

Using Low DMD, Laser Optimized Multimode Fiber to Expand 10-Gigabit Network Design Options

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Increasing your Optical Fiber Cabling System's Link-loss Budget

In the early 1980s, fiber Ethernet systems were limited to a data rate of 10 Mbps. At that time, the IEEE 802.3 standard allowed for an generous cable plant loss budget (total attenuation allowed in the fiber link for the fiber cable, connections and splices) of 12.5 dB at a maximum length of two kilometers. This was indicative of the cable attenuation and connector insertion loss values that were achievable at that time. Even when Ethernet speeds increased to 100 Mbps using long wavelength (1300 nm) transceivers, the loss budget was still 11.0 dB. Subsequently, in the late 1990s, with the advent of Gigabit Ethernet and reliable low-cost short wavelength (850 nm) transceivers, loss budgets decreased significantly. In order to guarantee link operation for maximum distances, the cable channel loss budget was reduced to less than 4.0 dB. As a result, the selection of fiber optic cable and connectors with low insertion loss became important to ensure robust system operation. Now, with 10-Gigabit Ethernet, the budget has been cut even further to 1.8 dB for standard 50-micron fiber (500 MHz•km overfilled bandwidth – reference IEEE 802.3ae, Table 52-10).

Today, laser optimized, 50-micron multimode fiber (LOMF) has gained in popularity. Development of this fiber involved close cooperation with manufacturers of low cost 850 nm vertical cavity surface emitting lasers (VCSELs). These devices are typically used for 1 or 10-Gigabit Ethernet transmission in local area network (LAN) or campus backbones whose lengths may extend to more than 300 meters. But for shorter link lengths, such as those commonly found in data centers or storage area networks (SANs), there is an additional advantage that 50 μ m LOMF can offer.

Managing Link Loss Budgets for Application Migration

The IEEE 802.3ae (10-Gigabit Ethernet) standard specifies conventional 50/125 μ m (500 MHz•km) multimode fiber (MMF) to a maximum distance of only 82 meters with a cable plant loss budget of 1.8 dB. This is important because the budget for a typical Gigabit Ethernet or 2-Gigabit Fibre Channel application over this same optical fiber at 82 meters may be in excess of 6.5 dB. The very low 1.8 dB budget for 10-Gigabit operation at 82 meters can only be achieved using cable plant components (cable, connectors and splices) with combined insertion loss below 1.8 dB. Such tight loss restrictions impede the benefits and flexibility associated with structured cabling design. Adhering to the 1.8 dB limit associated with the use of conventional MMF could negate the benefits of using cassette-based modular fiber connector systems. When compared to a point-to-point link consisting of cable and two mated-pair (LC or SC) connectors, these systems incorporate two additional mated pairs – MTP®/MPO 12-fiber ribbon array connectors. The cassette-based solution enables installers to connect twelve or more fibers simultaneously, providing significant labor savings during installation as well as enables higher density within a cabinet. Table 1 shows the typical link losses of these two examples.

Connection Type	Number of Mated Connections	Loss (dB)	Typical Cable Attenuation (dB/km)	Maximum Link Loss (dB)
LC or SC	2	0.75/mated pair	3.5	1.79
MTP Cassette*	4	1.50/mated cassette	3.5	3.29

* Each MTP/MPO cassette contains an MTP/MPO mated-pair connection, a short piece of fiber inside the cassette and a LC mated pair connection.

While this may not be a problem for Gigabit Ethernet and 2-Gigabit Fibre Channel applications, it would prohibit migration to a 10-Gigabit system over a standard 50/125 μ m (500 MHz•km) channel using a MTP/MPO solution. By specifying enhanced 50-micron LOMF that has a *minimum* effective modal bandwidth (EMB) of 2000 MHz•km, an easy upgrade to a 10-Gigabit network can be ensured.

Leveraging Enhanced Cabling Technology Containing Low DMD Optical Fiber

When the IEEE established the cable plant loss budget limits for Ethernet, it included certain assumptions for the characteristic attenuation and inter-symbol interference (ISI)¹ that is primarily caused by the link differential modal delay (DMD)². For Gigabit applications, these assumptions were based on industry standard 50/125 (500/500 MHz•km) MMF and connectors. In the 10-Gigabit Ethernet standard, the IEEE recognized that the superior DMD performance of 50-micron laser optimized multimode fiber (LOMF) offered significantly better performance than standard 50-micron MMF. This resulted in the extended distance and cable plant loss budget specifications for Gigabit and 10-Gigabit transmission utilizing this newer type of fiber. In the 10-Gigabit case, link length was extended to 300 meters and the cable plant loss budget associated with the 300 meter length was conservatively calculated as 2.6 dB at 850 nm.

However, there is another advantage associated with a low-DMD LOMF link. At shorter distances, the same characteristics that enable it to support longer distances can be leveraged to achieve higher than expected allowable link loss. Because of the exceptionally low DMD of LOMFs such as Berk-Tek's GIGAlite-10 and GIGAlite-10XB, a portion of the loss budget that the IEEE had reserved for ISI can be reassigned. This increased optical headroom can be used for additional connections (connector mated pairs) or for multi-fiber connectors such as the MTP/MPO optical cassette found in state-of-the-art "ready to connect" systems like Ortronics' Momentum[®] solutions. This benefit is particularly advantageous in the design of mission critical data centers where short channel lengths and increased connector density are typical.

Figure 1 shows the link loss values allowed when using Berk-Tek's 50 µm GIGAlite LOMF.

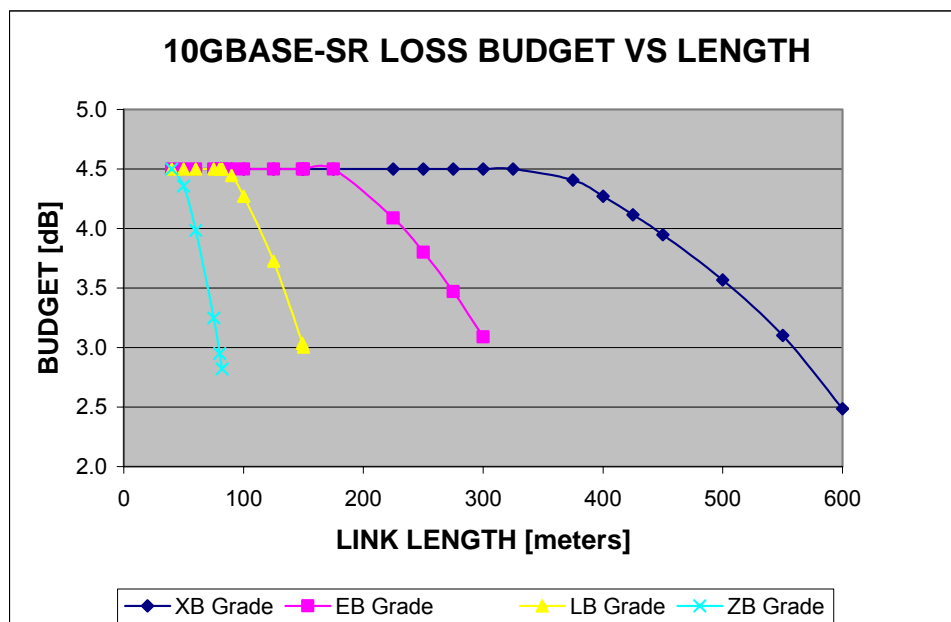


Figure 1: 10-Gigabit Ethernet Link Loss versus Length for Different Grades of 50-micron LOMF

¹ ISI or inter-symbol interference is a link penalty due to the spreading of light pulses between adjacent bit periods; ISI is lower in fiber with lower DMD.

² DMD or differential mode delay is the difference in time between the leading edge of the first arriving pulse and the trailing edge of the last arriving pulse at the receiver. Multiple light pulses, numbering in the 100s, are transmitted through multimode fiber. Superior process control in the manufacturing process can minimized the DMD.

Table 2 details the various GIGALite fiber cables that enable this superior link-loss performance.

Table 2: 50/125 GIGALite Fiber Cable Specifications at 850 nm				
Parameter	XB	EB	LB	ZB (conventional)
EMB (MHz•km)	4,900	2,000	950	NA
Attenuation (dB/km)	3.0	3.0	3.0	3.5

The increased channel loss budget associated with GIGALite fiber provides system designers greater flexibility in link configurations while enabling a migration path to 10-Gigabit applications utilizing low-cost 850 nm optics. For example, when specifying an 82-meter link in a data center currently supporting Gigabit Ethernet or 2-Gigabit Fibre Channel with the intention of providing support for future upgrades to 10-Gigabit Ethernet or Fibre Channel, a designer recommending the use of standard (500/500 MHz•km) 50-micron MMF would be limited to a total link loss of 1.8 dB. This would severely limit the link configuration and choice of connectors. By specifying GIGALite-10XB that loss budget can be increased to 4.5 dB (at 82-meters), allowing significantly more flexibility in the type and number of connections.

NetClear Link Loss Model

To take advantage of the high bandwidth and improved DMD performance of laser optimized multimode fibers for shorter link, higher insertion-loss environments, the NetClear team modified the standard IEEE 10-Gigabit link-loss model. These modifications included transferring a portion of the ISI penalty allocation to increase the cable plant loss budget for shorter link lengths and more accurately accounting for connector modal noise³. Using a greater number of connectors than specified in the original IEEE model not only increases the total connection insertion loss, but may also introduce more connector “modal noise”. The NetClear model expands upon the original IEEE 10-Gigabit Ethernet model by accounting for the variability in connector modal noise when using more than two connections. This model takes a conservative approach to this phenomenon by increasing the modal noise penalty from a constant 0.3 dB to a variable that is a function of the connector loss. Figure 2 shows a diagram of the modal noise penalty versus connector insertion loss for both the IEEE model and the new NetClear model.

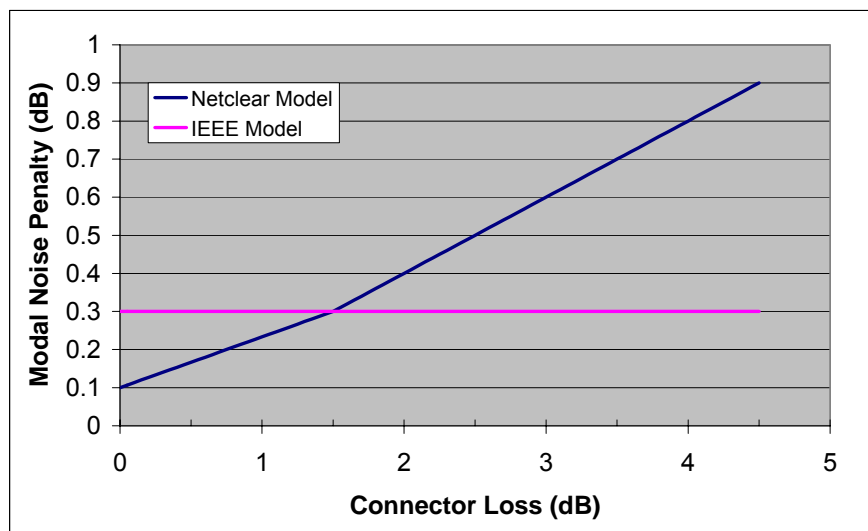


Figure 2: Modal Noise Penalty versus Connector Loss

³ Connector modal noise is caused by the interference of the wavefronts of different modes within the fiber at the connector interface.

Figure 2 shows that, with lower connector loss, the modal noise penalty is very low. But, as the connector loss increases, the new NetClear model becomes more conservative than the original IEEE model.

To validate this model, systems-level testing was performed at the Data Communications Competence Center (DCCC) at Nexans, Inc. The results are shown in Table 3.

Table 3: Systems-level Testing of LB-grade Fiber with Multiple Connections									
Test Length (meters)	Number of SC Mated Pairs	Number of MTP/MPO Cassettes*	Total Number of Mated Pairs	Results	Measured Link Loss (dB)	Measured Cable Loss (dB)	Total Connection Loss (dB)*	Predicted Max Length (meters)	
								IEEE Model	NetClear Modified Model
150	4	4	12	Fail	5.2	0.9	4.3	80	60
150	4	2	8	Pass	2.1	0.9	1.2	135	135
100	3	6	15	Fail	8	0.6	7.4	0	0
100	5	4	13	Pass	6.4	0.6	5.8	20	0
100	4	4	12	Pass	5.6	0.6	5.0	60	15
100	3	4	11	Pass	5.2	0.6	4.6	75	45
100	3	2	7	Pass	2.7	0.6	2.1	120	120
50	6	4	15	Fail	5.9	0.3	5.7	30	0
50	5	4	13	Fail	5.2	0.3	5.0	60	15
50	4	4	12	Pass	6	0.3	5.8	20	0

* Each MTP/MPO cassette contains an MTP/MPO mated-pair connection, a short piece of fiber inside the cassette and a LC mated pair connection.

** The total connection loss was calculated by subtracting the cable loss from the total link loss.

Test equipment used in the experiments consisted of an IXIA® packet generator and a FOTEC FM 310 optical power meter. Packets transmitted consisted of actual 10-Gigabit Ethernet 64-byte frames with a minimum inner-packet gap. Packet volume was generated in sufficient quantity to ensure a bit-error-rate of better than 10⁻¹².

The NetClear model is clearly more accurate for links incorporating higher than “normal” link loss. This is demonstrated by the case highlighted in the table where the test length was shorter than that predicted by the IEEE model (60 meters), yet the systems-level test failed. Again, this is due to the connector modal noise that may change every time a new connection is introduced in the link and which is accounted for in the NetClear model, but not in the IEEE model.

To assist the end user in design of short wavelength, 10-Gigabit Ethernet fiber links, NetClear has developed a Microsoft® Excel-based link-loss calculator tool that can be downloaded at no charge from the NetClear web site (www.netclear-channel.com). Sample outputs of a variety of links using this tool are shown in Table 4.

Table 4: NetClear Link-loss Calculator Tool for Typical Short Lengths Using LC and SC Connectors (10GBASE-SR Application)						
Two Mated Pairs	Maximum Insertion Loss (dB)	Length (meters)	Fiber Grade			
			Standard	LB	EB	XB
Standard LC or SC	1.5	50	PASS	PASS	PASS	PASS
NetClear LC or SC	1.0	50	PASS	PASS	PASS	PASS
Standard LC or SC	1.5	100	FAIL	PASS	PASS	PASS
NetClear LC or SC	1.0	100	FAIL	PASS	PASS	PASS
Standard LC or SC	1.5	150	FAIL	PASS	PASS	PASS
NetClear LC or SC	1.0	150	FAIL	PASS	PASS	PASS
Standard MTP/MPO	1.5	100	FAIL	FAIL	FAIL	FAIL
NetClear Momentum	1.25	100	FAIL	PASS	PASS	PASS

When systems designers are developing links to support Gigabit Ethernet applications with the intention of supporting 10-Gigabit Ethernet in the future, the use of LOMF, such as GIGAlite-equipped Berk-Tek fiber cables, allows them to consider configurations that either exceed the distances specified by the IEEE, or utilize additional or higher-loss connections. These scenarios allow more options for the network engineer who desires to reduce costs, either by using LOMF in order to minimize optoelectronics cost, or by providing rapidly-deployable cassette-based products. The NetClear MM10 solution provides the flexibility needed not only for today's networks, but for local area networks and data centers of the future.

About Berk-Tek, A Nexans Company

Berk-Tek is an industry leader in the development and manufacturing of high-performance optical fiber and copper cables designed to transport high-speed data and voice transmissions. Berk-Tek has major manufacturing facilities at New Holland, PA, Fuquay-Varina, NC and Elm City, NC. For more information, visit www.berktek.com (<http://www.berktek.com>).

About Ortronics/Legrand

Ortronics/Legrand, based in New London, Connecticut, is the Global Technology Center for fiber optic, copper and wireless connectivity and systems for Legrand. The Center includes a Fiber Optic Competency Center where, together with Berk-Tek, the companies co-engineer integrated and seamless optical solutions for state-of-the-art enterprise and data center applications.