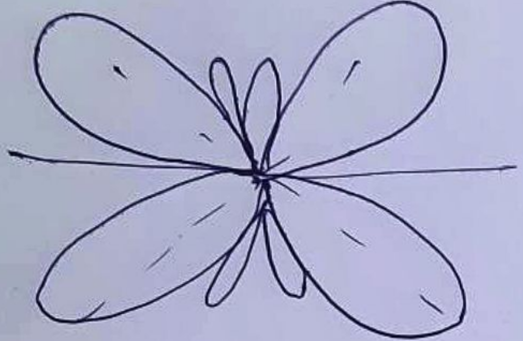
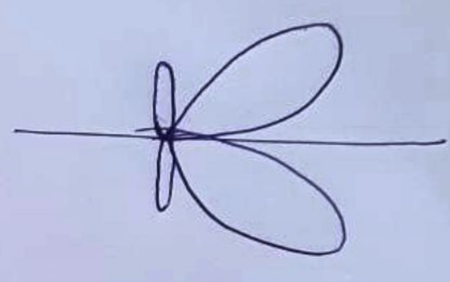
Comparison between Resonant and Non-resonant Antenna

	Resonant Antenna	Non resonant antenna
1.	It has a resonant transmission line with an exact number of half wave length long and open at both ends.	It has a transmission line excited at one end while properly terminated at other end into its characteristic impedance
2.	In this antenna, standing waves exist as there are incident and reflected waves.	No reflections, hence standing waves does not exist.
3	It has bi-directional radiation pattern. 	It has unidirectional radiation pattern 
4	The antenna used at fixed frequency	The antenna used at various frequencies Ex: Long wire antenna V-antenna Inverted V-antenna Rhombic antenna.

Introduction:-

The Antennas which operate between frequency range of 3-30 MHz are called High-Frequency (HF) Antennas. In this Antennas, the wave length ranges in 100m to 10m, so the size of HF band Antennas are comparable with the wave length. In case of Low Frequency (LF) band and Mid Frequency (MF) band, the wave length is greater, the size of Antenna becomes larger and it becomes difficult to achieve highly directive system.

For point to point communication in HF band an Antenna with large aperture producing a beam of radiation is used. Such Antenna is either a resonant (i.e. periodic) or non-resonant (i.e. aperiodic) Antenna.

Resonant Antenna and Non-Resonant Antenna:-

* The Antennas which correspond to the resonant transmission line are known as "resonant Antennas."

The Resonant transmission lines are unmatched Antennas and used for operation at fixed frequency. The standing waves are produced in Resonant Antennas.

*. In which Antennas, the standing waves do not exist, then such Antenna is called "Non-Resonant Antenna". In this Antenna, the transmission line is excited at one end while other end is terminated with the characteristic impedence. Hence no wave is reflected back, indicates that the wave in non-resonant Antenna travels in one direction. So, the name for non-resonant Antenna is also called as "travelling-wave Antenna".

*. The examples of travelling wave Antennas are listed below.

→ Long wire Antenna
→ V Antenna
→ Inverted V Antenna
→ Rhombic Antenna.

Travelling wave Antennas:-

* The Antenna in which the standing wave does not exist along the length of the Antenna is called Travelling wave Antenna. Because of the Reflections does not occur in the travelling wave Antenna, these Antennas are also called as "Non-Resonant type Antenna" or "Aperiodic Antenna."

* In travelling wave Antennas, one of the end is terminated into the characteristic impedence Zo while other end is connected to the input signal. Due to the proper termination at the load, the Reflections are avoided. Because of this, the unidirectional Radiation pattern is observed.

* The travelling wave Antennas have larger bandwidth hence, these Antennas are used for the Radio communication system.

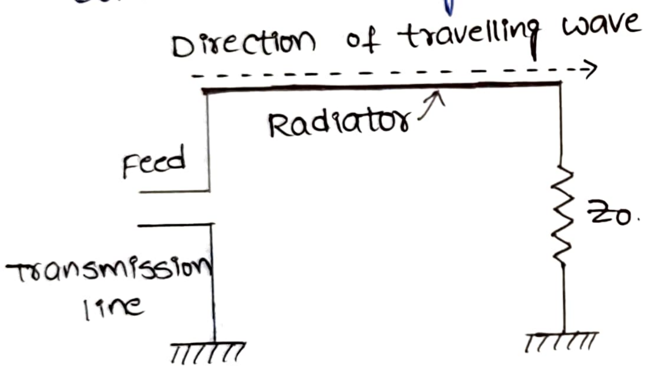


fig: Travelling wave Antenna Arrangement.

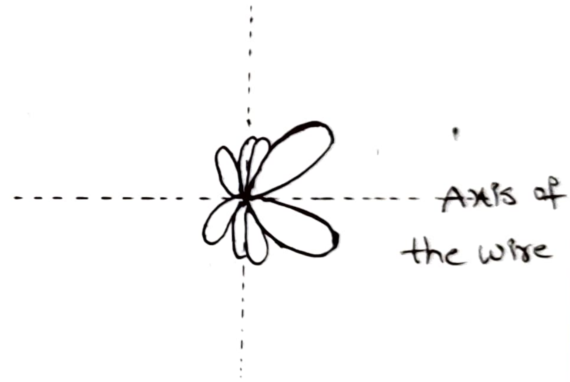


fig: unidirectional Radiation pattern.

* The strength of the electric field at a distance 'r' away from the radiator is given by

$$E = \frac{60\, I_{r.m.s}}{r}\left[\frac{\sin\theta}{1-\cos\theta}\right]\sin\left[\frac{\pi L}{\lambda}(1-\cos\theta)\right]$$

where 'r' = Distance at a point from Radiator.

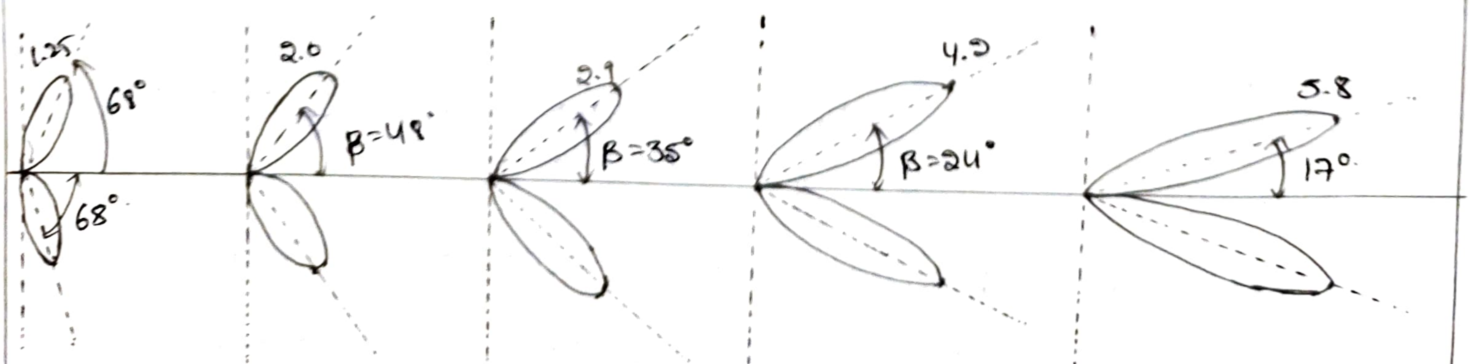
'L' = Length of the wire or Radiator.

* The Angle of Major lobe and the amplitude of the Major lobe depends on the length of the wire. As the length of the wire increases, the Amplitude of the Major lobe also increases and the angle of the Major lobe with respect to the axis of wire decreases. Hence, the Major lobe comes closer to the axis of wire.

* The below table indicates, the different values of Angle of Major lobe and Amplitude of the lobes for the increasing length.

Length of the travelling wave	Angle of Major lobe (β)	Amplitude of Major lobe
$L = \lambda/2$	68°	1.25
$L = \lambda$	48°	2.0
$L = 2\lambda$	35°	2.9
$L = 4\lambda$	24°	4.2
$L = 8\lambda$	17°	5.8

Diagramatic Representation:



a) $L=\lambda/2$ b) $L=\lambda$ c) $L=2\lambda$ d) $L=4\lambda$ e) $L=8\lambda$.

Fig: Radiation pattern for diff. lengths of travelling wave ...

Advantages :-

→ standing waves do not exist.
→ compared to single wire Antenna Bandwidth is more.
→ less power Dissipation.
→ shows sharp null in forward direction.
→ with increasing length, the major lobe becomes narrower and closer.
→ useful in Radio communication applications.

DisAdvantages :-

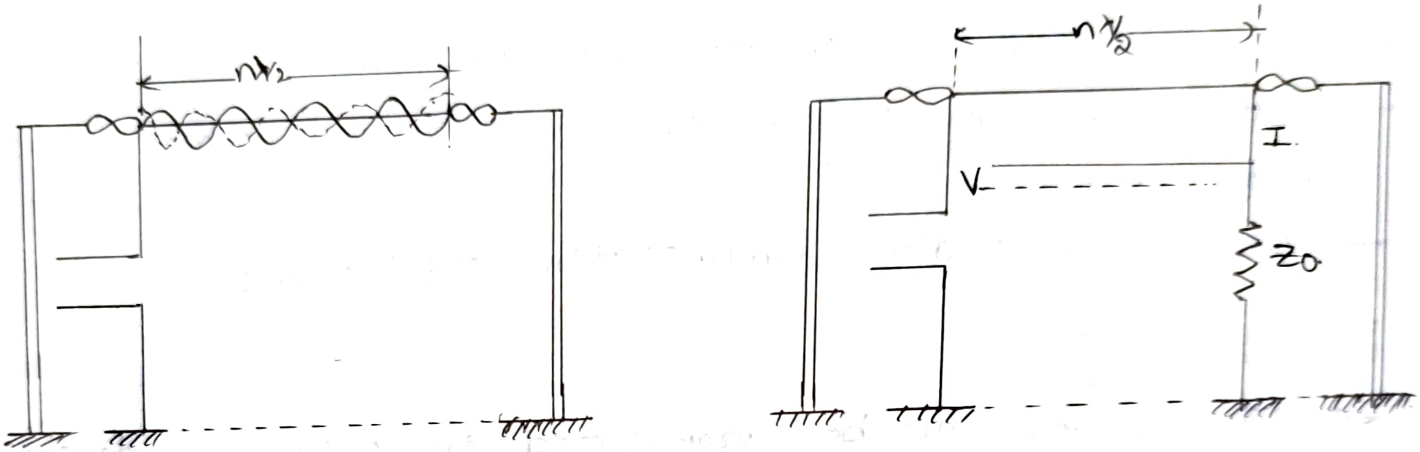
→ The waves can be propagated in only one direction i.e. forward direction.
→ Large space requirement.
→ Not useful at higher frequencies.

Long wire of Harmonic Antenna :-

* A long wire Antenna is linear wire Antenna which is many wavelength long. It can be considered as an array of λ/2 elements connected in a continuous linear way such that each element acts as Radiator and transmission line both.

* The Long wire can be considered as a resonant or non-resonant Antenna. The resonant Antenna means the Antenna is open circuit at load end or

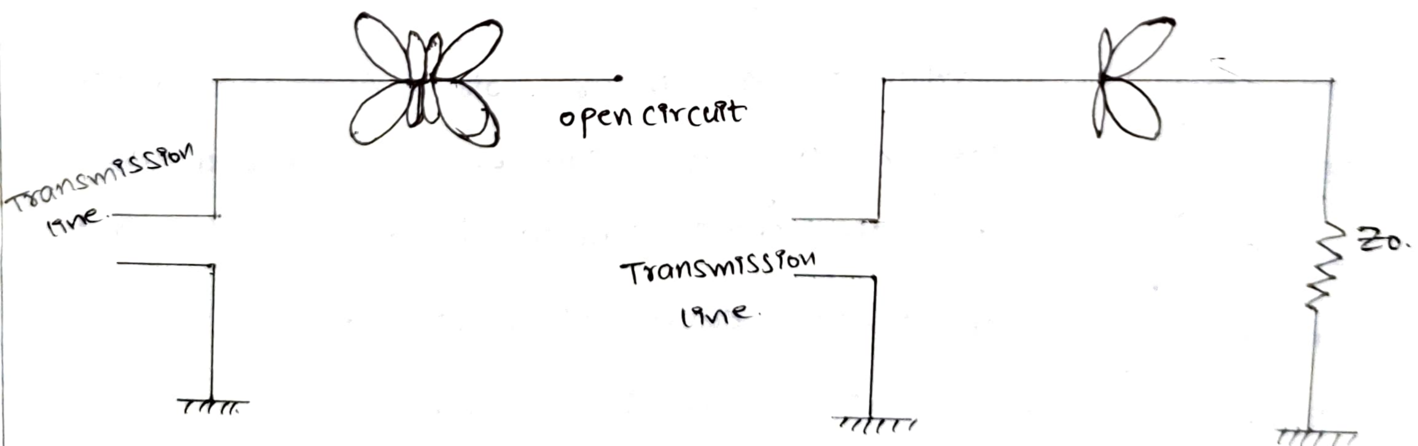
it is unterminated. while the non-resonant Antenna means the antenna which is terminated in the characteristic impedence of the line i.e. Zo.



a) Resonant long wire Antenna

b) Non-Resonant long wire Antenna

Fig: Different forms of long wire Antenna.

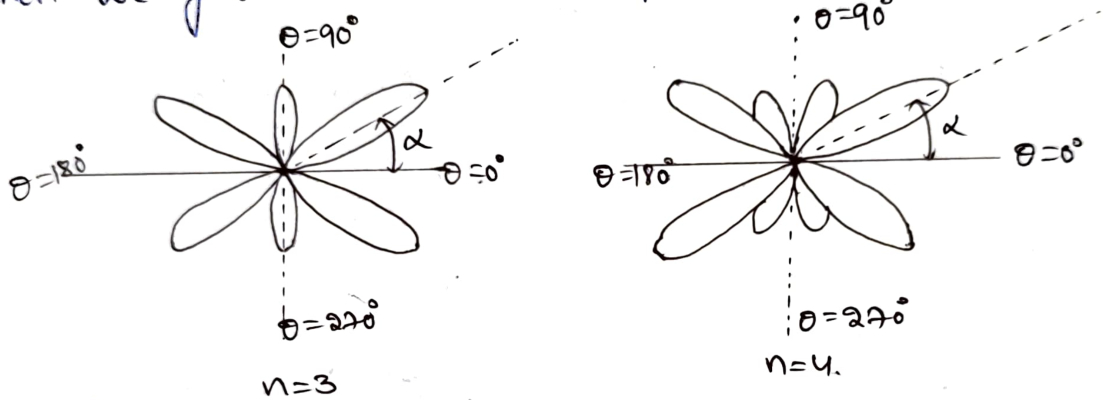


a) Bidirectional in resonant Antenna.

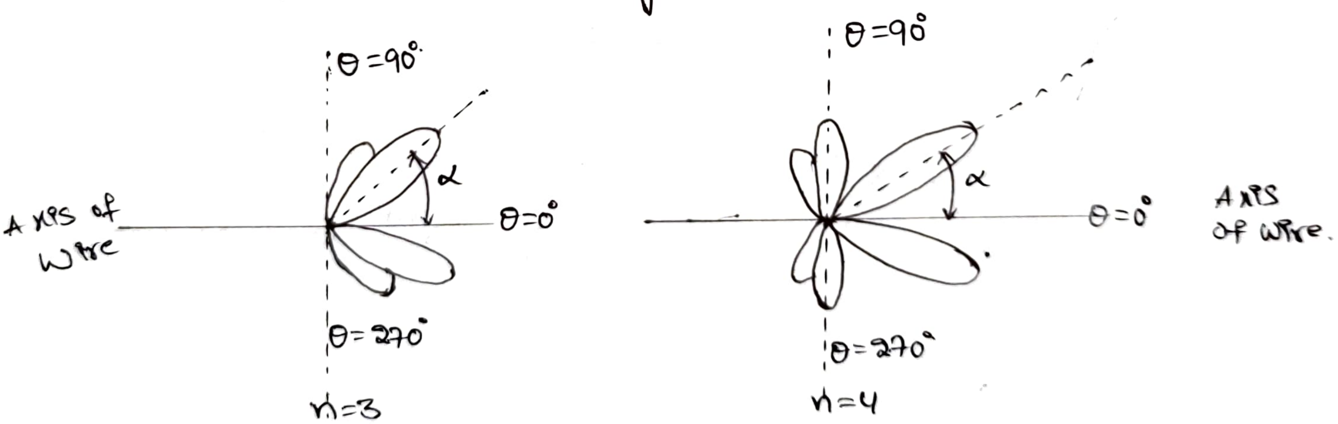
b) unidirectional in non-resonant Antenna.

fig: patterns of Resonant & Non-Resonant long wire Antenna.

In case of a long wire Antenna, the number of integer multiple of λ/2 i.e. n is very important. Depending on if n is even and odd, the directional pattern changes. Also if the wire is terminated we get unidirectional pattern and if wire is unterminated, then we get bidirectional pattern.



a) Resonant long wire Antenna.



b) Non-Resonant long wire Antenna.

For the half wavelength long wire Antenna, the physical length is given by

$$\text{Length} = \frac{492(n-0.05)}{f(MHz)} \text{ feet.}$$

where 'n' = Number of integer multiple half wave length.

* The voltage current Distribution Along the Resonant wire working a fundamental frequency (i.e. λ/2) & first harmonic (i.e. λ/2), second harmonic (i.e. 2λ/2) & third harmonic (i.e. 3λ/2) are as shown below.

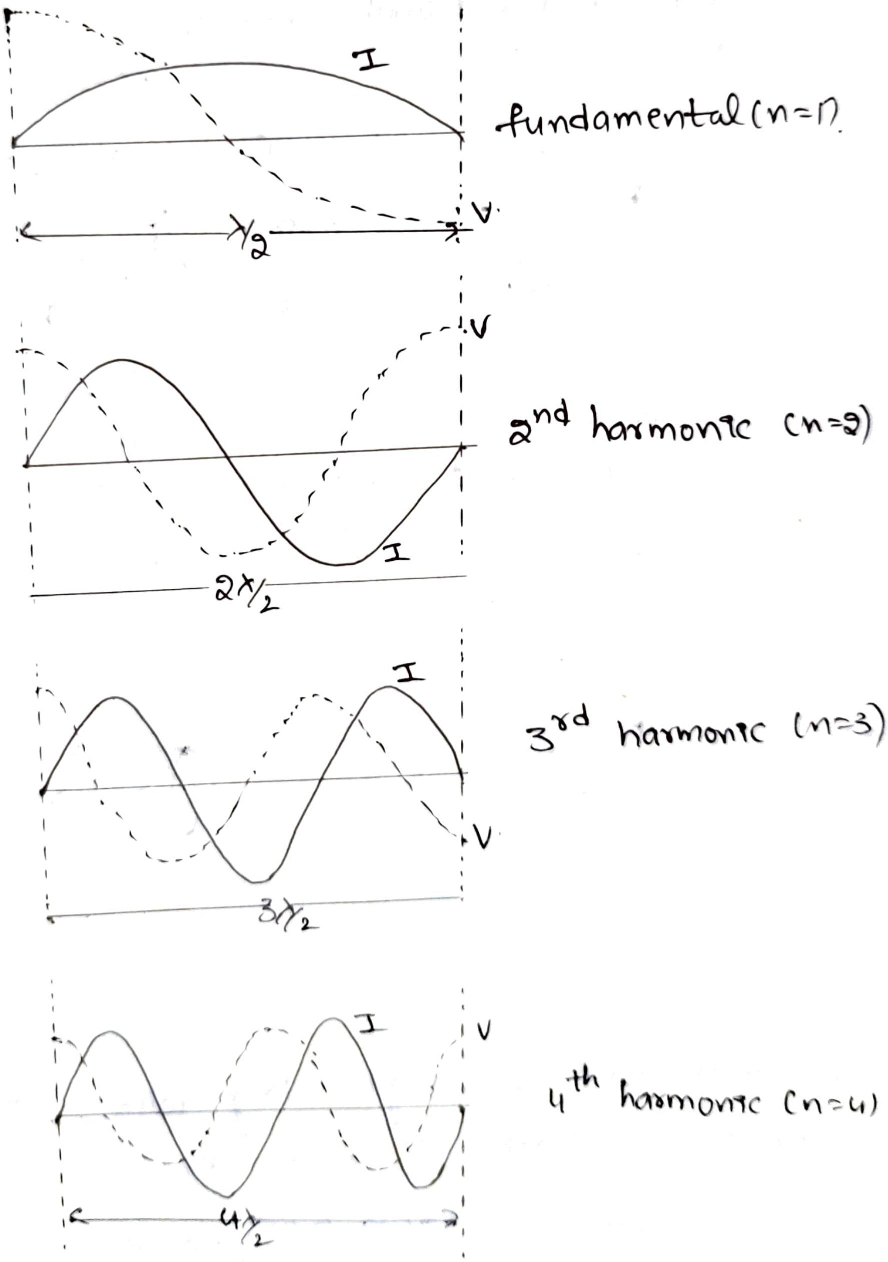


fig: Distribution of V & I at diff. harmonics.

The field strength for the Resonant type long-wire Antenna is given by

$$E = \frac{60 I_{r.m.s.}}{r} \frac{\cos\left[\frac{n\pi}{2}\cos\theta\right]}{\sin\theta} \quad ; n \text{ is odd}$$

$$E = \frac{60 I_{r.m.s}}{r} \frac{\sin\left[\frac{n\pi}{2}\cos\theta\right]}{\sin\theta} \quad ; n \text{ is even.}$$

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

$$E = \frac{60 I_{r.m.s.} \sin\theta}{r(1-\cos\theta)} \sin\left[\frac{\pi L}{\lambda}(1-\cos\theta)\right].$$

For the Resonant long wire Antenna of n wavelength, the Radiation Resistance is given by

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

The angle of maximum radiation is given by

$$\theta_{max} = \cos^{-1}\left[\frac{n-1}{n}\right].$$

→ The ~~Angle of~~ long wire Antennas of resonant and Non-Resonant type are generally used to operate in the frequency range 300KHz to 30MHz.

Travelling Wave Antennas :-

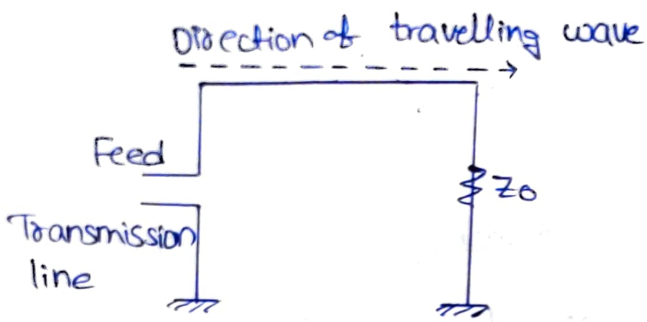
The antenna in which standing waves does not exist along the length of the antenna is called "Travelling Wave Antenna".

→ The standing waves travel due to reflections in resonant antenna. But in travelling wave antenna, the standing waves do not exist. Hence it is also called as non-resonant type antenna or aperiodic antenna.

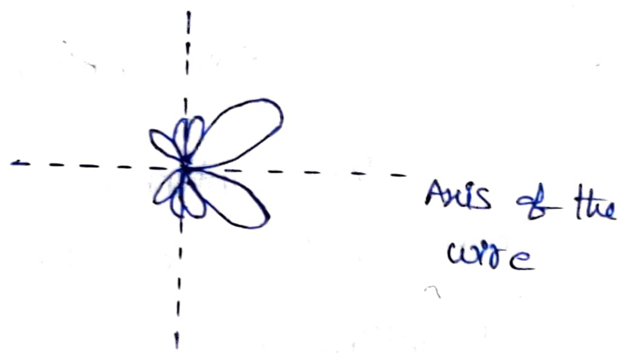
→ The antenna used in radio communication requires larger band width. In this case the travelling wave antenna is the best option.

→ In such antennas one of the ends is terminated with characterstic impedance Z_0, while other end is connected to i/p signal.

→ Due to proper termination at the load, the reflections are avoided. Hence we obtain uni directional radiation pattern as shown in figure.



a) Travelling wave Antenna arrangement.



b) Uni directional radiation pattern

→ In this arrangement the current phase changes progressively with distance like in end-fire arrays. If we assume, velocity of light same in wire as wells as free space, the radiation pattern will be similar to end fire array as shown in (b).

→ The strength of the electric field at a distance 'r' away from the radiator is given by

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

where

r – Distance at a point from radiator

L – Length of the wire or radiator

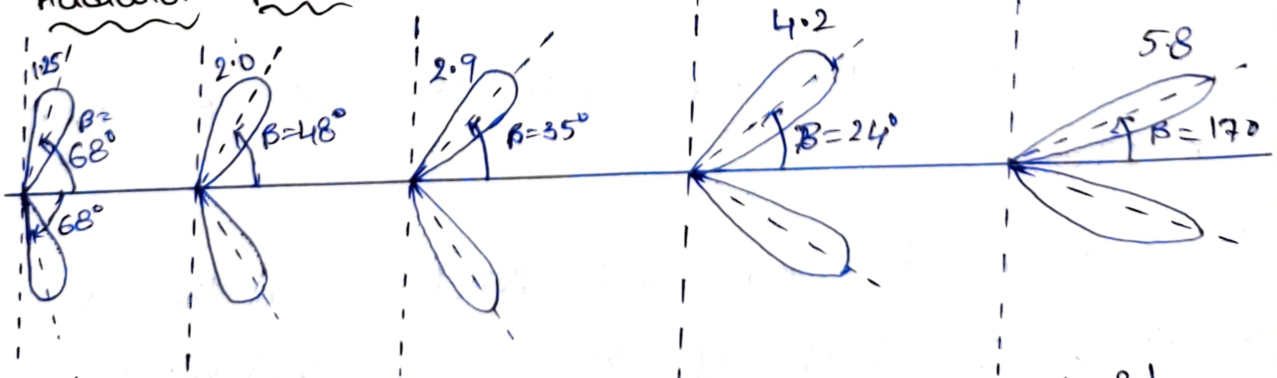
Expt. No.

→ If the length of the wire increases, the angle of major lobe w.r. to axis of wire decreases. Hence the major lobe comes closer to axis of wire.

→ Also the increase in length, the amplitude of major lobe also increases. The below table is for different values of angle & amplitud of major lobe with increase in length.

Length of the wave		Angle of major lobe (β)	Amplitude of MJ
a.	$L=\frac{\lambda}{2}$	68°	1.25
b.	$L=\lambda$	48°	2.0
c.	$L=2\lambda$	35°	2.9
d.	$L=4\lambda$	24°	4.2
e.	$L=8\lambda$	17°	5.8

Radiation Pattern for



a) $L=\frac{\lambda}{2}$ b) $L=\lambda$ c) $L=2\lambda$ d) $L=4\lambda$ e) $L=8\lambda$

V- Antenna :-

→ The V- antenna is made up of two long wire antennas which are arranged in the form of the horizontal V and it is fed at the apex by transmission feed line. The long wire antennas are called legs of the V- antenna.

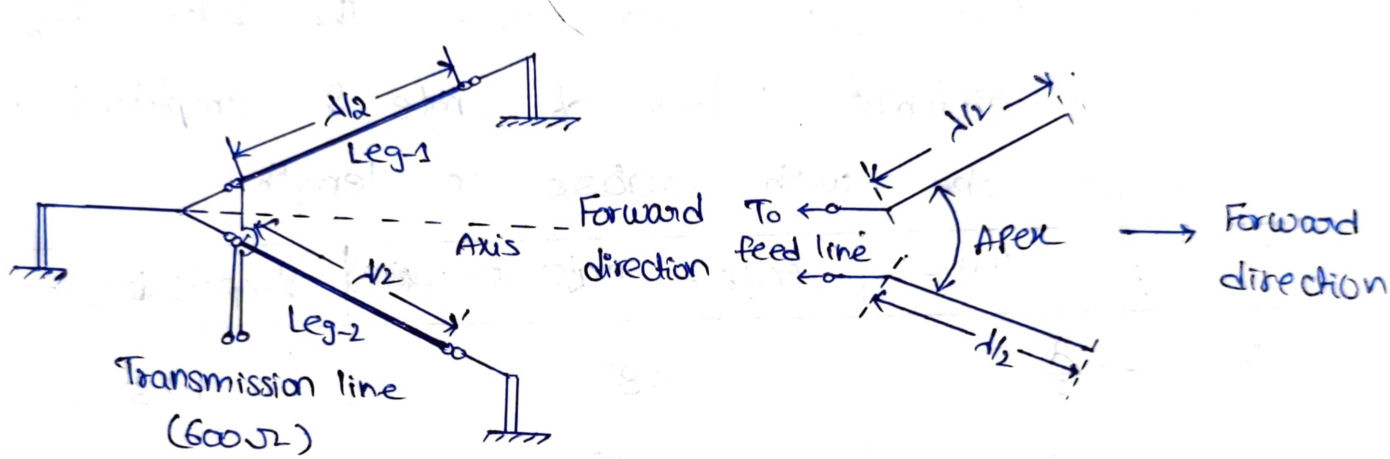


Fig: Arrangement for V- Antenna

→ The angle made by the two legs of the V- antenna is called apex angle which is denoted by α.

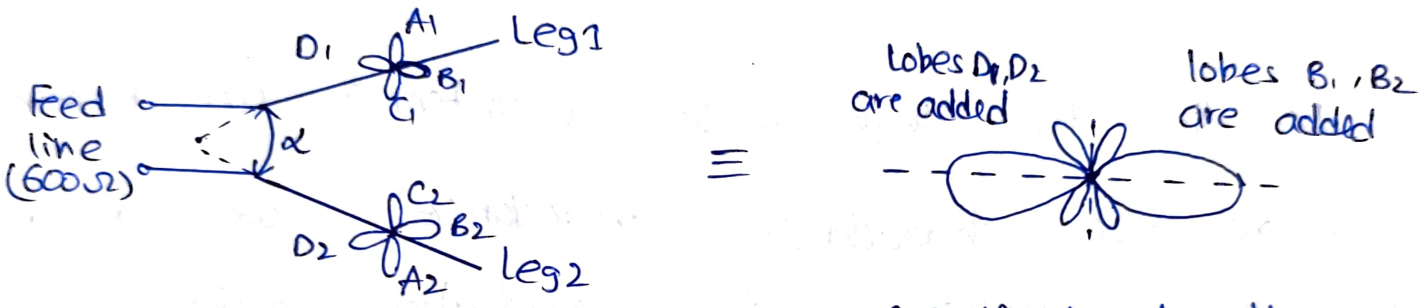
→ The two legs are feed with 180° out of phase w.r.t each other.

→ To increase the gain and directivity in the desired direction, the legths of legs are increased in proporti

→ Because of this, the side lobes gets cancelled out a the major lobes gets added to gether.

→ The radiation pattern obtained is much sharper than that obtained with same length single long wire antenna.

→ The arrangement for "resonant V- antenna" is shown below.



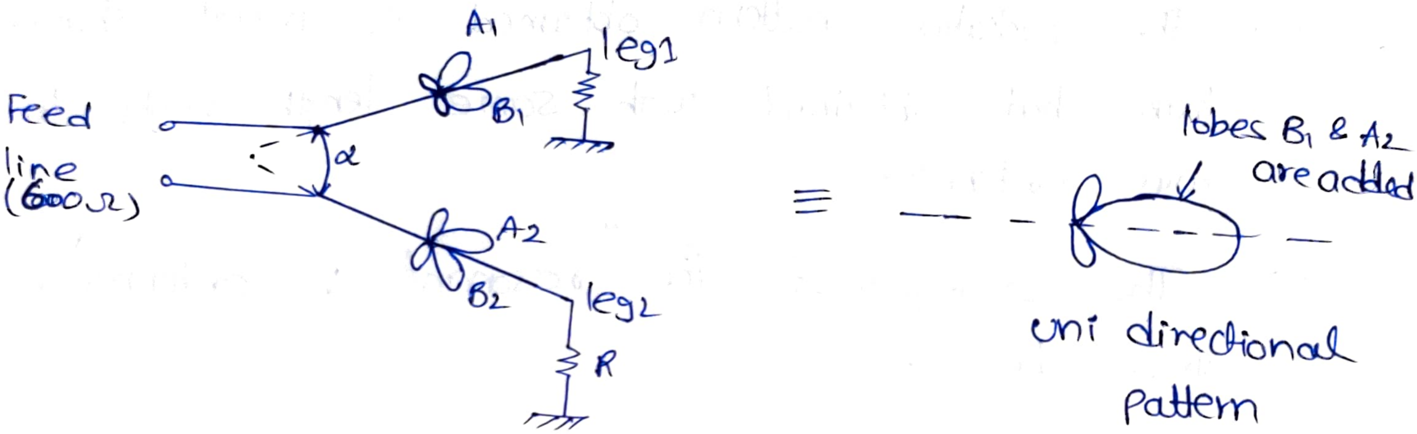
(Bidirectional pattern)

Where both legs are not terminated at one end. Thus in such arrangement we get bidirectional pattern.

→ In this the lobes D_1, D_2 will be added being in same backward direction. Similarly B_1, B_2 will get added is same forward direction. But the lobes A_1 and C_1 will be cancelled due to opposite lobes of A_2 and C_2.

Finally we get bidirectional pattern with increased gain and directivity in both directions.

→ Now the Non-resonant V antenna is shown below



If the two legs of the V-antenna are terminated with resistive characterstic impedance, we get non resonant V-antenna. Its radiation pattern is unidirectional.

In this the lobes B_1 & A_2 are added being in the same direction. while lobes B_2 & A_1 are get cancelled due to opposite directions. Thus the resultant pattern is unidirectional with increased gain and directivity.

→ Typically the gain of V-antenna is two times the gain of single long wire antenna. for example the each leg of length 8λ the gain is 12 dB it is very large.

→ The variation in length of leg from 2λ to 8λ the apex angle varies from 72° to 36°.

→ The directivity of V-antenna can be increased further using an array of V-antennas in stacked form.

→ Due to this bidirectional pattern with increased directivity is obtained. For uni direction, one more V-antenna is stacked at a distance odd multiple of $\frac{d}{4}$ in back & existing the next with certain phase difference of 90°.

→ The main dis-advantage of V-antenna is that the minor (or) side lobes are also high strength.

Inverted V- Antenna

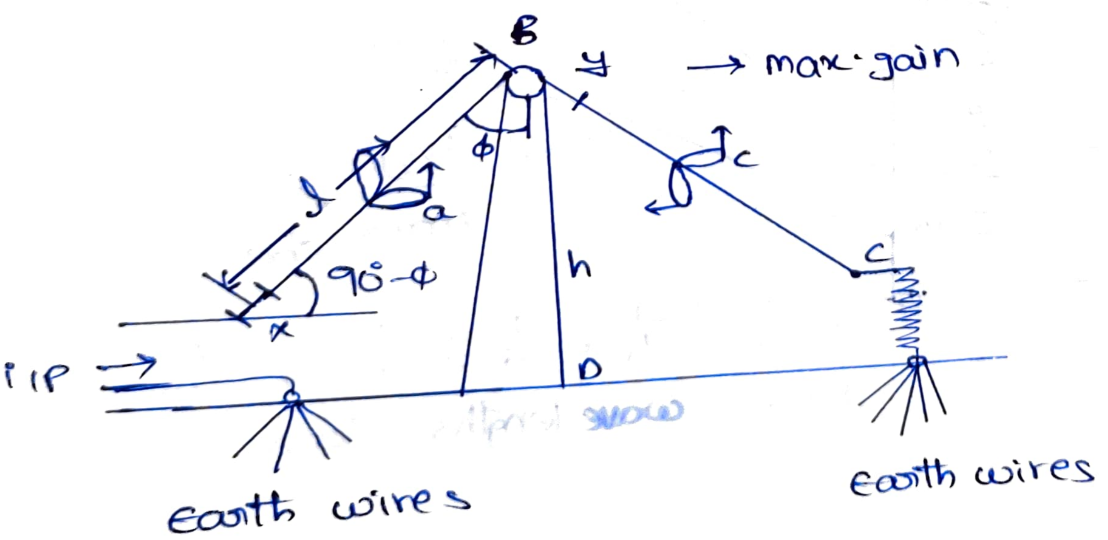


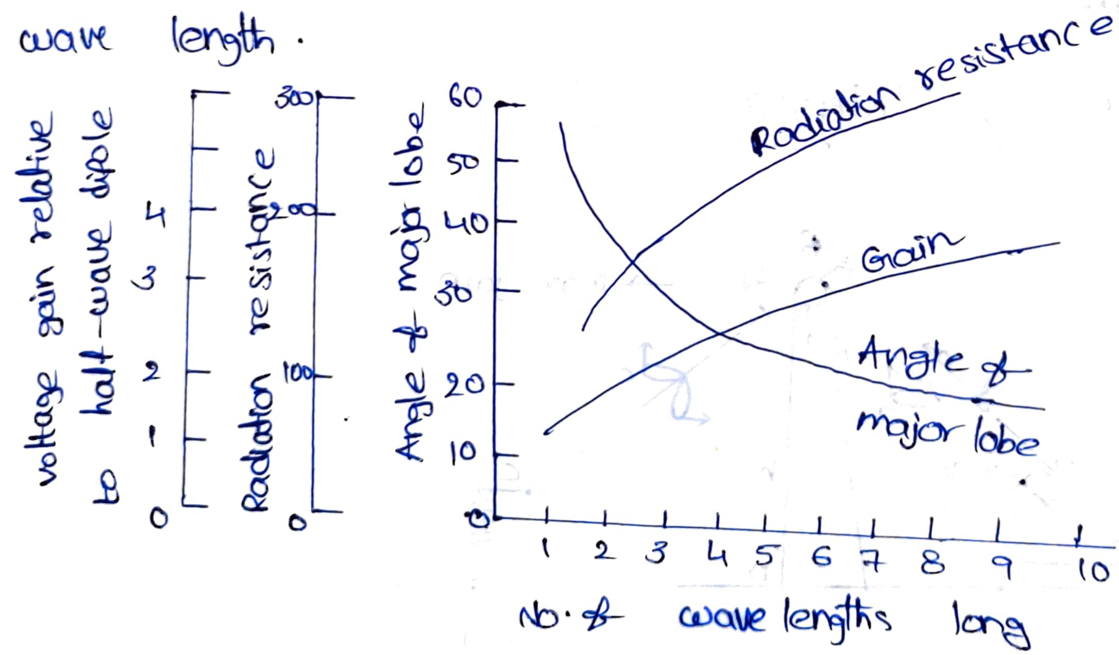
Fig: The inverted-V receiving aerial

→ The inverted v-antenna is very simple to construct as it requires only one non conducting mast. The direction of max gain is also indicated.

→ When used as transmitting antenna, the energy is fed by the unbalanced feeder to its input end A.

→ At the end c, a resistor connects the aerial to a no. of radial earth wires. The value of resistor is so choosen that it gives substantial travelling waves in the aerial wire ABC. This value is normally 400Ω.

→ The radiation resistance, angle of major lobe and field strength gain of travelling wave radiators relative to half-wave dipole are plotted against length of radiators in wave length.



Rhombic Antenna :-

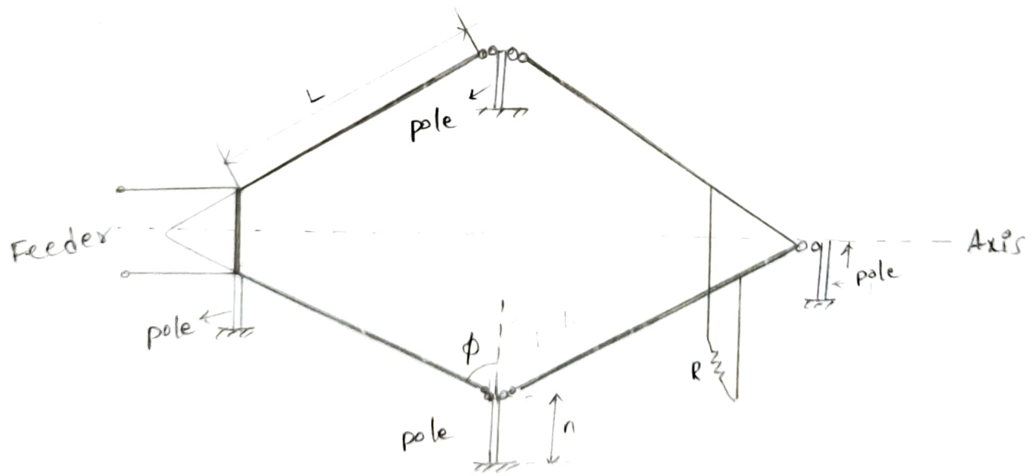
1. The Rhomic Antenna is based on the principle of the "travelling Wave Radiator" or "travelling Wave Antenna"

2. In this Antenna four long wires are connected together they are look like Rhombous or diamond shape. it is Considered two inverted V antennas Connected in Series end to end and form the angle is "obtuse angles".

3. It is also known as "diamond Antenna".

4. The size and physical form of rhombic Antenna is decided by tilt angle which is always acute and length of side of a Rhombous.

5. Each side of Rhombous formed by the wires is called "leg of Rhomic Antenna".

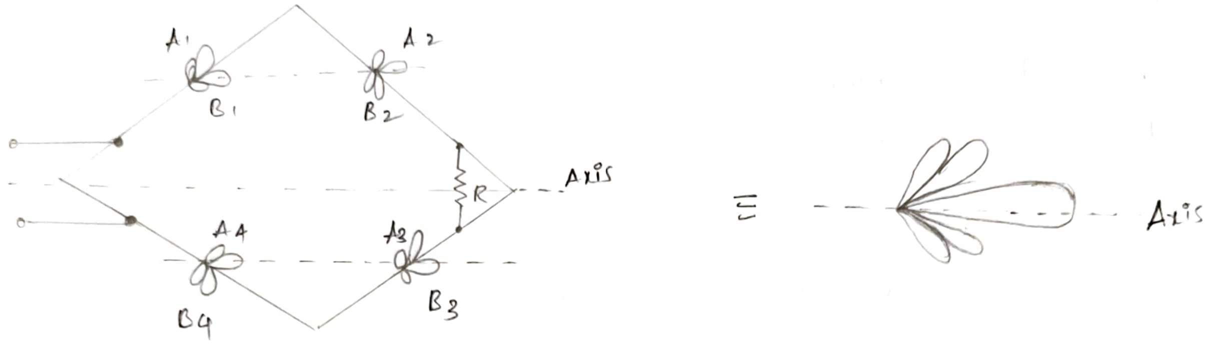


⇒ One end of Rhomic Antenna is fed through the balanced transmission line as feeder. other end terminated with non-inductive Resistor.

⇒ hence there is no standing waves exist in any of four legs.

⇒ The four legs are Terminated with (Z_0) characteristic imped-
-ence, it gives non Resonant condition. here legs provide Unidirectional distribution.

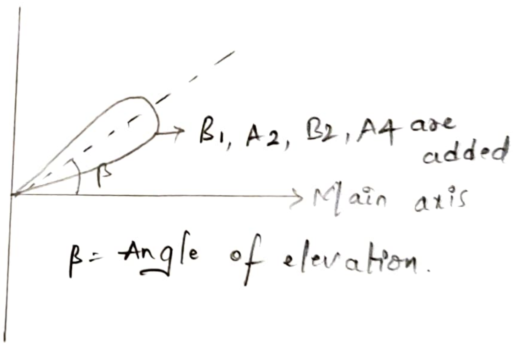
⇒ Thus it provide max. Radiation along axis of Antenna.



(a) Radiation pattern in each leg

(b) Unidirection Resultant radiation pattern.

→ Here due to effect of ground polaraization of the wave in horizontal direction is elevated in the upward direction with some angle. the angle of elevation denoted by "β".



β = Angle of elevation.

⇒ The angle of tilt denoted by ϕ.

⇒ angle of major lobe for an individual leg varies from 24° to 17° for 4λ to 8λ. so it operated over wide freeq. band.

⇒ Z_0 is 600Ω to 800Ω match with Z_0 of 600Ω feeder transmission line.
↑
terminating "R"

Design of Rhomic Antenna :-

→ Tilt angle (ϕ)
→ length of leg (L)
→ Height above the ground (h)

Approaches :-

i) Allignment
ii) Max. Electric field Intensity Design.

↳ Allignment is made by increasing length of leg. (L) if height is less than desired condition.

→ Changing tilt angle ϕ if h is desired value L reduced.

→ Changing tilt angle ϕ if both L, H reduced.

$$E = \frac{2\cos\phi \left[\sin\left(\frac{2\pi H}{\lambda}\sin\beta\right)\right]\left\{\sin\left(\frac{\pi L}{\lambda}\right)\left[1-\cos\beta\sin\phi\right]\right\}^2}{(1-\cos\beta\sin\phi)}$$

ϕ = tilt angle = $(90^\circ - \beta)$

β = Angle of elevation, h = Height above ground

L = length of leg in λ

λ = Wavelength.

$$E = \frac{2\cos\phi \left[\sin 2\pi h'\sin\beta\right]\left[\sin(\pi L')(1-\cos\beta\sin\phi)\right]^2}{(1-\cos\beta\sin\phi)}$$

$[h' = h/\lambda]$

$[L' = L/\lambda]$

$$E = K\sin(2\pi h'\sin\beta)$$

$$K = \frac{2\cos\phi\left[\sin(\pi L')(1-\cos\beta\sin\phi)\right]^2}{1-\cos\beta\sin\phi}.$$

$$E = k'\left[\sin(\pi L')(1-\cos\beta\sin\phi)\right]^2$$

$$k' = \frac{2\cos\phi\left[\sin(2\pi h'\sin\beta)\right]}{1-\cos\beta\sin\phi}.$$

Maximum Relative field Intensity Design :-

$$\Rightarrow \left.\frac{\partial E}{\partial h'}\right|_{L' = \text{constant}} = 0$$

$$\frac{\partial}{\partial h'}\{K\sin(2\pi h'\sin\beta)\} = 0$$

$$K\cos(2\pi h'\sin\beta)\cdot 2\pi = 0$$

$$\cos(2\pi h'\sin\beta) = 0$$

$$2\pi h'\sin\beta = \cos^{-1}(0) = n\frac{\pi}{2} \qquad n = 1, 2, 3\ldots$$

$n = 1$

$$h' = \frac{1}{4\sin\beta}$$

$$h' = \frac{h}{\lambda} \qquad h = \frac{\lambda}{4\sin\beta}\ \text{meter}$$

$$\Rightarrow \left.\frac{\partial E}{\partial L'}\right|_{h' = \text{const.}} = 0$$

$$= \frac{\partial}{\partial L'}\left[k'\sin(\pi L')(1-\cos\beta\sin\phi)\right]^2 = 0$$

$$= k'\ 2\sin\left[(\pi L')(1-\cos\beta\sin\phi)\right]\cos\left[(\pi L')(1-\cos\beta\sin\phi)\right]\} = 0$$

$$k'\sin 2\left[\pi L'(1-\cos\beta\sin\phi)\right] = 0 \qquad (2\sin\theta\cos\theta = \sin 2\theta)$$

Condition for max. E :-

$$\left[\pi L'(1-\cos\beta\sin\phi)\right] = \sin^{-1}(0) = n\frac{\pi}{2} \qquad (n = 1, 2, 3\ldots)$$

$n = 1$

$$L' = \frac{1}{2(1-\cos\beta\sin\phi)}\ m.$$

$$L' = \frac{L}{\lambda}$$

$$L = \frac{\lambda}{2(1-\cos\beta\sin\phi)} \text{ m}$$

$$\phi = 90 - \beta$$

$$\sin\phi = \sin(90-\beta) = \cos\beta.$$

$$L = \frac{\lambda}{2(1-\cos\beta\cos\beta)} = \frac{\lambda}{2\sin^2\beta} \qquad (1-\cos^2\theta = \sin^2\theta)$$

$$\boxed{L = \frac{\lambda}{2\sin^2\beta}}$$

Allignment Design

$$h = \frac{\lambda}{4\sin\beta} \text{ m}$$

$$L = \frac{0.37\lambda}{\sin^2\beta}$$

$$\phi = 90 - \beta.$$

Advantages of Rhomic Antenna :-

⇒ The i/p impedence and Radiation pattern do not Vary rapidly Over a considerably large range as compared to any other radiating s/t.

⇒ Received power is max. along main axis.

→ high efficiency so Used for Radio communication.

→ Use for space for installation of Antenna is not critical.

⇒ Mostly used in f-layer Propagation due to Verticle angle of Radiation

⇒ Used for short wave Application with very low height.

⇒ It is non-resonant use for wide band application.

⇒ i/p impedence is twice as that of single side Radiator.

⇒ This Antenna used for long distance short wave reception of horizontally polaraized waves.

The structure is called "Multiple Unit sterrable Antenna" (MUSA).

⇒ Construction simple. easy to erect at a lower cost.

Disadvantages :-

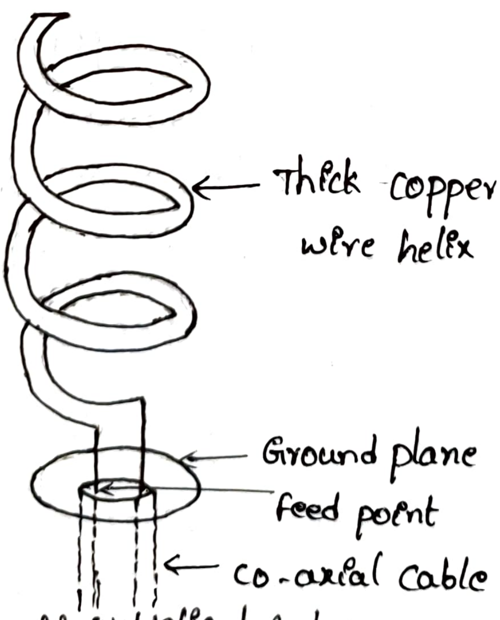
→ It requires very large space for installation.

→ It provides no. of side lobes along with highly directive major lobe.

→ It dissipates half of the output power in the terminating impedence, hence transmission efficiency poor.

Helical Antenna (or) Broad band Antenna:

Helical antenna is basic, simple broadband VHF and UHF antenna which provides circular polarization. It consists of a thick copper wire wound in the form of a screw thread forming a helix as shown in fig(a). In general, the helix is used with ground planes. There are different forms of the ground planes such as flat ground plane, cylindrical cavity (or) frustrum cavity. In general the helical antenna is fed with co-axial transmission line in which the central conductor is connected to the helix at the feed point, while the ~~order~~ outer conductor is attached to the ground plane.



fig(a): Helical Antenna

→ The helical Antenna can operate in many modes but the two important modes are normal mode and axial mode of operation.

→ In the "normal mode", the field radiated by the antenna is maximum in a plane normal to the axis of helix and minimum along the axis. This mode is also termed as "broadside mode". In the "axial mode", the field radiated by the antenna is maximum in the plane along the axis.

→ In axial mode there is only one major lobe with maximum intensity along the axis of the helix. The axial mode is the most practical mode and it is also known as "Endfire mode".

→ The dimensions of the helix in the axial mode are not critical. Hence the end fire (or) axial helical antenna can be used to achieve circular polarization over a wider bandwidth.

→ For the space communication applications, the helical antennas are most suitable as they have wide bandwidth, higher directivity and circular polarization.

→ To transmit (or) receive VHF signals through ionosphere generally an array of helical antennas is used.

→ It is widely used for space and satellite communications.

Consider a helical antenna as shown in fig(b). It basically consists of a helix of thick copper wire (or) tubing wound on a shape of screw thread and used with a flat metal plate called "ground plane" (or) "ground plate".

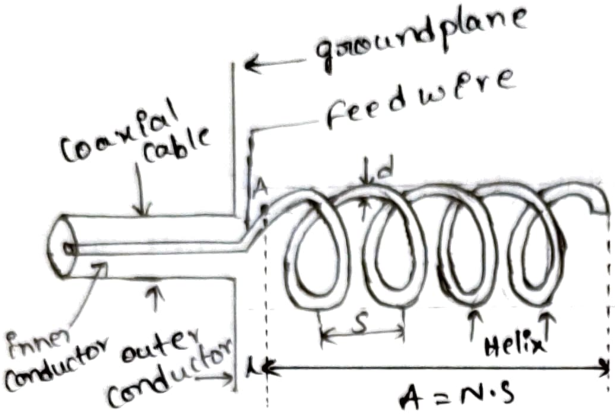


fig (b): Structural of helical Antenna

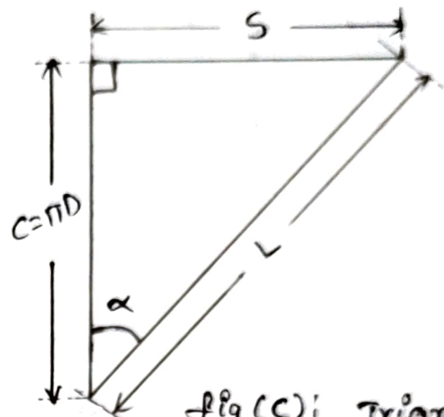


fig (c): Triangle terminology for one turn of helix unrolled on a plane surface

→ The helix is fed by a coaxial cable. one end of the helix is connected to the centre (or) inner conductor of the cable and outer conductor is connected to the ground plane.

→ The mode of the radiation of the antenna depends on the diameter of the helix i.e. D, the spacing between turn S which is measure between two centres of the turns.

→ The circumference of the helix is denoted by 'c' and it is equal to πD. Then the pitch angle 'α' is given by

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

Then the axial length $A = N \times S$

where, N = no. of turns

L = length of one complete turn

→ The spacing of the helix from the ground plane is denoted by l.

→ For N turns of the helix, the total length of the antenna is equal to N·S while the circumference equals to πD.

→ If we unroll one turn of helix on a plane surface, then the circumference, spacing between turns (S), turn length (L) and pitch angle (α) can be related to each other through the triangle terminology as shown in fig (c). Then we can write,

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

The pitch angle is defined as the angle between a line tangential to the helix wire and the plane normal to the axis of helix. The pitch angle then can be expressed as

$$\tan \alpha = \frac{S}{C} = \frac{S}{\pi D}$$

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

Thus the properties of the helical antennas are expressed in terms of these geometric parameters. By changing these parameters in relation to the wavelength, different radiation characteristics can be obtained.

In general, a helical antenna can radiate in many modes. But the most important modes of radiation are as follows:

(i) Normal (or) perpendicular mode of radiation.

(ii) Axial (or) End fire (or) Beam mode of radiation.

(a) Normal Mode;

In this mode of helical antenna, the radiation is maximum in broadway direction i.e. normal (or) perpendicular to the axis of the helix, hence the mode is called "normal (or) perpendicular mode of radiation". The radiation in the direction normal to the helix axis is circularly polarized wave.

→ This mode of radiation can be obtained if the helix dimensions are made very small as compared with radiation is $N \cdot S << \lambda$.

→ But with this mode of radiation, the bandwidth of antenna becomes narrow and the radiation efficiency also becomes very less.

→ The radiation pattern of a helical antenna in a normal mode is the combination of the equivalent radiation from a short dipole located one the same helix and from a small loop which is coaxial with the same helix axis.

→ This is the condition obtained for different pitch angle. when pitch angle $\alpha = 0$, helix corresponds to a loop and when $\alpha = 90°$ then it corresponds to a linear dipole shown in fig (d).

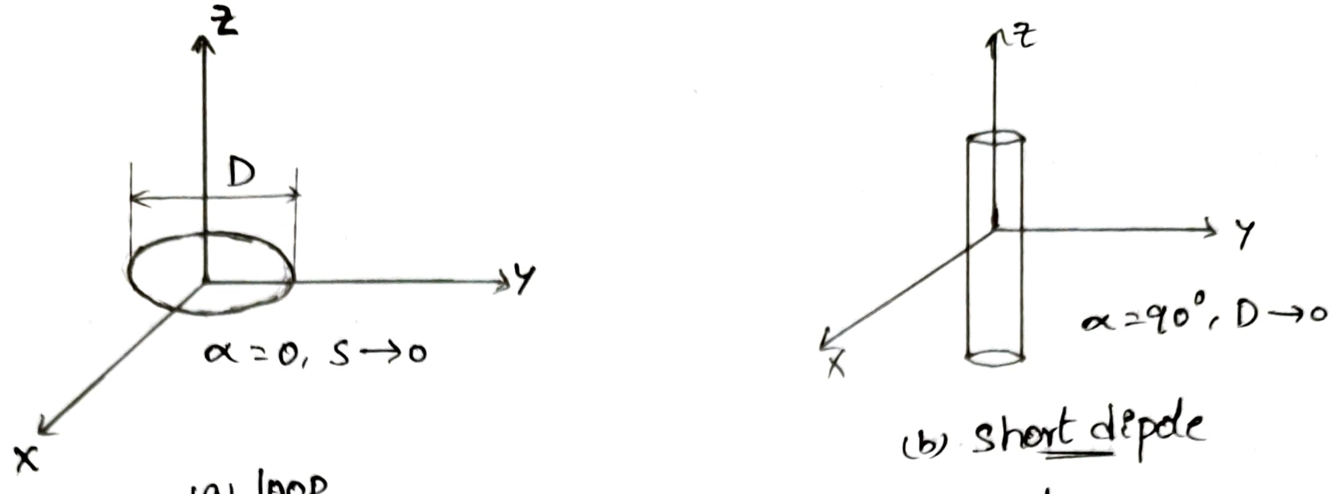


fig (d): limiting conditions of helix

→ consider a helix in spherical co-ordinate system as shown in fig (e). So considering that the helical antenna is made up of number of small loops and short dipoles arranged in series such that loop diameter equal to helix diameter D and length of the short dipole equal to the spacing between two helix S.

→ the far field of a small loop is given by,

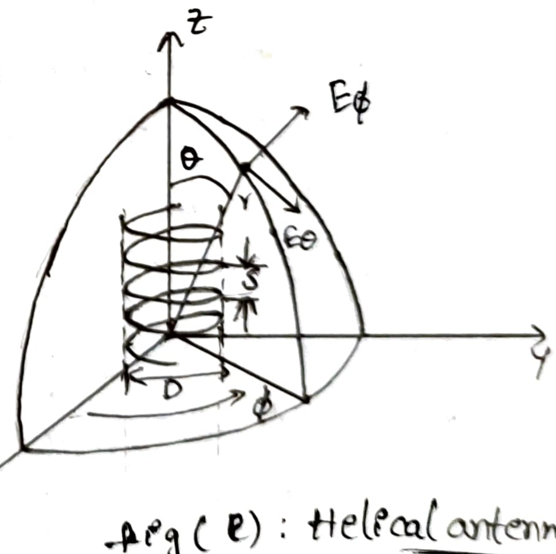


fig (e): Helical antenna with spherical co-ordinates

$$E_\phi = \frac{120\pi^2 [I] \sin\theta}{r} \cdot \frac{A}{\lambda^2} \longrightarrow (1)$$

where, $[I]$ = retarted current in 'A'

r = distance at a point in 'm'.

A = area of loop = $\pi\left(\frac{D}{2}\right)^2$

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

λ = wavelength in 'm'.

similarly the far field of the short dipole is given by,

$$E_\phi = j\,\frac{60\pi[I]\sin\theta}{r}\cdot\frac{S}{\lambda} \quad \longrightarrow (2)$$

where, $S = dL$ = length of the dipole.

From above eq^{n}s, it is clear that two fields are in phase quardrature (phase of 90°). To get axial ratio (AR) of elliptical polarization,

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

$$AR = \frac{S\lambda}{2\pi A} \qquad \because A = \frac{\pi D^2}{4}$$

so,

$$AR = \frac{S\lambda}{2\pi\left(\frac{\pi D^2}{4}\right)} = \frac{4S\lambda}{2\pi^2 D^2}$$

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

Now, depending up on values of AR, we get three conditions.

Condition-1: when AR = 0, the elliptical polarization becomes linear horizontal polarization.

Condition-2: when AR = ∞, the elliptical polarization becomes linear vertical polarization.

Condition-3: when AR = 1, the elliptical polarization becomes circular polarization.

Thus, the condition for the circular polarization is given by

$$AR = 1 = \left|\frac{E_\theta}{E_\phi}\right| = \frac{2S\lambda}{\pi^2 D^2} \qquad \text{i.e. } |E_\theta| = |E_\phi|$$

Hence, we can write,

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

i.e. $$\boxed{S = \frac{\pi^2 D^2}{2\lambda} = \frac{C^2}{2\lambda}} \longrightarrow (3)$$

where, C = circumference
C = πD

Hence the pitch angle for the circular polarization is

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

$$\boxed{\alpha = \tan^{-1}\left(\frac{\pi D}{2\pi}\right) = \tan^{-1}\left(\frac{C}{2\lambda}\right)} \longrightarrow (4)$$

Thus the resultant radiation pattern for the helical antenna in the normal mode can be obtained by superposing the field patterns of the loop and the dipole for circular polarization as shown in fig (f).

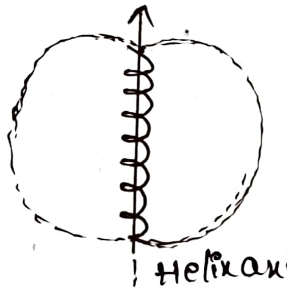


fig (f)

(b) Axial Mode:

The helical antenna radiating field maximum in the end fire direction i.e. along the axis of the helix is called as "axial mode (or) endfire mode helical antenna". With the axial mode radiation, the polarization of the wave is either circular (or) nearly circular. The main difference in the radiation pattern of the normal mode and axial mode is that in the axial mode, radiation is maximum along the helix axis while in normal mode, radiation is maximum in the direction normal to the helix axis.

The two parameters of the helical antenna which decide the mode of radiation are spacing between two turns (s) and the diameter of helix (D). when these two parameters are of the order of one wavelength to achieve axial mode of radiation. Note that in the normal mode, the dimension N.S << λ. The axial mode radiation of the helical antenna is more important because most of the practical antennas produce similar radiation patterns with the features like broad and directional beam in axial direction and minor lobes at oblique angles. This mode is possible in the helical antenna if the circumference is selected of the order of one wavelength and spacing is selected approximately equal to π/4 as shown in fig (9): (i) or two wire transmission line as shown in fig (9): (ii)

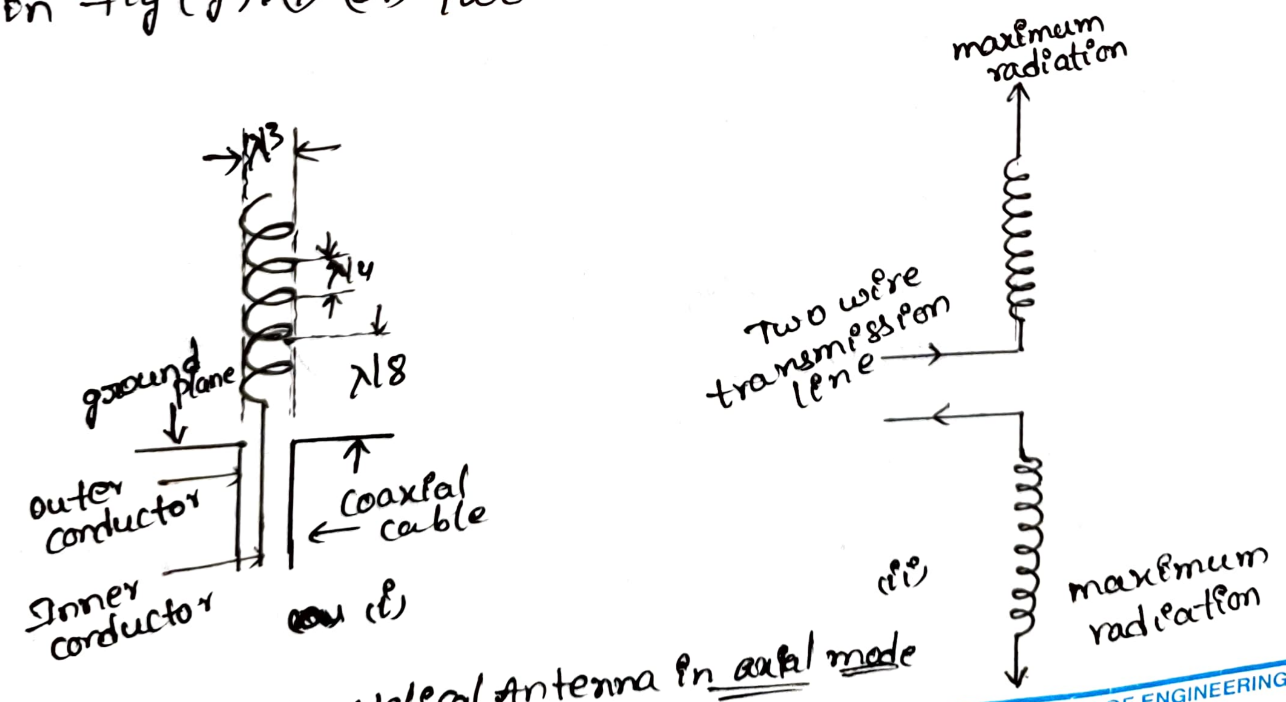


fig (9): Helical Antenna in axial mode

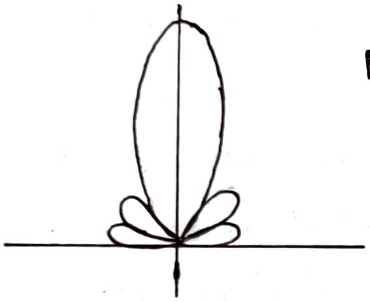
The terminal impedence is given by, $R = \frac{140C}{\lambda}$

The Beamwidth between half power points is given (HPBW) = $\frac{52}{C}\sqrt{\frac{\lambda^3}{N \cdot S}}$ degrees

similarly the beamwidth b/w first nulls is given by (BWFN) = $\frac{115}{C}\sqrt{\frac{\lambda^3}{N \cdot S}}$ degrees

The maximum directive gain in the axial mode $(G_D) = \frac{15NSC^2}{\lambda^3}$

The axial ratio (AR) is given by, $(AR) = 1 + \frac{1}{2N}$



fig(h): Radiation pattern of helical antenna in axial mode

The helix can have either right handed pitch ~~pitch~~ or left handed pitch. Then accordingly the circular polarization may be right handed or left handed. The radiation pattern for axial mode is shown in fig (h).

Applications:

⇒ Axial mode helical antennas are used to achieve circularly polarized waves over extremely wide bandwidth.

⇒ The axial mode antennas are extensively used in the space communication systems. such as transmitting telemetry data from moon to the earth.

⇒ A single helical antenna or an array of helical antennas are useful in transmitting or receiving VHF signals through the ionosphere.

⇒ The helical antennas are most extensively used in the satellite communication and space probe communication.

Log periodic Antenna :-

In general, any antenna when ~~did~~ defined interms of angles only, then it comes under the category of the frequency independent antenna. In any frequency independent ~~of~~ antenna, the impedance and the radiation pattern both are independent frequency. so the basic concept to obtain frequency independent characteristics is that the antnna structure should be adjusted i.e, either expanded or contracted, in proportion to wavelength. It is not possible to adjust antenna mechanically, then the size of the radiating region in the pattern should be in proportion with the wavelength.

The log periodic antenna is a broadband antenna in which the geometry of the antenna structure is adjusted such all the electrical properties of the antenna. are repeated periodically with the logarithm of the frequency. Thus the basic geometric structure is repeated with the structure size changed. For every repettion, the structure sizes changes by a constant scale factor, with which the structure can either expand or contract. the principle of the log periodic antenna can be understood with the help of a array of the log periodic antenna known as "Log periodic Dipole Array". (LPDA).

A typical LPDA consists number of dipoles of differen lengths and spacings. A typical arrangement is as shown in the figure such an array is fed using a balanced transmission line and it is further transposed between each adjust pari pairs of terminals of dipoles. The feed line is connected at narrow end or apex of the array. The length of the dipoles increases from feed point towards other end such that the include angle 'α' remains constant. The dipole length and the spacing between two adjust adjacent dipoles are related through parameter called design ration or scale factor which is denoted by τ. the relationship between S_n and S_{n+1} and L_n and L_{n+1} is given by.

$$\frac{S_n}{S_{n+1}} = \frac{L_n}{L_{n+1}} = \tau \quad \text{——— (1)}$$

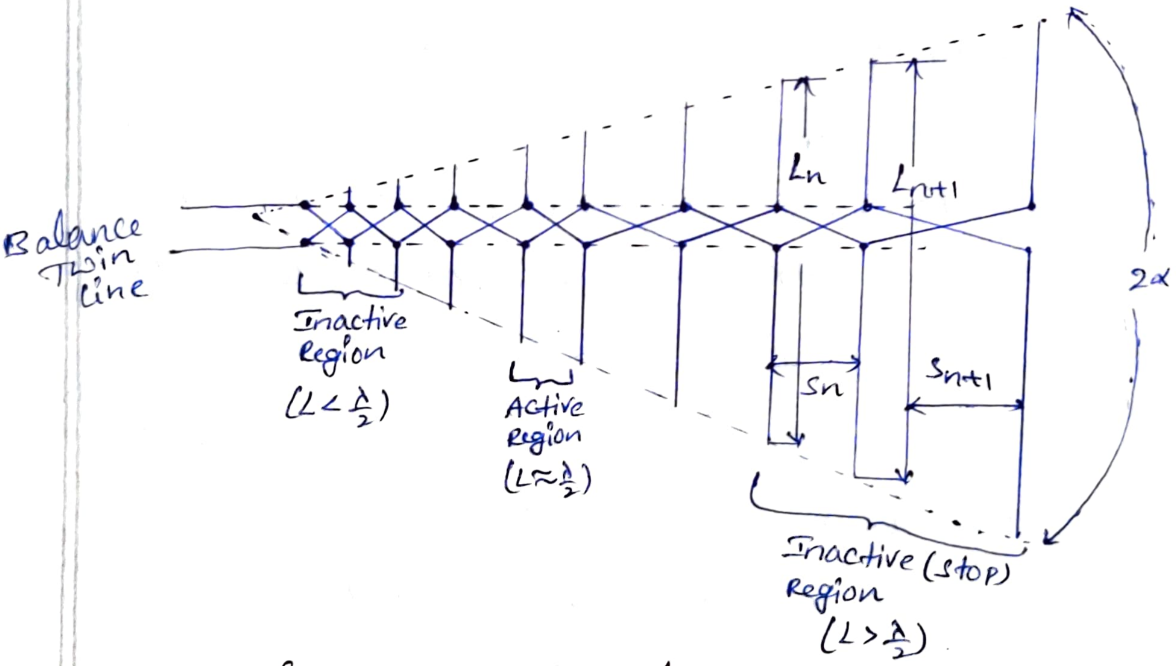


Fig. Log periodic dipole array (LPDA).

This τ is also called periodicity factor which is always less than 1.

The same expression can be written in terms of constant k as

$$\frac{S_{n+1}}{S_n} = \frac{L_{n+1}}{L_n} = k = \frac{1}{\tau}$$

The ends of the dipoles lie along straight lines on both the sides. These two straight line meet at feed point or apex giving angle 2α which is angle include by two stright line.

(i) Inactive transmission line region ($L<\frac{\lambda}{2}$):-

It is the region in which the length of dipoles is less than $\frac{\lambda}{2}$. The elements in this region provide capacitive impedance. The element spacing in this region is comparatively smaller. The currents in the region are very small hence it is considered as inactive region. These currents load the voltage supplied by the transmission line.

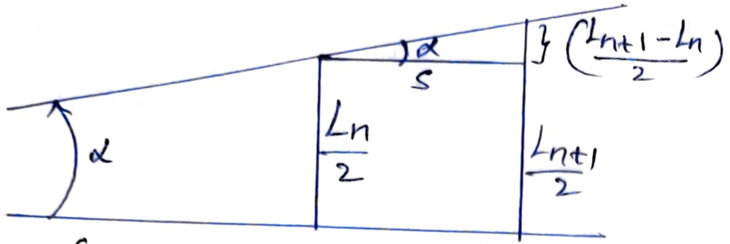
(ii) Active region:-

In this region, the lengths of dipoles are approximately equal to $\frac{\lambda}{2}$ i.e equal to resonant length. This is the central region of the array from where maximum radiation takes place. the dipoles offer resistive impedance. the currents are of large value and in phase with the base voltage.

(iii) Inactive stop region:-

In this region, the lengths of the dipoles are greaterthan $\frac{\lambda}{2}$ i.e greater than resonant lengths. The dipoles offers inductive impedance. The currents are smaller in this region and also lags the base voltage. This is also called reflective region as any small incident wave gets reflected due to the large inductive impedance.

To find the relationship between the apex angle α, spacing s and length L consider a part of a log periodic array as show in the fig.



Geometry of log-periodic array

From above fig.

$$\tan\alpha = \frac{\left[\frac{L_{n+1}-L_n}{2}\right]}{S}$$

$$\tan\alpha = \frac{L_{n+1}-L_n}{2S}$$

$$\tan\alpha = \frac{\left[1-\frac{L_n}{L_{n+1}}\right]\cdot L_{n+1}}{2S}$$

But $\frac{L_{n+1}}{L_n} = k$, i.e $\frac{L_n}{L_{n+1}} = \frac{1}{k}$, substituting in above equation we get,

$$\tan\alpha = \frac{\left(1-\frac{1}{k}\right)L_{n+1}}{2S} = \frac{\left(1-\frac{1}{k}\right)L_{n+1}}{2S}$$

For active region $L_{n+1} = \frac{\lambda}{2}$

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

$$= \frac{1-\frac{1}{k}}{4\left(\frac{S}{\lambda}\right)}$$

$$\boxed{\tan\alpha = \frac{\left(1-\frac{1}{k}\right)}{4S_k}}$$

Where α = apex angle

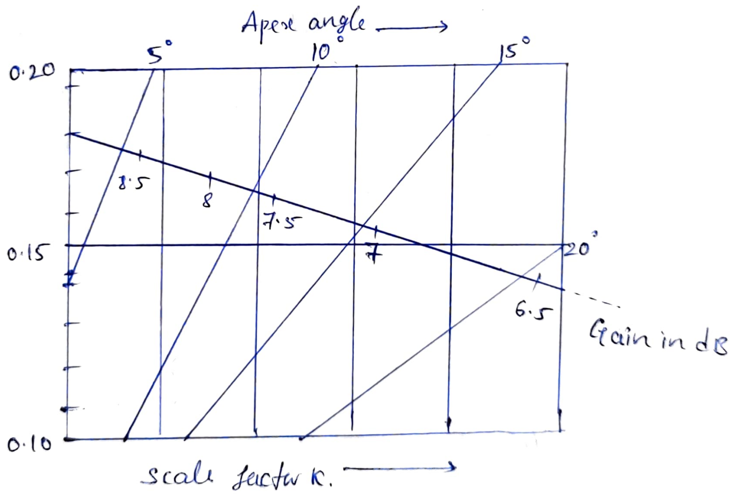
k = scale factor

$S_k = \left(\frac{s}{\lambda}\right)$ = spacing in wavelength shortword of $\frac{\lambda}{2}$ elements.

The length of any element say $n+1^{th}$ element and length of frist element is related as,

$$\frac{L_{n+1}}{L_n} = k^n = F$$

The relation between the apex angle α, scale factor k and spacing S_λ. with optimum design line and gain is represented in the fig.



- Relationship between the parameters of a log periodic dipole array

Consider the frequency in the middle of the operating range, ~~in inactive~~ inactive ~~transmission~~ transmission line region the dipole length is smaller than $\frac{\lambda}{2}$ resonant length, so the current is smaller and leading the base voltage. As the spacing between the dipoles is very small in the inactive transmission line region, the transmission provides 180° phase shift between adjacent dipoles. Hence the radiation is very small in backward direction.

When in active region, the spacing between the dipoles is sufficient large, the transmission provides 90° phase shift between adjacent dipoles. It can be illustrated as follows. When the field radiated from element (n+1) reaches n^{th} element, the phase advances by 90° and the field of n^{th} element adds to that of $(n+1)^{th}$ element in phase. A large field is resulted towards left. Hence we get very large radiation in the left direction which is also the backward direction. It is observed that the radiation in forward direction is very small. so it is necessary to feed the neighbouring dipoles at opposite phase so that the maximum radiation occurs in the backward direction. To accomplish this, the wires of the transmission line are transposed leading to alternate dipoles as shown in the figure.

Thus entire array operates in an end-fire fashion with the main beam of radiations in the backward direction i.e, towards the direction of short dipoles. Hence the array is fed with a transmission line at the end with shorter dipole.

Micro strip antenna:-

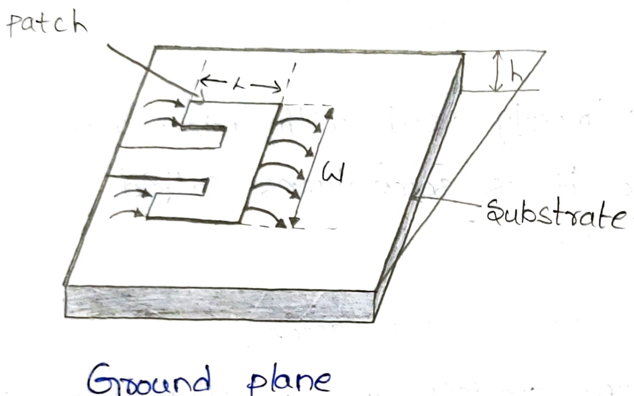
The antenna which is made of metal patches placed on dielectric and fed by microstrip or coplanar transmission line is called "micro strip antenna" or "patch antenna".

this antenna is mostly used with micro wave integrated circuits, hence it is some times called integrated antenna.

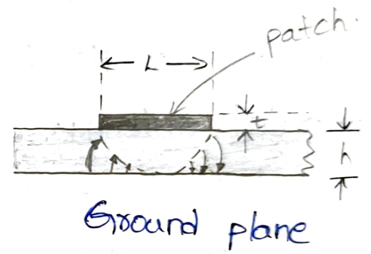
charecteristics of micro strip antenna:-

1. the micro strip antenna consists a very thin metallic "strip" or "patch" over a substrate.
2. the thickness of the micro strip is small ($t << \lambda_0$) as compared to the free space wave length λ_0.
3. the substrate is placed only a small fraction of free space wave length above the ground plane. this height (h) is small ($h << \lambda_0$) as compared to free space wave length λ_0 and typically it is $0.003\lambda_0 \leq 0.05\lambda_0$
4. the substrate in between the patch and ground plane is a dielectric sheet.
5. By properly selecting the field configuration by

choosing the mode of excitation beneath the patch, the pattern maximum normal to the patch can be achieved. Typically the length of the patch is selected in between $\frac{\lambda_0}{3} < L < \frac{\lambda_0}{3}$, as shown in the fig.



(a) Micro strip antenna.

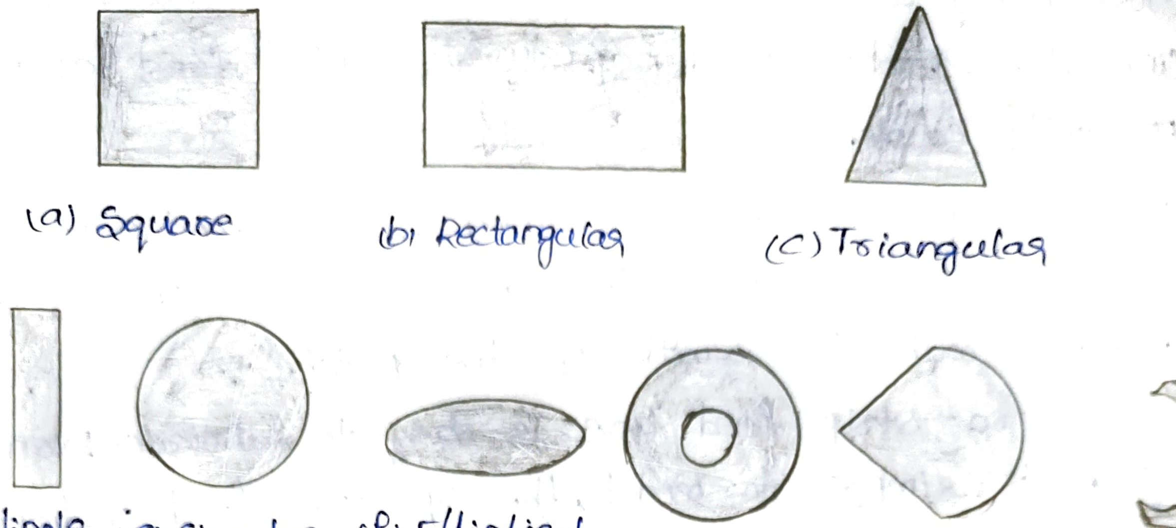


(b) Side view of path on a substrate.

6, In general, the no. of different dielectric substrates can be used in the micro strip antenna. The value of dielectric constant typically varies in the range of $2.2 \leq \epsilon_r \leq 12$ for the micro strip antenna.

Types of patch in micro strip antenna:-

1, In micro strip antenna, the radiating elements i.e. patch and the feed lines are generally photoetched on the dielectric substrate. The shapes of the radiating element or patch are as



(a) Square (b) Rectangular (c) Triangular

(d) dipole (e) Circular (f) Elliptical (G) Circular ring (h) Disc sector

2. Out of these shapes, square, rectangular, triangular, dipole and circular are the most commonly used shapes for the patch because of ease in fabrication.

3. Besides this, these shapes are useful for low cross polarization radiation. Also the radiation pattern can be easily analyzed.

4. To obtain the linear and circular polarization, either a single element or an array of microstrip antennas can be used.

5. To achieve greater directivities, array of microstrip elements with single or multiple feeds are used.

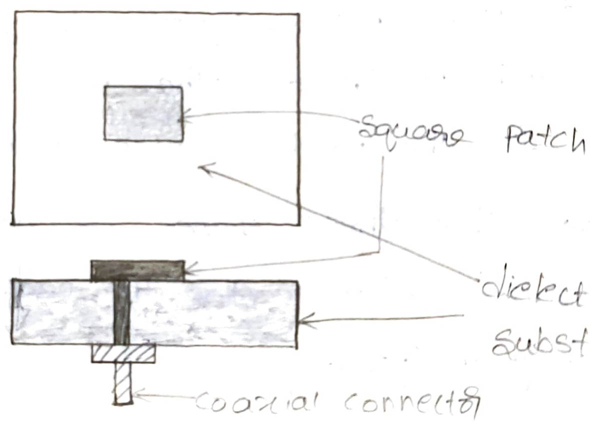
Feeding methods in microstrip antennas:-

1. Most widely used feed configurations are microstrip line feed, probe feed, aperture coupled feed and proximity coupled feed.

2. Micro strip feed line is nothing but a conducting strip. the width of the feed line is very much smaller as compared with the width of the patch.

3. the micro strip feed line is easy to fabricate. Eventhough it is simple to model, the spurious feed radiation increases with increase in the thickness. thus the band width limited.

(a) probe feed system.



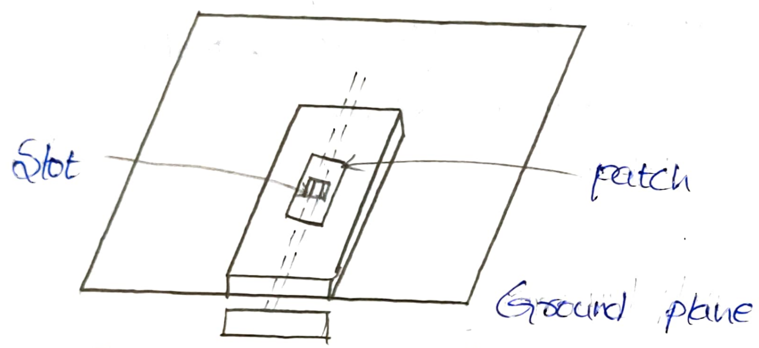
4. In case of probe feed configuration, the outer conductor is connected to the ground plane, while the inner conductor is connected to patch.

5. It is very easy to fabricate, the band width is further narrower.

6. To overcome aperture coupled feed systems are used. In

c) Half wave dipole array with plane reflector   reflector the aperture coupled feed system 2 substrates are used. The 2 substrates are seperated by ground plane.

7, The energy of this line is coupled to the patch through the slot on ground plane. This feed system minimizes the spurious radiations and interference for the pattern formation as the feed & radiating elements are isolated from each other.



ⓐ aperture coupled feed.

8, Out of the four feed systems, it has largest band width.

Advantages:-

1, The micro strip antennas are best suited where size, cost, weight, performance, ease of installation demand a low profile antenna.

2, It is suitable for planar & non-planar surfaces.

3, By properly selecting the shape of patch they can be made useful in terms of resonant frequency, pattern, impedence and polarization.

Disadvantages :-

1, The efficiency and power of antenna are low.

2, poor polarization and narrow bandwidth is required.

Applications :-

1, ~~Th~~ In high performance space crafts, air crafts, satellite applications.

2, It is used in mobile applications, mobile radio and and wire less communication.

UNIT – V

VHF, UHF and Micro wave Antennas

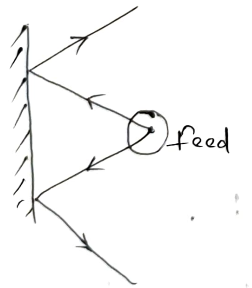
* Reflector Antennas:

→ The reflector antennas are most important in microwave radiation applications. At microwave frequencies the physical size of the high gain antenna becomes so small that practically any suitable shaped reflector can produce desired directivity. In reflector antenna, another antenna is required to excite it. Hence the antenna such as dipole, horn, slot which excites the reflector antenna is called primary antenna, while the reflector antenna is called secondary antenna. The most commonly used shapes are: plane reflector, corner reflector and curved or parabolic reflector.

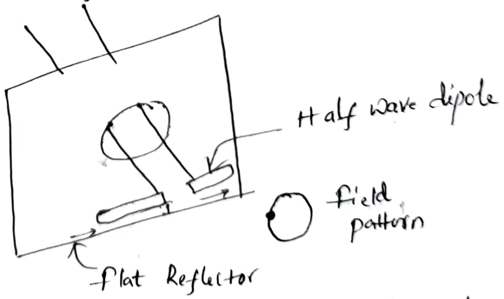
* Flat Sheet Reflector or Plane Reflector.

→ The plane reflector is the simplest form of the reflector antenna. When the plane reflector is kept in front of the feed, the energy is radiated in the desired direction. The plane reflector is shown in below fig:

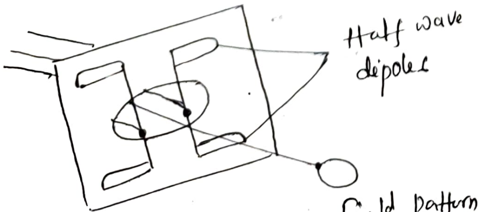
Fig: Plane reflector and examples.



(a) Plane reflector



(b) Half wave dipole with plane



(c) Half wave dipole array

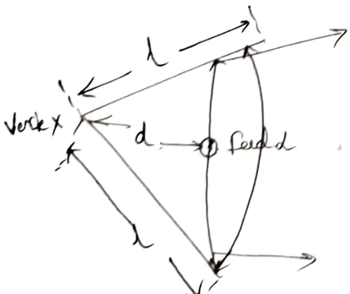
d). Half wave dipole with reflector element.

→ To increase the directivity of the antenna, a large flat sheet can be kept as plane reflector in front of a half dipole as shown in fig. The main advantage of the plane reflector is that for the dipole backward radiations are reduced and the gain in the forward direction increases. To increase the directivity further we can use array of two half wave dipoles in front of flat plane reflector shown in fig c. Flat sheet is less frequency sensitive than the thin element. Hence only a reflector element can be used to increase directivity. Such arrangement is shown in fig. d.

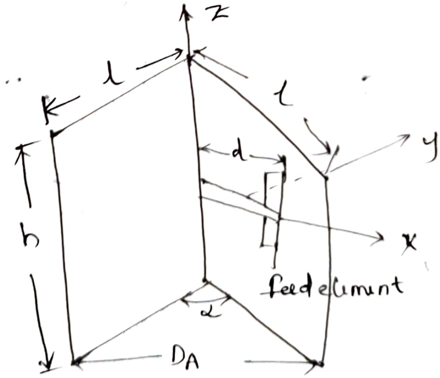
* Corn Reflector:

→ The disadvantage of plane reflector is that there is radiation in back and side directions. Hence in order to overcome this limitation, the shape of the plane reflector is modified, so that the radiation is in forward direction only. This arrangement is called Corn Reflector. The angle at which two plane reflectors are joined is called included angle (α). In most of practical applications included angle is 90°.

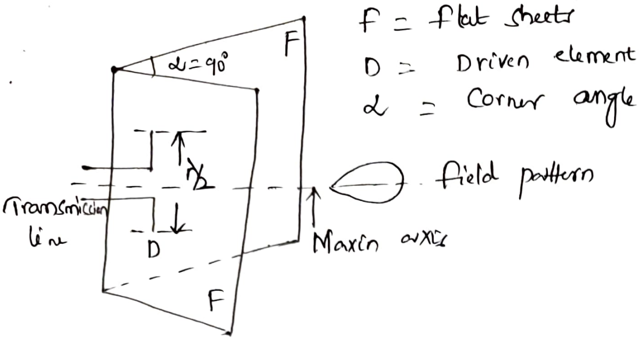
A typical corn reflector is shown in below.



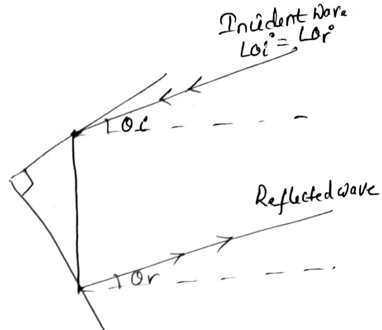
corn reflector
Top view



Corner reflector
front view.



c) Vertical corner reflector with field pattern along main axis



d) Passive corner reflector without any driven element.

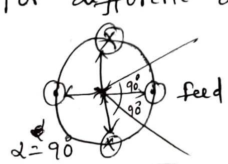
→ In most of the corner reflectors, the feed element is either a dipole or array of collinear dipoles placed parallel to the vertex at a distance 'd' shown in the fig b. To increase bandwidth biconical or cylindrical dipoles are preferred.

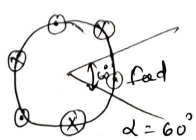
The spacing between the vertex of the reflector and the feed element is $\lambda/3 < d < 2\lambda/3$. The length of the reflector is twice the spacing between feed and vertex. i.e $l \approx 2d$.

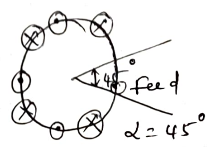
A corner reflector with two flat conducting sheets at a corner angle α and driven antenna is called active corner reflector antenna or simply corner reflector antenna. Without driven element is called passive corner reflector shown in fig d.

The analysis for the radiated field of the source with the corner reflector be useful with included angle $\alpha = \frac{\pi}{N}$.

The no. of images, polarity and position is controlled by the included angle and polarization of the feed element with ⊥r polarization of the feed element, the pattern of multiple images on a circular path for different angles are shown in below fig.







If $N = 1$, $\alpha = \frac{\pi}{1}$ rad $= \pi$ rad or $180°$ → Flat sheet or plane reflector

If $N = 2$, $\alpha = \frac{\pi}{2}$ rad or $90°$ → Square corner reflector

If $N = 3$, $\alpha = \frac{\pi}{3}$ rad or $60°$ → Corner reflector with corner angle $\alpha = 60°$

If $N = 4$, $\alpha = \frac{\pi}{4}$ rad $= 45°$ → corner reflector with corner angle $\alpha = 45°$.

* **Design Equations for Corner Reflector:**

D_A = Dimension of aperture

d = Distance between feed and the vertex of the reflector

l = side length of the reflector sheet.

$d = \frac{l}{2}$ or $l = 2d$.

Now $D_A = \sqrt{l^2 + l^2} = \sqrt{2l^2} = \sqrt{2}\, l = 1.414 l$.

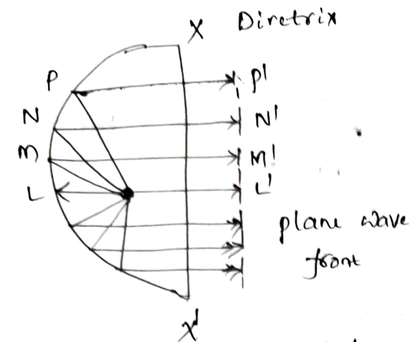
But $l = 2d$ $\therefore D_A = 1.414 (2d) = 2.828d$

$= 2.828d$

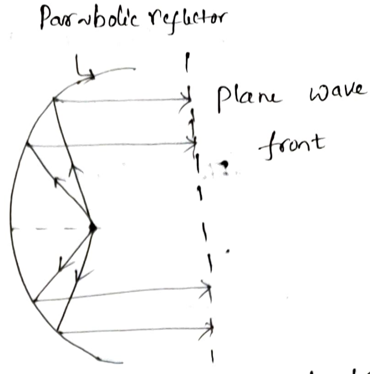
* **Principle of Parabolic Reflector:**

→ To improve the overall radiation characteristics of the reflector antenna, the parabolic structure is oftenly used. Basically a parabola is a locus of a point which moves in such a way that the distance of the point from fixed point called focus plus the distance from the straight line called directrix is constant. shown fig a.

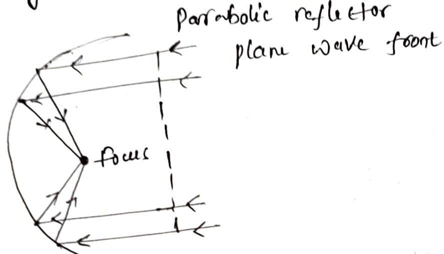
By the geometrical optics, when the point source is placed at the focus or focal point, then the rays reflected by the parabolic reflector form parallel wave front shown in fig. b. This principle is used in transmitting antenna. Similarly when the beam of parallel rays is incident on a parabolic reflector, then the radiations focus at a focal point as shown in fig c.



a): Geometry of parabola



b): Parabolic reflector at transmitting end.

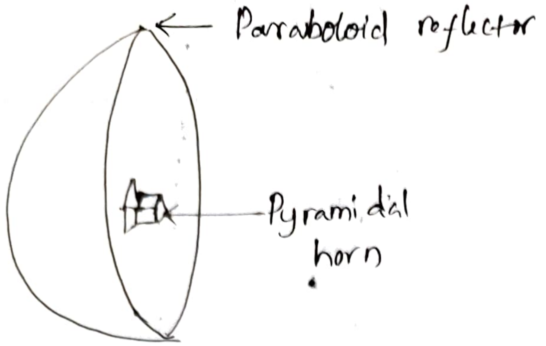


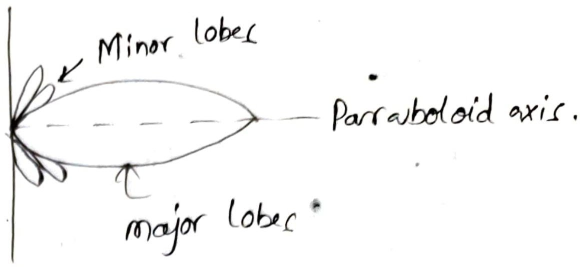
c): Parabolic reflector at receiving end.

consider a parabolic reflector as shown in fig b. When the point source is kept at the focus or focal point of the parabola, the radiations striking the parabolic reflector are reflected parallel to the axis of parabola irrespective of the angle at which the reflector level same distance to reach near the mouth of reflector. The open end of the parabolic reflector is called aperture. The wave front at the aperture of the parabolic reflector is uniform phase front and very strong and concentrated beam is obtained along the axis due the waves or reflected rays travel up to directrix of parabola is same.

* Paraboloid (or Paraboloidal Reflector):

→ The three dimensional structure of the parabolic reflector can be obtained by rotating the parabola around its axis and it is called paraboloid. It is the microwave dish which produces sharp major lobe and smaller minor lobes. shown in below fig.





a). Paraboloid b).

Consider that the power gain of the paraboloid, with circular mouth or aperture, w.r.t half wave dipole is given by,

$$G_p = \frac{4\pi A_0}{\lambda^2}$$

Where A_0 is the capture area, which is less than the area A of the mouth and it is given by

$$A_0 = k \cdot A.$$

Where k = Constant dependent on feed antenna used.

It is 0.65 for dipole.

Hence $G_p = \frac{4\pi(kA)}{\lambda^2} = \frac{4 \times \pi \times 0.65 \times A}{\lambda^2}$

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

$$\therefore G_p = \frac{4\pi \times 0.65 \times \frac{\pi d^2}{4}}{\lambda^2} = \frac{\pi \times 0.5 \times d^2}{\lambda^2}$$

$$= 6\left(\frac{d}{\lambda}\right)^2.$$

Where $\frac{d}{\lambda}$ is aperture ratio.

for small diameter of paraboloid $d = 1$, $\lambda = 0.02\,m$

$$G_p = 6\left(\frac{1}{0.02}\right)^2 = 15000.$$

Beam width between first null is

$$BWFN = \frac{140\lambda}{d}.$$

Where d = Diameter of circular aperture in terms of λ in m.

λ = free space wave length in m.

for rectangular aperture BWFN is

$$BWFN = \frac{115\lambda}{L}°$$

where L = Length of rectangular aperture interms of λ.

$$HPBW = \frac{58\lambda}{d}°$$

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

$$A_e = \pi\left(\frac{d}{2}\right)^2 = \frac{\pi d^2}{4} \rightarrow \text{for circular aperture.}$$

$$\therefore D = \frac{4\pi \frac{\pi d^2}{4}}{\lambda^2} = \pi^2\left(\frac{d}{\lambda}\right)^2 = 9.87\left(\frac{d}{\lambda}\right)^2$$

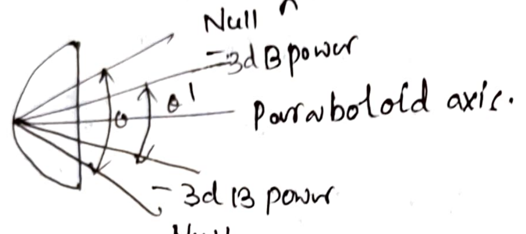


fig: Illustration of BWFN and BWHP.

*f/d Ratio, Spill over, Back Lobe:

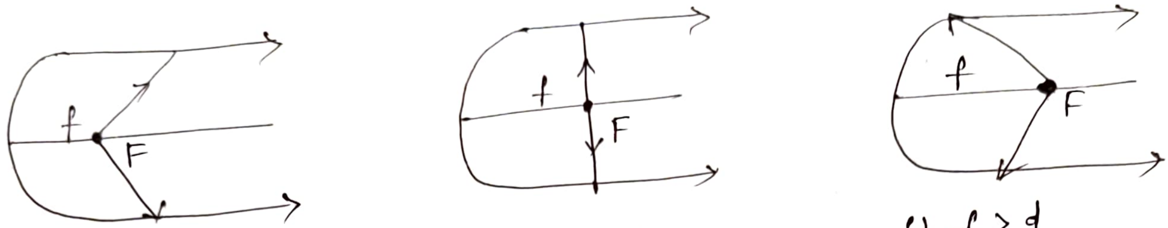
→ The paraboloid can be designed to obtain pencil shape radiation beam by keeping the diameter of the aperture fixed and changing the focal length f. The three possible cases are:

i) focal point inside the aperture of paraboloid

ii) " along the plane of open mouth of "

iii) " beyond the " ".

→ When the focal length is very small, the focal point lies inside the open mouth of paraboloid as shown in fig. It is very difficult to obtain uniform illumination over a wide angle. When the focal point lies on the plane of the mouth of the paraboloid by geometry the focal length f is one fourth of the open mouth diameter d. This condition gives maximum gain pencil shape radiation equal in horizontal and vertical plane. When the focal length is too large focal point lies beyond the open mouth of the paraboloid as shown in the fig c.



a) $f < \frac{d}{4}$ b) $f = \frac{d}{4}$ c) $f > \frac{d}{4}$

fig: Effect of variation of focal length f keeping diameter of aperture d fixed in paraboloid.

→ Practically the reflection is able to focus the parallel rays at the focal point F or the reflector can develop a parallel beam from radiations originated from the focal point. Practically it is observed that some of the rays are not fully captured by reflector, such non-captured rays from spill over.

→ While receiving spill over, the noise pick up increases which is trouble some. In addition to this, few radiations originated from the primary radiators are observed in forward direction. Such radiation get added with desired parallel beam. This is called back lobe radiation.

* Types of paraboloid Reflectors:

1. Truncated paraboloid or Cut paraboloid:

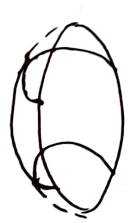


fig: Truncated or cut paraboloid.

This type of paraboloid is formed by cutting some of the portion of the Paraboloid to meet the requirements.

2. Parabolic right Cylinder:

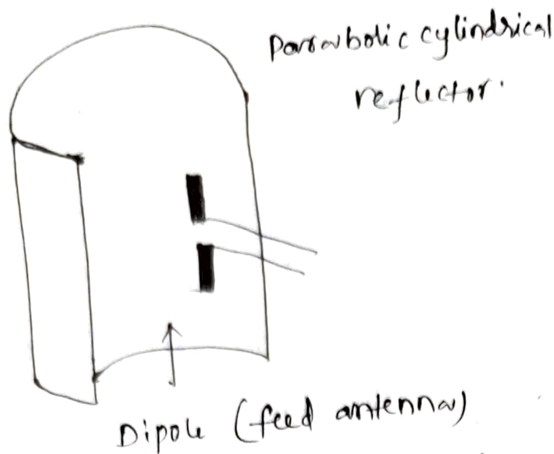


fig: Parabolic right Cylinder.

The right cylindrical structure is shown in the fig. This structure is obtained by moving the parabola side ways. It has focal line instead of focal point and vertex instead of vertex. In this energy is collimated at a line which is parallel to the axis through the focal point of the reflector. In practice, linear dipole or linear array or a slotted wave guide is used as primary antenna.

3. Pill box or Cheese antenna:

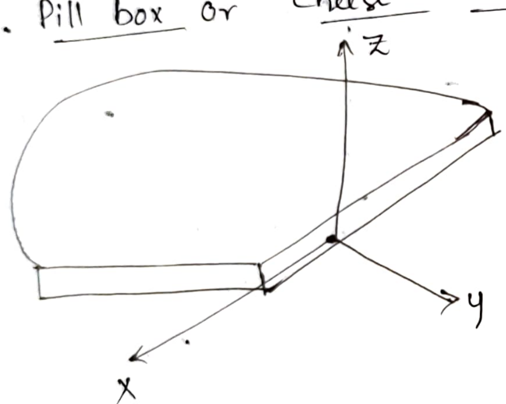


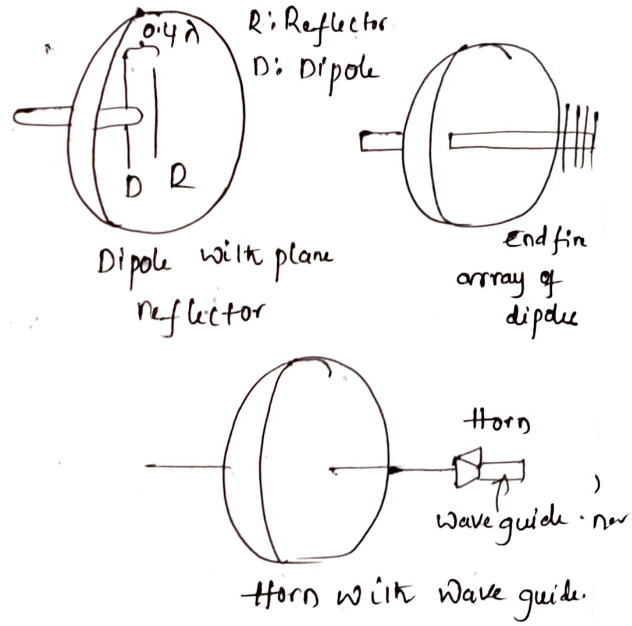
fig: Pill box paraboloid.

It is a short parabolic right cylinder enclosed by parallel plates as shown in fig. This antenna is useful in producing wide beam in one of the planes while narrow in other.

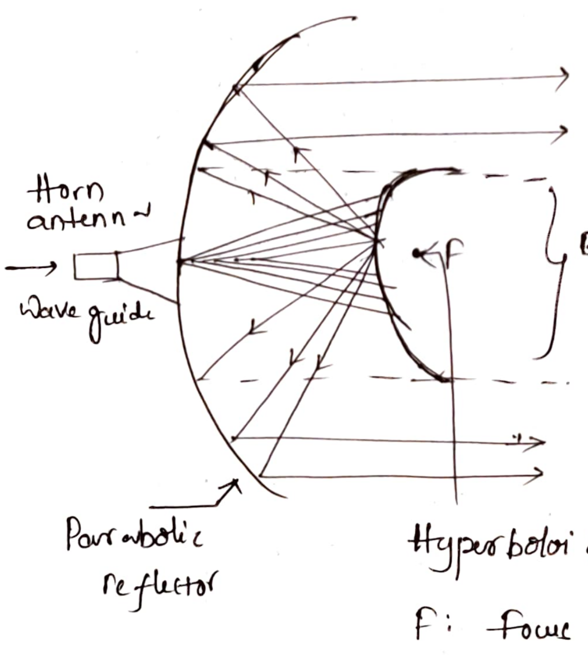
* Feed Systems for Paraboloid Reflectors:

→ In parabolic reflector antenna has two systems/parts. The source placed at the focus is called primary radiator, while the reflector is called secondary radiator. The primary radiator is called feed radiator or feed. Practically there are no. of possible feeds to the parabolic reflector antenna. The secondary radiator is paraboloid. The simplest type of the feed that can be used is a dipole. But it is not suitable feed for the parabolic reflector antenna.

Instead of dipole parasitic reflector i.e Yagi Uda antenna can be used. In such cases the spacing between driven element and parasitic element is 0.125λ. The most widely used feed system in parabolic reflector antenna is horn antenna. The horn antenna is fed with wave guide. In case of circular polarization required, then in place of rectangular horn, circular or conical horn is used at the focus. In all cases, the feed or primary radiators are placed at focus, to obtain maximum beam pattern. If the feed is moved along the line ⊥r to the main axis then beam deteriorates. But if the feed is moved along the main axis then the beam gets broadened. Hence focus is the important point on the main axis at which feed is placed to obtain the maximum radiation pattern.



* Cassegrain feed system:



F: Focus of parabolic reflector.

Fig: Cassegrain feed system.

→ In Cassegrain feed system, the feed radiator is placed at the vertex of the parabolic reflector, instead of placing it at the focus. This system uses a hyperboloid reflector placed such that its one of the foci coincides with the focus of the parabolic reflector.

This type of reflector is called cassegraind secondary or sub reflector. It is shown in above fig.

→ When the feed radiator towards the cassegrain or sub-reflector, it radiates all radiations and due to these radiations, the parabolic reflector gets illuminated similar to the radiations from the feed placed at the focus.

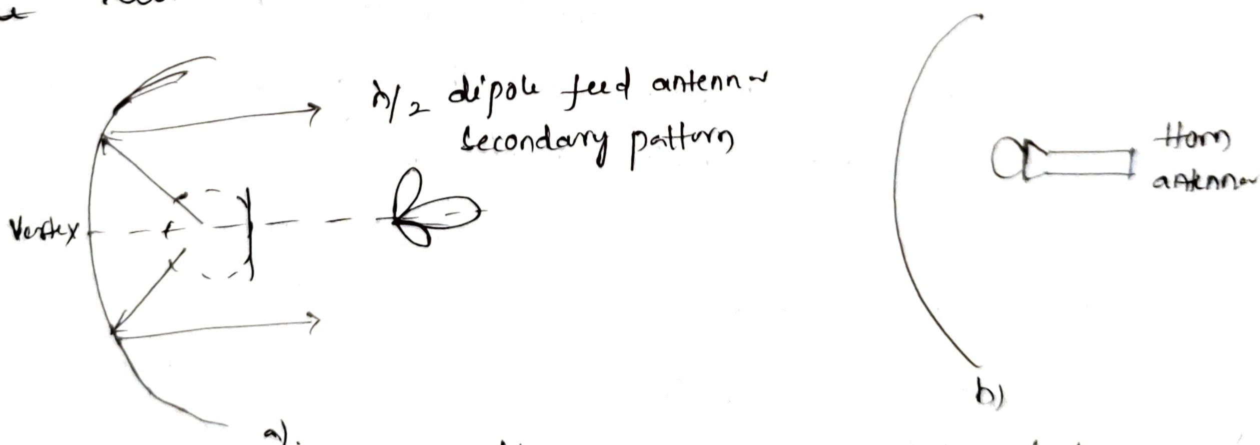
*Advantages:

1. It reduces spill over and minor lobes radiations.
2. It achieves greater focal length than the physical focal length.
3. It has ability to place a feed at convenient place.
4. By using this system, beam can be broadened.

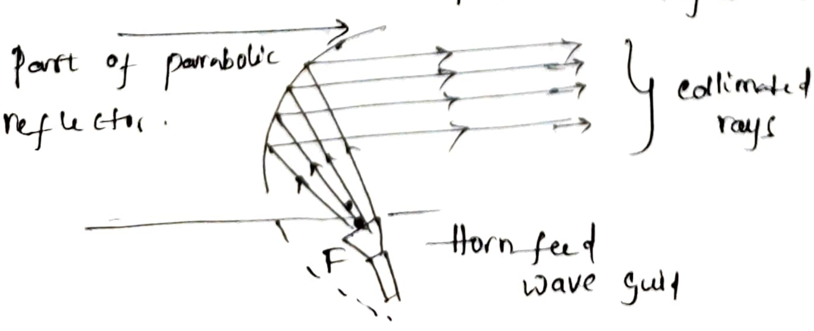
*Disadvantages:

1. Blocked rays infront of Cassegrain.
2. Small dimension of parabolic reflector.

* Offset feed system:



Parabolic reflector with offset feed.



Offset feed system.

→ To overcome the aperture blocking effect due to the dependence of the secondary reflector dimensions on the distance between feed and sub-reflector, the offset feed system as shown in the fig. Here feed radiator is placed at the focus. With this system all the rays are collimated without formation of region of blocked rays.

* 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 throughout the world. As it is widely used at microwave frequencies, may be considered as aperture antenna.

→ The horn antenna can be considered as a wave guide with hollow pipe of different cross sections which is flared or tapered into a large opening. While one end of the waveguide is excited, while other end is kept open, it radiates in open space in all directions. As one end of the waveguide is open circuited, the impedance matching with the free space is not perfect. At the edge of the waveguide, diffraction takes place. Which results in poor radiation.

→ Inorder to overcome these limitations, the mouth of the waveguide is flared opened out such that it assumes shape like horn. The advantage of terminating the waveguide into an electromagnetic horn is that instead of open circuit one end of the waveguide properly shaped gradual transition takes place.

* Types of Horn Antennas:

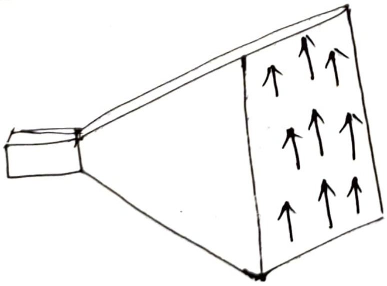
→ Basically horn antennas are classified as rectangular horn antennas, and circular horn antennas. The rectangular horn antennas are fed with rectangular waveguide, while the circular horn antennas are fed with circular waveguide.

→ Depending upon the direction of flaring, the rectangular horns are further classified as Sectoral horn and Pyramidal horn.

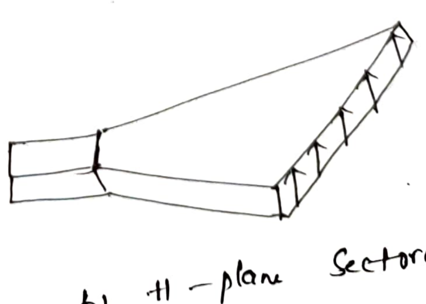
Sectoral horn further classified as E-plane horn and H-plane sectoral horn. The E-plane horn is obtained when the flaring is done in the direction of electric field vector. The H-plane horn is obtained when the flaring is done in the direction of magnetic field vector. In both cases, the arrows indicate direction of the electric field $\bar{E}$ and the lengths of the arrows indicate approximate magnitude of the field intensity.

→ When the flaring is done along both the walls of the rectangular waveguide in the direction of both the electric and magnetic field vectors, the horn obtain is called pyramidal horn as shown in the fig.

The circular horn antennas can be obtained by flaring the walls of the circular waveguide. The circular horn antennas are of two types namely conical horn antenna and biconical horn antenna as shown in the below figs.

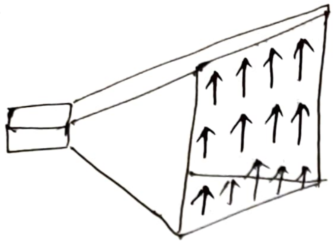


a) E-plane sectoral horn



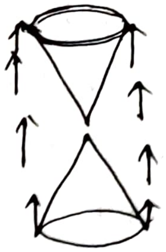
b) H-plane sectoral horn.

Fig: Rectangular sectoral horns..



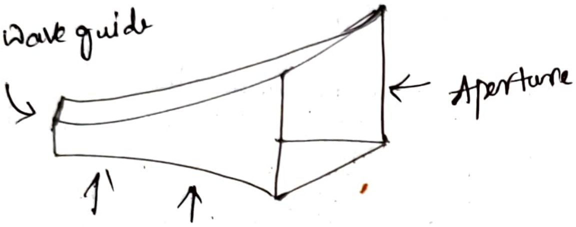
Pyramidal horn

Conical horn



Biconical horn.

fig: Circular horn antennas.



a). Exponentially tapered pyramidal.

b) Exponentially tapered conical

fig: Exponentially tapered horn antennas.

* Design Equations for Horn Antenna:

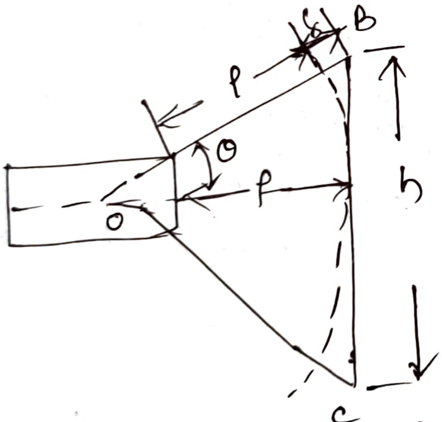


fig: E-plane view.

By observing this fig;

$$\cos\theta = \frac{\rho}{\rho+\delta}$$

$$\tan\theta = \frac{h/2}{\rho} = \frac{h}{2\rho}$$

$$\text{Hence } \theta = \cos^{-1}\left[\frac{\rho}{\rho+\delta}\right] = \tan^{-1}\left[\frac{h}{2\rho}\right]$$

From right angle triangle OBA,

$$(\rho+\delta) = \sqrt{\rho^2+\left(\frac{h}{2}\right)^2}$$

$$= (\rho+\delta)^2 = \rho^2+\left(\frac{h}{2}\right)^2$$

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

$$4\rho^2+4\delta^2+8\rho\delta = \rho^2 - h^2 = 0$$

δ^2 will be smaller than δ, hence neglecting

~~$\cos\theta$~~

$$2l\delta = \frac{h^2}{4}$$

$$l = \frac{h^2}{8\delta} \qquad \text{where } \delta << l.$$

for optimum plane horn, the half power beamwidth can be expressed as,

$$\theta_H = \frac{67^\circ \lambda}{a_H}$$

and $\theta = \frac{56^\circ \lambda}{a_E}$

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

where A_e = Effective aperture in m^2

A_p = physical " "

$\epsilon_{ap} = \frac{A_e}{A_p}$ = Aperture effeciency.

for rectangular horn,

$A_p = a_E \cdot a_H$

where a_E = E-plane aperture in m.

a_H = H-plane "

λ = 1m, $\epsilon_{ap} = 0.6$, → for rectangular horn.

$$D = \frac{4\pi(0.6)A_p}{\lambda^2} \simeq \frac{7.5 A_p}{\lambda^2}$$

$$D(\text{in dB}) = 10\log_{10}\left[\frac{7.5 A_p}{\lambda^2}\right]$$

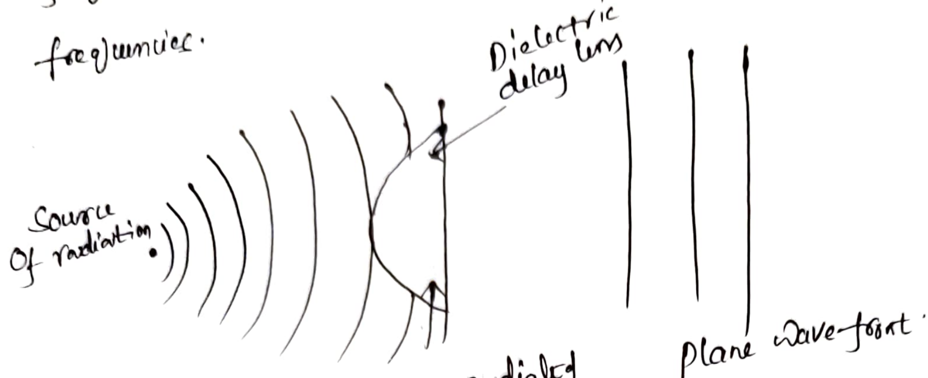
Similarly for a conical horn,

$A_p = \pi r^2$

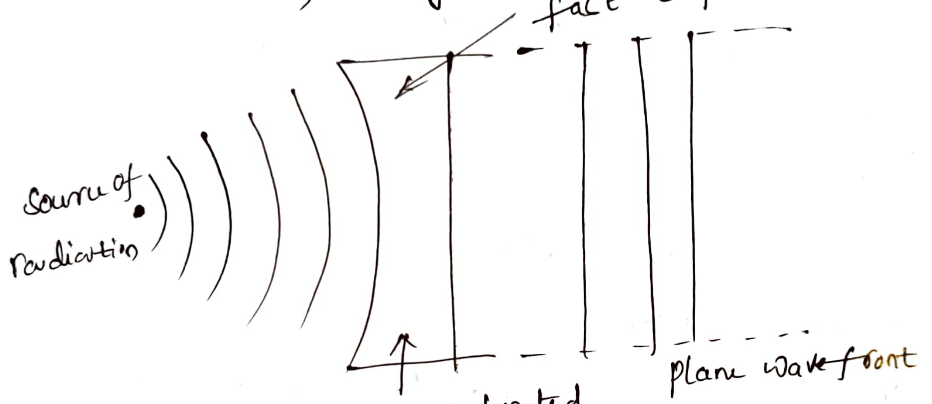
r = Radius of Aperture in m.

* Lens Antenna:

→ The main application of lenses is to collimate incident divergent energy to prevent it from spreading undesired direction. These antennas are used to transform the divergent energy into the plane waves by properly choosing lens material and geometric shape. These are used at high frequencies as their dimension and weight become extremely large at lower frequencies.



a) Delay lens antenna.



b) fast lens antenna

fig: Delay and fast lens antennas.

→ Basically lens antennas can be classified as,

i) Delay lens : electric path length is increased by the lens medium and the wave retarded

ii) fast lens. : electric path length is decreased by the lens medium and wave is accelerated.

* Principle of Lens Antenna:

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

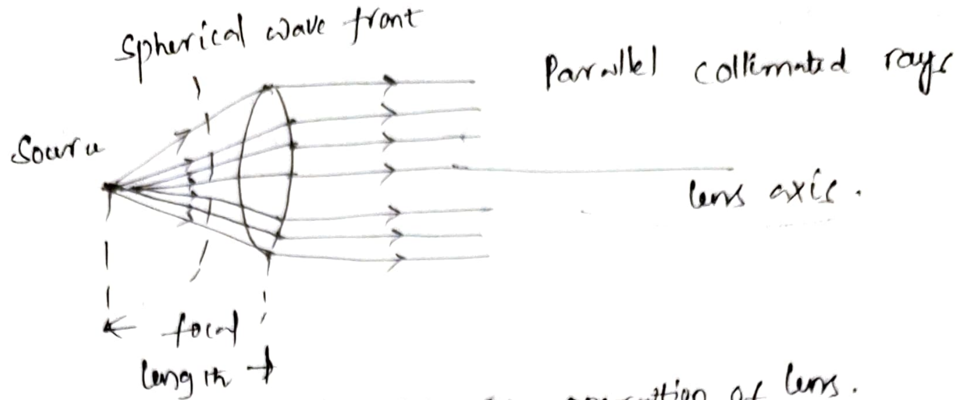


Fig: Principle of operation of lens.

→ Due to the radiation from the point source, we get spherical wavefront. When the rays travel to the lens, refraction takes place, due to refractive index of lens. So, more rays are collimated to obtain plane wave in front of the parallel rays. The refraction is more at the edges than that at centre.

→ To operate a lens at a radio frequencies, a dielectric lens is preferred. Such lens with point source producing spherical wave front on left side of the lens produces collimated parallel rays to give plane wavefront. This operation illustrates transmitting lens antenna. If the parallel rays are incoming from right hand side of the lens, then these rays will converge to a point at the focal point on left hand side of antenna, illustrating operation of the receiving lens antenna.

* Feed System of Lens Antenna:

→ The feed system of lens antenna is similar to that of parabolic reflector. So parabolic reflector fed with a horn antenna as shown in the fig.

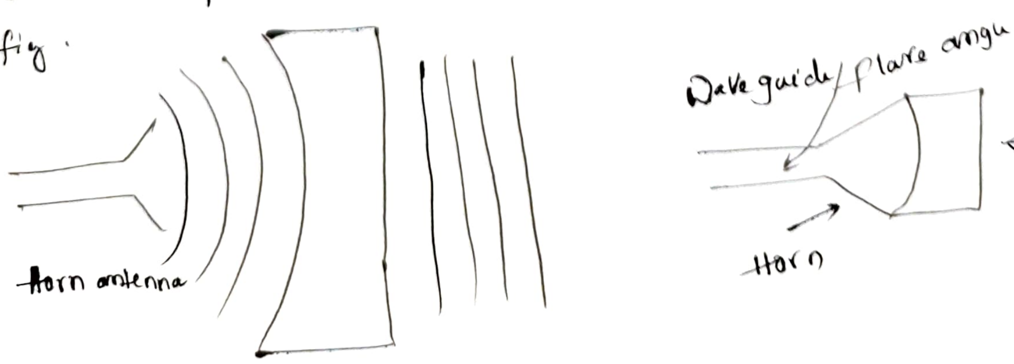


Fig: Horn antenna feed to lens antenna.

→ To have better performance of lens antennas, the aperture dimension of the horn is selected equal to the focal length of a lens antenna; so, feed becomes more directive. To avoid stray radiations flared side of lens are continued.

*Advantages of Lens Antennas:

1. The rays are transmitted away from the feed system, hence aperture is not obstructed due to the feed and feed support.

2. Waves entered from one side and leaves from another side, twisting possible without disturbing.

3. They are extensively used at beam is moving angularly w.r.t axis.

*Disadvantages:

1. Bulkier
2. Design is complicated.
3. Comparative with reflector, they are expensive.

*Applications:

1. Used as microwave antennas.
2. Used for narrow bandwidth applications.

Yagi - Uda Array:

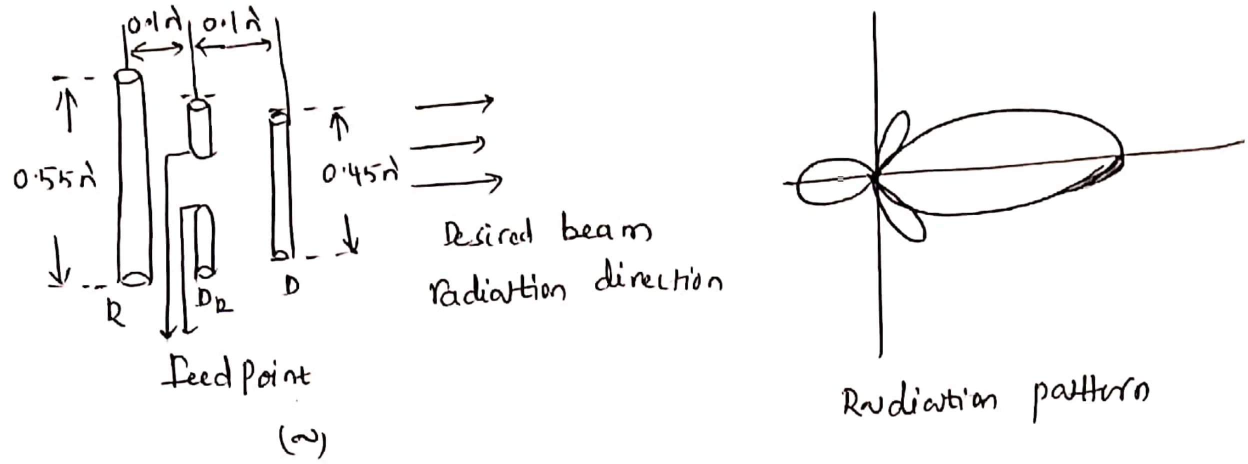


fig: Yagi - Uda antenna.

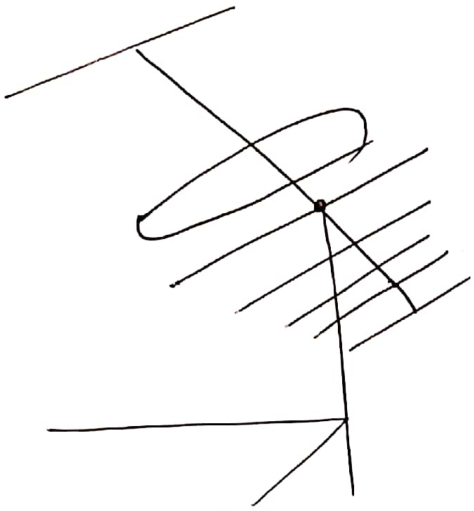


fig: Yagi antenna.

Yagi-Uda arrays or Yagi-Uda antennas are high gain antennas. The antenna was first invented by a Japanese Prof. S. Uda, after the english prof. by H. Yagi. Hence name Yagi-Uda antenna.

A basic Yagi-Uda antenna consist a driven element, one reflector and one or more directors. Basically it is an array of one driven element and of more parasitic elements. The driven element is a resonant half wave dipole made of a metallic rod. The parasitic elements which are continuous are arranged parallel to the driven elements and at the same line of sight. All the elements are placed parallel to each other and close to each other. shown in above fig.

The parasitic element receive excitation through the induced e.m.f as current in the driven element. The phase and amplitude of the currents through the parasitic elements mainly depends on the length of the elements and spacing between elements. Generally the spacing between the driven and the parasitic elements is kept nearly 0.1λ to 0.15λ. A Yagi-Uda antenna uses both the reflector (R) and the director (D) elements in the same antenna. The element at the back side of the driven element is the reflector. It is of the larger length compared with remaining elements. The elements infront of the driven element is the director which is of lowest length in all the three elements. The length of different elements are

$$\text{Reflector length} = \frac{152}{f(MHz)} \text{ meter}$$

$$\text{Driven element length} = \frac{143}{f(MHz)} \text{ meter.}$$

$$\text{Director length} = \frac{137}{f(MHz)} \text{ meter.}$$

Operation: The parasitic element is used either to direct or to reflect, the radiated energy forming compact directional antenna. If the parasitic element is greater than length $\lambda/2$, then it is inductive nature. Hence the phase of the current in such element in reflector lags the induced voltage. While if the parasitic element is less than the resonant length $\lambda/2$, then it is capacitive nature. Hence the current in director leads the induced voltage. The directors adds the fields of the driven element in the direction away.
The Yagi-Uda antenna, the no. of directors is increased in the beam direction. To get good excitation the elements are closely spaced.

The Yagi-Uda antenna is the most widely used antenna for television signal reception. The gain of such antenna is very high and radiation pattern is very much directive in one direction.

The signal strength of the Yagi-Uda antenna can be increased by increasing no. of directors in antenna.

General Characteristics of Yagi-Uda Antenna:

1. The Yagi-Uda antenna with 3 elements including one reflector, one driven element and one director is commonly called beam antenna.
2. It is generally a fixed frequency operated unit. This antenna is frequency sensitive and the bandwidth of 3% can be easily obtained. Such bandwidth is sufficient for television reception.
3. The bandwidth of 2% to 3% can be easily achieved if the spacing between the elements is between 0.1λ to 0.15λ.
4. The gain of Yagi-Uda antenna is about 7 to 8dB. Its front to back ratio is 20dB.
5. This antenna gives a radiation beam which is unidirectional with a moderate directivity.
6. The Yagi-Uda antenna is light weight, low cost and simple in feeding with signal.
7. To achieve greater directivity more no. of directors are used.
8. This antenna provides high gain and beam width greater than that is obtainable from the uniform distribution.

Folded Dipole Antenna:

→ If the half wave dipoles have been folded and joined together called folded Dipole Antenna.

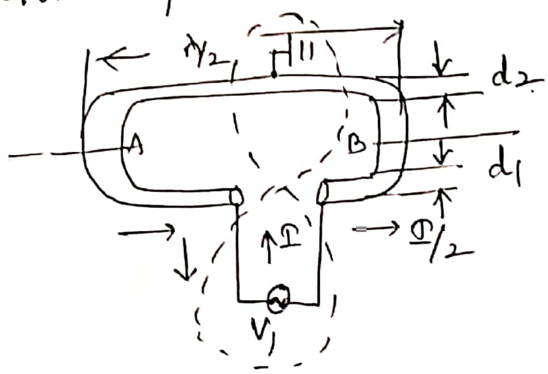


Fig: Folded Dipole and radiation pattern.

The folded dipole which is splited at the centre is fed with the balanced transmission line. As a result the voltages at the ends of two dipoles are same. When the radiation fields are concerned, the two dipoles are found to be in parallel essentially. There are two more important factors, which differ folded dipole from the conventional halfwave dipole. They are directivity and bandwidth.

If the conductors of the folded dipole are of same radii, then the currents with equal in magnitude and phase flows through the two dipoles.

Power $P = I^2 R$.

Input impedance i.e radiation resistance $R_{rad} = (2^2) 73 = 4(73) = 292\,\Omega$.

→ The three wire folded dipole, commonly called tripole is shown in below fig. 1/3 of the radiating current would be supplied at the input terminals.

Then the input impedance or the radiation resistance of tripole is given as 9 times greater than impedance of conventional dipoles.

$R_{rad} = (3^2) 73 = 657\,\Omega$.

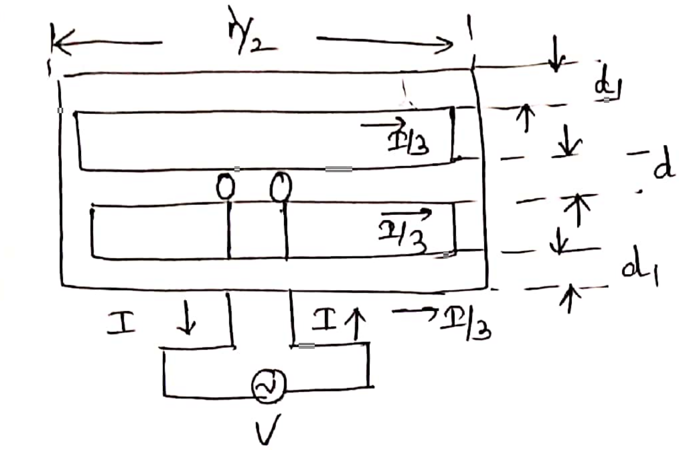


fig: Three wire folded dipole or tripole

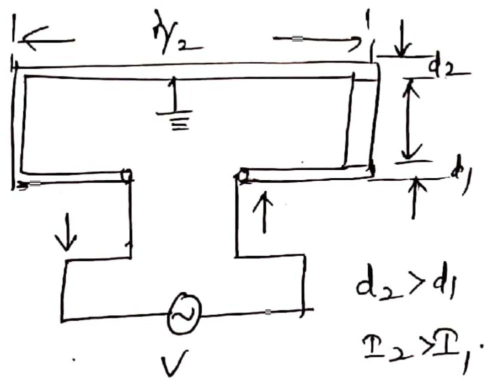


fig: folded dipole with unequal radii dipoles.

Input Impedance of folded Dipole Antenna:

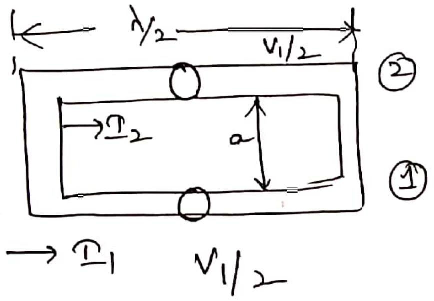


fig: Equivalent circuit of folded dipole of λ/2 length.

The applied voltage V_1 which is applied across terminals 1–1' gets equally divided in each dipole as voltage $\frac{V_1}{2}$. Then

$$\frac{V_1}{2} = Z_{11} I_1 + Z_{12} I_2 \rightarrow ①$$

$$I_1 = I_2 \rightarrow ②$$

$$\frac{V_1}{2} = (Z_{11} + Z_{12}) I_1 \rightarrow ③$$

$Z_{11} = Z_{12}$ Hence eq ③ becomes,

$$\frac{V_1}{2} = (Z_{11} + Z_{11}) I_1$$

$$V_1 = 2(2Z_{11}) I_1 = 4 Z_{11} \cdot I_1 \rightarrow ④$$

$$Z = 4(73) = 292\Omega.$$

$$\frac{V_1}{3} = (Z_{11} + Z_{12} + Z_{13}) I_1$$

$$I_1 = I_2 = I_3.$$

$$\frac{V_1}{3} = (3Z_{11}) I_1$$

$$= (9 Z_{11}) I_1.$$

$$Z = 9(73) = 657\Omega.$$

$$Z = Z_{11}\left[1 + \frac{r_2}{r_1}\right]^2$$

$$= 73\left(1 + \frac{r_2}{r_1}\right)^2.$$

r_1 = Radius of dipole 1

r_2 = " 2

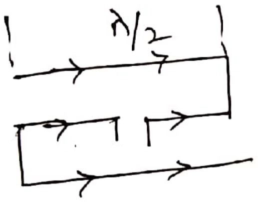
$r_1 = 2r_1$.

$$Z = 73\left[1 + \frac{(2r_1)}{r_1}\right]^2 = 9(73) = 657\ \Omega.$$

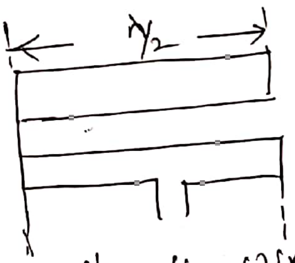
$$Z = Z_{11}\left[1 + \frac{\log\left(\frac{a}{r_1}\right)}{\log\left(\frac{a}{r_2}\right)}\right]^2$$

$$\frac{Z}{Z_{11}} = \left(1 + \frac{\log\left(\frac{a}{r_1}\right)}{\log\left(\frac{a}{r_2}\right)}\right)^2 = Z_r.$$

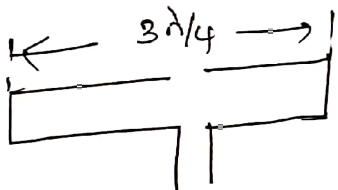
Different types of folded Dipole Antennas:



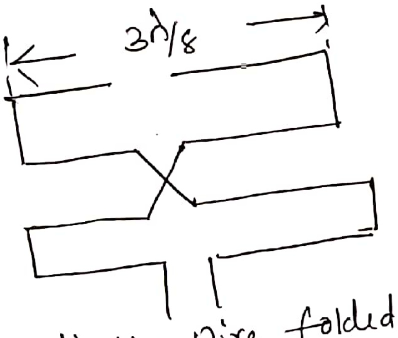
a) 3-wire folded λ/2 dipole antenna



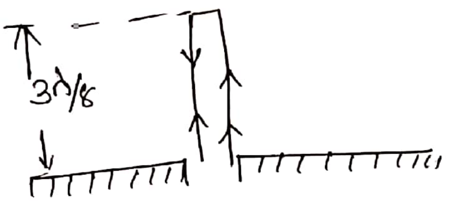
(b). 4-wire folded λ/2 dipole antenna



c) 2-wire folded 3λ/4 dipole antenna



d). 4-wire folded 3λ/8 Dipole antenna



e). 2-wire 3λ/8 stub antenna.

Applications of folded Dipole Antenna:

1. Two wire folded dipole antenna is most extensively used as feed element of TV antenna such as Yagi-Uda antennas.
2. As the terminal impedance of the folded dipole antenna can be adjusted over a wide range of impedances using different techniques it can be used as feed element for the antennas