Increasing Power Margin with High-Performance Optical Fiber

Specify lower loss cable and optical fiber rated for longer distances than the intended use. BY ANDREW OLIVIERO

In planning for a LAN, data center, or storage area network, network designers must ensure that the optical fiber products they specify can provide the performance and reliability they need. Specifically, they may want to provide power headroom to increase their channel insertion loss budgets for such things as additional connections or higher loss connectors, and to improve overall reliability. This is especially critical in 850 nm 10 gigabit Ethernet applications, since channel insertion loss budgets for these systems are lower than previous applications.

There are two keys to achieving greater power headroom, also known as power margin:

1. Reducing Channel Insertion Loss (CIL). CIL is the end-to-end loss resulting from all connections and splices in the link, plus the attenuation of the cable itself.
2. Reducing Inter-Symbol Interference (ISI) by using a higher-bandwidth optical fiber. ISI occurs when bits of data run together due to high differential mode delay (DMD), causing low bandwidth in the optical fiber.

Channel Insertion Loss Reduction

Certain network configuration and connection assumptions were made by IEEE to establish the power budgets for 10GBASE-SR at 300 m (see Figure 1, column A). According to the link model, 77 percent of the total link power penalty of 7.3 dB is caused by CIL (accounting for 36 percent, at 2.6dB) and by ISI (41 percent, 3.0 dB). Therefore, improving CIL or ISI power penalties, or both, is the easiest way to create power margin.

One strategy for reducing CIL directly is to improve cable attenuation and connection loss. This strategy involves the use of:

- Small form factor (SFF) connectors (e.g., LC connectors).
- Optical fiber with improved core centering tolerances to improve core to core alignment:
  - Low core/clad concentricity error (< 1.5 mm).
  - Tight clad diameter tolerance (125 +/- 1 mm).
  - Tight core diameter tolerance (+/- 2.5 mm).
- Low 850 nm optical fiber attenuation (< 2.3 dB/km).
- A bend-insensitive coating.
- Low 850 nm cable attenuation (≤ 3.0 dB/km)

Reduce the Inter-Symbol Interference Penalty

In addition to creating power margin by directly improving CIL, margin can also be created by lowering ISI power penalties. In fact, the most significant way to

Figure 1

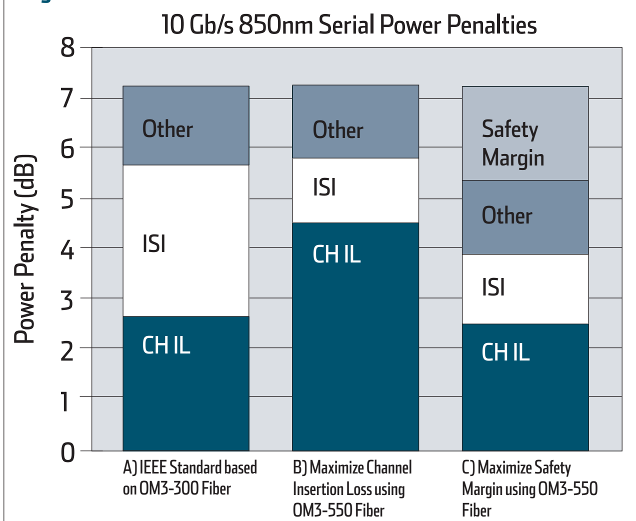
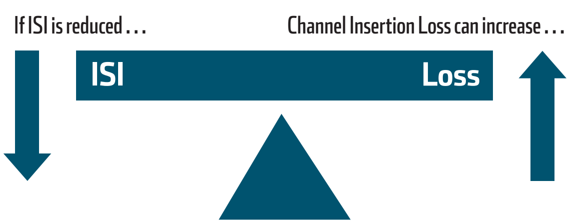


Figure 2



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increase the power margin—and create a higher CIL budget—is to reduce the actual ISI penalty of the link. ISI is lowered by lowering DMD and increasing the bandwidth of an optical fiber for a given link distance.

The "pulse spreading" that causes ISI is a result of DMD. Multimode optical fiber is so named because it has hundreds of light pathways, or modes, in which light can travel along the core of the optical fiber. If the speed of the light in each mode is equal, then all modes arrive at the transceiver at the same time; in other words, the optical fiber will have zero DMD. But imperfections in optical fiber manufacturing and design can result in large differences in modal speed, causing DMD to increase. If the laser transmits a pulse into an optical fiber with high DMD, different parts of the laser pulse will travel along the optical fiber at different speeds. As a result, some parts of the pulse may spread into the adjacent bit slots, causing the system to fail.

Controlling and minimizing DMD minimizes the ISI—and therefore maximizes the bandwidth—of a multimode optical fiber system. Using an optical fiber with low DMD can dramatically improve system performance while preserving the low cost benefits of multimode optical fiber-based systems.

Thanks to advancements in DMD testing (see next page), it is now possible to produce optical fiber with accurate, defect-free refractive index profiles. The refractive index has to be well designed and controlled to ensure that all modes exhibit minimal DMD and all arrive at the other end of the optical fiber at the same time. No matter which modes in the optical fiber are actually guiding the light, those modes will have minimal DMD and provide high bandwidth.

Designers should ensure that the optical fiber contained in the cable they purchase has been DMD-controlled to the very center of the optical fiber. Selecting a multimode optical fiber with DMD specified in the zero to five µm range can double the bandwidth for lasers that launch power in the optical fiber's center. This, along with higher resolution DMD measurements, help ensure that the optical fiber cable can withstand deviations in laser characteristics over time.

High Bandwidth, High Performance

Interestingly, one can trade the power headroom attained by improving the ISI penalty to increasing the channel insertion loss, shown in Figure 2.

By specifying a higher-bandwidth optical fiber, a designer can trade off bandwidth headroom to increase CIL budgets. For example, many designers specify use of 850 nm laser-optimized 10 Gb/s multimode optical fibers (known as OM3 optical fibers) in data centers. If this optical fiber is used at distances shorter than its maximum rating, the ISI penalty is reduced and the "liberated" power (e.g., bandwidth headroom) can be devoted to increasing the CIL budget. The result is that designers of data centers or LANs can use "plug and play" connectivity solutions, and can support the high loss of some of these systems while supporting bandwidth and reach requirements.

Consider an 850 nm laser optimized multimode, 10 Gb/s cable solution rated to 550 meters under typical conditions. If this optical fiber is used to shorter distances (e.g., 300 meters), 1.9 dB of power headroom is created from the extra bandwidth. This can be added to the 2.6 dB of

What to Look for in Differential Mode Delay Testing

DMD testing provides such a clear picture of how individual mode groups carry light down the optical fiber, and which mode groups are causing DMD, that the standards require optical fiber to be DMD-tested to ensure adequate bandwidth for the rated distances for 10 Gb/s applications.

DMD testing involves transmitting short-duration, high-powered laser pulses in small steps across the entire core of the optical fiber. Each pulse excites only a few modes at each step, and the individual pulse shapes and arrival times are captured at the other end of the optical fiber. The DMD of the optical fiber is the difference between the earliest and latest arrival times of all pulses at all steps.

From this information, adjustments can be made to the optical fiber manufacturing process to produce low DMD (high bandwidth) optical fiber. With a highly advanced process for making optical fiber, DMD testing serves as a powerful process control tool to maintain a precise refractive index profile, even to the center region of its optical fiber.

budgeted CIL to allow a total of 4.5 dB of CIL, shown in Figure 1, column B. This can now be devoted to the higher-loss connections of some MTP/MPO cassettes that are used with a plug and play design in a data center or LAN. This level of performance can also be achieved by using a 300 m rated 850 nm laser optimized multimode optical fiber product to 150 meters.

Conclusion

Because network downtime can be very expensive, reliability is a key requirement for high performance networks. These two strategies provide more power margins to enable greater flexibility in network design and, ultimately, greater reliability (Figure 1, column C).

First, it is wise to specify lower loss cables and connectors that provide more power margins to enable higher levels of performance.

Second, to provide more power margins to enable higher levels of performance and reliability, it is wise to specify an optical fiber that is rated for a longer distance than what it will be used for. When it comes to demanding 10 gigabit Ethernet optical fiber applications, do not assume that all products that meet a particular standard are equal. In fact, it is possible to find higher performing products that exceed the standards. The most cost-effective solution is OM3 optical fibers that have been designed and manufactured specifically for laser transmission. These are available in various performance grades, all featuring a DMD-controlled core that helps ensure 10 Gb/s support with low-cost 850 nm serial applications up to their rated distances. These optical fibers also support 1 Gb/s operation, and their 50 micron core size couples sufficient power from LED sources to support legacy applications such as Ethernet, Token Ring, fiber distributed data interface (FDDI), and Fast Ethernet for virtually all in-building networks and most campus networks. ■

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