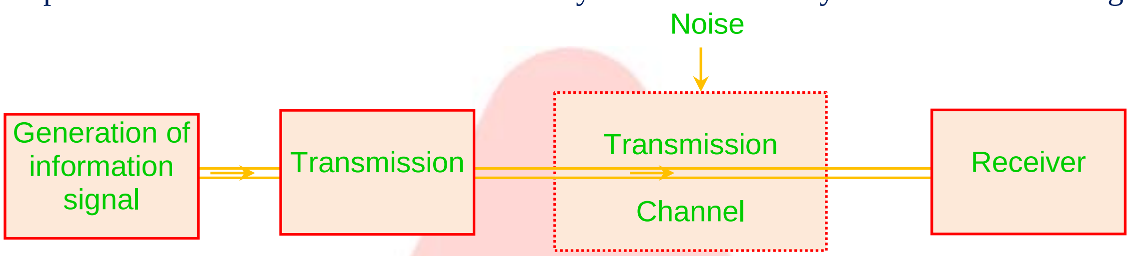
COMMUNICATION SYSTEMS

1 INTRODUCTION

Communication refers to transfer of information or message in an intelligent form from one point to another point. The basic units which constitute any communication systems are shown in figure.



The audio frequency signals (20 Hz to 20 KHz) cannot be transmitted without distortion over long distances due to less energy carried by low frequency audio waves.

In modern communication systems the information is first converted into electrical signals and then sent electronically. The communication through electrical signal has made communication more widespread because the electrical signal can be transmitted over much longer distances at extremely high speed. ($\approx 3\times10^8$ m/s)

For efficient radiation and reception, the height of transmitting and receiving antennas (more details about antennas in latter part of this chapter) should be comparable to a quarter wave length of the frequency used.

$$\text{wavelength} = \frac{\text{velocity}}{\text{Frequency}} = \frac{3\times10^8}{\text{Frequency}}$$

Audio frequencies are concentrated in the range 20 Hz to 20 KHz. This range is so narrow that there will be overlapping of signals.

Communication can be classified according to the nature of information mode of transmission type of transmission channel used and type of modulation.

1.1 NATURE OF INFORMATION

1. *Speech transmission (as in radio)*
2. *Picture transmission (dynamic as well as static)*
3. *Facsimile transmission (Fax): This involves exact reproduction of a document or picture which are static*

1.1 DATA AND DOCUMENT TRANSMISSION

The digital data is 0 and 1. It has only discrete values and can be said to be quantised. The analog input varies smoothly, while the quantised signal holds it self at one or the other of the fixed levels v_1, v_2, v_3…….. Therefore, the quantised signal is an approximation of the original signal. The quality of the approximation may be improved by reducing the size of the steps. Each quantised signal level, subsequently can be assigned a binary code or any other code. During the quantisation step, the noise gets eliminated which makes the digital communication more reliable than the analog.

MODEM

The name modem is contraction of the terms **Modulation and DE Modulator (MO+DEM).** The modem at the transmitting station changes the digital output from computer or any other business machine to a form which can be easily sent via a communication channel. While the receiving modem reverse the process. At the receiver end of the system, the carrier is demodulated to recover the data.

FAX

Facsimile (commonly called FAX) is used to transmit a document or a photograph unlike TV where the seen to be transmitted may be live. The different regions of the document to be transmitted are first scanned by a light source and signals carrying the information are converted into electrical signals by a photo-detector

1.2 MODE OF TRANSMISSION

1. **Analog communication:** In an analog signal current or voltage value varies continuously with time.
2. **Digital communication:** In a digital communication, signal, have discrete values and are designed for two-state operation.

1.3. TRANSMISSION CHANNEL

Path over which the signal is being transmitted.

(a) Line communication

(i) Twisted cable

(ii) Coaxial cable

(iii) Optical fibre cable

(b) Space communication

1.4. TYPE OF MODULATION

It is possible to transmit high frequency signals to long distances by superimposing on a high frequency wave which acts as carrier of the information. This process is known as modulation.

1. For sinusoidal continuous carrier wave: The types of modulation are

(A) Amplitude modulation (AM)

(B) Frequency modulation (FM)

(C) Phase modulation

2. For pulsed carrier waves: The various modes of modulation are

(A) Pulse amplitude modulation (PAM)

(B) Pulse width modulation (PWM) or pulse duration modulation

(C) Pulse position modulation (PPM)

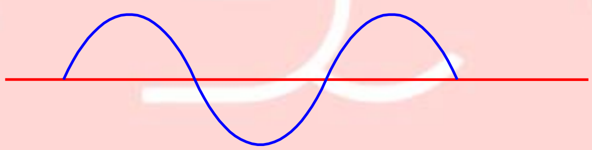
(D) Pulse code modulation (PCM)

PCM is the preferred modulation scheme for digital communication, while others are more suited to analog system.

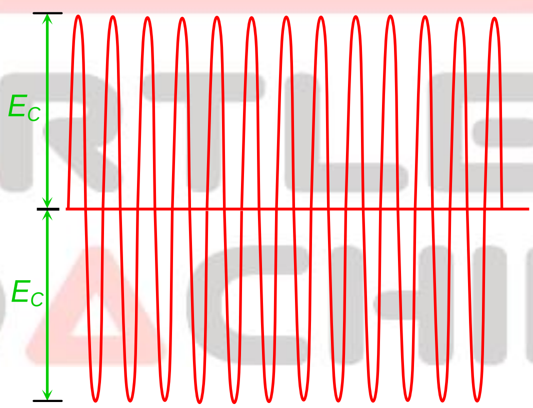
1. CONTINUOUS MODULATION

(A) Amplitude modulation

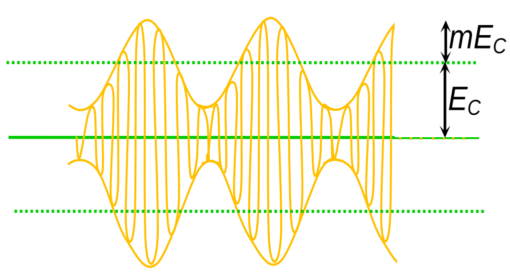
When the amplitude of high frequency carrier wave is changed in accordance with the intensity of the modulating signal, it is called **amplitude modulation.** The frequency of the modulated wave is equal to carrier frequency.



Modulating signal



Carrier



AM wave

Modulation Factor

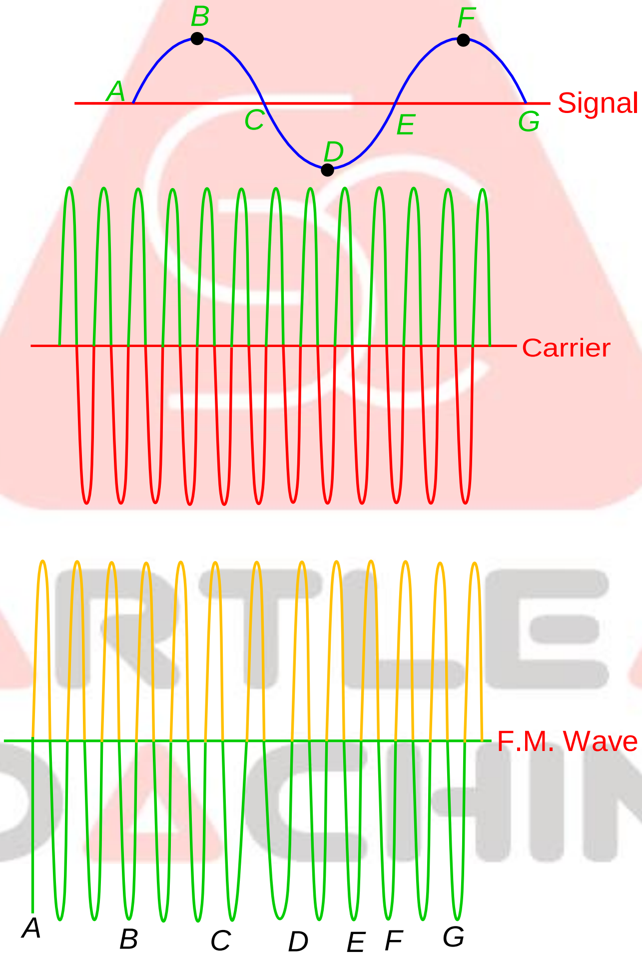
The extent to which the amplitude of carrier wave is changed by the signal is described by modulation factor.

The ratio of change of amplitude of carrier wave to the amplitude of normal carrier wave is called the modulation factor or index of modulation (m)

$$\text{Modulation factor, } (m) = \frac{\text{Amplitude change of carrier wave}}{\text{Amplitude of normal (unmodulated) carrier wave}}$$

(B) Frequency Modulation

When the frequency of carrier wave is changed in accordance with the instantaneous value of the (modulating) signal it is called **frequency modulation**. In frequency modulation the amplitude of the modulated wave remains the same, as of carrier wave. The frequency variations of carrier wave depend upon the instantaneous amplitude of the signal as shown in figure. When the signal voltage is zero as at A, C, E, the carrier frequency is unchanged. When the signal approaches its positive peaks as at B, the carrier frequency is increased to maximum as shown by the closely spaced cycles. When the modulating signal attains its negative peak at D, the carrier frequency is reduced to minimum as shown by the widely spaced cycles. This type of modulation gives noiseless reception. Since noise is a form of amplitude variations, a FM receiver will reject such variations.



The modulation index for FM wave is defined as

$$m_f = \frac{\text{maximum frequency deviatory}}{\text{modulating frequency}}$$

(C) Phase Modulation (PM)

Here the phase angle ϕ of the carrier signal varies in accordance with the modulating voltage. The phase term is an angle like ωt in the equation of sinusoidal wave therefore it will be as a varying frequency.

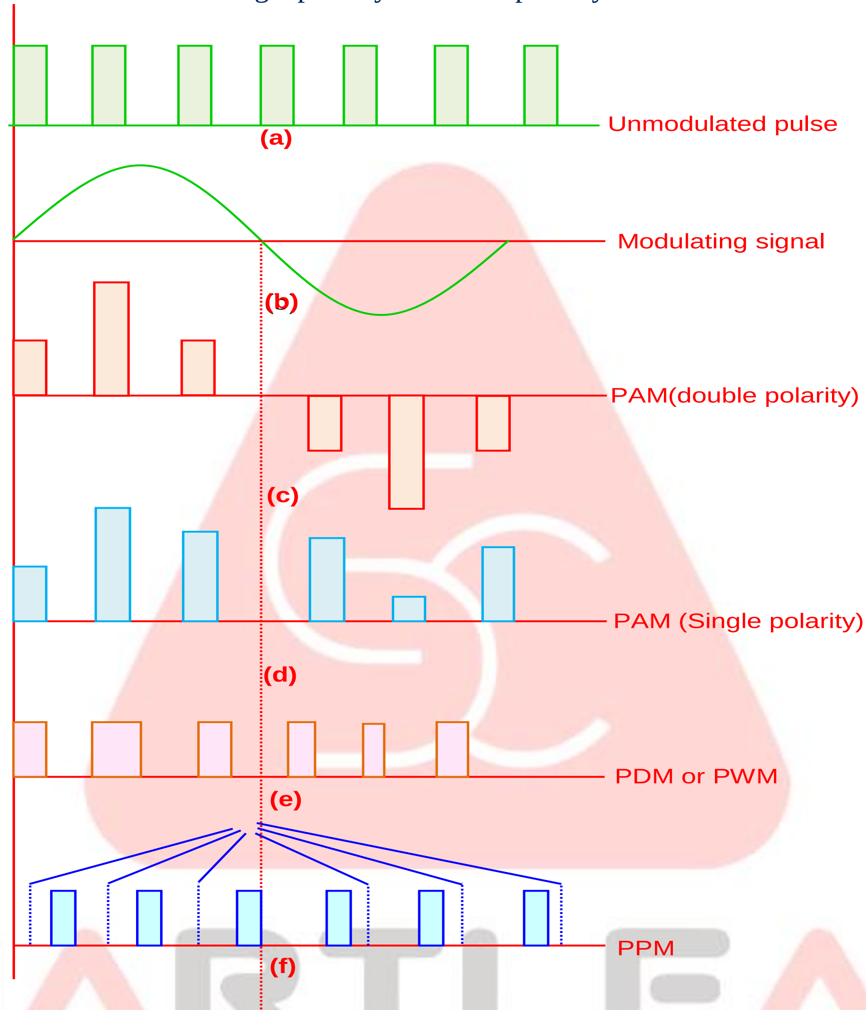
In FM signals information or message signal is in the form of frequency variations and therefore, the noises which are generally amplitude changes do little harm. Therefore frequency modulation (FM) gives better quality transmission and has a large band width.

2. Pulse Modulation

Here the carrier wave is in the form of pulses. The common pulse modulation systems are

(A) Pulse amplitude modulation (PAM)

The amplitude of the pulse varies in accordance with the modulating signal as shown in figure. The pulse amplitude modulation could be either single polarity or double polarity PAM as illustrated in the figures.



Different types of pulse modulated signals

(B) Pulse Duration Modulation (PDM) or Pulse Width Modulation (PWM)

The pulse duration varies in accordance with the modulating signal. The pulse duration is large, when amplitude of the modulating sinusoidal signal is large and vice-versa.

(C) Pulse Position Modulation (PPM)

In this the position of the pulse varies in accordance with amplitude of the signal at the instant of sampling. The dashed lines in this figure show the original position of the pulse. The shift is more if modulating amplitude is high and vice-versa.

Since in all these cases the modulated signal has a characteristic which is variable and proportional to the modulating voltage.

(D) Pulse Code Modulation (PCM)

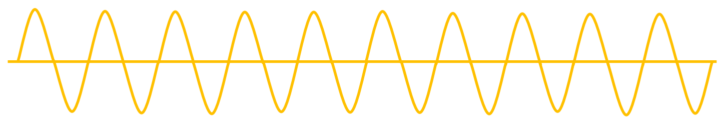
There is another variant of pulse modulation called as pulse code modulation, which is digital in nature. Modulating signal is first discretised or digitised in binary code. Which in turn is used to produce the modulated signal for transmission.

The common modulation techniques employed for the digital data are

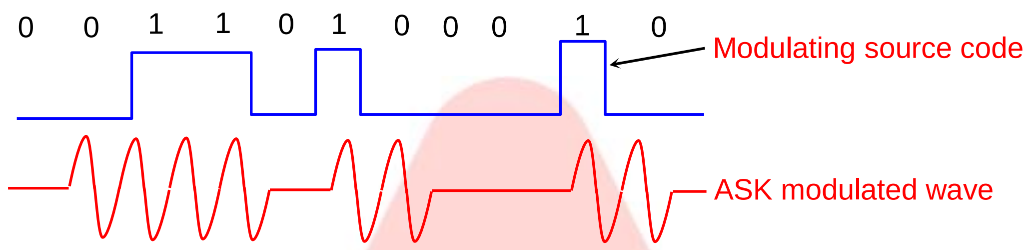
(a) **Amplitude shift keying (ASK)**: The amplitude of the carrier changes in accordance with the data signal.

(b) **Frequency shift keying (FSK)**: The frequency of the carrier increases for 1 while it remains unaffected for data signal 0.

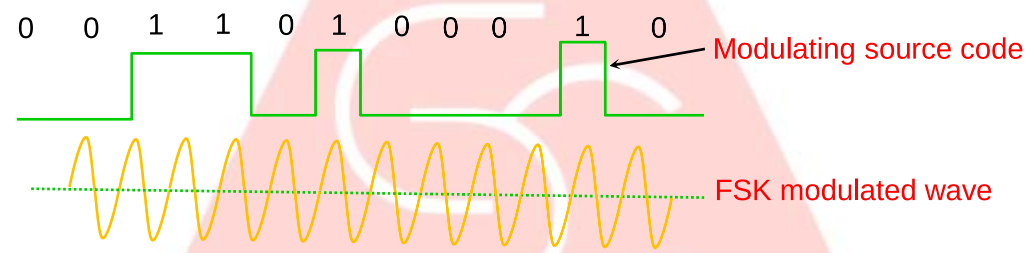
(c) **Phase shift keying (PSK)**: It is the phase which changes with 0 and 1.



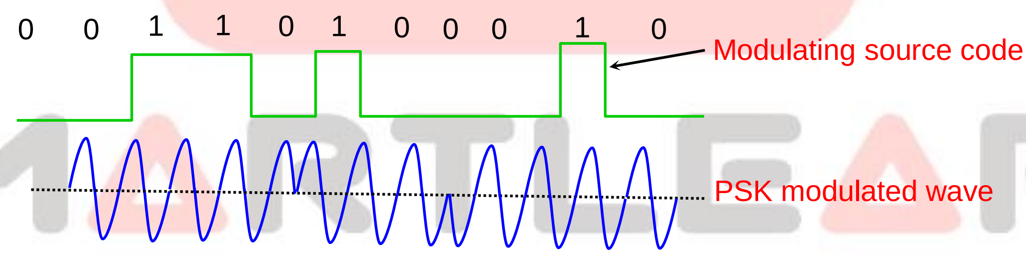
(a)



(b)



(c)



(d)

Amplitude frequency and phase shift keying used for digital data transmission

1.5 COMMUNICATION CHANNELS

We need a physical medium through which signals may propagate for establishing a communication between a transmitting and receiving station. This medium referred to as communication channel.

One simple method is using wire for sending information between two points some distance apart. This mode of communication is broadly referred to as line communication. The other method is to transmit the signal freely in space by using an antenna and receiver at the other end by intercepting the signal with the help of another antenna.

Mainly there are two types of communication

(i) Line communication
(ii) Space communication

A new dimension recently added to the space communication is satellite communication.

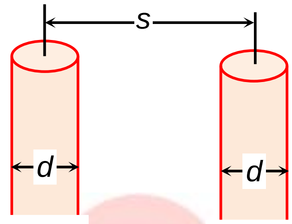
Line communication: The oldest point to point communication mode is communication through wires as in earlier telephone and telegraph links. The various types of such communication channels are

(i) Two wire transmission lines
(ii) Coaxial cables

(iii) Optical fibres

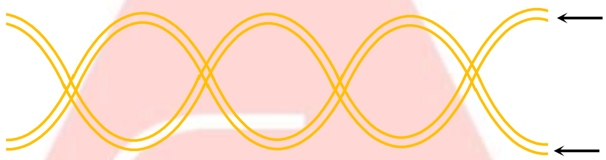
(i) Two wire transmission lines: Commonly used two-wire lines are

(a) Parallel wire lines: The parallel wire line is used where balanced properties are required.



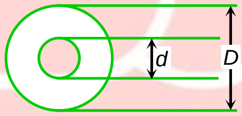
Parallel-wire

(b) Twisted pair wires lines: Twisting helps in minimizing electrical interference they cannot transmit signals over very large distances.



Twisted wire

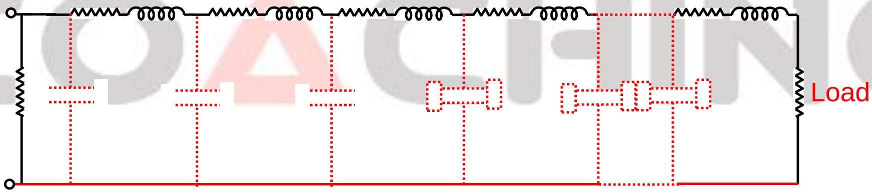
(c) Co-axial wire lines : These wires are used when un balanced properties are needed often used to interconnect a transmitter and an earthed antenna co-axial line wires can be used for microwaves and ultra high frequency waves (1 GHz).



Co-axial wire

System of conductors radiates *RF* energy if the conductor separation becomes appreciably approaching a wavelength half that of the operating frequency. It occurs more in the case of parallel wires than in a axial line.

Characteristic impedance: A two wire line consists of conductors of certain length and diameter with dielectric between them. So it must have resistance *R*, inductance *L* and capacitance between them. As the high frequency signals travels as a wave in the transmission line each portion of the transmission line can be considered as a small inductor resistor and capacitor as shown in the figure. Such inductors, resistors and capacitor are distributed throughout the transmission line. As a result each length of the transmission as line has characteristic impedance.



As the frequencies being transmitted increases towards *RF* or more, the impedance effects frequencies due to skin effect) become significant. So such transmission lies become very lossy. (*R* increase with frequency due to skin effect)

Losses in Transmission lines: The energy applied to transmission line may be dissipated in the following three ways.

(i) Radiation losses

(ii) Conductor heating

(iii) Dielectric heating

Radiation losses are more in case of parallel wire lines than co-axial lines. When separation of conductors in a parallel wire line is a fraction of a wavelength, the transmission lines act as antennas and radiate energy. These losses increase with the frequency.

The conductor heating rate ($=I^2R$) varies directly as square of current and inversely as characteristic impedance (Z_0) of the line. The loss also increases with frequency (because of skin effect)

The dielectric heating is proportional to voltage across the dielectric and inversely proportional to the characteristic impedance of the line. The loss increases with frequency (for solid dielectric lines). For air ($K = 1$), dielectric losses remain negligible. The line losses are usually expressed in terms of **decibels per 100 metre.**

1.6 OPTICAL COMMUNICATION

There are some inherent advantages of optical communication over the conventional two-wire or cable electronic communication systems. Some of these are

(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 accessible to interference. You will see that the optical signals is confined to the inside of fibre and cannot be tempered easily. So secret information like banking, defence etc. is more secure.

Optical 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)

The three most important component of an optical communication link are

(i) Optical source and modulator: Light sources which can be modulated by our information carrying signal.

(ii) Optical signal detector or photo detector: The optical signal reaching the receiving end has to be detected by a detector which converts light in to electrical signal so that the transmitted information may by decoded. Semiconductor based photo detectors are used because they fulfill all the criteria required for the detector of an optical communication system.

(iii) Cables which can carry optical signal (light cannot travel along a metallic wire or cable) but can pass through a transparent glass, polymers or dielectric. Therefore, optical transmission line called optical fibre is made from any of these materials. Total internal reflection is the principal behind fibre optics. Light can be transmitted along it with almost no loss because of total internal reflection.

The optical fibre and fibre cables:

An optical fibre consist typically of a transparent core fibre of glass of refractive index n_1 surrounded by a transparent glass sheath or cladding of slightly lower refractive index n_2, with both enclosed in an opaque protective jacket.

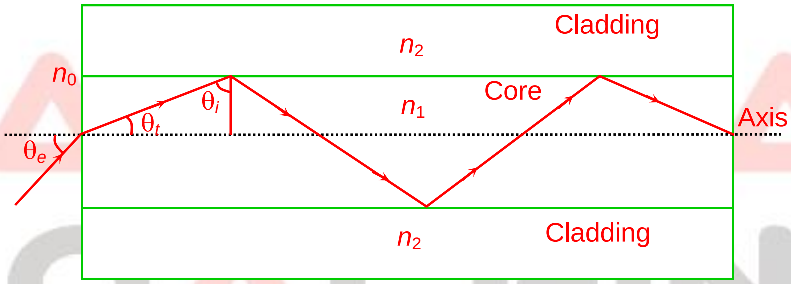


Figure shows a cross-section through the axis of an optical fibre. A ray entering the core from an external medium of index n_0 at an angle θ_e will make an angle θ_t with respect to axis inside the core.

From Snell's law

$$\sin\theta_t = \frac{n_0}{n_1}\sin\theta_e \qquad \dots \text{(i)}$$

The ray continuing in the core will be incident on the core-cladding boundary at an angle θ_i. If $\theta_i > \theta_{ic}$, where θ_{ic} is the critical angle, the ray will be totally internally reflected and continue to propagate inside the core.

$$\sin\theta_{ic} = \frac{n_2}{n_1} \qquad \dots \text{(ii)}$$

we have, $\sin\theta_e = \frac{n_1}{n_2}\sin\theta_t = \frac{n_1}{n_0}\sin\left(90^0 - \theta_{ic}\right) = \frac{n_1}{n_0}\cos\theta_{ic}$ … (iii)

or $$\sin\theta_e = \frac{\sqrt{n_1^2 - n_2^2}}{n_0} \qquad \dots \text{(vi)}$$

where, θ_e = entrance angle on the axis of the core,
n_1 = refractive index of core,
n_2 = refractive index of cladding,
n_0 = refractive index of external medium

For air as the external medium ($n_0 = 1$), equation (iv) reduces to

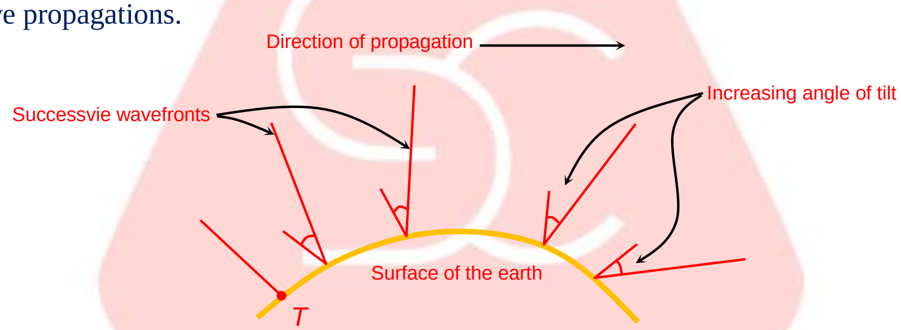
$$\sin\theta_e = \sqrt{n_1^2 - n_2^2}$$

1.7 SPACE COMMUNICATION

The communication process utilizing the physical space around the earth is termed as space communication. An electromagnetic wave is launched by an antenna and can be transmitted (i) along the ground (ground waves) (ii) directly in a straight line through intervening troposphere space (space wave or tropospheric wave or surface wave and (iii) upwards in sky followed by reflection from the Ionosphere (sky wave)

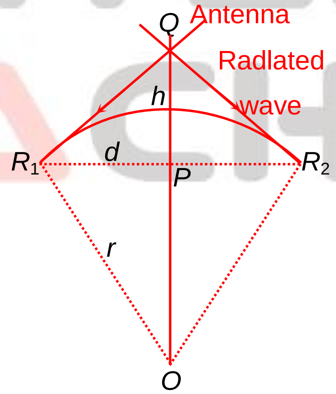
1.8 GROUND WAVE PROPAGATION

This mode of propagation can exist when the transmitting and receiving antenna are close to the surface of the earth. Any horizontal component of electric field in contact with the earth is short circuited therefore the field component of such a launched wave soon becomes vertically polarised as it glides over the surface of the earth. As the ground wave passes over the surface of the earth, it is weakened as a result of energy absorbed by the earth. Due to these losses the ground waves are not suited for very long range communication. Further, these losses are higher for high frequencies. Therefore the higher frequencies propagate through the following two modes viz, space wave and sky wave propagations.



1.9 SPACE WAVE PROPAGATION OR TROPOSPHERIC WAVE PROPAGATION

The transmitted waves, travelling in a straight line, directly reach the receiver end and are then picked up by the receiving antenna as shown in figure. It can be seen that due to the finite curvature of the earth, such waves cannot be seen beyond the tangent points R_1 and R_2. The effective reception range of the broadcast is essentially the region from R_1 to R_2 which is covered by the line of sight in a conventional sense. Hence, sometimes this mode of communication is termed as line of sight communication



Calculation for the range R_1R or $PR_1 = d$ which is half the total range.

In the right –angled triangle OQR_1 we have

$$OQ^2 = QR_1^2 + OR_1^2$$

$$QR_1^2 = h^2 + d^2$$

$$(r+h)^2 = r^2 + d^2 + h^2$$

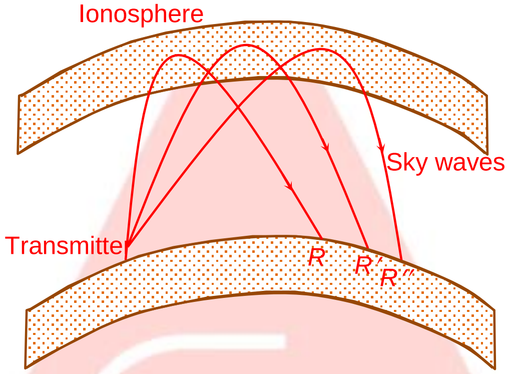
$$r^2 + h^2 + 2rh = r^2 + d^2 + h^2$$

$d = \sqrt{2rh}$

This distance is of the order of 40 km

1.10 SKY WAVE PROPAGATION OR IONOSPHERIC PROPAGATION

A transmitted wave going up in the sky is reflected back from the ionised region of the earth's atmosphere, the ionosphere. The ionosphere extends from a height of ≈ 80 KM to 300 KM above the earth's surface. The UV and other high energy radiations coming from sun are absorbed air molecules which get tonised and form an ionised layer of electrons and ions around the earth.



Refractive index of ionosphere is less than its free space value. As we go deep into the ionosphere, the refractive index keeps on decreasing. The refraction or bending of the beam will continue till it reaches critical angel after which it will be refracted back.

Critical frequency:

It is the maximum frequency of radio wave, which gets reflected from ionosphere and returns to the earth when beamed straight towards the layer of ionosphere. This is the maximum frequency above which rays go through the ionosphere. The f_c ranges approximately from 5 to 10 MHz. Frequencies higher than this cross the ionosphere and do not return back to the earth.

Long distance communication beyond 10 to 20 MHz was not possible before 1960 because all the three modes of communication failed (ground waves due to conduction losses, space wave due to limited line of sight, sky wave due to the penetration of the ionosphere by the high frequencies beyond f_e) Now, this is possible with the advent of the new concept of satellite communication.

REMOTE SENSING: An application of satellite communication

Remote sensing is the science and art of obtaining information about an object, area or phenomenon, acquired by a sensor that is not in direct contact with the target of investigation. Any photography is a kind of remote sensing.

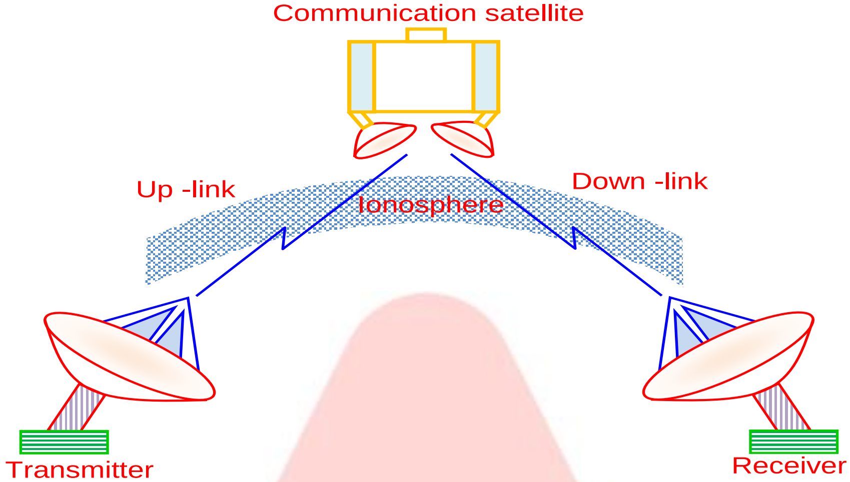
A satellite equipped with appropriate senses to acquire data can be placed in an orbit around the earth at any height having a period of revolution. It takes photographs or collects any other information desired and transmits it back to an earth station. This is known as remote sensing.

Photography using reflected electromagnetic radiation also extends into the ultraviolet and infrared, immediately adjacent to the visible red region, in which reflected rays can be recorded by cameras with suitable film and filter combinations. Colour infrared film is often used in aerial photography. In this type of film, the red colour is produced as a response to infrared light; the green colour is produced by red light and the blue colour by green light. Healthy, growing vegetation reflects strongly in the infrared band, vegetation has a characteristic red appearance on colour infrared film. Crops and dried vegetation (dormant grasses) appear yellow or brown. Unbaized areas typically appear in tones of blue and gray. Shallow water areas appear blue; deep water appears dark blue to blue-back. Colour infrared photography is particularly useful in geographic interpretation and land use planning, and thus has found wide application.

Computer processing of pictorial data, however, requires that images be in digital format. The picture can be thought of as consisting of a very large number of grid cells, each of which records a brightness value. The cells are referred to a pixel, a tiny spot at a time, in proportion to the brightness values with in the digital image.

1.11 SATELLITE COMMUNICATION

Present day requirements of information technology demand a very large number of communication channels and hence large frequency band width. For this we require high communication frequency, the communication through a satellite has revolutionized communication technology.



Communication satellite is a space craft place in an orbit around the earth which carries a transmitting and receiving equipment (termed as radio transponder) for steady reliable transmission it is preferred that the satellite should be geostationary. A geostationary satellite is one that appears to be stationary relative to the earth. If we use three geostationary satellites placed at the vertices of an equilateral triangle as shown in figure the entire earth (globe) can be linked / covered by the communication network, each satellite covering one-third of the globe