Topic 2

* Question on Electric fields and the V/m relationship.

Recall that

- Electrostatic fields (time-invariant) are produced by static charge distributions.
- Charge motion in resistors, capacitors, transistors, etc, are initiated by electrostatic fields.
- Electric field intensity (E-field strength) "E" is the force that a unit charge experiences when placed in an E-field.

$$\underset{\text{E-field}}{E} = \frac{F \ \text{force}}{Q \ \text{charge}}$$

- usually we have a charge distribution on lines, surfaces or volumes, thus the field in a specific region in space is the summation from the charge contributions. for example, due to a surface charge distribution, the E-field at a certain location $\vec{R}$ away is

$$\vec{E} = \int_S \rho_s \frac{ds}{4\pi\varepsilon_0 R^2} \hat{a}_R$$

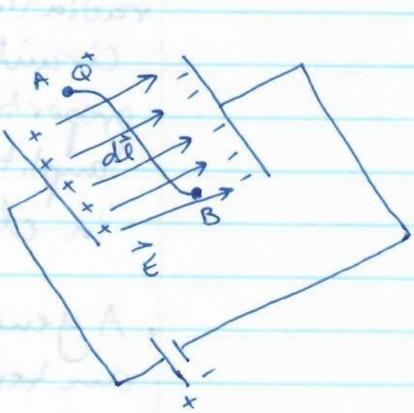
$\hat{a}_R$ unit vector at point of interest

ρ_s Surface charge

R radial distance

- E-fields are given in V/m

$$\vec{E} = \frac{\vec{F}}{Q}$$



- The work done in moving a charge within an E-field over a path $\vec{dl}$ (from A to B) is

$$dW = -\vec{F}\cdot\vec{dl} = -Q\vec{E}\cdot\vec{dl}$$

• Thus, the total work done (W), or potential energy required to move a charge Q^+ from A to B is

$$W = -Q\int_A^B \vec{E}\cdot d\vec{l}$$

• We define the potential difference between points A and B within a field is

$$V_{AB} = \frac{W}{Q} = -\int_A^B \vec{E}\cdot d\vec{l} = \underbrace{V_B - V_A}_{\text{Voltage at B with refence to A}}$$

Which is the amout of work done to move a charge within an external E-field.
the -ve sign is because there is a loss in potential energy in moving from A to B (work done by field).

⇒ meaning that, more work is needed to move further in an E-field, resulting in higher voltage drop.

• Now, if we consider time varying fields (i.e. antenna radiation, ~~[illegible]~~ wireless devices, fields from switching circuits, ...), the electric field intensity is inversly proportional with traveled distance, meaning the amplitude of the wave will decrease (as I mentioned in class).

• A general expression for $\vec{E}$ from a wire antenna is

$$\vec{E}_\theta = \underbrace{j\eta \frac{I_0 \cos(\pi \cos\theta)}{2\pi \underbrace{r}_{\text{distane from wire}} \sin\theta}}_{\text{complex amplitude as a function of elevation angle } (\theta)} \; \underbrace{e^{-j\beta r}}_{\text{Propagating wave}}$$

$$= [\,\cdot\,] * \frac{1}{r}$$

the inverse distane relationship with wave magnitude

- This shows that as you move away from a radiating EM source (i.e. cell tower), your signal strength gets weaker.

- now, at the receiving end, the receiving antenna (wire) length (or aperture) size directly infuences the received voltage at the antenna output (conversion of fields to voltages) such that

$$V_{ind} = \vec{E}^i \cdot \underbrace{\vec{l}_{eff}}_{\text{effective aperture}}$$

This means that, given a receiving antenna at a fixed distance from a source, an antenna with a larger effective length (or aperture) will capture more signal power (i.e. generate higher voltages) than a lower effective length one.

$\cancel{X}$