Choosing a Small Form Factor Connector
Advantages of the LC connector over the MT-RJ
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Use of Small Form Factor Connectors is Now Widespread

With the increasing deployment of fiber in the LAN, especially for building and campus backbone installations, the use of Small Form Factor (SFF) fiber optic connectors is becoming more widespread. The main drivers for this deployment are cost and space savings for cabling hardware and equipment interfaces. A multitude of SFF connector designs are currently available. The trend towards SFF connectors is also apparent in LAN and WAN equipment, with the newer devices from most vendors available with SFF ports, and more recently SFP (Small Form Pluggable) interfaces.

SFF Connectors and Cabling Standards

Meanwhile, cabling standards organizations have decided "not to decide" in this matter. Instead, they have given their blessing to the use of SFF connectors and have chosen to open up the infrastructure to any SFF connector that meets the relevant performance specifications, leaving it up to the market to decide which connector best meets the requirements. The 2nd Edition of ISO/IEC 11801, published in September 2002, maintains the SC connector at the Telecommunications Outlet (TO), but in recognition of the increasing role of fiber in the enterprise networks, it now recommends the use of SFF connectors in high-density locations such as Telecommunications Closets and Consolidation Points. The TIA-568B standard allows the use of SFF connectors in any infrastructure location, including the TO.

Equipment Interfaces and Infrastructure Choice

Lacking guidance from cabling standards, some end users are swayed to choose the SFF connector for their cabling infrastructure based on the type of SFF connector currently available on the equipment from their preferred LAN or WAN vendor. However, using this criterion as the sole decision point overlooks the fact that equipment and infrastructure connectors have widely different life cycles, and connector selection should be made on an expanded set of criteria.

Equipment interfaces have never driven connector selection for the cabling infrastructure. Witness the demise of the FDDI and ESCON connectors, the longstanding popularity of the ST connector, and the fact that just as the SC connector had begun to gain in popularity in equipment, it is now being overtaken by SFF and SFP interfaces. Both FDDI and ESCON connectors were very popular equipment interfaces, but have never been a factor in the infrastructure.

SFF Transceiver Multisource Agreement

A key milestone towards the adoption of SFF connectors in electronics was the signing of a Multisource Agreement (MSA) for SFF transceivers by AMP Incorporated, Hewlett Packard, Nortel Networks, Lucent Technologies, Siemens AG and Sumitomo Electric Lightwave. As a result of this agreement, the signatories agreed to develop specifications for transceivers based on common packaging and pinouts (independent of the type of SFF connector used). This allows equipment manufacturers to design electronics based on a common transceiver form factor, available from multiple vendors. The end result is that multiple SFF interfaces can be supported while maintaining inventory flexibility through a common PCB design.

SFP Transceiver Multisource Agreement

A group including some of the same companies later developed a similar MSA for Small Form Pluggable interfaces. In addition to the advantages offered by the SFF specification, the SFP specification allows for the use of short or long wavelength transceivers interchangeably on the same board or NIC card, depending on the best fit for the customers' infrastructure.

The LC Connector Leads the Installed Base

In the emerging SFF connector landscape, the LC connector is clearly the leader in performance as well as installed base. Since the LC connector has been licensed widely and is now offered by most major cabling system vendors (including some early proponents of MT-RJ), the exact number of LC connectors shipped is difficult to ascertain. However, at least one vendor has shipped over 24 million LC connectors, with a mix of approximately 60% multimode and 40% singlemode. The MT-RJ connector places a distant second in both performance and installed base. The multimode version has found some support with a few large transceiver vendors and LAN equipment manufacturers, particularly for the less demanding 100BASE-FX interfaces. However, the LC connector is quickly becoming the preferred transceiver connector for high bit rate applications (1 Gb/s and above) due to its numerous advantages for transceiver design. More transceiver manufacturers support the LC interface than any other SFF connector, and LC transceivers are available from numerous sources for applications ranging from 10 Mb/s to 10 Gb/s.

Design Comparison

The specific characteristics of the LC connector, including wide fiber spacing, better fiber alignment, precision mating, ease of connector cleaning, and simplex/duplex configuration, combine to produce overall superior performance for both factory-terminated and field installed connectors. From a brief discussion of these characteristics, it is apparent that the LC connector is the best choice for a cabling infrastructure.

Fiber Spacing

Just like the ST and SC connectors, the LC connector was designed for compatibility with standard (900 micron) buffered fiber, of the type used in the vast majority of indoor building cables and jumper cordage. The MT-RJ, on the other hand, is an evolution of the MT connector designed for 250 micron coated fiber ribbons. As a result, the fiber spacing in the MT-RJ is a mere 750 microns. This makes it more difficult to mount the connector on widely available building cables, especially in the field. With a fiber spacing of 6.25 mm, the LC is better suited for both indoor and outdoor cable types.

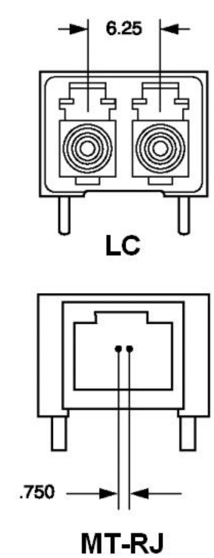


Figure 1

Figure 1 is a front view of LC and MT-RJ transceivers, illustrating the difference in fiber spacing. The tight fiber spacing in the MT-RJ presents significant challenges for transceiver manufacturers. To minimize crosstalk between source and receiver, MT-RJ transceivers require the use of waveguides or optical mirrors to guide the light to the tightly spaced connector fibers. The challenge is greater when using laser sources or operating at higher data rates (at 1 Gb/s and higher), where smaller spot sizes result in higher sensitivity to the distortions introduced by the guiding mechanism. This added complexity can result in a reduction of output power of up to 2 dB at the transceiver. In comparison, by offering sufficient fiber spacing, the LC connector simplifies transceiver manufacture by allowing direct coupling between the active device and the fiber.

Additionally, the use of individual ferrules for each fiber allows for more efficient confinement and management of electromagnetic energy, as opposed to the much larger opening presented by MT-RJ transceiver types. Higher frequency signals leak out of small openings to a greater degree than lower frequency signals, so the containment problem also intensifies at higher data rates.

The fiber spacing in the LC makes for an inherently better transceiver connector for both multimode and singlemode applications, and the benefits increase as the data rates increase.

Fiber Alignment

The performance of fiber connectors is directly related to the precision in fiber alignment. The LC continues the tradition of single-ferrule connectors such as the ST and SC, with individual 1.25 mm diameter ferrules for each fiber. Proper fiber alignment relies on the precision manufacturing tolerances of the coupling (or transceiver receptacle bore), and the ferrule itself (including ferrule outer diameter and fiber-ferrule concentricity).

With the two fibers installed in the same physical connector, fiber alignment is inherently more complex and less precise in MT-RJ connector, requiring simultaneous alignment of two fiber locations and two locating pins. The use of metal alignment pins retained in plastic openings is also likely to cause alignment degradation over time, resulting in higher loss as the installation ages.

Return loss is a measure of the amount of light that is reflected back down the transmitting fiber. Precise control over the connector endface geometry is necessary for acceptable return loss performance. Ideally, this geometry is spherical in nature at a prescribed radius, with the apex of that radius centered about the fiber longitudinal axis. While this is easily achieved with the individual ferrules of the duplex LC, it is substantially more difficult with the MT-RJ. This is primarily due to the difference in material hardness between the plastic ferrule and the fiber, subsequent polishing differences, and the difficulty of creating such a geometry on two fibers in one rectangular ferrule.

The individual fiber alignment approach in the LC consistently results in ***superior insertion loss and return loss performance for multimode and singlemode applications.***

Mating

Physical fiber contact is also a critical factor in connector performance. In the MT-RJ, microscopic fiber protrusion or angular displacement can prevent the other fiber from making physical contact, with significant impact on both insertion loss and return loss performance. With individually spring-loaded ferrules for each fiber, *LC connectors mate more precisely* and ensure that both fibers are always in physical contact (see Figure 2).

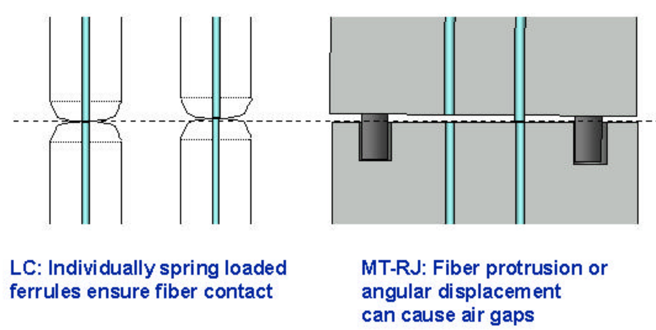


Figure 2 (not to scale)

Cleaning

Proper cleaning of fiber optic connectors is another critical aspect to achieve and maintain the desired performance. Dirt, grit and airborne contaminants can degrade optical connections over time and result in mysterious link problems. The single ferrule approach in the LC makes fiber cleaning extremely simple, while the alignment mechanisms in the MT-RJ serve to complicate the cleaning process. The alignment pins make it difficult to clean the fiber end surfaces on the male connector, and the alignment holes on the female connector are a natural trap for solid and/or liquid contaminants which cannot be readily removed.

The LC is easier to clean, making it a more robust connector over time.

Simplex vs. Duplex

In contrast with the hard-duplex configuration offered by the MT-RJ and other SFF connectors, the LC is a simplex connector arranged in a duplex configuration (see figure 3). In addition to the performance advantages mentioned above in mating and alignment properties, *the LC connector provides additional flexibility* in application support (i.e. for single-fiber video applications), and eliminates the need to cut-off and re-terminate connectors to correct or modify polarity requirements.

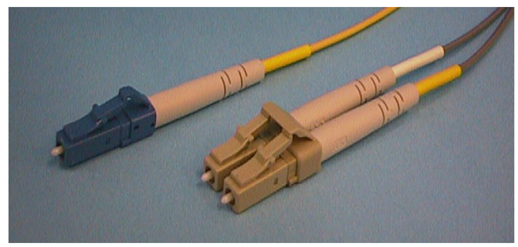


Figure 3
Single-fiber & Duplex LC Connector Configurations

Field Installation and Connector Performance

Performance claims for the MT-RJ connector appear to be largely based on the performance of factory terminated patch cords; with early data sheets claiming 0.2 dB mean insertion loss (with 0.25 dB standard deviation) for multimode connectors. The LC connector offers the best performance; with 0.1 dB mean insertion loss (0.1 dB standard deviation) for polished multimode connectors. Field installation of SYSTIMAX LC connectors can be performed in approximately 2 minutes with the EZ adhesive method, and splicing of factory-terminated pigtails is also an option. Field installation of MT-RJ connectors requires the use of splicing or crimp-on style connectors with inherently higher losses (which may even exceed the 0.75 dB maximum specified by standards).

The move towards SFP transceivers

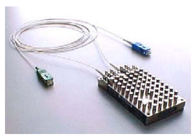
The initial wave of fixed small form factor transceivers on equipment has now been overtaken by the SFP version. SFP transceivers offer a key advantage to equipment vendors and end-users in the ability to support short wavelength (850 nm) or long wavelength (1310 or 1550 nm) in the same slot. SFP transceivers also offer big benefits for the equipment vendor since pluggables drastically reduce the complexity of their product line and associated inventory.

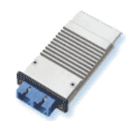
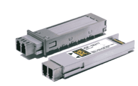
As an increasing number of equipment vendors offer SFP-based modules for Gigabit Ethernet and Fibre Channel switches and network interface adapters, the LC connector has become the defacto standard for SFP transceivers for Gigabit Ethernet and Fibre Channel. The vast majority of transceiver vendors (including Agilent, JDS Uniphase, Finisar, Stratos Lightwave, Picolight, Infineon, Molex, and Samsung) only offer LC transceivers in the SFP version, and recently Tyco Electronics, the main proponent of the MT-RJ, has announced that it will offer an LC-based SFP range for multimode and singlemode applications.

10 Gigabit Transceivers and Small Form Factor Connectors

With the recent ratification of the IEEE 802.3ae standard for 10 gigabit Ethernet and the ratification of associated standards for Laser Optimized Multimode Fiber (OM3) targeted at enabling the rapid migration towards 10 Gb/s for enterprise customers, end users are advised to prepare their infrastructure for 10 Gb/s support in backbones and Storage Area Networks.

10 Gigabit vendors have formed several MSAs to address the fast-emerging 10 Gigabit Ethernet market, and a rapid evolution is already apparent from fixed to pluggable transceivers, and towards small form factor interfaces. Table 1 illustrates some of the key transceiver MSAs, highlighting their size, intended application, and connector types.



Type	200 Pin	Xenpak	XPAK	XFP
Dimensions (in)	3.0 x 1.6 x 0.6	4.8 x 1.4 x 0.7	2.7 x 1.4 x 0.4	2.7 x 0.7 x 0.4
Application	WAN Ent. Switch	WAN Ent. Switch	Ent. Switch Adapter Cards Storage	Ent. Switch Adapter Cards Storage
Connector MSA: Available:	N/A SC LC	SC SC LC	SC* SC LC	SFF LC
10GbE, 10GFC Support	10GbE Serial	All 10GbE	All 10GbE All 10GFC	10GbE Serial 10GFC Serial
Hot Pluggable	NO	YES	YES	YES

Table 1 – 10 Gigabit Ethernet and Fibre Channel Transceivers

Initial designs were based on the transceivers employed for SONET/SDH. The 200 pin MSA (and a similar 300 pin MSA) specify fixed transceivers that are implemented internally to the switch module, utilizing pigtail connections that are coiled up inside the module and presented to a coupling adapter at the edge of the board.

The first pluggable 10 Gigabit transceivers on the market were based on the Xenpak MSA, which specifies a relatively large device and supports all 10 Gigabit Ethernet options. The Xenpak transceiver is targeted at WAN and Enterprise Switch applications, and it is well suited for long distance requirements, although its large size limits port density.

More recently, several vendors have announced pluggable XPAK transceivers. The XPAK MSA also supports all 10 Gigabit Ethernet options as well as 10 Gigabit Fibre Channel applications in a package that is roughly half the size as Xenpak. XPAK is targeted at Enterprise Switches, Adapter Cards and Storage Area Networks.

Finally, the XFP MSA is the closest approximation, in both size and function, to the SFP transceivers now commonly used for Gigabit Ethernet and Fibre Channel. The XFP transceiver only supports the serial implementations of 10 Gigabit Ethernet and Fibre Channel, while offering the highest port density.

In terms of optical connector design and selection, the trend towards SFF optical connectors is also apparent in the 10 Gigabit arena. SC and LC pigtail options are commonly available for 200-pin transceivers. The Xenpak MSA specifies SC connectors, but at least two vendors have announced LC versions. The XPAK MSA states that the connector "should" be SC but leaves the door open for smaller connectors, and Intel has already announced their first XPAK transceiver, available only with LC connectors. Due to its small size, the XFP transceiver requires SFF connectors, and although the specific type is not stated in the MSA, the LC is expected to be the most popular option. Several transceiver vendors have already announced XFP transceivers, and the LC connector is the only one featured.

The LC Connector is also the Choice For Servers, Hosts and Workstations

The LC connector has also proven a popular choice for Gigabit Ethernet and Fibre Channel adapter cards targeted at servers, hosts and high-end workstations.

Already the defacto standard for Fibre Channel Host Bus Adapter cards (LC or SFP HBAs are offered by Agilent, Adaptec, Atto Tech, Cambex, Emulex, Qlogic, LSI Logic, and others), the LC connector has been chosen by Intel for its recently introduced range of Gigabit Ethernet server adapters, including single and dual transceiver cards for 1000BASE-SX and 1000BASE-LX. Gigabit Ethernet server adapters with LC or SFP options are also available from Emulex, Ramix, and others.

10 Gigabit transceivers targeted at adapter cards such as XPAK and XFP are set to continue this trend.

Channel Performance is the Determining Factor for the Infrastructure

As data rates increase, power budgets for optical fiber applications are shrinking, and infrastructure designers comfortable with the generous 10-12 dB power budgets available for 10 Mb/s and 100 Mb/s applications now have to design the infrastructure for applications such as 1000BASE-SX with a 2.5 dB loss budget and 10 Gigabit Ethernet with with a 2.5 dB loss budget for 2000 Mhz.km fiber and as low as 1.6 dB for 200 MHz fiber. This means that the overall fiber optic channel performance should be the primary criteria in the infrastructure choice.

More recent applications standards (such as 1000BASE-SX and 10GBASE-SR) specify channel loss based on an allocation for two standard connections at 0.75 dB insertion loss each. Given the loss budgets mentioned above, it is obvious that connector loss now consumes a much larger share of overall budget. Due to its outstanding insertion loss performance, the LC connector provides additional channel margin and offers the capability to support the additional connections required for ease of administration and link re-configurations.

Channel Loss Comparison

To evaluate the loss performance of LC channels compared to MT-RJ channels, SYSTIMAX Labs performed channel attenuation tests and a statistical study using 590 m (including patch cords) channels with six LC or MT-RJ connections as shown in Figure 4.

Five channels of each type were constructed with field-polished LC or crimp-on MT-RJ connectors. The intent of the study was to demonstrate the superior performance in the same product/solution class across vendors, and the crimp-on MT-RJ is the most commonly offered design for field termination to end customers. Each channel consists of 3 links with lengths of 45, 450 and 90 meters from transmitter end to receiver end. 20 factory-produced patch cords of each type were randomly cycled in groups of 4 through the links based on a selection algorithm. A total of 195 data points were gathered for each type of channel. The results showed that the LC channels had 47% lower loss, and half the standard deviation of the MT-RJ channels (see Figure 5).

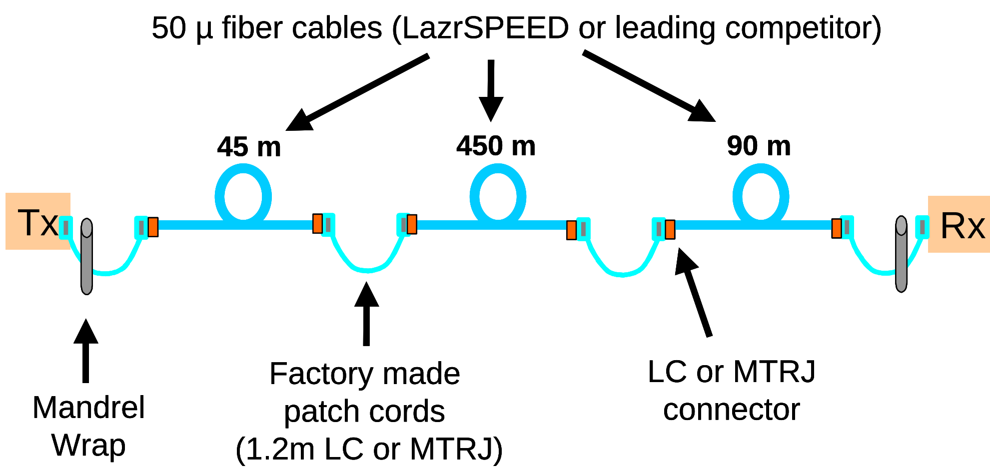


Figure 4. Channel Loss Comparison Set-Up

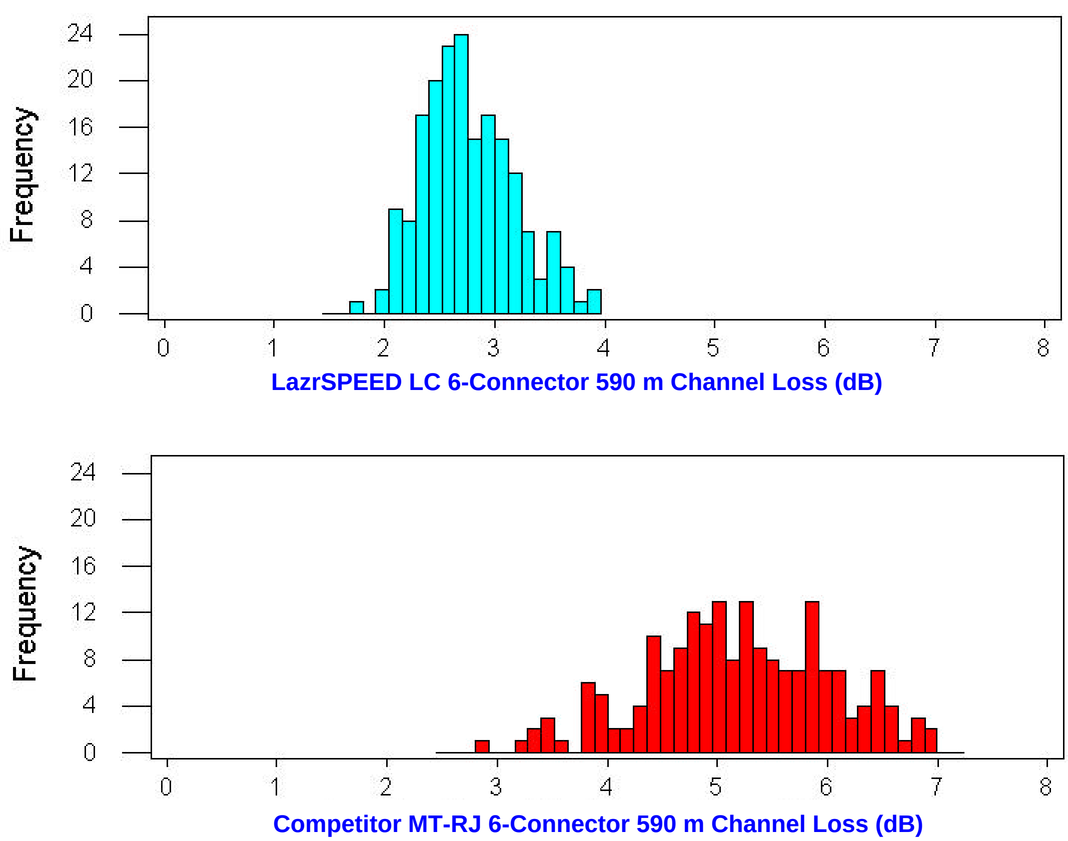


Figure 5 – Channel Loss Comparison

Choosing a Small Form Factor Connector for the Infrastructure

When choosing a Small Form Factor connector for the cabling infrastructure the end user must keep in mind that LAN equipment has an expected life cycle of 2-3 years, and equipment vendors may change their choice of interface connector without notice. Since channel loss budgets are shrinking as data rates increase, end users must ensure that the infrastructure SFF connector offers the best performance to future proof their installation. End users should be careful not to penalize the performance of their infrastructure based on the connector featured in their preferred vendors equipment, since the equipment connector may have been chosen years ago based on criteria that do not necessarily apply to the permanent infrastructure.

Based on a wide range of criteria that cover issues relevant to infrastructure requirements, the LC connector offers clear advantages over the MT-RJ, as summarized in Figure 6. The LC offers better insertion loss and return loss, as well as the ability to support simplex and duplex configurations. The LC is also easier to install and clean, and its ceramic ferrule is better matched to the fiber properties. Additionally, the industry trend towards the LC connector is evident in the evolution of multimode and singlemode LAN, SAN and WAN electronics, since the LC is the most widely available SFP option and is also the SFF connector of choice for 10 Gigabit transceivers.

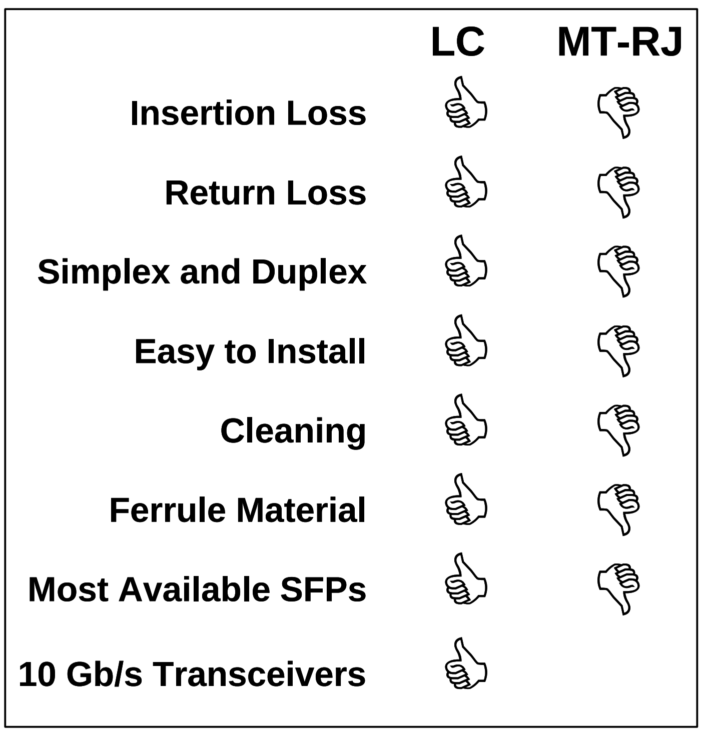


Figure 6 –Feature Comparison

The international cabling standard ISO/IEC 11801 is targeted at infrastructures that have a usable life in excess of 10 years, and end users often design their infrastructure expecting a usable life up to twice as long. By providing superior channel performance and other features that make installation and maintenance easier and more reliable, the LC connector allows for the implementation of a cabling infrastructure that will support multigigabit applications with unmatched administration flexibility and long life expectancy.