

UNIT-3

VHF, UHF And Microwave Antennas-1

Array with parasitic elements- In this concept, let us discuss about antenna array and parasitic elements are considered.

Actually, antenna array is a set of multiple connected antennas which work together as a single antenna to transmit (or) receive radio waves. The individual antenna elements are connected to a single receiver (Rx) (or) transmitter (Tx) by feed lines that feed power to the elements in a specific phase relationship. An antenna array can be achieved higher gain by single antenna. They are various types of antenna arrays such as; end fire array, Broadside array, Colinear array, In all these arrays all the elements are driven by a source. All the individual elements are supplied with a power by means of a transmission line.

Such directional array can be constructed by using some other elements in which the current is induced due to the field in other elements is called "parasitic element".

The effect of parasitic element on the directional pattern of the antenna depends on the magnitude and the phase of induced current in the parasitic element.

Thus ultimately the effect on the direction of pattern depends on the spacing b/w antenna elements and tuning of the parasitic element.

Folded Dipole Antenna:-

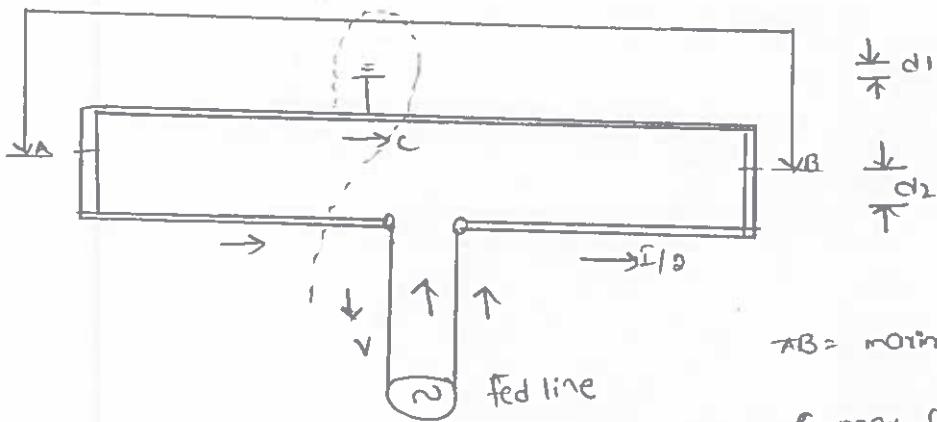
A very important variation of conventional half wave dipole is a folded dipole shown in fig 2.3. In which two half wave dipoles - one continuous and other split at the centre - have been folded and joined together in parallel at the ends. The split dipole is fed at the centre by a balanced transmission line.

The two dipoles, therefore have the same voltages at their ends. The radiation pattern of the folded dipole and a conventional half wave dipole is same.

But, the input impedance of the folded half dipole is higher. It differs from the conventional dipole in two respects. e.g. directivity and bandwidth in bandwidth. The directivity of folded dipole is bi-directional but, because of the distribution of currents in the parts of the folded dipole the input impedance becomes higher.

If, the radii of two conductors are equal, then equal currents flow in both conductors in the same direction. i.e., currents are equal in magnitude and phase in the two dipoles. Since the total power developed in folded dipole is equal to that developed in the conventional dipole, therefore the input (a) terminal impedance of folded dipole is greater than that of conventional dipole.

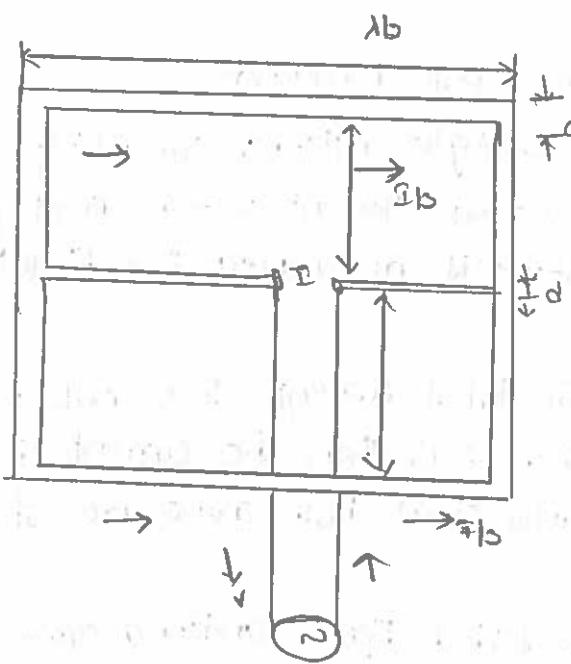
as shown in fig 2.3(b), then only one third of current (or) total radiating current would be supplied at the input terminals and



AB = maximum Current Point

C = max current point (w)
min voltage point

$d_1=d_2$ unit-3(2)



(b) 3 wire folded dipole with current distribution. The currents in the transmission line is equal and opposite and hence have canceling effect.

hence, the input impedance (or) terminal impedance would be 9 times of the impedance of conventional dipole.

$$\text{I.e., } 3^2 \times 73 = 657 \Omega$$

$$\frac{L=469}{f(\text{MHz})}$$

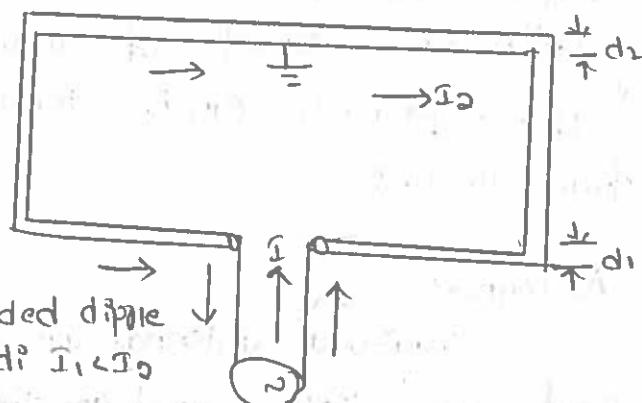


Fig:-23 (c) folded dipole with unequal radii $I_1 < I_2$

$$\text{and } I = I_1 + I_2$$

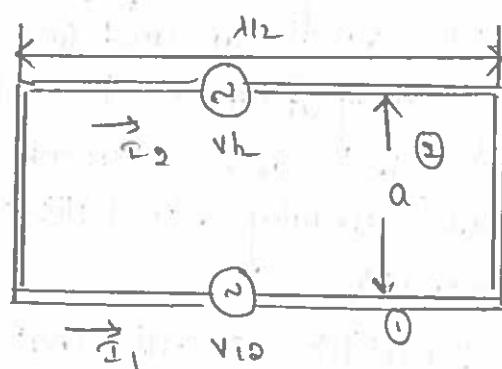


Fig:-24

Characteristics of folded dipole antenna:-

- i) It is basically a single antenna consisting two (or) three elements. The first element is fed directly while second (or) third elements are coupled inductively at the ends.
- * In a straight dipole, the total current is I . But, in folded dipole if current fed is I , then the current in each arm is $I/2$ with condition that both arms are of same dimension.
- * The radiation pattern of folded dipole antenna same as that of same straight dipole.
- * The input impedance of a folded dipole, is 4 times that of straight dipole.
i.e., $R_{Input} = 4(73) = 292 \Omega$
- * The spacing between arms of the folded dipole is very small and it is of the order of $\frac{\lambda}{100}$.
- * In yagi-uda, the folded dipole is used extensively, as an active element.
- * By using different diameter of two arms of folded dipole, the impedance can be transformed by factor ranging from 1.5 to 25.

Yagi-Uda Antenna:-

Yagi-Uda antennas are the most high gain antennas and are known and are the known after the names of professor S.Uda and H.Yagi. It consists of a driven element, a reflector and one (or) more directors. i.e, Yagi-Uda is an array of driven element and one (or) more parasitic elements. The driven elements are a resonant half-wave dipole usually a metallic rod at a frequency of operation.

The parasitic elements that are arranged parallel to the driven element and at the same line of straight level. They are arranged collinearly and close together as shown in fig 2.5 with one reflector and one director.

* The parasitic elements receives their excitation from the voltages induced in them by the current flow in the driven element. The phase and currents flowing due to the induced voltage depend on the spacing between the elements and upon the reactance of the elements. To obtain required phase shift an element can be made either inductive or capacitive.

The reactance may be varied by dimensioning the length of parasitic element. The spacing between and parasitic elements are usually used in practice, are of order of $\frac{1}{10}$.

i.e., 0.01 to 0.15 λ. The parasitic element in front of driven element is known as director and its number may be more than one, whereas the element in

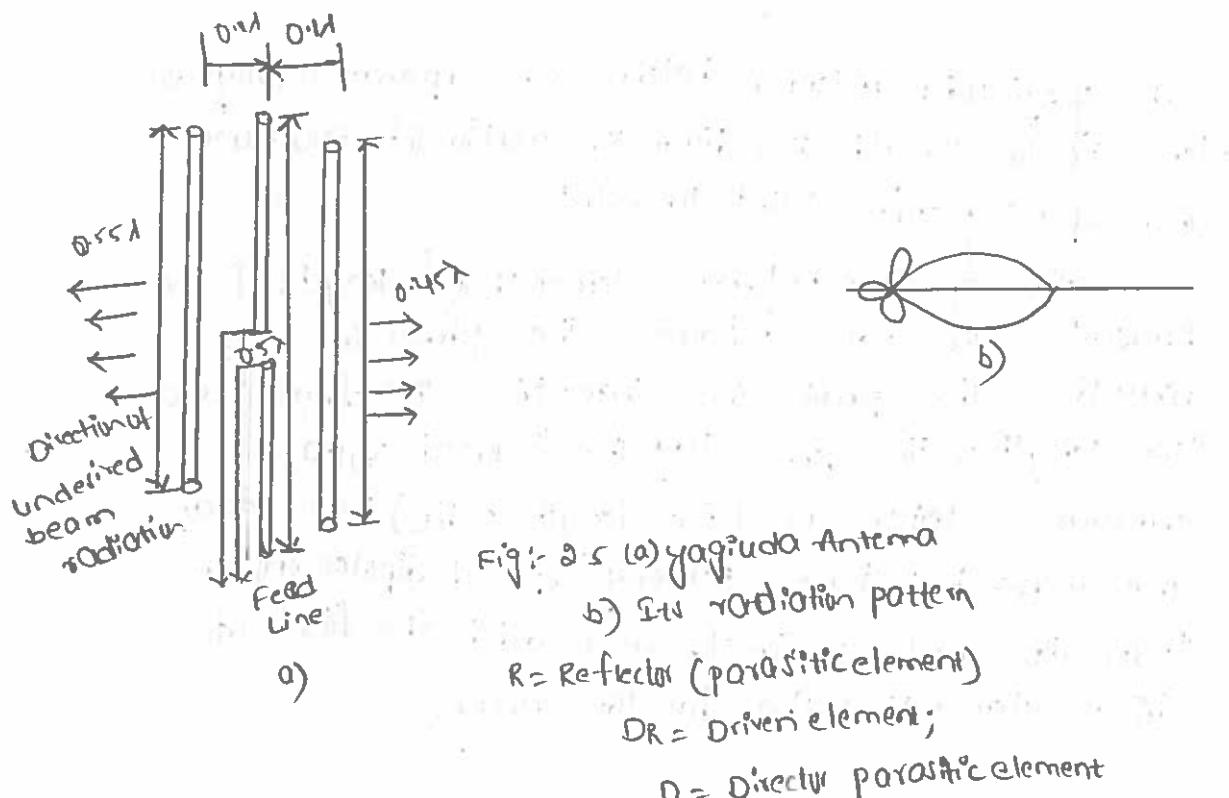


Fig:- 2.5 (a) Yagi-Uda Antenna
b) Its radiation pattern

R = Reflector (parasitic element)

DR = Driver element;

D = Director parasitic element

back of it is known as 'reflector'. Generally, both directors and reflectors are used in the same antenna. The reflector is 5% more and director is 5% less than the driven element. which is $\frac{1}{2}$ at resonant frequency.

$$\text{Reflector length} = \frac{500}{f(\text{MHz})} \text{ feet}$$

$$\text{Driven element length} = \frac{475}{f(\text{MHz})} \text{ feet}$$

$$\text{Director length} = \frac{455}{f(\text{MHz})} \text{ feet}$$

The above expression provides average length

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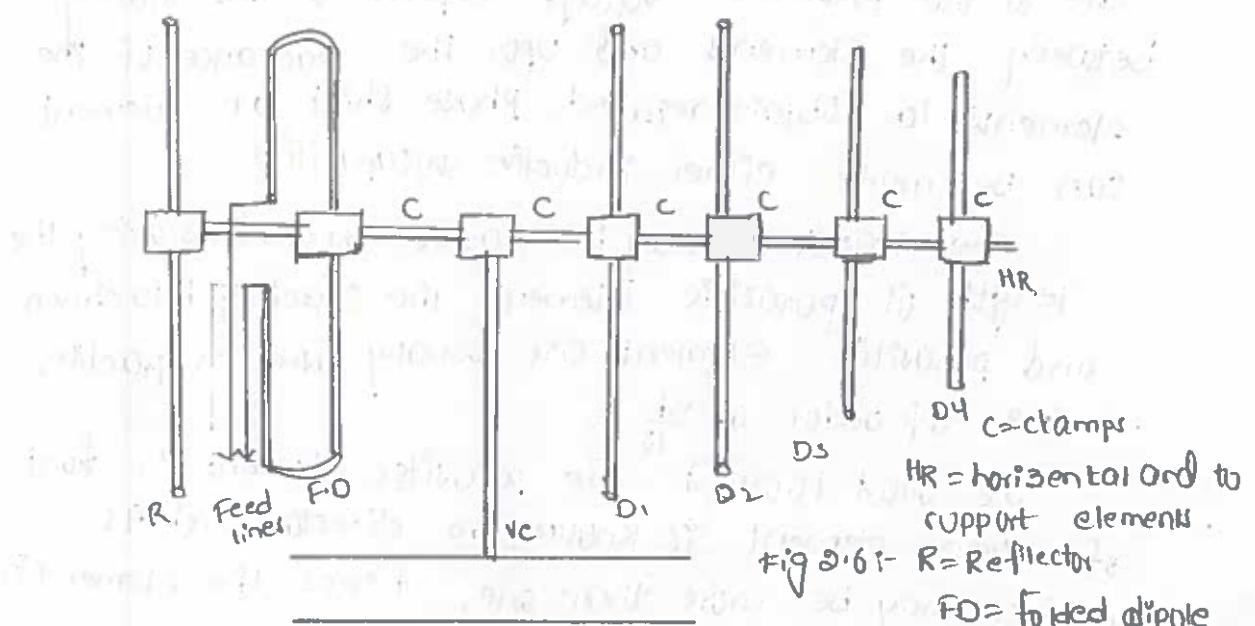


Fig 2.6.1 - R = Reflector

FD = folded dipole

D₁, D₂, D₃ and D₄ = Directly

VR = vertical rod to support

elements of length (λ) diameter ratio of 200 to 400 and spacing from 0.101 to 0.201.

The spacing between elements and lengths of the parasitic elements determine the phases of the currents. The phases of currents in the former case (i.e., length $> \lambda/2$) will lag the induced voltage.

Whereas in latter case (i.e., length $< \lambda/2$) will lead the induced voltage, properly spaced dipoles shorter than $\lambda/2$ acts as director and add the fields of driven elements in the director away.

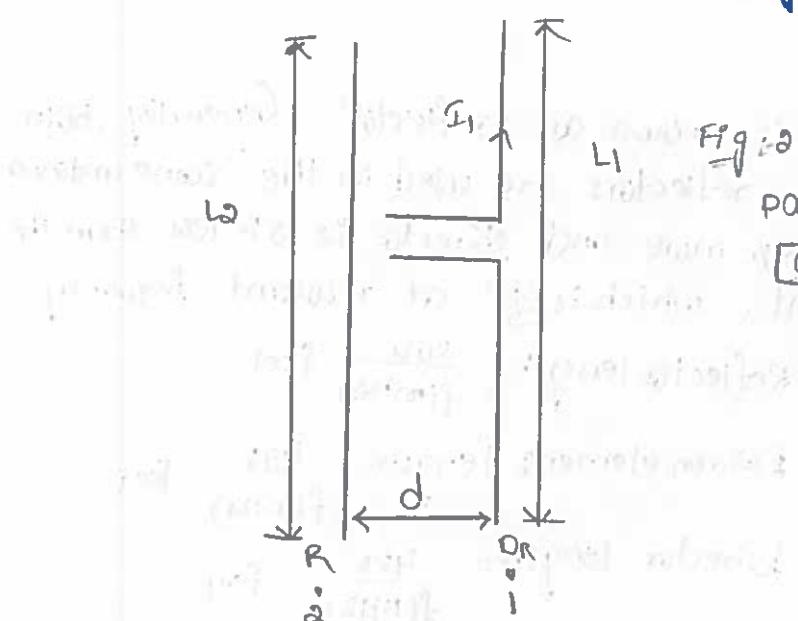
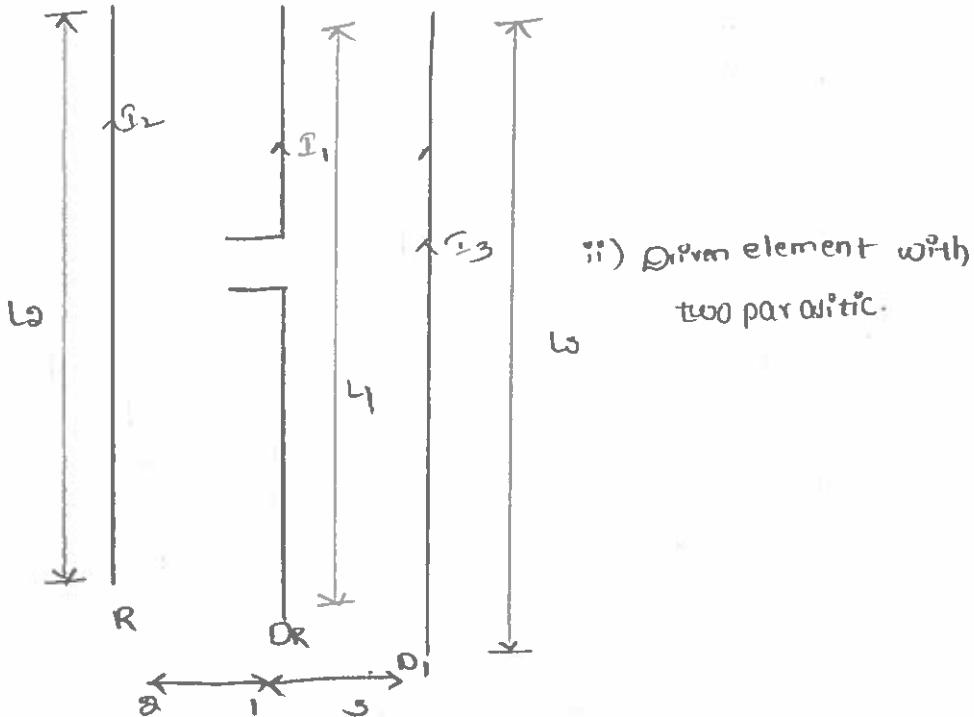


Fig 2.7. i) Drive element with parasitic

[\square = Horizontal plane
○ = vertical plane]



from the driven element.

The driven element radiates from front to rear, part of this radiation induces current in the parasitic elements which, in turn reradiate virtually all the radiation.

By suitable dimensioning the length of parasitic elements and spacing b/w two elements the radiated energy is added up in front and tend to cancel the backward direction. If the distance b/w parasitic and driven element is decreased, then it will load the driven element, irrespective of its length.

Helical Antenna:-

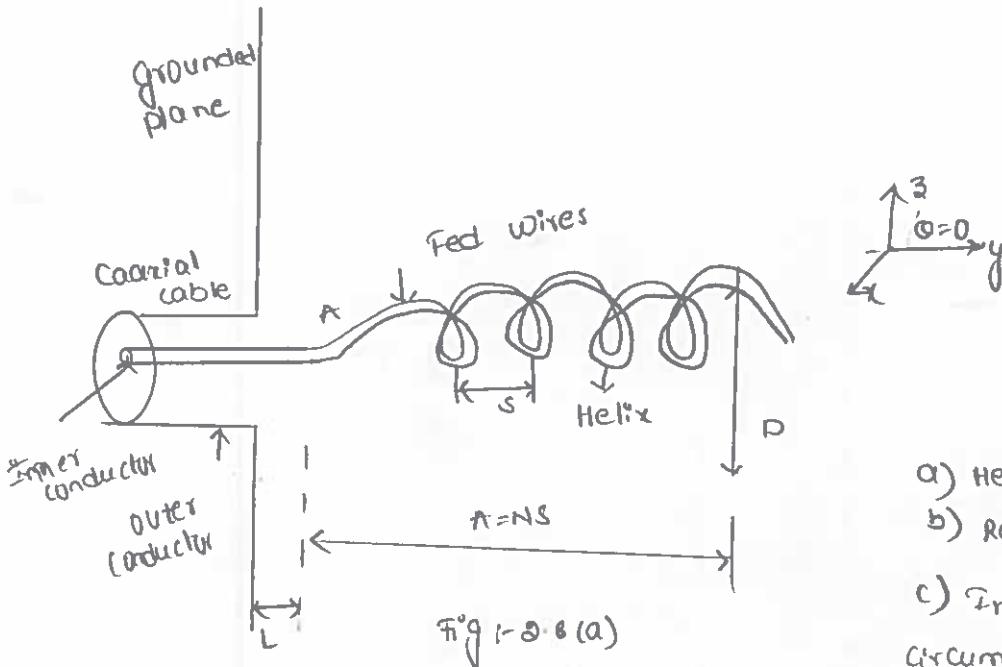
It is another type of basic radiator and perhaps it is the simplest antenna to provide circularly polarized waves. Helical antenna is broad band VHF and UHF antenna to provide circular polarization characteristics.

It consists of a helix of thick copper wire in the shape of screw thread and used with a flat metal plate called "ground plane(+) ground plate".

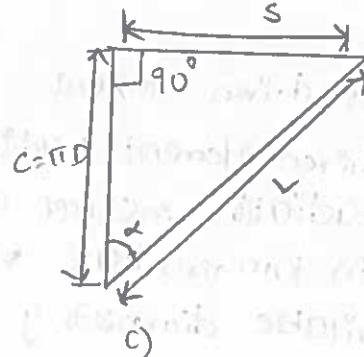
The parameter on which the mode of radiation depends are the diameter of helix 'D' and turn spacing 's'. The dimensions of the helix are shown in below.

$c = \text{circumference of helix} (\pi D)$

$\alpha = \text{pitch angle} = \tan^{-1}\left(\frac{s}{\pi D}\right)$



- a) Helical Antenna
 b) radiation pattern of Helical Antenna
 c) Inter relation between circumference, turn length and pitch angle.



d = diameter of helix conductor

A = axial length = Ns

N = Number of turns

L = length of one turn

t = spacing of helix from ground plane.

For, 'N' turns of helix the total length of the antenna is equal to Ns and circumference πD . If one turn of helix is unrolled on a free surface, the Circumference (πD), spacing (s), by triangle shown in fig 2.8(c).

$$L = \sqrt{s^2 + t^2} = \sqrt{s^2 + (\pi D)^2}$$

The pitch angle is the angle b/w a line tangent to the helix wire and the plane normal to the helix axis. pitch angle is important parameter of the helix and can be calculated from the triangle shown in fig 2.8(c) as

$$\tan \alpha = \frac{t}{s} = \frac{s}{\pi D}$$

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

The properties of helical antenna can be described in terms of these geometric parameters. The different radiation characteristics are obtained by changing these parameters in relation to wavelength.

A helical antenna may radiate in many modes but prominent modes of radiation are two.

i.e., normal (or) perpendicular mode of radiation and axial (or) endfire mode of radiation.

⇒ Normal mode of Radiation:-

In the normal mode of radiation, the radiation field is maximum in broadside i.e., in the direction of polarized waves. This mode of radiation is obtained if the dimensions of the helix is small compared with wavelength.

i.e., $\lambda \ll R$. The bandwidth of such a small helix is very narrow and the radiation efficiency is low.

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

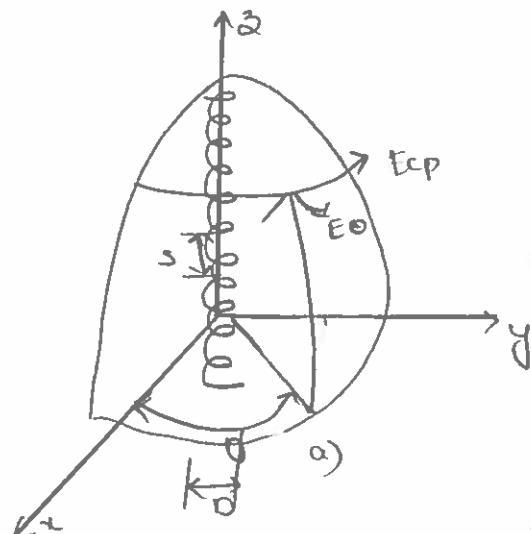
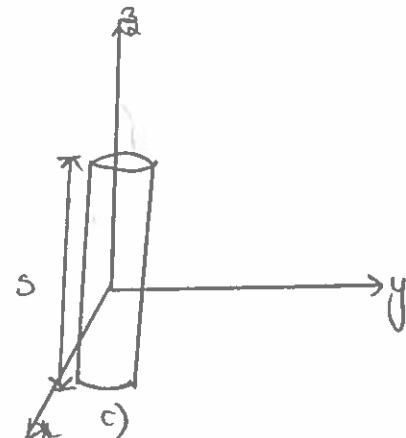
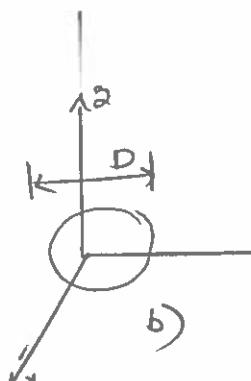


Fig:-2.9 a) Helix antenna in spherical coordinate
b) loop $\alpha = 0^\circ$
c) short dipole $s = \text{Const} \cdot d = q_1$
Helix antenna and its limiting conditions.



current in phase along the helix axis. Some type of phase shift and intervals are required which put practical limitation. The radiation pattern is a combination of the equivalent radiation from the short dipole.

Positioned on the same helix and a small loop which is also coaxial with the helix axis. It is because pitch angle $\alpha=0$ corresponds to loop and when $\alpha=90^\circ$ the helix becomes a linear antenna as illustrated in fig. The loop and linear antenna are the limiting case of helix. Thus in a helix of

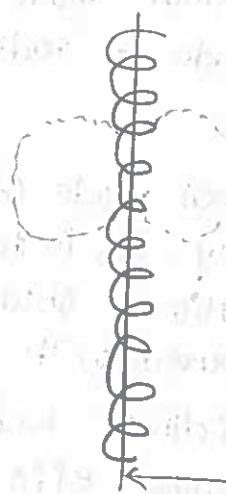
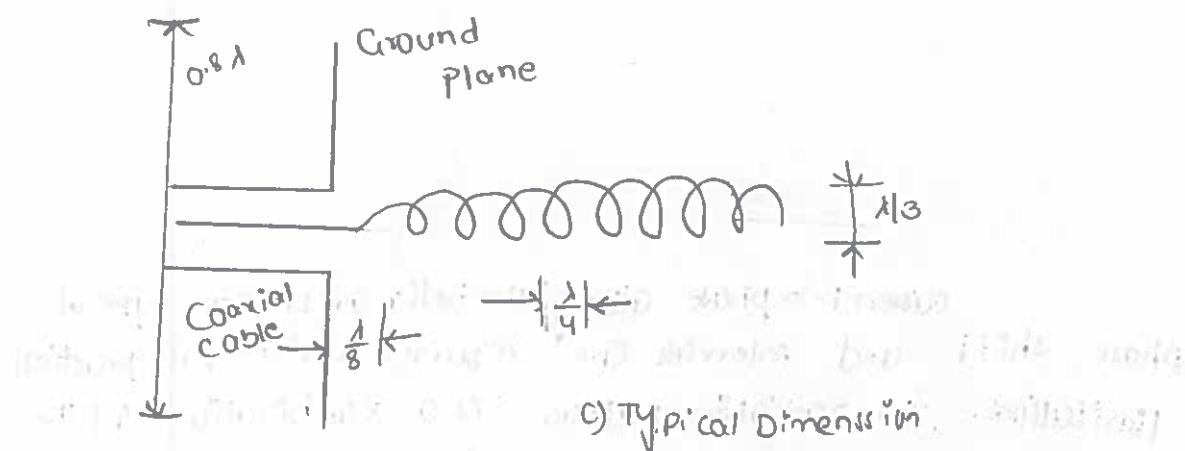
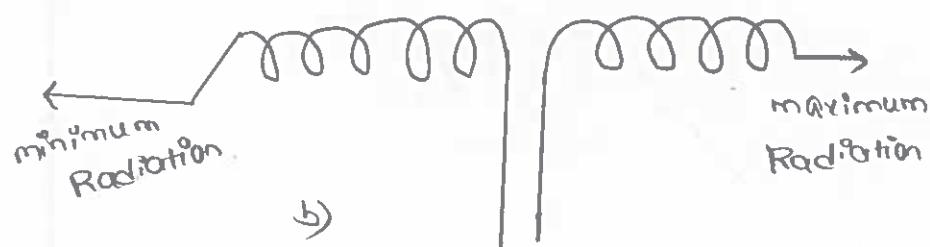
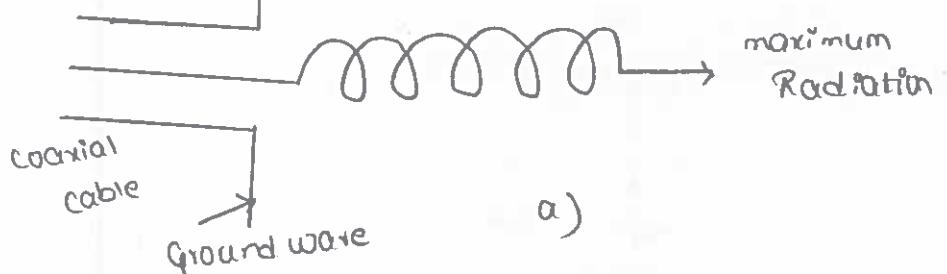


Fig :- 2.10 Normal mode of radiation
(Circular polarization)



c) Typical Dimension

Fig :- 2.11 Arrangement for generating axial mode.

fixed diameter, if $s \rightarrow 0$ helix collapses to loop and if $s = \text{constant}$ and $D \rightarrow 0$, the helix straightens into a linear conductor. The radiation pattern of the two equivalent radiators are same. However, the polarizations are at straight right angle and phase angle at any point in space are 90° apart.

$$\begin{aligned} AR &= \left| \frac{E_\theta}{E_\phi} \right| \\ &= \left| \frac{j 60\pi [I] \sin\theta}{r} \cdot \left(\frac{s}{r} \right) \right| \\ &\approx \left| \frac{120\pi^2 [I] \sin\theta}{r} \cdot \frac{1}{\lambda} \right| \\ &= \frac{S_A}{8\pi A} \\ \Rightarrow AR &= \frac{S_A}{8\pi A} \end{aligned}$$

substituting value of $\lambda' \text{ as } \frac{\pi D}{4}$

$$\Rightarrow AR = \frac{S_A}{8\pi \left(\frac{\pi D}{4} \right)} = \frac{4S_A}{8\pi^2 D}$$

$$\Rightarrow AR = \frac{4S_A}{8\pi^2 D}$$

Now depending on the values AR, we get 3 conditions.

Condition 1:- When, $AR=0$

the elliptical polarization becomes linear horizontal polarization.

Condition 2:- When, $AR=\infty$

the elliptical polarization becomes linear vertical polarization.

Condition 3:- When, $AR=1$

then, the elliptical polarization becomes circular polarization.

Thus, the condition for the circular polarization is given as;

$$\begin{aligned} AR &= 1 \\ &= \left| \frac{E_\theta}{E_\phi} \right| = \frac{8\pi}{\pi D} \\ \text{i.e., } |E_\theta| &= |E_\phi| \end{aligned}$$

hence, we can write

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

$$\text{ie, } s = \frac{\pi^2 D^2}{2\lambda} = \frac{C}{2\lambda}$$

where, C = Circumference $= \pi D$

Hence, the pitch angle for the circular polarisation is the given by;

$$\begin{aligned}\alpha &= \tan^{-1}\left(\frac{f}{\pi D}\right) \\ &= \tan^{-1}\left(\frac{\pi^2 D^2}{2\lambda}\right) \\ &= \tan^{-1}\left(\frac{\pi D}{2\lambda}\right) = \tan^{-1}\left(\frac{f}{2\lambda}\right) \\ \Rightarrow \alpha &= \tan^{-1}(4/\lambda)\end{aligned}$$

This is the condition for pitch angle to get circular polarisation. This mode of operation is very narrow in bandwidth and radiation efficiency is very small.

Horn Antenna:-

A horn antenna is most widely used simplest form of the microwave antenna. The horn antenna serves as a feed element for communication dishes and satellite tracking throughout the world. As it was widely used at microwave frequencies it may be considered as an aperture antenna.

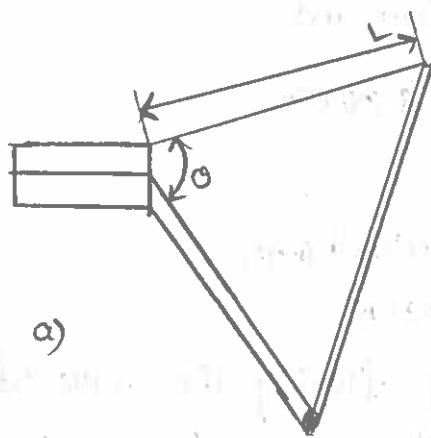
A horn antenna may be regarded as a flared out (or) opened out waveguide. A waveguide is capable of radiating radiation into open space provided the same is excited at one end and opened at the other end.

In a waveguide a small portion of the incident wave is radiated and large portion is reflected back by open ckt.

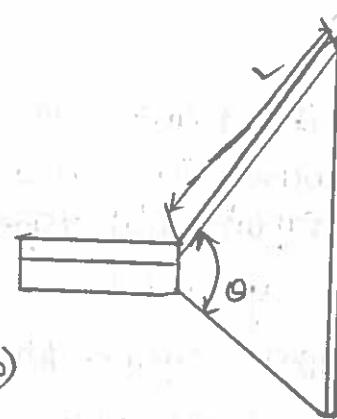
The open ckt is discontinuity which matches the waveguide to space very poorly. Besides, deflection around the edges will provide a poor radiation and an non-directive radiation pattern.

If the waveguide is terminated by any type of the horn antenna the abrupt discontinuity

existed is replaced by a gradual transformation, in all



(a)



(b)

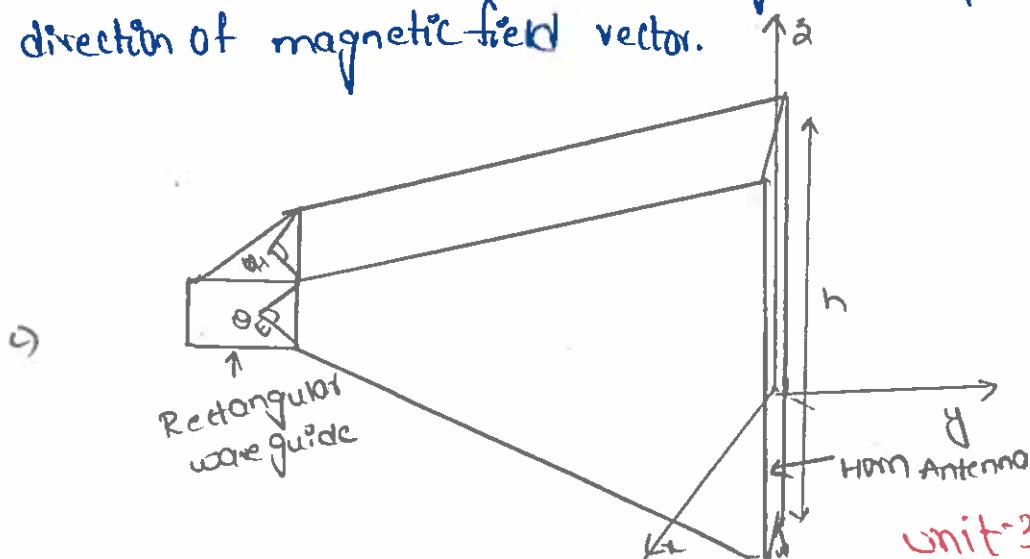
The energy incident in forward direction in the waveguide will now be radiated, provided the impedance matching is proper.

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 classified as sectoral horn and pyramidal horn.

A sectoral horn is obtained if the flaring is done in one direction only classified as 'E' plane and 'H' plane sectoral horn is obtained if the flaring is done in the direction of magnetic field vector.



In both E and H plane sectoral horns the flaring is done along the single wall of the rectangular waveguide in one direction.

The E-plane spectral horn and H-plane spectral horn is shown in figure.

Similar to the rectangular horns, the circular horn antennas

can be obtained by flaring the walls of antenna are of two types namely unical horn antenna and biconical as shown in figure.

Many times, the transmission region between the throat of the waveguide and the aperture is tapered with gradual exponential taper. This minimizes the reflection of the guided waves.

Such horns are called "exponentially tapered horn antenna" as shown in figure below.

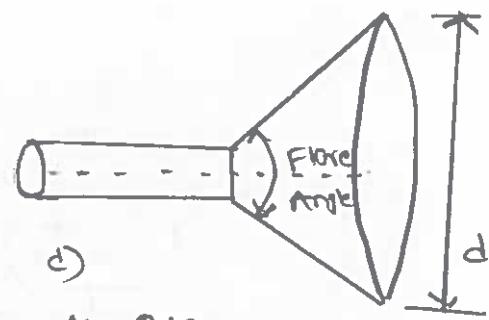
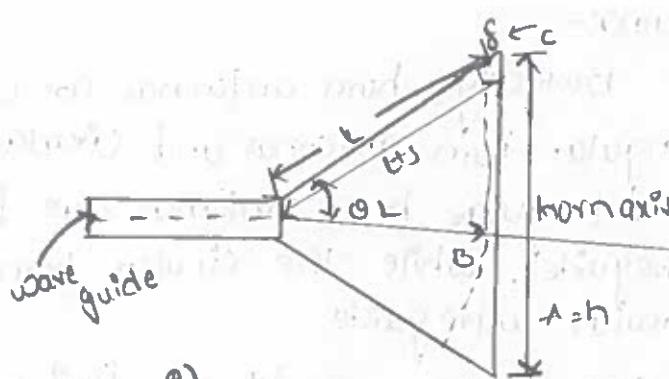


fig-2.12

Many times, the transmission region between the throat of the waveguide and the aperture is tapered with gradual exponential taper. This minimizes the reflection of the guided waves.

Such horns are called "exponentially tapered horn antenna" as shown in figure below.



(c)

a) sectoral H-plane horn

b) sectoral E-plane "

c) pyramidal horn

d) conical horn

e) path differences

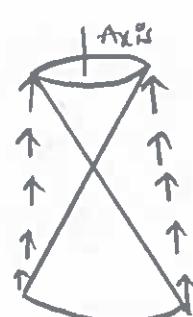
L = Axial length

A = Aperture

θ = flare angle

Fig 2.2(a) to f) important horn shapes.

f) conical horn



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Design equations of Horn Antenna-

since, the waveguide impedance and free space
are not equal. Hence, to avoid standing wave ratio,
flaring of walls of waveguide is done, which besides
matching impedance also provide concentration radiation
pattern i.e., greater directivity and narrower beam width.
It is flared structure that is given the name
"Electromagnetic horn radiator".

The function of the electromagnetic horn is to
produce an uniform phase front with larger aperture
in comparison to waveguide and thus the directivity is
greater.

From the figure (a) (i.e.)

$$\cos \theta = \frac{L}{L+\delta} \text{ and}$$

$$\tan \theta = \frac{h/\delta}{L} = \frac{h}{\delta L}$$

$$\Rightarrow \theta = \tan^{-1}\left(\frac{h}{\delta L}\right) \text{ and}$$

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

where; δ = permissible phase angle variation
expressed as function of 360° .

From the right angled OBC

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

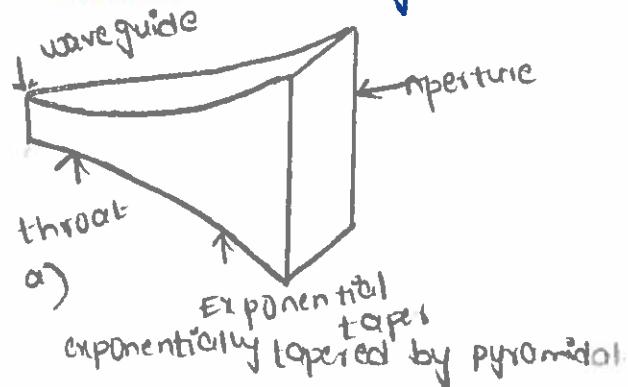
$$\Rightarrow L^2 + \delta^2 + 2L\delta = L^2 + \frac{h^2}{\delta^2}$$

If δ is small, then δ^2 can be neglected

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

$$\Rightarrow L = \frac{h^2}{2\delta^3}$$

the above equation give the design equation.



b)
Exponentially tapered
conical
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