Chapter 2: Mobile Radio Propagation I:

Free Space Propagation Model:

The free space propagation model is used to predict received signal strength when the transmitter and receiver have a clear, unobstructed line-of-sight path between them. Satellite communication systems and microwave line-of-sight radio links typically undergo free space propagation. 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 to some power (i.e. a power law function). 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,

$$Pr(d) = PtGtGr\lambda^2/(4\pi d)^2$$

where P_t is the transmitted power, P_r (d) is the received power which is a function of the T-R separation, G_t is the transmitter antenna gain, G_r is the receiver antenna gain, d is the T-R separation distance in meters and λ is the wavelength in meters. The gain of an antenna is related to its effective aperture, A_e by,

$$G = 4\pi Ae/\lambda^2$$

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

$$\lambda = c/f = 2\pi c/\omega c$$

where f is the carrier frequency in Hertz, ω_c , is the carrier frequency in radians per second, and c is the speed of light given in meters/s.

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 e/7'ective isotropic radiated power (EIRP) is defined as

$$EIRP = PtGt$$

and represents the maximum radiated power available from a transmitter in the direction of maximum antenna gain, as compared to an isotropic radiator. In practice, effective radiated power (ERP) is used instead of EIRP to denote the maximum radiated power as compared to a half-wave dipole antenna (instead of an isotropic antenna).

The path loss, which represents signal attenuation as a positive quantity measured in dB, is defined as the difference (in dB) between the effective transmitted power and the received power, and may or may not include the effect of the antenna gains. The path loss for the free space model when antenna gains are included is given by

$$PL\ (dB) = 10\log(Pt/Pr) = -10\log[PtGtGr\lambda^2/(4\pi d)^2]$$

When antenna gains are excluded, the antennas are assumed to have unity gain, and path loss is given by

$$PL\ (dB) = 10\log(Pt/Pr) = -10\log[\lambda^2/(4\pi d)^2]$$

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 far-field, or Fraunhofer region, of a transmitting antenna is defined as the region beyond the far-field distance d_f, which is related to the largest linear dimension of the transmitter antenna aperture and the carrier wavelength. The Fraunhofer distance is given by

$$\mathbf{df = 2D^2/\lambda}$$

where D is the largest physical linear dimension of the antenna. Additionally, to be in the far-field region, d_f must satisfy

$d_f >> D$

 # If a transmitter produces 50 watts of power, express the transmit power in units of (a) dBm, and (b) dBW If 50 watts is applied to a unity gain antenna with a 900 MHz carrier frequency, find the received power in dBm at a free space distance of 100 m from the antenna. What is Pr(10 km) ? Assume unity gain for the receiver antenna.

<u>The Three Basic Propagation Mechanisms:</u>

Reflection, diffraction, and scattering are the three basic propagation mechanisms which impact propagation in a mobile communication system.

Reflection occurs when a propagating electromagnetic wave impinges upon an object which has very large dimensions when compared to the wavelength of the propagating wave. Reflections occur from the surface of the earth and from buildings and walls.

Diffraction occurs when the radio path between the transmitter and receiver is obstructed by a surface that has sharp irregularities (edges). The secondary waves resulting from the obstructing surface are present throughout the space and even behind the obstacle, giving rise to a bending of waves around the obstacle, even when a line-of-sight path does not exist between transmitter and receiver. At high frequencies, diffraction, like reflection depends on the geometry of the object, as well as the amplitude, phase, and polarization of the incident wave at the point of diffraction.

Scattering occurs when the medium through which the wave travels consists of objects with dimensions that are small compared to the wavelength, and where the number of obstacles per unit volume is large. Scattered waves are produced by rough surfaces, small objects, or by other irregularities in the channel. In practice, foliage, street signs, and lamp posts induce scattering in a mobile communications system.

Reflection:

When a radio wave propagating in one medium impinges upon another medium having different electrical properties, the wave is partially reflected and partially transmitted. If the plane wave is incident on a perfect dielectric, part of the energy is transmitted into the second medium and part of the energy is reflected back into the first medium, and there is no loss of energy in absorption. If the second medium is a perfect conductor, then all incident energy is reflected back into the first medium without loss of energy. The electric field intensity of the reflected and transmitted waves may be related to the incident wave in the medium of origin through the Fresnel reflection coefficient (Γ). The reflection coefficient is a function of the material properties, and generally depends on the wave polarization, angle of incidence, and the frequency of the propagating wave.

Reflection from dielectrics:

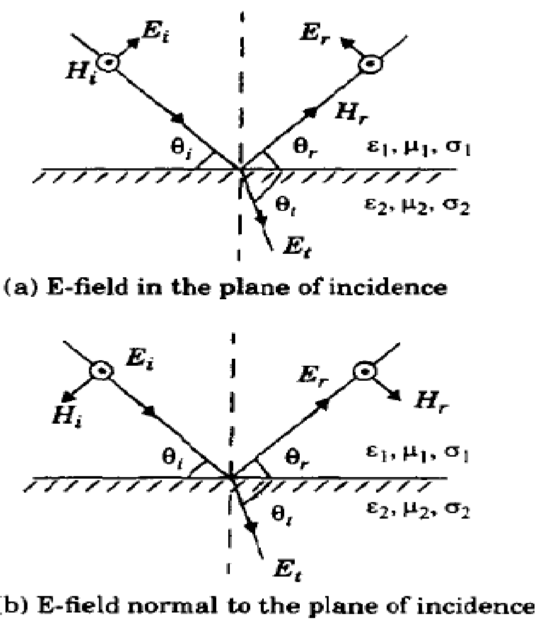


Figure 3.4
Geometry for calculating the reflection coefficients between two dielectrics.

Figure 3.4 shows an electromagnetic wave incident at an angle θ_i with the plane of the boundary between two dielectric media. As shown in the figure, part of the energy is reflected back to the first media at an angle θ_r, and part of the energy is transmitted (refracted) into the second media at an angle θ_t. The nature of reflection varies with the direction of polarization of the E-field. The behavior for arbitrary directions of polarization can be studied by considering the two distinct cases shown in Figure

The plane of incidence is defined as the plane containing the incident, reflected, and transmitted rays. In Figure 3.4a, the E—field polarization is parallel with the plane of incidence (that is, the E-field has a vertical polarization, or normal component, with respect to the reflecting surface) and in Figure 3.4b, the E-field polarization is perpendicular to the plane of incidence (that is, the incident E-field is pointing out of the page towards the reader, and is perpendicular to the page and parallel to the reflecting surface).

Because of superposition, only two orthogonal polarizations need be considered to solve general reflection problems. The reflection coefficients for the two cases of parallel and perpendicular E-field polarization at the boundary of two dielectrics are given by

$$\Gamma_{\parallel} = \frac{E_r}{E_i} = \frac{\eta_2 \sin\theta_t - \eta_1 \sin\theta_i}{\eta_2 \sin\theta_t + \eta_1 \sin\theta_i} \quad \text{(E-field in plane of incidence)}$$

$$\Gamma_{\perp} = \frac{E_r}{E_i} = \frac{\eta_2 \sin\theta_i - \eta_1 \sin\theta_t}{\eta_2 \sin\theta_i + \eta_1 \sin\theta_t} \quad \text{(E-field not in plane of incidence)}$$

Where η is the intrinsic impedance of the respective medium.

Or,

$$\Gamma_{\parallel} = \frac{-\varepsilon_r \sin\theta_i + \sqrt{\varepsilon_r - \cos^2\theta_i}}{\varepsilon_r \sin\theta_i + \sqrt{\varepsilon_r - \cos^2\theta_i}}$$

$$\Gamma_{\perp} = \frac{\sin\theta_i - \sqrt{\varepsilon_r - \cos^2\theta_i}}{\sin\theta_i + \sqrt{\varepsilon_r - \cos^2\theta_i}}$$

Where ε is the permittivity of the respective medium.

Brewster Angle:

The Brewster angle is the angle at which no reflection occurs in the medium of origin. It occurs when the incident angle BB is such that the reflection coefficient $\Gamma_{||}$ is equal to zero (see Figure 3.6), The Brewster angle is given by the value of θ_B which satisfies

$\text{Sin}(\theta_B) = \sqrt{(\varepsilon_1)}/\sqrt{(\varepsilon_1+\varepsilon_2)}$

For the case when the first medium is free space and the second medium has a relative permittivity ε_r, above equation can be expressed as

$\text{Sin}(\theta_B) = \sqrt{(\varepsilon_r-1)}/\sqrt{(\varepsilon_r^2-1)}$

Note that the Brewster angle occurs only for vertical (i.e. parallel) polarization.

 # Calculate the Brewster angle for a wave impinging on ground having a permittivity of $\varepsilon_r = 4$.

Reflection from Perfect Conductors:

Since electromagnetic energy cannot pass through a perfect conductor a plane wave incident on a conductor has all of its energy reflected. As the electric field at the surface of the conductor must be equal to zero at all times in order to obey Maxwel1's equations, the reflected wave must be equal in magnitude to the incident wave. For the case when E-field polarization is in the plane of incidence, the boundary conditions require that

$\theta_i = \theta_r$

and $E_i = E_r$ (E-field in plane of incidence)

Similarly, for the case when the E-field is horizontally polarized, the boundary conditions require that

$\theta_i = \theta_r$

and $E_i = -E_r$ (E-field not in plane of incidence)

Ground Reflection (2-ray) Model:

In a mobile radio channel, a single direct path between the base station and a mobile is seldom the only physical means for propagation, and hence the free space propagation model is in most cases inaccurate when used alone. The 2-ray ground reflection model shown in Figure 3.7 is a useful propagation model that is based on geometric optics, and considers both the direct path and a ground reflected propagation path between transmitter and receiver. This model has been found to be reasonably accurate for predicting the large-scale signal strength over distances of several kilometers for mobile radio systems that use tall towers (heights which exceed 50 m), as well as for line of-sight, microcell channels in urban environments.

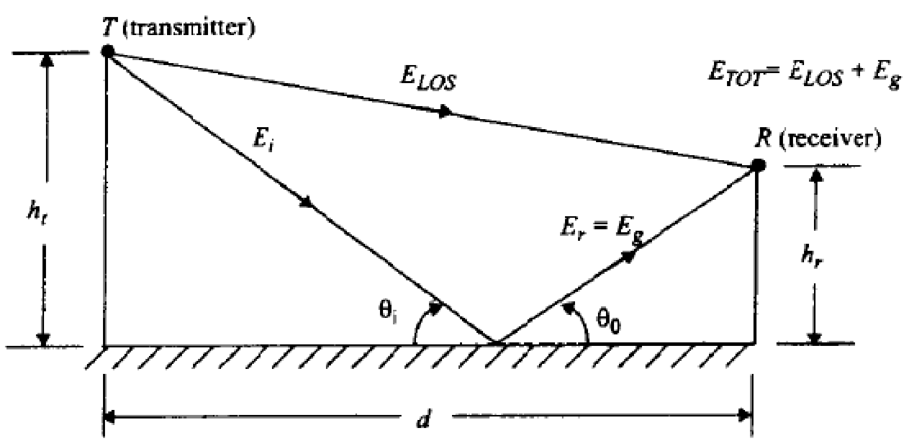


Figure 3.7
Two-ray ground reflection model.

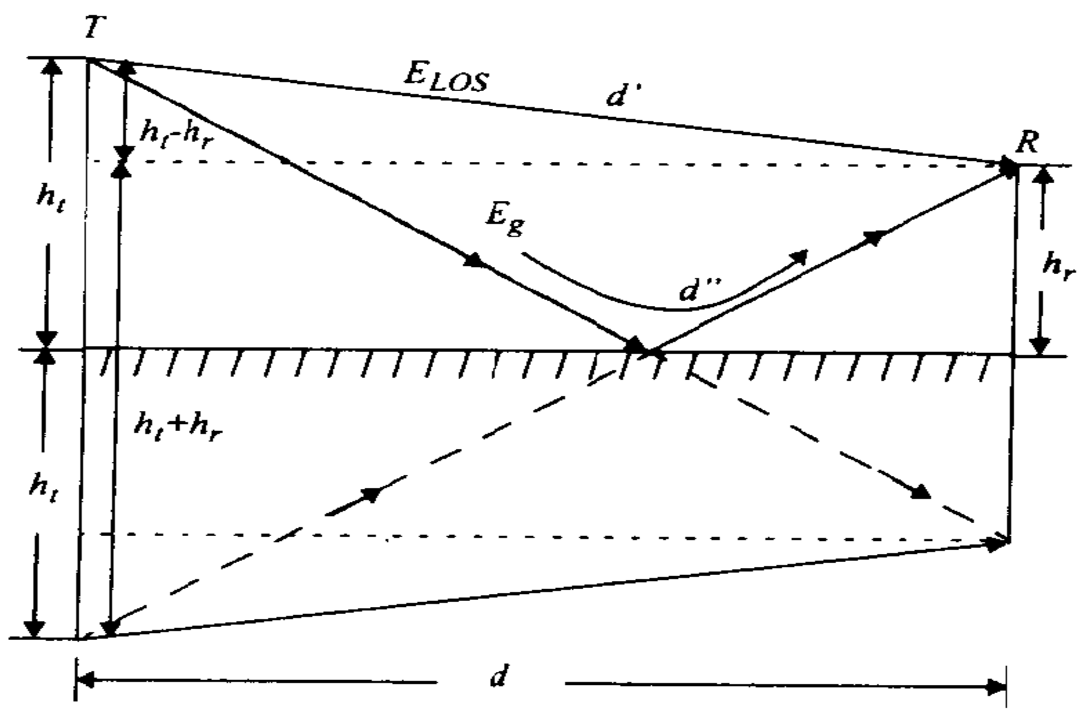
Referring to Figure 3.7, ht is the height of the transmitter and hr is the height of the receiver. If Eo is the free space E-field (in units of V/m) at a reference distance do from the transmitter, then for d > do , the free space propagating E—field is given by

$$E(d,t) = \frac{E_0 d_0}{d}\cos\left(\omega_c\left(t - \frac{d}{c}\right)\right) \qquad (d > d_0)$$

Two propagating waves arrive at the receiver: the direct wave that travels a distance d'; and the reflected wave that travels a distance d".

The electric field E_{TOT}(d, t) can be expressed as the sum of equations for distances d' and d" (i.e. direct wave and reflected wave.

$$E_{TOT}(d,t) = \frac{E_0 d_0}{d'}\cos\left(\omega_c\left(t - \frac{d'}{c}\right)\right) + (-1)\frac{E_0 d_0}{d''}\cos\left(\omega_c\left(t - \frac{d''}{c}\right)\right)$$



- The received signal is effected by the path difference delta
- Given by

$$\Delta = d'' - d' = \sqrt{(h_t + h_r)^2 + d^2} - \sqrt{(h_t - h_r)^2 + d^2}$$

- **<u>The received power can be depend upon the path difference given by</u>**

$$P_r = P_t G_t G_r \frac{h_t^2 h_r^2}{d^4}$$

Diffraction:

Diffraction allows radio signals to propagate around the curved surface of the earth, beyond the horizon, and to propagate behind obstructions. Although the received field strength decreases rapidly as a receiver moves deeper into the obstructed (shadowed) region, the diffraction field still exists and often has sufficient strength to produce a useful signal.

The phenomenon of diffraction can be explained by Huygen`s principle, which states that all points on a wavefront can be considered as point sources for the production of secondary wavelets, and that these wavelets combine to produce a new wavefront in the direction of` propagation. Diffraction is caused by the propagation of secondary wavelets into a shadowed region. The field strength of a diffracted wave in the shadowed region is the vector sum of the electric field components of all the secondary wavelets in the space around the obstacle.

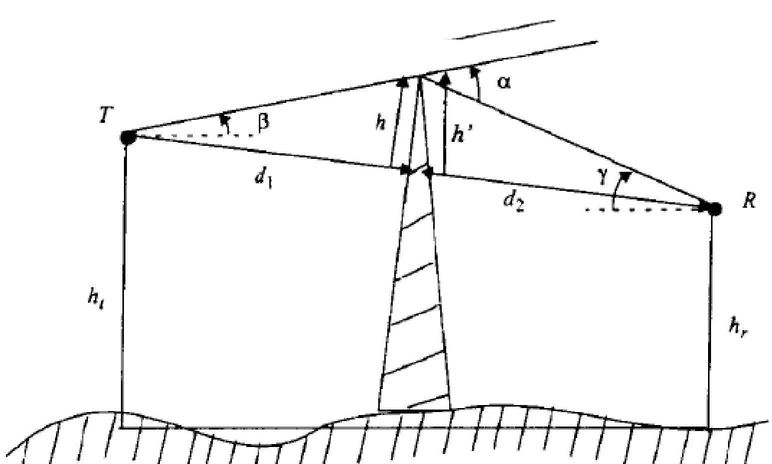
Fresnel Zone Geometry:

Consider a transmitter and receiver separated in free space as shown in Figure 3.10a. Let an obstructing screen of effective height h with infinite width (going into and out of the paper,) be placed between them at a distance d_1 from the transmitter and d_2 from the receiver. It is apparent that the wave propagating from the transmitter to the receiver via the top of the screen travels a longer distance than if a direct line-of-sight path (through the screen) existed. Assuming $h << d_1, d_2$ and $h >> \lambda$, then the difference between the direct path and the diffracted path, called the excess path length (Δ) , can be obtained from the geometry of Figure 3.10b as

$$\Delta \approx \frac{h^2}{2} \frac{(d_1 + d_2)}{d_1 d_2}$$

The corresponding phase difference is given by

$$\phi = \frac{2\pi\Delta}{\lambda} \approx \frac{2\pi}{\lambda} \frac{h^2}{2} \frac{(d_1 + d_2)}{d_1 d_2}$$



(b) Knife-edge diffraction geometry when the transmitter and receiver are not at the same height. Note that if α and β are small and $h << d_1$ and d_2, then h and h' are virtually identical and the geometry may be redrawn as shown in Figure 3.10c.

Knife-edge Diffraction Model:

Estimating the signal attenuation caused by diffraction of radio waves over hills and buildings is essential in predicting the field strength in a given service area. Generally, it is impossible to make very precise estimates of the diffraction losses, and in practice prediction is a process of theoretical approximation modified by necessary empirical corrections. Though the calculation of diffraction losses over complex and irregular terrain is a mathematically difficult problem, expressions for diffraction losses for many simple cases have been derived. As a starting point, the limiting case of propagation over a knife-edge gives good insight into the order of magnitude of diffraction loss.

When shadowing is caused by a single object such as a hill or mountain, the attenuation caused by diffraction can be estimated by treating the obstruction as a diffracting knife edge. This is the simplest of diffraction models, and the diffraction loss in this case can be readily estimated using the classical Fresnel solution for the field behind a knife edge (also called a half-plane).

Multiple Knife-edge Diffraction:

In many practical situations, especially in hilly terrain, the propagation path may consist of more than one obstruction, in which case the total diffraction loss due to all of the obstacles must be computed. Bullington suggested that the series of obstacles be replaced by a single equivalent obstacle so that the path loss can be obtained using single knife-edge diffraction models. This method, illustrated in Figure 3.15, oversimplifies the calculations and often provides very optimistic estimates of the received signal strength. In a more rigorous treatment, Millington et. al. gave a wave-theory solution for the field behind two knife edges in series. This solution is very useful and can be applied easily for predicting diffraction losses due to two knife edges. However, extending this to more than two knife edges becomes a formidable mathematical problem. Many models that are mathematically less complicated have been developed to estimate the diffraction losses due to multiple obstructions.

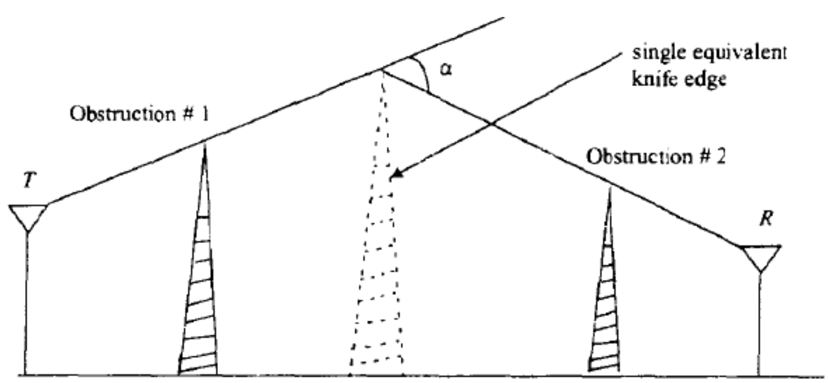


Figure 3.15
Bullington's construction of an equivalent knife edge [From [Bul47] © IEEE].

__Scattering:__

The actual received signal in a mobile radio environment is often stronger than what is predicted by reflection and diffraction models alone. This is because when a radio wave impinges on a rough surface, the reflected energy is

spread out (diffused) in all directions due to scattering. Objects such as lamp posts and trees tend to scatter energy in all directions, thereby providing additional radio energy at a receiver. Flat surfaces that have much larger dimension than a wavelength may be modeled as reflective surfaces. However, the roughness of such surfaces often induces propagation effects different from the specular reflection described earlier in this chapter. Surface roughness is often tested using the Rayleigh criterion which defines a critical height (hc) of surface protuberances for a given angle of incidence i.e. givenby $hc = \lambda/(8\sin\theta_i)$

A surface is considered smooth if its minimum to maximum protuberance h is less than hc, and is considered rough if the protuberance is greater than hc. For rough surfaces, the flat surface reflection coefficient needs to be multiplied by a scattering loss factor, ρs, to account for the diminished reflected field.

Link Budget Design Using Path Loss Models:

- **A calculation of signal powers, noise powers, and/or signal-to-noise ratios for a complete communication link is called link budget.**
- **It is a useful approach to the basic design of a complete communication system.**
  - **The performance of any communication link depends on the quality of the equipment being used.**
  - ***Link budget* is a way of quantifying the link performance.**
  - **The received power in a link is determined by three factors: *transmit power*, *transmitting antenna gain*, and *receiving antenna gain*.**
  - **If that power, minus the *free space loss* of the link path, is greater than the *minimum received signal level* of the receiving radio, then a link is possible.**
  - **The difference between the minimum received signal level and the actual received power is called the *link margin*.**

Practical path loss estimation techniques are given below:

1. Log-distance Path Loss Model

2. Log normal Shadowing

Log-distance Path Loss Model:

- **Both theoretical and measurement based propagation models indicate that average received signal power decreases logarithmically with distance.**
- **The average large-scale path loss for an arbitrary T-R separation is expressed as a function of distance by using path loss exponent, *n***

$$PL(d) \propto \left(\frac{d}{d_0}\right)^n$$

or

$$\overline{PL}(\text{dB}) = \overline{PL}(d_0) + 10n\log\left(\frac{d}{d_0}\right)$$

Where *n* is the path loss exponent which indicates the rate at which the path loss increases with distance.

d_0 **Is the reference distance which is determined from measurements close to the transmitter.**

d **is the T-R separation distance**

The bars in the above equations denote the ensemble average of all possible path loss values for a given value of *d.*

- **The Path Loss exponents for different environments is shown below**

Environment	Path Loss Exponent, n
Free space	2
Urban area cellular radio	2.7 to 3.5
Shadowed urban cellular radio	3 to 5
In building line-of-sight	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factories	2 to 3

- **Log-normal Shadowing:**
- **Log-normal Shadowing implies that the measured signal levels at a specific T-R separation have a normal (Gaussian) distribution about the distance.**

Measurements have shown that at any value of 'd' the path loss PL(*d*) at a particular location is random and distributed log-normally(normal in dB) about the mean distance.

$$PL(d)[dB] = \overline{PL}(d) + X_\sigma = \overline{PL}(d_0) + 10n\log\left(\frac{d}{d_0}\right) + X_\sigma$$

where X_σ is a zero-mean Gaussian distributed random variable (in dB) with standard deviation σ (also in dB).

Thus the close in reference distance *do*, the path loss exponent *n* and standard deviation *σ* statistically describe the path loss model for an arbitrary location having specific T-R separation distance.

Outdoor propagation model:

Longley-Rice Model:

The Longley-Rice model is applicable to point-to-point communication systems in the frequency range from 40 MHz to 100 GHz, over different kinds of terrain. The median transmission loss is predicted using the path geometry of the terrain profile and the refractivity of the troposphere. Geometric optics techniques (primarily the 2-ray ground reflection model) are used to predict signal strengths within the radio horizon. Diffraction losses over isolated obstacles are estimated using the Fresnel-Kirchoff knife-edge models. Forward scatter theory is used to make troposcatter predictions over long distances.

The Longley-Rice method operates in two modes. When a detailed terrain path profile is available, the path-specific parameters can be easily determined and the prediction is called a point-to-point mode prediction. On the other hand, if the terrain path profile is not available, the Longley-Rice method provides techniques to estimate the path-specific parameters, and such a prediction is called an area mode prediction.

Okumura Model:

Okumura`s model is one of the most widely used models for signal prediction in urban areas. This model is applicable for frequencies in the range 150 MHz to 1920 MHz (although it is typically extrapolated up to 3000 MHz) and distances of 1 km to 100 km. It can be used for base station antenna heights ranging from 30 m to 1000 m. Okumura developed a set of curves giving the median attenuation relative to free space (Amu), in an urban area over a quasi-smooth terrain with a base station effective antenna height (h_{te}) of 200 m and a mobile antenna height (h_{re}) of 3 m. These curves were developed from extensive measurements using vertical omni-directional antennas at both the base and mobile, and are plotted as a function of frequency in the range 100 MHz to 1920 MHz and as a function of distance from the base station in the range 1 km to 100 km. To determine path loss using Okumura`s model, the free space path loss between the points of interest is first determined, and then the value of $A_{mu}(f, d)$ (as read from the curves) is added to it along with correction factors to account for the type of terrain. The model can be expressed as

$$L_{50}(dB) = L_F + A_{mu}(f, d) - G(_{te}) - G(_{re}) - G_{AREA}$$

where L50 is the 50th percentile (i.e., median) value of propagation path loss, L_F is the free space propagation loss, A_{mu} is the median attenuation relative to free space, $G(h_{te})$ is the base station antenna height gain factor, $G(h_{re})$ is the mobile antenna height gain factor, and G_{AREA} is the gain due to the type of environment. Note that the antenna height gains are strictly a function of height and have nothing to do with antenna patterns.

$$G(h_{te}) = 20\log\left(\frac{h_{te}}{200}\right) \qquad 1000\text{ m} > h_{te} > 30\text{ m}$$

$$G(h_{re}) = 10\log\left(\frac{h_{re}}{3}\right) \qquad h_{re} \le 3\text{ m}$$

$$G(h_{re}) = 20\log\left(\frac{h_{re}}{3}\right) \qquad 10\text{ m} > h_{re} > 3\text{ m}$$

Hata Model:

The Hata model [Hat90] is an empirical formulation of the graphical path loss data provided by Okumura, and is valid from 150 MHz to 1500 MHz. Hata presented the urban area propagation loss as a standard formula and supplied correction equations for application to other situations. The standard formula for median path loss in urban areas is given by

$L_{50}(urban)(dB) = 69.55 + 26.16\log f_c - 13.82\log h_{te} - a(h_{re}) + (44.9 - 6.55\log h_{te})\log d$

where fc is the frequency (in MHz) from 150 MHz to 1500 MHz, h_{te} is the effective transmitter (base station) antenna height (in meters) ranging from 30 m to 200 m, h_{re} is the effective receiver (mobile) antenna height (in meters) ranging from 1 m to 10 m, d is the T-R separation distance (in km), and $a(h_{re})$ is the correction factor for effective mobile antenna height which is a function of the size of the coverage area. For a small to medium sized city, the mobile antenna correction factor is given by

$a(h_{re}) = (1.11ogf_c - 0.7)h_{re} - (1.56\log f_c - 0.8)$ dB

and for a large city, it is given by

$a(h_{re}) = 8.29(\log 1.54h_{re})^2 - 1.1$ dB for $f_c <= 300$ MHz

$a(h_{re}) = 3.2(\log 11.75h_{re})2 — 4.97$ dB for $f_c >= 300$ MHz

To obtain the path loss in a suburban area the standard Hata formula in equations are modified as

$L_{50}(dB) = L_{50}(urban) - 2[\log(f_c/28)]^2 - 5.4$

and for path loss in open rural areas, the formula is modified as

$L_{50}(dB) = L_{50}(urban) – 4.78(\log f_c)^2 + 18.33\log f_c - 40.94$

Indoor Propagation Models:

With the advent of Personal Communication Systems (PCS), there is a great deal of interest in characterizing radio propagation inside buildings. The indoor radio channel differs from the traditional mobile radio channel in two aspects - the distances covered are much smaller, and the variability of the environment is much greater for a much smaller range of T-R separation distances. It has been observed that propagation within buildings is strongly influenced by specific features such as the layout of the building, the construction materials, and the building type. This section outlines models for path loss within buildings.

Indoor radio propagation is dominated by the same mechanisms as outdoor: reflection, diffraction, and scattering. However, conditions are much more variable. For example, signal levels vary greatly depending on whether interior doors are open or closed inside a building. Where antennas are mounted also impacts large-scale propagation. Antennas mounted at desk level in a partitioned office receive vastly different signals than those mounted on the ceiling. Also, the smaller propagation distances make it more difficult to insure far-field radiation for all receiver locations and types of antennas.

Partition Losses (same floor):

Buildings have a wide variety of partitions and obstacles which form the internal and external structure. Houses typically use a wood frame partition with plaster board to form internal walls and have wood or non-reinforced concrete between floors. Office buildings, on the other hand, often have large open areas (open plan) which are constructed by using moveable office partitions so that the space may be reconfigured easily, and use metal reinforced concrete between floors. Partitions that are formed as part of the building structure are called hard partitions, and partitions that may be moved and which do not span to the ceiling are called soft partitions. Partitions vary widely in their physical and electrical characteristics, making it difficult to apply general models to specific indoor installations.

Partition Losses between Floors:

The losses between floors of a building are determined by the external dimensions and materials of the building, as well as the type of construction used to create the floors and the external surroundings. Even the number of windows in a building and the presence of tinting (which attenuates radio energy) can impact the loss between floors. It can be seen that for all three buildings, the attenuation between one floors of the building is greater than the incremental attenuation caused by each additional floor. After about five or six floor separations, very little additional path loss is experienced.

$$\Delta L = L_{c,d} - L_{c,u} = [P_{BS\text{-}tx} - A_c - L_{BS\text{-}fi} + G_{BS}]$$

$$- \quad [P_{MS\text{-}rx} + L_{MS\text{-}f} - G_{MS} + L_{dpx\text{-}rx}]$$

$$- \quad [P_{MS\text{-}tx} - L_{dpx\text{-}tx} - L_{MS\text{-}f} + G_{MS}]$$

$$+ \quad [P_{BS\text{-}rx} + L_{BS\text{-}fi} - G_{BS} - G_{div}]$$

$$= P_{BS\text{-}tx} - A_c - P_{MS\text{-}rx} - P_{MS\text{-}tx} + P_{BS\text{-}rx} - G_{div}$$

$$= 40 - 3 + 102 - 30 - 104 - 7 = -2 \text{ dB}$$

The uplink direction is thus 2 dB better. This difference can be neglected in practical network design.

For the car mounted telephone the power unbalance is:

FORMULA

$$\Delta L = P_{BS\text{-}tx} - A_c - P_{MS\text{-}rx} - P_{MS\text{-}tx} + P_{BS\text{-}rx} - G_{div}$$

$$= 40 - 3 + 104 - 37 - 7 - 104 = -7 \text{ dB}$$

The uplink direction is now 7 dB better. From the operator’s point of view it would be better if the power unbalance were in favor of the downlink. This would guarantee better network control. However the real time power control used in GSM can easily rectify situation and produce almost perfect power balance.