Chapter 4 :

Large scale path loss

قسم هندسة تقنيات الحاسوب

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Chapter 4

4.1 Mobile Radio Propagation

- The transmission path between the transmitter and the receiver can be either Simple line-of-sight (LOS), or Obstructed by buildings, mountains, and foliage.
- The speed of motion impacts how rapidly the signal level fades as a mobile terminal moves.
- The signal strength decreases as the distance between the transmitter and receiver increases.
- Propagation models have focused on predicting the average received signal strength at a given distance from the transmitter.
  a. **Large-scale propagation models**: used for estimating the radio coverage area of a transmitter for large T-R separation distances.
  b. **Small-scale fading models:** models that characterize the rapid fluctuations of the received signal strength over very short travel distances.
- As mobile moves over very small distances, the instantaneous received signal strength may fluctuate rapidly giving rise to small-scale fading. The reason for this is that the received signal is a sum of many rays coming from different directions.

4.2 Free Space Propagation loss

- The free space propagation model is used to predict received signal strength when the transmitter and receiver have a clear, unobstructed LOS path between them.
- As with most large-scale radio wave propagation models, the free space model predicts that received power decays as a function of the T-R separation distance raised.

The free space power received by a receiver antenna which is separated from a radiating transmitter antenna by a distance *d*, is given **by the Friis free space equation**,

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

where

P_t is the transmitted power in watts,

$P_r(d)$ is the received power which is a function of the T-R separation in watts,

G_t is the transmitter antenna gain,

G_r is the receiver antenna gain,

d is the T-R separation distance in meters,

L is the system loss factor not related to propagation ($L \geq 1$),

λ is the wavelength in meters.

The gain of an antenna is related to its effective aperture A_e by

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

The effective aperture A_e is related to the physical size of the antenna, and λ is related to the carrier frequency by

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

where

f is the carrier frequency in Hertz (Hz),

ω_c is the carrier frequency in radians per second (rad/s),

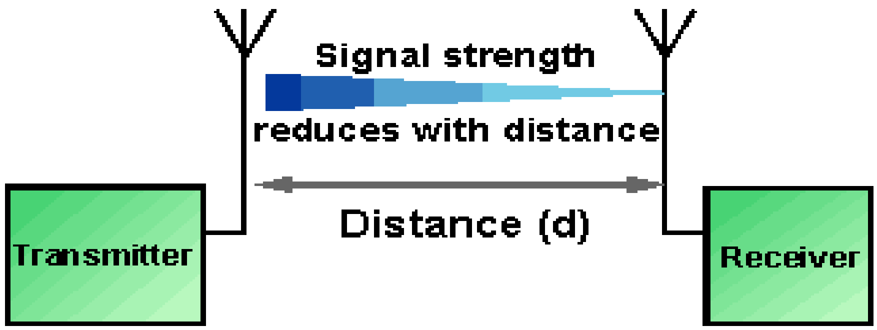
c is the speed of light ($\approx 3\times10^8$ m/s).

- The values for P_t and P_r must be expressed in the same units, and G_t and G_r are dimensionless quantities.
- The losses L ($L \geq 1$) are usually due to transmission line attenuation, filter losses, cable loss, and antenna losses in the communication system.
- A value of $L = 1$ indicates no loss in the system hardware.
- An isotropic radiator is an ideal antenna which radiates power with unit gain uniformly in all directions, and is often used to reference antenna gains in wireless systems.

The effective isotropic radiated power (*EIRP*) is defined as

$$EIRP = P_t \, G_t$$

- In practice, antenna gains are given in units of *dBi* (*dB* gain with respect to an isotropic source) or *dBd* (dB gain with respect to a half-wave dipole).
- The Friis free space model is only a valid predictor for P_r for values of *d* which are in the far-field of the transmitting antenna.

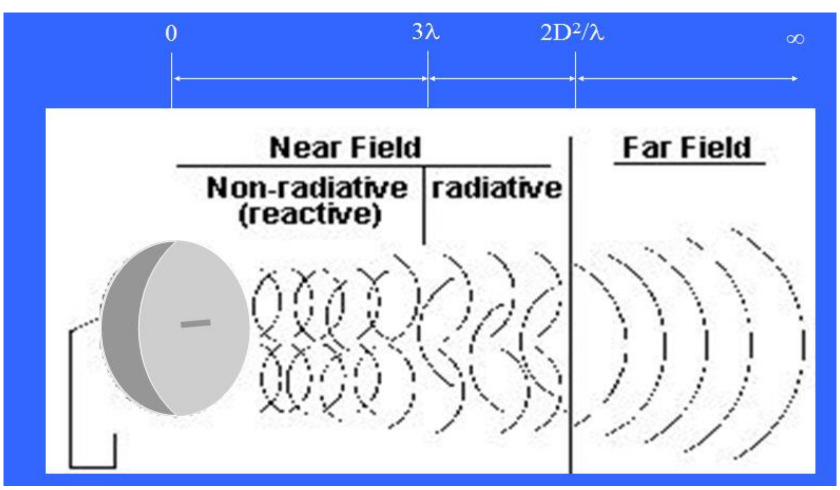


The **path loss** represents signal attenuation as a positive quantity measured in *dB*, is defined as the difference between the transmitted power and the received power.

$$PL(dB) = -20\log\left(\frac{\lambda}{4\pi d}\right)$$

4.2.2 Understanding the Antenna Near Field & Far Field Distances

The fields surrounding an antenna are divided into 3 main regions:



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1- **Reactive Near Field**

The reactive near field ad the radiating near field. The reactive near field is the region where the fields are reactive i.e the E and H fields are out of phase by 90 degrees to each other. For propagating or radiating fields, the fields must be orthogonal to each other but in phase.

2- **Radiating Near Field (Fresnel region)**

The radiating near field or Fresnel region is the region between the reactive near and far field. The reactive fields do not dominate in this region. However unlike the far field region, the shape of the radiation pattern varies significantly with distance.

3- **Far Field**

When talking about antennas the far field is the region that is at a large distance from the antenna. In the far field the radiation pattern does not change shape as the distance increases. There are three conditions which must be satisfied to ensure that the antenna is at a distance which qualifies as the far field.

$$\text{Reactive Near Field} \leq 0.62 \times \sqrt{\frac{D^3}{\lambda}}$$

$$\text{Radiating Near Field (Frensel Region)} \leq \frac{2D^2}{\lambda}$$

$$\text{Far Field } \geq \frac{2D^2}{\lambda}$$

$$\lambda = \frac{\text{Speed of Light}}{\text{Frequency}}$$