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22G21A04D2

ASSIGNMENT - V

Short Questions :-

1. what is the inversion layer in space wave propogation?
2. what is critical frequency?
3. what is actual height and virtual height?
4. what are the different modes of wave propogation?
5. what is the lowest usable high frequency?
6. what is optimum frequency in sky wave propogation?
7. what are the different Ionization layers present in the ionosphere?

Long Questions :-

1. Explain Ground wave propogation.
2. what is MUF and derive the expression for MUF for a flat earth using snell's law?
3. Consider the reflection takes place at a height of 400km and the maximum density in the ionosphere corresponds to a refractive index of 0.9 at 6MHz. what will be the skip distance for flat earth, so that the MUF is 6MHz?
4. Explain the space wave propogation and derive the expression for the maximum possible range.
5. Draw the basic structure of the Ionosphere and explain its operation.
6. what are M-curves and explain duct propogation?
7. How the troposphere ducts are formed. Describe the duct propagation loss.
8. Describe the properties of the Ionosphere what is its height from the earth? Describe the importance of various layers in radio wave propogation.
9. Derive the expression for the transmission path loss using the friss transmission formula.
10. Define virtual height and skip distance.
11. consider that the reflection takes place at a height of 400km and the max density in the ionosphere corresponds to $\eta = 0.9$ at 10MHz. what will be the skip distance for flat earth so that "MUF = 10MHz".

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Short Answers :-

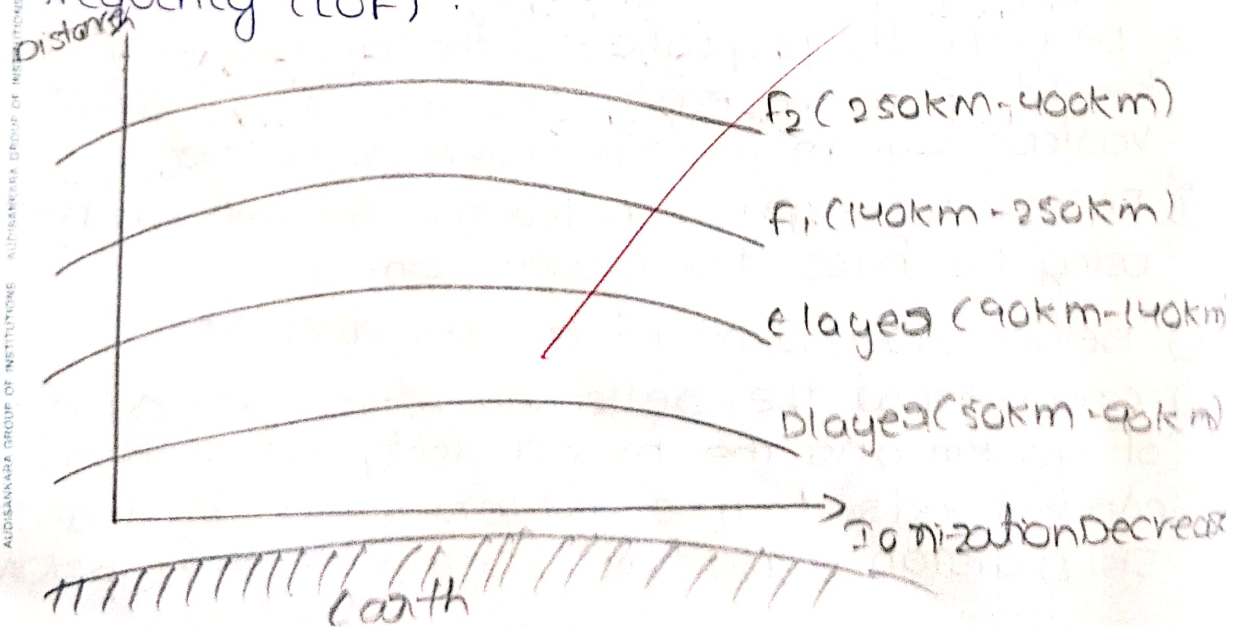
① Inversion layer :- It is the region where Atmospheric conditions are exactly opposite to that of standard Atmosphere.

② Critical frequency :-
For any given time, each Ionospheric layer has the maximum frequency at which radio waves can be transmitted vertically and reflected back to earth. This frequency is known as critical frequency for Ionosphere.
* η - is refractive index of Ionospheric layer.
* N - number density or no. of electrons per cubic meter.

$$\eta = \sqrt{1 - \frac{81N}{f^2}}$$

④ Different modes of propagation :-
① Ground wave propogation.
2) Tropospheric propogation.
③ Ionospheric or sky wave propogation.
④ space wave or line of site (LOS) propogation.

⑤ Lowest Usable-frequency :-
* The ~~lowes~~ frequency below which the entire power gets absorbed is referred to as lowest usable frequency (LUF).

⑦ 

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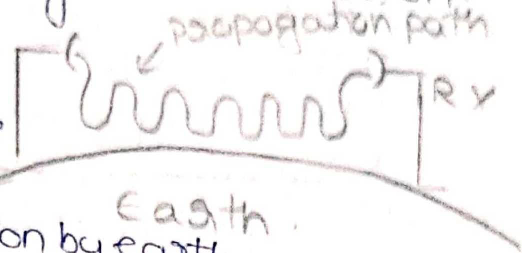
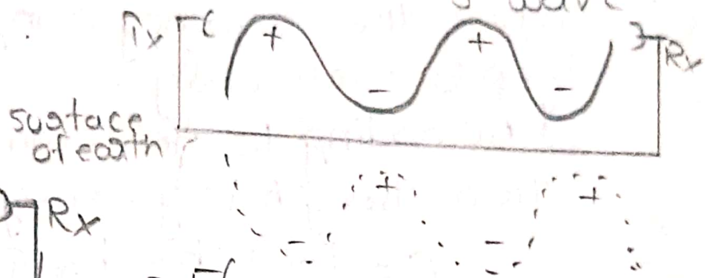
Long Questions:-

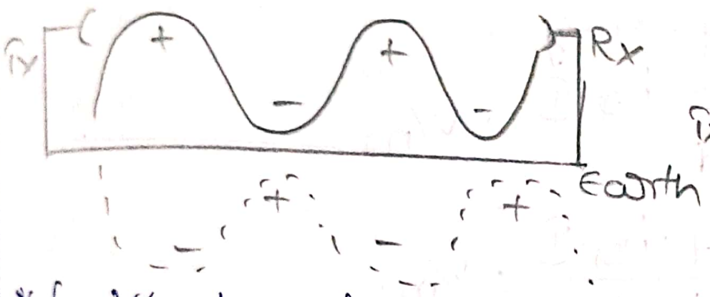
① Ground wave propogation :-

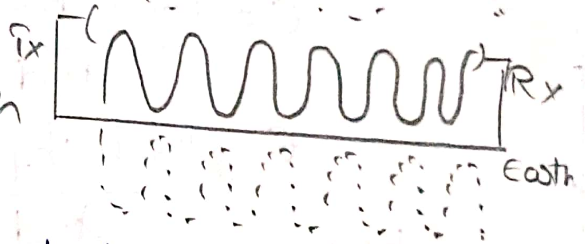
* It is utilised for short range communication
* Induced wave by the ground attenuates the signal
* As distance increases magnitude of propogating signal decreases by large amount due to attenuation by earth



* It is used for low freq operation. Electromagnetic wave
* It is used upto 2MHz

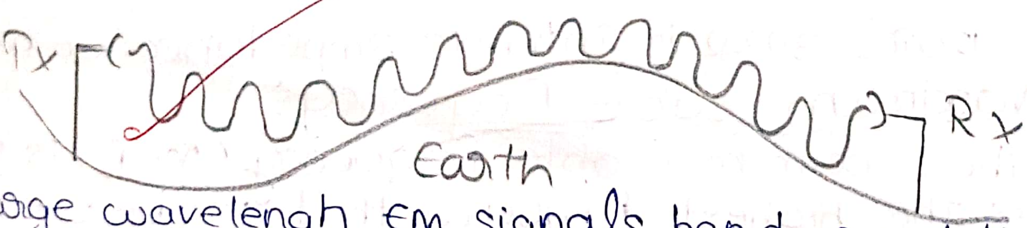






* $f = V/\lambda$; low frequency leads to high wavelength.
* Attenuation increases due to induced wave from gnd.
* At lower wavelength (freq is high) attenuation by earth is high.

Advantages of large wavelength :-



* large wavelength EM signals bend around the obstruction more effectively. θ is bending angle.

  $\sin\theta \propto \lambda$; $\theta\uparrow = \lambda\uparrow$.
* The EM waves which are propogated near the earth surface are called as ground waves and the corresponding propogation is called ground wave propogation.
* A vertically polarized wave that travels along the

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surface of the earth. For the ground wave propogation vertical antennas are useful

* If horizontally polarized wave is used to propogate as a ground wave, then the electric field of the wave gets short circuited due to the conductivity of the earth surface. Hence ground wave is always a vertically polarized wave.

* The important consideration for ground wave propogation is lower frequency, because of ground losses increases rapidly with increase in frequency. Hence the frequency range for ground wave propogation is up to 2 MHz only.

* According to the sommerfeld the ground wave field strength is given by

$$E = \frac{120\pi \cdot h_r \cdot h_r \cdot I}{\lambda \cdot d} ; V/m$$

$$E = \frac{120\pi \cdot h_t \cdot h_r \cdot I}{\lambda \cdot d} ; V/m.$$

h_t, h_r are the effective heights of receiving and transmitting antennas.

d - Distance at a point from the transmitter.

λ - wavelength.

I = Antenna current

$120\pi = 377\Omega$ is Intrinsic Impedance of free space

② Maximum usable frequency :-

The maximum usable frequency (MUF) is defined as the highest frequency that can be used for sky wave communication between the two given points on earth. Beyond MUF the wave will not be reflected back to the earth.

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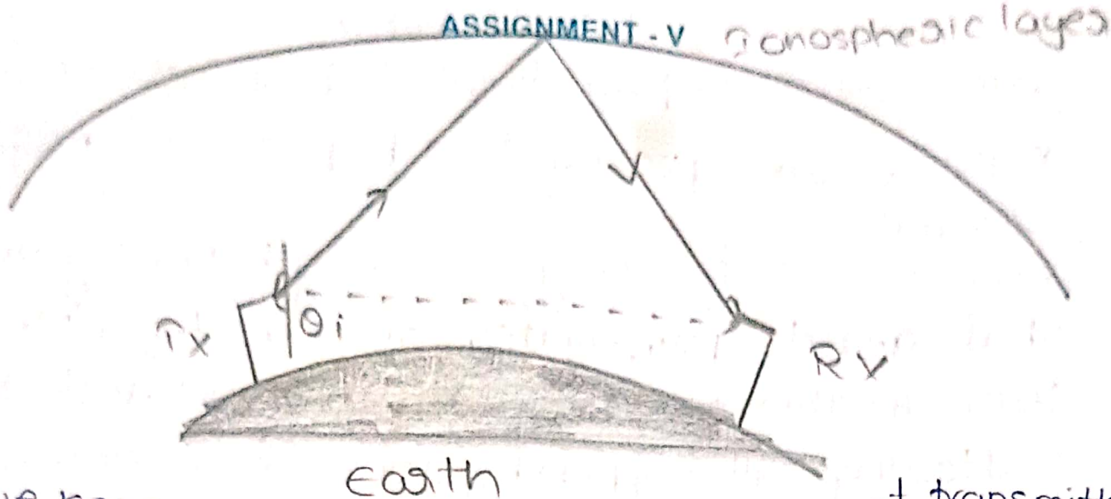

* we keep on increasing the frequency ~~of oscillator~~ at transmitter till receiver receives the signal and we will find the maximum frequency up to which we receive the signal. θ_i, θ_r.

* For Ionospheric layer from snell's law, we know that

$$\eta = \frac{\sin\theta_i}{\sin\theta_r} = \sqrt{1 - \frac{81N}{f^2}}$$

* where
η - Refractive Index.
θ_i = Angle of incident, θ_r - Refracted Angle.
N = Number density/charge density → f = frequency.

* From EM wave to return back to earth the angle of refraction θ_r should be 90°.

* $\theta_r = 90^\circ$; $f = f_{muf}$ and $N = N_{max}$ $\eta = \frac{\sin\theta_i}{\sin\theta_r} = \sqrt{1 - \frac{81N}{f^2}}$

$$\sin^2\theta_i = 1 - \frac{81N}{f^2_{muf}}$$

By rearranging $\cos^2\theta_i = \frac{81N}{f^2_{muf}}$

we know that

$$f_c = \sqrt{81 \cdot N_{max}}$$

$$\cos^2\theta_i = \frac{f_c^2}{f^2_{muf}}$$

$$\cos\theta_i = \frac{f_c}{f_{muf}}$$

$$\therefore f_{muf} = f_c \cdot \sec\theta_i$$

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④ Space wave propogation/LOS propogation :-

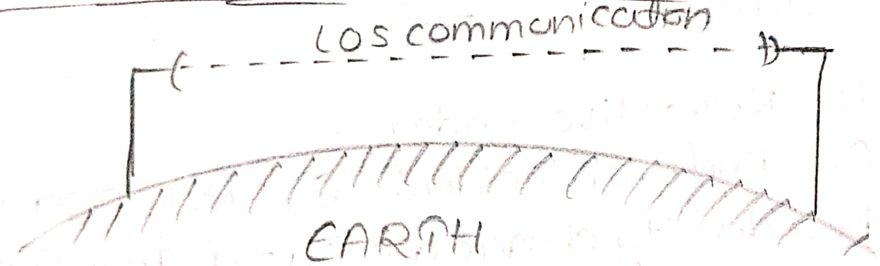
* space wave propogation happens at frequencies >30MHz.

* Due to high frequency, wavelength is very small, that results propogation of wave by a straight Path. At this frequencies there is no reflection and Scattering will happen by Ionosphere and Troposphere

* space wave propogation has two different categories of propogation.

1. satellite communication.
2. (LOS) Line of site communication.

LOS (Line of site) communication :-

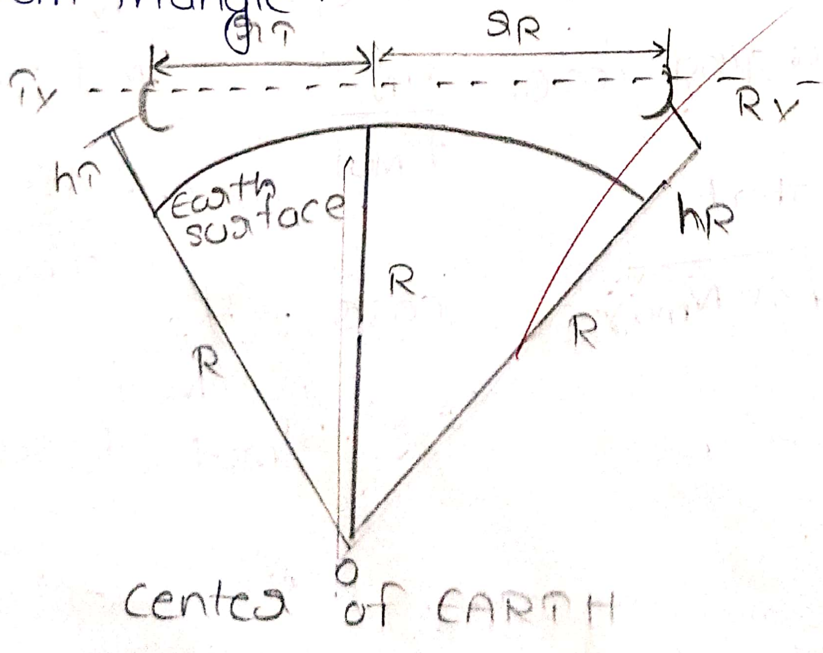


LOS - Line of sight propogation.

* Here signal travels from Tx Antenna to Rx Antenna by a straight path.

Maximum possible range :-

* From triangle.



r_R - Range of Received Antenna.

r_T - Range of Transmitted Antenna.

$$r_T^2 + R^2 = (h_T + R)^2$$

$$r_T^2 + R^2 = h_T^2 + R^2 + 2 \cdot h_T \cdot R$$

$$r_T^2 = h_T^2 + 2 \cdot h_T \cdot R$$

R - in kilo meters.

r_T - in kilo meters.

h_T - in meters

h_T^2 - is very small compared to r_T^2 and $2 \cdot h_T \cdot R$.

$$r_T^2 = h_T^2 + 2 \cdot h_T \cdot R$$

$$r_T^2 = 2 \cdot h_T \cdot R$$

$$r_T = \sqrt{2 \cdot h_T \cdot R}$$

* similarly range of the received antenna.

$$r_R = \sqrt{2 \cdot h_R \cdot R}$$

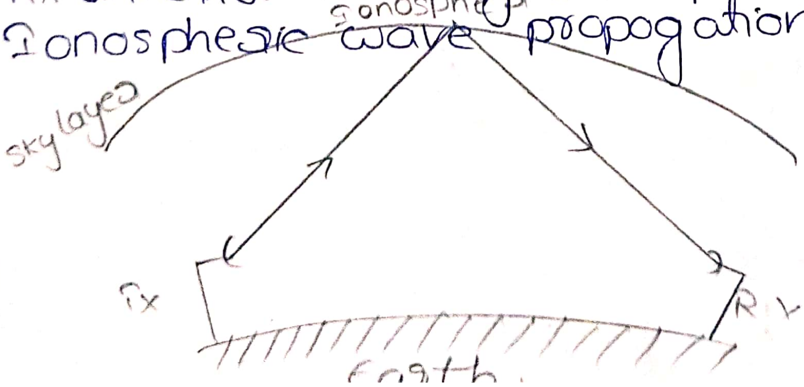
r - is the total Range

$$r = r_R + r_T$$

$$r = \sqrt{2 \cdot h_R \cdot R} + \sqrt{2 \cdot h_T \cdot R}$$

(5) <u>Inospheric wave propogation</u> :-

* Transmitted signal from the Tx antenna reflected by the Ionospheric layer (sky) and received by Rx antenna is a sky wave propogation or Ionospheric wave propogation.



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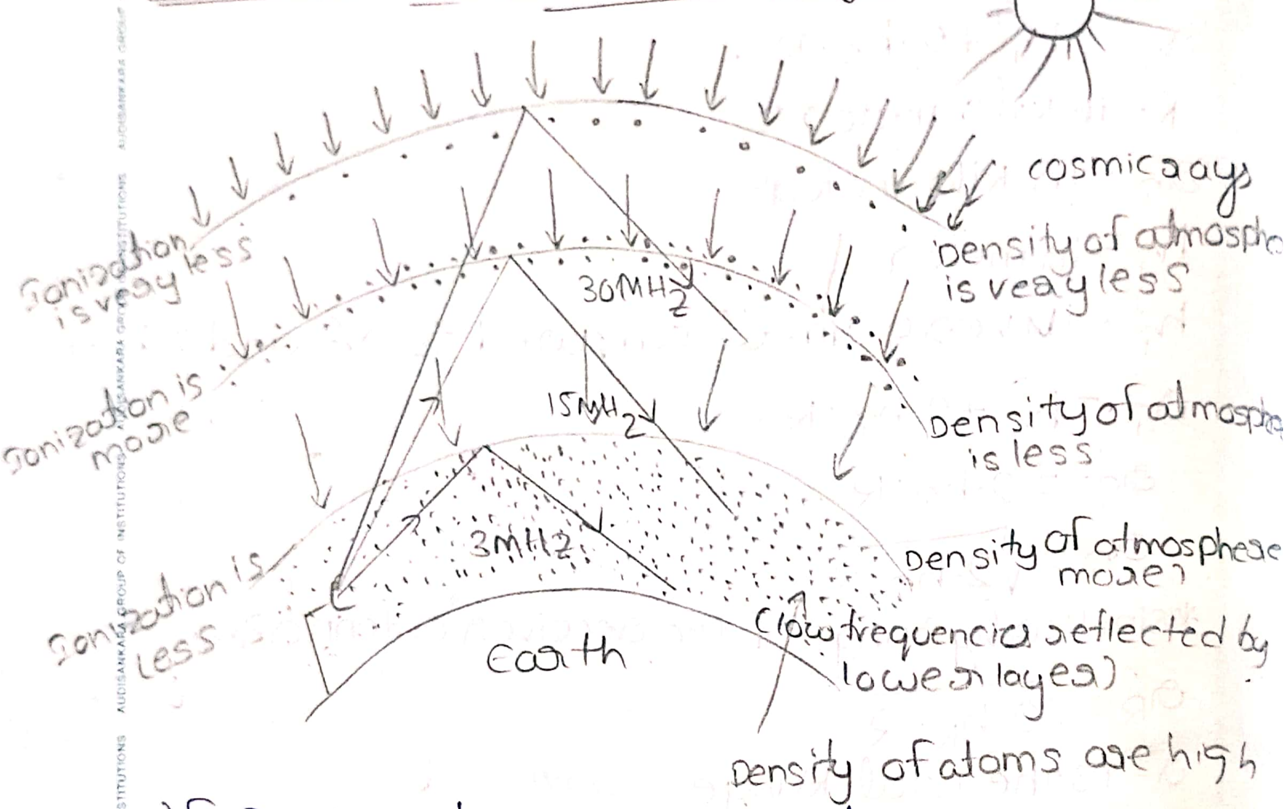
For ground wave propogation the range was limited this can be overcome by sky wave propogation.

The frequency range from 3MHz to 30MHz are used for sky wave propogation.

Formation of Ionization layer:-

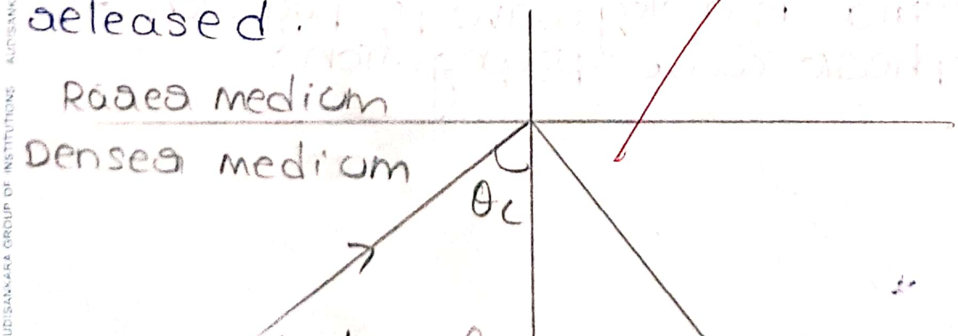


-> For ground wave propogation range was limited.

-> This can be overcome by sky wave propogation.

-> The range of frequencies for sky wave propogation is 3MHz to 300MHz.

* cosmic rays are coming from sun and hits the atoms and forms ions and electrons will be released.



If the incident angle $> \theta_c$, then there is a reflectio

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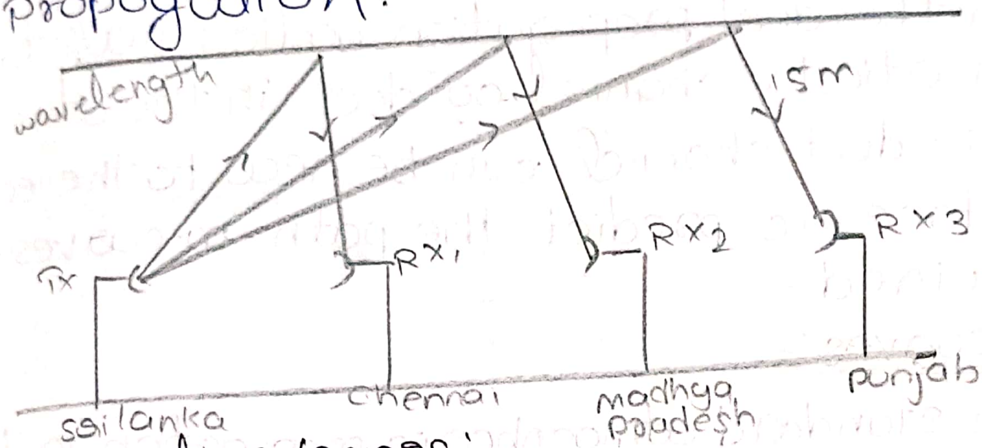
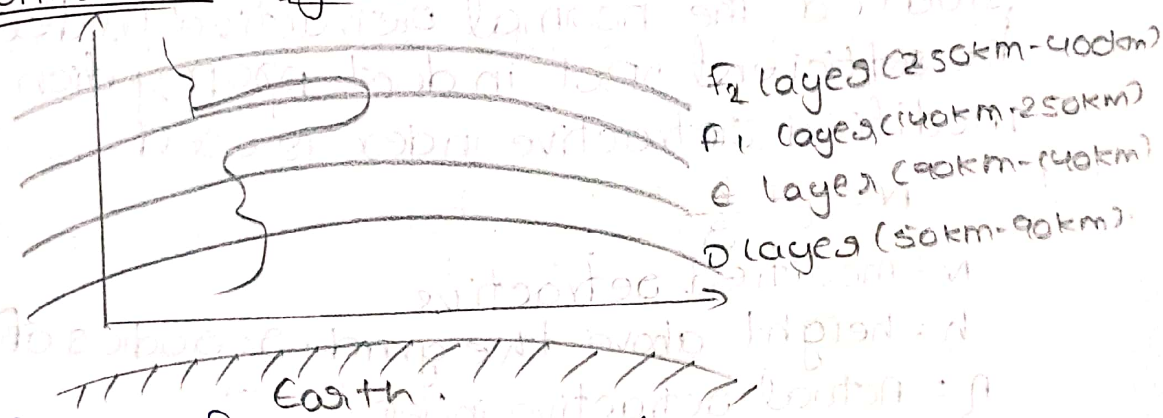
* Frequency increased for long distance communication frequencies up to 30MHz used for sky wave propogation.



Ionisation layers :-



* Range of skywave propogation is controlled by two parameters

(1) frequency (wavelength).
(2) Angle of propogation.

Applications :-

* since it is not limited by the curvature of the earth, sky wave propogation can be used to communicate beyond international distances.
* It is used for long distances short wave (sw) radio communication.

(3) M-curves and duct propogation :-

* surface refraction or Troposhperic scattering :-
* Ground wave propogation is used for low frequency applications.

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* space wave propogation is used for VHF, UHF and MW frequencies
* In the duct propogation radio signals follow a particular channel or duct in the atmosphere.
* This duct channel can be near to the earth surface. To predict the path m-curves are required.

<u>M-curves :-</u>

For standard atmospheric propogation to be studied the normal refractive index will be sufficient. But in duct propogation excess modified refractive index is used.

$$N = \eta + \frac{h}{a}$$

N = modified refractive

h = height above the grnd. a = radius of earth.

η = Actual refractive index.

Here the value of N is close to unity and it is depending on h/a

* m the excess modified refractive index is given by 'm'

$m = (N-1) \cdot 10^6$, so for that

$$N - 1 = n - 1 + \frac{h}{a}$$

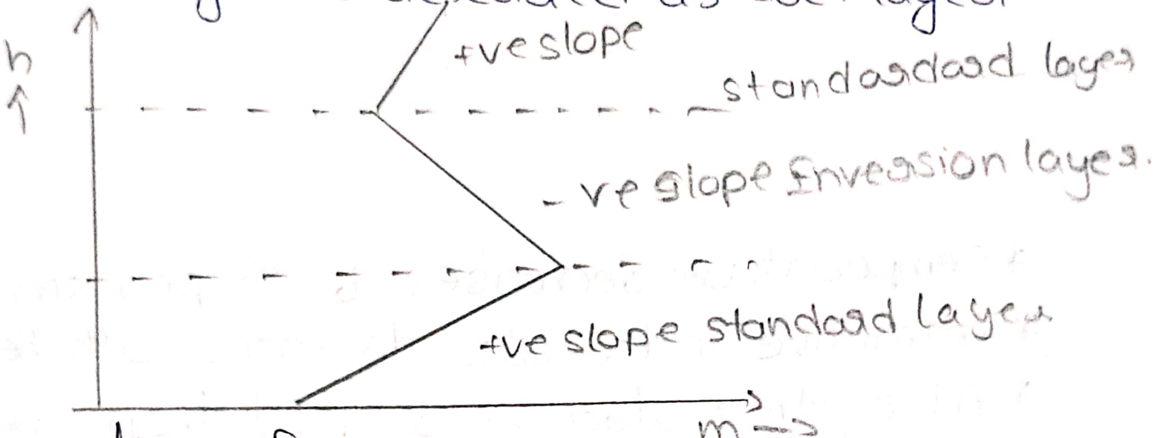
$$(N-1) \cdot 10^6 = (n \cdot 1 + \frac{h}{a}) \times 10^6$$

$$m = (N-1) \cdot 10^6 = (n - 1 * h/a) \times 10^6$$

* when we plot m against h. it is called m-curves
* Note that in non-saturated atmosphere, simple refraction does not occur But when m-curves are available, it is possible to predict roughly.
* The gradient $\frac{dm}{dh}$ and its sign is depending on the troposphearic conditions.

inversion layer :- It is the region where Atmospheric conditions are exactly opposite to that of standard Atmosphere.

* For standard atmosphere, slope of m is '+ve'
* For inversion layer, slope of m is -ve'. This inversion layer is referred as duct layer.



(7) **Formation of tropospheric ducts :-**

* when the temperature increases with height over a certain regions. It is known as temp inversion
* cool air is having largest density and hot air is having less density.
* when inversion layer is sandwiched b/w earth surface and standard atmosphere, then the cool air is trapped b/w the earth surface and the warm air. This cool air behaves like a duct for radio waves
* There is elevated inversion layer is present, in such a case the cool air is trapped b/w the warm air above and below it.
* warm air and cool air has different densities so when Em signal goes from cool air to warm air it will refelected back to the earth, that reflected signal may again reflects from transistion of cool air to warm air.
* For single hop propagation, reflection of wave happens one time.
* for time hop propogation, the reflection of wave happens more than 3 times.

Density low 22Q21A04P2

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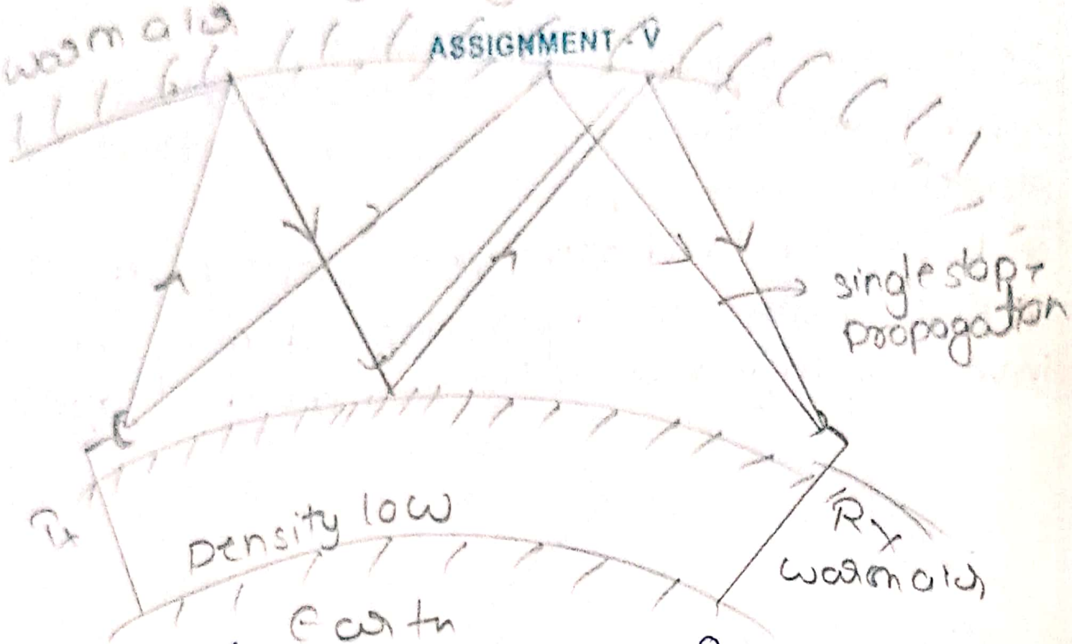
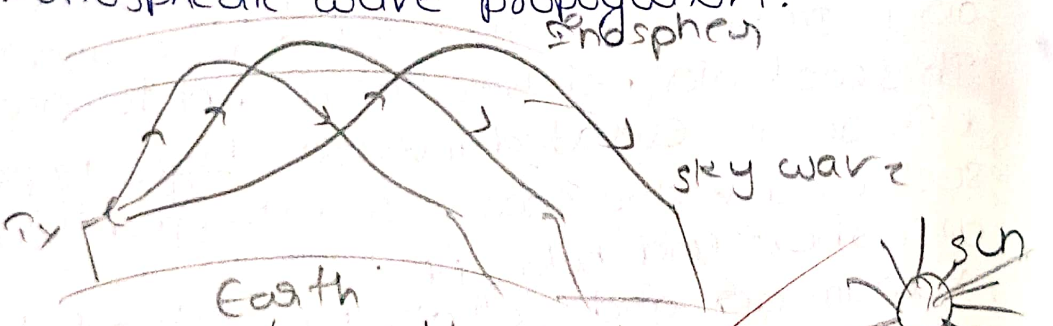


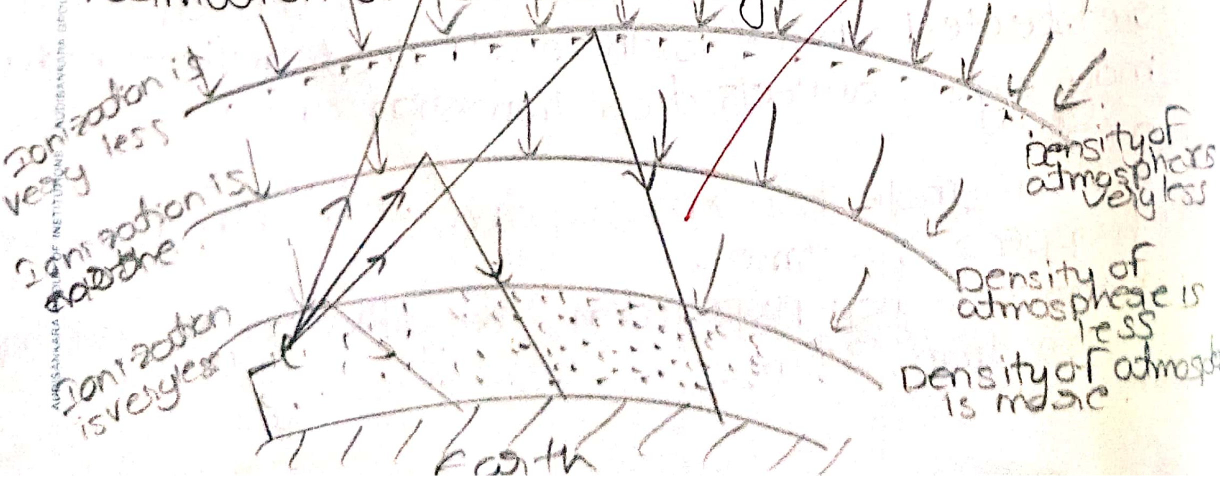
* Temperature decreases 6.5°C per km.
* Refractive index also decreases with height.
* At earth surface >1 and at troposphere = 1

② Properties of Ionosphere and height of Ionosphere from earth :-

* Transmitted signal from the Tx antenna reflected by Ionospheric layer (sky) and received by Rx antenna is a sky wave propagation or Ionospheric wave propagation.



Formation of Ionization layer :-



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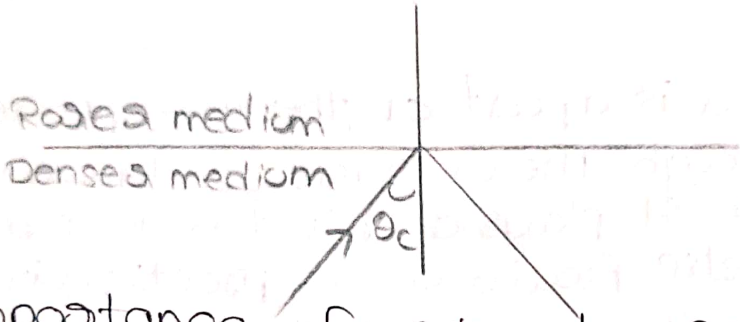
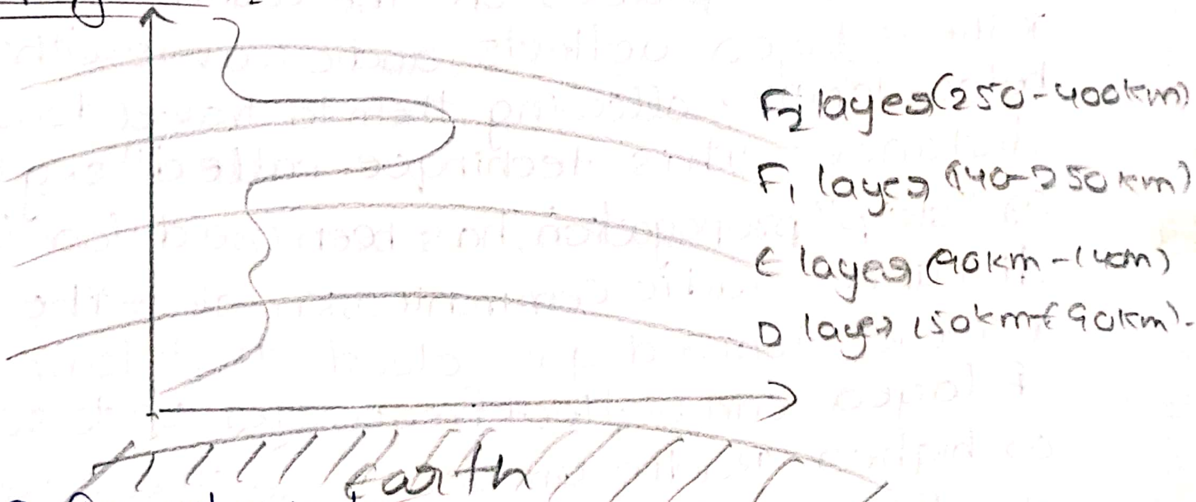
* For ground wave propogation range was limited.
* This can be overcome by sky wave propogation.
* The range of frequencies for sky wave propogation is 3MHz to 30MHz.
* cosmic rays are coming from sun and hits the atoms and forms ions and electrons will be released.



<u>Importance of various layers in radio wave Propogation</u> :-



The Ionospheric layers, the D, E and F layers are important for radio waves propogation because they affect radio waves differently based on their ionization levels.

<u>D-layer</u> :- The D-layer absorbs radio signals particularly FM radio waves. below 8MHz
* lower frequencies are absorbed more because they move electrons further, increasing the likelihood of collisions.

* The D-layer absorbs most of the HF signals that pass through it. HF signals pass through the D-layer to reach altitudes where they are reflected back to ground.
* During rare - solar proton events, ionization in the D layer (as) increase significantly, which can absorb most or all the trans polar HF radio signal transmissions.

E-player:-

* The E-layer is a part of the ionosphere that's ionised through the UV rays of the sun. It is important as it plays a pivotal role in electro-magnetic flow and has practical importance due to its influence on radio propogation to far-off places on the earth.
* The E layer reflects radio waves with frequenci below 10MHz, allowing them to travel long distances. This techinque called "sky wave" or "skip" propogation, has been used for long distance radio commnication since the 1920s.
* These ionized gas clouds that form in the F layer can reflect frequencies up to 50MHz or higher. Radio amateurs use these layers for long distance VHF operation.
* The F layers height increases after sunset, increasing the range of radio waves that can be reflected.
* Ionization in the F layer is caused by solar radiation ionization of molecular oxygen.

F layer:-

The F layer, also known as the Appleton Barnett layer, is the most important region for radio

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wave propogation because it's where radio waves are bend back down to earth

* The F layer has highest concentration of charged particles in earth's atmosphere, which is what allows radio waves to bend back down to earth

* The F layer has highest concentration of charged particles in the earth's atmosphere, which is what allows radio waves to bend back down

* The F layer is responsible for most sky wave propogation of radio waves.

* The F layer is most important region for long distance high frequency radio communications

* The F layer extends from about 250km to 400 km above the earth surface.

During the day, the F layer splits into two layers. At night, the two layers merge back into one.

(a) Expression for the transmission path loss using the friss transmission Formula:-

Friss transmission formula.

$$\frac{P_R}{P_T} = \frac{G_T G_R}{\left(\frac{4\pi d}{\lambda}\right)^2}$$

In decibals

$$10 \log\left(\frac{P_R}{P_T}\right) = 10 \log\left(\frac{G_T G_R}{\left(\frac{4\pi d}{\lambda}\right)^2}\right).$$

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$$10\log\left(\frac{P_R}{P_T}\right) = 10\log G_T + 10\log G_R - 10\log\left(\frac{4\pi d}{\lambda}\right)^2$$

$$10\log\left(\frac{P_R}{P_T}\right) = 10\log G_T + 10\log G_R + \underbrace{20\log\left(\frac{\lambda}{4\pi d}\right)}_{\text{Transmission loss during the wave propagation}}$$

$$= 10\log G_T + 10\log G_R - L_S$$

Here L_S is transmission attenuation loss

$$-L_S = 20\log(\lambda/4\pi d)$$

$f = c/\lambda$

$\lambda = c/f = \frac{3\times10^8}{f}$

$$-L_S = 20\log\left(\frac{3\times10^8}{4\pi}\cdot\frac{1}{df}\right).$$

if f is MHz and distance in km

$$-L_S = 20\log\left(\frac{3\times10^8}{4\pi}\times\frac{1}{10^3}\times\frac{1}{10^6}\times\frac{1}{df}\right).$$

$$= 20\log\left(\frac{3}{40\pi}\right) - 20\log d_{km} - 20\log f_{MHz}$$

$$-L_S = -32.44 - 20\log d_{km} - 20\log f_{MHz}$$

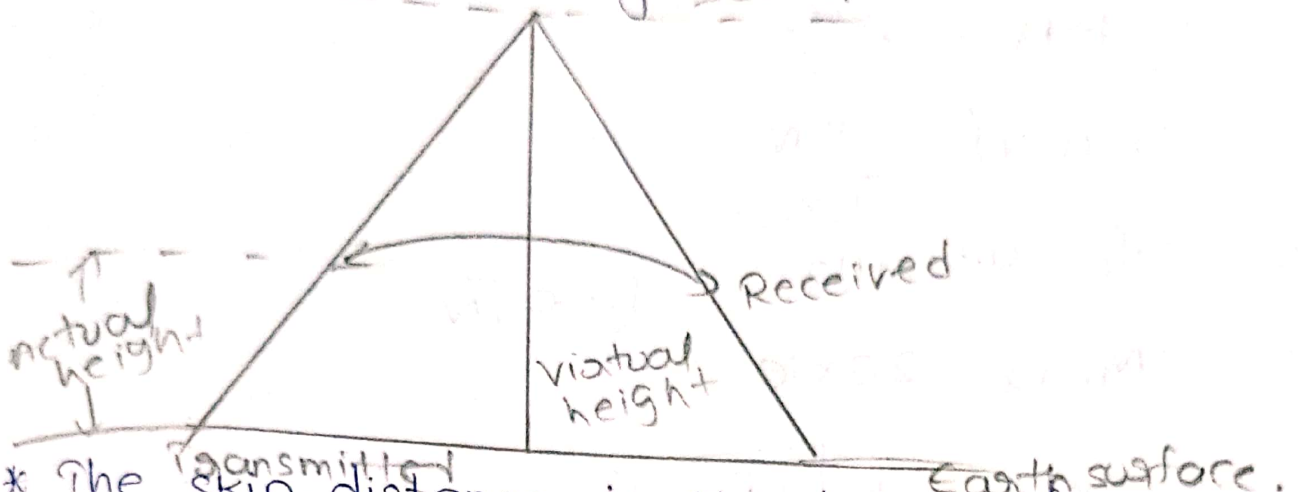
$$L_S = 32.44 + 20\log d_{km} + 20\log f_{MHz}.$$

(ii) **Virtual height and skip distance :-**

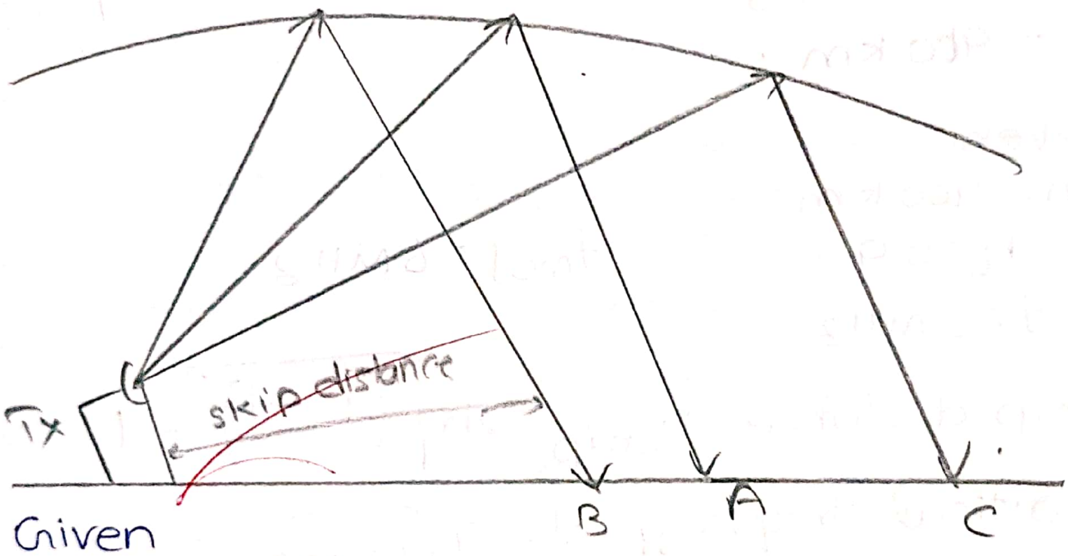
According to the law of refraction when the wave enters into rarer medium from the denser medium, the wave bends gradually and moves away from the normal and follow the path LMN as shown in the figure.

* The height at a point above the surface.

at which the wave bends down to the earth's called the "actual height" ionosphere



* The skip distance is the distance from the transmitter to the point where the sky wave is first returned to earth.
* The size of the skip distance depends on the frequency, angle of incidence and ionization.



(ii) Given

$h = 400km$
$\eta = 0.9$ $\quad f_{muf} = 10MHz$
$f = 10MHz$

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

critical frequency $f_c = 9\sqrt{N_{max}}$

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$$\eta = \sqrt{1 - \frac{81N}{f^2}}$$

$$1 - \eta^2 = \frac{81N}{f^2}$$

$$1 - (0.9)^2 = \frac{81N}{10 \times 10^6}$$

$f_c = 4.31 MHz$ $\qquad f_c = 9\sqrt{N}$

$N_{max} = 2.3 \times 10$

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

$$= 2 \times 400 \sqrt{\frac{(10 \times 10^{-3})^2}{4.3 \times 10^{-3}} - 1}$$

$$= 800 \sqrt{\frac{10^2}{4.3} - 1}$$

$= 960 \text{ km}$

(3) Given

$h = 400 \text{ km}$

$\eta = 0.9$ $\qquad f_{muf} = 6 MHz$

$f = 6 MHz$

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

critical frequency $f_c = 9\sqrt{N_{max}}$

$$\eta = \sqrt{1 - \frac{81N}{f^2}}$$

$$1 - \eta^2 = \frac{81N}{f^2}$$

$$1 - (0.9)^2 = \frac{81N}{6 \times 10^6}$$

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$0.19 = \frac{81N}{6\times10^6}$

$1.14MHz = 81N$

$N_{max} = 0.01\times10^6$

critical freq $f_c = 9\sqrt{N_{max}}$

$= 9\sqrt{0.01\times10^6}$

$= 900Hz$

$D_{skip} = 2h\sqrt{\frac{(f_{muf})^2}{f_c} - 1}$

$= 2\times400\sqrt{\frac{(6MHz)^2}{6MHz} - 1}$

$= 800\sqrt{6\times10^6 - 1}$

$= 794km$//

Short Answers:-

(6) optimum frequency of sky wave propogation:-

* The range of frequencies for sky wave propogation is 3MHz to 30MHz

* for ground wave propogation range was limited.

* This can be overcome by sky wave pro pogation

(3) Actual height and virtual height:-

According to the Law of refraction when the wave enters into rarer medium from the denser medium, the wave bends gradually ·lmnas shown in the figure.

* The height at a point above the surface at which the wave bends down to the earth's called the "actual height".

* The viatual height is the height above Earth's surface from which a refracted wave ~~options~~ appears to have been reflected ionosphere.