# Antenna  Wave Propagation

Topic

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

=

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

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

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

$$-\frac{Qq_1}{4\pi\epsilon}\left[-\frac{1}{r}\right]_{\infty}^{R} = \frac{Qq_1}{4\pi\epsilon r}$$

➤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;

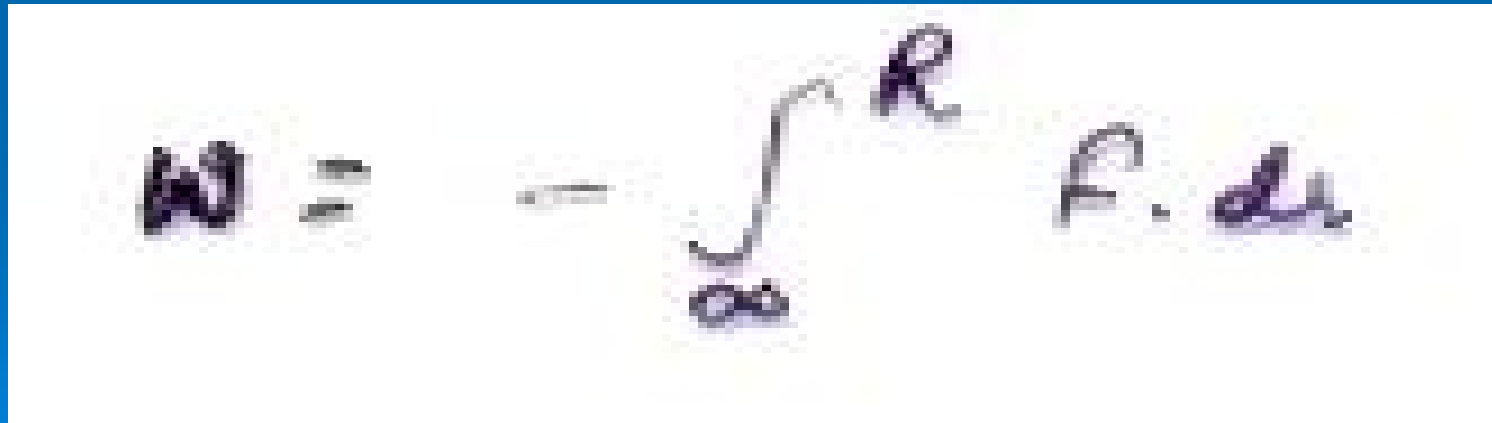Electric Field Intensity = Negative of Potential gradient at that
point

$$E = -\nabla V = - \text{Grad } V \qquad \text{.............} \quad 1$$

# 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 )

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

# From Coulombs' law :

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

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

# Magnetic Vector Potential

**creates**

q   =>   Electric Field

**creates**

I.dl  =>   Electric Field

(Current element : Vector)

# Biot Savarts Law

$$dA = K \cdot \left( \frac{I\,dl}{r} \right)$$

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

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

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

$$A = \int_{0} \frac{\mu}{4\pi} \cdot \frac{I \, du}{z}$$

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' − $3*10^8$ 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

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

- **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**

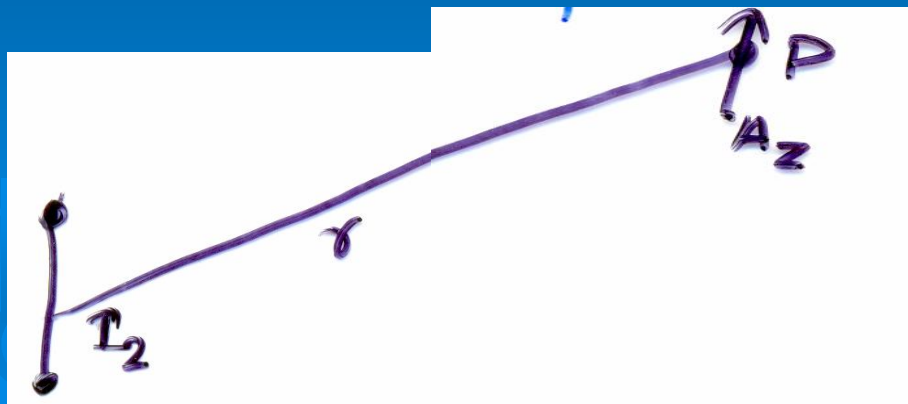➤ Similarly for $\vec{A}$

$$\vec{A}(P,t) = \frac{\mu_0}{4\pi} \int_{v_0} \frac{J(t-r/c)}{r} \cdot dv$$

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 –

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

## 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**