UNIT - I

Radiation properties

Antenna:

A radio antenna may be defined as the structure associated with the region of transition between a guided wave and a free space wave or vice versa.

Antennas convert electrons to photons or vice-versa.

* It is also defined as a transition device or transducer, between a guided wave and a free space wave (or) vice-versa. It interfaces a circuit and space.

Radiation pattern

- Graphical representation of radiation as a function of direction. 2 Types.

(i) Field pattern

If the Radiation ~~pattern~~ is expressed in terms of its field strength E volts/metre, then the pattern is known as field pattern.

(ii) Power pattern

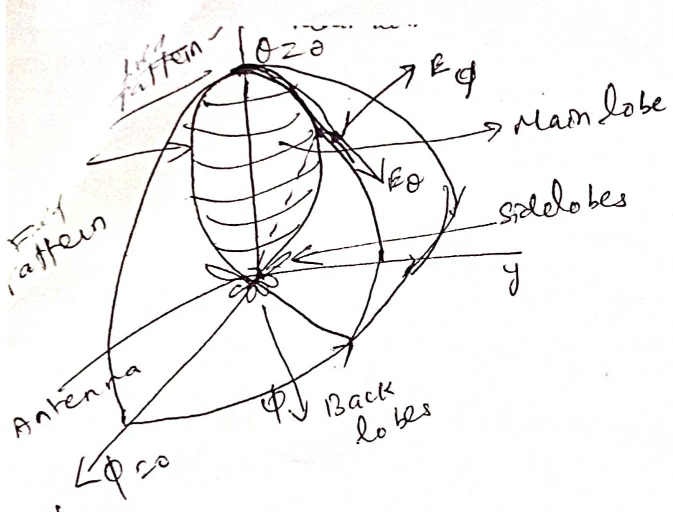
If the radiation is expressed interms of the pattern of Power per (or) (Poynting vector) unit solid angle, then it is is known as power pattern.

Major lobe → Max. Radiation lobe

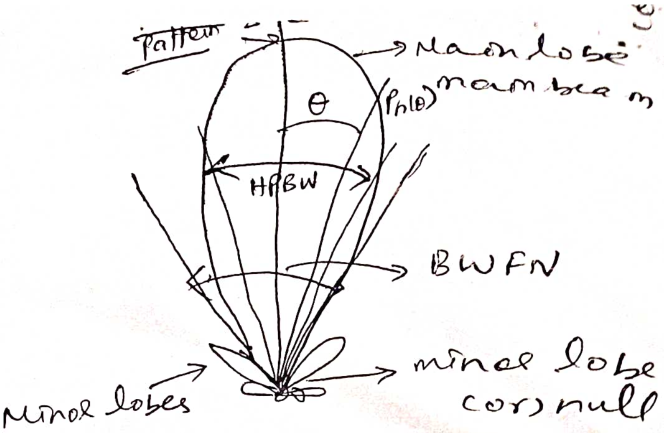
Minor lobe → any lobe except major lobe

Side lobe → minor lobe adjacent to main lobe

back lobe → minor lobe in the direction opposite to major lobe



Field pattern



Power pattern

Normalized field pattern

* Dimensionless number, obtained by dividing a field component by its maximum value.

It's maximum value is unity.

Normalized field pattern

$$E_\theta(\theta,\phi)_n = \frac{E_\theta(\theta,\phi)}{E_\theta(\theta,\phi)_{max}}$$ (dimensionless)

Normalized power pattern

Normalizing power per unit area (or) Poynting vector $S(\theta,\phi)$ with respect to its maximum value yields Normalized power pattern as a function of angle which is a dimensionless number with a maximum value of unity.

Normalized power pattern $P_n(\theta,\phi) = \frac{S(\theta,\phi)}{S(\theta,\phi)_{max}}$

(dimensionless)

where,

$S(\theta,\phi)$ = Poynting vector = $[E_\theta^2(\theta,\phi) + E_\phi^2(\theta,\phi)]/Z_0$ $W\,m^{-2}$

$S(\theta, \phi)_{max}$ = maximum value of $S(\theta, \phi)$ wm^{-2}.

Z_0 = Intrinsic Impedance = 376.7 Ω.

Radiation Intensity

The power radiated from an antenna per unit solid angle is called the radiation intensity U (w/s (or) / square degree)

Normalised power pattern

$$P_n(\theta, \phi) = \frac{U(\theta, \phi)}{U(\theta, \phi)_{max}} = \frac{S(\theta, \phi)}{S(\theta, \phi)_{max}}.$$

Directivity D and Gain G

The directivity of an antenna is equal to the ratio of the maximum power density $P(\theta, \phi)_{max}$ (watts/m^2) to its average value over a sphere as observed in the far field of an antenna. Thus,

$$D = \frac{P(\theta, \phi)_{max}}{P(\theta, \phi)_{av}} \quad \text{(dimensionless)}$$

$$D \geq 1$$

The average power density over a sphere

$$P(\theta, \phi)_{av} = \frac{1}{4\pi} \int_{\phi=0}^{\phi=2\pi} \int_{\theta=0}^{\theta=\pi} P(\theta, \phi) \sin\theta \, d\theta \, d\phi$$

$$= \frac{1}{4\pi} \iint_{4\pi} P(\theta, \phi) \, d\Omega \quad \text{(w/sr)}$$

$$= \frac{P(\theta, \phi)_{max}}{\left(\frac{1}{4\pi}\right) \iint_{4\pi} P(\theta, \phi) \, d\Omega}$$

$$= \frac{1}{(1/4\pi)\iint_{4\pi}[P(\theta,\phi)/P(\theta,\phi)_{max}]\,d\Omega}$$

the

now

$$= \frac{4\pi}{\iint_{4\pi} P_n(\theta,\phi)} = \frac{4\pi}{\Omega_A}$$

$$\boxed{D = \frac{4\pi}{\Omega_A}}$$

$\Omega_A \rightarrow$ beam Area

$= \Omega_M + \Omega_m$.

Beam efficiency $\varepsilon_M = \frac{\Omega_M}{\Omega_A}$

(for isotropic antenna $D = 1$)

$\varepsilon_m = \frac{\Omega_m}{\Omega_A}$ = Stray factor

$$\boxed{\varepsilon_m + \varepsilon_M = 1}$$

Gain (G)

It is an actual (or) realized quantity which is less than the directivity D due to ohmic losses in the antenna or its radome (if it is enclosed).

The ratio of gain to the directivity is the antenna efficiency factor.

$$k = G/D$$

$$\boxed{G = kD} \quad (0 < k \leq 1) \text{ dimensionless.}$$

$$\text{Gain} = G = \frac{P_{max}\,(AUT)}{P_{max}\,(\text{ref. ant})} \times G\,(\text{ref. ant})$$

Max R.I

with same power input.

AUT → Antenna Under Test.

ref. ant → reference antenna such as short. dipole.

If the half-power beamwidths of an antenna are known,

$$D = \frac{41,253}{\theta^{\circ}_{HP}\,\phi^{\circ}_{HP}} \rightarrow (1)$$

where,

41, 253 = number of square degrees in sphere

$= 4\pi\,(180/\pi)^2$ ($\Box$ square degrees)

θ°_{HP} = half-power beamwidth in one principal plane

ϕ°_{HP} = Half-power Beamwidth in other principal plane.

(1) → neglects minor lobes, better approximation is

$$\boxed{D = \frac{40,000}{\theta^{\circ}_{HP}\,\phi^{\circ}_{HP}}}$$ Approximate directivity

$$D = \frac{4\pi\ (sr)}{\Omega_A\ (sr)}$$

~~Directive gain~~ (Gd)

Gd in a given direction is defined as the ratio of the radiation intensity in that direction to the average radiated power.

$$\text{Directive gain (Gd)} = \frac{\text{Radiation Intensity in a particular direction}}{\text{Average radiated power}}$$

$$Gd(\theta,\phi) = \frac{\phi(\theta,\phi)}{\phi_{av}} = \frac{\phi(\theta,\phi)}{W_r/4\pi}$$

$$= \frac{4\pi\,\phi(\theta,\phi)}{W_r}$$

$$Gd(\theta,\phi) = \frac{4\pi\,\phi(\theta,\phi)}{\int \phi\, d\Omega}$$

$$db\ G_d = 10 \log_{10} G_d(\theta, \phi)$$

$$db\ G_d = 10 \log_{10} \left\{ \frac{4\pi\, \phi(\theta, \phi)}{\int \phi \, d\Omega} \right\}$$

$G_d \rightarrow$ depend on distribution of radiated power in space.

→ it does not depend on power i/p to the antenna, antenna losses.

G_d = $\dfrac{\text{Power density radiated in a particular direction by subject antenna}}{\text{Power density radiated in that particular direction by an isotropic antenna.}}$

Power gain

G_p = $\dfrac{\text{Power density radiated in a particular direction by the subject antenna}}{\text{Power density radiated in that direction by an isotropic antenna}}$

for the same total input power and at the same given distance)

$$G_p = \eta\, G_d$$

$\eta \rightarrow$ efficiency factor $0 < \eta < 1$

If $\eta = 1$

$$\boxed{G_p = G_d}$$

$$G_p = \frac{\text{R.I in a given direction}}{\text{Avg total Input power.}}$$

$$G_p = \frac{\phi(\theta, \phi)}{W_T / 4\pi}, \quad W_T = W_r + \underset{\text{ant ohmic loss}}{\underbrace{W_l}}$$

$$G_p = \frac{4\pi\, \phi(\theta, \phi)}{W_T}$$

$$G_p = \frac{\text{Power i/p supplied to subject antenna in the direction of maximum radiation}}{\text{Power input applied to reference antenna}}$$

<u>Gp depends on</u>

(i) sharpness of lobe

(ii) volume of the solid radiation pattern

$$G_p(db) = 10 \log_{10} \frac{P_1}{P_2}$$

$$= 10 \log_{10} \left(\frac{V_1}{V_2}\right)^2 = 20 \log_{10} \left(\frac{V_1}{V_2}\right)$$

<u>Beam width</u> (measure of directivity)

<u>HPBW</u> → Antenna Beamwidth is an angular width in degrees, measured on the radiation pattern (major lobe) between points where the radiated power has fallen to half its maximum value. This is called <u>HPBW</u> because at half power points the power is just half. It is also known as '3-dB <u>Beamwidth</u>'

* At HP point power $\frac{1}{2}$, field intensity $\frac{1}{\sqrt{2}}$ times of its max/. value (or) 3 db down from max/. value

<u>~~BWFN~~</u> The angular width (in degrees) of the major lobe between the two directions at which the radiated (or) received power is one half the max/. power.

<u>BWFN</u> → It is the angular width between first nulls (or) first side lobes known as BWFN

... BW ... the pattern maximum.

$$D = \frac{4\pi}{\Omega_A} = \frac{4\pi}{B} \rightarrow \text{Beam area}$$

Beam solid angle.

$$D = \frac{4\pi}{\underbrace{\theta_E \times \theta_H}_{}} \rightarrow B \text{ in Radians}$$

$$= \frac{4\pi \times (57.3)^2}{\theta_E^\circ \theta_H} \text{ square degrees.}$$

$$D = \frac{41,257}{\theta_E^\circ \times \theta_H^\circ}$$

Factors affecting BW of an antenna are

(i) shape of radiation pattern
(ii) wavelength &
(iii) Dimensions (Ex: aperture radius in case of horn antennas).

$$D \propto \frac{1}{BW}$$

Narrow beamwidth → high directivity.

Half wave dipole antenna

This is the fundamental radio antenna of metal rod (or) tubing or wire which has a physical length of approx. $\lambda/2$ in freespace at the frequency of operation. This is also called as half wave doublet (or) Hertz antenna.

It is also defined as "a symmetrical antenna in which the two ends are at equal ~~Poten~~ potential w.r.t centre point.

This is the unit from which many