Chapter - 5

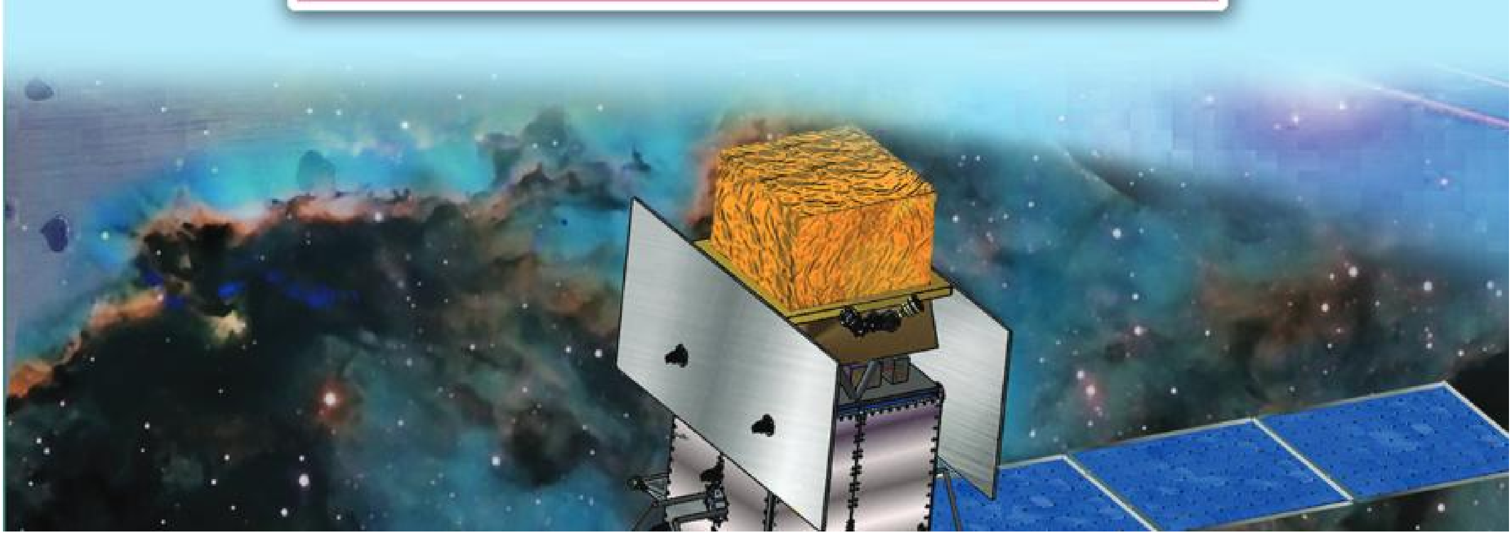
COMMUNICATION SYSTEMS

✤ Basic Components of Communication System ✤

✤ Electromagnetic Waves and their Propagation ✤

✤ Range of Transmission ✤

✤ Modulation ✤ Band width ✤



5.1 INTRODUCTION

Communication is the basic need of every living being. The cry of a just born baby, the sounds produced by birds and animals are always communicating some thing to the world around. We only need to have the knowledge of that language in which it is communicated. The communication becomes complete and successful only when it is properly received and understood. Therefore from feeling to expression on one hand and the reception to the right understanding on the other a whole process is involved in the communication systems. Technology based on basic scientific principles has made this task successful to a great extent. The untiring efforts of scientists starting from Jagadish Chandra Bose (1895) Marconi (1899) to Tern Berners – Lee (1991) has made the communications so easy that the whole world could be communicated and receive through a 'Lap Top' and a 'Palm Top'.

The communication through electric signals has made communication more wide spread because the electric signals can be transmitted over much longer distances, at an extremely high speed 3×10^8 m/s. Fig 5.1 shows the block diagram of a basic communication system.

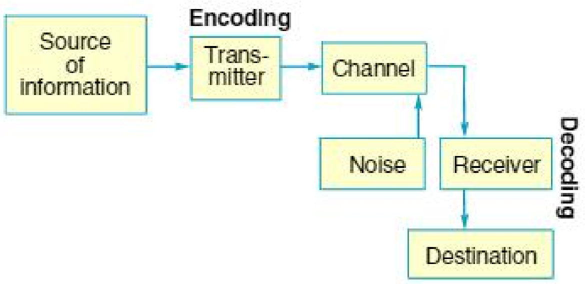


Fig 5.1

5.2 BASIC COMPONENTS OF A COMMUNICATION SYSTEM

Information

The message that is to be conveyed is information. The message may be a symbol, code, group of words etc... This message comes from the information source. The amount of information contained in any given message can be measured in bits.

Transmitter

The information in the incoming signal is first converted into electric variations. e.g : sound signal is to be converted to electrical signal. A transmitter processes and encodes the incoming information so as to make it suitable for transmission and subsequent reception. In a transmitter, information is impressed on a high frequency carrier wave in long-distance communication through a process called modulation. If the information is communicated between two points, this method of communication is called point to point mode. If the information is communicated from one point to several points, this method of communication is called broadcasting mode.

The block diagram of Transmitter :

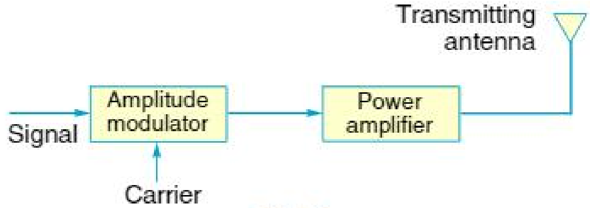


Fig 5.2

Channel

The term channel refers to the frequency range allocation to a particular transmission and reception. During the transmission electrical disturbances sometimes interfere with signals, providing noise. Noise is unwanted induction of energy due to atmospheric, extraterrestial or industrial disturbances. Noise has its greatest effect when the signal is weak.

Receiver

The signals received by receiver are quite weak, therefore the receiver first amplifies the signal and select the actual signal. The most important function of receiver is demodulation and some+times decoding as well which is the reverse of modulation in a transmitter. The output of a receiver may be fed to speaker or monitor.

The block diagram of Receiver :

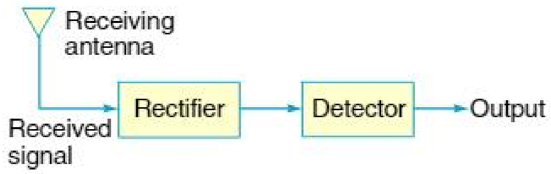


Fig 5.3

5.3 BASIC TERMS IN ELECTRONIC COMMUNICATION SYSTEM

(a) **Transducer :** Transducer is any device that converts one form of energy into another. An electrical transducer converts physical variable like pressure, displacement etc., into corresponding variations in the electrical signals at its output.

(b) **Signal :** Information converted in electrical form and suitable for transmission is called a signal. Signals are of two types, analog and digital.

Analog signal : Any physical variable is converted into continuous variations of current or voltage. These changes are analogous to the changes of the information.

Digital signal : The physical variables are converted into step wise variations of current or voltages. Generally two steps of signals are used, low level corresponds to zero and high level corresponds to 1.

(c) **Attenuation :** While propagating a signal through a medium, the loss of strength is known as attenuation.

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

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

(f) **Band width :** The frequency range over which an equipment operates.

(g) **Repeater :** Repeaters are used to extend the range of a communication system.

(h) **Noise :** It refers to the unwanted signals that tend to disturb the transmission and processing of message signals.

(i) **Transmitter :** It is a device which processes the incoming message signal so as to make it suitable for transmission through a channel.

(j) **Receiver :** It is a device which extracts the desired message signals from the received signals at the output.

(k) **Modulation :** Superimposition of low frequency message signal on high frequency wave is known as modulation.

(l) **Demodulation :** It is the process of retrieval of information from the carrier wave at the receiver. It is the reverse process of modulation.

5.4 ELECTROMAGNETIC WAVES AND THEIR PROPAGATION

During the electromagnetic wave propagation near the earth, several factors, which do not exist in free space, affect it. These waves will be reflected by ground, mountains and buildings. They will be refracted as they pass through layers of the atmosphere which differ in densities or degrees of ionization. Also, electromagnetic waves may be diffracted around tall objects. They may even interfere with each other when two waves from the same source meet. Thus in an earth environment, E.M waves propagate in ways that depend not only on their own properties but also on those of environment itself. Since the various effects and method of propagation of E.M waves depends on their frequency, the complete electromagnetic spectrum once again is now shown for reference.

Cosmic rays	γ - rays	X- rays	UV rays	Visible	I, R	Radio waves	Sonar mechanism

$\longrightarrow$ in Hz

Fig 5.4

The electromagnetic waves with frequency ranging from a few KHz to few hundred MHz are called radio waves. The various frequency ranges used in radio waves or micro waves communication system is are as follows.

(i) Medium frequency band (MF)
300 to 3000 KHz

(ii) High frequency band (HF)
3 to 30 MHz

(iii) Very high frequency band (VHF)
30 to 300 MHz

(iv) Ultra high frequency band (UHF)
300 to 3000 MHz

(v) Super high frequency band (SHF)
3000 to 30,000 MHz.

Waves travel in straight lines, except where the earth and its atmosphere, alter their path. Except in unusual circumstances, frequencies above the HF generally travel in straight lines. They propagate by means of so called space waves. These are sometimes called tropospheric waves, since they travel in the troposphere, the portion of the atmosphere closest to ground.

Frequencies below the HF range travel around the curvature of the earth. These waves undergo diffraction, reflection and refraction etc on the earth surface and the lowest ionized layer of the atmosphere and are called ground waves or surface waves. All broadcast radio signals received in day time propagate by means of surface waves.

Waves in the HF range, and sometimes frequencies just above or below it are reflected by ionized layers of the atmosphere and are called sky waves. Such signals are beamed into the sky and come down again after reflection, returning to earth well beyond the horizon. To reach receivers on the opposite side of the earth, these waves must be reflected by the ground and ionosphere several times. Neither surface waves nor sky waves are possible in space or on airless bodies such as the moon.

Radio waves emitted from transmitter can reach the receiver by any of the following modes of propagation, depending on the factors like frequency of operation, distance between transmitter and receiver antennas etc.

These are (i) Ground wave propagation
(ii) Sky wave propagation
(iii) Space wave propagation

5.4.1 BANDWIDTH OF SIGNALS

In a communication system, the message signal may be voice, music, picture or data etc. Each of these signals has a spread of different range of frequencies. Hence, the type of communication system needed depends upon the band of frequencies involved. Speech signal requires the band width of 2800 Hz (3100 Hz to 300Hz). For music, a bandwidth of about 20KHz is required (due to high frequency produced by musical instruments).

The audible range of frequencies extends from 20Hz to 20KHz. Video signals require band width of 4.2 MHz for picture transmission. However, a band width of 6MHz is needed for T.V signals. (as it contains both voice and picture)

Digital signals are in the form of rectangular waves as shown in Fig 5.5. One can show that this rectangular wave can be decomposed into a superposition of sinusoidal waves of frequencies f_0, $2f_0$, $3f_0$, $4f_0$ ....nf_0 where n is an integer extending to infinity and $f_0 = 1/T_0$. The fundamental (f_0), fundamental (f_0) + second harmonic ($2f_0$) and fundamental (f_0)+ second harmonic ($2f_0$) + third harmonic ($3f_0$) are shown in the same figure to illustrate this fact. It is clear that to reproduce the rectangular wave shape exactly we need to superimpose all the harmonics f_0, $2f_0$, $3f_0$, $4f_0$ .... which implies an infinite bandwidth. However, for practical purposes, the contribution from higher harmonics can be neglected this limiting the bandwidth. 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.

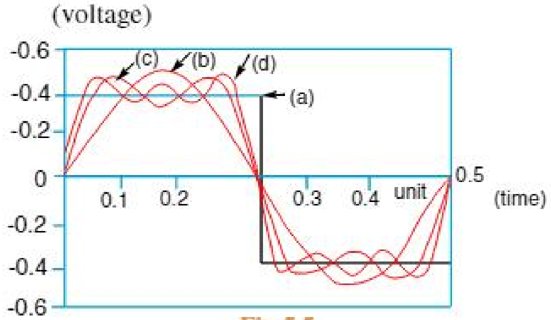


Fig 5.5

(a) Rectangular wave

(b) Fundamental (f_0)

(c) Fundamental (f_0)+ second harmonic ($2f_0$)

(d) Fundamental (f_0)
Second harmonic ($2f_0$) +
third harmonic ($3f_0$)

5.4.2 BANDWIDTH OF TRANSMISSION MEDIUM

The most used transmission media are wire, free space, and fibre optic cable. Different transmission media offer different band width. Coaxial cable offers a band width of about 750MHz . Radio wave communication through free space takes place over a wide range of frequencies (from 100kHz - GHz) . This range of frequencies is further classified and allocated for various services as shown below. An optical communication using fibres is performed in the frequency range of 1THz - 1000 THz (microwaves to ultraviolet) Optical fibres can offer transmission bandwidth greater than 100 Ghz.

5.4.3 GROUND WAVE OR SURFACE WAVE PROPAGATION

In surface wave propagation, the radio waves are guided along the surface of earth because of the electrical discontinuity that exists between the earth and the atmosphere and follow a curved surface from the transmitter to receiver. These waves are vertically polarized i.e, the electric vector of the wave is vertical. If there is any horizontal component of electric field, it will be short circuited by the earth.

Due to electric field, the surface wave in its passage induces charges on the earth, which travel with the wave and thus constitute a current. In carrying this induced current, the earth behaves like a leaky capacitor. As the ground wave passes over the surface of the earth, energy, is consumed due to flow of charge through the earth's resistance and hence the wave loses some energy. The wave also attenuated (loss in energy) due to the tilting electric vector due to diffraction effects as shown in Fig 5.6. As the wave propagates it tilts more and more and hence a greater part of energy is lost.

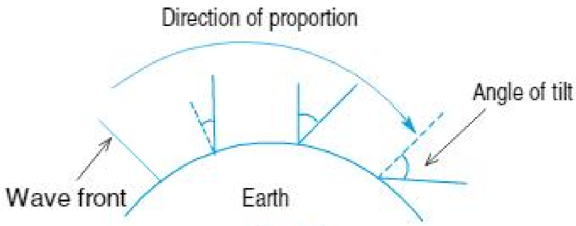


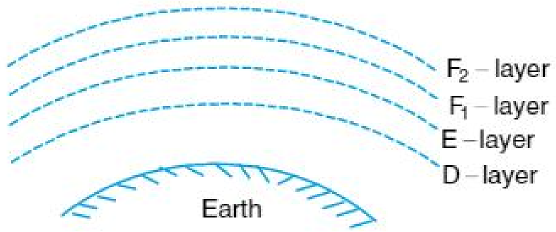
Fig 5.6

The loss in energy also depends on conductivity of surface and frequency of wave. At frequencies above 2 MHz, the loss in energy of the wave is high. Hence the ground wave propagation is suitable only for low and medium frequencies (up to 2MHz). Also the ground waves can't go up to very long distances. The maximum range of the ground wave can be increased by increasing the power of the transmitter.

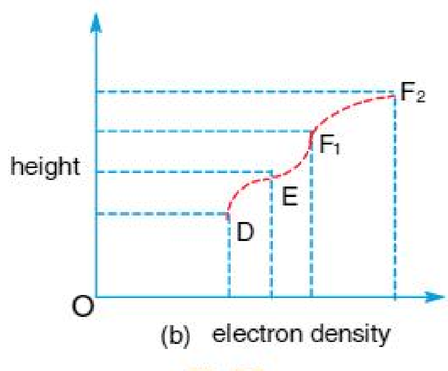
5.4.4 SKY WAVE PROPAGATION

The ionization of the upper parts of the earth's atmosphere plays a part in the propagation of waves of high frequency range (2MHz to 30MHz). Experimental work by Appleton showed that the atmosphere receives sufficient energy from the sun for its molecules to split into positive and negative ions. They remain thus ionized for long period of time. Hence there were several layers of ionization at different heights, which reflects back to earth the high frequency waves. The various layers of the ionosphere have specific effects on the propagation of waves.

The ionosphere is the upper portion of the atmosphere, which absorbs large quantities of radiant energy from the sun, becoming heated and ionized. It is located between about 50 and 350 km above the earth's surface. There are variations in the physical properties of the atmosphere, such as temperature, density and composition at different heights due to the pressure of different kind of radiations eg : X-rays, cosmic rays, U.V rays etc... Hence the ionization in the ionosphere is not uniform throughout. The overall result as shown in Fig 5.7(a) is a range of four main layers D, E, F_1 and F_2 in ascending order. The corresponding height with ionization density is as shown in Fig 5.7(b). The last two layers combine at night to form a single layer.



(a)



(b)

Fig 5.7

The D layer is the lowest, existing at an average height of 70 km, with an average thickness 10 km. The degree of ionization depends on the altitude of the sun above the horizon and thus it disappears at night. It is least important layer in view of HF propagation. It reflects some VLF and LF waves and absorbs MF and HF waves to a certain extent.

The E-layer is next in height, existing at about 100 km, with a thickness of 25 km. It also disappears at night, the reason for this being recombination of ions into molecules. The main effects of the E-layer is that it reflects some HF waves during daytime.

F_1 layer exists at a height of 180 km in daytime and combine with the F_2 layer at night. Its day time thickness is about 20 km. Although some HF waves are reflected from it, most waves pass through to be reflected from F_2 layer.

F_2 layer is the upper most layer and most important reflecting medium for H.F radio waves. Its approximate thickness can be up to 250 km.

The bending of waves can be easily explained on the basis of variation of refractive index of the ionosphere with change in electron density. Suppose that a radio wave enters the ionosphere from the underlying unionized medium. Since the refractive index of ionosphere decreases from D layer to F_2 layer, consequently the incident ray will move away from the normal drawn at the point of incidence following the ordinary laws of refraction as shown in Fig 5.8.

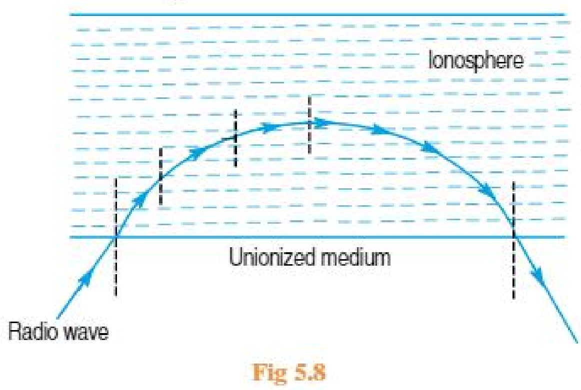


Fig 5.8

During the propagation in ionosphere, the angle of refraction gradually increases and the ray goes on bending more and more till some point, the angle of refraction becomes 90° and the wave travel parallel to the earth surface. This point is called point of reflection. Then the ray tends to move in the downward direction and comes back to earth because of symmetry. Super high frequency (SHF) waves under group propagate as sky wave paking reflection at satellites.

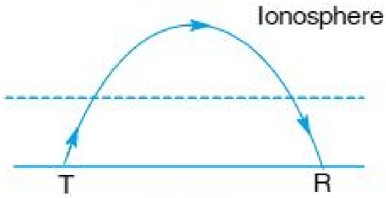


Fig 5.9

The sky wave propagation can cover a very long distance and so round the globe communication is possible.

5.4.5 SPACE WAVE PROPAGATION

This type of propagation is also called the tropospheric propagation. It is used at frequencies above 30 MHz where neither surface wave nor sky wave propagation is possible. They travel more or less in straight lines. However, since they depend on line of sight conditions, space waves are limited in their propagation by the curvature of earth. Thus they propagate very much like E.M waves in free space.

Fig 5.10 illustrates the manner of space wave propagation.

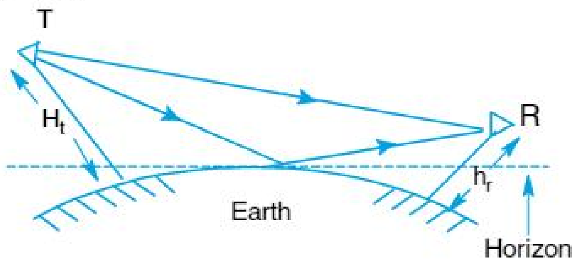


Fig 5.10

It may be seen that energy reaches the receiver in two ways. (i) By a ray travelling directly between transmitting and receiving antenna. (ii) By a ray travelling via reflection from the earth. The field strength at the receiving antenna 'R' is the vector sum of fields represented by these two rays. Only when the receiving and transmitting antenna are above the horizon of the curved earth, E.M waves are received by the receiver. The greater the height of transmission antenna, the greater is the range of transmission and vice versa. FM and TV signals are transmitted by direct waves.

The different types of wave propagation is given in the Fig 5.11.

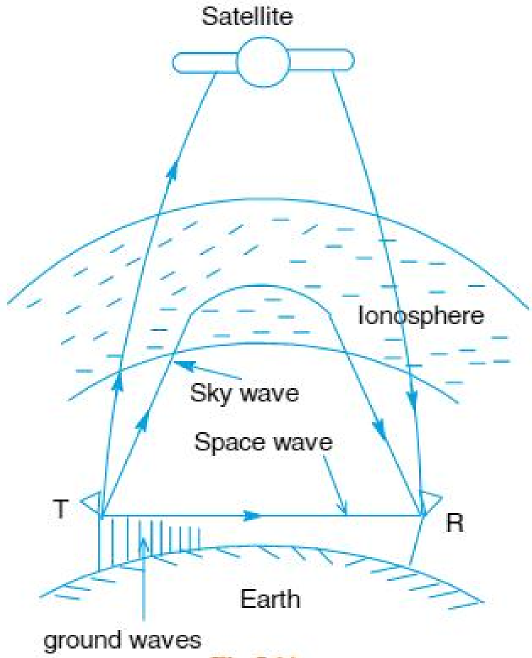


Fig 5.11

5.5 RANGE OF TV TRANSMISSION

As the frequency range of TV signals is 100 - 200 MHz, such signals via ground waves is not possible. In such situations, we use line of sight transmission.

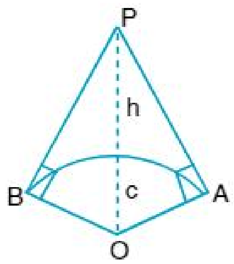


Fig 5.12

Let CP be the TV tower on the earth's surface. It's antenna is at P. Let PC = h. When TV broadcast is made, the signal can reach the earth upto A or B. There will be no reception of the signal beyond A and B. Arc length CA or CB is the range of TV transmission. If O is center of the earth, OA = OB =R is radius of the earth. From right angled triangle OAP,

$$OP^2 = OA^2 + PA^2$$

$$\Rightarrow (h+R)^2 = R^2 + PA^2$$

As h << R we can write $PA = PB = d$

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

or $d^2 = h^2 + 2Rh$

As R >>h, we can ignore h^2

$$\Rightarrow d^2 = 2Rh \text{ and } d = \sqrt{2Rh}$$

Range of TV transmission depends upon the height of the transmitting antenna. Broadcasts are made from tall transmitting antenna.

Note - 1 :

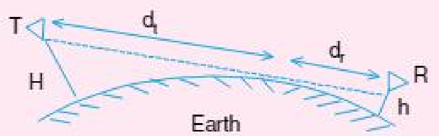


Fig 5.13

If H and h are heights of antenna of transmitter and receiver below the earth horizon as shown in the figure 5.13, the optical horizon of transmitter and receiver are $d_t = \sqrt{2RH}$ and $d_r = \sqrt{2Rh}$, where 'R' is the radius of the earth.

Then the maximum possible separation between T and R to communicate data is

$d = d_t + d_r = \sqrt{2RH} + \sqrt{2Rh}$.

For example, if transmitting antenna height is 225m above the ground level, and the receiving antenna is 16m above the ground level, the total distance is 76 km. Greater distance between antenna's may be obtained by locating them on top of mountains.

Note - 2 :

If the population density is given around the tower region, then the number of persons covered by the tower is product of area covered by the signal on the ground and population density.

i.e., number of persons covered

$= \pi d^2 \times$ Population density.

5.6 MODULATION

Since the energy of a wave is directly proportional to its frequency, low frequency waves cannot travel long distances. For transmission of low frequency waves over long distances, we take help of high frequency waves, called carrier waves. For this low frequency wave is superimposed on the high frequency carrier wave. This process of raising the frequency of the message by superposition over a high frequency wave is known as modulation. Here low frequency wave is called modulating wave and the high frequency wave, carrier wave. The resultant wave is known as modulated carrier wave.

5.6.1 Need for modulation

(i) Audio frequency signals due to their low frequency, have very small energy content and hence a very short range.

(ii) If the low frequency signals are directly transmitted, there will be millions of such signals present in the atmosphere simultaneously. Mutual interference will rander all of them ineffective and they will be indistinguishable from one another.

(iii) If audio frequency signals are transmitted directly into space, the height of antenna required for their efficient radiation would be too high.

For transmitting a wave effectively the height of transmitting antenna should be approximately equal to the wavelength of the wave. For transmitting an audio signal of frequency 20 KHz, the height of antenna needed is

$$\text{Wavelength} = \frac{\text{Velocity of radiowaves}}{\text{frequency(Hz)}}$$

$$\therefore \lambda = \frac{3\times10^8}{20000} = 15000\text{m} = 15\text{km}$$

This size is unthinkable to construct and keep it safe against the wind, rains and storm etc.

Due to the reasons discussed above, modulation is required. It enables a low frequency signal to travel long distances, needs only a small antenna and produces no interference with other carrier waves that are made to propagate at different frequencies.

5.6.2 MODULATION AND ITS NECESSITY

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, is a single frequency sinusoid, but it spreads over a range of frequencies called the signal bandwidth to transmit an electric signal in the audio frequency (AF) range (Baseband signal frequency less than 20 kHz) over a long distance directly. It is clear that low frequency waves, can not travel long distances. Hence, to transmit low frequency wave over long distance, we take the help of high frequency waves called carrier wave. The low frequency wave is superposed over high frequency carrier wave. This process is called the modulation. The low frequency wave is called the modulating wave and the high frequency wave is called the carrier wave, and the resultant wave is called modulated wave. In this section we will discuss in detail about modulation. What is it ? What is the need of modulation or how modulation is done etc.

5.6.3 MIXING UP SIGNALS FROM DIFFERENT TRANSMITTERS

Transmitting base band signals directly is more practical in nature. Many people are talking at same time (or) many transmitters are transmitting base band information signals simultaneously. These signals are mixed up and there is not simple way to distinguish between them. By using communication at high frequencies and allotting a band of frequencies to each message signal for its transmission. So there is need for translating the original low frequency base band message signal into high frequency wave before transmission such that the translated signal continues to possess the information contained in the original signal. For this purse high frequency signal called carrier wave is used the process of mixing signals is called modulation.

A sinusoidal carrier wave can be represented as $C(t) = A_c \sin(\omega_c t + \phi)$, where C(t) is signal strength (voltage (or) current), A_c = amplitude; ω_c = Angular frequency & ϕ is initial phase of carrier wave.

In the process of modulation any of three parameters A_c, ω_c and ϕ of the carrier wave can be controlled by the message (or) information signal. This results three types of modulation. (i) Amplitude modulation (AM) (ii) Frequency modulation (FM) (iii) Phase modulation.

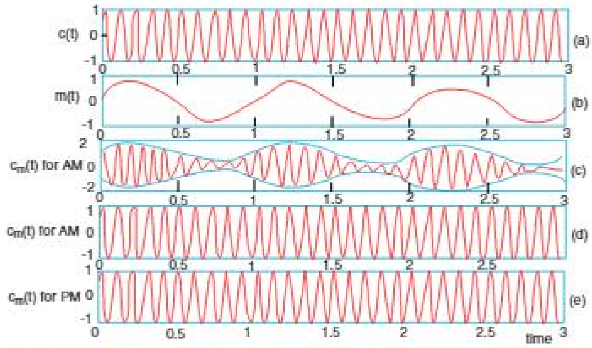


Fig 5.14 Modulation of a carrier wave : (a) sinusoidal carrier wave; (b) a modulating signal; (c) amplitude modulation; (d) frequency modulation; and (e) phase modulation

The significant characteristics of pulse are pulse amplitude, pulse duration (or) pulse width and pulse position (denoting the time of rise (or) fall of the pulse amplitude) 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).

5.7 TYPES OF MODULATION

Modulation means to change. It changes some characteristic of carrier wave in accordance with the intensity of the signal. The equation of a sinusoidal carrier wave may be represented (electric vector) as $e_c = E_c \sin(\omega_c t + \phi)$ (or) $e_c = E_c \sin(2\pi f_c t + \phi)$

where E_c is the amplitude, f_c is the frequency and ϕ is the phase of the wave. Thus the carrier wave has three parameters to be varied leading to the following three types of modulation.

5.7.1 AMPLITUDE MODULATION (AM)

In amplitude modulation, the amplitude (voltage) of a carrier signal is varied in accordance with the intensity of the signal to be transmitted while there is no change in frequency and phase of the carrier wave. Here the peak amplitude of a high frequency sinusoidal carrier wave is varied in proportion to the instantaneous amplitude of the modulating wave. Greater the amplitude of modulating wave greater are the fluctuations in the amplitude of the modulated carrier wave.

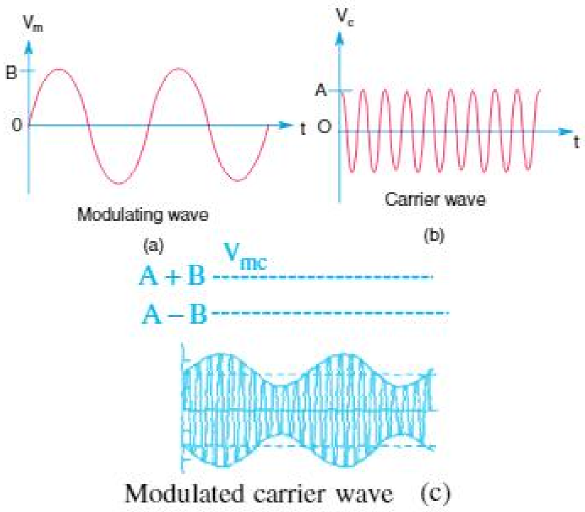


Fig 5.15

Fig 5.15 shows graphically the principle of amplitude modulation. It may be seen that the amplitude of both positive and negative half cycles of the carrier wave vary in accordance with the instantaneous amplitude of the modulating wave.

When the modulating signal increases in the positive sense, the amplitude of the modulated wave also increases but during the negative half cycle of signal, the amplitude of modulated carrier wave decreases. Thus the rate of fluctuations in the amplitude of modulated wave depends on the frequency of modulating wave.

The ratio of amplitude change of carrier wave to the amplitude of normal carrier wave is called modulation factor (or) modulation index (m). It determines the strength and quality of transmitted signal. In India amplitude modulation is used in radio broadcasting and for picture signal transmission in television, while frequency modulation is used for sound signal transmission in TV.

$$m = \frac{\text{Amplitude change of carrier wave}}{\text{Amplitude of normal carrier wave}} \text{ (or)}$$

$$m = \frac{\text{maximum value of signal wave}}{\text{maximum value of carrier wave}} = \frac{B}{A}$$

It is generally expressed in percentage

$$\therefore \text{ Percentage of modulation } = \frac{B}{A} \times 100$$

Example :

$$m = \frac{(A+B)-(A-B)}{(A+B)+(A-B)} \times 100 = \frac{B}{A} \times 100$$

(i) $A = 1, B = 0.5, \; m = \frac{0.5}{1} \times 100 = 50\%$

(ii) If $A = 1, B = 1, \; m = \frac{1}{1} \times 100 = 100\%$

(iii) $A = 0.5, B = 1, \; m = \frac{1}{0.5} \times 100 = 200\%$

Modulation with index $m > 1$ or more than 100% is said to be over modulation. Actually if modulation index exceeds 100% it produces several distortion and interference in the transmitter output. Hence modulation index should never exceed 100%. Greater the value of m, the stronger and clearer will be the signal. If the instantaneous voltage of carrier wave is

$e_c = E_c \sin \omega_c t = E_c \sin 2\pi f_c t$ and the instataneous voltage of modulating wave (signal) is

$$e_s = E_s \sin \omega_s t = E_s \sin 2\pi f_s t,$$

$\therefore$ The amplitude of modulated wave is

$$E = E_c \sin \omega_c t + \frac{mE_c}{2} \cos(\omega_c - \omega_s)t - \frac{mE_c}{2} \cos(\omega_c + \omega_s)t$$

It may be concluded that modulated wave is the sum of three sinusoidal waves.

(i) First having amplitude E_c and frequency f_c

(ii) Second having amplitude $\frac{mE_c}{2}$ and frequency $(f_c - f_s)$.

(iii) Third having amplitude $\frac{mE_c}{2}$ and frequency $(f_c + f_s)$.

Therefore the process of modulation does not change original frequency f_c but processes two new frequencies $(f_c + f_s)$ and $(f_c - f_s)$ which are called upper side band and lower side band frequencies.

The difference between upper side band frequency and lower side band frequency is called band width or channel width.

$\therefore$ Band width $= 2 \times f_s$

The power carried by the carrier wave is

$P_c = (E_c)^2_{r.m.s} / R = E_c^{\ 2} / 2R$ and that by each side band is

$$P_{SB} = \frac{\left(\frac{mE_c}{\sqrt{2}}\right)^2}{2R} = \frac{m^2 E_c^{\ 2}}{4R}$$

where R is the resistance of the antenna.

$\therefore$ The total power carried by the modulated wave is $P_t = P_c + P_{SB}$

$$P_t = \frac{E_c^{\ 2}}{2R}\left(1 + \frac{m^2}{2}\right); \quad P_t = P_c\left(1 + \frac{m^2}{2}\right)$$

Therefore, the fraction of total power carried by side bands $\frac{P_{SB}}{P_T} = \frac{m^2}{2 + m^2}$. Hence the useful power is in the side bands which depends upon the value of modulation factor m. Greater the value of m greater is useful power carried by the side bands.

5.7.2 PRODUCTION AND DETECTION OF AM WAVE

The block diagram of a simple modulator for obtaining AM signal is as shown in Fig 5.16(a). Here modulating signal $E_s \sin \omega_s t$ is added to the carrier signal $E_c \sin \omega_c t$ to produce the signal E(t). The signal E(t) is passed through a square law device which is non-linear and produces output G(t). The signal G(t) consists of both AC and DC, which is passed through a band pass filter. Here the DC component will be rejected and the output will be an AM wave retaining frequencies ω_c, $(\omega_c - \omega_s)$ and $(\omega_c + \omega_s)$. The modulated signal cannot be transmitted directly. A power amplifier is used to provide necessary power and the modulated signal is then fed to an antenna of proper size as shown in Fig 5.16 (b).

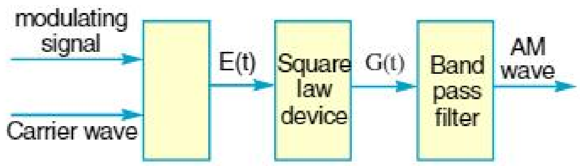


Fig 5.16 (a)

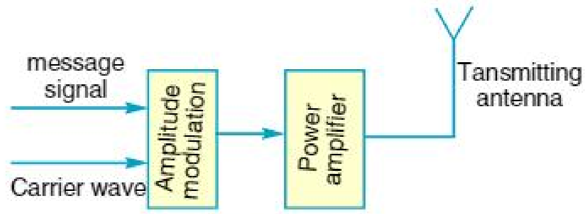


Fig 5.16 (b)

The transmitted message while propagating through channel, gets attenuated. So signal strength will be lost. So, the receiving antenna is followed by an amplifier and a detector. The carrier frequency is usually changed to a lower frequency which is called intermediate frequency (IF) stage preceeding the detection. As the detected signal may not be strong enough, it is to be amplified. A block diagram of receiver is as shown in Fig. 5.16(c).

The recovery of modulating signal from the modulated carrier wave is called detection. The modulated signal is passed through a rectifier. Later it is passed through an envelope detector (usually a simple RC circuit). The block diagram of this recovery will be as shown in Fig 5.16(d).

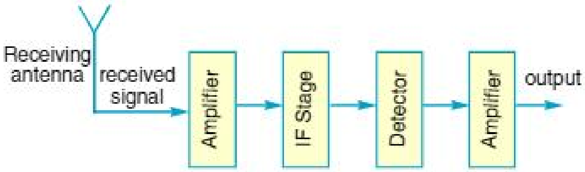


Fig 5.16 (c)

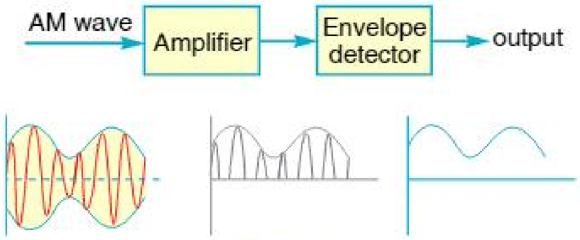


Fig 5.16 (d)

5.7.3 FREQUENCY MODULATION (FM)

Here the frequency of the carrier wave is changed in accordance with the intensity of the signal while the amplitude and phase of the carrier wave remain unchanged. The amount by which the carrier frequency is varied from its unmodulated value is called the deviation.

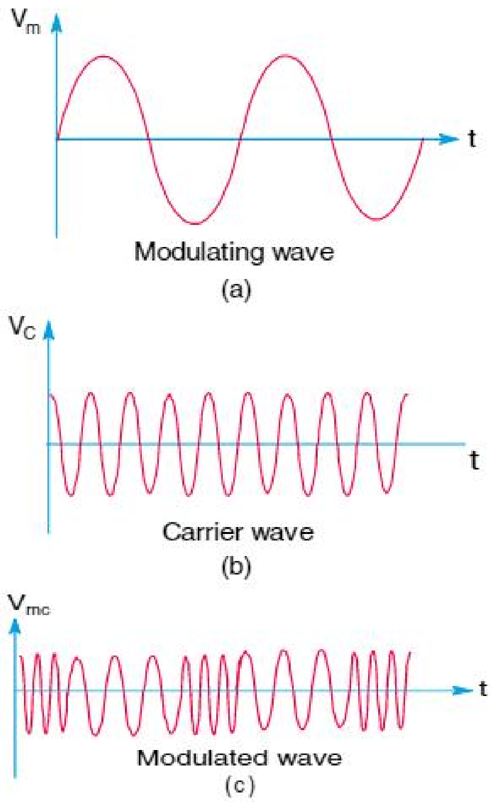


Fig 5.17

Note : In phase modulation (P M) the phase of the carrier wave is changed while the amplitude and frequency remain unchanged.

Example-5.1

An audio signal given by $e_S = 15\sin 2\pi(2000t)$ modulates a carrier wave given by $e_C = 60\sin 2\pi(100{,}000)t$. Calculate (a) the percentage modulation (b) frequency spectrum of the modulated wave.

Solution :

a) Signal Amplitude, B = 15, Carrier amplitude,

$A = 60$

$$m = \frac{B}{A} = \frac{15}{60} = 0.25$$

$\therefore$ Percentage modulation $= 0.25 \times 100 = 25\%$

b) By comparing the given equations of signal and carrier with their standard form

$e_S = E_S \sin\omega_S t = E_S \sin 2\pi f_S t$ and

$e_C = E_C \sin\omega_C t = E_C \sin 2\pi f_C t$

we have signal frequency f_S = 2000 Hz and carrier frequency f_C = 100, 000 HZ

The frequencies present in modulated wave

i) $f_C = 100{,}000\text{Hz} = 100\text{kHz}$

ii) $f_C - f_S = 100{,}000 - 2000 = 98\text{kHz}$

iii) $f_C + f_S = 100\text{kHz} + 2\text{kHz} = 102\text{kHz}$

Therefore, frequency spectrum of modulated wave extends from 98 kHz to 102 kHz (This is called band width.)

Example-5.2

The antenna current of an AM transmitter is 8A when only the carrier is sent but it increases to 8.93 A when the carrier is modulated. Find percentage modulation.

Solution :

The modulated or total power carried by AM wave

$$P_T = P_C\left(1 + \frac{m^2}{2}\right)$$

It R is load resistance, I_m is the current when carrier is modulated and I_C the current when unmodulated, then

$$\frac{P_T}{P_C} = \frac{I_m^2 R}{I_C^2 R} \qquad \therefore 1 + \frac{m^2}{2} = \frac{I_m^2 R}{I_C^2 R}$$

Given $I_m = 8.93\text{A}, I_c = 8\text{A}$

$$\therefore\ m^2 = 2\left[\left(\frac{8.93}{8.0}\right)^2 - 1\right] \qquad \therefore\ m = 0.7$$

Therefore, modulation index = 70%

Example-5.3

A sinusoidal carrier voltage of 80 volts amplitude and 1 MHz frequency is amplitude modulated by a sinusoidal voltage of frequency 5kHz producing 50% modulation. Calculate the amplitude and frequency of lower and upper side bands.

Solution :

Amplitude of both LSB and USB are equal and given by

$$=\frac{mEc}{2}=\frac{0.5\times 80}{2}=20\text{volts}$$

Now frequency of LSB = $f_C - f_S = (1000-5)\text{kHz}$

$= 995$ kHz

Frequency of USB = $f_C - f_S = (1000+5)\text{kHz}$

$= 1005$ kHz

Example-5.4

The load current in the transmitting antenna of an unmodulated AM transmitter is 6 Amp. What will be the antenna current when modulation is 60%.

Solution :

Total power carried by AM wave

$$P_T = P_C\left(1+\frac{m^2}{2}\right) \qquad \text{........ (1)}$$

where P_C is the power of carrier component and m is the modulation factor. If R is the resistance, I_m the antenna load current when modulation is 60% and I_C is the antenna load current when unmodulated, then

$$\frac{P_T}{P_C}=\frac{I_m^2 R}{I_C^2 R} \qquad \therefore 1+\frac{m^2}{2}=\frac{I_m^2}{I_C^2} \quad \text{using (1)}$$

$$\text{or } I_m = I_C\sqrt{\left\{\left(1+\frac{m^2}{2}\right)\right\}}$$

Given $I_C = 6\text{Amp}, m = 0.6$

$$I_m = 6\left[1+\frac{(0.6)^2}{2}\right]^{1/2}$$

$$= 6[1.086] = 6.52\text{Amp}.$$

Example-5.5

A carrier wave of 1000 W is subjected to 100% modulation. Calculate (i) Power of modulated wave, (ii) Power in USB, (iii) Power in LSB.

Solution :

i) Total power of modulated wave

$$P_T = P_C\left(1+\frac{m^2}{2}\right) = 1000\left(1+\frac{1^2}{2}\right) = 1500 \text{ watt}$$

ii) Power in USB $=\frac{1}{2}P_{SB}$

where power carried by side bands is given by Amplitude Modulation and Detection

$$P_{SB} = P_C\left(\frac{m^2}{2}\right) = 1000\left(\frac{1^2}{2}\right) = 500 \text{ watt}$$

$$P_{USB} = \frac{1}{2}P_{SB} = \frac{1}{2}\times 500 = 250 \text{ watt}$$

iii) Since power in LSB = Power in USB

$P_{LSB} = P_{USB} = 250$ watt

EXERCISE

SHORT ANSWER QUESTIONS

1. Draw the block diagram of a generalised communication system and explain it briefly.
2. What is a ground wave? When is it used for communication?
3. What are sky waves? Explain their propagation briefly.
4. Explain space wave propagation briefly.
5. Explain the ground wave and sky wave propagation of radio waves.
6. Explain the need for modulation.
7. Explain different type of modulation. Define modulation index.
8. How amplitude modulation is achieved.
9. What are the limitations of A.M.?
10. What do you understand by modulation factor? Give its importance.

VERY SHORT ANSWER QUESTIONS

1. What are the basic blocks of communication system?
2. What are different modes of propagation of radio waves?
3. Why are radiowaves attennuated?
4. What is sky wave propagation?
5. Mention the various parts of the ionosphere.
6. How can sky waves be used for long distance transmission?
7. It is necessary to use satillites for long distance TV transmission Why?
8. What is frequency modulation?
9. What is phase modulation?
10. Long distance radio broadcasts use short-wave band. Why?

11. Mention the frequency range of speech signals.
12. What should be the band width of frequencies required for transmission of pictures using video signals?
13. What is "world wide web" (www)?
14. Which type of communication is employed in Mobile Phones?

PROBLEMS

LEVEL - I

1. A transmitting antenna is at a height of 40 m and the receiving antenna is at a height of 60m. Find the maximum distance between them for satisfactory communication. **[Ans: 50 km]**
2. A T V transmitting antenna is 80m tall. If the receiving antenna is on the ground. Find the service area. **[Ans: 1024 π sq km]**
3. If height of a transmitting tower increases by 21% find the percentage increase in area to be covered. **[Ans: 21%]**
4. A.T.V tower is 150 m tall. If the area around the tower has a population density of 750 km^2, find the population covered by the broadcasting tower ($R_e = 6400$ km). **[Ans: 4.5×10^6]**

LEVEL - II

1. A modulated carrier wave has maximum and minimum amplitudes of 1500 mV and 500 mV. Calculate the value of percentage modulation. **[Ans : 50%]**
2. An audio signal given by 10 sin2 π (1500)t is superimposed on a carrier of 50 sin2 π (1,00,000)t by AM technique. Determine
   (a) Modulation index
   (b) % of modulation
   (c) Frequency of audio signal and carrier
   (d) Frequency spectrum of modulated wave.
   [Ans: (a) 0.2 ; (b) 20% ; (c) f_s= 1500Hz, f_c= 1,00,000Hz; (d) 98.5 to 101.5 kHz]
3. An AM wave is represented by the expression $V = 5(1 + 0.6 \cos 6280\, t) \sin 211 \times 10^4\, t$ volts. What are minimum and maximum amplitude of AM wave? **[Ans: 2V, 8V]**
4. Draw amplitude modulated wave forms for
   (i) 50% modulation
   (ii) 100% modulation
   (iii) 150% modulation
5. The total power contain of an AM wave is 2.64 kW at a modulation factor of 80%. Calculate
   (i) Power of carrier wave
   (ii) Power in USB
   (iii) Power of LSB
   [Ans: (i) 2000 watt ; (ii) 320 watt ; (iii) 320 watt]
6. Show that for 100% modulation, a single side-band contains 1/6th of the total power radiated by the transmitter.
7. What is the power developed by an amplitude modulated wave in a load of 100Ω when the peak voltage of the carrier is 100 volts and the modulation factor is 0.4? **[Ans: 54 watt]**
8. How much audio power is necessary to fully modulate a 100kW carrier if the modulation system is 75% efficient? **[Ans: 66.7 kW]**
9. A transmitter transmits a power of 10 KW when modulation is 50%. Find power of carrier wave ? **[Ans: 8.89 KW]**
10. A transmitter supplies 9 KW to the aerial when modulated to 40%. Find the power radiated? **[Ans: 9.72 KW]**
11. The total power content of an AM wave is 900 W. For 100% modulation find the power transmitted by each side band? **[Ans: 150 W]**
12. The maximum peak to peak voltage of an AM wave is 24 mV and the minimum peak voltage is 8 mV. Find the modulation factor. **[Ans: 50%]**
13. An antenna current of an AM broadcast transmitter modulated by 50% is 11A. Find the carrier current. **[Ans: 10.35 A]**