

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 volt/metre, then the pattern is known as field pattern.

(ii) Power pattern

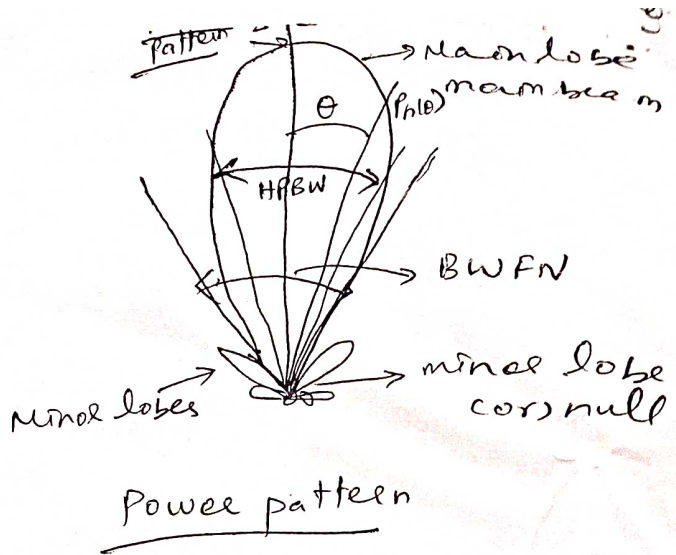
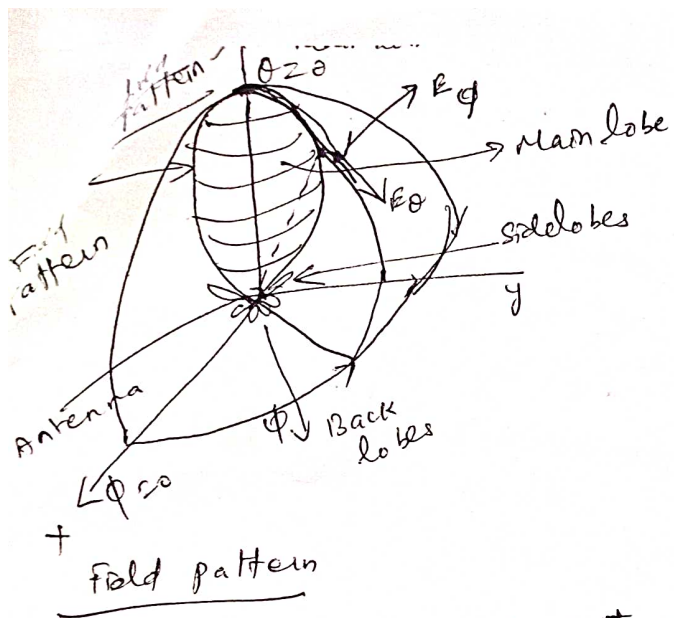
If the radiation is expressed in terms of power per unit solid angle, then it is known as power pattern.

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



Normalized field pattern

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

Normalized field pattern

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

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.

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

where,

$$S(\theta, \phi) = \text{Poynting vector} = \frac{[E_\theta^2(\theta, \phi) + E_\phi^2(\theta, \phi)]}{z_0} \quad \text{W m}^{-2}$$

$S(\theta, \phi)_{\max} = \text{maximum value of } S(\theta, \phi) \text{ in } \text{W m}^{-2}$
 $Z_0 = \text{intrinsic impedance} = 376.7 \Omega$

Radiation Intensity

The power radiated from an antenna per unit solid angle is called the radiation intensity U ($\text{W / s (or) / square degree}$)

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

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

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

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

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

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

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

$\Omega_A \rightarrow$ mean Area
 $= \Omega_M + \Omega_m$

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

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

$$\boxed{\epsilon_m + \epsilon_M = 1}$$

(for isotropic antenna $D = 1$)

Gain (G)

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

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

$$k = G/D$$

$$\boxed{G = kD}$$

($0 \leq k \leq 1$) dimensionless.

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

with same power input

AUT \rightarrow Antenna Under Test.

ref. ant \rightarrow reference antenna such as short dipole.

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

$$D = \frac{41,253}{\theta_{HP}^{\circ} \phi_{HP}^{\circ}} \rightarrow \textcircled{1}$$

where,

41,253 = number of square degrees in sphere
 $= 4\pi (180/\pi)^2$ (□ square degrees)

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

ϕ_{HP}° = half-power beamwidth in other principal plane.

② → neglects minor lobes, better approximation is:

$$D = \frac{40,000}{\theta_{HP}^{\circ} \phi_{HP}^{\circ}} \quad \text{Approximate directivity}$$

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

Directive gain (G_d)

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

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

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

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

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

$$db \ G_d = 10 \log_{10} \left(\frac{4\pi r^2 \phi(\theta, \phi)}{P_{in}} \right)$$

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

G_d ^{depend on} → distribution of radiated power in space.

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

G_d = Power density radiated in a particular direction by subject antenna

Power density radiated in that particular direction by an isotropic antenna.

Power gain

G_p = Power density radiated in a particular direction by the subject antenna

Power density radiated in that direction by an isotropic antenna for the same total input power and at the same given distance

$$G_p = \eta \ G_d$$

η → efficiency factor $0 < \eta < 1$

If $\eta = 1$

$$\boxed{G_p = G_d}$$

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

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

$$W_T = W_r + W_l$$

↓
ant ohmic loss

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

G_p = Power i/p supplied to subject antenna in the direction of maximum radiation

Power input applied to reference antenna.

G_p depends on

- (i) sharpness of lobe
- (ii) volume of the solid radiation pattern

$$G_p(\text{db}) = 10 \log_{10} \frac{P_1}{P_2}$$
$$= 10 \log_{10} \left(\frac{V_1}{V_2} \right)^2 = 20 \log_{10} \left(\frac{V_1}{V_2} \right)$$

Beam width (measure of directivity)

HPBW → 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 HPBW because at half power points the

Power is just half. It is also known as 3-dB Beamwidth

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

BWFA → The angular width (in degrees) of the major lobe between the two directions at which the radiated (or) received power is one half the

maxl. power.

BWFN → It is the angular width between first null (or) first side lobes known as BWFN

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

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

\downarrow Beam solid angle.

$$D = \frac{4\pi}{\theta_E \times \theta_H} \rightarrow B \quad \text{in radians}$$
$$= \frac{4\pi \times (57.3)^2}{\theta_E^\circ \theta_H} \quad \text{square degrees}$$

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

Factors affecting BW of an antenna are

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

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

Narrow beamwidth \rightarrow 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 potential w.r.t centre point."

This is the unit from which many