UHF,VHF AND MICROWAVE ANTENNAS-1

P.RAJESH
Dept of E.C.E
JNTUA CE ANANTAPUR

- **UNIT II**
- **VHF, UHF AND Microwave Antennas - I: Arrays with Parasitic Elements, Yagi - Uda Arrays, Folded Dipoles & their characteristics, Helical Antennas - Helical geometry, Helix Modes, Practical Design Considerations for Monofilar Helical Antenna in Axial and Normal Modes. Horn Antennas - Types, Fermat's Principle, Optimum Horns, Design Considerations of Pyramidal Horns, Illustrative Problems.**

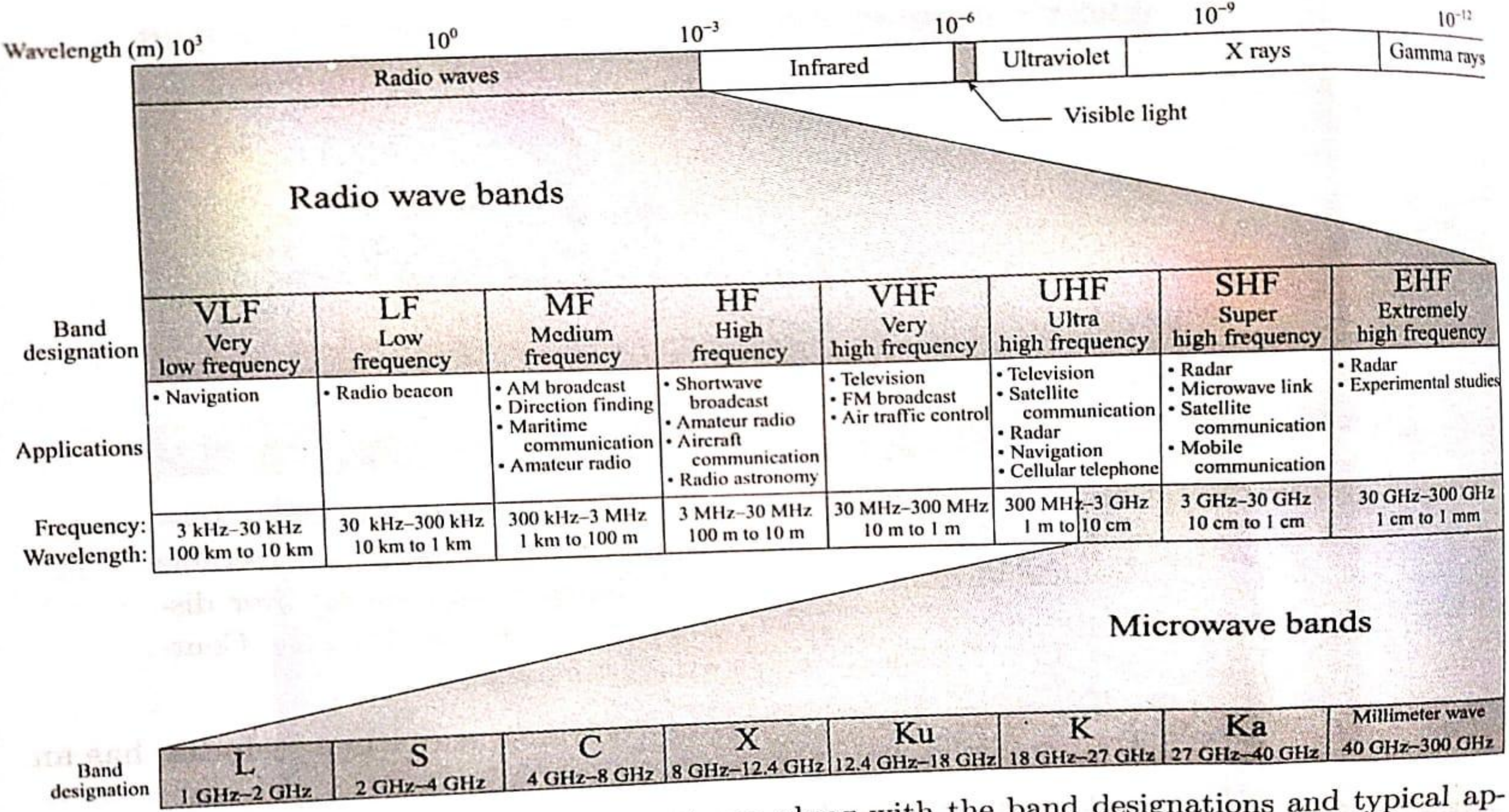
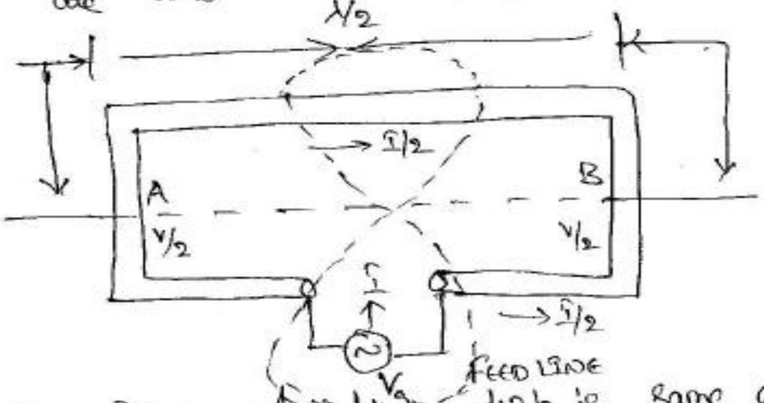


Fig. 1.3 Radio wave spectrum along with the band designations and typical ap-

1) Folded Dipole Antenna :- (used at VHF & yagi-uda Antenna).

Conventional half wave dipole is the folded dipole in which two half wave dipoles - one continous 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 transmission line with a voltage source hence the volts in both the dipoles are same and currents are also divided equally.



→ The radiation pattern of folded dipole is same as half wave dipole it differs from directivity & beam width.

→ The i/p impedance of folded dipole is very high.

→ The radius (or) radii of two dipoles are same so the current flowing through the two half wave dipoles are same.

→ The folded dipole has impedance transformer property means that i/p impedance can be changed by choosing different diameters for the half wave dipoles.

→ The i/p impedance of folded dipole antenna is square equal to the product of square of no. of conductors and radiation resistance of half wave dipole 73 Ω.

For Equation i/p impedance for 2-wire dipole is

$$Z_{in} = n^2 * R_{rad}(\lambda/2)$$

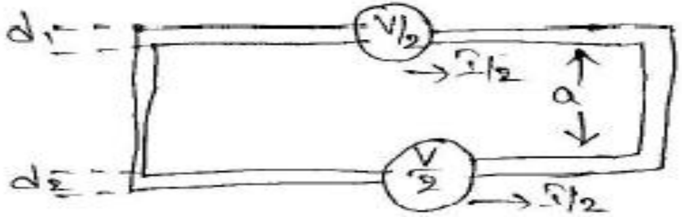
$$= (2)^2 \times 73\Omega$$

$$= 4 \times 73\Omega$$

$$Z_{in} = 292\Omega$$

(i) Equation for i/p impedance of 2-wire folded dipole :-

Let V be the applied volts to the two wire folded dipole since the diameter of 2-half wave dipoles are same so the currents flowing through 2-dipoles are same and volts is divided equally i.e V/2



$$I_1 = I_2$$

The diameters of 2-dipoles is same

by Z-parameters

by Z-parameters

$$V_1 = Z_{11} I_1 + Z_{12} I_2$$

∵ The Volt is divided Equally for 2-dipoles

$$\frac{V}{2} = Z_{11} I_1 + Z_{12} I_2$$

$$= I_1 \left[Z_{11} + Z_{12} \right] \quad (\because Z_{11} = Z_{12})$$

Spacing b/w the dipoles are same

$$\frac{V}{2} = I_1 \left[Z_{11} + Z_{11} \right]$$

$$\frac{V}{2} = 2 I_1 Z_{11}$$

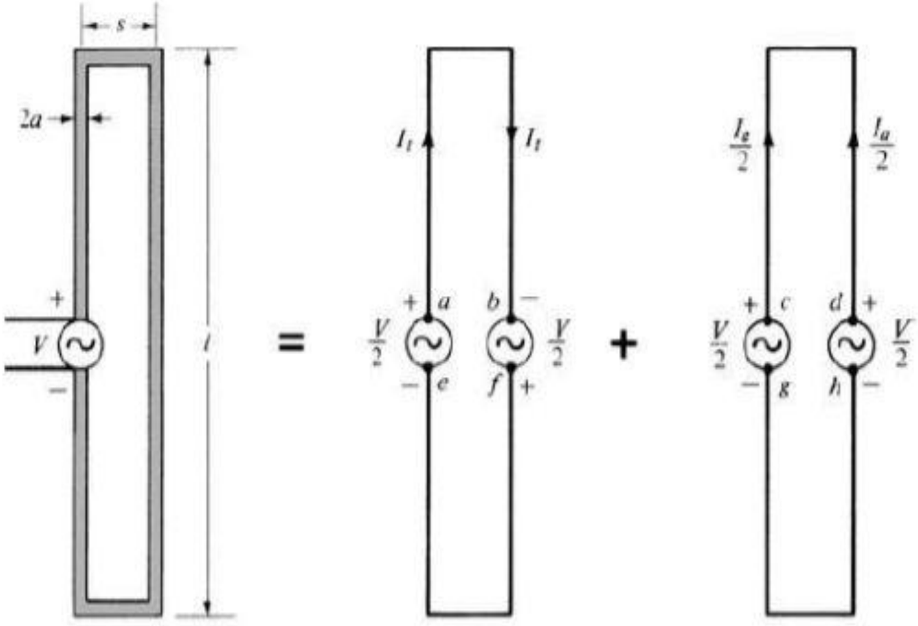
$$V = 4 I_1 Z_{11}$$

$$4 Z_{11} = \frac{V}{I_1}$$

$$\Rightarrow \frac{V}{I_1} = 4 \times 73 \quad (\because Z_{11} = 73\Omega)$$

$$= 292\,\Omega$$

Z_{11} = radiation resistance of halfwave dipole.

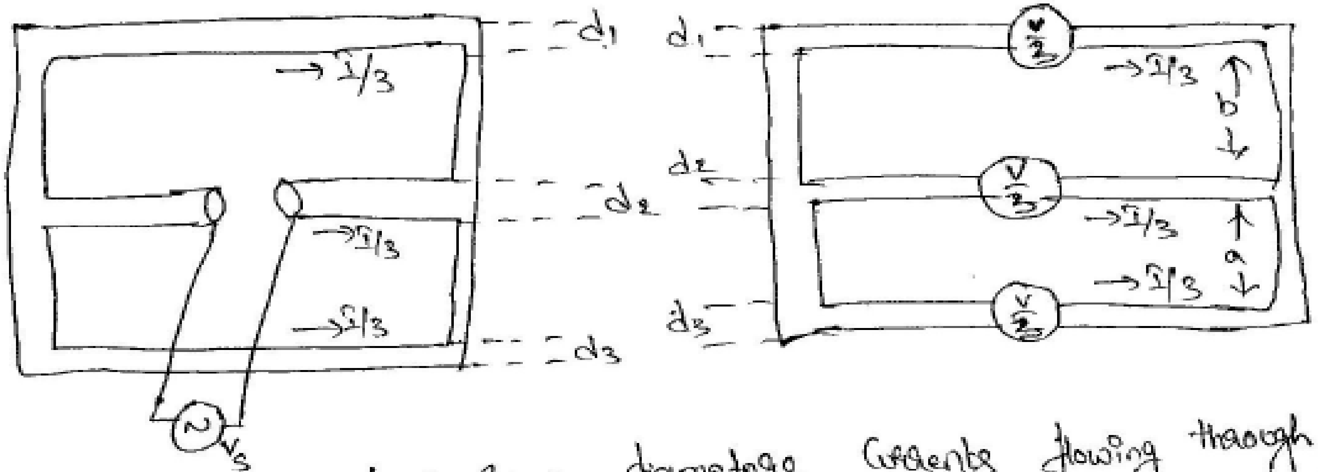


(a) Folded dipole

(b) Transmission-

(c) Antenna mode

(ii) Equation for tripole (or) 3-wire folded dipole :-



Since 3-dipoles have same diameters currents flowing through them is same and volts are divided equally and assume spacing b/w the dipole is less (a, b).

$$Z_{11} = Z_{12} = Z_{13} \quad (\text{spacing})$$

$$I_1 = I_2 = I_3 \quad (\text{diameter})$$

from Z - parameters

$$V = Z_{11} I_1 + Z_{12} I_2 + Z_{13} I_3$$

$$\frac{V}{3} = Z_{11} I_1 + Z_{12} I_2 + Z_{13} I_3$$

$$\frac{V}{3} = Z_{11} I_1 + Z_{11} I_1 + Z_{11} I_1$$

$$\frac{V}{3} = 3 Z_{11} I_1$$

$$V = 9 Z_{11} I_1$$

$$\frac{V}{I_1} = 9 Z_{11}$$

$$= 9 \times 73$$

$$\frac{V}{I_1} = 657\,\Omega$$

In general the i/p impeadence of folded dipole is given by :-

Two wire $\frac{V}{2} = 2 Z_{11} I_1$

Three wire $\frac{V}{3} = 3 Z_{11} I_1$

n-wire $\frac{V}{n} = n Z_{11} I_1$

$V = n^2 Z_{11} I_1$ n = no of half wave dipole

$$\boxed{Z_{in} = \frac{V}{I_1} = n^2 Z_{11}}$$

Z_{11} = radiation resistance of half wave dipole

we know that i/p impeadance depends on spacing b/w the half wave dipoles so it is given by

$$Z_{in} = \left[1 + \frac{\log \frac{a}{r_1}}{\log \frac{a}{r_2}}\right] \cdot Z_{11}$$

$r_1 \rightarrow$ radius of first half wave dipole

$r_2 \rightarrow$ radius of second half wave ".

$a \rightarrow$ spacing b/w dipoles depends of diameter it is given by

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

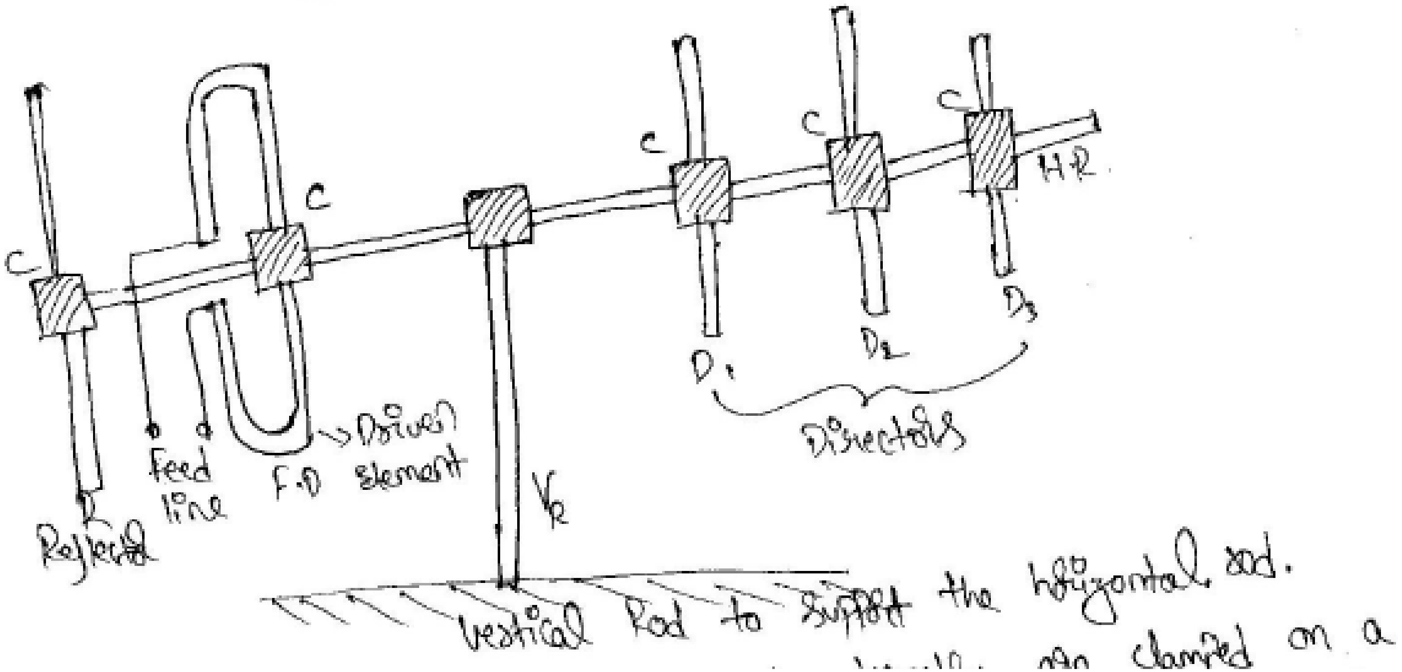
Advantages of Folded dipole:-

* It has high impedance
* Act as a impedance transformer
* Directivity is very high since 2-dipoles arranged in Parallel.

Applications:-

→ Used as a driven Element in Yagi-Uda Antenna
→ Used in wide band applications i.e TV, Applications.

Yagi-Uda Antenna



2) Yagi-uda Antenna :-

It is a high gain Antenna used in television applications this antenna is otherwise called as Yagi-uda array it contains 3-Elements

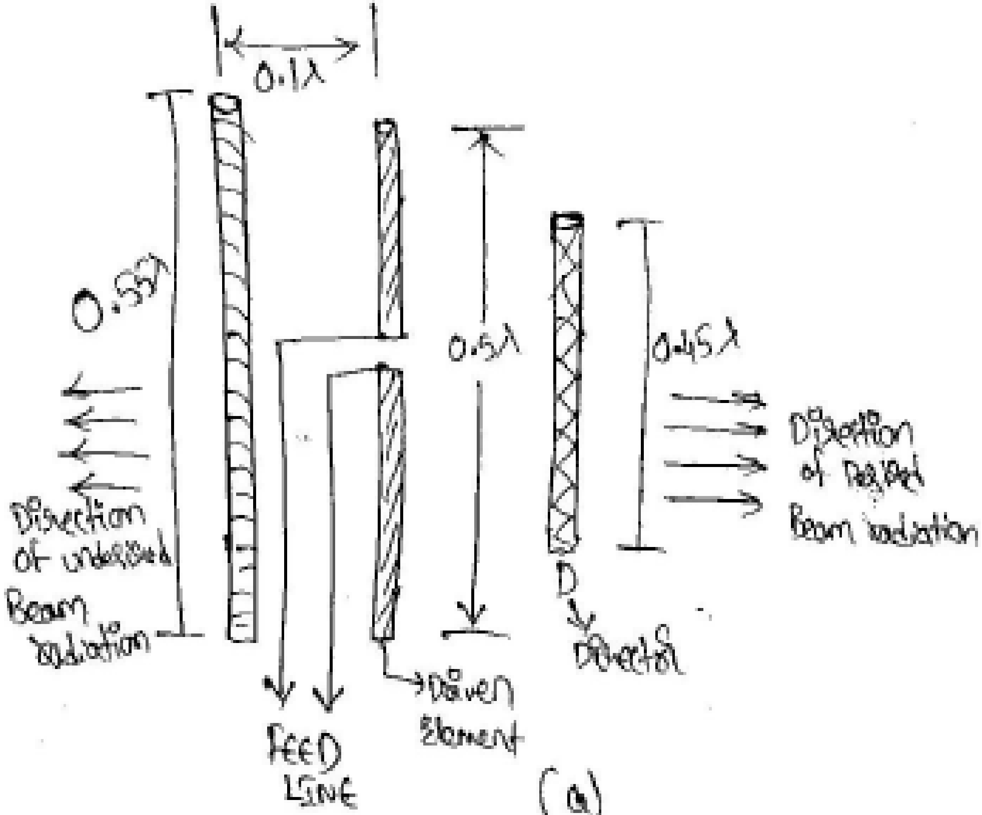
(i) Driven Element
(ii) Reflector
(iii) Director

The Driven element is connected to the transmission line through which signal source connected and it is a resultant half wave dipole.

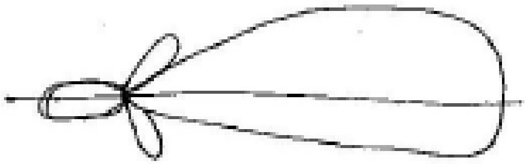
Reflector and director elements are Parasitic elements because they are not connected to the source directly but they are connected to the driven element through the magnetic coupling.

The Parasitic element infront of the driven element is called as the director. It directs the signal towards the desired directions.

The Parasitic element behind & back to the driven element is called as Reflector. It reflects the signal from driven element to towards the desired directions.



(a)



(b) Radiation Pattern

The length of the driven element is 0.5λ & director length is (I) 5% < driven element and also the reflector length is 5% > driven element.

the spacing b/w elements is 0.1λ.

vertical rod to

the Parasitic elements reflector and directors are clamped on a metallic rod parallel to the driven element either to reflect & direct the radiated energy.

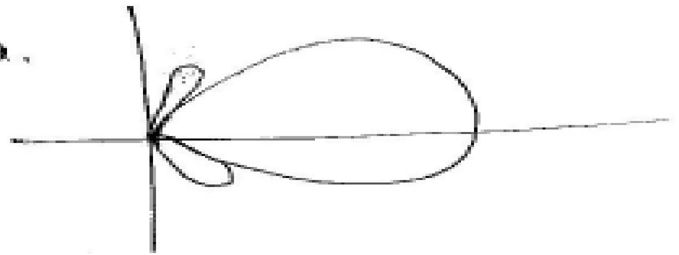
The Parasitic elements of equal & > $\lambda/2$ will be inductive in nature (lagging phase).

The Parasitic elements of equal & < $\lambda/2$ will be capacitive ie leading in phase.

The additional gain will be achieved by increasing the no. of director.

(a) Radiation Pattern :-

It is a fixed frequency Antenna.



(b) Designed Parameters :-

(i) Reflector length $l_R = \frac{500}{f(MHz)}$

(ii) Driven element length $l_{DR} = \frac{475}{f(MHz)}$

(iii) Director length $l_D = \frac{455}{f(MHz)}$

(c) General Characteristics of Yagi-Uda Antenna:-

→ This Antenna Contains three Elements i.e, Driven Element, director, and reflector such an Antenna is called as Beam Antenna.

→ This Antenna is otherwise called as uni-directional Antenna, which moderate directivity, light weight and low Cost.

→ The gain & directivity are high so the Antenna is called as super gain (or) super directive antenna.

→ It is a fixed freq device the band width is about 3% and is sufficient for the reception of T.V. signals.

→ It Provides a gain of 8dB and front to back ratio of 20dB.

[illegible] in Parasitic Antenna's:-

(d) Voltage and Cuurent relations in Parasitic Antenna's:-

One or more Passive elements Coupled magnetically to driven element is known as Parasitic antenna. The Presence of Parasitic elements effect the directional Pattern. The effect on the directional Pattern Produced depends upon the magnitude and phase of the induced current in Parasitic elements. i.e on spacing of antenna and tuning of the Parasitic Antenna.

The relations b/w currents and volts of yagi-udas array is obtained by the Z-parameterr.

$$V_1 = Z_{11} I_1 + Z_{12} I_2 \rightarrow (1)$$

$$V_2 = Z_{21} I_1 + Z_{22} I_2 \rightarrow (2)$$

$$\vdots$$

$$V_n = Z_{n1} I_1 + Z_{n2} I_2 + \dots Z_{nn} I_n \rightarrow (n)$$

$V_1, V_2, V_n \ldots \rightarrow$ Voltage applied to antenna no: 1, 2, 3 ... n (9)

$I_1, I_2 \ldots I_n \rightarrow$ Current flowing in antenna 1, 2, 3 .... n

$Z_{11}, Z_{22}, Z_{33} \ldots Z_{nn} \rightarrow$ Self impedance of Antenna no: 1, 2, 3 ... n

$Z_{12}, Z_{21}, Z_{13} \ldots Z_{ij} \rightarrow$ Mutual impedance b/w Antenna of subscripts

V_1 is driven volt ; V_2 is induced volt

$$V_2 = 0$$

now:

$$\therefore \quad V_1 = I_1 Z_{11} + I_2 Z_{12}$$

$$0 = I_1 Z_{21} + I_2 Z_{22}$$

$$Z_{21} I_1 = - Z_{22} I_2$$

$$I_1 = \left(\frac{-Z_{22}}{Z_{21}} \right) I_2 \rightarrow (3)$$

$$\Rightarrow I_2 = \left(\frac{-Z_{21}}{Z_{22}} \right) I_1 \rightarrow (4)$$

Substitute eq (3) in eq (1)

$$V_1 = Z_{11}\left(-\frac{Z_{22}}{Z_{21}}\right) I_2 + Z_{12} I_2$$

$$V_1 = I_2\left(Z_{12} - \frac{Z_{11} \cdot Z_{22}}{Z_{21}}\right)$$

Impedance of Parasitic Elements

$$\boxed{\frac{V_1}{I_2} = Z_{12} - \frac{Z_{11} Z_{22}}{Z_{21}}}$$

By Reciprocity theorem $Z_{12} = Z_{21}$

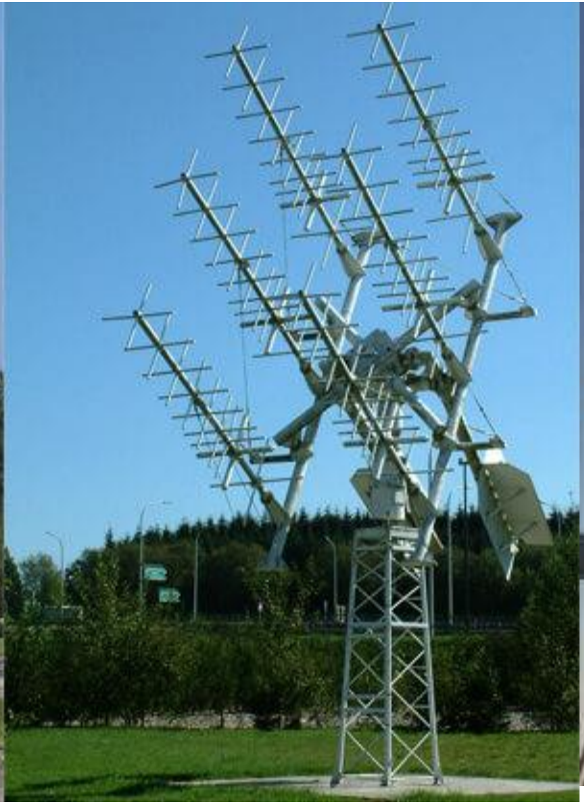
Substituting eq (4) in (1)

$$V_1 = Z_{11} I_1 + Z_{12}\left[-\frac{Z_{21}}{Z_{22}}\right] I_1$$

$$V_1 = I_1\left[Z_{11} - \frac{Z_{12} \cdot Z_{21}}{Z_{22}}\right]$$

$$\boxed{\frac{V_1}{I_1} = Z_{11} - \frac{Z_{12} \cdot Z_{21}}{Z_{22}}}$$

Helical Antenna

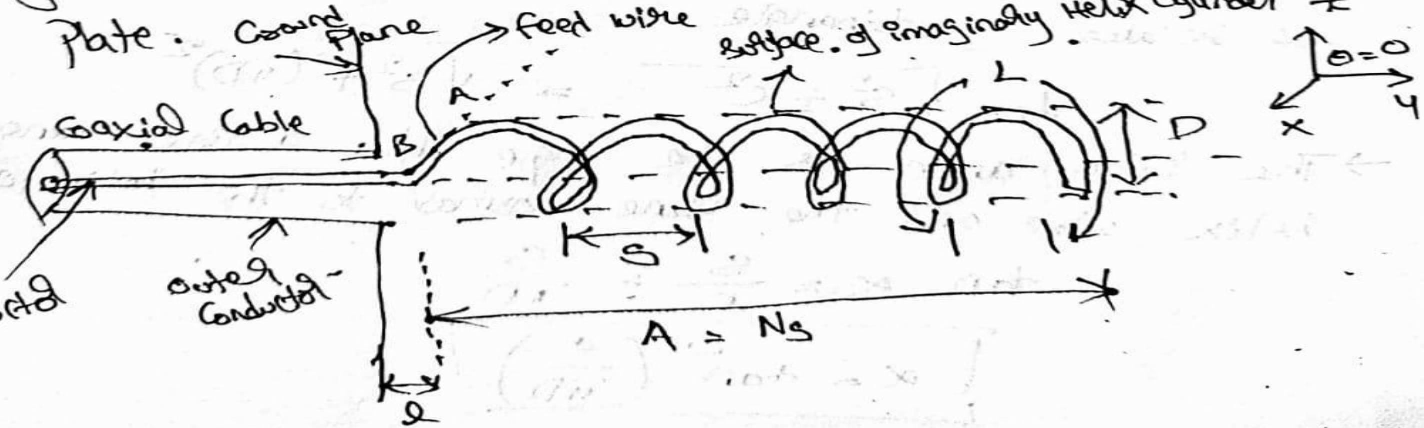



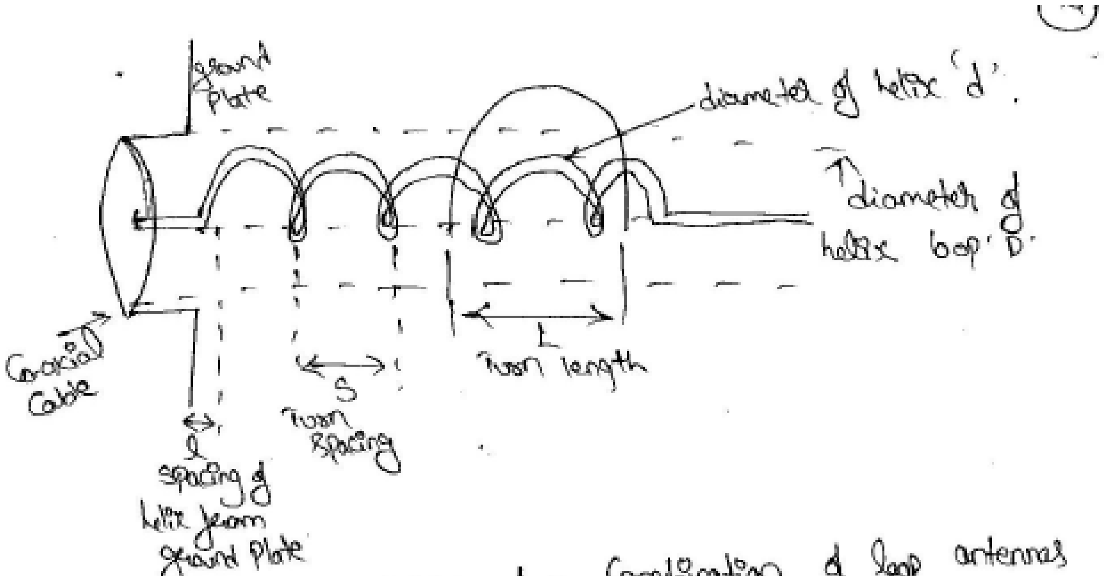

*) Helical Antenna :-

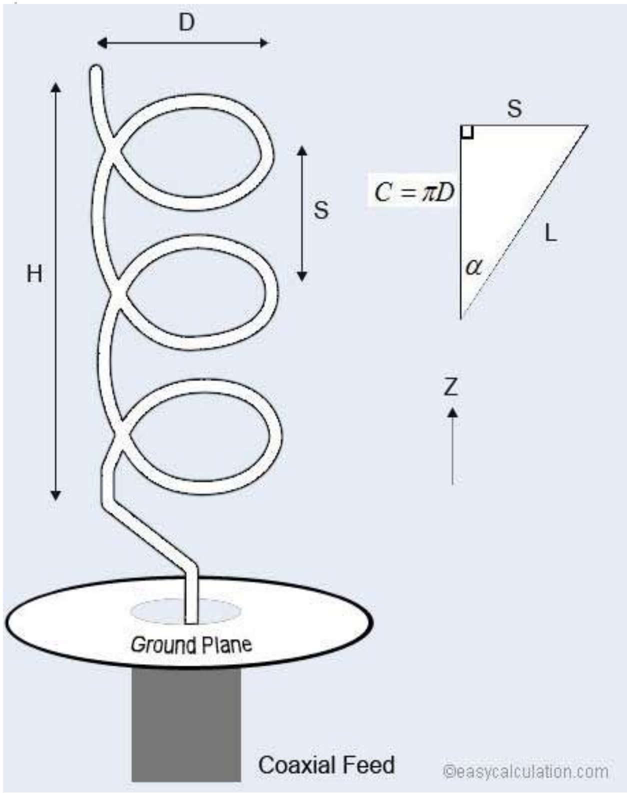
→ Is another basic type of radiator and Perhaps simplest antenna to Provide circular Polarized waves (or) nearly so which are used in Extra-terrestrial communication in which satellite relays etc.,

→ Helical Antenna is broad band VHF & UHF antenna Provides circular Polarization characteristics.

→ Consists of Helix of thick copper wire (or) tubing wound in shape of a screw thread and used as an antenna in conjunction with a flat metal Plate called ground Plate.





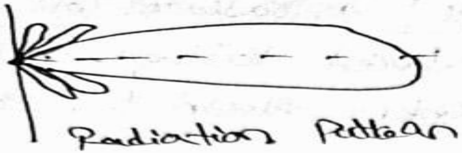


→ This antenna is a series of a combination of loop antennas and dipole antennas.

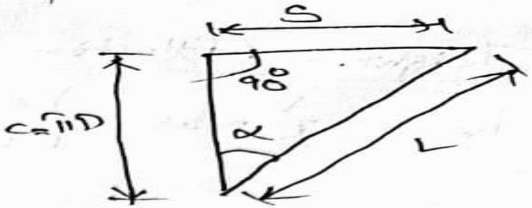
→ The radiation pattern of helical antenna depends on a diameter of the helics (d), the turn spacing (S) and also axial length ($A = N.S$) and also the circumference of helics.

→ There is a relation b/w circumference $C=(\pi D)$ and turn spacing (S) and pitch angle (α).

②



Radiation Pattern



C = circumference of helix (πD)

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

d = dia of helix conductor

A = Axial length $= NS$

N = no of turns

L = length of one turn

l = spacing of helix from ground plane.

→ for N turn of helix the total length of antenna is equal to NS and circumference πD.

→ If one turn of helix is unrolled on a plane. Surface the circumference (πD), spacing 'S', turn length 'L' and pitch angle 'α' are related by triangle

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

→ The pitch angle is the angle b/w a line tangent to helix wire and the plane normal to the helix axis.

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

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

→ Coaxial line is coincident with the helix axis and feed wire (b/w A & B) lies in the plane through helix axis.

→ After the point A the conductor lies in the surface of imaginary helix cylinder the helix axial length (A) starts.

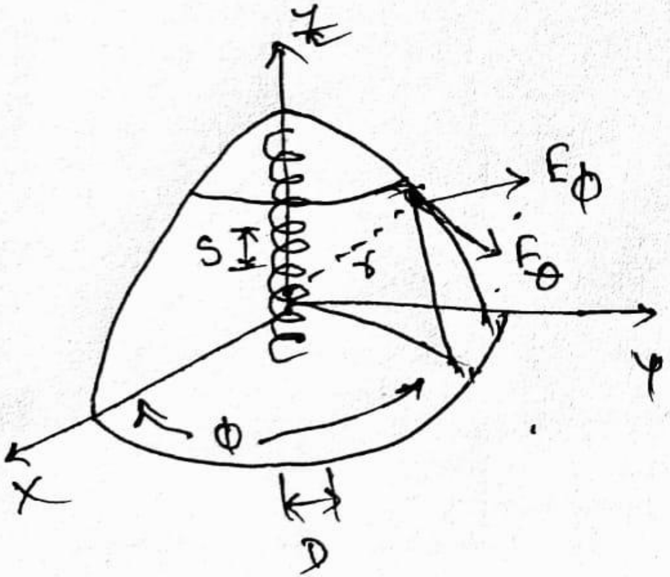
→ The component of the feed wire length parallel to axis is 'l'. This is about a length equal to $\frac{S}{2}$.

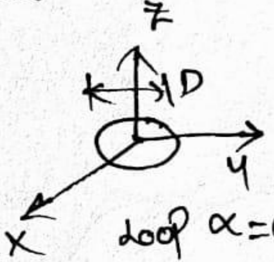
→ The antenna terminals are considered at the point B. And all the impedances are referred to this point. The variations of feed wire geometry affects the i/p impedance of the antenna.

* Helix Modes:-

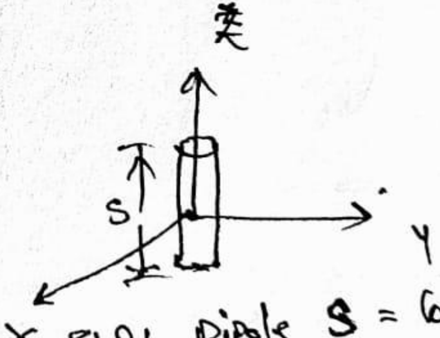
Transmission Mode:-

EM waves Propagate along an infinite helix as through the helix constitutes an infinite transmission line (or) waveguide





Loop $\alpha = 0^\circ$



Short Dipole S = Const $\alpha = 90^\circ$

8–4b Radiation (R) Mode

It describes the general form of the far field pattern of a finite helical antenna. Though there is a possibility of many R modes, but the following two modes have higher significance.

1. Normal or omni mode of radiation is denoted by R_0 in which the radiation beam is perpendicular to the helix axis.
2. Axial or beam mode of radiation is denoted by R_1 in whsich the radiation beam is parallel to the helix axis.

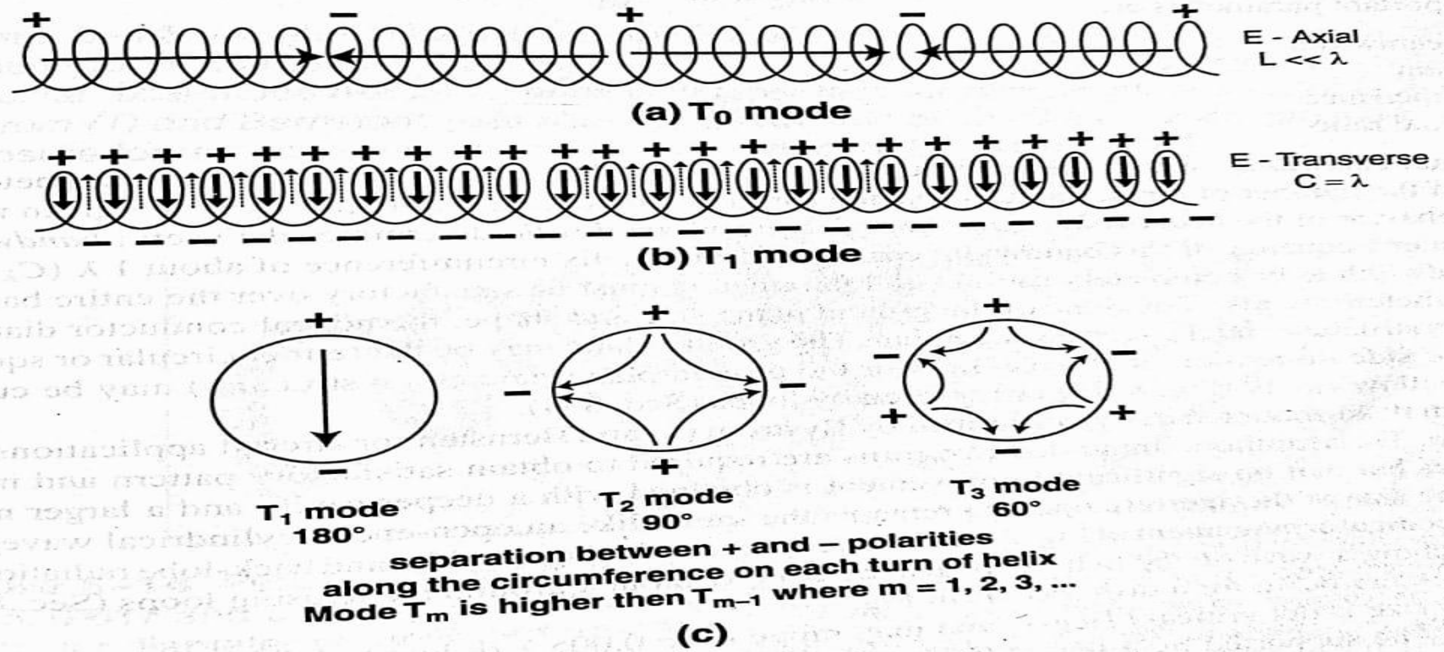
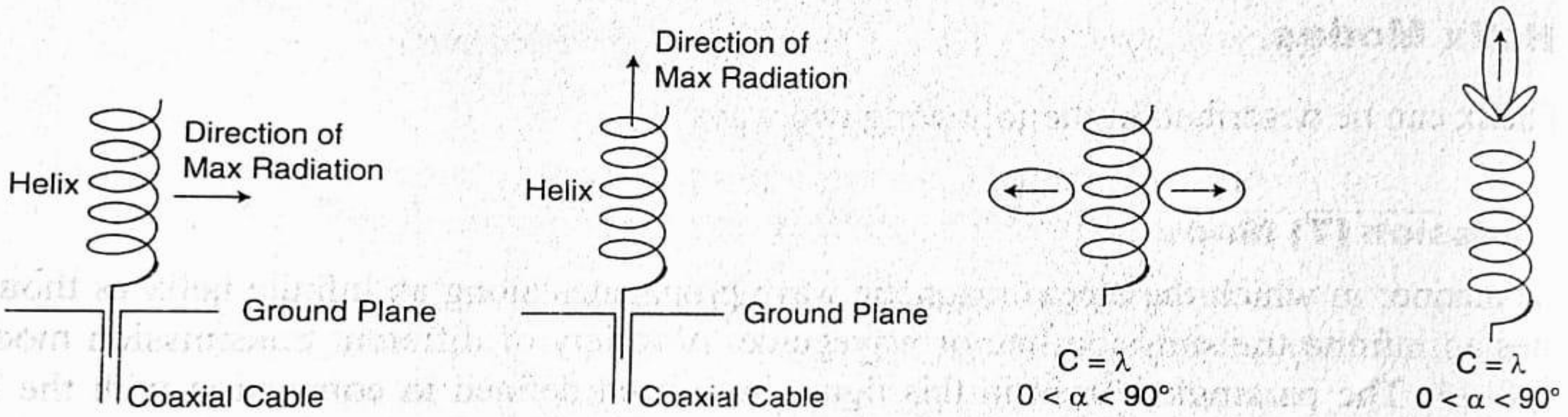


Figure 8–11



(a) R_0 mode (b) R_1 mode (c) T_0 R_1 mode (d) T_1 R_1 mode

Figure 8–12

Both of these modes are shown in Fig. 8–12 (*a* and *b*). As illustrated in Fig. 8–12 (*c* and *d*) both transmissi and radiation modes may also be specified.

(ii) Axial ratio :-

(Ar) Axial ratio $= \dfrac{E_\theta}{E_\phi}$

$\because E_\phi = \dfrac{120\pi^2 I \sin\theta}{r} A/\lambda^2$; $E_\theta = \dfrac{j60\pi I \sin\theta}{r} s/\lambda$

Where I is retarded current ; A is area of helix $= \dfrac{\pi D^2}{4}$
r is distance ; S → spacing (or) length of the dipole

$$A_r = \frac{E_\theta}{E_\phi} = \frac{\dfrac{j60\pi I\sin\theta}{r} \cdot s/\lambda}{\dfrac{120\pi^2 I \sin\theta}{r} \cdot A/\lambda^2}$$

$$A_r = \frac{j\cancel{60}\cancel{\pi}\,\cancel{I\sin\theta}}{\cancel{r}} s/\cancel{\lambda} \times \frac{\cancel{r}}{\cancel{120}_{2}\,\pi^{\cancel{2}}\,\cancel{I\sin\theta}} \cdot \lambda^{\cancel{2}}/A$$

$$A_r = \frac{J S \lambda}{2\pi A}$$

$$(A_r) = \frac{S\lambda}{2\pi A} = \frac{S\lambda}{2\pi \times \frac{\pi D^2}{4}}$$

$$(A_r) = \frac{2 S \lambda}{\pi^2 D^2} = \frac{2 S \lambda}{C^2} \quad (\because C = \pi D)$$

from above A_r when $A_r = 0$ then linear horizontal Polarization takes place.

→ when $A_r = \infty$ linear vertical Polarization takes place

→ when $A_r = 1$ then we get circular Polarization.

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

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

$$\boxed{S = \frac{\pi^2 D^2}{2\lambda} = \frac{C^2}{2\lambda}}$$

$$2\lambda \qquad 2\lambda$$

∴ Pitch Angle :-

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

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

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

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

*) Axial (or) Beam mode of radiation :-

→ In axial mode of radiation the radiation field is maximum in the End. fire direction. i.e along the helix axis. and the Polarization is circular (or) nearly circular.

↳ This mode occurs when the helix circumference (D) and spacing 'S' are appreciable. of the order of one wavelength.

→ The axial mode of radiation is produced in practice with great case simply by raising helix circumference (C/λ) of order of one wavelength and spacing of $\lambda/4$.

→ The Pitch angle 'α' varies from 12° to 18° and about 14° is optimum Pitch angle.

whole Antenna gain and beam width depends upon the helix length (NS)

→ The terminal impedance is 100Ω resistive components.

In general in axial mode the terminal impedance of helical antenna lies b/w 100Ω to 200Ω Roe resistive within ±20% approximation.

the terminal impedance is $\boxed{R = \frac{140 C}{\lambda} \text{ ohms}}$

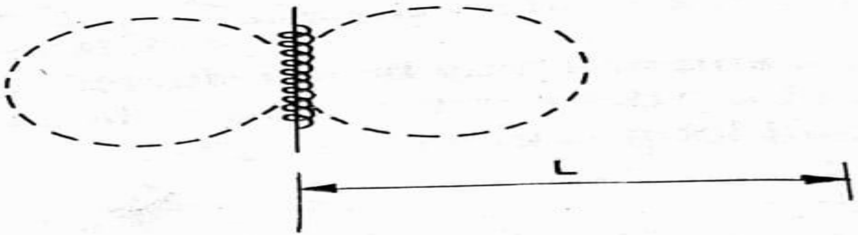
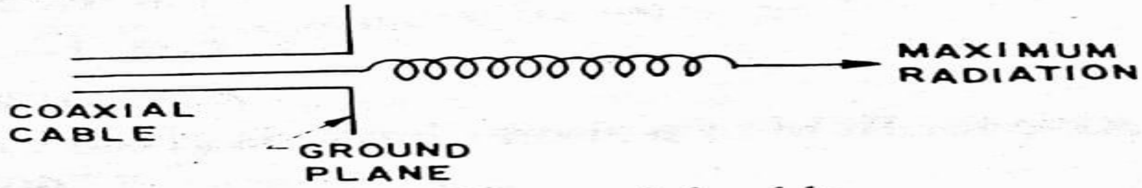
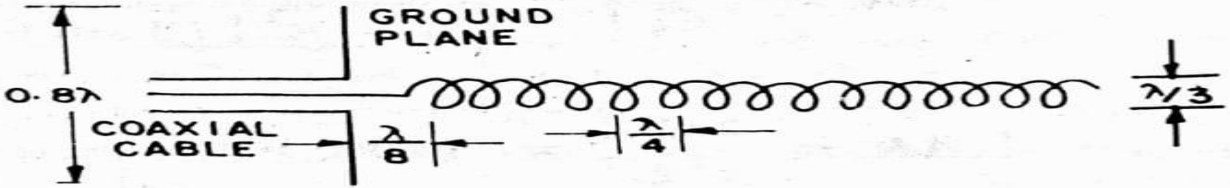


Fig. 9.26. Normal mode of radiation (Circular polarization).



(a) With coaxial cable.

(b) Two wire transmission line..



(c) Typical dimensions..

Fig. 9.27. Arrangement for generating axial mode.

(4)

The beam pattern has axial symmetry.
i.e. In 3-dimensional spherical co-ordinate $\theta = 0°$

The Beam width b/w HPBW is

$$(HPBW)\ \theta_{(-3dB)} = \frac{52}{C}\sqrt{\frac{\lambda^3}{NS}}\ \text{degree}$$

λ = Free space wavelength.
C = circumference.
N = no of turns
S = Spacing

The Beam width b/w first nulls is

$$BWFN = \frac{115}{C}\sqrt{\frac{\lambda^3}{NS}}\ \text{degree}$$

The max Directive gain is given by (axial mode)

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

$\therefore$ Axial ratio $\boxed{AR = 1 + \frac{1}{2N}}$

(10)

(3) Horn Antenna :-

→ It is a flared wave guide to transmit the EM waves into free spaces. It is a micro waves antenna.

→ A microwave is capable of radiating radiation in to open space provided the same is excited at one end and opened at other end.

→ In a wave guide a small amount of energy incident at i/p end results a large amount of energy reflected back if it is open circuited to improper impedance matching.

To overcome this drawback waveguide is terminated with a proper of horn (or) o/p end ~~so~~ which is wired. So that entire energy is transmitted towards the forward direction.

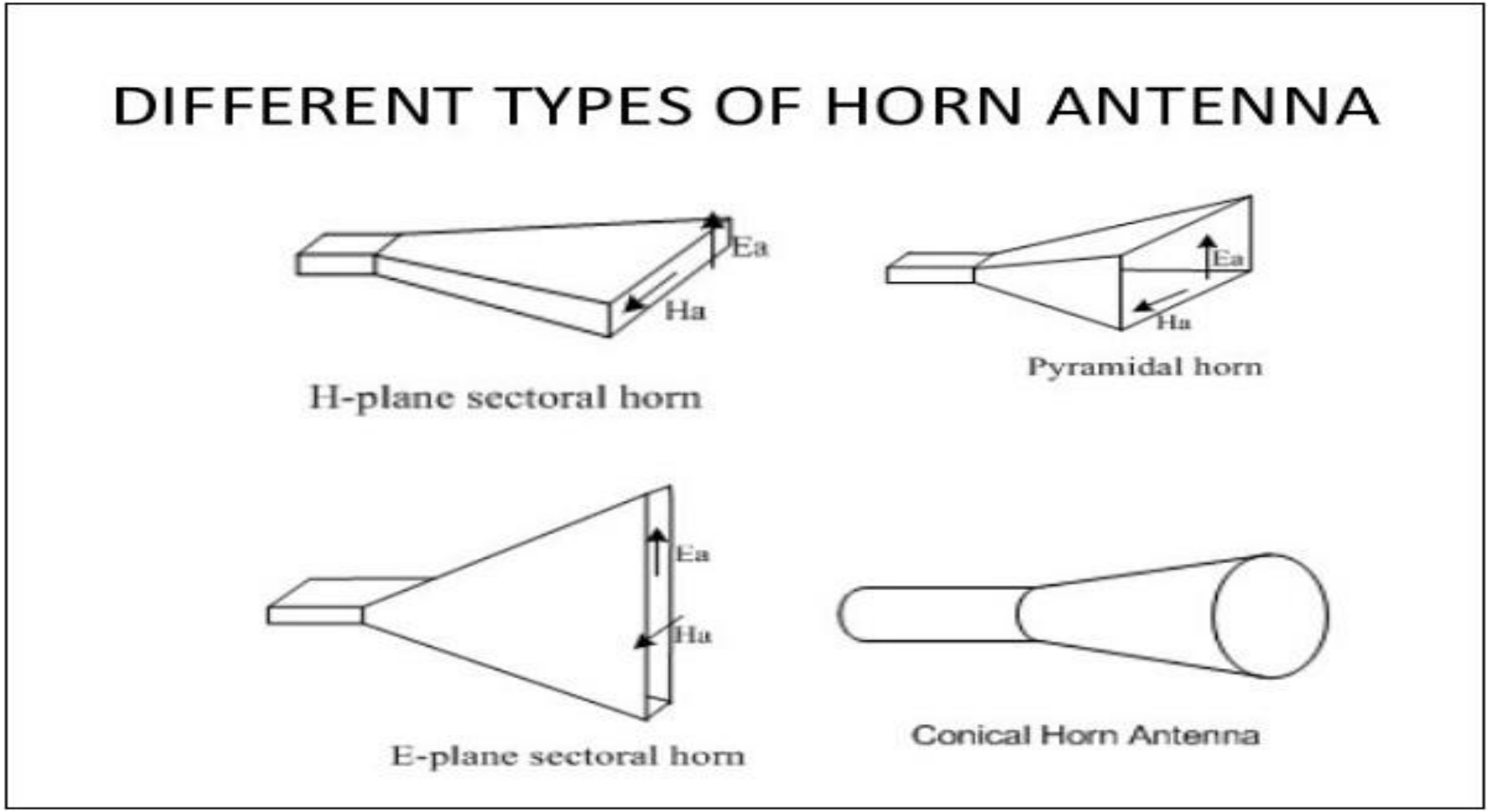
There are 2-types of horn Antenna's

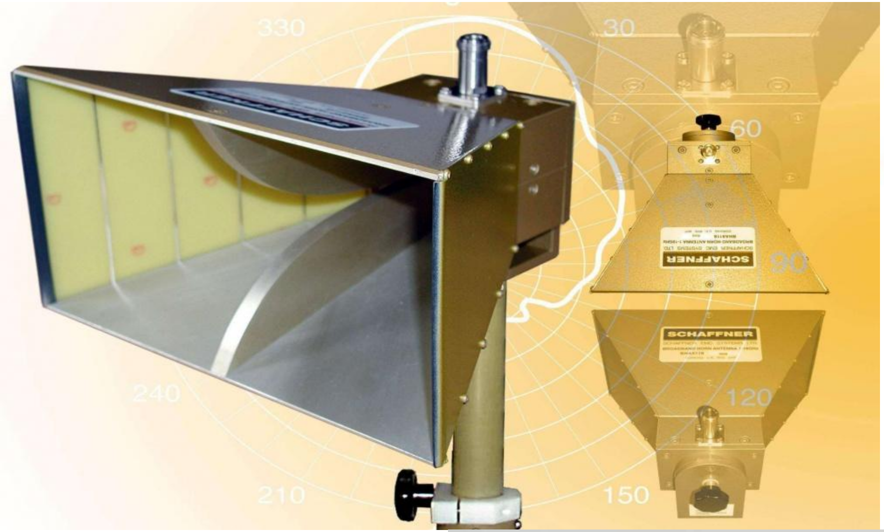
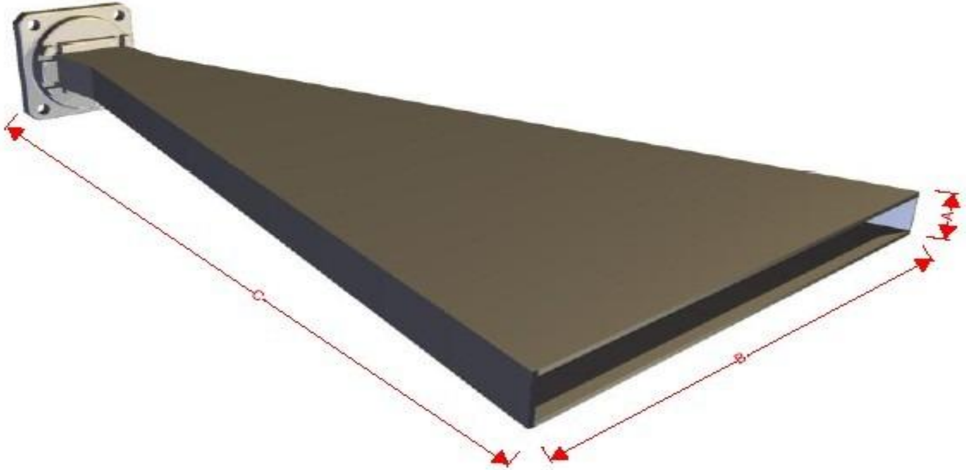
(i) Rectangular horn Antenna

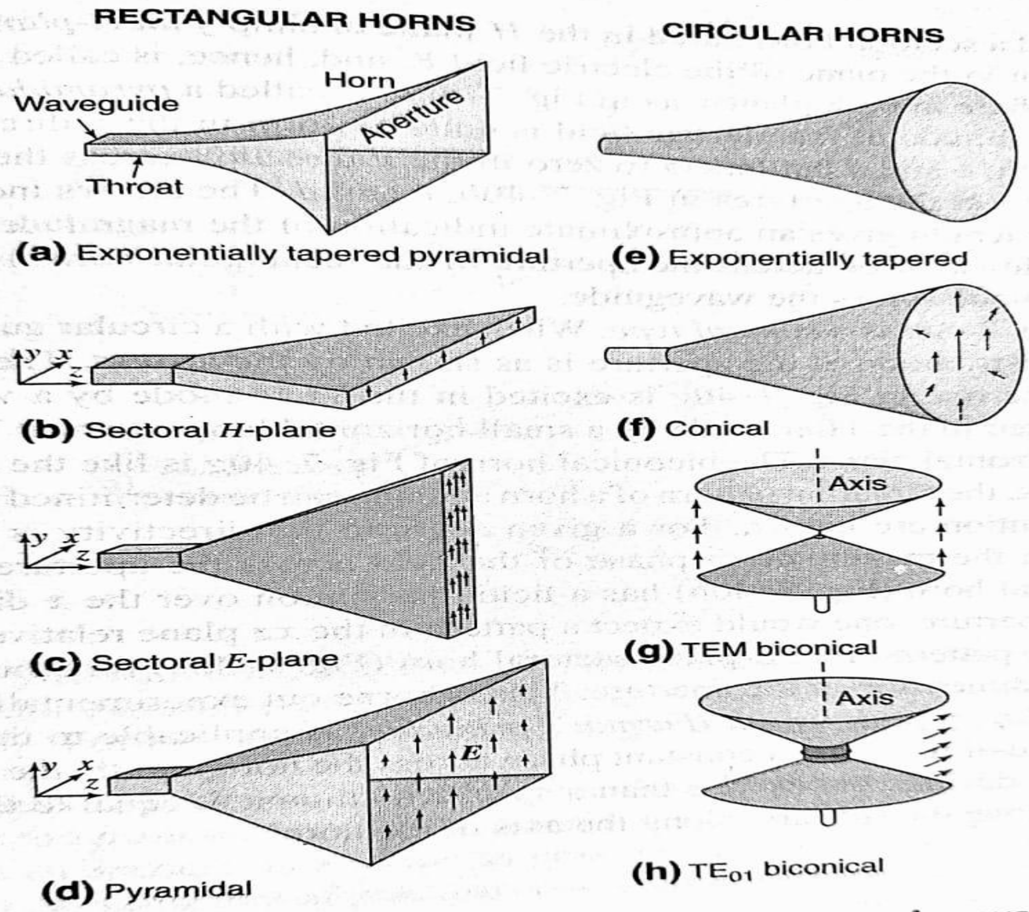
(ii) Circular horn Antenna.

... line, the

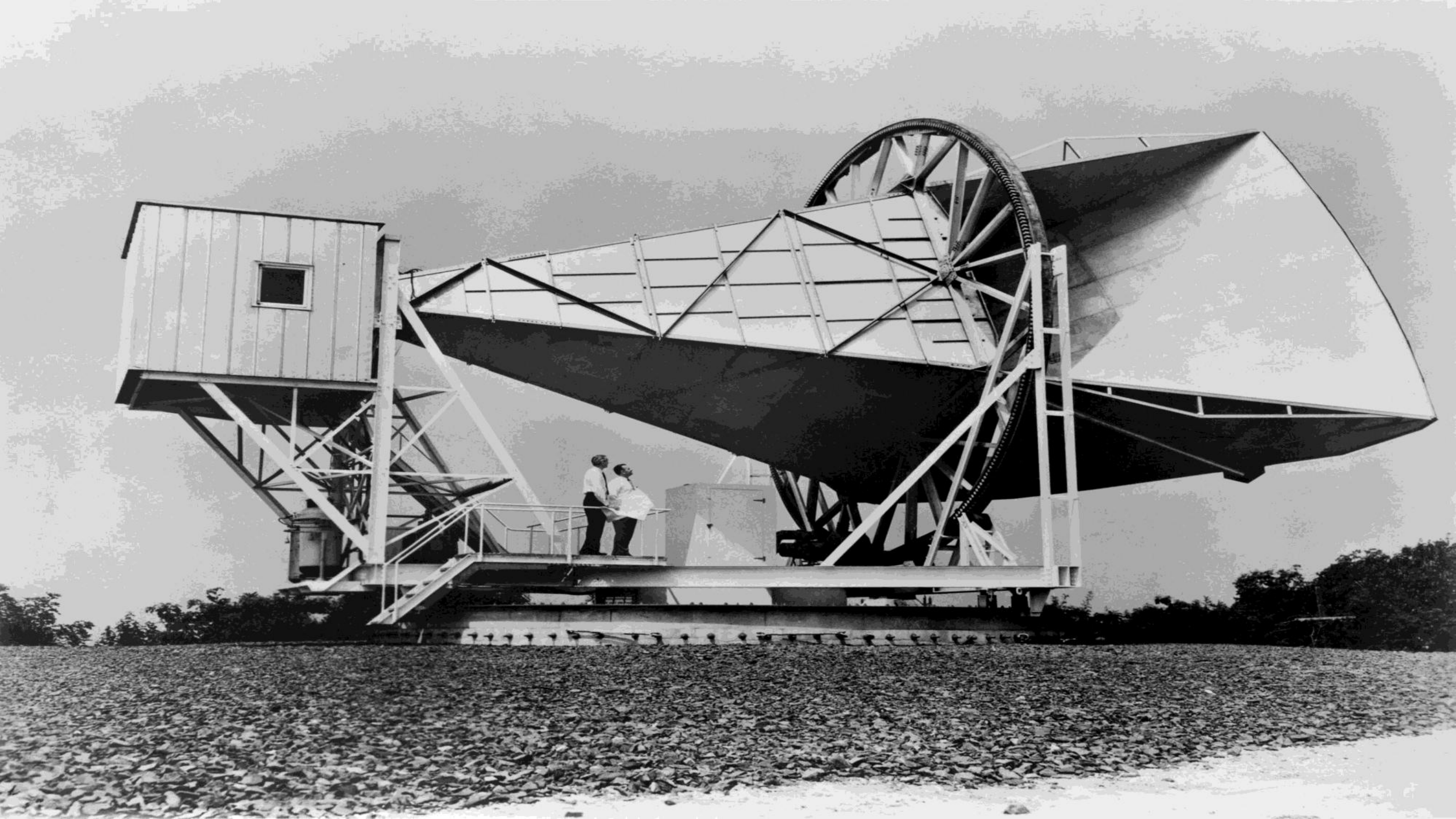
Horn Antennas



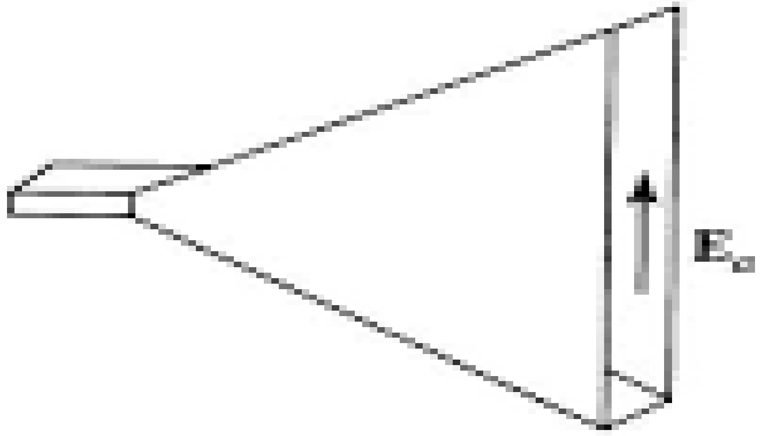

330
30
60
SCHAFFNER
SCHAFFNER
240
120
210
150

C
B

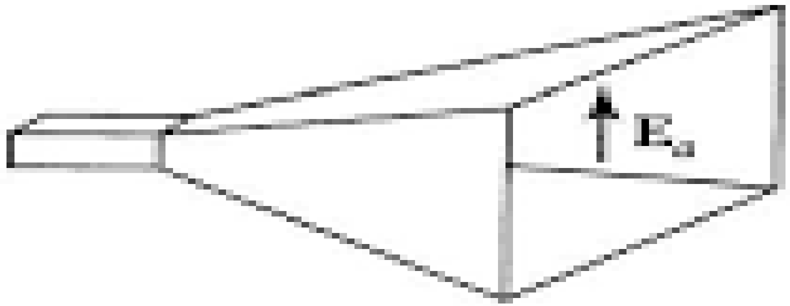
e 7–40 Types of rectangular and circular horn antennas. Arrows indicate **E**-fie
ons.



(*a*) *H*-plane sectoral horn.

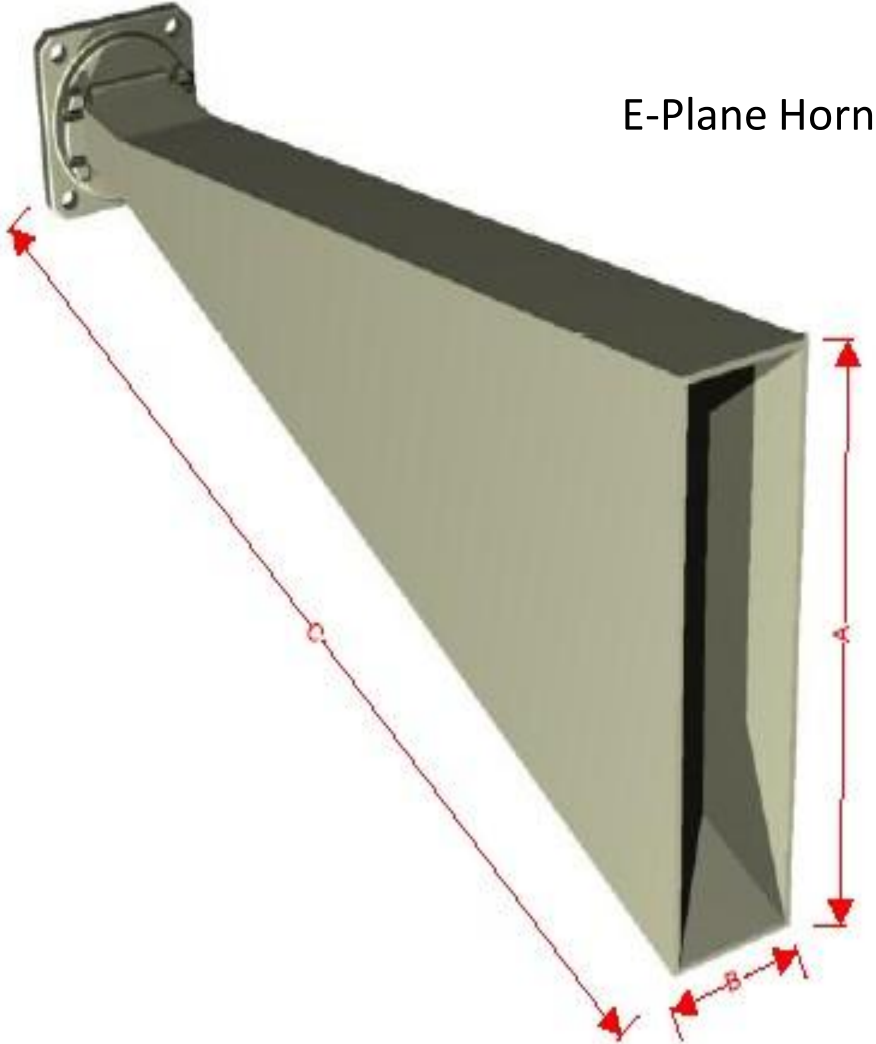


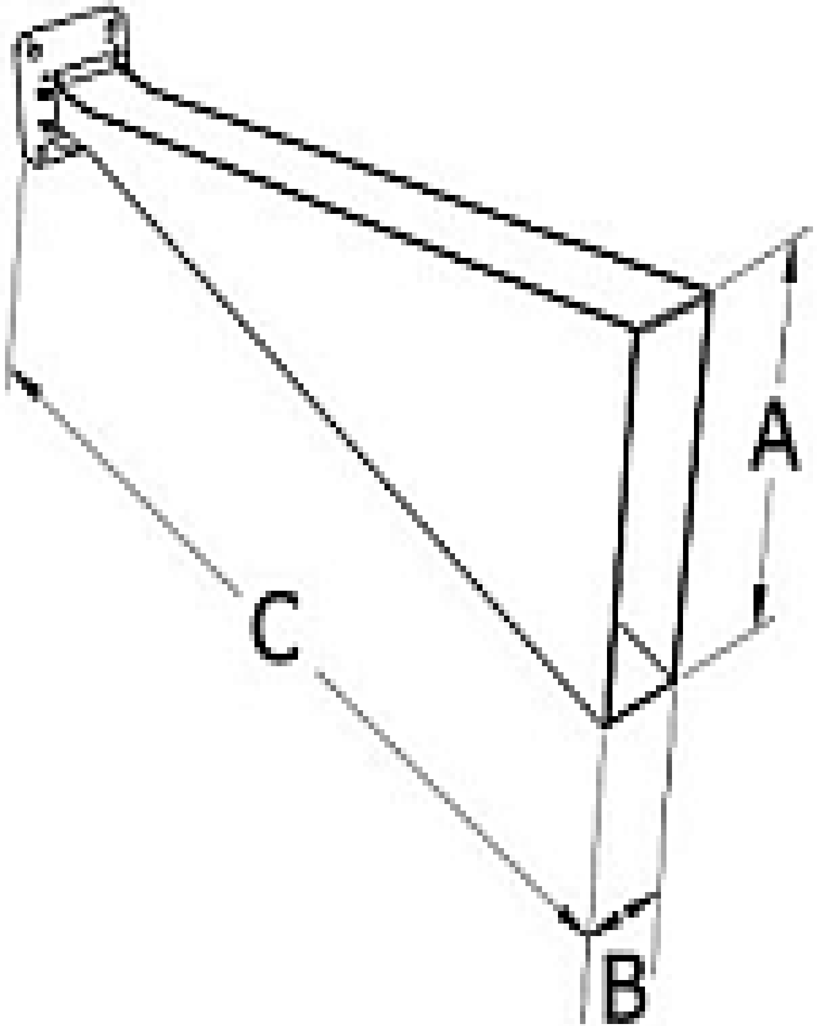
(*b*) *E*-plane sectoral horn.

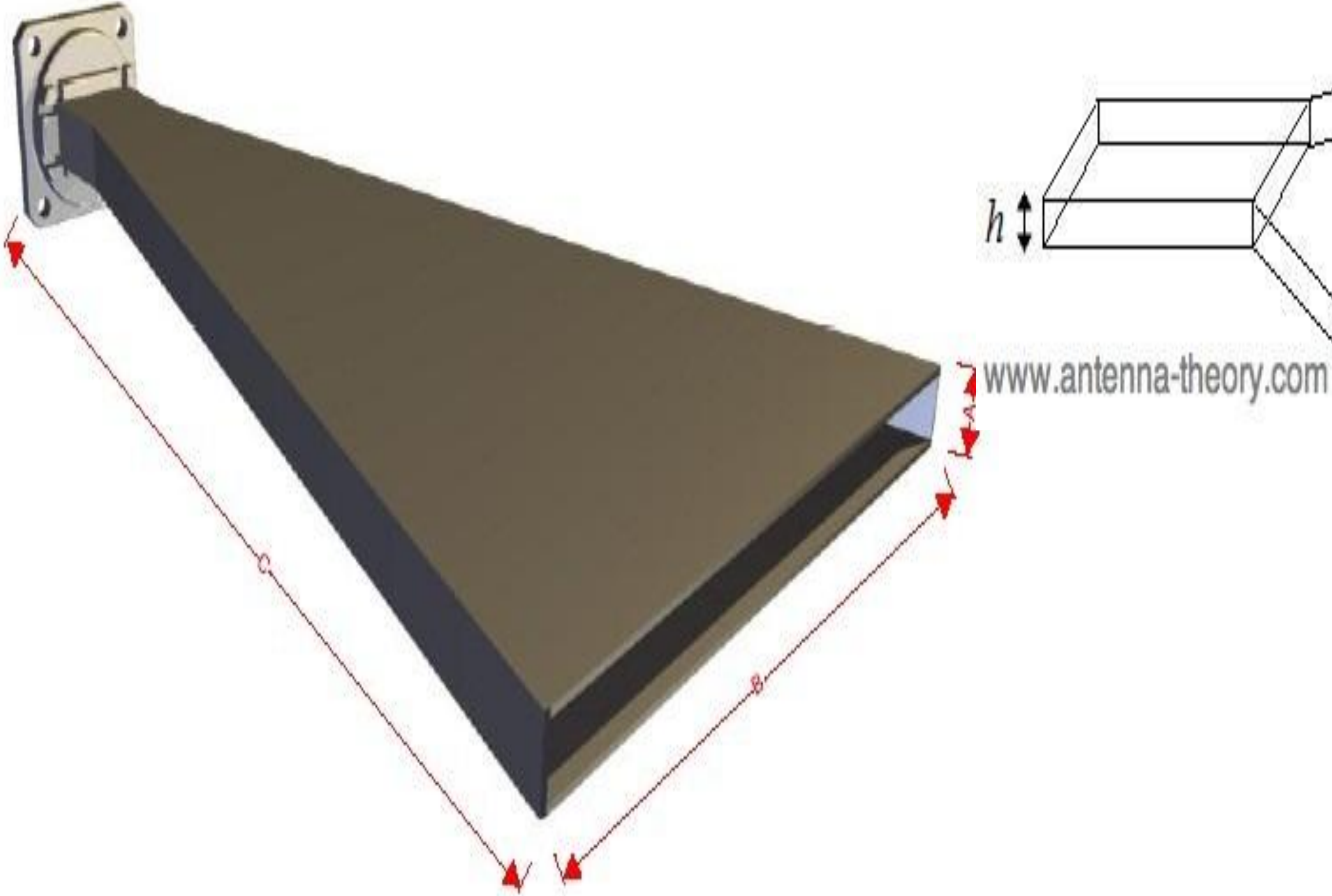


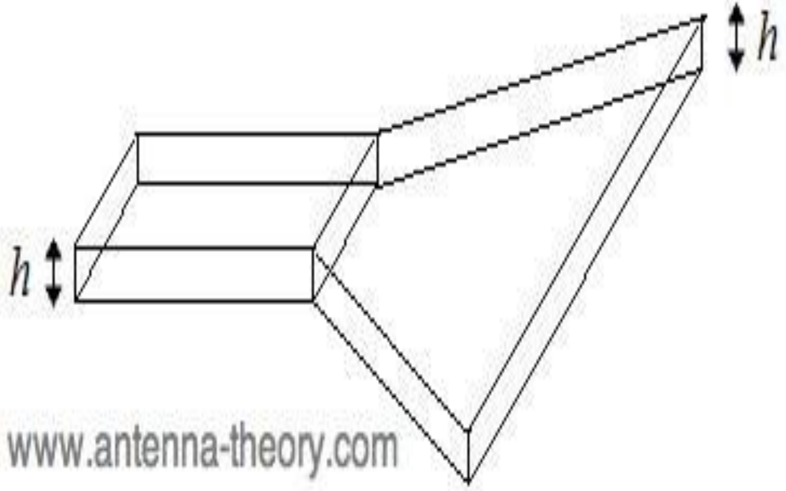
(*c*) Pyramidal horn.

E-Plane Horn






C
B
A
www.antenna-theory.com


h
h

(ii) [illegible]

As Compared with radiation through transmission line, the radiation through the waveguide is larger.

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

A Sectoral horn is obtained if the flaring (tapering) is done in one direction.

further classified as

(i) E-Plane sectoral horn

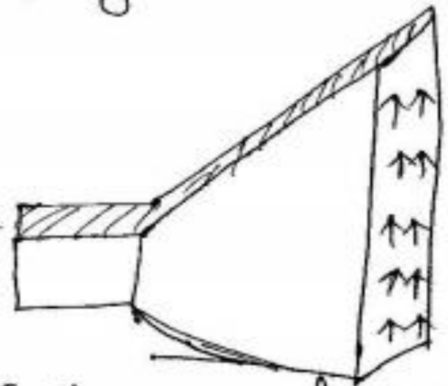
(ii) H-Plane Sectoral horn

(iii) Pyramidal horn

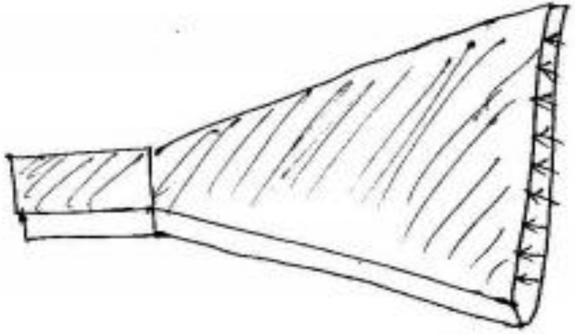
*) The E-plane sectoral horn is obtained when the flaring is done in the direction of electric field vectors.

*) The H-plane sectoral horn is obtained if the flaring is done in the direction of magnetic field vectors.

*) In both E & H-Plane sectoral horn the flaring is done along a single wall of the rectangular waveguide in one direction.



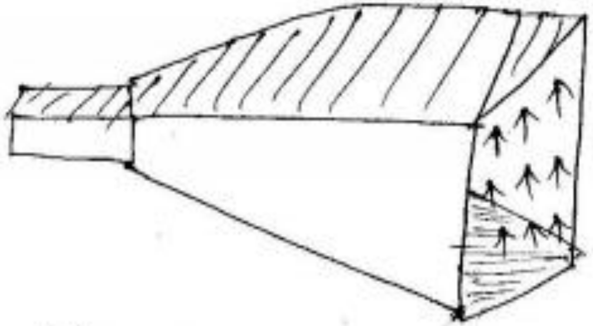
E-Plane sectoral horn



H-Plane sectoral horn

... of the

→ Pyramidal horn:- 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 is obtained Pyramidal horn.



(ii)

Types of Circular Horn Antennas

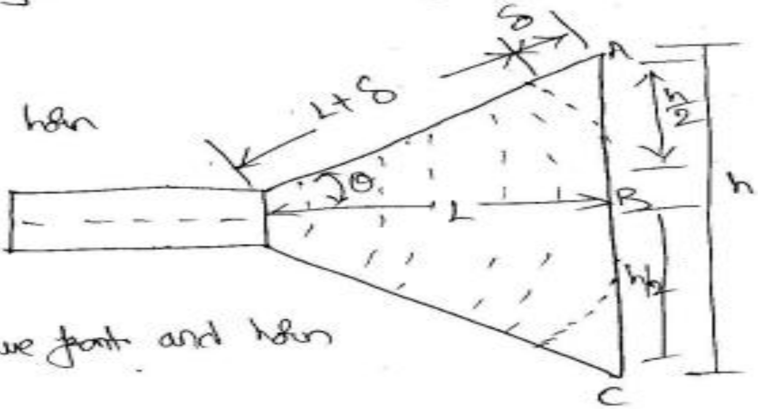
12

(a) Conical horn   (b) Biconical horn

By providing proper impedance matching we can avoid the standing wave ratio and we get maximum directivity.

<u>Design</u> <u>Equations</u>:-

Consider a E-plane sectoral horn



where θ is flare angle

L - is axial length

h - is height of the mouth

δ - is path difference b/w wave front and horn

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

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

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

from right angled Δle

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

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

Let δ as small so δ^2 is negligible

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

$$2\delta L = \frac{h^2}{4} \Rightarrow \boxed{L = \frac{h^2}{8\delta}} \Rightarrow \boxed{h = \sqrt{8\delta L}}$$

Here δ-varies values for E-plane horn $\delta_E = 0.2\lambda$ (13)

For H-plane horn $\delta_H = 0.4\lambda$

For conical horn $\delta_{conical} = 0.3\lambda$

The approximate formulaes for half power beamwidth of optimum horn antenna is

$$\theta_E = \frac{57\lambda}{h}\ \text{deg}$$

$$\theta_H = \frac{67\lambda}{w}\ \text{deg}$$

Area = height × width

$$\text{Directivity } (D) = \frac{7.5hw}{\lambda^2} = \frac{7.5A}{\lambda^2}$$

$$\text{Directive gain } G_d = \frac{4.5hw}{\lambda^2} = \frac{4.5A}{\lambda^2} \quad hw - \text{half width}$$

small flare angle represents small aperture and also less directivity. For optimum operation flare angle varies from 40° – 15° and beam width of 66°.

Example 9.1. *Calculate in db the directivity of 20 turn helix, having $\alpha = 12°$, circumference equal to one wavelength.*

Solution. The directivity of a helical antenna is given by eqn. 9.57 *i.e.*

$$D = \frac{15\,NSC^2}{\lambda^3}\ ;\ N = 20 \text{ turns}\ ;\ C = \lambda\ ;\ \alpha = 12°$$

$$\therefore \qquad \tan\alpha = \frac{S}{C} \quad \text{or} \quad S = C\tan\alpha$$

$$\text{or} \qquad \lambda\tan 12° = \lambda \times 0.2126$$

Putting these values in above eqn. we have

$$D = \frac{15 \times 20 \times 0.2126\,\lambda \times \lambda^2}{\lambda^3} = 63.78$$

$$D\ db = 10\log D = 10\log 63.78 = 10 \times 1.8046 = 18.046$$

$$\mathbf{D \simeq 18\ db} \qquad \textbf{Ans.}$$

$$D \simeq 18\ db \quad \textbf{Ans.}$$

Example 9.2. *Calculate the power gain of an optimum horn antenna approximately with a square aperture of 10 λ on a side.*

Solution. Formula to be used $D \simeq \dfrac{4.5\,A}{\lambda^2} = \dfrac{4.5 \times 10\,\lambda \times 10\,\lambda}{\lambda^2}$

$$= 4.5 \times 100 = 450 \quad \textbf{Ans.}$$

... half flare angles θ_E and θ_H of a pyramidal horn

Example 9.6. *A standard-gain horn antenna has power gain of 12.5. This is used to measure the gain of a large directional antenna by comparison method. The antenna under test is connected to the receiver and it becomes necessary to introduce an attenuator adjusted to attenuate 23 db, in order to have the same receiver output that was observed with the horn antenna connected. Find out the gain of the large antenna either in db or power ratios.*

Solution. By eqns. 9.169 (b) and 9.170 (a)

$$P_{(db)} = 10 \log P$$
$$G = G_p \times P$$

and
$$G_{(db)} = G_{p(ab)} + P_{(db)}$$

$$P_{(db)} = 23$$
$$G_p = 12.5$$
$$23 = 10 \log P$$
$$P = A \log \frac{23}{10} = 0.1698 \times 10^3$$
$$P = \mathbf{169.8}$$
$$G_{p(db)} = 10 \log G_p = 10 \times \log 12.5$$
$$= 10 \times 1.0969 = 10.969$$
$$G_p = \mathbf{10.97}$$

$\therefore$
$$G = 12.5 \times 169.8$$
$$= \mathbf{2494\ Ans.}$$

$\therefore$
$$G_{(db)} = G_{p(db)} + P_{(db)}$$
$$= 10.97 + 23$$
$$= 10.97 + 23$$
$$= 33.97\ db$$
$$G_{(db)} \cong \mathbf{34\ db\ \ Ans.}$$

Example 9.19. *While measuring gain of a horn antenna the gain oscillator was set for 9.00 GHz frequency and the attenuation inserted was found to be 9.8 db. Calculate the gain of the horn. The distance between the two horn was 35 cm.*

(BHU, 1983)

Solution. Since

$$10 \log_{10} \frac{W_T}{W_r} = 9.8\, db$$

or
$$\frac{W_T}{W_r} = \text{A}' \log_{10} 0.98 = 0.9550 \times 10 = 9.55$$

or
$$\frac{W_r}{W_T} = \frac{1}{9.55} = 0.1047$$

Now
$$D = \frac{4\pi r}{\lambda}\sqrt{\frac{W_r}{W_t}} \quad \Bigg| \quad \text{Given} \quad r = 0.35 \text{ m}, \ \lambda = \frac{300}{9 \times 10^3} = \frac{3}{90} = \frac{1}{30}$$

$$= \frac{4\pi \times 0.35 \times 90}{3}\sqrt{0.1047}$$

$$= 12.56 \times 0.35 \times 30\sqrt{0.1047} = 131.88 \times 0.3235 = 42.6631$$

or
$$D\,(db) = 10 \log_{10} 42.6631 = 10 \times 1.6300 = \mathbf{16.300\ db} \quad \textbf{Ans.}$$

Example 9.20. A cylindrical

Ans.

Example 9.20. *A cylindrical antenna with a length to diameter ratio of 100 is resonant when the length is about 0.475 λ. The terminal impedance is resistance and equal to about 67 ohms. Find out the dimensions and terminal impedance of the complementary slot antenna of 10 cms wavelength.*

(Roorkee Univ. Applied EMT, 1972-73)

Solution. Given $\frac{L}{d} = 100$ or $L = 0.475\ \lambda$

The terminal impedance of the cylindrical antenna is about $Z_d = 67$ ohms. Then terminal impedance of the complementary slot is

$$Z_s = \frac{35{,}476}{Z_d} = \frac{35476}{67} = 529.4925 + j.0$$

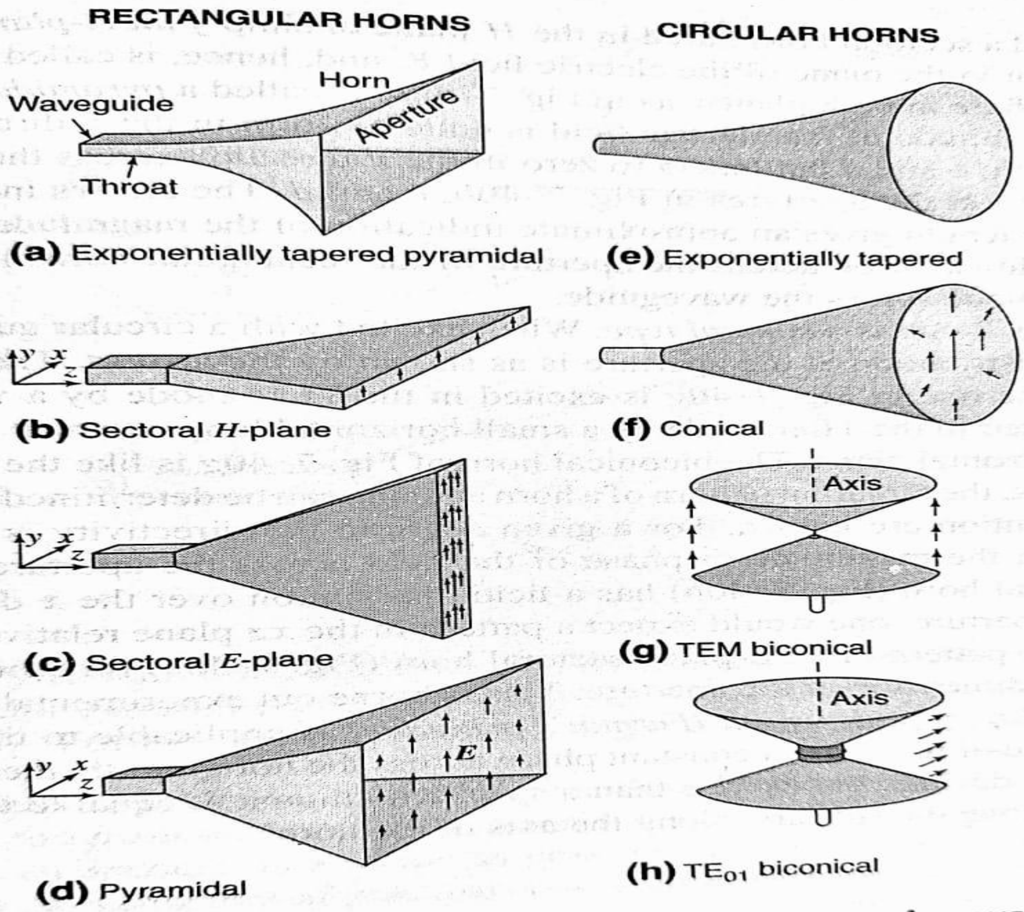
$$Z_s \simeq 530 + j0$$

EXAMPLE 7–20.1 (*a*) Determine the length L, H-plane aperture and flare angles θ_E and θ_H (in the E and H planes, respectively) of a pyramidal horn as in Fig. 7–40*d* for which the E-plane aperture $a_E = 10\lambda$. The horn is fed by a rectangular waveguide with TE_{10} mode. Let $\delta = 0.2\lambda$ in the E plane and 0.375λ in the H plane. (*b*) What are the beamwidths? (*c*) What is the directivity?

Solution

Taking $\delta = \lambda/5$ in the E plane, we have from (7–19–4) that the required horn length

$$L = \frac{a^2}{8\delta} = \frac{100\lambda}{8/5} = 62.5\lambda \tag{5}$$



7–40 Types of rectangular and circular horn antennas. Arrows indicate **E**-fie
ons.

and from (7–19–5) that the flare angle in the E plane

$$\theta_E = 2\tan^{-1}\frac{a}{2L} = 2\tan^{-1}\frac{10}{125} = 9.1^\circ \tag{6}$$

Taking $\delta = 3\lambda/8$ in the H plane we have from (7–19–5) that the flare angle in the H plane

$$\theta_H = 2\cos^{-1}\frac{L}{L+\delta} = 2\cos^{-1}\frac{62.5}{62.5+0.375} = 12.52^\circ \tag{7}$$

and from (7–19–5) that the H-plane aperture

$$a_H = 2L\tan\frac{\theta_H}{2} = 2\times 62.5\lambda\tan 6.26^\circ = 13.7\lambda \tag{8}$$

From Table 7–4,

$$\text{HPBW } (E \text{ plane}) = \frac{56^\circ}{a_{E\lambda}} = \frac{56^\circ}{10} = 5.6^\circ \tag{9a}$$

$$\text{HPBW } (H \text{ plane}) = \frac{67^\circ}{a_{H\lambda}} = \frac{67^\circ}{13.7} = 4.9^\circ \tag{9b}$$

From (3),

$$D \simeq 10\log\left(\frac{7.5A_p}{\lambda^2}\right) = 10\log(7.5\times 10\times 13.7) = 30.1 \text{ dBi} \tag{10}$$

4. **Design a three element yagi-uda antenna to operate at a frequency of 172 MHz.**

Solution:

Given f = 172 MHz

$$\text{Length of driven element} = \frac{475}{f(MHz)} \text{ feet} \quad \text{(or)}$$

$$= \frac{475 \times 0.3 \text{ m}}{f(MHz)} \quad [1 \text{ feet} = 0.3 \text{ m}]$$

$$L_{DR} = 0.83 \text{ m}$$

$$\text{Length of reflector,} \quad L_r = \frac{500}{f(MHz)} \text{ feet} \quad \text{(or)} = \frac{500 \times 0.3 \text{ m}}{f(MHz)}$$

$$= \frac{500 \times 0.3}{172}$$

$$L_r = 0.87 \text{ m}$$

$$\text{Length of director,} \quad L_d = \frac{450}{f(MHz)} \text{ feet} \quad \text{(or)}$$

$$= \frac{450 \times 0.3 \text{ m}}{172}$$

$$L_d = 0.785 \text{ m}$$

Spacing between the driven element and the reflector/director,

$$S = 0.1\,\lambda$$

$$= 0.1\, C/f = \frac{0.1 \times 3 \times 10^8}{172 \times 10^6}$$

$$\text{Element spacing,} \quad S = 0.174 \text{ m}$$

5. **For a 20 turn helical antenna operating at 3 GHz with circumference C = 10cm and the spacing between the turns is 0.3λ. Calculate the directivity and HPBW.**

Solution:

Given

$S = 0.3\,\lambda$, $f = 3$ GHz, $C = 10$cm $N = 20$

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{3\times10^9} = 0.1\text{m}$$

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

$$D = \frac{15\times20\times.3\lambda\times\left(10\times10^{-2}\right)^2}{\lambda^3}$$

$$= \frac{15\times20\times.3\times\left(10\times10^{-2}\right)^2}{(.1)^2}$$

$$D = 90$$

Half power beam width, HPBW $= \dfrac{52}{C}\sqrt{\dfrac{\lambda^3}{NS}}$ degree

$$\text{HPBW} = \frac{52}{10\times10^{-2}}\sqrt{\frac{(.1)^3}{20\times3(.1)}}$$

$$\text{HPBW} = 21.23$$

6. **Calculate the directivity in db of 20 turn helix, having $\alpha = 12^\circ$, circumference equal to one wave length.**

Solution:

Given

$C = \lambda,$ $\alpha = 12^\circ,$ $N = 20$

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

$$\tan\alpha = S/C$$

or
$$S = C\tan\alpha$$

$$S = \lambda\,(.2126)$$

$$D = \frac{15 \times 20 \times 0.2126\lambda \times \lambda^2}{\lambda^3}$$

$$D = 63.78$$

$$D \text{ in db} = 10\log_{10} D = 10\log_{10} 63.78$$

$$D \approx 18\text{db}$$

7. **A 16 turn helical antenna has a circumference of λ and turn spacing of $\lambda/4$. Determine half power beam width and axial ratio.**

Solution:

Given

$N = 16, \; C = \lambda, \quad \& \quad S = \lambda/4$

Half power beam width, $\text{HPBW} = \dfrac{52}{C}\sqrt{\dfrac{\lambda^3}{NS}}$

$$\text{HPBW} = \frac{52}{\lambda}\sqrt{\frac{\lambda^3}{16\frac{\lambda}{4}}}$$

$$= \frac{52}{\lambda}\sqrt{\frac{\lambda^2}{4}} = \frac{52}{\lambda}\frac{\lambda}{2}$$

$$\text{HPBW} = 26^\circ$$

Axial ratio, $AR = \dfrac{2N+1}{2N}$

$$AR = \frac{2(16)+1}{2(16)}$$

$$= \frac{33}{32} = 1.03$$

Axial ratio $= 1.03$