5.1 INTRODUCTION

- In the block diagram of communication system there is a block **'channel'** between the transmitter and receiver.
- The information signal is conveyed to the receiver through this channel.
- In radio communications (i.e. wireless communication), the channel is simply free space between the transmitting and receiving antennas, here we have to study the behaviour of signals in that medium.
- The chapter is divided into two pars – The first is electromagnetic radiation, it deals with the nature, propagation, the attenuation and the absorption that they undergo while travelling in free space.
- When a radio wave is radiated from the transmitting antenna it spreads in all directions decreasing in amplitude with increasing distance. Because of spreading of high frequency currents in the form of electromagnetic waves of same nature as light through larger and larger surface areas.
- Broadly, speaking by radio waves, means that band of electromagnetic energy which covers the frequency range from few kHz to a few MHz.
- In an earth environment, the electromagnetic waves propagate (spread) in ways that not only depend on their own properties but are also dedicated by the environment itself.
- The actual environment in which the radio waves are propagated may have obstacles, discontinuities and propagation medium variations.
- In recent years, radio has invaded 'out space' too. In many respects, the concept of free space propagation is realized in the space far from the earth.
- Free space is the space which does not interfere with the normal radiation and propagation of radio waves.

- The concept of free space propagation simplifies the approach to wave propagation.
- The second part is aspect of the propagation waves.
- Also frequency used plays a important role in the method of propagation, as do the existence and proximity of the earth.
- Three methods of propagation are ground wave, sky wave and space wave. Propagation mainly depends on frequency around the curvature of earth by reflection from the ionized portions of the atmosphere.
- Microwave propagation, so called superrefraction, tropospheric scatter and effects of the ionosphere on waves trying to travel through it.

6.2 ELECTROMAGNETIC RADIATION

- The process of signal travel from the transmitter to receiver can be divided in two parts.

  (i) Radiation of the signal.

  (ii) Propagation.

6.2.1 Radiation

- Whenever, a high frequency current flows through a conductor, the power measured on both the sides of the conductor is not same.
- A part of the power is dissipated in the resistance of the conductor and a part of it '**escapes**' into the free space. **This escape of power is known as radiation.**

6.2.2 Propagation

- **This 'radiated' power then propagates in space in the shape what is known as propagation.**
- Radiation and propagation of radio waves cannot be seen.

6.3 FUNDAMENTALS OF ELECTROMAGNETIC WAVES

- Electromagnetic waves are nothing but oscillations which propagate in free space.
- They travel through free space at the speed of light i.e. 3×10^8 m/sec.
- ***These waves consist of simultaneous electric and magnetic fields, so called Electromagnetic waves.***
- For example, visualize yourself standing on a bridge looking towards a calm body of water.
- If you throw a stone into the pond, you would see this energy process in action.

- As the stone travels downward, there would be a path of bubbles generated in the same direction (vertical) as the stone, but there would also be a circular wave pattern radiating from the point of impact and spreading horizontally across the body of water.
- These two energy reactions approximates the electromagnetic and electrostatic radiation pattern in free space.
- The energy created by the displacement of the liquid is converted into both the vertical and horizontal components.
- The energy level of these components varies inversely to the distance and spreads the total energy generated over this expanding wavefront.
- This action can be related to the term **power density**, where power density is defined as the radiated power per unit area.

6.4 TRANSVERSE ELECTROMAGNETIC WAVES (TEM)

- The electromagnetic waves are oscillations, which propagate through free space.
- EM waves travel in free space at the speed of light.
- Fig. 6.1 shows the simple electromagnetic wave, in which the direction of 'electric field', the magnetic field and propagation are mutually perpendicular.

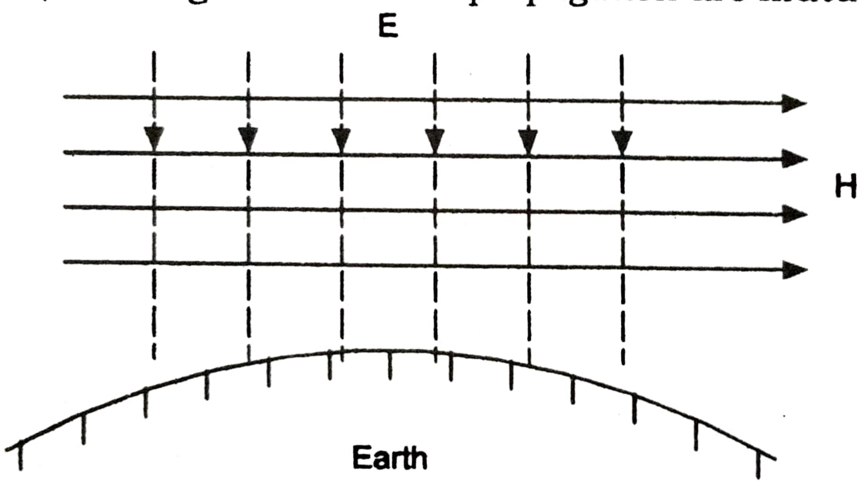


Fig. 6.1 : Simple Electromagnetic Wave

- The electromagnetic waves are transverse in nature i.e. oscillations are perpendicular to the direction of propagation of waves so the name **Transverse Electromagnetic Wave (TEM).**
- The nature of TEM wave is shown in Fig. 6.2.

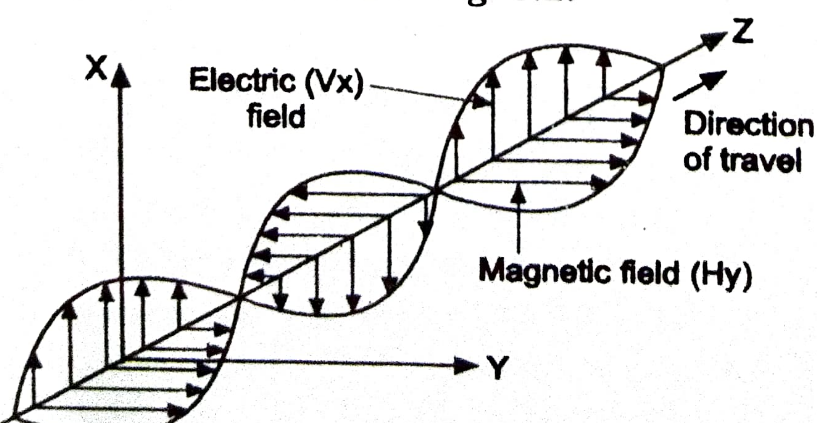


Fig. 6.2 : Transverse Electromagnetic Wave

- The propagation is somewhat similar to the outward travel of waves in a water pond when stone is thrown into it.
- But there is a fundamental difference between the two i.e. the ripples on the surface of water are **'Longitudinal'**. So the oscillations are in the direction of propagation. However, EM are **'transverse'** i.e. the oscillations are perpendicular to the direction of propagation shown in Fig. 6.2.
- EM waves cannot propagate well through the lossy conductors such as sea water. The waves reflects from good conductors such as copper, aluminium.
- Also EM waves get refracted when passed from one medium to the other.

6.4.1 Behaviour of EM Wave in Free Space

- Since no interference or obstacles are present in free space, EM waves will spread uniformly in all directions from point of source.
- A wavefront from a source point becomes spherical in shape shown in Fig. 6.3.

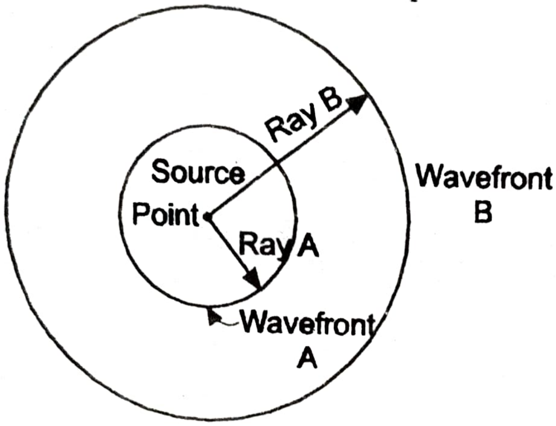


Fig. 6.3 : Wavefront from a Source Point in Free Space

- **A wavefront is plane joining all points of identical phase.**
- **Power density is defined as the radiated power per unit area.**
- As shown in Fig. 6.3, if wavefront A travels from its present position to that of wavefront B i.e. it doubles the distance from the source point.
- Then the power density will be reduced to one-forth at location of B as compared to that of A.
- The **inverse square law** is applicable to all radiations in free space.
- It states that "Power density is inversely proportional to the square of the distance from the source point".

Mathematically,

$$\boxed{P = \frac{P_t}{4\pi r^2}} \quad \ldots (6.1)$$

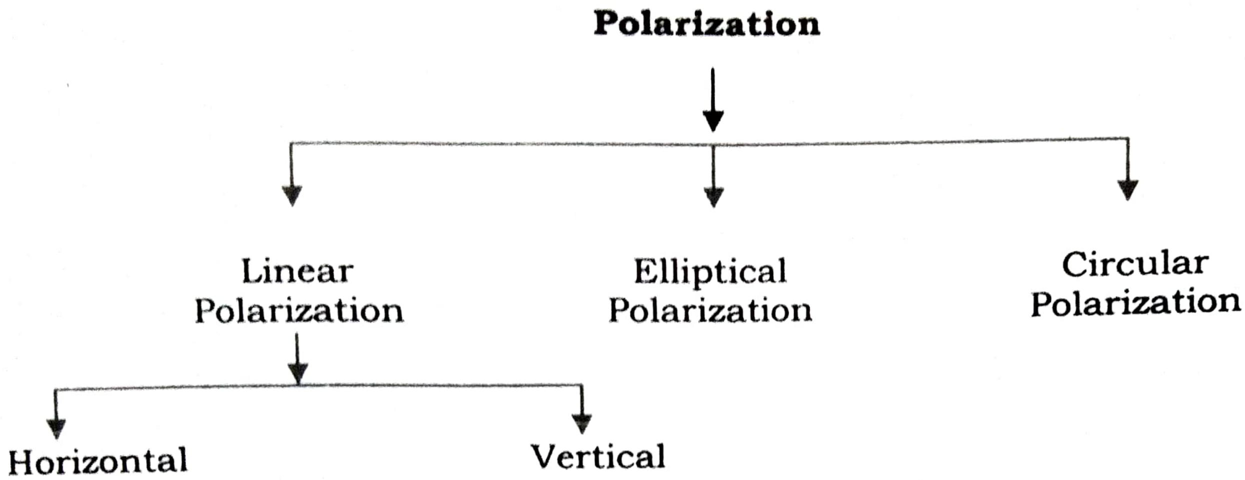
where, P = Power density at distance r from an isotropic source point

P_t = Transmitted power

- An isotropic source is one that radiates uniformly in all directions in space.

6.5 POLARIZATION

- Polarization refers to the physical orientation of the radiated EM waves in space.
- **The polarization of a EM wave is simply the orientation of the electric field vector with respect to the earth surface.**
- **Types of Polarization :**



(i) Linear Polarization :

- If the polarization remains constant then it is called linear polarization.
- Linear polarization is of two types.
  - (a) Horizontal Polarization
  - (b) Vertical Polarization

(a) Horizontal Polarization :

- ***If the electric field propagates (i.e. travels) in parallel with the earth surface the EM wave is said to be horizontally polarized.***
- Means electrical field travels only in horizontal direction so the name.

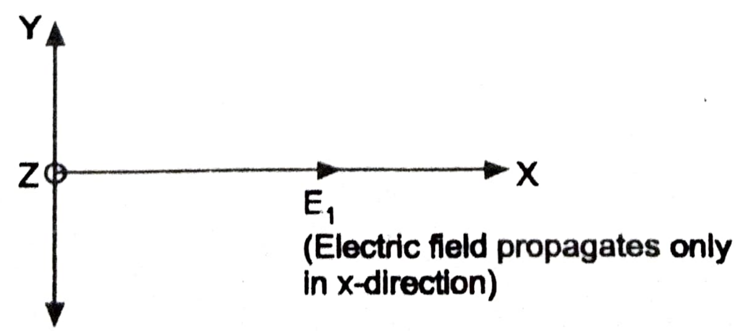


Fig. 6.4 : (a) Horizontal Polarization

In horizontal polarization,

$$E_2 = 0$$

$\therefore$ Axial ratio

$$AR = E_2/E_1 = \frac{0}{E_1} = 0$$

(b) Vertical Polarization :

- ***If the electric field propagates perpendicular to the surface of earth, the EM wave is said to be vertically polarized.***
- Means electric field travels only in vertical direction so the name.

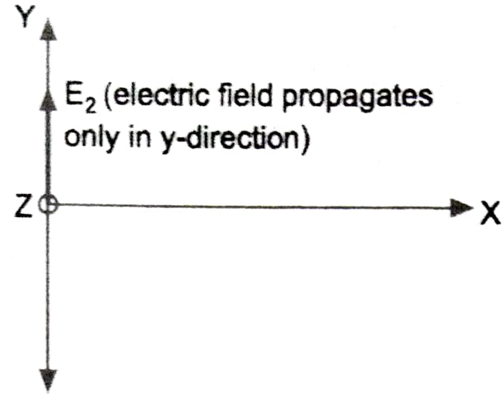


Fig. 6.4 : (b) Vertical Polarization

In vertical polarization,

$$E_1 = 0$$

$$\therefore \quad \text{Axial ratio,} \quad AR = \frac{E_2}{E_1} = \frac{E_2}{0} = \infty$$

For Example,

In Direct To Home (DTH) service, dual polarization is used in Ku band.

Dual polarization means both horizontally polarized and vertically polarized EM waves.

(ii) Elliptical Polarization :

- ***If the electric field propagates in all direction that forms the shape of ellipse, then EM wave is said to be elliptically polarized.***
- Means electric field propagate in all direction but the more towards Y-direction and less towards X-direction, and forms the shape of ellipse.

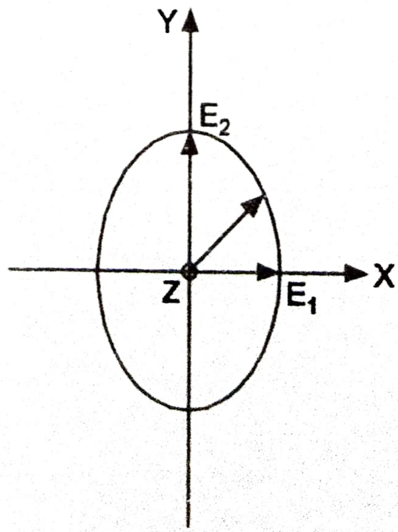


Fig. 6.5 : Elliptical Polarization

- The ratio of major axis to minor axis of polarization is known as **Axial Ratio (AR).**
- In Fig. 6.5, Axial ratio is given by the ratio of semi-major to semi-minor axis (E_2/E_1).

In elliptical polarization,

$$E_1 < E_2$$

$\therefore$ Axial ratio

$$AR = \frac{E_2}{E_1}$$

AR is greater.

(iii) Circular Polarization :

- ***If the electric field propagates equally in all directions then the EM wave is said to be circularly polarized.***
- Means electric field propagates equally in all directions.

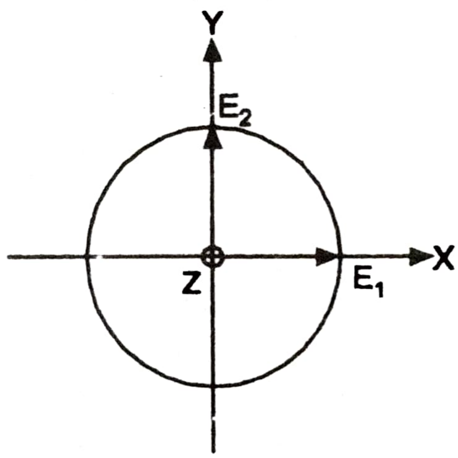


Fig. 6.6 : Circular Polarization

In circular polarization,

$$E_1 = E_2$$

$$\therefore \quad AR = 1$$

6.6 ELECTROMAGNETIC SPECTRUM

The propagation of EM wave depends on :

1. The properties of waves.
2. The environment in which they travel.

The various methods of propagation depends on frequency. Hence it is necessary to first look into the designation of frequency based. It is called electromagnetic spectrum.

Following figure shows the spectrum of electromagnetic waves.

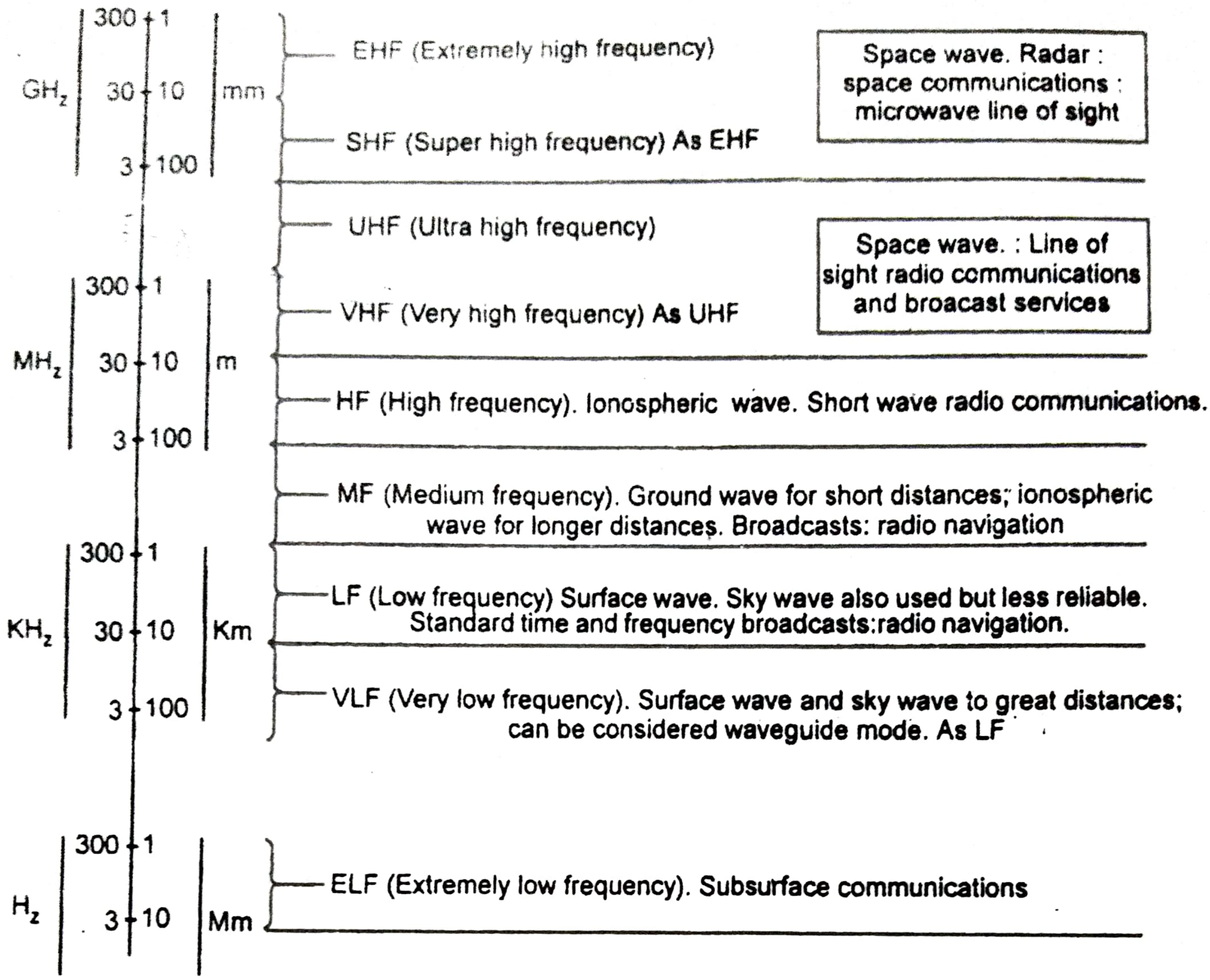


Fig. 6.7

6.6.1 Frequency Ranges and Applications

- We know that EM spectrum means its entire frequency range.
- This frequency range is divided into number of bands and these bands ar used for different applications in communication.

Sr. No.	Frequency Band	Applications
1.	300 Hz – 3 kHz	Voice or audio communication (Used in telephone lines).
2.	VLF → 3 kHz – 30 kHz	Submarine, military, navy communication.
3.	LF → 30 kHz – 300 kHz	Marine, navigation, also used as subcarrier frequency
4.	MF → 300 kHz – 3 MHz	MW band of AM radio broadcast.
5.	HF → 3 MHz – 30 MHz	SW i.e. shortwave band of AM radio.
6.	VHF → 30 MHz – 300 MHz	TV and FM radio broadcasting.
7.	UHF → 300 MHz – 3 GHz	UHF TV channels, mobile phones.
8.	SHF → 3 GHz – 30 GHz	Satellite and radar.
9.	EHF → 30 GHz – 300 GHz	Satellite and radar

6.7 EFFECT OF ENVIRONMENT ON WAVE PROPAGATION

- Propagation of EM waves near the earth is examined, and causes number of changes in an EM wave.
- There are three types of effects on EM wave.
  - (i) A wave near earth is susceptible to **reflection**. Reflection is caused due to the earth's surface, mountains, buildings and any other similar structures.
  - (ii) While passing through atmospheric layers of different densities, electromagnetic waves get **refracted**.
  - (iii) **Diffraction** may be caused due to tall, massive objects, such as mountains, buildings etc.

6.7.1 Reflection

Reflection of electromagnetic waves is quite similar to that of light waves.

- Two basic laws of light reflection :
  - (i) The angle of reflection of the incident and reflected rays is same and
  - (ii) The incident ray, the reflected rays and the normal at the point of incidence lie in one plane. These both laws are applicable to EM reflection also.
- Besides, the image concept of light waves can also be used to advantage in the analysis.

Fig. 6.8 shows the reflection properties.

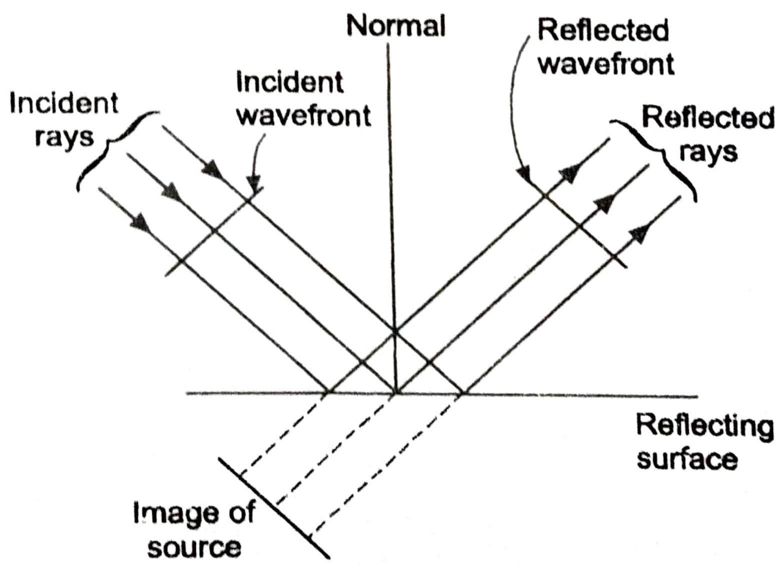


Fig. 6.8 : Reflection of Waves, Image Formation

- Now, we will do one experiment.
- Just stand before a mirror. Place another mirror at your back and look into the first mirror.
- What do you find in this mirror· of course, a number of your images.
- You will note that the brightness of the images goes on decreasing progressively.

- This indicates that after each reflection, a part of the light waves are absorbed and lost.
- With radio waves, the situation is exactly same.
- To define the amount of absorption in each reflection, we define a parameter called ***reflection co-efficient***, denoted by P.
- *Reflection co-efficient is defined as the ratio of the electric intensity of the reflected wave to that of the incident wave.*
- In case of a perfect conductor, reflection coefficient P is unity i.e. 100% reflection takes place and for other practical cases it is always less than unity.
- For a wave to get reflected from a conducting surface, the electric vector must be perpendicular to the surface; otherwise surface currents are set-up, and no reflection takes place.

6.7.2 Refraction

- **Refraction is defined as the change in direction of a ray when it passes from one medium to another having different densities.**
- As with light, refraction takes place when an electromagnetic wave passes from one propagating medium to another having a different density.
- The velocity of the wave also changes, while it changes the medium.
- A simple case of refraction of radio waves while changing over from one medium to another for propagation is shown in Fig. 6.8.

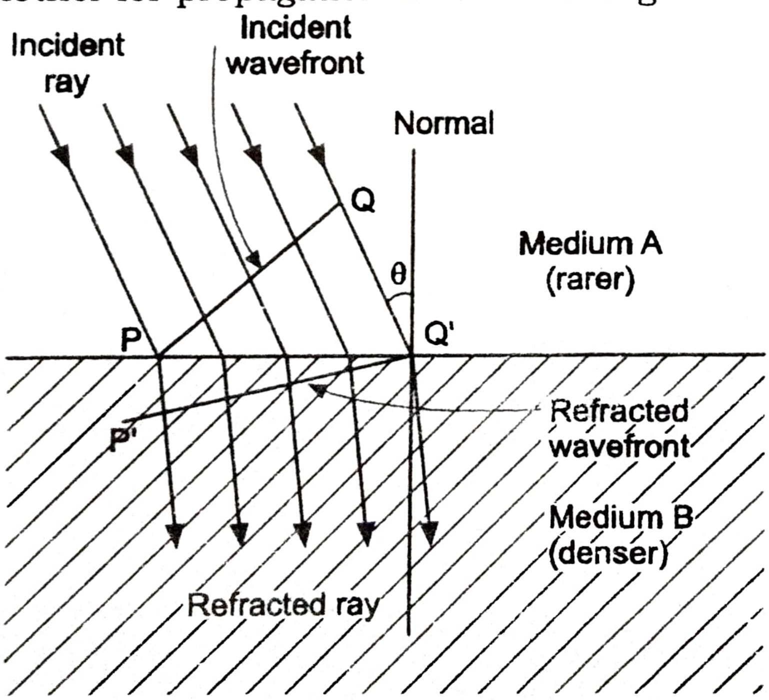


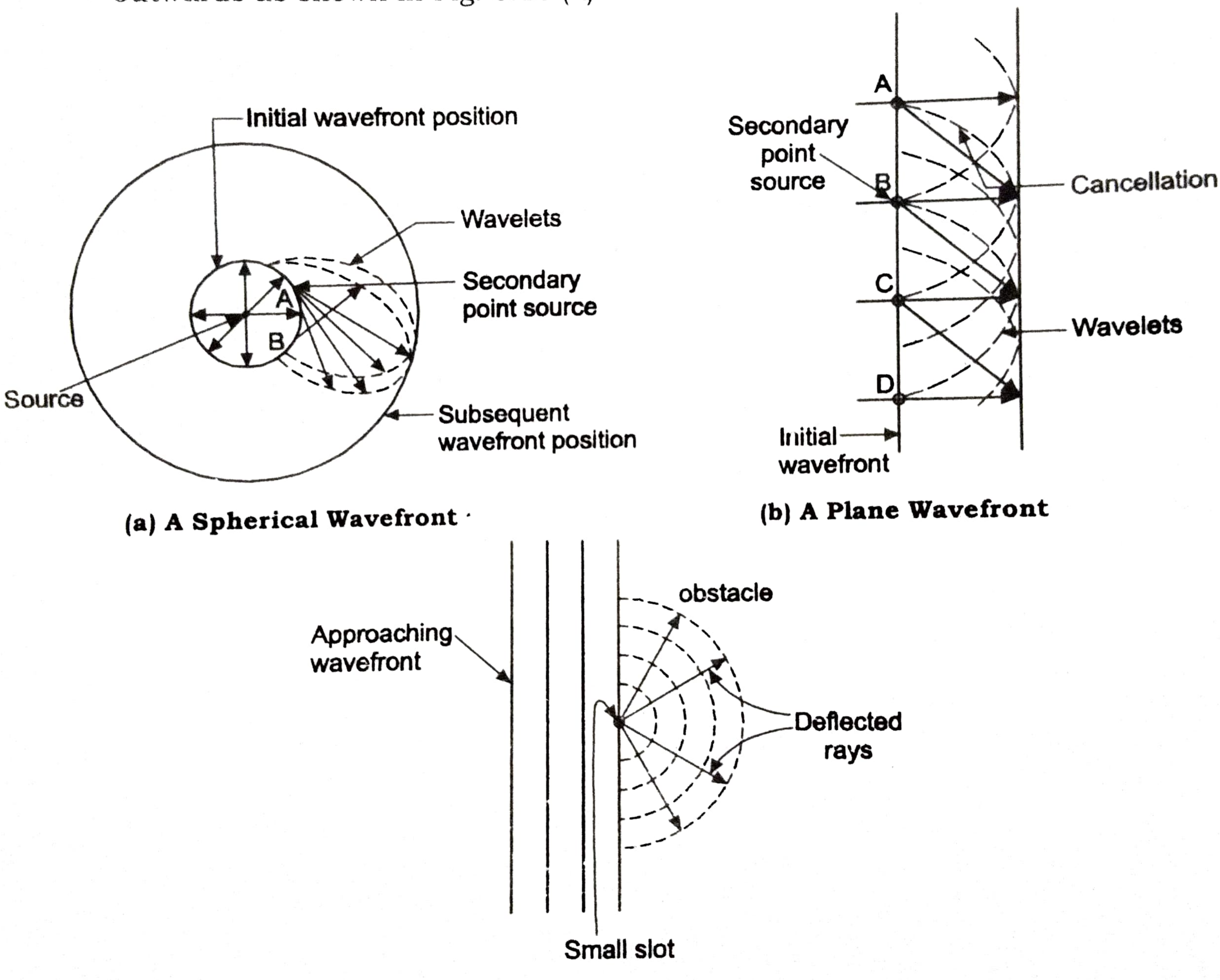
Fig. 6.9 : Refraction at a Plane Surface by Radio Waves

- As shown in Fig. 6.9, the wavefront acquires a new direction after refraction.

6.7.3 Diffraction

- This property describes the behaviour of electromagnetic waves when these waves strike the conducting plane with small slits.

- Diffraction is based on 'Huygen's principle which states that no matter how small a slit is made in an opaque plane, light on the side opposite the source would spread out in all directions, and no matter how small light source is constructed, a sharp shadow cannot be obtained at the edge of the sharp opaque-obstacle.
- This principle of light can be easily applied to electromagnetic waves.
- In other words, we can state that every point on a given (spherical) wavefront can be regarded as a source of waves from which further waves are radiated outwards as shown in Fig. 6.10 (a).



(a) A Spherical Wavefront · **(b) A Plane Wavefront**

(c) Through a Small Slot

Fig. 6.10 : Diffraction

- Consider now an infinite plane wavefront as shown in Fig. 6.10.
- Mathematically, it can be proved that all the secondary wavelets except the one in the original direction of the wavefront are cancelled.

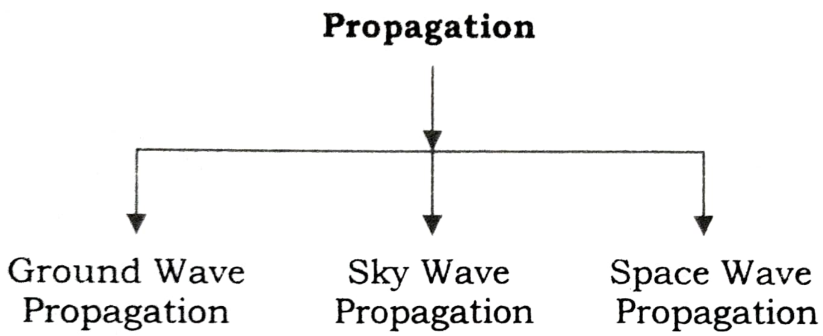
8 PROPAGATION OF WAVES

- Once the signal leaves the transmitting antenna, it can take any of the following paths to travel in free space.
- The type of propagation is decided by the path adopted by the signal to reach from transmitter to receiver.
- Three types of propagation (or paths) are as follows :

  (i) Along the surface of the earth (Ground Wave Propagation).

  (ii) Upto the layer called 'Ionosphere' and back (sky wave propagation).

  (iii) From transmitter to receiver in a straight line (space wave propagation).



- The path adopted by radio signal depends on many factors i.e. frequency of the signal atmosphere conditions and time of day.
- The frequency range, propagation used and its applications are shown in Fig. 6.11.

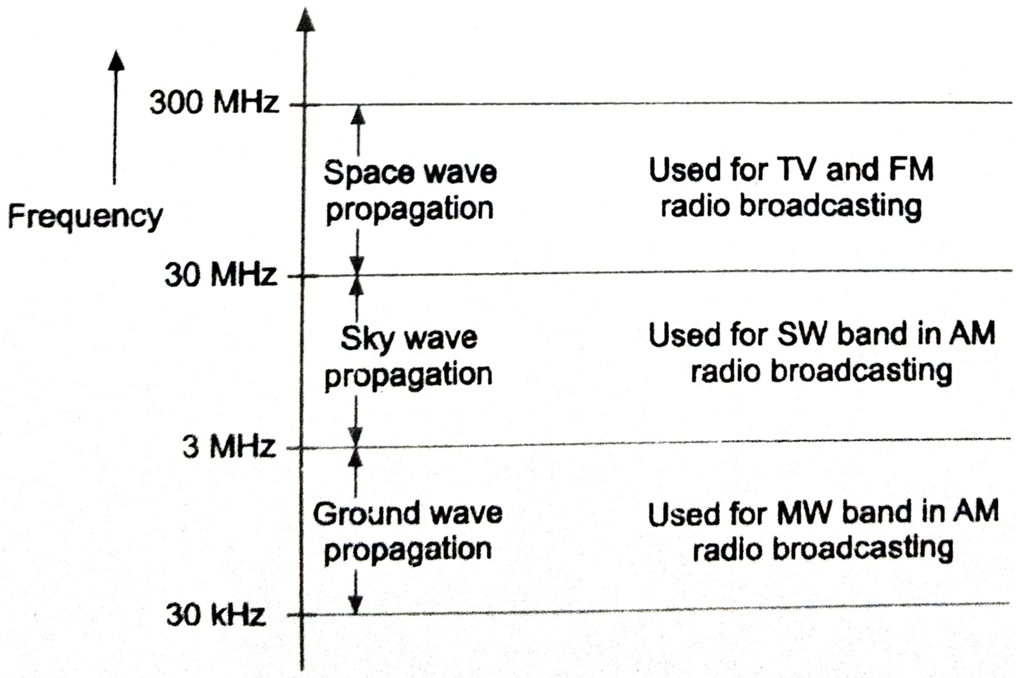


Fig. 6.11

- The electromagnetic waves travel in a straight lines unless and until their path is changed by earth or atmosphere].

- Frequencies above HF (i.e. 300 MHz) travel in straight lines. They propagate in the portion of atmosphere called as troposphere which is closest to the ground. Hence they are called as tropospheric **waves** or **space waves**.
- Frequencies below HF range (300 kHz – 3 MHz) travel around the curvature of earth. They are called as **ground waves** or **surface waves**.
- The HF waves (3 MHz to 30 MHz) travel by reflection through an atmospheric level called ionized layer. They are called **sky waves**.
- Apart from these three basic paths of propagation methods that are **tropospheric scatter** and **stationary satellite communication** which are recently developed.

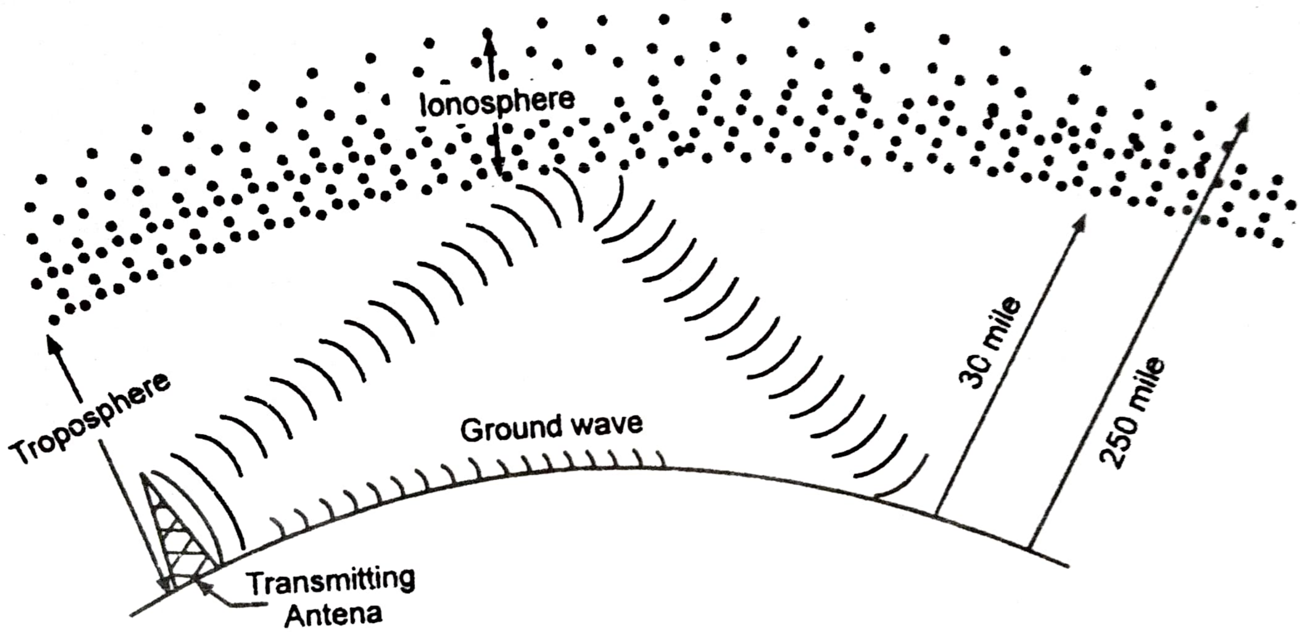


Fig. 6.12

6.9 GROUND WAVE PROPAGATION

- Ground wave consists of the direct wave which travels near the ground from transmitter to receiver.
- Fig. 6.13 shows the path followed by the radiated EM waves.

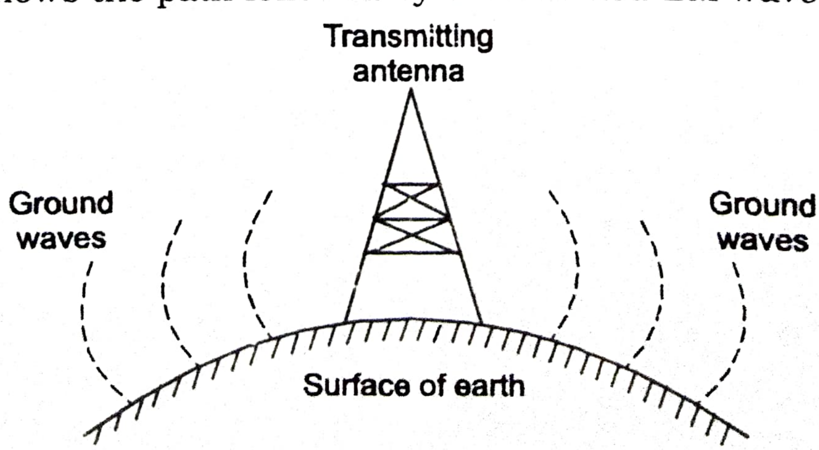


Fig. 6.13 : Ground (Surface) Wave Propagation

Explaination :

1. The ground wave represents the transmitted electromagnetic waves travelling along the surface of the earth.
2. The ground wave exists when the transmitting antenna is vertical and close to earth's surface, like a tower or mast.
3. The EM wave leaves the transmitting antenna and remains close to the earth surface. The ground wave actually follow the curvature of earth and hence can travel beyond the horizon.
4. The ground waves are vertically polarized to prevent short circuting of electric field component.
5. The ground wave propagation is strongest at the low and medium frequency ranges. The ground waves is the path chosen by the signal when the frequency is between **30 kHz and 3 MHz.**

6.9.1 Attenuation of Ground Waves

The ground waves get attenuated due to following reasons :

1. While travelling over the earth's surface, the ground waves induce some current into it. Thus, they lose some of energy due to absorption.
2. Due to diffraction the wavefronts will tilt over the surface shown in Fig. 6.14. This angle of tilt goes on increasing due to curvature of the earth surface. So, the waves **'lies down'** and **'dies'**.
3. This distance depends on the type of surface, frequency of operation and transmitted power.

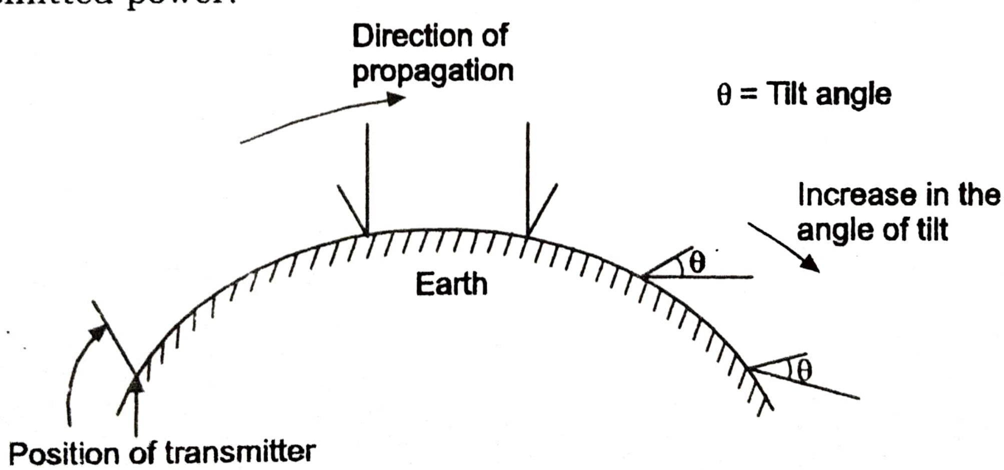


Fig. 6.14

4. As the tilt angle increases with increase in frequency, it puts the limitation on the range of transmission if the transmission takes place near the top of medium frequency range. (i.e. Near 3 MHz). Increase in the transmitted power does not help in increasing in the range of these frequencies. **This is the reason, why the ground wave propagation cannot be practically used above 3 MHz.**

6.9.2 VLF Propagation

- The ground waves can be used for a long distance communication, if the operating frequency is less than 100 kHz.

- **Such type of propagation takes place over the sea water.** Because water is better conductor than earth surface.
- Thus, the power loss due to absorption in the surface is very low.
- Thus, the range of propagation depends mainly on tilt angle. The degree of tilt angle depends on the distance from antenna in wavelengths.
- The strength of low-frequency signals changes very gradually, so that rapid fading does not occur.

6.9.3 Advantages of Ground Wave Propagation

(i) Atmospheric conditions do not affect the ground wave propagation.

(ii) If the transmitted power is large enough, then ground wave propagation has applications in communication.

6.9.4 Disadvantages of Ground Wave Propagation

(i) Limited range of frequency.

(ii) The antenna should be very tall at low operating frequencies.

6.9.5 Applications of Ground Wave Propagation

(i) VLF transmission used for ship communications such as radio, navigation and maritime, mobile communication.

(ii) VLF transmission used for time and frequency transmissions.

(iii) It is also used in AM radio broad-casting operating in MW band.

$$\boxed{\text{MW band frequency range} - 540 \text{ kHz to } 1640 \text{ kHz}}$$

Pune station operates in MW band at frequency 791 kHz.

6.10 SKY-WAVE PROPAGATION : THE IONOSPHERE

- The ionization of the upper parts of the earth's surface play an important part in the propagation of radio waves at high frequencies.
- Experimently Sir Appleton showed that the atmosphere receives sufficient energy from the sun for its molecules to split into positive and negative ions. Thus, they remain ionized for long period of time.
- There are several layers of ionization at different heights, which is reflected back to earth.
- ***In sky wave propagation, the transmitted signal travels into the upper atmosphere where it is bent i.e. reflected back to earth. This bending or reflection of the signal takes place due to the presence of a layer called as ionosphere in the upper atmosphere.***

Fig. 6.15 shows the ionosphere layers and the principle of sky wave propagation.

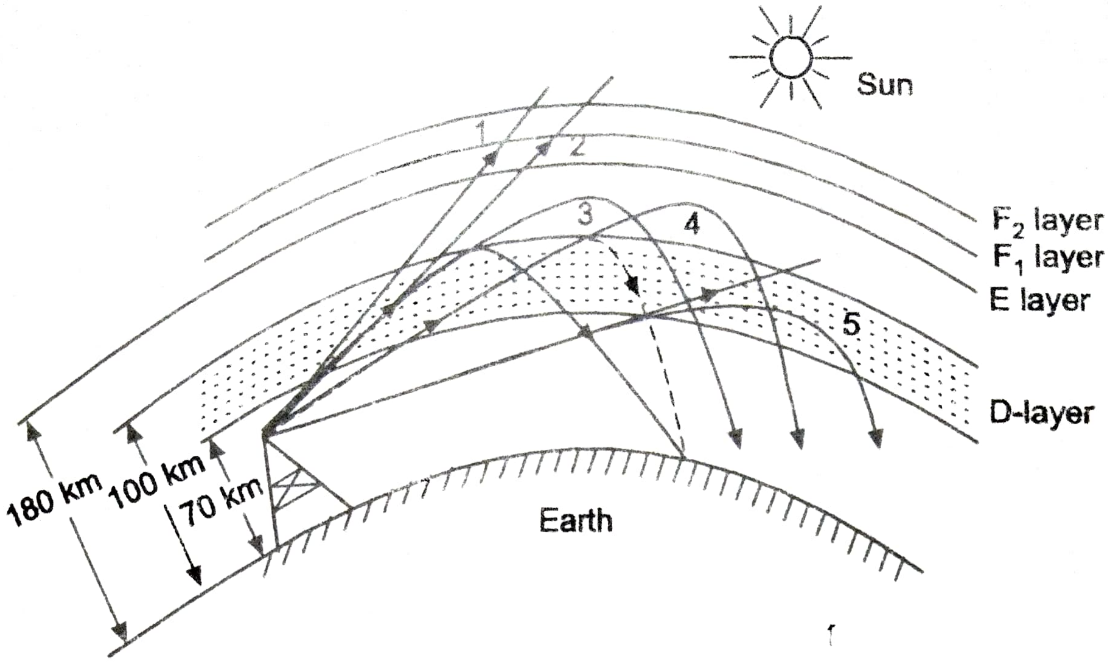


Fig. 6.15 : Principle of Sky Wave Propagation

- The ionized layers cause refraction to take place i.e. the electromagnetic waves deflect or bend. This happens because these waves cross boundary lines of ionosphere.
- When the radiated signal from antenna reach the ionosphere, the different levels of ionization makes the signal bend slowly. The direction of bending depends on angle of incidence of the wave at ionosphere and also on the levels of the ionization layers shown in Fig. 6.15.
- As we travel up into the ionosphere the ionization density of the layers keeps on increasing causing reduction in refraction index.
- The electromagnetic wave incident at the ionosphere starts bending.
- If the rate of change of refractive index is enough for the wave become parallel to layer it can bend downward and return back to the earth surface. Due to this signal propagate over a long distance.
- The HF wave (3 MHz – 30 MHz) exhibit the effect more.
- The angle of incidence at the ionosphere also decides whether the refraction will take place or not.

6.10.1 The Ionosphere, its Layers and their Effects

- The ionosphere is the upper portion of the atmosphere, which absorbs large quantities of radiant energy from sun, becoming heated and ionized.
- Thus, we can say that, '***the ultraviolet radiation from sun will ionize the upper layer of atmosphere.***
- Due to ionization, this part of atmosphere becomes electrically charged. The atoms take the extra electrons or lose them to become positive or negative ions. Here free electrons are also present. So this layer of ions is known as **ionosphere**. This layer is thick and invisible which is shown in Fig. 6.16.

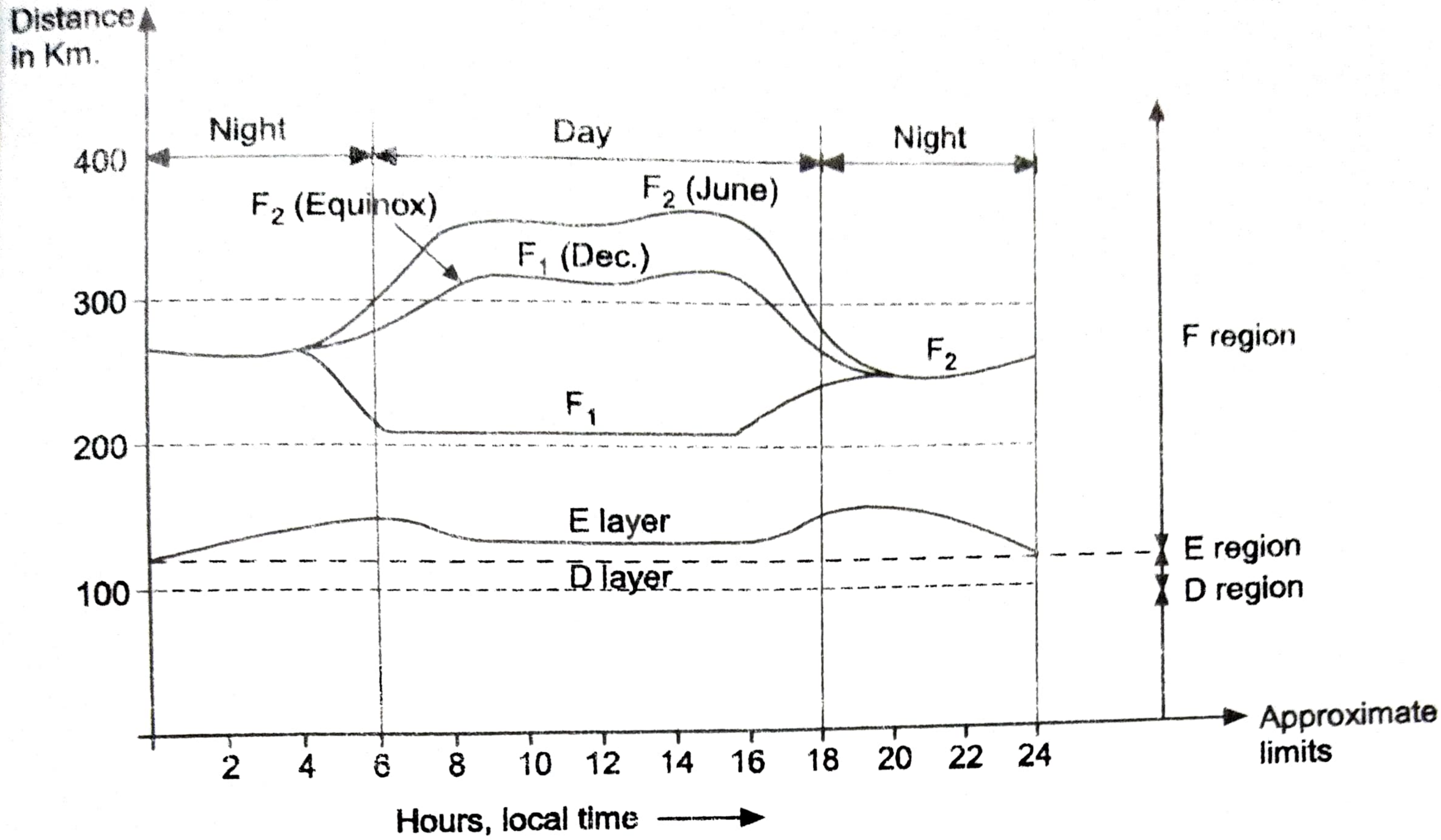


Fig. 6.16 : Ionospheric Layers and Their Regular Variations

- There are main four layers D, E, F_1 and F_2 layer in descending order.

D layer (region) :

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

E-layer :

- The E layer is the next in height, existing at about 100 km, with a thickness of 25 km.
- **The E-layer also disappears at night due to recombination of ions and molecules**. This is due to absence of radiation for sun at night time.
- The main effects of E layer are to aid MF surface wave propagation and to reflect some HF waves in day time.

Sporadic E-layer :

- The E_s layer is a thin layer of very thin ionization density and it may appear with normal E layer. It is also known as **sporadic E layer.**
- But when it appears, it remains present during the night also.
- It is a thin and high density layer, so actual reflection will take place form this layer.
- It does not have an important part in long-distance communication, but it sometimes permits good reception.

4. **F_1 layer :**

- F_1 layer exists at height of 180 km in daytime and combines with the F_2 layer at night, its daytime thickness is about 20 km.
- It provides more absorption for HF waves.

5. **F_2 layer :**

- The F_2 layer is most important reflecting medium for high-frequency radio waves.
- Its approximate thickness is upto 200 km and its height ranges from 250 to 400 km in daytime.
- ***It is upper most region having highest electron density of all layers. Due to this F_2 layer remains present during the night times.***

Table 6.2

Sr. No.	Layer name	Average Height (above earth)	Thickness	Remark
1.	D	70 km	10 km	Disappears at night. Better for VLF and LF wave propagation .
2.	E	100 km	25 km	Disappears at night. Better for MF wave propagation.
3.	F_1	180 km	20 km (day time)	Combines with F_2 at night.
4.	F_2	250 km to 450 km	200 km (day time)	Better of HF wave propagation.

6.13 SPACE WAVE PROPAGATION

- The space wave or line of sight propagation is useful at higher frequencies above **30 MHz** because the sky wave and ground wave propagation both fail at such frequencies.
- The space wave propagation is practically limited to line of sight distance and is also limited by the curvature of earth.
- Hence, space waves travel in straight line and frequencies above 30 MHz.
- The space wave propagation takes place by space wave or direct wave shown in Fig. 6.21 (a).

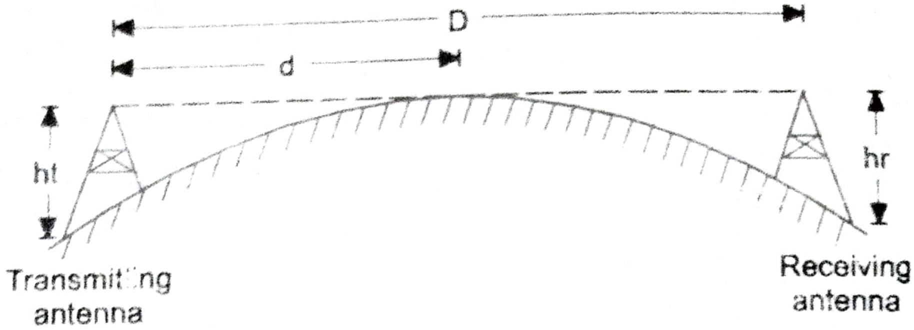


Fig. 6.21 : (a) Space Wave Communication by Space Waves

- These waves travels in a straight line from the transmitting antenna to the receiving antenna.
- Due to straight line nature, they will be blocked at some points due to curvature of earth as shown in Fig. 6.21 (a).
- If the signal is to be blocked beyond the horizon then receiving antenna must be tall enough as shown in Fig. 6.21 (a).

6.13.1 Multi-path Space Wave Propagation

- In actual practice to increase the range of communication (i.e. distance), the signal received at the receiving antenna is not due to direct ray but due to ground reflected ray shown in Fig. 6.21 (b).

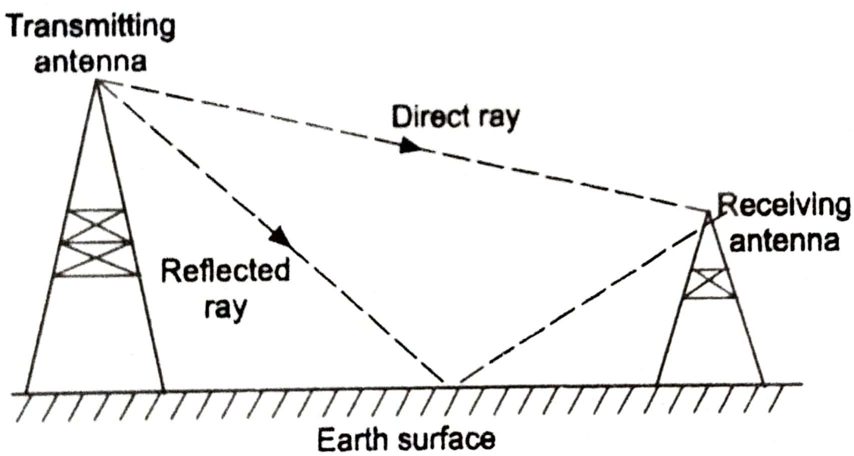


Fig. 6.21 : (b) Multi-Path Space Wave Propagation

- **Such type of reception is used in TV signal reception.**
- The resultant signal strength at the receiving antenna is the vector sum of direct and reflected ray strengths at receiver.

6.13.2 Optical Horizon

- **Optical horizon is the farthest point on earth surface which can be seen by transmitting antenna.** In Fig. 6.21 (a), distance 'd' is the optical horizon.
- If the space wave travels in a straight line then the maximum range of space wave communication would be restricted to the optical horizon.

6.13.3 Radio Horizon

- **Radio horizon** for a space is slightly greater than the optical horizon which is shown in Fig. 6.21 (c).

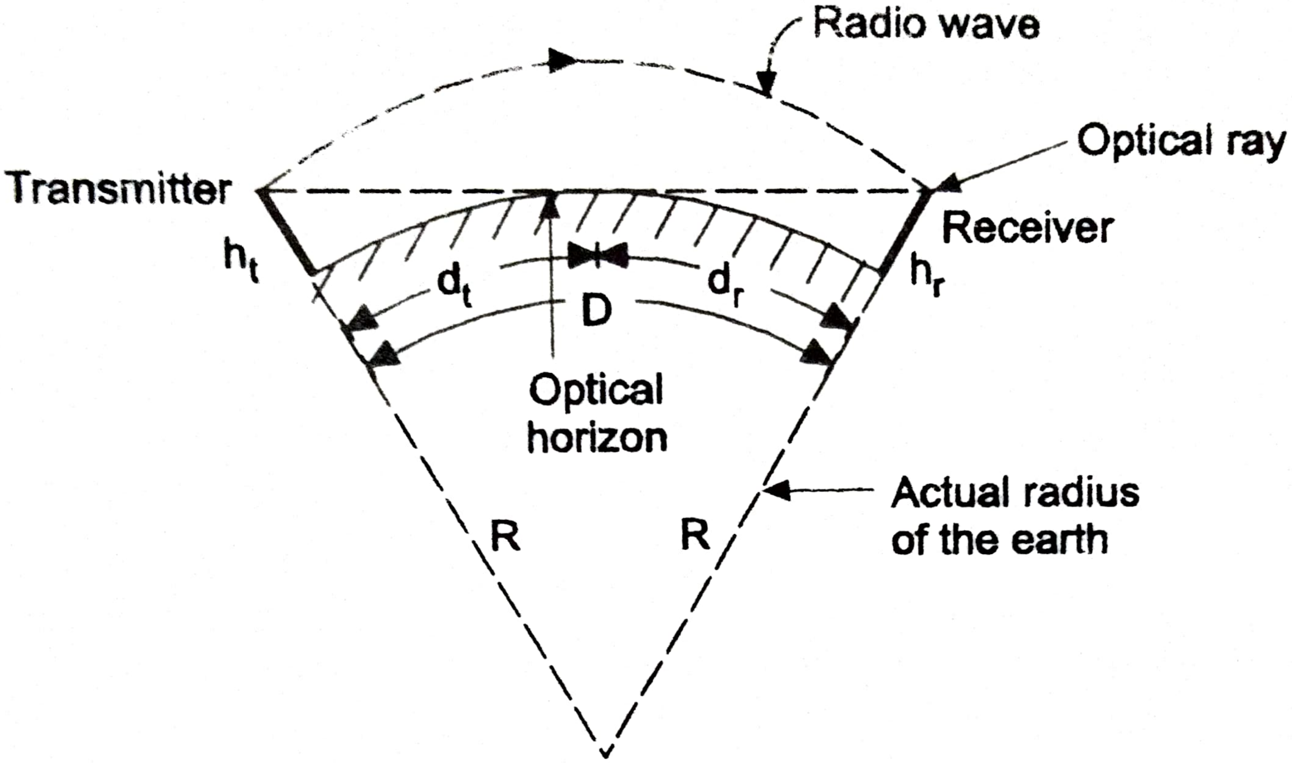


Fig. 6.21 : (c) Radio Horizon

6.15 TROPOSPHERIC SCATTERING PROPAGATION

- It is also called as troposcatter, or forward scatter propagation and is means of **beyond the horizon propagation for UHF signals.**
- It uses the properties of troposphere which is the nearest portion of the atmosphere within about 15 km of the ground.

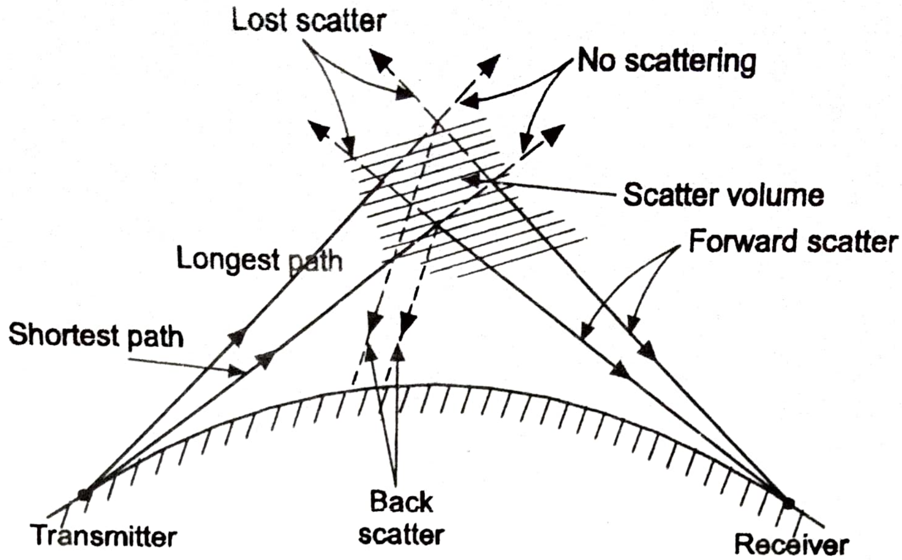


Fig. 6.23 : Tropospheric Scatter Propagation

As shown in Fig. 6.23,

(i) Two directional antennas are pointed so that their beams intersect midway between them, above the horizon.

(ii) One of these antenna is a UHF transmitting antenna and the other a UHF receiving one, where as sufficient radio energy will be directed towards the receiving antenna to make this a useful communication system.

(iii) The reasons for the scattering are not fully understood, but there are two theories behind this.

- One suggest the reflections from **'blobs'** in the atmosphere similar to the scattering of a search light beam by duct particles and
- The other due to reflection from atmospheric layers.

(iv) This phenomenon is a permanent and not a sporadic one. The most commonly used are 900 MHz, 2000 and 5000 MHz.

(v) The energy contents of the forward scatter which is received by the receiver is very small of the incident power. It is very small as one millionth of the incident power. Hence, a very high transmitting power is required.

Effect of troposcatter

Practically troposcatter is not reliable method for over the horizon communication. It can serve as an alternative to microwave links for long distance telephone links.

Troposcatter is affected by two types of fadings :

1. Rayleigh's fading which is caused by multipath propagation. It occurs several times per minute i.e. it is faster.
2. Fading which occurs due to variations in atmospheric conditions using the path. It is slower.

Troposcatter propagation gives better performance, if we elevate antenna and direct them towards horizon. Diversity systems are used to avoid fading problems.

Advantages :

- Troposcatter propagation is not affected by the normal phenomena which affect the sky wave propagation. Hence, is very reliable type of communication system.
- It is alternative to the microwave links or co-axial cables.

Application :

Troposcatter propagation used in long distance telephone and other communication links in the unaccessible areas.

6.16 COMPARISON BETWEEN GROUND WAVE, SKY WAVE AND SPACE WAVE PROPAGATION

Sr. No.	Parameter	Ground Wave Propagation	Sky Wave Propagation	Space Wave Propagation
1.	Frequency Range	30 kHz – 3 MHz	3 MHz – 30 MHz	30 MHz to 300 MHz
2.	Polarization Used	Vertical	Vertical	Horizontal
3.	Limitation	Ground waves tilt progressively and die. This limits the range of the communication	The transmission path is limited by skip distance and curvature of earth.	The transmission path is limited by the line of sight and radio horizon.
4.	Applications	Used for AM radio broadcasting MW band.	Used for AM radio broad-casting SW band.	Used for TV and FM broadcasting.
5.	Power Loss	Power loss due to absorption of energy by ground and tilting waves.	Power loss due absorption of energy by ionospheric layer.	Power loss due to absorption and scattering by the tall and massive objects.
5.	Service Range	Few hundred km.	Few thousand km.	Not more than 100 km.