1. Radiation of the signal
2. Propagation

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".

2. Propagation

This "radiated" power then propagates in space in the form of electromagnetic (EM) waves. The radiation and propagation of the radio waves cannot be seen. The theory of electromagnetic radiation was propounded by the British physicist J.C. Maxwell in 1857. His theory and mathematical expressions explaining the behaviour of the electromagnetic waves is universally accepted and used.

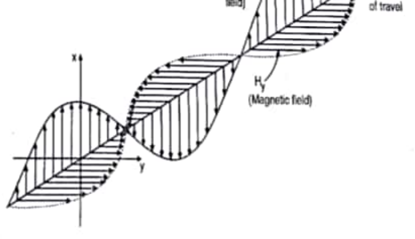

Fig. 11.1 : Transverse electromagnetic wave

The directions of these fields are perpendicular to each other and to the direction of propagation of the wave.

The electromagnetic waves are as shown in the Fig. 11.1. The propagation is somewhat similar to the outward travel of the waves in a water pond when a stone is thrown into it. However there is a fundamental difference between the two. The ripples on the surface of the water surface are **"Longitudinal"**. That means the oscillations are in the direction of propagation. The EM waves in contrast are **"transverse"** i.e. the oscillations are perpendicular to the direction of propagation. (Refer Fig. 11.1).

Electromagnetic Waves :

In this chapter we are going to discuss only about the EM waves travelling through the space. These waves are characterized by frequency and wavelength.

The EM waves are different from the other waves found in nature such as water waves or sound waves. Because EM waves consist only of time varying electric and magnetic fields and there is absolutely no need of any physical medium for their propagation.

Q. 3 Define plane of polarization.

Ans. :

The polarization of a plane EM wave is simply the orientation of the electric field vector with respect to the earth surface (i.e. looking at the horizon).

If the polarization remains constant then it is called as the **linear polarization.** The linear polarization can be of four types :

1. Horizontal polarization
2. Vertical polarization
3. Circular polarization
4. Elliptical polarization

Horizontal polarization :

If the electric field propagates in parallel with the earth surface then the EM wave is said to be horizontally polarized.

Vertical polarization :

If the electric field propagates perpendicular to the surface of earth, then the EM wave is said to be vertically polarized.

Circular polarization :

If the polarization vector rotates 360° as the EM wave travels wavelength through the space and the field strength is equal at all angles of polarization then the EM wave is said to have a circular polarization.

Elliptical polarization :

In the circular polarization, if the field strength varies with change in polarization, the wave is said to have an elliptical polarization.

Q.4 Write note on wave propagation with ground waves.

Ans. : Refer to the Fig. 11.2(a) showing the path followed by the radiated EM waves in ground wave propagation.

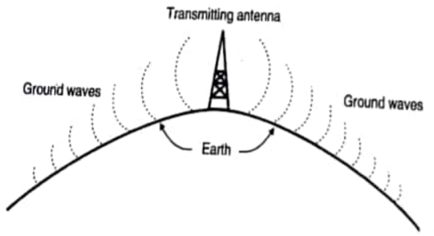

Fig. 11.2(a) : Ground wave propagation

The important points about the ground wave propagation are as follows :

1. The ground or surface wave leaves the antenna and remains closed to the earth. The ground wave will actually follow the curvature of the earth and therefore can travel a distance beyond the horizon.
2. The ground wave propagation is the 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.
3. The ground waves must be vertically polarized to prevent short circuiting of the electric field component. The EM waves are said to be vertically polarized if all its electric intensity vectors are vertical. The EM wave shown in Fig. 11.1 is vertically polarized.

Attenuation of the Ground Waves

The ground waves get attenuated due to the following reasons :

While passing over the earth surface, the ground waves induce some current into it. Thus they loose some energy due to absorption.

Due to diffraction the wavefronts will gradually tilt over as shown in the Fig. 11.2(b). The angle of tilt (θ) goes on increasing as the ground waves progress over the surface of the earth. Eventually the wave "lies down" and "dies".

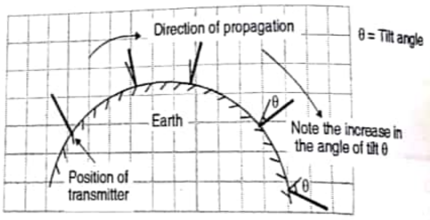

Fig. 11.2(b)

This distance depends on the type of surface, frequency of operation and the transmitted power.

The tilt angle (θ) increases with increase in frequency, hence puts a limitation on the range of transmission if the transmission takes place near the top of the medium frequency range (near 3 MHz).

Q. 5 What are ground waves and sky waves ?

Ans. :

Ground Waves

The ground waves get attenuated due to the following reasons :

1. While passing over the earth surface, the ground waves induce some current into it. Thus they loose some energy due to absorption.
2. Due to diffraction the wavefronts will gradually tilt over as shown in the Fig. 11.3 The angle of tilt (θ) goes on increasing as the ground waves progress over the surface of the earth. Eventually the wave "lies down" and "dies".
3. This distance depends on the type of surface, frequency of operation and the transmitted power.

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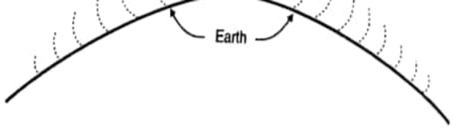

Fig. 11.2(a) : Ground wave propagation

2. Due to diffraction the wavefronts will gradually tilt over as shown in the Fig. 11.3 The angle of tilt (θ) goes on increasing as the ground waves progress over the surface of the earth. Eventually the wave "lies down" and "dies".
3. This distance depends on the type of surface, frequency of operation and the transmitted power.

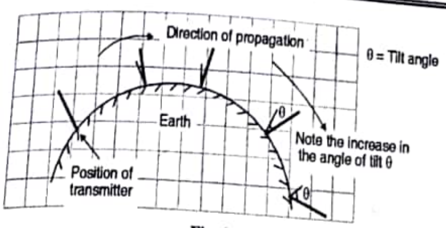

Fig. 11.3

4. The tilt angle (θ) increases with increase in frequency, hence puts a limitation on the range of transmission if the transmission takes place near the top of the medium frequency range (near 3 MHz).

Sky Waves

In sky wave propagation, the transmitted signal travels into the upper atmosphere, then it is bent or reflected back from there 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. The layers of ionosphere and the principle of sky wave propagation is as illustrated in the Fig. 11.4

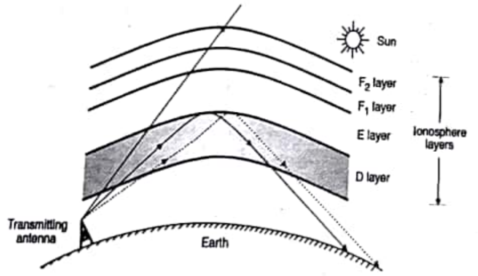

Fig. 11.4 : Principle of sky wave propagation

Q. 6 In respect to sky wave propagation explain the following terms : Virtual height And Critical Frequency (f_c)

Ans. :

Virtual Heigh

The concept of virtual height can be understood by looking at Fig. 11.5. The incident wave returns back to earth due to refraction.

In this process it bends down gradually and not sharply. But it is interesting to see that the incident and reflected rays follow exactly the same paths as though the signal would have been reflected from a surface located at greater height.

This height is called as the **virtual height**. If the virtual height of a layer is known then it is possible to find the angle of incidence required to return the wave to the ground at a selected point.

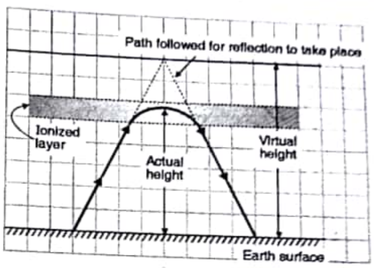

Fig. 11.5 : Virtual height of an ionized layer

Critical Frequency (f_c)

The critical frequency of a layer is defined as the maximum frequency that is returned back to the earth by that layer, when the wave is incident at an angle 90° (normal) to it. The critical frequency for the F_2 layer is between 5 to 12 MHz.

Q. 7 In respect to sky wave propagation explain the following terms : MUF

Ans.

The maximum usable frequency (MUF) is defined for a certain value of the angle of incidence θ rather than defining it at normal (θ = 90°) as in case of critical frequency.

This definition tells us that if angle θ is increased, then it is possible to operate at higher frequency than the critical frequency f_c. The MUF is given as,

$$\text{MUF} = \frac{\text{Critical frequency}}{\cos\theta} \quad ...(1)$$

$$= f_c \sec\theta \quad ...(2)$$

This equation is also known as the "Secant law". However the MUF is not defined in terms of the angle in practice. Rather it is defined as, MUF is the highest frequency that can be used for the sky wave communication between two given points on the earth.

Normally the values of MUF are in the range of 8 to 35 MHz. The highest operating frequency between two points is selected to be slightly less than MUF but it is not too less. Fig. 11.6 illustrates the effect of varying the angle of incidence keeping the frequency constant.

Skip Distance

The **skip distance** is defined as the shortest distance from a transmitter, measured along the surface of the earth at which a sky wave of fixed frequency returns back to the earth.

This frequency should be greater than the critical frequency f_c. Now refer Fig. 11.6 which shows the effect of variation in the angle of incidence θ keeping the frequency constant.

The angle of incidence θ is quite large for ray 1 and it is progressively reduced, as represented by the rays 2 and 3. Due to the reduction in angle θ, the rays return at points which are more and more close to the transmitter. In other words with decrease in angle θ, the skip distance decreases.

For the angle of incidence much less than that of ray 3, the rays 4 and 5 cannot return back to the earth surface and escape as shown in the Fig. 11.6.

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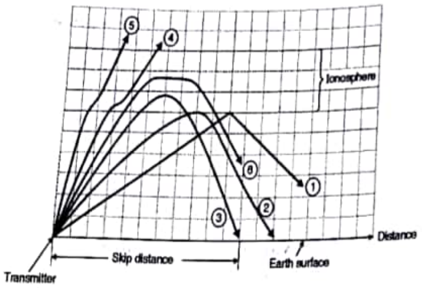

Fig. 11.6 : Effect of variation in θ at constant frequency

Finally if the angle of incidence is just slightly smaller than that corresponding to ray 3, then the wave will return but at a farther point on the earth (see ray 6). This is called as the upper ray and as shown in Fig. 11.6, it bends back very gradually as the ion density is changing very gradually at this angle. Due to its longer journey, through the ionosphere ray 6 is a weak signal.

Thus at a given frequency the angle corresponding to ray 3 will result in the shortest distance upto the point of return. Therefore this distance is the "skip distance".

Now if a higher frequency is beamed up at the angle of incidence of ray 3 then it will not return back to the earth. Thus MUF for given two points between which the communication takes place is the frequency which makes a given distance to be equal to the skip distance.

Q. 8 Explain the following terms : Skip zone and skip distance.

Ans. :

Skip Distance :

The **skip distance** is defined as the shortest distance from a transmitter, measured along the surface of the earth at which a sky wave of fixed frequency returns back to the earth. This frequency should be greater than the critical frequency f_c.

Now refer Fig. 11.7(a) which shows the effect of variation in the angle of incidence θ keeping the frequency constant.

The angle of incidence θ is quite large for ray 1 and it is progressively reduced, as represented by the rays 2 and 3. Due to the reduction in angle θ, the rays return at points which are more and more close to the transmitter. In other words with decrease in angle θ, the skip distance decreases.

For the angle of incidence much less than that of ray 3, the rays 4 and 5 cannot return back to the earth surface and escape as shown in the Fig. 11.7(a).

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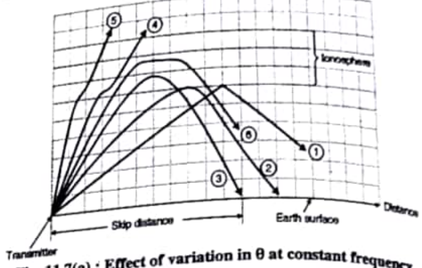

Fig. 11.7(a) : Effect of variation in θ at constant frequency

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Skip Zone :

We have seen what is meant by the term "skip distance". Now let us understand the meaning of skip zone. Refer to Fig. 11.7(b), where the distance A to B is the skip distance.

The distance A to C is the ground wave range, for the transmitter located at point A. Then the distance C to B is called as the skip zone.

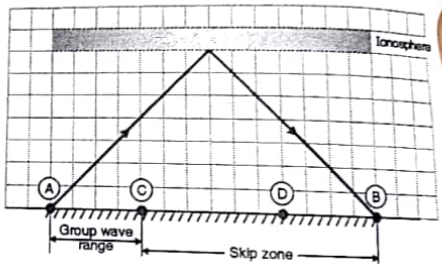


Fig. 11.7(b) : Concept of skip zone

Q. 9 Write short notes on : Diversity reception.

Ans. :

Diversity Reception :

Even though the AGC helps to a great extent to minimize the effect of fading, it is not helpful when the signal fades so much that it enters into the noise level.

The principle of diversity reception is based on the fact that the signal at different points on the earth or different frequency signals do not fade simultaneously.

There are two types of diversity reception systems :

1. Space diversity system
2. Frequency diversity system

longer journey, through the ionosphere ray 6 is a weak signal.

There are two types of diversity reception systems :

1. Space diversity system
2. Frequency diversity system

1. Space diversity

(i) In this system two or more receiving antennas are used. They are placed at points which are separated by about nine or more wavelengths.

(ii) Receivers equal to the number of antennas are employed. The output stage of all the receivers is made common.

(iii) As all the receivers receive the signal, the AGC from the receiver with the strongest signal at that moment is used to cut off all the other receivers. Thus only the signal from the strongest receiver is passed to the common output stage.

2. Frequency diversity

(i) This system works on the similar principle of the space diversity. The signal is transmitted simultaneously at two or three different frequencies.

(ii) Out of the signals received by different receivers which are tuned to different frequencies, only the strongest signal at a particular frequency is selected.

(iii) Due to the use of two or three frequencies for transmitting the same signal more bandwidth is required and the frequency spectrum is wasted.]

(iv) Therefore frequency diversity system is used only when it is not possible to use the space diversity.

Q. 10 Describe line of sight propagation for Electromagnetic waves.

Ans.: The sky wave propagation cannot take place above the frequencies of 30 MHz because the ionosphere cannot reflect back such high frequencies and the ground wave dies out near the transmitting antenna itself, due to the wavefront tilting.

Hence at frequencies above 30 MHz the space wave propagation is used.

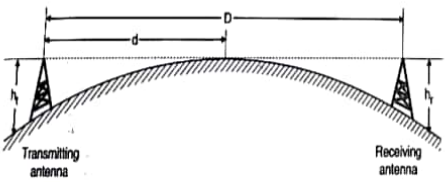


Fig. 11.8 : Space wave communication by space waves

The space wave propagation takes place by the space waves or direct waves as shown in Fig. 11.8. These waves travel in a straight line directly from the transmitting antenna to the receiving antenna. The direct or space waves are not refracted like sky waves nor do they follow the curvature of the earth like the ground waves.

Due to the straight line nature of the space waves they will at some point be blocked due to curvature of earth. If the signal is to be received beyond the horizon then the receiving antenna must be tall enough as shown in Fig. 11.8. The sky wave propagation is also called known as the line of sight propagation.

Q. 11 Write short notes on : Tropospheric scatter propagation.

Ans. : This type of propagation is also known as troposcatter or forward scatter propagation. The troposcatter propagation is used to obtain propagation of UHF signals beyond the horizon.

It uses the properties of the "troposphere" which is the nearest portion of the atmosphere. It is about 15 km above the earth surface.

The tropospheric scatter propagation can be explained as follows :

1. As shown in Fig. 11.9, two directional antennas are placed at points T and R, so that their beams will intersect each other midway, above the horizon.
2. The transmitting UHF antenna at T beams up the energy. The energy will be scattered by the troposphere in different directions as shown in Fig. 11.9 Sufficient radio energy is guided towards the receiving UHF antenna R. This happens due to the forward scatter as shown in Fig. 11.9. The receiving antenna will receive this radiation. Thus tropospheric scatter propagation can become a useful communication system.
3. The reason for the scattering is not fully known. There are two theories suggested. One of them suggests that scattering takes place due to the reflections from the "blobs" in the atmosphere. This is similar to scattering of a search light beam by the dust particles. The other theory suggests that scattering is due to the reflections from the atmospheric layers.
4. This phenomenon is a permanent and not a sporadic one. The frequencies most commonly used are 900 MHz, 2 GHz and 5 GHz.
5. The energy contents of the forward scatter which is received by the receiver is a very small percentage of the incident power. Hence a very high transmitting power is needed.

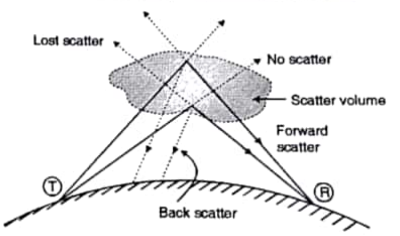
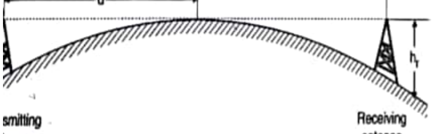


Fig. 11.9 : Tropospheric scatter propagation

Q.12 Comparison of Ground, Sky and Space Wave Propagation.

Ans. :

Sr. No.	Ground Wave Propagation	Sky Wave Propagation	Space Wave Propagation
1.	It exists in the frequency range of 30 kHz to 3 MHz.	Exists in the range of 3 MHz to 30 MHz.	Used for frequencies above 30 MHz.
2.	Used for radio broadcasting. (MW range).	Used for radio broadcasting. (SW range).	Used for TV and FM broadcasting.
3.	Ground waves are vertically polarized.	Vertically polarized.	Horizontally polarized.



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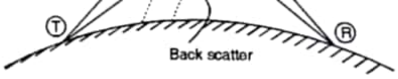

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3.	Ground waves are vertically polarized.	Vertically polarized.	Horizontally polarized.

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Sr. No.	Ground Wave Propagation	Sky Wave Propagation	Space Wave Propagation
4.	Ground waves tilt progressively and eventually die. This limits the range of communication.	The transmission path is limited by the skip distance and curvature of earth.	The transmission path is limited by the line of sight and radio horizon.
5.	Ground waves are surface waves which travel along the surface of the earth.	Sky waves are reflected from the ionosphere. This is how communication takes place.	Space waves travel in a straight line from transmitter to receiver through space.
6.	The service range is a few hundred km.	Service range can be few thousand km.	Service range is not more than 100 km.
7.	Power loss takes place due to absorption by ground and due to tilting of waves.	Power loss due to absorption of energy by the layers of ionosphere.	Power loss due to the power absorption and scattering by the tall and massive objects.
8.	Problem of fading is not very severe.	Problem of fading is severe. Diversity reception is used.	Fading is not severe but shadow zones due to tall objects and ghost interference are serious problems.
9.	Application in MW band radio.	Short wave (SW) band radio.	TV transmission, FM transmission, Satellite communication.
10.	Limitations : Limited range, tall antennas required, high transmission power required.	Skip distance, power loss due to absorption of energy by the layers.	Distance (range) is limited, fading takes place due to rain and fog.

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