CHAPTER 1

Unit I

Introduction to Mobile Computing

Syllabus

1.1 Introduction to Mobile Computing, Telecommunication Generations, Cellular systems,

1.2 Electromagnetic Spectrum, Antenna, Signal Propagation, Signal Characteristics, Multiplexing, Spread Spectrum : DSSS & FHSS

Introduction to mobile computing

Mobile Computing is a technology that allows transmission of data, voice and multimedia via any wireless enabled device without having to be connected to a fixed physical link. This chapter basically introduces the reader with the basics of mobile computing and communication. It also covers the journey of wireless communication from 1G to 5G and focuses on fundamental aspects of wireless transmission at physical layer such as signals, antenna, modulation, multiplexing. Most of today's wireless telecommunication systems are based on the concept of cellular systems. With billions of mobile phones in use around the globe today, it is necessary to re-use the available frequencies many times over without mutual interference of one cell phone to another.

1.1 Telecommunication Generations

The following section discusses different mobile generations (1G, 2G, 3G,4G and 5G).

First Generation (1G) : 1980s

- Analog cellular systems were the first generation of mobile telephone communication systems.
- They use **analog frequency modulation** and **circuit switched** techniques for voice transmission.
- The individual calls used different frequencies and shared the available spectrum through Frequency Division Multiple Access (FDMA).
- 1G system provided only voice communication.
- 1G was not supporting roaming between different network operators and countries.

  Examples of 1G networks are :

  - AMPS (Advanced Mobile Phone System) USA
  - NMT (Nordic Mobile Telephone) Sweden

Second Generation (2G) – 2.5 Generation (2.5G) : 1990s

- The second generation (2G) of mobile cellular started in the early 1990s.
- It was completely digital and used either Time Division Multiple Access (TDMA) or Code Division Multiple Access (CDMA).

- It provides increased capacity and security due to the uses of digital cellular technology.
- 2G systems support international roaming.
- 2G systems not only provide better voice quality using digital voice telephony but also a new range of low data rate services such as mobile Fax, voice mail, short message service (SMS).
- In addition to digital voice telephony, Cordless, public mobile radio, satellite and wireless-local area network (WLAN) solutions began to emerge.

2.5G

- Between 2G and 3G there was not much change in the technology hence an intermediary phase, 2.5G was introduced in the late 1990s.
- **2.5G** is used to describe 2G-systems that have implemented a packet-switched domain in addition to the circuit-switched domain.
- GPRS (General Packet Radio Service) is a 2G service, which delivers packet-switched data capabilities to existing GSM networks. It allows users to send graphics-rich data as packets.
- The importance of packet-switching increased with the rise of the Internet and the Internet Protocol (IP).
- Another example of 2.5G mobile technology is EDGE (Enhanced Data rates for GSM Evolution). EDGE provides data rate up to 384 kbps which is higher than GSM.

Advantages of 2G over 1G

- 2G standards support roaming between different operators and countries.
- In addition to circuit-switched voice services, 2G enabled the first wave of mobile data and Internet services, now widely adopted by users.
- 2.5G services enable high speed data transfer over upgraded existing 2G networks.

  Some 2G standards are :
  - GSM(TDMA-based)
  - D-AMPS
  - IS-95/CDMAone
  - PDC(Personal Digital Cellular)
  - PHS (Personal Handy Phone System)
  - HSCSD (High Speed Circuits Switched Data) (2.5)
  - GPRS (General Packet Radio Service) (2.5)
  - EDGE (Enhanced Data rates for Global Evolution)(2.5)

Third Generation (3G) - 2000

- The third generation (3G) systems started in 2000.
- The 3G revolution allowed mobile telephone customers to use audio, graphics and video applications.
- Over 3G it is possible to watch streaming video and engage in video telephony.
- They provide the ability to transfer simultaneously both voice data (a telephone call) and non-voice data (such as downloading information, exchanging email and instance messaging).
- 3G mobile technologies support greater number of voice and data customers as well as higher data rates at lower incremental cost than 2G.

3G standards are :

- W-CDMA
- CDMA2000
- UWC-136
- TD-CDMA / TD-SCDMA
- DECT

Fourth Generation (4G) - 2004

- The fourth generation will be fully IP-based integrated systems.
- It will allow accessing the Internet anytime from anywhere, global roaming, and wider support for multimedia applications.
- It will be network of networks achieved after the convergence of wired and wireless networks as well as computer, consumer electronics, communication technology, and several other convergences.
- These networks will be capable of providing 100 Mbps in outdoor environment and 1Gbps in indoor with end-to-end QoS and high security.

  4G standards are :

  - LTE (Long Term Evolution)
  - WiMAX (Worldwide Interoperability for Microwave Access)

Fifth Generation - 5G (2018)

- 5G is not just one technology, it is actually a combination of several technologies in one. The system, however, will be a smart and know when to make use of which technology for maximum efficiency.
- 5G will be much more faster than 4G. It will provide data rate up to 10Gbps. It will provide 100% coverage area. That is better coverage even at the cell boundaries.
- 5G will also provide low network latency (up to 1 msec) which will be helpful for the critical applications like industry, healthcare and medical. 5G technology aims to provide wide range of future industries from retail to education, transportation to entertainment and smart homes to healthcare.
- 5G technology will provide ubiquitous connectivity means everything from vehicles to mobile networks to industries to smart homes will be connected together.
- 5G will utilize Extremely High frequency spectrum band between 3GHz to 30 GHz. These are called millimetre waves. These wave can travel at very high speed but covers short distance since they cannot penetrate obstacles.
- Unlike 4G that requires high powered cellular base stations to transmit signal over long distance, 5G will use a large number of small cell stations that may be located on small towers or building roofs.
- 5G makes the use of Massive MIMO (Multiple Input Multiple Output) standards to make is 100 times faster as opposed to standard MIMO. Massive MIMO makes the use of as much as 100 antennas. Multiple antennas allow for better and faster data transmission. The 5G network will come with 100 times more devices in market.

5G standards

- 5G technology standard are still under development. So, no firm standards is in place at this time; the market is still figuring out the essential 5G features and functionalities.
- The primary 5G standards bodies involved in these processes are the 3rd Generation Partnership Project (3GPP), the Internet Engineering Task Force (IETF), and the International Telecommunication Union (ITU).

Table 1.1.1 : Comparison between 1G, 2G, 3G, 4G and 5G

Parameter	1G	2G	3G	4G	5G
Introduced in	1980	1993	2001	2009	Currently under development expected to roll out by 2020
Technology	AMPS	D-AMPS, IS-95, GSM	W-CDMA CDMA2000 UWC-136 TD-CDMA DECT	LTE , WiMAX	LTE Advanced , OMA and NOMA, WWWW
Multiplexing	FDMA	TDMA/ CDMA	CDMA	CDMA	CDMA
Switching type	Circuit switching	Circuit switching for voice , packet switching for data	Packet switching	All Packet switching	All Packet switching
Speed	2.4 kbps to 14.4 kbps	14.4 kbps	3.1 mbps	100 mbps	>10 Gbps
Services	Voice only	Voice + data	Voice + data + Multimedia, video calling and video streaming	High speed High quality voice over IP, 3D gamming , HD video conferencing, HD multimedia streaming	Super fast internet access, Low latency network for mission critical applications, IoT and surveillance, autonomous driving and many more.
Bandwidth	Analog	25MHz	25 MHz	100 MHz	60GHz
Operating Features	800 MGHz	GSM: 900MHZ, 1800MHz CDMA: 800MHz	2100 MHz	2600 MHz	3 To 90 GHz
Band (Frequency) Type	Narrow band	Narrow Band	Wide band	Ultra Wide band	Extremely high frequency
Hand over	NA	Horizontal	Horizontal	Horizontal/ Vertical	Horizontal/ Vertical
Advantages	Simpler	Multimedia features (SMS, MMS), Internet access and SIM introduced	High security, international roaming	Speed, High speed handoffs, MIMO technology, Global mobility	Super fast internet, Low network latency , Ubiquitous connectivity, Global coverage.

Parameter	1G	2G	3G	4G	5G
Disadvantages	Limited capacity, not secure, poor battery life, large phone size, background interference	Low network range, slow data rates	High power consumption, Low network coverage, High cost of spectrum license	Hard to implement, complicated hardware required	Hard to implement, Many of the old devices would not be competent to 5G, Developing infrastructure needs high cost.
Applications	Voice Calls	Voice calls, Short messages, browsing (partial)	Video conferencing, mobile TV, GPS	High speed applications, mobile TV, Wearable devices	Super High speed mobile networks, Smart Vehicles, IoT, Virtual and Augmented Reality, Low latency mission critical applications etc.

1.2 Cellular Systems

- Cellular systems are mobile systems for two-way wireless communication between the fixed part of the system (transmitters or base stations) and the mobile part of the system (mobile stations) which move in the area covered by each base station.
- In a cellular system, the entire coverage area is divided into 'cells' i.e. they implement SDM (Space Division Multiplexing). Each cell is served by a single base station. Each cell has a size depending on the number of users. More the users, smaller the cell size.
- Cell radii ranges from tens of meters in buildings, and hundreds of meters in cities, up to tens of kilometers in the country side.
- The shapes of cells are never perfect circles or hexagons actually, it depends on environment, on whether conditions etc. Hexagon shape cellular system is shown in Fig. 1.2.1.

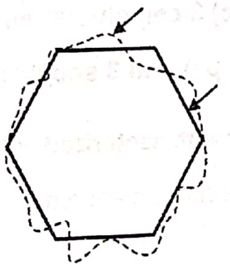


Fig.1.2.1 : Diagrammatic cell

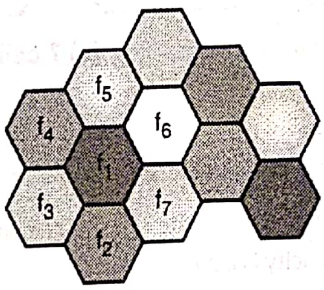


Fig. 1.2.2 : Cellular System with seven cell cluster vs. actual cell coverage

1.2.1 Frequency Reuse in Cellular Systems

MU - May 14

Q. What is frequency reuse concept in cellular communication? (May 14, 5 Marks)

- **Frequency reuse** is the technique of using the same radio **frequencies** on radio transmitter sites within a geographic area that are separated by sufficient distance to cause minimal interference with each other.

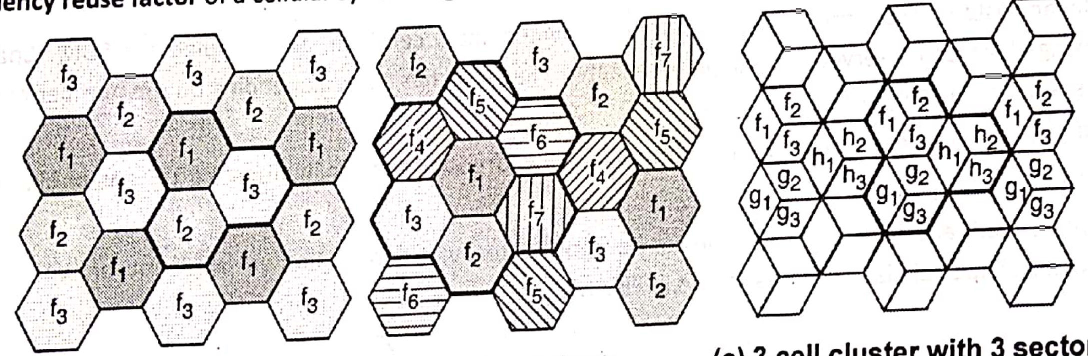
- To avoid interference in cellular system, each cell uses a different set of frequencies as compared to its immediate neighbors. In other words, no two neighbors use the same set of frequencies as there will be interference.
- A set of several cells are further grouped into clusters. Cells within the same cluster do not use the same frequency sets.
- Fig. 1.2.3 shows 3 cell cluster and 7 cell cluster. In Fig 1.2.3 (a) one cell in a cluster uses frequency f1, another cell uses f2 and the third cell uses f3. The same pattern is repeated for another cluster. Fig. 1.2.3 (b) shows a 7 cell cluster.

1.2.1(a) Frequency Reuse Concept

MU - May 17

Q. What is frequency reuse concept in cellular system? (May 17, 5 Marks)

- Consider a cellular system which has S full duplex channels available for use.
- Assume that the S channels are divided into N number of cells and each cell is allocated a group of K channels (K<S).
- Thus, total number of channels per cell is K = S/N.
- Therefore, the total number of available channels can be expressed as S = KN
- The N cells which collectively use the complete set of available frequencies is called **cluster.**
- The factor N is called the cluster size and is typically 4, 7 or 12.
- **Frequency reuse factor** of a cellular system is given by reciprocal of the cluster size i.e. 1/N.



(a) 3 cell cluster

(b) 7 cell cluster

(c) 3 cell cluster with 3 sector per cell 3 sector antennas

Fig. 1.2.3 : 3 cell cluster, 7 Cell Cluster and 3 cell cluster with sectorized antennas

- If the cluster size N is reduced while the cell size remains constant, more clusters are required to cover that particular area and hence more capacity is achieved.
- A large cluster size indicates that the ratio between cell radius and the distance between co channel cells is small.

Locating Co-channel cells in a cellular System

- For a hexagonal cell structure, it is possible to cluster cells so that no two adjacent cells use the same frequency. This is only achievable for a certain cell-cluster sizes, which can be determined from the relationship

$$N = i^2 + ij + j^2 \quad \text{Where } i,j = 0,1,2,3 \text{ etc.}$$

- To find nearest co-channel neighbors of a particular cell
  - o Move i cells through the center of successive cells.
  - o Turn 60° in the counter clockwise direction.
  - o Move j cells forward through the center of successive cells.

- Fig. 1.2.4 shows the process of locating the nearest co-channel neighbors of cell f4 in cluster 1.
- We first move i=2 successive cells in downward direction. From there we turn 60° in counterclock wise direction. And then move j=1 cell forward through the centre of the cell thus locating cell f4 in cluster 3. Similarly we can locate cell f4 in neighboring clusters – cluster 2 and cluster 4.

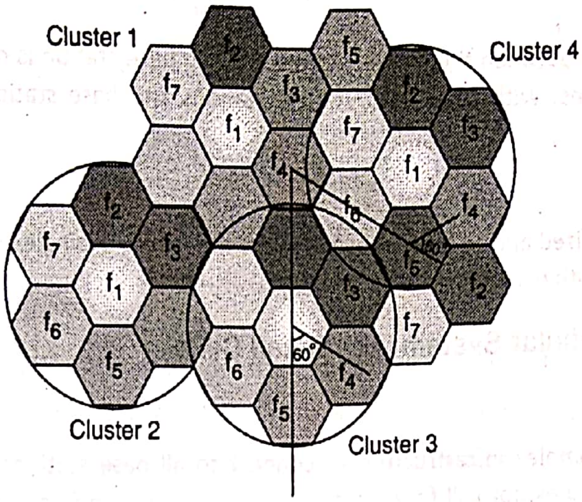


Fig. 1.2.4 : Method of locating co-channel cells in a cellular system (here i=2, j=1)

1.2.1(b) Assignment of Frequencies to Cells

Assignment of frequencies to cells can be done in following three ways.

1. Fixed Channel Allocation (FCA)

- This scheme assigns fixed set of frequencies to each cell or cluster. The scheme is easy to implement but not very efficient if traffic load varies.
- GSM system uses this scheme.

2. Borrowing Channel Allocation (BCA)

- In this scheme, if a one cell has heavy load then it can borrow frequencies from another neighboring cell which is having light load.
- Here cells with more traffic are dynamically allotted more frequencies.

3. Dynamic Channel Allocation (DCA)

- This scheme is similar to BCA. As in BCA here also frequencies can be borrowed from a neighboring cell. In addition to that, the assignment of frequencies is dynamic, that is frequencies can be assigned freely to cells.
- Since frequencies are assigned dynamically to a cell, there is a chance of interference with cells using the same frequencies.
- To avoid interference the 'borrowed' frequencies can be blocked in the neighboring cells.
- This scheme is used in DECT.

1.2.2 Advantages of Cellular Systems with Small Cells

1. Higher capacity

Implementing SDM allows frequency reuse. If one transmitter is far away from another transmitter then the transmitters can use the same frequency without any interference. Thus smaller cells allow more number of users.

2. Less transmission power

If the transmitter is far away from the receiver then it requires high power to transmit the signal. For mobile devices power is the main constraint, so reduced cell size requires less transmission power.

3. Local interference only

With larger cells, the distance between the mobile station and the base station is more and hence there are chances of more interference problems. With small cells, mobile stations and base stations only have to deal with 'local' interference.

4. Robustness

Cellular systems are decentralized and so more robust against the failure of single components. If one antenna fails, it only affects communication within a small area.

1.2.3 Disadvantages of Cellular System with Small Cells

1. Complex infrastructure

Cellular systems require a complex infrastructure to connect to all base stations. If the cell size is small, then it requires many antennas, switches, for call forwarding, location registers to find a mobile station etc. This will make the whole system expensive.

2. Handover needed

When mobile station moves from one cell to another cell, the process called handover is carried out. Depending on the cell size and the speed of movement, this can happen quite often.

3. Frequency Planning

Cellular system needs proper planning of frequency distribution to avoid interference between transmitters.

1.2.4 Why Hexagonal Pattern is Preferred for Cellular System ?

- When considering geometric shapes, which cover an entire region without overlapping or leaving gaps and with equal areas, there are three sensible choices.
  1. Equilateral triangle
  2. Square
  3. Hexagon
- The Table 1.2.1 describes the unit coverage area for each of the above mentioned shapes.

Table 1.2.1 : Unit coverage area for Triangle, square and Hexagon shapes

Cell type	Centre to centre distance	Unit coverage area
Triangle	R	$1.3 R^2$
Square	$R\sqrt{2}$	$2 R^2$
Hexagon	$R\sqrt{3}$	$2.6 R^2$

- A study of above table reveals the following points.
- Area coverage of hexagon is twice that of triangular area.
- To cover an area of three hexagonal cells i.e. $7.8 R^2$, 6 triangular cells or 4 square cells are required.
- In other words, if hexagonal area of $7.8 R^2$ requires three frequencies, the triangular cells require 6 frequencies and square cells require 4 frequencies.

In general with the Hexagon pattern :

1. The fewest number of cells can cover a given geographical region
2. We can closely approximate a circular radiation pattern which would occur for an omnidirectional base station antenna.

1.2.5 Methods of Increasing Cell Capacity

There are basically three ways of increasing capacity of cellular system.

1. Cell Splitting
2. Cell Sectorization
3. Microcell Zones

1. Cell Splitting

- Cell splitting is the process of dividing the radio coverage of a cell in a cellular system into two or more new cell sites.
- Cell splitting is one of the ways to increase the capacity within the region of the original cell.
- To minimize interference, a certain distance must be maintained between cells using the same frequencies. However, this distance can be reduced without disturbing the cell reuse pattern.
- As the size of the cells are reduced, the same frequencies can be utilized in more cells, which in turn means more subscribers can be accommodated on the system.
- Particularly in congested areas, the cellular operator often splits an existing cell into two or more smaller cells.
- New transceivers are placed and the power of the transmitters are reduced in order to confine the signals to the newly created cells.
- For example, a cell that originally had a radius of 6 m could be split into three cells with each new cell having a 2 m radius.

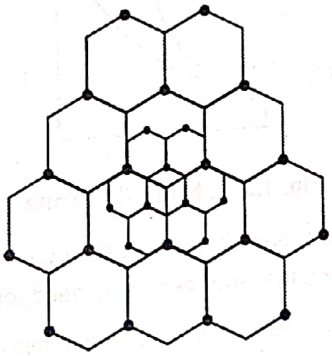


Fig. 1.2.5 : Cell splitting

Cell Sectorization

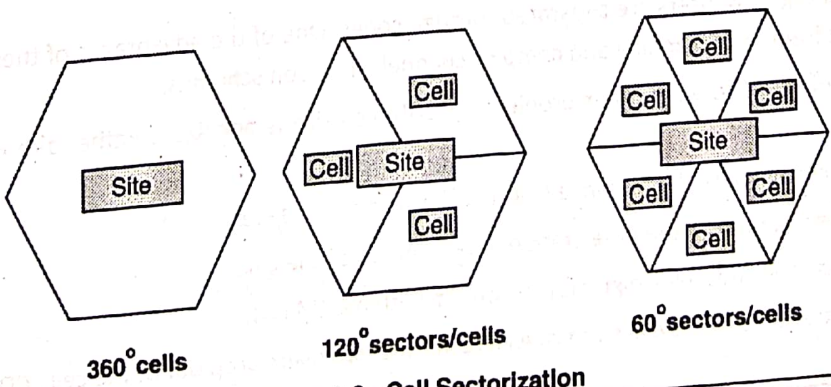


Fig. 1.2.6 : Cell Sectorization

- Another way to increase cellular system's capacity is to replace the omnidirectional antenna at each base station by three or more sector antennas.
- Use of directional sector antennas substantially reduces the interference among co-channel cells.
- This allows denser frequency reuse.
- The base station can either be located at the center of the original (large) cell, or the corners of the original (large) cell.
- Sectorization is less expensive than cell-splitting, as it does not require the acquisition of new base station sites.

Using Micro cell zone

- The disadvantage of cell sectoring concept is the need for an increased number of handoffs.
- The technique known as microcell that uses zones instead of sectors to reduce the number of handoffs.
- As shown in Fig. 1.2.7 this technique employs three antennas that provide coverage into the micro cell. All three antennas are connected to the same base station.

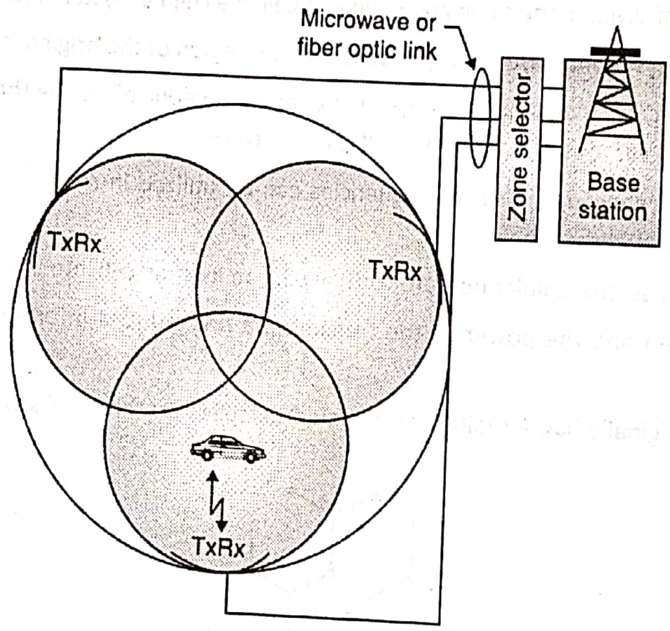


Fig. 1.2.7 : Micro Cell Zone

- The antenna with the best reception of the mobile is used for both the uplink and the downlink. As the mobile travels within a same micro cell it uses the same channel and there is no need for handoff.
- As the mobile moves into another zone the base station simply switches the channel to a different zone.

1.2.6 Cellular System Using CDM

- In cellular systems using CDM users are separated through codes. One of the advantages of these systems is that they don't need complex frequency planning and complex channel allocation schemes.
- But cell planning with CDM faces another problem. In CDM cell size is not fixed. Rather size of cell depends on the current load.
- Under a light load a cell becomes larger while it shrinks if the load increases.
- Mobile station further away from the base station may drop out of the cell.
- Fig. 1.2.8 shows a user transmitting a high bit rate stream within CDM cell.
- Because of this additional user, the cell shrinks. As a result the two users drop out of the cell. CDM cells are commonly said to **breathe.**

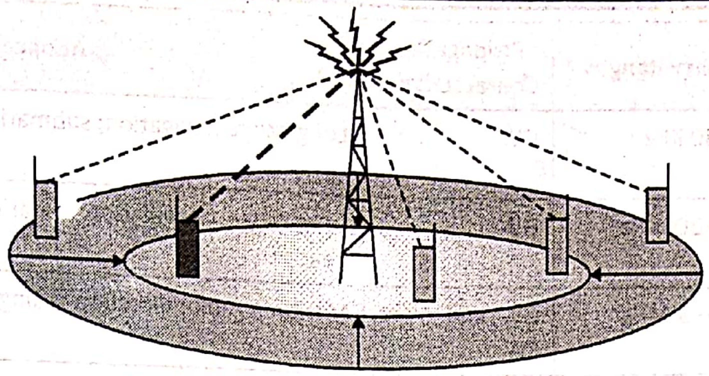


Fig. 1.2.8 : Cell breathing depending on the current load

1.3 Electromagnetic Spectrum

MU – May 15, Dec. 15

Q. Draw and explain electromagnetic spectrum for communication. (May 15, Dec. 15, 5 Marks)

- For radio transmission, there are many frequency bands. Each frequency band has some advantages and disadvantages and can be used as per the application.
- Fig. 1.3.1 illustrates the frequency spectrum for radio transmission. Frequencies start at 300Hz and go up to over 300THz.

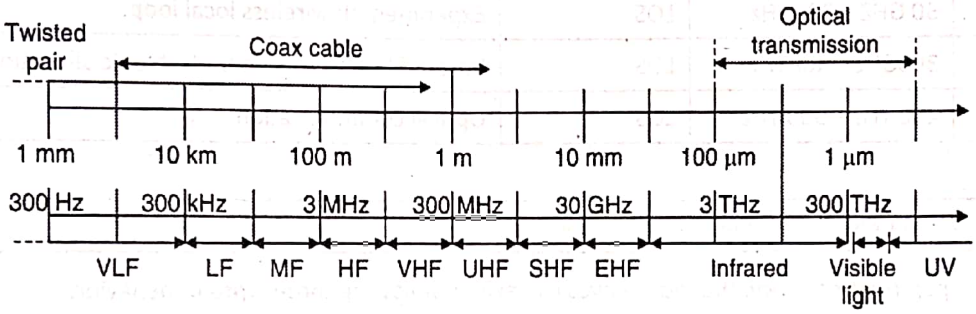


Fig. 1.3.1 : Frequency spectrum

- The relation between frequency f and wavelength λ is given by the equation

$\lambda = c / f$ where, $c = 3\times 10^8$ m/s (the speed of light in vacuum)

Frequency ranges for wired networks

Table 1.3.1 : Frequency ranges for wired networks

Medium	Frequency Range
Twisted Pair	0-3.5 KHz
Co-axial cable	0 – 500 MHz
Fiber Optics	186 - 370 THz

Frequency ranges for radio transmission

Table 1.3.2 : Frequency ranges for radio transmission

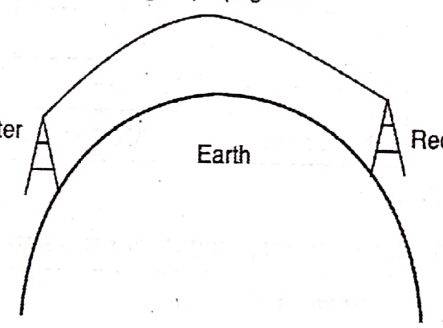
Frequency Band	Frequency Ranges	Propagation Characteristics	Application
VF(Voice Frequency)	300 Hz – 3KHz	GW	Used by telephone system for analog subscriber lines

Frequency Band	Frequency Ranges	Propagation Characteristics	Application
VLF (Very Low Frequency)	3 KHz – 30 KHz	GW	Long-range navigation; submarine communication
LF (Low Frequency)	30 KHZ – 300KHz	GW	Long-range navigation; marine communication radio beacon
MF(medium frequency)	300 KHz – 3 MHz	GW and night SW	Maritime radio; direction fading; AM broadcasting
HF(High Frequency)	3 MHz – 30MHz	SW	Amateur radio; international broadcasting; military communication; Long distance aircraft and ship communication.
VHF (Very High Frequency)	30 MHz – 300 MHz	LOS	VHF television; FM broadcast and two-way radio, AM aircraft communication; aircraft navigational aids
UHF(Ultra High Frequency)	300 MHz – 3GHz	LOS	UHF television; cellular telephone; radar; microwave links; personal communication systems
SHF(Super High Frequency)	3 GHz – 30 GHz	LOS	Satellite communication; radar; terrestrial microwave links; wireless local loop
EHF	30 GHZ – 300GHz	LOS	Experimental; wireless local loop
Infrared	300GHz – 400THz	LOS	Infrared LANs; consumer electronic allocations
Visible light	400 THz – 900 THz	LOS	Optical communication

Note : GW - Ground Wave, LOS - Line-of-Sight., SW - Sky Wave

Depending upon the frequency, the radio waves can exhibit following three types of behavior.

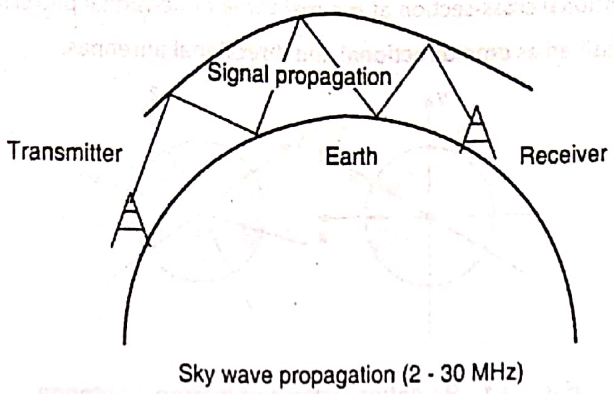
1. **Ground Wave (<2 MHz) :** Low frequency waves usually follow the Earth's surface and can propagate long distance. These waves are used for submarine communication or AM radio.
2. **Sky wave (2-30 MHz) :** These waves are reflected at the atmosphere and hence can bounce back and forth between the ionosphere and the Earth's surface, traveling around the world. They are used for international broadcast.
3. **Line-of-Sight (>30 MHz) :** These waves follow a straight line of sight. They are used in Mobile phone systems. Also, Satellite systems, cordless telephones etc. use these waves.



Ground wave propagation (< 2MHz)

(a)

Fig. 1.3.2 : Contd...



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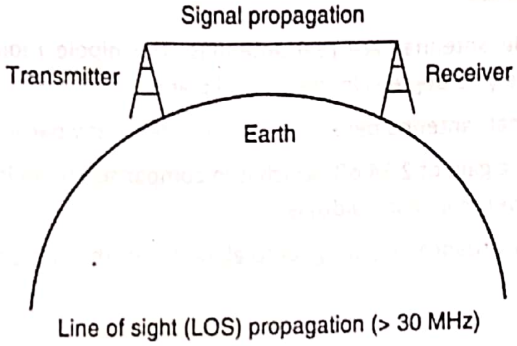

(c)

Fig. 1.3.2 : Ground Wave propagation, Sky wave Propagation and Line-of –Sight propagation

- Fig. 1.3.2 shows all three types of signal propagation.

1.4 Antennas

MU – Dec. 14, May 17, Dec. 18

Q.	Write about types of antennas and their radiation pattern.	**(Dec. 14, 5 Marks)**
Q.	What is an antenna? Explain different types of antennae.	**(May 17, 5 Marks)**
Q.	Write a short note on antenna.	**(Dec. 18, 10 Marks)**

- An **antenna** is a device that converts electromagnetic radiation in space into electrical currents in conductors or vice-versa, depending on whether it is being used for receiving or for transmitting, respectively.
- The **radiation pattern** of an antenna describes the relative strength of the radiated field in various directions from the antenna, at a constant distance.
- In reality the radiation pattern is three-dimensional, but usually the measured radiation patterns are a two-dimensional slice of the three-dimensional pattern, in the horizontal or vertical planes.
- There are various types of antennas discussed below.

1.4.1 Isotropic Antenna

- An **isotropic antenna** is a theoretical antenna that radiates its power uniformly in all directions.
- In other words, a theoretical isotropic antenna has a perfect 360 degree spherical radiation pattern. Radiation pattern of isotropic antenna is shown in Fig. 1.4.1.
- It is an **ideal** antenna which radiates equally in all directions and has a gain of 1 (0 dB), i.e. zero gain and zero loss.

- It is used to compare the power level of a given antenna to the theoretical isotropic antenna.
- Fig. 1.4.1 shows a two dimensional cross-section of the real three dimensional pattern.
- Antennas can be broadly classified as **omnidirectional** and **directional** antennas.

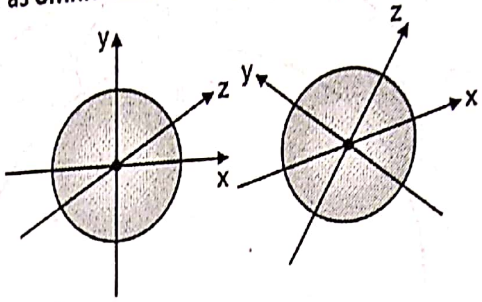

Fig. 1.4.1 : Radiation pattern of Isotropic antenna

1.4.2 Omnidirectional Antennas

- Unlike isotropic antennas, dipole antennas are real antennas. The dipole radiation pattern is 360 degrees in the horizontal plane and approximately 75 degrees in the vertical plane.
- It is also called the "non-directional" antenna because it does not favor any particular direction.
- Dipole antennas are said to have a gain of 2.14 dB, which is in comparison to an isotropic antenna. The higher the gain of the antennas, the smaller the vertical beam width is.
- This type of antenna is useful for broadcasting a signal to all points of the compass or when listening for signals from all points.

Dipoles

- The most commonly used antenna is **Hertzian** dipole.
- The dipole consists of two collinear conductors of equal length, separated by a small feeding gap.
- The length of the dipole is half the wavelength λ of the signal (for efficient radiation of energy).
- Fig. 1.4.2 shows a typical Hertzian dipole.

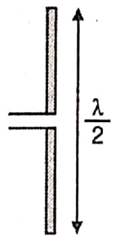

Fig. 1.4.2 : Hertzian dipole

- A $\lambda/2$ dipole has a uniform or omnidirectional radiation pattern in one plane and a figure **eight** pattern in the other two planes. This is shown in Fig. 1.4.3.
- This type of antennas are used in area such as mountain, valley etc.
- Although this is a simple antenna, it is difficult to mount on a roof top of a vehicle.

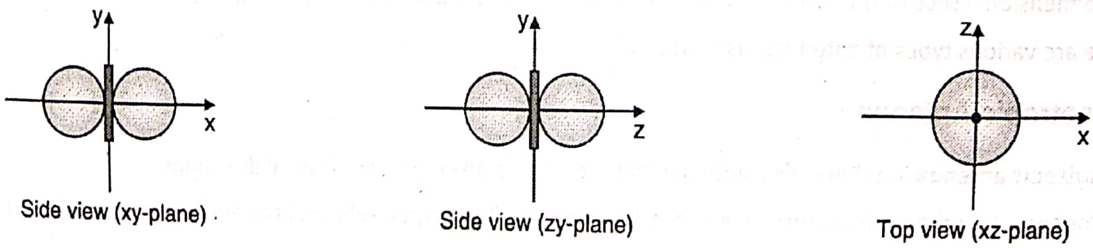

Fig. 1.4.3 : Radiation pattern of Hertzian dipole

Monopoles

- Shown in Fig. 1.4.4 is the ideal vertical monopole antenna.
- It has the length λ/4 and also known as **Markoni** antenna.
- A monopole over an infinite ground plane is theoretically the same as the dipole in free space.
- The flat surface of a vehicle's trunk or roof can act as an adequate ground plane.
- This type of antenna is efficient for mounting on a roof top of a car.

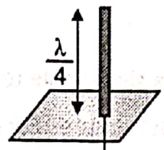

Fig. 1.4.4 : Monopole

Directional Antenna

- A **directional antenna** or **beam antenna** is an antenna which radiates or receives greater power in specific directions.
- This allows increased performance and reduced interference from unwanted sources.
- Unlike omnidirectional antennas, directional antennas must be aimed in the direction of the transmitter or receiver.
- Examples of directional antennas are parabolic and Yagi antenna shown in Fig. 1.4.5 and Fig. 1.4.6 respectively.
- Fig. 1.4.7 shows the radiation pattern of a directional antenna with the main lobe in the direction of X-axis.

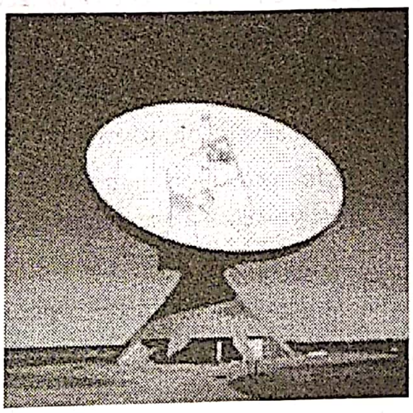

Fig. 1.4.5 : Parabolic antenna

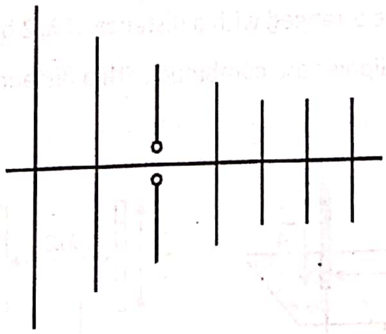

Fig. 1.4.6 : Yagi antenna

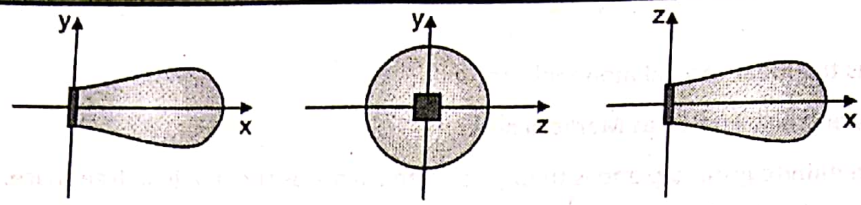

Fig. 1.4.7 : Radiation pattern of directional antennas

Sectorized Antenna

- Several directional antennas can be combined on a single pole to construct a sectorized antenna.
- They are widely used in cellular telephony infrastructure. For example, A cell can be sectorized into three or six sectors. Fig. 1.4.8 shows radiation pattern of these sectorized antennas.

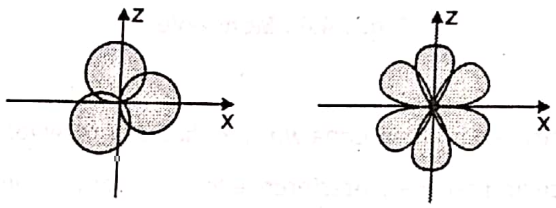

Fig. 1.4.8 : Radiation pattern of sectorized antennas

Antenna arrays

- An antenna array is a configuration of multiple antennas (elements) arranged to achieve a given radiation pattern.
- Multiple antennas allow different diversity schemes to improve the quality and reliability of a wireless link.
- Antenna diversity is especially effective at mitigating effects of multipath propagation.
- This is because multiple antennas allow a receiver several observations of the same signal.
- Each antenna will experience a different interference environment. If one antenna is experiencing a deep fade, it is likely that another has a sufficient signal. Collectively such a system can provide better link.
- Different diversity schemes are possible.
- One such scheme is **selection diversity** where the receiver always uses the antenna element with the largest output.
- The other type of diversity is **diversity combining** in which a combination of power of all the signals is taken to produce gain.

  Fig. 1.4.9 shows two such different schemes.

  - In Fig. 1.4.9 (a) two λ/4 antennas are arranged with a distance of λ/2 between them.
  - In Fig. 1.4.9 (b) three standard λ/2 dipoles are combined with a distance of λ/2 between them.

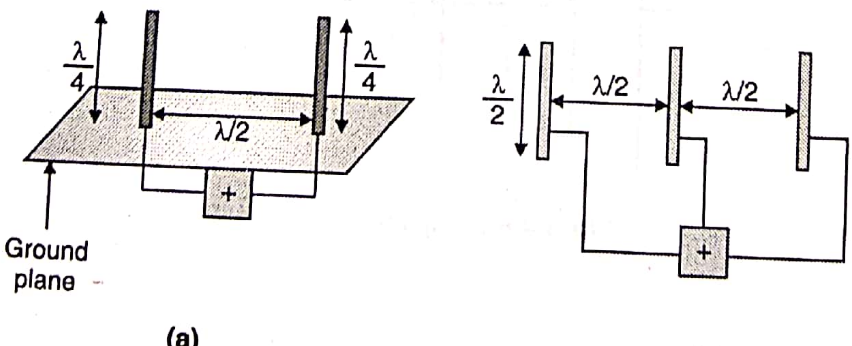

Fig. 1.4.9 : Diversity antenna systems

1.5 Signal Propagation

MU – Dec. 18

Q. What are various issues in signal propagation ? (Dec. 18, 10 Marks)

- Since wireless networks use unguided media such as radio waves, the signal has no wires to determine the direction of propagation, where as signals in wired network only travel along the wire.
- In wired network, one can easily determine the behavior of a signal traveling along this wire such as received power depending on the length.
- For wireless transmission, this predictable behavior is only valid in a vacuum. As shown in Fig. 1.5.1 depending upon the distance from the sender, the transmitted signal can fall into the following ranges.

1. Transmission Range

Within this range the receiver receives the signals with a very low error rate and hence able to communicate.

2. Detection Range

Within this range the receiver can detect the transmission i.e. the transmitted power is large enough to differ signal from background.

3. Interference Range

Within this range, the sender may interfere with other transmissions by adding to background noise. The receiver will not be able to detect the signal but the signal may disturb other signals.

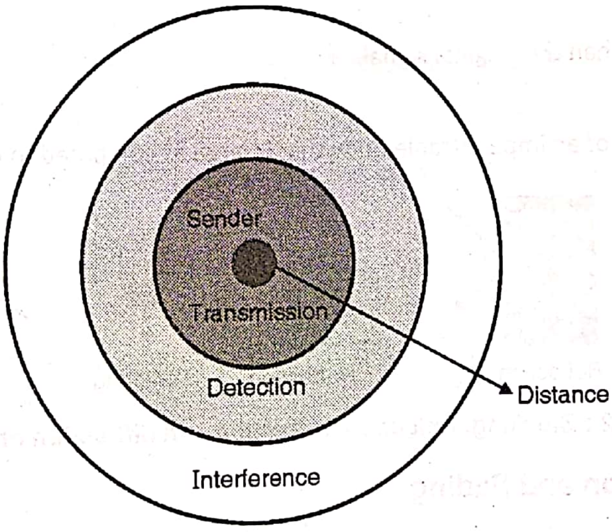

Fig. 1.5.1 : Ranges for transmission, detection and interference of signals

1.5.1 Path Loss of Radio Signals

Free Space Loss

- In free space, the signal follows a straight line. If such a straight line exists between the sender and the receiver, it is called the line of sight (LOS).
- The signal experiences free path loss even if no object exists between the sender and the receiver. This is because the receiver power P_r is proportional to $1/d^2$. Here d is the distance between the sender and the receiver. Hence, as d increases, the received power P_r decreases.

Other Parameters affecting signal Strength

- The received power also depends on the wavelength and the gain of the receiver and transmitter antenna.
- For long distance communication, most radio transmission takes place through air, rain, snow, fog, etc. The atmosphere heavily influences the quality of the signal. E.g. satellite transmission.

1.5.2 Additional Signal Propagation Effects

1. Blocking / Shadowing

- The signals with higher frequency behave like a straight line.
- These signals are blocked by even small obstacles like a wall, a car or a truck on a road. This phenomenon is called blocking or shadowing.

2. Reflection

- When a signal encounters a surface that is large relative to the wavelength of the signal, a phenomenon called reflection occurs.
- The reflected signal is not as strong as the original, as the object can absorb some of the signal's power.

3. Refraction

- This effect occurs because the velocity of the electromagnetic waves depends on the density of the medium through which it travels.
- As shown in Fig. 1.5.2, waves that travel into a denser medium are bent towards the medium.

4. Scattering

- If the object size is in the order of the wavelength of the signal or less, then the signal can be scattered into many small signals.
- Scattered signals are weaker than the original signal.

5. Diffraction

Diffraction occurs at the edge of an impenetrable body that is large as compared to the wavelength of a radio wave.

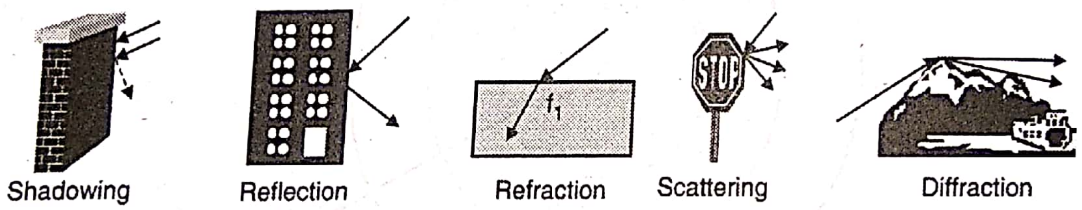

Fig. 1.5.2 : Blocking, reflection, refraction and diffraction of waves

1.5.3 Multi-path Propagation and Fading

1.5.3(a) Multi-path propagation

- The wireless channel is a multipath propagation channel.
- The radio waves that emanate from the transmitter do not reach the receiver only by a single path. The signal can take many different paths from the sender to the receiver due to reflection, scattering and diffraction. This effect is called multi-path propagation.
- Multi-path propagation is one of the most severe radio channel impairments.
- Fig. 1.5.3 shows a sender on the left hand side and one possible receiver on the right hand side.
- A radio wave emitted by a sender can take the LOS path (i.e. travel in straight line), or it may be scattered at small obstacles or reflected at large buildings.

- As a result, we have multiple copies of the same signal being transmitted and received with different delays, different amplitudes and phases.
- This effect caused by multi-path propagation is called **delay spread** i.e. the original signal is spread due to different delays of parts of the signal.

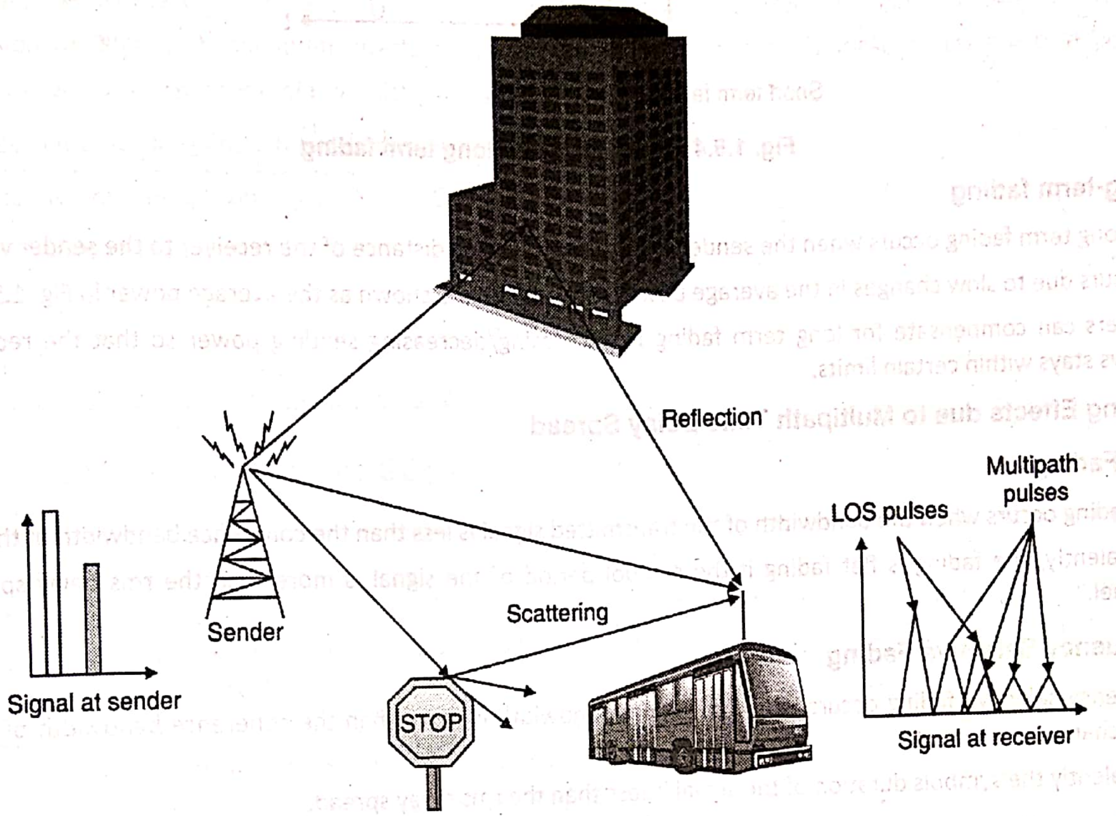

Fig. 1.5.3 : Multi-path propagation and inter-symbol interference

- As shown in Fig. 1.5.3, a short impulse will be smeared out into a broader impulse or into several weaker impulses. As a result, energy intended for one symbol spills over the adjacent symbol. This effect is called **inter symbol interference** (ISI).
- ISI makes detection of the signal difficult at the receiver. In real situation many weaker impulses arrive at the receiver. Some of the received pulses are too weak to be detected and appear as noise.

1.5.3(b) Fading

The term fading means rapid fluctuations of the amplitudes, phases, or multipath delays of a radio signal over a short period or short travel distance.

1. Fading effect due to mobility

In addition to multipath propagation, another problem called fading occurs due to mobility. Following two types of fading may occur due to mobility.

(i) Short-term fading

- Short term fading occurs when receivers or senders or both move. It occurs due to the quick changes in the received power.
- The receiver now has to try to continuously adapt to the varying channel characteristics.
- However, if such changes are too fast then (e.g. driving on a highway through a city) receiver cannot adapt fast enough and the error rate of the transmission increases dramatically. Short term fading is shown in Fig. 1.5.4.

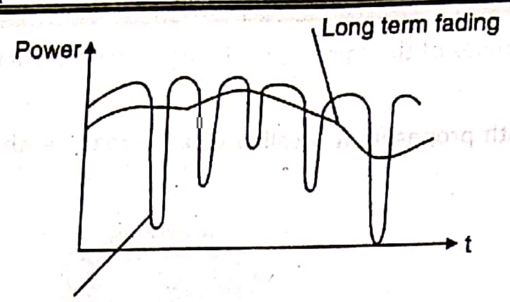

Fig. 1.5.4 : Short term and long term fading

(ii) Long-term fading

- The long term fading occurs when the sender is stationary and the distance of the receiver to the sender varies slowly.
- It occurs due to slow changes in the average power received. This is shown as the average power in Fig. 1.5.4.
- Senders can compensate for long term fading by increasing/decreasing sending power so that the received signal always stays within certain limits.

2. Fading Effects due to Multipath Time Delay Spread

(i) Flat Fading

- Flat fading occurs when the bandwidth of the transmitted signal is less than the coherence bandwidth of the channel.
- Equivalently, the fading is flat fading if the symbol period of the signal is more than the rms delay spread of the channel.

(ii) Frequency Selective Fading

- Frequency selective fading occurs when the signal bandwidth is more than the coherence bandwidth of the mobile radio channel.
- Equivalently the symbols duration of the signal is less than the rms delay spread.

1.6 Signal Characteristics

- Signals are the physical representation of data. Data in a communication system can be exchanged through the signals. Signals are functions of time and location.
- Signal parameters represent the data values. Signal parameters are the Amplitude (A), frequency (f) and phase shift (Φ). The most interesting type of signal for radio transmission is periodic signal (especially sine wave), used as carriers.
- The general function of a sine wave is, $s(t) = A_t \sin(2\pi f_t t + \varphi_t)$

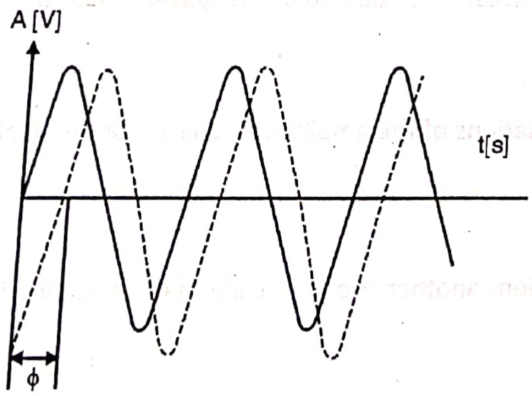

Fig. 1.6.1 : Time Domain representation of a signal (a sine wave without phase shift and with a phase shift ϕ)

1.7 Multiplexing

MU - May 18

Q. Discuss multiplexing in wireless communication. (May 18, 10 Marks)

- Multiplexing means the ability to send data coming from multiple sources, users or channels over a common shared transmission medium with minimum interference and maximum utilization. To make efficient use of high-speed communication lines, some form of multiplexing is used.
- Four types of multiplexing are commonly used in communication systems.

1. Space Division Multiplexing (SDM)
2. Time Division Multiplexing (TDM)
3. Frequency Division Multiplexing (FDM)
4. Code Division Multiplexing (CDM)

1.7.1 Space Division Multiplexing (SDM)

- In space division multiplexing, the entire region of transmission is divided into multiple spaces. For exchanging data, each user is allocated a communication channel.
- Fig. 1.7.1 shows six channels k_1 to k_6 and a three dimensional coordinate system. The dimensions are code c, time t and frequency (f). It also shows space S_i represented via circles. Channel k_1 to k_3 can be mapped onto the three spaces S_1 to S_3 which clearly separates the channel.
- It can be noted that there is some space between each channel. This space is called a **guard channel**. For the remaining channels, three additional spaces would be needed.

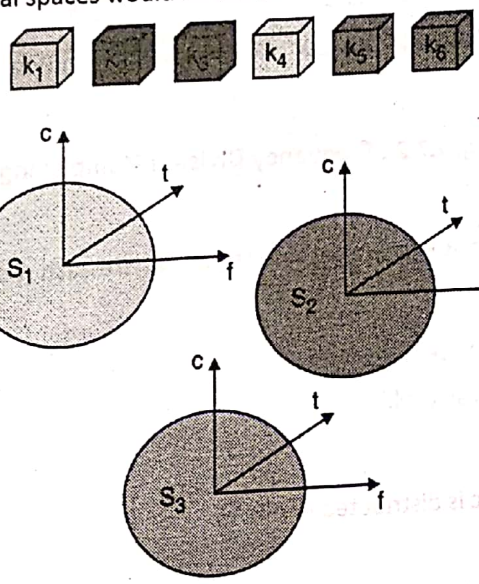

Fig. 1.7.1 : Space Division Multiplexing

Application

- This multiplexing scheme can be used for FM radio stations if a single FM station transmits in a given region (say some city) only. The same transmission ranges can then be shared by different radio stations around the world without interference.
- SDM is also used in cellular systems where the service area is divided into different cells. Each cell is assigned different frequency band such that there is no interference in adjacent cells.

Advantage

SDM is easy to implement.

Problem

If two or more channels are established in the same space (For example, several radio stations want to broadcast into the same city), then SDM alone cannot be used.

1.7.2 Frequency Division Multiplexing (FDM)

- In frequency division multiplexing, the entire frequency range is divided into frequency bands.
- Each channel gets a certain band of the spectrum for the whole time.
- Different frequency bands are separated by guard spaces.

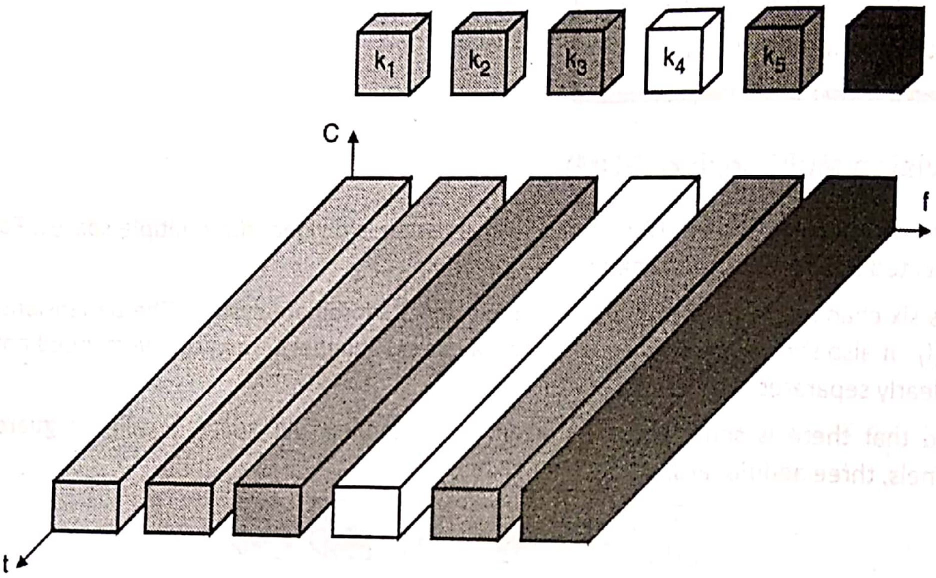

Fig. 1.7.2 : Frequency Division Multiplexing

Application

This scheme is used for radio stations within the same region, where each radio station uses its own frequency.

Advantages

- No complex coordination between sender and receiver is required.
- This scheme works for analog signals as well.

Disadvantages

- The bandwidth is wasted if the traffic is distributed unevenly.
- The scheme is inflexible.

1.7.3 Time Division Multiplexing (TDM)

- In TDM, the entire spectrum is given to a particular channel for a certain time interval.
- As shown in Fig. 1.7.3, a channel k_i is given the whole bandwidth for a certain amount of time.
- Guard spaces are needed in TDM as well, which are now represented by time gaps.
- Thus, in TDM all the channels use the same frequency but at different time.

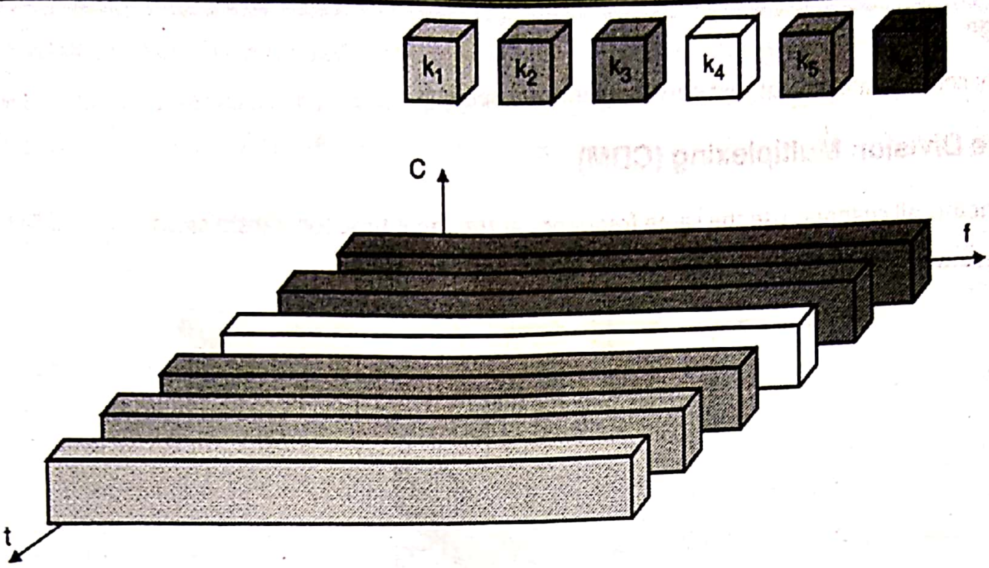

Fig. 1.7.3 : Time division multiplexing

Advantage

There is only one carrier in the medium at any time which results in high throughput even if there are many users.

Disadvantage

1. If two transmissions overlap in time, **co-channel interference** may occur.
2. To avoid co-channel interference, it is required that different senders are precisely synchronized.

1.7.4 Frequency and Time Division Multiplexing

- In this multiplexing scheme, frequency and time division multiplexing are combined.
- As shown in Fig. 1.7.4, channel k_i uses certain frequency band for a certain amount of time. Now guard spaces are required in both dimensions.

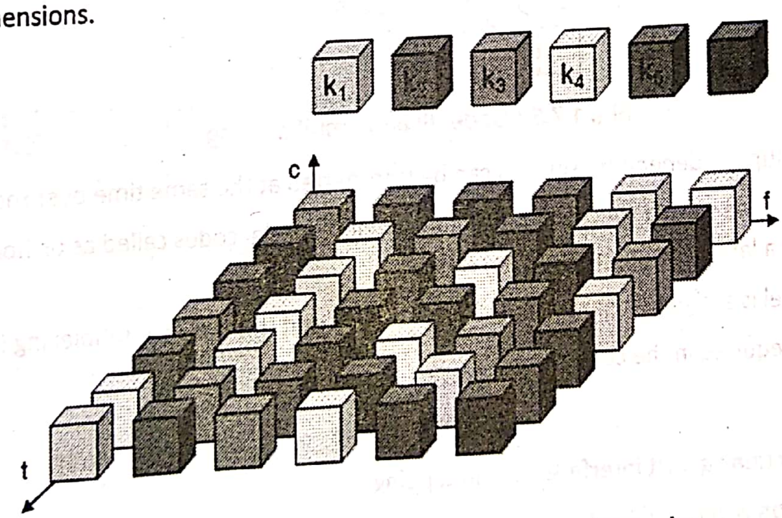

Fig. 1.7.4 : Frequency and time division multiplexing

Application

The scheme is used in GSM (Global System for Mobile Communication)

Advantages

1. Offers better protection against tapping.
2. Provides protection against frequency selective interference.

Disadvantage

Necessary coordination is required between different senders.

1.7.5 Code Division Multiplexing (CDM)

– In this scheme, all channels use the same frequency at the same time for transmission.

– Users are now separated using codes.

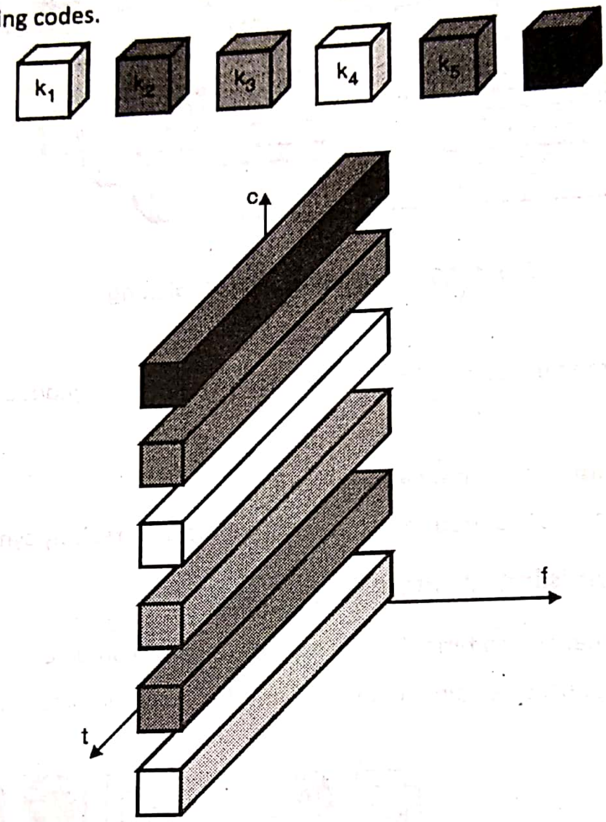

Fig. 1.7.5 : Code division multiplexing

– In this, signals from multiple independent sources can be transmitted at the same time over the same frequency band.

– This task can be achieved via spread spectrum technique in which special codes called as orthogonal codes are used to spread each signal over a large, common frequency band.

– So, in CDM, each channel is assigned a particular orthogonal code and this is how multiplexing is achieved.

– Guard spaces are now required in the code dimension.

Advantages

1. It gives good protection against interference and tapping.
2. Bandwidth utilization is very efficient.
3. No synchronization is needed between the sender and the receiver.

Disadvantages

1. Varying user data rates.
2. More complex signal regeneration and hence high complexity at the receiver.
3. It is implemented using spread spectrum technology.

4. A receiver must be precisely synchronized with the transmitter to apply decoding correctly.
5. Precise power control is required. All signals should reach the receiver with more or less the same power otherwise low power signals could be drained by high power ones.

1.8 Spread Spectrum Techniques

MU - May 12, Dec. 12, May 13, May 14

Q.	What are the main benefits of spread spectrum system ? Explain direct sequence spread spectrum in detail. How can DSSS systems benefit from multipath propagation ?	(May 12, 10 Marks)
Q.	What are benefits of Spread Spectrum systems ?	(Dec. 12, 5 Marks)
Q.	Explain different types of Spread Spectrum technique used in cellular system.	(May 13, 5 Marks)
Q.	What is Spread Spectrum ?	(May 14, 5 Marks)

- Spread spectrum is an important form of encoding for wireless communications.
- In contrast to regular narrowband technology, the spread-spectrum process is a wideband technology.
- In this technique the frequency of the transmitted signal is deliberately spread in the frequency domain. The resultant signal has much greater bandwidth than the original signal.
- The process of spreading and de-spreading is shown in Fig. 1.8.1.

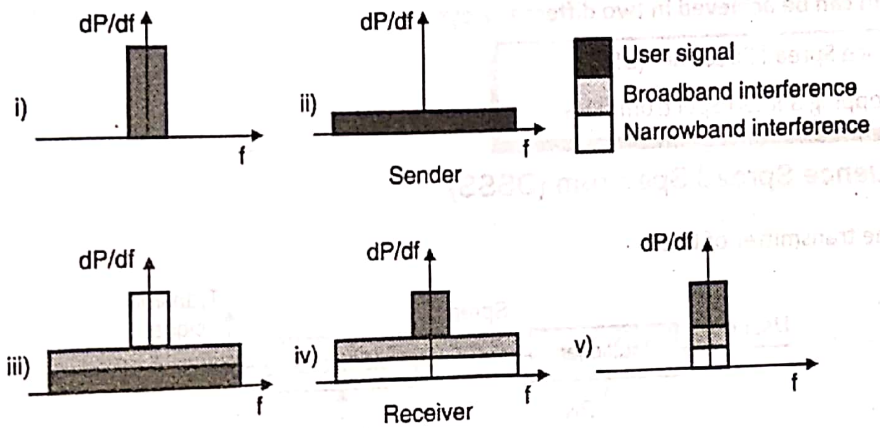

Fig. 1.8.1 : Spread Spectrum: Spreading and despreading

(i) Fig. 1.8.1 (i) shows narrowband signal transmitted form a sender. This is the signal user wants to send.

(ii) dP/df is the power density of this signal. The energy required to transmit the signal is equal to the area covered by the signal.

(iii) Second step is to spread the user signal. The process of spreading the signal is nothing but converting a narrowband signal into broadband signal. This can be achieved by multiplying a PN sequence with the user data. The energy required to transmit the signal is same, but the power level is much lower than the narrowband signal.

(iv) During the transmission, narrow band and broadband interference get added to the signal (shown in Fig. 1.8.1 (iii)).

(v) At the receiver sum of interference and user signals is received (shown in Fig. 1.8.1 (iv)).

(vi) The receiver now despreads the signal i.e. converts the spread user signal into a narrowband signal. This is achieved by multiplying the received signal with the same PN sequence used in step 2 and by using bandpass filter to cut off frequencies left and right of the narrowband signal (shown in Fig. 1.8.1 (v)).

Advantages of Spread Spectrum Techniques

1. Good protection against narrowband interference : A signal with narrow frequency is subject to catastrophic interference that can wipe out narrow band signals for the duration of the interference. Spread spectrum technique spreads the narrow band signal into a broad band signal using a special code to achieve resistance against this narrow band interference.
2. Resistance to interception : A constant-frequency signal is easy to intercept, and is therefore not well suited to applications in which information must be kept confidential. In spread spectrum technique, the signal is spread using a specific, but complicated mathematical function. In order to intercept the signal, a receiver must know how to de-spread the signal.
3. Spread Spectrum systems can co-exist with other radio systems, without being disturbed by their presence and without disturbing their activity. Thus the spread spectrum systems may be operated without the need for license.
4. Spread spectrum techniques can resist multi-path fading.

Disadvantages of Spread Spectrum Techniques

1. Complexity of receiver is increased.
2. Large frequency band is needed for spreading the signal.
3. Spread signals with low strength may interfere with other transmissions and appear as noise.
4. Precise power control is needed.

Spreading the spectrum can be achieved in two different ways

1. Direct Sequence Spread Spectrum (DSSS)
2. Frequency Hopping Spread Spectrum (FHSS)

1.8.1 Direct Sequence Spread Spectrum (DSSS)

- Fig. 1.8.2 shows the transmitter of DSSS.

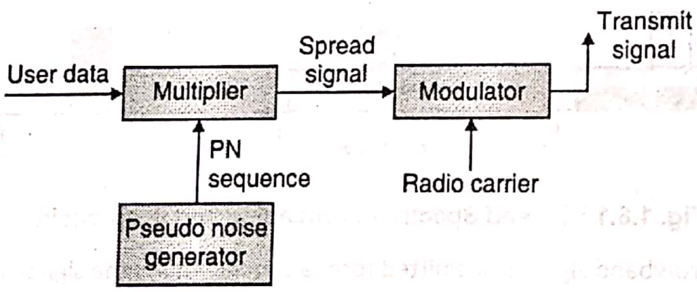

Fig. 1.8.2 : DSSS Transmitter

1. DSSS Transmitter

DSSS transmitter involves two major steps.

Step 1 : Spreading the signal

- Spreading in Direct Sequence modulation is achieved by modulating the carrier signal (user data) with a digital code sequence which has a bit rate much higher than that of the message to be sent.
- This digital code sequence is typically a pseudorandom binary code. It is also known as PN ("pseudo-noise") sequence or chipping sequence.
- Spreading can be done by simply XORing user bit stream with chipping sequence.
- The time period of a single bit in the PN code is termed a *chip*, and the bit rate of the PN code is termed the *chip rate*.
- The spreading process is shown in Fig. 1.8.3.

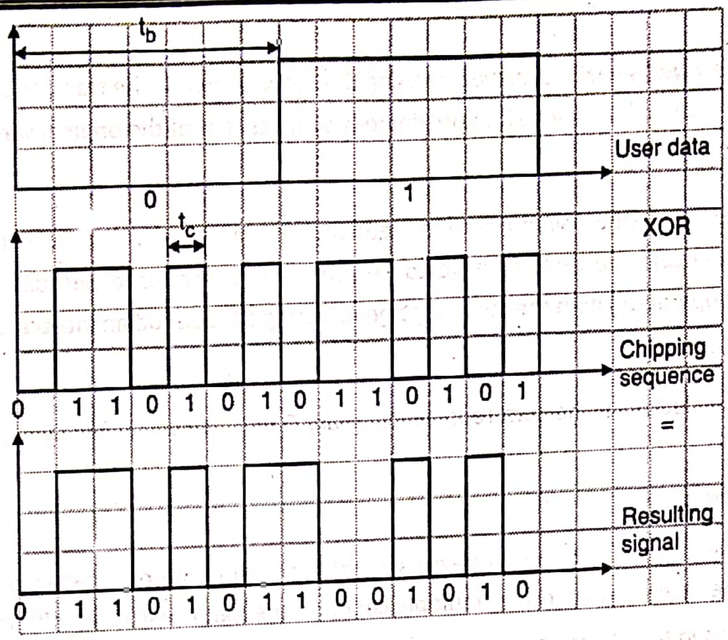

Fig. 1.8.3 : Spreading with DSSS

- Consider the chipping sequence as 0110101.
- If the user bit is 0 the result of XORing is the chipping sequence itself.
- If the user bit is 1 the result is the complement of chipping sequence.
- If the bit duration of user data is t_b and the duration of one chip in chipping sequence is t_c, then the spreading factor $s = t_b / t_c$ determines the bandwidth of a signal.
- If the original signal has bandwidth **w** then the resulting signal needs (**s . w**) bandwidth.

Step 2 : Radio modulation

- The spread signal is now modulated with a radio carrier.
- The radio carrier shifts this signal to the carrier frequency.
- This signal is then transmitted.

2. DSSS Receiver

The DSSS receiver involves three steps :

(i) Demodulation

(ii) Correlation

(iii) Decision Making

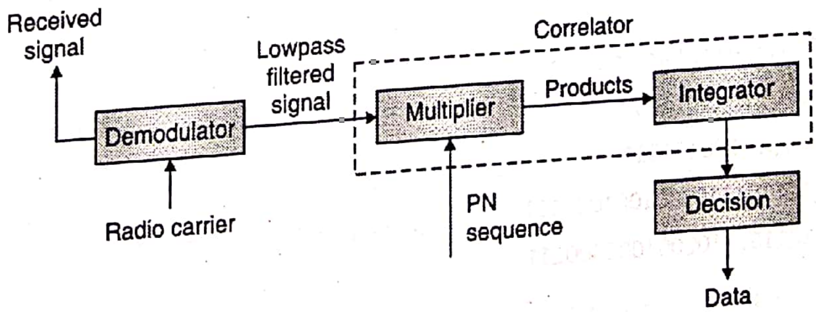

Fig. 1.8.4 : DSSS Receiver

(i) Demodulator

Demodulation of the received signal is achieved by using the same carrier as the transmitter, reversing the modulation process. Bandwidth of the resultant signal is approximately same as that of the original spread spectrum signal.

(ii) Correlator

Here the receiver uses the same pseudo random sequence (Chip sequence) as the transmitter. Pseudo random sequences at the sender and the receiver have to be precisely synchronized because the receiver calculates the product of a chip (XOR operation) with the incoming signal. During a bit period an integrator adds all these products.

(iii) Decision Unit

Finally the decision unit decides if the sum represents binary 0 or 1, based on the sum generated by the integrator during each bit period.

DSSS and Multipath fading

- We know that in multipath propagation there exist several paths with different delays between a transmitter and a receiver. As a result the receiver may receive multiple copies of the signal, each with different delays.
- **Rake receivers** can be used to mitigate the effect of multipath propagation.
- A rake receiver uses **n** correlators called **fingers** for **n** strongest paths.
- Each correlator is synchronized to the transmitter plus the delay on that specific path.
- As soon as the receiver detects a new path which is stronger than the currently weakest path, it assigns this new path to the correlator with the weakest path.
- The outputs of the correlators are then combined and fed into the decision unit.

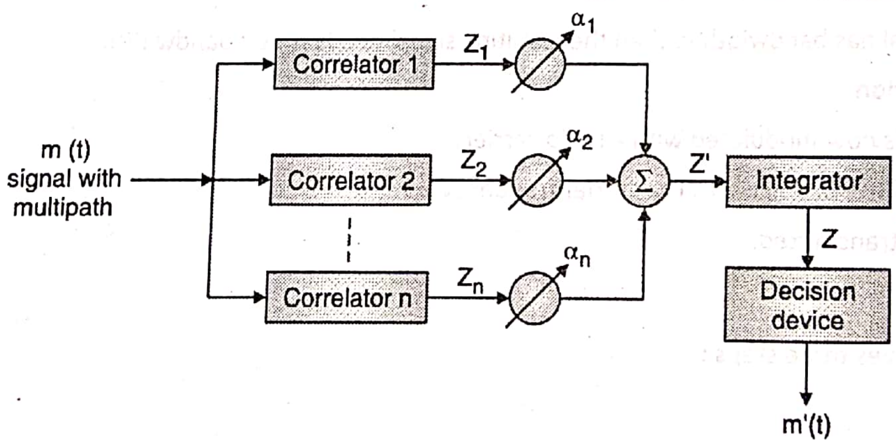

Fig. 1.8.5 : Rake receivers

Example of DSSS

User Data : 01

Chip : 10110111000 (11-chip Barker code)

XOR of bit 0 with chip: 10110111000

XOR of bit 1 with chip: 01001000111

Spread signal : 1011011100001001000111

Received signal : 1011011100001001000111

XOR of received signal with chip:

(1011011100010110111000) XOR (1011011100001001000111) = (0000000000011111111111)

Result of Integrator: 0 , 11

Result of Decision unit: 0 < 4 so bit is 0

11 > 7 so bit is 1

Decoded data: 01

Even if error occurs during transmission, received signal can still be decoded correctly.

For e.g. fourth, fifth, seventh and fourteenth bit in received signal is changed, then the received signal would be 1010110100001101000111

Now XOR of received signal with chip :

(1011011100010110111000) XOR (1010110100001101000111) = (00011010000 11011111111)

Result of integrator: 3, 10

Result of Decision unit: 3 < 4 so bit is 0

10 > 7 so bit is 1

Decoded data: 01

Note : Decision maker decides on to 0 if the sum is between 0-4 and 1 if sum is between 7-11.

Advantages of DSSS

1. Resistance to narrow band interference and anti-jamming effects.
2. Resistance to Interception.
3. Resistance to Fading (Multipath Effects).

Disadvantages of DSSS

1. Precise power control necessary.
2. Overall system is complex.
3. Is required between the sender and the receiver.

Applications of DSSS

The DSSS Communications are widely used today for Military, Industrial Scientific, and Civil uses. The applications include the following :

1. **CDMA radios**

   It is useful in multiple access communications wherein many users communicate over a shared channel. For example, CDMA.

2. **WLAN**

   Wireless LAN widely use spread spectrum communications. IEEE 802.11 is a standard that is developed for mobile communication, and widely implemented throughout the world. The standard defines three types of Physical Layer communications. These are Infrared (IR) Communications, Direct Sequence Spread Spectrum Communications, Frequency Hopping Spread Spectrum communications.

3. **Cordless Phones**

   Several manufacturers implement Spread Spectrum in Cordless phones due to their advantages like security, immunity to noise and longer range.

1.8.2 Frequency Hopping Spread Spectrum (FHSS)

- FHSS implements TDM plus FDM.
- In this scheme total available bandwidth is split into many channels of smaller bandwidth.
- Transmitter and receiver stay on one of these channels for some predefined time and then hop to another channel.
- The pattern of channel uses (frequency pattern) is called the **hopping sequence.**
- Time spent on a channel with certain frequency is called the **dwell time.**
- There are two variants of FHSS called slow and fast hopping.

1. Slow hopping

- Transmitter uses one frequency for several bit periods. Fig. 1.8.6 shows six user bits with a period t_b. Transmitter uses frequency f_2 for transmitting the first three bits and takes dwell time t_d. Then transmitter hops to the next frequency f_3.
- Slow hopping is cheaper and has relaxed tolerance.
- It is less immune to narrowband interference.

2. Fast hopping

- Transmitter changes frequency several times during a bit period. In Fig. 1.8.6 the transmitter hops three times during a bit period.

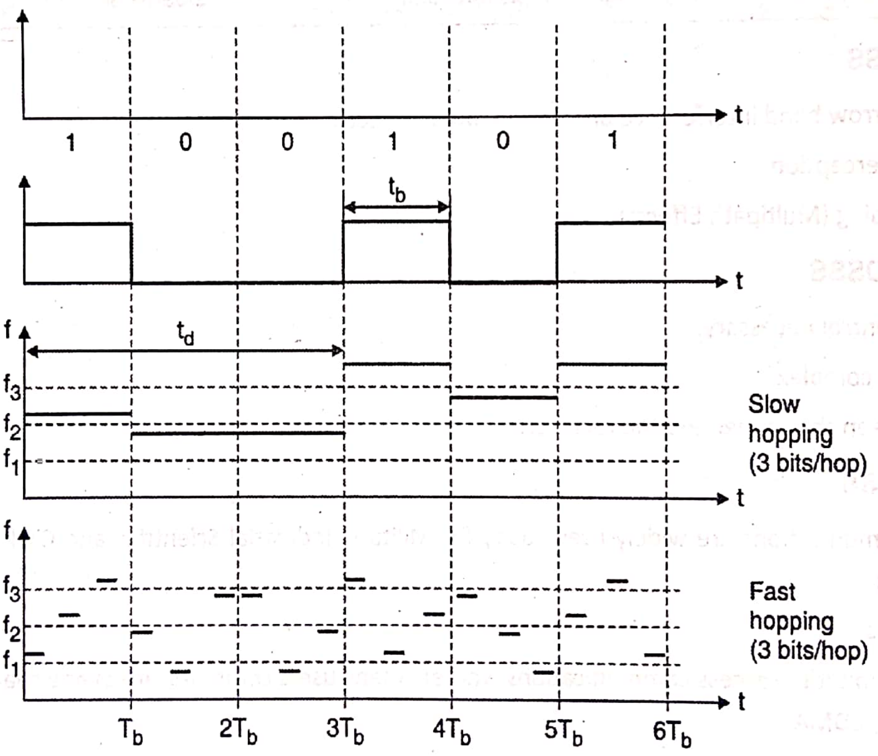

Fig. 1.8.6 : Slow and fast frequency hopping

- Fast frequency hopping systems are more complex to implement because transmitter and receiver should stay synchronized.
- These systems have better resistance against narrowband interference and frequency selective fading.

FHSS Transmitter

Fig. 1.8.7 shows simplified block diagram of FHSS transmitter.

Step 1 : Modulate user data using digital-to-analog modulation such as FSK or BPSK. For example, frequency f_0 is used for a binary 0 and f_1 is used for binary 1.

Step 2 : Frequency hopping is performed by using hopping sequence. The hopping sequence is fed into a frequency synthesizer generating the carrier frequency f_L.

Step 3 : Second modulation is done. It uses modulated narrowband signal and carrier frequency to generate a new spread signal with frequency of $f_l + f_0$ for a bit 0 and $f_L + f_1$ for a bit 1.

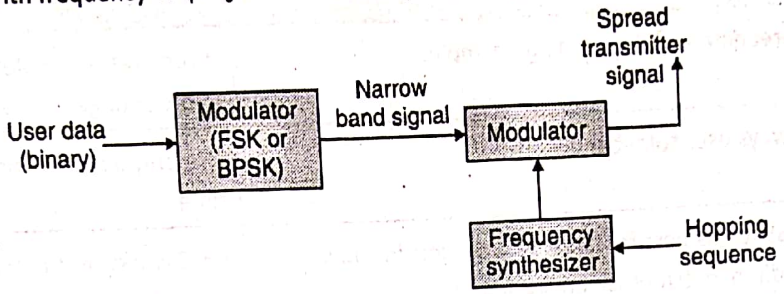

Fig. 1.8.7 : FHSS transmitter

FHSS Receiver

FHSS receiver performs reverse functions to reconstruct user data.

Step 1 : Demodulate received data by using hopping sequence and convert signal into narrowband signal.

Step 2 : Perform analog-to-digital modulation to reconstruct user data.

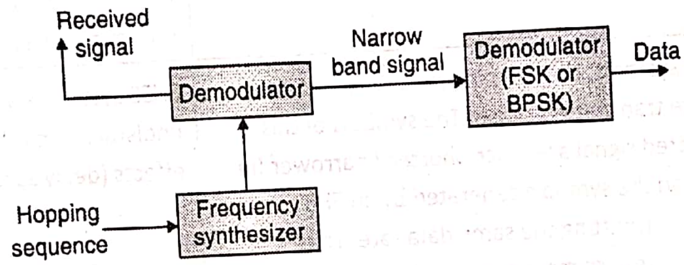

Fig. 1.8.8 : FHSS receiver

Slow hopping Vs. Fast hopping

Table 1.8.1 : Slow hopping Vs. Fast Hopping

Parameter	Slow Hopping	Fast Hopping
Main Idea	Several bits are transmitted using a same frequency.	One bit is transmitted using several different frequencies.
Resistance to narrowband interference	Provides lesser resistance to narrowband interference.	Better resistance to narrowband interference and frequency selective fading.
Security	Lower security as compared to fast hopping.	More secured since one bit is transmitted using several different frequencies.
Complexity	Less complex to implement as compared to fast hopping.	More complex as compared to slow hopping.

Applications of FHSS

1. GSM uses slow frequency hopping to avoid co-channel interference and to increase the channel capacity.
2. Bluetooth uses FHSS. It uses 79 frequencies with 1600 hops/sec.
3. WLAN : Most of the Wireless LAN standards define three types of Physical Layer communications. These are Infrared (IR) Communications, Direct Sequence Spread Spectrum Communications, Frequency Hopping Spread Spectrum communications.

1.8.3 Comparison between DSSS and FHSS

Table 1.8.2 : Difference between DSSS and FHSS

Parameter	DSSS	FHSS
Complexity	Spreading and dispreading is simple.	It requires a complex frequency synthesizer in order to generate the hops.
Bandwidth utilization	Always uses total bandwidth.	Use only a portion of total bandwidth at a time.
Resistance to interference	DSSS works best for large data packets in a low to medium interference environment.	FHSS works best for small data packets in high interference environment.
Effect of multipath fading	DSSS systems operate over wider bands, transmitting their signal over a group of frequencies simultaneously. As long as the average level of the received signal is high enough, the DSSS receiver will be able to detect the radio signal.	FHSS systems operate with narrow band signals located around different carrier frequencies. If at a specific moment, the FHSS system is using a carrier frequency significantly faded as a result of multipath, the FHSS receiver could not get enough energy to detect the radio signal.
Effect of delay spread	In DSSS systems, the chipping process generates a high rate transmitted signal. The symbols of this transmitted signal are much shorter / narrower (in time) than the symbols generated by an FHSS system transmitting the same data rate. These narrow pulses are more sensitive to delays than a wider pulse used in FHSS systems.	FHSS systems have better chances to be undisturbed by the presence of multipath effects (delay spread).
Power control	Near far problem exists in DSSS and therefore precise power control is required.	It is not much affected by near far problem as in DSSS hence power control is not a problem
Acquisition Time	Due to long PN codes it requires long acquisition time	It has relatively short acquisition time because the chip rate is considerably less in the frequency hopping system.

Review Questions

Q. 1 What types of mobile and wireless devices are available in the market ?

Q. 2 Explain the needs of mobile communication with its applications.

Q. 3 Explain multi-path propagation and Different types of path losses and signal propagation effects in wireless transmission.

Q. 4 Explain various wideband modulation techniques employed in cellular / mobile technologies.

Q. 5 Draw the block diagram of FHSS transmitter and receiver. Differentiate between slow hopping and fast hopping.

Q. 6 Explain what is spread spectrum? How spreading can be achieved? What are the merits of spread spectrum technique?

Q. 7 Explain different methods to increase the capacity of an analog cellular system and without increasing number of antennas.

Q. 8 What are the advantages of cellular System? Explain cellular system in detail also explain frequency reuse concept in cellular system.

Q. 9 What do you mean by frequency reuse concept? Explain.

Q. 10 What is CDMA? How does it suit to mobile cellular systems ?

Q. 11 Discuss different multiplexing techniques.

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