

Fiber Optic Cable and Connector Selection

By Andy Devine and Ron Deppen
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Use these 11 steps as a guide to selecting fiber optic cables and connectors for high-reliability applications.

Proper selection of fiber optic cables and connectors for specific uses is growing even more important as fiber optic systems become the transmission medium of choice for communications and aircraft applications, and even antenna links. The following 11 steps guide readers through the choices that must be made in selecting fiber optic cables and connectors for high-reliability applications. This provides the knowledge to know what questions to ask and what tradeoffs are being made when designing a fiber optic system.

1. Define Environmental Requirements

While some fiber optic systems are in benign environments such as inside a building, others are strapped to rockets and blasted into space where they must work reliably for years. The environment that the system will operate in greatly affects how it is designed. The major concern in local area networks (LANs) is cost, while the major concern in space applications is reliability. These two examples are at the extremes; many systems fall in between, such as Regional Bell Operating Companies (RBOCs) systems, long-haul terrestrial and sub-sea systems, and systems in ships, airplanes and cars. Many environmental factors should be considered such as temperature extremes, humidity and vibration, as well as the loads the cable will experience during installation and operation.

2. Select Transmission Standard

As the applications for fiber optics have expanded and data rates have increased, the number of transmission standards has also increased. See Table 1 for the most common standards. Not all fiber optic systems utilize these standards. Most system decisions are driven by the current availability of the fiber optic transmitters, receivers and components that meet the environmental requirements.

3. Select System Architecture

The biggest advantage of using fiber optics is the ability to handle a large amount of data over a single piece of fiber. This reduces the amount of hardware required and, therefore, increases the reliability of the system. When designing a system, it is important to maximize the amount of insertion loss and return loss that can be tolerated to increase the reliability. System designers must also account for degradation over the life of the system, taking into account beginning- and end-of-life performance parameters.

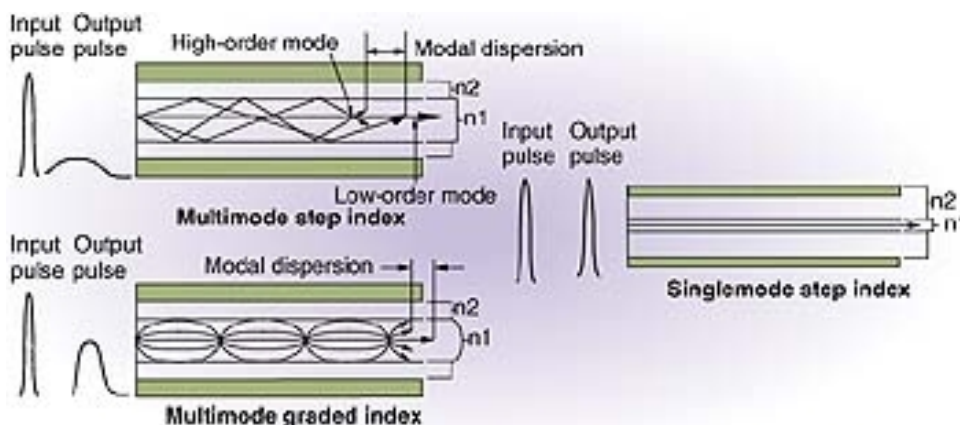


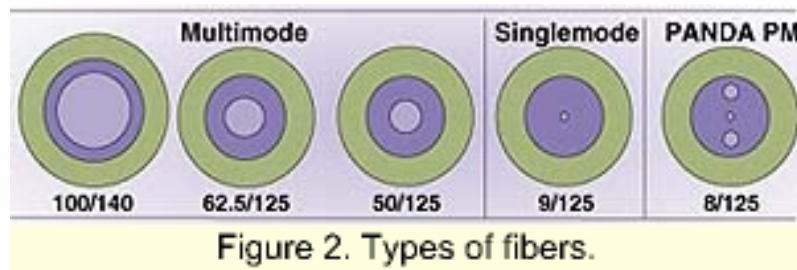
Figure 1. Multimode vs. singlemode transmission.

System designers must keep in mind that specifying less than 0.5 dB insertion loss from a connector manufacturer does not mean that the system in the field will have less than 0.5 dB. Connector manufacturers guarantee less than 0.5 dB insertion loss relative to their reference cable. Two connectors that have 0.5 dB insertion loss relative to a reference cable might have 0.8 dB when mated together. Imagine the loss of these two connectors when mated in the field or after five years of thermal cycling. Some system designers feel that they can avoid this by specifying low-loss connectors with less than 0.1 dB insertion loss. However, this only works if the low-loss connectors can withstand the environment they are being used in.

Another consideration when designing a fiber optic system is field-reparability and spares. Certain connectors are field-installable, but they offer less reliability and lower performance than factory-installed connectors. Some systems use spare, terminated fibers, which are used to replace fibers that are damaged during installation or fail during life. Spare fibers also offer future expandability of the system.

4. Select Type of Fiber

There are two main types of fiber to choose from — multimode and singlemode. The fiber type is predominantly determined by the data rate of the system (see Table 1). Multimode fibers cannot handle data rates as high as singlemode fibers because of modal dispersion. A simple explanation of modal dispersion is that the different modes traveling down a multimode fiber arrive at the receiver in a different order than they were sent (see Figure 1). There are two subsets of singlemode fibers — polarization maintaining (PM) and polarization fiber (PZ). PM fibers maintain the polarity of light as it travels down the fiber while PZ fibers polarize unpolarized light as it travels down the fiber. PM and PZ fibers are expensive to terminate because they require the fiber to be axially and radially aligned in the connector.



It is easier and cheaper to terminate multimode fibers with their large core diameters than singlemode fibers (see Figure 2). If the core of a 100 mm multimode fiber is off by 2 mm there is much less loss than if the core of a 9 mm singlemode fiber is off by 2 mm.

5. Select Optoelectronic Packages

Optoelectronic packages house the electronics that convert electrical impulses to optical signals or optical signals to electrical impulses. They can be divided into two groups: those that are used commercially, and those that are suitable for harsh environments. Optoelectronic packages that are used commercially include components in fixed devices and either single port or multiport components with fixed interfaces. For harsh environments, optoelectronic packages with pigtailed are required to meet the environmental demands. Pigtailed allow the optoelectronic packages to be isolated from the harsh environmental inputs transmitted by the fiber optic connector.

6. Select Type of Connector

The main connector choices for commercial applications are DIN, E2000, FC, LC, SC, SMA and ST for simplex cables. For multichannel cables, the connector choices are Duplex E200, Duplex LC, MT, MT-RJ and Duplex SC. The choice of commercial connectors is usually driven by the connectors already utilized in the system or by the optoelectronic device interface.

TRANSMISSION STANDARDS	STANDARD TYPE	SPEED	FIBER TYPE
MIL-STD-1773	Aerospace	1 Mbps	Multimode
AR1773	Aerospace	Dual mode: 1/20 Mbps	Multimode
ARINC636	Aerospace	100 Mbps	Multimode
FDDI	Commercial	100 Mbps	Multimode
ATM	Commercial	12.5 to 150 Mbps 0.15 to 10 Gbps	Multimode Singlemode
Ethernet (1 to 10 Mbps) Fast Ethernet (100 Mbps) Gigabit Ethernet (1 Gbps)	Commercial	1 Mbps to 1 Gbps	Multimode or Singlemode
Fibre Channel Gigabit Fibre Channel	Commercial	12.5 Mbps to 2 Gbps	Multimode or Singlemode
SONET	Commercial	50 to 150 Mbps 0.15 to 48 Gbps	Multimode Singlemode
DWDM/SONET	Commercial	20 to 640+ Gbps	Singlemode

FDDI = fiber distributed data interface; ATM = asynchronous transfer mode;
SONET = synchronous optical network; and DWDM = dense wavelength division multiplexing.

Table 1. Transmission standards.

Most of these connectors are not suitable for harsh environments, as they do not perform well when exposed to shock or vibration. Another limitation of many of these connectors is that the ferrules unmate when tension is applied to the fiber optic cable.

Simplex connectors for harsh environments include SMA, AVIM (which is compatible with DIN connectors) and Deutsch Ltd.'s RSC/HA. For multichannel connectors in harsh environments, the choices include the MC3, MC5, MSS, Minicon, and 38999 and 28876 series connectors.

7. Select the Cable Configuration

There are three main types of cable configurations: buffered fiber, simplex cable and multichannel cable. Buffered fiber from 250 to 900 mm is common in commercial fiber optic systems but it does not offer much protection for the fiber. The next step up in protection is creating a simplex cable by adding Kevlar, or some other strength member, and a 2 to 3 mm jacket. A jacketed 2 to 3 mm cable can be constructed with configurations where the fiber is tightly held in place or the fiber can be allowed to slide in the cable. Connectors securing the cable jacket to the connector body and terminating the fiber in the ferrule require a fiber that slides within the cable.

Building multiple fibers into one cable creates a multichannel cable. This type of cable is usually built with either a central or external strength member and fiber bundled around or within the strength member. An external jacket is used to keep the cable together (see Figure 3).

8. Select Backshell for Multichannel Connectors

When using a multichannel connector on a multichannel cable, a backshell must be specified to seal the back of the connector and to secure the strength member of the cable. Backshells also help guide the cable in a particular direction. They are typically straight or angled at 45° or 90°.

9. Select Cable Clamping Method

Improper installation and clamping of fiber optic cables can put microbends into the fiber and add stress to the connectors, which increases the loss throughout the cable. P-clamps are the preferred method of securing cables; however, clips and straps may be used. Cushioning material should always be placed between clips or straps and the fiber to reduce microbending.

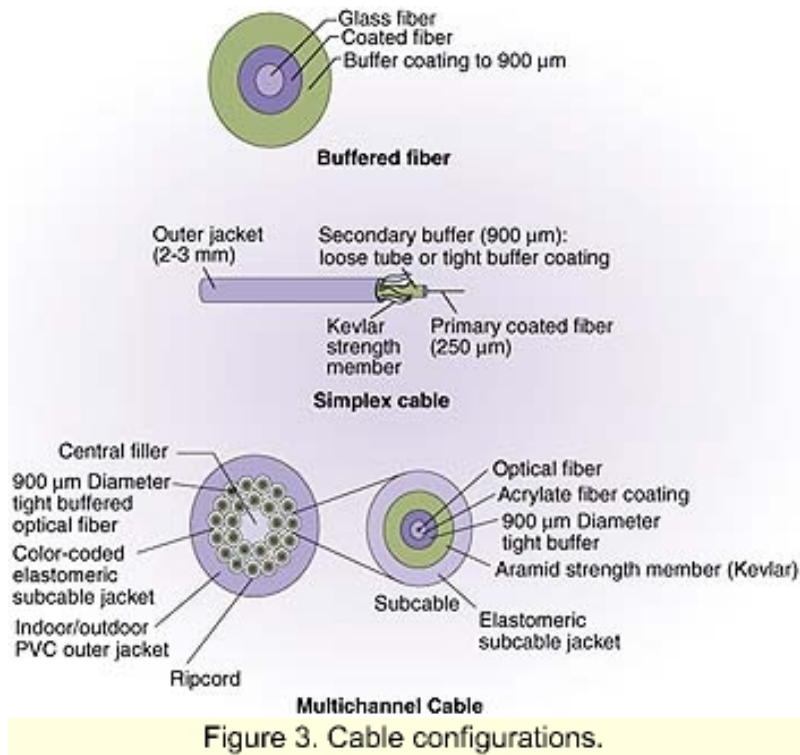


Figure 3. Cable configurations.

Cushioning is sometimes required with P-clamps to provide proper fit between the clamp and the cable. Clamp spacing should prevent cable sag and define the proper routing path.

Other factors that must be considered when routing cables are: minimum bend radius, conduit size, bundle configuration and installation guidelines. Electrical and fiber optic cables should be run separately to minimize stress on the fiber, if possible. Installation guidelines should be created so that accepted installation processes are utilized.

Personnel must be familiar with the proper installation tools and techniques to assure a properly performing system.

10. Select Tools for Inspection, Cleaning and Testing

To properly inspect fiber optic connectors, a 200X microscope should be used. Fiber optic connectors require cleaning before each and every mating to prevent dust from interfering with the connection. Connector cleaning tools are preferred for cleaning connectors; however, alcohol and a non-scratching tissue also work. Visual fault finders send visible light down fibers and are helpful in determining if fibers and connectors are intact.

A stabilized light source (SLS), an optical power meter (OPM) and an optical return loss meter (ORLM) are required to determine the performance of cables. Insertion loss measurements are performed with an SLS and an OPM. Return loss is measured with an SLS and an ORLM. The SLS should be the same wavelength as the system because connector and cable performance can vary dramatically with wavelength. For locating faults in cables, an optical time domain reflectometer (OTDR) is required.

More elaborate tests can be run on systems to look for specific problem areas. These tests are usually driven by the environment, such as performing drop-out testing on aircraft connectors to determine if a connection is temporarily broken during vibration.

11. System Qualification

For critical applications, such as in aircraft, qualification testing is required to determine if a fiber optic system will perform properly. Most connectors and cables have been qualified to meet certain environmental requirements but this does not mean they meet all environmental requirements. System designers must examine what environment a connector is qualified to and with what cable. Different cables on the same connector act differently when subject to vibration or thermal cycling.

Most qualification testing is well-defined in Bellcore and military standards and can be performed in a relatively short time. The one test that can take a long time is thermal life testing, which is required for systems that will go through thermal cycles and must work for long periods of time without failure.

Conclusion

Fiber optic systems have performed flawlessly in environments as diverse as the bottom of the ocean and in space. The key to designing a successful fiber optic system is understanding the performance and environmental requirements, implementing good designs utilizing the appropriate components, properly testing the system to verify requirements compliance, and using validated installation configurations and methodologies to assure system integrity and longevity.

ANDREW DEVINE is President of Coastal Connections, 2368 Eastman Ave., Ventura, CA 93003; (805) 644-5051 Fax: (805) 644-5355; E-mail: andy@coastalcon.com; Web site: www.coastalcon.com. RON DEPPEN was business unit leader, Mil/Aero, RIFOCS Corp.

SPEC SHEET

End Applications: High-reliability applications such as communications, aerospace, automotive and marine systems

Related Products: Fiber optic cables and connectors

Main Point: These 11 steps provide readers with the knowledge to know what questions to ask and what tradeoffs are being made when designing a fiber optic system.

The keys to designing a successful system are:

- Understanding the performance and environmental requirements
- Implementing good designs utilizing the appropriate components
- Properly testing the system to verify requirements compliance
- Using validated installation configurations and methodologies to assure system integrity and longevity