# Unit - IV

## Cell Coverage for Signal and Traffic

### Introduction

→ Cell Coverage can be based on Signal Coverage & on Traffic Coverage. The task is to cover the whole area with a minimum no. of Cell sites but 100% Cell Coverage of an area is not possible, the cell sites ~~must~~ ~~be~~ Coverage must have some holes are located in the no traffic Conditions

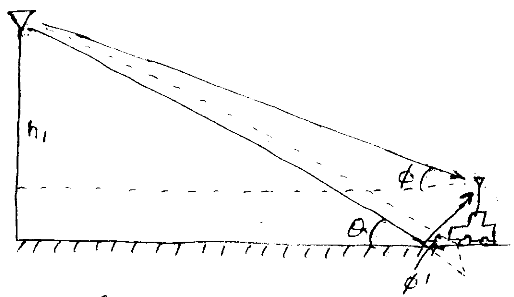
→ we have to Examine the Service area as occuring in one of the following Environments

| Human made Structures | Natural Terrains |
|---|---|
| a) In an open area | Over flat terrain |
| b) In a Suburban area | Over hilly terrain |
| c) In an Urban area | Over water |
| | Through foliage losses. |

→ we cannot use area to area prediction models for Cellular System design because of the large uncertainty of the prediction.

→ Ground Incident angle & Ground Elevation angle:

In a flat terrain:




→ The ground incident angle $\theta$ is the angle of wave arrival incidently pointing to the ground

→ The ground elevation angle $\phi$ is the angle of wave arrival at the mobile unit

$\theta$ is the incident angle
$\phi$ is the elevation angle.

**Example:** In a mobile radio Environment, the average cell site antenna height is about 50 m, the mobile antenna height is about 3 m, and the Communication path length is 5 km. then find $\theta, \phi$. ?

Ans:

The Incident angle is $\theta = \tan^{-1}\left[\frac{50\text{ m} + 3\text{m}}{5\text{ km}}\right] = 0.61^\circ$

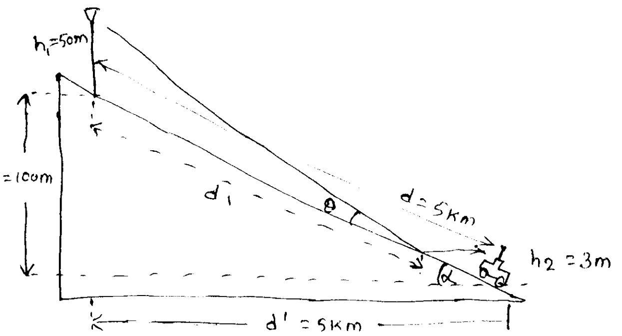
The Elevation angle at the antenna of the mobile unit is

$$\phi = \tan^{-1}\left[\frac{50\text{ m} - 3\text{m}}{5\text{km}}\right] = 0.54^\circ$$

The Elevation angle at the location of mobile unit is

$$\phi' = \tan^{-1}\left[\frac{50\text{m}}{5\text{km}}\right] = 0.57^\circ$$

Ground Reflection angle & Reflection point:




Ex: Let $h_1 = 50m$, $h_2 = 3m$, $d = 5km$ and $H = 100$

a) using the appropriate method $d \approx d' \approx 5km$ then the slope angle $\alpha$ of the hill is

$$\alpha = \tan^{-1}\left[\frac{100\ m}{5\ Km}\right] = 1.14576^{\circ}$$

The incident angle is

$$\theta = \tan^{-1}\left[\frac{50m + 3m}{5km}\right] = 0.61$$

The reflection point location from the cell site antenna

$$d_1 = \frac{50}{\tan\theta} = \frac{50}{\tan(0.61)} = 4.717\ Km$$

b) using the accurate method, the slope angle $\alpha$ of the hill is

$$\alpha = \tan^{-1}\left[\frac{100\ m}{\sqrt{(5\ Km)^2 - (100m)^2}}\right] = \tan^{-1}\frac{100}{4999} = 1.14599^{\circ}$$

$\therefore$ The incident angle $\theta$ & the reflection point location $d_1$ are the same as above.

## * Obtaining the Mobile Point to Point Model (Lee Model):

The Mobile point to point model is obtained in three steps

a) Generating a standard Condition

b) obtain an area to area prediction Model

c) a Mobile point to point model using area to area Prediction

The philosophy of developing this model is to try to separate two Effects i.e one Caused by natural terrain Contour & other is human made Structure, in the received Signal strength.

Generating a Standard Conditions: The advantage of using these standard Values is to obtain directly a predicted value in decibles above 1mw Expressed in dBm.

| | Standard Condition | | Correction factors. |
|---|---|---|---|
| At Base Station :- | Transmitted power $P_t = 10w$ (40dBm) | then | $\alpha_1 = 10 \log \frac{P_t'}{10}$ |
| | Antenna Height $h_1 = 100ft$ (30m) | | $\alpha_2 = 20 \log \frac{h_1'}{h_1}$ |
| | Antenna gain $g_1 = 6\,dB$ / pole | | $\alpha_3 = g_{t2}' - 6$ |
| At Mobile unit :- | Antenna Height $h_2 = 10ft$ (3m). | | $\alpha_4 = 10 \log \frac{h_2'}{h_2}$ |
| | Antenna gain $g_m = 0\,dB$ / dipole | | $\alpha_5 = g_m'$ |

Obtain area to area prediction Curves for human made Structures:

→ The area to area prediction Curves are different in different areas. In this area to area prediction, all areas are Considered to be flat Even through the data may be obtained from nonflat areas. because that the area to area prediction is an average process. The standard deviation of the average value indicates the degree of Terrain roughness

→ The path loss Curve obtained on virtually flat ground indicates the Effects of the Signal loss due to Solely human made Structures. This means that the different Path loss Curves obtained in Each City Show the different human made Structure in that City.

→ To do this, we may have to measure Signal strengths at these high spots & low spots along different paths in Surroundings of Cell Site represents the Signal received as if it is from a flat area affected only by a different local human made Structured Environment

→ Any area to area prediction model Can be used as a first step toward achiving the point to point Prediction model.

→ when the Structures are uniformly distributed, depending on the density (Avg Separation b/w buildings), the 1mi intercept Could be high or low, but the Slope may also kept at 40dB/dec

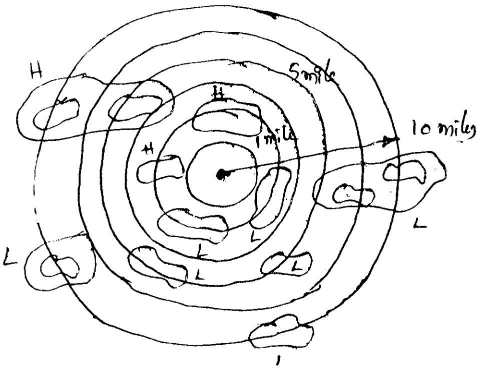
→ An area to area prediction model can be represented by two parameters
a) The 1 mi intercept point
b) The path loss slope

→ The 1 mi intercept point is the power received at a distance of 1 mi from the transmitter

→ Set up a transmitting antenna at the center of general area. As long as the building height is comparable to the others in the area, the antenna location is not critical.

→ Take 6 or 7 measured data points around the 1 mi intercept & around the 10 mi boundary based on high & low spots. Then compute the average of the 1 mi data points & of the 10 mi data points. By connecting the two values, the path loss slope can be obtained.

→ If the terrain of the hilly area is generally sloped, then we have to convert the data points that were measured on the sloped terrain to a fictiously flat terrain in that area.




→ The conversion is based on the effective antenna height gain as

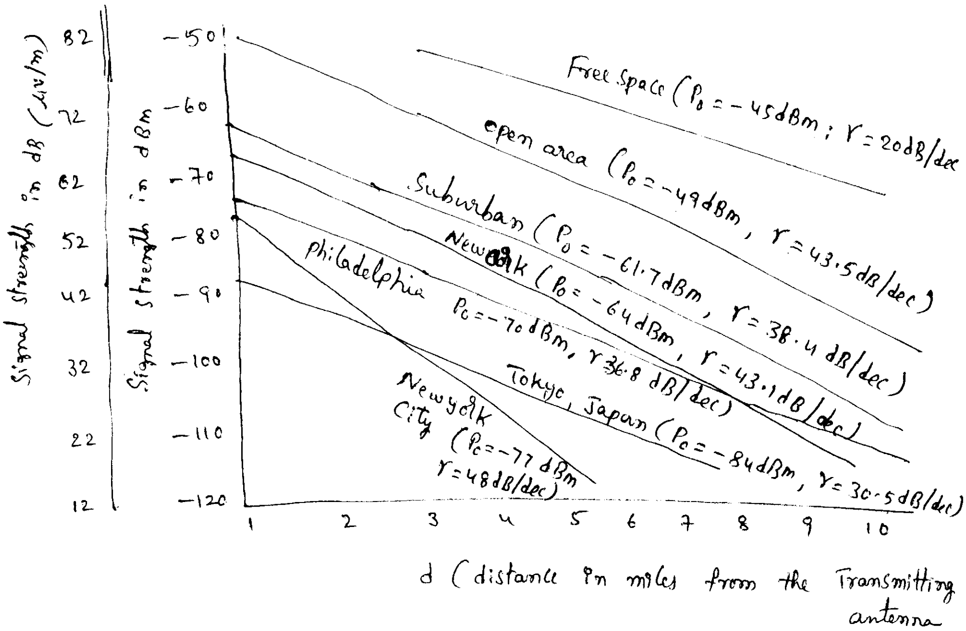
$$\Delta G = \text{Effective antenna height gain} = 20 \log \frac{h_e}{h_1}.$$

Here $h_1$ is the actual height

$h_e$ is the effective antenna height at either 1 mi or 10 mi locations.

~~The phase difference between a Direct path & Ground reflected path.~~

The Suburban area curve is a commonly used curve.




d (distance in miles from the Transmitting antenna

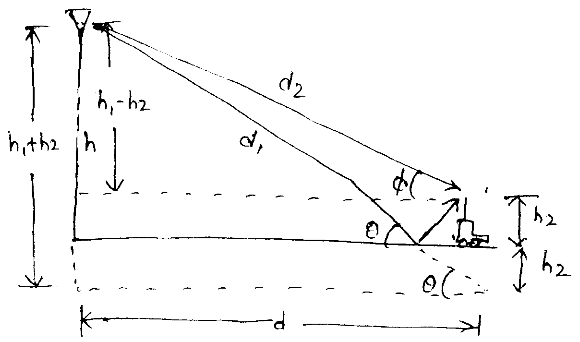
Propagation path loss in different cities

(3)

## * The phase difference between a Direct path and Ground Reflected path:

For Direct wave Signal : $e_0$

For Reflected wave Signal : $e_0 \cdot a_v e^{j\Delta\phi}$




$$\Rightarrow \quad e_0 + e_0 a_v e^{j\Delta\phi}$$

$$e_0 \left( 1 + a_v e^{j\Delta\phi} \right)$$

Interms of power, the received power is

$$P_r = \text{Direct wave Signal power} \times \left[ 1 + a_v e^{j\Delta\phi} \right]^2$$

$$P_r = \frac{P_0 \lambda^2}{(4\pi d)^2} \left[ 1 + a_v e^{j\Delta\phi} \right]^2 \quad \text{--- (1)}$$

where $a_v$ is reflection Co-efficient

$\Delta\phi$ is the phase difference b/w direct & reflected paths

$P_0$ is the transmitted power

$d$ is the distance

$\lambda$ is wavelength

In a mobile radio Environment $a_v = -1$ because of the small incident angle of ground wave caused by a relatively low cell site antenna height thus

$$P_r = \frac{P_0 \lambda^2}{(4\pi d)^2} \left[ 1 + (-1)(\cos\Delta\phi + j\sin\Delta\phi) \right]^2$$

$$= \quad '' \quad \Big[ \underbrace{1 - \cos\Delta\phi}_{a} - j\underbrace{\sin\Delta\phi}_{b} \Big]^2$$

$$\because \boxed{|a - jb|^2 = \left( \sqrt{(a^2+b^2)} \right)^2 = a^2 + b^2}$$

$$= \quad '' \quad \left[ (1-\cos\Delta\phi)^2 + \sin^2\Delta\phi \right]$$

$$= \quad '' \quad \left[ 1 + \cos^2\Delta\phi - 2\cos\Delta\phi + \sin^2\Delta\phi \right]$$

$$= \quad '' \quad \left[ 2 - 2\cos\Delta\phi \right] \Rightarrow \frac{P_0 \lambda^2}{(4\pi d)^2} \, 2(1 - \cos\Delta\phi)$$

$$\boxed{\because (1-\cos\theta) = 2\sin^2\theta/2}$$

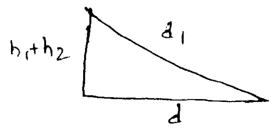
$$= \frac{P_0 \lambda^2}{(4\pi d)^2} \cdot 2\left( 2\sin^2\frac{\Delta\phi}{2} \right)$$

$$P_r = \frac{P_0 \lambda^2 4 \sin^2\frac{\Delta\phi}{2}}{(4\pi d)^2}$$

where $\Delta\phi = \beta \Delta d$

and $\Delta d$ is the difference i.e $\Delta d = d_1 - d_2$

From fig: $d_1 = \sqrt{(h_1+h_2)^2 + d^2}$




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

$$\therefore \Delta d = \sqrt{(h_1+h_2)^2 + d^2} - \sqrt{(h_1-h_2)^2 + d^2}$$

$$= d\left[\sqrt{\frac{(h_1+h_2)^2}{d^2} + 1} - \sqrt{\frac{(h_1-h_2)^2}{d^2} + 1}\right]$$

From Binominal Theory Expansion

$$= d\left[\left(1 + \frac{1}{2}\frac{(h_1+h_2)^2}{d^2} + \dots\right) - \left[1 + \frac{1}{2}\frac{(h_1-h_2)^2}{d^2} + \dots\right]\right]$$

$$= d\left[1 + \frac{1}{2d^2}\left(h_1^2 + h_2^2 + 2h_1h_2 + \dots\right) - \left[1 + \frac{1}{2d^2}\left[h_1^2 + h_2^2 - 2h_1h_2 + \dots\right]\right]\right]$$

$$= \cancel{d}\left[\frac{\cancel{4}^{2} h_1 h_2}{2d^{\cancel{2}}}\right]$$

$$= \frac{2h_1h_2}{d}$$

Here $\Delta\phi = \beta \Delta d$

$$= \frac{2\pi}{\lambda} \times \frac{2h_1h_2}{d} \Rightarrow \frac{4\pi h_1h_2}{\lambda d}$$

If $\Delta\phi < 0.6$ rad then $\sin\frac{\Delta\phi}{2} \approx \frac{\Delta\phi}{2}$. then the Equation is

$$P_r = \frac{P_0 \lambda^2 4}{(4\pi d)^2}\left(\frac{\frac{\cancel{4}^{2}\pi h_1h_2}{\cancel{\lambda} d}}{\cancel{2}}\right)^2$$

$$= \frac{P_0 \cancel{\lambda}^2 \cancel{4}}{1\cancel{6}\cancel{\pi}^2 d^2} \times \frac{\cancel{4}\cancel{\pi}^2 h_1^2 h_2^2}{\cancel{\lambda}^2 d^2}$$

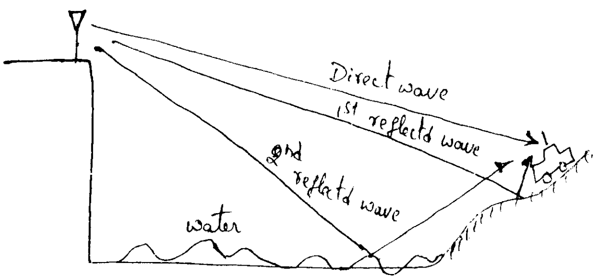
$$\boxed{P_r = P_0\left(\frac{h_1h_2}{d^2}\right)^2}$$

## * Propagation over water & Flat open area :-

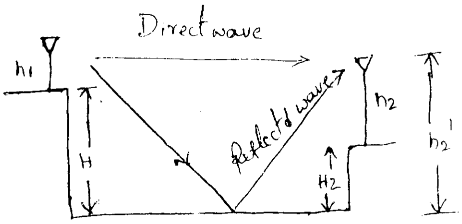
→ Propagation over water & flat open area is becoming a big Concern because it is very easy to interfer with other Cells if we do not make the Correct arrangements

→ In general the permitivities $\epsilon_r$ of Seawater and freshwater are the Same, but the Conductivities of Sea water & freshwater are different

→ Here we have two antennas, one at the Cell Site and other at the mobile Unit, are well above Sea level, two reflection points are generated




(i) Propagation over water




(ii) Propagation b/w two fixed Stations over water & flat open land

→ The one reflected from the ground is Close to the mobile unit, the other reflectd from the water is away from the mobile unit.

a) Between fixed stations :

→ The point to point transmission between the fixed Stations Over the water & flat Open land Can be Estimated as follows

The received Power $P_r = \frac{P_t}{\left(\frac{4\pi d}{\lambda}\right)^2}\left[1 + a_v e^{-j\phi_v} e^{j\Delta\phi}\right]^2$

where $P_t$ = transmitted power
$d$ = distance b/w two Stations
$\lambda$ = wavelength
$a_v, \phi_v$ = amplitude & phase of Complex reflection respectively

$$a_v e^{-j\phi_v} = \frac{\epsilon_c \sin\theta_1 - \sqrt{(\epsilon_c - \cos^2\theta_1)}}{\epsilon_c \sin\theta_1 + \sqrt{\epsilon_c - \cos^2\theta_1}}$$

Here $\epsilon_c$ is dielectric Constant i.e different for different media, however when $a_v e^{-j\phi_v}$ is independent of $\epsilon_c$ & The vertical incident angles is very smal. i.e $a_v \approx -1$ & $\phi_v = 0$ whether the wave is propagated over water or wet land or dry land or ice etc.

$\Delta\phi$ is the phase difference Caused by Pathdifference $\Delta d$ between the direct wave & reflected wave

$$\Delta\phi = \beta\Delta d = \frac{2\pi}{\lambda}\Delta d$$

$$P_r = \frac{P_t}{(4\pi d/\lambda)^2}\left[1 - e^{j\Delta\phi}\right]^2$$

$$= \frac{P_t}{(4\pi d/\lambda)^2}\left[1 - \cos\Delta\phi - j\sin\Delta\phi\right]^2$$

$$P_r = \frac{P_t}{(4\pi d/\lambda)^2}\, 2\left[1 - \cos\Delta\phi\right]$$

→ The effective antenna height at antenna 1 is the height above the Sea level

$$h_1' = h_1 + H_1 \quad \text{— (a)}$$

→ The effective antenna height at antenna 2 is the height above the Sealevel

$$h_2' = h_2 + H_2 \quad \text{— (b)}$$

Here $h_1$ & $h_2$ are actual heights
$H_1$ & $H_2$ are heights of hills

In general both antennas at fixed stations are hight, So the reflection point of the wave will be found toward the middle of Path. Then the path difference $\Delta d$ Can be obtained as.

$$\Delta d = \sqrt{(h_1' + h_2')^2 + d^2} - \sqrt{(h_1' - h_2')^2 + d^2}$$

Since $d >> h_1'$ & $h_2'$ then

$$\Delta d \approx d\left[1 + \frac{(h_1'+h_2')^2}{2d^2} - 1 - \frac{(h_1'-h_2')^2}{2d^2}\right]$$

$$\approx \frac{2h_1'h_2'}{d}$$

$$\Delta\phi = \frac{2\pi}{\lambda}\frac{2h_1'h_2'}{d} = \frac{4\pi h_1' h_2'}{\lambda d}$$

$P_r$ → Received power
$P_0$ → Power received in free space

If

1) $P_r < P_0$, $2 - 2\cos\Delta\phi < 1$ & $\Delta\phi < \frac{\pi}{3}$
2) $P_r = 0$ that is $2 - 2\cos\Delta\phi = 0$ & $\Delta\phi = \frac{\pi}{2}$
3) $P_r = P_0$ that is $2 - 2\cos\Delta\phi = 1$ & $\Delta\phi = \pm 60^\circ = \pm\frac{\pi}{3}$
4) $P_r > P_0$ that is $2 - 2\cos\Delta\phi > 1$ & $\frac{\pi}{3} < \Delta\phi < \frac{5\pi}{3}$
5) $P_r = 4P_0$ that is $2 - 2\cos\Delta\phi = \max$ & $\Delta\phi = \pi$

Problem: Let a distance between two fixed stations is 30 km, The Effective antenna height at one End $h_1$ is 150 m above sea level. Find the $h_2$ at othe End. So that received Power always meets the Condition $P_r < P_0$ at 850 MHz Tx'on of ($\lambda$ at $= 0.35$ m)

Solution:

$$\frac{4\pi h_1' h_2'}{\lambda d} \le \frac{\pi}{3} \quad \text{then} \quad h_2' \le \frac{d\lambda}{12 h_1'} = \frac{30{,}000 \times 0.35}{12 \times 150} = 6\,m$$

b) Land to Mobile Propagation over water :

→ The propagation model would be different for land to mobile Transmission over water because there are always two Equal Strength reflected waves ; one from the water and one from the proximity of the mobile unit inaddition to the direct wave.

→ The reflected power of the two reflected waves can reach the mobile unit without noticable attenuation.

→ The total received power at the mobile unit would be obtained by Summing three Components

$$P_r = \frac{P_t}{(4\pi d/\lambda)^2} \left| 1 - e^{j\Delta\phi_1} - e^{j\Delta\phi_2} \right|^2 \quad — ①$$

$$= \frac{P_t}{(4\pi d/\lambda)^2} \left| 1 - (\cos\Delta\phi_1 + j\sin\Delta\phi_1) - (\cos\Delta\phi_2 + j\sin\Delta\phi_2) \right|^2$$

$$= \frac{P_t}{(4\pi d/\lambda)^2} \left| 1 - \cos\Delta\phi_1 - j\sin\Delta\phi_1 - \cos\Delta\phi_2 - j\sin\Delta\phi_2 \right|^2$$

$$= \frac{P_t}{(4\pi d/\lambda)^2} \left| 1 - \cos\Delta\phi_1 - \cos\Delta\phi_2 - j(\sin\Delta\phi_1 + \sin\Delta\phi_2) \right|^2$$

Follow the Same approximation for the land to mobile propagation over water

$\cos\Delta\phi_1 \approx \cos\Delta\phi_2 \approx 1$ ; $\sin\Delta\phi_1 \approx \Delta\phi_1$ ; $\sin\Delta\phi_2 \approx \Delta\phi_2$

then $$P_r = \frac{P_t}{(4\pi d/\lambda)^2} \left| \cancel{1} - \cancel{1} - 1 - j(\Delta\phi_1 + \Delta\phi_2) \right|^2$$

$$= \frac{P_t}{(4\pi d/\lambda)^2} \left[ 1 + (\Delta\phi_1 + \Delta\phi_2)^2 \right]$$

In most practical Cases $\Delta\phi_1 + \Delta\phi_2 < 1$ ; then $(\Delta\phi_1 + \Delta\phi_2)^2 \ll 1$ & The Equation Should be

$$\boxed{P_r \approx \frac{P_t}{(4\pi d/\lambda)^2}}$$

→ There fore we may Conclude that the path loss for land to mobile Propagation over land 40 dB/dec is different for land to mobile Propagation over water

→ So in this Case of propagation over water, the free Space path loss 20 dB/dec Should be applied.

## General formula for Mobile Radio Propagation :

→ we are taking Suburban area as a general propagation path loss in a general mobile radio Environment.

The one mile intercept for Suburban area is $-61.7$ dBm

The 10 mile intercept for suburban area is $-100$ dBm.

General formula for one mile intercept in suburban area

$$P_r = (P_t - 40) - 61.7 - 38.4 \log \frac{r_1}{1mi} + 20 \log \frac{h_1}{100ft} + 10 \log \frac{h_2}{10ft} + (G_t - 6) + G_m$$

when it is Simplified

$$P_r = P_t - 157.7 - 38.4 \log r_1 + 20 \log h_1 + 10 \log h_2 + G_t + G_m$$

For 10 mile intercept level :

$$P_r = P_t - 156 - 40 \log r_1 + 20 \log h_1 + 10 \log h_2 + G_t + G_m$$

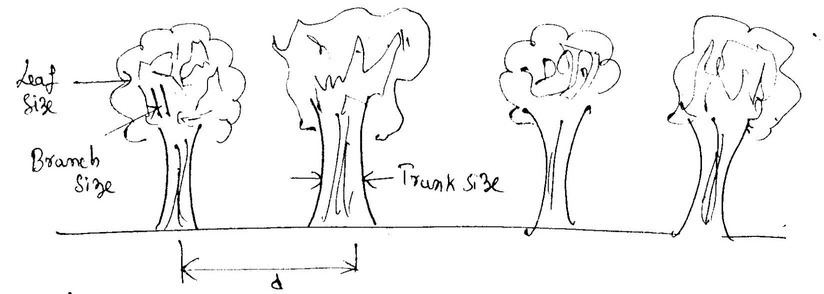
∴ The most general formula is expressed as follower.

$$\boxed{P_r = P_t - K - \gamma \log r_1 + 20 \log h_1 + 10 \log h_2 + G_t + G_m}$$

where $\boxed{P_r = P_t - K}$ at $r_1 = 1$ mile, $h_1 = h_2 = 1$, $G_t = G_m = 0$

The value of $K$ & $\gamma$ will be different & need to be measured in different human made Environment.

## * Foliage Loss :




→ Foliage loss mainly depends on
a) Size of trunk
b) Size of branch
c) Size of leaf
4) Height of tree
5) Distance b/w trees
6) Density of branch & leaves

→ In Summer the foliage loss is very heavy, but in winter the leaves of the OAK & maple trees fall & loss is less.

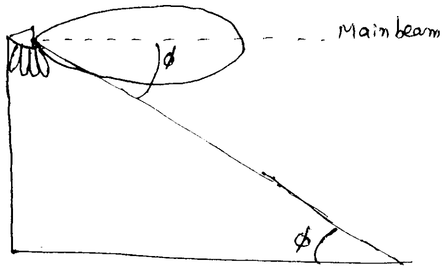
→ In tropic zones, the sizes of tree leaves are so large & thick that the signal can hardly penetrate. In this case the signal will propagate from top of the tree and deflect to mobile receiver.

→ At 800 MHz the foliage loss along the radio path is 40 dB/dec. A foliage loss in the Suburban area of 58.4 dB/dec.

The total loss (60 dB/dec) = [20 dB/dec of free Space loss + Additional 20 dB due to foliage loss + Additional 20 dB due to mobile Communication]

## * Propagation in Near In Distance :

→ within a 1 mi radius, the antenna beamwidth especially of a high gain omnidirectional antenna is narrow in the vertical plane. Thus the signal reception at mobile unit less than 1 mi alway will be reduced because of the large elevation angle which causes the mobile unit to be in the outside the main beam ( shadow region)
i.e The larger the elevation angle, the weaker the reception level due to the antenna's vertical plane



Elevation angle of the shadow of the antenna pattern

→ The near by surroundings of the cell site can bias the reception level either up & down when the mobile unit is within the 1 mi radius

→ we usually worry about propagation at the far distance for coverage purposes.

→ At $d = 100$ m, [mobile antenna height 3m] the incident & elevation angles are $11.77°$ & $10.72°$ respectively

| Antenne height $h_1$ in mts | Incident angles $\theta$ degrees | Elevation angle $\phi$ degrees | Attenuation $\alpha$ in dB |
|---|---|---|---|
| 90 (300) | 30.4 | 29.6 | 21 |
| 60 ( 200) | 21.61 | 20.75 | 16 |
| 30 ( 100) | 11.77 | 10.72 | 6 |

If the antenne beam is aimed at the mobile unit, we will observe
24 dB/dec for antenna height of 100 ft
22 dB/dec for " " 200 ft
20 dB/dec " " " 400 ft. This slope of 20 dB/dec is the free space. At 1 mi intercept the received level in suburban area is −61.7 dBm

→ Calculation of Near field propagation.

The Range $d_F$ of near field can be obtained by letting $\Delta\phi = \pi$
( $P_r = 4P_0$ that is $2 - 2\cos\Delta\phi = \max$ or $\Delta\phi = \pi$)

$$\Delta\phi = \pi$$

$$\frac{4\pi h_1 h_2}{\lambda d_F} = \pi$$

$$d_F = \frac{4 h_1 h_2}{\lambda}$$

→ The signal received within the near field ( $d < d_F$ ) uses the free space loss formula. $P_r = P_t / (4\pi d/\lambda)^2$

→ The signal received outside the near field ( $d > d_F$) can use the mobile radio path loss formula

$$P_r = P_t - 157.7 - 38.4 \log r_1 + 20 \log h_1 + 10 \log h_2 + G_t + G_m$$

# Long Distance propagation :

- The advantage of a high cell site is that it covers the signal in a large area especially in a noise limited system where usually different frequencies are repeatedly used in different areas.
- A noise limited system gradually becomes an interference system as the traffic increases & this interference is due to not only the existence of many cochannels & adjacent channels in the system but the long distance propagation also effects the interference.
- Tropospheric wave propagation prevails at 800 mHz for long distance propagation i.e the signal reach 320 km & 200 mi away.
- The wave is received 200 mi away because of abrupt change in the effective dielectric constant of troposhere (10 km above the Earth).
- The dielectric constant changes with temparature & decreases the height at a rate of about 6.5°/km & reaches -50°c at the troposphere.
- In tropospheric propagation the wave may be divided by refraction & Reflection.

Tropospheric Refraction : This refraction is gradually bending of the rays due to the changing effective dielectric constant of atmosphere through which the wave is passing

Trophospheric Reflection : This reflection will occur where there are abrupt changes in the dielectric constant of atmosphere. The distance of propagation is much greater than the line of sight propagation.

Moistness : Actually water content has much more effect than temparature changes on the dielectric constant of temparature & on the manner in which the radio waves are effected. The vapour water pressure decreases as the height increases.

- If the refraction index decreases with height over a portion of the range of hight, the rays will be curved downward & a condition known as Trapping & Duct propagation.
- Troposhperic wave propagation does cause interference & can only be reduced by umberella antenna beam pattern.

## * Obtain path loss from a Point - Point Prediction Model:

→ The point to point prediction can be used to provide overall coverage of all cell sites and to avoid cochannel interference.

→ This model is a basic tool that is used to generate a signal coverage map, an interference area map, a handoff occurance map or an optimum system design configuration.

→ The Point - Point Prediction can be predicted in two conditions

a) In Non obstructive Condition

b) In obstructive Contition

→ In Nonobstructive Condition: In this condition, the direct path from the cell site to the mobile unit. it is not obstructed by the terrain contour. The non obstructive direct path is a path unobstructed by the terrain contour. The line of sight path is a path which is unobstructed by the terrain contour & by human made structures

→ The method for finding the antenna - height gain is as follows

1) Find the Specular reflection point:

Take two values from two conditions stated as follows

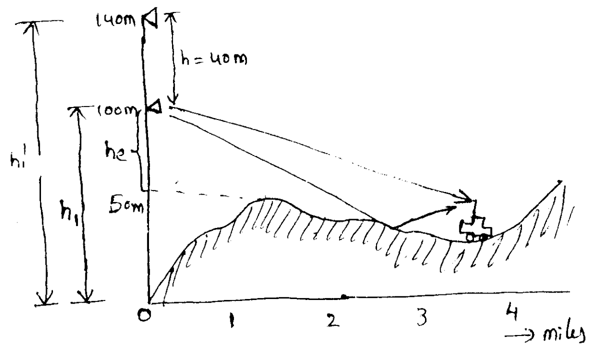
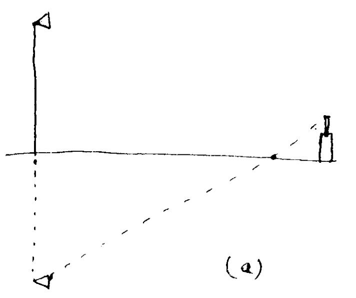
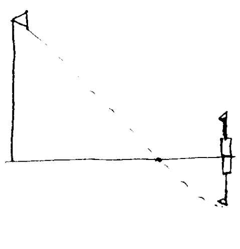


fig (a)

a) Connect the image antenna of the cell site antenna to the mobile antenna; the intercept point at the ground level is considedered as a potential reflection point

b) Connect the image antenna of the mobile antenna to the cell site antenna; the intercept point at the ground level is also considerd as a potential reflection point


(a)


(b)

Between two reflection points, we choose the point which is close to the mobile unit to be the real one because more energy will be reflected to the mobile point at the point.

2) Extend the reflected ground plane, which the reflection point is on can be generated by drawing a tanget line to the point where the ground structure is, the extending the reflected ground plane to the location of the cell site antenna.

3) Measure the effective antenna height. The effective antenna height is measured from the point where the reflected ground plan and the cell site antenna location.

Between these two cases $h_e = 40m$ in fig (a)

$h_e = 200m$ in fig (b)

Actual antenna height $h_1 = 100$ m.

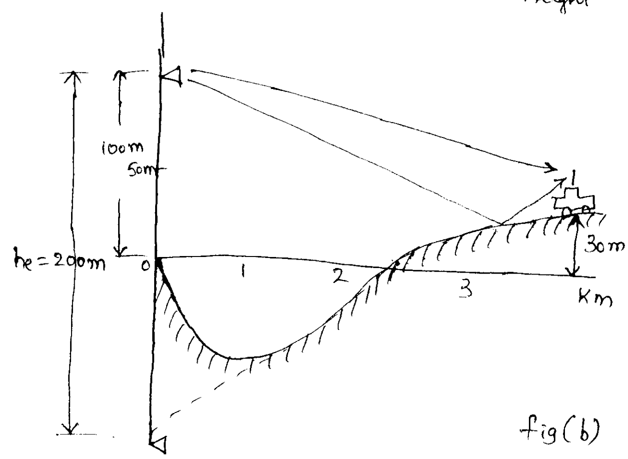



fig (b)

4) Calculate the antenna height gain $\Delta G$.

$$G = 20 \log \frac{h_e}{h_1}$$

From fig (a) $\Rightarrow$ $\Delta G = 20 \log \frac{40}{100} = -8$ dB (-ve gain)

From fig (b) $\Rightarrow$ $\Delta G = 20 \log \frac{200}{100} = 6$ dB (+ve gain)

→ we have to realize that the antenna height gain $\Delta G$ changes as the mobile unit moves along the road.

→ In otherwords, the effective antenna height at the cell site changes as the mobile unit moves to a new location although the actual antenna remains unchanged.

→ The effect of changing different effective antenna heights $h_e$ & $h_e'$ at different positions of mobile unit. Then the effective antenna gain $\Delta G = 20 \log \frac{h_e}{h_e'}$

→ The path loss slope in suburban area is $-38.4$ dB/dec, ~~then the~~ .
The point to point prediction is based on the actual terrain contour along a particular radio path & has a standard deviation of less than 2 to 3dB
The area to area prediction has a standard deviation of 8 dB

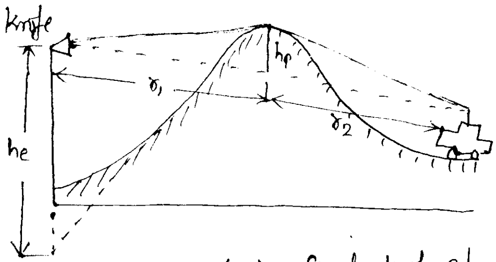
## * In obstructive Condition :

→ In this Condition, the direct path from the cell site to the mobile unit is obstructed the terrain Contour.

(i) Apply area to area prediction :

(ii) Obtain the diffraction loss : The diffraction loss Can be found from a Single knife Edge & double knife Edge as shown in figure

(a) Find the four parameters for a Single knife Edge Case. They are



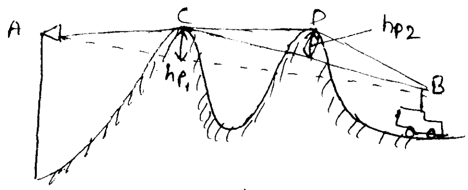

(a) Single knife Edge

(i) The distances $r_1$ & $r_2$ from the knife Edge to the Cell site & to the mobile unit

(ii) The hight of the knife Edge $h_p$

(iii) The operating wave length '$\lambda$'.

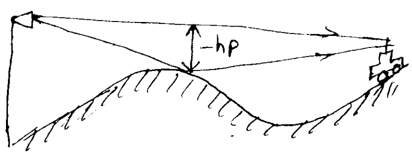
(iv) All these are used to fined a new parameter $v$




(b) Double knife Edge

$$v = -h_p \sqrt{\frac{2}{\lambda}\left(\frac{1}{r_1}+\frac{1}{r_2}\right)}$$

with the value of $v$ we can know the diffraction loss $L$ Can be found from the Curves.




(c) Non clear path

→ when $h_p = 0$, the direct path is tangential to the knife Edge & $v = 0$. with $v = 0$, the diffraction loss $L = 6\,dB$ Can be obtained.

(b) → A double knife Edge Case : Two knife edges Can be formed by the two triangles ACB & CDB from fig.

→ Each one Can be used to Calculate $v$ as $v_1$ & $v_2$. and the Corresponding $L_1$ & $L_2$ Can be found from fig.

→ The total diffraction loss of this double knife edge model is the Sum of the two diffraction losses

$$L_t = L_1 + L_2$$

From graph

$1 \le v$ ; $L = 0\,dB$

$0 \le v \le 1$ ; $L = 20 \log (0.5 + 0.62v)$

$-1 \le v < 0$ ; $L = 20 \log (0.5\, e^{0.95v})$

$-2.4 \le v < -1$ ; $L = 20 \log \left(0.4 - \sqrt{0.1184 - (0.1v + 0.38)^2}\right)$

$v < -2.4$ ; $L = 20 \log \left(-\frac{0.225}{v}\right)$

## * Cell site Antenna Heights and Signal Coverage Cells :

→ **Effects of Cell Site antenna Heights** : There are Several points which need to be clarified Concerned Cell Site antenna Height Effects.

a) **Antenna height unchanged** : If the power of the Cell site transmitter changes, the whole Signal strength Can be linearly updated according to the change in transmitted Power.

If the transmitted power increases by 3 dB, just add 3dB to Each grid in the Signal strength

b) **Antenna height changed** : If the antenna height changes ($\pm \Delta h$), then the whole Signal strength map obtained from the old antenna height Cannot be updated with a Simple antenna gain formula as

$$\Delta g = 20 \log \frac{h_1'}{h_1}$$

Here $h_1$ is old actual antenna height
$h_1'$ is new actual antenna height

→ with the Same terrain Contour data along the radio paths to figure out the difference in gain resulting from the different Effective antenna heights in Each grid

$$\Delta g' = 20 \log \frac{he'}{he} = 20 \log \frac{he \pm \Delta h}{he}$$

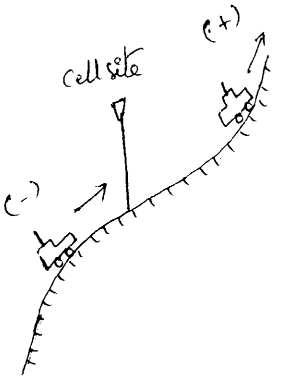
Here $he$ is old Effective antenna height
$he'$ is the new Effetive antenna height

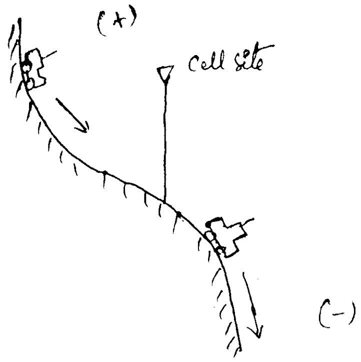
∴ The additional gain will be added to the Signal Strength grid based on the old antenna height

c) **location of the antenna changed** : If the location of the antenna Changes, the point to point Program has to start all over again i,e Everytime the antenna location changes, the new point-point Prediction Calculation Starts again.

d) **Visualization of the Effective antenna height** : The Effective antenna height changes, when the location of the mobile unit changes. we Can Visualize the Effective antenna height as always Changing up & down while the mobile unit is moving

Case i) The mobile unit is driven up a positive slope :
The Effective antenna height increases if the mobile unit is driving away from the Cell site antenna.
and it decreases if the mobile unit is approaching the Cell site antenna

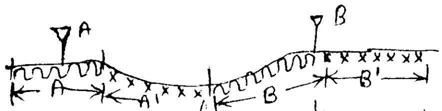



Case ii) The mobile unit is driven down a hill :

→ The Effective antenna height decreases if the mobile unit is driving away from the cell site antenna and it increases if the mobile unit is approaching the cell site antenna

Visualization of Signal Coverage Cells :




→ A physical cell is usually visualized as a signal reception region around the cell site. within the region, there are weak spots called holes.

→ The cell site A can not cover area A', but cell site B can. Now everytime the vehicle enters area A', a handoff is requested as if it were in cell B.

→ Therefore, the holes in one cell are covered by the other sites. As long as the processing capacity at the MTSO can handle excessive handoff. This overlapped arrangement for filling the holes is a good approach in a non interference condition

## * Mobile To Mobile Propagation:

In mobile to mobile land communication, both the transmitter and the receiver are in motion.

# III Unit Questions

1) a) Derive the relation for received power in when the wave is propagating over water & flat open area between two fixed stations

b) write short notes on Mobile to Mobile propagation

2) a) Explain the effects of cell site antenna heights

b) State the merit of point to point model and give the general formula of Lee's point to point model

3) a) Discuss the mobile point to point model

b) The distance between two fixed stations

(i) 40 km the effective height at one end $h_1$

(ii) 100 m above the sea level. Find the $h_2$ at the end under the two conditions

a) $P_r < P_o$ at 850 MHz Transmission

b) $P_r > P_o$ & find the max received power $P_r$ for $P_r = 4P_o$

4) a) Discuss about the near in distance & long distance propagation

b) Explain the propagation path loss due to natural & man made structures

5) a) Describe the effects of cell site antenna heights & signal coverage cells.

b) for the given figure antenna height 300 m, transmitting power is 5 W antenna gain is 2 dB per dipole under suburban condition find the path loss? (use necessary assumptions where required)

6) If the old cell antenna height is 30 m & the new one $h_1'$ is 45 m the mobile unit 8 km away sees the old cell site effective antenna height ($h_e$) being 60 m. Then ~~new~~ find the effective antenna gain?

$$h_e' = h_e + (h_1' - h_1)$$

$$= 60 + (45 - 30) = 75 \text{ m}$$

$$\Delta g' = 20 \log \frac{h_e'}{h_e} = 20 \log \left(\frac{75}{60}\right) = 1.938$$