CMR GROUP OF INSTITUTIONS

Propogation Path loss

Loss Tx in path loss

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

In Decibel, $10\log\left(\frac{P_R}{P_T}\right) = 10\log\left[\frac{G_T \cdot G_R}{\left(\frac{4\pi d}{\lambda}\right)^2}\right]$

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

$$10\log\left(\frac{P_R}{P_T}\right) = 10\log(G_T) + 10\log(G_R) + 20\log\left(\frac{\lambda}{4\pi d}\right)$$

$-L(s) = -20\log\left(\frac{\lambda}{4\pi d}\right)$ = Spatial transmission Attenuation Loss.

$$\Rightarrow 10\log\left(\frac{P_R}{P_T}\right) \Rightarrow 20\log\left(\frac{\lambda}{4\pi d}\right) = -L(s)$$

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

$$\Rightarrow -L(s) = 20\log\left(\frac{3\times10^8}{4\pi} \times \frac{1}{df}\right)$$

If freq f is considered in MHz and distance in km

$$-L(s) = 20\log\left(\frac{3\times10^8}{4\pi} \times \underset{\downarrow km}{\frac{1}{10^3}} \times \underset{\downarrow MHz}{\frac{1}{10^6}} \times \frac{1}{df}\right)$$

$$-L(s) = 20\log\left(\frac{3\times10^8}{4\pi\times10^9} \times \frac{1}{df}\right)$$

$$-L(s) = 20\log\left(\frac{3}{4\pi}\right) - 20\log d_{km} - 20\log f_{MHz}$$

$$-L(s) = -32.44 - 20\log d_{km} - 20\log f_{MHz}$$

$$\boxed{L(s) = 32.44 + 20\log d_{km} + 20\log f_{MHz}}$$

↓

Transmission Path Loss

→ Electric field at Rx antenna

$$\boxed{E = \frac{\sqrt{30 G_T \cdot P_T}}{d}}$$

~~Case: iii) Two point~~

Skywave | Ionospheric Wave propogation

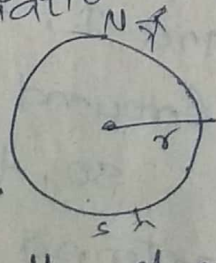
(b/w 2 - 30 MHZ).

This is also called as Short Wave propogation because wkt. in skywave, the frequencies are more and waves are entering into the Ionosphere. As f ↑ i.e it is more, wavelength (λ). ↓ . low. Therefore, it is called as Shortwave propogation.

As this is used for longer distance communication, this is called point-point communication. Single Reflection (4000km) from Ionosphere is called Single hope reflection. Due to multiple reflections from the Ionosphere, very long com" communication over the entire earth surface.

Radius = r = 6, 370 km

The verylong distance Comm^n is not possible by the space wave & ground wave propogation bcz they are limited by the Earth curvature. Space wave is the direct wave that is occuring in Tropo ~~Ionospheric~~ region. so, for the direct radiations, the antennas height should equal to the radius of the Earth. (6,370km). But, practically, it is impossible.



so, very long distances are not suitable for space wave propogation. Hence, the advantage is that for skywave is that it can achieve very long distance commⁿ.

disadvantage:

Fading: Variation in E due to multiple reflections from Ionosphere reaching at Rx antenna. with varying time, As by Multiple path reflections ↑, the different timings are taken by waves to reach Earth surface, there E also varies. These results in ↑ or Fading. So, Inorder to overcome this disadvantage, to minimise the fading techniques are used a) Diversity Reception b) AVC c) AGC (Automatic Gain Control).

Refraction of sky waves in Ionosphere:

Pm = Point of reflection / max height reached by skywave

N = $\bar{e}$ density (or) Ionic density

$N_6 > N_5 > N_4 > N_3 > N_2 > N_1$

$\mu_6 < \mu_5 < \mu_4 < \mu_3 < \mu_2 < \mu_1$

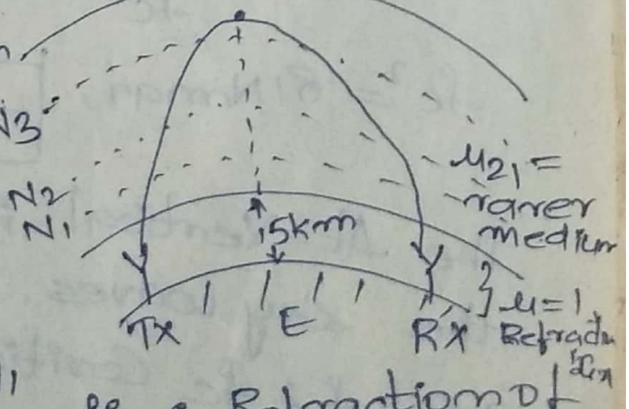


fig 1: Refraction of sky Waves.

~~Case iii) Two point~~

According to Snell's law

μ = Refractive Index = $\frac{\sin i}{\sin r} = \sqrt{1 - \frac{81N}{f^2}}$

If $\angle r = 90°$, $\sin i_{max} = \sqrt{1 - \frac{81 N_{max}}{f^2}}$

When $\angle r = 90°$, the skywave starts reflecting towards the Rx antenna.

Critical frequency: If $i = 0$, $r = 90°$, then the frequency is called critical frequency.

Maximum usable frequency (MUF): If $r = 90°$, $I \neq 0$, & vary from $I > 0°$ ($0°$ to $90°$), then it is called MUF.

Critical Frequency: The Max. frequency that can be reflected by the Ionosphere at vertical incidence. At vertical Incidence, therefore, $\bar{e}$ density is Max

$$\frac{\sin i}{\sin r} = \sqrt{1 - \frac{81 N_{max}}{f^2}}$$

$$0 = 1 - \frac{81 N_{max}}{f_c^2} \Rightarrow \frac{81 N_{max}}{f_c^2} = 1$$

$$f_c^2 = 81 N_{max}, \quad \boxed{f_c = 9\sqrt{N_{max}}}$$

~~The~~ At Vertical incidence (i.e at $i = 0$), the sky waves of frequency (f), which are $f \leq f_c$ (critical frequency) are easily reflected by the Ionospheric region

MUF: At, $0 < i < 90°$, the Maximum reflected by the Ionospheric region is called MUF.

$81 N_{max} = f_c^2$,

$$\frac{\sin i}{\sin r} = \sqrt{1 - \frac{81 N_{max}}{f_{MUF}^2}}$$

$$\sin i = \sqrt{1 - \left(\frac{f_c^2}{f_{MUF}^2}\right)} \sin r = \sqrt{1 - \left(\frac{f_c}{f_{MUF}}\right)^2},$$

$(\because r = 90°, \sin(90°) = 1) = \sin r)$

$$\sin i = \sqrt{1 - \left(\frac{f_c}{f_{MUF}}\right)^2}$$

$$\sin^2 i = 1 - \left(\frac{f_c}{f_{MUF}}\right)^2 \Rightarrow \frac{f_c^2}{f_{MUF}^2} = 1 - \sin^2 i$$

$$\frac{f_c^2}{f_{MUF}^2} = \cos^2 i$$

$$f_{MUF}^2 = \sec^2 i \cdot f_c^2$$

$\boxed{f_{MUF} = \sec i \cdot f_c}$ This is called secant law.

$\boxed{f_{MUF} > f_c}$ by a factor 'sec'.

Optimum Working Frequency

let us take the MUF as 30MHz in (3-30) MHz. So, in day time, as the $\bar{e}$ density is more, then these 30MHz, can be reflected by the Ionosphere. But in Night time, the $\bar{e}$ density is less and these $\bar{e}$ " is not sufficient to reflect the 30MHz towards the Earth's surface. So, the excess frequencies

Case (iii) Two point

penetrate (i.e move into space) and the energy is less. So, the total energy is not travelled towards the Rx antenna. Eventhough 30MHz is MUF, it is not suitable in night time to transmit. i.e Wastage of power.
So, 85% of MUF is called optimum (suitable) usable frequency.

Lowest usable frequency

As in Night time, the attenuation is less, the lowest frequency of MUF is sufficient in Night time. This, lowest frequency of MUF is called lowest usable frequency (LUF). LUF is not usable in Day times.

Classification of Fading:

1. Selective fading
2. Interfere "
3. Skip "
4. Absorption fading
5. Polarization "

① **Selective fading:** Due to selectivity of Rx antenna

② **Interfere fading:** The fading due to Interference of sky wave due to multiple reflections.

③ **Absorption fading:** Different frequencies are absorbed by the different amount. The fading result due to this is called Absorption fading

Skip Fading: The skip fading to skip distance b/w Tx & Rx antenna is called skip fading

Polarization fading: The fading due to Polarization of different sky waves by the different amounts.

Calculation of MUF:

case i) Thin layer (flat Earth):

r = radius of Earth.

R = radius of earth curvature.

R = 4r

r' = effective radius

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

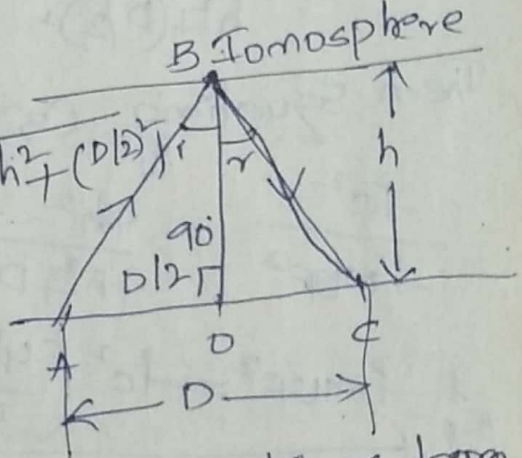


fig: Reflections from thin ionised e layer on flat earth

From the Equation

$f_{MUF} = \sec i \cdot f_c$

From figure, $\cos i =$

$\cos i = \frac{OB}{AB} = \frac{h}{\sqrt{h^2+(D/2)^2}}$ —— (1)

Now, apply MUF condition

$f = f_{muf}$, $N = N_{max}$ = Electron density

$\angle r = 90°$

$\cos i = \frac{h}{\sqrt{h^2+(D/2)^2}}$ —— (2)

~~Case: iii) Two point~~

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

$$\sin i^{\circ} = \sqrt{1 - \frac{f_c^2}{f_{muf}^2}}$$

$$\cos^2 i^{\circ} = 1 - \sin^2 i = 1 - \left(1 - \frac{f_c^2}{f_{MUF}^2}\right)$$

$$= 1 - 1 + \frac{f_c^2}{f_{MUF}^2} = \frac{f_c^2}{f_{MUF}^2}$$

$$\cos^2 i^{\circ} = \frac{f_c^2}{f_{MUF}^2} \quad \text{--- (3)}$$

from (1), $\cos i = \frac{h}{\sqrt{h^2 + (D/2)^2}}$

$$\cos^2 i = \frac{h^2}{h^2 + (D/2)^2} = \frac{h^2}{h^2 + D^2/4} = \frac{4h^2}{4h^2 + D^2} \quad \text{--- (4)}$$

Then Equating (3) & (4)

$$\frac{f_c^2}{f_{MUF}^2} = \frac{4h^2}{4h^2 + D^2}$$

$$* \quad f_{MUF}^2 = f_c^2\left(\frac{4h^2 + D^2}{4h^2}\right) = f_c^2\left(1 + \left(\frac{D}{2h}\right)^2\right)$$

**

$$\boxed{f_{MUF} = f_c \sqrt{1 + (D/2h)^2}}$$

Generally, Earth can be considered as flat upto 500 – 1000 km for skywave propogatio[n]

Case : ii) (CURVED EARTH :) & Thin layer

Angle = $\frac{\text{Arc}}{\text{Radius}}$

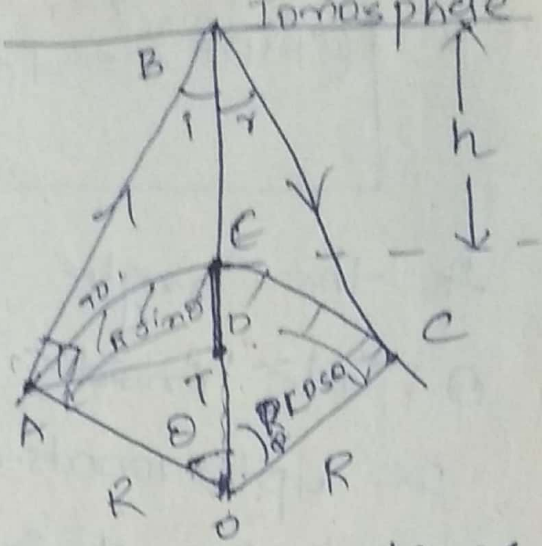
$= \frac{D}{R} = 2\theta$

$D = 2R\theta$ —— ①

bcz, As

$\theta = 0,\ D = 0,$

Using diagram



fig(b): Reflections from thin layer or curved earth.

$\cos\theta_i = \frac{BT}{AB}$

$BT = BE + EO - OT$

$BT = h + R - R\cos\theta$

$AB = \sqrt{\cancel{AB_1^2} + (AT^2) + BT^2}$

$AB = \sqrt{(R\sin\theta)^2 + (h + R - R\cos\theta)^2}$

$AB = \sqrt{R^2\sin^2\theta + (h+R)^2 - R\cos\theta)^2}$

$\cos\theta_i = \frac{BT}{AB} = \frac{h + R - R\cos\theta}{\sqrt{R^2\sin^2\theta + (h+R-R\cos\theta)^2}}$

Since $\left(\frac{f_c}{f_{MUF}}\right)^2 = \cos^2 i$

$\frac{f_c^2}{f_{MUF}^2} = \frac{(h+R-R\cos\theta)^2}{(\sqrt{R^2\sin^2\theta + (h+R-R\cos\theta)^2})^2}$

$f_{MUF}^2 = f_c^2 \cdot \frac{(\sqrt{R^2\sin^2\theta + (h+R-R\cos\theta)^2})^2}{(h+R-R\cos\theta)^2}$

$f_{MUF}^2 = f_c^2 \frac{(R^2\sin^2\theta) + (h+R-R\cos\theta)^2}{(h+R-R\cos\theta)^2}$

$f_{MUF} = f_c \sqrt{\frac{(R^2\sin^2\theta + (h+R-R\cos\theta)^2}{(h+R-R\cos\theta)^2}}$

Case (iii) ~~Two point~~

$$\boxed{(f_{MUF}) = f_c \sqrt{1 + \left(\frac{R\sin\theta}{h + R - R\cos\theta}\right)^2}}$$

As the angle made by the antennas θ ~~rate~~ inside the earth far away i.e upto 1000 km. Therefore, 'θ' is neglected & it is expressed interms of ~~D R, R~~ D, R

$\sin\theta \cong \theta$, $D = 2R\theta \Rightarrow \theta = D/2R$

~~Co~~ Take $\angle OAB$, then $\cos\theta = \frac{OA}{OB}$

$OA = R$, $OB = R + h$.

$\cos\theta = \frac{R}{R+h} = \frac{1}{(1 + h/R)} = (1 + h/R)^{-1}$

$h/R << 1$, since ($h = 400$ km, $R = 4 \times 6000$ km)

h → Ionosphere heigh

R → Radius of Earth

$\cos\theta = \left(1 - \frac{h}{R} + \frac{(h/R)^2}{2} \cdots\right)$

$\because h/R << 1$, remaining terms are negl

$\cos\theta = \left(1 - \frac{h}{R}\right)$

$1 - 2\sin^2\theta/2 = 1 - h/R$

$1 - 2\sin(\theta/2)^2 = 1 - h/R$ $\qquad$ $\sin\theta = \theta$

$\sin\theta^2 = \theta^2$

$1 - 2(\theta/2)^2 = 1 - h/R$

$2(\theta/2)^2 = h/R \Rightarrow 2 \times \frac{\theta^2}{4} = \frac{h}{R}$

$\theta^2/2 = h/R \Rightarrow \theta^2 = \frac{2h}{R} \Rightarrow \theta = \sqrt{\frac{2h}{R}}$

Since, $\theta = \frac{D}{2R} \Rightarrow \frac{D}{2R} = \sqrt{\frac{2h}{R}}$

$$\frac{D^2}{4R^{\cancel{2}}} = \frac{2h}{\cancel{R}} \Rightarrow D^2 = 8hR$$

$$\boxed{D = \sqrt{8hR}}$$

$$1 - \theta^2/2 = 1 - h/R = \cos\theta.$$

$$\theta = \frac{D}{2R} \quad , D = \sqrt{8hR}$$

$$f_{MUF} = f_c \sqrt{1 + \frac{R(\theta)^2}{(h + R - R\cancel{\cos}\left(\frac{D}{2R}\right)\cos\theta}}$$

$$= f_c \sqrt{1 + \frac{R\,(D/2R)^2}{(h + R - R\left(1 - \frac{\theta^2}{2}\right))}}$$

$$= f_c \sqrt{\frac{1 + R \cdot \frac{8hR}{4R^2}}{(h + R - R\left(1 - \frac{D^2}{4R^2 \cdot 2}\right)}}$$

$$= f_c \sqrt{1 + \frac{8h/4}{(h + R - R\left(1 - \frac{\cancel{8}h\cancel{R}}{\cancel{8}R^{\cancel{2}}}\right)}}$$

$$= f_c \sqrt{1 + \frac{2h}{(h + R - R\left(1 - \frac{h}{R}\right)}}$$

$$= f_c \sqrt{1 + \frac{2h}{(h + \cancel{R} - \cancel{R} + R \cdot h/R}}$$

$$= f_c \sqrt{1 + \frac{2h}{h + h}} = f_c \sqrt{1 + \frac{2h}{2h}}$$

$$= f_c \sqrt{2}$$

~~case iii) Two point~~

Skip distance: Distance b/w Tx to first sky wave

The distance at which no reception

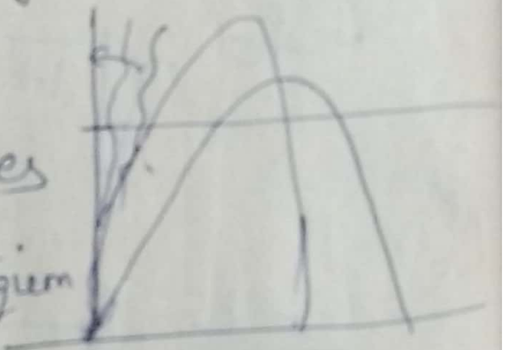
$$\frac{f_{mot}^2}{f_c^2} = 1 + \frac{D^2}{(2h)^2}, \quad f_{mot} = f_c\sqrt{1+\left(\frac{D}{2h}\right)^2}$$

$$\frac{D^2}{4h^2} = -1 + \frac{f_{muf}^2}{f_c^2}$$

$$D^2 = 4h^2\left[-1 + \frac{f_{muf}^2}{f_c^2}\right]$$

$$D = 2h\sqrt{\left[-1 + \frac{f_{muf}^2}{f_c^2}\right]}$$

Skip distance is directly proportional to Angle of incidence



As ~~frequency~~ ↓, θ_i ↓

skip distance decreases

~~As~~ fr. skipdistance ∝ frequency

∴ $f_1 > f_2 > f_3 > f_4$

$D_1 > D_2 > D_3 > D_4$

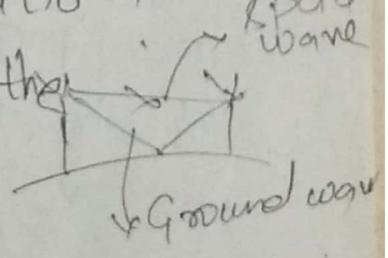
→ When angle of incidence is constant and waves are of different frequencies.

→ When ~~skip~~ the angle of distance dominates frequency, i.e, θ_i ↑ by 50%, f_i ↑ by 10% then skip distance is ↑ due to θ_i

→ When θ_i ~~dom~~ f_i dominates θ_i, When f ↑ by 60% & θ_i ↑ by 10%, then skip distance is ↑ due-to fi.

Space wave Propogation | (30 to 300 MHz)

When these highe frequencies, the waves gets penetrate & doesn't reflect back to the earth surface. Therefore, sky wave Propogation is not possible with these high frequencies. If such antennas are exactly 90° (vertically upwards), the waves gets penetrate, so, that the antenna are mount in bend towards the Earth's surface. If the antenna are towards the ground, as f is high, the absorption takes place by earth's surface. Therefore, Groundwave is also not possible with these frequencies. So, these frequencies are made to travel in Troposphere (upper layer), i.e direct, & these propogation is called space wave propogation.



The disadvantage is that the Commn around the globe is not possible. The range order of communication range

~~sky wave~~ > space waves > Ground wave

space wave < sky wave

The Advantage of space wave

(1) As frequency is high, the time

~~case iii) Two point~~

take for communication is less.

② long distance " " possible.

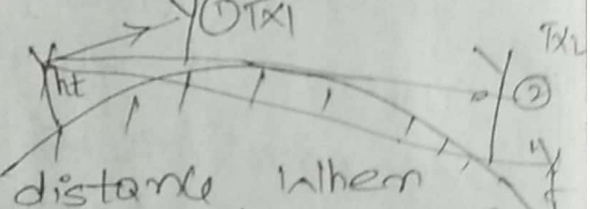
within less time (∵ f is high)

In Ground wave prop^n, there are two types, Surface wave, Ground wave.

Surface wave is at far distance from the Earth. Ground wave is along the surface of earth. And the resultant $\bar{E}$ is $\bar{E}$ due to surface wave & $\bar{E}$ due to Ground wave.

LINE OF SIGHT PROPOGATION:

When the Two antenna radiations are directly received & transmitted without reflection, the distance b/w them tx is called light of sight distance. When light of sight distance, the communication range ↑. And this propogation is called L.O.S prop^n.



If the TX$_2$ height ↑, L.O.S is possible for this TX$_2$ also. So, L.O.S depends upon height of Antennas. As the Earth Curvature is limiting the space wave prop^n, there wave can be achieved by ↑ heights of Antenna.

M-Curve Propogation : ~~Multi~~ It is the matter of multiple reflections of sky wave.

If the multiple reflections takes place all the curves forms like M shape so, ~~they~~ thats why this is called M-curve Propogation. These takes when super Refraction.

Super Refraction: fast bend of reflection from Ionosphere due to high Electron density.

Determining light of sight ~~pro~~distance

Range of LOS.

Fundemental Theory of Radiation

$$\boxed{\text{Transmitter}} \xrightarrow{\text{media}} \boxed{\text{Receiver}}$$

1) wire
2) wireless

In any communication system, there are three types. Transmitter, Receiver and media. The media may be wire or wireless. As we are talking about radiation, media is wireless. When current passes to the radiating system at transmitter side, the waves are generated and escapes into the media between transmitter and receiver. So, the radiating elements is called antenna and the waves are known as EM waves. The EM waves propagates into media and those are governed by characteristics of media. The propogating waves always reach the receiver. Now, the major takes place by media only. The general important media is free space only because of its following charactaristics.

Free space characteristics

1. It does not Interfere with the normal radiation and propogation of radio wave
2. No magnetic or gravitational fields
3. No Solid bodies
4. It has no Ionized particles.

It is impossible to have a free space practically, the only possibility is to consider Isotropic source which radiates equal amount of power in all the directions. Now, power density at any point is calculated as power per unit surface area,

$$P_{avg} = \frac{\text{radiated power}}{\text{Unit area}}$$

$$P_{avg} = \frac{P_T}{4\pi r^2} \; W/m^2$$

As distance is Inversely proportional it is also called as Inverse square law.

According to poynting theorem,

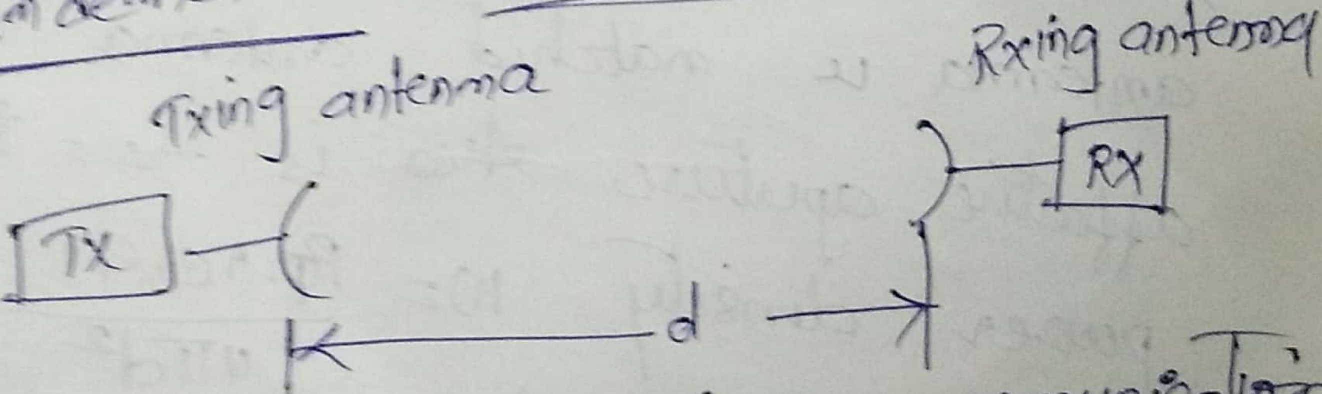
$$\cancel{P_T = \oint_S P_r . ds} \qquad P_{avg} = \frac{E^2}{\eta}$$

$$\boxed{E = \sqrt{P_{avg} \times \eta}}$$, we know that

$\eta = 120\pi$ for free space, $P_{avg} = \frac{P_T}{4\pi r^2}$

$$E = \sqrt{\frac{30 P_T}{r^2}} \ V/m$$

Fundemental Eq^n for free Space paropogat



We have Transreceiver communication System as shown in figure.

When we consider Txing antenna as Isotropic source, it radiates over all the directions.

→ Now, the power density at Rxing antenna is

$$W = \frac{P_T}{A} = \frac{P_T}{4\pi d^2} \quad \text{--- (1)}$$

→ Now, if we consider Gain of transmitting antenna is G_T, then power density $W = \frac{P_T \cdot G_T}{4\pi d^2}$ --- (2)

→ Under Ideal Condition, if receiving antenna is matched antenna and affective aperture Area is A_e, then power density $W = \frac{P_T \cdot A_{eR} \cdot G_T}{4\pi d^2}$ will be received

(or)

$$P_R = W \cdot A_{eR} = \frac{P_T \cdot G_T}{4\pi d^2} \cdot A_{eR}$$

Now, GT = Gain of Txing antenna.

where, $$GT = \frac{4\pi AeT}{\lambda^2}$$

Now, received power,

$$PR = \frac{PT}{\cancel{4\pi} d^2} \cdot AeR \cdot \frac{\cancel{4\pi} AeT}{\lambda^2}$$

$$PR = PT \left[\frac{AeT \cdot AeR}{d^2 \lambda^2} \right].$$

$$\boxed{\frac{PR}{PT} = \frac{AeT \cdot AeR}{d^2 \lambda^2}}$$

Now, Gain of receiving antenna is

$$GR = \frac{4\pi AeR}{\lambda^2} \Rightarrow AeR = \frac{GR \cdot \lambda^2}{4\pi}$$

$$\cancel{\frac{PR}{PT} = \frac{GT \cdot \lambda^2}{4\pi} \cdot \frac{GR \cdot \lambda^2}{4\pi}}$$

$$\cancel{\frac{PR}{PT} = \frac{GT \cdot GR}{(4\pi}}$$

$$\boxed{\frac{PR}{PT} = \frac{GT \cdot GR}{\left(\frac{4\pi d}{\lambda}\right)^2}}$$ → Friss Transmission formulae

Wave propogation path Losses / Transmission Path Losses

→ Friss Transmission ~~path~~ loss formulae is

$$\frac{PR}{PT} = \frac{GT \cdot GR}{\left(\frac{4\pi d}{\lambda}\right)^2}$$

→ In Decibel

$$\Rightarrow 10\log\left(\frac{PR}{PT}\right) = 10\log\left(\frac{GT \cdot GR}{\left(\frac{4\pi d}{\lambda}\right)^2}\right)$$

$$10\log\left(\frac{PR}{PT}\right) = 10\log(GT) + 10\log(GR) - 10\log\left(\frac{4\pi d}{\lambda}\right)^2$$

$$10\log\left(\frac{PR}{PT}\right) = 10\log(GT) + 10\log(GR) + 20\log\left(\frac{\lambda}{4\pi d}\right)$$

$$10\log\left(\frac{PR}{PT}\right) = 10\log(GT) + 10\log(GR) - L(S)$$

$L(S)$ - Spatial Attenuation Transmission Loss

$$\Rightarrow -L(S) = 20\log\left(\frac{\lambda}{4\pi d}\right)$$

So, Here $f = c/\lambda \Rightarrow \lambda = c/f = \frac{3\times10^8}{f}$

$$-L(s) = 20\log\left(\frac{3\times10^8}{4\pi} \times \frac{1}{df}\right)$$

If frequency f is considered in MHz and distance in km

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

$\frac{1}{10^3}$ ↓ As d in km; $\frac{1}{10^6}$ ↓ As f in MHz

$$\Rightarrow -L(s) = 20\log\left(\frac{3\times10^8}{4\pi\times10^9} \times \frac{1}{d_{km} f_{MHz}}\right)$$

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

$$-L(s) = -32.44 - 20\log d_{km} - 20\log f_{MHz}$$

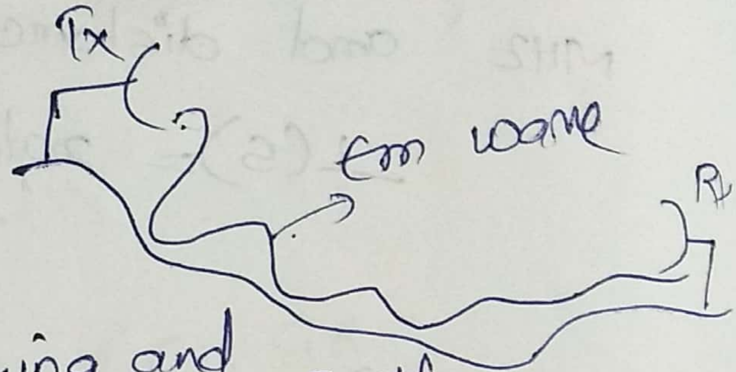
$$\boxed{L(s) = 32.44 + 20\log d_{km} + 20\log f_{MHz}}$$

This is transmission path loss in dB.

→ GROUND WAVE PROPOGATION

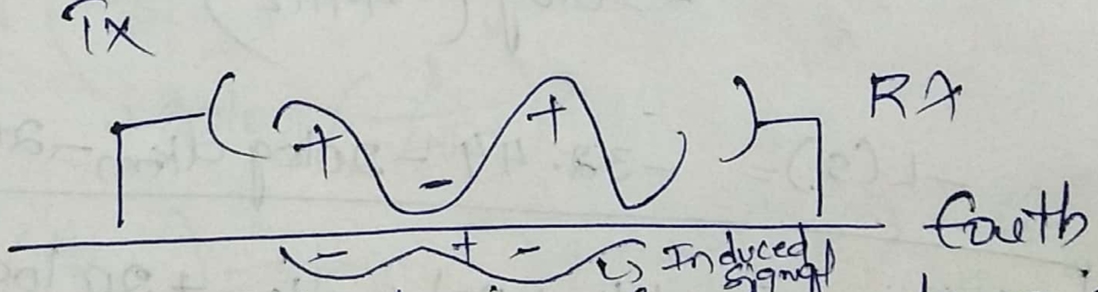
→ In this propogation signal (Em wave) propogates along the ground.

→ It is utilized for short range communication.



→ When we have Txing and Rxing antenna and ground source, and we send signal by Txing antenna, signl of Em wave will propogates along the ground.

→



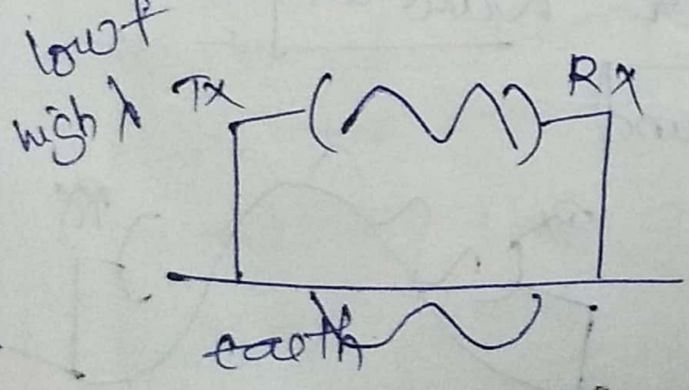
When any signl is sended from Txing to Rxing antenna, one wavelength of signl will be travelled. With respect to ground also, there is Induced signal and the phase is also opposite with respect to propogated signal.

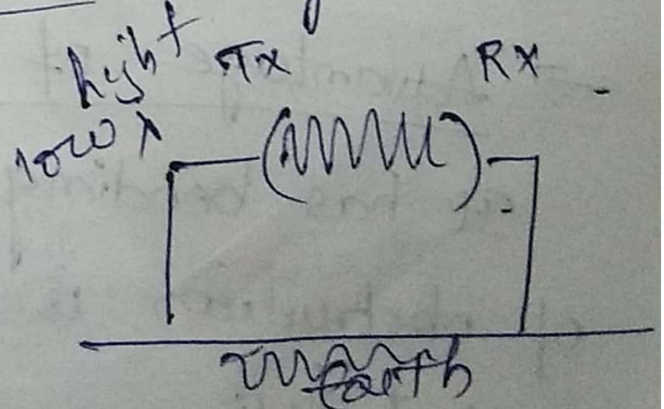
→ Induced wave ~~is~~ ~~Gro~~ by Ground attenuates signal from Txing antenna to Rxing antenna, signal gets weak with respect to distance

→ If i have 100m distance, sgnl reduced by half, then after 200m, sgnl gets reduced by 1/4 times, and after 300m, sgnl get reduces by 1/8 times, so, sgnl gets weak as distance weak

That's why Ground wave propogation is used for short distance communication

→ It is used for low frequency operation like generally upto 2MHz frequency. $f = c/\lambda$





$f \propto \frac{1}{\lambda}$,

→ There are two cases in which in one case we will use low frequency and in other case we will use high frequency.

→ For low f, high λ, Induced Sgnl by earth will be lower when compared to high f.

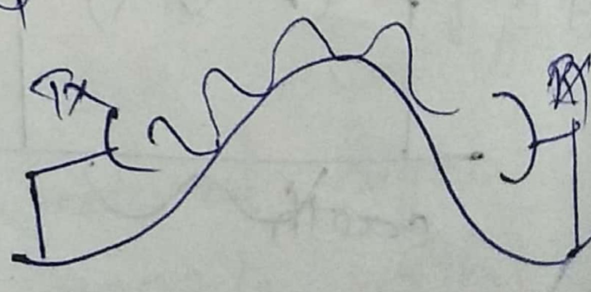
→ This is because for high f, more no. of waves are there below the ground, attenuation ↑ses.

→ That's why Ground wave propogation is used for low frequency of propogation

→ At lower wavelength, attenuation by Earth is high.

→ <u>Advantage of Larger Wavelength</u>

It has bending around of obstruction is very effectively



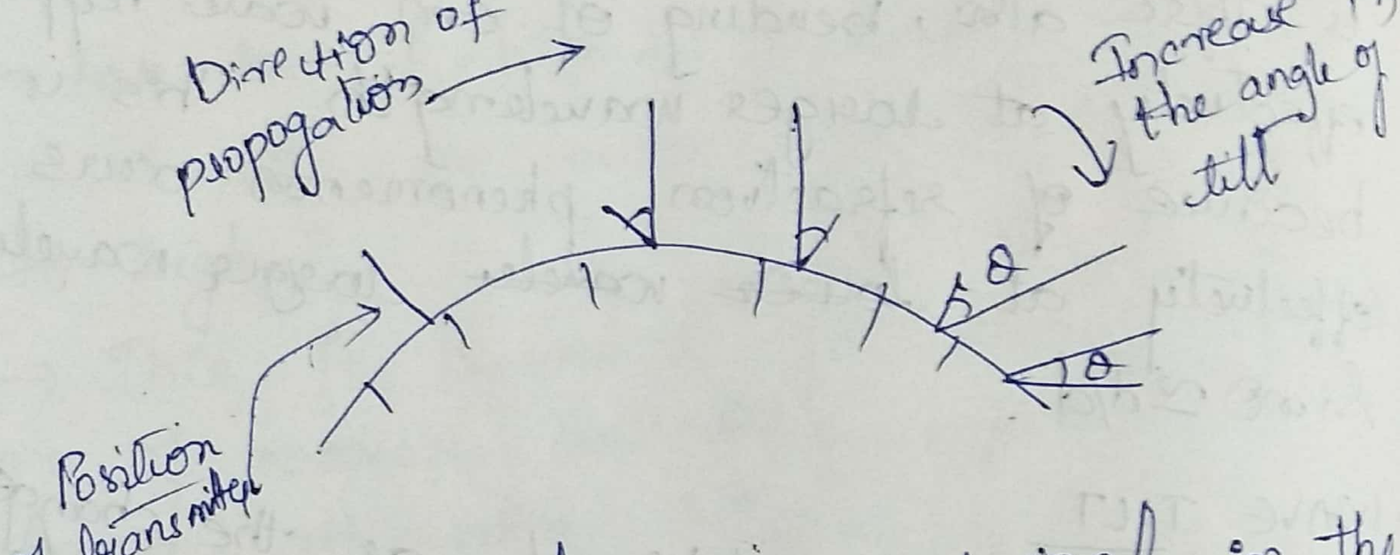
→ There is lower wavelength, bending will be more efficient

→ When we send sgnl ~~from~~ from Txing antenna to Rxing antenna if obstruction is there also, bending of em wave happens effectively at larger wavelength. This is because of refraction. phenomenon occurs effectively at ~~lower wavele~~ larger wavelength $\sin\theta \simeq \lambda/d$.

→ WAVE TILT

Wave tilt is defined as the change of orientation of the vertically polarized ground wave at the surface of the Earth. This occurs due to diffraction. Due to tilt, both horizontal and vertical components of the Electric Field are not in phase. This tilt changes the originally vertically polarized wave into an elliptically polarized wave.

As the wave progresses, it tilts over the surface of the Earth. This results in power dissipation and ultimately waves lie down and die.



For a ground wave polarized in the plane of propogation, the angle between the electric vector and the normal to the surface of the Ground

→SPACE WAVE PROPOGATION

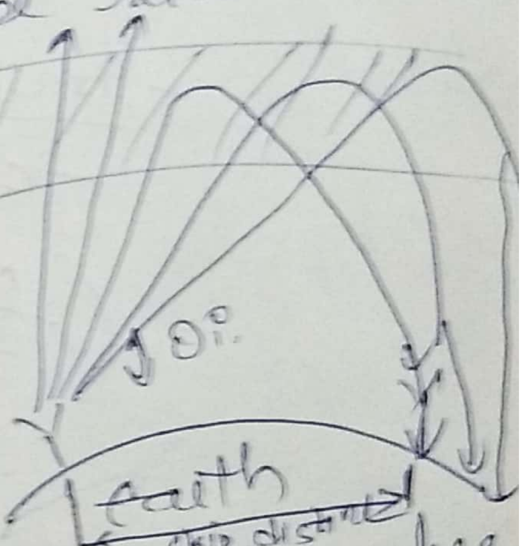
Space wave propogation happens at frequency >30MHz. At this frequency wavelength is shorter, so signal propogates from Txer to Rxer very shortly. Wave travels through straight path

SKIP DISTANCE

The skip distance is the shortest distance from a transmitter measured along earths surface at which sky wave of fixed frequency ($> f_c$) will be returned to earth

→ let Txing antenna transmits signal greater than fixed frequency. By changing angle of Txing antenna, the signal reflected by Ionosphere and reaches to Ground. θ_i → angle of Incidence. ~~Earlier~~, when θ_i is not adjusted for Txing antenna, the wave skips out of Ionospheric layer.

Ionisation layer



→ So, ~~sky~~ is now the min or shortest distance, from Tx to Rx when signal reflects by Ionosphere is called skip distance. Now. So, skip wave propogation is possible for greater than skip distance.

Based on equation of MUF & critical frequency.

$$f_{MUF} = f_c \sqrt{1 + \left(\frac{d}{2H}\right)^2}$$

$$\frac{f_{MUF}}{f_c} = \sqrt{1 + \left(\frac{d}{2H}\right)^2}$$

$$\left(\frac{f_{MUF}}{f_c}\right)^2 = 1 + \left(\frac{d}{2H}\right)^2$$

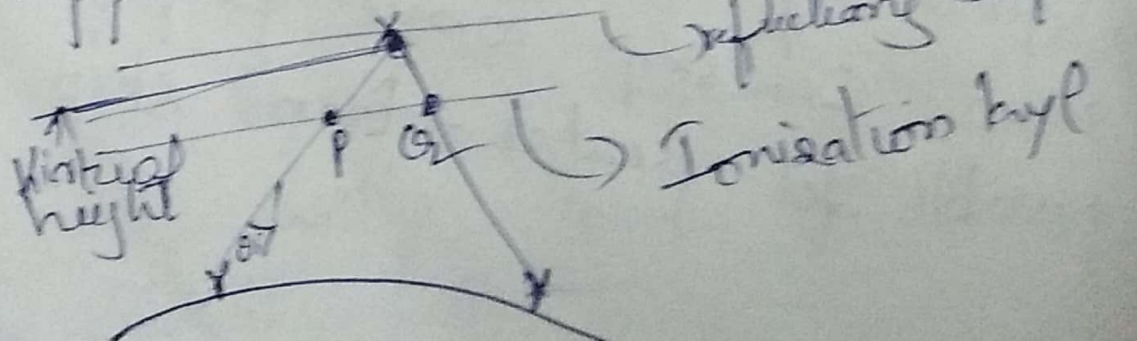
$$1 - \left(\frac{f_{MUF}}{f_c}\right)^2 = \left(\frac{d}{2H}\right)^2$$

$$\frac{d}{2H} = \sqrt{1 - \left(\frac{f_{MUF}}{f_c}\right)^2}$$

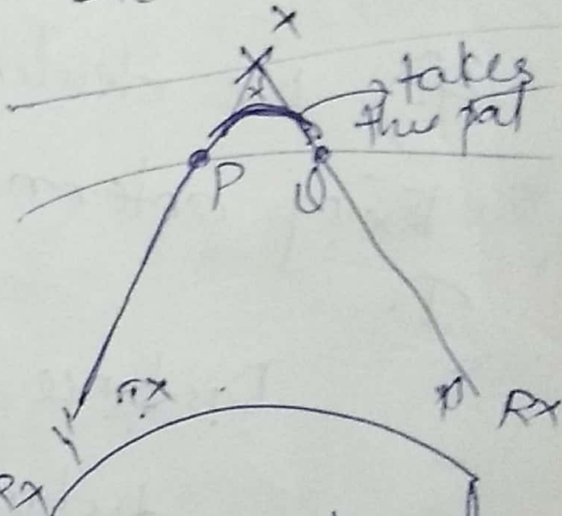
$$d = 2H\sqrt{1 - \left(\frac{f_{MUF}}{f_c}\right)^2}$$

VIRTUAL HEIGHT

The virtual height is that height from which a wave sent up at an angle appears to be reflected!



practically, Signal will not go straight path as ~~refractive index~~ angle of incidence changes gradually. That's why Signal takes bend. This is because refractive index of Ionization layer changes when Signal enter into this Ionization layer. So, due to refractive index,



actual path is

$Tx \rightarrow P \rightarrow X' \rightarrow Q \rightarrow Rx$

But virtual path is

$Tx \rightarrow P \rightarrow X \rightarrow Q \rightarrow Rx$

So, height associated with this virtual path is called Virtual height.

→ Measurement

(i) To measure the virtual height, the Instrument used is Ionospheric sound instrument. This is also called as Ionosonde. This is called bcz the Signal what we used to send is in the range of Sound frequency range. Thats it is named so.

2) Txing send vertically upward radio wave set of pulse duration of 150 μs

3) The Rxing antenna placed closed to Tx antenna receive this 150 μsec as it is vertically sended

4) We identify delay b/w Txing and Rxing antennas and that delay is now T.

Distance = velocity x Time

Distance = upward + downward = h+h = 2h

~~distance =~~

$2H = C \times T$

$$\boxed{H = \frac{CT}{2}}$$

REFRACTIVE INDEX CALCULATION

→ Ionized medium having free electrons and ions when radio wave pass of set the charge particles.

→ Vibration of ~~curren~~ e ~~power~~ represent ac current proportional to the velocity of vibration

Capacitive current lead the voltage 90° and ē current lag the voltage 90°.

→ free ē space decrease the current dielectric constant also decrease.

→ Reduction of dielectric constant due to the presence of ē Ionosphere causes the path of radio wave to bend ~~to~~ toward the earth.

electric field value, $E = E_m \sin \omega t$ volt/m

ω = avg. value

E_m = max. amplitude

Force extended by electric field on each ē

$F = -eE$ newton.

If there is no collision ē instantaneous velocity meter/sec.

Force = mass × acceleration

$$-Ee = m \cdot \frac{dv}{dt}$$

$$\frac{dv}{dt} = \frac{-Ee}{m}$$

$$dv = \frac{-eE}{m} \cdot dt$$

$$\int dv = \frac{-eE}{m} \int dt$$

$$\cancel{v = \frac{-Ee}{m}} \quad v = \frac{-e}{m} \int E\,dt$$

$$v = \frac{-e}{m} \int E_m \sin\omega t$$

$$v = \frac{-e}{m} E_m \left[-\frac{\cos\omega t}{\omega} \right]$$

$$v = \left[\frac{e}{m\omega}\right] E_m \cos\omega t$$

$$v = \left[\frac{e}{m\omega}\right] E_m \cos\omega t$$

N no. of $\bar{e}$ per cube meter and electric current constitute by N electrons

$$i_e = -Nev \ \text{amp}/m^2$$

$$v = \left(\frac{e}{m\omega}\right) E_m \cos\omega t$$

$$i_e = -Ne \cdot \left(\frac{e}{m\omega}\right) E_m \cos\omega t.$$

i_e = lags behind electric field

$E = E_m \sin\omega t$ by 90.

Inductive current usually capacitive current i_c, capacitance of unit volume is $k_0 = 8.8854 \times 10^{-12}$ F/m

$$i_c = \frac{dD}{dt}, \quad i_c = \frac{d}{dt} k_0 E.$$

$i_c =$

D = Displacement current through capacitance

$$i_c = \frac{d}{dt} k_0 \left[E_m \sin\omega t\right]$$

$$\cancel{i_c = \frac{d}{d}} \quad i_c = k_0 E_m \cos\omega t \cdot \omega$$

$$i_e = -Ne\left(\frac{e}{m\omega}\right) E_m \cos\omega t$$

Total current $i = i_c + i_e$.

$$i = k_0 E_m \cos\omega t \cdot \omega - \frac{Ne^2}{m\omega} E_m \cos\omega t$$

$$i = E_m \cos\omega t \cdot \omega \left[k_0 - \frac{Ne^2}{m\omega^2}\right]$$

① K

but $i = \cancel{E_m \cos\omega t\, \omega} \cdot K$

we have

$$k = \left[k_0 - \frac{Ne^2}{m\omega^2}\right] E_m \cos\omega t \cdot \omega = k_0 \left[1 - \frac{Ne^2}{m\omega^2 k_0}\right] E_m \cos\omega t\, \omega$$

$$k = k_0 \left[1 - \frac{Ne^2}{k_0 \omega^2 m}\right] E_m \cos\omega t \cdot \omega$$

Relative Dielectric Constant, $k = k_r k_0$

$$k_r = \frac{k}{k_0} = 1 - \left[\frac{Ne^2}{k_0 \omega^2 m}\right]$$

Relative refractive index $= \mu$

$$\mu = \sqrt{k_r}$$

$$\mu = \sqrt{\frac{k}{k_0}}$$

$$\boxed{\mu = \sqrt{1 - \frac{Ne^2}{k_0 \omega^2 m}}} \quad — (2)$$

put the value $m = 9.107 \times 10^{-31}$ kg

$e = 1.602 \times 10^{-18}$ coulombs.

$k_0 = 8.854 \times 10^{-12}$ $\omega = 2\pi f$, Sub this in eq (2)

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

Scanned with CamScanner

DUCT PROPOGATION

In the duct propogation radio signal follows a particular channel or duct in this atmosphere.

→ This duct can be near to earth surface. To predict the path M curves are required.

M-curves

For standard atmospheric propogation to be studied the normal refractive index will be sufficient. But to understand non standard propogation, we require a modified refractive index

It is given by. $N = n + h/r$.

n = Actual refractive index

h = height above Ground

r = readius of Earth.

Hence, value of N is close to unity and it is depending on h/r. Hence we will calculate excess modified refractive index $M = (N-1)10^6$. So, for that

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

$\rightarrow (N-1)\times 10^{6} = \left(n-1 + \frac{h}{r}\right)\times 10^{6}$

$M = (N-1)\times 10^{6} = (n-1+h/r)\times 10^{6}$

→ When we plot M against h it is called M-curves.

→ Note that in non standard 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 tropospheric condition.

→ $\boxed{\text{INVERSION LAYER}}$

Inversion layer is a region where atmospheric condition are exactly opposite to that of standard atmosphere.

→ For standard atmosphere.

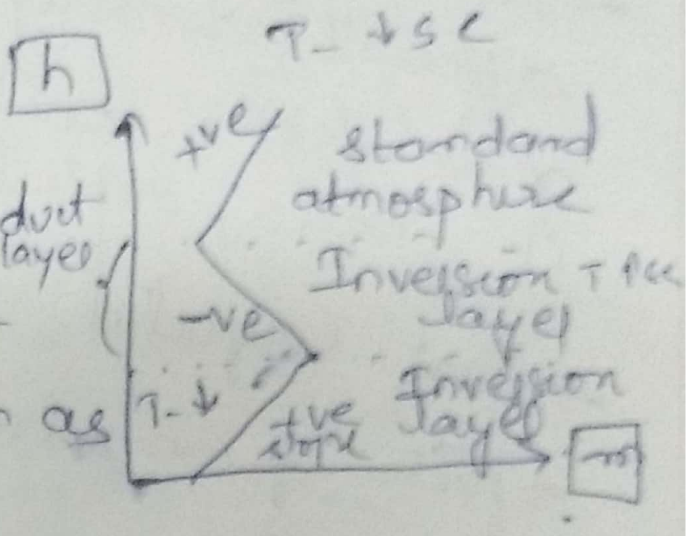
slope of M curve is +ve

→ for Inversion layer

slope of M curve is −ve

→ This Inversion layer is referred as duct layer.

DUCT PROPOGATION



→ When the temperature increases with height over certain range of heights, it is known as temperature Inversion

→ When the inversion layer is sandwitched between ~~two~~ ~~atmospheric~~ ~~layers~~, the Earth surface and standard atmosphere, then the cool air trapped between the Earth surface and warm air. The region of cool air behaves like duct for radio wave.

→ There is elevated inversion layer is present, in such a case the cool air is trapped between the warm air above and below it.

cool air → higher density.
warm air → Lower density

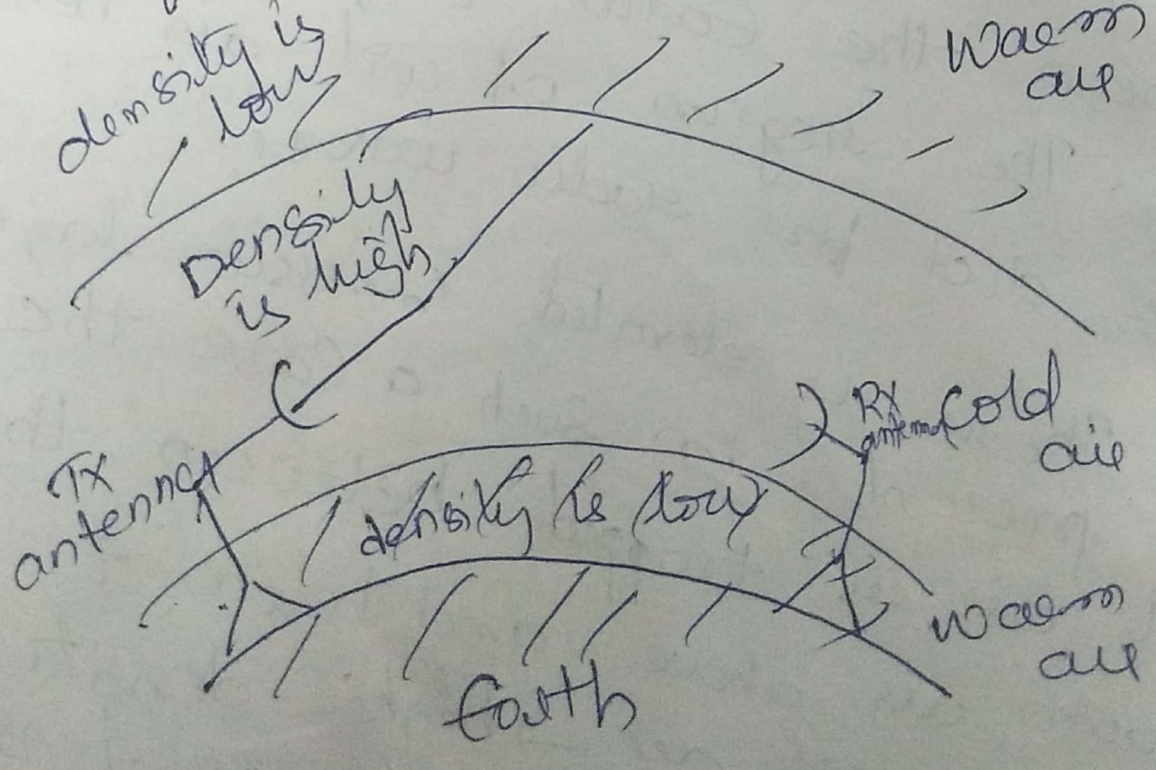
~~single~~

→ As warm air and cool air have different density, so when signal goes from cool air to warm air it phases reflection back to earth

→ That reflected signal may again reflects from transition of cool air to warm air

→ For single hop propogation Reflection of wave happens one time

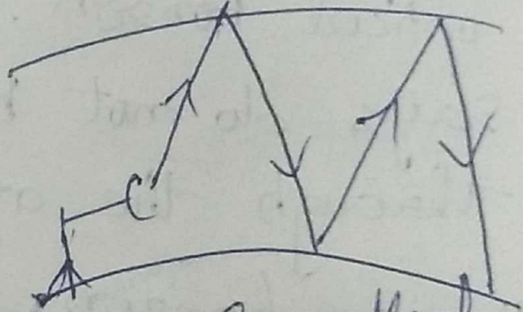
→ For multi hop propogation Reflection more than three times



The signal is sending from Txing antenna to Rxing antenna, strikes a from cold air to warm, there will be a transition of high density to low density. So, ultimately signal get reflected back to Rxing antenna. This is so called <u>Single hop propogation</u>.

<u>Multihop propogation</u>

The signal gets reflected back and again transition takes place back as the density changes. As reflection takes three times, This is so called Multihop propogation



<u>condition for duct propogation</u>

→ The Txing antenna is inside duct.

→ The radio wave enters the duct at very low angle of incidence.

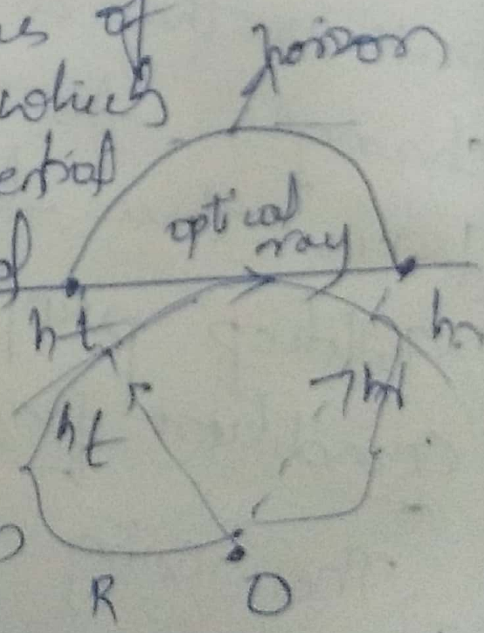
RADIO HORIZON - LOS

~~Due to curvature~~ of earth,

<u>Horizon</u> → the line at which the earths surface and the sky appear to meet.

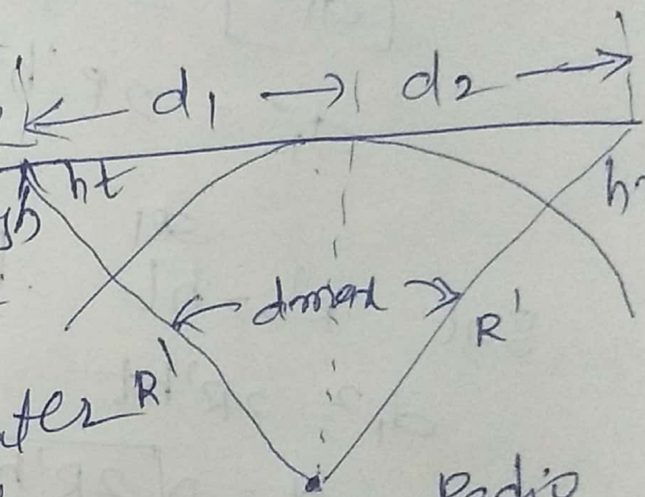
Due to Curvature of Earth, the line of sight transmission is limited to horizon. The effect of earths atmosphere is to bend the radio wave, making the radio horizon to lie beyond the optical horizon. Note that the light rays do not bend while travelling through the atmosphere.

<u>Radio horizon</u> → The locus of points at distance at which direct rays become tangential to the surface is called Radio. horizon. The radio horizon is seen as seen as circular on Spherical Surface.



A max. distance b/w the two antennas along the surface of the Earth such that the ray ~~jus~~ from the transmitter just touches the surface of Earth is called optical horizon.

→ The Effect of bending of radio wave while travelling through atmosphere can be taken into account by assigning a greater radius to the earth that it actually has and then radio wave is taken to travel in straight path.



For standard atmospheric conditions

$R' = 4/3 R$

R = Actual radius of Earth

R' = Radius of Earth for standard Atmospheric conditions.

from figure $[R' + ht]^2 = [R']^2 + [d_1^2]$ —(1)

$[R' + hr]^2 = [R']^2 + [d_2^2]$ —(2)

Rewriting Eq^n (1), we get

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

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

$d_1^2 = 2R'ht + ht^2$ —(3)

But $R' >> ht$, hence $ht R' >> ht^2$

$d_1^2 = 2R'ht$

$d_1 = \sqrt{2R'ht}$ —(4)

Similarly rewriting Eq^n (2), we get

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

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

$d_2^2 = hr^2 + 2R'hr$

$R' >> hr \Rightarrow R'hr >> hr^2$

So.. $d_2^2 = 2R'hr$

$d_2 = \sqrt{2R'hr}$

The max. radio range is given by

$d_{max} = d_1 + d_2$.

$d_{max} = \sqrt{2R'h_t + 2R'h_r}$.

But the radius R' is 4/3 times greater than the ideal value of radius of the earth.

$$R' = 4/3 R$$

Hence, Eqn (7) becomes

$$d_{max} = \sqrt{8/3 h_t} + \sqrt{8/3 h_r} \quad \text{--- (8)}$$

The radius of earth is given by R = 6370 km.

Sub the value of R in Eqn (8), we get

$$d_{max} = \sqrt{8/3 \times 6370 \times 10^3 \times h_t} + \sqrt{8/3 \times 6370 \times 10^3 \times h_r} \quad \text{--- (9)}$$

Note that in above expression d_{max} is expressed in meter.

We can further modify expression

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

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

d → line of sight distance

h_t → heights in mts.