Application Notes From Communications Specialties

CALCULATING TRANSMISSION DISTANCE FOR FIBER OPTIC EQUIPMENT

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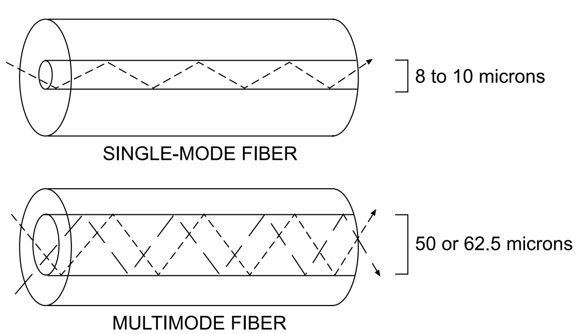
Overview:

One of the many advantages of fiber optic transmission is that it can transmit video, audio, and data over much farther distances than traditional coax cable and twisted pair wire. The exact distance that can be supported by any given system is a function of many factors, including type of cable being used, frequency of the signal transmission, the bandwidth of the fiber, and the number of splices and connectors used across the entire transmission distance. This TECHnique will help to clarify some of these issues and provide some guidance in determining what type of fiber optic equipment is necessary for transmission over a given distance.

Details:

Types of Fiber Optic Cable: Most fiber optic transmission systems are designed to work with one of two types of fiber optic cable: *single-mode* or *multimode*.

The glass core in the center of single-mode fiber is thinner than in multimode fiber, typically 8 to 10 microns (millionths of a meter) in diameter. In fact, it is so thin that only a single "mode" of light can be transmitted along its core. As a rule, single-mode fiber can transmit signals over a farther distance than multimode fiber. For an explanation of why, refer to CSI's Educational Guide entitled "Introduction to Fiber Optics."



Fibers with wider core diameters are called *multimode* fiber. These types of fibers allow for multiple modes of light to pass along their core. The two most common sizes of multimode fiber are 62.5/125 and 50/125. The first number represents the "core" diameter size measured in microns and the second number indicates the diameter of the fiber's "cladding" – the outer coating that surrounds the core and keeps light within the fiber.

Frequency of Transmission: When calculating the maximum distance a given fiber optic transmission system can support, it is also necessary to consider the frequency at which the fiber optic signal will be transmitted. The higher the frequency, the greater distance the system will be able to support. For multimode systems, commonly used frequencies are 850 and 1300 nanometers. For single-mode systems, 1300 and 1550 nanometers are standard.

Fiber Bandwidth: Bandwidth of fiber is described in MHz per kilometer. As the length of fiber increases, the bandwidth decreases proportionally. For example, a fiber that can support 500 MHz bandwidth at a distance of one kilometer will only be able to support 250 MHz at 2 kilometers and 100 MHz at 5 kilometers.

Due to the way in which light passes through them, single-mode fiber has an inherently higher bandwidth than multimode fiber. For an explanation of why this is the case, refer to CSI's Educational Guide "Introduction to Fiber Optics." Typical fiber bandwidth range from hundreds of MHz per km for multimode fibers to thousands of MHz per km for single-mode fibers.

Splices and Connectors: The maximum distance a system can support will also be a function of how many splices and connectors are used across the entire transmission distance. Each splice or connector that the optical signal must pass through causes some signal loss to occur. The exact amount of loss depends on the types of connectors or splices used, as well as how well they are installed. Today, the most common connector types in use are *ST* and *FCPC* and the most common splices are *mechanical splices* and *fusion splices.* For an explanation of

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each, refer to CSI's Educational Guides "Introduction to Fiber Optics" and "Fiber Optic Cables and Connectors." As a general rule, it is safe to calculate a loss budget of .5 to .75dB for each splice and connector used. However, more exact specifications can be obtained from the manufacturer of the fiber and connectors.

Calculating a System's Transmission Distance: When designing a fiber optic system, all the above parameters must be taken into consideration. To determine the system's total optical loss, calculate the sum of the cable loss (as a function of desired transmission distance), splice loss and connector loss. Then, for safety measures, add an additional 3dB.

Compare this figure with the allowable optical loss budget of the receiver to be used within the transmission system. If the loss level is acceptable, and if the fiber's bandwidth is adequate to pass the type of signal desired, then you can feel confident that the system can transmit over the distances desired.

The following charts might be helpful in determining how much optical loss will occur when using different fiber types, transmission frequencies and fiber bandwidths over various transmission distances.

Suggestions:

Remember – the ultimate goal when designing a fiber optic system is to ensure that enough light reaches the receiver. If this does not happen, the entire system will not operate properly.

To assure maximum system performance, it is necessary to use high quality methods of splicing fiber optic cables and installing fiber optic connectors. Pre-terminated cables and splicing kits are available from Communications Specialties.

CSI Products Used In This TECHnique:

- All Fiberlink transmission systems
- Fiber optic cables, assemblies, termination and splicing kits from Communications Specialties

Related TECHniques:

- Educational Guide: *An Introduction to Fiber Optics*
- Educational Guide: *An Introduction to Fiber Optic Cable and Connectors*

Typical Optical Loss Budget as a Function of Fiber Type, Transmission Frequency and Transmission Distance

	1 km	3 km	4 km	5 km	7 km	10 km	20 km	40 km	60 km
850 nm (multimode)	4 dB	12 dB	16 dB	20 dB					
1300 nm (multimode)	2 dB	6 dB	8 dB	10 dB	14 dB	20 dB			
1300 nm (single-mode)	.5 dB	1.5 dB	2 dB	2.5 dB	3.5 dB	5 dB	10 dB	20 dB	30 dB
1550 nm (single-mode)	.2 dB	.6 dB	.8 dB	1 dB	1.4 dB	2 dB	4 dB	8 dB	12 dB

Maximum Usable Bitrate as a Function of Fiber Type, Transmission Frequency and Transmission Distance

	1 km	3 km	4 km	5 km	7 km	10 km	20 km	40 km	60 km
850 nm (multimode)	320 Mb/s	107 Mb/s	85 Mb/s	64 Mb/s					
1300 nm (multimode)	1 Gb/s	333 Mb/s	266 Mb/s	200 Mb/s	167 Mb/s	100 Mb/s	50 Mb/s		
1300 nm (single-mode)	>25 Gb/s	>20 Gbs	>15 Gb/s	>12 Gb/s	>10 Gb/s	>6 Gb/s	>4 Gb/s	>2 Gb/s	>1 Gb/s
1550 nm (single-mode)	>25 Gb/s	>20 Gbs	>15 Gb/s	>12 Gb/s	>10 Gb/s	>6 Gb/s	>4 Gb/s	>2 Gb/s	>1 Gb/s

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