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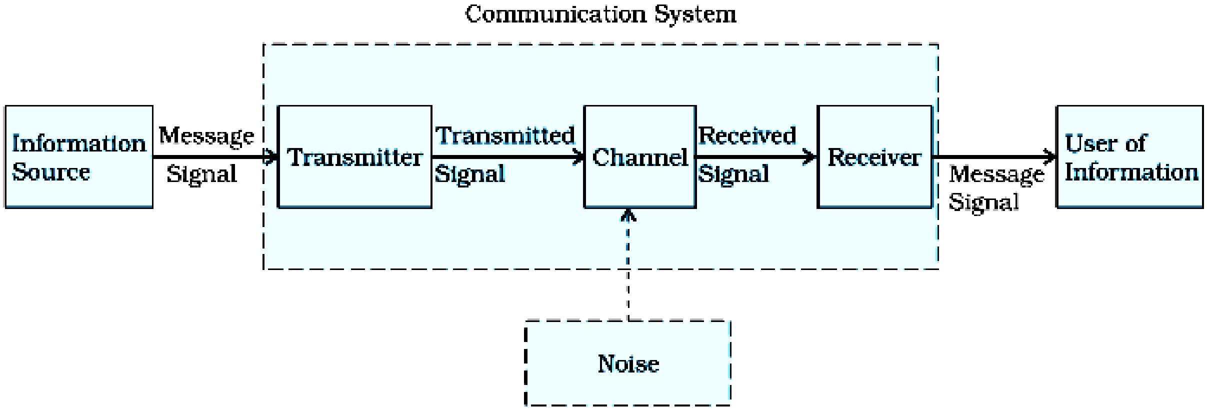
ELEMENTS OF A COMMUNICATION SYSTEM

Every communication system has three essential elements-transmitter, medium/channel and receiver.

The block diagram shows the general form of a communication system



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 this type of communication.

In the broadcast mode, there are a large number of receivers corresponding to a single transmitter. Radio and television are examples of broadcast mode of communication.

BASIC TERMINOLOGY USED IN COMMUNICATION SYSTEMS

(i) **Transducer:** An electrical transducer is 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. It is of two types - analog and digital.

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Analog signals are continuous variations of voltage or current , which are single-valued functions of time. Sine wave is a fundamental analog signal.

Digital signals are those which can take only discrete stepwise values. Binary system is used in digital electronics employing just two levels of a signal. '0' corresponds to a low level and '1' corresponds to a high level of voltage/current.

(iii) **Noise:** Noise refers to the unwanted signals that tend to disturb the transmission and processing of message signals in a communication 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:** It is the loss of strength of a signal while propagating through a medium. (vii) **Amplification:** It is the process of increasing the amplitude (and consequently the strength) of a signal using an electronic circuit called the amplifier. Amplification is necessary to compensate for the attenuation of the signal in communication systems.

(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. 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. There are several types of modulation, 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:** It is a combination of a receiver and a transmitter , which picks up the signal from the transmitter, amplifies and retransmits it to the receiver.
Repeaters are used to extend the range of a communication system

BANDWIDTH OF SIGNALS

The bandwidth for speech signals is 2800 Hz (3100 Hz– 300 Hz) for commercial telephonic communication.
To transmit music, an approximate bandwidth of 20 kHz is required because of the high frequencies produced by the musical instruments.
Video signals for transmission of pictures require about 4.2 MHz of bandwidth.
A TV signal contains both voice and picture and require 6 MHz of bandwidth .

BANDWIDTH OF TRANSMISSION MEDIUM

Coaxial cable is a wire medium, offers a bandwidth of 750 MHz.
Communication through free space using radio waves , has a very wide range of frequencies: from a few hundreds of kHz to a few GHz.
Optical communication using fibers , has the frequency range of 1 THz to 1000THz
An optical fiber can offer a transmission bandwidth in excess of 100 GHz.

PROPAGATION OF ELECTROMAGNETIC WAVES:-

Ground wave:-

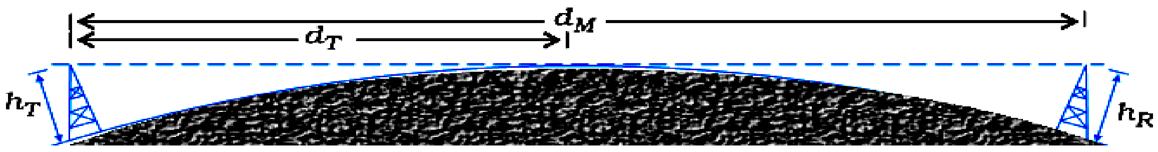
In standard AM broadcast, for ground based transmitting antennas , ground has a strong influence on the propagation of the signal. The mode of propagation is called surface or ground wave propagation The wave glides over the surface of the earth. A wave induces current in the ground over which it passes and it is attenuated due to 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 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. 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 heights, there occurs a peak of ionisation density. The ionospheric layer acts as a reflector for a certain range of frequencies (3 to 30 MHz). Electromagnetic waves of frequencies higher than 30 MHz penetrate the ionosphere and escape.

Space wave:--

A space wave travels in a straight line from transmitting antenna to the receiving antenna and it is 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. 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



If the transmitting antenna is at a height h_T ,then the distance to the horizon d_T is given as $d_T = \sqrt{2Rh_T}$ where R is the radius of the earth. d_T is also called the radio horizon of the transmitting antenna.

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

Q:- What is the need of modulation ? (three points) 3 marks

Ans- Modulation is needed to overcome the certain factors , which prevent us in transmitting an electronic signal in the audio frequency (AF) range (baseband signal frequency less than 20 kHz) over a long distance directly.

Let us dicuss those factors .

1. Size of the antenna or aerial :- For transmitting a signal, we need an antenna , whose size should be atleast $1/4^{th}$ of the wavelength of the original signal , so that the antenna properly senses the time variation of the signal.

For a signal of frequency 20 kHz ,i.e. the wavelength λ is 15 km , it is practically not possible to construct an antenna of length $^{15}/_{4}$ km .and operate. Hence direct transmission of such baseband signals is not practically possible .

So, there is a need of translating the information contained in our original low frequency baseband signal into high or radio frequencies before transmission.

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2. Effective power radiated by an antenna:- Theoretical study of radiation shows that the power radiated from a linear antenna of length L is proportional to **(L / λ)** ^{2} , i.e. inversely proportional to λ or directly proportional to □ .

For a good transmission, we need high powers and hence we need a high frequency transmission.

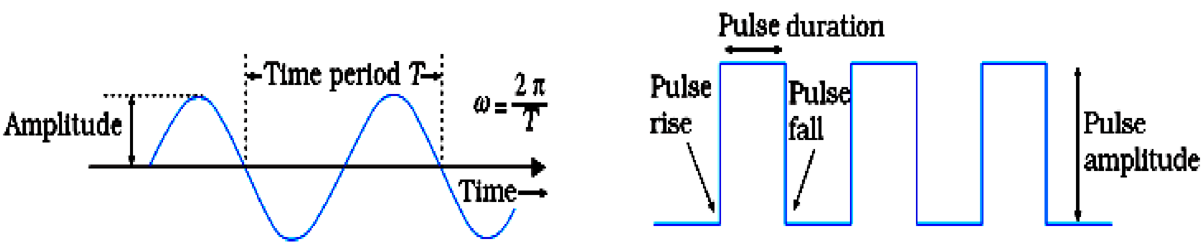
3 Mixing up of signals from different transmitters:- Many transmitters are transmitting baseband information signals simultaneously , then they will get mixed up and there is no simple way to distinguish between them. This points out towards a possible solution by using communication at high frequencies 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 information signal into high frequency wave before transmission such that the translated signal continues to possess the information contained in the original signal.

Q:- What is carrier waves ?

The carrier wave is a high frequency signal , with which the original low frequency baseband information signal is mixed , in a way such that the translated signal continues to possess the information contained in the original signal .

The carrier wave may be continuous (sinusoidal) or in the form of pulses as shown in figure below



(a) Sinusoidal signals (b) pulse shaped signals.

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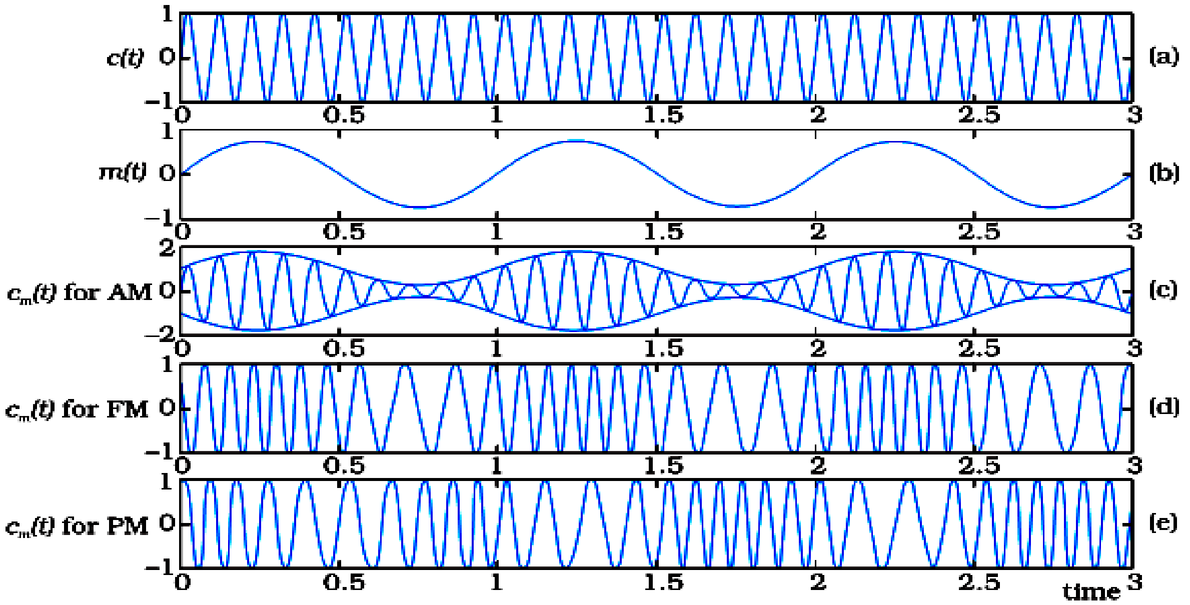
A sinusoidal carrier wave can be represented as **$c(t) = A_c \sin(\omega_c t + \varphi)$** ,where c(t) is the signal strength (voltage or current), **A_c** is the amplitude, **ω_c (= 2π□$_c$)** is the angular frequency and φ is the initial phase of the carrier wave.

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) Phase modulation (PM), as shown in Fig. below



__**Modulation of a carrier wave**__:
(a) a sinusoidal carrier wave;
(b) a modulating signal;
(c) amplitude modulation;
(d) frequency modulation; and
(e) phase modulation.

Q:- What is amplitude modulation ? Find the expression for modulated signal Prove that in amplitude modulated wave , along with original frequency , two other frequencies are present .

Draw the frequency spectrum of the amplitude modulated signal .

Ans:- [FIG (a) , (b) AND (c) are needed]

In amplitude modulation the amplitude of the carrier is varied in accordance with the information signal.

Let **$c(t) = A_c \sin \omega_c t$** represent carrier wave with angular frequency **$\omega_c = 2\pi \nu_c$** and **$m(t) = A_m \sin \omega_m t$** represent the modulating signal or message signal with angular frequency **$\omega_m = 2\pi \nu_m$**

The modulated signal **$c_m(t)$** can be written as

$$c_m(t) = (A_c + A_m \sin \omega_m t) \sin \omega_c t = A_c \left(1 + \frac{A_m}{A_c} \sin\omega_m t\right) \sin\omega_c t$$

$$= A_c \sin\omega_c t + \mu A_c \sin\omega_m t \sin\omega_c t \quad \text{....(1)}$$

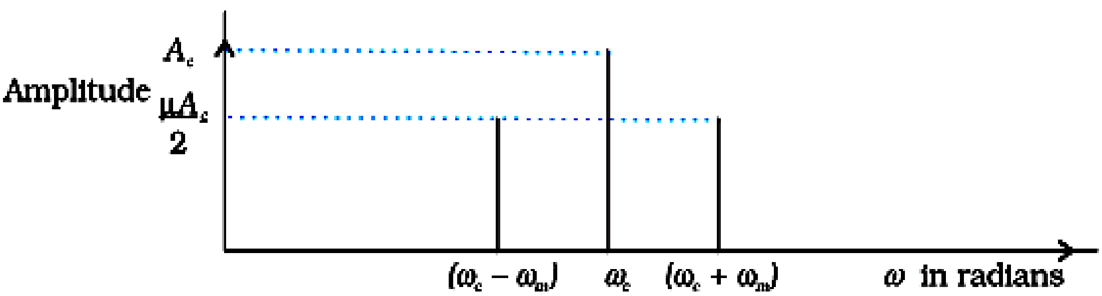
Here **$\mu = A_m / A_c$** is the modulation index; in practice,μ is kept $1 \le$ to avoid distortion.

Eq (1) can be written as

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

Here **$\omega_c - \omega_m$ and $\omega_c + \omega_m$** are respectively called the lower side and upperside frequencies. The modulated signal now consists of the carrier wave of frequency **ω_c** and two sinusoidal waves each with a frequency slightly different from, known as side bands.

The frequency spectrum of the amplitude modulated signal , is a plot of amplitude versus ω for an amplitude modulated signal. It is shown in figure below



TRANSMISSION OF AMPLITUDE MODULATED WAVE

In order to transmit the modulated signal , 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 . The whole thing is shown in figure below

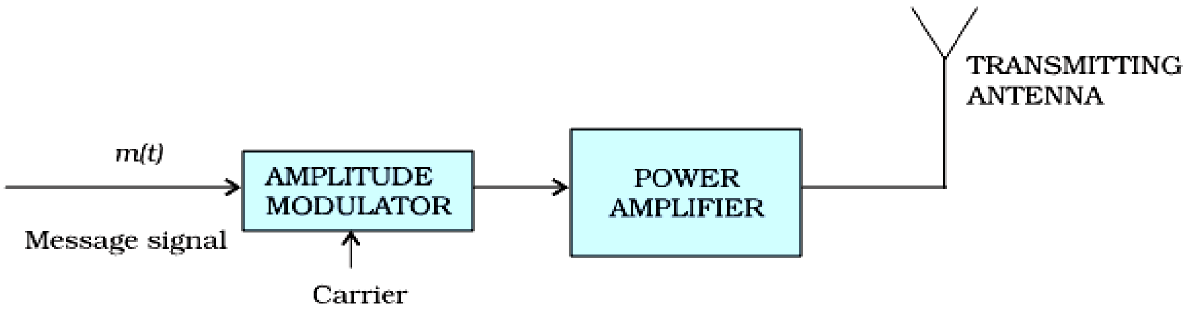


Fig :- Block diagram of a transmitter.

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 below

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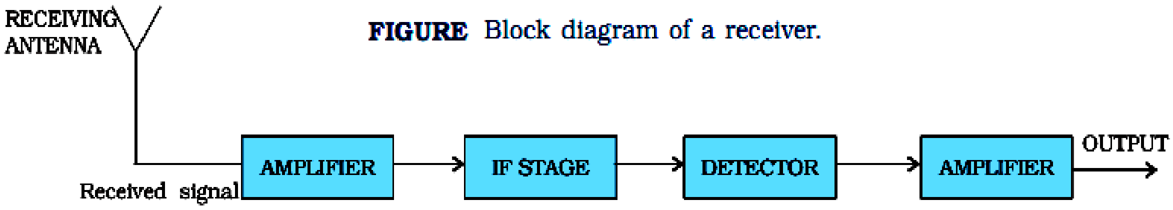
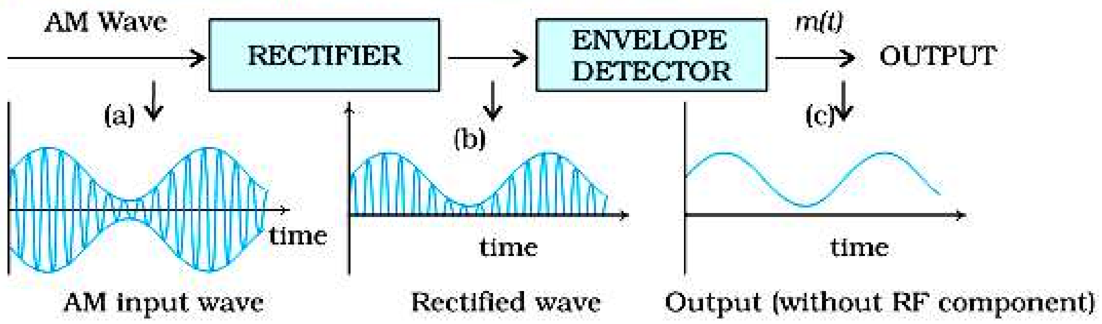


FIGURE Block diagram of a receiver.

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 below.

FIGURE Block diagram of a detector for AM signal.



The modulated signal of the form given in (a) of fig. above 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 is consisting of a simple RC circuit .