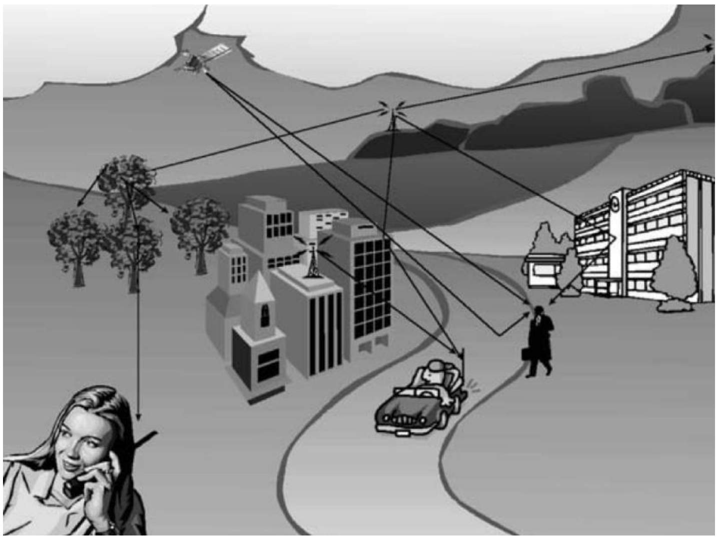
Large Scale Fading

The objective of this chapter is to learn

- Basic physical phenomenon such as Reflection, diffraction and transmission.
- Free-space model and two-ray model.
- Path Loss model.
- Empirical Model for microcell and picocell
- Deterministic Model with Reflection, Diffraction and Transmission
- Ray-tracing algorithm



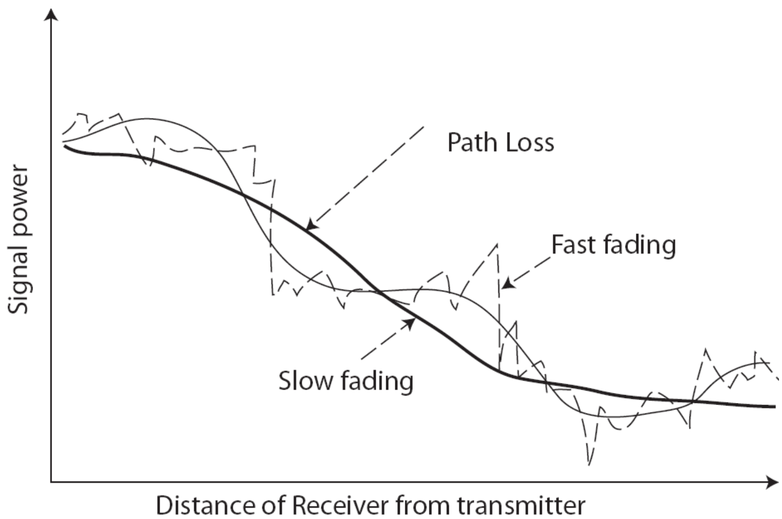


Figure 3: (a) A Scenario with multiple obstacles (b) Fast fading, Slow fading and Path loss

4.1 Free-Space Model

This model is the simplest model which is generally applicable in a scenario where the Tx and Rx hights are very high and they are not surrounded by any scattering. Though such scenario is not realist and yet such model is important as it works as a reference for comparison with other realistic scenario.

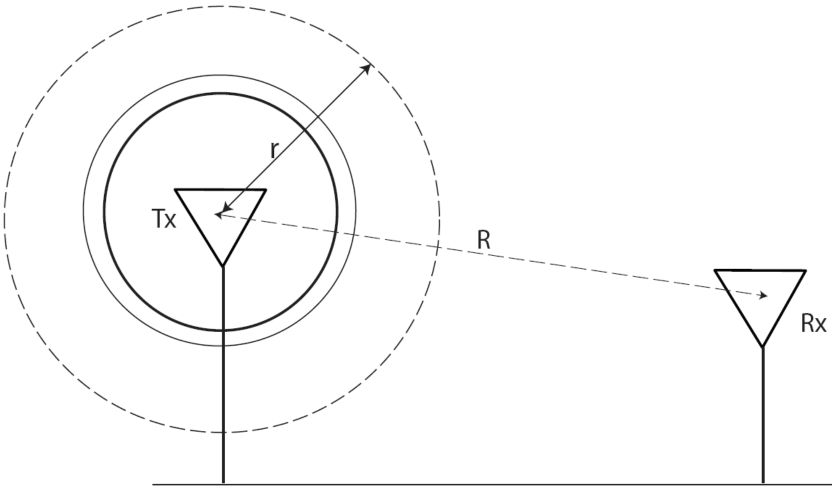


Figure 1: Free-space model

$$P_R = \frac{P_T G_T A_R}{4\pi R^2} \qquad G_R = \frac{4\pi A_R}{\lambda^2} \tag{A}$$

P_R= Received power

P_T = Transmitted power

G_T = Gain of the Transmitting Antenna

R = distance between Tx and Rx

G_R = gain of the Receiver Antenna

λ = Wavelength

$$\left.\begin{aligned} P_R &= (P_T G_T) G_R \left(\frac{\lambda}{4\pi R}\right)^2 \\ \left(\frac{4\pi R}{\lambda}\right)^2 &= L_s = \text{Free Space path loss} \end{aligned}\right\} \quad \textbf{(B)}$$

$L_s(dB) = 92.47 + 20 \log R + 20 \log f$ R in Km, f in GHz

It may be noted from (A) that the gain of the receiving antenna depends upon the effective aperture area of the antenna as well as frequency. If the effective aperture area is constant, then, gain increases with the increase in the frequency. Also it is evident from (B) that free-space path loss increases with the frequency. Therefore, including both the abovementioned fact, it can be concluded that for a given aperture area of the receiving antenna, total received power does not change with increase in the frequency.

Example1: If the effective aperture area of the receiver antenna is 0.03 square meter and the operating frequency is 2GHz. The Tx antenna is assumed to be omnidirectional and transmitter power is 10 dBW. The transmitter and receiver are situated in a open area where free-space path loss model is applicable. Compute the received power in dB. Assume the distance between Tx and Rx to be 1 Km. Also compute the free-space path loss in dB.

<u>Solution:</u>

$$A_e = 0.03m^2$$
$$f = 2GHz = 2\times10^9\,Hz$$
$$G_t = 1 \quad (\text{Omni-directional antenna})$$
$$P_t = 10dBW$$
$$R = 1\ km, P_r = ?$$
$$P_r(dB) = (P_t)_{dB} + (G_r)_{dB} - L_s(dB)$$
$$L_s(dB) = 92.47 + 20\log R + 20\log f$$

Where R in Km and f is in GHz.

Hence

$$L_s(dB) = 82.47 + 20\log(1) + 20\log(2)$$
$$= 98.49dB$$

$$G_r = \frac{4\pi A_e}{(0.15)^2} \qquad c = f\lambda \Rightarrow \lambda = \frac{3\times10^8}{2\times10^9} = 0.15m$$
$$= 16.76 \Rightarrow (G_r)_{dB} = 10\log 16.76 = 12.2dB$$
$$\Rightarrow (P_r)_{dB} = 10dBW + 12.2dB - 98.49dS = -76.29dB$$

Example 2: Consider an Indoor wireless LAN with fc=900 MHz, cell of radius 100m and non-directional antennas. Under the free-space path loss model, compute the transmitter power required such that all the receiving terminals within the cell receives a minimum of 1 μW. How does this change if the system frequency changes to 10 GHz.

Solution:

$$f_c = 900MHz \Rightarrow \lambda = \frac{3\times10^8}{9\times10^8} = 0.33m, R = 100m = 0.1\ km$$

$$G_t = 1 = 0dB = G_r,$$

$$P_r = 1\mu W = 10^{-6}W \Rightarrow P_r(dB) = 10\log\frac{10^{-6}W}{1W} = -60dB$$

$$P_t = ?$$

$$L_s\left(dB\right) = 92.47 + 20\log\left(10^{-1}\right) + 20\log\left(0.9\right) = 71.5549dB$$

$$\left(P_t\right)_{dB} = \left(P_r\right)_{dB} + L_s\left(dB\right) = -60dBW + 71.5549dB = 11.55\ dBW$$

$$f = 10GHz \Rightarrow L_s\left(dB\right) = 92.47dB$$

Since receiving antenna gain is omni-directional and hence, its gain is fixed at 0dB. If this is to remain constant by increasing frequency to 10GHz, then, this is possible only be reducing effective aperture area. Thus, given the fixed antenna gain of receiving antenna to be 0dB, the required transmitted power is given by

$$\left(P_t\right)_{dB} = \left(P_\gamma\right)_{dB} + \left(L_s\right)_{dB} = -60dBW + 92.47dB = 32.47dB$$