Narasimha Reddy, MTech, Asst prof.

NON-RESONANT RADIATORS :-

* The antennas which operate between frequency range of 3-30 MHz are called high-frequency antennas.
* For the HF band, the wavelength ranges in 100m to 10m.
* So the HF antennas can be made in size comparable with the wavelength.
* The directional properties can also be obtained for such antennas.
* In case of Low frequency and ~~high~~ medium frequency band, the wavelength is greater, the size of antenna becomes larger, and it becomes difficult to achieve highly directive system.

Resonant Antenna :-

→ Resonant antennas are antennas which correspond to transmission line and standing waves are exist. (Incident waves + Reflected waves)

* the resonant antennas are also called as periodic antennas
* Examples of Resonant antennas are half wave dipoles, quarter wave monopoles, folded dipoles.
* The radiation pattern is bi-directional.

Non-Resonant antenna :-

* The Non-Resonant antennas are antennas which is also corresponds to transmission line, but there is no standing waves occurs. Because it exists only travelling waves (Incident wave).

* In the HF band vertical radiators is not a suitable choice. so practically the simplest antenna that can be used is horizontal antenna $\frac{\lambda}{2}$ dipole.

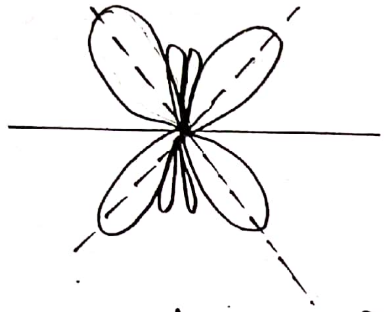
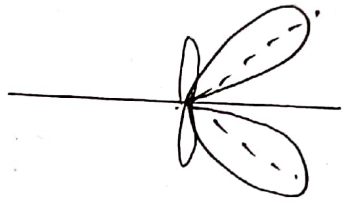
* The Non-Resonant radiator (or) antenna is also called as "aperiodic" antenna.

* Examples are travelling wave antennas, long wire antenna, V-antenna, inverted V-antenna, Rhombic antenna.

* The Radiation pattern is uni-directional.

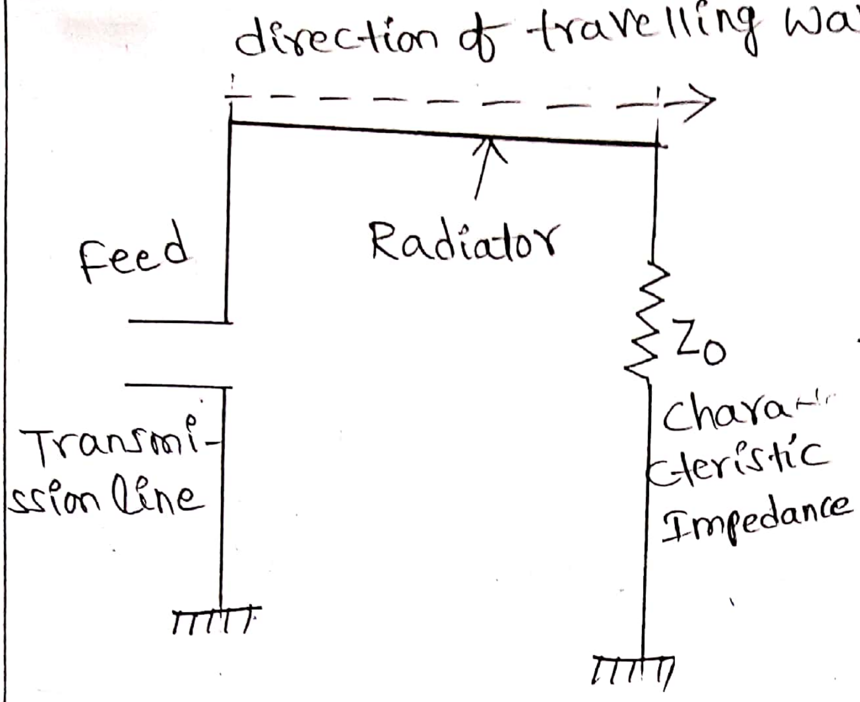
Comparision between Resonant and Non-Resonant antennas :-

Resonant Antenna	Non-Resonant Antenna
* Resonant antennas are antennas having exact no.of $\frac{\lambda}{2}$ wavelength long, and open at both the ends.	→ It is a transmission line excited at one end and properly terminated at other end.

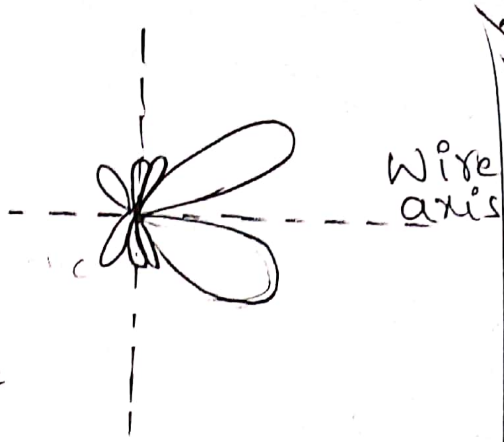
In this antenna, the standing waves are exist	→ No standing waves are exist due to No Reflected waves.
It has bi-directional radiation pattern 	→ It has uni-directional radiation pattern. 
→ It operates at fixed frequency	→ It operated at various types of frequencies.

Travelling wave Radiators :- [Travelling wave Antennas].

* The antenna in which the standing waves does not exist along the length of the antenna this is called as "travelling wave antenna".
* Generally the standing waves exist when the Antenna wire is not properly terminated which causes reflections are produced at load.
* Therefore the standing waves exist in the Resonant antenna and not exist in the non-Resonant antenna
* In travelling wave antenna no reflections are produced. due to which No standing waves occurs.



(a) Travelling wave antenna



(b) uni-directional Radiation pattern.

* The current will change phase with distance that is progressive phase change in the end-fire array case.
* The velocity of light in wire is same as in the freespace.

The strength of the electric field at a distance 'r' is given by

$$E = \frac{60\, I_{rms}}{r}\left(\frac{\sin\theta}{1-\cos\theta}\right)\sin\left(\frac{\pi L}{\lambda}(1-\cos\theta)\right)$$

r = distance at a point from radiator

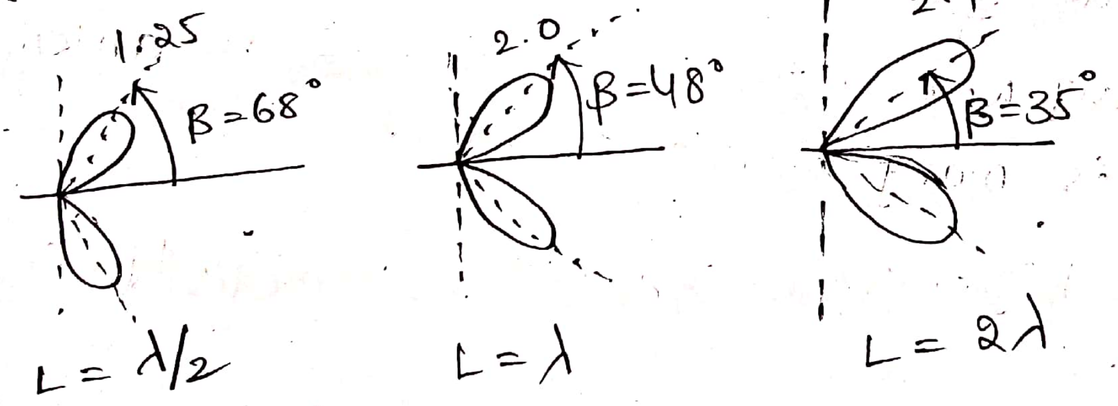
L = Length of wire. (or) radiator.

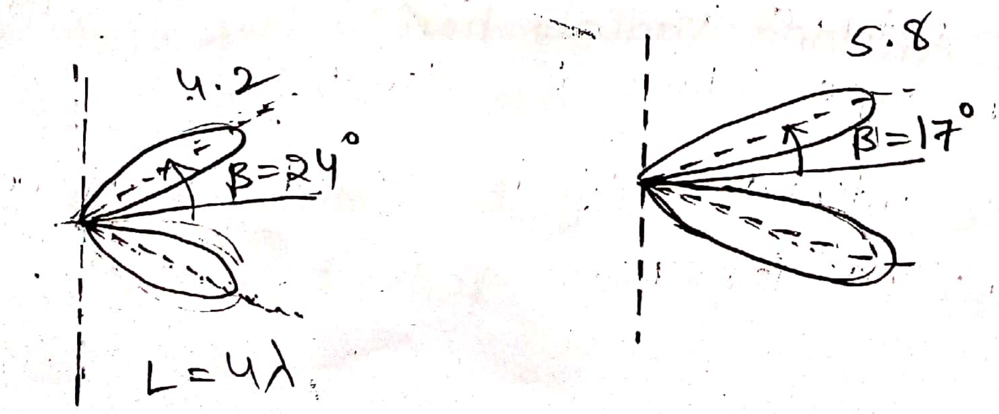
The angle and amplitude of the major lobe depends on the length of the wire.

- If the length of wire increases then the angle of major lobe decreases and amplitude of major lobe Increases.

Length of wire	Angle of major lobe	Amplitude of major lobe
$L = \frac{\lambda}{2}$	68°	1.25
λ	48°	2.0
2λ	35°	2.9
4λ	24°	4.2
8λ	17°	5.8

The radiation pattern for different lengths of travelling wave antenna





Advantages:-

* standing waves doesnot exist
* compared to single wire antenna Band width is more.
* Less power dissipation.
* used in Radio communications, applications.

Dis advantages:-

* The waves can be propagated in only one direction.
* Large space requirement.

Long wire antenna:- (Hormonic Antenna)

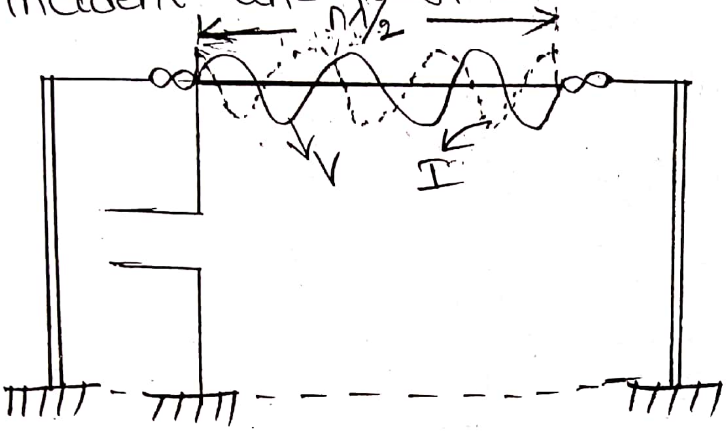
* A long wire antenna is defined as a single long wire, typically n times of $\frac{\lambda}{2}$ long at the operating frequency
* It is also an integer multiple of Half wave-length (ie) $\frac{n\lambda}{2}$.
* ∴ A long wire antenna is linear wire antenna which is many wavelength long.
* If the higher value of 'n', the directivity is better.
* A long wire antenna radiates horizontally polarized wave at an angle which are 17° to 25°.
* A long wire antenna may be considered as a resonant antenna (or) non-resonant antenna.

Resonant Long wire Antenna:-

(4)

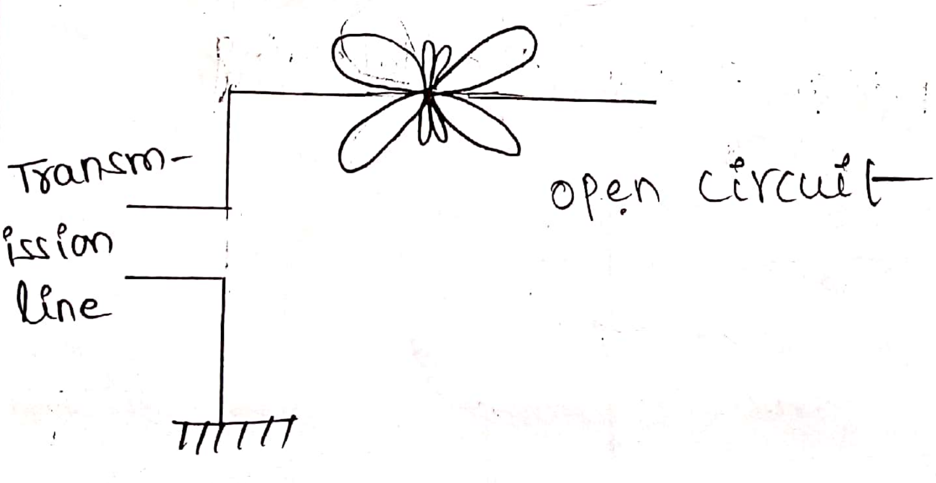
→ In the Resonant Long wire antenna, the load end is open (or) unterminated. Therefore the standing waves are observed along the length of antenna.

→ Thus the pattern is bidirectional due to the incident and reflected waves.



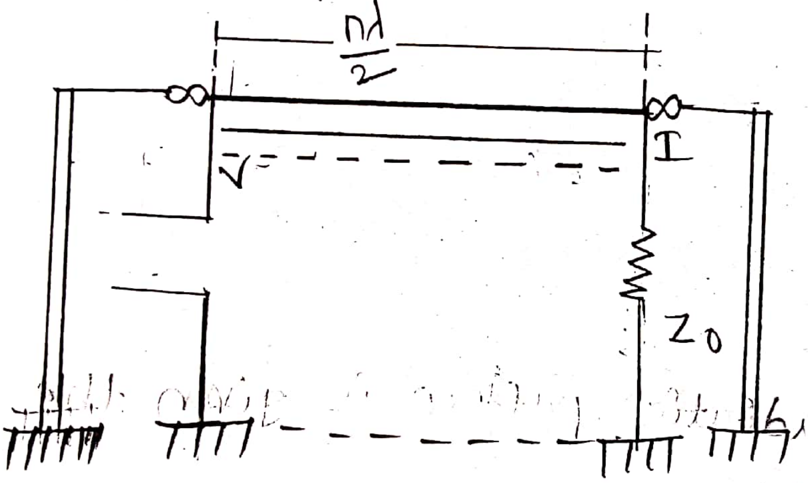
Resonant Long wire Antenna

Bidirectional radiation pattern is given the following figure



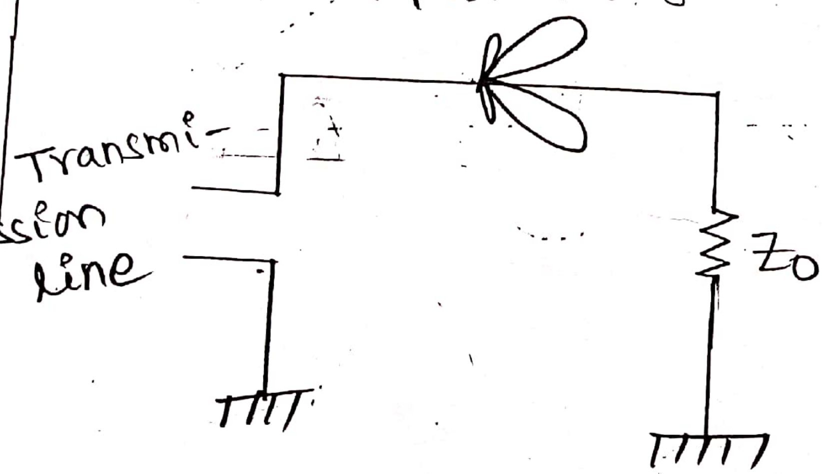
Non - Resonant Long wire Antenna:-

- In non- Resonant long wire antenna, the load end is terminated with characteristic impedance (or) non inductive resistance.
- ∴ No standing waves are exist along the length of antenna.
- All the incident waves are absorbed and no reflections are produced.
- Thus the pattern is uni-directional.



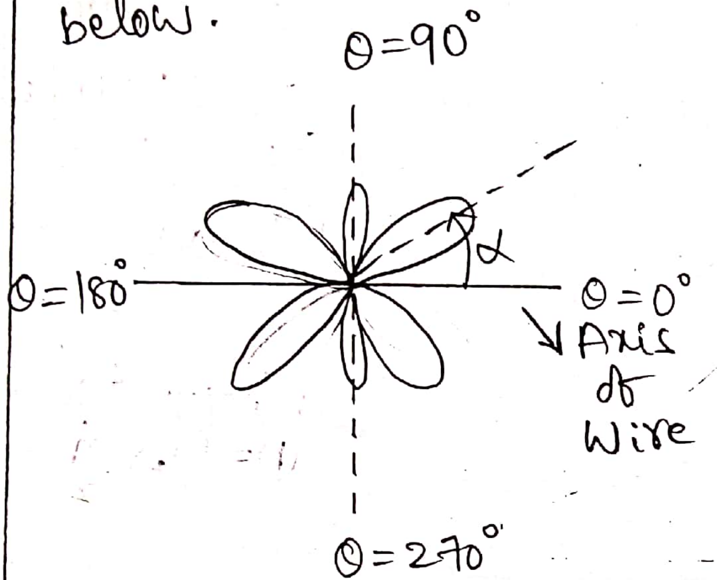
Non Resonant Long wire antenna

Unidirectional pattern is given the following

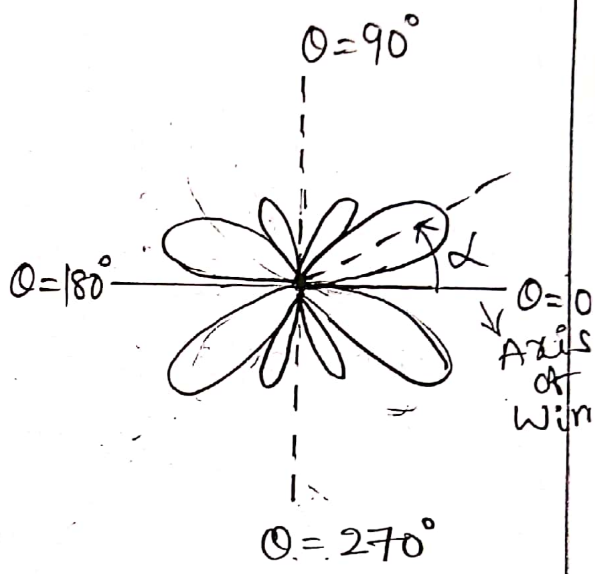


Depending on if 'n' is even and odd, the directional pattern changes.

→ The patterns of long wire antenna for different integer multiples (ie) n=3 and n=4 are given below.



n=3

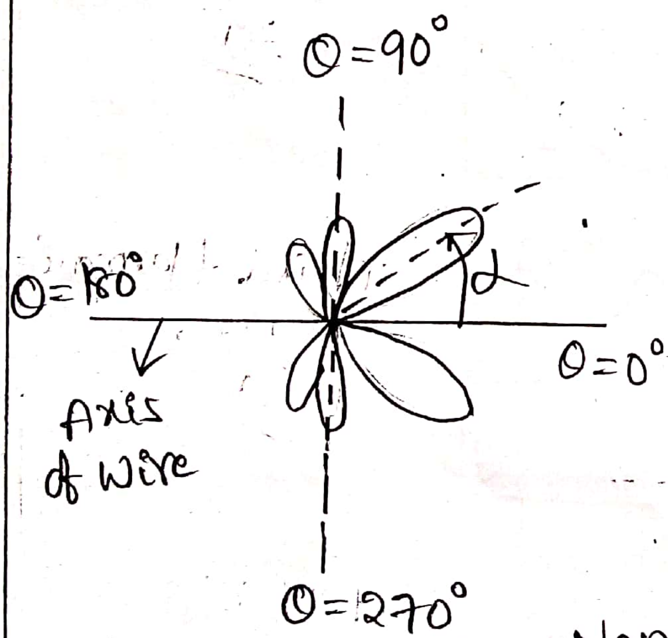


n=4

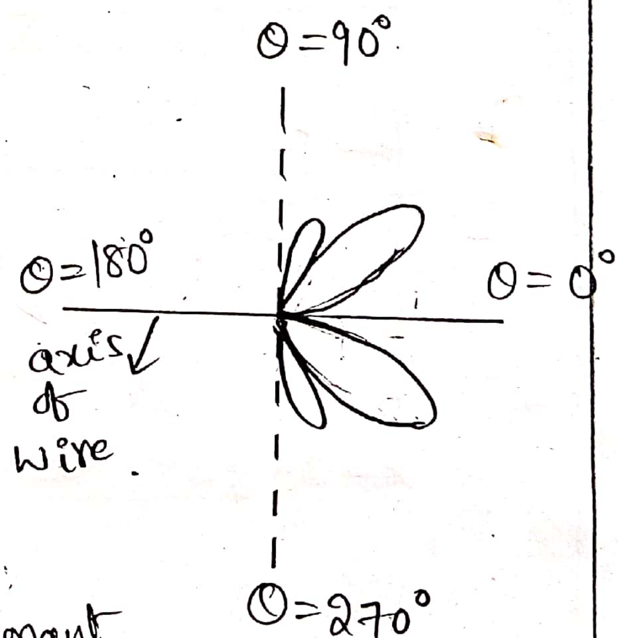
n=3 → odd }
n=4 → even }

Resonant long wire Antenna.

n-odd $E = \frac{60 I_{rms}}{r} \frac{\cos\left(\frac{n\pi}{2}\cos\theta\right)}{\sin\theta}$



n=3



n=4

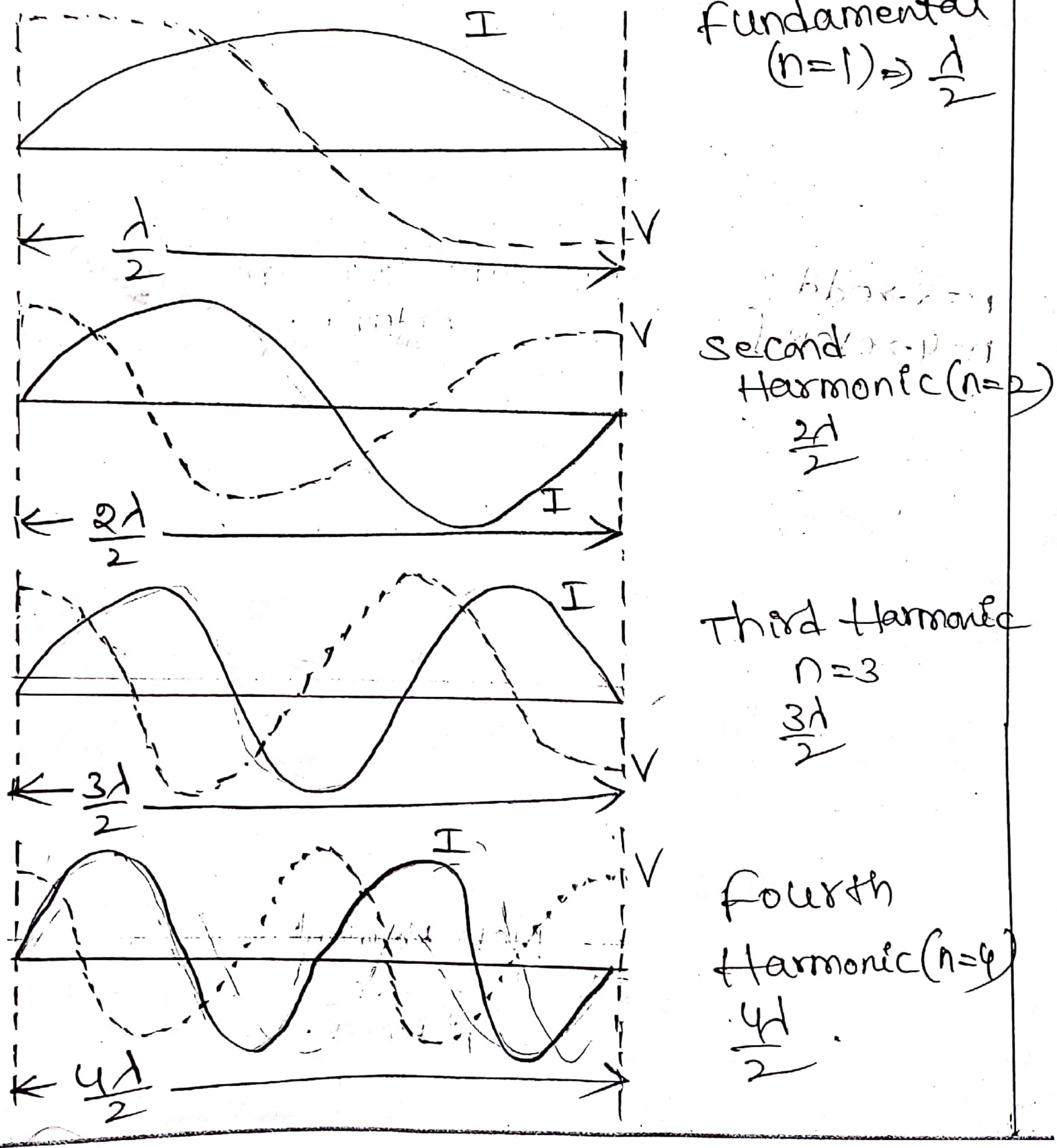
Non Resonant long wire Antenna.

* for the half wavelength long wire antenna, the physical length is given by

$$\text{Length} = \frac{492(n-0.5)}{f(MHz)} \text{ feet}$$

n = no. of integer multiple half wavelength.

→ The voltage and current distribution along resonant wire working a fundamental frequency ($\lambda/2$) and second harmonic ($\frac{2\lambda}{2}$), 3rd harmonic ($\frac{3\lambda}{2}$) are shown below.



The field strength for resonant long wire antenna with length even and odd integer multiples of $\frac{\lambda}{2}$ are given by

$$E = \frac{60 I_{rms}}{r}\left[\frac{\cos\left(\frac{n\pi}{2}\cos\theta\right)}{\sin\theta}\right] \dashrightarrow n \text{ is odd}$$

$$E = \frac{60 I_{rms}}{r}\left[\frac{\sin\left(\frac{n\pi}{2}\cos\theta\right)}{\sin\theta}\right] \dashrightarrow n \text{ is even.}$$

Similarly the field strength for non-resonant long wire antenna is given by

$$E = \frac{60 I_{rms}}{r} \cdot \frac{\sin\theta}{1-\cos\theta} \cdot \sin\left(\frac{\pi L}{\lambda}(1-\cos\theta)\right)$$

→ When the integer value of 'n' is increased, that increases the no. of lobes in proportion with major lobe.

→ For the resonant long wire antenna of 'n' wavelength long, the radiation resistance is

$$R_{rad} = 73 + 69 \log_{10} n \ \Omega$$

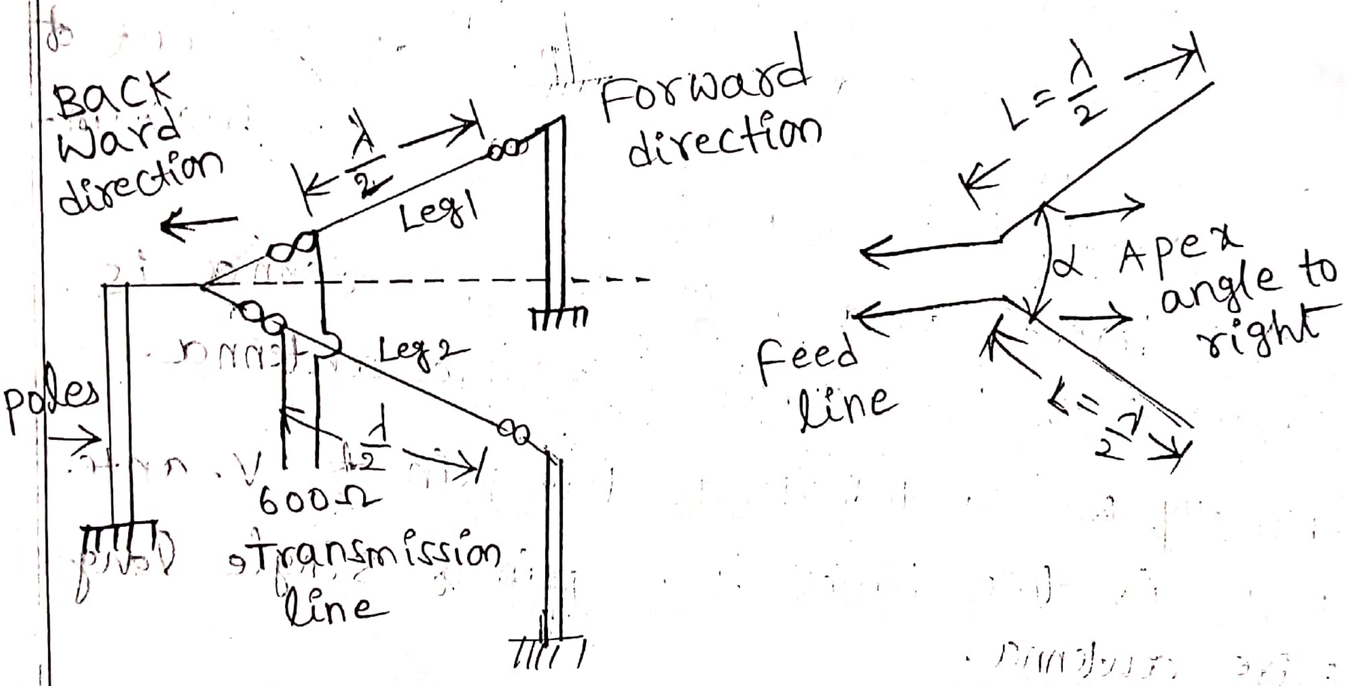
→ The angle of maximum radiation is given by

$$\theta_{max} = \cos^{-1}\left(\frac{n-1}{n}\right)$$

V-antenna :-

* The V-antenna is extension of long wire antenna. the two long wires are arranged in the form of horizontal 'V' fed at apex angle.

* The Resonant V-antenna arrangement is given below.



Resonant V-antenna

* if the two legs of V-antenna not terminated at load end then such antenna is "Resonant V-antenna.
* Therefore we get bi-directional pattern.
* if the two legs of the V-antenna terminated in terms of characteristic impedance then such antenna is " non-Resonant V-antenna.
* ∴ We get uni-directional pattern.

* The angle between two legs of the V-antenna is called as "apex angle α".

* The apex angle is equal to twice the angle that the cone of maximum direction with wires (legs) makes by the axis of V-antenna.

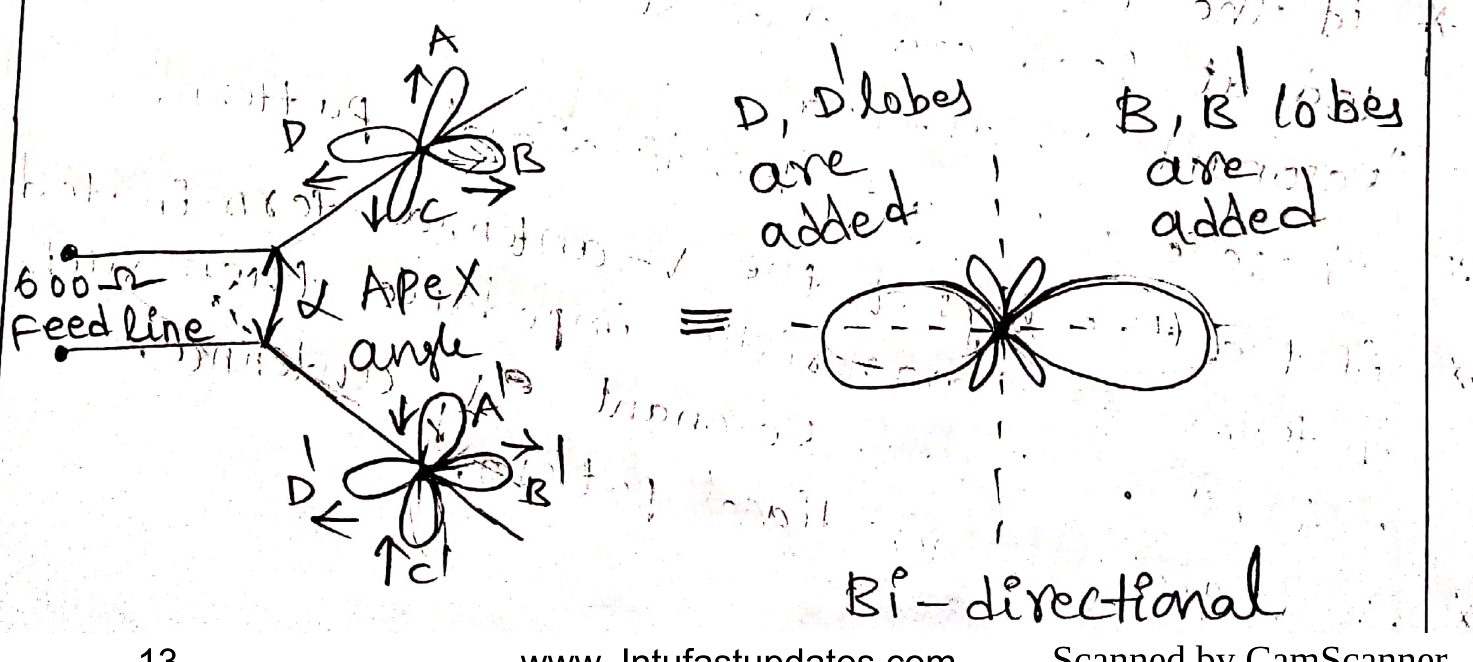
* ∴ The two cone angles are adding to get the maximum radiation.

* The two wires are connected at 180° out of phase with each other. So we get maximum directivity and gain.

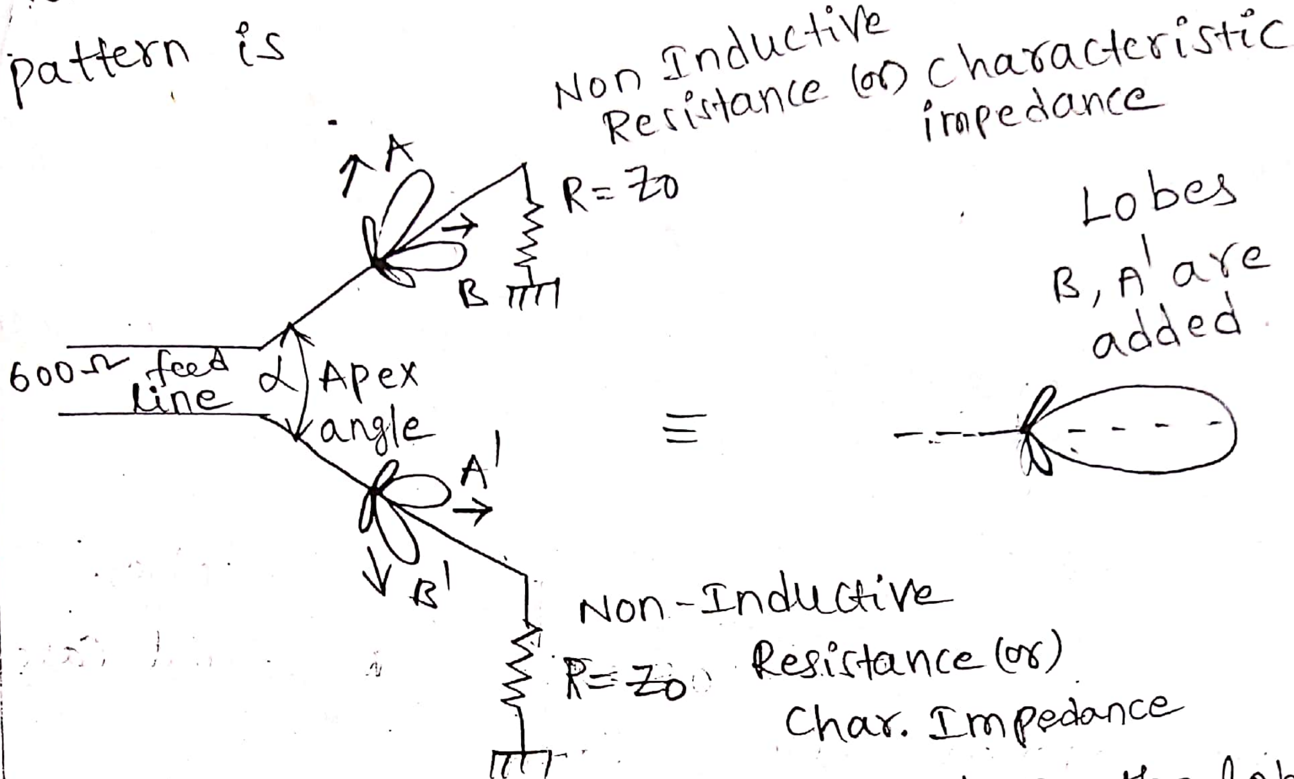
* The directivity and gain of V-antenna is larger than the single long wire antenna.

* Finally we conclude that the gain of V-antenna is two times the gain of single long wire antenna.

Resonant V-antenna with bi-directional pattern is



Non-Resonant V-antenna with uni-directional pattern is



* "In the Resonant V-antenna pattern the lobes D and D' are added in the backward direction as they are in the same direction.
* similarly the lobes B and B' are added in the forward direction, as they are also in the same direction.
* The ~~remaining~~ remaining lobes A, A' and C, C' are cancelled due to opposite direction.
* Thus we get bi-directional pattern with increased directivity and gain.
* "In the Non-Resonant V-antenna pattern the lobes B and A' are added in the same direction, A and B' are cancelled.
* Thus we get uni-directional radiation pattern with increased directivity & gain.

Advantages :-

1. It is the cheapest form of Transmitting and Receiving antenna for lower beam.

2. It has high directivity & gain

3. The apex angle varries from 36° to 72° for the length of 8λ to 2λ

Drawbacks :-

1. It produces too many strong side lobes.
2. The band width is less in Resonant case.
3. More expensive [high cost].

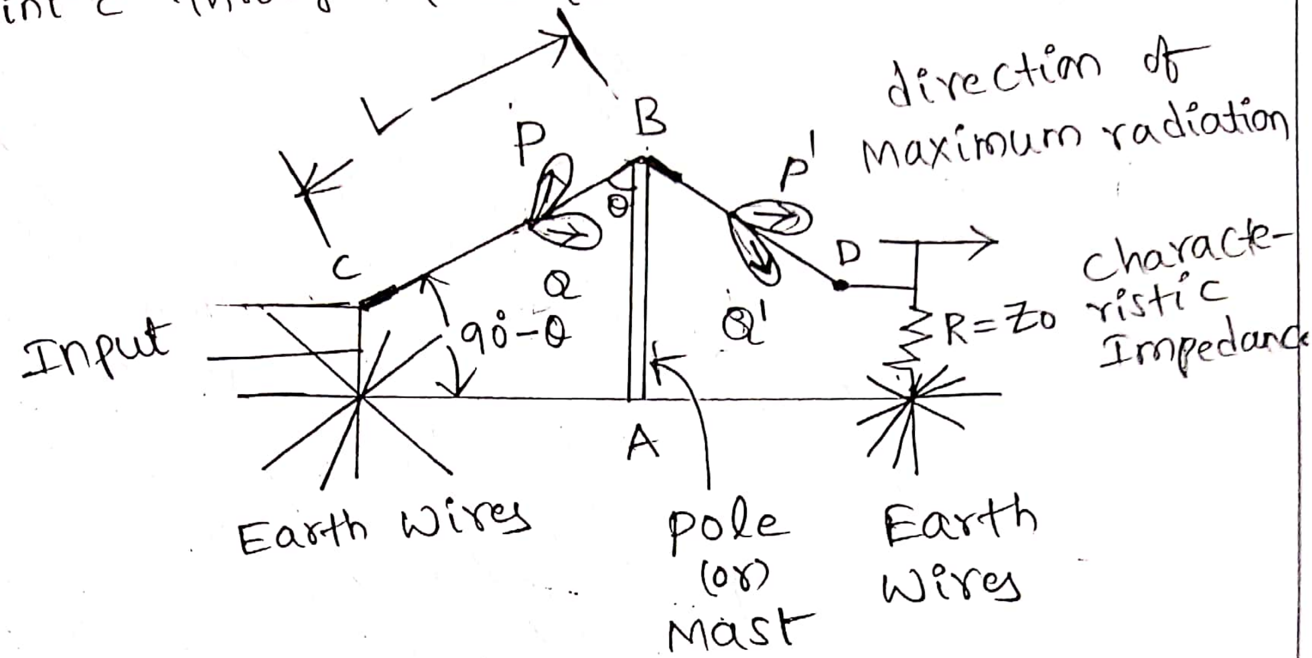
Inverted V- antenna :-

* The resonant (or) Tuned antennas, are having small band width and more expensive.
* ∴ Resonant antennas are operated at fixed frequency
* The large band width can be achieved by Travelling wave antennas in which no standing waves produced.
* The inverted V-antenna used in the high frequency band is one of the travelling wave antenna.

The principle and working as given below.

Principle :-

The input from transmitter is applied at point 'c' through the transmission line.



Inverted V-antenna

* One end is connected to no. of radial earth wires, the next end of antenna wire 'D' is connected to earth wires and terminated with characteristic impedance (or) Non-Inductive resistance.

* This resistance is typically 400 Ω and adjusted to set the travelling waves in the BCD (or) CBD wire.

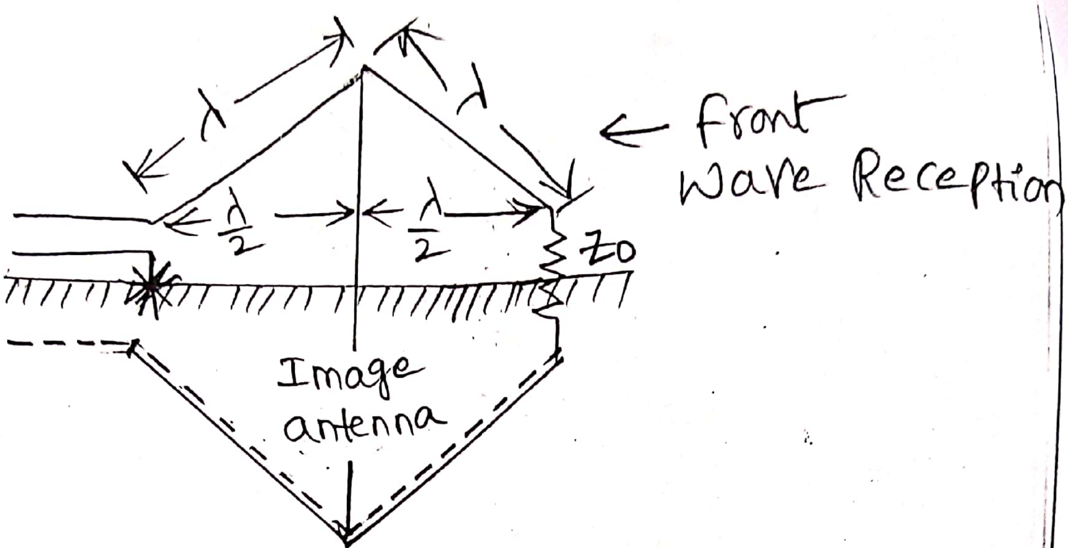
* The angle 'θ' is known as "tilt angle". It is given by

(i) The angle of major lobe corresponding to $\frac{L}{\lambda}$

(ii) The angle of tilt, where the fields from BC, BD combined to give max. gain, directivity

* From above figure the lobes Q, P' are added and P, Q' are cancelled.

Inverted V-earthed antenna is given below



The inverted V-antenna and its image antenna combinely to give the Rhombic antenna with maximum gain along the ground plane.

* The maximum gain occurs at half of the breaster angle (θB)
* It is the critical angle of incidence in the vertical polarized waves.

Advantages :-

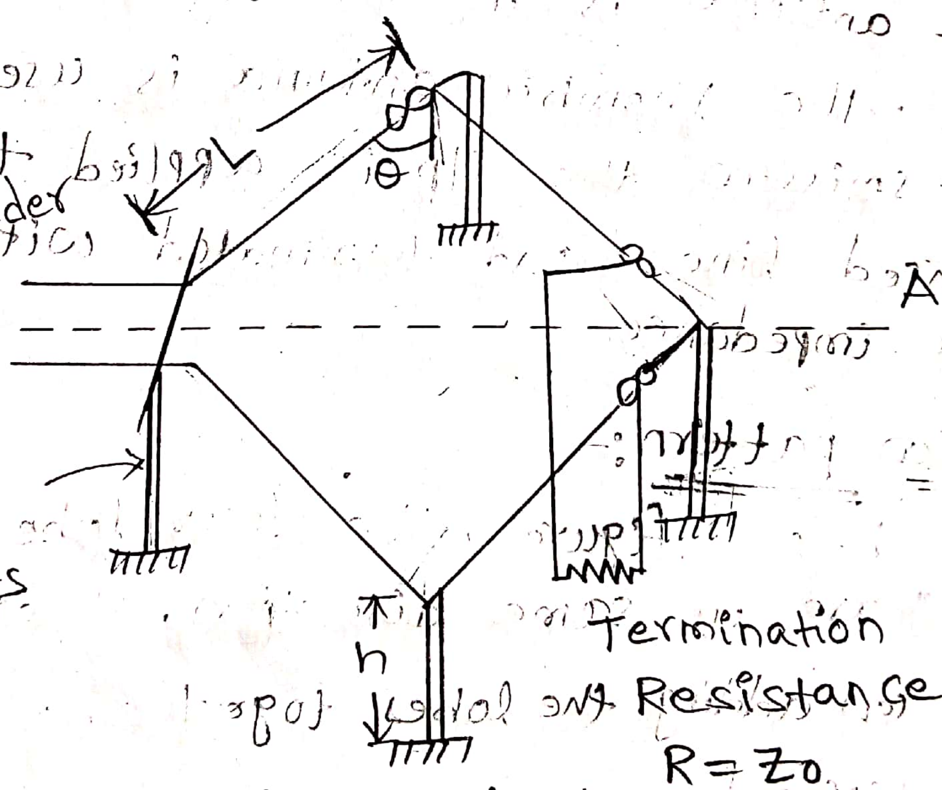
1. The max gain & directivity
2. The Band width is large
3. It is Better suitable for upper end of high frequency transmission.
4. The signal Receiving is better.

Disadvantages :-

1. It has unwanted side lobes.
2. These side lobes produce horizontal polarized waves.

Rhombic antenna :- [Diamond Antenna]

* A rhombic antenna is equilateral parallelogram, generally with two opposite acute angles.
* The rhombic antenna is based on the principle of travelling wave radiator.
* The two sides are pulled at one point to get the Rhombus (or) diamond shape.



Rhombic Antenna

The tilt angle (Θt) is approximately equal to (90°−θ). where 'θ' is angle of major lobe.

* Rhombic antenna consists of four sides are arranged in the form of diamond (or) rhombus.

* The Rhombic antenna is obtained by connecting two inverted V-antennas in parallel.

* The inverted V-antenna and its image antenna gives Rhombic antenna.

* Rhombic antenna is installed on the horizontally over the ground at height of h.

* The polarized waves from the horizontal Rhombic antenna is in the rhombus plane.

* Whenever, the rhombic antenna is used for the transmission, the i/p is applied through a balanced line and terminated with characteristic impedance.

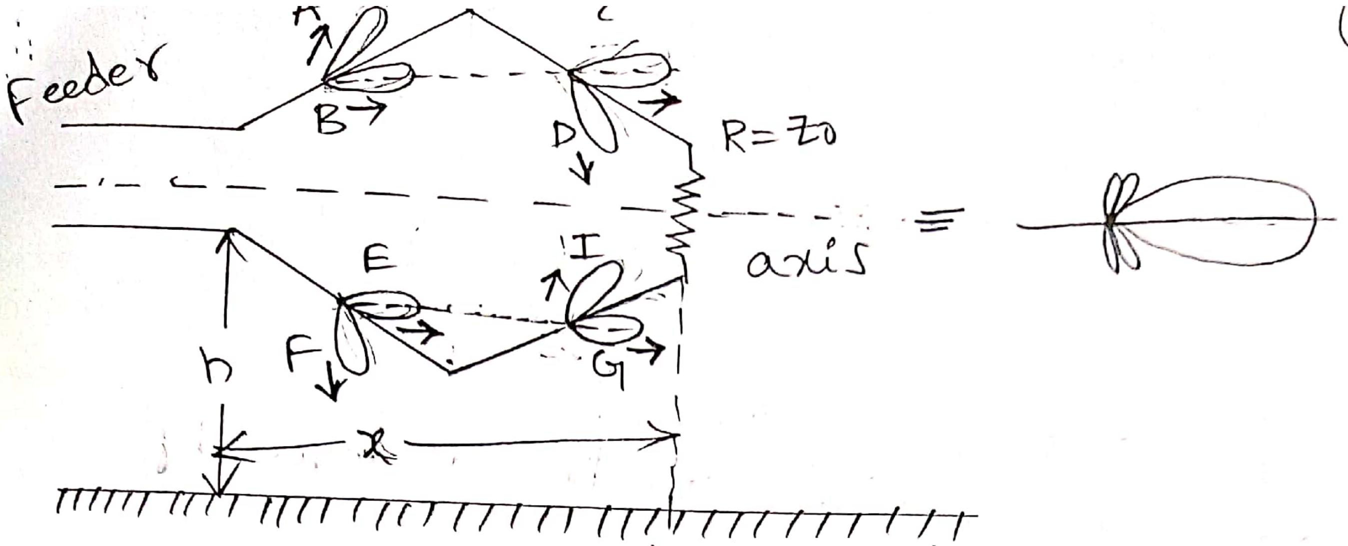
Radiation pattern:-

* In the below figure, the four lobes B, C, E, G all are in same direction. therefore combine (or) adding the lobes together.

* The additional gain is achieved.

* the lobes A, D, F, I are in opposite direction and cancelled these lobes.

∴ We get unidirectional radiation pattern.



Advantages:-

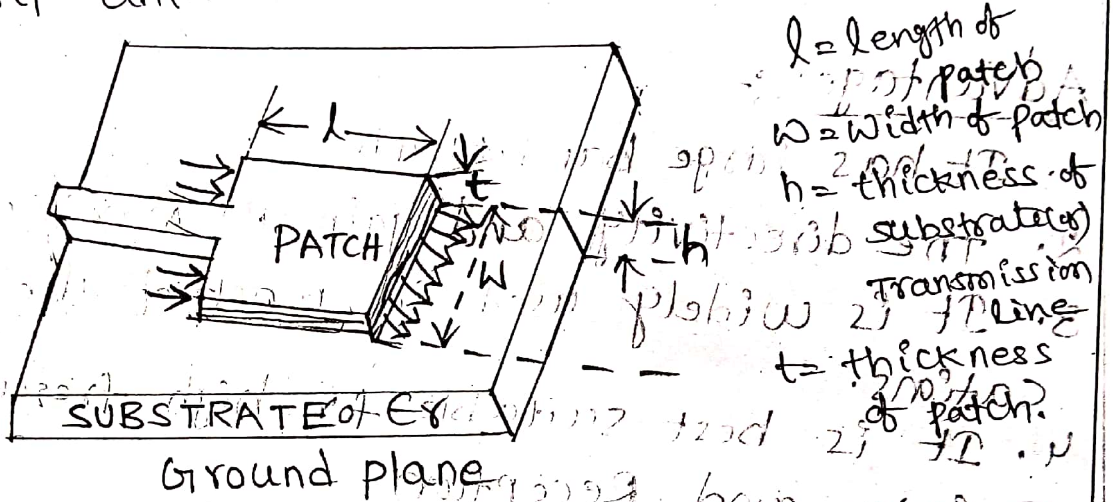
1. It has large band width
2. The directivity and gain is maximum
3. It is widely used in most of the communications.
4. It is best suitable for high frequency Transmission and Reception

disadvantages:-

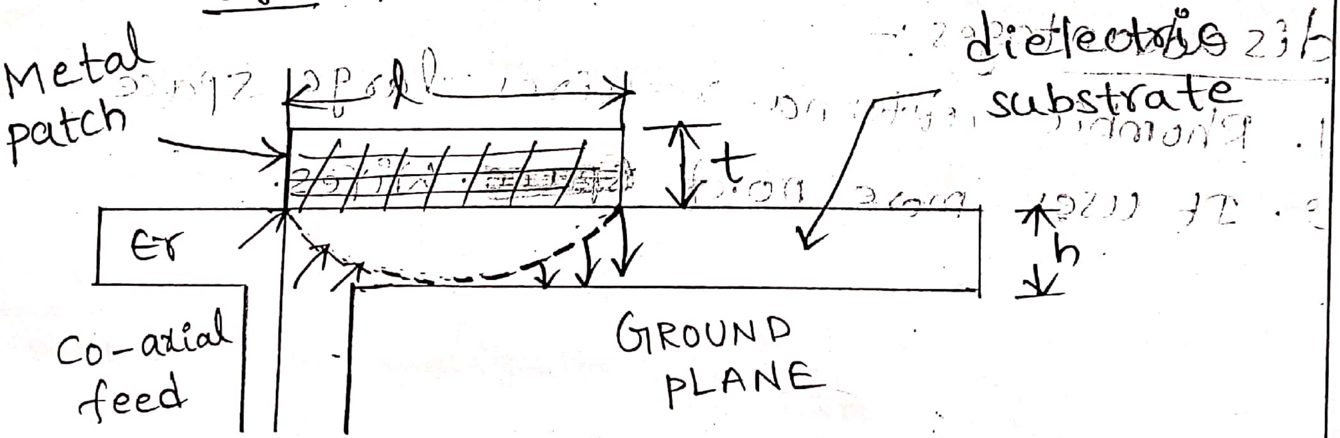
1. Rhombic antenna requires large space
2. It uses more no.of ~~Space~~ Wires.

Micro strip antennas :- [patch Antennas].

* Micro strip antennas are also called as patch antennas (or) printed antennas.
* the specifications required for aircraft applications are size, weight, cost, performance, easy of installation.
* These specifications can be achieved by "micro strip" antennas.



fig(a) :- patch (or) Micro strip antenna



fig(b) :- side view of patch antenn (or) Micro strip.

* The Micro strip antennas are usually used for the low profile applications at a frequencies above 100 MHz with $\lambda < 3m$. wavelength.

The Radiation Conductance is

$$G = \frac{1}{90}\left(\frac{W}{\lambda}\right)^2 \text{ if } W << \lambda$$

$$G = \frac{1}{120}\left(\frac{W}{\lambda}\right) \text{ if } W >> \lambda.$$

Advantages :-

1. Low fabrication cost
2. High performance
3. Low cost
4. Less weight
5. It supports both linear and circular polarization.
6. It operates on dual and triple frequencies
7. Less size.

Dis advantages :-

1. Narrow Bandwidth
2. gain is low (6 db)
3. Less efficiency

Remedy :- The bandwidth can be increased by increasing thickness 'h' of dielectric substrate

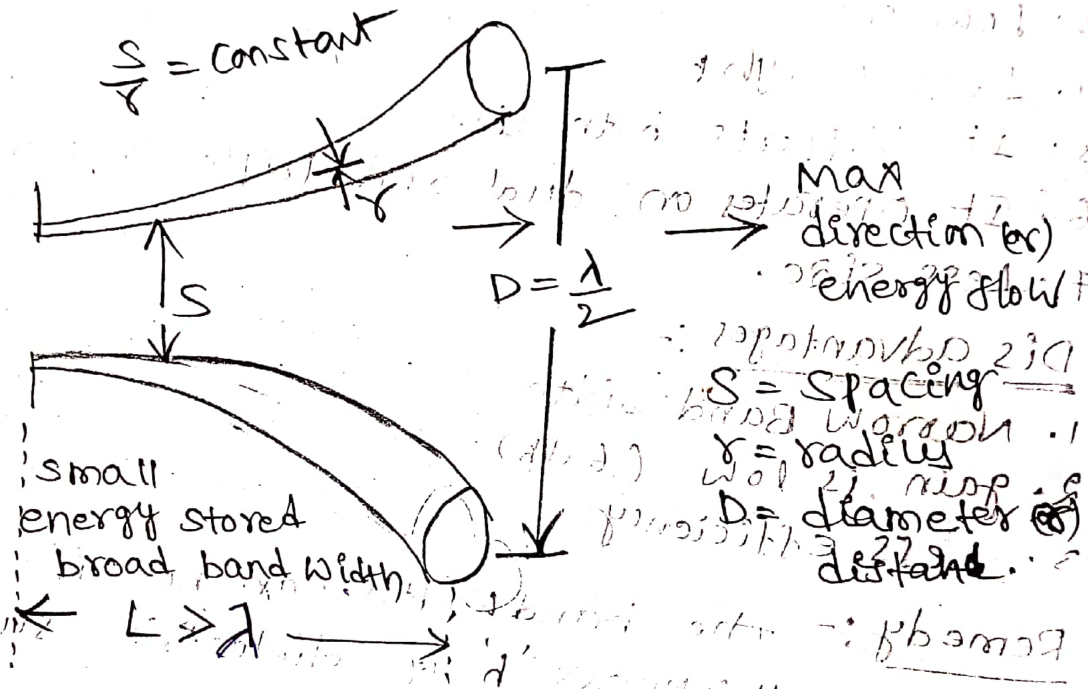
* By increasing Inductance
* Adding reactive components to reduce VSWR. (Voltage Standing Wave Ratio)

Features (Applications)

1. Microstrip antennas are used in mobile & satellite communications
2. It also used in Radio broadcastings.
3. Missile communications.
4. Space craft applications, Radar Communications

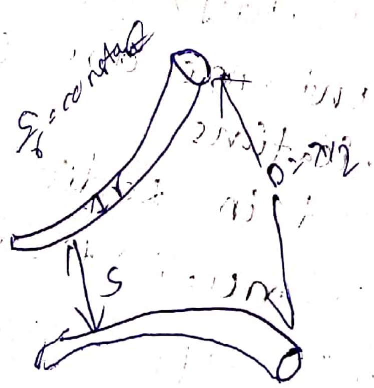
Broad band Antennas:-

* The broad band antenna is the antenna, which is a low-Quality factor radiator, the input impedance is constant over a wide range of frequencies.
* It consists of broad band width. (More b.w)



* The arrows in the diagram represents direction and magnitude of energy flow (radiation)

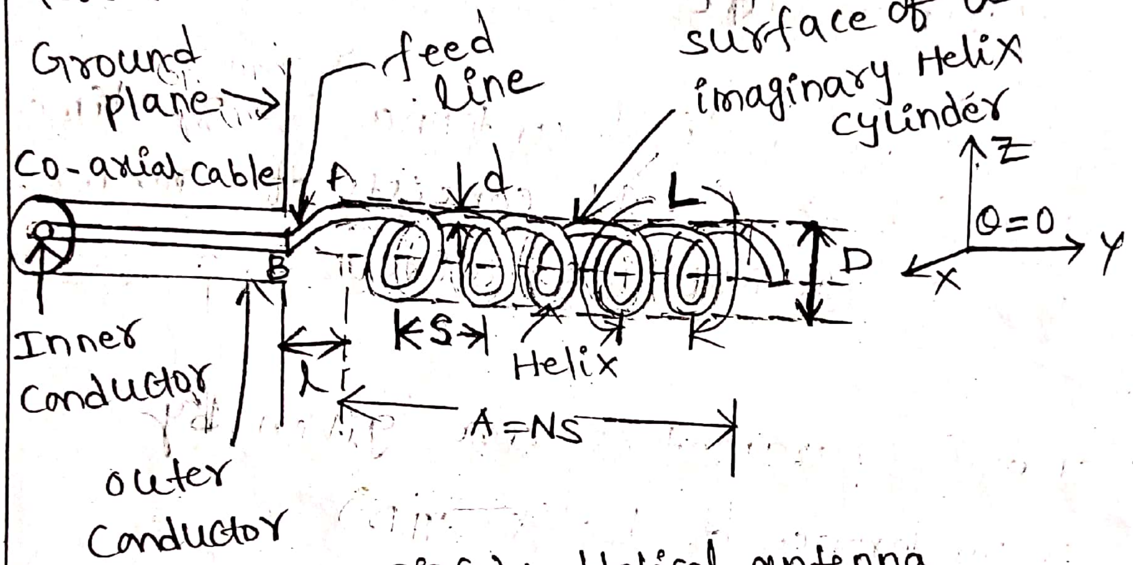
EX:- Helical antennas.



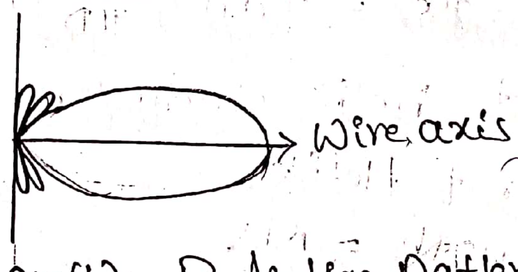
Helical Antenna :- significance :- (14)

Helical antenna is another basic type of radiator It is the simplest antenna to provide circular polarized waves.

* The Helical antenna is broad band VHF and UHF antenna to provide circular polarization characteristics.



fig(a) :- Helical antenna



fig(b) :- Radiation pattern.

* The Helical antenna is small dimension in wave length acts as "Guiding structure.
* It consists of helix of thick copper wire is in the shape of screw thread, and is used as an antenna in conjunction with "flat metal plate is called as "ground plate".

* The Helix is generally fed by a co-axial Cable.
* The inner conductor of cable is connected to one end of the helix, outer conductor is connected to the ground plane.
* finally the mode of radiation depends on the geometric parameters are D and S.

Geometry:- the helical antenna is 3-dimensional geometry form. It consists of geometric shapes of straight line, circle and cylinder shapes.

* The geometric parameters are given by

C = circumference of helix (πD)

α = pitch angle = $\tan^{-1}\left(\frac{S}{\pi D}\right)$

d = diameter of helix Conductor

D = diameter of Helix

A = Axial length = NS

N = no. of Turns

S = Turn spacing

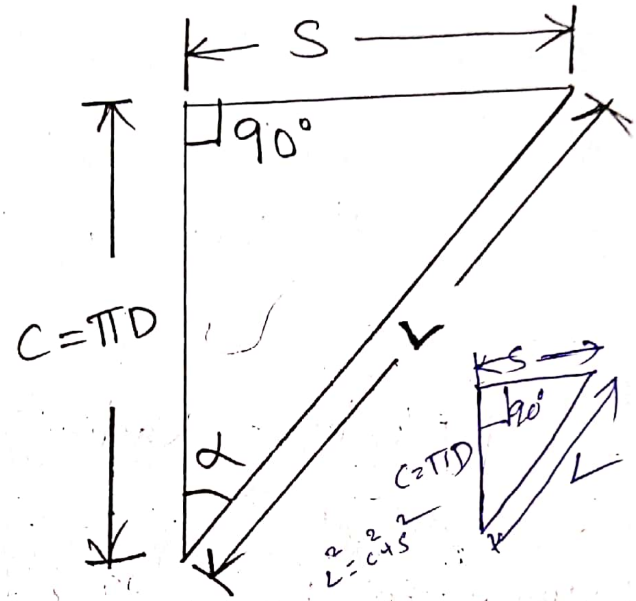
L = Turn Length

l = spacing of helix from ground plane

* for 'N' no. of turns the total length of the antenna is NS.

C = πD
α = pitch angle
$\tan^{-1}\left(\frac{S}{\pi D}\right)$

Let us consider one turn of helix, the relation between circumference (c), spacing (s), Turn length (L), pitch angle (α) is given by Triangle.



According to pythogorous theorem

$L^2 = S^2 + C^2$

$\Rightarrow L^2 = S^2 + (\pi D)^2$

$\therefore \boxed{L = \sqrt{S^2 + (\pi D)^2}}$

The pitch angle is angle between line parallel to helix wire, and plane perpendicular to helix axis.

$\therefore$ The pitch angle is 'α'

$\tan\alpha = \frac{S}{C} = \frac{\text{opposite side}}{\text{adjacent side}}$

$L^2 = S^2 + \pi^2 D^2$

$\boxed{L = \sqrt{S^2 + \pi^2 D^2}}$

$\therefore \alpha = \tan^{-1}\left(\frac{S}{C}\right)$

$\boxed{\alpha = \tan^{-1}\left(\frac{S}{\pi D}\right)}$ $(\because C = \pi D)$

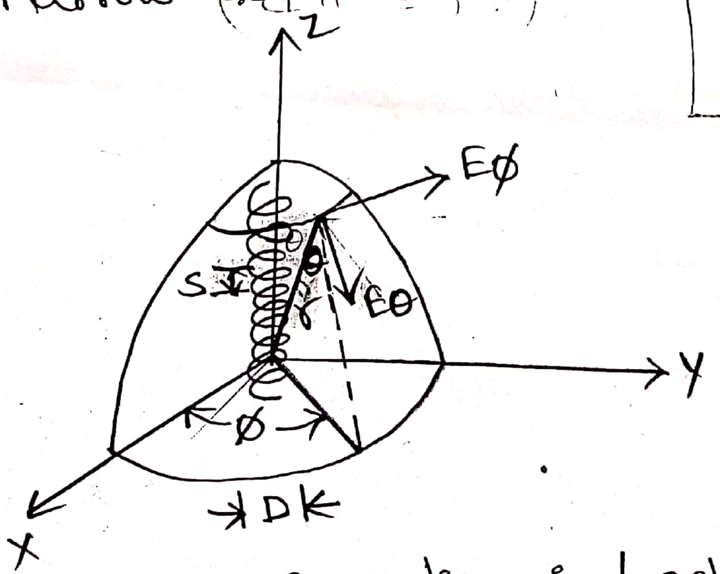
Design considerations for monofilar helical antenna:-

> The helical ~~ang~~ antenna may be radiate in two modes of radiation.

They are (i) Normal mode (or) perpendicular mode
(ii) Axial mode (or) End fire mode (or) beam mode

) Normal mode of Radiation :-

* In the normal mode of radiation, the radiation field is maximum in broad side way.
* That is, the direction of maximum radiation is perpendicular to helix axis and is circularly polarized waves.
* This mode of radiation is obtained, if the dimensions of the helix is small compared with wavelength λ. $(NL << \lambda)$
* Therefore the band width of a small helix is very narrow and radiation efficiency is low.



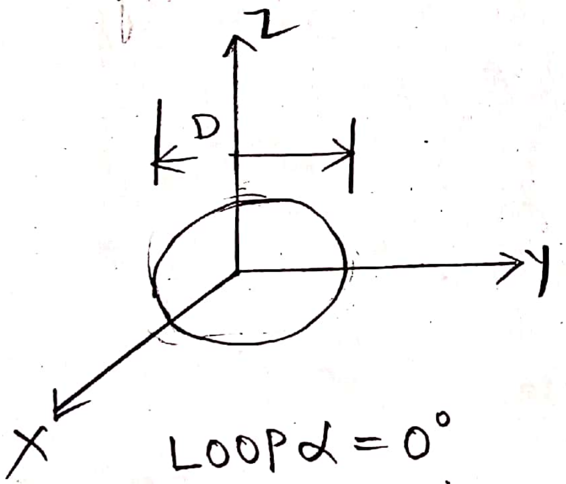
helix in 3-dimensional spherical coordinates

The bandwidth and radiation efficiency can be increased by increasing the size of helix and to have current in phase. (16)

* The radiation pattern is a combination of equivalent radiation from a short dipole located on the same helix axis and a small loop which is also coincidents (or) co-axial with helix axis.

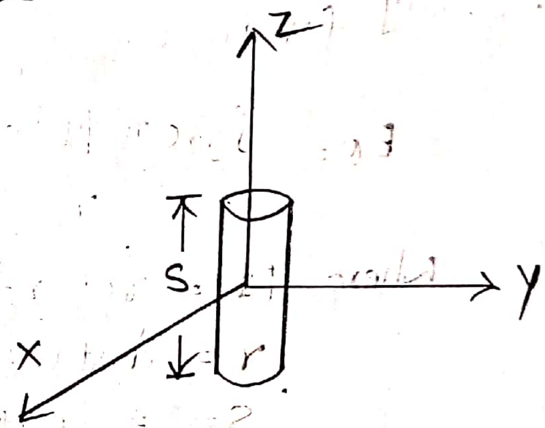
* In a helix if spacing $S \to 0$, diameter is fixed and pitch angle $\alpha = 0°$ then helix becomes a loop.

* if S = constant and Diameter $D \to 0$ and pitch angle $\alpha = 90°$ then helix becomes a short dipole.



LOOP $\alpha = 0°$

D = fixed (or) constant



short dipole

$\alpha = 90°$,

S = constant

* The polarizations are at right angle and the phase angles are 90° at any point in space.

* Hence the resultant field is either circularly polarized (or) elliptically polarized depend upon field strength ratio.

A helix antenna may be considered of having a number of small loops and short dipoles connected in series. In which loop diameter is same as helix diameter and helix spacing 's' is same as dipole length (L).

The far field of small loop is given by

$$E_\phi = \frac{120\pi^2 |I| \sin\theta}{r} \frac{A}{\lambda^2} \rightarrow (1)$$

$|I|$ = retarded current

r = distance

A = Area of loop = $\frac{\pi D^2}{4}$

similarly far field of a short dipole is given by

$$E_\theta = j\frac{60\pi |I| \sin\theta}{r} \frac{L}{\lambda}$$

where $|I|$ = retarded current

r = distance

$S = L$ = Length of dipole

$$\therefore E_\theta = j\frac{60\pi |I| \sin\theta}{r} \frac{S}{\lambda} \rightarrow (2)$$

The axial ratio (AR) of Elliptical polarization is

$$AR = \frac{|E_\theta|}{|E_\phi|} = \frac{\left| j\frac{60\pi |I| \sin\theta}{r} \cdot \frac{S}{\lambda}\right|}{\left|\frac{120\pi^2 |I| \sin\theta}{r} \cdot \frac{A}{\lambda^2}\right|} = \frac{S}{\left(2\pi \frac{A}{\lambda}\right)}$$

$$\left(\because A = \frac{\pi D^2}{4}\right)$$

$$\Rightarrow A.R = \frac{S\lambda}{2\pi \cdot \frac{\pi D^2}{4}} = \frac{2S\lambda}{\pi^2 D^2}$$

$$\therefore A.R = \frac{2S\lambda}{\pi^2 D^2} \rightarrow (3) \text{ Axial Ratio}$$

* When Axial Ratio is '0' the elliptical polarization becomes Linear horizontal polarization.
* When Axial Ratio (AR) is '∞' the elliptical polarization becomes Linear Vertical polarization.
* When Axial Ratio is '1' (unity) the elliptical polarization becomes Circular polarization.

$$AR = 1 = \frac{|E_\theta|}{|E_\phi|} \text{ (or) } |E_\theta| = |E_\phi|$$

$$\Rightarrow AR = 1 = \frac{2S\lambda}{\pi^2 D^2}$$

$$\Rightarrow 2S\lambda = \pi^2 D^2$$

$$\therefore \boxed{S = \frac{\pi^2 D^2}{2\lambda}} \rightarrow (4)$$

($\because$ Circumference $C = \pi D$)

$$\boxed{S = \frac{C^2}{2\lambda}} \rightarrow (5)$$

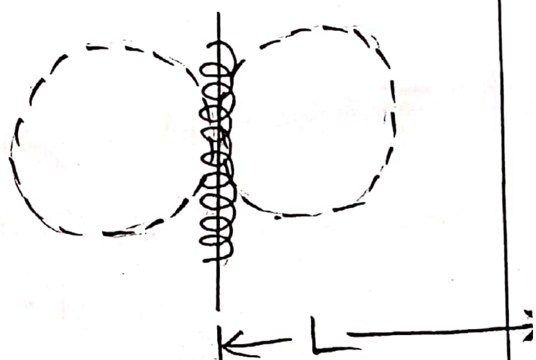
$\therefore$ The pitch angle is given by

$$\alpha = \tan^{-1}\left(\frac{S}{\pi D}\right) = \tan^{-1}\left(\frac{\frac{\pi^2 D^2}{2\lambda}}{\pi D}\right)$$

$$\Rightarrow \boxed{\alpha = \tan^{-1}\left(\frac{\pi D}{2\lambda}\right)}$$

$$\boxed{\alpha = \tan^{-1}\left(\frac{C}{2\lambda}\right)}$$

This is the pitch angle to get circular polarization.

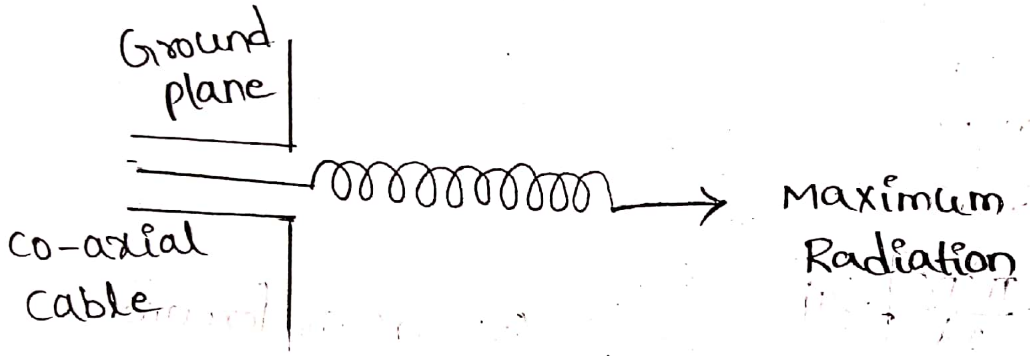


Radiation pattern for Normal mode of Radiation

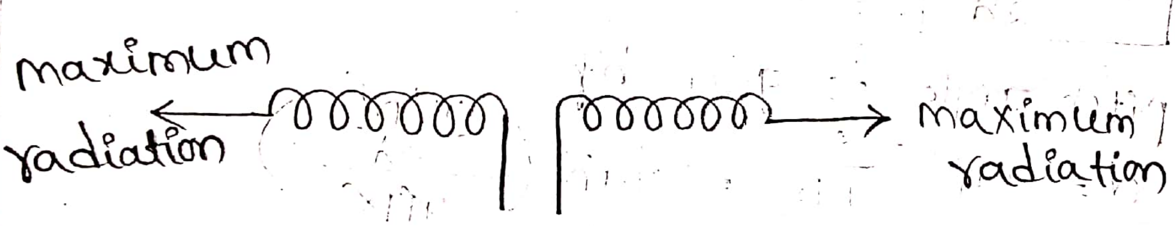
$\therefore$ practically this mode is not suitable and hardly used.

Axial (or) Beam mode of Radiation :-

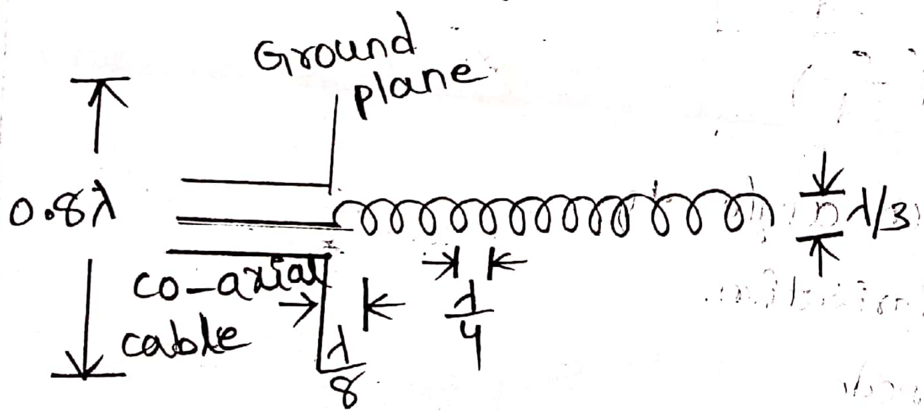
* In axial mode of radiation, the radiation field is maximum in end-fire direction.
* That is the direction of maximum radiation is co-incidence with Helix axis, the polarization is circular (or) nearly circular
* This mode occurs when the helix circumference (C) and spacing (S) are in the order of one wavelength.



(a) With co-axial cable



(b) Two wire Transmission line



(c) Typical dimensions

This mode produces a broad and fairly directional beam in the axial direction with minor lobes at oblique angles.

* This mode of radiation is used in most practical applications.
* The axial mode of radiation is produced very easily by raising helix circumference (C) of the order of one wavelength (λ) and spacing (S) is $\frac{\lambda}{4}$.
* The ground plane having atleast half wavelength in diameter.
* The pitch angle α varies from 12° to 18° and optimum pitch angle is 14°.
* The terminal impedance is 100 Ω resistive at frequency $C \cong \lambda$ ($\because \lambda = \frac{c}{f}$)
* Generally in axial mode, the terminal impedance of helical antenna lies between 100 Ω to 200 Ω

∴ for ±20% approximation, the terminal impedance is given by $R = \frac{140\,C}{\lambda}$ ohms.

* The antenna gain and beam width depends on the helix axial length ($A = NS$)

The half power beam width is given by

$$(HPBW)\ \theta_{(-3db)} = \frac{52^\circ}{C}\sqrt{\frac{\lambda^3}{NS}}\ \text{degrees}$$

λ = free space wavelength
C = circumference ~~wavelength~~
N = no. of Turns
S = spacing

The beamwidth between first nulls is

$$BWFN = 2 \times HPBW$$

$$BWFN = \frac{104^\circ}{C}\sqrt{\frac{\lambda^3}{NS}}\ \text{degrees}$$

The maximum directive gain (or) directivity is

$$D = \frac{15NSC^2}{\lambda^3}$$

Axial Ratio $AR = 1 + \frac{1}{2N}$

Farfield pattern is given by

$$E = \sin\left(\frac{\pi}{2N}\right)\cos\theta \cdot \frac{\sin\left(\frac{N\psi}{2}\right)}{\sin\frac{\psi}{2}}$$

$$\psi = 2\pi\left[\frac{S}{\lambda}(1-\cos\theta) + \frac{1}{2N}\right]$$

$\alpha = 12^\circ$ to 15°, $N \geq 3$, $NS \leq 10$, $C = \frac{3}{4}\lambda$ to $\frac{4}{3}\lambda$

Features of Helical Antenna:-

* Helical antenna is used for circular polarization
* The helical antenna is used most widely in VHF and UHF bands.
* The axial mode of helical antenna is most widely used.
* The antenna in axial mode has larger band width
* It's construction is simple and directivity is higher.

Applications of Helical antennas:-

* The dimensions for axial mode are not critical.
* Hence helical antennas are used to achieve circularly polarized waves over wide band width.
* A single helical antenna (or) array of helical antennas are useful in Transmitting (or) receiving VHF signals through the Ionosphere.
* The helical are also most useful in satellite communications.
* these antennas are able to produce circular polarized waves.

A. Narasimha Reddy, ECE Dept.

UNIT-5 :- VHF, UHF, and Microwave Antennas :-

Introduction to Reflector antennas :-

→ The reflector antennas are most important in microwave radiation applications. At microwave frequencies the physical size of the high gain antenna becomes so small to produce desired directivity.

→ In reflector antenna another antenna is required to excite it.

→ The antennas such as dipole, Horn, slot which feeds the reflector antenna.

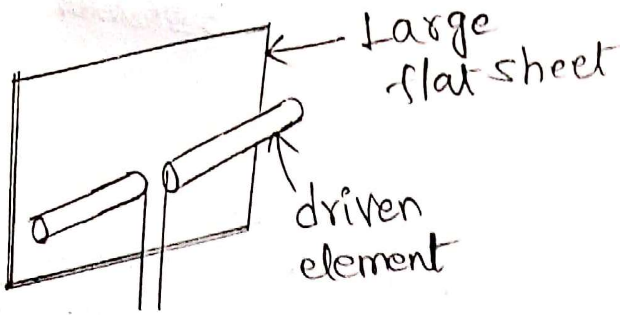
→ Dipole, Horn, slot antenna is called as "primary antenna", and reflector is called as "secondary antenna".

→ Reflector antenna canbe represented in any geographical configuration, but the most commonly used shapes are plane reflector, corner reflector and curved (or) parabolic reflectors.

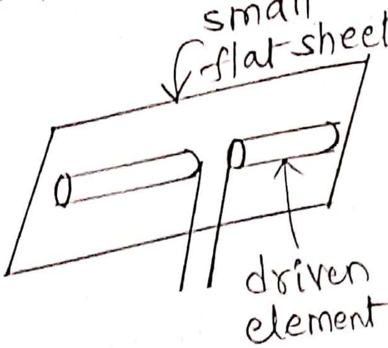
→ By using reflectors, the backward radiations from the antenna can be eliminated. Thus improving radiation pattern of an antenna.

→ using reflectors, the radiation pattern of a radiating antenna can be modified.

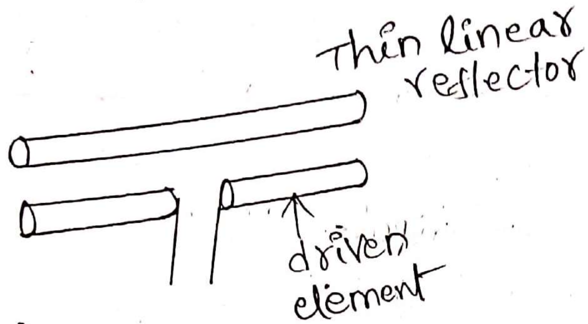
Different types of reflector antennas are



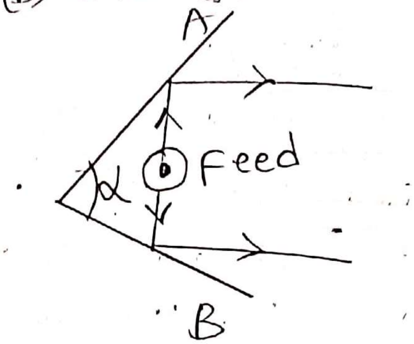
(a) Large flat sheet



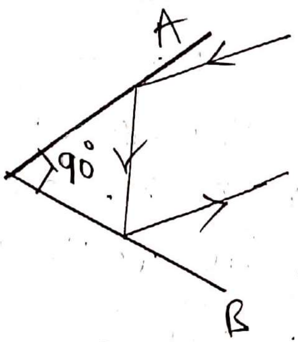
(b) small flat sheet



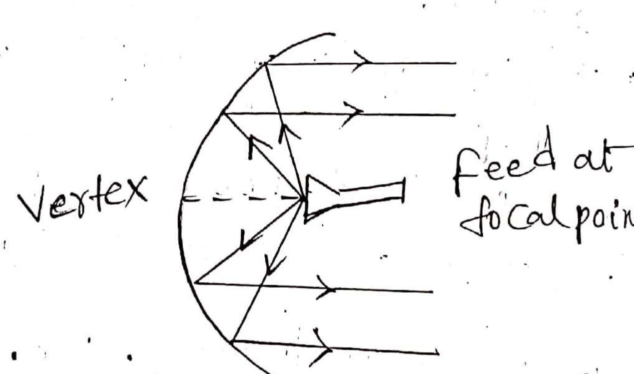
(c) Thin linear reflector antenna



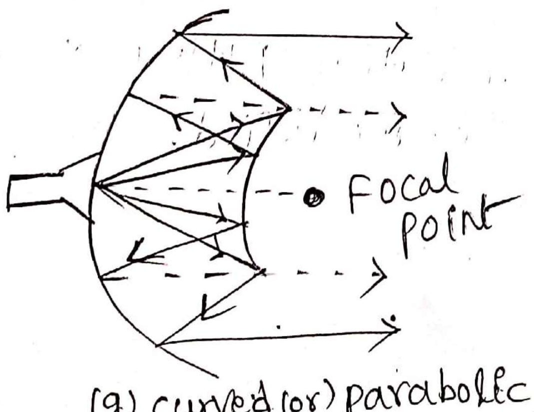
(d) Active corner reflector.



(e) passive corner reflector.

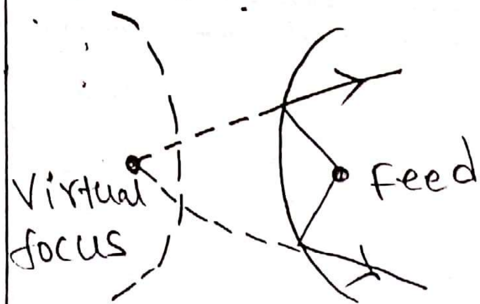


(f) curved reflector with front feed.

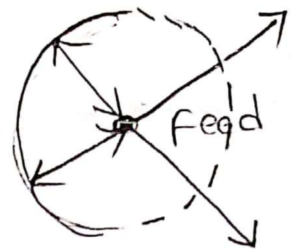


(h) elliptical reflector

(g) curved (or) parabolic reflector with Cassegrain feed.



(i) hyperbolic reflector.

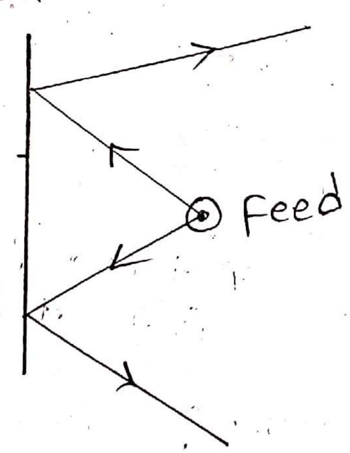


(j) Circular reflector

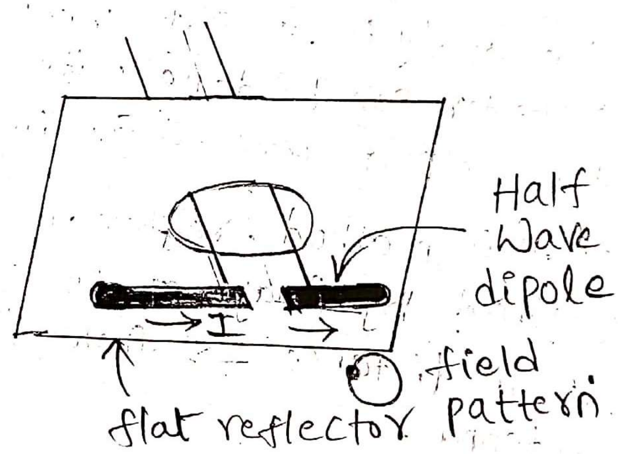
Flatsheet (or) plane reflectors :-

* The plane reflector is the simplest form of the reflector antenna. A flat sheet reflector can be considered to be made up of two flat sheets intersecting each other at an angle $\alpha = 180°$

* When the plane reflector is placed infront of the feed, the energy is radiated in the desired directions.

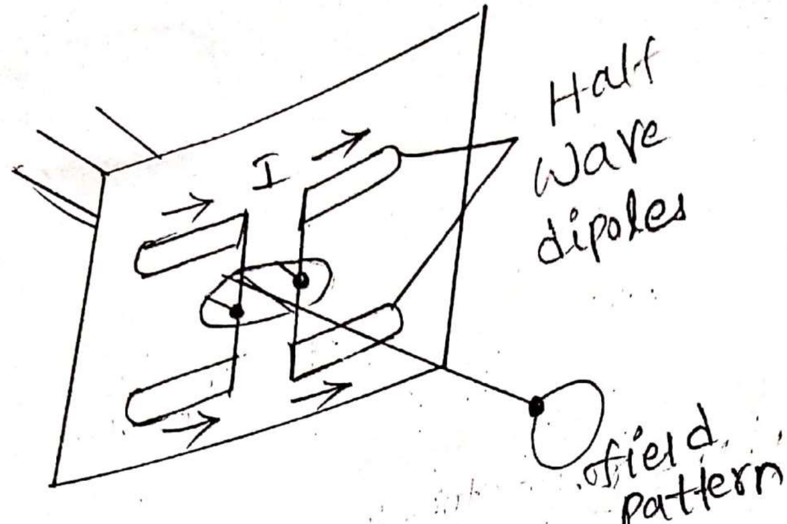


(a) plane reflector.



Examples :- Half wave dipole with plane reflector.

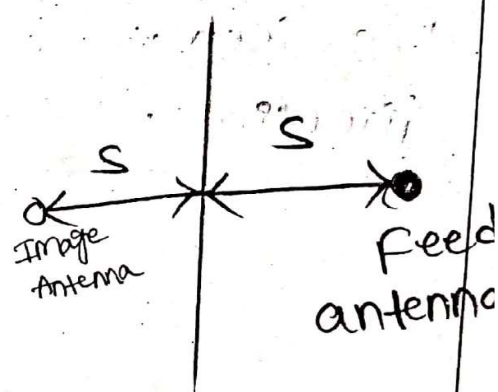
half wave dipole with reflector element



Half wave dipole array with plane reflector.

* The polarization of the radiating source and its position with respect to the reflector both are important as one can control radiating pattern, directivity, Impedance.

* The analysis of flat sheet reflector can be done with the help of method of images.



Antenna & its image at a distance 's'.

* In this method, reflector can be replaced by image of an antenna at a distance 2S from feed antenna.

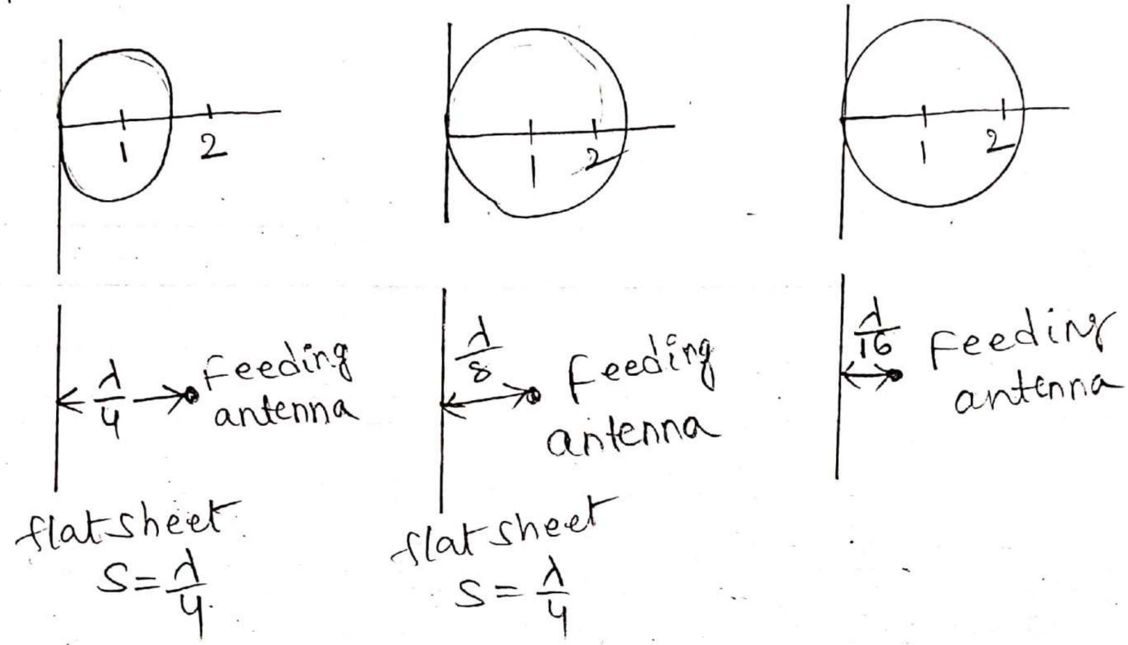
For an infinite plane reflector, assuming zero reflector losses, the gain of a $\frac{\lambda}{2}$ dipole antenna at a distance 's' is given by

$$G_f(\phi) = 2\sqrt{\frac{R_{11} + R_{LOSS}}{R_{11} + R_{LOSS} - R_{12}}}\,|\sin(S_r \cos\phi)|$$

and $S_r = \left(\frac{2\pi}{\lambda}\right) S$. ($\because$ S_r = radial distance, S = distance.)

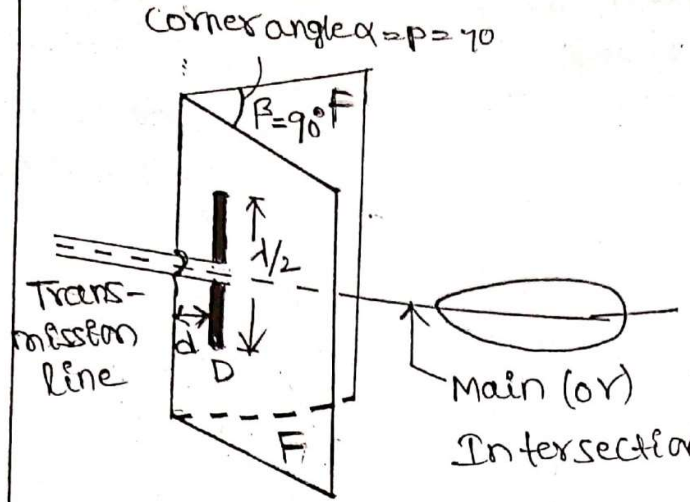
The gain of reflector relative to half wave dipole antenna is a function of the spacing between flat sheet and half wave dipole antenna.

* When the spacing between half wave dipole and infinite sheet decreases, the gain will be increases.



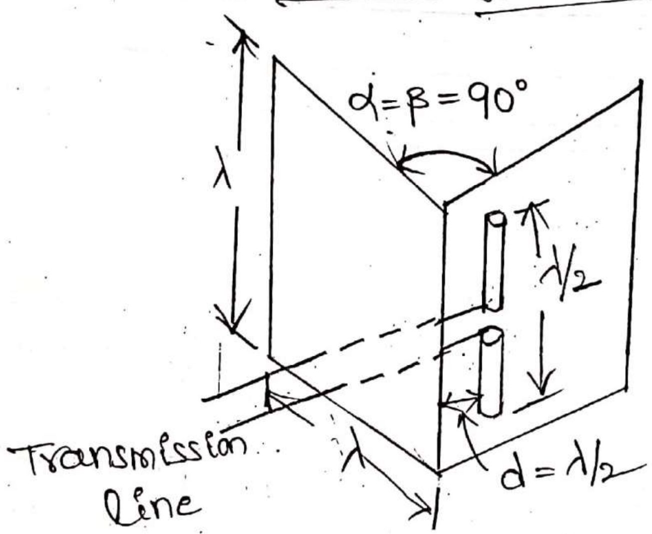
Corner Reflector :-

* The corner reflector antenna can be considered to be made up of two flat sheets meet at angle $\alpha = 90°$.
* The flat reflecting sheets meeting at angle (or) corner form an effective directional antenna.
* The corner reflector antenna is a driven antenna associated with a reflector
* Generally driven antenna is a Half wave dipole and reflector can be constructed of two flat sheets meet at a corner (or) angle to form corner.
* This arrangement with corner reflector and driven antenna is known as "corner reflector antenna".

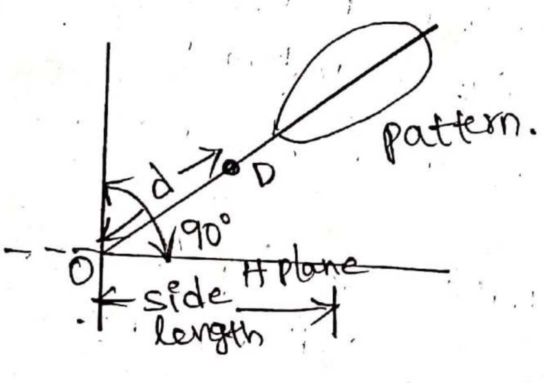


F = flat reflecting sheets
D = driven antenna

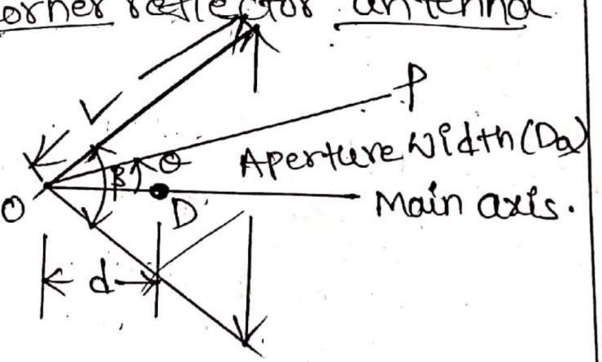
(a) Vertical corner reflector antenna.



(b) Horizontal corner reflector antenna

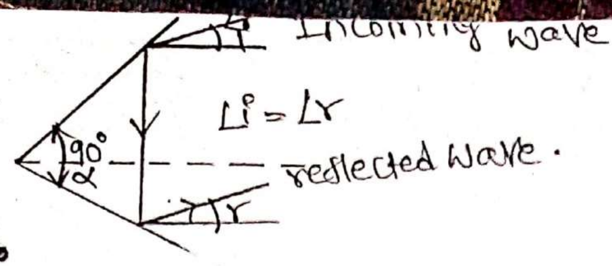


(c) Radiation pattern.



d = spacing between driven elements
α = β = corner angle
D = driven antenna.

(d) Active corner reflector



(e) passive corner reflector.

* If corner angle $\beta = \alpha = 90°$ then the two flat sheets meeting at a right angle forming a square corner reflector.
* When the corner reflector with the driven antenna is called "active corner reflector" for a wide range of corner $0 < \beta < \pi$
* When the corner reflector without the driven antenna is called "passive corner reflector" for a wide range of angle of incidence $0 < i < \pm\frac{\pi}{4}$
* The corner reflector antenna may be analysed by using the method of images for corner angle.

$$\boxed{\alpha = \beta = \frac{180°}{n}}$$ Where n = an integer = 1, 2, 3 ....

Thus if $n = 1$, $\beta = 180°$ (or) π radian ⟶ flat sheet reflector

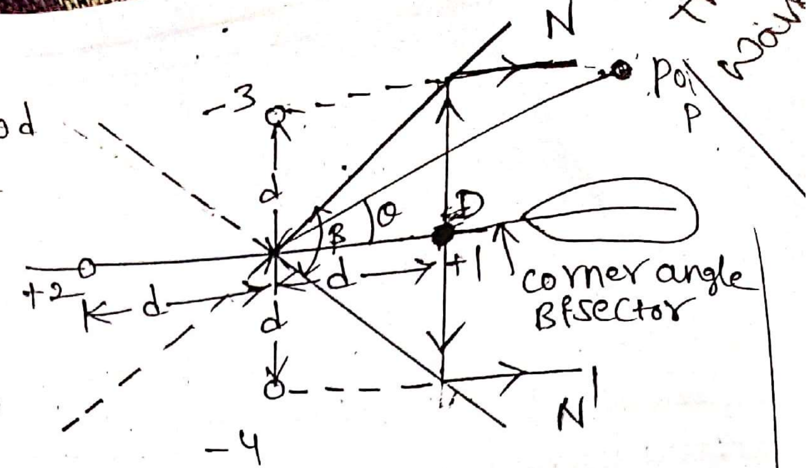
if $n = 2$, $\beta = 90°$ (or) $\frac{\pi}{2}$ radian ⟶ square corner reflector.

if $n = 3$, $\beta = 60°$ (or) $\frac{\pi}{3}$ radian → corner reflector 60°

if $n = 4$ $\beta = 45°$ (or) $\frac{\pi}{4}$ radian → corner reflector 45°

∴ By method of images corner angles of $\pi, \frac{\pi}{2}, \frac{\pi}{3}, \frac{\pi}{4}$ can only be used.

* Let us consider method of images for square corner reflector
* The driven antenna is shown by 'D' and three images (+2, -3, -4) corresponding to driven antenna (+1).
* the driven antenna (half wave dipole) and its three images carry equal currents.



square corner reflector with driven element (+1) and three images (+2, -3, -4).

* driven antenna (+1) and image element (+2) are in same phase & -3 and -4 image elements are also in same phase.
* But there exists a 180° phase shift between phase of elements (+1, +2) and (-3, -4). The two negative images corresponds to single reflection of rays N and N', third +ve image (+2) corresponds to driven element (+1)

the field pattern $E_\phi(\theta)$ in the horizontal plane at a large distance r from the antenna is given by

$$E_\phi(\theta) = K' I_1 [\cos(\beta d \cos\theta) - \cos(\beta d \sin\theta)] \rightarrow (1)$$

Where K' = Constant,

I_1 = current in each element

$\beta = \frac{2\pi}{\lambda}$

d = distance between driven element & corner along bisector the terminal voltage at the centre of the half wave dipole can be expressed as

$$V_1 = I_1 Z_{11} + I_1 Z_{12} - I_1 Z_{13} - I_1 Z_{14} \rightarrow (2)$$

$$V_1 = I_1(Z_{11} + Z_{12} - 2Z_{14}) \rightarrow (3) \quad (\because Z_{13} = Z_{14})$$

where Z_{11} = self impedance of driven antenna (+1) $= 73\Omega$

Z_{12} = mutual impedance between +1 and +2

Z_{13} = Mutual impedance between +1, −3.

Z_{14} = Mutual impedance between +1, −4.

the power supplied to driven antenna is

$$P = I_1^2 R$$

$$\Rightarrow I_1^2 = \frac{P}{R} \Rightarrow \boxed{I_1 = \sqrt{\frac{P}{R}}} \rightarrow (4)$$

from eqn (3)

$$\frac{V_1}{I_1} = Z = Z_{11} + Z_{12} - 2Z_{14} \quad \text{(OR)}$$

$$\frac{V_1}{I_1} = R = R_{11} + R_{12} - 2R_{14} \rightarrow (5)$$

from equations (4), (5)

$$I_1 = \sqrt{\frac{P}{R}} = \sqrt{\frac{P}{R_{11} + R_{12} - 2R_{14}}} \rightarrow (6)$$

substitute eq (6) in eq (1)

$$E_\phi(\theta) = K' \sqrt{\frac{P}{R_{11} + R_{12} - 2R_{14}}} \times [\cos(\beta d \cos\theta) - \cos(\beta d \sin\theta)]$$

if reflector is removed then $R_{12} = R_{14} = 0$ then

$$\boxed{E_\phi(\theta)_{\lambda/2} = K' \sqrt{\frac{P}{R_{11}}}}$$

The gain in the θ direction is given by

$$G = \frac{E_\phi(\theta)}{E_\phi(\theta)\,\lambda/2}$$

$$\Rightarrow G = \frac{K'\sqrt{\frac{P}{R_{11}+R_{12}-2R_{14}}} \times \left[\cos[\beta d\cos\theta] - \cos[\beta d\sin\theta]\right]}{K'\sqrt{\frac{P}{R_{11}}}}$$

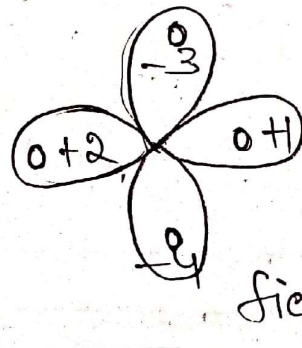
$$\Rightarrow G = \sqrt{\frac{R_{11}}{R_{11}+R_{12}-2R_{14}}} \times \left[\cos(\beta d\cos\theta) - \cos(\beta d\sin\theta)\right] \rightarrow \text{eq } (7)$$

Where $\left[\cos(\beta d\cos\theta) - \cos(\beta d\sin\theta)\right]$ = pattern factor

$\sqrt{\frac{R_{11}}{R_{11}+R_{12}-2R_{14}}}$ = coupling factor.

The maximum radiation from the corner reflector antenna is in the direction $\theta = 0$ hence putting $\theta = 0$ in eq (7)

$$\therefore G_0 = \sqrt{\frac{R_{11}}{R_{11}+R_{12}-2R_{14}}}\left[\cos(\beta d) - 1\right] \rightarrow (8)$$



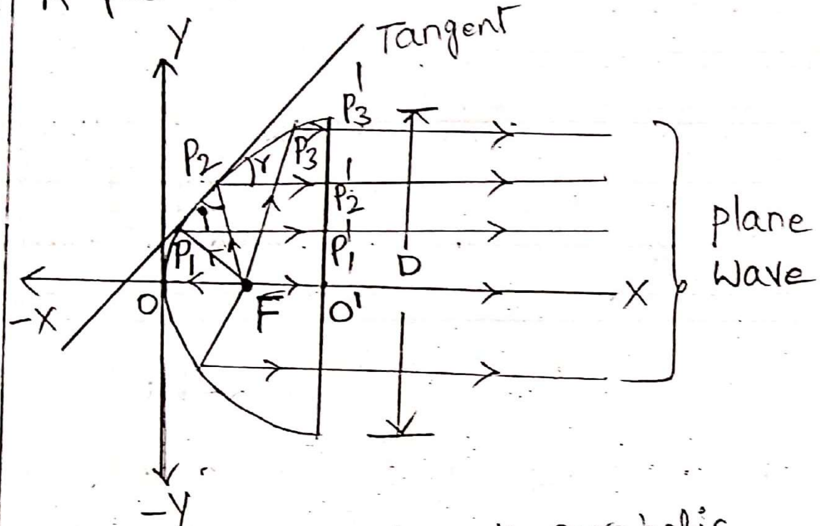
(∵ combination of broadside & end fire patterns in UNIT-3)

field pattern.

Parabolic reflectors :- (2-Dimensional)

A parabola may be defined as the focus of a point which moves in such a way that its distance from the fixed point (focus) plus its distance from a straight line (directrix) is constant.

* A para bola is a two dimensional plane curve.



OF = focal length = f

K = constant depends on shape of parabola curve

F = focus

O = Vertex

OO' = Axis of parabola

Geometry of parabolic Reflector

By definition of parabola

$$FP_1 + P_1P_1' = FP_2 + P_2P_2' = FP_3 + P_3P_3' = \text{constant} = k \text{ (say)}$$

the equation of parabola curve interms of its coordinate is given by

$$\boxed{y^2 = 4fx}$$

* the open mouth (D) of the parabola is known as aperture.

* Generally F/D ratio is an important parameter of parabolic reflector. its value is 0.25 to 0.50.

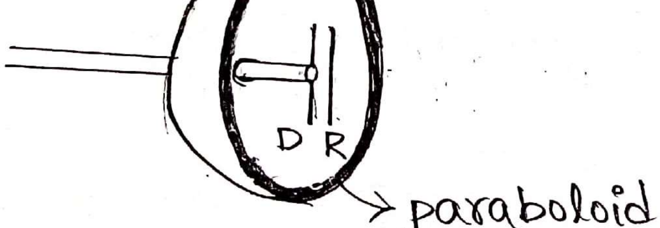
* The parabola converts a spherical wave front coming from a focus into a plane wave front at the mouth (D) of the parabola.

If a perpen of

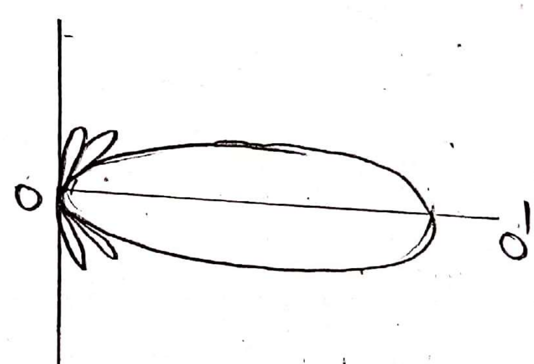
* Let us consider a source of radiation at the focus. A ray starts from focus (F) with respect to parabolic axis (OO')
* Let a tangent is drawn at P_2 on the curve. According to law of reflection the angle of incidence ∠i and angle of reflection (∠r) will be equal.
* this results the reflected ray is parallel to the parabolic axis. That means all the waves originating from the focus will be reflected parallel to the parabolic axis.

Paraboloidal Reflector (or) Micro wave Dish (3-Dimensional)

* A practical reflector is a three dimensional curved surface. Therefore a practical reflector is formed by rotating a parabola about its axis (OO'). The generated surface is known as "paraboloid". (or) Micro wave dish.
* paraboloid produces a parallel beam of circular cross section, because the mouth of the paraboloid is circular



D = Dipole
R = Reflector



Radiation pattern of paraboloid of

If a third cartesian coordinate z has its axis perpendicular to both x-axis and y-axis then eqn of paraboloid will be

$$y^2 + z^2 = 4fx$$

* the intersection of any plane perpendicular to x-axis with the paraboloid surface is a circle.

Characteristics :-

If the feed or primary antenna is isotropic then the paraboloid will produce a beam of radiation. Assume the circular aperture is large, the beam width between first nulls is given by

$$BWFN = \frac{140\lambda}{D} \text{ degree}$$

Where

λ = free space wave length

D = diameter of aperture in 'm' (or) Mouth diameter

The Beam width between first nulls for large uniformly illuminated rectangular aperture is given by

$$BWFN = \frac{115\lambda}{L} \text{ (degree)}$$

where L = length of aperture in λ

Half power Beam Width for large circular aperture is given by

$$HPBW = \frac{58\lambda}{D} \text{ degree}$$

The directivity D of a large uniformly illuminated aperture is

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

For a circular aperture

$$D = \frac{4\pi}{\lambda^2}\left(\frac{\pi D^2}{4}\right) = \frac{4\pi}{\lambda^2} \times \frac{\pi D^2}{4} \quad \left(\because A = \frac{\pi D^2}{4} \text{ for circle}\right)$$

$$\therefore D = \frac{\pi^2 D^2}{\lambda^2} = \pi^2 \left(\frac{D}{\lambda}\right)^2$$

Directivity: $$\boxed{D = 9.87\left(\frac{D}{\lambda}\right)^2}$$

where D = diameter of aperture in 'λ'

We know that ~~Actual~~ capture area $A_0 = KA$

where A_0 = capture area

A = Actual area of mouth

K = constant depends on type of antenna used for feed

= 0.65 (approx for dipole)

There fore power gain of circular Aperture paraboloid with respect to half wave dipole is given by

$$G_p = \frac{4\pi A_0}{\lambda^2} = \frac{4\pi \times KA}{\lambda^2} \quad (\because A_0 = KA)$$

$$= \frac{4\pi K}{\lambda^2}\left(\frac{\pi D^2}{4}\right) \quad \left(\because A = \frac{\pi D^2}{4} \text{ for circular aperture}\right)$$

$$G_p = \pi^2 K \cdot \frac{D^2}{\lambda^2}$$

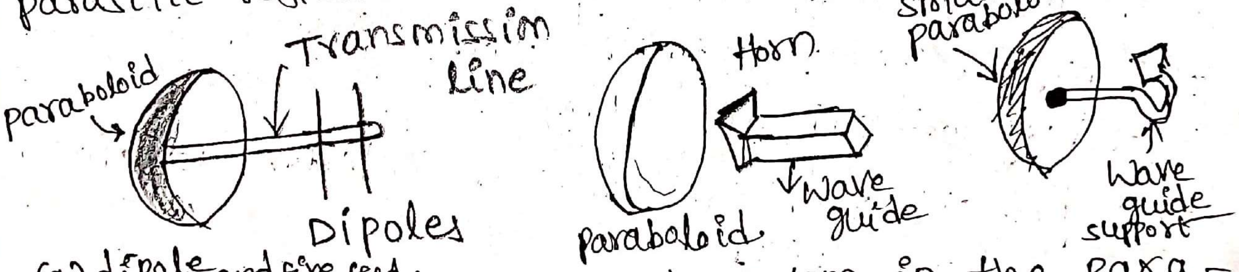
$$\therefore G_p = (3.14)^2 (0.65)\left(\frac{D}{\lambda}\right)^2 \quad (\because K = 0.65)$$

$$G_p = 6.389\left(\frac{D}{\lambda}\right)^2$$

$$\boxed{G_p \cong 6\left(\frac{D}{\lambda}\right)^2}$$

Types of feeds :-

* A parabolic reflector antenna as a system consists two parts.
  → source
  → Reflector
* The source placed at the focus is called "primary" radiator, while the reflector is called "secondary" radiator.
* The primary radiator (or) the source is commonly called "feed radiator" (or) simply feed.
* The simplest type of the feed that can be used is a dipole antenna. But it is not suitable feed for the parabolic reflector antenna.
* Instead of only dipole, a feed consisting dipole with parasitic reflectors can be used as feed system.



* The most widely used feed system in the parabolic reflector antenna is horn antenna. Horn antenna is feed with a wave guide.

There are two types of feeds :

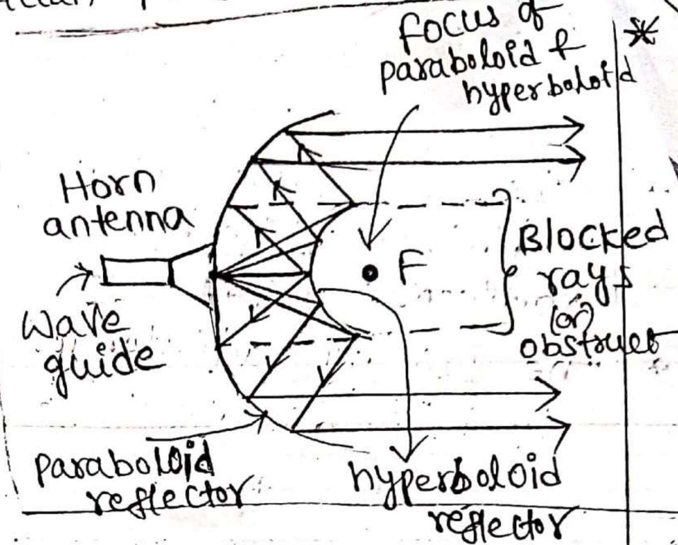
→ cassegrain feed system

→ offset feed system.

Cassegrain feed system :-

* This system of feeding paraboloid reflector is named after a mathematician prof. Cassegrain discovered.

* In all the feed systems the feed is located at the focus. But in cassegrain feed, the feed radiator is placed at the vertex of parabolic reflector.



* This system uses a hyperboloid reflector placed such that one of the foci co-incides with the focus of parabolic reflector, (or) paraboloid.

* This hyperboloid reflector is called "Cassegrain" secondary (or) sub-reflector.

* the primary radiator (or) feed radiator generally used a horn antenna

Advantages :-

→ It reduces spillover and minor lobe radiations.

→ the system has ability to place a feed at convenient place.

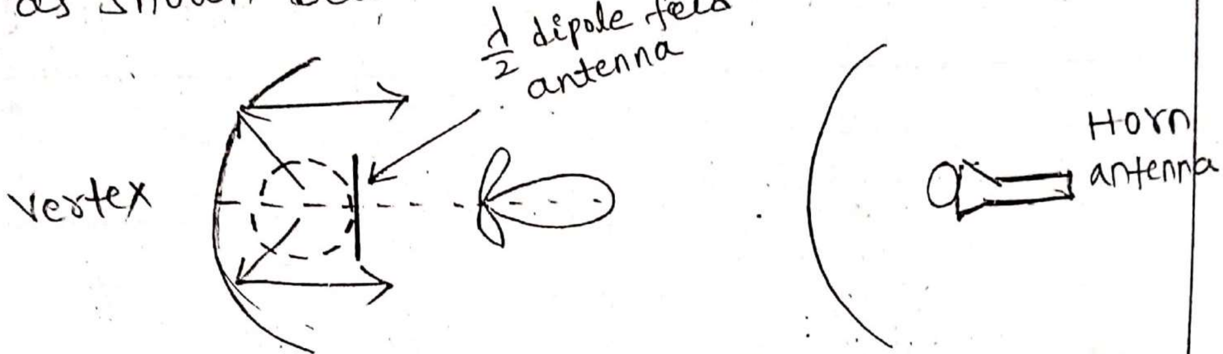
Dis-adv :-

→ There is a region of blocked rays infront of cassegrain reflector, that means Aperture Blocking.

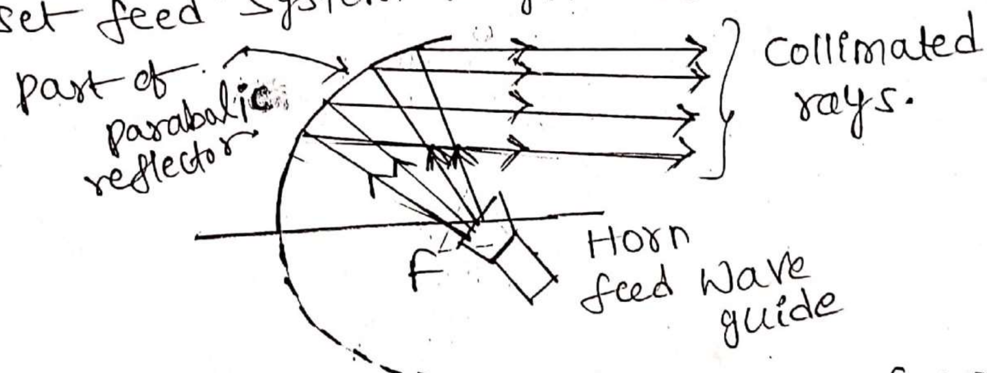
Offset feed system:-

To overcome the aperture blocking effect in cassegrain feed, we are using the offset feed system.

* By suitably selecting primary antenna, correct directional pattern for any arrangement can be obtained.
* the parabolic reflector can be fed using $\frac{\lambda}{2}$ antenna with a small ground plane (or) a horn antenna as shown below.



* the offset feed system is given below.



* Here the feed radiator is placed at the focus. with this system all the rays are properly collimated without formation of the region of blocked rays.

* Therefore the aperture blocking effect can be reduced by offset feed system.

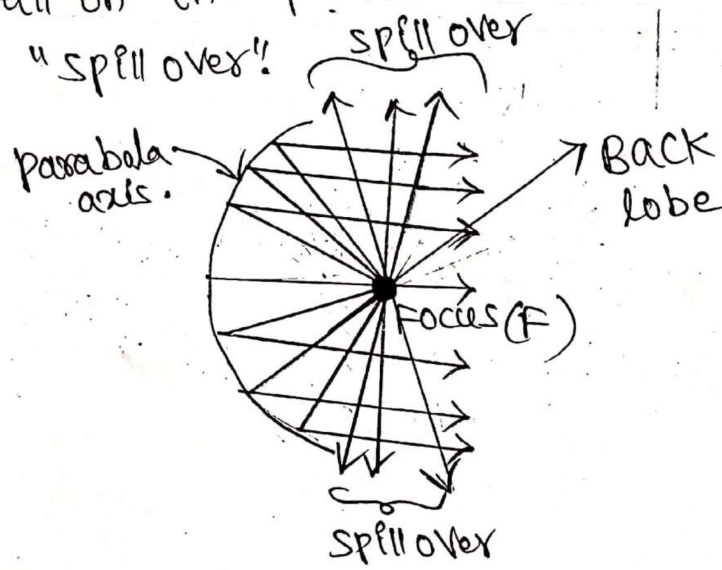
F/D Ratio :-

* In the case of paraboloids, the ratio of focal length to dish diameter is referred as the F/D ratio.

$$\frac{F}{D} = \frac{\text{Focal length}}{\text{Diameter of dish.}}$$

Spillover :- The waves originating from focus will be reflected parallel to the axis of parabola.

* Some of the waves originating from focus may not fall on the parabola. This phenomenon is called "spill over".

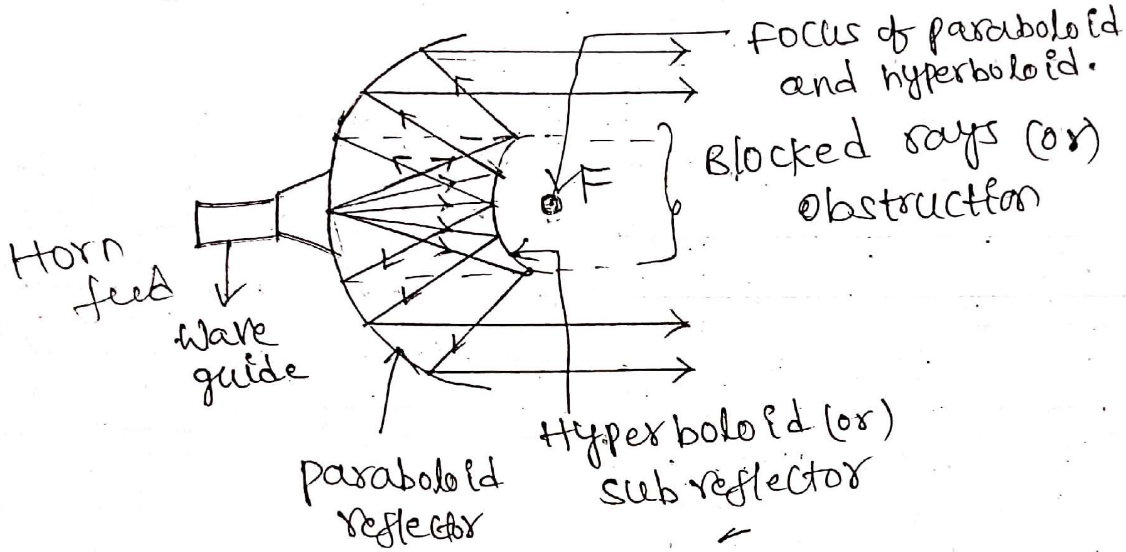


Back lobe :-

* While receiving spill over, the noise pick-up increases which is some defect. In addition to this, few radiations originated from the primary radiators are observed in forward direction, such radiations get added with desired parallel beam, this is called as "Back lobe radiation".

Aperture Blocking :-

An unwanted phenomenon occured in cassegrain feed parabolic antennas, in which the obstruction of primary reflector takesplace due to the effect of sub reflector known as "aperture blocking".



Horn Antennas :-

* the horn antenna is most widely used simplest form of the microwave antenna. the horn antenna serves as a feed element for large radio astronomy, communication dishes and satellite tracking over the world.
* the horn antenna can be considered as a flared out (or) opened out, wave guide, which is feeded and
* When one end of the wave guide is feeded and other end is open, it radiates in open space in all directions.
* As compared with the two wire Transmission line, the radiation through the wave guide is larger.

- In waveguide, the small amount of power is radiated in incident wave, while due to open circuit at other end large amount of power is reflected back.
- As one end of the waveguide is open circuited, the impedance matching with the free space is not perfect.
- So at the edges of waveguide, diffraction occurs. that means interference of electromagnetic waves.
- Therefore To overcome these problems the mouth of the waveguide is flared (or) opened out in the shape of Horn.

Types of Horn Antennas :-

- A horn antenna is nothing but a flared out (or) opened out waveguide. The main function is to produce an uniform phase front with a aperture larger than waveguide to give higher directivity

Horn Antennas.

- Rectangular Horn antennas
  - Sectorial Horn antennas
    - E-plane Sectorial Horn
    - H-plane Sectorial Horn.
  - Pyramidal Horn antennas
- Circular Horn antennas.
  - Conical Horn
  - Bi-Conical Horn.

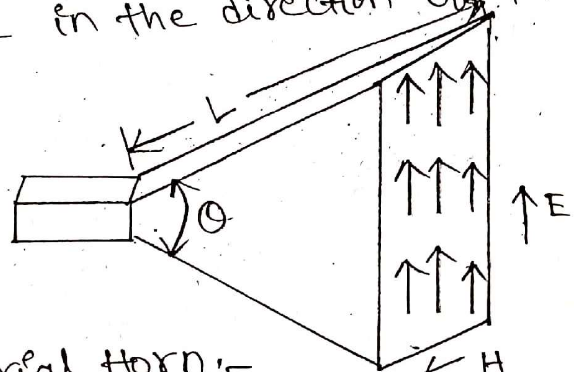
The rectangular Horn antennas are fed with rectangular waveguide, while the circular horn antennas are fed with circular wave guide.

* Depending upon the direction of flaring (opening), the rectangular horns are further classified as sectorial horn and pyramidal horn.

* A sectorial horn is obtained if the flaring is done in one direction only. This is further classified as E-plane sectorial horn and H-plane sectorial horn.

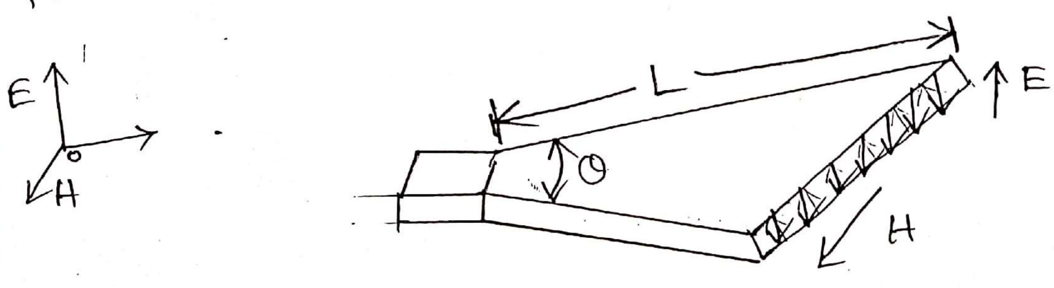
E-plane sectorial horn :-

* The E-plane sectorial horn is obtained, when the flaring is done in the direction of the electric field vector.



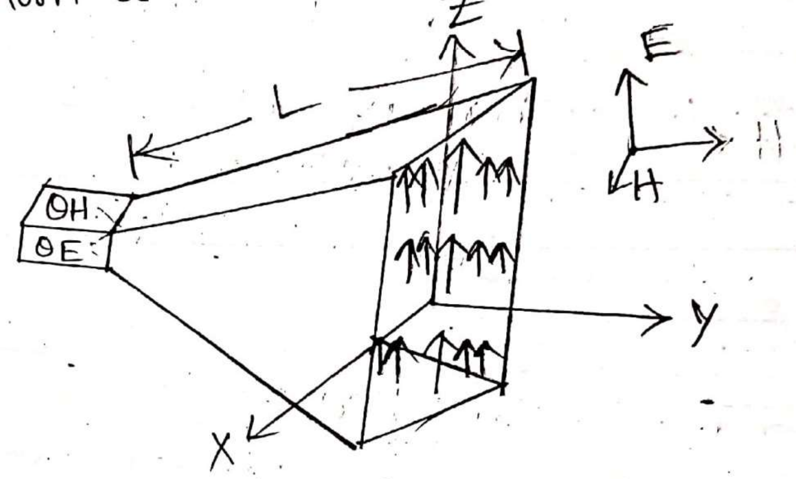
H-plane sectorial Horn :-

* The H-plane sectorial Horn is obtained, when the flaring is done in the direction of magnetic field vector.



Pyramidal Horn :-

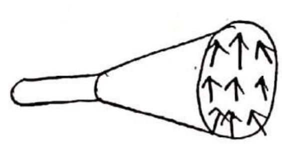
* Pyramidal horn antenna is obtained, when the flaring is done along the both the walls of the rectangular wave guide in the direction of both the electric and magnetic field vectors.
* For pyramidal horn antenna gain is 12-25 dB.



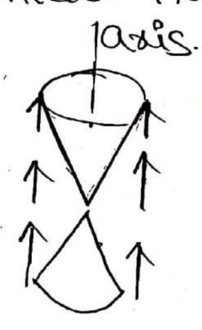
circular Horn antennas :-

* circular Horn antennas can be obtained by flaring the walls of circular wave guide.

conical horn



Biconical Horn

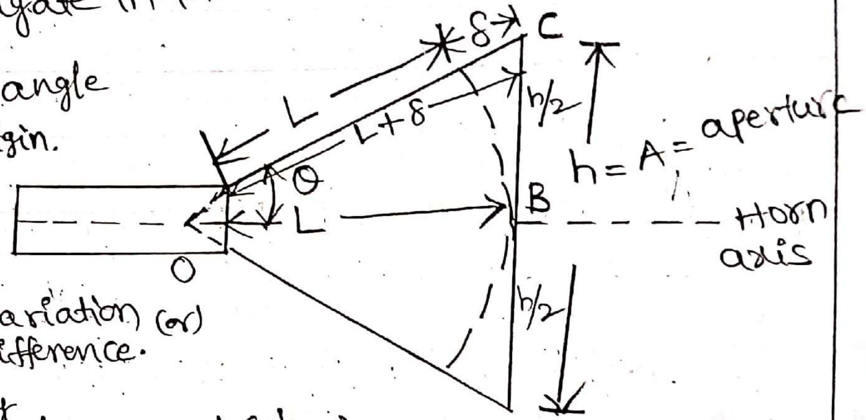


Design characteristics of Horn antennas :-

Let us consider E-plane sectorial Horn. The electromagnetic Horn produces uniform phase front with a larger aperture as compared to waveguide.

* consider an imaginary apex of horn. Assume that there exists a line source which radiates cylindrical waves.
* The constant (or) uniform wave fronts are cylindrical as the waves propagate in the direction radially outwards.

θ = optimum aperture angle
A = aperture , O = origin.
L = axial length
2θ = flare angle.
δ = phase difference variation (or) path difference.



From the geometry,

$$\cos\theta = \frac{L}{L+\delta} \Rightarrow \theta = \cos^{-1}\left(\frac{L}{L+\delta}\right)$$

$$\text{also } \tan\theta = \frac{h/2}{L} = \frac{h}{2L} \Rightarrow \theta = \tan^{-1}\left(\frac{h}{2L}\right)$$

$$\therefore \boxed{\theta = \cos^{-1}\left(\frac{L}{L+\delta}\right) = \tan^{-1}\left(\frac{h}{2L}\right)} \rightarrow (1)$$

From right angle triangle OBC

$$(L+\delta)^2 = L^2 + \left(\frac{h}{2}\right)^2 \quad (\because \text{ pythagorous theorem})$$

$$\Rightarrow L^2 + \delta^2 + 2L\delta = L^2 + \frac{h^2}{4}$$

$$\therefore \delta^2 + 2L\delta = \frac{h^2}{4}$$

if 'δ' is small then δ^2 is Neglected

$$\therefore 2L\delta = \frac{h^2}{4} \quad \text{where } \delta \ll L$$

$$\boxed{L = \frac{h^2}{8\delta}} \rightarrow (2)$$

Equations ① ② are called as Design equations.

When flare angle (2θ) is small, the aperture area for a specified Length 'L' becomes small. ∴ the directivity decreases.

* The directivity of maximum value can be obtained at the largest flare angle for which 'δ' does not exceed typical value such as 0.25λ for E-plane horn, 0.32λ for conical horn, 0.40λ for H-plane sectoral horn.

The directivity of pyramidal and conical horn is highest as compared to other types of horns.

for E-plane horn phase difference up to 72° for $\delta < 0.2\lambda$

for H-plane horn phase difference upto 135° for $\delta < 0.375\lambda$

In practical horn antennas flare angle varies from 40° to 15° which gives beam width $= 66^\circ$, Directivity $= 40$, for $L = 6\lambda$;

for $L = 50\lambda$, beam width $= 23^\circ$ and Directivity $= 120$.

for optimum flare horn, the half power beam width is

$$\theta_E = \frac{56^\circ\lambda}{a_E} \text{ (or) } \frac{56^\circ\lambda}{h}$$

$$\theta_H = \frac{67^\circ\lambda}{a_H} \text{ (or) } \frac{67^\circ\lambda}{\omega}$$

The relation between directivity and aperture area is

$$D = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi \times \varepsilon_{ap} \times A_p}{\lambda^2}$$

But $\frac{A_e}{A_p} = \varepsilon_{ap}$ = aperture efficiency.

A_e = effective aperture in m^2

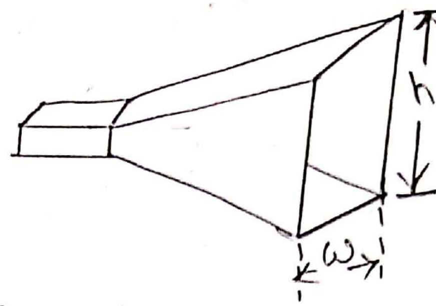
A_p = physical aperture in m^2

For a rectangular horn

$A_p = a_E \times a_H = h \times w$

Where $a_E = h$ = aperture in E-plane

$a_H = w$ = aperture in H-plane.



$\therefore$ Directivity $D \cong \frac{4\pi \times E_{ap} \times A_p}{\lambda^2}$

$\cong \frac{4\pi \times 0.6 \times A_p}{\lambda^2}$

$\therefore D = \frac{7.5 A_p}{\lambda^2}$

The gain is $G_p = \frac{4.5 A_p}{\lambda^2}$

Features of Horn antennas:-

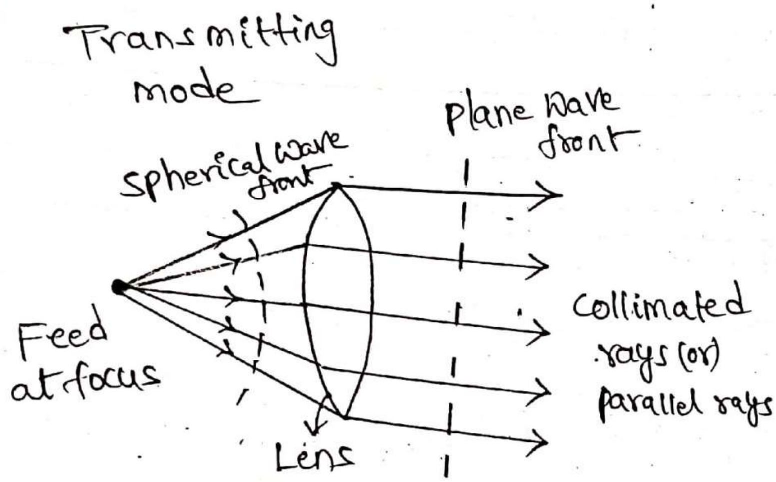
* Horn antenna is used with waveguide and it is used as radiator.
* It is generally used with paraboloidal antenna as a primary antenna.
* For pyramidal horn, the directivity increases if the flare of the horn is in more than one direction.

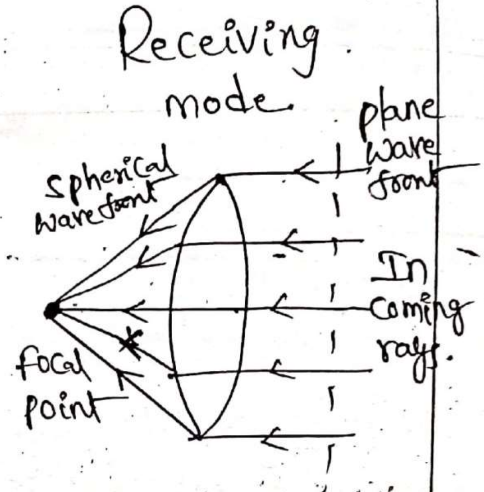
Applications of Horn antennas:-

* The horn antenna is used as feed element in antennas such as parabolic reflectors.
* It is the most wide used antenna for measurement of various antenna parameters.

Lens antennas:-

- A lens antenna is an antenna consisting an elec- magnetic lens with a feed. It is a three dimens electromagnetic device having refractive index $n \geq 1$.
- Its operation is similar to a glass lens used in optics. The lens antenna can be used in Transmitting mode and receiving mode.

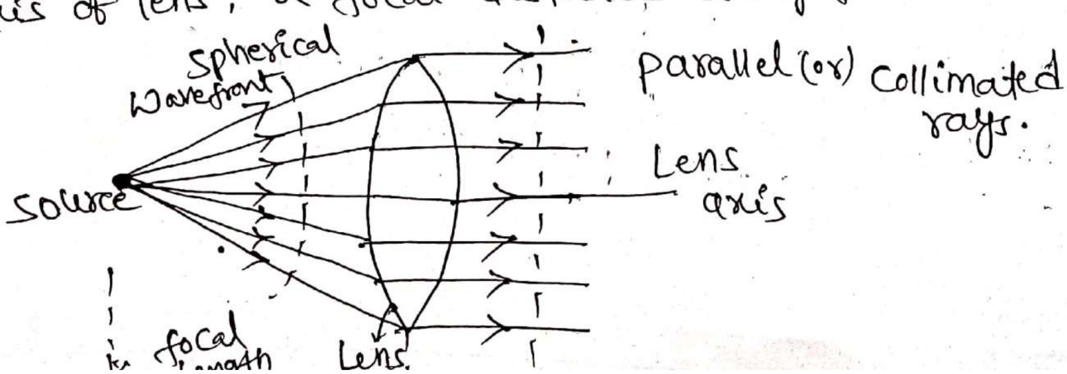




* Functions of Lens antennas are
  - → It Controls the illumination of aperture
  - → It Collimates the electromagnetic rays.
  - → It produces directional characteristics.

principle of Lens antenna:-

→ consider an optical concave lens. If a point source is placed at the focal point of lens, which is along the axis of lens, a focal distance away from lens.



Due to radiation from point source, we get spherical wave front. When the rays travel to the lens refraction takes place, due to the refractive index of lens and rays are collimated, to obtain plane wave front.

* The refraction is more at the edges than refraction at the centre.
* To operate a lens at radio frequencies, a dielectric lens is preferred. Such lens with a point source producing spherical wavefront on left hand side of lens to plane wave front on right hand side of lens.

Types of lens antennas:-

* The main application of lenses is to collimate incident divergent energy and to overcome energy spreading in unwanted directions.

There are 2 types of lens antennas

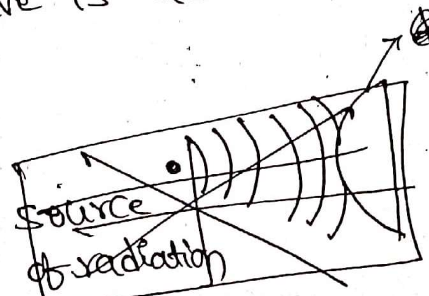
(i) E-plane metal plate lens (or) Fast lens

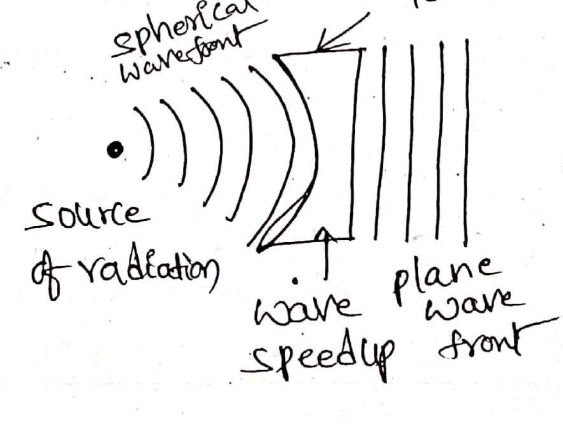
(ii) H-plane metal plate lens (or) Delay lens. (or) ~~dielectric~~ dielectric lens.

E-plane metal plate lens :- (Fast lens)

E-plane metal plate lens antenna is the antenna in which

→ The fast lens antenna is decreased by the lens medium electrical path length is decreased (or) speed up. and wave is accelerated (or) speed up.

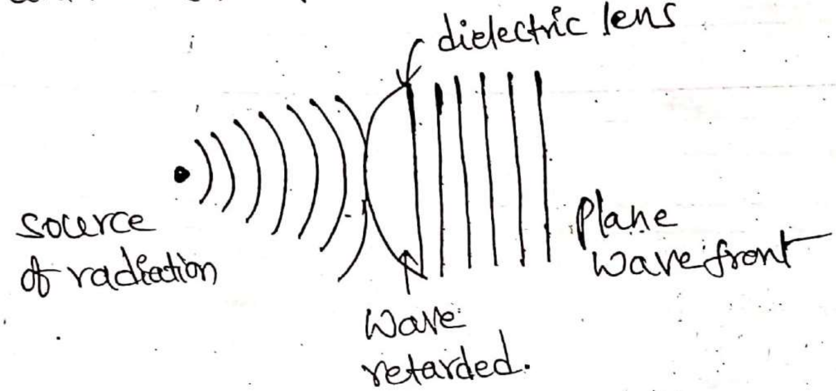




H-plane metal plate lens (or) delay lens (or) Dielectric lens antenna.

→ The delay lens antenna is the antenna in which the electrical path length is increased by the lens medium and the wave is retarded.

→ The delays lens antennas are also called as dielectric lens antenna. (or) H-plane metal plate lens antenna.



Zoning of Lens:-

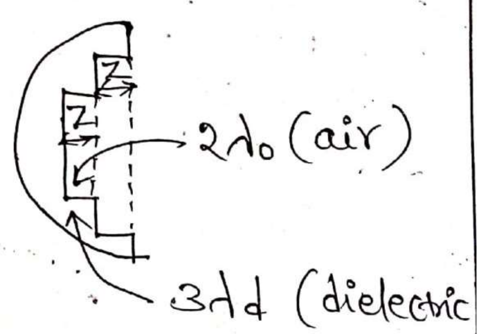
→ The weight of the lens can be reduced by removing sections of lens, which is called "zoning" of lens.

Zoning can be classified into two types.

(i) curved surface zoning

(ii) plane surface zoning.

→ In general the zoning of lens is carried out in such a way that particular design frequency, the performance of lens antenna is not affected. The zone step is denoted by 'Z'.



for dielectric zone step is $3\lambda_d$

for air zone step is $2\lambda_0$.

for 1λ difference

$$\frac{z}{\lambda_d} - \frac{z}{\lambda_0} = 1$$

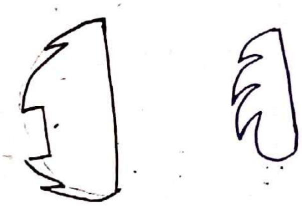
But refractive index $n = \frac{\lambda_0}{\lambda_d} \Rightarrow \lambda_d = \frac{\lambda_0}{n}$

$$\therefore \frac{z}{(\lambda_0/n)} - \frac{z}{\lambda_0} = 1$$

$$\Rightarrow \frac{nz}{\lambda_0} - \frac{z}{\lambda_0} = 1$$

$$\therefore \frac{(n-1)z}{\lambda_0} = 1$$

$$\boxed{z = \frac{\lambda_0}{n-1}}$$

Curved surface Zoning	plane surface Zoning
* As the zoning is done along the curved surface of lens, it is called curved surface zoning 	* As the zoning is done along the plane surface of lens it is called plane surface zoning. 
* It is mechanically stronger than plane surface zoning	* It is mechanically weaker than curved surface zoning
* It has less weight	* It has more (or) bulky weight.
* The power dissipation of curved surface zoning antenna is less.	* The power dissipation of ~~cur~~ plane surface zoning is more.
*	

Measurement of gain of an antenna:-

> The performance of any antenna can be described interms of figure of merit (or) gain of antenna.

> generally the gain can be measured above 1GHz, free space ranges are used.

> In addition to this microwave Techniques are also used for gain measurements.

> Antenna gains are not measured below 1MHz.

Basically there are two standard methods for measurement of gain.

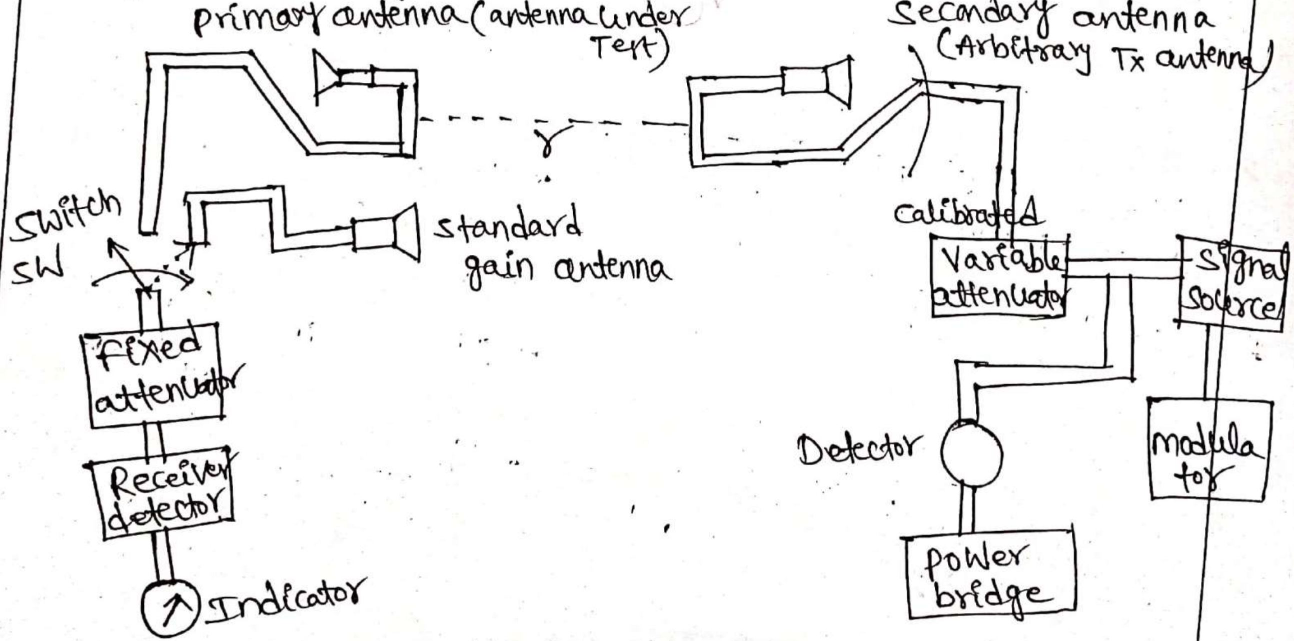
(i) Gain- comparison (or) Direct Comparison Method.

(ii) Absolute gain method.

$$\text{Gain} = \frac{\text{Max radiation Intensity (Test or subject antenna)}}{\text{Max radiation Intensity (Reference antenna)}}$$

Direct Comparison Method:-

> At high frequencies the gain measurement is done using direct comparison method.



In this Method the gain measurement is done by comparing the strengths of the signals Transmitted or Received by the antenna under Test and standard gain antenna. 16

→ The antenna whose gain is accurately known that is called as "standard gain" antenna. generally standard gain antenna is Horn antenna.

→ This method uses two antennas termed as primary antenna and secondary antenna.

→ The primary antenna consists of two different antennas seperated through a switch SW. The first primary antenna is standard gain antenna and second primary is subject antenna under Test

→ These two primary antennas are located at sufficient distance of seperation.

The two steps for gain comparison method are

* Through the switch SW, the first standard gain antenna is connected to Receiver. The antenna is adjusted in the direction of secondary antenna to have maximum signal Intensity. The i/p connected to the secondary or Transmitting antenna is adjusted to required level. for this i/p corresponding primary antenna reading is recorded at Receiver. corresponding attenuator and power bridge readings are recorded as A_1 and P_1.

* secondly the antenna under test is connected to Receiver by changing the position of switch SW. To get the same reading at Receiver, the attenuator is adjusted. Then corresponding Attenuator and power bridge readings are A_2 and P_2.

Case I :- If $P_1 = P_2$, then no correction need to applied and the gain of the subject antenna under is given by

power gain $= G_P = \frac{P_2}{P_1}$, where P_1 and P_2 are power levels.

Taking logarithms on b/s. We get

$$\log_{10} G_P = \log_{10}\left(\frac{P_2}{P_1}\right) = \log_{10} P_2 - \log_{10} P_1$$

(ie) $\boxed{G_P(dB) = P_2(dB) - P_1(dB)}$

Case II :- If $P_1 \neq P_2$ then the correction need to be included.

Let $\frac{P_1}{P_2} = P$ then

$$\log_{10}\left(\frac{P_1}{P_2}\right) = P(dB)$$

Power gain is given by

$$G = G_P \times \frac{P_1}{P_2}$$

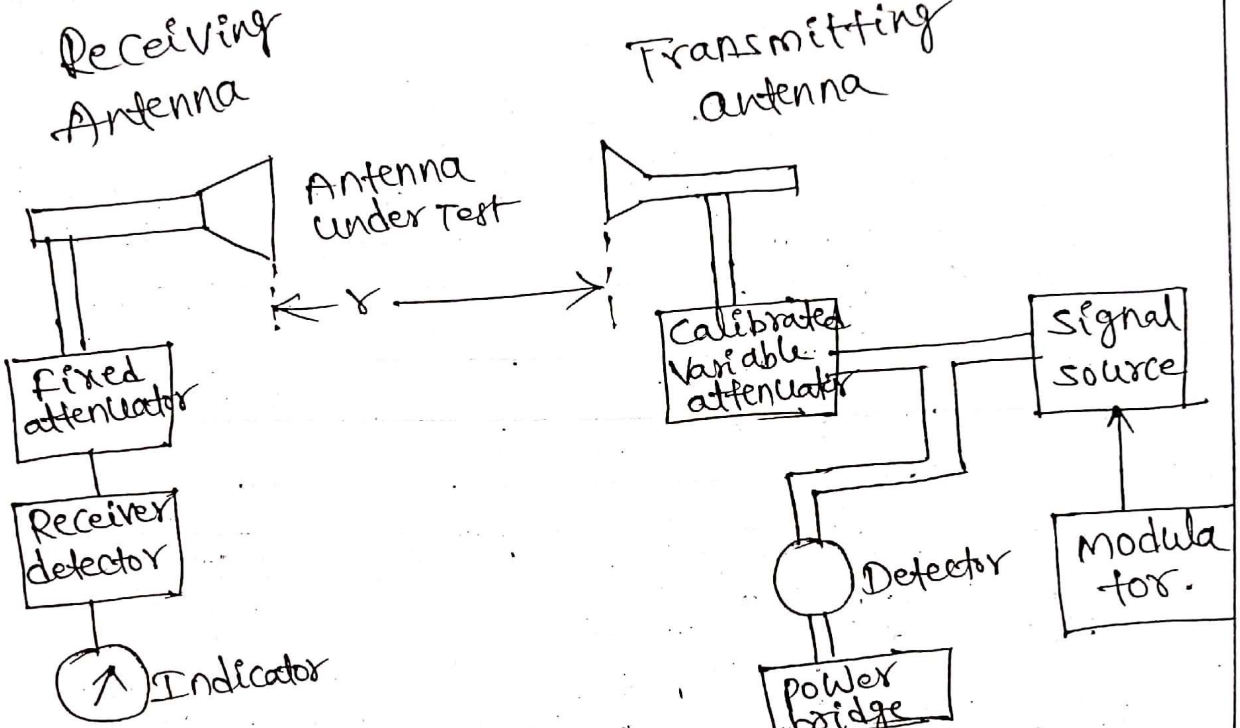
Taking log on both sides

$$\log_{10} G = \log_{10}\left(G_P \cdot \frac{P_1}{P_2}\right) = \log_{10} G_P + \log_{10} \frac{P_1}{P_2}$$

$\therefore \boxed{G(dB) = G_P(dB) + P(dB)}$

Measurement of Absolute gain method

Consider two identical antennas seperated by distance 'r'



Let the transmitted power be denoted by 'Pt' and Received power be denoted by Pr. effective aperture are of Aet for Transmitting antenna, Aer for Receiving antenna.

$$A_{et} = A_{er} = \frac{G_D \lambda^2}{4\pi} \quad (\because G_D = \text{Directive gain (or)} = \text{directivity})$$

from friis Transmission equation

$$\frac{P_r}{P_t} = \frac{A_{er} \cdot A_{et}}{\lambda^2 \cdot r^2} = \left(\frac{G_D \lambda^2}{4\pi}\right)\left(\frac{G_D \lambda^2}{4\pi}\right)\frac{1}{\lambda^2 r^2}$$

$$\frac{P_r}{P_t} = \left(\frac{G_D \lambda}{4\pi r}\right)^2 \Rightarrow \frac{G_D \lambda}{4\pi r} = \sqrt{\frac{P_r}{P_t}}$$

$$\therefore G_D = \frac{4\pi r}{\lambda}\sqrt{\frac{P_r}{P_t}}$$

Measurement of directivity :- (3-Antenna method)

Directivity is defined by

$$D = \frac{\text{Max Radiation Intensity}}{\text{Avg Radiation Intensity}}$$

$$\boxed{D = \frac{U_{max}}{U_{avg}}}$$ (OR).

$$D = \frac{r^2 P_d(max)}{\left(\frac{P_{rad}}{4\pi}\right)}$$ $\left(\because U_{max} = r^2 P_d(max),\ U_{avg} = \frac{P_{rad}}{4\pi}\right)$

$$\Rightarrow D = \frac{P_d(max)}{\left(\frac{P_{rad}}{4\pi r^2}\right)}$$ $\left(\because P_{avg} = \frac{P_{rad}}{4\pi r^2}\right)$

$$\therefore \boxed{D = \frac{P_d(max)}{P_{avg}}}$$

$$D = G_{Dmax} = \frac{4\pi U_{max}}{P_{rad}} = \frac{4\pi |E_{max}|^2}{\int_0^{2\pi}\int_0^{\pi} |E(\theta,\phi)|^2 \sin\theta . d\theta . d\phi}$$

$$= \frac{4\pi}{\int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi} \frac{|E(\theta,\phi)|^2}{|E_{max}|^2} \sin\theta\, d\theta . d\phi}$$

$$\therefore \boxed{D = G_{Dmax} = \frac{4\pi}{\int_0^{2\pi}\int_0^{\pi} f_n(\theta,\phi) \sin\theta\, d\theta\, d\phi}}$$

and $\boxed{D = \frac{41,253}{\theta_E \times \theta_H}}$

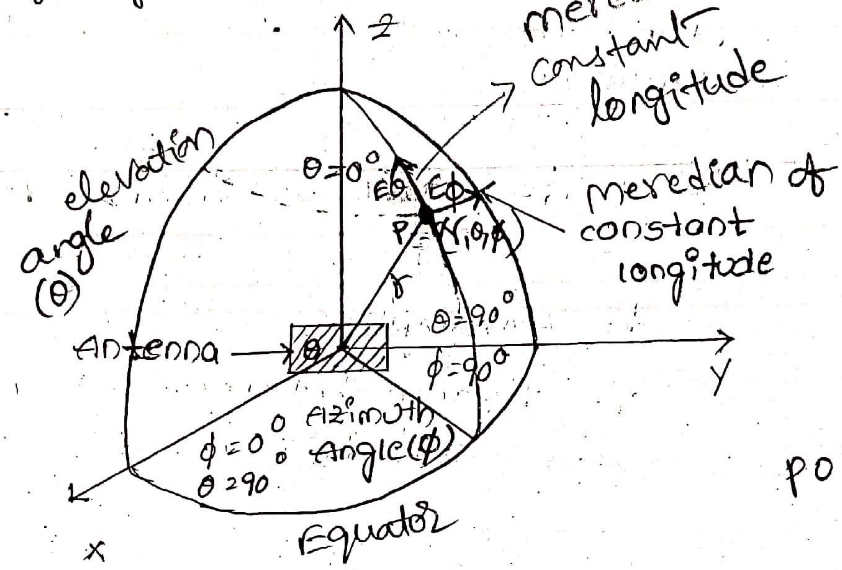
where $f_n(\theta,\phi)$ = normalized field Radiation.

Set up:-

Radiation pattern Measurement:-

→ Radiation pattern of a Transmitting antenna is described as the field strength or power density at a fixed distance from the antenna as function of direction

→ The Test antenna is assumed to be placed at the origin of spherical coordinates.



point $P=(r,\theta,\phi)$

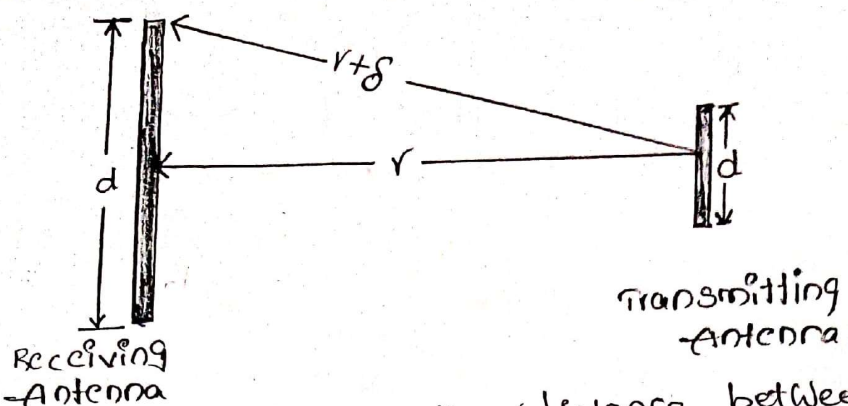
→ For most antennas it is generally necessary to take radiation pattern in XY plane (Horizontal plane) and XZ plane (vertical plane).

Distance criteria:-

→ In order to obtain accurate far field, the distance between primary and secondary antenna must be large.

→ If the distance between two antennas is very much small, then near field pattern is obtained.

→ The phase difference between centre and edges of Receiving antenna shown in the figure.



→ under this condition, the distance between primary and secondary antenna should be

$$r \geq \frac{2d^2}{\lambda}$$

where d = maximum linear dimension of either (Both) antennas.

λ = Wavelength

r = distance between Transmitter and Receiver

→ ALL THE BEST ←