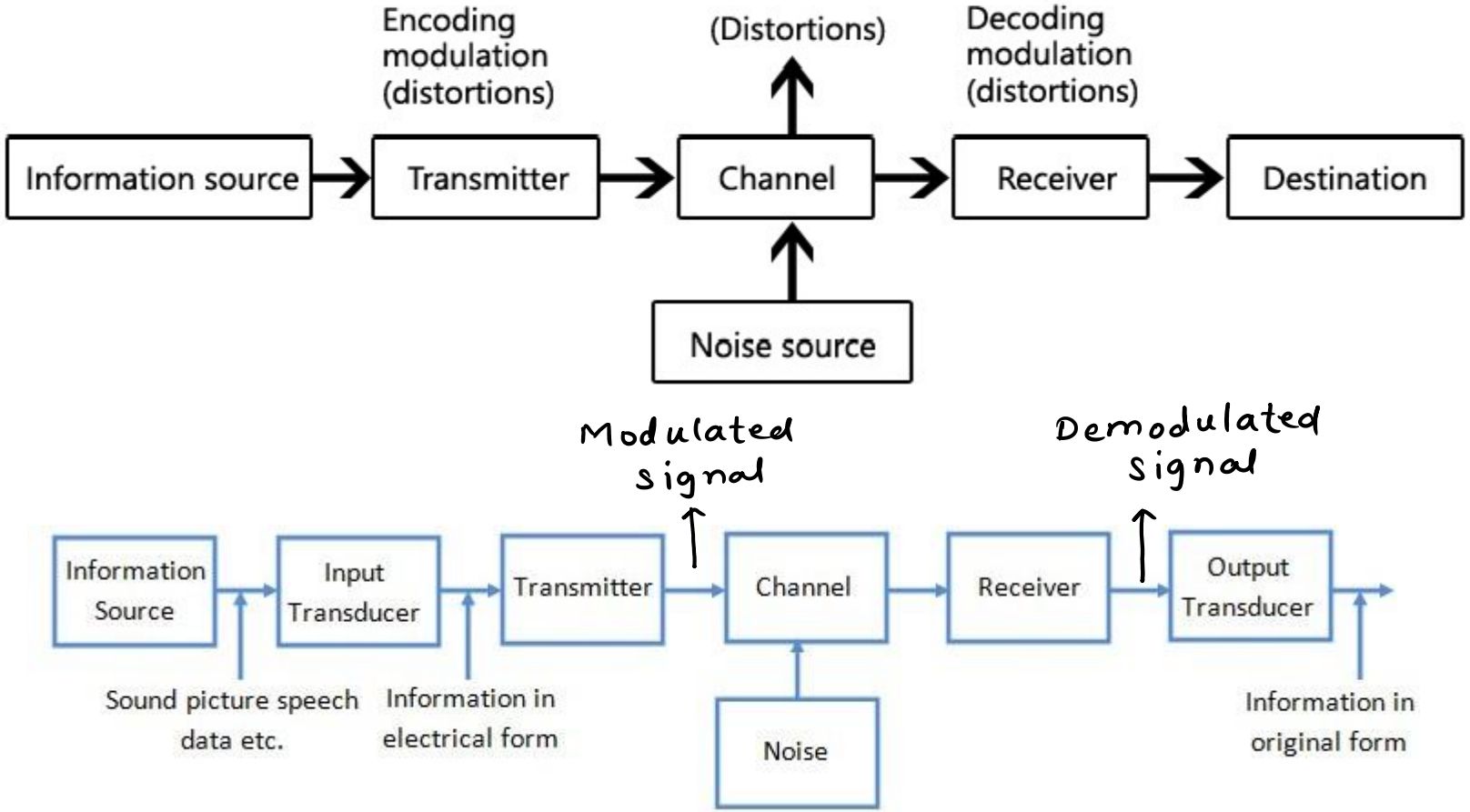
Basic Electronics Engineering: Unit 6: Communication Systems

Contents

- Basic Communication System
  - Block Diagram of Basic Communication System
  - Modes of Transmission
  - Communication Media: Wired and Wireless
  - Electromagnetic Spectrum, Allotment of frequency band for different applications
  - Block Diagram of AM and FM Transmitter and receiver

- Mobile Communication System
  - Cellular concept
  - Simple block diagram of GSM system

Block Diagram of Basic Communication System



Block Diagram of Basic Communication System

- Communication is the process of exchanging the information.
- It is used by human beings to convey their thoughts, ideas and feelings to one another from the beginning of the humankinds.
- The purpose of a communication system is to transmit an information-bearing signal, from a source, located at point, to a user or destination, located at another point some distance away.

Block Diagram of Basic Communication System

- The essential components of a communication system
  - Information source
  - Input transducer
  - Transmitter
  - Communication channel
  - Receiver and destination

Information Source

- The main function of information source is to produce required message which must be transmitted.
- In other words, a communication system use to communicate a message or information.
- This information originates in the information source.
- There are various messages present
  - Group of words
  - Code
  - Sound signal
  - Symbols
  - Audio
  - Video

Examples -

1) 1D signal : speech

2) 2D signal : Image

3) 3D signal : Video

Input Transducer

- A transducer is a device which converts energy signal into electrical signal.
- The message from the information source may or may not be electrical signal in nature.
- In a case when the message produced by the information source is not electrical in nature, an input transducer is used to convert the message signal into a time-varying electrical signal.
- For example, in case of radio-broadcasting, a microphone converts the information or massage signal which is in the form of sound waves into electrical signal.

Transmitter

- The function of the transmitter section is to process the electrical from different aspects.
- For example, in radio broadcasting the electrical signal is obtained from sound signal, is processed to restrict its range of audio frequencies (upto 5 kHz in amplitude modulation radio broadcast) and is often amplified.
- In modulation technique, the message signal is superimposed upon the high-frequency carrier signal.
- We can say that inside the transmitter, signal processing such as restriction of range of audio frequencies, modulation and amplification of signal are achieved.
- All the processing of the message signal are done just to ease the transmission of the signal through the channel.

Channel

- Channel means the medium through which the message travels from the transmitter section to the receiver section.
- Channel is the physical medium which connects the transmitter with that of the receiver.
- Function of the channel is to provide a physical connection between the transmitter and the receiver.
- Point-to-point channels: Ex: Wired Telephone, Wireless : Mobile.
- Broadcast channels: Radio, TV, Satellite.

Noise

- During the process of transmission and reception of the signal noise introduced in the system and signal gets distorted.
- Noise enters in any communication system through channel.
- Noise is an unwanted signal, random in nature.
- It can not be removed but minimized to some extent.

Receiver

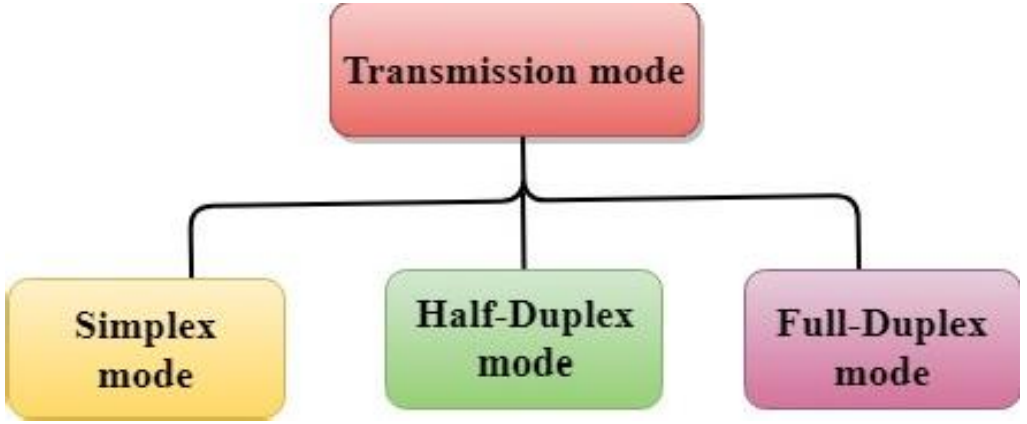
- The main function of the receiver is to reproduce the message signal which is distorted in electrical form.
- This reproduction of the original signal is obtained by a process known as the demodulation or detection.
- Demodulation is the reverse process of modulation in transmitter

Destination Transducer

- Last stage and final stage is Destination which is used to convert an electrical message signal into its original form.
- For example, in radio broadcasting, the destination is a loudspeaker which works as a transducer i. e. converts the electrical signal in the form of original sound signal.

Modes of Transmission

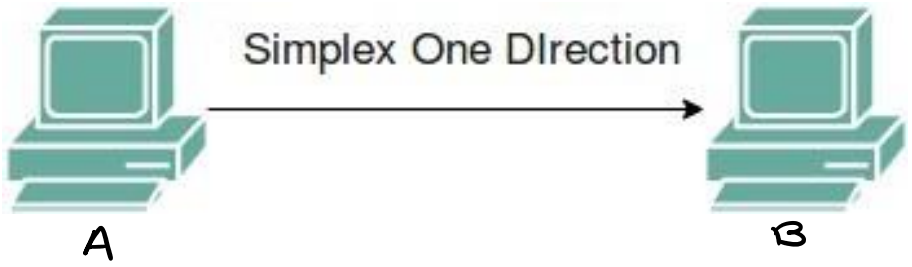
- Transmission mode means transferring of data between two devices
- It is also known as communication mode.
- Buses and networks are designed to allow communication to occur between individual devices that are interconnected.
- There are three types of transmission mode:
  - Simplex Mode
  - Half-Duplex Mode
  - Full-Duplex Mode



Simplex Mode

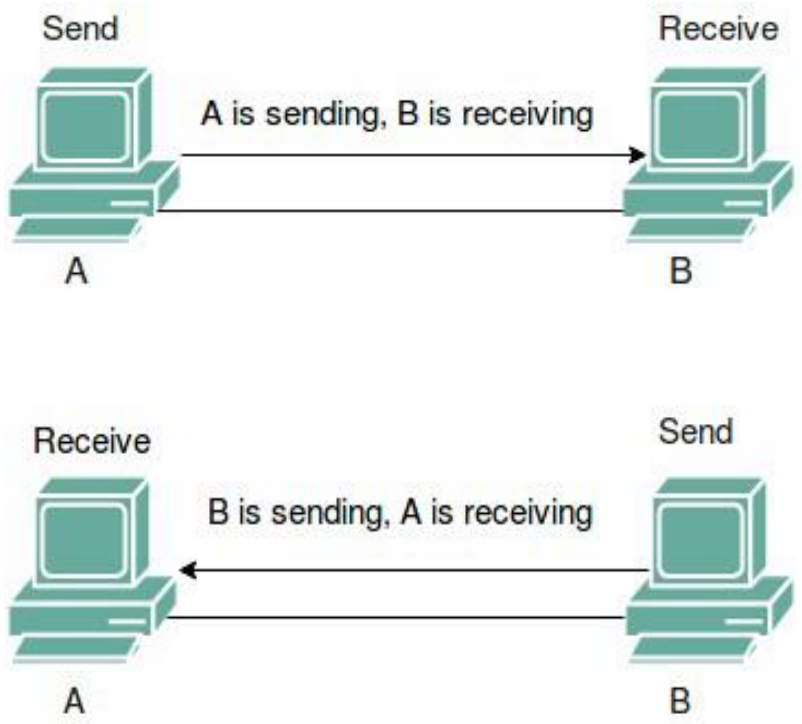
- In Simplex mode, the communication is unidirectional, as on a one-way street.
- Only one of the two devices on a link can transmit, the other can only receive.
- The simplex mode can use the entire capacity of the channel to send data in one direction.
- Example: Keyboard and traditional monitors.
- The keyboard can only introduce input, the monitor can only give the output.

1) Keyboard to CPU communication



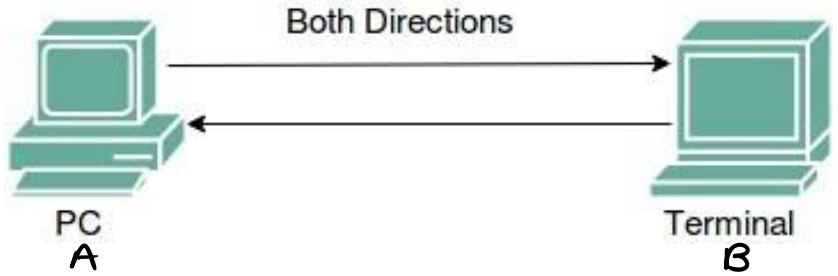
Half Duplex Mode

- In half-duplex mode, each station can both transmit and receive, but not at the same time.
- When one device is sending, the other can only receive, and vice versa.
- The half-duplex mode is used in cases where there is no need for communication in both direction at the same time.
- The entire capacity of the channel can be utilized for each direction.
- Example: Walkie- talkie in which message is sent one at a time and messages are sent in both the .directions

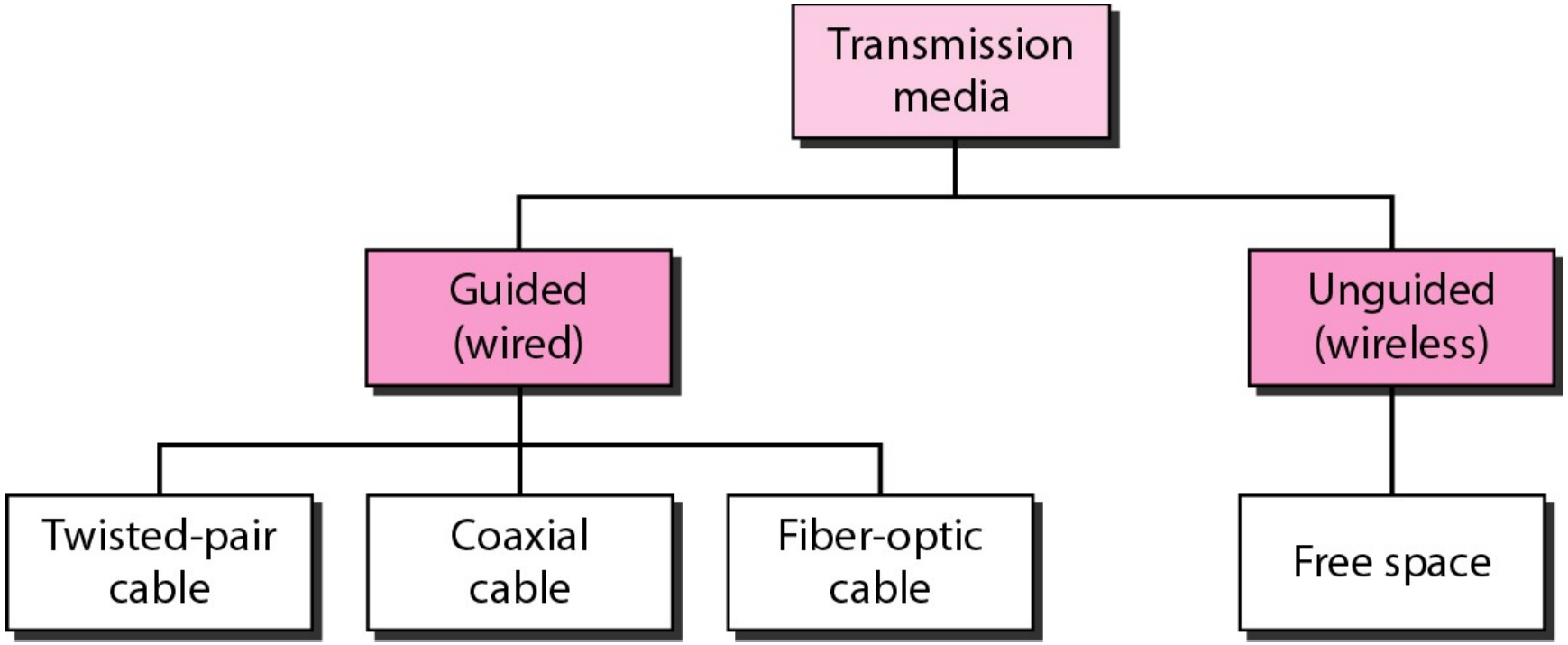


Full Duplex Mode

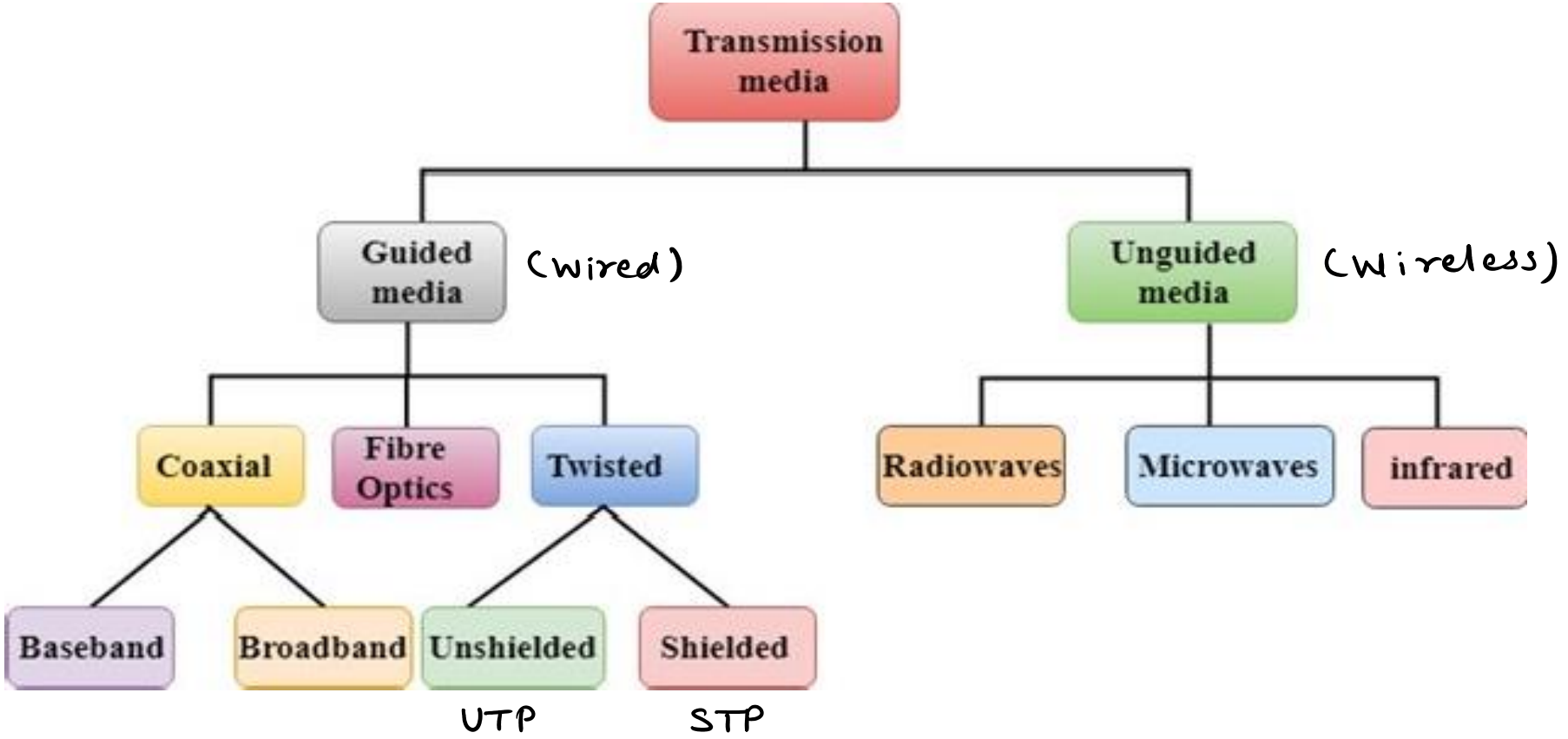
- In full duplex mode, both stations can transmit and receive simultaneously.
- In full duplex mode, signals going in one direction share the capacity of the link with signals going in other direction, this sharing can occur in two ways.
- Either the link must contain two physically separate transmission paths, one for sending and other for receiving.
- The capacity is divided between signals travelling in both directions.
- Full-duplex mode is used when communication in both direction is required all the time.
- Telephone Network in which there is communication between two persons by a telephone line, through which both can talk and listen at the same time.



Transmission Media



Transmission Media

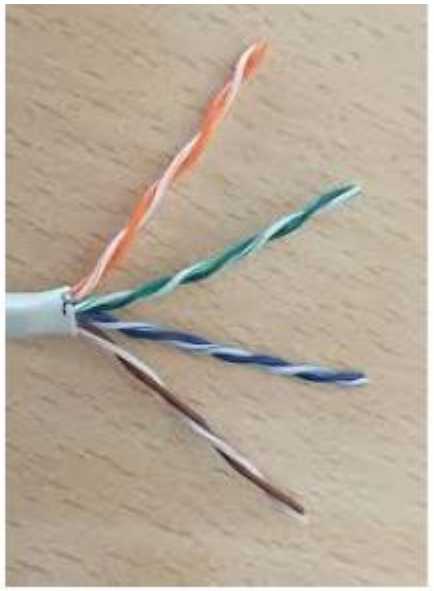


Twisted Pair Cables

- Twisted pair cables have been around for a long time.
- They were mainly invented for voice transmissions.
- Twisted pair is a widely used medium in networking because it's lighter, cheaper, more flexible, easy to install, and provides greater speeds than coaxial cables.
- There are two types of twisted pair cables:
  - The unshielded twisted pair (UTP)
  - The shielded twisted pair (STP) → More resistance to crosstalk

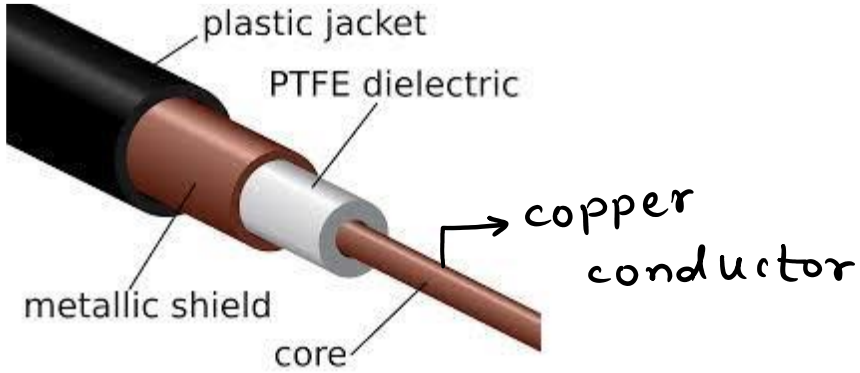
STP

UTP



Coaxial Cables

- The coaxial cables have a central copper conductor, surrounded by an insulating layer, a conducting shield, and the outermost plastic sheath.
- There are three insulation layers for the inner copper cable.
- There are two basic modes of data transmission in coaxial cables:
  - Baseband mode that has dedicated bandwidth.
  - Broadband mode that has distributed cable bandwidth.



Coaxial Cables

- Cable TV and analog televisions mainly use coaxial cables. Coaxial cables have better resistance to cross talk than twisted pair cables.
- The coaxial cables are used for long distance communication.
- The most widely used types of coaxial cables are RG-59 and RG-6 (RG stands for 'radio guide').
- RG-59 has lesser shielding and is suitable for short cable lengths and cable TV connections.
- Advantages of Coaxial Cables
  - High bandwidth
  - Easy and cheap installation
  - Better immunity from noise
  - Better scaling

Fiber Optical Cables

- Optical fibers use light waves for transmission.
- Crosstalk, EMI, and attenuation aren't issues with optical fibers.
- These cables are well-suited for voice, data, and video transmissions.
- Optical fibers are the most secure of all the cable media.
- Installation and maintenance are difficult and costly.
- Advantages
  - Greater transmission speed
  - High bandwidth
  - Travel longer distances
  - Most secure for all cable media

Wireless or Unguided Media

- In wireless media, signal gets broadcasted without any guided medium through the air and is less secure.
- There are three types of wireless transmission media:
  - Radio wave
  - Infrared
  - Microwave
- The advantages of unguided transmission media include the following:
  - They are useful in wireless remote accessing methods.
  - Networks can be expanded without disturbing the current users.
- Disadvantages
  - Potential Security Issues
  - Limited Speed compared to guided media

Terminologies in Communication Systems

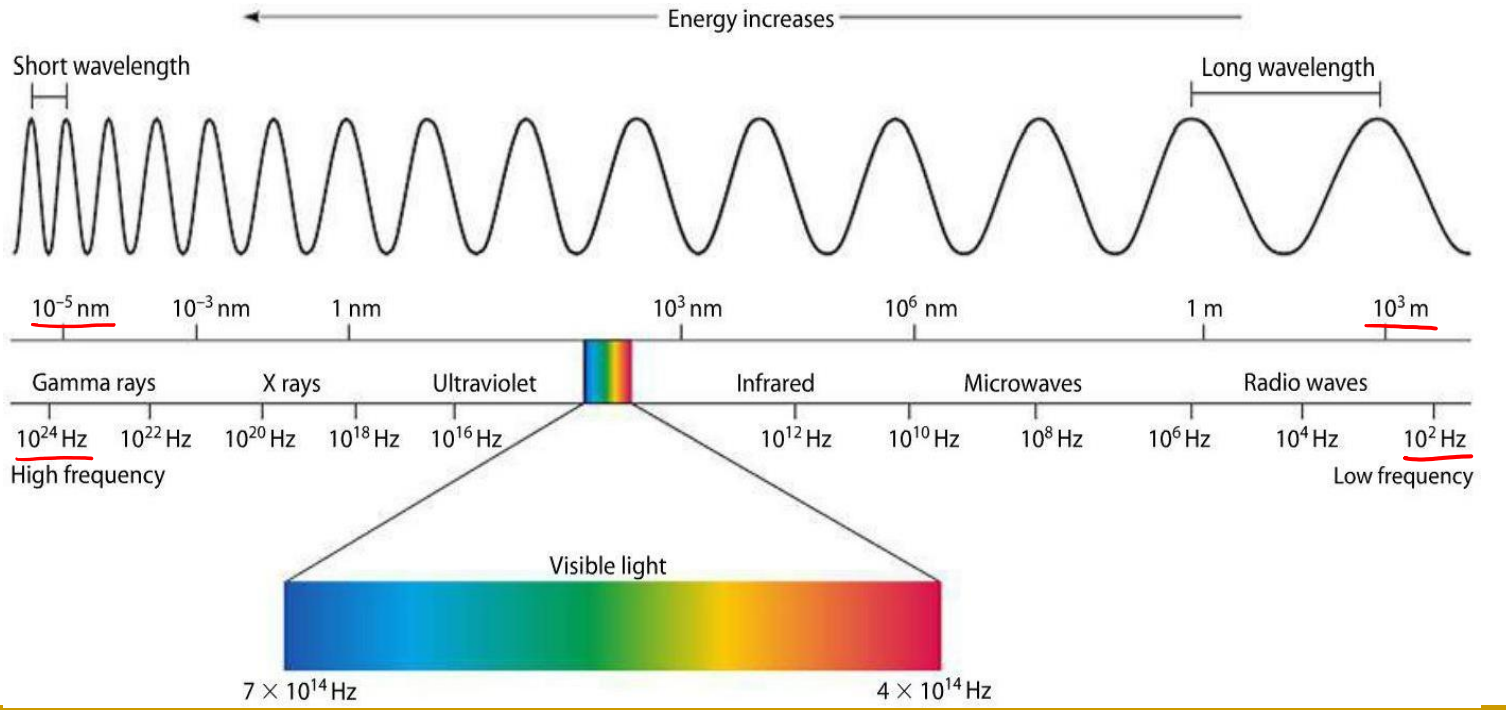
- **Time:** Time (t) is a fundamental quantity with reference to which all communications happen. It is typically measured in seconds (sec).
- **Frequency:** Frequency is defined as the number of oscillations per second and is measured in Hertz.
- **Wavelength:** Wavelength is defined as the distance travelled by an EM wave during the time of one cycle.
- **Spectrum:** The frequency domain representation of the given signal. Range of frequencies. It is the graphical representation of amplitude verses frequency.

Terminologies in Communication Systems

- **Bandwidth:** It is that portion of the EM spectrum occupied by a signal. More specifically it is the range of frequencies over which the information is present in the original signal and hence it may also be termed as signal bandwidth.
- **Channel Bandwidth:** The range of frequencies that are present in the signal or information that a channel can transmit without causing loss of information

Electromagnetic Spectrum

- The electromagnetic spectrum is the range of frequencies (the spectrum) of electromagnetic radiation and their respective wavelengths and photon energies.
- The electromagnetic spectrum covers electromagnetic waves with frequencies ranging from below 1 Hz to above 10^{25} Hz.



Electromagnetic Spectrum

- Wavelengths from thousands of kilometers down to a fraction of the size of an atomic nucleus.
- This frequency range is divided into separate bands, and the electromagnetic waves within each frequency band are called by different names, including,
  - Radio
  - Microwaves
  - Radar
  - Infrared
  - Visible Light
  - Ultraviolet
  - X-Rays
  - Gamma Rays
- The electromagnetic waves in each of these bands have different characteristics, such as how they are produced, how they interact with matter, and their practical applications

IEEE Electromagnetic Spectrum

- Following table shows various frequency bands allocated for various applications as per the IEEE standard:

Name	Frequency Range	Principal Use
Super Low Frequency(SLF)	30-300Hz	Power Grids
Very Low Frequency(VLF)	3-30KHz	Submarine Communication Sonar
Low Frequency(LF)	30-300KHz	Radio beacons, navigational aids
Medium frequency(MF)	300-3000KHz	AM broadcasting, Coast Guide Communications, direction finding
High Frequency(HF)	3-30MHz	Shortwave broadcasting, telephone, telegraph, international, amateur radio, citizen's band

IEEE Electromagnetic Spectrum

Name	Frequency Range	Principal Use
Very High frequency(VHF)	30-300MHz	FM broadcasting, TV, air traffic control, police, taxicab, and mobile radio
Ultra High Frequency(UHF)	300-3000MHz	TV, Satellite Communication, Surveillance radar, WiLAN, Cellular Phone, GPS
Super High Frequency(SHF)	3-30GHz	Radar, Automotive Radar

Baseband Communication

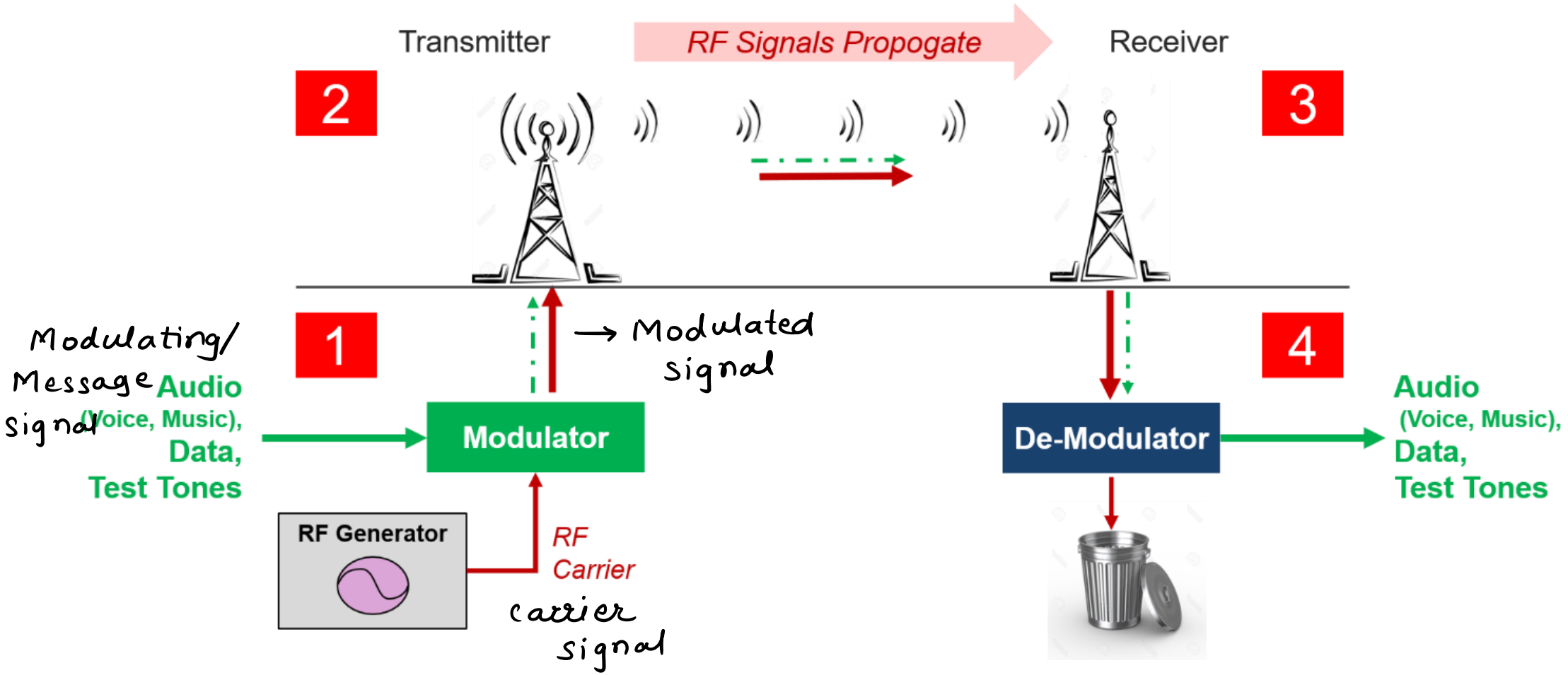
- **Baseband** means frequency band of message signal in actual form (Without any modulation).
- Message signal in actual form is known as Baseband Signal, **Example: Voice, Video, Data, Telegraph, etc.**
- Communication without using modulation is known as **Baseband Communication**, because frequency band of channel is same as of the message signal.
- CCTV is an example for Baseband communication.
- It is used only for short distances, for limited applications without broadcasting, without sharing a common channel.

Modulation

- Message signal attributes, frequency, amplitude, phase are superimposed on carrier signal for a long-distance transmission on a common (Shared) channel.
- In electronics and telecommunications, modulation is the process of varying one or more properties of a periodic waveform, called the carrier signal, with a modulating signal that typically contains information to be transmitted.
- Most radio systems in the 20th century used frequency modulation (FM) or amplitude modulation (AM) for radio broadcast.

* Modulating signal : original message signal
* Carrier Signal : High Frequency signal

Modulation and Demodulation



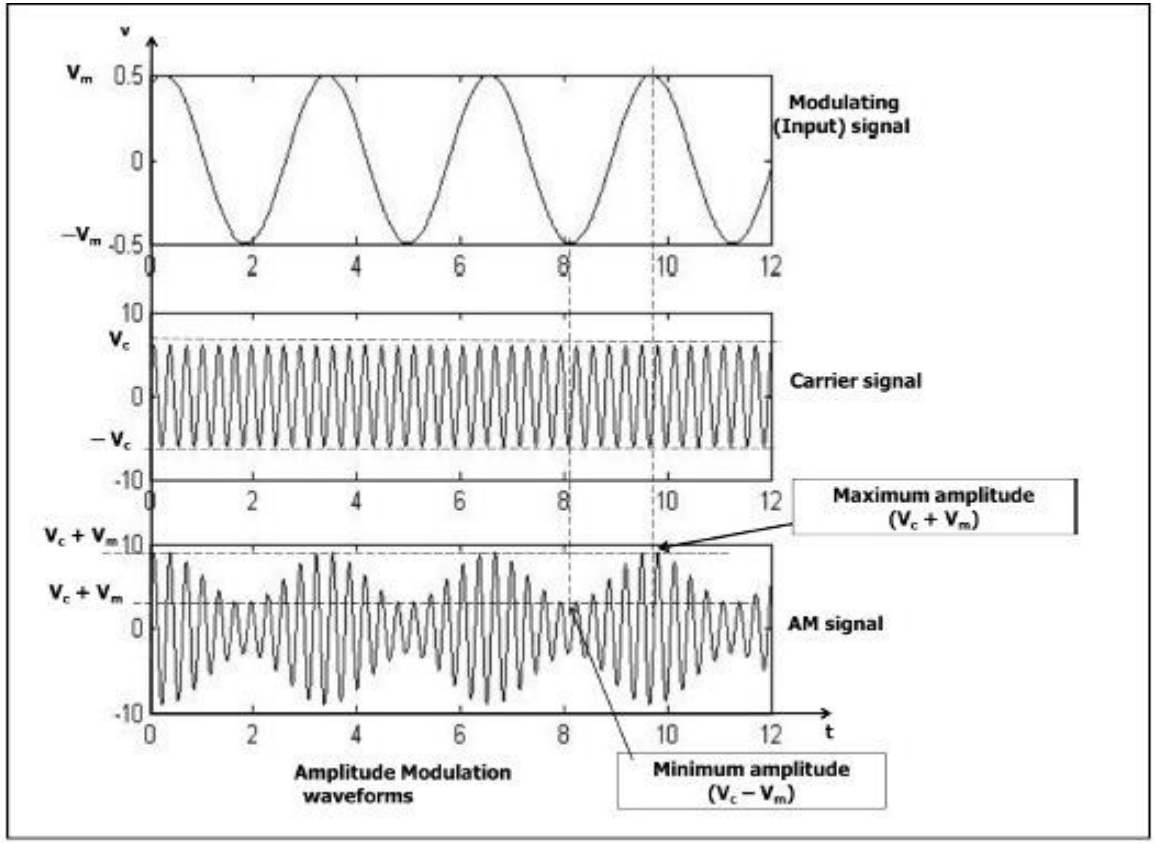
Slide Credit: https://blogs.keysight.com/blogs/tech/rfmw.entry.html/2019/10/04/the_abcs_of_analogd-mkFg.html

Need for Modulation

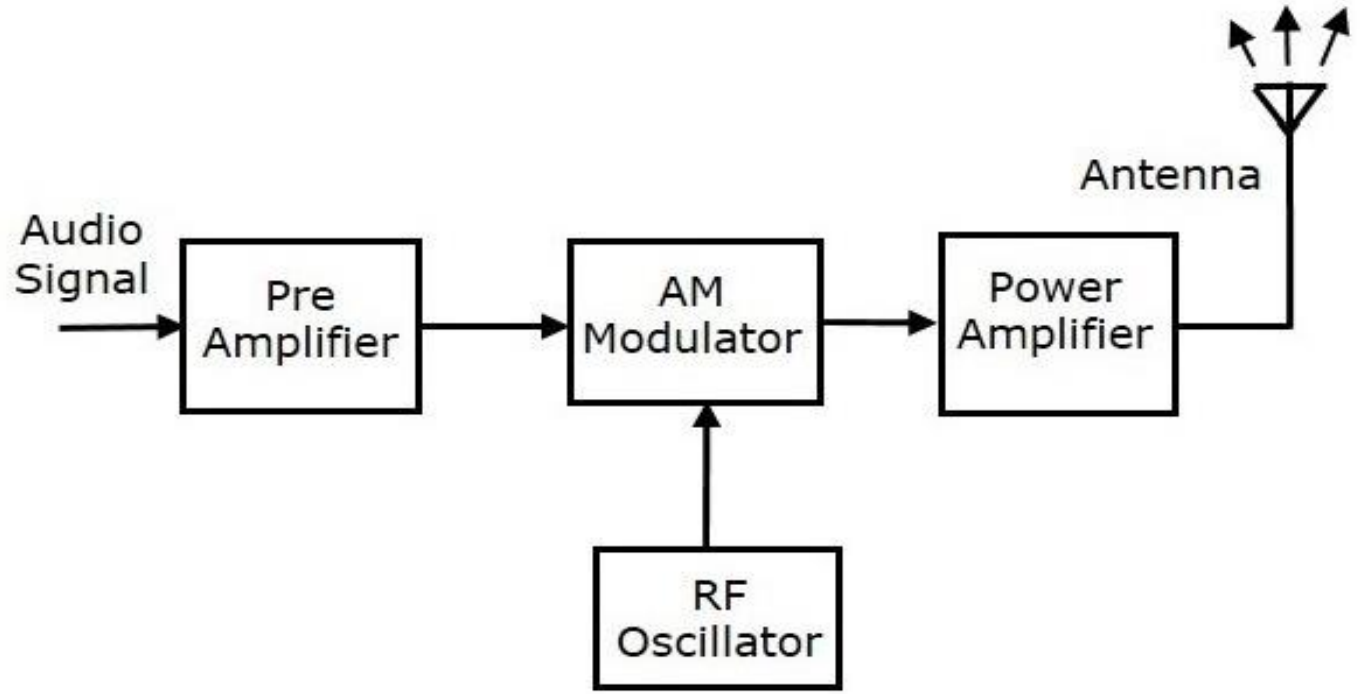
- Baseband signal transmission cannot be used for radio communication. To transmit the baseband signal for radio communication, modulation must be used.
- Modulation is necessary because of following advantages:
  - Reduction in height of antenna.
  - Avoids mixing of signals.
  - Increase the range of communication.
  - Multiplexing is possible.
  - Improves quality of reception

Amplitude Modulation

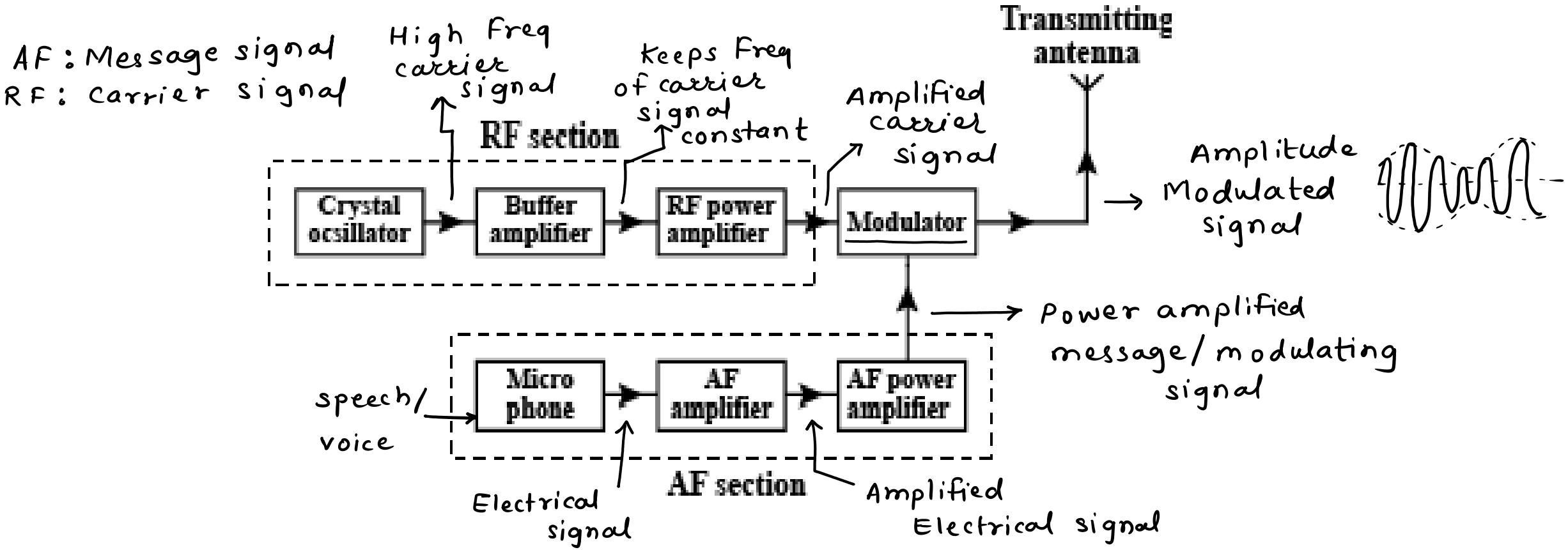
- Amplitude of the carrier signal is varied in accordance with various attributes of the modulating signal as shown in figure.



Block Diagram of AM Transmitter



Block Diagram of AM Transmitter



Functional Block Diagram of Amplitude Modulated Radio Transmitter

Block Diagram of AM Transmitter

- The figure in last slide shows the block diagram of amplitude modulated radio transmitter.
- It consists of two sections
  - Audio frequency (AF) section
  - Radio frequency (RF) section

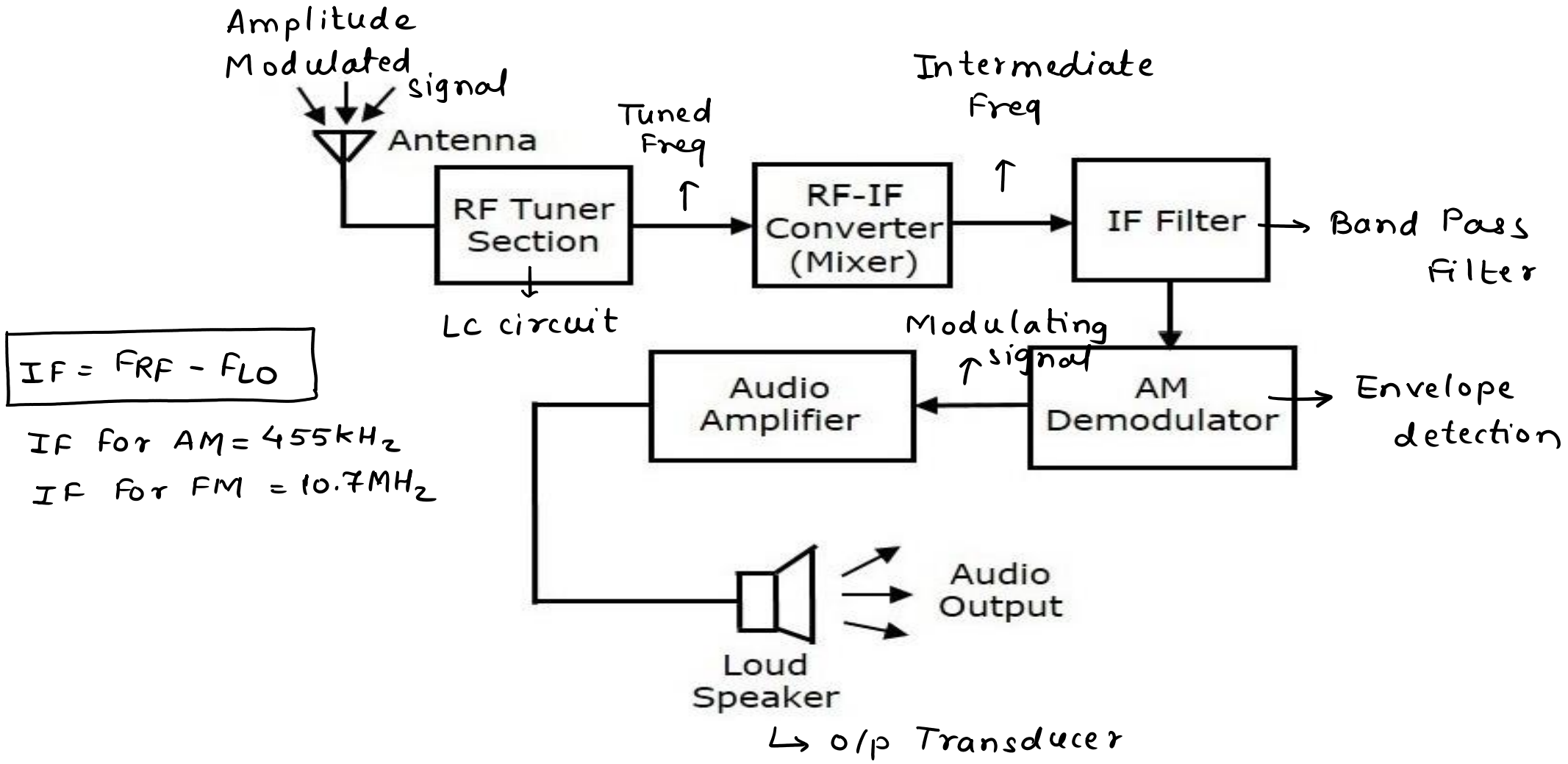
AF Section

- The AF section of the transmitter generates the modulating wave (message signal).
- The conversion of sound energy into electrical energy is performed by the microphone.
- The electrical energy available from the microphone is very low. It is amplified through an amplifier.
- The output from the AF amplifier if fed to the AF power amplifier. The power amplifier provides the required power to audio.
- The output of the AF power amplifier is given to the modulator.
- A modulator is an electronic circuit with transistor, and passive components, which performs the process of modulation.

RF Section

- The high-frequency carrier wave is generated by a crystal controlled oscillator.
- The output of the crystal controlled oscillator is power amplified by RF power amplifier.
- The buffer isolates the RF power amplifier from the oscillator.
- This arrangement keeps the frequency of the crystal controlled oscillator as a constant.
- In the modulator, the RF wave and modulating AF signal are mixed to produce the amplitude modulated wave.
- The output of this section is fed to the antenna for transmission.

Block Diagram of AM Receiver



$IF = F_{RF} - F_{LO}$

IF for AM = 455 kHz

IF for FM = 10.7 MHz

AM Receiver

- **RF Tuner Section:**
  - The amplitude modulated wave received by the antenna is first passed to the tuner circuit through a transformer.
  - The tuner circuit is nothing but a LC circuit, which is also called as resonant or tank circuit.
  - It selects the frequency, desired by the AM receiver. It also tunes the local oscillator and the RF filter at the same time.

- **RF Mixer:**
  - The signal from the tuner output is sent to the RF-IF converter, which acts as a mixer.
  - It has a local oscillator, which produces a constant frequency.
  - The mixing process is done here, having the received signal as one input and the local oscillator frequency as the other input.
  - The resultant output is a mixture of the two frequencies [(f1+f2),(f1−f2)] produced by the mixer.

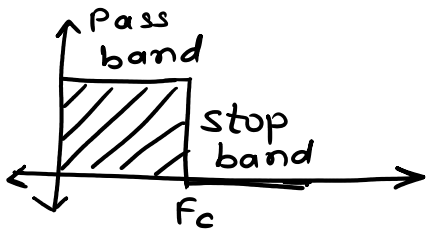
AM Receiver

- **Intermediate Frequency (IF):**
  - The production of IF helps in the demodulation of any station signal having any carrier frequency.
  - Hence, all signals are translated to a fixed carrier frequency for adequate selectivity.

- **IF Filter:**
  - Intermediate frequency filter is a band pass filter, which passes the desired frequency.
  - It eliminates all other unwanted frequency components present in it.
  - This is the advantage of IF filter, which allows only IF frequency.

Filters

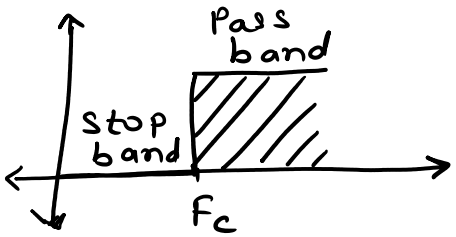
1. Low Pass Filter:



f_c = cut-off frequency

– Allows frequencies less than f_c.

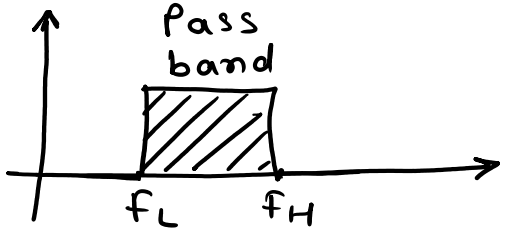
2. High Pass Filter:



f_c = cut-off frequency

– Allows frequencies greater than f_c.

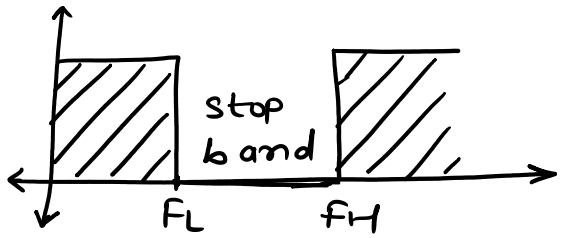
3. Band Pass Filter:



– Allows frequencies between f_L and f_H

Filters

4. Band Stop Filter :



- Allows frequencies less than f_L and greater than f_H
- Blocks frequencies between f_L and f_H.

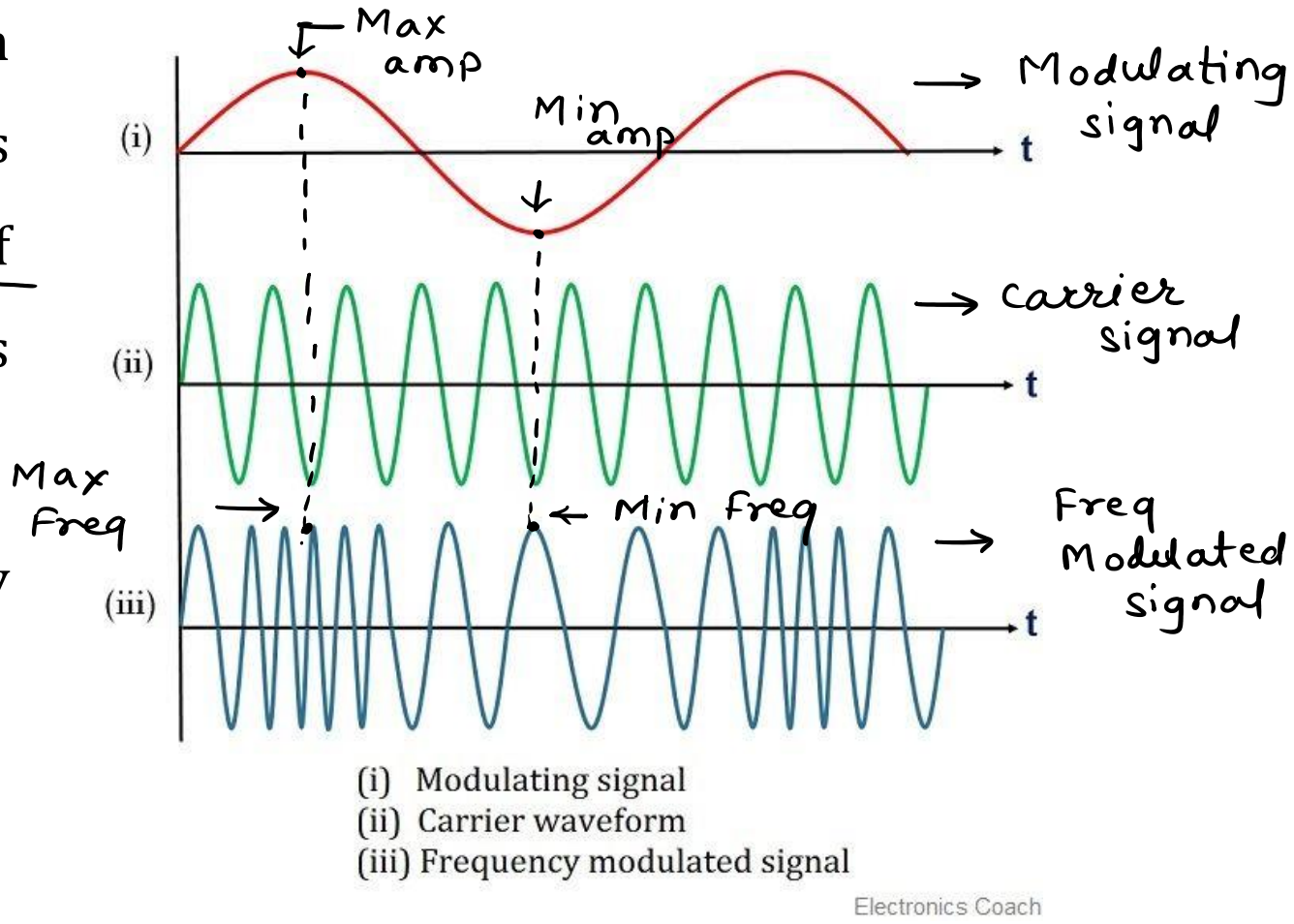
AM Receiver

- **AM Demodulator:**
  - The received AM wave is now demodulated using AM demodulator.
  - This demodulator uses the envelope detection process to receive the modulating signal.

- **Audio Amplifier:**
  - This is the power amplifier stage, which is used to amplify the detected audio signal.
  - The processed signal is strengthened to be effective.
  - This signal is passed on to the loudspeaker to get the original sound signal.

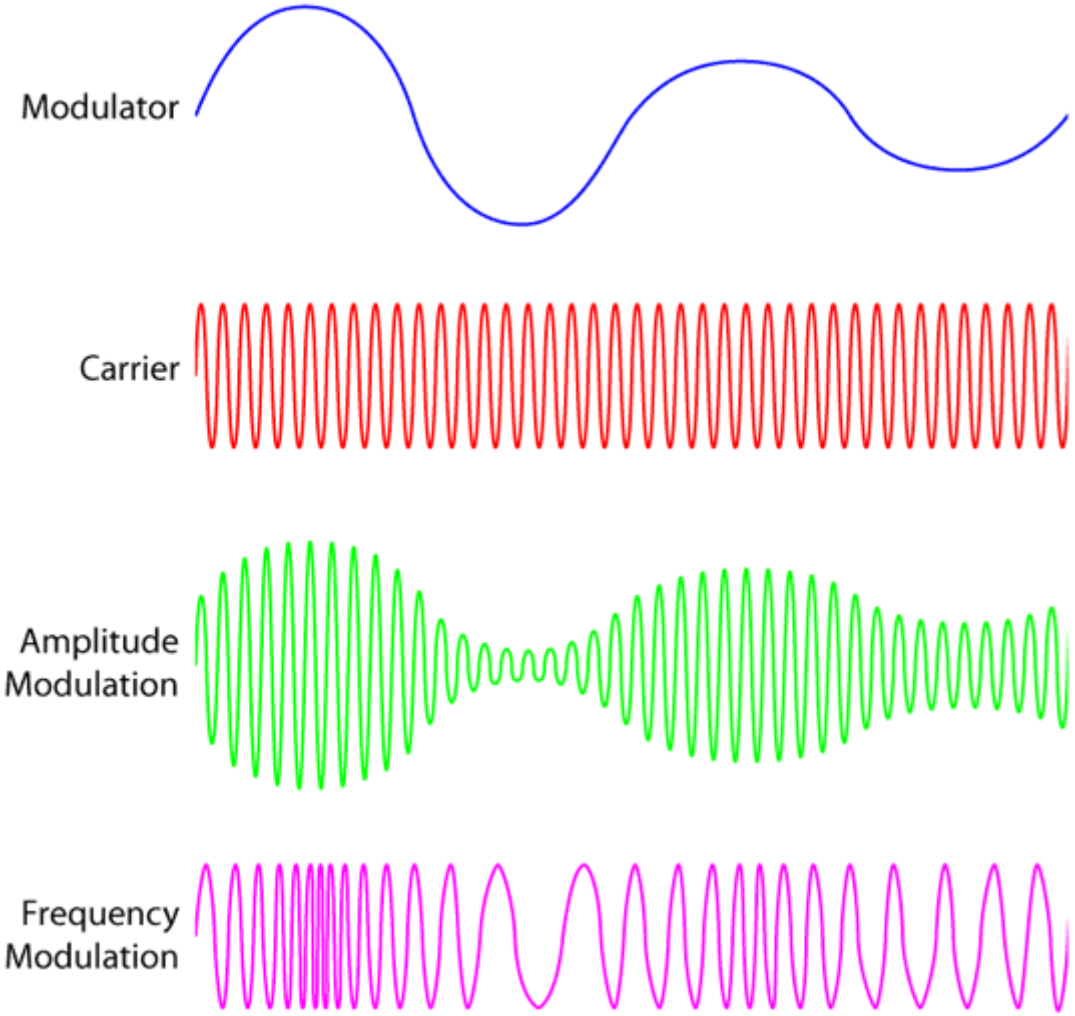
Frequency Modulation

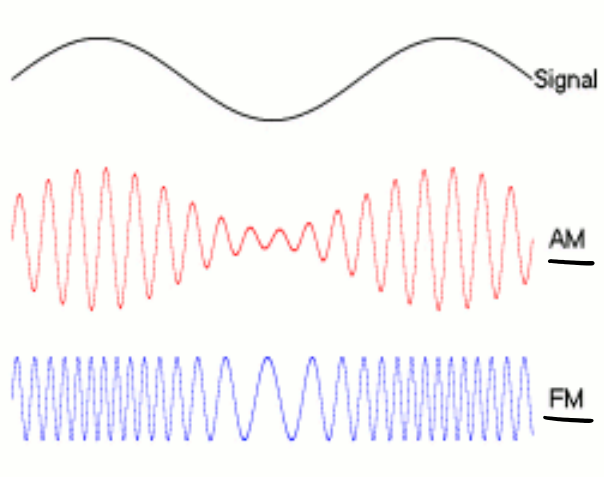
- A category of angle modulation in which the frequency of the carrier wave is changed according to the amplitude of the message signal is known as frequency modulation.
- It is abbreviated as FM and is a widely used analog modulation technique.



Slide Credit: https://electronicscoach.com/frequency-modulation.html

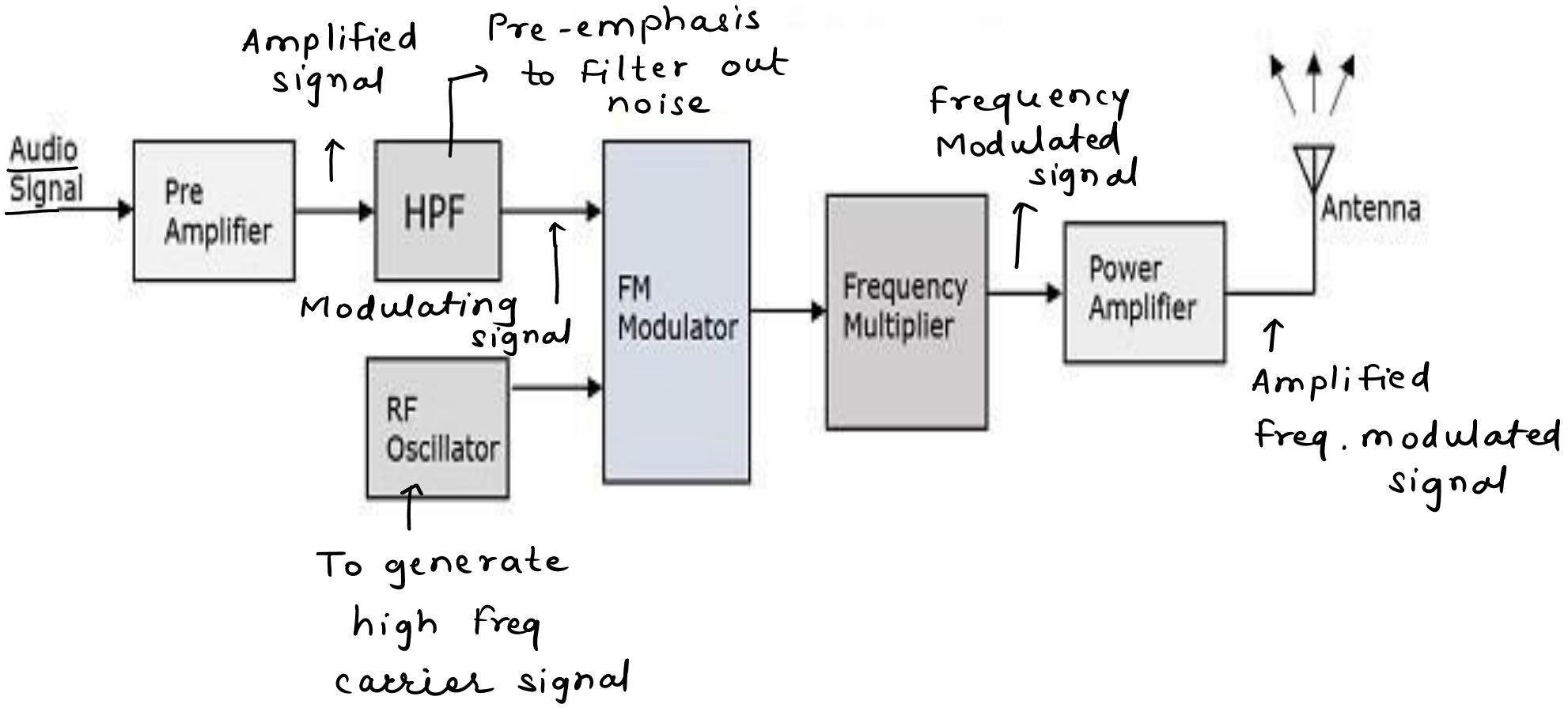
AM and FM





Slide Credit: http://mriquestions.com/signal-squiggles.html & https://commons.wikimedia.org/wiki/File:Amfm3-en-de.gif#/media/File:Amfm3-en-de.gif

Block Diagram of FM Transmitter



FM Transmitter

- The audio signal from the output of the microphone is sent to the pre-amplifier, which boosts the level of the modulating signal.
- This signal is then passed to high pass filter, which acts as a pre-emphasis network to filter out the noise and improve the signal to noise ratio.
- This signal is further passed to the FM modulator circuit.

1> Pre-emphasis Network:

pre-emphasis: Amplification of high freq components as compared to low freq components

- RC circuit with time constant of 75 μsec
- cut-off freq is 2122 Hz
- Frequencies higher than 2122 Hz will be enhanced linearly at the rate of 6dB per octave.

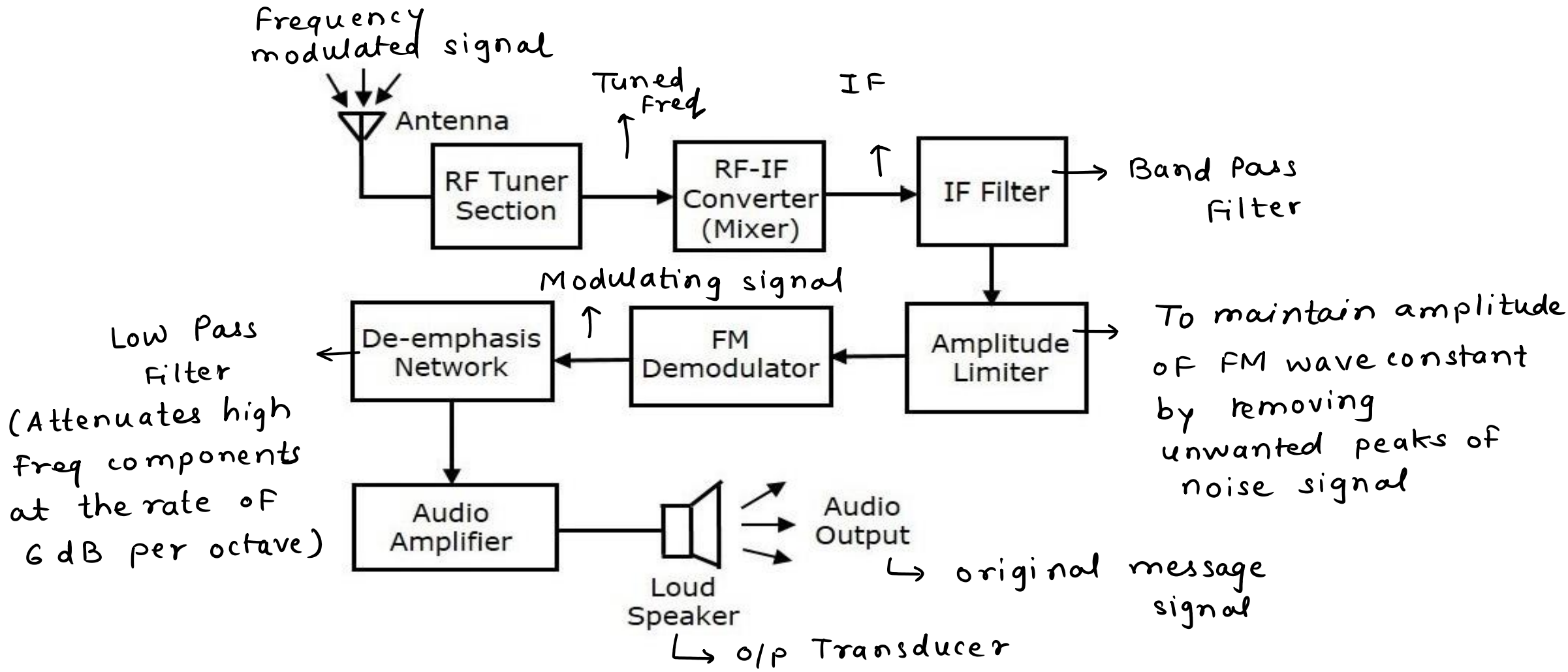
2> Signal to Noise Ratio (SNR):

$$SNR = \frac{\text{Signal power}}{\text{Noise power}} \quad (dB)$$

FM Transmitter

- The oscillator circuit generates a high frequency carrier, which is sent to the modulator along with the modulating signal.
- Several stages of frequency multiplier are used to increase the operating frequency.
- Even then, the power of the signal is not enough to transmit.
- RF power amplifier is used at the end to increase the power of the modulated signal.
- This FM modulated output is finally passed to the antenna to be transmitted

FM Receiver



FM Receiver

- This block diagram of FM receiver is similar to the block diagram of AM receiver.
- The two blocks Amplitude limiter and De-emphasis network are included before and after FM demodulator.
- The operation of the remaining blocks is the same as that of AM receiver.

FM Receiver

- In FM modulation, the amplitude of FM wave remains constant.
- If some noise is added with FM wave in the channel, due to that the amplitude of FM wave may vary.
- With the help of amplitude limiter we can maintain the amplitude of FM wave as constant by removing the unwanted peaks of the noise signal.
- In FM transmitter, the pre-emphasis network (High pass filter), which is present before FM modulator.
- This is used to improve the SNR of high frequency audio signal.
- The reverse process of pre-emphasis is known as de-emphasis.

FM Receiver

- Thus, in this FM receiver, the de-emphasis network (Low pass filter) is included after FM demodulator.
- This signal is passed to the audio amplifier to increase the power level.
- Finally, we get the original sound signal from the loudspeaker.

Cellular Concept

- A mobile communication does not depend on any physical connection between any two communication systems.
- It has a flexibility to be mobile during communication.
- A cellular phone is a portable telephone that does not use a wired connection.
- It connects to a wireless carrier network using radio waves.
- As the name indicates, cellular telecommunications technology is based around the concept of using a large number of base stations each covering a small area or cell.

Cellular Concept

- Each base station communicating with a reasonable number of users.
- It means that the whole system can accommodate a huge number of connections, and the levels of frequency use are good.
- A cellular communications system consists of various fundamental blocks.
- Each of block performs a different function.
- User Equipment
  - The user equipment or mobile phone is the element of a mobile communications system that the user sees.
  - It connects to the network and enables the user to access voice and data services.

Cellular Concept

- **Radio Access Network:**
  - The radio access network is at the periphery of the cellular communications system.
  - It provides the link to the user equipment from the cellular network.
  - It comprises a number of elements and broadly includes the base station and base station controller.
- **Core Network:**
  - The core network is the hub of the cellular communications system.
  - It manages the overall system as well as storing user data, manages access control, links to the external world and provides a host of other functions.

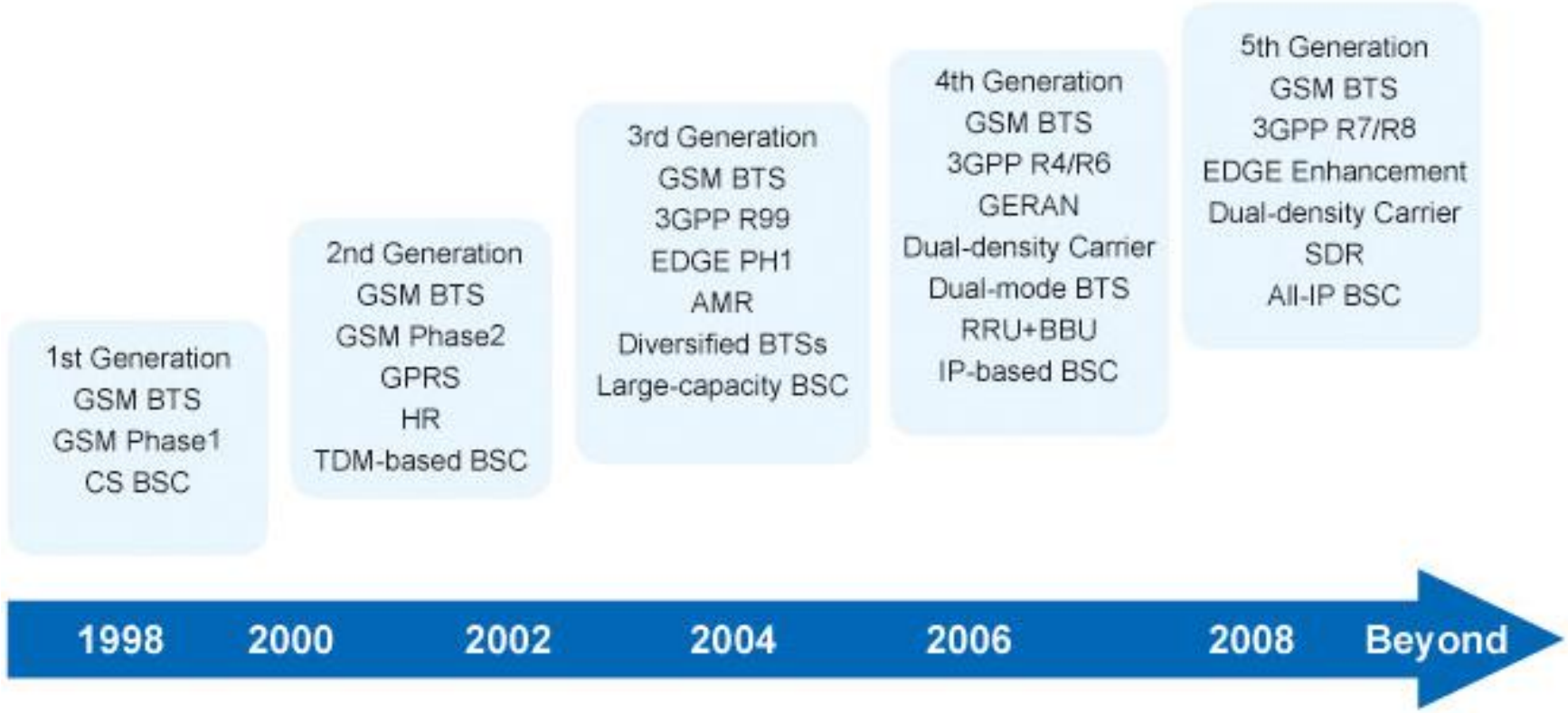
Cellular Concept

- **Mobile** wireless communication system has gone through several evolution stages in the past few decades after the introduction of the first generation mobile network in early 1980s.
- Due to huge demand for more connections worldwide, mobile communication standards advanced rapidly to support more users.
- All the developments in mobile or cellular communications have been categorized into generations of standards.
- First Generation (1G), Second Generation (2G), 3G, 4G, 5G and so on…

Cellular Communication Technology

- Use of multiple low power transmitters.
- Area divided into cells.
- Each served by its own antenna.
- Served by base station, consisting of transmitter, receiver, antenna.
- Band of frequencies allocated.
- Cells set up such that all the antennas of neighboring cells are equidistant.

Evolution of GSM



Basic Components in Cellular Communication System: GSM

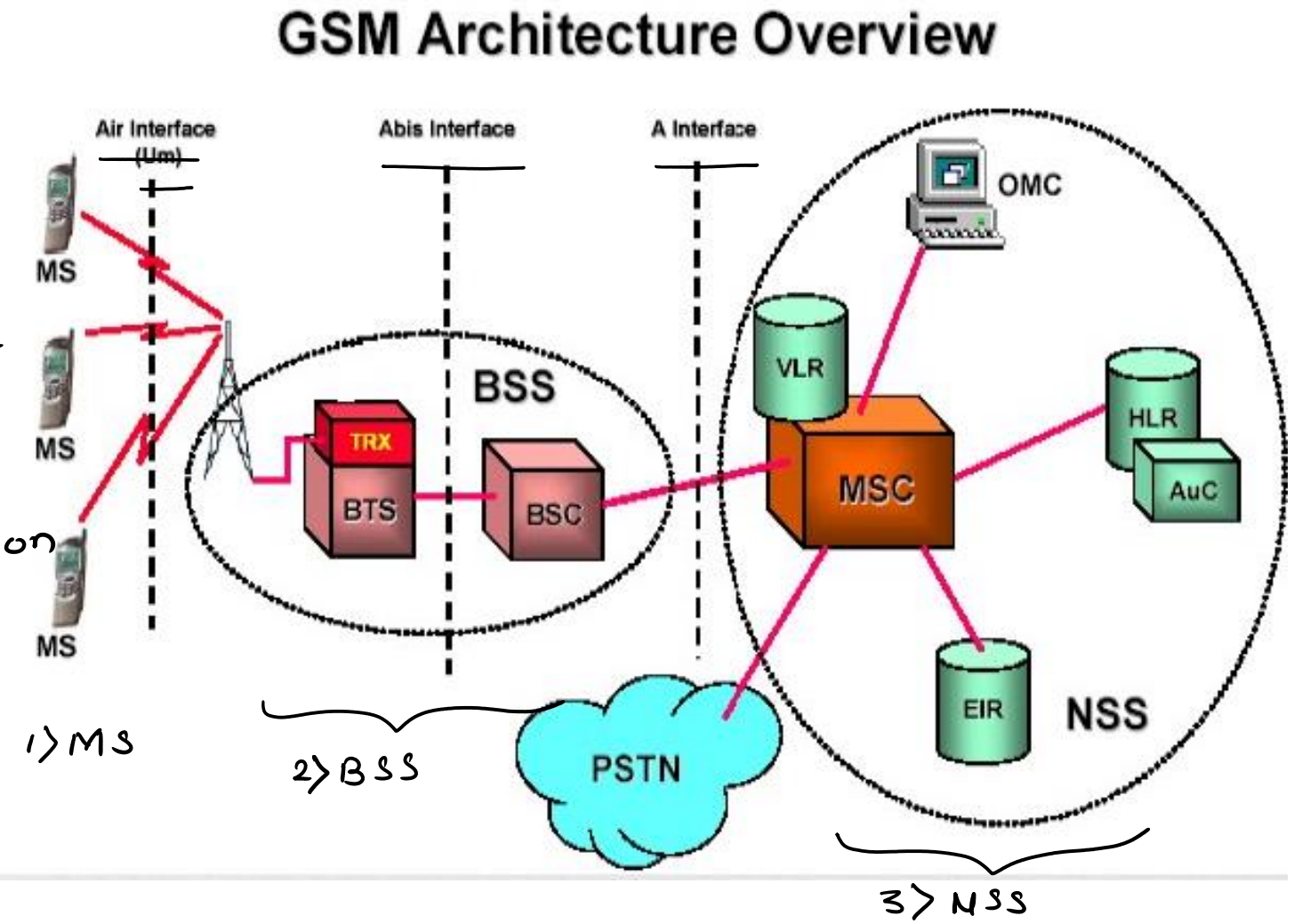
- Global System for Mobile Communication(GSM)
- Mobile Station : User Equipment (UE), SIM (Subscriber Identity Module)
- Base Station (BSS): BTS, RBS, BSC
- Network and Switching Subsystem

GSM Architecture

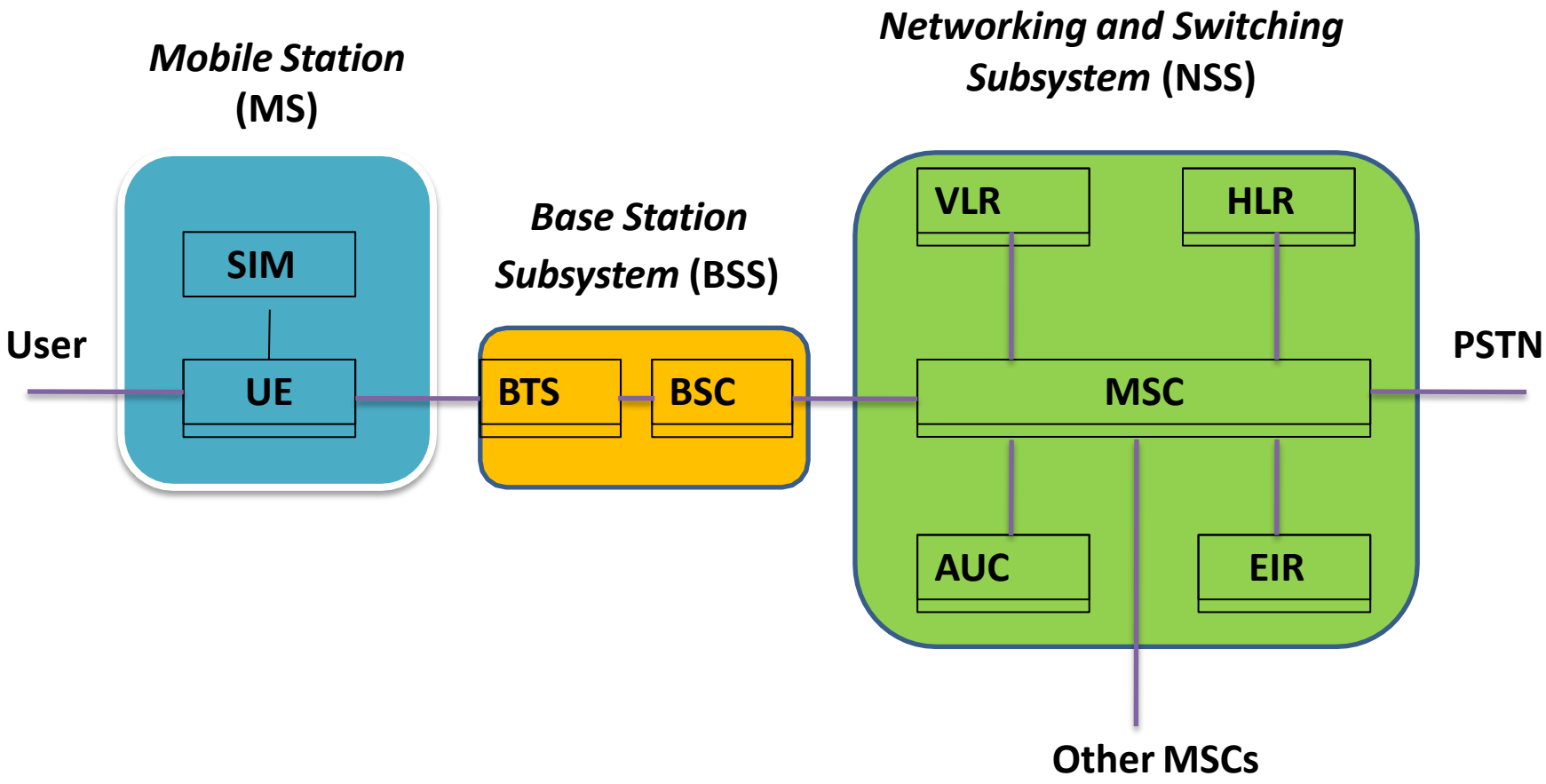
1) Um Interface:
→ Air or radio interface (ME and BTS)

2) Abis Interface:
→ Internal interface between BTS & BSC
→ Allows control of radio equipment & radio freq allocation in BTS.

3) A Interface:
→ Between BSS & MSC
→ Information to enable channels & timeslots.



GSM Architecture



Mobile Station

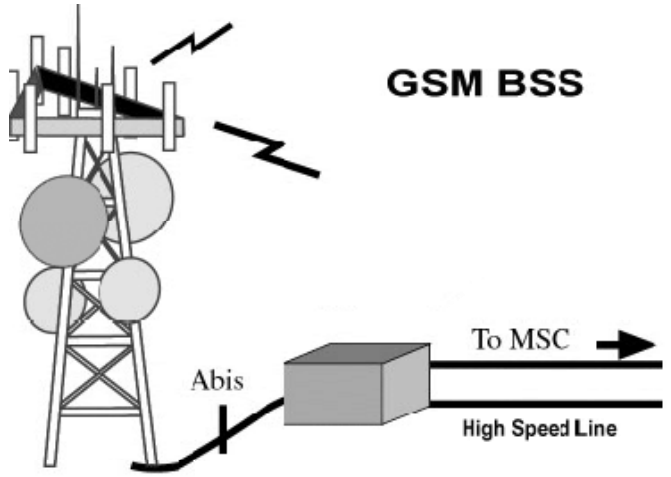
- The MS consists of the physical equipment.
  - The radio transceiver
  - Display and digital signal processors
  - SIM card
    - IMSI → International Mobile Subscriber Identity
- It provides the air interface to the user in GSM networks. As such, other services are also provided, which include:
  - Voice tele services
  - Data bearer services
  - The features' supplementary services

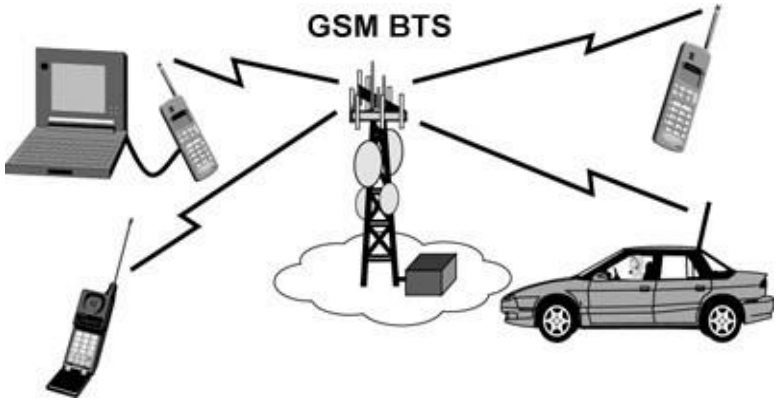
Base Station

- The BSS is composed of two parts:
  - The Base Transceiver Station (BTS)
  - The Base Station Controller (BSC)
- The BTS and the BSC communicate across the specified interface, enabling operations between components that are made by different suppliers.
- The radio components of a BSS may consist of four to seven or nine cells.
- A BSS may have one or more base stations.
- The BSS uses the Abis interface between the BTS and the BSC.
- A separate high-speed line (T1 or E1) is then connected from the BSS to the Mobile MSC.

Base Transceiver Station

- The BTS houses the radio transceivers that define a cell and handles the radio link protocols with the MS. In a large urban area, a large number of BTSs may be deployed.
- The BTS corresponds to the transceivers and antennas used in each cell of the network.
- A BTS is usually placed in the center of a cell. Its transmitting power defines the size of a cell.





Functions of BTS

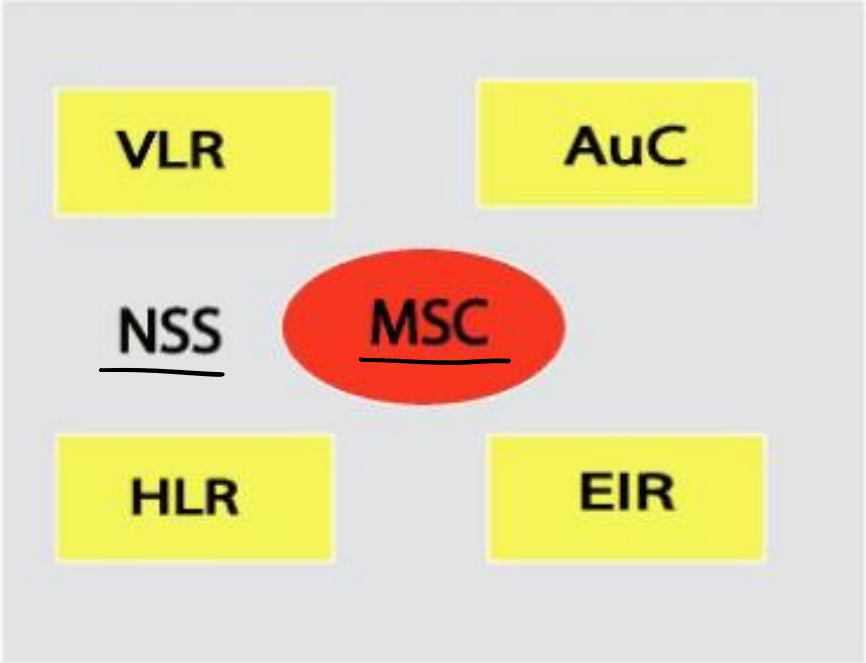
- Functions of BTS include:
  - Encoding, encrypting, multiplexing, modulating, and feeding the RF signals to the antenna
  - Trans coding and rate adaptation
  - Time and frequency synchronizing
  - Voice through full- or half-rate services
  - Decoding, decrypting, and equalizing received signals
  - Random access detection
  - Timing advances
  - Uplink channel measurements

Base Station Controller

- The BSC manages the radio resources for one or more BTSs.
- It handles radio channel setup, frequency hopping, and handovers.
- The BSC is the connection between the mobile and the MSC.
- The BSC also translates the 13 Kbps voice channel used over the radio link to the standard 64 Kbps channel used by the Public Switched Telephone Network (PSDN) or ISDN.
- It assigns and releases frequencies and time slots for the MS.
- The BSC also handles inter cell handover.
- The function of the BSC is to allocate the necessary time slots between the BTS and the MSC.
- It is a switching device that handles the radio resources.

Network Switching System

- The Network switching system (NSS), the main part of which is the Mobile Switching Center (MSC), performs the switching of calls between the mobile and other fixed or mobile network users, as well as the management of mobile services such as authentication.



Mobile Services Switching Center (MSC)

- The central component of the Network Subsystem is the MSC.
- The MSC performs the switching of calls between the mobile and other fixed or mobile network users.
- The management of mobile services such as registration, authentication, location updating, handovers, and call routing to a roaming subscriber.
- It also performs such functions as toll ticketing, network interfacing, common channel signaling, and others.
- Every MSC is identified by a unique ID.

Registers

- Home Location Register
  - The HLR is a database used for storage and management of subscription.
- Visitor Location Register
  - The VLR is a database that contains temporary information about subscribers that is needed by the MSC in order to service visiting subscribers.
- The Authentication Center
  - Is a protected database that stores a copy of the secret key stored in each subscriber's SIM card, which is used for authentication and ciphering of the radio channel.

Registers

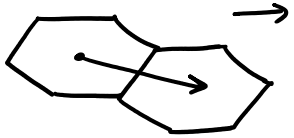
- The Equipment Identity Register (EIR)
  - Is a database that contains a list of all valid mobile equipment on the network, where its International Mobile Equipment Identity (IMEI) identifies each MS.
  - An IMEI is marked as invalid if it has been reported stolen or is not type approved.

GSM Handovers

- Handover or hand off is a process in telecommunication and mobile communication in which cellular transmission (voice or data) is transferred from one base station (cell site) to another without losing connectivity to the cellular transmission.
- "Handover is a mechanism of transferring a call or a data transfer from one cell to another or from channel to another".
- Types:
  - Hard Handover
    - ↳ Break before make
  - Soft Handover
    - ↳ Make before Break

1) Intra-cell →

2) Inter cell - Intra BSC →



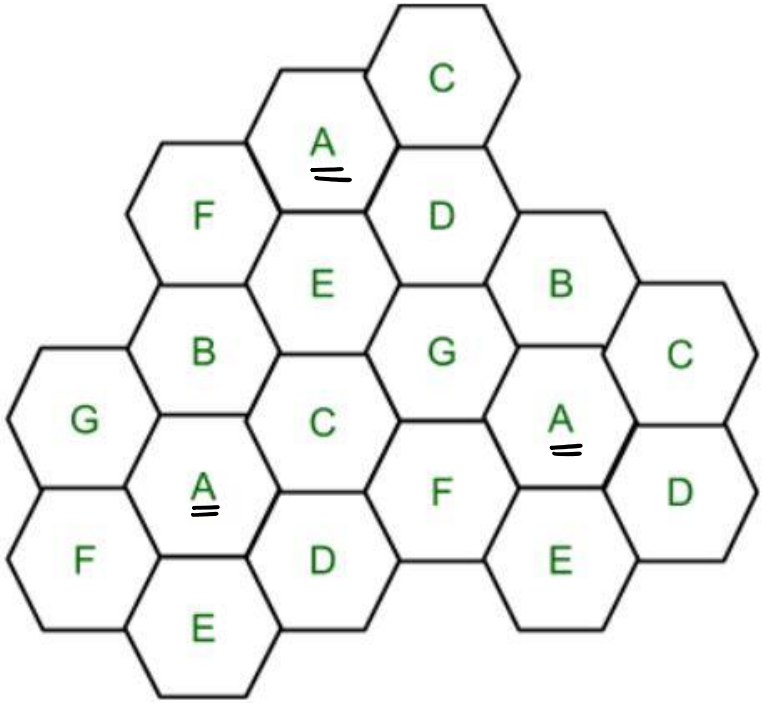
→ cells belong to same BSC

3) Inter BSC - Intra MSC
   ↳ one BSC → BSC belonging to same MSC

4) Inter MSC
   ↳ cells belonging to different MSCs.

Frequency Reuse

- Frequency reusing is the concept of using the same radio frequencies within a given area, that are separated by considerable distance, with minimal interference, to establish communication.
- In the above diagram cluster size is 7 (A,B,C,D,E,F,G) thus frequency reuse factor is 1/7. (1/ N)
- N is the number of cells which collectively use the complete set of available frequencies is called a Cluster.



↳ Seven cells forming a cluster

Frequency Reuse Factor = $1/N$

N = Total no. of cells in cluster

Comparison of AM and FM

Sr.No.	FM	AM
1	Amplitude of FM wave is constant. It is independent of the modulation index.	Amplitude of AM will change with the modulating voltage.
2	Hence transmitted power remains constant. It is independent of m_f.	Transmitted power is dependent on the modulation index.
3	All the transmitted power is useful.	Carrier power and one sideband power are useless.
* 4	FM receivers are immune to noise.	AM receivers are not immune to noise.
5	It is possible to decrease noise further by increasing deviation.	This feature is absent in AM.
6	Bandwidth = 2 [$\delta + f_m$]. The bandwidth depends on modulation index.	BW = 2 f_m . It is not dependent on the modulation index.
* 7	BW is large. Hence wide channel is required.	BW is much less than FM.
8	Spacewave is used for propagation. So radius of transmission is limited to line of sight.	Ground wave and sky wave propagation is used. Therefore larger area is covered than FM.
9	Hence it is possible to operate several transmitters on same frequency.	Not possible to operate more channels on the same frequency.
10 *	FM transmission and reception equipment are more complex.	AM equipments are less complex.

Noise Immunity of FM receiver is better as compared to AM.

→ m
m<1
m>1

Acknowledgements

- “Electronic Communication Systems” by Kennedy & Davis, 4th Edition, Tata McGraw Hill.
- “Mobile Wireless communication” by M. Schwartz, Cambridge University Press.
- Web Resources

Thank you!