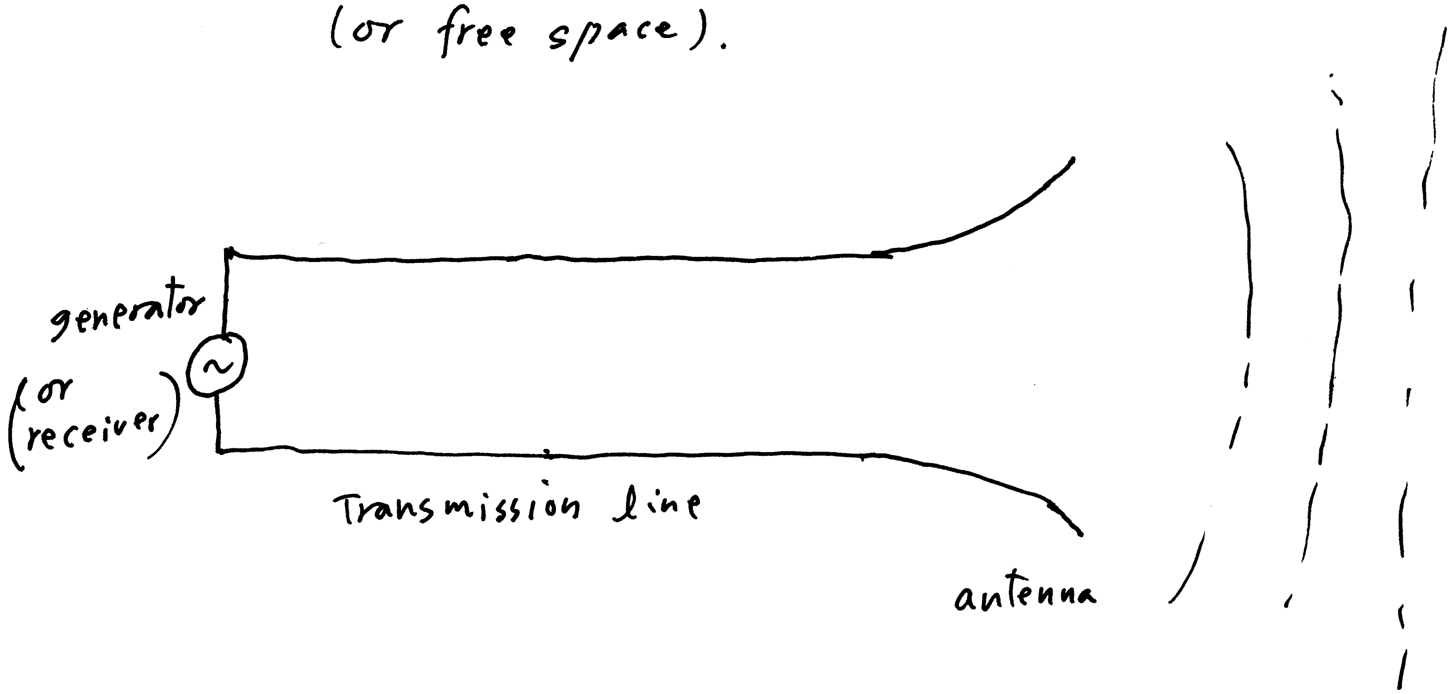
Phys 221

Lecture 31.

Ref. 10-1, 2. Radiation and Antennas

- Antenna — A transducer between a guided wave in a transmission line and an electromagnetic wave propagating in an unbounded medium (or free space).



- Can be sending or receiving E & M signals.

- Reciprocity — same pattern for sending and receiving

  — NOT always True

  but we only deal with reciprocal antennas in this course.

- Two important aspects of antenna performance

  ① radiation properties

  — directional pattern

  — polarization state

  ② . antenna impedance .

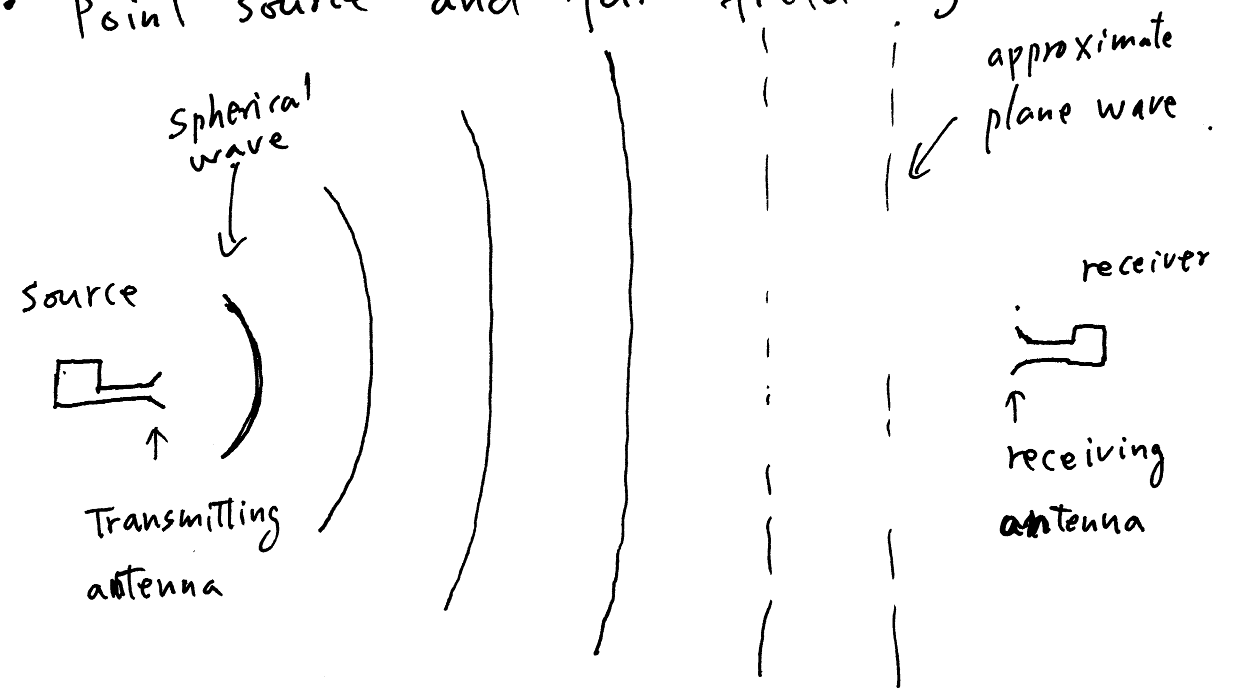
  — impedance matching .

- Radiation sources

  time - varying current

  (moving charge)

- Point source and far field region .

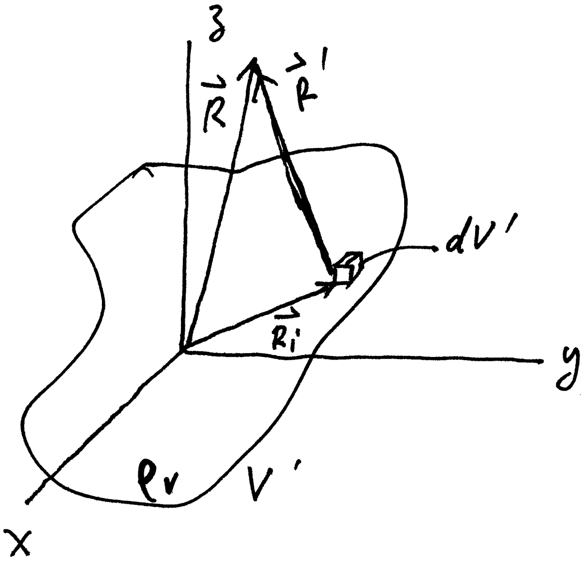


- Retarded Potentials.

Coulomb's law.

$$V(\vec{R}) = \frac{1}{4\pi\varepsilon}\int_{V'} \frac{\rho_v(\vec{R}_i)}{R'}\,dV' \qquad (10.1).$$

$$\vec{R}' = \vec{R} - \vec{R}_i$$



It takes time $\frac{R'}{u_p}$ for the E & M action to reach $\vec{R}$ from $\vec{R}_i$.

∴ (10.1) should be modified to:

$$\underline{V(\vec{R}, t)} = \frac{1}{4\pi\varepsilon}\int_{V'} \frac{\rho_v\left(\vec{R}_i,\, t - \frac{R'}{u_p}\right)}{R'}\,dV'$$

↑

retarded scalar potential because there is a time retardation of $\frac{R'}{u_p}$.

• Retarded vector potential (same idea):

$$\vec{A}(\vec{R},t) = \frac{\mu}{4\pi}\int_{V'} \frac{\vec{J}(\vec{R}_i, t - R'/u_p)}{R'}\, dV'$$

• For harmonic time-dependence. $\underbrace{e^{j\omega t}}$ in ρ_v, $\vec{J}$, V, $\vec{A}$, $\vec{E}$, $\vec{H}$, etc...

use phasor.

$$\tilde{V}(\vec{R}) = \frac{1}{4\pi\epsilon}\int_{V'} \frac{\tilde{\rho}_v(\vec{R}_i)e^{-jkR'}}{R'}\, dV'$$

$$\tilde{\vec{A}}(\vec{R}) = \frac{\mu}{4\pi}\int_{V'} \frac{\tilde{\vec{J}}(\vec{R}_i)e^{-jkR'}}{R'}\, dV'$$

$\left(k = \frac{\omega}{u_p} = \frac{2\pi}{\lambda} \right.$ — wave number. $\left.\right)$

Then: $\tilde{\vec{H}} = \frac{1}{\mu}\nabla \times \vec{A}$.

$$\nabla \times \tilde{\vec{H}} = j\omega\epsilon\tilde{\vec{E}} \Rightarrow \tilde{\vec{E}} = \frac{1}{j\omega\epsilon}\nabla \times \tilde{\vec{H}}.$$

(find $\vec{A}$, then $\vec{H}$, then $\vec{E}$)

- The short dipole (Hertzian dipole)

$\uparrow$

$\frac{l}{\lambda} < \frac{1}{50}$

So that $i(t)$ is ind. of z.

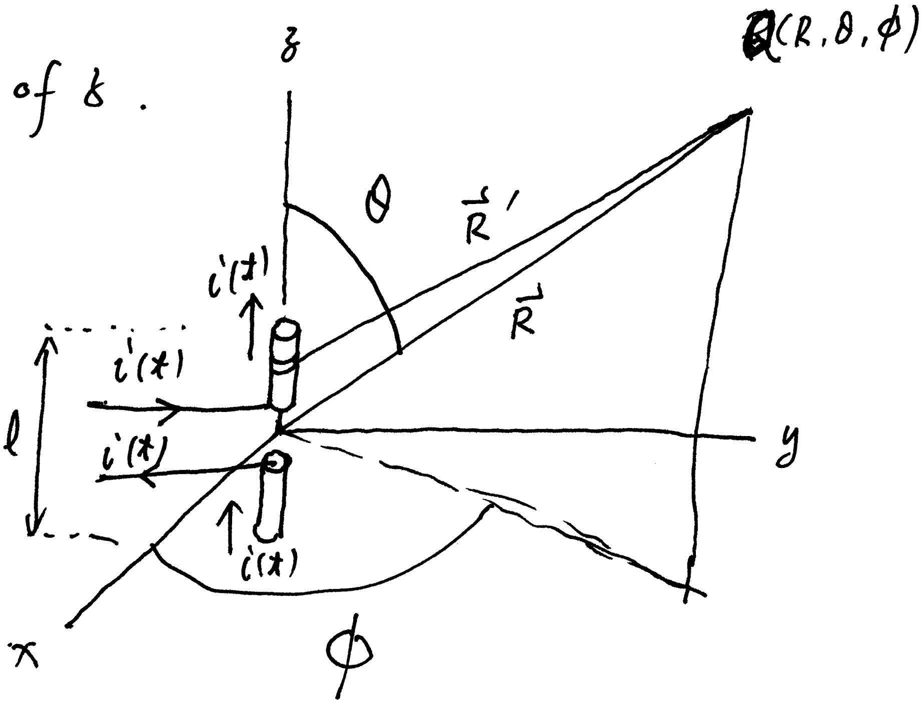
also, $R' \approx R$.

spherical coordinates.

R - range

θ - zenith angle

ϕ - azimuth angle.



$$\tilde{\vec{A}}(\vec{R}) = \frac{\mu_0}{4\pi}\int_{V'} \frac{\tilde{\vec{J}}\, e^{-jkR'}}{R'}\, dV'$$

$$= \frac{\mu_0}{4\pi}\,\frac{e^{-jkR}}{R}\int_{-l/2}^{l/2} \hat{z}\, I_0\, dz$$

$$= \hat{z}\,\frac{\mu_0}{4\pi} I_0\, l\, \underbrace{\frac{e^{-jkR}}{R}}_{\text{spherical propagation vector}}.$$

$i(t) = I_0 \cdot \cos\omega t$.

$= \mathrm{Re}\left[I_0\, e^{j\omega t}\right]$

$\tilde{I} = I_0$

$$= \left(\hat{R}\cos\theta - \hat{\theta}\sin\theta\right)\frac{\mu_0 I_0 l}{4\pi}\,\frac{e^{-jkR}}{R} \qquad (A_\phi = 0).$$

Then. $\tilde{\vec{H}} = \frac{1}{\mu_0}\nabla\times\vec{A}$, $\quad \tilde{\vec{E}} = \frac{1}{j\omega\varepsilon_0}\nabla\times\vec{H}$.