Subject Name: **Wireless & Mobile Computing**

Subject Code: **IT-7003**

Semester: **7th**

Wireless & Mobile Computing (IT7003)

Unit I:

An antenna is a specialized transducer that converts radio-frequency (RF) fields into alternating current (AC) or vice-versa. There are two basic types: the receiving antenna, which intercepts RF energy and delivers AC to electronic equipment, and the transmitting antenna, which is fed with AC from electronic equipment and generates an RF field.

Radiation Pattern(VariationPattern)

The energy radiated by an antenna is, represented by the **Radiation pattern**of the antenna. Radiation Patterns are diagrammatical representations of the distribution of radiated energy into space, as a function of direction.

Let us look at the pattern of energy radiation.

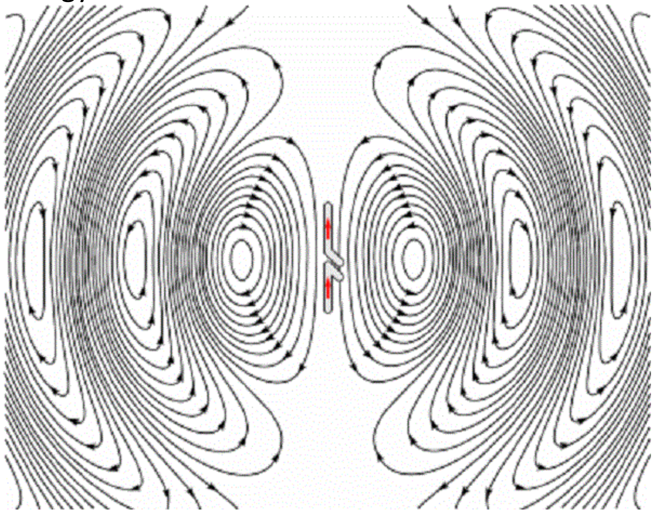


Figure 1: Energy radiation

The figure given above shows radiation pattern of a dipole antenna. The energy being radiated is represented by the patterns drawn in a particular direction. The arrows represent directions of radiation.

The radiation patterns can be field patterns or power patterns.

- The **field patterns** are plotted as a function of electric and magnetic fields. They are plotted on logarithmic scale.
- The **power patterns** are plotted as a function of square of the magnitude of electric and magnetic fields. They are plotted on logarithmic or commonly on dB scale.

Radiation Pattern in 3D

The radiation pattern is a three-dimensional figure and represented in spherical coordinates (r, θ, Φ) assuming its origin at the center of spherical coordinate system. It looks like the following figure –

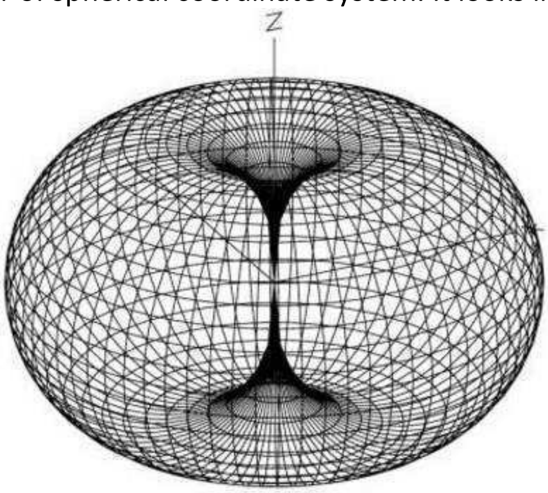


Figure 2 : 3D Radiation pattern

The given figure is a three dimensional radiation pattern for an **Omni directional pattern**. This clearly indicates the three co-ordinates (x, y, z).

Radiation Pattern in 2D

Two-dimensional pattern can be obtained from three-dimensional pattern by dividing it into horizontal and vertical planes. These resultant patterns are known as **Horizontal pattern** and **Vertical pattern** respectively.

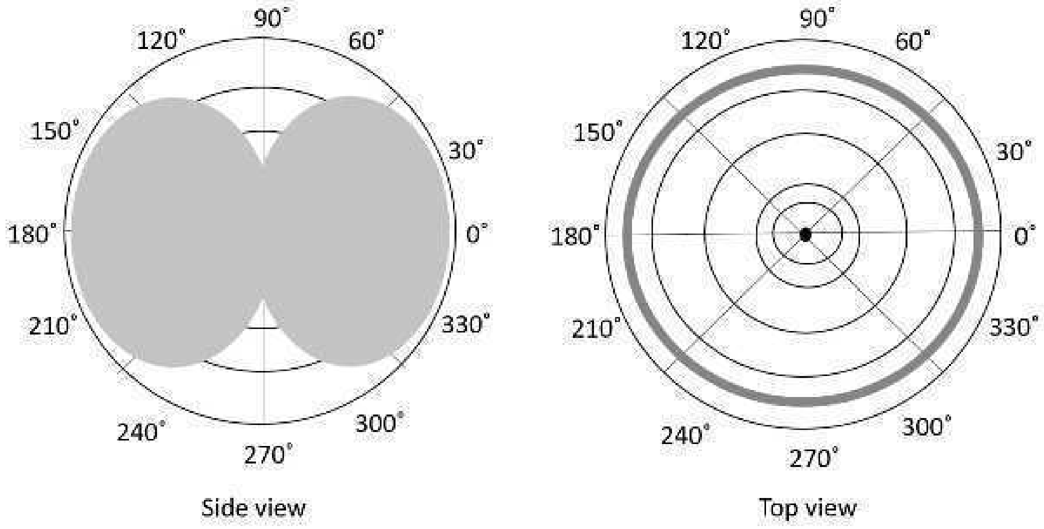


Figure 3: Omni directional radiation pattern in H and V planes

The figures show the Omni directional radiation pattern in H and V planes as explained above. H-plane represents the Horizontal pattern, whereas V-plane represents the Vertical pattern.

Lobe Formation

In the representation of radiation pattern, we often come across different shapes, which indicate the major and minor radiation areas, by which the **radiation efficiency** of the antenna is known.

To have a better understanding, consider the following figure, which represents the radiation pattern of a dipole antenna.

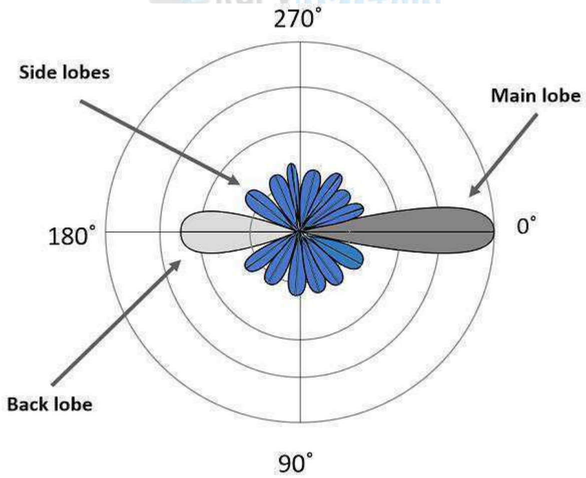


Figure 4: Radiation pattern of a dipole antenna.

Here, the radiation pattern has main lobe, side lobes and back lobe.

- The major part of the radiated field, which covers a larger area, is the **main lobe** or **major lobe**. This is the portion where maximum radiated energy exists. The direction of this lobe indicates the directivity of the antenna.
- The other parts of the pattern where the radiation is distributed side wards are known as **side lobes** or **minor lobes**. These are the areas where the power is wasted.
- There is other lobe, which is exactly opposite to the direction of main lobe. It is known as **back lobe**, which is also a minor lobe. A considerable amount of energy is wasted even here.

Type of antenna	Examples	Applications
Wire Antennas	Dipole antenna, Monopole antenna, Helix antenna, Loop antenna	Personal applications, buildings, ships, automobiles, space crafts
Aperture Antennas	Waveguide (opening), Horn antenna	Flush-mounted applications, air-craft, space craft
Reflector Antennas	Parabolic reflectors, Corner reflectors	Microwave communication, satellite tracking, radio astronomy
Lens Antennas	Convex-plane, Concave-plane, Convex-convex, Concave-concave lenses	Used for very highfrequency applications
Micro strip Antennas	Circular-shaped, Rectangularshaped metallic patch above the ground plane	Air-craft, space-craft, satellites, missiles, cars, mobile phones etc.
Array Antennas	Yagi-Uda antenna, Micro strip patch array, Aperture array, Slotted wave guide array	Used for very high gain applications, mostly when needs to control the radiation pattern

Table 1: Antenna Types

Antenna Gain: The parameter that measures the degree of directivity of antenna's radial pattern is known as gain. An antenna with a higher gain is more effective in its radiation pattern. Antennas are designed in such a way that power raises in wanted direction and decreases in unwanted directions.

G = (power radiated by an antenna)/(power radiated by reference antenna)

Radio Wave Propagation (Propagation Modes)

In **Radio communication systems**, we use wireless electromagnetic waves as the channel. The antennas of different specifications can be used for these purposes. The sizes of these antennas depend upon the bandwidth and frequency of the signal to be transmitted.

The mode of propagation of electromagnetic waves in the atmosphere and in free space may be divided in to the following three categories −

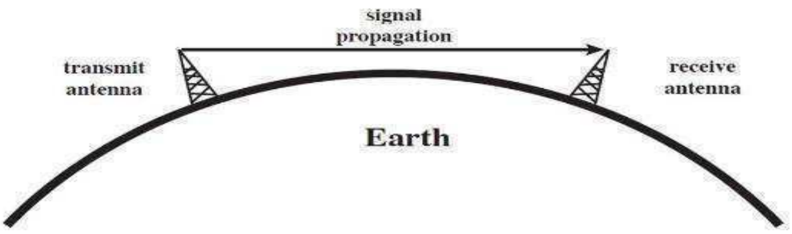
- Line of sight (LOS) propagation
- Ground wave propagation
- Sky wave propagation

In ELF (Extremely low frequency) and VLF (Very low frequency) frequency bands, the Earth, and the ionosphere act as a wave guide for electromagnetic wave propagation.

In these frequency ranges, communication signals practically propagate around the world. The channel band widths are small. Therefore, the information is transmitted through these channels has slow speed and confined to digital transmission.

Line of Sight (LOS) Propagation

Among the modes of propagation, this line-of-sight propagation is the one, which we commonly notice. In the **line-of-sight communication**, as the name implies, the wave travels a minimum distance of sight. Which means it travels to the distance up to which a naked eye can see. Now what happens after that? We need to employ an amplifier cum transmitter here to amplify the signal and transmit again.



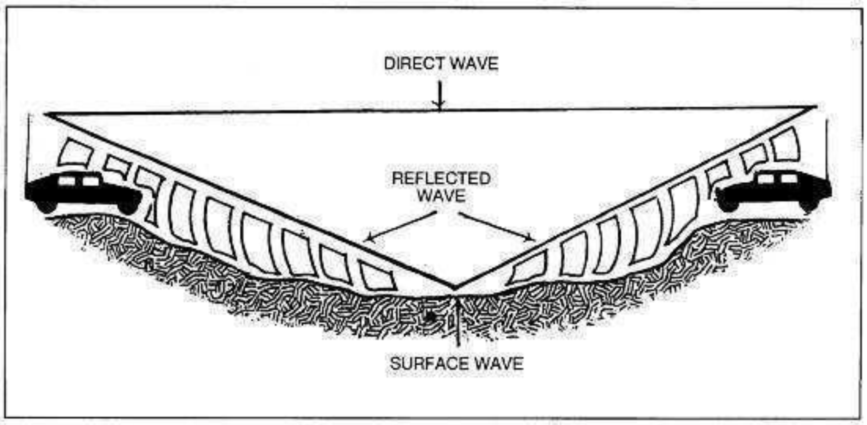
Line-of-sight (LOS) propagation (above 30 MHz)

Figure 5: Line-of-sight propagation

The figure depicts this mode of propagation very clearly. The line-of-sight propagation will not be smooth if there occurs any obstacle in its transmission path. As the signal can travel only to lesser distances in this mode, this transmission is used for **infrared** or **microwave transmissions**.

Ground Wave Propagation

Ground wave propagation of the wave follows the contour of earth. Such a wave is called as **direct wave**. The wave sometimes bends due to the Earth's magnetic field and gets reflected to the receiver. Such a wave can be termed as **reflected wave**.



Components of ground wave.

Figure 6: Components of Ground wave propagation

The above figure depicts ground wave propagation. The wave when propagates through the Earth's atmosphere is known as **ground wave**. The direct wave and reflected wave together contribute the signal at the receiver station. When the wave finally reaches the receiver, the lags are cancelled out. In addition, the signal is filtered to avoid distortion and amplified for clear output.

Sky Wave Propagation

Sky wave propagation is preferred when the wave has to travel a longer distance. Here the wave is projected onto the sky and it is again reflected back onto the earth.

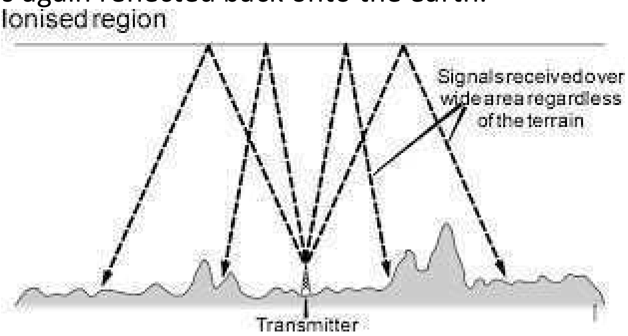


Figure 7: Sky wave propagation

The **sky wave propagation** is well depicted in the above picture. Here the waves are shown to be transmitted from one place and where it is received by many receivers. Hence, it is an example of broadcasting.

The waves, which are transmitted from the transmitter antenna, are reflected from the ionosphere. It consists of several layers of charged particles ranging in altitude from 30- 250 miles above the surface of the earth. Such a travel of the wave from transmitter to the ionosphere and from there to the receiver on Earth is known as **Sky Wave Propagation**. Ionosphere is the ionized layer around the Earth's atmosphere, which is suitable for sky wave propagation.

Fading

Fadingis variation of the attenuation of a signal with various variables. These variables include time, geographical position, and radio frequency. Fading is often modeled as a random process. A fading channel is a communication channel that experiences fading. In wireless systems, fading may either be due to multipath propagation, referred to as multipath induced fading, weather (particularly rain), or shadowing from obstacles affecting the wave propagation, sometimes referred to as shadow fading.

Slow fading arises when the coherence time of the channel is large relative to the delay requirement of the application. In this regime, the amplitude and phase change imposed by the channel is considered roughly constant over the period of use. Slow fading can be caused by events such as shadowing, where a large obstruction such as a hill or large building obscures the main signal path between the transmitter and the receiver. The received power change caused by shadowing is often modeled using a log-normal distribution with a standard deviation according to the log-distance path loss model.

Fast fading occurs when the coherence time of the channel is small relative to the delay requirement of the application. In this case, the amplitude and phase change imposed by the channel varies considerably over the period of use**.**

Rayleigh fading: The magnitude of a signal that has passed through such a transmission medium (also called a communications channel) will vary randomly, or fade, according to a Rayleigh distribution — the radial component of the sum of two uncorrelated Gaussian random variables.
Rayleigh fading is viewed as a reasonable model for tropospheric and ionospheric signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. If there is a dominant line of sight, Rician fading may be more applicable. Rayleigh fading is a special case of two-wave with diffuse power (TWDP) fading.

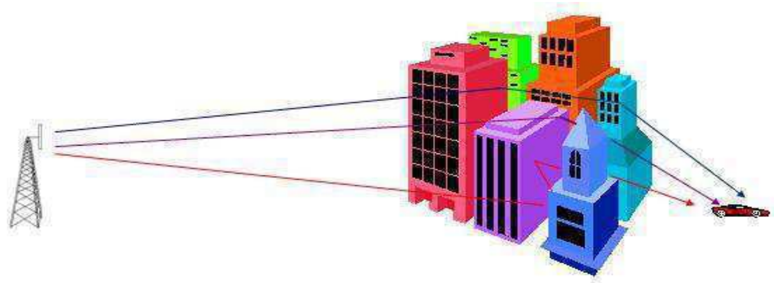


Figure 8: Rayleigh fading

Rician fading or Ricean fading: The radio propagation anomaly caused by partial cancellation of a radio signal by itself — the signal arrives at the receiver by several different paths (hence exhibiting multipath interference), and at least one of the paths is changing (lengthening or shortening). Rician fading occurs when one of the paths, typically a line of sight signal, is much stronger than the others. In Rician fading, the amplitude gain is characterized by a Rician distribution.

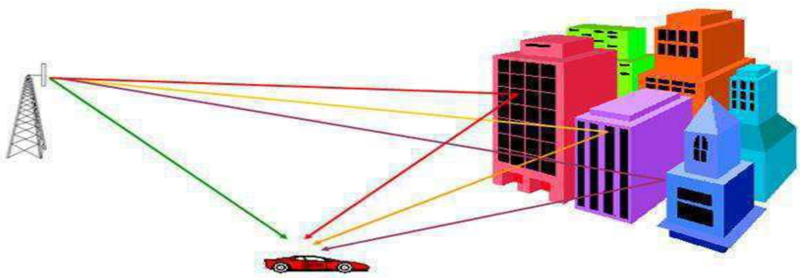


Figure 9: Rician fading

Rayleigh fading is the specialized model for stochastic fading when there is no line of sight signal, and is sometimes considered as a special case of the more generalized concept of Rician fading. In Rayleigh fading, the amplitude gain is characterized by a Rayleigh distribution. Rician fading itself is a special case of two-wave with diffuse power (TWDP) fading.

Model for wireless digital communication

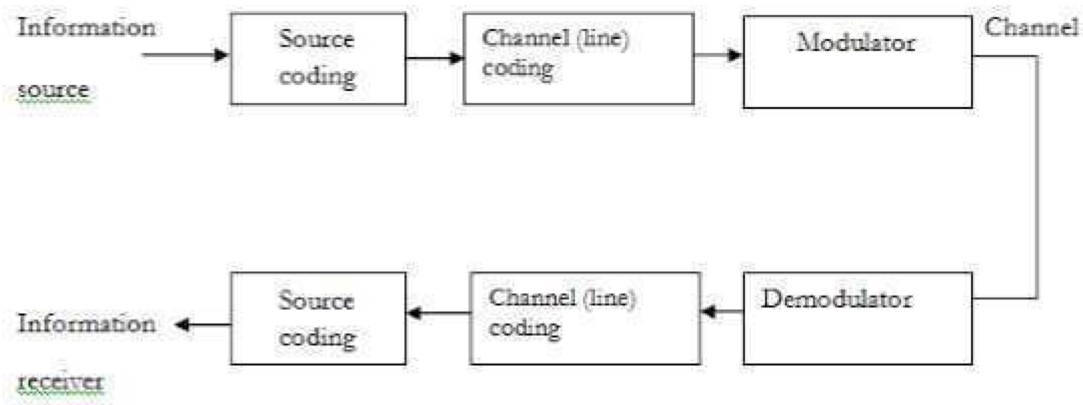


*Figure 10 :**Wireless digital communication***

In this diagram, three basic signal-processing operations have been included. They are:

Source coding:

- In source, coding the encoder converts the digital signal generated at the source output into another signal in digital form.
- Different source coding techniques are PCM (Pulse code modulation) DM(Delta modulation).

Channel coding:

- Channel encoding done to minimize the effect of channel noise.
- This will reduce the number of errors in the received data and will make the system more reliable.

Modulation:

- Modulation is used for providing an efficient transmission of the signal over the channel.
- The detector is used for demodulation channel decoder and source decoder has exactly the opposite roles to play as compared to the channel encoder and source encoder respectively.
- If the information rate is maximum, Digital modulation technique can be used because due to the digital nature of the signal, it is possible to use the advanced processing techniques such as digital signal processing, image processing, and data compression

The **Media Access Control** (MAC) data communication protocol sub-layer, also known as the Medium Access Control, is a sublayer of the Data Link Layer specified in the seven-layer OSI model (layer 2). The hardware that implements the MAC is referred to as a Medium Access Controller. The MAC sub-layer acts as an interface between the Logical Link Control (LLC) sublayer and the network's physical layer. The MAC layer emulates a full-duplex logical communication channel in a multi-point network. This channel may provide unicast, multicast or broadcast communication service.

Approach	**SDMA**	**TDMA**	**FDMA**	**CDMA**
Concept	Segment spaced into cells or sectors.	Segments sending time into disjoint time slots demand driven or fixed patterns.	Segment the frequency band into disjoint sub-bands	Spread the spectrum using orthogonal codes.

Approach	SDMA	TDMA	FDMA	CDMA
Terminals	Only one terminal can be active in one cell or one sector.	All terminals are active for short periods of time on same frequency.	Every terminal has its own frequency uninterrupted	All terminals can be active at the same place at the same moment uninterrupted.
Signal separation	Cell structure, directed antennas	Synchronization in time domain	Filtering in the frequency domain.	Code plus special receivers.
Transmission scheme	Continuous	Discontinuous	Continuous	Continuous
Cell capacity	Depends on cell area	Limited	Limited	No absolute limit on channel capacity but it is an interference limited system
Advantages	Very simple, increases capacity	Established fully digital, flexible	Simple, established, robust	Flexible, less frequency planning needed, soft handover
Disadvantages	Inflexible, antennas typically fixed	Guard space needed (multipath propagation), synchronization difficult	Inflexible, frequencies are scarce resource	Complex receivers, needs more complicated power control for senders

Table 2: Comparison of Media Access Techniques

Demand Assigned Multiple Access (DAMA) is a technology used to assign a channel to clients that don't need to use it constantly. DAMA systems assign communication channels based on requests issued from user terminal to a network control system. When the circuit is no longer in use, the channels are then returned to the central pool for reassignment to other users.

Channels are typically a pair of carrier frequencies (one for transmit and one for receive), but can be other fixed bandwidth resources such as timeslots in a TDMA burst plan or even physical party line channels. Once a channel is allocated to a given pair of nodes, it is not available to other users in the network until their session is finished.

Packet Reservation Multiple Access (PRMA) refers to a multiple access strategy with frames of a fixed number of slots. In case a terminal contains a set of data packets or speech segments to deliver, it competes to gain access in any free slot.
If it can successfully capture the base station (BS), the terminal acquires reservation in the associated slots of the next frames, right until it releases the reservation. In PRMA, adjacent cells make use of distinct carrier frequencies in line with a cellular reuse plan. The fundamental process of PRMA includes occupying a time slot only at the time of speech talkspurts and releasing the channel at the time of silence periods.

Cellular network organization: A cellular network or mobile network is a communication network where the last link is wireless. The network is distributed over land areas called cells, each served by at least one fixed-location transceiver, but more normally three cell sites or base stations. These base stations provide the cell with the network coverage which can be used for transmission of voice, data and others. A cell typically uses a different set of frequencies from neighboring cells, to avoid interference and provide guaranteed service quality within each cell.
When joined together these cells provide radio coverage over a wide geographic area. This enables a large number of portable transceivers (e.g., mobile phones, pagers, etc.) to communicate with each other and with fixed transceivers and telephones anywhere in the network, via base stations, even if some of the transceivers are moving through more than one cell during transmission

Operation of cellular systems
The operation of a cellular mobile system can be described as five major functionalities and four additional utilities. All the functions together make a complete mobile cellular system.
Mobile unit initialization

- When mobile unit is turned on, it scans and selects the strongest setup control channel used for system.
- Cells with different frequency bands repetitively broadcast on different setup channels.
- The receiver selects the strongest setup channel and monitors that channel.
- With this the mobile station has automatically selected the BS antenna of the cell within which it will operate.
- Then handshake takes place b/w the mobile unit and MTSO controlling this cell through the BS in this cell.
- Handshake is used to identify the user and register its location.
- As long as the mobile station is on, scanning is repeated periodically to account for the motion of the unit.
- If the unit enters a new cell, then a new BS is selected.

Mobile-originated call

- A mobile unit originates a call by sending the number (Mobile Identification Number, MIN) of the called unit on the preselected setup channel.
- The receiver of mobile unit checks if the forward channel (from BS) is idle.
- If idle the mobile may transmit over the reverse channel(To base station)
- BS sends request to the MTSO.

Paging
MTSO attempts to complete connection
MTSO sends a paging message to certain BSs depending on called mobile number.
BS sends paging signal on its own assigned setup channel.
Call accepted

- Called mobile unit recognizes its number on the setup channel being monitored and responds to that BS, which sends the response to the MTSO.
- MTSO stes up a circuit between calling and called BSs.

- MTSO selects available traffic channel within each BS's cell and notifies each BS, which in turn notifies its mobile unit (a data msg called alert is transmitted over FVC to instruct the mobile to ring).
- The two mobile units tune to their respective channels.

Ongoing call

- While connection is maintained, two mobile stations exchange voice or data, through BSs and MTSO.

Handoff

- If a mobile unit moves from range of one cell to another the traffic channel has to change.
- System makes this change without either interrupting the call or alerting the user.

Radio Propagation Effects : These are the effects of Propagation:

- **Attenuation**The strength of signal falls with distance over transmission medium. The extent of attenuation is a function of distance, transmission medium, as well as the frequency of the underlying transmission.
- **Distortion**Since signals at different frequencies attenuate to different extents, a signal comprising of components over a range of frequencies gets distorted, i.e., the shape of the received signal changes.A standard method of resolving this problem (and recovering the original shape) is to amplify higher frequencies and thus equalize attenuation over a band of frequencies.
- **Dispersion:** Dispersion is the phenomenon of spreading of a burst of electromagnetic energy during propagation. Bursts of data sent in rapid succession tend to merge due to dispersion.
- **Noise**The most pervasive form of noise is thermal noise, which is often modeled using an additive Gaussian model. Thermal noise is due to thermal agitation of electrons and is uniformly distributed across the frequency spectrum

Handoff: In a cellular telephone network, handoff is the transition for any given user of signal transmission from one base station to a geographically adjacent base station as the user moves around. In an ideal cellular telephone network, each end user's telephone set or modem (thesubscriber's hardware) is always within range of a base station. The region coveredby each base station is known as its cell. The size and shape of each cell in anetwork depends on the nature of the terrain in the region, the number of base stations,and the transmit/receive range of each base station. In theory, the cells in anetwork overlap; for much of the time, a subscriber's hardware is within range of morethan one base station. The network must decide, from moment to moment, which basestation will handle the signals to and from each and every subscriber's hardware.

Power Control: It is the intelligent selection of transmitter power output in a communication system to achieve good performance within the system. The notion of "good performance" can depend on context and may include optimizing metrics such as link data rate, network capacity, outage probability, geographic coverage and range, and life of the network and network devices. Power control algorithms are used in many contexts, including cellular networks, sensor networks and wireless LANs.

Sectoring (Sectorization)

The co-channel interference in a cellular system may be reduced by replacing a single omni-directional antenna at the basestation by several directional antennas radiating withinspecified sectors. A cell is normally partitioned in three 120 degreesectors or six 60 degree sectors. A given cell will receive interference and transmit with only a fraction of the available co-channel cells. In the sectoring scheme,the co-channel interference is reduced and thus system capacity is improved. Co-channel interference is reduced because the number of interferer gets reduced

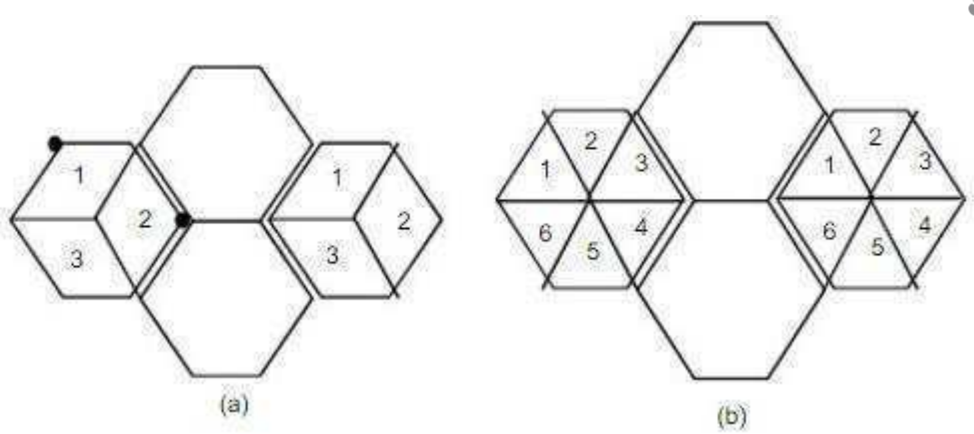


Figure 11: Sectors

Traffic engineering is a method of optimizing the performance of a telecommunications network by dynamically analyzing, predicting and regulating the behavior of data transmitted over that network. Traffic engineering is also known as tele-traffic engineering and traffic management. The techniques of traffic engineering can be applied to networks of all kinds, including the PSTN (public switched telephone network), LANs (local area networks), WANs (wide area networks) andcellular telephone networks**.**

Infinite Sources, Lost Call Cleared, Grade of Service

Lost Call Cleared: The LCC model assumes that, the subscriber who does not avail the service, hangs up the call, and tries later, the next attempt assumed as a new call. Hence, the call said to be **cleared**. This also referred as blocked calls lost assumption.

Blocked calls may be handled in one of two ways. First, blocked calls can be putin a queue awaiting a free channel; this is referred to as lost calls delayed (LCD),although in fact the call is not lost, merely delayed. Second, a blocked call can berejected and dropped. This in turn leads to two assumptions about the action of theuser. If the user hangs up and waits some random time interval before another callattempt, this is known as **lost calls cleared** (LCC). If the user repeatedly attempts calling,it is known as lost calls held (LCH).

For each of these blocking options, formulashave been developed that characterize the performance of the system. For cellularsystems, the LCC model is generally used and is generally the most accurate.

The second key element of a traffic model is whether the number of users assumed finite or infinite. For an infinite source model, there assumed a fixed arrival rate. For the finite source case, the arrival rate will depend on thenumber of sources already engaged. In particular, if the total pool of users is *L,* eachof which generates calls at an average rate of *AIL,* then, when the cell is idle,the arrival rate is A. However, if there are *K* users occupied at time *t,* then the instantaneousarrival rate at that time is 11.(*L* - *K)/L.* Infinite source models are analyticallyeasier to deal with. The infinite source assumption is reasonable when thenumber of sources is at least 5 to 10 times the capacity of the system.

Infinite Sources, Lost Calls Cleared For an infinite source LCC model, the keyparameter of interest is the probability of loss, or **grade of service**. Thus a grade of serviceof 0.01 means that, during a busy hour, the probability that an attempted call isblocked is 0.01 Values in the range 0.01 to 0.001 generally considered quite well.

The equation of infinite source LCC, known as Erlang B, has the following form:

$$P = \frac{\frac{A^N}{N!}}{\sum_{x=0}^{N} \frac{A^x}{x!}}$$

Where
A = offered traffic
N = number of servers
P = probability of blocking (grade of service)

Poisson Arrival Process

A commonly used model for random, mutually independent message arrivals is the Poisson process. The Poisson distribution can obtain by evaluating the following assumptions for arrivals during an infinitesimal short period of time delta t

The probability that one arrival occurs between t and t+delta t is λt + o(t), where λ is a constant, independent of the time t, and independent of arrivals in earlier intervals λ is called the arrival rate.

The number of arrivals in non-overlapping intervals is statistically independent.

The probability of two or more arrivals happening during t is negligible compared to the probability of zero or one arrival, i.e., it is of the order o(t).

Combining the first and third assumption, the probability of no arrivals during the interval t, t+ delta t is found to be 1-λt + o(t).

Arrival Rate:The arrival rate λ is expressed in the average number of arrivals during a unit of time.