Radio Propagation and Propagation Path-Loss Models

Introduction:

Exponential growth of mobile communications has increased interest in many topics in radio propagation. Much effort is now devoted to refi ne radio propagation path-loss models for urban, suburban, and other environments together with substantiation by fi eld data. Radio propagation in urban areas is quite complex because it often consists of reflected and diffracted waves produced by multipath propagation. Radio propagation in open areas free from obstacles is the simplest to treat, but, in general, propagation over the earth and the water invokes at least one reflected wave. For closed areas such as indoors, tunnels, and underground passages, no established models have been developed as yet, since the environment has a complicated structure.

In general, radio wave propagation consists of three main attributes: reflection, diffraction and scattering (see Figure below). **Reflection** occurs when radio wave propagating in one medium impinges upon another medium with different electromagnetic properties. The amplitude and phase of the reflected wave are strongly related to the medium’s intrinsic impedance, incident angle, and electric fi eld polarization. Part of the radio wave energy may be absorbed or propagated through the reflecting medium, resulting in a reflected wave that is attenuated.

Diffraction is a phenomenon by which propagating radio waves bend or deviate in the neighborhood of obstacles. Diffraction results from the propagation of wavelets into a shadowy region caused by obstructions such as walls, buildings, mountains, and so on.

Scattering occurs when a radio signal hits a rough surface or an object having a size much smaller than or on the order of the signal wavelength. This causes the signal energy to spread out in all directions. Scattering can be viewed at the receiver as another radio wave source. Typical scattering objects are furniture, lamp posts, street signs, and foliage.

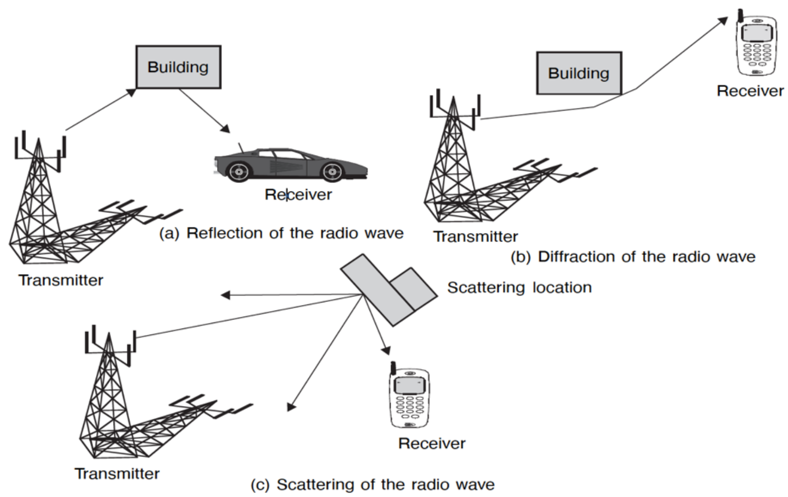

Figure-1 Reflection, diffraction and scattering of radio wave.

Free-Space propagation:

The simplest wave propagation case is that of a direct wave propagation in free space. In this special case of line-of-sight (LOS) propagation there are no obstructions due to the earth's surface or other obstacles (see Figure below). We consider radiation from an isotropic antenna. This type of antenna is completely omni-directional, radiating uniformly in all directions. While there is no such thing as a purely isotopic antenna in practice, it is a useful theoretical concept.

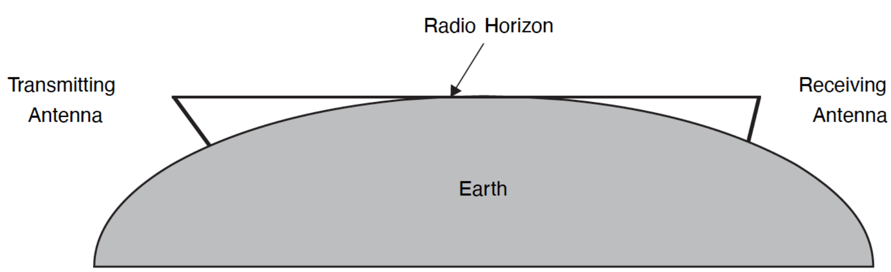

Figure-2 Line-of-sight propagation.

The received power, Pr, at the receiving antenna (mobile station), located at a distance, d, from the transmitter (base station) is given for free space propagation as:

$$P_r = P_t \left(\frac{\lambda}{4\pi d}\right)^2 G_b G_m$$

where:

Pr : received power.
Pt : transmitted power.
λ : wave length.
Gb : gain of the transmitting (base station) antenna.
Gm: gain of the receiving (mobile) antenna.
d : antenna separation distance between transmitter and receiver (i.e., base station and mobile station).

Note-1: the free space path loss is given by:

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

Note-2: the Antenna gain is given by: where Ae is antenna effective area.

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

Example:

Consider a base station transmitting to a mobile station in free space. The following parameters relate to this communication system:

- Distance between base station and mobile station: 8000 m
- Transmitter frequency: 1.5 GHz.
- Base station transmitting power, Pt =10 W.
- Antenna gains are 8 dB and 0 dB for the base station and mobile station, respectively.
- Total system losses: 8 dB.

Calculate the received signal power at the mobile receiver antenna.

Solution:

λ= c / f = (3*10^8) / (1.5*10^9) = 0.2 m.

Path loss = 20 log ((4*3.14*8000)/0.2) = 114.02 dB.

Received power = Pt + Gb +Gm – path loss – system losses. (dB)

= 10 +8 – 114.02 - 8 = -104.02 dB

Home Work: Write the free space propagation equation expressed in d in Km and f in MHz.