



PDHonline Course E143 (2 PDH)

Introduction to Fiber Optic Cable Technology

Instructor: Jerry R. Bednarczyk, P.E.

2020

PDH Online | PDH Center

5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

An Approved Continuing Education Provider

Introduction to Fiber Optic Cable Technology

Jerry Bednarczyk, PE

Course Content

GENERAL

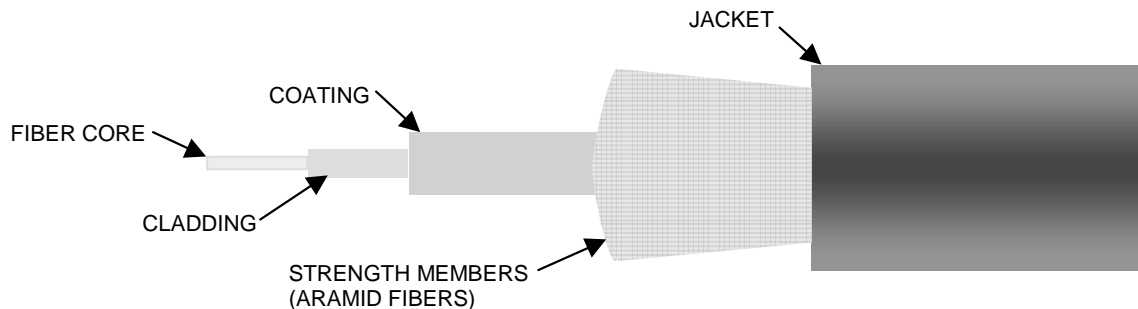
A fiber optic cable system is very similar to a copper wire system in that it is used to transmit data from one location to another. The primary difference between the two is that the fiber optic cable system uses light pulses to transmit data instead of electrical impulses. At one end of the cable, a transmitter receives electric signals, translates the information into coded light pulses and channels the resultant light pulses into the fiber optic cable. Light emitting diodes or injection laser diodes are typically used to generate the light pulses.

The light pulses are transmitted through the fiber optic cable. Because of the characteristics of the fiber optic cable, the majority of the light pulses are reflected into and along the fiber core with very little loss of light through the cable. Like the losses experienced in copper wires, the light signals do lose strength through the dispersion of light within the cable. An optical detector (receiver) at the opposite end of the cable then converts the light pulse signals back to the original digital electrical signals. PIN diodes or avalanche photodiodes (APD) are typically used as detectors. Depending upon the length of the fiber cable run, repeater stations may be inserted to boost the strength of the light signals.

Unlike copper wires, which have limited capacity, the fiber optic cable is capable of transmitting billions of digital bits per second or the equivalent of thousands of telephone calls simultaneously. Other benefits of fiber optic cable include tremendously higher rates of transmission, lower losses in signal strength, increased resistance to electromagnetic interference. While initial installation costs are generally higher, maintenance costs are lower.

BASIC FIBER OPTIC CABLE CONSTRUCTION

A fiber optic cable is essentially constructed in two concentric layers of hair-like silica glass fibers forming the core and the cladding. The core is the center of the cable and is where the light is transmitted. Around the core is the cladding. The cladding forms the outer optical layer of the fiber. The index of refraction of the core is always higher than the index of the cladding so that the light can be trapped in the core and guided along the fiber. The coating or buffer is the outermost layer of the fiber cable and provides protection from physical damage and moisture.



TYPICAL FIBER OPTIC CABLE

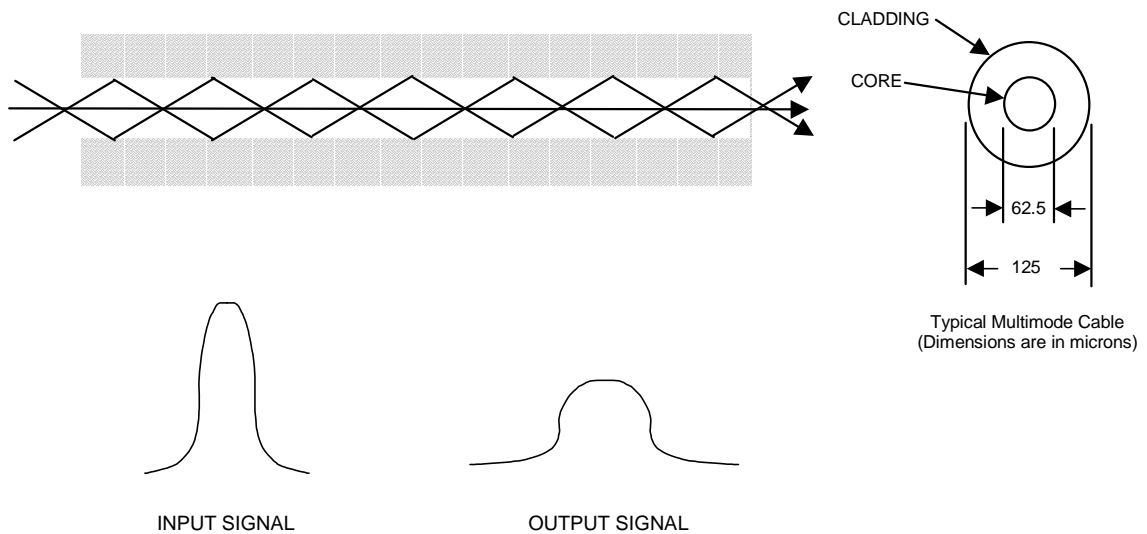
To provide protection and strength, the fiber optic cable is encased in a tough outer covering, called the jacket. Additional strength members, typically “aramid” type fibers (i.e. Kevlar® by Dupont) and occasionally an overall armor shielding are also added. These components provide the physical strength to allow the cable to be installed in buildings, outdoors, underground and underwater. The cable itself can have as few as one fiber to hundreds of fibers.

FIBER OPTIC CABLE TYPES

Multimode Fiber Cable: The multimode fiber optic cable has a larger core that is typically manufactured to 62.5 microns but can range from 50 to 100 microns in diameter. The 62.5 microns dimension is used with light sources at wavelengths of 850nm (bandwidth of 160 MHz) and 1300nm (bandwidth of 500 MHz) which are the wavelengths that produce the lowest losses in the cable. The less popular 50 micron cable is also used with light sources at wavelengths of 850 and 1300nm, however the bandwidth associated with each wavelength is 500 MHz. Since the total bandwidth is greater than the 62.5 micron cable, the 50 micron cable is gaining in popularity.

Because of the larger core diameter, the light pulses travelling down the cable will not all travel in a direct route. Some of the light rays, or modes, that make up the pulse will travel in a more direct route, while others will be reflected off the cladding causing the pulses to bounce back and forth as the light travels down the core. The result is an output signal that is attenuated and undergoes a time dispersion compared to the original pulse. The attenuation decreases and the dispersion increases with the length of the cable.

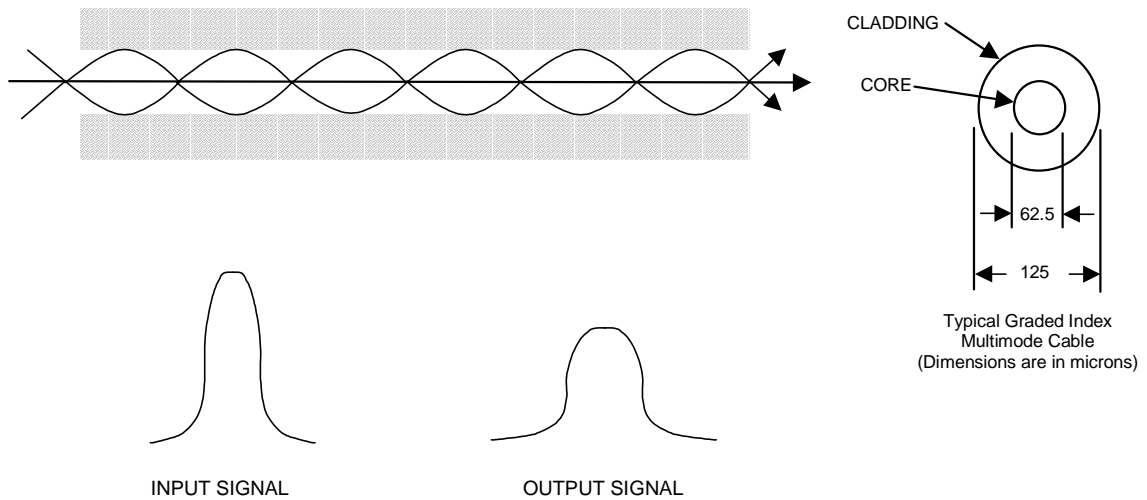
For these reasons, multimode fiber cable is typically used for installations involving shorter distances and lower speed networks, such as a small LAN system or in certain medical applications.



MULTIMODE FIBER CABLE

Graded Index Multimode Fiber Cable: The graded index multimode fiber cable is constructed with a core with a lower refractive index near the cladding as compared to the center of the core. This causes the light rays, or modes, that are on a more direct route down the center of the core to travel slower relative to those that are near the cladding. Also, instead of bouncing off the cladding at sharper angles, the light tends to curve in a helical pattern due to the graded refractive index. The result is an output signal that is less dispersed and undergoes less attenuation compared to the standard multimode cable.

While the cost of this type cable is higher, the quality of the output signal is greatly increased making it the preferred choice for “on premise” data and communications installations.

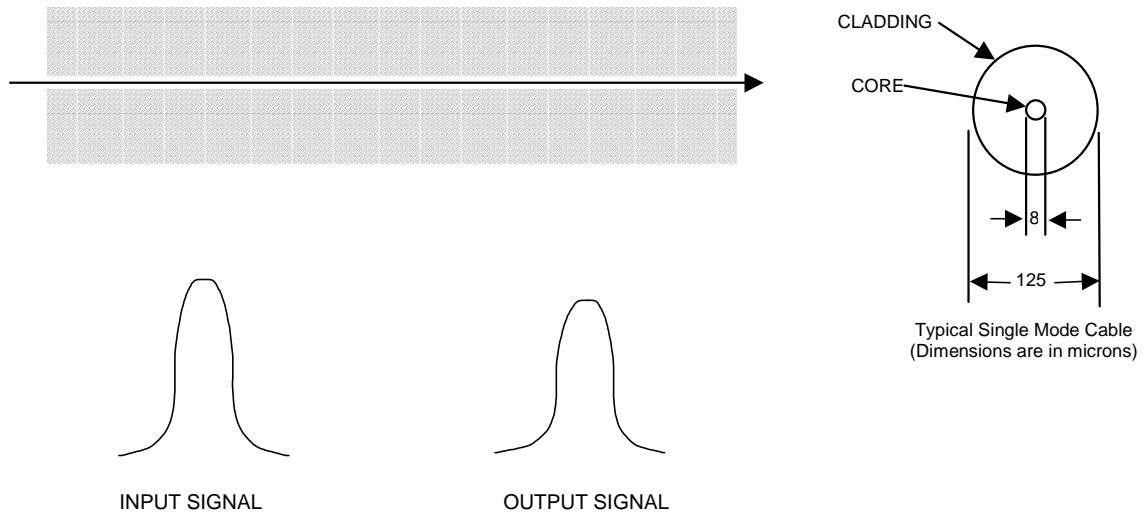


GRADED INDEX MULTIMODE FIBER CABLE

Single Mode Fiber Cable: Single mode fiber optic cable is constructed of a single glass fiber core approximately 8.5 microns in diameter. The cladding surrounding the core is several times thicker than the core. As the name indicates, only one mode will propagate along the single mode cable either at a wavelength of 1300 nm or 1550 nm in a bandwidth in the gigahertz range. Operating at the higher wavelengths greatly reduces the attenuation of the signal. Because of the huge bandwidth, the capacity of a single mode fiber cable is tremendous.

Due to the small diameter core, virtually all of the light travels in a direct route along the fiber with extremely minimal amounts of light bouncing off the cladding, as happens with the multimode cable. Very little light is lost through the cladding, resulting in very low attenuation rates and minimal dispersions.

Single mode fiber cable is used when the lengths of the cable runs are large. Experimental installations have demonstrated that signals can be transmitted over 1,000 miles. The telephone and cable television industries install hundreds of thousands of miles of single mode cable yearly. Although it is somewhat more expensive than multimode cable, college campuses and large industrial facilities have found that the benefits of the single mode cable are well worth the added installation costs.



SINGLE MODE FIBER CABLE

Plastic Fiber: The cables discussed above are manufactured with extremely high quality silica glass fibers. Fiber optic cable is also manufactured using plastic core and cladding. The cable is huge, sometimes approaching 1 mm in diameter, compared to the dimensions of glass fiber cable. Plastic fiber optic cable operates at longer wavelengths, using visible light with very low bandwidths. Because of the large cable and longer wavelengths, there are considerable losses to the signal. These cables are generally used in applications requiring lengths of only a few feet. It is used in some automotive applications and in some high-end audio applications. Costs of the cable are relatively low and installation of plastic cable is fairly simple.

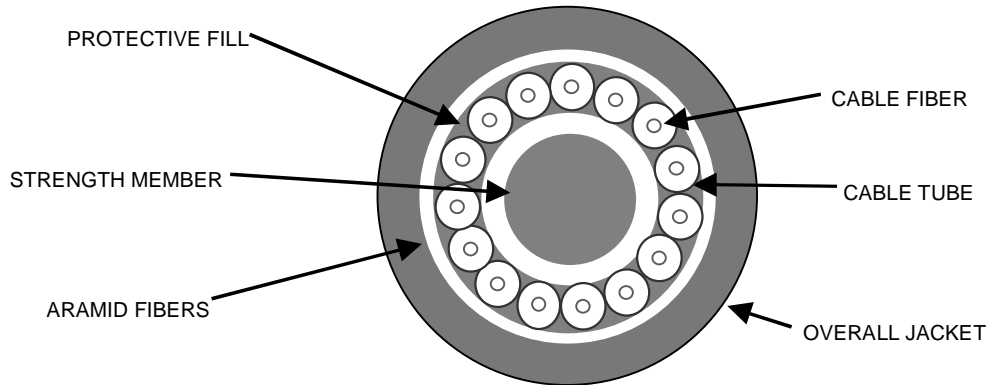
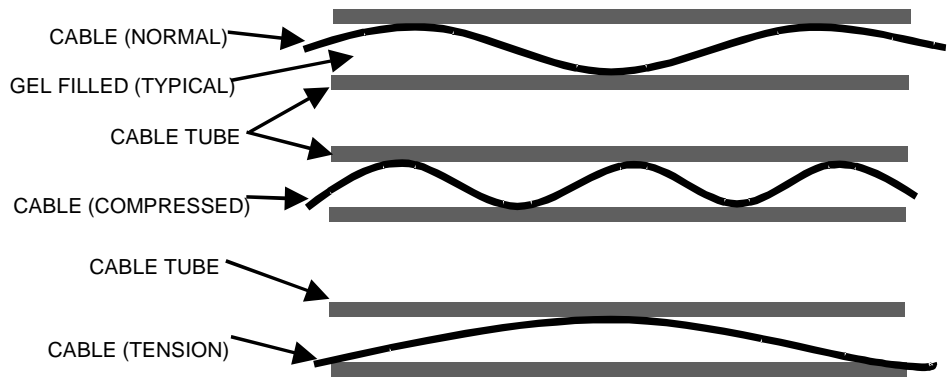
CABLE DESIGNS

There are two basic cable designs for fiber optic cables, loose tube (or loose buffered tube) and tight buffered types. The cables are designed to protect the fibers and to minimize the stresses on the fiber optic bundles. The properties of the cables are impacted by the stresses that are imposed on the cables. Any stress to the cable that cause density deviations to the fibers, will alter the propagation characteristics of the cable. If the damage is significant, the cable will be rendered useless and will have to

be abandoned or replaced. Loose tube cable is generally used for outside plant installations (that is, longer cable runs). Tight buffered type cable is primarily used inside buildings.

Cable Designs – Loose Tube Cable: In a loose tube cable, the fiber cable is housed in a soft plastic tube, generally gel filled, to provide protection from moisture. The fiber in the tube is longer than the tube itself allowing the fiber to coil while under compression and to straighten when under tension. The tubes/fiber are joined with other color-coded tubes/fiber around a central strength member. They are surrounded by other protective materials and are finally enclosed in an overall polyethylene jacketing material. The outer jackets may also be encased in some form of armor jacketing and an additional overall plastic sheath.

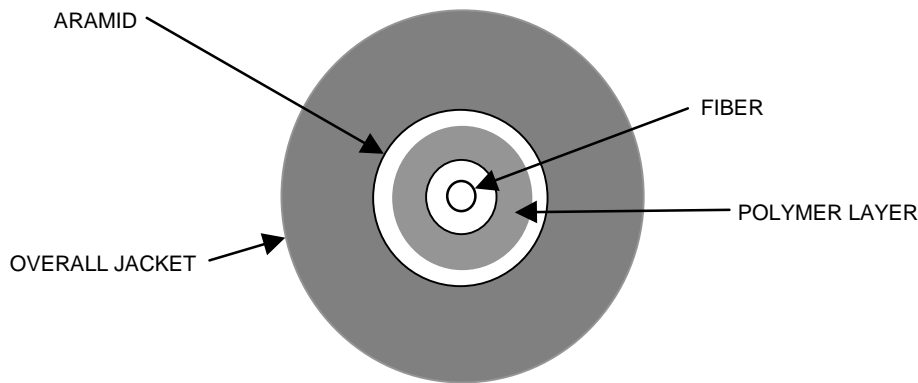
The construction of the overall cable provides protection to the fibers both during installation and while in service. The strength members are used to assist in pulling and/or supporting the cable structure. Loose tube cables are generally preferred for longer distance installations where high fiber quantities, lower attenuation and the ability to handle wider temperature ranges are desired. Splices and terminations of loose tube cables can be difficult and messy due to the gel used to protect the fiber cables. Also, if the tubes are damaged while installing the cable, the protective gel could leak and allow water to penetrate to the fiber making it unusable.



LOOSE TUBE CABLE

Cable Designs – Tight Buffered Cable: In a tight buffered constructed cable, a soft polymer layer is fabricated in direct contact with the fiber cable. This layer provides the fiber cable with protection from external strains. The cable assembly can then be encased with aramid fibers and an overall cable jacket.

Tight buffered cables are better suited to on-site, or intra-building installations. The design of the tight buffered cable is more flexible than the loose tube cable. This makes it easier to install particularly in areas with tight bending radii. Also, the fiber itself is easier to access and there is no gel layer. This makes this type of cable easier to splice and terminate.



TIGHT BUFFERED CABLE

CONNECTORS AND SPLICES

In a fiber optic cable system, it is extremely important to minimize the losses in the light rays being transmitted on the cable. Two locations that can cause significant increases in cable losses occur at Connectors and in Splices.

The electrical signal into the transmitter and exiting the receiver are generally sent along copper conductors. After the signals are converted to digital light rays and before they leave the transmitter and enter the fiber optic cable (or enter the receiver at the end of the run), they must pass through a Connector. The connector is a mechanical device that is attached to the fiber optic cable and can be easily attached to, or detached from, the transmitter or receiver.

A Splice is used when two fiber optic cables need to be permanently joined to one another. For example, splices are required when the total length of the cable run exceeds the length that could be reasonably manufactured or shipped. They are also installed in order to bypass natural obstructions in the cable route, or at building entrances.

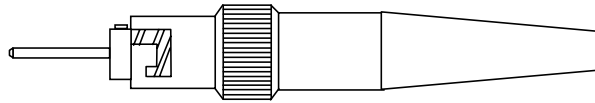
Connectors

Where the fiber cable transitions from the transmitter or to the receiver in a circuit is where significant losses can occur. The type of connector used and the quality of the installation can have a large impact on the quality of the signal. In the years since fiber optics became a commercially viable technology, the quality of available connectors has improved dramatically. Some of the most widely-used types are described below.

TYPICAL ST CONNECTOR

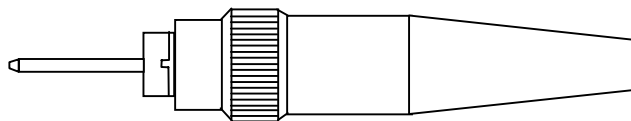
(ST is a registered trademark of AT&T)

One of the most popular type of connectors on the market, especially for multimode operation, is the ST[®] type. The ST[®] connector is a bayonet type with a ferrule made of either ceramic, plastic or metal. The connection is keyed and spring loaded to help assure that the cable is properly seated. The installation of the ST[®] connector is relatively simple and is generally made up on the project site.



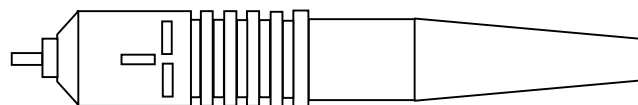
TYPICAL FC CONNECTOR

For years, the FC/PC connector has proven to be an extremely popular single mode connector. The connection is notched and screws together providing a very secure and accurate connection that minimizes system losses.



TYPICAL SC CONNECTOR

Another type of single mode connector that is rapidly taking the place of the FC/PC type, is the SC connector. The SC is a push-pull type mechanism with a locking tab to hold the connection in place. It also provides a very accurate connection. This connection's low cost, ease of installation and durability, are making it the connector of choice for single mode installations.

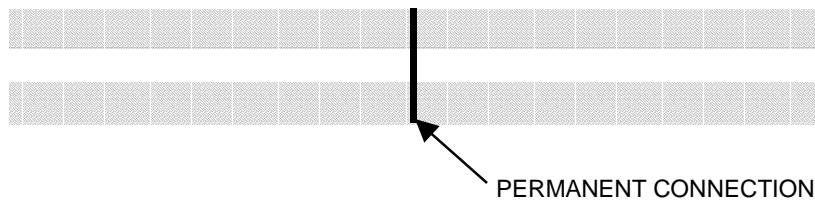


Splices

While connectors are considered as temporary connections, splices provide a permanent connection between two fibers. Splices are used when cable runs are very long, when cable are accidentally cut or when splitting a multi-conductor fiber cable into several smaller multi-conductor cables.

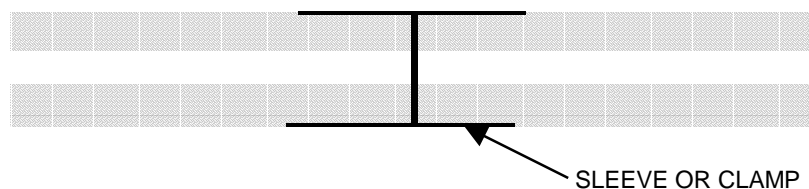
There are two types of splices, fusion and mechanical. A fusion splice is made by welding, or fusing, two fibers together. A mechanical splice is comprised of some form of clamping mechanism to hold the fibers in place with the actual fibers being joined by a glue or gel compound to facilitate the signal transfer. With either type of splice, the fibers must be precisely lined up in order to minimize the losses across the splice junction.

Fusion splice



With a fusion splice, the fiber cables to be joined are arranged so the ends of the cables are touching. The connection point is then heated past the cables' melting point with an electric arc until the cables are fused.

Mechanical splice

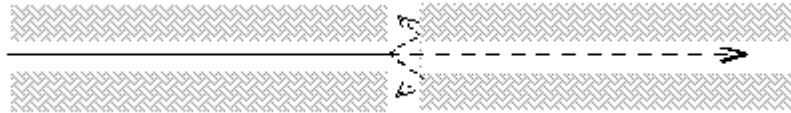


A mechanical splice is considered a temporary connection. The cable is cleaved, polished, and joined together with a clamp or crimp mechanism often in combination with an epoxy or gel.

Connector and splice losses: Earlier, we discussed the losses in signal strength that occur in the transmission along a fiber optic cable that depend on the type of cable used, the length of the run and the quality of the signal. Losses can also occur at every connector or splice. If a connector or splice is installed perfectly and the fiber cores are identical, the losses will be minimized.

Common problems that can cause losses in connectors and splices are gaps at the point of connection, improper cleaning and finishing of the cables, Numerical Aperture (NA) mismatches, improper alignment or mismatches in cable core diameters at splice points.

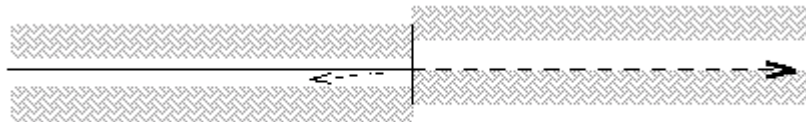
End Gap: A gap at a splice or termination will allow the light signal to disperse out of the core and be lost. The air gap will also cause losses due to the light reflecting off the end of the adjoining cable.



NA Mismatch: The Numerical Aperture (NA) of the cable is one measure of the performance characteristics of a fiber optic cable. Splicing cables with differing NA values will cause losses in the signal. A multimode fiber cable will transmit light efficiently only when the angle of incidence of the light is within a specific number of degrees of the axis of the fiber. The numerical aperture of a cable is the angle the cable can accept light. The value is dependent on the construction characteristics of the cable.



Improper Alignment: A misalignment of a cable splice will cause losses in the signals being transmitted along the cable.



SUMMARY

Unlike copper cables, fiber optic cables can be used to transmit large volumes of data along a single cable. Electrical signals are converted into light pulses which are then transmitted along the fiber cable. Due to the advances made in fiber cable technology, thousands of signals can be transmitted over hundreds of miles simultaneously with minimal losses in signal strength. Multimode cables, while generally lower in cost, have higher losses in signal strength as compared to single mode cables. Single mode cables are usually used in installations that are very long and require low losses.