Introduction To Mobile Computing

Module 1

Introduction

What is computing?

Operation of computers

What is the mobile?

That someone /something can move or be moved easily and quickly from place to place

What is mobile computing?

- Mobile Computing is using a computer (of one kind or another) while on the move
- Users with portable computers still have network connections while they move
- Computing enabled by presence of wireless enabled portable devices

Why Go Mobile?

- Enable anywhere/anytime connectivity
- Bring computer communications to areas without pre-existing infrastructure
- Enable mobility
- Enable new applications
- An exciting new research area

Different names of Mobile Computing

- Nomadic computing –moving along with user
- Pervasive computing - existing everywhere
- Ubiquitous computing –Integrating computers with everything

Types of Wireless Devices

- Laptops
- Palmtops
- PDAs
- Cell phones
- Smartphone,
- Pocket PCs,
- Tablet PCs

Comparison to Wired Network.

Wired Networks

- high bandwidth
- low bandwidth variability
- high power machines
- high resource machines
- need physical access(connection)
- low propagation delay
- connected operation
- No channel interference
- Cover particular distance
- Difficult installation
- High cost

Mobile Networks

- low bandwidth
- high bandwidth variability
- low power machines
- low resource machines
- need proximity
- higher propagation delay
- disconnected operation
- Channel interference is present
- Cover large distance
- Easy installation
- Low cost

Mobile Computing Applications

- Home appliances: refrigerator, washer/dryer, thermometer, microwave, dishwasher, vacuum cleaner
- Mobile devices: laptop, PDA, Pocket PC, iPhone, cell phones
- Home electronics: TV, DVD player, satellite TV set-top boxes, cd-players, Stereos, iPod,
- Location positioning devises : GPS, MPS
- Automobiles: every modern car is a network of computers
- Tags: RFIDs, Smart Cards
- Sensor network and Smart Dust, Smart homes, wearable computing, ….
- For Estate Agencies ,In courts, In companies
- Stock Information Collection/Control
- Credit Card Verification
- Taxi/Truck Dispatch
- Electronic Mail/Paging

1. Traffic:

- During travelling in traffic ,if we require to know road situation ,latest news and when if feel more stress in driving then can play music and other important broadcast data are received through digital audio broadcasting(DAB).
- If we forget the road then we can know our exact location with the help of global positioning system (GPS).
- In case if got accident then, to inform police and ambulance via an emergency call to service provider, which help to improve organization and save time & money.

2.Business:

- Managers can use mobile computers for critical presentations to major customers. They can access the latest market share information.
- To enable the company to keep track of all activities of their travelling employees, to keep databases consistent etc. With wireless access, the laptop can be turned into a true mobile office, but efficient and powerful synchronization mechanisms are needed to ensure data consistency.

3.Emergencies Situation:

An ambulance with a high-quality wireless connection to a hospital can carry vital information about injured persons to the hospital from the scene of the accident. All the necessary steps for this particular type of accident can be prepared and specialists can be consulted for an early diagnosis.

4.Credit card verification

Credit card verification using this computing is most secure. In respect of Sale terminals(POS) when customer buy items in malls and other small shops and pay bill in form of swap credit card for transactions.

This needs to establish network in between POS terminal and bank central computer, then over protected cellular network verify the credential information of card, if match it then proceed further otherwise denied.

This helps to boost up speed of transaction process and relieve the burden at the POS network.

5.Infotainment

- Now a days there is a huge market of Entertainment for humans while they are on move. Watching movies, listening music and playing a game has become a part of life for entertainment. In this case mobile computing performs a major role to provide uninterrupted internet connection to digital devices.

6.Tourism

It is the largest industry for all the countries. Mostly tourism places are at remote location from the developed cities.

In this case wireless communication performs a vital role in connectivity for people who are enjoying their tour. They are continuously in contact with the family and friends and searching for travel services, hotel services food services etc.

7.E-Governance

To provide health, education, safety , farming , weather forecast and many other related information to governance, governments are connecting rural areas with head quarter offices for monitoring.

Governments are using many communication services to update their rural areas

8.Education:

2020 COVID Pandemic teach us a great lesson to provide distance education to all who can not reach to the college or schools. Wireless communication and digital devices are the backbone for such distance learning concept. Now all private and public industries are moving towards the online education with help of good wireless connectivity.

9.Social Media and Group Message :

Some mobile applications allows user to keep in touch with their friends and relatives by sending messages, images, audio and video clips.

10.Manage Personal Records And Transaction :

Some mobile applications allows user to manage their personal records such as day to day activities, some useful notes, etc…

- Some mobile applications allow the facility of transaction such as recharge mobile, pay bills etc…

11.Replacement of Wired Networks:

wireless networks can also be used to replace wired networks. e.g., remote sensors, for tradeshows, or in historic buildings. Due to economic reasons, it is often impossible to wire remote sensors for weather forecasts, earthquake detection, or to provide environmental information.

Challenges

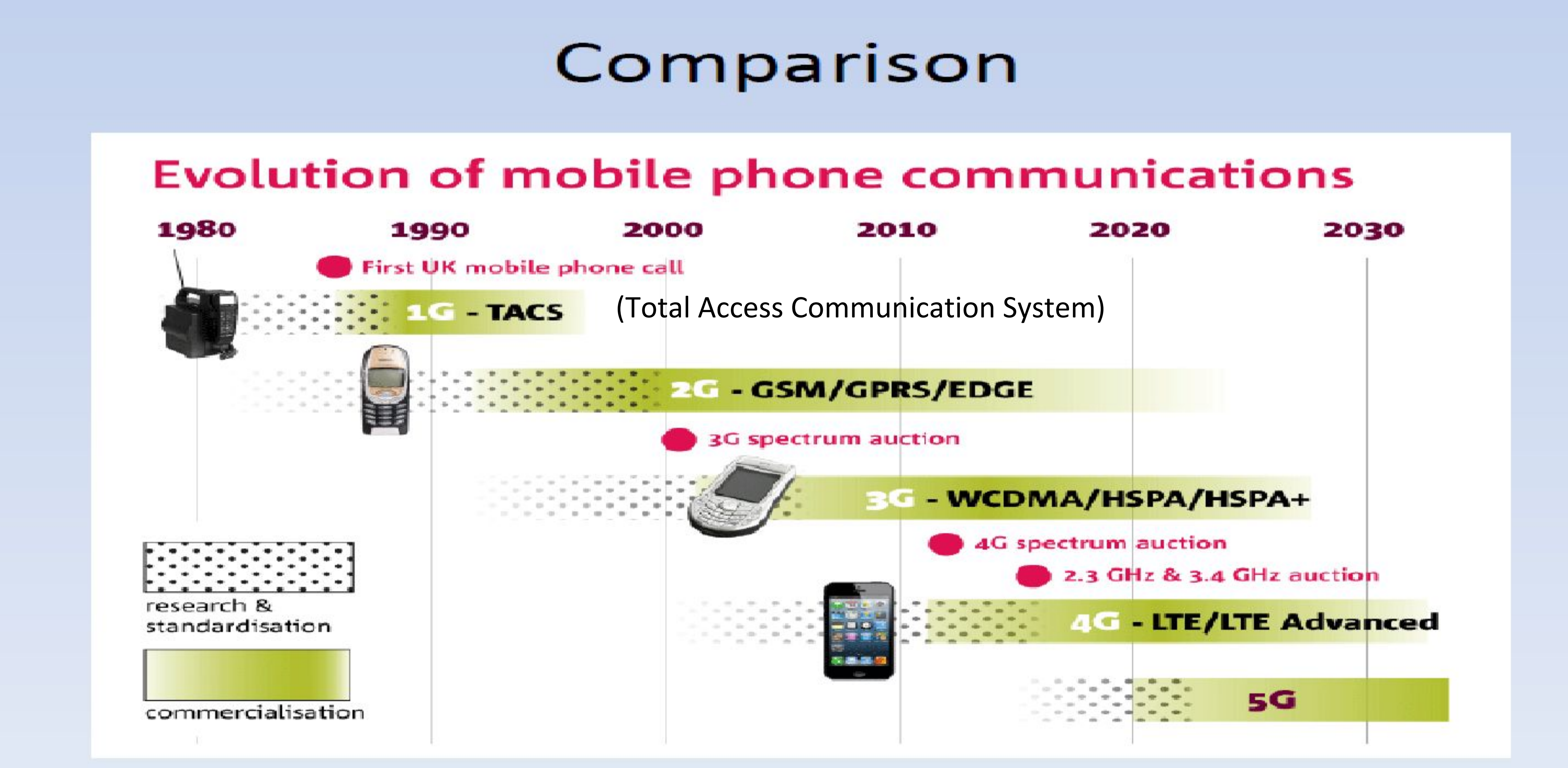
- Disconnection
- Low bandwidth
- High bandwidth variability
- Low power and resources
- Security risks
- Wide variety terminals and devices with different capabilities
- Device attributes
- Fit more functionality into single, smaller device

Future of Mobile Computing

- Use of Artificial Intelligence
- Integrated Circuitry-> Compact Size
- Increases in Computer Processor speeds

1980 1992 2001 2011 2020

Telecommunication Generations



(Total Access Communication System)

1G (1st Generation):

- was introduced in 1980s, in the USA.
- First-time calling was introduced in mobile systems.
- The data is transmitted between the devices using analog signals.
- Used the Analog Frequency Modulation and Circuit switched techniques
- The individual calls used different frequencies and shared the spectrum through Frequency Division Multiple Access(FDMA)
- The Operating frequency of 1G is 800 MHz and 900 MHz.
- The Maximum rate of speed can be up to 2.5Kbps
- The Capacity of data to transmit via 1G will have a bandwidth of 30 KHz
- The coverage area was small.
- No roaming support between various operators.
- Low sound quality.
- Mobile Phones cannot have a long life in battery usage and are very bigger which is very difficult to carry.

2G (2nd Generation) :

- The GSM (Global System for Mobile Communication) was introduced in 1990s in Finland.
- Shifted from analog to digital and used Time Division Multiple Access(TDMA) / Code Division Multiple Access(CDMA).
- The data speed of 2G is nearly up to 64 Kbps.
- This generation is responsible for the upgradation from voice calls to MMS (Multimedia Messaging System) and SMS (Short Message Systems).
- Supported all 4 sectors of the wireless industry namely Digital Cellular Systems(DCS), Mobile Data, Personal Communication Service(PCS), WLAN,
- Provides increased capacity and security, supports International roaming.
- 2G WLAN provided a high data rate & large area coverage.
- It needs strong network coverage for data transmission.
- Even though it helps in sending messages, it cannot handle videos for transmission.

2.5G and 2.75G

- The First technology **2.5G** is the GPRS(General Packet Radio Service) with a high data rate of 171kbps.
- Using the packet switching technique, the data is transferred, by dividing the data into small packets for an easy mode of transmission.
- The Second technology **2.75G** is the EDGE (Enhanced Data Rates for GSM Evolution) with an increased data rate of up to 473.6 Kbps.
- Later the technology used is CDMA with a data rate of 384 Kbps.
- It supports Email transmission and Internet browsing and also features cameras in cellular phones.

3G (3rd Generation) :

- was introduced in Japan in 2000
- It comes with data transfer technology such as UMTS (Universal Mobile Terrestrials System) for use in smartphones.
- With this feature, we can have the video calling option and play games online on cellular phones.
- It supports both voice and data with a data rate of 3.1 Mbps.
- The Internet Service provided is broadcast.
- It has high security and international roaming.
- It provides a wider capacity for data transmission at a faster speed.
- The time taken to download via 3G is faster but more expensive to buy.
- The power consumption of using 3G technology is high.

4G (4th Generation) :

- 4G was introduced in South Korea.
- Long Term Evolution (LTE) and Wireless Fidelity (Wi-Fi) is data technology used and it provides faster data rate to upload and download data.
- The Data rate provides a capacity of 100Mbps to 1Gbps and is highly securable by using the Encryption Technique.
- The Internet Service provided by 4G is Ultra-Broadband.
- It provides high speed and global mobility using the internet and International calls.
- It provides costlier hardware and infrastructure setup.
- Due to the high data rate speed, the battery usage is less.

5G (5th generation):

- It is specially designed to fulfill the demands of current technological trends, which includes a large growth in data and almost global connectivity along with the increasing interest in the Internet of Things.
- In its initial stages, 5G Technology will work in conjugation with the existing 4G Technology and then move on as a fully independent entity in subsequent releases.
- Peak data rate: At least 20Gbps downlink and 10Gbps uplink per mobile base station
- Real-world data rate: Download speed of 100Mbps and upload speed of 50Mbps
- Spectral efficiency:30bits/Hz downlink and 15 bits/Hz uplink. This assumes 8×4 MIMO (multiple-input, multiple-output)
- Latency : Maximum latency of just 4ms (compared to 20ms for LTE
- Connection density : At least 1 million connected devices per square kilometre (to enable IoT support)

Comparison

	1G	2G	3G	4G	5G
Period	1980 – 1990	1990 – 2000	2000 – 2010	2010 – (2020)	(2020 - 2030)
Bandwidth	150/900MHz	900MHz	100MHz	100MHz	1000x BW pr unit area
Frequency	Analog signal (30 KHz)	1.8GHz (digital)	1.6 – 2.0 GHz	2 – 8 GHz	3 – 300 GHz
Data rate	2kbps	64kbps	144kbps – 2Mbps	100Mbps – 1Gbps	1Gbps <
Characteristic	First wireless communication	Digital	Digital broadband, increased speed	High speed, all IP	
Technology	Analog cellular	Digital cellular (GSM)	CDMA, UMTS, EDGE	LTE, WiFi	WWWW

- https://www.linkedin.com/pulse/evolution-mobile-communication-from-1g-4g-5g-6g-7g-pmp-cfps

Cellular Systems

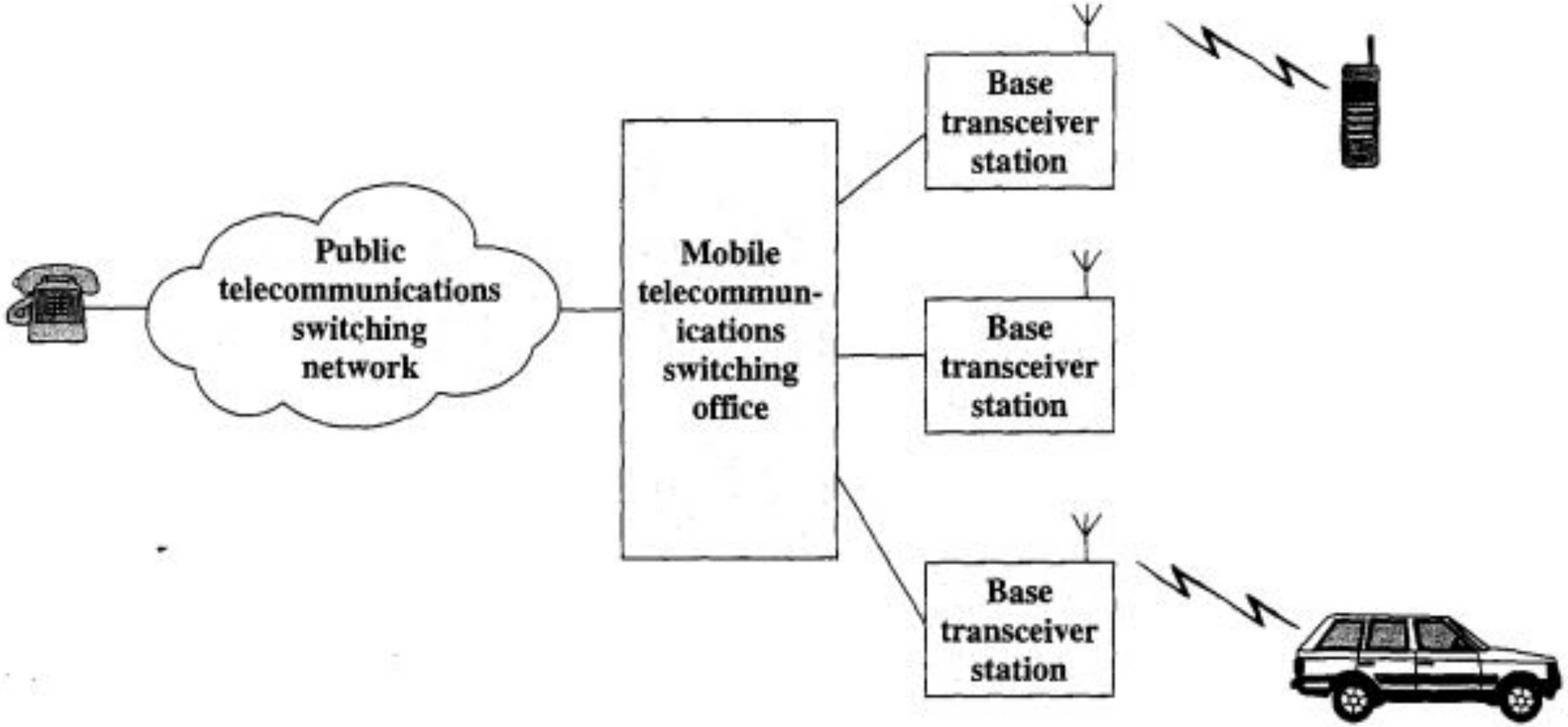
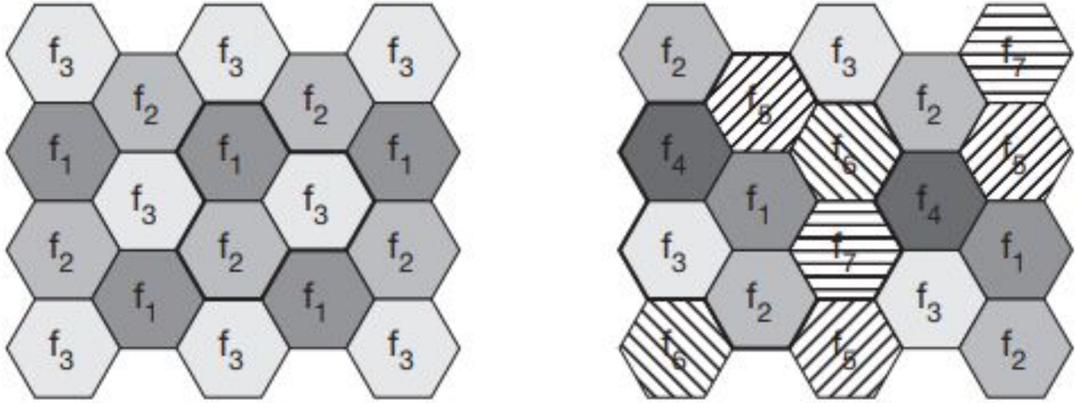


Figure 10.5 Overview of Cellular System

- The essence of a cellular network is the use of multiple low-power transmitters, on the order of 100 W or less.
- Cellular systems for mobile communications implement SDM(Space Division Multiplexing).
- Because the range of such a transmitter is small, an area can be divided into cells, each one served by its own antenna.
- Adjacent cells are assigned different frequencies to avoid interference or crosstalk.
- However, cells sufficiently distant from each other can use the same frequency band
- Each cell is allocated a band of frequencies and is served by a base station, consisting an antenna, a controller, and a number of transceivers, for communicating on the channels assigned to that cell.
- The controller is used to handle the call process between the mobile unit and the rest of the network.

- Each BS is connected to a mobile telecommunications switching office (MTSO), with one MTSO serving multiple BSs
- Typically, the link between an MTSO and a BS is by a wire line, although a wireless link is also possible. The MTSO connects calls between mobile units.
- The MTSO is also connected to the public telephone or telecommunications network and can make a connection between a fixed subscriber to the public network and a mobile subscriber to the cellular network.
- The MTSO assigns the voice channel to each call, performs handoffs and monitors the call for billing information.
- Two types of channels are available between the mobile unit and the base station (BS): control channels and traffic channels.
- Control channels are used to exchange information having to do with setting up and maintaining calls and with establishing a relationship between a mobile unit and the nearest BS.
- Traffic channels carry a voice or data connection between users



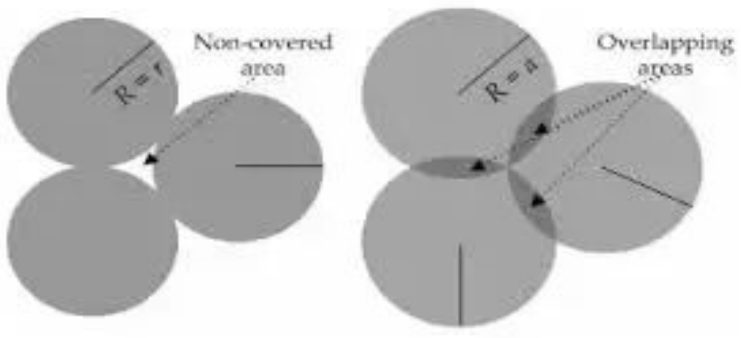
Cellular system with three and seven cell clusters

- Cell radii can vary from tens of meters in buildings, and hundreds of meters in cities, up to tens of kilometers in the countryside.
- The shape of cells are never perfect circles or hexagons, but depend on the environment (buildings, mountains, valleys etc.), on weather conditions, and sometimes even on system load.

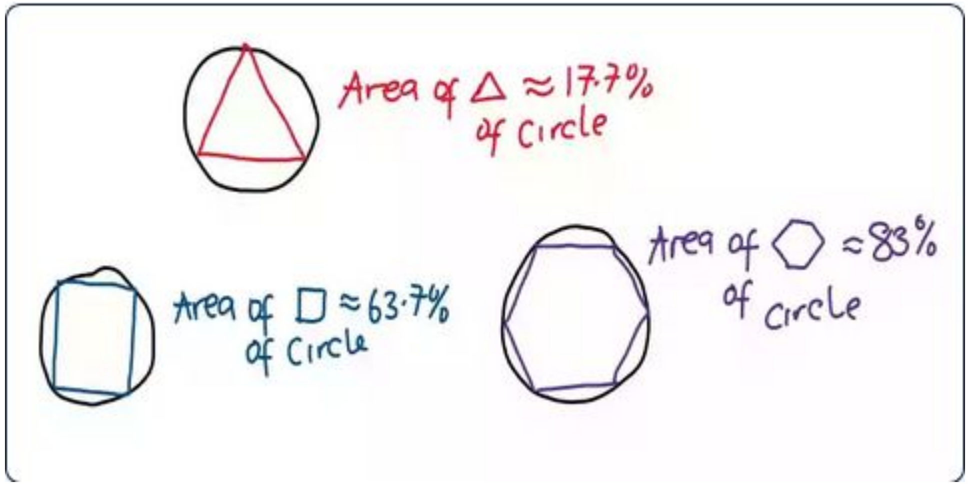
Why Hexagonal Shape Is Used in Cellular Network

- The geometrical shape used in a cellular network can be circular, triangular, rectangular, or hexagonal.
- But in choosing the shape of the cell to be used, the following criteria are considered.

1. The cell has to be geometrical.
2. There should be area without overlapping.
3. The area of the cell should be maximum



- The radiation of radio waves from a mobile phone base station antenna, can be approximated to be circular. But the issue is that using a circular shape leads to overlapping or dead spot (which results in interference and region where signal cannot be received)



- When a triangular shape is used, there is minimal to no overlapping, but the area it can cover compared to that of the circle is 17.7% of the area of the circle.
- For a rectangular shape, there is minimal overlapping and the area it can cover in respect to the circle is 63.7%.
- When hexagonal is used, it covers about 83% of the area of a circle and there is no overlapping.

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

- The area coverage of hexagon is twice that of triangular area.
- Using hexagons in a cellular network provides a number of advantages.
- The hexagonal shape allows for complete and balanced coverage with minimal overlap, reducing the number of base stations required to cover an area.
- The use of hexagons ensures that the cells are as close to circular as possible, which helps to minimize interference between neighboring cells.
- The hexagonal shape allows for efficient use of available resources, such as power and bandwidth, by ensuring that the base stations are evenly distributed throughout the service area.

- Advantages of cellular systems with small cells are the following:

1. Higher capacity:

- Implementing SDM allows frequency reuse. If one transmitter is far away from another, i.e., outside the interference range, it can reuse the same frequencies.
- As most mobile phone systems assign frequencies to certain users (or certain hopping patterns), this frequency is blocked for other users. But frequencies are a scarce resource and, the number of concurrent users per cell is very limited.
- Huge cells do not allow for more users. On the contrary, they are limited to less possible users per km^2. This is also the reason for using very small cells in cities where many more people use mobile phones.

2.Less transmission power:

- While power aspects are not a big problem for base stations, they are indeed problematic for mobile stations. A receiver far away from a base station would need much more transmit power than the current few Watts. But energy is a serious problem for mobile handheld devices

3.Local interference only:

- Having long distances between sender and receiver results in even 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, this only influences communication within a small area

Small cells also have some disadvantages:

1. Infrastructure needed:

- Cellular systems need a complex infrastructure to connect all base stations. This includes many antennas, switches for call forwarding, location registers to find a mobile station etc, which makes the whole system quite expensive

2.Handover needed:

- The mobile station has to perform a handover when changing from one cell to another. Depending on the cell size and the speed of movement, this can happen quite often.

3.Frequency planning:

- To avoid interference between transmitters using the same frequencies, frequencies have to be distributed carefully. On the one hand, interference should be avoided, on the other, only a limited number of frequencies is available.

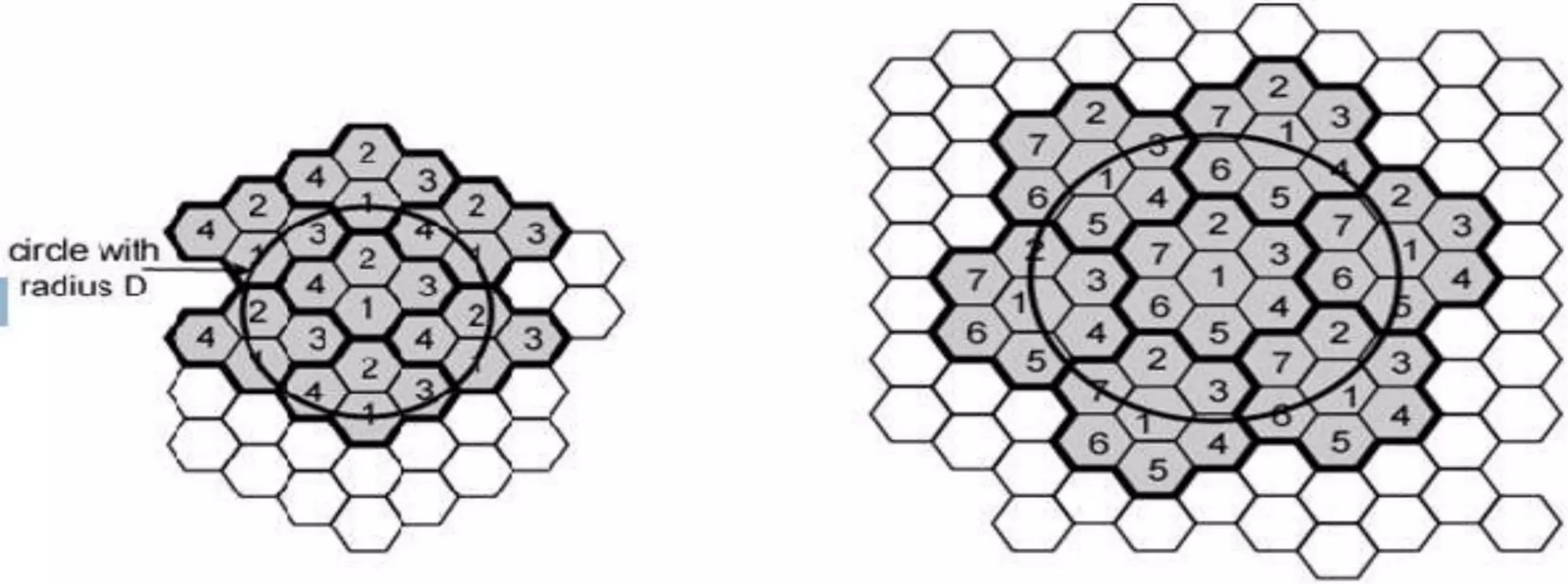
Frequency Reuse

- Each cellular base station is allocated a group of radio channels or Frequency sub-bands to be used within a small geographic area known as a cell. The shape of the cell is Hexagonal.
- ***The process of selecting and allocating the frequency sub-bands for all of the cellular base station within a system is called Frequency reuse or Frequency Planning.***

Salient features of using Frequency Reuse:

1. Frequency reuse improve the spectral efficiency and signal Quality (QoS).
2. Frequency reuse offers a protection against interference.
3. The number of times a frequency can be reused is depending on the tolerance capacity of the radio channel from the nearby transmitter that is using the same frequencies.
4. In Frequency Reuse scheme, total bandwidth is divided into different sub-bands that are used by cells.

Frequency Reuse Patterns



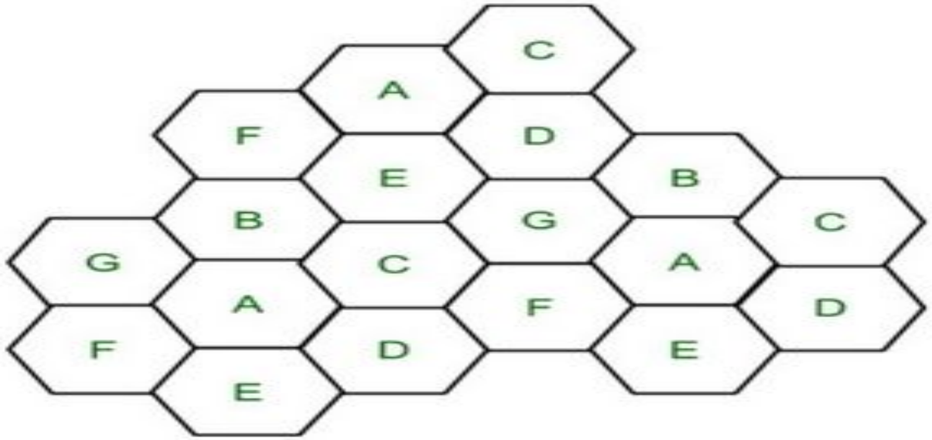
(a) Frequency reuse pattern for N = 4 (b) Frequency reuse pattern for N = 7

Locating co-channel cells

- To find the total number of channel allocated to a cell:
- S = Total number of duplex channels available to use
- k = Channels allocated to each cell (k<S)
- N = Total number of cells or Cluster Size
- Then Total number of channels (S) will be,

$$S = kN$$

$$\text{Frequency Reuse Factor} = 1/N$$



- Cell with the same letter uses the same set of channels group or frequencies sub-band. In the above diagram cluster size is 7 (A,B,C,D,E,F,G) thus frequency reuse factor is 1/7.
- N is the ***number of cells which collectively use the complete set of available frequencies is called a Cluster***. The value of N is calculated by the following formula:

$$N = I^2 + I*J + J^2$$

- Where **I,J** = 0,1,2,3… Hence, possible values of N are 1,3,4,7,9,12,13,16,19 and so on

- If a Cluster is replicated or repeated M times within the cellular system, then Capacity, C, will be,

$$C = MkN = MS$$

- ***In Frequency reuse there are several cells that use the same set of frequencies. These cells are called Co-Channel Cells***. These Co-Channel cells results in interference.
- So to avoid the Interference cells that use the same set of channels or frequencies are separated from one another by a larger distance.
- The distance between any two Co-Channels can be calculated by the following formula:

$$D = R * (3 * N)^{1/2}$$

- Where, R = Radius of a cell N = Number of cells in a given cluster.

Advantages :

1. **Improved Spectral Efficiency**: By reusing the same frequency in different geographic areas, spectral efficiency can be improved, enabling more efficient spectrum usage.
2. **Better Quality of Service**: With the ability to reuse the same frequency in different cells, the interference between cells can be minimized, leading to better quality of service.
3. **Cost-Effective:** Frequency reuse can reduce the cost of building a cellular network since fewer frequency bands are required.
4. **Increased Network Capacity**: Frequency reuse allows more cells to be served with the same amount of spectrum, resulting in increased network capacity.
5. **Scalability:** Frequency reuse enables the network to be easily scaled by adding more cells as needed.

Disadvantages:

1. **Increased Interference**: Frequency reuse can result in increased interference, particularly in areas where cells are closely spaced. This can reduce the quality of service and network capacity.
2. **Implementation Complexity**: Frequency reuse requires careful planning to ensure that cells are appropriately spaced and that interference is minimized. This can make the implementation process more complex and time-consuming.
3. **Reduced Coverage**: With the use of smaller cells to achieve higher capacity, the coverage area of each cell is reduced, requiring more base stations and infrastructure.
4. **Increased Power Consumption**: Due to the use of smaller cells, more base stations are required, leading to higher power consumption and operational costs.
5. **Increased Network Cost:** The cost of implementing a frequency reuse system may be higher due to the need for additional infrastructure and careful planning to ensure proper frequency reuse

Assignments of frequencies to cells

fixed channel allocation (FCA)

- The fixed assignment of frequencies to cell clusters and cells respectively, It is not very efficient if traffic load varies.
- FCA is used in the GSM system as it is much simpler to use, but it requires careful traffic analysis before installation

borrowing channel allocation (BCA)

- For instance, in the case of a heavy load in one cell and a light load in a neighboring cell, it could make sense to 'borrow' frequencies. Cells with more traffic are dynamically allotted more frequencies.

dynamic channel allocation (DCA)

- frequencies can only be borrowed, but it is also possible to freely assign frequencies to cells.
- With dynamic assignment of frequencies to cells, the danger of interference with cells using the same frequency exists. The 'borrowed' frequency can be blocked in the surrounding cells
- scheme has been implemented in DECT (Digital Enhanced Cordless Telecommunicetion)

Methods of Increasing Cell Capacity

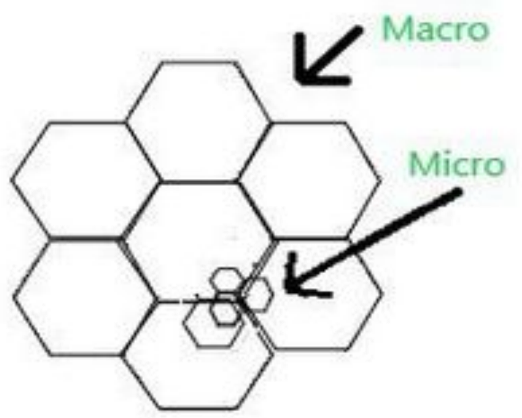
- Why do we need more capacity?

1. With the growing number of mobile users, it is important for the cellular capacity to also keep growing to meet the needs of the users.
2. Share more information throughout the network
3. New technologies will require more complex solutions that can be achieved with more space available

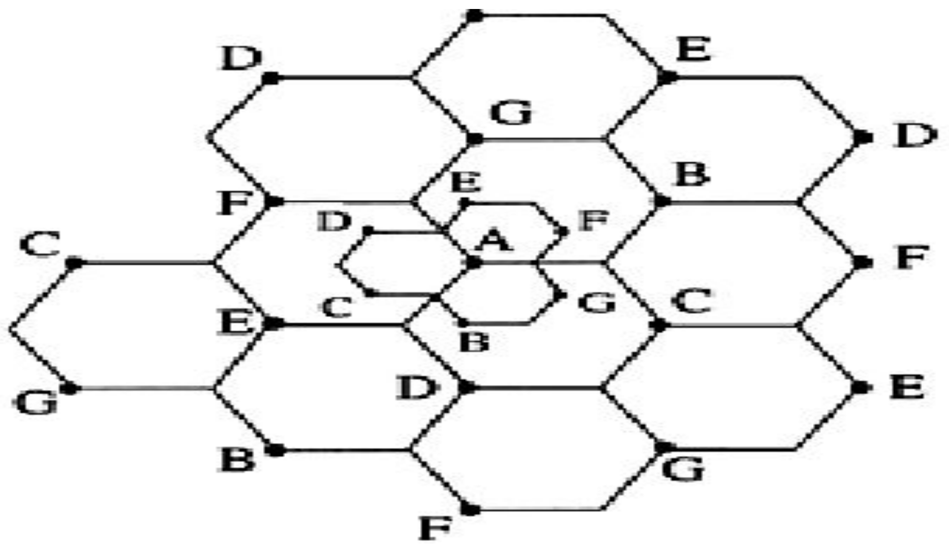
- There are basically three ways of increasing cell capacity

1. Cell Splitting
2. Cell Sectoring
3. Microcells

1. Cell Splitting



- Cell Splitting is the process of subdividing a cell into smaller cells each with its own Base Station
- In splitting, ***new cells with smaller radius are added called microcells***. Each new cell created is independent and has reduced antenna height and transmitter power.
- The creation of new smaller cells increases the capacity of the system as a whole.
- Cell Splitting increases the frequency reuse factor. A higher frequency reuse factor increases the capacity of the cellular system in Cell Splitting.



- In figure 1, the original base station A has been surrounded by six new microcells.
- The smaller cells were added in such a way to preserve the frequency reuse plan of the system.
- For example, the microcell base station labeled G was placed half way between two larger stations utilizing the same channel set G.
- In this case, the radius of each new microcell is half that of the original cell.

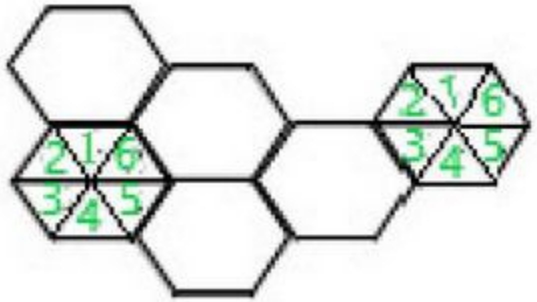
Advantages

1. Increases the capacity of the channel considerably.
2. Enhances dependability of cellular networks.
3. Increases the frequency reuse factor.
4. Increases signal-to-noise (SNR) ratio.
5. Reduces interference.

Disadvantages

1. For each individual cell, an individual base station is required so a huge number of base stations are needed in this process.
2. Handoff occurs frequently.
3. Assigning channels is difficult

2. Cell Sectoring



- Cells are divided into a number of wedge-shaped sectors, each with its own set of channels.
- By wedge-shaped we mean that the cells are divided at an angle of 120° or 60°. These sectored cells are called microcells.
- Like Cell Splitting, it also helps in increasing channel capacity and decreases channel interference. 3 or 6 sectors are created from a given cell.
- But unlike Cell Splitting, here the cell radius does not change after sectoring the cells although the co-channel reuse ratio has decreased.
- It increases system performance by using a directional antenna

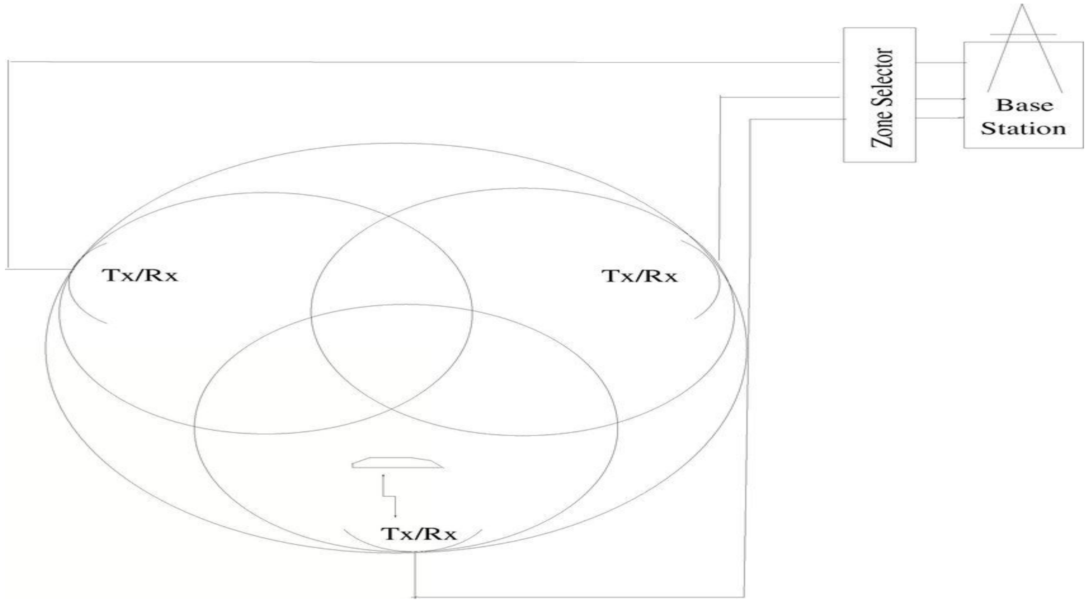
Advantages

1. Sectoring increases the signal-to-interference ratio which means the cluster size gets reduced.
2. Reduces interference without altering the system performance.
3. Increases channel capacity without necessarily changing the cell radius.
4. Increases frequency reuse by reducing the number of cells in the cluster.
5. Assigning a channel is easier.

Disadvantages

1. Increases the number of antennas per base station.
2. It decreases efficiency as sectoring reduces the channel groups.
3. Excessive interference leads to traffic loss.
4. The number of handoffs increases as the working area of the cell decreases in Cell Sectoring.

3. Using a Microcell



- A microcell is a device in a cellular network that is linked to a tower and is used to enhance or extend the signal strength in a certain small area, often a public places such as airports, malls and other crowded places
- a microcell provides a small region of coverage with a strong signal strength for more devices to connect or where service is poor or non-existent.

- The range of a microcell is a few hundred meters, and it is controlled by the tower by changing the voltage value.
- High density areas are served by placing more cells in the region to optimize capacity.
- Large control base station is replaced by several lower powers transmitters on the edge of the cell.
- The mobile retains the same channel and the same base station simply switches the channel to a different zone site and the mobile moves from zone to zone
- Since a given channel is active only in a particular zone in which mobile is travelling, base station radiation is localized and interference is reduced

Benefits of the micro-cell zone concept:

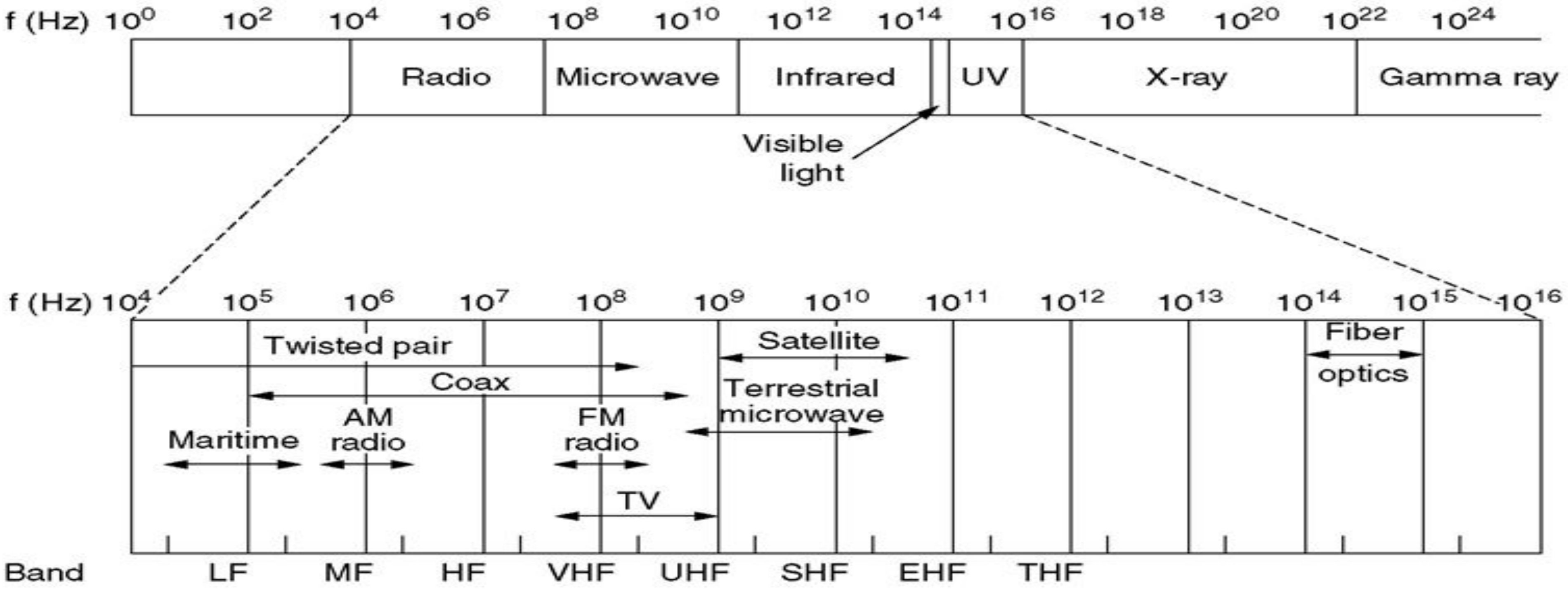
1) Interference is reduced in this case as compared to the scheme in which the cell size is reduced.

2) Handoffs are reduced (also compared to decreasing the cell size) since the micro- cells within the cell operate at the same frequency; no handover occurs when the mobile unit moves between the microcells.

3) Size of the zone apparatus is small. The zone site equipment being small can be mounted on the side of a building or on poles.

4) System capacity is increased. The new microcell knows where to locate the mobile unit in a particular zone of the cell and deliver the power to that zone. Since the signal power is reduced, the microcells can be closer and result in an increased system capacity.

The Electromagnetic Spectrum



The electromagnetic spectrum and its uses for communication.

Type of wave	Range of frequency and wavelength	Applications
Radio wave	$f < 1 \times 10^9$ Hz $\lambda > 30$ cm	AM and FM radio; television broadcasting; radar; aircraft navigation
Microwave	$1 \times 10^9 \text{ Hz} < f < 3 \times 10^{11}$ Hz $30 \text{ cm} > \lambda > 1$ mm	Atomic and molecular research; microwave ovens
Infrared (IR) wave	$3 \times 10^{11} \text{ Hz} < f < 4.3 \times 10^{14}$ Hz $1 \text{ mm} > \lambda > 700$ nm	Infrared photography; remote-control devices; heat radiation
Visible light	$4.3 \times 10^{14} \text{ Hz} < f < 7.5 \times 10^{14}$ Hz $700 \text{ nm (red)} > \lambda > 400 \text{ nm (violet)}$	Visible-light photography; optical microscopes; optical telescopes
Ultraviolet (UV) light	$7.5 \times 10^{14} \text{ Hz} < f < 5 \times 10^{15}$ Hz $400 \text{ nm} > \lambda > 60$ nm	Sterilizing medical instruments; identifying fluorescent minerals
X ray	$5 \times 10^{15} \text{ Hz} < f < 3 \times 10^{21}$ Hz $60 \text{ nm} > \lambda > 1 \times 10^{-4}$ nm	Medical examination of bones, teeth, and organs; cancer treatments
Gamma ray	$3 \times 10^{18} \text{ Hz} < f < 3 \times 10^{22}$ Hz $0.1 \text{ nm} > \lambda > 1 \times 10^{-5}$ nm	Food irradiation; studies of structural flaws in thick materials

Antenna

- An Antenna is a transducer, which converts electrical power into electromagnetic waves and vice versa.
- An Antenna can be used either as a **transmitting antenna** or a **receiving antenna**.
- A **transmitting antenna** is one, which converts electrical signals into electromagnetic waves and radiates them.
- A **receiving antenna** is one, which converts electromagnetic waves from the received beam into electrical signals.
- In two-way communication, the same antenna can be used for both transmission and reception.
- Antenna can also be termed as an **Aerial**.
- **Antenna** has the capability of sending or receiving the electromagnetic waves for the sake of communication, where you cannot expect to lay down a wiring system

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, Concaveconcave 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

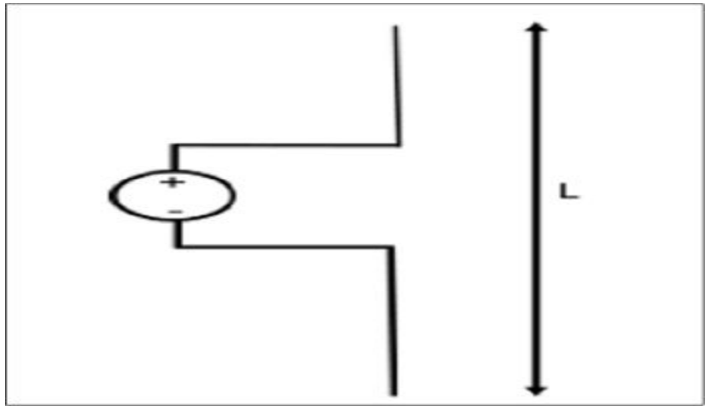
1.Wire Antennas

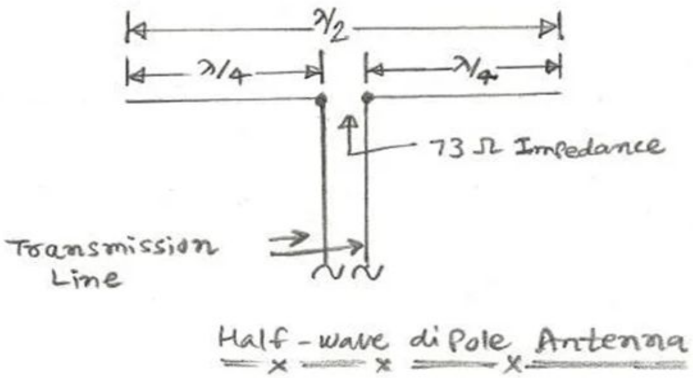
- They can be found in vehicles (automobiles), ships, aircrafts, buildings etc. Wire Antennas come in different shapes and sizes like straight wire (Dipole), Loop and Helix.
- Radiation Pattern :omni-directional pattern.

A. Dipole Antenna

- A Dipole Antenna is made up two conductors in the same axis and the length of the wire need to be small compared to the wavelength.
- In its simplest form, it is basically an open circuit wire with the signal being fed at the centre.
- The length of the wire is less than the one tenth of the wavelength of the frequency of operation.

- If both the ends of transmission line are connected to circuits, then the information will be transmitted or received using this wire between these two circuits.
- If one end of this wire is not connected, then the power in it tries to escape. This leads to wireless communication. If one end of the wire is bent, then the energy tries to escape from the transmission line, more effectively than before. This purposeful escape is known as **Radiation**
- For the radiation to take place effectively, the impedance of the open end of the transmission line should match with the impedance of the free-space.
- The radiation of energy when done through such a bent wire, the end of such transmission line is termed as **dipole** or dipole antenna





- The length of the total wire, which is being used as a dipole, equals half of the wavelength (i.e., $l = \lambda/2$). Such an antenna is called as **half-wave dipole antenna**. This is the most widely used antenna because of its advantages. It is also known as **Hertz antenna**.
- **Frequency range**
- The range of frequency in which half-wave dipole operates is around 3KHz to 300GHz. This is mostly used in radio receivers.
- If the length of the dipole, i.e. the total wire, equals the full wavelength ($L=\lambda$), then it is called as **full wave dipole**.
- The **Short dipole** is the dipole antenna having the length of its wire shorter than the wavelength. The wire that leads to the antenna must be less than one-tenth of the wavelength

B.Monopole Antenna

- A special case of Dipole antenna is the monopole antenna i.e. it is half of the dipole antenna.

C. Loop Antenna

- A Loop antenna is formed by a single or multiple turn of wire forming a loop. The radiation produced by loop antenna is comparable to a short dipole antenna.
- An RF current carrying coil is given a single turn into a loop, can be used as an antenna called as **loop antenna**. The currents through this loop antenna will be in phase. The magnetic field will be perpendicular to the whole loop carrying the current.
- **Frequency Range**
- The frequency range of operation of loop antenna is around **300MHz to 3GHz**. This antenna works in **UHF** range.

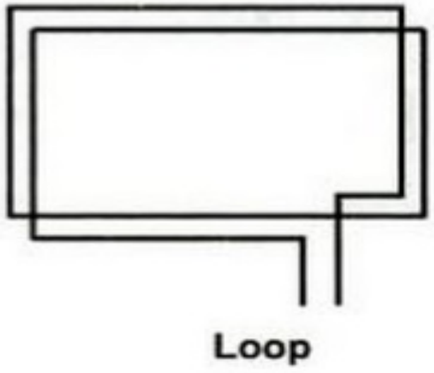
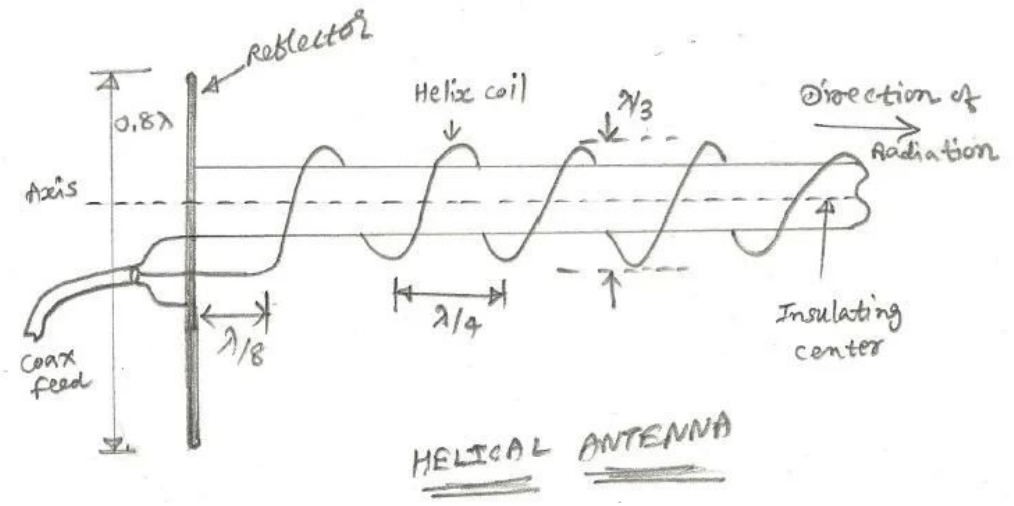


Fig 1: Circular loop antenna

Fig 2: Square loop antenna

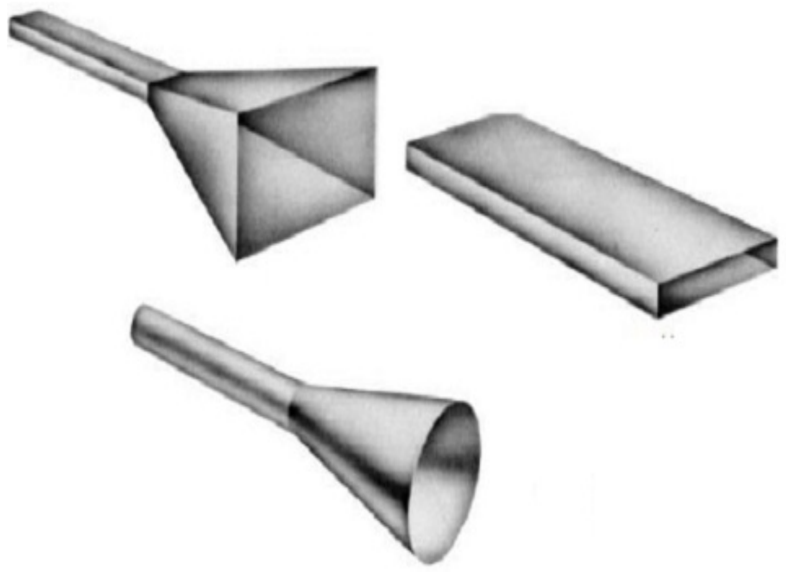
D. Helical antenna or helix antenna

- It is the antenna in which the conducting wire is wound in helical shape and connected to the ground plate with a feeder line. It is the simplest antenna, which provides **circularly polarized waves**.
- **Frequency Range**
- The frequency range of operation of helical antenna is around **30MHz to 3GHz**. This antenna works in **VHF** and **UHF** ranges.
- This is a broadband VHF and UHF antenna. It is used in extra-terrestrial communications in which satellite relays etc., are involved



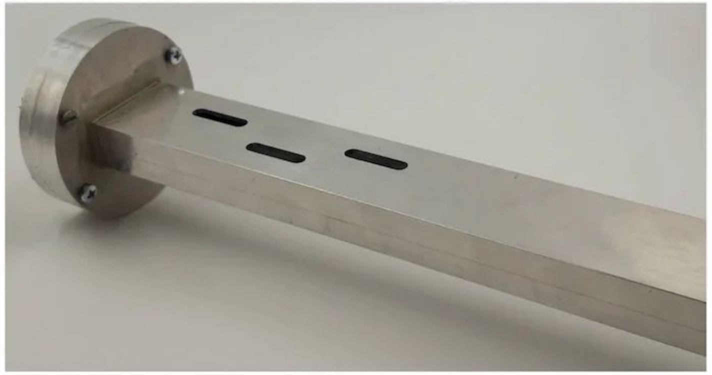
2.Aperture Antennas

- An Antenna with an aperture at the end can be termed as an **Aperture antenna**
- The edge of a transmission line when terminated with an opening(aperture), radiates energy.
- Usually, aperture antenna consists of Dipole or Loop Antenna in a guiding structure with an opening to emit radio waves.



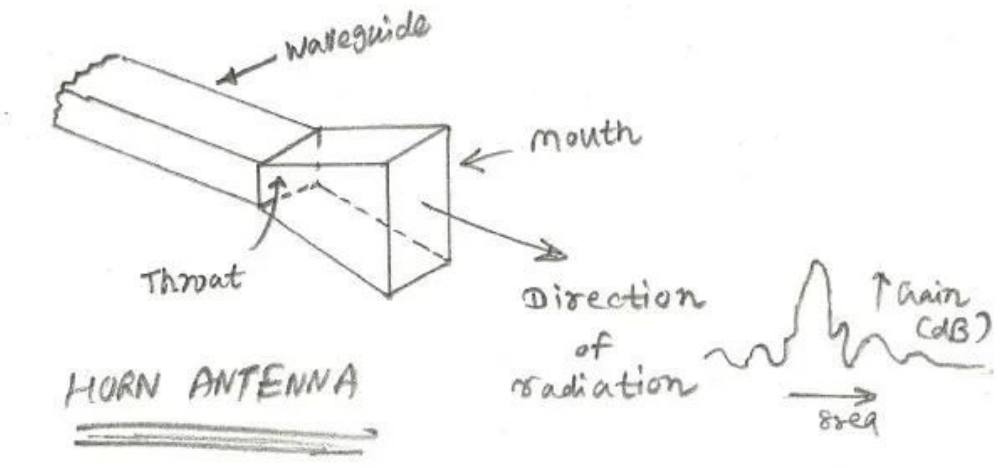
A. Slot Antenna

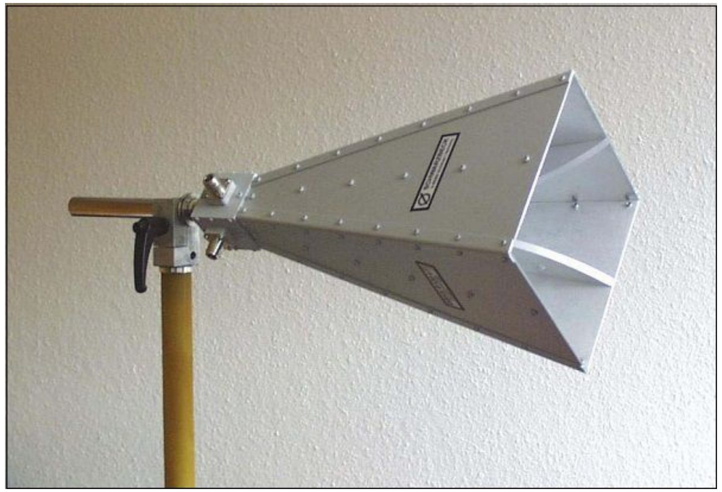
- **Slot Antenna** is an example of Aperture antenna. A rectangular slot is made on the conducting sheet. These slot antennas can be formed by simply making a cut on the surface, where they are mounted on.
- **Frequency Range**
- The frequency range used for the application of Slot antenna is **300 MHz to 30 GHz**. It works in **UHF** and **SHF** frequency ranges.
- A type of aperture antenna which contains one or more slots cut on the surface of the waveguide. They are usually used in microwave frequencies.
- The radiation pattern of the Slot antenna is **Omni-directional.**



B. Horn Antenna

- To improve the radiation efficiency and directivity of the beam, the wave guide should be provided with an extended aperture to make the abrupt discontinuity of the wave into a gradual transformation. So that all the energy in the forward direction gets radiated. This can be termed as **Flaring**.
- A **Horn antenna** may be considered as a **flared out wave guide**, by which the directivity is improved and the diffraction is reduced.
- **Frequency Range**
- The operational frequency range of a horn antenna is around **300MHz to 30GHz**. This antenna works in **UHF** and **SHF** frequency ranges.
- Horn antenna is used in satellite/microwave applications
- The radiation pattern of a horn antenna is a **Spherical Wave front**.





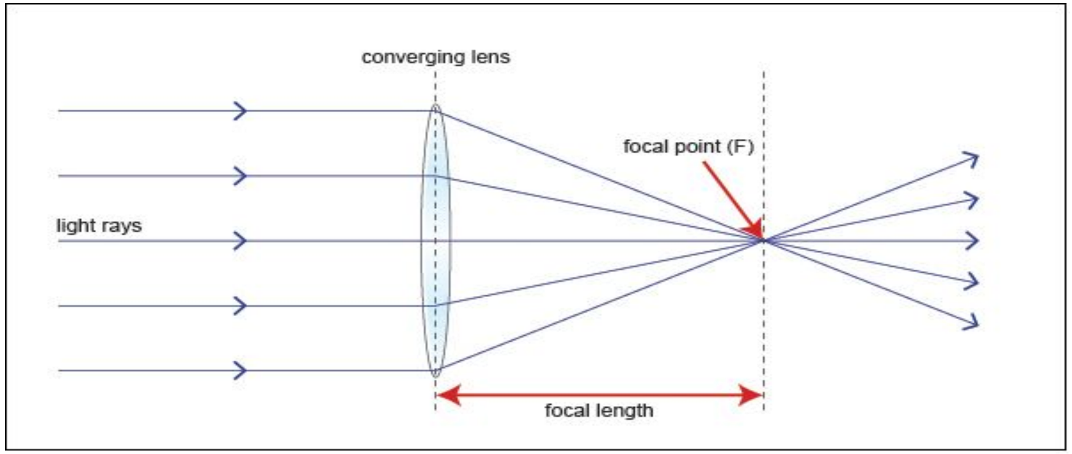
3.Parabolic Reflector Antenna

- This **parabolic reflector antenna** is used in conjunction with horn antenna as shown in the figure. It is made of metal or screen mesh.
- During transmission EM-waves fall on to the wide dish and gets radiated into the air, while during reception EM- waves fall on to the dish and gets focused to the horn antenna.
- **Frequency Range**
- The frequency range used for the application of Parabolic reflector antennas is **above 1MHz.** These antennas are widely used for radio and wireless applications.

[Transmission and reception using Parabolic Reflector Antenna]

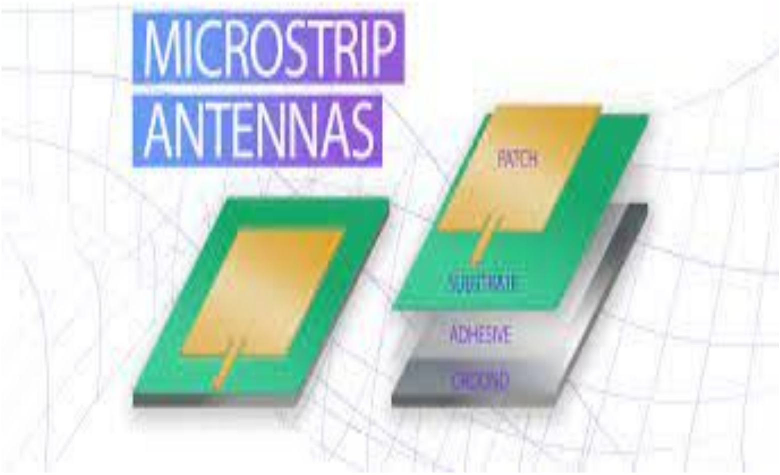
4.Lens antennas

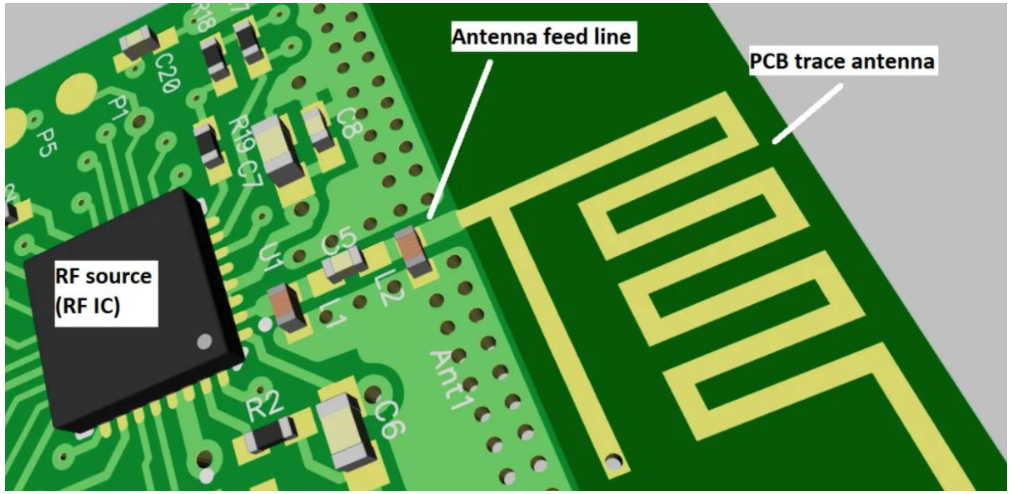
- The lens antennas use the curved surface for both transmission and reception. **Lens antennas** are made up of glass, where the converging and diverging properties of lens are followed. A normal glass lens works on the principle of refraction.
- **Frequency Range**
- The frequency range of usage of lens antenna starts at **1000 MHz** but its use is greater at **3000 MHz and above**
- The lens antennas are used for higher frequency applications.



5.Micro strip antennas

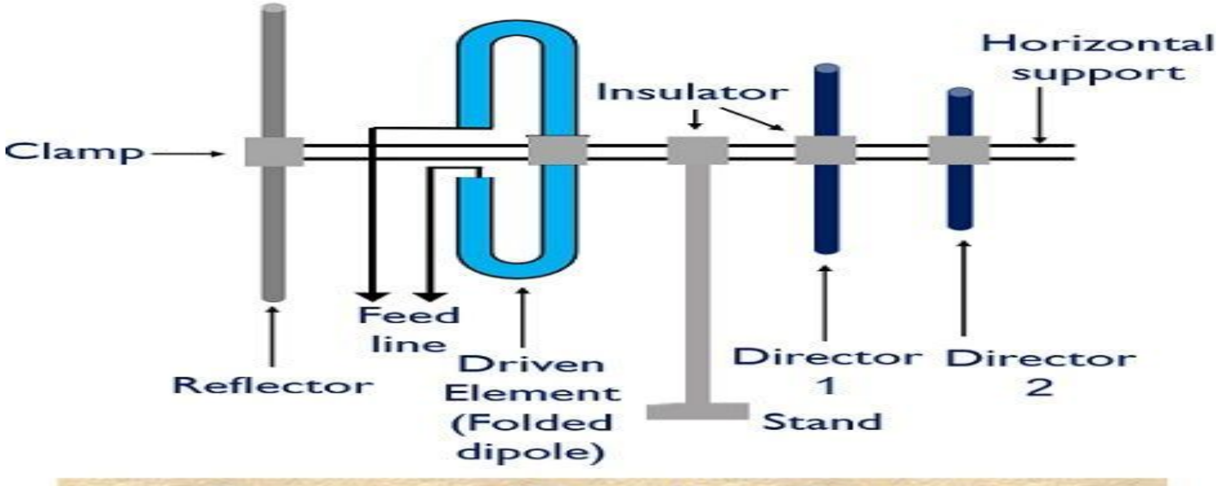
- Micro strip antennas are low-profile antennas. A metal patch mounted at a ground level with a di-electric material in-between constitutes a **Micro strip** or **Patch Antenna**. These are very low size antennas having low radiation.
- **Frequency Range**
- The patch antennas are popular for low profile applications at frequencies above **100MHz**.
- The radiation pattern of microstrip or patch antenna is **broad**





6. Array Antenna

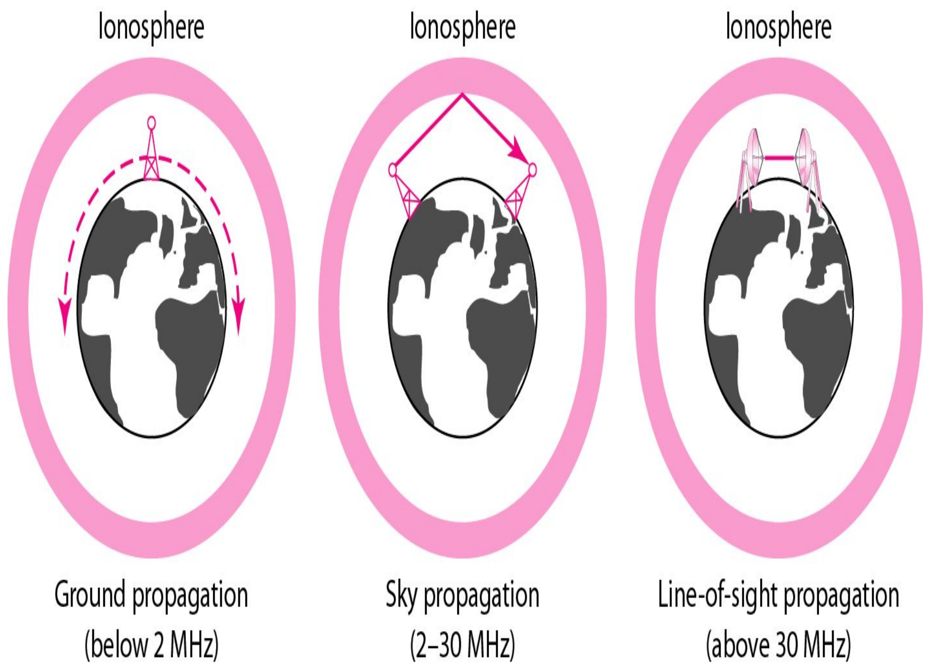
- **Yagi-Uda antenna** is the most commonly used type of antenna for TV reception over the last few decades. It is the most popular and easy-to-use type of antenna with better performance, which is famous for its high gain and directivity
- **Frequency range** : **30 MHz to 3GHz** which belong to the **VHF** and **UHF** bands.
- It is seen that there are many directors placed to increase the directivity of the antenna. The feeder is the folded dipole. The reflector is the lengthy element, which is at the end of the structure
- The directional pattern of the Yagi-Uda antenna is **highly directive**



Structure of Yagi-Uda Antenna

Signal Propagation methods

Band	*Range*	*Propagation*	*Application*
VLF (very low frequency)	3–30 kHz	Ground	Long-range radio navigation
LF (low frequency)	30–300 kHz	Ground	Radio beacons and navigational locators
MF (middle frequency)	300 kHz–3 MHz	Sky	AM radio
HF (high frequency)	3–30 MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF (very high frequency)	30–300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF (ultrahigh frequency)	300 MHz–3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF (superhigh frequency)	3–30 GHz	Line-of-sight	Satellite communication
EHF (extremely high frequency)	30–300 GHz	Line-of-sight	Radar, satellite



1.Ground Wave Propagation

- The wave when propagates through the Earth's atmosphere is known as **ground wave**.
- 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**
- 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.

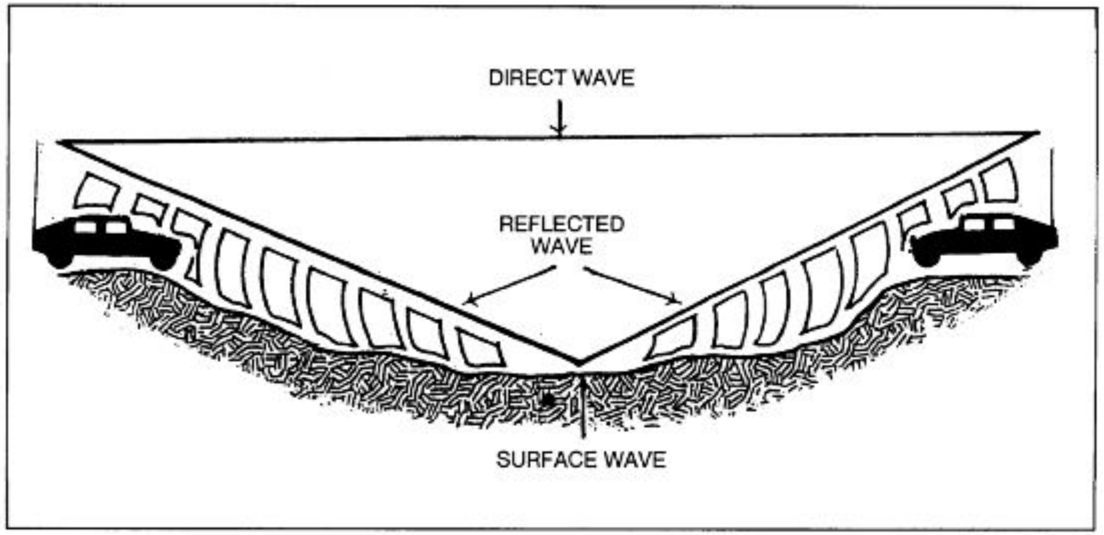
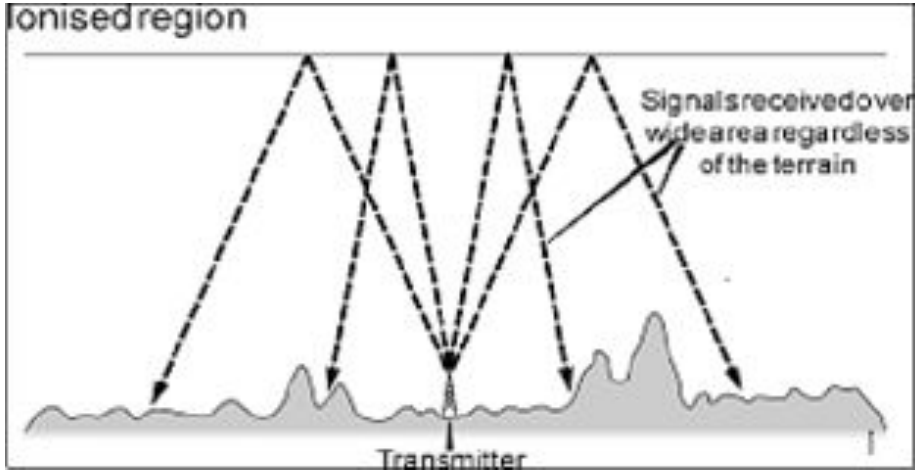


Figure D-2. Components of ground wave.

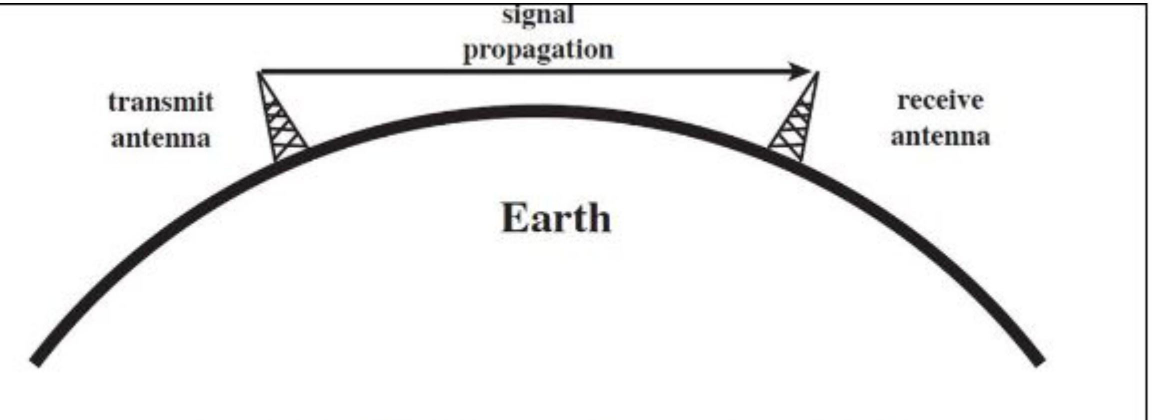
2.Sky Wave Propagation

- Sky wave propagation is preferred when the wave has to travel a longer distance.
- The waves, which are transmitted from the transmitter antenna, are reflected from the ionosphere back onto the earth.
- Ionosphere is the ionized layer around the Earth's atmosphere, which is suitable for sky wave propagation**.** 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.**



3.Line of Sight (LOS) Propagation

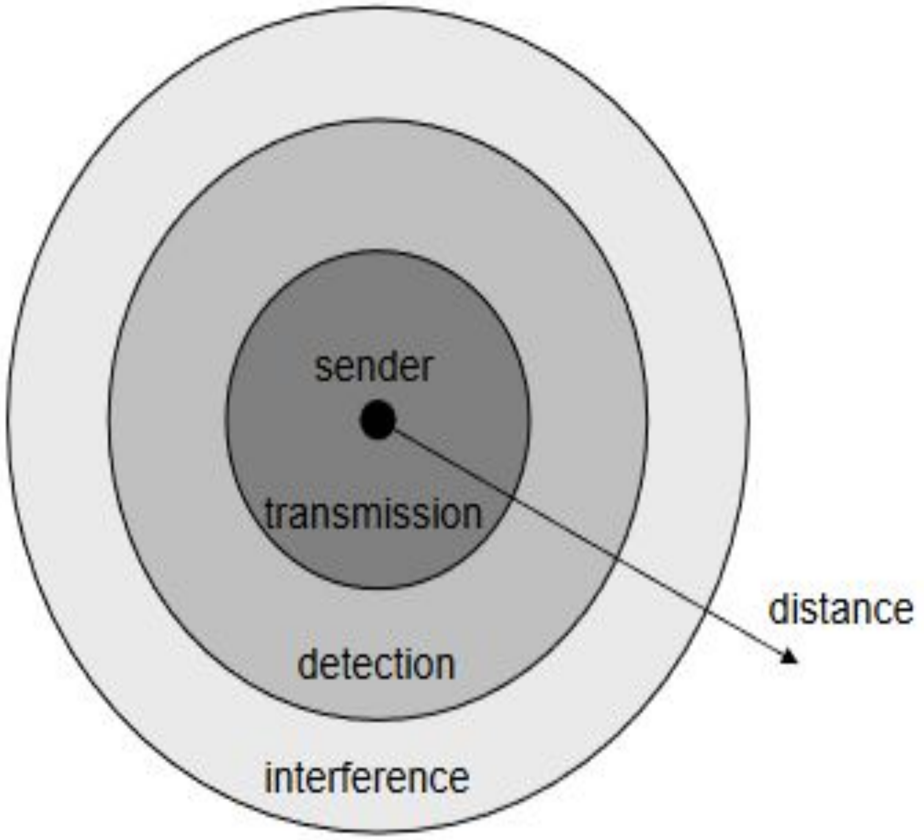
- In the **line-of-sight communication**, as the name implies, the wave travels a minimum distance of sight.
- The line-of-sight propagation will not be smooth if there occurs any obstacle in its transmission path.
- As the signal can travel only to lesser distances in this mode, this transmission is used for **infrared** or **microwave transmissions**.



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

Signal propagation ranges

- Transmission range
- communication possible in both directions
- relatively low error rate
- Detection range
- detection of the signal possible
- no communication possible
- error rate too high
- Interference range
- signal may not be detected
- signal adds to the background noise
- may interfere other transmissions



Transmission Limitations

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.

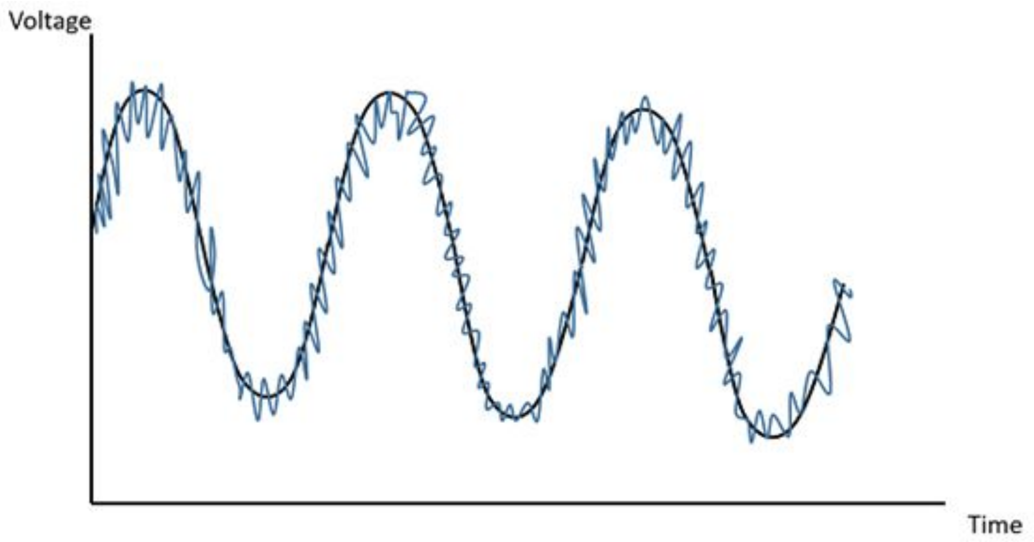
Dispersion

- Dispersion is the phenomenon of spreading of a burst of electromagnetic energy during propagation.

Noise

The most pervasive form of noise is thermal noise. Thermal noise is due to thermal agitation of electrons and is uniformly distributed across the frequency spectrum.

- **Inter modulation noise** (caused by signals produced at frequencies that are sums or differences of carrier frequencies)
- **Crosstalk** (interference between two signals)
- **Impulse noise** (irregular pulses of high energy caused by external electromagnetic disturbances).
- While an impulse noise may not have a significant impact on analog data, it has a noticeable effect on digital data, causing **burst errors**.



The noise signal overlaps the original signal and tries to change its characteristics.

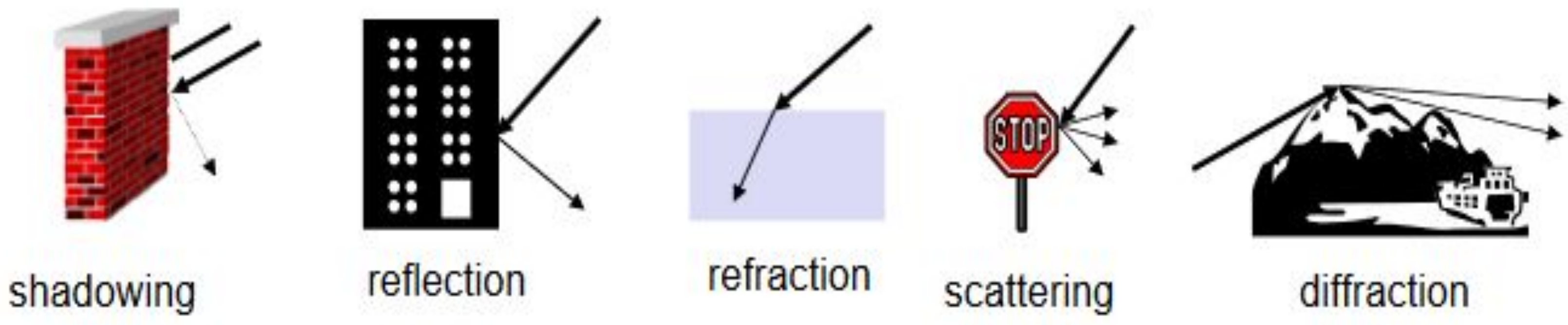
• Multipath propagation

- Propagation of signal in free space is always like light (straight line). If such straight line exist between sender and receiver it is known as line of sight
- The signal experiences free path loss even no object exists between sender and receiver. This is because receiving power is proportional to $1/d^2$ in vacuum

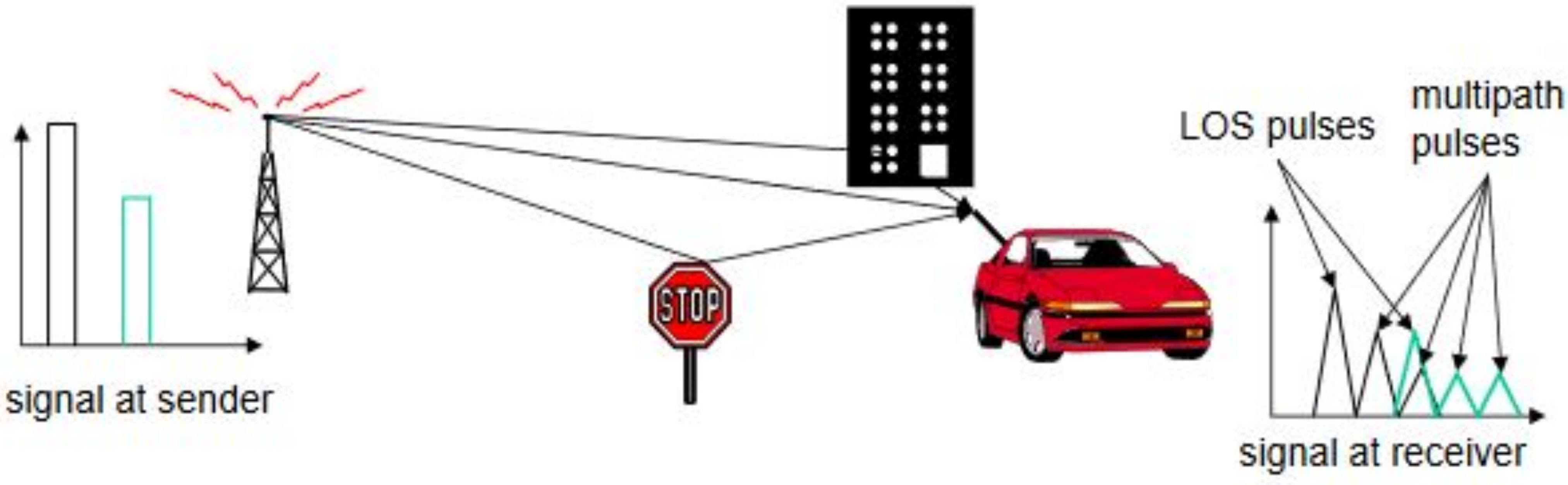
  (d = distance between sender and receiver)
- Receiving power in real environments additionally affected by

1. fading due to the atmosphere and large distances
2. shadowing
3. reflection at large obstacles
4. refraction depending on the density of a medium
5. scattering at small obstacles
6. diffraction at edges

- **Reflection** occurs when the signal encounters a large solid surface, whose size is much larger than the wavelength of the signal, e.g., a solid wall.
- **Refraction** occurs because the velocity of electromagnetic waves depends on the density of medium through which it travel
- **Diffraction** occurs when the signal encounters an edge or a corner, whose size is larger than the wavelength of the signal, e.g., an edge of a wall.
- **Scattering** occurs when the signal encounters small objects of size smaller than the wavelength of the signal



- One consequence of multipath propagation is that multiple copies of a signal propagation along multiple different paths, arrive at any point at different times.
- Radio waves emitted by the sender can either travel along a straight line, or they may be reflected at a large building, or scattered at smaller obstacles..
- So the signal received at a point is not only affected by the **inherent noise, distortion, attenuation**, and **dispersion** in the channel but also the **interaction of signals** propagated along multiple paths.

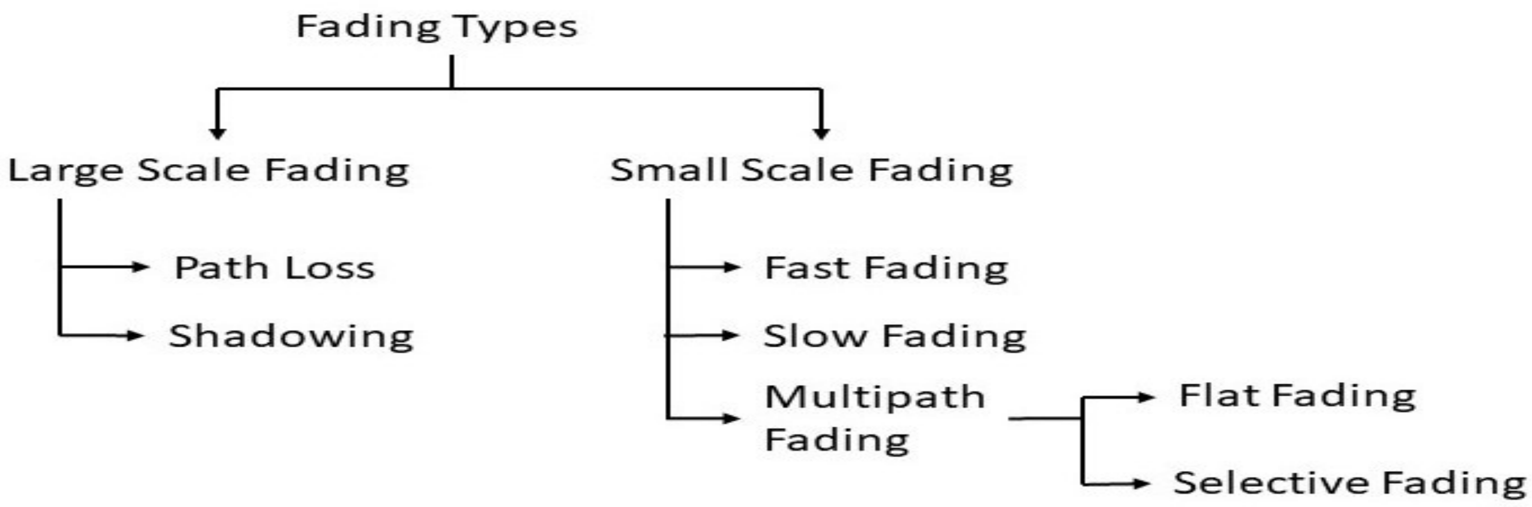


- Due to the finite speed of light, signals travelling along different paths with different lengths arrive at the receiver at different times. This effect (caused by multi-path propagation) is called delay spread.
- On the sender side, both impulses are separated. At the receiver, both impulses interfere, i.e., they overlap in time. Now consider that each impulse should represent a symbol(a pulse in digital baseband transmission that *persists*, for a fixed period of time), and that one or several symbols could represent a bit.
- The energy intended for one symbol now spills over to the adjacent symbol, an effect which is called intersymbol interference (ISI).
- The higher the symbol rate to be transmitted, the worse the effects of ISI will be, as the original symbols are moved closer and closer to each other.
- Due to this interference, the signals of different symbols can cancel each other out leading to misinterpretations at the receiver and causing transmission errors.

Fading

- Fading is a phenomenon that occurs due to varying parameters and conditions of the channel during wireless propagation. **Fading refers to the variation of the signal strength with respect to time/distance and is widely prevalent in wireless transmissions**.
- The most common causes of fading in the wireless environment are

1. multipath propagation and
2. mobility (of objects as well as the communicating devices).



- **Large Scale Fading**: **This refers to the attenuation of signal power due to obstacles between the transmitter and receiver**. It also covers the attenuation and fluctuations of signal when the signal is transmitted over a long distance (usually in kilometres).

a) Path Loss: It refers to the attenuation when a signal is transmitted over large distances. Wireless signals spread as they propagate through the medium and as the distance increases, the energy per unit area starts decreasing .This is a fundamental loss that is independent of the type of transmitter and medium. Although, we can minimize its effects by increasing the capture area/dimension of the receiver.

b) Shadowing: This refers to the loss in signal power due to the obstructions in the path of propagation. There are a few ways in which shadowing effects can minimize signal loss. One that is most effective, is to have a Line-Of-Sight propagation.

Shadowing losses also depend on the frequency of the EM wave. As we know, EM Waves can penetrate through various surfaces but at the cost of loss in power i.e signal attenuation. The losses depend on the type of the surface and frequency of the signal. Generally, the penetration power of a signal is inversely proportional to the frequency of the signal

- **Small Scale Fading**: **This refers to the fluctuations in signal strength and phase over short distance and small duration of time**. It is also called Rayleigh Fading. Small Scale Fading affects almost all forms of wireless communication and overcoming them is a necessity to increase efficiency and decrease error.
- **Doppler spread**
- This is a measure of **spectral broadening** caused by the rate of change of the mobile radio channel. It is caused by either relative motion between the mobile and base station or by the movement of objects in the channel.

a) When the velocity of the mobile is high, the Doppler spread is high, and the resulting channel variations are faster than that of the baseband signal, this is referred to as **fast fading**.

b) When channel variations are slower than the baseband signal variations, then the resulting fading is referred to as **slow fading**.

c) Multipath Fading: It occurs when a signal reaches the receiver from various path i.e. when multipath propagation takes place.

Multipath fading can affect all ranges of frequencies starting from low frequency to microwave and beyond.

It affects both the amplitude and the phase of the signal causing phase distortions and ISI. Multipath fading can affect signal transmission in two ways:

1. Flat Fading: In flat fading, all frequency components get affected almost equally. Flat multipath fading causes the amplitude to fluctuate over a period of time.

2. Selective Fading: Selective Fading or Selective Frequency Fading refers to multipath fading when the selected frequency component of the signal is affected.

It means selected frequencies will have increased error and attenuation as compared to other frequency components of the same signal.

Multiplexing

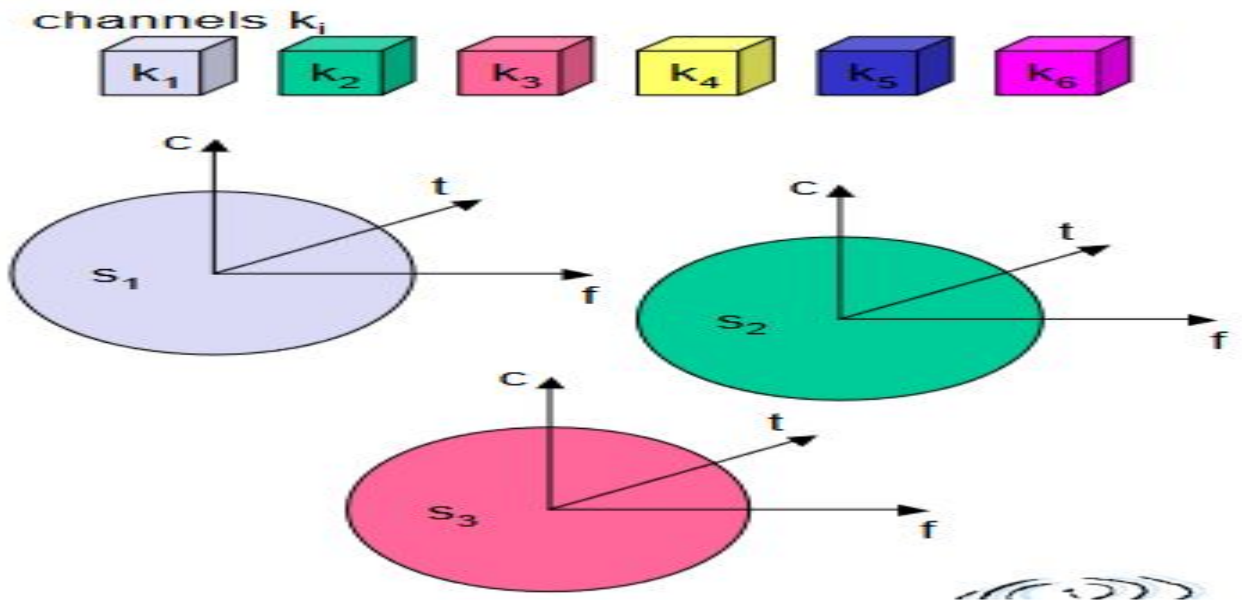
- **Multiplexing** is the sharing of a medium or bandwidth. It is the process in which multiple signals coming from multiple sources are combined and transmitted over a single communication/physical line.
- Multiplexing describes how several users can share a medium with minimum or no interference
- The main motive behind the development of Multiplexing is to provide simple and easy communication, proper resource sharing and its utilization. This is the best way to utilize and share a limited resource equally among multiple devices.

- One example, is highways with several lanes. Many users (car drivers) use the same medium (the highways) with hopefully no interference (i.e., accidents).
- This is possible due to the provision of several lanes (space division multiplexing) separating the traffic.
- In addition, different cars use the same medium (i.e., the same lane) at different points in time (time division multiplexing)
- **Types of Multiplexing**
  There are Four types of Multiplexing :
- Frequency Division Multiplexing (FDM)
- Time-Division Multiplexing (TDM)
- Code-division multiplexing (CDM)
- Space-division multiplexing (SDM):

Space division multiplexing (SDM)

- Space Division Multiplexing is a technique used in wireless communication systems to increase the capacity of the system by exploiting the physical separation of users
- SDM is commonly used in wireless communication systems such as cellular networks, Wi-Fi, and satellite communication systems. It is used in GSM (Global Service for Mobile) Technology.
- In cellular networks, SDM is used in the form of Multiple Input Multiple Output (MIMO) technology, which uses multiple antennas at both the transmitter and receiver ends to improve the quality and capacity of the communication link.

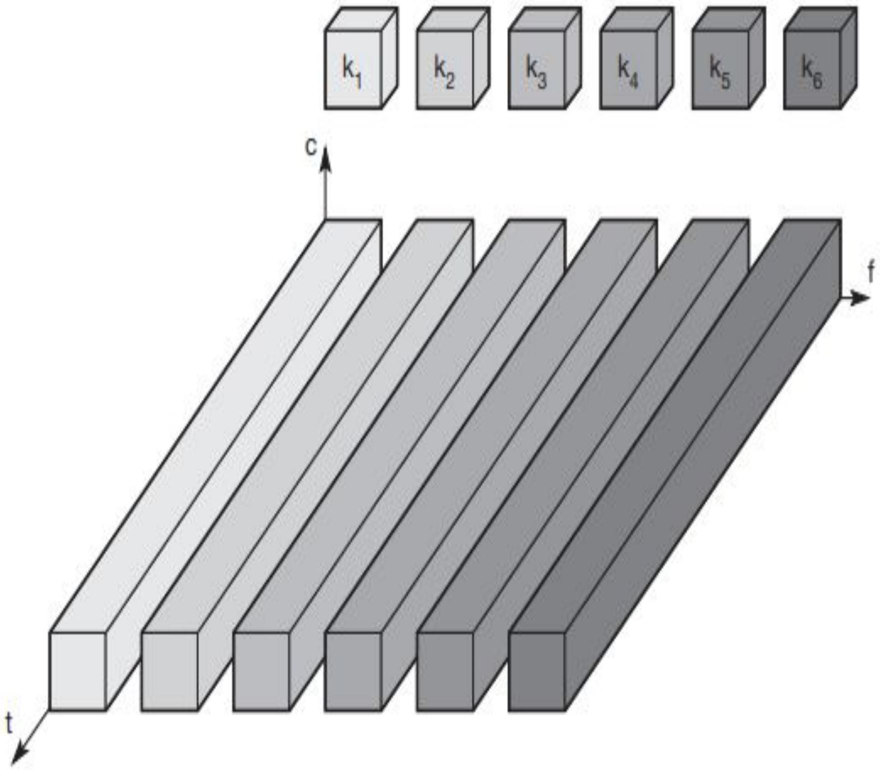
- Fig. shows six channels k_i and introduces a three dimensional coordinate system. This system shows the dimensions of code c, time t and frequency f. For space division multiplexing (SDM), the (three dimensional) space s_i is also shown. Here space is represented via circles indicating the interference range
- The channels k1 to k3 can be mapped onto the three ‘spaces’ s1 to s3 which clearly separate the channels and prevent the interference ranges from overlapping. The space between the interference ranges is sometimes called guard space



- For the remaining channels (k4 to k6) three additional spaces would be needed. In our highway example this would imply that each driver had his or her own lane.
- Although this procedure clearly represents a waste of space, this is exactly the principle used by the old analog telephone system: each subscriber is given a separate pair of copper wires to the local exchange.
- In wireless transmission, SDM implies a separate sender for each communication channel with a wide enough distance between senders. This multiplexing scheme is used, for example, at FM radio stations where the transmission range is limited to a certain region
- **Advantages of SDM**
- In SDM, the data transmission rate is high.
- It uses Time and Frequency bands at its maximum potential.
- **Disadvantages of SDM**
- An inference may occur.
- It faces high inference losses.

Frequency division multiplexing (FDM)

- Frequency division multiplexing (FDM) describes schemes to subdivide the frequency dimension into several non-overlapping frequency bands as shown in Figure.
- Each channel ki is now allotted its own frequency band as indicated. Senders using a certain frequency band can use this band continuously.
- Again, guard spaces are needed to avoid frequency band overlapping (also called adjacent channel interference). This scheme is used for radio stations within the same region, where each radio station has its own frequency.



- This very simple multiplexing scheme does not need complex coordination between sender and receiver: the receiver only has to tune in to the specific sender

Advantages

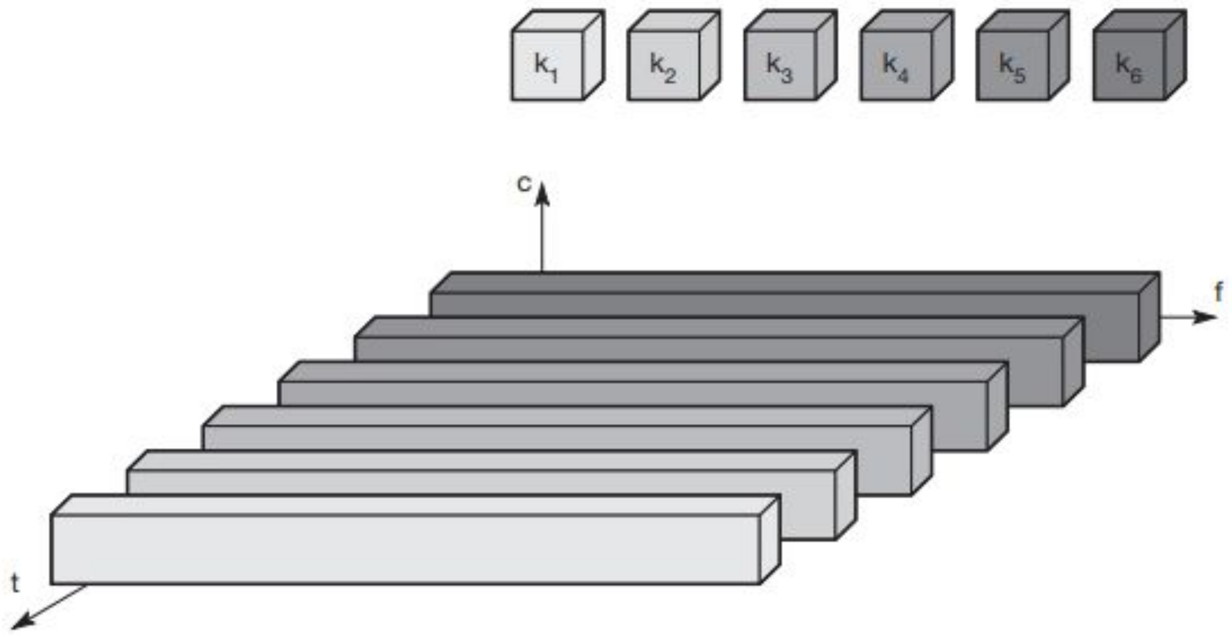
- No dynamic coordination necessary
- Works also for analog signal

Disadvantages:

- While radio stations broadcast 24 hours a day, mobile communication typically takes place for only a few minutes at a time. Assigning a separate frequency for each possible communication scenario would be a tremendous waste of (scarce) frequency resources.
- Additionally, the fixed assignment of a frequency to a sender makes the scheme very inflexible and limits the number of senders

Time division multiplexing (TDM).

- A more flexible multiplexing scheme for typical mobile communications is time division multiplexing (TDM). Here a channel ki is given the whole bandwidth for a certain amount of time, i.e., all senders use the same frequency but at different points in time



- Again, guard spaces, which now represent time gaps, have to separate the different periods when the senders use the medium. In our highway example, this would refer to the gap between two cars. If two transmissions overlap in time, this is called co-channel interference.

Advantages:

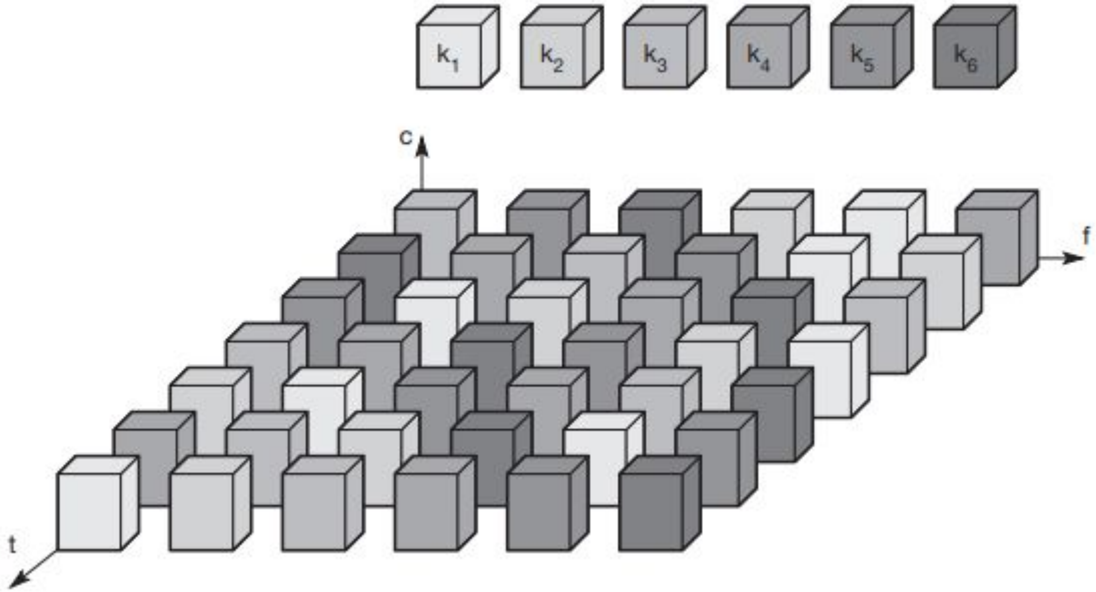
- However, this scheme is quite flexible as one can assign more sending time to senders with a heavy load and less to those with a light load.
- Only one carrier in the medium at any time
- Throughput high even for many users.

Disadvantages

- To avoid co-channel interference, precise clock synchronization between different senders is necessary

Frequency and time division multiplexing

- Frequency and time division multiplexing can be combined, i.e., a channel ki can use a certain frequency band for a certain amount of time as shown in Figure. Now guard spaces are needed both in the time and in the frequency dimension.



Advantages

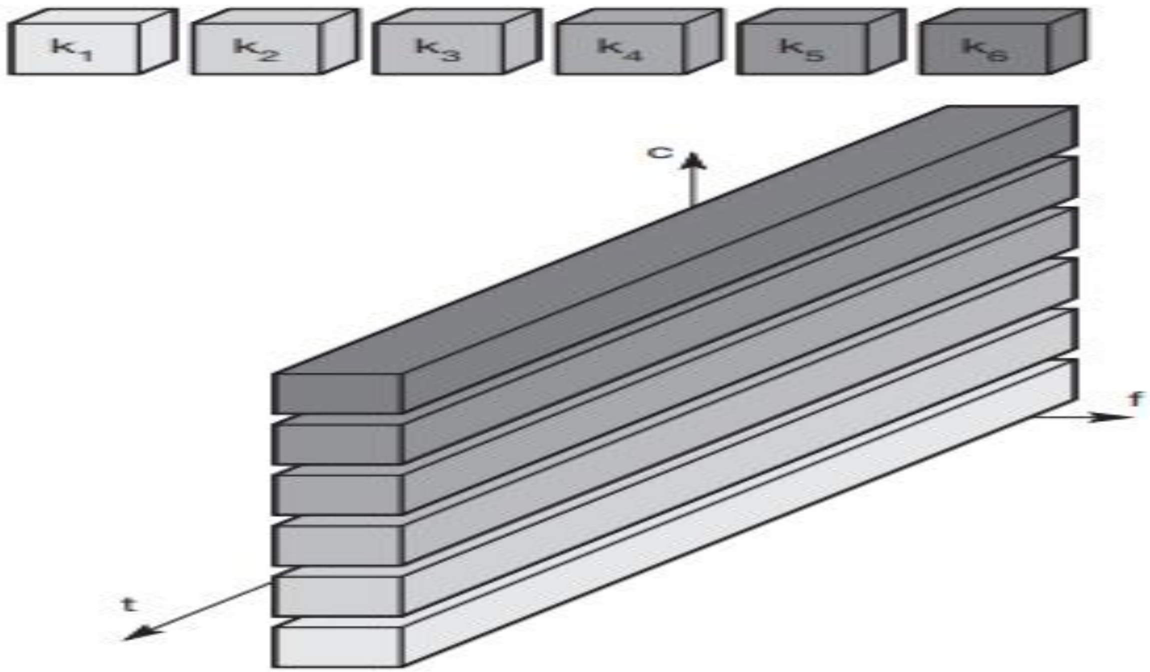
1. This scheme is more robust against frequency selective interference, i.e., interference in a certain small frequency band. A channel may use this band only for a short period of time.
2. Additionally, this scheme provides some (weak) protection against tapping, as in this case the sequence of frequencies a sender uses has to be known to listen in to a channel. The mobile phone standard GSM uses this combination of frequency and time division multiplexing for transmission between a mobile phone and a so-called base station

Disadvantage

1. A disadvantage of this scheme is again the necessary coordination between different senders. One has to control the sequence of frequencies and the time of changing to another frequency. Two senders will interfere as soon as they select the same frequency at the same time.
2. However, if the frequency change (also called frequency hopping) is fast enough, the periods of interference may be so small that, depending on the coding of data into signals, a receiver can still recover the original data.

Code division multiplexing

- Figure shows how all channels ki use the same frequency at the same time for transmission. Separation is now achieved by assigning each channel its own ‘code’, guard spaces are realized by using codes with the necessary ‘distance’ in code space, e.g., orthogonal codes.



Advantages

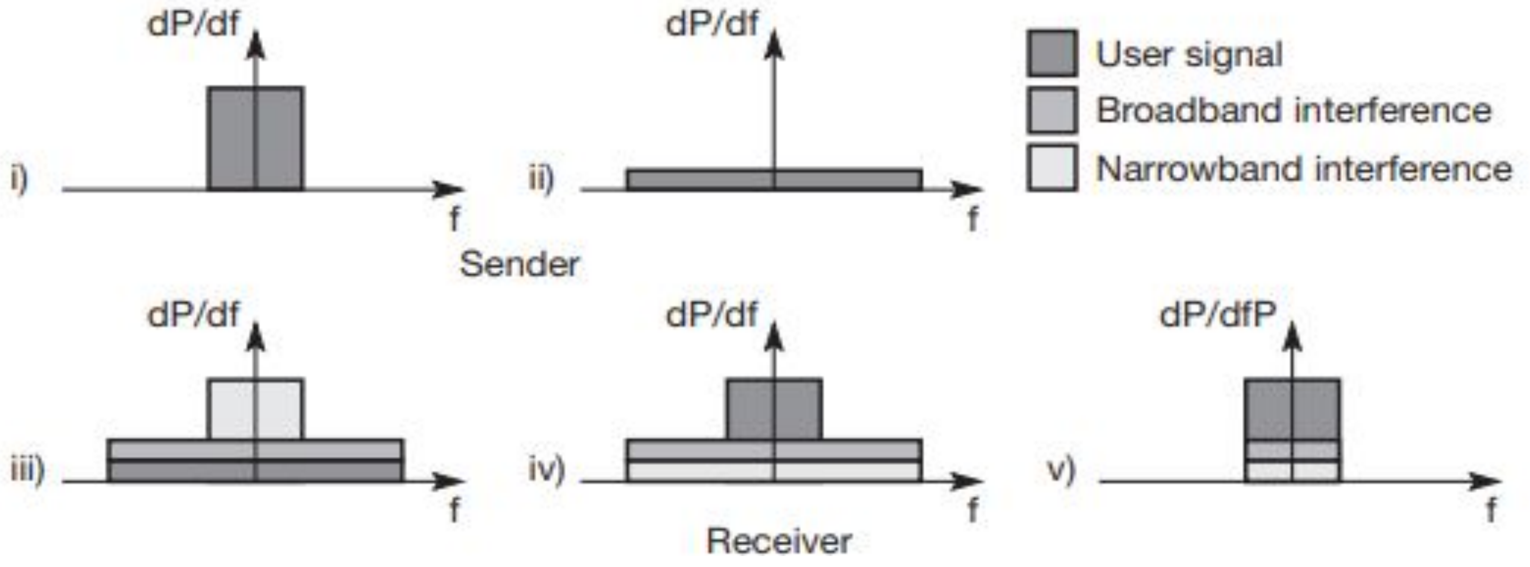
- It gives good protection against interference and tapping. Different codes have to be assigned, but code space is huge compared to the frequency space. Assigning individual codes to each sender does not usually cause problems.

Disadvantage

- The main disadvantage of this scheme is the relatively high complexity of the receiver .A receiver has to know the code and must separate the channel with user data from the background noise composed of other signals and environmental noise.
- Additionally, a receiver must be precisely synchronized with the transmitter to apply the decoding correctly.

Spread Spectrum

- spread spectrum techniques involve spreading the bandwidth needed to transmit data. Spread Spectrum is a technique in which the transmitted signals of specific frequencies are varied slightly to obtain greater bandwidth as compared to initial bandwidth.
- Spread spectrum signals are distributed over a wide range of frequencies and then collected and received back to the receiver. On the other hand, wide-band signals are noise-like and challenging to detect. The main advantage is the resistance to narrowband interference.
- spread spectrum technology is widely used in radio signals transmission because it can easily reduce noise and other signal issues.
- Initially, the spread spectrum was adopted in military applications because of its resistance to jamming and difficulty intercepting.
- Now, this is also used in commercial wireless communication.
- It is most preferred because of its useful bandwidth utilization ability.



- i) shows an idealized narrowband signal from a sender of user data (here power density dP/df versus frequency f).
- ii) The sender now spreads the signal i.e., converts the narrowband signal into a broadband signal. The energy needed to transmit the signal (the area shown in the diagram) is the same, but it is now spread over a larger frequency range. The power level of the spread signal can be much lower than that of the original narrowband signal without losing data.

- Depending on the generation and reception of the spread signal, the power level of the user signal can even be as low as the background noise. This makes it difficult to distinguish the user signal from the background noise and thus hard to detect.
- iii)During transmission, narrowband and broadband interference add to the signal. The sum of interference and user signal is received. The receiver now knows how to despread the signal, converting the spread user signal into a narrowband signal again, while spreading the narrowband interference and leaving the broadband interference.
- v) the receiver applies a bandpass filter to cut off frequencies left and right of the narrowband signal. Finally, the receiver can reconstruct the original data because the power level of the user signal is high enough, i.e., the signal is much stronger than the remaining interference.

Characteristics of the Spread Spectrum are:

1. Higher channel capacity.
2. Ability to resist multipath propagation.
3. They cannot easily intercept any unauthorized person.
4. They are resistant to jamming.
5. The spread spectrum provides immunity to distortion due to multipath propagation.
6. The spread spectrum offers multiple access capabilities.

Spread spectrum technologies also exhibit drawbacks.

- One disadvantage is the increased complexity of receivers that have to despread a signal. Today despreading can be performed up to high data rates thanks to digital signal processing.
- Another problem is the large frequency band that is needed due to the spreading of the signal. Although spread signals appear more like noise, they still raise the background noise level and may interfere with other transmissions if no special precautions are taken.

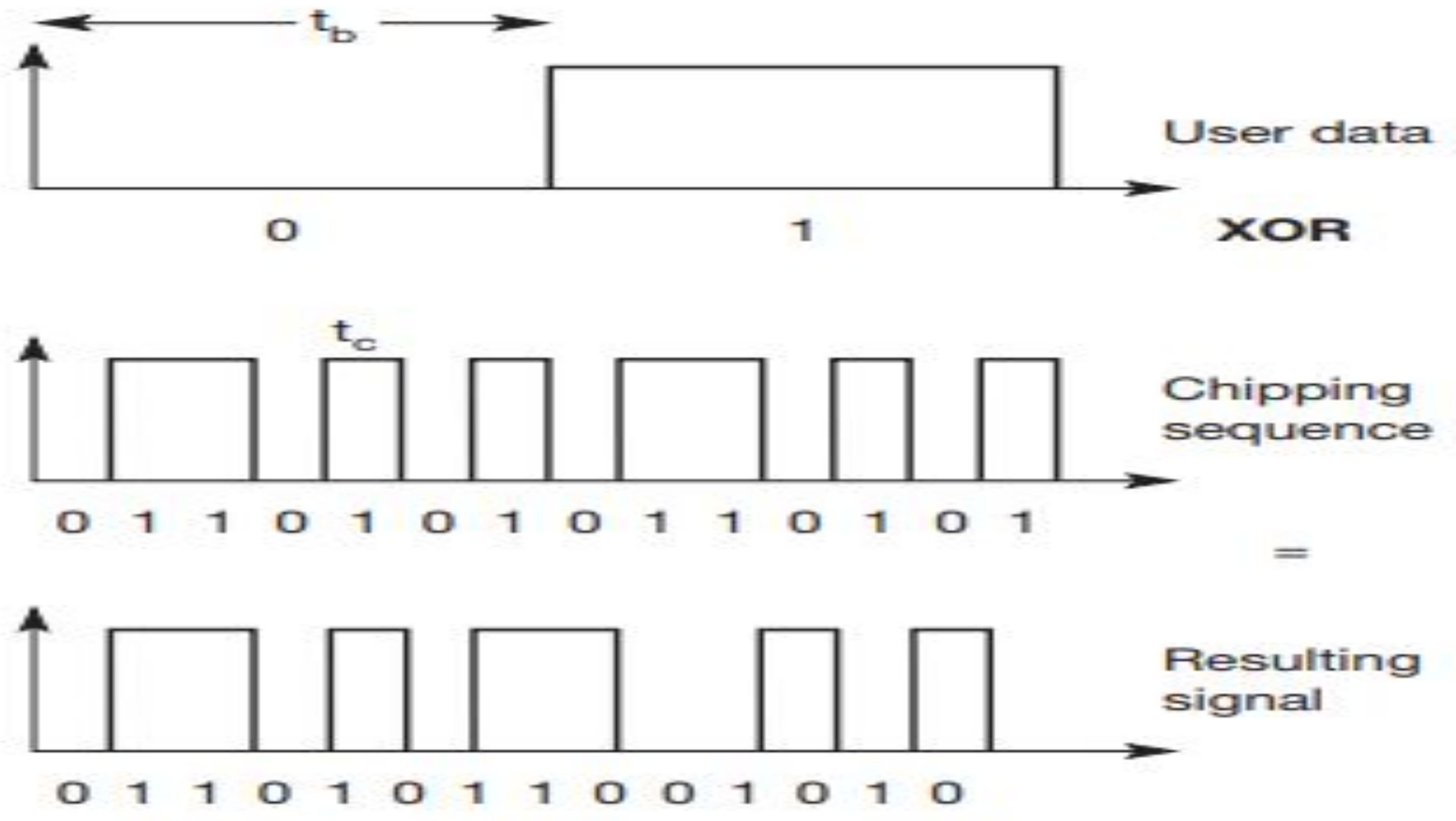
Two types of techniques for Spread Spectrum are:

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

Direct Sequence Spread Spectrum (DSSS)

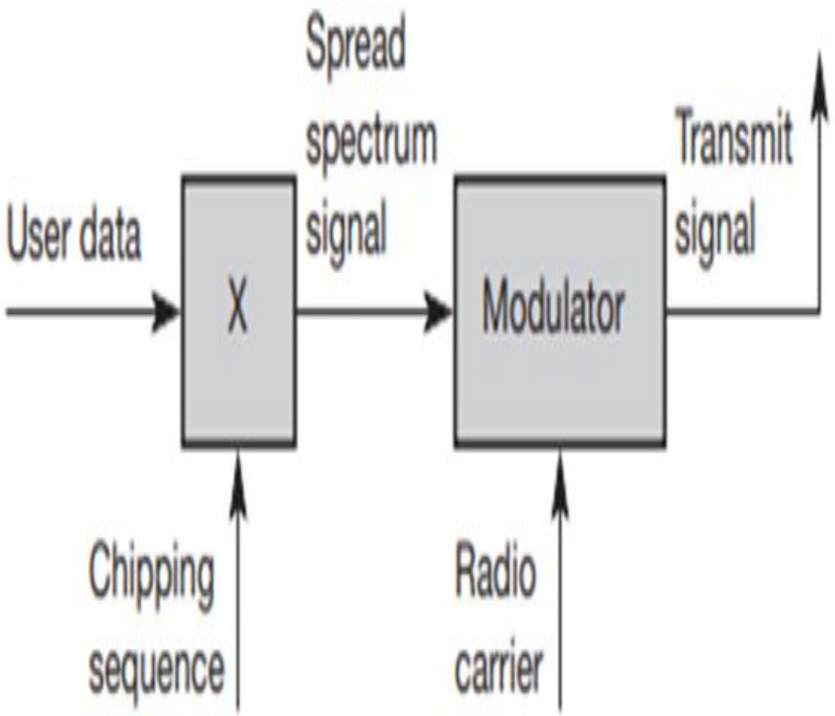
- The Direct Sequence Spread Spectrum (DSSS) is a spread-spectrum modulation technique primarily used to reduce overall signal interference in telecommunication.
- The Direct Sequence Spread Spectrum modulation makes the transmitted signal wider in bandwidth than the information bandwidth.
- In DSSS, the message bits are modulated by a bit sequencing process known as a spreading sequence. This spreading-sequence bit is known as a chip. It has a much shorter duration (larger bandwidth) than the original message bits.

- Direct sequence spread spectrum (DSSS) systems take a user bit stream and perform an (XOR) with a chipping sequence as shown in Figure.

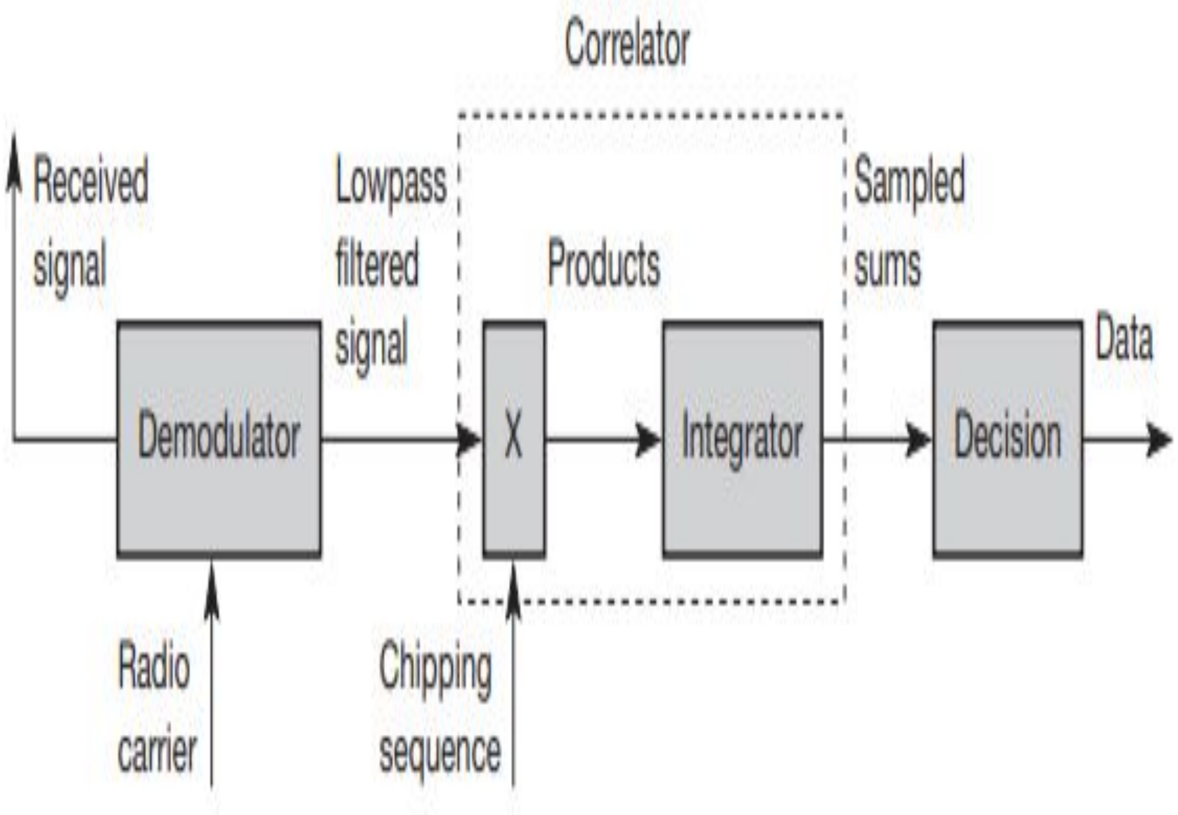


- The example shows that the result is either the sequence 0110101 (if the user bit equals 0) or its complement 1001010 (if the user bit equals 1).
- While each user bit has a duration tb, the chipping sequence consists of smaller pulses, called chips, with a duration tc. If the chipping sequence is generated properly it appears as random noise: this sequence is also sometimes called pseudo-noise sequence.
- The spreading factor s = tb/tc determines the bandwidth of the resulting signal. If the original signal needs a bandwidth w, the resulting signal needs s·w after spreading.
- While the spreading factor of the very simple example is only 7 (and the chipping sequence 0110101 is not very random), civil applications use spreading factors between 10 and 100, military applications use factors of up to 10,000.
- Wireless LANs complying with the standard IEEE 802.11 use, for example, the sequence 10110111000, a so-called Barker code, if implemented using DSSS. Barker codes exhibit a good robustness against interference and insensitivity to multi-path propagation

DSSS transmitter



DSSS receiver



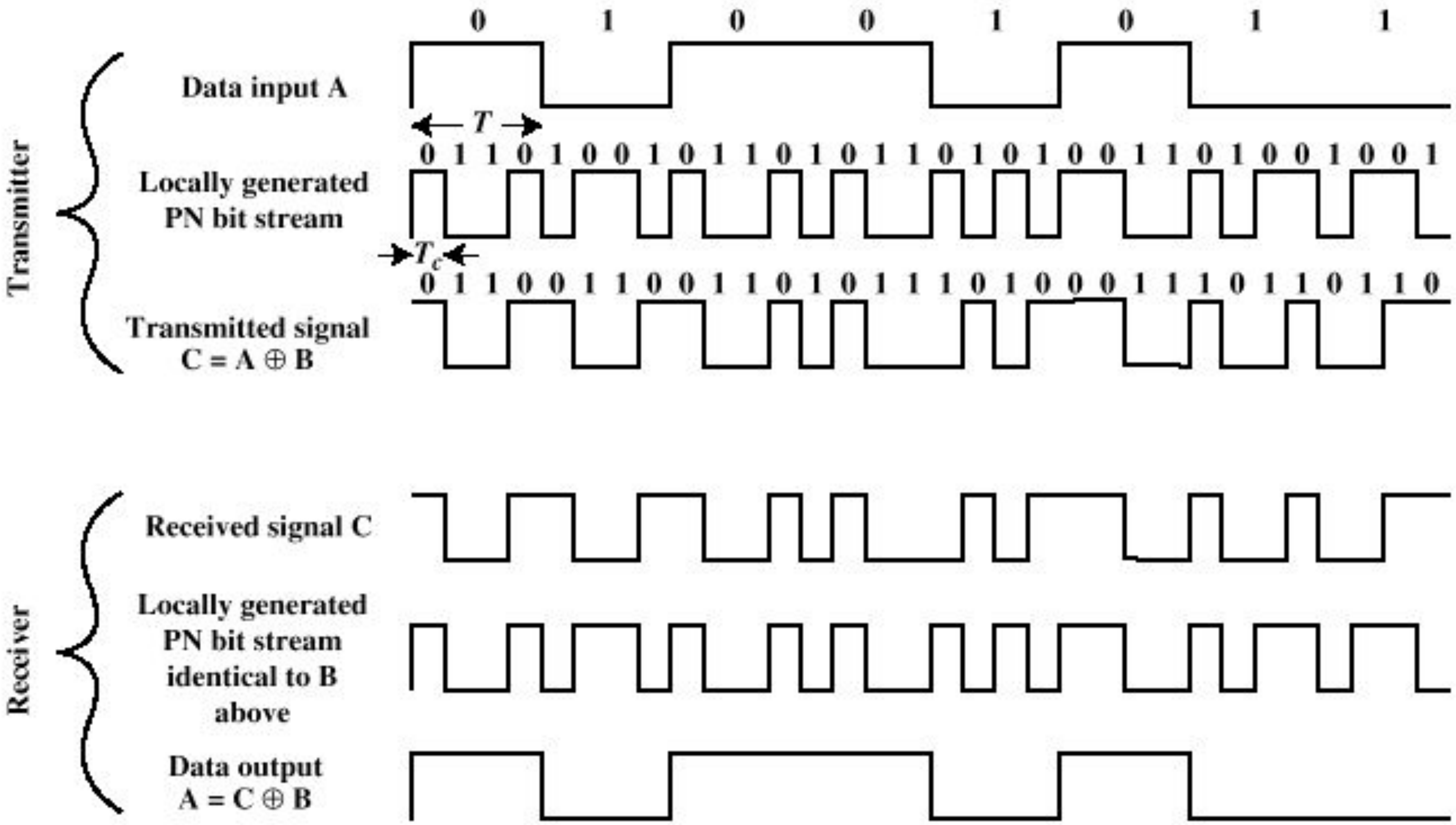


Figure 7.6 Example of Direct Sequence Spread Spectrum

DSSS transmitter

- The first step in a DSSS transmitter, is the spreading of the user data with the chipping sequence (digital modulation).
- The spread signal is then modulated with a radio carrier (radio modulation). Assuming for example a user signal with a bandwidth of 1 MHz. Spreading with the above 11-chip Barker code would result in a signal with 11 MHz bandwidth.
- The radio carrier then shifts this signal to the carrier frequency (e.g., 2.4 GHz in the ISM band). This signal is then transmitted.

DSSS receiver

- The DSSS receiver is more complex than the transmitter. The receiver only has to perform the inverse functions of the two transmitter modulation steps. However, noise and multi-path propagation require additional mechanisms to reconstruct the original data
- The first step in the receiver involves demodulating the received signal. This is achieved using the same carrier as the transmitter reversing the modulation and results in a signal with approximately the same bandwidth as the original spread spectrum signal.

- Additional filtering can be applied to generate this signal.This comprises another XOR operation, together with a medium access mechanism. During a bit period, which also has to be derived via synchronization, an integrator adds all these products.
- Calculating the products of chips and signal, and adding the products in an integrator is also called correlation, the device a correlator.
- Finally, in each bit period a decision unit samples the sums generated by the integrator and decides if this sum represents a binary 1 or a 0.
- Still, the decision unit can map, e.g., sums less than 4 to a binary 0 and sums larger than 7 to a binary 1

- **Advantages of Direct Sequence Spread Spectrum (DSSS)**

1. Direct Sequence Spread Spectrum or DSSS is less reluctant to noise; that's why the DSSS system's performance in the presence of noise is better than the FHSS system.
2. In Direct Sequence Spread Spectrum or DSSS, signals are challenging to detect.
3. It provides the best discrimination against multipath signals.
4. In Direct Sequence Spread Spectrum, there are very few chances of jamming because it avoids intentional interference such as jamming effectively.

Disadvantages of Direct Sequence Spread Spectrum (DSSS)

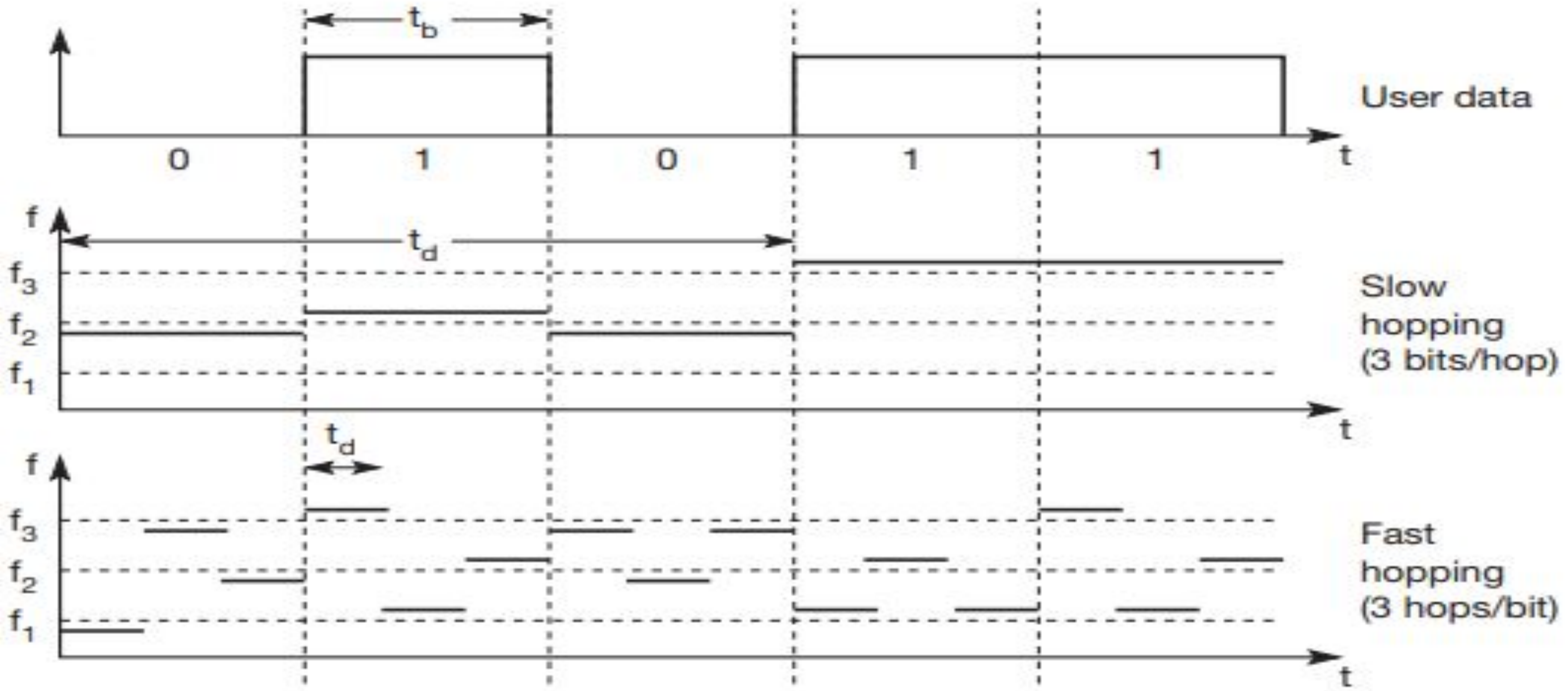
1. The Direct Sequence Spread Spectrum or DSSS system takes large acquisition time; that's why its performance is slow.
2. It requires wide-band channels with small phase distortion.
3. In DSSS, the pseudo-noise generator generates a sequence at high rates.

Applications of Direct Sequence Spread Spectrum (DSSS)

1. Following is the list of most used applications of Direct Sequence Spread Spectrum or DSSS:
2. Direct Sequence Spread Spectrum or DSSS is used in LAN technology.
3. Direct Sequence Spread Spectrum or DSSS is also used in Satellite communication technology.
4. DSSS is used in the military and many other commercial applications.
5. It is used in the low probability of the intercept signal.
6. It supports Code division multiple access.

Frequency hopping spread spectrum (FHSS)

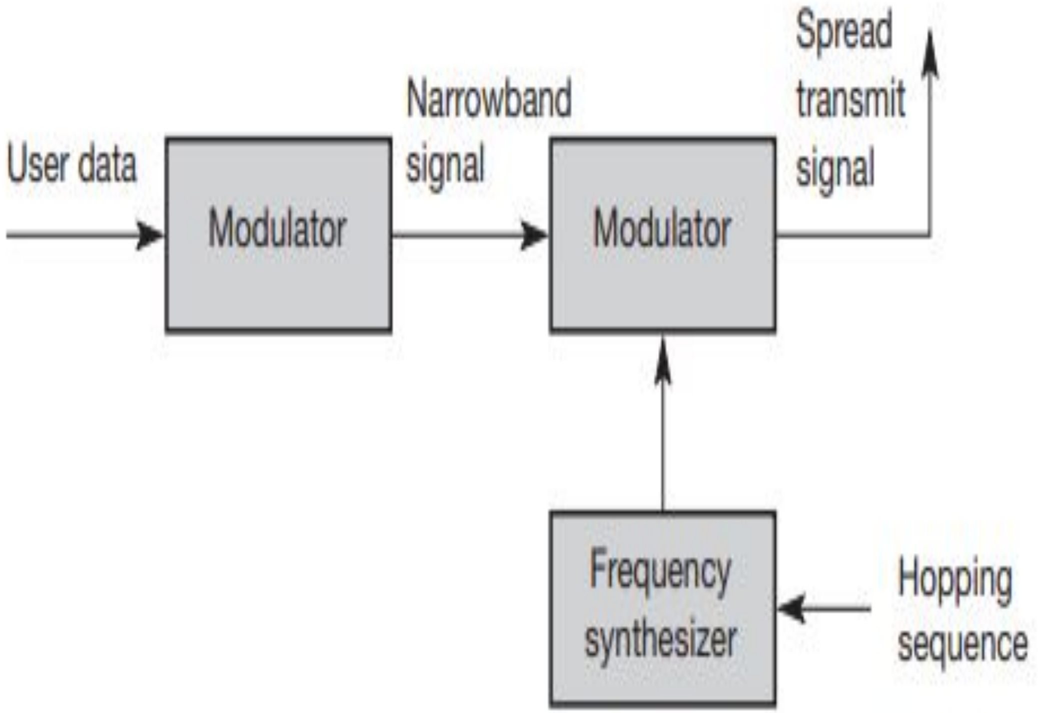
- For frequency hopping spread spectrum (FHSS) systems, the total available bandwidth is split into many channels of smaller bandwidth plus guard spaces between the channels.
- Transmitter and receiver stay on one of these channels for a certain time and then hop to another channel. This system implements FDM and TDM. The pattern of channel usage is called the hopping sequence, the time spend on a channel with a certain frequency is called the dwell time
- FHSS comes in two variants, slow and fast hopping



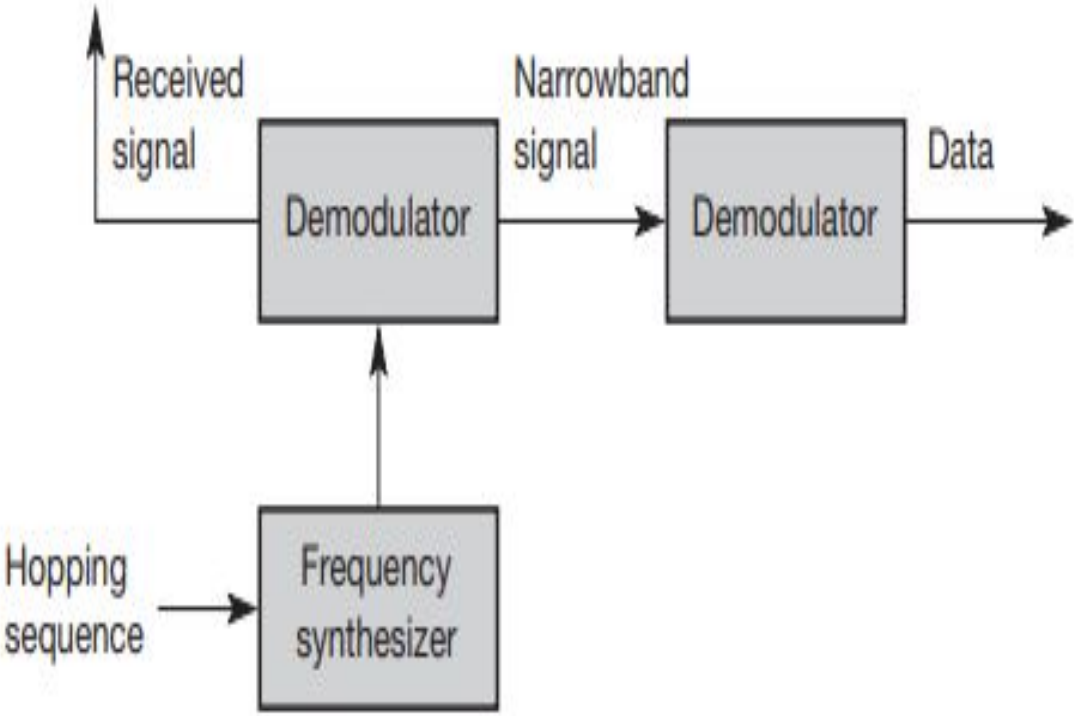
t_b
User data
0
1
0
1
1
t
f
t_d
f_3
f_2
f_1
Slow hopping (3 bits/hop)
t
t_d
f
f_3
f_2
f_1
Fast hopping (3 hops/bit)
t

- In slow hopping, the transmitter uses one frequency for several bit periods. Figure shows five user bits with a bit period tb. Performing slow hopping, the transmitter uses the frequency f2 for transmitting the first three bits during the dwell time td. Then, the transmitter hops to the next frequency f3.
- Slow hopping systems are typically cheaper and have relaxed tolerances, but they are not as immune to narrowband interference as fast hopping systems.
- For fast hopping systems, the transmitter changes the frequency several times during the transmission of a single bit. In the example of Figure, the transmitter hops three times during a bit period.
- Fast hopping systems are more complex to implement because the transmitter and receiver have to stay synchronized within smaller tolerances to perform hopping at more or less the same points in time.
- However, these systems are much better at overcoming the effects of narrowband interference and frequency selective fading as they only stick to one frequency for a very short time.

FHSS transmitter



FHSS receiver



- The first step in an FHSS transmitter is the modulation of user data according to one of the digital-to-analog modulation schemes, e.g., FSK or BPSK. This results in a narrowband signal, if FSK is used with a frequency f0 for a binary 0 and f1 for a binary 1.
- In the next step, frequency hopping is performed, based on a hopping sequence. The hopping sequence is fed into a frequency synthesizer generating the carrier frequencies fi .
- A second modulation uses the modulated narrowband signal and the carrier frequency to generate a new spread signal with frequency of fi +f0 for a 0 and fi +f1 for a 1 respectively.
- If different FHSS transmitters use hopping sequences that never overlap, i.e., if two transmitters never use the same frequency fi at the same time, then these two transmissions do not interfere. This requires the coordination of all transmitters and their hopping sequences.

- The receiver of an FHSS system has to know the hopping sequence and must stay synchronized.
- It then performs the inverse operations of the modulation to reconstruct user data.

Applications of Frequency Hopping Spread Spectrum (FHSS)

- The Frequency Hopping Spread Spectrum or FHSS is used in wireless local area networks (WLAN) standard for Wi-Fi.
- FHSS is also used in the wireless personal area networks (WPAN) standard for Bluetooth.

Advantages of Frequency Hopping Spread Spectrum (FHSS)

1. The biggest advantage of Frequency Hopping Spread Spectrum or FHSS is its high efficiency.
2. The Frequency Hopping Spread Spectrum or FHSS signals are highly resistant to narrowband interference because the signal hops to a different frequency band.
3. It requires a shorter time for acquisition.
4. It is highly secure. Its signals are very difficult to intercept if the frequency-hopping pattern is not known; that's why it is preferred to use in Military services.
5. We can easily program it to avoid some portions of the spectrum.
6. Frequency Hopping Spread Spectrum or FHSS transmissions can share a frequency band with many types of conventional transmissions with minimal mutual interference. FHSS signals add minimal interference to narrowband communications, and vice versa.
7. It provides a very large bandwidth.
8. It can be simply implemented as compared to DSSS.

Disadvantages of Frequency Hopping Spread Spectrum (FHSS)

1. FHSS is less Robust, so sometimes it requires error correction.
2. FHSS needs complex frequency synthesizers.
3. FHSS supports a lower data rate of 3 Mbps as compared to the 11 Mbps data rate supported by DSSS.
4. It is not very useful for range and range rate measurements.
5. It supports the lower coverage range due to the high SNR requirement at the receiver.
6. Nowadays, it is not very popular due to the emerging of new wireless technologies in wireless products.

Sr. No.	Parameter	Slow frequency hopping	Fast frequency hopping
1	Definition	Multiple symbols are transmitted in one frequency hop.	Multiple hops are taken to transmit one symbol.
2	Chip rate	Symbol rate is equal to chip rate.	Hop rate is equal to chip rate.
3	R_h and R_s	Hop rate is lower than symbol rate.	Hop rate is higher than symbol rate.
4	Carrier frequencies	One or more symbols are transmitted over the same carrier frequency.	One symbol is transmitted over multiple carriers in different hops.
5	Jammer interference	This signal can be detected by jammer if carrier frequency in one hop is known.	This signal is difficult to detect since one symbol is transmitted on multiple carrier frequencies.

Characteristics	FHSS	DSSS
Signal Transmission Speed	FHSS signal transmission speed is slow.	DSSS signal transmission speed is high.
Size of Network	The size of the FHSS network is small to medium.	Size of DSSS network is large
Price	Less Expensive	More Expensive
Complexity	Complexity is less	Complexity is More
Reliable	Less reliable	More reliable
Communications	FHSS is suitable for single- point and multipoint communications.	DSSS is suitable for point- to-point communications.
Rate of Signal Transmission	The FHSS signal transmission rate is 3 Mbps.	The DSSS signal transmission rate is 11 Mbps.
Abrreviation	Frequency-hopping spread spectrum	Direct-Sequence Spread Spectrum
Examples	It is used in military and industrial applications.	It is used in consumer applications such as wireless LANs, GPS, and Bluetooth.