UNIT-1

Cellular mobile telephone system and deploying it in many cities is the operational ***limitations of***

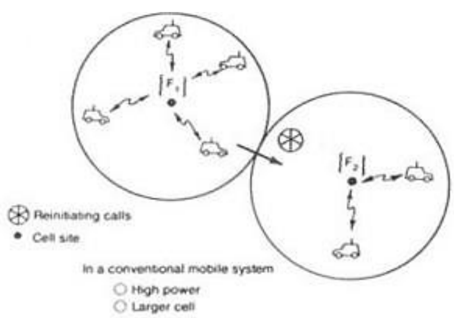
conventional mobile telephone systems*:*

1. limited service capability

2. poor service performance

3. inefficient frequency spectrum utilisation.

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 below Fig. The user who starts a call in one zone has to reinitiate the call when moving into a new zone 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 hand-off capability. The hand-off is a process of automatically changing frequencies as the mobile unit moves into a different frequency zone so that the conversation 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.



Conventional Mobile System

2. Poor service performance: Mobile Telephone Service (MTS), Improved Mobile Telephone Service (IMTS).MTS operates around 40 MHz and MJ operates at 150 MHs; both provide 11 channels. IMTS MK operates at 450 MHz and provides 12 channels. These 33 channels must cover an area 50 mi in diameter.

3. Inefficient frequency spectrum utilization: In conventional mobile telephone system, the frequency utilization measurement Mo. defined as the maximum number of customers that could be served by one channel at the busy hour.

Mo = Number of customers/channel

Mo = 53 for MJ

= 37 for MK

The offered load can then be obtained by

A = Average calling time (minutes) x total customers / 60 min (Erlangs)

Assume average calling time = ***1.76 min.***

A1 = 1.76 * 53 * 6 / 60 = 9.33 Erlangs (MJ system)

A2 = 1.76 * 37 * 6 / 60 = 6.51 Erlangs (MK system)

If the number of channels is 6 and the offered loads are A1 = 9.33 and A2 = 6.51, then from the Erlang B model the blocking probabilities, B1 = 50 percent (MJ system) and B2 =30 percent (MK system), respectively.

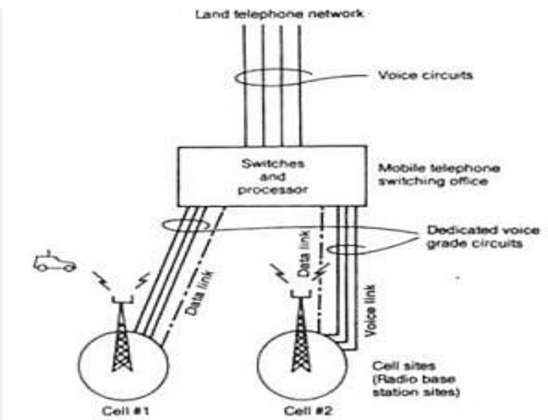
Basic Cellular System:-

A basic cellular system consists of three parts: a mobile unit, a cell site, and a mobile telephone switching office (MTSO), as Fig shows, with connections to link the three sub systems.

1. Mobile units
2. Cell site
3. MTSO
4. Connections

1. Mobile units: A mobile telephone unit contains a control unit, a transceiver, and an antenna system.
2. Cell site: The cell site provides interface between the **MTSO** and the mobile units. It has a control unit, radio cabinets, antennas, a power plant, and data terminals.
3. MTSO: The switching office, the central coordinating element for all cell sites, contains the cellular processor and cellular switch. It interfaces with telephone company zone offices, controls call processing,and handles billing activities.
4. Connections: The radio and high-speed data links connect the three subsystems. Each mobile unit can only use one channel at a time for its communication link. But the channel is not fixed: it can be any one in the entire band assigned by the serving area, with each site having multichannel capabilities that can connect simultaneously to many mobile units.

* The MTSO is the heart of the ***cellular mobile system***
* Its processor provides central coordination and cellular administration.
* 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-carriers (wire lines).
* Microwave radio links or T-carriers carry both voice and data between the cell site and the MTSO.



Severe Fading:

1. If 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 the surrounding structures, multipath waves are generated.

2. At the mobile unit, the sum of the multipath waves causes a signal-fading phenomenon.The signal fluctuates in a range of about 40 dB (10 dB above and 30 dB below the average signal).

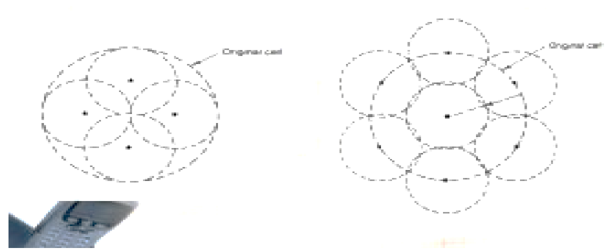
3. We can visualize the nulls of the fluctuation at the baseband at about every half wavelength in space, but all nulls do not occur at the same level. If the mobile unit moves fast, the rate of fluctuation is fast.

4. For instance, at 850 MHz, the wavelength is roughly 0.35 m (1 ft). If the speed of the mobile unit is 24 km/h (15 mi/h), or 6.7 m/s, the rate of fluctuation of the signal reception at a 10-dB level below the average power of a fading signal is 15 nulls per second.

Permanent splitting and dynamic splitting:-

There are two types of cell-splitting techniques:
1. Permanent splitting
2. Dynamic splitting
1. Permanent splitting: The installation of every new split cell has to be planned ahead of time; the number of channels, the transmitted power, the assigned frequencies, the choosing of the cell-site selection, and the traffic load consideration should all be considered. When ready, the actual service cutover should be set at the lowest traffic point, usually at midnight on a weekend. Hopefully, only a few calls will be dropped because of this cut-over, assuming that the downtime of the system is within 2 h.
2. Dynamic splitting: Based on using the allocated spectrum efficiency in real time. The algorithm for dynamically splitting cell sites is a tedious job, as we cannot afford to have one single cell unused during cell splitting at heavy traffic hours.

CELL SPLITTING



Different Types of Noises in cellular frequency ranges:-

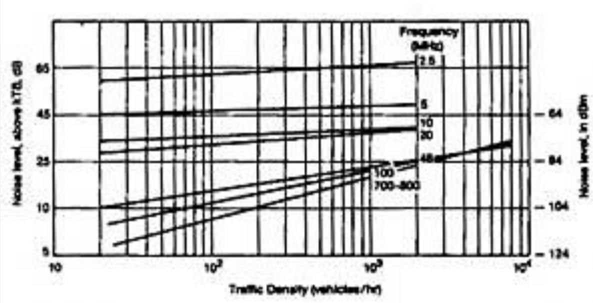
Noise level in cellular frequency band: The thermal noise kTB at a temperature T of 290 K (17°C) and a bandwidth B of 30 kHz is -129 dBm, where k is Boltzmann's constant. Assume that

the received front-end noise is 9 dB, and then the noise level is -120 dBm.
There are two kinds of man-made noise.

1. ignition noise

2. 800-MHz emission noise

1. ignition noise:- In the past, ***800 MHz*** was not widely used. Therefore, the man-made noise at 800 MHz is merely generated by the vehicle ignition noise. The automotive noise introduced at 800 MHz with a bandwidth of ***30 kHz*** can be deduced from Fig



Noise in Cellular Networks

2. 800-MHz emission noise: Cellular mobile systems operating in all the major cities in the United States and the spurious energy generated outside each channel bandwidth, the early noise data measurements are no longer valid. The 800-MHz-emission noise can be measured at an idle channel in the ***869- to 894-MHz*** region while the mobile receiver is operating on a car battery in a no-traffic spot in a city.

Amplifier noise: A mobile radio signal received by a receiving antenna, either at the cell site or at the mobile unit, will be amplified by an amplifier.

The input signal-to-noise (S/N) ratio is Ps/Ni, the output signal-to-noise ratio is Po/No, and the internal amplifier noise is Na. Then the output Po/No becomes.

$$\frac{P_o}{N_o} = \frac{gP_s}{g(N_i) + N_a} = \frac{P_s}{N_i + (N_a/g)}$$

The ***Noise figure*** F is defined as

$$F = \frac{\text{maximum possible S/N ratio}}{\text{actual S/N ratio at output}}$$

the maximum possible ***S/N ratio*** is measured when the load is an open circuit.
The noise figure of the amplifier is

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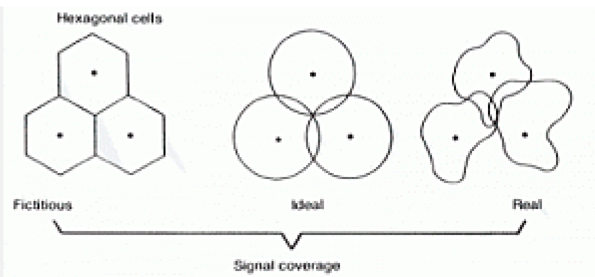
The term kTB is the thermal noise. The noise figure is a reference measurement between a minimum noise level due to thermal noise and the noise level generated by both the external and internal noise of an amplifier.

Marketing Image of Hexagonal-shaped cells:-

The hexagonal-shaped communication cells are artificial and that such a shape cannot be generated in the real world. Engineers draw hexagonal-shaped cell 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 fit the planned area nicely, as shown in Fig

A simple mechanism which makes the cellular system implement- able based on hexagonal cells will be illustrated in later chapters. Otherwise, a statistical approach will be used in dealing with a real-world situation. Fortunately, the outcomes resulting from these two approaches are very close, yet the latter does not provide a clear physical picture, as shown later. Besides, today these hexagonal-shaped cells have already become a widely promoted symbol for cellular mobile systems.



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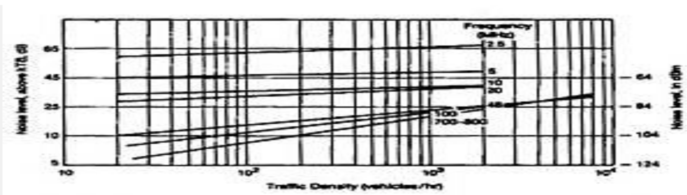

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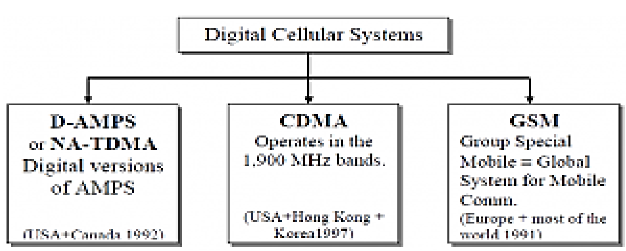
Digital Cellular System:-

Digital cellular systems are the cellular systems that use the digital communication techniques like in ***modulation, transmission*** format and d***emodulation*** and so on. The characteristics of these systems are:



1. These offer an effective data transmission compared to the conventional analog cellular systems. These systems employ the packet switched communication technique which is faster than the circuit switching technique.

2. These systems employ powerful error detection and Correction techniques, which can country the debilitating effect of noise, fading and interference on the signal.
3. These systems also provide the security on transmitting data through encryption and decryption techniques authentication.
4. These systems also require very less transmit power, this properly increases the battery life (in portable mobile units).
5. The range of services provided by the digital cellular system is quite large compared to that provided by the analog cellular systems.
6. The speed of services provided by digital systems is quite high and thus, they support high capacity data transfers.
7. The digital cellular systems employ ***TDMA*** technique for communication.

A direct wave path is a path clear from the terrain contour. The line-of-sight path is a path clear from buildings. In the mobile radio environment, we do not always have a line-of-sight condition. When a lineof-sight condition occurs, the average received signal at the mobile unit at a 1-mi intercept is higher, although the ***40 dB/dec*** path-loss slope remains the same. In this case the short-term fading is observed to be a rician fading. It results from a strong line-of-sight path and a ground-reflected wave combined, plus many weak building-reflected waves.

When an out-of-sight condition is reached, the 40-dB/dec path-loss slope still remains. However, all reflected waves, including ground reflected waves and building-reflected waves, become dominant.The short-term received signal at the mobile unit observes a Rayleigh fading. The Rayleigh fading is the most severe fading. When the terrain contour blocks the direct wave path, we call it the obstructive path. In this situation, the shadow loss from the signal reception can be found by using the knife-edge diffraction curves.

Evaluation of the Analog and digital cellular mobile system:-

Cellular telephone systems can be “***Analog***” or “***Digital***”. Older Cellular Systems (AMPS, TACS, NMT) are analog and newer systems (GSM, CDMA, PCS) are “Digital”.

1. *Analog Cellular Mobile System*
2. *Digital Cellular Mobile System*

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 is like audio cassettes and CDs. Audio cassettes are analog and CDs are digital. 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.

1. Digital systems, the audio is converted to digitized samples at about ***8000 samples*** per second or so. The digital samples are numbers that represent the time varying voltage level at specific points in time.These samples are now transmitted as **1s** and **0s**. At the other end the samples are converted back to voltage levels and smoothed out so that you get about the same audio signal.
2. Analog transmissions, interference (RF noise or some other anomaly that affects the

transmitted signal) gets translated directly in to the recovered signal and there is no check that the received signal is authentic.

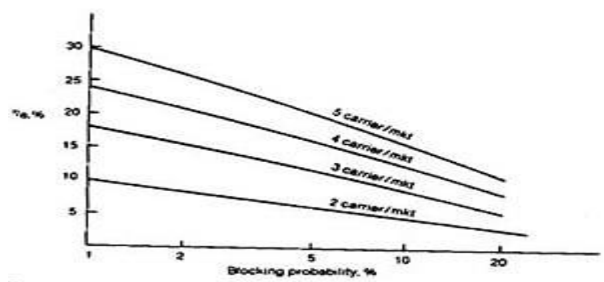
Trunking Efficiency:-

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.

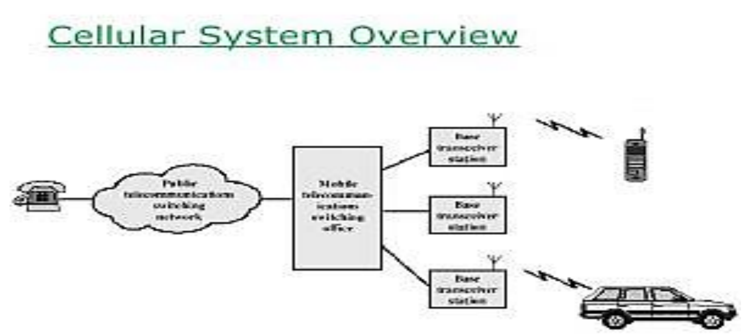
$$A_1 \geq 2A_2$$

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



The ***Trunking efficiency factor*** can be calculated as $\eta_e = \frac{2832.95 - 2590.9}{2832.95} = 8.5\%$

General view of telecommunication and function:-



Antenna: Antenna pattern, antenna gain, antenna tilting, and antenna height 6 all affect the cellular system design. The antenna pattern can be omnidirectional, directional, or any shape in both the vertical and the horizon planes. Antenna gain compensates for the transmitted power. Different antenna patterns and antenna gains at the cell site and at the mobile units would affect the system performance and so must be considered in the system design. The antenna patterns seen in cellular systems are different from the patterns seen in free space. If a mobile unit travels around a cell site in areas with many buildings, the omnidirectional antenna will not duplicate the omnipattern. In addition, if the front-to-back ratio of a directional antenna is found to be ***20 dB*** in free space, it will be only ***10 dB*** at the cell site. Antenna tilting can reduce the interference to the neighboring cells and enhance the weak spots in the cell. Also, the height of the cellsite antenna can affect the area and shape of the coverage in the system.

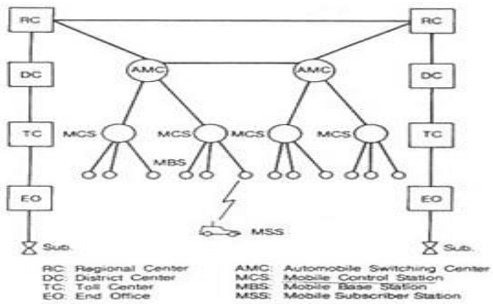
Switching Equipment:

1. The capacity of switching equipment in cellular systems is not based on the number of switch ports but on the capacity of the processor associated with the switches
2. In a big cellular system, this processor should be large.
3. The service life of the switching equipment is not determined by the life cycle of the equipment but by how long it takes to reach its full capacity
4. If the switching equipment is designed in modules, or as distributed switches, more modules can be added to increase the capacity of the equipment.
5. For decentralized systems, digital switches may be more suitable.
6. This means that switching equipment can link to other switching equipment so that a call can be carried from one system to another system without the call being dropped.

Data Links: Each data link can carry multiple channel data (10 kbps data transmitted per channel) from the cell site to the MTSO. This fast-speed data transmission cannot be passed through a regular telephone line. Therefore, data bank devices are needed. They can be multiplexed, many-data channels passing through a wideband T-carrier wire line or going through a microwave radio link where the frequency is much higher than ***850MHz***. Leasing T1-carrier wire lines through telephone companies can be costly. Although the use of microwaves may be a long-term money saver, the availability of the microwave link has to be considered.

NMT & NTT Systems:-

NTT: ***Nippon Telegraph and Telephone Corporation*** (NTT) developed an ***800-MHz*** land mobile telephone system and put it into service in the Tokyo area in 1979. The general system operation is similar to the AMPS system. It accesses approximately 40,000 subscribers in 500 cities. It covers 75 percent of all Japanese cities, 25 percent of inhabitable areas, and 60 percent of the population. In Japan, 9 automobile switching centers (ASCs), 51 mobile control stations (MCSs), 465 mobile base stations (MBSs), and 39,000 mobile subscriber stations (MSSs) were in operation as of February 1985.



Japanese mobile telephone service network configuration

The **Japanese mobile telephone service network configuration** is shown in above fig in the metropolitan Tokyo area, about 30,000 subscribers are being served. The 1985 system operated over a spectrum of ***30 MHz***. The total number of channels was 600, and t he channel bandwidth was 25 kHz. This system comprised an automobile switching center (ASC), a mobile control station (MCS), a mobile base station (MBS), and a mobile subscriber station (MSS).

NMT: The NMT System built mostly by Scandinavian countries (Denmark, Norway, Sweden, and Finland) in cooperation with Saudi Arabia and Spain and is called the ***NMT network***. It is currently a 450-MHz system. But an 800-MHz System will be implemented soon since the frequency transparent concept as the AURORA 800 system is used to convert the ***450-MHz*** system to the ***800-MHz*** System. The total bandwidth is 10 MHz, which has 200 channels with a bandwidth of 25 kHz per channel.

Severe Fading:

1. If 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 the surrounding structures, multipath waves are generated.
2. At the mobile unit, the sum of the multipath waves causes a signal-fading phenomenon.The signal fluctuates in a range of about 40 dB (10 dB above and 30 dB below the average signal).
3. We can visualize the nulls of the fluctuation at the baseband at about every half wavelength in space, but all nulls do not occur at the same level. If the mobile unit moves fast, the rate of fluctuation is fast.
4. For instance, at 850 MHz, the wavelength is roughly 0.35 m (1 ft). If the speed of the mobile unit is 24 km/h (15 mi/h), or 6.7 m/s, the rate of fluctuation of the signal reception at a 10-dB level below the average power of a fading signal is 15 nulls per second.

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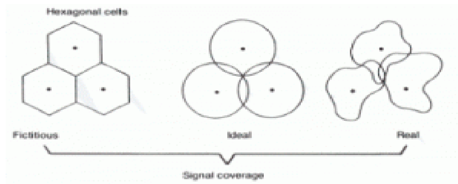


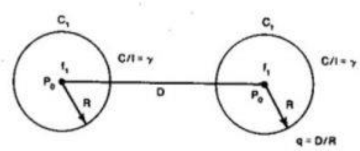
Hexagonal Cells and the real shapes of their coverages

Concept of Frequency Reuse Channels:-

A radio channel consists of a pair of frequencies one for each direction of transmission that is used for full-duplex operation. Particular radio channels, say F1, used in one geographic zone to call a cell, say C1, with a coverage radius **R** can be used in another cell with the same coverage radius at a distance D away.

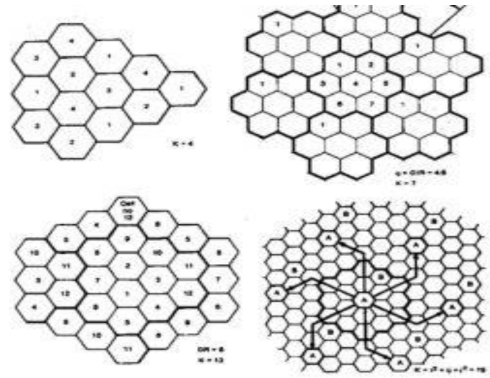
1. Frequency reuse is the core concept of the cellular mobile radio system. In this frequency reuse system users in different geographic locations (different cells) may simultaneously use the same frequency channel

2. Interference due to the common use of the same channel is called co-channel interference and is our major concern in the concept of frequency reuse.



Frequency reuse scheme*:* The frequency reuse concept can be used in the time domain and the space domain. Frequency reuse in the time domain results in the occupation of the same frequency in different time slots. It is called time division multiplexing **(TDM)**. Frequency reuse in the space domain can be divided into two categories.

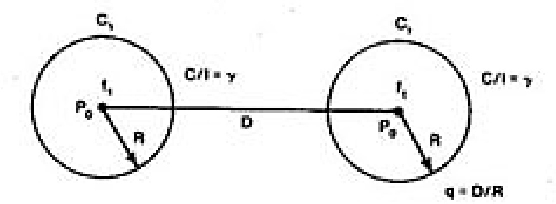
1. Same frequency assigned in two different geographic areas, such as **A.M or FM** radio stations using the same frequency in different cities.
2. Same frequency repeatedly used in a same general area in one system – the scheme is used in cellular systems. There are many co-channel cells in the system. The total frequency spectrum allocation is divided into K frequency reuse patterns, as illustrated in Fig for **K — 4, 7, 12, and 19.**



Frequency reuse distance cellular radio system:-

The minimum distance which allows the same frequency to be reused will depend on many factors, such as the number of co-channel cells in the vicinity of the center cell, the type of geographical terrain contour, the antenna height and the transmitted power at each cell site.

$$D = \begin{cases} 3.46R & K = 4 \\ 4.6R & K = 7 \\ 6R & K = 12 \\ 7.55R & K = 19 \end{cases}$$



1. If all the cell sites transmit the same power, then K increases and the frequency reuse distance D increases. This increased D reduces the chance that co-channel interference may occur.

2.Theoretically, a large K is desired. However, the total number of allocated channels is fixed. When K is too large, the number of channels assigned to each of K cells becomes small. It is always true that if the total number of channels in K cells is divided as K increases, trunking inefficiency results.

3. **The same principle applies to spectrum inefficiency:** if the total numbers of channels are divided into two network systems serving in the same area, spectrum inefficiency increases.

The smallest number K involves estimating co-channel interference and selecting the minimum frequency reuse distance D to reduce co-channel interference. The smallest value of K is **K = 3**, obtained by setting i = 1, j = 1 in the equation.

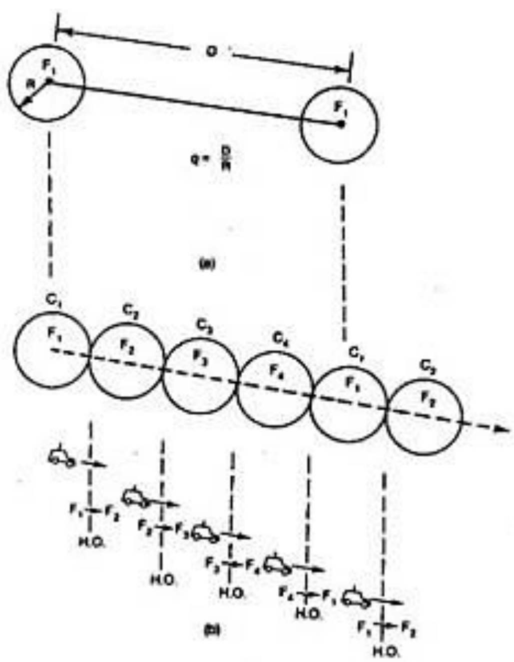
Hand-off Mechanism of a control system:-

Hand-off is the process of automatically changing the frequencies. When the mobile unit moves out of the coverage areas of a particular cell site, the reception becomes weak. At this instant the present cell site requests Hand-off, then system switches the call to a new frequency channel in a new cell site without interrupting either call or user.

This phenomenon is known as "***hand -off***' or 'handover'. Hand -off processing scheme is an important task for any successful mobile system. This concept can he applied to one dimensional as well as two dimensional cellular configurations. The mobile unit by the cell site, the Hand-off is required in the following two situations. They are

1. The level for requesting a Hand-off in a noise limited environment is at the cell boundary say-***l00 dBm***.

2. In a particular cell site, when the mobile unit is reaching the signal strength holes (gaps). The usage of frequency F1 in two co-channel cells which arc separated by a distance D. Now, we have to provide a communication system in the whole area by filling other frequency channels F2,F3 and F4 between two co-channel cells.



Co-channel interference reduction factor:-

Reusing an identical frequency channel in different cells is limited by co-channel interference between cells, and the co-channel interference can become a major problem.

1. Assume that the size of all cells is roughly the same.
2. The cell size is determined by the coverage area of the signal strength in each cell. As long as the cell size is fixed, co-channel interference is independent of the transmitted power of each cell.

3. It means that the received threshold level at the mobile unit is adjusted to the size of the cell.
4. Actually, co-channel interference is a function of a parameter q defined as

$$q = D/R$$

The parameter q is the co-channel interference reduction factor. When the ratio q increases, co-channel interference decreases.

Furthermore, the separation D is a function of K, and C/I.

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

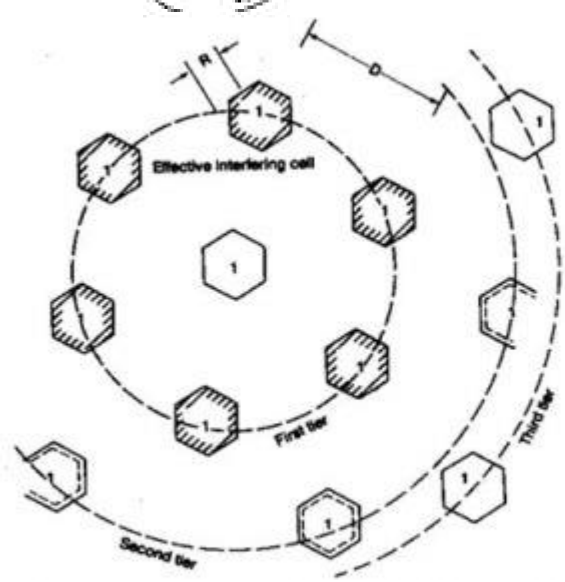
$$\frac{C}{I} = \frac{C}{\sum_{k=1}^{K_I} I_k}$$

hexagonal-shaped cellular system, there are always six co-channel interfering cells According to both the reciprocity theorem and the statistical summation of radio propagation, the two C/I values can be very close. In a mobile radio medium γ, usually is assumed to be 4. K is the number of co-channel interfering cells and is equal to 6 in a fully developed system.

$$\frac{C}{I} = \frac{1}{\sum_{k=1}^{K_I} \left(\frac{D_k}{R}\right)^{-\gamma}} = \frac{1}{\sum_{k=1}^{K_I} (q_k)^{-\gamma}}$$

Where *qk* is the cochannel interference reduction factor with *Kth* cochannel interfering cell

$$q_k = \frac{D_k}{R}$$



C/I for normal case in an omnidirectional antenna system:-

1.The signal and co-channel interference received by the **mobile unit**
2.The signal and co-channel interference received by the **cell site**

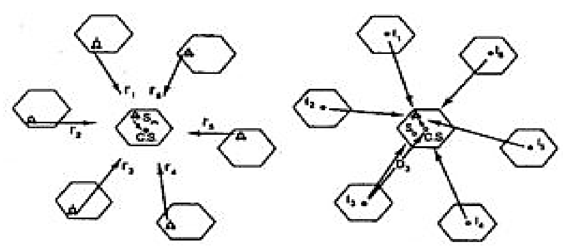
Nm and Nb are the local noises at the mobile unit and the cell site, respectively. Usually Nm and Nb are small and can be neglected as compared with the interference level. As long as the received carrier-to interference ratios at both the mobile unit and the cell site are the same, the system is called a balanced system. balanced system, we can choose either one of the two cases to analyze the system requirement; the results from one case are the same for the others.

$$q = D/R = (6 \times 63.1)^{1/4} = \underline{4.41}$$

The 90th percentile of the total covered area would be achieved by increasing the transmitted power at each cell increasing the same amount of transmitted power in each cell does not affect the result. This is because q is not a function of transmitted power. The factor q can be related to the finite set of cells K in a ***hexagonal-shaped cellular system***.

$$q \triangleq \sqrt{3K}$$

q = 4.41 in above equation yields k=7.



Cell Splitting:-

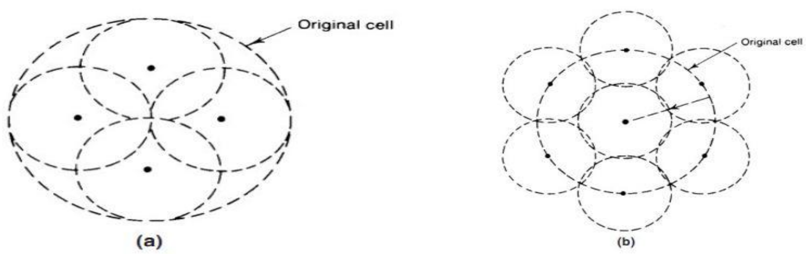
The motivation behind implementing a **cellular mobile system** is to improve the utilization of spectrum efficiency. The frequency reuse scheme is one concept, and cell splitting is another concept. When traffic density starts to build up and the frequency channels Fi in each cell Ci cannot provide enough mobile calls, the original cell can be split into smaller cells.

There are two ways of splitting:
1. Permanent splitting
2. Dynamic splitting
New cell radius = Old cell radius/2
Then, **New cell area = Old cell area/4**
Let each new cell carry the same maximum traffic load of the old cell, then
New traffic load/Unit area = 4 X Traffic load/Unit area.

1. Permanent splitting: The installation of every new split cell has to be planned ahead of time; the number of channels, the transmitted power, the assigned frequencies, the choosing of the cell-site selection, and the traffic load consideration should all be considered. When ready, the actual service cuttover should be set at the lowest traffic point, usually at midnight on a weekend.

Hopefully, only a few calls will be dropped because of this cut-over, assuming that the downtime of the system is within 2 h.

2. Dynamic splitting: This scheme is based on using the allocated spectrum efficiency in real time. The algorithm for dynamically splitting cell sites is a tedious job, as we cannot afford to have one single cell unused during cell splitting at heavy traffic hours.



Cell splitting

Maximum number of frequency channels per cell:-

The maximum number of frequency channels per cell N is closely related to an average calling time in the system.

The standard user's calling habits may change as a result of the charging rate of the system and the general income profile of the users If an ***average calling time T*** is ***1.76*** min and the maximum calls per hour per cell is **Qi**, then the offered load can be derived as

A = Qi*T/60 (Erlangs)

blocking probability is given, then it is easy to find the required number of radios in each cell. If a large area is covered by 28 cells, Kt = 28.

the total number of customers in the system increases. Therefore, we may assume that the number of subscribers per cell Mi is somehow related to the percentage of car phones used in the busy hours and the number of calls per hour per cell **Qi** as

$$M_i = f(Q_i, \eta_c)$$

Qi is a function of the blocking probability B, the average calling time T, and the number of channels N.

$$Qi = f(B, T, N)$$

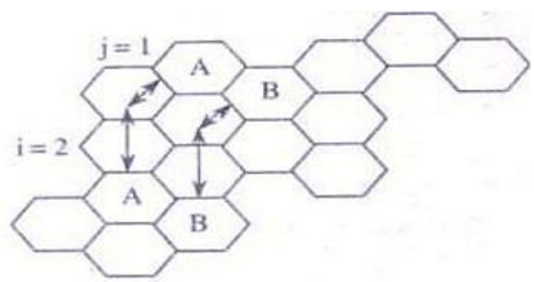
K = 7 frequency reuse pattern is used, the total number of required channels in the system is Nt = 7 X N.

Explain the importance of $K=i^2+ij+j^2$:-

For hexagonal cells i.e. with "***honeycomb***" cell layouts commonly used in mobile radio with possible cluster sizes are **$K=i^2+ij+j^2$,** Where i, j — Non negative integers The integers i, j determine the relative location of co channels. The main reason for obtaining the above expression is to calculate the smallest number K which can still meet our system performance requirements. This process involves estimating co-channel interference and selecting the minimum frequency reuse distance D to reduce co-channel interference. Thus, the smallest possible value for K is 3, obtained by putting i=1, j=1.

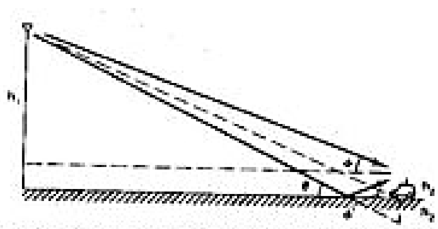
The nearest co-channel neighbors of a particular cell can be obtained by the following two steps
(i) Moving i cells along any chain of hexagons.
(ii) Turn 60 degrees counter-clockwise and move j cells.

The method of locating co channel cells in a 7-cell reuse pattern with i=2 and j=1 is shown figure.



The equation for frequency reuse pattern $K=i^2+ij+j^2$ can also be used to measure the following The distance between co-channel cells in adjacent clusters is given by **$D=\sqrt{i^2+ij+j^2}$**The frequencyreuse factor, Q is obtained by **<u>$Q=D/R = \sqrt{3N} = \sqrt{3(i^2+ij+j^2}$</u>**

UNIT-2


Representation of Ground Incident Angle θ and Ground Elevation Angle φ

Ground incident angle, elevation angle, ground reflection and reflection point.

The ground incident angle and the **ground elevation angle** over a communication link are described as follows. The ground incident angle 0 is the angle of wave arrival incidentally pointing to the ground as shown in Fig. The ground elevation angle is the angle of wave arrival at the mobile unit as shown in Fig.

Based on Snell's law, the reflection angle and incident angle are the same. Since in graphical display we usually exaggerate the hilly slope and the incident angle by enlarging the vertical scale, as shown in Fig. 1.2, then as long as the actual hilly slope is less than 100, the reflection point on a hilly slope can be obtained by following the same method as if the reflection point were on flat ground. Be sure that the two antennas (base and mobile) have been placed vertically, not perpendicular to the sloped ground. The reason is that the actual slope of the hill is usually very small and the vertical stands for two antennas are correct. The scale drawing in Fig. somewhat misleading however, it provides a clear view of the situation.

Direct path and the ground reflected path:

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

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

where a_v = the reflection coefficient
$\Delta\phi$ = the phase difference between a direct path and a reflected path
P_0 = the transmitted power
d = the distance
λ = the wavelength

indicates a two-wave model which is used to understand the path-loss phenomenon in a mobile radio environment. It is not the model for analyzing the multipath fading phenomenon. In a mobile environment av = – 1 because of the small incident angle of the ground wave caused by a relatively low cell-site antenna height. Thus,

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

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

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

and Δd is the difference, $\Delta d = d_1 - d_0$, from Fig. 4.4.

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

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

Since Δd is much smaller than either d_1 or d_2,

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

Then the received power of Eq. (4.2-3) becomes

$$P_r = P_0 \frac{\lambda^2}{(4\pi)^2 d^2} \sin^2\frac{4\pi h_1 h_2}{\lambda d}$$

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

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

, thus

$$\Delta P = 40 \log\frac{d_1}{d_2} \qquad \text{(a 40 dB/dec path loss)}$$

$$\Delta G = 20 \log\frac{h'_1}{h_1} \qquad \text{(an antenna height gain of 6 dB/oct)}$$

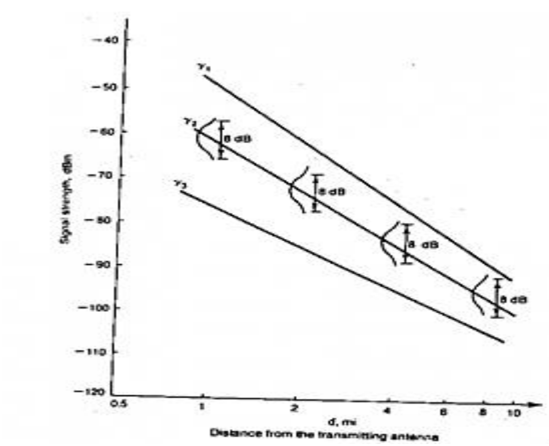
Where P is the power difference in decibels between two different path lengths and G is the gain (or loss) in decibels obtained from two different antenna heights at the cell site. From these measurements, the gain from a mobile antenna height is only 3 dB/oct, which is different from the 6 dB/oct . Then

$$\Delta G' = 10 \log\frac{h'_2}{h_2}$$

Why there is a constant standard deviation along a path-loss curve

When plotting signal strengths at any given radio-path distance, the deviation from predicted value. is approximately 8 dB. This standard deviation of 8 dB is roughly true in many different areas. The explanation is as follows. When a line-of-sight path exists, both the direct wave path and reflected wave path are created and are strong. When an out-of-sight path exists, both the direct wave path and the reflected wave path are weak. In either case, according to the theoretical model, the 40-dB/dec path-loss slope applies. The difference between these two conditions is the 1-mi intercept (or 1-km intercept) point. It can be seen that in the open area, the 1-mi intercept is high. In the urban area, the 1-mi intercept is low. The standard deviation obtained from the measured data remains the same along the different path-loss curves regardless of environment.

Support for the above argument can also be found from the observation that the standard deviation obtained from the measured data along the predicted path-loss curve is approximately 8 dB. The explanation is that at a distance from the cell site, some mobile unit radio paths are line-of-sight, some are partial line-of-sight, and some are out-of-sight. Thus the received signals are strong, normal, and weak, respectively. At any distance, the above situations prevail. If the standard deviation is 8 dB at one radio-path distance, the same 8dB will be found at any distance. Therefore a standard deviation of 8 dB is always found along the radio path as shown in Fig. The standard deviation of 8 dB from the measured data near the cell site is due mainly to the close-in buildings around the cell site. The same standard deviation from the measured data at a distant location is due to the great variation along different radio paths.



Merits of point-to-point model:

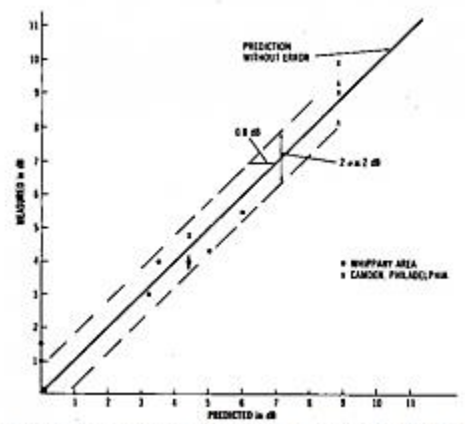
The area-to-area model usually only provides an accuracy of prediction with a standard deviation of **8bdB**, which means that 68 percent of the actual path-loss data are within the ± 8 dB of the predicted value. The uncertainty range is too large. The point-to-point model reduces the uncertainty range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

The differences between the predicted values and the measured ones for the point-to-point model were determined in many areas. In the following discussion, we compare the differences shown in the Whippany, N.J., area and the Camden-Philadelphia area. First, we plot the points with predicted values at the x-axis and the measured values at the y-axis, shown in Fig. The 450 line is the line of prediction without error. The dots are data from the Whippany area, and the crosses are data from the Camden Philadelphia area. Most of them, except the one at 9 dB, are close to the line of prediction without error.

The mean value of all the data is right on the line of prediction without error. The standard deviation of the predicted value of 0.8 dB from the measured one.

In other areas, the differences were slightly larger. However, the standard deviation of the predicted value never exceeds the measured one by more than 3 dB. The standard deviation range is much reduced as compared with the maximum of 8 dB from area-to-area models. The point-to-point model is very useful for designing a mobile cellular system with a radius for each cell of 10 mi or less. Because the data follow the log-normal distribution, 68 percent of predicted values obtained from a point-to-point prediction model are within 2 to 3 dB. This point-to-point prediction can be used to provide overall coverage of all cell sites and to avoid co channel interference. Moreover, the occurrence of hand-off in the cellular system can be predicted more accurately.

The point-to-point prediction model is a basic tool that is used to generate a signal coverage map, an interference area map, a hand-off occurrence map, or an optimum system design configuration, to name a few applications.



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

Foliage loss:

Foliage loss is a very complicated topic that has many parameters and variations. The sizes of leaves, branches, and trunks, the density and distribution of leaves, branches, and trunks, and the height of the trees relative to the antenna heights all be considered. An illustration of this prv1em is shown in Fig.There are three levels: trunks, branches, and leaves. In each level, there is a distribution of sizes of trunks, branches, and leaves and also of the density and spacing between adjacent trunks, branches, and leaves. The texture and thickness of the leaves also count. This unique problem can become very complicated and is beyond the scope of this book. For a system design, the estimate of the signal reception due to foliage loss does not need any degree of accuracy.

Furthermore, some trees, such as maple or oak, lose their leaves in winter, while others, such as pine, never do. For example, in Atlanta, Georgia, there are oak, maple, and pine trees. In summer the foliage is very heavy, but in winter the leaves of the oak and maple trees fall and the pine leaves stay. In addition, when the length of pine needles reaches approximately 6 in., which is the half wavelength at 800 MHz, a great deal of energy can be absorbed by the pine trees. In these situations, it is very hard to predict the actual foliage loss.

Sometime the foliage loss can be treated as a wire-line loss, in decibels per foot or decibels per meter, when the foliage is uniformly heavy and the path lengths are short. When the path length is long and the foliage is non uniform, then decibels per octaves or decibels per decade are used. In general, foliage lose occurs with respect to the frequency to the fourth power. Also, at 800 MHz the foliage Lou along the radio path is 40 dB/dec, which is 20 dB more than the free- space loss, with the same amount of additional loss for mobile communications. Therefore, if the situation involves both foliage loss and mobile communications, the total loss would be 60 dB/dec (=20 dB/ dec of free-space loss + additional **20 dB** due to foliage loss + additional 20 dB due to mobile communication).

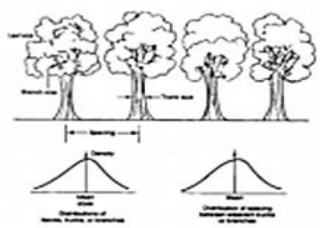


Fig. A characteristic of foliage environment

This situation would be the case if the foliage would line up along the radio path. A foliage loss in a suburban area of 58.4 dB/dec is shown in Fig.5.2. As demonstrated from the above two examples, close-in foliage at the transmitter site always heavily attenuates signal reception. Therefore, the cell site should be placed away from trees.

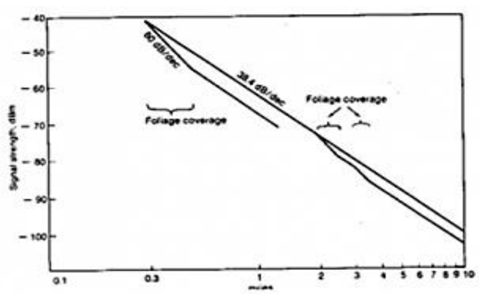


Fig. Foliage loss calculation in suburban areas

Lee model:

In general, the mobile point-to-point model can be obtain in three steps.

(i) Generate a standard condition.

(ii) Obtain an Area-to-Area prediction model.

(iii) Obtain a mobile Point-to-Point model using Area-to-Area prediction model.

The purpose of developing this model is try to separate two effects.

(a) Natural terrain contour.

(b) Human made structures.

(i) Standard Condition: To generate the standard condition, transmitted power and antenna height at base station and mobile unit should satisfy the following requirements.

	Standard Condition	Correction Factors
	At the mobile Unit	
1.	Antenna height $h_2 = 10$ ft (3m)	$\alpha_1 = 10\log\left(\frac{h_2'}{h_2}\right)$
2.	Antenna gain $g_m = 0$ dB/dipole	$\alpha_2 = g_m'$
	At the Base Station	
1.	Transmitted power $P_t = 10$ w (40 dBm)	$\alpha_3 = 10\log\left(\frac{P_t'}{10}\right)$
2.	Antenna height $h_1 = 100$ ft (30 m)	$\alpha_4 = 20\log\left(\frac{h_1'}{h_1}\right)$
3.	Antenna gain $g_t = 6$ dB/dipole	$\alpha_5 = g_t' - 6$

(ii) Obtain Area-to-Area Predication Curves for Human Made Structures: In the Area-to-Area prediction model, all the areas are considered. as flat even though the data may be received from non flat area.

(iii) Effect of the Human Made Structures: The terrain configuration of each city is different, and the human made structure of the each city unique. So that, try to separate the two effects. The path loss curve obtained on virtually flat ground indicates the effects of the signal loss due to solely human made structures. The average path loss slope shown below which is a combination of measurements from high spots and low spots along different radio paths.

The Area-to-A prediction curve is obtained from the mean value of the measured data and used for further prediction in that area The Area-to-Area prediction model can be used as a first step towards achieving the point-to-point prediction model. The performance of d Area-to-Area prediction model can be represented by two parameters.

1. 1 mi intercept point.
2. The path loss slope.

The 1 ml intercept point is the power received at a distance of 1 mi from the transmitter. The 1 mi intercept point is depends upon the effective antenna height gain.

G = Effective antenna – height gain = 20 log(he/h1)

Where, he= Effective antenna height

h1= Actual height

Derive the relation for the maximum coverage distance in mobile environment

The structure of a **mobile environment** is shown in below figure.

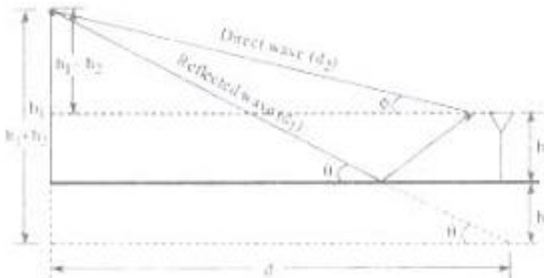


Figure: Mobile Unit Environment

Consider a cell site antenna of height ‘h1’ and a mobile antenna of height ‘h2’ is moving away from cell site. The maximum distance up to which, the mobile antenna receives the signal is the maximum coverage distance. Let the maximum coverage distance is‘d’. So when mobile antenna moving away from the cell site we can observe two waves of propagation, i.e., direct wave and reflected wave.

Direct wave is the direct propagation from cell site to mobile antenna, without any deviation and the distance travelled by this wave is considered to be (d2), a range ‘φ’ with surface angle φ is known as elevation angle. Reflected wave is the wave propagated from cell site to surface and then surface to mobile antenna, let the distance travelled by it is ‘d1’ angle done by it with surface is ‘θ’.

Based on direct path and ground reflected path the received power ‘Pr’ is given by

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

P0 = Transmitted Power,
d = Maximum coverage distance,
av = Reflection coefficient.

Δφ = The phase difference between direct path and reflected path
λ=Wave length.

We know that,

$$e^{j\theta} = \cos\theta + j\sin\theta,\ a_v = -1$$

∴ Equation (1) can be rewritten as,

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

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

We know that from algebra

$$|a - jb| = |a + jb| = \sqrt{a^2 + b^2}$$

$$\therefore\ |(1-\cos\Delta\phi) - (\sin\Delta\phi)|^2$$

$$= \left(\sqrt{(1-\cos\Delta\phi)^2 + (\sin\Delta\phi)^2}\right)^2$$

$$= \left(\sqrt{1-2\cos\Delta\phi + (\cos^2\Delta\phi + \sin^2\Delta\phi)}\right)^2$$

$$= \left(\sqrt{1-2\cos\Delta\phi+1}\right)^2$$

$$= \left(\sqrt{2-2\cos\Delta\phi}\right)^2$$

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

$$= 2(1-\cos\Delta\phi).$$

$\therefore$ By substituting this value in equation (2), we get,

$$\therefore \quad P_r = P_0 \frac{2}{\left(\frac{4\pi d}{\lambda}\right)^2}(1 - \cos\Delta\phi)$$

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

$$\Rightarrow \boxed{P_r = P_0 \frac{4}{(4\pi d/\lambda)^2}\sin^2\frac{\Delta\phi}{2}} \quad \text{--- (3)}$$

Where,

$\Delta\phi = \beta\Delta d$ and Δd is the path difference,

i.e., $\Delta d = d_1 - d_2$

But from figure, $d_1 = \sqrt{(h_1 + h_2)^2 + d^2}$

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

and also Δd is much smaller than d_1 and d_2.

$$\therefore \quad \text{As } \Delta\phi = \beta\,\Delta d = \frac{2\pi}{\lambda} \cdot \frac{2h_1h_2}{d}$$

Then the received power from equation (3) becomes,

$$P_r = P_0 \frac{\lambda^2}{(4\pi)^2 d^2}\sin^2\frac{4\pi h_1 h_2}{\lambda d}$$

If $\Delta\phi$ is very small then $\sin\left(\frac{\Delta\phi}{2}\right) = \left(\frac{\Delta\phi}{2}\right)$

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

$$= P_0\left(\frac{h_1 h_2}{d^2}\right)^2$$

$$\therefore \quad P_r = P_0\left(\frac{h_1 h_2}{d^2}\right)^2$$

Where, 'd' is maximum coverage distance and is given by,

$$\boxed{d = \sqrt{\frac{h_1 h_2}{\left(P_r/P_0\right)^{1/2}}}} \quad \text{--- (4)}$$

From equation (4), we can deduce two relationships.

First

$$\boxed{\Delta P = 40\log\frac{d_1}{d_2}} \quad \text{(a 40 dB/dec path loss)}$$

When ΔP is the power difference in decibels between two different path lengths.

Second **G = 20 log (he/h1)**
Where, h1= Height of the cell antenna
he= Effective antenna height
= (h1 + h2) and G is the gain in decibels obtained from two different antenna heights at the cell site. Hence, equation (5) represents, equation for the system gain.

Factors effecting the Accuracy of Prediction:

The standard deviation is constant along a path loss curve. The **path-loss slope** is 40dB/dec in case of both line-of-sight path and out-of-sight path. However, the direct path and reflected path in case of line-off sight path are strong and in out-of-sight path is weak. By media ting these two conditions, 1-mi intercept is obtained, which is strong in open area but weak in urban areas.

The standard deviation obtained from the predicted path-loss curve is almost equal to S dB and is constant throughout the radio path. But the received signals vary based on the type of path. i.e. for line-of-sight path the received signal is strong for partial line-of-sight path it is norm al and for out-of-sight path the received signal is weak. These are few factors, which affect the accuracy of the prediction.

Small Scale Multi path Propagation:

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

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

1. Fast variations in signal strength of the transmitted signal for a lesser distance or time interval.
2. The variations in Doppler shift on various multipath signals are responsible for random frequency modulation
3. The time dispersed signals are resulted due to multipath propagation delays.

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

1. Direct RF pulse measurement
2. Spread spectrum sliding correlator measurement.
3. Swept frequency measurement.
4. The first technique provides a local average power delay profile.
5. The second technique detects the transmitted signal with the help of a narrow band receiver preceded by a wide band mixer though the probing (or received) signal is wide band.
6. The third technique is helpful in finding the impulse response of the channel in frequency domain. By knowing the impulse response we can easily predict the signal obtained at the receiver from the transmitter.

Propagation over Water or Flat Open Area:

Propagation over water or fiat open area is becoming a big concern because it is very easy to interfere with other cells if we do not make the correct arrangements. Interference resulting from propagation over the water can be controlled if we know the cause. In general, the permittivities Er of seawater and fresh water are the same, but the conductivities of seawater and fresh water are different. We may calculate the dielectric constants Ec where Ec = Er -j60σλ. The wavelength at 850MHz is 0.35m. Then Eo (sea water) = 80 – j84 and Ec (fresh water)=80-jO.021.

However, based upon the reflection coefficients formula with a small incident angle both the reflection coefficients for horizontal polarized waves and vertically polarized waves approach .

Since the 180* phase change occurs at the ground reflection point, the reflection coefficient is -1. Now we can establish a scenario, as shown in Fig . Since the two antennas, one at the cell site and the other at the mobile unit, are well above sea level, two reflection points are generated. The one reflected from the ground is close to the mobile unit; the other reflected from the water is away from the mobile unit. We recall that the only reflected wave we considered in the land mobile propagation is the one reflection point which is always very close to the mobile unit.

Fig model for propagation over water

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

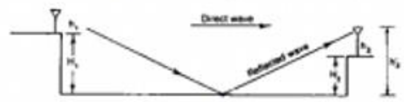


Fig .Propagation between two fixed stations over water or flat open land.

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

where P_t = transmitted power
d = distance between two stations
λ = wavelength
a_v, ϕ_v = amplitude and phase of a complex reflection coefficient, respectively

$\Delta\phi$ is the phase difference caused by the path difference Δd between the direct wave and the reflected wave, or

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

The first part of i.e. the free-space loss formula which shows the 20 dB/dec slope. that is, a 20-dB loss will be seen when propagating from 1 to 10 km.

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

The complex reflection co-efficients and can be found from the formula

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

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

h’1 = h1 +H1

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

h’2 = h2 + H2

As shown in Fig. where h1 and h2 are actual heights and H1and H2 are the heights of hills. In general, both antennas at fixed stations are high, so the resection point of the wave will be found toward the middle of the radio path. The path difference d can be obtained from Fig. as

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

Since $d \gg h_1'$ and h_2', then

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

Then

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

We can setup five conditions:

1. $P_r < P_0$. The received power is less than the power received in free space; that is,

$$2 - 2\cos\Delta\phi < 1 \quad \text{or} \quad \Delta\phi < \frac{\pi}{3}$$

2. $P_r = 0$; that is,

$$2 - 2\cos\Delta\phi = 0 \quad \text{or} \quad \Delta\phi = \frac{\pi}{2}$$

3. $P_r = P_0$; that is,

$$2 - 2\cos\Delta\phi = 1 \quad \text{or} \quad \Delta\phi = \pm 60^\circ = \pm\frac{\pi}{3}$$

4. $P_r > P_0$; that is,

$$2 - 2\cos\Delta\phi > 1 \quad \text{or} \quad \frac{\pi}{3} < \Delta\phi < \frac{5\pi}{3}$$

5. $P_r = 4P_0$; that is,

$$2 - 2\cos\Delta\phi = \max \quad \text{or} \quad \Delta\phi = \pi$$

UNIT-3

Co-channel Interference:

Co-channel Interference: The frequency-re method is useful for increasing the efficiency of spectrum usage but results in co-channel interference because the same frequency channel is used repeatedly in different co-channel cells. Application of the co-channel interference reduction factor **q= D/R = 4.6** for a seven-cell reuse pattern (K = 7). In most mobile radio environments, use of a seven-cell reuse pattern is not sufficient to avoid co-channel interference. Increasing K > 7 would reduce the number of channels per cell, and that would also reduce spectrum efficiency.

But co-channel interference may be the result, in this situation the received voice quality is affected by both the grade of coverage and the amount of co-channel interference. For detection of serious channel interference areas in a cellular system, two tests are suggested.

Test 1-find the co-channel interference area from a mobile receiver:

Co-channel interference which occurs in one channel will occur equally in all the other channels in a given area. We can then measure co-channel interference by selecting any one channel (as one channel represents all the channels) and transmitting on that channel at all co-channel sites at night while the mobile receiver is travelling in one of the co-channel cells. While performing this test we watch for any change detected by a field-strength recorder in the mobile unit and compare the data with the condition of no co-channel sites being transmitted. This test must be repeated as the mobile unit travels in every co-channel cell. To facilitate this test, we can install a channel scanning receiver in one car. One channel (f1) records the signal level (no cochannel condition), another channel (f2) records the interference level (six-co-channel condition is the maximum), while the third channel receives f, which is not in use. Therefore the noise level is recorded only in f3.

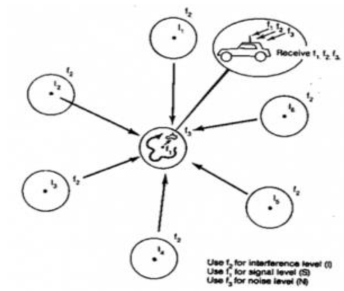
We can obtain, in decibels, the carrier to interference ratio C/I by subtracting the result obtained from f2 from the result obtained from f1 (carrier minus interference C – I) and the carrier-to noise ratio C/N by subtracting the result obtained from f3 from the result obtained from f2 (carrier minus noise C — N). Four conditions should be used to compare the results.

1. If the carrier-to-interference ratio C / I is greater than 18 dB throughout most of the cell, the system is properly designed.

2. If C/I is less than 18 dB and C/N is greater than 18 dB in some areas, there is co channel interference

3. If both C/N and C/I are less than 18 dB 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 18 dB and C/N> C/I in a given area, there is a coverage problem and co channel interference.

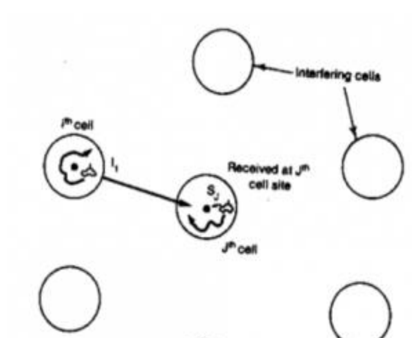


Co channel interference at mobile unit.

Test 2—find the co-channel interference area which affects a cell site:

The reciprocity theorem can be applied for the coverage problem but not for co-channel interference. Therefore, we cannot assume that the first test result will apply to the second test condition. We must perform the second test as well. Because it is difficult to use seven cars simultaneously, with each car travelling in each co-channel cell for this test, an alternative app roach may be to record the signal strength at every co-channel cell site while a mobile unit is travelling either in its own cell or in one of the co-channel cells. Then we can reestablish the carrier-to-interference ratio received at a desired cell, say, the Jth cell site as follows.

The number of co-channel cells in the system can be less than six. We must be aware that all Cj and Ii were read in decibels, Therefore, a translation from decibels to linear is needed before summing all the interfering sources. The test can be carried out repeatedly for any given cell. We then compare Cj/I and Cj/N and determine the co-channel interference condition, which will be the same as that in test 1. Nj is the noise level in the Jth cell assuming no interference exists,



Co- Channel Interference at the cell site

Design of an Omnidirectional Antenna System in the Worst Case*:* The value of q = 4.6 is valid for a normal interference case in a K=7 cell pattern. In this section we would like to prove that a K=7 cell pattern does not provide a sufficient frequency re-use distance separation eyen when an ideal condition of flat terrain is assumed. The worst case is at the location where the weakest signal from its own cell site but strong interferences from all interfering cell sites. In the worst case the mobile unit is at the cell boundary R, as shown in Fig. The distances from all six cochannel interfering sites are also shown in the figure: two distances of D – R, two distances of D, and two distances of D + R. Following the mobile radio propagation rule of 40 dB/dec, we obtain $C \propto R^{-4}$ $\quad I \propto D^{-4}$

Then the carrier-to-interference ratio is

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

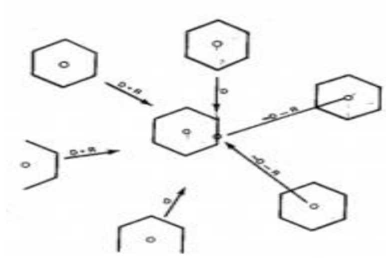


Fig. co-channel interference

around the C/I of the worst case. In that case, a cochannel interference reduction factor of q=4.6 is insufficient. Therefore, in an omnidirectional-cell system, K = 9 or K 12 would be a correct choice. Then the values of q are

$$q = \begin{cases} \frac{D}{R} = \sqrt{3K} \\ 5.2 & K = 9 \\ 6 & K = 12 \end{cases}$$

Substituting these values in Eq. (6.4-1), we obtain

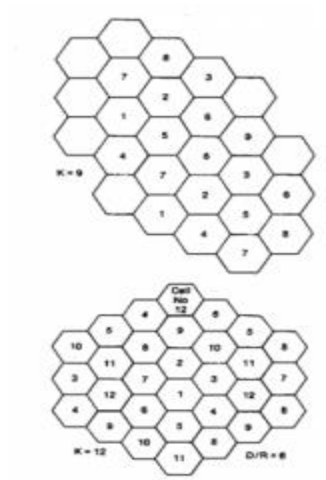
$$\frac{C}{I} = 84.5 \; (=) \; 19.25 \text{ dB} \qquad K = 9$$

$$\frac{C}{I} = 179.33 \; (=) \; 22.54 \text{ dB} \qquad K = 12$$

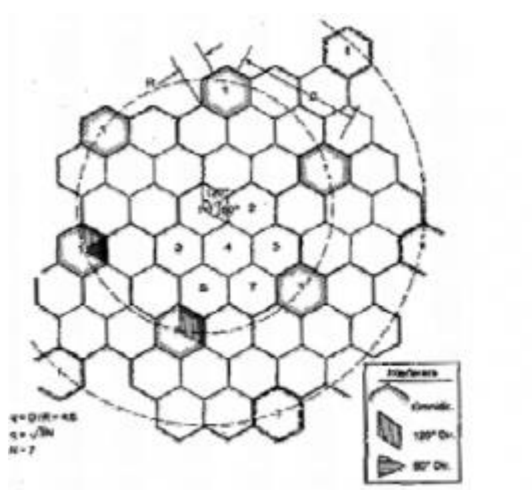
Design of a Directional Antenna System: When the call traffic begins to increase, we need to use the frequency spectrum efficiently and avoid increasing the number of cells K in a seven-cell frequency reuse pattern. When K increases, the number of frequency channels assigned in a cell must become smaller (assuming a total allocated channel divided by K) and the efficiency of applying the frequency reuse scheme decrease.

Instead of increasing the number K in a set of cells, let us keep K =7 and introduce a directional antenna arrangement. The cochannel interference can be reduced by using directional antenna. This means that each cell is divided into three or six sectors and uses three or six directional antennas at a base station. Each sector is assigned a set of frequencies (channels). The interference between two cochannel cells decreases as shown Fig.

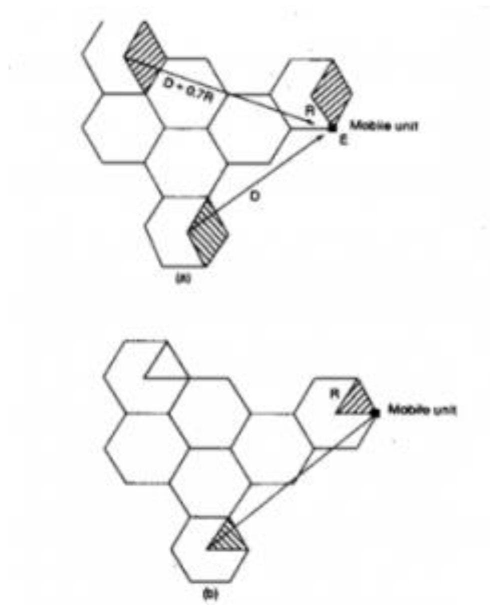
Directional antennas in K=7 cell patterns: Three sector case: The three-sector case is shown in Fig. To illustrate the worst case situation, two cochannel cells are shown in Fig.. The mobile unit at position E will experience greater interference in the lower shaded cell sector than in the upper shaded cellsector site. This is because the mobile receiver receives the weakest signal from its own cell but fairly strong interference from the interfering cell.



In a three-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 10 dB or more in a mobile radio environment. The worst-case co channel interference in the directional-antenna sectors in which interference occurs may be calculated. Because of the use of directional antennas, the number of principal interferers is reduced from six to two (Fig.4.2). The worst case of C/I occurs when the mobile unit is at position E, at which point the distance between the mobile unit and the two interfering antennas is roughly D + (R/2); however, C/I can be calculated more precisely as follows. The value of C/I can be obtained by the following expression (assuming that the worst case is at position E at which the distances from two interferers are D + 0.7R and D).



.Interfering cells shown in a seven cell system (two-tiers)



The C/I received by a mobile unit from the 120° directional antenna sector system expressed in Eq. above greatly exceeds 18 dB in a worst case. Equation above shows that using directional antenna sectors can improve the signal-to-interference ratio, that is, reduce the cochannel interference. However, in reality, the C/I could be 6 dB weaker than in Eq. given above in a heavy traffic area as a result of irregular terrain contour and imperfect site locations. The remaining 18.5 dB is still adequate.

Six-sector case: We may also divide a cell into six sectors by using six 60°-beam directional antennas as shown in Fig. In this case, only one instance of interference can occur in each sector as shown in Fig,. Therefore, the carrier-to-interference ratio in this case is which shows a further reduction of cochannel interference. If we use the same argument as we did for Eq. above and subtract 6 dB from the result of Eq. the remaining 23 dB is still more thanadequate. When heavy traffic occurs, the 60°-sector configuration can be used to reduce cochannel interference. However, fewer channels are generally allowed in a 60° sector and the trunking efficiency decreases. In certain cases, more available channels could be assigned in a 60° sector.

Directional antenna in K = 4 cell pattern:

Three-sector case: To obtain the carrier-to-interference ratio, we use the same procedure as in the K = 7 cell-pattern system. The 120° directional antennas used in the sectors reduced the interferers to two as in K = 7 systems, as shown in Fig.4.4. We can apply Eq. here. For K = 4, the value of q = 3.46; therefore, Eq. becomes

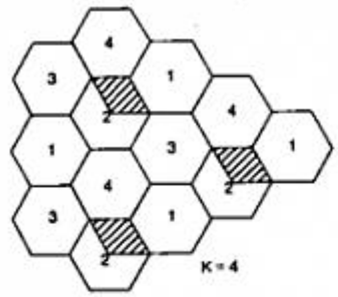
$$\frac{C}{I}\text{(worst case)} = \frac{1}{(q+0.7)^{-4} + q^{-4}} = 97 = 20 \text{ dB}$$

If, using the same reasoning used with Eq. above, 6 dB is subtracted from the result of Eq. above, the remaining 14 dB is unacceptable.

Six-sector case: There is only one interferer at a distance of D + R shown in Fig.4.4. With q=3.46, we can obtain

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

If 6 dB is subtracted from the above result, the remaining 20 dB is adequate.



Interference with frequency reuse pattern K=4.

Under heavy traffic conditions, there is still a great deal of concern over using a K =4 cell pattern ina60°sector.

Comparing K =7 and N =4 systems: A K =7 cell pattern system is a logical way to begin an omnicell system. The co-channel reuse distance is more or less adequate, according to the designed criterion. When the traffic increases, a three sector system should be implemented, that is, with three 120° directional antennas in place. In certain hot spots, 60° sectors can be used locally to increase the channel utilization. If a given area is covered by both K=7 and K=4 cell patterns and both patterns have a six-sector configuration, then the K=7 system has a total of 42 sectors, but the K=4 system has a total of only 24 sectors and, of course, the system of K=7 and six sectors has less cochannel interference.

Co-channel Interference:

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

fading frequency, measurement of the signal carrier-to-interference ratio C/I reveals that the signal is

$$e_1 = S(t)\sin(\omega t + \phi_1) \qquad (6.3\text{-}1)$$

and the interference is

$$e_2 = I(t)\sin(\omega t + \phi_2) \qquad (6.3\text{-}2)$$

The received signal is

$$e(t) = e_1(t) + e_2(t) = R\sin(\omega t + \psi) \qquad (6.3\text{-}3)$$

where

$$R = \sqrt{[S(t)\cos\phi_1 + I(t)\cos\phi_2]^2 + [S(t)\sin\phi_1 + I(t)\sin\phi_2]^2} \qquad (6.3\text{-}4)$$

and

$$\psi = \tan^{-1}\frac{S(t)\sin\phi_1 + I(t)\sin\phi_2}{S(t)\cos\phi_1 + I(t)\cos\phi_2} \qquad (6.3\text{-}5)$$

The envelope R can be simplified in Eq. (6.3-4), and R^2 becomes

$$R^2 = [S^2(t) + I^2(t) + 2S(t)I(t)\cos(\phi_1 - \phi_2)] \qquad (6.3\text{-}6)$$

Following Kozono and Sakamoto's[2] analysis of Eq. (6.3-6) the term $S^2(t) + I^2(t)$ fluctuates close to the fading frequency V/λ and the term $2S(t)I(t)\cos(\phi_1 - \phi_2)$ fluctuates to a frequency close to $d/dt(\phi_1 - \phi_2)$, which is much higher than the fading frequency. Then the two parts of the squared envelope can be separated as

$$X = S^2(t) + I^2(t) \quad (6.3\text{-}7)$$

$$Y = 2S(t)I(t)\cos(\phi_1 - \phi_2) \quad (6.3\text{-}8)$$

Assume that the random variables $S(t)$, $I(t)$, ϕ_1, and ϕ_2 are independent; then the average processes on X and Y are

$$\overline{X} = \overline{S^2(t)} + \overline{I^2(t)} \quad (6.3\text{-}9)$$

$$\overline{Y^2} = 4\overline{S^2(t)}\,\overline{I^2(t)}(1/2) = 2\overline{S^2(t)}\,\overline{I^2(t)} \quad (6.3\text{-}10)$$

The signal-to-interference ratio Γ becomes

$$\Gamma = \frac{\overline{S^2(t)}}{\overline{I^2(t)}} = k + \sqrt{k^2 - 1} \quad (6.3\text{-}11)$$

where

$$k = \frac{\overline{X}^2}{\overline{Y^2}} - 1 \quad (6.3\text{-}12)$$

Since X and Y can be separated in Eq. (6.3-6), the preceding computation of Γ in Eq. (6.3-11) could have been accomplished 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

$$S(t) \approx S(t + \Delta t), \qquad I(t) \approx I(t + \Delta t) \quad (6.3\text{-}13)$$

and

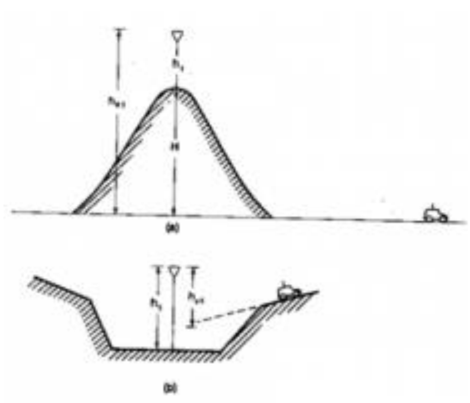
$$\overline{\cos[\phi_1(t) - \phi_2(t)]\cos[\phi_1(t + \Delta t) - \phi_2(t + \Delta t)]} \approx 0 \quad (6.3\text{-}14)$$

Determining the delay time Δt to meet the requirement of Eq. (6.3-13) for this calculation is difficult and is a drawback to this measurement technique. Therefore, real-time cochannel interference measurement is difficult to achieve in practice.

Lowering the Antenna Height:

Lowering the antenna height does not always reduce the co channel interference. In some circumstances, such as on fairly flat ground or in a valley situation, lowering the antenna height will be very effective for reducing the co channel and adjacent channel interference, However, there are three cases where lowering the antenna height may or may not effectively help reduce the interference.

On a high hill or a high spot: The effective antenna height, rather than the actual height, is always considered in the system design. Therefore, the effective antenna height varies according to the location of the mobile unit. When the antenna site is on a bill, as shown in Fig. The effective antenna height is h1 + H.



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

If we reduce the actual antenna height to 0.5h1, the effective antenna height becomes 0.5h1 + H. The reduction in gain resulting from the height reduction is

$$G = \text{gain reduction} = 20 \log_{10} \frac{0.5h_1 + H}{h_1 + H}$$

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

If h1<<H, then the above equation becomes

$$G = 20 \log10\ 1 = 0 \text{ db}$$

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

In a valley: The effective antenna height as seen from the mobile unit shown in Fig. 5.1(b) is he1, which is less than the actual antenna height h1. If he1= 2/3 h1, and the antenna is lowered to ½ h1, then the new effective antenna height is

$$h_{e2} = \tfrac{2}{3}h_1 - (h_1 - \tfrac{1}{2}h_1) = \tfrac{1}{6}h_1$$

Then the antenna gain is reduced by

$$G = 20 \log \frac{\frac{1}{6}h_1}{\frac{2}{3}h_1} = -12 \text{ dB}$$

This simply proves that the lowered 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. The power reduction caused by decreasing antenna height by half is only

$$20 \log \frac{\frac{1}{2}h_1}{h_1} = -6 \text{ dB}$$

In a forested area: In a forested area, the antenna should clear the tops of any trees in the vicinity, especially when they are very close to the antenna. In this case decreasing the height of the antenna would not be the proper procedure for reducing cochannel interference because excessive attenuation of the desired signal would occur in the vicinity of the antenna and in its cell boundary if the antenna were below the treetop level.

Power Control:-

Power Control: The power level can be controlled only by the mobile transmitting switching office (MTSO), not by the mobile units, and there can be only limited power control by the cell sites as a result of system limitations. The reasons are as follows. The mobile transmitted power level assignment must be controlled by the MTSO or the cell site, not the mobile unit or, alternatively, the mobile unit can lower the power level but cannot arbitrarily increase it. This is because the MTSO is capable of monitoring the performance of the whole system and can increase or decrease the transmitted power level of those mobile units to render optimum performance. The MTSO will not optimise performance for any particular mobile unit unless a special arrangement is made.

Function of the MTSO: The MTSO controls the transmitted power levels at both the cell sites and the mobile units. The advantages of having the MSTO control the power levels are described here.

1. Control of the mobile transmitted power level. When the mobile unit is approaching the cell site, the mobile unit power level should be reduced for the following reasons.

a) Reducing the chance of generating inter-modulation products from a saturated receiving amplifier.
b) Lowering the power level is equivalent to reducing the chance of interfering with other co-channel cell sites.
c) Reducing the near-end-far-end interference ratio.

2. Control of the cell-site transmitted power level. When the signal received from the mobile unit at the cell site is very strong, the MTSO should reduce the transmitted power level of that particular radio at the cell site and, at the same time, lower the transmitted power level at the mobile unit. The advantages are as follows.

a) For a particular radio channel, the cell size decreases significantly, the cochannel reuse distance increases, and the cochannel interference reduces further. In other words, cell size and cochannel interference are inversely proportional to cochannel reuse distance.

b) The adjacent channel interference in the system is also reduced. However, in most cellular systems, it is not possible to reduce only one or a few channel power levels at the cell site because of the design limitation of the combiner. The channel isolation in the combiner is 18 dB. If the transmitted power level of one channel is lower, the channels having high transmitted power levels will interfere with this low-power channel. The manufacturer should design an unequal power combiner for the system operator so that the power level of each channel can be controlled at the cell site.

3. The power transmitted from a small cell is always reduced, and so is that from a mobile unit. The MTSO can facilitate adjustment of the transmitted power of the mobile units as soon as they enter the cell boundary.

Diversity Receiver: The diversity scheme applied at the receiving end of the antenna is an effective technique for reducing interference because any measures taken at the receiving end to improve signal performance will not cause additional interference. The diversity scheme is one of these approaches. We may use a selective combiner to combine two correlated signals as shown in Fig. 7.1. The performance of other kinds of combiners can be at most 2 dB better than that of selective combiners. However, the selective combining technique is the easiest scheme to use.

Figure shows a family of curves representing this selective combination. Each curve has an associated correlation coefficient p; when using the diversity scheme, the optimum result is obtained when p = 0. We have found that at the cell site the correlation coefficient p < 0.7 should be used for a two branch space diversity; with this coefficient the separation of two antennas at the cell site meets the requirement of h / d= 11, where h is the antenna height and d is the antenna separation.

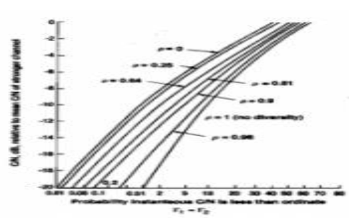


Fig. selective combination of 2 correlated signals

At the mobile unit we can use p =0, which implies that the two roof-mounted antennas of the mobile unit are 0.5 Lambda or more apart. This is verified by the measured data shown in Fig.

Now we may estimate the advantage of using diversity. First, let us assume a threshold level of 10 dB below the average power level.

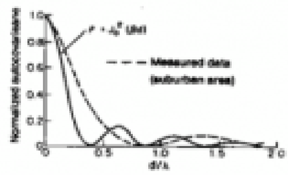


Fig. Autocorrelation coefficient versus spacing for uniform angular distribution (applied to diversity reciever)

Then compare the percent of signal below the threshold level both with and without a diversity scheme.

1. At the mobile unit: The comparison is between curves p = 0 and the p=1. The signal below the threshold level is 10 percent for no diversity and 1 percent for diversity. If the signal without diversity were 1 percent below the threshold, the power would be increased by 10 dB. In other words, if the diversity scheme is used, the power can be reduced by 10 dB and the same performance can be obtained as in the non diversity scheme. With 10 dB less power transmitted at the cell site, cochannel interference can be drastically reduced.

2. At the cell site: The comparison is between curves of p=0.7 and p =1. We use curve p=0.64 for a close approximation as shown in Fig. The difference is 10 percent of the signal is below threshold level when a non diversity scheme is used versus 2 percent signal below threshold level when a diversity scheme is used. If the non diversity signal were 2 percent below the threshold, the power would have to increase by 7 dB . Therefore, the mobile transmitter (for a cell-site diversity receiver) could undergo a 7dB reduction in power and attain the same performance as a non diversity receiver at the cell site. Thus, interference from the mobile transmitters to the receivers can be drastically reduced.

Explain different methods to reduce the co-channel interferences.

The different methods used to reduce **co-channel interference** are broadly classified into three.They are

1. By providing large separation among the two co-channel cells.
2. By reducing the antenna heights at the base station.
3. By the usage of directional antennas at the base station.

The first two techniques ne not employed because they have disadvantageous effects i.e., method 1 is responsible for reducing the system efficiency for increase in number for frequency range channels. While method 2 is responsible for reducing the reception level at the mobile unit. The method 3 is most commonly used because, along with reducing co-channel interference, it also increases the channel capacity (during heavy traffic).

There are different techniques to generate directional antennas

1. Tilting the antenna and creating a notch along the unwanted space.

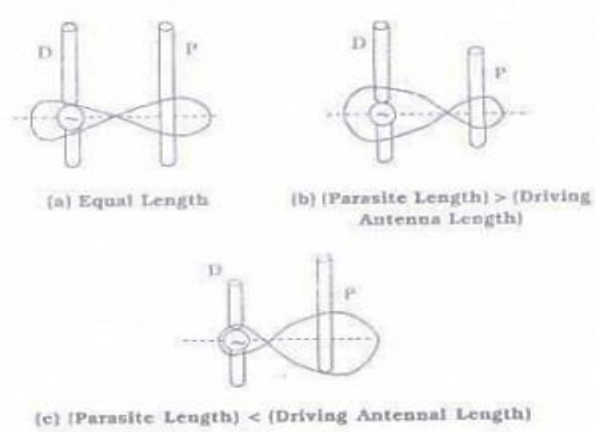
2. Using umbrella patterns.

3. Using parasitic elements.

1. Tilting the Antenna: The tilting of an antenna in a desired manner produces an energy pattern with a notch in the desired direction. Hence, ibis notch prevents the co-channel interference problem. The tilting of the antenna is done in two ways.
(1) Electrically
(ii) Mechanically
In the electronic down tilting, the phases between the elements of a co-linear array antenna are varied. In the mechanical down tilting the physical rotation of antenna is occurred.

2. Umbrella Pattern: The umbrella pattern is obtained with the help of a staggered discone antenna. The umbrella pattern reduces the long distance co-channel interference problems, particularly cross talk. Even though, the umbrella pattern is not used for a directional antenna pattern, it can be used for an omnidirectional antenna pattern. In hilly areas, where the height of antenna cannot be increased to cover weak signal spots, results in co-channel interference. In this case also we can use umbrella pattern. The umbrella pattern allows us to increase the antenna height but, we can still decrease cochannel interference.

3. Parasitic Elements: The use of parasitic elements provides the desired pattern and hence we can avoid the cochannel interference. This antenna combination has a parasitic antenna and a driving antenna, the driving antenna is the source of current flowing in the parasitic antenna. The different combinations of their arrangements produce different patterns as described below. When the lengths of the elements are identical and closely spaced the current flowing through the parasitic clement is strong. This creates equal level of patterns. When the length of parasite is more than drive antenna, the parasite act as reflector and the pattern in the reflected direction is more. When the length of parasite is less than drive antenna, the parasite acts as a director and the pattern is more inclined in the forward direction. These three patterns are illustrated in figure (a) figure (b) and figure (c) respectively.



Channel Combiner:

1. A Fixed Tuned Channel Combiner: At the travelling side, a fixed tunable combined unit is used. In every cell site, a channel combiner circuit is installed. The transmitted channels have to be combined based on the following two criteria,

a) The signal isolation between the radio channels must be maximum
b) The insertion loss should be minimum. However, the usage of channel combiner
can be avoided by feeding each channel to its corresponding antenna.

But, if there are 16 channels available in a cell site, there will be requirement of 16 antennas for operation which is bottle neck for real time functionalities. It is not economical to hive huge hardware setups. Thus, a conventional combiner can he used, which has 16 channel combining capacity and it is based on the frequency subset of 16 channels of cell site. The channel combiner would be responsible for each of the 16 channels to exhibit a 3 dB loss due to the signal insertion in to the channel combiner. The signal isolation would be 17dB, if every channel is separated from its neighboring channels by 630 kHz frequency.

2. Tunable Combiner: Tunable combiner is also referred as frequency agile combiner. The frequency agile combiner is an advanced combiner circuit with additional features. It can return any frequency in real time by remote control device, namely microprocessor. This combiner is essentially a waveguide resonator with a tuning bar facility. A motor makes the tuning bar to rotate and once the motor starts rotating, the Voltage Standing Wave Ratio (VSWR) can be measured.

The controller unit has self-adjusting feature and it accepts an optimum value of VSWR as the motor complete, a full turn. The controller is compatible only with dynamic frequency assignment. The cell-sites should be flexible to change their operating frequency ‘f’ that is controlled by MTSO/MSC. Thus, we can use this frequency agile combiner in the cell site transceiver setup.

3. Ring Combiner: Ring combiner is used to combine two groups of channels to give one output. This combiner has an insertion loss of 3 dB. For example, using a ring combiner two 16 channel groups into one 32 channel output. Even 64 channels can be used with this combiner if two antennas arc available in the cell site. In case of low transmitter power more than one ring combiner can be used for combining. However, the demerits of ring combiners are.
a) It reduces adjacent-channel separation.
b) They may be affected from the problem of power limitations.

Near-End-Far-End Interference:

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 our only at the reception point in the cell site.

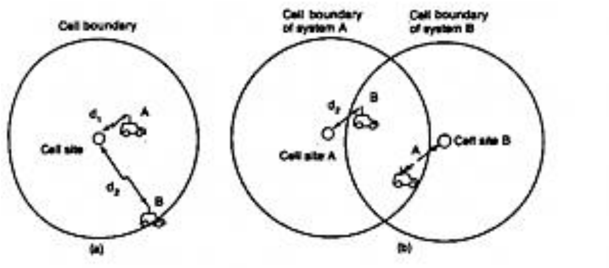


Fig. Near-end-far-end interface (a). In one cell (b). In Two Systems

If a separation of 5dB (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 5dB required between each adjacent channel used with one cell.

Because the total frequency channels are distributed in a set of N cell, each cell only has I/N of total frequency channels. We denote {Fl}, {F2},{F3},{F4} for the sets of frequency channels assigned in their corresponding cells C1.,C2, C3, C4.

The issue here is how can we construct a good frequency management chart to assign the N sets of frequency channels properly and thus avoid the problems indicated above. The following section addresses how cellular system engineers solve this problem in two different systems.

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

For instance, mobile unit A can be located at the boundary of its own home cell A in system A but very close to cell B of system B as shown in the figure .The other situation would occur if the mobile unit B were at the boundary of cell B of system B but very close to cell A of system A. Following the definition of near-end-far-end interference the solid arrow indicates that interference may our at cell site A and the dotted arrow indicates that interference may occur at mobile unit A. Of course, the same interference will be introduced at cell site B and mobile unit B.

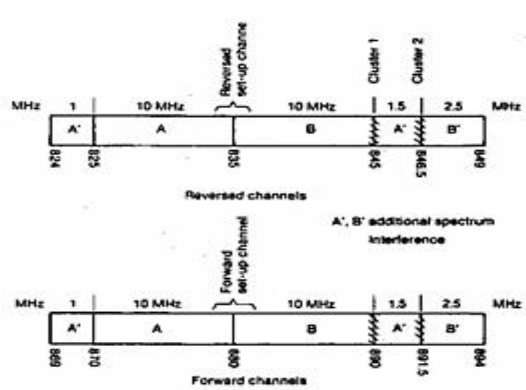


Fig. Spectrum allocation with new additional spectrum

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

1. Interference caused on the set-up channels. Two systems try to avoid using the neighborhood of the set-up channels as shown in Fig.
2. Interference caused on the voice channels. There are two clusters of frequency sets as shown in Fig which may cause adjacent-channel interference and should be avoided.
3. The cluster can consist of 4 to 5 channels on each side of each system, that is, 8 to 10 channels in each cluster. The channel separation can be based on two assumptions.
   a. Received interference at the mobile unit. The mobile unit is located away from its own cell site but only 0.25 ml away from the cell site of another system.
   b. Received interference at the cell site. The cell site is located 10 ml away from its own mobile unit but only 0.25 mi from the mobile unit of another system

UNIT-4

Frequency Management:

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 a fixed fashion or dynamically (i.e., in response to any channel among the available channels). The terms "frequency management" and"channel assignment" often create some confusion. Frequency management refers to designating setup channels and voice channels (done by the FCC), numbering the channels (done by the FCC), and grouping the voice channels into subsets (done by each system according to its preference). Channel assignment refers to the allocation of specific channels to cell sites and mobile units. A fixed channel set consisting of one more subsets is assigned to a cell site on a 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). Ideally channel assignment should be based on causing the least interference in the system. However, most cellular systems cannot perform this way.

Numbering the channels: The total number of channels at present (January 1988) is 832. But most mobile units an systems are still operating on 666 channels. Therefore we describe the 666 channel numbering first. A channel consists of two frequency channel bandwidths, one in the low band and one in the high band. Two frequencies in channel 1 are 825.030 MHz (mobile transmit) 870.030MHz (cell-site transmit). The two frequencies in channel 666 are 844.98 MHz(mobile transmit) and 898 MHz (cell-site transmit). The 666 channels are divided into two groups: block A system and block B system. Each market (i.e., each city) has two systems for a duopoly market policy. Each block has 333 channels, as shown in Fig. The 42 set-up channels are assigned as follows.

Channels 313-333 block A

Channels 334-354 block B

The voice channels are assigned as follows.

Channels 1-312 (312 voice channels) block A

Channels 355-666 (312 voice channels) block B

These 42 set-up channels are assigned in the middle of all the assigned channels to facilitate scanning of those channels by frequency synthesizers. In the new additional spectrum allocation of 10 MHz , an additional 166 channels are assigned. Since a 1 MHz is assigned below 825 MHz (or 870 MHz) in the future, additional channels will be numbered up to 849 MHz (or 894 MHz) and will then circle back. The last channel number is 1023. There are no Channels between channels 799 and 991.

Frequency –Spectrum Utilization:

Set-up channels can be classified by usage into two types: access channels and paging channels. An access channel is used for the mobile-originating calls and paging channels for the land originating calls. For this reason, a set-up channel is sometimes called an 'access channel' and sometimes called a 'paging channel.' Every two- way channel contains two 30-kHz bandwidth. Normally one set-up channel is also specified by two operations as a forward set-up channel (using the upper band) and a reverse set-up channel (using the lower band). In the most common types of cellular systems, one set-up channel issued for both access and paging. The forward set-up channel functions as the paging channel for responding to the mobile-originating calls. The reverse set-up channel functions as the access channel for the responder to the paging call. The forward set-up channel is transmitted at the cell site, and the reverse set-up channel is transmitted at the mobile unit. All set-up channels carry data information only

ACESS CHANNEL

In mobile-originating calls, the mobile unit scans its 21 set-up channels and chooses the strongest One Because each set-up channel is associated with one cell, the strongest set-up channel indicates which cell is to serve the mobile-originating calls. Th. mobile unit detects the system information transmitted from the cell site. Also, the mobile unit monitors the Busy/Idle status bits over the desired forward setup channel. When the idle bits are received, the mobile unit cause the corresponding reverse set-up channel to initiate a call. Frequently only one system operates in a given city; for instance, block B system might be operating and the mobile unit could be set to "preferable A system." When the mobile unit first scans the 21 set-up channels in block A, two conditions can occur.

1. If no set-up channels of block A are operational, the mobile unit automatically switches to block B.
2. If a strong set-up signal strength is received but no message can be detected, then the scanner chooses the second strongest set-up channel. If the message still cannot be detected, the mobile unit switches to block B and scans to block B set-up channels. The operational functions are described as follows:

1. Power of a forward set-up channel [or forward control channel (FOCC)]: The power of the setup channel can be varied in order to control the number of incoming calls served by the cell. The number of mobile-originating calls is limited by the number of voice channels in each cell site, when the traffic is heavy, most voice channels are occupied and the power of the set-up channel should be reduced in order to reduce the coverage of the cell for the incoming calls originating from the mobile unit. This will force the mobile units to originate calls from other cell sites, assuming that all cells are adequately overlapped.
2. The set-up channel received level: The setup channel threshold level is determined in order to control the reception at the reverse control channel (RECC). If the received power level is greater than the given set-up threshold level, the call request will be taken.
3. Change power at the mobile unit: When the mobile unit monitors the strongest signal strength from all Set-up channels and selects that channel to receive the messages, there are three types of message.

a. Mobile station. control message This message is used for paging and consists of one, two, or four words -DCC, MIN, SCC and VMAX.
b. System parameter overhead message. This message contains two words, including DCC, SID, CMAX, or CPA.
c. Control-filler message. This message may be sent with a system parameter overhead message, CMAC—a control mobile attenuation code (seven levels).

4. Direct call retry. When a cell site has no available voice channels, it can send a direct call-retry message through the set-up channel. The mobile unit will initiate, the call from a neighboring cell which is on the list of neighboring cells in the direct call-retry message.

Paging channels:

Each cell site has been allocated its own setup 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 message. Because the same message is transmitted by the different set-up channels, no simulcast interference occurs in the system. The algorithm for paging & mobile unit can be performed in different ways. The simplest way is to page from all the cell sites. This can occupy a large amount of the traffic load. The other way is to page in an area corresponding to the mobile unit phone number. If there is no answer, the system tries to page in other areas. The drawback is that response time is sometimes too long. When the mobile unit responds to the page on the reverse set-up channel, the cell site which receives the response checks the signal reception level and makes a decision regarding the voice channel assignment based on least interference in the selected sector or underlay-overlay region

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Self location scheme at the mobile unit and the autonomous registration.

Self -location scheme at the mobile unit: In the cellular system, 80 percent of calls originate from the mobile unit but only 20 percent originate, from the land line. Thus, it is necessary to keep the reverse set-up channels as open as possible. For this reason, the self-location scheme at the mobile unit is adapted. The mobile unit selects a set-up channel of one cell site and makes a mobile-originating call. It is called a self-location scheme. However, the self-location scheme at the mobile unit prevents the mobile unit from sending the necessary information regarding its location to the cell site. Therefore, the MTSO does not know where the mobile is. When a landline call is originated, the MTSO must page all the cell sates In order to search for the mobile unit. Fortunately land-line calls constitute only 20 percent of land-line originating calls, so the cellular system has no problem in handling them. Besides, more than 50 percent of landline originating calls are no response.

Autonomous registration:

If a mobile station is equipped for autonomous registration, then the mobile station stores the value of the last registration number (REGID) received on a forward control channel. Also, a REGINCR (the increment in time between registrations) is received by the mobile station. The next registration ID should be

NXTREG = REGID + REGINCR

This tells the mobile unit how long the registration should be repeatedly sent to the cell site, so that the MTSO can track the location of the mobile. This feature is not used in cellular systems at present. However when the volume of land-line calls begins to increase or the number of cell sites increases, this feature would facilitate paging of the mobile units with less occupancy time on all set-up channels.

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Fixed Channel Assignment Schemes:

Adjacent-Channel Assignment:
Adjacent-channel assignment includes neighboring-channel assignment and next-channel assignment. The near-end–far-end (ratio) interference, can occur among the neighboring channels (four channels on each side of the desired channel). Therefore, within a cell we have to be sure to assign neighboring channels in an omnidirectional-cell system and in a directional-antenna-cell system properly. In an omnidirectional-cell system, if one channel is assigned to the middle cell of seven cells, next channels cannot be assigned in the same cell. Also, no next channel (preferably including neighboring channels) should be assigned in the six neighboring sites in the same cell system area In a directional-antenna-cell system, if one channel is assigned to a face, next channels cannot be assigned to the same face or to the other two face sin the same cell. Also, next channels cannot be assigned to the other two faces at the same cell site. Sometimes the next channels are assigned in the next sector of the same cell in order to increase capacity. Then performance can still be in the tolerance range if the design is proper.

Handoff and their characteristics:

Definition: When a user moves from one frequency zone to other frequency zone then without disturbing the user, without alerting the user, the call will be continuously in progress. That technique is called HANDOFF. Different types of handoff techniques are available. Out of them we are concentrating on few handoffs only.

Why Handoffs:

In an analog system, once a call is established, the set-up channel is not used again during the call period. Therefore, handoff is always implemented on the voice channel. The value of implementing handoffs is dependent on the size of the cell. For example, if the radius of the cell is 32 km (20 mi), the area is 3217 km2 (1256 mi2). After a call is initiated in this area, there is little chance that it will be dropped before the call is terminated as a result of a weak signal at the coverage boundary.

Handoff is needed in two situations where the cell site receives weak signals from the mobile unit: (1) at the cell boundary, say, −100 dBm, which is the level for requesting a handoff in a noise-limited environment; and (2) when the mobile unit is reaching the signal-strength holes (gaps) within the cell site as shown in Fig.

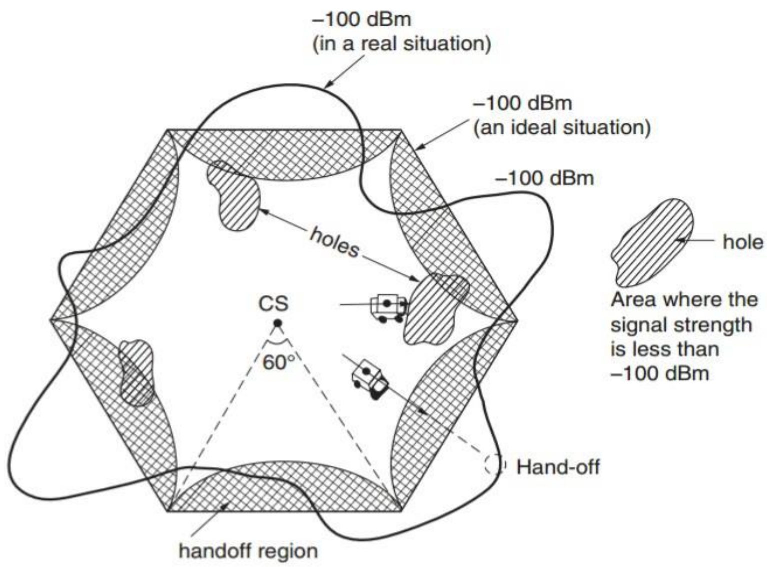


Fig. Occurrence of Handoff

Two Decision Making Parameters of Handoff:

There are two decision-making parameters of handoff:

(1) that based on signal strength and

(2) that based on carrier-to-interference ratio.

The handoff criteria are different for these two types. In type 1, the signal-strength threshold level for handoff is −100 dBm in noise-limited systems and −95 dBm in interference-limited systems. In type 2, the value of C/I at the cell boundary for handoff should be at a level, 18 dB for AMPS in order to have toll quality voice. Sometimes, a low value of C/I may be used for capacity reasons.

Number of Handoffs per call:

The smaller the cell size, the greater the number and the value of implementing handoffs.

The number of handoffs per call is relative to cell size. From the simulation, we may find

0.2 handoff per call in a 16- to 24-km cell

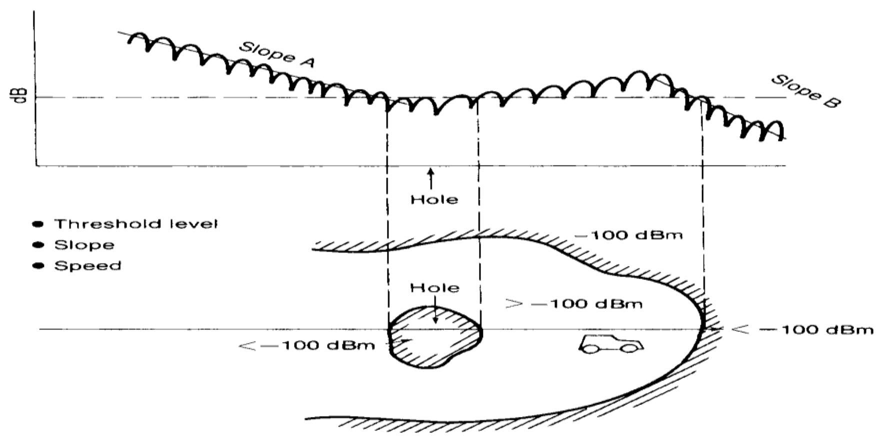
1–2 handoffs per call in a 3.2- to 8-km cell

3–4 handoffs per call in a 1.6- to 3.2-km cell

Initiation of handoff:

At the cell site, signal strength is always monitored from a reverse voice channel. When the signal strength reaches the level of a handoff (higher than the threshold level for the minimum required voice quality), then the cell site sends a request to the mobile switching (MSO)∗ for a handoff on the call. An intelligent decision can also be made at the cell site as to whether the handoff should have taken place earlier or later. If an unnecessary handoff is requested, then the decision was made too early. If a failure handoff occurs, then a decision was made too late.

The following approaches are used to make handoffs successful and to eliminate all unnecessary handoffs. Suppose that −100 dBm is a threshold level at the cell boundary at which a handoff would be taken. Given this scenario, we must set up a level higher than −100 dBm—say, −100 dBm + _ dB—and when the received signal reaches this level, a handoff request is initiated. If the value of _ is fixed and large, then the time it takes to lower −100 dBm + _ to −100 dBm is longer. During this time, many situations, such as the mobile unit turning back toward the cell site or stopping, can occur as a result of the direction and the speed of the moving vehicles. Then the signals will never drop below −100 dBm. Thus, many unnecessary handoffs may occur simply because we have taken the action too early. If _ is small, then there is not enough time for the call to hand off at the cell site and many calls can be lost while they are handed off. Therefore, _ should bevaried according to the path-loss slope of the received signal strength and the level-crossing rate (LCR) of the signal strength as shown below.



Delaying handoff:

Two Handoff level Algorithm:

In many cases, a two-handoff-level algorithm is used. The purpose of creating two request handoff levels is to provide more opportunity for a successful handoff. A handoff could be delayed if no available cell could take the call.

A plot of signal strength with two request handoff levels and a threshold level is shown in Fig. The plot of average signal strength is recorded on the channel received

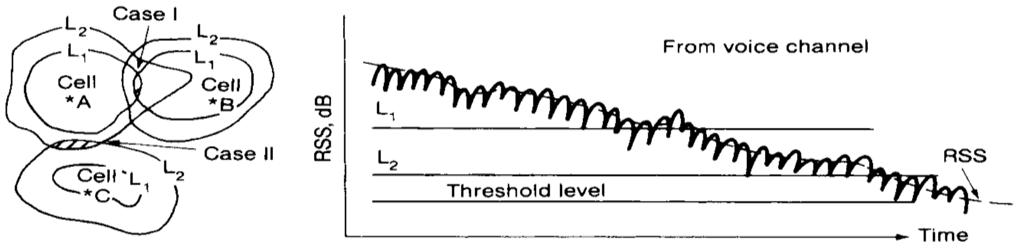


Fig. A Two Level Handoff scheme

signal-strength indicator (RSSI), which is installed at each channel receiver at the cell site. When the signal strength drops below the first handoff level, a handoff request is initiated. If for some reason the mobile unit is in a hole (a weak spot in a cell) or a neighboring cell is busy, the handoff will be requested periodically every 5 s. At the first handoff level, the handoff takes place if the new signal is stronger (see case I in Fig.). However, whenthe second handoff level is reached, the call will be handed off with no condition (see case II in Fig.).

The MSO always handles the handoff call first and the originating calls second. If no neighboring calls are available after the second handoff level is reached, the call continues until the signal strength drops below the threshold level; then the call is dropped. In AMPS systems if the supervisory audio tone (SAT) is not sent back to the cell site by the mobile unit within 5 s, the cell site turns off the transmitter.

Forced handoffs:

A *forced handoff* is defined as a handoff that would normally occur but is prevented from happening, or a handoff that should not occur but is forced to happen.

Controlling a Handoff

The cell site can assign a low handoff threshold in a cell to keep a mobile unit in a cell longer or assign a high handoff threshold level to request a handoff earlier. The MSO also can control a handoff by making either a handoff earlier or later, after receiving a handoff request from a cell site

Creating a Handoff

In this case, the cell site does not request a handoff but the MSO finds that some cells are too congested while others are not. Then, the MSO can request call sites to create early handoffs for those congested cells. In other words, a cell site has to follow the MSO's order and increase the handoff threshold to push the mobile units at the new boundary and to handoff earlier.

Cell-Site Handoff:

This scheme can be used in a non-cellular system. The mobile unit has been assigned a frequency and talks to its home cell site while it travels. When the mobile unit leaves its home cell and enters a new cell, its frequency does not change; rather, the new cell must tune into the frequency of the mobile unit (see Fig. 11.9). In this case only the cell sites need the frequency information of the mobile unit. Then the aspects of mobile unit control can be greatly simplified, and there will be no need to provide handoff capability at the mobile unit. The cost will also be lower. This scheme can be recommended only in areas of very low traffic. When the traffic is dense, frequency coordination is necessary for the cellular system. Then if a mobile unit does not change frequency on travel from cell to cell, other mobile units then must change frequency to avoid interference.

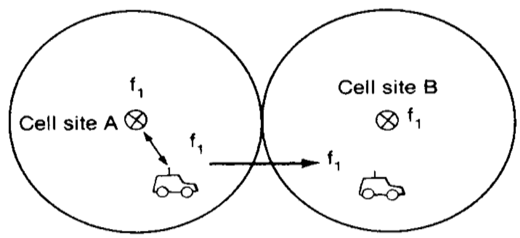
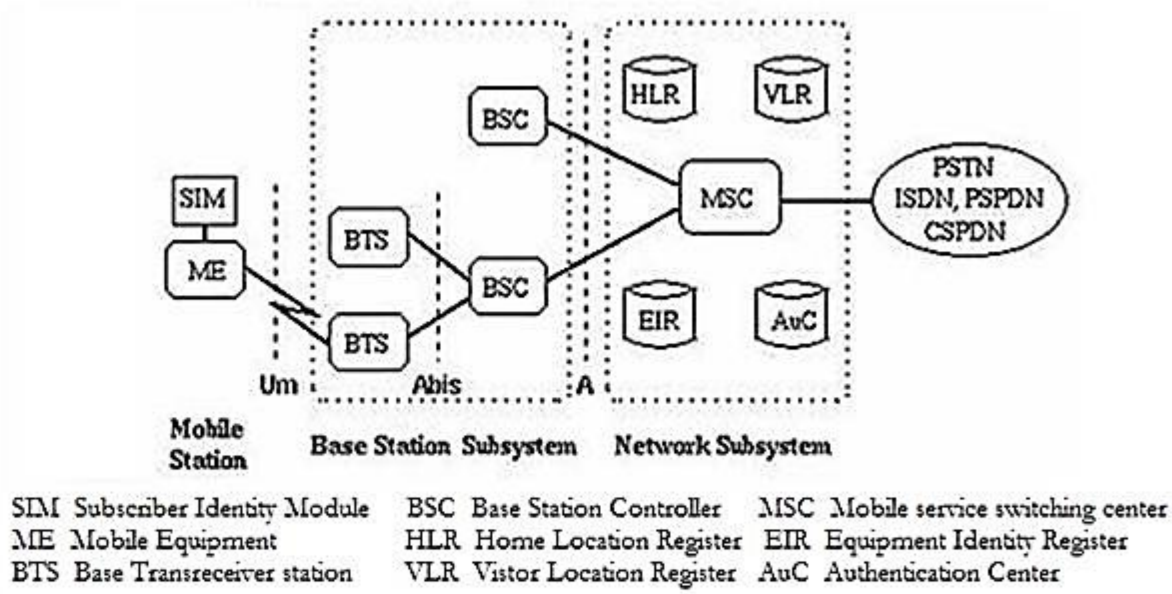


Fig. Cell-Site Handoff scheme

Therefore, if a system handles only low volumes of traffic, that is, if the channels assigned to one cell will not reuse frequency in other cells, then it is possible to implement the cell-site handoff feature as it is applied in military systems.

UNIT-5

GSM Architecture



- The GSM network architecture consists of three major subsystems:
- Mobile Station (MS)
- Base Station Subsystem (BSS)
- Network and Switching Subsystem (NSS)
- The wireless link interface between the MS and the Base Transceiver Station (BTS), which is a part of BSS. Many BTSs are controlled by a Base Station Controller (BSC). BSC is connected to the Mobile Switching Center (MSC), which is a part of NSS. Figure shows the key functional elements in the GSM network architecture.

1. Mobile Station (MS):

A mobile station communicates across the air interface with a base station transceiver in the same cell in which the mobile subscriber unit is located. The MS communicates the information with the user and modifies it to the transmission protocols if the air-interface to communicate with the BSS. The user's voice information is interfaced with the MS through a microphone and speaker for the speech, keypad, and display for short messaging, and the cable connection for other data terminals. The MS has two elements. The Mobile Equipment (ME) refers to the physical device, which comprises of transceiver, digital signal processors, and the antenna. The second element of the MS is the GSM is the Subscriber Identity Module (SIM). The SIM card is unique to the GSM system. It has a memory of 32 KB.

2. Base Station Subsystem (BSS):

A base station subsystem consists of a base station controller and one or more base transceiver station. Each Base Transceiver Station defines a single cell. A cell can have a radius of between 100m to 35km, depending on the environment. A Base Station Controller may be connected with a BTS. It may control multiple BTS units and hence multiple cells. There are two main architectural elements in the BSS – the Base Transceiver Subsystem (BTS) and the Base Station Controller (BSC). The interface that connects a BTS to a BSC is called the A-bis interface. The interface between the BSC and the MSC is called the A interface, which is standardised within GSM.

3. Network and switching subsystem (NSS)

The NSS is responsible for the network operation. It provides the link between the cellular network and the Public switched telecommunicates Networks (PSTN or ISDN or Data Networks). The NSS controls handoffs between cells in different BSSs, authenticates user and validates their accounts, and includes functions for enabling worldwide roaming of mobile subscribers. In particular the switching subsystem consists of:

- Mobile switch center (MSC)
- Home location register (HLR)
- Visitor location Register (VLR)
- Authentications center (Auc)
- Equipment Identity Register (EIR)
- Interworking Functions (IWF)

The NSS has one hardware, Mobile switching center and four software database element: Home location register (HLR), Visitor location Register (VLR), Authentications center (Auc) and Equipment Identity Register (EIR). The MSC basically performs the switching function of the system by controlling calls to and from other telephone and data systems. It includes functions such as network interfacing and common channel signalling.

HLR: The HLR is database software that handles the management of the mobile subscriber account. It stores the subscriber address, service type, current locations, forwarding address, authentication/ciphering keys, and billings information. In addition to the ISDN telephone number for the terminal, the SIM card is identified with an International Mobile Subscribes Identity (IMSI) number that is totally different from the ISDN telephone number. The HLR is the reference database that permanently stores data related to subscribers, including subscriber’s service profile, location information, and activity status.

VLR: The VLR is temporary database software similar to the HLR identifying the mobile subscribers visiting inside the coverage area of an MSC. The VLR assigns a Temporary mobile subscriber Identity (TMSI) that is used to avoid using IMSI on the air. The visitor location register maintains information about mobile subscriber thatis currently physically in the range covered by the switching center. When a mobile subscriber roams from one LA (Local Area) to another, current location is automatically updated in the VLR. When a mobile station roams into anew MSC area, if the old and new LA's are under the control of two different VLRs, the VLR connected to the MSC will request data about the mobile stations from the HLR. The entry on the old VLR is deleted and an entry is created in the new VLR by copying the database from the HLR.

AuC: The AuC database holds different algorithms that are used for authentication and encryptions of the mobile subscribers that verify the mobile user's identity and ensure the confidentiality of each call. The AuC holds the authentication and encryption keys for all the subscribers in both the home and visitor location register.

EIR: The EIR is another database that keeps the information about the identity of mobile equipment such the International mobile Equipment Identity (IMEI) that reveals the details about the manufacturer, country of production, and device type. This information is used to prevent calls from being misused, to prevent unauthorised or defective MSs, to report stolen mobile phones or check if the mobile phone is operating according to the specification of its type.

White list: This list contains the IMEI of the phones who are allowed to enter in the network.

Black list: This list on the contrary contains the IMEI of the phones who are not allowed to enter in the network, for example because they are stolen.

Grey list: This list contains the IMEI of the phones momentarily not allowed to enter in the network, for example because the software version is too old or because they are in repair.

IWF- **Interworking Function:** It is a system in the PLMN that allows for non speech communication between the GSM and the other networks. The tasks of an IWF are particularly to adapt transmission parameters and protocol conversions. The physical manifestations of an IWF may be through a modem which is activated by the MSC dependent on the bearer service and the destination network. The OSS (Operational Support Systems) supports operation and maintenance of the system and allows engineers to monitor, diagnose, and troubleshoot every aspect of the GSM network.

TDMA

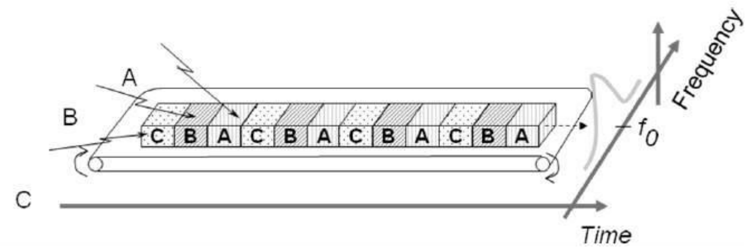
Time Division Multiple Access (TDMA) is a digital cellular telephone communication technology. It facilitates many users to share the same frequency without interference. Its technology divides a signal into different timeslots, and increases the data carrying capacity.

TDMA Overview

Time Division Multiple Access (TDMA) is a complex technology, because it requires an accurate synchronization between the transmitter and the receiver. TDMA is used in digital mobile radio systems. The individual mobile stations cyclically assign a frequency for the exclusive use of a time interval.

In most of the cases, the entire system bandwidth for an interval of time is not assigned to a station. However, the frequency of the system is divided into sub-bands, and TDMA is used for the multiple access in each sub-band. Sub-bands are known as **carrier frequencies**. The mobile system that uses this technique is referred as the **multi-carrier systems**.

In the following example, the frequency band has been shared by three users. Each user is assigned definite **timeslots** to send and receive data. In this example, user **'B'** sends after user **'A,'** and user **'C'** sends thereafter. In this way, the peak power becomes a problem and larger by the burst communication.



FDMA and TDMA

The period of time assigned to a timeslot for a mobile station also determines the number of TDMA channels on a carrier frequency. The period of timeslots are combined in a so-called TDMA frame. TDMA signal transmitted on a carrier frequency usually requires more bandwidth than FDMA signal. Due to the use of multiple times, the gross data rate should be even higher

Advantages of TDMA

Here is a list of few notable advantages of TDMA −

- Permits flexible rates (i.e. several slots can be assigned to a user, for example, each time interval translates 32Kbps, a user is assigned two 64 Kbps slots per frame).
- Can withstand gusty or variable bit rate traffic. Number of slots allocated to a user can be changed frame by frame (for example, two slots in the frame 1, three slots in the frame 2, one slot in the frame 3, frame 0 of the notches 4, etc.).
- No guard band required for the wideband system.
- No narrowband filter required for the wideband system.

Disadvantages of TDMA

The disadvantages of TDMA are as follow −

- High data rates of broadband systems require complex equalization.
- Due to the burst mode, a large number of additional bits are required for synchronization and supervision.
- Call time is needed in each slot to accommodate time to inaccuracies (due to clock instability).
- Electronics operating at high bit rates increase energy consumption.

- Complex signal processing is required to synchronize within short slots.

CDMA

CDMA, which stands for *Code Division Multiple Access*, is a competing cell phone service technology to GSM, the world's most widely used cell phone standard.

You've probably heard of these acronyms when being told that you can't use a certain phone on your mobile network because they're using different technologies that are not compatible with each other. For example, you may have an AT&T phone that can't be used on Verizon's network for this very reason. The CDMA standard was originally designed by Qualcomm in the U.S. and is primarily used in the U.S. and portions of Asia by other carriers. Of the five most popular mobile networks, here is a breakdown of which are CDMA and GSM:

CDMA:

- Sprint
- Verizon Wireless
- Virgin Mobile

GSM:

- T-Mobile
- AT&T

More Information on CDMA

CDMA uses a "spread-spectrum" technique whereby electromagnetic energy is spread to allow for a signal with a wider bandwidth. This allows multiple people on multiple cell phones to be "multiplexed" over the same channel to share a bandwidth of frequencies. With CDMA technology, data and voice packets are separated using codes and then transmitted using a wide frequency range. Since more space is often allocated for data with CDMA, this standard became attractive for 3G high-speed mobile internet use.

CDMA vs GSM

Most users probably don't need to worry about which cell phone network they choose in terms of which technology is better. However, there are some key differences that we'll look at here.

Coverage

While CDMA and GSM compete head on in terms of higher bandwidth speed, GSM has more complete global coverage due to roaming and international roaming contracts. GSM technology tends to cover rural areas in the U.S. more completely than CDMA. Over time, CDMA won out over less advanced TDMA (*Time Division Multiple Access*) technology, which was incorporated into more advanced GSM.

Device Compatibility and SIM Cards

It's really easy to swap phones on a GSM network versus CDMA. This is because GSM phones use removable SIM cards to store information about the user on the GSM network, while CDMA phones do not. Instead, CDMA networks use information on the carrier's server side to verify the same type of data that GSM phones have stored in their SIM cards.

This means that the SIM cards on GSM networks are interchangeable. For instance, if you're on the AT&T network, and therefore have an AT&T SIM card in your phone, you can remove it and put it into a different GSM phone, like a T-Mobile phone, to transfer all your subscription information over, including your phone number.

What this effectively does is lets you use a T-Mobile phone on the AT&T network.

Such an easy transition is simply not possible with most CDMA phones, even if they do have removable SIM cards. Instead, you typically need your carrier's permission to perform such a swap. Since GSM and CDMA are incompatible with one another, you can't use a Sprint phone on a T-Mobile network, or a Verizon Wireless phone with AT&T. The same goes for any other mix of device and carrier that you can make out of the CDMA and GSM list from above.

Tip: CDMA phones that use SIM cards do so either because the LTE standard requires it or because the phone has a SIM slot to accept foreign GSM networks. Those carriers, however, still use CDMA technology to store subscriber information.

Simultaneous Voice and Data Usage

Most CDMA networks do not allow voice and data transmissions at the same time. This is why you may get bombarded with emails and other internet notifications when you end a call from a CDMA network like Verizon. The data is basically on pause while you're on a phone call. However, you'll notice that such a scenario works just fine when you're on a phone call within range of a wifi network because wifi, by definition, isn't using the carrier's network.

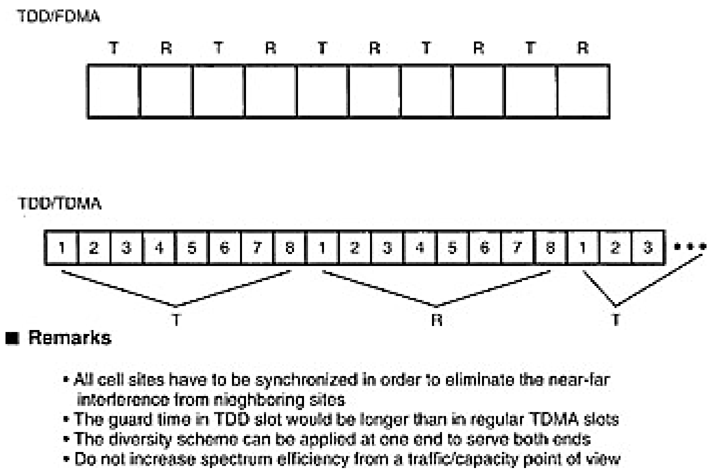
MISCELLANEOUS MOBILE SYSTEMS

In the previous sections, GSM, NA-TDMA, and CDMA were introduced. This section will briefly introduce other systems such as PDC, CT-2, DECT, CDPD, PCN, and PCS. iDEN and PHS

TDD Systems

Time-division duplexing (TDD) systems are digital systems and use only one carrier to transmit and receive information. There are two kinds of TDD systems

1. TDD/FDMA each carrier serves only one user.
2. TDD/TDMA each carrier can have many time slots and each slot can serve one user. Then *N* transmit time slots can serve *N* users.



Time-division duplexing

A TDD system is used when only one chunk of spectrum is allocated. In cellular systems, there are two chunks of spectrum, separated by 20 MHz. In each cellular channel, the base transmit frequency and the mobile transmit frequency are 45 MHz apart. Therefore, the separation in frequency between transmitting and receiving is adequate to avoid interference. In TDD, there is no separation in frequency between transmitting and receiving but a separation in time interval.

The advantages of TDD are as follows:

1. When only one chunk of spectrum is available, TDD is the best use of spectrum.
2. Diversity can be applied at one end (terminal) to serve both ends, as the fading characteristics of one carrier are the same when received at both ends. At the base station, the information on selecting antennas for the space-diversity selective combining receiver can be used to switch to one...

Multiple Access Techniques

Multiple access techniques are used to allow a large number of mobile users to share the allocated spectrum in the most efficient manner. As the spectrum is limited, so the sharing is required to increase the capacity of cell or over a geographical area by allowing the available bandwidth to be used at the same time by different users. And this must be done in a way such that the quality of service doesn't degrade within the existing user

Multiple Access Techniques for Wireless Communication

In wireless communication systems it is often desirable to allow the subscriber to send simultaneously information to the base station while receiving information from the base station.A cellular system divides any given area into cells where a mobile unit in each cell communicates with a base station. The main aim in the cellular system design is to be able to increase the capacity of the channel i.e. to handle as many calls as possible in a given bandwidth with a sufficient level of quality of service. There are several different ways to allow access to the channel. These includes mainly the following:

1) Frequency division multiple-access (FDMA)
2) Time division multiple-access (TDMA)
3) Code division multiple-access (CDMA)

any cellular system or cellular technology, it is necessary to have a scheme that enables several multiple users to gain access to it and use it simultaneously. As cellular technology has rogressed different multiple access schemes have been used. They form the very core of the way in which the radio technology of the cellular system works.

There are four main multiple access schemes that are used in cellular systems ranging from the very first analogue cellular technologies to those cellular technologies that are being developed for use in the future. The multiple access schemes are known as FDMA, TDMA, CDMA and OFDMA.

Requirements for a multiple access scheme

In any cellular system it is necessary for it to be able have a scheme whereby it can handle multiple users at any given time. There are many ways of doing this, and as cellular technology has advanced, different techniques have been used.

There are a number of requirements that any multiple access scheme must be able to meet:

- Ability to handle several users without mutual interference.
- Ability to be able to maximise the spectrum efficiency
- Must be robust, enabling ease of handover between cells.

FDMA - Frequency Division Multiple Access

FDMA is the most straightforward of the multiple access schemes that have been used. As a subscriber comes onto the system, or swaps from one cell to the next, the network allocates a channel or frequency to each one. In this way the different subscribers are allocated a different slot and access to the network. As different frequencies are used, the system is naturally termed Frequency Division Multiple Access. This scheme was used by all analogue systems.

TDMA - Time Division Multiple Access

The second system came about with the transition to digital schemes for cellular technology. Here digital data could be split up in time and sent as bursts when required. As speech was digitised it could be sent in short data bursts, any small delay caused by sending the data in bursts would be short and not noticed. In this way it became possible to organise the system so that a given number of slots were available on a give transmission. Each subscriber would then be allocated a different time slot in which they could transmit or receive data. As different time slots are used for each subscriber to gain access to the system, it is known as time division multiple access. Obviously this only allows a certain number of users access to the system. Beyond this another channel may be used, so systems that use TDMA may also have elements of FDMA operation as well.

CDMA - Code Division Multiple Access

CDMA uses one of the aspects associated with the use of direct sequence spread spectrum. It can be seen from the article in the cellular telecoms area of this site that when extracting the required data from a DSSS signal it was necessary to have the correct spreading or chip code, and all other data from sources using different orthogonal chip codes would be rejected. It is therefore possible to allocate different users different codes, and use this as the means by which different users are given access to the system.

The scheme has been likened to being in a room filled with people all speaking different languages. Even though the noise level is very high, it is still possible to understand someone speaking in your own language. With CDMA different spreading or chip codes are used. When generating a direct sequence spread spectrum, the data to be transmitted is multiplied with spreading or chip code. This widens the spectrum of the signal, but it can only be decided in the receiver if it is again multiplied with the same spreading code. All signals that use different spreading codes are not seen, and are discarded in the process. Thus in the presence of a variety of signals it is possible to receive only the required one.

In this way the base station allocates different codes to different users and when it receives the signal it will use one code to receive the signal from one mobile, and another spreading code to receive the signal from a second mobile. In this way the same frequency channel can be used to serve a number of different mobiles.

OFDMA - Orthogonal Frequency Division Multiple Access

OFDMA is the form of multiple access scheme that is being considered for the fourth generation cellular technologies along with the evolutions for the third generation cellular systems (LTE for UMTS / W-CDMA and UMB for CDMA2000).

As the name implies, OFDMA is based around OFDM. This is a technology that utilises a large number of close spaced carriers.

Note on OFDM:

Orthogonal Frequency Division Multiplex (OFDM) is a form of transmission that uses a large number of close spaced carriers that are modulated with low rate data. Normally these signals would be expected to interfere with each other, but by making the signals orthogonal to each other there is no mutual interference. The data to be transmitted is split across all the carriers to give resilience against selective fading from multi-path effects.

To utilise OFDM as a multiple access scheme for cellular technology, two different methods are used, one for the uplink and one for the downlink. In the downlink, the mobile receives the whole signal transmitted by the base station and extracts the data destined for the particular mobile. In the uplink, one or more carriers are allocated to each handset dependent upon the data to be transmitted, etc. In this way the cellular network is able to control how the data is to be sent and received.

Situation today

Although the current 3G cellular systems use CDMA as their basis, elements of TDMA and FDMA are also used. Both the major schemes, UMTS and CDMA2000 have a limit on the number of users who are able to use a single channel. In some instances two or more channels may be allocated to a particular cell. This means that the system still uses an element of FDMA. Additionally UMTS incorporates some timeslots, and this means that the scheme uses elements of TDMA. While CDMA is currently the dominant technology, both the other forms of access scheme are still in evidence, not just in legacy technologies, but utilised as part of the main access scheme in the latest 3G systems. In addition to this, LTE and LTE Advanced utilise OFDMA / SC-FDMA to provide the multiple access technology. This technology has been adopted because if its suitability for wideband high data rate transmissions.

Frequency Division Multiple Access

This was the initial multiple-access technique for cellular systems in which each individual user is assigned a pair of frequencies while making or receiving a call as shown in Figure. One frequency is used for downlink and one pair for uplink. This is called frequency division duplexing (FDD). That allocated frequency pair is not used in the same cell or adjacent cells during the call so as to reduce the cochannel interference. Even though the user may not be talking, the spectrum cannot be reassigned as long as a call is in place. Different users can use the same frequency in the same cell except that they must transmit at different times. The features of FDMA are as follows: The FDMA channel carries only one phone circuit at a time. If an FDMA channel is not in use, then it sits idle and it cannot be used by other users to increase share capacity. After the assignment of the voice channel the BS and the MS transmit simultaneously and continuously. The bandwidths of FDMA systems are generally narrow i.e. FDMA is usually implemented in a narrow band system. The symbol time is large compared to the average delay spread. The complexity of the FDMA mobile systems is lower than that of TDMA mobile systems. FDMA requires tight filtering to minimize the adjacent channel interference.