Module 5

Radio communication

Communication system:

- The term communication refers to the transmission, reception and processing of information by electrical means.
- The forms of communication may include radio telephony and telegraphy, broadcasting point to point and Mobile communications
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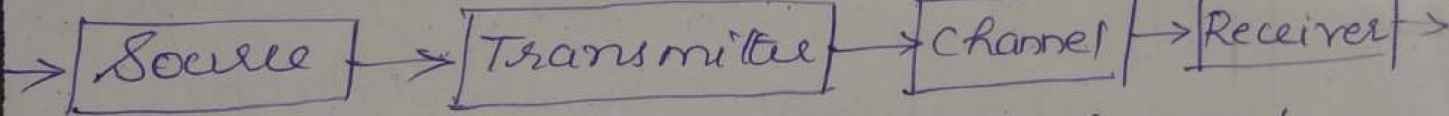


Block diagram of communication system

- It consists of information source, transmitter, channel and Receiver.
- Information source:
  provides the message to be communicated
- Transmitter
  The transmitter should process the signal (amplify, filter, modulate) before directing through the channel.
- Channel
  The channel is the medium through which the signal travels and it can be cables, wires, spaces, fibers etc

If the medium used for transmission is cables or wires, then the communication is called line communication.

If it is by radiowaves, the communication is radio communication

- If the Medium is light, then it is called optical communication
- During Propagation, the signal may mix with the some type of noise and the noisy signal is picked up by the Receiver

Receiver

The Receiver should remove unwanted noise and extract the original Message from Modulated Signal (demodulation).

Modulation & Need for Modulation.

Modulation: The process of mixing a low frequency signal. (Audio signal) with a high frequency signal (carrier signal) is known as Modulation.

The need for Modulation are

1) To reduce the Size of the Antenna:

By Mixing audio signal with a carrier wave, the size of antenna can be reduced to a great extent.

2) Modulation allows several broadcasting Stations to transmit simultaneously at different carrier frequencies.

3. It permits Multiplexing by which Several signals can be tramitted over the same channel without any mixing

4. The effect of noise & interference can be reduced to a great extent.

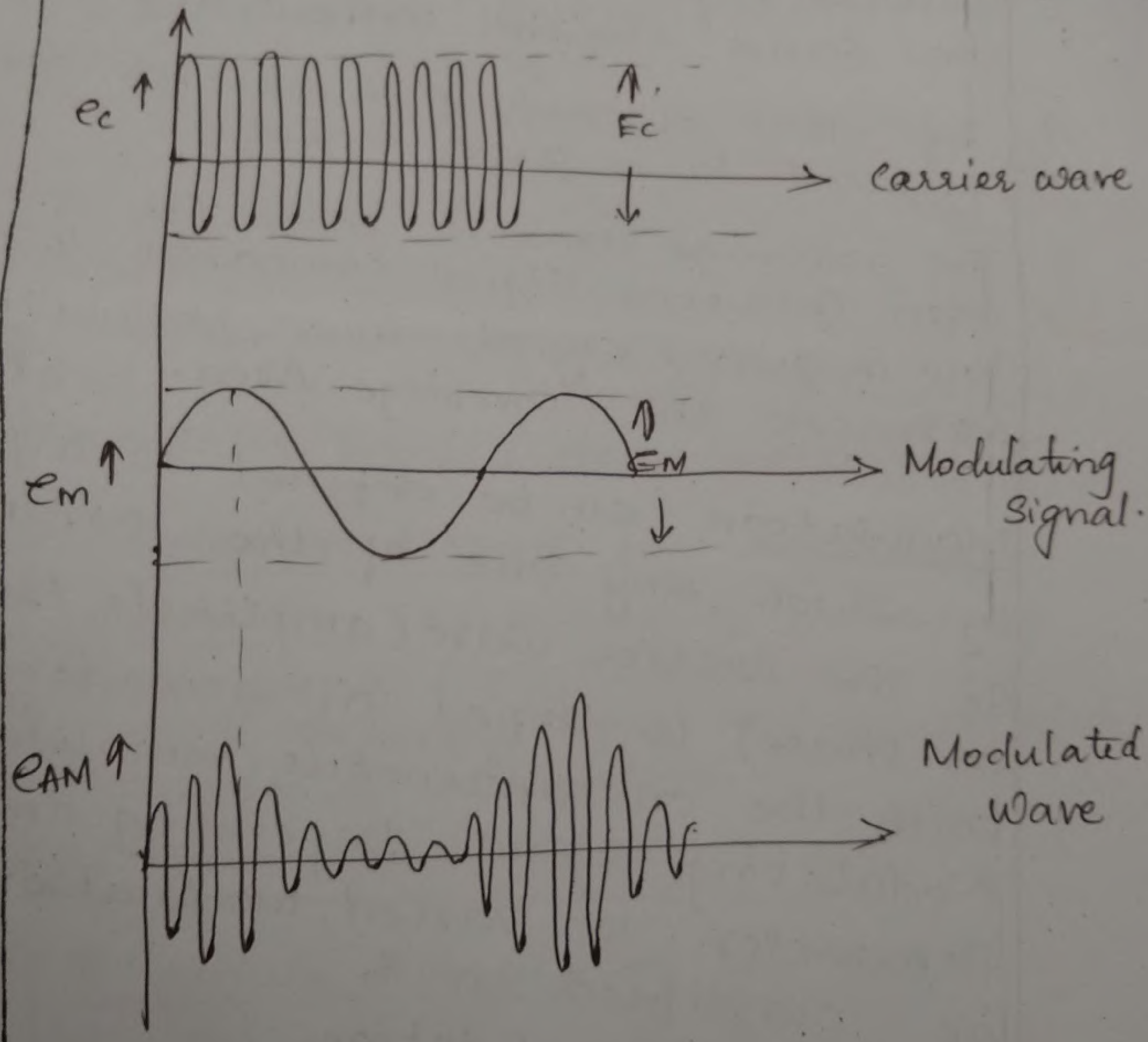
5 The coverage area is more for a High frequency signal compared to low frequency signal. Thus Modulation increases the coverage Area.

Modulation can be defined as a parameter by which any one of the parameter of the carrier wave (amplitude, frequency or phase) is varied in accordance with the instantaneous amplitude of Modulating signal Depending on which parameter is varied, Modulation can be classified in to

1. Amplitude Modulation
2 Frequency Modulation
3 phase Modulation.

(AMPLITUDE MODULATION) AM

In Amplitude Modulation, the amplitude of the carrier wave is varied in accordance with the instantaneous amplitude of Modulating signal.



Let the Modulating signal be $e_m = E_m \sin \omega_m t$
Let the Carrier signal be $e_c = E_c \sin \omega_c t$
The resulting modulated wave

$$e_{AM} = (E_c + e_m) \sin \omega_c t \qquad e_m = E_m \sin \omega_m t$$

$$= (E_c + E_m \sin \omega_m t) \sin \omega_c t$$

$$= ~~E_c \sin \omega_c t + E_m~~$$

$$= E_c \left(1 + \frac{E_m}{E_c} \sin \omega_m t \right) \cdot \sin \omega_c t$$

$$\frac{E_m}{E_c} = m.$$

m = modulation index of AM wave.

<u>Modulation index</u>: is defined as the ratio of amplitude of modulating signal to the amplitude of carrier signal.

$$= E_c (1 + m \sin \omega_m t) \cdot \sin \omega_c t$$

$$= E_c \sin \omega_c t + m E_c \cdot \sin \omega_c t \cdot \sin \omega_m t$$

$$= E_c \sin \omega_c t + \frac{m E_c}{2} \cdot \left[\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t \right]$$

$$\sin A \sin B = \tfrac{1}{2}\left(\cos(A-B) - \cos(A+B) \right)$$

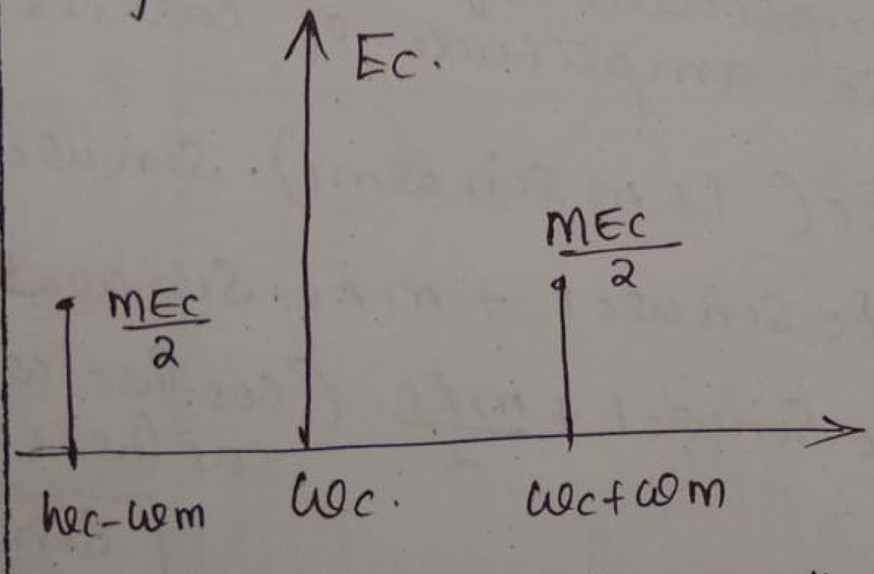
$$= E_c \sin \omega_c t + \frac{m E_c}{2} \cdot \cos(\omega_c - \omega_m)t - \frac{m E_c}{2} \cos(\omega_c + \omega_m)t$$

The above expression shows that the amplitude modulated wave contains three different components.

1. carrier wave located at ωc and of amplitude Ec.
2. upper sideband at $(\omega c+\omega m)$ of amplitude $\frac{MEc}{2}$
3. Lower sideband at $(\omega c-\omega m)$ of amplitude $\frac{MEc}{2}$.

Frequency spectrum:

Is a graph b/w frequency vs amplitude of modulated signal.



Bandwidth requirement of AM

$= f_H - f_L$

$= \omega c+\omega m-(\omega c-\omega m)$

$= \omega c+\omega m-\omega c+\omega m = 2\omega m$

B/W is twice the frequency of modulating signal.

Frequency Modulation (FM). (~~fig~~ Missing figure)

In frequency Modulation, the frequency of the carrier wave is varied in accordance with the instantaneous amplitude of Modulating signal.

Let the Modulating signal be

$$e_m = E_m \sin \omega_m t$$

The instantaneous frequency of frequency Modulated signal is

$$f_i = f_c + \underline{k_f \cdot E_m} \sin \omega_m(t)$$

$$= f_c + k_f \; e_m$$

where $k_f E_m = \Delta f$, represents the minimum frequency deviation from the instantaneous frequency of carrier signal.

modulation index of FM

The ratio of frequency deviation to the modulating signal frequency is known as Modulation index and is given by

$$m_f = \frac{\Delta f}{f_m}$$

Approximate Bandwidth of FM wave is

$$BW = 2(\Delta f + f_m).$$

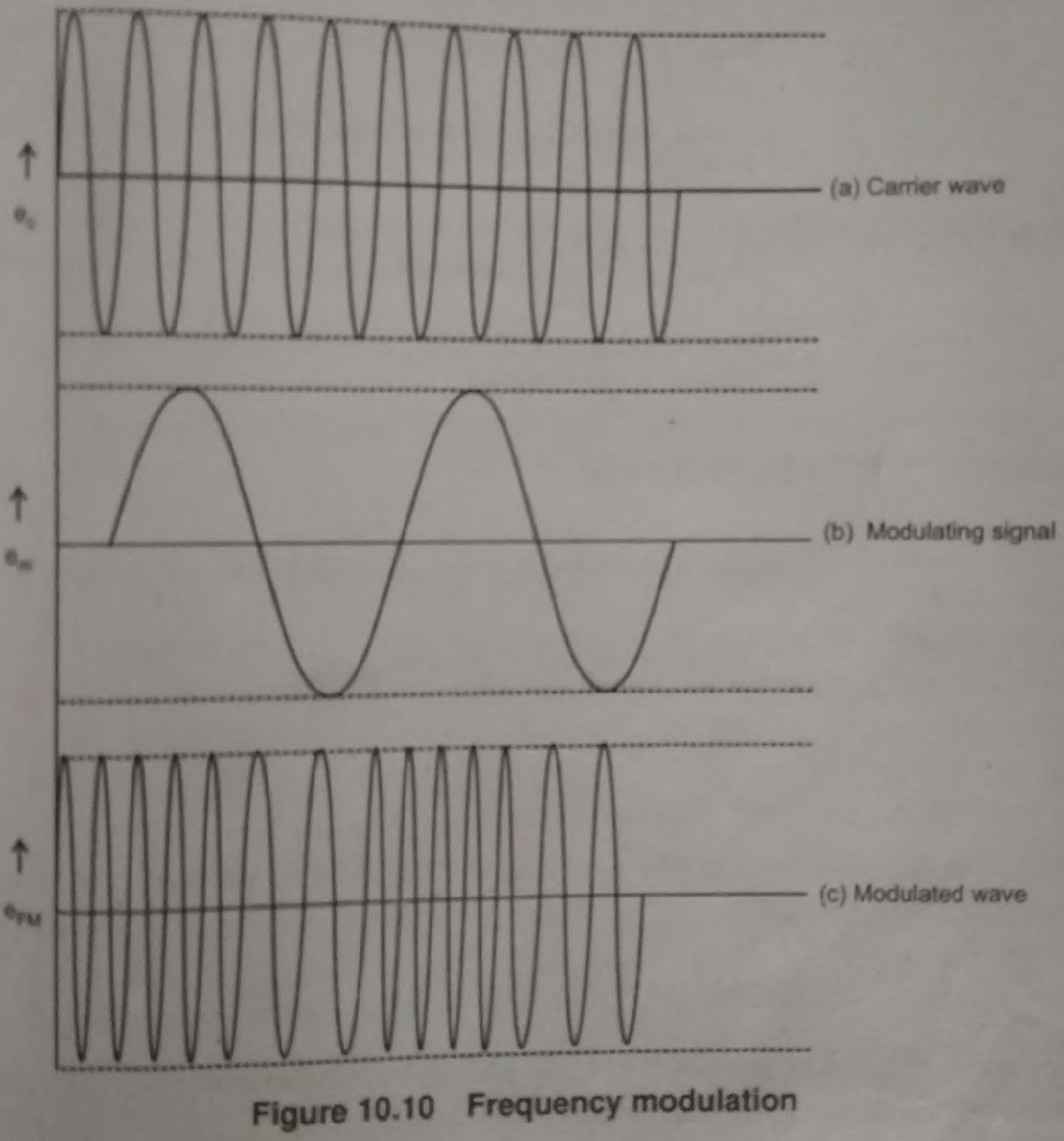


Figure 10.10 Frequency modulation

COMPARISON BETWEEN AM AND FM.

FM has several advantages over AM. They are

1. The amplitude of FM wave remains constant, which is independent of modulation index, where in AM, it's amplitude is dependent on Modulation index. (In AM, $m = \frac{Em}{Ec}$)

2) There is a large decrease in noise in the case of FM. The main reasons are

a) FM is used in the VHF & UHF range where noise is less. AM uses MF & HF range where there is more noise

b) Amplitude limiters are used in FM receiver which removes any amplitude variation occured due to noise

3. FM receiving circuit is more complex than AM & this provides FM more secure than AM

Drawbacks of FM over AM.

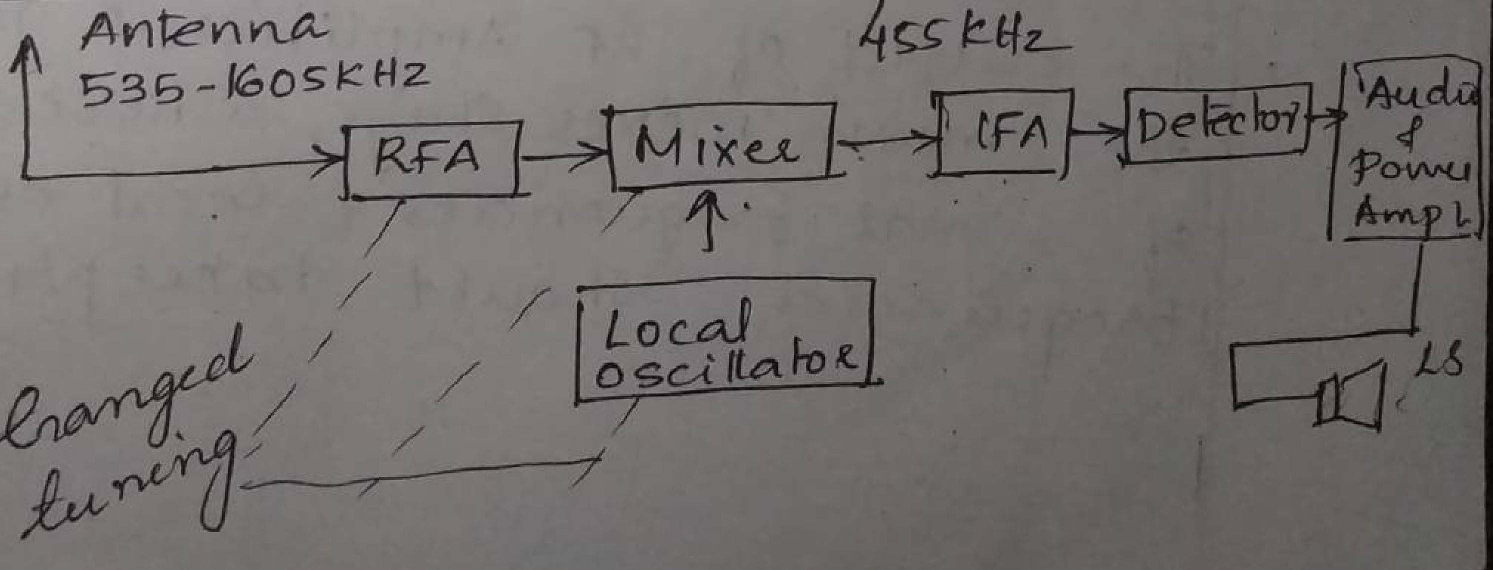
- FM contains infinite number of Sidebands and therefore Bandwidth requirement is more compared to AM
- AM is easy to generate & demodulate compared to FM
- The area covered by FM is much Smaller than AM.

SUPERHETRODYNE RECEIVERS.

Receiver.

The function of a receiver is to receive the signal and recover the original signal (Audio signal) from the Modulated signal.

AM Receiver



→ Antenna: Antenna Receivers AM signals of frequency ranges from 535 KHz – 1605 KHz

→ AM consists of 106 channels with a BW of 10 KHz.

→ The signals received from the Antenna is given to RF Amplifier.

RF Amplifier:

1. The signal coming from the Antenna is amplified by RF Amplifier
2. The Main function of RF Amplifier is to Select the desired band of frequencies & rejects the unwanted signals.

Ganged tuning

The RF Amplifier, Mixer & local oscillator are connected together for simultaneous tuning.

- The output of RF Amplifier is given to the ~~mixer~~ mixer stage, where mixing of signal frequencies & local oscillator frequencies should takes place.

The process of mixing signal frequencies & local oscillator frequencies to produce a new frequency is known as **Superheterodyning**

(fo is always greater than fs).

→ The o/p of mixer stage is $f_{IF} = f_o - f_s$. & this frequency difference is a constant value ie, 455 KHz termed as intermediate frequency (IF)

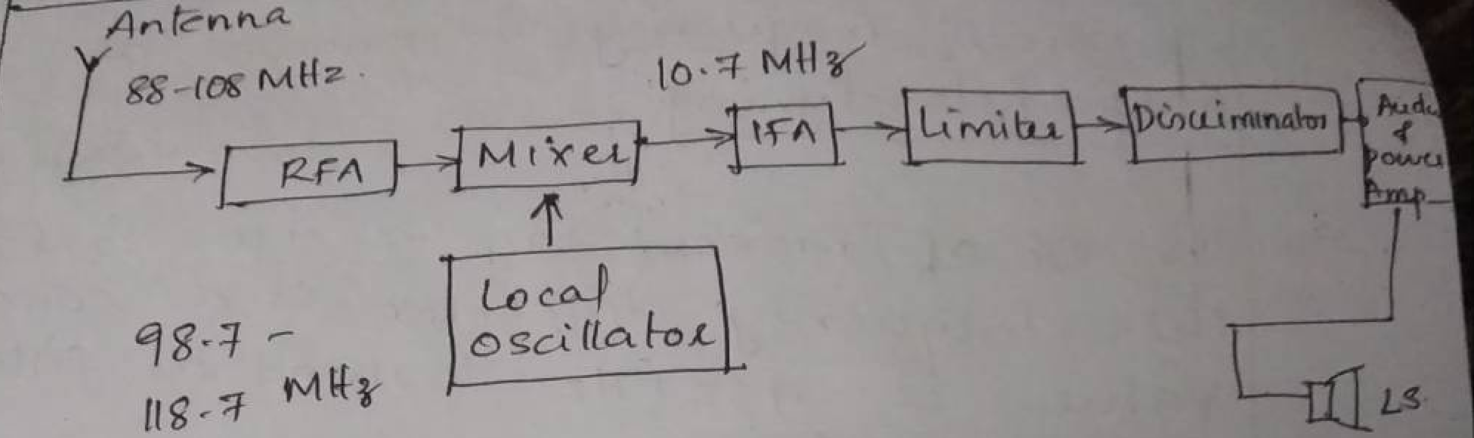
→ This IF is then amplified by IF amplifier & given to the ~~mixer~~ detector stage.

Detector

The main function of detector stage is to recover or detect the modulating signal from the Modulated signal.

The o/p of detector stage is given to the audio & Power amplifier to raise the amplitude & power of the audio si[gnal] & with the help of loudspeaker we can hear that audio signal

FM Receiver.



Antenna:
Antenna receives signals of frequency ranges from 88-108 MHz.

RFA: The FM signals from the antenna is given to the RFA. RFA will receives only the desired band of signals & reject all other unwanted signals

The output of RF Amplifier is given to the mixer stage where mixing of signals will takesplace.

FM signal frequency varies b/w 88 to 108 MHz
IF frequency of FM is 10.7 MHz
local oscillator frequency should be varied b/w 88 + 10.7 to 108 + 10.7 MHz

Always local oscillator frequency is

always greater than the incoming signal frequency.

The difference frequency coming from the mixer stage is 10.7 MHz known as intermediate frequency (f_{IF}).

This IF frequency is amplified with the help of IF amplifier & the o/p is given to the discriminator stage

Discriminator

The discriminator stage demodulates the modulating signal from the modulated signal.

Audio & power Amplifier

The Audio signal is again amplified and given to the L.S (loudspeaker) & from that we can hear the sound signal

The Frequency bands for Various Communication Systems:

	Class	Frequency range	Propagation characteristics (& application)
①	Very Low Frequency (VLF)	10 to 30 kHz	Low attenuation used for Telegraphy
②	Low Frequency (LF)	30 to 300 kHz	Used for Marine Communication
③	Medium Frequency (MF)	300 to 3000 KHZ	High attenuation Used for broadcasting Communication
④	High Frequency (HF)	3MHz to 30MHz	Used for point to-point Communication
⑤	Very High Frequency (VHF)	30 to 300MHz	Used for TV, FM, radar, telephony communication
⑥	Ultra High Frequency (UHF)	300 to 3000MHz	Used for TV transmission
⑦	Super High Frequency (SHF)	3 GHz to 30 GHz	Used for Radar and Satellite Communication
⑧	Extra High Frequency (EHF)	30 to 300 GHz	Used for amateur radio

Mobile Communication

→ Mobile communication refers to the communication using mobile phones and portable computing devices such as smart phones and tablet computers.

→ Mobile communication is the provision of telephone services to phones which may move around freely rather than stay fixed in one location.

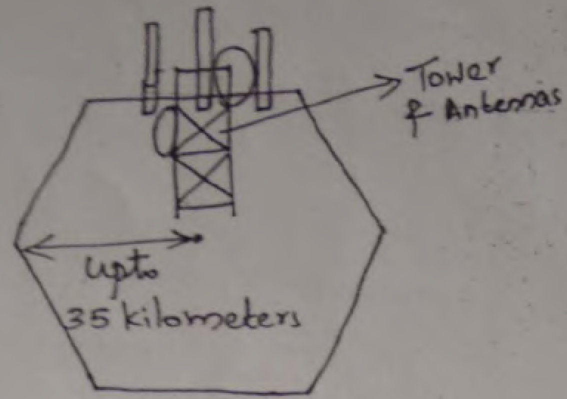
There are two types of mobile communication:-

1. Mobile Phone
2. Satellite Phone.

Mobile Phones connect to a terrestrial cellular network of base stations. Satellite Phones connect to orbiting satellites. Both networks are interconnected to the Public Switched Telephone Network (PSTN) to allow any phone in the world to be dialed.

Mobile Telephone System using the cellular Concept

The cellular concept is a system-level idea that replace a single high power transmitter with many low power transmitters (small cells), each providing coverage to only a small portion of the service area. A cell is a the basic geographic unit of a cellular system. Cells are base stations transmitting over small geographic areas that are represented as hexagons.



A single cell

A cluster of size, n=7
n → number of cells.

A cluster is a group of cells. In a cluster, no channels are reused The above figure illustrates a seven-cell-cluster.

★ Imp

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 neighboring 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.

- Frequencies allocated to different cells are reused to save 'Bandwidth'.
- To ensure that, interference between different users remains low, adjacent cells are assigned with different frequencies.

Consider a cluster of seven cells in a region. We use a set of different frequencies for the seven cells, with one frequency assigned to each cell.

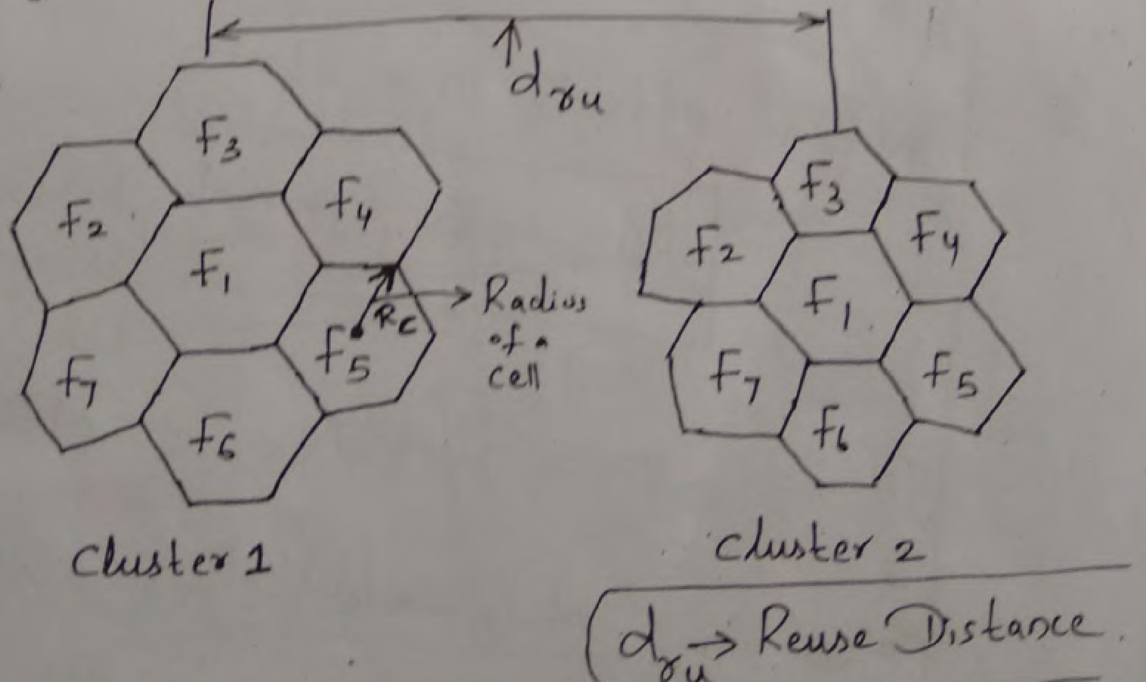


Fig: Frequencies used in cluster 1 reused in cluster 2

It should be observed that the distance between two cells transmitting at the same frequency must be such that, there should be minimum interference between signals emitted by them.

Consider the figure mentioned above. It shows two clusters of 7 cells each. Each cluster can be seen to use the same set of 7 different frequencies (f_1 to f_7). For this, the reuse distance,

$$d_{ru} = R_c \cdot \sqrt{N}$$

Where,
- $R_c \rightarrow$ Radius of the cell
- $N \rightarrow$ Number of cells in a cluster

Number of cells in a cluster,

$$N = i^2 + j^2 + ij$$

Where i and j are integers based on cell parameters.

If $i=1$, $j=2$, then, $N = 1^2 + 2^2 + 2 = 7$

Then the inter-cluster distance for safe frequency reuse, if the cell radius is 1 km is given by,

$$d_{ru} = R_c\sqrt{7} = 1\,km \cdot \sqrt{7} = 2.65\,km$$

GSM (Global Systems for Mobile Communication)

→ GSM is a second generation cellular standard developed to cater voice services and data delivery using digital modulation.

The main services offered by GSM are:-

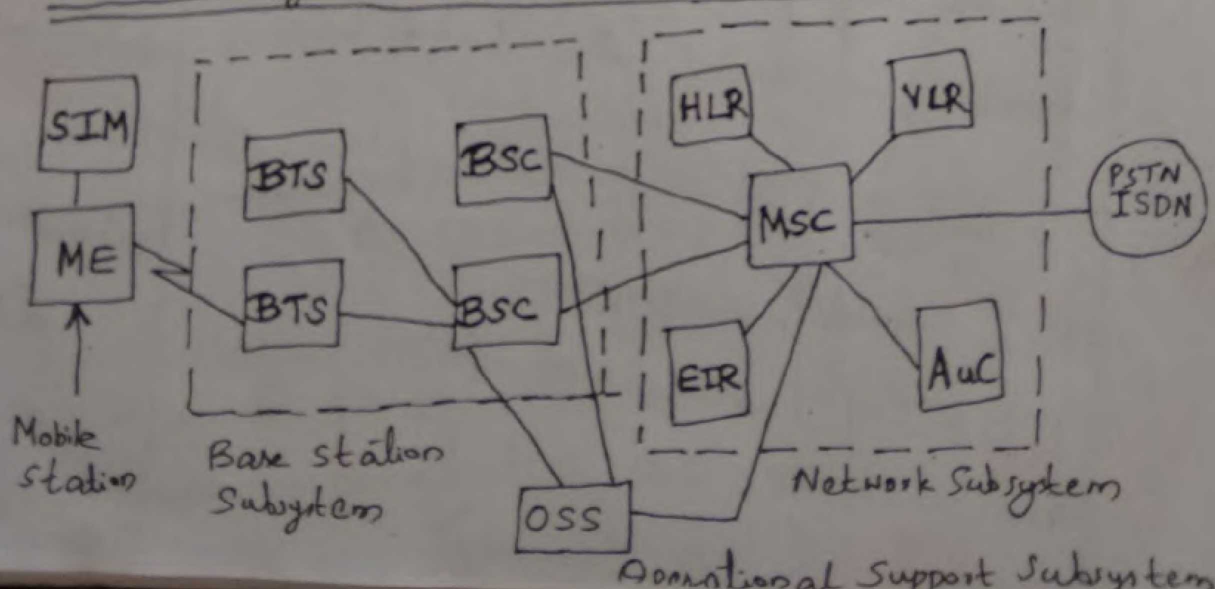
1. Teleservices → Telephony
2. Data Services → Short Message Service (SMS), electronic mail, Fax etc.
3. Supplementary Services → Call forwarding, Call barring, Call conferencing etc.

GSM Architecture

The GSM architecture consists of three main parts:-

1. Mobile station (MS)
2. Base station Subsystem (BSS)
3. Network Switching Subsystem (NSS)

Fig:- Block diagram of GSM architecture



where

SIM - subscriber Identity module.
ME - mobile equipment.
BTS - Base transceiver station
BSC - Base station Controller.
HLR - Home location register.
VLR — Visitor location register.
EIR - Equipment Identity register.
AuC - Authentication center.
OSS - Operational support subsystem.
PSTN - Public switching Telephone network
ISDN - Integrated services digital network.

GSM canbe explained asfollows.

① Mobile station (MS)
It consist of mobile equipment and a smart card called the subscriber Identity module (SIM)

ME + SIM = mobile

Sim provides security and authentication of the subscriber. The mobile equipment is uniquely identified by international mobile ~~identity~~ equipment identity (IMEI)

a secret key for authentication and other user informa
The IMEI and IMSI are independent, thereby providing
personal mobility. The SIM card may be protected agai
unauthorised use by a password or PIN (Personal Ider
Number)

② Base Station Subsystem (BSS)

The Base station Subsystem is composed of two parts, the Base Transceiver Station (BTS) and the Base Station Controller (BSC). The base transceiver stati is the radio equipment. The BTS encodes, encrypts, multiplexes modulates and feeds the RF signals to the antenna. It communicates with mobile station and BSC.

The Base Station Controller provides the control functions and physical links between the MSC and BTS. It provides functions such as frequency handover, control of RF power levels in base transceiver stations. A number of BSC are served by a MSC.

③ Network Switching Subsystem (NSS)

NSS Consists of the following:-

a) Mobile Switching Center (MSC)
b) Home Location Registers (HLR)
c) Visitor Location Registers (VLR)

d) Authentication Center (AuC)

e) Equipment Identity Register. (EIR)

a) Mobile Services Switching Center (MSC)

→ It performs the switching of calls between the mobile and other fixed or mobile network users.

b) Home Location Register (HLR)

→ HLR is the most important database that stores permenant data about subscribers, including a subscriber's service profile, Location information and activity status.

c) Visitor Location Register (VLR)

→ It is also a database that contains information about subscribers that is needed by the Mobile Services Switching Center (MSC) in order to serve visiting subscribers. When a mobile station roams into a new MSC area, the VLR connected to that MSC will request data about the mobile station from HLR.

d) Authentication center (AuC) → Protected Database that stores a copy of secret key stored in SIM card.

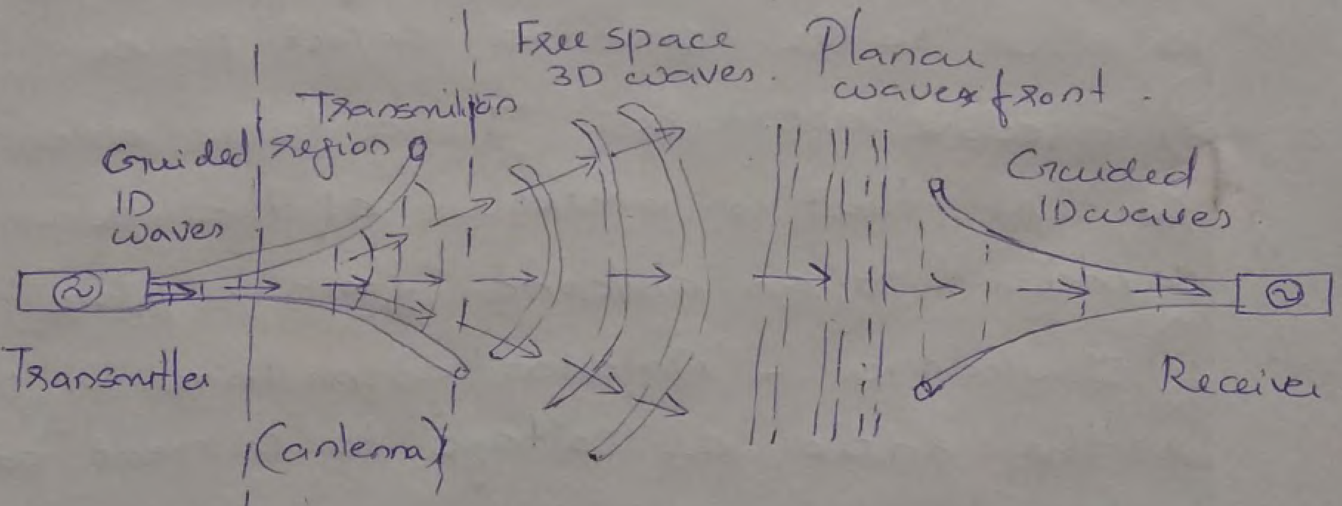
e) Equipment Identity Register (EIR)
→ Contains a list of all valid mobile equipm on the Network.

Operational Support Subsystem (OSS) → Maintain all hardware and Network operations.

Principle of Antenna:

An antenna is a transducer which convert electrical power in to electromagnetic waves and vice versa.

The working principle of an antenna is that it converts electrical currents in to Electromagnetic radiation in free space or vice versa. The Power fed to an antenna from a signal source is radiated in to free space as electromagnetic waves shown in fig.



An antenna is used to both transmit and receive EM waves and obeys reciprocity principle. reciprocity states that the receive and transmit properties of an antenna are identical. Hence antennas do not have distinct transmit and receive radiation patterns. The EM waves that are generated then propagate through space.

Antenna Parameters are

1) Radiation Pattern - describes the relative strength of radiated field in various direction from the antenna at a constant distance.

2) Directivity — Measure of how 'directional' an antenna's radiation Pattern is.

3) Antenna gain - Is a measure of power radiated in a particular direction.

4) Antenna Efficiency - Is a measure of how much power is radiated by the antenna relative to the antenna input power.

5) Effective aperture: It's a basic antenna concept that is a measure of the power captured by an antenna from a plane wave.

6) Impedance :- Antenna impedance is presented as the ratio of voltage to current at the antenna's terminals.

7) Bandwidth :- BW of an antenna is the frequency range over which the antenna radiates.

Radiation Mechanism

The functioning of an antenna depends upon the radiation mechanism of a transmission line.

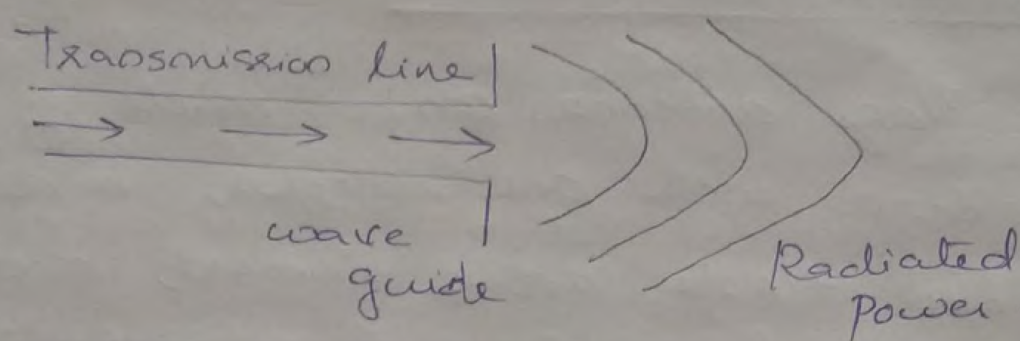
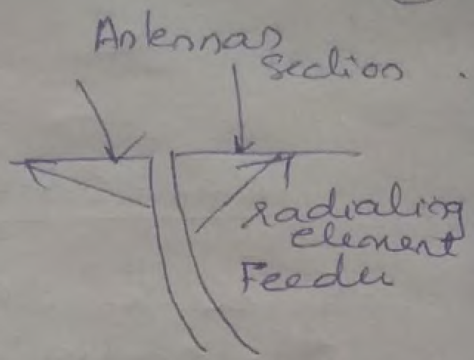


fig represents a waveguide, which act as an antenna. The power from the transmission line travels through the waveguide which ~~how~~ has an aperture, to radiate the energy.

Types

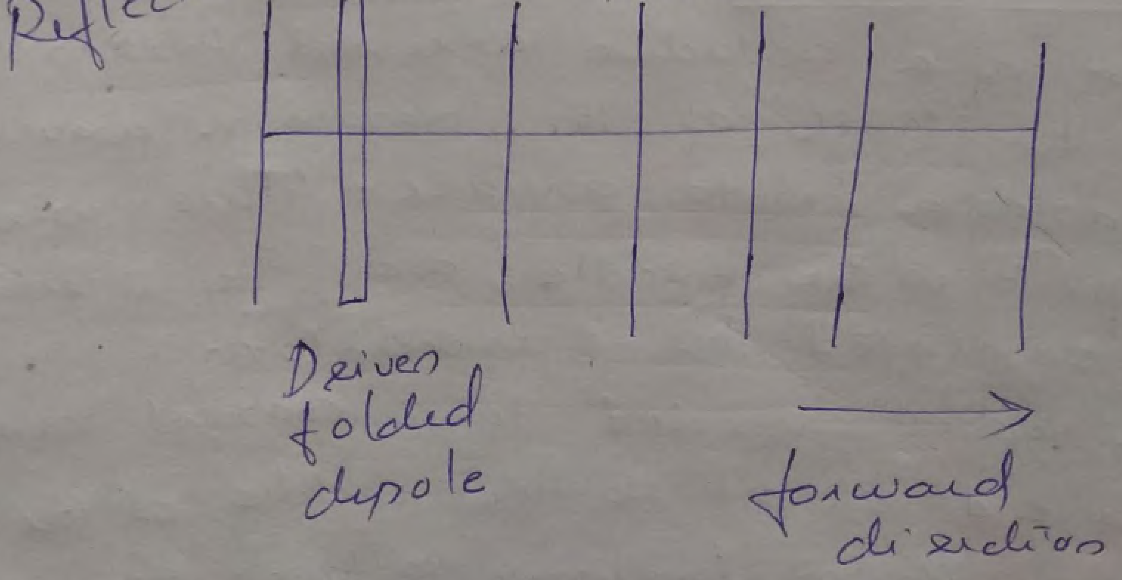
1) Dipole Antenna : Is the simplest antenna. Consist of a conductive wire rod that is the half the length of the maximum wavelength the antenna is to generate. This wire rod is split in the middle, and the 2 sections are seperated by an insulator.
Each rod is connected to a coaxial cable at the end closest to the middle of the antenna. Radio frequency voltages are applied to dipole antennas at the center b/w the

2 conductors.



Yagi - Uda Antenna

Yagi antennas can be made by using an antenna with one reflector, a driven folded-dipole active element, and directors mounted for horizontal polarization in the forward direction. There are many directors placed to ↑se the directivity of the antenna. The reflector is the lengthy element which is at the end of the structure.



Parabolic Reflector Antenna

This antenna is used for transmitting a signal, the signal from the feed, comes out of a dipole or a horn antenna, to focus the wave onto the parabolala i.e. The waves come out of the focal point and strike the parabolic reflector. This waves now gets reflected as colliminated wavefront to get transmitted. The same antenna is used as a receiver. When the electromagnetic wave hits the shape of the parabola, the wave gets reflected on to the feed point. The dipole which acts as the receiver antenna at its feed, receives the signal, to convert it into electric signal and forwards it to the receiver circuitry.