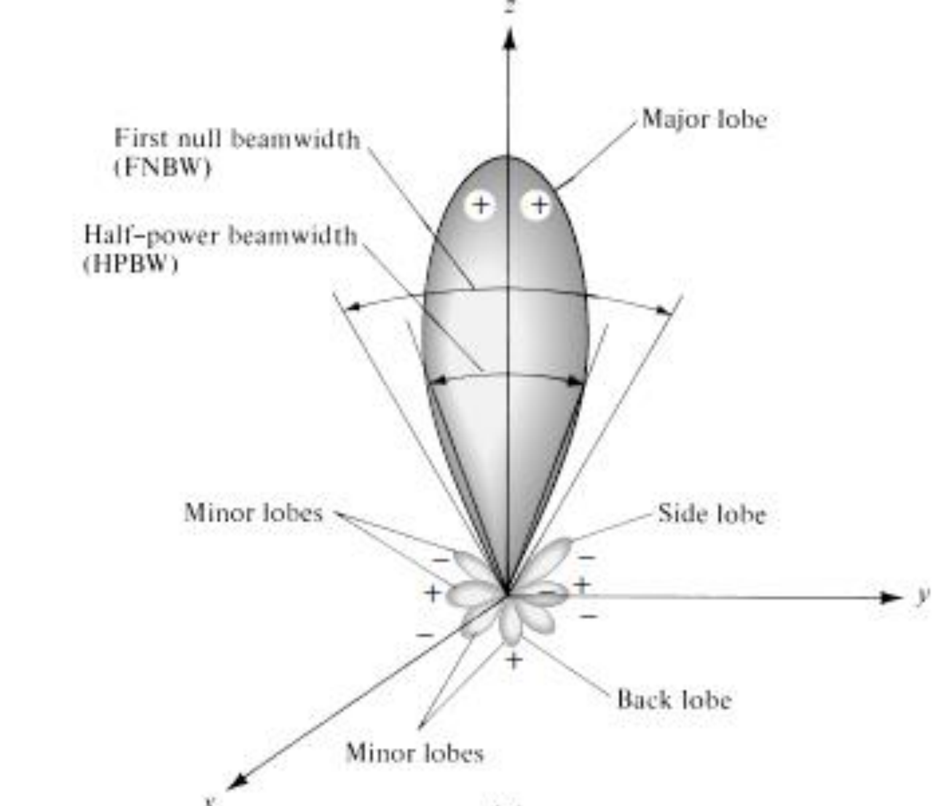




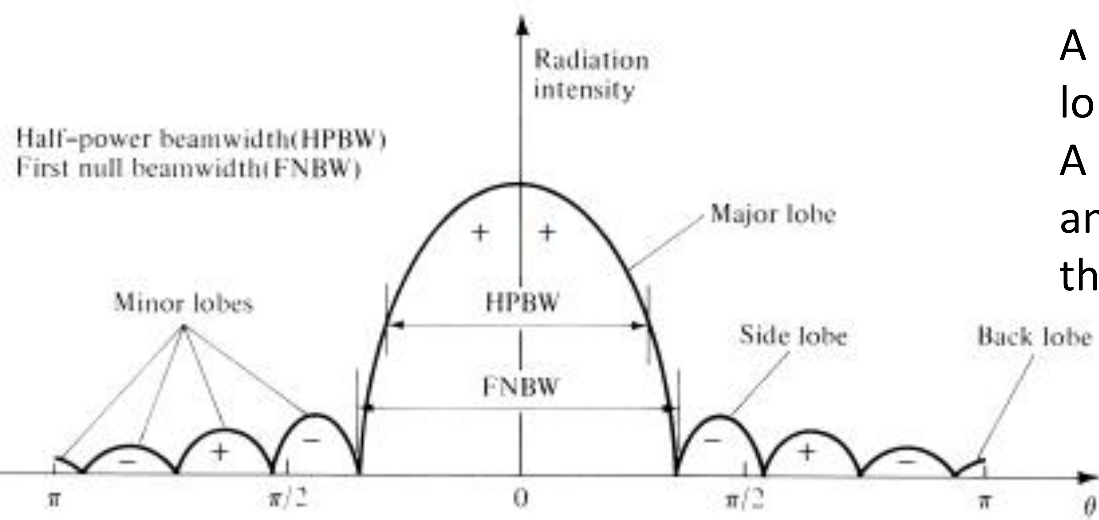
3D radiation pattern of a short current element



3D radiation pattern of a horn antenna



(a)



(b)

Various parts of a radiation pattern are referred to as ***lobes, ie. Main lobe, minor lobe, and back lobes***

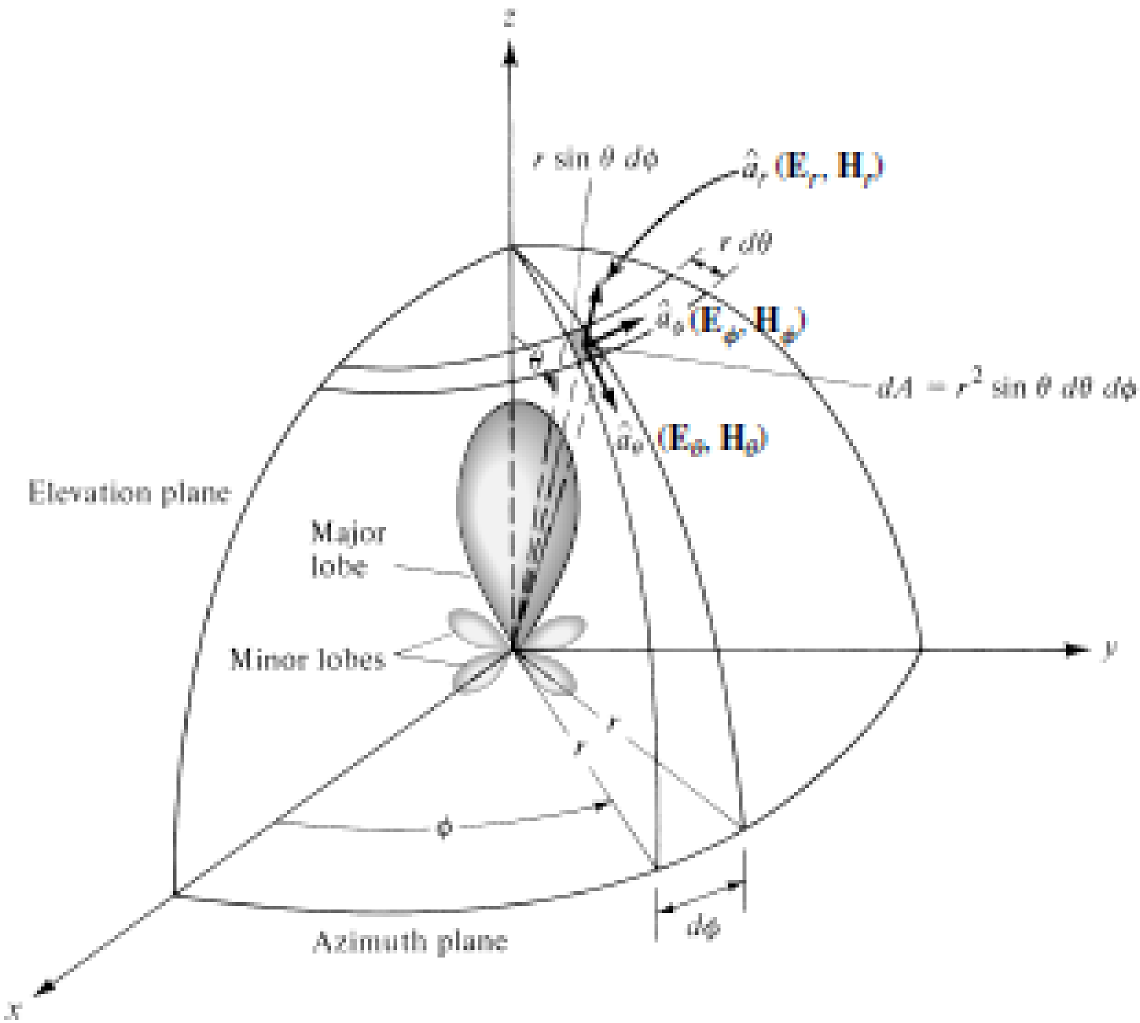
The type of lobes depends on the radiation intensity at that part of the radiation pattern

A major or main lobe is the radiation lobe containing the direction of maximum radiation (From the fig, Θ = 0 degrees)

A minor lobe is any lobe other than the main lobe.

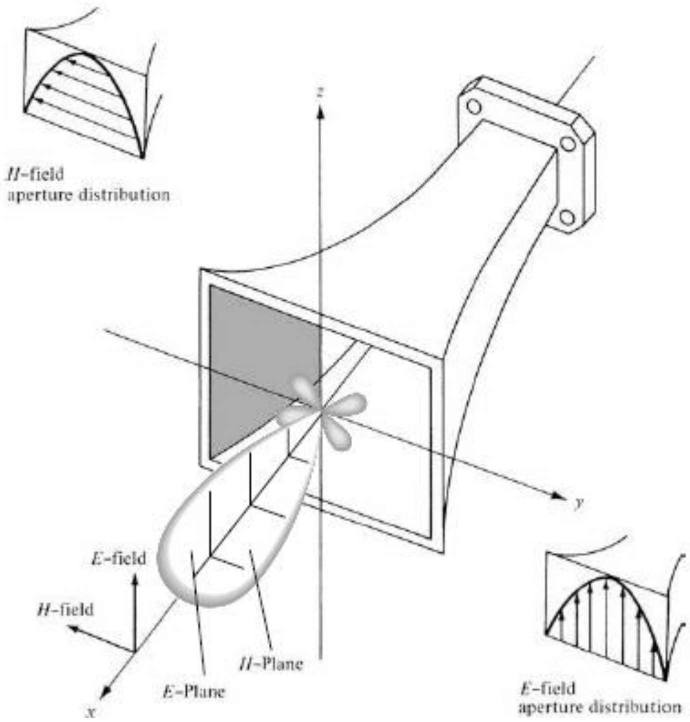
A side lobe is usually adjacent to the main lobe

A back lobe is the radiation lobe whose angle makes an angle of 180 degrees to the main lobe

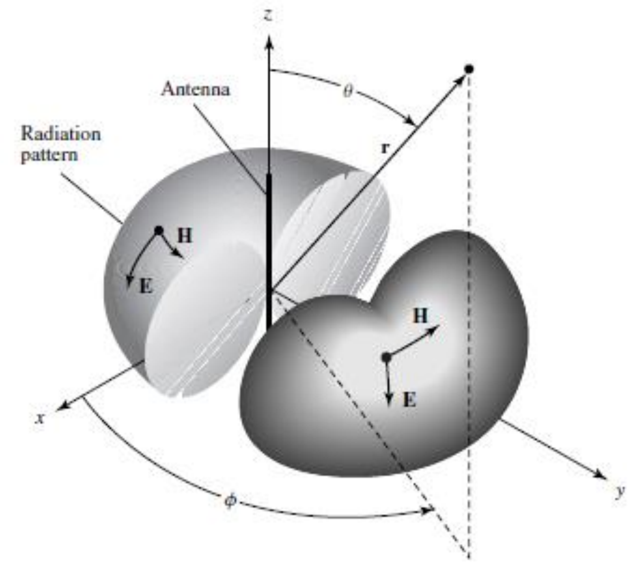


Coordinate system for antenna analysis (spherical coordinate system)

Isotropic, Directional, and Omnidirectional Patterns



A horn antenna with a directional antenna pattern



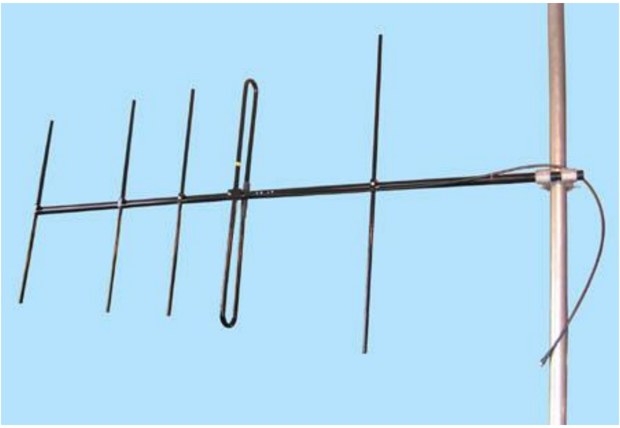
An omnidirectional antenna pattern

•An **isotropic antenna** is a lossless antenna having equal radiations in all directions. It is ideal and NOT practically realizable. Often used a reference for expressing directivity of actual antennas

•A **directional antenna** is one that radiates in EM waves /energy more in some directions than others (eg. Horn antenna, patch antenna, Yagi-uda antenna)

•An **omnidirectional antenna** has non-directional radiation pattern in a given plane, especially the azimuth plane (mobile antenna, wire antenna, whip antennas,monopole antennas

OMNIDIRECTIONAL ANTENNA EXAMPLES



DIRECTIONAL ANTENNA EXAMPLES

Directivity

$$D = \frac{U(\theta,\phi)}{U(\theta,\phi)_{av}} = \frac{4\pi U(\theta,\phi)}{P_t} = \frac{4\pi U(\theta,\phi)}{\oiint_{\Omega} U\, d\Omega}$$

- Directivity is a measure of the concentration of radiated power in a particular direction

- Its defined as the "ratio of the radiation intensity in a given direction to the radiation intensity average over all directions"

$$D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}}$$

U = radiation intensity (W/unit solid angle)

- The average radiation intensity is equal to the total power radiated by the antenna divided by 4π

$$D_{max} = D_0 = \frac{U|_{max}}{U_0} = \frac{4\pi U_{max}}{P_{rad}}$$

P_{rad} = total radiated (Tx) power (W)

- If the direction is not specified, the direction of maximum radiation intensity is used

- Directivity is dimensionless (no SI unit)

- The radiation intensity is linked to the averaged radiated power density ***Sav*** as shown

$$U = r^2 S_{av}$$

S_{av} = average radiated power (W/m²)

- Gain and directivity is related as shown

$$G = \frac{P_t}{P_{in}} D = \eta_e D$$

η_e =radiation efficiency factor

If the efficiency of the electrically short current element with directivity D = 1.5 is 50 %, the VSWR at the antenna input is 3 and the supplied power is 1 W. Find:

- The power gain (ans. 0.75/-1.24 dBi)
- The total radiated power (ans. 0.375 W/-4.26 dB)
- Find EIRP (ans. 0.2813/-5.5 dB)

Telecom: The radiated power density of the electrically short current element is given below

$$\boldsymbol{S} = \boldsymbol{E} \times \boldsymbol{H}^* = \hat{\boldsymbol{r}} \left(\frac{I \Delta l}{4\pi r} \beta \sin\theta \right)^2 \eta$$

- Find the MAXIMUM DIRECTIVITY OF A SMALL/SHORT CURRENT ELEMENT.

Ans. 1.76 dBi

ELECTRICAL: PROVE THAT: At ***near field ($\beta r < 1$, or $r < \lambda/2\pi$).***

E_θ is maximum at $\Theta = 90^0$ and E_r peaks at $\Theta = 0, 180^0$

Prove it theoretically/mathematically, and explain using a practical current element antenna

EIRP

- EIRP stands for - Effective Isotropic Radiated Power
- ***EIRP = P_t G***
- P is the transmitted power and G is the transmitter antenna gain
- EIRP is often stated in dBi (dBW or dB)
- If an antenna's EIRP = 10 dB, and the gain of the antenna is 7dBi, the radiated power from the antenna is 3 dB

Effective aperture and aperture Efficiency

- Usually the antennas effective aperture is less than the physical aperture
- Here, the ratio of the effective to physical aperture is known as aperture efficiency: $$\boxed{\eta_{ap} = \frac{A_e}{A_p}}$$
- Usually in the range of 50% to 80%

  Effective aperture is given by:

$$\boxed{A_e = \frac{\lambda^2}{4\pi} D}$$

- Similarly, the directivity D can be found as: $$\boxed{D = \frac{4\pi}{\lambda^2} A_e = \frac{4\pi}{\lambda^2} A_p \eta_{ap}}$$

The directivity of a pyramidal horn antenna of aperture width *a* and height *b* is

$$D = 6.4\,\frac{ab}{\lambda^2}$$

- Find the aperture efficiency (ans. 50.93 %)

- If the power density is 1 W/m^2, find the received power (ans. 0.5093*ab* W)

Antenna Temperature

Radiation from different sources appears at the antenna terminals as an antenna temperature. It is defined as:

$$T_A = \frac{\int_0^{2\pi}\int_0^{\pi} T_B(\theta,\phi)G(\theta,\phi)\cdot\sin\theta d\theta d\phi}{\int_0^{2\pi}\int_0^{\pi} G(\theta,\phi)\cdot\sin\theta d\theta d\phi}$$

Where $\mathbf{T_B}$ is the source brightness temperature of the radiation source, and **G** is the antenna gain pattern

Source could be remote, such as the sky, or Mars, and the antenna can be viewed as a remote temperature-sensing device

This temperature $\boldsymbol{T_A}$, is **NOT** the physical temperature of the antenna.

Antenna Factor

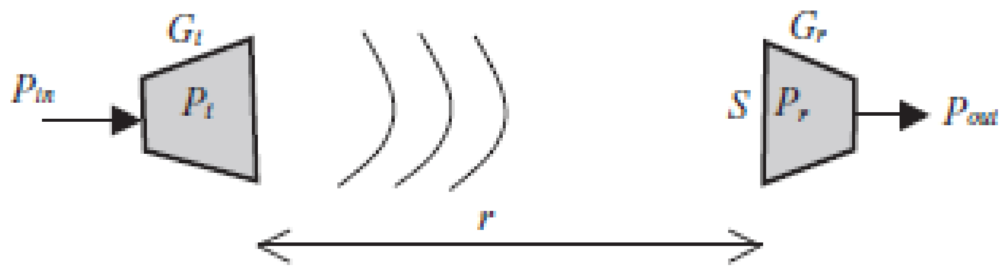
Antenna factor is defined as the ratio of the incident electric field ***E*** to the induced voltage $\boldsymbol{V_o}$ at the antenna terminal when it is connected to a load or cable

$$A_F = \frac{E}{V_0} \quad (m^{-1})$$

This parameter links the received field strength to the voltage at the antenna terminal. It is very useful in the study of ***Electromagnetic Compatibility (EMC).***

However, it is not a common antenna terminology

Friis's Transmission Formula



Transmitting and receiving antennas for the Friis transmission formula

The ***Friis*** formula relates the power received to the power transmitted between two antennas by a distance ***r.*** This is derived below:

S *is given in Watts/meter sq.* $\quad S = \dfrac{P_{in}G_t}{4\pi r^2}$ Power leaving transmit antenna at a distance ***r***

$$P_r = \frac{P_{in}G_t}{4\pi r^2}\cdot\frac{\lambda^2}{4\pi}D_r$$

Received power at receiving antenna input

$$P_{out} = P_r\eta_{er} = \frac{P_{in}G_t}{4\pi r^2}\cdot\frac{\lambda^2}{4\pi}D_r\eta_{er} = \frac{P_{in}G_t}{4\pi r^2}\cdot\frac{\lambda^2}{4\pi}G_r$$

Received power at receiving antenna output

$$P_{out} = P_{in}G_tG_r\cdot\left(\frac{\lambda}{4\pi r}\right)^2$$

FRIIS Equation

$\left(\dfrac{\lambda}{4\pi r}\right)^2$ *is the free space loss factor* Resulting from the spherical spreading of the radiated energy

Polarization

Antenna polarization come in three types: Linear, circular, elliptical polarization

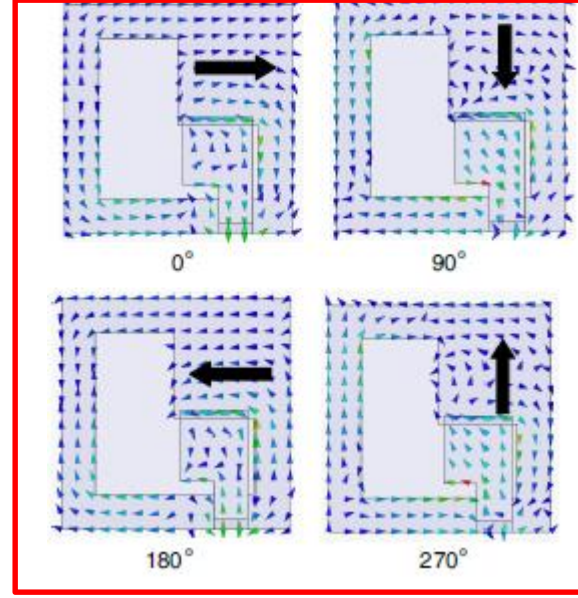
The type of polarization generated by the antenna depends on how the currents move in/on the antenna

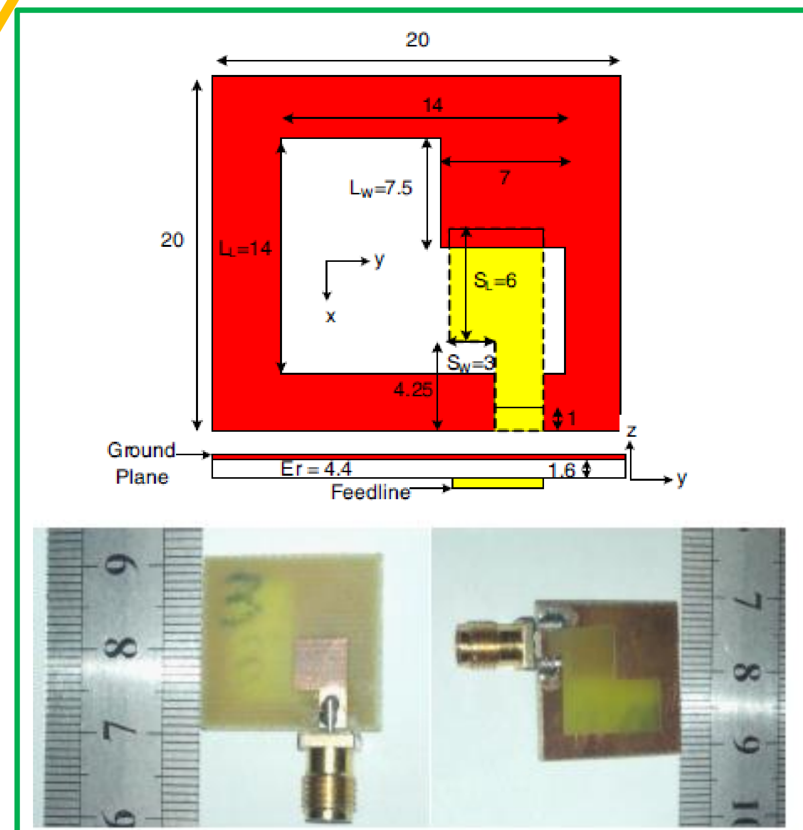
For Linear polarization, the currents should travel along one axis

For **circular/elliptical polarization**, the antenna should create two orthogonal currents with **90 degrees** phase shift between the currents.

Most communication antennas are linearly polarized (TV, FM, mobile). Some applications like satellite requires circular polarization

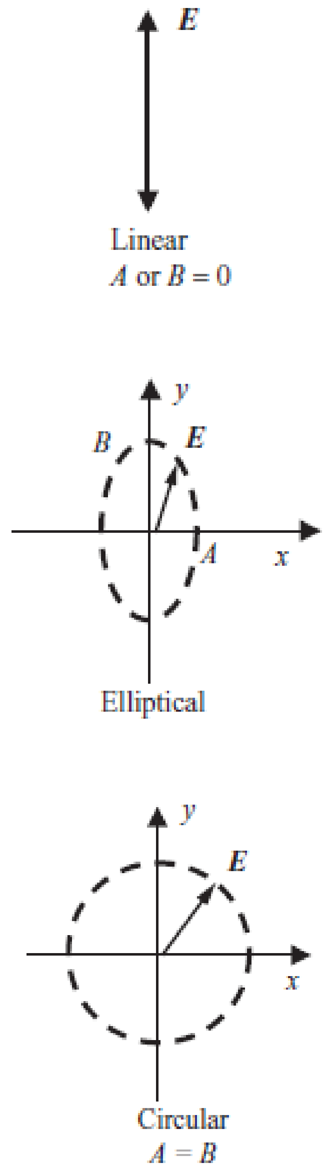
Circular polarization at 7.2 GHz





A wave propagating towards the z direction can be expressed as:

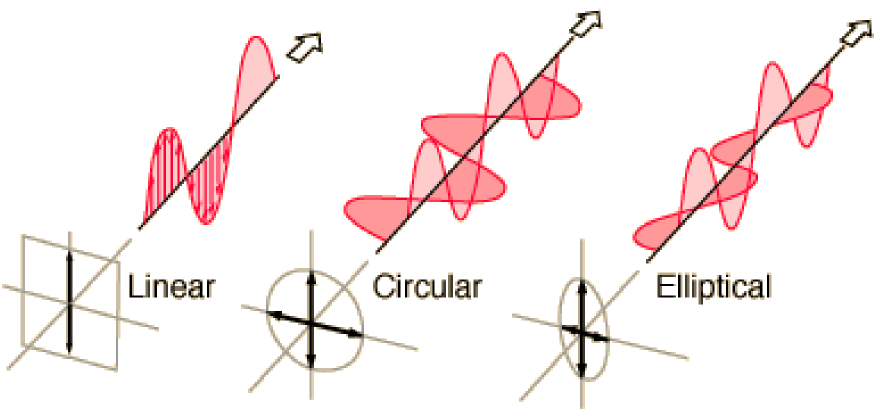
$$\boxed{\boldsymbol{E} = \tilde{\boldsymbol{x}}\,\boldsymbol{A}cos\,(wt - \beta z) + \tilde{\boldsymbol{y}}\,\boldsymbol{B}sin\,(wt - \beta z)}$$

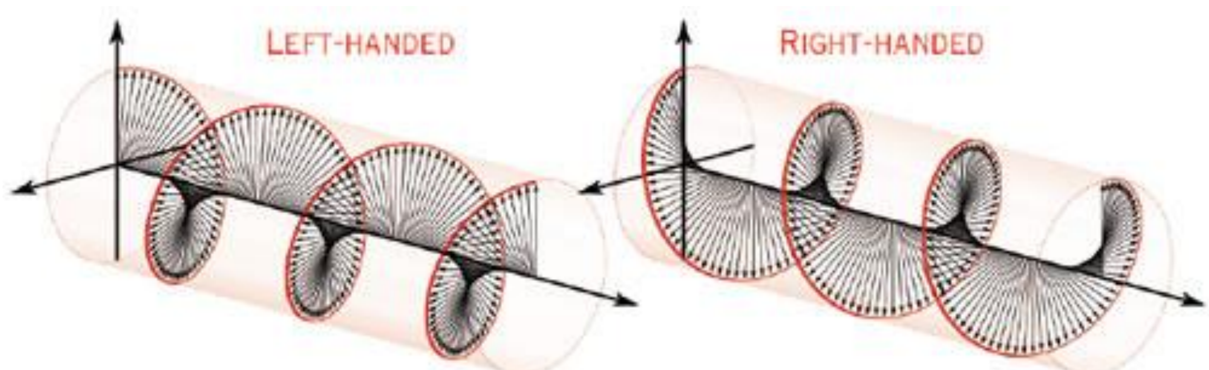


- If A or B = 0, this expression is a linearly polarized (LP) wave (Vertical or Horizontal)
- If A ≠ 0 or B ≠ 0, It is an elliptically polarized wave.
- If A = B, it represents a circularly polarized (CP) wave.
- Ionosphere causes faraday rotation to an EM wave. Therefore the linearly polarized EM wave may be rotated by an unknown amount which may cause polarization mismatch between transmit and receive antennas
- For circularly polarized waves, this problem is not present. This is why it is used in satellite systems like GPS, etc.
- Circularly polarized wave classified Right Hand Circular Polarization (RHCP) or Left Hand Circularly Polarization (LHCP)

A ratio of the amplitudes A to B is called the axial ratio. For a circularly polarized wave the axial ratio, AR is 1. For a Linearly polarized wave, AR is infinite or zero

$$\boxed{Axial\ Ratio\ (AR) = \frac{\boldsymbol{A}}{\boldsymbol{B}}}$$





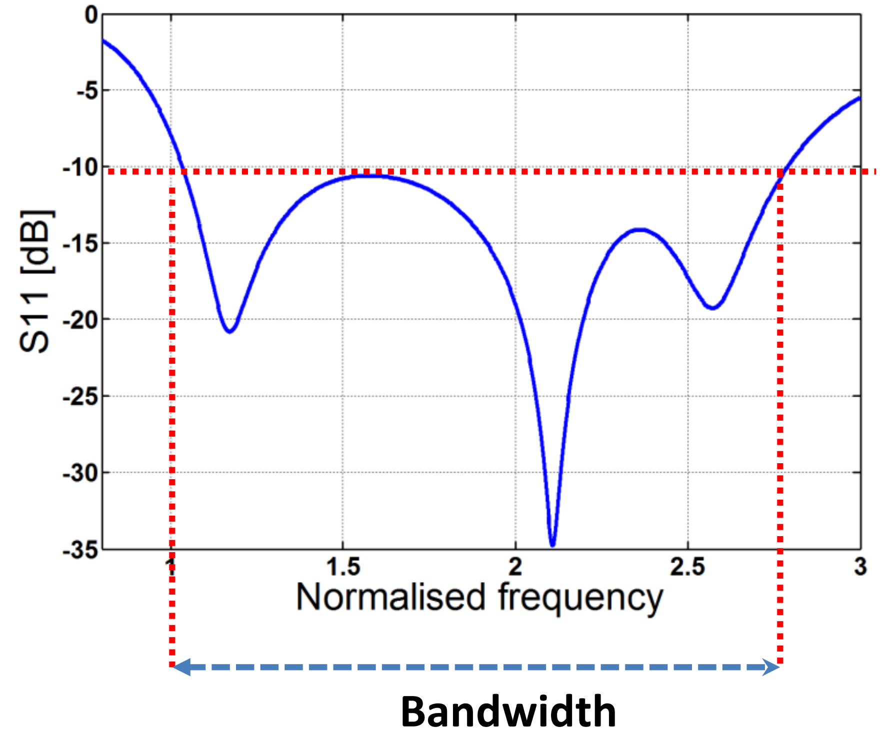
LHCP and RHCP

Bandwidth

- Bandwidth describes the range of frequencies over which the antenna can properly radiate or receive energy

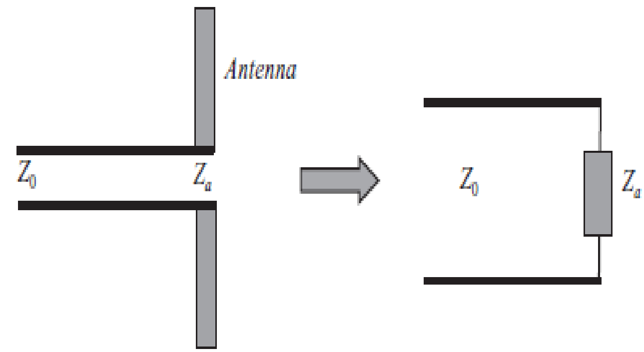
- Often the desired bandwidth is one of the determining parameters used to decide upon an antenna

- Bandwidth usually quoted in terms of VSWR, Return Loss, or Reflection Coefficient



Radiation Resistance

Antenna input impedance *Za* is defined as the impedance presented by an antenna at its terminals **Or** The ratio of the voltage to current at its terminals



Mathematically, the input impedance is given by

$$Z_a = \frac{V_{in}}{I_{in}} = R_a + jX_a$$

Where *Vin* and *In* are the input voltage and current input respectively. The input impedance is a complex impedance. The real part *Ra* is given by

$$R_a = R_r + R_L$$

Where *Rr* is the radiation resistance and *RL* is the loss resistance of the antenna from conductor loss or dielectric loss if lossy materials ar used

The radiation resistance is equivalent to the resistance

$$R_r = \frac{2P_t}{I^2{}_{in}}$$

In reality, the antenna is normally connected to a short transmission line with a standard characteristic impedance of ***50 Ohm or 75 Ohm***

Classification of Antennas

- **WIRE ANTENNAS**

Product Details:

Minimum Order Quantity	1 Piece

Product Description:

Electrical specifications

GSM/GPS WIRE ANTENNA

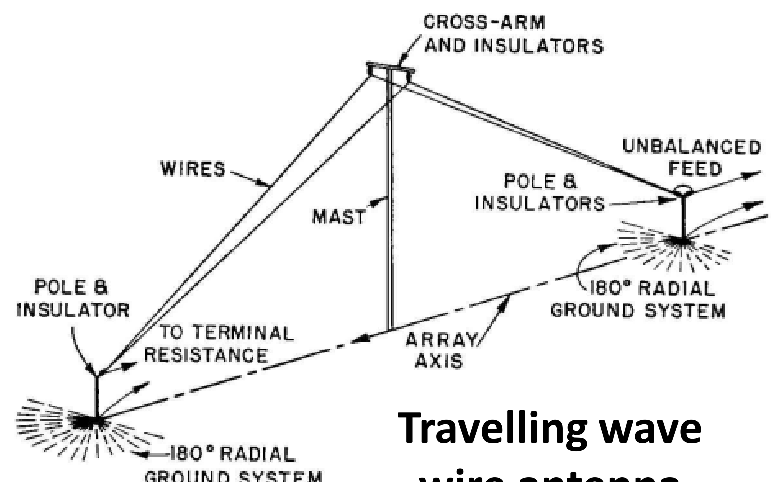
Frequency range -MHz

800MHz-960MHz,

1880MHz-1930MHz

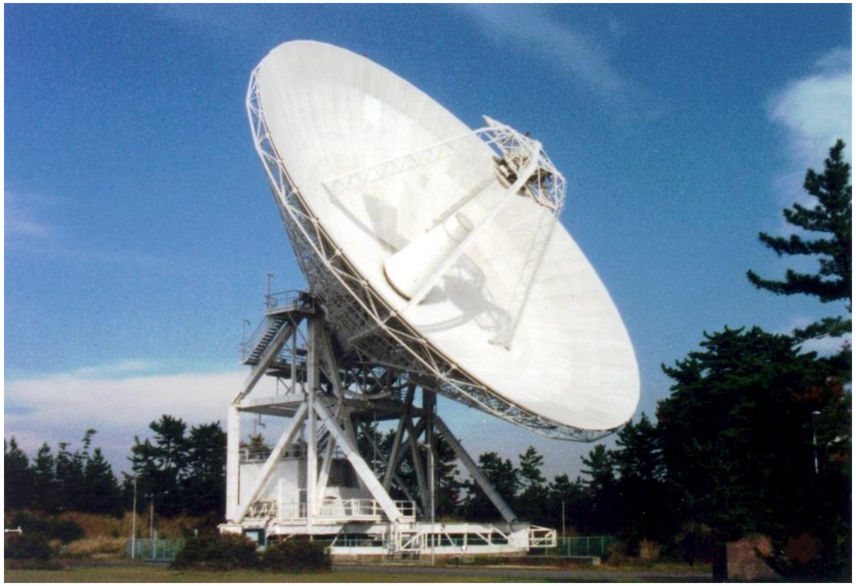
V.S.W.R ≤ 2.0 Gain-dBi 2.0 Polarization Vertical Impedance- Ω 50 Maximum

Input Power-W 10

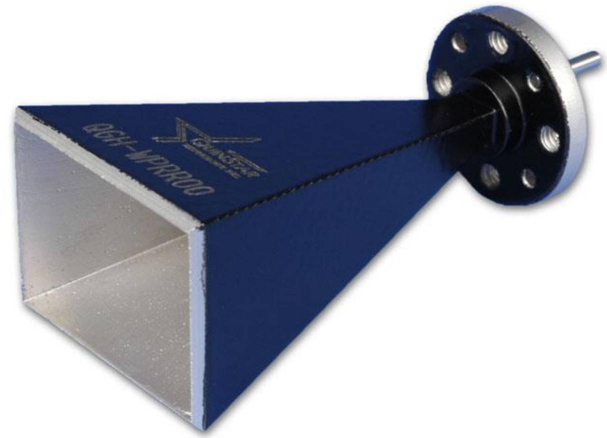


Travelling wave wire antenna

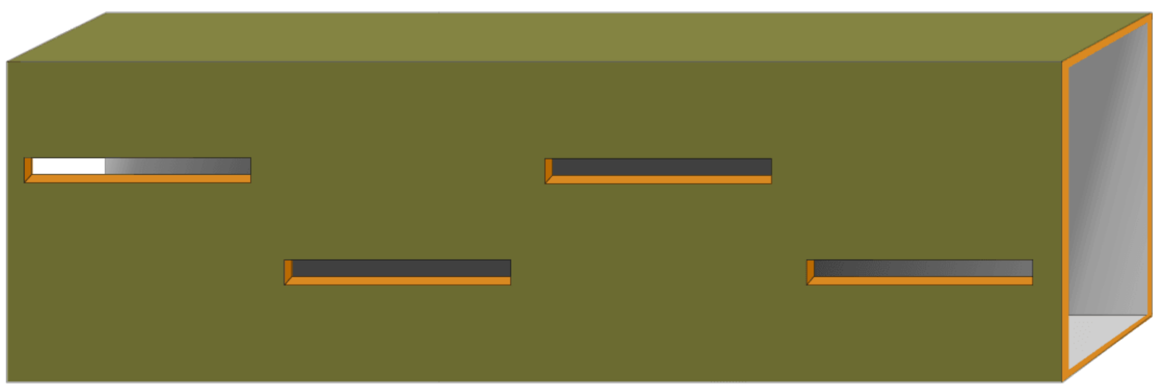
- # APERTURE ANTENNAS



DISH ANTENNA



HORN ANTENNA

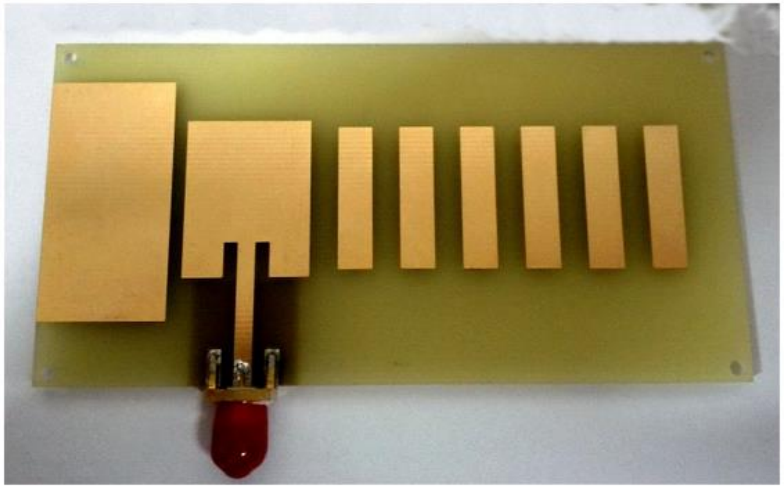


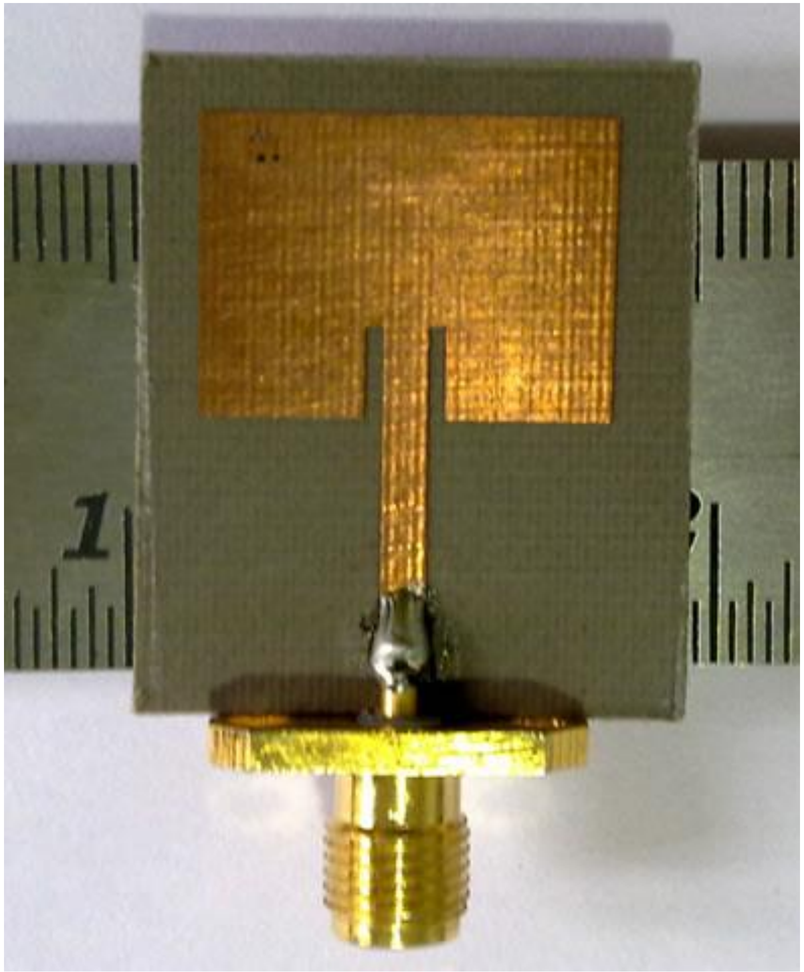
SLOT ANTENNA

• REFLECTOR ANTENNA

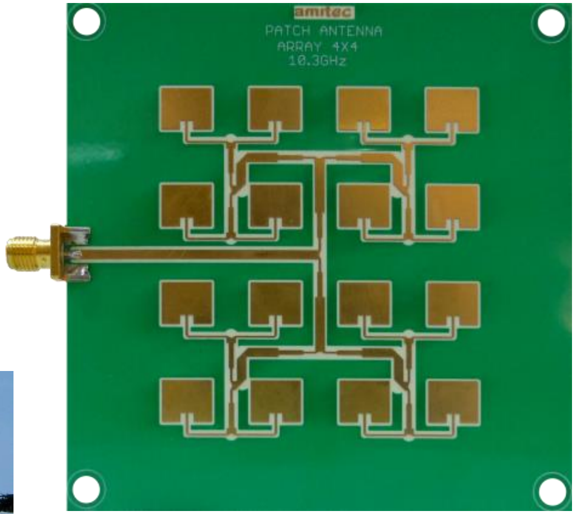
PARABOLIC REFLECTOR ANTENNA

• MICROSTRIP ANTENNA





- **ARRAY ANTENNA**



Telecom:

What is a Diversity Antenna? What is its purpose in a Cell Phone ?

How will the phone’s electrical performance be affected without it ?

Illustrate using PPT and include images to explain your answers

Electrical:

How many antennas are in a smart cellular phone ?

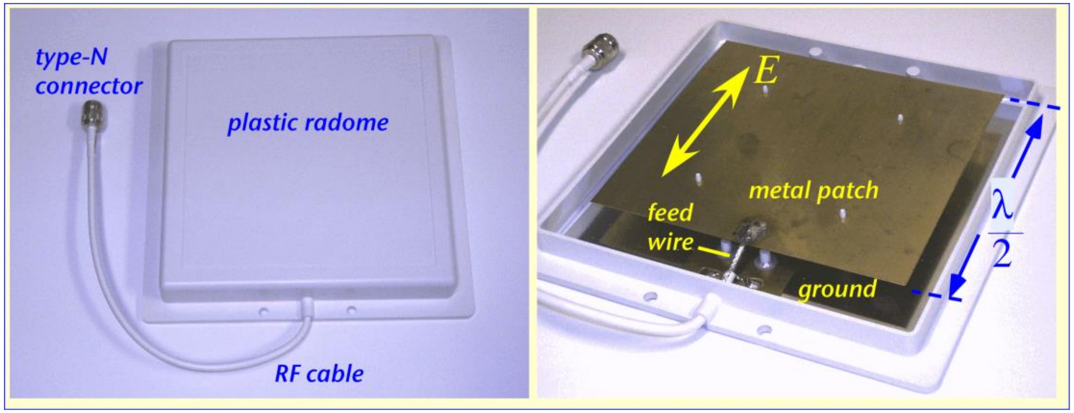
What functions do they perform in the cellular phone ?

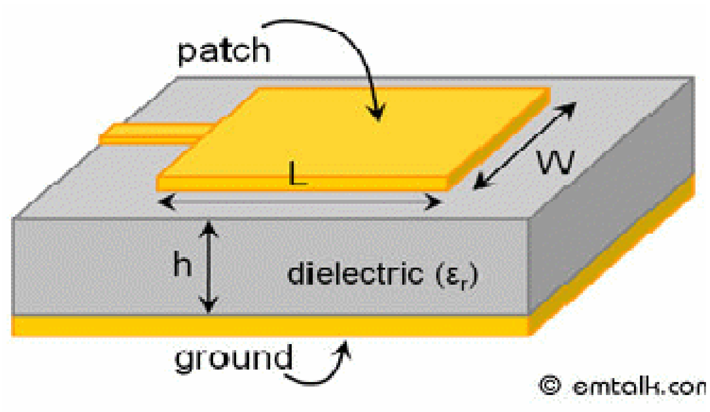
What antenna classifications do these antenna fall in ?

Illustrate using PPT and include images to explain your answers CONVINCINGLY

3. POPULAR ANTENNAS

A. MICROSTRIP PATCH ANTENNA

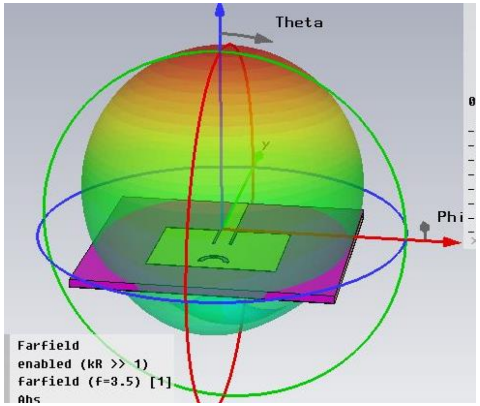




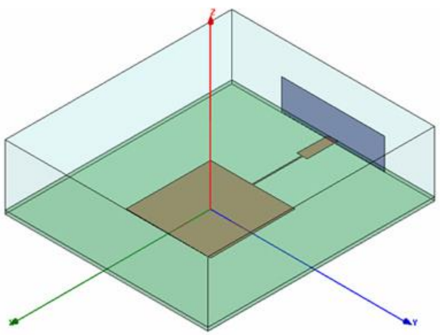
- The patch, feedline and ground plane are metals of high conductivity, typically copper
- The patch can be any shape; rectangular, square, circular, triangular

- Microstrip patch antenna, simply known as Patch antenna can be simply printed a circuit board, substrate or dielectric
- Patch antennas are low cost, low profile and easy to design and fabricate
- The patch antenna consists of a patch of metal which is the main radiator, a feed-line which is a transmission line, a ground plane, and a dielectric
- The radiating patch and the feed-line are usually printed on top of the dielectric and the ground plane is printed on the bottom of the dielectric

PATCH ANTENNA DESIGN



Radiation pattern



$$Z_{in} = \frac{{Z_0}^2}{Z_L}$$

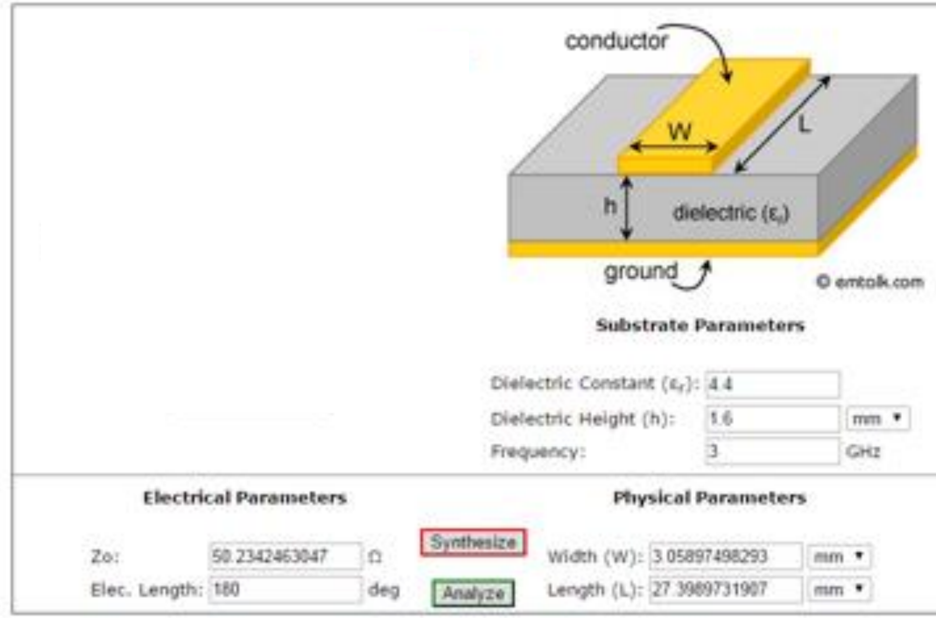
$$Z_0 = \sqrt{Z_{in} \times Z_L}$$

Impedance of quarter-wave transformer

$$L \approx \frac{\lambda_g}{2} \approx \frac{\lambda_0}{2\sqrt{\varepsilon_{ff}}} \approx \frac{\lambda_0}{2\sqrt{\frac{\varepsilon_r + 1}{2}}} \approx \frac{c}{2f\sqrt{\frac{\varepsilon_r + 1}{2}}}$$

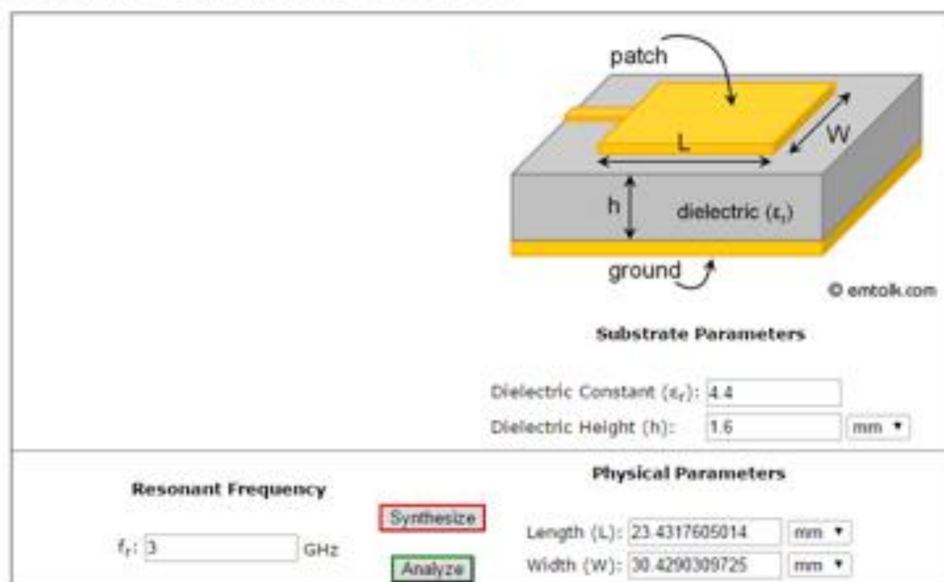
Length of Radiating Patch

Microstrip Line Calculator



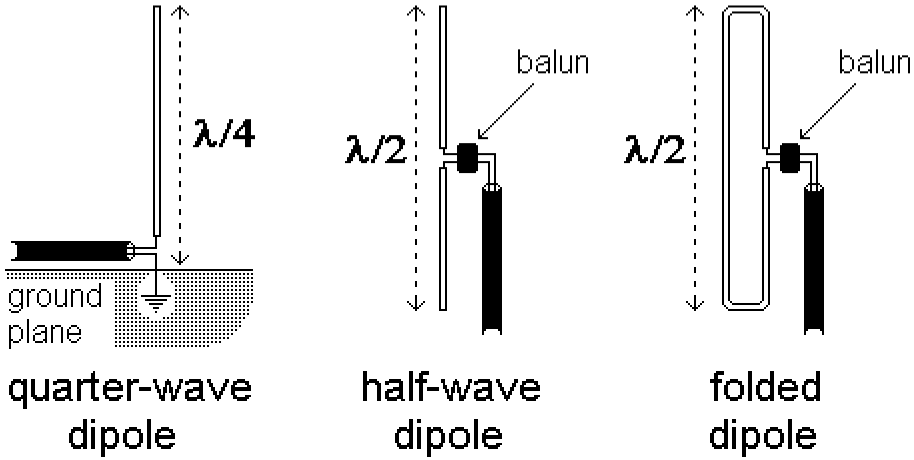
www.emtalk.com/mscalc.php

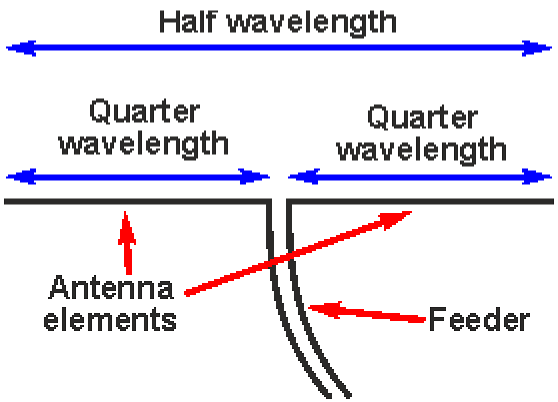
Microstrip Patch Antenna Calculator

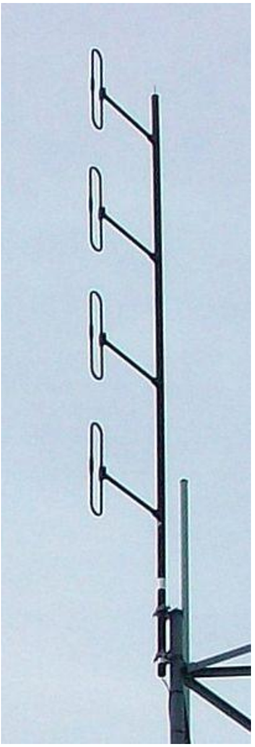


www.emtalk.com/mpacalc.php

B. DIPOLE ANTENNA



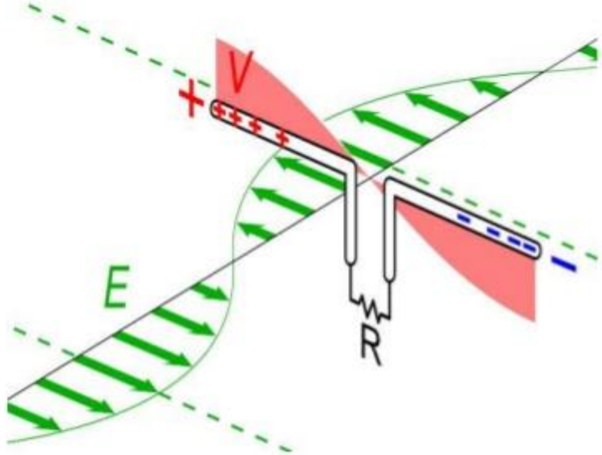


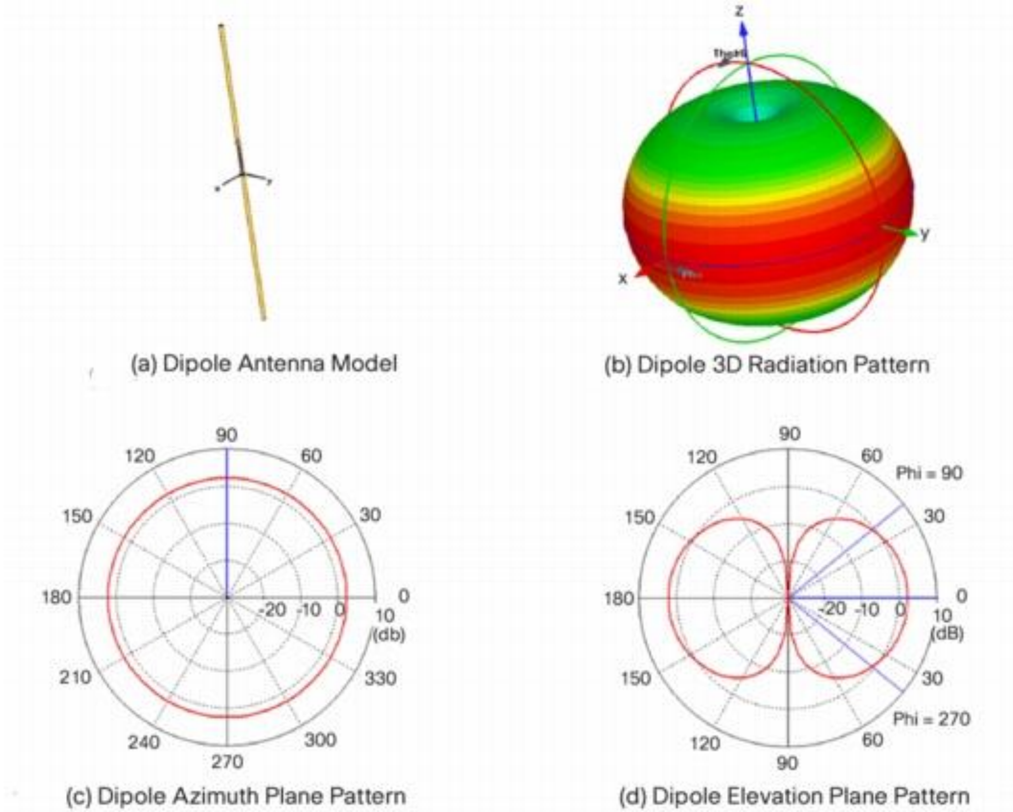


Folded Dipole Array Antenna (Collinear folded dipole)

WORKING (CONTD)

A half-wave dipole antenna receiving power from a radio wave. The electric field of the wave (E, green arrows) pushes the electrons in the antenna elements back and forth (black arrows), charging the ends of the antenna alternately positive and negative. Since the antenna is a half-wavelength long at the radio wave's frequency, it excites standing waves of voltage (V, red) and current in the antenna. These oscillating currents flow down the transmission line into the radio receiver (represented by the resistor R). The action is shown slowed down in this animation.





Azimuth angle

Elevation angle

Radiation pattern of a Dipole Antenna

- Ideally, Gain of a dipole antenna is 2.15 dBi or 1.64, compared to short element (monopole) with gain 1.5 or 1.76dBi
- Probably the most widely used antenna
- Radiates equal power in the azimuth direction, therefore considered an *omnidirectional* antenna
- Also called a doublet, meaning two times a monopole antenna
- It is also called a Hertzian antenna or Hertzian dipole since it was discovered by Hertz

C. Yagi-Uda Antenna

Design (1) A matched patch antenna (2) An un-matched patch antenna using HFSS and compare the results between the (1) and (2)

Each student should choose a different frequency between
Telecom: ***300 MHz – 800 MHz*** (steps of 10 MHz)
Electrical: ***1 GHz - 15 GHz*** (Steps of 1 GHz)

COMPARE YAGI-UDA ANTENA AND A LOG-PERIODIC ANTENNA IN TERMS OF:

- Antenna Structure
- Design principle
- Electrical performance

4. Antenna Measurement

Two main equipment is used in measuring a fabricated antenna:

1. Anechoic Chamber
2. Vector Network Analyzer

Typically used for frequencies above 300 MHz

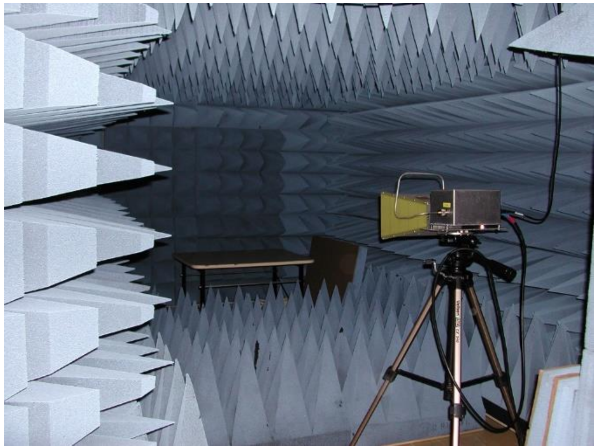
1. ANECHOIC CHAMBER

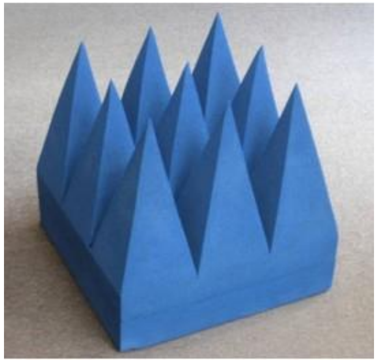
Used to measure far field results : gain, radiation pattern, axial ratio, efficiency..etc

Chamber is designed to completely absorb reflections of electromagnetic waves and even sound

They use absorbing material that is cut to a certain dimension for proper absorption (jagged triangular shape)

When the floor of the chamber is solid with no absorbing material, it is termed as semi-anechoic chambers. In this case, the floor is used for supporting heavy items such as cars, airplanes.



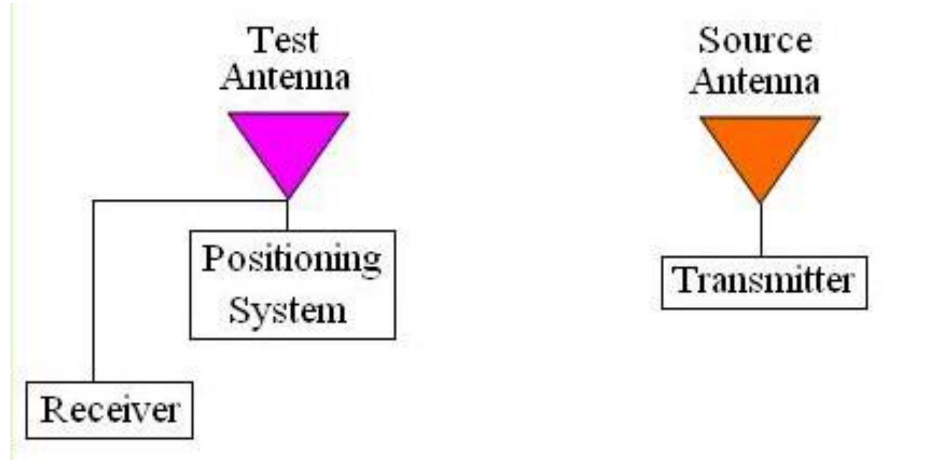


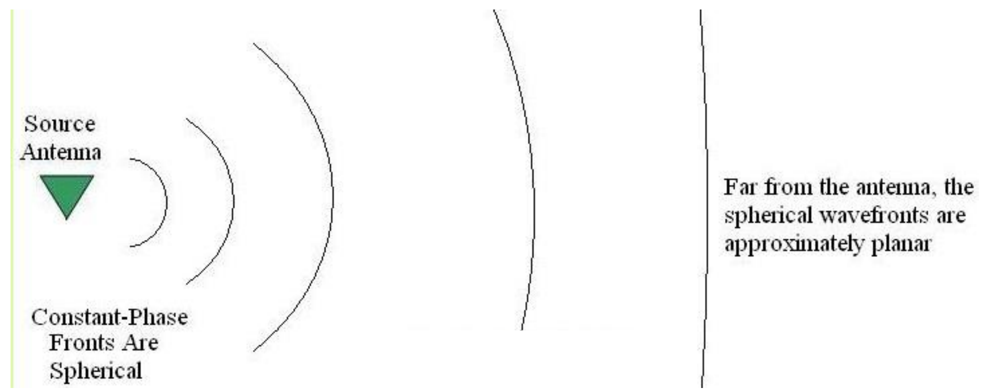
The setup is shown in the figure below

The antenna-under-test will be illuminated with a plane wave from a well known antenna (usually a horn antenna)

The antenna-under-test is rotated while being illuminated by the source antenna to measure the radiation pattern as different angles

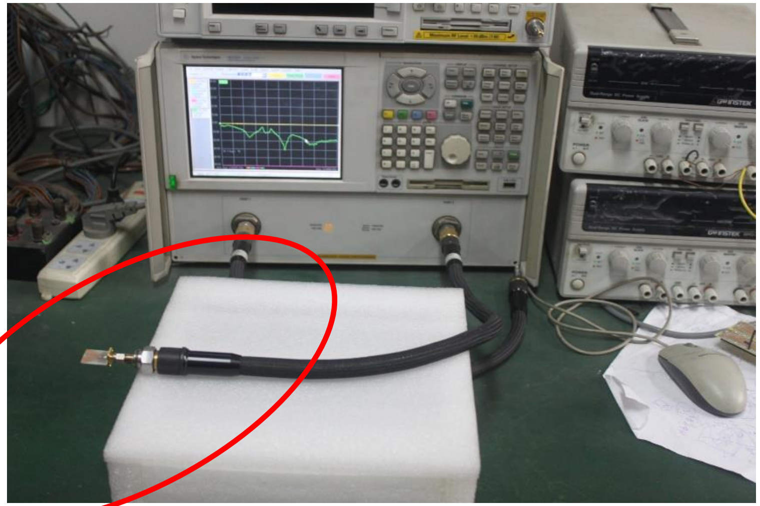
The positioning systems rotates the antenna-under-test so the radiation pattern can be measured as a function of angle (in spherical coordinates)



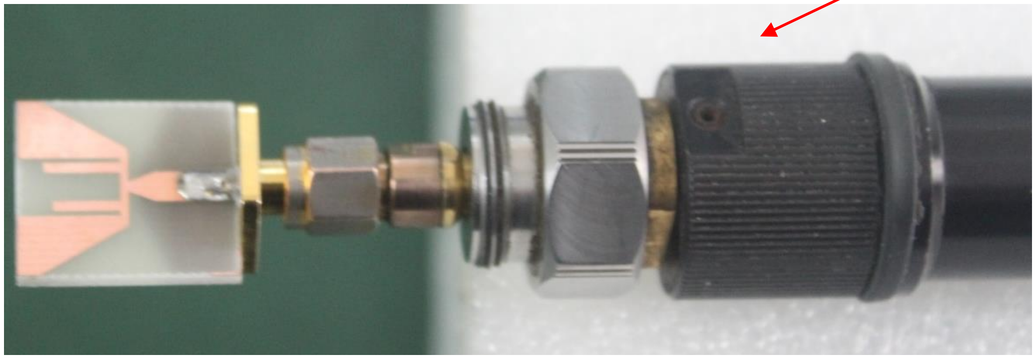


2. VECTOR NETWORK ANALYZER (VNA)

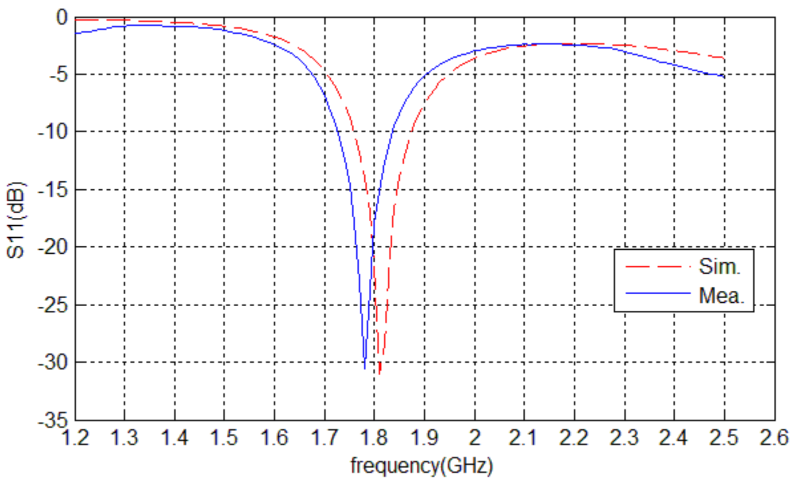
- A VNA is a test system that enables the RF performance of radio frequency and microwave devices to be characterised in terms of scattering parameters, or S parameters (S_{11}, S_{12}…etc)

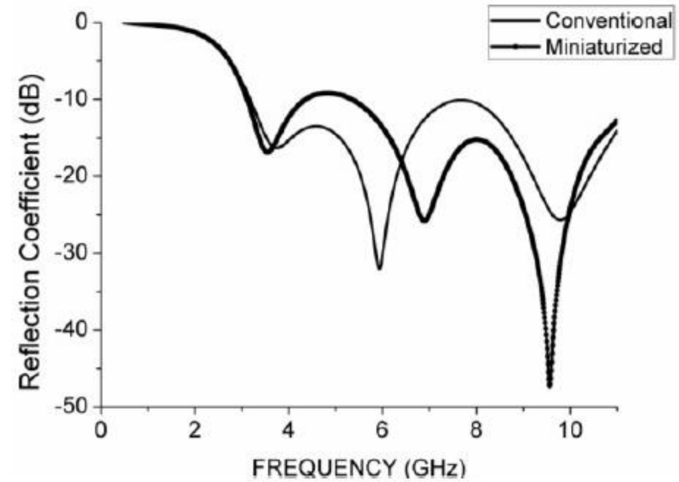


- A fabricated antenna is usually tested with a VNA first before it is tested with an anechoic chamber



Simulation and Measurement Errors/Discrepancies





It is impossible to achieve the exact same measurement and simulation results

Usually, the discrepancies in the results are accredited to the power connectors (SMA connectors) and the use of imperfect materials (metals and dielectrics) used in fabrication