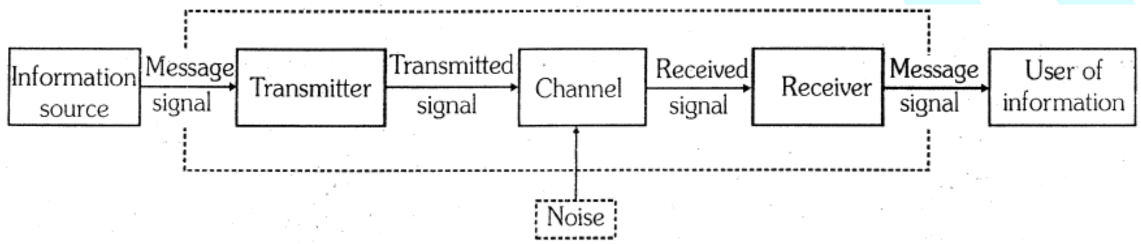
Principles of Communication

INTRODUCTION

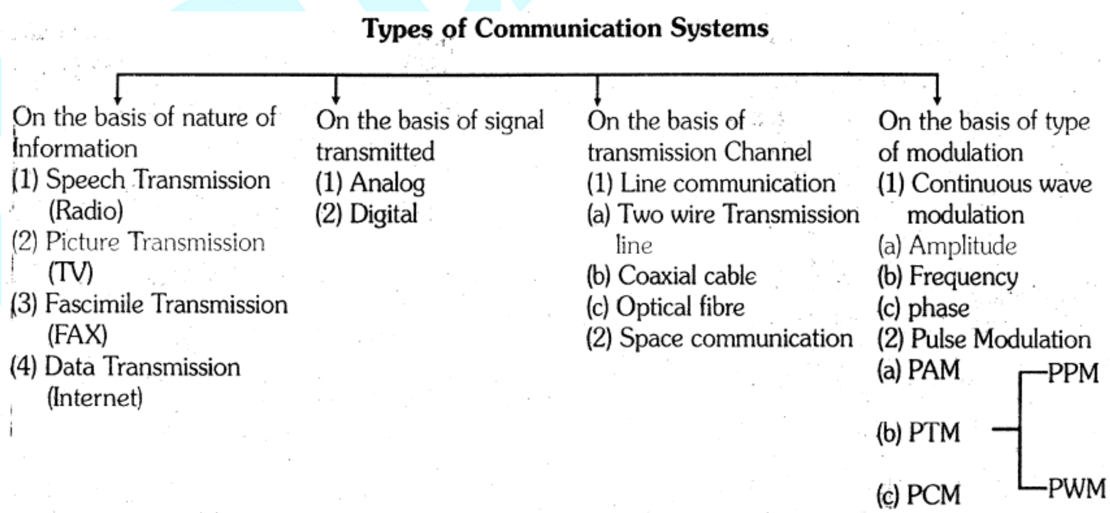
Communication means transmission of information. Everyone experiences the need to impart or receive Information continuously in the surrounding and for this , we speak, listen, send message by a messenger, use coded signalling methods through smoke or flags or beating of drum etc. and these days we are using telephones, TV, radio, satellite communication etc. The aim of this chapter is to introduce the concepts of communication namely the mode of communication, the need for modulation, production and detection of amplitude modulation.

PROPAGATION OF LIGHT

Every communication system has three essential elements –
(i) transmitter (ii) medium/ channel (iii) receiver



Transmitter converts the message signal into an electric signal and transmits through channel. The receiver receives the transmitted signal and reconstructs the original message signal to the end user. There are two basic modes of communication: (i) point-to-point and (ii) broadcast.
In point-to-point communication mode, communication takes place over a link between a single transmitter and a single receiver as in telephony. In the broadcast mode, there are a large number of receivers corresponding to a single transmitter. Radio and television are most common examples of broadcast mode of communication. However the communication system can be classified as follows :



Basic terminology Used in Electronic Communication systems :

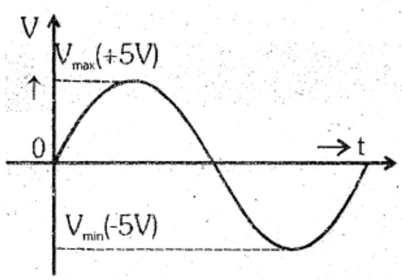
(i) **Transducer.** Transducer is the device that converts one form of energy into another. Microphone, photo detectors and piezoelectric sensors are types of transducer.

(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.

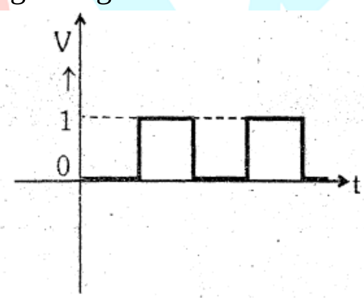
Signals are two types :

(a) **Analog Signal :**
A continuously varying signal (Voltage or Current) is called an analog signal. A decimal 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) **Transmitter :** A transmitter processes the incoming message signal 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 signals while propagating through a medium. It is like damping of oscillations.

(vii) **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 systems.

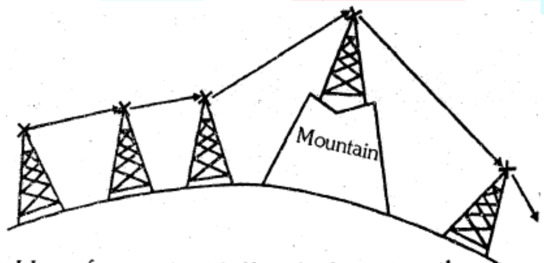
(viii) **Range :** It is the largest distance between the source and the destination upto which the signal gets received with sufficient strength.

(ix) **Bandwidth :** It is 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 distance. So, at the transmitter end, 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.

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

(xii) **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

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 difference 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 splitted 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. This implies that the infinite band width is required to reproduce the rectangular waves. However, for practical purposes, higher harmonics are neglected for limiting the bandwidth.

Band width of Transmission Medium

Different types of transmission media offer different band width in which some of are listed below :

Frequency Bands			
1	Wire (most common : Coaxial Cable)	750 MHz (Bandwidth)	Normally operated below 18 GHz
2	Free space (radio waves)	Few hundred kHz to GHz	
	(i) Standard AM broadcast	540kHz – 1600 kHz	
	(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 ratio	896–901 MHz 840–935 MHz	Mobile to base Station Base station to mobile
	(v) Satellite Communication	5.925–6.425 GHz 3.7 – 4.2 GHz	Uplinking Downlinking
3	Optical communication using fibres	1THz–1000 THz (microwaves–ultra violet)	One single optical fibre offers bandwidth > 100 GHz

PROPAGATION OF ELECTROMAGNETIC WAVES

In case of radio waves communication, an antenna at the transmitter radiates the electromagnetic waves (em waves). The em waves travel through the space and reach the receiving antenna at the other end. As the em wave travels away from the transmitter, their strength keeps on decreasing. Many factors influence the propagation of em waves including the path they follow. The composition of the earth's atmosphere also plays a vital role in the propagation of em waves, as summarised below.

Layers of atmosphere and their interaction with the propagating em waves

	Atmospheric stratum (layer)	Height over earth's surface (approx)	Exists during	Frequencies most likely affected
1.	Troposphere	10 km	Day and night	VHF (upto several GHz)
2.	Ionosphere			
	(i) D (part of stratosphere)	65–75 km	Day only	Reflects LF, absorbs MF & HF to some degree
	(ii) E (part of stratosphere)	100 km	Day only	Helps surface waves, reflects HF
	(iii) F_1 (Part of Mesosphere)	170–190 km	Daytime, merges with F_2 at night	Partially absorbs HF waves yet allowing them to reach F_2
	(iv) F_2 (Thermosphere)	300 km at night, 250–400 km during daytime	Day and night	yet allowing them to reach F_2 Efficiently reflects HF waves particularly at night

Ground Wave Propagation :

(a) The radio waves which travel 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.

(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 or 3 MHz only.

(d) The ground wave propagation is generally used for brand 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

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). Electromagnetic waves of frequencies higher than 30 MHz penetrate the ionosphere and escape.

(c) The highest frequency of radiowaves 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 $f_c = 9\,(N_{max})^{1/2}$, where N is the number density of electron/m^3.

Space wave propagation :

(a) The space waves are the radiowaves 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 heights of transmitting and receiving antenna.

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

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

where h_R is the height of receiving antenna.

MODULATION

* It is a process by which any electrical signal called input / baseband or modulating signal, is mounted onto another signal of high frequency which is known as carrier signal.
* It is defined as the process by which some characteristic (called parameter) of carrier signal is varied in accordance with the instantaneous value of the baseband signal.
* The signal which results from this process is known as modulated signal.

Need for Modulation :

(i) To avoid interference :

If many modulating signals travel directly through the same transmission channel, they will interfere with each other and result in distortion.

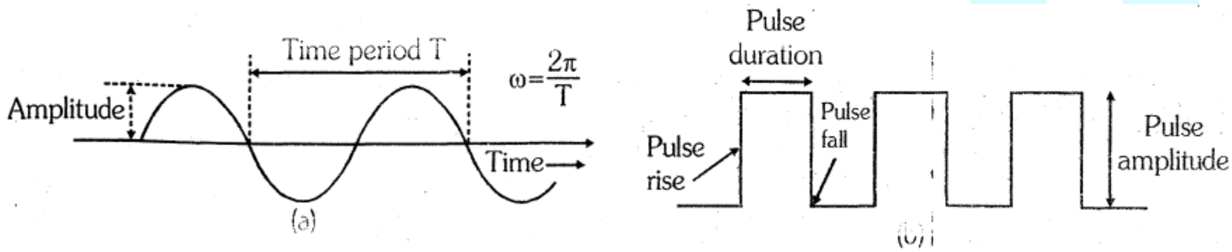
(ii) To design antennas of practicable size :

The minimum height of antenna (not of antenna tower) should be $\lambda/4$ where λ is wavelength of modulating signal. This minimum size becomes impracticable because the frequency of the modulating signal can be upto 5 kHz which corresponding 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. $(l/\lambda)^2$. For a good transmission, we need high powers and hence this also points out to the need of using high frequency transmission.

The above discussion suggests that there is a need for translating the original low frequency baseband message signal into high frequency wave before transmission. In doing so, we take the help of a high frequency signal, which we already know now, is 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.

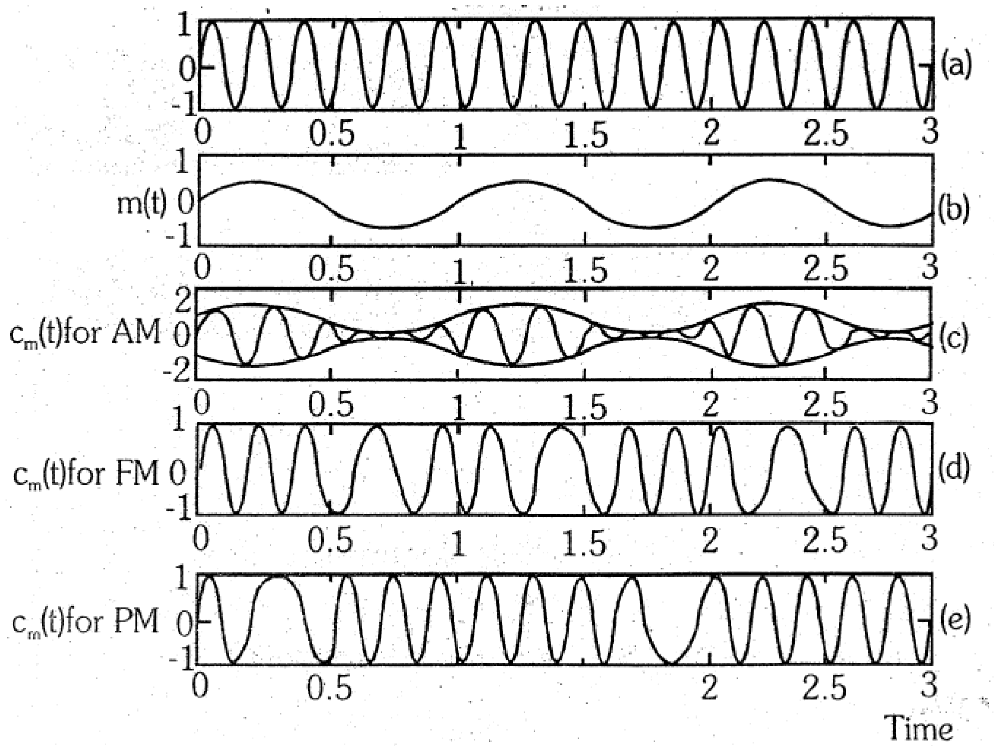


Carrier wave : sinusoidal

A sinusoidal carrier wave can be represented as

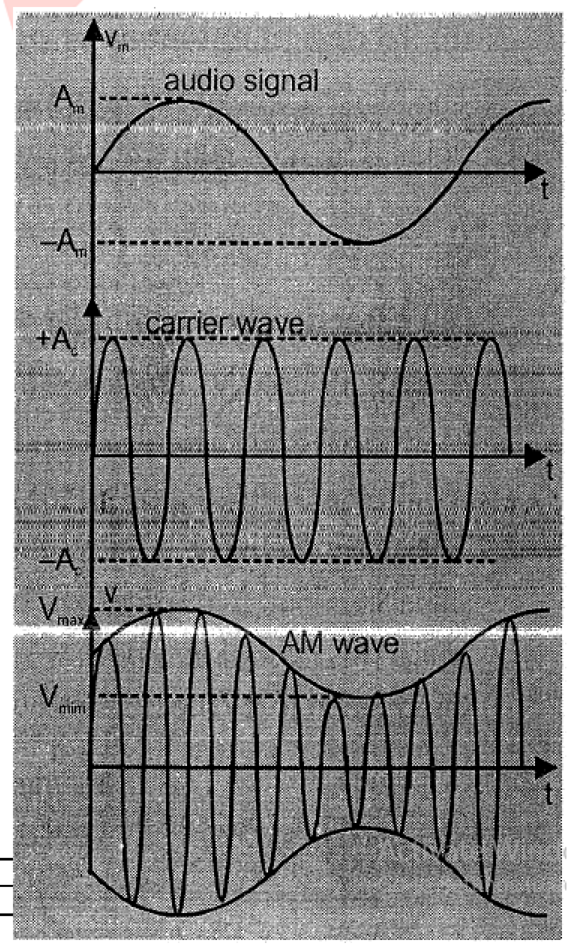
$c(t) = A_C \sin (w_c t + \phi)$

where c(t) is the signal strength (voltage or current), A_C is the amplitude, ω_c (= $2\pi f_c$) is the angular frequency and ϕ is the initial phase of the carrier wave. Thus, modulation can be affected by varying, any of three parameters, viz A_c, ω_c and ϕ, of the carrier wave can as per the parameter of 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 figure.



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

AMPLITUDE MODULATION



In amplitude modulation the amplitude of the carrier is varies in accordance with the information signals. 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

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

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

Note that the modulated signal now contains the message signal & it can be written as :

Here **$\mu = A_m/A_c$ is the modulation index**

$V_{max.} = A_c + A_m$ (See figure)

$V_{min.} = A_c - A_m$

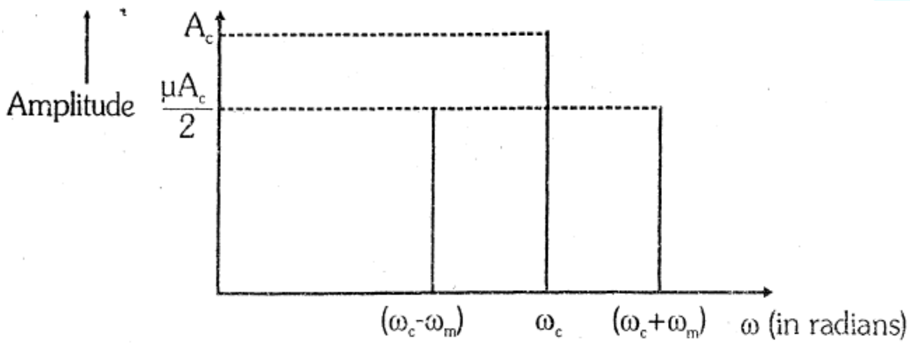
$$\Rightarrow \quad \mu = \frac{V_{max.} - V_{min}}{V_{max.} + V_{min}}$$

In practice, μ is kept ≤ 1 to avoid distortion.

Using the trigonometric relation sinA sinB = $\frac{1}{2}[\cos(A-B)-\cos(A+B)]$, we can write c_m (t) of eq. (2) as

$$c_m(t) = A_c \sin\omega_c t + \frac{\mu A_c}{2}\cos(\omega_c - \omega_m)t - \frac{\mu A_c}{2}\cos(\omega_c + \omega_m)t \qquad \ldots(3)$$

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, know as side bands. The frequency spectrum of the amplitude modulated signal is shown in figure.



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

Power in AM Wave :-

Power of carrier wave : $P_c = \frac{V_c^2}{2R}$; R → RESISTANCE OF ANTENNA IN WHICH POWER IS DISSIPATED.

Total power of sidebands : $P_{sidebands} = \left(\frac{\mu V_C}{2\sqrt{2}}\right)^2 \frac{1}{R} + \left(\frac{\mu V_C}{2\sqrt{2}}\right)^2 \frac{1}{R} = \frac{\mu^2 V_c^2}{4R} = \frac{\mu^2}{2} P_c$

Total power of AM wave : $\frac{V_c^2}{2R} + \frac{\mu^2}{2}\frac{V_c^2}{2R} = P_c\left(1+\frac{\mu^2}{2}\right)$

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

Note : – When $\mu = 0$; Power carries by sidebands = 0

When $\mu = \frac{1}{2}$; Power carried carried by sidebands = $\frac{1}{9}P_{total} \equiv \frac{100}{9} = 11.1\%$

When $\mu = 1$; Power carried by sidebands = $\frac{1}{3}P_{total} = 33.3\%$

Limitation of Amplitude Modulation :-

(i) **Noisy reception :–** In case of AM the reception is mostly noisy. This is because a radio receiver cannot distinguish between amplitude variations that represent noise and these contain the desired signal.

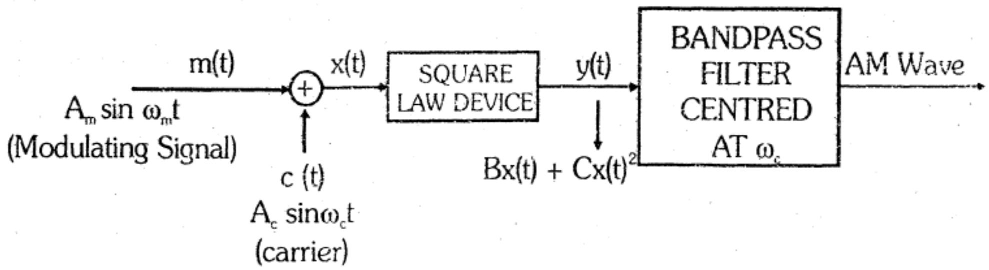
(ii) **Low Efficiency :–** In AM, useful power is in the sidebands as they contain the signal. But this sideband power is quite low and hence the efficiency of AM system is low.

(iii) **Small Operating Range :–** The transmitting range of AM transmitters is small due to low efficiency. Hence we cannot transmit message over large distances.

(iv) **Lack of audio quality** (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.



Here the modulating signal A_m sin ω_mt is added to the carrier signal A_c sin ω_c t to produce the signal x (t). This signal x (t) = A_m sin ω_m t + A_c sin ω_ct is passed through a square law device which is a non–linear device which produces an output

$y(t) = B\,x(t) + Cx^2(t)$ ....(4)

where Band C are constants. Thus,

$y(t) = BA_m \sin\omega_m t + BA_c \sin \omega_c t + C[A_m^2 \sin^2 \omega_m t + A_c^2 \sin^2 \omega_c t + 2A_m A_c \sin\omega_m t \sin \omega_c t]$ ...(5)

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

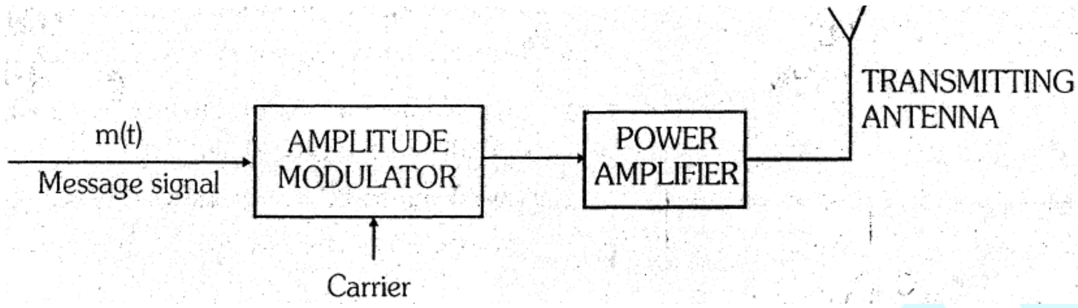
$$\frac{CA_m^2}{2} + A_c^2 - \frac{CA_m^2}{2}\cos 2\omega_m t - \frac{CA_c^2}{2}\cos 2\omega_c t$$

$+ CA_m A_c \cos(\omega_c - \omega_m)t - CA_m A_c \cos(\omega_c + \omega_m)t$ ...(6)

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

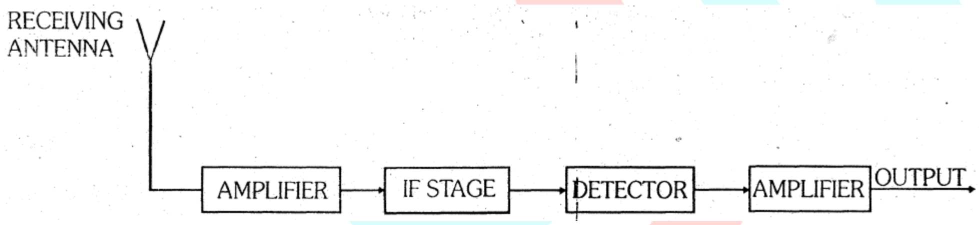
In equation (6), there is a dc term C/2 $(A_m^2 + A_c^2)$ and sinusoids of frequencies ω_m, $2\omega_m$, $\omega_c - \omega_m$ and $\omega_c + \omega_m$. The output of the band pass filter therefore is of the same fom1 as equation (3) and is therefore an AM wave.

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.

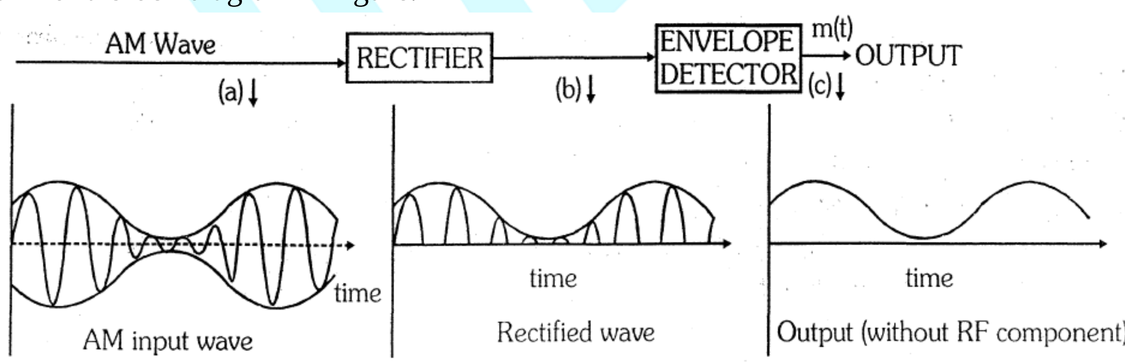


Detection of Amplitude Modulated Wave :

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 in required to be amplitude. A block diagram of a typical receiver is shown in figure.



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.



The modulated signal of the form given in (a) of above figure 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).

SPECIAL POINTS

The internet

Students must be quite familiar with internet these days. The information provided by different these days. The information provided by different bodies all over the world is centralised at one place which is then used by anyone having a computer and internet facility. It's main uses are :

(a) E–mail (b) File transfer (c) WWW – World Wide Web
(d) E–commerce (e) Chatting

Facsimile (FAX) :

FAX is abbreviation for facsimile which means exact reproduction. A fax machine sends a printed document or a photograph besides speech, music or coded data from one place to another by data communication system which, as we already know, consists of three elements.

Transmitter Transmission channel Receiver

It scans the contents of a document (as an image, not test) to create electronic signals. These signals are then sent to the destination (another FAX machine) in an orderly manner using telephone lines. At the destination, the signals are reconverted into a replica of the original document.

Mobile telephony

The concept of mobile telephony was developed first in 1970's and it was fully implemented in the following decade. The central concept of this system is to divide serice area into a suitable number of cells centred on an office called MTSO (Mobile Telephone Switching Office). Each cell contains a low–power transmitter called a base station and castomers. When a mobile receiver crosses the coverage area of one base station, it is necessary for the mobile user to be transferred to another base station. This procedure is called handover or handoff. This process is carried out very rapidly, to the extent that the consumer does not even notice it. Mobile telephones operate typically in the UHF range of frequencies (about 800–950 MHz).

Remote Sensing :

Remote sensing is a technique which is used to observe and measure the characteristic of the object at a distance. The remote sensing instruments acquire information about an object without being in physical contact with it. Remote sensing depends upon, forming an image by gathering, focusing and recording reflected light of sun from the object, the energy emitted by the object itself or reflected radar waves which were emitted by satellites. Thus the working of remote sensing is related with measuring some kind of energy that is emitted, transmitted or reflected from an object in order to determine certain physical properties (like location, size, colour, nature, temperature etc.) of the object.

Application of Remote Sensing

(1) Weather forecasting
(2) Climatology (monitoring of climate change)
(3) Oceanography (Sea surface temperature changes)
(4) Coastal studies (Sewage, industrial waste and pollution monitering)
(5) Water surveys

(6) Geological surveys
(7) Agriculture and forestry surveys
(8) Urban and land surveys

Line Communication :

(1) Two wire transmission lines
(i) Parallel wire lines,
(ii) Twisted pair wire lines
(iii) Co-axial wire lines
(2) Coaxial cables
(3) Optical fibres

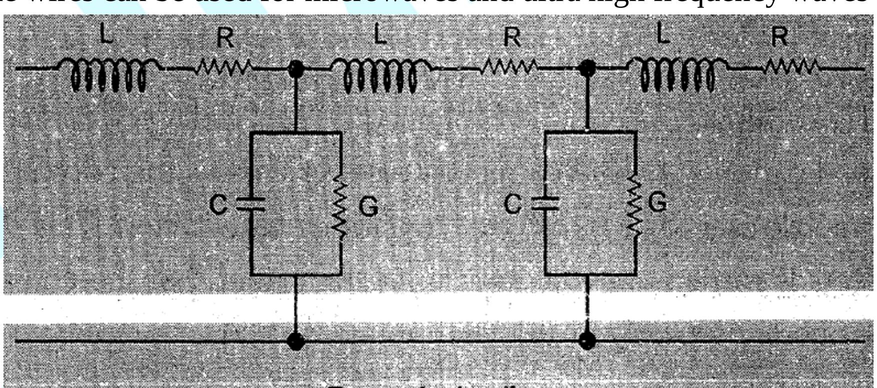
Parallel wire lines : They are commonly used for connecting an antenna with the T.V. receiver set and am in the form of a black ribon as shown in fig. The conductors used in such wires can be flexible or rigid. Spacing between the conductors and insulation between them are chosen according to the power to be handled. Parallel wire lines are also called balanced lines.

Twisted pair wire lines : Consist of two insulated copper wires twisted around each other almost regularly as shown in fig. Twisting helps in minimising electrical interference. They are often used to connected telephone systems. The advantages of twisted pair wire lines are that their cost is low and they can transmit both, the analog and digital signals. However, over very large distances, the transmitted signals become weak.

Co-axial wire lines : These are often used by. T.V. cable operators to interconnect a transmitter and an earthed antenna.

The essential parts of a co-axial wire line are shown in fig. The inner and outer conductors are separated by low dielectric insulators e.g. polyethylene and teflon. Co-axial line wires can also be gas filled.

Co-axial line wires can be used for microwaves and ultra high frequency waves (≈ GHz).



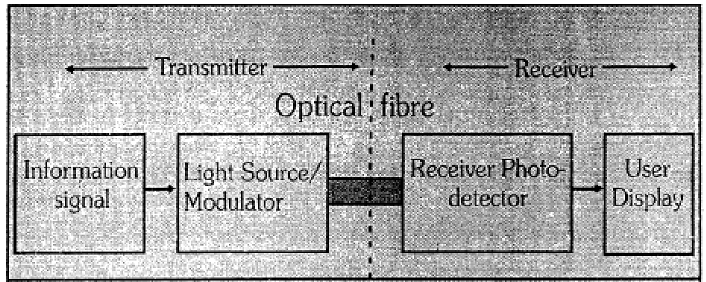
Transmission line

Optical communication :

It is a system of communication by which we transfer the information over any distance from one point to another through optical range of frequencies.

The name implies that the communication is through carrier optical signals. Easily accessible optical frequencies lie in the range 10^{12} to 10^{16} Hz. it is very high as compared to the radio frequencies (10^6 to 10^8 Hz) or microwaves (10^9 to 10^{11} Hz). We have already pointed out that a large number of channels and higher bandwidth transmission is possible with high frequency carriers.

There are some inherent advantages of optical communication over the conventional two–wire or cable electronic communication system. Some of these are :



Point–to–Point optical communication link

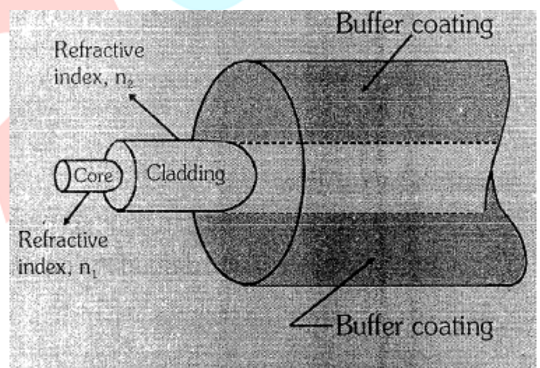
(i) Wide channel bandwidth and large channel carrying capacity because of the use of higher frequencies ~ 10^{14} Hz as compared to the electronic communication links.

(ii) Low transmission losses : In optical fibres losses per km are less.

(iii) Signal security and not accesible to interference. You will see that the optical signal is confined to the inside of fibre and cannot be tempered easily. So secret information like banking, defence etc. is more secure.

Optical fibre :

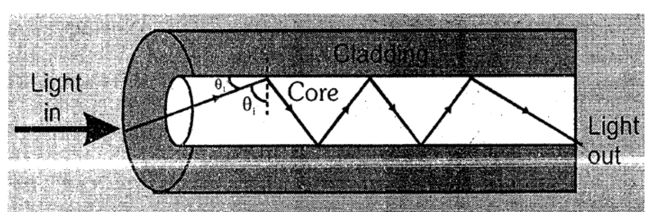
(i) **Core** of glass/silica/plastic with approximate diameter of 10 to 100 μm with refractive index n_1. The plastic core has high loss and hence glass cores are preferred.



A schematic diagram of single optical fibre structure

(ii) The core is surrounded by a glass or a plastic cladding with refractive index n_2 such that $n_2 < n_1$. The difference $\Delta n = n_1 - n_2$ is typically very small of the order of 10^{-3}. The refractive index of cladding can change either abruptly from n_1 to n_2 (a step–index fibre, (fig) or gradually (graded–index fibre)

(iii) For providing safety and strength, a buffer plastic coating or housing encapsulates the core–cladding of the fibres.



Ray confinement in actual optic fibre

There are three types of optical fibre configurations.

(a) Single–mode step–index fibre.

(b) Multi–mode step–index fibre.

(c) Multi–mode graded–index fibre.

Light Source –

Light Emitting Diode (LED) and diode lasers are preferred as light source in optical fibre communication due to following reason.

(1) These gives adequate power.

(2) Diode laser light is monochromatic and coherent source of light.

(3) Compatible in size with optical fibre.

(4) Light from LED and diode laser can be varied or modulated by varying the applied voltage so we can easily transmit the information.

(5) Thermal stability.

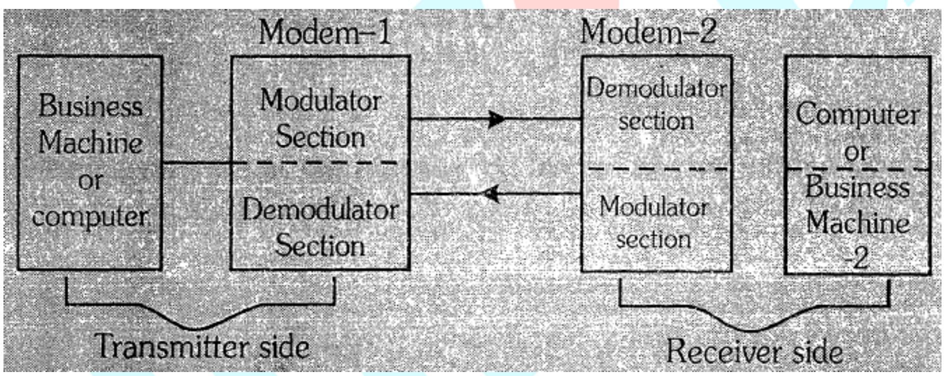
Photo Detector–Photodiodes are used as photo detector in optical fibre due to following reasons –

(1) Size compatible with fibre (2) High sensitivity at desired wave length

(3) High response time for fast speed data transmission

MODEM (Modulator + Demodulator) :–

It is a interfacing device which is connected in between digital device and analog communication channel which convert analog signal into digital or digital signal into analog.



<u>GOLDEN KEY POINTS</u>

- **Fax** is the electronic reproduction of a document at a distance.
- In order to have the communication link over the entire globe of earth, at least three geo–stationary satellite are required, which are 120° apart from each other.
- A **modem** is a device that can connect one computer to another across ordinary telephone lines. Basically a modem is modulating and demodulating device.
- **Remote sensing** is a technique which is used to observe and measure the characteristics of the object at a distance. (it is done through satellite)
- Amplitude modulating is employed in India for radio transmission.
- The earth's atmosphere is transparent to visible radiations but absorbs most of the infrared radiations **(green house effect)** but blocks the passage of ultraviolet radiations.
- **Ozone layer** [in stratosphere] absorbs major portion of ultraviolet radiations coming from sun.
- **Intel sat satellite** is used for intercontinental communication and it works as repeater.
- **Optical fibres** are free from electromagnetic disturbances because there are electrically

insulated.

- The **geostationary satellite** is stationary w.r.t. a place on earth. So the relative angular velocity of geostationary satellite w.r.t. earth is zero.
- Microwaves (freq. 100GHz – 300GHz) have wavelength range of few millimetre. They do not show diffraction effect during propagation in earth's atmosphere. Hence they have a good directional properties.
- If carrier is modulated more than 100% (i.e. $\mu > 1$) then distortions would appear.

ILLUSTRATIONS

Illustrations 1

How many AM broadcast stations can be accomodated in a 100 kHz bandwidth if the highest modulating frequency is 5 kHz.

Solution

Any station being modulated by a 5 kHz signal will produce an upper side frequency 5 kHz above its carrier and the lower side frequency 5 kHz below its carrier, thereby requiring a bandwidth of 10 kHz.

Number of stations accomodated = $\dfrac{\text{Total bandwidth}}{\text{Bandwidth per station}} = \dfrac{100}{10} = 10$

Illustration 2

A separate high freq. wave (i.e. carrier wave) is needed in modulation why?

Solution

This is because we cannot change any of the characteristics (amplitude, frequency or phase) of the audio signal as this would change the message to be communicated. So keeping the audio signal same, the amplitude of freq. or phase of the high freq. carrier wave is modified in accordance with the modulating (i.e. audio signal) signal.

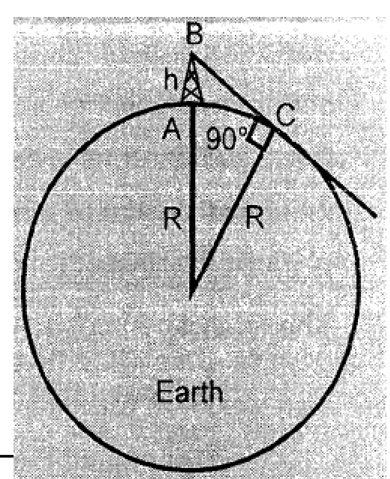
Illustration 3

TV transmission tower at Kota has a height of 80 m. Radius of earth is 6400 km.

(i) What is its coverage range.

(ii) How much population is covered by transmitting if the average population density around the tower is 2000 km^{-2} ?

Solution



(Note : h = 80 m <<< R = 6400 km)

Here BC ≈ AC (∵ h <<< R)

$BC = \sqrt{(R+h)^2 - R^2}$

$BC = \sqrt{2hR + h^2} \approx \sqrt{2hR}$

Coverage range = AC ≈ BC = $\sqrt{2hR}$

(i) Coverage range = $\sqrt{2 \times 80 \times 6400 \times 10^3}$ = 32000 m = 32 km.

(ii) Coverage area = $\pi(AC)^2 = \pi(32)^2$ km^2

Population covered = $2000 \times \pi \times (32)^2 = 6430720$

Illustration 4

Find the critical frequency for reflection of radio waves from a layer in ionosphere of earth's atmosphere having ions density $9 \times 10^{12}\ m^{-3}$.

Solution

Critical frequency $f_c = 9\sqrt{N_{max.}} = 9\sqrt{9\times10^{12}} = 27$ MHz

Illustration 5

A message signal of frequency 10 kHz and peak voltage of 10 volts is used to modulate a carrier of frequency 1 MHz and peak voltage of 20 volts. Determine (a) modulation index, (b) the side bands produced.

Solution

(a) Modulation index = 10/20 = 0.5

(b) The side bands are at (1000 + 10 kHz) = 1010 kHz and (1000 – 10 kHz) = 990 kHz.

Illustration 6

A modulated carrier wave has maximum and minimum amplitudes of 800 mV and 200 mV. What is the percentage modulation?

Solution

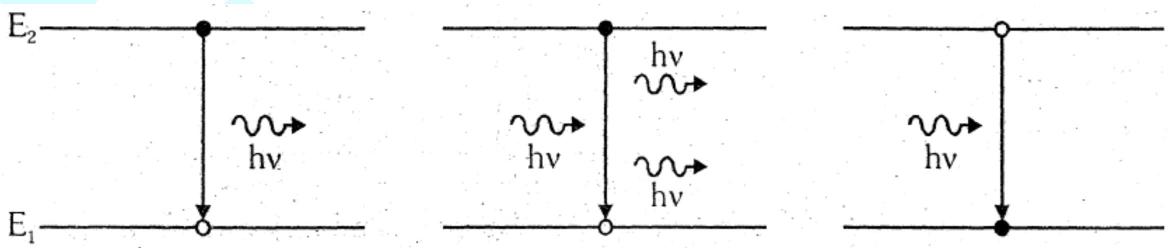
$$\text{Percentage modulation} = \left(\frac{A_{max} - A_{min}}{A_{max} + A_{min}}\right)\times100 = \left(\frac{800-200}{800+200}\right)\times100 = \frac{600}{1000}\times100 = 60\%$$

LASER :

The name laser is acronyn for Light Amplification by Stimulated Emission of Radiation. Before discussing the process we look into some terms encountered.

(i) **Spontaneous and Stimulated radiative transitions :** At atom, a molecule or a solid or a nucleus in an excited state may fall to a lower energy State spontaneously. The system may also be induced or stimulated into a lower level and in each case a photon of frequency given by $\Delta E = h\nu$, is emitted, where DE = $E_2 - E_1$.

If the spontaneously emitted photon strikes the same excited atom, it can stimulate the atom to make the



(a) Spontaneous emission (b) Induced emission (c) Induced absorption transition sooner to the lower state. This phenomenon is called **stimulated emission**. It can be seen that besides original photon, there is also a second one of the same frequency as a result of the atoms transition. And these two photons are exactly in phase and they are moving in the same direction. That means that in the case induced emission of monochromatic **coherent radiation**. Spontaneous emission occur at random, therefore phase is distributed randomly resulting in **incoherent radiations**.

Resultant coherent intensity = N^2 × source intensity

Resultant incoherent intensity = N × source intensity

For large no. of atoms the coherent stimulated radiation may have intense radiations, which is the basic principle of laser.

(ii) **Metastable state** : Spontaneous de–excitation is statistical in nature, with excited states having a mean life time of the order of 10^{-8} s. Some levels have significantly longer lifetimes, ranging upto miliseconds to minutes or even hours. These levels are inhibited and slowed in de–exciting because their quantum numbers differ from those of available lower levels. These relatively stable state are called **metastable states**. The transitions from metastable states to lower states occur by stimulated emission rather than spontaneously.

(iii) **Population inversion :** When a solid is in thermal equilibrium, the number N_2 of atoms in an excited state E_2 is less than the number N_1 of atoms in lower energy state.

The natural population of atoms in thermal equilibrium at any temperature T (in K) is given by the Boltzmann distribution

$$N = Ce^{-\frac{E}{kT}}$$

where N is number of atoms in the state with energy E. For two states 1 and 2, the ratio of atoms in two states is

$$\frac{N_2}{N_1} = e^{\left(\frac{E_1 - E_2}{kT}\right)}$$

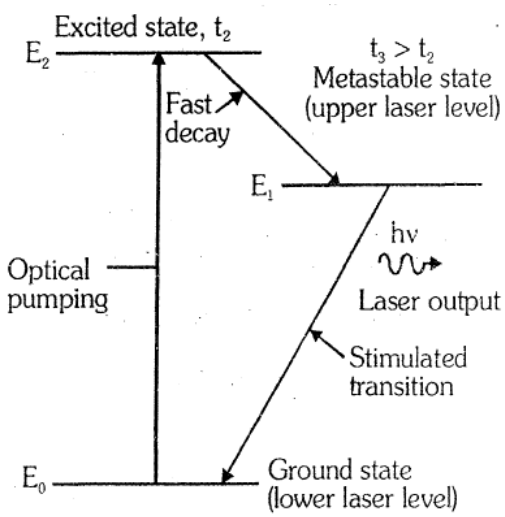
most atoms are in ground state unless temperature is very high.

When the no. of atoms I n excited level is increased at the expense of population of the ground level, the situation is called **Population inversion**. In this condition, emission of photons will dominate over absorption, hence the system will not be in thermal equilibrium. If radiation is passed through such material it will result in more photons of frequency v = $(E_2 - E_1)/h$ than the incident radiation, resulting in coherent **amplification**.

(iv) Radiation energy is supplied either continuously or in burst to excite atoms from the ground state E_0 to a higher energy state E_2. The process of excitation with intense illumination is called **optical pumping**.

(v) **Laser action :** The essential features are :

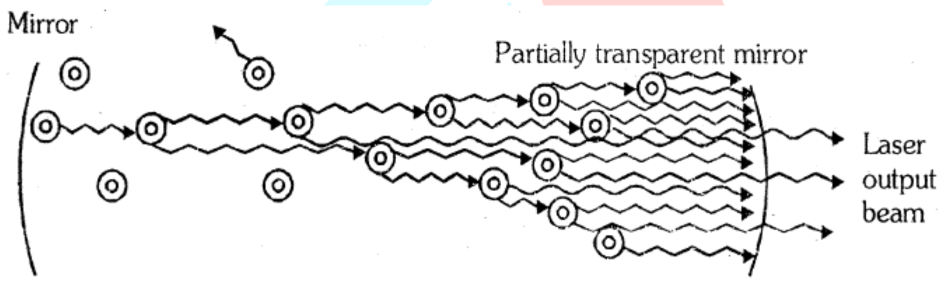
(i) An energy source is required for producing pulsed or continuous population inversion by optical pumping. In helium–neon laser then energy source is an electrical discharge that imparts energy by electron atoms collisions. In the case of the ruby crystal laser the population inversion is produced by intense flash lamps.



Three-level Laser

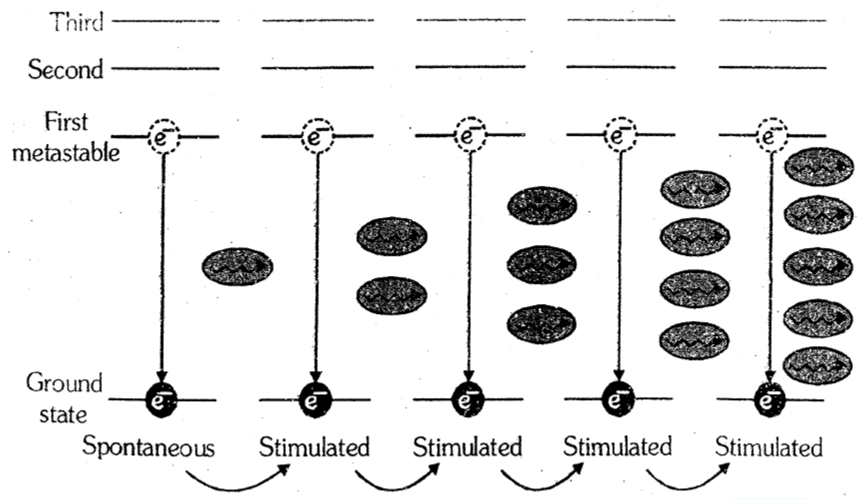
(ii) The medium must have at least three energy levels a ground state, a metastable state, with a long life time t_3; and a high energy pump state. The population inversion can be achieved if $t_3 > t_2$ as shown in the figure. The population inversion may result in coherent amplification as discussed earlier.

(iii) Figure shows schematic diagram of a laser.



The laser material is placed in a long narrow tube at the end of which are two mirrors, one of which is partially transparent. One of the atom is shown at the left hand. If the emitted photon strikes another atom in the excited state, it stimulates this atom to emit a photon of the same frequency, moving in the same direction and in phase with it. These photons are reflected from mirrors and as they move in the opposite direction, they continue to simulate more atoms to emit photons. A small percentage of photons pass through partially transparent mirrors to constitute narrow external laser beam.

Some photons are emitted at angle to the axis, in a well designed laser the spreading of beam is limited by diffraction, so the angular spread is ; λ/a, where a is the diameter of the end mirror. The diffraction spreading is very small. The light instead of spreading out in space is directed in a pencil beam.


Third
Second
First
metastable
Ground
state
Spontaneous
Stimulated
Stimulated
Stimulated
Stimulated