UNIT 6

1. What is meant by zoning? What are their advantages?

Ans: Lens, antennas are suitable for frequencies above 3000 MHz .If the frequency is less than 3000 MHz, lens antennas have more thickness.

The thickness of lens antennas can be reduced with the help of zoning. Thickness (*t*) is given by,

$$t = \frac{\lambda}{\mu - 1}$$

Where,

t = Thickness

λ= Free space wavelength

μ = Refractive index =(*c/v*)

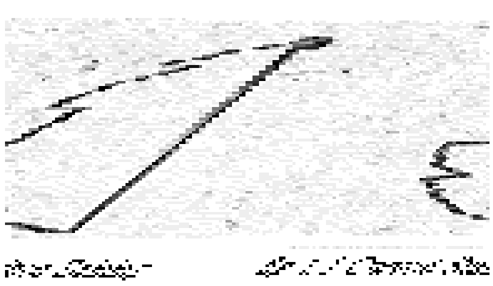
Zoning is classified into two types

(i) Curved surface zoning

(ii) Plane surface zoning.

(a) Curved Surface Zoning

1. In curved, surface zoning stepping or zoning is done to the curved surface of lens antenna.
2. Thickness of curved surface zoned lens is $t = \frac{\lambda}{\mu - 1}$
3. Curved surface zoned lens is mechanically stronger than the plane surface zoned lens,
4. Curved surface zoning lens antennas have less weight and less power dissipation
5. Example



(b) Plane Surface Zoning

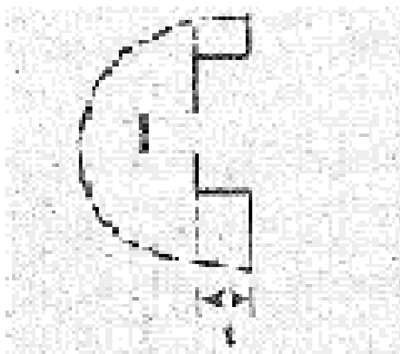
1. In plane surface zoning stepping or zoning is done to the plane surface.

2 .Thickness of plane surface zoned lens is, $t = \frac{\lambda}{\mu - 1}$

3. Plane surface zoned lens is less strong

4. Here the power dissipation is more.

Example



Curved surface zoning is preferable compared to the plane surface zoning.

Advantages of Zoning

1. This process reduces the weight of lens considerably.
2. The zoned dielectric lens antenna ensures that signals are in phase after emergence, despite difference in appearance.
3. The zoned lens is having less power dissipation.

Disadvantage

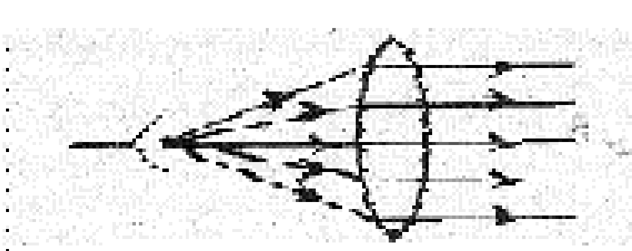
The zoned lens antennas are frequency sensitive

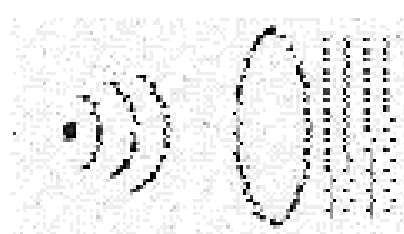
i.e., they are dependent on wavelength, λ

2. Explain the basic principal of operation of lens antenna and also distinguish between natural dielectric and artificial dielectric lenses.

Ans:

Lens antenna work on the principle of refraction. Lens antennas are made of a dielectric material. Figure 2.1(a) illustrates the principle of operation of such an antenna. A point source of radiation is placed at the focus of the km. The rays arriving at the lens closer to the edges of the lens encounter a larger curvature as compared to those arming at the center portion of the lens. The rays closer to the edges are refracted more than the rays closer to the censor





Similarly, on reception the rays arriving parallel to the lens axis are focused on to the focal point where the feed antenna is placed. Figure 2.1(b) shows that spherical waves emitted by the point source are transformed in to plane waves during transmission. The reason for this is that those portions of the wave front closer to the center are slowed down relatively more than those portions that are closer to the edges, with result that outgoing waves are planar. The same way plane waves incident on the lens antenna during reception emerge as spherical waves travelling towards the feed.

The precision with which these transformations take place depends upon the thickness of the lens in terms of operating wavelength. This makes the lens antennas less attractive at lower microwave frequencies.

Differences between Natural Dielectric Lenses and Artificial Dielectric Lenses

1. Artificial dielectric lenses have less weight compared to natural dielectric lenses.

2. Artificial dielectric lenses are made up of discrete metal particles whereas natural dielectric lenses consist of molecular particles.

3. Natural dielectric lenses, does not have any resonant effect

Characteristics

1. Both type of lens can be used to speed up (or) delay the travelling wave front.
2. Artificial and natural dielectric lenses are not much dependent on the wavelength.
3. The variation in thickness front ideal contour and variations in refractive index causes change in path length.
4. Lenses may be turned frequency sensitive with the help of zoning.
5. The thickness of lens antenna depends upon the refractive index **(u).** Thickness can be increased by reducing the refractive index.
6. The design conditions of artificial and natural dielectric lens antennas are same for same refractive index.

Merits and Demerits

1. Artificial dielectric lenses have less weight compared to the natural dielectric lenses.
2. Disadvantage of artificial dielectric lens is that they may have resonance effects.
3. Power dissipation is more in natural dielectric lenses.

3. Distinguish between sartorial, pyramidal and conical horns .Explain their utility?

Ans: Horn Antenna:

A Horn Antenna is similar to the opened out waveguide. It is excited at one end and kept opened at the other to get the energy radiated out of it.

The radiation is more from a waveguide compared to two wire transmission lines.

The amount of energy radiated from (out of) the waveguide is very less compared to the reflected energy due to impedance mismatch. In order to overcome the non-directive radiation pattern and poor radiation, we use horn antenna. The horn antenna is similar to the opened waveguide only difference is abrupt discontinuity is replaced by a gradual transformation.

Horn antennas are classified as,

1. Sectoral horn antenna
2. Pyramidal horn antenna
3. Conical horn antenna.

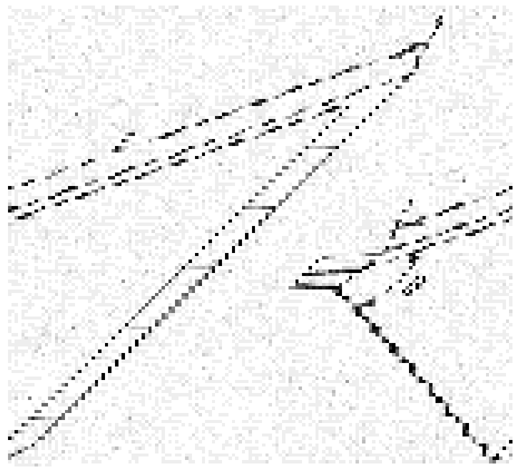
Depending upon the flaring, all the above horn antennas are classified.

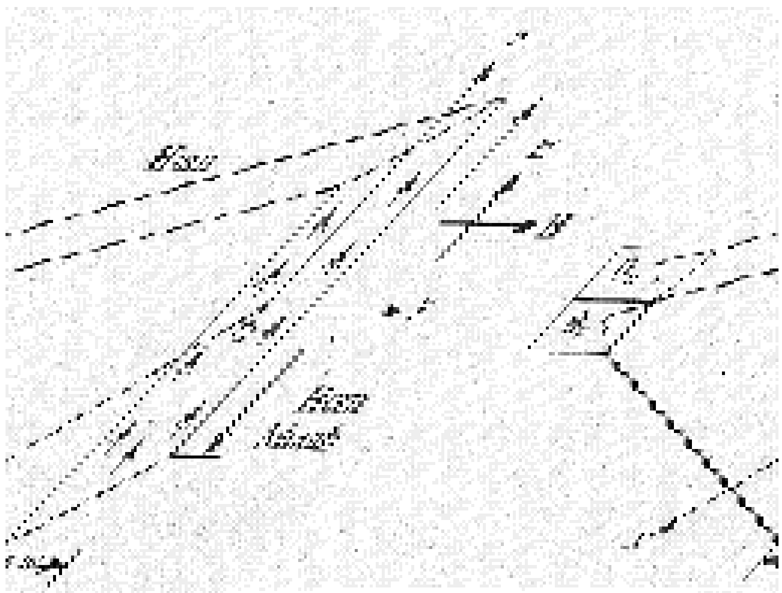
Sectoral Horn Antenna

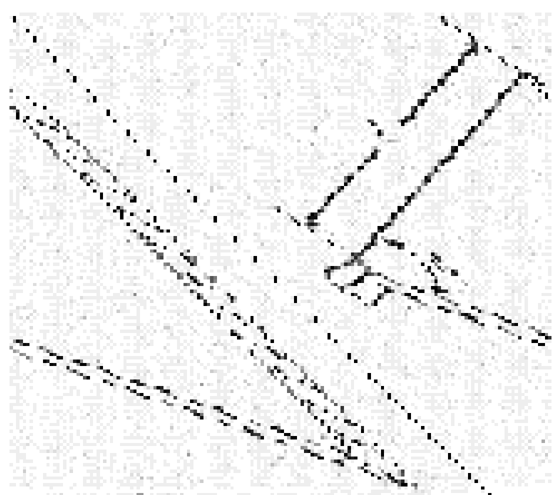
When the flaring is done at only one particular direction, it is known as sectoral horn antenna, depending upon the direction of flaring, sectoral horn antenna is classified as,

(i) H-plane sectoral horn antenna

(ii) E-plane sectoral horn antenna.







If the flaring is done to the walls of circular waveguide it is known as **Conical Horn** as shown below.

The main function of electromagnetic horn antenna is the impedance matching and to produce uniform phase front with a larger aperture to provide greater directivity. The general equation for flare angle (2θ) in horn antenna is given as,

$\theta = \tan^{-1}(h/2L) = \cos^{-1}(L/ L + \delta)$ and $L = h^2/8\delta$

Here,

h = Height of horn antenna

L=Axial length

δ = Permissible phase angle variations expressed as a fraction of 360° and 1
θ = (1/2) of flare angle.

The above equations are design conditions of horn antenna. If the value of flare angle (26) is very large, the wave front on the mouth of the horn antenna will be curved rather than plane.

General expressions for Half Power Beam Width (HPBW) of optimum flare horn in *E* and *H* directions, is given approximately as,

$$\theta_E = (56\lambda/h) \text{ and } \theta_H = (67\lambda/\omega)$$

Uses:

1. Horn antennas are generally used at microwave frequencies for moderate power gain.
2. Horn antennas are also used as a universal standard for calibration and gain measurement of other high gain antennas.
3. They are also used as primary radiators for reflector antennas.

4. What is the principal of equality of path length? How is it applicable to horn antenna and also explain the frii's transmission formula and its applicability for gain measurements?

Ans:

All the rays from the source to the plane surface of a lens will have equal path lengths as shown in the figure below.

Principal of equality of path Lengths

All the rays from the source to the plane surface of a lens will have equal path lengths as shown in the figure below.

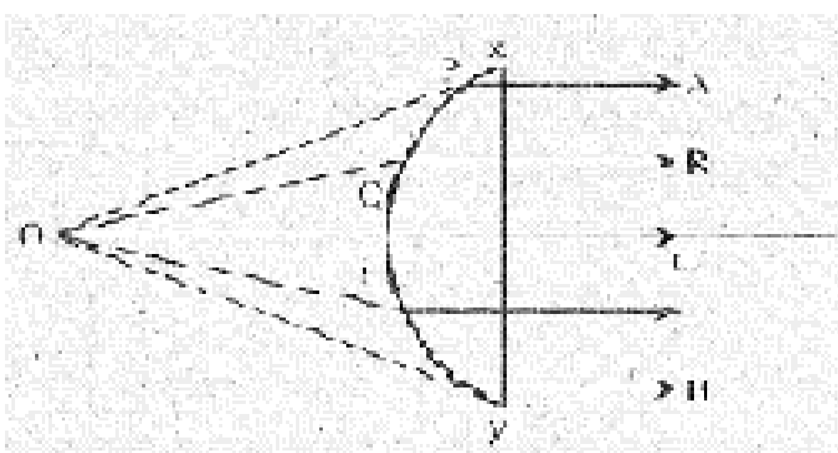


Fig. 4.1 Equality of path length

This principle is also applicable if we consider the source of electromagnetic radiations at '*O*'.

Hence, if the waves coming out of '*O*' are made to reach the aperture 'xy' at the same time, by properly designing the lens, they will all be in phase producing a uniform beam of radiation.

The same principle is applicable to the horn antennas. The horn antennas are designed so that the waves coming out of the plane of horn mouth is in phase with a slight deviation (not more than a specified amount).

This can be achieved by properly selecting the flare angle '2θ'. If the flare angle is greater than the optimum value, the waveform on the mouth of the horn will be curved which results in poor directivity. If the flare angle is less than optimum, the directivity again decreases due to decrease in aperture area (resulting from small flare angle).

Hence, by keeping the optimum flare angle of

$$2\theta = 2\tan^{-1}(h/2L)$$

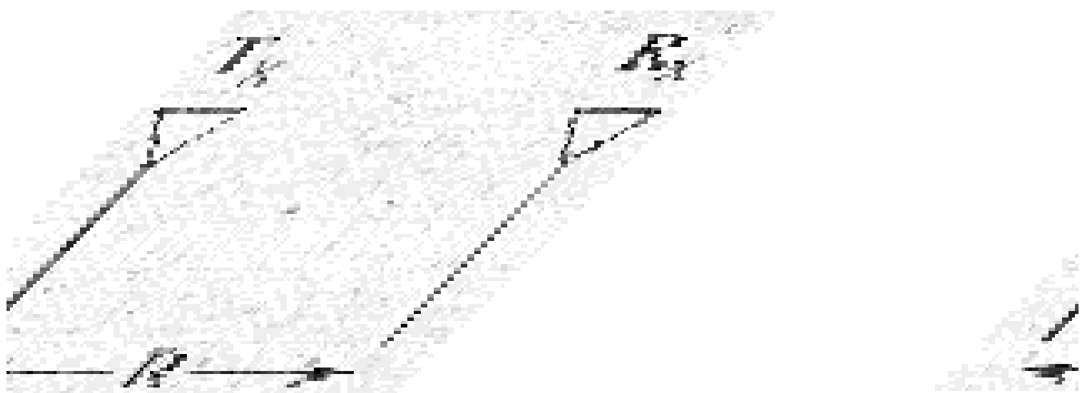
Maximum directivity can be achieved.

First transmission formula:

Frii's transmission formula is used to evaluate the power received by one antenna under idealized condition given another antenna some distance away transmitting a known amount of power,

Derivation

Consider two antennas in free space separated by distance R.



Assume that PT watts of total power are delivered to transmit antenna. For the moment, assume that the transmit antenna is Omni directional, lossless, and the receive antenna is in the far field of the transmit antenna. Then the power 'P' of the plane wave incident on the receive antenna a distance 'R" from the transmit antenna is given by,

$$P = P_T / 4\Pi R^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

If the transmitting antenna has a gain 'Gr' in the direction of the receiving antenna, then the above power equation becomes,

$$P = (P_T / 4\Pi R^2) G_T \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The gain term factors in the directionality and losses a real antenna. Assume now that the receive antenna an effective aperture given by *Ae*. Then the power received by this antenna P_R is given by,

$$P_R = (P_T / 4\Pi R^2)\ GT.Ae$$

Since the effective aperture for any antenna can also be expressed as,

The resulting received power in expression (3) can be written as,

$$P_R = ((P_T / (4\Pi R)^2) G_T A_e \lambda^2 G_R$$

This is known as frii’s transmission formula. It relates the free space path loss, antenna gains and wavelength to the received and transmits powers

Measurement of Antenna Gain Using above Formula

Assume that transmitting and receiving antennas are identical and separated by a distance 'R' such that

$$R \geq 2d^2/\lambda$$

Where, *d*=Depth of antenna

Since Antennas are identical, $G_T = G_r = G0.$

Equation (1) can be written as

Equation (1) can be written as,

Gain of antenna using first transmission formula is,

$$P_R = \frac{P_T G_0^2 \lambda^2}{(4\pi R)^2}$$

$$G_0^2 = \left(\frac{4\pi R}{\lambda}\right)^2 \frac{P_R}{P_T}$$

$$G_0 = \frac{4\pi R}{\lambda} \sqrt{\frac{P_R}{P_T}}$$

Therefore the gain of the of antenna using first transmission formula is ,

$$\boxed{G_0 = \frac{4\pi R}{2} \sqrt{\frac{P_R}{P_T}}}$$

5.Write a short note on "Antenna Pattern Measurements " ?
Ans:

The antenna pattern is also termed as radiation pattern of an antenna. The radiation pattern is nothing but the plot of the intensity of radiation taken at different points that are at equal distance from the antenna. It is also defined as plot of power density with respect to the direction. The radiation pattern of an antenna is a 3-D figure. Hence, it needs intensity of radiation measurement over all spatial angles.

Let us assume a 3-coordinate Cartesian system in which the antenna, whose pattern is to be measured, is placed at the origin as shown in figure 5.1

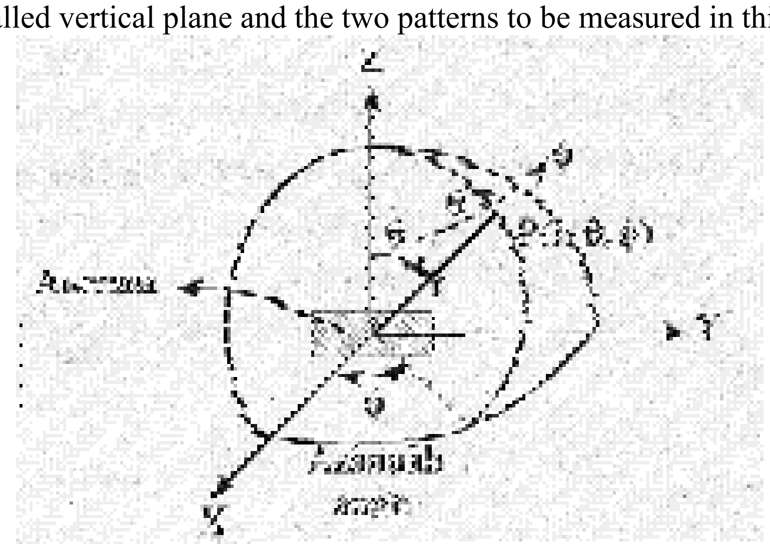
The plane *XY* is horizontal plane. For horizontal plane antenna, the two patterns exhibited are,

(a) The ‘θ’ component of E-field (horizontal) is measured as a function of (j) in *XY* plane (0 = 90°). This is indicated as E_{Φ} (θ = 90°, (j>) and called as *E*-plane pattern.

(b)The Φ component of *E*-field is measured as a function of c in *XZ* plane (Φ = 0°). This is represented as E_{Φ} = (θ, Φ = 0°) and called as H-plane pattern.

These E-plane and H-plane patterns are mutually perpendicular to the major lobe.

The plane *XZ* is called vertical plane and the two patterns to be measured in this plane are,



(a) The ' θ ' component of it-field is measured as a function of Φ in *XY* plane (θ = 90°). This is represented by E_θ (θ=90°, Φ) and called as H-plane pattern.

(b) The θ component of *E*-field is measured as a function of θ in *XZ* plane ((j) = 0°). This is represented as E_θ(θ, (j) = 90°) and called as E-plane pattern.

For circularly or elliptically polarized antennas, these four patterns should be measured.

The two types of techniques for measuring antenna pattern in any one of the plane are,

1. The primary antenna is fixed, and the secondary antenna is equipped for free rotation around the primary antenna in circular fashion. The field strength and direction of secondary antenna with respect to primary is noted at different points on the circular path of secondary antenna. Then, the required antenna pattern plot is made.

2. In this procedure, the primary antenna is rotated along vertical axis with respect to secondary antenna. The field strength at primary receiving antenna with respect to transmitting secondary antenna is recorded at different point on the vertical rotation path of primary antenna. Then, with recorded values, plot is made.

6.Describe the method of measuring the gain and radiation pattern of an antenna ?

Ans:

Absolute Method of Gain Measurement:

To measure the absolute gain of an antenna another identical antenna is used. They are arranged at a distance V from each other as shown in the figure.

The directions of both the antennas are adjusted for maximum signal. Then the input to the transmitting antenna is adjusted to a specified level and the corresponding receiver reading is recorded, i.e., the attenuator dial setting and power bridge readings are recorded as *Wr* and *Pt1* respectively.

Then the transmitter is connected to the receiver directly (through pads). The attenuator dial is adjusted until the receiver shows the same previous level. Now the attenuator dial setting and the power bridge readings are recorded as Wr and Pt2

Since the two antennas are identical pt1 = pt2 and the gain 'G ' is calculated as,

Measurement of Field Pattern

The energy radiated by an antenna is not same in all directions it is more in one direction and less in another direction. The energy radiated by an antenna is measured in terms of field strength. Consider the general arrangement shown below.

Here primary antenna (transmitting antenna) and receiving antenna are separated by a distance of

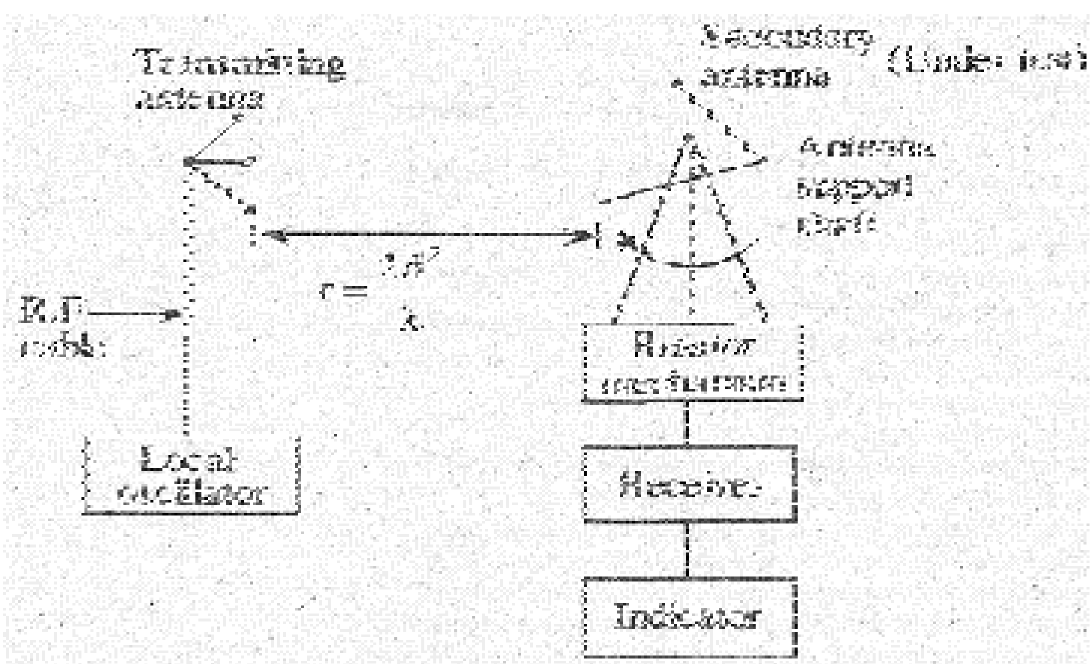
$$R \geq 2d^2/\lambda$$

Depending upon the direction of rotation, the antenna support shaft is rotated.

(i) $E_\Phi (\theta = 90°)$

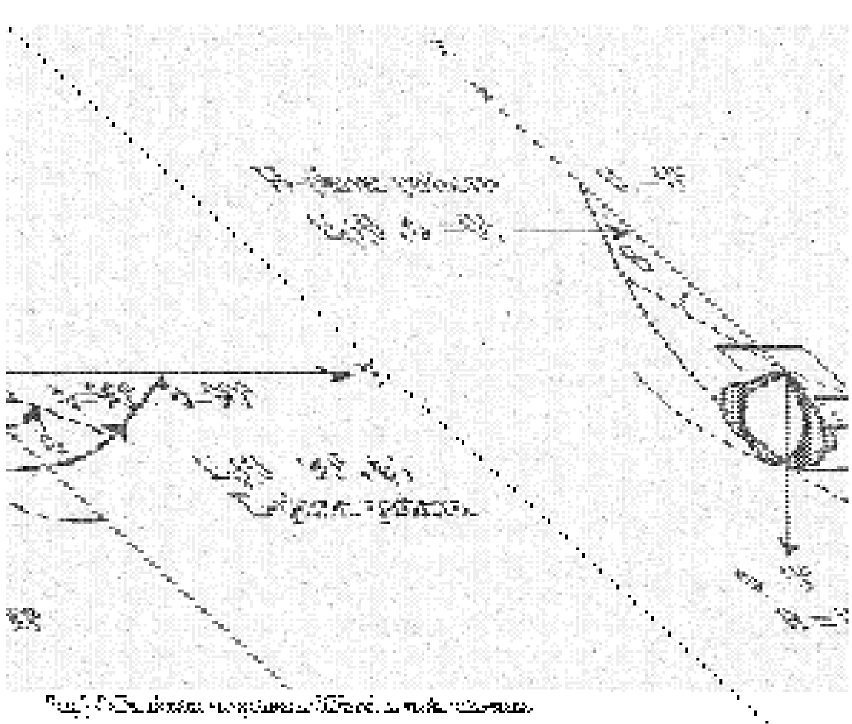
In this measurement, the antenna support shaft is rotated and both primary and secondary antennas are horizontal. .

(ii) $E_\Phi (\theta, \Phi = 0°)$



In this pattern measurement, the antenna support shaft is rotated both primary and secondary antennas are vertical. Radiation pattern of an antenna is generally expressed in terms of horizontal and vertical plane,

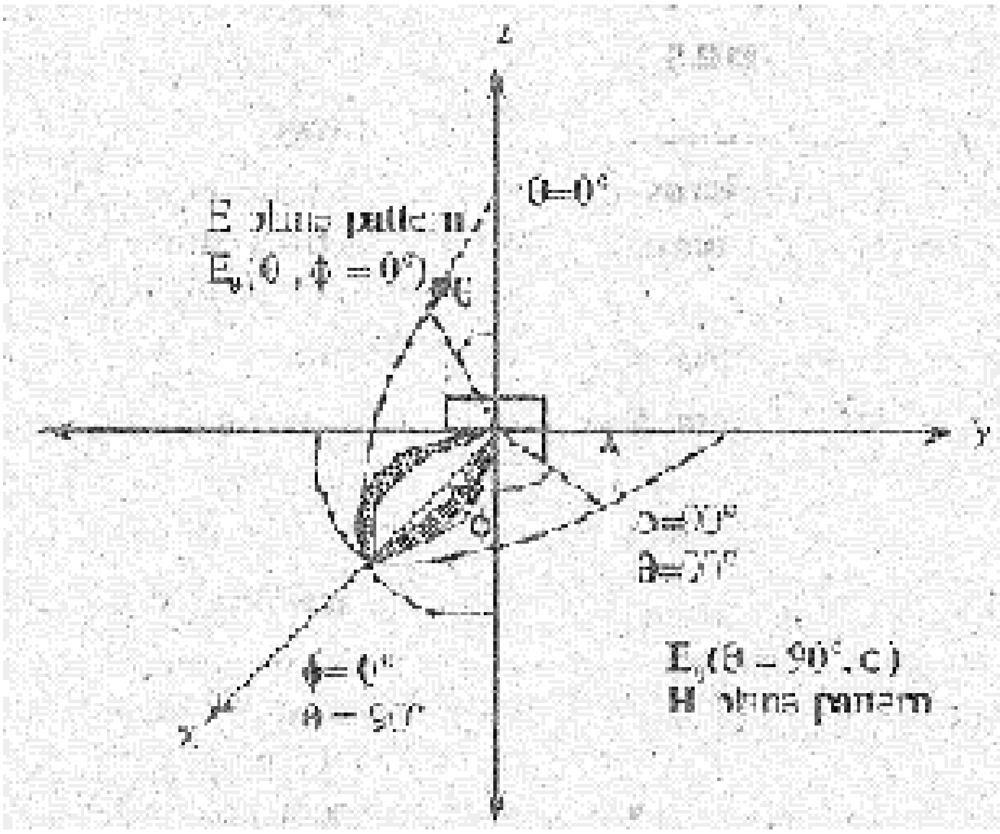
(a)Radiation Pattern (Horizontal and Vertical) of Horizontal Antenna



(i) *E* $_{\Phi}$ (θ= 90°, Φ) is known as E-plane pattern because the electric field is function of Φ

(ii) *E* $_{\Phi}$ (θ, Φ=90°) is known as H-plane pattern because the electric field is function of 6.- From reciprocity theorem the pattern of an antenna is same for receiving mode and transmitting mode. Hence figure (a) and figure (b) are valid under receiving mode also.

(b) Radiation Pattern (Horizontal and Vertical) of Vertical Antenna



(i) E $_{\theta}$(θ= 90°, Φ) is known as H-plane pattern because the electric field component Eθ as a function of Φ

(ii) E $_{\theta}$(θ, Φ = 0°) is known as E-plane pattern because the electric field Eθ as a function of Φ

After calculation of radiation pattern directivity can be calculated as follows. Directivity is defined as the ratio of maximum radiation intensity to the average radiation intensity.

$$D=\frac{\text{Maximum Radiation Intensity}}{\text{Average radiation intensity}}$$

$$D=4\Pi U(\theta,\ \Phi)/W_T$$

Where,

$$W_T=\int_{\theta=0}^{\Pi}\int_{\Phi=0}^{2\Pi}\boldsymbol{U}(\theta,\Phi)\ sin\theta d\theta d\Phi$$

7. Explain the impedance measurement of a horn antenna by using slotted line method with necessary relations?

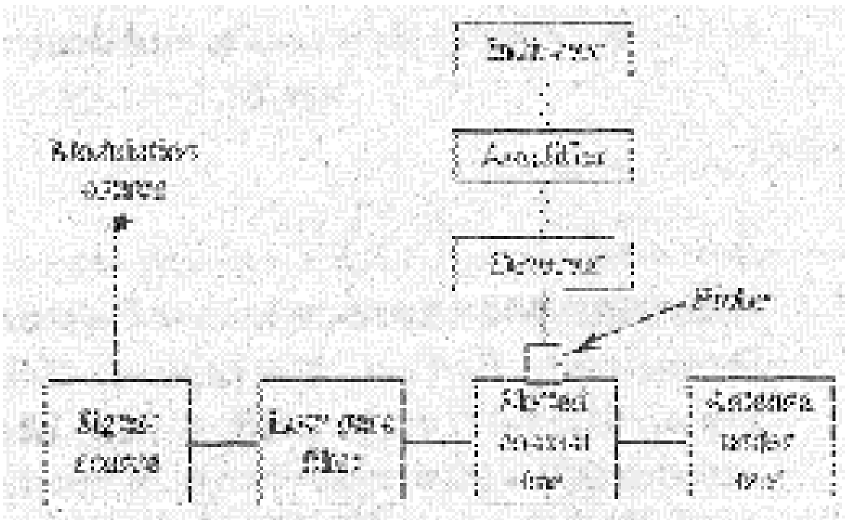
Ans:

Slotted Line Method for Impedance Measurement

Measurement of antenna impedance depends upon the frequency.
Impedance measurement can be done by two| methods,

1. Bridge method
2. Slotted line method,

The slotted line method is of practical important at frequencies 30 MHz - 1000 MHz . The block diagram of slotted line method is shown below.



7.1 [illegible]

In this method, impedance of antenna is determined from the voltage and current standing wave ratio. So that, this method is also known as "Standing wave ratio method".

The load impedance (or antenna input impedance) (Z_L) is given by,

$$Z_L = Z_0\frac{(1+K)}{(1+K)}$$

Where,

Z_L = Load impedance

Z_0 = Characteristic impedance

K = Reflection coefficient

Voltage standing wave ratio is defined as the ratio of maximum voltage to the minimum voltage.

$$\text{VSWR}=\left|\frac{Vmax}{Vmin}\right|$$

$$\text{VSWR}=\frac{|Vi|+|Vr|}{|Vi|-|Vr|}$$

$$\text{VSWR}=\frac{1+|Vr|/|Vi|}{1-|Vr|/|Vi|}$$

Where,

Vr = Reflected voltage

Vi= Incident voltage

The ratio of reflected voltage to the incident voltage is known as reflection coefficient

$$K=|Vr|/|Vi|$$

Therefore $$\text{VSWR}=\frac{1+|K|}{1+|K|}$$

i.e. $$|K| =\frac{\text{VSWR}-1}{\text{VSWR}+1}$$

and phase angle ,$\theta=180\left(1-\frac{4d}{\lambda}\right)$

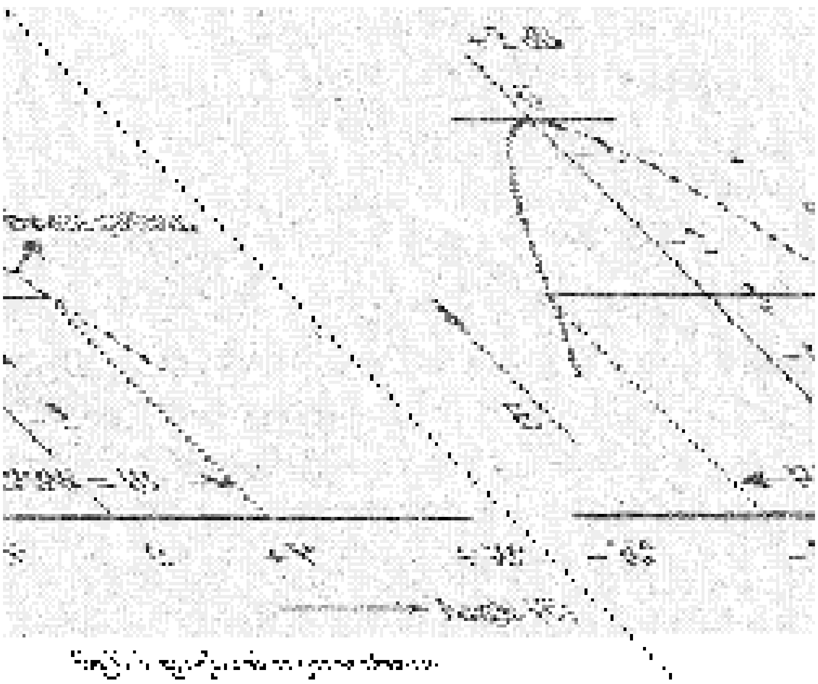
8.Explain the method of measurement of HPBV of a horn antenna in H-plane with a neat sketch ?and also explain the method to find the directivity of the horn antenna?

Ans: Measurement of HPBW

Measurement of Half power beam width depends upon the radiation patterns. We know that half power beam width is defined as the product of beam angle in electric and magnetic field direction.

HPBW = $\theta_E * \theta_H$

The graph of various values of 0 corresponding to the field is shown below.



Beam width is defined as angular width in degrees (or) maximum width of beam pattern. From figure, beam width is 3 dB (or) - 3 dB.

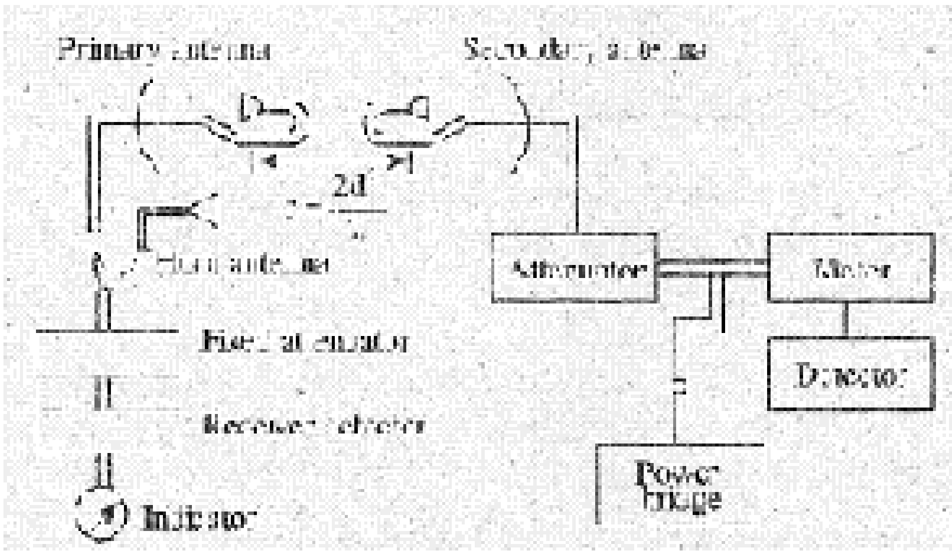
Without knowing the radiation pattern, we can measure the half power beam width by rotating the primary antenna instead of secondary. The meter is adjusted until

the voltage level of primary antenna becomes = (or) 0.707.

The same process applied to the secondary antenna and the meter is adjusted to the voltage level of $1/\sqrt{2}$(or)

0.707. The difference between the two maximum angle readings gives the beam width.

General setup for measurement of half power beam-width of horn antenna is shown below.



The above setup is similar to the gain measurement. Here primary and secondary antenna are separated by a distance

r =2d2/λ . The primary antenna is rotated with respect to the secondary antenna, the meter reading adjusted to 0.707 of voltage level.

Directivity of Horn Antenna

The general expressions for half power beam width in E and H-plane is,

$\theta_E = \frac{56\lambda}{h}$ degree

$\theta_H = \frac{63\lambda}{h}$ degree……………….(1)

We known that , directivity is defined is defined as the product of HPBW in E and H-plane direction.

$$D= \frac{41,257}{\theta E*\theta H}\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Substitute equation (1) in equation (2),then

$$D=\frac{10.9hw}{\lambda^2}$$

The product of *h* and ω is the area of horn mouth,

$A=h*w$

$D=10.9A/\lambda^2$

9.Calculate the minimum distance required to measure the field pattern of an antenna of diameter 2 m at a frequency of 3GHz.Derive the necessary equation ?

Ans: Given that,

For the measurement of field pattern,
Diameter of the antenna, d= 2 m
Operating frequency, f= 3 GHz
Minimum distance required to measure the field pattern, r= ?
Then,
Operating wavelength,

$$\lambda=C/f$$

Thus, the minimum distance required to measure the field pattern of an antenna is given by,

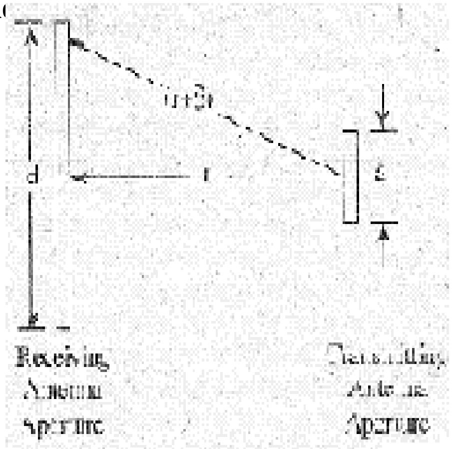
$$r=2d^2/\lambda$$

$$r=2(2)^2/0.1$$

Therefore $r=80m$

Derivation

The distance between transmitting and receiving antennas should be very large in order to obtain the Fraunhofer (or) far field region. Hence distance requirement is one of the important parameters for measuring radiation pattern of an antenna .If this distance is very small, then near field (or) Fresnel pattern is obtained . So the antenna under test should be illuminated by a plane wave front which is available only at infinite distances.



But the upper limit is that the phase difference between centre and end of the receiving antenna aperture should not exceed λ/16

Hence for the measurement of radiation pattern the distance between transmitting and receiving antennas should be greater than $2d^2/\lambda$

i.e. $r \geq 2d^2/\lambda$

In general the value of r is expressed in terms of d and phase difference error (δ) as,

$$(r+\delta)^2 = \left(\left(\frac{d}{2}\right)^2 + r^2\right)$$

$$r^2 + \boldsymbol{\delta}^2 + 2\boldsymbol{\delta r} = \left(\left(\frac{d}{2}\right)^2 + r^2\right)$$

$$\boldsymbol{\delta}^2 + 2\boldsymbol{\delta r} = \left(\frac{d}{2}\right)^2$$

Since $\boldsymbol{\delta}^2$ is very small, then

$$2\boldsymbol{\delta r} = \left(\frac{d}{2}\right)^2$$

Therefore

$$2\boldsymbol{\delta} r = \frac{d^2}{4}$$

$$r = \frac{d^2}{8\delta}$$

From above equation, we can say that the minimum distance required for transmitting and receiving antenna are $\frac{d^2}{8\delta}$

10. Explain the principal of operation of dielectric lens antenna ?

Ans:

Lens antennas are useful at higher frequencies above 3000 MHz

Dielectric Lens

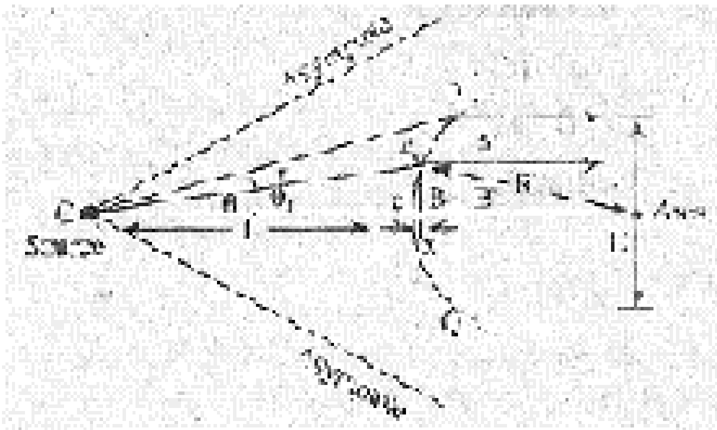
Dielectric lens are also known as "H-plane Metal Plate Lens".

Here the travelling wave fronts are delayed or retorted by the lens medium.
Again dielectric lens antennas are classified into two types,

(a) Non-metallic dielectric lens antennas
(b) Metallic dielectric lens antennas.

Non-Metallic Dielectric Lens Antennas

Consider, the general arrangement of non-metallic dielectric lens antenna is shown in fig 10.1



Here source is located at point **O,** the rays are incident on the plane surface **PQ** of the lens. The rays emerging from source have equal distance and constant phase. According to the geometry,

$OA + AA' = OC + CE = OC + CB + B B^1$ since From figure, $AA' = BB^1$

$OA + AA' = OC + CB + BB^1$ $OA = OC + CB$

Here, c = Velocity of wave in air
v = Velocity of wave in lens medium

Multiplying "c" on both side

$$c\left(\frac{r}{c}\right) = c.\frac{L}{c} + c.\frac{x}{v}$$

$$(r) = L + \frac{x.c}{v}$$

$r = L + x(\mu)$ since $\mu = \left(\frac{c}{v}\right)$

$r = L + \mu(r\cos\theta - L)$ since $x = \mu(r\cos\theta - L)$

$r = L + \mu r\cos\theta - \mu L$

Therefore $r = \frac{L(1-\mu)}{\mu\cos\theta - 1}$

The above expression represents the contour of lens in polar coordinates

b) Metallic Dielectric Lens Antennas

The metallic dielectric lenses are made with discrete metal particles of microscopic size.

The particles should be so small compared to the design wave length that the maximum particle dimension (parallel to the E-field) is less than λ and the spacing to avoid diffraction effects