UNIT-7

1. Briefly the describe the terms related to the sky wave propagation: virtual heights, critical frequency, maximum usable frequency, skip distance and fading?

Ans:

Sky wave propagation:

It is also called as Ionosphere wave propagation. The ionosphere acts like a reflecting surface and is able to reflect back the electromagnetic waves of frequencies between 2 MHz to 30MHz .Since, long distance point to point communication is possible with sky propagation, it is also called as point to point propagation. This mode of propagation is also known as short wave propagation.

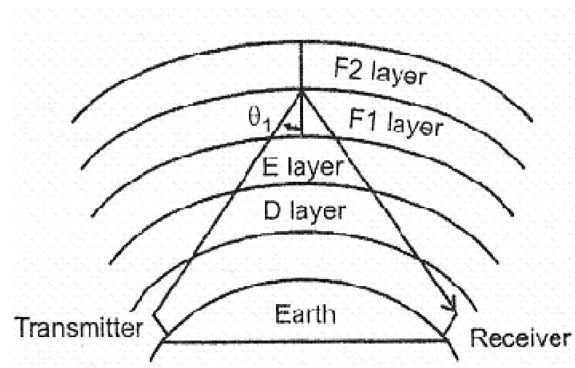

fig 1.1 Sky Wave Propagation

Virtual heights:

The virtual height *(h)* has the great advantage of being easily measured, and it is very useful in transmission path calculations.

For fiat earth approximation and assuming that ionosphere conditions are symmetrical for incident and refracted waves,

The transmission path distance, $TR = 2h/\tan\beta$

Where β=Angle of elevation

h =Virtual height

Critical frequency:

When the refractive index, n has decreased to the point where $n = \sin\varphi_i$ *the* angle of refraction φ will be 90° and wave will be travelling horizontally. The higher point reached by the wave is free. The electron density N at the that point satisfies the relation

$$\sqrt{1 - \frac{81N'}{f^2}} = \sin\phi_i$$

(or)

$$N' = \frac{f^2 \cos^2\phi_i}{81}$$

If the electron density at some level in a layer is sufficient great to satisfy the above condition. then the wave will be returned to earth from that level.

If maximum electron density in a layer is less than n', the wave will penetrate the layer

(Though it may be reflected back from a higher layer for which N is greater).

The largest electron density required for reflection occurs when the angle of incident φ_i is zero, i.e., for vertical incidence. For any given layer the highest frequency that will be reflected back for vertical

$$f_{Cr} = \sqrt{81 N\max}$$

Where fcr = Critical frequency for the layer

N_{max} = Maximum ionization density (electrons per cubic meter).

The characteristics of the ionospheric layers are usually described in terms of their virtual heights and critical frequencies, as these quantities can be readily measured. The virtual height is the height that would be reached by a short pulse of energy showing the same time delay as the actual pulse reflected from the layer travelling with the speed of light. The virtual height is always greater than the true height of reflection, because the interchange of energy taking place between the wave and electrons of the ionosphere causes the velocity of propagation to be reduced. The extent of this difference is influenced, by the electron distributions in the regions below the level of reflection. It is usually very small, but on occasions may be as large as 100 Kms or so.

The critical frequency is the highest frequency that is returned by a layer at vertical incidence. For regular layers,

$$f_c = \sqrt{\text{max electron density in the layer}}$$

i.e.

$$f_c = \sqrt{N\mathrm{e}}$$

The critical frequencies of the E and F_1 layers primarily depend on the zenith angle of the sun. It, therefore, follows a regular diurnal cycle, being maximum at noon and tapering off an either side. The f_c of the F_2 layer, shows much larger seasonal variation and also changes more from day to day. It can be seen that the critical frequencies of the regular layers decrease greatly during night as a result of recombination in the absence of solar radiation. But the f_c of sporadic E shows regular variation through-out the day and night suggesting that sporadic *E* is affected strongly by factors other than solar radiation.

There is a long term variation in all ionospheric characteristics closely associated with the *11 year sunspot cycle.* From the minimum to maximum of the cycle, f_c of F_2 layer varies from about 6 to 11 MHz (ratio of 1:1.8), f_c of *E* layer varies from 3.1 to 3.8 MHz (a ratio of mere 1 to 1.2). Long term predictions of ionospheric characteristics are based on predictions of the sunspot number. Reliable estimates can be made, for as much as a year, in advance.

Maximum usable Frequency :

Although the critical frequency for any layer represents the highest frequency that will be reflected back from that layer at vertical incidence, it is not the highest frequency that can be reflected from the layer. The highest frequency that can be reflected depends also upon the angle of incidence, and hence, for a given layer height, upon the distance between the transmitting and receiving points.

The maximum, frequency that can be reflected back for a given distance of transmission is called the maximum usable frequency (MUF) for that distance.

It is seen that the MUF is related to the critical frequency and the angle of incidence by the simple expression

$$MUF = f_{cr} \sec\varphi_i$$

The MUF for a layer is greater than the critical frequency by the factor $\sec\varphi_i$ the largest angle of incidence φ_i that can be obtained in F-layer reflection is of the order of 74°. This occurs for a ray that leaves the earth at the grazing angle. The geometry for this case is shown by Fig. 1.2

Where $\varphi_{imax} = \sin^{-1}(r/r+h)$

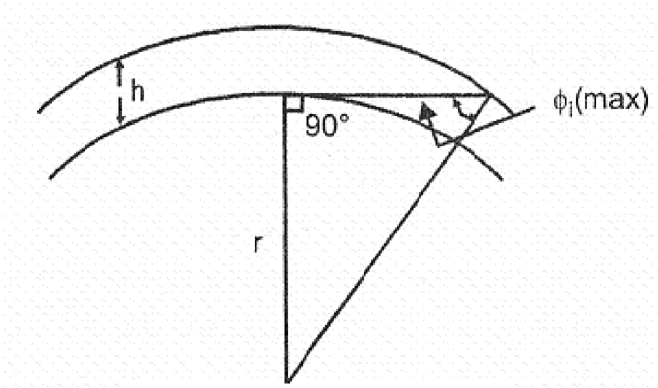

fig 1.2 Geometric of MUF

The MUF at this limiting angle is related to the critical frequency of the layer by

$$MUFmax = f_{cr}/\cos 74^{\circ} = 3.6\, f_{cr}$$

2. Explain the structure of ionosphere on the surface of the earth ?

Ans: Structure of **the ionosphere**

As the medium between the transmitting and receiving antennas plays a significant role, it is essential to study the medium above the earth, through which the radio waves propagate. The various regions above the earth's surface are illustrated in Fig.2.1

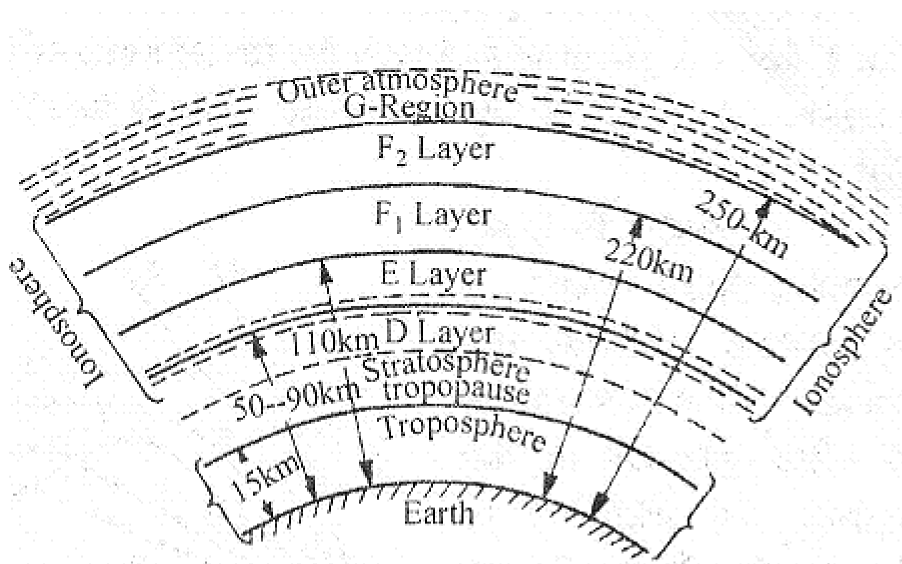

fig 2.1 Structure of ionosphere

The portion of the atmosphere, extending up to a height *(average of 15 Km)* of about 16 to 18 Kms from the earth's surface, at the equator is termed as troposphere or region of change.

Tropopause starts at the top of the *troposphere* and ends at the beginning of or region of calm.

Above the stratosphere, the upper *stratosphere* parts of the earth's atmosphere absorb large quantities of radiant energy from the sun. This not only heats up the atmosphere, but also produces some ionization in the form of free electrons, positive and negative ions. This part of the atmosphere where the ionization is appreciable, is known as the *ionosphere.* The most important ionizing agents are ultraviolet UV radiation, α , β and cosmic rays and meteors. The ionization tends to be stratified due to the differences in the physical properties of the atmosphere at different heights and also because various kinds of radiation are involved.

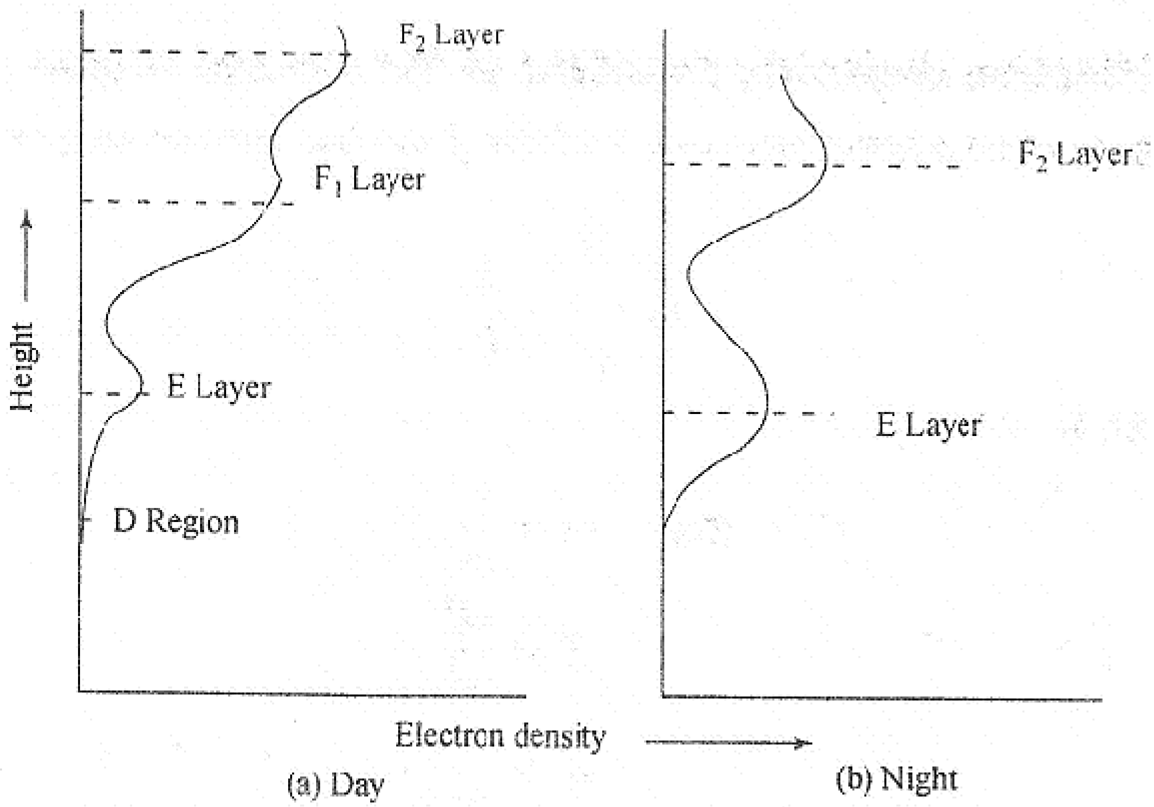

fig 2.2 Electron density of ionosphere layers

The levels, at which the electron density reaches maximum, are called as layers. The three principal day time maxima are called E, F_1, and F_2 layers. In addition to these three regular layers, there is a region (below E) responsible for much of the day time attenuations of HF radio waves, called D region (ref. Fig. 4a). It lies between the heights of 50 and 90 Km (ref. Fig. 3). The heights of maximum density of regular layers **E** and **F_1** are relatively constant at about 110 Km and 220Km respectively. These have little or no diurnal variation, whereas the **F_2** layer is more variable, with heights in the range of 250 to 350 Km.

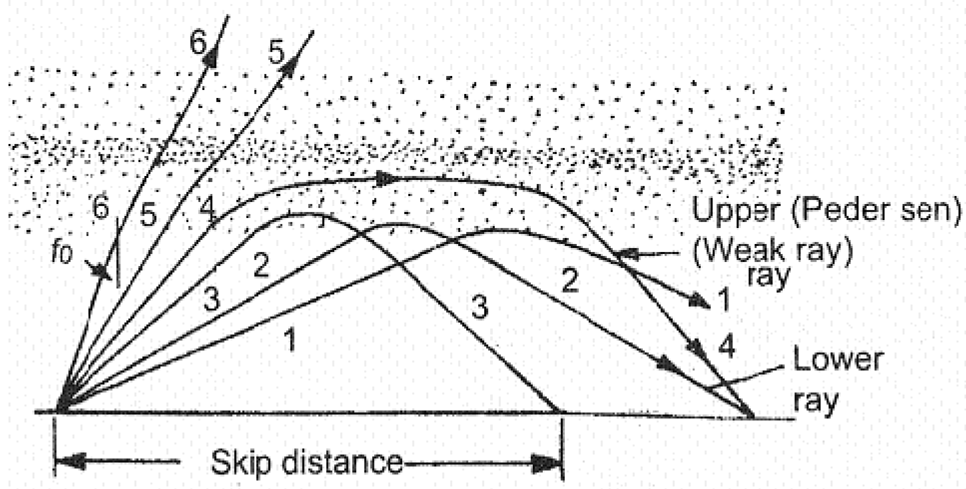

fig 2.3 Effect of ionosphere on rays

At night **F_1** and **F_2** layers combine to form a single night time **F_2** layer (Fig. 4b). The **E** layer is governed closely by the amount of UV light from the sun and at night tends to decay uniformly with time. The **D** layer ionization is largely absent during night

A sporadic **E** layer is not a thick layer. It is formed without any cause. The ionization is often present in the region, in addition to the regular **E** ionization. Sporadic **E** exhibits the characteristics of a very thin layer appearing at a height of about 90 to 130 Kms. Often, it occurs in the form of clouds, varying in size from 1 Km to several 100 Kms across and its occurrence is quite unpredictable. It may be observed both day and night and its cause is still uncertain.

3 Explain the mechanism of refraction , under what circumstances do it occurs and what causes it ?

Ans :

We have mentioned earlier, that the path of the radio wave is bent by the ionosphere. Neglecting the effect of the earth's magnetic field and the effect of energy loss, the refractive index of the ionosphere is given by

$$n = \sqrt{\mu r * €r}$$

$$\mu_r = 1$$

$$n = \sqrt{€r} = \sqrt{1 - (81N/f^2)} \text{......................(1a)}$$

This will always show the values of n < 1. Lower the frequency and higher the electron density, greater is the deviation of the Refractive Index from unity. When $f^2 < 81N$, n is imaginary, i.e. the ionized region is not able to transmit a wave freely at such a frequency. Instead, attenuation takes place, analogous to the action of a waveguide operating beyond cut off.

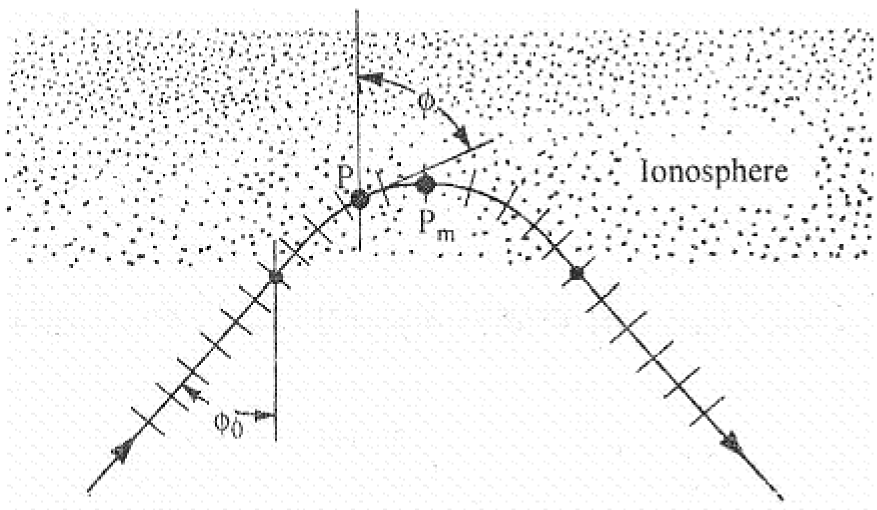

fig 3.1 Refraction of sky waves

The phase velocity of a wave travelling through the ionosphere behaves in the same way as the phase velocity of a wave on a transmission line, i.e. the velocity is inversely proportional to the square root of the dielectric constant.

$$\text{i.e. Phase velocity} = \frac{\text{Velocity of light}}{n} = \frac{c}{n} \text{...................(1b)}$$

since $n < 1$ for an ionized medium, the phase velocity in the ionosphere, is always greater than V by an amount that is greater, larger the quantity .

$$\frac{N}{f^2}$$

. As a result, when a wave enters the ionosphere, the edge of the wave front in the region of the highest electron density will advance faster than the part of the waveforms encountering regions of lower electron density. Accordingly, the path of the wave is bent in the ionosphere as illustrated in Fig. 6. This bending of the wave follows ordinary optical laws. The direction, in which a wave travels at *P,* in the ionosphere, is given by Snell's Law.

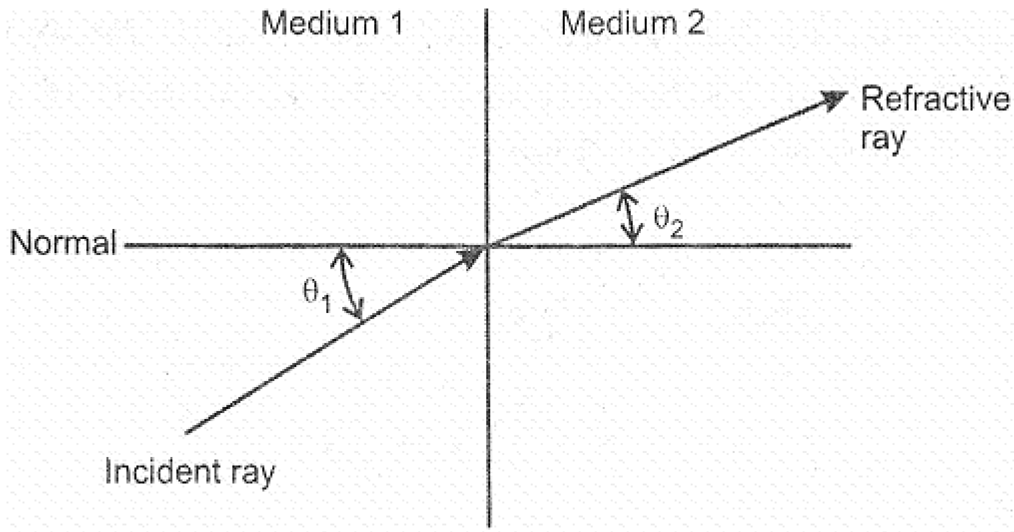

fig 3.2 Refraction

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 \text{.....................(2)}$$

Where θ_1 = angle of incidence
θ_2 = angle of refraction
n_1 = refractive index of 1st medium
n_2 =refractive index of 2nd medium

Here, it is assumed that below the ionosphere, where the direction of travel is given by φ_0 ,n =1

$$\frac{\sin\theta 1}{\sin\theta 2} = \sqrt{\frac{€r1}{€r2}}$$

The top P_m of the path corresponds to φ= 90° and occurs at a point in the ionosphere where

$$n = \sin\varphi_0 \text{…………..(3)}$$

P_m is commonly referred to as the point of reflection, though, actually, it is the point of refraction. Eq. (3) shows that smaller the φ_0, smaller is the 'n' required to return the wave to the earth.

With vertical incidence, i.e. $\varphi_0 = 0$, n must be reduced to 0 for reflection to take place. The wave then penetrates the ionized region until it reaches a point, where the electron density N and the frequency f_v of the vertically incident wave are so related that

$$f^2_v = 81\text{N………… (4)}$$

4.Explain briefly about ground wave propagation with neat sketch ?

Ans: Ground Wave Propagation

The ground wave is a wave that is guided along the surface of the earth just as an electromagnetic wave is guided by a wave guide or transmission line. This ground wave propagation takes place around the curvature of the earth in the frequency bands up to 2 MHz This also called as surface wave propagation.

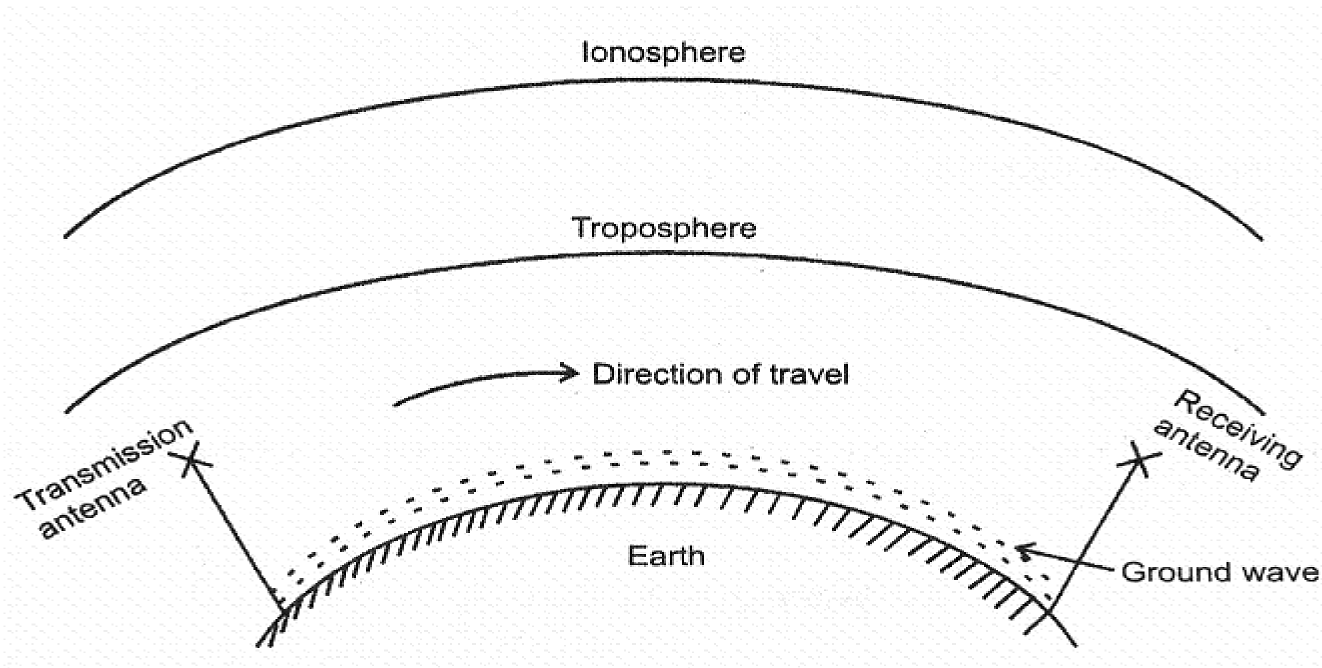

fig 4.1 Ground Wave Propagation

The ground wave is vertically polarized, as any horizontal component of the E field in contact with the earth is short-circuited by it. In this mode, the wave glides over the surface of the earth and induces charges in the earth which travel with the wave, thus constituting a current, (see Fig. 4.1). While carrying this current, the earth acts as a leaky capacitor. Hence it can be represented by a resistance or conductance shunted by a capacitive reactance. Thus, the characteristics of the earth as a conductor can be described in terms of conductivity (a) and dielectric constant (e).

As the ground wave passes over the surface of the earth, it is weakened due to the absorption of its energy by the earth. The energy loss is due to the induced current flowing through the earth's resistance and is replenished partly, by the downward diffraction of additional energy, from the portions of the wave in the immediate vicinity of the earth's surface.

5. Discuss the characteristics of F_1 and F_2 layers ?

Ans:

Characteristics of F1 Layer:

1. F1 layer is the lower end region of F-layer and which will be situated at an average height of 220 km. (generally, 140 km to 250 km).
2. The behavior of F1 layer is similar to that of E-region (normal) and obeys the Chapman's law of variations.
3. Its critical frequency ranges from 5 MHz to 7 MHz at noon time.
4. The value of electron density varies from 2 x 105 to 4.5 x 105.

5. F1 layer is formed by the ionization of oxygen atoms, due to an accepted view.

6. Maximum HF waves are penetrated through the F1 layer, even though some of them are reflected back.

7. The main function of F1 layer is to provide more absorption for HF waves.

8. The density of F1 layer is lowers in winter than summer, even though no great variations in height.

Characteristics of F2 Layer

F2 layer is the upper end region of F-layer and which will be situated at a height range of 250 km to 400 km.

Its critical frequency ranges from 5 MHz to 12 MHz (basically 10 MHz) and may be even more at low altitude stations.

The electron density of F2 layer may varies from 3 x 105 to 2 x 106.

Being the upper most regions, the air density is very low due to which ionization disappears very slowly.

F2 layer is formed by ionization of UV, X-rays and corpuscular radiations.

The earth's magnetic field, atmospheric, ionosphere storms and other geomagnetic disturbances have large effect on the ionization in F2 layer.

This layer does not follow Chapman's law of variations.

This is the most important reflecting medium for high frequency radio waves.

6. Write a short note on,

(a) Selective fading and interference fading

(b) Lowest usable high frequency

(c) Field strength calculation for radio AM Broadcast waves .

Ans:

(a) Selective Fading

This type of fading produces serious distortion in modulated signal. Selective fading is important at higher frequencies. Selective fading generally occurs in amplitude modulated signals. SSB signals become less distorted compared to the AM signals due to selective fading.

Interference Fading

Interference fading occurs due to the variation in different layers of ionospheric region. This type of fading is very serious and produces interference between the upper and lower rays of sky wave propagation. Interference fading can be reduced with the help of frequency and space diversity reception.

(b) Lowest Usable High Frequency (LUHF)

The lowest usable frequency can be defined as the maximum value of frequency necessary to establish (or maintain) point to point communication. As the frequency decreases, the sensitivity and external noise increases. The lowest usable frequency (LUF) depends on the transmitted power.

Lowest usable frequency is higher in day time compared to night time depending upon the noise level at the receiving side, lowest usable frequency is measured.

Where,

1. Sky wave absorption and
2. Atmospheric noise.

(c) Field strength calculation for radio AM Broadcast waves:

Ground wave propagation is very useful at lower frequencies between 1 -2 MHz this mode of propagation exists when the transmitting and receiving antennas ***ART*** very close to the surface of the earth. The genera expression for field strength of ground wave propagation is given as,

$$E = (120\pi\, h_t\, h_r\, I_s)/\lambda\, d$$

Where

E = Field strength due to ground wave propagation

h_t = Height of transmitting antenna

h_r = Height of receiving antenna

λ = Wavelength (meters)

d = Distance between the transmitting and receiving antenna

I_s = Current in antenna

The above expression is valid when distance *(d)* is very small. As the distance increases, ground attenuation and absorption increases. Field strength of ground wave propagation according to sommerfield is,

$$E_g = (E_0 A)/d$$

Where, A = Attenuation factor

d = Distance between the transmitting and receiving antenna

E_0 = Ground field strength at the surface of earth

E_g = Ground field strength.

The value of ground field strength at the surface of earth *(E_o)* depends upon,

(i) Directivity of planes which are vertical and horizontal.

(ii) Power radiation of transmitting antenna.

The field at unit distance (1Km) for a radiated power of 1 kW, can be calculated as,

$$E_0 = (300\sqrt{P})/d \text{ (V/m)}$$

Where,

d = Distance in kilometers (km)

P= Radiated power (1 kW)

In case of vertical uni-pole antenna, the field strength E_0 at a distance of d is,

$$E_0 = \sqrt{90P}/d \text{ volts/meter}$$

From above, field strength is directly proportional to the square root of the power radiated.

E_0= 300 mV/mt. at P = I kW, d = 1 km

= 186.45 mV/m at J = 1 mile

7. Discuss the following

(i) Ionospheric storms

(ii) Sudden ionospheric disturbances.

And also discuss the reason for reduction of field strength in sky wave propagation?

Ans:

(i) Ionospheric Storms

Ionospheric storms are the disturbances which occur with the rapid and excessive fluctuations associated with magnetic storms in ionosphere. These disturbances are dependent on the magnetic storms that occur in earth's magnetic field. Ionospheric storm disturbance causes absorption of sky waves and change in critical frequency of F_2 and E layers.

These ionospheric storms occur throughout the day and night and may extend up to two or more days. During ionospheric storms, the ionosphere loses its layered structure. In order to establish communication in this situation, we have to lower the working frequency. The virtual height of F_2 layer increases because of sudden decrease in critical frequency due to ionospheric storm.

Ionospheric storm is caused by α and β ray particles that are emitted from sun. The ionosphere storm effect decreases as one moves from poles to equator. The ionospheric effect causes narrowing of range of frequencies on radio transmission.

(ii) Sudden Ionosphere Disturbances (SID)

Sudden Ionospheric Disturbances (SIDs) are also called as Mongel-Dellinger effect. SID is caused due to appearance of bright spots on solar disc suddenly. These bright spots are caused due to large emission of hydrogen from the sun. The X-rays along with bright spot causes a tremendous increase in the ionization electron density till the D-layer.

This causes increase in absorption, reflection and atmospheric noise. Hence, the value of LUF increases and exceeds MUF, causing complete blackout of sky wave communication over ionosphere. This blackout effect is known as sudden ionospheric disturbance. SID is high at noon and at equator position SID doesn't occur during nights. SID takes place for a very less duration and it will depend on the sunlit portions of globe. It doesn't affect E, F_1 and F_2 layers. SID is caused due to UV radiation intensity from solar flares (bright spot on solar disk), that penetrates through E, F_1 F_2 layers and cause tremendous increase in ionization density in D-layer.

Reduction of Field Strength in Sky Wave Propagation

The low frequency radio signals lie in the band of 30-300 kHz. The electric field strength of three low frequency broadcasting stations, CLT, MCO and CZE has been monitored by a sampling frequency. The low frequency signals are characterized by the ground wave and the sky wave propagation modes.

The daytime electric field strength is lower than at night because the sky wave is greatly attenuated by the lower ionosphere and the ground wave alone is providing the signal which is faint. At nighttime, the low attenuation of the lower ionosphere permits an increase of 10-15 dB in the sky wave signal such that the received signal is practically all due to the sky wave propagation. The decrease in CLT radio-signal is mainly due to a reduction of electric field strength of the ground wave.

8. Bring out the various problems associated with sky way mode of propagation. How are these problems overcome ?

Ans: Sky wave propagation is also called as ionospheric propagation. Since propagation takes place after reflection from ionosphere. The waves cannot be reflected back to earth if the frequency is above 30 MHz

Ionospheric Abnormalities

Various problems associated with skyways propagation are due to abnormalities in ionosphere and are of two types.

1. Normal
2. Abnormal

Normal variations include seasonal, height as thickness variation, noise.

Abnormal variation includes tides and winds, sunspot cycle, fading, whistles.

Some of the important variations are as follows.

Tides and Winds

Atmosphere experiences tidal pulls of the sun and moon. As the free period of isolation of the atmosphere coincides with the solve tidal period of 12 hours, it results in resonance phenomenon. This becomes more important and complicated by thermal heating of the atmosphere by the sun rays which have a 24 hours time period, which is twice that of tidal period.

The $\boldsymbol{F_2}$ layer has the highest speed of tidal motion with lowest particle density sighted at the height level.

Hence, F_2 layer suffers maximum from effect of tides and result in irregularities in its layer and causes a small peak of maximum ionization density in $\boldsymbol{F_2}$ layer at midnight.

Sudden Ionospheric Disturbances

Sudden appearance of height spot on solar disc increases the ionization density of D-region. This intern causes increased absorption of high frequency signals resulting in a complete blackout of all high frequency. It is known as Sudden Ionospheric Disturbance (SID).

Sunspot Cycle

SID are measured by sunspot cycle. In the graph below, critical frequency of the ionosphere are highest during sunspot maxima and lowest during sunspot minima.

Critical frequency of $\boldsymbol{F_2}$ layer is minimum at 6 MHz and maximum at 10MHz.

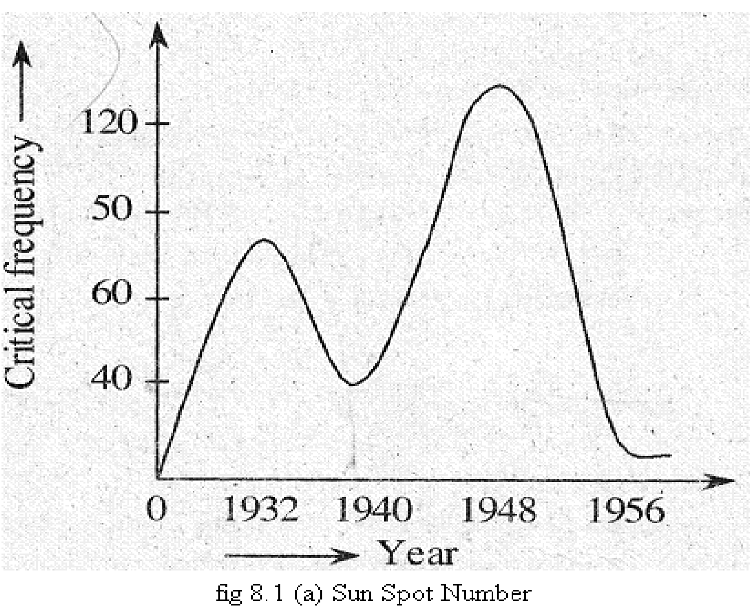

fig 8.1 (a) Sun Spot Number

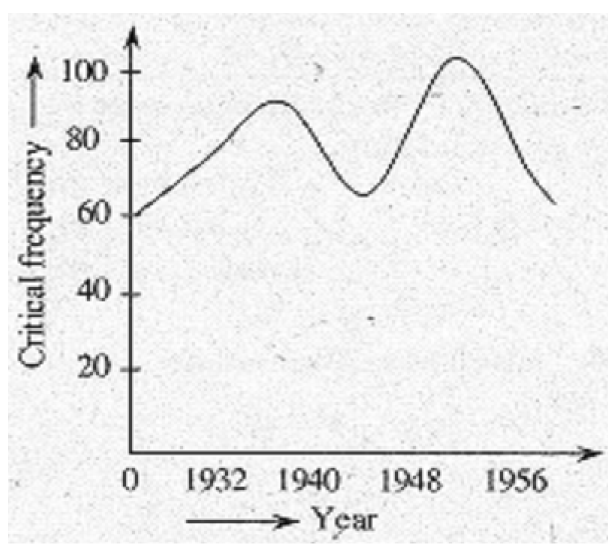

fig 8.2 Critical Frequency of F2 layer

Fading

Sky wave propagation largely suffers from fading variations or a fluctuation in the received signal strength is defined as fading. Wherever the signals that are propagated through sky wave propagation, at the receiver end the signals or wave follow different paths due to variations in the height and density of the ionization layer.

Fading is one of the important parameter in sky wave propagation and occurs due to reflections from the earth.
The values of fading are very small when the variation in signal strength is 20 to 30 dB.
Fading can be reduced by using diversity reception.

Sudden Ionospheric Disturbances

With the sudden appearance of strong solar flares i.e., bright spot on the solar disc, there occurs an intense increase in *D* layer ionization. 'An increase in the D-layer, causes increased absorption of high frequency signals resulting in a complete blackout of all high frequencies. It is known as "sudden ionospheric disturbances".

9. What are the different mechanisms of propagation of electromagnetic waves ?Explain ?

Ans:

Modes of Propagation

Electromagnetic waves may travel from transmitting antenna to the receiving antenna in a number of ways.

Different propagations of electromagnetic waves are as follows,

(i) Ground wave propagation
(ii) Sky wave propagation
(iii) Space wave propagation
(iv) Tropospheric scatter propagation.

This classification is based upon the frequency range, distance and several other factors.

(i) Ground Wave Propagation

Ground wave propagation is also known as surface wave propagation. This propagation is practically important at frequencies up to 2 MHz. Ground wave propagation exists when transmitting and receiving antenna are very close to the earth's curvature.

Ground wave propagation suffers attenuation while propagating along the surface of the earth. This propagation can be subdivided into two types which are space wave and surface wave propagation

Applications

Ground wave propagation is generally used in TV, radio broadcasting etc.

(ii) Sky Wave Propagation

Sky wave propagation is practically important at frequencies between 2 to 30 MHz Here the electromagnetic waves reach the receiving point after reflection from an atmospheric layer known as ionosphere. Hence, sky wave propagation is also known as 'ionospheric wave propagation'.

It can provide communication over long distances.

Hence, it is also known as point-to-point propagation or point-to-point communication.

Disadvantage

Sky wave propagation suffers, from fading due to reflections from earth surface, fading can be reduced with the help of diversity reception.

Applications

2. Global communication is possible.

(iii) Space Wave Propagation

Space wave propagation is practically important at frequencies above 30 MHz It is also known as tropospheric wave propagation because the waves reach the receiving point after reflections from tropospheric region.

In space wave propagation, signal at the receiving point is a combination of direct and indirect rays. It provides communication over long distances with VHF .UHF and microwave frequencies. Space wave propagation is also known as "line of sight propagation".

Applications

1. Space wave propagation is used in satellite communication.
2. It controls radio traffic between a ground station and a satellite.

(iv) Troposcatter Propagation

Troposcatter propagation is also known as forward 1 scatter propagation, it is practically important at frequencies above 300 MHz..

This propagation covers long distances in the range of 160 to 1600 km.

10. Discuss the propagation characteristics of EM wave ?

Ans:

Electromagnetic waves carry energy or momentum from one point in space to another by means of their electric and magnetic fields. It consists of electric and magnetic field components which oscillate in phase perpendicular to each other and perpendicular to the direction of energy propagation.- Depending on the frequency of the EM waves they are classified into different types, such as radio waves, microwaves, visible light, ultraviolet radiation, x-rays and gamine rays.

Some of the significant characteristics of electromagnetic wave; are as follows.

1. Speed (c)

For most practical purposes the speed is taken as 3 x 10s m/s although the more exact value is 299792500 m/s. Although exceedingly fast, they still take a finite time to travel over a given distance.

2.Wavelength (λ)

This is distance between a given point on one cycle and the same point on the next cycle as shown in figure.

It is denoted by 'λ'

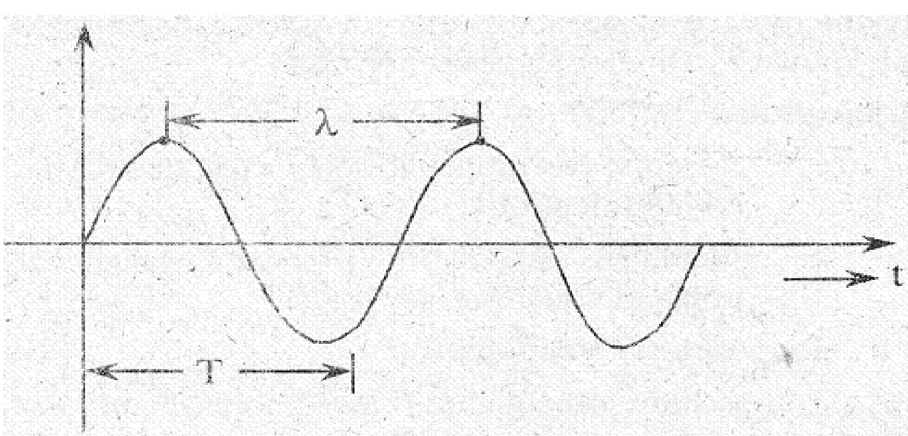

fig 10.1 EM Waves

The easiest points to choose are the peaks as these are the easiest to locate.

3. Frequency (f) :

It is defined as the inverse of the time period of the wave. Time period of a wave is the time taken by a wave to repeat itself. Figure shows that the time taken by sinusoidal wave to repeat itself is T (seconds).

$$f = 1/T$$

The three characteristics of the wave are related by the equation.

$$C = f\lambda$$

Or

$$\lambda = C/f$$