Subject Name: **Cellular Mobile Communication**

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EC-6001 Cellular mobile communication
Unit-II

Cell coverage for signal and traffic General introduction, mobile point -to-point model, propagation over water or flat open area, foliage loss, propagation in near - in distance, long distance propagation, path loss from point-to-point prediction model, cell site antenna heights and signal coverage cells, mobile -to-mobile propagation.

Cell site antennas and mobile antennas Equivalent circuits of antennas, gain and pattern relationship, sum and difference patterns, antennas at cell site, unique situations of cell site antennas, mobile antennas

2.1 INTRODUCTION:

Cell coverage is can be describe on basis of traffic coverage or signal coverage. The main goal of cell coverage is to cover the whole area but practically it is not possible due the earth surface. The service area/ coverage area of cellular system is one of the following environments:

1. Human-made structures	2. Natural terrains
• In a building area • In an open area • In a suburban area • In an urban area	• Over flat terrain • Over hilly terrain • Over water

In the prediction of the cell coverage, the above-mentioned environments are taken into consideration and on the basis of the environments, prediction models are prepared. The results of the prediction model will differ to each other depending on which service area is used.

2.2 MOBILE POINT-TO-POINT MODEL

The mobile point-to-point model can be obtained in three steps as follows

- Generate a standard condition.
- Obtain an Area-to-Area prediction model.
- Obtain a mobile Point-to-Point model using Area-to-Area prediction model.

The purpose of developing this model is to know the effect of following two cases on received signal strength.

A. Natural terrain contour.
B. Human made structures.

2.2.1 Standard Condition:

To generate the standard condition, we use the predefine values with some correction factors for transmitted power and antenna height at base station and mobile unit. The predefined values are listed in the table are used to obtain the direct values which is helpful in later prediction.

Standard Condition	**Correction Factors**
At the Base Station	
Transmitted power $P_t = 10 \ W (40 \ dBm)$	$\alpha_1 = 10 \ \log \frac{P'_t}{10}$
Antenna height $h_1 = 100 \ ft (30 \ m)$	$\alpha_2 = 20 \ \log \frac{h'_1}{h_1}$
Antenna gaint $g_t = 6 \ dB/dipole$	$\alpha_3 = g'_{r2}$
At the Mobile Unit	
Antenna height $h_2 = 10 \ ft (3 \ m)$	$\alpha_2 = 10 \ \log \frac{h'_2}{h_2}$
Antenna gaint $g_m = 0 \ dB/dipole$	$\alpha_3 = g'_m$

2.2.2 Obtain Area-to-Area Predication Curves for Human Made Structures:

Area to area prediction model is different for different area. It is an averaging process hence all areas are considered as flat even the data may be received from non flat area.

- Effect of the human made structures:

The terrain configuration or structure of each city is different, and the human made structures of the each city is unique. The path loss curve obtained on virtually flat ground indicates the effects of the signal loss due to solely human made structures.

The area-to-area prediction curve is obtained by the mean value of measured data and it is used for further prediction in that particular area. The area-to-area prediction model can be used as a first step towards achieving the point-to-point prediction model.

- The Phase Difference between a Direct Path and a Ground-Reflected Path:

A simple model is considered where a mobile is at a distance of d from the transmitting antenna as shown in figure 2.1.

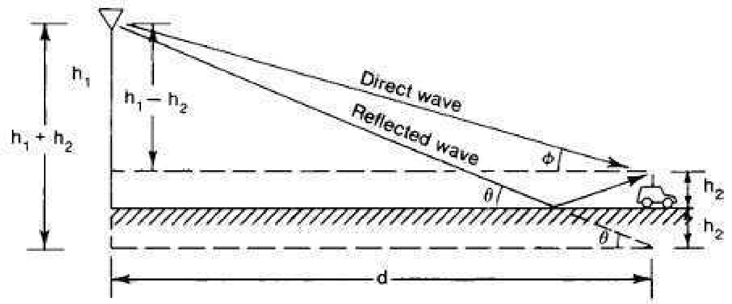

Figure 2.1 A simple model.

Based on a direct path and a ground-reflected path as shown in figure 2.1, where a direct path is a line-of-sight (LOS) path with its received power

$$P_{LOS} = P_0(\frac{1}{4\pi d/\lambda})^2 \qquad \text{.................. 2.1}$$

A ground-reflected path with its reflection coefficient and phase changed after reflection, the received power by mobile station is given by

$$P_r = P_0(\frac{1}{4\pi d/\lambda})^2|1 + a_v e^{j\Delta\emptyset}|^2 \qquad \text{.................. 2.2}$$

Where P_0 is transmitted power, a_v is reflection coefficient, λ is wavelength, d is distance between base station and mobile station and ΔΦ is phase difference between direct and ground reflected path.

In a mobile environment $a_v = -1$ because of the small incident angle of the ground wave caused by a relatively low cell-site antenna height. By putting the value in equation 2.2 we have

$$P_r = P_0(\frac{1}{4\pi d/\lambda})^2|1 - \cos\Delta\emptyset - j\sin\Delta\emptyset|^2 \qquad \text{.................. 2.2}$$

$$= P_0 \frac{2}{\left(\frac{4\pi d}{\lambda}\right)^2}|1 - \cos\Delta\emptyset|$$

$$= P_0 \frac{4}{\left(\frac{4\pi d}{\lambda}\right)^2}\sin^2\frac{\Delta\emptyset}{2} \qquad \text{.................. 2.3}$$

Where ΔΦ is the phase difference

$$\Delta\emptyset = \frac{2\pi f \Delta d}{c}$$

Where $\Delta d = d_1 - d_2$

By the figure 2.1

$$d_1 = \sqrt{(h_1 + h_2)^2 + d^2}$$
$$d_2 = \sqrt{(h_1 - h_2)^2 + d^2}$$

Here the value of Δd is much smaller then

$$\Delta\emptyset \approx \frac{2\pi}{\lambda}\frac{2h_1h_2}{d}$$

Where h_1 and h_2 are transmitter antenna height and receiver antenna height respectively.

2.3 PROPAGATION OVER WATER OR FLAT OPEN AREA

The mobile signal propagation over water or flat open area has to be given proper design setups because probability of occurrence of inference is high we do not make the correct arrangements. The permittivity ε_r of seawater and fresh water are the same, but the conductivities are different.

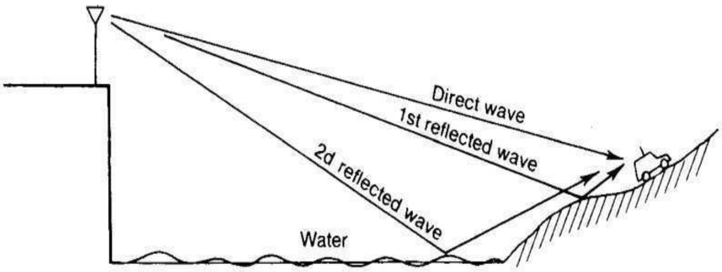

Figure 2.2 A model for propagation over water.

The wavelength λ is 0.35 m at frequency 850 MHz. The reflection coefficient is -1 because there is 180° phase shift occurs at ground reflection point.

- Between Fixed Stations

The point-to-point transmission between the fixed stations over the water or flat open land can be estimated. The received power P_r can be expressed as

$$P_r = P_t(\frac{1}{4\pi d/\lambda})^2\left|1 + a_v e^{j\emptyset_v} e^{j\Delta\emptyset}\right|^2 \qquad \text{………………. 2.2}$$

Where P_t = the transmitted power
d = distance between two stations
λ = wavelength
a_v = amplitude of a complex reflection coefficient
ϕ_v = phase of a complex reflection coefficient

2.4 FOLIAGE LOSS

Foliage loss includes the sizes of leaves, branches, trunks, distribution of leaves,the density , branches and the height of the trees relative to the antenna heights all be considered.

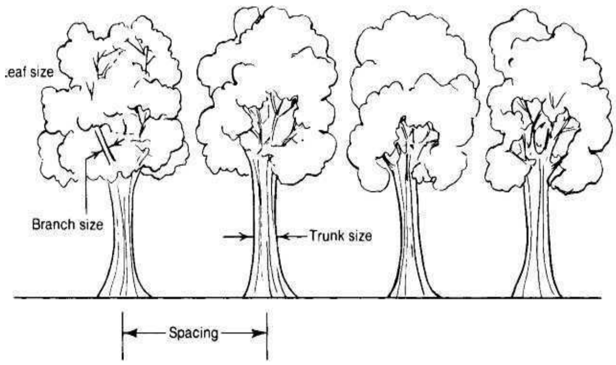

Figure 2.3 A characteristic of foliage environment.

Figure 2.3 shows this problem. There are three levels: trunks, branches, and leaves. In each level, there is

a distribution of sizes of trunks, branches, and leaves and also of the spacing and density between adjacent trunks, branches, and leaves.
For a system design, the estimate of the signal reception due to foliage loss does not need accuracy. Some trees, such as maple or oak, lose their leaves in winter, while others, such as pine, never do. For example, in Atlanta, Georgia, there are oak, maple, and pine trees. In summer the foliage is very heavy, but in winter the leaves of the oak and maple trees fall and the pine leaves stay.
Sometime the foliage loss can be measured as a wire-line loss, in decibels per foot or decibels per meter, when the foliage is uniformly heavy and the path lengths are short. When the path length is long and the foliage is non-uniform, then decibels per octaves or decibels per decade are used. In general, foliage loss occurs with respect to the frequency to the fourth power ($\sim f^{-4}$).

2.5 PROPAGATION IN NEAR- IN DISTANCE

We use 1-mile intercept for analysis of propagation in near in distance. A high gain omni-directional antenna has narrow beam-width in the vertical plane within the radius of 1 mile. Thus the signal reception at a mobile unit less than 1 mile away will be reduced because of the large elevation angle which causes the mobile unit to be in the shadow region i.e. outside the main beam. The larger the elevation angle, the weaker the reception level due to the antenna's vertical pattern, as shown in figure. 2.4.

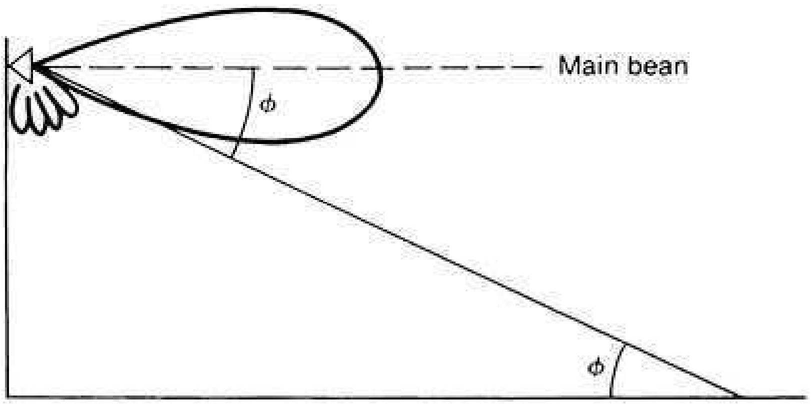

Figure 2.4 Elevation angle of the shadow of the antenna pattern.

Generally propagation at the far distance for coverage purposes is considered but propagation in near in distance should be consider for proper planning of cell coverage. We consider suburban area for the near-in distance propagation. The signal received level is −61.7 dBm for a suburban area at the 1-mi intercept based on the reference set of parameters like the antenna height is 30 m (100 ft). If the antenna height increases to 60 m (200 ft), a 6-dB gain is obtained. An increase from 60 to 120 m (20 to 400-ft), another 6 dB is obtained. At the 120-m (400-ft) antenna height, the mobile received signal is the same as that received at the free space.

2.6 LONG-DISTANCE PROPAGATION

In cellular mobile communication for short and long distance propagation having some advantages and disadvantages. The advantage of a high cell site is that it covers a large area in case of a noise-limited system where usually different frequencies are repeatedly used in different areas. A noise-limited system gradually becomes an interference-limited system as the traffic density increases. The interference is due to not only the existence of many co-channels and adjacent channels in the system, but the long-distance propagation also affects the interference.

2.7 PATH LOSS FROM A POINT-TO-POINT PREDICTION MODEL:

The area to area prediction model will provide accuracy only within the standard deviation of 8 dB value and it has larger uncertainty. The uncertainty is overcome in point to point model. Point to point model provide the detail of trainer counters for prediction of the path loss.
In the point to point method the predicted values were placed at x axis and actual measured values at y

axis. A line of 45 degree as shown in figure 2.5 is drawn between these two values and this 45-degree line is the errorless prediction line.

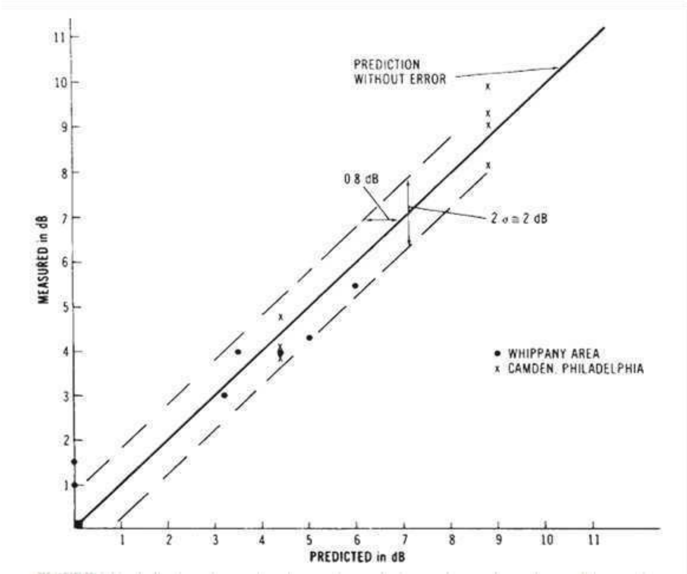

Figure 2.5 Indication of errors in point-to-point predictions

The point-to-point model is useful in designing a mobile cellular system with a radius for each cell of 10 mi or less. This point-to-point prediction can be used to avoid co-channel interference and provide overall coverage of all cell sites. Moreover, the occurrence of handoff in the cellular system can be predicted more accurately. This model is a basic tool that is used to generate a signal coverage map, an interference area map, a handoff occurrence map, or an optimum system design configuration, to name a few applications.

2.8 CELL-SITE ANTENNA HEIGHTS

Effects of Cell-Site Antenna Heights

Several points need to be considered while examining the effect of antenna height as follows.

1. Antenna height unchanged- If the transmitted power increases by 3 dB, just add 3 dB to each grid in the signal-strength map. The relative differences in power among the grids remain the same.
2. Antenna height changed- If the antenna height changes (±Δh), then the whole signal-strength map obtained from the old antenna height cannot be updated. The additional gain (increase or decrease) will be added to the signal-strength grid based on the old antenna height.
3. Location of the antenna changed- If the location of the antenna changes, the point-to-point program has to start all over again. The old point-to-point terrain contour data are no longer useful. The old effective antenna height seen from a distance will be different when the location of the antenna changes, and there is no relation between the old effective antenna height and the new effective antenna height. Therefore, every time the antenna location changes, the new point-to-point prediction calculation starts again.
4. Visualization of the effective antenna height- The effective antenna height changes when the location of the mobile unit changes. Therefore, we can visualize the effective antenna height as always changing up or down while the mobile unit is moving.

2.9 GAIN AND PATTERN RELATIONSHIP

Antenna Gain: Antenna gain is defined as the ration of the radiation intensity in a given direction to the radiation intensity by reference antenna. Antenna gain is a measure of directional capability and efficiency of antenna.

$$\text{Antenna Gain} = \frac{4\pi.\text{Maximum radiated intensity}}{\text{Total power radiated}}$$

Sum and Difference Pattern: If the field strength of any area and the antenna pattern is known then radio coverage can be obtained. The sum synthesis and difference synthesis methods can be used for

generating desired antenna configuration. The antenna main beam is known as sum pattern that point to an angle θ whereas the difference pattern produce two main beams.
Consider 2N elements available in antenna array and they are separated with distance d. The general formula for sum and difference pattern is given by

$$A(\theta) = \sum_{n=1}^{N} I_n \ exp\left[j\frac{2n-1}{2} \ \beta d(\cos\theta - \cos\theta_0\right] + \ I_{-n} \ exp\left[-j\frac{2n-1}{2} \ \beta d(\cos\theta - \cos\theta_0\right]$$

Where $\beta = \text{wave number} = \frac{2\pi}{\lambda}$

I_n = Normalized current distributions

N= total number of elements

For the sum pattern all the current amplitudes are same hence

$$I_n = I_{-n}$$

For the difference pattern, the current amplitudes of one side i.e. half of the total elements are positive and the current amplitudes of the other side are negative

$$I_n = -I_{-n}$$

2.10 ANTENNAS AT CELL SITE

For Coverage Use:

The Omni-directional antennas have the characteristics of radiating uniformly in all directions. There are standard 6-dB and 9-dB gain Omni-directional antennas. The antenna patterns for 6-dB gain and 9-dB gain are used for coverage.

Start-Up System Configuration. In a start-up system, an Omni-cell is used. In which all the transmitting antennas are Omni-directional. Each transmitting antenna can transmit signals from N radio transmitters simultaneously using an N-channel combiner or a broadband linear amplifier. Each cell normally can have three transmitting antennas and two receiving antennas which serve 3N voice radio transmitters simultaneously.

Abnormal Antenna Configuration: When the call traffic in each cell increases as the number of customers increases. Some cells required a greater number of radios to handle the increasing traffic. An Omni-cell site can be equipped with up to 90 voice radios for advanced mobile phone service (AMPS) systems. In such cases six transmitting antennas should be used

For Interference Reduction Use:

When the frequency reuse scheme is used in AMPS, co-channel interference will occurs. The co-channel interference reduction factor q = D/R = 4.6 is based on the assumption that the terrain is flat. Because actual terrain is rarely flat, we must either increase q or use directional antennas. To reduce the inference we use directional antennas

Umbrella-Pattern Antennas:

In certain situations umbrella-pattern antennas should be used when the mobile traffic in busy hours are more for the cell-site antennas.

There are many types of umbrella pattern antennas available as follows

1. Normal Umbrella-Pattern Antenna:
2. Broadband Umbrella-Pattern Antenna
3. High-Gain Broadband Umbrella-Pattern Antenna.

2.11 MOBILE ANTENNAS

The requirement of a mobile antenna is always in mobile communication. An Omni-directional antenna can be located as high as possible from the point of reception. Due to the physical limitation of antenna height on the vehicle limit this requirement. Generally, the antenna should at least clear the top of the vehicle.

- **Roof-Mounted Antenna:**

The antenna pattern of a roof-mounted antenna is more or less uniformly distributed around the mobile unit when measured at an antenna range in free space. The 3-dB high-gain antenna shows a 3-dB gain over the quarter-wave antenna. However, the gain of the antenna used at the mobile unit must be limited to 3 dB because the cell-site antenna is rarely as high as the broadcasting antenna and out-of-sight conditions often prevail. The mobile antenna with a gain of more than 3 dB can receive only a limited portion of the total multipath signal in the elevation as measured under the out-of-sight condition.

- **Glass-Mounted Antennas**

Many kinds of glass-mounted antennas are available. Energy is coupled through the glass in glass mount antennas hence there is no need to drill a hole. But some energy is dissipated on passage through the glass. The gain of antenna depends on the operating frequency which range is 1 to 3 dB . The position of the glass-mounted antenna is always lower than that of the roof-mounted antenna.

