Understanding Losses in Fiber Optic Interconnections

Understanding fiber optic losses is valuable in designing and choosing components in a fiber optic communications system. These losses are important variables in the network design phase with a loss budget in mind. In turn, meeting this loss budget is critical in the functioning of the whole system.

TYPES OF LOSSES

There are different reasons for light losses which may occur during transmission of light signal inside the fiber or during the interconnection process of two fibers.

1. **Absorption Loss**
   Light travels best in clear substances. Impurities such as metal particles or moisture in the fiber can block some of the light energy, it absorb the light and dissipate it in the form of heat energy, which caused absorption loss. The solution is to use ultra-pure glass and dopant chemicals to minimize impurities, and to eliminate loss at the water peak wavelength during the process of fiber manufacturing.

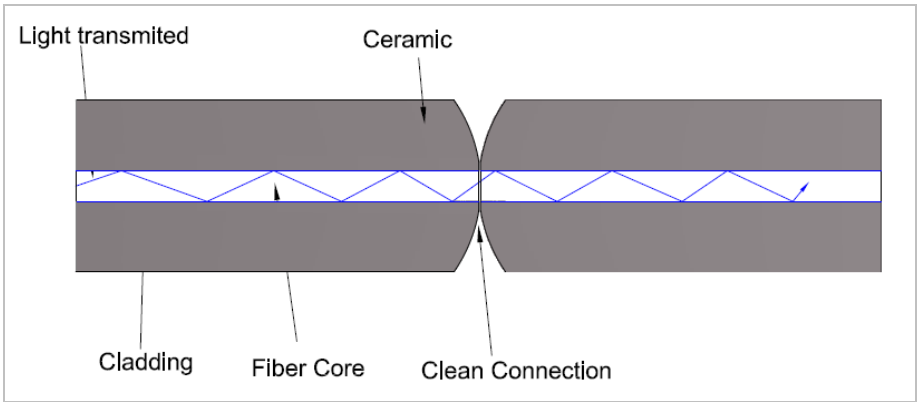

Diagram-1: Having a clean fiber can minimize absorption loss

2. **Rayleigh Scatter**
   Rayleigh scatter occurs at random when there are small changes in the refractive index of materials in which the light signal travels. In this case, it is the changes in the refractive index of the core and the cladding of the fiber optic cable. This loss is caused by the miniscule variation in the composition and density of the optical glass material itself, which is related to the fiber manufacturing process.

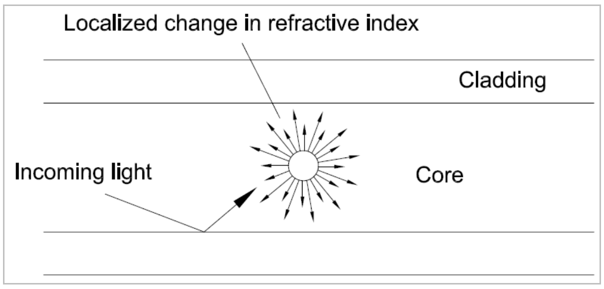

Diagram-2: Light scattered during transmission

3. **Bending Loss**

Bending losses occurs in two forms - macrobending and microbending. When a cable is bent and it disrupts the path of the light signal. The tighter the bends of a cable, the greater it is of the light loss.

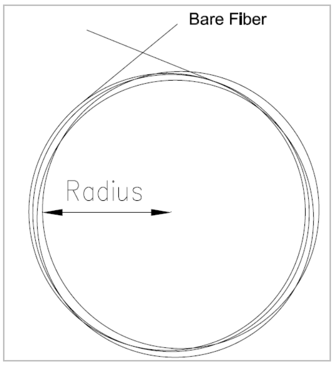

Diagram-3: Bending Radii of an optical fiber

(i) Macrobends

Macrobends describes the bending of the fiber optic cable in a tight radius. The bend curvature creates an angle that is too sharp for the light to be reflected back into the core, and some of it escapes through the fiber cladding, causing optical loss. This optical power loss increases rapidly as the radius is decreased to an inch or less. Different fiber optic cables have different specifications on how much the cable can bend without affecting the stated performance or loss. The industry has seen gradual improvements in the bending performances of the fiber. One such example is the recent **G.657.B.3** fiber standard recommended by the International Telecommunication Union (ITU), where the bending radius is standardized as low as 5mm.

(ii) Microbends

Microbends refer to minute but sever bends in fiber that result in light displacement and increased loss, it typically caused by pinching or squeezing the fiber. Microbends deform the fiber's core slightly, causing light to escape at these deflections. Most microbending can be avoided by the correct selection of materials and proper cabling, handling, and installation techniques.

4. **Insertion Loss (IL)**

Insertion loss is the most important performance indicator of a fiber optic interconnection. This is the loss of light signal, measured in decibels (dB), during the insertion of a fiber optic connector.

Some of the common causes of insertion losses includes:

(i) the misalignment of ferrules during connection,

(ii) the air gap between two mating ferrules, and

(iii) absorption loss from impurities such as scratches and oil contamination

Insertion loss can be minimized by proper selection of interconnect materials, good polishing and termination process of fiber connectors.

5. **Return Loss (RL)**

Return loss, which is also known as back reflection, is the loss of light signal that is reflected back to the original light source. This occurs as the light is reflected off the connector and travels back along the fiber to the light source. This phenomenon is also known as the Fresnel reflection. It occurs also when there are changes in the refractive index of materials in which the light travels, such as the fiber core and the air gap between fiber interconnection. When light passes through these two different refractive indexes, some of the light signal is reflected back.

As a general rule, the greater the difference between two materials refractive index, the higher the loss. When reading return loss figures, the higher the absolute value of the decibel unit means the better the performance of the interconnection.

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