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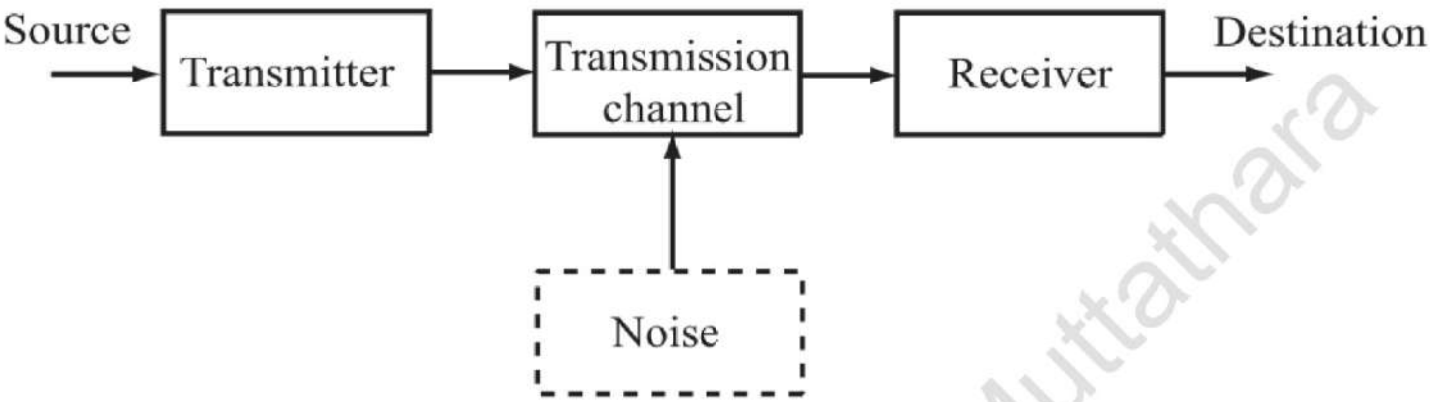
SFI GEC PALAKKAD

MODULE 6

Block Diagram of a Communication System

- The purpose of a communication system is to transmit information bearing signals through a communication channel.
- Three basic blocks in any communication system are: 1) Transmitter 2) Channel and 3) Receiver.



- **Source information or signal** may consist of speech, music, computer data, visual information, type written messages or signals etc.
- **Transmitter** is a collection of electronic components and circuits designed to convert the information into an electrical signal suitable for transmission over a given communication medium.
- Modulation and Coding are performed at the transmitter.
- **The original message signals usually contain frequencies in the low frequency or audio frequency range. Therefore, some form of frequency-band shifting (converting to high frequency range) is necessary in order to make the signals suitable for transmission. This shifting in the range of frequencies is achieved by the process known as modulation.**
- Transmitter puts the information from the source onto the channel.
- **Transmission Channel or simply "channel" is the medium connecting the transmitter and the receiver**. It may be a pair of wires, coaxial cable, open space (wireless) or optical fibre.
- The transmitted information travels through this channel until it reaches the destination.
- Every channel introduces some amount of transmission loss or attenuation. So, the signal power progressively decreases with increasing distance.
- **Receiver** is a collection of electronic components and circuits that accept the transmitted message from the channel and convert it back to the original information.
- The important function of the receiver is demodulation.
- Demodulation and decoding are the reverse of the signal processing performed at the transmitter.
- The figure represents **one-way or simplex (SX) transmission**.
- Two-way communication of course requires a transmitter and receiver at each end.
- A full-duplex (FDX) system has a channel that allows simultaneous transmission in both directions.
- A half-duplex (HDX) system allows transmission in either direction but not at the same time.
- Noise is an unwanted signal that interferes with the transmitted message.
- Noise are generally classified into two types: Internal and External Noise.
- External Noise are generated by external environment conditions.
- Internal Noise are generated by any components in transmitter/receivers.
- Noise is one of the more serious problems of electronic communications. It cannot be completely eliminated.

Evolution of communication systems

Telegraphy	1838	• A "telegraph" is a device for transmitting and receiving messages over long distances, i.e., for telegraphy. • The word "telegraph" alone now generally refers to an electrical telegraph. • Used Morse Code for sending message
Telephone	1876	• It was available to use for individuals interested in contacting others from the comfort of their own homes or offices, depending on their financial situations • Alexander Graham Bell patented the telephone.
Acoustic Phonographs	1877	• It was developed by Thomas Edison • Sound vibrations waveforms were used to help in transferring sound and communicating to another line or phonograph.
Wireless Telegraphy	1893	• Wireless telegraphy is transmission of messages over radio with telegraphic codes
Radio	1896	• **Simplex transmission** of music, news, and other types of programs from single broadcast stations to multiple individual listeners equipped with radio receivers.
Commercial Radio-Telephone Service	1927	• The very first commercial radio-telephone service within the UK and the US was released
Fibre Optical Telecommunications	1978	• Fibre optic cables were first installed to create a network system. • Having the ability to use fibre optical telecommunications was possible at this time, allowing for better connections, less problems, and an entirely speedier network on which to communicate. • **Today, fibre optics are used to help provide even faster speeds and bandwidth for internet service that is being provided for a business or in a residential home.**
Television	mid-1900s	• Using television as a means of communication was possible with local and national news stations, allowing individuals to consume news and information without buying the latest newspaper that had been printed.
Computer Networking		• It became possible to communicate and connect with other users who also owned computers and similar electronics. • Computer networking itself is a means of communicating with the use of multiple devices that are also electronic.
Mobile/Cellular Networks Established		• Cellular phones that were released in the 1980s through the late 1990s were often large, bulky, and similar to land-line telephone models. • It was First Generation
Email	late 1980s	• With the use of email, it became much easier to share messages, new information, and ideas
Instant Messaging		• With the development and release of instant messaging programs such as Yahoo! Instant Messenger, talking with family, friends, and even strangers across the world had never been easier
Widespread Internet Access	late 1990s	• With millions of URLs and domains to visit individuals began to learn more and had multiple methods of communicating with family, friends, and coworkers.

Social Media		• Sharing updates with multiple networks and cross-promoting new brands or products has become a trend with the use of social media, as most networks are free to join and use the network for personal or commercial purposes.
Smartphones		• Smartphones are considered mobile or cellular devices, but often they act more like a typical computer.
Mobile Apps and Video communications		• Mobile applications are used with smartphones to communicate with strangers. family, and friends. • There are thousands of mobile apps that are available to help things such as getting organized, saving money, and building business. • Mobile communication apps are steadily on the rise and in-demand from consumers. • Mobile apps are ideal when you are on-the-go or in need of a quick video call with a friend or family member.

Evolution of Mobile Generation

- The nomenclature of the cellular wireless generations generally refers to a change in **the fundamental nature of the service, non-backwards compatible transmission technology, and new frequency bands**.
- New generations have appeared about every ten years since the first move from 1981 analog (1G) to digital (2G) transmission in 1992.
- This was followed, in 2001, by 3G multi-media support, spread spectrum transmission and peak throughputs of 200 kb/s; and in 2011 by 4G, which refers to all-IP switched networks, mobile ultra-broadband (gigabit speed) access and multi-carrier transmission.

❖ **First Generation (1G)**
- First generation refers to the analog "brick phones" and "bag phones" as they were first introduced for mobile cellular technology.
- Cell phones began with 1G and signify first generation wireless analog technology standards that originated in the 1980s.
- 1G was replaced by 2G wireless digital standards.

❖ **Second Generation (2G)**
- 2G emerged in late 1980s.
- It uses digital signals for voice transmission and has speed of 64 kbps.
- It provides facility of SMS (Short Message Service) and use the bandwidth of 30 to 200 KHz.
- Next to 2G, 2.5G system uses packet switched and circuit switched domain and provide data rate up to 144 kbps. E.g. GPRS, CDMA and EDGE.

❖ **Third Generation (3G)**
- 3G is the third generation of mobile phone standards and technology.
- 3G is a global development of communication technologies and standards.
- 3G systems are expected to deliver quality multimedia to mobile devices by way of faster and easier wireless communications as well as “anytime, anywhere” services.
- As originally proposed, the idea behind 3G was to unify the different standards used in 2G wireless networks. Instead of different network types being adopted in the Americas, Europe and Japan, the plan called for a single network standard to be agreed on and implemented. Although it was fine in theory, in actuality, the International Telecommunication Union (ITU) sanctioned five terrestrial IMT- 2000 standards in its 3G standardization process.

❖ **Fourth Generation (4G)**

- 4G offers a downloading speed of 100 Mbps.
- 4G provides same feature as 3G and additional services like Multi-Media Newspapers, to watch T.V programs with more clarity and send Data much faster than previous generations.
- LTE (Long Term Evolution) is considered as 4G technology.
- 4G is being developed to accommodate the by forthcoming applications like wireless broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV; HDTV content, Digital Video Broadcasting (DVB), minimal services like voice and data, and other services that utilize bandwidth.

❖ **Fifth Generation (5G)**

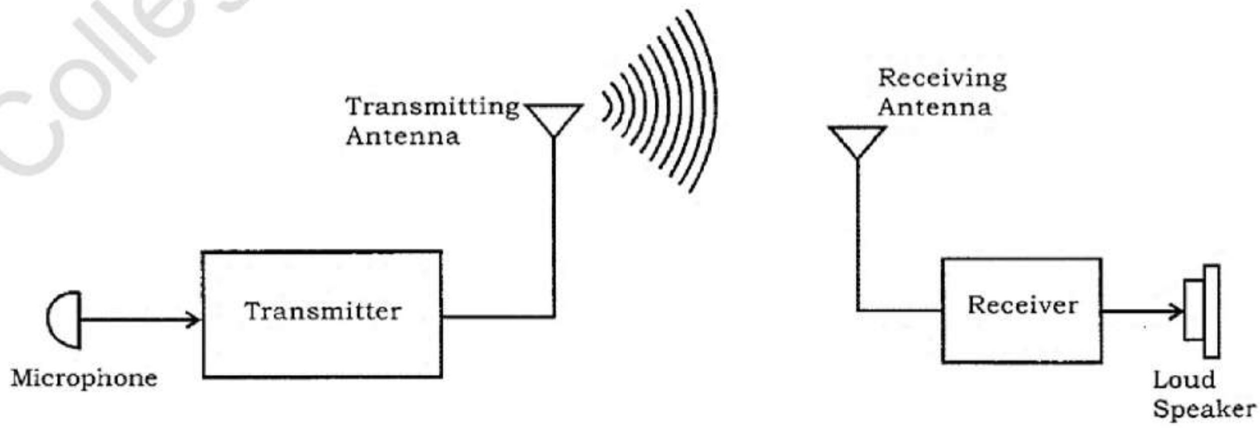
- 5G Technology stands for fifth Generation Mobile technology.
- 5G is the next evolution in mobile phone networks.
- Fifth generation network provide affordable broadband wireless connectivity (very high speed) with zero lag.
- Currently 5G term is not officially used in India.
- In 2019 (onward), 5G mobiles are launched outside India
- 5G technologies are expected to support applications such as smart homes and buildings, smart cities, 3D video, work and (game)play in the cloud, remote medical services, virtual and augmented reality, and massive machine-to-machine communications for industry automation.

Communication Systems

- Depending on the type of communication channel or medium, the communication systems can be classified as
  1. Wireline communication or Line communication
  2. Wireless communication or **Radio communication**
- Wireline communication or Line communication In line communication, the medium of transmission is a pair of conductors. e.g., Telegraphy and telephony

Radio Communication

- o In order to reduce the problems occurring in line communication, a wireless or radio communication is used. In this communication, the message signals are **transmitted through open space** by **electromagnetic waves called radio waves**. This mode of communication is known as radio communication.
- Radio communication makes possible communication over very large distances, even from Earth to Moon.
- The basic elements of a radio communication system are shown in figure.



- The microphone converts the physical signal (sound) to electrical signal.

- This message signal is also known as the modulating signal.
- Input to the transmitter is the **modulating signal.**
- **Modulation is performed at the transmitter.**
- The transmitter produces radio waves based on **modulating signal.**
- So, those Radio waves produced at the output of the transmitter is known as the **modulated signal.**
- The transmitting antenna radiates the radio waves in some specified direction or in all directions.
- The receiving antenna receives a part of the radiated wave.
- The receiver selects, amplifies and detects the desired message signal.
- The loud speaker converts the electrical signal into sound.
- Thus, reproducing the information.

Modulation

- **Modulation is defined as the process by which any one parameter of the carrier wave (amplitude, frequency or phase) is varied in accordance with the instantaneous amplitude of modulating signal.**
- The **reverse process**, the extraction of this message signal from the radio wave at the receiver, is known as **Demodulation.**
- **Need for Modulation**

1. **To reduce the height of antenna. By mixing audio signal with a carrier wave, the size of the antenna can be reduced to a great extent.**

   Explanation:

   - Audio frequencies range from 20 Hz to 20 kHz.
   - If they are transmitted directly into space, the length of the transmitting antenna required would be extremely large.

$$\boldsymbol{c = f\lambda}$$

velocity of light in Vacuum, $\boldsymbol{c} = 3 \times 10^8\ m/s$

f = frequency (Unit; **hertz** or **Hz**) $frequency = 1/\ time\ period$

$\boldsymbol{\lambda}$ = wavelength (Unit: **metre** or **m**): distance travelled by wave during one complete cycle.

$$\boldsymbol{\lambda = \frac{c}{f}}$$

   - **Length of the antenna required is comparable to the wavelength of the radio wave**
   - For instance, to radiate a frequency of 20 kHz directly into space, we would need an antenna length of $\frac{3 \times 10^8\ m/s}{20 \times 10^3\ Hz} = 15{,}000\ metres = 15\ km$

     This is too long antenna to be constructed practically.
   - If a carrier wave say of 1000 kHz is used to carry the signal, we need an antenna length of $\frac{3 \times 10^8\ m/s}{1000 \times 10^3\ Hz} = 300\ metres$ only and this size of the antenna can be easily constructed.

2. **To increase the Operating range of communication: The coverage area is more for a high frequency signal compared to a low frequency signal. Thus, modulation increases the coverage area**

   Explanation:

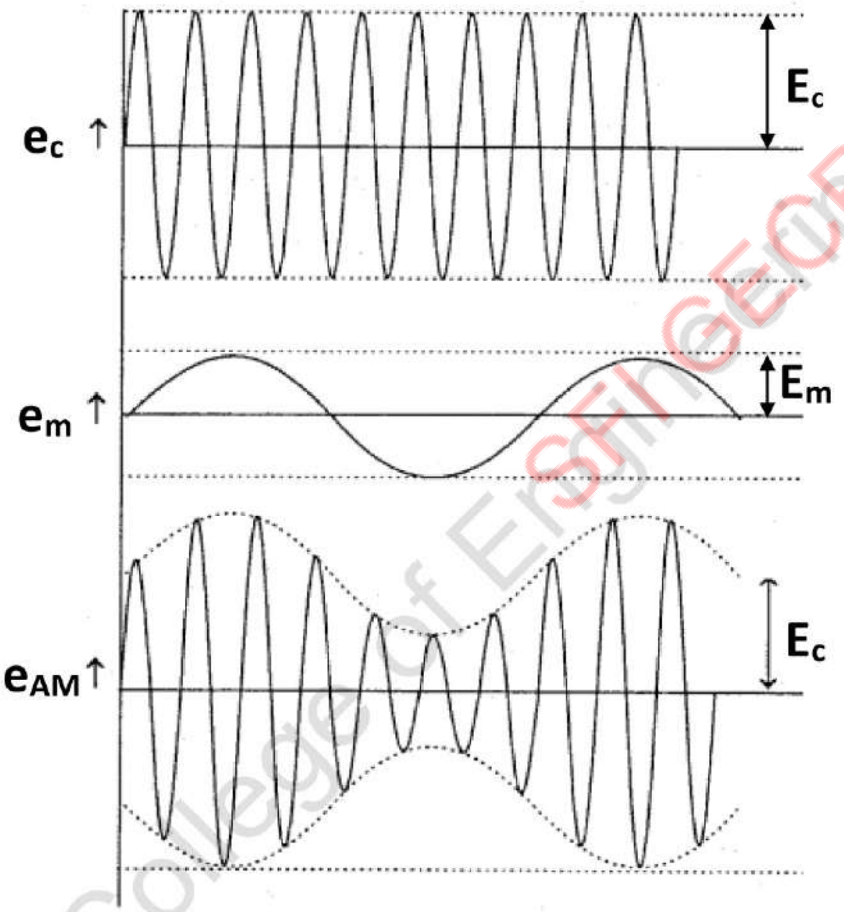
   - The energy of a wave depends upon its frequency.
   - The greater the frequency of the wave, the greater the energy possessed by it.
   - As the audio signal frequencies are small, therefore, these cannot be transmitted over large distances if radiated directly into space.
   - Thus, modulate a high frequency carrier wave with audio signal and permit the transmission to occur at this high frequency (i.e. carrier frequency).

3. **To avoid mixing of signals. Modulation allows several broadcasting stations to transmit simultaneously at different carrier frequencies.**
4. **To allow multiplexing of signals. It permits multiplexing by which several signals can be transmitted over the same channel without any mixing.**
5. **To improve the quality of reception. The effect of noise and interference can be reduced by modulation**

- The three main types of modulation are
    1. Amplitude modulation (AM)
    2. Frequency modulation (FM)
    3. Phase modulation (PM)

Principle of AM

- **In amplitude modulation, the amplitude of the high frequency carrier wave is varied in accordance with the instantaneous value of the modulating signal keeping its frequency and phase constant.**
- The amplitude modulation is illustrated in figure



(a) **Carrier wave of high frequency**

(b) **Modulating signal** of low frequency (i.e. Message Signal)

(c) **Modulated AM signal**

Let the modulating signal (voltage form), $\boldsymbol{e_m = E_m \sin w_m t}$

& the carrier, $\boldsymbol{e_c = E_c \sin w_c t}$

Then, modulated AM signal is given by

$$\boldsymbol{e_{AM} = (E_c + e_m) \sin w_c t}$$

Substituting for $\boldsymbol{e_m}$, we get

$$\boldsymbol{e_{AM} = (E_c + E_m \sin w_m t) \sin w_c t}$$

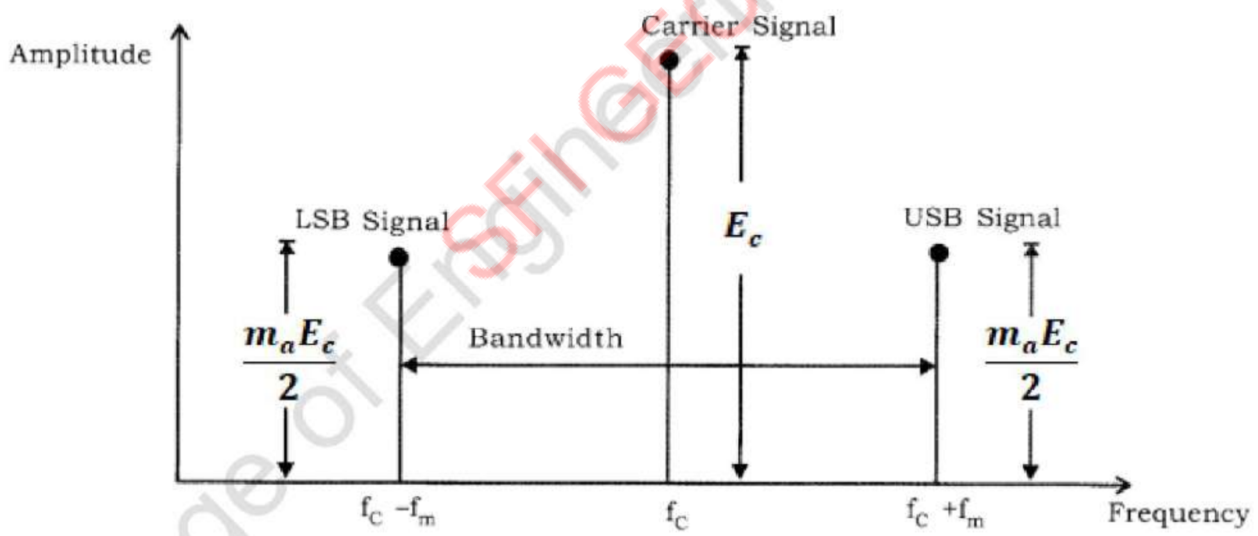
$$e_{AM} = E_c\,(1 + \frac{E_m}{E_c}\sin w_m t)\sin w_c t$$
$$e_{AM} = E_c\,(1 + m_a \sin w_m t)\sin w_c t$$

where m_a **is the modulation Index for AM;** $m_a = \frac{E_m}{E_c}$

$$e_{AM} = E_c \sin w_c t\ + m_a E_c\ \sin\ (w_m t)\ \sin\ (w_c t)$$
$$e_{AM} = E_c \sin w_c t\ + m_a E_c \left(\frac{1}{2}(\cos(w_c - w_m)t + \cos(w_c + w_m)t)\right)$$
$$e_{AM} = E_c \sin w_c t\ + \frac{m_a E_c}{2}\cos(w_c - w_m)t + \frac{m_a E_c}{2}\cos(w_c + w_m)t$$

Angular frequency, $w = 2\pi f$

- This equation shows that the amplitude modulated wave contains three different components, namely
  1. Carriers wave located at f_c of amplitude E_c
  2. Upper side band (USB) at $(f_c + f_m)$ of amplitude $\frac{m_a E_c}{2}$
  3. Lower side band (LSB) at $(f_c - f_m)$ of amplitude $\frac{m_a E_c}{2}$



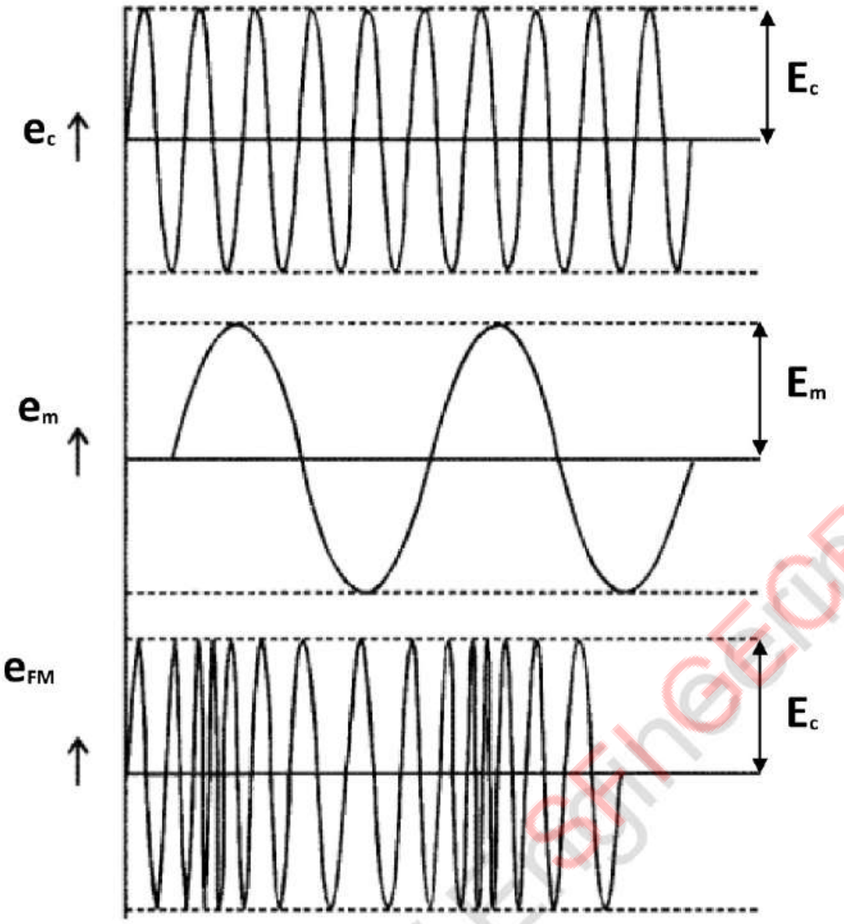
- The frequency spectrum for a carrier frequency signal modulated by a single audio frequency signal is shown in figure.
- When a RF carrier is modulated by an AF signal wave by mixing the two frequencies, two new frequencies equal to the sum and difference of the combining frequencies are produced.
- Modulation index is a number lying between 0 and 1. This can be expressed as a percentage; it is then called the depth of modulation.
- **Limitations of Amplitude Modulation**

  1. Low efficiency 2. Small operating range

  3. Noise transmission 4. Poor audio quality

Principle of FM

- In frequency modulation, the frequency of the carrier wave is varied in accordance with the instantaneous value of the modulating signal.
- The amplitude and phase of the carrier signal remain constant.
- The amount by which the carrier frequency is varied from its unmodulated value is called frequency deviation (δ).



(a) **Carrier wave of high frequency**

(b) **Modulating signal** (i.e. Message Signal)

(c) **Modulated FM signal**

m_f is the modulation Index for AM;

$$m_f = \frac{\delta}{f_m}$$

Advantages of FM

- An FM signal has a constant amplitude and hence transmitted power is constant.
- FM offers better noise immunity and it rejects interfering signals.
- FM has greater transmission efficiency.
- FM operates in VHF and UHF ranges.

Disadvantages of FM

- A major disadvantage of FM is that its bandwidth is wider than the bandwidth of AM.
- The circuits that are used to produce and demodulate FM are complex and expensive.
- The area of FM reception is less than that of AM

Comparison between AM & FM

	AM	FM
1	The amplitude of the carrier signal varies in accordance with modulating signal, keeping frequency and phase constant.	The frequency of the carrier signal varies in accordance with modulating signal, keeping amplitude and phase constant.
2	Modulation index (m_a) varies from **0 to 1**	Modulation index (m_f) can have values from **1 to any value.**
3	AM has only two sidebands.	FM has an infinite number of sidebands
4	Lower Bandwidth compared to FM	Higher Bandwidth (ideally infinite) compared to AM
5	In AM, all transmitted power is not useful. Most of the transmitted power is carrier which does not carry any information.	**In FM, all transmitted power is useful.** The total power remains constant.
6	**Area of reception is large**	Area of reception is smaller than AM
7	AM broadcasts operate in the medium and high frequency (MF and HF) ranges	FM broadcasts operate in very high frequency and ultra-high frequency (VHF and UHF) ranges.
8	Noise suppression not good	**Noise suppression is better than AM**
9	**AM is less complex and less expensive**	FM is more complex and more expensive.
10	Adjacent channel interference is more in AM than present in FM	**Adjacent channel interference is less in FM**
11	Modulating voltage amplitude determines RF carrier amplitude.	Modulating voltage amplitude determines RF carrier frequency

Frequency bands used for various communication systems

Class	Frequency range	Details
Very low frequency (VLF)	3 to 30 kHz	• Low attenuation. • Used for long distance communication, telegraphy.
Low frequency (LF)	30 to 300 kHz	• Day-time absorption more. • Used for marine communication and navigational aid.
Medium frequency (MF)	**300 kHz to 3 MHz**	• High attenuation during day and less during night. • Used For broadcasting communication.
High frequency (HF)	3 to 30 MHz	• Propagation characteristics vary with time of day, season etc • Used for point-to-point communication.
Very high frequency (VHF)	30 to 300MHz	• LOS - not affected by ionosphere. Used for TV, FM transmission, radar, telephony.
Ultra high frequency (UHF)	**300 MHz to 3 GHz**	• LOS (Line of Sight) • Used for TV and short distance communication.
Super high frequency (SHF)	3 to 30 GHz	• Same as UHF. • Used for radar and satellite communication.
Extra high frequency (EHF)	30 to 300 GHz	• Same as UHF. • Used for specialized radar, satellite communication government purposes etc.

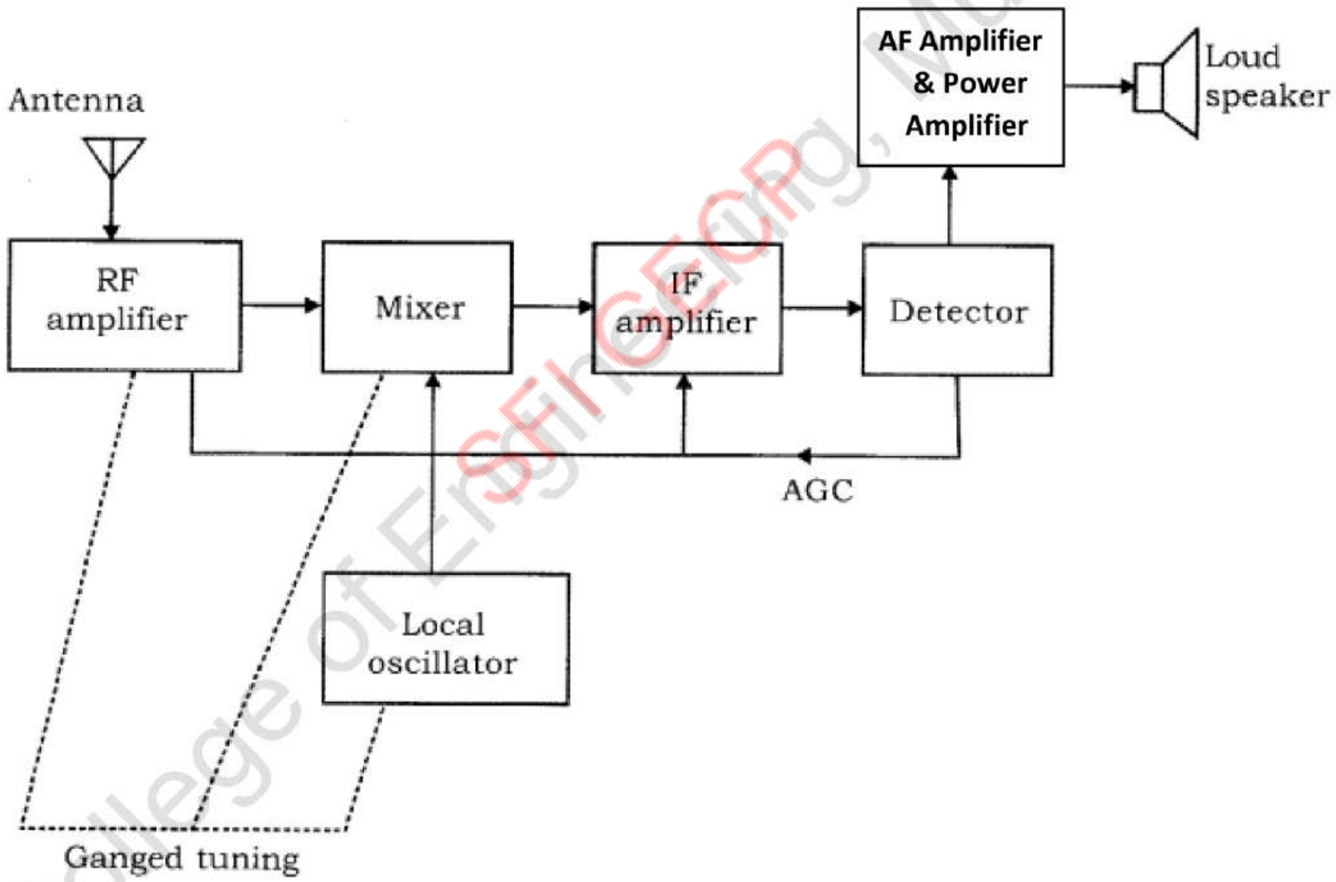
The frequency allotment for different applications are listed below

Radio	
AM broadcast	

Medium wave (MW)	535 - 1605 kHz
Short wave (SW)	3- 30 MHz
FM broadcast	88 - 108 MHz
Television (using Yagi Antenna)	
VHF (lower) Band I	47 - 68 MHz
VHF (Upper) Band III	174 - 230 MHz
UHF (Lower) Band IV	470 - 598 MHz
UHF (Upper) Band V	606 - 870 MHz
Microwave	
Ultra high frequency (UHF)	300 MHz - 3 GHz
Super high frequency (SHF)	3GHz - 30 GHz
Extra high frequency (EHF)	30 GHz -300 GHz

Block diagram of super heterodyne receiver

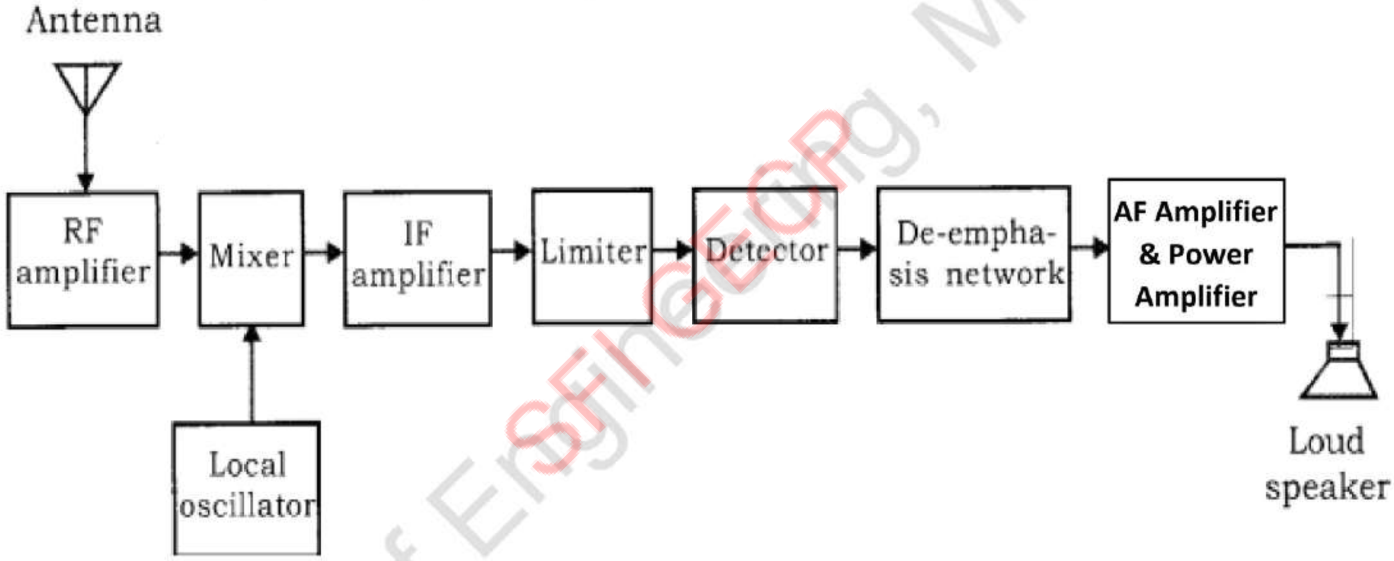
The super heterodyne method of reception is widely used for both amplitude and frequency modulated signal. The block diagram of a typical **AM super heterodyne receiver** is shown in figure.



- The incoming signal from the antenna is amplified by the RF amplifier.
- This amplified signal is mixed with the signal from the local oscillator to produce the intermediate frequency (IF).
- The process of **combining or mixing of signals of different frequencies** in order to **produce a signal of new frequency** is called the **heterodyning action.**
- A constant frequency difference is maintained between the local oscillator and RF circuits normally through **capacitance tuning**, in which **all the capacitors are ganged together** and operated in unison by **one control knob**.
- The IF signal is amplified by several IF stages and the output of the last IF stage is fed to the detector to retrieve the modulating signal.

- The **automatic gain control (AGC)** circuit keeps the output signal level constant irrespective of the increase or decrease in the signal level at the input of the receiver.
- The retrieved modulating signal is then amplified by the AF amplifier, passed through a Power Amplifier and then fed to the speaker, which converts the audio signal into sound waves corresponding to the original sound at the broadcasting station.
- The super heterodyne receiver has the following advantages.
  1) **Large amplification**
     The amplification is carried out at intermediate frequency which is much lower than radio frequency, so the signal can be amplified to a higher level.
  2) **Improved selectivity.**
     The quality factor Q of the tuned circuit is improved and the amplifier circuits operate with maximum selectivity.
  3) **Smaller cost**
     The super heterodyne receiver is cheaper than straight radio receiver because in super heterodyne receiver Fixed RF amplifiers are used.

FM Receiver or FM super heterodyne Receiver



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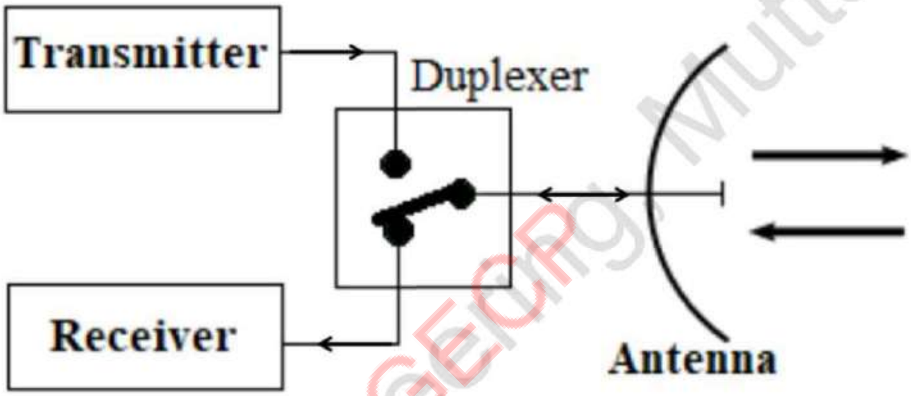
- A constant frequency difference is maintained between the local oscillator and RF circuits normally through **capacitance tuning**, in which **all the capacitors are ganged together** and operated in unison by **one control knob**.
- The IF signal is amplified by several IF stages and the output of the last IF stage is fed to the **Limiter** and then to the detector to retrieve the modulating signal.
  (The functions of components other than limiter and de-emphasis network are the same as explained in case of super heterodyne receiver.)
  - **In FM receiver, limiter is provided to remove all amplitude variations, caused by noise from IF signal which might have crept into the FM signal.**
  - **The de-emphasis network is provided to reduce the amplitude of high frequencies in the audio signal which was earlier increased at the transmitting station.**

Antenna

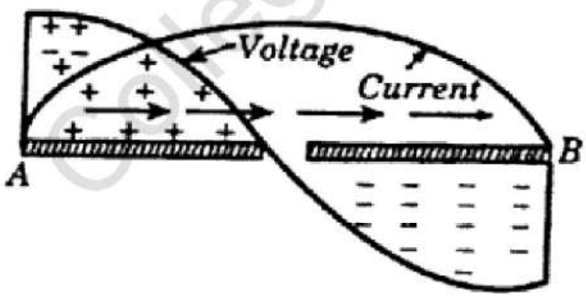
- An Antenna is an electrical device which converts electric power into radio waves, and vice versa.
- It is device for radiating (or transmitting) and receiving of Electromagnetic (EM) waves.
- An antenna is basically a length of a conductor that acts as a conversion device.
- It serves as a link between the transmitter and the receiver.
- Transmitting Antenna converts electrical energy to electromagnetic waves.
- Receiving Antenna converts electromagnetic waves into electrical signal that is applied to the input of the receiver.
- **Antenna reciprocity**: In most of the cases, an antenna performs both the functions equally well.
  - The phenomenon of using same antenna for transmission as well as for reception is known as antenna reciprocity.
  - Thus, in those applications where transmission and reception are not simultaneous, a single antenna can serve the purpose of transmission and reception both.



  - E.g.: **Radar systems** where during transmission, the output of the transmitter is connected to the antenna whereas during reception, antenna is connected to the input of the receiver. This switching over of connection is performed by a device called **Duplexer**.
- In wireless communication systems, **signals are radiated in space as an electromagnetic wave by using a receiving transmitting antenna and a fraction of this radiated power is intercepted by using a receiving antenna.**

Working Principle of Antenna (when used in a radio transmitter)

a) Current distribution and voltage distribution



- When RF signal is applied to the input of the antenna, current flows along the length as shown in Fig.
- The electrons in the "antenna conductor" start towards the positive input terminal whereas they get repelled from negative input terminal.
- As a result, end **"A"** becomes continuously positively charged due to loss of electrons whereas end **"B"** becomes negatively charged due to gain of electrons.
- Thus, the charge is maximum at A and B and minimum at centre.

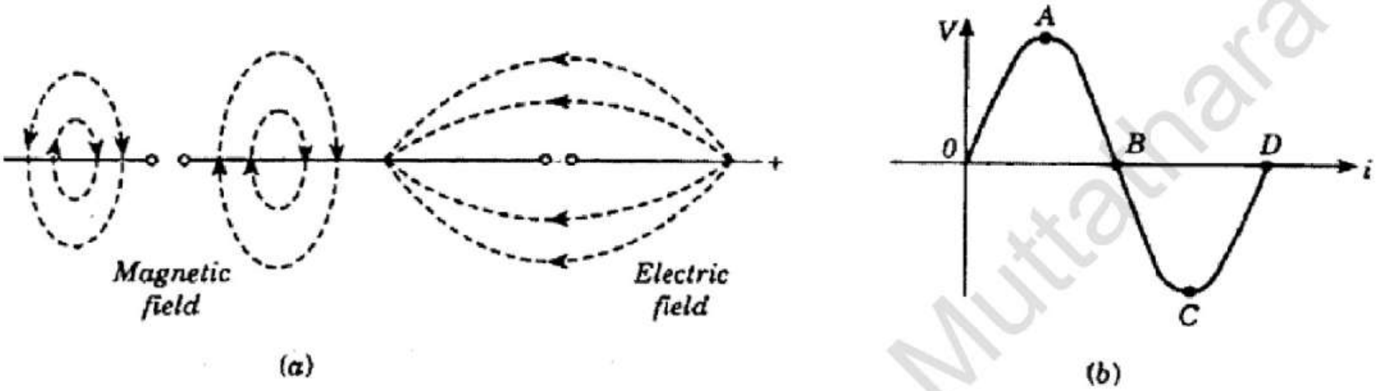
$$Current = Rate\ of\ change\ of\ Charge$$

- So, Current is maximum at the centre and minimum at the ends.
- If input is sinusoidal, the current waveform is also sinusoidal as shown.

- The voltage distribution (or charge distribution) is also shown with maximum at the ends and minimum at the centre. It is seen that voltage and current are having a phase difference of 90° with respect to each other.

b) Electromagnetic energy radiated by antenna

- When RF (Radio Frequency) signal is applied to the antenna input, the result is a current and a voltage distribution.
- Now **a current** flowing through a conductor is surrounded by a **magnetic field** whereas **voltage** produces an **electric field**. They are shown in Fig



- If the signal applied to antenna input is as shown in Fig., at A, the electric field around the antenna is maximum but after that it starts decreasing.
- If the frequency of RF signal is low, then the electrical field may collapse in the antenna.
- But if the frequency is very high, the field cannot collapse so fast and the result is that there is large electric field even if there is no voltage or charge across the antenna.
- Thus, there is an electric field with no voltage to support it.
- When (during next cycle) the electric field builds up again, the previously sustained electric field gets repelled from the newly produced field. This phenomenon is repeated again and again and a series of detached electric fields move outwards from the antenna.
- Similarly, magnetic fields are also detached
- According to laws of electromagnetic induction,
  (i) A moving electric field produces a magnetic field
  (ii) A moving magnetic field produces an electric field.

  These fields are in phase with the fields that produce them and their direction is perpendicular to the direction of propagation. Thus, detached electric and magnetic fields produce magnetic and electric fields respectively. **These fields add vectorially to give one EM wave which travels in a direction perpendicular to the direction of electric field and magnetic field. Here electric field and magnetic field are perpendicular to each other as well.**

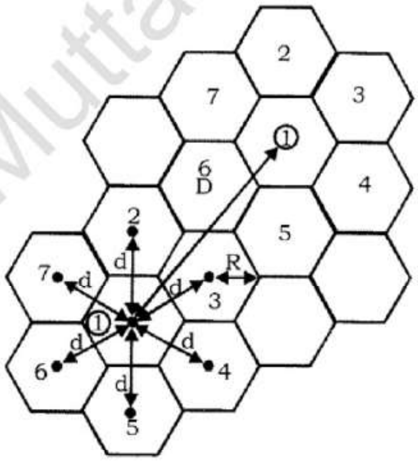
Mobile communication

- A cellular mobile communications system uses a large number of low – power wireless transmitters to create cells - the basic geographic service area of a wireless communications system.
- Variable power levels allow cells to be sized according to the subscriber density and demand within a particular region.
- As mobile users travel from cell to cell, their conversations are " handed off" between cells in order to maintain seamless service.
- Channels (frequencies) used in one cell can be reused on another cell some distance away.

- Cells can be added to accommodate growth, creating new cells in unserved areas or overlaying cells in existing areas.

Basic principles of cellular communications

1) **Cellular Network Organization**
   - The essence of a cellular network is the use of multiple low - power transmitters, on the order of 100 W or less.
   - Because the range of such a transmitter is small, an area can be divided into cells, each one served by its own antenna.
   - Each cell is allocated a band of frequencies and is served by a base station, consisting of transmitter, receiver, and control unit.
   - Adjacent cells are assigned different frequencies to avoid interference or cross talk.
   - However, cells sufficiently distant from each other can use the same frequency band.
   - **A hexagonal pattern provides for equidistant antennas**.
   - The radius of a hexagon is defined to be the radius of the circle that circumscribes it (equivalently, the distance from the centre to each vertex; also equal to the length of a side of a hexagon).
   - For a cell radius R, the distance between the cell centre and each adjacent cell centre is $d = \sqrt{3}R$
   - **In practice, a precise hexagonal pattern is not used.**
   - Variations from the ideal are due to topographical limitations, local signal propagation conditions, and practical limitation on siting antennas.



2) **Concepts of cells**
   - The basic concept behind the cellular radio system is that rather than serving a given geographic area with a single transmitter and receiver, the system divides the service area into many smaller areas known as cells.
   - The typical cell covers only several square miles and contains its own receiver and low power transmitter.
   - The coverage of a cell depends upon the density (number) of users in a given area.
   - For a heavily populated city, many small cells are used to ensure service. In less populated rural areas, fewer cells are used.
   - Short cell antenna towers limit the cell coverage area.
   - Higher towers give broader coverage.
   - The cell site is designed to reliably serve only persons and vehicles in its small cell area.
   - Each cell is connected by telephone lines or a microwave radio relay link to a **master control centre** known as the **mobile telephone switching office** (**MTSO**).
   - The MTSO controls all the cells and provide the interface between each cell and the main telephone office.
   - As the person with the cell phone passes through a cell, it is served by the cell transceiver. The telephone call is routed through the MTSO and to the standard telephone system.
   - As the person moves, the system automatically switches from one cell to the next.

3) **Cellular System infrastructure & Operation**
   - Cellular communication system is a technique that was developed to increase the capacity available for mobile radio telephone service.

- A basic cellular system consists of three parts:

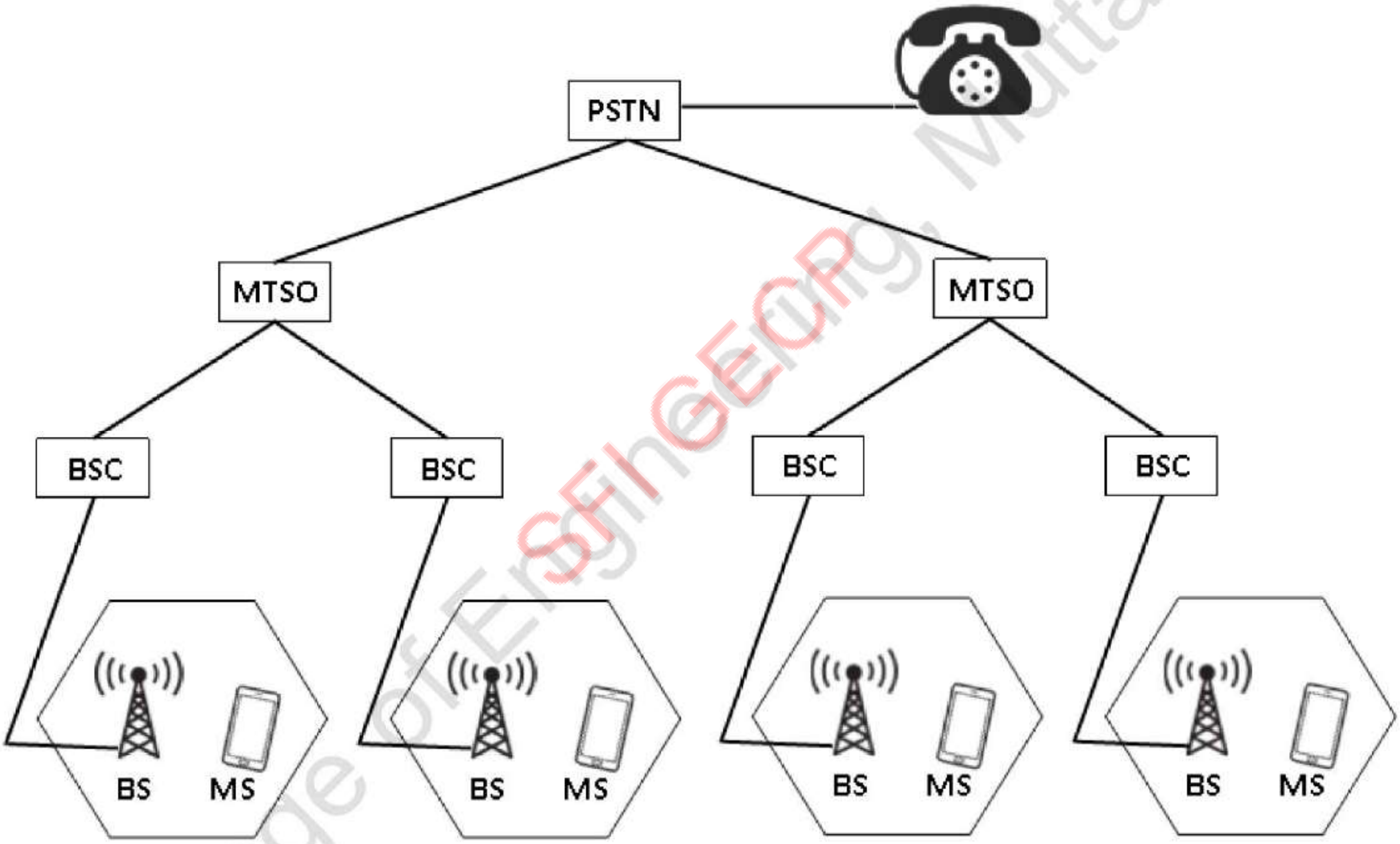
  1. Mobile unit (MS)

  2. Basic Station (BS)

  3. Mobile telephone switching office (MTSO)

- To provide the better perspective of the cellular communication technology, an appropriate block diagram is shown in figure.

PSTN	:	Public Switched Telephone Network
MTSO	:	Mobile Telephone Switching Office
BSC	:	Base Station Controller
BS	:	Base Station
MS	:	Mobile Station (or Mobile Unit)

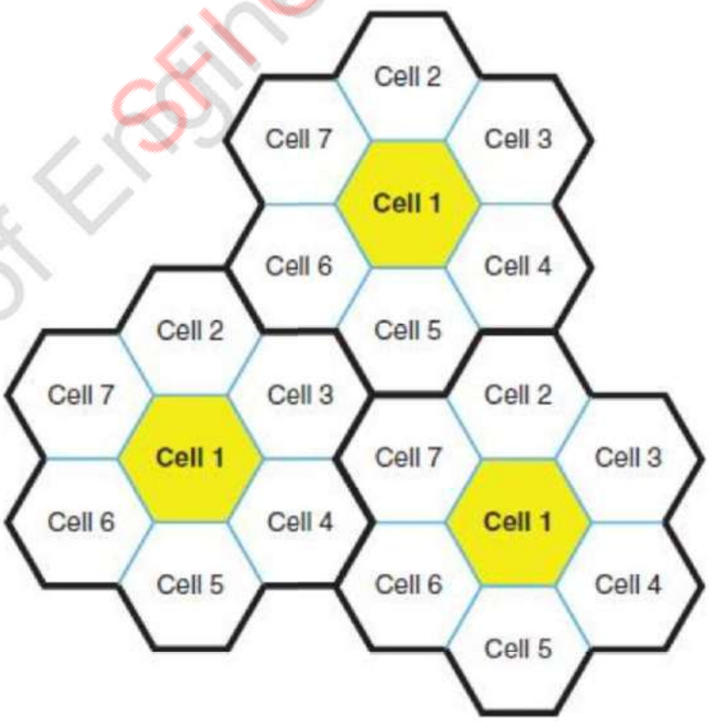


- The **base station** includes an **antenna, a controller and a number of transceivers** for communicating on the channels assigned to that cell.
- The **controller** is used to **handle the call process between the Mobile Station and the rest of the network**.
- At any time, a number of mobile user unit may be active and moving about within a cell communicating with the base station.
- **Each BSC is connected to a MTSO, with one MTSO serving multiple base stations.**
- The **MTSO connects calls between Mobile Stations**.
- The MTSO is also **connected to the PSTN** (or the conventional telephone network) and **can make a connection between a fixed subscriber to the PSTN and a mobile subscriber to a cellular network**.

- The MTSO assigns the **voice channel to each call, performs hand off, and monitors the call for billing information.**
- The use of a cellular system is **fully automated** and requires no action on the part of the user other than placing or answering a call.
- The **Home Location Register** (**HLR**) and **Visitor Location Register** (**VLR**) and two sets of pointers that support mobility and enable the use of the same telephone number world. wide.
- HLR is located at the MTSO where the MS is registered.
- **VLR** basically contains information about **all visiting mobile systems in that particular MTSO area**.
- Two types of channels are available between the Mobile Station and the base station control channels and the traffic channels.
- The control channels are used to transfer actual data between two.
- The links from BS to MS are known as '**forward links**' and the links from MS to BS are known as '**reverse link**'.

4. Concepts of Frequency Reuse

- Because only a small number of radio channel frequencies were available for mobile systems, engineers had to find a way to reuse radio channels to carry more than one conversation at a time.
- The solution adopted by the industry was called **frequency planning or frequency reuse.**
- Frequency reuse was implemented by restructuring the mobile telephone system architecture into the cellular concept.
- The concept of frequency reuse is based on assigning to each cell a group of radio channels, used within a small geographic area.
- Cells are assigned a group of channels that is completely different from neighbouring cells.
- **The coverage area of cells is called the footprint**.



- This footprint is limited by a boundary so that the same group of channels can be used in different cells that are far enough away from each other so that their frequencies do not interfere.
- Cells with the same number have the same set of frequencies. Here, because the number of available frequencies is 7, the frequency reuse factor is 1/7. That is, each cell is using 1/7 of available cellular channels.

5. **Handoff**
- When the mobile unit travels along a path, it crosses different cells.
- As the frequency of different cells are different, the transfer of call should be done between different channels or cells. This process is called **hand-off or handover**.
- The decision of hand off is taken based on the received signal strength and the carrier to interference ratio information.
- The different types of Hand-off are :
  a) channels in the same cell
  b) cells under the same BSC (Internal handover
  c) cells under different BSCs in the same MSC
  d) cells under the control of different MSCs (external handover).
- Base station (BS) monitors the signal strength throughout the call.
- **If the signal strength goes below a certain level, the base station assumes that the mobile is on the move and initiates the procedure for a 'hand-off'**.
- Mobile Telephone Switching Office (MTSO) requests the base station covering adjacent cells to monitor the traffic.
- This information is passed back to the MTSO which decides when hand-off is necessary.
- Retune command is given to the mobile and after tuning to the new frequency, it sends information to the new Base Station Controller (BSC).
- **Roaming** is defined as the ability for a cellular customer to automatically make and receive voice calls, send and receive data, or access other services, including home data services, when travelling outside the geographical coverage area of the home network.

Global System for Mobile Communications (GSM)

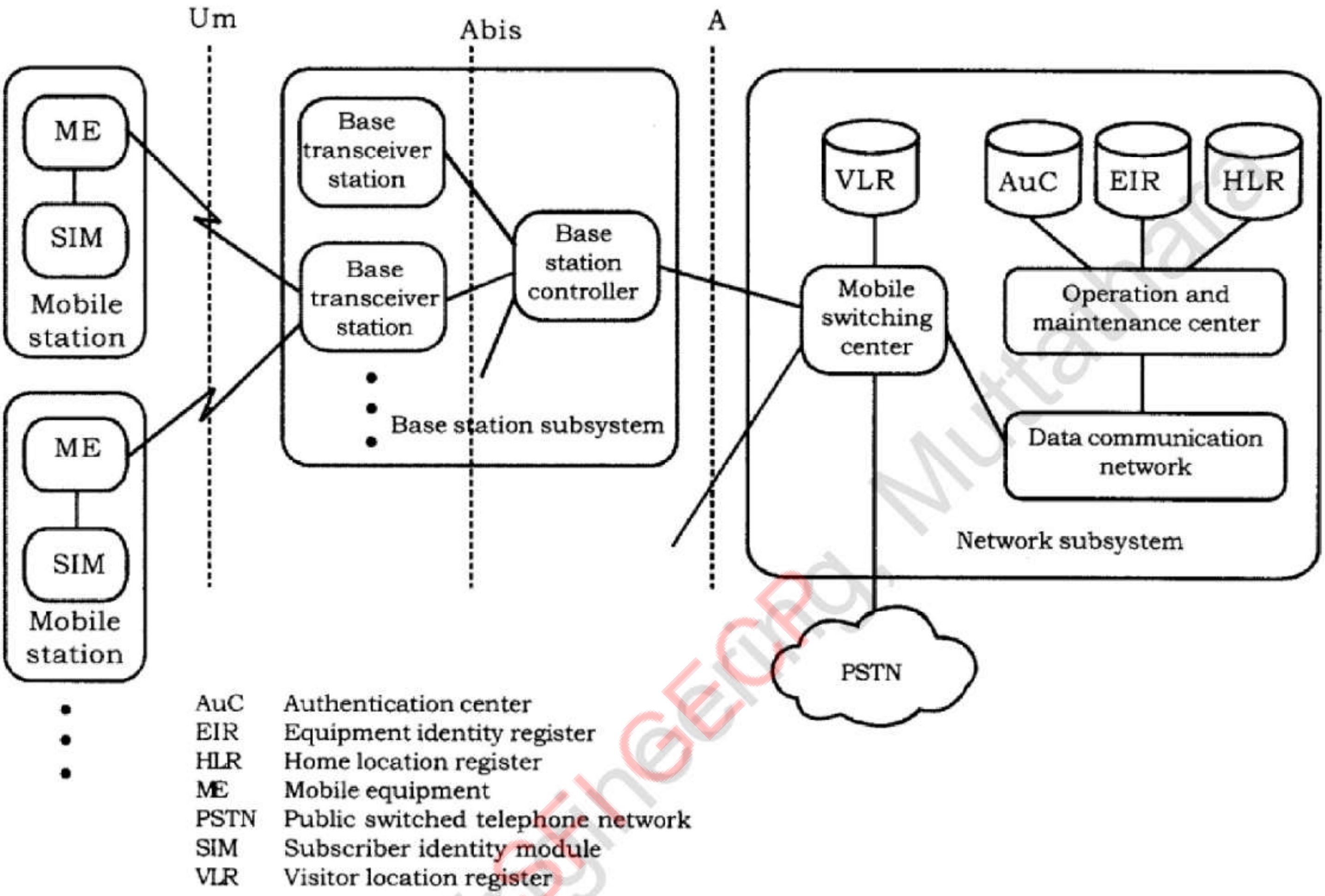
- GSM is a second-generation cellular standard developed to cater voice services and data delivery using digital modulation.
- It was the World's first cellular system to specify digital modulation and network level architectures and services, and is the most popular 2G technology.
- GSM services are divided into three groups.
  - **Telecommunication services** that enable voice communication via mobile phones.
  - **Data services** include various data services for information transfer between GSM and other networks like PSTN, ISDN etc.
  - **Supplementary services** are digital in nature that includes call diversion, closed user groups and caller identification.

Principle and block diagram of GSM

- Figure (given in page no 66) shows the key functional elements in the GSM system. The boundaries at **Um**, **Abis** and **A** refer to interfaces between functional elements that are standardized in the GSM documents.

1) **Mobile Station**
- A mobile station communicates across the **Um** interface, also known as the **air interface**, with a base station transceiver in the same cell in which the mobile unit is located.
- It consists of **mobile equipment** and a smart card called the **Subscriber Identity Module** (SIM).
- The SIM provides security and authentication of the subscriber so that the user can have access to subscribed services of a particular Network.
- The mobile equipment is uniquely identified by the **International Mobile Equipment Identity (IMEI).**

- An IMEI is marked as invalid if it has been reported stolen or is not type approved.
- The **SIM card** contains an **International Mobile Subscriber Identity (IMSI)** which is used to identify the subscriber to the system.
- The **IMEI and the IMSI are independent**, thereby **allowing personal mobility.**



Overall GSM Architecture

2) Base Station Subsystem (BSS)

- It is the part of the network that provides radio interconnection between the Mobile Station (MS) and the switching equipment.
- It consists of one **Base Station Controller** (BSC) and many **Base Transceiver stations** (BTS).
- The BSC manages the radio resources for one or more BTSs.
- The BSC handles radio frequencies, manages the handoff of a mobile unit from one cell to another within the BSS, etc
- BSC is the connection between the mobile station and the Mobile Switching Centre (MSC).
- BTS is located at the centre of a cell and acts as the mobile interface to the cellular network.
- A group of BTSs are controlled by a BSC.

3) Network Subsystem

- It consists of the Mobile Service Switching Centre (MSC) and its associated systems, control databases and provides for interconnection between the GSM network and the Public Switched Telephone Network (PSTN).

- The NS controls handoffs between cells in different BSSs, authenticates users and validates their accounts, and includes functions for enabling worldwide roaming of mobile users.
- MSC is the central component of the network subsystem and provides all the functionalities needed to handle a mobile subscriber, such as registration, authentication, location updating, handoffs and call routing to a roaming subscriber.
- The MSC provides the connection to fixed networks (such as PSTN or ISDN).
- It is supported by four databases that it controls:
  a) **Home location register (HLR) data base** : The HLR contains the administrative information of each subscriber registered in the corresponding GSM network, along with the current location of the mobile.
  b) **Visitor location register (VLR) data base** :
  The VLR acts as a temporary subscriber data base for all subscribers and contains similar information as that in HLR.
  It records
     i. whether the subscriber is active or not and
     ii. other parameters associated with the subscriber.

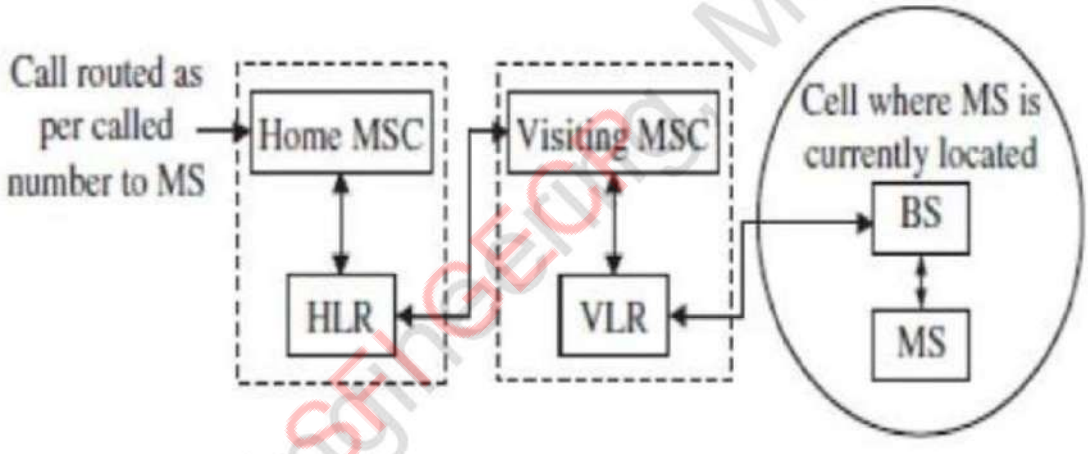


Fig: Redirection of a call to MS at a visiting location

The Home Location Register (HLR) and Visitor Location Register (VLR), together with the MSC, provides the call routing and roaming capabilities of GSM.

In simple words, any incoming call, based on the calling number, is directed to the HLR of the home MS where the MS is registered. The HLR then points to the VLR of the MSC where the MS is currently located.

  c) **Authentication Centre database (AuC)** : It provides authentication and encryption parameters that verify the user's identity and ensure the confidentiality of each cell.
  d) **Equipment Identity Register database (EIR) :** The EIR keeps track of the type of equipment that exists at the mobile station. It also plays a role in security (e.g., blocking calls from stolen mobile stations and preventing use of the network by stations that have not been approved).

Questions (Module 6)

PART A
Each question carries 4 marks

1. **Explain the principle of radio communication with block diagram.**
2. **What is the working principle of an antenna when used in a radio transmitter?**
3. What is the need of two separate sections RF section and IF section in a super heterodyne receiver?
4. What is meant by a cell in a cellular communication?
5. **Define amplitude modulation with neat sketches.**
6. **Define Frequency modulation with neat sketches**
7. **List the Comparison between AM and FM.**
8. **Explain the concept of cells in cellular mobile communication.**
9. **Explain the concept of frequency reuse in cellular mobile communication**
10. **Explain the concept of hand-off in cellular mobile communication**
11. What is modulation. Explain the need for modulation.
12. **Modulation reduces the height of the Antenna. Justify.**
13. **What is meant by Super heterodyning?**
14. **Explain the terms BSC, SIM, MSC, PSTN related to cellular communication system.**

PART B
Each question carries 10 marks

15. (a) With the help of a block diagram, explain the working of Super heterodyne receiver. (6)
    (b) Explain the importance of antenna in a communication system. (4)
16. **(a) With neat sketches, explain a cellular communication system. (5)**
    (b) Explain GSM communication with the help of a block diagram. (5)
17. **Explain the concept of cells, frequency reuse and hand off in cellular mobile communication. (10)**
18. (a) **Define amplitude modulation with graph. Derive an expression for representing amplitude modulated wave.** (6)
    (b) List the Comparison between AM and FM. (4)
19. **(a) With the help of a block diagram, explain the working of AM Super heterodyne receiver. (6)**
    (b) Explain Antenna reciprocity (4)
20. **With the help of a block diagram, explain the working of FM Super heterodyne receiver**. (6)
    (b) What is modulation. Explain the need for modulation. (4)
21. Explain the Evolution of communication systems from Telegraphy to Smartphones.
22. Explain the Evolution of Mobile Generation.
23. List the Frequency bands used for various communication systems
24. (a) **How does a GSM network connect people around? Describe the sequence of operations and components involved.** (6)
    (b) Modulation reduces the height of the Antenna. Justify. (4)
25. **With the help of a block diagram, explain the working of Super heterodyne receiver. (10)**
26. **With neat sketches, explain a cellular communication system (10)**
27. **With neat sketches, explain a GSM system (10)**