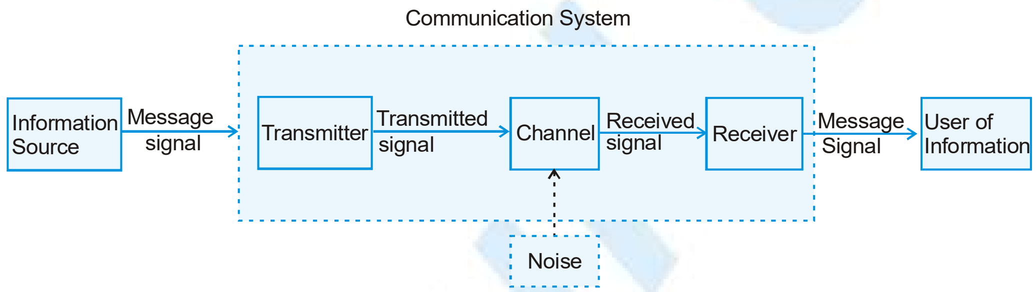
PRINCIPLES OF COMMUNICATIONS

INTRODUCTION

Communication is the act of transmission of information. Every living creature in the world experiences the need to impart or receive information almost continuously with others in the surrounding world. For communication to be successful, it is essential that the sender and the receiver understand a common language. Man has constantly made endeavors to improve the quality of communication with other human beings. languages and methods used in cummication have kept evolving from prehistoric to modern times, to meet the growing demands in terms of speed and complexity of information.

ELEMENTS OF A COMMUNICATION SYSTEM

Communication pervades all stages of life of all living creatures. Irrespective of its nature, every communication system has three essential elements transmitter, medium/channel and receiver. The block diagram shown in figure-1 depicts the general form of a communication system.



FIGURE–1

In a communication system, the transmitter is located at one place, the receiver is located at some other place (far or near) separate from the transmitter and the channel is the physical medium that connects them. Depending upon the type of communication system, a channel may be in the form of wires or cables connecting the transmitter and the receiver or it may be wireless. The purpose of the transmitter is to convert the message signal produced by the source of information into a form suitable for transmission through the channel. If the output of the information source is a non-electrical signal like a voice signal, a tranducer converts it to electrical form before giving it as an input to the transmitter. When a transmitted signal propagates along the channel it may get distorted due to channel imperfection. Moreover, noise adds to the transmitted signal and the receiver receives a corrupted version of the transmitted signal. The receiver has the task of operating on the received signal. It reconstructs a recognisable form of the original message signal for delivering it to the user of information.

There are two basic modes of communication : Point -to-point and broadcast.

In point-to-point communication mode, communication takes place over a link between a single transmitter and a receiver. Telephony is an example of such a mode of communication. In contrast, in the broadcast mode, there are a large number of receivers corresponding to a single transmitter. Radio and television are example of broadcast mode of communication.

(1) Digital and analog signals to be transmitted are usually of low frequency and hence cannot be transmitted as such.

(2) These signals require some carrier to be transported. These carriers are known as carrier waves or high frequency signals.

(3) The process of placement of a low frequency (LF) signal over the high frequency (HF) signal is known as modulation.

BASIC TERMINOLOGY USED IN ELECTRONIC COMMUNICATION SYSTEMS

By now, we have become familiar with some terms like information source, transmitter, receiver, channel, noise, etc. It would be easy to understand the principles underlying any communication, if we get ourselves acquainted with the following basic terminology.

(i) Transducer : Any device that converts one form of energy into another can be termed as a transducer. In electronic communication systems, we usually come across devices that have either their inputs or outputs in the electrical form. An electrical transducer may be defined as a device that converts some physical variable (pressure, displacement, force, temperature, etc) into corresponding variations in the electrical signal at its output.

(ii) Signal : Information converted in electrical form and suitable for transmission is called a signal. Signals can be either analog or digital. Analog signals are continuous variations of voltage or current. They are essentially single-valued functions of time. Sine wave is a fundamental analog signal. All other analog signals can be fully understood in terms of their sine wave components. Sound and picture signals in TV are analog in nature.
Digital signals are those which can take only discrete stepwise values. Binary system that is extensively used in digital electronics employs just two levels of a signal '0' corresponds to a low level and '1' corresponds to a high level of voltage/current. There are several coding schemes useful for digital communication. They employ suitable combinations of number sytems such as the binary coded decimal (BCD). American Standard Code for Information Interchange (ASCII) is a universally popular digital code to represent numbers, letters and certain characters.

(iii) Noise : Noise refers to the unwanted signals that tend to disturb the transmission and processing of message signals in a communication system. The source generating the noise may be located inside or outside the system.

(iv) Transmitter : A transmitter processes the incoming message signal so as to make it suitable for transmission through a channel and subsequent reception.

(v) Receiver : A receiver extracts the desired message signals from the received signals at the channel output.

(vi) Attenuation : The loss of strength of a signal while propagating through a medium is known as attenuation.

(vii) Amplification : It is the process of increasing the amplitude (and consequently the strength) of a signal using a electronic circuit called the amplifier. Amplification is necessary to compensate for the attenuation of the signal in communication systems. The energy needed for additional signal strength is obtained from a DC power source. Amplification is done at a place between the source and the destination wherever signal strength becomes weaker than the required strength.

(viii Range : It is the largest distance between a source and a destination up to which the signal is received with sufficient strength.

(ix) Bandwidth : Bandwidth refers to the frequency range over which an equipment operates or the portion of the spectrum occupied by the signal.

(x) Modulation : The original low frequency message/information signal cannot be transmitted to long distances because of reasons given in further section. Therefore, at the transmitter, information contained in the low frequency message signal is superimposed on a high frequency wave, which acts as a carrier of the information. This process is known as modulation. As will be explained later, there are several types of modulation abbreviated as AM, FM, and PM.

(xi) Demodulation : The process of retrieval of information from the carrier wave at the receiver is termed demodulation. This is the reverse process of modulation.

(xii) Repeater : A repeater is a combination of a receiver and a transmitter. A repeater, picks up the signal from the transmitter amplifies and retransmits it to the receiver sometimes with a change in carrier frequency. Repeaters are used to extend the range of a communication system as shown in figure-2 below. A communication satellite is essentially a repeater station in space.

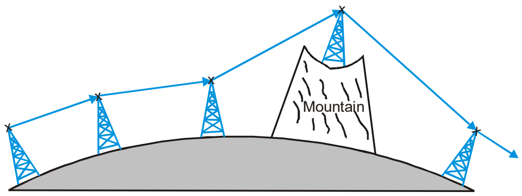


FIGURE-2 : use of repeater station to increase the range of communication

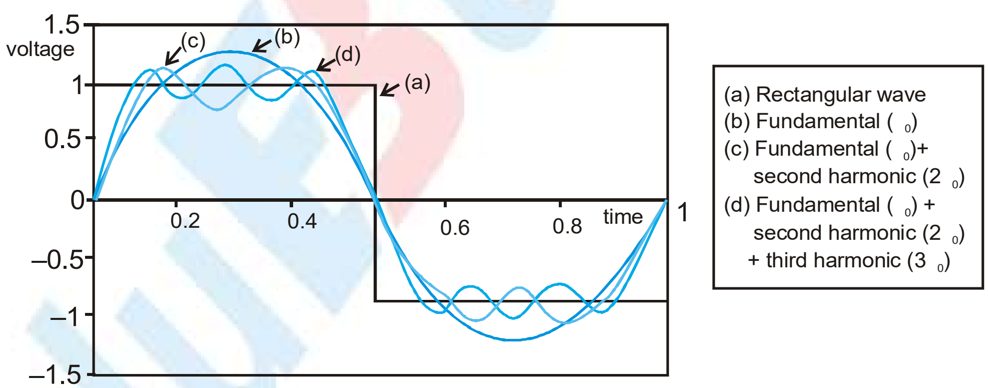
Bandwidth of signals

In a communication system, the message signal can be voice, music picture or computer data. Each of these signals has different ranges of frequencies. The type of communication system needed for a given signal depends on the band of frequencies which is considered essential for the communication process.

For speech signals, frequency range 300 Hz to 3100 Hz is considered adequated. Therefore speech signal requires a bandwidth of 2800Hz (3100 Hz – 300Hz) for commerical telephonic communication. To transmit music, an approximate bandwidth of 20 kHz is required because of the high frequencies produced by the muscial instruments. The audible range of frequencies extends from 20 Hz to 20 kHz.

Video signals for transmission of pictures requires about 4.2 MHz of bandwidth. A TV signal contains both voice and picture and is usually allocated 6 MHz of bandwidth for transmission.

In the preceeding paragraph, we have considerd only analog signals. Digital signals are in the form of rectangular waves as shown in figure-3 below. One can show that this rectangular wave can be decomposed into a superposition of sinusoidal waves of frequencies ν_0 , $2\nu_0$, $3\nu_0$, $4\nu_0$ .... $n\nu_0$ where 'n' is an integer extending to infinity and $\nu_0 = 1/T_0$. The fundamental (ν_0), fundamental (ν_0) + second harmonic ($2\nu_0$), and fundamental (ν_0) + second harmonic ($2\nu_0$) + third harmonic ($3\nu_0$), are shown in the same figure to illustrate this fact.



FIGURE–3

It is clear that to reproduce the rectangular wave shape exactly we need to superimpose all the harmonics ν_0, $2\nu_0$, $3\nu_0$, $4\nu_0$ ......which implies an infinite band width. However, for practical purposes, the contribution from higher harmonics can be neglected, thus limiting the bandwidht. As a result received waves are a distorted version of the transmitted one. If the bandwidth is large enough to accommodate a few harmonics, the information is not lost and the rectangular signal is more or less recovered. This is so because the higher the harmonic, less is its contribution to the wave form.

BANDWIDTH OF TRANSMISSION MEDIUM

Similar to message signals, different type of transmission media offer different bandwidths. The commonly used transmission media are wire, free space and fiber optic cable.Coaxial cable is a widely used wire medium, which offers a bandwidth of approximately 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 subdivided and allocated for various services. Optical communication using fibers is performed in the frequency range of 1 THz to 1000 THz (microwaves to ultraviolet). An optical fiber can offer a transmission bandwidth in excess of 100 GHz.

PROPAGATION OF ELECTROMAGNETIC WAVES

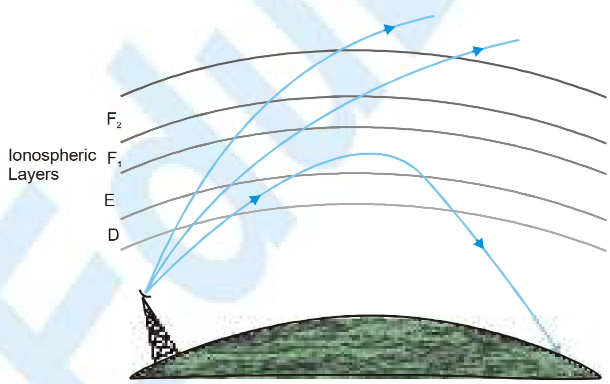
In communication using radio waves, an anetnna at the transmitter radiates the electromagnetic wave (em waves), which travel through the space and reach the receiving antenna at the other end. As the em wave travels away from the transmitter, the strength of the wave keeps on decreasing. Several factors influenece the propagation of em waves and the path they follow. At this point, it is also important to understand the composition of the earth's atmosphere as it plays a vital role in the propagation of em waves.

Ground wave

To radiate signals with high efficiency, the antennas should have a size comparable to the wavelength λ of the signal (at least $\sim\lambda/4$). At longer wavelengths (i.e., at lower frequencies), the antennas have large physical size and they are located on or very near to the ground. In standard AM broadcast, ground based vertical towers are generally used as transmitting antennas. For such antennas, ground has a strong influence on the propagation of the signal. The mode of propagation is called surface wave propagation and the wave glides over the surface of the earth. A wave induces current in the ground over which it passes and it is attenuated as a result of absorption of energy by the earth. The attenuation of surface waves increases very rapidly with increase in frequency. The maximum range of coverage depends on the transmitted power and frequency (less than a few MHz).

Sky waves

In the frequency range from a few MHz up to 30 to 40 MHz, long distance communication can be achieved by ionospheric reflection of radio waves back towards the earth. This mode of propagation is called sky wave propagation and is used by short wave broadcast services. The ionosphere is so called because of the presence of a large number of ions or charged particles. It extends from a height of ~65 Km to about 400 Km above the earth's surface. Ionisation occurs due to the absorption of the ultraviolet and other high-energy radiation coming from the sun by air molecules. The ionosphere is further subdivided into several layers. The degree of ionisation varies with the heights. The density of atmosphre decreases with heigth. At great heights the solar radiation is intense but there are few molecules to be ionised. Close to the earth, even though the molecular concentration is very high, the radiation intensity is low so that the ionisation is again low. However at some intermediate height, there occurs a peak of ionisation density. The ionosphere layer acts as a reflector for a certain range of freqeuncies (3 to 30 MHz). Electromagnetic waves of frequencies higher than 30 MHz penetrate the ionosphere and escape. These phenomena are shown in the figure-4 below. The phenomenon of bending of em waves so that they are diverted towards the earth is similar to total internal reflection in optics.



D – Part of stratosphere (65 to 75 km height)

E – Part of stratosphere (100 km height)

F_1 – Part of mesosphere (170 to 190 km height)

F_2 – Part of thermosphere (250 to 400 km height)

FIGURE–4: Sky wave propagation

SPACE WAVE

Another mode of radio wave propagation is by space waves. A space wave travels in a straight line from transmitting antenna to the receiving antenna. Space waves are used for line-of-sight (LOS) communication as well as satellite communication. At frequencies above 40 MHz, communication is essentially limited to line-of-sight paths. At these frequencies, the antennas are relatively smaller and can be placed at heights of many wavelengths above the ground. Because of line-of-sight nature of propagation, direct waves get blocked at some point by the curvature of the earth as illustrated in figure-5 below. If the signal is to be received beyond the horizon then the receiving antenna must be high enough to line-of-sight waves.

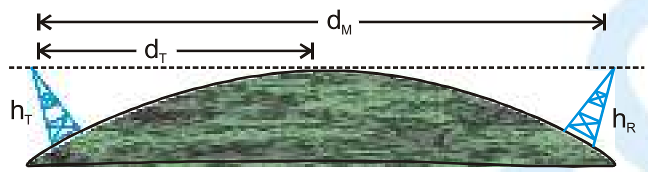


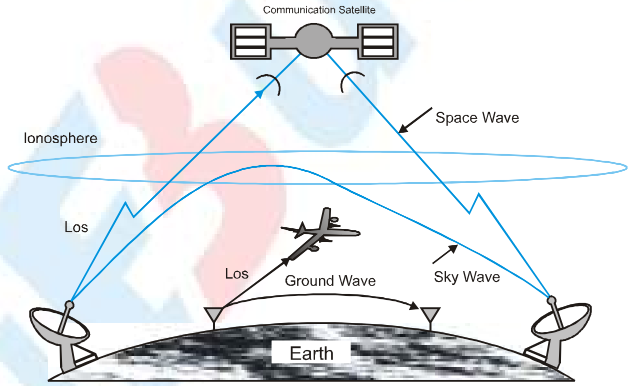
FIGURE-5: Line of sight communication by space waves.

If the transmitting antenna is at a heigth h_T , then you can show that the distance to the horizon d_T is given as $d_T = \sqrt{2Rh_T}$, where R is the radius of the earth (approximately 6400 km). d_T is also called the radio horizon of the transmitting antenna. With reference to figure above the maximum line-of–sight distance d_M between the two antennas having height h_T and h_R above the earth is given by

$$d_M = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

where h_R is the height of receiving antenna.

Television broadcast, microwave links and satellite communication are some examples of communication systems that use space wave mode of propagation. Figure–6 below summarises the various modes of wave propagation discussed so far.



FIGURE–6: Various propagation modes for em waves

Ex. In which frequency range, space waves are normally propagated

(1) HF **(2)** VHF **(3)** UHF **(4)** SHF

Ans. 3

Ex. An antenna behaves as resonant circuit only when its length is

(1) $\frac{\lambda}{2}$ **(2)** $\frac{\lambda}{4}$ **(3)** λ **(4)** $\frac{\lambda}{2}$

or integral multiple of $\frac{\lambda}{2}$

Ans. 4

Ex. The process of superimposing signal frequency (i.e. audio wave) on the carrier wave is known as

(1) Transmission **(2)** Reception **(3)** Modulation **(4)** Detection

Sol. **(3)** Carrier + signal $\rightarrow$ modulation.

Ex. Long distance short-wave radio broadcasting uses

(1) Ground wave **(2)** Ionospheric wave **(3)** Direct wave **(4)** Sky wave

Ans. 3

Ex. The maximum distance up to which TV transmission from a TV tower of height h can be received is proportional to

(1) $h^{1/2}$ **(2)** h **(3)** $h^{3/2}$ **(4)** h^2

Sol. (1) $d = \sqrt{2hR} \Rightarrow d \propto h^{1/2}$

Ex. A transmitting antenna at the top of a tower has a height 32 m and the height of the receiving antenna is 50 m. What is the maximum distance between them for satisfactory communication in LOS mode? Given radius of earth 6.4×10^6 m.

Sol. $d_m = \sqrt{2\times 64\times 10^5 \times 32} + \sqrt{2\times 64\times 10^5 \times 50}$ m

$= 64 \times 10^2 \times \sqrt{10} + 8 \times 10^3 \times \sqrt{10}$ m $= 144 \times 10^2 \times \sqrt{10}$ m $= 45.5$ km

Ex. In a communication system, noise is most likely to affect the signal

(1) At the transmitter **(2)** In the channel or in the transmission line

(3) In the information source **(4)** At the receiver

Ans. (2)

Ex. The waves used in telecommunication are

(1) IR **(2)** UV **(3)** Microwave **(4)** Cosmic rays

Sol. (3) In telecommunication microwaves are used.

Ex. Television signals on earth cannot be received at distances greater than 100 km from the transmission station. The reason behind this is that

(1) The receiver antenna is unable to detect the signal at a distance greater then 100 km

(2) The TV programme consists of both audio and video signals

(3) The TV signals are less powerful than radio signals

(4) The surface of earth is curved like a sphere

Ans. (4)

Modulation and its necessity

As already mentioned, the purpose of a communication system is to transmit information or message signals. Message signals are also called baseband signals, which essentially designate the band of frequencies representing the original signal, as delivered by the source of information. No signal, in general, is a single frequency sinusoid, but it spreads over a range of frequencies called the signal bandwidth. Suppose we wish to transmit an electronic signal in the audio frequency (AF) range (baseband signal frequency less than 20 kHz) over a long distance directly. Let us find what factors prevent us from doing so and how we overcome these factors.

Size of the Antenna or Aerial

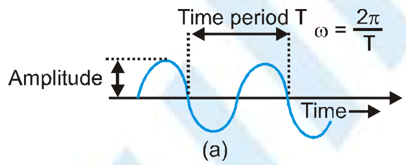
For transmitting a signal, we need an antenna or an aerial. This antenna should have a size comparable to the wavelength of the signal (at least $\lambda/4$ in dimension) so that the antenna properly senses the time variation of the signal. For an electromagnetic wave of frequency 20 kHz. the wavelength λ is 15 km. Obviously, such a long antenna is not possible to construct and operate. Hence direct transmission of such baseband signals is not practical. We can obtain transmission with reasonable antenna lengths if transmission frequency is high (for example, if υ is 1MHz, then λ is 300 m). Therefore, there is a need of translating the information contained in our original low frequency baseband signal into high or radio frequencies before transmission.

Effective Power Radiated by an Antenna

A theoretical study of radiation from a linear antenna (length ●) shows that the power radiated is proportional to (● $/\lambda)^2$. This implies that for the same antenna length, the power radiated increases with decreasing λ, i.e., increasing frequency. Hence, the effective power radiated by a long wavelength baseband signal would be small. For a good transmission, we need high powers and hence this also points out to the need of using high frequency transmission.

Mixing up of Signals from Different Transmitters

Another important argument against transmitting basband signals directly is more practical in nature. Suppose many people are talking at the same time or many transmitters are transmitting baseband information signals simultaneously. As these signals will get mixed up and there is no simple way to distinguish between them. This points out towards a possible solution by using communication at high frequencies and allotting a band of frequencies to each message signal for its transmission.



The above arguments suggest that there is a need for translating the original low frequency baseband message or information signal into high frequency wave before transmission such that the translated signal continues to possess the information contained in the original signal. In doing so, we take the help of a high frequency signal, known as the carrier wave, and a process known as modulation which attaches information to it. The carrier wave may be continuous (sinusoidal) or in the form of pulses as shown in figure-7 below.

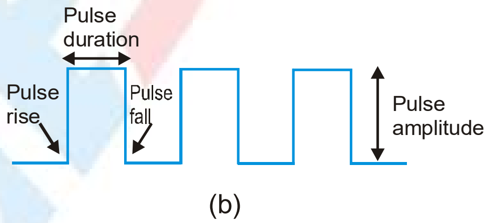


FIGURE-7: (a) Sinusoidal, and (b) Pulse Shaped Signals

A sinusoidal carrier wave can be represented as $c(t) = A_C \sin(\omega_c t + \phi)$

where c(t) is the signal strength (voltage or current), A_C is the amplitude, ω_c $(= 2\pi\upsilon_c)$ is the angular frequency and ϕ is the initial phase of the carrier wave. During the process of modulation, any of the three parameters, i.e. A_c, ω_C and ϕ, of the carrier wave can be controlled by the message or information signal. This results in three types of modulation. **(i)** Amplitude modulation (AM), **(ii)** frequency modulation (FM) and **(iii)** pulse modulation (PM) as shown below.

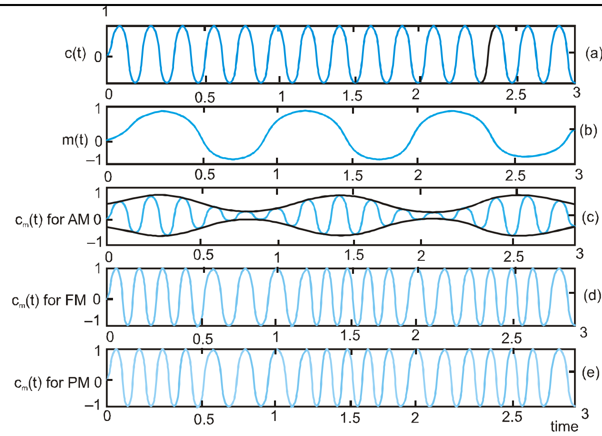
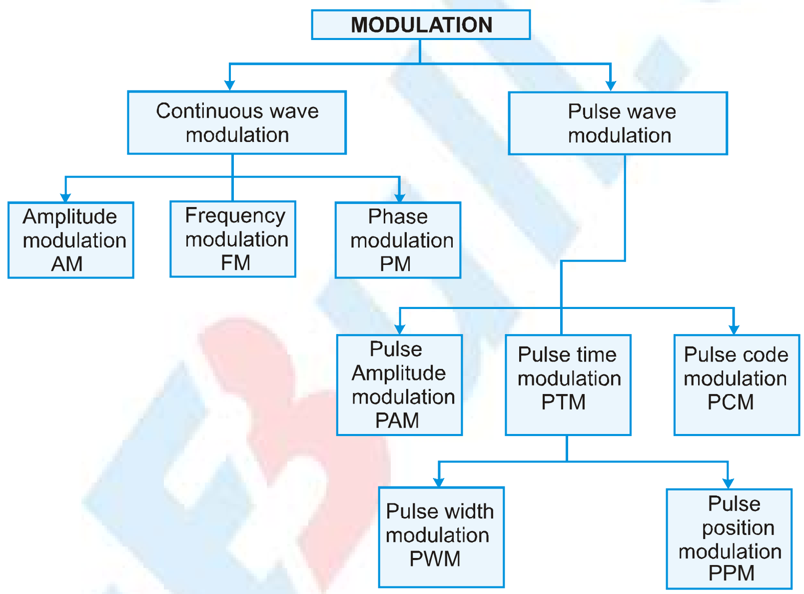


FIGURE-8

Similarly, the significant characteristics of a pulse are : pulse amplitude, pulse duration or pulse Width, and pulse position (denoting the time of rise or fall of the pulse amplitude) as shown in Fig. 15.7(b). Hence, different types of pulse modulation are : (a) pulse amplitude modulation (PAM), (b) pulse duration modulation (PDM) or pulse width modulation (PWM), and (c) pulse position modulation (PPM). In this chapter, we shall confine to amplitude modulation only.



Amplitude Modulation

In amplitude modulation the amplitude of the carrier is varied in accordance with the information signal. Here we explain amplitude modulation process using a sinusoidal signal as the modulating signal.

Let $c(t) = A_C \sin \omega_c t$ represent carrier wave and $m(t) = A_m \sin \omega_m t$ represent the message or the modulating signal where $\omega_m = 2\pi f_m$ is the angular frequency of the message signal. The modulated signal $c_m(t)$ can be written as

$$c_m(t) = (A_C + A_m \sin \omega_m t) \sin \omega_c t$$

$$= A_C \left(1 + \frac{A_m}{A_c} \sin \omega_m t\right) \sin \omega_c t \qquad \text{..........(i)}$$

Note that the modulated signal now contains the message signal. This can also be seen from figure–8(c). From Eq. (i), we can write,

$$c_m(t) = A_c \sin \omega_c t + \mu A_c \sin \omega_m t \sin \omega_c t \qquad \text{..........(ii)}$$

Here $\mu = A_m/A_c$ is the modulation index; in practice, μ is kept ≤ 1 to avoid distortion.

Using the trignomatric relation sin A sin B = 1/2 (cos (A – B) – cos (A + B),

we can write c_m (t) of Eq. (ii) as

$$c_m(t) = A_c \sin \omega_c t + \frac{\mu A_c}{2} \cos(\omega_C - \omega_m) t - \frac{\mu A_c}{2} \cos(\omega_C + \omega_m) t \quad \text{..........(iii)}$$

Here $\omega_C - \omega_m$ and $\omega_C + \omega_m$ are respectively called the lower side and upper side frequencies. The modulated signal now consists of the carrier wave of frequency ω_c plus two sinusoidal waves each with a frequency slightly different from, known as side bands. The frequency spectrum of the amplitude modulated signal is shown in figure–9.

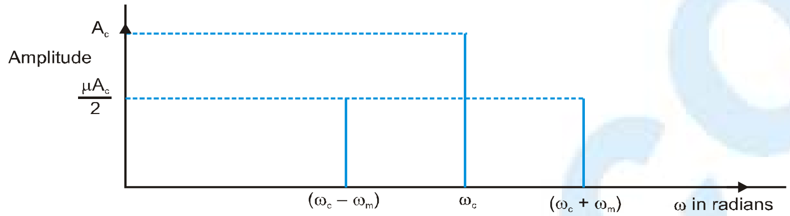


FIGURE-9: A plot of amplitude versus for an amplitude modulated signal

As long as the broadcast frequencies (carrier waves) are sufficiently spaced out so that side bands do not overlap, different stations can operate without interferring with each other.

Modulation index : The ratio of change of amplitude of carrier wave to the amplitude of original carrier wave is called the modulation factor or degree of modulation or modulation index (m_a).

$$m_a = \frac{\text{Change in amplitude of carrier wave}}{\text{Amplitude of original carrier wave}} = \frac{kE_m}{E_c}$$

where k = A factor which determines the maximum change in the amplitude for a given amplitude E_m of the modulating. If k = 1 then $m_a = \frac{E_m}{E_c} = \frac{E_{max} - E_{min}}{E_{max} - E_{min}}$

If a carrier wave is modulated by several sine waves the total modulated index m_t is given by

$$m_t = \sqrt{m_1^2 + m_2^2 + m_3^2 + ...}$$

Side Band Frequencies and Band Width in AM Wave

(i) Side band frequencies : The AM wave contains three frequency f_c, $(f_c + f_m)$ and $(f_c - f_m)$, f_c is called carrier frequency,

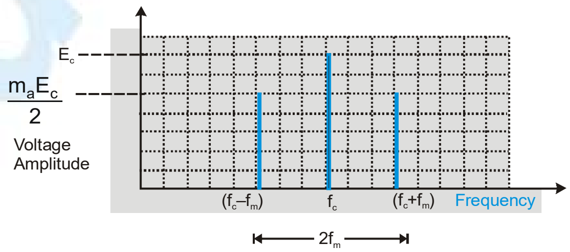
$(f_c + f_m)$: Upper side band (USB) frequency

$(f_c - f_m)$: Lower side band (LBS) frequency

Side band frequency are generally close to the carrier frequency.

(ii) Band width : The two side bands lie on either side of the carrier frequency at equal frequency interval f_m.

So, band width = $(f_c + f_m) - (f_c - f_m) = 2f_m$



Power in AM waves : Power dissipated in any circuit $P = \dfrac{V_{rms}^2}{R}$.

Hence **(i)** carrier power $P_c = \dfrac{\left(\dfrac{E_c}{\sqrt{2}}\right)^2}{R} = \dfrac{E_c^2}{2R}$

(ii) Total power of side bands $P_{sb} = \dfrac{\left(\dfrac{m_a E_c}{2\sqrt{2}}\right)^2}{R} = \dfrac{\left(\dfrac{m_a E_c}{2\sqrt{2}}\right)}{2R} \dfrac{m_a^2 E_c^2}{4R}$

(iii) Total power of AM wave $P_{Total} = P_c + P_{ab} = \dfrac{E_c^2}{2R}\left(1+\dfrac{m_a^2}{2}\right)$

(iv) $\dfrac{P_t}{P_c} = \left(1+\dfrac{m_a^2}{2}\right)$ and $\dfrac{P_{sb}}{P_t} = \dfrac{m_a^2/2}{\left(1+\dfrac{m_a^2}{2}\right)}$

(v) Maximum power in the AM (without distortion) will occur when $m_a = 1$ i.e., $P_t = 1.5\, P = 3P_{ab}$

(vi) If I_c = Unmodulated current and I_t = total or modulated current

$$\Rightarrow \quad \frac{P_t}{P_c} = \frac{I_t^2}{I_c^2} \qquad \Rightarrow \quad \frac{I_t}{I_c} = \sqrt{\left(1+\frac{m_a^2}{2}\right)}$$

Limitation of amplitude modulation

(i) Noisy reception

(ii) Low efficiency

(iii) Small operating range

(iv) Poor audio quality

PRODUCTION OF AMPLITUDE MODULATED WAVE :

Amplitude modulation can be produced by a variety of methods. A conceptually simple method is shown in the block diagram of figure–10.

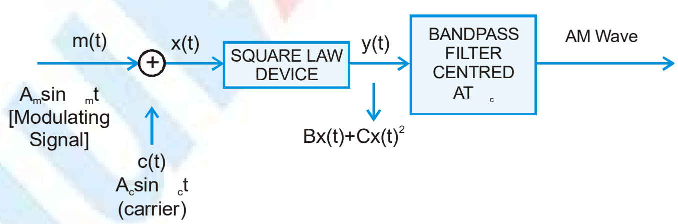


FIGURE-10: Block diagram of a simple modulator for obtaining an AM signal

Here the modulating signal $A_m \sin \omega_m t$ is added to the carrier signal $A_C \sin \omega_c t$ to produce the signal x(t). This signal $x(t) = A_m \sin \omega_m t + A_C \sin \omega_c t$ is passed through a square law device which is a non–linear device which produces an output

$$y(t) = B\,x(t) + Cx^2(t)$$

where B and C are constants. Thus,

$$y(t) = BA_m \sin \omega_m t + BA_c \sin \omega_c t$$

$$+ C[A_m^2 \sin^2 \omega_m t + A_c^2 \sin^2 \omega_c t + 2A_m A_c \sin\omega_m t \sin \omega_c t]$$

$$= BA_m \sin \omega_m t + BA_c \sin \omega_c t$$

$$+ \frac{CA_m^2}{2} + A_c^2 - \frac{CA_m^2}{2} \cos 2\omega_m t - \frac{CA_c^2}{2} \cos 2\omega_c t$$

$$+ CA_m A_c \cos(\omega_c - \omega_m)t - CA_m A_c \cos(\omega_c + \omega_m)\, t \qquad \text{..........(v)}$$

where the trigonometric relations $\sin^2 A = (1 - \cos 2A)/2$ and the relation for sin A sin B mentioned earlier are used.

In equation **(v)**, there is a dc term $C/2\ (A_m^2 + A_c^2)$ and sinusoids of frequencies $\omega_m, 2\omega_m, \omega_c, 2\omega_c, \omega_c - \omega_m$ and $\omega_c + \omega_m$. As shown in figure–10 this signal is passed through a band pass filter which rejects dc and the sinusoids of frequencies ω_m, $2\omega_m$ and $2\omega_c$ and retains the frequencies ω_c, $\omega_c - \omega_m$ and $\omega_c + \omega_m$. The output of the band pass filter therefore is of the same form as equation **(iii)** and is therefore an AM wave.

It is to be mentioned that the modulated signal cannot be transmitted as such. The modulator is to be followed by a power amplifier which provides the necessary power and then the modulated signal is fed to an antenna of appropriate size for radiation as shown in figure.

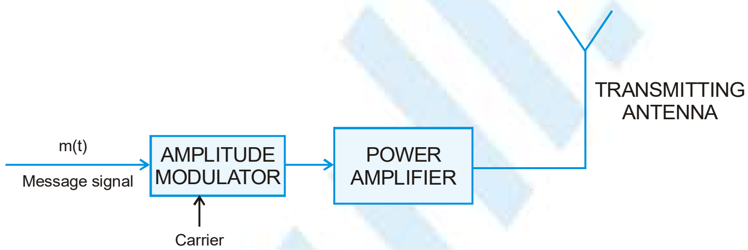


FIGURE-11: Block diagram of a transmitter

DETECTION OF AMPLITUDE MODULATED WAVE

The transmitted message gets attenuated in propagating through the channel. The receiving antenna is therefore to be followed by an amplifier and a detector. In addition, to facilitate further processing, the carrier frequency is usually changed to a lower frequency by what is called an intermediate frequency (IF) stage preceding the detection. The detected signal may not be strong enough to be made use of and hence is required to be amplified. A block diagram of a typical receiver is shown in figure-12.

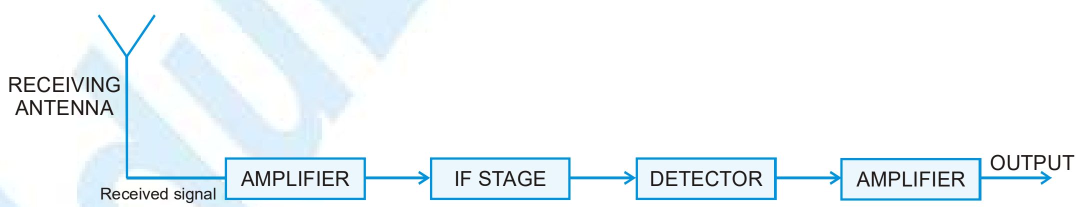


FIGURE-12: Block diagram of a receiver

Detection is the process of recovering the modulating signal from the modulated carrier wave. We just saw that the modulated carrier wave contains the frequencies ω_c and $\omega_c \pm \omega_m$. In order to obtain the original message signal m(t) of angular frequency ω_m a simple method is shown in the form of a block diagram in figure-13.

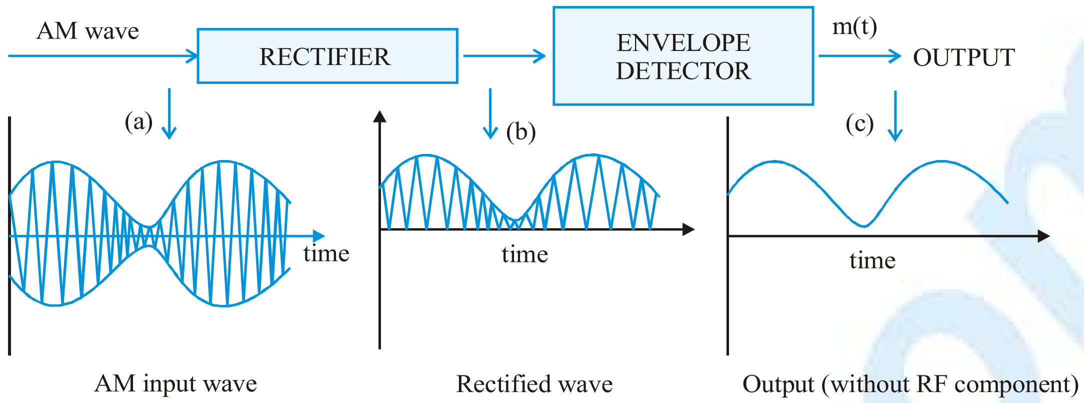


FIGURE-13: Block diagram of a detector for AM signal. The quantity on y–axis can be current or voltage

The modulated signal of the form given in (a) of figure-13 is passed through a rectifier to produce the output shown in (b). This envelope of signal (b) is the message signal. In order to retrieve m(t), the signal is passed through an envelope detector (which may consist of a simple RC circuit).

Ex. AM is used for broadcasting because

(1) It is more noise immune than other modulation systems

(2) It requires less transmitting power compared with other systems

(3) Its use avoids receiver comlexity

(4) No other modulation system can provide the necessary bandwidth faithful transmission

Ans. (3)

Ex. Range of frequencies allotted for commercial FM radio broadcast is

(1) 88 to 108 MHz **(2)** 88 to 108 kHz **(3)** 8 to 88 MHz s **(4)** 88 to 108 GHz

Ans. (1)

Ex. The velocity factor of a transmission line x. If dielectric constant of the medium is 2.6, the value of x is

(1) 0.26 **(2)** 0.62 **(3)** 2.6 **(4)** 6.2

Sol. velocity factor = $\frac{1}{\sqrt{k}} = \frac{1}{\sqrt{2.6}} = 0.62$

Ex. If μ_1 and μ_2 are the refractive indices of the materials of core and cladding of an optical fibre, then the of light due to its leakage can be minimised by having

(1) $\mu_1 > \mu_2$ **(2)** $\mu_1 < \mu_2$ **(3)** $\mu_1 = \mu_2$ **(4)** None of these

Ans. (1)

Ex. The radio waves of frequency 300 MHz to 3000 MHz belong to

(1) High frequency band

(2) Very high frequency band

(3) Ultra high frequency band

(4) Super high frequency band

Ans. (3)

Ex. The maximum peak to peak voltage of an AM wire is 24 mV and the minimum peak to peak voltage is 8 mV. The modulation factor is

(1) 10% **(2)** 20% **(3)** 25% **(4)** 50%

Sol. **(4)** Here, $V_{max} = \frac{24}{2} = 12\text{ mV}$ and $V_{min} = \frac{8}{2} = 4\text{ mV}$

Now, $m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} = \frac{12-4}{12+4} = \frac{8}{16} = \frac{1}{2} = 0.5 = 50\%$

Ex. If a number of sine waves with modulation indices n_1, n_2, n_3 ....modulate a carrier wave, then total modulation index (n) of the wave is

(1) $n_1 + n_2 ....+ 2(n_1 + n_2 ....)$
(2) $\sqrt{n_1 - n_2 + n_3..........}$
(3) $\sqrt{n_1^2 + n_2^2 + n_3^2..........}$
(4) None of these

Ans. **(3)**

Ex. An AM wave has 1800 watt of total power content, for 100% modulation the carrier should have power content equal to

(1) 1000 watt
(2) 1200 watt
(3) 1500 watt
(4) 1600 watt

Sol. **(2)** $P_t = P_c\left(1 + \frac{m_a^2}{2}\right)$; Here $m_a = 1 \Rightarrow 1800 = P_c\left(1 + \frac{(1)^2}{2}\right) \Rightarrow P_c = 1200\text{ W}$

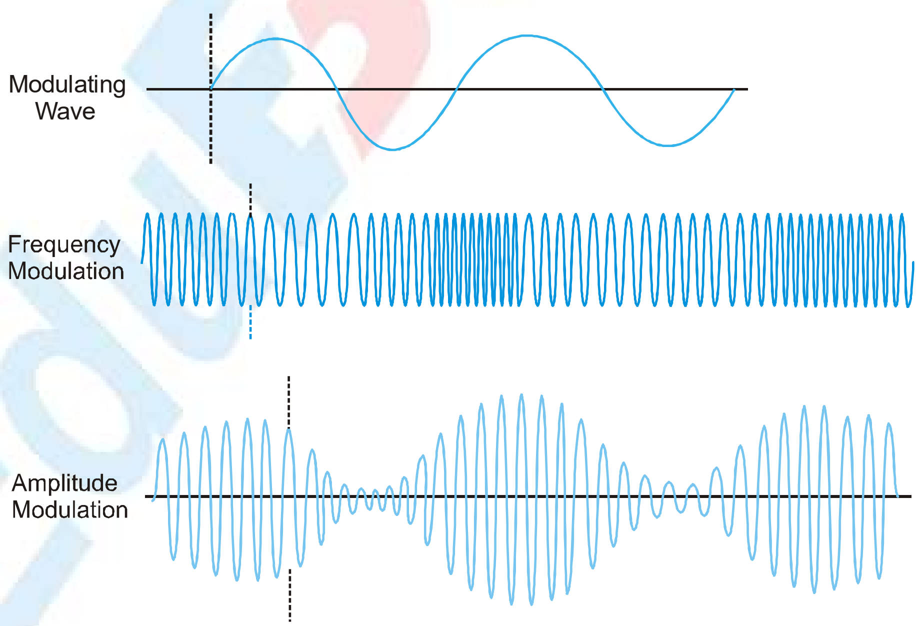
FREQUENCY MODULATION

It is the second type of continuous wave or sinusoidal wave modulation.

In this mode of modulation, the frequency of the carrier signal varies in accordance with the modulating signal. The amplitude of the carrier wave is fixed while its frequency is changing.

In frequency modulation, the frequency of the carrier wave is modified in accordance with the amplitude of the modulating wave.

The amplitidue of the carrier remains unchanged at all times. In other words, the amplitude of the modulated wave remains the same as the amplitude of the carrier wave. The frequency of the carrier is made to fluctuate symmetrically above and below its unmodulated frequency. As an example, a carrier frequency, of 1000 kHz may be caused to swing between 925 kHz and 1075 kHz



or any other amount chosen in accordance with the signal voltage. In frequency modulation, the deviation of the carrier frequency from its average value is proportional to the instantaneous amplitude of the modulating signal. When the signal voltage is zero, the carrier frequency is unchanged. When the signal approaches its positive peaks, the carrier frequency is increased to maximum as indicated by the closely spaced cycles. However, during the negative peaks of signal, the carrier frequency is reduced to minimum as shown by widely spaced cycles.

Necessity of Frequency Modulation

1. Various electrical machines and noises cause amplitude disturbance in the transmission of amplitude-modulated wave. This makes the reception noisy. So, there is a need for different type of modulation which

   can reduce the noise factor. Frequency modulation (FM) was proposed as a means of improving the signal-to-noise ratio of a radio system. The first practical system was put forward in 1936 as an alternative to AM in an effort to make radio transmissions more resistant to noise.

2. Fidelity or audio quality of amplitude modulated transmission is poor. This type of transmission is also not good for musical programmes. There is a need to eliminate amplitude-sensitive noise. This is possible if we eliminate amplitude variation. In other words, there is a need to keep the amplitude of the carrier constant. This is precisely what we do in frequency modulation.

FM is Preferred for Transmission of Music

Frequency modulation (FM) gives better quality transmission and has a larger bandwidth. In FM signals, the intelligence (information or message signal) is in the form of frequency variations and, therefore, the atmospheric or man-made noises (which are generally amplitude changes) do little harm. It is preferred for transmission of music. The range of frequencies allotted for commercial FM radio and TV -broadcast are given in table below.

Range of Frequencies allotted for FM Radio and TV Broadcast

Nature of broadcast	Frequency band
FM radio	88 to 108 MHz
VHF TV	47 to 230 MHz
UHF TV	470 to 960 MHz

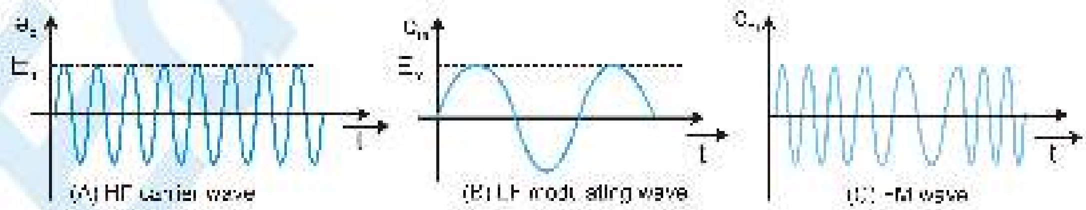
Frequency Modulation (FM)

The process of changing the frequency of a carrier wave in accordance with the audio frequency signal is known as frequency modulation.

(1) Audio quality of AM transmission is poor. There are need to eliminate amplitude sensitive noise. This is possible if we eliminate amplitude variation (i.e., a need to keep the amplitude of the carrier constant). This is precisely what we do in FM.

(2) In FM the overall amplitude of FM wave remains constant at all times.

(3) In FM the total transmitted power remains constant.



(4) **Frequency Deviation :** The maximum change in frequency from mean value (v_c) is known as frequency deviation. This is also the change or shift either above or below the frequency v_c and is called as frequency deviation.

$$\therefore \quad \delta = (f_{max} - f_c) = f_c - f_{min} = k_f \cdot \frac{E_m}{2\pi}$$

k_f = Constant of proportionality. It determines the maximum variation in frequency of the modulated wave for a given modulating signal.

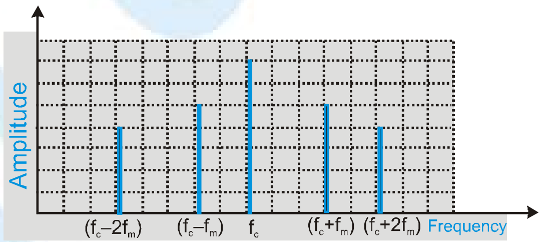
(5) **Carrier Swing (CS) :** The total variation in frequency from the lowest to the highest is called the carrier swing

i.e., CS = 2 × Δf

(6) **Frequency Modulation Index (mf) :** The ratio of maximum frequency deviation to the modulating frequency is called modulation index. $m_f = \frac{\delta}{f_m} = \frac{f_{max} - f_c}{f_m} = \frac{f_c - f_{min}}{f_m} = \frac{k_f E_m}{f_m}$

(7) **Frequency Spectrum :** FM side band modulated signal consist of infinite number of side bands whose frequencies are $(f_c \pm f_m), (f_c \pm 2), (f_c \pm 3f_m)$.........

The number of side bands depends on the modulation index m_f.



In FM signal, the information (audio signal) is contained in the side bands. Since the side bands are separated from each other by the frequency of modulating signal f_m So

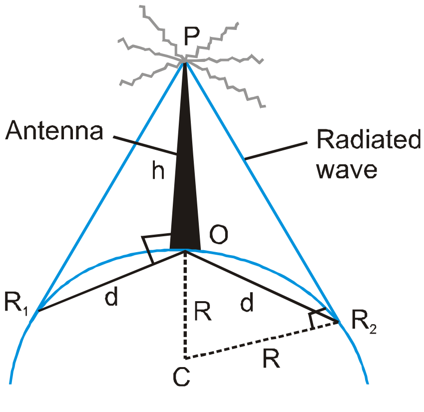
Band width = $2n \times f_m$; where n = number of significant side band pairs

(8) **Deviation Ratio :** The ratio of maximum permitted frequency deviation to the maximum permitted audio frequency is known as deviation ratio. Thus, deviation ratio = $\frac{(\Delta f)_{max}}{(f_m)_{max}}$

(9) **Percent Modulation :** The ratio of actual frequency deviation to the maximum allowed frequency deviation is defined as percent modulation. Thus, percent modulation, m = $\frac{(\Delta f)_{actual}}{(\Delta f)_{max}}$

FREQUENCY-MODULATED COMMUNICATION (Height of Transmitting Antenna)

The TV signals are frequency-modulated. Their transmission cannot be obtained by ground wave propagation. This is because the signals get absorbed by ground due to their high frequency. The transmission via sky wave propagation is also not desirable. This is becasuse the ionosphere is unable to reflect radio waves of frequencies greater than 40 MHz.



The only way for the transmission of TV signals is that the receiving antenna should directly intercept the signal from the transmitting antenna.

The transmitted waves, travelling in a straight line, directly reach the receiver end and are then picked up by the receiving antenna as shown in figure.

It can be seen that due to the finite curvature of the earth, such waves cannot be seen beyond the tangent points R_1 and R_2. The effective reception range of the broadcast is essentially the region from R_1 to R_2 which is covered by the line of sight in a conventional sense. Hence, sometimes this mode of communication is termed as **line of sight communication.**

Fig. Ray-path of transmitted waves following space-wave (or line of sight) mode of propagation. The transmitter is located at the ground on a tall tower.

For large TV coverage, the transmission of TV signal is done from a tall antenna.

Consider a TV antenna OP of height h. The transmitted signal cannot be received beyond points R_1 and R_2 . This is due to curvature of earth.

Clearly, OR_1 and OR_2 are the maximum distances, from the antenna, upto which the transmission signal can be received.

Let $OR_1 = OR_2 = d$ [d is half the total range]

The TV signal will be received in a circle of radius d.

The relation between height h of the TV antenna and the maximum distance d upto which the TV signal can be received can be derived on the basis of geometrical considerations.

From right-angled triangle CR_2P, $CP^2 = CR_2^2 + PR_2^2$

In right-angled triangle POR_2, $PR_2^2 = h^2 + d^2$

[Note that $\angle POR_2$ can be taken as right angle.]

Also, $CR_2 = CO = R$ and $CP = R + h$

From Equation **(1)**,

$$(R + h)^2 = R^2 + (h^2 + d^2)$$

or $R^2 + h^2 + 2Rh = R^2 + h^2 + d^2$ or $d = \sqrt{2Rh}$

It is clear from this equation that if h is large, d will be large. This explains as to why the television broadcasts are made from tall antennas.

If one wishes to send signals at far away stations, then either Repeater transmitting stations are necessary or h is increased (by locating the transmitter on a satellite). However, much before the advent of satellites, radio broadcast covered distances much longer than the line of sight propagation. This was found possible due to the presence of an ionised layer in the upper portion of earth's atmosphere called ionosphere. This mode of propagation known as ionospheric propagation or sky wave propagation.

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Ex. A TV tower has a height of 75m. What is the maximum distance and area up to which this TV transmission can be received? Take radius of the earth as 6.4×10^6 m.

Sol. $d = \sqrt{2Rh}$

$= \sqrt{2 \times 6.4 \times 10^6 \times 75} = 3.1 \times 10^4 \text{ m} = 31 \text{ km}$

Area covered $= \pi r^2 =$ **3018 km²**

Ex. A TV tower has a height of 100 m. How much population is covered by the TV broadcast if the average population density around the tower is 1000 km^{-2} ? Given : radius of earth = 6.37×10^6 m.

Sol. h = 100 m, R = 6.37×10^6 m, Average population density = 1000 km^{-2} = 1000 $(10^3)^{-2}$ m^{-2} = 10^{-3} m^{-2}

Distance up to which the transmission could be viewed, $d = \sqrt{2hR}$

Total area over which transmission could be viewed = $\pi d^2 = 2\pi hR$

Population covered = $10^{-3} \times 2\pi hR = 10^{-3} \times 2 \times 3.14 \times 100 \times 6.37 \times 10^6$ = 40 lakh

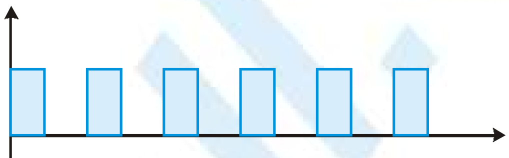
Pulse Modulation

Here the carrier wave is in the form of pulses.

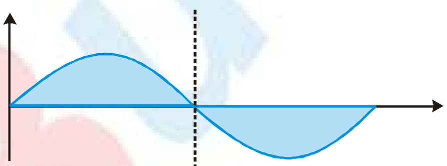
(1) **Pulse amplitude modulation (PAM) :** The amplitude of the pulse varies in accordance with the modulating signal.

(2) **Pulse width modulation (PPM) :** The pulse duration varies in accordance with the modulating signal.

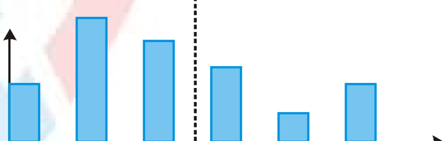
(3) **Pulse position modulation (PPM) :** In PPM, the position of the pulses of the carrier wave train is varied in accordance with instantaneous value of the modulating signal.



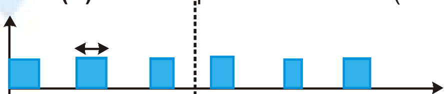
(A) Unmodulated pulse



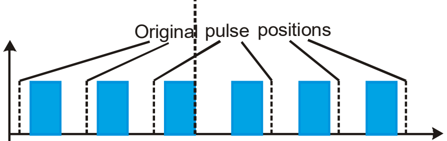
(B) Modulating signal



(C) Pulse amplitude modulation (PAM)



(D) Pulse with modulation (PWM)



(E) Pulse position modulation (PPM)

Pulse code Modulation

The pulse amplitude, pulse width and pulse position modulations not completely digital.

A completely digital modulation is obtained by pulse code modulation (PCM).

An analog signal is pulse code modulated by following three operation.

(1) **Sampling :** It is the process of generating pulses of zero width and of amplitude equal to the instantaneous amplitude of the analog signal.

The number of samples taken per second is called sampling rate.

(2) **Quantisation :** The process of dividing the maximum amplitude of the analog voltage signal into a fixed number of levels is called quantisation.

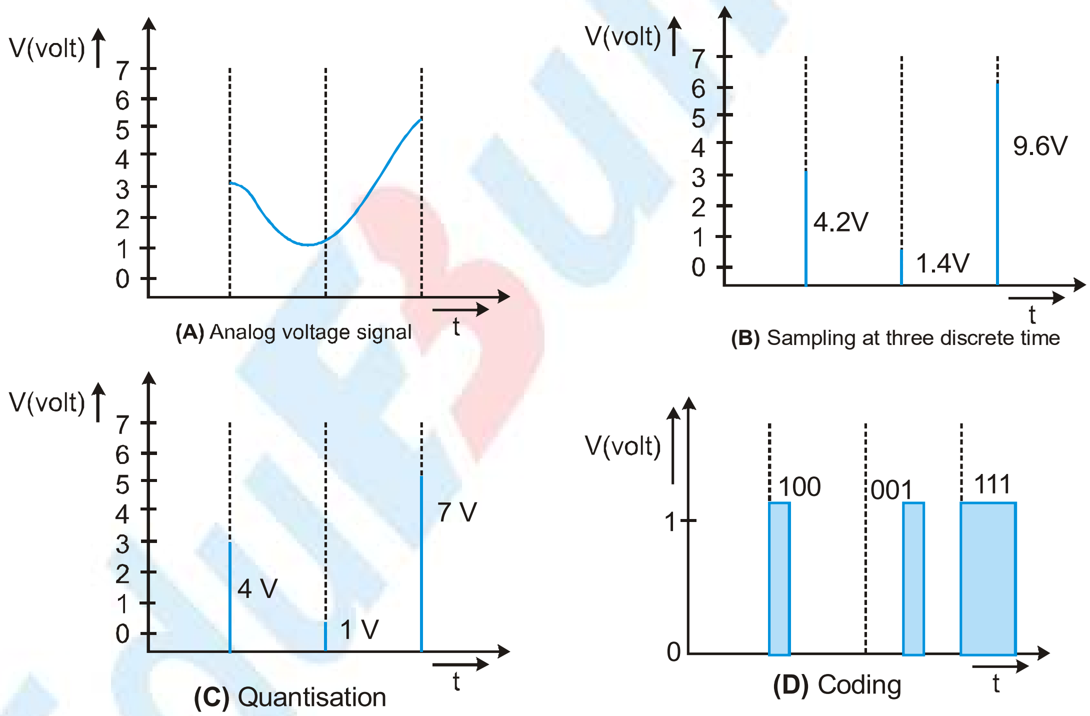
i.e. amplitude 5 V of the analog voltage signal divides into six. Quantisation level viz 0,1, 2, 3, 4, 5.

Pulses having amplitude between – 0.5 V to 0.5 V are approximated (quantised) to a value 0 V, amplitude between 0.5 V to 1.5 V are approximated to a value of 1 V and so on.

(3) **Coding :** The process of digitising the quantised pulses according to some code is called coding.

Quantized Level	0	1	2	3	4	5	6	7
Binary Code	000	001	010	011	100	101	110	111

For example consider that voltage amplitude of analog signal varies between 0 and 7 V.



(A) Analog voltage signal

(B) Sampling at three discrete time

(C) Quantisation

(D) Coding

Demodulation

The process of extracting the audio signal from the modulated wave is known as demodulation or detection.

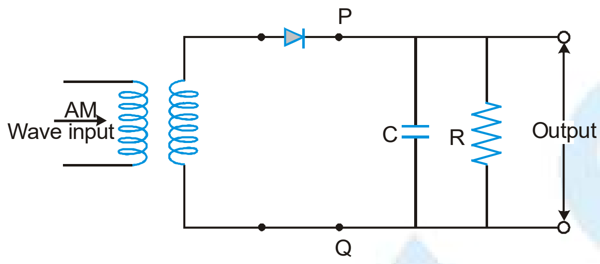
The wireless signals consist of radio frequency (high frequency) carrier wave modulated by frequency (low frequency). The diaphragm of a telephone receiver of a loud speaker cannot vibrate with high frequency. So it is necessary to separate the audio frequenies from the radio frequency carrier wave.

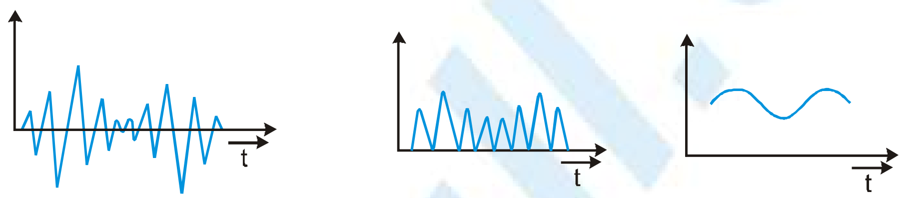
Simple Demodulator Circuit

A diode can be used to detect or demodulate an amplitude modulated (AM) wave. A diode basically acts as a rectifier i.e., it reduces the modulated carrier wave into positive envelope only.

The AM wave input is shown in figure. It appears at the output of the diode across PQ as a rectified wave (since a diode conducts only in the positive half cycle). This rectified wave after passing through the RC network does not contain the radio frequency carrier componet. Instead, it has only the envelope of the modulated wave.

In the actual circuit the value of RC is chosen such that $\frac{1}{f_c} << RC$; where f_c = frequency of carrier signal.





(A) (B) (C)

Data Transmission and Retrieval :

The term data is applied to a representation of facts, concepts or instructions suitable for communication interpretation or processing by human beings or by automatic means. Data in most cases consists of pulse type of signals.

The pulse code modulated (PCM) signal is a series of 1's and 0's. The following three modulation techinques are used to transmit a PCM signal.

(1) **Amplitude shift keying (ASK) :** Two different amplitudes of the carrier represent the two binary values of the PCM signal. This method is also known as on-off keying (OOK)

(1) : Presence of carrier of same constant amplitude.

(0) : Carrier of zero amplitude.

(2) **Frequency shift keying (FSK) :** The binary values of the PCM signal are represented by two frequencies.

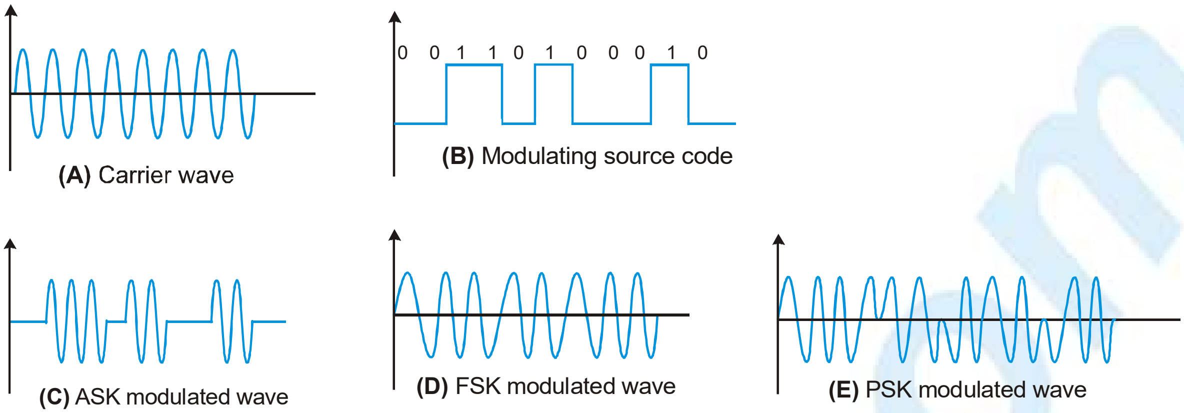
(1) : Increase in frequency

(0) : Frequency unaffected

(3) **Phase shift keying (PSK) :** The phase of the carrier wave is changed in accordance with modulating data signal.

(1) : Phase changed by π

(0) : Phase remains unchanged.



Ex. Consider telecommunication through optical fibres. Which of the following statements is not true

(1) Optical fibres may have homogeneous core with a suitable cladding

(2) Optical fibres can be of graded refractive index

(3) Optical fibres are subject to electromagnetic interference from outside

(4) Optical fibres have extremely low transmission loss

Ans. (3)

Ex. The phenomenon by which light travels in an optical fibres is

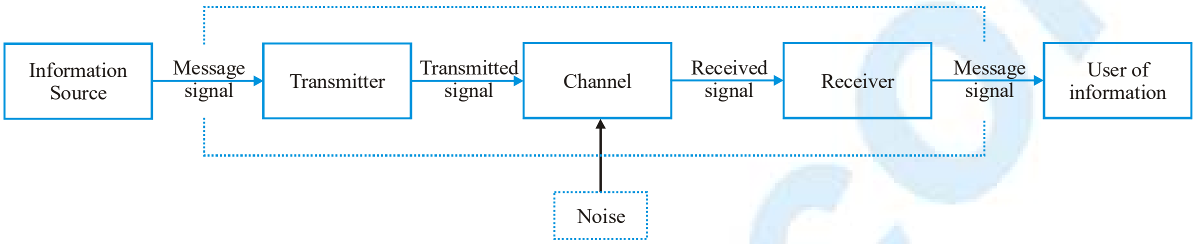
(1) Reflection **(2)** Refraction

(3) Total internal reflection **(4)** Transmission

Ans. (3)

Faithful transmission of information from one place to another place is called communication.

1. Basic components of a communication system



Transmitter : Transmitter c.onverts the message signal produced by information source into a form (e.g. electrical signal) that is suitable for transmission through the channel to the recevier.

Communication channel : Communication channel is a medium (transmission line, an optical fibre or free space etc.) which connects a receiver and a transmitter. It carries the modulated wave from the transmitter to the receiver.

Receiver : It receives and decode the signal into original form.

2. Important terms used in communication

(i) Transducer : Transducer is the device that electrical form. Signals can be analog or digital. Sound and picture signals in TV are analog.

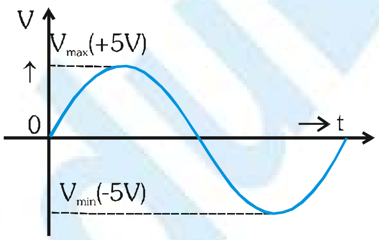
It is defined as a single-valued function of time which has a unique value at every instant of time.

(ii) Signal : Signal is the Information converted in electrical form. Signals can be analog or digital. Sound and picture signals in TV are analog.

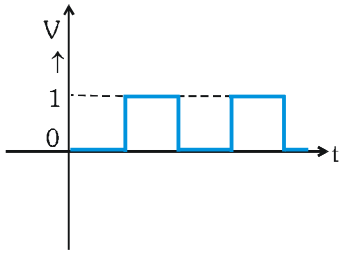
It is defined as a single-valued function of time which has a unique value at every instant of time.

(a) Analog Signal : -A continuously varying signal (Voltage or Current) is called an analog signal. A number with system base 10 is used to deal with analog signal.

(b) Digital Signal :- A signal that can have only discrete stepwise values is called a digital signal. A binary number system with base 2 is used to deal with digital signals.



An Analog Signal



An Digital Signal

(iii) Noise : There are unwanted signals that tend to disturb the transmission and processing of message signals. The source of noise can be inside or outside the system.

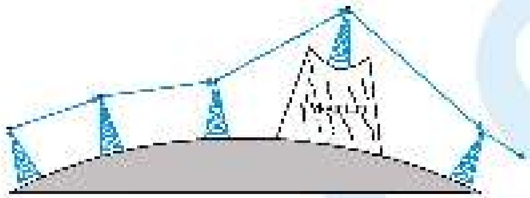
(iv) **Attenuation :** It is the loss of strength of a signals while propagating through a medium. It is like damping of oscillations.

(v) **Amplification :** It is the process of increasing the amplitude (and therefore the strength) of a signal using an electronic circuit called the amplifier.

Amplification is absolutely necessary to compensate for the attenuation of the signal in communication system.

(vi) **Range :** It is the largest distance between the source and the destination upto which the signal is received with sufficient strength.

(vii) **Repeater :** A repeater acts as a receiver and a transmitter. A repeater picks up the signal which is coming from the transmitter, amplifies and retransmits it with a change in carrier frequency. Repeaters are necessary to extend the range of a communication system as shown in figure. A communication satellite is basically a repeater station in space.



Use of repeater station to
increase the range of communication

Use of repeater station to increase the range of communication

3. BANDWIDTH :

Bandwidth of signals : Different signals used in a communication system such as voice, music, picture, computer data etc. all have different ranges of frequency. The different of maximum and minimum frequency in the range of each signal is called bandwidth of that signal.

Bandwidth can be of message signal as well as of transmission medium.

(i) **Bandwidth for analog signals :** Bandwidth for some analog signals are listed below :

Signal	Frequency range	Bandwidth required
Speech	300 – 3100 Hz	3100 – 300 = 2800 Hz
Music	High frequencies produced by musical instrument audible range = 20 Hz - 20 kHz	20 kHz
Picture		4.2 MHz
TV	Contains both voice and picture	6 MHz

(ii) **Bandwidth for digital signal :** Basically digital signals are rectangular waves and these can be splited into a superposition of sinusoidal waves of frequencies $\nu_0, 2\nu_0, 3\nu_0, 4\nu_0, \ldots n\nu_0$ where n is an integer extending to infinity. This implies that the infinite band width is required to reproduce the rectangle waves. However, for practical purposes, higher harmonies are neglected for limiting the bandwidth

4. Bandwidth of Transmission Medium

Different types of transmission media offer different bandwidth of which some are listed below

	Service	Frequency range	Remarks
1	Wire (most common : Coaxial cable)	750 MHz (Band width)	Normally operated below 18 GHz
2	Free space (radio waves)	540kHz - 4.2 GHz	
	(i) Standard AM	540 kHz to 30 MHz	
	(ii) FM	88 - 108 MHz	
	(iii) Television	54 – 72 MHz 76 – 88 MHz 174 - 216 MHz 420 - 890 MHz	VHF (Very high frequencies) TV UHF (Ultra high frequency) TV
	(iv) Cellular mobile radio	896 - 901 MHz 840 - 935 MHz	Mobile to base station Base station to mobile
	(v) Satellite Communication	5.925 - 6.425 GHz 3.7 - 12 GHz	Uplinking Downlinking
3	Optical communication using fibres	1 THz - 1000 THz (microwaves-ultra violet)	One single optical fibre offers band width > 100 GHz

5. Ground Wave Propagation :

(a) The radio waves which travels through atmosphere following the surface of earth are known as ground waves or surface waves and their propagation is called ground wave propagation or surface wave propagation. These waves are vertically polarised in order to prevent short-circuiting of the electric components. The electrical field due to the wave induce charges in the earth's surface. As the wave travels, the induced charges in the earth also travel along it.This constitutes a current in the earth's surface. As the ground wave passes over the surface of the earth, it is weakened as a result of energy absorbed by the earth. Due to these losses the ground waves are not suited for very long range communication. Further these losses are higher for high frequency. Hence, ground wave propagation can be sustained only at low frequencies (500 kHz to 1500 kHz).

(b) The ground wave transmission becomes weaker with increase in frequency because more absorption of ground waves takes place at higher frequency during propagation through atmosphere.

(c) The ground wave propagation is suitable for low and medium frequency i.e. upto 2 MHz only.

(d) The ground wave propagation is generally used for local band broadcasting and is commonly called medium wave.

(e) The maximum range of ground or surface wave propagation depends on two factors :
(i) The frequency of the radio waves and. (ii) Power of the transmitter.

6. Sky Wave Propagation :

(a) The sky waves are the radio waves of frequency between 2 MHz to 30 MHz.

(b) The ionospheric layer acts as a reflector for a certain range of frequencies (3 to 30 MHz). Therefore it is also called has ionspheric propagation or short wave propagation. Electromagnetic waves of frequencies higher than 30 KHz penetrate the ionosphere and escape.

(c) The highest frequency of radio waves which when sent straight (i.e. normally) towards the layer of ionosphere gets reflected from ionosphere and returns to the earth is called critical frequency. It is given by $f_c = 9\sqrt{N_{max}}$, where N is the number density of electron/m^3.

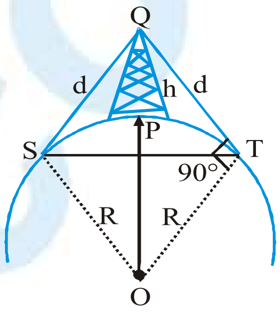
7. Space Wave Propagation :

(a) The space wave are the radio waves of very high frequency (i.e. between 30 MHz to 300 MHz or more).

(b) The space waves can travel through atmosphere from transmitter antenna to receiver antenna either directly or after reflection from ground in the earth's troposphere region. That is why the space wave propagation is also called as tropospherical propagation or line of sight propagation.

(c) The range of communication of space wave propagation can be increased by increasing the height of transmitting and receiving antenna.

(d) **Height of transmitting Antenna :**



The transmitted waves, travelling in a straight line, directly reach the received end and are then picked up by the receiveing antenna. Due to finite curvature of the earth, such waves cannot be seen beyond the tangent points S and T.

$(R + h)^2 = R^2 + d^2$

As R >> h, So $h^2 + 2Rh = d^2$

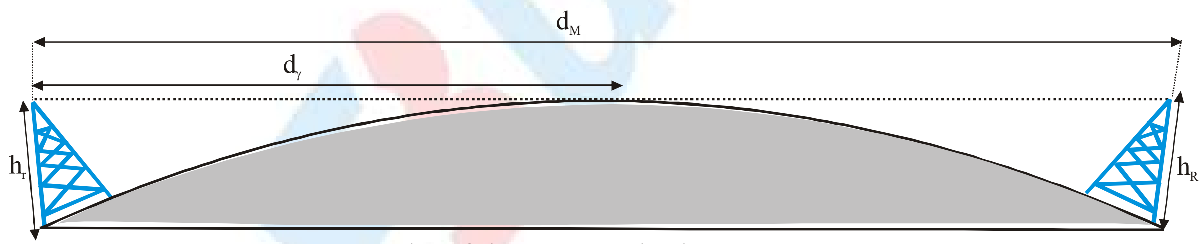
$\Rightarrow d = \sqrt{2Rh}$

Area covered for TV transmission : $A = \pi d^2 = 2\pi Rh$

Population covered = population density × area covered

If height of receiving antenna is also given in the question then the maximum line of sight

$$d_M = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$



Line of sight communication by space waves

where ;

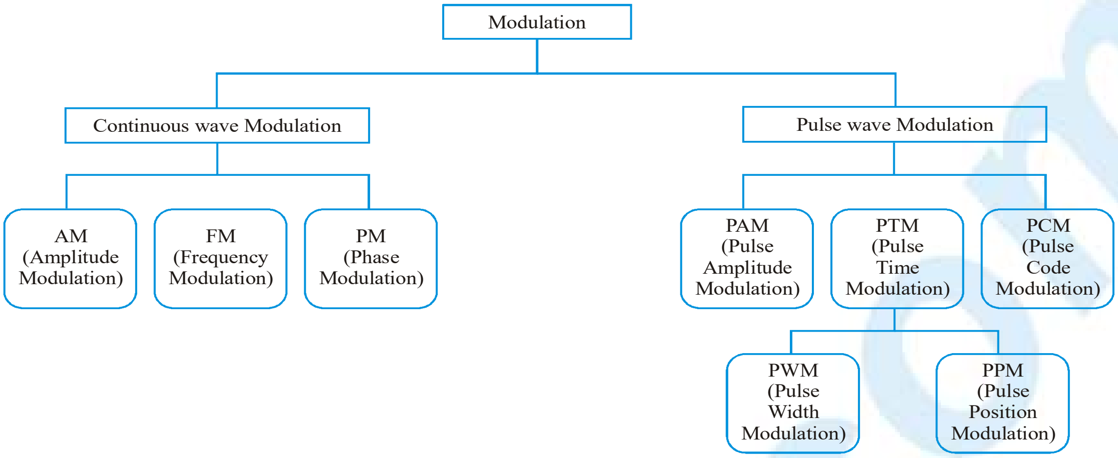
R = radius of earth (approximately 6400 km)

h_T = height of transmitting antenna

h_R = height of receiving antenna

8. MODULATION

The phenomenon of superposition of information signal over a high frequency carrier wave is called modulation. In this process, amplitude, frequency or phase angle of high frequency carrier wave is modified in accordance with the intantaneous value of the low frequency information.



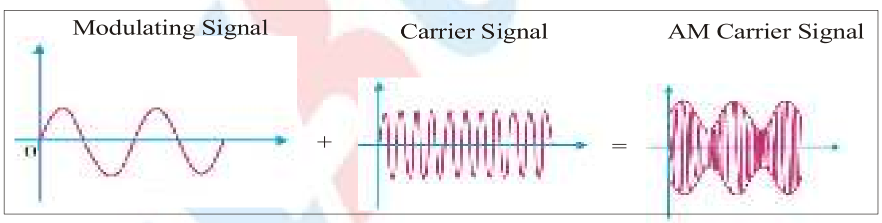
9. Need for Modulation :

(i) **To avoid interference :** If many modulation signals travel direclty through the same transmission channel, they will interfere with each other and result in distortion.

(ii) **To design antennas of practical size :** The minimum height of antenna (not of antenna tower) should be $\lambda/4$ where λ is wavelength of modulating signal. The minimum size becomes impracticalbe because the frequency of the modulating signal can be upto 5 kHz which corresponds to a wavelength of $3 \times 10^8/5 \times 10^3 = 60$ km. This will require an antenna of the minimum height of $\lambda/4 = 15$ km. This size of an antenna is not practical.

(iii) **Effective Power Radiated by an Antenna :** A theoretical study of radiation from a linear antenna (length l) shows that the power radiated is proportional to (frequency)^2 i.e., $(1/\lambda)^2$. For a good transmission, we need high powers and hence this also point out to the need of using high frequency transmission.

10. Amplitude Modulation :



Modulation factor, $m = \dfrac{\text{amplitude of modulation wave}}{\text{amplitude of normal carrier wave}}$

If $v_m = V_m \cos\omega_m t$ and $v_c = V_c \cos\omega_c t$ then $m = \dfrac{V_m}{V_c}$

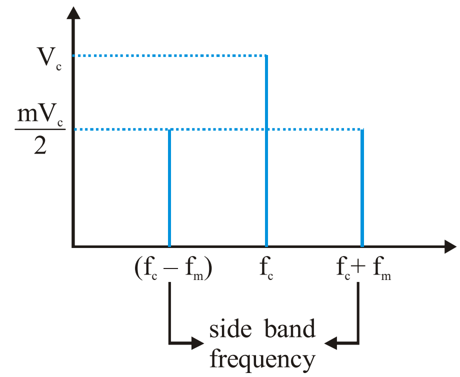
As amplitude of the carrier wave varies at signal frequency f_m so the amplitude of AM wave $= V_c + mV_c\cos\omega t$ &

frequency of AM wave $= \dfrac{\omega_c}{2\pi}$

Therefore $v = [V_c(1 + m)\cos\omega_m t]\cos\omega_c t$

$$\Rightarrow v = V_C\cos\omega_c t + \frac{mV_C}{2}\cos(\omega_C + \omega_m)t + \frac{mV_C}{2}\cos(\omega_C - \omega_m)t$$

11. Frequency spectrum of AM wave



12. Power in AM wave :

Power of carrier wave : $P_C = \frac{V_c^2}{2R}$ where R = resistance of antenna in which power is dissipated.

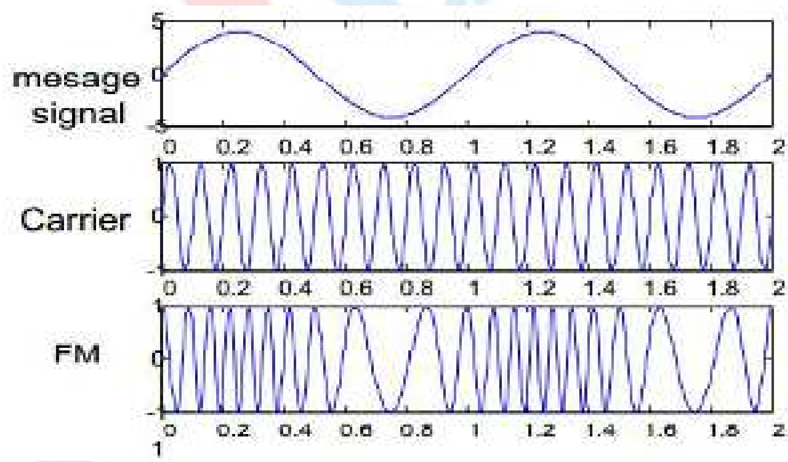
Total power of side bands : $P_{sideband} = 2 \times \frac{1}{2R}\left(\frac{mV_C}{2}\right)^2 = \frac{m^2}{2}P_c$

Total power of AM wave $= P_C = \left(1 + \frac{m^2}{2}\right)$

Fraction of total power carried by sidebands $= \frac{m^2}{2 + m^2}$

13. Frequency Modulation (FM) :

When the frequency of carries wave is changed in accordance with the instantaneous value of the modulating signal, it is called frequency modulation.



14. MODULATION FACTOR OR INDEX AND CARRIER SWING (CS)

Modulation factor : $m = \frac{\text{max. frequency deviation}}{\text{Modulation frequency}} = \frac{\Delta f}{f_m}$

$$\Delta f = f_{max} - f_c = f_c - f_{min}; v_{FM} = V_c \cos[\omega_C t + m_1 \cos \omega_m t]$$

Carrier Swing (CS)

The total variation in frequency from the lowest to the highest is called the carrier swing $\Rightarrow CS = 2\times\Delta f$

Side Bands

FM wave consists of an infinite number of side frequency components on each side of the carrier frequency f_c, $f_c - f_m$, $f_c - 2f_m$, $f_c + 3f_m$ & so on.

	Frequency Modulation	Amplitude Modulation
1	The amplitude of FM wave is constant, whatever be the modulation index.	The amplitude of AM signal varies depending on modulation index.
2	It require much wider channel (Band width) [7 to 15 times] as compared to AM.	Band width is very small (One of the biggest advantage)
3	Transmitters are complex and hence expensive.	Relatively simple and cheap
4	Area of reception is small since it is limited to line of sight. (This limits the FM mobile communication over a wide area)	Area of reception is large
5	Noise can be easily minimised amplitude variation can be eliminated by using limiter.	It is difficult to eliminate effect of noise
6	Power contained in the FM wave is useful. Hence full transmitted power is useful.	Most of the power which contained in carrier is not useful. Therefore carrier power transmitted is a waste
7	The average power is the same as the carrier wave.	The average power in modulated wave is greater than carrier power
8	No restriction is placed on modulation index (m).	Maximum m = 1, otherwise over modulation (m > 1) would result in distortion.
9	It is possible to operate several independent transmitter on same frequency.	It is not possible to operate without interference.

15. MODEM:

The name modem is a contraction of the terms Modulator and Demodulator. Modem is a device which can modulate as well as demodulate the signal.

16. FAX (Facsimile Telegraphy)

FAX is abbreviation for facsimile which means exact reproduction. The electronic reproduction of a document at a distance place is called Fax.