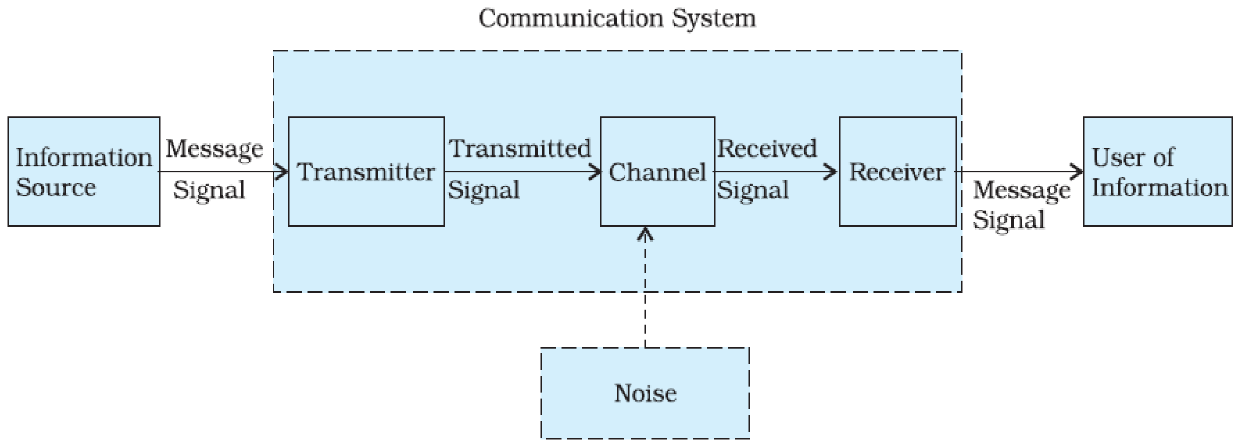
COMMUNICATION SYSTEMS

Communication is the act of transmission of information. Modern communication has its root in the 19th and 20th centuries in the work of scinetists like J. C. Bose, F B Morse, G Marconi and Alexander Graham Bell.

Elements of Communication system.

Every communication system has three essential elements - transmitter, medium/channel and receiver. The block diagram of a generalised communication system is shown below.



In a communication system, the transmitter is located at one place, the receiver at some other place separated from the transmitter and the channel is a physical medium that connects them.

Depending on 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 into a form suitable for the transmission through the channel. If the output of the information source is a nonelectrical signal like a voice signal, a **transducer converts it into electrical form** before giving it as an input to the transmitter. When transmitted signal propagates along the cahnnel, it may get distorted due to channel imperfections.Moreover, noise adds to the transmitted signal and the receiver receives a corrupeted version of the signal. The **receiver** has the task of operating on the received signal. It reconstructs a recognisable form of the original message signal for delivering in to the **user of information**.

There are two basic modes of communication:- (i) Point ot point and (ii) Broad cast.

In point to point mode, communication takes place over a link between a single transmitter and receiver. Eg: Telephone.

In broadcast mode, there are a large number of receivers corresponding to a single transmitter. Eg: radio, TV etc.

It would be easy to understand the principles of any communication if we get knowledge about the following basic terms:-

(i) Transducer: Any device that converts one form of energy into another can be termed as transducer.

(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. 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 signal. '0' corresponds to low level and '1' to a high level of voltage/current.

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

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

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

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

(vii) Reveater: A repeater is a combination of a receiver and a transmitter. A repeater, picks up the signal from the transmitter, amplifies and retransmits it into the receiver sometimes with a change in carrier frequency. They are used to extend the range of communication system. A communication satellite is essentially a repeater station in space.

Propagation of electromagnetic waves

In communication using radiowaves, an antenna at the transmitter radiates the electromagnetic waves which travel through the spqace and reach the receiving antenna at the other end. This type of communication which utilises the Physical space around the earth is called **space communication**. The transmitting antenna radiates em waves in three modes viz (i) Ground wave, (ii) space wave (iii) sky wave.

(i) **Ground wave propagation**

Ground wave follows the curvature of the earth and has carrier frequency up tp 2 M Hz. Eg: radiowaves. For this type of propagation, the transmitting and receiving antennas must be close to the surface of earth. It is not suited for very long distance communication because of attenuation. It is effective only at very low frequencyes. (VLF).

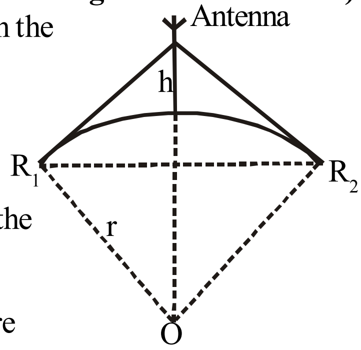
(ii) Sky wave propagation

It is that mode of wave propagation in which the radio waves emitted from the transmitting antenna reach the receiving antenna after reflection in the ionosphere. The ionosphere extends from a height of nearly 80 km to 300 km above the earths surface. The uv rays and other higher energy radiations coming from sun are absorbed by air molecules. Due to this absorption, the air molecules get ionised and forms an ionised layer of electrons and ions around the earth.

The refractive index of ionosphere decreases as we go into the ionosphere. Therefore as em wave coming from ground undergoes total internal reflection. This is a frequency dependent phenomena. There is a critical frequency (from 5 M Hz to 10 M Hz) above which the wave incident on the ionosphere will not reflect back. So sky wave propagation is not possible above 10 M Hz. This limitation is overcome with satellite communication. (Space wave communication)

(iii) **Space wave communication (Tropospheric wave propagation or line of sight communication)**

In this mode, the transmitted wave travel in straight line and directly reach the receiving antenna. Due to the finite curvature of earth, the transmitted waves cannot be seen beyond the points R_1 and R_2. Thus effective reception range of broad cast is the regions between R_1 and R_2. This region is covered by the line of sight. hence this mode of communication is called line of sight communication. If **h** is the height of the transmitting antenna, **r** the radius of the earth (6400km) then distance d can be given as $d = \sqrt{2rh}$. To incerease the value of d, height h can be increased or repeated transmitting stations are provided. Television broadcast, microwave links and satellite communication are some examples of communication system that use space wave mode of propagation.

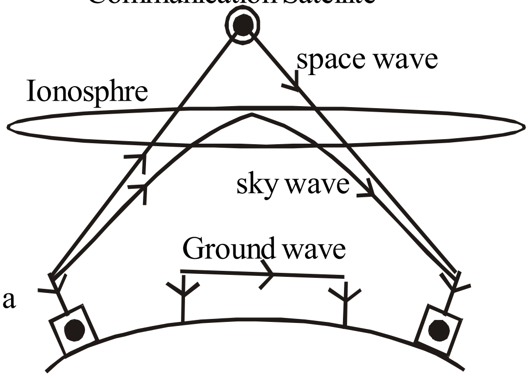


Modulation and its necessity

We know that, the purpose of a communication system is to transmit information or message signal (also called base band signals). We wish to transmit an electrical signal in the audio frequency (AF) range (frequency less than 20 kHz) over a long distance directly. Let us find the factors which prevent us from doing so and how we overcome these factors.

1. **Size of the antenna or aerial**.

For transmitting and receiving signal we need antenna having a size comparable to the wavelength of the signal. (should have length at least 1/4 th the wavelength). Therefore, to transmit a 20 kHz signal, it requires an antenna having length about 3.76 km.



Various propagation modes of EM waves

It is practically impossible.

$\left[v = \nu\lambda \ ; \ \lambda = \frac{v}{\nu} = \frac{3 \times 10^8}{20 \times 10^3} = 15 \times 10^3 \text{ m} \ \therefore \ \frac{\lambda}{4} \approx 3.7 \text{ km} \right]$ This demands that the audiosignal is converted into a high frequency signal for transmission.

2. **Effective power radiated by an antenna**.

A theoritical study of radiation from a linear antenna (length λ) shows that the power radiated is proportional to $\left(\frac{\lambda}{\lambda}\right)^2$. This shows that for the same antenna length, the power radiated increases with decreasing wavelength. (increasing frequency) For a good transmission, we need high powers and hence this also points out to the need of using high frequency transmission.

3. **Mixing up of signals from different transmittors.**

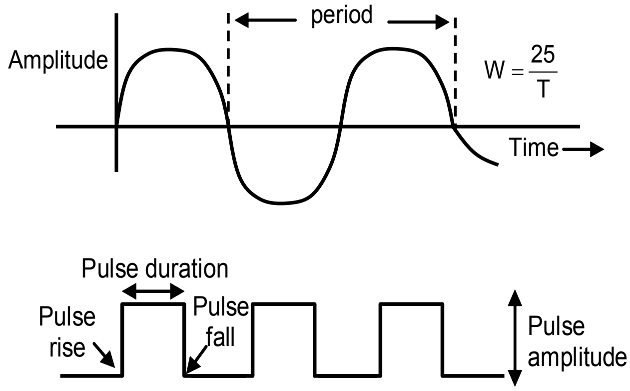
Suppose many people are talking at the same time or many transmitters are transmitting base band information signals simultaneously, all these signals will get mixed up and there is no way to distinguish between them. This problem can be solved by transmitting the audio signals in the form of high frequency signals and allottting a band of frequencies to each message signal for its transmission.

Modulation.

To overcome all these difficulties, we make use of the technic called modulation. *Modulation is the process of super posing a low frequency (audio signal) information on to a high frequency wave (carrier wave)*.

Carrier wave: - The carrier wave may be sinusoidal wave (continuous wave) or in the form of pulses.

A sinusoidan carrier wave can be mathematically expressed 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, $\omega_C = 2\pi\nu_C$ is the angular fequency and ϕ is the initial phase of the carrier wave.



a) Sinusoidal and (b) Pulse shaped signals.

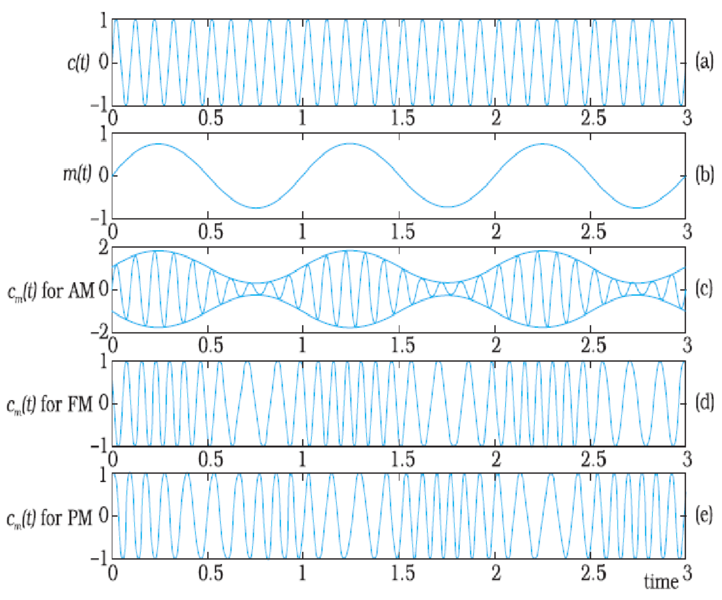
During the process of modulation, any of the three parameters - A_C, ω_C and ϕ of the carrier wave can be controlled by the message or information signal. This result in three types of modulation. (i) Amplitude modulation (AM) (ii) frequency modulation (FM) (iii) Phase modulation (PM).

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). Hence different types of pulse modulation are

(a) Pulse amplitude modulation

(b) Pulse duration modulation or pulse width modulation.

(c) Pulse position modulation.



Amplitude Modulation.

In amplitude modulatin, the amplitude of the carrier is varied in accordance with the information signal. Here we use a sinusoidal wave as carrier wave. Let the *sinusoidal carrier wave* be represented as $C(t) = A_C \sin\omega_C t$ .....(1)

A modulating signal (message signal) can be represented as $m(t) = A_m \sin\omega_m t$ .....(2) .
The message signal is added in such a way to change the amplitude of carrier wave. Hence the *modulated signal* can be represented as

$$C_m(t) = (A_C + A_m \sin\omega_m t)\ \sin\omega_C t$$
$$= A_C \sin\omega_C t + A_m \sin\omega_m t\ \sin\omega_C t \text{ ......(3)}$$

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Take $\frac{A_m}{A_C} = \mu$ called modulation index. So $A_m = \mu A_C$. Substitute in the above equation

So $C_m(t) = A_C \sin\omega_C t + \mu A_C \sin\omega_m t\ \sin\omega_C t$.

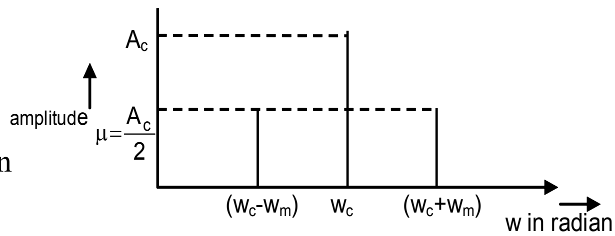
But we know, $\sin A \sin B = \frac{1}{2}\left[\cos(A - B) - \cos(A + B)\right]$

$$\text{So } C_m(t) = A_C \sin\omega_C t + \frac{\mu A_C}{2}\left[\cos(\omega_C - \omega_m)t + \cos(\omega_C + \omega_m)\right] \text{ .....(4)}$$

The above equation shows that, the modulated signal consists of three frequencies, (1) ω_C (2) $\omega_C - \omega_m$ (3) $\omega_C + \omega_m$

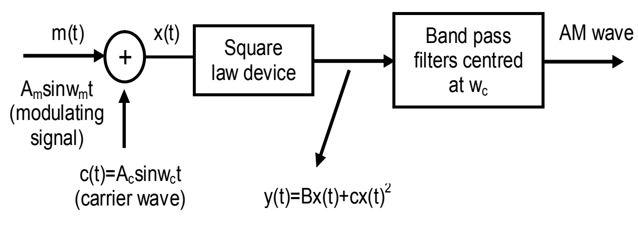
ω_C is the carrier frequency, $\omega_C - \omega_m$ is called lower side band frequency and $\omega_C + \omega_m$ is called upper side band frequency.
A plot of amplitude versus angular frequency for an amplitude modulated signal is as shown below.

Note:- 1) Modulation index (μ) is always kept ≤ 1 to avoid distortion.
2) As long as the broadcast frequencies (carrier waves)are sufficietly spaced out, the sidebands do not overlap. Hence different stations can operate without interfering each other.



Production of AM wave.
The block diagram showing the production of an amplitude modulated wave is given below.

Step 1. The modulating signal $m(t) = A_m \sin\omega_m t$ is added to the carrier signal $C(t) = A_C \sin\omega_C t$. to produce X(t).
So $X(t) = A_m \sin\omega_m t + A_C \sin\omega_C t$ ....(1) .

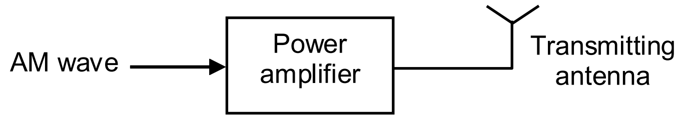


Step 2. This signal X(t) is passed through a square law

modulated (AM) wave. Hence the output of the band pass filter is an AM wave.

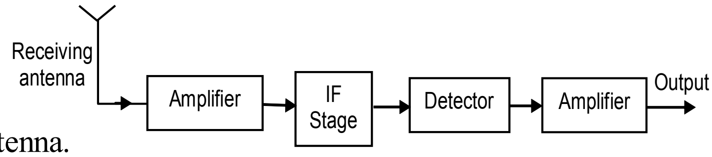
Transmission of AM wave.

The AM Wave is given to a power amplifier. The power amplifier provides the necessary power and then it is fed to an antenna for transmission.



Detection of Amplitude Modulated wave.

The block diagram of AM receiver is shown :



<u>Step I</u>

The AM wave is received by the Receiving antenna.

<u>Step II</u>

The signal from the antenna is given to the amplifier. The amplifier will give sufficient strength to the receiving signal.

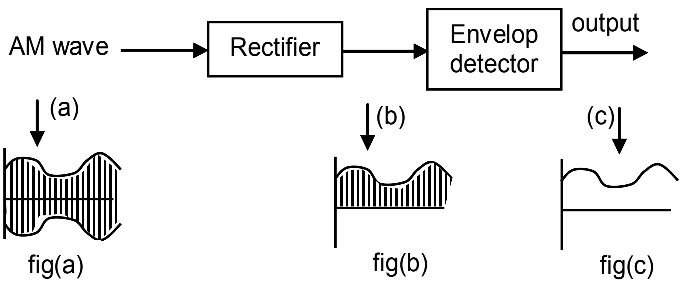
<u>Step III</u>

The output from the amplifier is given to the IF (intermediate frequency) stage. Here the carrier frequency is changed into a lower frequency.

<u>Step IV</u>

<u>Detection</u>

Detection is the process of recovering the modulating signal from the modulated carrier wave. The process of detection is shown in block diagram.



The modulated signal is given to the rectifier. The rectifier removes the negative part of the A.M and gives the positive part only. This output is given to the envelop detector. It will give an output of message signal.

<u>Step V</u>

The message signal from the detector is given to the amplifier. The amplifier, amplifies the signaland given to the loud speaker.

Homework Problems.

1. A 5 kHz audio signal is used to frequency modulate a 100 MHz carrier causing a frequency deviation of 20 kHz. Determine the modulation index. {4}

2. In a diode AM detector, the output circuit consists of R = 1 kΩ and C = 10pF. A carrier signal of 100 kHz is to be detected. Is it good? If not, what value would you suggest.

Answer: For demodulation $\frac{1}{f_C} << RC$,

$f_c = 100kHz$, R = 1 kΩ and C = 10pf

$$\frac{1}{f_C} = \frac{1}{100 \times 10^3} = 10^{-5}s, \qquad RC = 10^3 \times 10 \times 10^{-2} = 10^{-8}s$$

Here $1/f_C$ is not less than RC, For satisfactory circuits. C = 1μF and R = 1kΩ would do.

3. A ground receiver station is receiving a signal at (a) 5MHz and (b) 100 MHz transmitted from a ground

transmitter at a height of 300m, located at a distance of 100 km. Identify whether it is coming via the propagation of space wave or sky wave or satellite transponder. Radius of the earth = 6.4×10^6m, N_{max} of ionosphere = 10^{12} m^3

Answer: Receiver transmitter distance = 100m, n Re = 6.4×10^6m, height of tower h = 300 m, $N_{max} = 10^{12} \times m^3$.

Maximum distance covered by space wave communication. d = $\sqrt{2R_e h} = \sqrt{2 \times 6.4 \times 10^6 \times 300}$

= 62×10^3 m

Since the receiver transmitter distance is 100 km and the maximum distance the space wave is $f_c = 9(N_{max})^{1/2}$, where Nmax is the maximum electron density of the ionosphere.

Here, $f_c = 9\times(10^{12})^{1/2} = 9\times10^6$Hz. Since 5Hz signal frequency is less than fc, it can be received via ionosphere mode. But 100 MHz frequency can be received via satellite mode only.

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