Physics Notes for Class 12 chapter 8 and 15 ELECTROMAGNETIC WAVES and COMMUNICATIONOMMUNICATION SYSTEMSYSTEMS

Displacement Current

It is a current which produces in the region in which the electric field and hence the electric flux changes with time.

Displacement current, $I_D = \varepsilon_o \cdot d\varphi_E / dt$

where, φ_E is the electric flux.

Ampere-Maxwell Law

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 (I + I_D)$$

where, μ_o = Permeability

$= 4\pi * 10^{-7}$ V / Am

Maxwell's Equations

(i) $\oint_S \mathbf{E} \cdot d\mathbf{S} = \frac{q}{\varepsilon_0}$

This equation is Gauss's law in electrostatics.

(ii) $\oint_S \mathbf{E} \cdot d\mathbf{S} = 0$

This equation is Gauss's law in magnetostatics.

(iii) $\oint_S \mathbf{E} \cdot d\mathbf{l} = -\frac{d}{dt} \oint_S \mathbf{B} \cdot d\mathbf{S}$

This equation is Faraday's law of electromagnetic induction.

(iv) $\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 \left(I + \varepsilon_0 \frac{d\phi_E}{dt} \right)$

This equation is Ampere-Maxwell law.

Electromagnetic Waves

Electromagnetic waves are those waves in which electric and magnetic field vectors changes sinusoidally and are perpendicular to each other as well as at right angles to the direction of propagation of wave.

The equation of plane progressive electromagnetic wave can be written as $E = E_o \sin \Omega (t - x / c)$ and $B = B_o \sin \Omega (t - x / c)$. Where, $\Omega = 2\pi v$

Electromagnetic waves are produced by accelerated charge particles.

Properties of EM Waves

(i) These waves are transverse in nature.

(ii) These waves propagate through space with speed of light, i.e., $3 * 10^8$ m / s.

(iii) The speed of electromagnetic wave,

$c = 1 / \sqrt{\mu_o \varepsilon_o}$

where, μ_{oo} is permittivity of free space,

$\therefore c = E_o / B_o$

where E_o and B_o are maximum values of electric and magnetic field vectors.

[According to Maxwell, when a charged particle is accelerated, it produces electromagnetic wave. The total radiant flux at any instant is given by,

$p = q^2a^2 / 6 \pi\varepsilon_o c^2$

(iv) The rate of flow of energy in an electromagnetic wave is described by the vector S called the poynting vector, which is ; defined by the expression,

$S = 1 / \mu_o E * B$

SI unit of Sis watt/m^2.

(v) Its magnitude S is related to the rate at which energy is transported by a wave across a unit area at any instant.

(vi) The energy in electromagnetic waves is divided equally between electric field and magnetic field vectors.

(vii) The average electric energy density.

$U_E = 1 / 2\ \varepsilon_o\ E^2 = 1 / 4\ \varepsilon_o\ E^2{}_o$

(viii) The average magnetic energy density,

$U_B = 1 / 2\ B^2 / \mu_o = 1 / B^2{}_o / \mu_o$

(ix) The electric vector is responsible for the optical effects of an electromagnetic wave.

(x) Intensity of electromagnetic wave is defined as energy crossing per unit area per unit time perpendicular to the directions of propagation of electromagnetic wave.

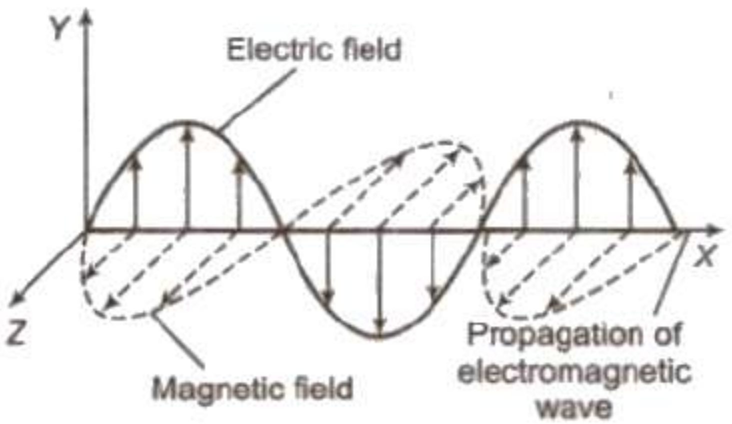
(xi) The intensity I is given by the relation,

$I = < \mu > c = 1 / 2\ \varepsilon_o\ E^2{}_o c$

(xii) The existence of electromagnetic waves was confirmed by Hertz experimentally in 1888.

Propagation of Electromagnetic Waves

In radio wave communication between two places. the electromagnetic waves are radiated out by the transmitter antenna at one place which travel through the space and reach the receiving antenna at the other place.



Electromagnetic Spectrum

The arranged array of electromagnetic radiations in the sequence of their wavelength or frequency is called electromagnetic spectrum

Radio and microwaves are used in radio and TV communication,

Infrared rays are used to

(i) Treat muscular straw.
(ii) For taking photographs' in fog or smoke.

(iii) In green house to keep plants warm.
(iv) In weather forecasting through infrared photography.

Ultraviolet rays are used

(i) In the study of molecular structure.
(ii) In sterilizing the surgical instruments.
(iii) In the detection of forged documents, £ringer prints.

X-rays are used

(i) In detecting faults, cracks, flaws and holes in metal products.
(ii) In the study of crystal structure.
(iii) For the detection of pearls in oysters.

γ – rays are used for the study of nuclear structure.

Earth's Atmosphere

The gaseous envelope surrounding the earth is called earth's atmosphere. It contain the following layers

(i) **Troposphere** This region extends upto a height of 12 km from earth's surface.

(ii) **Stratosphere** This region extends from 12 km to 50 km. In this region, most of the atmospheric ozone is concentrated from 30 to 50 km. This layer is called ozone layer.

(iii) **Mesosphere** The region extends from 50 km to 80 km.

(iv) **Ionosphere** This region extends from 80 km to 400 km.

In ionosphere the electron density is very large in a region beyond 110 km from earth's surface which extends vertically for a few kilometer.

This layer is called **Kennelly Heaviside layer.**

In ionosphere a layer having large electron density is found at height 250 km from earth's surface, called **Appleton layer.**

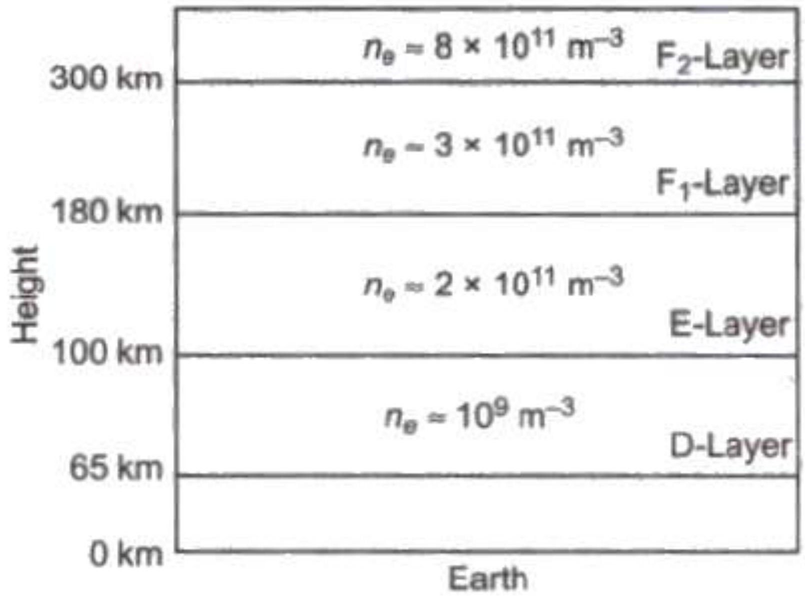
There are four main layers in earth's atmosphere having high density of electrons and positive ions, produced due to ionisation by the high energy particles coming from sun. star or cosmos. These layers play their effective role in space communication. These layers are D, E, F_1 and F_2.

(i) **D-layer** is at a virtual height of 65 km from surface of earth and having electron density = 10^9 m^{-3}

(ii) **E-layer** is at a virtual height of 100 km, from the surface of earth, having electron density = $2 * 10^{11}$ m^{-3}

(iii) **F_1-layer** is at a virtual height of 180 km from the surface of earth, having electron density = $3 * 10^{11}$ m^{-3}

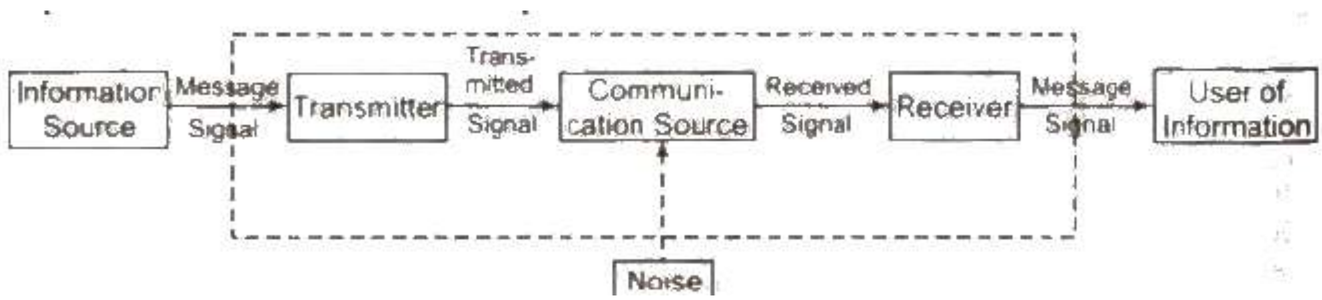
(iv) **F_2 – layer** is at a vertical height of about 300 km in night time and about 250 to 400 km in day time. The electron density of this layer is = $8 * 10^{11}$ m^{-3}



Communication

Faithful transmission of information from one place to another place is called communication.

Optical fibers are used in optical communication.



Communication System

A communication system contains three main parts

(i) **Transmitter** It process and encode the information and make it suitable for transmission.

The message signal for communication can be analog signals or digital signals.

An analog signal can be converted suitably into a digital signal and vice-versa.

[An analog signal is that in which current or voltage value varies continuously with time.

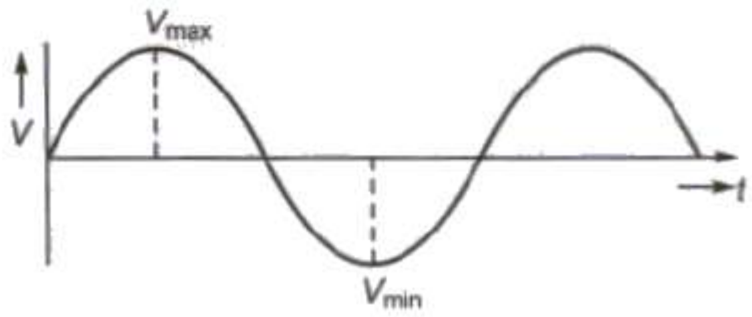
A digital signal is a discontinuous function of time. Such a signal is usually in the form of pulses.]

(ii) **Communication Channel** The medium through which information propagate from transmitter to receiver 1S called communication channel.

(iii) **Receiver** It receives and decode the signal.

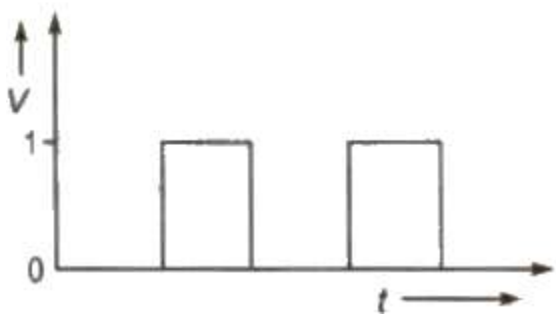
Analog Signal

A signal in which current or voltage changes its magnitude continuously with time, is called an analog signal.



Digital Signal

A signal in which current or voltage have only two values, is called a digital signal.



Note An analog signal can be converted suitable Into a digital signal and vice-versa.

Modulation

The process of superimposing the audio signal over a high frequency carrier wave is called modulation.

In the process of modulation anyone characteristic of carrier wave is varied in accordance with the instantaneous value of audio signal (modulating signal).

Need of Modulation

(i) Energy carried by low frequency audio waves (20 Hz to 20000 Hz) is very small.

(ii) For efficient radiation and reception of signal. the transmitting and receiving antennas should be very high approximately 5000 m.

(iii) The frequency range of audio signal is so small that overlapping of signals create a confusion.

Types of Modulation

(i) A**mplitude Modulation** In this type of modulation, the amplitude of high frequency carrier wave is varied in accordance to instantaneous amplitude of modulating signal.

Band width required for amplitude modulation

= twice the frequency of the modulating signal.

(ii) **Frequency Modulation** In this type of modulation, the frequency of high frequency carrier wave is varied in accordance to instantaneous frequency of modulating signal.

(iii) **Pulse Modulation** In this type of modulation, the continuous waveforms are sampled at regular intervals. Information is transmitted only at the sampling times.

Demodulation

The process of separating of audio signal from modulated signal is called demodulation.

Antenna

An antenna converts electrical energy into electromagnetic waves at transmitting end and pick up transmitted signal at receiving end and converts electromagnetic waves into electrical signal.

Modem

The term modem is contraction of the term modulator and demodulator. Modem is a device which can modulate as well as demodulate the signal. It connect one computer to another through ordinary telephone lines.

Fax (Facsimile Telegraphy)

The electronic reproduction of a document at a distant place is called FAX

Radio Waves

The radio waves are the electromagnetic waves of frequency ranging from 500 kHz to about 1000 MHz. These \V8VeS are used In the field of radio communication. With reference to the frequency range and wavelength range, the radio waves have been divided into various categories shown in table.

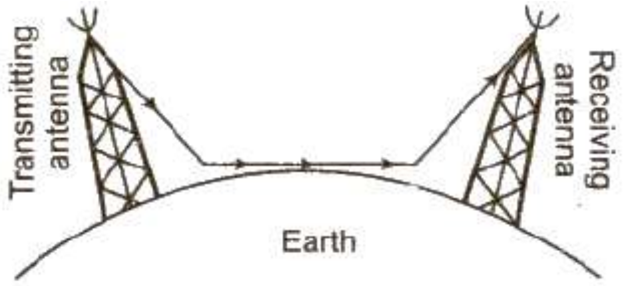
Frequency Range and Wavelength Range of Radio Waves

S.No.	Frequency band	Frequency range	Wavelength range	Main Use
1.	Very-Low Frequency (VLF)	3 kHz to 30 kHz	10 km to 100 km	Long distance point to point communication
2.	Low Frequency (LF)	30 kHz to 300 kHz	1 km to 10 km	Marine and navigational purposes
3.	Medium Frequency (MF)	300 kHz to 3 MHz	100 m to 1 km	Marine and broadcasting purposes
4.	High Frequency (HF)	3 MHz to 30 MHz	10 m to 100 m	Communication of all types
5.	Very-High Frequency (VHF)	30 MHz to 300 MHz	1 m to 10 m	T V Radar and air navigation
6.	Ultra-Hign Frequency (UHF)	300 MHz to 3000 MHz	10 cm to 1 m	Radar and microwave communication
7.	Super-High-Frequency (SHF)	3 GHz to 30 GHz	1 cm to 10 cm	Radar, Radio relays and navigation purposes
8.	Extremely-High - Frequency (EHF)	30 GHz to 300 GHz	1 mm to 1 cm	Optical fibre communication

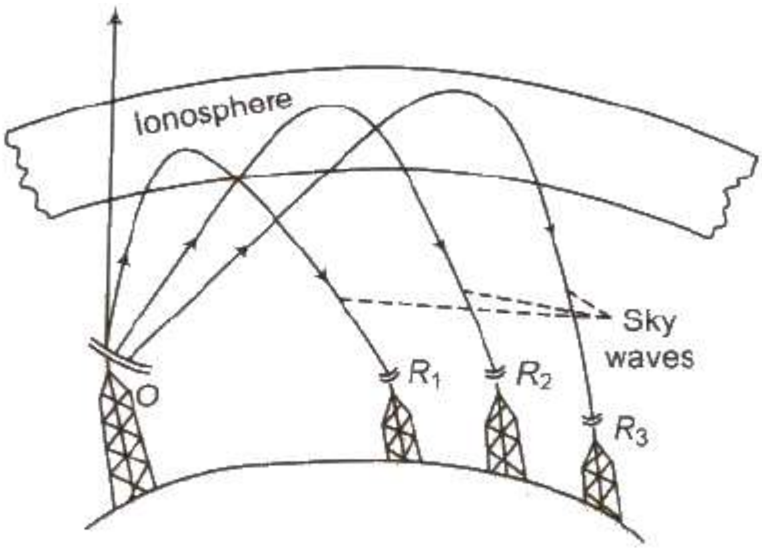
Propagation of Radio Waves

The three modes are discussed below.

(i) **Ground Wave or Surface Wave Propagation** It is suitable for low and medium frequency up to 2 MHz. It is used for local broad casting.



(ii) **Sky Wave Propagation** It is suitable for radio waves of frequency between 2 MHz to 30 MHz. It is used for long distance radio communication.



Critical Frequency The highest frequency of radio wave that can be reflected back by the ionosphere is called critical frequency.

Critical frequency, $v_c = 9 (N_{max})^{1/2}$

Where, N_{max} = number density of electrons/metre^3.

Skip Distance The minimum distance from the transmitter at which a sky wave of a frequency but not more than critical frequency, is sent back to the earth.

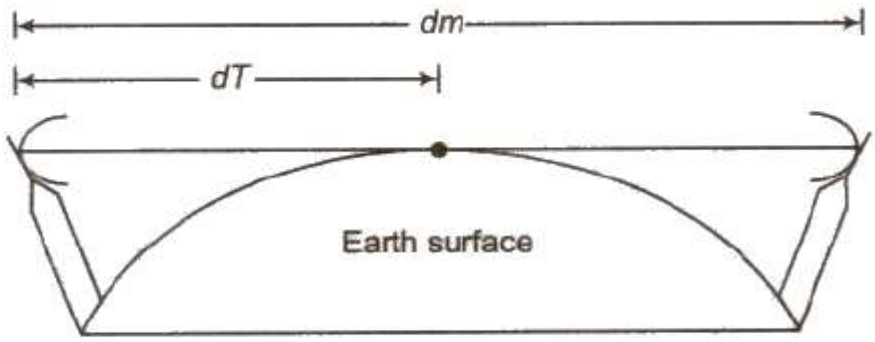
Skip distance (D_{skip}) = $2h (V_{max} / V_c)^2 - 1$

where h is height of reflecting layer of atmosphere,

V_{max} is maximum frequency of electromagnetic waves and V_c is critical frequency.

Fading The variation in the strength of a signal at receiver due to interference of waves, is called fading.

(iii) **Space Wave Propagation** It is suitable for 30 MHz to 300 MHz. It is used in television communication and radar communication. It is also called line of sight communication.

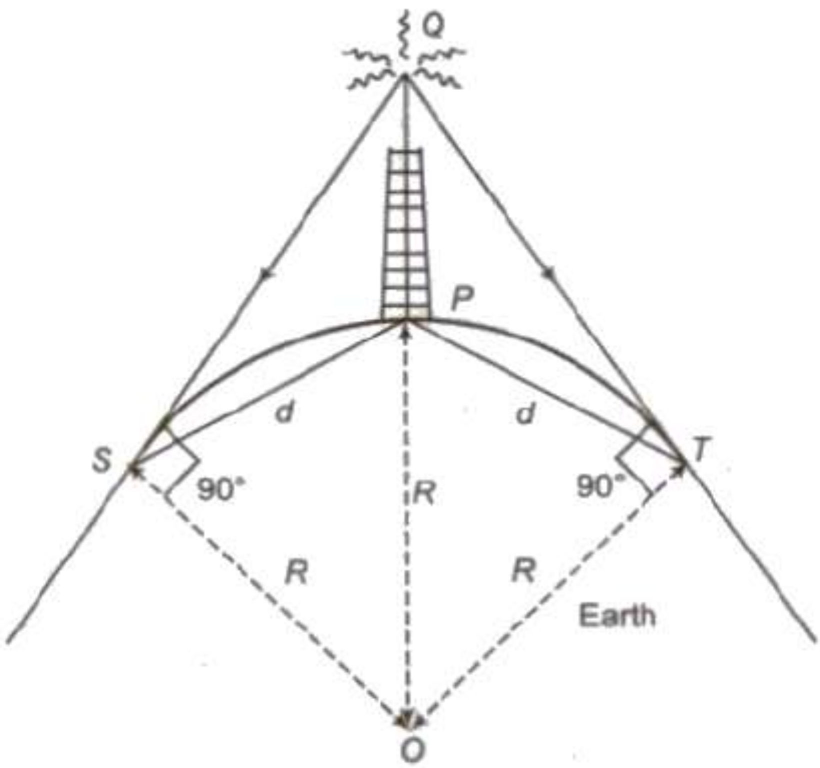


- Range is limited due to curvature of earth. If h be the height of the transmitting antenna, then signal can be received upto a maximum distance

d = √2RH

- If height of transmitting and receiving antennas be h_T and h_R respectively. The effective range will

$$d = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$



Microwave Propagation

- Microwaves are electromagnetic wave of frequency 1 to 300 GHz, greater than those of TV signals. The wavelength of microwaves is of the order of a few mm.
- Microwave communication is used in radar to locate the flying objects In space.
- These waves can be transmitted as beam signals in a particular direction, much better than radiowave,
- There is no diffraction of microwave around corners of an obstacle which happens to lie along its passage.

Satellite Communication

It IS carried out between a transmitter and a receiver through a satellite. A geostationary satellite is utilized for this purpose, whose time period is 24 hours.

A communication satellite is a space craft, provided with microwave receiver and transmitter. It is placed in an orbit around the earth. The India remote sensing satellites are

IRS-IA, IRS-IB and IRS-IC

The line-of-sight microwave communication through satellite is possible if the communication satellite is always at a fixed location with respect to the earth, e.g., the satellite which is acting as a repeater must be at rest with respect to the earth. It is so far a satellite known as geo-stationary satellite.

The basic requirements for geostationary satellites are as follows:

1. The time period of revolution of the satellite around the earth is equal to the time period of rotation of earth about its polar axis i.e., 24 h.
2. The sense of revolution of the satellite around the earth is the same as that of the earth about its polar axis i.e., from west to east.
3. The orbital plane of revolution of satellite is concentric and coplanar with the equatorial plane of earth.
4. The height of geostationary satellite above the equator of earth is nearly 36000 km and its orbital velocity is nearly 3.1 km/s.

The orbit in which the gee-satellite above revolves around the earth is known as geo-synchronous orbit. As its angular speed is synchronised with the angular speed of the earth. therefore, the geo-stationary satellite is also known as geo-synchronous satellite.

Merits of Satellites Communication

1. The satellite communication covers wide area for broadcasting a8 compared to other communication systems i.e. it has wide coverage range.
2. The satellite communication is also used effectively in mobile communication.

3. The satellite communication is found to be much economical as compared to other communication systems on earth. Infact. the cost involved in satellite communication is independent of the distance.
4. The satellite communication is most cost effective in remote and hilly areas, such as Ladakh, Himachal Pradesh etc.
5. The satellite communication permits transmission of data at rate.
6. The satellite communication is very accurate and economical search. rescue and navigation purposes.

Demerits of Satellite Communication

1. If a system on the satellite goes out of order due to environmental stresses, it is almost impossible to repair it.

2. In satellite communication, there is a time delay between transmission and reception, due to extremely large communication path length (greater than 2 x 36000 km). This delay causes a time gap during talking, which proves quite annoying.

Remote Sensing

It is a technique of observing or measuring the characteristics of the object at a distance. A polar satellite is utilized for this purpose.

Distance upto which a signal can be obtained from an antenna is given by

$d = \sqrt{2hR}$

where, h is height of antenna and R is radius of earth.

LED and Diode Laser in Communication

Light Emitting. Diode (LED) and diode laser are preferred sources for optical communication links to the following features.

1. Each produces light of suitable power required in optical communication. Diode laser provides light which is monochromatic and coherent. This light is obtained as a parallel beam. It is used in very long distance transmission.
2. LED provides almost monochromatics light. This suitable for small distance transmission. It is infact, a low cost device as compared to diode lasers.

Line Communication

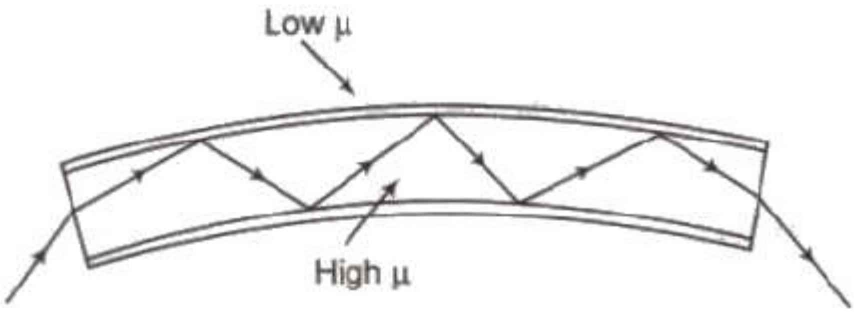
- Transmission lines are used to interconnect points separated from each other. For example interconnection between a transmitter and a receiver or a transmitter and antenna or an antenna and a receiver are achieved through transmission lines.
- Line communication may be in the form of electrical signal or optical signal.

Optical Fibres

An optical fibre is a long thread consisting of a central core of glass or plastic of uniform refractive index. It is surrounded by a cladding of material of refractive index less than that of the core and a protective Jacket of insulating material.

There are three types of optical fibre configuration

1. Single mode step index fibre
2. Multi mode step index fibre
3. Multi mode graded index fibre.



Applications of Optical Fibres

1. A bundle of optical fibres is called light pipe. This pipe can transmit as image. Since the pipe is flexible, it can be twisted in any desired manner. Hence it is used medical and optical examination of even the inaccessible parts of human body, e.g., in endoscopy.
2. Optical fibres are used in transmission and reception of electrical signals by coverting them first into light signals.
3. Optical fibres are used in telephone and other transmitting cables. Each fibre can carry upto 2000 telephone messages without much loss of intensity.