RADIATION PATTERN:-

Practically any antenna cannot radiate energy with same strength uniformly in all directions- radiation will be large in one direction , while zero or minimum in other directions.

The radiation from the antenna in any direction is measured in terms of field strength at a point located at a particular distance from an antenna.

The field strength can be calculated by measuring voltage at two points on an electric links of face and their dividing by distance between two points. Hence unit of radiation pattern is V/m. The radiation pattern of an antenna is the important characteristic of antenna because it indicates the distribution of energy radiated by an antenna in the space.

The radiation pattern is nothing but a graph which shows the variation of actual field strength of EM field at all the points equidistant from the antenna. Hence, it is 3-D graph.

Radiation patterns are of two types:

(i) If the radiation of the antenna is represented graphically as a function of direction it is called ***radiation pattern***. But if the radiation of the antenna is expressed in terms of the field strength E (V/m) , then the graphical representation is called ***field strength pattern or field radiation pattern.***

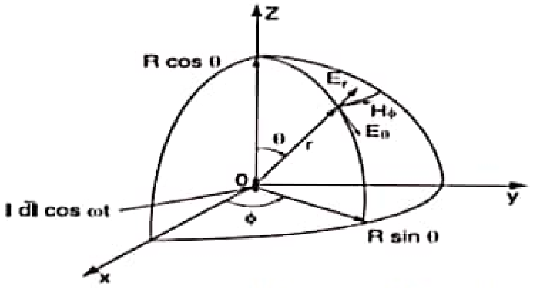
BASED ON MODE OF DIRECTION OF PATTERN, TYPES OF PATTERNS ARE:-

(1)DIRECTIONAL PATTERNS AND OMNIDIRECTIONAL PATTERNS:-

A radiator acting as a lossless, hypothetical antenna radiating equally in all directions is called ***isotropic radiator***.

An antenna with a property of radiating or receiving the EM waves more effectively in same direction than in other directions is called ***directional antenna***.

The radiation pattern of such antenna is called directional pattern when antenna has max. directivity greater than that of a half wave dipole is know as directional antenna.



Configuration of filamentary current carrying conductor.

(2)FIELD RADIATION PATTERN:-

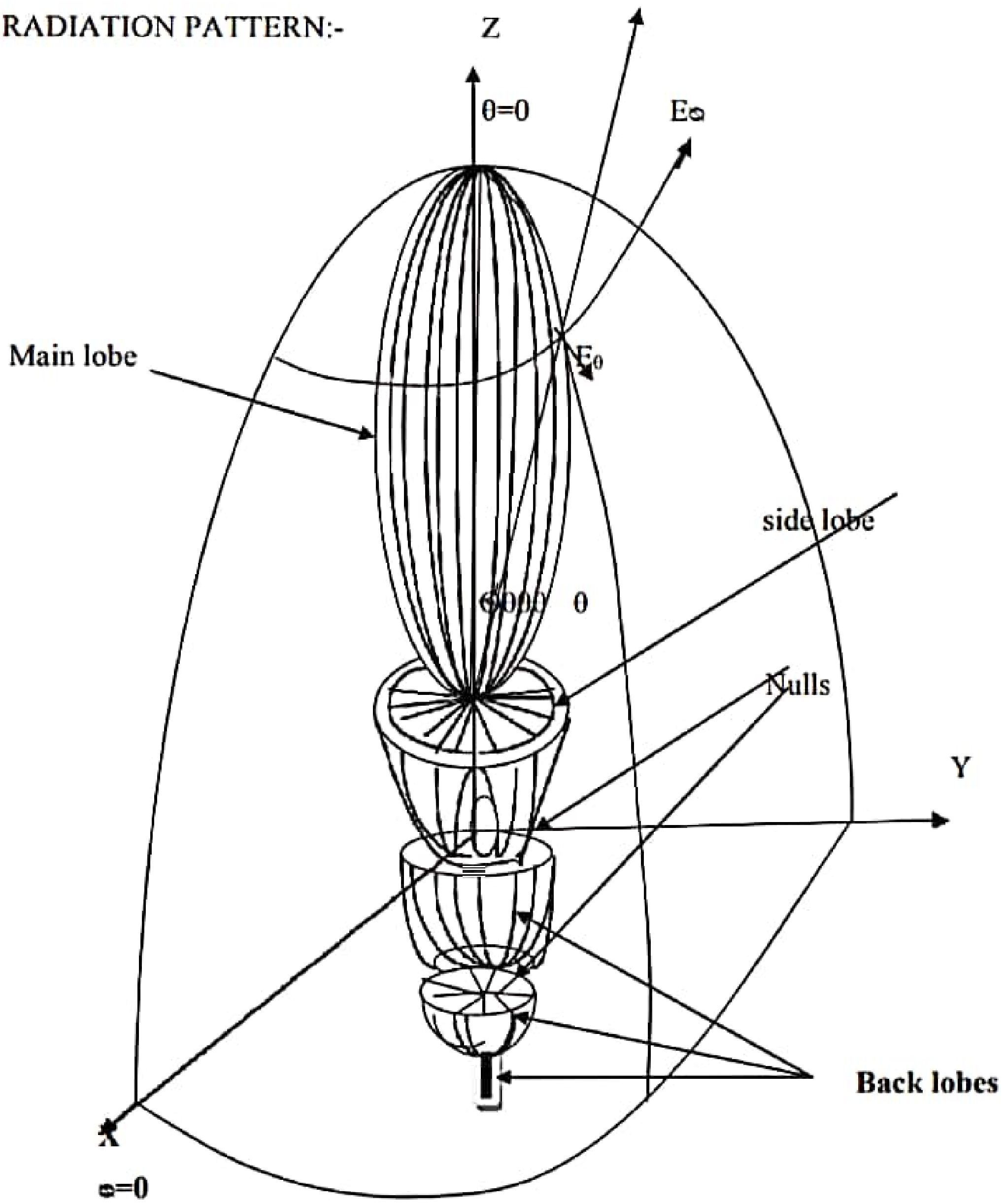


Fig. 3-D radiation pattern with main lobe, side lobes and back lobes.

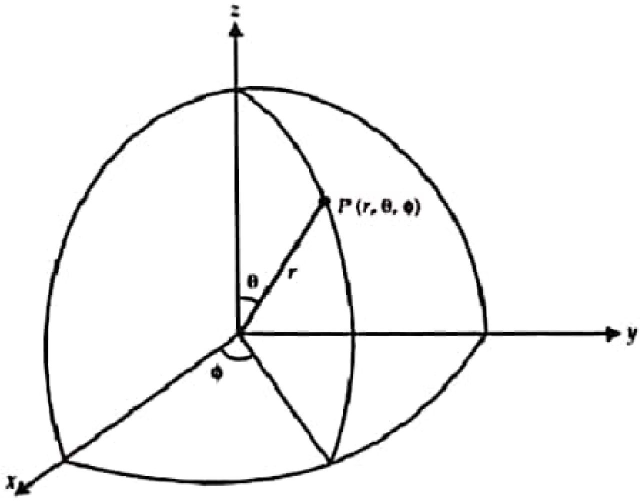


Figure 1.3 *A point in spherical coordinate system*

$$\theta = \cos^{-1} \frac{z}{\sqrt{x^2 + y^2 + z^2}} \qquad 0 \le \theta \le \pi$$

$$\phi = \tan^{-1} \frac{y}{x} \qquad 0 \le \phi \le 2\pi$$

The relations between the variables of cylindrical and spherical coordinates are given by

$$\begin{aligned} \mathbf{A} &= (A_r, A_\theta, A_\phi) \\ &= [(A_x \sin\theta \cos\phi + A_y \sin\theta \sin\phi + A_z \cos\theta), \\ &\qquad (A_x \cos\theta \cos\phi + A_y \cos\theta \sin\phi - A_z \sin\theta), \\ &\qquad (-A_x \sin\phi + A_y \cos\phi)] \end{aligned}$$

The dot products of $\mathbf{a}_x$, $\mathbf{a}_y$ and $\mathbf{a}_z$ with $\mathbf{a}_r$, $\mathbf{a}_\theta$ and $\mathbf{a}_\phi$ are given by

$$\mathbf{a}_x \cdot \mathbf{a}_r = \sin\theta \cos\phi$$
$$\mathbf{a}_x \cdot \mathbf{a}_\theta = \cos\theta \cos\phi$$
$$\mathbf{a}_x \cdot \mathbf{a}_\phi = -\sin\phi$$
$$\mathbf{a}_y \cdot \mathbf{a}_r = \sin\theta \sin\phi$$
$$\mathbf{a}_y \cdot \mathbf{a}_\theta = \cos\theta \sin\phi$$
$$\mathbf{a}_y \cdot \mathbf{a}_\phi = \cos\phi$$
$$\mathbf{a}_z \cdot \mathbf{a}_r = \cos\theta$$
$$\mathbf{a}_z \cdot \mathbf{a}_\theta = -\sin\theta$$
$$\mathbf{a}_z \cdot \mathbf{a}_\phi = 0$$

Here,

$$A_r = A_x \sin\theta \cos\phi + A_y \sin\theta \sin\phi + A_z \cos\theta$$
$$A_\theta = A_x \cos\theta \cos\phi + A_y \cos\theta \sin\phi - A_z \sin\theta$$
$$A_\phi = -A_x \sin\phi + A_y \cos\phi$$

The point $A(x, y, z) = A(\rho, \phi, z) = A(r, \theta, \phi)$ in Cartesian, cylindrical and spherical coordinate systems is shown in a single Figure 1.4 to explain the concept at a glance.

$\rho = r \sin\theta$

$\phi = \phi$

$z = r\cos\theta$

$r = \sqrt{\rho^2 + z^2}$

$\theta = \tan^{-1}\frac{r}{z}$

$\phi = \phi$

The unit vectors of spherical coordinates in terms of Cartesian coordinates are given by

$\mathbf{a}_r = \sin\theta\ \cos\phi\ \mathbf{a}_x + \sin\theta\ \sin\phi\ \mathbf{a}_y + \cos\theta\ \mathbf{a}_z$

$\mathbf{a}_\theta = \cos\theta\ \cos\phi\ \mathbf{a}_x + \cos\theta\ \sin\phi\ \mathbf{a}_y - \sin\theta\ \mathbf{a}_z$

$\mathbf{a}_\phi = -\sin\phi\ \mathbf{a}_x + \cos\phi\ \mathbf{a}_y$

A vector $\mathbf{A} = (A_x, A_y, A_z)$ is expressed in spherical coordinates as

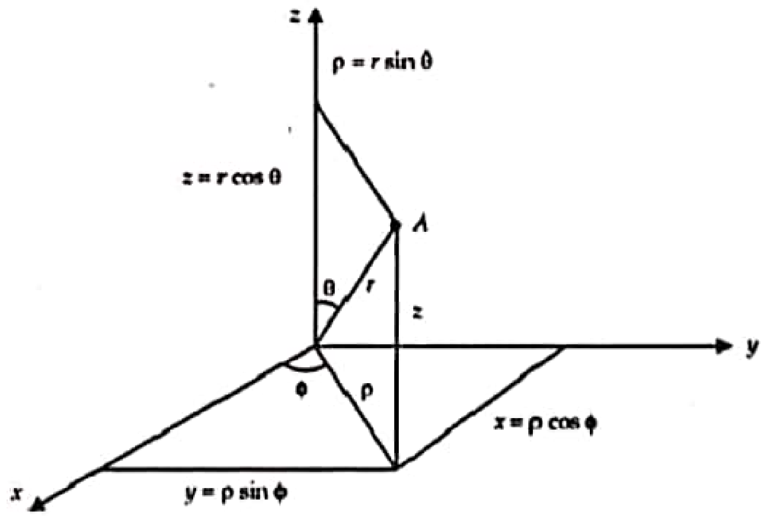
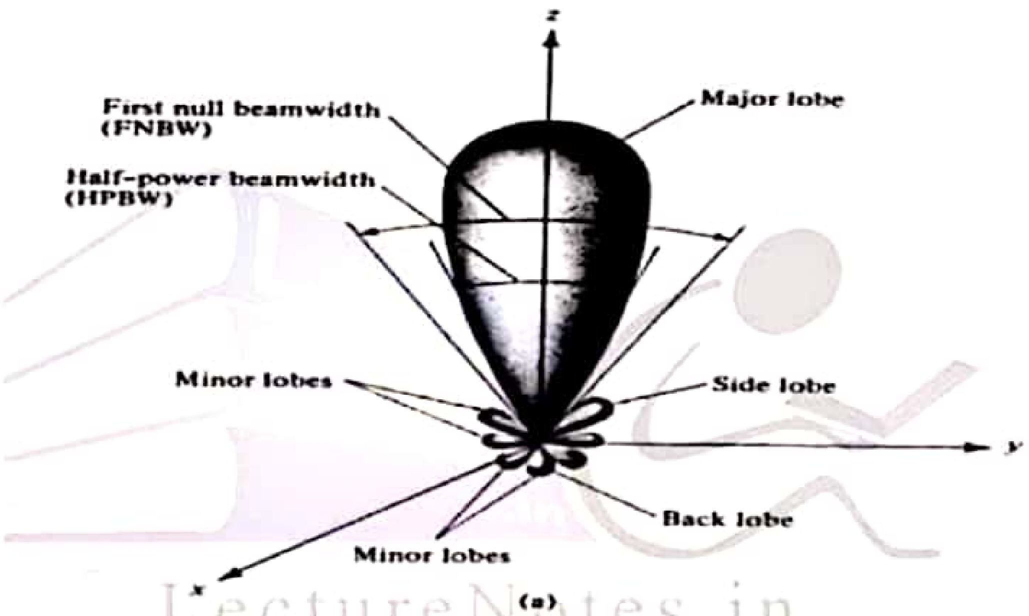


Figure 1.4 *Coordinates in all the three systems*

Pattern lobes and beam widths



(a)

Pattern in spherical co-ordinate system

The relations for differential length, area and volume are given in Table 1.1.

Table 1.1 Differential quantities in different coordinates

Coordinate System	*dL*	*dS*	*dv*
Cartesian	$dx\,\mathbf{a}_x + dy\,\mathbf{a}_y + dz\,\mathbf{a}_z$	$dx\,dy\,\mathbf{a}_z$ or $dy\,dz\,\mathbf{a}_x$ or $dz\,dx\,\mathbf{a}_y$	$dx\,dy\,dz$
Cylindrical	$d\rho\,\mathbf{a}_\rho + \rho\,d\phi\,\mathbf{a}_\phi + dz\,\mathbf{a}_z$	$\rho\,d\rho\,d\phi\,\mathbf{a}_z$ or $\rho\,d\phi\,dz\,\mathbf{a}_\rho$ or $d\rho\,dz\,\mathbf{a}_\phi$	$\rho\,d\rho\,d\phi\,dz$
Spherical	$dr\,\mathbf{a}_r + r\,d\theta\,\mathbf{a}_\theta + r\sin\theta\,d\phi\,\mathbf{a}_\phi$	$r\,dr\,d\theta\,\mathbf{a}_\phi$ or $r\sin\theta\,dr\,d\phi\,\mathbf{a}_\theta$ or $r^2\sin\theta\,d\theta\,d\phi\,\mathbf{a}_r$	$r^2\sin\theta\,dr\,d\theta\,d\phi$

The relations between the polar coordinates, (ρ, ϕ) and (x, y) of Cartesian Coordinates are

$$x = \rho\cos\phi$$

$$y = \rho\sin\phi$$

$$\rho = \sqrt{x^2 + y^2}$$

$$\phi = \tan^{-1}\left(\frac{y}{x}\right)$$

$$dx\,dy = \rho\,d\rho\,d\phi.$$

1.9 DECIBEL AND NEPER CONCEPTS

Decibel (dB) is defined as ten times the common logarithm of the power ratio. That is, $1\,\text{dB} = 10\log_{10}\left(\frac{P_1}{P_2}\right)$

If P_1 and P_2 are input and output powers respectively of an electric circuit, then dB is negative if $P_2 > P_1$. This indicates power loss. If $P_1 > P_2$, dB is positive. This indicates power gain.

Decibel has no dimensions and it is used to express the ratio of two powers, voltages, currents or sound intensities.

One Bel (B) is equal to 10 decibels.

When input and output currents and voltages are known, we have

$$1\,\text{dB} = 20\log_{10}\left(\frac{V_2}{V_1}\right)$$

$$= 20\log_{10}\left(\frac{I_2}{I_1}\right)$$

Neper (*NP*) It has no dimensions and it is used to express the ratio of powers in communications.

A Neper is defined as the natural logarithm of the square root of the power ratio. That is, $1\,\text{Np} = \log_e\sqrt{\frac{P_2}{P_1}} = \frac{1}{2}\log_e\left(\frac{P_2}{P_1}\right)$

It's a 3-D pattern to represent field radiation pattern, spherical co-ordinate system is most suitable.

_r' indicates the distance from antenna located at origin to the distance point P. The field intensity at point P is proportional to the distance _r'. From the above fig. it is clear that field pattern consists of main lobe in z-direction where θ=0 (which represents maximum radiation in that direction) then minor lobes on the sides (which are also called side lobes) and nulls between different lobes indicating minimum or zero radiation.

The pattern consists a small lobe exactly opposite to the main lobe which is called back lobe. The field radiation pattern can be expressed completely w.r.t. field intensity and polarization using 3 factors.

(1) $E_\theta(\theta,\phi)$ →The θ-component of the electric field as a function of angles θ and ϕ (v/m)

(2) $E_\phi(\theta,\phi)$ → The ϕ-component of electric field as a function of angle θ and ϕ (v/m)

(3) $\delta_\theta(\theta,\phi)$ or $\delta_\phi(\theta,\phi)$ → The phase angles of both the field components (deg. Or rad.)

The field pattern is expressed in terms of relative field pattern which is commonly called normalized field pattern. The normalized field pattern is defined as the ration of the field component to its max. value.

Normalized field pattern is a dimensionless quantity with max. value =1.

The normalized field patterns for θ and ϕ components of Electric Field are given as

$E_{\theta n}(\theta,\phi) = E_\theta(\theta,\phi)/E_\theta(\theta,\phi)_{max.}$

Similarly $E_{\phi n}(\theta,\phi) = E_\phi(\theta,\phi)/E_\phi(\theta,\phi)_{max.}$

We don't go for 3D pattern design instead we are preferring polar plots of the relative magnitude of the field in any desired plane are sketched.

These polar plots are plotted in two planes – one containing the antenna and the other normal to it. These planes are called *-Principle planes and the two plots or patterns are called Principle plane patterns."* These patterns are obtained by plotting by plotting the magnitude of the normalized field strengths. When the magnitude of the normalized field strength is plotted versus θ with constant ϕ. The pattern is called E-plane pattern or vertical pattern.

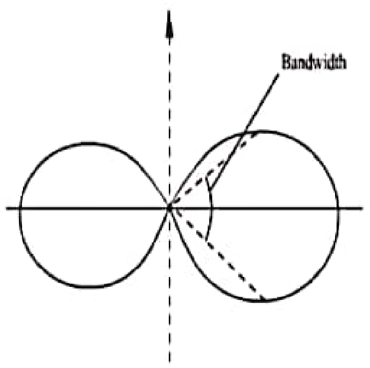


Figure16 (a) Principal E plane pattern

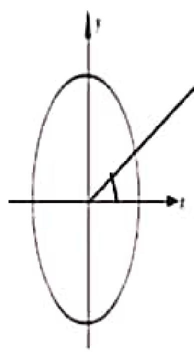
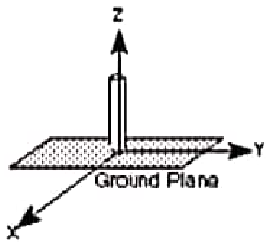
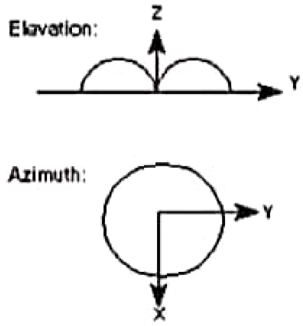
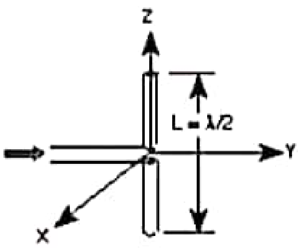
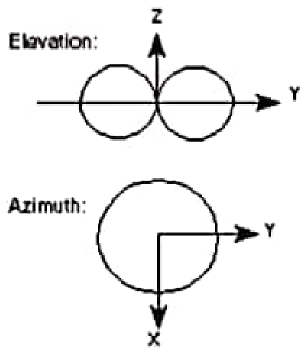


Fig ure16(b) Principal H plane pattern

The bandwidth (3 dB beam width) can be found to be 90^0 in the *E* plane.

Different Antennas and its Radiation Patterns with their characteristics-

Antenna Type	Radiation Pattern	Characteristics
MONOPOLE 		**Polarization: Linear** Vertical as shown **Typical Half-Power Beamwidth** 45 deg x 360 deg **Typical Gain:** 2-6 dB at best **Bandwidth:** 10% or 1.1:1 **Frequency Limit** **Lower:** None **Upper:** None **Remarks:** Polarization changes to horizontal if rotated to horizontal
λ/2 DIPOLE 		**Polarization:** Linear Vertical as shown **Typical Half-Power Beamwidth** 80 deg x 360 deg **Typical Gain:** 2 dB **Bandwidth:** 10% or 1.1:1 **Frequency Limit** **Lower:** None **Upper:** 8 GHz (practical limit) **Remarks:** Pattern and lobing changes significantly with L/f. Used as a gain reference < 2 GHz.