SYLLABUS:

Factors involved in the propagation of Radio Waves. The ground wave, Ionosphere and its effects on radio waves. Mechanism of Ionospheric propagation. Refraction and Reflection of sky wave by the ionosphere, Ray paths, skip distance, Maximum usable frequency, Fading of signals. Selective fading - Diversity reception. Space wave propagation, Considerations in space wave propagation. Atmospheric effects in space wave propagation. Super Refraction - Duct Wave Propagation

4.1. FACTORS AFFECTING THE RADIO WAVES PROPAGATION

There exist a number of factors which affect the propagation of radio waves in actual environment. The most important of these are –

(a) Spherical shape of the earth:- since the radio waves travel in a straight line path in free space, communication between any two points on the surface of earth is limited by the distance to horizon. Therefore, for establishing a communication link beyond the horizon, the radio waves need to undergo a change in the direction of propagation. Several mechanisms can be made use of to effect the change.

(B) The atmosphere:- The earth's atmosphere extends all the way up to about 600 km. The atmosphere is divided into several layers, viz., troposphere, stratosphere, mesosphere, and ionosphere. The propagation of the radio waves near the surface of earth is affected mostly by the troposphere which extends up to height of 8-15 km. Higher up in the atmosphere; it is the ionosphere which interacts with radio waves.

(C) Interaction with the objects on the ground:- The radio waves travelling close to the surface of earth encounter many obstacles such as building, trees, hills, valleys, water bodies, etc. The interaction of such objects with the radio waves is mostly manifested as the phenomena of reflection, refraction, diffraction, and scattering.

4.2. 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 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, 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. 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.

Applications

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

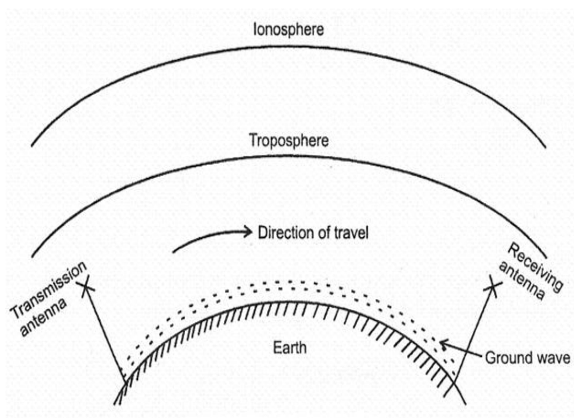

Fig 4.1 Ground wave Propagation

4.3 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.

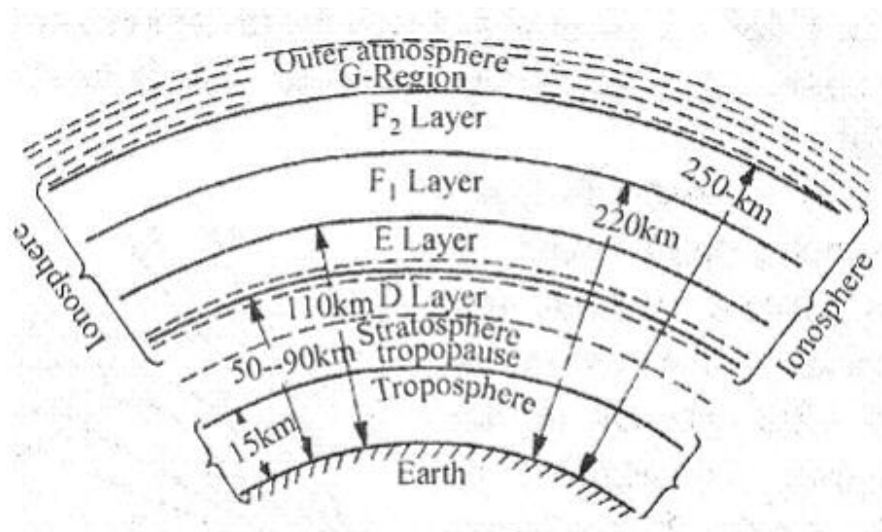

Fig 4.2 Structure of the ionosphere

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, ά , 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.

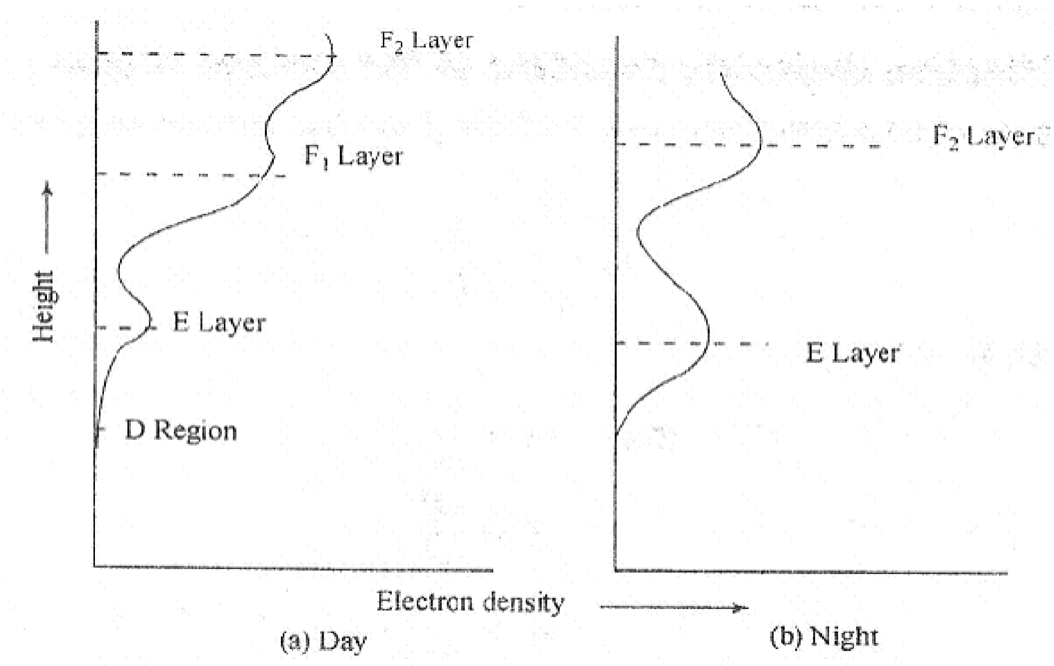

Fig. 4.3 Electron Density Layers

The levels, at which the electron density reaches maximum, are called as layers. The three principal day time maxima are called E, F1, and F2 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. It lies between the heights of 50 and 90 Km.The heights of maximum density of regular layers E and F1are relatively constant at about 110 Km and 220Km respectively. These have little or no diurnal variation, whereas the F2 layer is more variable, with heights in the range of 250 to 350 Km.

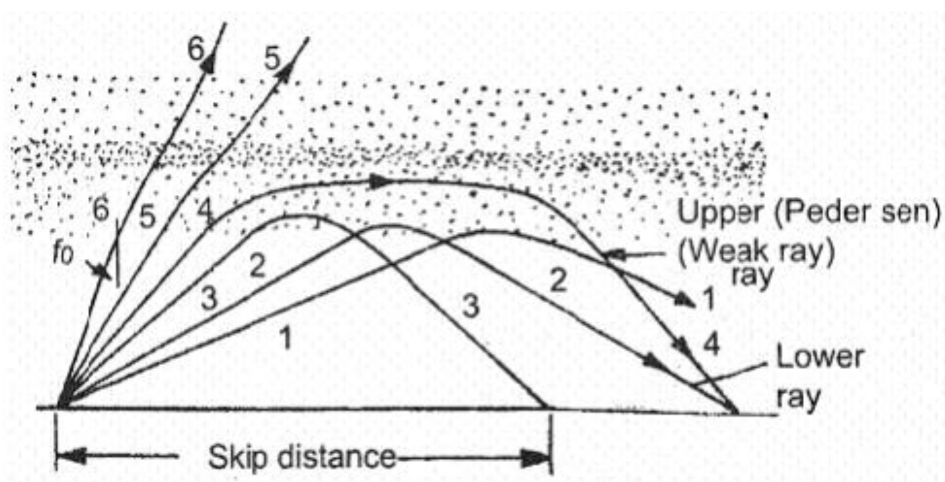

Fig 4.4 Effect of ionosphere on rays

At night F1 and F2 layers combine to form a single night time F2 layer .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.

Basically the troposphere is the region atmosphere. It is adjacent to the earth and is located up to about 1 kilometers with the height temperature of this region decreases 6.5▫c per kilometer it is observed that up to upper boundary of the troposphere, temperature may decreases up to 5 in this region the clouds are formed next to the troposphere. troposphere exists. The propagation through the troposphere takes place due to mechanisms such as diffraction normal refraction, abnormal reflection and refraction and troposphere scattering. Let us consider few of them in brief it clear that the radius of curvature depends on the rate of change of the dielectric constant with the height .thus it is observed that the radius of curvature varies from hour to hour, day to day and season.eventhough there is such a variation in radius of curvature, for the practical calculation, average value of four times the radius of earth is used.

In the analysis of propagation problems practically ray in the straight path is considered. then to compensate for the curvature, the effective radius of the earth is selected very large. the actual path of radius a is .the imagined straight line path.Thus when the radius of curvature p equals to four times radius of the earth, then the effective radius of the earth equals to 4/3 times actual radius of the earth.

Abnormal Reflection and Refraction

As discussed previously, the refraction of waves take place in the troposphere even under normal conditions. along with this, there are chances of further refractions and reflections which are due to the abrupt variation in the refractive index and its gradient.

The important point here is that where the permittivity of the medium changes abruptly, the reflections are resulted can produce usable signal beyond the range compared with only ground wave propagation

Reflection

Reflection occurs when an electromagnetic wave falls on an object, which has very large dimensions as compared to the wavelength of the propagating wave. For example, such objects can be the earth, buildings and walls. When a radio wave falls on another medium having different electrical properties, a part of it is transmitter into it, while some energy is reflected back. Let us see some special cases. If the medium on which the e.m. wave is incident is a dielectric, some energy is reflected back and some energy is transmitted. If the medium is a perfect conductor, all energy is reflected back to the first medium. The amount of energy that is reflected back depends on the polarization of the e.m. wave. particular case of interest arises in parallel polarization, when no reflection occurs in the medium of origin. This would occur, when the incident angle would be such that the reflection coefficient is equal to zero. This angle is the Brewster's angle. By applying laws of electro-magnetic, it is found to be sin(θB) =_1_1 + _2Further, considering perfect conductors, the electric field inside the conductor always zero. Hence all energy is reflected back. Boundary conditions require that θi = θr and Ei = Er for vertical polarization, and Ei = −Er for horizontal polarization.

Mechanism of ionospheric propagation _reflection &refraction

Ionospheric propagation involves reflection of wave by the ionosphere .In actual mechanism, refraction takes place as shown in fig. 4.5

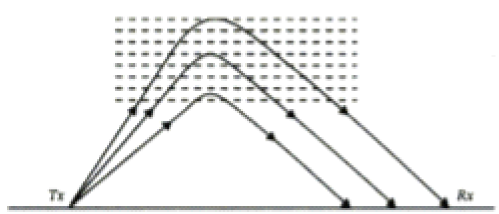

Fig 4.5 Ionospheric reflection and refraction

At ionization density increases at an angle for the incoming wave, the refraction index of the layer decreases and the dielectric constant also decreases; hence the incident wave is gradually bent away from the normal. Sufficient, the refracted ray finally becomes parallel to the layer .then it bends downwards and returns from the ionized at an equal to the angle of incidence. Although, some absorption takes place depending on the frequency the wave is returned by the ionosphere to the receiver on earth. As a result ionosphere propagation takes place through reflection and refraction of EM waves in the ionosphere.

The bending of wave produced by the ionosphere follows the optical laws the direction of propagating wave at a point in the ionosphere is given by Snell's law that is,

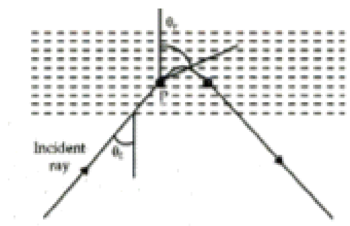

Fig 4.6 Refraction of EM waves in ionosphere

The skip distance defined as the shortest Distance from the transmitter that is covered by a fixed Frequency (>fc).When the angle of incident is large ray 1 returns to ground at a long distance from the transmitter. if the angle is reduced.ray 2 returns to a point closer to the transmitter .so there is always possibility that short distance may not be covered by sky-wave propagation under certain conditions. The Transmission path is limited by the skip distance and curvature of the earth.

4.4 SKY WAVE PROPAGATION

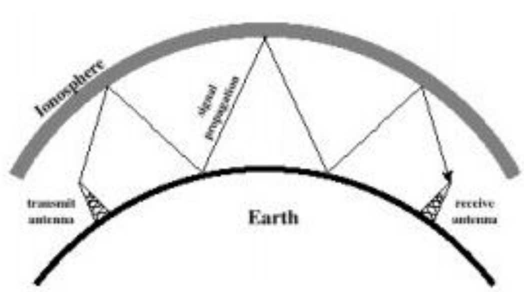

Fig 4.7 Sky wave propogation

When the critical angle is less than 90 degree there will always be a region around the transmitting site where the ion spherically propagated signal cannot be heard, or is heard weakly. This area lies between the outer limit of the ground-wave range and the inner edge of energy return from the ionosphere. It is called the skip zone, and the distance between the originating site and the beginning of the ionosphere return is called the skip distance. This terminology should not to be confused with ham jargon such as “the skip is in,” referring to the fact that a band is open for sky-wave propagation. The signal may often be heard to some extent within the skip zone, through various forms of scattering, but it will ordinarily be marginal in strength. When the skip distance is short, both ground wave and sky-wave signals may be received near the transmitter. In such instances the sky wave frequently is stronger than the ground wave, even as close as a few miles from the transmitter. The ionosphere is an efficient communication medium under favorable conditions. Comparatively, the ground wave is not.

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.

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. 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 incidence.

The characteristics of the ionosphere 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. $f_c = \sqrt{N_e}$

The critical frequencies of the E and F1 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 fc of the F2 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 fc of sporadic E shows regular variation throughout 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 ionosphere characteristics closely associated with the 11 year sunspot cycle. From the minimum to maximum of the cycle, fc of F2 layer varies from about 6 to 11 MHz (ratio of 1:1.8), fc of E layer varies from 3.1 to 3.8 MHz (a ratio of mere 1 to 1.2). Long term predictions of ionosphere characteristics are based on predictions of the sunspot number.

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 secφi

The MUF for a layer is greater than the critical frequency by the factor sec φi the largest angle of incidence φi 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 Where φimax =sin - 1 (r/r+h)

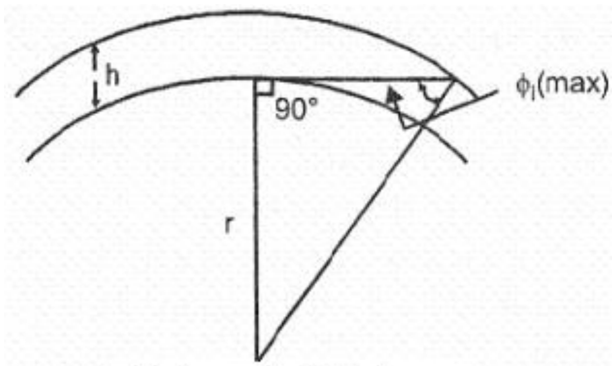

Fig. 4.8 Geometry of MUF

Geometry of MUF

The MUF at this limiting angle is related to the critical frequency of the layer by MUFmax = f cr/ cos 74 o =3.6 f cr

Disadvantage

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

Applications

1. It can provide communication over long distances.
2. Global communication is possible.

4.5 FADING

The term fading, or, small-scale fading, means rapid fluctuations of the amplitudes, phases, or multipath delays of a radio signal over a short period or short travel distance. This might be so severe that large scale radio propagation loss effects might be ignored.

Factors Influencing Fading

The following physical factors influence small-scale fading in the radio propagation channel:

(1) Multipath propagation – Multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. The effects of multipath include constructive and destructive interference, and phase shifting of the signal.

(2) Speed of the mobile – The relative motion between the base station and the mobile results in random frequency modulation due to different doppler shifts on each of the multipath components.

(3) Speed of surrounding objects – If objects in the radio channel are in motion, they induce a time varying Doppler shift on multipath components. If the surrounding objects move at a greater rate than the mobile, then this effect dominates fading.

(4) Transmission Bandwidth of the signal – If the transmitted radio signal bandwidth is greater than the "bandwidth" of the multipath channel (quantified by coherence bandwidth), the received signal will be distorted.

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 ionosphere 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.

4.6 DIVERSITY RECEPTION

- To reduce fading effects, diversity reception techniques are used. Diversity means the provision of two or more uncorrelated (independent) fading paths from transmitter to receiver

- These uncorrelated signals are combined in a special way, exploiting the fact that it is unlikely that all the paths are poor at the same time. The probability of outage is thus reduced.

- Uncorrelated paths are created using polarization, space, frequency, and time diversity

Frequency Diversity

Different frequencies mean different wavelengths. The hope when using frequency diversity is that the same physical multipath routes will not produce simultaneous deep fades at two separate wavelengths.

Space Diversity

Deep multipath fade have unlucky occurrence when the receiving antenna is in exactly in the 'wrong' place. One method of reducing the likelihood of multipath fading is by using two receive antennas and using a switch to select the better signal. If these are physically separated then the probability of a deep fade occurring simultaneously at both of these antennas is significantly reduced. ·

Angle Diversity: In this case the receiving antennas are co-located but have different principal directions. ·

Polarization Diversity: This involves simultaneously transmitting and receiving on two orthogonal polarizations (e.g. horizontal and vertical). The hope is that one polarization will be less severely affected when the other experiences a deep fade. ·

Time Diversity: This will transmit the desired signal in different periods of time. The intervals between transmissions of the same symbol should be at least the coherence time so that different copies of the same symbol undergo independent fading.

4.7 FREE SPACE RADIO WAVE PROPAGATION

There are two basic ways of transmitting an electro-magnetic (EM) signal, through a guided medium or through an unguided medium. Guided mediums such as coaxial cables and fiber optic cables are far less hostile toward the information carrying EM signal than the wireless or the unguided medium. It presents challenges and conditions which are unique for this kind of transmissions. A signal, as it travels through the wireless channel, undergoes many kinds of propagation effects such as reflection, diffraction and scattering, due to the presence of buildings, mountains and other such obstructions. Reflection occurs when the EM waves impinge on objects which are much greater than the wavelength of the traveling wave. Diffraction is a phenomena occurring when the wave interacts with a surface having sharp irregularities. Scattering occurs when the medium through the wave is traveling contains objects which are much smaller than the wavelength of the EM wave. These varied phenomena's lead to large scale and small scale propagation losses. Due to the inherent randomness associated with such channels they are best described with the help of statistical models. Models which predict the mean signal strength for arbitrary transmitter receiver distances are termed as large scale propagation models. These are termed so because they predict the average signal strength for large Tx-Rx separations, typically for hundreds of kilometers.

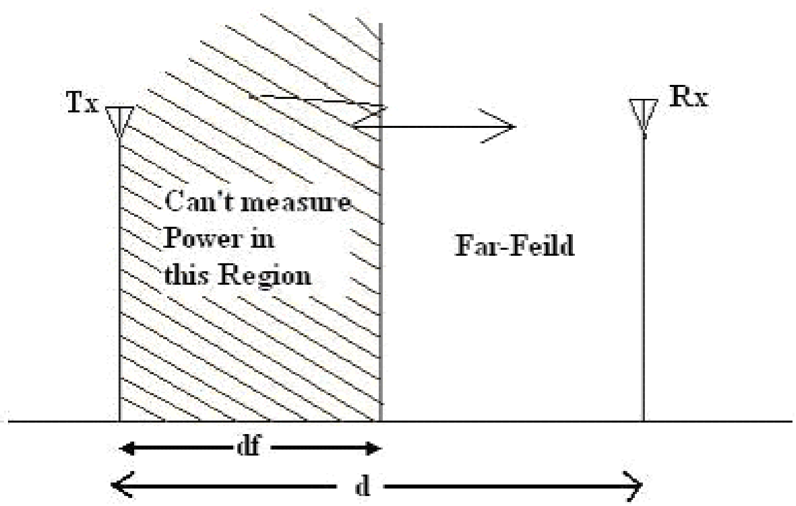

Fig 4.9 Space wave propagation

4.8 CONSIDERATION IN SPACE WAVE PROPAGATION

The space wave field strength is affected by the following

1. Curvature of the earth
2. Earth's imperfections and roughness
3. Hills, tall buildings and other obstacles
4. Height above the earth.
5. Transition between ground and space wave
6. Polarization

4.9 ATMOSPHERIC EFFECTS IN SPACE WAVE PROPAGATION

There is a significant effect of the atmosphere through which the space wave travels on the propagation. this is basically because of presence of gas molecules particularly of a water vapor. Water vapor has a high dielectric constant and its presence causes the air of the troposphere to have a dielectric constant and its presence causes the air of troposphere to have a dielectric constant slightly greater than unity. the distribution of water vapor is not uniform through out of the air and along with it the density of the air varies with height .As a consequence of the dielectric constant and in turn the refractive index of air also depend upon the height it is in general observed to be deceasing with increasing height gives rise to a variety of phenomena like reflection,refraction ,scattering, duct transmission and fading of signals. The behavior of the space wave under the different conditions can be better studied by changing the co - ordinates in such a manner that the particular ray path of interest is a straight line instead of a curve. for this , the radius of curvature of the earth is required to be simultaneously readjusted to preserve the correct relative relation.

4.10 **DUCT PROPAGATION**

Duct propagation is phenomenon of propagation making use of the atmospheric duct region. The duct region exits between two levels where the variation of modified refractive index with height is minimum . It is also said to exist between a level .where the variation of modified refractive index and a surface bounding the atmosphere. The higher frequencies or microwaves are continuously reflected in the duct and reflected by the ground.So that they propagate around the curvature for beyond the line of sight. This special refraction electromagnetic waves is called super refraction and the process is called duct propagation. Duct propagation is also known as super refraction. Consider the figure,

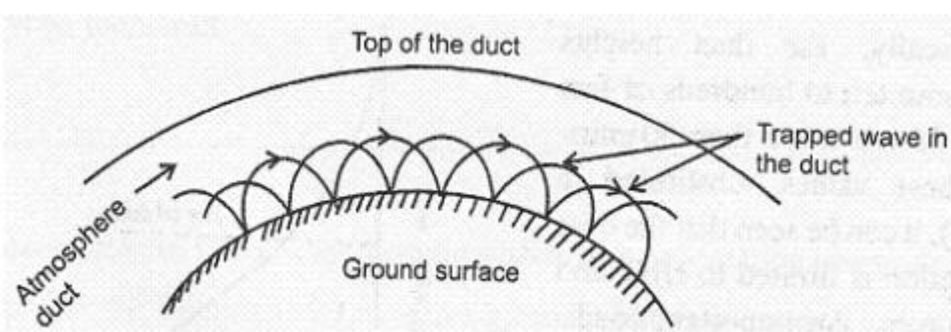

Fig. 4.10 Duct Propagation

Here, two boundary surfaces between layers of air form a duct or a sort of wave guide which guides the electromagnetic waves between the walls. Temperature inversion is one of the important factor for the formation of duct. For proper value of curvature, the refractive index (n) must be replaced by a modified refractive index (N). N = n + (h/r) The term modified index of refractive modules (m) is related to N as N = n + (h/r) (N-1) = n-1+ h/r (N-1) x 106 = [n-1+ h/r] x 106 m = (N-1) x 106 = [n-1+ h/r] x 106 Where, n = Refractive index h = Height above ground r = Radius of the earth = 6370 km Duct can be used at VHF, UHF and microwave frequencies. Because, these waves are neither reflected nor propagated along earth surface. So, the only possible way to transmit such signal is to utilize the phenomenon of refraction in the troposphere.