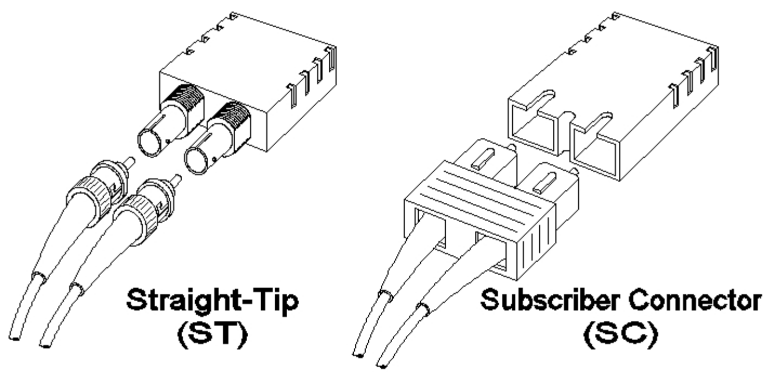
N-Tron Fiber Optic White Paper

Fiber Optic Connectors

There have been many types of connectors developed for fiber cable. A connector is used to join a fiber cable to a transmitter or receiver, or is used to join together strands of fiber. A connector for fiber is similar in concept to a traditional electrical connector, but the fiber connector is actually more delicate, as it must precisely align the internal fibers to insure a proper flow of data through the cables. Early connectors suffered from several deficiencies, including high data loss, misalignment of fibers, damage due to connection tightness, and lack of repeatability, which is the ability to connect and re-connect many times without an increase in data losses.

Current fiber connectors have resolved many of the issues with past connectors. Today, fiber networks offer a multitude of options when it comes to connectors. By far two most commonly used for Ethernet communication are the SC and ST connectors.



The Straight-Tip (ST) connector is a well-known connector in the fiber industry and is particularly popular in the US. The ST connector was one of the first robust connectors targeted at industrial environments. The ST connector is easily recognizable by its bayonet coupling, designed to prevent the fiber and ferrule from rotating, and provides a high degree of strain relief. The prevention of rotation misalignment insures a reliable connection under situations where vibration and shock waves are high. The bayonet coupling is spring loaded in order to supply the appropriate amount of pressure to the connection.

ST connectors are used with multi-mode and single mode fiber. The insertion loss is approximately 0.5 to 1 dB. Repeatability of an ST connector is .2dB for multimode and .4dB for singlemode fiber. ST connectors are popular in industrial, military, and commercial environments where vibration and shock levels are high.

The Subscriber Connector (SC) is a popular choice for Datacom networks. As the number of connections in a typical Datacom network tends to grow larger over time, the rectangular shape of the SC connector allows for a high packing density, providing a large number of connectors being able to fit into a junction box. The connector body is designed to give an audible click when inserted, indicating a solid and secure connection. Strain relief is by friction only.

The SC is suitable for single mode and multimode fiber and has low loss characteristics. An SC connector has insertion loss of .2dB - .45dB and has a repeatability of .10 dB. To prevent the ferrule, the alignment mechanism that houses the fiber, from decoupling from the cable and connector body, the SC connector is designed to be pull-proof. The push-pull design also provides a safe-guard from rotational misalignment.

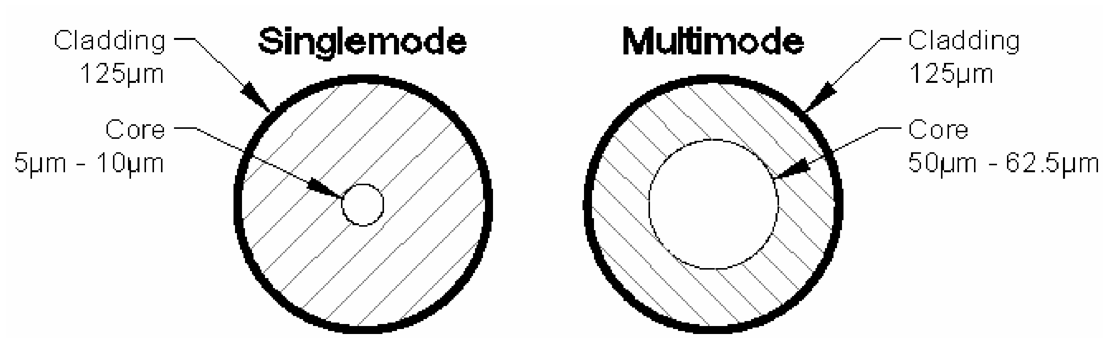
Single Mode and Multi-Mode Fiber

Light can travel down a fiber in several possible paths. These paths taken by the light are referred to as modes. The number of modes in a fiber is always an integer and must increase in discrete steps. The diameter of the core determines the number of modes that can exist in a fiber cable. Modes are important because they can affect the quality of the data. Depending on the path actually traveled in the fiber, the data coming into the receiver could be indecipherable due to high bit error rates. This effect is called modal dispersion. Modal dispersion is a loss of data integrity due to the multiple paths of light taken through the fiber. Modal dispersion causes the light pulses of data to become spread out, eventually blending together and resulting in lost information.

In a fiber cable, there are 2 main ways to handle the effects of modal dispersion. One is to restrict the size of the core of the fiber, thus restricting the number of possible modes that are possible for the light. This method results in a singlemode fiber and allows only one wavelength, the fundamental wavelength, to travel down the length of the fiber.

Singlemode fiber is designed to allow only one wavelength through the fiber core. The reduction in the diameter of the fiber core prevents multiple wavelengths through the cable. Since singlemode fiber only allows one mode to propagate, the light can't suffer mode delay differences and the data reaches the receiver at the same time. Singlemode fiber has high bandwidth throughput and is ideally suited for long haul capacity circuits.

Another method of handling the effects of dispersion is to control the modes that are possible. Controlling the modes is accomplished by special manufacturing techniques of the fiber. The manufacturing process allows for the different paths of light to run at different speeds. By varying the speeds of the various paths of light, the multiple rays of light are made to reach the end of the fiber at approximately the same time. This type of fiber is called multi-mode fiber. Compared to a singlemode fiber, the diameter of the multimode core is much larger and allows more than one mode to propagate through the fiber. There are 2 types of multimode fiber: Step-Index and Graded-Index. Step-index fiber reduces the refractive index of the fiber in comparison with the core. Graded index fiber modifies the refractive index of the glass from the center of the fiber to the outer edge.



Fiber Optic Cable Comparison

Typical multimode fiber characteristics are: 62.5/125 um, 1310nm, -1 to -2 db/km loss.

Typical singlemode fiber characteristics are: 8/125 um, 1310nm, -0.5 db/km loss.

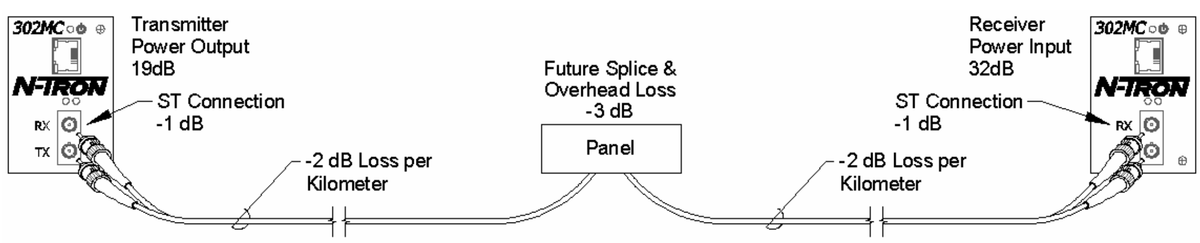
Power Loss Budget

A simple network will contain several components: a receiver, a transmitter, a fiber line, and several connectors. In the design of the system, consideration must be made for the loss of signal as the light travels through the network. There should be ample signal for the receiver to receive the data.

In order for a signal to reach the end receiver, there must be enough power for the receiver to read the signal. This sounds like a simple task. However, there are several components that prevent the signal from reaching the receiver full strength. These components must be taken into consideration when designing the system.

The power loss of a system consists of several components including the fiber loss per unit length of the line, the number of splices, and the number of connectors. Generally, there is also a system variable used for system degradation over time, or an overhead margin. This overhead margin is used to anticipate changes in the network over time, including temperature variations, LED aging, mechanical stress in fiber, and bend loss in fiber.

A simple view of a network can be represented like:



Typical Multimode Fiber Optic Network Cable dB Loss Diagram

To calculate the power loss budget, you would need the following pieces of information:

- Transmitter Level
- Receiver Level
- # of Connectors and Type
- # of Splices
- Type and Length of Fiber
- Margin (Minimum of 2 dB to allow for aging of components and a splice)

You can find the values associated with these things from the manufacturer's specifications. The general equation for finding the power budget is as follows:

Power Budget = Tx Power – Rx Sensitivity

You can find the total Power Margin by:

Power Margin = Power Budget – Cable Losses – Splice Losses – Termination Losses

An Example Calculation:

Let's assume you have a data network inside your industrial environment and you are looking to calculate the power loss budget. You have a fiber cable length of 2km, using multimode fiber. You are going to use 1310nm wavelength and N-TRON's 302MC media converter. There are 2 ST connectors in your network.

Reviewing the 302MC datasheet, you find the following specifications:

TX Power Min. for 2km, 1310nm, multimode = -19 dB
RX Sensitivity Max. for 2km, 1310nm, multimode = -32 dB

Therfore the worst case power budget is: -19 - (-32) = 11 dB.

Assuming two connectors with -1db of loss for each termination, and a cable loss of -2db per km:

Power Margin = 11 – (2 x 1) – (2x2) = 5dB

This gives and additional 3db of headroom over the minimum for possible addition of fiber patch panels, degredation of optical components, and future splices.