..rasimha Reddy, M.Tech. Asst prof.

NON-RESONANT RADIATORS:-

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

Resonant Antenna:-

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

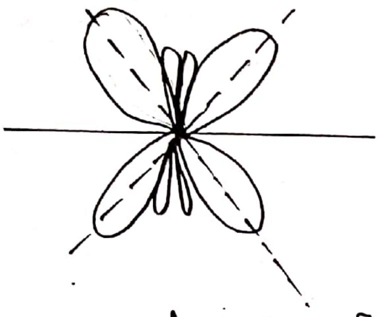
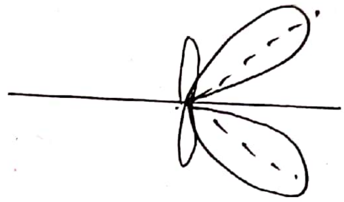
* The resonant antennas are also called as periodic antennas
* Examples of Resonant antennas are half wave dipoles, quarter wave monopoles, folded dipoles.
* The radiation pattern is bi-directional.

Non-Resonant antenna :-

* The Non-Resonant antennas are antennas which is also corresponds to transmission line, but there is no standing waves occurs. Because it exists only travelling waves (Incident wave).
* In the HF band vertical radiators is not a suitable choice. so practically the simplest antenna that can be used is horizontal antenna $\frac{\lambda}{2}$ dipole.
* The Non-Resonant radiator (or) antenna is also called as "aperiodic" antenna.
* Examples are travelling wave antennas, long wire antenna, V-antenna, inverted V-antenna, Rhombic antenna.
* The Radiation pattern is uni-directional.

Comparision between Resonant and Non-Resonant antennas :-

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

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

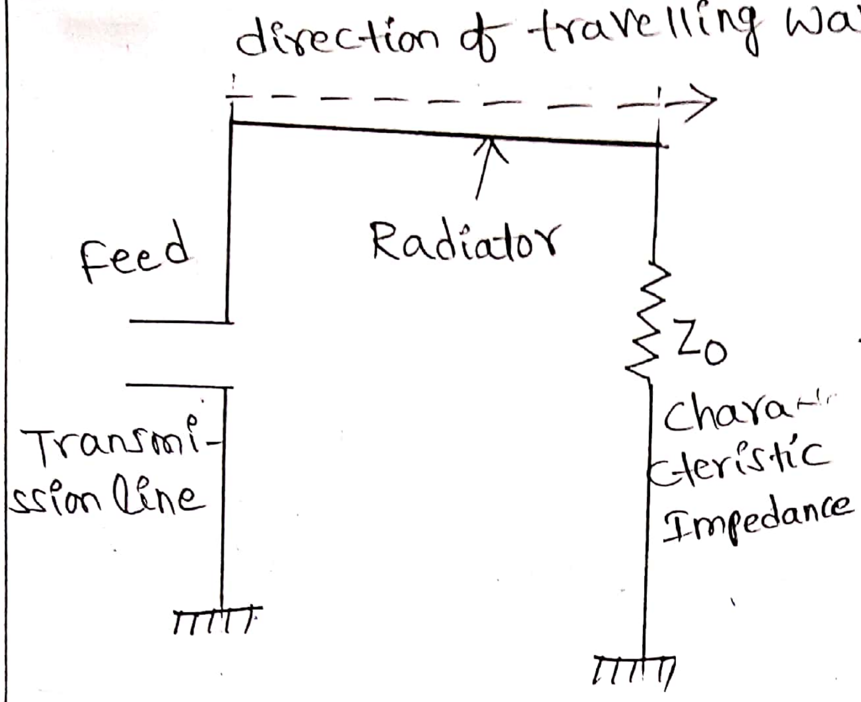
Travelling Wave Radiators :- [Travelling wave Antennas].

* The antenna In which the standing waves does not exist along the length of the antenna this is called as "travelling wave antenna".

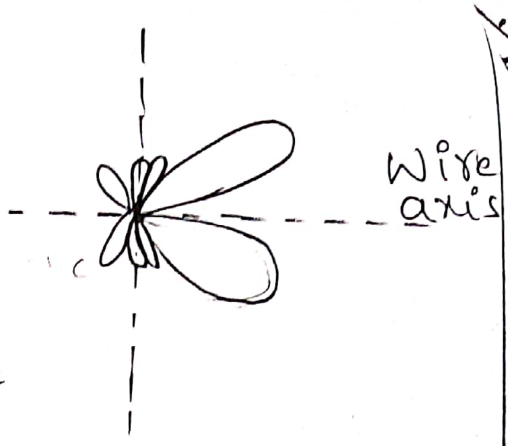
* Generally the Standing waves exist when the Antenna wire is not properly terminated which causes reflections are produced at load.

* Therefore the standing waves exist in the Resonant antenna and not exist in the non-Resonant antenna

* In travelling wave antenna no reflections are produced. due to which No standing waves occurs.



(a) Travelling wave antenna



(b) uni-directional Radiation pattern.

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

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

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

r = distance at a point from radiator

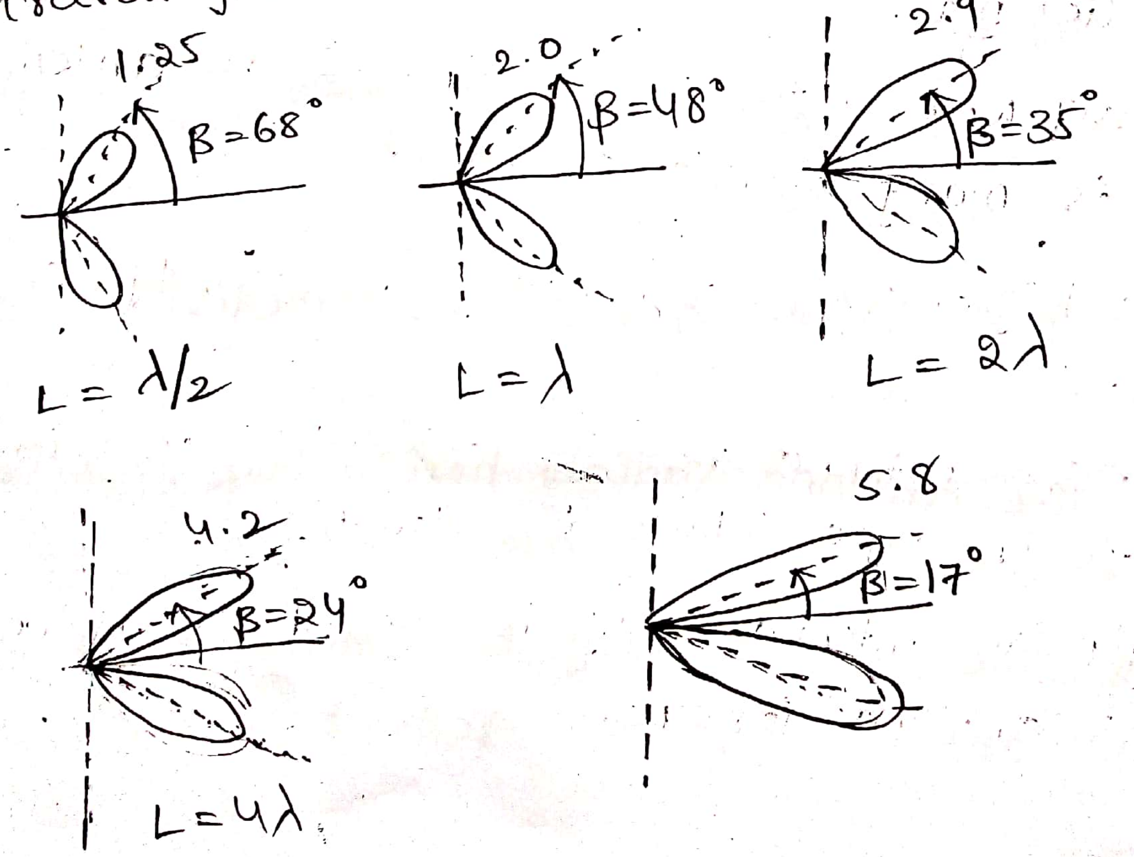
L = Length of wire (or) radiator.

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

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

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

The radiation pattern for different lengths of travelling wave antenna



Advantages:-

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

Dis advantages:-

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

Long wire antenna:- (Hormonic Antenna)

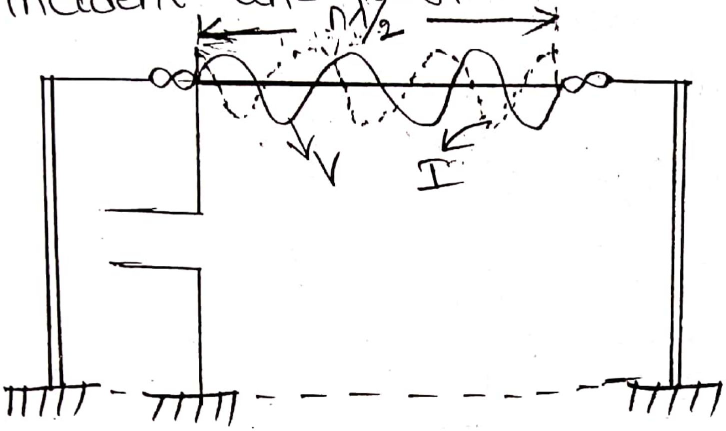
* A long wire antenna is defined as a single long wire, typically n times of $\frac{\lambda}{2}$ long at the operating frequency
* It is also an integer multiple of Half wave-length (ie) $\frac{n\lambda}{2}$.
* ∴ A long wire antenna is linear wire antenna which is many wavelength long.
* If the higher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

Resonant Long wire Antenna:-

(4)

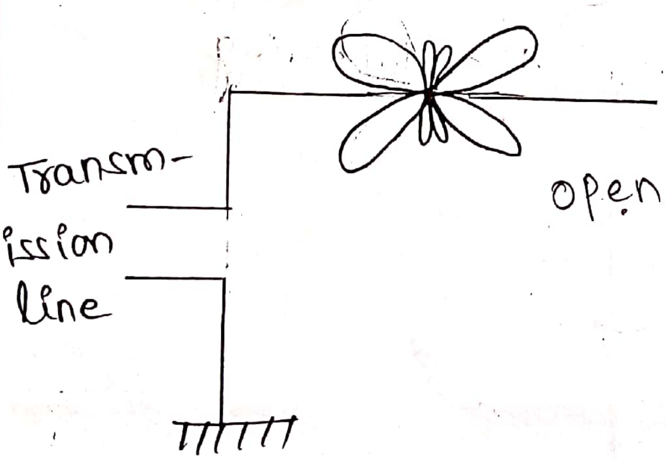
→ In the Resonant Long wire antenna, the load end is open (or) un terminated. There fore the standing waves are observed along the length of antenna.

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



Resonant Long wire Antenna

Bidirectional radiation pattern is given the following figure



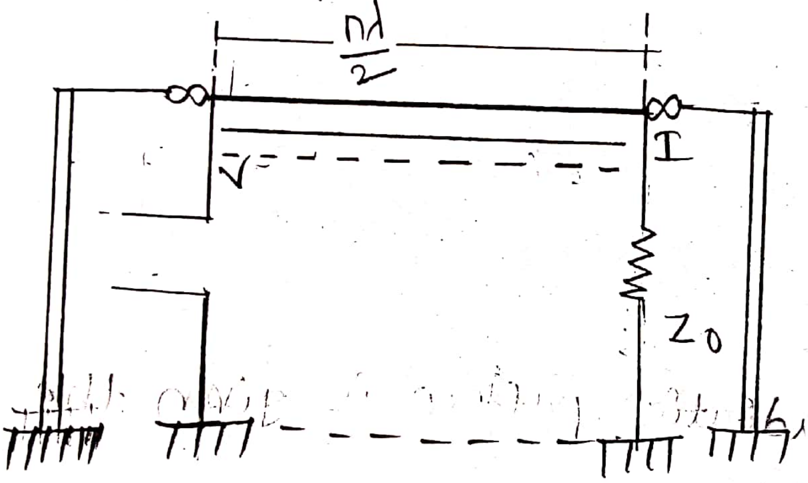
Non - Resonant Long wire Antenna:-

→ In non- Resonant long wire antenna, the load end is terminated with characteristic impedance (or) non inductive resistance.

→ ∴ No standing waves are exist along the length of antenna.

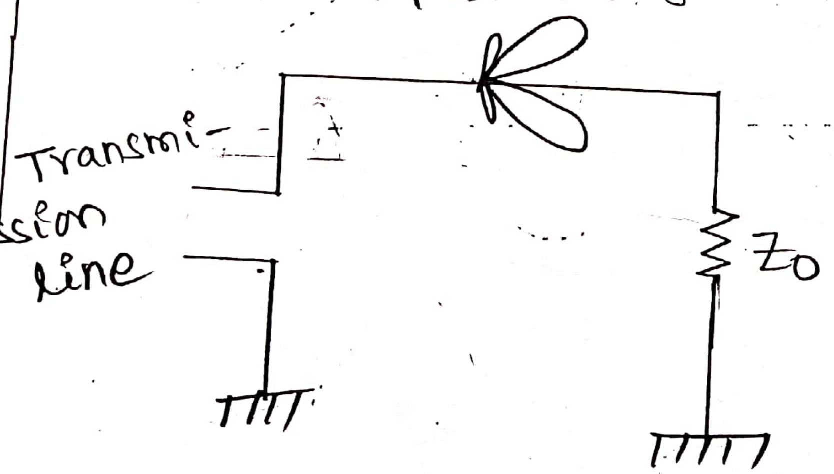
→ All the incident waves are absorbed and no reflections are produced.

→ Thus the pattern is uni-directional.



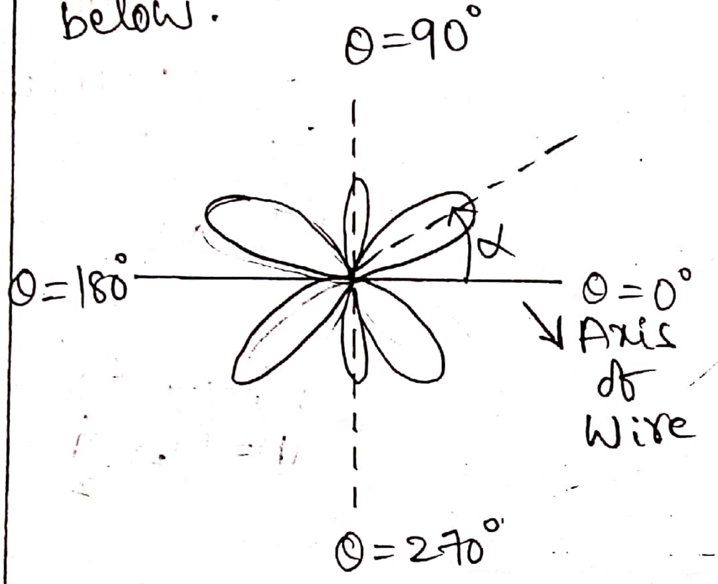
Non Resonant Long wire antenna

Unidirectional pattern is given the following

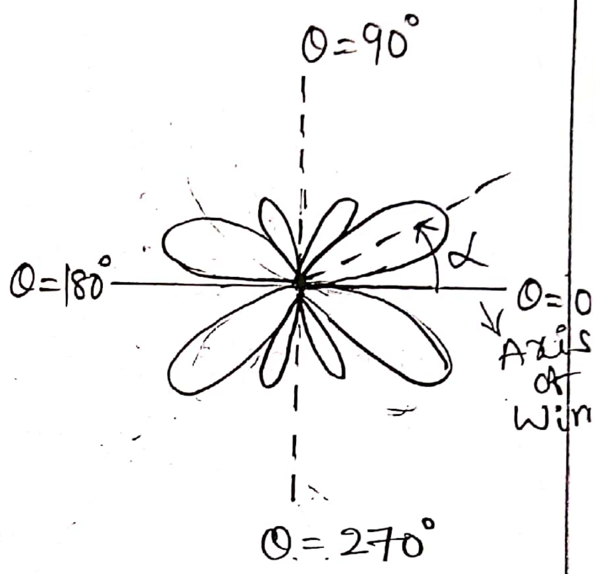


Depending on if 'n' is even and odd, the directional pattern changes.

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



n=3

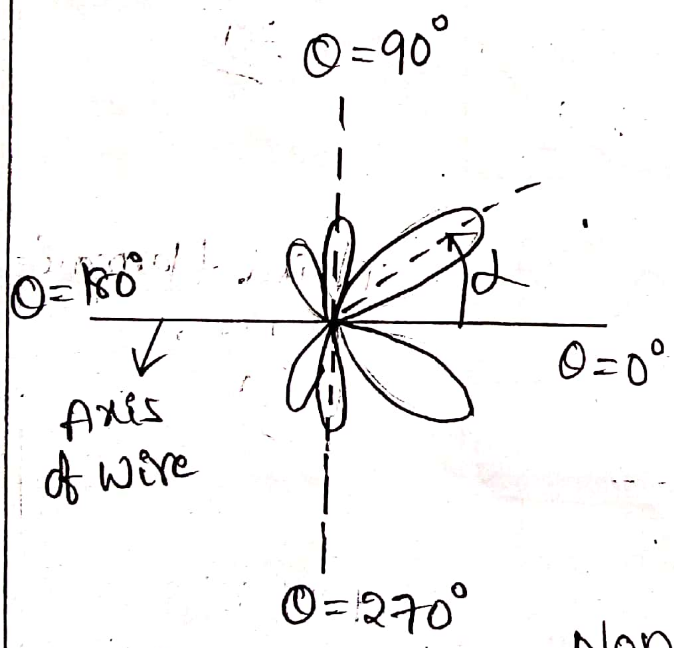


n=4

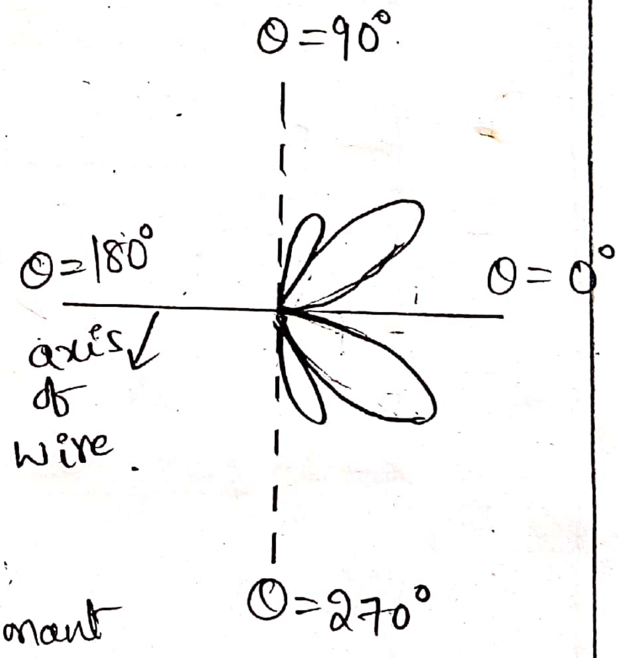
n=3 → odd
n=4 → even

Resonant long wire Antenna.

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



n=3



n=4

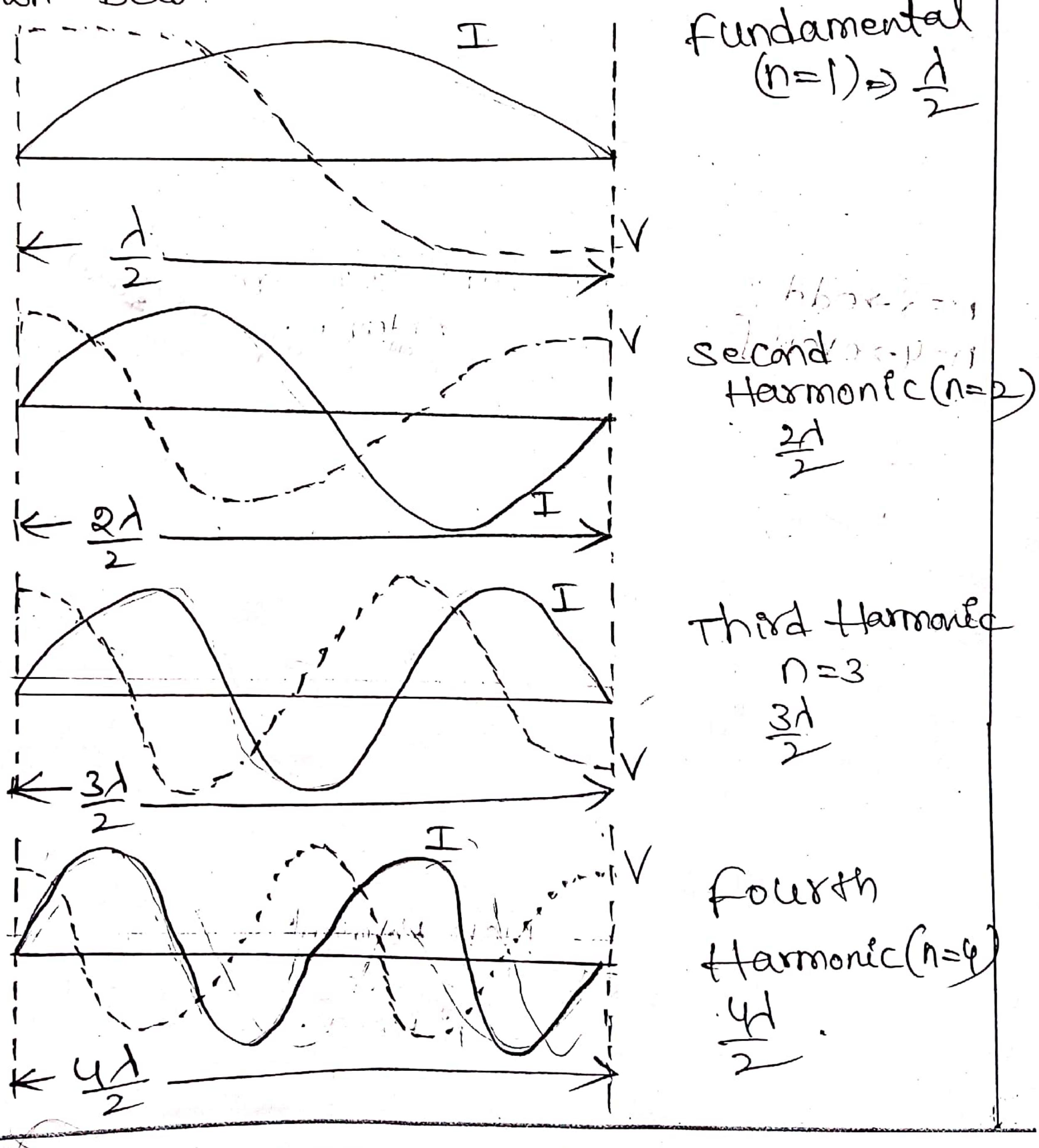
Non Resonant long wire Antenna.

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

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

n = no. of integer multiple half wavelength.

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



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

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

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

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

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

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

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

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

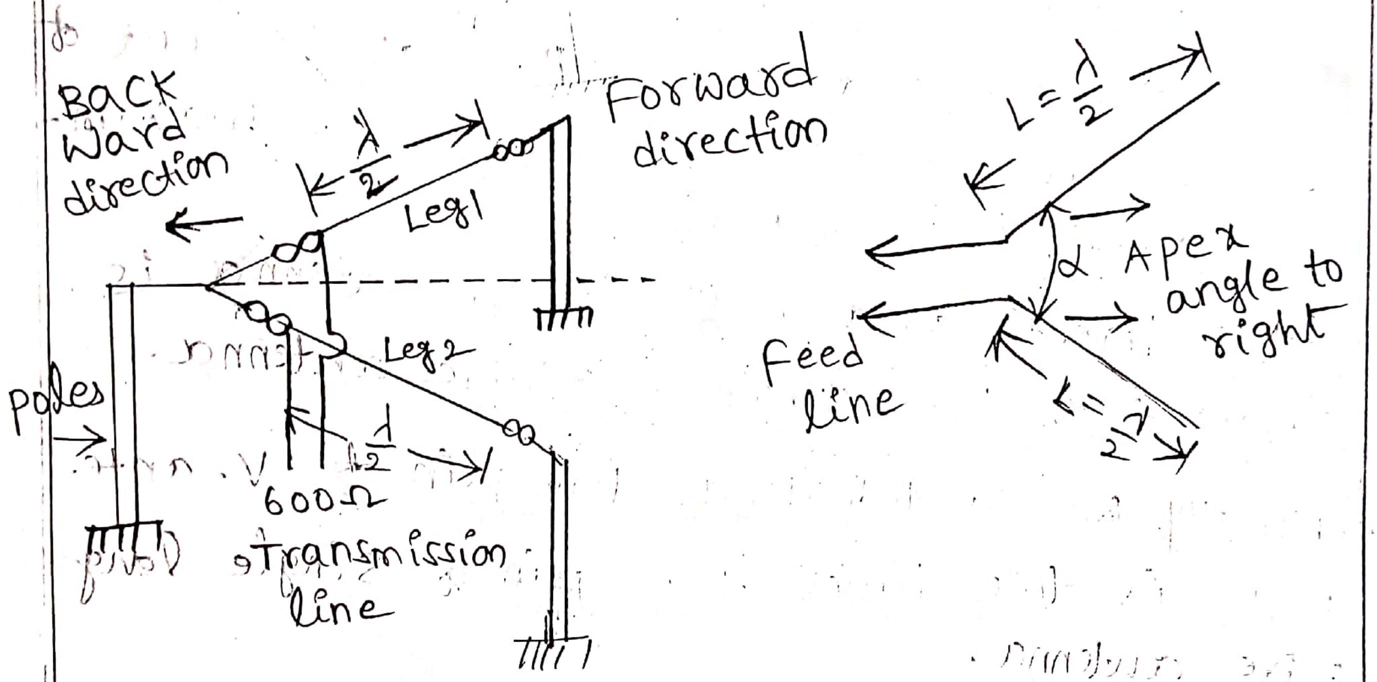
→ The angle of maximum radiation is given by

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

V- antenna :-

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

* The Resonant V- antenna arrangement is given below.

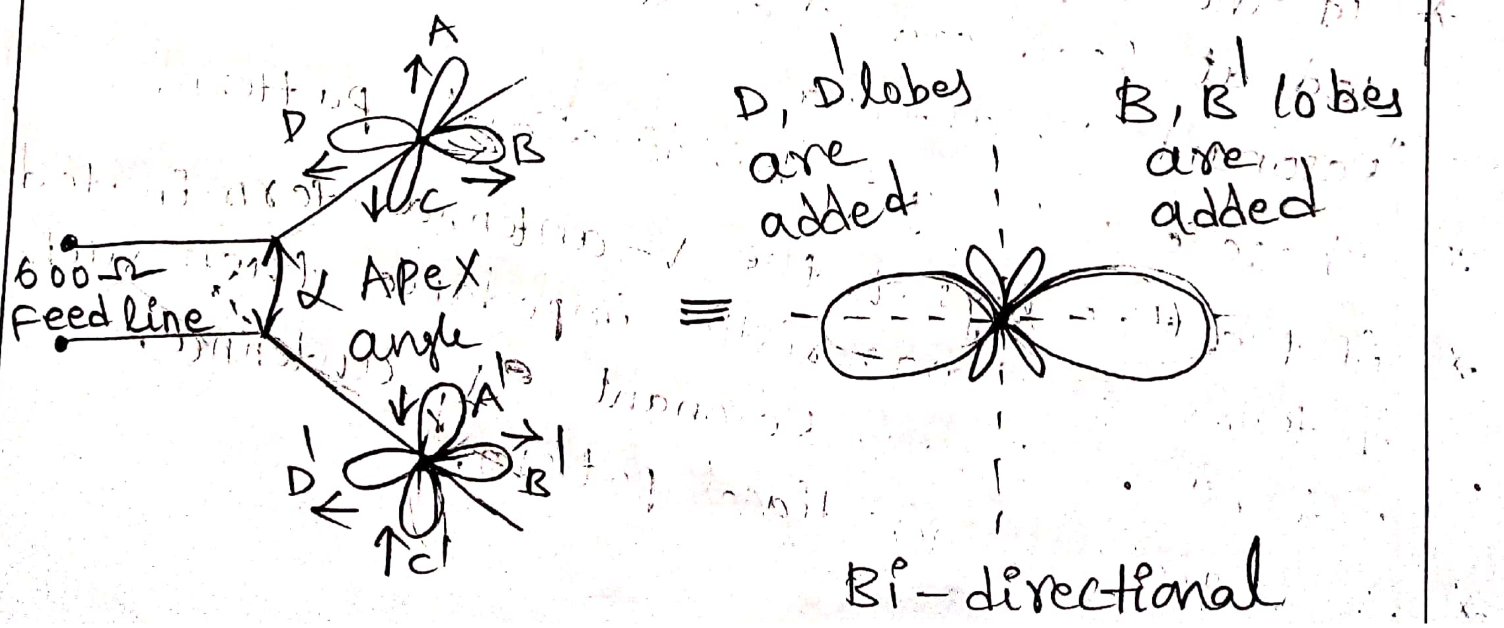


Resonant V- antenna

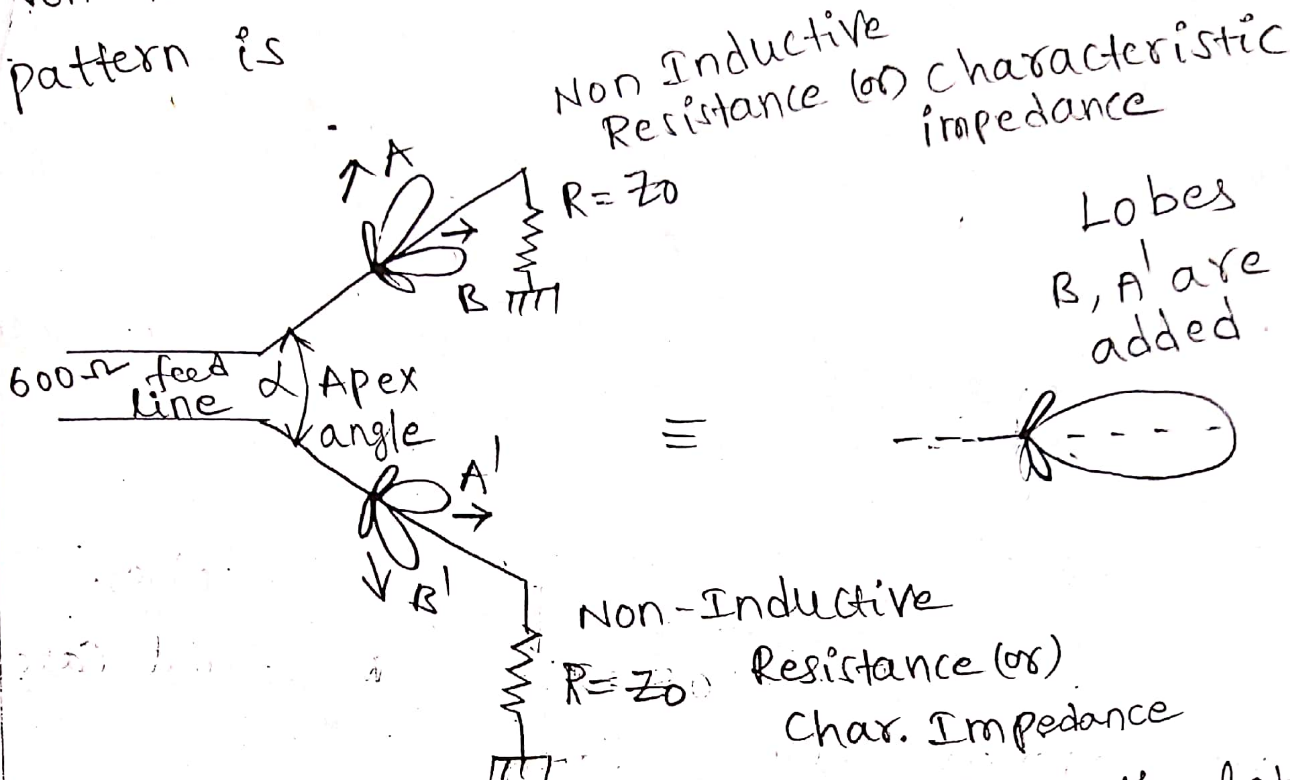
* if the two legs of V- antenna not terminated at load end then such antenna is "Resonant V- antenna.
* Therefore We get bi-directional pattern.
* if the two legs of the V- antenna terminated in terms of characteristic impedance then such antenna is " non - Resonant V- antenna.
* ∴ We get uni-directional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

* The angle between two legs of the V-antenna is called as "apex angle α".
* The apex angle is equal to twice the angle that the cone of maximum direction with ~~width~~ wires (legs) makes by the axis of V-antenna.
* ∴ The two cone angles are adding to get the maximum radiation.
* The two wires are connected at 180° out of phase with each other. So we get maximum directivity and gain.
* The directivity and gain of V-antenna is larger than the single long wire antenna.
* Finally we conclude that the gain of V-antenna is two times the gain of single long wire antenna.

Resonant V-antenna with bi-directional pattern is



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



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

Advantages :-

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

2. It has high directivity & gain

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

Drawbacks :-

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

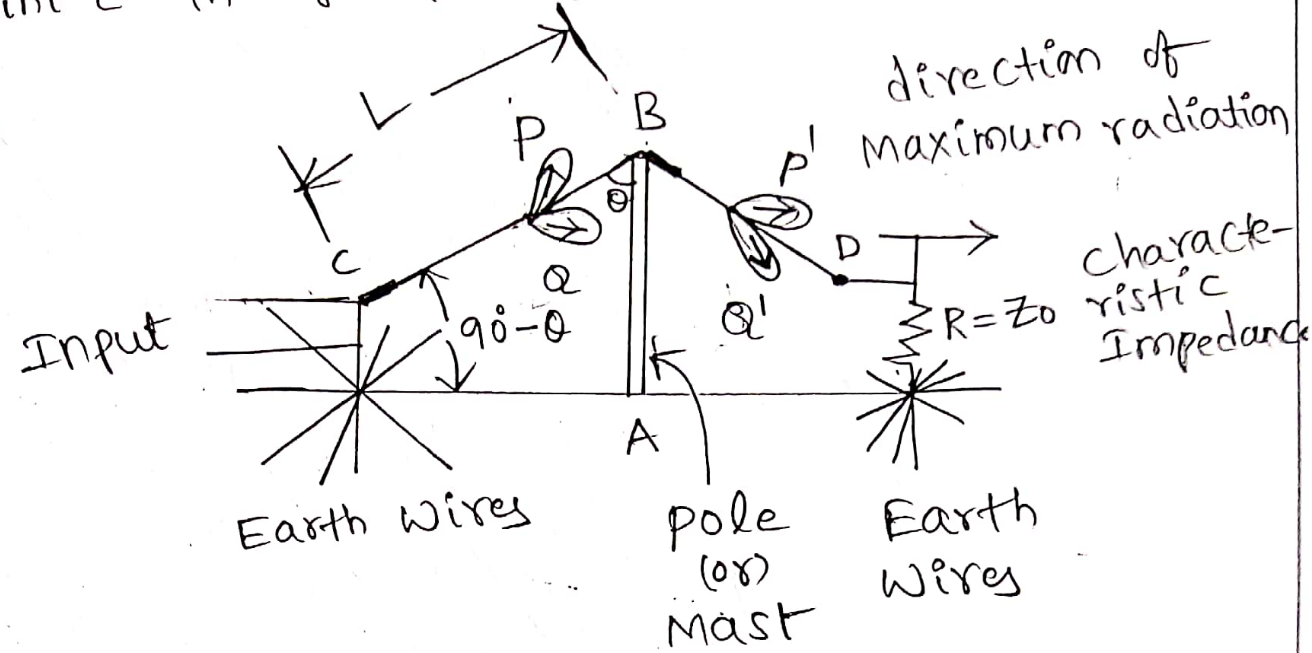
Inverted V- antenna :-

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

The principle and working as given below.

Principle :-

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

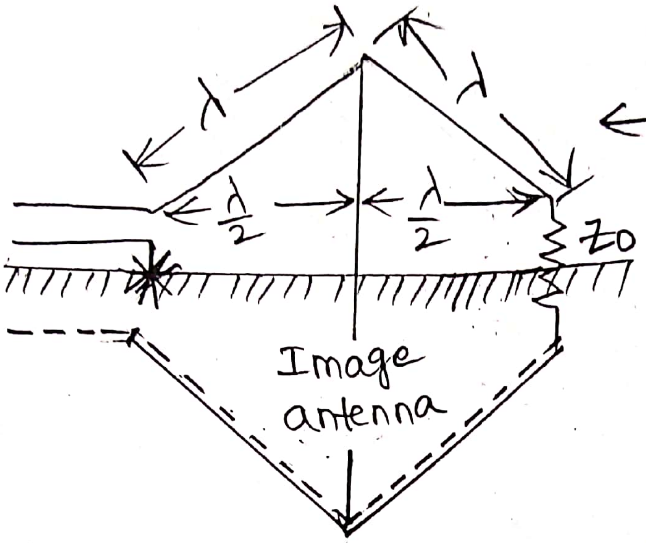


Inverted V-antenna

* one end is connected to no. of radial earth wires, the next end of antenna wire 'D' is connected to earth wires and terminated with characteristic impedance (or) Non-inductive resistance.
* This resistance is typically 400 Ω and adjusted to set the travelling waves in the BCD (or) CBD wire.
* The angle 'θ' is known as "tilt angle". It is given by
  (i) The angle of major lobe corresponding to $\frac{L}{\lambda}$
  (ii) The angle of tilt, where the fields from BC, BD combined to give max. gain, directivity

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

Inverted V-earthed antenna is given below.



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

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

Advantages :-

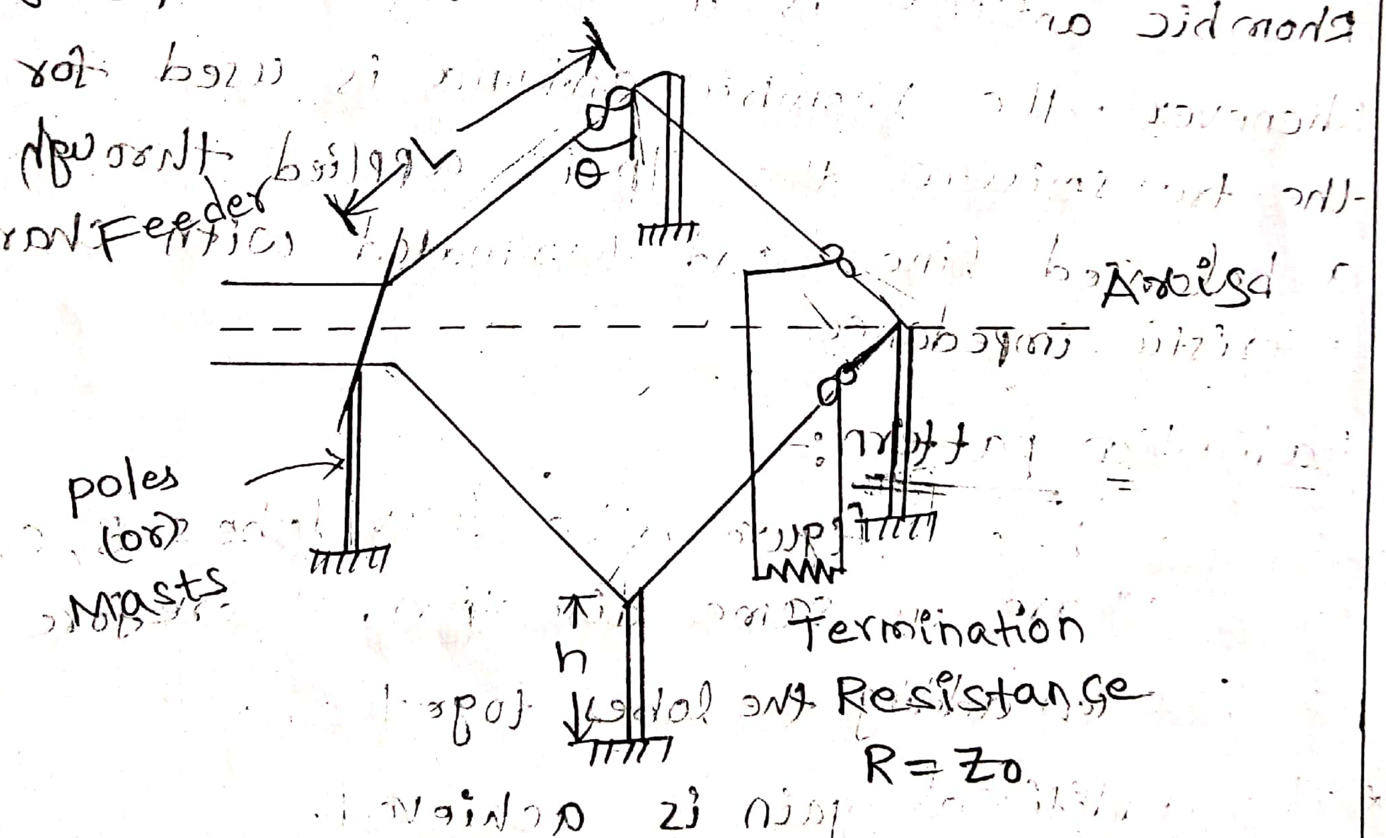
1. The max gain & directivity
2. The Band width is large.
3. It is Better suitable for upper end of high frequency transmission.
4. The signal Receiving is better.

Disadvantages :-

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

Rhombic antenna :- [Diamond Antenna]

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



Rhombic Antenna

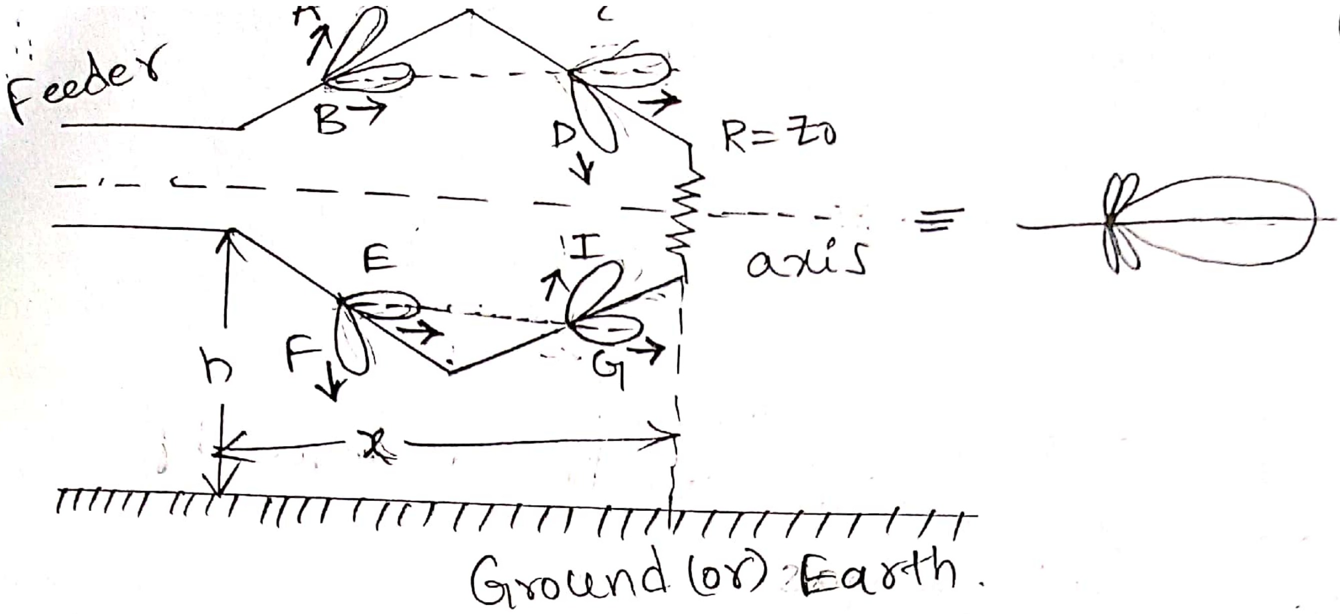
The tilt angle (θt) is approximately equal to (90° − θ). Where 'θ' is angle of major lobe.

* Rhombic antenna consists of four sides are arranged in the form of diamond (or) rhombus.
* The Rhombic antenna is obtained by connecting two inverted V-antennas in parallel.
* The inverted V-antenna and its image antenna gives Rhombic antenna.
* Rhombic antenna is installed on the horizontally over the ground at height of h.
* The polarized waves from the horizontal Rhombic antenna is in the rhombus plane.
* Whenever, the rhombic antenna is used for the transmission, the i/p is applied through a balanced line and terminated with characteristic impedance.

Radiation pattern:-

* In the below figure, the four lobes B, C, E, G all are in same direction. therefore combine (or) adding the lobes together.
* The additional gain is achieved.
* the lobes A, D, F, I are in opposite direction and cancelled these lobes.

∴ We get unidirectional radiation pattern.



Advantages:-

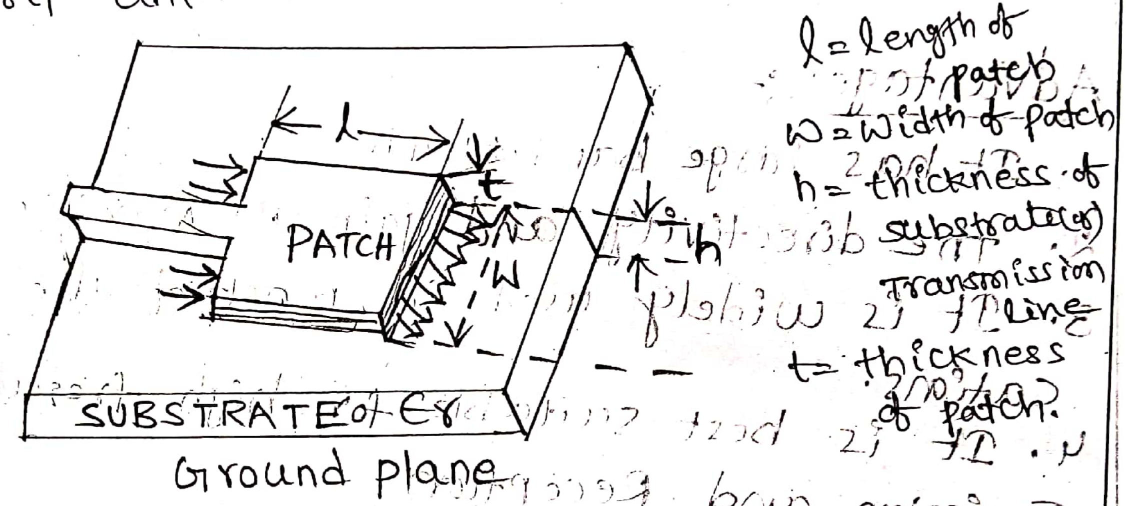
1. It has large band width
2. The directivity and gain is maximum
3. It is widely used in most of the communications.
4. It is best suitable for high frequency Transmission and Reception.

disadvantages:-

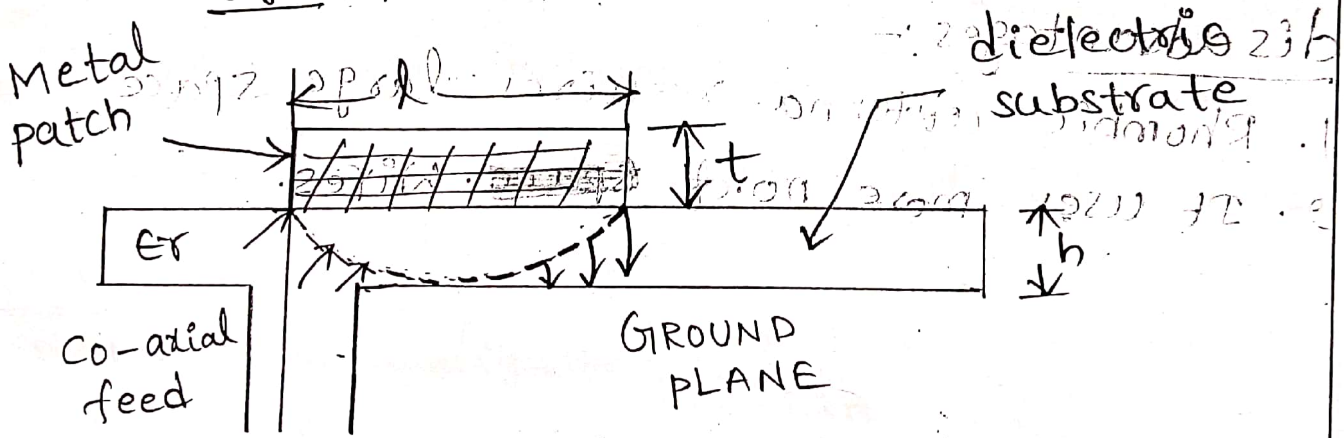
1. Rhombic antenna requires large space
2. It uses more no.of ~~Space~~ wires.

Micro strip antennas :- [patch Antennas].

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



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



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

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

The Radiation Conductance is

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

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

Advantages :-

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

Dis advantages :-

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

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

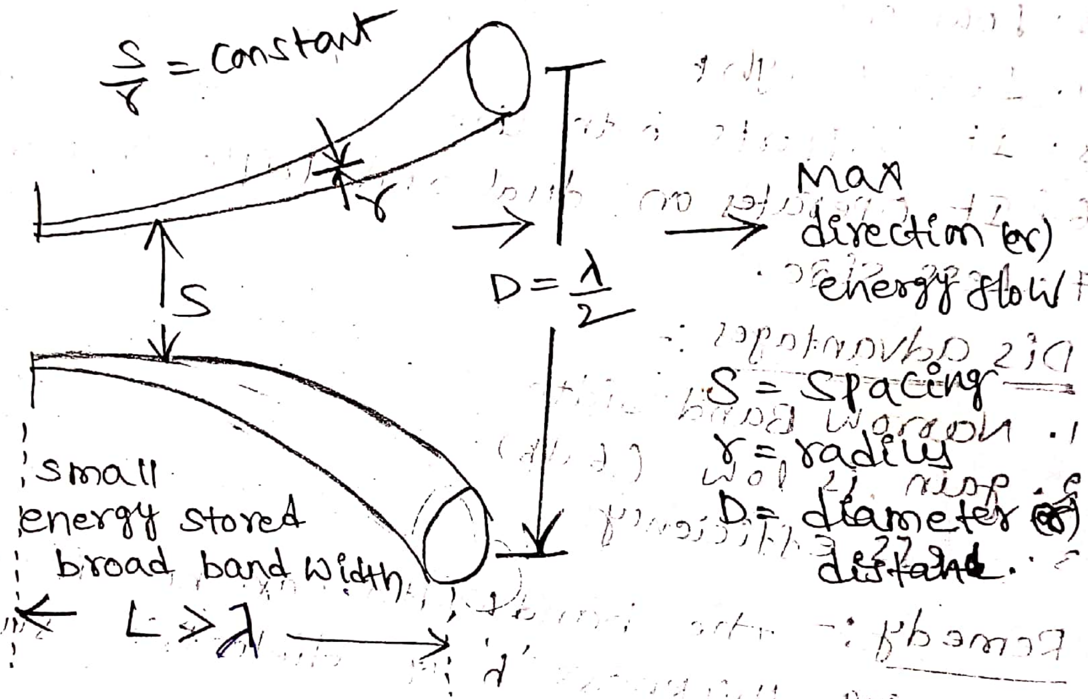
* By increasing Inductance
* Adding reactive components to reduce VSWR. (Voltage Standing Wave Ratio)

Features (Applications)

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

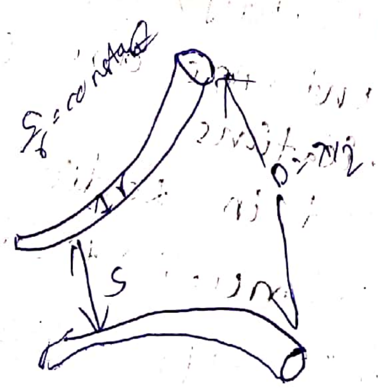
Broad band Antennas:-

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



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

EX:- Helical antennas.

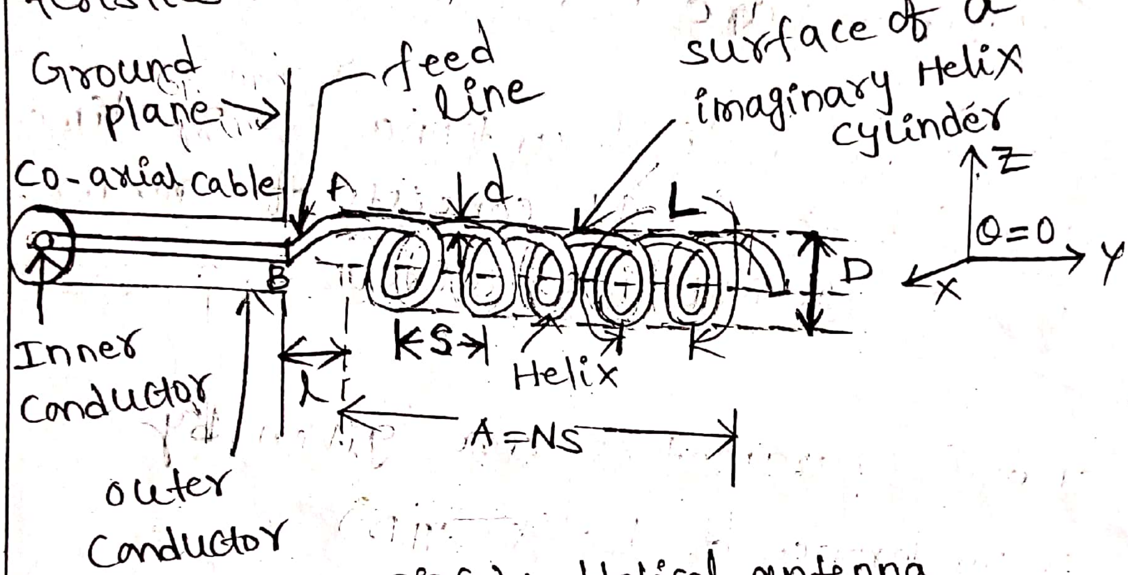


Helical Antenna :-

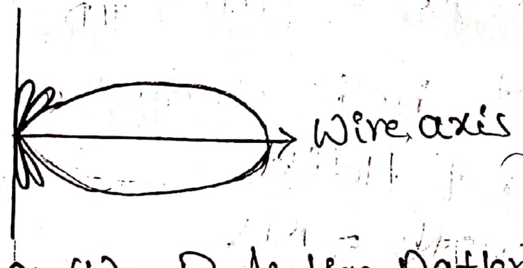
significance :-

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

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



fig(a) :- Helical antenna



fig(b):- Radiation pattern.

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

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

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

* The geometric parameters are given by

C = circumference of helix (πD)

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

d = diameter of helix conductor

D = diameter of Helix

A = Axial length = NS

N = no. of Turns

S = Turn spacing

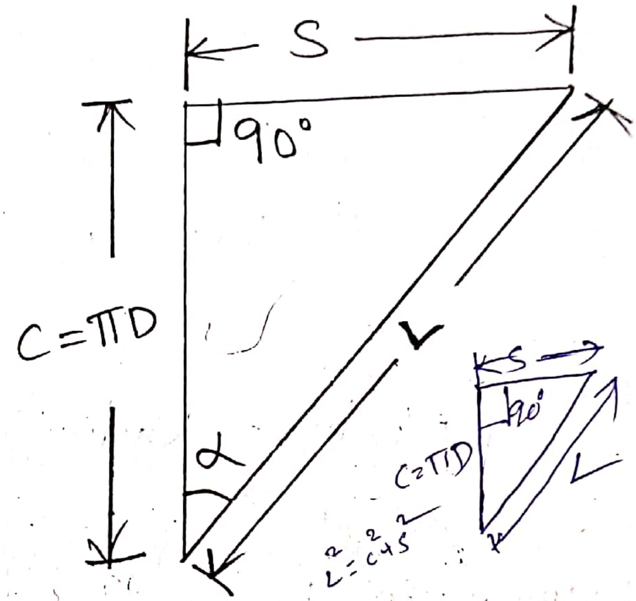
L = Turn Length

l = spacing of helix from ground plane

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

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

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



According to pythogorous theorem

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

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

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

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

$\therefore$ The pitch angle is 'α'

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

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

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

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

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

Design considerations for monofilar helical antenna:-

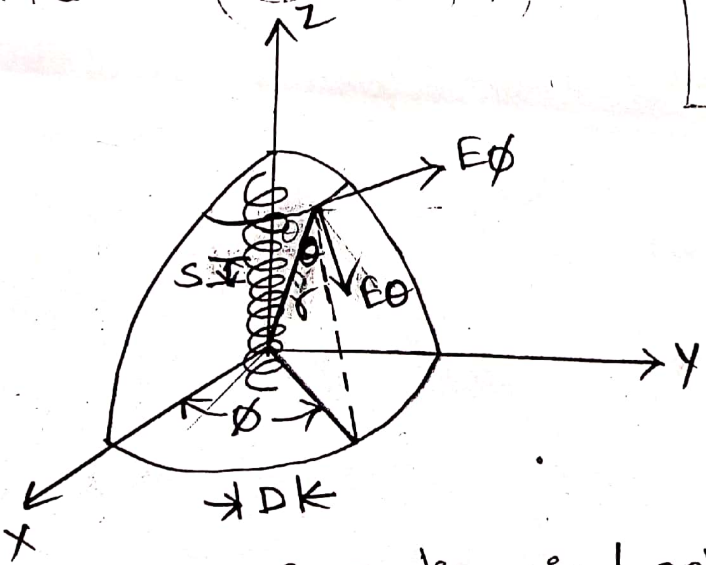
> The helical antenna may be radiate in two modes of radiation.

They are (i) Normal mode (or) perpendicular mode

(ii) Axial mode (or) End fire mode (or) beam mode

) Normal mode of Radiation :-

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



helix in 3-dimensional spherical coordinates

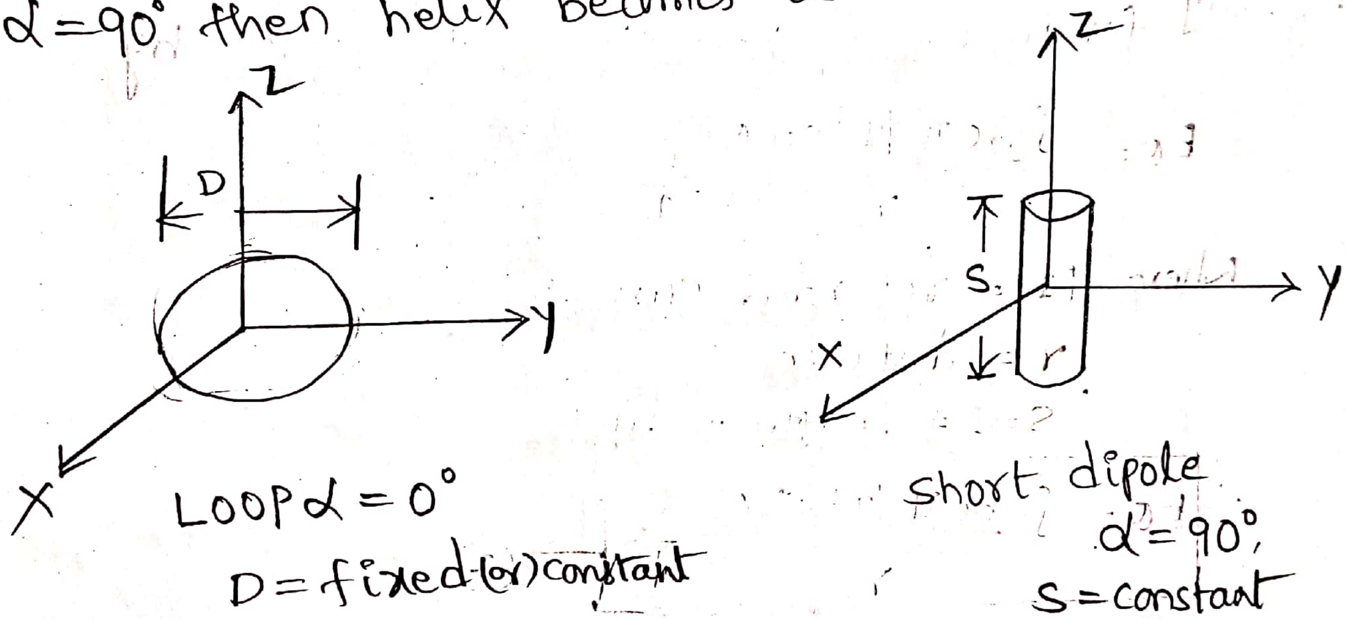
(16)

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

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

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

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



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

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

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

The far field of small loop is given by

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

$|I|$ = retarded current

r = distance

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

similarly far field of a short dipole is given by

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

where $|I|$ = retarded current

r = distance

$S = L$ = Length of dipole

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

The axial ratio (AR) of Elliptical polarization is

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

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

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

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

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

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

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

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

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

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

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

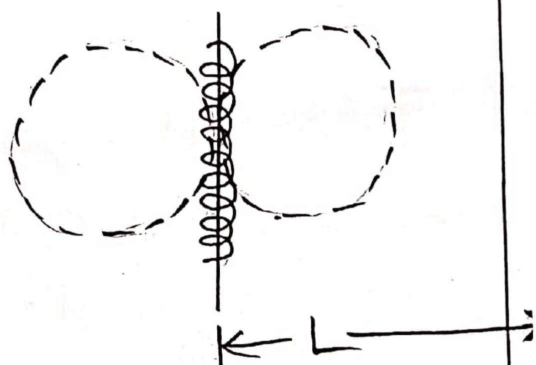
$\therefore$ The pitch angle is given by

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

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

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

This is the pitch angle to get circular polarization.

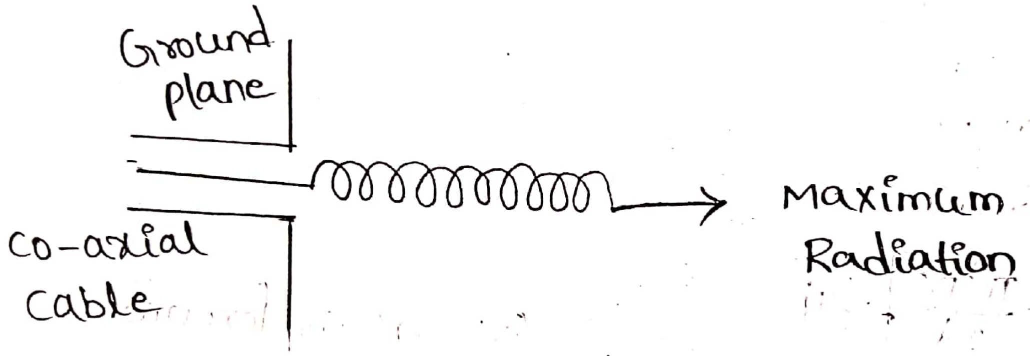


Radiation pattern for Normal mode of Radiation

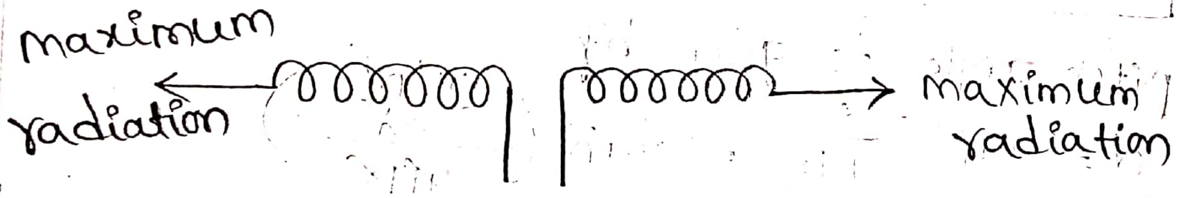
$\therefore$ practically this mode is not suitable and hardly used.

Axial (or) Beam mode of Radiation :-

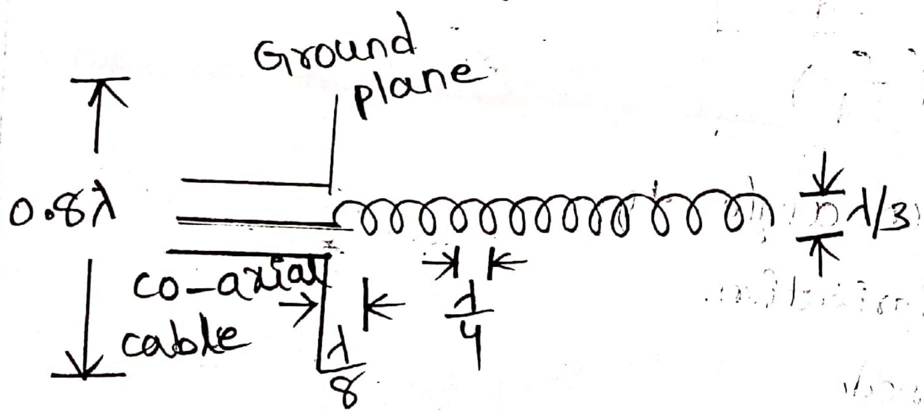
* In axial mode of radiation, the radiation field is maximum in end-fire direction.
* That is the direction of maximum radiation is co-incidence with Helix axis, the polarization is circular (or) nearly circular
* This mode occurs when the helix circumference (c) and spacing (s) are in the order of one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



(a) With Co-axial cable



(b) Two wire Transmission line



(c) Typical dimensions

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

* This mode of radiation is used in most practical applications.

* The axial mode of radiation is produced very easily by raising helix circumference (C) of the order of one wavelength (λ) and spacing (S) is $\frac{\lambda}{4}$.

* The ground plane having atleast half wavelength in diameter.

* The pitch angle 'α' varies from 12° to 18° and optimum pitch angle is 14°.

* The terminal impedance is 100Ω resistive at frequency $C \cong \lambda$ $(\because \lambda = \frac{c}{f})$

* Generally in axial mode, the terminal impedance of helical antenna lies between 100Ω to 200Ω

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

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

The half power beam width is given by

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

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

The beamwidth between first nulls is

BWFN = 2 x HPBW

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

The maximum directive gain (or) directivity is

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

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

Farfield pattern is given by

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

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

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

Features of Helical Antenna :-

(19)

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

Applications of Helical antennas :-

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