UNIT I FUNDAMENTALS OF ANTENNA

BASIC ANTENNA THEORY:

An antenna is a device that provides a transition between electric currents on a conductor and electromagnetic waves in space. A transmitting antenna transforms electric currents into radio waves and a receiving antenna transforms an electromagnetic field back into electric current.

An antenna is basically a transducer .It converts radio frequency (RF) electrical current into an electromagnetic wave of the same frequency.

BASIC ANTENNA ELEMENTS:

a) **SHORT DIPOLE:** A short linear conductor is so short that current may be assumed to be constant throughout its length and is often called a short dipole or a Hertizian dipole.
b) **SHORT MONOPLOE:** It is a linear antenna whose length is less than ʎ/8 and the current distribution is assumed to be triangular.
c) **HALF WAVE DIPOLE:** It is a linear antenna whose length is ʎ/2 and the current distribution is assumed to be sinusoidal.
d) **QUARTER WAVE MONOPOLE:** It is a linear antenna whose length is ʎ/4EW and the current distribution is assumed to be sinusoidal.
e) **ELEMENTAL SHORT DIPOLE:** Do not generally have uniform current throughout their length but approximate uniformity of current may be obtained by capacitive end loading.
f) **INFINITESIMAL DIPLOE:** Here the length of the short dipole is vanishingly small.

RETARDED POTENTIAL:

The retarded potentials are the electromagnetic potential for the electromagnetic field generated by time varying electric current or charge distributions.

It is given by $A(r) = \frac{\mu}{4\pi}\int \frac{J\left(t-\frac{r}{c}\right)}{r}\, dv$ (1)

RADIATION FROM AN ALTERNATING CURRENT ELEMENT:

Here the concept of retarded vector potential is used to find the fields everywhere around its free space. Let the elemental length of the wire is placed at the origin of the spherical coordinate system, then a current in the dipole is accompanied by magnetic field surrounding the region of short dipole.

The magnetic field components are given by

H_r =0 ,H_θ =0 1

$$H_\phi=\frac{I_m dl\sin\theta}{4\pi}\left[\frac{-\omega \sin\omega t_1}{cr}+\frac{\cos\omega t_1}{r^2}\right] \quad (2)$$

The electric field components are given by

$$E_r=\frac{2\, I_m dl\cos\theta}{4\pi\epsilon}\left[\frac{\cos\omega t_1}{cr^2}+\frac{\sin\omega t_1}{\omega r^3}\right] \quad (3)$$

$E_\phi = 0$

$$E_\theta=\frac{I_m dl\sin\theta}{4\pi\epsilon}\left[\frac{-\omega \sin\omega t_1}{rc^2}+\frac{\cos\omega t_1}{cr^2}+\frac{\sin\omega t_1}{\omega r^3}\right] \quad (4)$$

ANTENNA FIELD ZONES:

a) Near field region:electromagnetic field created by an antenna that is only significant at distances of less than 2D/λ from the antenna, where D is the longest dimension of the antenna.
b) Far field region:electromagnetic field created by the antenna that extends throughout all space. At distances greater than 2D/λ from the antenna, it is the only field. It is the field used for communications

A distance is reached from the conductor at which both the induction and radiation fields becomes equal and the particular distance depends on the wavelength used

It is given by = 0.159ʎ

POWER RADIATED BY A CURRENT ELEMENT AND RADIATION RESISTANCE:

The radial component of the pointing vector is given by

$$P_r = \left|H_\phi\right|^2 \sqrt{\frac{\mu_0}{\epsilon_0}} \quad (5)$$

The total power radiated by antenna is given by

$$W=\sqrt{\frac{\mu_0}{\epsilon_0}}\left(\frac{(\beta I_m\, l)^2}{12\pi}\right) \text{ watts} \quad (6)$$

The radiation resistance is given by

$$R_r=790\left(\frac{l}{ʎ}\right)^2 \Omega \quad (7)$$

CURRENT DISTRIBUTION IN DIPOLE:

Consider the centre fed dipole antenna .From the fundamentals of transmission line theory, the current distribution is written. Since in each antenna arm the current is sinusoidal

$I(Z)=A'\cos\beta z + B'\sin\beta z \quad ; z>+0$ (10)

$I(-Z)=A''\cos\beta z + B''\sin\beta z \quad ; z<-0$ (11)

Where z is the length of the conductor, and A', B', A'' and B'' are the arbitrary constants of a transmission line, which defines the magnitude of the travelling wave with the boundary condition.

At the ends of the conductor where z=+h and z=-h, there is no conductor where current can flow then

$I(+h)=I(-h)=0$ (12)

Applying the boundary condition and solving the above equation we get

$I=I(z)=I_m\sin\beta(h-Z) \quad ; z>+0$ (13)

$I=I(z)=I_m\sin\beta(h+Z) \quad ; z<-0$ (14)

HALF WAVE DIPOLE:

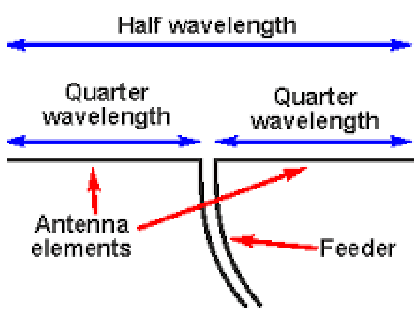


Fig.a.Half wave Dipole

It is one of the simplest antenna and is frequently employed as an element of a more complex directional system. It is made of metal rod or tubing or thin wire which has a physical length of half wavelength in free space at the frequency of operation

RADIATION FROM AN HALF WAVE DIPOLE:

A dipole antenna is defined as a symmetrical antenna in which the two ends are at equal potential relative to mid point

Let us consider a centre fed half wave dipole system, the asymptotic current distribution is

$I=I(z)=I_m\sin\beta(h-Z) \quad ; z>+0$ (15)

$I = I(z) = I_m \sin\beta(h+Z)$;z<0 (16)

I_m is the maximum current at the current loop

Vector potential at a distant point P due to the current element 'Idz' is

$$dA_z = \frac{\mu I dz e^{-j\beta R}}{4\pi R} \quad (17)$$

where R is the distance between Idz to distant point P

The total vector potential due to all such current elements at distant point p is given by

$$\int dA_z = \int_{-h}^{0} \frac{\mu I dz e^{-j\beta R}}{4\pi R} + \int_{0}^{h} \frac{\mu I dz e^{-j\beta R}}{4\pi R} \quad (18)$$

For λ/2 antenna l=2h

βh=π/2

The current is symmetrical with respect to centre

Sin(π/2 +βz)=sin(π/2 -βz)= cos βz

Solving, we get

$$A_z = \frac{\mu \ I_m}{2\pi\beta r} e^{-j\beta r} \left[\frac{\cos(\frac{\pi}{2} cos\theta}{sin^2 \ \theta}\right] \quad (19)$$

Radiative field intensity from the fundamental short dipole system, it is identified that H_ϕ and E_Θ only can produce far field pattern.

It is given by

$$E_\Theta = \frac{60 I_m}{r} \frac{\cos\frac{\pi}{2}\cos\theta}{\sin\theta} \text{ v/m} \quad (20)$$

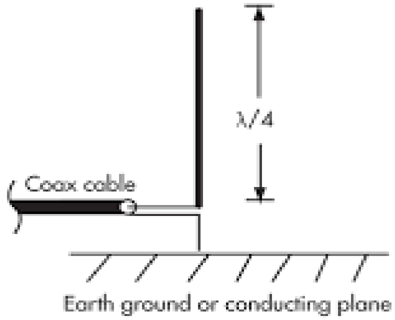
$$H_\phi = \frac{I_m}{2\pi r} \frac{\cos\frac{\pi}{2}\cos\theta}{\sin\theta} \text{A/m}^2 \quad (21)$$

Power radiated by a half wave dipole is given by

$W = 73.140 \ I^2 rms$ Watts

The radiation resistance $R_r = 73 \ \Omega$

QUARTER WAVE MONOPOLE:



Radiation field of a half wave dipole and quarter wave monopole are same. For a quarter wave monopole antenna, the radiation resistance is half of the half wave dipole resistance.

R_r =36.57Ω

Only difference between a λ/2 antenna and λ/4 antenna is that dipole radiates power more or less in all directions, whereas monopole radiates power in a hemisphere surface and that is why radiation resistance is half of the dipole. The field expression is same as that of half wave dipole

ANTENNA PARAMETRES:

1.FIELD PATTERNS:

The energy radiated in a particular direction by an antenna is measured in terms of field strength at a point which is at a particular distance from the antenna.

Radiation pattern of an antenna is a graph which shows the variation in actual field strength of electromagnetic field at all points which are at equal distance from the antenna. The graph is 3D and hence cannot be represented on a plain paper

If the radiation in a given direction is expressed in terms of field strength E, the radiation pattern is called field strength pattern.

If the radiation in a given direction is expressed in terms of power per unit solid angle, then the resulting pattern is power pattern

2.GAIN:

It is defined as the ratio of maximum radiation intensity from subject or test antenna to the maximum radiation intensity from a reference antenna with the same power input.

3.DIRECTIVITY:

An antenna does not radiate uniformly in all directions. The variation of the intensity with direction in space is referred as Directivity. It is defined as the ratio of power radiated per unit solid angle to the average power radiated per unit solid angle.

If an antenna has no losses like ohmic ,dielectric mismatch i.e 100% efficient, the directivity and gain are same.However for an antenna with losses, gain will be less than directivity by a factor which corresponds to efficiency

G=k D is the relation between Gain and Directivity

4.EFFECTIVE LENGTH(l_e):

It represents the electrical length of an antenna really utilized as an radiator or as collector of electromagnetic wave energy. It is mainly dependent with the current distribution along a short dipole.

For the case of transmitting antenna:

Effective length is the product value of physical length dl and the average current distribution

$$l_e=\frac{1}{I_0}\int_0^{dl} I(Z)dz \qquad (22)$$

$$=\frac{I_{av}}{I_0}dl \qquad (23)$$

l_e- effective length in metres

dl- physical length in metres

I_{av} –average current

i) If the current distribution is uniform then l_e=dl

ii)If the same dipole is used at a longer wavelength, then the distribution of current varies linearly from the central feed point to zero at the ends in a triangular distribution. Therefore l_e= 0.5dl

iii) If the current distribution is nearly sinusoidal then $l_e=\frac{2}{\lambda}dl$

For receiving antenna:

The effective length is the ratio of induced voltage at the terminal of the receiving antenna under open circuited condition to the incident electric field strength

$l_e=V_{oc}/E$

5.EFFECTIVE APERTURE:

It is a cross sectional area over which it extracts electromagnetic energy form the travelling electromagnetic waves. It is the ratio of power received at the antenna load terminals to the poynting vector of incident wave.

Relation between D and effective aperture Ae:

$$D=\frac{4\pi}{\lambda^2} A_p \quad (24)$$

Relation between effective length and effective aperture Ae:

$$A_{e(max)} = \frac{l_e^2}{4R_r} Z \quad (25)$$

6.RADIATION RESISTANCE:

It is a equivalent resistance which would dissipate the same amount of power as the antenna radiates when the current in that resistance equals the input current at the antenna terminals.

$$R_r = \frac{W}{I^2} \quad (26)$$

7.ANTENNA TERMINAL IMPEDANCE:

It is the impedance at the point where the transmission line carrying RF power from the transmitter is connected. Since at this point input to the antenna is supplied, it is called as Antenna Input impedance

If the antenna is lossless and isolated then the antenna terminal impedance is same as the self impedance((Z_{11}) which is given by

$$Z_{11} = R_{11} + jX_{11} \quad (27)$$

Self impedance of an antenna is defined as its input impedence when all other antennas are completely removed .

8.POLARIZATION:

Polarization, also called wave polarization, is an expression of the orientation of the lines of electric flux in an electromagnetic field . Polarization can be constant -- that is, existing in a particular orientation at all times, or it can rotate with each wave cycle.

Types:

a) **Elliptical polarization:**

It is the polarization of electromagnetic radiation such that the tip of the electric field vector describes an ellipse in any fixed plane intersecting, and normal to, the direction of propagation.

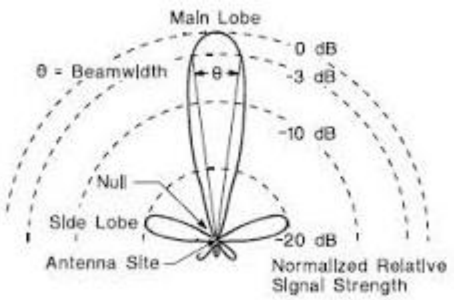
b) Circular polarization:

Polarization of an electromagnetic wave in which either the electric or the magnetic vector executes a circle perpendicular to the path of propagation with a frequency equal to that of the wave. It is frequently used in satellite communications.

c) **Linear polarization:**

It is a confinement of the electric field vector or magnetic field vector to a given plane along the direction of propagation

9.BEAM WIDTH:



Angular region of a far field pattern is referred as beamwidth, and it is a measure of directivity.Half power beam width is measured between two points on the major lobe where the power is half of its maximum power whereas angular region between two successive first null points is referres as First Null Beam width

10.BANDWIDTH:

It defines the width or the working range of frequencies over which the antenna maintains its characteristics and parameters like gain , Radiation pattern, directivity, impedance and so on without considerable change.