UNIT-I

CELLULAR MOBILE RADIO SYSTEM

Introduction to Cellular Mobile Systems

Limitations of conventional mobile telephone systems

One of many reasons for developing a cellular mobile telephone system and deploying it in many cities is the operational li8mitations of conventional mobile telephone systems:
1.limited service capability
2. poor service performance
3. Inefficient frequency spectrum utilization.

1. Limited service capability:

A conventional mobile telephone system is usually designed by selecting one or more channels from a specific frequency allocation for use in autonomous geographic zones, as shown in Fig.1. The communications coverage area of each zone is normally planned to be as large as possible, which means that the transmitted power should be as high as the federal specification allows. The user who starts a call in one zone has to reinitiate the call when moving into a new zone (see Fig.1) because the call will be dropped. This is an undesirable radio telephone system since there is no guarantee that a call can be completed without a handoff capability.

The handoff is a process of automatically changing frequencies as the mobile unit moves into a different frequency zone so that the conversion can be continued in a new frequency zone without redialing. Another disadvantage of the conventional system is that the number of active users is limited to the number of channels assigned to a particular frequency zone.

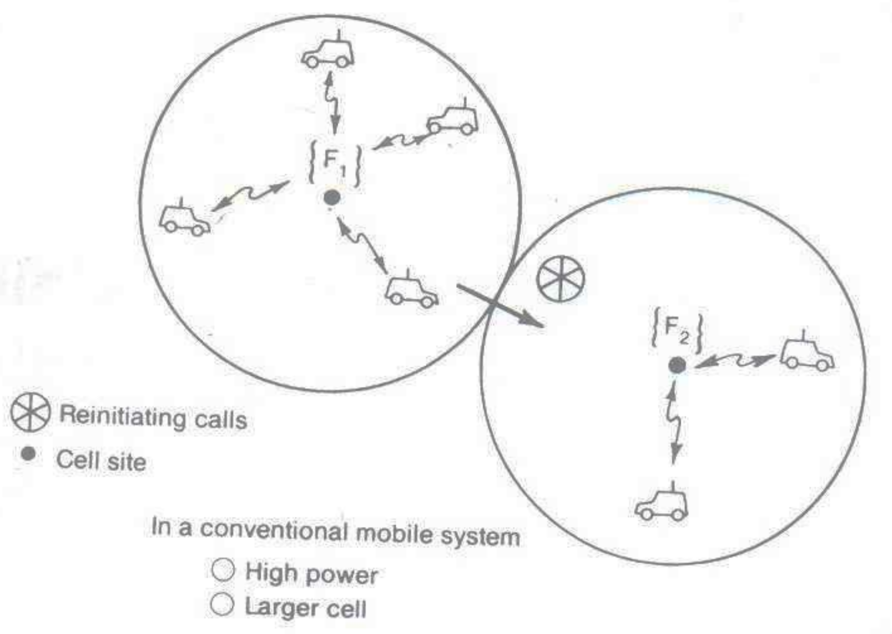


Figure 1.1 Conventional mobile system.

Poor service performance:

In the past, a total of 33 channels were allocated to three mobile telephone systems: Mobile Telephone Service (MTS),Improved Mobile Telephone Service (IMTS) MK systems.MTS operates around 40MHz and MJ operates at 150 MHz; both provide 11 channles;IMTS MK operates at 450 MHz and provides 12 channels. These 33 channels must cover an area 50 mi in diameter. In 1976, New York City had 6 channels of MJ serving 320 customers, with another 2400 customers on a waiting list. New York City also had 6 channels of MK serving 225 customers, with another 1300 customers on a waiting list. The large number of subscribers created a high blocking probability during busy hours. The actual number of blocking probability during busy hours. The actual number of blocking will be shown later. Although service performance was undesirable, the demand was still great. A high-capacity system for mobile telephones was needed.

Inefficient frequency spectrum utilization:

In a conventional mobile telephone system, the frequency utilization measurement M_0 is defined as the maximum number of customers that could be served by one channel at the busy hour. Equation (1.1-1) gives the 1976 New York City data cited earlier.

$$M_0 = \frac{no.of\ customers}{channel} : (conventional\ systems) \qquad (1.1-1)$$

Or

$$M_0 = \begin{cases} 53\ customers / channel & (MJ\ system) \\ 57\ customers / channel & (MK\ system) \end{cases}$$

Assume an average calling time of 1.76 min and apply the Erlang B model (lost-calls-cleared conditions). Calculate the blocking probability as follows: Use 6 channels, with each channel serving the two different numbers of customers shown in Eq. (1.1-1). The offered load can then be obtained by Eq. (1.1-2).

$$A = \frac{av\ calling\ time\ (\min utes) \times total\ customers}{60\ \min}\ erlangs \qquad (1.1-2)$$

$$A_1 = \frac{1.76 \times 53 \times 6}{60} = 9.33\ erlangs \qquad (MJ\ systems)$$

$$A_2 = \frac{1.76 \times 37 \times 6}{60} = 6.51\ erlangs \qquad (MK\ systems)$$

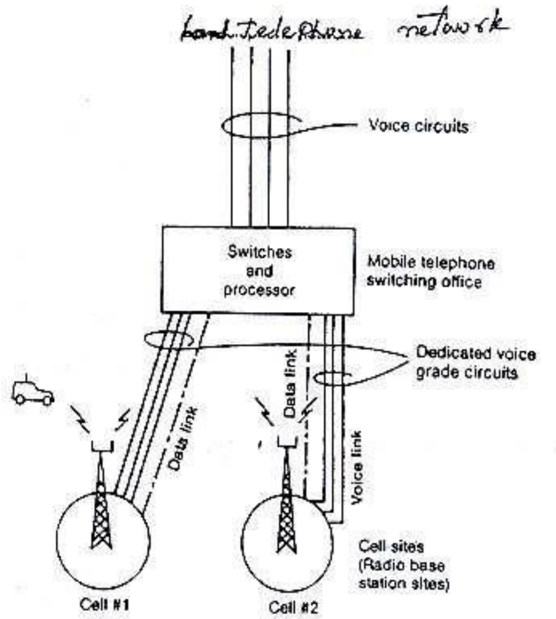
Given that the number of channels is 6 and the offered loads are $A_1 = 9.33$ *and* $A_2 = 6.51$,read from the table in Appendix 1.1 to obtain the blocking probabilities $B_1 = 50$ % (MJ system) and $B_2 = 30$ % (MK system), respectively. It is likely that half the initiating calls will be blocked in the MJ system, a very high blocking probability.

If the actual average calling time is greater than 1.76 min, the blocking probability can be even higher. To reduce the blocking probability, we must decreases the value of the frequency spectrum utilization measurement M_0 as shown in Eq. (1.1-1)

As far as frequency spectrum utilization is concerned, the conventional system does not utilize the spectrum efficiently since each channel can only serve one customer at a time in a whole area. A new cellular system that measures the frequency spectrum utilization differently from Eq. (1.1-1)

Basic Cellular system

A basic cellular system consists of three parts: a mobile unit, a cell site, and a mobile telephone switching office (MTSO) as shown in the following figure shows, with connections to link the three subsystems



A general view of cellular Telecommunications systems

***Mobile unit*:** Contain a control unit, a Trans receiver and an antenna system.

***Cell site*:** this is an interface unit between the MTSO and the mobile units. It is also having control unit, radio cabinets, Antennas, a power plant and data terminals.

***MTSO*:** is a central coordinating element for all sites. It contains the cellular processor and cellular switch. It control call processing, interfaces with voice circuits of telephone network, billing activities etc.

***Connections*:** The radio and high speed data links connect the above three sub-systems. Each mobile unit can only use one channel at a time for its communication link. But the channels is not fixed, it can be any one in the entire band assigned by the serving area. Each cell site having multi-channel capabilities can be connected simultaneously too many mobile units.

The MTSO is the heart of the cellular mobile system. Its processor provides central coordination and cellular administration. The cellular switch (analog or digital), switches calls to connect mobile subscribers to other mobile subscribes and to telephone network. It uses the voice trunks to telephone company interoffice voice trunks. It also contains data links providing supervision links between the processor and the switch and between the cell sites and the processor. The radio link carries the voice and signaling between the mobile unit and the cell site. The high-speed data links cannot be transmitted over the standard telephone trunks and therefore must use either microwave links or T-carries (wire lines). Microwave radio links or T-carries carry both voice and data between the cell site and the MTSO

Performance criteria

The performance criteria can be specified in the following three categories.

1.Voice Quality:

Voice quality is very hard to judge and can be judged by subjective test from user's opinions. The voice quality is based on a set value x at which y percent of customers rate the system voice quality (from transmitter to receiver) as good or excellent and the circuit merits (CM) are listed below:

CM	SCORE	QUALITY SCALE
CM - 5	5	Excellent (perfectly understandable)
CM - 4	4	Good (speech understandable, some Noise)
CM - 3	3	Fair (understandable with occasional repetitions)
CM - 2	2	Poor (understandable only with effort)
CM - 1	1	Unsatisfactory (not understandable)

If the customers choose CM - 4 and CM - 5, the cost of the system increases. The CM score is the mean opinion score (MOS) from all the listeners and usually MOS score is around **MOS $\geq$ 4.**

2.Service Quality

The service quality of a cellular system is decided by three factors, they are

1. Coverage
2. Required grade of service
3. Number of dropped calls.

1. Coverage:

The cellular system must cover a large area for good service quality. But due to improper terrain structures it is not possible to serve the complete area for two reasons.

(i) In order to illuminate weak spots in the coverage area with adequate reception of high transmitted power is required. This requirement adds cost factor.

(ii) As the transmitted power increases the ability to control interference decreases. Hence, systems generally serve 90 percent of an area in flat terrain and 75 percent of an area in hilly terrain.

The criteria of both voice quality and coverage in AMPs cellular system assert that,

(i) In flat terrain conditions, 75 percent users rank the voice quality as good or excellent in 90 percent of an area covered.

(ii) In hilly terrain conditions 90 percent of users must rank the voice quality as good or excellent in 75 percent of an area covered.

The percentage values of voice quality and coverage can be adjusted according to various terrain conditions.

Uniqueness of Mobile Radio Environment

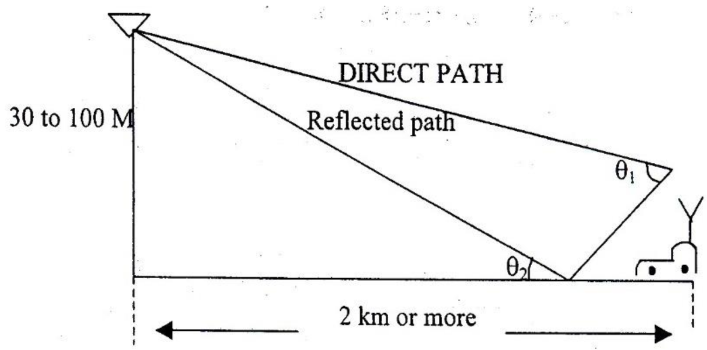
1. Description of mobile radio transmission medium.

In mobile radio transmission medium, we need to consider two parameters for good line- of-sight propagation, they are

1. Propagation attenuation 2. Fading

1. ***Propagation Attenuation*** *there is a loss in signal power as the radio wave propagates from* cell site to mobile unit, this loss is known as propagation attenuation or propagation path loss. This increases with increase in distance between cell site and mobile unit.

Figure (a) shows the direct path and reflected path of a signal propagating from cell site to mobile unit. The angles θ_1 and θ_2 represent the incident angles of direct wave and reflected wave respectively. The angle θ_1 is also known as elevation angle. The angles and θ_2 are very small if the height of antenna at cell site is between 30 to 100m, height of antenna at mobile unit is around 3 m and the distance between cell site and mobile unit is 2km.



A propagation path loss of 40 dB/dec is a general rule for the mobile radio environment, where dec is a short form of decade. That is the receiver of the mobile unit perceives a loss 40 dB, when it moves from 1 to 10km.

Hence, C is inversely proportional to $R^{4.}$

$$C \alpha \frac{1}{R^4}$$

$$C \alpha \frac{\alpha}{R^4}$$

$$\boxed{C = \alpha R^{-4}} \qquad - \qquad (1)$$

Where,

- α = constant
- R^4 = Distance between transmitter and receiver
- C= Received carrier power

If C_1 is power received at a distance R_1 and

C_2 is power received at a distance R_2 then,

C= α R_2^{-4}

C= α R_1^{-4} and

$$\frac{C_2}{C_1} = \left(\frac{R_2}{R_1}\right)^{-4} \qquad - \qquad (2)$$

The difference in power reception is obtained by equation (2) in decibels as,

$$\Delta C(in\ dB) = C_2 - C_1(in\ dB)$$

$$= 10\log\frac{C_2}{C_1} = 40\log\frac{R_1}{R_2} \qquad - \qquad (3)$$

$$\Delta C = -12dB,\ \ when\ R_2 = 2R_1$$

$$\Delta C = -40dB,\ \ when\ R_2 = 10R_1$$

The propagation attenuation in real mobile radio environment is given as,

$C\alpha\ R^{-\gamma}$

C= α $R^{-\gamma}$ --- (4)

The value of γ(gamma) varies between 2 and 5 based on the conditions of environments. In free space condition the value of γ is 2.

Equation (4) can be written in decibel scale as,

$$C = 10\log a - 10\gamma\log R \qquad - \qquad (5)$$

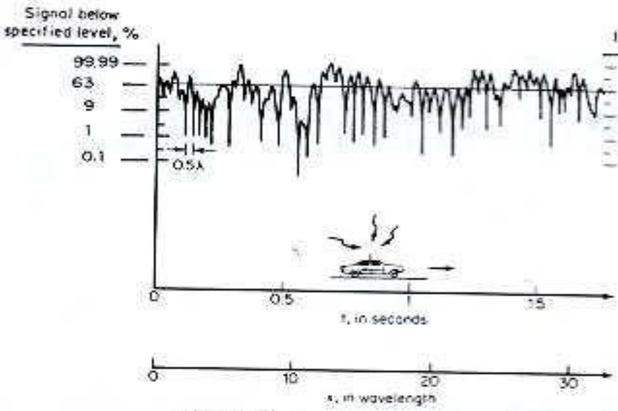
Fading:

The rapid fluctuations of the amplitudes, phases or multipath delays of a radio signal over a short period of time or travel distance is known as fading.

In radio propagation multipath waves are generated due to,

1. Lower antenna height of mobile unit compared to its surroundings.
2. Much less wavelength of carrier frequency compared to its surrounding structures.

This multipath components combine vectorially at the receiver antenna and causes the signal received by the mobile to fade. Figure shows the nulls of the fluctuation at the baseband and an amplitude fading of 10dB above the average signal and 30dB below the average signal is noticed. If the speed of the mobile unit increases the rate of fluctuations also increases.



R level, dB	$\bar{n}_R$	$\bar{t}_R$
10	0.00014	7142.14
0	0.36788	1.71
-10	0.28593	0.31476
-20	0.1	0.1
-30	0.03157	0.03168

(from Fig. 1.10)

$p(R) = Re^{-R^2}$ cumulative probability distribution

$\bar{n}(R) = \frac{\beta V}{\sqrt{2\pi}} \times n_R$ level crossing rate

$\bar{t}(R) = \frac{\sqrt{2\pi}}{\beta V} \times \bar{t}_R$ average duration of fades

Figure A typical fading signal received while the mobile unit is moving.

Model of Transmission Medium

Depending on natural physical phenomena, a mobile radio signal r(t) shown in figure (a) is mathematically described as,

$$r(t) = m(t) r_0(t) \qquad - \qquad (1)$$

Where the component m (t) is known as local mean or long-term fading or log normal fading, this occurs due to path loss of signal as a function of distance and shadowing by large objects such as hills. The component r_0 (t) is known as multipath fading (or) short-term fading (or) Rayleigh fading, this occurs due to constructive and destructive interference of the multiple signal paths between transmitter and receiver. The expression for long-term fading is given as,

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

Where 2T is the time period for averaging r (t). The value of T is obtained using fading rate of r (t) which is general between 40 to 80 fades. Hence, m(t) is the envelope of r (t) as shown in figure (a). the long term fading m(t) can be expressed in spatial scale as,

$$m(x_1) = \frac{1}{2L}\int_{x_1-T}^{x_1+T} r(x)dt \qquad - \qquad (3)$$

The length of 2L is in between 20 to 40 wavelength and is obtained by averaging 36 to 50 samples in an interval of 40 wavelengths.

The short-term fading $r_0(t)$ is given by,

$$r_0(in\ dB) = r(t) - m(t) \qquad - \qquad (4)$$

This shown in figure (b). The short term fading component $r_0(t)$ exhibits a Rayleigh distribution. Hence, it is known as Rayleigh fading.

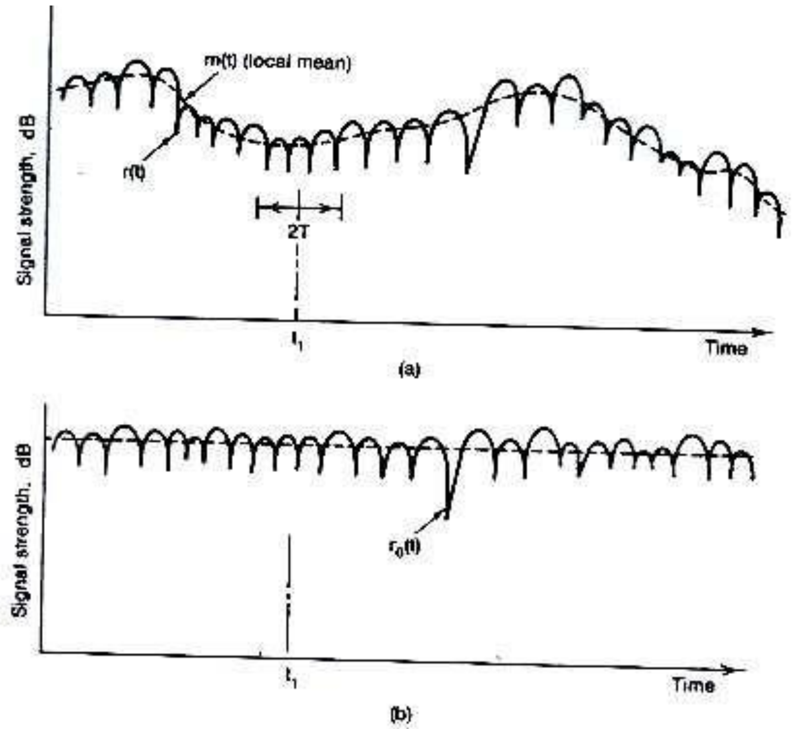


Figure A mobile radio signal fading representation. (a) A mobile signal fading. (b) A short-term signal fading.

Mobile Fading Characteristics.

Since the antenna height of the mobile unit is lower than its typical surroundings and the carrier frequency wavelength is much less than the sizes of its surrounding structures, multipath waves are generated. At the mobile unit, the sum of multipath waves, causes the fluctuations in signal in a particular range of bandwidth (i.e., about 40 dB). This phenomenon is popularly known as signal fading.

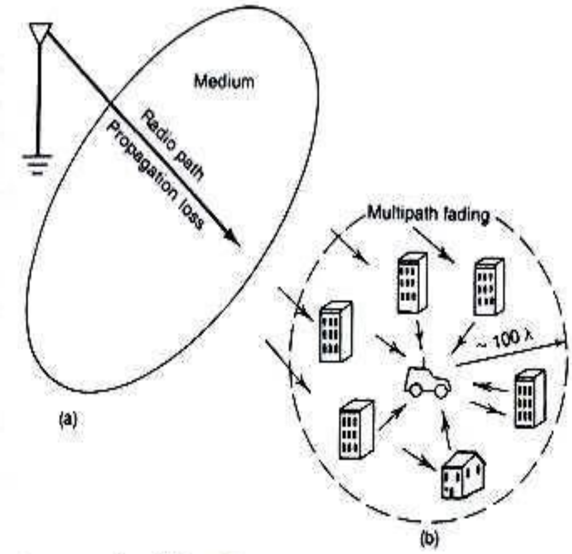


Figure A mobile radio environment—two parts. (1) Propagation loss; (2) multipath fading.

The multipath waves bounce 'back and forth' due to the buildings and houses, they form many standing wave pairs in space which are summed together and become an irregular wave fading structure. When a mobile unit is standing still, a constant signal is observed. But if the mobile unit is moving, the fading structure of wave in the space is received. It is known as multipath fading.

Therefore, the characteristics of mobile fading are changed by the following components,

i. The radius of the active scatter region

ii. standing waves expressed in a linear scale and log scale

iii. First order and second order statistics of fading

iv. Delay spread and coherence bandwidth. (i)The

Radius of the Active Scatter Region

The radius of the active scatter region at 850 MHz can be roughly 100wavelengths. Always the active scatter region moves with the mobile unit as its center. It means that some houses were inactive scatters and became active as the mobile unit approached them, some houses which are active scatters become inactive as the mobile unit drive away from them.

(ii)Standing Waves Expressed in a linear scale and log scale

The symmetrical waveform in a log plot becomes an unsymmetrical waveform when plotted in linear scale. Hence, it is clear that the sine waveform in a log scale becomes a complete different waveform when expressed on a linear scale and vice-versa which indirectly causes change in fading.

First Order and Second Order Statistics of Fading

When the mobile unit is moving, generally the fading occurs on the signal reception. The first order characteristics such as average power probability cumulative Distribution Function (CDF) and bit error rate are independent of time. Whereas the second order characteristics, such as level crossing, average duration of fades and word rate either time or velocity related functions. So the mobile fading may be changed depending upon these characteristics.

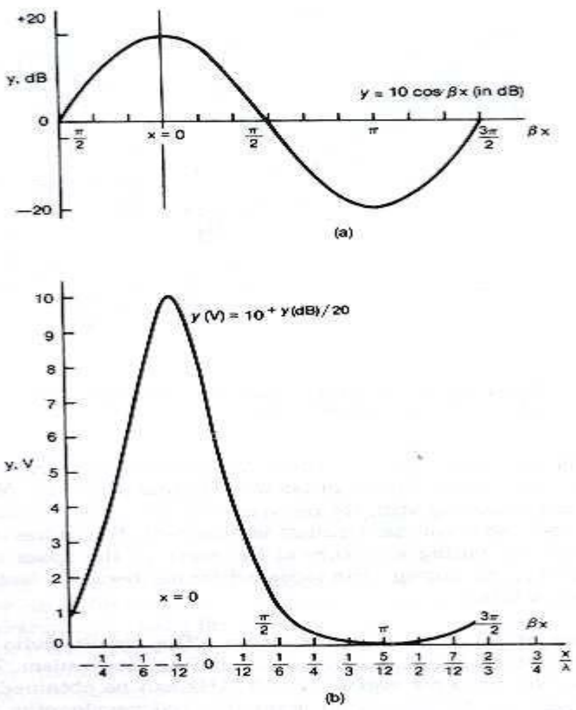


Figure The linear plot and the log plot of a sine wave. (*a*) In linear scale; (*b*) in log scale.

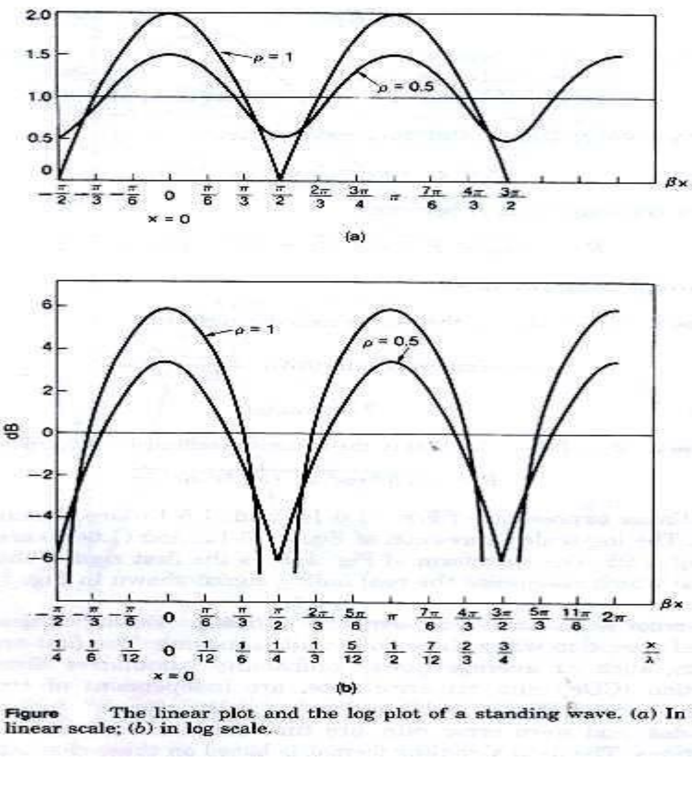


Figure The linear plot and the log plot of a standing wave. (*a*) In linear scale; (*b*) in log scale.

Delay spread and coherence bandwidth

In mobile radio environment, as a result of multipath reflection phenomenon, the signal transmitted at the cell site reach the mobile unit takes different paths.

The radio signal can take two paths

i. Direct path

ii. Indirect path.

(i) Direct Path

The signal from cell site to mobile unit is called "direct path" and the angle of direct path is denoted by $\theta 1$.

(ii) Indirect Path

The signal from cell site to surface and surface to the mobile unit is "indirect path". The angle is known as reflection angle (or) elevation angle.

Each path has a different path length, the time arrival of each path is different.

For an impulse transmitted at the cell site, by the time this impulse is received at the mobile unit it is no longer an impulse but rather a pulse with a spread width, we call "delay spread".

The value of the delay spread is varied depending upon the type of environment.

Type of Environment		Delay Spread $\Delta(\mu s)$
1.	Open area	<0.2
2.	Urban area	3
3.	Suburban area	0.5
4.	Inside the building	<0.1

Delay Spread

In the mobile communication, due to the occurrence of multipath reflection, the signal conveyed from a cell site will travel through different path and appear at a mobile unit. Because every single path has a distinct path length, the time of arrival for every single path at a mobile unit is different. For instance, if an impulse signal is transmitted from the cell site, then by the time it reaches a mobile unit it will be a 'pulse' with a spread width (Δ) known as delay spread.

Typical values of delay spread in various environments is shown in table below.

Type of Environment		Delay Spread $\Delta(\mu s)$
1.	Inside the building	<0.1
2.	Open area	<0.2
3.	Suburban area	0.5
4.	Urban area	3

Coherence Bandwidth

Coherence bandwidth is defined as, the bandwidth in which either amplitudes (or) the phases of two received signals have a high degree of similarity. It is a statistical measurement of the range of frequencies over which the channel can be considered "flat", or in other words the approximate maximum bandwidth or frequency interval over which two frequencies of a signal are likely to experience comparable or correlated amplitude fading. If the multipath time delay spread equals Δ seconds, then the coherence
Bandwidth W_c in hertz is given approximately by the equation,

$$W_C = \frac{1}{2\pi\Delta}$$

For cellular communication in an urban area the coherence bandwidth is,

$$W_C = \frac{1}{2\pi \times 3 \times 10^{-6}}$$

Since, $\Delta = 3\mu s$ for urban areas from table, W_c= 53Khz.

Amplifier noise in the cellular system

The amplifier present either at cell site or at the mobile unit will amplify the mobile radio signal received by the receiving antenna. Consider the available noise power at the output of amplifier is N_0 and the available power gain is 'g'.

Therefore if input signal to noise (S/N) ratio P_S / N_i The output signal to noise ratio is P_0/N_0 and the internal amplifier noise is N_0.

Then the output 'P_0/N_0' becomes.

$$\frac{P_0}{N_0} = \frac{gP_s}{g(N_i) + N_a} = \frac{gP_s}{g\left[N_i + \left(\frac{N_a}{g}\right)\right]}$$

$$\Rightarrow \boxed{\frac{P_0}{N_0} = \frac{P_s}{N_i + \frac{N_a}{g}}} \qquad - \qquad (1)$$

The noise figure of an amplifier (F) is given by,

$$F = \frac{Maximum\ possible\ S/N\ ratio}{Actual\ S/N\ ratio\ at\ output}$$

$$\Rightarrow \boxed{F = \frac{P_S/KTB}{P_0/N_0} = \frac{N_0}{(P_0/P_S)KTB} = \frac{N_0}{G(KTB)}} \quad - \quad (2)$$

Since, (P_s/KTB) is the maximum possible signal to noise (S/N) ratio when load is open circuit.

Therefore from equations (1) and (2) we get

$$\boxed{F = \frac{P_S/KTB}{P_s/[N_i + (N_a/g)]} = \frac{N_i + (N_a + g)}{KTB}}$$

Hence, the noise figure is a reference measurement between a minimum noise level due to thermal noise and the noise level generated by both the external and internal noise of an amplifier. Accordingly the mobile radio signal passing through the radio systems is by amplifier noise.

Hexagonal- shaped cells

We have to realize that hexagonal shaped communication cells are artificial and that such a shape cannot be generated in the real world. Engineers draw hexagonal-shaped cells on a layout to simplify the planning and design of a cellular system because it approaches a circular shape that is the ideal power coverage area. The circular shapes have overlapped areas which make the drawing unclear. The hexagonal shaped cells do not have overlapping areas. Today, these hexagonal shaped cells have already become a widely promoted symbol for cellular mobile systems.

Operation of Cellular system:

Mobile Unit Initialization

When a cellular phone is turned-on-but is not yet engaged in a call, it first scans the group of forward control channels to determine the one with the strongest signal and then monitors that control channel until the signal drops below a usable level. At this point, it again scans the control channels in search of the strongest base station signal. For each cellular system the control channels are defined and standardized over the entire geographic area covered. Since the control channels are standardized and are identical throughout different markets within the country or continent, every phone scans the same channels while idle.

Network Originated Call

When a telephone call is initiated by a landline subscriber to connect a mobile user, the Mobile switching Center (MSC) forwards the request to all base stations in the cellular system.

The mobile identification number, which is the subscriber’s telephone number, is then broadcast as a paging message over all of the forward control channels throughout the cellular system. The mobile receives the paging message sent by the base station which it monitors and responds by identifying itself over the reverse control channel.

The base station relays the acknowledgement sent by the mobile and informs the MSC of the handshake. Then, the MSC instructs the base station to move the call to an unused voice channel within the cell. AT this point the base station signals the mobile to change the frequencies to an unused forward and reverse voice channel pair, at which point another data message (called an alert) is transmitted over the forward voice channel to instruct the mobile phone to ring, thereby instructing the mobile user to answer the phone.

Mobile Originated Call

When a mobile originates a call, call initiation request is sent on the reverse control channel. With the request the mobile unit transmits its telephone number (MIN), Electronics Serial Number (ESN) and the telephone number of the called party. The cell base station receives this data and sends it to the MSC. The MSC validates the request, makes connection to the called party through the PSTN and instructs the base station and mobile user to move to an unused forward and reverse voice channel pair to allow conversation to begin.

Call Termination

When the cellular phone is turned off, a signaling tone is conveyed to the cell site, which frees the voice channel at both the ends.

Handoff

Once a call is in progress, the MSC adjusts the transmitted power of the mobile and changes the channel of the mobile unit and base station in order to maintain call quality as the subscriber moves in and out of range of each base station. This is called a handoff. Special control signal is applied to the voice channels, so that the mobile unit any be controlled by the base station and the MSC while a call is in progress.

Planning of cellular system

Planning is very crucial in the design of cellular system. The service provided by the system is poor if we does not have the skill to develop a good plan. Initially, we must find out two elements.

1. Regulation
2. Market situation.

Regulation The federal regulations controlled by the Federal communications Commission (FCC) are similar in every part of the United States. The regulation may vary from state to state and within the state, each city and town have their own building codes and zoning laws. So, we must be acquainted with all rules and regulations.

Market Situation

The marketing division has to manage three tasks. They are,

(i) Prediction of gross income

(ii) Understanding competitors

(iii) Decision of geographic coverage.

(i) Prediction of gross income

In this task we have to find out the population of the market area (in which we are constructing the cellular system). We also need to find out the average income, business types and business zone. All this information is utilized to predict the gross income.

(ii) Understanding competitors

We must have a knowledge of the competitor's coverage area, system performance and the number of customers the competitor is serving. To overcome the competition, we must design a system that provides unique and magnificent service.

(iii) Decision of geographic coverage.

In this task, we need to answer the following questions before passing the decisions onto the engineering department.

(a) What general area should ultimately be covered?

(b) What near-term service can be provided in a limited area?

Analog and Digital Cellular systems

NTT Network

NTT is acronym for Nippon Telegraph and Telephone Corporation. The corporation has developed an 800MHz land mobile telephone system in the year 1979 to provide service to Tokyo area. The operation of this system is analogous to AMPs system. The system provides service to approximately 40000 subscriber 500 cities. It serves 60 percent of Japan's population, covers 25 percent of livable areas and assist 75 percent of Japan cities.

As on February 1985, in Japan there are

9Automobile switching Centers (ASCs)

51 Mobile control stations (MCSs)

465 Mobile Base Stations (MBSs)

39000 Mobile Subscriber Stations (MSSs)

In operation, around 30,000 subscribers are served in the metropolitan Tokyo area by the Japanese mobile telephone network. The structure of the network is as shown in figure (a). The system functions with a total bandwidth of 30MHz and contains 600 channels each with a bandwidth of 25 kHz.

Advanced Mobile Phone Systems (AMPS):

AMPS is the analog mobile [phone system developed by Bell labs and officially introduced in America in 1983 and Australia in 1987. It was the primary analog phone system in North America through the 1980's and into the 2000's. AMPS isb the first-generation cellular technology that uses separate frequencies or "Channels" for each conversation. It therefore requires considerable bandwidth for a large number of users. In general terms AMP is very similar to the older "0G" (Zero-Generation) improved mobile telephone service, but uses considerably more computing power in order to select frequencies, handoff conversations to PSTN lines, and handle filling and call setup.

In AMPS, the cell centers can flexibly assign channels to handsets based on signal strength, allowing the same frequency to be reused in various locations without interference. This allowed a large number of phones to be supported over a geographical area.

In suffered from some weakness when compared to today's digital technologies. Since it is an analog standard, it is very susceptible to static noise and has no protection from eavesdropping using a scanner. In the 1990s, "cloning" was an epidemic that cost the industry millions of dollars. An unscrupulous eavesdropper with specialized equipment can intercept a headset Electronic Serial Number (ESN) AND Mobile Identification Number (MIN). The ESN is a packet of data which is sent by handset to the cellular system for billing activities effectively identifying the phone on the network. The system then allows or disallows calls and or features based on its customer file. If an ESN/MSN pair is intercepted, it could then be cloned on to a different phone and used in other areas for making calls without paying.

AMPS has been replaced by newer digital standards such as digital AMPS, GSM and CDMA2000 which brought improved security as well as increased capacity though cloning is still possible even with digital technologies. The cost of wireless service is so low that the problem has virtually disappeared.

AMPS and D-AMPS are now being replaced by either CDMA 2000 or GSM, which allows higher capacity data transfers for services such as WAP, multimedia messaging system and wireless internet access.

The Evaluation of the Analog and Digital Cellular Mobile System

Cellular telephone systems can be “analog” or “digital” older systems (AMPS, TACs, NMT) are analog and newer systems (GSM, PCs) are “digital”.

The major difference between the two systems is, how the voice signal is transmitted between the phone and base station. Analog and “Digital” refer to this transmission mechanism. It like audio cassettes and CDs. Audio cassettes are analog and CDs are digital.

In either system, the audio at the microphone always starts out as a voltage level that varies continuously over time. High frequencies cause rapid changes and low frequencies cause slow changes. With analog system, the audio is directly modulated on to a carrier. This is very much like FM (not identical) radio where the audio signal is translated to the RF signal.

With digital systems, the audio is converted to digitized samples at about 800 samples per second so. The digital samples are numbers that present the time varying level at specific points in time. The samples are now transmitted as 1’s and 0s’. At the other end the samples are converted back to voltage levels and “smoothed out” so that, you get about the audio signal.

With analog transmission interference (RF noise or some other anomaly that affects the transmitted signal) gets translated directly into the recovered signal there is no “check” that the signal make sense. The neat thing about the digital is that the 1s’ and 0s’ cannot be easily confused or distorted during transmission, plus extra data typically included in the transmission to help, detect and correct any errors.

Difference between the analog and digital cellular systems with their operating capacities:

The most commonly used digital cellular system in America is IS-136, colloquially known as D-AMPS. This system is all digital, unlike the analog AMPS. IS-136 uses multiplexing technique called TDMA or time division multiple access. The TDMA based IS- 136 puts three calls into the same 30 kHz channel space that AMPS uses carry one call. AMPS is analog cellular system.

TDMA is a transmission technique or access technology while IS-136 or GSM are operating systems. Similarly, AMPS is an operating system using FDMA access technology or transmission technique. FDMA is the acronym for frequency division multiple access. Frequency division means calls are placed or divided by frequency that is one call goes on frequency, say 100MHz and another call goes on 200MHz.

Multiple access means the cell site can handle many calls at once. Time division multiple access handles multiple and simultaneous calls by dividing them in time, not by frequency. This is purely digital transmission. Voice traffic is digitized and portions of many calls are put into a single bit stream, one sample at a time.

TDMA's chief benefit to carriers or cellular operations comes from increasing call capacity. A channel can carry three conversations instead of just one. The analog systems like AMPS, NAMPS locked the error correction that digital system provided and are not sophisticated enough to handle encryption or advanced services, like calling number identification, extension phone service and messaging.

The most noticeable disadvantage that is directly associated with the digital systems is the additional bandwidth necessary to carry the digital signal as opposed to it analog counterpart. A standard T1 transmission ink carrying a DS-1 signal transmits 24 voice channels of about 4 kHz each. The digital transmission rate on the link is 1.544 Mbps and the bandwidth required is about 772 kHz. Since, only 96 kHz would be required to carry 24 analog channels (4 KHz * 24), about 8 times as much bandwidth is required to carry the digital signals (722 kHz 196 = 8.04). The extra bandwidth is effectively traded for the lower signal to noise ratio.

Another important drawback of digital cellular systems is audio quality. Analog cellular phones sounds worlds better. In poor signal areas or when cell sites are struggling with high call volume. Digital phones often lose full duplex capability and your voice may break up and sound garbled.

Differentiate the generations in the cordless phones and cellular phones.

Cellular Phones In 1945, the zero Generation (OG) of mobile telephones was introduced. OG mobile phones, like mobile telephone service, were not cellular, and so did not feature "handover" from one base station to the next and reuse of radio frequency channels. Like other technologies of the time, it involved single, powerful base station covering a wide area, and each telephone would effectively monopolize a channel over that whole area while in use. The concepts of frequency reuse and handoff as well as a number of other concepts that formed the basis of modern cell phone technology are first described in U.S. patent 4, 152,647 issued on May 1, 1979 to Charles A. Gladden and Martin H. Parelman, and assigned by them to the United States Government. This is the first embodiment of all the concepts that formed the basis of the next major step in mobile telephony, the analog cellular telephone.

The first commercial city wide cellular network was launched in Japan by NTT in 1979. Fully automatic cellular networks were first introduced in the early to mid-1980s (the IG generation). The Nordic Mobile Telephone (NMT) system went on-line in Denmark, Finland, Norway and Sweden in 1981.

Personal Handy-phone system and modems used in Japan around 1997-2003. In 1983, Motorola Dyna TAC was the first approved mobile phone by FCC in the United States. In 1984, Bell labs developed modern commercial cellular technology, which employed multiple, centrally controlled base stations (cell sites), each providing service to a small area (a cell). The cell sites would be set up such that cells partially overlapped. In a cellular system a signal between a base station (cell site) and a terminal (phone) only need, be strong enough to reach between the two, so the same channel can be used simultaneously for separate conversations in different cells.

The first "modern" network technology on digital 2G (Second Generation) cellular technology was launched by Radiolinja in 1991 in Finland on the GSM standard which also marked the introduction of competition in mobile telecoms when Radiolinja challenged incumbent Telecom Finland who ran a I G NMT network.

The first data services appeared on mobile phones starting with person-to-person SMS text messaging in Finland in 1993. First trial payments using a mobile phone to pay for a Coca Cola vending machine were set in Finland in 1998. The first commercial payment system to mimic banks and credit cards was launched in the Philippines in 1999 simultaneously by mobile operators Glove and Smart. The first content sold to mobile phones was the ringing tone, first launched in 1998 in Finland. The first full internet service on mobile phones was i-mode introduced by NTT DoCoMo in Japan in 1999.

In 2001 the first commercial launch of 3G (third generation) was again ill Japan by NTT DoCo1Vlo on the WCDMA standard. Until the early 1990's. most mobile phones were too large to be earned in a Jacket pocket, so they were typically installed in vehicles as car phones with the miniaturization of digital components and development of more sophisticated batteries, mobile phones have become smaller and lighter. George Sweigert, an amateur radio operator and inventor from Cleveland, Ohio, is largely recognized as the father of the cordless phone. He submitted a patent application in 1966 for a "fulduplex wireless communication apparlus". The U.S. patent and trademark office awarded him a patent in June of 1969. Sweigert, a radio operator in World War II stationed at the south pacific islands of Guadalcanal and Bouganville, developed the full duplex-concept for untrained personnel, to improve battlefield communications for senior commanders. He was also licensed as W8ZIS and N9LC in the amateur radio service. He also held a first class radio telephone operator's permit issued by the Federal Communications Commission.

In the 1980's a number of manufacturers, including Sony, introduced cordless phones for the consumer market. They used a base station that was connected to' a telephone line and a handset with a microphone, speaker, keypad and telescoping antenna. The handset contained a rechargeable battery, typically Ni Cd. The base unit is powered by household current, via a wall wart. The base included a charging cradle, which was generally a form of trickle charger, on which the handset rested when not in use.

Some cordless phones now utilize two rechargeable AA or AAA batteries in place of the more expensive traditional proprietary telephone batteries cordless phones because commercially feasible. In the United States only with the breakup of the Bell systems monopoly on land-line telephone service around 1984. Before breakup, all telephones were made by Western electric and rented to the customer.

Since the 1980s, several companies have entered the cordless phone market: V-Tech, Uniden, Philips, Giga Set and Panasonic. They advertise many new features, a few provided by the phone and most provided by the network.

Consideration of the components of Cellular systems

The elements of cellular mobile radio system are mobile radios, antennas, cell site controller and MTSO. These will effect the system design if not selected property.

Antennas:

Antenna pattern, antenna gain antenna tilting and antenna height effect the design of cellular system. The antenna pattern can be omni directional, directional or any shape in both the vertical and horizontal planes. Antenna gain compensates for the transmitted power. The antennas will effect the system performance at cell site and mobile units.

The antenna patters in cellular systems are different from free space. If mobile unit travels around a cell site having buildings, omni directional antenna is not omni pattern. Also the front to back ratio of a directional antenna is found to be 20db in free space and will be 10db at cell site.

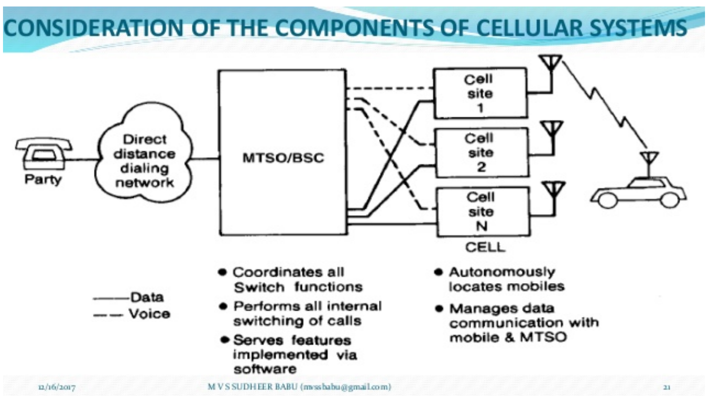
Antenna tilting reduce the interference to the neighboring cells and increase the weak spots in the cell. Also the height of the cell-site antenna can effect the area and shape of the coverage in the system.

Switching equipment

The capacity of switching equipment in cellular system is based on the capacity of the processor associated with switches. The processor should be large in big cellular system. The service life of the switching equipment is determined by the time period it takes to reach its full capacity. If the equipment is modular, modules can be added to meet the demand. In future trend, the switching equipment can link to other switching equipment so that a call can be carried out form one system to another system without dropping a call.

Data links

Each Data link can carry multiple channel data (10Kb data transmitted per channel) from the cell site to the MTSO. This fast speed data cannot be passed on telephone lines but special devices are needed. The data can be multiplexed on many channels passing on micro-wave radio line at higher frequencies (>850MHz) or wide band T- carrier wire line.



CELLULAR CONCEPTS:

Evolution of cellular systems:

Mobile wireless technologies is a system used by cellular telephone manufacturers and service providers to classify wireless communication into several generations, Each generation is characterized by new frequency bands, higher data rates and non–backward compatible transmission technology.in recent past mobile wireless technologies have undergone technology evolution from 0G TO 4G. More research is being carried purposely to introduce a newer shift with more efficiency and advanced functionalities and capabilities compared to the previous.

1. Zero generation (0G)

This is the generation which came before cell phones mobile telephony technology. They were introduced before the first generation of cellular telephones, therefore labeled zero generation systems. Such technologies include radio telephones mostly used in cars. Mobile radio telephone systems came before modern cellular mobile telephony technology.

2. First generation (1G)

The first commercially automated cellular network (1G) was launched in the year 1979 in Japan. This forms the first generation of cell phones, labeled as analog cell phones. It was used for voice communications and were cordless. This phase of technology used a technology called Advanced Mobile Phone System (AMPS). Advanced Mobile Phone System was frequency modulated and used frequency division multiple access (FDMA). The difference between the first and previous technology of mobile phones was the use of multiple cell sites, and the ability to transfer calls from one site to the next as the user traveled between cells during a conversation.

3. Second generation (2G)

The second generation wireless mobile communication system was introduced in the 1980s.This generation was very imperative since it forms the start of digital cellular technology. Makes use of digital signals for voice transmission, has a higher bandwidth (30-200 KHz).and above all supports services such as short message services (SMS), picture messages and multimedia message services (MMS). SMS text messaging became possible and widely used, initially supported by Global System for Mobile Communication (GSM) networks and eventually on all digital networks. Use of SMS today is a communication mostly preferred by the youths.

Also many advanced markets the general public prefers sending text messages rather than placing voice calls.The second generation introduction saw many communication benefits and among them are, Digital signals require to consume less battery power, so it helps mobile batteries to last long. Digital coding improves the voice clarity and reduces noise in the line while conversing, therefore interruptions in are widely reduced. Digital signals are considered environment-friendly. Digital encryption has provided secrecy and safety to the data and voice calls, therefore, security is improved. Security is a key factor which has been the main concern to every cellular technology user.

4. 2.5 generation (2.5G.)

This cellular wireless technology was developed after the 2G and before the 3G.this technology was not popular among the general public as it saw fewer improvements.it mainly used GPRS (General Packet Radio Service). GPRS could provide data rates and can also be used for services such as Wireless Application Protocol (WAP) access, Multimedia Messaging Service (MMS), and for Internet communication services such as email and World Wide Web access.

5. 2.75 generation (2.75G)

This technology is basically labeled as the EDGE (Enhanced Data rates for GSM Evolution) .some advantages include, it allows the clear and fast transmission of data and information speed (up to 384kbit/s) Generally, the spread of and the use of 2G phones became more widespread and people began to use mobile phones in their day to day lives, this led to high demand for data services (example, access to the internet) and greater data speeds. Therefore this saw a need to introduce a better performance cellular technology and therefore 3G was introduced to cater for such demands.

6. Third generation (3G)

This generation of wireless mobile communication technology system was introduced in the year 2000. The objective is to offer increased data rates (from 144kbps to384kbps) in wide coverage areas and 2Mbps in local coverage areas. This technology is very improved compared to 1G,2G, along with voice communication it includes data services, access to television/videos, Web browsing, e-mail, video conferencing, paging, fax and navigational maps. It has a high bandwidth (of 15-20MHz) used for high-speed internet, video chatting. 3G technology revolution saw a great transformation in the industry for the first time, 3G technology enabled media streaming of radio and even television content. Later other versions were introduced as 3G improvement these are, 3.5G and 3.75G but not widely popular.

7. Fourth generation (4G)

This technology was introduced after the third generation. The main objective of 4G technology was to provide high speed, high quality, high capacity, security and low-cost services for voice and data services, multimedia and internet over internet protocol.

4G is a great technology in that it has optimized data with high-speed improvement, more bandwidth, high-quality video and audio streaming over end to end Internet Protocol

One of the main ways in which 4G differ from 3G was by doing away with circuit switching, instead of employing an all internet protocol network. Another advantage of 4G is that, apart from usual voice and other services of 3G technology, 4G provides mobile broadband Internet access, example to laptops with wireless modems, smartphones, and to other mobile devices. Most remarkable current applications of 4G, include amended mobile web access, internet protocol (IP) telephony, gaming services, high-definition mobile television, video conferencing, 3D (dimension) television, and cloud computing.

8. Fifth generation (5G)

This is the generation which is under development. Majorly will be an improvement from the 4G technology. The following are some characteristics and requirements expected to be attached with the release of the 5G as defined by Next Generation Mobile Networks Alliance. Data rates of several tens of Mb/s should be supported for tens of thousands of users, several hundreds of thousands of simultaneous connections to be supported for massive sensor deployments among others. This alliance feels that 5G should be introduced out by 2020 to meet business and consumer demands. Major improvements expected on 5G are, Provide large broadcasting of data in Gigabit, use different modulation techniques and error-control techniques, provides hundreds of channels without streaming, technology support for virtual network, offers bi-directional bandwidth and less traffic among others.

Cellular mobile technology has improved over the years to meet different consumer requirements. This has influenced greatly day to day communication way of lives.

Concept of frequency reuse channels:

A radio channel consists of a pair of frequencies for duplex operation, one frequency for each direction of transmission. A particular radio channel (say F) is 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.

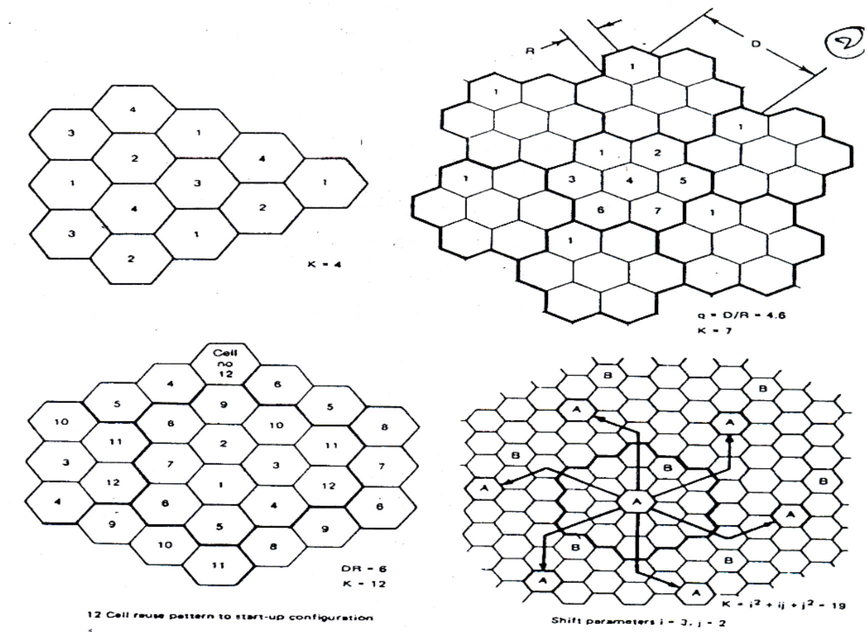
In the frequency reuse system, users in different geographic locations (different cells) must simultaneously use the same frequency channels. The frequency reuse system will increase the spectrum efficiency but if the system is not designed properly by serious interference problems may occur. Interference due to common use of the same channel is called co-channel interference.

Frequency reuse scheme:

Frequency reuse in the time domains results occur of the same frequency in different time slots and is called Time Division Multiplexing (TDM). Frequency reuse in the space domain is divided into two categories:

1)Same frequency assigned in two different geographic areas (AM or FM)

2)Same frequency repeatedly used in a same general area in cellular systems. There are many co-channel cells in the system. The total frequency allocation divided k frequency reuse patterns as shown in fig. for k = 4, 7, 12 and 19.



Frequency reuse Ratio (distance):

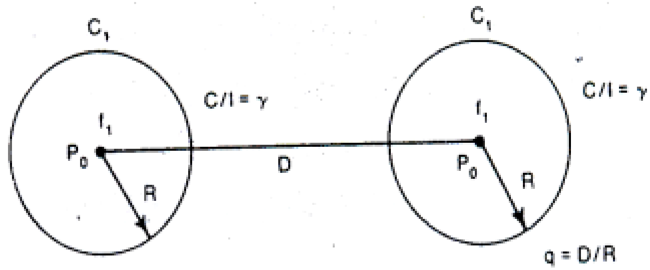
The minimum distance which allows the same frequency to be reused depends on

- Number of co-channel cells around a particular center cell.
- The type of geographic terrain contour
- The antenna height.

The frequency reuse distance 'D' is given by

$$D = \sqrt{3k}R$$

Where k is frequency reuse pattern



The ratio of D/R

$$D = \begin{cases} 3.46 \times R & for \quad k = 4 \\ 4.6 \times R & for \quad k = 7 \\ 6.0 \times R & for \quad k = 12 \\ 7.55 \times R & for \quad k = 19 \end{cases}$$

If all the cell sites transmit the same power, when k increases, the frequency reuse distance D increases. This increase in D, reduce the chance of co-channel interference. Generally large k value is desired. However the number of channels is fixed.

When k is too large, the member of channels assigned to each of k cells becomes small. If the total number of channels in k-cells is divided as k-increases and results in trunking in efficiency. If the total number of channels are divided into two networks serving in the same area, spectrum inefficiency increases.

Number of channels in a cellular systems:

At present total number of channels is 832. But most mobile units are still operating on 666 channels.

A channel consists of two frequency channel bandwidth one in the low band and the other in the high band. The two frequencies in channel 1 are 825.03MHz (mobile transmit) and 870.03MHz (cell site transmit). The two frequencies in channel 666 are 844.98MHz (mobile transmit) and 889.98MHz (cell-site transmit)

The 666 channels are divided into A-Group and B-Group with each block having 333 channels as shown in .fig

Block A system

1A	2A	3A	4A	5A	6A	7A	1B	2B	3B	4B	5B	6B	7B	1C	2C	3C	4C	5C	6C	7C	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	
43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	
64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	
85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	
106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	
127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	
148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	
169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	
190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	
211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	
232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	
253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	
274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	
295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	–	–	–	
313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	Control channel sets
334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	
355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	
376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	
397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	
418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	
439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	
460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	
481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	
502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	
523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	
544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	
565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	
586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	
607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	
628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	
649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	–	–	–	

Block B system

There are 312 voice channels in each block and 42 set-up channels are assigned in the idle of blocks A and B.

Grouping into sub-sets:

Since there are 21 set-up channels (42/2) for each system, the remaining 312 voice channels in each system can be divided into 21 sub-sets and each sub consists of 16 voice channels. These voice channels are made into one FRAME and connected to a channel combiner. In a seven cell freq reuse system, each cell contains 3-sub sets. The minimum separation between three subsets is 7 channels.

Trunking and blocking Efficiency: To explore the trunking efficiency degradation inherent in licensing two or more carriers rather than one, compare the trunking efficiency between one cellular system per market operating 666 channels and two cellular systems per market each operating 333 channels. Assume that all frequency channels are evenly divided into seven subareas called cells. In each cell, the blocking probability of 0.02 is assumed. Also the average calling time is assumed to be 1.76 min.

With N1=666/7 = 95 and B= 0.02 to obtain the offered load A1 =83.1 and with N2=333/7=47.5 and B=0.02 to obtain A2= 38. Since two carriers each operating 333 channels are considered, the total offered load is 2A. We then realize that

$$A_1 \geq 2A_2$$

By converting above eqn. to the number of users who can be served in a busy hour, the average calling time of 1.76 mm is introduced. The number of calls per hour served in a cell can be expressed as

$$Q_i = \frac{A \times 60}{1.76} \text{ calls/h}$$

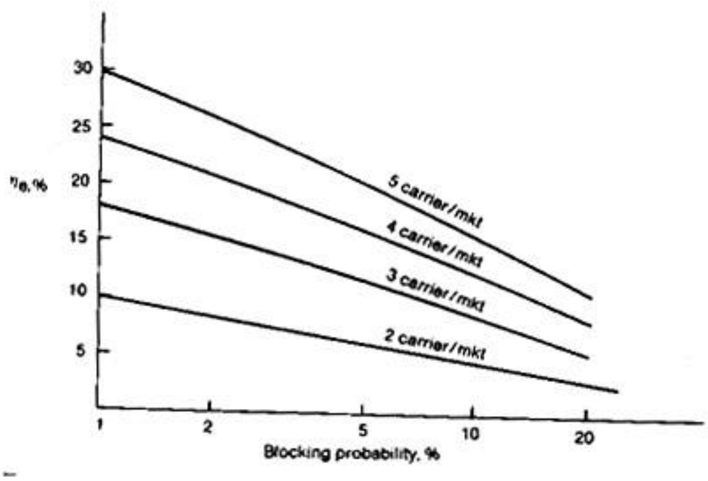


Fig: degradation of trunking efficiency

$$Q_i = \begin{cases} 2832.95 \text{ calls/h} & \text{(1 carrier/market)} \\ 1295.45 \times 2 = 2590.9 \text{ calls/h} & \text{(2 carriers/market)} \end{cases}$$

The trunking efficiency factor can be calculated as

$$\eta_e = \frac{2832.95 - 2590.9}{2832.95} = 8.5\%$$

For a blocking probability of 2 percent, Figure 13 shows, by comparing one carrier per market with more than one carrier per market situations with different blocking Probability conditions. The degradation of trunking efficiency decreases as the blocking probability increases. As the number of carriers per market increases the degradation increases. However, when a high percentage of blocking probability, say more than 20 percent, occurs, the performance of one carrier per market is already so poor that further degradation becomes insignificant, as above fig.

Required Grade of Service:

The blocking probability of 0.02 for initiating calls at the busy hour. To decrease blocking probability requires good system plan and sufficient number of radio channels. The traffic carried by the system is generally lower than the actual traffic offered to the system by the subscribers. The overload traffic is rejected and hence is not carried by the network. The amount of traffic rejected by the network is an indication of the quality of service offered by the system. This is termed as Grade of Service (GOS) and is defined as ratio of lost traffic to offered traffic. The smaller the value of grade of service, the better is the service. The recommended value of GOS is 0.02 for initiating calls at the busy hour. The GOS value is not same for all cells sites. Due to heavy automobile traffic near freeways during busy hours the GOS value is greater than 2 percent at some cell sites. A good system plan and adequate number of radio channels are required to decrease the value of Grade of Service (GOS).

Number of Dropped calls During Q calls in an hour, if a call is dropped (Q-1 calls completed), then the call drop ratio is 1/Q and this rate must be kept low. A high drop rate will be caused by either coverage problems or hand off problems (due to limited channel availability).

Special features:

The special features like call forwarding, call waiting, automatic roaming etc. are to be provided.

Cellular structures: macro, micro, pico & femto cells.

Macro cells: A macrocell or macrosite is a cell in a mobile phone network that provides radio coverage served by a high power cell site. The antennas for macrocells are mounted on ground-based masts, rooftops and other existing structures, at a height that provides a clear view over the surrounding buildings and terrain. The term macrocell is used to describe the widest range of cell sizes. Macrocells are found in rural areas or along highways.

Micro cells: A microcell is a cell in a mobile phone network served by a low power cellular base station (tower), covering a limited area such as a mall, a hotel, or a transportation hub. Typically the range of a microcell is less than two kilometers wide, whereas standard base stations may have ranges of up to 35 kilometres (22 mi). Microcells are usually used to add network capacity in areas with very dense phone usage, such as train stations. Microcells are often deployed temporarily during sporting events and other occasions in which extra capacity is known to be needed at a specific location in advance.

Pico cells: A picocell is a small cellular base station typically covering a small area, such as in-building (offices, shopping malls, train stations, stock exchanges, etc.), or more recently in-aircraft.In cellular networks, picocells are typically used to extend coverage to indoor areas where outdoor signals do not reach well and range of a picocell is 200 meters or less

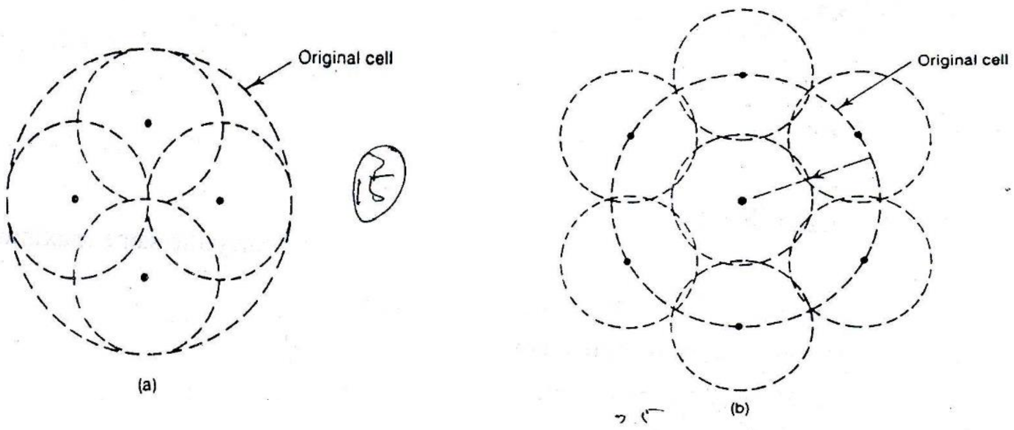
Femto cells: femtocell is a small, low-power cellular base station, typically designed for use in a home or small business.

Comparison of all in terms of area:

The term macrocell is used to describe the widest range of cell sizes. Macrocells are found in rural areas or along highways. Over a smaller cell area, a microcell is used in a densely populated urban area. Pico cells are used for areas smaller than microcells, such as a large office, a mall, or train station. Currently the smallest area of coverage that can be implemented with a femtocell is a home or small office.

<u>Cell splitting</u>:

To improve the utilization of spectrum efficiency, the frequency reuse and cell splitting are the concepts. When the traffic density increases and the frequency channels Fi in each cell Ci cannot provide sufficient mobile calls, the original cell can be split into smaller cells. Usually the new radius is one half the original radius as shown in fig.2there are two ways, that is using original cell site fig. and not using original cell site



$$New\ Cell\ Radius = \frac{Old\ cell\ radius}{2}$$

$$Then\ New\ Cell\ Area = \frac{Old\ cell\ area}{4}$$

Let each new cell carry the same maximum traffic load of the old cell, then

$$\frac{New\ Traffic\ load}{Unit\ Area} = 4 \times \frac{Traffic\ load}{Unit\ Area}$$

There are two kinds of cell splitting:

(1) Permanent Splitting:

For installation of new split cell, it is necessary to plan the number of channels, the transmitted power, the assigned frequencies, choosing of cell – site selection and the traffic load condition. When the system is ready after splitting, the service cutover should be set at the lowest traffic point (midnight and at week end) and only few calls will be dropped in this cut over and assuming that the down time of the system is within 2 hours.

(2)Dynamic splitting

This is for utilizing the allocated spectrum efficiency in real time. The algorithm for dynamically splitting cell sites is a difficult job.

The transmitted power for a new cell of reduced size must be 12db less than the old transmitted power when the cell splitting occurs, and the value of frequency re-use ratio (q) is always held constant. The traffic load can be increased to four times in the same area after the original cell is split into four sub-cells. Each sub-cell can again be split into four sub-cells, which allow the traffic to increase 16times. As splitting continues, new traffic load is four times the traffic load of startup cell, where n is the number of splitting. For n=4, the traffic load is 256 times larger than the startup cell.

Splitting limitations

(1) Radio aspect - the size depends on coverage pattern control and accuracy of vehicle locations.

(2) The capacity of switching processor: The small the cells, more handoffs will occur and the capacity of a switching processor is larger than that required for coverage areas of small cells.

Sectorized Cells: There are three basic types.

1. The 120◦-sector cell is used for both transmitting and receiving sectorization. Each sector has an assigned a number of frequencies. Changing sectors during a call requires handoffs.

2. The 60◦-sector cell is used for both transmitting and receiving sectorization. Changing sectors during a call requires handoffs. More handoffs are expected for a 60◦ sector than a 120◦ sector in areas close to cell sites (close-in areas).

3. The 120◦ or 60◦-sector cell is used for receiving sectorization only. In this case, the transmitting antenna is omnidirectional. The number of channels in this cell is not sub-divided for each sector. Therefore, no handoffs are required when changing sectors. This receiving sectorization only configuration does not decrease interference or increase the D/R ratio; it only allows for a more accurate decision regarding handing off the calls to neighboring cells.

UNIT-II INTERFERENCE

Types of interference:

The common types of interference in cellular networks are: self-interference, multiple access interference, co-channel interference (CCI) and adjacent channel interference (ACI). Self-interference is induced by signals that are transmitted on a shared transmitter. Multiple access interference is induced by transmission from multiple radios using the same frequency resource. CCI occurs in links that re-use the same frequency channel. ACI is the interference induced between links that communicate in the same geographical location using neighboring frequency bands.

Introduction to co-channel interference and types.

Co channel interference is generated when two or more independent (modulated or unmodulated) are transmitted simultaneously in the same frequency band. The same frequencies (frequency bands) are reused many times. Frequency reuse leads to CCI- limited system designs.

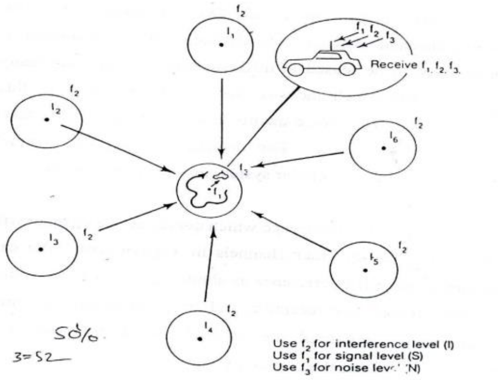
Application of the co channel interference reduction factor cell reuse pattern (K=7) is already described. In most mobile radio environments, use of a 7-cell reuse pattern is not sufficient to avoid co-channel interference. Increasing K>7, would reduce the number of channels per cell and this also reduce spectrum efficiency. There-fore to retain the same number of radios as the 7-cell system by sectoring the cell and this will reduce co-channel interference.

Co channel Interference area from a mobile receiver:

The areas of the holes in mobile telephone coverage area result in call drops during customer conversation. When customer demand increases, the channels which are limited in number have to be reused in different areas and provide many co channel cells which increase the system capacity. In this situation the received voice quality is reduced and also increase co-channel interference. For detection of serious channel interference areas in a cellular system this test is carried out.

Co channel interference which occurs in one channel will occur equally in all other channels in a given area. We can measure co channel interference as shown in fig. by selecting any one channel for reception and transmitting on the same channel at all co channel sites at night, while the mobile is traveling in one of the co channel cells.

One channel (f1) records the signal level (no co channel condition), another channel (f2) records the interference level six co channel condition and is maximum and is while the 3rd channel receives (f3) noise which is not is use.



Co channel interference at the mobile unit

As the readings are taken in db, the carrier to Interference ratio (C/I) is obtained by subtracting the result obtained F2 from the result obtained from f1 that is (C-I).

The carrier of Noise (C/N) is obtained by subtracting the result of f3 from f2 result. For comparing the results the following 4-conditions are used.

(1)If C/I is greater than 18db throughout the cell, then the system is properly designed.
(2)If C/I is less than 18db and C/N is greater than 18db in some areas, there is co channel interference.

(3)If C/N and C/I are less than 18db and C/N ≈C/I, in a given area, there is a coverage problem.

(4)If both C/N and C/I are less than 18db and C/N > C/I in given area there is both coverage and interference problem.

Real-time Cochannel Interference Measurement at Mobile Radio transreceivers

The carriers are angularly modulated by the voice signal and RF freq difference between them is much higher than fading frequency. The measurement of signal carrier-to-interference ratio C/I gives that the signal is

$$e_1 = S(t)\sin(wt + \phi_1)$$

And interference is $e_2 = I(t)\sin(wt+\phi_2)$

The received signal is $e(t) = e_1(t) + e_2(t) = R\sin(wt+\psi)$

Where

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

$$And\,\psi = \tan^{-1}\frac{S(t)\sin\phi_1 + I(t)\sin\phi_2}{S(t)\cos\phi_1 + I(t)\cos\phi_2}$$

Bysimplifying R we get

$$R2 = [S^2(t) + I^2(t) + 2S(t)I(t)\cos\phi_1 - \phi_2]$$

In analyses it was shown that the term $[S^2(t) + I^2(t)]$ fluctuates close to the fading freq

V/λ and the term $2S(t)I(t)\cos\phi_1 - \phi_2$ fluctuates close to a freq $\frac{d}{dt}(\phi_1 - \phi_2)$ which is much higher than fading freq. The two parts can be separated as $X = S^2(t) + I^2(t)\ and\,Y = 2S(t)I(t)\cos(\phi_1 - \phi_2)$

Assume S(t), I(t), $\phi 1$ and $\phi 2$ are random variables and are independent the signal to interference ratio (Γ)

$$\Gamma = \frac{\overline{S^2(t)}}{\overline{I^2(t)}} = K + \sqrt{K^2 - 1} \quad where \quad K = \frac{\overline{X^2}}{\overline{Y^2}} - 1$$

The computation of Γ can be obtained by means of an envelope detector and analog to digital converter and a microcomputer. The sampling delay time Δt should be small enough to satisfy. $S(t) \approx S(t + \Delta t), \quad I(t) = I(t + \Delta t)$ And

$$\cos[\phi_1(t) - \phi_2(t)] \cdot \cos[\phi_1(t + \Delta t) - \phi_2(t + \Delta t)] \approx 0$$

As determining the delay time t to meet this requirement is difficult to measure. Therefore real-time co channel interference measurement is difficult in practice.

Co-channel Interference reduction factor

Reuse of an identical frequency channel in different cells is limited by a co- channel interference between cells. To reduce this co-channel interference, it is necessary to find the minimum frequency reuse distance.

Assume nearly all cells are of the same size. The cell size is determined by the coverage area of the signal strength in each cell. As long as the call size is fixed, co channel interference is independence of the transmitted power of each cell. The co channel interference is a function of parameter q, defined as

$$q = \frac{D}{R}$$

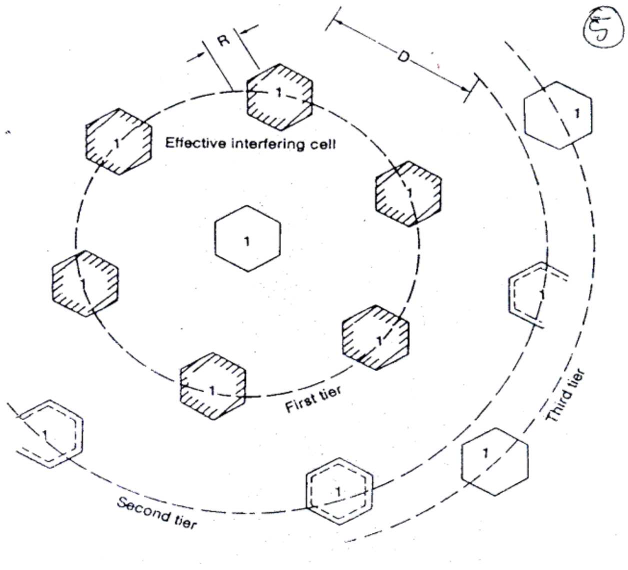
And q is the co-channel interference reduction factor when the ratio q increase, co channel interference decreases. The separation D in the equation is a function of KI and C/I.

$$D = f(K_I, C/I)$$

When KI is the number of co channel interfering cells in the first tier and C/I is the received carrier to interference ratio at the mobile receiver.

$$\frac{C}{I} = \frac{C}{\sum_{K=1}^{I_K} I_K}$$

In a hexagonal – shaped cellular system, there are six co channel interfering cells in the first tier as shown in fig. and KI = 6.



The maximum number of KI in the first cell is (6*2piD/D=6) Co channel interference will be both at cell site and the mobile units at the center. If the interference is much greater, then the carrier interference ratio (C/I) at the mobile units caused by the six interference sites is the same as C/I received at the center cell site caused by the interfering mobile units in the six cells. These two values of C/I are very close.

For a mobile environment, the propagation path loss slope varies as

$C C \alpha R^{-\gamma}$

(γ varies between 2 and 5) *then* $\frac{C}{I} = \frac{R^{-\gamma}}{\sum_{K=1}^{K_I} I_K}$

In a mobile radio medium, gamma is assumed to be 4. The six co channel interfering cells in the second tier cause weaker interference than those in the first tier. Therefore the co channel interference from the second tier of interfering cells is negligible. The above C/I can be written as

$$\frac{C}{I} = \frac{1}{\sum_{K=1}^{K_I} \left(\frac{D_K}{R} \right)^{-\gamma}} = \frac{1}{\sum_{K=1}^{K_I} (q_K)^{-\gamma}}$$

Where qK is the co-channel interference reduction factor with kth cochannel interfering cell $q_k = \frac{D_k}{R}$

Desired C/I from a Normal case in an omnidirectional system

Analytic solution:

The two cases to be considered are

(1)The signal and co-channel interference received by the mobile unit.

(2)The signal and co-channel interference received by the cell site.

The local noises at the mobile unit (Nm) and the cell site (Nb) are small and neglected when compared to interference level.

As long as the received carrier-to-interference ratios at both mobile unit and cell site are the same, the system is called balanced system and in this, we can choose either of the two cases to arrive at the system requirement as the result is the same for other.

Assume all D_k are same, then $D = D_k$ and $q = q_k$ and $\frac{C}{I} = \frac{R^{-\gamma}}{6D^{-\gamma}} = \frac{q^{\gamma}}{6}$

Thus $q^{\gamma} = 6\left(\frac{C}{I}\right)$ *and* $q = \left(6.\frac{C}{I}\right)^{1/\gamma}$

In this equation (C/I) value is based on the required system performance and gamma value is based the terrain environment. For the given (C/I) and gamma values, q can be determined.

Normal cellular practice is to specify (C/I) to be 18 db or higher, based on acceptance of voice quality. The path loss slope gamma in equal to 4 in a mobile radio environment.

$$q = (6 \times 63.1\%)^{1/4} = 4.41 \qquad (10\log 18 = 63.1)$$

$$q = \frac{D}{R}$$

The 90% of covered area will be attained by increasing the transmitter power at each cell, which does not effect the value of q (4.41) as it is not dependent on transmitter – power. The factor q is also related to finite set of cells K in a hexagonal shaped cellular system by

$$q \cong \sqrt{3k}$$

Substituting q = 4.41 and then K =7. This indicates that 7-cell re use pattern is needed

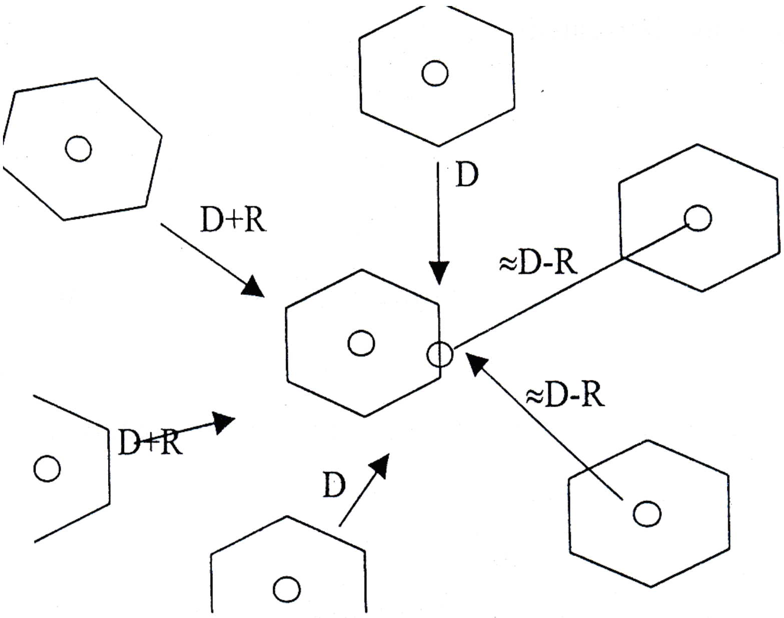
For a C/I of 18 db as $q = \frac{D}{R} = 4.41,$ D can be calculated by choosing a radius (R). Usually value of q is taken greater than 4.41. Greater q value leads to the lower co channel interference.

Design of an Antenna System:

Omnidirectional Antenna system in worst case:

For a normal interference case, we proved that q = 4.6 for K = 7 cell Pattern. The K = 7 pattern does not provide sufficient freq reuse distance separation even for flat terrain. The WORST case is at the location where the mobile unit would receive the weakest signal from its own cell site but strong interference from all interfering cell sites.

In the worst case, the mobile unit is at the cell boundary ‘R’ as shown in



Co channel interference (a worst case)

The distances from all 6- Co-channel interfering sites are also shown in fig

Two distance D - R, two distances of d and two distance of D+R, the propagation delay slope of Non-LOS is 40db/decade mile.

$$C \,\alpha R^{-4} \; and \quad I \alpha D^{-4}$$

The C/I ratio is

$$\frac{C}{I} = \frac{C^{-\gamma}}{\sum_{k=1}^{6} D_K^{-\gamma}} = \frac{R^{-4}}{2(D-R)^{-4} + 2(D+R)^{-4} + 2D^{-4}}$$

$$= \frac{1}{2(q-1) + 2(q+1)^{-4} + 2q^{-4}} \qquad \left(\because q = \frac{D}{R}\right)$$

Substituting q= 4.6, we obtain C/I = 54 or 17 db, which is lower than 18 db. If we use shortest distance (D-R) for all 6 interferers, then

$$\frac{C}{I} = \frac{R^{-4}}{6(D-R)^{-4}} = \frac{I}{6(q-1)^{-4}} = 28 = 14.47db \;\; for \; q = 4.6$$

In reality, due to improper distance locations and non-uniform geographical locations, the C/I value is always worse than the above values (i.e.) instead of 17 db, it may be around 13 to 14db. For heavy traffic situation, the system must be designed for C/I value of the worst case and the co channel interference reduction factor of q = 4.6 is insufficient.

Therefore in an omni directional-cell system, K=9 or 12 would be correct choice, then the q values are

$$\left(q = \sqrt{3k} = \frac{D}{R} \right)$$

Q = 5.2 for K = 9 and q = 6 for K = 12

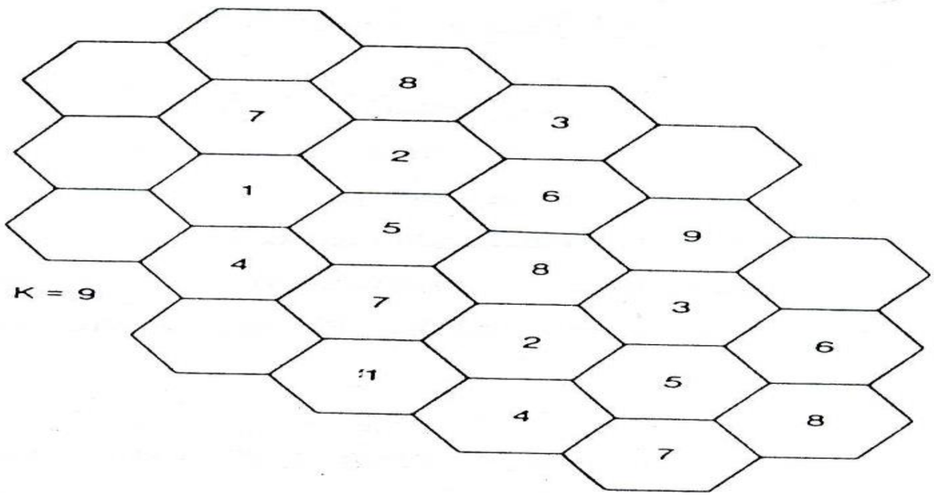
we derived that

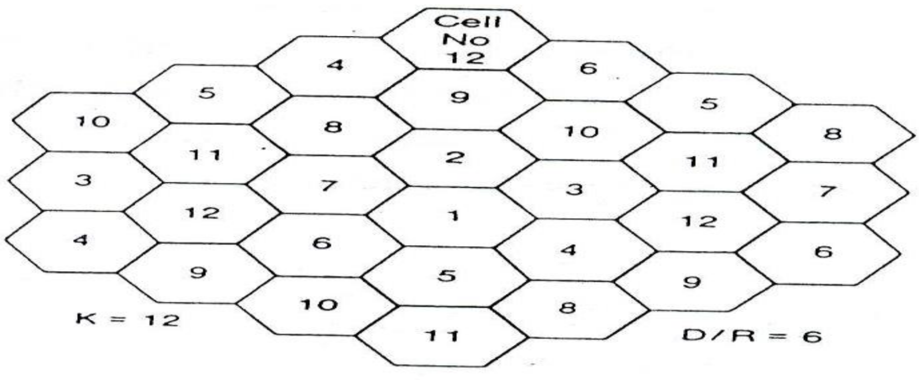
$$\frac{C}{I} = \frac{1}{2(q-1) + 2(q+1)^{-4} + 2q^{-4}}$$

Then C/I = 84.5 =19.25*db for K* = 9

C/I = 179.33 = 22.54*db for K* = 12

The K = 9 and K = 12 cell patterns are shown in fig.3.2 used when traffic is less.





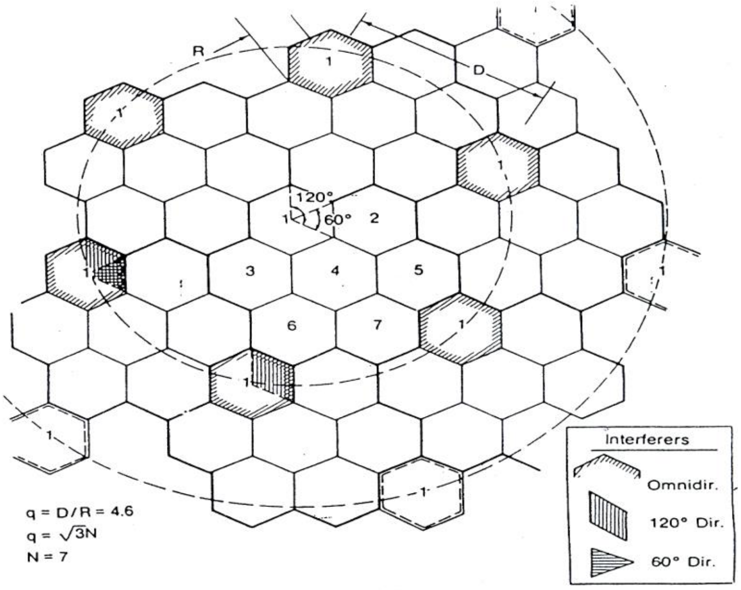
Interference with freq reuse for K = 9 and 12

Design of Directional Antenna system:

When the traffic increases and efficient utilization of spectrum, cell splitting is carried out. When K increases the number of freq channels assigned in a cell will become less (total allocated channels divided by K) and efficiency of freq reuse decreases.

Hence it is necessary not to increase the number of cells K in a demand- required environment.

To meet the increased demand, a directional antenna arrangement is introduced, keeping K = 7. This will also reduce co-channel interference. Each cell is divided into three 1200 or six 600 sectors in the directional antenna system, at the base station as shown in fig.3.4. Each sector is assigned a set of channel frequencies

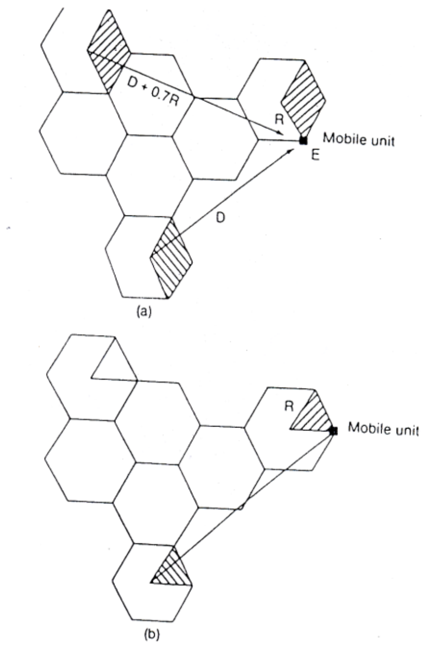


Interfering cells shown in a 7 cell system (two tiers)

Directional Antennas in K=7 cell patterns

(i)Three sector case (1200each):

For the worst case situation, two co-channel cells are shown in fig



Determination of carrier - to interference ratio C/I in a directional antenna system.

(a) Worst case in a 1200 directional antenna system. (N=7)

(b) worst case in a 600 directional antenna system (N=7)

The mobile unit at position ‘E’ is having more interference from the lower shaded sector (distance at D) than from the upper shaded sector (distance at D+0.7R). This is because that the mobiles receiver, receives the weakest signal from its own cell (signal strength about - 100dbm) but fairly strong interference signals from the other two cells.

In a 3-sector case, the interference is effective in only one direction because the front to back ratio of a cell site directional antenna is at least 10db or more in a mobile ratio environment.

Because of the use of directional antennas, the number of principal interferers is reduced from six to two only as shown in fig.3.5. The worst case C/I occurs when the mobile unit is at e and the distances to E from the two interfering antennas in the 1st tier are (D+R/2). Assuming e is at (D+0.7R) and D, the C/I value is

$$\frac{C}{I}(WorstCase) = \frac{R^{-4}}{(D+0.7R)^{-4}} = \frac{1}{(q+0.7)^{-4} + q^{-4}}$$

When q= 4.6, C/I (worst case) =285=24.5db

Thus by using directional antenna system of 1200, the (C/I) received by the mobile unit is far higher than 18db (i.e.) reduce co-channel interference. However, the (C/I) could be 6-db lower in a heavy traffic area due to irregular terrain contour and imperfect site locations. The remaining 18.5db is still sufficient.

Six - sector case:

The cell can be divided into six sectors using 600 beam directional antennas shown in fig.3.5 (b) above. In this only one interference cell can occur in each sector as shown in fig.35. (b). Therefore, C/I ratio is given by

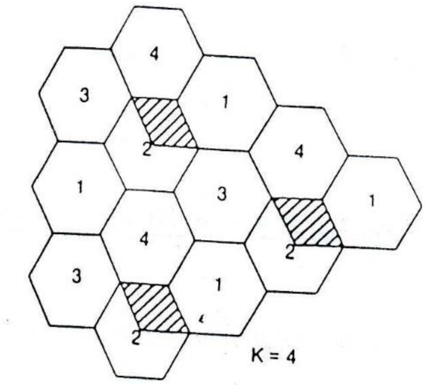
$$\frac{C}{I} = \frac{R^{-4}}{(D+0.7R)^{-4}} = (q+0.7)^{-4}$$

For q= 4.6 C/I = 794 = 29db

Which shows that a further reduction of co-channel interference and subtracting 6-db for the reasons said above, the remaining 23db is still more than adequate.

When heavy traffic occurs, the 600 sector antenna configuration is used to reduce co-channel interference. However only fewer channels are allowed in a 600 sector and the trunking efficiency decreases.

Directional Antenna in K=4 cell pattern Three sector case:
In K = 7 cell pattern system, the 1200 directional antennas used in the sectors reduce the number of interferers to TWO as shown in fig.3.5 (a).
For K = 4, the value of $q = \sqrt{3k} = 3.46$



Interference Pattern with frequency reuse pattern K = 4

$$\frac{C}{I}(Worst\ Case) = \frac{1}{(q+0.7)^{-4} + q^{-4}} = 97 = 20db$$

If 6-db subtracted from this, the remaining 14db is unacceptable.

Six-sector case :

For this directional antenna system there is only ONE interferer at a distance of D+R shown in fig

$$\frac{C}{I}(Worst\ Case) = \frac{R^{-4}}{(D+R)^{-4}} = \frac{1}{(q+1)^{-4}} = 355 = 26db$$

Comparing K=7 and k= 4 systems

In an omni directional antenna system for K = 7, the co-channel reuse distance used is sufficient for design considerations. When the traffic increases a 3 sector system with three 1200 directional antennas are to be used and in certain weak signal arrears 600 sector antennas are to be used.

For K = 7, a 6-secotr directional antenna system requires a total of 42 sectors but for K = 4 requires a total of 26 sectors. But the system of K = 7 with six sectors has less co-channel interference.

One advantage of 600 sectors with K = 4 require fewer cell sites than 1200 sectors with K = 7. The two disadvantages of 600 sectors are

- They require more antennas to be mounted on the antenna mast.
- They often require more frequent hand offs because of increase of chance of the mobile units travel across the six sectors of the cell.

Also assigning the freq channel to the mobile unit in each sector is more difficult unless the antenna height at the cell site is increased. Also the directional antenna front-to-back ratio is difficult unless the antenna height at the cell site is increased.

Also the directional antenna front-to-back ratio is difficult to predict. In small cells, interference will become uncontrollable. Thus the use of a K = 4 pattern with 600 sectors in small cells is considered only for special applications of portable cellular systems or narrow beam applications. For small cells, alternative scheme is to be used with a K = 7 system with 1200 sectors.

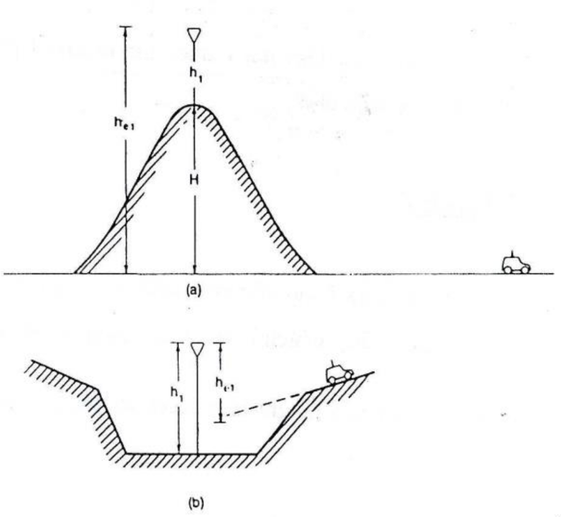
Antenna parameters and their effects:

Lowering the Antenna height

Lowering the antenna height will be very effective for reducing the co channel and adjacent channel interference. The three cases of lowering antenna height are given below

On a high hill or a high spot:

In designing antenna height, the effective antenna height is to be considered but not actual height. The effective height varies according to the location of the mobile unit.



Lowering the antenna height (a) on a high hill and (b) in a valley.

When the antenna site is on a hill as shown in fig 3.7 the effective antenna height is h1+H. If we reduce the actual antenna height to 0.5h1, the effective antenna height becomes 0.5h1+H. The reduction in gain due to height reduction is

G = Gain reduction = $20\log_{10}\frac{0.5h_1+H}{h_1+H} = 20\log_{10}\left[1-\left(\frac{0.5h_1}{h_1+H}\right)\right]$

If h1<< H, then G = 20 log1 = 0db.

This shows that lowering antenna height on the hill does not reduce the received power either at cell site or mobile unit.

2. in a valley :

As shown in the effective antenna height as seen from the mobile unit is he1, which is less than actual height h1. If $h_{e1} = \frac{2}{3}h_1$ and the antenna height is reduced to 1/2h1, then the new effective height is

$$h_{e1} = \frac{1}{2}h_1 - \left(h_1 - \frac{2}{3}h_1\right) = \frac{1}{6}h_1$$

Then the antenna gain is reduced by

$$G = 20 \log_{10} \frac{\frac{1}{6} h_1}{\frac{2}{3} h_1} = -12 \quad db$$

By lowering the antenna height in a valley is very effective in reducing the radiated power in a distant high elevation area. However in the area adjacent to the cell site antenna, the effective antenna height is the same as the actual antenna height. By decreasing the antenna height to ½ h1, then

$$G = 20 \log \frac{\frac{1}{2} h_1}{h_1} = -6 \quad db$$

Reduction of Cochannel Interference by means of a Notch in the tilted Antenna pattern

The co channel interference can be reduced by

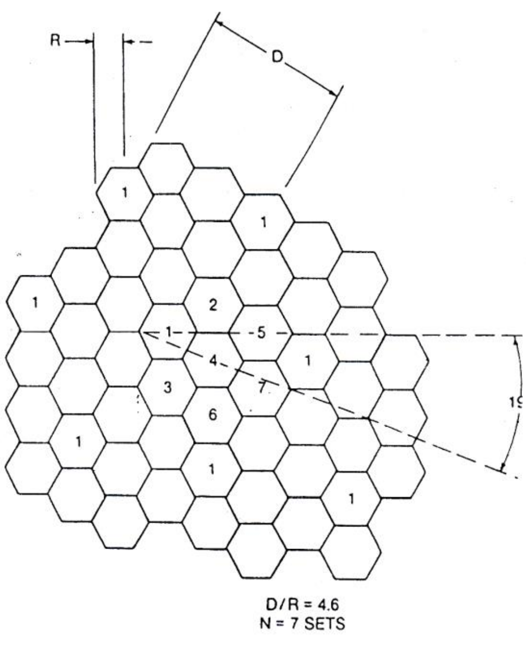
(i) Increasing the separation between two co channel cells

(ii) Using directional antennas at the base stations

(iii) Lowering the antenna heights at the base stations.

When the number of frequency reuse channels is fixed, the directional antennas is more effective to reduce (C/I).

For a 7-cell cellular system, the co-channel reduction factor q= 4.6 and the co channel cell separation = D = q.R = 4.6R. Installation of 1200 directional antenna can reduce the interference by eliminating radiation to the rest of 2400 sector. With a separation of 4.6R, the area of interference at the interference receiving cell is illumination by 190 sector as shown in fig.



A Seven - cell cellular configuration

If three identical directional antennas are installed in every cell, with each antenna covering 190 sector at the interfering cell. Therefore attempts should be made to reduce the signal strength of the interference in the 190 sector. There are two ways in tilting down the antenna patterns either electronically or mechanically.

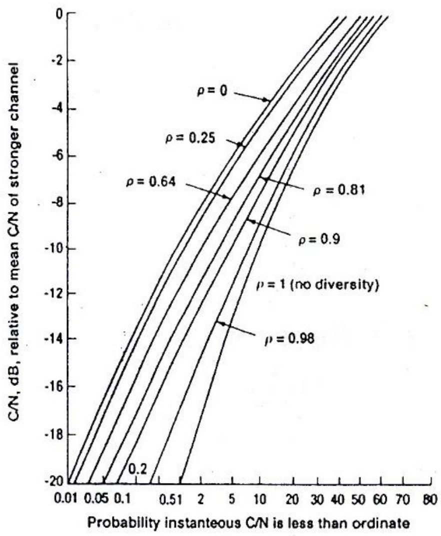
To achieve better C/I in the interference receiving cell, a notch in the center of the antenna pattern has to be created. This notch can be obtained by tilting the high gain directional antenna mechanically downward. When the base station antenna is tilted by 100, the strength of the received signal in the horizontal direction is reduced by 4db. If the tilt is increased to 200, the received power drops by 16db and interference reduction is 1db only. With 100 tilts, the C/I improvement is 0.5db. Tilting the antenna upward will increase signal coverage.

Diversity receiver:

Diversity technique requires number of signal transmission paths named diversity branches that carry same information but have uncorrelated multi path fading and a circuit to combine the received signals or selects one of them.

The diversity scheme is applied at the receiving end of the antenna to reduce interference because methods adopted to improve signal strength will not cause additional interference.

A selective combiner is used to combine two correlated signals shown in fig. and other types of combiner may give 2db better signal.



Selective combining of two correlated signals

In the fig each curve is represented for a correlation coefficient ρ when using diversity scheme and optimum result is obtained for ρ=0.

For a two branch space diversity, at cell site the correlation coefficient ρ≤0.7 should be used. With this coefficient, the separation of two antennas at the cell site meets the requirement, h/d = 11 where h is antenna height and d is antenna separation.

At the mobile unit, use ρ= 0 which means that the two roof-mounted antennas of the mobile unit are 0.5λ or more.

The signal levels both with and without a diversity scheme are as follows.

1.At the mobile unit :

If the diversity scheme is used the power can be reduced by 10db and performs the same way as in the non-diversity scheme. With a 10db less power transmitted at the cell site, co-channel interference can be reduced drastically.

2.At the cell site :

Due to the diversity scheme, a mobile transmitter for a cell site diversity receiver can operate at 7-db reduction in power to attain the same performance as a non-diversity receiver at the cell site. Thus interference from the mobile transmitters to the cell site receivers can be drastically reduced.

Non co channel Interference-different types

1. Adjacent channel interference:

Adjacent channel interference can be eliminated on the basis of the channel assignment, the filter characteristics. Adjacent channel interference is a broad term. It includes next channel (the channel next to the operating channel) interference and neighboring channel interference (more than one channel away from the operating channel) interference. Adjacent channel interference can be reduced by the frequency management.

2. Next-channel Interference

Next channel interference affecting particular mobile unit cannot be caused by transmitters in the common cell site, but must originate at several other cell sites. This is because any channel combiner at the cell site must combine the selected channels.

3. Neighboring channel interference

The channels which are several channels away from the next channel will cause interference with the desired channel. Usually, a fixed set of serving channels is assigned to each cell site. If all the channels are simultaneously transmitted at one cell-site antenna, a sufficient amount of band isolation between channels is required for a multi-channel combiner to reduce intermediation products. This requirement is no different from other non-mobile radio systems. Assume that band separation requirements can be resolved, for example, using multiple antennas instead of one antenna at the cell site.

Another type of adjacent channel interference is unique to the mobile radio system. In the mobile radio system, most mobile units are in motion simultaneously. Their relative positions change from time to time. One unique station that causes adjacent-channel interference in mobile radio systems.

4. Near-End-Far-End Interference

(a)In one cell

Because motor vehicles in a given cell are usually moving, some mobile units are close to the cell site and some are not. The close in mobile unit has a strong signal which causes adjacent-channel interference. In this situation, near-end-far-end interference can occur only at the reception point in the cell site.

If a separation of 5B (five channel bandwidths) is needed for two adjacent channels in a cell in order to avoid the near-end-far-end interference, it is then implied that a minimum separation of 5B is required between each adjacent channel used with one cell.

(b) In cells of two systems

Adjacent-channel interference can occur between two systems in a duopoly-market. In this situation, adjacent-channel interference can occur at both the cell site and the mobile unit..

The two causes of near-end-far-end interference of concern here are

1. Interference caused based on the set-up channels. Two systems try to avoid using the neighborhood of the set-up channels

2. Interference caused on the voice channels. There are two clusters of frequency sets which may cause adjacent-channel interference and should be avoided.

UNIT-III

FREQUENCY MANAGEMENT AND CHANNEL ASSIGNMENT

Introduction:

The function of frequency management is to divide the total number of available channels into subsets which can be assigned to each cell either in fixed fashion or dynamically (in response to any channel among the total available channels) Frequency management refers to designating setup channels and voice channels, numbering the channels and grouping the voice channels into subsets. Channel assignment referees to allocation of specific channels to cell sites and mobile units.

Fixed channel set: (consisting of one or more subsets) is assigned to a cell site on long term basis.

During a call, a particular channel is assigned to a mobile unit on a short term basis. For a short term assignment, one channel assignment per call is handled by the Mobile Telephone Switching Office (MTSO)

Numbering the Channels:

At present total number of channels is 832. But most mobile units are still operating on 666 channels.

A channel consists of two frequency channel bandwidth one in the low band and the other in the high band. The two frequencies in channel 1 are 825.03MHz (mobile transmit) and 870.03MHz (cell site transmit). The two frequencies in channel 666 are 844.98MHz (mobile transmit) and 889.98MHz (cell-site transmit)

The 666 channels are divided into A-Group and B-Group with each block having 333 channels as shown in .fig

	1A	2A	3A	4A	5A	6A	7A	1B	2B	3B	4B	5B	6B	7B	1C	2C	3C	4C	5C	6C	7C	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	
	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	
	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	
	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	
	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	
	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	
	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	
	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	
	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	
	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	
	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	
Block A system	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	
	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	
	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	–	–	–	
	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	Control channel sets
	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	
	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	
Block B system	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	
	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	
	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	
	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	
	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	
	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	
	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	
	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	
	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	
	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	
	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	
	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	
	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	
	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	–	–	–	

There are 312 voice channels in each block and 42 set-up channels are assigned in the idle of blocks A and B.

Grouping into sub-sets:

Since there are 21 set-up channels (42/2) for each system, the remaining 312 voice channels in each system can be divided into 21 sub-sets and each sub consists of 16 voice channels. These voice channels are made into one FRAME and connected to a channel combiner. In a seven cell freq reuse system, each cell contains 3-sub sets. The minimum separation between three subsets is 7 channels.

Set-up channels:

Set-up channels, also called control channels, are the channels designated to setup calls. We should not confused by the fact that a call always needs a setup channel. A system can be operated without setup channels Setup channels can be classified by usage into two types: Access channels and paging channels

Access channels

An access channel is used for the mobile-originating calls .Here, the mobile unit scans its 21 set-up channels and chooses the strongest one. Because each set-up channel is associated with strongest set-up channel indicates which cell to serve the mobile-originating calls.

Paging channels

The paging channel is used for land-originating calls. Each cell site has been allocated its own set-up channel (control channel) .The assigned forward set-up channel (FOCC) of each cell site is used to page the mobile unit with the same mobile station control massage.

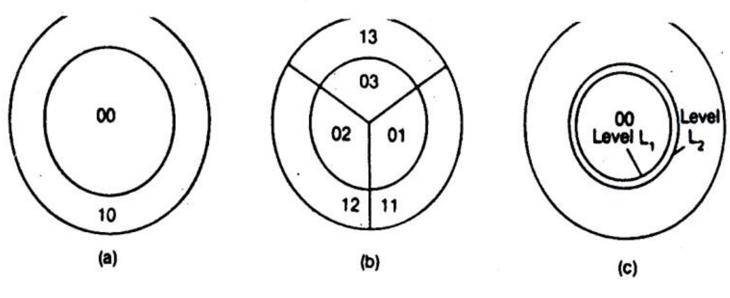
Channel assignment to the cell sites-fixed channel assignment

In a fixed channel assignment, the channels are assigned to cell site for long periods for SETUP channels and voice channels. There are 21-set up channels assigned to each cell for K = 4, 7 or 12 frequency reuse pattern

Channel assignment to traveling mobile units

Under Lay-over Lay Arrangement: Overlaid cells

The traffic capacity can be increased in an omni directional or a directional cell by using underlay - overlay arrangement. The under lay is the inner circle and the overlay is the outer ring as shown in fig.

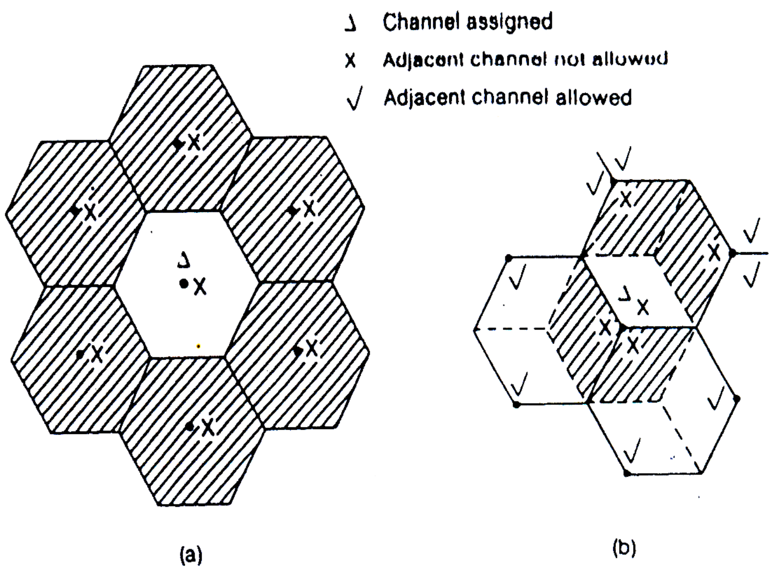


The transmitted powers of the voice channels at the cell site are adjusted for these two areas. Then different voice frequencies are assigned to each area. Different set of frequencies are used in an overlay area and underlay areas and this is to avoid adjacent channel and co channel interference.

When an incoming signal strength for a call is higher than a specified level L, then under laid cell is assigned and if low, overlaid cell is assigned. Handoffs are implemented between the under laid and overlaid cells. To avoid unnecessary hand offs, the two levels L1 and L2 are chosen such that L1 > L2.

(i) Adjacent channel assignment :

Adjacent channel assignment includes neighboring - channel assignment (four channels on either side of the desired channel) and next channel assignment.



a)Omni directional-antenna cells b)directional antenna cells

In an omni directional – cell system, if one channel is assigned to the middle of seven cells, next channels cannot be assigned in the same cell. Also next channel (including neighboring cannot be assigned in the six neighboring cells. In a directional antenna cell system, if one channel is assigned to a face, next channels can be assigned to the same face or to the other two faces in the same cell. Also next channels cannot be assigned to the other two faces of the same cell site. The next channels can be assigned in the next sector of the same cell in order to increase capacity.

Channel sharing & Borrowing :

(a) Channel Sharing :

Channel sharing is a short term traffic relief scheme. There are 21 channel sets with each set consisting of 16 channels. Sharing always increases the trunking efficiency of channels.

(b) Channel borrowing :

Channel borrowing is on a long term basis. The borrowing of channels form other cells arises when the density in a cell increases. The channel borrowing scheme is used, traffic for slowly growing areas instead of immediate cell splitting as it is costly.

Sectorization:

The total number of channels available can be divided into sets depending on 120^0 or 60^0 or 45^0 sectorization of the cell configuration a seven-cell system uses three 1200 sectors per cell, to cover 45 channels. Sometimes the sector angle is reduced (narrower) to assign more channels in one sector without increasing neighboring channel interference. Due to sectorizaiton, cell splitting can be delayed and also channel coordination is easier.

Non fixed channel Assignment algorithms:

(i) Description of Different Algorithms:

(1) Fixed channel Algorithm (FCA): In this algorithm of cellular system, each cell assigns its own radio channels to the vehicles within its cell.

(2) Dynamic channel assignment (DCA): No fixed channels are assigned to each cell in DCA. Therefore any channel of 312 radio channels can be assigned to the mobile unit that is a channel is assigned directly to a mobile unit.

(3) Hybrid channel assignment (HCA): Out of the total channels, a portion of these channels use FCA and the rest of channels DCA.

(4) Borrowing channel assignment (BCA): When all fixed channels are occupied, then the cell borrows channels from the neighboring cells.

(5) Forcible – borrowing channel assignment (FBCA) : In this, if a channel is in operation and in case of necessity, channels must be borrowed from the neighboring cells and at the same time, another voice channel is assigned to continue the call in the neighboring cell. No channel can be borrowed frequently in the neighboring cells. The channels which are in operation can be forcibly borrowed and replaced by a new channel in the neighboring cell or neighboring of the neighboring cell.

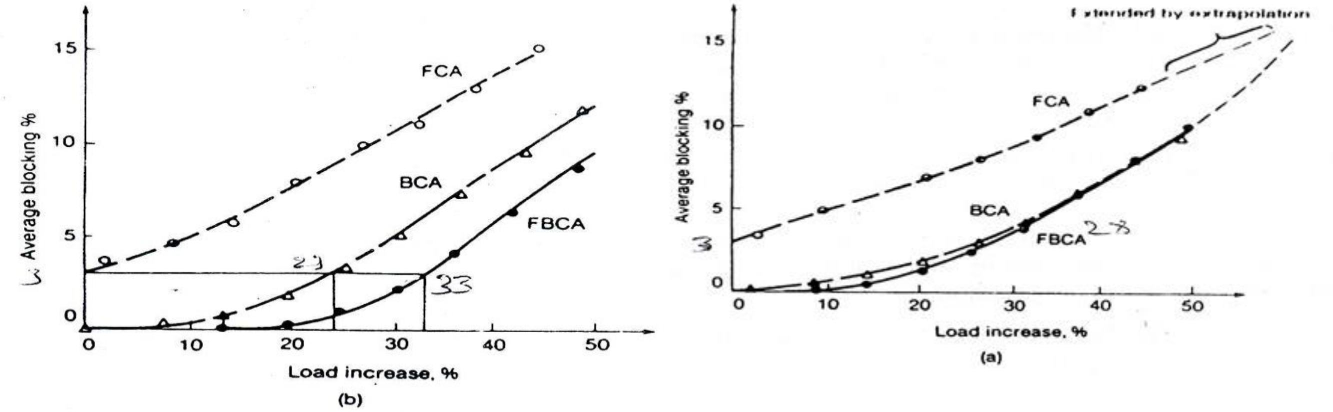
(ii) Simulation Process and Results:

On the basis of FBCA, FCA and BCA algorithms, a 7-cells reuse pattern with an average blocking of 3 percent is assumed and the traffic service in an area is 250 earlangs. The simulation model is described as follows.

- Randomly select the cell (among 41 cells)
- Determine the state of the vehicle in the cell (idle, off hook, on hook, hand off)
- In off hook and hand off state, search for an idle channel. The average number of hand offs is assumed to be 0.2times per call. FBCA will increase the number of hand offs.

(1) ***Average blocking:***

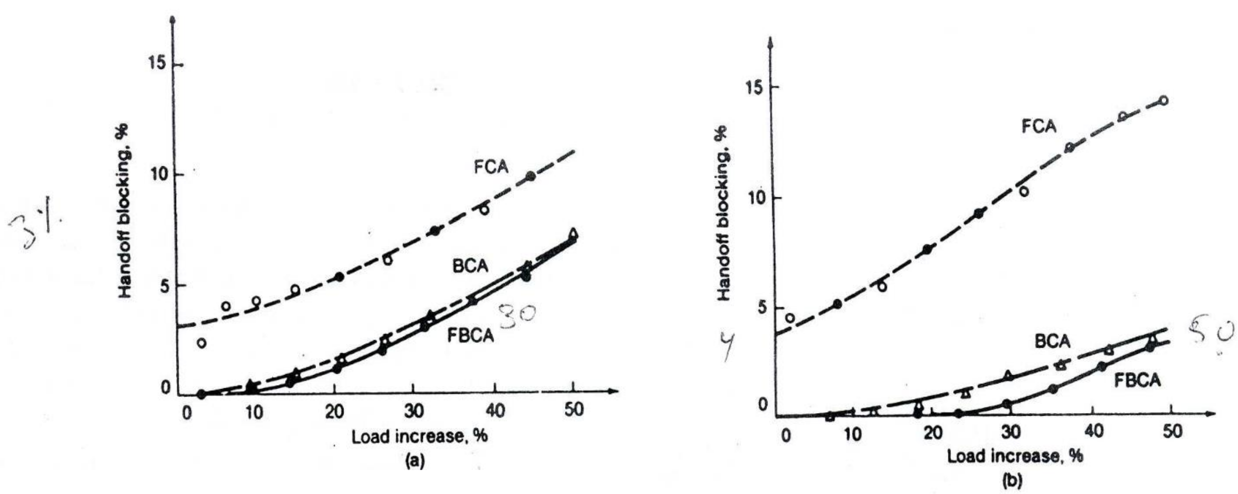
Two average blocking cases are shown in fig.



(a) In a uniform traffic distribution 911-channels per cell) condition of (fig.6.4 (a)), the 3 percent blocking of both BCA and FBCA, will result in 28 percent load increase compared to 3 percent blocking of FCA. There is no difference between BCA and FBCA.

(b) In a non-uniform traffic distribution (i.e. number of channels in each cell is dependent on the vehicle distribution), the load increase in BCA drops to 23 percent and that of FBCA increase to 33 percent at an average blocking of 3 percent as shown in fig.6.4(b). The percentage of increase in land is the same as the percent reduction in the number for channels.

(2) ***Handoff blocking:*** *This can occur only at cell setup stage.*



In fig (a), for a uniform blocking, load is increased to 30 percent both for BCA and FBCA when compared to FCA, for a 3% handoff blocking. As shown in fig. (b) For 4 percent blocking, load increase in 50 percent for both BCA and FBCA and this will reduce the interference and blocking.

CELL COVERAGE FOR SIGNAL AND TRAFFIC

Introduction

The main task is to cover the whole area with a minimum number of cell sites and to see that the signal holes are located in the no-traffic locations. To arrive a prediction model the service area has to be examined for human made structures (open area, urban area, and sub urban area) and natural terrains (flat, hilly water, foliage areas). Field strength are to area prediction models are within 6 to 8 db corresponding to measured value and for a point-to-point prediction model provide a standard deviation from the predicted value of less than 3db.

<u>Signal reflections in flat and hilly terrain:</u>

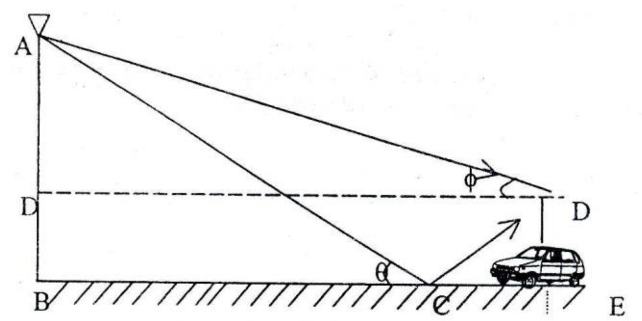


Figure: A coordinate sketch in a flat terrain

Ground Incident angle and ground elevation angle

θ = Incident angle

ϕ = Elevation angle

The ground incident angle θ is the angle of the wave arrival at the ground $\tan \theta = \frac{AB}{BC}$

The ground elevation angle ϕ is the angle of the wave arrival at the mobile unit is

$$Tan\phi = \frac{AB - BD}{BE}$$

Ground reflection angle & reflection point:

Based on Snell's law, the reflection angle and incident angle are the same. As long as the actual hill slope is less than 100, the reflection point on hilly slope as that of flat ground.

For h1 = 50m, h2 = 3m, d = 5km, H = 100m as shown in fig.

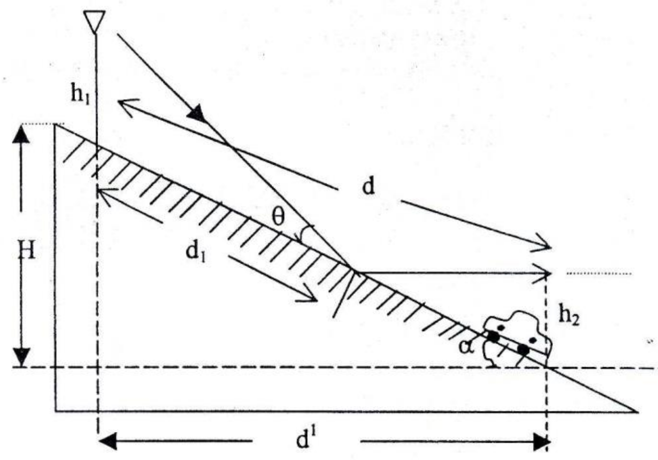


Figure: A coordinate sketch in a hilly terrain

For $d \approx d'$ =5km, the slope angle α, of the hill

$$\alpha = \tan^{-1}\frac{100}{5} = 1.14576$$, the incident angle θ,

$$\theta = \tan^{-1}\frac{50+3}{5} = 0.61$$

And the reflection point location from the cell site antenna is

$$d_1 = \frac{50}{\tan\theta} = 4.717 \quad kms$$

Mobile point-to-point model (Lee model)

This model is obtained in three steps:

(1) Generate a standard condition

(2) Obtain an area to area prediction model

(3) Obtain a mobile point-to-point model using area-to-area model as a base.

(1)Standard condition:

Table: Generating a standard condition

Standard condition	Correction factor
At the Base station	
Transmitted power Pt=10w(40dbm)	$\alpha_1 = 10 \log \frac{P_t}{10}$
Antenna height h1 = 100ft(30m)	$\alpha_2 = 20 \log \frac{h_t}{h_1}$
Antenna gain gt = 6dB/dipole	$\alpha_3 = g_{t2}' - 6$
At the mobile station	
Antenna height, h2 = 10ft (3m)	$\alpha_4 = 10 \log \frac{h_2}{h_2}$
Antenna gain, gm = 0 dB/dipole	$\alpha_5 = g_m'$

All the parameters with primes are the new conditions

To generate a standard correction and provide correction factors, as shown in table we have used a standard condition on the left side and correction factors on the right side. The advantage of standard values is to obtain directly predicted value in dbs above 1mw in dbm.

(2) Obtain area-to-area prediction curves for human made structures:

For different areas, the curves are different in different area. It is assumed that all the areas are flat and the standard deviation of the average value indicate the degree of terrain roughness. The area-to-area is prediction is an average process.

<u>Effect of human made structures:</u>

The terrain configuration of cities is different and the human made structures of each city is same. Obtain the path loss curve for the area assuming it as flat and this path loss is due to human made structures only. As these path loss curves are different for different areas, we have to measure signal strengths at those high spots and at low spots surrounding the cell sites as shown in figure below

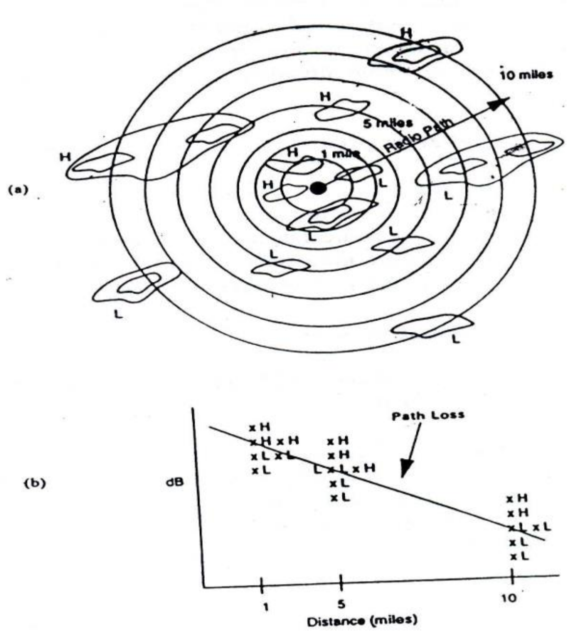


Figure : Propagation path loss curves for human - made structures (a for selecting measurement areas (b) path loss phenomenon.

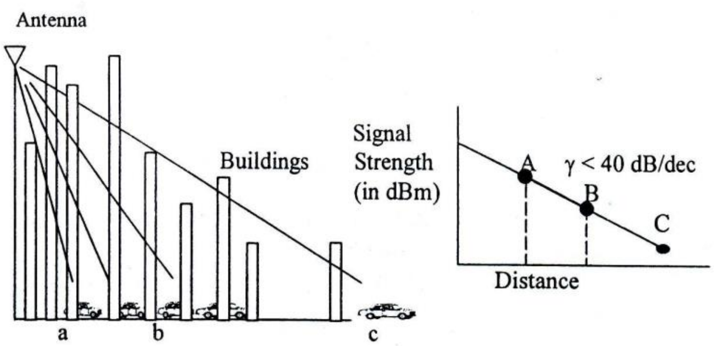
The then average path loss slope of high and low spots along different radio paths in the area represents signal received as if it is a flat area due to local human made structures.

Area-to-Area prediction model can be represented by two parameters.

(1)The one mile intercept point-power received at a distance of 1 mile from transmitter. (2) The path loss slope.

These two parameters can be experimentally obtained as follows. Set up the transmitting antenna at the center of a general area. Take 6 or 7 measurements around 1 mile intercept and around 10 mile boundary. Based on high and low points at these two distances, path loss slope can be obtained by joining these measured values. In hilly areas, obtain more measured data points to obtain average path loss slope.

Path Loss Slope Explanation:



When the base station is located in the city, then 1mile intercept could be low and the slope is flattened out.

When the base station is located outside the city, the intercept could be much higher and the slope is deeper.

When the structures are uniformly distributed, depending on density (Separation between buildings), the 1 mile intercept could be high or low but slope may keep at 40db/dec.

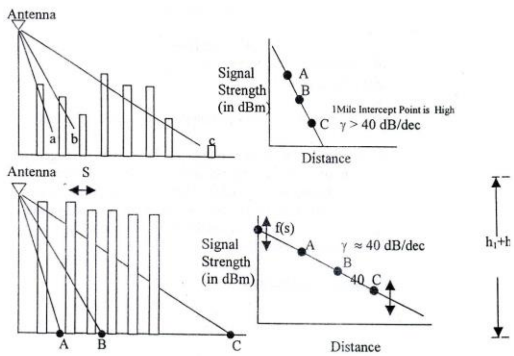
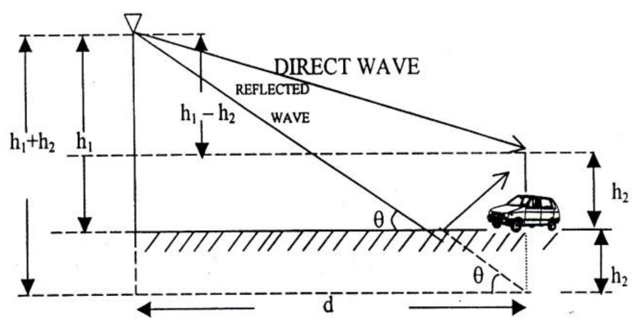


Figure: Path – loss phenomenon

Phase difference between a direct path & a ground reflected path:



Based on a direct path and ground reflected path, the received power when Δϕ (phase difference between direct path and reflected path) is less than 0.6 radians.

$$P_r = P_0 \frac{4}{16\pi(d/\lambda)^2}\left(\frac{2\pi h_1 h_2}{\lambda d}\right)^2 = P0\left(\frac{h_1 h_2}{d^2}\right)^2 \; where$$

P0 = Transmitted power,

d = the distance between Antenna and mobile unit,

λ = wavelength,

h1 = cell station antenna height and

h2 = mobile unit antenna height above ground.

From the above equation, we can deduce the relations:

ΔP = Difference in power in two different paths = $40\log\frac{d_1}{d_2}(40db/dec \; path \; loss)$

ΔG = Difference in gain (or Loss) in dbs from two different antenna heights at the cell site = $20 \log \frac{h_2}{h_1}$ (an antenna height gain of 6db/dec).

The gain from a mobile antenna height is only 3 db/dec which is different from the 6db/dec for h_1'. Then

$$\Delta G' = 10 \log \frac{h_2}{h_1}$$ (an antenna height gain of 3db/oct)

Constant standard deviation along a path – loss curve

When plotting signal strengths at any given radio-path distance, the deviation from predicted values is approximately by 8-db. When line of sight exists, both direct and reflected waves are strong and in out-of-sight paths both the wave paths are weak. In both cases, the theoretical model the 40db/dec path loss slope applies.

In the open area, 1 mile intercept point is high and in urban area it is low. From the cell site, mobile unit's area having LOS, some are partial LOS and some are out of sight. Thus the received signals are strong, normal and weak respectively.

Land to mobile transmission over water

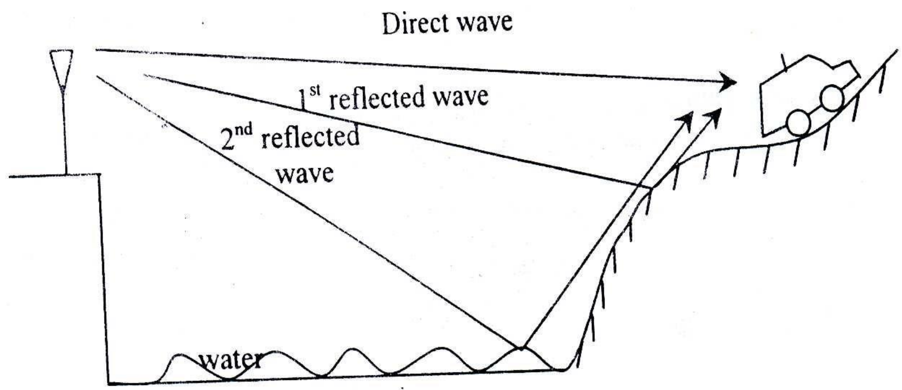


Figure: A model for propagation over water

As shown in fig there are always two equal strength reflected waves, one from water and one from the proximity of the mobile unit in addition to the direct wave. As there are no surroundings for water reflected wave the reflected energy is strong and the reflected wave near the mobile unit is also strong. Therefore the reflected power of the two reflected waves can reach the mobile unit without much attenuation. The total received power at the mobile unit is summing of the three components.

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

Δϕ1 and Δϕ2 are the path length difference between direct wave and two reflected waves and are small. In most cases

$$P_r = P_T \big/ (4\pi d / \lambda)^2$$

$\Delta\phi 1 + \Delta\phi 2 < 1$, then

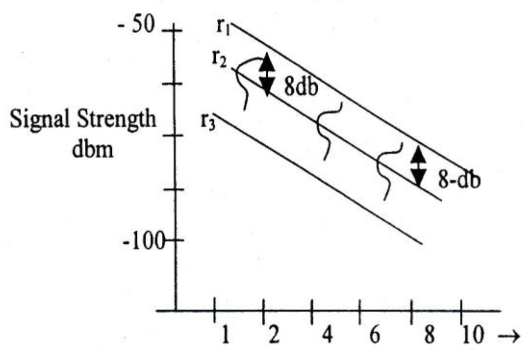
Which is same as power received form the free space condition.

Therefore, the path loss for and to mobile propagation over land, 40db/dec is different for land to mobile propagation over water.

In this case of propagation over water the free space path loss of 20db/dec is applied.

Straight- line path- loss slope

At one radio path distance, the standard deviation is 8-db, the same 8-db is found at any distance as shown in fig



8-db Local mean spread

The standard deviation of 8-db from the measured value is due to close buildings around cell site and deviation at distant locations is due to great variation along different radio paths.

General formula for mobile Propagation over water or flat open area

The permittivity $\in_r$ of sea water and fresh water are same but their conductivities are different. The dielectric constants $\in_c$ $(\in_c = \in_r - J60\sigma\lambda)$ can be calculated. The λ = 0.35 meter at 850MHz.

Then

$$\in_c \ (Sea \ \ water) = 80 - J84$$

$$\in_c \ (Fresh \ \ water) = 80 - J0.021$$

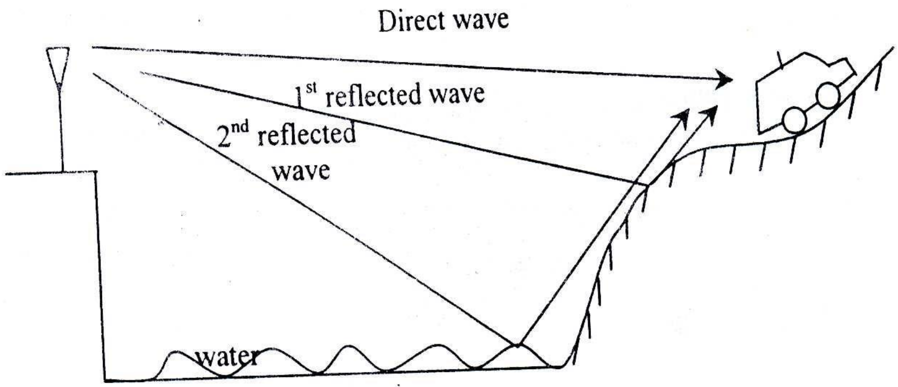
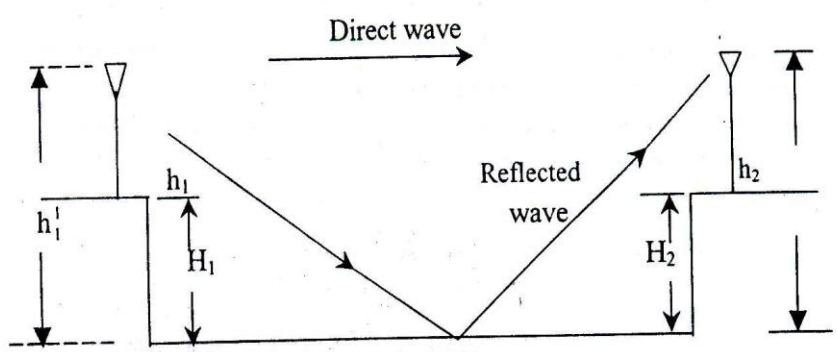


Figure: propagation model over sea water

For small incident angle, both reflection coefficients for horizontal polarized waves and vertically polarized waves. since 1800 phase change occurs at the ground reflection point, the reflection coefficient is -1. As shown in fig 4.3, the two antennas, one at cell site and the other at mobile unit are above sea level and the one reflected from the ground is close to the mobile unit and the other reflected from sea water is away from the mobile unit. Now we have to find formula for field strength for a fixed point-to-point transmission and land mobile transmission over water.

Propagation between fixed stations:



Propagation between two fixed stations over water on flat open land the received power is

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

Pt = Transmitter power, d = distance between two stations. λ = wavelength, av,

ϕv = Amplitude and phase of a complex reflection coefficient respectively.

Δϕ = phase difference caused by the path difference Δd between the direct and reflected wave. $\Delta\phi = \beta.\Delta d = \frac{2\pi}{\lambda}\Delta d$

The first part of Pr formula is a free space formula having 20db/dec propagation slope. The av.e-jϕv are the complex reflection coefficients.

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

Where θ is small and av = -1 and ϕv = 0. $\in_c$ is a dielectric constant which is different media. Since $a_v e^{-J\phi_v}$ is independent of $\in_c$, the reflection coefficient is equal to -1 irrespective of the wave propagating over water dry land, we land, ice etc. then

$$\Pr = \frac{Pt}{(4\pi d/\lambda)^2} \left|1 - \cos \Delta\phi - J \sin \Delta\phi\right|^2 = P0(2 - 2\cos \Delta\phi) ....(A)$$

Since $\Delta\phi$ is a function of Δd, Δd can be calculated as follows

antenna 1 height above sea level = $h_1' = h_1 + H_1$

Antenna 2 height above sea level $= h_2' = h_2 + H_2$

Where h1 and h2 are actual antenna heights and H1 and H2 are hill heights. The path difference Δd is (from fig.4.4)

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

Since d>>h1 and h_2' then $\Delta d = \frac{2h_1' h_2'}{d}$

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

Examining equation (a), the following 5-conditions can be seen :

(1) $P_r < P_0$, the received power is less than the power received in free space :

(2) $P_r = 0,\ 2 - 2\cos\Delta\phi = 0, \Delta\phi = 0,$

(3) $P_r < P_0, 2 - 2\cos\Delta\phi = 0, \Delta\phi = \pm\pi/3,$

(4) $P_r > P_0, 2 - 2\cos\Delta\phi > 1\ or\ ,\pi/3 < \Delta\phi < 5\pi/3$

(5) $P_r > 4P_0, 2 - 2\cos\Delta\phi = \max\ imum\ , \Delta\phi = \pi$

Propagation in Near-in distance:

Within a 1 mile radius, the antenna beam width for a high gain omni-directional antenna is narrow in the vertical plane. The signal reception at a mobile unit located within 1 mile is less due to large elevation angle of the mobile unit, is in shadow region (outside Main beam). The larger the elevation angle, the weaker the reception level.

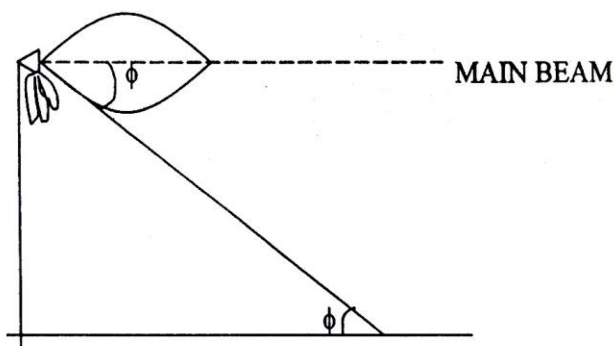


Figure: Elevation angle of the shadow of the antenna pattern

The signal reception levels is less by 10 to 20 db in the areas close to the cell site. Thus the surroundings of the cell site, the reception level is either up or low at the mobile unit within 1 mile radius. When the mobile unit is away form 1 mile radius, the effect due to near-by surroundings of the cell site is negligible.

If the antenna height is 30 meters in suburban area, the signal is -61.7dbm. For 60 meters height, 6db and 120 meters another 60db gain is obtained. If it is 120 meters above, the mobile unit receive signal same as that of free space.

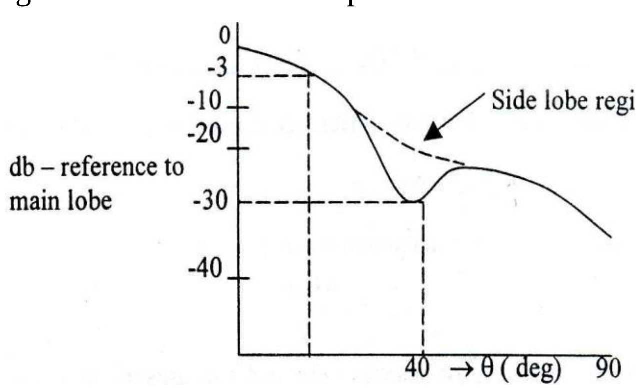


Figure: Typical 60db omni-direction antenna Beam width

The antenna pattern is not isotropic in the vertical plane and typical 6-db omni- directional antenna. Vertical beam width is shown in figh.4.6. If the antenna beam is aimed at mobile unit, we observe 24db/dec for antenna height of 30 meters, 22db/dec for 60meters and 20db/dec for 90 meters. The power of 11dbm received at 0.001 mile is obtained from fig

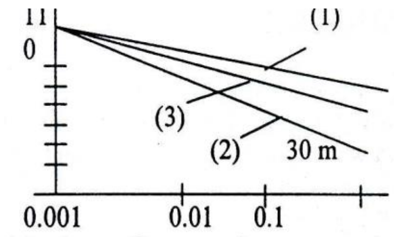


Figure: Curves for near-in-propagation

For curve (1) 120meters - 20db/dec (free space)

For curve (2) 30meters - 24db/dec (free space)

For curve (3) 60meters - 22db/dec as shown in fig.4.7.(free space)

Calculation for near field propagation:

The range of over water, the phase difference caused by path difference is

$$\Delta\phi = \frac{4\pi h_1' h_2'}{\lambda \cdot d}, P_r = P_0\left(2 - 2\cos\Delta\phi\right)$$

For Pr = 4P0, 2-2cos $\Delta\phi$ is maximum when $\Delta\phi = \pi$.

$$\Delta\phi = \frac{4\pi h_1' h_2'}{\lambda \cdot d} = \pi \qquad \therefore d_F = \frac{4h_1h_2}{\lambda}$$

The signal received within the near field that is d < dF uses the free space formula,

$$P_r = \frac{P_t}{(4\pi d / \lambda)^2}$$ and the signal received outside the near field, d > dF, use mobile radio path formula.

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

Pt in dbs above 1mw, r1 in miles, h1 and h2 are in feet. Gt & Gm antenna gain in dbs.

Long-Distance propagation:

When the cell site is high, the signal covers large area. As the traffic increases, a noise – limited system gradually becomes interference limited system. The interference is due to co-channel and adjacent channels in the system and also long distance propagation.

Within area of 50 miles, for a high site the waver propagate in a-non-straight line fashion due to low atmospheric phenomenon. The wave path can bend either upward or down ward. It may happen at one point the signal may be strong and weak at another point.

At a distance of 320km, due to troposphere wave propagation and due to sudden change in dielectric constant, the wave is received. Due to troposphere propagation, the wave is divided by refraction and reflection. The distance of propagation is much greater than the line-of-sight propagation. As the refractive index decreases with height, the rays will be curved down at a particular height, duct propagation occur. Troposphere propagation cause interference and can be reduced by a directional antenna or low power low antenna mast or umbrella antenna.

Path loss from a point-point prediction model:

Non obstructive direct path:

It is path unobstructed by the terrain contour. The cell site antenna cannot be seen by mobile user.

Line of sight path:

It is a path unobstructed by the terrain contour and by manmade structures. The user can see cell site antenna. The signal strength in this case is strong.

In mobile environment, LOS will not be possible continuously and hence direct path condition exists and not obstructed by the terrain contour. In this case, the antenna height gain will be calculated for every location where the mobile unit travels as shown in fig

(1) Find the specula reflection point for the two conditions

(a) Connect the image antenna of the cell site antenna to the mobile antenna.

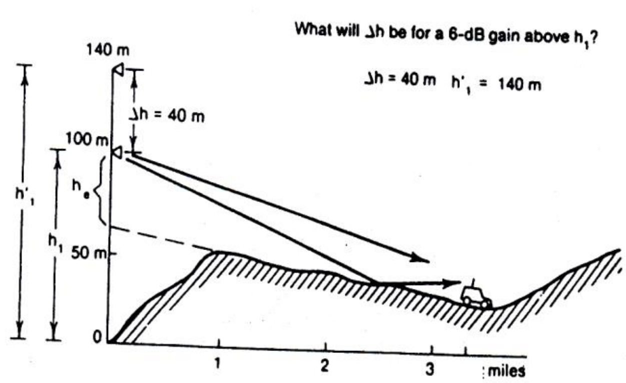
(b) Connect the image antenna of the mobile antenna to the cell site antenna. Between the above two intercept points at the ground, choose one intercept point close to the mobile unit which is having more energy.

(2) Extend the reflected ground plane.

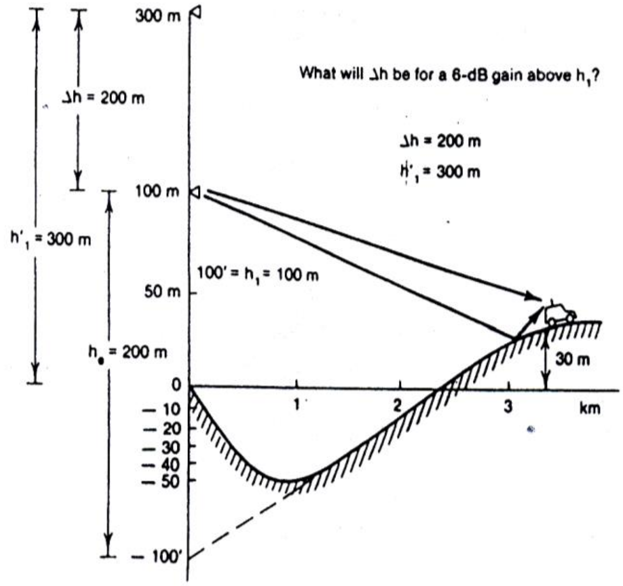
(3)Measure the effective antenna height. In fig. (a), he is 40 meters and In fig.

(b)he is 200 meters the actual antenna height h1 is 100 meters. (4)Calculate the

antenna height gain ΔG $G = 20 \log \frac{h_e}{h_1}$



(a)



Calculation of effective antenna height : a) case 1 ; (b) case 2.

For fig (a), $\Delta G = 20 \log \frac{40}{100} = -8\ db \quad (a \quad negative \quad gain)$

For fig (b), $\Delta G = 20 \log \frac{200}{100} = 6\ db \quad (a \quad negative \quad gain)$

The antenna height gain ΔG changes as the mobile unit moves along the road. That is the effective antenna height changes at cell site due to mobile unit moves to a new location, although actual antenna height remain unchanged.

Contribution of antenna-height gain:

If the antenna-height gain due to terrain contour between cell site and the mobile unit is not taken into consideration, the path loss slope will have a standard deviation of 8db. If taken into consideration, the deviation is within 2 to 3db.

As shown in fig. the changing effective antenna heights he and h_e' a different positions of mobile unit are illustrated.

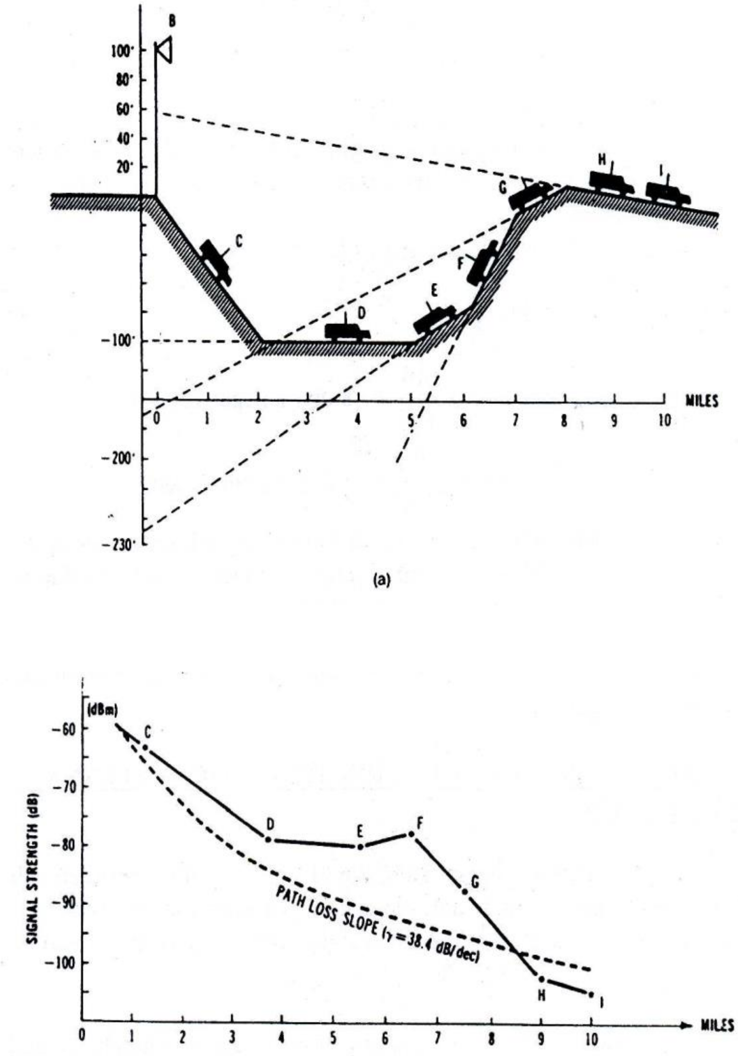


Illustration of the terrain effect on the effective antenna gain at each position

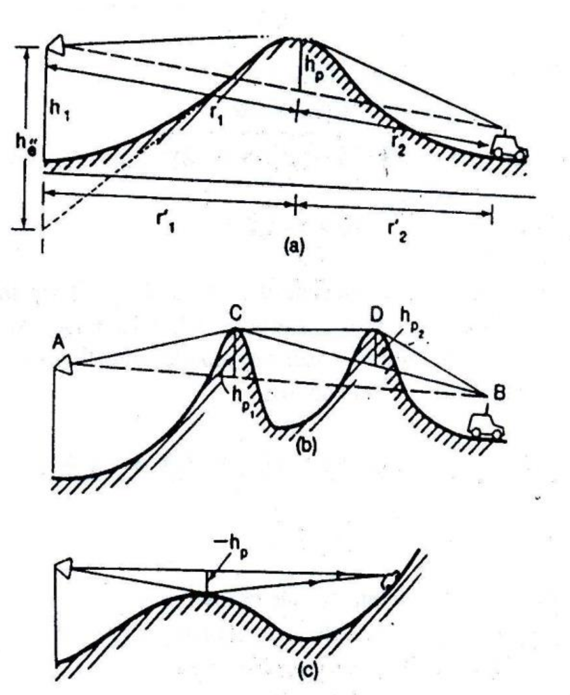
(a) Hilly terrain contour. (b) Point-to-point prediction.

The effective antenna gain $\Delta G = 20\log\frac{h_e}{h_1}$ for a suburban area, the path loss slope is shown in fig. (b). then the antenna there is a difference between an area-to area prediction (use path loss slope) and a point-to-point prediction (after antenna gain correction) The point-to-point is based on actual terrain contour.

Path loss from a point-to-point prediction model in obstructive condition

The terrain contour obstructs the direct path between cell sites on the mobile unit. This obstruction can be studies at follows.

To obtain diffraction loss :



diffraction loss due to obstructive conditions.

(a) single knife-edge (b) double knife-edges, (c) non clear path.

(i) Single Knife edge: There are 4 parameters. The distances r1 and r2 from the knife edge to the cell and mobile sites, the height of knife edge hp, operating wave length λ from these, obtain new parameter V.

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

hp is positive for fig (a) and (b)

hp is negative for fig (c)

The diffraction Loss L = 0 db for $v \geq 1$.

$$L = 20\log\left(0.5 + 0.62v\right) for \ 0 \leq v < 1$$

$$L = 20\log\left(0.5e^{0.95v}\right) for \ -1 \leq v \leq 0$$

$$L = 20\log\left[0.4 - \sqrt{0.1184 - \left(0.1v + 0.38\right)^2}\right] for \ -2.4 \leq v - 1$$

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

ii) For double knife edge calculate v as v1 and v2. Then the total diffraction loss for double knife edge = L = L1 +L2. When the heavy foliage is observed near the mobile unit, this loss can be obtained from the diffraction loss.

Form of a point-point model:

(a)General formula of LEE model :

The formula of the Lee model for the following 3 - cases

(1) Direct wave case: The effective antenna height varies with the location of the mobile unit when it travels.

(2) Shadow case: No effective antenna height exists and the loss is due to knife - edge diffraction loss.

(3) Over the water condition: Free space path loss is applied.

(a)For Non - obstructive path,

$$P_r = \underbrace{P_{r0} - \gamma \log \frac{r}{r0}}_{} + \underbrace{20\log \frac{h_e'}{h_1}}_{} + \alpha$$

$$\left[\textit{By human made structure} \qquad \textit{By terrian contour} \right]$$

(b) For obstructive path,

$$P_r = P_{r0} - \gamma \log \frac{r}{r0} + 20\log \frac{h_e'}{h_1} + L + \alpha. \qquad (\textit{where } h_e' \textit{ shown in fig} 4.10 \textit{ knife edge})$$

$$P_r = \underbrace{P_{r0} - \gamma \log \frac{r}{r0}}_{} + \quad L + \alpha \ \ (\textit{for } h_e' = h_1)$$

By human made structure   *By terrian contour*

(c)for land to mobile over water, the free space path – loss is applied

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

$\gamma = 20$ for free space path loss, $\gamma = 40$ for mobile path loss

Remarks:

(1) Pr cannot be more than free space path loss.

(2) For within 2 mile radius, the received power at the mobile unit traveling along an in-line road can be 10db higher than that along a perpendicular road.

(3) α is the effective antenna height gain.

(4) Foliage loss is added depending on the situation. In forest, the antenna height at the cell site is higher than the top of trees.

(5) Within one mile in manmade environment, the strength of the received signal is effected by buildings and orientation of roads. Point to point model is very useful in mobile cellular system designing for a cell radius of less than 10miles, as the prediction model is within 2 to 3 db only.

The point-to-point prediction can be used to predict the overall coverage of all cell sites and to avoid co-channel interference. Also the occurrence of hand off in the cellular system can be predicted accurately.

The applications of point-to-point prediction model is used to generate a signal coverage map, an interference area map, a hand off occurrence map, an optimum system design etc.

Cell-site antenna heights and Signal coverage cells

Effects of cell heights antenna heights:

(i)Antenna height unchanged :

If the power of the cell site transmitter changes, the signal strength map can be linearity updated according to the change in power.

(ii)Antenna height changed.

If the antenna height changes (±Δh), the signal strength map of old antenna height cannot be update d with a antenna gain formula Δg

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

Where h_1^1 is the antenna new height and h1 is the antenna old height. The same terrain contour can be used to find the difference in gain due to different effective heights.

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

he is the old effective antenna height and h_1^1 is the new effective antenna height.

The additional gain (increase or decrease) is added to the signal strength of the old antenna height.

Location of the Antenna changed:

If the location is changed the point-to-point model has to do again. The old effective antenna height seen from a distance is different and there is no relation between the old effective antenna height and new effective antenna height. Hence new point-to-point model has to be started.

Visualization of the effective Antenna Height:

The effective antenna height is always changing high or low as 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 going away from the cell site antenna and decreases if the mobile unit approaching the cell site.

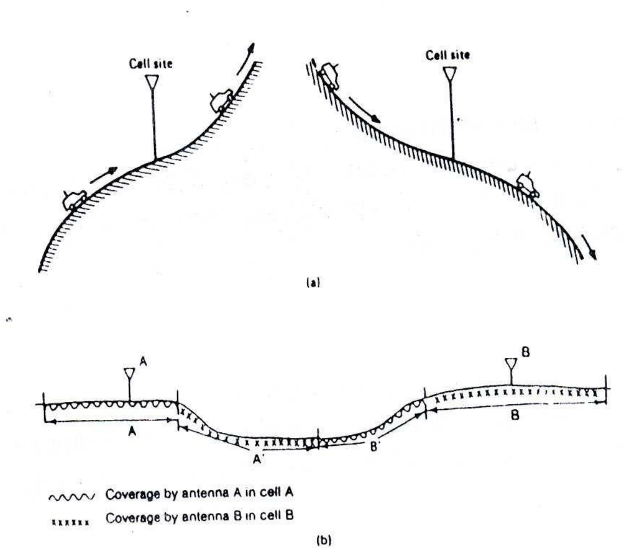
Case (ii):

The mobile unit is driven down a hill:

The effective height decreases if mobile unit is moving away from the cell site antenna and increases if it is approaching cell site antenna:

Signal coverage cells:

In the signal reception region around the cell site, there are weak spots called HOLES for a flat terrain.



Different coverage concept (a) signal coverage due to effective antenna heights.

(b) Signal coverage served by two cell sites.

The signal coverage for a hilly terrain is shown in fig.4.11 and the two cell sites separated by a river. Due to shadow loss, cell site A cannot cover area A' but can cover cell site B and the same holds good for cell site 'B'. When a vehicle enters A', a hand off is requested for cell site B.

Therefore, the holes in one cell are covered by the other sites. If the processor at MTSO can handle excessive hand offs, this approach of filling the holes is good in a noninterference condition.

UNIT-IV

CELL SITE AND MOBILE ANTENNAS

Sum and difference patterns and their synthesis

The antenna pattern can be designed for uniform coverage after obtaining the field-strength contour. For different antenna pointing in different directions and with different spacing's, we can use any of a number of methods. If we know the antenna pattern and the geographic configuration of the antennas, a computer program can help us to find the coverage. Several synthesis methods can be used to generate a desired antenna configuration. Many applications of linear arrays are based on sum and difference pattern .The main lobe of the pattern is always known as the sum pattern pointing at an angle. The difference pattern produces twin main beams. For a sum pattern, all the current amplitudes are the same. For difference pattern, the current amplitudes of one side (half of the total elements) are positive and the current amplitudes of the other side (half of the total elements) are negative. Most pattern synthesis problems can be solved by determining the current distribution.

Synthesis of sum patterns:

Dolph-chebyshev synthesis of sum patterns.

This method can be used to reduce the level of sidelobes; however, one disadvantage of further reduction of sidelobe level is broadening of the mainbeam.

Taylor synthesis

A continuous line-source distribution or a distribution for discrete arrays can give a desired pattern which contain a single mainbeam of a prescribed bandwidth and pointing direction with a family of sidelobes at a common specified level.

Symmetrical pattern

For production of a symmetrical pattern at the mainbeam, the current – amplitude distribution!g(l)! Is the only factor. The phase of the current distribution can remain constant.

Asymmetrical pattern

For production of an asymmetrical pattern, both current amplitude (l)! and phase arg(l) should be considered.

Synthesis of difference patterns

A continuous line source that will produce a symmetrical difference pattern, with twin mainbeam patterns and specified sidelobes.

Null-free patterns

In mobile communications applications, filed-strength patterns without nulls are preferred for the antennas in vertical plane.

Antennas at cell site

<u>Omni directional antennas –for coverage use</u>

6db and 9db gain omni directional antennas whose directional pattern is shown in fig below

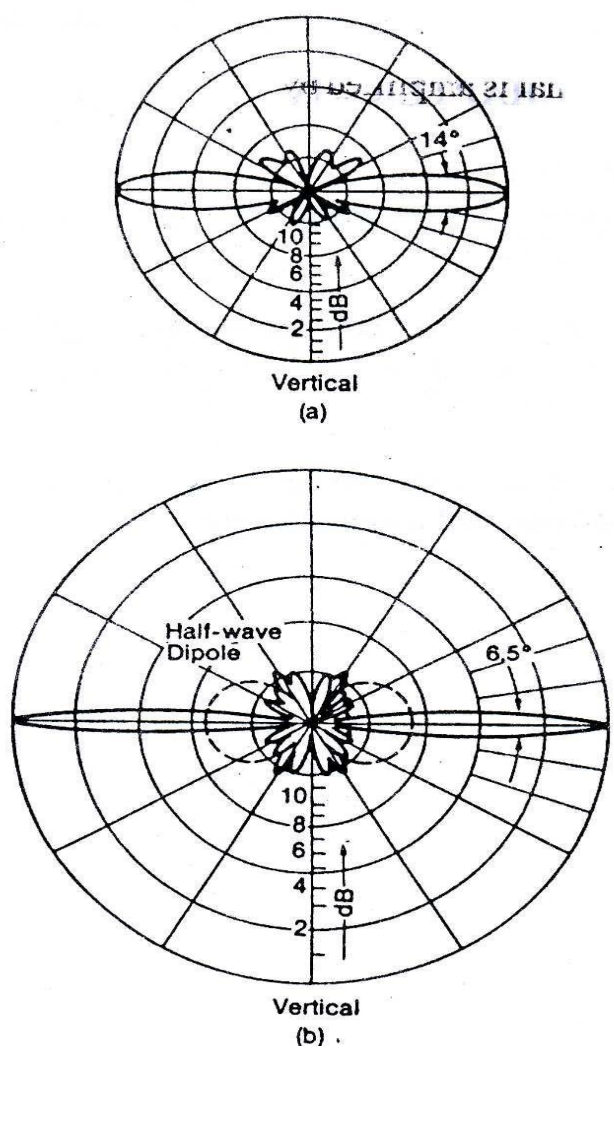
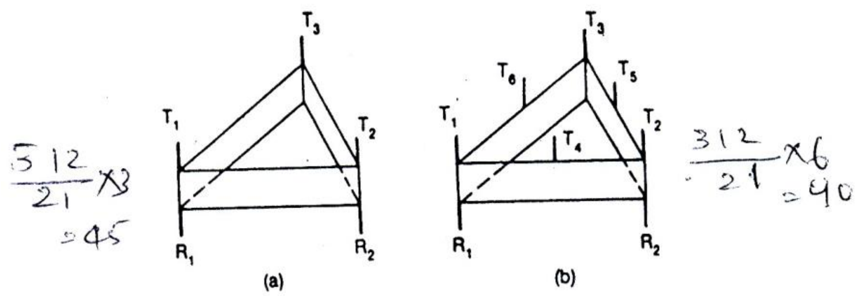


Fig: High gain omni directional antennas Gain with reference to dipole: (a) 6db(b) 9db

Start-up system configuration**:**

In a start-up system, an omni cell in which all the transmitting antennas are omni directional is used. Each transmitting antenna has to transmit signals from 16 radio transmitters simultaneously using 16 channels combiner. Each cell have 3 – transmitting antennas which serve 45 voice radio transmitters. (The combiner combines 16 voice channels. The cellular system divides 312 voice channels into 21 sets, as there are 21 set- up channels and each set has about 15 voice channels. A dummy load has to be put on empty ports of the combiner).Each sending signal is amplified by its own channel amplifier in each radio transmitter, then 16 radio channels are combined and transmit the signals by transmitting antenna. Two receiving antennas receive all 45 voice radio signals simultaneously. The two identical signals received by the two receiving antennas pass through a diversity receiver.



Cell-site antennas for omni cells: (a) for 45 channels; (b) for 90 channels

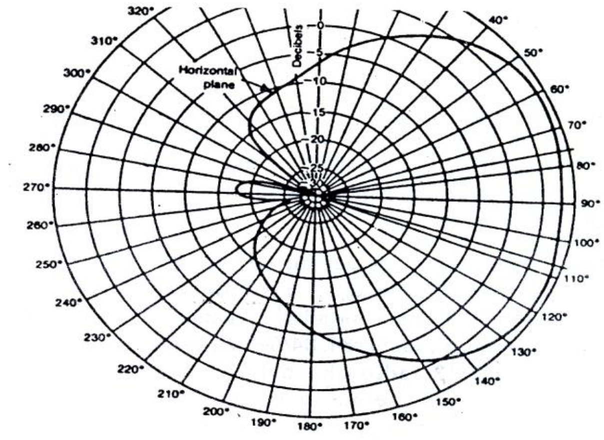
Abnormal Antenna Configuration**:**

To meet the increase demand, the cell site can be equipped with up to 90 radio voice channels and the transmitting antennas fo 6nos. should be used, as shown in fig and two receiving antennas only are required as in the 45 channels. By using hybrid ring combiner, two 16-channels can be combined and then only 3 number of transmitting antennas are sufficient.

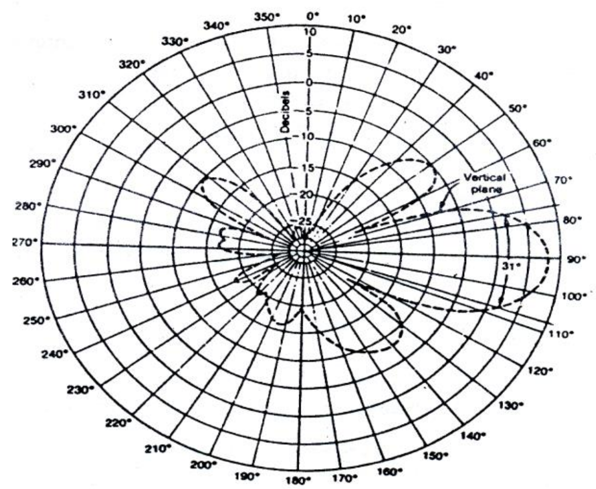
Directional Antennas for interference reduction at cell site

For reduction of co-channel interference in freq reuse, Directional antennas are used. The co-channel reduction factor = q = D/R = 4.6 for flat terrain. So for interference reduction either q has to be increased or directional antennas required. For 1200 sector cell, a 1200 corner or plane reflector and for 600 sector cell, a 600 corner reflector are to be used. The radiation pattern for

Case (i): For 7 cell, it requires 1200 sector directional antenna. In 333 chanenels (333/7=45), each cell has 45 voice channels. Each 1200 sector has one transmitting antenna and two receiving antennas (diversity techniques) are required to receive (45/3 sectors) 16 radio channels.



(a)



(b)

Case (ii): Transmitting and Receiving 600 sectors: For 4 cell requires 68 sector antenna is sufficient for interference reduction. For all 333 channels coverage, each sector (333/4 = 84, 84/6 = 14), each 600 sector carry 13 radio channels by one transmitting antenna use and one receiving antenna. At the receiving end two of the 6 receiving antennas are selected for angel diversity for each radio channel.

(b) Receiving 600 sectors:

Only 600 sector receiving antennas are used to locate the mobile unit and hand off to the neighboring cell accurately. All the transmitting antennas are omni directional in each cell .At the receiving end ,the angle diversity for each radio channel same as above is used.

(3) Location antennas:

The location receiver at cell site is tuned to one of the 333 channels either on demand or periodically. The receiver receives its signal on omni directional or shared directional antenna.

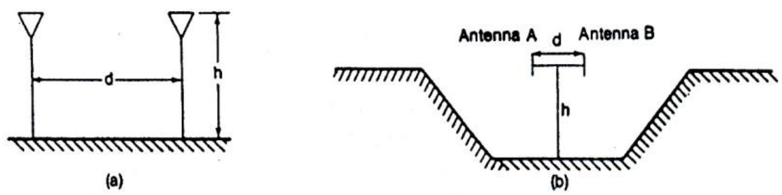
(4) Set-up channel antennas:

This antenna is used to page a called number by MTSO or access to call from a mobile unit. It transmits only data. The setup channel antenna is either several directional antennas or omni directional antenna at one cell site.

Space diversity antennas:

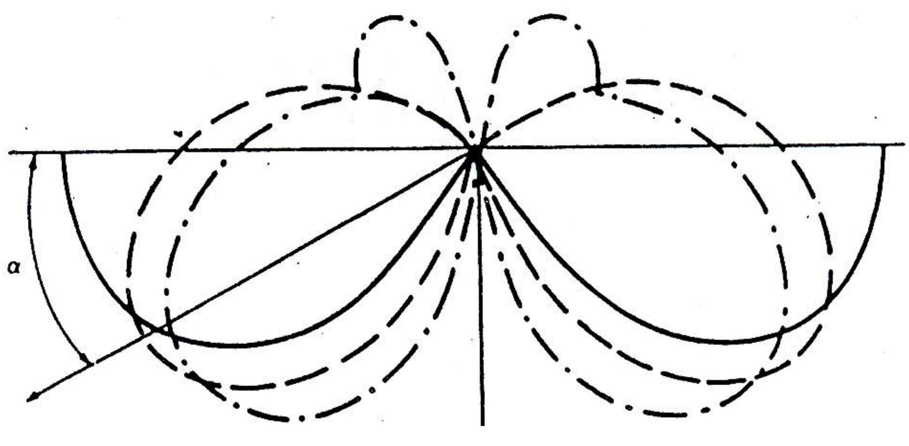
At cell site, two branch space diversity antennas are used to receive the same signal with different fading envelope. By the location of these two receiving antennas, the degree of correlation between the two fading envelopes is determined.

For design of antenna, the parameter $\lambda = h/d = 11$ where h is antenna, D is antenna separation should be $d \geq 8\lambda$ and for 50 meters, $d \geq 14\lambda$. In any omni cell system ,the two space diversity antennas should be aligned with the terrain.

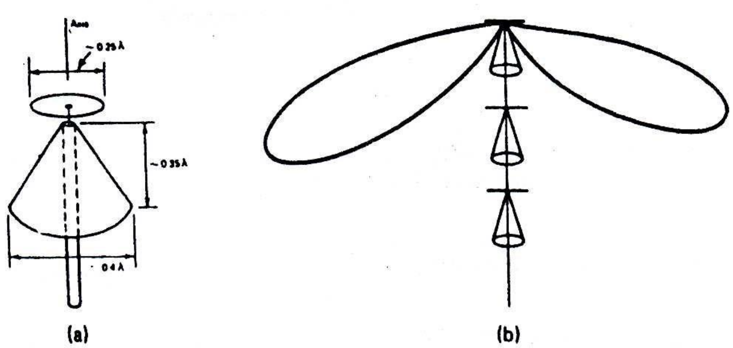


Umbrella-Pattern antennas

At cell sites for controlling the energy radiation / reception, an umbrella pattern antenna which consists of a mono-pole with a top disk loading as shown in figure below (Normal Umbrella-Pattern antennas).Size of the disk determines the tilting angle (α) of the pattern and smaller the disk the larger the tilting angle of the umbrella pattern.

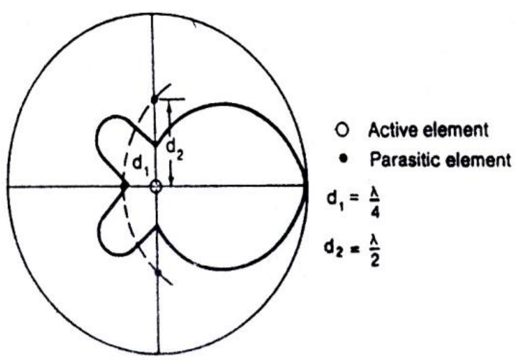


(b)Broad brand umbrella pattern antenna:



The diameter of the disk, the length of the cone and opening of the cone can be adjusted for an umbrella pattern antenna.

Interference reduction antenna



The parasitic (insulation) element of 1.05 times longer than the active element and the separation between the elements, will reduce interference.

<u>Minimum separation of cell site antennas</u>

The radiation pattern of an antenna measured in free space is different from the antenna pattern of cell site antenna with respect to mobile antenna. The strongest reception is with the strongest signal strength of the directional antenna. The pattern is distorted in urban and suburban areas.

For a 120^0 directional antenna, the back lobe is 10db less than front lobe. As the Strong signal radiates in front, the signal can be received from the back of the antenna due to bouncing back, from the surroundings.

To reduce the antenna pattern ripple effects, a minimum separation between two receiving antennas is to be maintained. For a space diversity, if the two receiving antennas are located closer the difference in power increases for a given pointing angle and this will happen for a small sector. At 850MHz, the separation of eight wavelengths between two antennas create a power difference of ±2db which is tolerable for a diversity scheme.

For reduction of interference, the antenna has to be located within a quarter of the size of cell (R/4). If the site is 8 mile radius, the antenna can be located within 2 miles radius.

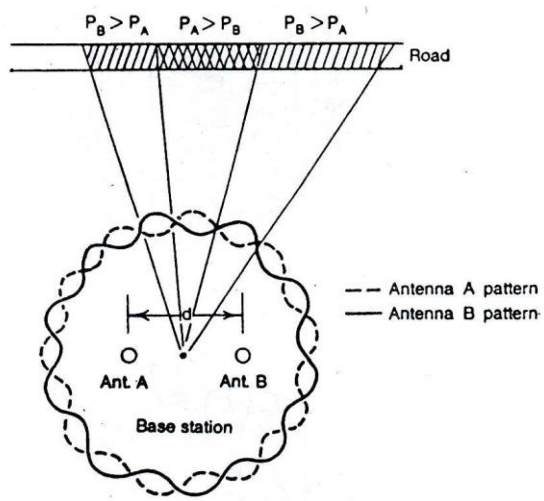
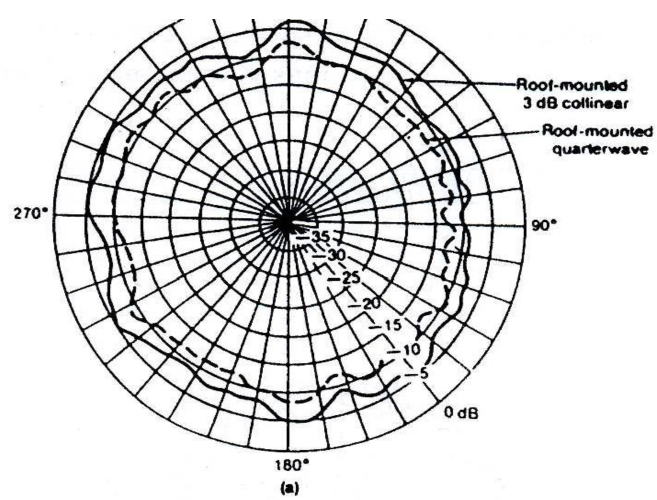
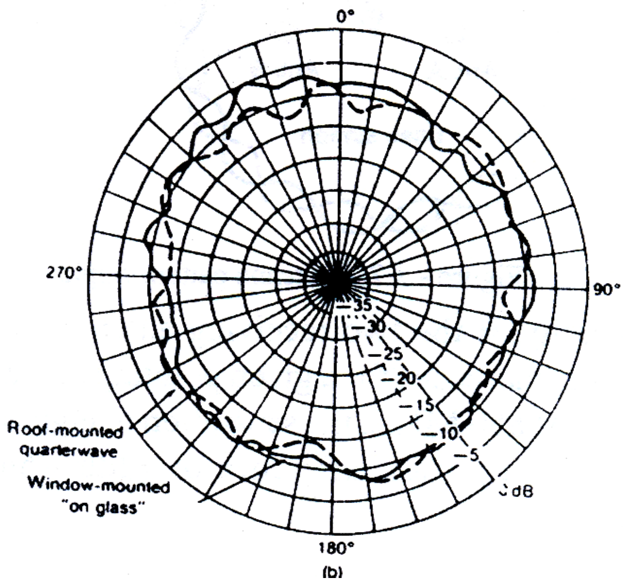


Figure: Antenna pattern ripple effect

Mobile Antennas-high gain antennas

From the point of reception, the antenna is an omni directional antenna and it has to be located as high as possible and at least is should clear the top of the vehicle. For roof mounted and window mounted mobile antenna patterns are shown in fig.





(a) Roof Mounted**:**

The antenna pattern of a roof mounted antenna is nearly uniform around, the mobile unit. The roof mounted collinear antenna shown a 3db gain over quarter wave antenna. At mobile unit, the antenna gain is to be limited to 3db. If it is more than 3db, it can then receive only a limited portion of the total multi path signal in the elevation under the out of sight condition.

(b) Glass mounted Antenna:

There are many types of glass mounted antennas. The energy is coupled through the glass and some energy is dissipated in it. Depending on the operating frequency the gain is 1 to 3db. The location of this antenna is lower than that of roof mounted and there is a difference in gain of 3db in these two types of antennas.

(C) Mobile high Gain Antennas:

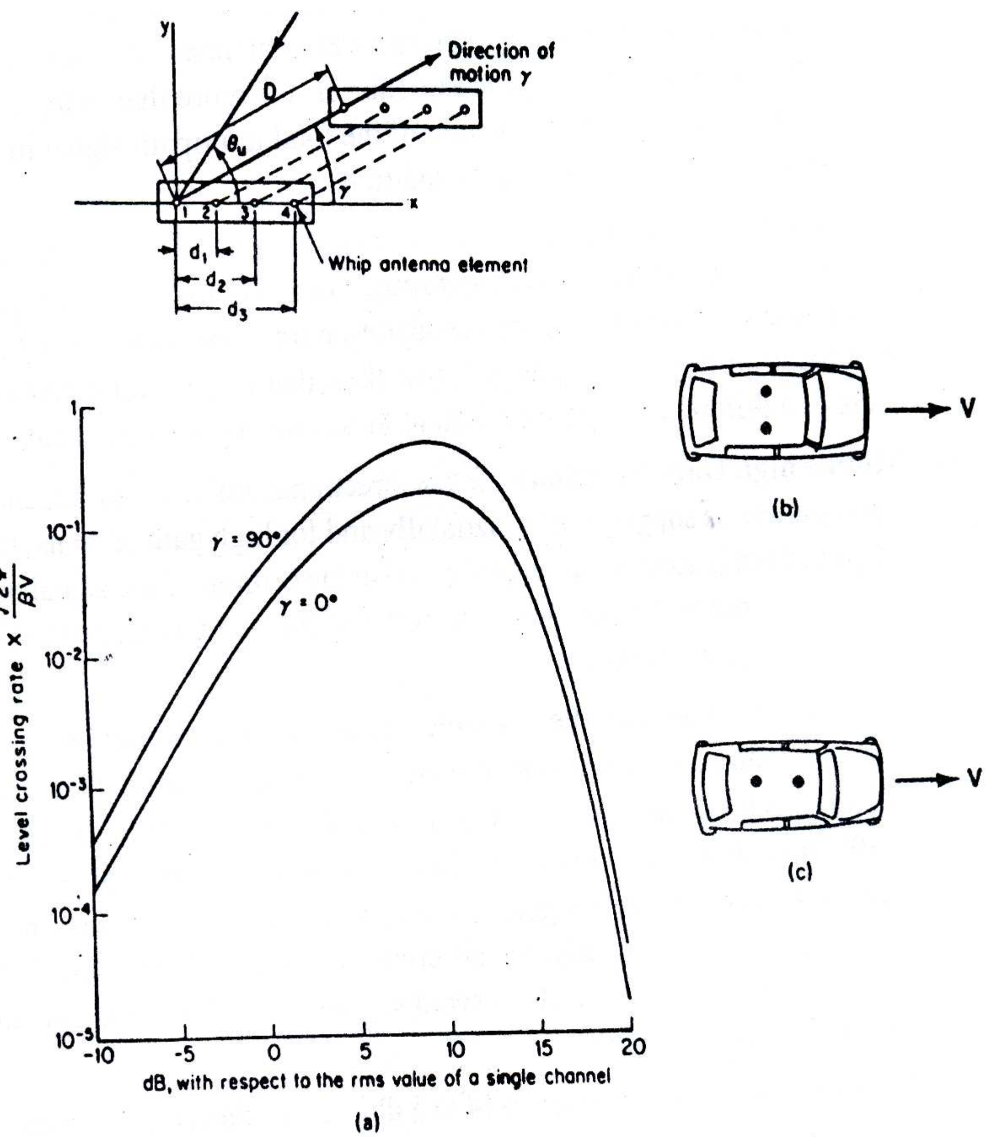
In the directional antennas, the antenna beam pattern is suppressed horizontally and for high gain antenna, the beam pattern is suppressed vertically. Also the origin of the signal has also to be known for reception for pointing the antenna direction for maximum signal reception.

In mobile environment, the scattered signals arrive at the mobile unit from every direction with equal probability and hence omni directional antenna has to be used. A □/4 whip antenna with an elevation coverage of 390 and 4db gain (relative to dipole) with an elevation of 160 are used to receive scattered signals from different directions. But when gain is measured practically, the difference in gain is observed as 2db only. This is due to arrival of scattered signals under Non-LOS spread over wide elevation angle.

Therefore 2 to 3db gain antenna (4 to 5dbi – I for relative to isotropic) is sufficient for general use. It does not increase the signal reception level for higher antenna gain and also in urban areas elevation angle for scattered signals is more than the suburban areas.

(d) Horizontally oriented space-diversity antennas:

A two branch space diversity receiver mounted on a motor vehicle reduce fading and operate at lower at lower reception level. In space diversity scheme, the two vehicle mounted antennas will be separated horizontally by 0.5λ.If two antennas mounted in line to the motion of the vehicle produce less fading than perpendicular antenna mounting.



Vertically oriented space diversity antennas:

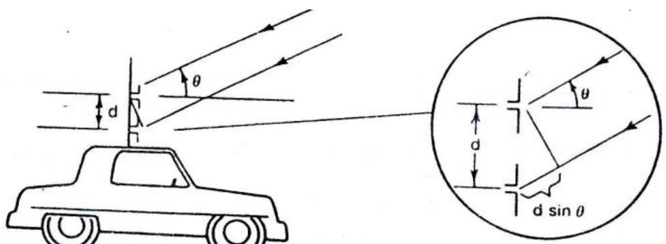
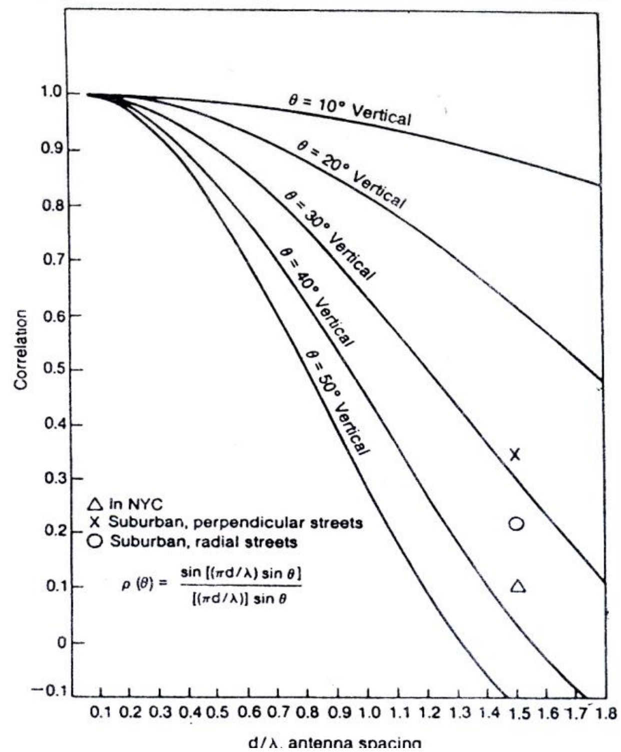


Figure - 5.10 - Vertical separation between two mobile antennas.



The vertical separation (d) between two space diversity antennas can be determined from the correlation between their received signals.

The correlation is $= \rho\left(\frac{d}{\lambda},0\right) = \sin\ (\pi d\ /\ \lambda\ )\cdot \sin\ \ \theta\ /(\pi d\ /\ \lambda\ )\cdot \sin\ \ \theta$

The correlation is measured for d = 1.5λ and it is more for perpendicular streets than radial streets and also measured that the arrival of signal at elevation angles of 29^0 for radial and 33^0 for perpendicular streets.

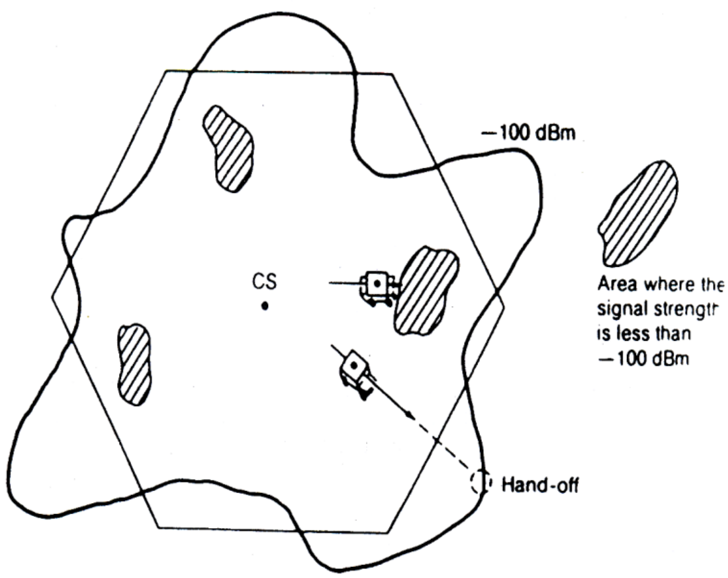
UNIT-V

HANDOFFS STRATEGIES

CONCEPT OF HANDOFF:

Once a call is established, the setup channel is not used again, during the call period, Therefore handoffs is always implemented on the voice channel. The implementation of handoffs is dependent on the size of the cell. For a 32km radius cell, after a call is initiated in this cell, there is a little chance of dropping it before the call is terminated as a result of weak signal at cell boundary. If a call is dropped in a fringe area, the customer redials and reconnects the call.

Handoff is needed in two situations where the cell site receives weak signals form the mobile unit.



1. At the cell boundary, where the signal level of -100 dbm for requesting handoff in a noise - limited environment.
2. When the mobile unit is reaching the signal strength holes (gaps) within the cell site as shown in figure.1.

Handoff initiation:

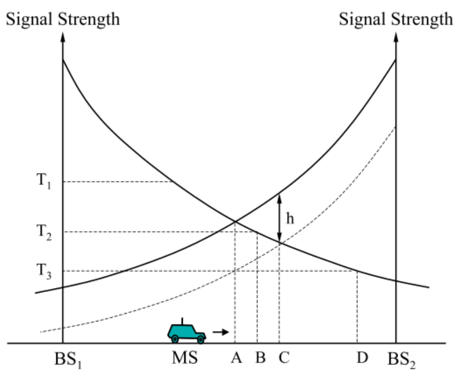
A hard handoff occurs when the old connection is broken before a new connection is activated. The performance evaluation of a hard handoff is based on various initiation criteria. It is assumed that the signal is averaged over time, so that rapid fluctuations due to the multipath nature of the radio environment can be eliminated. Numerous studies have been done to determine the shape as well as the length of the averaging window and the older measurements may be unreliable. Figure 1.2 shows a MS moving from one BS (BS_1) to another (BS_2). The mean signal strength of BS_1 decreases as the MS moves away from it. Similarly, the mean signal strength of BS_2 increases as the MS approaches it. This figure is used to explain various approaches described in the following subsection.

Relative Signal Strength

This method selects the strongest received BS at all times. The decision is based on a mean measurement of the received signal. In the below figure the handoff would occur at position A. This method is observed to provoke too many unnecessary handoffs, even when the signal of the current BS is still at an acceptable level.

Relative Signal Strength with Threshold

This method allows a MS to hand off only if the current signal is sufficiently weak (less than threshold) and the other is the stronger of the two. The effect of the threshold depends



Signal strength and hysteresis between two adjacent BSs for potential handoff.

on its relative value as compared to the signal strengths of the two BSs at the point at which they are equal. If the threshold is higher than this value, say T_1 in Figure, this scheme performs exactly like the relative signal strength scheme, so the handoff occurs at position A. If the threshold is lower than this value, say T_2 in Figure, the MS would de- lay handoff until the current signal level crosses the threshold at position B. In the case of T_3, the delay may be so long that the MS drifts too far into the new cell. This reduces the quality of the communication link from BS_1 and may result in a dropped call. In addition, this results in additional interference to co-channel users. Thus, this scheme may create overlapping cell coverage areas.

Types of Handoffs:

There are two types of handoffs.

(1) Based on signal strength in which the signal strength threshold level for handoff is – 100dlm in noise limited systems and – 95 dbm interference limited system.

(2) Based on carrier to interference ratio: The value of C/I at the cell boundary for handoff should be 18db to have good voice quality.

The location receiver at each cell site measures all the signal strengths of all the mobile receivers at cell site the received signal strength (RSS) includes interference.

$$RSS = C + I$$

Where C is the carrier signal power and I is the interference.
Handoff can be controlled by using carrier-to-interference ratio (C/I).

$$\frac{C + I}{I} = \frac{C}{I}$$

A level of (C/I) can be setup and level of C is function of distance and I is dependent on location. When increase in propagation distance or increase in interference, (C/I) reduces bellow threshold and handoff takes place in both cases. In today's cellular system it is difficult to measure (C/I) ratio when a call is in progress and analog modulation is used.

Suppose a mobile unit in a cell is moving randomly in speed (5 to 60 km/h) and direction (00 to 3600), the probability of reaching the boundary for handoff is dependent on the call holding time. If the call holding time. If the call holding time is 1.76minute, the handoff probability is 11.3%, for 6minutes 42.6% and for 9 minutes is 59.3%.

The number of handoffs per call is dependent on cell size. 0.2handoffs per call for 16 to 24km cell, 1 to 2 handoffs for 3 to 8km cell and 3 to 4 handoffs per call in a 1 to 3km cell.

Delaying a Handoff:

A handoff could be delayed when the mobile unit approaches a cell boundary if no available cell could take the call. When a signal strength drops below the first handoff level, a handoff request is initiated and when the second handoff level is reached the call is handed over with no condition. If the mobile unit is in a hole or neighboring cell is busy, the handoff will be requested periodically every 5 seconds. Thus two-level handoffs are present.

The MTSO always handles the handoff call first and the originating call second because call drops upset the customers.

Forced Handoff:

A handoff will not occur but is forced to happen. The MTSO can control and can make handoff earlier or later after receiving a handoff request from a cell site.

Queuing of Handoffs:

The MTSO will queue the requests of handoff calls instead of rejecting them if the new cell sites are busy. This scheme is effective only when the requests for handoffs arrive at the MTSO in batches or bundles and when the requests arrive uniformly. This scheme is not effective.

Power difference (⊗) Handoffs:

This handoff is based on the power difference ($\otimes$) of a mobile signal received by two cell sites. The handoff depends on a preset value of $\otimes$.

$\otimes > 3$db, request a handoff

1db $< \otimes <$ 3db prepare a handoff

-3db $< \otimes <$ 0 monitoring the signal strength

$\otimes <$ -3db no handoff. But dropped call

The value of $\otimes$ can be changed to the processor capacity.

Normally, the request for handoff is based on the signal strength or the supervisory audio tone (SAT) range of a mobile signal received at the cell site from the reverse link. In the digital cellular system, the mobile receiver is capable of monitoring the signal strength of the setup channels of the neighboring cells while serving a call. In TDMA system, one time slot is used for serving a call and the rest of the time slots to monitor the signal strengths of the setup channels.

<u>Mobile Assisted Handoff (MAHO)</u>

In a normal handoff procedure, the request for a handoff is based on the signal strength of a mobile signal received at the cell site from the reverse link. In the digital cellular system, the mobile receiver is capable of monitoring the signal strength of the setup channels of the neighboring cells while serving a call. This is called Mobile Assisted Handoff.

<u>Intersystem handoff</u>

Occasionally a call may be initiated in one cellular system (controlled by one MTSO) and enter another system (Controlled by another MTSO) before terminating. In some instances, intersystem handoff can take place; this means that a call handoff can be transferred from one system to a second system so that the call be continued while the mobile unit enters the second system.

<u>Vehicle-locating methods</u>

By locating the vehicle and calculating the distance to it, we can obtain information useful for assigning proper frequency channels.

There are many vehicle-locating methods. In general, we can divide these into two categories: Installation of equipment (1) in the vehicles and (2) at the cell site

Installing equipment in the vehicles

Triangulation

Three or more transmitting antennas are used at different cell sites. Since the locations of the sites are known, the vehicle's location can be based on identification of three or more sites. However, the accuracy is limited by the multipath phenomenon.

Fifth-wheel and gyroscope equipment

A gyroscope and a fifth wheel are used for determining the direction and distance a vehicle has traveled from a predetermined point at any given time.

The Global-position satellite (GPS)

There are seven active GPSs, each of them circling the earth roughly twice a day at an altitude of 1840 Km (11,500 mi) and transmitting at a frequency of approximately 1.7.GHz.Atleast three or more GPS satellites should be seen in space at any time, so that a GPS receiver can locate its locate its position according to the known positions of the GPS satellite.

Installing equipment at the cell site.

In general, either of the following three methods alone cannot provide sufficient accuracy for locating vehicles; a combination of two or all three methods is recommended.

Triangulation based on signal strength

Record the signal strength received from the mobile unit at each cell site and then apply the triangulation method to find the location of the mobile unit. The degree of accuracy is very poor because of the multipath phenomenon

Triangulation based on angular arrival

Record the direction of signal arrival at each cell site and then apply the triangulation method to find the location of the mobile unit

Present cellular locating receiver

Each cell site is equipped with a locating receiver which can both scan and measure the signal strength of all channels. This receiver can be used to continuously scan the frequencies, or to scan on request.

Dropped call rates and their evaluation:

Definition:

The dropped call is after the call is established but before it is properly terminated. “The call is established” means that the call is setup completely by the setup channel. If there is no availability of voice channels, the call is then blocked call but not dropped call.

The dropped call rate by the subscribers are higher due to:

- The subscriber unit not functioning properly
- The user operating the portable unit in a vehicle
- The user not knowing to get good reception from a portable unit.

(i) Consideration of dropped calls:

The dropped call rate can be low if the voice quality is not considered. The dropped call rate and the specified voice quality are inversely proportional. For a certain voice quality, the dropped call rate can be calculated by considering the following factors.

(1) The received signal level in the signal coverage area (90% percent of the area) is above a given signal level.

(2) Maintain the co channel and adjacent channel interference levels in a busy hour.

(3) When the cell becomes small, the response time for handoff has to be shorter, to reduce the call dropped a rate.

(4) The relationship among the voice quality, system capacity and call dropped rate can

be expressed by C/I parameter.

Relationship among capacity, voice quality, dropped call rate:

Radio capacity

$$m = \frac{B_T / B_C}{\sqrt{\frac{2}{3}\left(\frac{C}{I}\right)_s}}$$

Where BT/BC is the total number of voice channels and (C/I) s is the required (C/I) for designing a system. This equation is obtained for a six co-channel interferers in a busy traffic. In an interference limited system, the adjacent channel interference has only a secondary effect.

The number of frequency-reuse cells in a cellular configuration is derived from the following equations:

a) $$q = \left(6\frac{C}{I}\right)^r \text{ where}$$

q = interference reduction factor and

r = slope path loss = 4 (for 40db/dec)

b) The factor q is related to number of cells (K) in a hexagonal shaped system by $q \cong \sqrt{3K}$

$$\sqrt{3K} = \left(6\frac{C}{I}\right)^4, \qquad 9K^2 \quad 6.\frac{C}{I}$$

$$\frac{C}{I} = \frac{3K^2}{2} \qquad or \qquad K = \sqrt{\frac{2C}{3I}}$$

$$m^2 = \frac{(B_T / B_C)^2}{\frac{2}{3}\left(\frac{C}{I}\right)_s}$$

$$\left(\frac{C}{I}\right)_s = \frac{3}{2}\left(\frac{B_T/B_C}{m}\right)^2 = \frac{3}{2}\left(\frac{B_T}{B_C}\right)^2 \frac{1}{m^2}$$

$\left(\frac{C}{\ }\right)$ *is* $\left(\frac{C}{\ }\right)$

Adjusting the parameters of the system

1. Increasing the Coverage for A Noise – Limited System:

In noise limited system, there is not co-channel or adjacent channel interference. To increase the coverage at cell site, the following approaches are used.

Increasing the transmitter Power:

By increasing the transmitter power of each channel, the coverage area is larger. When the power level is doubled, the gain increases by 3-db. The received power Pr and Pt the transmitted power.

$$P_{r1} = \alpha Pt_1 r_1^{-4}$$

Area covered $= A_1 = \pi r_1^{2}$ where alpha is a constant.

Case (i) :

The transmitted power remains uncharged but the receiver power changes. For a strong receiver power, the cell radius is small.

$$\frac{P_{r1}}{P_{r2}} = \frac{r_1^{-4}}{r_2^{4}} = \frac{r_2^{4}}{r_1^{4}}$$

$$r2 = \left(\frac{P_{r1}}{P_{r2}}\right)^{1/4} r1$$

If Pr2=2Pr1, the transmitter power remains same, the radius reduces to

$r_2 = (0.5)^{1/4}.r1 = 0.84 \times r_1$ The area reduces to

$$\frac{A_2}{A_1} = \frac{\pi r_2^{\,2}}{\pi r_1^{\,2}} = \frac{r_2^{\,2}}{r_1^{\,2}} = \frac{(0.84 r_1)^2}{r_1^{\,2}} = 0.71$$

Case (ii) : The transmitter power changes but the received power remains unchanged. Then 1 mile recepton level changes if the transmitted power changes.

$$P_{r1} = \alpha P_{t1} r_1^{-4}, \quad P_{r2} = \alpha P_{t2} r_2^{-4}$$

In this case since Pr1 = Pr2, then $\frac{P_{r1}}{P_{r2}} = 1$,

$$\therefore \left(\frac{Pt\,1}{Pt\,2}\right)\left(\frac{r_1}{r_2}\right) = \frac{Pt\,1}{Pt\,2}\left(\frac{r_2}{r1}\right)^4$$

$$\frac{r_2^{\,4}}{r_1^{\,4}} = \frac{Pt2}{Pt1} \qquad \therefore r_2 = \left(\frac{Pt2}{Pt1}\right)^{1/4} \cdot r_1$$

If the transmitted power Pt2 is 3-db higher than Pt1 then r2 = (2)1/4.r1=1.19r1

Then the area increases is $\frac{A2}{A1} = \frac{r_2^{\,2}}{r_1^{\,2}} = (1.19)^2 = 1.42$

General equations are

$$r_2 = \left(\frac{\mathrm{Pr1}.Pt2}{\mathrm{Pr2}.Pt1}\right)^{1/4} r_2 \quad (or) \quad A_2 = \left(\frac{\mathrm{Pr1}.Pt2}{\mathrm{Pr2}.Pt1}\right)^{1/2} A_1$$

(b) Increasing cell site antenna height:

Doubling the antenna height causes gain increase of 6-db for a flat terrain. If it is hilly, effective antenna height is to be used depending on the location of the mobile unit.

(c) Using a high gain or a directional antenna at the cell site:

The gain and directivity increases with the received level and the same effect with an increase in transmitted power.

(d) Lowering the threshold level of received signal:

When the threshold level is lowered, the acceptable received power is lower and the radius of the cell increases

$$r_2 = \left(\frac{\mathrm{Pr}\,1.Pt\,2}{\mathrm{Pr}\,2.Pt\,1}\right)^{1/4} .r_1$$

(e)A Low-Noise Receiver:

A low noise receiver can receive a signal from a longer distance than that of a high noise receiver.

(f) Diversity Receiver:

This type of receiver is used in reducing the multi path fading, which in turn increase the reception level.

(g) Selecting cell site locations:

With a given actual antenna height and transmitted power, coverage area can be increased by selecting a high site.

(h) Using repeater and enhancers to increase the coverage area or to fill in holes.

(i) Engineering the antenna pattern to cover a derived service area.

(2)Reducing the Interference:

Increasing coverage area cause interference if co channels and adjacent channels are used in the system. The Interference can be reduced as follows:

(a)A good frequency Management chart

(b)An intelligent frequency assignment.

(c)Design of an antenna pattern on basis of direction.

(d)Tilting antenna patterns.

(e)Reducing the antenna height.

(f)Reducing the transmitted power.

(g) Choosing the cell site location.

Increase The Traffic Capacity:

Traffic capacity can be increased by

(a) Small cell size

(b)Increasing the number of radio channels in each cell

(c)Queuing

(d)Enhanced frequency spectrum.

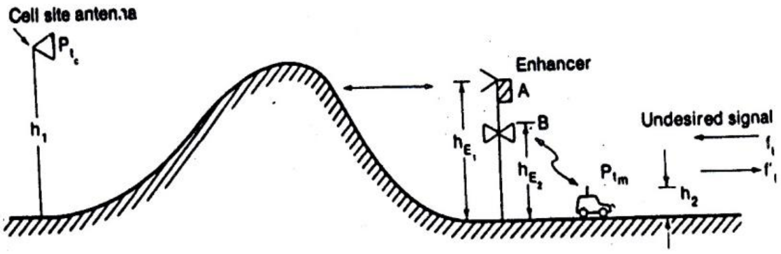
(e)Dynamic channel assignment.

Coverage-Hole Filler

As the ground is not flat, many holes (weak signal spots) are created in the cell area during antenna radiation. The methods for filling these holes are as follows.

Enhancers or repeaters

There are two types of enhancers - wide band and channelized enhancers. The wideband enhancer is a repeater. The signal transmitted by the cell site is received by a high directional antenna mounted at high altitude at the enhancer site as shown in fig



The signal received in the forward channel will be radiated by a lower omni directional or directional antenna at the enhancer. The mobile units in the enhancer site will receive the signal. The mobile unit uses reverse channel to respond to calls (or originate calls) through the enhancer to the cell site.

The gain of the enhancer can be adjusted from 10 to 70db and range is from 0.5 to 3.0kms. The undesired signal received by antenna at height hE2 is transmitted back to the cell site and may result co-channel or adjacent channel interference. The channelized enhancer should amplify only the channels that it selected.

Passive Reflectors:

To redirect the incident energy, the reflector should be located far from both the transmitting antenna and the receiving antenna with a separation such that

$$d_1 > \frac{2.A_T}{\lambda} + \frac{2.A_1}{\lambda} \text{ and } d_2 > \frac{2.A_1}{\lambda} + \frac{2.A_R}{\lambda}$$

AT and AR are the apertures of both transmitting and receiving antennas, d1 and d2 are distances of reflector form antennas. The dimensions of the reflector should be many wavelengths. The excessive loss from a reflector is greater in a mobile environment.

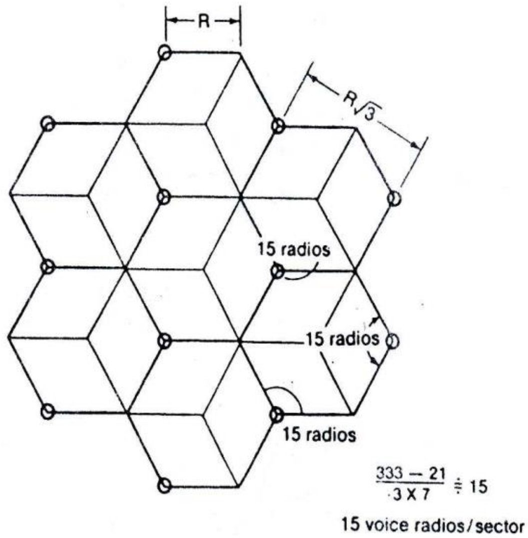
Diversity: The diversity receiver can be used to fill the holes.

(4) Cophase technique:

The cophase technique is used to bring all signal phases from different branches to a common phase point. The two kinds of cophase techniques are feed forward and feedback. The feedforward is used for satellite communications. The feedback is also called GRANLUND COMBINER is better than feed forward.

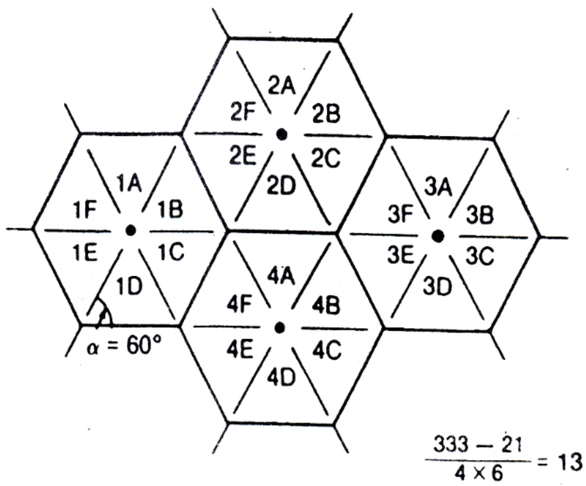
Narrow beam concept

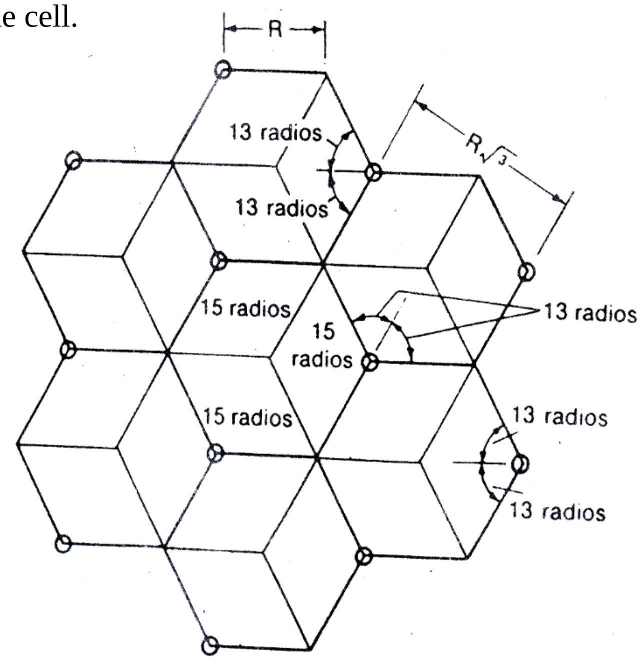
For increasing the traffic capacity, the narrow beam – sector concept is very much used.



For a K = 7 freq reuse pattern with 120^0 sectors, each sector can cover 15 voice channels $\frac{333\ -\ 21}{3\times 7}$ and for k = 4 with 600 sectors, each sector can cover 13 channels $\frac{333\ -\ 21}{6\times 4}$ In the k = 7 pattern there are 21 sectors with 15 channels in each sector and in k = 4 pattern. The antennas erected in each site with a k = 4 pattern, is higher than those with k = 7 pattern to avoid channel interference. The number of channels can then be increased from 15 to 26 as shown in fig.8.5. This scheme is suitable for small-cell systems. The antenna height for 600 sector is higher than 1200 sector.

This sector-mixed system for a k = 7 freq reuse pattern, the traffic capacity is increased very much and the 24 sub group channels (each subgroup containing 13 channels) can be distributed according to the traffic need in the cell.





(b)

As shown in fig. (b), the 120^0 and 60^0 sectors can be mixed. Some 120^0 sectors can be replace by two 60^0 sectors in K = 7 pattern.