ANTENNAS , WAVE PROPAGATION &TV ENGG

Lecture : Various Potentials used in Antenna theory

Topics to be covered

- Various Potentials used in Antenna theory

Electric Scalar Potential V

- Electric Field is a field of force. If a body being acted upon by the force from one point to another, work will be done on or by the body.

Taking reference point as infinity, if test charge **‘ q ‘** is moved from infinity along a radius line to a point ‘**P’** at a distance ‘**R**’ from charge ‘**Q’**, work is done in moving test charge **q** against the force **F** & is given by

=

$$W = -\int_{\infty}^{R} F \cdot dr$$

$$\frac{Qq}{4\pi \epsilon r^{2}}$$

$$\boxed{W} = \boxed{-\int_{\infty}^{R} \frac{Qq}{4\pi\epsilon r^{2}}}\ dr$$

$$-\frac{Qq}{4\pi\epsilon}\left[-\frac{1}{r}\right]_{\infty}^{R} = \frac{Qq}{4\pi\epsilon r}$$

- If test charge q = Unit charge 1,

Work done on test charge per unit charge in moving from infinity to point P due to charge Q

Electric Potential

$$V = \frac{Q \times 1}{4\pi\varepsilon r} = \frac{Q}{4\pi\varepsilon r}$$

= Magnitude without direction

Electric Potential V is a “Scalar Potential” work;

Electric Field Intensity = Negative of Potential gradient at that point

$E = - \nabla V$ - Grad V 1

Scalar Electric Potential : V

Defined as the work done on the test charge per unit charge in moving a charge from the infinity to the point (Unit = Volt = Joules/Coulomb)

$$W = -\int_{\infty}^{R} F \cdot dl$$

From Coulombs' law :

$$F = \frac{Qq}{4\pi\epsilon r^2} \quad =$$

$$= \frac{Qq}{4\pi\epsilon R}$$ (if test charge $q = 1$ then)

Magnetic Vector Potential

$q \xrightarrow{\text{creates}}$ Electric Field

$I.dl \xrightarrow{\text{creates}}$ Electric Field

(Current element : Vector)

Biot Savarts Law

$$dA = K.\left(\frac{Idl}{r}\right)$$

where $K = \frac{\mu}{4\pi}$

- So Magnetic vector Potential $\vec{A}$ e to the current flow in the entire circuit is obtained by

$$\int$$

$$\int dA = \int \frac{\mu}{4\pi}\left(\frac{I\,dl}{r}\right)$$

$$A = \int_{l} \frac{\mu}{4\pi} \cdot \frac{I\,dl}{r}$$

Unit of $\vec{A}$ is Wb/m^2 or Tesla (T)

- If it is generalized, Idl = Idv i.e. current flows throughout the volume.

$$A = \int \frac{\mu}{4\pi} \cdot \frac{I\,dv}{r}$$

Retarded Potentials:

- We have evaluated all the equation based on the basis of charges being fixed on position for ‘V’ and on the basis of constant charge velocities or constant current for A.
- We must take “time rate of change” into account in the dynamic case because all electric & magnetic effects are propagated with a velocity of ‘c’ – 3*10 m/s

- The retarded scalar potentials that can be expressed in terms of retarded time

  (t – r/c)

- The expression for retarded scalar potential is given by

$$V_{(P,t)} = \frac{1}{4\pi\epsilon_0}\int_V \frac{[\rho]_{(t-r/c)}\, dv}{r}.$$

- **Potential at point P, time t**

$[\rho]_{(t-r/c)}$ = Charge at earlier times (t-r/c)

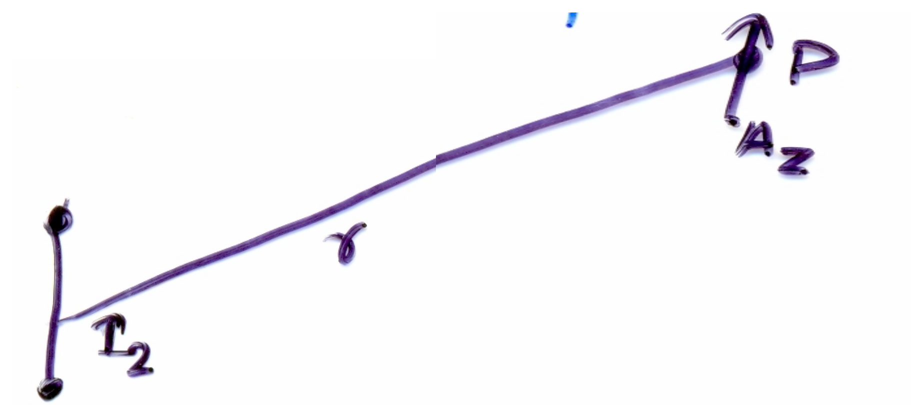
r/c = Retardation time is the time for the effect to be propagated the distance **r** at velocity c

- Similarly for $\vec{A}$

$$\vec{A}(P,t) = \frac{\mu_0}{4\pi} \int_v \frac{\vec{J}(t - r/c)}{r} \cdot dv.$$

Time varying potentials are called Retarded Potentials

Application in Radiation problems in which the distribution of the source is known approximately eg:



- For any filamentary current –

$$\vec{A} = \frac{\mu}{4\pi} \int \frac{I\left(t - \frac{r}{c}\right) dl}{r}$$

- For particular case when l is small in comparison with r

$$A_z = \frac{\mu}{4\pi} \cdot \frac{I_z\left(t - \frac{r}{c}\right)}{r} \, l \qquad =$$

$$I_z = I_m \sin \omega t \quad \text{then}$$

$$A_z = \frac{\mu l \, I_m \sin \omega \left(t - \frac{r}{c}\right)}{4\pi r}$$

Thus the value of electric field & A may be derived

Retarded Vector Potential

- Vector potential expression represents superposition's of potentials due to varying current elements I.dl at a distance pt P at a distance r.

But we made a assumption:

“ Time of propagation was ignored also called as Retardation Time”

- Hence instead of

$$I = I_m \sin \omega t$$

$$[I] = I_m \sin \omega \left(t - \frac{r}{c}\right)$$

$$= I_m \sin \left(\omega t - \frac{\omega}{c} \cdot r\right)$$

$$= I_m \sin(\omega t - \beta r)$$

where, $\sin(\omega t - \beta r)$ **Is Travelling of spherical waves in radial direction**