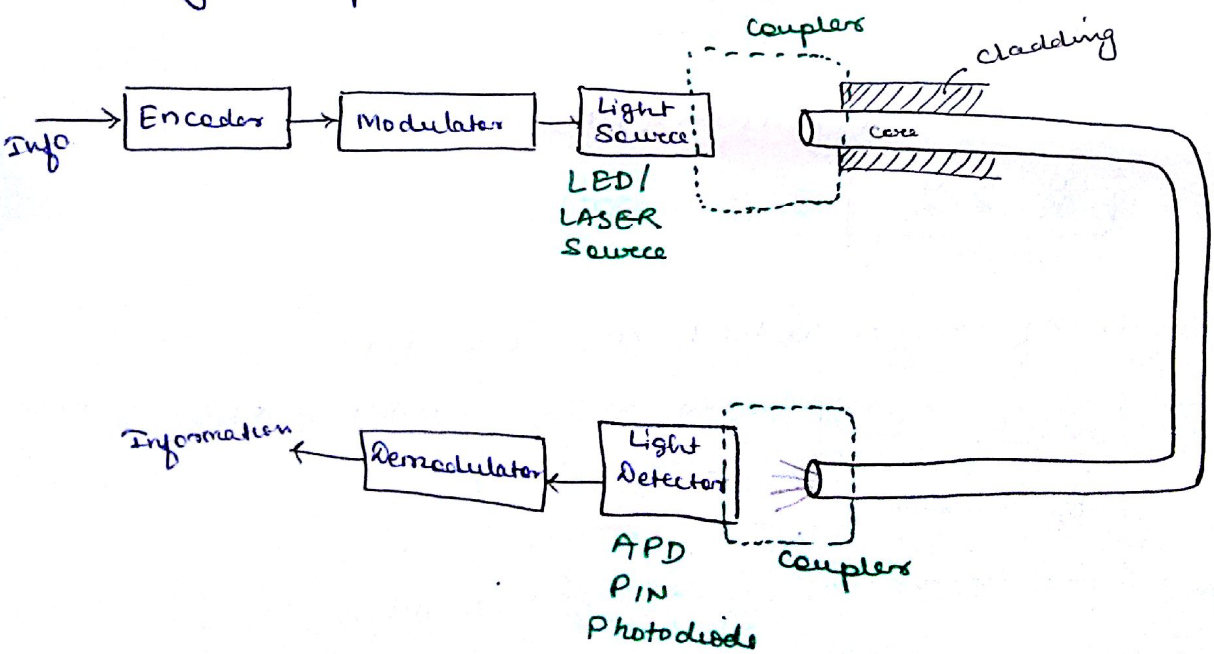
FIBRE OPTIC COMMUNICATION

- Frequency of operation is 10^3 to 10^{15} Hz.
- Band uses in optical fibre is → Ultraviolet, Visible light, Infra red.
- optical fibre can capable of transmission of a data at a rate of 1000 Mbps.

Advantage

1. Larger Bandwidth
2. Cable thickness is very less (μm)
3. Silica (Glass) (cost is less)
4. Security is more
5. No fire accident
6. No cross talk
7. wave division multiplexing present (WDM)
8. LED / Laser modulation method lend themselves ideally digital operation.



APD → Avalanche Photo Diode

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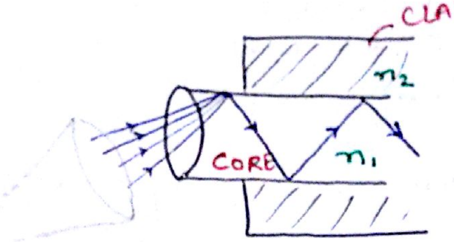
Basic Principle

The basic principle of fibre optics is Total Internal Reflection.



$n_1 \rightarrow$ Refractive Index of core

$n_2 \rightarrow$ Refractive Index of cladding.

For proper operation

$$n_1 > n_2$$

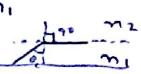
- Core is made up of either plastic (or) Glass.
- Cladding helps to guide the light in the core.
- The critical angle is the minimum angle where reflection will starts.

$$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

$n_1 \sin\theta_c = n_2 \sin 90^\circ$

$n_1 \sin\theta_c = n_2$

$\sin\theta_c = \frac{n_2}{n_1}$



- For Total Internal Reflection (TIR)

$$\theta_i > \theta_c$$

- The Range of angle which are incident on to core will form Acceptance Cone in fibre optics Comm.

$$\theta_A = \sin^{-1}\left(\frac{\sqrt{n_1^2 - n_2^2}}{n_0}\right)$$

max. Acceptance Angle.

where $n_0 = 1$

Figure of merit of optic fibre = Numerical Aperture (NA)

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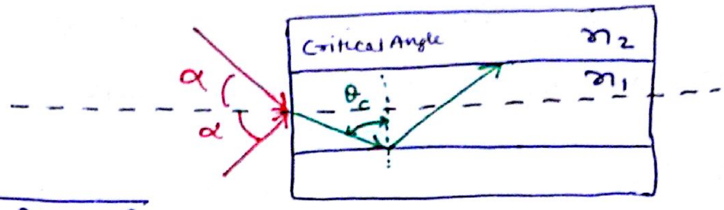
$$NA = \sin \theta_A = \sqrt{n_1^2 - n_2^2}$$

- NA is a measure of the light gathering ability of a fibre. It also indicates how easy it is to couple light into a fibre.



$$NA = \sin \alpha = \sqrt{n_1^2 - n_2^2}$$

Full Acceptance Angle = 2α

- The Numerical Aperture (NA) of a fibre is defined as the sine of the largest angle of incident ray can have for total internal reflection in the core.

- NA ↑ — Resolution ↑, Brighter Image ↑ — Losses ↑, BW ↓

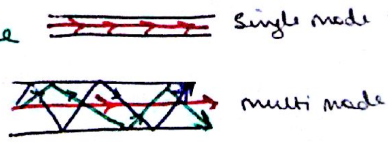
Sometimes $NA = n_1 \sqrt{2\Delta}$

where $\Delta \rightarrow$ Relative Refractive Index difference

$\Delta \rightarrow \dfrac{n_1^2 - n_2^2}{2n_1^2}$ $\qquad \Delta = \dfrac{2(n_1 - n_2)}{(n_1 + n_2)}$

Structure of Fibre optics Cable

1. Step Index fibre — Single mode / multimode
2. Graded Index fibre — Multimode



- multimode fibres have core diameter much larger to single mode fibre.
- Pulse broadening is a phenomena associated with multimode fibre.

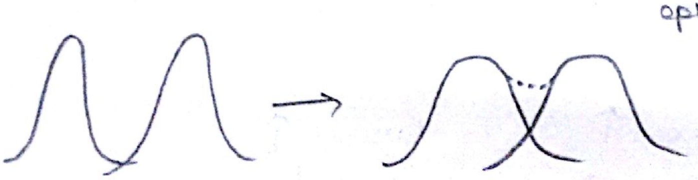
Single mode Fibre
- ↳ waveguide Dispersion
- ↳ material Dispersion
- ↳ Polarization Mode Dispersion (PMD)

multimode fibre
- ↳ Intermodal Dispersion

✳ Modal Noise in multimode fibre Can be reduced by
- ↳ use of broad spectrum source
- ↳ using fibre having larger NA
- ↳ use of single mode fibre.

✳ DISPERSION is the spreading of the optical pulses as they travel down the fibre. The result is that pulses then begin to spread into one another and the symbol become indistinguishable.

As a pulse travel down a fibre dispersion causes pulse spreading. This limits the distance and the bit rate of data on an optical fibre.



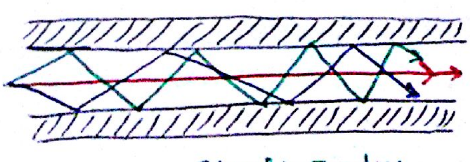
1 0 1

Symbol become unrecognizable.

STEP INDEX FIBRE	GRADED INDEX FIBRE
1. The refractive index of the Core is uniform throughout and undergoes an abrupt Change at the Core cladding boundary.	⇒ The refractive index of the Core is made to vary gradually such that it is maximum at the Centre of the Core.
2. The diameter of the core is about 50 - 200 μm in the Case of multimode fibre and 10 μm in the Case of Single mode fibre.	⇒ The diameter of the core is about 50 μm in the Case of multimode fibre.
3. The path of light propagation is Zig-Zag in manner.	⇒ The path of light is helical in manner.
4. Attenuation is more for multimode step index fibre but for Single mode it is very Less.	⇒ Attenuation is less.

Explanation

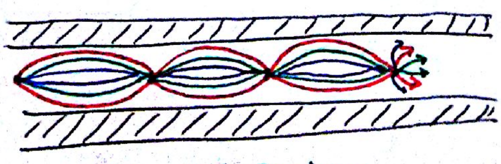
When a ray travel through the Longer distance there will be some difference in reflected angles. Hence high angles rays arrives later than low angle rays Causing despersion resulting in distorted output



Single Index multimode

Explanation

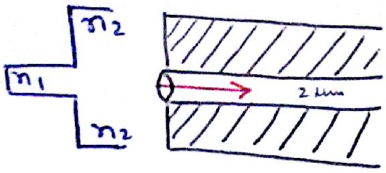
Here the light travel with different velocity in different path because of their variation in their R.I. At the outer edge it travel faster than near the centre. But almost all the rays reach the exit at the same time due to helical path. Thus there is no (less) dispersion.



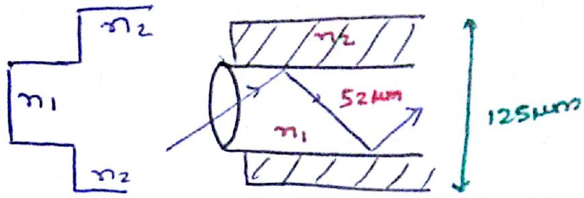
Graded Index multimode.

1. Step Index fiber

i) Single mode

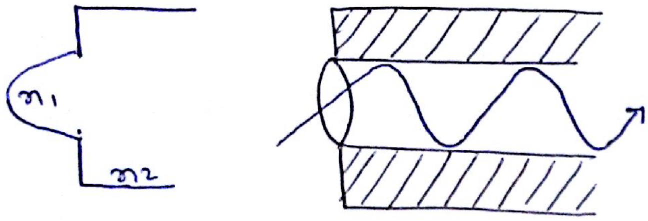


ii) Multi mode



2. Graded Index fibers

It has several layers of Clad and each layer having a small index numbers relative to its distance from the Core.



* Number of modes in fibre optics depends on V number.

where V → Normalized frequency.

Number of modes

$$M_n = \frac{V^2}{2}$$ Step Index fiber

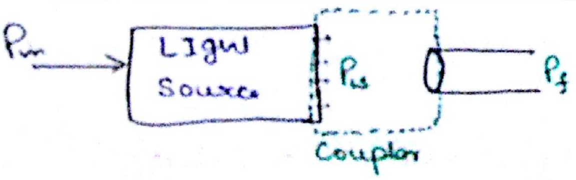
$$M_n = \frac{V^2}{4}$$ Graded Index fibre

* To provide single mode fiber $V = 2.404$

$$V = \frac{2\pi a}{\lambda} \cdot (NA)$$

a : Radius of core
λ : wavelength.

* FIBER OPTICS TRANSMISSION



$$\eta_{ls} = \frac{P_{ls}}{P_{in}}$$

$$\eta_c = \frac{P_f}{P_{ls}}$$

$$\eta_{Total} = \frac{P_f}{P_{in}} = \frac{P_f}{P_{ls}} \times \frac{P_{ls}}{P_{in}} = \eta_c \times \eta_{ls}$$

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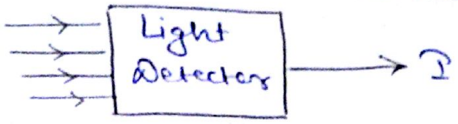
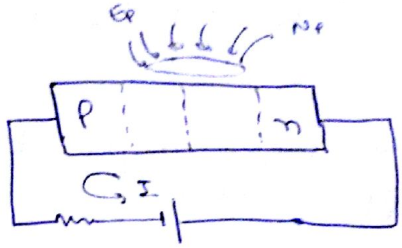
* In multimode fibre due to propagation of different wave all light wave will not reach same time due to this multipath Time Dispersion (MTD) will present.

$$MTD = \frac{n_1}{n_2} \times \frac{\Delta n}{c}$$

$$\Delta n = n_1 - n_2$$

* FIBRE OPTICS RECEIVER





Light Detector performance is given by Responsivity (R)

$$R = \frac{I}{\text{Light power}}$$

Total photon Energy $= N_p E_p$

Light power incident $= \frac{N_p E_p}{t}$ —(1)

Total charge $= N_e \cdot e$

current (I) $= \frac{\text{Charge}}{\text{time}} = \frac{N_e \cdot e}{t}$ —(2)

$$R = \frac{\frac{N_e \cdot e}{t}}{\frac{N_p \cdot E_p}{t}}$$

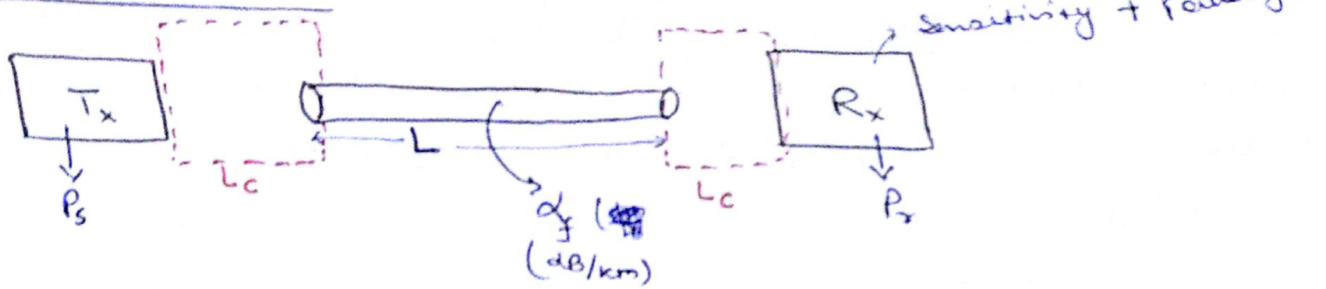
$$\boxed{R = \frac{N_e}{N_p} \times \frac{e}{E_p}}$$

$$= \frac{N_e}{N_p} \times \frac{\lambda}{hc}$$

Here $\frac{N_e}{N_p} \longrightarrow \theta$ Quantum Efficiency (60–80%)

$$\boxed{R = \theta \times \frac{e}{E_p}}$$

LINK BUDGET



$$P_s = 2L_c + L\alpha_f + P_r$$

$$P_s = 2L_c + L\alpha_f + \text{Sensitivity} + \text{Power margin}$$

- optical fibre have broader BW compare to Conventional Copper Cable.
- The information carrying Capacity of optical fibre is limited by Rayleigh Scattering Loss.

Absorption Loss → It occurs because of impurity present in Core.

Scattering Loss → Because of impurity atom present in core

Bending Loss / Radiation Loss → If $\theta_i < \theta_c$ the light ray will escape out the material hence bending loss occur.

Coupling loss → when two fibre optics are joined.

FADING

Fading means rapid fluctuations of the amplitudes, phases or multipath delay of a radio signal over a short period or short travel distance.

(or)

Fading will occur due to multipath reception.

(Or)

Fading is ~~fluction~~ fluctuation in signal strength at receivers end.

Fading Increases due to

→ Increase in signal frequency.

→ Distance between Tx and Rx

- In microwave comm. link when fading due to rain attenuation occurs, to solve it Path Diversity & Frequency Diversity system will be used.

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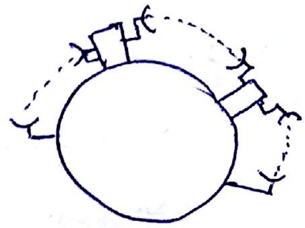
SATELLITE COMMUNICATION

- Satellite is a microwave repeater which is placed at certain height above ground.

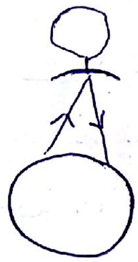
In 1965 → Intel Satellite
Early Bird.

- Space wave is limited to (restricted to) LOS



- microwave or GHz frequency range is used in Satellite communication because
  - Ionosphere donot reflect microwave frequency.
  - Size of antenna is inversely proportional to frequency. $h_{min} = \frac{c}{4f}$

- Firstly ballon passive Satellite used



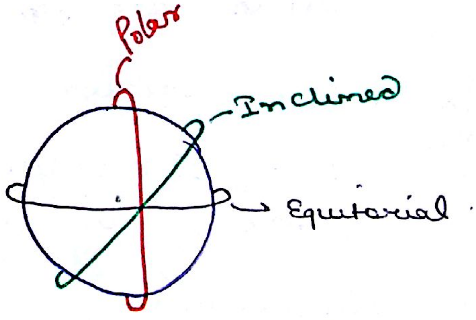
- India's first satellite built by ISRO, Aryabhata, which was launched by Soviet Union on 19th April, 1975.

Classification

1. Based on principle of operation
   1) Active Satellite
   2) Passive Satellite

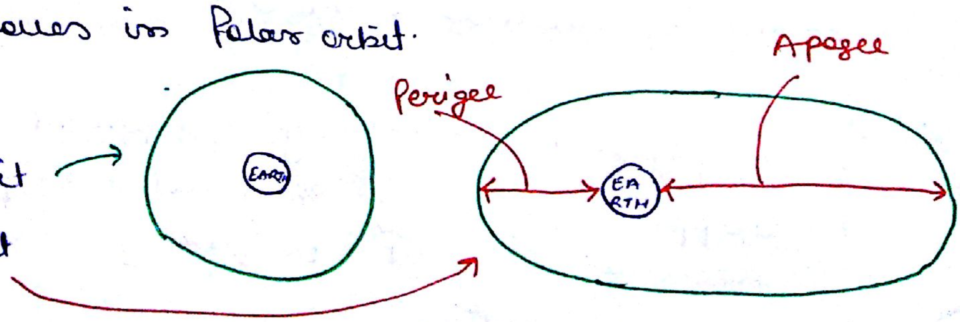
(Passive Satellite only reflect back signal)

2. Based on Orbit
   1) Equitorial orbit
   2) Polar orbit
   3) Inclined orbit



→ Random Satellite moves in Polar orbit.

3. Based on Path
   1) Circular orbit
   2) Elliptical Orbit



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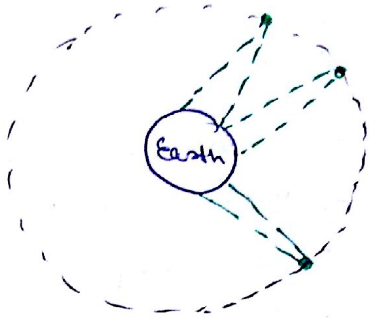
4. Based on Altitude

1. LEO (Lower Earth Orbit) 150 — 1000 km
2. MEO (medium Earth Orbit) 2000 — 10,000 km — GPS
3. GEO Geo Synchronous Earth Orbit 36,000 km
   Geo stationary Earth orbit — Communication

1. Lower Earth Orbit LEO



1. It is placed 150 km — 1000 km
2. Velocity : 28000 km/hr
   8 km/sec
3. Number of satellite to cover the Entire world is 66.
4. It takes $1\frac{1}{2}$ hr for complete rotation

Advantage

1. Path loss is less hence tx power is less. (about 1 W)
2. Cost is less
3. t_{pd} (Propagation delay time) is less
4. In LEO, one way communication
   $$t_{pd} = \frac{300\text{ km}}{3\times10^5\text{ km}} = 1\text{ msec}$$
   for two way communication = 2 msec.
5. Cell is used in this system.

(The coverage region of a satellite is called its footpoints)

Since LEO satellite is nearer to Planet compare to MEO, GEO, it has small footpoint or cell coverage.

Disadvantage

1. No. of Satellite is more
2. Coverage area is less
3. Complicated tracking Equipment
4. Doppler frequency shift will be present in received signal frequency.
5. Short life 5-8 years.
6. Special Hand over mechanism is required.

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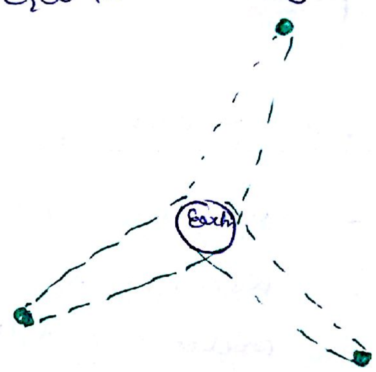
2. Geo Stationary Orbit (Synchronous)

1. The satellite are placed in the altitude of 36000 km
2. velocity = 10800 km/hr
   3 km/sec.
3. 24 hrs. to take one complete rotation.
4. minimum number of Geo synchronous to cover entire world is 3 (Each Geosynchronous satellite covers 40%. of Earth)
5. When Geo synchronous satellite placed in equitorial orbit then satellite looks stationary in the given region.
6. Relative angular velocity of Geo stationary satellite with Earth is zero.
7. It is most widely used of all satellite for communication purpose.
8. Polar region are well covered.



Advantage

1. Less no. of satellite.
2. Coverage area is more
3. Stationary
4. No doppler shift present.
5. Life time of GEO satellite is quite high (15yrs.)

Disadvantage

1. more Tx power
2. cost more
3. tpd is more.

one way comm.

$$t_{pd} = \frac{72000 \text{ km}}{3 \times 10^5 \text{ km}}$$

for two way comm.
480 ms

t_{pd} : 240 ms.

Due to this International call is late audible.

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3. Medium Earth Orbit

Advantage

1. Compared to LEO, MEO requires only a dozen satellite to cover entire Earth.

2. Simple in Design.

3. Require very few handovers.

Disadvantage

1. Satellite require higher transmission power.
2. Special antenna are required.

5. Based on application

1. Communication Satellite
2. Remote Sensing
3. military Satellite.

6. Based on coverage

1. National (INSAT)
2. Regional (ARAB)
3. International (INTEL)

INTEL → International Telecomm. Satellite.

~~Derivation~~

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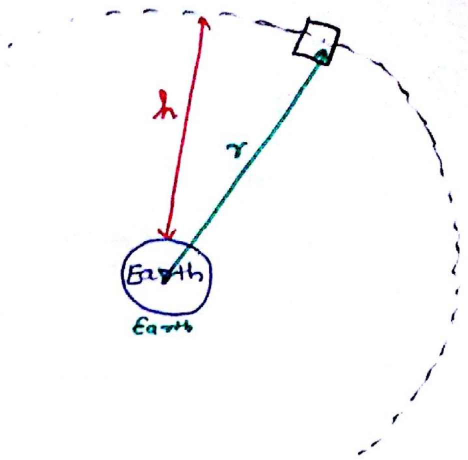
Derivation for Time Period of Satellite



- When Satellite is placed certain height above Earth, it is required to rotate around Earth to avoid gravitational force.
- In Satellite communication, Faraday's Rotation is caused by Earth's magnetic field.
- Due to rotation the force acquired by satellite is $F_1 = \frac{mV^2}{r}$ ——— (1)

Gravitational force present on satellite is given by

$$F_G = G\frac{Mm}{r^2} \quad \text{——— (2)}$$

m → mass of satellite.
V → velocity of Satellite.
G → Gravitational constant 6.67×10^{-11} Nm^2/kg^2
M → Mass of Earth 5.98×10^{24} kg.

To keep satellite in same orbit $F_1 = F_G$

$$\therefore \frac{mV^2}{r} = G\frac{Mm}{r^2}$$

$$\boxed{V = \sqrt{\frac{GM}{r}}}$$

- Velocity of satellite is independent of mass of satellite.

$$\downarrow V \propto \frac{1}{\sqrt{r}}\uparrow$$

- In one rotation satellite travel an angular distance of $2\pi r$
- Time period of satellite

$$\boxed{T = \frac{2\pi r}{V}} \text{ sec.}$$

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$$T = \frac{2\pi r^{3/2}}{\sqrt{GM}} \quad \text{sec.}$$

$$T = \frac{2\pi}{\sqrt{Gm}} r^{3/2} \quad \text{sec.}$$

$$T = \frac{2\pi}{60\sqrt{Gm}} r^{3/2} \quad \text{min}$$

$$\boxed{T = 1.66 \times 10^{-4} \, r^{3/2}} \quad \text{min}$$

卐 For 24 hrs Time period.

$$24 \times 60 \text{ min} = 1.66 \times 10^{-4} \times r^{3/2}$$

then $r = 42216$ km.

卐 when satellite is placed in Geo stationary orbit then satellite is placed in

$$h = 42216 - 6370 \text{ (Earth's radius)}$$

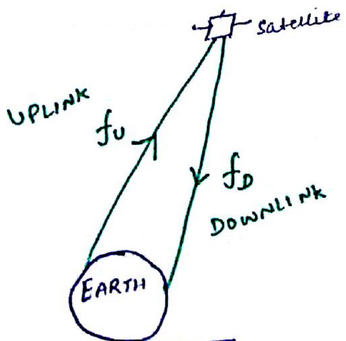
$$\boxed{\begin{aligned} h &= 35850 \text{ km} \\ h &\approx 36000 \text{ km} \end{aligned}}$$

Earth Station

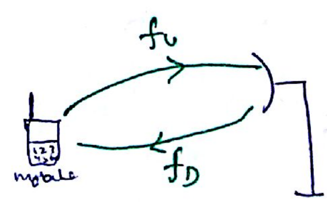
Earth Station is used to Transmit & receive signal from Satellite.

Ground Station

Ground station Transmit, Receive & Control the Satellite.



$$\boxed{f_U > f_D}$$



$$\boxed{f_U < f_D}$$

GSM sig.

890 – 915 f_U

935 – 960 f_D

Mnemonic :- Satellite UP है तो UPLINK ज्यादा Mobile Down (Earth) है तो DOWNLINK ज्यादा

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$$G = \frac{4\pi A_e}{\lambda^2}$$ Gain↑ λ↓ f↑

- Since size of receiver antenna in satellite is very small in comparision to that in Earth Station. Therefore to achieve higher gain uplink carrier frequency is greater than downlink ($f_U > f_D$)

- Satellite link uses a different frequency for receiving & transmitting in order to minimise the free space path losses.

	UP / DN	
C band	6 / 4	GHz
Ku band	14 / 12	GHz.

- C band commonly used for satellite communication. Frequency in this band can easily depend upon the atmosphere of the Earth.

- Several Satellites have been designed to operate in Ku band inspite of higher atmospheric absorption than C band because use of smaller, narrower beam antenna in the Ku band result in lower interference.

- In Satellite Communication TDMA & FDMA are used, but CDMA is not used properly because of wastage of power.

- Total Bandwidth available in one Satellite is 500 MHz.

- 500 MHz is divided into 12 channel using FDMA.

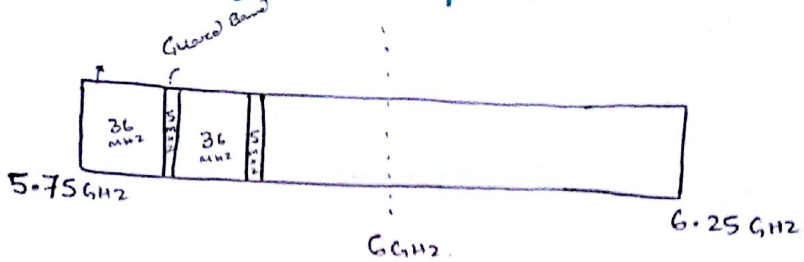
- Each have 36 MHz B.W + 5 MHz Guard Band.

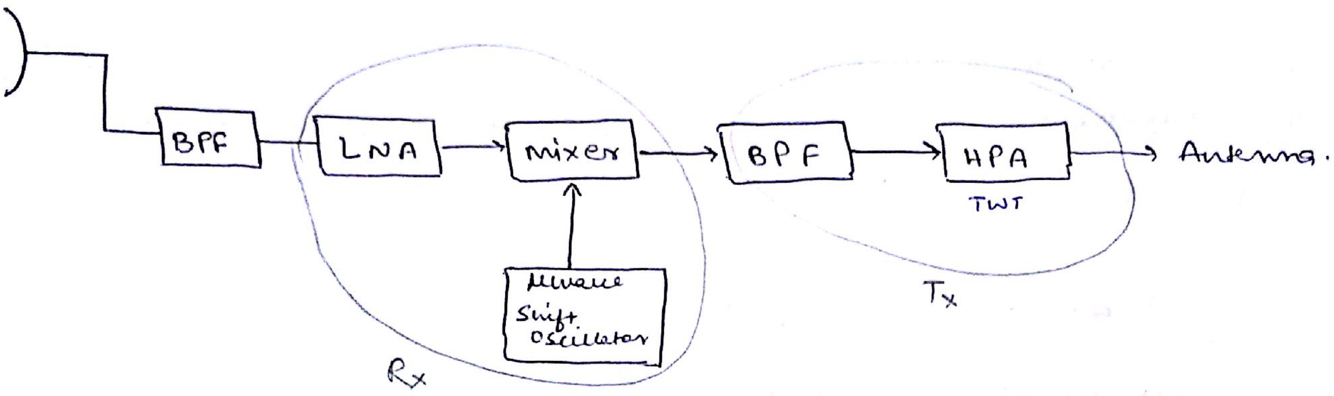
- Each Channel is Called Transponder.

- Digital modulation technique are used in Satellite Comm. since they are less prone to interference.

- Comm. Satellite are alloted B.W of 500 MHz this can be increased by frequency and Polarization reuse.

Block Diagram of Transponder





- In Each transponder separate Band pass filter is there to Select required frequency for receiver and Transmitter.
- High power Amplifier used in Satellite is TWT
- master Control Facility (MCF) for Indian Satellite is Situated in Hasan (Banglore)
- Primary source of energy for Satellite is Solar Cell.
- Ni-Cd battery are used as a secondary power source in Satellite.
- In satellite comm. highly directional antennas are used to direct the spot beam to a particular region of space on Earth.

Satellite on board

1. Power Supply
2. Orbit & Antenna Control.
3. Telemetry and Tracking
4. Communication Substation.

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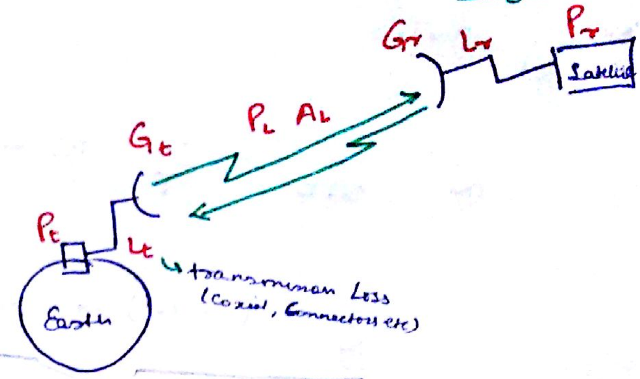
Link Budget Calculations



A simple link budget eqn is

Received Power (dB) = Transmitted Power (dB) + Gain (dB) − Losses (dB)

$$P_r(dB) = P_t(dB) + G_t(dB) - L_t(dB) - P_L(dB) - A_L(dB) + G_r(dB) - L_r(dB)$$

$$\because \quad EIRP = \frac{P_t G_t}{L_t}$$

↳ Each station EIRP

EIRP → Equivalent Isotropic Radiated Power.

If $A_L(dB)$ and $L_r(dB)$ not given then

$$P_r(dB) = C = EIRP(dB) - P_L(dB) + G_r(dB)$$

(Carrier Power)

$\frac{C}{T}$ Ratio

T = System noise Temp (kelvin, K)
C = Carrier Power

$$\frac{C}{T} = P_r(dB) - T(dB)$$

$$\frac{C}{T} = P_t(dB) + G_t(dB) - L_t(dB) - P_L(dB) + G_r(dB) - T(dB)$$

$$\frac{C}{T} = P_t(dB) + G_t(dB) - P_L(dB) + \frac{G}{T}(dB)$$

Hence $\frac{G}{T}(dB)$ is known as figure of merit of Satellite or sensitivity of Receiver

$$\frac{G}{T}(dB) = G_r(dB) - T(dB)$$

- In satellite $\frac{G}{T}(dB)$ ratio should be high. (Sometimes atmospheric condition degrade it)
- To increase $\frac{G}{T}(dB)$ ratio Parabolic reflector are used in Satellite Communication.

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※ $\frac{C}{N}$ Ratio

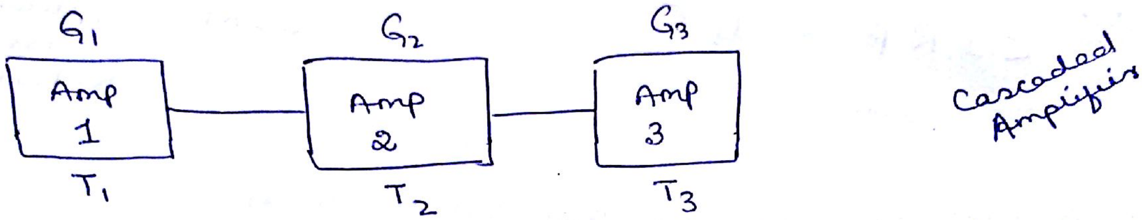
N → Noise power
→ KTB

$$\frac{C}{N} = \frac{P_r}{KTB} = \frac{C}{T}(dB) - 10\log K - 10\log B$$

$$\frac{C}{N} = P_r(dB) - N(dB)$$

$$\boxed{\frac{C}{N} = P_r(dB) - 10\log_{10} T - 10\log_{10} K - 10\log_{10} B}$$

※



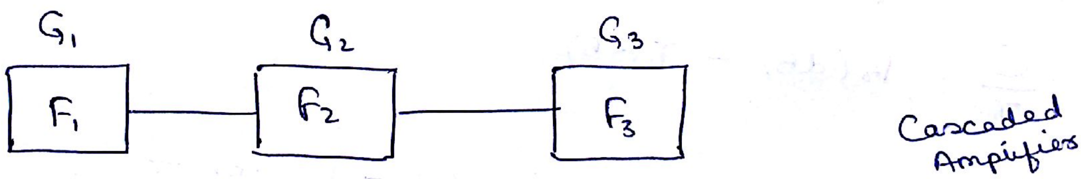
T_1, T_2, T_3 → Noise Equivalent Temp.

Effective Noise temp. $= T_e = T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 G_2} + \ldots$

$$\boxed{T_e = (F_n - 1) T_0}$$

NOISE IN CASCADED AMPLIFIER

※



F → Noise factor

~~Noise~~

$$F = F_1 + \left(\frac{F_2 - 1}{G_1}\right) + \frac{(F_3 - 1)}{G_1 G_2} + \ldots\ldots + \frac{F_n - 1}{G_1 G_2 \cdots G_{n-1}}$$

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Wave Propagation

1. Ground wave propagation VLF, LF, MF (low freq)
2. Sky wave Propagation → HF
3. Space wave Propagation VHF, UHF & μwaves.
4. Duct wave → microwaves
5. Troposcatter wave → UHF & μwaves.

Extremely low freq	ELF	—	30HZ — 300HZ
voice freq	← VF	—	300HZ — 3000HZ
very low	← VLF	—	3KHZ — 30KHZ
low	← LF	—	30KHZ — 300KHZ
medium	← MF	—	300KHZ — 3MHZ
High	← HF	—	~~3MHZ — 30MHZ~~
very high	← VHF FM.	—	30MHZ — 300MHZ
Ultra high	← UHF	—	300MHZ — 3GHZ
	microwaves	→	microwaves — > 1GHZ.

microwaves

DME, TACAN, IFF	L	—	1 – 2GHZ
Search Radars	S	—	2 – 4GHZ
Satellite communication	C	—	4 – 8GHZ
Satellite communication; military RADARS	X	—	8 – 12GHZ
Satellite communication	Ku	—	12 – 18GHZ
military RADARS	K	—	18 – 27GHZ
military RADARS	Ka	→	27 — 40GHZ

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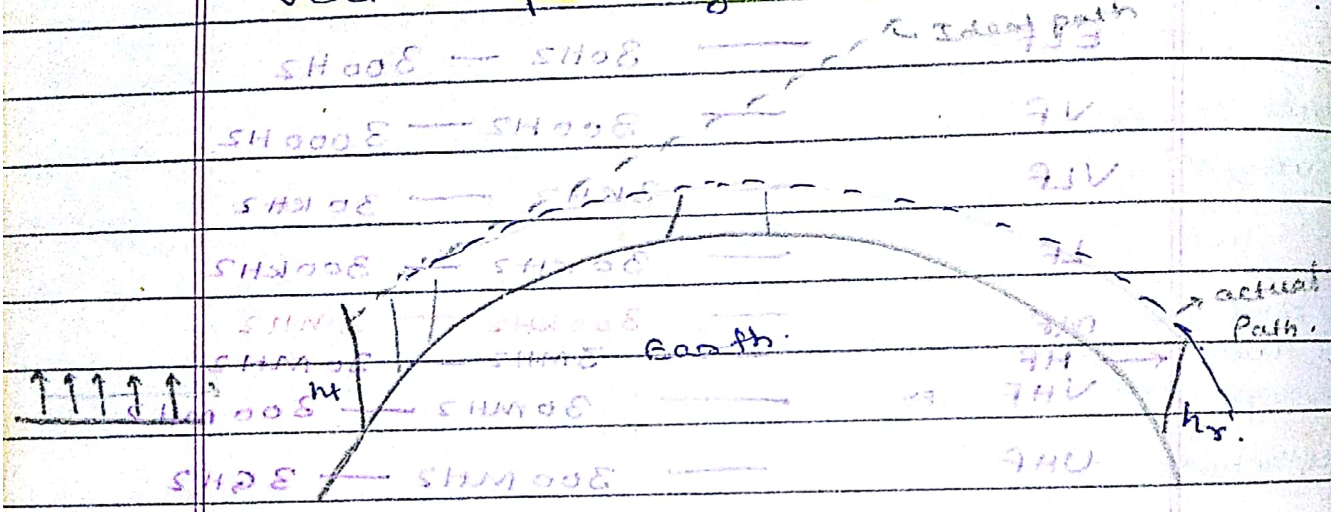
~~Surface~~ Ground wave Propagation

- Lower frequencies → VLF, LF, MF.
- At lower frequencies, due to earth conductivity horizontal polarized signal will be short circuited by Ground.
- In Ground wave propagation vertical polarization is used.



- upto 1000 km.
- In Ground wave propagation when Em wave is radiated, then it will propagate along earth curvature due to refraction of Em wave to overcome absorption of Em wave.
- In Ground wave propagation coverage distance is around 1000 km.
- In Ground wave propagation as frequency is increased atmospheric absorption will increases due to this max. frequency that can propagate

Sea water → more conductivity than Earth. due to salt.

VP → HP → shorted by Grow.

Page No.
Date :

in Ground wave propagation is 2 MHz.

- It is also ~~know~~ known as Surface wave propagation due to travelling of EM wave near earth surface.
- Electric field in Ground wave is given by.

$$E = \frac{120\pi h_t I_0}{\lambda d} \text{ V/m.}$$

(I_0 → current; d → distance)

h_t → height of transmitting antenna.

$$V = \frac{120\pi h_t h_r I_0}{\lambda d} \text{ volt}$$

- due to sea water conductivity Ground wave will travel more distance in sea surface compared to earth surface. hence, ground wave propagation most used in Ship to Ship communication.
- AM broadcasting is through Ground wave propagation.
- Ground wave will gradually disappears after certain distance due to tilting (vertical Polarized wave will become horizontal wave & that ~~with~~ is short circuited by Ground).

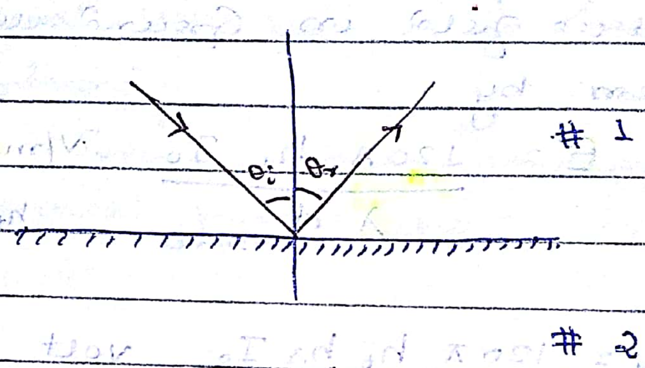
due to diffraction

Page No.
Date :

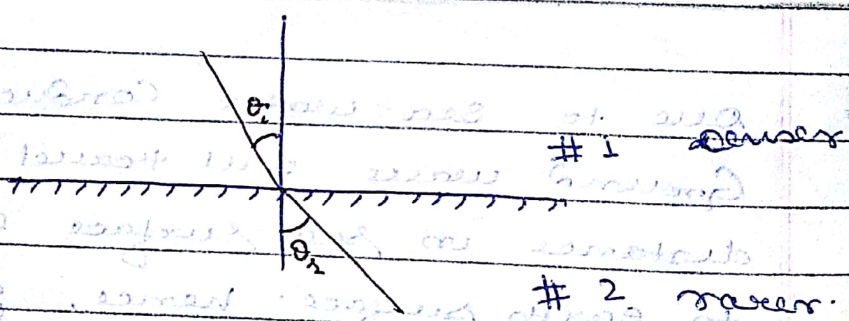
Sky wave Propagation

max. 4000km

Basic Principle: Sky wave Propagation is due to refraction of EM wave in Ionosphere.

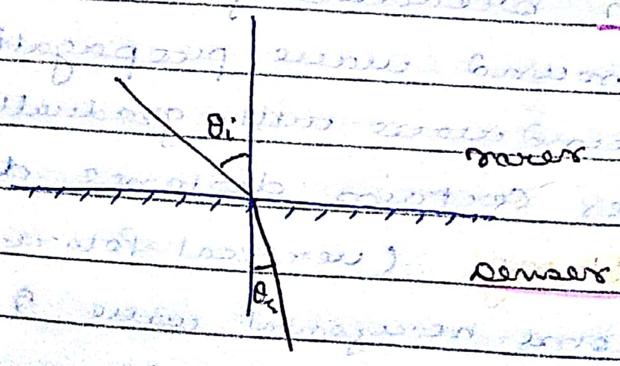


Reflection $\theta_i = \theta_r$.



$\theta_i < \theta_r$

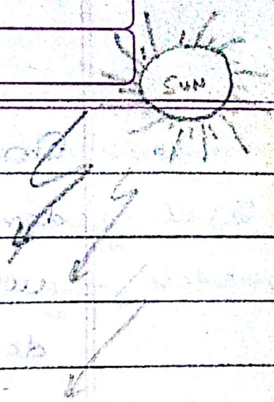
Refraction



$\theta_i > \theta_r$

refraction

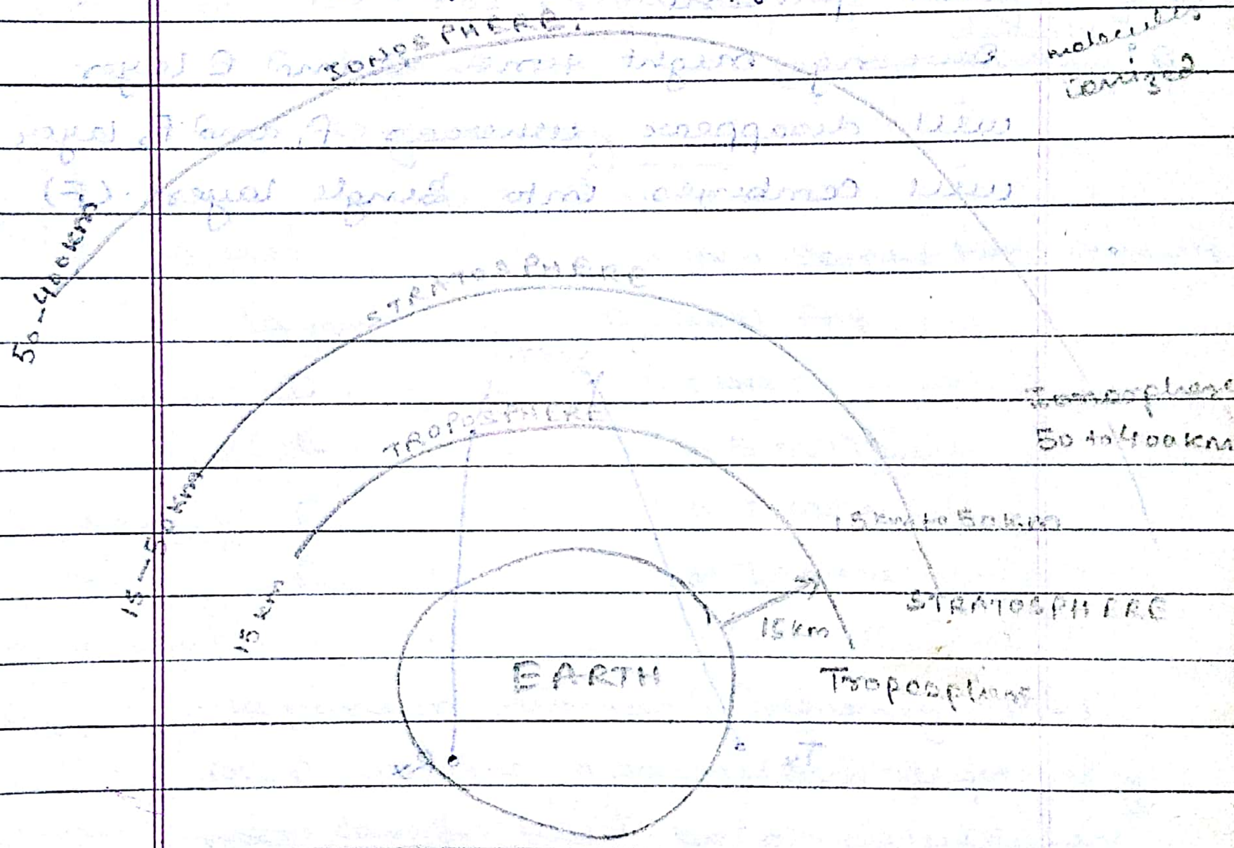
Page No.
Date :



Snell's law

$$n_1 \sin \theta_i = n_2 \sin \theta_r$$

$$\frac{\sin \theta_i}{\sin \theta_r} = \frac{n_2}{n_1} = \sqrt{\frac{\epsilon_{r2}}{\epsilon_{r1}}}$$



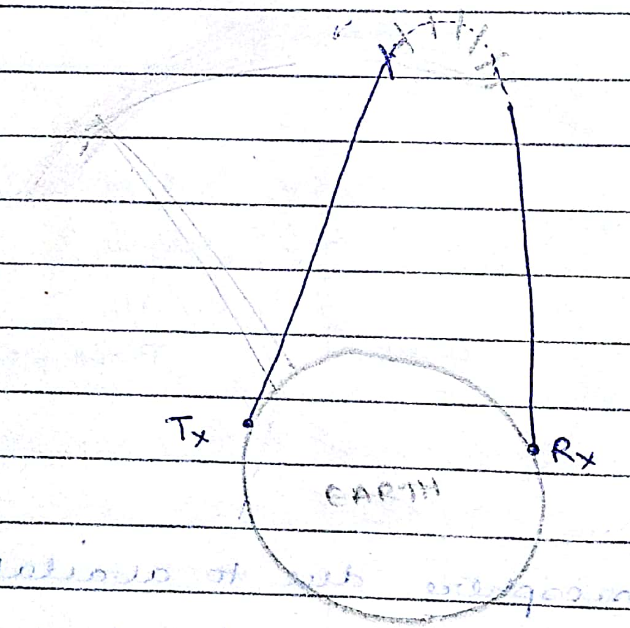
In Ionosphere due to availability of Sun energy during day time ionization will occur. based on Ionization, Ionosphere is divided into various layers such as D, E, f_1, f_2.

more Ionization less denser → f_2, f_1, E, D ← more denser less ionizat

- D → 50 km — 90 km
- E → 90 km — 140 km
- F_1 → 140 km — 250 km
- F_2 → 250 km — 400 km

Page No.
Date :

- In this D layer have higher atmospheric density but lower ionization density whereas F_2 layer lower atmospheric density and higher ionization density will present.
- During night time D and E layer will disappear whereas F_1 and F_2 layer will combines into single layers. (F)
-



In sky wave propagation when EM wave is incident on to ionosphere then ~~to~~ refraction will occur due change in atmospheric density due to this the signal can be received after certain distance at receiving point. (earth)

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Relative Permittivity of the Ionosphere is less than Unity.

Page No.
Date :

Critical frequency → It is the maximum frequency that can be reflected back by particular layer when vertically incident. (90°)

- Critical frequency of any layer depends on ionization density & is given by

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

$N \rightarrow$ Ionization density

Layer	Critical freq.
D	100 kHz
E	3 to 5 MHz
F_1	5 to 7 MHz
F_2	5 to 12 MHz

Maximum usable frequency MUF

MUF is the maximum frequency that can be used by a particular layer which will provides communication between two points always.

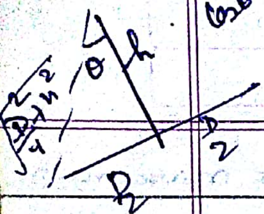
$$MUF = f_c \sec\theta$$

If f_c is critical frequency & θ is angle of incidence then MUF is given by above formula.

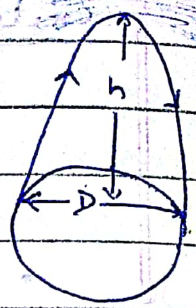
$$MUF = \frac{f_c}{\cos\theta}$$

So, $MUF > f_c$

$\cos\theta = \frac{h}{\sqrt{h^2+\frac{D^2}{4}}}$



$$MUF = f_c\sqrt{1+\left(\frac{D}{2h}\right)^2}$$



- Maximum frequency that can be used in ionospheric wave Prop. is 30MHZ.
- Frequency above 30MHZ will not refract by ionosphere.
  (Above 30MHZ penetration of Ionosphere hence, we use GHZ range in Satellite comm.)

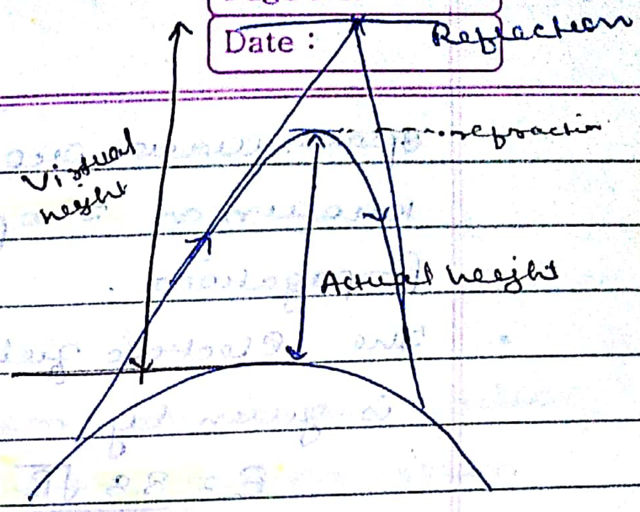
- Sky wave propagation is mostly used for HF point to point communication.

Skip distance

Skip distance is a minimum distance b/w transmitter to first signal received where no sky wave propagation is possible.

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

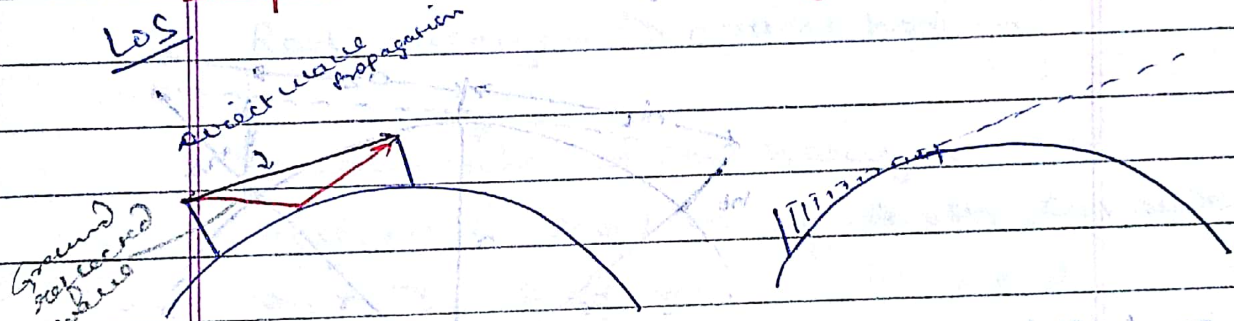
Virtual height



Virtual height > actual height.

Direct Space wave Propagation VHF, UHF, Mwaves

LOS



In space wave propagation, Em waves will travels straight line due to this the signal at a point can be receive by direct wave or ground reflected wave.
most of signals is received due to direct wave hence, space wave propagation is also known as direct wave propagation.

In space wave propagation, the communication is restricted to LOS. due to earth curvature hence, space wave propagation is also known as (LOS) line of sight propagation.

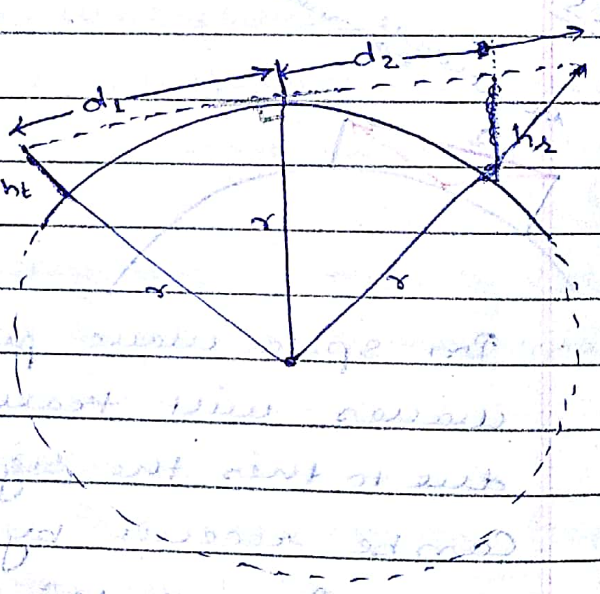
Page No.
Date :

- space wave propagation is also known as Tropospheric wave Propagation.
- The electric field strength in space wave Prop. is given by:

$$E = \frac{88\sqrt{P_t}\, h_t h_r}{\lambda d^2}$$

conventional

Calculation of LOS distance :



$r = 6370$ km actual

LOS distance = $d_1 + d_2$

LOS distance with only h_t

$$d_1 = \sqrt{(r+h_t)^2 - r^2}$$

r = 6400km

$$= \sqrt{r^2 + h_t^2 + 2rh_t - r^2}$$

Neglect h_t^2

$h_t = 100m = 0.1$ km

$r = 6370$ km

$$= \sqrt{(0.1)^2 + 2 \times 6370 \times 0.1}$$

$$= \sqrt{0.01 + 1270}$$

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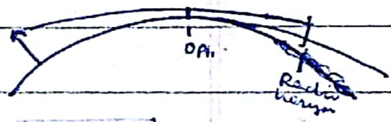
$d_1 = \sqrt{2 r h_t}$
⇓
optical Horizon

Due to refraction EM wave, radio horizon is always greater than optical horizon (distance)



Radio horizon > optical horizon

To calculate radio horizon, the effective radius of Earth considered as $r_E = \frac{4}{3} r$ → actual radius
↙ effective radius

$$d_1 = \sqrt{2 \times \frac{4}{3} \times 6370 \times h_t \times 10^3} \text{ m}.$$

$$d_1 = \sqrt{\left(2 \times \frac{4}{3} \times 6.37\right) \times 10^6 \times h_t} \text{ m}.$$

$$\boxed{d_1 = \sqrt{17 h_t} \text{ km}.}$$

h_t in meters

$$\boxed{d_1 = 4.123 \sqrt{h_t}}$$

Similarly, $d_2 = \sqrt{17 h_r}$

$= 4.123 \sqrt{h_r}$

Page No.
Date :

LOS distance $= d_1 + d_2$

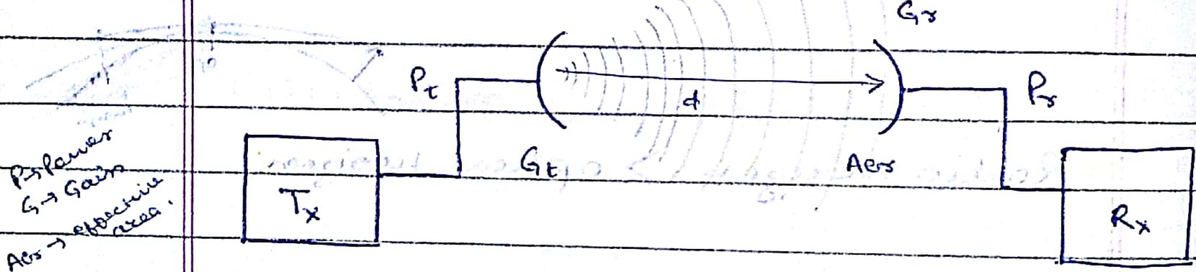
$= \sqrt{17 h_t} + \sqrt{17 h_r}$ km.

where, $h_t, h_r \rightarrow$ m.

$= 4.123 (\sqrt{h_t} + \sqrt{h_r})$ km.

Conventional

Path Loss Calculation in Space wave Propagation



Let us consider, P_t is transmitting power, G_t is Gain of antenna then power density available at distance d is given by

$$P_D = \frac{P_t G_t}{4\pi d^2}$$

$P_t G_t$ = EIRP (Effective Isotropic radiated power)

Power received by receiver is given by

$$P_r = \frac{P_t G_t}{4\pi d^2} \times A_{er}$$

$$A_{er} = \frac{\lambda^2}{4\pi} \times G_r$$

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2}$$

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Page No.
Date :

$$P_r = \frac{P_t G_t G_r}{\left(\frac{4\pi d}{\lambda}\right)^2}$$

The path loss factor is given by $\left(\frac{4\pi d}{\lambda}\right)^2$

$$\text{Path Loss factor} = \left(\frac{4\pi}{c} \times d \times f\right)^2$$

Path loss $\propto d^2$
$\propto f^2$.

Exam.

Factor	dB
2	→ 3 dB
4	→ 6 dB
8	→ 9 dB
16	→ 12 dB
20	→ 13 dB

$$\text{Path Loss in dB} = 10\log\left(\frac{4\pi}{c}\right)^2 + 10\log_{10} d^2 + 10\log_{10} f^2$$

$$= 20\log\left(\frac{4\pi}{c}\right) + 20\log_{10} d + 20\log_{10} f$$

$d \to m$

$f \to Hz$.

$$P_L(dB) = \text{Path Loss in dB} = 20\log_{10}\left(\frac{4\pi}{c}\right) + 20\log_{10}(d) +$$

$$\underbrace{20\log_{10}(10^3)}_{60} + 20\log_{10}(f) + \underbrace{20\log_{10}(10^6)}_{120}$$

Now, $d \to km$

$f \to MHz$

*** $\text{Path Loss in dB} = 32.5 + 20\log_{10} d + 20\log_{10} f$ dB

AM → 1000 km
FM → 40 to 60 km LOS

Page No.
Date :

$$P_r = \frac{P_t G_t G_r}{\left(\frac{4\pi d}{\lambda}\right)^2}$$

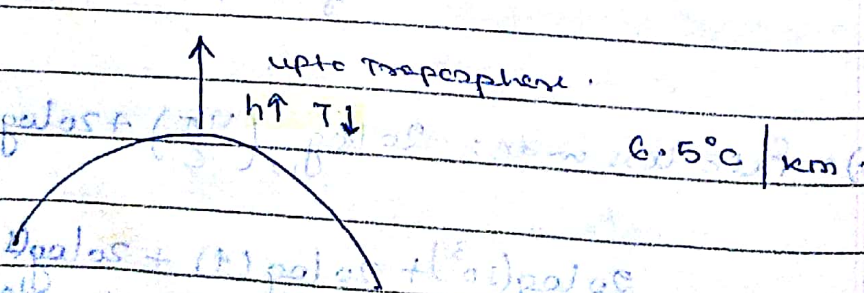
Imp. ** JTO / NAI

$$P_r(dB) = P_t(dB) + G_t(dB) + G_r(dB) - P_L(dB).$$

- main limitation of space wave propagation is communication is restricted to only line of sight due to Earth curvature.
- Range → 40 – 60 km.
- main Application.
  Satellite comm., Broadcasting, FM, Space craft.

Duct Propagation

- At microwave frequency.
- It is mainly due temperature inversion layer (TIL)



- It is generally present in stratosphere & Ionosphere. (as h↑, T↑)
- In normal atmosphere as height increases temp. will decrease (6.5°C / km).

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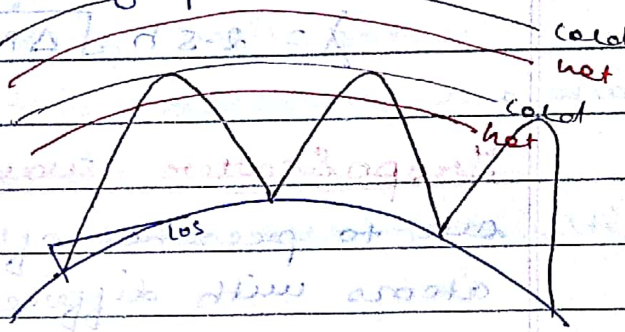
- In temp. inversion layer as height increases temp. required to increase.
- If TLI is found with in 50 m height, then duct wave propagation will present in microwave frequencies.



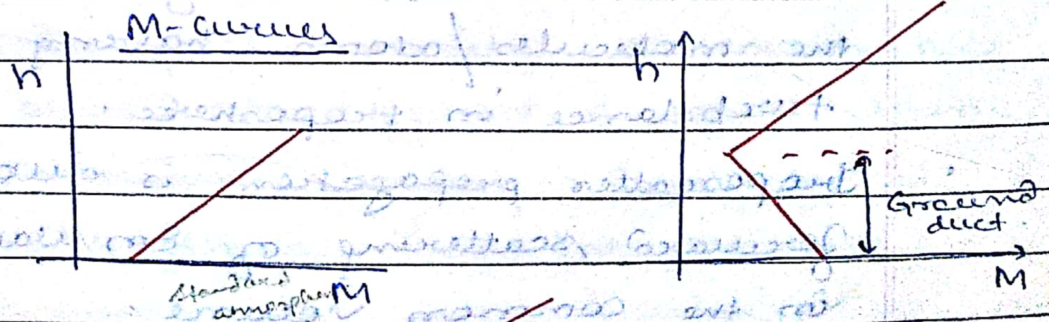
When T.I.L is found then super-refraction occur & signal will propagate upto 1000 km

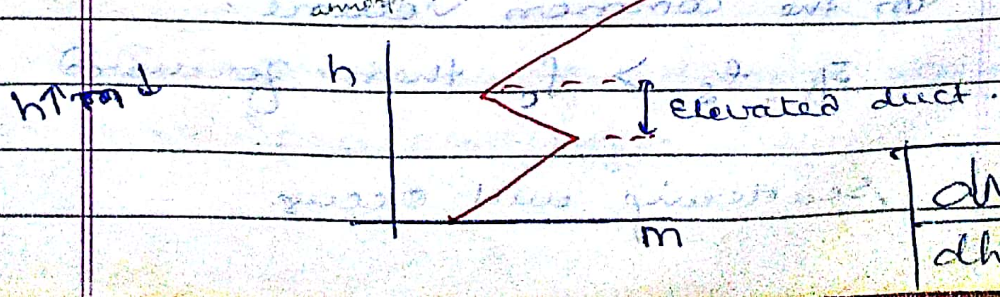
When TIL is present then normal optical laws will not work and modified refractive Index is used given by,

$$M = \left(\mu - 1 + \frac{h}{R}\right) \times 10^6$$

h: height of layer

M-curves





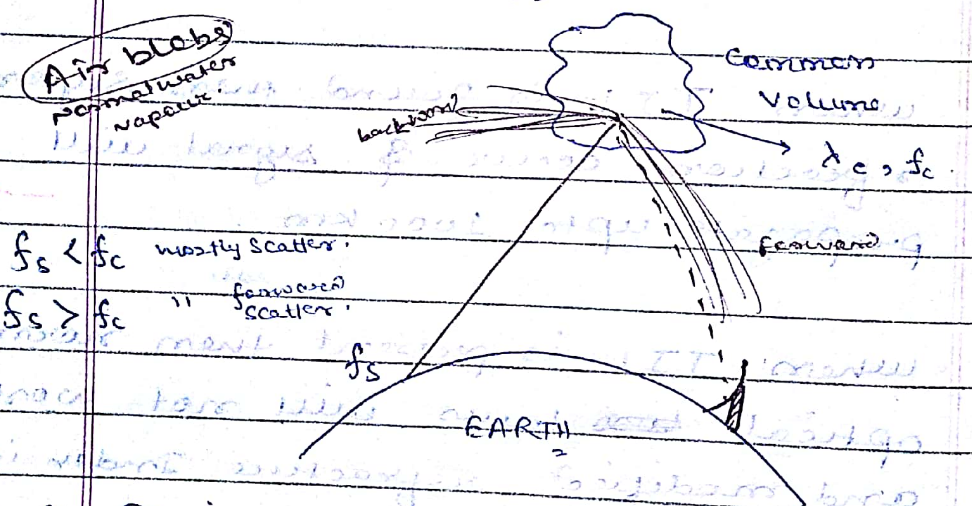
$$\frac{dM}{dh} = -ve$$

- To provide duct wave propagation $\frac{dm}{dh}$ is negative.
- The frequency which can propagate in duct wave propagation is given by

$$\lambda = 2.5 h \sqrt{\Delta M \times 10^{-6}} \text{ cm.}$$

TropoScatter wave propagation UHF, Microwave

due to presence of molecules or atoms with different turbalance



- It is due to presence of common volume in troposhere.
- Common volume is formed with the molecules/atoms having turbalance in troposhere.
- Troposcatter propagation is due to forward scattering of Em wave in the common volume.
- If $f_s > f_c$ then forward scattering will occur.

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Fading → Variation of signal strength due to multipath reception.

to Parabolic antenna

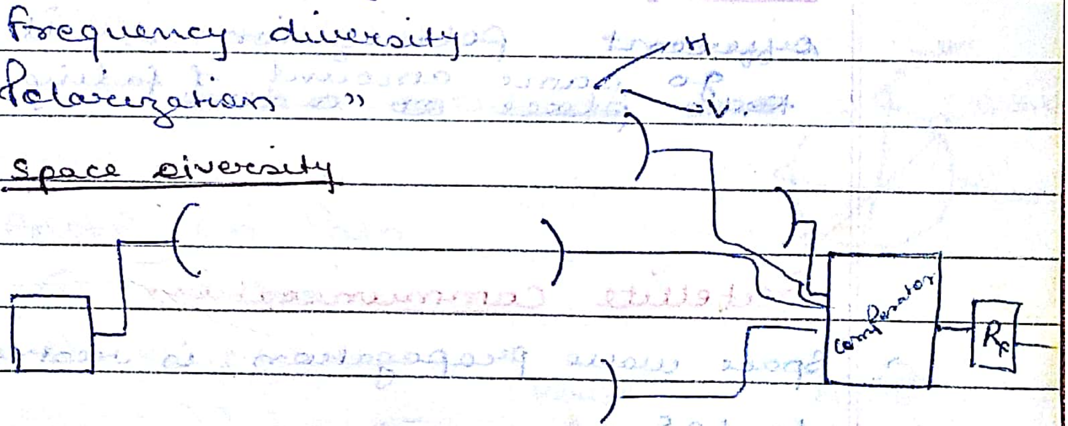
To provide troposcatter propagation, high transmitting power & high gain transmitting & receiving antennas are required.

- In troposcatter wave Propagation. Rayleigh Fading will occur to overcome this diversity reception System is used.
- Fading will occur due to multipath reception.

Diversity reception

1. Space diversity
2. Frequency diversity
3. Polarization "

- Space diversity

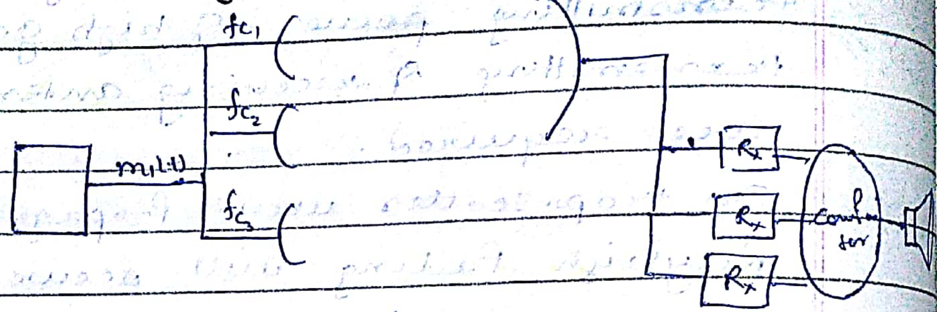


In space diversity, antennas are placed at different distance then whichever having Good signal Strength used in the receiver.

It is most using diversity reception i.e. Space diversity.

Page No.
Date :

Frequency diversity



Ship to Ship

- It is mostly used in ship to ship communication.
- It is used where area availability is small.

Polarization diversity

Different polarization & will not go same amount of fading.

Satellite communication

→ Space wave propagation is restricted to LOS

→ This problem can be overcomed by using Tx.

- For every ≈ 50 km we need repeater.
- For 1500 km we need 300 repeater.
- Maintenance is difficult for repeater.

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