UNIT 1

1. Explain the radiation from two-wire.

Ans:

Radiation from Two – wire

Figure1.1.1 shows a voltage source connected two-wire transmission line which is further connected to an antenna. An electric field is created between the conductors, when a voltage is applied across the two-wire transmission line. The produced electric lines of force are tangent to the electric field at each point and whose strength is proportional to the electric field intensity. The free electrons associated with conductor are acted upon by the electric line of force. A magnetic field intensity is created by a current, due to the movement of charges. Similarly, the magnetic lines of force are tangent to the magnetic field.

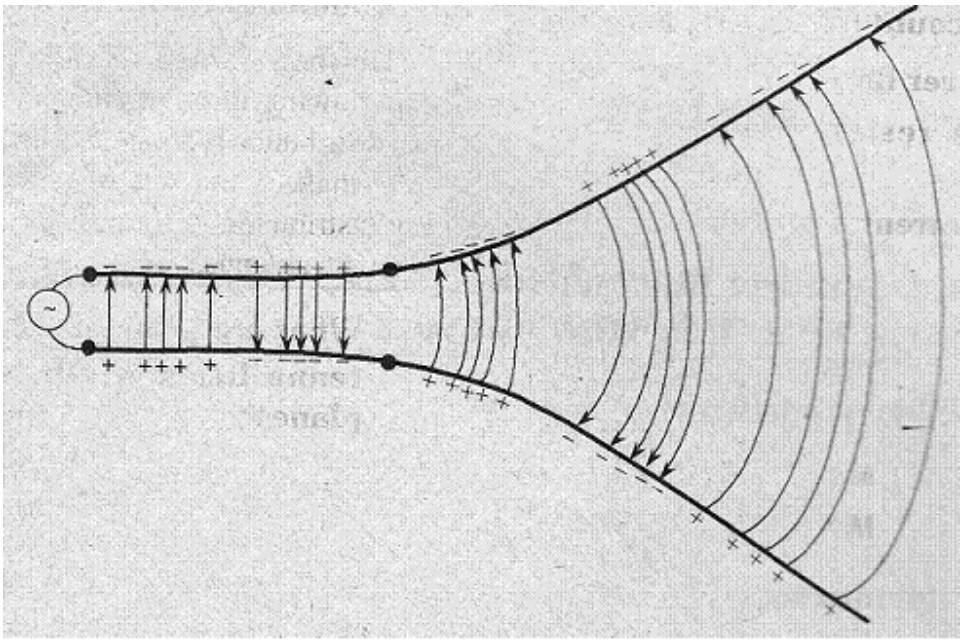


Fig 1.1.1 Radiation from Two-wire

Since the electric field lines, start on positive charges and end on negative charges. These lines can also start at infinity and end on a negative charge or start on a positive charge and end at infinity or form closed loops neither starting nor ending on any charge. Due to the absence of magnetic charges, the magnetic field lines always form closed loops encircling current carrying conductors.

The distribution of charge property is exhibited by the electric field lines drawn between the two conductors. When a sinusoidal signal is applied at the source, the electric field between the conductors may be sinusoidal with a period of applied source. Electromagnetic waves are formed by the time-varying electric and magnetic fields between the conductors and which will travel along the transmission line shown in figure 1.1.1.

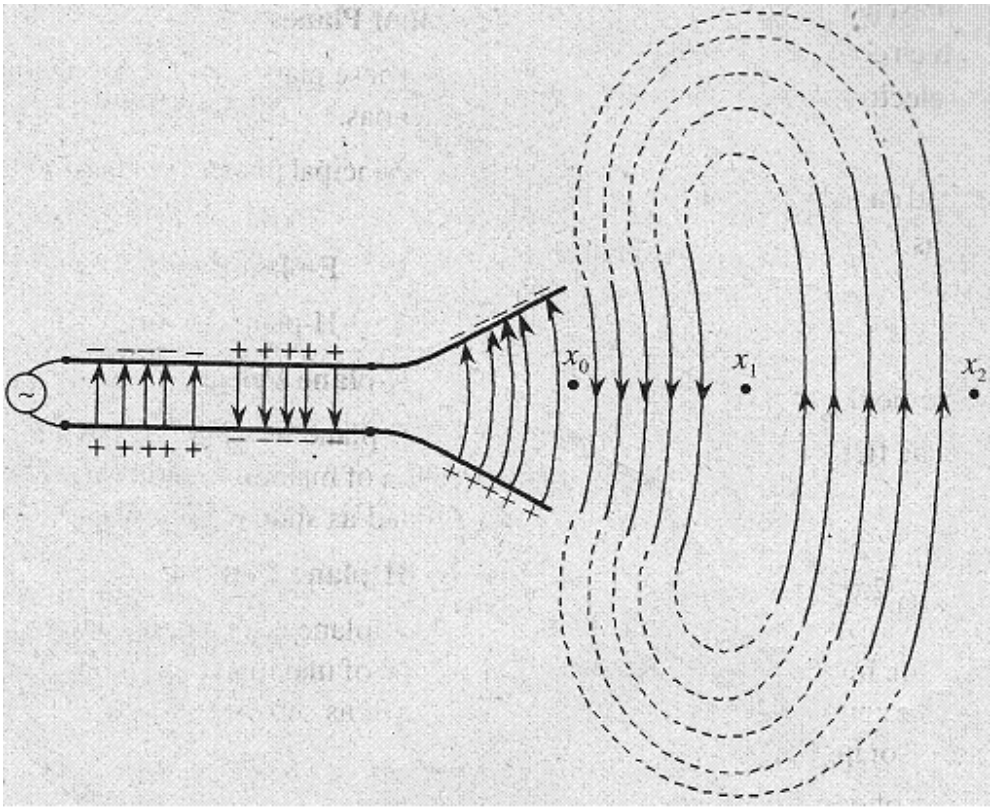


Fig 1.1.2 Radiation from Two- wire

The electromagnetic waves enter into the antenna with associated electric charges and corresponding currents. When a part of antenna structure is removed (as shown in figure (1.1.2)), by connecting the open ends of the electric lines, free space waves are formed. The free space waves are also periodic but a constant phase point 'x_0' moves outwardly with the speed of light and travels a distance λ/2 (to 'x_1') in the time of one-half a period. The constant phase point 'x_0' moves faster than the speed of light but approaches the speed of light at points far away from the antenna.

2. Define and account for the presence of,

(i). Radial power flow

(ii) Radiation resistance for a short dipole

(iii) Uniform current distribution.

Ans:

(i) Radial power flow

Radial power flow represents the amount of power moving in radial direction, which corresponds to the power density associated with the electromagnetic fields of an antenna.

The total power radiated can be calculated with the help of pointing vector (P) as,

$$P = E \times H$$

Where,

E = Electric field

H = Magnetic field.

Therefore Total radiated power,

$$P_r = \oint \Pr 2\pi r^2 sin\theta \, d\theta \, d\Phi$$

Therefore, the integration involves combination of imaginary part and real part. The combination of imaginary and real power is known as "Complex Power". Radial power is the part of complex power moving in radial direction. It corresponds to the real radiated power.

(ii) Radiation Resistance for a short dipole

The resistance observed, (or) experienced by transmission line when it is terminated by a short dipole is known as radiation resistance of short dipole.

General expression is,

$$(R_r)_{\text{short dipole}} = 80\pi^2(dl/\lambda)^2$$

Where,

dl = Length of the dipole

λ = Operating wavelength.

(iii) Uniform Current Distribution

Uniform current distribution signifies that the current flowing through antenna is constant. Uniform current distribution is possible, when the size of the antenna is very small. If the size of antenna is finite, uniform current distribution is not possible. This is valid for only small length antennas.

3. What are principle planes? How the antenna beam width is defined in such planes?

Ans:

Principle planes

These planes are used to describe the performance of antennas. Principle planes are classified into two types. They are,

1. E-plane pattern
2. H-plane pattern.

1.E-plane pattern

E-plane pattern is defined as the plane containing electric field vector in the direction of maximum radiation. The E-plane pattern is shown in the figure 1.3.1

2. H-plane pattern

H-plane pattern is defined as the plane containing magnetic field vector in the direction of maximum radiation. The H-plane pattern is shown in the figure 1.3.1

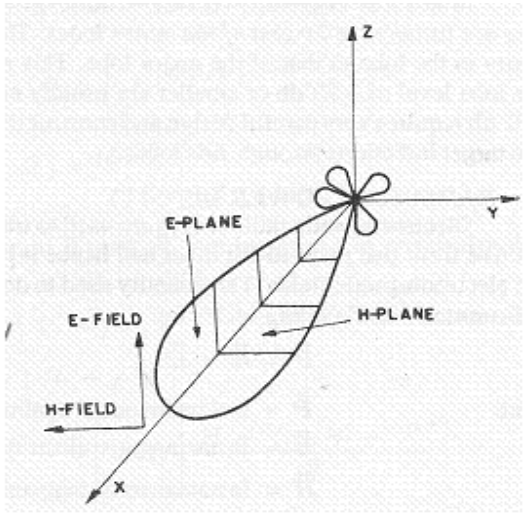


Fig 1.3.1 E-plane and H-plane Principle Patterns

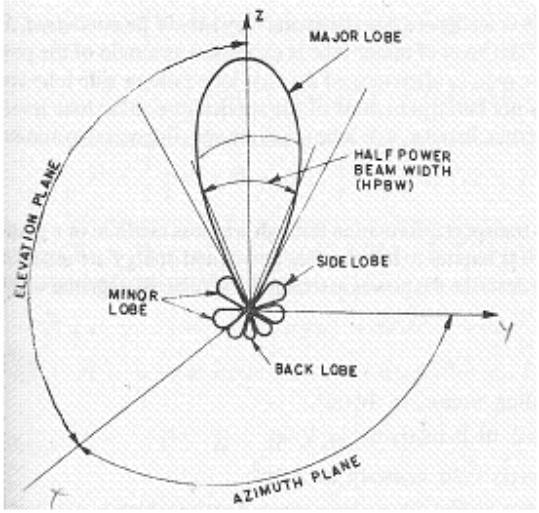


Fig 1.3.2 Radiation Lobes and Beam Width of an Antenna

4. Explain the following terms,

(i) Beam width

(ii) Omni directional pattern

(iii)Side lobe level

(iv)Field pattern of antenna

Ans:

(i) Beam Width

It is used to measure the directivity of an antenna. In general antenna beam width is defined as "the angular width of the major lobe between the two directions at which maximum power is twice the radiated or received power.

$$\text{Beam width} = (\text{HPBW})_{\text{Vertical}} \times (\text{HPBW})_{\text{Horizontal}}$$

$$\boxed{B = \theta_E^{\,0} \times \theta_H^{\,0}}$$

There are two factors effecting the beam width. They are,

1. Wavelength
2. Radiation pattern shape.

(ii) Omnidirectional Pattern

The radiation pattern which is distributed equally well in all directions is called as omnidirectional patterns. The antenna which exhibits such a property is known as omnidirectional antenna or nondirectional antenna (since it does not favour any particular direction). Figure 1.4.1 shows omnidirectional pattern with and without minor lobes. The omnidirectional pattern can be approximated by,

$$U = |\sin^n \theta| \; ; \; 0 \le \theta \le \pi, \; 0 \le \Phi \le 2\pi$$

Where,

n = Either integer or non integer value.

This type of pattern is commonly associated with verticals, ground planes and other antenna types in which the radiator element is vertical with respect to the earth's surface. The approximated formula for directivity of an omnidirectional antenna with minor lobes can be calculated as,

$$\boxed{D_0 = 101/HPBW(degrees) - 0.0027[HPBW(degrees)]^2}$$

and, the directivity of an omnidirectional antenna without minor lobes can be calculated using,

$$\boxed{D_0 = -172.4 + 191\sqrt{0.818 + 1/HPBW(degrees)}}$$

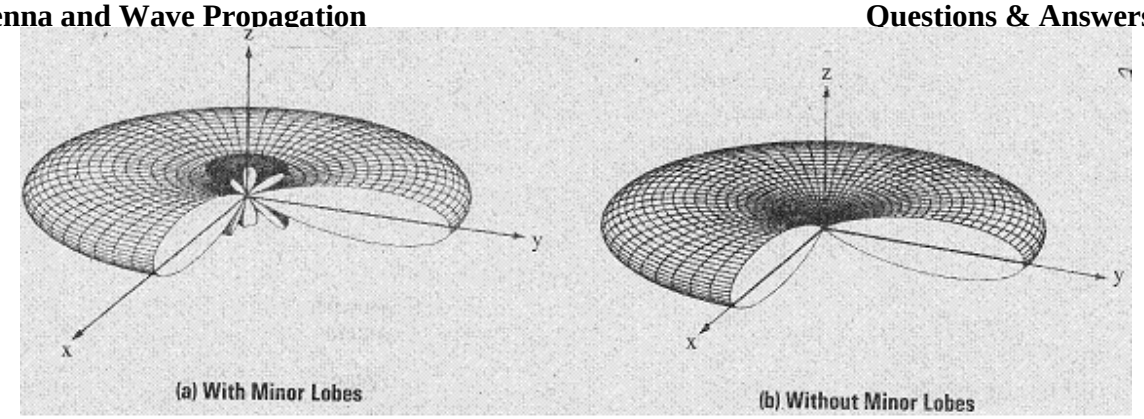


Fig 1.4.1 Omnidirectional Radiation Pattern

(iii) Side Lobe Level

The ratio (in dB) of the amplitude at the peak of the main lobe to the amplitude at the peak of a side lobe is known as side lobe level. Where the side lobe is a radiation lobe in any direction other than the intended lobe. Normally a side lobe is adjacent to the main lobe and occupies the hemisphere in direction of main lobe. Usually, the side lobes are the largest of the minor lobes, figure 1.4.2 shows the linear plot of power patterns.

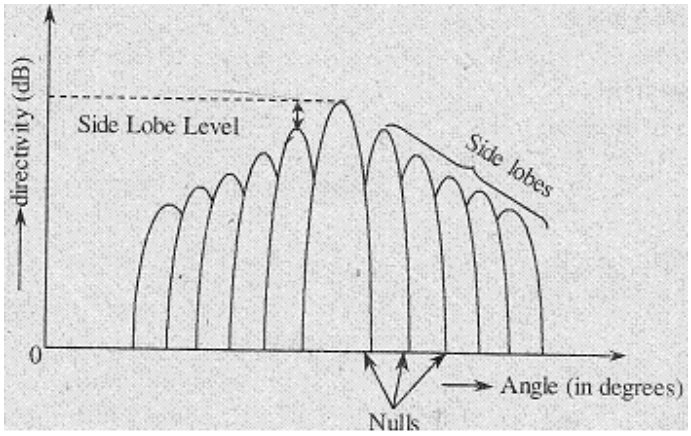


Fig 1.4.2 Side Lobe Level

The side lobe level can be reduced by tapering the edges of the aperture distribution at the expense of reduced directivity. The null between side lobes occur when the radiation pattern passes through the origin in the complex plane. Hence, adjacent side lobes are generally 180^0 out of phase to each other.

(iv) Field Pattern of Antenna

There are two different types of field patterns of antenna namely. Far-field and near-field patterns. The near-field pattern is most commonly defined over a plane placed in front of the source or over a cylindrical or spherical surface enclosing it. The far-field pattern of an antenna may be determined experimentally at an antenna range. The near-field pattern may be found using a near-field scanner and the radiation pattern deduced from it by computation.

The far-field pattern may be represented graphically as a plot of one of a number of related variables including, the field strength at a constant radius, the power per unit solid angle and the directive gain. The plotted quantity may be taken on a linear scale or in dB.

5. Define the terms,
(i) Bandwidth
(ii) Polarization
(ii) Effective aperture area.
Ans:

(i) Bandwidth

There is the range of frequencies for which the antenna maintains certain specific characteristics. It is given as,

Bandwidth, $\Delta\omega = \omega_2 - \omega_1$

$$\Delta\omega = \omega_r/Q$$

Where,

ω_r = Angular resonating frequency

Q = Quality factor.

(ii) Polarization

The time varying behavior of the electric field strength vector at a fixed point in space is known as polarization of a uniform plane wave. Consider a plane wave is travelling in the z-direction with '*E*' and *'H'* components lying in the xy plane. The wave is said to be polarized in *x*-direction, if $E_x \neq 0$ and $E_y = 0$. Similarly, the wave is said to be polarized in *y*-direction, if $E_x = 0$ and $E_y \neq 0$.

The resultant electric field has a direction dependent on the relative magnitudes of E_x and E_y, if both the fields are present and are in phase. The direction with the x-axis is given by,

$$\theta = \tan^{-1}[E_y/E_x]$$

A linearly polarized wave in which the direction of the resultant vector is constant with time. An elliptically polarized wave in which the two field components are not equal and are in out of phase (i.e., if they are reached maximum values at different instances) and the resultant vector direction is varied with time. A circularly polarized wave in which the two field components are having equal magnitudes and a 90° phase difference.

(iii) Effective Aperture Area

Effective area is defined as the ratio of power received at the antenna load terminal to the poynting vector (P), of the incident wave. Effective area is also known as effective aperture (or) capture area.

Effective Area,

$$(A_e) = Power\ Received / Poynting\ Vector$$

$$A_e = W/P$$

Where,

W = Power received (watts)

P = Poynting vector (watts/m^2)

6. Distinguish between directive gain and power gain.

Ans:

Differences between Directive Gain and Power Gain

Directive Gain (G_d)	**Power Gain (G_p)**
1. Directive gain in a given direction is defined as the ratio of the radiation intensity in that direction to the average radiated power.	1. Power gain is defined as the ratio of radiation intensity in given direction to the total input power.
2. In the calculation of directivity, the radiated power is considered for the directive antenna.	2. In the calculation of power gain, the power fed to the antenna is considered.
3. The concept of directive gain is most convenient to antenna theorist because, it depends only up on the antenna pattern.	3. The concept of power gain is most important to a radio system designer.
4. The directive gain is solely depends on the distribution of radiated power in space.	4. The power gain is depends on the power input to the antenna, antenna losses or the power consumed in a terminating resistance.
5. It is basically measured in dB G_d (dB) = 10 $\log_{10}(Gd)$	5. It is also basically measured in dB G_p (dB) = 10$\log_{10}(Gp)$

7. Draw the dual characteristics of an antenna.

Ans:

Dual Characteristics of an Antenna

The duality of an antenna specifies a circuit device on one band and a space device on the other hand. Figure 1.7.1 shows the schematic diagram of basic antenna parameters, illustrating dual characteristics of an antenna.

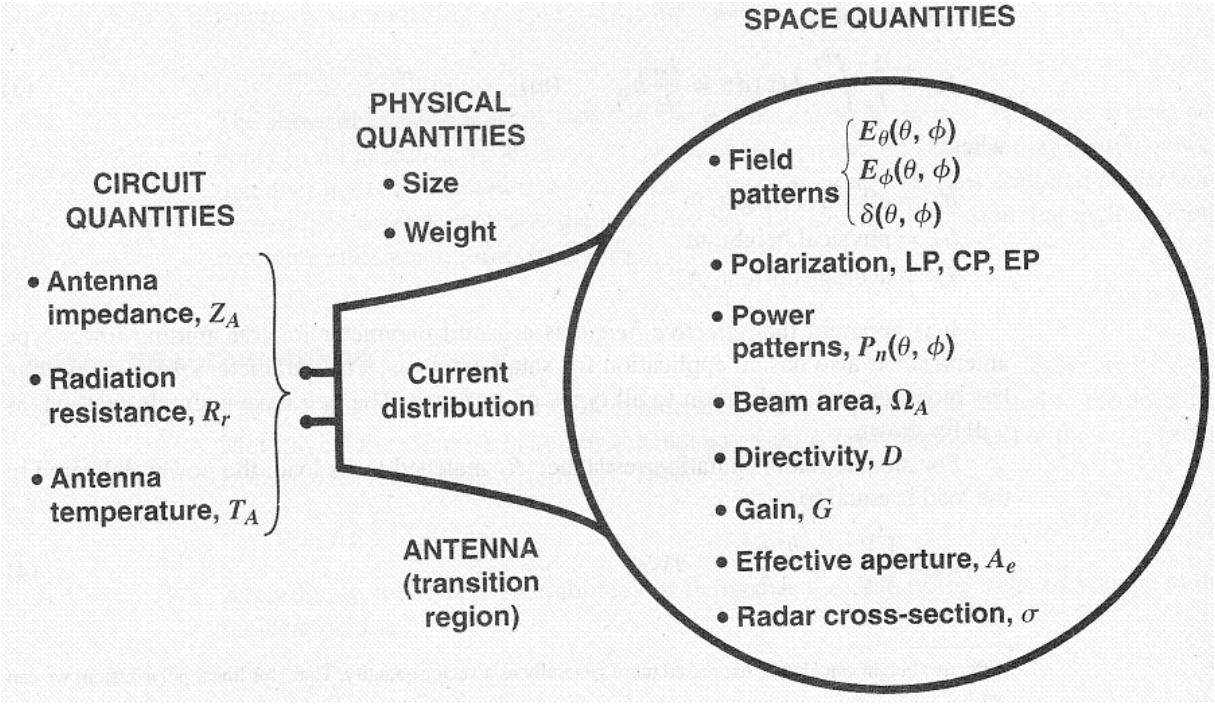


Fig 1.7.1 Schematic Diagram of a Basic Antenna Parameters

8. Explain briefly radiation mechanism in single wire antenna?

Ans:

Radiation Mechanism in Single Wire Antenna

Let us consider a single wire and a circular cross sectional cylinder with volume charge density, qv.

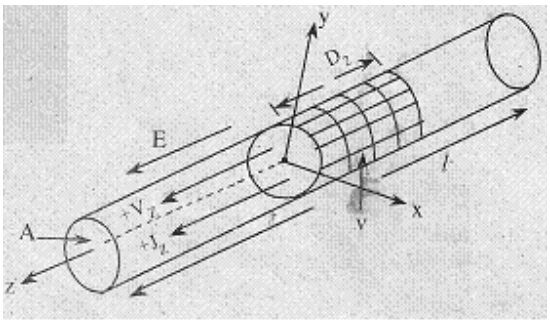


Fig 1.8.1 Charge Uniformly Distributed in a Circular Cross Section Cylinder

The field is distributed in a wire of cross-sectional area, A and volume, V as shown in figure 1.8.1. The current density, J_z over the cross-section of the wire is,

$$J_z = q_v . V_z \quad ....(1)$$

Where,

q_v = Volume charge density (columbs/m^3)

V_z = Velocity in z-direction.

The radius of the wire is zero, and then the current in the wire is given by,

$$I_z = q_1 V_z \quad .....(2)$$

If the current is time varying then the equation (2),

$dI_z/dt = q_1 \, dV_z/dt = q_1.a_z$

Where, a_z is the acceleration.

Hence,

(i) There is no radiation for a stationary charge

(ii) If a charge has uniform velocity and the wire is straight and infinite in extent, there is no radiation unless the wire is curried, bent, discontinued, terminated or truncated.

(iii) If the charge is oscillating in a time-motion, it develops radiation at the surrounding even for straight wire.

9. Write short note on Normalized field pattern.

Ans:

Normalized Field Pattern

Normalized field pattern is the field pattern, which is obtained by dividing a field component by its maximum value. It is a dimensionless number and whose maximum value is one. Normalized field pattern for an electric field is expressed as,

$$\text{Normalized Field Pattern, } E_\theta(\theta,\Phi) = E_\theta(\theta,\Phi)/ E_\theta(\theta,\Phi)_{max}$$

Where,

$E_\theta(\theta,\Phi)$ = Electric field component

$E_\theta(\theta,\Phi)_{max}$ = Maximum value of electric field component.

Figure 1.9.1 shows the normalized field pattern for the electric field 'E'. For $E_\theta(\theta,\Phi)_n = 1/\sqrt{2} = 0.707$, the half power levels occurs at those angles θ and Φ. The shape normalized field pattern is independent of distance for,

1. The distance that are large compared to the size of the an antenna.

2. The distance that are large compared to the wavelength.

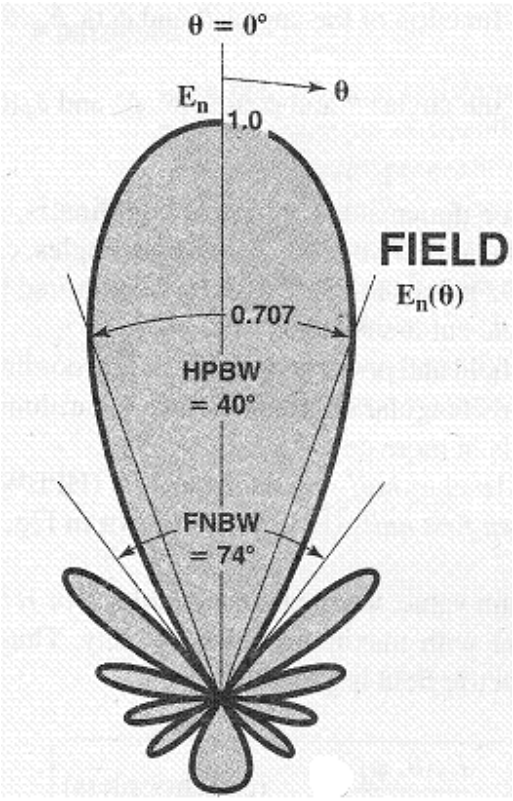


Fig 1.9.1 Normalized Fied Pattern

10. Explain the following,

i. Beam area
ii. Radiation intensity
iii. Beam efficiency
iv. Directivity.

Ans:

i. Beam Area

In polar two-dimensional coordinates an incremental area dA on the surface of sphere is the product of the length $r\ d\theta$ in the θ direction and $r\ sin\ \theta\ d\Phi$ in the Φ direction as shown in figure 1.10.1.

Thus,

$dA = (rd\theta)\ (r\ sin\theta\ d\Phi) = r^2\ d\Omega$

Where,

$d\Omega$ = solid angle expressed in steradians.

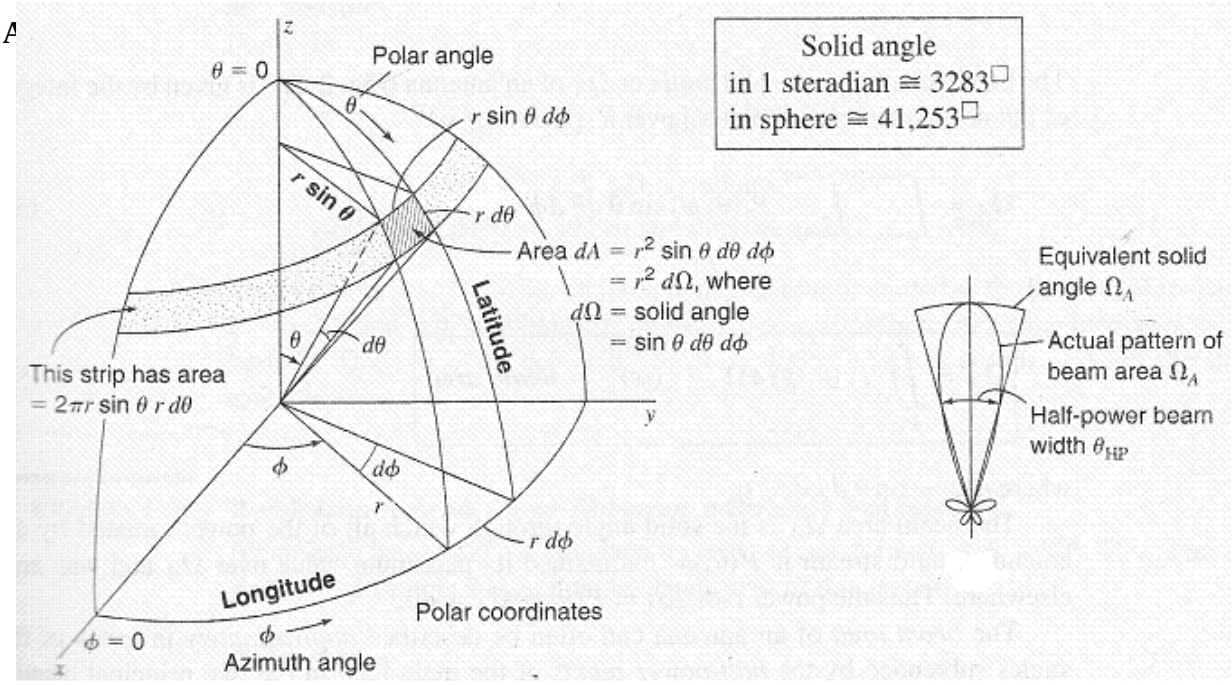


Fig 1.10.1 Beam Solid Angle

The area of the strip of width $r\,d\theta$ extending around the sphere at a constant angle θ is given by $(2\pi r \sin\theta)\,(r\,d\theta)$. Integrating this for θ values from 0 to π yields the area of the sphere. Thus,

$$\text{Area of sphere} = 2\pi r^2 \int_0^{\pi} \sin\theta\, d\theta = 2\pi r^2 [-\cos\theta]_0^{\pi} = 4\pi r^2$$

Where,

4π = Solid angle subtended by a sphere

The beam area or beam solid angle or Ω_A of an antenna is given by the integral of the normalized power pattern over a sphere

$$\text{Beam area, } \Omega_A = \iint P(\theta,\pi)\,d\Omega \quad \text{(sr)}$$

Where,

$d\Omega = \sin\theta\, d\theta\, d\Phi$

ii.Radiation Intensity

The power radiated from an antenna per unit solid angle is called the radiation intensity U (watts per steradian or per square degree). The normalized power pattern of the previous section can also be expressed in terms of this parameter as the ratio of the radiation intensity $U\ (\theta,\ \Phi)$, as a function of angle, to its maximum value. Thus,

$$P_n(\theta,\Phi) = U(\theta,\Phi)/U(\theta,\Phi)_{max} = S(\theta,\Phi)/S(\theta,\Phi)_{max}$$

Whereas the Poynting vector S depends on the distance from the antenna (varying inversely as the square of the distance), the radiation intensity U is independent of the distance, assuming in both cases that we are in the far field of the antenna.

iii. Beam Efficiency

The beam area Q_A (or beam solid angle) consists of the main beam area (or solid angle) Ω_M plus the minor-lobe area (or solid angle) Ω_m. Thus,

$$\Omega_A = \Omega_M + \Omega_m$$

The ratio of the main beam area to the (total) beam area is called the (main) beam efficiency ε_M. Thus,

Beam Efficiency = $\varepsilon_M = \Omega_M / \Omega_A$ (dimensionless)

The ratio of the minor-lobe area (Ω_m) to the (total) beam area *is* called the stray factor. Thus,

$\varepsilon_m = \Omega_m / \Omega_A$ = stray factor.

iv. Directivity

It is defined as the ratio of maximum radiation intensity of subject or test antenna to the radiation intensity of an isotropic antenna.

(or)

Directivity is defined as the ratio of maximum radiation intensity to the average radiation intensity.

Directivity, $D = U_{max}/U_{avg} = \frac{Maximum\ radiation\ intensity}{Average\ radiation\ intensity}$

Directivity (D) in terms of total power radiated is,

D = 4π x Maximum radiation intensity/ Total power radiated