Cellular and Mobile Communication

<u>**Prepared by:**</u>
Dr S.Fayaz Begum
Dept of ECE
Assisitant Professor
Annamacharya University
Rajampet

Introduction to cellular mobile systems:

conventional mobile telephone systems:

In conventional mobile telephone systems available frequency spectrum is divided into mobile radio telephone channels using FDM without reuse facility, serving an area with large size. A dedicated channel is allocated for each user, whether user it or not. It has several limitations such as

→ limited service capability

→ poor service performance.

→ Inefficient frequency spectrum utilization

limited service capability:

→ specific frequency allocation for use in autonomous geographic zones, as shown in Fig 1.1. The coverage area of each zone is planned to be as large as possible.

→ the user need to reinitiate the call when moving into a new zone bcz the call will be dropped.

→ one freq per channel and the number of active users is limited to the number of channels assigned to a particular freq zone.

poor service performance:

The blocking probability is high during busy hours in conventional mobile telephone systems, to overcome this high-capacity sys for mobile telephone was needed.

Inefficient frequency spectrum utilization:

$$M_0 = \frac{\text{no. of customers}}{\text{channel}} \text{ (conventional systems).}$$

M_0 = frequency spectrum utilization measurements.

In conventional system each channel can only serve one customer at a time in a whole are which results inefficient utilization of spectrum.

cellular systems:

In cellular system is developed to overcome the limitations in the conventional mobile telephone system.

Basic cellular system:

A basic cellular system consists of three parts.

1. mobile units:

A mobile telephone unit contains a control unit, a transceiver, and an antenna system.

2. cell site:

A cell site provides interface between the MTSO and the mobile units. It has a control unit, radio cabinets, antennas, a power plant, and data terminals.

3. MTSO:

The switching office is the central co-ordinator element for all cell sites, contains the cellular processor & cell switch.

4. connections:

The radio and high-speed data connect the three subsystems. Each mobile unit can only use 1 channel at a time for its communication link but the channel is not fixed.

a. The transmitted power would have to be very high to illuminate weak spots with sufficient reception, a significant added cost factor.
b. Higher the transmitted power, harder it becomes to control interference.

2. Required grade of service:
The grade of service is specified for a blocking probability of 02 for initiating call at the busy hour, this is an average value.

3. Number of dropped calls:-
During Q calls in an hour, if a call is dropped & Q-1 calls are completed, then the call drop rate is 1/Q. The drop rate must be kept low.

special features.
System would like to provide as many special features as possible, such as call forwarding, call waiting, voice stored (VSR) box, automatic roaming (loss of a signal receiver will be detected by the mobile unit as it moves) & navigation services.

Uniqueness of mobile radio environment.

. mobile radio transmission medium:
The propagation path loss increases not only with freq but also with distance. the propagation path loss of 40dB/dec is the general rule for the mobile radio environment.

Therefore $C \propto R^{-4} = \alpha R^{-4}$

where C = received carrier power
R = distance measured from the transmitter to the receiver
α = constant.

The MTSO provides central co-ordination a cellular administration. The cellular switch, which can be either analog or digital, switches cells to connect mobile subscribers to other mobile subscribers and to the nationwide telephone network.

Performance criteria;

There are three categories for specifying perform

Voice quality:

For commercial communication system, a set value x at which y percent of customers rate the system voice quality and circuit merit as follows

CM5 excellent

CM4 good

CM3 fair

CM2 poor

CM 1 unusable.

Service quality:

Three items are required service quality.

1. coverage: The system should serve an area as large as possible. Because of irregular terrain configuration.

as the vehicle moves faster. The radius of the

$r(t) = m(t)\, r_0(t)$

m(t) is called local mean, long-term fading or lognormal fading.

The factor r_0 is called multipath fading, a short-term fading or rayleigh fading.

$$m(t_1) = \frac{1}{2T} \int_{t_1 - T}^{t_1 + T} r(t)\, dt.$$

2T is the time interval for avg r(t).

In space scale

$$m(x_1) = \frac{1}{2L} \int_{x_1 - L}^{x_1 + L} r(x)\, dx.$$

the length of 2L has been determined to be 20 to 40λ

$$r_0(\text{in dB}) = r(t) - m(t) \text{ dB}.$$

mobile fading characteristics :-

when the mobile unit is moving, the fading structure of the wave in the space is received it is a multipath fading. The recorded fading becomes fast as the vehicle moves faster. The radius of the

$$\frac{C_2}{C_1} = \left(\frac{R_2}{R_1}\right)^{-4}$$

$$\Delta C \text{ (in dB)} = C_2 - C_1 \text{ (in dB)}$$
$$= 10 \log \frac{C_2}{C_1} =$$
$$= 40 \log \frac{R_1}{R_2}$$

When $R_2 = 2R_1$, $\Delta C = -12$ dB; when $R_2 = 10R_1$, $\Delta C = -40$ dB.

Thus 40dB/dec is the general rule for the mobile radio environment.

Similarly general rule for free-space propagation is 20dB/dec

$C \propto R^{-2}$ (free space)

$$\Delta C = C_2 \text{ (in dB)} - C_1 \text{ (in dB)}$$
$$= 20 \log \frac{R_1}{R_2} \text{ (free space)}$$

$$C = R^{-\gamma} = \alpha R^{-\gamma}$$
$$C = 10 \log \alpha - 10 \gamma \log R \text{ dB}$$

γ usually lies between 2 & 5 and cannot be less than 2.

Model of transmission medium:

The antenna height of the mobile unit is lower than its typical surroundings and their carrier wavelength is much less than the size of the surrounding structures, multipath waves are generated causes a signal fading phenomenon. The signal fluctuate at the baseband at about every half wavelength in space, but all nulls do not occur at same level. If the mobile unit moves fast, the rate of fluctuation is fast.

A mobile radio signal $r(t)$, can be artificially characterized by two components $m(t)$ & $r_0(t)$ based on natural physical phenomenon.

Hexagonal-shaped cells:

The hexagonal-shaped cells on a layout are used to simplify the planning and design of a cellular system instead of circular cell shaped cells.

Elements of cellular radio system design:

The major elements are

-> The concept of freq reuse channels
-> the co-channel interference reduction factor.
-> The desired carrier-to-interference ratio
-> The handoff mechanism
-> cell splitting.

concept of freq reuse channel.

The particular radio channel say f1 used in one geographic zone to call a cell, say c1 with a coverage radius R can be used in another cell with the same coverage radius at a distance D away.

frequency reuse schemes

The freq reuse concept is used in time domain and space domain

Summary same in the space domain
The radius of the active scatterer region is roughly 100 wavelengths. The active scatter region always moves with the mobile unit as it center.

operation of cellular system:-

1) mobile unit initialization:
The receiver of the mobile unit scans 21 set-up channels which are designated among the 333 channels and selects the strongest one and locks for a certain time.

2) mobile originated call:
The user places the called number into an originating register in the mobile unit and pushes the "send" button. A request for service is sent on a selected setup channel obtained from a self-location scheme.

Network originated call:
A land-line party dials a mobile unit number. The telephone company zone office recognizes that the number is mobile & forwards the call to the MTSO. The MTSO sends message to required party

call termination:
when the mobile user turns off the transmitter, a particular signal transmits to the cell site, & both sides free the voice channel.

Handoff procedure:
During the call, two parties are on a voice channel, when the mobile unit moves out of coverage area of a particular cell site, the reception becomes weak. The present cell site requests a handoff. The sys switches the call to a new frequency channel in a new site without either interrupting the call or alerting the user

frequency reuse in the space domain.
-> same frequency assigned in two different geographic areas.
-> same freq repeatedly used in same general area in one system.

Frequency reuse distance:
The minimum distance which allows the same freq to be reused.

factors:
-> the no. of cochannel cells in the vicinity of the center cell.
-> the type of geographic terrain contour.

The freq reuse distance $D = (3K)^{1/2} R$

Where K is the freq reuse pattern.

$3.46R = K = 4$
$4.6R = K = 7$
$6R = K = 12$
$7.55R = K = 19$.

If all the cell sites transmit the same power, then K increases and the frequency reuse distance D increases the increased D reduces the chance that cochannel interface may occur.

Handoff mechanism:
Two co-channel cells using the frequency f_1 separated by a distance D. The radius R and the distance D are governed by the value of q. Now we have to fill in with other frequency channel such as f_2, f_3 & f_4 b/w two co-channel cells in order to provide a communication system in whole area.

cell splitting:-

There are two kinds of cell-splitting

permanent splitting:

the installation of every new split cell has to be planned ahead of time, number of channels, the transmitted power, the assigned freq, the choosing of the cell-site selection.

Dynamic splitting:

This scheme is based on utilizing the allocated spectrum efficiency in real-time. The algorithm for dynamically splitting cell sites is a tedious job since we cannot afford to have one single cell unused during cell splitting at heavy traffic hour.

where

$$R = \sqrt{[s(t)\cos\phi_1 + I(t)\cos\phi_2]^2 + [s(t)\sin\phi_1 + I(t)\sin\phi_2]^2} \rightarrow (4)$$

and $$\psi = \tan^{-1}\frac{s(t)\sin\phi_1 + I(t)\sin\phi_2}{s(t)\cos\phi_1 + I(t)\cos\phi_2} \rightarrow (5)$$

the envelope R can be simplified in eqn (3) and R^2 becomes

$$R^2 = \{s^2(t) + I^2(t) + 2s(t)I(t)\cos(\phi_1 - \phi_2)\} - (6)$$

following Kozono and Sakamoto's analysis of Eq (6) the term $s^2(t) + I^2(t)$ fluctuates close to the fading frequency V/λ and the term $2s(t)I(t)\cos(\phi_1 - \phi_2)$ fluctuates to a frequency close to $d/dt(\phi_1 - \phi_2)$, which is much higher than the fading frequency. Then the two parts of the squared envelope can be separated as

$$x = s^2(t) + I^2(t)$$

$$y = 2s(t)I(t)\cos(\phi_1 - \phi_2)$$

Assume that the random variables $s(t)$, $I(t)$, ϕ_1, and ϕ_2 are independent; then the average processes can be separated as

$$\bar{x} = \overline{s^2(t)} + \overline{I^2(t)}$$

$$\bar{y}^2 = \overline{4s^2(t)\,I^2(t)\,(1/2)} = \overline{2s^2(t)I^2(t)}$$

the signal-to-interference ratio Γ becomes

$$\Gamma = \frac{\overline{s^2(t)}}{\overline{I^2(t)}} = K + \sqrt{K^2 - 1}$$

where $K = \frac{\overline{x^2}}{\overline{y_2}} - 1$

since x and y can be separated in the above quation the preceding computation of Γ in quation Γ could have been meas of an envolope detector and analog-to-digital converter, and a microcomputer. The sampling delay time of should be small enough to .

and $\frac{s(t) - s(t+\Delta t),\ \Im(t) \sim \Im(t-\Delta t)}{\cos(\varnothing_1(t) - \varnothing_2(t)) \cos[\varnothing_1(t+\Delta t) - \varnothing_2(t-\Delta t)] - 0}$

Design of an omnidirectional Antenna system in the worst case :-

* The value of $q = 4.6$ is valid for a normal interference case in $K=7$ cell pattern.
* the figure the distance from all six cochannel interfering sites are also shown in the figure. two distance of D-R two distances of D, and two distances of D+R :
* the following $C = R^{-4}$ $I = D^{-4}$

then the carrier-to-interference ratio is

$$\frac{C}{I} = \frac{R^{-4}}{2(D-R)^{-4} + 2(D)^{-4} + 2(D-R)^{-4}}$$

$$= \frac{1}{2(q-1)^{-4} + 2(q)^{-4} + 2(q+1)^{-4}}$$

Test 2: find the cochannel interference area which affects a cell site:

Real time cochannel interference measurement at mobile Radio Transceiver:-

when the carriers are angulary modulated by the voice signal and the RF frequency difference between them is much higher than the

fading frequency are angular ~~modulated~~ measurement of the signal carrier-to-interference ratio C/I reveals that the signal is

$$e_1 = s(t)\sin(\omega t + \phi_1) \rightarrow ①$$

and the interference is

$$e_2 = I(t)\sin(\omega t + \phi_2) \rightarrow ②$$

The received signal is

$$e(t) = e_1(t) + e_2(t) = R\sin(\omega t + \psi) \rightarrow ③$$

co-channel interferene (a worst case)

Design of a Directional Antenna system:-

* when the call traffic begins to increase, we need to use the frequency spectrum efficiently and avoid increasing the number of cells K in a seven-cell frequency reuse pattern. when K increase, the number of frequen channels assigned in a cell must become smaller.

(b)

fig:- Lowering the antenna height (a) on a hight hill
(b) in a valley

$$G = \text{gain reduction} = 20\log \frac{0.5h_1 + H}{h_1 + H}$$

$$= 20\log_{10}\left(1 - \frac{0.5h_1}{h - H}\right)$$

$$G = 20\log_{10} 1 = 0\,dB$$

In a valley :- The effective antenna height as seen from the mobile unit shown in the above figure. is he_1, which is less than the actual antenna height h_1. If $he_1 = 2/3 h_1$, and the antenna is lowered to $1/2\, h_1$. Then the new effective antenna height is

$$he_1 = 1/2 h_1 - (h_1 - 1/2 h_1) = 1/2 h_1$$

Then the antenna gain is reduced by

$$G = 20\log \frac{1/2 h_1}{2/2 h_1} = -12\,dB$$

the simply proves that the lowered antenna height in a valley very effective in reducing the radiated power in a distance hight elevation area.

$$20\log \frac{1/2 h_1}{h_1} = -6\,dB.$$

Cochannel Interference :

* The frequency-re method is useful for increasing the efficiency of spectrum usage but result in cochannel interference because the same frequency channel is used repeatedly in different cochannel cells.

* Application of the cochannel interference reduction factor $q = D/R = 4.6$ for a seven-cell reuse pattern $(k=7)$.

* In most mobile radio environments, use of a seven cell reuse pattern is not sufficient to avoide co channel interference.

Test 1 : find the cochannel interference area from a mobile receiver

Determination of C/I in a directional antenna system.

(a) worst case in a 120 directional antenna system (N=7)

(b) worst case in a 60 directional antenna systems (N=7)

(b)

(a)

C/I (worst case) = 285 (=) 24.5 dB

Directional antenna in k=4 cell pattern :-

Three sector case :- To obtain the carrier - to - interference ratio, we use the same procedure as in the k = 7 cell - pattern system.

$$C/I \text{ (worst case)} = \frac{1}{(q+0.7)^{-4} + q^{-4}} = 97 = 20\,dB$$

Six - sector case :- There is only one interferer at a distance D + R shown in below figure.

we can obtaine $q = 3.46$

$$C/I \text{ (worst case)} = \frac{R^{-4}}{(D+R)^{-4}} = \frac{1}{(q+1)^{-4}} = 355 = 26\,dB$$

Interference with frequency reuse pattern K=4

Lowering the Antenna Height :-

On a high hill or a high spot :-

* The effective antenna height, rather than the actual height, is always considered in the system design
* Therefore, The effective antenna height varies according to the location of the mobile unit.
* when the antenna site is on a hill, as shown in the below figure.

(a)

Unit - III

Cell coverage for signal and traffic

Signal Reflections in flat and hilly terrain

The ground incident angle and the ground elevation angle over a communication link are described as follows. The ground incident angle θ is the angle of wave arrival incidentally pointing to the ground as shown in fig 1.1 The ground elevation angle is the angle of wave arrival to the mobile unit as shown in fig 1.1.

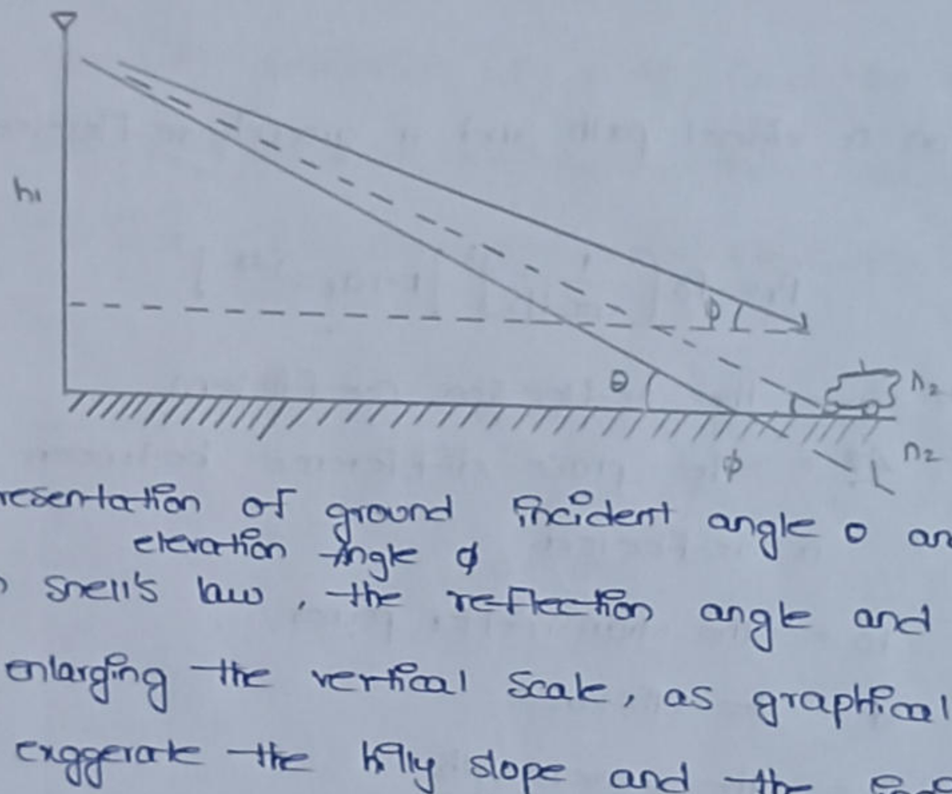


Figure: Representation of ground incident angle θ and ground elevation angle φ

Based on Snell's law, the reflection angle and incident angle by enlarging the vertical scale, as graphical display we usually exaggerate the hilly slope and the incident angle by enlarging the vertical scale, as shown in fig 1.2. Then as long as the actual hilly slope in less than 10°, the reflection point on hilly slope can be obtained by following the same method.

fig: A model propogation over water

of point-to-point: standard deviation along a path-loss slope in

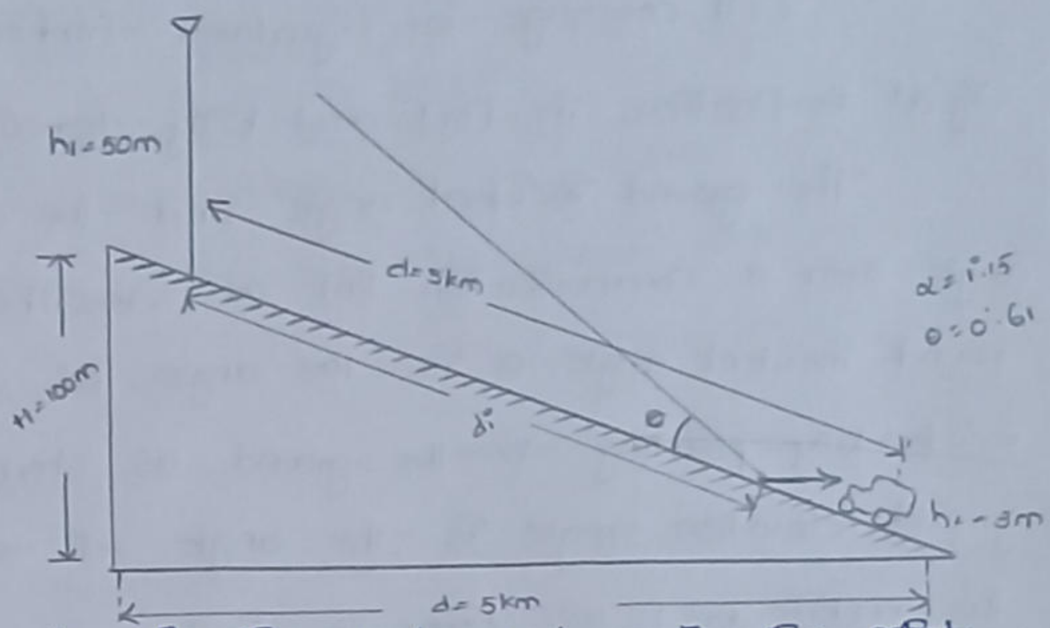


Fig: Ground reflection angle and reflection point

phase difference between the direct path and Reflected path :-

Based on a direct path and a ground reflected path the equation.

$$P_r = P_0 \left[\frac{1}{4\pi d/\lambda}\right]^2 \left|1 + a_v e^{j\Delta\phi}\right|^2$$

Where a_v = the reflection coefficient

$\Delta\phi$ = the phase difference between a path and a reflected.

P_0 = the transmitter power

d = the distance

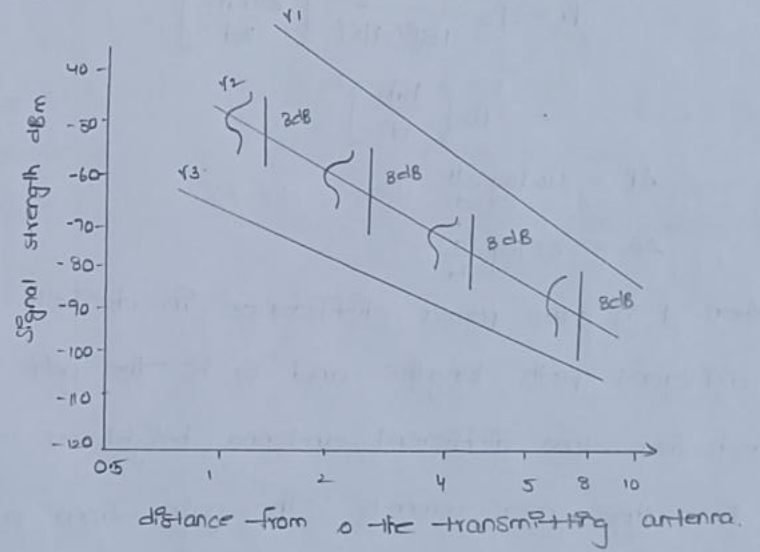
λ = the wavelength.

Indicates a two-wave model which is used to understand the path-loss phenomenon in a mobile radio environment. It is not the model for analyzing the multipath fading phenomenon. In a mobile environment $a_v = -1$ because of the small incident angle.

Constant standard deviation along a path-loss slope

When plotting signal strengths at any given radio-path distance, the deviation from predicated value. is approximately this standard of 8 dB is roughly true in many different areas. The explanation is as follows. when a line-of-sight path exists. both the direct wave path are created and an strong when an out-of-sight path exists, both the direct wave path we weak. In either case, according to the theoritical model, the 40-dB/dec path loss slope applies. The difference between these two

The standard deviation of 8 dB from the measured data near the cell site due mainly to the close-in buildings around the cell site. The same standard deviation from the measured data.



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

$$= P_0 \frac{2}{(4\pi d/\lambda)^2}(1-\cos\Delta\phi)$$

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

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

and Δd is the difference,

$\Delta d = d_1 - d_0$, from fig 4.4

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

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

Since Δd is much smaller than either d_1 or d_2

$$\Delta\phi = \beta\Delta d = \frac{2\pi}{\lambda}\frac{2h_1h_2}{d}$$

Then the received power of Eq(4.2.3) becomes

If $\Delta\phi$ is less than 0.6 rad, then $\sin(\Delta\phi/2) \simeq (\Delta\phi/2)$, $\cos(\Delta\phi/2) = 1$

$$P_r = P_0\frac{4}{16\pi^2(d/\lambda)^2}\left[\frac{2\pi h_1h_2}{\lambda d}\right]^2$$

$$= P_0\left[\frac{h_1h_2}{d^2}\right]^2$$

$$\Delta P = 40\log\frac{d_1}{d_2}$$

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

When P is the power difference in decibels between two different path lengths and G is the gain in decibels obtained from two different antenna height at the cell site. From these measurements, the gain from a mobile antenna height is only 3 dB/oct,

$$\Delta G' = 10\log\frac{h_2'}{h_2}$$

Merits of point-to-point model

The area to area model usually provides an accuracy of prediction standard deviation of 8 dB, which means that 68 percent and the actual path-loss data are within the ±8 dB of predicted value. The uncertainty range is too large. The point-to-point models reduces the uncertainty range by including the detailed terrain contour information in the path-loss predictions.

The point-to-point prediction model is basic tool that is used to generate a single coverage map, an interface area map, a handoff occurence map, or an optimum system design configuration to name a few applications.

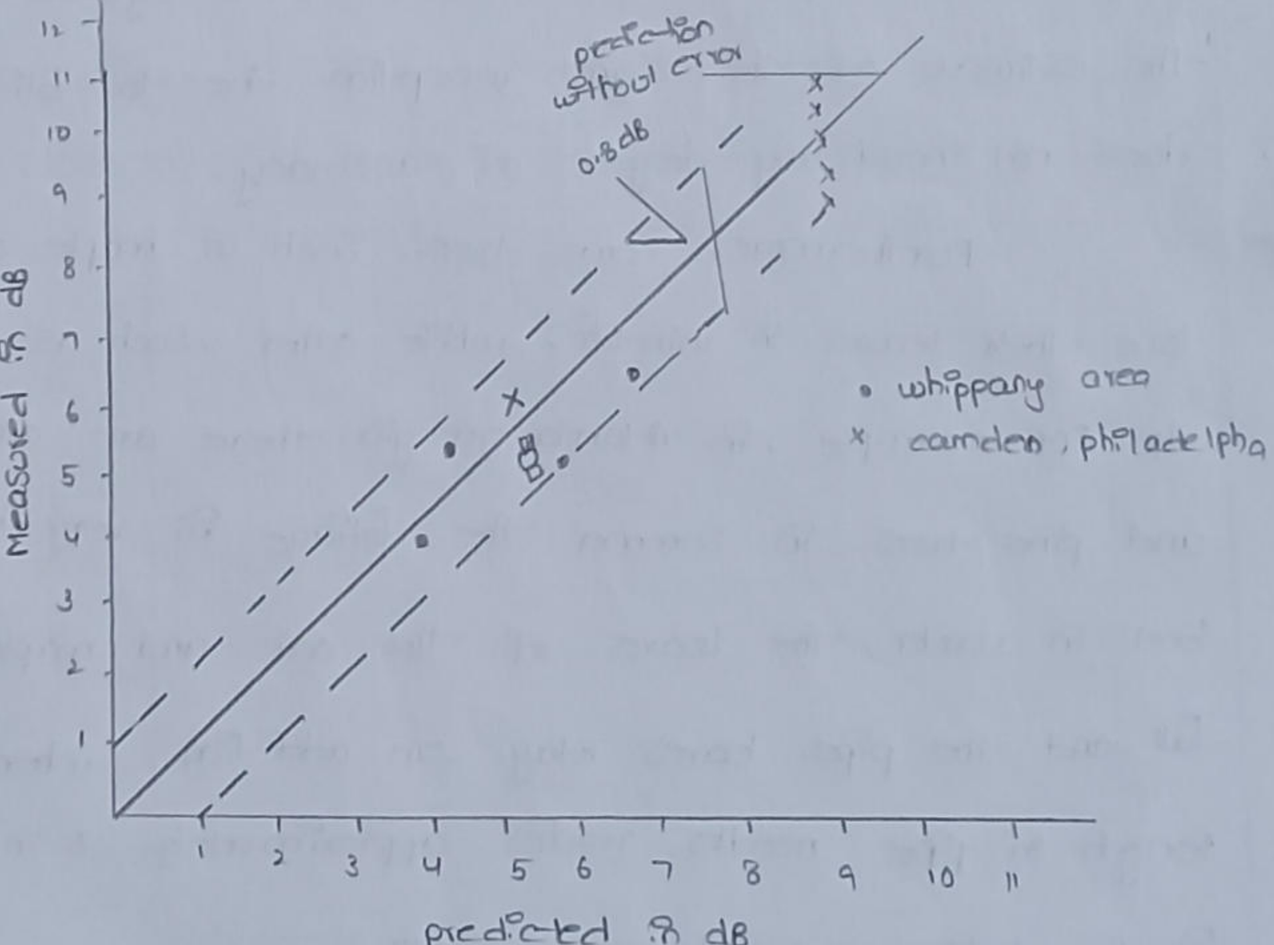


Fig: Indication of errors in point-to-point predictions under non-obstructive conditions.

Foliace Loss

Foliace loss is very complicated topic that has many parameters and variations. The size of leaves, branches, and truck the density and distribution of leaves, branches, and truck, and the height of tree relative to the antenna heights all be considered. An illustration of this pvlem. There are three levels, think, branches and leaves. In each level, there is a distribution. of sizes of trucks, branches. and leaves and also of the density and spacing between adjacent trock, branches, and leaves. the texture and thickness of the leaves also count. this unique problem can become very complicated and is beyond the scope of this book. For a system design the estimate of the signal reception due to foliage loss does not need any degree of accuracy.

Furthermore, Some trees, Such as maple or oak, lose their leaves in winter, while other, Such as pipe, never, do. For example, in Atlanta georgia, there are oak, maple and pine trees, in Summer the foliage is very heavy, but in water, the leaves of the oak and maples trees fall and the pipe leaves stay. In addition, when the length of pipe needles reaches approximately 6 in. which is the half wavelength at 80 MHz.

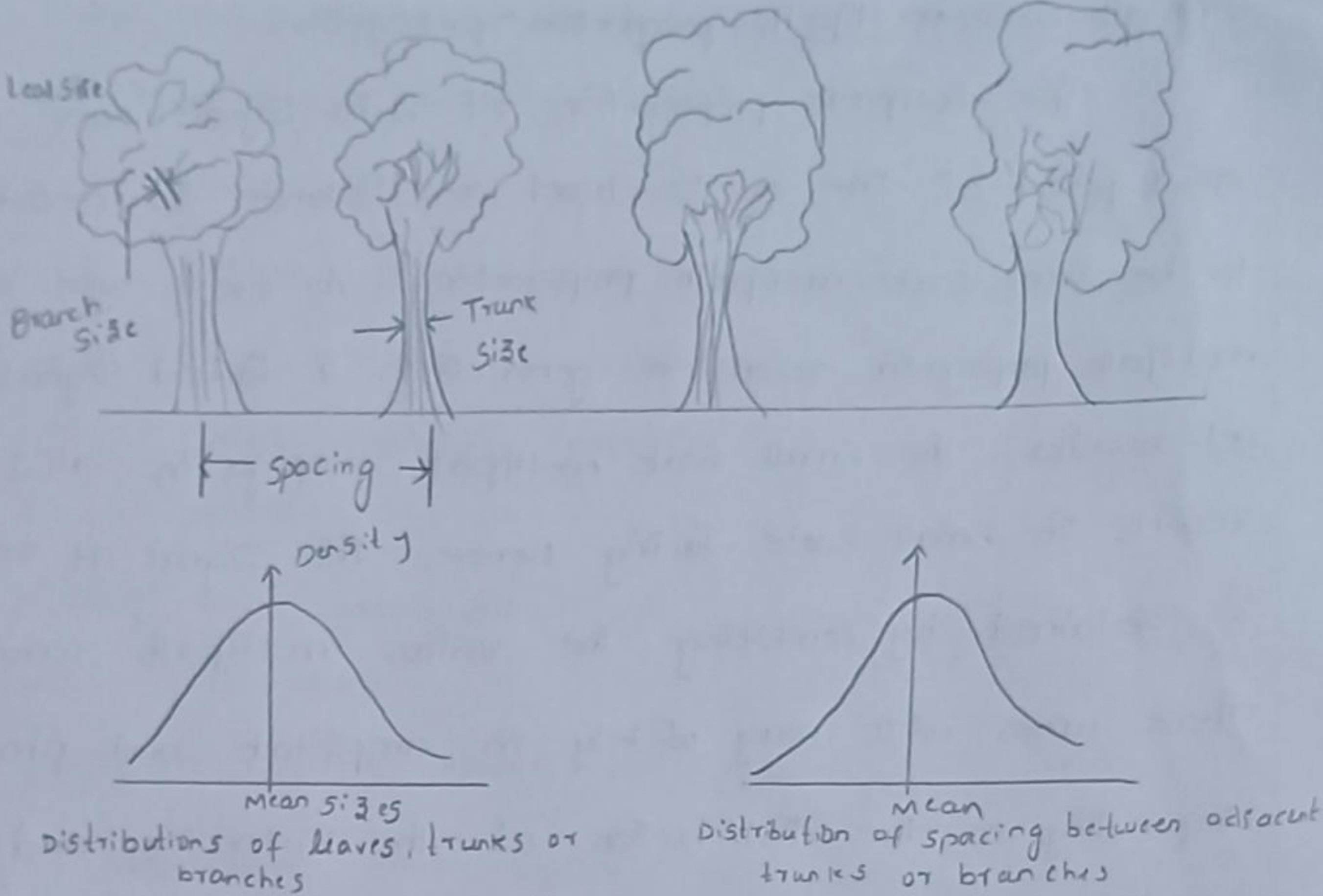


Fig : A characteristic of foliage environment

The situation would be the case if the foliage would line up along the radio path. A foliage loss in a suburban area 58.4 dB/dec. As demonstrated from the above two examples close in foliage at the transmitter site always.

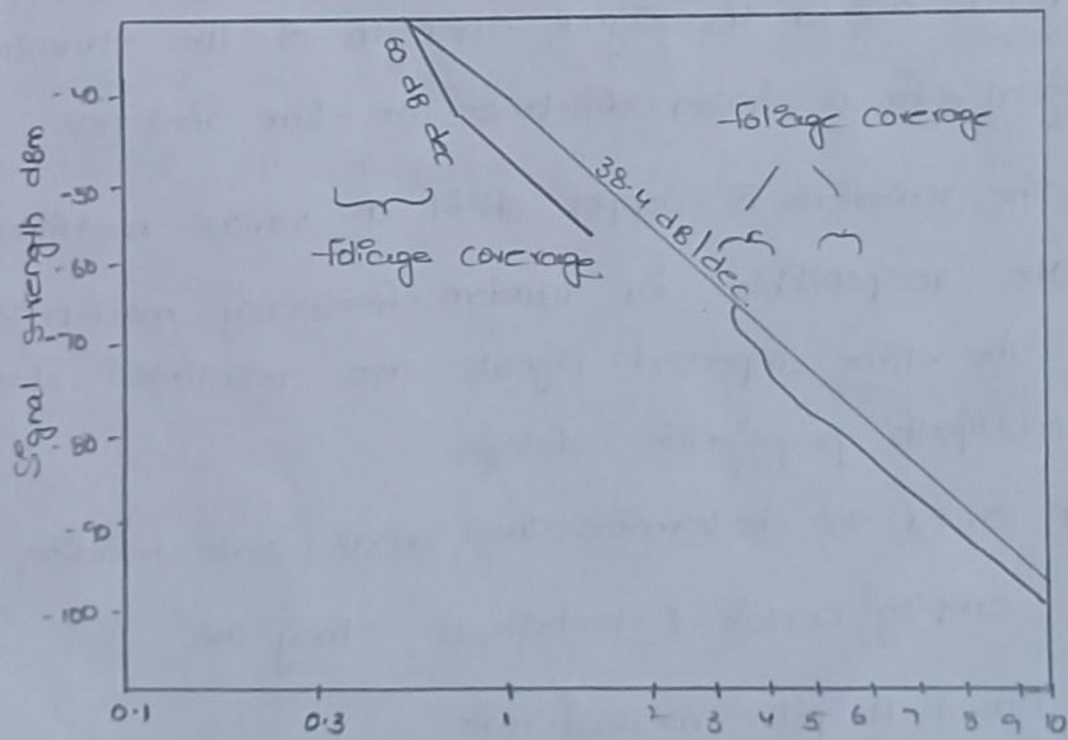


Fig: Foliage loss calculation in suburban areas.

Small Scale multipath propagation " propogation

The multipath propogation of radio signals over a short period of time or to travel a distance is considered to be small scale multipath propogation. As every type of multipath propogation results in generating a faded signal at receiver, the small scale multipath propogation also results in small scale fading Hence, the signal at receiver is obtained by combining the various multipath waves. These waves will vary widely in amplitude and phase depending on the distribution of the intensity and relative propogation time of waves and bandwidth of the transmitted signal.

The three fading effects are generally observed due to the small scale multipath propogation are,

1. Fast variation in signal strength of the transmitted signal for a lesser distance or time interval.
2. The variations is doppler shift on various multiple signals are responsible for random frequency modulation.
3. The time dispersed signals are resulated due to multipath propogation delays.

In order to determine the small scale fading effects, we employ certain techniques. they are

D. Direct RF pulse measurement

C spread spectrum sliding correlation measurement

The third technique is helpful the impulse response of the channel in frequency domain.

G Direct Rf pulse measurement

H Spread spectrum sliding correlation measurement.

I Swept frequency measurement.

The first technique provides a local average power delay profile.

Effect of propogation of Mobile signals over water and flat Area

propogation over water or flat open area;

propogation over water or flat open area is becoming a big concern because it is very easy to interfere with other cells if we do not make the correct arrangements. Interference resulting from the propogation over the water can be controlled if we know the cause. In general the permittivity's εr of seawater and fresh water ar the same, but the conductivities of seawater & fresh water are different.

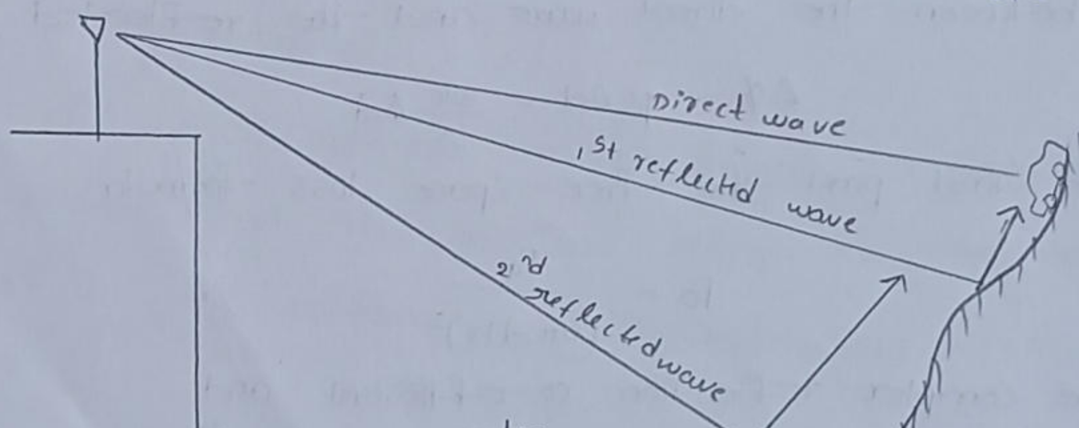
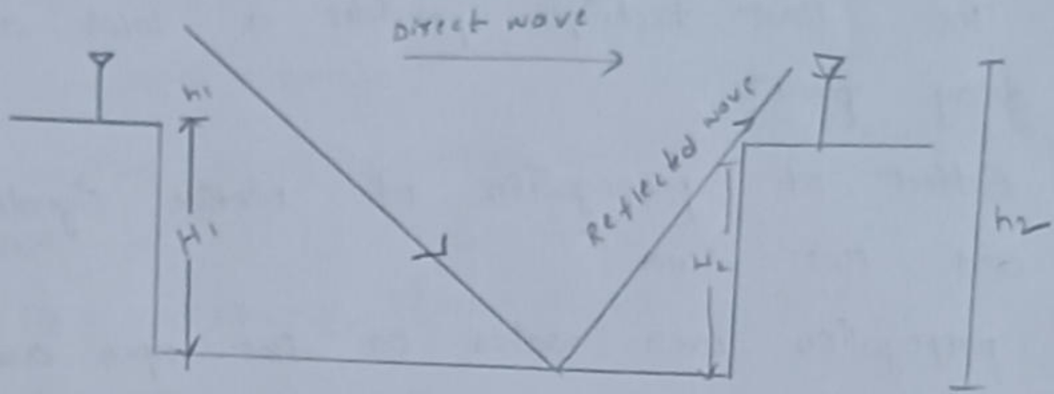


fig: A model propogation over water

Between fixed Stations:

The point-to-point transmission between the fixed stations over the water or flat open land can be estimated as follows. The received power P_r can be expressed as (see fig 10.2)



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

Where P_t = transmitted power

d - distance between two stations.

λ = wavelength

$a_v \phi_v$ = amplitude and phase of a complex reflection coefficient, respectively.

ϕ is the phase difference caused by the path difference Δd between the direct wave and the reflected wave, or

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

The first part the free-space loss formula

$$P_0 = \frac{P_t}{(4\pi d/\lambda)^2}$$

The complex reflection co-efficient and

$$a_v e^{-j\phi_v} = \frac{\epsilon_c \sin\theta_1 - (\epsilon_c - \cos^2\theta_1)^{1/2}}{\epsilon_c \sin\theta_1 + (\epsilon_c - \cos^2\theta_1)^{1/2}}$$

Mobile -to-mobile propagation

path in this case is usually obstructed by building and obstacles between the transmitter and receiver. The propagation channel acts like a filter with a time varying function $H(f,t)$.

$$a(t) = u(t)e^{j\omega t}$$

Two receiver signal at the mobile unit M_2 from an ith path is

$$S_t = r_i u(t-\tau_i) e^{j[(\omega_0 + \omega_0 + \omega_a)(t-\tau) + \phi]}$$

where $u(t)$ = signal

ω_0 = RF carrier

r_t = Rayleigh - distributed random variable

ϕ_i = uniformly distributed random phase

τ_i = time delay on ith path

and

ω_{1i} = Doppler shift of transmitting mobile unit on ith path

$= \frac{2\pi}{\lambda} v_1 \cos \alpha_{1i}$

ω_{2i} = Doppler shift of receiving mobile unit on ith path

$= \frac{2\pi}{\lambda} v_2 \cos \alpha_{2i}$

where α_{1i} and α_{2i} are random angles as shown in

Now assume that the received signal is the summation of n paths uniformly distributed around the azimuth

When the vertical incidence is small θ, is very small and

$a_v \approx -1$ and $\phi_v = 0$

It can be found from equation ϵ_c is a dielectric constant that is different for different media.

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

$$= P_0 (2 - 2\cos\Delta\phi)$$

Since ϕ is a function of d and d can be obtained from the following calculation.

$$h_1' = h_1 + H_1$$

The effective antenna height at antenna 2 is the height above the sea level.

$$h_2' = h_2 + H_2$$

As shown in fig 10.2 where h_1 and h_2 are actual heights and H_1 and H_2 are the heights of hills. In general both antennas at fixed stations.

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

Since $d > h_1'$ and h_2' then

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

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

then

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

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

Separation of cell-site receiving Antennas

$$S_r = \sum_{i=1}^{n} S_i(t) = \sum_{i=1}^{n} r_i u(t - T_i)$$

$$\times \exp\{j(\omega_0 + \omega_{1i} + \omega_{2i})(t - T_i + \phi_i)\}$$

$$= \sum_{i=1}^{n} Q(a_i, t)\, u(t - \tau_i)\, e^{j\omega(t-\tau_1)}$$

where

$$Q(a_i, t) = \tau_i \exp\{j(\omega_{1i} + \omega_{2i})t + \phi_i)\}$$

$$\phi_i' = \phi - (\omega_{1i} + \omega_{2i})\tau_1$$

Cellsite and mobile Antennas

Two-branch space-diversity antennas are used the cell site to receive the same signal with different fading envelops, one at each antenna. the degree of correlation between two fading developers is determined by the degree of separation between two receiving.

$$\eta = h/D = 11 (8.13-1)$$

Where h is the antenna height and D is the antenna separation.

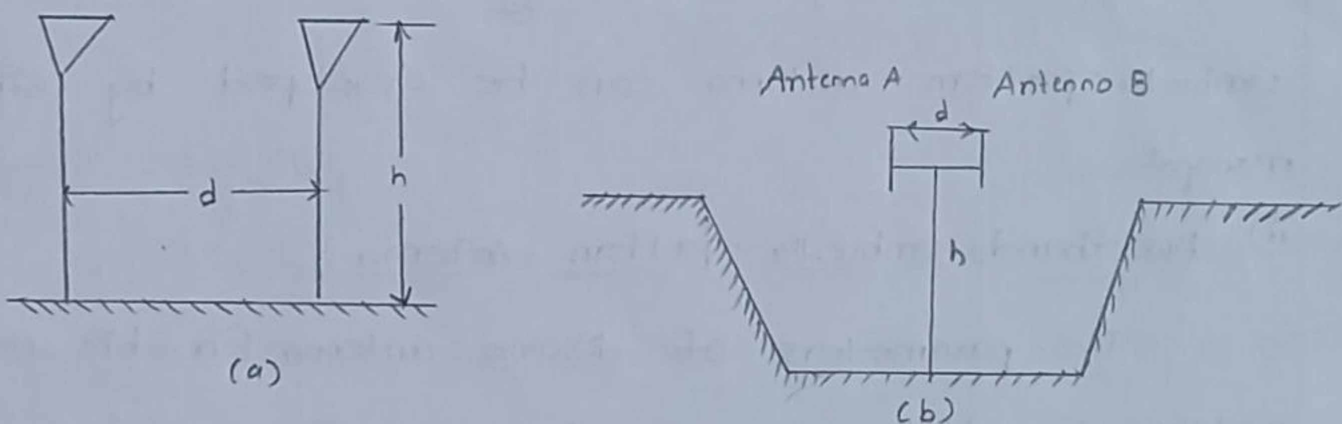
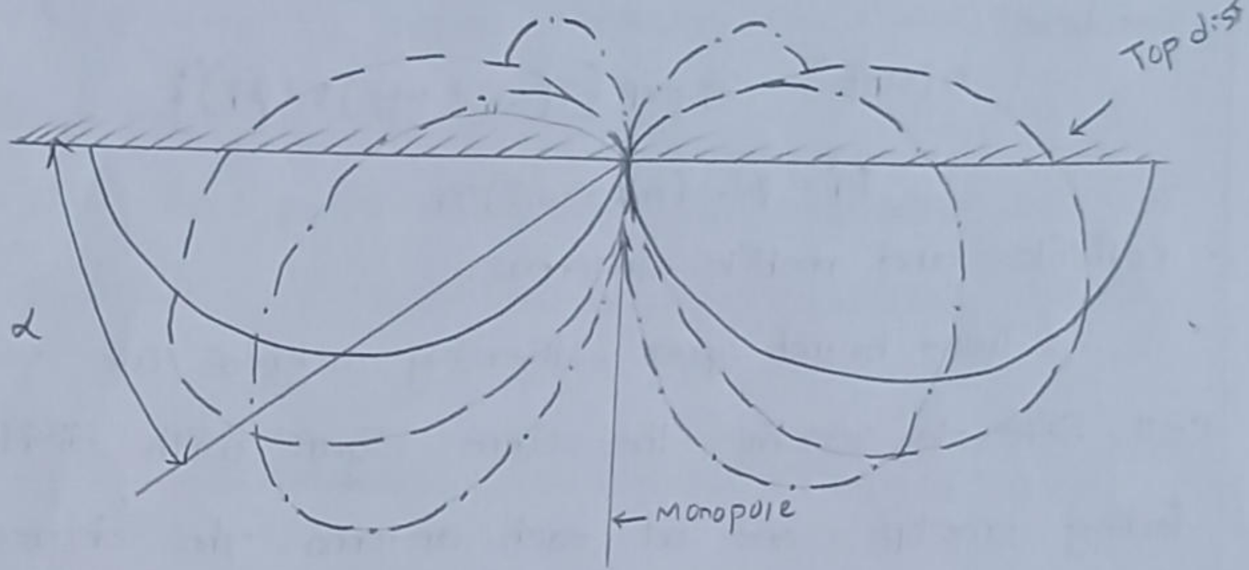


Fig: Diversity antenna spacing at cell site
(a) $n = h/d$
(b) proper arrangement with two antennas

Umbrellas - pattern - Antennas

In certain situations, umbrella-pattern antenna should be used for the cell-site antennas.



vertical-plane patterns pad of quarter-wavelength stub antenna on infinite ground plane and on finite ground planes.

i) Normal umbrella-pattern Antenna :-

For controlling the energy in a confined area, the umbrella-pattern antenna can be developed by using monopole.

ii) Broadband umbrella-pattern Antenna :

The parameters of discone antenna (a bi conical antenna in which one of the cones is executed to 180° to form) are shown in fig.

Minimum Separation of cell-site receiving Antennas

Separation between two transmitting antennas should be minimized to avoid the inter modulation. The minimum separation between a transmitting antenna and receiving antenna is nessa necessary to avoid receiver desensitization. Here we are describing.

If the power difference is excessive, use of space diversity will have no effect reducing fading

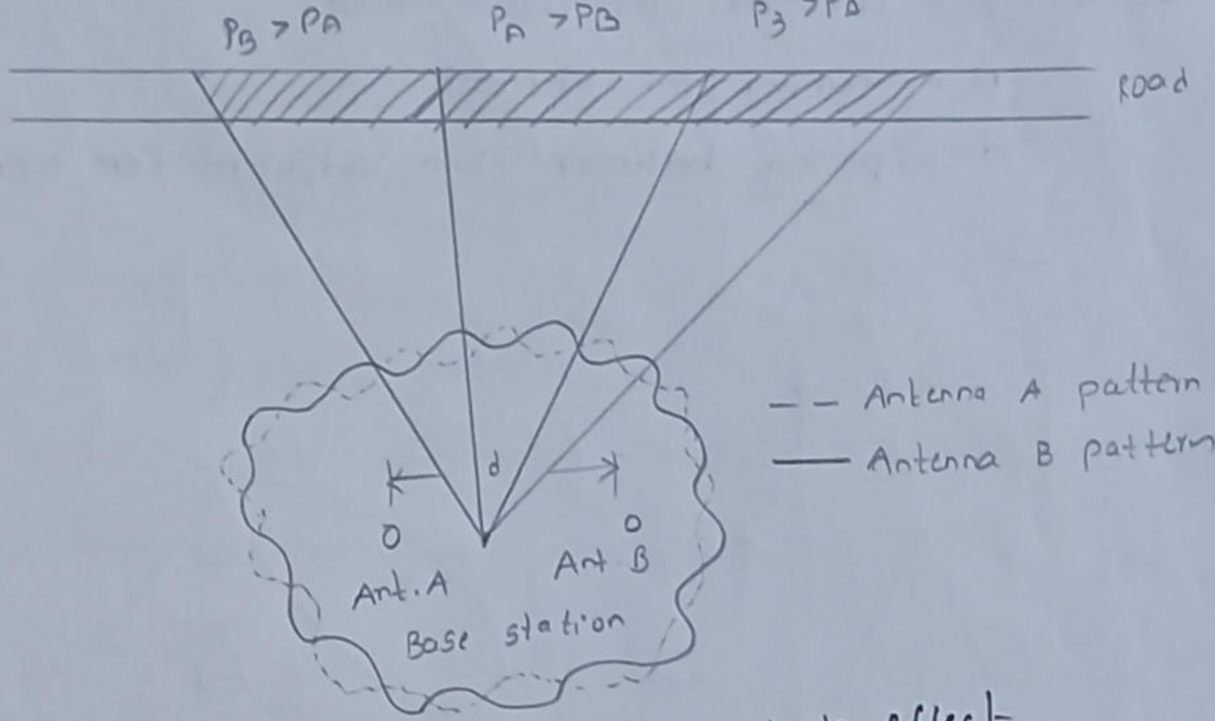


Fig : Antenna pattern ripple effect

mobile antennas :

The requirement of a mobile antenna is an omni-directional antenna that can be located as high as possible from the point of receives. However the physical limitation of antenna height on the vehicle restricts this requirement

iii) Interference reduction Antenna:

A design for antenna configuration that reduces interference in two critical directions is shown in fig

iv) High - gain broadband umbrella- pattern Antenna

A high - gain antenna can be constructed by vertically stacking a number of umbrella pattern antennas

$$E_0 = \frac{\sin((Nd/2\lambda)\cos\phi)}{\sin[(d/2\lambda)\cos\phi]}$$ (individual umbrella pattern)

where ϕ = direction of wave travel

N = number of elements

d = spacing between two adjacent cen elements

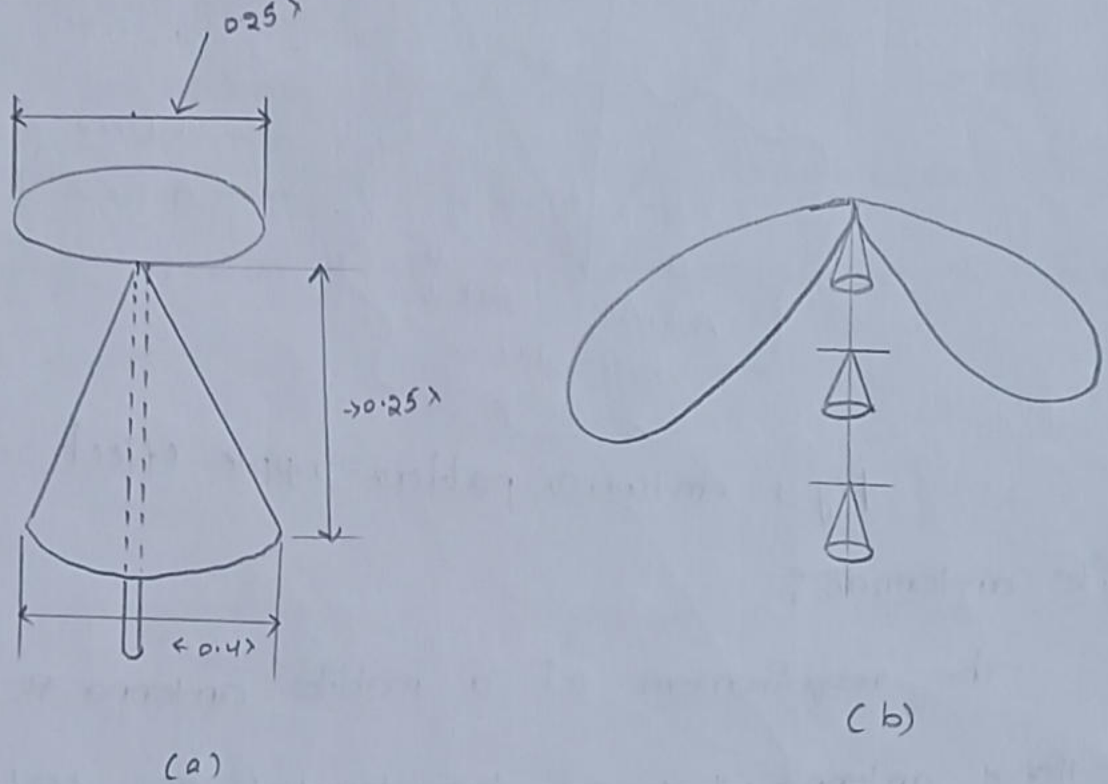
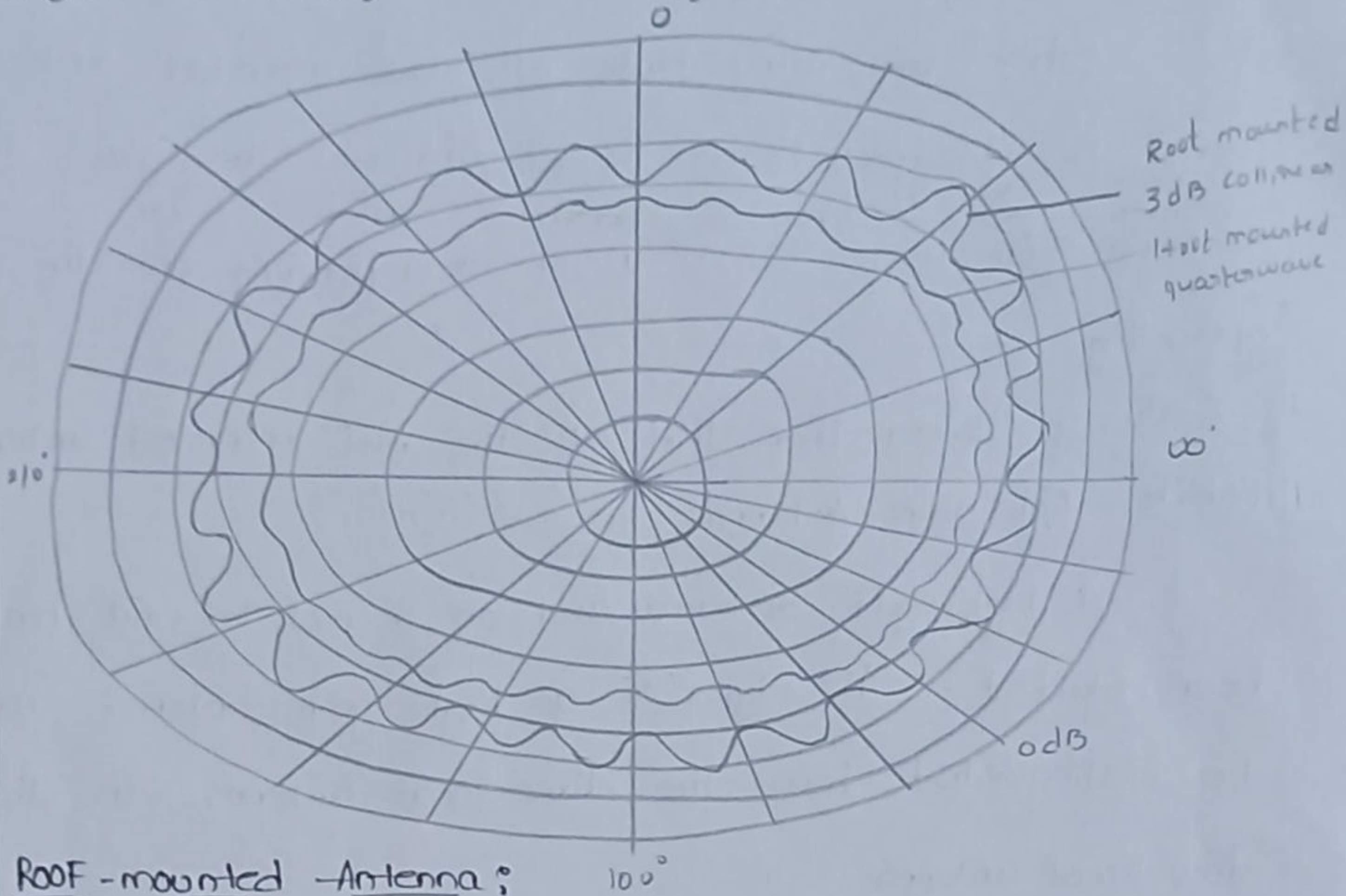


Fig : Discone antenas (a) Single Antenna

(b) An Array of Antenna

mobile Antennas:



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 dBgain.

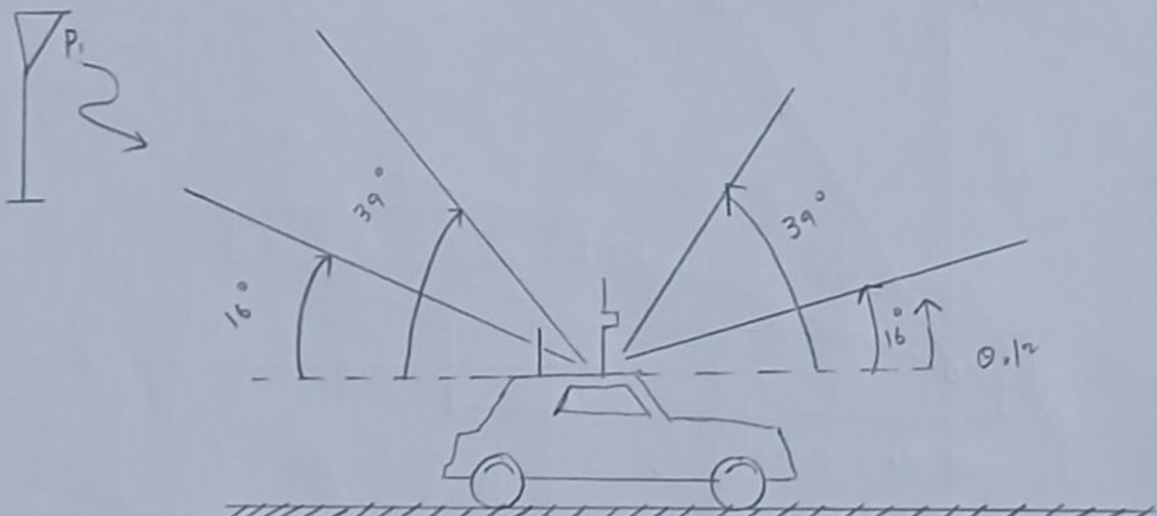


fig: Vertical angle of signal arrival

Glass - mounted - Antennas

There are many kinds of glass-mounted antennas. Energy is dissapated on passes through the glass. The antenna gain range is to 1 to 3dB depending on the operating.

always lower than that of the roof-mounted antenna.

mobile - High - gain - Antennas

A high-gain antenna and on a mobile unit has been studied. This type of high-gain antenna should be distinguished from the directional antenna. In the directional antenna