Chapter 28

# Communication



The term communication refers to the transmitting, receiving and processing of information by electronic means.

## Basic Communication System

A basic communication system consists of an information source, a transmitter, a link and a receiver.

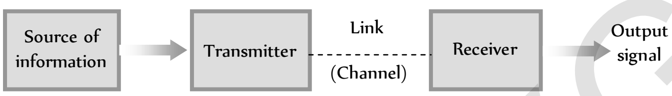



Fig. 28.1

(1) **Information :** The idea/message that is to be conveyed is information. The message may be individual one or a set of messages. The message may be a symbol, code, group of words or any pre decided unit.

(2) **Transmitter :** In radio transmission, the transmitter consists of a transducer, modulator, amplifier and transmitting anteena.

Transducer : Converts sound signals into electric signal.

Modulator : Mixing of audio electric signal with high frequency radio wave.

Amplifier : Boosting the power of modulated signal.

Anteena : Signal is radiated in the space with the aid of an anteena.

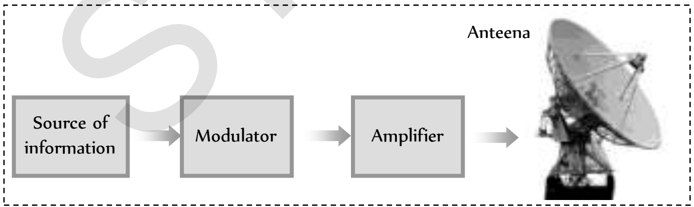



**Fig. 28.2 :** Transmitter

(3) **Communication channel :** The function of communication channel is to carry the modulated signal from transmitter to receiver. The communication channel is also called transmission medium or link.

The term channel refers to the frequency range allocated to a particular service or transmission.

**Table 28.1 : Different channels**

| Type of communication | Channels or links |
|---|---|
| Radio communication | Free space |
| Telephony and Telegraphy communication | Transmission line |
| Optical communication | Optical fibre |

(4) **Receiver :** The receiver consists of

Pickup anteena : To pick the signal

Demodulator : To separate out the audio signal from the modulated signal

Amplifier : To boost up the weak audio signal

Transducer : To convert back audio signal in the form of electrical pulses into sound waves.

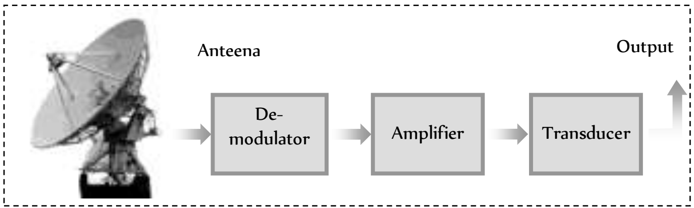



**Fig. 28.3 :** Receiver

## Types of Communication System

Communication systems can be classified according to the nature of information or mode of transmission or types of transmission channel.

(1) **According to the nature of information source**

(i) Speech transmission

(ii) Picture transmission

(iii) **Facsimile transmission (FAX) :** This involves exact reproduction of a document or picture which are static.

(2) **According to the mode of transmission**

(i) **Analog communication :** The communication system, which make use of analog signals are called analog communication system.

**Table 28.2 : Few analog communication system**

| System | Specification |
|---|---|
| Telegraphy | Message in the form of codes are sent. |
| Television broadcast | Both sound as well as pictures are sent. |
| Telephony | It sends voice signal from one place to another by means of wire. |
| Radar | It means radio detection and ranging. It is used for determining the distance and direction of objects using microwave. |
| Teleprinting | Message can be typed and telegraphed to distant receivers |

(ii) **Digital communication :** In this system digital signals are used.

**Table 28.3 : Few digital communication system**

| System | Specification |
|---|---|
| Facsimile transmission (FAX) | This involves exact reproduction of a document or picture which are static |
| Mobile phone | Such telephones are also called cellular phones, because they operate within a network of radio cells. |
| E-mail | the message sent via a computer network are called e-mail |
| Tele conferencing | It is a system in which persons sitting at coloured television screens. See and talk to each other via a computer communication network. |
| Communication satellite | Used to relay radio and television programmers. |
| Global positioning system (GPS) | It is a navigation system based on a network of earth orbiting satellites. The users can find their positions within an accuracy of 100 $m$ by receiving. |

(3) **According to the transmission channel**

(i) Line communication (ii) Space communication

(4) **According to the type of modulation**

(i) Amplitude modulation (AM)

(ii) Frequency modulation (FM)

(iii) Phase modulation (PM)

(iv) Pulse amplitude modulation (PAM)

(v) Pulse time modulation (PTM)

(vi) Pulse code modulation (PCM)

## Analog and Digital Signals

In communication system, a signal means a time varying electrical signal containing informations.

(1) **Analog signals :** It is a continuous wave form which changes smoothly over time.

(i) Such signals can be easily generated from the source of information by using an appropriate transducer *e.g.* pressure variations in the sound waves can be converted into corresponding current or voltage pulses with the help of a microphone.

(ii) A simple analog signal is represented by a sine wave

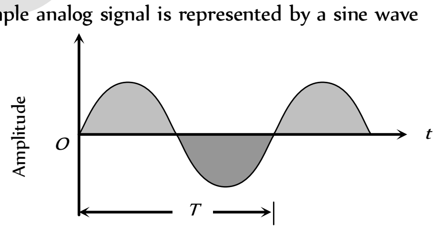



Fig. 28.4

(iii) The frequency of analog signals associated with speed or music varies over a range between 20 $Hz$ to 20 $KHz$.

(iv) The range over which the frequencies of a signal vary is called band width.

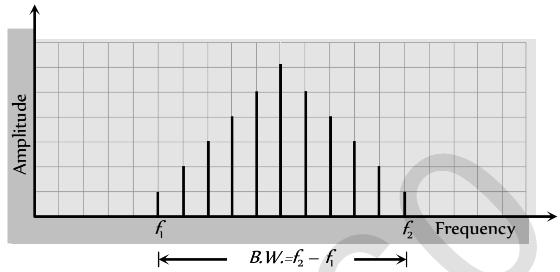



Fig. 28.5

(v) The term base band designates the band of frequencies representing the signal supplied by the source of information.

(vi) A signal consist of two or more waves of different frequencies is known as a complex analog signal.

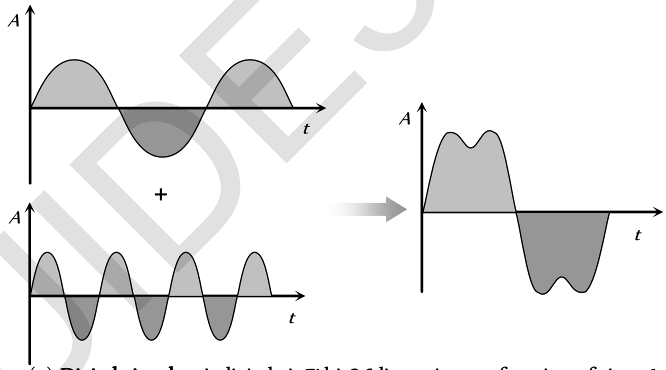



Fig. 28.6

(2) **Digital signals :** A digital signal is a discontinuous function of time. It has only two voltage level *i.e.* either low (0) or high (1).

Either of 0 and 1 is known as bit. A group of bit is called byte.

A byte comprising of 2 bits can give on the four code combination *i.e.* 00, 01, 10 and 11.

The number of code combination increase with number of bits in a byte is given by $N = 2^x$, where $x$ = number of bits in a byte.

The number of binary digits (bits) per second, which describe a digital signal is called it's bit rate. Bit rate is expressed in bits per second (bps).

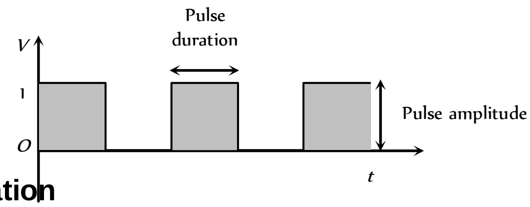


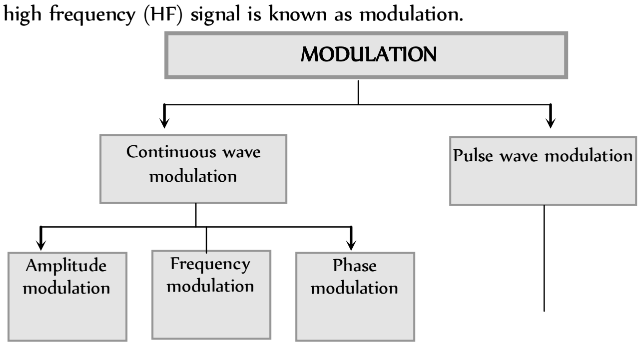

Fig. 28.7

## Modulation

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

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

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



(4) **Need for modulation :** The sound wave (20 *Hz* to 20 *KHz*) cannot be transmitted directly from one place to another for the following reasons.

(i) **Height of anteena :** For efficient radiation and reception , the height of transmitting and receiving antennas should be comparable to a quarter of wavelength of the frequency used. For 15 *KHz* it is 5000 *m* (too large) and for 1 *MHz* it is 75 *m*.

The energy radiated from an anteena is practically zero, when the frequency of the signal to be transmitted is below 15 *Hz*.

(ii) **Detecting signals :** All audible signals are in the range of 20 *Hz* to 20 *KHz* so the signals from all sources remains heavily mixed up in air. It will be very difficult to differentiate or detect the broadcast signal at the receiving station.

Thus modulation is necessary for a low frequency signal. When it is to be sent to a distant place so that the information may not die out in the way it self as well as for the proper identification of a signal and to keep the height of anteena small also

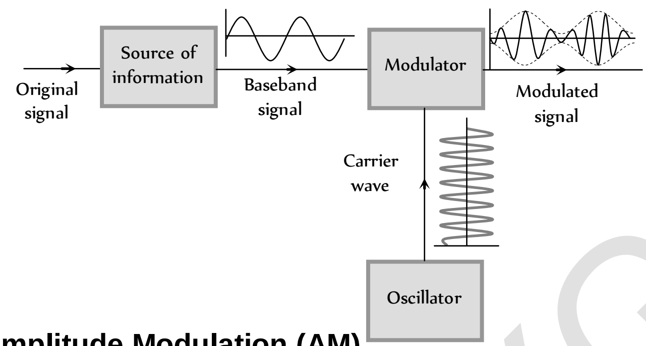


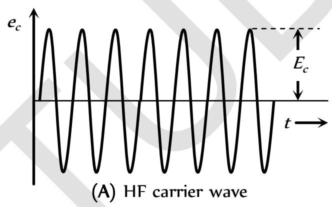

Fig. 28.9

## Amplitude Modulation (AM)

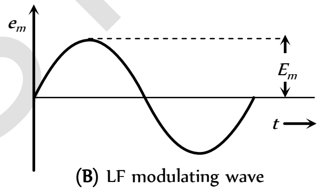
The process of changing the amplitude of a carrier wave in accordance with the amplitude of the audio frequency (AF) signal is known as amplitude modulation (AM).

In AM frequency of the carrier wave remains unchanged.

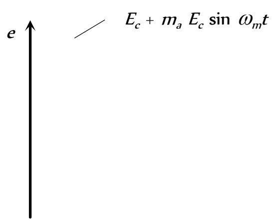
The amplitude of modulated wave is varied in accordance with the amplitude of modulating wave.




(A) HF carrier wave




(B) LF modulating wave




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

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

where $k$ = A factor which determines the maximum change in the amplitude for a given amplitude $E_m$ of the modulating signal. If $k$ = 1 then

$$m_a = \frac{E_m}{E_c} = \frac{E_{\max} - E_{\min}}{E_{\max} + E_{\min}}$$

If a carrier wave is modulated by several sine waves the total modulated index $m_t$ is given by $m_t = \sqrt{m_1^2 + m_2^2 + m_3^2 + ........}$

(2) **Voltage equation for AM wave :** Suppose voltage equations for carrier wave and modulating wave are $e_c = E_c \cos \omega_c t$ and $e_m = E_m \sin \omega_m t = mE_c \sin \omega_m t$

where $e_c$ = Instantaneous voltage of carrier wave, $E_c$ = Amplitude of carrier wave, $\omega_c = 2\pi f_c =$ Angular velocity at carrier frequency $f_c$, $e_m =$ Instantaneous voltage of modulating, $E_m =$ Amplitude of modulating wave, $\omega_m = 2\pi f_m =$ Angular velocity of modulating frequency $f_m$

Voltage equation for AM wave is

$$e = E \sin \omega_c t = (E_c + e_m) \sin \omega_c t = (E_c + e_m \sin \omega_m t) \sin \omega_c t$$

$$= E_c \sin \omega_c t + \frac{m_a E_c}{2} \cos(\omega_c - \omega_m)t - \frac{m_a E_c}{2} \cos(\omega_c + \omega_m)t$$

The above AM wave indicated that the AM wave is equivalent to summation of three sinusoidal wave, one having amplitude $E_c$ and the other two having amplitude $\frac{m_a E_c}{2}$.

(3) **Side band frequencies and band width in AM wave**

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

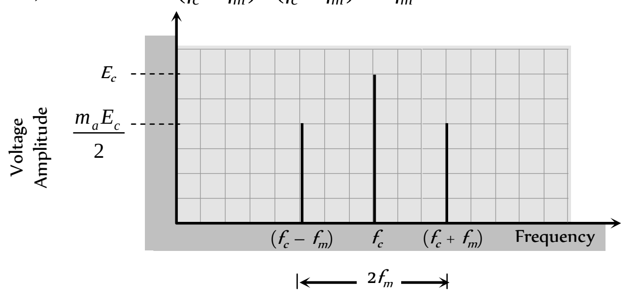
$(f_c + f_m)$ : Upper side band (USB) frequency

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

Side band frequencies are generally close to the carrier frequency.

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

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



(4) **Power in AM waves** : Power dissipated in any circuit $P = \frac{V_{rms}^2}{R}$.

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

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

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

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

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

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

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

(5) **Limitation of amplitude modulation**

(i) Noisy reception (ii) Low efficiency

(iii) Small operating range (iv) Poor audio quality

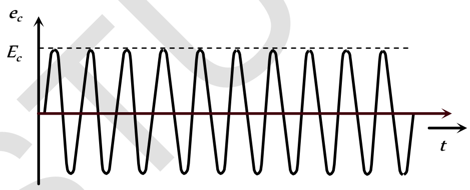
## Frequency Modulation (FM)

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

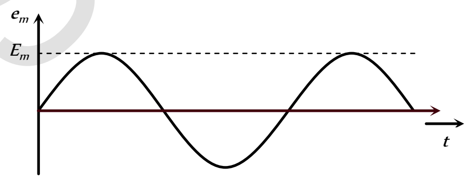
(1) Audio quality of AM transmission is poor. There are need to eliminate amplitude sensitive noise. This is possible if we eliminate amplitude variation. (*i.e.* a need to keep the amplitude of the carrier constant). This is precisely what we do in FM.

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

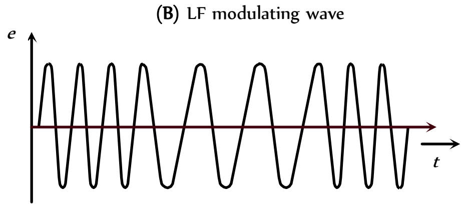
(3) In FM, the total transmitted power remains constant.




(A) HF carrier wave




(B) LF modulating wave




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

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

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

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

*i.e.* $CS = 2 \times \Delta f$

(6) **Frequency modulation index (*m*)** : The ratio of maximum frequency deviation to the modulating frequency is called modulation index.

$$m_f = \frac{\delta}{f_m} = \frac{f_{\max} - f_c}{f_m} = \frac{f_c - f_{\min}}{f_m} = \frac{k_f E_m}{f_m}$$

(7) **Frequency spectrum** : FM side band modulated signal consist of infinite number of side bands whose frequencies are

$$(f_c \pm f_m), (f_c \pm 2f_m), (f_c \pm 3f_m) \ldots\ldots$$

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

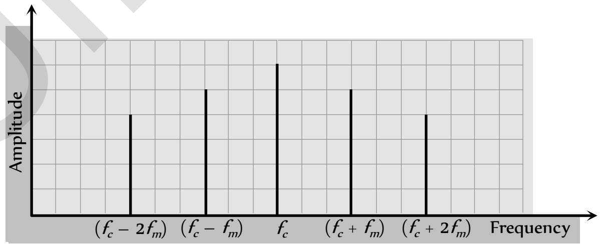



**Fig. 28.13**

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

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

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

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

**Table 28.4 : Range of frequency allotted for FM radio/TV broadcast**

| Type of broadcast | Frequency band |
|---|---|
| FM radio | 88 to 108 *MHz* |
| UHF TV | 47 to 230 *MHz* |
| UHF TV | 470 to 960 *MHz* |

## Pulse Modulation

Here the carrier wave is in the form of pulses.

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

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

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

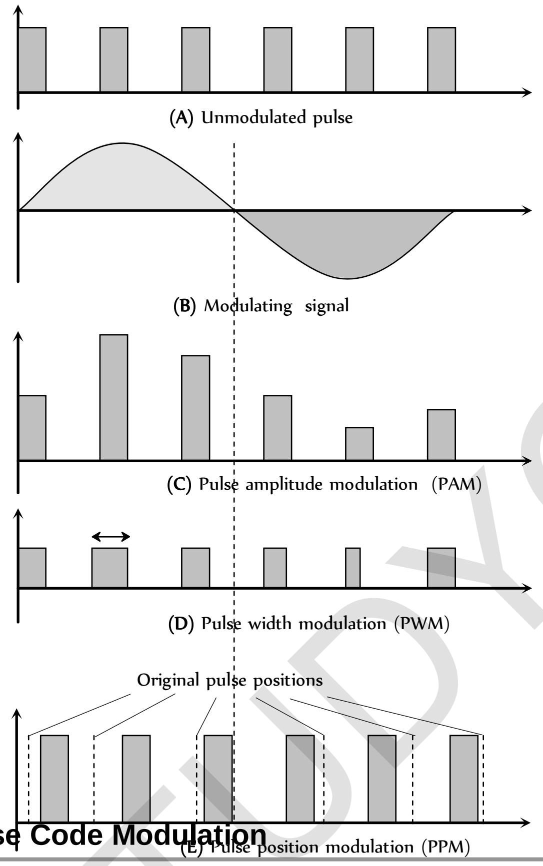



Fig. 28.14

## Pulse Code Modulation

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

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

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

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

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

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

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

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

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

**Table 28.5 : Coding**

| Quantis-ation level | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Binary code | 000 | 001 | 010 | 011 | 100 | 101 | 110 | 111 |

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

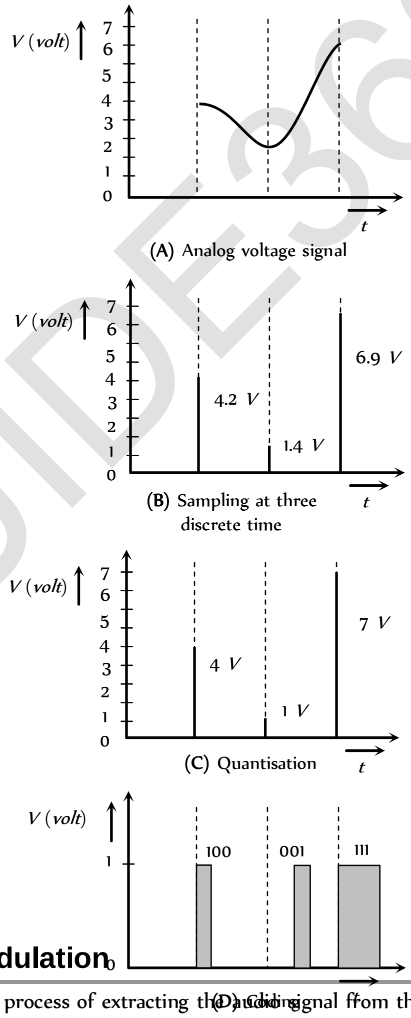



Fig. 28.15

## Demodulation

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

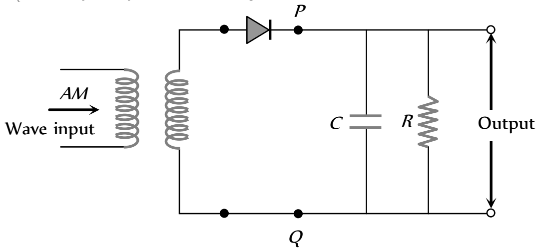
The wireless signals consist of radio frequency (high frequency) carrier wave modulated by audio frequency (low frequency). The diaphragm of a telephone receiver or a loud speaker cannot vibrate with high frequency. So it is necessary to separate the audio frequencies from the radio frequency carrier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

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

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

In the actual circuit the value of $RC$ is chosen such that $\frac{1}{f_c} << RC$ ;

where $f_c$ = frequency of carrier signal.



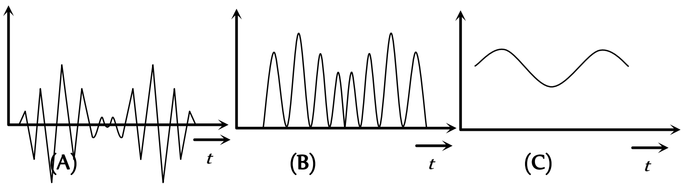




Fig. 28.16

## Data Transmission and Retrieval

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

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

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

**1 :** Presence of carrier of same constant amplitude.

**0 :** Carrier of zero amplitude.

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

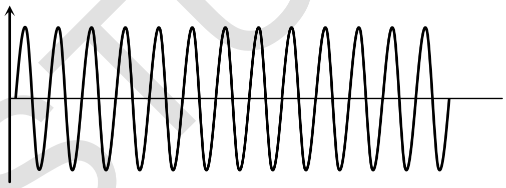
**1 :** Increase in frequency

**0 :** Frequency unaffected

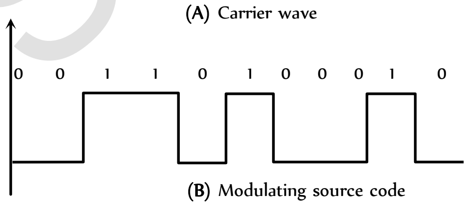
(3) **Phase shift keying (PSK) :** The phase of the carrier wave is changed in accordance with modulating data signal.

**1 :** Phase changed by $\pi$

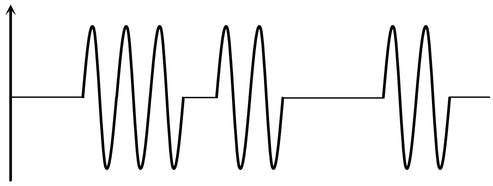
**0 :** Phase remains unchanged.



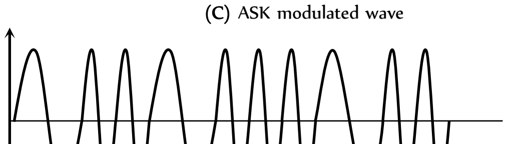
(A) Carrier wave



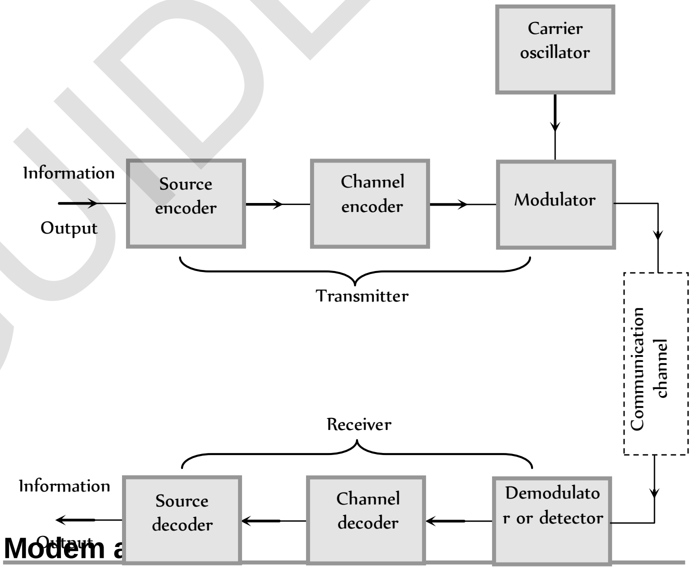

(B) Modulating source code



(C) ASK modulated wave



The analog signal is sampled by the sampler. The sampled pulses are then quantised. The encoder codes the quantised pulses according to the binary codes. After modulating the PCM signal (by ASK, FSK or PSK method) the modulated signal is, then transmitted into free space in the form of bits.




## Modem a

Fig. 28.18

(1) **Modem :** Modems are used to interface two digital sources/receivers.

(i) Word modem has been obtained from the words modulator and demodulator. As the name implies both the functions (modulation) and demodulation) are included in a signal unit.

(ii) Modems are placed at both ends of the communication circuit as shown.

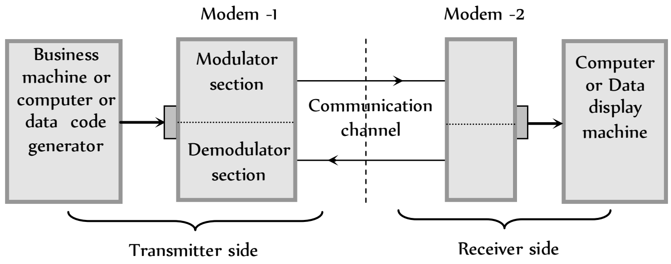



Fig. 28.19

(iii) The modem at the transmitting station changes the digital output from a computer (or any other business machine) to a from (analog signal) which can be easily sent via a communication channel (Telephone line *etc.*). While the receiving modem reverses the process.

(iv) There are three modes of operation of a modem.

(a) Simplex mode : In this mode data is transmitted in only one direction.

(b) Half duplex : In this mode data is transmitted between the transmitter and the receiver in both direction, but only in one direction at a time.

(c) Full duplex : In this mode, the data are transmitted between the transmitter and receiver in both directions at the same time.

**Table 28.6 : Modem data transmission speed**

| Types | Speed in bits per sec and (bps) |
|---|---|
| Low speed modem | 600 bps |
| Medium speed modem | 600 to 2400 bps |
| High speed modem | 2400 to 10,800 bps |

(2) **Fax (Facsimile transmission) :** The electronic reproduction of a document at a distance place is known as facsimile transmission (FAX).

The original written document is converted into transmittable codes at the sending end. These codes are converted back into a copy of the original document at the receiving end.

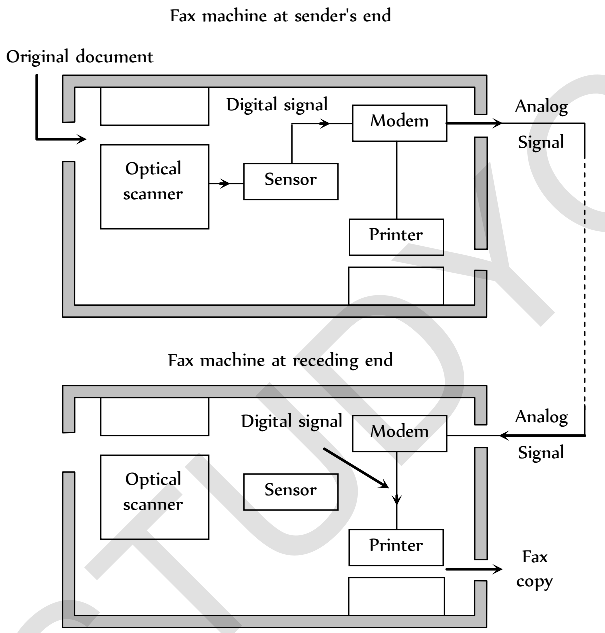



Fig. 28.20

The original written document is put into the machine. A scanner scans the whole document.

The scanned written document is then moved on a glass plate. A beam of light from a given source is projected through the glass and is reflected from the surface of the document.

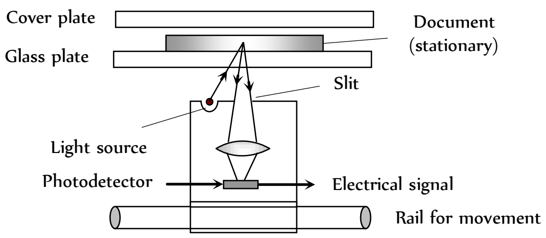



Fig. 28.21

The reflected light is focussed on a device known as photo detector which converts the optical signals (carrying the information regarding the patterns/writings/signatures *etc.*) in to electrical signals.

These electrical signals are then modulated and transmitted on to the telephone lines to the receiving end.

## Space Communication

The communication process utilising the physical space around the earth is termed as space communication.

Electromagnetic waves which are used in Radio, Television and other communication system are radio waves and microwaves.

The radio waves emitted from a transmitter anteena can reach the receiver antenna by the following mode of operation.

+ Ground wave propagation

+ Sky wave propagation.

+ Space wave propagation.

(1) **Ground wave propagation**

(i) In ground wave propagation, radio waves travel along the surface of the earth (following the curvature of earth).

(ii) These waves induce currents in the ground as they propagate due to which some energy is lost.

(iii) The decrease in the value of energy (*i.e.* attenuation) increases with the increase in the frequency of radiowave.

(iv) As the ground wave propagates over the earth, it tilts over more and more due to diffraction. (This is another cause of attenuation of ground wave). After covering some distance, the wave just lie down which means it's death.

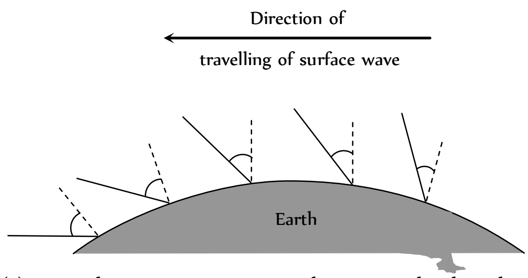


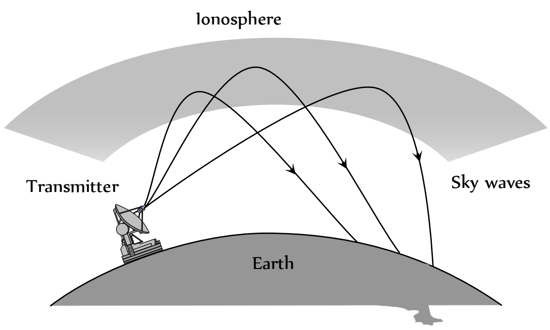

Fig. 28.22

(v) Ground wave propagation can be sustained only at low frequencies (~ 500 *kHz* to 1500 *kHz*) or for radio broadcast at long wavelengths.

(2) **Sky wave propagation**

(i) These are the waves which are reflected back to the earth by ionosphere.

Ionosphere is a layer of atmosphere having charged particles, ions and electrons and extended above 80 *km* – 300 *km* from the earth's surface.



(ii) These are the radio waves of frequency range 2 *MHz* to 30 *MHz*.

(iii) Sky waves are used for very long distance radio communication at medium and high frequencies (*i.e.* at medium waves and short waves).

(iv) The sky waves being electromagnetic in nature, changes the dielectric constant and refractive index of the ionosphere. The effective refractive index of the ionosphere is

$$n_{eff} = n_0\left[1-\frac{Ne^2}{\varepsilon_0 m\omega^2}\right]^{1/2} = n_0\left[1-\frac{80.5N}{f^2}\right]^{1/2}$$

where $n_0$ = refractive index of free space, $N$ = electron density of ionosphere, $\varepsilon_0$ = dielectric constant of free space, $e$ = charge on electron, $m$ = mass of electron $\omega$ = angular frequency of EM wave.

(v) As we go deep into the ionosphere, $N$ increases so $n_{eff}$ decreases. The refractions or bending of the beam will continue and finally it reflects back.

(vi) **Critical frequency ($f_c$) :** It is defined as the highest frequency of radio wave, which gets reflected to earth by the ionosphere after having been sent straight to it.

If maximum electron density of the ionosphere is $N_{max}$ per $m$, then $f_c \approx 9(N_{max})^{1/2}$. Above $f_c$ a wave will penetrate the ionosphere and is not reflected by it.

(vii) **Maximum usable frequency (MUF) :** It is the highest frequency of radio waves which when sent at some angle of incidence $\theta$, towards the ionosphere, get reflected and return to the earth. $MUF = \dfrac{f_c}{\cos\theta}$

(viii) **Skip distance :** It is the smallest distance from a transmitter along the earth's surface at which a sky wave of a fixed frequency but more than $f_c$ is sent back to the earth.

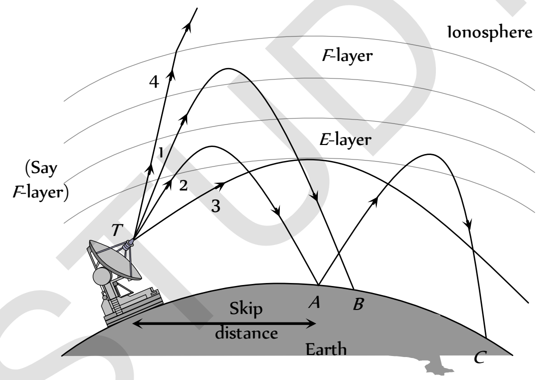



**Fig. 28.24**

(ix) **Fading :** It is defined as the fluctuation in the strength of a signal at a receiver due to interference of two waves.

Fading is more at high frequencies. It results into errors in data transmission and retrieval.

The space waves are the radio waves of very high frequency (30 *MHz* to 300 *MHz*) ultra high frequency (300 *MHz* to 3000 *MHz*) and microwave (more than 3000 *MHz*). At such high frequencies, the sky wave as well as ground wave propagation both fails.

These waves can be transmitted from transmitting to receiving antenna either directly or after reflection from the ground or in troposphere, the wave propagation is called space wave propagation.

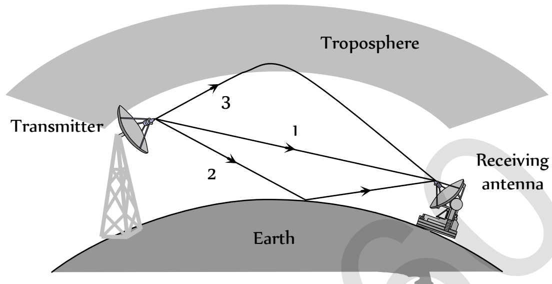



**Fig. 28.25**

The space wave propagation is also called as line of sight propagation. The line of sight distance is the distance between transmitting antenna and receiving antenna at which they can see each other.

Space wave propagation can be utilised for transmitting high frequency TV and FM signals.

(1) **Television signal propagation :** Frequency range for propagation is 80 *MHz* to 200 *MHz*

Height of transmitting antenna : $h = \dfrac{d^2}{2R}$ ($d$ = distance covered by the signal, $R$ = Radius of the Earth)

Area covered : $A = \pi d = 2\pi Rh$

Population cover : Population density × Area covered

(2) **Microwave communication :** Microwave communication systems are used for long distance communication. Since at microwave frequencies, electromagnetic waves cannot bend across the obstacles, such as the top of the buildings, mountains *etc.*, it is therefore necessary that microwave transmission is in line-of-sight.

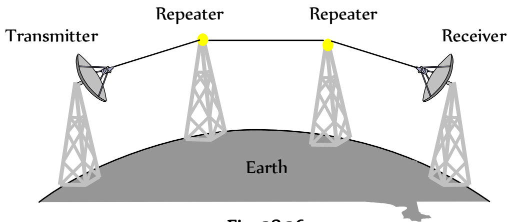


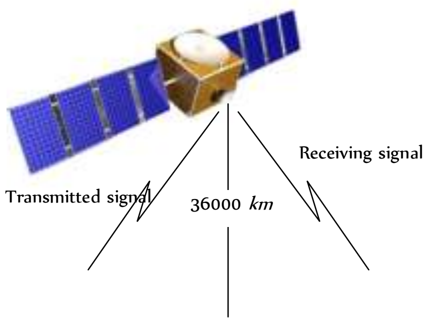

**Fig. 28.26**

Due to curvature in the surface of earth, the range of microwave transmission is very small (≈ 50 *km*). The range of microwave transmission is also limited by the fact that signals gets weaker and weaker as it propagates. However, these problems are overcome by using repeaters (A repeater is basically an amplifier, which amplifies the attenuated signal and then retransmits it.) at intervals between the transmitter and the receiver. Due to this, the cost of transmission of signal between the two stations increases.

The problems faced in a microwave communication system are solved to a large extent by using a geostationary satellite as a communication satellite.

## Satellite Communication

(1) Satellite communication is like the line-of-sight microwave transmission. In this case, a beam of modulated microwave is projected towards the satellite.



(2) Satellite communication is mainly done through geostationary satellites (for steady reliable transmission and reception)

(3) A geostationary satellite has the same time period of revolution of earth (*i.e.* 24 *hrs*.). It appears stationary *w.r.t.* earth. It locates at the height of 36000 *km* above the earth's surface (well above the ionosphere).

(4) A communication satellite is a spacecraft placed in an orbit around the earth which carriers a transmitting and receiving equipment called radio transponder. It amplifies the microwave signals emitted by the transmitter from the surface of earth and send then to the receiving station on earth.

(5) The transmitted signal is UP-LINKED and received by the satellite station which DOWN-LINKS it with the ground station through it's transmitter.

The up-link and down-link frequencies are kept different (both frequencies being in the regions of UHF/microwave).

(6) A single satellite cannot cover the entire surface of the earth. At least three geo-stationary satellites are required which are 120° apart from each other to have the communication link over the entire globe of earth.

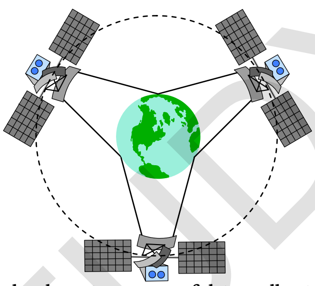


Fig. 28.28

(7) Satellite technology is very useful in collecting information about various factors of the atmosphere which governs the weather and climatic conditions.

The satellite communication can be used for establishing mobile communication with great use the communication satellites are now being used in Global Positioning System (GPS). The ordinary users can find their positions within an accuracy of 100 *m*.

There are two types of satellites used for long distance transmission.

(i) Passive satellite : It act as reflector only for the signals transmitted from earth. Moon the natural satellite of earth is a passive satellite.

(ii) Active satellite : It carries all the equipment used for receiving signals sent from the earth, processing them and then re-transmitting them to the earth. Now a days active satellites are in use.

(8) The Indian communication satellites INSAT-2B and INSAT-2C are positioned in such away in the outer space that they are accessible from any place in India.

## Remote Sensing

Remote sensing is the technique to obtain information about an object (in respect of it's size, colour nature, location, temperature *etc*.) by observing it from a distance and without coming to actual contact with it.

(1) There are two types of remote sensing instruments : active and passive. Active instruments provide their own energy to illuminate the object of interest, as radar does. They send an energy pulse to the object and then receive and process the pulse reflected from the object. Passive instruments sense only radiations emitted by the object or solar radiation reflected from the object.

(2) The remote sensing is done through a satellite. The satellite used in remote sensing should move in an orbit around the earth in such away that it always passes over the particular area of the earth at the same local time.

The orbit of such a satellite is known as sun-synchronous orbit. A remote sensing orbit can be circular polar orbit or in highly inclined elliptical orbit.

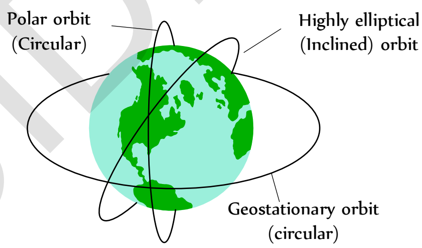



Fig. 28.29

(3) A remote sensing satellite takes, photographs of a particular region which nearly the same illumination every time it passes through that region.

(4) The most useful remote sensing technology is that it makes possible the repetitive surveys of vast areas in a very short time, even if the areas are inaccessible.

(5) Space based remote sensing is a new technology. It has high potential for applications in nearly all aspects of resource management.

(6) The Indian remote sensing satellites are IRS-1A, JRS-1B, and IRS-1C.

(7) **Some applications of remote sensing includes**

(i) Meteorology : (development of weather systems and weather for casting).

(ii) Climatology : Monitoring climatic changes.

(iii) Oceanography : (Sea surface temperatures, mapping of sea-ice and oil pollution monitoring).

(iv) Archaeology, geological surveys.

(v) Water resource surveys,

(vi) Urban land use surveys.

(vii) Agriculture and forestry and natural disaster.

(viii) In the field of spying to detect movements of enemy army an their positions.

(ix) It is used to locate the place where under ground nuclear explosion has carried out.

## Line Communication

Line communication means interconnection of two points that are at some distance from each other with the help of wires for exchange of information *e.g.* interconnection between a transmitter and receiver or a transmitter and anteena or an anteena and receiver.

## Two Wire Transmission Line

The most commonly used two wire lines are : Parallel wire, twisted pair wires and co-axial cable.

(1) **Parallel wire line :** In a two wire transmission line, two metallic wires are arranged parallel to each other inside a protective insulation coating.

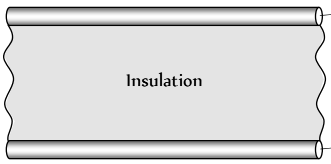



Fig. 28.30

(i) The wires may be hard or flexible depending on the power to be handled.

(ii) It is commonly used to connect an anteena with TV receiver.

(iii) Such wires can suffer from interferences and losses.

(2) **Twisted pair wire :** It consists of two insulated copper wires twisted around each other at regular intervals to minimize electrical interference.

(i) Twisted pair wires are used to connect telephone systems. It works well up to a distance of about 10 *cm*. They cannot transmit signals over very large distances.

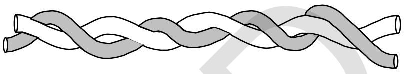


Fig. 28.31

(ii) They can be used for transmitting both, the analog and digital signals.

(iii) They are easy to install and cost effective.

(3) **Coaxial wire lines :** It consist of a central copper wire (which transmits the signals) surrounded by a PVC insulation over which a sleeve of copper mesh (outer conductor) is placed. The outer conductor is normally connected to ground and thus it provides an electrical shield to the signals carried by the central conductor. The outer conductor is externally covered with a polymer jacket for protection.

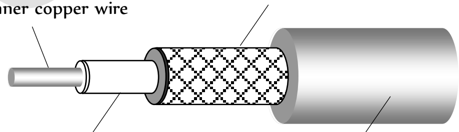



Fig. 28.32

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

(ii) The communication through co-axial lines is more efficient than through a twisted pair wire lines.

(iii) Co-axial cables can be gas filled also. To reduce flash over between the conductor handling high power, $N_2$-gas is used in the cable.

## Impedance of Line

Each portion of the transmission line can be considered as a small inductor, resistor and capacitor as shown.

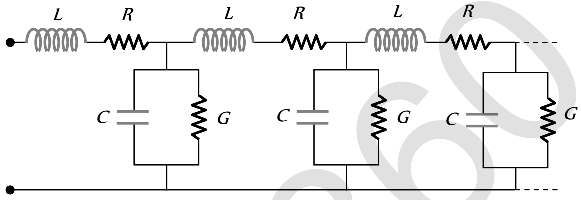



Fig. 28.33

(1) Such inductors, resistors and capacitors are distributed throughout the transmission line.

As a result each length of transmission line has a characteristic impedance.

(2) In case of co-axial cable, the dielectric can be represented by a shunt resistance *G*.

(3) When co-axial cable is used to transmit a radio frequency signal, $X_L$ and $X_C$ are large as compared to *R* and *G* respectively. Hence *R* and *G* can be neglected.

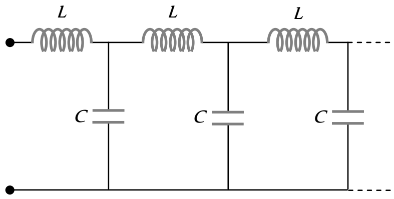



Fig. 28.34

(4) In co-axial cable, *R* is zero, so no loss of energy and hence no attenuation of frequency signal occurs when transmitted along it. That's why co-axial cables are specially used in cable TV network.

(5) **Characteristic impedance ($Z_0$) :** It is defined as the impedance measured at the input of a line of infinite length.

**For parallel line** $Z_0 = \dfrac{276}{\sqrt{k}} \log \dfrac{2s}{d}$

*d* = Diameter of each wire

*s* = Separation between the two wires

*k* = Dielectric constant of the insulating medium

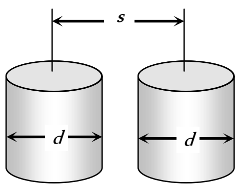



Fig. 28.35

**For co-axial line wire** $Z_0 = \dfrac{138}{\sqrt{k}} \log \dfrac{D}{d}$

*d* = Diameter of inner conductor

*D* = Diameter of outer conductor

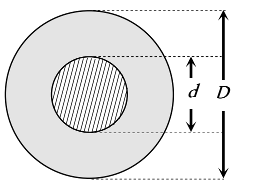



Fig. 28.36

**At radio frequency** $Z_0 = \sqrt{\dfrac{L}{C}}$

the usual range of characteristic impedance for parallel wire lines is 150Ω to 600 Ω and for co-axial wire it is 40 Ω to 150 Ω.

(6) **Velocity factor of a line** (*v. f.*) **:** It is the ratio of reduction of speed of light in the dielectric of the cable

$$v.f. = \frac{v}{c} = \frac{\text{Speed of light in medium}}{\text{Speed of light in vacuum}} = \frac{1}{\sqrt{K}}$$

For a line *v.f.* is generally of the order of 0.6 to 0.9.

## Telephone Links

(1) Telephone is the most common means of communication. Now a days, the telephone system is required to converse from earth to another heavenly bodies like moon *etc.*

(2) A telephone link can be established with the help of co-axial cables, ground waves, sky waves, microwaves or optical fibre cables.

(3) Simultaneous transmission of a number of messages over a single channel without their interfering with one another is called multiplexing. Two types of multiplexing techniques are in use :

(i) Frequency division multiplexing uses analog modulation of message signals.

(ii) Time division multiplexing makes use of pulse modulation of message signals.

(4) Twisted pair wire lines provide a band width of 2 *MHz*, while co-axial cable provides a band width of 20 *MHz*. For further increase in band width, we use

(i) microwave link

(ii) communication satellite link.

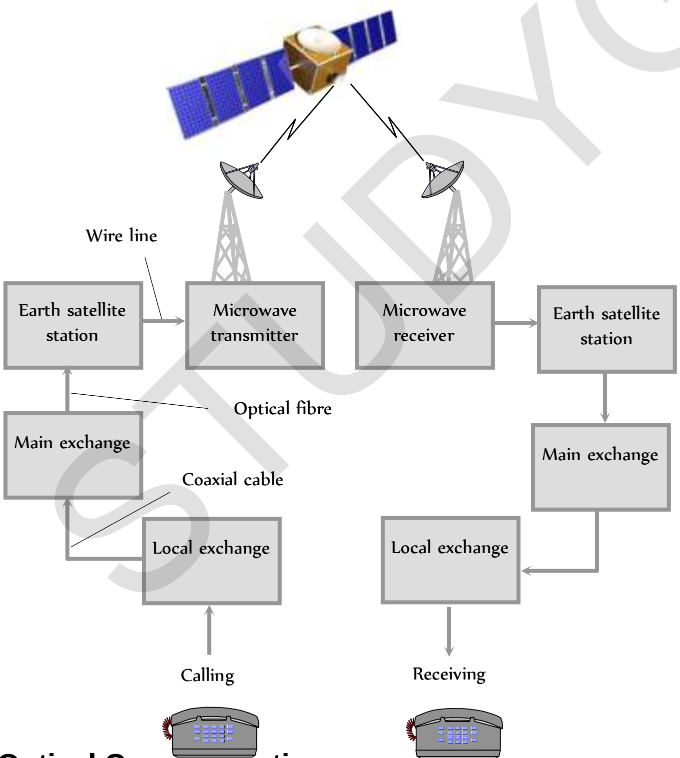



Fig. 28.37

## Optical Communication

(1) The use of optical carrier waves for transmission of information from one place to another is called optical communication.

(2) The useful optical frequency range is $10^{12}$ *Hz* to $10^{16}$ *Hz* which is very high as compared to radio and microwave frequencies ($10^{6}$ *Hz* – $10^{11}$ *Hz*).

(3) The information carrying capacity ∝ bandwidth ∝ frequency of carrier wave. So optical communication is better than others. (because of high frequency).

(4) Basic setup of optical communication shown below

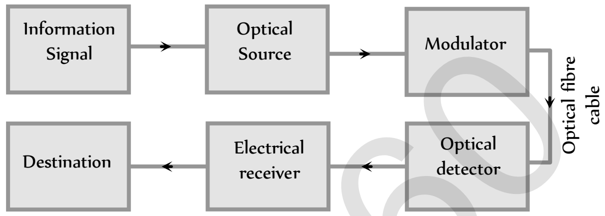



Fig. 28.38

(5) Light emitting diodes (LED) and diode lasers are preferred for optical source. LED's are used for small distance transmission while diode laser is used for very large distance transmission.

(6) In order to transmit information signal via an optical communication system, it is necessary to modulate light with the information signal.

(7) The optical signal reaching the receiving end has to be detected by a detector which converts light into electrical signals, So that the transmitted information may be decoded. Semiconductor based photo-electors are used

## Optical Fibre

The optical fibres are used to transmit light signals from one place to another without any practical loss in the intensity of light signal.

(1) **Design :** Optical fibre is made of a thin glass core (diameter 10 to 100 $\mu m$) surrounded by a glass coating called cladding are protected by a jacket of plastic.

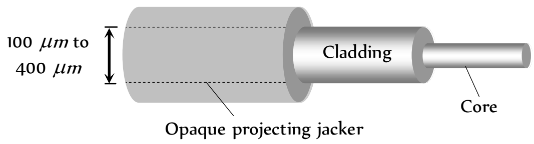



Fig. 28.39

(2) **Principle :** It works on the principle of total internal reflection.

(3) **Action :** The refractive index of the glass used for making core ($\mu_1$ ≈ 1.7) is a little more than the refractive index of the glass ($\mu_2$ ≈ 1.5) used for making the cladding *i.e.* $\mu_1 > \mu_2$.

The core dimension is so small (≈ 10 $\mu m$) that the light entering will almost essentially be having incident angle ($\theta_i$) more than the critical angle ($\theta_c$) and will suffer total internal reflection at the core. Cladding boundary such successive total reflections at opposite boundaries will confine the light to the core as shown in figure.

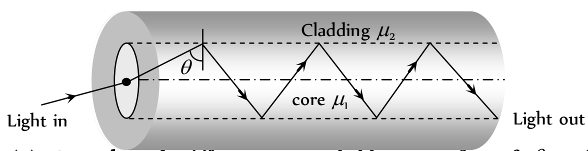



Fig. 28.40

(4) **Critical angle** ($\theta_c$) **:** At core-cladding interface if $\theta = \theta_c$ then

$$\cos\theta_c = \frac{\sqrt{\mu_1^2 - \mu_2^2}}{\mu_1} \Rightarrow \theta_c = \cos^{-1}\left(\frac{\sqrt{\mu_1^2 - \mu_2^2}}{\mu_1}\right)$$

(5) **Acceptance angle ($\theta$) :** The value of maximum angle of incidence with the axis of fibre in air for which all the incident light is totally reflected is known as acceptance angle.

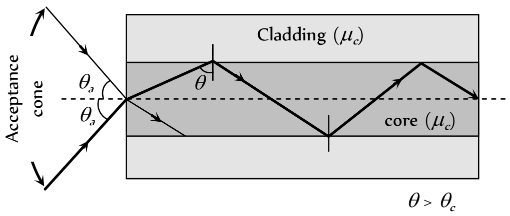



Fig. 28.41

If $\theta_a$ = Acceptance angle then $\mu_1$ = refractive index of core, $\mu_2$ = refractive index of cladding.

$$\sin\theta_a = \frac{\sqrt{\mu_1^2 - \mu_2^2}}{\mu_0} \Rightarrow \theta_a = \sin^{-1}\sqrt{\mu_1^2 - \mu_2^2} \quad \text{(for air } \mu_0 = 1\text{)}$$

(6) **Numerical aperture :** Light gathering capability of a fibre is related to numerical aperture. This is defined as the sine of acceptance angle *i.e.*

$$NA = \sin i = \sqrt{\mu_1^2 - \mu_2^2}$$

The numerical aperture can also be given in terms of relative core-cladding index difference ($\Delta$), where $\Delta = \dfrac{\mu_1^2 - \mu_2^2}{2\mu_1^2}$

Thus, $NA = \sqrt{\mu_1^2 - \mu_2^2} = \mu_1\sqrt{2\Delta}$

(7) **Fibre attenuation :** In practice a very small part of light energy is lost from an optical fibre. This reduction in energy of the light is called attenuation and is described by $I = I_0 e^{-\alpha x}$

where $I_0$ = Intensity of light when it enters the fibre

$I$ = Intensity of light at a distance $x$ along the fibre

$\alpha$ = Absorption co-efficient or attenuation co-efficient

Also attenuation (in $dB$) $= 10 \log_{10} \dfrac{I}{I_0}$

(8) **Types of optical fibre**

(i) **Monomode optical fibre :** It has a very narrow core of diameter about $5\mu m$ or less, cladding is relatively big.

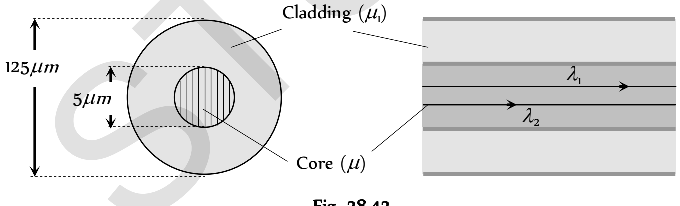



Fig. 28.42

(ii) **Multimode optical fibre :** It is again of two types

(a) Step index multimode fibre :

The diameter of the core is about 50 $\mu m$.

Core has constant R.I $\mu_1$ from it's centre to boundary.

The refractive index then changes to a lower value of $\mu_2$ which remains constant through the cladding.

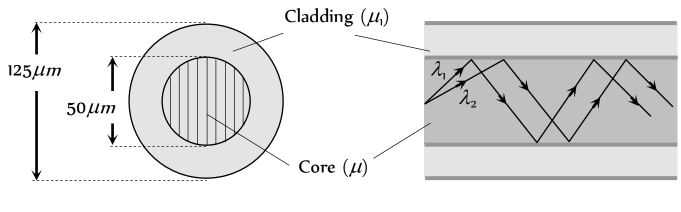



Fig. 28.43

Since refractive index of a material depend on the wavelength of light. The wavelength fellow diff. paths.

The overall time difference between two wavelengths reaches the other end is of the order of $33 \times 10^{-9}$ *sec/cm* length of the fibre.

(iii) **Graded index multimode fibre :** Refractive index decreases smoothly from it's centre to the outer surface of the fibre (cladding). There is no notieable boundary between core and cladding.

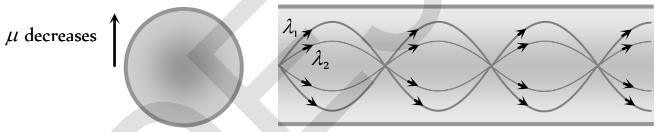



Fig. 28.44

## Advantages of Optical Fibres Over Wires

(1) Lower cost in the long run.

(2) Low loss of signal typically less than 0.3 *dB/km*), so repeater-less transmission over long distances is possible.

(3) Large data-carrying capacity (thousands of times greater, reaching speeds of up to 1.6 *Tb/s* in field deployed systems and up to 10 *Tb/s* in lab systems).

(4) No electromagnetic radiation; difficult to eavesdrop.

(5) High electrical resistance, so safe to use near high-voltage equipment or between areas with different earth potentials.

(6) Low weight.

(7) Signals contain very little power.

(8) No cross talk between cables.

(9) No sparks (*e.g.* in automobile applications)

(10) Difficult to place a tap or listening device on the line, providing better physical network security.

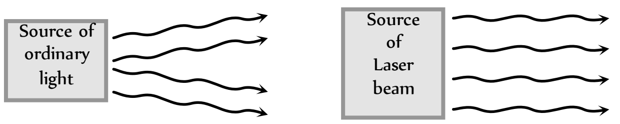
## Laser

Laser is a process by which we get a beam which is coherent, highly monochromatic and almost perfectly parallel. Such a beam is also called laser.

**Coherent** : Because all the photons in the light beam, emitted by different atoms, at different instant are in phase.

| | |
|---|---|
| **Monochromatic :** | Because, the spread $\Delta\lambda$ in wavelength is very small, of the order of $10^{-6}$ *nm*. |
| **Perfectly parallel :** | Because, a laser beam can be sent to a far off place and returns back without any practical loss of intensity. |

The term LASER stands for **L**ight **A**mplification by **S**timulated **E**mission **R**adiation.




(A) In coherent beam (B) Coherent beam

Fig. 28.45

## Concepts Related to Production of LASER

(1) **Stimulated absorption :** Consider an atom which has an allowed state at energy $E_1$ and another allowed state at a higher energy $E_2$. Suppose the atom is in the lower energy state $E_1$. If a photon of light having energy $E_2 - E_1$ is incident on this atom, the atom may absorb the photon and jump to the higher energy state $E_2$. This process is called stimulated absorption of light photon. The incident photon has stimulated the atom to absorb the energy.

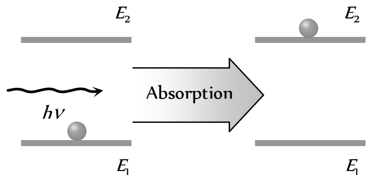



Fig. 28.46

(2) **Spontaneous emission :** If an atom is present in the higher energy state, it tends to return to the lower energy state within a time of $10^{-8}$ *sec* by emitting a photon of energy $h\nu = E_2 - E_1$. We call this process spontaneous emission. Spontaneous because the event was not triggered by any outside influence.

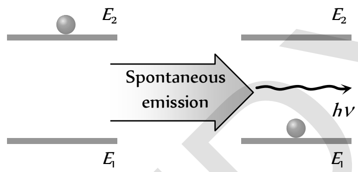



Fig. 28.47

(3) **Stimulated emission :** Suppose a photon of energy $h\nu = E_2 - E_1$ interacts with an atom that is already in the excited state $E_2$.

The incident photon may stimulate the atom to emit a photon, the energy, phase, and direction of travel of this second photon are exactly the same as those of the incident photon. That is the quantum state of the stimulated photon is identical to that of the incident photon. This process is called stimulated emission.

If these two photons then interact with two more excited state atoms, two more photons are produced, and soon. Therefore, the stimulation process leads to photon amplification.

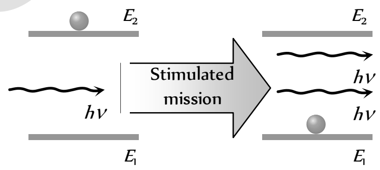



Fig. 28.48

(4) **Population inversion :** Usually the number of atoms in the lower energy state is more than the number of atoms in the excited state. To emit photons which are coherent (*i.e.* in phase), the number of atoms in the higher state must be greater than the number of atoms in the lower energy state. In other words, population of atoms in the higher energy state must be larger than the population of atoms in the lower energy state. The process of making the population of atoms in the higher energy state more than that of lower energy state is known as population inversion.

The method used to invert the population of atoms is known as pumping.

(5) **Metastable states :** A metastable state is one, which has a mean life time of the order of $10^{-3}$ *s* or more *i.e.* much larger than $10^{-8}$ *s*, the life time of a higher energy state. Some atomic systems, such as chromium, neon, *etc* possess metastable states. The atom of such an atomic system, when in higher energy state, does not come down to lower energy state directly. It first returns to metastable state and then after a finite lapse of time of the order of $10^{-3}$ *s*, returns to the lower energy state. Since such atom stays in metastable state for a sufficiently long time, the population inversion can sustain in such atomic system.

A system in which population inversion is achieved is called the active system.

## Principle of Laser

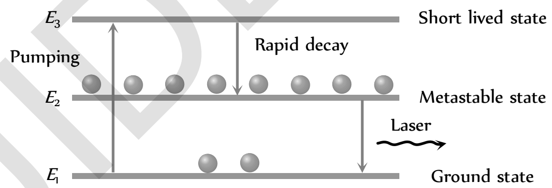



Fig. 28.49

Atoms from the ground state $E_1$ are 'pumped' up to an excited state $E_3$. From $E_3$ the atom decay rapidly to state of energy $E_2$. For lasing (lasing means laser action) to occur, this state must be metastable. If conditions are right, state $E_2$ can then become more heavily populated than state $E_1$, thus providing the needed population inversion.

When photon of energy $h\nu = E_2 - E_1$ is incident on one of the atoms present in the metastable state, the atom will drop to lower energy state $E_1$ emitting a photon of same energy as that of the incident photon, which is in phase with it and is emitted in the same direction. The two photons, then interact with two more atoms present in metastable state and so on. This process is called amplification of light.

For smooth process two conditions are necessary

(1) The metastable state should all the time have larger number of atoms than the number of atoms in lower energy state.

(It is achieved by pumping)

(2) The photons emitted due to stimulated emission should stimulate other atoms to multiply the photons inside the system.

(It is achieved by two mirrors are fixed at the ends of the system containing lasing material. The mirrors reflect the photons back and forth to keep them inside the region for a long time.)

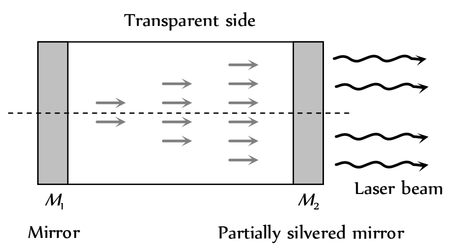



Fig. 28.50

## Helium-Neon Laser

This laser contains a mixture of helium (≈ 90%) and neon (≈ 10%) at low pressure in a cylindrical tube with mirrors at each end. The energy level diagram in figure shows the important energy levels for the helium and neon atoms. A large electric field is established in the tube by electrodes connected to a high-voltage power supply, Electrons from ionized atoms are accelerated by the field and collide with atoms.

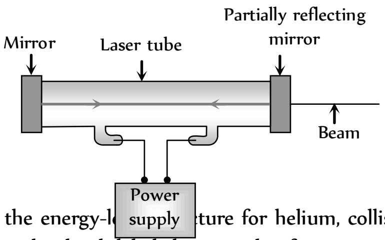



Fig. 28.51

Because of the energy-level structure for helium, collisions often excite helium atoms to the level labeled $E$ in the figure. In a process called collision transfer, energy is transferred from excited helium atoms to neon atoms during collisions, thus producing a population of neon atoms in the $E$ level. The transition from level $E$ to $E$ in neon is forbidden, but the transition out of the $E$ level is allowed. This means that the population of atoms in the $E$ level builds up, and that of the $E$ level is rapidly depleted.

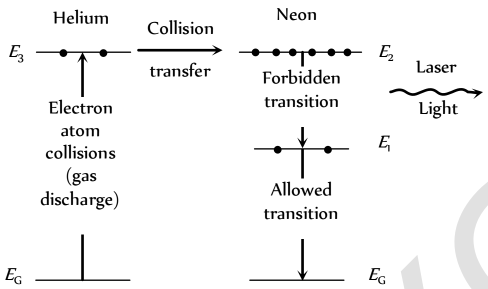



Fig. 28.52

Stimulated emission from $E$ to $E$ predominates and laser light is generated.

The mirrors at each end of the tube encourage emissions along the tube axis by reflecting the light back and forth inside the tube. One of the mirrors is slightly leaky, transmitting about 1 percent of the incident light. This transmitted light forms the laser beam which we find so useful.

## T Tips & Tricks

✍ Parallel wire lines are never used for transmission of microwaves. This is because at the frequency of microwaves, separation between the two wires approaches half a wavelength ($\lambda/2$). Therefore radiation loss of energy becomes maximum.

✍ Number of channel accommodated for

$$\text{Transmission} = \frac{\text{Total band width of channel}}{\text{Band width needed per channel}}$$

✍ Bit rate = Sampling rate × no. of bits per sample.

✍ Modulation factor determines the strength and quality of the transmitted signal.

✍ A Hertz antenna is a straight conductor of length equal to half the wavelength of radio signals to be transmitted or received. A Marconi antenna is a straight conductor of length $l = \lambda/4$

✍ In a digital signal, information is carried by the pattern of pulses and not by the shape of pulses.

✍ Sampling converts an analog signal into digital. For example when an analog signal is sampled at interval of 125 $\mu$-*sec* the number of samples taken per second $= \dfrac{1}{125 \times 10^{-6}} = 8000.$

✍ AGC stands for automatic gain control. It is used in receive.

✍ Sputinik-I launched by Russia in 1957 was the first active satellite.

✍ First communication satellite was put in an orbit by USA in 1958.

✍ The first India experimental satellite *i.e.* Apple was launched on June 19, 1981.

✍ The national information cenre at Delhi has linked computers at all head quarters through INSAT 2B.

✍ First communication satellite was put in an orbit by USA in 1958.

✍ Just as $\sqrt{\dfrac{Z}{Y}}$ represents characteristic impedance ($Z$) of a transmission line, $\sqrt{ZY}$ represents propagation constant of the line.

✍ Glass-core and glass cladding (often called SCS fire *i.e.* silica clad silica fibre) have the best propagation characteristics.

✍ The dish type antenna's used for satellite communication are generally of cassegrain type

✍ Ground waves propagate along the surface of the earth. These are vertically polarised to prevent short circuiting of the electric field at a distance $d$ is given by $E = \dfrac{120\,\pi h_t I}{\lambda d}$ and signal received by an antenna of height $h$ is given by $V\,(\text{volts}) = \dfrac{120\pi h_t h_r I}{\lambda d}$

✍ Receivers may be of two types, tuned radio frequency (TRF) receivers and superheterodyne receivers. Super heterodyne receivers use local oscillators and intermediate frequency amplifiers before the signal is detected. In this way the reception becomes free of signal frequency but depends only on intermediate frequency which is fixed.

✍ A rectifier with peak detection is used in the AM wave detection and FM detection is achieved by an *LC* circuit tuned at off resonant frequency.

✍ APDs (Avalanche photodiodes) are best suited for detection in fiber optic communication.

✍ MASER is microwave amplification by stimulated emission of radiation. It is used as a microwave amplifier or oscillator. The principle of MASER is identical to that of LASER. Only frequency range is ≤ 10 *Hz* in masers.

✍ In frequency modulation $m$ (frequency modulation index) is inversely proportional to modulating frequency $f$. While in PM it does not vary with modulating frequency. Moreover, FM is more noise immune.

✍ AM with single side band suppressed carrier is better as it contains