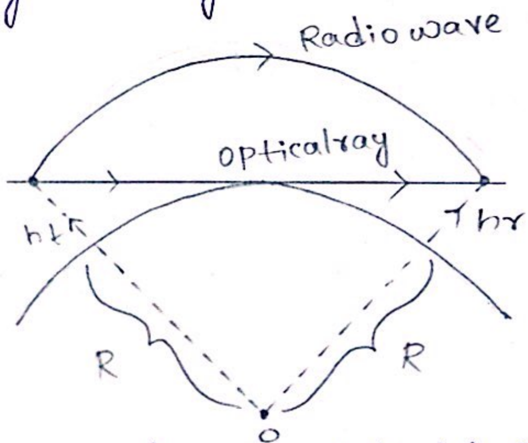
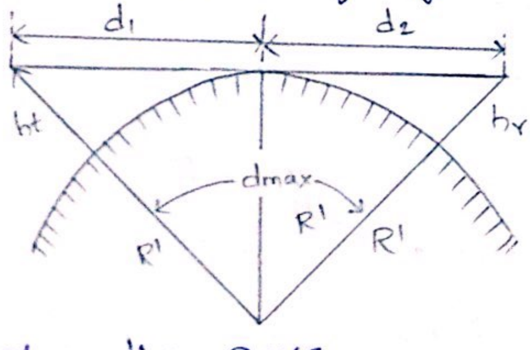
1) Deduce the expression for radio horizon distance between transmitting and receiving antennas. Take their heights as h_t and h_r respectively.

A: Radio Horizon: line of sight Distance (LOS)

Due to the curvature of the earth, the line of sight transmission is limited to the horizon. The effect of earth's atmosphere is to bend the radio wave, making the radio horizon to lie beyond the optical horizon. Here the light rays donot bend while travelling through the atmosphere.



a) optical horizon and path of light ray.



b) Bending of radio wave

where h_t = height of transmitting antenna

h_r = height of receiving antenna

For standard atmospheric condition,

$$R' = \frac{4}{3} R$$

where R = actual radius of earth

R' = radius of earth for standard atmospheric conditions

Now from the fig,

$$[R'+h_t]^2 = [R']^2 + [d_1]^2 \longrightarrow (1)$$

and $$[R'+h_r]^2 = [R']^2 + [d_2]^2 \longrightarrow (2).$$

Rewriting eqn (1), we get

$$[d_1]^2 = [R'+h_t]^2 - [R']^2$$

$$[d_1]^2 = \cancel{R'^2} + h_t^2 + 2R'h_t - \cancel{R'^2}$$

$$(d_1)^2 = 2R'h_t + h_t^2 \longrightarrow (3)$$

But $R' >> h_t$ & hence $R'h_t >> h_t^2$, thus eqn (3) becomes,

$$d_1^2 = 2R'h_t$$

$$d_1 = \sqrt{2R'h_t} \longrightarrow (4)$$

IIly rewriting eqn (2), we get.

$$[d_2]^2 = [R'+h_r]^2 - [R']^2$$

$$[d_2]^2 = \cancel{R'^2} + 2h_rR' + h_r^2 - \cancel{R'^2}$$

$$[d_2]^2 = 2h_rR' + h_r^2 \longrightarrow (5)$$

But $R' >> h_r$ i.e, $R'h_r >> h_r^2$. Hence eqn (5) becomes

$$d_2^2 = 2R'h_r$$

$$d_2 = \sqrt{2R'h_r} \longrightarrow (6)$$

The maximum radio range dmax is given by,

$$d_{max} = d_1 + d_2$$

Substituting values of d_1 and d_2 from eq^{n}s (4) and (5) we get, $d_{max} = \sqrt{2R'h_t} + \sqrt{2R'h_r}$ → (7)

But the radius R' is $\frac{4}{3}$ times greater than the ideal value of the radius of the earth.

i.e, $R' = \frac{4}{3}R$

Hence eq^n (7) becomes,

$$d_{max} = \sqrt{\frac{8}{3}Rh_t} + \sqrt{\frac{8}{3}Rh_r}$$

The radius of the earth is given by $R = 6370$ km. Substituting value of R in eq^n (8), we get

$$d_{max} = \sqrt{\frac{8}{3} \times 6370 \times 10^3 \times h_t} + \sqrt{\frac{8}{3} \times 6370 \times 10^3 \times h_r} \rightarrow (9)$$

Here d_{max} is expressed in meters.

$$d_{max} = \sqrt{\frac{8}{3} \times 6.37 \times 10^6 \times h_t} + \sqrt{\frac{8}{3} \times 6.37 \times 10^6 \times h_r}$$

$$d_{max} = \left[\sqrt{\frac{8}{3} \times 6.37 \times h_t} + \sqrt{\frac{8}{3} \times 6.37 \times h_r}\right] \times 10^3$$

$$d_{max\,(km)} = \sqrt{\frac{8}{3} \times 6.37 \times h_t} + \sqrt{\frac{8}{3} \times 6.37 \times h_r}$$

$$\boxed{d_{max\,(km)} = 4.12\left[\sqrt{h_t} + \sqrt{h_r}\right]}$$

In above eq^n, d is the line of sight distance which is expressed in km. the heights of transm-itting and receiving antennas are expressed in meters only.

2) a) A radio link has to be established between two earth station at a distance of 25000kms. If the height of ionosphere is 200kms and its critical frequency is 5MHz. Calculate the MUF for the given path. Also calculate the electron density in the ionosphere layer.

A:

Given,

h = Height of Ionosphere = 200kms.

f_{cr} = Critical frequency = 5MHz.

D = propogation distance = 2500km.

we know that,

maximum Usable frequency $MUF = f_{cr}\sqrt{1+\left(\frac{D}{2h}\right)^2}$

$$MUF = 5\times10^6\sqrt{1+\left(\frac{25000}{2(200)}\right)^2}$$

$$\boxed{MUF = 312.5MHz}$$

electron density $N_{max} = ?$

w.k.T $f_{cr} = \sqrt{81 N_{max}}$

$$f_{cr}^2 = 81 N_{max}$$

$$N_{max} = \frac{f_{cr}^2}{81} = \frac{(5\times10^6)^2}{81} = 3.08\times10^{11}$$

$$\boxed{N_{max} = 3.08\times10^{11}/m^3}$$

b) Given N_{max} at a height 250km from the earth's Surface is 6×10^{11} per cubic meter. Calculate the skip distance for 8 degrees angle of incidence.

Given,

$N_{max} = 6\times10^{11}/m^3$, $h = 250\,km$, $\theta_i = 8^\circ$

$$D_{skip} = 2h\sqrt{\left(\frac{f_{MUF}}{f_{cr}}\right)^2 - 1}$$

$$f_{cr}\ \text{(Critical frequency)} = \sqrt{81 N_{max}}$$

$$= \sqrt{81(6\times10^{11})}$$

$$f_{cr} = 6.97\,MHZ$$

(Maximum Usable frequency) $f_{MUF} = (\sec\phi_i) f_{cr}$

$$= (\sec 8^\circ)(6.97\times10^6)$$

$$f_{MUF} = 7.038\,MHZ$$

$$D_{skip} = 2(250)\sqrt{\left(\frac{7.038}{6.97}\right)^2 - 1}$$

$$= 500(0.14)$$

$$\boxed{D_{skip} = 70\,km}$$

3) Derive the fundamental equation for free space Propogation.

The average power can be expressed in terms of radiated power as

$$P_{avg} = \frac{P_{rad}}{4\pi r^2} \, w/m^2 \longrightarrow (1)$$

The max directive gain or directivity of the test antenna is given by,

$$(G_{Dmax}) = \frac{P_{dmax}}{\frac{P_{rad}}{4\pi r^2}}$$

$$P_{dmax} = G_{max} \frac{P_{rad}}{4\pi r^2} \longrightarrow (2)$$

$$P_{rec} = P_{dmax}(A_e)_r$$

where $(A_e)_r$ is effective appeture of receiving antenna.

$$P_{rec} = (G_{Dmax})_t \frac{P_{rad}}{4\pi r^2} (A_e)_r \longrightarrow (3)$$

But, $G_{Dmax} = \frac{4\pi}{\lambda^2}(A_e) \longrightarrow (4)$

let $(G_{Dmax})_r$ be the directivity of the receiving antenna, then we can write

$$(G_{D}max)_r = \frac{4\pi}{\lambda^2} (A_e)_r$$

$$(A_e)_r = \frac{\lambda^2}{4\pi} (G_{Dmax})_r \longrightarrow (5)$$

sub value of $(A_e)_r$ in eq^n (3), we get

$$P_{rec} = (G_{Dmax})_t \frac{P_{rad}}{4\pi r^2} \left[\frac{\lambda^2}{4\pi} (G_{max})_r\right]$$

$$\boxed{\frac{P_{rec}}{P_{rad}} = (G_{Dmax})_t (G_{Dmax})_r \left(\frac{\lambda}{4\pi r}\right)^2} \longrightarrow (6)$$

eqn (6) called fundamental eqn for freespace propogation. This is also called Friss free space eqn.

The factor $\left(\frac{\lambda}{4\pi r}\right)^2$ is called free space path loss. This indicates the loss i.e, attenuation of signal as the power spreads with distance r. The path loss Can be expressed as

$$\boxed{P_{Loss} = 10\log_{10}\left(\frac{4\pi r}{\lambda}\right)^2 dB} \rightarrow (7)$$

The alternate forms of the eqn are as follows

$$\boxed{\frac{P_{rec}}{P_{rad}} = (G_{Dmax})_t (G_{Dmax})_r \left(\frac{\lambda}{4\pi r}\right)^2} \rightarrow (8)$$

$$\boxed{P_{rec} = P_{rad} \frac{(G_{Dmax})_t (G_{Dmax})_r}{\left(\frac{4\pi r}{\lambda}\right)^2}} \rightarrow (9)$$

$$l_s = \left(\frac{4\pi r}{\lambda}\right)^2 \rightarrow (10)$$

Consider eqn (8), we can express the ratio in dB, as

$$10\log_{10}\left(\frac{P_{rec}}{P_{rad}}\right) = 10\log_{10}\left[(G_{Dmax})_t\right] + 10\log_{10}\left[(G_{Dmax})_r\right] + 10\log_{10}\left[\left(\frac{\lambda}{4\pi r}\right)^2\right] \rightarrow (11)$$

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Ily, eqⁿ (9)

$$\boxed{(P_{rec})_{dB} = P_{rad\,(dB)} + (G_{0max})_{(dB)} + (G_{Dmax})_{(dB)} - L_{s\,(dB)}} \longrightarrow (12)$$

where $L_{s\,(dB)} = 10\log_{10}\left(\frac{\lambda}{4\pi r}\right)^2 = 20\log_{10}\left(\frac{\lambda}{4\pi r}\right)$

simplifying,

$$\boxed{L_{s\,(dB)} = 32.45 + 20\log_{10} r + 20\log_{10} f} \longrightarrow (13)$$

According to poynting theorem,

$$\bar{P} = \bar{E} \times \bar{H}$$

Thus the magnitude of power delivered can be obtained as,

$$P_{dmax}(E)\left(\frac{E}{\eta_0}\right) = \frac{E^2}{\eta_0} \longrightarrow (14)$$

$$E^2 = P_{dmax}\,\eta_0$$

$$E = \sqrt{P_{dmax}\cdot\eta_0}$$

But η_0 = Intrinsic impedance of free space
$= 120\pi\,\Omega = 377\,\Omega$.

Sub value P_{dmax} from eqⁿ (2), we get

$$E = \sqrt{\frac{G_{0max}P_{rad}}{4\pi r^2}(120\pi)}$$

$$E = \sqrt{\frac{30 G_{Dmax} P_{rad}}{r^2}} \Rightarrow \boxed{E = \frac{\sqrt{30 G_{Dmax} P_{rad}}}{r}\ V/m.}$$

4. a) Write short notes on Troposcatter.

Troposcatter or Tropospheric scatter is a method of communicating with microwave radio signals over considerable distances often upto 300km, and further depending on terrain and climate factors. This method of propagation uses the tropospheric scatter phenomenon, where radio waves at UHF and SHF frequencies are randomly scattered as they pass through the upper layers of the troposphere. Radio signals are transmitted in a narrow beam aimed just above the horizon in the direction of the receiver station. As the signals pass through the troposphere, some of the energy is scattered back toward the Earth, allowing the receiver station to pick up the signal. Normally, signals in microwave frequency range travel in straight lines, and so are limited to line of sight applications in which the receiver can be seen by the transmitter. Frequencies of transmission around 2GHz are best suited for tropospheric scatter systems as at this frequency the wavelength of the signal interacts well with the moist, turbulent areas of the troposphere, improving signal to noise ratios

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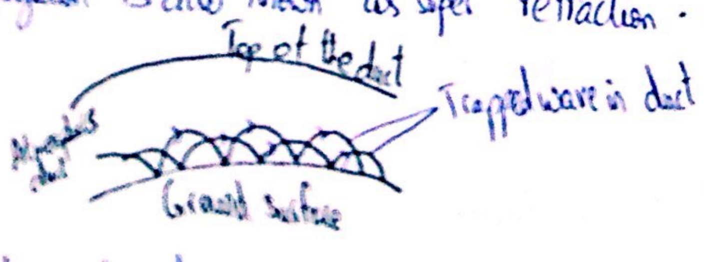
b) Write short notes on M curves and Duct propogation.

M-Curves: M- curves are known as modified index curves. These curves show the variations of refractive index with height. In order to account for the curvature of earth, the actual index of refraction modified to another refractive index. Due to the change in index of refraction, the straight rays are converted into curved rays above flat earth. The effects of non standard atmospheric conditions can be estimated easily by transforming temperature data, meteorological data into M-curves. Mcurves are used to predict the type of transmission path for propogation of electromagnetic waves.

Duct propogation: The higher frequencies or microwaves are continuously reflected in the duct and reflected by the ground. So that they propagate around the curvature beyond the line of sight. This special refraction of electromagnetic waves is called super refraction and the process is called duct propogation. Duct propogation is also known as super refraction. Consider the figure,



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)

$$N = n + (h/r)$$

$$(N-1) = (n-1) + h/r$$

Height above ground

Refractive index

$$(N-1) \times 10^6 = [(n-1) + h/r] \times 10^6$$

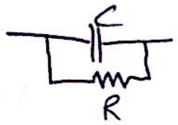
$$m = (N-1) \times 10^6 = [n-1 + h/r] \times 10^6.$$

Radius of earth (6370) km.

Duct can be used at VHF, UHF and microwave frequencies.

5 Discuss the salient features of Ground wave propagation.

The waves which while traveling glide over the earth's surface are called ground waves. Ground waves are always vertically polarized and induce charges in the earth. The number and polarity of these charges keep on changing with the intensity and location of the wavefield. This variation causes the constitution of a current. In carrying this current, the earth behaves like a leaky capacitor. As the wave travels over the surface it gets weakened due to absorption of some of its energy. This absorption in fact, is the power loss in the earth's resistance due to flow of current.



(OR)

The energy propagated over paths near the earth's surface is considered to be made possible through ground waves.

$$d = \frac{50}{(f)^{1/3}_{MHz}} \quad \text{in miles}$$

where d is the barrier distance between transmitter and receiver. Beyond this distance, the effect of the curvature of the earth is to be accounted.

→ constituents of groundwave
→ Sommerfield's eqn
→ Rayleigh criterion & attenuation
→ Variation with height, Wave tilt

8 What is fading? Discuss various types of fading as applicable to sky waves.

The tropospheric signals often suffer from fading which is a phenomenon of reduction of signals due to variation in refractive index. This variation is attributed to sudden changes in temperature, pressure and humidity.

Fading normally is of Rayleigh nature. It can be classified in many ways. It can be fast or slow, single path or multipath and short term or long term. For fast or multi-path fading, the duration is of the order of 0.01 second. Also, for long-term fading on an average, the variation of the signal is of the order of 10dB. It has been observed that the summer signals are about 10dB stronger than winter signals. Also, the morning and evening signals are nearly 5dB more than afternoon signals.

The fading phenomenon may occasionally result in sudden disruption of communication. To avoid the same the techniques employed are called diversity techniques. These include space diversity, frequency diversity, time diversity, modulation diversity and polarization diversity.

Long term Fading:

- Terrain configuration & man made environment causes longterm fading.
- Due to various shadowing and terrain effects the signal level measured on a circle around base station shows some random fluctuations around the mean value of received signal strength.

Rayleigh fading:

- This phenomenon is due to multipath propagation of the signal

- The Rayleigh fading is applicable to obstructed propagation paths.

Ricean fading:

- This phenomenon is due to multipath propagation of the signal
- In this case there is a partially scattered field
- One dominant signal
- Others are weaker.

→ Selective fading
→ Interference fading (Multipath effect)
→ Polarization fading
→ skip fading
→

7 Write short notes on

(i) Critical Frequency:- (f_{cr})

The critical frequency is defined as the highest frequency that can be reflected back to the Earth by a particular layer for a vertical incidence.

__Note__: critical frequency is different for different layers

For the vertical incidence ϕ_i becomes zero, the electron density becomes maximum. Then critical frequency can be defined as

$$\boxed{f_{cr} = \sqrt{81 N_{max}} \text{ (or) } 9\sqrt{N_{max}}.}$$

N_{max} - Electron density per cubic meter.

f_{cr} - critical frequency in (MHz)

Eventhough the critical frequency is the highest frequency that is reflected back for vertical incidence, it is not the highest frequency that can be reflected back to the Earth for any other angle of incidence. So, it represents that a radio wave with frequency less than or equal to critical frequency will certainly reflected back to the Earth by the Ionospheric layer for any angle of incidence.

When the angle of incidence is smaller, the refractive index of the layer is also smaller; which indicates that the value of electron density necessary to return the radio wave from the layer back to the Earth should be higher. When the angle of incidence ϕ_i becomes zero, the refractive index also becomes zero which indicates that the value of the electron density should be maximum ie., Nmax

In general refractive index is given by,

$$n = \sin\phi_i$$

If the radio wave with a frequency greater than the critical frequency is propogated through the ionosphere then this wave can also be reflected back to the earth but the angle of incidence must be such that at the frequency greater than fcr, $n = \sin\phi_i$ must be satisfied, otherwise the wave penetrates the layer. Thus for a radio wave with a frequency greater than fcr to be reflected back to the earth, the condition is given by,

$$\sin\phi_i > n$$

ie., $$\sin\phi_i > \sqrt{1 - \frac{81 N_{max}}{f^2}}$$

But $f_{cr} = \sqrt{81 N_{max}}$, hence the condition can be given by,

$$\boxed{\sin\phi_i > \sqrt{1 - \left(\frac{f_{cr}}{f}\right)^2}}$$

ii) Maximum usable Frequency (FMUF):-

The limiting maximum frequency that can be reflected back to the Earth by the Ionosphere layer for a specific angle of incidence rather than the angle of incidence for vertical incidence. denoted by fmuf)

(or) FMUF can also be defined as the maximum frequency that can be used for the sky wave propogation for specific distance between two points on the Earth. Thus fmuf is the highest frequency used for the sky wave communication for each pair of points on the globe, the value of fmuf will be different.

Fmuf ranges between 8MHZ to 35MHZ. Even up to 50MHZ due to solar activity

But the highest frequency used for propogation between is slightly less than f_{MUF}.

Expression for the refractive index.

$$n = \frac{\sin\phi_i}{\sin\phi_r} = \sqrt{1 - \frac{81N}{f^2}} \quad \text{--- (1)}$$

For the radio wave to return back to the earth, the angle of incidence refraction must be equal to 90° ie, $\phi_r = 90^\circ$. Thus for this condition N becomes N_{max} and f becomes f_{MUF} ie, maximum usable frequency.

Substitute values in Eq (1)

$$\frac{\sin\phi_i}{\sin 90^\circ} = \sqrt{1 - \frac{81 N_{max}}{f^2_{MUF}}} \Rightarrow \sin\phi_i = \sqrt{1 - \frac{81 N_{max}}{f^2_{MUF}}}$$

squaring both sides we get

$$\sin^2\phi_i = 1 - \frac{81 N_{max}}{f^2_{MUF}}$$

rearranging terms we get

$$\frac{81 N_{max}}{f^2_{MUF}} = 1 - \sin^2\phi_i \quad \text{-- (2)} \qquad [\because (1-\sin^2\theta) = \cos^2\theta]$$

$$\frac{81 N_{max}}{f^2_{MUF}} = \cos^2\phi_i \Rightarrow \frac{f^2_{cr}}{f^2_{MUF}} = \cos^2\phi_i$$

Hence the MUF is given by,

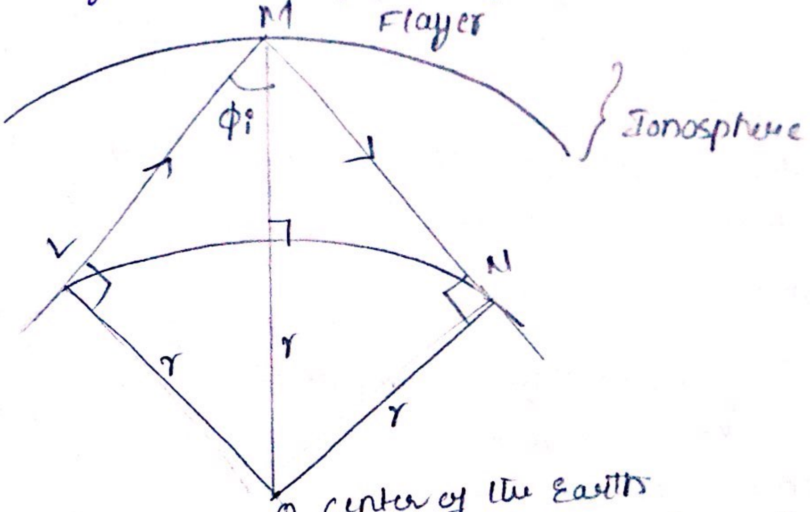
$$\boxed{f_{MUF} = \frac{f_{cr}}{\cancel{f_{MUF}} \cos^2\phi_i}} \quad \text{--(3)}$$

$$\boxed{f_{MUF} = (\sec\phi_i) f_{cr}} \quad \text{--(4)}$$

From above Equation (4) it is clear that the value of f_{MUF} is always greater than that of critical frequency f_{cr} of the layer by the factor $\sec\phi_i$. This is called secant law & it indicates the highest frequency to be used for sky wave propagation b/w the 2 points on Earth for given angle of incidence ϕ_i. Because of curved surface of Earth, the max angle for reflection from the last layer of ionosphere i.e, F layer found to be approximately equal to 74°. thus for this limiting angle,

$$\boxed{f_{MUF}(\text{maximum}) = \sec(74^\circ) f_{cr} = (3.6) f_{cr}}$$

above equation indicates max frequency in MHZ which can reflected from the ionosphere back to the earth. Any other frequency greater than this frequency will penetrate through the ionosphere layer



Geometry of the earth's surface and an ionospheric layer at height 'h'

If the wave is transmitted from the transmitter at point L, at the grazing angle then the angle of incidence is maximum is given by.

$$\phi_{imax} = \sin^{-1}\left[\frac{r}{r+h}\right]$$

iii) Skip distance :- is the shortest distance from the transmitter, measured along surface of the Earth, at which a sky wave of fixed frequency will return back to Earth.

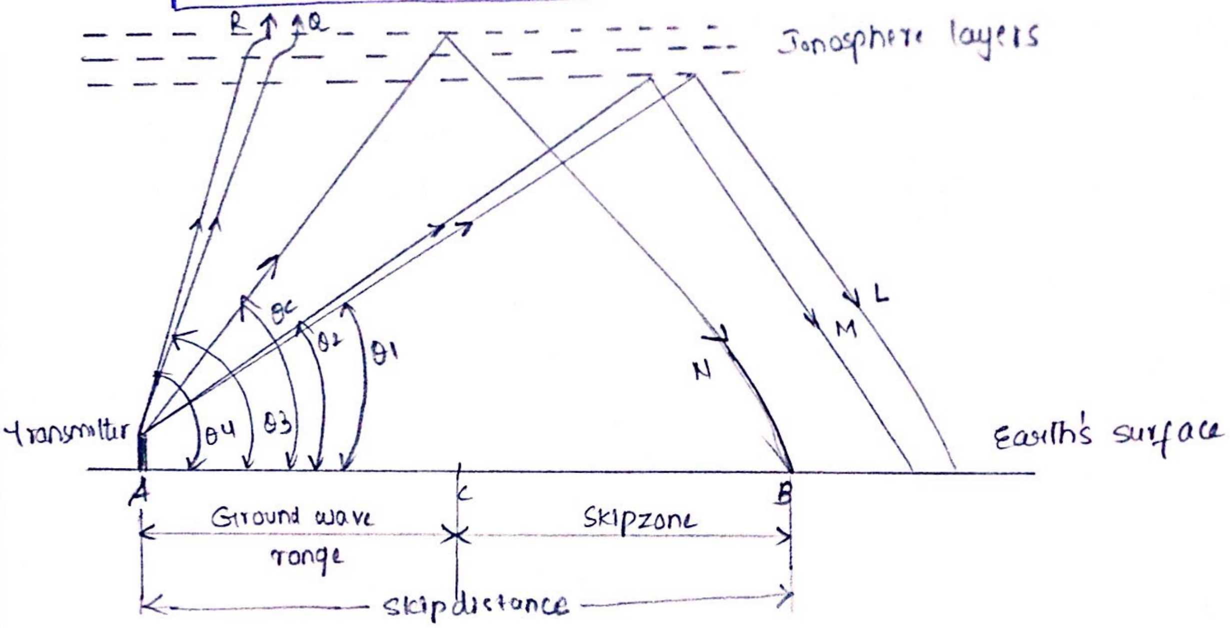
The angle of incidence for which the wave returns back to the Earth at minimum distance from the transmitter i.e., at the skip distance is called critical incidence ~~an~~ (θ_c)

This angle depends on the frequency of the wave transmitted. Higher the frequency, lower is the angle of critical incidence

$$f = f_{muf} = f_{cr}\sqrt{1+\left(\frac{D_{skip}}{2h}\right)^2}$$

$$\left(\frac{f_{muf}}{f_{cr}}\right)^2 - 1 = \left(\frac{D_{skip}}{2h}\right)^2$$

$$\boxed{D_{skip} = 2h\sqrt{\left(\frac{f_{MUF}}{f_{cr}}\right)^2 - 1}}$$



distance AB — Skip distance

$$f_{MUF} = f_{cr}\frac{\sqrt{\frac{D^2}{4} + \left[h + \frac{D^2}{8R}\right]^2}}{\left[h + \frac{D^2}{8R}\right]}$$

Squaring on both sides.

$$\frac{D^2_{skip}}{4} + \left[h + \frac{D^2_{skip}}{8R}\right]^2 = \left[\frac{f_{MUF}}{f_{cr}}\right]^2 \left[h + \frac{D^2_{skip}}{8R}\right]^2$$

$$\frac{D^2_{skip}}{4} = \left(\frac{f_{MUF}}{f_{cr}}\right)^2 \left[h + \frac{D^2_{skip}}{8R}\right]^2 - \left[h + \frac{D^2_{skip}}{8R}\right]^2$$

$$\frac{D^2_{skip}}{4} = \left[h + \frac{D^2_{skip}}{8R}\right]\left[\left(\frac{f_{MUF}}{f_{cr}}\right)^2 - 1\right]$$

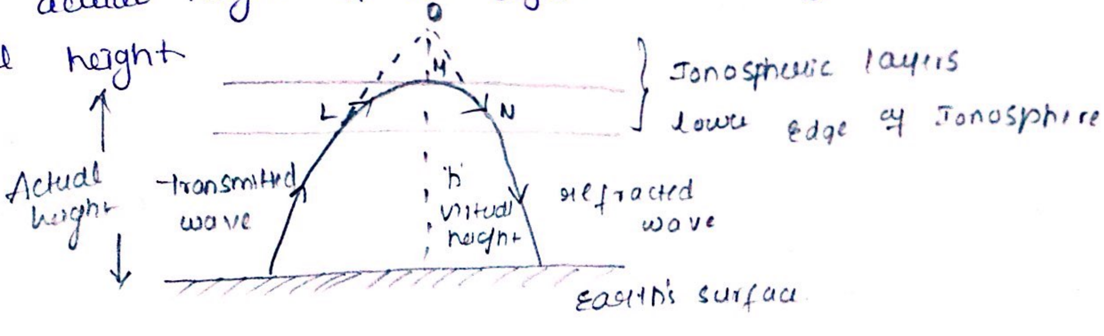
Square root on both sides

$$D_{skip} = 2\left[h + \frac{D^2_{skip}}{8R}\right]\sqrt{\left(\frac{f_{MUF}}{f_{cr}}\right)^2 - 1}$$

$$D_{skip} = 4h\sqrt{\left(\frac{f_{MUF}}{f_{cr}}\right)^2 - 1}$$

v) Virtual height :-

- the height at a point above the surface at which the wave bends down to the Earth is called actual (or) true height. However, below the ionized layer, the incident and reflected wave follow the paths which are exactly the same if reflection takes place along path at a height above the Earth surface, which is greater than the actual height of the layer. Such height is called Virtual height



$$h = c\left[\frac{T}{2}\right]$$

c → Speed of light

T — time required for the pulse to go to the layer and return back to Earth

iv) Lowest usable High frequency (LUHF)

For the Ionospheric transmission, the optimum working frequency is selected as value about 15% less than MUF. Because the attenuation varies inversely with the square of frequency high value of optimum working frequency is selected. But for the high frequencies, the reflection takes from the F layer and the waves suffer absorption. The absorption in F layer is comparatively smaller. But for the high frequencies near MUF, the waves undergo abnormal retardation and considerable amount of absorption take place. Hence the strength of the signal received on the Earth becomes very less. Hence there is a limit on the highest frequency used as the optimum working frequency and is denoted as the lowest usable high frequency (LUHF)

For the given transmission distance and transmitter power, the lower usable high frequency is defined as the lowest frequency in the high frequency band that useful, satisfactory reception for the given transmission distance and power. Thus for the useful ionospheric propogation the frequency should be selected in between MUF and the lowest usable high frequency (LUHF)

The lowest usable high frequency (LUHF) depends on

(i) The Effective radiated power

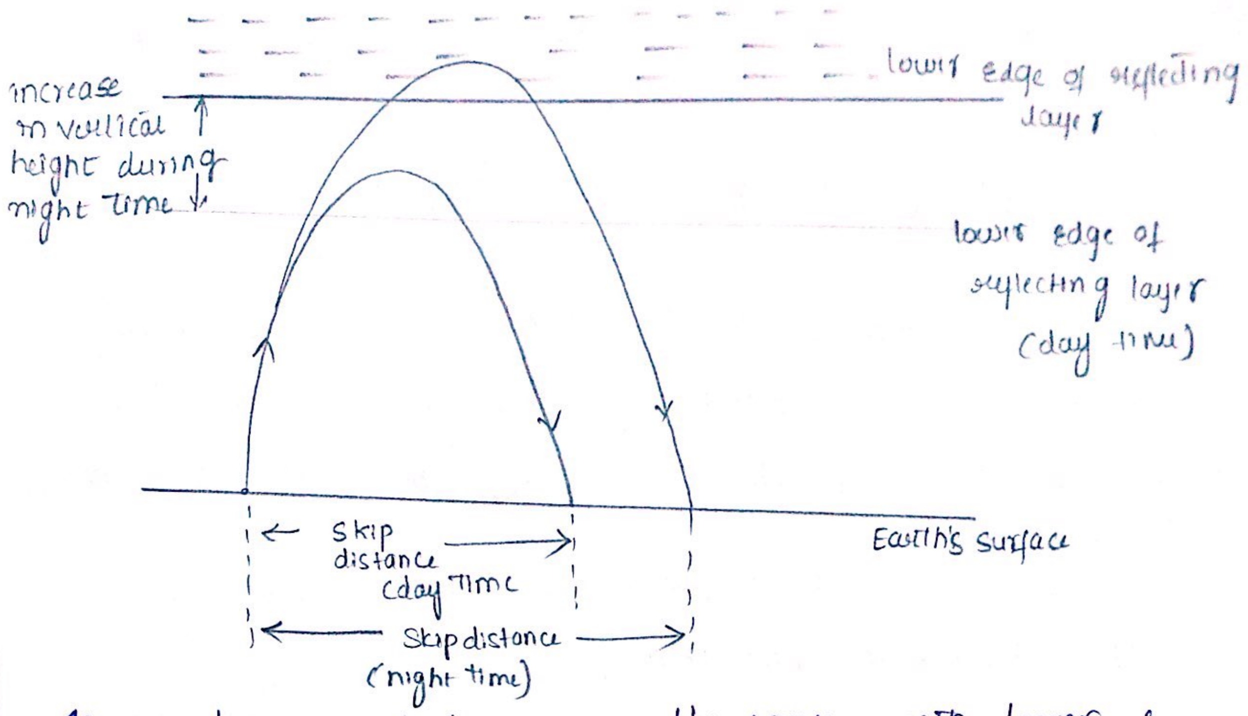
ii) The ionospheric characteristics between transmission distance, and.

iii) The radio noise of the receiver and type of the receiver.

Optimum working frequency :-

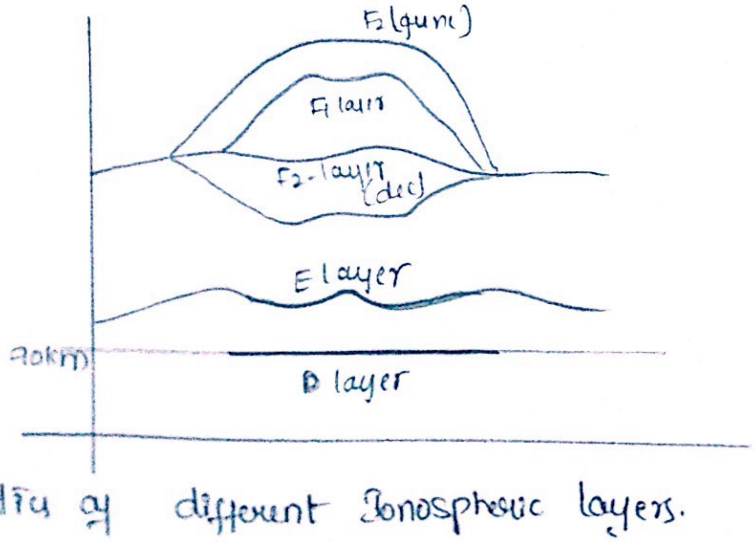
For Ionospheric propogation, it is desirable to use as high a frequency as possible. This clearly points out that the frequency used for the Ionospheric cond transmission should be the maximum usable freq (MUF). It depends on distance b/w the Tx and Rx and also upon the state of Ionosphere and also varies due irregularity of Ionosphere about 15% of its max value. Hence practically the frequency used should be 15% less than MUF. Thus, the frequency normally used for the ionospheric propogation is known as optimum working frequency.

OWF between the Tx and Rx for the Ionospheric transmission is defined as the frequency laying b/w 50% to 85% of the predicted MUF between the transmission and the reception points.



As we have studied that, the wave with lower frequency is bent more quickly as compared to the wave with higher frecuency. Hence the increase in the skip distance during night time is cancelled by using lower frequency during night time.

Q8 Explain about structure of Ionosphere.



Characteristics of different Ionospheric layers.

D-layer:

1) The D-layer is located about 50 to 90 km above the surface of Earth and it is nearest layer to the Earth's surface.

ii) Its thickness is about 10km.

iii) This layer is Ionized by photoionization of O_2 molecules.

iv) This layer is present during day time while disappears during night time.

v) It has an ionic density of about $400/cm^2$ and Electron density of maximum value at noon.

vi) This layer reflect very low frequency and low frequency waves.

vii) At vertical incidence, the critical frequency of the layer is about 100KHz.

E layer:-

i) The E-layer is located about 90 to 140km above The surface of Earth.

ii) Its Thickness is about 25 km.

iii) In E-Layer the Ionization of all gases by x ray radiation takes place.

iv) during night time its Ionization is weak.

v) The maximum Electron density $4 \times 10^5 / cm^3$ and is at height of 100 km.

vi) It is useful for HF waves during day time.

vii) Its critical frequency is about 3 to 5 MHz and it provides sometimes better reception during night time.

Flayer:

(1) located at 140 to 400km height

F1 (140 to 200 km) & F2 (250 to 400 km).

(2) Electron density - 220km (approx)

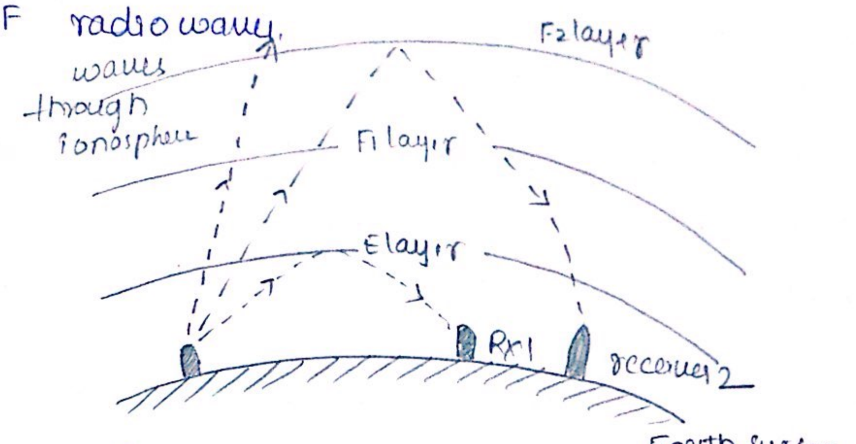
3. f_c is 5 to 12 MHz of F layer.

4. this is only layer which is Ionized during day and night time.

5. It is topmost layer

8) F_1 layer reflects the high frequency (HF) waves

9) F_2 layer is most important for the reflection of HF radio waves.



Refraction by different layers

- Dielectric constant (ε) relative permittivity of Ionosphere

$$\varepsilon_r' = 1 - \frac{Ne^2}{m\varepsilon_0(\omega_0^2+\omega^2)}$$

- When the height is more, ω_0 is very small as compared to the given frequency ω ($\omega >> \omega_0$), the conductivity becomes very small. Under such condition the effective dielectric constant is given by $\varepsilon_0\left[1-\left(\frac{Ne^2}{\varepsilon_0 m\omega^2}\right)\right]$

When the height is small, ω_0 is very large as compared to the given frequency ω, ($\omega_0 >> \omega$), then the conductivity again becomes very small, while the dielectric constant reduces to zero. This is due to rapid reduction of the charged particle density with height up to 80km

Thus from above, ~~can~~ that the region of high conductivity i.e., the region of high absorption is nothing but a thin layer in b/w the lower region of E layer & upper region of D layer

9 a) write short notes on Diversity reception principle

Some of the Fading Effect is minimized by using AGC, but it becomes helpless when the signal fades much below the noise level. In such case the best option is to use diversity reception system. there are two forms of such system; namely space diversity and frequency diversity. Any diversity reception system is based on the fact that although fading may be Severe at some particular time, at some particular time, at some frequency and at some point on the earth, it is Extremely unlikely that the signals at different points or signals with different frequencies will fed simultaneously.

Both these systems are used frequently in the commercial as well as military operations.

In space diversity system, 2 (or) more antennas are separated by about 9 or 10 wavelengths. The receivers are arranged in such away that the AGC from the Rx for the stronger signal cuts off other Rx's instantaneously. thus only the signal with more strength from the stronger Rx is passed to common o/p stage.

The frequency diversity principle is very much Similar to space diversity but the difference b/w the 2 is that in freq diversity same antenna is used for the receivers, which work with simultaneous transmission at 2 or more frequencies.

disadvantage

→ It requires a large frequency range to work with more frequencies. so here the frequency spectrum is wasted without proper utilization

→ Its use is limited in the voice Communication system

(B) Write short note on Faraday rotation

In Ionosphere, the Electrons are set in motion by the Electric field of radio wave and the Earth's magnetic field Exerts force on vibrating Electrons producing a twisting Effect on their paths

This has an Effect on the incident radio waves called Faraday rotation.

→ Any linearly polarized wave may be regarded as the vector sum of two counter-rotating circularly polarized waves

→ If such a wave propogates in the direction of magnetic field in a lossless plasma, the two circularly polarized components will travel at different phase velocities and thus the plane of polarization will rotate with distance. This Phenomemon is known as Faraday rotation

The Propogation of two Equal magnitude circularly Polarized waves in a lossless plasma may be represented by the writing the Electric field strength

$$E = \hat{R}\, e^{-j\beta_R z} + \hat{L}\, e^{-j\beta_L z} = \hat{R} E_R + \hat{L} E_L$$

$\hat{R}$ & $\hat{L}$ are right handed and left handed rotating unit vectors respectively

β_L and β_R are real

Z - distance travelled

The complex polarization ratio is

$$Q = \frac{E_L}{E_R} = e^{j(\beta_L - \beta_R)Z}$$

because the polarization is linear $E_L = E_R$

on $Q = 1$

The tilt angle of the plane of polarization is given as

$$\phi = \frac{1}{2}(\beta_L - \beta_R)Z$$

→ For signals of several hundred MHz most of Faraday rotation occurs in the 90-100km altitude range.

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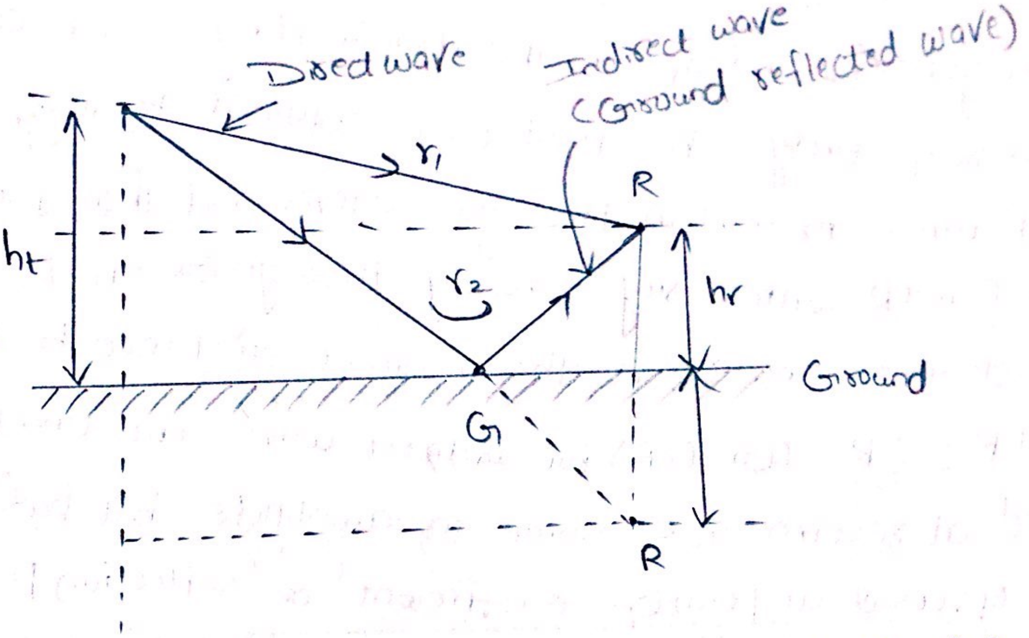
10) obtain an expression for space wave field component taking into account a direct wave field and a reflected wave from the earth's surface?



consider 2 antennas ie; transmitting antenna and receiving antenna are placed above the ground anywhere in the troposphere but not more than 15 Km above from the surface of the earth as shown in fig.

At receiver, the total field strength is equal to the vector addition of the fields of these two waves ie; one that reaches directly from transmitter while other which reaches receiver after reflected from ground. under normal circumstances, the space waves are not suffered by attenuation heavily.

During analysis, we must consider the coefficient of reflection of the ground as the propagation deals with a wave reflected from ground. To simply analysis, assume that distance between 2 antennas along the earth's surface is very large as compared with heights h_t and h_r of the transmitting and receiving antenna respectively. The point G is obtained by image point R' at a distance h_r below the ground level and then joining points T and R' with a ray passing through G. r_1 is the Direct distance and r_2 is the Indirect distance between T and R. (TR = (TG + GR) for Indirect wave. The two waves received at receiver are same in amplitude but has a phase reversal at point G. coefficient of reflection $P = 1\angle 180$

From geometry

$$r_1 = \sqrt{d^2 + (h_t - h_r)^2} = d\sqrt{1 + \left(\frac{h_t - h_r}{d}\right)^2}$$

$$= d\left[1 + \frac{1}{2}\left(\frac{h_t - h_r}{d}\right)^2 + \cdots\right]$$

Neglecting higher order terms and simplifying, we get

$$r_1 = d + \frac{(h_t - h_r)^2}{2d} \quad \text{—— (1)}$$

Illy

$$r_2 = \sqrt{d^2 + (h_t - h_r)^2} = \sqrt{1 + \left(\frac{h_t + h_r}{d}\right)^2}$$

$$= d\left[1 + \frac{1}{2}\left(\frac{h_t + h_r}{d}\right)^2 + \cdots\right]$$

Assuming $\frac{4\pi h_t h_r}{\lambda d} << \omega t$ for high frequencies we get

$$E_R = 2E_0 \sin(\omega t) \cdot \sin\left(\frac{2\pi h_t h_r}{\lambda d}\right)$$

$$\boxed{E_R = \left[2E_0 \sin \frac{2\pi h_t h_r}{\lambda d}\right] \sin \omega t}$$

the term in square bracket Indicates magnitude. Hence actual Field strength at Distance D is given by

$$\frac{2E_0}{d} \sin \frac{2\pi h_t h_r}{\lambda d}$$

Field strength at receiver $= \frac{2E_0}{d}\left[\frac{2\pi h_t h_r}{\lambda d}\right]$

$\left(\because \sin \frac{2\pi h_t h_r}{\lambda d} = \frac{2\pi h_t h_r}{\lambda d}\right)$

$$\boxed{\text{Field Strength at receiver} = \left(\frac{4\pi h_t h_r}{\lambda}\right) \frac{E_0}{d^2}}$$

The Field Strength Varies Inversly with the square of the distance between between them Field Strength becomes zero when the value of $\frac{2\pi h_t h_r}{\lambda d}$ is equal to Integral multiple of π.

11) Discuss the Various energy loss mechanism encountered by em waves in ionosphere by Em waves-in-ionosphere.

The Variations in the ionosphere are of 2 types

1) normal Variations
2) Abnormal Variations

normal variations include daily and seasonal variations in in height and thickness of the ionosphere layers while abnormal variations include Sudden ionospheric distubances, ionospheric storms, sunspot cycle, tides and winds etc.

Sudden Ionospheric Disturbances (SID)

The sudden ionospheric distrubances are produced due to sudden solar flares produced randomly. The radiation of X-rays along with the solar flares Increases ionization density down to D-layer. Due to this absorption of high frequency signals and atmospheric noise reflection Increases Becoz of which Lowest usable frequency Increases than the maximum usable frequency (fMUF) which blocks the propagation of all high frequencies via Ionosphere. It was first observed by Mongel and Dellinger so, It is called as Mongel-Dollinger effect.

Sun spot cycle:-

The sunspot cycle is about 11 years. During this cycle, the solar output variations are considerable. It is observed that during maximum sun spot count the critical frequency is highest while It is lowest during the period of minimum sunspot count. The critical frequency of F2-layer may vary from 6MHz to 11MHz and for E-layer 3.1MHz to 3.8MHz

Thus from the plots of variations in the critical frequency following the sunspot cycle, one can predict ionospheric characteristics during next sunspot cycle in advance and thus helps in selecting frequencies over period best suitable for communication.

Ionospheric Storms:-

Ionospheric storms are the disturbances in the layers of ionosphere which are related with excessive variations due to magnetic storms. Such stromes occur due to emissions like α-rays and β-rays from the sun.

Tides and winds in Ionosphere:-

Ionosphere experiences tidal forces of the sun and the moon. In Ionosphere the solar tidal pulls are amplified as the period of oscillations in the ionosphere equal the 12 hours period of solar tidal force creating resonance effect. - The lunar tidal forces are also notable and are observed by Appleton and weeks

The tidal pulls cause speedy motion of the ionized particles whic is called wind. Obviously F2- layer is greatly affected by such ionospheric winds

Fading:-

Fading is defined as the fluctuations in the received signal strength caused due to variations in height and density of the ionization in different layers. Bascilly the fading is the common characteristic of the high frequency short wave propagation ie; sky wave propagation

Energy loss in Ionosphere:-

The loss of energy mostly depends on i) gas pressure ii) vibration velocity iii) frequency of collisions and iv) nature of collisions. absorption loss is maximum at gyro frequency and lower frequencies while less at higher frequencies.

the loss of higher frequencies, due to collision is called non-derivative absorption loss. The attenuation constant for non-derivative absorption is expressed in dB per unit length

$$\alpha = k\left(\frac{f_E}{f}\right)^2 \text{ and } \alpha = k\left(\frac{f_D}{f}\right)^2$$

f_D and f_E are the critical frequencies of D-layer and E-layer respectively. k is function of collision frequency and f is wave frequency.

+ Earth's magnetic field:- (Gyro? freq and hence lower limit on ~~cut~~ frequencies used in sky wave propagation)

a) write short note on surface wave tilt?

For a vertically polarized wave, a forward tilt is observed at surface of the earth. By how much amount the wave tilts depends on conductivity and permittivity of the earth. The electric field vector has 2 components one parallel and other is perpendicular to surface of the earth. when there is a slight forward tilt, these two components are not in phase and thus just above the surface of the earth, the electric field is found to be elliptically polarized.

For a good conductor, over most of the frequency ranges and conductivity values the surface Impedance of the earth is given by

$$Z_s = \sqrt{\frac{\omega\mu}{(\sigma^2+\omega^2\varepsilon^2)^{1/2}}} \angle \frac{1}{2}\left\{\tan^{-1}\frac{\sigma}{\omega\varepsilon}\right\}$$

where μ = permeability of the earth

σ = conductivity of the earth

ε = permittivity of the earth

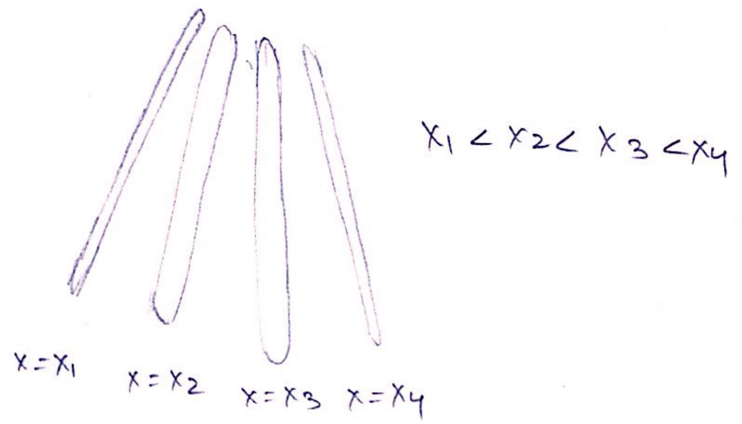
Horizontal Component $\bar{E}_H = \bar{J}_s Z_s$

Vertical component $E_V = H \cdot \eta_0$

The ratio of the horizantal component to vertical component is given by

$$\frac{\bar{E}_H}{\bar{E}_V} = \frac{\bar{J}_s Z_s}{\bar{H}\eta_0} = \frac{Z_s}{\eta_0} = \frac{1}{377}\sqrt{\frac{\omega\mu}{(\sigma^2+\omega^2\varepsilon^2)^{1/2}}} \angle \frac{1}{2}\left\{\tan^{-1}\frac{\sigma}{\omega\varepsilon}\right\}$$

If we plot the electric field $\bar{E}$ at various instants, then the locus of the end point of E give rise to elliptical Shape. The elliptical polarization of field is shown in fig



Note that the angle $\tan^{-1}\frac{\sigma}{\omega\varepsilon}$ gives the tilt angle as it indicates by how much amount wave is tilted.