Modulation

Radio communication involves transmission of speech, music etc. from the transmitter to the receiver.
Audio Frequency range – 20 Hz – 20 KHz.

Difficulties / Problems encountered in direct transmission of audio signals.

1) **Length of antenna**
   For efficient transmission and reception, receiving and transmitting antenna should have heights about quarter of the wavelength of frequencies used.

   For 20 Hz audio frequency
   $\lambda/4 = 3.75 \times 10^6$ m
   For 20 KHz audio frequency
   $\lambda/4 = 3.75 \times 10^3$ m
   Such lengths are too long to be constructed practically.

2) **Interference**
   If all the radio broadcast stations in a particular geographic area try to broadcast simultaneously at the same audio frequency, they would interfere with each other and no one station can be distinguished.
3) **Poor reception**
   Energy of a wave depends upon its frequency.
   As audio frequencies are small, they cannot travel large distances when radiated directly into space i.e. they die out over large distances. At the receiving end, reception is poor.
4) **Wireless communication**
   At audio frequencies, radiation is not practicable because efficiency of radiation is poor and wireless communication fails.

All the above difficulties can be overcome if high frequencies are transmitted .
With high frequency, length of antenna is reduced, audio quality is improved at receiving end and wireless communication possible.

Hence audio signal is superimposed on a high frequency signal and transmission done at high frequency.

Audio signal is carried by the high frequency signal either as a change in its amplitude or change in its frequency or change in phase. This process of changing some characteristic (e.g. amplitude, frequency or phase) of the high frequency wave in accordance with the intensity of the audio signal is known as modulation.

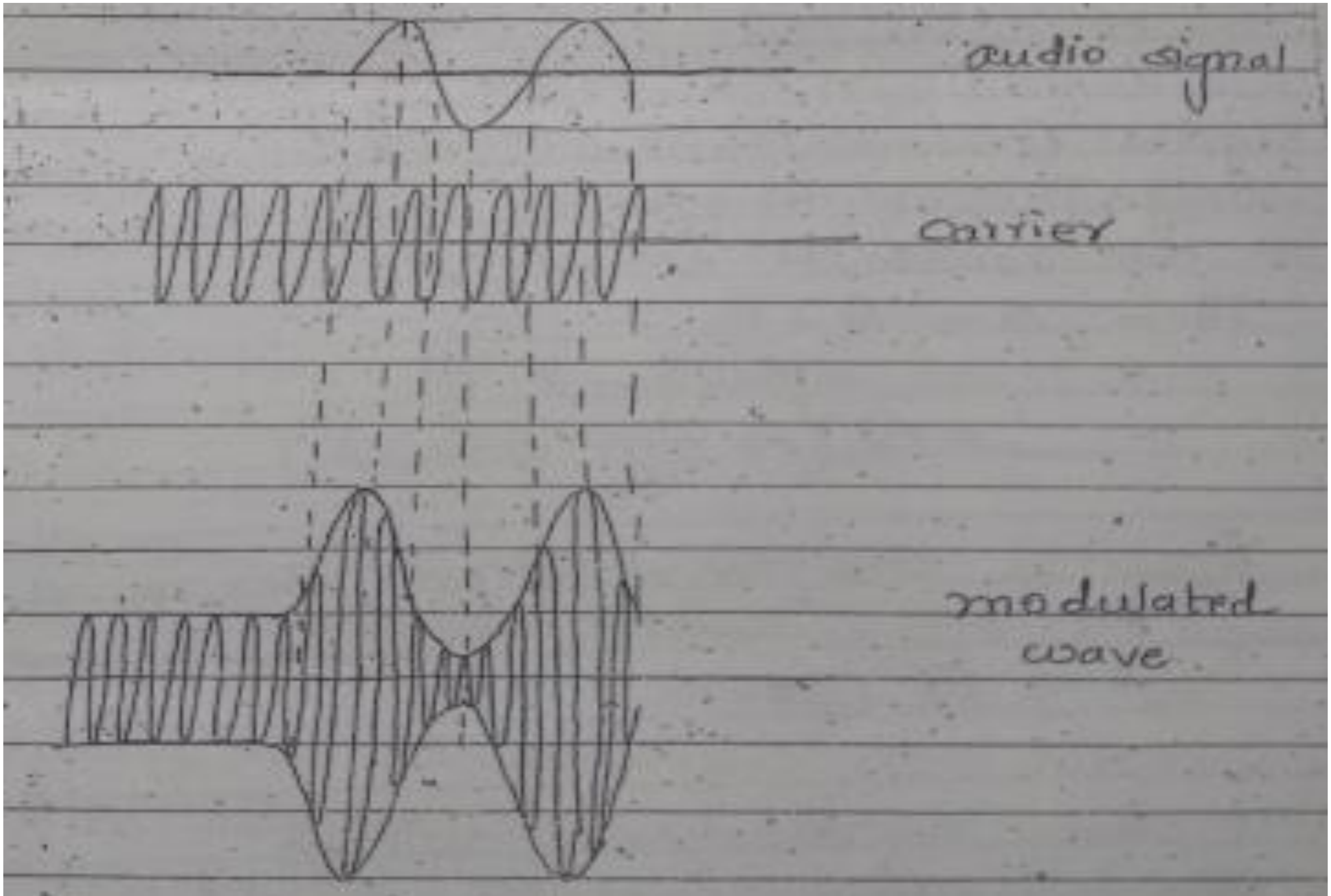
This high frequency signal is called the carrier signal.

There are three types of modulation:

1) **Amplitude modulation (AM)**
2) **Frequency modulation (FM)**
3) **Phase modulation (PM)**

AM

When the amplitude of the high frequency carrier wave is changed in accordance with the instantaneous value of the audio signal, it is called AM.



A Carrier wave may be represented as $e_c = E_c \sin w_c t$ and a modulating signal (audio signal) may be represented as $e_m = E_m \sin w_m t$

where e_c-instantaneous carrier voltage

E_c - amplitude of carrier

w_c – $2\pi f_c$ (f_c – carrier frequency)

e_m – instantaneous modulating voltage

E_m – amplitude of modulating signal

w_m – $2\pi f_m$ (f_m – audio frequency)

Amplitude E_c of carrier wave is varied in accordance with the intensity of the signal. Let A be the amplitude of the resultant AM signal.

Then $A = E_c + e_m$

$= E_c + E_m \sin w_m t$

$= E_c \left(1 + \frac{Em}{Ec} \sin w_m t\right)$

$\frac{Em}{Ec}$ is the modulation index m

Therefore $A = E_c(1 + m \sin w_m t)$.

$e_{AM} = A \sin w_c t$

$= E_c(1 + m \sin w_m t) \sin w_c t$

$= E_c \sin w_c t + mE_c \sin w_m t \sin w_c t$

Since $\sin w_c t . \sin w_m t = \frac{1}{2} [\cos(w_c - w_m)t - \cos(w_c + w_m)t]$

Therefore $e_{AM} = E_c \sin w_c t + \frac{mEc}{2} [\cos(w_c - w_m)t - \cos(w_c + w_m)t]$

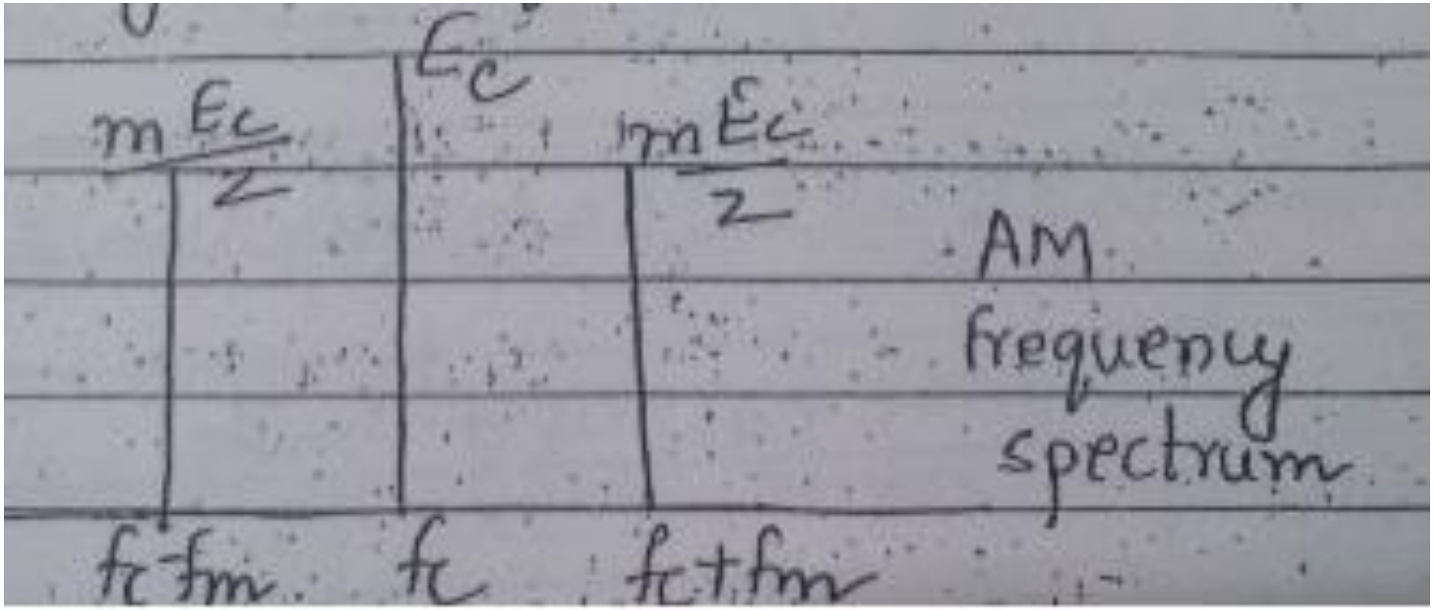
Therefore $e_{AM} = E_c \sin w_c t + \frac{mE_c}{2} \cos(w_c - w_m)t - \frac{mE_c}{2} \cos(w_c + w_m)t$

AM wave is summation of 3 sine waves – one with amplitude E_c and Frequency f_c, second with amplitude $mE_c/2$ and frequency f_c+f_m, third with amplitude $mE_c/2$ and frequency f_c-f_m.

f_c+f_m – upper sideband frequency
f_c-f_m – lower sideband frequency
f_c-original carrier frequency

Bandwidth = USB – LSB = $2f_m$

AM FREQUENCY SPECTRUM

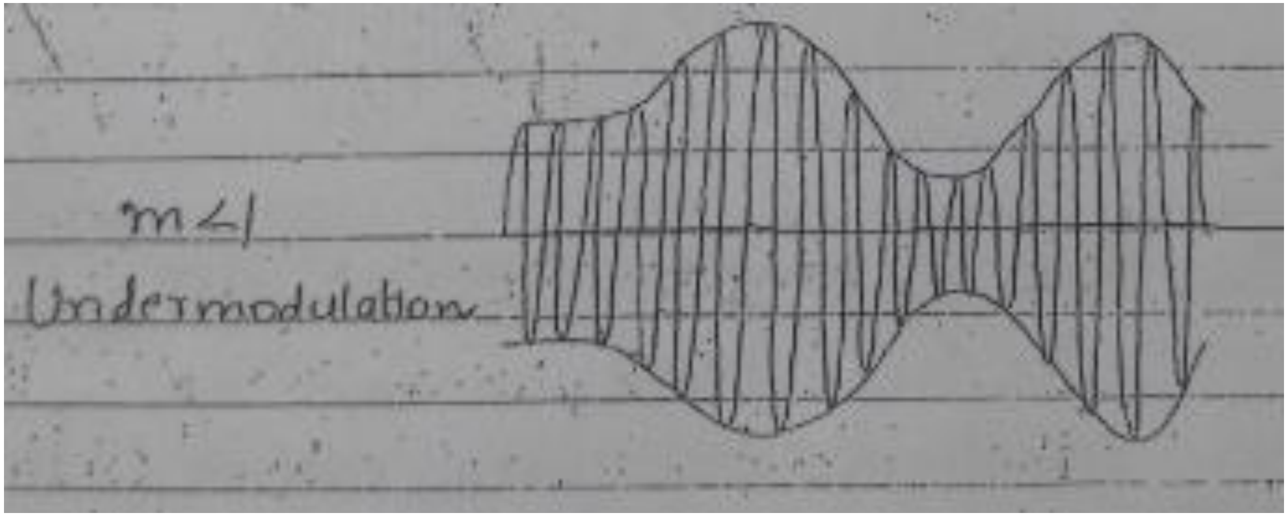


Modulation Index – indicates the extent of modulation. It determines the strength and quality of the transmitted audio signal.

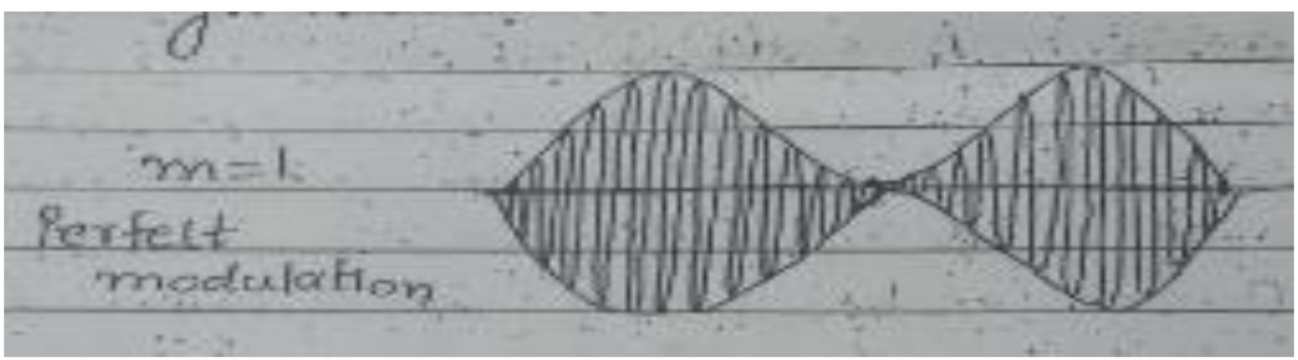
$$\frac{Em}{Ec} = m$$

$$\% \, m = \frac{Em}{Ec} \times 100$$

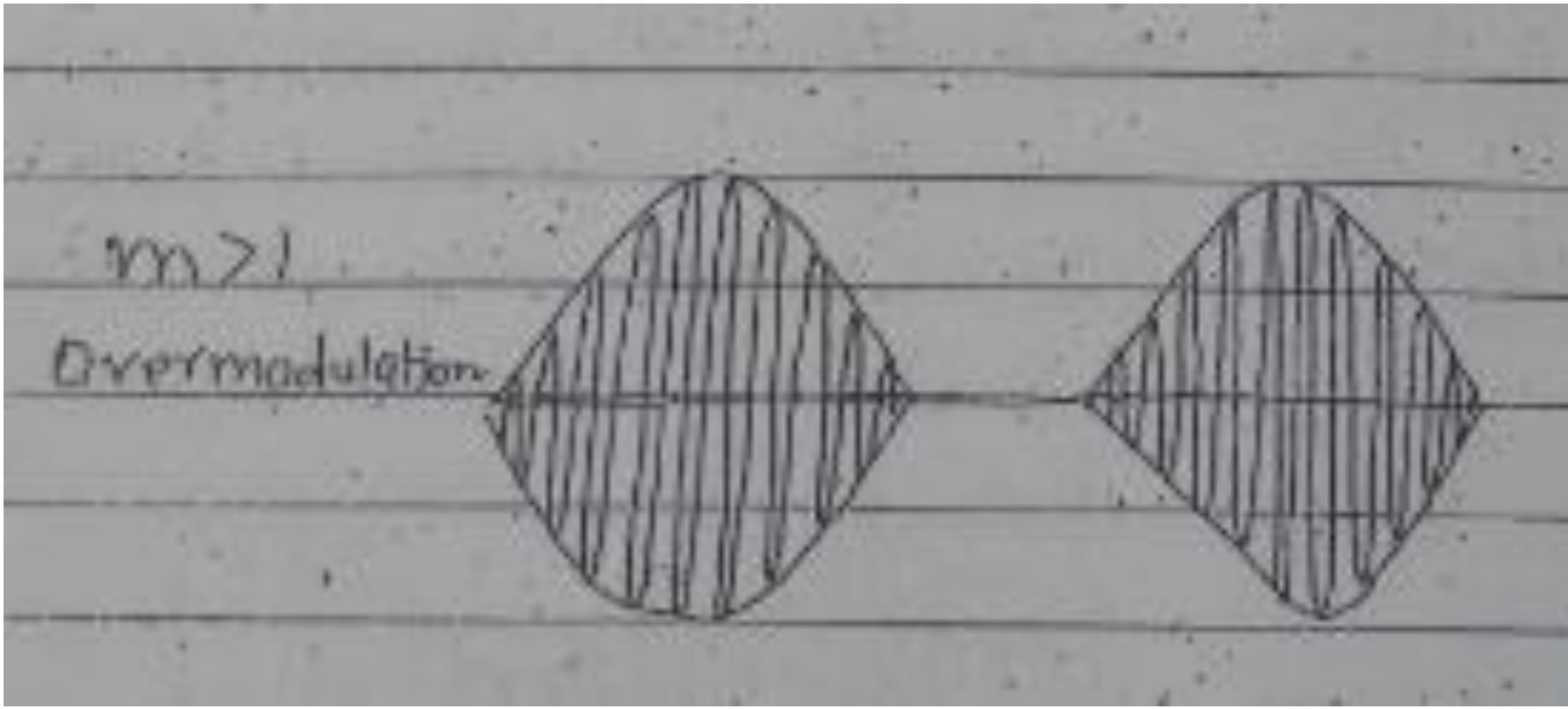
If m<1, $E_m<E_c$ i.e. amplitude of modulating signal is less than amplitude of carrier. AM signal is undistorted but after detection audio signal strength is poor. This is undermodulation.



If m=1, $E_m=E_c$ i.e. amplitude of modulating signal is equal to amplitude of carrier. After detection maximum strength of audio signal. This is perfect modulation.



If m>1, E_m>E_c i.e. amplitude of modulating signal is greater than amplitude of carrier. AM signal is distorted and is therefore undesirable. This is overmodulation.
Hence m should never be > 1.



Limitations of AM

1) **Noisy reception**

   In the AM wave, the signal is in the amplitude variations of the carrier. All natural and manmade noises consist of electrical amplitude disturbances and they can change the amplitude of the AM wave. Thus, unwanted noise cannot be removed at the receiver end as part of the signal will also be removed along with the noise.

2) **Low efficiency**

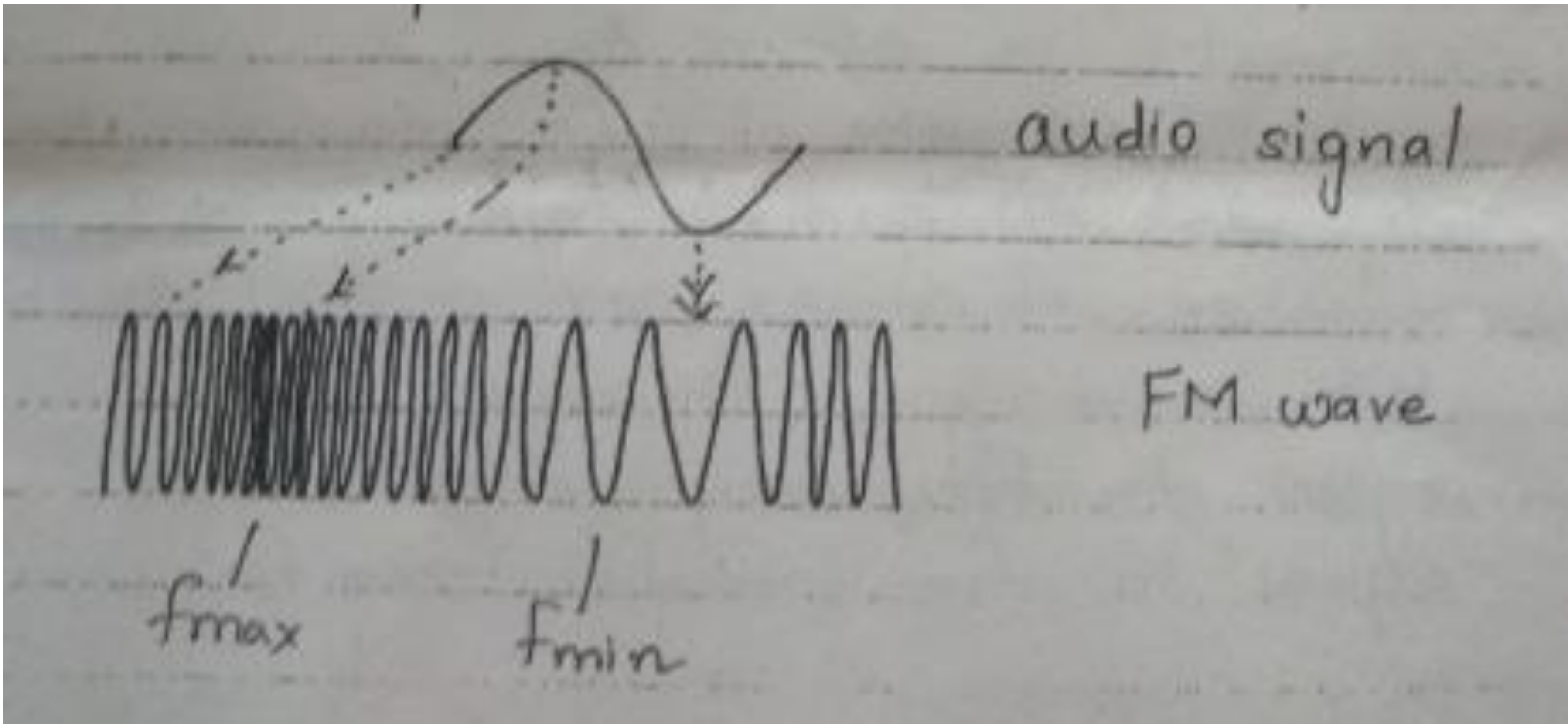
   In AM, useful power is only in the sidebands as they contain the signal. But sidebands in an AM wave have very low power. Thus efficiency of AM is very low.

3) Lack of audio quality

In order to attain high quality reception, all audio frequencies upto 15 kHz must be reproduced. This necessitates a bandwidth of 30 kHz since both sidebands must be reproduced. But AM broadcasting stations are assigned a bandwidth of only 10 kHz to minimise interference from adjacent broadcast stations. This means that highest modulating frequency can be 5 kHz which is hardly sufficient to reproduce the music properly.

<u>FM</u> (Frequency modulation)

It is the process in which the frequency of a high frequency carrier wave is changed in accordance with the instantaneous value of the modulating signal by keeping amplitude and phase constant.



Centre Frequency – The original carrier frequency is called the centre frequency or resting frequency.

Frequency deviation (Δf) – The change or shift either above or below the resting frequency, is called frequency deviation (Δf)

$$\Delta f = f_{max} - f_{centre}$$
$$= f_{centre} - f_{min}$$

Carrier swing – The total variation in frequency, from the lowest to the highest is called carrier swing

i.e $CS = 2\,\Delta f = f_{max} - f_{min}$

Modulation Index (m) – The ratio of frequency deviation to the modulating frequency is known as 'modulation index'.

$$m = \frac{\Delta f}{fm}$$

Percentage Modulation

$$\% \text{ modulation} = \frac{\text{Actual frequency deviation}}{\text{frequency deviation allowed}} \times 100$$

Deviation Ratio - In FM, this is the ratio of maximum allowable frequency deviation to the maximum modulating frequency.

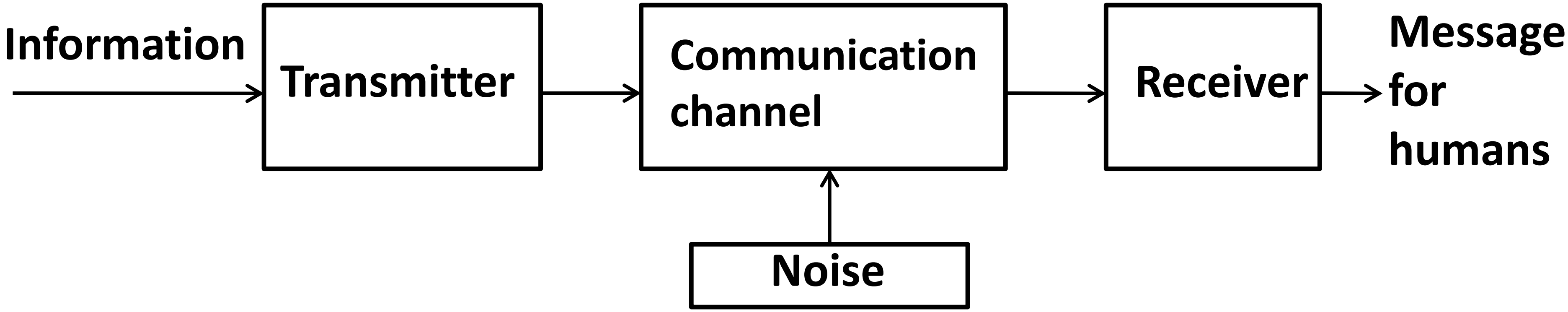
$$d = \frac{\Delta f_{max}}{f_{m\,max}}$$

Guard Bands – In FM radio broadcast, the channel width is 150 kHz. On both sides of the channel, there are bands of 25 kHz each which is allotted to avoid interference with neighbouring channels. These bands are called as'Guard bands'.

	AM		FM
1)	Amplitude of carrier is varied in accordance with the instantaneous amplitude of modulating signal	1)	Frequency of carrier is varied in accordance with the instantaneous amplitude of modulating signal
2)	Frequency and phase of carrier remains constant	2)	Amplitude and phase of carrier remains same
3)	In AM, most of the power is in carrier which is of no use. Useful power is in the sidebands only	3)	All the transmitted power in FM is useful.
4)	Bandwidth = 10 kHz	4)	Bandwidth = 200 kHz
5)	Due to narrow BW, poor audio quality	5)	Good audio quality due to large BW

	AM		FM
6)	Absence of guard band. Interference possible	6)	Guard bands present. Adjacent channel interference minimised.
7)	Very simple equipment required for transmitting and receiving	7)	Requires complex and expensive transmitting and receiving equipment
8)	Two sidebands	8)	Infinite sidebands
9)	Low efficiency	9)	High efficiency
10)	Noisy reception since natural and manmade noises which are electrical amplitude disturbances tends to interfere with the AM signal	10)	Good noise-free reception since audio signal is in frequency variation and not in amplitude variation of carrier

Elements of a communication system



Information in the form of voice, pictures, data etc. is given to the transmitter. The transmitter converts the information into a signal suitable for transmission over a given channel eg. microphone, radio transmitter.

The signal is sent from the transmitter to the receiver by the channel or medium which could be radio, wires or fibre-optic cable. The medium transmits the information but at the same time it attenuates and degrades the signal which causes decrease in its amplitude. Therefore for successful communication, amplification is necessary both at transmitter and receiver ends. Random and undesirable interference called noise is added to the signal in the channel.

Though noise is undesired it cannot be completely eliminated.
The receiver accepts the transmitted message from the channel and converts it back into a form understandable by humans e.g. Earphone.

Types of communication

Simplex or Duplex

One-way communication is Simplex.
e.g – Radio, TV, Broadcast.

Two-way communication is Duplex.
When both ends transmit and receive simultaneously – full duplex.
e.g – Telephone.

When only one end transmits at a time i.e. both ends transmit alternatively – half duplex.
e.g. – Walkie Talkie

Analog or Digital

Communication system which handles analog signals like sine wave are called analog communication systems.

Systems which handle digital signals like square wave are called digital communication systems.

Baseband or Modulated.

Original information signal is called baseband signal. When this signal is directly transmitted through a medium, it is called baseband transmission.
However when modulation is done at the transmitting end and the modulated signal is transmitted through a medium, it is called modulated transmission.
i.e. Baseband signal is superimposed on a high frequency carrier to make the transmitted signal compatible with the medium.

Data / Digital communication

Transmission of binary or digital information from one point to the another is called data communication.

Methods

(1) Parallel transmission

All bits of the binary data are transferred simultaneously to the receiving register. There is one wire for each bit of information to be transmitted. Hence multi-wire cables are necessary.

This method is very fast.

Fails for long distance data communication because of cost and signal attenuation.

(2) Serial transmission

Each bit of the binary data is transferred one after the other. LSB is transmitted first and MSB last. Each bit is transmitted for a fixed time.

A single data line is needed. A very slow method.

Long distance communication is possible with this method.

Computer Networks

A network is an interconnection of 2 or more stations that wish to communicate.

Types of network

(1) Wide area network (WAN):
Large networks such as those that cover complete country or state are called WANS.
e.g. Long distance telephone systems are WANS. Radio links using microwave relay stations or satellites also form a part of this network.

(2) Metropolitan area network (MAN):
This is a medium-sized network .
e.g. Cable TV network

(3) Local area network (LAN):
They are small size network with few users less than 100.
e.g. Network setup in offices within the same building.

Network Topology

The stations or nodes can be interconnected in many ways to form a network.

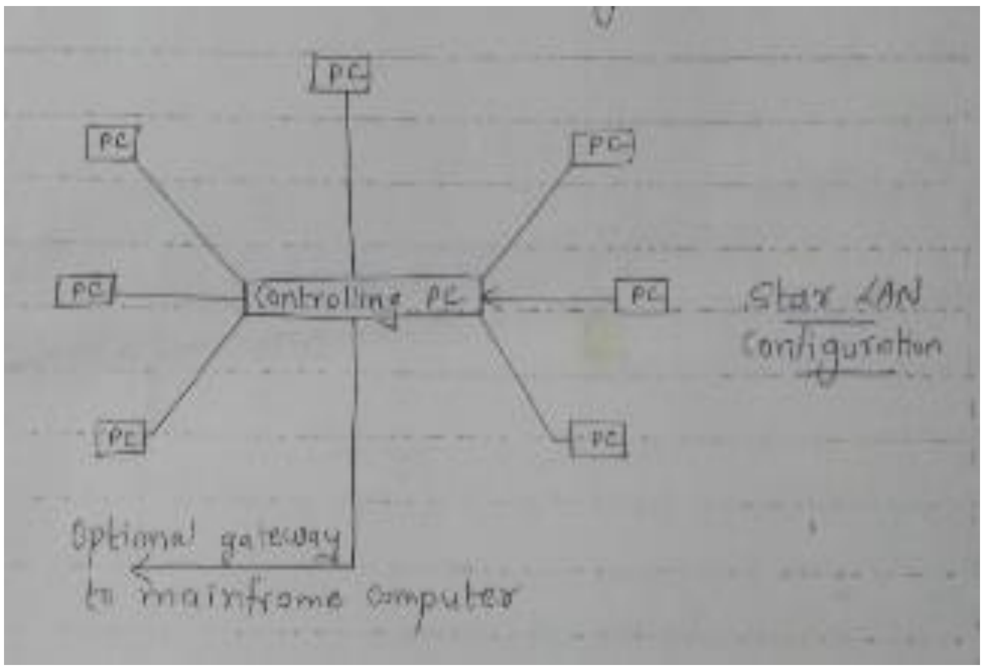
These different network configurations or arrangements are called as network topologies.

Types of network topology are Star, Ring and Bus

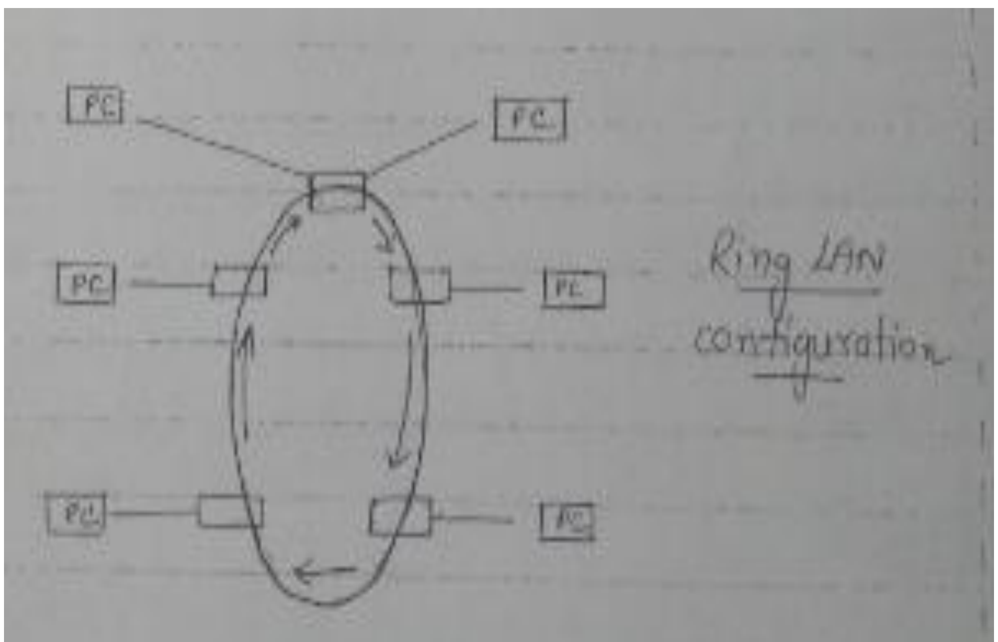
1) **Star – This network consists of a central controller node and each individual station. The communication from one station to another must take place through the central controller station e.g. PBX (Private Branch Exchange) system which is a small telephone system within an office or building. Another example of a star network is a mainframe computer which serves as the central controller for many video terminals or PCs. Each station must go through the controller to communicate with any other station.**

Advantage – Failure of one node does not disable the system.

Disadvantage – Slow speed response during heavy use.



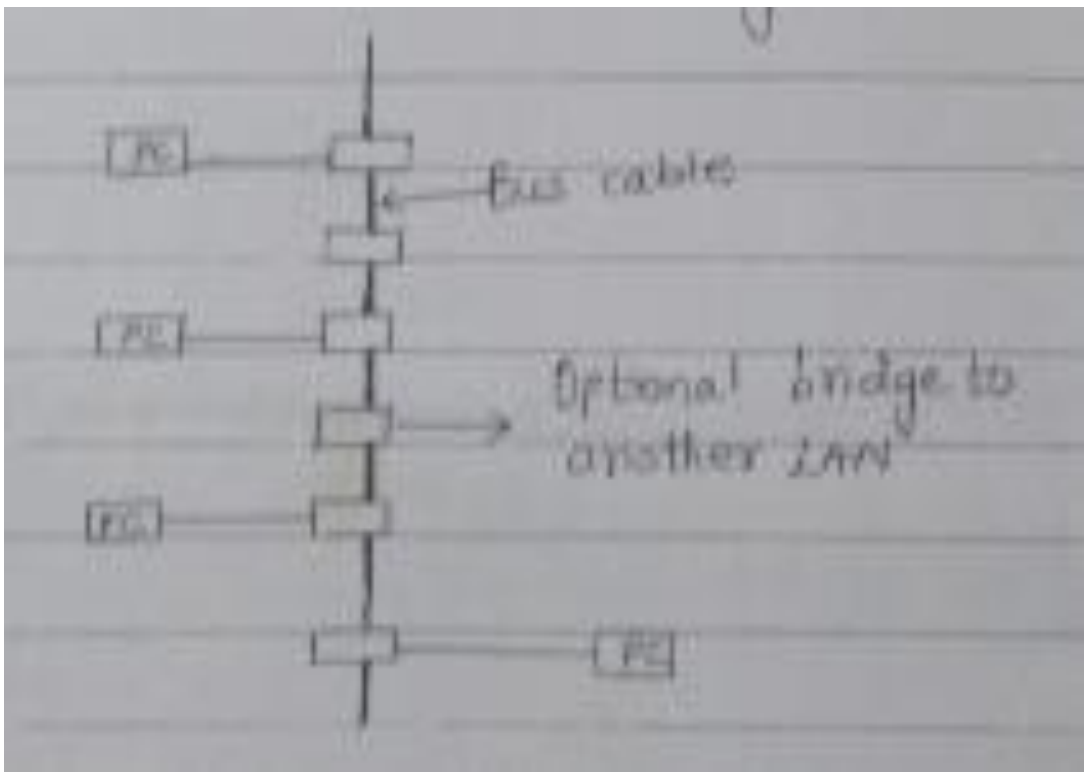
2) Ring – There is no central controller station. All stations are connected to form a continuous loop. Each small box in the diagram is the interface circuitry. Stations (nodes) have the ability to recognize their assigned code or address and the capability of retransmitting a received signal. In the ring, the direction of communication is unidirectional. In ring of LAN, message is passed from one station to the next until the destination is reached.
Advantage – Low cost.
Disadvantage – If one station fails, the whole system fails.



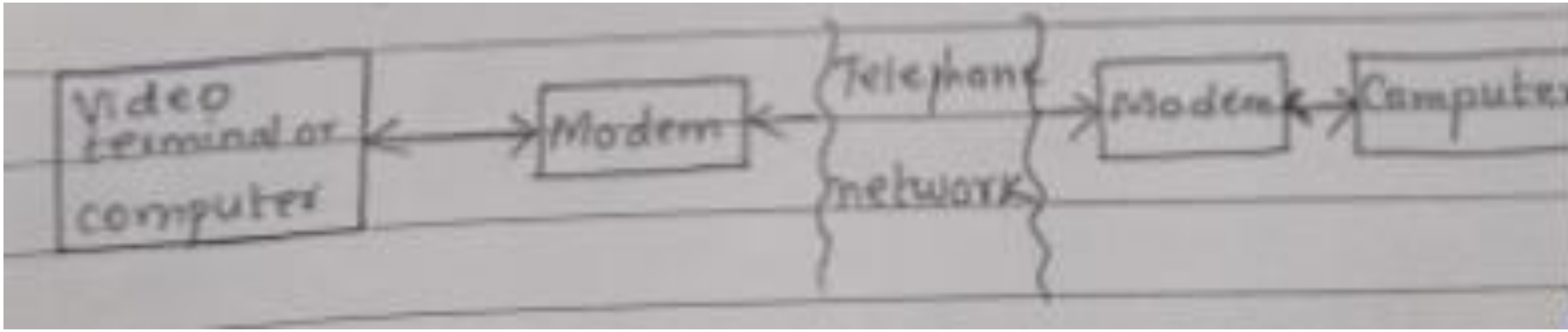
3) Bus – In this type all stations share a common cable called as Bus. Communication is bidirectional on the bus which allows any station to talk to any other station. Two stations can communicate directly without interference from any other station.

Advantages – Fast speed due to direct access.

Failure of one node will not disable the system.



Modem



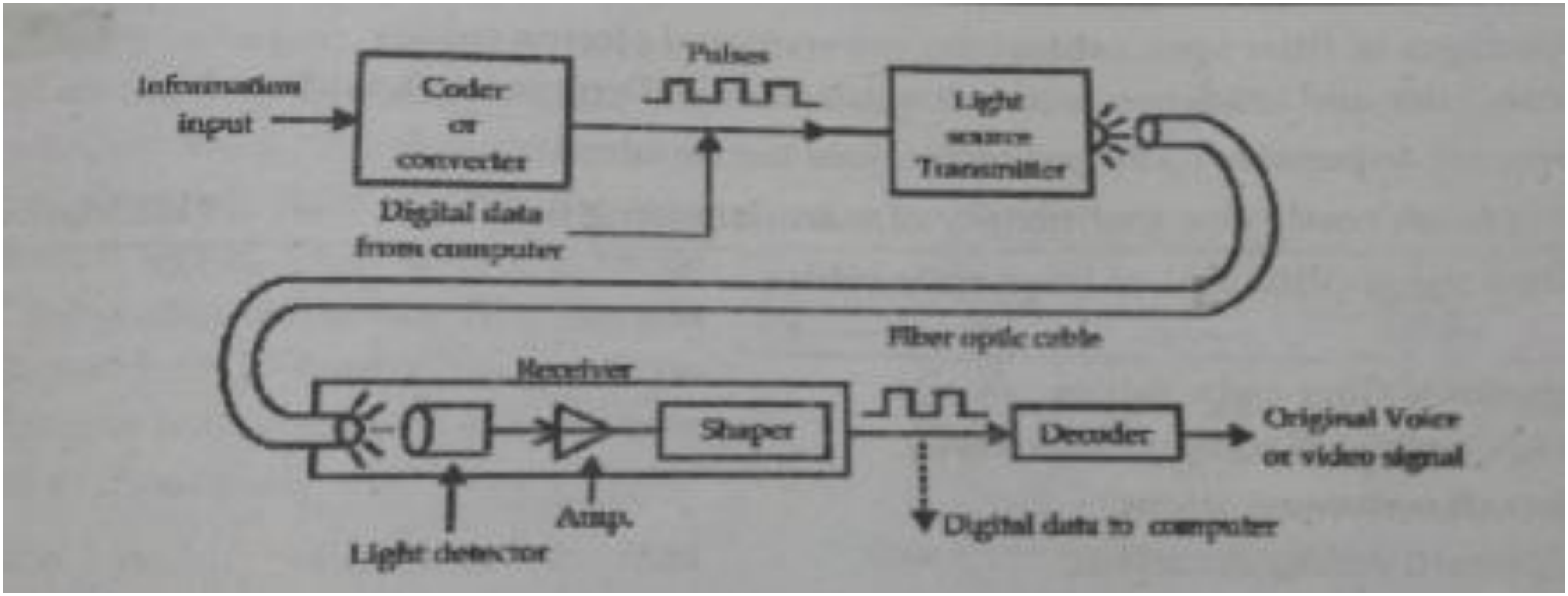
A modem is a device which has a modulator and a demodulator. The figure shows the manner in which a modem can be used in digital data transmission.
A large mainframe computer or personal computer can communicate with another large mainframe computer using modems.
A modem causes the binary dc pulses to modulate an analog sine wave carrier that is compatible with the telephone line. This modulated wave passes through the telephone network to the other end where the modem works as a demodulator. That is, it demodulates the analog signal into its equivalent binary output.

Fibre-optic communication

A fibre-optic cable is a light pipe that is used to carry a light beam from one place to another. Light is an electromagnetic signal which can be modulated by information and sent over the fiber-optic cable. These cables are made of glass or plastic.

Advantages of fiber-optic cables over conventional electric cables:

1) Small size – Fiber-optic cables are much smaller in diameter than electric cables.
2) Wider bandwidth – They have higher number information-carrying capacity.
3) Lower Loss – There is less signal attenuation over long distances.
4) Light weight – Glass or plastic cables are much lighter than copper cables.
5) Strength – They are stronger than electric cables and can support more weight.
6) Greater safety – They do not carry electricity. So there is no danger of electrical shocks or lightening strikes.



Three main types of information carried by fibre-optic cables are: voice, video and computer data. First the information is converted into a form compatible with the medium. Continuous analog signals (voice and video) are converted into a series of digital pulses by using A/D converter. Computer data can be directly given as it is in digital form. These digital pulses are used to switch off and on a powerful light source very rapidly. For short distances, the light source is light-emitting diode. (LED). Infrared beams or solid-state lasers also can be used.

The light-beam pulses are then fed into a fibre-optic cable. Light beams have a large information carrying capacity. Fibre-optic cable has very less attenuation than electric cables. It is smaller, lighter and stronger than electric cable. It has wide bandwidth.
At the receiving end, a light sensitive device called as light detector or photocell is used to detect light pulses. It converts the light pulses into electrical signal. These pulses are amplified and reshaped back into digital form. They are fed to a decoder (D/A Converter) where the original video-or voice is recovered.

Satellite communication

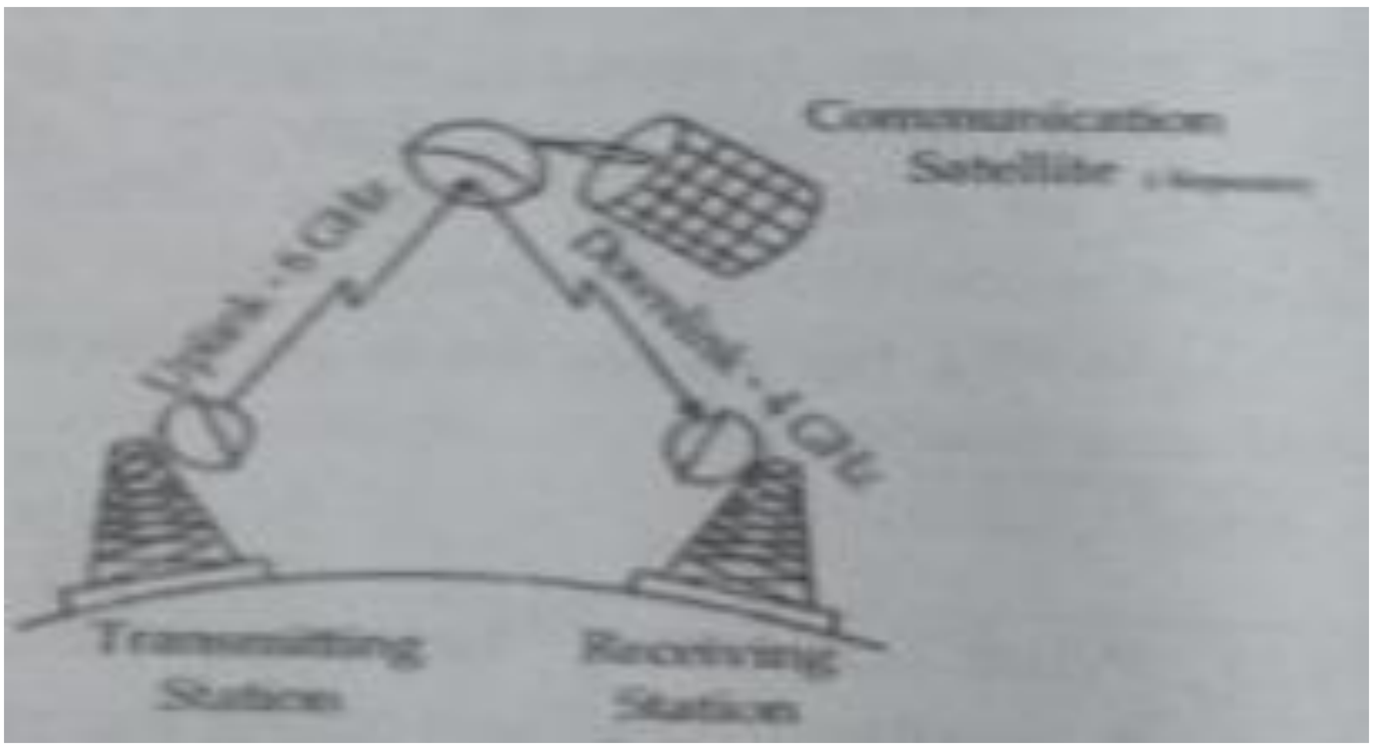
For communication purpose, a geosynchronous satellite is used. Such a satellite appears stationery from the earth.

This is because for communication, the ground station antenna must be able to follow or track the satellite even when it passes overhead . However for a short period of time when it is not visible from the earth communication will fail. So, a geosynchronous satellite is used. The antenna on the earth tracking the satellite will then remain in a fixed position pointed at the satellite and continuous communication will be possible.

Satellite as a relay station or repeater.

Communication satellites work as relay station.

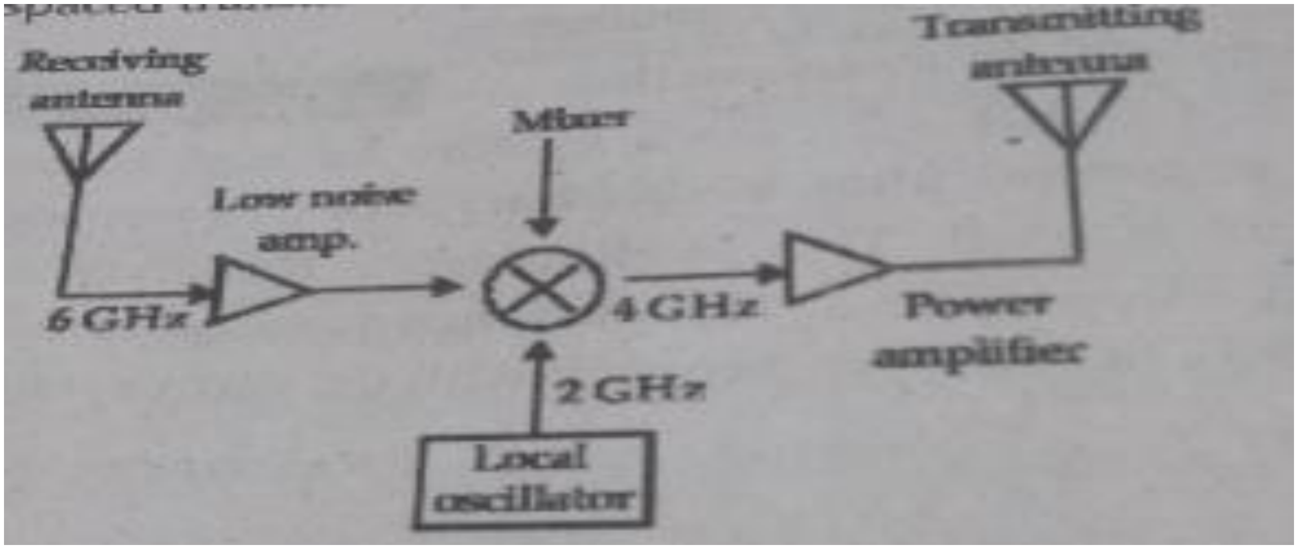
Whenever a transmitting station cannot directly communicate with other receiving stations due to certain restrictions, a satellite is used as a repeater. The transmitting station sends information to the satellite which retransmits it to the receiving station.



An earth station transmits information to the satellite. This is called as uplink. The uplink frequency is 6 GHz.

The satellite contains a receiver which picks up the transmitted signal, amplifies it, and translates it to another frequency called as downlink frequency of 4 GHz. This signal is retransmitted to the receiving stations back on earth.

Transponder



The transmitter – receiver combination in the satellite is called as Transponder.

The basic function of a transponder is amplification and frequency translation. The frequency translation is necessary because the transponder cannot transmit and receive on the same frequency. The transmitter's strong signal would overload the received and block out the weak uplink signal.
By using widely spaced transmit and receive frequencies, interference is avoided.

Transponder consists of receiving antenna, low-noise amplifier (LNA), mixer, local oscillator, power amplifier and transmitting antenna. LNA amplifies the weak uplink signal. The mixer and local oscillator work as frequency translator. The downlink frequency signal is amplified by power amplifier and transmitted back to earth by transmitting antenna.

A transponder has a wide bandwidth of 500 MHz but it is used with a single signal. A typical communication satellite has 12 or more transponders. Most communication satellites operate in the microwave frequency spectrum. The uplink frequencies are in 5.825 to 6.425 GHz range and downlink frequencies are in 3.7 to 4.2 GHz range. Generally these frequencies are referred ad 6 GHz/4 GHz.

Six applications of satellite:

1) In Communication (TV and Telephony etc.)
2) Observation (Meterological),
3) Monitoring earth’s resources
4) Surveillance using film cameras, radars
5) Navigation using GPS,
6) Intelligence and infrared sensors, satellites collect information about enemies and nuclear tests etc.

FAX

FAX is an electronic system for transmitting graphical information by wire or radio waves. With FAX, documents such as letters, photographs, any printed information can be converted into an electrical signal and transmitted by means of communication techniques.

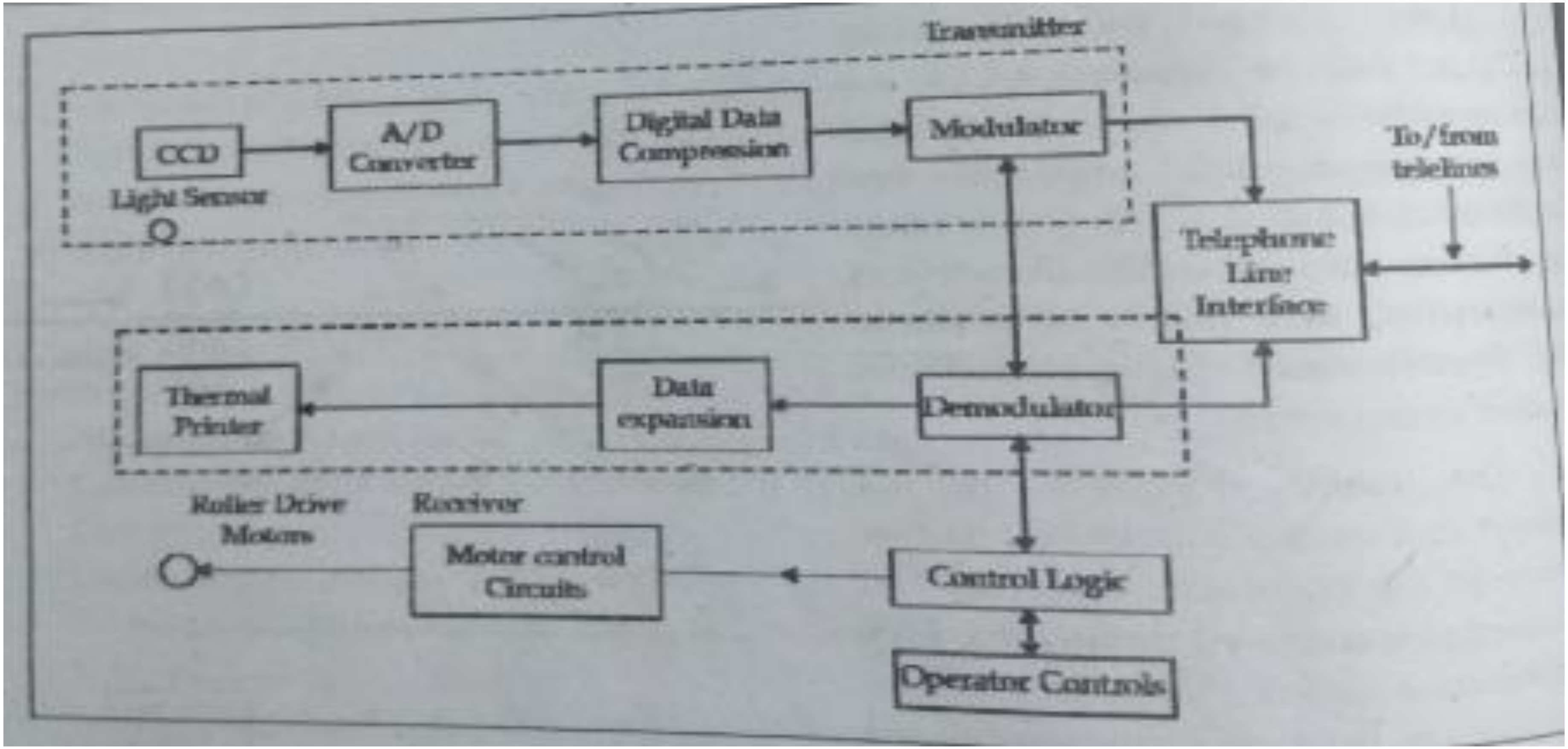
Concept of scanning –

In today's modern Fax machine, scanning is done electronically and the scanned signal is converted into a binary signal. Then modems are used for digital transmission.

Charge-coupled devices (CCDS) are used for scanning. A CCD is a light-sensitive semiconductor device that converts varying light amplitudes into an electrical signal. The CCD is made up of many capacitor like devices manufactured in a matrix on a silicon chip. The capacitors are actually tiny reverse-biased silicon photodiodes.

In desktop fax machines, the entire document is not focussed on a single CCD. Only a narrow portion of the document is lighted and examined as it is moved through the fax machine with rollers. A complex system of mirrors is used to focus the lighted area on the CCD.

When light falls on CCD, the CCD capacitors charge to a value proportional to the light intensity. The capacitors are then scanned electronically to determine their charge. This produces an analog output signal that accurately depicts the image focussed on the CCD.



Scanning is done by CCD and analog output is obtained. This output is then sent to an A/D converter which provides digital data to the data compression circuits. This circuit reduces redundancy (not useful) in the converted image so that fewer bits are needed to represent the image and storage memory is reduced. The binary output is then used to modulate a carrier which is transmitted over the telephone line.

In the receiver section the received signal is demodulated and is then sent to the data expansion circuit where the binary signal are restored to their original form. This signal is then applied to a thermal printer. In thermal printers a special heat-sensitive paper is used. The print head contains tiny heating elements that are turned on and off by the received signal.

CONCEPT OF RADAR

Radar (Radio Detection and Ranging) is an electronic communication system used to detect objects at distances that cannot be observed. The range, direction and elevation of remote objects like airplane, missile, ship or automobile can be determined.

Radar is based on the principle that when a radio signal is transmitted from the radar station, it gets reflected from the target and travels an equal distance back to the radar station.

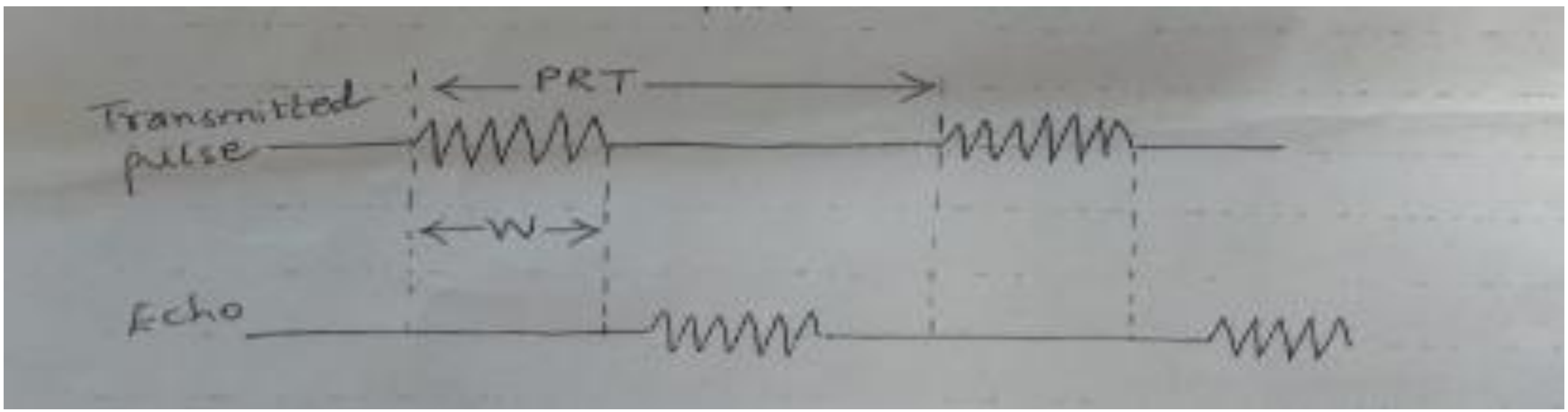
Therefore, $$\text{distance} = \frac{\text{speed} \times t}{2}$$

Where 't' is the time interval between the transmission of the radio signal and the reception of the echo.

<u>Types</u> of RADAR systems:

1) **<u>Pulsed radar</u>:**
   In this type, signals are transmitted in short bursts or pulses as shown below. The duration or width of the pulse is w. The time between transmitted pulses is the pulse repetition time (PRT).

   Pulse repetition frequency (PRF) = 1/PRT

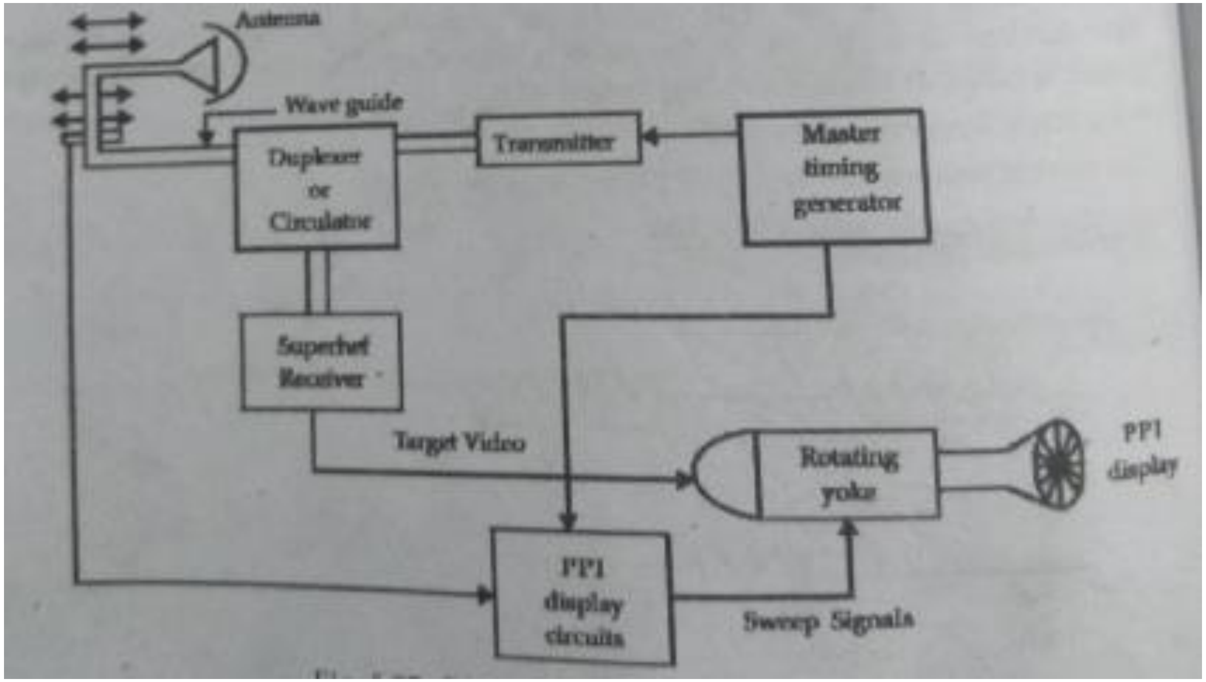


The echo will be received in the time interval between the end of first transmitted signal and the beginning of the next pulse as show above.

2) <u>Continuous wave (CW) RADAR</u>:

In this type, a constant-amplitude continuous microwave sine wave is transmitted . The echo is also a constant amplitude sine wave of the same frequency but of lower amplitude.

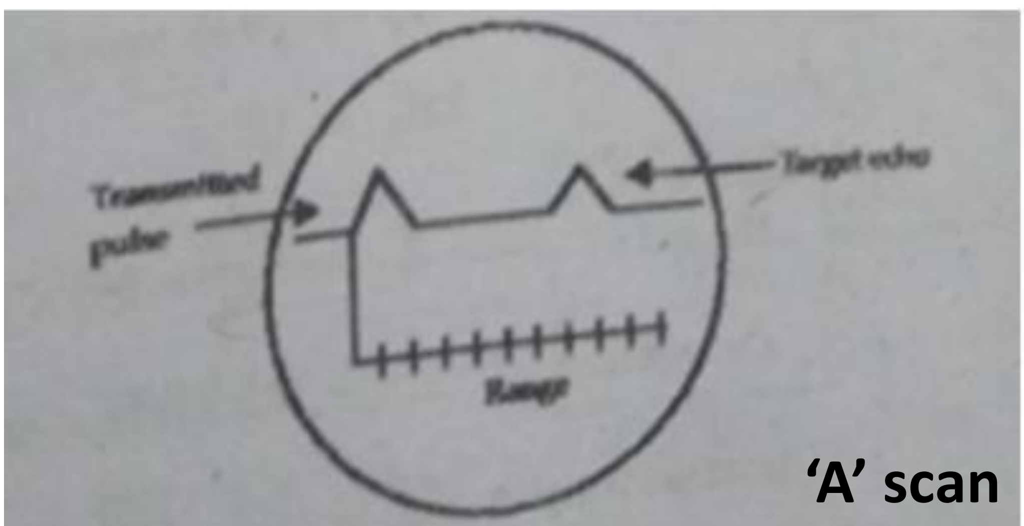
<u>Pulsed Radar</u> – block diagram



Pulsed radar works by sending signals in short pulses or bursts.

Transmitter uses a magnetron – a high power vacuum tube oscilltor. Master timing generator develops the basic pulses used for triggering the magnetron. The timing generator sets the pulse duration, PRT. When triggered into oscillation, the magnetron emits short bursts of wave. This output is passed through a duplexer to the antenna.

Duplexer allows the transmitter and receiver to share a single antenna. The receiver is of superheterodyne type. It has a RF amplifier, mixer, Local oscillator, IF amplifier & demodulator. The output of the demodulator is fed to a video amplifier which creates signals that are finally displayed. The display is a CRT. The display known as ‘A’ scan type displays the transmitted and received pulses. The ‘P’ type or ‘Plan Position Indicator (PPI) display shows both the range and direction of the target. The centre of the display indicates location of radar unit and concentric circles indicate the range. Direction is indicated by the position of the reflected target on the screen. The target shows up as lighted blip on the screen.



‘A’ scan