COMMUNICATION SYSTEM

Basic Terms used in communication system

(1) Transducer - A transducer is a device which converts one form of energy into another.
An electrical transducer is one which converts ~~variable~~ some physical variable (pressure, displacement, force, temperature etc) into corresponding variations in electrical signals.

(2) Signal - The information which is converted into electrical form and which is suitable for transmission is called signal.
Signals can be analog and digital. Analog signals are continuous variations of voltage or current where as digital signals can only take discrete step-wise values.

~~(3) Noise - It refers to unwanted~~

(3) Noise. They are unwanted signals that tend to disturb the transmission & processing of message signals in a communication system.
Atmospheric electricity, fluctuations of power in industries etc are the sources of noise.

(4) Modulation. A low frequency signal cannot be transmitted over long distances. Therefore it is superimposed on a high frequency wave (carrier wave) such that some characteristic of carrier wave changes in accordance with signal. The process of mixing carrier wave & signal is called modulation.

(5) Demodulation - The process of separating the original signal from the modulated wave at the receiver is called demodulation.

(6) Transmitter - A device that converts the signal into an electrical signal. mixes it with carrier wave and then transmits it into a medium is called transmitter.

(7) Receiver - A device that extracts the original signal from the modulated signal is called receiver.

(8) Attenuation. The loss of strength of a signal while propagating through a medium is called attenuation.

(9) Amplification - It is the process of increasing the amplitude and hence the strength of a signal using an amplifier. Amplification is necessary to

compensate for the attenuation of the signal in communication system.

(10) Range - The largest distance between a source and a destination upto which the signal is received with sufficient strength is called range.

(11) Bandwidth - The range over which frequencies of a signal varies is called its bandwidth.

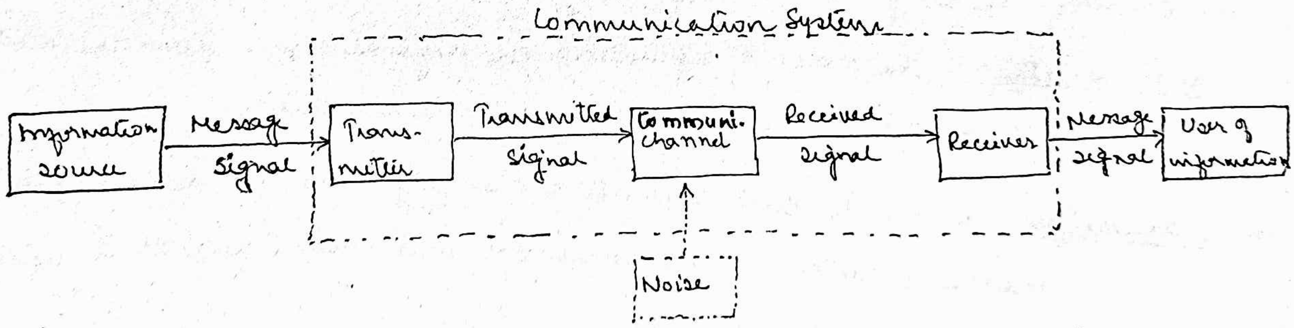
(12) Repeater - It is a combination of a receiver and a transmitter. A repeater picks up signal from the transmitter amplifies it and then retransmits it to the receiver. Repeaters are used to increase the range of a communication system.

Communication system

The exchange of information between two persons located at two different places is called communication and the set up used for this purpose is called a communication system.

A communication system consists of three parts -

(a) transmitter (b) communication channel (c) receiver



Example. Two persons living in a city may converse by using telephone as a communication system. Here the mouth piece of the telephone at the speaker's end acts as transmitter and the earpiece of the telephone at the listener's end acts as the receiver and the telephone lines connecting the two telephones acts as the communication channel.

Note 1. Due to ~~additio~~ addition of noise to the transmitted signal the receiver receives corrupted version of transmitted signal.

2. There are two basic modes of communication - point to point & broadcast. In point to point communication mode there is only one transmitter and one receiver eg. telephone where as in broadcast mode there are a large number

receivers corresponding to a single transmitter.

Bandwidth of signals

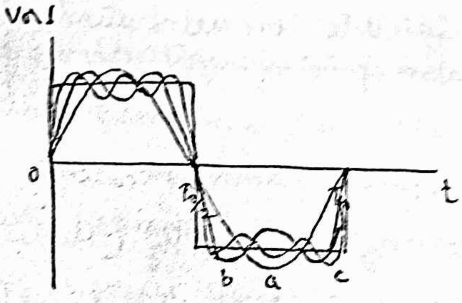
1. Bandwidth of analog signal - In a communication system, the signal may be in the form of speech, music or picture. They may be considered as of superposition of large no. of sinusoidal signals of varying amplitude and frequency. In practice, an analog signal does not have a single frequency. Its frequency varies from a lowest value to a highest value (called bandwidth).

The frequency range of speech signals in telephonic communication system is from 300 Hz to 3100 Hz therefore the bandwidth of speech signal is 2800 Hz. The frequency range of audible signals produced by musical system is from 20 Hz to 20 kHz therefore the bandwidth of audible signal is 20 kHz (approx)

The video signals requires a bandwidth of 4.2 MHz for their transmission. As T.V. signals contain both audio and video signals therefore they require a bandwidth of 6 MHz for their transmission.

2. Bandwidth of digital signal - Digital signal is in the form of rectangular waves. It can be shown that such a signal of rectangular shape is superposition of a number of sinusoidal waves of frequencies $f_0, 2f_0, 3f_0, 4f_0 \ldots\ldots nf_0$, where n is an integer extending upto infinity.

In fig. the variation of amplitude of fundamental frequency f_0 with time has been shown by curve (a), of fundamental frequency f_0 together with second harmonic $2f_0$ by curve (b) and of fundamental frequency f_0 together with second and third harmonics $2f_0$ and $3f_0$ by curve (c). It follows that shape of these curves approaches the rectangular shape of a digital signal as more and more higher harmonics are added to the fundamental frequency. The exact rectangular shape of digital signal will be reproduced when all the infinite number of harmonics are added to the fundamental frequency. Thus, the bandwidth of a digital signal is infinite.



Band width of transmission medium

Similar to message signals, different types of transmission media offer different bandwidths. The commonly used transmission media are wire, free space and fibre optic cable. Coaxial cable is a widely used wire medium which offers a bandwidth of approx. 750 MHz. Such cables are normally operated below 18 GHz. Communication through free space using radio waves takes place over a very wide range of frequencies from a few hundreds of kHz to a few GHz. This range of frequencies is further sub-divided and alloted for various services are indicated in table-

Service	Frequency band	Comments
Standard AM broadcast	540-1600 kHz	Radio
Standard FM broadcast	88 - 108 MHz	Radio
Television		
	54-72 MHz	VHF (Very high frequency)
	76- 88 MHz	TV
	174 - 216 MHz	UHF (Ultra high frequency)
	420 - 890 MHz	TV
Cellular mobile radio	896 - 901 MHz	Mobile to base station
	840 - 935 MHz	Base station to mobile
Satellite Communication	5.925 - 6.425 GHz	Uplink
	3.7 - 4.2 GHz	Downlink

Optical communication using fibres is performed in the frequency range of 1 THz to 1000 THz (Microwaves to ultraviolet). An optical fibre can offer a transmission bandwidth in excess of 100 GHz.

Note: The International Telecommunication Union administers the present system of frequency allocations.

Size of antenna or aerial

For transmitting a signal, we need an antenna whose size should be comparable to the wavelength of the signal (at least $\lambda/4$ in dimension) so that the antenna properly senses the time variation of the signal.

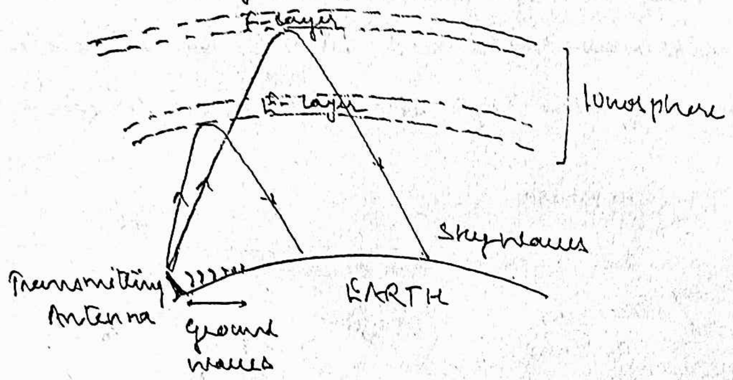
For an electromagnetic wave of frequency 20 kHz, the wavelength λ is 15 km. Since such a long antenna is not possible to construct and operate hence direct transmission of such baseband signals is not practical. Therefore, there is need of translating the information contained in low frequency baseband signal into high or radio frequencies before transmission.

Types of Wave Propagation

ground wave propagation - When the radiowaves from the transmitting antenna reach the receiving antenna following the surface of earth, the wave propagation is called ground wave or surface wave propagation.

These are amplitude modulated waves whose frequency ranges from 500kHz to 1500 kHz. The region of AM band in which ground waves lie is called medium wave band. As the ground waves travels, they induces current in the ground over which it passes & it is attenuated as a result of absorption of energy by the earth. Due to this, the ground waves are not suited for long distance communication.

Note: The attenuation of ground waves increases with the increase in frequency therefore for FM and TV signals ground waves are not used.



② **Sky wave propagation** - When the radiowaves from the transmitting antenna reach the receiving antenna after reflection from ionosphere, the wave propagation is called sky wave or ionospheric propagation.

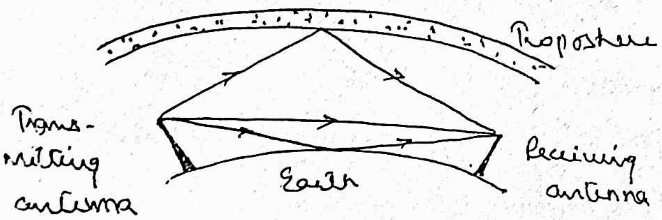
These are amplitude modulated waves whose frequency ranges from 3MHz to 30 MHz. The region of AM band in which sky waves lie is called short wave band. Sky waves of low frequency are reflected from E-layer and sky waves of high frequency are reflected from F-layer. Those radio waves whose frequencies are higher ~~frequency are greater~~ than 30 MHz are not reflected by ionosphere and escape into space.

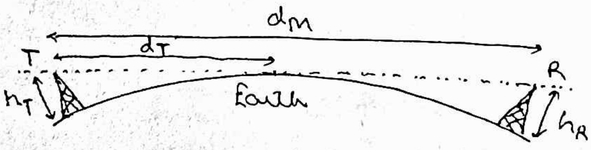
Note: The sky waves of different frequencies are reflected from different region of ionosphere having different electron density (N). If the frequency is too high then the electron density may not be so high to fulfill the condition of reflection. The frequency above which the radio waves are not reflected from ionosphere is called critical frequency (f_c). If the maximum electron density of the ionosphere be N_{max} per m^3 then the critical frequency f_c is approx. given by $\boxed{f_c = 9(N_{max})^{1/2}}$

(3) <u>Space waves or Tropospheric propagation</u> - When the radio waves from the transmitting antenna reach the receiving antenna either directly or after reflection from the ground or in troposphere, the wave propagation is called space wave propagation.

These are frequency modulated waves whose frequency ranges from 40 MHz 1000 MHz. Space wave communication is essentially limited to line of sight. Because of line of sight nature of space wave propagation, the waves travelling directly from the transmitting antenna to the receiving antenna get blocked due to curvature of the earth. If the signal is to be received beyond the horizon then the receiving antenna must be high enough to intercept the line of sight waves.

Television broadcast, microwave links and satellite communication are some examples of communication systems that uses space wave mode of propagation.





<u>Note:</u> The maximum line-of-sight distance d_M between the two antennas having heights h_T and h_R above the earth is given by $d_M = d_T + d_R$

$$\text{or} \quad d_M = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

where R is the radius of earth; and h_T and h_R are the heights of transmitting & receiving antenna. (d_T is also called the radio horizon of transmitting antenna)

<u>Relation b/w height of antenna and distance upto which signals can be received</u> (from the notes of EMW)

<u>Effective power radiated by an antenna</u> - The power radiated by a linear antenna of length l is proportional to $(l/\lambda)^2$. This implies that for the same length of antenna, the power radiated increases with decreasing λ or increasing ν. Thus, the effective power radiated by a long wavelength baseband signal would be small. Therefore, for good transmission, the signal should be transmitted with high power i.e. the signal should be of small wavelength or high frequency.

The frequency range of audible sound waves is 20Hz to 20kHz. The sound waves cannot be transmitted from a radio transmitter by converting into electrical waves (audio signal) because of the following reasons.

(a) For effective transmission and reception of audio signal antenna whose length is $\frac{15}{4}$ km (for 20 kHz) is required. To set up such a large antenna is practically impossible.

(b) For linear antenna of length l, the power radiated $\propto \left(\frac{l}{\lambda}\right)^2$. If the audio signals are directly transmitted into space then they die out after covering some distance due to low power radiated by the antenna

(c) If audio signal is directly transmitted then the audio signals from different transmitting stations will get inseparably mixed up.

The above problems during the transmission of audio signal are overcome by the process of modulation

(Analog) Modulation

The process of generating a continuous high frequency wave some characteristic of which varies as a function of instantaneous value of audio signal is called (Analog) modulation.

There are three different types of (analog) modulation -

(a) Amplitude modulation (b) Frequency modulation (c) Phase modulation

Amplitude Modulation

When a modulating wave is superimposed on a high frequency carrier wave in such a manner that the frequency of modulated wave is same as that of carrier wave but its amplitude changes in accordance with the instantaneous value of modulating wave then the process is called amplitude modulation.

Let the instantaneous voltages of carrier wave and modulating wave be represented by

$$e_c = E_c \sin \omega_c t$$

and $e_m = E_m \sin \omega_m t$ respectively.

Since in amplitude modulation, the amplitude of modulated wave changes in accordance with the instantaneous value of modulating wave but the frequency of modulated wave is same as the frequency of carrier wave. Therefore, the instantaneous voltage of modulated wave is given by

$$e = E \sin \omega_c t \quad -(1)$$

where E is the amplitude of modulated wave which is given by

$$E = E_c + e_m$$

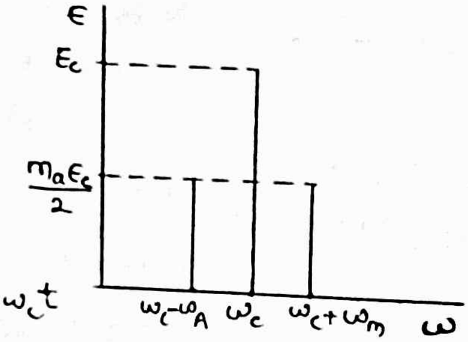
or $$E = E_c + E_m \sin \omega_m t$$

$$\therefore e = (E_c + E_m \sin \omega_m t) \sin \omega_c t \quad - (ii)$$

$\cancel{e = E_c \sin \omega_c t}$

In amplitude modulation, the ratio of the change in the amplitude of the carrier wave to the amplitude of the original carrier wave is called modulation factor. It is also called degree of modulation or modulation index which is given by

$$m_a = \frac{E_m}{E_c} \Rightarrow E_m = m_a E_c$$



from relation (ii), we have

$$e = (E_c + m_a E_c \sin \omega_m t) \sin \omega_c t$$

or $$e = E_c \sin \omega_c t + m_a E_c \sin \omega_m t \sin \omega_c t$$

or $$e = E_c \sin \omega_c t + \frac{m_a E_c}{2} 2 \sin \omega_m t \sin \omega_c t$$

or $$e = E_c \sin \omega_c t + \frac{m_a E_c}{2} \{ \cos(\omega_c t - \omega_m t) - \cos(\omega_c t + \omega_m t) \}$$

or $$e = E_c \sin \omega_c t + \frac{m_a E_c}{2} \cos(\omega_c - \omega_m)t - \frac{m_a E_c}{2} \cos(\omega_c + \omega_m)t$$

Thus, the expression of instantaneous voltage of modulated wave of three terms. The first term represents a waveform of frequency ω_c, the second terms represents a waveform of frequency $\omega_c - \omega_m$ called lower side band and the third term represents a waveform of frequency $\omega_c + \omega_m$ called upper side band. Since, the modulated signal lies in the frequency range of $\omega_c - \omega_m$ to $\omega_c + \omega_m$ therefore the bandwidth of amplitude signal is $2\omega_m$.

i.e. Bandwidth = 2 × frequency of modulating signal

<u>Note</u>: In amplitude modulation, the amplitude of modulated signal $E = E_c + E_m \sin \omega_m t$

$$\therefore E_{min} = E_c + E_m (\sin \omega_m t)_{min} = E_c + E_m(-1) = E_c - E_m \quad - (iii)$$

$$\& \quad E_{max} = E_c + E_m (\sin \omega_m t)_{max} = E_c + E_m(+1) = E_c + E_m \quad - (iv)$$

Dividing eq. (iv) by (iii)

$$\frac{E_{max}}{E_{min}} = \frac{E_c + E_m}{E_c - E_m}$$

or $$\frac{E_{max}}{E_{min}} = \frac{E_c + m_a E_c}{E_c - m_a E_c}$$

or $\frac{E_{max}}{E_{min}} = \frac{E_c(1+m_a)}{E_c(1-m_a)}$

or $E_{max} - m_a E_{max} = E_{min} + m_a E_{min}$

or $E_{max} - E_{min} = m_a E_{min} + m_a E_{max}$

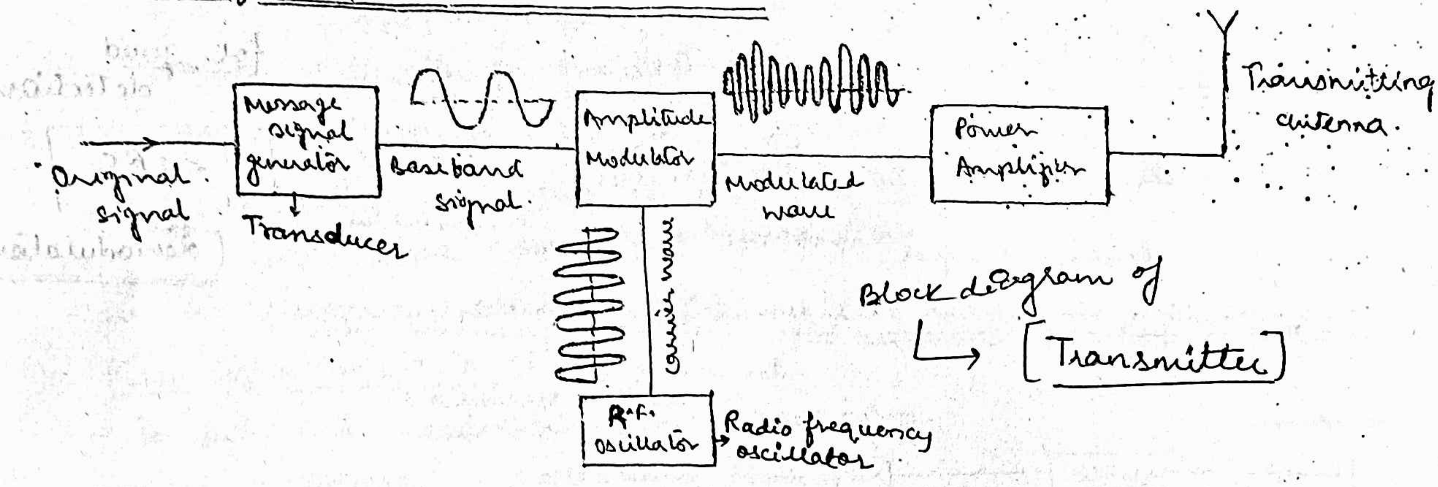
or $E_{max} - E_{min} = m_a (E_{min} + E_{max})$

or $m_a = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}$

→ Unmodulated carrier amplitude

$$E = \frac{E_{max} + E_{min}}{2}$$

Transmission of amplitude modulated wave



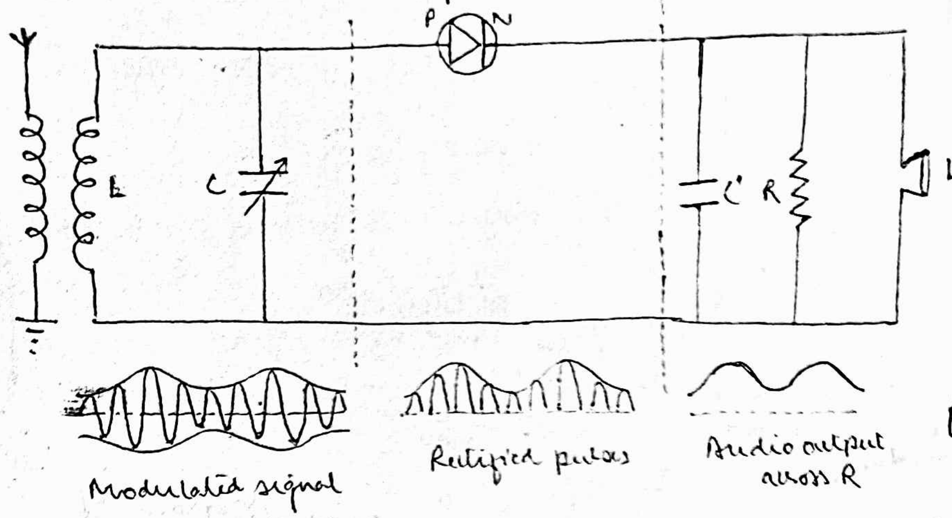
Block diagram of → [Transmitter]

Figure shows a block diagram for the transmitter of an amplitude modulated wave. The information signal is fed to the message signal generator. The message signal generator is a transducer which converts original signal into an electric signal called baseband signal (modulating signal). A frequency oscillator generates high frequency carrier wave. The modular superimposes the baseband signal over the carrier wave and gives out the modulated wave. The modulated wave is passed through a power amplifier to increase its power and then fed to a transmitting antenna for transmission into space.

Demodulation or detection of amplitude modulated wave

The process of separating audio signal from modulated signal is called demodulation or detection.

The input circuit of detector consists of an inductor L and a capacitor C connected in parallel which is called tuning circuit. This circuit helps to select desired modulated radio frequency signal from different signals picked by the antenna. Since diode behaves like half wave rectifier therefore its output is a series of positive half cycles of radio frequency pulses whose amplitude changes in accordance with the instantaneous value of audio signal (modulating signal). The rectified output is then fed to the parallel combination of a capacitor C' and resistor R. The value of C' is chosen in such a manner that its reactance is high to low frequency audio waves. Therefore the capacitor C' allows high frequency carrier waves to pass through it but obstructs the low frequency audio waves which appear across the resistor R (in the form of voltage), which sends current through the speaker to produce the original sound.

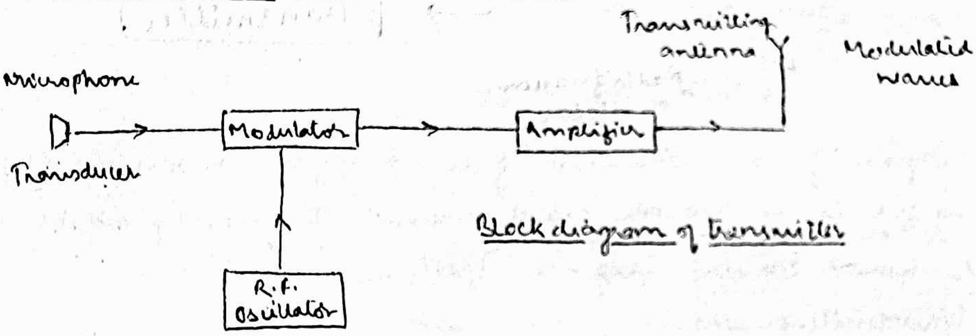


for good detection

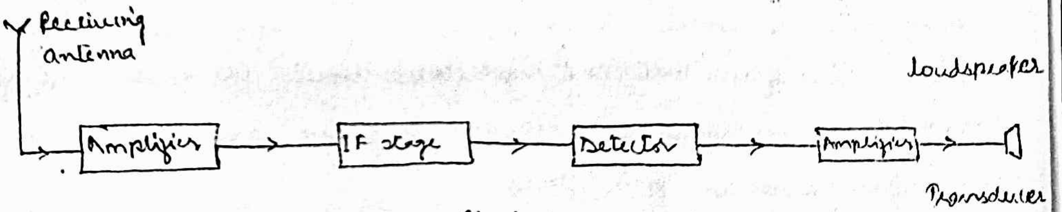
$$\boxed{\frac{1}{f_c} << RC}$$

(for demodulator)

Basic elements of modulation and demodulation of an audio signal



Block diagram of transmitter



Block diagram of receiver

A brief description of various elements is as follows -

1. A radio frequency oscillator generates high frequency carrier waves (radio frequency wave
2. A microphone converts sound waves (original signal) into audio signal (base band signal)
3. The modulator mixes the audio signal with the carrier waves and feeds the modulated waves to the amplifier.
4. The receiving antenna intercepts the transmitted modulated waves.
5. The intercepted modulated waves are amplified and then changed to a lower frequency by an intermediate frequency stage (IF stage) preceding the detection.
6. The detector (demodulator) separates audio signal from the modulated waves and then fed the output into the amplifier
7. The loud speaker converts audio signal back into sound waves

1. Pulse Amplitude Modulation (PAM)

In pulse amplitude modulation, the amplitude of the pulses is varied in accordance with the instantaneous ~~value~~ amplitude of modulating signal.

2. Pulse Width Modulation (PWM)

In pulse width modulation, the width of the pulses is varied in accordance with the instantaneous amplitude of modulating signal.

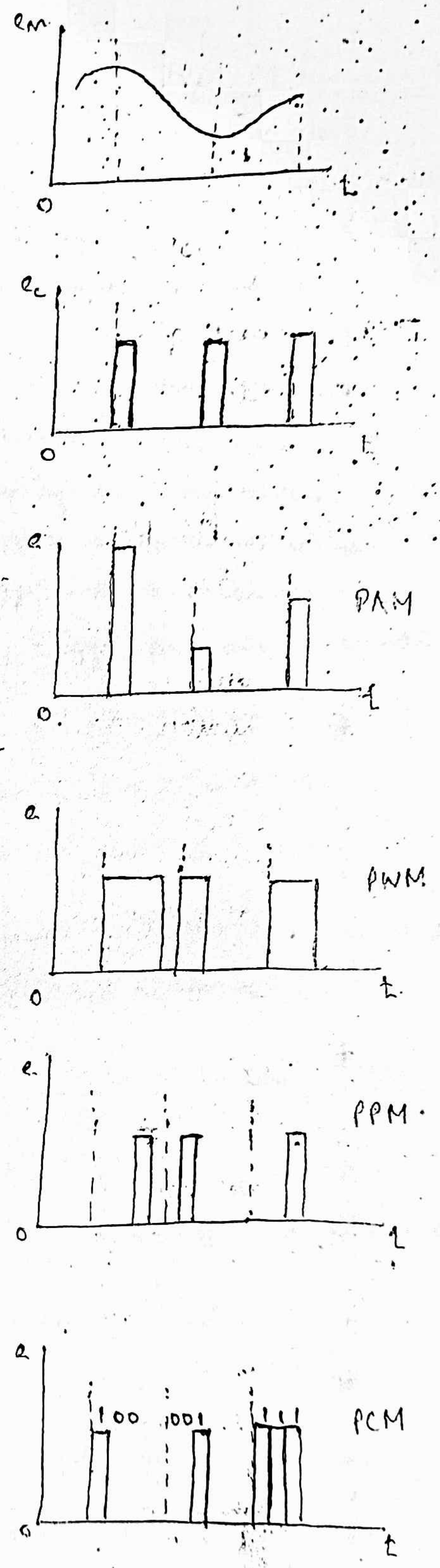
It is also called Pulse Duration Modulation (PDM) or Pulse Length Modulation (PLM).

3. Pulse Position Modulation (PPM)

In pulse position modulation, the position of the pulses is varied in accordance with the instantaneous amplitude of modulating signal.

4. Pulse Code Modulation (PCM)

In pulse code modulation, the analog signal is sampled, quantised, coded and then transmitted as electrical signal.



Frequency Modulation

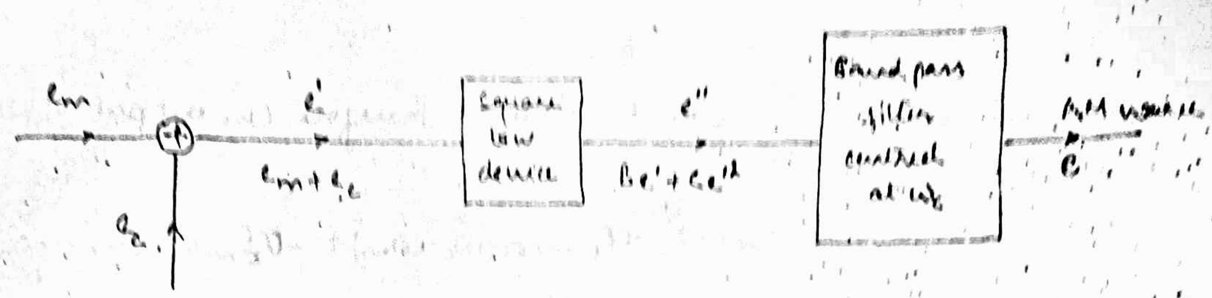
When a modulating wave is superimposed on a high frequency carrier wave in such a manner that the amplitude of modulated wave is same as that of carrier wave but its frequency changes in accordance with the instantaneous value of modulating wave then the process is called frequency modulation.

Pulse Modulation

In pulse modulation, the audio signal is sampled at regular intervals. Each sample of signal is then transmitted as short pulse of radio frequency carrier wave whose some characteristic changes in proportion to the instantaneous value of modulating signal (at the sampling instant).

Depending on the type of variation in pulse characteristics, pulse modulation is of following types -

...tion of amplitude modulated wave



Initially the modulating signal $E_m \sin \omega_m t$ is added to carrier signal $E_c \sin \omega_c t$ to produce the input signal

$$e' = e_m + e_c$$

$$\text{or } e' = E_m \sin \omega_m t + E_c \sin \omega_c t$$

This signal is passed through the square law device which gives the output

$$e'' = Be' + Ce'^2$$

where B and C are constants.

$$\therefore \quad e'' = B(E_m \sin \omega_m t + E_c \sin \omega_c t) + C(E_m \sin \omega_m t + E_c \sin \omega_c t)^2$$

$$\text{or } e'' = B(E_m \sin \omega_m t + E_c \sin \omega_c t) + C(E_m^2 \sin^2 \omega_m t + E_c^2 \sin^2 \omega_c t + 2E_m \sin \omega_m t \, E_c \sin \omega_c t)$$

$$\text{or } e'' = BE_m \sin \omega_m t + BE_c \sin \omega_c t + CE_m^2 \sin^2 \omega_m t + CE_c^2 \sin^2 \omega_c t + C2E_m \sin \omega_m t \, E_c \sin \omega_c t$$

$$\text{or } e'' = BE_m \sin \omega_m t + BE_c \sin \omega_c t + CE_m^2 \left(\frac{1 - \cos 2\omega_m t}{2}\right) + CE_c^2 \left(\frac{1 - \cos 2\omega_c t}{2}\right) + CE_m E_c \{\cos(\omega_c t - \omega_m t) - \cos(\omega_c t + \omega_m t)\}$$

$$\left[\because \sin^2 A = \frac{1 - \cos 2A}{2} \text{ and } 2 \sin A \sin B = \cos(A-B) - \cos(A+B)\right]$$

$$\text{or } e'' = BE_m \sin \omega_m t + BE_c \sin \omega_c t + \frac{CE_m^2}{2} - \frac{CE_m^2}{2} \cos 2\omega_m t + \frac{CE_c^2}{2} - \frac{CE_c^2}{2} \cos 2\omega_c t + E_c C E_m \cos(\omega_c - \omega_m)t - CE_m E_c \cos(\omega_c + \omega_m)t$$

This equation has DC terms $\frac{CE_m^2}{2}$ and $\frac{CE_c^2}{2}$ and sinusoidal terms of frequencies ω_m, $2\omega_m$, ω_c, $2\omega_c$, $\omega_c - \omega_m$ and $\omega_c + \omega_m$. When this signal is passed through a bandpass filter centred at ω_c, it rejects DC signals and the sinusoidal signals of frequencies ω_m, $2\omega_m$ and $2\omega_c$ and allows the frequencies ω_c, $\omega_c - \omega_m$ and $\omega_c + \omega_m$. Therefore the output of band pass filter is

$$e = BE_c \sin \omega_c t + CE_c E_m \cos(\omega_c - \omega_m)t - CE_c E_m \cos(\omega_c + \omega_m)t$$

which is an amplitude modulated wave.