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

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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.

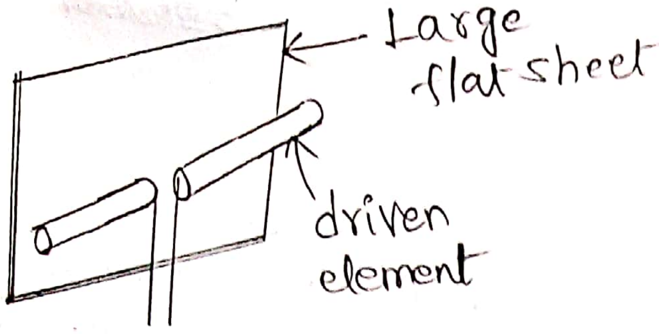
→ Dipole, Horn, slot antenna is called as "primary antenna", and reflector is called as "secondary" antenna.

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

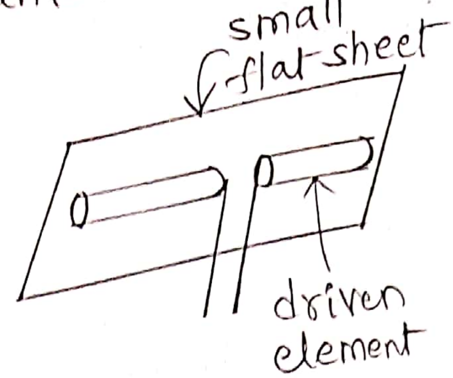
→ By using reflectors, the backward radiations from the antenna can be eliminated. Thus improving radiation pattern of an antenna.

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

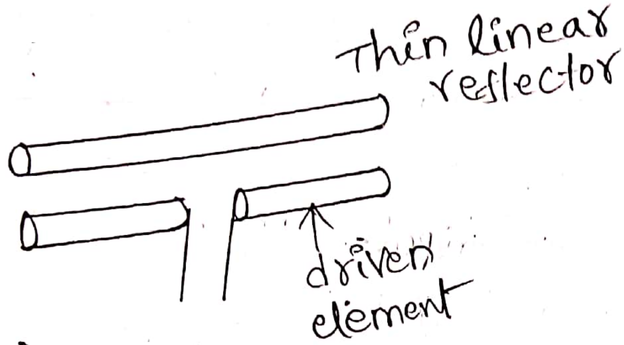
Different types of reflector antennas are



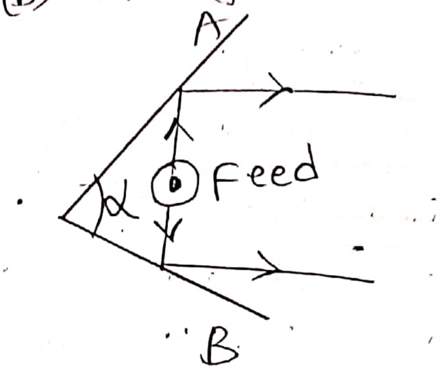
(a) Large flat sheet



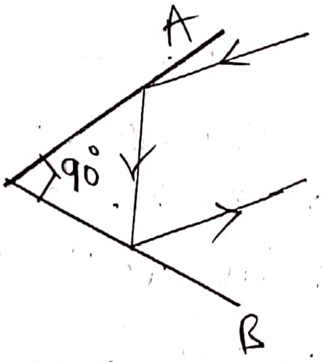
(b) small flat sheet



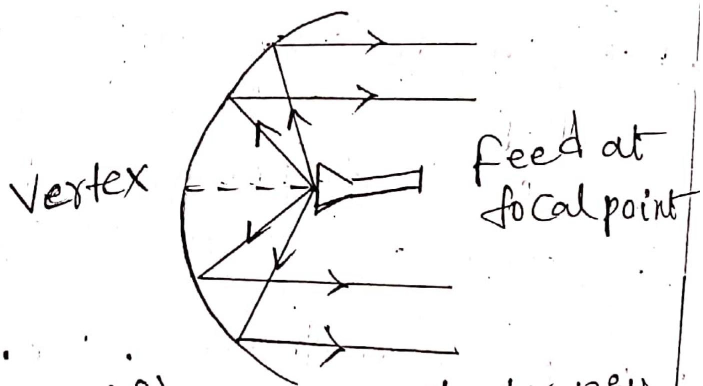
(c) Thin linear reflector antenna



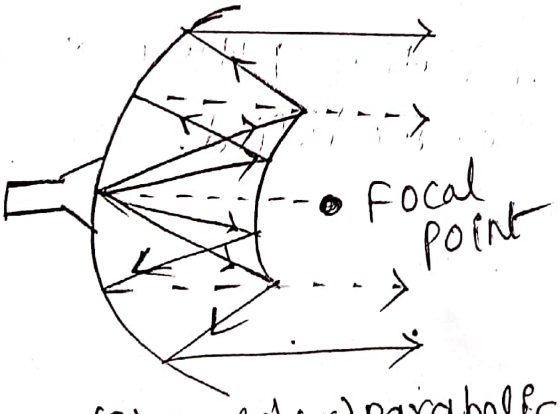
(d) Active corner reflector.



(e) passive corner reflector.

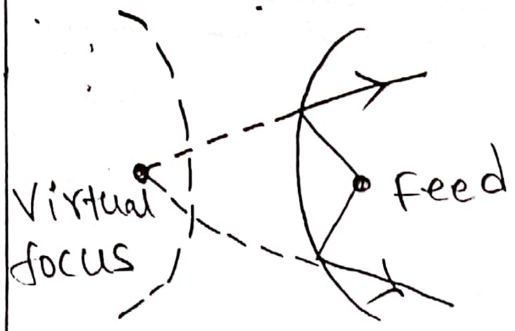


(f) curved reflector with front feed.

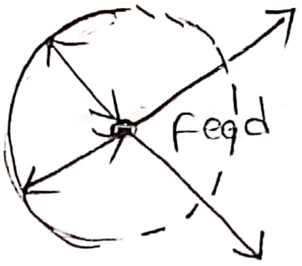


(h) elliptical reflector

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



(i) hyperbolic reflector.

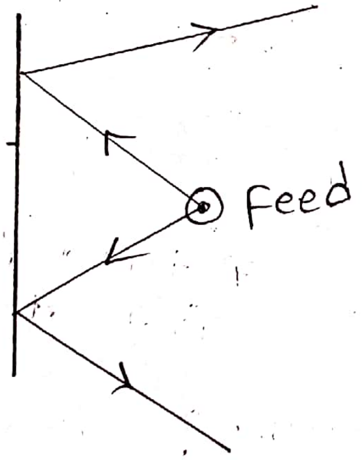


(j) Circular reflector

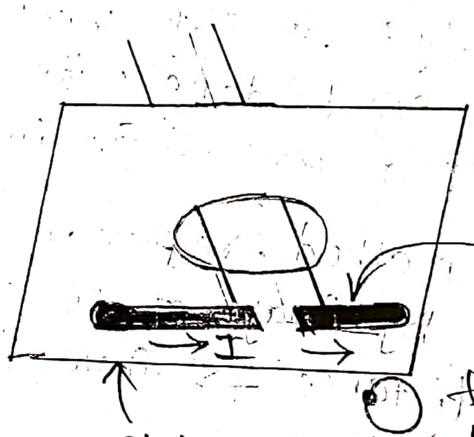
Flatsheet (or) plane reflectors :-

* 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.

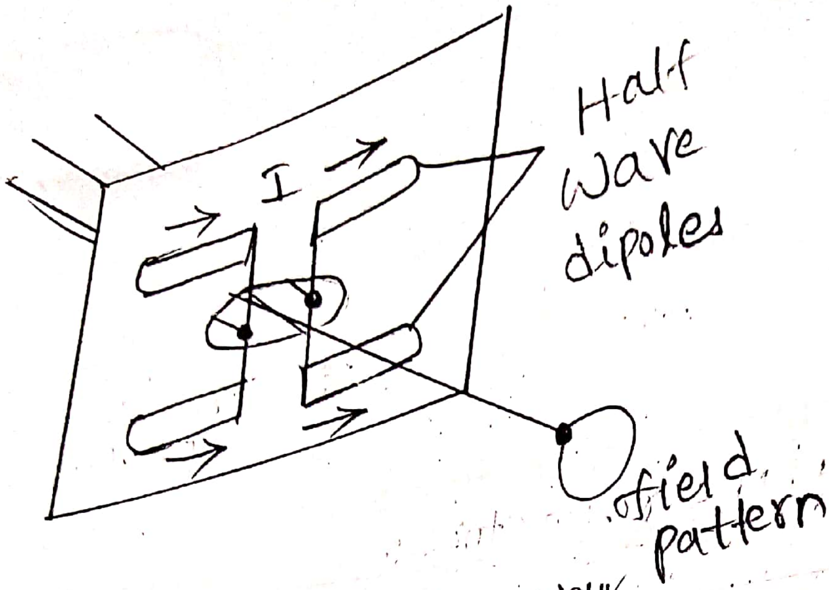


(a) plane reflector.



Examples :- Half Wave dipole with plane reflector

half wave dipole with reflector element

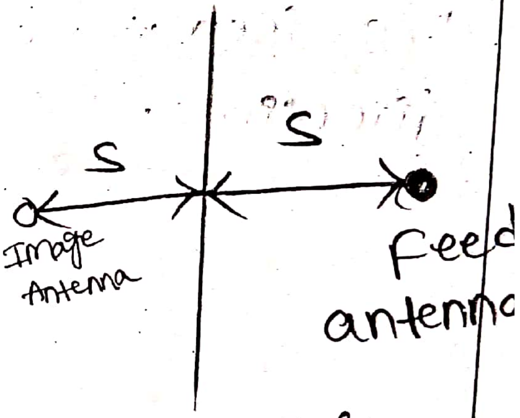


Half Wave dipole array with plane reflector.

* 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.

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



Antenna & its image at a distance 'S'.

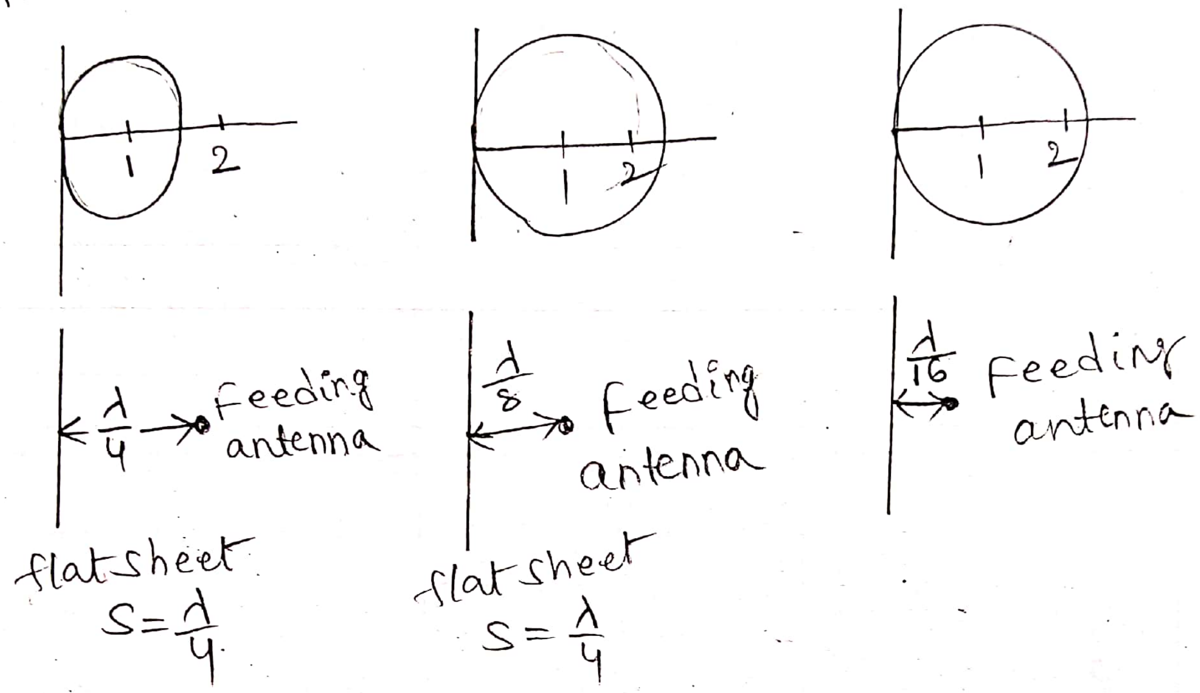
For an infinite plane reflector, assuming zero reflector losses, the gain of a $\frac{\lambda}{2}$ dipole antenna at a distance 's' is given by

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

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

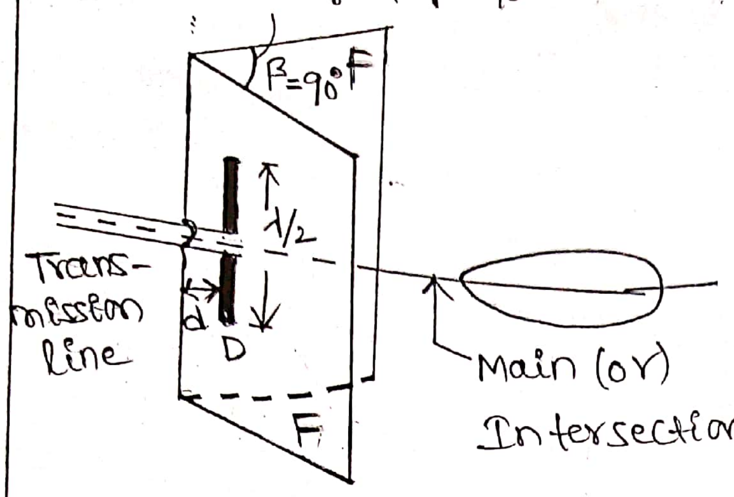
The gain of reflector relative to half wave dipole antenna is a function of the spacing between flat sheet and half wave dipole antenna. ③

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



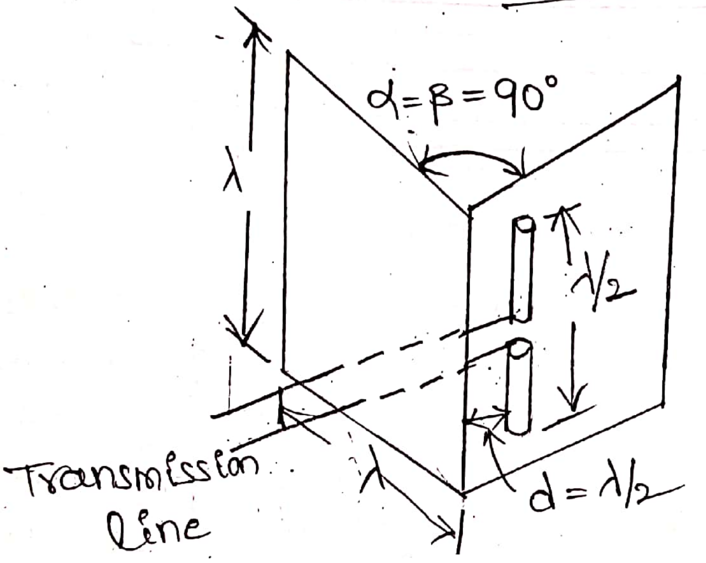
Corner Reflector :-

* 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".

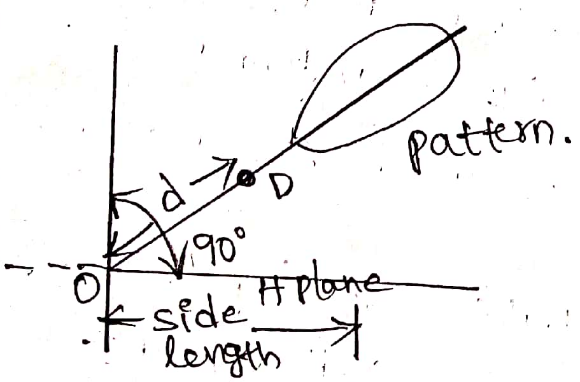


f = flat reflecting sheets
D = driven antenna

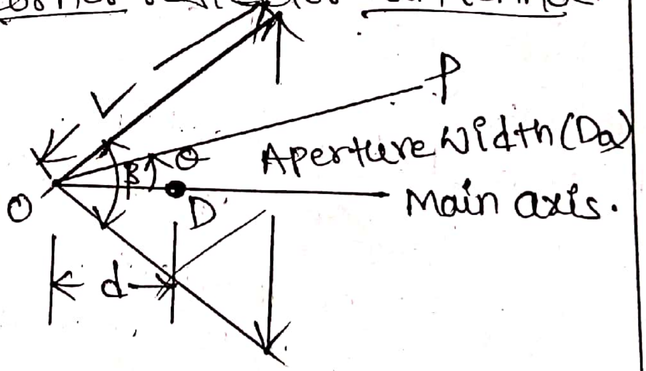
(a) Vertical corner reflector antenna.



(b) Horizontal corner reflector antenna

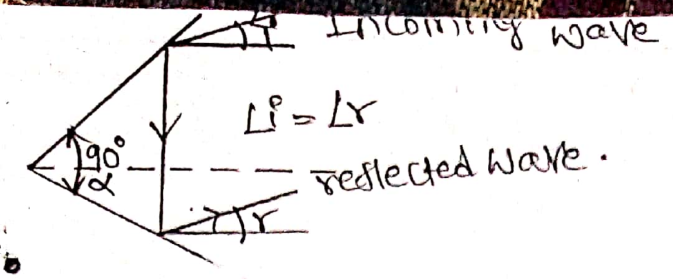


(c) Radiation pattern.



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

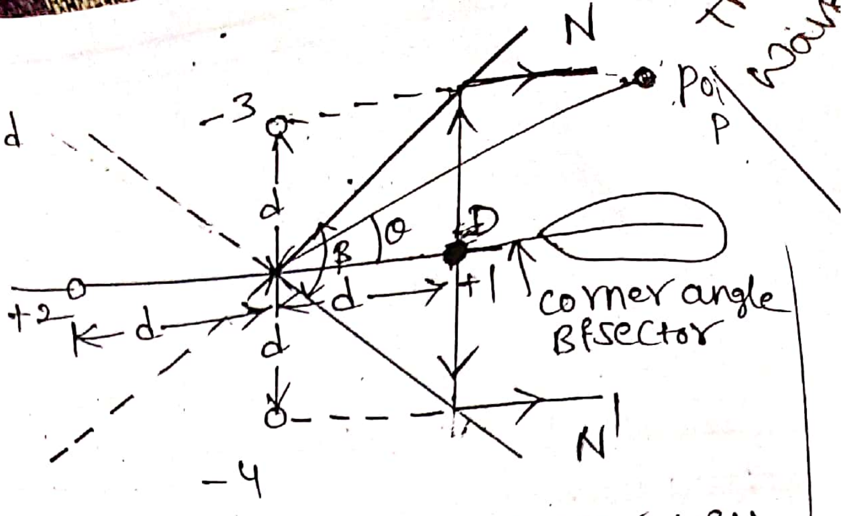
if $n = 2$, $\beta = 90°$ (or) $\frac{\pi}{2}$ radian → square corner reflector.

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).



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

* The driven antenna (half wave dipole) and its three images carry equal currents.
* 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

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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

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

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

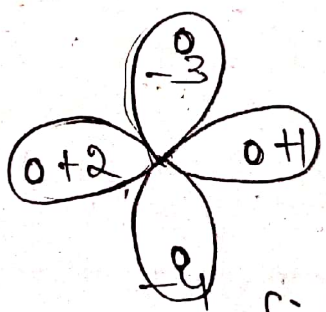
$$\Rightarrow G = \sqrt{\frac{R_{11}}{R_{11}+R_{12}-2R_{14}}} \times \left[\cos(\beta d \cos\theta) - \cos(\beta d \sin\theta)\right] \quad \to \text{eq } (7)$$

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 θ = 0 hence putting θ = 0 in eq (7)

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



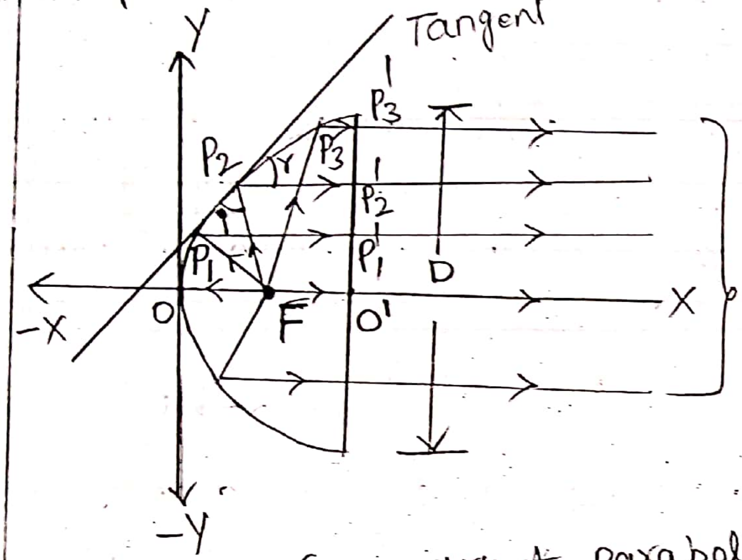
(∵ combination of broadside & end fire patterns in UNIT-3)

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 parabola 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 in terms of its coordinate is given by

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

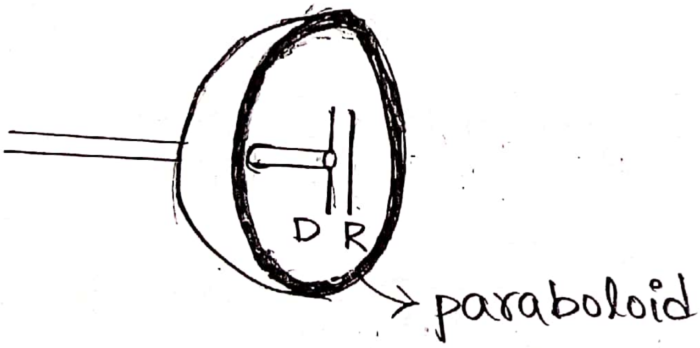
* The open mouth (D) of the parabola is known as aperture.

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

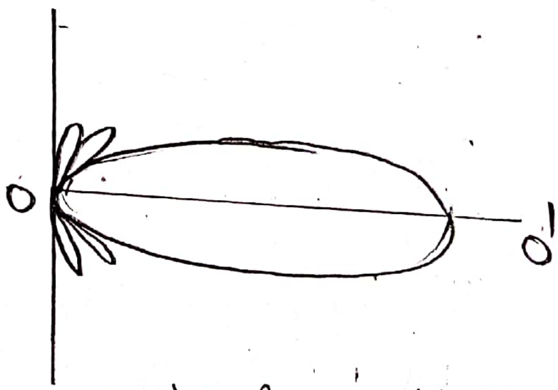
* The parabola converts a spherical wave front coming from a focus into a plane wave front at the mouth (D) of the parabola.
* Let us consider a source of radiation at the focus. A ray starts from focus (F) with respect to parabolic axis (OO')
* Let a tangent is drawn at P_2 on the curve. According to law of reflection the angle of incidence $\angle i$ and angle of reflection ($\angle r$) 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 $D = 10\lambda$

7

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

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)

Therefore powergain of circular Aperture paraboloid with respect to half wave dipole is given by

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

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

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

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

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

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

Types of feeds :-

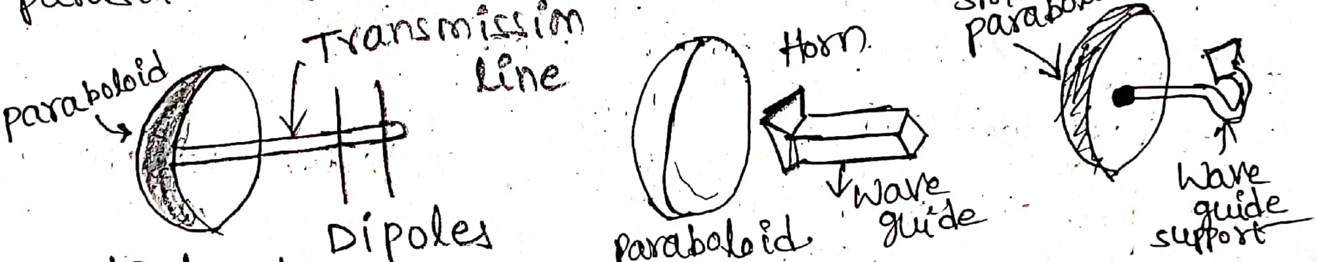
* A parabolic reflector antenna as a system consists two parts.
  - → source
  - → Reflector

* 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.



(a) dipole endfire feed

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

There are two types of feeds:

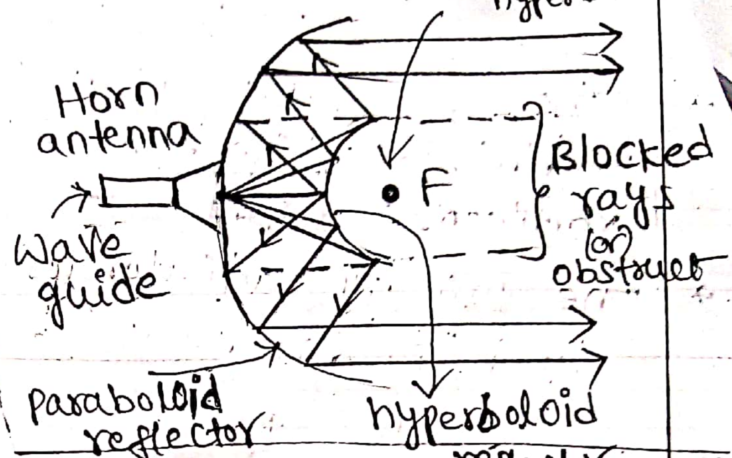
→ cassegrain feed system

→ 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.

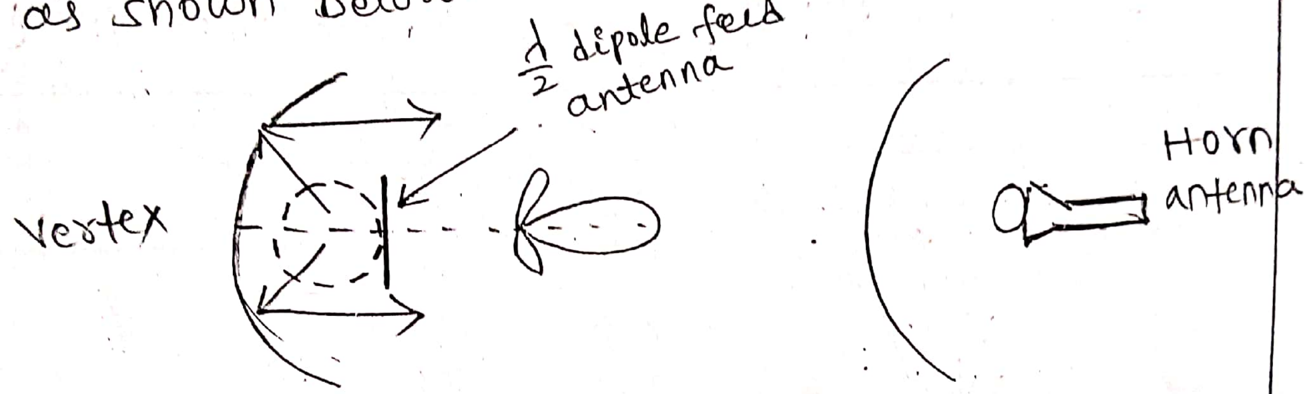
Dis-adv:-

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

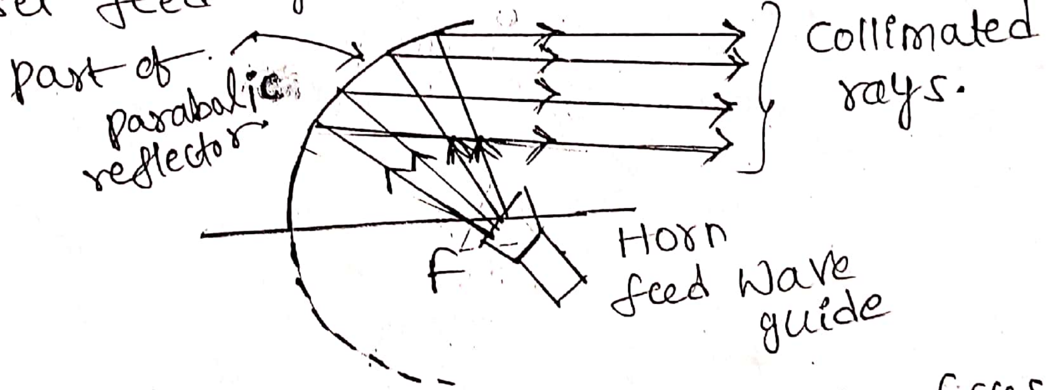
Offset feed system:-

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.

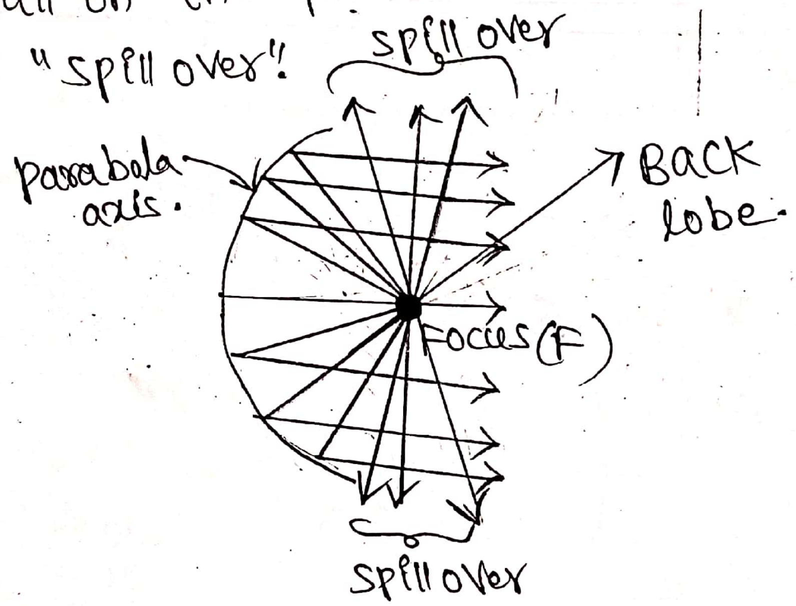
F/D Ratio :-

* 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".



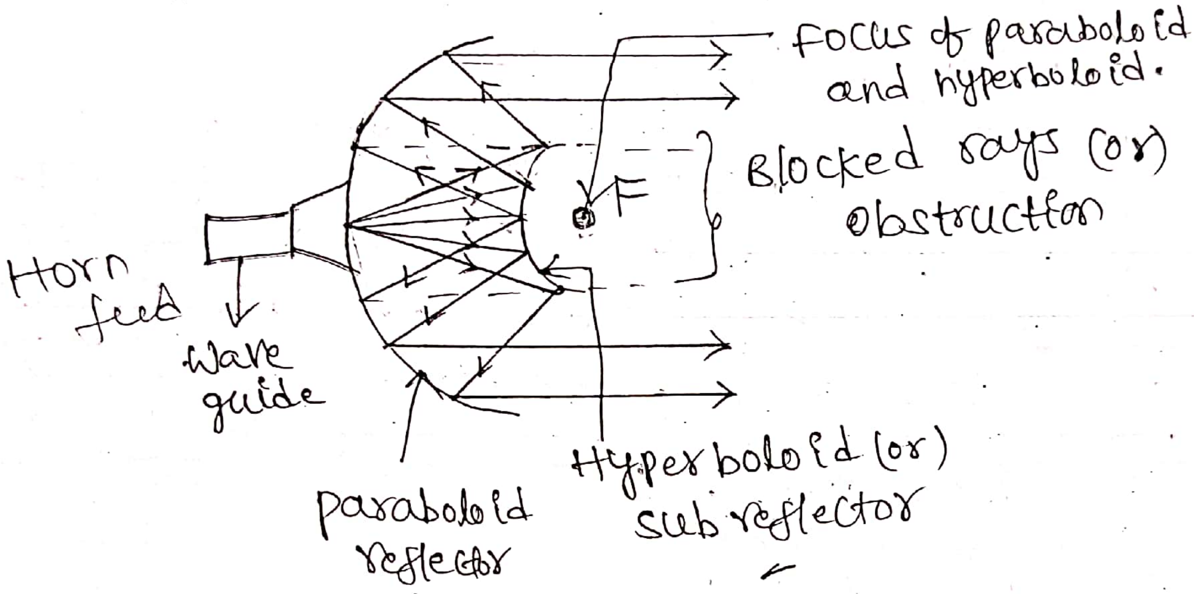
Back lobe :-

* 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 :-

(10)

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, satellite tracking over communication dishes and the world.

* The horn antenna can be considered as a flared out (or) opened out wave guide, which is

* 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, deffraction 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.

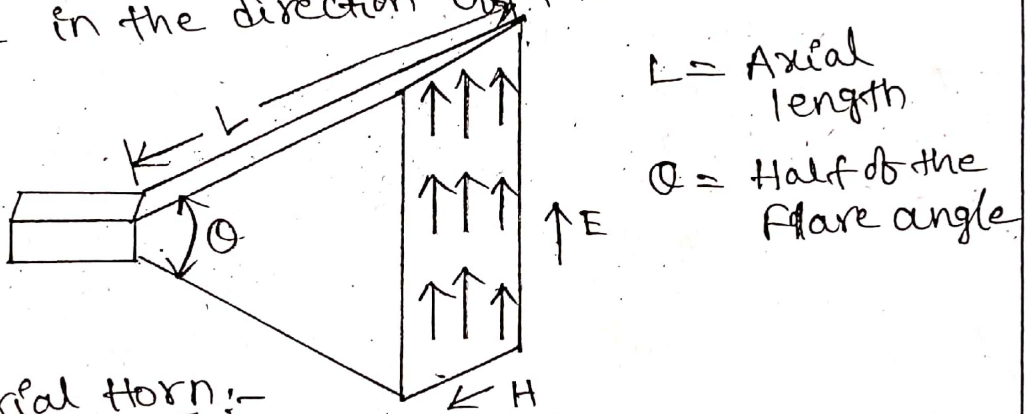
The rectangular Horn antennas are fed with rectangular waveguide, while the circular horn antennas are fed with circular wave guide.

* 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.

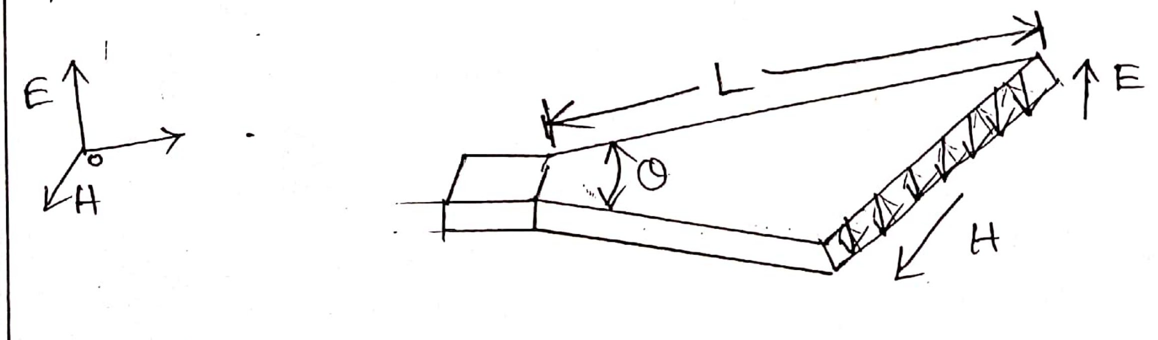
<u>E-plane sectorial horn</u> :-

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



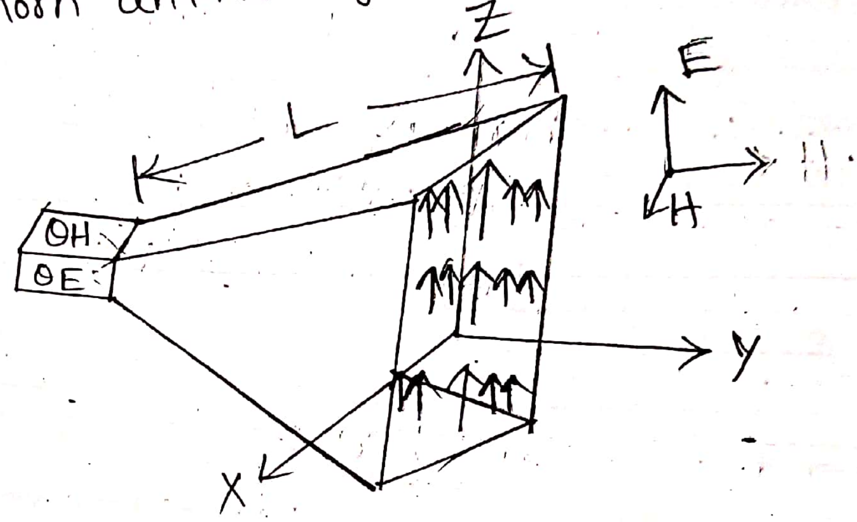
<u>H-plane sectorial Horn</u> :-

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



Pyramedal Horn :-

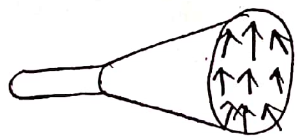
* pyramidal horn antenna is obtained, when the flaring is done along the both the walls of the rectangular waveguide in the direction of both the electric and magnetic field vectors.
* for pyramedal horn antenna gain is 12-25 dB.



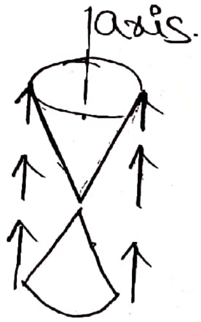
Circular Horn antennas :-

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

conical horn



Biconical Horn



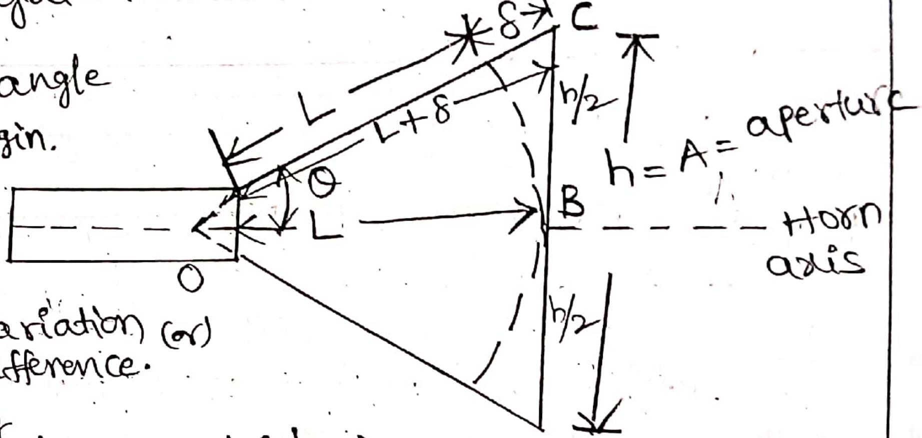
Design characteristics of Horn antennas :-

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 wavefronts are cylindrical in the direction radially outwards as the waves propagate.

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



From the geometry,

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

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 of

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

$$\theta_E = \frac{56^\circ\lambda}{a_E} \text{ (or) } \frac{56^\circ\lambda}{h} \qquad \theta_H = \frac{67^\circ\lambda}{a_H} \text{ (or) } \frac{67^\circ\lambda}{\omega}$$

The relation between directivity and aperture area is

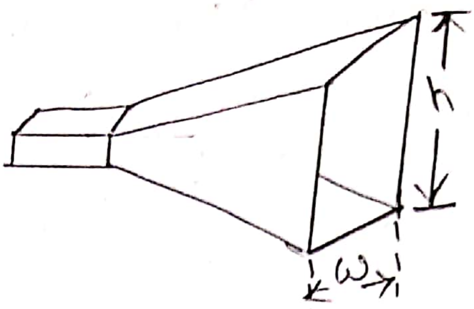
$$D = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi \times \epsilon_{ap} \times A_p}{\lambda^2}$$

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

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

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

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.

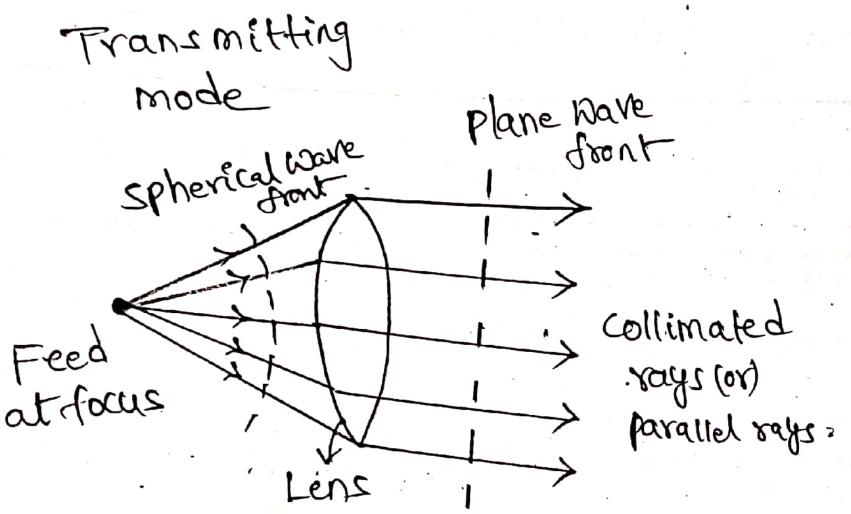
Applications of Horn antennas:-

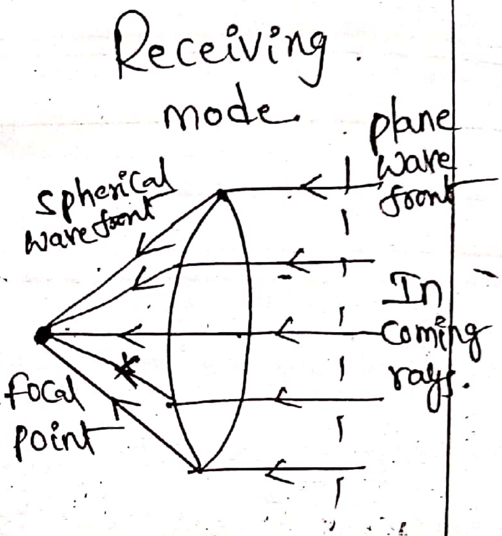
* The horn antenna is used as feed element in antennas such as parabolic reflectors.
* It is the most wide used antenna for measurement of various antenna parameters.

Lens antennas:-

* A lens antenna is an antenna consisting an electro magnetic lens with a feed. It is a three dimensional electromagnetic device having refractive index $n > 1$.

* Its operation is similar to a glass lens used in optics. the lens antenna can be used in Transmitting mode and receiving mode.

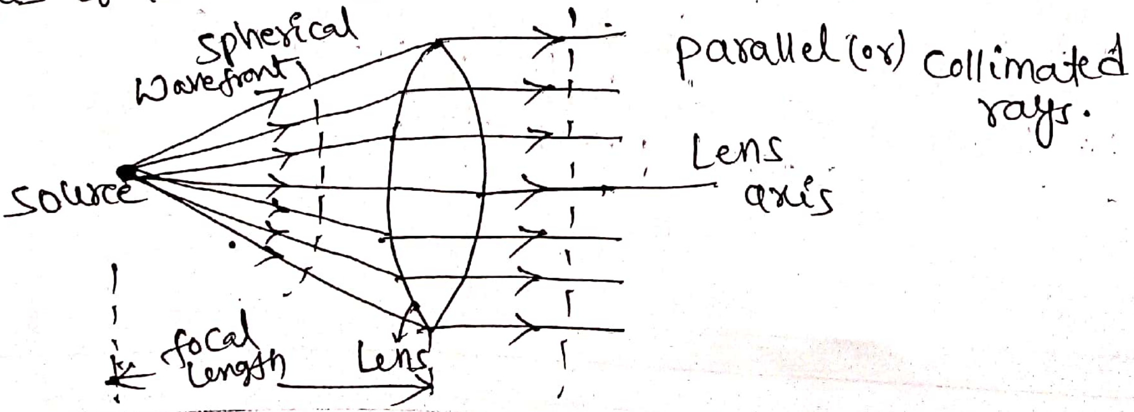




* Functions of Lens antennas are
  - → It Controls the illumination of aperture
  - → It Collimates the electromagnetic rays.
  - → It produces directional characteristics.

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 wave front 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.

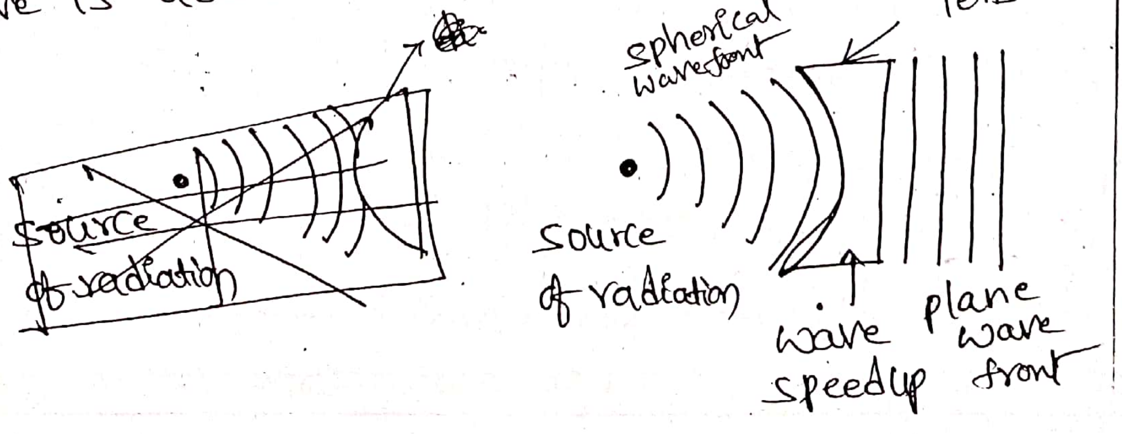
there are 2 types of lens antennas

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

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

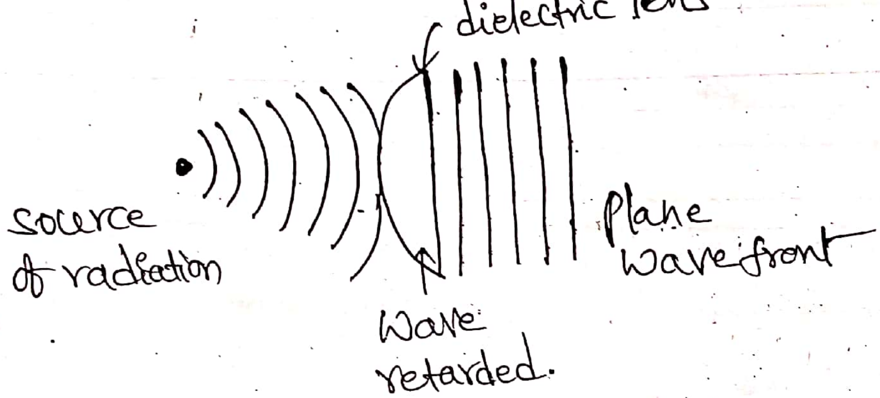
E-plane metal plate lens :- (Fast lens)

→ The fast lens antenna is the antenna in which the lens medium electrical path length is decreased by the lens medium 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.



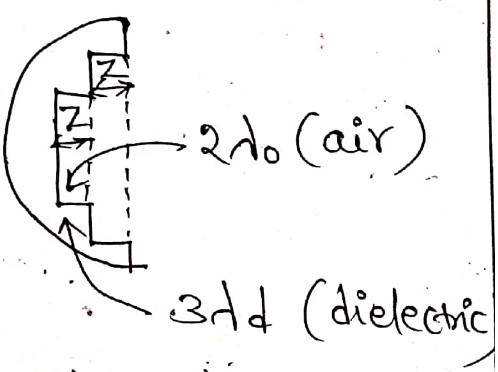
Zoning of Lens:-

- 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

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

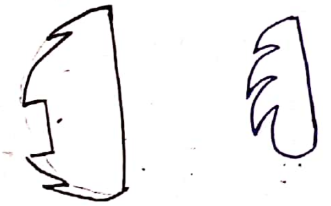
But refractive index $n = \frac{\lambda_0}{\lambda_d} \Rightarrow \lambda_d = \frac{\lambda_0}{n}$

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

$$\Rightarrow \frac{nZ}{\lambda_0} - \frac{Z}{\lambda_0} = 1$$

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

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

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 plane surface zoning is more

Measurement of gain of an antenna:-

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

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

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

> Antenna gains are not measured below 1 MHz.

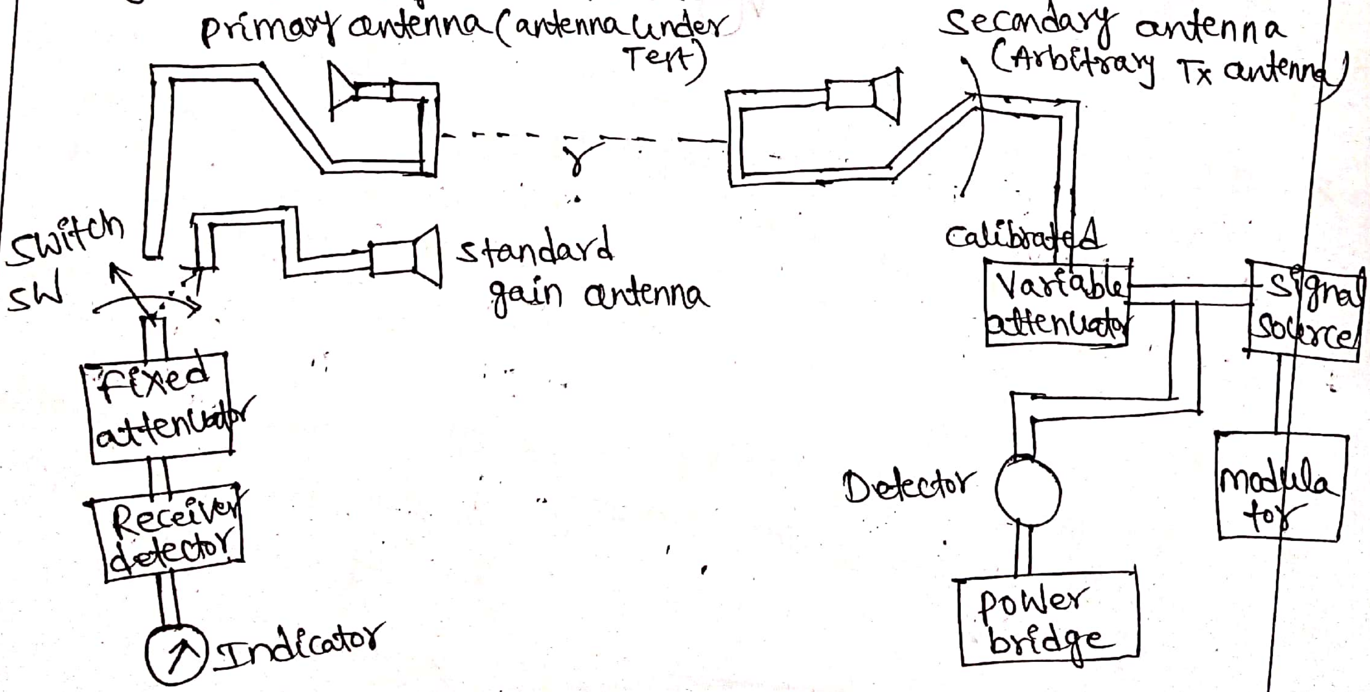
Basically there are two standard methods for measurement of gain.

(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.

→ 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 require 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

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

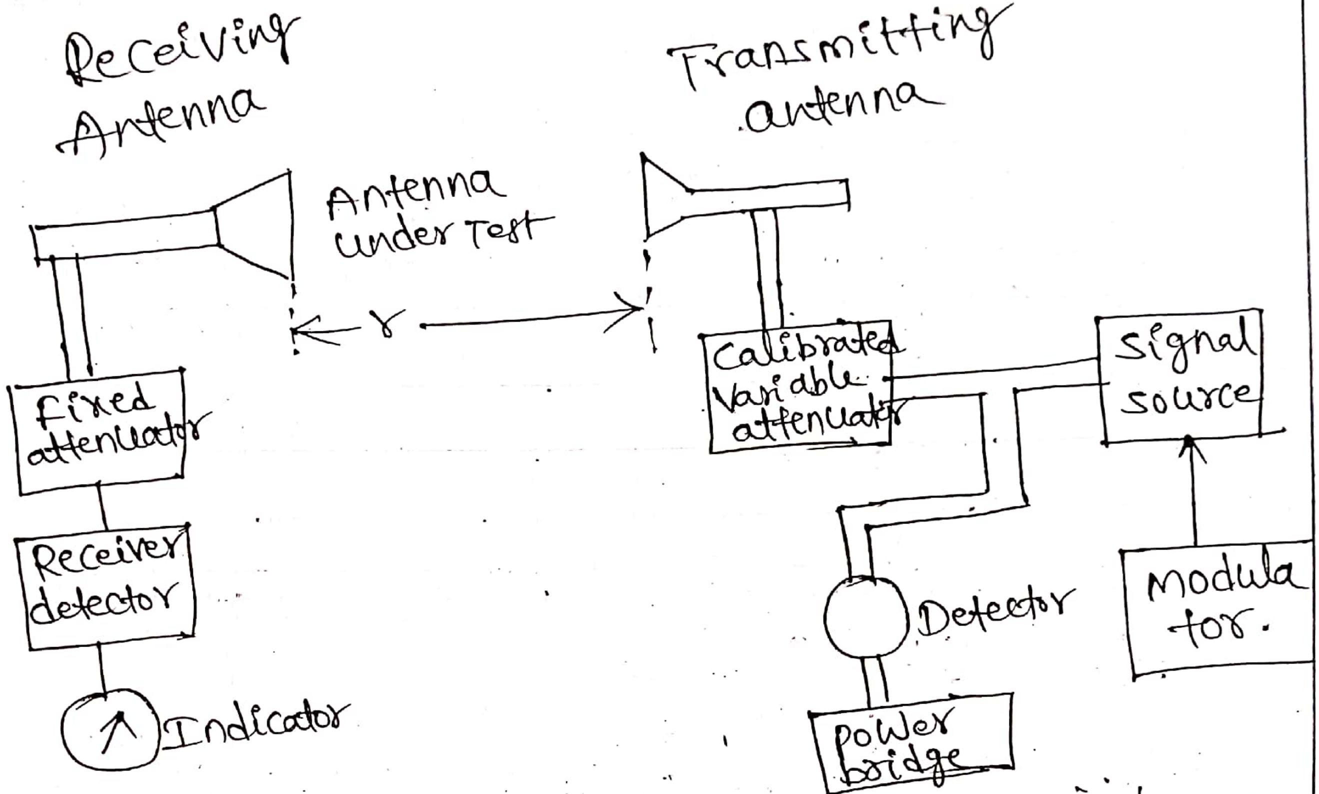
Taking log on both sides

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

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

Measurement of Absolute gain method:

Consider two identical antennas seperated by distance 'r'



Let the transmitted power be denoted by P_t and Received power be denoted by P_r. effective aperture are of A_{et} for Transmitting antenna, A_{er} 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

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

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

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

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

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

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

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

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

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

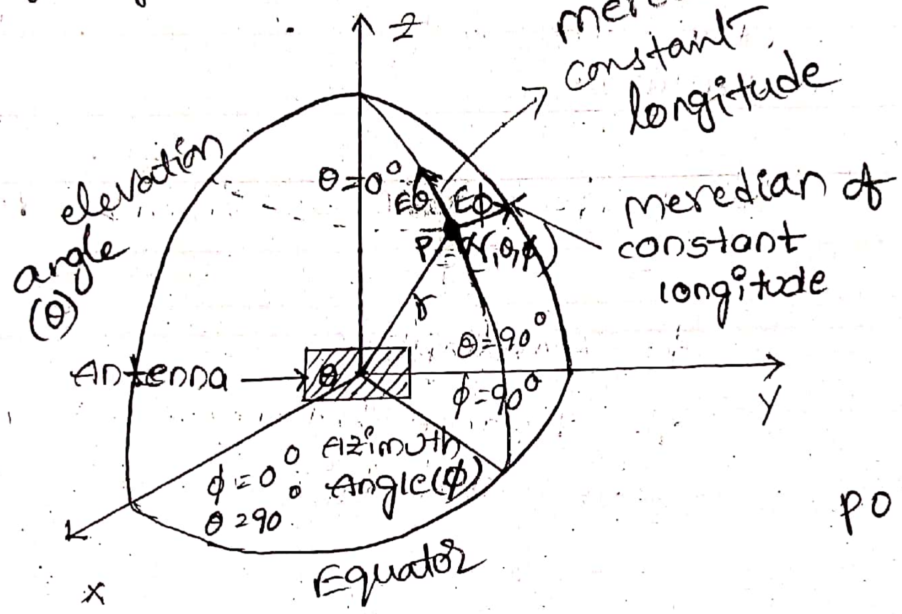
and $$\boxed{D = \frac{41,253}{\theta_E \times \theta_H}}$$

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

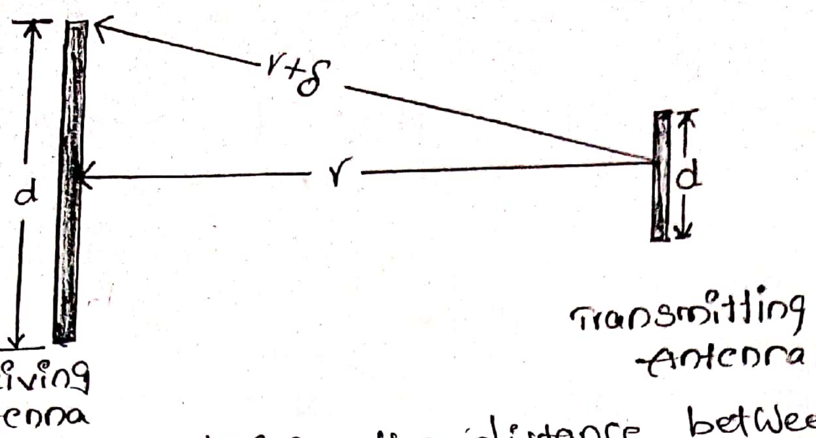
→ For most antennas it is generally necessary to take radiation pattern in XY plane (Horizontal plane) and XZ plane (vertical plane).

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 ←