Notes on

Advance Communication Engineering

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RADAR BASICS, WORKING and APPLICATIONS :-

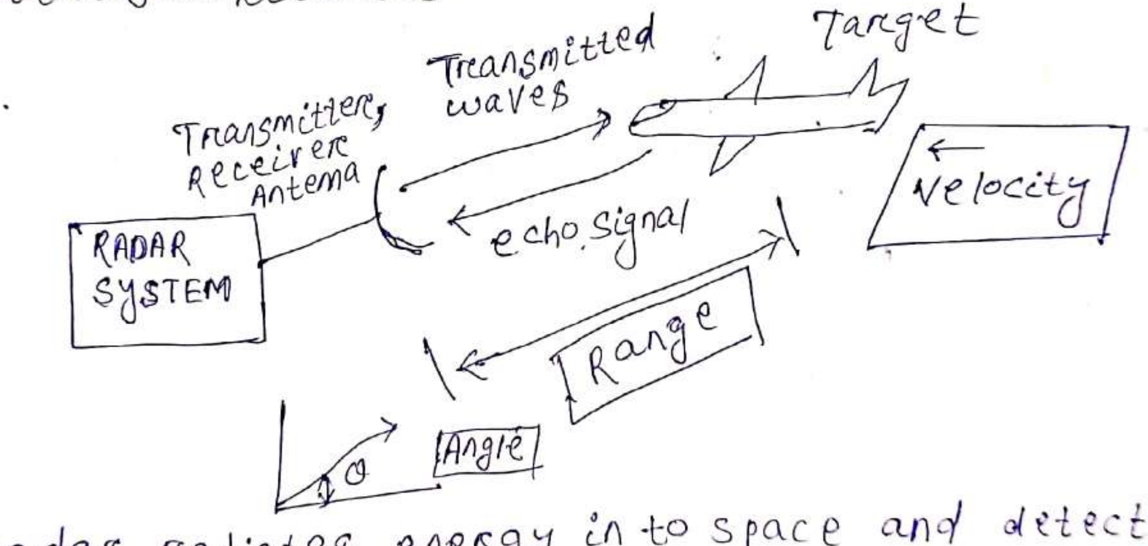
Basics :- ① RADAR is an object-detection system that uses radio waves to determine the range, angle (or) velocity of objects.

(ii) It can be used to detect aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formations and terrain.

(iii) RADAR was developed secretly for military use by several nations in period before World War-II.

(IV) RADAR [Radio Detection And Ranging, Radio Direction And Ranging.]

Working of RADAR system :-



Radar radiates energy in to space and detects the echo signal reflected from an object (or) Target. Based on echosignal Radar can identify range of Radar, Angle at which target is present, velocity at which Target is moving.

Advantages of RADAR system :-

(i) Radar can see through darkness, haze, fog, rain and snow.

(ii) RADAR can determine the position, range, angle and velocity of object.

LIMITATIONS OF RADAR SYSTEM :-

(i) RADAR can not resolve in details like the human eye, especially at short distance.
(ii) RADAR can not recognize the color of the target.
(iii) RADARS can not identify internal aspects of the target.

APPLICATIONS OF RADAR SYSTEM :-

Civilian Applications :- (i) Navigational aid on ground and sea. (ii) Radar Altimeters for determining the height of plane above ground. (iii) Airborne radar for satellite surveillance. (iv) police radars for directing and detecting speeding vehicles.

Military Applications :- (i) Detecting and ranging of enemy targets. (ii) we can aim guns at aircraft and ships. (iii) Bombing ships, aircrafts even at night. (iv) Directing missiles. (v) Early warning regarding approaching aircraft (or) Ships.

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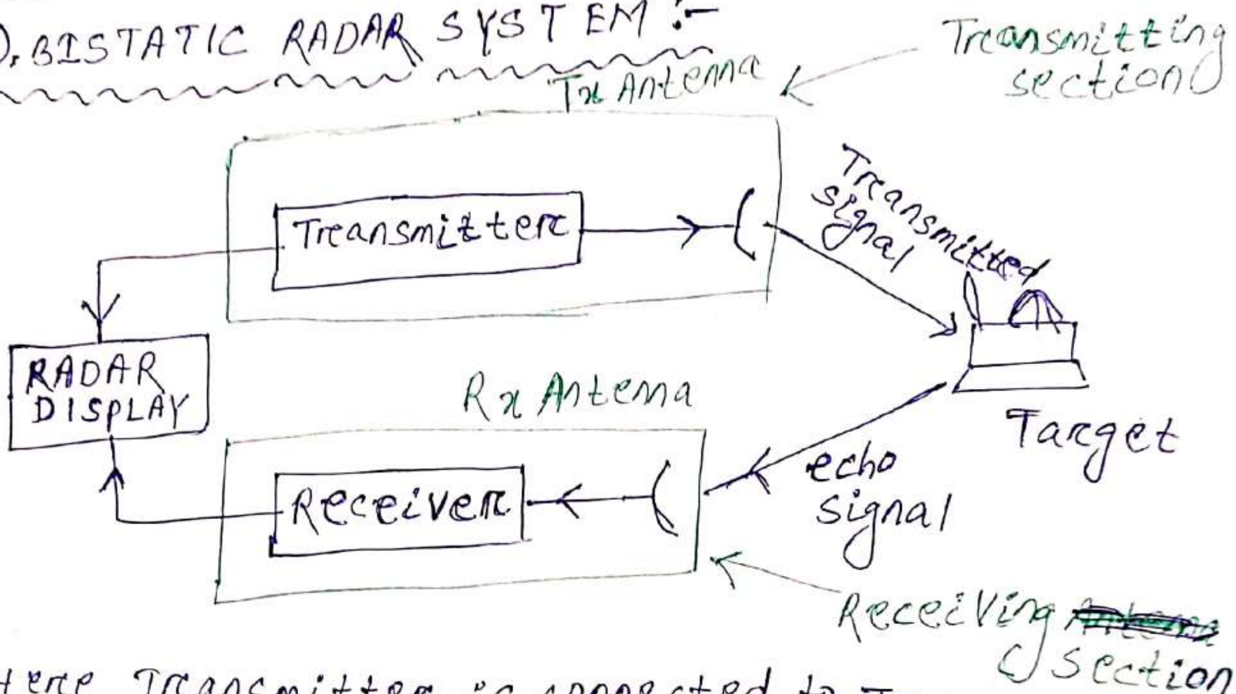
RADAR BLOCK DIAGRAM :-

(MONOSTATIC RADAR and BISTATIC RADAR)

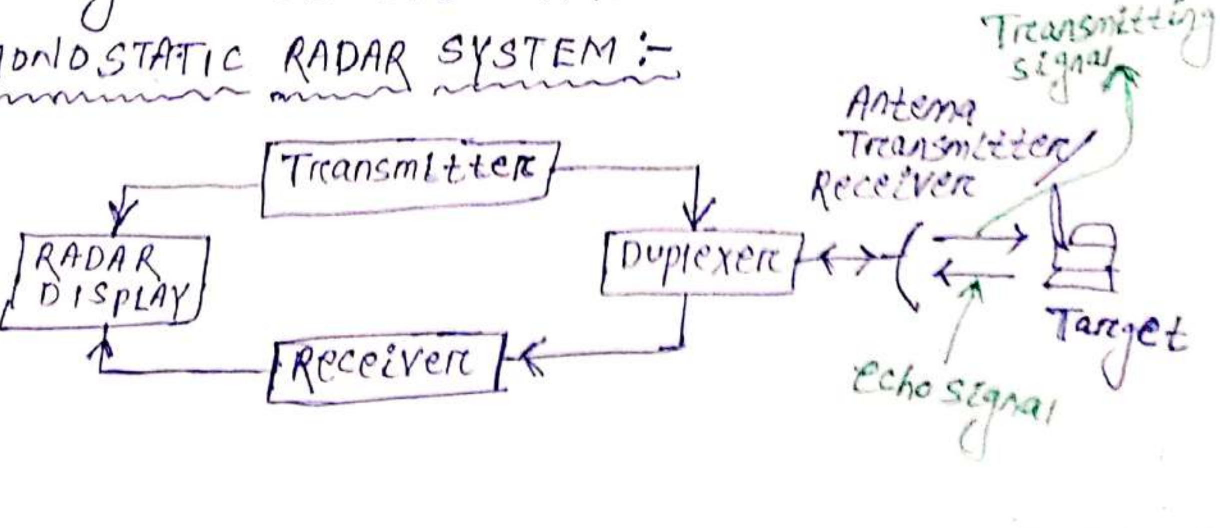
↳ Basic Types of RADAR :- ① Bistatic RADAR
② MONOSTATIC RADAR.

①. BISTATIC RADAR SYSTEM :-



↳ Here Transmitter is connected to Transmitting Antenna and Transmitting signal is given to RADAR DISPLAY. Radio waves are transmitted to the Target. Based on received echo signal RADAR DISPLAY will show what is the position, speed, Angle, range, of the target. So, in Bistatic RADAR we can see Transmitting section and receiving section both are having different Antennas.

②. MONOSTATIC RADAR SYSTEM :-



↳ Here Both Transmitting and Receiving section uses single Antenna For Transmission and Reception purpose. So, For That purpose we will use Duplexer circuit.

Duplexer is used to isolate Transmitting circuit from Receiving circuit. Transmitting circuit is functioning in terms of Megawatt (MW) power. Receiver circuit is Functioning in terms of Microwatt (MW) power. power Difference between Transmitter and Receiver circuit is 10^{12}. So it is very compulsory ~~to~~ protect Receiver circuit from high power Transmitter circuit. So we use Duplexer. Duplexer will provide bidirectional communication with Transmitter and Receiver, where Transmitter will Transmit the signal and Receiver will receive the signal.

FUNctions of DUPLEXER:- ① To isolate the Transmitter and Receiver during Transmission and reception. ② To protect the Receiver from high power Transmitter. ③ To help using a single Transmitter/Receiver Antenna.

Monostatic RADAR	Bistatic RADAR
(i) It uses single Antenna.	① It uses two Antenna.
② It needs duplexer to separate Transmitter (Tx) and Receiver (Rx).	② No need of Duplexer.
③ It needs less space.	③ It needs more space.
④ complex system.	④ Simplex system.
⑤ costly system.	⑤ Low cost system.

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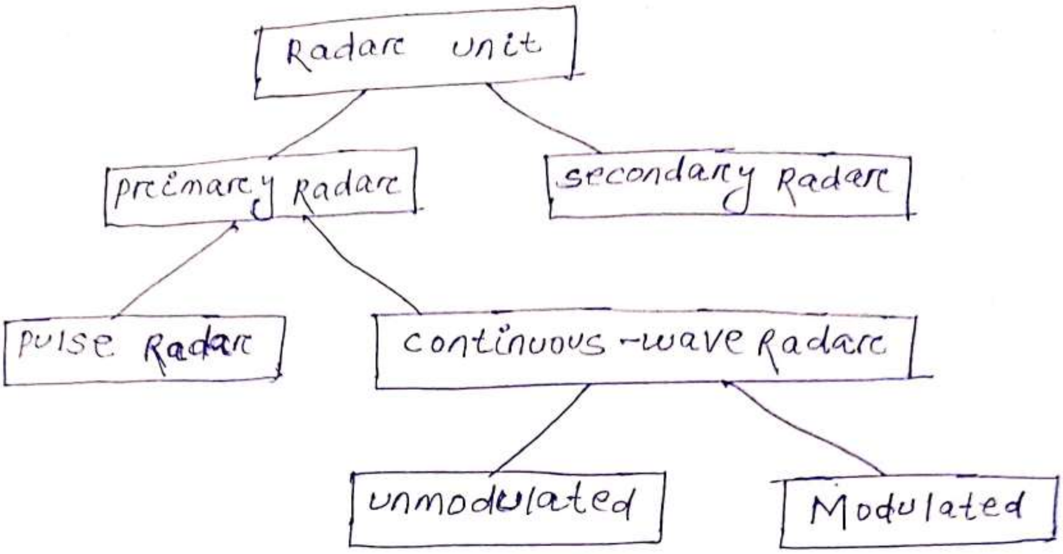
CLASSIFICATION OF RADAR :-



↳ primary Radar transmits high power, high frequency EM signals towards target and receives low power echo signal.

↳ In secondary Radar Transponder (Both Transmitter and Receiver) available. Echo signals are in Digital code form which are used to identify the Target Types. It is used in military Applications.

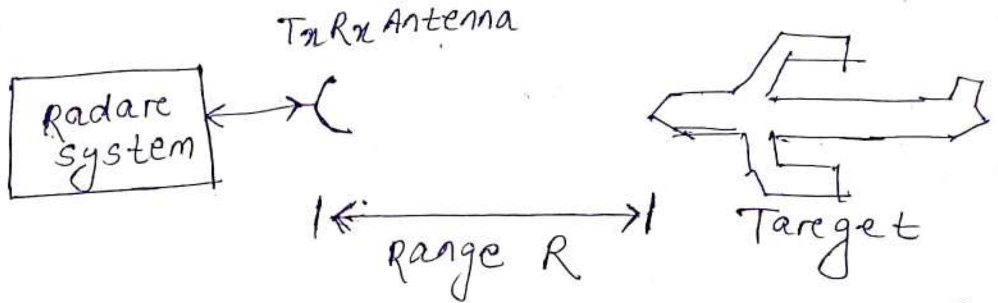
↳ pulse Radar Transmits high power, high frequency in pulse signal. After this longer break echo can receive and then again new signal is transmitted. Direction, Distance, Altitude of target can be determined from measuring Antenna position.

↳ In continuous-wave Radar high frequency signals are generated. The echo signals are continuously received and processed. The receiver need not to be placed at the same position of Transmitter.

↳ In unmodulated continuous wave Radar Transmitted signals are constant Amplitude and Frequency. These are used for speed measurement. Distance can not be measured.

↳ In modulated continuous wave RADAR, transmitted signals are constant in Amplitude but modulated in frequency. These are used ~~to~~ measure short Distance. In Altitude measuring ~~RADAR~~ Aeroplane, Radar continuously measure the Altitude.

RADAR RANGE EQUATION :-



↳ power Density by Isotropic source is $\frac{P_t}{4\pi R^2}$

↳ If Gain of Antenna in the direction of Target is G_t Then power Density is $\frac{P_t \cdot G_t}{4\pi R^2}$.

↳ If Target Area is σ (sigma) Then power at target = power Density X Area

$$= \left(\frac{P_t \cdot G_t}{4\pi R^2}\right) \times \sigma$$

↳ power Density by Reflected signal is

$$= \frac{\text{Reflected power}}{\text{Surface Area}} = \left(\frac{P_t \cdot G_t \cdot \sigma}{4\pi R^2}\right) \times \frac{1}{4\pi R^2}$$

$$= \frac{P_t \cdot G_t \cdot \sigma}{(4\pi R^2)^2}$$

↳ Let Effective Area of Receiving Antenna is A_e.

↳ Then received Refted signal power

P_r = Reflected signal power Density X Area of Receiving Antenna

$$\boxed{\Rightarrow P_r = \frac{P_t \cdot G_t \cdot \sigma}{(4\pi R^2)^2} \times A_e}$$

↳ For maximum Range R_{max}, Received signal power P_r = Minimum Detectable signal S_{min}

$$S_{min} = \frac{P_t \cdot G_t \cdot \sigma \cdot A_e}{(4\pi)^2 \cdot R_{max}^4} \Rightarrow \boxed{R_{max} = \left[\frac{P_t \cdot G_t \cdot \sigma \cdot A_e}{(4\pi)^2 \cdot S_{min}}\right]^{1/4}} \quad \text{—①}$$

Generally we use in Radare Receiver system, parabolic Antenna as Receiving Antenna. For that case Gain of parabolic Antenna is $G = \frac{4\pi A_e}{\lambda^2}$

put this value in Rmax equation

$$\Rightarrow R_{max} = \left[\frac{P_t \cdot \left(\frac{4\pi A_e}{\lambda^2}\right) \cdot \sigma \cdot A_e}{(4\pi)^2 \cdot S_{min}}\right]^{1/4}$$

$$\Rightarrow \boxed{R_{max} = \left[\frac{P_t \cdot A_e^2 \cdot \sigma}{4\pi \cdot \lambda^2 \cdot S_{min}}\right]^{1/4}}$$

This is RADAR RANGE EQUATION.

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FACTORS AFFECTING RADAR RANGE :-

↳ In Last session, Radar Range Equation is

$$R_{max} = \left[\frac{P_t \cdot G_t \cdot A_e \cdot \sigma}{(4\pi)^2 \cdot S_{min}}\right]^{1/4} = \left[\frac{P_t \cdot A_e^2 \cdot \sigma}{4\pi \cdot \lambda^2 \cdot S_{min}}\right]^{1/4}$$

↳ Transmitting power (P_t)

$R_{max} \propto (P_t)^{1/4}$, if we increse $P_t' = 16 \cdot P_t$ Then $R'_{max} = 2 \cdot R_{max}$

↳ Frequency (f)

$F = \frac{c}{\lambda} \propto \frac{1}{\lambda}$, $R_{max} \propto \frac{1}{\sqrt{\lambda}} \propto \sqrt{f}$

If we increase frequency 4 times, i.e $f' = 4f$ Then

$R'_{max} = 2 \cdot R_{max}$.

↳ size of Target (Area of Target σ)

$R_{max} \propto (\sigma)^{1/4}$

↳ Effective Area of Transmitting/Receiving Antenna A_e

$R_{max} \propto \sqrt{A_e}$

↳ Minimum Detectable signal, $R_{max} \propto \frac{1}{(S_{min})^{1/4}}$

$S_{min} \downarrow \rightarrow R_{max} \uparrow$

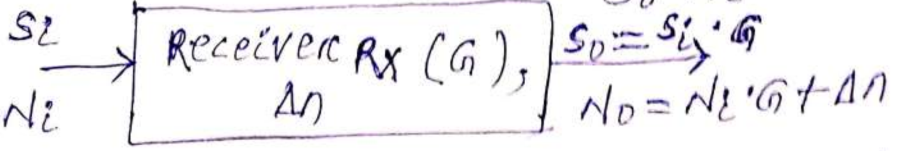
So Higher the sensitive circuit which is at Receiver section, Higher the Range of Radar system.

RADAR Range based on Noise Figure :-

↳ Radar Range Equation is $R_{max} = \left[\frac{P_t \cdot A_e^2 \cdot \sigma}{4\pi \cdot \lambda^2 \cdot S_{min}}\right]^{\frac{1}{4}}$ —①

↳ Noise Figure $F = \frac{\text{Signal to Noise Ratio at input side}}{\text{signal to Noise Ratio at output side}}$

$$\Rightarrow F = \frac{S_i/N_i}{S_o/N_o} = \frac{S_i \cdot N_o}{S_o \cdot N_i}$$



Here, Δn is Receiver Noise.

Now Noise Figure $F = \frac{S_i \cdot (N_i \cdot G + \Delta n)}{S_i \cdot G \cdot N_i} = \frac{1}{G}\left(G + \frac{\Delta N}{N_i}\right)$

$$= 1 + \frac{\Delta N}{G \cdot N_i}$$

$\Rightarrow F-1 = \frac{\Delta N}{G \cdot N_i} \Rightarrow \Delta N = G \cdot N_i \cdot (F-1)$

↳ Input Noise N_i is based on Temperature $N_i = K T_o B$
where, K = Boltzman constant = 1.38×10^{-23} SI, T_o is Temperature in Kelvin, B is Bandwidth.

$\Rightarrow \boxed{\Delta N = (F-1) G \cdot K T_o B}$ — ②, This is added noise due to Receiver.

By placing $S_{min} = \Delta N$ from Equation -① and Equation -② $R_{max} = \left[\frac{P_t \cdot A_e^2 \cdot \sigma}{4\pi \cdot \lambda^2 \cdot (F-1) G K T_o \cdot B}\right]^{1/4}$

↳ For parabolic Antenna, Effective Area $A_e = \frac{0.65 \pi D^2}{4}$
D = Diameter of parabolic Dish. Take T_o = 300 Kelvin
put A_e value and T_o value in above R_{max} Equation we will get

$$\boxed{R_{max} = 48 \left[\frac{P_t \cdot D^4 \cdot \sigma}{B \cdot \lambda^2 \cdot (F-1)}\right]^{1/4}}$$

If Noise figure $F = 1$ then $R_{max} = \infty$ (Higher value practically)

↳ In RADAR to optimize received signal, Anti-Jamming Techniques are used like frequency hopping.
In frequency Hopping we continuously change the frequency of operation which is in RADAR.

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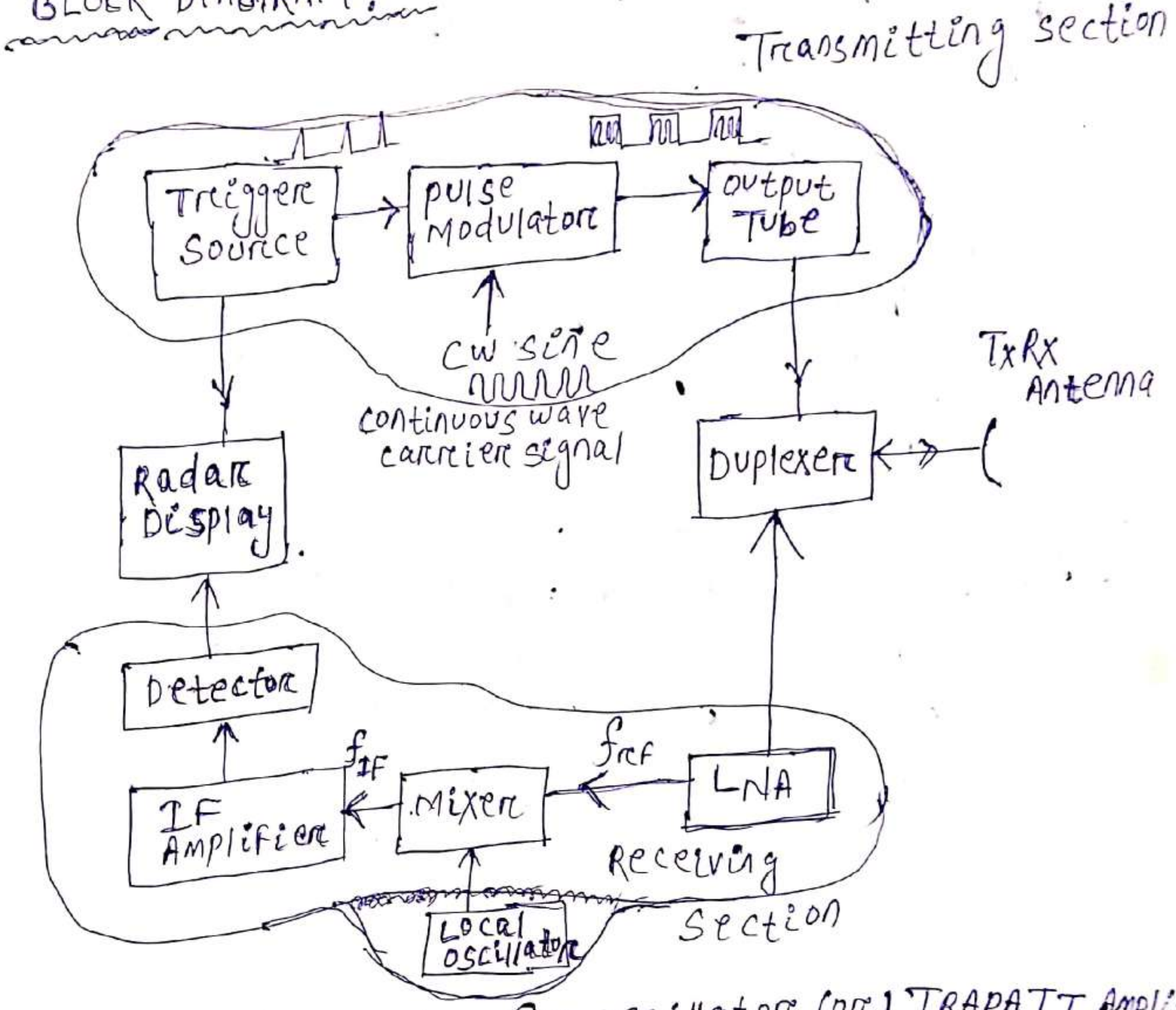
PULSED RADAR SYSTEM :-

BLOCK DIAGRAM :-

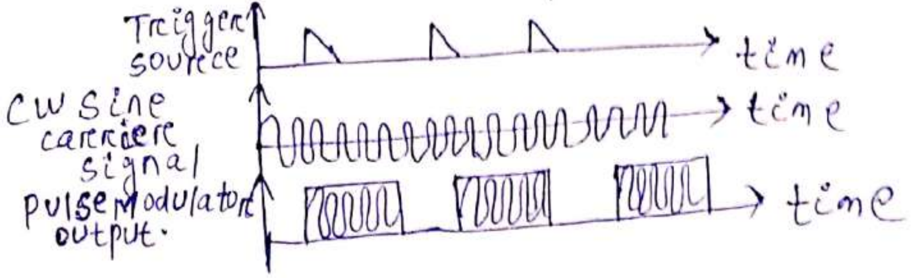


↳ output Tube may be Gun oscillator (or) TRAPATT Amplifier, (or) IMPATT Amplifier.

↳ In LNA block we may use parametric Amplifier (or) TWT Amplifier. [Low noise Amplifier]

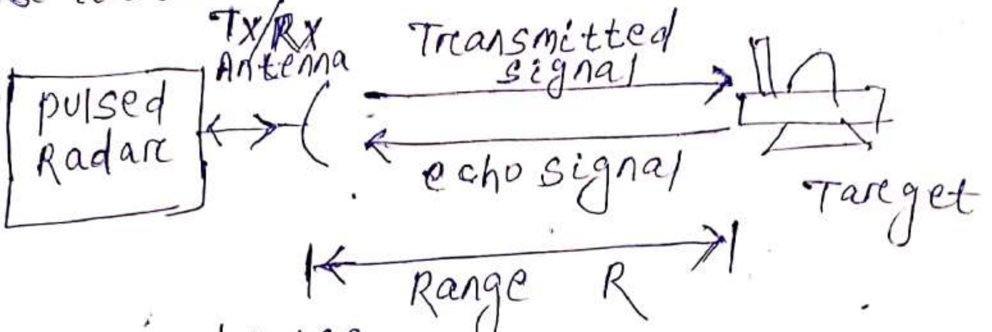
↳ Detector circuit could be made up of Schottky Barrier Diode. (SBD).

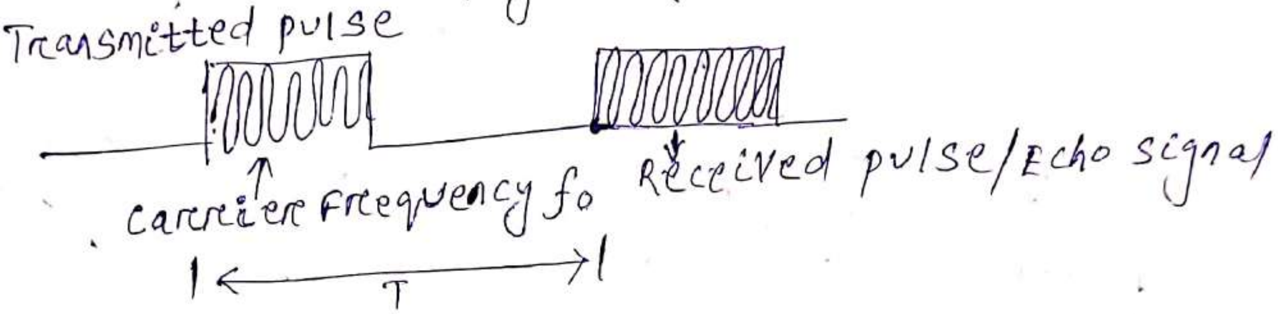
↳ By comparing Trigger source output and Detector output RADAR DISPLAY can identify what is the position of Target.



↳ Based on Echo signal we can identify what is the position of Target.

Range Identification :-





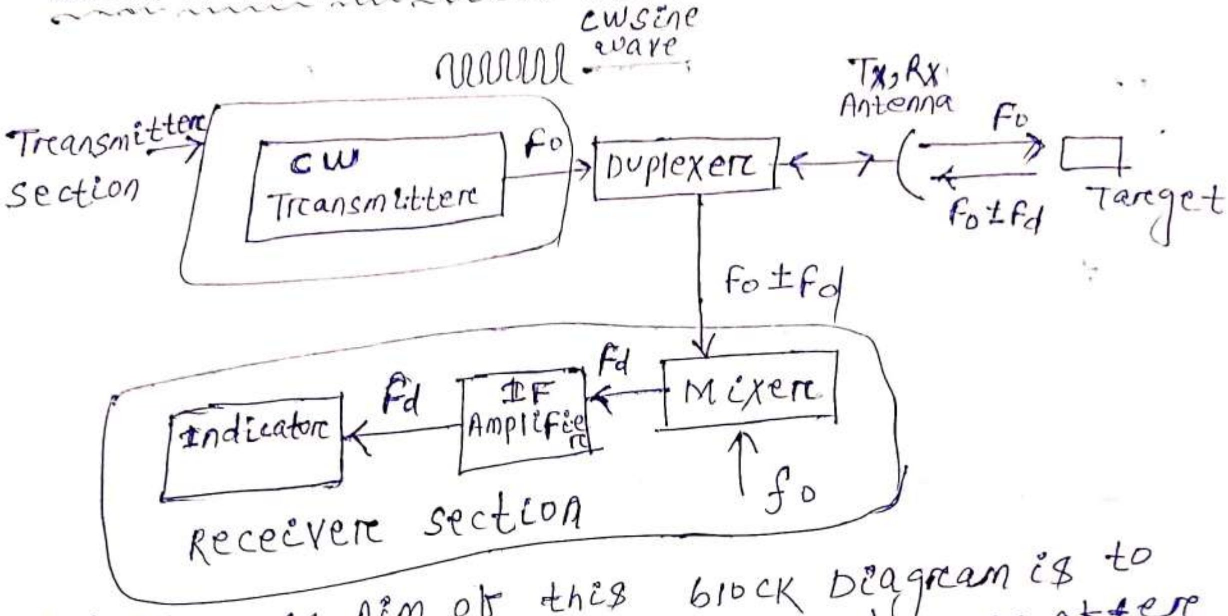
Total Travelling distance = R+R = 2·R,
Time requrre to receive echo pulse is T.
Here velocity of signal is c (3×10^8 m/sec)
Total Distance of Signal is 2R

$$\Rightarrow \quad V = C = \frac{2R}{T} \Rightarrow \boxed{R = \frac{CT}{2}}$$

Range of Radar

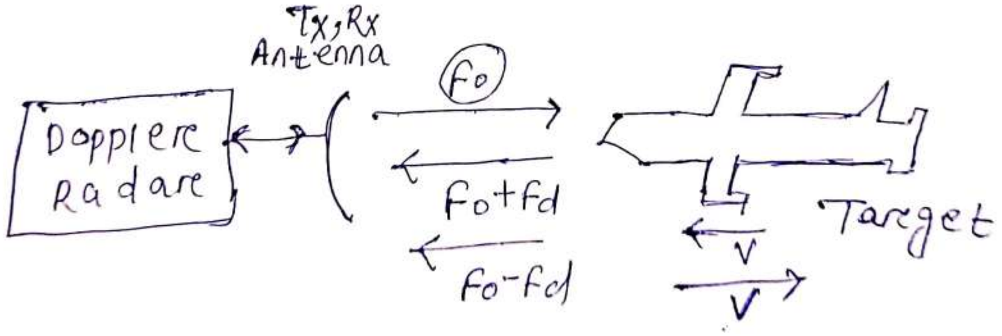
DOPPLER RADAR (OR) CONTINUOUS WAVE RADAR :-

BLOCK DIAGRAM OF DOPPLER RADAR SYSTEM :-



↳ Here Basic Aim of this block Diagram is to extract Doppler shifted frequency (fd). Then after we can identify what is the velocity of Target.

working of Doppler Radar System :-



↳ Here we are sending fo frequency signal towards target.

↳ If Target is moving with v velocity towards Doppler Radar. In that case Reflected received signal having frequency fo+fd. (Increase in frequency)

↳ If Target moves far from radar system with velocity v. In that case the Reflected received signal having frequency fo-fd. [Decrease in Frequency.]

↳ That means there is a drift in frequency due to motion in target. That is called as Doppler effect.

DOPPLER EFFECT :- It is drift in frequency due to motion of object.

↳ Based on Drift in frequency we can identify the velocity of Target.

$$\boxed{f_d = \frac{2 \cdot V}{\lambda}},$$

where V = velocity of Target.

$\lambda = \frac{c}{f}$ = wavelength

c = velocity of Light = $3 \times 10^8 \frac{mtr}{sec}$

MTI RADAR:-

↳ MTI Radar can be used to detect the moving target such as aircrafts, ships.

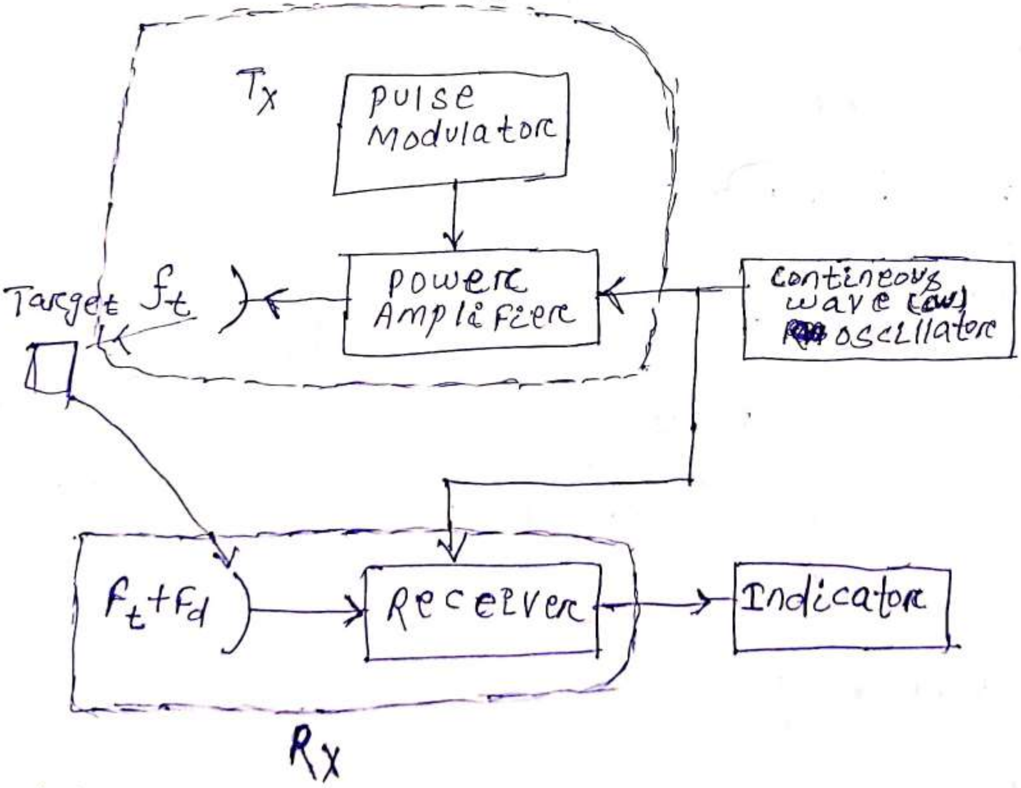
↳ MTI RADAR is based on the principle of Doppler effect.

↳ MTI RADAR can determine the range and velocity of moving target.

BASIC PRINCIPLE:- (i) The basic principle of an MTI RADAR is to compare a set of returned echoes with those received during the previous sweep.

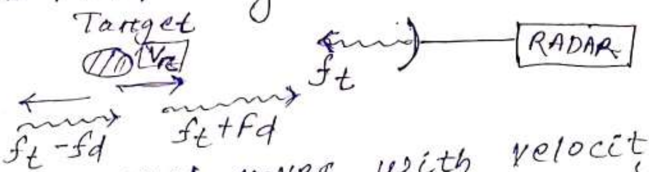
(ii) while comparison, if the phase of received echoes remain same due to stationary targets then these will be cancelled out.

(iii) Again, while comparison, if the phase of received echoes changed due to moving target, then these will not cancelled out. These echoes display on screen.



↳ pulse Modulator is having fixed pulse frequency which is getting repeated with respect to time. During that pulse only we will give signal. signal is transmitted through f_t frequency. Based on motion of Target Receiving signal frequency is having f_t+f_d.

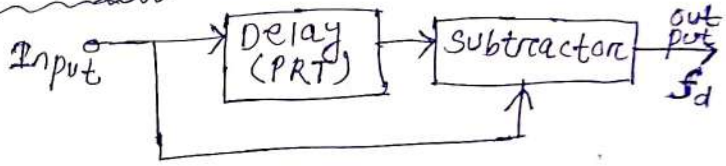
↳ fd is Frequency drift due to motion of Target.



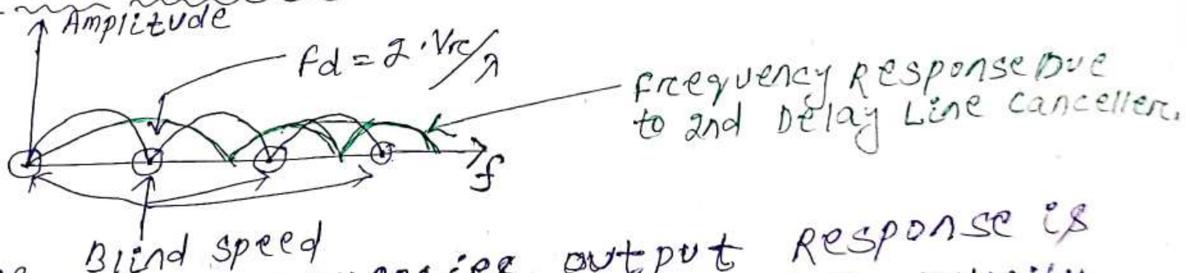
↳ If the Target moves with velocity (Vr) towards the RADAR system then receiving signal frequency is having $f_t + f_d$, if away from RADAR system then receiving signal frequency is $f_t - f_d$. $\boxed{f_d = \frac{2V_r}{\lambda}}$ where λ is operating wavelength.

our goal is to findout fd, Then we can find motion of object/Target. In Receiving system has Delay Line canceller. Delay Line canceller will identify fd.

Delay Line canceller structure:-



Frequency Response of Delay Line canceller:-



↳ At those given frequencies output Response is Zero. So if Target is moving with Vr velocity having frequency fd that comes under output Response is zero, That is called Blind speed. moving Target can not be detected by Delay Line canceller. The speed associated with moving Target is called Blind speed.

↳ MTI Radar calculates Range by knowing Time period of Receiving signal. Velocity can also be calculated based on Drift frequency. If fd is associated with blind speed then moving Target can not be detected by Delay Line canceller.

↳ By using Multi Delay Line canceller in series we can avoid Blind speed.

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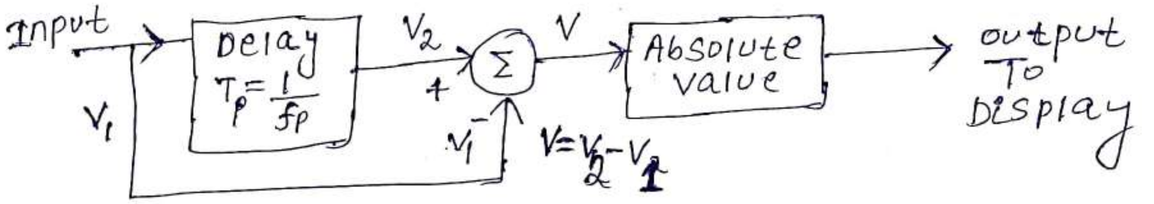
DELAY LINE CANCELLER :-

BASICS :- (i) It is used in MTI RADAR system. (ii) It works as filter. (iii) It will eliminates Low Frequency (Low Frequency) clutter in received signal at RADAR, i.e. Low frequency component is eliminated. (iv) It improves resolution of object identification.

BLOCK DIAGRAM OF DELAY LINE CANCELLER :-



Here received Radar signal is $V_1 = A\cdot\sin(2\pi f_d\cdot t+\phi)$

f_d is pulse repetition frequency.

$V_2 = A\cdot\sin[2\pi f_d\cdot(t-T_p)+\phi]$

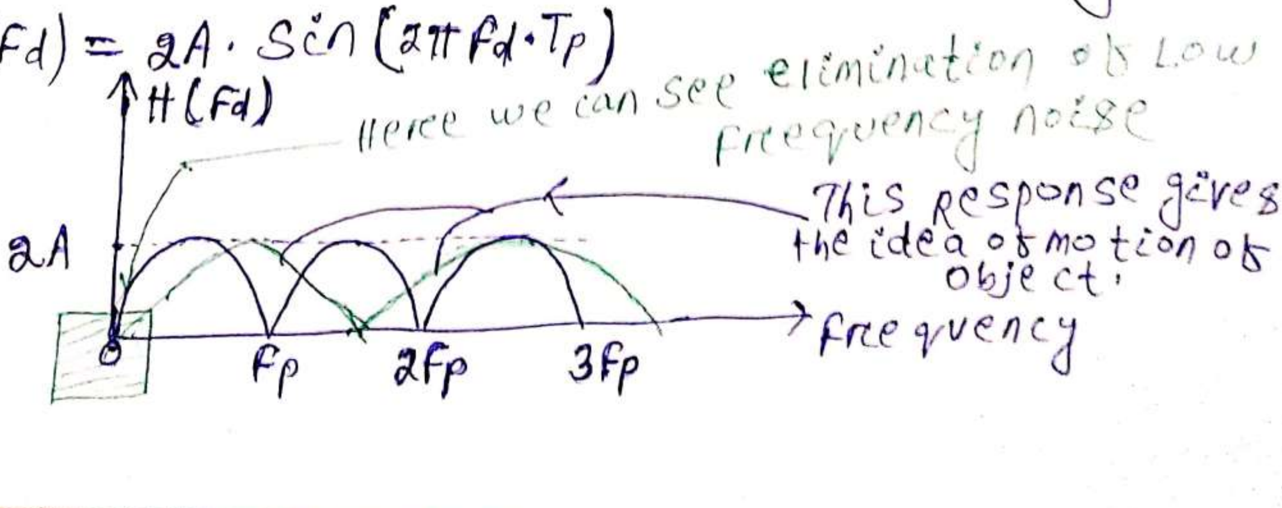
output $V = V_2 - V_1$

$$= A[\sin(2\pi f_d(t-T_p)+\phi) - \sin(2\pi f_d t+\phi)]$$

$$= \underbrace{2A\sin(2\pi f_d\cdot T_p)}_{H(f_d)\ [\text{Amplitude}]}\cdot\cos\left[2\pi f_d\left(\frac{t-T_p}{2}\right)+\phi\right]$$

It is Response of the system that defines Amplitude. That gives idea about how much ~~noise~~ cancellation of noise is happening.

$H(F_d) = 2A\cdot\sin(2\pi f_d\cdot T_p)$



Here we can see elimination of Low frequency noise

This response gives the idea of motion of object.

BLIND SPEED OF OBJECT :-

when the object is moving the ~~the~~ Drift Frequency

$fd = \frac{2 \cdot V_r}{\lambda}$ where V_r is relative Velocity.

$= \frac{n}{T_p}$, where n is super multiple number.

$= n \cdot f_p$ = super multiple of pulse Repetition Frequency.

↳ At a frequency at which $fd = n \cdot f_p$, we can not identify object motion. Because Response is null/zero at these frequencies.

↳ To avoid Blind speed we can cascade multiple Delay Line canceller before we give signal to Display.

↳ By cascading 2 Delay Line canceller we will have 2 responses.

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RADAR TRACKING :-

parameters of RADAR Tracking :-

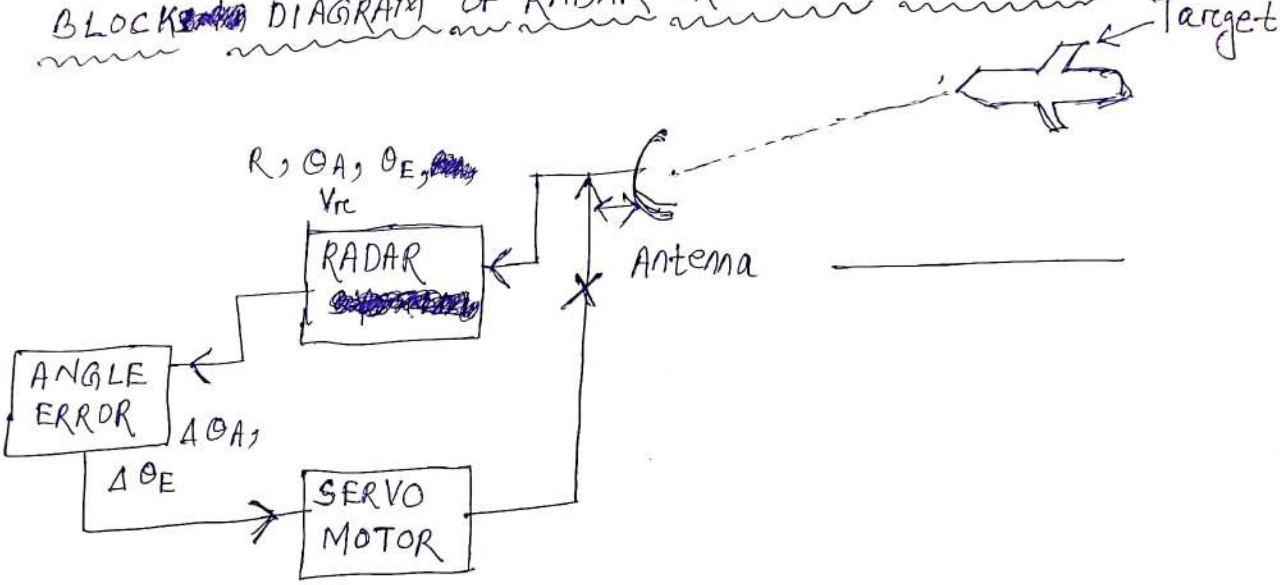
3 parameters we have to identify while tracking the object by RADAR.

(i) Range of object. It determines Distance of object.

(ii) Azimuth and Elevation Angle. It determines the direction of the target (or) object.

(iii) Frequency Drift. It determines the velocity of object.

BLOCK DIAGRAM OF RADAR TRACKING SYSTEM :-



↳ RADAR SYSTEM is calculating 3 Things: Range (R), Azimuthal Angle (θ_A), Elevation Angle (θ_E), Velocity of object (V_{rc}). Based on Error in Angle that is given to one system that gives idea about what is that angle and that is connected to SERVO MOTOR. Let Azimuthal Error Angle $\Delta\theta_A$, Elevation Error Angle $\Delta\theta_E$ that is given to Antenna. Based on that Antenna will turn in its position for Azimuthal Angle correction, Elevation Angle correction.

↳ If the Target is moving and beam is detecting. Based on Frequency Drift we can identify velocity of object.

↳ Abter receiving Angle errore signal the servomotore changes physical orientation of Antenna. In this way direction is modified to track the object.

RADAR TRACKING METHOD :-

① Sequential Lobbing.
② A conical scanning.
③ A mono pulse scanning.

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Scanned by CamScanner

GEO STATIONARY EARTH ORBIT [GEO] :-

(i) These satellites are in orbit 35,863 Km above the earth surface along the equator.

(ii) GEO satellites have a 24 hour View (or) period. (iii) A Latency (or) propagation delay of atleast 240 milliseconds.

(iv) It is possible to cover almost all parts of the earth with just 3 GEO satellites.

(v) Angle of inclination of this satellite with respect to orbit is zero. It moves along same direction of earth Rotation. It is used for Radio broad-casting. (vi) satellite Life is long. (vii) No. of Handoffs is Least(none). (viii) Gateway cost is cheap. (ix) propagation Loss is Highest. EX:- INMARSAT

MEDIUM EARTH ORBIT (MEO) :-

(i) The MEO satellite operates at about 5000 to 12000 Km away from the earth's surface.

(ii) period of revolution is between 2 to 8 hours.

(iii) Latency (or) propagation delay is 100ms.

(iv) 8 to 20 MEO Satellites require to cover the earth. (v) satellite Life is Long. (vi) No. of Handoffs Low. (vii) Gateway cost is expensive. (viii) propagation Loss is High. EX:- GPS, ODDYSEY.

LOW EARTH ORBIT [LEO] :-

(i) LEO satellites operates at a distance of about 500 to 1500 Km. (ii) period of Revolution is 10-40 minutes (iii) Latency (or) propagation delay is very Low.

(iv) 40 to 80 LEO satellites require to cover the entire earth.

(v) Number of Handoffs is High. (vi) satellite Life is short. (vii) Gateway cost is very Expensive. (viii) propagation Loss is Least. EX:- IRIDIUM, GLOBSTAR.

→ A Handoff refers to the process of Transferring an active call (or) data session from one cell in a cellular network to another (or) from one channel in a cell to another.

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GLOBAL POSITIONING SYSTEM [G.P.S.]

(i) Gps provides quickly, accurately, inexpensively to determine the time, position and velocity of any object on the globe at any time with the help of signals received from satellite put in earth centered orbits.

NAVSTAR Gps is a satellite based radio positioning and time transfer system design is operated by US. department of defence, and it is freely accessible by anyone with a Gps Receiver.

Gps is a collection of 24 satellites which orbit 12000 miles above the earth surface constantly transmitting the precise time and their position in space.

Gps ELEMENTS :-

① space/satellite segment :- It consists of 24 operational satellites in 6 orbit of planes (4 satellites in each plane.). The satellites continuously orient themselves to point their solar panels towards the sun and their Antena towards earth. satellites are powered by solarcells. The satellite operate in circuler → → 20200 Km orbits an inclination of 55° with a 12 hour period.

② Control segment :- It consists of Tracking stations located around the world.

one master control station, 5 Monitor stations and sufficient ground antennas are used for this purpose.

③ User segment :- It consists of Antenna, Receivers, processors a that positioning velocity and precise timing to the user.

NAVSTAR Gps → Navigational satellite Timing and Ranging Global positioning system.

GPS Advantages :- (i) Accuracy, poor visibility, rain, fog, no inter visibility, day(or) night used.

DisAdvantages :- High cost, MSL

2.A MASTER CONTROL STATION :- (i) It is located at Falcon Air Force Base in colorado springs. (ii) It is Responsible for overall management of the remote monitoring and Transmission sites. (iii) checkup is performed twice a day, by each of 6 stations, as the satellites complete their journeys around the earth. (iv) It can reposition satellites to maintain an optimal GPS constellation.

2.B MONITOR STATIONS :- (i) It checks the exact altitude, position, speed and overall health of the orbiting satellites. (ii) The control segment ensures that the GPS satellite orbits and clocks remain within acceptable limits. (iii) A station can track up to 11 satellites at a time. (iv) This "check-up" is performed twice a day, by each station.

2.C GROUND ANTENNAS :- (i) Ground antennas monitor and track the satellites from horizon to horizon. (ii) They also transmit correction information to individual satellites. (iii) communicate with the GPS satellites for command and control purposes.

③ USER SEGMENT :- (i) GPS Receivers are generally composed of ① An Antenna (Tuned to the Frequencies transmitted by the satellites. Ⓐ Receiver-processors. Ⓑ Highly-stable clock (commonly a crystal oscillator), (ii) They can also include a display for showing location and speed information to the user. (iii) A Receiver is often described by its number of channels (This signifies how many satellites it can monitor simultaneously). (iv) As of recent, receivers usually have between twelve and twenty channels.

WORKING PRINCIPLE OF GPS :-

Geometric principle :- you can find one's location if you know its distance from others, already-known locations.

Things which need to be determined :- (i) current Locations of Gps satellites. (ii) The Distance between Receiver's position and the Gps satellites.

CURRENT LOCATIONS OF GPS SATELLITES :-

(i) Gps satellites are orbiting the earth at an altitude of 11,000 miles. (1 mile ≈ 1.6 KM)

(ii) The orbits, and the locations of the satellites are known in advance.

(iii) Gps receivers store this orbit information for all of the Gps satellites in an ALMANAC.

(iv) The ALMANAC is a file which contains positional information for all of the Gps satellites.

DISTANCE BETWEEN RECEIVER'S POSITION AND GPS SATELLITES :-

↳ A Gps receiver can tell its own position by using the position data of itself, and compares that data with 3 (or) more Gps satellites.

To get the distance to each satellite :-

(i) By measuring the amount of time taken by radio signal (The Gps signal) to travel from the satellite to the Receiver.

(ii) Radio waves travel at the speed of light, i.e. about 186,000 miles per second.

(iii) The distance from the satellite to the receiver can be determined by the formula "distance = speed X Time".

(iv) Hence receiver's position find out using trilateration.

↳ Distance measurements from two satellites limits our location to the intersection of two spheres, which is a circle.

↳ A Third measurement narrows our location to just two points. A Fourth measurement determines which point is our True location. we require 4 satellites to get our exact location.

ACCURACY :- ① The position calculated by a GPS receiver relies on three accurate measurements: ① current Time ② position of the satellite ③ Time Delay for the signal.

(ii) The GPS signal in space will provide a "worst case" accuracy of 7.8 meters at a 95% confidence level.

(iii) GPS Time is accurate to about 14 nanoseconds.

(IV) Higher accuracy is available today by using GPS in combination with augmentation systems. These enable real time positioning to within a few centimeters.

——x—— x —— x ——

VERY SMALL APERTURE TERMINAL (VSAT) :-

↳ VSAT is a small satellite earth station that transmits and receives data, voice (or) video via satellite.

↳ The "very small" component of the VSAT refers to the size of the VSAT dish antenna- typically about 60cm to 3.8mtr.

↳ It requires no additional technology to operate it.

↳ It simply plugs in to existing terminal equipment.

↳ If the size of the Antenna decreases Then Transmitted power increases and frequency of Transmitting signal increases.

↳ Early Earth stations in commercial systems were very large and expensive.

↳ Need to make system more affordable to end user:-

(i) Increased Transmit power from Satellite.

(ii) Higher frequencies.

↳ So, smaller Earth station (ES) antenna size required.

VSAT Implementation :- There are several ways VSAT services might be implemented.

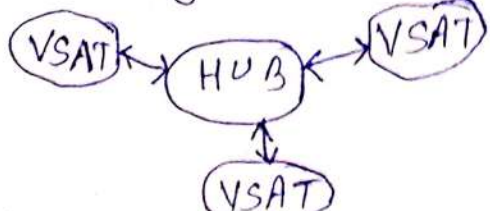
(i) one-way (Example- TV Broadcasting satellites.)

(ii) Split-Two-way (split IP) Implementation (return link from user is not via the satellite : ex:- Direct TV).

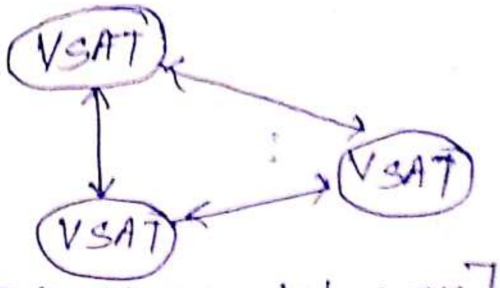
(iii) Two-way Implementation (up and down-link)

TWO-WAY IMPLEMENTATION :- It is further classified in to two types.

① STAR VSATs are linked via a HUB. ② MESH VSATs are linked together without going through a large hub.



[STAR VSAT Network]



[MESH VSAT Network.]

↳ In star Network Architecture, all of the traffic is routed via the Master control station (or) Hub.

↳ If a VSAT wishes to communicate with another VSAT, first VSAT sends signal to Satellite, Then satellite send signal to HUB, HUB retransmits the signal to Satellite and through satellite the signal will reach to another ~~sat~~ VSAT.

↳ Thus necessitating a "double hop" link via satellite.

↳ Since all of the traffic radiates from the HUB, This architecture is referred to as a STAR Network.

↳ In mesh Architecture, each of the VSATs has the ability to communicate directly with any of the other VSATs.

↳ Since The traffic can go to (or) from any VSAT, This architecture is referred to as a MESH network.

↳ It will still be necessary to have network control and the duties of the hub can either be handled by one of the VSATs. (OR) The master control station functions can be shared amongst the VSATs.

ADVANTAGES OF STAR NETWORK:- ① It reduces the transferring of the packets from the excessive number of nodes. ② central Hub facilitates the easy addition of the new devices. ③ It is easy to understand, install and navigate. ④ Faulty parts can be easily detected and eliminated. ⑤ It is interference free at the time of adding and removing devices.

LIMITATIONS:- ① The functioning of the system highly depends upon the central hub. (ii) Any lapse in the central hub can result in the inoperability of the entire system. (iii) Scalability relies on the capability of the central HUB.

ADVANTAGES OF MESH NETWORK:- ① The mesh topology helps more than one transmission of data from one node to another node simultaneously. ② provides privacy and security with the point-to-point links. ③ It is robust, failure of one link does not affect the other system. ④ Fault identification and isolation are also easy.

LIMITATIONS:- ① It can create redundant n/w connections, as there are some connections which are useless. ② The overall cost of the topology is also increased because of an excessive amount of cabling and need of i/o ports. ③ wiring is complex.

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Satellite Frequencies :-

↳ There are specific frequency ranges used by commercial satellites.

① L-band, 1·0 to 2 GHZ (Mobile Satellite Services)
② S-band, 1·55 to 3·9 GHZ (MSS, DARS -XM, SIRIUS)
③ C-band, 3·7 to 6·2 GHZ (FSS, VSAT)
④ X-band, 8 to 12 GHZ (Military / satellite Imagery)
⑤ KU-band, 11·7 to 14·5 GHZ (FSS, DBS, VSAT)
⑥ Ka-band, (FSS "broadband" and inter satellite Links.)
(17·7 to 21·2 GHZ and 27·5 to 31 GHZ)

Frequency Efficiency :-

↳ The vital resource in satellite communications is spectrum.

↳ As the demand for satellite services has grown, the solution has been:

(i) To space satellites close together.
(ii) Allocate new spectrum in higher bands.
(iii) Make satellite transmissions more efficient so that more bits/HZ can be transmitted and
(iv) To find ways to re use allocated spectrum such as through geographic separation in to separated cells (or) beams (or) through polarization separation.

↳ Today the satellites systems transmit more efficiently than ever before but interference is now a bigger problem - there is a basic trade off :

(i) The higher the frequency the more spectrum that is available.
(ii) But, the higher the frequency the more problems with interference from other users terrestrial, unlicensed etc.

—— x ——

SATELLITE :- (i) An artificial body placed in orbit around the earth to collect information (or) for communication.

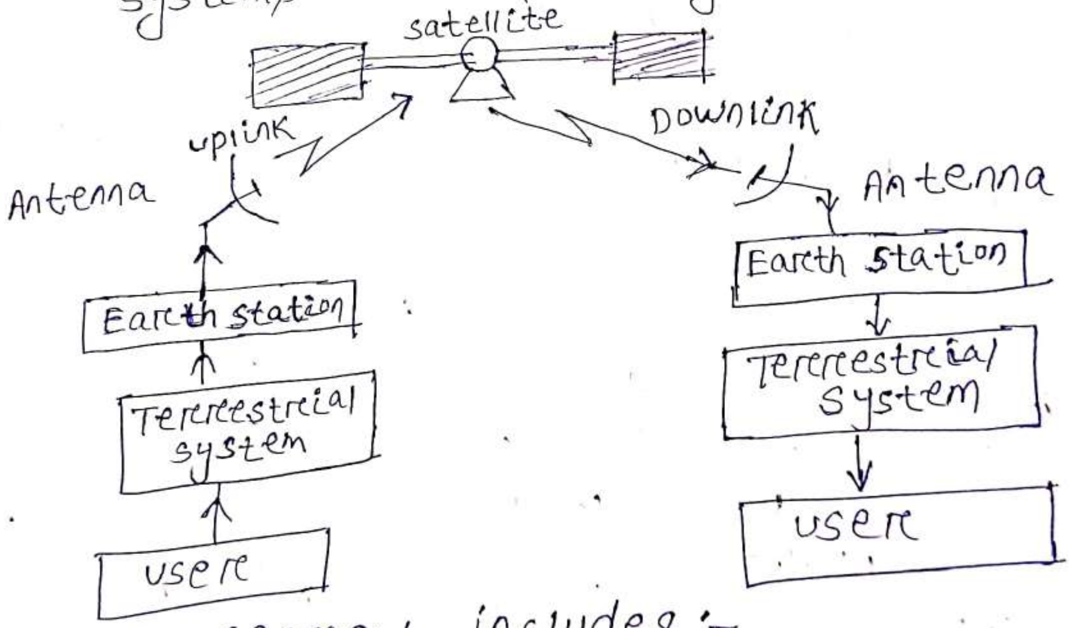
(ii) For example, Earth is a satellite because it orbits the sun.

(iii) A communications satellite is a radio relay station in orbit above the earth.

(iv) It receives, amplifies and redirects analog and digital signals carried on a specific radio frequency.

(v) satellite communications play a vital role in the global telecommunications system.

(vi) Two major elements of satellite communications systems are: ① space segment. ② Ground segment.



① **space segment includes:-**
(i) satellite, (ii) Means for launching satellite, (iii) Electrical power system (iv) Mechanical structure. (v) communication Transponders, (vi) communication Antennas & (vii) Attitude and orbit control system.

② **Ground segment includes :-** (i) Earth stations. (ii) Rear ward communication links. (iii) user terminals and interfaces. (iv) Network control centre. (v) Transmit equipment. (vi) Receive equipment. (vii) Antenna system.

Satellite control centre function : ②

(i) Tracking of the satellite. (ii) Receiving Data.
(iii) Eclipse Management of satellite.
(iv) commanding the satellite for station keeping.
(v) Determining orbital parameters from Tracking and Ranging data.
(vi) switching on/off of different subsystems as per the operational reequirements.

ORBITS :-

↳ The path of a satellite follows around a planet is defined as an orbit.

↳ satellite orbits are classified in two broad categories : (i) Non Geostationary orbit (NGSO)
(ii) Geo stationary orbit (GSO)

(i) NGSO :-

↳ Early ventures with satellite communications used satellites in Non-geostationary Low earth orbits due to the technical limitations of the launch vehicles in placing satellites in higher orbits.

classification of NGSOs as per the orbital plane are :-

① polar orbit :- In polar orbit the satellite moves from pole to pole and the inclination is equal to 90 degrees.

② Equatorial orbit :- In equatorial orbit the orbital plane lies in the equatorial plane of the earth and the inclination is zero (or) very small.

③ Inclined orbit :- All orbits other than polar orbit and equatorial orbit are called inclined orbit.

Advantages of NGSO :-

① Less booster power required. ② Less delay in transmission path. ③ Reduced problem of echo in voice communications. ④ Suitability for providing service at higher latitude. ⑤ Lower cost to build and launch satellites at NGSO.

Disadvantages of NGSO :-

① Complex problem of transferring signal from one satellite to another.

② Less expected life of satellites at NGSO.

③ Requires frequent replacement of satellites compared to satellite in GSO.

④ Problem of increasing space trash in the outer space.

⑤ Requirement of a large number of orbiting satellites for global coverage.

⑥ As each Low earth orbit satellite covers a small portion of the earth's surface for a short time.

GEOSTATIONARY ORBIT (GSO) :-

① There is only one geostationary orbit possible around the earth:

ⓐ Lying on the earth's equatorial plane.

ⓑ The satellite orbiting at the same speed as the rotational speed of the earth on its axis.

Advantages :- (i) Simple ground station tracking. (ii) Nearly constant range. (iii) Very small frequency shift.

Disadvantages :- (i) Transmission delay of the order of 250 msec. (ii) Large free space loss. (iii) No polar coverage.

Satellite orbits interms of the orbital height :

↳ According to distance from earth:

① GEOsynchronous Earth orbit (GEO), 35786 Km above the earth.

② Medium Earth orbit (MEO), 8000 to 20,000 Km above the earth.

③ Low Earth orbit (LEO), 500 to 2000 Km above the earth.

FREQUENCY BANDS :-

Band	Frequency Range	wavelength Range
Extreemely Low Frequency (ELF)	< 3 KHZ	> 100 Km
Very Low Frequency (VLF)	3 to 30 KHZ	10 to 100 Km
Low Frequency (LF)	30 to 300 KHZ	1 to 10 Km
Medium Frequency (MF)	300 KHZ to 3 MHZ	100m to 1 Km
High Frequency (HF)	3 to 30 MHZ	10 to 100m
Very high Frequency (VHF)	30 to 300 MHZ	1 to 10m
Ultra high Frequency (UHF)	300 MHZ to 3 GHZ	10m to 1m
Super high Frequency (SHF)	3 to 30 GHZ	1 to 10 cm
Extreemely high Frequency (EHF)	30 to 300 GHZ	1mm to 1 cm

Where used frequency bands :

L-band → Mobile satellite service (MSS), Narrow-Band Voice and Data.

S-band → Digital Audio Radio service (DARS).

C-band → Fixed satellite service (FSS), shared with Terrestrial.

X-band → FSS-Government Exclusive use.

KU-band → FSS- Broadband services, Not shared with Terrestrial

Ka-band → FSS -Broadband services,

EVOLUTION OF SATELLITE COMMUNICATION :-

↳ During early 1950s, both passive and active satellites were considered fore the purpose of communications over a large distance.

↳ passive satellites through successfully used in the early years of satellite communications, with the advancement in technology active satellites have completely replaced the passive satellites.

PASSIVE SATELLITES :- ① A satellite that only reflects signals from one Earth station to another, (or) from several Earth stations to several others.
② It reflect the incident electromagnetic radiation without any modification (or) amplification.
③ It cannot generate power, they simply reflect the incident power.
④ The first artificial passive satellite Echo-1 of NASA was launched in August 1960.

Disadvantages :- ① Earth stations required high power to transmit signals. ② Large Earth stations with tracking facilities were expensive. ③ A global system would have required a large number of passive satellites accessed randomly by different users. ④ control of satellites not possible from ground. ⑤ The large attenuation of the signal while traveling the large distance between the transmitter and the receiver via the satellite was one of the most serious problems.

ACTIVE SATELLITES :- ① In active satellites, it amplify or modify and retransmit the signal from the earth. ② satellites which can transmit power are called active satellite.

Advantages :- ① Require lower power earth station. ② Less costly. ③ Not open to random use. ④ Directly controlled by operators from ground.

↳ world's first active satellite was SCORE (satellite communication by orbiting Relay Equipment) Launched by US Air force in 1958. At orbital height of 110 miles to 900 miles.

↳ The first fully active satellite was Courier, Launched into an orbit of 600 to 700 mile, By department of Defense in 1960.

Disadvantages :-

↳ Requirement of larger and powerful rockets to launch heavier satellites in orbit.

↳ Requirement of on-board power supply.

↳ Interruption of service due to failure of electronics components.

one-way satellite services are :-

① Broadcast Satellite service:- Radio, TV, Data broadcasting.

② safety services : search and Rescue, Diaster warning.

③ Radio Determination satellite service (position Location.)

④ standard frequency and time signal satellite service.

⑤ space Research service. ⑥ space operations service. ⑦ Earth Exploration satellite service.

Two-way satellite services are :-

① Fixed satellite service : Telephone, Fax, high bit rate data etc.

② Mobile Satellite service : Land mobile, Maritime mobile, Aero-mobile, personal communications.

③ satellite News Gathering. ④ Inter satellite service.

Advantages of satellite communication :-

① universal : satellite communications are available virtually everywhere.

② versatile : satellites can support all of ~~the~~ today's communications needs.

③ RELIABLE : Satellite is a proven medium for supporting a company's communications needs.

④ SEAMLESS : Satellite's inherent strength as a broadcast medium makes it prefect.

⑤ FAST : since satellite networks can be setup quickly, companies can be fast-to-market with new services.

⑥ Flexible, ⑦ Expandable, ⑧ High quality, ⑨ Quick provision of services, ⑩ Mobile and Emergency communication, ⑪ Suitable for both Digital and Analog Transmission.

Applications of satellite communication :-

↳ Telephone, Television, Digital cinema, Radio, Internet access, Military.

DIRECT BROADCAST SATELLITE (DBS) :-

↳ Direct broadcast satellite (DBS) refers to satellite television (TV) systems in which the subscribers, or end users, receive signals directly from geostationary satellites. Signals are broadcast in digital format at microwave frequencies. DBS is the descendant of direct-to-home (DTH) satellite services.

↳ A DBS subscriber installation consists of a dish antenna two to three feet (60 to 90 centimeters) in diameter, a conventional TV set, a signal converter placed next to the TV set, and a length of coaxial cable between the dish and the converter. The dish intercepts microwave signals directly from the satellite. The converter produces output that can be viewed on the TV receiver.

Components of DTH :- The major components of DTH are ① satellites. ② Broadcasting centre. ③ Multiplexers, ④ Modulators, ⑤ Encoders.

satellite :- (i) A Geostationary satellite plays an important role in DTH systems. Satellites are higher in the ~~[illegible]~~ SKY than TV antennas, so they have a much larger "Line of sight" range.

(ii) The television satellites are all in geosynchronous orbit, meaning that they stay in one place in the SKY relative to the Earth.

(iii) Each satellite is launched in to space at about 7,000 mph (11,000 Kmph), reaching approximately 35,700 KM above the earth.

(iv) In India DD Direct and Dish TV transmission services are from NSS-6 satellite.

Broadcast centre:-

① The provider does not create original programming itself. It pays other companies (Ex: ESPN) for the right to broadcast their content via satellite. In this way, the provider is kind of like a broker between you and the actual programming sources.

② The Broadcast centre is the central Hub of the system.

③ At the broadcast center, the television provider receive signals from various programming sources and beams a broadcast signal to satellites in geostationary orbit.

④ The satellites receive the signals from the broadcast station and rebroadcast them to the ground.

⑤ The viewer's dish picks up the signal from the satellite (or multiple satellites in the same part of the sky) and passes it on to the receiver in the viewer's house. The receiver processes the signal and passes it on to a standard television.

Multiplexer:- ① A multiplexer is a device which transmits the information of many channels in one channel. ② The multiplexer is built in the broadcasting centre. ③ The multiplexer in the broadcasting centre compresses all the frequency signals in to one single channel and transmits it to the geostationary satellite. ④ It sends the single channel to the modulator.

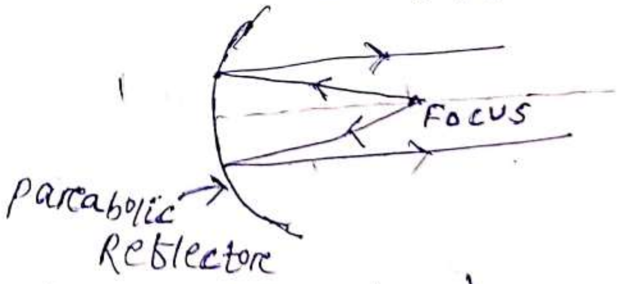
Modulator :- ① Modulation is a process in which the information signal is imposed on a carrier signal which is of high strength and greater frequency. ② This process is done in the modulator. ③ The Modulator modulates the signals and sends to the encoder.

Encoder :- ① The encoder encodes the signals to transmit the signals. ② The satellite sends the signals to the DTH antenna. The antenna transmits the signals to the set top box.

③ The other components of DTH are: DTH antenna, LNB, set top box.

DTH Antenna :- ① The reflector's surface material must be constructed out of metal inorder to reflect the incoming microwave signals.

② Some antenna reflectors appear to be manufactured out of plastic (or) fiber glass; however, these dishes actually have an embedded metal mesh material that reflects the incoming satellite signals to the front and centre of the dish.



LNB (Low Noise Block Down Converter) :-

① The incoming satellite signal propagates down the waveguide of the feed horn and exits in to a rectangular chamber mounted at the front of the Low-noise block down converter (LNB), in which a tiny resonant probe is located.

② This pickup probe, which has a wavelength that resonates with the incoming microwave frequencies, conducts the signal onto the first stage of electronic amplification.

③ LNB in addition to amplifying the incoming signal, the first stage ~~of~~ of electronic amplification also generates thermal noise internally. The internal noise contribution of the LNB is amplified along with the incoming signal and passed on to succeeding amplifier stages.

④ A wide band product called a "universal" KU-band LNB is available that can switch electronically between the 10.7 to 11.7 and 11.7 to 12.75 GHZ frequency spectra to provide complete coverage of the entire KU-band frequency range.

Set-Top Box :- ① It accepts the entire down converted band and separates out the individual transponder frequency.

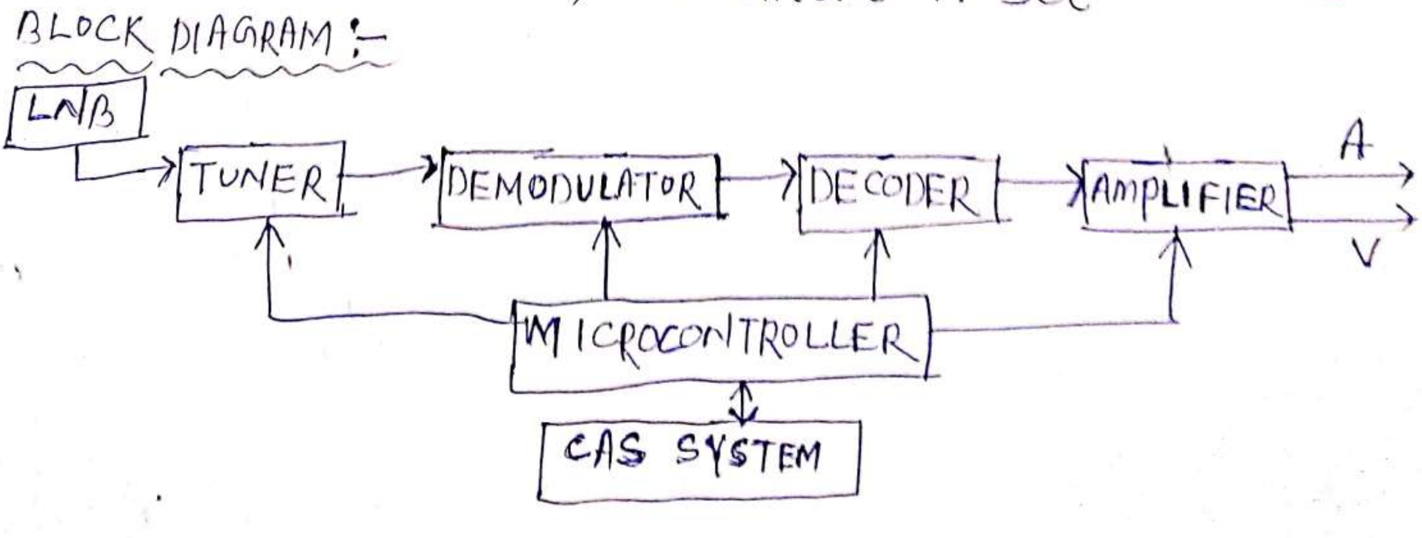
② Then signals are first converted to fixed IF and then QPSK demodulated. ③ The bandwidth of QPSK signals is 27.5 MHZ as the bitrate is 27.5 Mb/s.

④ It is observed that 11 digital channels are multiplexed in 27.5 MHZ bandwidth. ⑤ After the QPSK demodulation the digital bit stream obtained contains several multiplexed channels as well as error control bits.

⑥ The bit stream is processed to correct and detect errors, deinterleaved and decrypted.

⑦ A digital demultiplexer then extracts the bits for wanted channel, and sends them to MPEG decoder, and finally generates analog Audio and video signals with D/A converters to drive TV set.

BLOCK DIAGRAM :-



working of DTH :-

↳ A DTH network consists of a broadcasting centre, satellites, encoders, multiplexers, modulators and DTH receivers. ↳ A DTH service provider has to lease KU-band transponders from the satellite.

↳ The encoder converts the audio, video and data signals into the digital format and the multiplexer mixes these signals.

↳ At the user end, there will be a small dish anteena and set-top boxes to decode and view numerous channels.

↳ on the user's end, receiving dishes can be as small as 45cm in diameter.

↳ DTH is an encrypted transmission that travels to the consumer directly through a satellite.

↳ DTH transmission is received directly by the consumer at his end through the small dish antena.

↳ A set-top box, unlike the regular cable connection, decodes the encrypted transmission.

compression :-

↳ The two major providers in the united states use the MPEG-2 compressed video format - The same format used to store movies on DVDs.

↳ with MPEG-2 compression, the provider can reduce the 270-Mbps stream to about 5 (or) 10 Mbps (depending on the type of programming).

↳ This is the crucial step that has made DBS service a success.

↳ with digital compression, a typical satellite can transmit about 200 channels.

↳ without digital compression, it can transmit about 30 channels.

Encryption and Transmission :-

↳ After the video is compressed, the provider needs to encrypt it in order to keep people from accessing it for free.

↳ Encryption scrambles the digital data in such a way that it can only be decrypted (converted back in to usable data) if the receiver has the correct decryption algorithm and security keys.

Advantages of DTH :- ① with DTH service we can get direct television services to our home which can be situated at any position.

② As the DTH service is based on satellite and there is not requirement of wires signal like cable TV connection anywhere of the country.

③ DTH also give us best sound and clear picture quality. ④ with DTH service we can select the channel programs as our choice.

⑤ we can pay the subscription fee online through net-banking (or) credit card.

—— x ——

SATELLITE TELEVISION :-

↳ satellite Television is television programming delivered by the means of satellite communications and received by an outdoor antenna, usually a parabolic reflector generally referred to as a "satellite dish.

↳ In many areas of the world satellite television provides a wide range of channels and services, often to areas that are not serviced by terrestrial (or) cable providers.

Technology of satellite TV :-

① satellite television, like other communications relayed by satellite, starts with a transmitting antenna located at an uplink facility.

② uplink satellite dishes are very large, as much as 9 to 12 meters (30 to 40 feet) in diameter.

③ The uplink dish is pointed toward a specific satellite and the uplinked signals are transmitted within a specific frequency range.

④ These signals received by one of the transponders tuned to that frequency range.

⑤ The transponder 're transmits' the signals back to Earth.

⑥ The satellite receiver (or) set top box demodulates and converts the signals to the desired form.

Cable TV (vs.) Satellite TV :-

↳ Cable TV is very similar to terrestrial television with the exception that the signal cable goes all the way to the provider where as terrestrial television goes over the air. A few drawbacks of cable TV include subscription costs as well as availability. Very few if any cable providers offer any basic cable service free of charge. Also the user is **limited** to whatever is provided from their cable operator.

↳ The main advantage of satellite TV over cable is the ability to freely explore free to air channels provided on a wide range of satellites. This is where a custom built satellite system becomes very useful particularly when accompanied by a multi dish setup. While custom built systems can work out rather expensive, the user gets far more features than a sky receiver when it comes to exploring foreign satellites.

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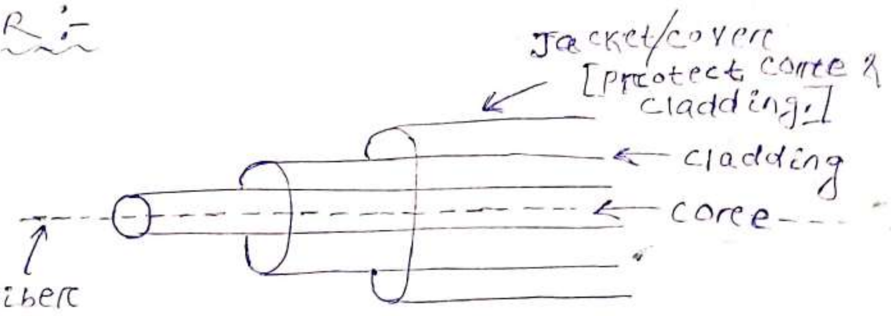
OPTICAL FIBER :-

STRUCTURE :-

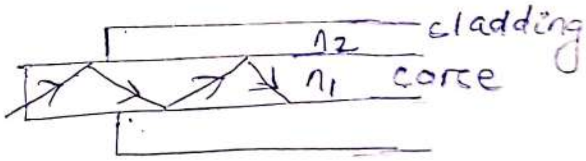


↳ signal always passes through only core. If Refractive Index of core is n_1 and refractive Index of cladding is n_2 Then $(n_1 > n_2)$

↳ optical Fiber consists of core, cladding and Jacket. Jacket/cover protects core and cladding.

TYPES :- There are 2 types of optical fiber.
① step Index optical Fiber. ② Graded Index optical Fiber.

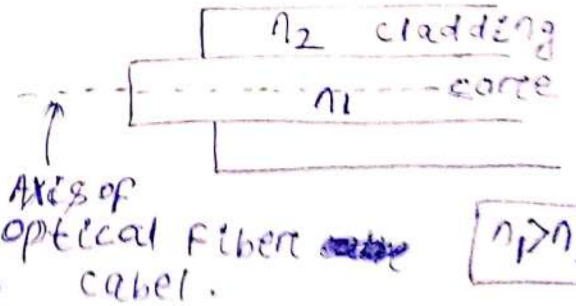
① step Index optical Fiber :- Here Refractive Index of core n_1 is uniform.



For Total Internal Reflection $\boxed{n_1 > n_2}$ and it occures at core-cladding border.

② Graded Index optical Fiber :-

↳ Here Refractive index n_1 is highest at fiber axis for core. It will decrease as we move towards peremeter of core.



$\boxed{n_1 > n_2}$

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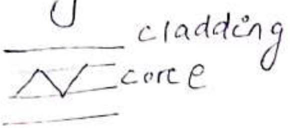
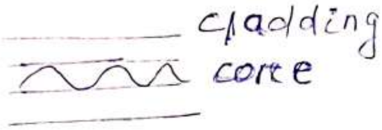
comparision of step Index and Graded Index Fiber :-

parameter	step Index	Graded Index
① Data Rate	slow	Higher
② coupling efficiency	Higher	Low
③ path Ray		
④ Index variation	$\Delta = \frac{n_1 - n_2}{n_1}$	$\Delta = \frac{n_1^2 - n_2^2}{2 n_1^2}$
⑤ Numerical Aperature [NA]	NA remains constant	NA will change
⑥ Material	Glass (or) plastic	Glass only
⑦ Bandwidth Efficiency	10 to 20 MHZ/Km	1 GHZ/Km
⑧ pulse spreading	More	Less
⑨ Light source	LED	LED, LASER
⑩ Applications	For Local Network communication	For Local and wide area Network

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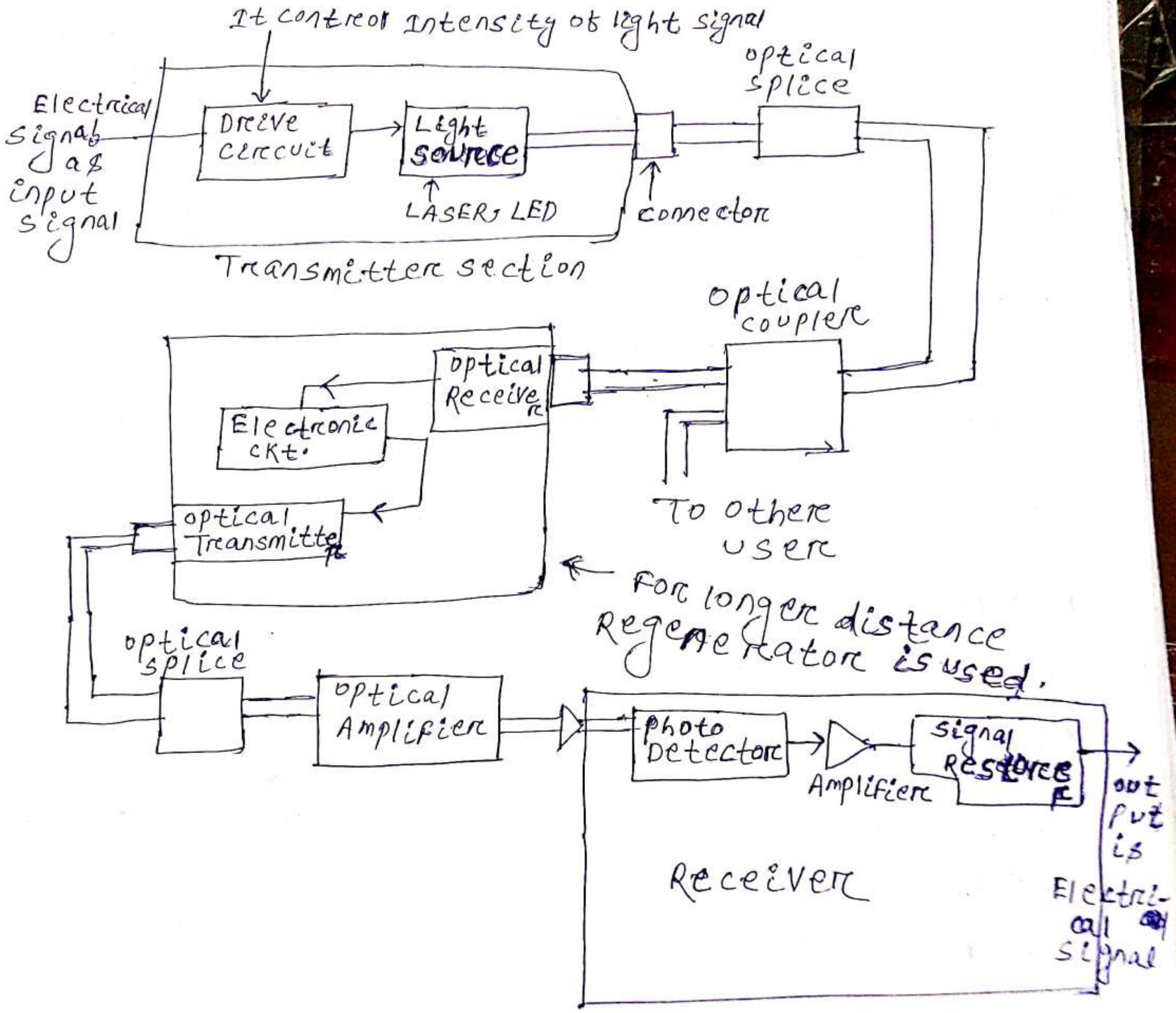
BLOCK DIAGRAM AND WORKING OF OPTICAL FIBER COMMUNICATION SYSTEM :-



- ↳ optical splice will connect two optical fibers.
- ↳ optical coupler will give the light signal to multiple users with multiple ends.
- ↳ Regenerator regenerates the original signal.

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MODES OF OPTICAL FIBER:-

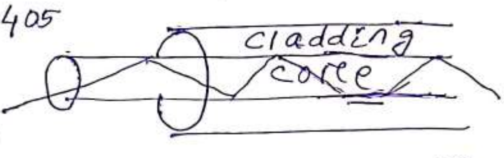
① Two Types of Modes. ⓐ single mode optical Fiber.
ⓑ Multimode optical Fiber.

V-NUMBER:- $V = \frac{2\pi n a \cdot \sqrt{2\Delta}}{\lambda}$, where Δ = Refractive Index Difference between core and cladding $M_1 - M_2$

n = Mode, λ = wavelength,
a = Radius of core.

ⓐ single Mode optical Fiber:- (i) we transmit only one mode through optical Fiber.

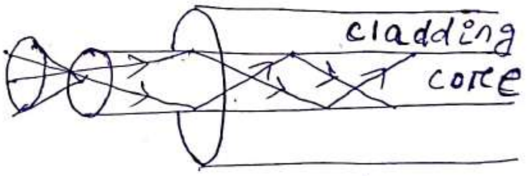
(ii) Here V-number is Less than 2·405



(iii) Here core Diameter is very Less for single Mode optical Fiber. (iv) There is no Dispersion effect. (v) Bandwidth is High (in terms of 1000 MHZ, 10^6), (vi) It is used for long haul communication. (vii) Fabrication is difficult and costly

ⓑ Multimode optical Fiber:- ① we transmit more than one mode through fiber.

(ii) Need of higher radius of core.
(iii) V-number is greater than 2·405.



(iv) Higher Dispersion. (v) Lower Bandwidth (50MHZ)
(vi) It is used for short distance communication.
(vii) Fabrication is easy and not costly.

TYPES OF OPTICAL FIBERS :- [4 (OR) 6 Marks.]

optical fibers in general are of 2 Types. ① single Mode fiber (SMF). ② Multi Mode fiber (MMF).

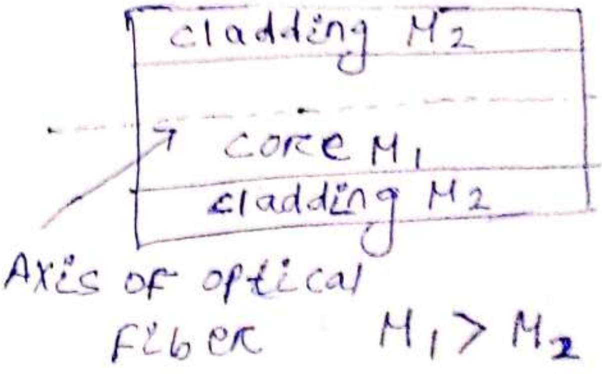
① single mode fiber :- (SMF) ↳ It has a very small core diameter and can support only one mode of propagation i.e. it can carry only one wavelength of light across its length. The wavelength is usually 1310 nm to 1550nm. SMF has higher bandwidth (1000MHz) & it is used for long distance high speed communication as there is no loss of intensity of light signal. They show no dispersion effect. They are highly efficient. V-number is less than 2.405

DISADVANTAGES :- (i) fabrication is difficult and costly. (ii) They are difficult to work with because of their small core diameter.

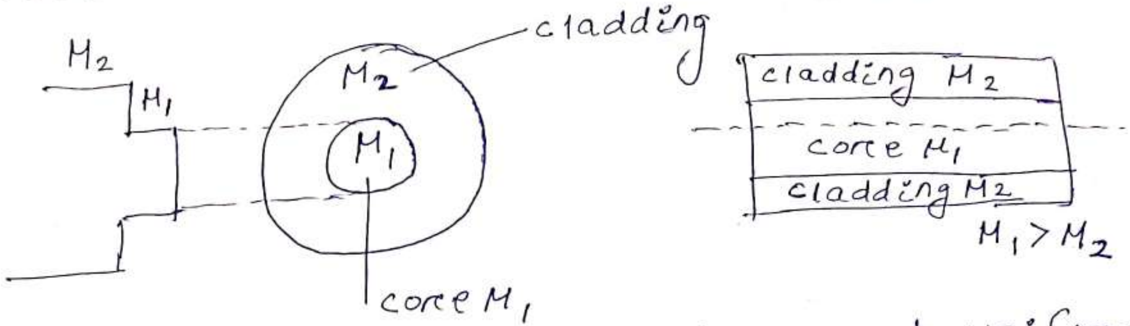
② MULTIMODE FIBER (MMF) :- ↳ MMF has a larger core diameter and can support large number of modes of propagation. The wavelengths of light waves in MMF are in visible spectrum ranging from 850nm to 1300nm.

Based on the Index profile SMF & MMF can be further classified in to following categories.

ⓐ step Index SMF.
ⓑ step Index MMF.
ⓒ Graded Index MMF.



ⓐ STEP-INDEX SINGLE MODE FIBER (SMF) :-



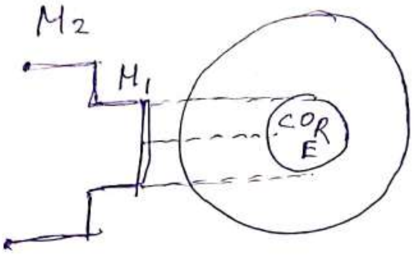
↳ step Index SMF has a very thin core of uniform refractive index ($\mu_1 = 1.5$) surrounded by a cladding of refractive Index ($\mu_2 = 1.48$) lower than that of core. Here the refractive Index abruptly changes at core - cladding interface. so it is known as step Index fiber. The core diameter is 2 to 8 μm while that of cladding is 125 μm. V-Number lies between 0 to 2.405. They have Low value of Numerical Aperture (N.A.) & hence Low acceptance Angle.

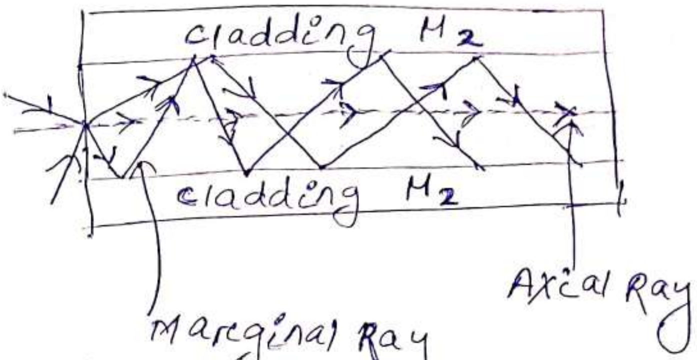
ⓑ STEP-INDEX MULTIMODE FIBER (MMF) :-

↳ Here core Diameter is of larger than step index SMF (50 to 200 μm). The diameter of cladding is ~~100-250~~ 100-250 μm. The V-number is greater than 2.405 so that it can support large number of modes of propagation. Here Refractive Index abruptly changes at the core-cladding interface so it is known as step Index MMF. There are 2 rays that travel along the core.

① **Axial Ray** :- The light rays which travel along the axis of fiber.

② **paraxial Ray** :- The light rays which suffers multiple Total Internal Reflection (TIR) at core-cladding interface.

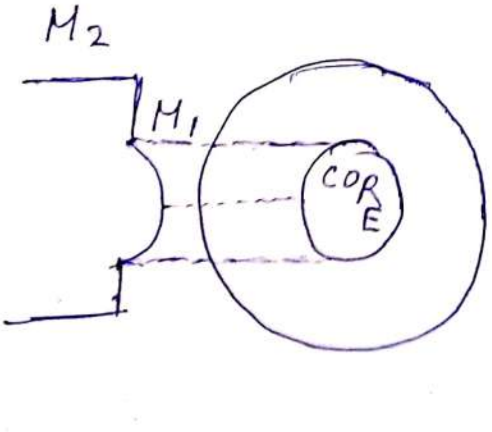


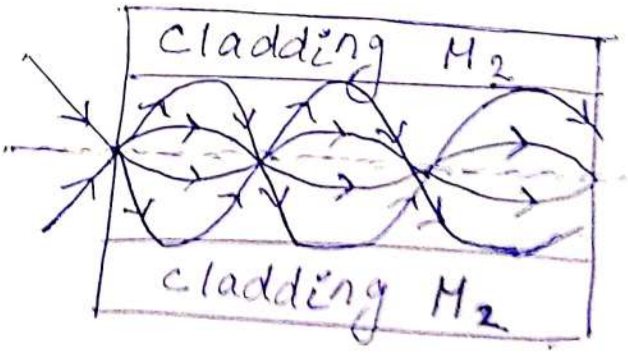


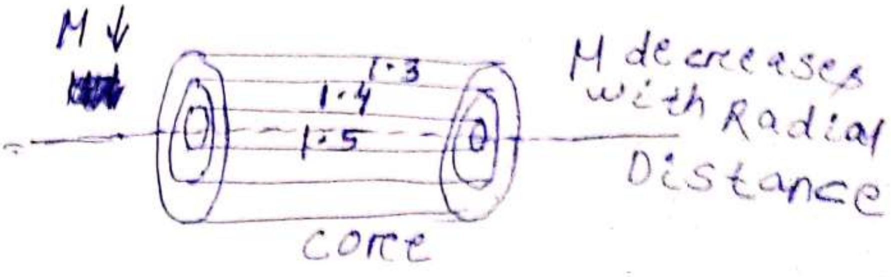
The marginal rays will travel more distance than axial ray and will take more time. This time delay in axial rays and marginal rays causes distortion in the pulse.

(c) Graded Index MULTIMODE FIBER (MMF) :-

It has a core which consists of concentric Layers of different refractive Indices and the value of refractive Index of core decreases with distance from the fiber axis. It has high value along fiber axis and falls off rapidly as the radial distance increases from fiber axis. But the Refractive Index of cladding is constant.



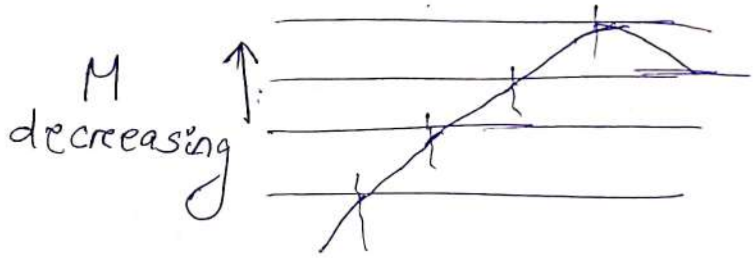




In this fiber, the propagation of Light wave due to refraction and Total Internal Reflection. The light rays propagating through fiber bend continuously and follows helical path.

Disadvantages of MMF :- ① short Bandwidth.
② It can be used only for short distance communication.
③ It shows Dispersion effect. ④ Less efficient.

Advantages :- ① Easy to work with because of Larger core diameter
(ii) Fabrication is easy and inexpensive.



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ADVANTAGES OF OPTICAL FIBER COMMUNICATION:-

① Low Transmission Loss and wide Bandwidth (GHz Range)

Here, ⓐ Losses on fiber Lines is 0.2dB/Km whereas in copper wire Loss is 5dB/Km.

ⓑ Less numbers of wires and repeaters needed.

ⓒ system cost reduced.

② Small size and weight.

③ Immunity to Interference.

④ Electric Isolation.

⑤ signal security.

⑥ Resistance to High Temperature.

⑦ Abundant Raw Material.

DISADVANTAGES OF OPTICAL FIBERS:-

① Branching of optical fiber.

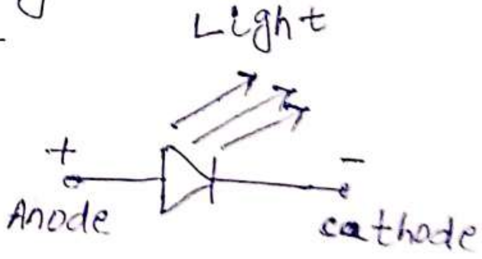
② Joining of fibers.

③ Effect of Gamma Radiation.

④ Installation cost is high.

—— x —— x ——

LIGHT EMITTING DIODE (LED):-



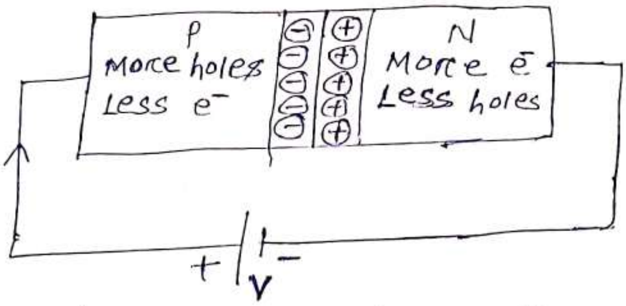
→ Here, The Diode that emits Light to outside.

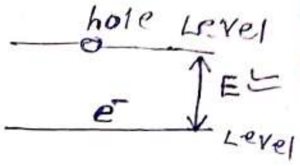
→ It is heavily doped p-n Junction.

→ In forward Bias LED emits Radiation (Energy photon)

→ It is having Transparent cover.

→ By making forward Bias, Holes in p-side move to n-side where more electrons are available. So, Electron Hole combination occurs and that gives Light Energy (E) in terms of photon having particular wavelength (λ).

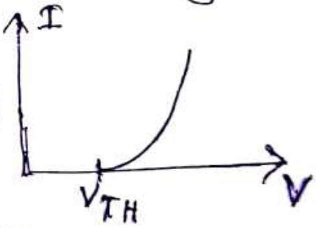




$$E = h \cdot f$$
$$= \frac{h \cdot c}{\lambda}$$
$$\boxed{\Rightarrow \lambda = \frac{h \cdot c}{E}}$$

↳ The Emitted Light should be visible Light (violet to Red). For violet color Light wavelength λ is 380-450nm, for Blue λ is 450-495nm, for Green λ is 495-570nm, For Yellow λ is 570nm-590nm, For orange λ is 590-620nm, For Red λ is 620-750nm.

↳ By giving More forward Bias voltage (V↑), current increases (I↑), so More electron and hole pair combination occurs. So More Light Intensity is produced.



↳ The V-I characteristics of a LED is similar to silicon Diode. For silicon(si) Diode V_{TH} (THRESHOLD VOLTAGE) = 0.7Volt. For LED, V_{TH} is higher. For Red LED V_{TH} is 1.6 to 2.03Volt, For Yellow LED V_{TH} is 2.1 to 2.18 Volt, For orange LED V_{TH} is 2.03 to 2.10 Volt, For Green LED V_{TH} is 1.9 to 4.0 Volt.

↳ Reverse Breakdown voltage are very Low, we can not apply more than 5 Volt across LED in Reverse Bias.

↳ The semiconductor Material used for making LED is GaAs for Infrared LED, $GaAs_{1-x}P_x$ for Different color LED. (Gallium Arsenide phosphide).

↳ LED is used in Remote control, optical communication.

ADVANTAGE:- ① Low power, Less operational Voltage, (5Volt). ② Fast Action and No-warmup time is required. ③ Long Life, ④ More efficient (Heat is not produced)

— x — x — x —

PIN PHOTODIODE :-

Basics :- (i) As name indicates, this diode has intrinsic layer sandwitched in between two highly doped p-Type and n-Type layer.

(ii) It gives performance improvement compared to pn-photodiode.

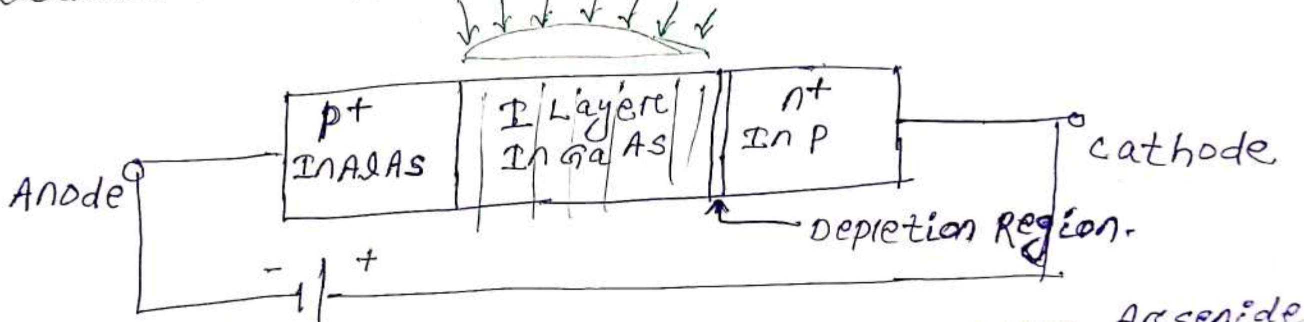
(iii) PIN photodiode has layers as per $p^+ - i - n^+$.

(iv) p^+ and n^+ layers has less resistivity around less than 1 Ω.

(v) I Layer has high resistivity ranges from 10 Ω/cm to 100 KΩ/cm. (Low Impurity)

(vi) PIN diode has larger depletion Area.

Structure of PIN Photodiode :-



↳ Here p^+ layer is madeup off Indium Aluminium Arsenide material, I-Layer is madeup off Indium Galium Arsenide material, n^+-Layer is made up off Indium Phosphide material.

↳ At no bias condition The depletion Region exists at I-n^+ Junction. To increase Depletion Region we will apply Reverse bias. Depletion Region covers entire I-Layer having large Depletion region Area. So more area available for light to generate more electron hole pair. So Large current flows here as compare to normal PN photodiode. So, Larger quantum efficiency we will get.

↳ Low capacitance is produced $c = \frac{\epsilon_0 \cdot \epsilon_r \cdot A}{d}$, since d is more so capacitance c is less in pin photodiode.

↳ Lower capacitance will result in to less current because of biasing. and more current because of light.

Advantages:- ① Very low reverse bias is necessary. ⑪ It has high quantum efficiency as compare to normal photodiode.
(iii) A large Bandwidth (BW) can be obtained by using this photodiode.
(iv) Lower noise ~~rate~~ performance is there with this photodiode.

Disadvantages:- ① It does not amplify signal.

—— x ——

LASER :-

Basics :- (i) LASER means Light Amplification by Stimulated Emission of Radiation.

(ii) The first LASER was built by Theodore H. Maiman at Hughes Research Lab. in 1960, based on theoretical work by Charles Hard Townes and Leonard Schawlow.

(iii) LASER has so many applications like Scientific, medical, commercial and medical applications.

Properties of LASER :-

(i) Line width of Light by LASER is very narrow.

(ii) It follows Monochromaticity (It has single frequency and wavelength.)

(iii) Light transmitted by LASER is coherence (It has same phase, frequency and wavelength.)

(iv) It has high directivity. Light can be sent to long distance.

(v) High intensity of beam is generated by LASER.

(vi) Stability of beam is excellent.

(vii) High quantam efficiency.

(viii) LASER Light can travel very long distance.

(ix) For LASER spectral width is very Narrow.

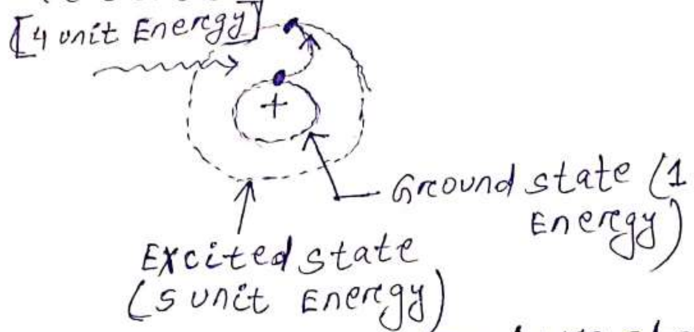
(x) It has very high Modulation rate.

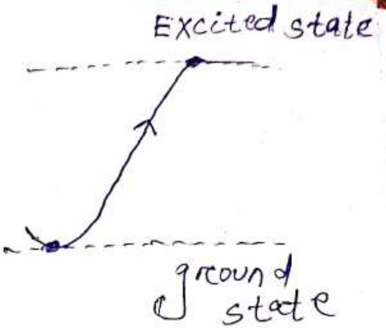
WORKING OF LASER :-

(i) LASER working is bisected in to three major parts.

(a) stimulated Absorption (b) spontaneous Emission. (c) stimulated Emission. (d) population Inversion.

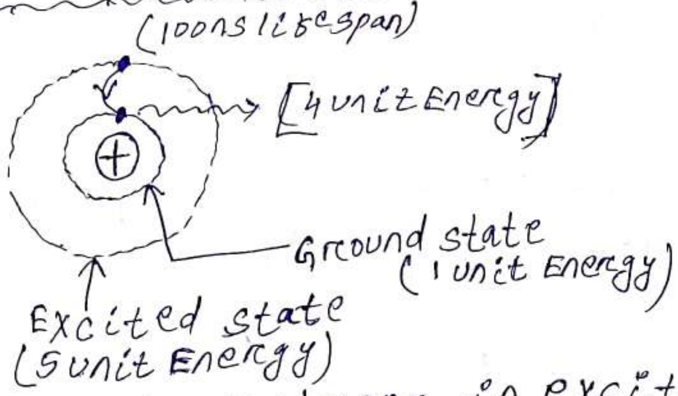
(a) stimulated Absorption :-

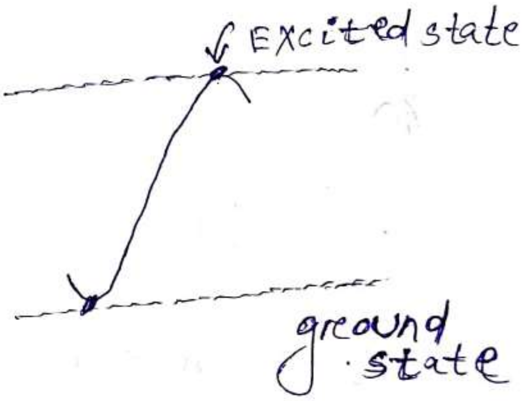




↳ In an Atom, proton (+ve charge) is at center Electrons are in orbits. Electrons are at Ground state with minimum energy having high stability. By applying photon energy ground state electrons can be transferred to Excited state.

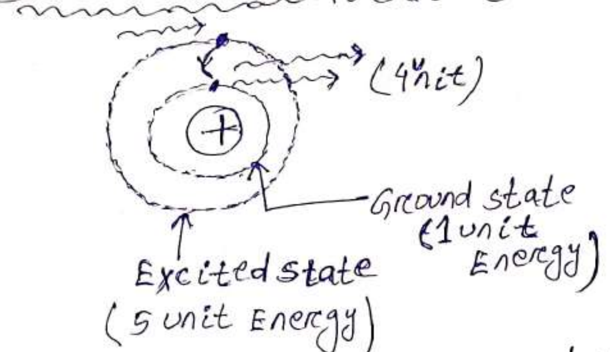
(b) spontaneous Emission :-

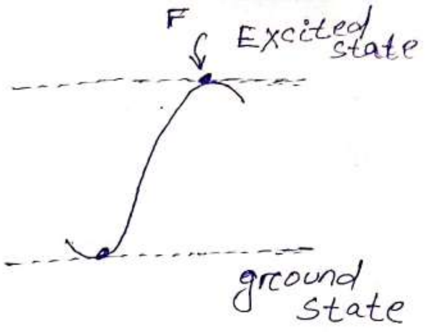




↳ Life span of electrons in excited state is very small i.e. in terms on nano second (ns). If very small amount of force is happening to excited Electrons Then thoese electrons will fall back to ground again. So Energy release occurs in terms of photon. Spontaneous Emission means we don't apply any manipulated force to move the excited electrons from excited state to Ground state.

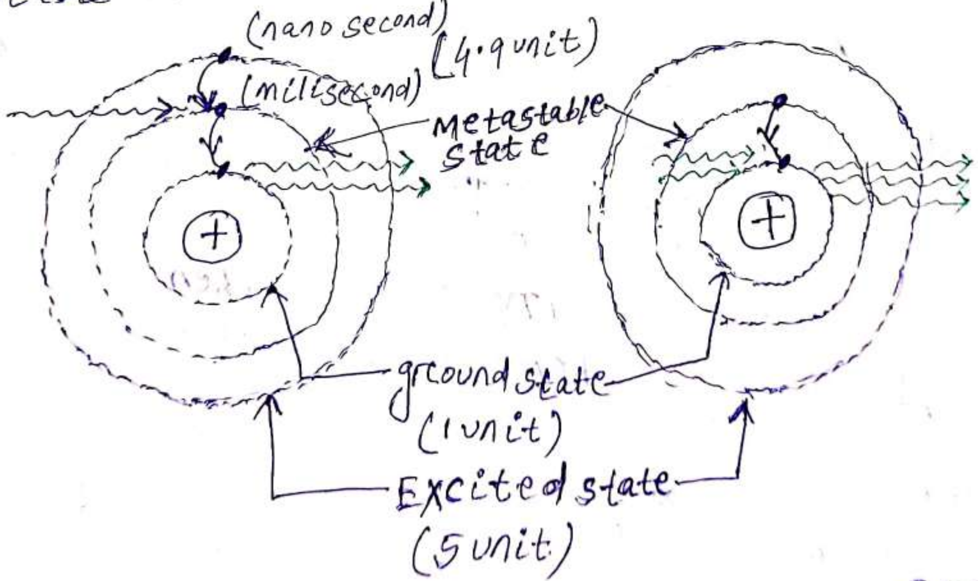
ⓒ Stimulated Emission :-





↳ Here Excited state Electrons having life span very Low i.e. in terms of nanosecond. So, By applying photon Energy to the Excited electrons, ~~the photon~~ ~~Energy~~ is not absorbed instead of that photon energy is released. This is called stimulated Emission.

POPULATION INVERSION :- ① Due to metastable state more electrons can stay in that state due to longer life time. ⑪ So, radiation with more electrons, with the same phase and frequency is possible. ⅲ In metastable state electron life span is interms of meli second (ms).



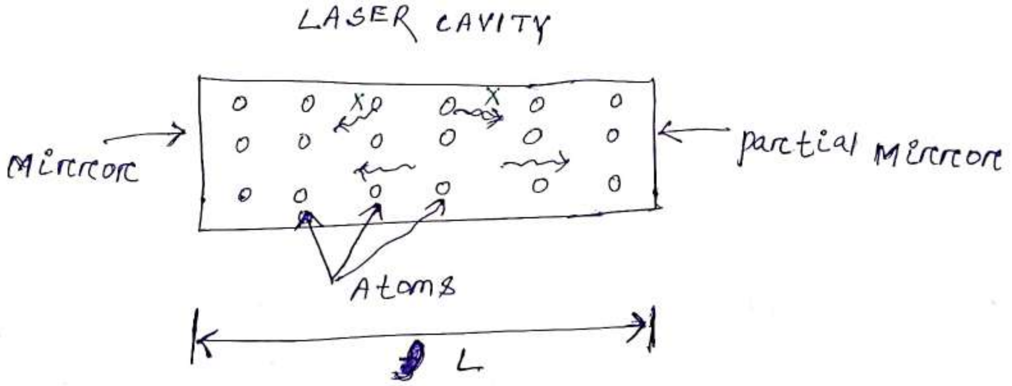
↳ Metastable state has less Energy than Excited state. consider 4·9 unit photon.

↳ Electrons in Excited state will move to Metastable state. Metastable state holds more electrons than Excited State because it can hold electrons for longer time.

↳ By Applying Photon energy ~~Met~~ Electrons in Metastable state will jump to Ground state.

Then energy release occurs with same Phase. Released Energy is given to another atom and again electron jumping occures from metastable state to Ground state. So, again more Energy is released. Because of population Inversion cohorence Energy release takes place That means released photons are having same frequency, phase, wavelength and higher amount of radiation and increased Directivity.

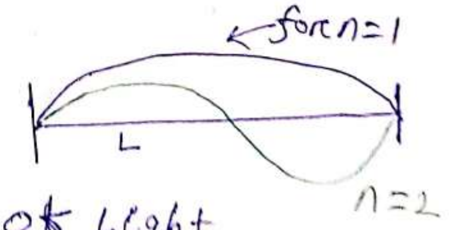
Light Amplification :-



↳ By Applying Light Energy, Metastable Electrons will generate Some transitions. Other than Mirror and partial Mirror side electrons Transitions are cancelled. when Transitions are in additive phase then signal will increase and when Mirror and partial mirror side transitions are in destructive phase then signal will decrease. So it will generate standing pattern.

↳ If Length of LASER CAVITY is L, Then Radiation Frequency $f = \frac{n \cdot v}{2 \cdot L}$, where n is no. of Mode.

Standing patterns for various Modes.



↳ Color of Light (or) frequency of Light is depending on 2 things (i) mode at which signal is generating standing pattern (ii) Type of Material used in LASER cavity.

——x——x——

AVALANCHE PHOTODIODE (APD) :-

Basics :- (i) In case of conventional photodiodes and PIN photodiodes, output current is very small (in order of 100 MA). So In these photodiode gain is less than 1.

(ii) To obtain high current and high gain, Avalanche photodiode (APD) is used.

operating principle of Avalanche photodiode :-

(i) Here, Reverse bias is applied near to Breakdown voltage. (ii) Incident light will produce electron hole pairs. (iii) These carriers will travel with their saturation velocity, because applied Reverse bias voltage is very nearer to Breakdown voltage. (iv) As velocity is maximum, These carriers will collide with other atoms. (v) So, new electron hole pairs are generated. (vi) These new carrier also travels along with initial carrier.

(vii) These increase in carrier will increase current.

(viii) This process of generating more number of carrier is called as impact Ionization.

structure of Avalanche photodiode :-

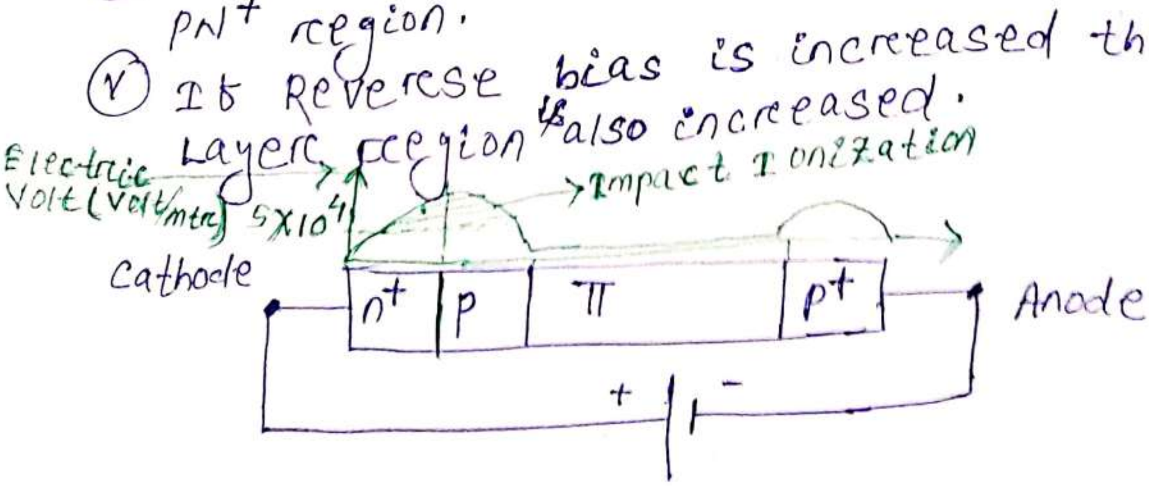
(i) Silicon material gives 90% of efficiency.

(ii) APD has layers as per $p^+ - \pi - p - n^+$.

(iii) Here p-layer is having high resistivity. (Lower Doping causes Higher Resistivity.)

(iv) So The reverse bias is mostly applied across pN^+ region.

(v) If Reverse bias is increased then depletion Layer, region is also increased.



(vi) π-Layer has maximum width. When Light falls on it, there will be generation of electron hole pairs from p^+ Layer. But more electron hole pair generated from π-Layer. Those electron hole pairs having saturation velocity because of ~~rev~~ applied reverse biasing is nearer to breakdown voltage. Those generated electron hole pairs will collide with Depletion Layer of $p-n^+$ region. There occurs generation of charge carrier multiplication ~~that~~ will result in to impact Ionization nearer to n^+-p region. So Electric field is high at this junction. This Impact Ionization that will increase gain of photo-current.

Working of Avalanche photoDiode :- ① Due to Light, electron-
hole pair is generated from p^+, more from π Layer. ② Due
to very high reverse bias voltage, These carrier moves
with very high velocity towards $p-n^+$ region. ③ At $p-n^+$
region impact ionization takes place. ④ That means more
charge carrier is there in highly resistive region.
⑤ Electric field required to do impact ionization is from
10^4 to 10^5 volt/mtr. ⑥ This will increase photo current.
⑦ About 200 gain could be obtained. ⑧ Here important
Factor is that the material should not have defects. If
such defects are present then the total photocurrent
will get reduced.

Advantage :- ① It is having Avalanche gain.

Disadvantages :- ① High operating Voltage is required.
(ii) At high voltage noise is high. (iii) Avalanche means
output is not Linear.

— x — x —

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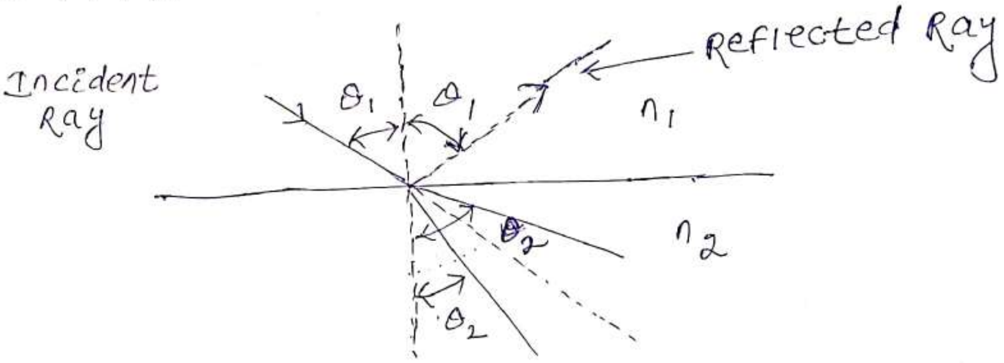
SNELL'S LAW AND CRITICAL ANGLE :-

↳ snell's Law states how light ray reacts when it meets the interface of two media having different Refractive index.

↳ when the light ray encounters a boundary separating two different media, part of the ray is reflected back in to the same medium and other part is refracted (or) bent as it enters the second medium.



n_1 = Refractive Index of medium 1. (Denser Medium)

n_2 = Refractive Index of Medium 2. (Rarer Medium)

If $n_1 > n_2$ then $\theta_1 < \theta_2$, θ_2 = Transmitted Angle

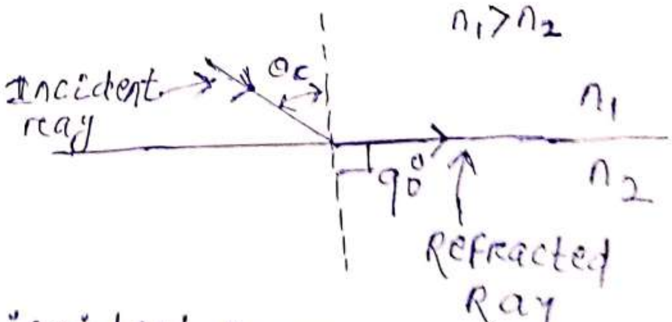
If $n_1 < n_2$ then $\theta_1 > \theta_2$, θ_1 = Incident Angle

According to snell's Law Explanation,

$$\boxed{n_1 \cdot \sin\theta_1 = n_2 \cdot \sin\theta_2}$$

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

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

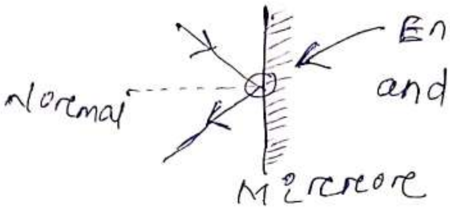


↳ critical Angle is the incident Angle for incident ray at which Angle of Refraction is 90° ($\theta_2 = 90^\circ$).

↳ If Incidence Angle ($\theta_1 > \theta_c$) is greater than critical Angle then incident ray completely return to ~~orig~~ incident medium only. In that case Angle of Incidence is equal to Angle of Reflection. This is Total Internal Reflection.

$\boxed{\theta_i = \theta_r}$

↳ when Ray enters from Denser Medium to Rarer medium with Refracted angle of 90°, angle of Incident is referred as critical Angle (θ_c).



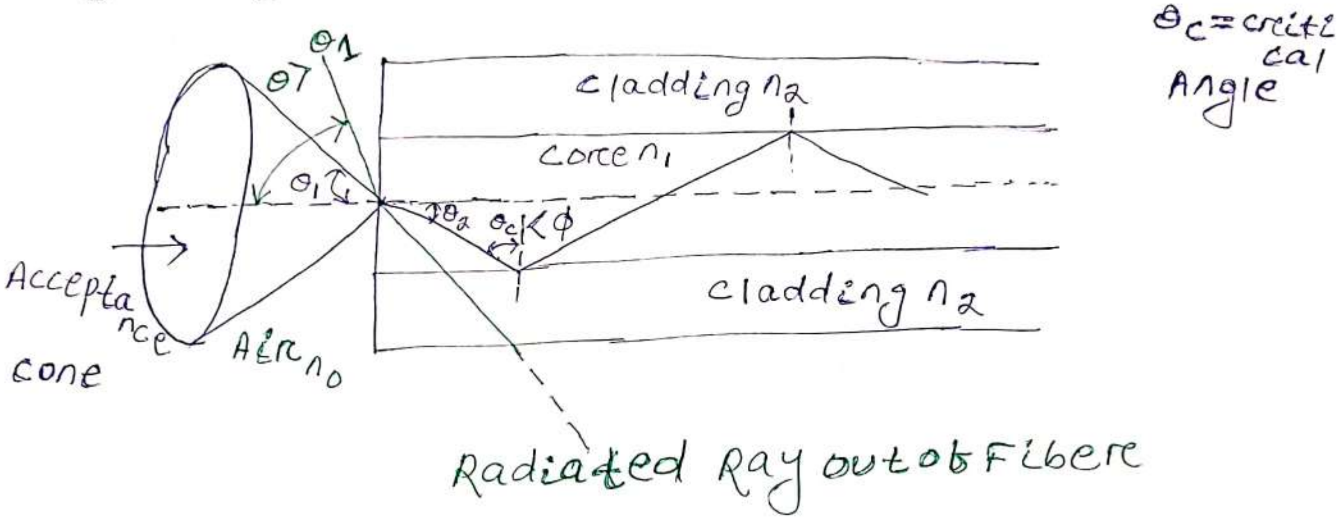
Energy absorbs by Mirror and partial energy is reflected by Mirror.

↳ Total Internal Reflection means Total Energy is reflected to same medium when we send Incident ray from denser medium to Rarer medium above critical Angle. ($\theta_i > \theta_c$)

Ex:- optical fiber communication is based on Total Internal Reflection.

ACCEPTANCE ANGLE :- It is the maximum angle to the fiber axis at which light ray may enter the fiber axis in order to get propagated.

NUMERICAL APERTURE :- It is used to describe the light gathering (or) light collecting ability of optical fiber.

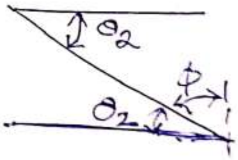


Applying snell's Law, $n_0 \cdot \sin\theta_1 = n_1 \cdot \sin\theta_2$

where n_0 = Refractive Index of Air.

n_1 = Refractive Index of core.

From Figure, $\theta_2 = \frac{\pi}{2} - \phi$



So, $n_0 \cdot \sin\theta_1 = n_1 \cdot \sin\left(\frac{\pi}{2} - \phi\right)$

$\Rightarrow n_0 \cdot \sin\theta_1 = n_1 \cdot \cos\phi$

$\Rightarrow n_0 \cdot \sin\theta_1 = n_1 \cdot \sqrt{1 - \sin^2\phi}$

For critical Angle $\sin\phi_c = \frac{n_2}{n_1}$

Hence, $\Rightarrow n_0 \cdot \sin\theta_1 = n_1 \cdot \sqrt{1 - \left(\frac{n_2}{n_1}\right)^2}$

$\Rightarrow n_0 \cdot \sin\theta_1 = \sqrt{n_1^2 - n_2^2}$

For Air Refractive Index $n_0 = 1 \Rightarrow \boxed{\sin\theta_1 = \sqrt{n_1^2 - n_2^2}}$

Numerical Aperture (NA) $= \sqrt{n_1^2 - n_2^2} = \sin\theta_1$

For Acceptance Angle $\theta_1 = \sin^{-1}(NA)$

$$= \sin^{-1}\sqrt{n_1^2 - n_2^2}$$

↳ If Incident signal is greater than Acceptance Angle ($\theta > \theta_1$) Then the ~~E~~ signal is Radiated out of the fiber.

↳ Index difference $\Delta n = n_1 - n_2$

$$NA = \sin\theta_1 = \sqrt{(n_1)^2 - (n_2)^2} = \sqrt{(n_1+n_2)(n_1-n_2)}$$

If $n_1 \approx n_2$ then

$$\boxed{NA = \sqrt{2n_1 \cdot \Delta n} = \sin\theta_1}$$

↳ Relative Refractive Index $\Delta = \frac{n_1 - n_2}{n_1}$

$$\Rightarrow \Delta \cdot n_1 = n_1 - n_2$$

Now, $NA = \sin\theta_1 = \sqrt{n_1^2 - n_2^2} = \sqrt{(n_1-n_2)(n_1+n_2)}$

$$= \sqrt{\Delta n_1 \cdot (2n_1)}$$

$$\boxed{\Rightarrow \text{Numerical Aperture (NA)} = \sin\theta_1 = n_1 \cdot \sqrt{2\Delta}}$$

— x —

Examples on Numerical Aperture, Acceptance Angle and critical Angle :-

Que:- A silica optical fiber with a core diameter large enough to be considered by ray theory analysis has a core refractive Index, of 1.5 and a cladding refractive index of 1.47. Determine ⓐ The critical Angle at the core-cladding interface. ⓑ The Numerical Aperture for the fiber. ⓒ The acceptance angle in air for the fiber.

Soln:- Given that Refractive Index of core $M_1 = 1.5$

Refractive Index of cladding $M_2 = 1.47$

ⓐ critical Angle $\theta_c = \sin^{-1}\left(\frac{M_2}{M_1}\right) = \sin^{-1}\left(\frac{1.47}{1.5}\right)$

$$= \boxed{78.5^\circ}$$

ⓑ Numerical Aperture $= \sqrt{(M_1)^2 - (M_2)^2}$

$$= \sqrt{(1.5)^2 - (1.47)^2} = \sqrt{2.25 - 2.16} = \boxed{0.3}$$

ⓒ Acceptance Angle $\theta_A = \sin^{-1}(NA) = \sin^{-1}(0.3)$

$$= \boxed{17.4^\circ}$$

Que:- A Typical Relative Refractive Index difference for an optical fiber designed for long distance Transmission is 1%. Estimate the NA and the Solid Acceptance Angle in air for the fiber when the core index is 1.46. Further calculate the critical Angle at the core-cladding interface within the fiber.

Soln:- Relative Refractive Index $\Delta = 1\% = 0.01$

core Refractive Index $n_1 = 1.46$

↳ Numerical aperture $NA = (n_1^2 - n_2^2)^{1/2} = n_1 \cdot \sqrt{2 \cdot \Delta}$

$$= 1.46 \times \sqrt{2 \times 0.01} = \boxed{0.21}$$

↳ Acceptance Angle $\theta_A = \sin^{-1}(NA) = \sin^{-1}(0.21) = 12.12^\circ$

$$= 12.12 \times \frac{\pi}{180} \text{ radian}$$

↳ Relative Refractive Index $\Delta = \frac{n_1 - n_2}{n_1}$

$\Rightarrow \Delta = 1 - \frac{n_2}{n_1} \Rightarrow \frac{n_2}{n_1} = 1 - \Delta = 1 - 0.01 = 0.99$

↳ critical Angle $\theta_c = \sin^{-1}(n_2/n_1) = \sin^{-1}(0.99)$

$= 81.9$ degree

——x——x——

Que:- The Refractive Index of the core of step Index fiber is 1.46 and the Relative Refractive Index is 2%. Find ① Numerical Aperture. ② critical Angle.

Sol^n:- Given that $n_1 = 1.46$, $\Delta = 2\% = 0.02$

① $NA = n_1 \cdot (2\Delta)^{1/2} = 1.46\,[2 \times 0.02]^{1/2} = 0.292$

② critical Angle $= \sin^{-1}\left(\frac{n_2}{n_1}\right) = \theta_c$

we know $\Delta = 1 - \frac{n_2}{n_1} \Rightarrow 0.02 = 1 - \frac{n_2}{1.46} \Rightarrow \frac{n_2}{1.46} = 1 - 0.02 = 0.98$

$\Rightarrow n_2 = 0.98 \times 1.46 = 1.4308$

$\Rightarrow \theta_c = \sin^{-1}\left(\frac{1.4308}{1.46}\right) = 78.52^\circ = 78.52 \times \frac{\pi}{180}$

$= 1.3697$ radias

Numerical Aperture (NA) $= \sin\theta_A = \sqrt{n_1^2 - n_2^2}$

$= n_1 \cdot (2\Delta)^{1/2}$

——x——

OPTICAL COUPLER :-

Basics :- ① couplers are the devices which couples (or) Transfers some amount of power from one fiber to other fiber.

(ii) Coupling Ratio is defined as output power to Input power.

(iii) using couplers we can mix two signals in one fiber.

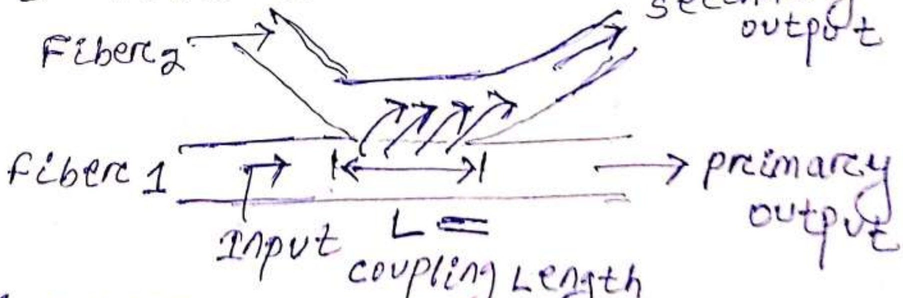
(iv) using couplers we can send signals to multiple fibers.

TYPES :- There are 3 major types of couplers.
① Diffusion couplers. ② Area splitting couplers.
③ Beam splitting couplers.

① DIFFUSION COUPLERS :- There are two diffusion couplers. ⓐ Evanscent wave couplers. ⓑ Twisted pair couplers.

ⓐ Evanscent wave coupler :-

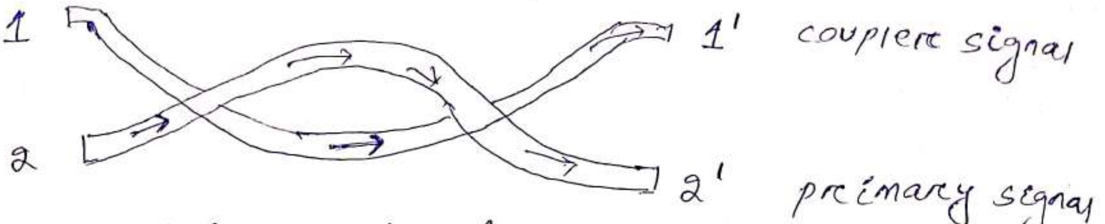
- ↳ Here it couples signal from fiber 1 to fiber 2.
- ↳ To achieve this coupling, for certain length two fiber cable are made parallel to each other.
- ↳ This length is called as coupling Length.
- ↳ Then Evanscent wave will couple from Fiber 1 to Fiber 2.



ⓑ Twisted pair coupler (Fused biconical tapper coupler) :-

- ↳ In this case a pair of optical fibers is twisted and then it is fused with the heat treatment.
- ↳ Because of the fusing action the core layer of one fiber acts as cladding layer for other.

↳ So, the coupling of signal takes place.



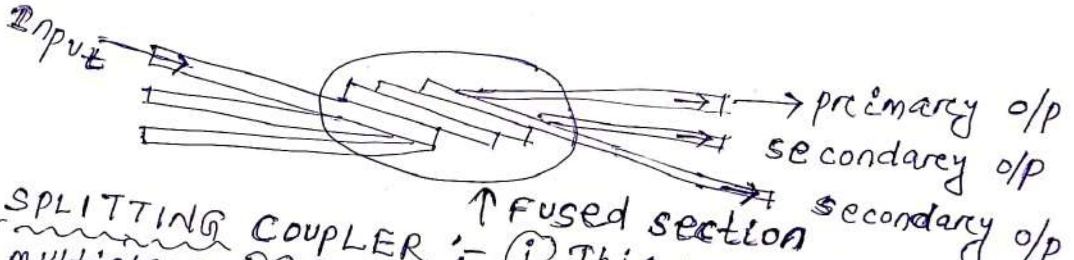
② Area splitting coupler (star coupler) :-

↳ Here the optical power is divided and apart of optical power is passed to the another fiber optic cable.

↳ In this case a portion of several optical fibers to be coupled is fused.

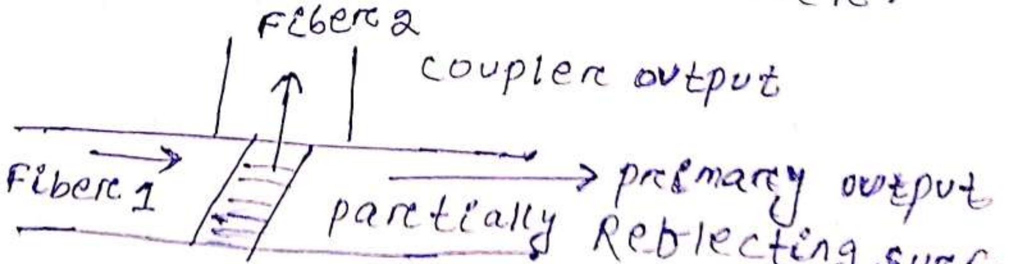
↳ Then the data transmitting through one fiber optic cable get coupled to all the remaining optical fibers.

↳ coupling is based on Area splitting of fiber.



③ BEAM SPLITTING COUPLER :-

(i) This type of couplers are used for multiplexing operation. (ii) It consists partially reflecting surface. The incident light beam gets reflected partially and the data is coupled to other optical fiber. (iii) Some times dichoric surfaces are used inside the optical fiber. (iv) This is a wavelength selective surface. So only required wavelength of light can be coupled in to another optical fiber.



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OPTICAL FIBER CONNECTORS :-

Basics :- ⓘ connectors are used to join optical sources as well as detectors with optical fiber.

(ii) Similarly connectors are also used to join two fibers.

(iii) The main criteria about the connectors is that the connectors should be aligned properly in order to reduce losses.

(iv) The separable connectors are used to join the optical fibers. Here the core should be taken that the two fiber optic ends should not be joined.

(v) And vibration that may be taking place in one optical fiber should not be transferred to the another fiber.

Requirements of connectors :-

① The connectors should have low coupling loss.

(ii) The design of connector should be such that the repeated connection and disconnection is possible without affecting the fiber alignment.

③ The demountable connector must provide reproducible accurate alignment of the fiber.

④ It should not affected by environmental factors.

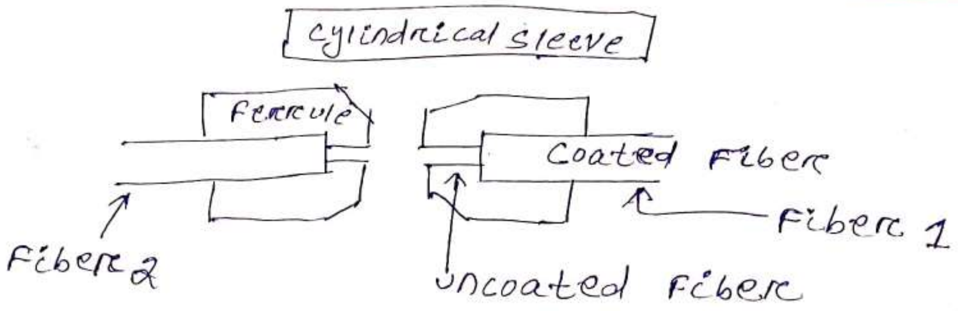
⑤ Easy of connection.

⑥ It should protect fiber ends.

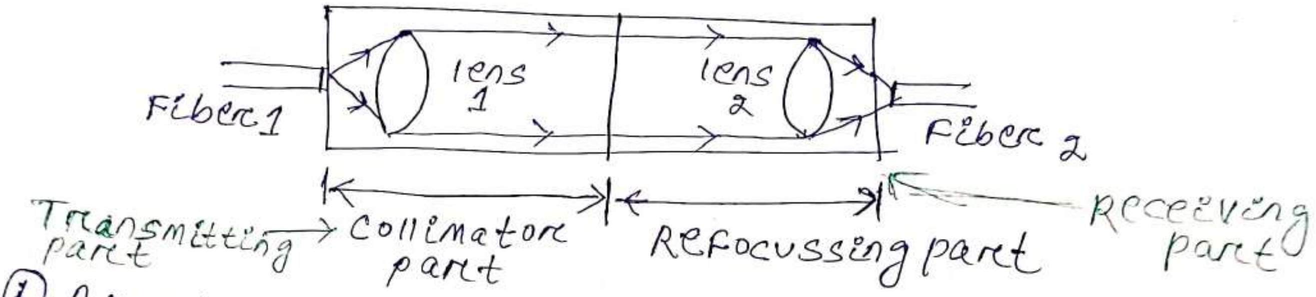
⑦ It should provide the strength to the joint.

Types of connectors :- There are two major types ① Ferrule Type connector ② Lensed type connectors.

① FERRULE TYPE CONNECTORS :- ⓘ The uncoated fiber are placed in ferrule. (ii) They are fixed by adhesive material. (iii) Then two ferrule are brought in connect in cylindrical sleeve



(11) LENSED TYPE CONNECTORS:-



① By adjusting two lens, one fiber is connected with other optical fiber.

② Here radial alignment is not critical as compared to other connector.

③ Here angular alignment is critical.

FIBER SPLICING :-

↳ The Splices are used to connect two optical fiber cables permanently.

↳ The basic requirements of splices are :-
① splices should cause minimum power Loss.
② They should be easy to install. ③ It should cause a low attenuation. ④ It should be strong mechanically and having light weight.

↳ There are two major splicing Technique.
① Fusion splicing ② Mechanical splicing.

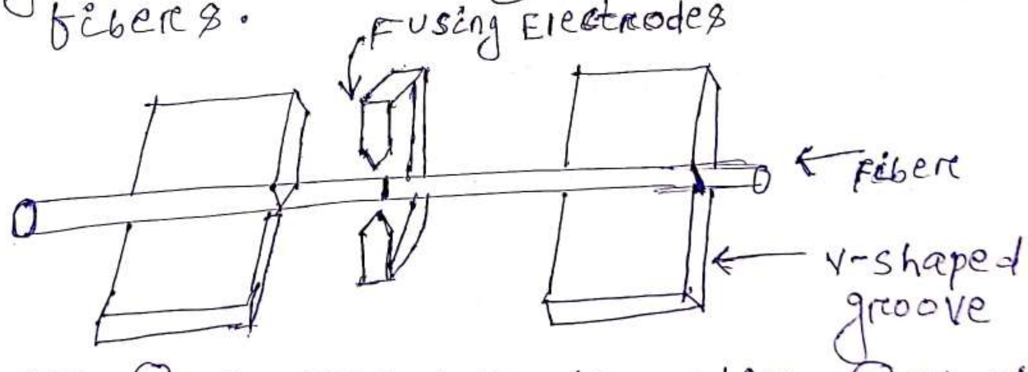
Fusion splicing :-

① Two ends of Fiber are initially cleaned and polished.

② Then cables are placed on V-shaped groove in tooling Fixture.

③ Then cables are fixed on V-shaped groove using clamps.

④ Then by electrodes heating is provided to joint two fibers.



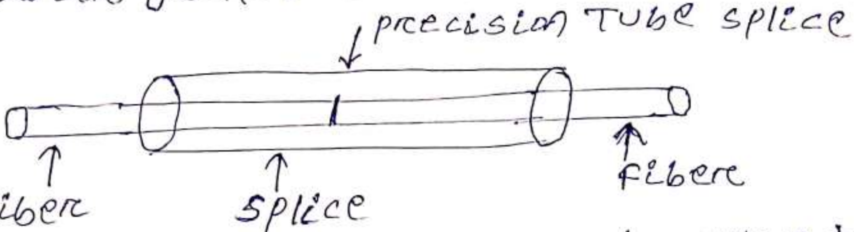
Advantages :- ① It gives Low attenuation. ② It gives high quality of joint. ③ It has small size of splice.

Disadvantages :- ① Heat will make Fiber week. ② After splicing, tensile strength of fiber decreases.

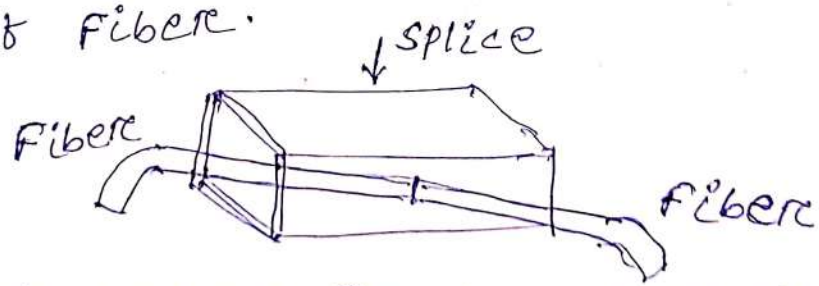
Mechanical splicing :- ① In this method, the fiber are aligned and then they are locked in position using various positioning devices.
② The different types of mechanical splicing are :-

(i) precision tube splice. (ii) Loose Tube splice. (iii) V-groove splice. (iv) Elastomeric splice. (v) precision pen splice. (vi) Spring groove splice.

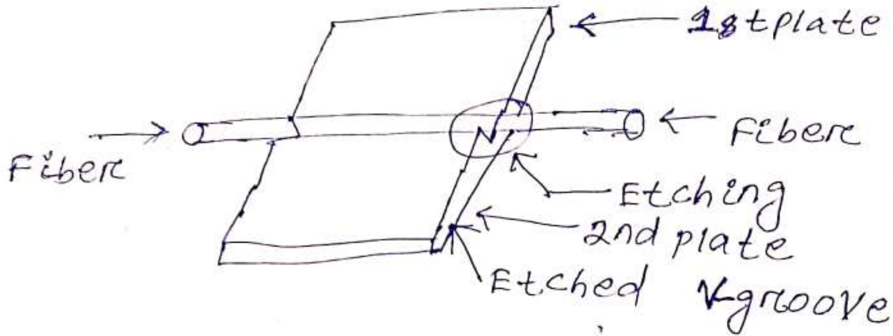
(i) **precision Tube splice** :- (i) In this case precision tube is used to splice two fiber. (ii) Initially ends of fiber is cleaned and polished. (iii) splice compound has same refractive Index as of fiber. (iv) Two Fibers inserted ~~inserted~~ in to splice and outer jacket is crimped.



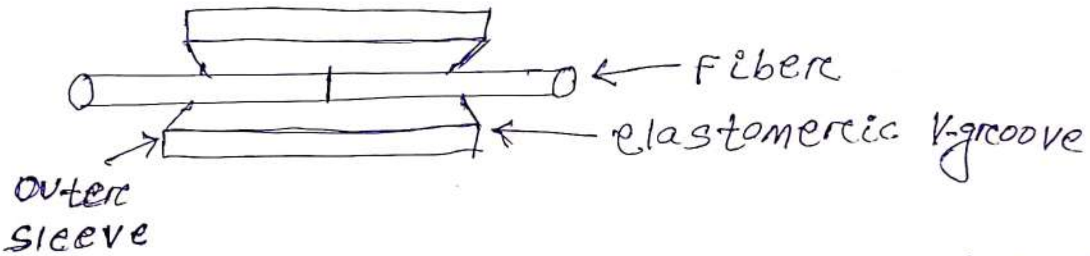
(ii) **Loose Tube splice** :- (i) Here Rectangular tube is used for splicing (ii) An Adhesive material is added in tube to join two fibers. (iii) After cleaning and polishing fiber, two ends are inserted in to splice. (iv) Because of adhesive material two ends of fiber will get joined. (v) Adhesive material has same reefreactive index as of fiber.



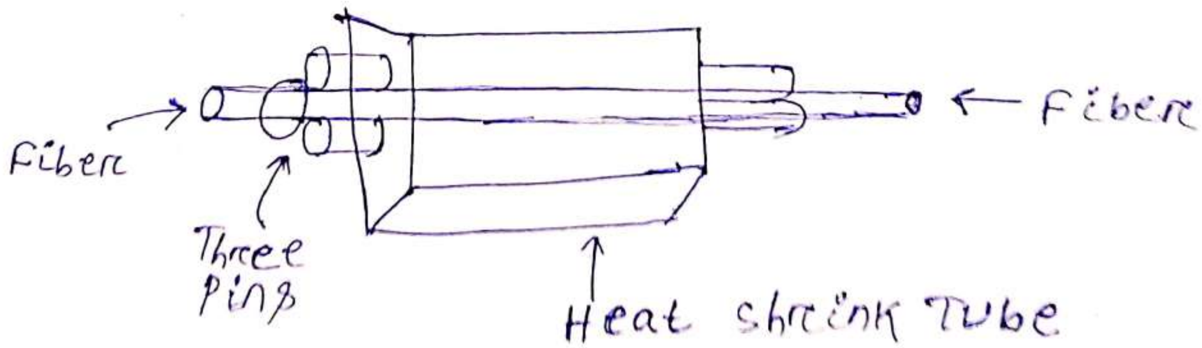
(iii) **V-groove splice** :- (i) It is also known as surface groove splice. (ii) Here V-shaped groove is made at the center of metal plate. (iii) The dimensions of groove is such that fiber can be easily placed in the groove. (iv) Then adhesive epoxy material is placed in the V-groove. (v) Then fiber optic ends are placed in one of the V-groove. (vi) Then they are butted together. (vii) Then 2nd plate is aligned and placed on 1st metal plate. After that the two metal plates are festened.

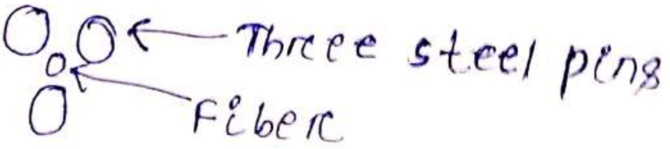


(iv) ELASTOMERIC SPLICE :- (i) It is another version of V-groove splice. (ii) using outer sleeve, two elastomeric parts gives compression on fibers aligned in V-groove.

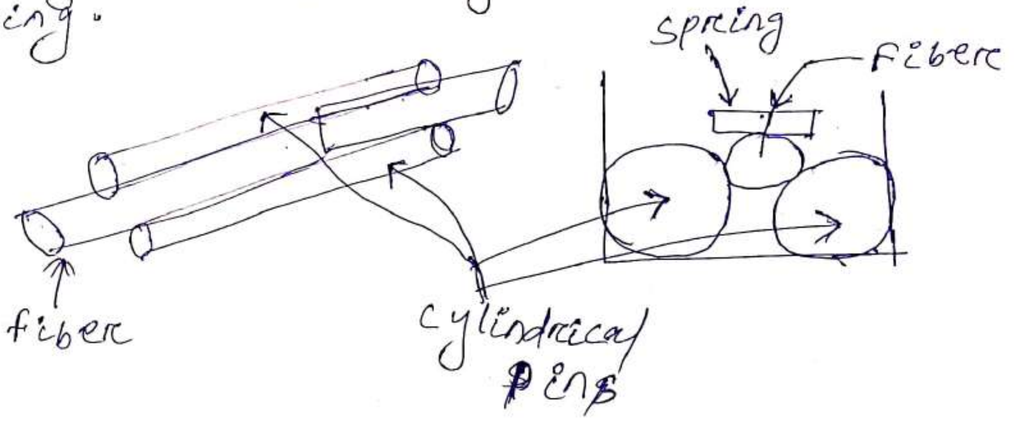


(v) precision pin splice :- (i) The heat shrink tube is used to held three steel pins together.
(ii) The fiber tubes are inserted in openings between three pins.
(iii) using index matching epoxy, splicing is done.





ⓥⓘ Spreing groove splice :- ⓘ Two cylindrecical pins are used as alignment guide for fiber cable. ⓘⓘ using spreing, the fiber is pressed in the groove. ⓘⓘⓘ Epoxy resin is used for splicing.



ATTENUATION OF SIGNAL IN OPTICAL FIBER COMMUNICATION:-

Basics :- ① Attenuation represents the reduction in amplitude of signal.

(ii) It is called as the transmission Loss and it represents the reduction in intensity of the light rays propagating through it.

(iii) It measure with respect to the distance travelled by light rays in optical cable.

(iv) Attenuation is usually expressed in decibel(dB).

Attenuation calculation :-

↳ Attenuation Loss α_L (dB) is calculated by

$$\alpha_L = 10 \cdot \log \frac{P_i}{P_o}$$, where P_i = Input power
P_o = output power.

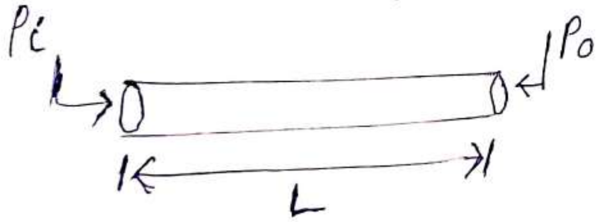
α_L = Attenuation Loss in dB

↳ Attenuation coefficient α (dB/Km) is calculated by

$$\alpha = \frac{10}{L} \cdot \log \frac{P_i}{P_o}$$, where L = Length of Fiber cable

for Voltage, current $\alpha_L = 20 \cdot \log\left(\frac{V_i}{V_o}\right)$

$= 20 \cdot \log\left(\frac{I_i}{I_o}\right)$



Attenuation Factors :- Attenuation produces Losses in the system, different factors are as follows :-

(i) Material Absorption (Intrinsic, Extrinsic)
(ii) Linear scattering Losses. (iii) Non Linear scattering Losses. (iv) stimulated Raman scattering Losses. (v) Fiber Banding Losses. (vi) Dispersion. (Chromatic Dispersion, Material Dispersion, waveguide Dispersion, Intermodal and Polarized Mode Dispersion.

V-NUMBER (OR) NORMALIZED FREQUENCY OF OPTICAL FIBER:-

(i) V-number decides number of modes in optical Fiber. (ii) V-number is defined as

$V = \sqrt{U^2 + W^2}$, where U = Radial propagation constant, W = cladding decay parameter

(iii) Radial propagation constant defined as

$U = a\cdot\sqrt{n_1^2\cdot\beta^2 - K^2}$, where a = Radius of core

n_1 = Refractive Index of core, $\beta = 2\pi/\lambda$,

K = propagation constant.

(iv) cladding Decay parameter is given as

$W = a\cdot\sqrt{K^2 - n_2^2\cdot\beta^2}$, where n_2 = Refractive Index of cladding.

(v) So, V Number will be $V = \sqrt{U^2 + W^2} = a\cdot\beta\sqrt{n_1^2 - n_2^2}$

$\Rightarrow V = a\cdot\frac{2\pi}{\lambda}\cdot\sqrt{n_1^2 - n_2^2} \Rightarrow \boxed{V = \frac{2\pi}{\lambda}\cdot a\cdot[NA]}$

NA = Numerical Aperture

$NA = \sqrt{n_1^2 - n_2^2} = n_1\cdot(2\Delta)^{1/2}$, By putting this in V-Number Equation, we will get

$\boxed{V = \frac{2\pi\cdot a}{\lambda}\cdot n_1\cdot(2\Delta)^{1/2}}$, $\Delta = \frac{n_1 - n_2}{n_1}$

= Relative Refractive Index Difference.

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RELATIONSHIP BETWEEN NUMBER OF MODES (M) and V-NUMBER :-

↳ The number of Modes is given by M, $\boxed{M=\frac{2A}{\lambda^2}\cdot\Omega}$

where, A = Area of core = πa^2, a = Radius of core in optical fiber

Ω = Solid Acceptance angle = $\pi\theta_a^2$

↳ Numerical Aperture $NA=\sqrt{(n_1)^2-(n_2)^2}=\sin\theta_a$

↳ For small values of θ_a, $\sin\theta_a \approx \theta_a$

↳ So, NA will be $\sqrt{n_1^2-n_2^2}=\theta_a$

↳ So, The number of Modes will be $M=\frac{2\cdot(\pi a^2)}{\lambda^2}\cdot\pi(n_1^2-n_2^2)$

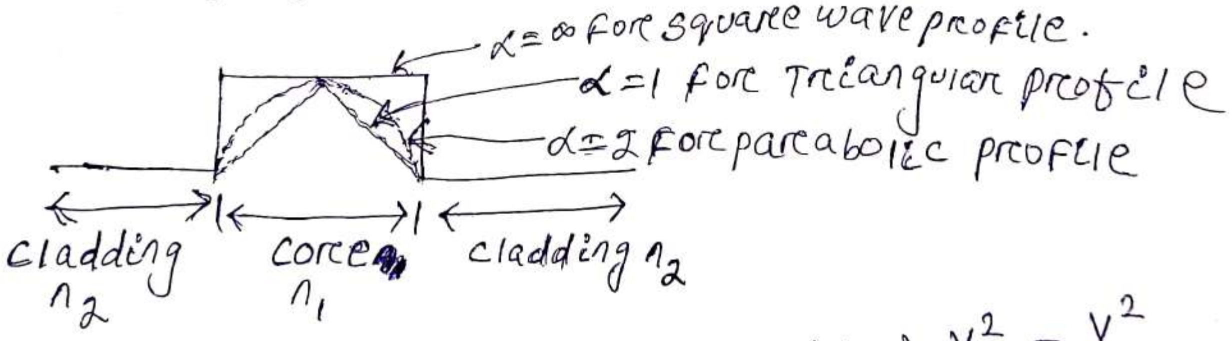
$$\Rightarrow M=\frac{2\cdot\pi^2\cdot a^2}{\lambda^2}\cdot(n_1^2-n_2^2)$$

$$\left[V=\frac{2\pi a}{\lambda}\cdot\sqrt{n_1^2-n_2^2}\right]$$

$\Rightarrow \boxed{M=\frac{V^2}{2}}$ ← No. of Modes for step Index fiber.

↳ For graded Index optical fiber,

$M_g=\left(\frac{\alpha}{\alpha+2}\right)\cdot\frac{V^2}{2}$, where α = Refractive Index profile



↳ For Triangular Index, $M_g=\left(\frac{1}{1+2}\right)\cdot\frac{V^2}{2}=\frac{V^2}{6}$

↳ For parabolic Index, $M_g=\frac{V^2}{4}$

—x—x—

ABSORPTION LOSSES IN OPTICAL FIBER :-

Basics :- ① During the Fabrication process of optical Fiber cable, some of the transmitted light is dissipated as heat. It is called as Material Absorption.

Factors of Material Absorption :-

(i) Intrinsic Absorption due to basic atoms of Fiber Material. (ii) Extrinsic Absorption due to Impurity atoms. (iii) Absorption due to atomic defects in the glass material.

Intrinsic Absorption :- ① In near Infrared Region, the intrinsic absorption takes place due to the basic fiber material properties. (ii) usually, pure silica glass shows low intrinsic Absorption.

(iii) At the short wavelengths (ultra violet Region), Intrinsic absorption is more dominant.

(iv) In IR region, the absorption peaks are present around the operating wavelength range 700nm to 1200nm.

(v) Basically an interaction between vibrating SiO band and electromagnetic field of optical region takes place and it produces intrinsic absorption.

Extrinsic Absorption :- ① optical fibers are manufactured using Melting techniques. During this process, the metallic ions like cu+2, Fe+2, Ni+2 etc. gets deposited.

(ii) These are metal element impurities, which causes absorption of incoming photons and it is called as extrinsic absorption.

(iii) Similarly the OH ions from SiOH bond and it has Fundamental absorption at 2700 nm.

(iv) But the harmonics of these Fundamental Frequencies at 1380nm, 1250nm and 950nm also produces extrinsic absorption.

(v) This type of absorption can be reduced by reducing amount of impurities and by reducing level of OH ions. (Hydroxyl Ion)

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FIBER BENDING LOSS :-

Basics :- (i) If there is abrupt change in the radius of curvature of fiber, then the radiation loss takes place from fiber. (ii) If there is sharp bend of the fiber then there is a probability of mechanical failure of optical cable. (iii) usually the higher order modes are not tightly bound to the core layer, so due to the sharp bends, the radiation losses of such modes take first.

There are two types of fiber bending losses. ① Macroscopic bending losses. ② Microbending Losses (or) Mode coupling Losses.

① Macroscopic Bending Loss :- (i) There is a radiation loss, when the radius of curvature of bend is greater than the diameter of fiber. such losses are also refered as large radius losses. (ii) As the radius of curvature of bend decreases, such losses increase exponentially. (iii) There is a certain critical value of radius of curvature up to which such losses can be observed. (IV) In optical cable, the wavefront perpendicular to the direction of propagation must be maintained to achieve this the part of mode, which is on the outside of bend has to travel faster. (V) It indicates that, the light rays travelling through cladding; should travel faster. (Vi) It is not possible, so the energy associated with that part is lost through radiation.

②. MICROBENDING LOSSES (OR) MODE COUPLING LOSSES :-

(i) These are the losses due to small bending (or) small distortion.

(ii) If there are small fluctuations in the radius of curvature of fiber axis, then microbends are created and light rays radiate out from these microbends.

(iii) The microbends are formed due to two main reasons :-

↳ Non uniformities in the core radius, while manufacturing the cable.

↳ During the cabling of fibers, non uniform lateral pressure can be created.

(iv) To minimize the losses due to microbends we should take following steps :-

↳ while manufacturing the cable, a precise control of core diameter is maintained.

↳ A compressible jacket is fitted over the fiber, so that when the external pressure is applied then the deformation of jacket place and there will not be creation of microbends in the core layer of fiber.

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LINEAR SCATTERING :- (i) In case of Linear scattering optical power transferred from one mode to another mode. But there is no change in frequency on the scattering.

(ii) There are 2 types of Linear scattering
ⓐ Rayleigh scattering. ⓑ Mie Scattering.

ⓐ **Rayleigh scattering :-** (i) The light from sun is scattered in atmosphere to give the sky color blue. (ii) Rayleigh scattering in the glass is having same phenomenon and this scattering takes place in all directions.

(iii) The Rayleigh scattering produces attenuation in the light rays and this attenuation is proportional to $\frac{1}{\lambda^4}$; where λ is optical wavelength.

(IV) Thus if we transmit the data through the fiber optic cable at lower wavelength; The scattering is minimized.

(V) The Rayleigh scattering coefficient is denoted by Y_R. $Y_R = \frac{8\pi^3}{3\cdot\lambda^4}\cdot n^8\cdot p^2\cdot\beta_c\cdot T_F\cdot K$, where n = Refractive Index of fiber, p = Average Photo elastic coefficient, β_c = Isothermal compressibility of fictive Temperature, T_F = Fictive Temperature (Thermal Equillibrium Temperature)

ⓑ **Mie Scattering :-** (i) The scattering caused by hologenetic atoms which are comparable in size with guided wavelength are called as Mie Scattering.

(ii) This is a linear scattering which is always in foreward direction. (iii) Factors responsible for Mie scattering are as follows :-

SCATTERING LOSSES IN OPTICAL FIBER :-

BASICS :- (i) Due to non uniformities in fiber optic cable, a straight line path of lightrays gets deviated. It is referred as scattering.

(ii) Incase of optical fiber, some of the optical power from one propagating mode gets transferred to another mode.

(iii) This transfer of power takes place through the leaky (or) radiation mode.

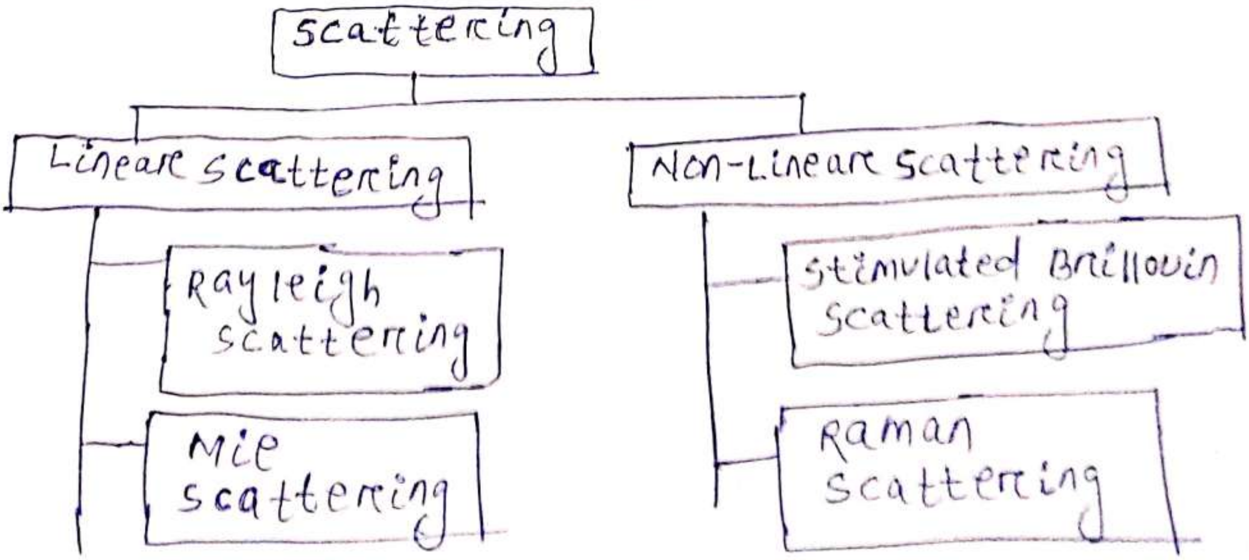
(iv) This leaky mode does not continue to propagate with in the fiber core, but it is radiated out from the fiber. It is scattering loss.

(v) This loss are mainly caused by interaction of light with density fluctuations with in a fiber.

(vi) Basically the glass is composed of randomly connected network of molecules, which is made up of several oxides and it increases the compositional fluctuations.

(vii) In case of multimode fibers, there is a higher dopant concentration and greater compositional fluctuations. Thus scattering losses are more.

CLASSIFICATIONS OF SCATTERING LOSS :-



ⓐ cylindrical structure of cable is not perefect. ⓑ Imperfection of core and cladding interface. ⓒ core and cladding refractive index is not uniform throughout of fiber. ⓓ There are fluctuation in core diameter. ⓔ Due ~~to~~ Bubble (or) strain in fiber.

(iv) Mie scattering results significant attenuation depending upon fiber material, size, design and manufacturing process. It can be reduce by following steps :-

ⓐ Removing imperfections during glass manufacturing process. ⓑ controlling the coating of fiber. ⓒ Increase refractive index difference between core and cladding.

NON LINEAR SCATTERING :- ⓘ when the optical power is transferred from one mode to other mode (or) same mode with different frequency, Non-Linear scattering happens. (ii) This scattering takes place either in forward (or) backward direction. (iii) It produces optical gain but there is a shift in frequency. (iv) This shift in frequency results loss of signal and creates attenuation. (v) There are 2 types of Non linear scattering :

ⓐ stimulated Brilliouin scattering.

ⓑ stimulated Raman scattering.

(a) stimulated Brilliouin scattering :-

(i) when the laser light beam is travelling in optical cable; there are variations in an electric field of this beam. (ii) These variations in electric field produces acostic vibrations in the optical cable. (iii) That means incident photon of acostic frequency as well as it produces a scattered photon. (iv) This type of scattering is called as stimulated Brillioun scattering and this scattering is usually in opposite direction to that of incoming beam. (v) The scattered light looks like upper and lower sidebands, which are separated from the incident light by the Modulation frequency. (vi) During this scattering, a frequency shift is produced which varies with the scattering angle. This frequency shift is maximum in the backward direction.

(b) stimulated Raman Scattering (SRS) :- (i) Raman scattering basically represents inelastic scattering of photons. (ii) when a LASER light is travelling through optical cable, the spontaneous scattering takes place. (iii) In this process, some of the photons are transferred to the near frequencies. (iv) when the scattered photons lose their energy then it is called as stokes shift and when the scattered photons gain energy then it is called as antistokes shift. (v) But if the photons of other frequencies are already present then the scattering of such photons takes place and in this case the two photons are generated. It is called as stimulated Raman Scattering. (vi) This scattering is similar to stimulated Brilliouin scattering but in SRS instead of acaustic photon; a high frequency optical photon is created. (vii) SRS can occure in both forward and reverse direction.

ⓐ Material Dispersion Losses :- (i) It depends on the refractive index of material used to manufacture the fiber cable. (ii) The Group velocity is the function of wavelength of light and the group velocity is also the function of refractive index of the material.

(iii) Now depending on the light source, each spectral component of input source will be having different wavelength. (iv) Thus each component is travelling with different speed through optical fibre. (v) It gives the spreading of the output pulse. (vi) This is called as the material dispersion. It is denoted by Dm .

$$\boxed{D_M = \frac{\sigma_m}{L \cdot \sigma_\lambda}},$$

where σ_m = width of pulse spread because of material dispersion.

σ_λ = spectral width of source.

L = Length of fiber cable.

In terms of wavelength $D_m = \frac{\lambda \cdot S_0}{4} \cdot \left[1 - \left(\frac{\lambda_0}{\lambda}\right)^4\right]$, where

S_0 = Zero Dispersion slope,

λ_0 = Zero Dispersion wavelength.

It is also given by $D_m = \frac{\lambda}{c} \cdot \left| \frac{d^2 n}{d\lambda^2} \right|$, where, n = Refractive Index

ⓑ WaveGuide Dispersion Losses :-

① whenever the optical signals are passing through the fiber optic cable, then the optical cable is acting as wave guide. (ii) Now There is a variation in the wavelength of each spectral component emitted from the source. (iii) As well as the angle made by each light ray with respect to the axis of optical cable will be different. (iv) Because this angle is the function of wavelength of light. (v) since there is variation in the angles, all the light rays are not reaching to the output at the same time. (vi) This gives dispersion at the output. This is called as waveguide Dispersion.

DISPERSION LOSSES IN OPTICAL FIBER CABLE :- ①

Basics :- ① Dispersion is basically one of the limiting factors which decides, how much data can be transmitted through optical cable.

(ii) Due to dispersion, broadening of the output pulse takes place as well as there can be Inter symbol Interference nce (ISI).

(iii) All these factors, limit the information carrying capacity of optical cable.

(iv) The two Major sources of dispersion are material dispersion and waveguide dispersion.

(v) Material dispersion arises due to frequency dependent response of a material used to manufacture the cable.

(vi) when the speed of wave in a waveguide depends on its frequency then waveguide disporsion takes place.

TYPES :- There are 2 types of dispersion. ① Intramodal Dispersion. ② Intermodal Dispersion.

① INTRAMODAL DISPERSION LOSSES :- ⓘ The Light source is used at input side. This converts an electrical signal in to optical signal. (ii) But this light source does not emits single wavelength. (iii) In actual practice, this light sources emits band of wavelength. If the LED is used as light source then this problem is more savior. (IV) so, the different spectral components will reach at the output at different times. (V) This gives the spreading of output pulse, This is called as intramodal dispersion. There are two types of Intramodal Dispersion. ⓐ Material Dispersion. ⓑ waveguide Dispersion.

(vii) In case of Multimode fibers almost all the light rays are travelling away from ~~cutoff~~ cutoff axis. (viii) So in this case the waveguide dispersion is negligible.

It is given as $\boxed{D_w = \frac{\sigma_w}{L\cdot\sigma_\lambda}}$, where σ_w = width of pulse spread because of waveguide dispersion.

σ_λ = spectral width of source.

L = Length of fiber cable.

(2) INTERMODAL DISPERSION LOSSES :-

(i) This type of Dispersion is also called as Modal Dispersion.

(ii) This dispersion takes place in case of Multimode fiber optic cables. (iii) Here the different mode are travelling with different group velocities inside an optical fiber. (iv) Some Modes are travelling with Maximum speed, while some are travelling with minimum Speed. (v) Thus there is difference between the transit time of these modes. (vi) So all the Modes are not coming to the output at the same time. (vii) This gives spreading of output pulse. (viii) This Type of dispersion is called as Inter modal dispersion.

(ix) In case of Multimode step index fiber, this dispersion is highest. (x) It can be reduced by choosing an optimum refractive Index profile. (xi) In case of graded index fiber it is less by a factor of 100 times. (xii) For single mode fiber, it is almost zero.

Overall Dispersion of Fibere :-

↳ Total dispersion of Fibere can be calculated by $\boxed{\sigma_T = \sqrt{\sigma_c^2 + \sigma_n^2}}$, where

σ_c = Intramodal Broadening

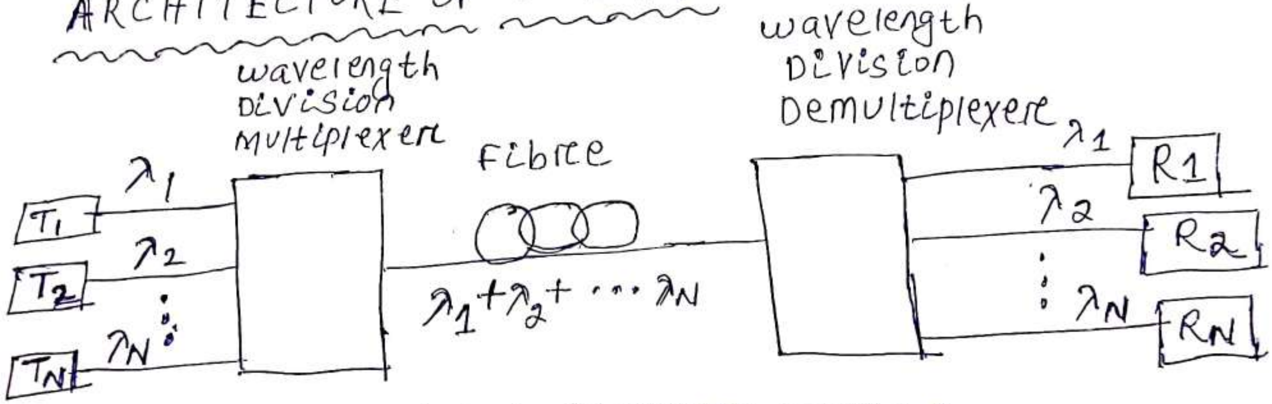
σ_n = Intermodal Broadening

— x —

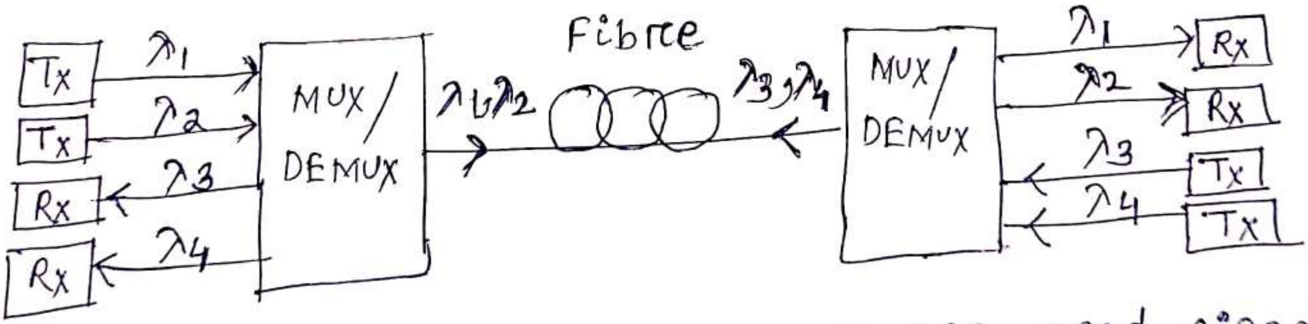
WAVELENGTH DIVISION MULTIPLEXING (WLDM) :-

BASICS :- (i) It is wavelength Division Multiplexing. (ii) WDM is used to increase capacity of single standard fiber. (iii) Here, a number of light sources are used with different wavelength. (iv) Using Multiplexer, all signals are transmitted by single fiber. (v) At Receiver side, Demultiplexer separates different wavelength and gives it to different receiver.

ARCHITECTURE OF WLDM :-



BIDIRECTIONAL WLDM ARCHITECTURE :-



↳ In both of the directions we can send signal.

COMPONENTS OF WLDM :- 3 components are

① optical Line Terminals OLT
② optical Add/Drop Multiplexer. ③ optical cross connect

TECHNOLOGIES OF WLDM :-

① Thin Film Filter. ② Fused fiber coupler. ③ Arrayed waveguide grating. ④ Interleaver.

Important Feature of WLDM :-

① wavelength reuse ② wavelength conversion
③ Transparency ④ circuit switching.
⑤ survivability.

——— x ——— x ———

PHASE VELOCITY IN OPTICAL FIBER :-

↳ when optical waves are propagating through optical fiber, there are certain points having constant phase. These points of constant phase travels with a phase velocity (v_p). $v_p = \frac{\omega}{\beta}$, where $\omega = 2\pi f = \frac{2\pi \cdot c}{\lambda}$

β = phase constant

Group velocity :- ↳ optical waves are travelling as wave packets. These wave packets have group velocity v_g. $v_g = \frac{d\omega}{d\beta} = \frac{c}{n_g}$, where c = velocity of light $= 3\times10^8$ mtr/second

n_g = Group Index of guide

——— x ———

Examples on Number of Modes M and Normalized Frequency :-

Que 1 :- A multimode step index fibere has a relative refractive index of 1% and a core refractive index of (1.5). The number of modes propagating at a wavelength of 1.3μm is 1100. Estimate the Diameter of the fiber core.

Sol :- Given that, $\Delta = 1\% = 0.01$, $n_1 = 1.5$, $\lambda = 1.3\mu m$

$M = 1100$

Numerical Aperture (NA) $= n_1 \cdot (2\Delta)^{1/2} = 1.5 \times [2 \times 0.01]^{1/2}$

$= 0.2121$

V-Number $= \frac{2\pi \cdot a}{\lambda} \times [NA] = \frac{2 \times 3.14 \times a}{1.3 \times 10^{-6}} \times 0.2121$

$$M = \frac{V^2}{2} \Rightarrow V^2 = 2M \Rightarrow V = \sqrt{2M} = \sqrt{2 \times 1100} = \sqrt{2200}$$

$$\Rightarrow \sqrt{2200} = \frac{2 \times 3.14 \times a}{1.3 \times 10^{-6}} \times 0.2121$$

$\Rightarrow a = 45.77\mu m$ = Radius of core

Now Diameter of fibere core $(D) = 2a = 91.55\mu m$

— x — x —

Que :- A multimode step index fibere with a core diameter of 80μm and a relative index of 1.5% is operating at a wavelength of 0.85 μm. If the core refractive index is 1.48. calculate Normalized frequency of fiber, The power in the cladding if the total input power is 500 mW, Also find total Modes in fiber.

Sol :- Given that $d = 80\mu m \Rightarrow$ Radius of core $a = 40\mu m$

$\Delta = 1.5\% = 0.015$, $\lambda = 0.85\mu m$, $n_1 = 1.48$

Numerical Aperture (NA) $= n_1 \cdot (2\Delta)^{1/2} = 1.48 [2 \times 0.015]^{1/2}$

$= \boxed{0.2563}$

↳ V-Number $= \frac{2\pi a}{\lambda} \cdot (NA) = \frac{2 \times 3.14 \times 40 \times 10^{-6}}{0.85 \times 10^{-6}} \times 0.2563$

$= 75.74$

↳ Total Number of Modes in Fiber is $M = \frac{V^2}{2}$

$\Rightarrow M = \frac{(75.74)^2}{2} = 2868.59 \approx 2869$

↳ power in the cladding is $P_c = P_{in} (NA)^2$

$= 500 (0.2563)^2$

$= \boxed{32.84 \text{ mW}}$

———x———x——— x ———x———x———

Que:- A Multimode step index fiber have core diameter of 60μm and relative refractive index is 1% operates on the wavelength of 0.8μm. If refractive Index of core is 1.5. Determine Normalized Frequency and No. of Modes are propagateing in fiber.

Soln:- Given that $d = 60 \mu m \Rightarrow$ Radius of core $= a = \frac{d}{2} = 30 \mu m$

$\Delta = 1\% = 0.01$, $\lambda = 0.8 \mu m$, $n_1 = 1.5$,

$NA = n_1 \times (2\Delta)^{1/2} = 1.5 \times [2 \times 0.01]^{1/2} = 0.2121$

↳ V-Number (V) $= \frac{2\pi a}{\lambda} \cdot (NA) = \frac{2 \times 3.14 \times 30 \times 10^{-6}}{0.8 \times 10^{-6}} \times 0.2121 \approx \boxed{50}$

↳ No. of Modes are propagating in fiber is

$M = \frac{V^2}{2} = \frac{(50)^2}{2} = \frac{2500}{2} = \boxed{1250}$

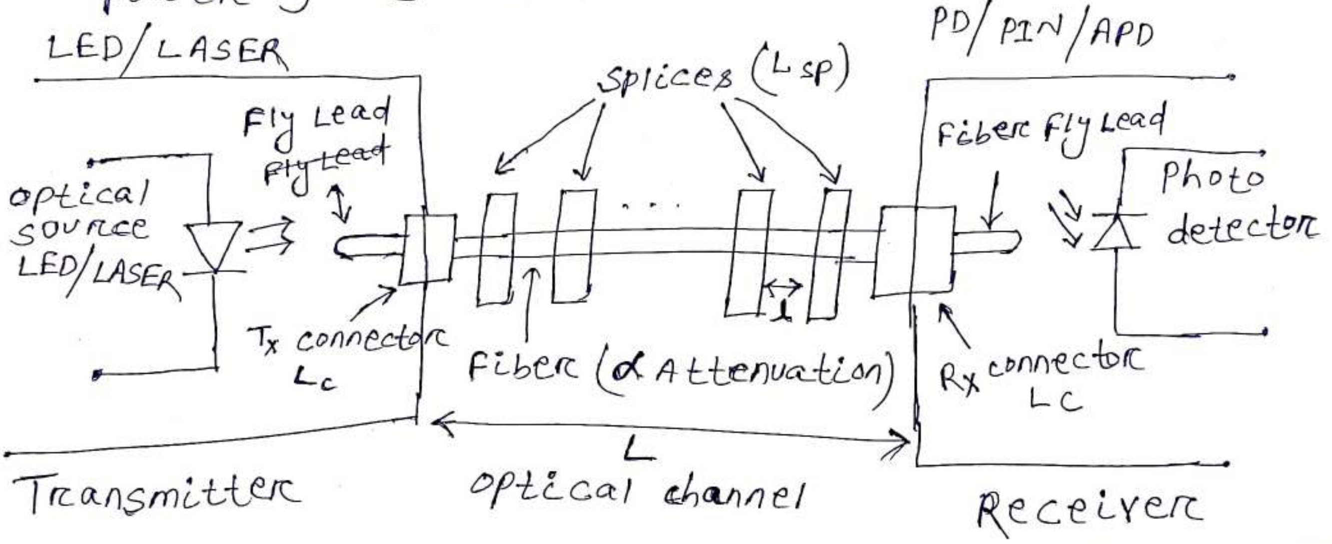
LINK POWER BUDGET ANALYSIS IN OPTICAL FIBER :-

↳ In optical fiber communication system, the total loss in the system is the addition of losses taking ~~ph~~ place because of all components.

↳ The loss produced in each element is calculated in terms of (dB).

↳ It is given by $\text{Loss in dB} = 10 \cdot \log\left(\frac{P_o}{P_{in}}\right)$

Here, P_o = output power of element, P_{in} = Input power of element.



↳ If Distance Between Two splices is l, Then Number of splices used is $n = \left(\frac{L}{l} - 1\right)$, where L = optical channel

↳ Here, L_{sp} = Loss due to single splice
L_c = Loss Due to connector, L = Length of fiber in (Km)
α = Attenuation of fiber (dB/Km)

↳ Here other Loss are considered in system Margin (6 to 8 dB).

↳ Total power loss in point to point Link is (Allowed Loss) $\underset{\text{in dB}}{\boxed{P_T = P_S - P_R}}$, Here P_S = power of source, P_R = Receiver sensitivity

↳ Total Losses also given by

$$P_T = \underbrace{2 L_c}_{\uparrow \text{ connector Loss}} + \underbrace{\alpha \cdot L}_{\uparrow \text{ Attenuation}} + \underbrace{L_{sp}}_{\uparrow \text{ Splice Loss}} + \underbrace{\text{system Margin}}_{\uparrow \text{ other Losses}}$$

—— x —— x —— x x ——

EXAMPLE ON LINK POWER BUDGET :-

Que:- components chosen for a digital fiber link of overall length 10Km and operating at 20Mbps are as follows:- ① LED capable of Launching an average power 0.1mW at 0.85 μm. ② Fiber attenuation 2.5dB/Km ③ Requires splicing every 2Km with a loss of 0.3dB per spice. connector Loss is of 1.5 dB. ④ The receiver power needed of -46dBm inorder to get 10^{-10} BER. ⑤ predicted safety margin 6 dB. Find Link power Budget for this given problem.

Solution:- Given that $L = 10\,Km$, Data Rate = 20Mbps

$P_t = 0.1\,mW = 0.1 \times 10^{-3}\,W = 10^{-4}$ watt, in dB $P_t = 10 \cdot \log 10^{-4}$

$P_S = \boxed{-40\,dB}$

$\lambda = 0.85\,\mu m$, $\alpha = 2.5\,dB/Km$, Distance between Two splices $l = 2Km$,

one splice loss $L_{sp} = 0.3\,dB$, connector Loss $L_C = 1.5\,dB$,

$P_R = -46\,dBm = -46 - 30 = -76\,dB$, predicted safety Margin = 6dB

Total Allowed Loss $P_T = P_S - P_R = -40 - (-76) = \boxed{36\,dB}$

↳ $$\text{Total Loss} = \underbrace{\alpha \cdot L}_{\substack{\text{Attenuation} \\ \text{Loss}}} + \underbrace{2 \cdot L_C}_{\substack{\text{Connector} \\ \text{Loss}}} + \underbrace{n \cdot L_{sp}}_{\substack{\text{splices} \\ \text{Loss}}} + \text{safety margin}$$

Attenuation Loss $= \alpha \cdot L = 2.5 \frac{dB}{Km} \times 10Km = 25\,dB$

connector Loss $= 2 \times L_C = 2 \times 1.5 = 3\,dB$

splices Loss $= n \times L_{sp} = \left(\frac{L}{l} - 1\right) \times L_{sp} = \left(\frac{10}{2} - 1\right) \times 0.3\,dB = \boxed{1.2\,dB}$

Safety margin = 6dB

Total Loss $= 25 + 3 + 1.2 + 6 = 35.2\,dB$

↳ Here Total Loss is 35.2dB is less than Total allowed Loss 36 dB. so, signal can be received without problem.

— x — x —

EXAMPLE OF ATTENUATION OF SIGNAL IN OPTICAL FIBER CABLE :-

Que-1 :- when the optical power launched in to a 10Km length fiber is 100μW, The optical power at Fiber output is 5μW. calculate
ⓐ overall signal attenuation in dB. ⓑ signal attenuation per Km. ⓒ The overall signal attenuation for a 12 Km optical link using same fiber with splices at 1 km interval, each giving attenuation of 0.5 dB.

Sol^n :- Given that Length of optical fiber cable $L = 10\text{ Km}$, $P_{in} = 100\,\mu W$, $P_0 = 5\,\mu W$

ⓐ α = overall signal attenuation in dB

$$= 10 \cdot \log\left(\frac{P_{in}}{P_{out}}\right) = 10 \cdot \log\left(\frac{100}{5}\right)$$

$$= 10 \cdot \log 20 = \boxed{13.01\,dB}$$

ⓑ α_L = signal Attenuation per km

$$= \frac{\alpha}{L} = \frac{13.01}{10} = 1.301\,\frac{dB}{Km}$$

ⓒ Total Attenuation $\alpha_T = 1.301\,\frac{dB}{Km} \times 12\text{ Km} + 0.5\,dB \times 11$ number of splices

$$= 15.6 + 5.5 = \boxed{21.1\,dB}$$

Que :- A continuous 12 Km long optical fiber link has a loss of 1.5 dB/Km.
ⓐ what is the minimum optical power level that must be launched in to the fibre to maintain an optical level of 0.3 μW at receiving end.
ⓑ what is the required input power if the fiber has a loss of 2.5 dB/Km.

Sol^n :- Given that $L = 12\text{ Km}$, $\alpha_L = 1.5\text{ dB/Km}$
$P_o = 0.3\,\mu W$,

Total Attenuation in dB $= 1.5\,\frac{dB}{Km} \times 12\text{ Km} = \boxed{18\,dB}$

Scanned by CamScanner

ⓐ $\alpha = 10\cdot\log\frac{P_{in}}{P_{out}} \Rightarrow 18 = 10\cdot\log\left(\frac{P_{in}}{0.3\,MW}\right)$

$\Rightarrow \frac{P_{in}}{0.3\,MW} = 10^{1.8} \Rightarrow \boxed{P_{in} = 18.92\,MW}$

ⓑ overall signal Attenuation in dB

$\alpha = 2.5\,\frac{dB}{Km} \times 12\,Km = 30\,dB$

$\Rightarrow$ ~~3~~ $\alpha = 30\,dB = 10\cdot\log\left(\frac{P_{in}}{P_{out}}\right)$

$\Rightarrow \frac{30}{10} = \log\left(\frac{P_{in}}{0.3\,MW}\right) \Rightarrow \boxed{P_{in} = 300\,MW}$

———x———

Que:- An optical signal at specific wavelength has a loss of 55% of its power after travelling 3.5 Km of fiber. what is the attenuation in dB/Km in this fiber.

Sol^n:- $P_{out} = 45\%\,P_{in} = 0.45\,P_{in}$

$L = 3.5\,Km$, $\alpha_L = \frac{10}{L}\cdot\log\left(\frac{P_{in}}{P_{out}}\right)\frac{dB}{Km}$

$\Rightarrow \alpha_L = \frac{10}{3.5}\log\left(\frac{P_{in}}{0.45\,P_{in}}\right) = 0.988\,\frac{dB}{Km}$

Que:- A 15 Km optical fiber link uses fiber with loss of 1.5 dB/Km. The fiber is joined every kilometer with connectors which give an attenuation of 0.8 dB each. Determine the minimum mean optical power which must be launched in to the fibere in order to maintain mean optical power level of 0.3 MW at detector.

Sol^n:- $\alpha_L = 1.5\,\frac{dB}{Km} \times 15\,Km = 22.5\,dB$

α_c = Attenuation Due to connector

= 0.8 dB × 14 connectors

= 11.2 dB

Total Attenuation $\alpha = \alpha_L + \alpha_c$

$\Rightarrow \alpha = 22.5 + 11.2 = 33.7\,dB$

$P_{out} = 0.3\,MW$, $\alpha = 10\cdot\log\frac{P_{in}}{P_{out}}$

$\Rightarrow 33.7 = 10\cdot\log\left(\frac{P_{in}}{0.3\,MW}\right) \Rightarrow \boxed{P_{in} = 0.8955\,mw}$

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TELECOMMUNICATION SYSTEM :-

TELEPHONE INTERNAL WORKING :- The components of a telephone system include: ① Microphone and Receiver ② Transmission system ③ switching and signalling system.

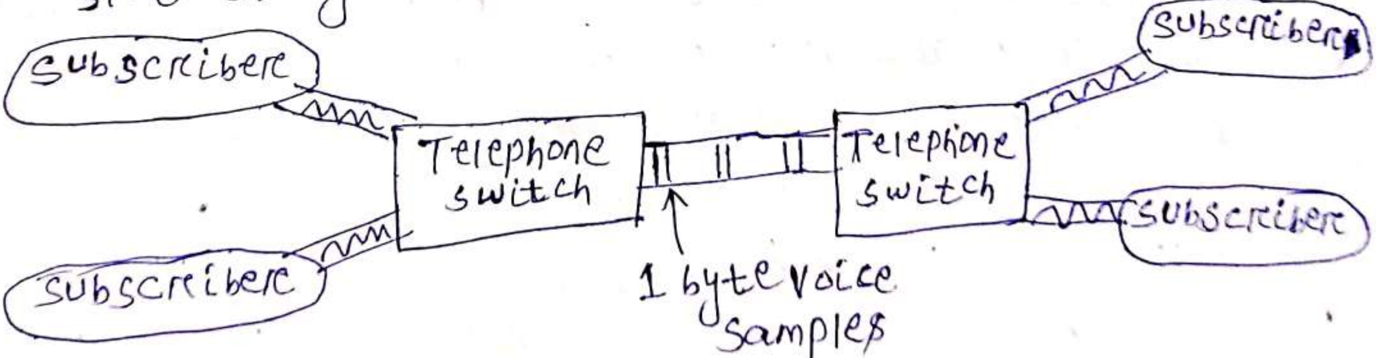
Microphone :- converts the vibrations in the air into an electrical signal.

Receiver :- converts the received electrical signal into sound waves (the reverse action of a microphone) example :- Loudspeaker.

Transmission system :- conveys the information representing the audio signal from the microphone to the receiver.

SWITCHING :- The first telephone switch digitizes a voice call (8000 8-bit samples per second) switching method is TDM.

↳ switch bundles multiple calls, by interleaving samples in time. Each call receives one 8-bit slot every 125ms.



SIGNALLING SYSTEM :-

↳ signalling refers to the control functions performed to setup a phone call.

↳ signalling between users and the local exchange in the central office is quite simple: dial tone, punch numbers, put phone down etc.

RINGING CIRCUIT :-

↳ The function of the ringing circuit is to provide the ring when the hook is off and also it has to provide the ringtone when hook is in on state.

↳ The function of the ringing circuit is controlled by SLIC (subscriber line interface circuit).

↳ SLIC will send the ring pulse continuously to all the device which are connected to the exchange by this function the user will come to know whether the device is in working state or not.

——x——x——

NUMBERING PLAN OF TELEPHONE NETWORKS :-

↳ A Telephone numbering plan is a type of numbering scheme used in telecommunication to assign telephone numbers to subscriber telephones (or) other telephony endpoints. Telephone numbers are the addresses of participants in a telephone network, reachable by a system of destination code routing. Telephone numbering plans are defined in each of administrative regions of the public switched telephone network (PSTN) and they are also present in private telephone networks. For public number systems, geographic location plays a role in the sequence of numbers assigned to each telephone subscriber.

↳ Many numbering plans subdivide their territory of service in to geographic regions designated by a prefix, often called an Area code (or) city code, which is a set of digits forming the most-significant part of the dialing sequence to reach a telephone subscriber.

↳ The International Telecommunication Union (ITU) has established a comprehensive numbering plan, for uniform interoperability of the networks of its member state (or) regional administrations. It is an open numbering plan, however, imposing a maximum length of 15 digits to telephone numbers. The standard defines a country calling code (country code) for each state (or) region which is prefixed to each national numbering plan telephone number for international destination routing.

↳ private numbering plans exist in telephone networks that are privately operated in an enterprise (or) organizational campus. such systems may be supported by a private branch exchange (PBX), which provides a central access point to the PSTN and also controls internal calls between telephone extensions.

↳ National numbering plan; a complete destination telephone number is composed of an area code and a subscriber telephone number. The subscriber number is the number assigned to a line connected to customer equipment. The first few digits of the subscriber number may indicate smaller geographical areas (or) individual telephone exchanges. In mobile networks they may indicate the network provider. callers in a given area (or) country sometimes do not need to include the particular area prefixes when dialing with in the same area. Devices that dial telephone numbers automatically may include the full number with area and access codes.

x — x — x

SWITCHING SYSTEM :-

↳ The purpose of a telecommunication switching system is to provide the means to pass information from any terminal device to any other terminal device selected by the originator.

↳ The switching centers receives the control signals, messages (or) conversations and forewards to the required destination.

↳ A switching system is a collection of switching elements arranged and controlled in such a way as to setup communication path between any two distant points.

↳ A switching center of a telephone network comprising a switching network and its control and support equipment is called a central office.

↳ In computer communication, the switching technique used is known as packet switching (or) message switch (store and forward switching).

↳ In telephone network the switching method used is called circuit switching.

↳ Some practical switching system are step by step, cross barred relay system, digital switching systems, electronic switching system etc.

Signalling systems :-

↳ A signalling system in a data communication networks exchanges signalling information effectively between subscribers.

↳ The signalling systems are essential building blocks in providing the ultimate objective of a worldwide automatic telephone services standardized.

↳ signalling provides the interface between different national system. The introduction of signalling system was the big step in improving the PSTN.

↳ The consultative committee on international telegraphy and telephony (CCITT) based in Geneva, recommended seven formats related to signalling.

↳ The first five formats related to inband signalling and the last two in the category of common channel signalling. In Inband signalling, voice information and signalling information travel on common paths, whereas in common channel signalling, they travel on separate paths.

Criteria for Design of Telecommunication System :-

. It depends on following parameters.

↳ The traffic Intensity is the product of the calling rate and the average holding time.

↳ The busy hour is defined as that continuous sixty-minute period during which the traffic intensity is highest.

↳ The calling rate is the average number of request for connection that are made per unit time.

↳ The calling rate is the probability that a call request will occur in a certain short interval of time.

↳ The holding time is the mean time that calls last. otherwise the average holding time is the average duration of occupancy of traffic path by a call.

Grade of Service (GOS) :-

↳ GOS is a measure of congestion expressed as the probability that a call will be blocked (or) delayed:

Blocking criteria :-

↳ If the design of a system is based on the fraction of calls blocked (the blocking probability), then the system is on blocking basis (or) call loss basis.

↳ Blocking can occure if all devices are occupied when a demand of service is initiated.

↳ Blocking criteria are often used for the dimension of switching networks and interoffice trunk groups.

↳ For a system designed on a loss basis, a suitable GOS is the percentage of calls which are lost because no equipment is available at the instant of call request.

Delay criteria :- ↳ If the design of a system is based on the fraction of calls delayed longer than a specified length of time, then the system is said to be a waiting system (or) engineered on a delay basis.

↳ Delay criteria are used in telephone systems for the dimensioning of registers.

↳ In waiting system, a GOS objective could be either the percentage of calls which are delayed (or) the percentage which are delayed more than a certain length of time.

CONGESTION :- ↳ It is the condition in a switching center when a subscriber can not obtain a connection to the wanted subscriber immediately.

↳ In a circuit switching system, there will be a period of congestion during which no new calls can be accepted. There are two ways of specifying congestion.

(i) Time congestion: It is the probability that all servers are busy. It is also called the probability of blocking.

(ii) call congestion: It is the proportion of calls arising that do not find a free server.

↳ Call congestion is a loss system and also known as the probability of loss while in a delay system it is referred to as the probability of waiting.

↳ If the number of sources is equal to the number of servers, the time congestion is finite, but the call congestion is zero.

↳ when the number of sources is large in comparison with servers, the probability of a new call arising is independent of the number already in progress and therefore the call congestion is equal to the time congestion.

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Operation of a PBX and Digital EPABX :-

↳ EPABX stands for Electronic private Automatic Branch Exchange which is a private telephone network used by the organizations and the companies for various types of communication, either between the employees (or) outside the clients. PBX which is private Brand Exchange is a telephone exchange which is used by a particular office (or) business, opposite to the one that a common carrier (or) telephone company operates for many companies and business for the general public. private Branch Exchange (PBX) is also known as (PABX) private Automatic Branch Exchange and (EPABX) Electronic private Automatic Branch Exchange.

↳ VOIP for PBX: VOIP Technology is voice over Internet protocol, and some of the Exchanges rely on this technology. This system turns phone calls into data packages and then sends them over a computer network. As compared to regular PBX, a VOIP cuts the extra cost because the company can use one network for phone calls and data instead of two. PBX has a central server and not a central switch-board. The phones in the office have particular software and hardware to connect to the server.

↳ Virtual PBX : Business is not required to set up the exchange inside the building as virtual PBX turns that responsibility over to another company. when the other company provides PBX services, it brings along alot of advantages. You are not restricted to any physical limits on the number of lines and can get more when needed. The Virtual PBX is also known as hosted PBX systems.

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INTERNET PROTOCOL TELEPHONY :-

↳ IP telephony (Internet protocol telephony) is a general term for the technologies that use the Internet protocol's packet-switched connections to exchange voice, fax and other forms of information that have traditionally been carried over the dedicated circuit-switched connections of the public switched telephone network (PSTN). using the Internet, calls travel as packets of data on shared lines, avoiding the tolls of the PSTN. The challenge in IP telephony is to deliver the voice, fax (or) video packets in a dependable flow to the user. Much of IP telephony focuses on that challenge.

↳ IP telephony service providers include (or) soon will include local telephone companies, long distance providers such as , AT&T, cable TV companies, Internet service providers (ISPs), and fixed service wireless operators. IP telephony services also affect vendors of traditional handheld devices.

↳ currently, unlike traditional phone service, IP telephony service is relatively unregulated by government. In the united states, the Federal Communications Commission (FCC) regulates phone to phone connections, but says they do not plan to regulate connections between a phone user and an IP telephony service provider.

↳ VoIP is an organized effort to standardize IP telephony. IP telephony is an important part of the convergence of computers, telephones and television in to a single integrated information environment. Also see another general term, computer telephony integration (CTI), which describes technologies for using computers to manage telephone calls.

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Que:- How is telephone network different from the principle behind the internet network?

Answer:- A Telephone Network (the PSTN not VoIP) is a circuit switched network. That means when someone places a call to another person a circuit is created and maintained for the duration of the call even if there is zero information being sent (silence). The network sets up the circuit at the beginning of the call (based on the digits beigng dialed), maintains the circuit for the duration of the call and then shuts down that circuit at the end of the call (when you hang up)

↳ The Internet network (IP Network) is packet based. In this kind of a network information is broken into packets that are sent over a 'shared' network.

Each of these packets contain the origination address and destination address so that the network knows where to foreward them. Each time a device has information to be sent it builds a packet and then sends that packet into the network. This is a shared resource. You may have several computers in your home but only one router and one connection to your ISP. Your computers can simultaneously use the internet and this is accomplished through time multiplexing the packets onto the connection to your ISP.

— x — x — x —

INTERNET TELEPHONY :-

↳ Internet telephony refers to all features of traditional telephony (phone calls, fax, Voicemail etc.) where all calls and data are sent over the internet rather than over traditional landlines.

↳ Voice over IP (VOIP) is the most common method for placing phone calls over the Internet. Traditionally phone calls were sent as analog signals through telephone lines. With VOIP, your call is converted into data that is sent over the Internet: Audio is sent over IP (Internet protocol).

Internet phone system working :-

↳ In order to use an Internet phone system, it is necessary to have a VOIP solution such as the NFON cloud Telephone system.

↳ As you speak through a microphone (Laptop, mobile or headset) your voice - the audio signal is digitized. This data is split into packets and given individual labels.

- ↳ Your call is made up of different packets of data. Each packet of data travels over the Internet to the recipient. When the data arrives at the end destination it is put back in to the correct order. The data is then converted in to audio and the recipient hears what you said.
- ↳ The data packets don't necessarily arrive in the order they were sent. They can overtake each other in the route. When they arrived reassembled in correct order and your message can be heared by the recipient.

—x—x—x—

SPACE AND TIME SWITCHING :-

- ↳ If the coded values are transferred during the same time interval from input to output, the technique is called space switching. If the coded values are stored and transferred to the output at a late time interval, the technique is called as Time-switching.