Unit → 5

Transmission Media....

1) Transmission....

27/01/25

» Introduction To Transmission lines:—

A transmission line is a device designed to guide electrical energy from one point to another. It is used, for example, to transfer the output of energy of a transmitter to an antenna. This energy will not travel through normal electrical wire without great losses. Although the antenna can be connected directly to the transmitter, the antenna is usually located some distance away from the transmitter. On board ship, the transmitter is located inside a radio room and its associated antenna is mounted on a mast. A transmission line is used to connect the transmitter and the antenna.

The transmission line has a single purpose for both the transmitter and the antenna. This purpose is to transfer the energy output of the transmitter to the antenna with the least possible power loss. How well this is done depends on the special physical and electrical characteristics. (impedence and resistance) of the transmission line.

* TERMINOLOGY

All transmission lines have two ends (see figure 1.1) The end of a two wire transmission line connected to a source is ordinarily called the INPUT END or the GENRATOR END. Other names given to this end are TRANSMITTER END, SENDING END, and SOURCE. The other end of the line is called the OUTPUT END or RECEVING END. Other names given to the output end are LOAD END and SINK.

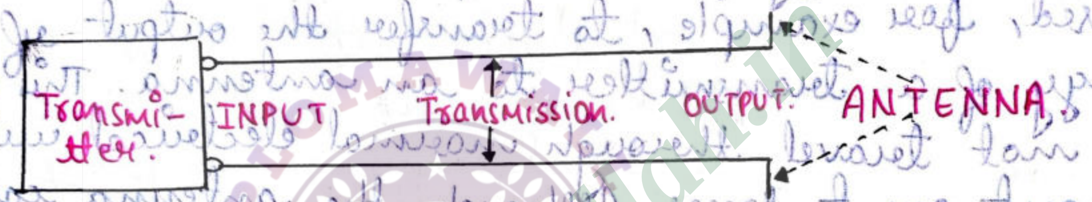


Figure: 1.1 Basic Transmission line.

→ The transmission media is categorized in following two types :-

1. Guided Media
2. Unguided Media.

(1) Guided Media :-

In Guided media, signals are transmitted through a physical path. The features of guide media are high speed and security. Guided media also known as wired or Bounded Transmission media.

→ There are three types of Guided Media :-

1. Twisted Pair
2. Coaxial cable
3. Optical fiber cable.

①

* Types of twisted pair cable :

→ There are two types of twisted pair cable :-

1.) Unshielded twisted pair - cable.

2.) Shielded Twisted Pair - cable.

1.) Unshielded Twisted - pair cable :-

Unshielded twisted pair cable is widely used in telecommunications. Unshielded Twisted pair (UTP) cable is categorized as follows:

Category 1 UTP : Mostly used in telephone line as it supports only low - speed data.

Category 2 UTP : It supports upto 4Mbps.

Category 3 UTP : It supports upto 16Mbps.

Category 4 UTP : It supports upto 20 Mbps. It can also be used for long - distance communications.

Category 5 UTP : It supports upto 200 Mbps

2.) Shielded Twisted - pair cable :-

Shielded twisted pair cable contains the metal foil surrounding the twisted copper wires to avoid external interference.

2.) Coaxial Cable :-

Coaxial Cable has a centre conductor enclosed in a insulating cover, which in turn is enclosed in a metal foil shield. The whole cable is covered in a plastic cover. The metal foil shield protects against the noise.

As the name suggests, it consist two conductors parallel to each other.

The inner conductor is made up of copper and the outer conducter is made up of copper mesh. There two conductors are separated by insulating cover.

The inner center conductor is used for data transfer while the outer copper mesh conductor protects against the noise (Electronic Interferance).

* Types of Coaxial cable :-

1.) Base Band Transmission Cable.

2.) Broad Band Transmission Cable.

1.) Base Band Coaxial Cable :-

It is used for transmission of single signal at high speed. It is used for digital transmission.

2.) Broaband Coaxial Cable :-

It is used for transmission of multiple signals simultaneously. It is used for analog transmission.

3.) Fiber - Optic Cable ...

Fiber Optic cable is also known as optical - fiber cable. It is made of glass and the transmission of data is based on the concept of reflection of light through glass.

In fibre optic cable, the optical fibres are coated in plastics. These optical fibres send the data by pulses of light.

The Plastic coating protects the cable from temperature, electromagnetic inference and other types of wiring issues.

(2.) Unguided Media...

Unguided Media does not use physical medium to transmit the data from source to destination. We already know that the guided media uses physical medium such as cables and wires to transfer the data from source to destination. However unlike guided media, the unguided media uses air as a transmission medium to transfer the data. Thus, it is called wireless transmission media.

The unguided media uses an atenna for transmitting and receiving the data in form of electromagnetic waves.

→ Types of Unguided Media :-

1. Microwave transmission
2. Radio transmission
3. Infrared transmission.

① Microwave Transmission :-

In Microwave transmission, the range of frequency of electromagnetic waves lies somewhere between 1-300 GHz.

→ Microwave transmission is two types :-

i) Terrestrial Type Microwave Transmission
ii) Satelite Type Microwave Transmission.

* Satelite Type Microwave Transmission :-

This type of communication uses the satelite antenna for communication. The sender antenna sends the signal to the satelite antenna which is revolving around the earth at a known height. The satelite antenna then amplifies the recieved signal and sends it to the receiver antenna.

* Terrestrial Type Microwave Transmission :-

Terrestrial microwave transmission is a method of transmitting data, voice or video signals wirelessly using high-frequency radio waves (microwaves) between antennas located on Earth's surface, typically within a line-of sight range.

② Radio Transmission :-

- Radio waves are very low frequency electromagnetic waves that are transmitted in all directions within the range.
- Radio transmission frequency ranges from 3KHz to 1GHz.
- In radio transmission, the antennas need to be in aligned nor required to be set in a particular manner to send and receive signals.
- Since radio waves are omnidirectional (all directions), it is not possible to isolate the communication inside a building.

③ Infrared Transmission :-

1. Infrared waves are highest frequency waves, frequency ranges from 300GHz to 400 THz.
2. Suitable for short distance communication.
3. Bandwidth is high so data transmit rate is high compared to other mediums.
4. These waves cannot penetrate walls thus they are ideal for isolated communications.

2.> Optical Fibre :-

↳ A thin flexible and transparent wire prepared for light propagation is called optical fibre.

→ **Need of Optical Fibre :-**

The optical fibre has been constructed for following reasons :-

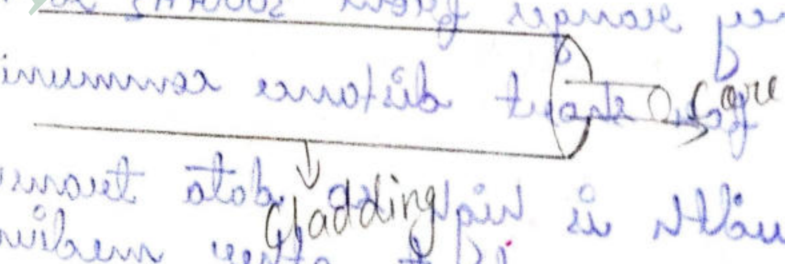
i) The light wave can't transverse long distance in air without any loses.

ii) To make lose less light wave communication the optical waves can be guided through optical fibre.

iii) The optical fibre consist of two media kept one inside the other.

iv) • The centre transparent medium of optical fibre is called "core."

• And the outter is called "cladding."

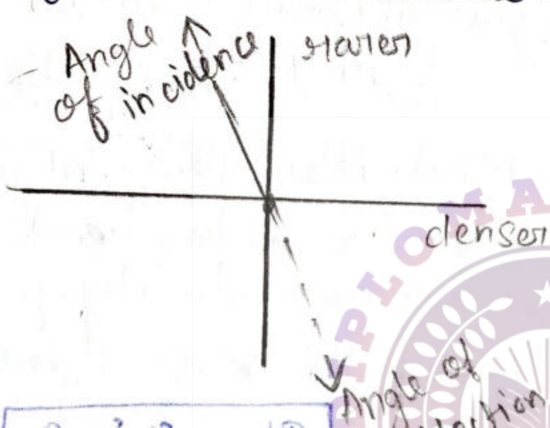


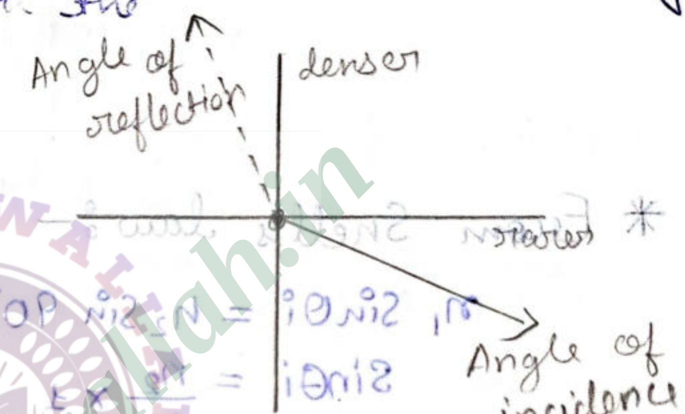
Principle of Operations-

* The light propagate through optical fibre, through "total internal reflection". The

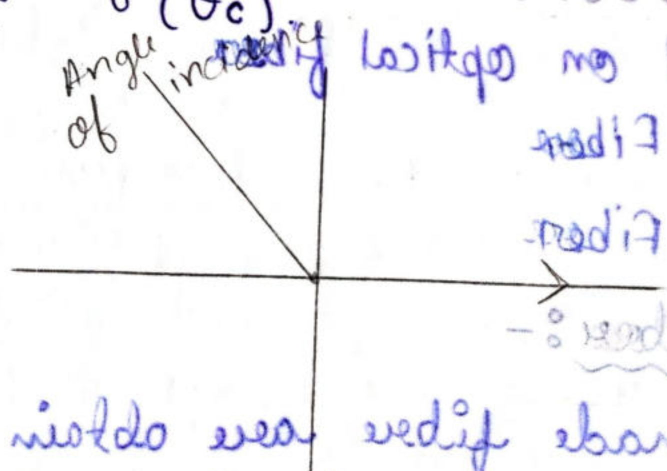
total internal reflection appears due to following reasons

i) when light transverse from rarer medium (air) to denser medium (glass) the refracted rays move towards the normal on the interface of media as in Snell's law. Conversely if light transverse from denser medium (glass) to rarer medium (glass) the refracted rays moves away from the normal. ~~on the~~

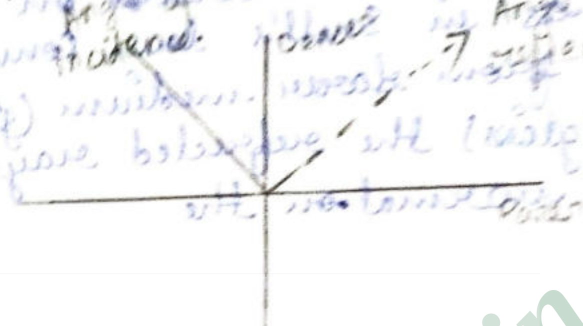




ii) If the angle of incidence increases to a certain value for which the refracted ray happened to be on the interferance medium. The angle of incidence known as critical angle. (θ_c)



iii) If the incident angle increases more than critical angle then the refracted ray falls on the same denser medium with no refraction. This reflection of light is called total internal reflection.



* From Snell's law :-

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

$$\sin\theta_i = \frac{n_2}{n_1} \times 1$$

$\boxed{\text{Since } \theta_i = \theta_c}$

$$\sin\theta_i = \frac{n_2}{n_1} \times 1$$

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

Classification :-

→ Material based on optical fibre

(i) Plastic made Fibre

(ii). Glass made Fibre

* Plastic Made Fibre :-

→ The plastic made fibre are obtain from polymers of transparent light, flexibility and interaction less to light.

more than
ray falls
no refraction.
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from
ibility

* Glass Made fibre :-

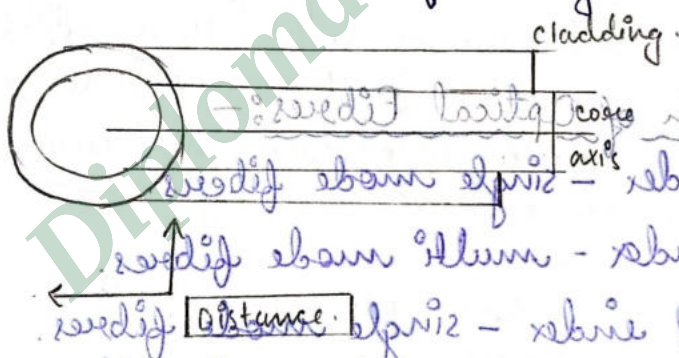
The glass made fibre is febricated from flexible glass as core.

Classification of optical fibre is based on refractive index.

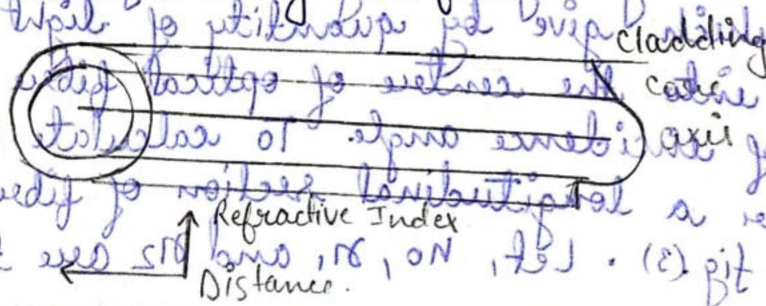
- Step index fibre.
- Graded index fibre.

* Step Index Fibre :-

If the refractive index of core remains the same from the centre of the core to the core cladding interface those optical fibre are known as step index fibres graded index.



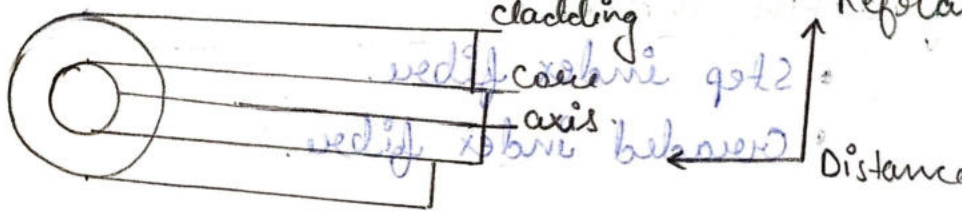
There type are made by varying refractive index of core material. Therefore the refractive index change with distance from the centre of fibre to core - cladding interface.



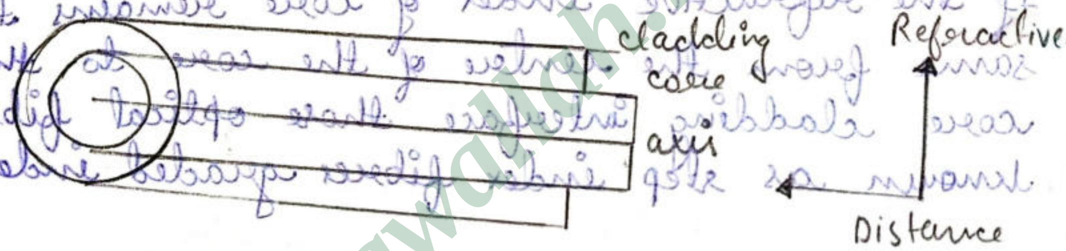
Modes of Propagation based Optical fibre:-

- Single Mode fibres.
- Multimode fibres.

▶ Single Mode Fibres:-



▶ Multimode fibres:-



Combination of Optical Fibres:-

- Step index - single mode fibers.
- Step index - multi mode fibres.
- Graded index - single mode fibres.
- Graded index - multi mode fibres.

v.v.

* Numerical Operature (NA):- Numerical Operature (NA) is a light gathering property of optical fibre which give by quantity of light that bought into the centre of optical fibre in terms of incidence angle. To calculate NA consider a longitudinal section of fibre as in fig (3). Let, n_0, n_1 and n_2 are the

refractive index of air (outside, optical fibre) core and cladding respectively.

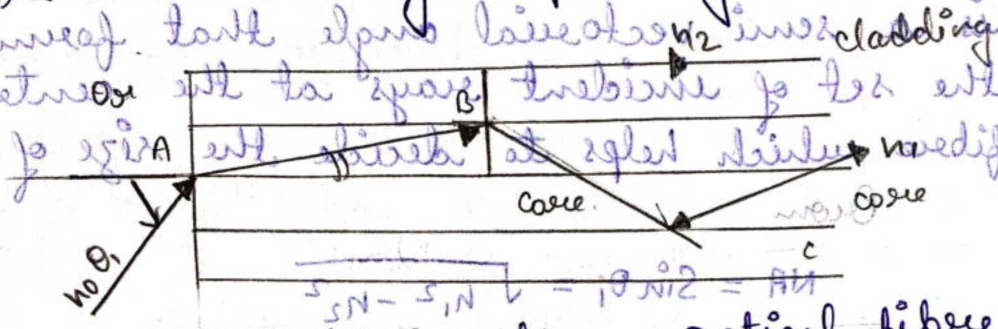


Fig 3: Longitudinal section of optical fibre θ_1 or are incidences angle and refracted angle of the light through fibre.

→ Applying Snell's law at A

$$n_0 \sin\theta_1 = n_1 \sin\theta_r$$

$$\sin\theta_1 = \frac{n_1}{n_0}\sin\theta_r = \frac{n_1}{n_0}\sqrt{1-\cos^2\theta_r}$$

Applying Snell's law at B

θ_i = Incidence Angle

θ_c = Critical Angle

θ_r = Refractive Angle.

$$n_1 \sin(90-\theta_r) = n_2 \sin 90$$

$$n_1 \cos\theta_r = n_2 \times 1$$

$$\cos\theta_r = \frac{n_2}{n_1}$$

Substituting (2) in (1)

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

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

$$\therefore NA = \sin\theta_1 = \frac{1}{n_0}\sqrt{n_1^2-n_2^2}$$

$$NA = \sin\theta_1 = \sqrt{n_1^2-n_2^2} \quad \therefore n_0 = 1 \text{ for air}$$

Acceptance angle :-

It is a semi vectorial angle that formed by the set of incident rays at the centre of fibre which helps to decide the size of core.

From

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

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

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

Replacing $\theta a = \sin^{-1}\left(\sqrt{n_1^2 - n_2^2}\right) = \sin^{-1}(NA)$

* Some losses in optic fibre :-

The optical fibre does not experience the loss in terms of intensity of light. However the presence of impurities scattering at the edge geometry of structure and dispersion of light cause some ~~tavet~~ losses.

→ The absorption losses appears as:

- Extrinsic looses.
- Intrinsic losses.
- Atomic defect losses.

- Extrinsic looses :- The extrinsic looses appears due to presence of impurities which absorbed the light the impurities may be to presence of fe, cr, co and cu in the core material.

- Intrinsic looses:- Since, the fibre | core itself absorbs some quantity of energy which is known as intrinsic loss.

- Scattering and radiation losses:-
Since, Optic fibre contain glass as core, where impurities are present. The scattering of light at these impurities causes. Raleyeigh scattering where the energy of scattered wave directly proportional to 4th power ($E = 1/\lambda$) of wave length.

* Geometrical Fibre:- Due to bending of optical there are 2 type of losses from macroscope bending microscopic bending microscopic. If the fibre be rounded as big circle of known radius of curvature, the loss may be called macroscopic bending loss.

Dispersion loss:- In the transmission of light through optical fibres the pulse width varies due to dispersion light throught the core.

- Material dispersion
- Wave guide dispersion.
- Inter modal dispresion.

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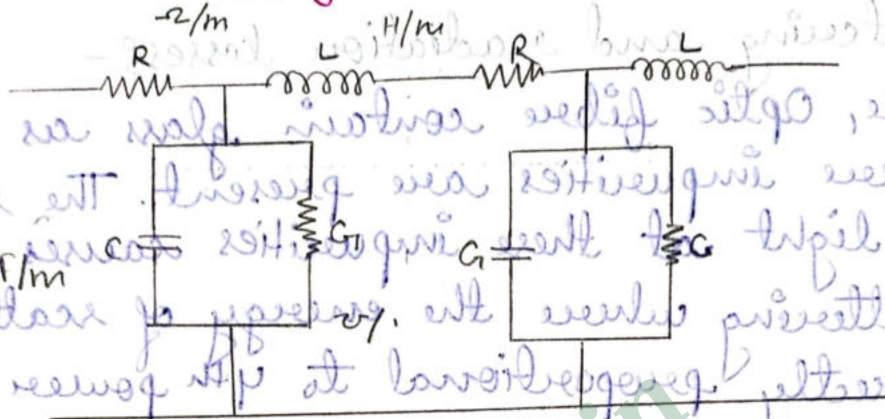
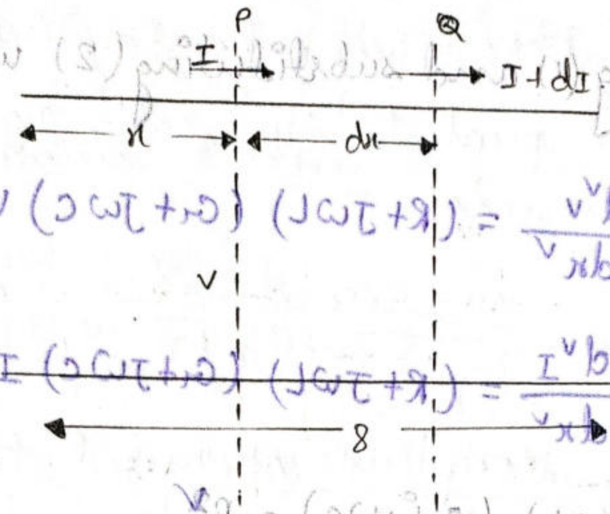
Equivalent circuit of a Transmission line:-



* Here, R, L, G, C are called as primary constituents of a transmission lines:-
  - Resistance (R):- o/p loop resistance per unit length.
    → units are ohms/km.
  - Inductance (L):- Loop inductance per unit length.
    → units are Henries / Km.
  - Capacitance (C):- shunt capacitance between two waves.
    → Units are Farad / Km.
  - Conductance (G):- Shunt conductance between two waves.
    → Units are (mho / Km).

Transmission line equation:-



Consider a shut section of line PQ of length dx at a distance x from the sending end A.

→ At P, 1st the voltage be V and current I.

→ At Q, 1st the voltage will be V+dV and current I+dI.

→ The series impedence of small section dx will be $(R+jWL)\,dx$.

→ The shunt admitance of small section dx will be $(G+jWC)\,dx$.

* The potential difference between two point is

$$V-(V+dV) = I\,(R+jWL)\,dx.$$

$$-dV = (R+jWL)\,I\,dx.$$

$$-\frac{dV}{dx} = (R+jWL)\,I \quad \text{——— (1)}$$

lly

$$I-(I+dI) = V(G+jWC)\,dx.$$

$$-\frac{dI}{dx} = (G+jWC)\,V \quad \text{——— (2)}$$

differenting (1) and substituting (2) we have

$$\frac{d^2V}{dx^2} = (R+JWL)(G+JWC)V$$

$$\frac{d^2I}{dx^2} = (R+JWL)(G+JWC)I$$

* Let $(R+JWL)(G+JWC) = P^2$

$$\frac{d^2V}{dx^2} = P^2V \quad \text{--- (3)}$$ Here P is Propagation Constant.

$$\frac{d^2I}{dx^2} = P^2I \quad \text{--- (4)}$$

▷ Secondary Constants of Transmission line :-

Characteristics impedence $Z_0 = \sqrt{\frac{R+JWL}{G+JWC}}$

Propagation Constant $P = \sqrt{(R+JWL)(G+JWC)}$

$= \sqrt{ZY}$.

where $Z = R+JWL$ = Series impedence.

$Y = G+JWC$ = Shunt Inductance

* Characteristics Impedence :-

We know $\frac{-dV}{dx} = (R+JWL)I$.

$$\frac{-d}{dx}(V_{si}\,e^{-Px}) = (R+JWL)\,I_{si}\,e^{-Px}$$

$$P.V_{si} = (R+j\omega L) I_{si}$$

$$\frac{V_{si}}{I_{si}} = \frac{R+j\omega L}{P}$$

$$Z_0 = \frac{V_{si}}{I_{si}} = \frac{R+j\omega L}{\sqrt{(R+j\omega L)(G+j\omega C)}} = \sqrt{\frac{R+j\omega L}{G+j\omega C}}$$

» Components of an Optical Fibre Cable :-

* Core :- Usually made from glass (silica) or plastic. It is the physical medium that transports the optical signals from one source to another. The core is the smallest part of a cable, with a diameter less than a human air.

* Cladding :- Surrounds the core and provide lower refractive index to make the optical fibre work. It is a thin layer that enables data to travel through the length of the cable.

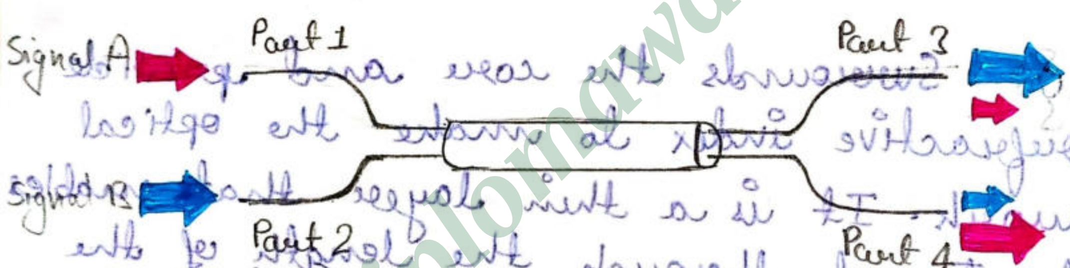
* Coating :- The protective layer of the optical fibre that absorbs shock, scrapes and moisture that can damage the cladding. It gives extra protection against excessive cable bends.

* Strengthening fibres :- Helps protect the core against tension and crushing during installation.

* Cable Jacket :- The outer layer of the cable. This layer protects the cable against environmental hazards.

▷ Coupler :-

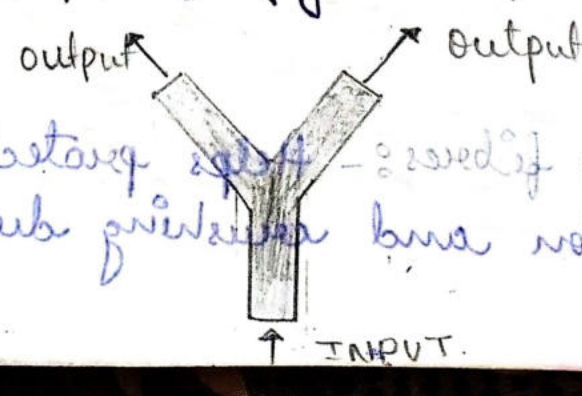
Fiber Optic couplers are used to split the input signals into two or more outputs, they are called splitters in this case. On the other hand, some types of coupler can be used to combine two or more inputs into one single output, they are called combiners in this case.



≫ FIBER OPTIC COUPLER TYPES :-

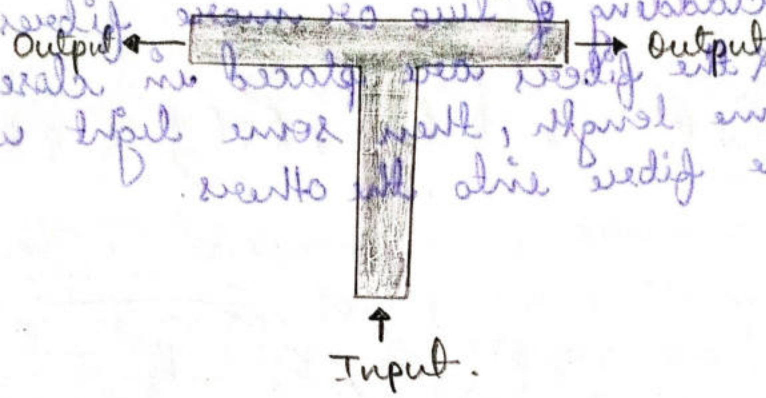
1. Y Coupler :-

Y coupler is also called tap coupler. This type of coupler simply divides the signal into two outputs.



2. T-Coupler :-

T coupler functions the same as Y coupler.



T couples can be cascade to connect multiple terminals on a network, as shown below.

3. Star Couplers :-

Star couplers have multiple inputs and outputs. The input and output port number could be the same or not, such as 2×2, 4×4, 8×8 etc.

4. Tree Couplers :-

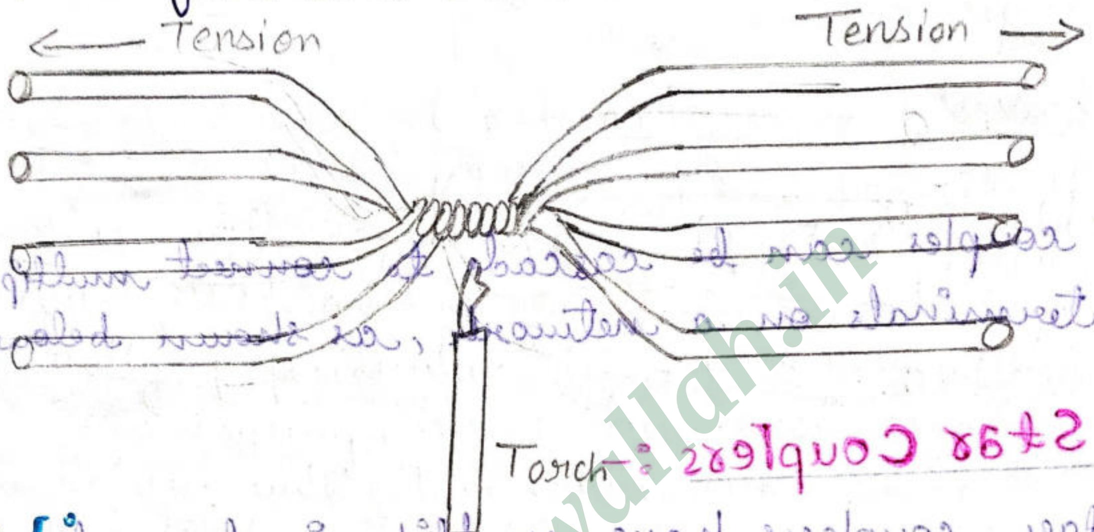
Tree couplers are called 1XN couplers because they take one or two inputs and spilt it into multiple outputs.

5. WDM Couplers :-

WDM couplers seprate optical signals according to their wavelengths. They look like 1X2 coupler but they do not just split the power blindly but rather split two different wavelengths into two O/P, such as 1310/1550nm & 980/1550nm couplers.

* Biconical Taper Coupler (or Fused Coupler)

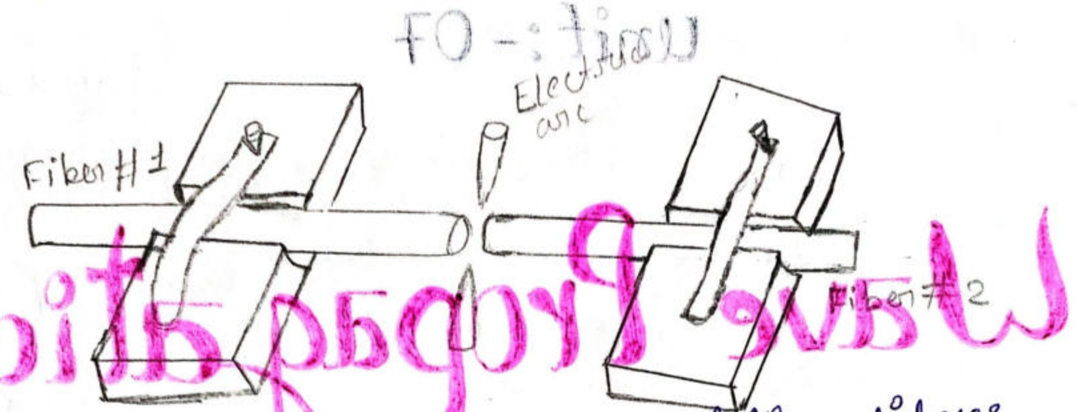
Fused coupler is the most common technology. If the cladding of two or more fibres are partially removed & the fibers are placed in closed proximity over some length, then some light will couple from one fibre into the others.



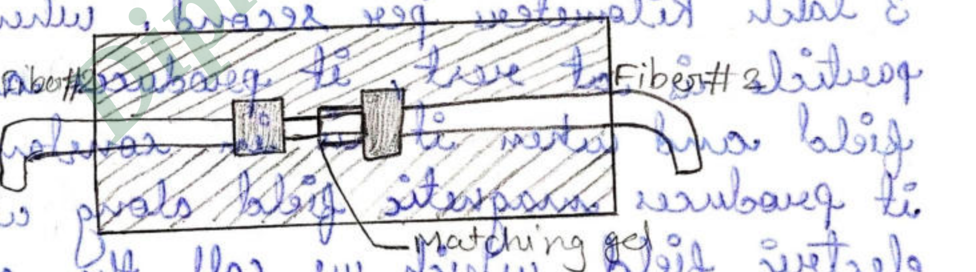
Splices...

Splices optical fibre is not done by twisting and soldering as done with copper cables. The splices may be made in two ways. The ends of the fibres can be joined either by fusion or with mechanical splies. In both the cases, a jig is required to hold the ends while they are melted and joined or adhesive is applied.

- Fibre Fusion Splice :- Fusion splicer can be used for both for single mode and multimode fibres joints. The two fibres to be fused are kept next to each other and then heat is applied by using electrical arc to fuse the ends together.



• Non-fused Splice :- Techniques of splicing fibres without fusion provide a rapid and convenient method of joining two fibres. In this mechanical splicing as shown in fig, the two fibres ends are glued together with a transparent, index matching adhesive. A snug fitting glass tube, a thermal shrinking tube and a glass sleeve with a center hole for insertion of adhesive are some structures that are used as precession alignment tools. If suitable bonding materials are used, this can serve as permanent splices.



CONNECTORS :-

These are essential components to allow direct transmission of optical power from one core to another. Demountable connectors are used to connect fibres to the terminal equipment. Losses at a connector result from three factors. They are the Fresnel reflection losses at the fibre faces, the mismatch in the mode field diameters & the effects of misalignment.