Mobile Radio Propagation Large-Scale Path Loss

Unit-1

4.2 Free Space Propagation Model

- The free space propagation model is used to predict received signal strength when the transmitter and receiver have a clear line-of-sight path between them.
  - satellite communication
  - microwave line-of-sight radio link
- Friis free space equation

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$

P_t : transmitted power

$P_r(d)$: received power

G_t : transmitter antenna gain

G_r : receiver antenna gain

d : T-R separation distance (m)

L : system loss

λ : wave length in meters

- The gain of the antenna

$$G = \frac{4\pi A_e}{\lambda^2}$$

A_e : effective aperture is related to the physical size of the antenna

- The wave length λ is related to the carrier frequency by

$(L \geq 1)$

$$\lambda = \frac{c}{f} = \frac{2\pi c}{\omega_c}$$

f : carrier frequency in Hertz

L

ω_c : carrier frequency in radians

c : speed of light (meters/s)

- The losses are usually due to transmission line attenuation, filter losses, and antenna losses in the communication system. A value of $L=1$ indicates no loss in the system hardware.

- Isotropic radiator is an ideal antenna which radiates power with unit gain.
- Effective isotropic radiated power (EIRP) is defined as

$$EIRP = P_t G_t$$

and represents the maximum radiated power available from transmitter in the direction of maximum antenna gain as compared to an isotropic radiator.

- Path loss for the free space model with antenna gains

- When antenna gains are excluded

- The Friis free space model is only a valid predictor for for values of *d* which is in the far-field (Fraunhofer region) of the transmission antenna.

$$PL(dB) = 10\log\frac{P_t}{P_r} = -10\log\left(\frac{G_t G_r \lambda^2}{(4\pi)^2 d^2}\right)$$

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P_r

- The far-field region of a transmitting antenna is defined as the region beyond the far-field distance

$$d_f = \frac{2D^2}{\lambda}$$

where *D* is the largest physical linear dimension of the antenna.

- To be in the far-filed region the following equations must be satisfied

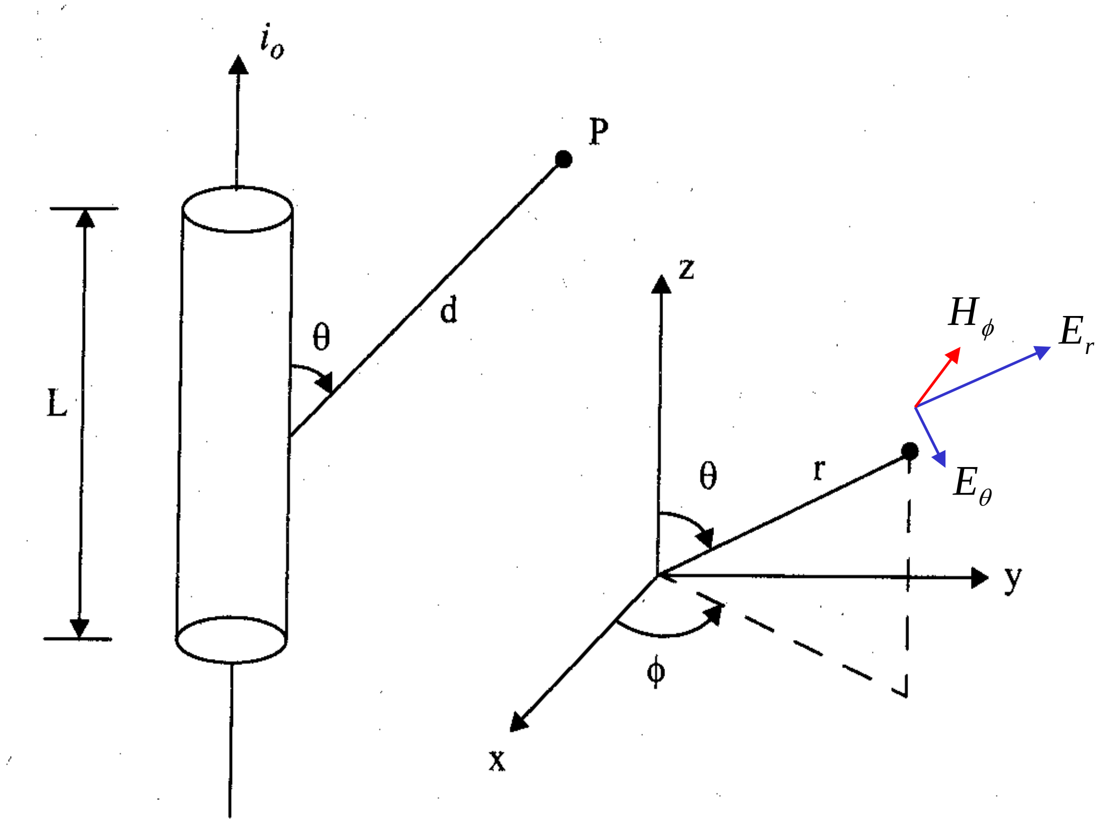
$$d_f >> D \qquad \text{and} \qquad d_f >> \lambda$$

- Furthermore the following equation does not hold for $d=0$.

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$

4.3 Relating Power to Electric Field

- Consider a small linear radiator of length L, placed coincident with z-axis, center with origin



- Current carrying of amplitude i_0

- Electric and magnetic fields for a small linear radiator of length *L*

$$E_r = \frac{i_0 L \cos\theta}{2\pi\varepsilon_0 c}\left\{\frac{1}{d^2} + \frac{c}{j\omega_c d^3}\right\} e^{j\omega_c (t-d/c)}$$

$$E_\theta = \frac{i_0 L \sin\theta}{2\pi\varepsilon_0 c}\left\{\frac{j\omega_c}{d} + \frac{c}{d^2} + \frac{c^2}{j\omega_c d^3}\right\} e^{-j\omega_c (t-d/c)}$$

$$H_\phi = \frac{i_0 L \sin\theta}{4\pi c}\left\{\frac{j\omega_c}{d} + \frac{c}{d^2}\right\} e^{j\omega_c (t-d/c)}$$

with $E_\phi = H_r = H_\theta = 0$

- At the region far away from the transmitter only E_θ and H_ϕ need to be considered.
- In free space, the power flux density is given by

$$P_d = \frac{EIRP}{4\pi d^2} = \frac{P_t G_t}{4\pi d^2} = \frac{|E|^2}{R_{fs}} = \frac{|E|^2}{\eta} \quad W/m^2$$

- where R_{fs} is the intrinsic impedance of free space given by $\eta = 120\pi \ \Omega$

$$P_d = \frac{|E|^2}{377 \ \Omega} \quad W/m^2$$