UNIT-I
CELLULAR MOBILE RADIO SYSTEMS

Limitations of conventional mobile systems over cellular mobile system

Limitations of conventional mobile telephone systems: One of many reasons for developing *a* cellular mobile telephone system and deploying it in many cities is the operational limitations of conventional mobile telephone systems: limited service capability, poor service performance, and inefficient frequency spectrum utilization.

1. Limited service capability: A conventional mobile telephone system is usually designed by selecting one or more channels from a specific frequency allocation for use in autonomous geographic zones, as shown in Fig.1.1. The communications coverage area of each zone is normally planned to be as large as possible, which means that the transmitted power should be as high as the federal specification allows. The user who starts a call in one zone has to reinitiate the call when moving into a new zone because the call will be dropped. This is an undesirable radio telephone system since there is no guarantee that a call can be completed without a handoff capability. The handoff is a process of automatically changing frequencies as the mobile unit moves into a different frequency zone so that the 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.

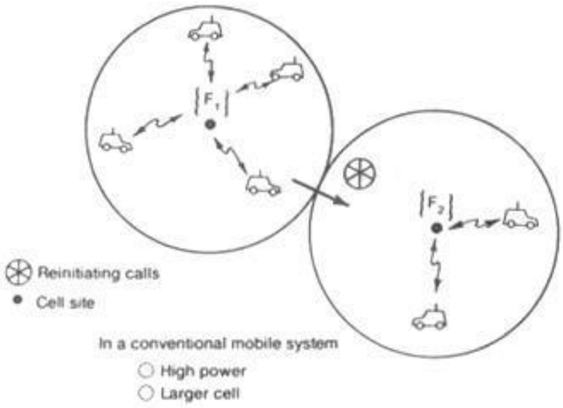


Fig1.1 Conventional Mobile System

2. Poor Service Performance: In the past, a total of 33 channels were all allocated to three mobile telephone systems: Mobile Telephone Service (MTS), Improved Mobile Telephone Service (IMTS) MJ systems, and Improved Mobile Telephone Service (IMTS) MK systems. 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. In 1976, New York City had 6 channels of(MJ serving 320 customers, with another 2400 customers on a waiting list. New York City also had 6 channels of MK serving 225 customers, with another 1300 customers on a waiting list. The large number of subscribers created a high blocking probability during busy hours. Although service performance was undesirable, the demand was still great. A high-capacity system for mobile telephones was needed.

3. Inefficient Frequency Spectrum Utilization: In a conventional mobile telephone system, the frequency utilization measurement Mo, is 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 (MKsystem)

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. It is likely that half the initiating calls will be blocked in the MJ system, a very high blocking probability. As far as frequency spectrum utilization is concerned, the conventional system does not utilize the spectrum efficiently since each channel can only serve one customer at a time in a whole area. This is overcome by the new cellular system.

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. We then realize that

$$A_1 \geq 2A_2$$

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

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

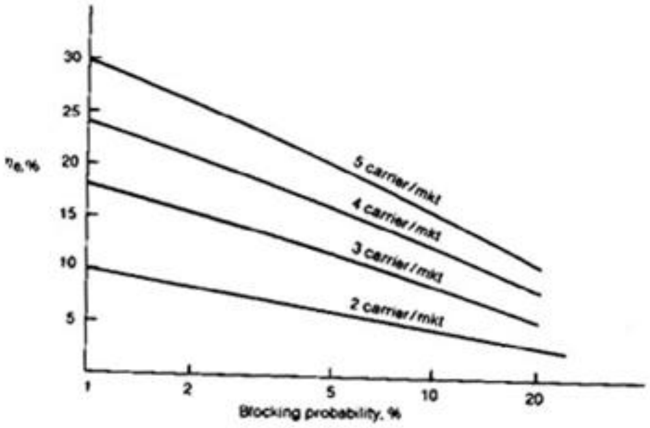


Fig. 1.2: Degradation of trunking efficiency

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

The trunking efficiency factor can be calculated as

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

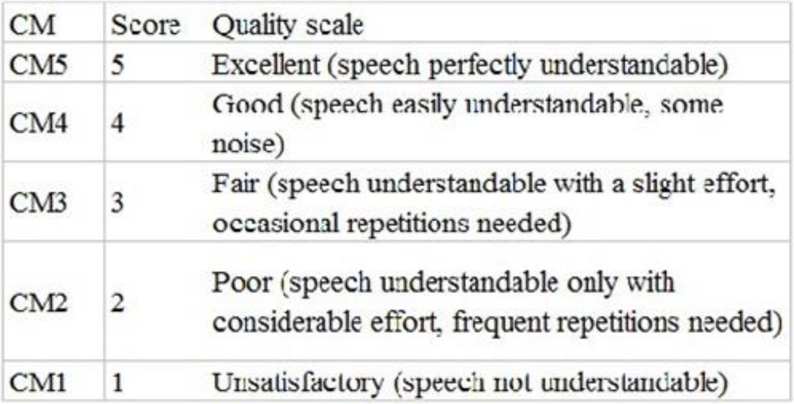
For a blocking probability of 2 percent, Figure 13 shows, by comparing one carrier per market with more than one carrier per market situations with different blocking Probability conditions. The degradation of trunking efficiency decreases as the blocking probability increases. As the number of carriers per market increases the degradation increases. However, when a high percentage of blocking probability, say more than 20 percent, occurs, the performance of one carrier per market is already so poor that further degradation becomes insignificant, as Fig.1.2 shows. For a 2 percent blocking probability, the trunking efficiency of one carrier per market does show a greater advantage when compared to other scenarios.

Performance Criteria

- Voice Quality
- Service Quality
- Special Features

1. Voice Quality

A set value *x* at which *y* percent of customers rate the system voice quality (from transmitter to receiver) as good or excellent, the top two circuit merits (CM) of the five listed below.



CM	Score	Quality scale
CM5	5	Excellent (speech perfectly understandable)
CM4	4	Good (speech easily understandable, some noise)
CM3	3	Fair (speech understandable with a slight effort, occasional repetitions needed)
CM2	2	Poor (speech understandable only with considerable effort, frequent repetitions needed)
CM1	1	Unsatisfactory (speech not understandable)

2. Service Quality

- Coverage

The system should serve an area as large as possible. The transmitted power would have to be very high to illuminate weak spots with sufficient reception, a significant added cost factor. The higher the transmitted power, the harder it becomes to control interference.

- Required grade of service

The grade of service specified for a blocking probability of 0.02 for initiating calls at the busy hour. This is an average value. However, the blocking probability at each cell site will be different. To decrease the blocking probability requires a good system plan and a sufficient number of radio channels.

- Number of dropped calls
  A high drop rate could be caused by either coverage problems or handoff problems related to inadequate channel availability.

3. Special Features
   - call forwarding
   - call waiting
   - voice stored (VSR) box
   - automatic roaming, or navigation services

   All these services are expected at no extra cost.

Uniqueness of Mobile Radio Environment

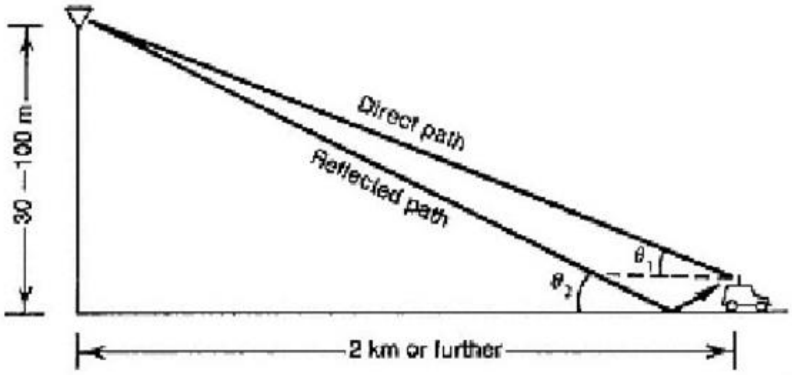


Fig. 1.3: Mobile radio transmission model

1. The Propagation Attenuation:

The propagation path loss increases not only with frequency but also with distance The propagation path loss would be 40 dB/dec. This means that a 40-dB loss at a signal receiver will be observed by the mobile unit as it moves from 1 to 10 km.

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

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

The difference in power reception at two different distances *R*1 and *R*2 will result in

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

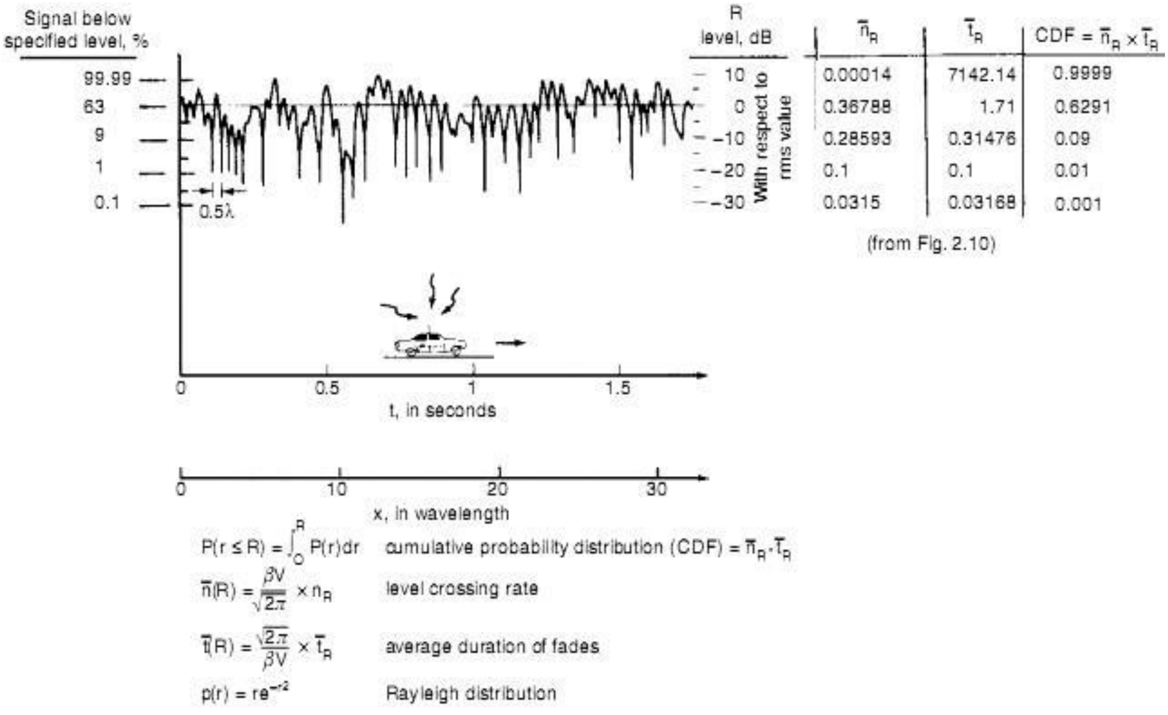
The decibel expression is

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

When $R2 = 2R1$, DC = 12 dB; when $R2 = 10R1$, DC = 40 dB

2. Severe Fading

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. 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). 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, as Fig.1.4 shows. If the mobile unit moves fast, the rate of fluctuation is fast. 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.



$\bar{n}_R$	$\bar{t}_R$	CDF = $\bar{n}_R \times \bar{t}_R$
0.00014	7142.14	0.9999
0.36788	1.71	0.6291
0.28593	0.31476	0.09
0.1	0.1	0.01
0.0315	0.03168	0.001

Fig.1.4: A typical fading signal received while the mobile unit is moving

3. Model of transmission medium: A mobile radio signal r(t), illustrated in Fig.14, can be artificially characterized by two components m(t) and r(t) based on natural physical phenomena.

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

The component m(t) is called local mean, long-term fading, or lognormal fading and its variation is due to the terrain contour between the base station and the mobile unit. The factor r0 is called multipath fading, short term fading, or Rayleigh fading and its variation is due to the waves reflected from the surrounding buildings and other structures. The long-term fading m(t) can be obtained from Eq. below

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

Where 2T is the time interval for averaging r(t). T can be determined based on the fading rate of r(t), usually 40 to 80 fades. Therefore, m(t) is the envelope of r(t), as shown in Fig.1.3. Equation also can be expressed in spatial scale as

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

The length of 2L has been determined to be 20 to 40 wavelengths. Using 36 or up to 50 samples in an interval of 40 wavelengths is an adequate averaging process for obtaining the local means.

The factor m(t) or m(x) is also found to be a lognormal distribution based on its characteristics caused by the terrain contour. The short- term fading r0 is obtained by

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

The factor ro(t) follows a Rayleigh distribution, assuming that only reflected waves from local surroundings are the ones received (a normal situation for the mobile radio environment). Therefore, the term Rayleigh fading is often used.

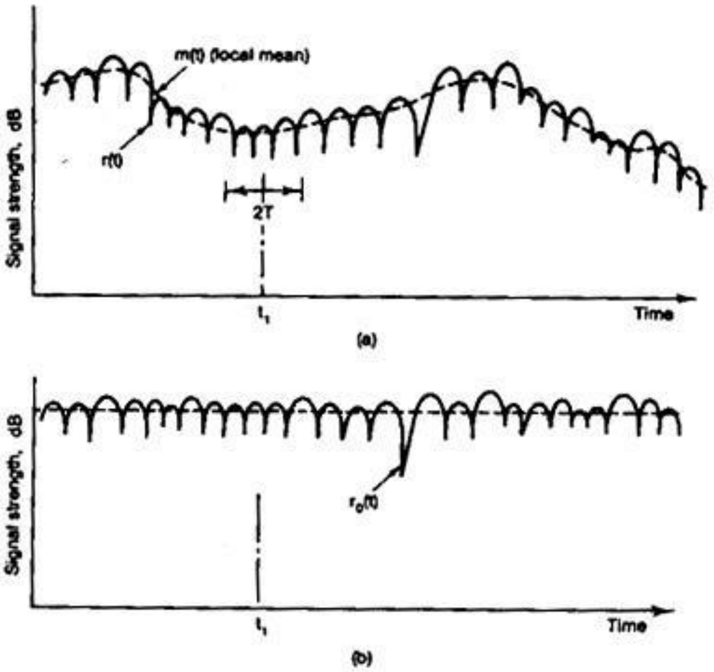


Fig.1.3: A mobile radio signal fading representation

Direct wave path, line of sight path, out of sight path, and obstructive path:

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 line-of-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.

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 frontend noise is 9 dB, and then the noise level is -120 dBm.

There are two kinds of man-made noise, the ignition noise generated by the vehicles and the noise generated by 800-MHz emissions.

The 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.1.5.

Fig.1.5 Noise in Cellular Networks

The 800-MHz emission noise: As a result of the 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 (a forward voice 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. In this Case, no automotive ignition noise is involved and no channe1 operation is in the proximity of the idle-channel receiver. We found that in some areas the noise level is 2 to 3 dB higher than -120 dBm at the cell sites and 3 to 4 dB higher than -120 dBm at the mobile stations.

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. We would like to understand bow the signal is affected by the amplifier noise. Assume that the amplifier baa an available power gain g and the available noise power at the output is N. 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

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

Where, the maximum possible S/N ratio is measured when the load is an open circuit.

The noise figure of the amplifier is

$$F = \frac{P_s/kTB}{P_o/N_o} \doteq \frac{N_o}{(P_o/P_s)kTB} = \frac{N_o}{g(kTB)}$$

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

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.

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 1.6 shows, with connections to link the three sub systems.

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

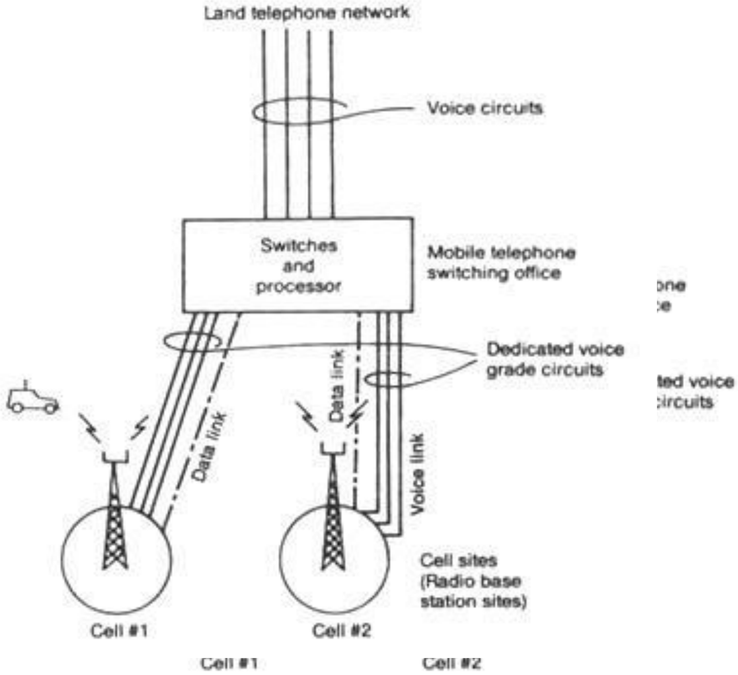


Fig.1.6: Basic cellular system

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.1.7 with no gap and no overlap between the hexagonal cells. The ideal cell shapes as well as the real cell shapes are also shown in Fig.1.7. 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.

An analysis using hexagonal cells, if it is desired, can easily be adapted by the reader.

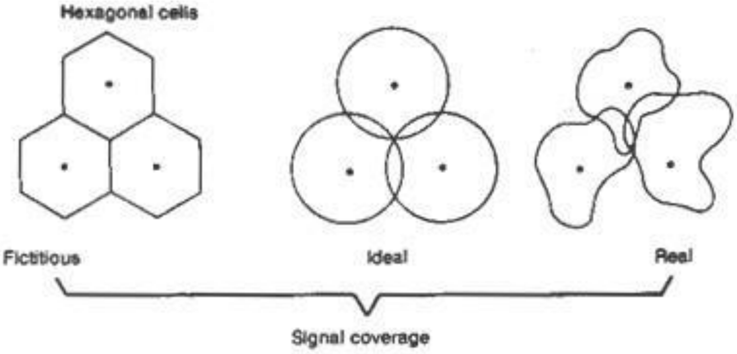


Fig.1.7 Hexagonal Cells and the real shapes of their coverage

General view of telecommunication and the function of the each unit

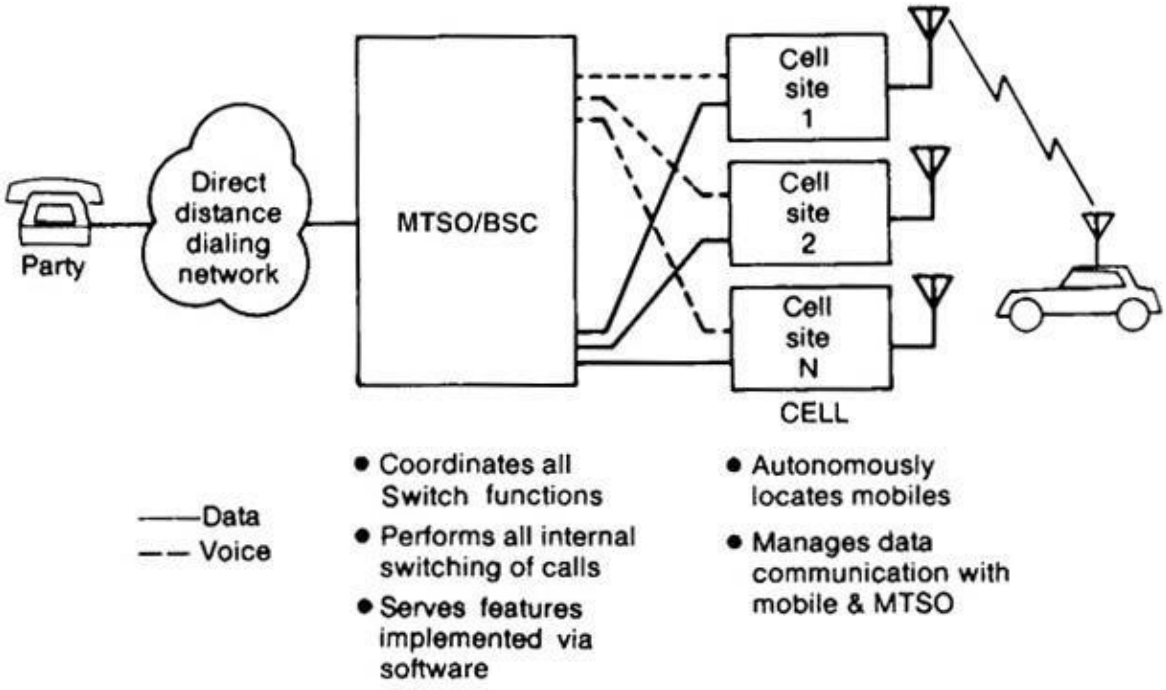


Fig.1.8: A general view of cellular telecommunications system

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 cell-site antenna can affect the area and shape of the coverage in the system.

Switching Equipment:

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. In a big cellular system, this processor should be large. Also, because cellular systems are unlike other systems, it is important to consider when the switching equipment would reach the maximum capacity. 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. If the switching equipment is designed in modules, or as distributed switches, more modules can be added to increase the capacity of the equipment. For decentralized systems, digital switches may be more suitable. The future trend seems to be the utilization of system handoff. 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:

The data links are shown in Fig 1.8. Although they are not directly affected by the cellular system, they are important in the system. 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.

Analog Cellular System:

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.

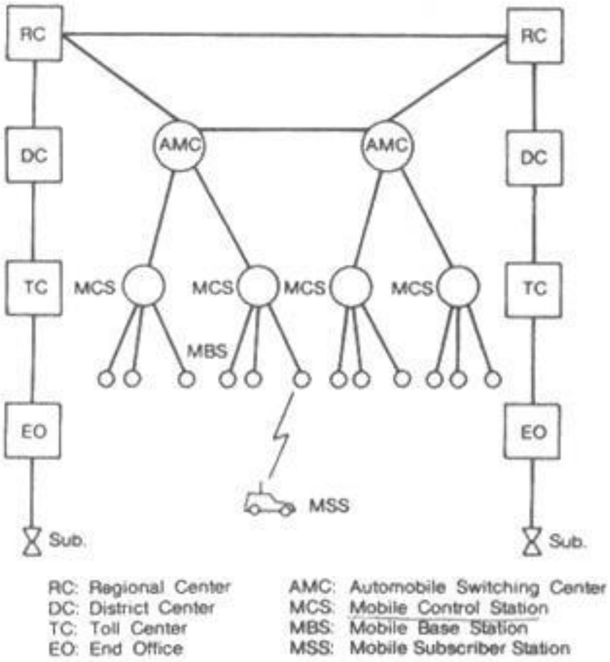


Fig.1.9: Japanese mobile telephone service network configuration

The Japanese mobile telephone service network configuration is shown in Fig.1.9. 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 the 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). At present there is no competitive situation set up by the government. However, the Japanese Ministry of Post and Telecommunication (MFT) is considering providing a dual competitive situation similar to that in the United States.

NMT: Nordic System: This system was 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. This system does have handoff and roaming capabilities. It also uses repeaters to increase the coverage in a low traffic area. The total number of subscribers is around 100,000

Cellular Phones: In 1945 the Zero Generation (0G) of mobile telephones was introduced. 0G mobile phones like mobile telephone service, were not cellular, and so did not feature 'handover' from one base station to the next and reuse of radio frequency channels. Like other technologies of the time it involved a single powerful base station covering a wide area and each telephone would effectively monopolize a channel over that whole area while in use. The concepts of frequency reuse and handoff as well as a number of other concepts that formed the basis of modem cell phone technology arc first described in U.S. patent 4.152.647 issued on May 1. 1979 to Charles A Gladden and Marlin H Parelman, and assigned by them to the United States Government. This is the first embodiment of all the concepts that formed the basis of the next major step in mobile telephony, the analog cellular telephone.

The first commercial city wide cellular network was launched in Japan by NTT in 1979. Fully automatic cellular networks were first introduced in the early to mid 1980s (the 1G generation). The Nordic Mobile Telephone (NMT) system went on-line in Denmark, Finland, Norway and Sweden in 1981.

Personal Handy phone system and modems used in Japan around 1997-2003. In 1983, Motorola DynaTAC was the first approved mobile phone by FCC in the United States. In 1984, Bell Labs developed modern commercial cellular technology, which employed multiple, centrally controlled base stations (cell sites), each providing service to a small area (a cell). The cell sites would be set up such that cells partially overlapped. In a cellular system a signal between a base station (cell SIC) and a terminal phone) only need, be s[ring enough to reach between the two, so the same channel can be used simultaneously for separate conversations in different cells. The first "modern' network technology on digital 20 (Second Generation) cellular technology was launched by Radiolinja in 199) in Finland on the OSM standard which also marked the introduction of competition in mobile telecoms when Radiolinja challenged incumbent Telecom Finland who ran a 1-G NMT network.

The first data services appeared on mobile phones starting with person-to-person SMS text messaging in Finland in 1993. First trial payments using a mobile phone to pay for a Coca Cola vending machine were set in Finland in 1998. The first commercial payment system to mimic banks and credit cards was launched in the Philippines in 1999 simultaneously by mobile operators Glove and Smart. The first content sold to mobile phones was the ringing tone, first launched in 1998 in Finland. The first full Internet service on mobile phones was i-mode introduced by NTT's DoCoMo in Japan in 1999. In 200, the first commercial launch of 3G (third generation) was again in Japan by NTT DoCoMo on the WCDMA standard.Until the early 1990's, most mobile phones were too large to be carried in a Jacket pocket, so they were typically installed in vehicles as car phones. With the miniaturization of digital components and development of more sophisticated batteries, mobile phones have become smaller and lighter.

Cordless phones: George Sweigert an amateur radio operator and inventor from Cleveland Ohio, is largely recognized as the father of the cordless phone. He submitted a patent application in 1966 for a "full duplex wireless communication apparatus'. The U.S. patent and trademark office awarded him a patent in June of 1969. Sweigert a radio operator in World War II stationed at the south pacific islands of Guadalcanal and Bougainville, developed the full duplex-concept for untrained personnel, to improve battlefield communications for senior commanders. He was also licensed as W8ZIS and N9LC in the amateur radio service. He also held a first class radio telephone operator's permit issued by the Federal Communication Commission.In the 1980s a number of manufacturers including Sony introduced cordless phones for the consumer market. They used a base station that was connected to a telephone line and a handset with a microphone, speaker, keypad and telescoping antenna. The handset contained a rechargeable battery typically NiCd. The base unit is powered by household current via a wall socket. The base included a charging cradle, which as generally a form of trickle charger, on which the handset rested when not in use. Some cordless phones now utilize two rechargeable AA or AAA batteries in place of the more expensive traditional proprietary telephone batteries.Cellular telephone systems can be "Analog" or "Digital". Older Cellular Systems (AMPS, TACS, NMT) are analog and newer systems (GSM, CDMA, PCS) are "Digital".

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

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

With digital systems, the audio is converted to digitized samples at about 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.

With 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. The neat thing about the digital is that the 1s and 0s cannot be easily confused or distorted during transmission plus extra data is typically included in the transmission to help, detect and correct any errors.

Digital Cellular System:

Digital cellular systems are the cellular systems that use the digital communication techniques like in modulation, transmission format and demodulation 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.

Some examples of the digital cellular systems are:

- (i) GSM
- (ii) NA-TDMA (North American TDMA)
- (iii) CDMA
- (iv) PDC
- (v) 1800-DCS.

In 1992, the first digital cellular system, GSM was developed in Germany. GSM is a European standard system. In the United States, an NA-TDMA system and a CDMA system have been developed. A Japanese system, PDC (Personal Digital Cellular) was deployed in Osaka in June 1994.

Planning of cellular system in detail

How to start planning: Assume that the construction permit for a cellular system in a particular market area is granted, the planning stage becomes critical. A great deal of money can be spent and yet poor service may be provided if we do not know how to create a good plan. First, we have to determine two elements: regulations and the market situation.

Regulations: The federal regulations administered by the FCC are the same throughout the United States. The state regulations may be different from state to state, and each city and town may have its own building codes and zoning laws. Become familiar with the rules and regulations. Sometimes waivers need to be applied for ahead of time. Be sure that the plan is workable.

Market situation: There are three tasks to be handled by the marketing department.

1. Prediction of gross income: We have to determine the population, average income, business types, and business zones so that the gross income can be predicted.
2. Understanding competitors: We also need to know the competitor's situation, coverage, system performance, and number of customers. Any system should provide a unique and outstanding service to overcome the competition.
3. Decision of geographic coverage: What general area should ultimately be covered? What near-term service can be provided in a limited area? These questions should be answered and the decisions passed on to the engineering department.

The engineer's role: The engineers follow the market decisions by

1. Initiating a cellular mobile service in a given area by creating a plan that uses a minimum number of cell sites to cover the whole area. It is easy for marketing to request but hard for the engineers to fulfill.

2. Checking the areas that marketing indicated were important revenue areas. The number of radios (number of voice channels) required to handle the traffic load at the busy hours should be determined.
3. Studying the interference problems, such as co-channel and adjacent channel interference, and the inter modulation products gene rated at the cell sites, and finding ways to reduce them.
4. Studying the blocking probability of each call at each cell site, and trying to minimize it.
5. Planning to absorb more new customers. The rate at which new customers subscribe to a system can vary depending on the service charges, system performance, and seasons of the year. Engineering has to try to develop new technologies to utilize fully the limited spectrum assigned to the cellular system. The analysis of spectrum efficiency due to the natural limitations may lead to a request for a larger spectrum.