System z

Planning for Fiber Optic Links (ESCON, FICON, InfiniBand, Coupling Links, and Open System Adapters)

GA23-0367-13

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Note!

Before using this information and the product it supports, be sure to read the information under "Safety" on page v, Appendix E, "Notices," on page 85, and *IBM Systems Environmental Notices and User Guide*, Z125–5823.

This edition, GA23-0367-13, applies to the IBM® System z™ processors, and replaces GA23-0367-12.

There may be a newer version of this document in PDF format available on Resource Link. Go to *http://www.ibm.com/servers/resourcelink* and click on Library on the navigation bar. A newer version is indicated by a lower-case, alphabetic letter following the form number suffix (for example: 00a, 00b, 01a, 01b).

Contents

Safety

Safety notices

Safety notices may be printed throughout this guide. **DANGER** notices warn you of conditions or procedures that can result in death or severe personal injury. **CAUTION** notices warn you of conditions or procedures that can cause personal injury that is neither lethal nor extremely hazardous. **Attention** notices warn you of conditions or procedures that can cause damage to machines, equipment, or programs.

World trade safety information

Several countries require the safety information contained in product publications to be presented in their translation. If this requirement applies to your country, a safety information booklet is included in the publications package shipped with the product. The booklet contains the translated safety information with references to the US English source. Before using a US English publication to install, operate, or service this IBM® product, you must first become familiar with the related safety information in the *Systems Safety Notices*, G229-9054. You should also refer to the booklet any time you do not clearly understand any safety information in the US English publications.

Laser safety information

All System z® models can use I/O cards such as PCI adapters, ESCON®, FICON®, Open Systems Adapter (OSA), InterSystem Coupling-3 (ISC-3), or other I/O features which are fiber optic based and utilize lasers or LEDs.

Laser compliance

All lasers are certified in the US to conform to the requirements of DHHS 21 CFR Subchapter J for Class 1 or Class 1M laser products. Outside the US, they are certified to be in compliance with IEC 60825 as a Class 1 or Class 1M laser product. Consult the label on each part for laser certification numbers and approval information.

CAUTION:
Data processing environments can contain equipment transmitting on system links with laser modules that operate at greater than Class 1 power levels. For this reason, never look into the end of an optical fiber cable or open receptacle. (C027)

CAUTION:
This product contains a Class 1M laser. Do not view directly with optical instruments. (C028)

About this publication

This publication provides information that can be used to plan for IBM Fiber Optic Links. This includes Enterprise Systems Connection (ESCON) channels, coupling facility links, Open System Adapter (OSA), and Fibre Connection (FICON) channels, which is IBM's implementation of the ANSI Fibre Channel Standard with additional support for multi-mode fibers. Although it contains general information relating to fiber optic cables, components, and optical fiber data processing environments, it includes only what is supported for these fiber optic links.

A technical change or illustration is indicated by a vertical line to the left of the change.

Notes:

1. When the term FICON is used, it refers to FICON Express (LX and SX), FICON Express2 (LX and SX), FICON Express4 (LX and SX) and FICON Express8 (LX and SX) channels.
2. When the term OSA is used, it refers to OSA-Express and OSA-Express2 adapters.
3. Refer to the publication *IBM 3044 Fiber-Optic Channel Extender Link: Fiber-Optic Cable Planning and Installation Guide*, GC22-7073, for information relating to Fiber Optic Channel Extender Link Models C01 and D01.
4. This publication, in conjunction with the publication *Maintenance Information for Fiber Optic Channel Links*, SY27-2597, replaces the publication *IBM 3044 Fiber-Optic Channel Extender Link Models C02 and D02: Fiber-Optic Cable Planning, Installation, and Maintenance Guide*, GC22-7130, and makes it obsolete.
5. This publication replaces *Cabling System Optical Fiber Planning and Installation Guide*, GA27-3943.

Organization of this publication

This publication contains five chapters and five appendixes:

- **Chapter 1,"Introduction to Fiber Optic Links,"** provides a brief introduction to fiber optic information transfer, lists the components that can be included in a fiber optic channel link, and shows an example of a fiber optic channel link.
- **Chapter 2, "Link, Trunk, and IBM Jumper Cable Planning,"**discusses fiber optic channel link planning tasks and contains considerations and recommendations related to planning for fiber optic channel links.
- **Chapter 3, "Calculating the Loss for a Multi-mode Link."** describes how to calculate the maximum allowable loss for a fiber optic channel link that uses multi-mode components. It shows an example of a multi-mode ESCON link and includes a completed work sheet that uses values based on the link example.
- **Chapter 4, "Calculating the Loss for a Single-mode Link."** describes how to calculate the maximum allowable loss for a fiber optic channel link that uses single-mode components. It shows an example of a single-mode link and includes a completed work sheet that uses values based on the link example.
- **Chapter 5,"Specifications,"** lists the specifications and optical properties for a fiber optic channel link, IBM jumper cables, and trunk cable.
- **Appendix A, "Measurement Conversion Tables,"** contains conversion tables from English measurements to metric and metric measurements to English.
- **Appendix B, "Multi-mode Calculated Link Loss Work Sheet,"** and **Appendix C, "Single-mode Calculated Link Loss Work Sheet,"** each contain a blank work sheet. The work sheet should be reproduced, used for fiber optic channel link loss calculation, and filed with other fiber optic documentation for the fiber optic channel link environment.
- **Appendix D, "Fiber Optic Interconnects,"** describes the different kinds of optical data links.
- **Appendix E, "Notices,"** contains trademark and service mark information.

Prerequisite publications

- *Introducing Enterprise Systems Connection*, GA23-0383, provides a summary of the products and services that are part of the ESCON environment.
- *zSeries Connectivity Handbook*, SG24-5444, provides connectivity alternatives available in the planning and design of a data center infrastructure.
- *FICON Implementation Guide*, SG24-6497, provides FICON and Fibre Channel architectures, terminology and supported technologies

Related publications

- *Enterprise Systems Connection Link Fault Isolation*, SY22-9533, contains information used to isolate link faults when the environment does not use the ESCON Analyzer.
- *Maintenance Information for Fiber Optic Links*, SY27-2597, provides problem determination, verification, and repair procedures for ESCON links. This publication also contains information from *Maintenance Information for Fiber Distributed Data Interface Links*, SY27-0331. This publication obsoletes form SY27-0331.
- *Introduction to IBM S/390 FICON*, SG24-5176, provides an overview of the Fiber Channel Connection (FICON).
- *Technical Service Letter No. 147 Fiber Optic Tools and Test Equipment*, (Revised 2/19/96 or later) contains a complete list of fiber optic support tools and test equipment.
- *Using the IBM Cabling System with Communications Products*, GA27-3620
- *IBM Cabling System Technical Interface Specification*, GA27-3773
- *Local Area Networks Concepts and Products*, SG24-4755
- *Coupling Facility Channel I/O Interface Physical Layer*, SA23-0395
- *Fiber Channel Connection (FICON) I/O Interface Physical Layer*, SA24-7172
- *Planning for the System/390 Open System Adapter Feature*, GC23-3870

In addition to this document, you should be familiar with the following Electronics Industries Association (EIA) and Telecommunications Industry Association (TIA) standards. The following standards are published as American National Standards Institute (ANSI) Standards:

- *Commercial Building Telecommunications Wiring Standards*, (EIA/TIA 568)
- *Commercial Building Standards for Telecommunication Pathways and Spaces*, (EIA/TIA 569)
- *Telecommunications Administration Standard of Commercial Buildings* EIA/TIA Project number 2290 (currently available only as a draft)
- *Telecommunications Distribution Methods Manual - Building Industry Consulting Service International (BICSI)*

Coupling links are designed to be optically compatible with the F0 or physical layer industry standard *ANSI Fibre Channel Standard Physical and Signaling Interface (FC-PH)*, published by the *American National Standards Institute*, New York, NY.

The open fiber control (OFC) timing for 531 megabits per second links follows this ANSI standard. The OFC timing for 1.0625 gigabits per second links uses the same timing as specified in the ANSI standard for 266 megabits per second links, which enables longer distances for gigabit links.

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Chapter 1. Introduction to fiber optic links (ESCON, FICON, coupling links, and Open System Adapter)

This chapter provides a brief introduction to fiber optic information transfer, and lists the components that can be included in an IBM fiber optic channel link. These links include both Enterprise Systems Connection (ESCON) coupling links, Open System Adapter (OSA), and Fibre Connection (FICON) links.

With the development of products that use optical cable as a transmission medium, data processing centers and LANs are expanding beyond the limitations of copper cable. Optical cable allows attaching products to take advantage of the following benefits

- Extended distances
- Higher data rates
- Smaller and lighter cable
- Less susceptibility to radio frequency interference (RFI) and electromagnetic interference (EMI).

Because of the physical characteristics of optical cable and the products that use it, planning an optical fiber installation should be approached with a thorough understanding of this technology. This includes the factors associated with extended distance links (for example, right-of-way considerations) and using component and distribution hardware. To plan an installation that supports current products and future products, plan carefully and early. This chapter also shows an example of a fiber optic channel link.

Unidirectional fiber optic information transfer

Information transfer through an optical fiber usually occurs in only one direction by using a transmitter and a receiver Figure 1. The transmitter accepts encoded digital information, converts it into an optical (light) signal, and sends it through the fiber. The receiver detects the optical signal, converts it into an electrical signal, and amplifies it. After being decoded, the digital output information is the same as the digital input.

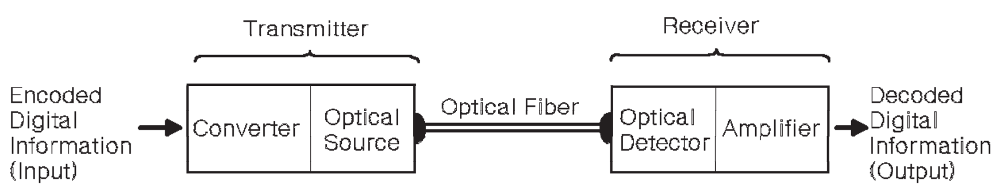

Figure 1. Unidirectional fiber optici Information transfer

Bidirectional fiber optic information transfer

Fiber optic information transfer can also occur in both directions simultaneously Figure 2. This method uses two optical fibers contained in one duplex fiber optic cable and combines the transmitter, receiver, and duplex receptacle functions into one transmitter-receiver subassembly (TRS) in each device.

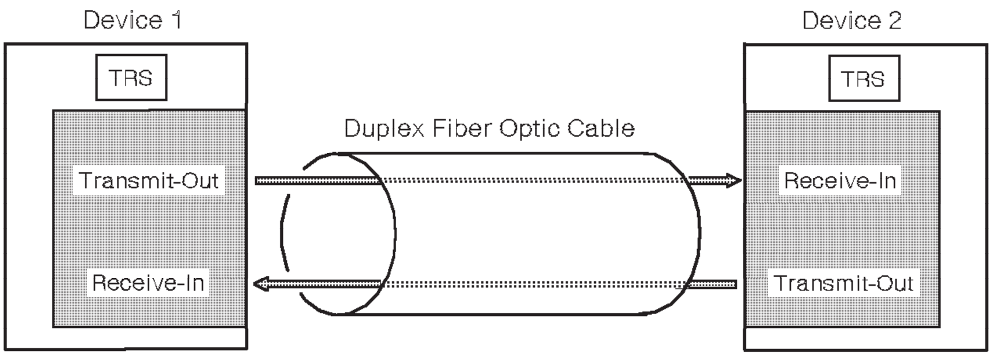

Figure 2. Bidirectional fiber optic information transfer

Optical fiber technology

Transmission of signals over optical fiber uses the phenomenon of total internal reflection to transmit data with rays of light through a strand of glass. This strand is called an optical fiber. Total internal reflection occurs because the *cladding* that surrounds the *core* of the optical fiber has a lower *index of refraction* than the core. This difference in index of refraction causes the light to be contained in the fiber as it travels from source to destination. See Figure 3 on page 3.

In optical fiber, *mode* describes the propagation of light rays in an optical fiber. Optical fiber supports many modes of propagation, depending on the size of the fiber.

When the core has a diameter that is large compared to the wavelength of the light signal, many modes of light are propagated. Such fiber is called *multi-mode* optical *fiber*. The different modes of light reach the end of the fiber at different times, because each mode takes a different path through the core. This causes the *pulse* to spread out; this is referred to as *modal dispersion*.

Optical fiber is usually referred to by the diameter of its core and cladding with its numerical aperture. For example, a multi-mode fiber with a diameter of 62.5 microns (millionths of a meter; hereafter, microns will be abbreviated as µm, which is the scientific notation) and a cladding diameter of 125 µm with a numerical aperture of .275, is designated as 62.5/125 NA .275 fiber (hereafter referred to as *62.5/125 fiber*). Based on the work of standards organizations, 62.5/125µm fiber was initially the recommended fiber cable for most multi-mode fiber applications. More recently, 50/125 NA .2 fiber (hereafter referred to as *50/125µm fiber*) has become the multi-mode fiber of choice. Multi-mode optical fiber is available with core diameters that range from 50 to 200 µm. Although other fiber sizes are supported by IBM, their use should be based on the requirements of the attaching products and is not recommended for new installations.

Most multi-mode optical fiber is *graded-index fiber*, which is manufactured with a gradually changing refractive index, instead of an abrupt change between the core and the cladding. This gradually changing refractive index allows for lower modal dispersion and thus a higher bandwidth. See Figure 3 on page 3 for an example of how the light in multi-mode optical fiber is propagated through a graded-index fiber.

In single-mode fiber, light is propagated as only one mode. This mode travels in both the core and the cladding, with most of the light within a diameter of 9 to 10 µm (9 to 10 µm being the mode field diameter). This fiber is called single-mode optical fiber. Single-mode optical fiber eliminates modal dispersion consideration.

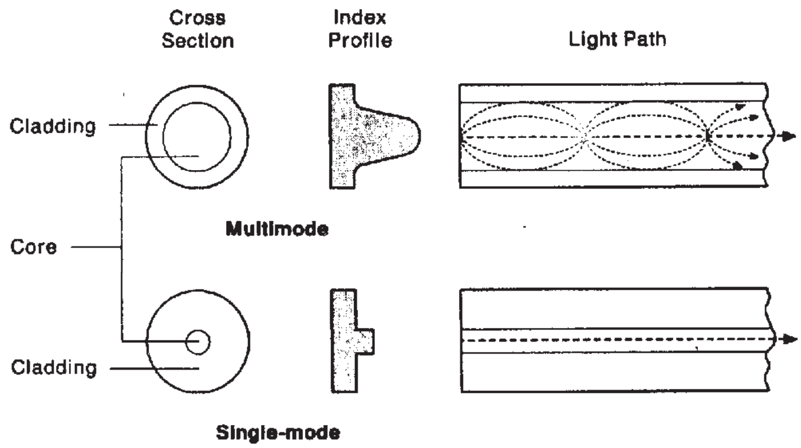

Figure 3. Single-mode and multi-mode optical fiber

Multi-mode fiber is usually used with light-emitting diodes (LEDs), whereas single-mode fiber is usually used with a laser light source. Because of the laser light source and the propagation of a single mode of light, single-mode fiber provides longer transmission distances and faster data rates.

Optical fiber elements and optical cable

The fiber element within an optical cable usually consists of a core and a cladding Figure 4 on page 4. The core provides the light path, the cladding surrounds the core, and the optical properties of the core and cladding junction cause the light to remain within the core.

Although the core and the cladding diameters, expressed in micrometers (μm), are often used to describe an optical cable, they actually indicate the physical size of the fiber element. For example, a fiber element having a core diameter of 62.5 μm and a cladding diameter of 125 μm is called 62.5/125-μm fiber.

In an optical cable, the core and cladding are typically surrounded by other layers (such as a primary and secondary buffer), a strength member, and an outer jacket (Figure 4 on page 4) that provide strength and environmental protection. It is possible to transmit multiple data channels over a single optical fiber by sending each data stream at a different optical wavelength. This is known as Wavelength Diversion Multiplexing (WDM). For more information, see the following red papers that describe several products offered by IBM strategic partners:

Adva http://www.redbooks.ibm.com/redpapers/pdfs/redp3903.pdf

Nortel http://www.redbooks.ibm.com/redpapers/pdfs/redp3904.pdf

Cisco http://www.redbooks.ibm.com/redpapers/pdfs/redp3905.pdf

Lucent http://www.redbooks.ibm.com/redpapers/pdfs/redp3906.pdf

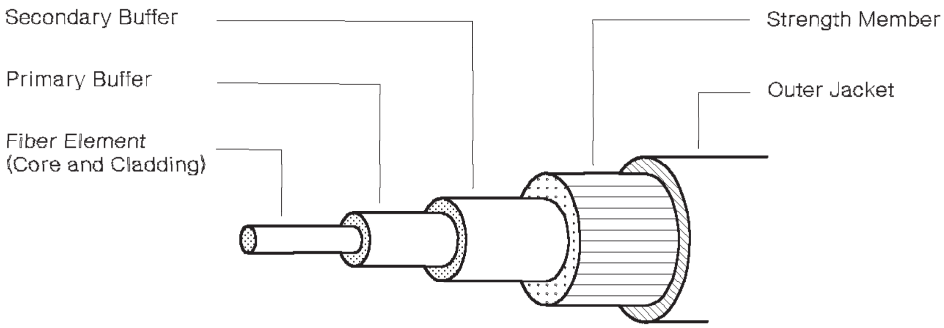

Figure 4. Optical cable elements (typical)

Because information transfer usually occurs in only one direction through an optical fiber, various fiber types have been developed for different applications. The optical properties and specifications of a fiber determine many characteristics. For example, **single-mode** fiber (nominally about 9.0 µm) provides one high-bandwidth information "path". Single-mode fiber is usually used to transfer information over greater distances compared to **multi-mode** fiber (62.5 µm, for example), which provides multiple paths and has a lower bandwidth. The terms single-mode and multi-mode are often used to describe the optical fiber and optical cable types.

Generally, long wavelength (LX or 1300 nm) laser diodes use single-mode fiber to transmit information, while long wavelength light-emitting diodes (LEDs) or short wavelength (SX or 850 nm) lasers use multi-mode fiber. An exception is the multi-mode coupling link, which uses a laser operating on multi-mode fiber or a FICON link operating on multi-mode fiber with an optical mode conditioner. In a data processing environment using optical fiber, product, distance, and right-of-way considerations usually determine if single-mode or multi-mode fiber is used.

Optical cable connectors

Optical cable connectors allow manual coupling and uncoupling of the fibers, but contribute to link attenuation (loss). Although several connector types have been developed to minimize this loss, all can be classified as either physical contact or nonphysical contact.

Physical-contact connectors

Physical-contact connectors, sometimes referred to as butt-coupled connectors, have a polished end-face surface with a slight outward (convex) curvature. When inserted into the receptacle, the fibers are precisely aligned and touch each other, thereby allowing maximum light transfer and minimum return loss. The IBM duplex connectors (Figure 5 on page 6 and Figure 6 on page 6), the ST connector (Figure 7 on page 7), the Fiber Channel Connector (FICON) SC-duplex connector (Figure 8 on page 7), the FC/PC connector (Figure 9 on page 7), the MT–RJ connector (Figure 13 on page 8), and the LC connector (Figure 14 on page 8), are types of physical-contact connectors.

Note: For more information on MT–RJ and LC interfaces, see the Planning section for the zSeries 900 on Resource Link at *http://www.ibm.com/servers/resourcelink*.

IBM duplex connectors, which combine the transmit and receive signals in one housing, provide high reliability and have low loss characteristics. They are keyed to provide correct orientation and use release tabs to prevent accidental removal.

Some IBM duplex connectors and receptacles used for single-mode fiber have additional keying. This prevents the plugging of multi-mode IBM duplex connectors into IBM products having single-mode receptacles.

The SC-duplex connector is another type of connector which may be keyed to prevent accidental plugging of a multi-mode fiber into a single-mode receptacle, and to provide correct orientation to the TRS.

The MT–RJ connector has distinct male ends (with metal guide pins) and female ends (with guide holes). Only male to female connections will transmit optical signals. Since all MT–RJ transceivers have a male interface, only female jumper cables are required for most installations.

For single-mode ESCON links, the SC-duplex connector is be used on both the transceiver receptacle and the fiber optic cable. The single-mode ESCON connector has been discontinued. The SC-duplex connector and receptacle are defined as part of the ANSI Fibre Channel Standard Physical and Signaling Interface (FC-PH) ref. X3T9.3/755D. The connector is shown in Figure 8 on page 7; it is the same connector which has been adopted for other industry standard data links including FIbre Connection (FICON). For single-mode ESCON links, the transceiver receptacle and connector is gray and the optical fiber cable is yellow, conforming to the established color coding for single-mode ESCON channels. The SC-duplex receptacle and connector are keyed to prevent accidental plugging of a multi-mode fiber into a single-mode receptacle. All of the physical layer characteristics for the single-mode ESCON interface must still be maintained by transceivers and cables using this alternative interface.

Nonphysical-contact connectors

Nonphysical-contact connectors do not allow the fiber end-faces to touch. Because an air gap exists, these connectors typically have a higher interface loss compared to physical-contact connectors. The biconic connector used by IBM (Figure 10 on page 7), which is equivalent to AT&T part number 1006A, is an example of a nonphysical-contact connector.

Connector color coding

IBM simplex connectors use color-coding to show the direction that light travels through a link (“Light propagation in an IBM link” on page 29). These connectors are black (or use a black marking) and white (or use a white marking).

IBM duplex cable connectors use color-coding to differentiate between multi-mode and single-mode. Multi-mode cables have black or beige connectors and single-mode cables have grey or blue connectors. They do not require color coding to determine the direction that light travels, or propagates, through the cable because the connectors are physically keyed. This provides proper orientation and allows the fibers to be labeled “A” and “B”, which is shown on the connector. See “Light propagation in an IBM jumper cable” on page 30.

The SC duplex connector is an industry standard optical connector (as defined in *ANSI Fibre Channel Standard Physical and Signaling Interface (FC-PH)*, published by the *American National Standards Institute*. Since it may be purchased from a variety of vendors, there is no consistent scheme of color coding or labeling the ends of a simplex cable with SC duplex connectors. These connectors can be identified by their shape (Figure 8 on page 7) and the direction of light propagation must be verified from the vendor specifications. For IBM supplied cables, the single-mode SC duplex jumper has a gray or blue connector and a yellow cable jacket, while the multi-mode has a black or beige connector with an orange jacket. This is the same color scheme used for ESCON connectors and cables.

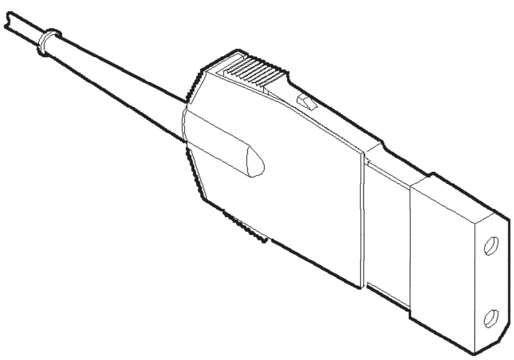

Figure 5. IBM duplex multi-mode connector

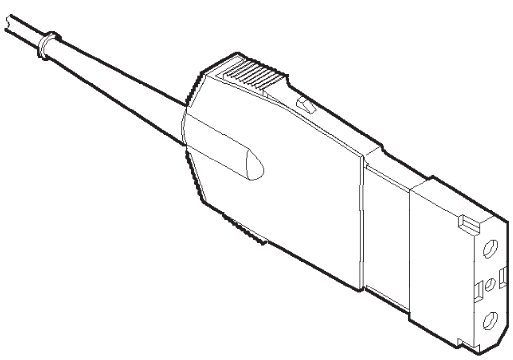

Figure 6. IBM Duplex single-mode connector

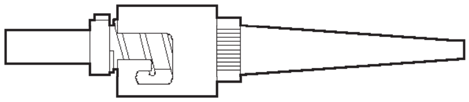

Figure 7. ST Physical-Contact Connector

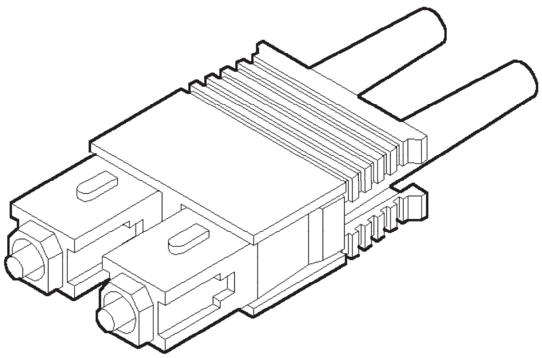

Figure 8. SC-Duplex Connector

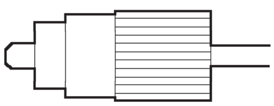

Figure 9. FC/PC Physical-Contact Connector

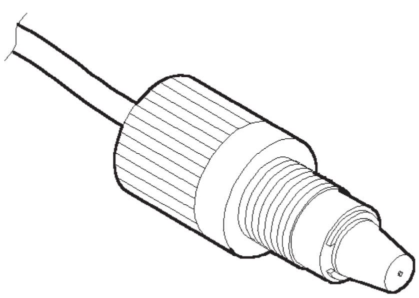

Figure 10. Biconic Nonphysical-Contact Connector

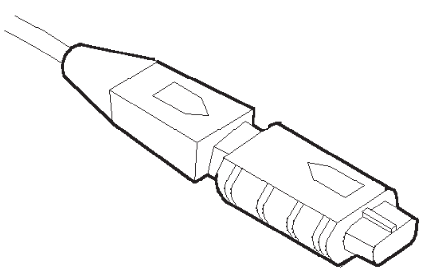

Figure 11. Multifiber Terminated Push-on Connector (MTP). Twelve fiber connector available on FTS-III Direct Attach trunk cables and harnesses. This connector is also used for 12x InfiniBand optical (IFB-O) cable but is referred to as an MPO connector.

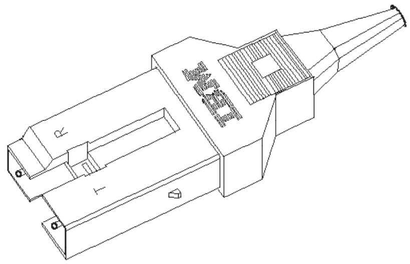

Figure 12. MIC Connector

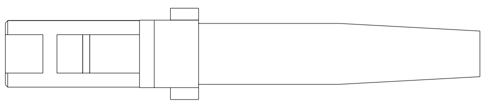

Figure 13. MT–RJ Connector

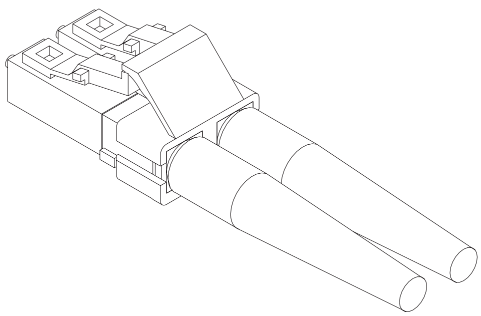

Figure 14. LC Duplex Connector

IBM jumper cables

IBM provides both single-mode (yellow) and multi-mode (orange or grey) jumper cables, which attach either between two devices or between a device and a distribution panel.

Note: Single-mode and multi-mode cables cannot coexist in the same fiber optic channel link. Additionally, we recommend that multi-mode cables of different core sizes (62.5µm and 50µm,) should not coexist in the same link, except in some ESCON channel installations where necessary. See "Mode Conditioning Patch cable (MCP)" on page 17.

The elements in an IBM duplex cable (Figure 15) consist of two tight-buffered optical fibers (core and cladding) surrounded by a strength member, all of which are encased in a common flexible jacket. Duplex cables for coupling facility channels (or ESCON XDF) are similar, see Figure 16, except that they are not encased in a single jacket. Both single-mode and multi-mode jumper cables have a cladding diameter of 125 µm. single-mode cable has a mode field diameter (MFD) of about 9 µm; multi-mode cable has a core diameter of 62.5 µm or 50.0 µm.

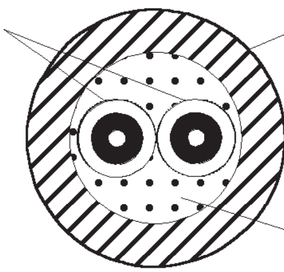

Figure 15. IBM Duplex Jumper Cable Elements

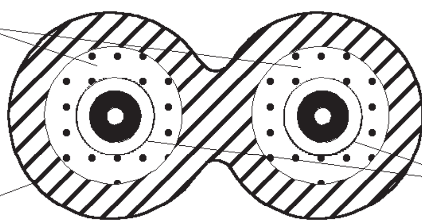

Figure 16. Coupling Facility and ESCON XDF jumper cable elements. (Jumper cables which use FICON SC duplex connectors.)

All IBM jumper cables have a duplex connector on one end, which attaches to an ESCON-capable device, FICON-capable device, or coupling facility channel. Attaching a jumper cable to a distribution panel, however, could require jumper cables with other connector types ("Optical cable connectors" on page 5). IBM offers these jumper cables:

- Single-mode and multi-mode applications:
  - Duplex-to-duplex jumper cables have an IBM duplex connector on both ends
  - Duplex-to-duplex jumper cables have an SC duplex connector on both ends
  - Duplex-to-duplex jumper cables have an LC duplex connector on both ends
  - Duplex-to-duplex jumper cable conversion kits:
    - IBM duplex receptacle on one end and an SC duplex connector on the other end
    - An LC connector on one end and a SC duplex receptacle on the other end
- Multi-mode applications only:
  - Duplex-to-biconic jumper cables have a pair of color-coded biconic connectors on one end and are available to support the 3044 Models C02 and D02

– Duplex-to-ST jumper cables have a pair of color-coded, physical-contact ST connectors on one end.
– Duplex-to-FC jumper cables have a pair of color-coded, physical-contact FC connectors on one end
– Duplex-to-unterminated jumper cables have an unterminated end (no connector) that allows the attachment of any connector type
– Duplex-to-duplex jumper cables with female MT–RJ on both ends
– Duplex-to-duplex jumper cables with male MT–RJ on both ends
– Adapter kits:
  - ESCON receptacle to female MT–RJ connector
  - ESCON connector to female MT–RJ connector

Note: If a single-mode ESCON XDF link using the SC-duplex connector interface must be connected to a single-mode ESCON XDF connector interface, use the ESCON XDF Adapter Kit (46H9223). The kit consists of a 2-meter single-mode jumper cable with SC-duplex-to-ST connectors (46H9222) assembled to the single-mode ESCON-to-ST adapter. Instructions are provided with each kit.

Jumper cable availability

Table 1 on page 11 shows the availability of IBM jumper cables according to, cable type (single-mode [SM], or multi-mode [MM]), and connector type. Table 2 on page 11 shows the availability of IBM jumper cables according to cable length.

Standard length IBM jumper cables are shipped with most ESCON capable devices. Additional jumper cables can also be purchased from IBM.

Standard length SC-duplex connector jumper cables are available from IBM.

Table 1. Available cable and connector types

ESCON		FICON, Coupling Links, and OSA	
Multi-mode	**Single-mode**	**Multi-mode 50 and 62.5 µm**	**Single-mode**
ESCON Duplex-to-duplex	SC Duplex-to-duplex	SC Duplex-to-duplex	SC Duplex-to-duplex
ESCON Duplex-to-ST		LC Duplex-to-LC Duplex	LC Duplex-to-LC duplex
MT–RJ to MT–RJ (female)		LC Duplex-to-SC duplex	LC Duplex-to-SC duplex
MT–RJ to MT–RJ (male)		LC Duplex-to-ST	LC Duplex-to-ST
Duplex MT–RJ (female) to duplex ESCON		IFB-O (12x MPO Duplex-to-12x MPODuplex) 50um (2000MHz*km)	
Duplex MT–RJ (female) to ST			

Table 2. Available lengths

All FICON, Coupling Links, OSA, and multi-mode ESCON jumpers	Single-mode ESCON jumpers	PSIB
7 m (20 ft)	4 m (12 ft)	
13 m (40 ft)	13 m (40 ft)	
22 m (70 ft)	22 m (70 ft)	
31 m (100 ft)	31 m (100 ft)	
46 m (150 ft)	61 m (200 ft)	
61 m (200 ft)	92 m (300 ft)	150m (492 ft)
custom	122 m (400 ft)	

Notes:
1. Before ordering, consider length requirements for future equipment relocation.
2. The maximum total jumper cable length cannot exceed 244 meters (800 ft) when using either 50/125 µm trunk fiber or when a 62.5/125 µm link exceeds 2 kilometers (1.24 miles).
3. English distances are approximate.
4. Custom lengths are available in 0.5 meter increments from 4 meters (12 ft) to 500 meters (1640 ft).

Jumper cable labels

Each IBM jumper cable has a jacket marking that contains the part number, EC number, length in meters and feet, and manufacturing/warranty data. Additional jacket markings may be added by the suppliers.

```
PN VVVVVVV/FFFFFFF EC1234567 31 m 100.0 ft 11210005 BAR CODE DATE CODE SNUM
```

Where V = variable length part number, F = fixed length part number. Manufacturing and warranty data includes: BAR CODE INFO

1 Vendor code

1 Last digit of year manufactured

210 Day-of-year manufactured (Julian date)

005 Sequence number

The above is bar code information for reference.

Trunk cable

Fiber optic trunk cable is generally used for longer links, such as between floors or buildings. It should also be used in single-floor ESCON or coupling link environments when many jumper cables and connections are required. If trunk cable is used, distribution panels must provide the hardware used to attach IBM jumper cables.

A trunk cable typically contains from 12 to 144 fibers and has a strength member and an outer jacket. Each ESCON link requires two trunk fibers. The physical trunk cable configuration varies and depends on user requirements, environmental conditions, and the type of installation required (for example, above ground or underground).

Splices

Fiber optic trunk cables can be joined by two splicing methods. Either method, when performed by a trained technician using high-quality materials, can produce a splice having a very low optical power loss.

- Fusion splices are joined by an electric arc.
- Mechanical splices are joined within a holder and sometimes use epoxy to bond the fibers.

Distribution panels

Many types of distribution panels exist. They are available in various sizes and styles and are called different names, depending primarily on their application or use. For example, they can be called central distribution panels, main distribution panels, zone panels, patch panels, building interface panels, enclosures, or cabinets. In a fiber optic channel link, they provide the hardware attachment capability between trunk cables and IBM jumper cables. They can also be used for floor-to-floor cable connections within a building or for connections between buildings. For more information about distribution panel requirements, contact your IBM marketing representative.

Couplers and adapters

Distribution panels must provide couplers or adapters to allow attachment of IBM jumper cables. Couplers join **the same** connector types, while adapters join **different** connector types. The following couplers and adapters, available from IBM, are shown in Figure 17 on page 14 through Figure 27 on page 16.

- IBM duplex coupler
- ST coupler
- FC/PC coupler
- MT–RJ duplex coupler (joins male to female MT–RJ)
- LC duplex coupler
- IBM duplex-to-ST adapter
- IBM duplex-to-FC/PC adapter
- FICON duplex-to-duplex coupler
- FICON duplex-to-ST adapter
- FICON duplex-to-FC adapter
- MTP-to-MTP coupler

Note: IBM recommends using IBM duplex-to-duplex jumper cables between ESCON-capable devices and distribution panels, FICON SC-duplex-to-duplex jumper cables between coupling link devices or FICON devices and distribution panels, and IBM duplex-to-ST or IBM duplex-to-FC/PC adapters in distribution panels.

Other adapters for patch panels may be available as RPQs.

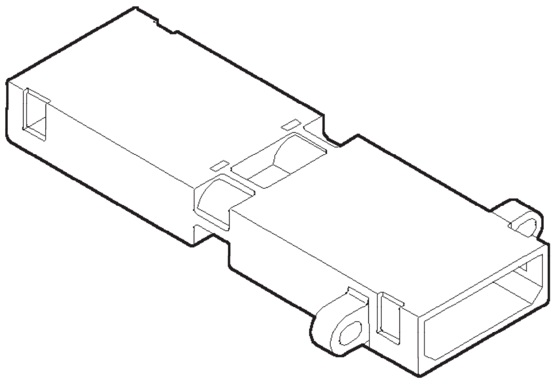

Figure 17. IBM Duplex Coupler

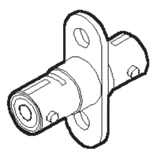

Figure 18. ST Coupler

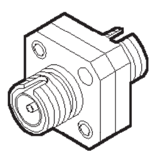

Figure 19. FC/PC Coupler

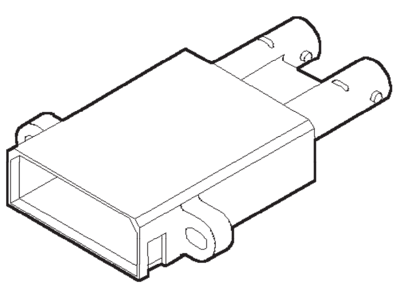

Figure 20. IBM Duplex-to-ST Adapter

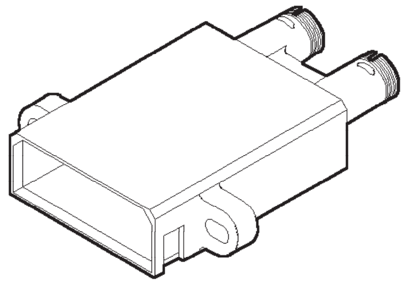

Figure 21. IBM Duplex-to-FC/PC Adapter

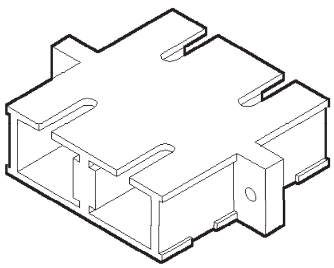

Figure 22. FICON Duplex-to-Duplex Coupler

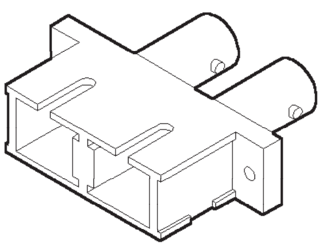

Figure 23. FICON SC Duplex-to-ST Adapter

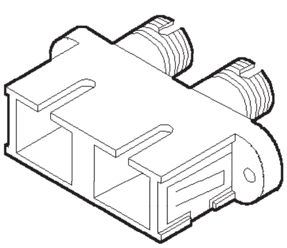

Figure 24. FICON SC Duplex-to-FC Adapter

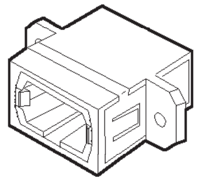

Figure 25. MTP-to-MTP Coupler

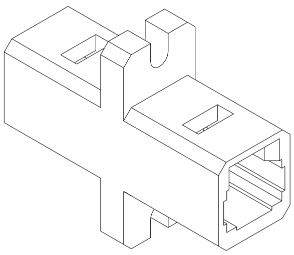

Figure 26. MT–RJ Coupler

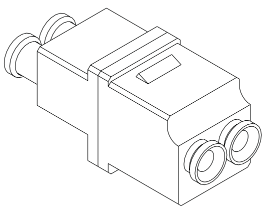

Figure 27. LC Coupler

Prior to 1995, the single-mode ESCON interface used an older style duplex connector (Figure 6 on page 6). The connector and receptacle are keyed to prevent multi-mode duplex connectors from plugging into single-mode duplex receptacles. Single-mode ESCON interfaces now use the SC-Duplex connector (Figure 8 on page 7). Both types of single-mode ESCON links will interoperate.

An adapter kit consisting of a fiber optic jumper cable and adapter is available from IBM (part number 46H9223) to convert from the new single-mode ESCON duplex receptacle to the old single-mode ESCON duplex receptacle (Figure 28 on page 17).

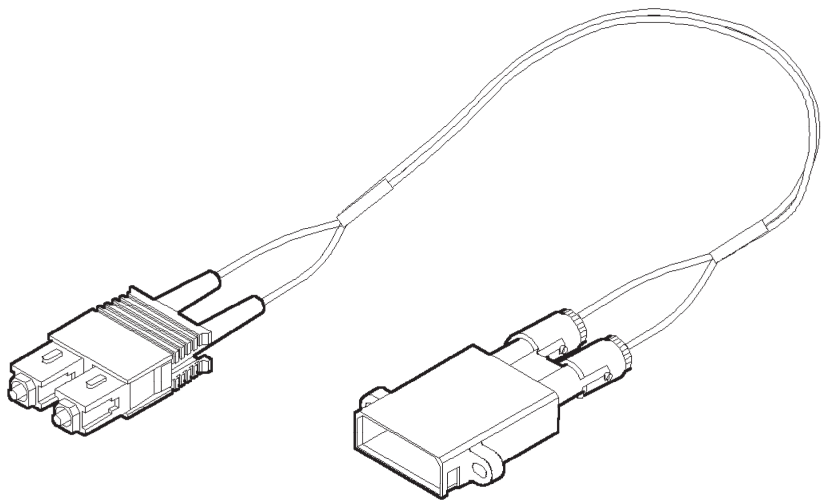

Figure 28. Single-mode ESCON Duplex to old single-mode ESCON Duplex Adapter Kit

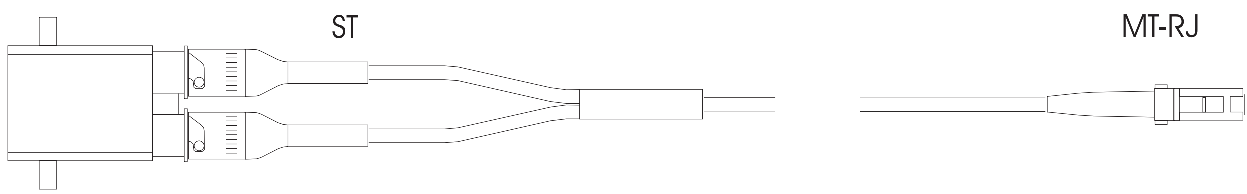

Figure 29. MT–RJ-to-ESCON Duplex Receptacle Conversion Kit

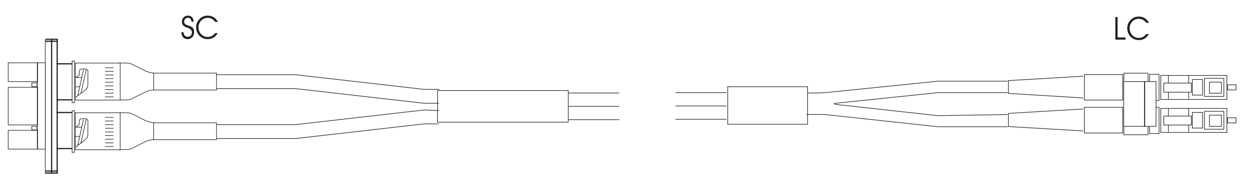

Figure 30. LC-to-SC Duplex Receptacle Conversion Kit

Mode Conditioning Patch cable (MCP)

In some fiber optic applications, it is possible to use a long wavelength (1300 nm) single-mode laser adapter with multi-mode fiber by placing a special device known as an optical mode conditioner at both ends of the link. The optical mode conditioner resembles a standard 2 meter jumper cable, and is sometimes known as a mode conditioning patch cable (MCP). As shown in Figure 31 on page 18, the MCP is unique in that it contains both single-mode (yellow) and multi-mode (orange) fibers in a single jumper cable assembly. Without the MCP, it is not possible to use a single-mode laser transmitter over multi-mode fiber because the laser source does not launch an equal amount of optical power into all modes of the fiber; this leads to excessive dispersion of the data pulses, and the link will not function. The MCP is designed to "condition" the laser launch so that the optical power fills all modes of the fiber equally.

Because of the bandwidth limitations of multi-mode fiber, future multi-gigabit fiber optic interconnects will likely be based on single-mode fiber cables. However, many current applications use multi-mode fiber extensively. There is a need to re-use the large installed base of multi-mode fiber as long as possible; the ability to continue using installed fiber with new adapter cards also facilitates migration to higher data rate links. The need to migrate from multi-mode to single-mode fiber affects all of the major datacom applications:

- Using MCPs, it is possible to run LX FICON channels over multi-mode fiber at reduced distances [550 meters (.31 miles)]. I/O applications currently using Multi-mode fiber for ESCON will need to migrate the cable plant to single-mode fiber in order to take full advantage of the extended distance FICON links. Although FICON is available in both multi-mode (SX) and single-mode (LX) versions, future FICON enhancements which extend this protocol to multi-gigabit data rates will also require single-mode fiber for distances beyond a few hundred meters.
- Coupling links for Parallel Sysplex® were originally offered as either 50 Mbyte/s data rates over 50 micron multi-mode fiber (using short wavelength 850 nm lasers) or 100 Mbyte/s data rates over single-mode fiber (using long wavelength 1300 nm lasers). In May 1998 support for multi-mode fiber was withdrawn. There is a need to support 100 MByte/s adapter cards over the installed 50 micron multi-mode fiber to facilitate migration from the 50 Mbyte/s links.

This support will continue on coupling links using the LC interface; an MCP which adapts single-mode LC to multi-mode SC duplex is available for compatibility mode (1 Gbit/s) links.

The MCP is installed on both ends of a link, and occupies the same space as a standard 2 meter jumper cable. Adapter kits containing the MCPs are available with either SC duplex connectors (to support coupling links) or ESCON connectors (to support ESCON-to-FICON migration). Different MCP adapter kits are required for 50 or 62.5 micron fiber. Using the MCPs reduces the maximum link distance to 550 meters for gigabit links (Chapter 5, “Specifications,” on page 59). The maximum supported distances and fiber types for OSA follow industry standards (Table 11 on page 82). Optical mode conditioners are supported for FICON, coupling links, and OSA (see Table 3 on page 19). ESCON links using 62.5 micron jumpers and trunks can support FICON by plugging existing ESCON cables into the appropriate MCP. Note that some ESCON installations use 62.5 µm jumper cables with a 50 µm trunk, which is a supported configuration provided that this is the only transition from 50 to 62.5 micron fiber in the link and the maximum distance does not exceed 2 km. However, transitions between 50 µm and 62.5 µm fiber are not supported in applications which use MCPs. If you are planning to migrate an application with 50 micron trunks from ESCON to FICON using MCPs, then the jumper cables must be replaced with 50 micron jumper cables as well. Since IBM does not support 50 micron ESCON jumpers, the use of 50 micron SC Duplex jumper cables is required (in other words, the 62.5 micron ESCON jumpers must be replaced with 50 micron SC Duplex jumpers). The appropriate MCPs and jumper cables are available from IBM.

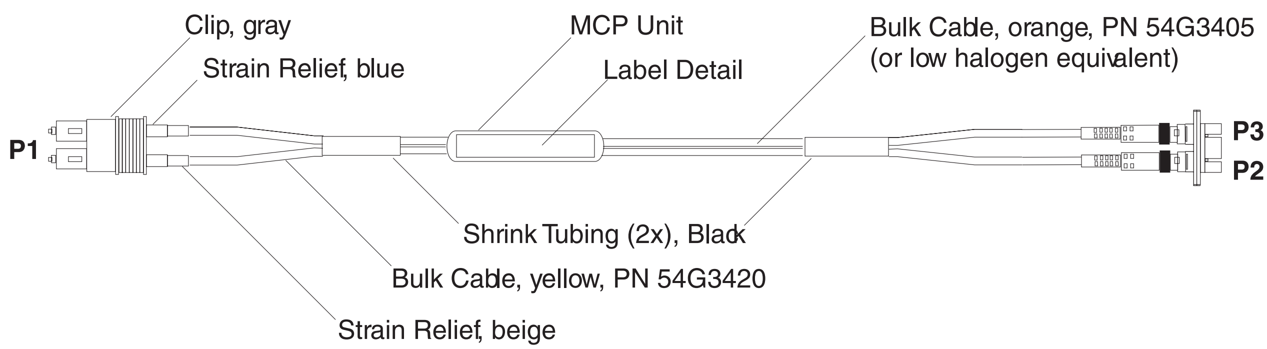

Figure 31. Mode Conditioner Patch cable (MPC) connections P2 and P3 may be terminated with either an SC duplex or an ESCON duplex coupler. Connector P1 is available on either an SC duplex or LC duplex connector.

Table 3. Applications That Support MCPs

Data Rate	Fiber type	Connectors for MCP	Maximum distance/link loss with MCP
FICON 1.06 Gbit/s	62.5 µm	SC duplex	550 meters/5 dB
FICON 1.06 Gbit/s	50.0 µm	SC duplex	550 meters/5 dB
FICON Express	62.5 µm	LC Duplex	550 meters/5 dB
FICON Express	50.0 µm	LC Duplex	550 meters/5 dB
CF links 1.06 Gbit/s	50.0 µm	SC duplex (single-mode connections available in either SC duplex or LC duplex)	550 meters/5 dB
Gigabit Ethernet LX 1.25 Gbit/s	62.5 µm	SC duplex	550 meters/5 dB
Gigabit Ethernet LX 1.25 Gbit/s	50.0 µm	SC duplex	550 meters/5 dB

Fiber optic channel link configuration

Note: IBM offers assistance in planning, design, and installation of fiber optic channel links through their Connectivity Services offering of IBM Global Services Advanced Connectivity System (IACS). For more details, contact your IBM marketing representative. Also, IBM's Fiber Transport Services (FTS) provides planning assistance, commodities, and installation for a multi-mode and single-mode fiber trunk system. See "IBM's connectivity services offering" on page 33.

Fiber optic links, which use one optical fiber for sending and another for receiving, use IBM duplex connectors, duplex jumper cables, and require two trunk fibers. A link could consist of only one jumper cable that connects two devices, or it could have many cables, distribution panels, adapters, couplers, and connectors.

Parallel Sysplex using InfiniBand (PSIFB) 12x links use InfiniBand optical (IFB-O) 12x cables which package 12 fibers for transmit and 12 fibers for receive. The IFB-O 12x cables utilize the Multi-fiber Push-On (MPO) connector.

Regardless of the number of cables and components, a fiber optic channel link attaches two devices and **must consist entirely of either single-mode or multi-mode cables and components**.

Figure 32 shows an example of a fiber optic channel link consisting of:
- Two IBM duplex-to-duplex jumper cables
- Two distribution panels, each containing an IBM duplex-to-ST adapter
- Four ST connectors
- Two trunk cable fibers
- Four trunk cable splices

For detailed diagrams of fiber optic channel link configurations, see Figure 44 on page 53 (multi-mode) and Figure 45 on page 57 (single-mode).

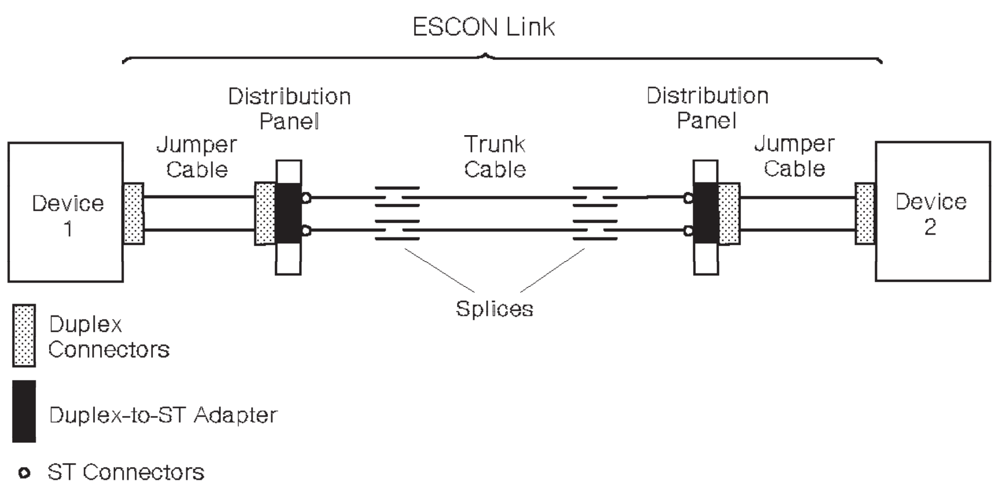

Figure 32. Example of components in a fiber Optic channel link

Chapter 2. Link, trunk, and IBM jumper cable planning

This chapter discusses fiber optic channel link planning tasks and also contains considerations and recommendations related to planning for fiber optic channel links. Refer to Chapter 5, “Specifications,” on page 59 for link specifications.

The physical location of the data processing equipment determines the link environment. This equipment can be located on a single floor within one building, on multiple floors or in multiple rooms within one building, between two or more buildings within a campus, or between two or more campuses. See “Link environments” on page 40 for a more detailed description.

IBM jumper cables are 9/125 µm, 50/125 µm, or 62.5/125 µm. Trunk cables used in a link can be 9/125 µm, 50/125 µm, or 62.5/125 µm. However, **a fiber optic channel link cannot use both 9-µm and 62.5-µm cable or both 9-µm and 50.0-µm cable.**

Certain IBM partners offer DWDM units to extend Coupling link distance beyond the 10 Km limit (6.2 miles). Please see your local IBM representative for more information.

The maximum ESCON, OSA, FICON, or coupling link distance, which includes both jumper cables and trunk cables, is determined by product features and cable size.

- With 9-µm cable and the ESCON Extended Distance feature, the maximum link distance is 20 kilometers (12.4 miles)
- With 62.5-µm cable on an ESCON link, the maximum link distance is 3 kilometers (1.86 miles)
- With 50-µm cable on an ESCON link, the maximum link distance is 2 kilometers (1.24 miles)
- With 9-µm cable on a single_mode coupling link, the maximum link distance is 10km (6.2 miles)
- With 50-µm (2000MHz*km) IFB-O cable on a 12x InfiniBand coupling link, the maximum link distance is 150m (0.09 miles)
- With 9-µm cable on an LX FICON link, the maximum link distance is 4km or 10km (see Table 11 on page 82)
- With 50-µm cable on a SX FICON link, the maximum link distance is 70m to 860m (Table 11 on page 82)
- With 62.5-µm cable on a SX FICON link, the maximum link distance is 55m to 250m (Table 11 on page 82)
- With 62.5-µm cable on a SX OSA-Express2 GbE link, the maximum link distance is 275 meters (0.17 miles)
- With 50-µm cable on a SX OSA-Express2 GbE link, the maximum link distance is 550 meters (0.35 miles)
- With 9-µm cable on a LX OSA-Express2 GbE link, the maximum link distance is 5 kilometers (3.17 miles)
- With 9-µm cable on a LX OSA-Express2 10GbE link, the maximum link distance is 10 kilometers (6.33 miles)

Certain IBM Partners offer DWDM units to extend Coupling link distances beyond the 10 Km limit. Contact the local IBM representative for more information.

Using an optical mode conditioner, the coupling links single_mode adapters may also operate over multi-mode fiber (50 µm) with a link range of up to 550 meters. Prior to May 1998, coupling facility channels were available for 50 µm multi-mode fiber at a range of 1 km; these have been discontinued.

Notes:

1. The distance between ESCON channels and ESCON-capable control units can be greater than 3 kilometers or 20 kilometers when using multiple links and either several Remote Channel Extenders (9036) or two ESCON Directors as signal repeaters. See the publication *Introducing Enterprise Systems Connection* for more information.
2. IBM will accept Request for Price Quotations (RPQs) for link distances greater than those specified above. Contact your marketing representative.
3. The distance between FICON capable devices can be greater than 10 km when using directors, channel extenders, or wavelength multiplexers. For more information, see *Introduction to IBM S/390® FICON*, SG24-5176.
4. The Fiber Channel Standard specifies a 4 hop limit for a network including directors.

IBM offers assistance in planning, designing, and installation of ESCON links through its Connectivity Services offering of IBM Global Services Fiber Transport Services. For more details, contact your IBM marketing representative. Also, IBM's Fiber Transport Services (FTS) provides planning assistance, commodities, and installation for a multi-mode or single-mode fiber trunk system. See "IBM's connectivity services offering" on page 33.

Planning considerations

Fiber optic link planning should be approached similar to planning for any other cabling system. Depending on the location of data processing equipment, links can consist of various combinations of optical cables and components. Fiber optic channel links will become an integral part of an IBM data processing system environment. They should, therefore, be considered a long-term investment in future communications requirements.

Links do not necessarily require distribution panels and trunk cables. For example, a link environment in one room could consist of only IBM duplex-to-duplex jumper cables. This method would not incur much additional cost because most devices are shipped with jumper cables. Because planning for links should include future growth, consider the following factors carefully.

Specifications

Links must operate within certain specifications to provide reliable transmission characteristics. See Chapter 3, "Calculating the loss in a multi-mode link," on page 49 for a multi-mode link loss calculation example, Chapter 4, "Calculating the loss in a single-mode link," on page 55 for a single-mode link loss calculation example, and Chapter 5, "Specifications," on page 59 for link and cable specifications.

Flexibility

Links should support installation and relocation of existing equipment and processes, while providing connectivity for future applications.

Growth

Links should support not only installation and relocation but system expansion as well. An ESCON, FICON, or coupling link environment can extend well beyond the 122 meter (400 ft.) distance restriction of a data processing environment containing bus-and-tag cables. Migrating to an ESCON, FICON, or coupling link environment not only enhances growth potential, but growth can occur with minimum system disruption.

Cable installation

Fiber optic cable is much smaller and lighter than bus-and-tag cable. Only one duplex fiber optic cable is required for information transfer. This allows a reduction in under-floor cable congestion, thereby simplifying installation, migration, and greatly reducing cable weight.

Cost

Although ESCON, FICON, PSIFB, or coupling links require an initial investment, they can provide long-term savings when considering the cost of future expansion and relocation of a data processing environment.

Right-of-ways

A right-of-way is a legal right of passage over another person's property. Right-of-way owners are usually government agencies or common carrier companies responsible for regulation of telecommunication facilities and could include public utilities, railroads, and state, city, or local governments. Because ESCON, FICON, PSIFB, and coupling links could require the use of one or more right-of ways, users must consider right-of-way access. Users may want to consider the ESCON Remote Channel Extender (9036) or one of several qualified DWDM solutions from our IBM business partners for help in solving their right-of-way problems.

Homologation exemption

The Long Reach 1x InfiniBand feature (HCA2-O LR, FC 0168) uses an LC Duplex connector and jumper cable qualified by IBM. Only IBM qualified cables plugging directly into the optics modules on the Long

Reach 1x InfiniBand feature are supported. These cables are for use within the building only and are not intended to go outside the building. All attachments to an outside cable plant (including public "dark fiber") are supported only through a patch panel or WDM unit..

FICON Express8 fiber optic cable requirements

The FICON Express8 10KM LX and SX features utilize the latest high bandwidth Fibre Channel technology and autonegotiate to 8 Gbps, 4 Gbps, or 2 Gbps based on the link data rate capability of the attached transceiver. Negotiation to 1 Gbps is not supported.

The FICON Express8 features utilize the existing single-mode and multi-mode cable plants. However, the 8 Gbps channel is more sensitive to the condition of the cable plant. The cable plant must satisfy the industry standard specification to minimize connector reflections and maintain link loss budget specification...

It is highly recommended that the fiber optic link be thoroughly analyzed to ensure the cable plant specifications (total cable plant optical loss as well as connectors/splices return loss) are being met for that link length. For example, the Fibre Channel standard requires all connectors and splices to have a return loss greater than 26 dB as measured by the methods of IEC 61300-2-6.

The most common source of cable plant optical link problems is associated with the various connections and splices in the optical link. Dust, dirt, oil or defective connections may cause a problem with high speed channels, such as 8 Gbps, whereas, lower link data rates, such as 1, 2, or 4 Gbps may be unaffected.

If you are experiencing excessive bit errors, it is recommended that you first clean and reassemble the connections, using the IBM Fiber Optic Cleaning Procedure (SY27-2604). The document includes the procedure and materials required. The cleaning is best performed by skilled personnel. The cleaning procedure may need to be performed more than once to ensure all dust, dirt, or oil is removed. Fiber Optic link testing information is contained in the System z Maintenance Information for Fiber Optic Links (ESCON, FICON, Coupling Links, and Open System Adapters), SY27-2597.

Link planning tasks

Consider the following link planning tasks only after determining data processing equipment needs and attachment requirements.

Physical layout

When planning the physical layout of data processing equipment, determine the:

- Location of the equipment
- Location of the users
- Number and location of the physical connections
- Availability and type of right-of-ways

Determine if the layout can be achieved by using only jumper cables or if it requires trunk cable and distribution panels. See “Link environments” on page 40 for a more detailed description.

Cabling requirements

After determining the logical link configuration, plan the cabling requirements:

1. Use a floor plan to assess the possible link paths; then:
   a. Determine the length and type of each link (for example, jumper only or jumper and trunk, and multi-mode or single-mode).
   b. Identify and locate each connector, splice, and distribution panel.
2. Make sure that the:

a. Link specifications agree with the fiber cable types. See Chapter 5, “Specifications,” on page 59.
b. Calculated link loss is within specifications. See Chapter 3, “Calculating the loss in a multi-mode link,” on page 49 or Chapter 4, “Calculating the loss in a single-mode link,” on page 55.
c. Links conform to national, state, and local building codes.
3. Determine a labeling scheme for ease of installation and future cable management considerations.

Installation planning

Before installing a link, consider the following:
- Cable routing diagrams
  - Location and length of each link
  - Type, location, and identification of connectors, adapters, and couplers
  - Locations of splices and distribution panels
- Manufacturer data sheets
  - Cables
  - Bend radius control
  - Connectors
  - Strain relief
  - Splices
  - Distribution panels
  - Attached devices
- Warranty statement (for new installations)
- Link verification. Contact IBM for more information.

The link must be compatible with the devices that attach to it. See Chapter 5, “Specifications,” on page 59 for the cable specifications required to support ESCON-capable, FICON-capable, or coupling facility channel-capable devices.

Other devices and applications can also attach to a trunk cable. Refer to the appropriate planning publications for specific device and cable requirements.

Trunk cable planning recommendations

Trunk cable

Optical fiber trunk cable provides a connection between distribution panels and is used between floors and between buildings. It may also be used on the same floor where the number and complexity of connections require the use of multiple jumper cables. Such cabling is frequently referred to as *backbone cabling*.

Optical fiber trunk cables typically contain from 12 to 144 fibers (6 to 72 pairs) with a strengthening material and an outer jacket. The jacket material may be composed of metal sheathing, fabric, or any one of several man-made materials, depending on the degree of environmental protection required. The physical configuration of the trunk cables will vary depending on user requirements, environmental conditions, and the type of installation required (for example, aerial or underground).

IBM trunk cable recommendations

The 62.5/125µm multi-mode optical fiber was initially recommended by IBM and the American National Standards Institute (ANSI) as the fiber of choice for long wavelength applications. Single-mode fiber is now recommended for all new installations. For short wavelength applications at limited distances, 50/125µm multi-mode optical fiber is preferred.

Note: Single mode and multi-mode cables cannot coexist in the same fiber optic channel link. Additionally, we recommend that multi-mode cables of different core sizes (62.5µm and 50µm) should not coexist in the same link, except in some ESCON channel installations where necessary. See “Mode Conditioning Patch cable (MCP)” on page 17.

For short wavelength applications at limited distances, 50.0/125 multi-mode optical fiber may be used. See Chapter 5, “Specifications,” on page 59. Maximum distances vary based on application and fiber specifications. Obtain all attaching product specifications before selecting fiber for a trunk installation. Various IBM products can use other fiber sizes to accommodate customer requirements worldwide. For example, 50/125 multi-mode fiber is used extensively in Japan and some European countries. However, use of these alternative fibers may not optimize distance capabilities.

The 9- to 10- µm single-mode optical fiber supports higher data rates and longer distances; therefore IBM considers it the direction for future products. See Chapter 5, “Specifications,” on page 59.

If you plan to install a multi-mode optical fiber trunk, IBM recommends that you also consider installing single-mode optical fiber at the same time to support future high-bandwidth applications. See Appendix D, “General fiber optic direction,” on page 75.

Horizontal cable

Some applications may require optical fiber cable between the distribution panel and the work area. IBM recommends that such cabling be installed in addition to copper cable for data transmission and that the cable installed should follow the recommendations of the EIA/TIA-568 *Commercial Building Telecommunications Wiring Standard*. Horizontal cabling with optical fiber generally requires no more than four strands of fiber (often only two) and may effectively be placed as part of a hybrid or composite cable that may consist of other transmission media.

IBM recommends that a duplex optical fiber connector be used in the work area and at the distribution panel to assist in maintaining polarity.

Connectors

Trunk fibers should be attached to high-quality, low-loss, physical-contact connectors, which are provided by several manufacturers. The most common optical connectors used in the data communications industry include the ST and FC/PC physical-contact connectors. Both are available for single-mode and multi-mode cables. IBM recommends using either ST or FC/PC physical-contact connectors for attaching trunk fibers to IBM duplex adapters installed in distribution panels. For equipment which is compatible with the Fiber Channel Connection (FICON) interface, the coupling link may provide connectivity with the industry-standard FICON SC-duplex connector, which is a physical contact connector available for both multi-mode and single-mode cable applications.

Also available are Multifiber Terminated Push-on (MTP) connectors that are used for connecting FTS-III Direct Attach trunk cables to FTS-III Direct Attach harnesses. (See “IBM's connectivity services offering” on page 33.)

Planning for future fiber requirements

Each link requires two trunk fibers. The cost of installing the trunk cable and cable conveyances usually far exceeds the cost of the cable. This is especially true when a trunk cable must enter or exit a building either above ground or underground. When planning the number of trunk fibers needed, therefore, consider allocating additional fibers for facility expansion and future data processing requirements. Each link and application should be considered individually to evaluate this recommendation.

Alternate trunks

Optical fiber allows much greater distances between devices than copper bus-and-tag cables. For this reason, link availability can be affected by more external factors, such as construction activities, extremes in temperature, and natural disasters. All trunk cable routing should therefore be reviewed for possibilities of interruption. If these interruptions can cause a critical situation, consider installing physically separate trunks. If one trunk becomes damaged, the other trunk can then be used to minimize interruption time.

Security

Although optical fiber is difficult to tap without being detected, it is possible. The level of data security needed should therefore determine the precautions taken to minimize this possibility.

Distribution panel planning recommendations

Trunk cables and jumper cables attach to a distribution panel through various connection methods. IBM offers 1) different types of distribution panels, 2) multi-mode jumper cables that have different connector types at the distribution panel end, and 3) adapters and couplers for the panel connections. See "Distribution panels" on page 13 and "Couplers and adapters" on page 13. Contact your IBM marketing representative for more information.

The following paragraphs describe recommendations for locating distribution panels and list some features that a panel should contain.

Panel locations

Distribution panels should be located to provide:

- An entry, exit, and connection point for trunk and jumper cables
- A concentration point for jumper cables to allow manual I/O reconfiguration

  Note: This requires additional jumper cables.
- An access point to service a zone or area of processors and devices

Because of fiber optic channel link distance capabilities, panels can also be located away from the processors and control units, thereby saving floor space.

Panel features

Distribution panels should contain an adapter and coupler panel, a splice tray, and a storage area for jumper cable slack. Its design should also provide strain relief and radius control for jumper cables.

- **Adapter and coupler panels** provide the hardware to join identical (coupler) or different (adapter) cable connectors. They can be used separately or in combination within the panel.
- **Splice trays** should have the same cable capacity as adapter and coupler panels and should be equipped with hardware to provide strain relief for all cables entering and exiting the tray.
- **Jumper cable slack storage** provides adequate organizing hardware and storage space for excess jumper cable. The hardware should allow identification and removal of an individual jumper cable, without having to disconnect or remove other jumper cables within the panel.
- **Jumper cable strain relief and radius control** provides hardware that prevents damage to the jumper cables caused by excessive bending or pulling of the cables.

Determining the direction of light propagation

In IBM applications, light travels (propagates) in only one direction within each fiber. The direction of light propagation must be considered when installing and connecting jumper and trunk cables. The following explains how to determine this direction for links that use trunk and IBM jumper cables.

The cables and connectors for the coupling facility channels are industry standard parts, and may not be supplied by IBM. Consult the manufacturer's specifications to determine the characteristics of this cable.

Light propagation in an IBM link

Figure 33 shows the physical fiber connections for three links. Notice that an odd number of physical "crossovers" of each fiber must exist for correct light propagation to occur. IBM duplex-to-duplex jumper cables are keyed, which maintains the crossover requirement within the cable. When a link uses both trunk and jumper cables, the trunk connections must ensure that an odd number of crossovers exist.

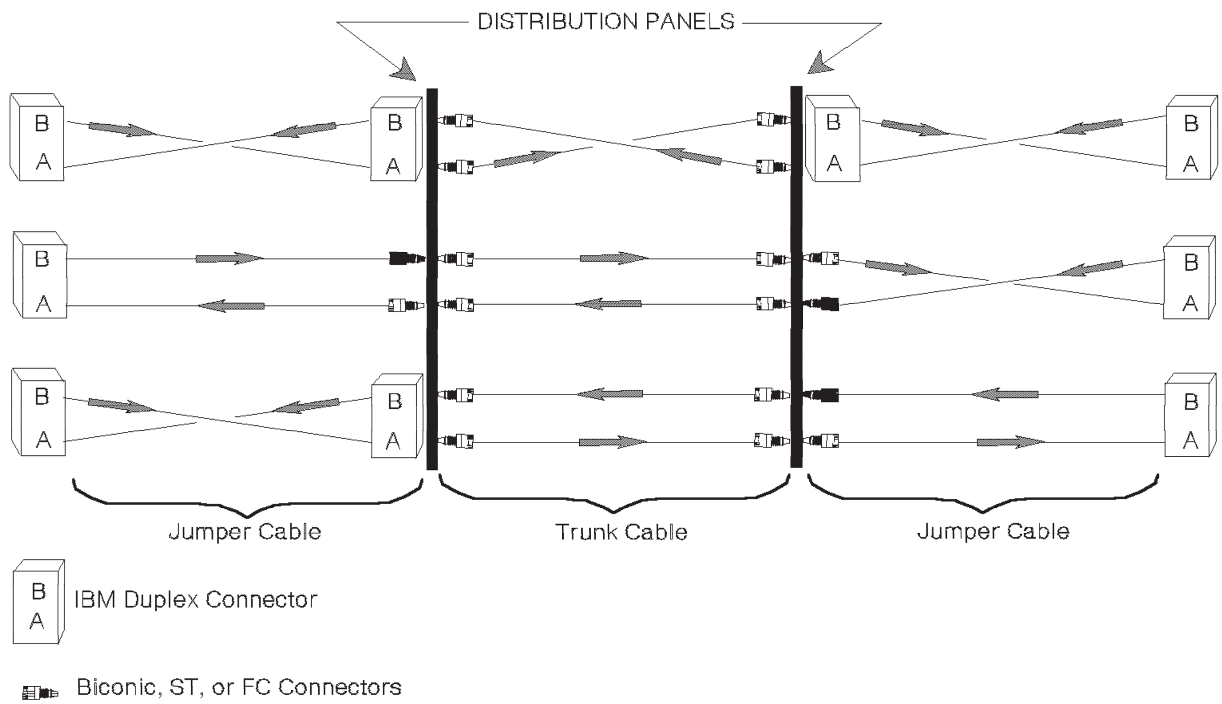

Figure 33. Determining direction of light propagation in a link

Light propagation in an IBM jumper cable

The transmitter (output) of each ESCON-capable, FICON capable, or coupling facility channel-capable device propagates light to the receiver (input) of the next device. IBM jumper cables provide a method to determine this direction:

- IBM duplex connectors have the letters **A** and **B** embossed on the plastic housing
- The connectors used on IBM's duplex-to-biconic, duplex-to-ST, and duplex-to-FC/PC cables are color-coded either by a white or black marking or by the connector color.
- "12x InfiniBand jumper cables contain two MPO connectors on each side, with one labeled TX for transmitter, the other RX for receiver. The ports on the Host Channel Adapter (HCA) cards also are labeled TX and RX. To properly attach the cables, connect the MPO connector labeled TX to the HCA port labeled TX, and connect the MPO connector labeled RX to the HCA port labeled RX. The maximum passive optical loss is limited to 2.06dB. There is no restriction placed on the number of intermediate connections for 12x InfiniBand coupling links, provided that the 2.06dB requirement is met. "
- System z10 does support going through a patch panel with 12x InfiniBand links. It is highley recommended that there be no greater than 2 hops"

Figure 34 shows the direction of light propagation in an IBM duplex-to-duplex jumper cable is from **B** to **A**. In IBM's duplex-to-biconic, duplex-to-ST, and duplex-to-FC/PC jumper cables, this direction is from **B** to **black**. Figure 35 shows an LC cable.

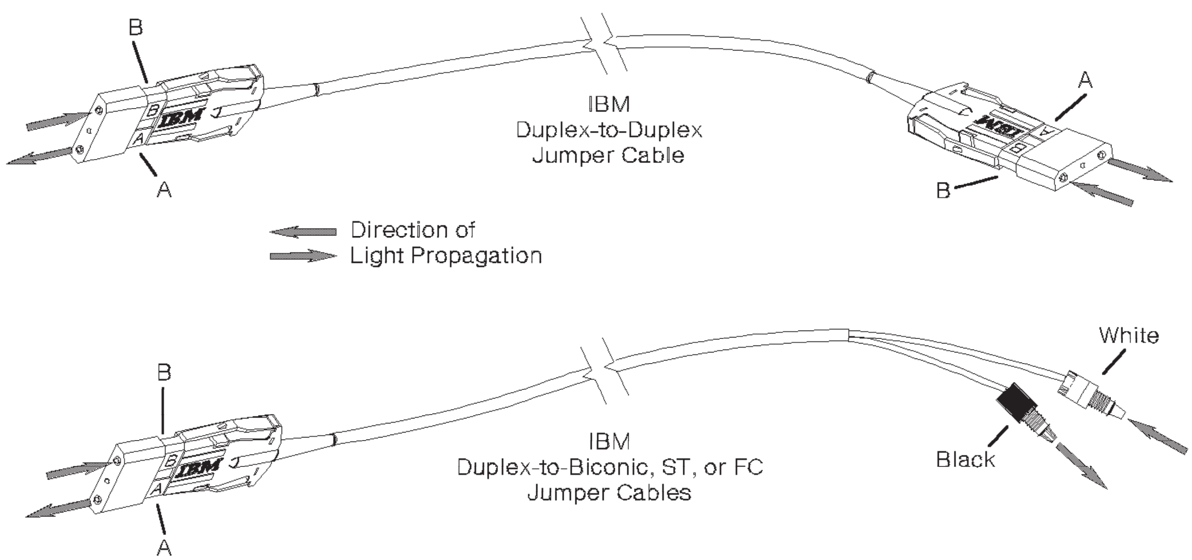

Figure 34. Determining direction of light propagation in an IBM jumper cable

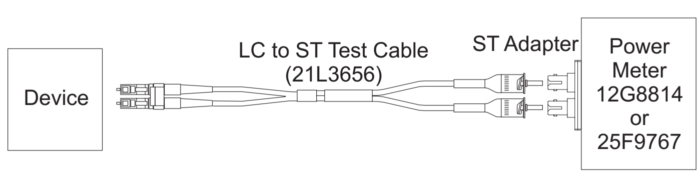

Figure 35. LC cable

Coexistence of jumper cables and bus-and-tag cables

Consider the information in the following paragraphs when installing fiber optic jumper cables in the same environment as copper bus-and-tag cables.

Physical characteristics

Similarities:

- Durable and rugged
- Highly reusable
- Withstands high tensile and compressive forces during installation and removal

Differences

- Bus-and-tag cable is about 75 times heavier and about five times the diameter of a jumper cable.
- Bus-and-tag cable has inherent radius control due to its stiffness, while jumper cable can be easily bent and requires radius control.

Note: Minimum bend radius specifications also apply when handling fiber cable. If not handled properly, small fractures of the glass medium can result in high attenuation losses.

Cable installation considerations

Jumper cables could become tangled with bus-and-tag cables or connectors, which could cause damage to a jumper cable or connector when moving bus-and-tag cables. When all cables are routed properly and the cable environment is organized, no additional fiber cable protection is required. The amount of cable activity in a particular environment, however, should determine this need.

Cable design considerations

The skills required to design a cabling system are very different from those required to install optical fiber cable physically. A cabling system design must meet the requirements and limitations of its environment while satisfying the needs of the attaching products. The cabling system design must be completed before the physical installation can begin.

The expertise of the cabling system designer becomes more important with the increasing complexity of the cabling system. The designer needs to understand the needs of the customer and the products to be installed before deciding how the optical fiber cable will be distributed throughout the property. This will require an on-site evaluation of the premises. If the system will be installed in a new facility, the system designer should be involved before the system blueprints are completed.

Typical cabling system designs include the following:

- Building entrance specifications for the cables
- Number, location, size, and environmental requirements for telecommunications closets and equipment rooms
- Location, protection, size, and type specifications for the horizontal and vertical backbone system
- Distribution system type, specifications, and routing information
- Fire prevention, electrical, and mechanical requirements
- Conduit system installation requirements
- Component specifications and installation requirements
- Cable construction and fiber count
- Labeling and cable management criteria
- Installation verification criteria

Recommendations

Each data center must be carefully analyzed to determine the amount of cable activity or disruption that could occur under the raised floor. If the activity creates a significant exposure to the fiber cables, do any or all of the following:

- Consider using IBM's Fiber Transport Services (FTS) to:
  - Determine the minimum number of additional under-floor multi-mode cables required
  - Route as much under-floor trunk cable along the perimeter of the data center as possible
  - Provide an efficient use of conveyance systems for the jumper cables.
- Educate personnel about proper installation and handling procedures for fiber cables.
- Bundle the fiber cables. For example, use tie wraps to reduce the possibility of damage.
- Route the fiber cables to minimize the exposure caused by sharp edges, excessive bends, or congestion caused by bus-and-tag cables.

If the previous methods cannot be implemented and protection is necessary, IBM provides conveyance kits that are designed to protect fiber cables. Also, fiber cables can be installed in conduits, tubings, raceways, troughs, or other protective devices.

IBM design recommendations

The following list outlines IBM's basic design recommendations:

- Minimum of 10% spare fibers between distribution points for maintenance
- The use of physical-contact connectors
- Single-mode fiber installed for trunk cabling, if future need or long-distance links are foreseen
- A conduit system with interduct and pull-cords for future expansion
- Sufficient trunk fibers to accommodate short-term growth and migration.

Note: One way to determine the quantity of spare fiber for growth is to increase the planned quantity by 30%. If the future applications are unknown, plan multi-mode so that loss does not exceed 5 dB at 1300 nm. This level of loss will accommodate all current applications and leave a margin for future applications that may have more stringent attenuation requirements than those that are currently available.

IBM's connectivity services offering

IBM's Connectivity Services can complement link planning and installation through a variety of offerings.

If the link environment is within one building on a single-floor (or possibly multiple floors or rooms), consider using the Fiber Transport Services (FTS) offering provided by Connectivity Services. With FTS, the planning, fiber optic commodities, and installation activities are packaged into a service that focuses on the migration to a fiber optic link environment. IBM's Fiber Transport Services (FTS) provides the following assistance for link installations:

- **Planning**: Determines the link components (commodities) required.
- **Commodities**: Provides trunk cables, Direct Attach harnesses, distribution panels, cable conveyance kits, and other link components that are manufactured for IBM.
- **Installation**: Provides physical installation of the trunk system commodities.

FTS-III Direct Attach trunk cables and FTS-III Direct Attach harnesses (hereafter called trunk cables and harnesses) can be connected to:

- Enterprise System/9000® (ES/9000®) 9021 Processor 340, 520, and 711 Based Models
- zSeries® servers
- zSystem® 9
- S/390 Parallel Transaction Server 9672 E and P Models
- S/390 Coupling Facility 9674 Models C01, C02, and C03
- 9032 Models 2 and 3 Enterprise Systems Connection (ESCON) Director

Each FTS III Direct Attach harness (here after called harness) has one MTP (multifiber terminated push-on connector) at one end and either six ESCON or coupling facility connectors at the other end. (See Figure 36 on page 34) One MTP connector contains twelve fibers and is the equivalent of plugging six ESCON or coupling facility jumper cables.

The FTS-III Direct Attach trunk cables (hereafter called trunk cables) also have MTP connectors which enables them to plug directly into the harnesses. The trunk cables have 3 MTP connectors for the 18 channel trunk or 6 MTP connectors for the 36 channel trunk. The MTP connectors can be on both ends of the trunk cable (Figure 37 on page 34) or one end of the trunk cable can be attached at the factory to an FTS-III panel mount box.

Once the harnesses are installed in the servers, all fiber connects and disconnects can be done using the trunk cable MTP connectors. The harnesses remain inside the server, plugged into the individual ESCON or coupling facility ports while the trunk cables can be quickly removed. The server can then be relocated within the data center, the trunk cables are easily re-routed to the new location and are plugged back into the harnesses. This greatly reduces the time spent unplugging, rerouting and plugging the individual fiber optic jumper cables back into the server ports.

FTS-III Direct Attach enhances the traditional fiber trunking connectivity solution of bringing all the ESCON processor and Director ports and/or coupling facility ports back to the main distribution cabinets for central control. The harnesses eliminate the need for the zone distribution cabinets at the processors, the ESCON Directors and the coupling facility.

FTS-III MTP-to-MTP trunk cables also introduce a new fiber trunking connectivity solution by going directly from harnesses plugged into ESCON channels in a processor to harnesses plugged into ESCON ports in an ESCON Director. MTP-to MTP trunk cables can easily distribute ESCON channels from each processor to multiple ESCON Directors in an organized manner. Then, the I/O zone cabinets connect directly to the ESCON Directors with the MTP trunks as well. This new connectivity solution eliminates the need for the main distribution cabinets altogether.

The trunk cables have easy-to-use strain relief brackets for attaching the trunk cables to the server frame. This eliminates the existing exposure of accidentally disconnecting a fiber optic jumper cable while moving other cables under the raised floor.

FTS-III Direct Attach harness

The harness has one MTP connector and six ESCON duplex connectors or one MTP connector and six coupling facility SC-duplex connectors (see Figure 36). It enables a trunk cable with MTP connectors to plug directly into six ESCON ports or six coupling facility ports. Once the harness is plugged, all connects and disconnects can be done using the trunk MTP connector. Also available is a harness MTP 12 Fiber to LC Duplex connector.

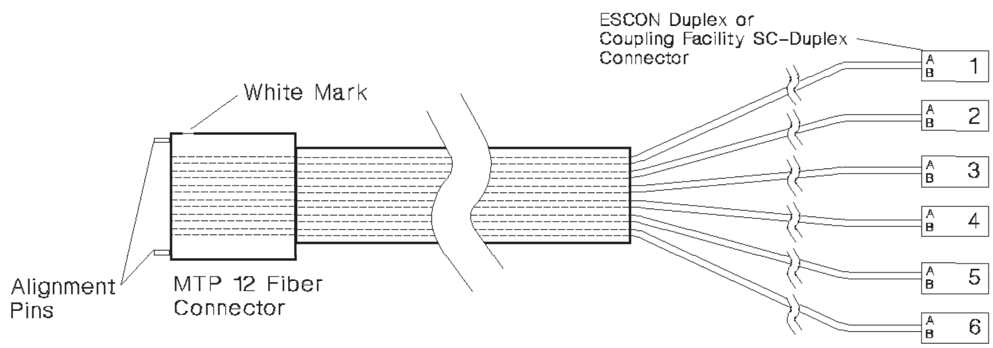

Figure 36. The FTS-III Direct Attach harness. The harness is available in 3, 5, and 12 foot lengths.

FTS-III Direct Attach MTP-to-MTP trunk cables

The FTS-III Direct Attach MTP-to-MTP trunk cable (available in 62.5µm multi-mode or 9.0µm single-mode) is terminated with MTP 12-fiber connectors at both ends so it can be quickly disconnected at either end (Figure 37). The MTP connectors at both ends are protected by a sleeve which has a loop to facilitate pulling the trunk cable through conduit or under the raised floor. The trunk cable can be used to connect to harnesses plugged in a 9672 or 9021 processor, 9032 Model 2 or 3 Director or a 9674 Coupling Facility. An MTP pluggable panel mount box can be attached to either end of this trunk cable using the MTP 12-fiber connectors as well.

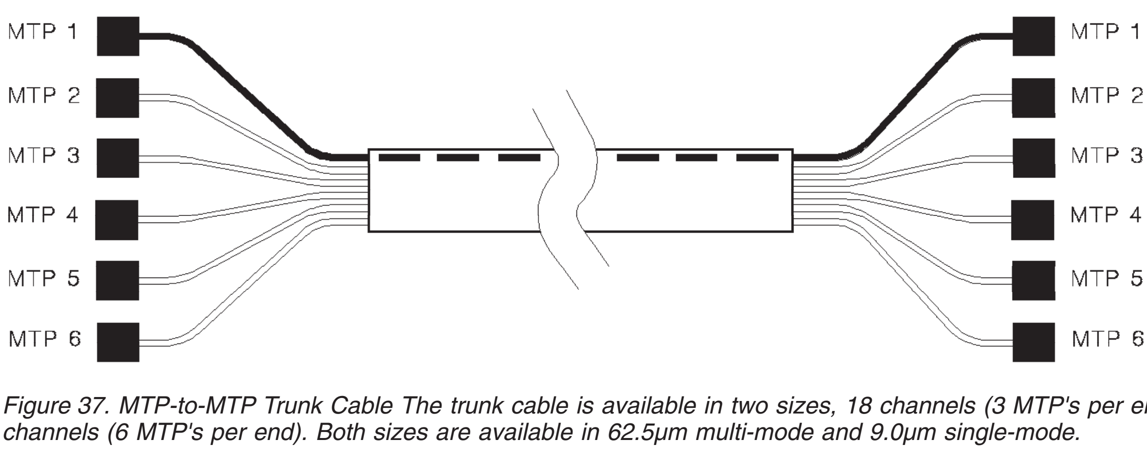

Figure 37. MTP-to-MTP Trunk Cable The trunk cable is available in two sizes, 18 channels (3 MTP's per end) and 36 channels (6 MTP's per end). Both sizes are available in 62.5µm multi-mode and 9.0µm single-mode.

Note: There is a 350 m (1130 ft) total link length limit when using FTS-III Direct Attach **multi-mode** trunks and harnesses for the 9674 Coupling Facility. This is the total link length from the 9674 Coupling Facility port to the coupling link port in the attached processor. An RPQ is required for any links over 350 m. Also, the FTS-III Direct Attach multi-mode trunks and harnesses are 62.5µm optical fiber. Any jumpers used in the link **must** also be 62.5µm fiber. 50µm jumpers and FTS-III Direct Attach multi-mode trunks cannot be mixed in a link.

For more information about FTS-III Direct Attach commodities see *Fiber Transport Services (FTS) Direct Attach Physical and Configuration Planning*, GA22-7234.

If the link environment is between buildings or campuses, other Connectivity Services offerings, including Consulting, Design, and Installation Support, are available. For more details about any of IBM's Availability Services offerings, contact your IBM marketing representative.

Sample views of installed FTS-III Direct Attach trunk cables and harnesses

Figure 38 shows a sample view of FTS-III Direct Attach trunk cables and harnesses installed in frames A and Z of a 9672 Model R*3 and Figure 39 on page 37 shows a sample view of an FTS-III Direct Attach installation in a 9032 Model 3 ESCON Director.

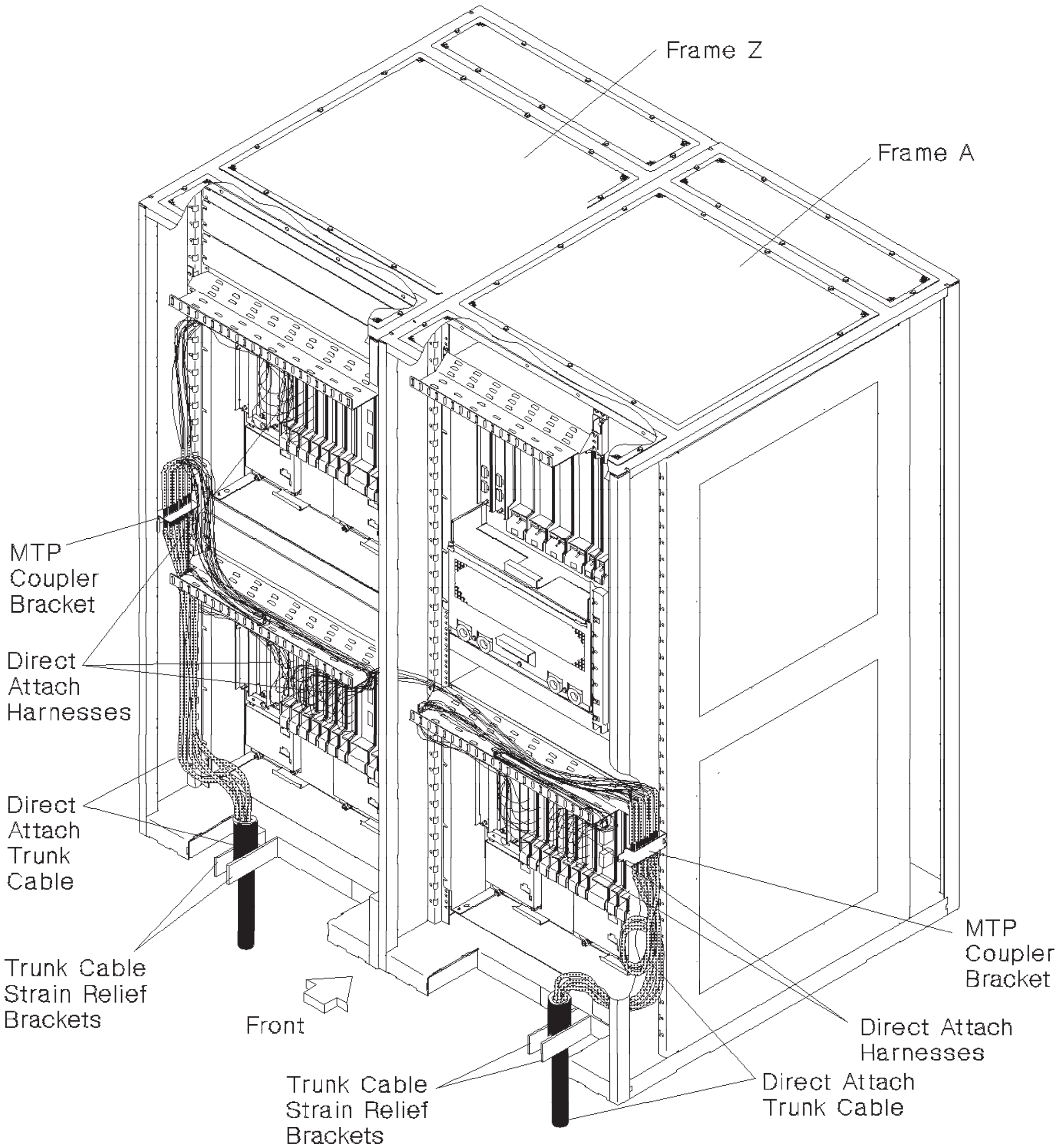

*Figure 38. FTS-III Direct Attach trunk cables and harnesses in a 9672 Model R*3*

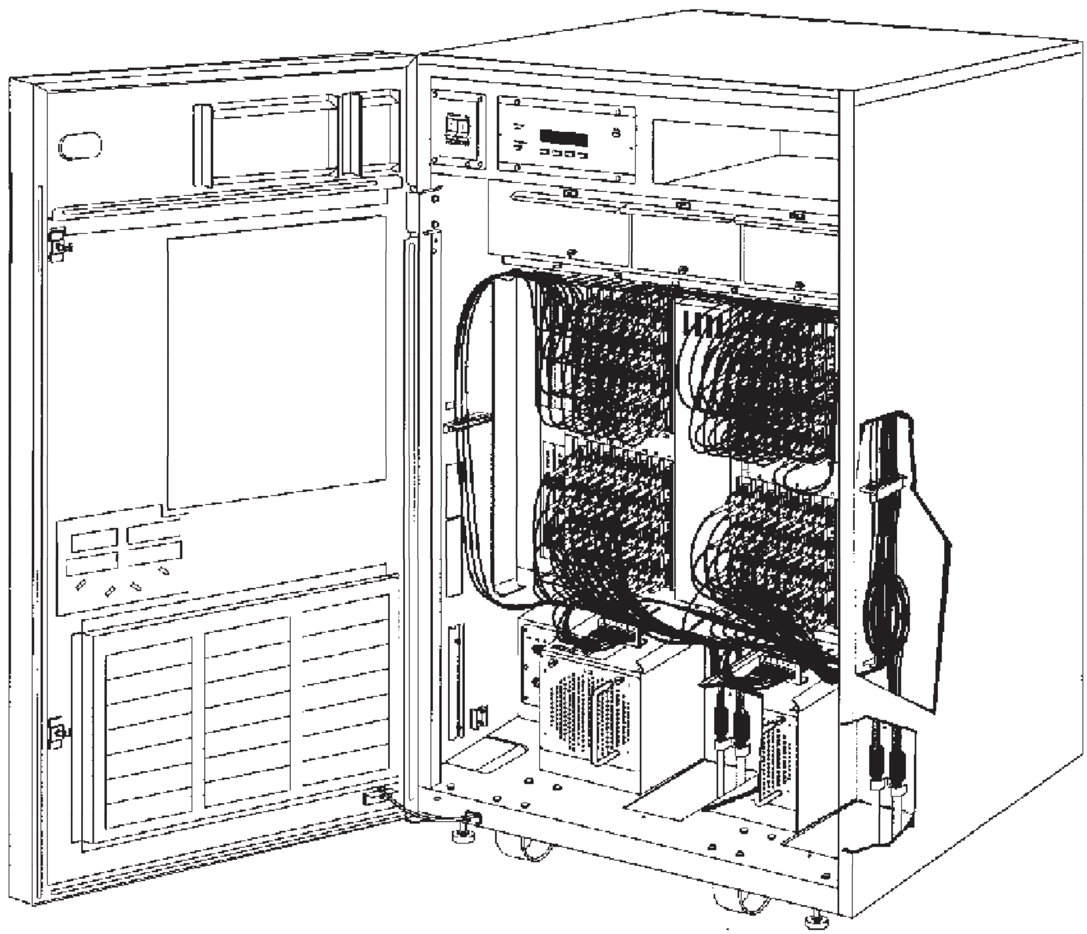

Figure 39. FTS-III Direct Attach Trunk cables and harnesses in a 9032 Model 3 ESCON Director Model 3

Planning for the use of existing fiber

Determine the link loss for the installed product using one of the Link Loss Worksheets in the appendixes. Compare the resulting loss value with the acceptable link loss for the product that you wish to support. Also, compare the bandwidth of existing fiber against available specifications. If these values are within product requirements, then the existing fiber can be used as planned. If these values do not meet the product requirements, then the link will not support the product without changes.

If the link **will not** support the product, contact your IBM installation and Planning Representative or IBM Global Services site and connectivity representative, through your nearest IBM branch office.

Radiation and temperature effects

Some optical fiber is specified for use in low-temperature or other special environments. All other optical fiber is subject to the following guidelines.

Optical fiber cable may suffer unacceptable levels of signal loss if exposed to ionizing radiation. Do not install optical fiber cable in areas where it will be exposed to radiation dosage rates greater than 200 millirays (mGy) per minute or an accumulation dosage exceeding 2000 mGy.

Optical fiber performance and transmission can also be adversely affected by temperatures below -10°C (14°F). Each optical fiber parameter is specified through a particular range of operating temperatures. Extremes are usually reached in either external installations or in building attics.

Management of slack cable and strain relief

Attention should be paid to managing slack cable and strain relief requirements at each entry and connection point of the optical fiber cabling system. Appropriate amounts of slack cable may be useful for minor changes and repairs. Strain relief will help prevent disruption of the system and is particularly beneficial in raised floor environments, where reconfigurations are frequent. Management of slack should be considered when storing excess jumper cable.

Right-of-way planning considerations

The introduction of optical fiber into the data communications environment has provided extended distance connections. This sometimes results in a requirement to enter and exit other public and private rights-of-way not under your direct control. This added requirement to installation planning may be a new consideration for many customers. The extended links offered today require dedicated pairs of fiber cable from one end of the link to the other. These dedicated fibers are sometimes referred to as **dark fiber** in that there are no active components on the link other than the customer's equipment at each end. The requirement for dark fiber is new not only for the customer but also, in many cases, for the traditional providers of services between facilities. Therefore, it is important to use early planning and negotiation for rights-of-way for dark fiber to install extended distance links on schedule.

Because every installation has unique characteristics, it is not possible to provide one approach to meet all planning considerations. The following factors should be considered when planning for any right-of-way requirements:

- Fiber specifications (See Chapter 5, "Specifications," on page 59).
- Growth and migration plans
- Numbers of fibers to include current, growth, and service spares.

  As a general rule, the total number of optical fibers installed should be equal to the sum of the following:

Total number of fiber strands required immediately	=	______
Plus 10% (for spares)	=	______
Plus two terminated pairs (if spares are not terminated)	=	______
Plus 30% of the number required immediately (for future growth)		
Total fiber strands required	=	______

  Be prepared to increase the total optical fiber required if the environment seems to have a high chance of damage. Once a trunk cable is terminated and installed, opportunities for damage are substantially reduced.
- Physical routing considerations include
  - Redundancy and alternate cable installation

    Additional optical fiber may be needed (beyond that needed to meet requirements, spares, and projected growth). Because optical fiber allows for increased distances, all external cable routings should be reviewed for tolerance to interruption. If quick availability is critical, redundant cables and trunks in several locations may minimize system downtime during restoration activity.

    Major factors to be considered in this decision should include
    - Security from physical damage
    - Disaster recovery

    - Cost and time to repair (as opposed to initial installation costs)
    - Physical limitations and risks of the proposed right-of-way route
    - Post Telegraph Telephone (PTT, the National Post and Telecommunication Authority), contractor, and vendor capabilities
    - Serviceability – ease of access to the installed cable and trunk for inspection, repair, and restoration
    - Environmental factors affecting long-term reliability. Adverse forces (such as extreme temperatures, precipitation, dust, chemicals, nuclear radiation, and construction activities) may degrade the installed cable.
  - Use new as opposed to existing facilities
  - Physical installation considerations
  - Reliability
  - Common carrier or governmental regulatory constraints
  - Tariffs
  - Incidental considerations (for example, removal and replacement of walkways and streets, relandscaping, and renegotiation of other utility rights-of-way).
- Building entry and exit
  - Connectors and adapters
  - Physical-contact connectors (SC, ST, or FC/PC) are recommended for trunk termination. Duplex-to-ST or Duplex-to-FC/PC adapters are recommended in distribution panels.
  - Selection of distribution panels
  - Interior building cable routing plans
  - Routing types (such as trays, conduit, and raceways)
  - Building and wiring codes (for example, National Fire Protection Association Codes (NFPA), National Electrical Codes (NECs), and local codes)
  - Cable densities, strain relief, bend radius control, splices, and considerations about storage of cable.
- Contractor selection and contract agreements.
- Labeling
  - Panel labeled with laser warning as required
  - Cable routing control
- Record keeping
  - Installed cable specification
  - Cables routing control
  - Serviceability
  - Warranty.
- Costs

  Installation costs as opposed to component costs must be balanced to accommodate growth and migration.
- Facility security requirements (such as lockable panels, lockable and controllable closets, security along rights-of-way, inspection schedules).
- Simultaneous use of optical fiber for video and voice is not an option for most data communications products at this time due to problems in multiplexing.
- Compatibility of all components is essential for reliability, serviceability, and aesthetics, especially in installations where optical fiber already exists.

Some skills required to install optical fiber components are different from those required to install copper. Contractors employed to install these components should have appropriate training and experience. This is especially important for optical fiber cable termination and splicing.

Correct handling procedures for optical fiber cable are identified by the manufacturer and should always be followed during installation. These specifications include minimum bend radius, maximum pulling tension, pulling lubricants allowed, and recommended pull-in procedure. The cable manufacturer should also recommend the correct procedures for cable sheath removal, stripping, and strain relief. The manufacturers of various types of connectors and splices ship instructions for the correct installation of their products (written for trained personnel).

Link environments

The physical location of the data processing equipment determines the link environment. This equipment can be located:

- On a single floor within one building
- On multiple floors or in multiple rooms within one building
- Between two or more buildings within a "campus"
- Between two or more campuses

The following paragraphs describe and show an example of each environment. The major differences are the type (single-mode or multi-mode) and location of trunk fiber, the purpose of the distribution panels, and the cable routing from the panels. Figure 40 on page 41, Figure 41 on page 43,Figure 42 on page 45, and Figure 43 on page 47 show examples of the four fiber optic channel link environments. In these figures:

- Trunk cables (dotted lines) attach to distribution panels. IBM recommends use of ST or FC/PC physical-contact connectors.
- IBM jumper cables (solid lines) attach devices to distribution panels, using various combinations of connectors, adapters, and couplers within the panel.

Single-floor link environment

A single-floor link environment (Figure 40 on page 41) uses multiple, strategically placed distribution panels that are connected by trunk cable to a central distribution panel. This environment provides flexibility and growth because installation or relocation of equipment can be performed by using short multi-mode jumper cables, while causing little or no disruption to operations. After the equipment is relocated or installed, it can be reconnected into the closest distribution panel.

Other advantages include enhanced cable management capabilities and a more organized under-floor cable layout.

Consider the following when planning for a single-floor link environment:

- The Fiber Transport Services (FTS) offering of IBM Global Services Advanced Connectivity System (IACS) provides planning assistance, the required commodities, and the installation of this type of link environment. Contact your IBM marketing representative for more information.
- Place the distribution panels according to the location and number of devices and channels.
- Install enough spare trunk fibers for future growth. Although spare trunk fibers can remain unterminated without causing system disruption, installing connectors during trunk cable installation could be more cost-efficient and convenient.
- Each trunk connection and splice causes additional link attenuation (loss). The cabling design must consider the number of connectors and splices when calculating the link loss.
- This environment requires additional fiber optic jumper cables, which must be purchased separately.

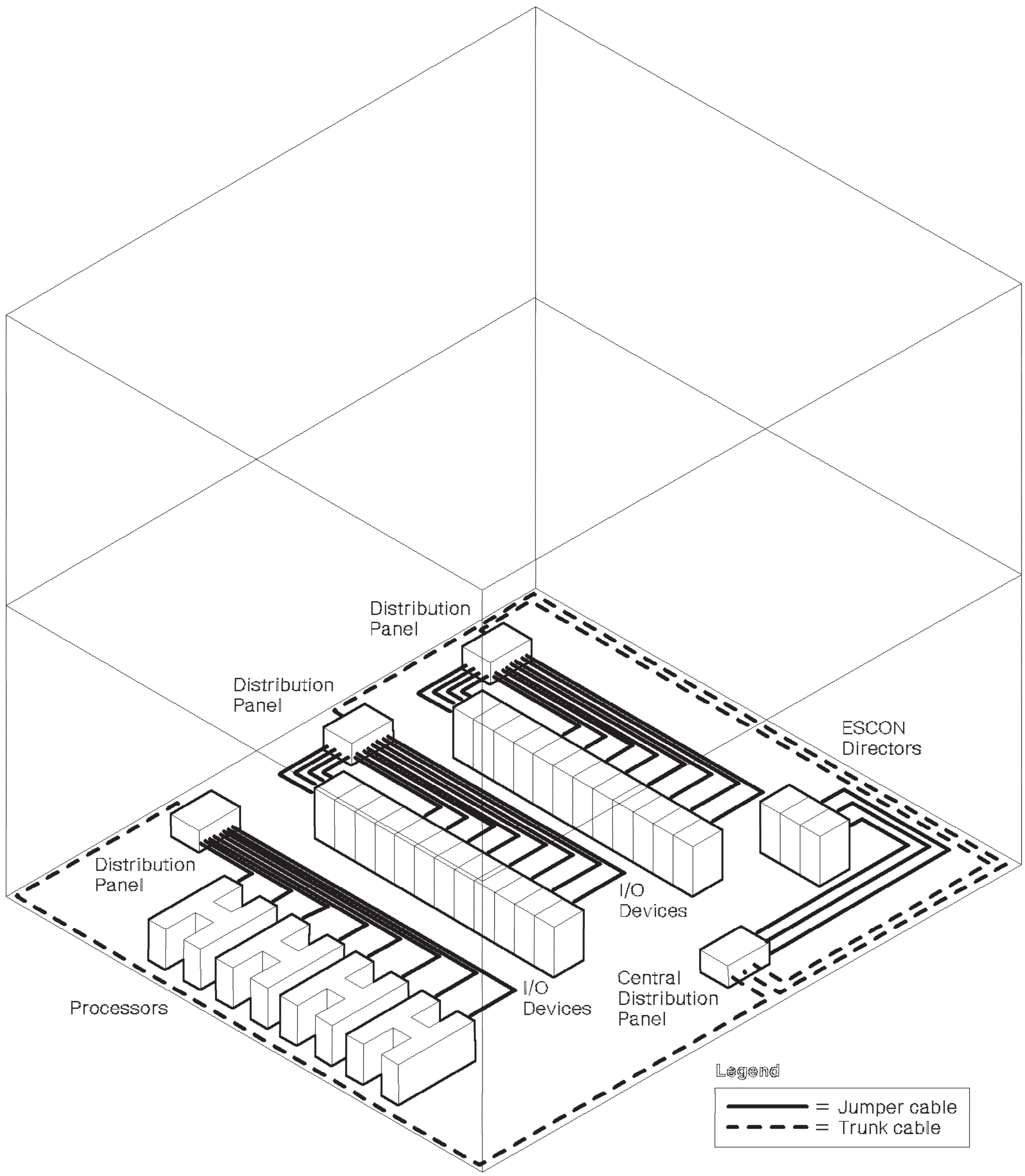

Figure 40. Example of a Single-floor link environment

Multifloor or multiroom link environment

Data processing equipment can be located on multiple floors or in multiple rooms. These could be adjacent rooms on a single floor, adjacent floors in a single building, or widely separated rooms or floors within a single building. This type of trunk system can be installed using multi-mode ESCON links because the total link distance should never exceed 3 kilometers (1.86 miles). Single-mode coupling facility channels and FICON channels can also exist in this environment, since they support a maximum distance of 10 km (6.2 miles).

Although the cost is similar to a single-floor environment, the design factors could be more complex. For example, access between floors or rooms could require structural modification. Also, trunk fiber cable routing could be through hazardous areas or in areas where building wiring also exists. As the complexity of this environment increases, it becomes necessary to have a more organized arrangement of trunk cables and distribution panels.

The flexibility that exists when using distribution panels and trunk cables allows easier initial installation and reconfiguration. It also allows placement of trunk cables between the floors or rooms in a more permanent location. This environment involves additional factors, such as building codes, cable routing, contractor information, security, redundancy, and damage and disaster protection. Because these factors did not exist in single-floor environments, installation planning decisions become more important. Also, because this environment requires distribution panels and trunk cables, the number of connections for each link increases. This causes a higher link loss, thereby making link-loss calculations more critical.

A multifloor or multiroom link environment usually has more relocation activity within a floor or room, but not necessarily between floors or rooms. For example, consider a configuration that has I/O devices in one room or on one floor and processors in another room or on another floor. The I/O devices should have connection capability to multiple processors, and processors should have connection capability to other processors. The need to physically move more I/O devices to the processor area or a processor to the I/O area, however, might never be necessary.

The fiber cabling planned for this link environment cannot, therefore, provide a single solution consisting of only trunks and distribution panels. Cable planning must provide flexibility for adding and relocating jumper cables and to allow connection capability for many devices.

Figure 41 on page 43 shows a data processing configuration that occupies two floors (or rooms) within the same building. The first floor or room contains processors, an ESCON Director, and I/O devices, while the second floor or room contains only I/O devices.

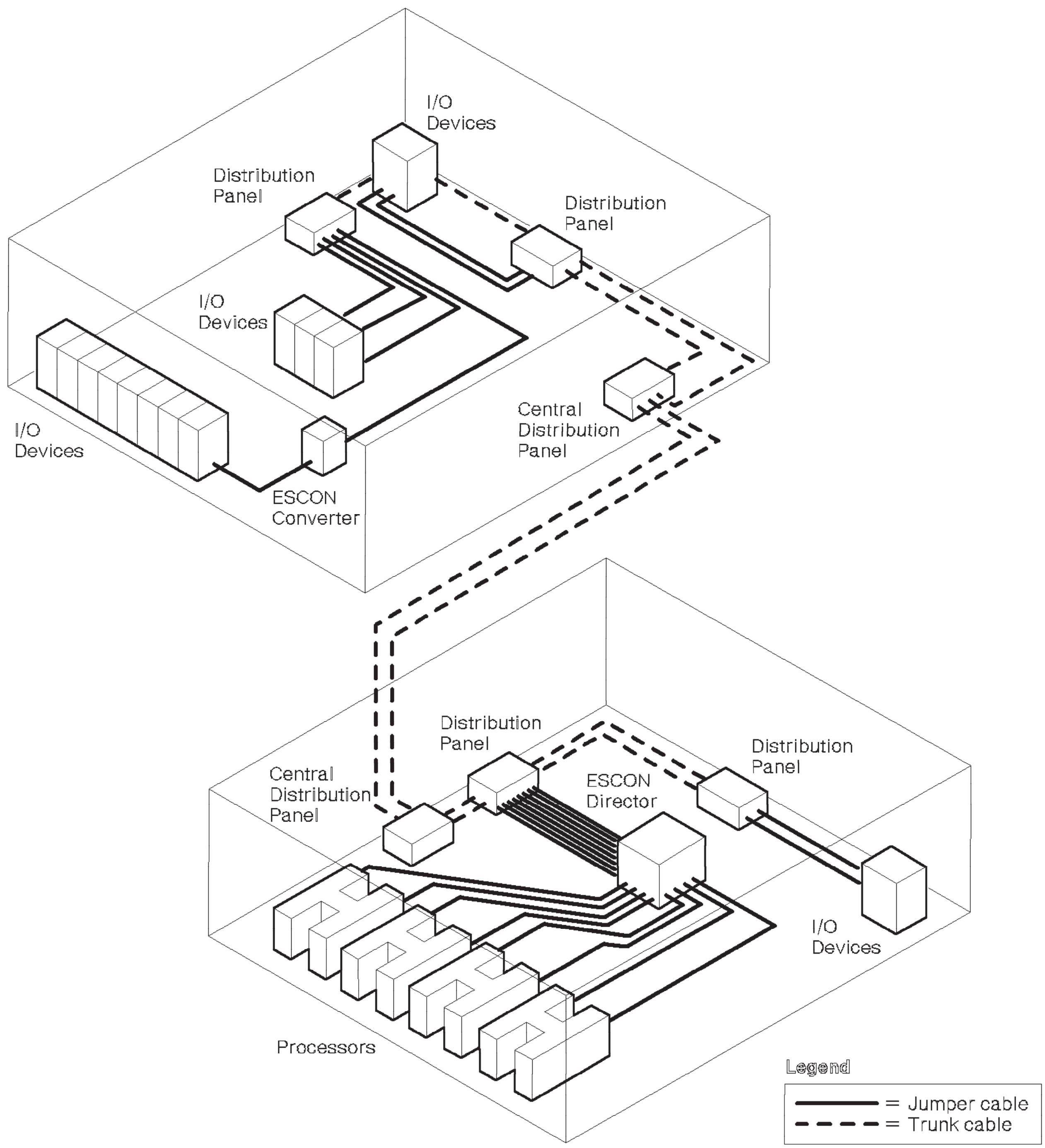

Figure 41. Example of a Multifloor or multiroom link environment

Single-campus link environment

Data processing equipment can be located in a multiple-building (campus) environment in which distances between buildings could vary greatly. The buildings could contain separate data centers, with each having distributed resources similar to a multiple-floor environment. The major planning factor in a single-campus is that the user controls all the land, and cable routing does not involve right-of-ways.

In addition to the considerations that exist for the single-building links, planning for a single-campus link environment involves outdoor trunk cables (above ground, underground, or both). This environment can use either multi-mode or single-mode trunk cable. The major consideration for which trunk type to use is the link distance and product features.

- For coupling linkl and LX FICON and LX OSA devices and distances up to 10 km (6.2 miles), use single-mode trunk.
- For SX FICON Express and SX FICON Express2 devices and distances up to 300 meters (0.19 miles) use 50.0 micron multi-mode trunk, up to 120 meters (0.07 miles) use 62.5 micron multi-mode trunk.
- For ESCON-compatible devices and distances of 3 kilometers (1.86 miles) or less, use multi-mode trunk. For distances up to 2 km, either 50 micron multi-mode trunk or 62.5 micron multi-mode trunk may be used. For distances between 2 and 3 km, use 62.5 micron multi-mode trunk.
- For ESCON-compatible devices and distances between 3 and 20 kilometers (12.4 miles), use single-mode trunk and the ESCON Extended Distance feature.
- For OSA GbE SX applications and distances less than 550 meters, 62.5 micron multi-mode fiber may be used. For distances up to 5 km or more with GbE LX and 10GbE LX, use single-mode fiber.
- For 12x InfiniBand coupling links up to 150m (0.09 miles), use IFB-O cables.

This environment could have existing facilities, such as utility poles or underground conduit, that can be used to install cables between buildings. When installing new trunk cable, only the building-to-building (interbuilding) facilities must be evaluated. If interbuilding trunk cable already exists, it must be evaluated and verified during cable installation planning. For example, users should supply information that specifies what cables, connectors, distribution panels, adapters and couplers are already installed. Interbuilding trunk cable installation could also involve using contractors who are familiar with installing and testing fiber optic cables.

Regardless of what facilities exist, each building in a single-campus link environment should contain a “building interface panel”. This panel provides a common access point for each building that can be used to splice trunk cable, prepare a fiber for installing a connector, and install connectors. Using a building interface panel is especially important when considering the possibility of damage to outdoor trunk cables caused by construction or some other activity. Using building interface panels, however, contributes to the total link loss because of additional connections. They should, therefore, be used only if the link loss introduced by additional connections will not exceed the maximum loss allowable for each link. If building interface panels are used, however, trunk fibers can be spliced at the panel rather than using connectors, thereby reducing the connection loss. See Chapter 5, “Specifications,” on page 59 for link specifications.

Figure 42 on page 45 shows an example of a data processing configuration that has two buildings within a campus. This environment uses building interface panels and includes two ESCON Directors.

- The two buildings are connected through an above ground or underground trunk cable, which enters both building interface panels.
- A trunk cable is installed in Building 001 (bottom of figure) between the distribution panel used for the I/O devices and another distribution panel attached to the building interface panel.
- Building 002 has an ESCON Director attached to the building interface panel that also attaches to another distribution panel.

This provides a common trunk (sometimes called a “backbone”) for these two buildings.

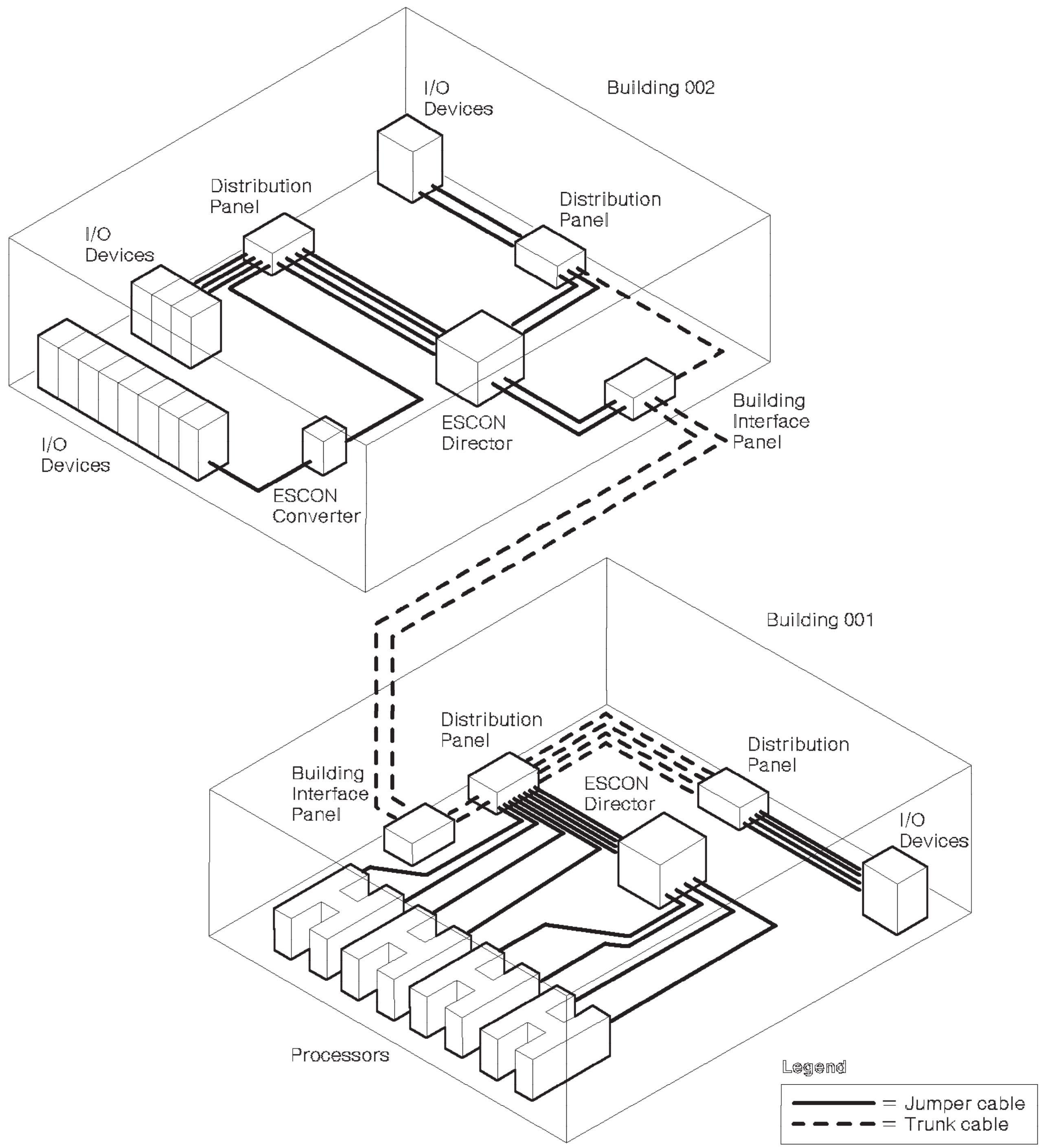

Figure 42. Example of a single-campus link environment between two buildings

Multicampus link environment

Planning for a multicampus link environment typically involves the same considerations as the other three environments and includes additional considerations. Multicampus links usually require single-mode trunk cable because 1) the distance between buildings is greater than 3 kilometers (1.86

miles), and 2) the connections between buildings are outside the user's control, thereby requiring access to a right-of-way. Negotiation for using a right-of-way, however, can greatly extend the time required to plan a multicampus link and must be considered.

The following lists additional planning considerations for a multicampus link:

- Leasing of dark fiber

  Most telecommunication facilities are terminated by data communications equipment (DCE) and have repeaters, conditioning, or exchanges within the link. A “dark” fiber has no active components either in the link or at the termination points. The ESCON Remote Channel Extender (9036) can be used to provide an interface between the customer's equipment and the third-party fiber optic network.
- Increased number of connections

  When private contractors, common carrier companies, or governmental agencies install fiber cables across public right-of-ways, they sometimes connect the fibers to a building interface panel. This adds to the link loss because it induces additional connections.
- Common carrier regulatory constraints
- Governmental regulatory constraints
- Tariff zones
- Reliability, availability, and serviceability factors

Figure 43 on page 47 conceptually shows a multicampus environment. Notice that the figure does not indicate building boundaries. This is because a multicampus environment could be distributed over a wide geographical area and each building could have an unequal amount of data processing equipment. Contact your IBM marketing representative.

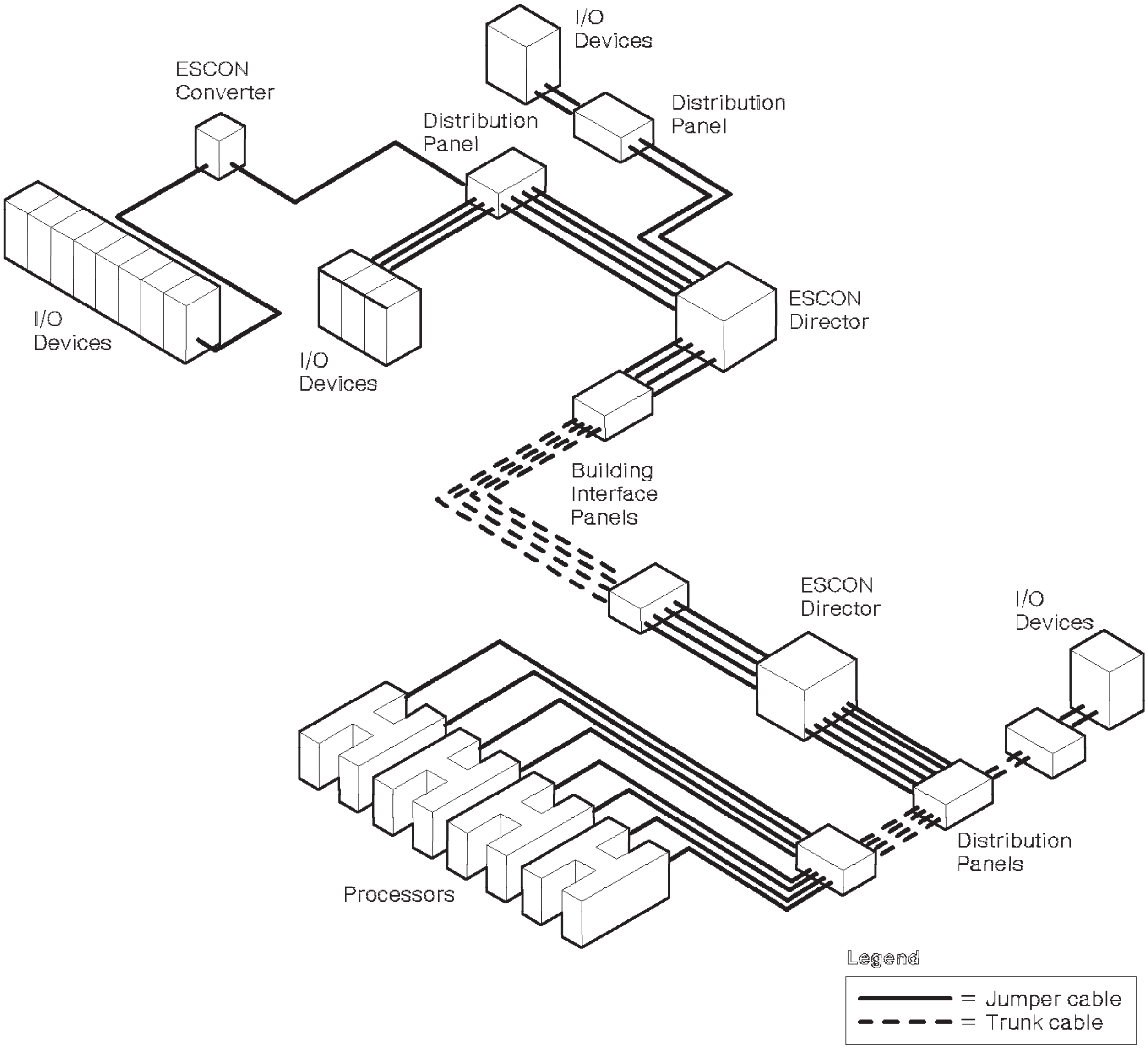

Figure 43. Example of a multicampus link environment

Chapter 3. Calculating the loss in a multi-mode link

This chapter describes how to calculate the maximum allowable loss for an ESCON link that uses multi-mode components. It shows an example of a multi-mode ESCON link and includes a completed work sheet that uses values based on the link example. The same procedures may be used to calculate the link loss for a coupling link or FICON link. Be sure to use the fiber loss corresponding to the proper wavelength for multi-mode links; refer to the ESCON, FICON, and coupling link physical layer documents for more information. The use of an optical mode conditioner is considered to be an extension of the source and receiver, and does not enter into the link loss analysis.

Each link has a loss (attenuation) whose value depends on the loss induced by each cable, connector, and splice. This value, when calculated, cannot be greater than the maximum link loss (see Table 6 on page 59).

Use the following explanation and refer to the configuration example (Figure 44 on page 53) and the work sheet example (Table 4 on page 54). Although actual values should be used if possible, this example uses the typical loss values shown in Table 10 on page 68.

Planning your individual optical fiber links involves:
- Determining the acceptable link loss of the supported products
- Calculating the link loss
- Determining whether new or existing fiber cable will be used
- Selecting jumper cables.

Prerequisites to link planning

You should obtain the following items when planning an optical fiber link:
- Cabling routing blueprints, which provide the following information
  - Location and length of each link segment
  - Type, location, and identification of connectors and splices
  - Locations of distribution, splice, and storage panels
- Manufacturer data sheets on the following link components
  - Cable
  - Connectors
  - Distribution, splice, and storage panels
  - Attached devices.
- Planning and installation guides specific to IBM products, available from your IBM marketing representative.
- Link measurements from the installer, if available.

Link configuration planning

Physical configuration is the actual path from one product to another.
- You will need the design plans for your facility to determine the following
  - The locations of data processing equipment
  - The locations of users who require links
  - The number and location of the physical connections of the cabling system.

Note: For optical fiber cabling requirements between telecommunications closets, you need two optical fibers for each device you want to connect plus 10% extra for maintenance and repair, at a minimum.

- Plan the paths for the cable link from the product location to attaching product location, and determine the following
  - Length and type of each segment of the link (such as jumper cable, or backbone)
  - Identification and location of each connector, splice, and distribution panel in the link.
- Check the design specifications (which are prepared for accepting bids) to verify that they contain at least the following information
  - Correct fiber cable type
  - Bandwidth requirements
  - Conformance to national, state, and local building codes.
- The physical configuration information is used during link loss calculations. The calculated loss budget for each link loss should become part of the design specifications. Installers should verify that the link loss budget has been met for each installed strand of optical fiber. Refer to the appropriate link loss calculation section for IBM product sets.

In the raised floor environment, the number and location of connection points can be large, which requires many long jumper cables. Consider installing a trunking system under the raised floor to facilitate the management of these connections.

When attaching other devices and applications to a common fiber trunk, first refer to each device's planning publication for specifications and cable requirements.

Completing a loss work sheet for a multi-mode link

Use Section A of the Link Loss Work Sheet to calculate the total component mean loss, Section B to calculate the component variance loss, and Section C to calculate the total link loss. When MCPs are used at either end of a link, it is only necessary to calculate the end-to-end link loss from one MCP to the other. You do not need to include the MCP loss in this calculation.

Section A: Calculating the multi-mode component mean loss

The fiber cable manufacturer should provide either the component mean (average) loss or worst-case specification data. If the mean value is not available, use the worst-case specification data to complete Section A. If the manufacturer's data is not available, use the typical component loss values from Table 10 on page 68.

Connections: Multiply the average connection loss value by the total number of connections in the link. Connections to coupling facility channel-capable, FICON-capable, or ESCON-capable devices are included in the device specification and **should not** be included in the connection calculation.

Note: A link consisting of one IBM duplex-to-duplex jumper cable is considered to have no connections when calculating the link loss.

Splice Loss: Multiply the splice loss value by the total number of link splices. If the link has both mechanical and fusion splices, calculate the losses separately, then enter the total on the work sheet.

Jumper Cable Loss: Multiply the combined length of the jumper cables in kilometers by the jumper cable loss per kilometer.

Trunk Cable Loss: Multiply the total length of the trunk cable in kilometers by the cable loss per kilometer.

Section B: Calculating the Multi-mode Component Variance Loss

The fiber cable manufacturer should provide the values used to determine variance loss. This loss, attributable to manufacturing tolerances or installation methods (or both), is induced by connections and splices.

- If the manufacturer's data is not available, use the typical component loss values from Table 10 on page 68.
- If the manufacturer has provided only worst-case specification data, it includes the variance loss. Enter a value of zero on the work sheet for the Total Component Variance Loss.
- If the manufacturer provides a standard deviation (σ) value, use the square of this value to determine the component variance loss. For example, if σ equals 0.24, then enter a value of 0.06 (0.24 squared) on the worksheet for the Total Component Variance Loss.

Connections: Multiply the connection variance value by the total number of connections in the link. Connections to ESCON-capable, FICON-capable, or coupling facility channel-capable devices are included in the device specification and **should not** be included in the connection calculation.

Splice Variance: Multiply the splice variance value by the total number of splices in the link.

Section C: Calculating the total multi-mode link loss

The total calculated link loss includes the following values:

- All calculated component mean losses.
- Three times the square root of the sum of the calculated component variances.
- The higher-order mode loss. This loss, induced by the connectors and the first few hundred meters of each link, is assigned a constant value, depending on the trunk fiber size. This loss should only be included for an ESCON link.
  – For 50.0-µm trunk fiber, use 1.5 dB.
  – For 62.5-µm trunk fiber, use 1.0 dB.

Loss calculation example for a multi-mode link

Figure 44 shows a link example consisting of:

- Jumper Cable 1 (IBM duplex-to-duplex, multi-mode, 13 meters).
- Jumper Cable 2 (IBM duplex-to-duplex, multi-mode, 77 meters). (Combined jumper cable length = 90 meters or 0.09 km).
- 1.5 km of 50-µm trunk cable (bandwidth = 800 MHz•km).
- One 62.5-µm-to-50.0-µm physical-contact connection (in each fiber).
- One 50.0-µm-to-62.5-µm physical-contact connection (in each fiber).
- Six 50-µm mechanical splices (in each fiber).
- Trunk cable connectors are ST (physical contact).

Note: The example of a completed Calculated Link Loss Work Sheet (Table 4 on page 54) uses Table 10 on page 68, which lists typical values for currently used components. Use Table 10 on page 68 **only** if the manufacturer's specifications are not available.

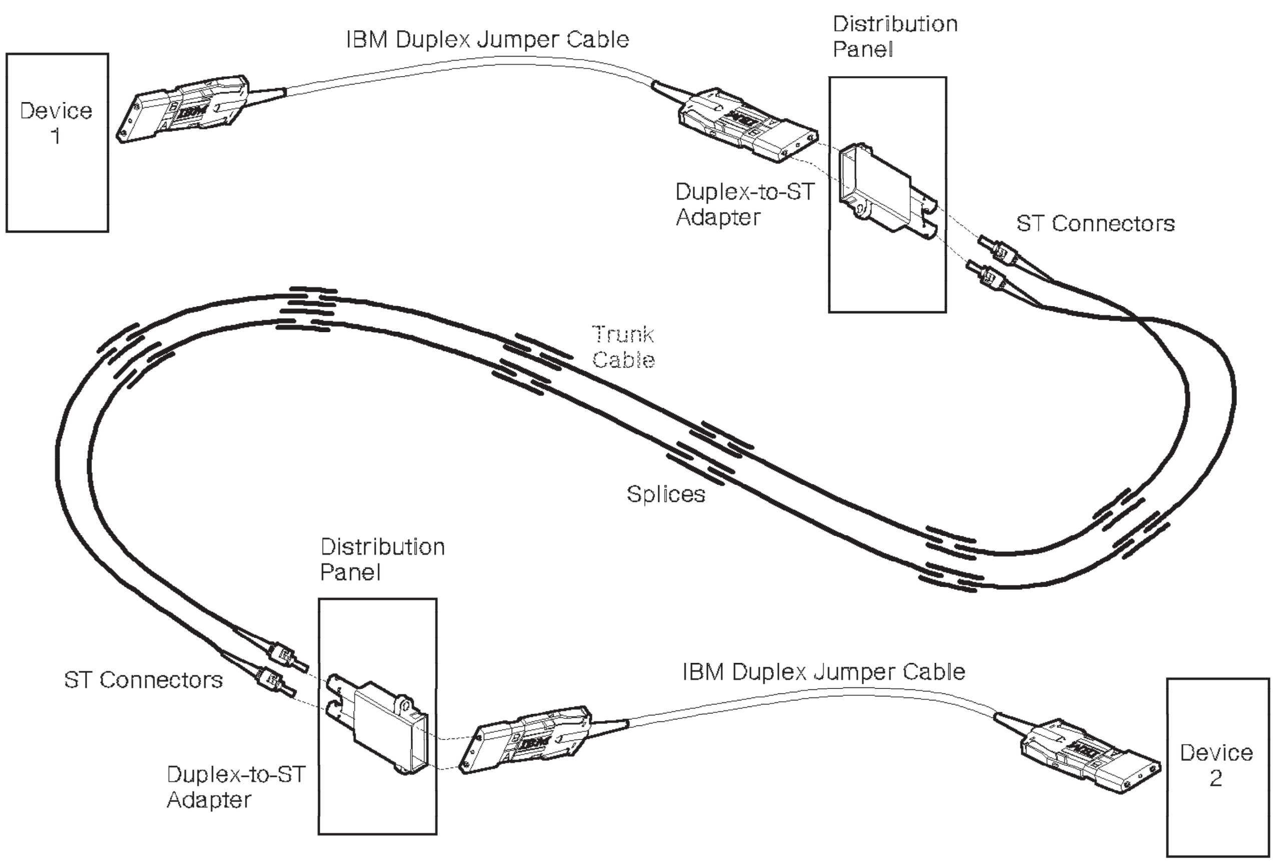

Figure 44. Example of a multi-mode ESCON link

Table 4. Example of a Completed Calculated Link Loss Work Sheet for a multi-mode link. This example was completed for an ESCON link.

A. Calculating the multi-mode component mean loss

Connection loss multiplied by the number of connections in the link:					
__**62.5**___- µm-to-__**50.0**__- µm connection:	__**2.10**__ dB	x	___**1**___	=	__**2.10**__ dB
__**50.0**___- µm-to-__**62.5**__- µm connection:	___**0**____ dB	x	___**1**____	=	___**0**____ dB
________- µm-to- _______- µm connection:	________ dB	x	_______	=	________ dB
Splice loss multiplied by total number of splices in the link:	__**0.15**__ dB	x	___**6**____	=	__**0.90**__ dB
Jumper cable loss multiplied by the combined length of the jumper cables:	__**1.75**__ dB/km	x	__**0.09**__ km	=	__**0.16**__ dB
Trunk loss per kilometer multiplied by the total trunk length (in km):	__**0.90**__ dB/km	x	__**1.5**___ km	=	__**1.35**__ dB
					(+) __________
			Total Component Mean Loss		__**4.51**__ dB

B. Calculating the multi-mode component variance loss

Connection variance multiplied by the number of connections in the link:					
__**62.5**__- µm-to-__**50.0**__- µm	__**0.12**__ dB^2	x	____**1**___	=	__**0.12**__ dB^2
__**50.0**__- µm-to-__**62.5**__- µm connection:	__**0.01**__ dB^2	x	____**1**___	=	__**0.01**__ dB^2
_______- µm-to-________- µm connection:	________ dB^2	x	________	=	________ dB^2
Splice variance multiplied by total number of splices in the link:	__**0.01**__ dB^2	x	____**6**___	=	__**0.06**__ dB^2
					(+) __________
			Total Component Variance Loss		__**0.19**__ dB^2

C. Calculating the total multi-mode link loss

Total component mean loss:				=	__**4.51**__ dB
Square root of total component variance loss multiplied by 3:	$\sqrt{\underline{0.19}\ dB^2}$	=	__**0.44**__ dB x 3	=	__**1.32**__ dB
High order mode loss (ESCON only): 50.0-µm trunk = 1.5 dB; 62.5-µm trunk = 1.0 dB				=	___**1.5**__ dB
					(+) __________
			Calculated link loss		__**7.3**___ dB

Chapter 4. Calculating the loss in a single-mode link

This chapter describes how to calculate the maximum allowable loss for an ESCON link that uses single-mode components. It shows an example of a single-mode ESCON link and includes a completed work sheet that uses values based on the link example. The same procedure can be used to calculate the loss for a single-mode coupling link or FICON link.

Each link has a loss (attenuation) whose value depends on the loss induced by each cable, connector, and splice. This value, when calculated, cannot be greater than the maximum link loss (see Table 6 on page 59).

Use the following explanation and refer to the configuration example (Figure 45 on page 57) and the work sheet example (Table 5 on page 58). Although actual values should be used if possible, this example uses the typical loss values shown in Table 10 on page 68.

Completing a Loss Work Sheet for a single-mode link

Use Section A of the Link Loss Work Sheet to calculate the total component mean loss, Section B to calculate the component variance loss, and Section C to calculate the total link loss.

Section A: Calculating the single-mode component mean loss

The fiber cable manufacturer should provide either the component mean (average) loss or worst-case specification data. If the mean value is not available, use the worst-case specification data to complete Section A. If the manufacturer's data is not available, use the typical component loss values from Table 10 on page 68.

Connections: Multiply the average connection loss value by the total number of connections in the link. Connections to coupling facility channel-capable, FICON-capable, or ESCON-capable devices are included in the device specification and **should not** be included in the connection calculation.

Notes:

1. A link consisting of one IBM duplex-to-duplex jumper cable is considered to have no connections when calculating the link loss.
2. The ESCON XDF Adapter kit does **not** add connection loss to the link.

Splice Loss: Multiply the splice loss value by the total number of link splices. If the link has both mechanical and fusion splices, calculate the losses separately, then enter the total on the work sheet.

Note: Because a single-mode link can be up to 20 kilometers (12.4 miles) and fiber cable is available in reels of from 1 to 7 kilometers (0.62 to 4.35 miles), single-mode trunk cable could require “reel-to-reel” splicing. If this loss is included in the trunk cable loss, **do not** include it in the splice loss calculation. If not certain about whether to include this value, contact your marketing representative.

Jumper Cable Loss: Multiply the combined length of the jumper cables in kilometers by the jumper cable loss per kilometer.

Trunk Cable Loss: Multiply the total length of the trunk cable in kilometers by the cable loss per kilometer.

Section B: Calculating the single-mode component variance loss

The fiber cable manufacturer should provide the values used to determine variance loss. This loss, attributable to manufacturing tolerances or installation methods (or both), is induced by connections and splices.

- If the manufacturer's data is not available, use the typical component variance loss values from Table 10 on page 68.
- If the manufacturer has provided only worst-case specification data, it includes the variance loss. Enter a value of zero on the work sheet for the Total Component Variance Loss.
- If the manufacturer provides a standard deviation (σ) value, use the square of this value to determine the component variance loss. For example, if σ. equals 0.24, then enter a value of 0.06 (0.24 squared) on the worksheet for the Total Component Variance Loss.

Connections: Multiply the connection variance value by the total number of connections in the link. Connections to coupling facility channel-capable, FICON-capable, or ESCON-capable devices are included in the device specification and **should not** be included in the connection calculation.

Note: The ESCON XDF Adapter kit does **not** add connection loss to the link.

Splice Variance Multiply the splice variance value by the total number of splices in the link.

Section C: Calculating the total single-mode link loss

The total calculated link loss includes the following values:

- All calculated component mean losses.
- Three times the square root of the sum of the calculated component variances plus the jumper assembly variance loss (0.05 dB).
- The jumper assembly loss and the excess connector loss. For a 9-µm trunk cable, these values are:
  - Jumper assembly loss = 0.3 dB
  - Excess connector loss = 0.2 dB.

Loss calculation example for a single-mode link

Figure 45 shows a link example consisting of:

- Jumper Cable 1 (IBM duplex-to-duplex, single-mode, 92 meters).
- Jumper Cable 2 (IBM duplex-to-duplex, single-mode, 122 meters) (combined jumper cable length = 214 meters or 0.21 km).
- 19.76 km of 9-µm trunk cable.
- Two physical-contact ST connections (in each fiber).
- Two mechanical splices (in each fiber).

Note: The example of a completed Calculated Link Loss Work Sheet (Table 5 on page 58) uses Table 10 on page 68, which lists typical values for currently used components. Use Table 10 on page 68 **only** if the manufacturer's specifications are not available.

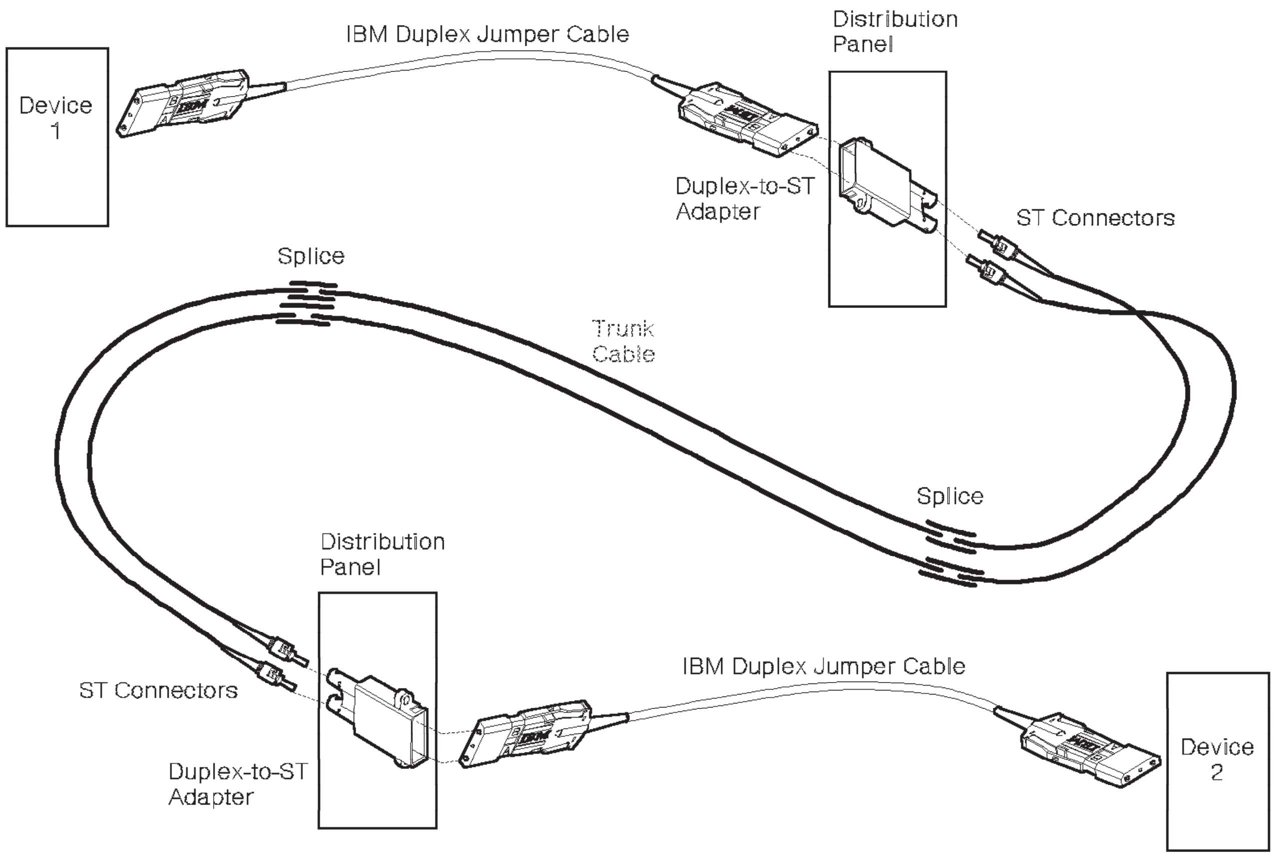

Figure 45. Example of a single-mode ESCON link

Table 5. Example of a completed Calculated Link Loss Work Sheet for a single-mode link. This example was completed for an ESCON link.

A. Calculating the single-mode component mean loss

Connection loss multiplied by the number of connections in the link:	__**0.35**__ dB	x	___**2**___	=	__**0.70**__ dB
Splice loss multiplied by total number of splices in the link:	__**0.15**__ dB	x	___**2**____	=	__**0.30**___ dB
Jumper cable loss multiplied by the combined length of the jumper cables:	__**0.8**___ dB/km	x	__**0.21**__ km	=	__**0.17**__ dB
Trunk loss per kilometer multiplied by the total trunk length (in km):	__**0.5**___ dB/km	x	__**19.76**__ km	=	__**9.88**__ dB
					(+) __________
			Total component mean loss		__**11.05**__ dB

B. Calculating the single-mode component variance loss

Connection variance multiplied by the number of connections in the link:	__**0.06**__	x	____**2**___	=	__**0.12**__ dB^2
Splice variance multiplied by total number of splices in the link:	__**0.01**__ dB^2	x	____**2**___	=	__**0.02**__ dB^2
					(+) __________
			Total component variance loss		__**0.14**__ dB^2

C. Calculating the total single-mode link loss

Total component mean loss:				=	__**11.05**__ dB
Square root of total component variance loss plus system variance loss (0.04 dB) multiplied by 3:	$\sqrt{\underline{\mathbf{0.14}} + 0.05\ dB^{2}}$	=	__**0.436**__ dB x 3	=	__**1.31**__ dB
Jumper assembly loss plus excess connector loss:				=	0.50 dB
					(+) __________
.			**Calculated link loss**		__**12.86**__ dB

Chapter 5. Specifications

This chapter lists the specifications and optical properties for a fiber optic channel link, IBM jumper cables, and trunk cable.

Link specifications

Table 6 lists the specifications for links using 9/125-, 62.5/125-, or 50/125-µm fiber cable. The trunk to which the IBM jumper cables are connected must have optical properties that conform to the specifications in the table.

Table 6. Maximum ESCON link loss (at 1300-nanometer wavelength)

Maximum link length in km (Miles)	Maximum link loss (dB)	Trunk size (µm)	Minimum trunk modal bandwidth (MHz•km)
2.0 (1.24)	8.0	62.5	500
2.0 (1.24)	8.0	50.0	800
2.0 to 3.0 (1.24 to 1.86)	8.0	62.5	800
20 (12.4)	14.0	9 to 10	NA

Notes:

1. The maximum link length includes both jumper and trunk cables.
2. The ESCON Extended Distance feature must be installed in both the channel and the ESCON Director to obtain a maximum link length of 20 kilometers (12.4 miles).
3. If using IBM's Fiber Transport Services offering, contact your marketing representative for distances.
4. The maximum total jumper cable length cannot exceed 244 meters (800 ft.) when using either 50/125-µm trunk fiber or when a 62.5/125-µm link exceeds 2 kilometers (1.24 miles).
5. Single-mode connectors and splices must meet a minimum return loss specification of 28 dB.
6. In a single-mode jumper cable, the minimum distance between connectors or splices is 4 meters (13.1 ft.).
7. In a single-mode trunk cable, the distance between connectors or splices must be sufficient to ensure that only the lowest-order bound mode propagates.
8. Some single-mode ESCON links use an FICON receptacle rather than an IBM duplex receptacle. The link loss and distance limitations are the same for both types of connectors on single-mode ESCON. The FICON-to-ESCON adapter kit (46H9223) does not add excess link loss or degrade the maximum distance.

Table 7. Maximum coupling link loss (at 1300-nanometer wavelength)

Maximum link length in km (Miles)	Maximum link loss (dB)	Trunk size (µm)	Minimum trunk modal bandwidth (MHz•km)
≤ 10 (6.2)	7	9 to 10	N/A to single-mode fiber
≤ 0.550* (.31)	5	50	500
* Requires mode conditioning patch cables on both ends of the link (1 Gbit/s links only).			
Note: Coupling links which support 1 km (0.62) with 50 µm fiber; 8 dB loss at 850 nm wavelength have been discontinued effective May 1998.			

Table 8. Maximum FICON link loss (at 1300-nanometer wavelength at 1, 2, 4 or 8 Gbit/s)

Data Rate	Maximum Link Length in km (Miles)	Maximum Link Loss (dB)	Trunk Size (µm)	Minimum Trunk Modal Bandwidth (MHz•km)
1 Gbit/s	10.00 (6.21)	7.80	9	N/A to single-mode fiber
1 Gbit/s	0.550 (0.34)	5.00	62.5*	200
1 Gbit/s	0.550 (0.34)	5.00	50*	500
2 Gbit/s	10.00 (6.21)	7.80	9**	N/A
4 Gbit/s	10.00 (6.21) ***	7.80	9**	N/A
4 Gbit/s	4.00 (2.48) ***	4.80	9**	N/A
8 Gbit/s	10.00 (6.21)***	6.4	9**	N/A
Notes: * Mode Conditioner Cable (FC0106) required for Trunk Fiber reuse. All Fiber between mode conditioners must be 62.5 µm. Requires matching LX optics. ** Use of Mode Conditioner Patch cables for MM Trunk Fiber reuse is not supported for 2/4 Gbit/s. *** IBM supports interoperability of 10 km transceivers with 4 km transceivers provided the unrepeated distance between a 10 km transceiver and a 4 km transceiver does not exceed 4 km (2.5 miles).				

Table 9. Maximum FICON link loss (at 850-nanometer wavelength)

Data rate	Maximum link length in km (Miles)	Maximum link loss (dB)	Trunk size (µm)	Minimum trunk modal bandwidth (MHz•km)
1 Gbit/s	0.860 (0.53)	4.62	50	2000
1 Gbit/s	0.500 (0.31)	3.85	50	500
1 Gbit/s	0.300 (0.19)	3.00	62.5	200
1 Gbit/s	0.250 (0.16)	2.80	62.5	160
2 Gbit/s	0.500 (0.31)	3.31	50	2000
2 Gbit/s	0.300 (0.19)	2.62	50	500
2 Gbit/s	0.120 (0.07)	2.10	62.5	200
4 Gbit/s	0.380 (0.23)	2.88	50	2000
4 Gbit/s	0.150 (0.09)	2.06	50	500
4 Gbit/s	0.070 (0.04)	1.78	62.5	200
8 Gbit/s	0.150 (0.09)	2.04	50	2000
8 Gbit/s	0.050 (0.03)	1.68	50	500
8 Gbit/s	0.021 (0.01)	1.58	62.5	200

Multi-mode trunk cable optical specifications

The following specifications for multi-mode trunk cable support attachment of ESCON-capable, FICON SX-capable, or coupling facility channel-capable devices. Use of trunk fiber having different specifications significantly alters link characteristics. Be sure to use the specification corresponding to the operating wavelength of the channel.

62.5/125-µm Multi-mode trunk cable	
Type of fiber	Graded index with glass core and cladding
Core diameter[1]	62.5 ±3.0 µm
Core noncircularity	6% maximum
Cladding diameter[2]	125 ±3.0 µm
Cladding noncircularity	2% maximum
Core and cladding offset	3µm maximum
Numerical aperture[3]	0.275 ± 0.015
Minimum modal bandwidth[4]	500 MHz• km at ≤ 2 km at 1300 nm or 160 MHz• km at 850 nm 800 MHz• km at > 2 km and ≤ 3 km at 1300 nm
Attenuation (See note)	1.0 dB/km at 1300 nm 4.0 dB/km at 850 nm
50.0/125-µm Multi-mode Trunk Cable	
Type of fiber	Graded index with glass core and cladding
Core diameter [1]	50.0 ±3.0 µm
Core noncircularity	6% maximum
Cladding diameter[2]	125 ±3.0 µm
Cladding noncircularity	2% maximum
Core and cladding offset	3µm maximum
Numerical aperture[3]	0.200 ± 0.015
Minimum modal bandwidth[4]	800 MHz•. km at ≤ 2 km at 1300 nm 0r 500 MHz• km at ≤ 1 km at 850 nm
Attenuation (See note)	0.9 dB/km at 1300 nm or 3.0 dB/km at 850 nm

Note: This attenuation is a typical value rather than a specification. Use the actual dB/km attenuation value when completing the Calculated Link Loss Work Sheet.

Notes:

1. Measured in accordance with EIA 455 FOTP 58, 164, 167 (or equivalent).
2. Measured in accordance with EIA 455 FOTP 27, 45, 48 (or equivalent).
3. Measured in accordance with EIA 455 FOTP 47 (or equivalent).
4. Measured in accordance with EIA 455 FOTP 51 (or equivalent).

Single-mode trunk cable optical specifications

The following specifications for single-mode trunk cable support attachment of ESCON-capable, FICON-capable, or coupling facility channel-capable devices. Use of trunk fiber having different specifications significantly alters link characteristics. These specifications conform to CCITT recommendation G.652.

Type of fiber	Dispersion unshifted
Mode field diameter[3]	9.0 to 10.0 µm ± 10% (coupling facility channel: 8.7-10.0 µm)
Core concentricity error[4]	1.0 µm maximum
Cladding diameter[4]	125 ±2.0 µm
Cladding noncircularity[4]	2% maximum
Zero dispersion wavelength[5]	1295-1322 nm (coupling facility channel: 1310-1322)
Zero dispersion slope[5]	0.095 ps/(nm^2•km) maximum
Cutoff wavelength (λ_c)[6]	1280 nm maximum
Cutoff wavelength (λ_{cc})[7]	1260 nm maximum
Attenuation above normal (See note 1)	0.06 dB/km maximum
Attenuation (See note 2)	0.5 dB/km at 1310 nm

Notes:

1. Maximum attenuation for wavelengths from 1270 to 1340 nm must not exceed the attenuation at 1310 nm by more than 0.06 dB/km. Typically, this specification can be met by fiber with 1383-nm OH absorption peaks below 2 dB/km.
2. This attenuation is a typical value rather than a specification. Use the actual dB/km attenuation value when completing the Calculated Link Loss Work Sheet.
3. Measured in accordance with EIA 455 FOTP 164, 167 (or equivalent).
4. Measured in accordance with EIA 455 FOTP 45, 48 (or equivalent).
5. Measured in accordance with EIA 455 FOTP 168 (or equivalent).
6. Measured in accordance with EIA 455 FOTP 80 (or equivalent).
7. Measured in accordance with EIA 455 FOTP 170 (or equivalent).

IBM multi-mode jumper cable specifications (62.5 µm)

Optical specifications

Core diameter[1]	62.5 ±3.0 µm
Cladding diameter[2]	125 ±2.0 µm
Numerical aperture[3]	0.275 ± 0.015
Minimum modal bandwidth[4]	800 MHz•. km at 1300 nm or 160 MHz• km at 850 nm
Optical loss	1.75 dB/km maximum at 1300 nm 4.0 dB/km maximum at 850 nm
Notes: 1. Measured in accordance with EIA 455 FOTP 58 (or equivalent). 2. Measured in accordance with EIA 455 FOTP 27, 45, 48 (or equivalent). 3. Measured in accordance with EIA 455 FOTP 47 (or equivalent). 4. Measured in accordance with EIA 455 FOTP 51 (or equivalent).	

Physical specifications

Connector color	Black or Beige
Jacket color	Orange
Jacket outside diameter	4.8 mm (0.189 in.), SC duplex; 2 mm (0.08 in.) MT–RJ
Weight (see note [for information only])	20 grams per meter (0.013 pound per foot)
Installation tensile strength (see note)	1000 newtons (225 lbf) maximum
Minimum bend radius (during installation)	4.0 mm (0.157 in.); 5 seconds maximum at 400 newtons (90lbf)
Minimum installed bend radius:	
No load	12 mm (approx. 0.5 in.)
Long-term residual	25 mm (approx. 1.0 in.) at 89 newtons (20 lbf) maximum
Flammability	Underwriters Laboratory-rated OFNR (Optical Fiber Nonconductive, Riser) UL-1666 (Plenum UL-910 is also acceptable)
Crush resistance	500 newtons per centimeter (286 lbf per inch) maximum
Maximum unsupported vertical rise	100 meters (328 feet)
Note: Cables only; connectors not included	

Environmental specifications

Operating environment	Inside buildings only
Operating temperature	10°C to +60°C (+40°F to +140°F)
Operating relative humidity	5% to 95%
Storage and shipping temperature	-40°C to +60°C (-40°F to +140°F)
Lightning protection	None required
Grounding	None required

IBM multi-mode jumper cable specifications (50 µm)

Optical specifications

Core diameter[1]	50.0 ±3.0 µm
Cladding diameter[2]	125 ±2.0 µm
Numerical aperture[3]	0.200 ± 0.015
Minimum modal bandwidth[4]	500 MHz•. km at 1300 nm or 850 nm
Optical loss	1.75 dB/km maximum at 1300 nm 4.0 dB/km maximum at 850 nm

Notes:
1. Measured in accordance with EIA 455 FOTP 58 (or equivalent).
2. Measured in accordance with EIA 455 FOTP 27, 45, 48 (or equivalent).
3. Measured in accordance with EIA 455 FOTP 47 (or equivalent).
4. Measured in accordance with EIA 455 FOTP 51 (or equivalent).

Physical specifications

Connector color	Black or Beige
Jacket color	Orange
Jacket outside dimensions	Zip cord
Installation tensile strength (see note)	800 newtons (180 lbf) maximum
Minimum bend radius (during installation)	50 mm (1.969 in.); 5 seconds maximum at 100 newtons (22.5lbf)
Minimum installed bend radius:	
No load	30 mm (approx. 1.2 in.)
Long-term residual	50 mm (approx. 2.0 in.) at 80 newtons (18 lbf) maximum
Flammability	Underwriters Laboratory-rated OFNP (Optical Fiber Nonconductive, Plenum) UL-910
Crush resistance	888.8 newtons per centimeter (508 lbf per inch) maximum[2]

Notes:
1. Cables only; connectors not included.
2. Measured in accordance with EIA 455-41.

Environmental specifications

Operating environment	Inside buildings only
Operating temperature	10°C to +60°C (+40°F to +140°F)
Operating relative humidity	5% to 95%
Storage and shipping temperature	-40°C to +60°C (-40°F to +140°F)
Lightning protection	None required
Grounding	None required

IBM single-mode jumper cable specifications

Optical specifications (at 1300-nm wavelength)

Operating wavelength	1270 to 1355 nm
Mode field diameter[1]	8.7 to 10 µm
Zero dispersion wavelength[2]	1310 ± 10 nm
Dispersion (1270-1340 nm)[2]	3.5 ps/(nm•km) maximum
Cutoff wavelength[3]	1260 nm maximum
Attenuation (1270-1340 nm)[4]	0.8 dB/km maximum

Notes:
1. Measured in accordance with EIA 455 FOTP 164, 167 (or equivalent).
2. Measured in accordance with EIA 455 FOTP 168 (or equivalent).
3. Measured in accordance with EIA 455 FOTP 80 (or equivalent).
4. Measured in accordance with EIA 455 FOTP 78 (or equivalent).

Physical specifications

Connector color	Grey or Blue
Jacket material	Yellow polyvinyl chloride (PVC)
Jacket outside dimensions	Zip cord
Weight[2]	20 grams per meter (0.013 pound per foot)
Installation tensile strength[2]	1000 newtons (225 lbf) maximum
Minimum bend radius (during installation)	50 mm (1.969 in.); 5 seconds maximum at 100 newtons (22.5lbf)
Minimum installed bend radius:	
No load	30 mm (approx. 1.2 in.)
Long-term residual	50 mm (approx. 2.0 in.) at 80 newtons (18 lbf) maximum
Flammability	Underwriters Laboratory-rated OFNR (Optical Fiber Nonconductive, Riser) UL-1666 (see note 1)
Crush resistance	889 newtons per centimeter (199.9 lbf per inch) maximum[3]
Maximum unsupported vertical rise	100 meters (328 feet)

Notes:
1. Contact your account representative for availability of plenum and halogen-free cables (UL-910).
2. Cables only; connectors not included.
3. Measured in accordance with EIA 455-41.

Environmental specifications

Operating environment	Inside buildings only
Operating temperature	0°C to +60°C (+32°F to +140°F)
Operating relative humidity	8% to 95%
Storage and shipping temperature	-40°C to +60°C (-40°F to +140°F)
Lightning protection	None required
Grounding	None required

Typical optical component loss values

The following loss values are typical for optical components used in the data communication industry. Use the manufacturer's loss values if available.

Note: Optical loss is not the only consideration in a link. Dispersion increases with distance and its effects increase with data rate.

Table 10. Typical Optical Component Loss

Component	Description	Size (µm)	Mean loss	Variance (dB^2)
Connector	Physical contact	62.5 to 62.5	0.40 dB	0.02
(See note 1)		50.0 to 50.0	0.40 dB	0.02
		9.0 to 9.0 **(See note 2)**	0.35 dB	0.06
		62.5 to 50.0 **(See note 3)**	2.10 dB	0.12
		50.0 to 62.5	0.00 dB	0.01
Connector	Nonphysical contact	62.5 to 62.5	0.70 dB	0.04
(See note 1)	(Multi-mode only)	50.0 to 50.0	0.70 dB	0.04
		62.5 to 50.0 **(See note 3)**	2.40 dB	0.12
		50.0 to 62.5	0.30 dB	0.01
Splice	Mechanical	62.5 to 62.5	0.15 dB	0.01
		50.0 to 50.0	0.15 dB	0.01
		9.0 to 9.0 **(See note 2)**	0.15 dB	0.01
Splice	Fusion	62.5 to 62.5	0.40 dB	0.01
		50.0 to 50.0	0.40 dB	0.01
		9.0 to 9.0 **(See note 2)**	0.40 dB	0.01
Cable	IBM Multi-mode jumper	62.5	1.75 dB/km	NA
	IBM Multi-mode jumper	50.0	3.00 dB/km at 850 nm	NA
	IBM Single-mode jumper	9.0	0.8 dB/km	NA
	Trunk	62.5	1.00 dB/km	NA
	Trunk	50.0	0.90 dB/km	NA
	Trunk	9.0	0.50 dB/km	NA

Notes:

1. The connector loss value is typical when attaching identical connectors. The loss can vary significantly if attaching different connector types.
2. Single-mode connectors and splices must meet a minimum return loss specification of 28 dB.
3. Connecting 62.5 to 50.0 with no mode conditioning patch cable is not recommended. It can cause modal noise in addition to the loss.

Appendix A. Measurement conversion tables

This appendix contains conversion tables from English measurements to metric and metric measurements to English.

English-to-metric conversion table

English value	Multiplied by	Equals metric value
Fahrenheit	(°F -32) x 0.556	Celsius
Inches	2.54	Centimeters (cm)
Inches	25.4	Millimeters (mm)
Feet	0.305	Meters (m)
Miles	1.61	Kilometers (km)
Pounds	0.45	Kilograms (kg)
Pound force (lbf)	4.45	Newtons (N)

Metric-to-english conversion table

English value	Multiplied by	Equals metric value
Celsius	(°C x 1.8) + 32	Fahrenheit
Centimeters (cm)	0.39	Inches
Millimeters (mm)	0.039	Inches
Meters (m)	3.28	Feet
Kilometers (km)	0.621	Miles
Kilograms (kg)	2.20	Pounds
Newtons (N)	0.225	Pound force (lbf)

Appendix B. Multi-mode Calculated Link Loss Work Sheet

A. Calculating the multi-mode component mean loss

Connection loss multiplied by the number of connections in the link:					
________- µm-to-________- µm connection:	________ dB	x	________	=	________ dB
________- µm-to-________- µm connection:	________ dB	x	________	=	________ dB
Splice loss multiplied by total number of splices in the link:	________ dB	x	________	=	________ dB
Jumper cable loss multiplied by the combined length of the jumper cables:	________ dB/km	x	________ km	=	________ dB
Trunk loss per kilometer multiplied by the total trunk length (in km):	________ dB/km	x	________ km	=	________ dB
					(+) __________
			Total component mean loss		________ dB

B. Calculating the multi-mode component variance loss

Connection variance multiplied by the number of connections in the link:					
________- µm-to-________- µm	________ dB^2	x	________	=	________ dB^2
________- µm-to-________- µm connection:	________ dB^2	x	________	=	________ dB^2
Splice variance multiplied by total number of splices in the link:	________ dB^2	x	________	=	________ dB^2
					(+) __________
			Total component variance loss		________ dB^2

C. Calculating the total multi-mode link loss

Total component mean loss:				=	________ dB
Square root of total component variance loss multiplied by 3:	$\sqrt{\underline{\hspace{2cm}}\ dB^2}$	=	________ dB x 3	=	________ dB
High order mode loss (ESCON only): 50.0-µm trunk = 1.5 dB 62.5-µm trunk = 1.0 dB				=	________ dB (+) __________
			Calculated link loss		________ dB

Appendix C. Single-mode Calculated Link Loss Work Sheet

A. Calculating the single-mode component mean loss

Connection loss multiplied by the number of connections in the link:	________ dB	x	________	=	________ dB
Splice loss multiplied by total number of splices in the link:	________ dB	x	________	=	________ dB
Jumper cable loss multiplied by the combined length of the jumper cables:	________ dB/km	x	________ km	=	________ dB
Trunk loss per kilometer multiplied by the total trunk length (in km):	________ dB/km	x	________ km	=	________ dB
					(+) __________
			Total component mean loss		________ dB

B. Calculating the single-mode component variance loss

Connection variance multiplied by the number of connections in the link:	________ dB^2	x	________	=	________ dB^2
Splice variance multiplied by total number of splices in the link:	________ dB^2	x	________	=	________ dB^2
					(+) __________
			Total component variance loss		________ dB^2

C. Calculating the total single-mode link loss

Total component mean loss:				=	________ dB
Square root of total component variance loss multiplied by 3:	$\sqrt{\_\_\_\_\_\_ + 0.05\ dB^2}$	=	________ dB x 3	=	________ dB
Jumper assembly loss plus excess connector loss:				=	0.50 dB
					(+) __________
			Calculated link loss		________ dB

Appendix D. General fiber optic direction

Introduction

Mainframes have undergone many changes in the past 10 years. One significant change occurred in 1990, with the introduction of ESCON and the use of fiber optic cabling in the data center. By now, the architectures and protocols utilizing fiber optic cabling are well understood:

- Coupling links (Inter System channels - ISCs) for clustering (Parallel Sysplex)
- ESCON for server-to-server and I/O - directors, disk, tape, printers
- FICON for server-to-server and I/O - switches, directors, disk, tape, printers
- Open Systems Adapter (OSA) for Local Area Network traffic - Gigabit Ethernet, 10 Gigabit Ethernet

These technologies have unique requirements - to link data rates, distances, and fiber types. This chapter provides a summary of the different capabilities provided by each type of optical interconnection.

Storage area networks

ESCON

From the introduction of the IBM System/360™ in 1964 until the first use of ESCON 26 years later, only incremental upgrades had been made to the enterprise server computer I/O interface. The basic interconnection technology for attachment to storage devices or I/O devices such as DASD or tape drives consisted of a parallel copper interface with a peak data rate of 4.5 Mbytes/s and a maximum distance of 122 meters (400 feet). Indeed, this distance limitation is one reason why most enterprise server complexes were contained in a single room or “glass house” with storage devices and peripherals clustered adjacent to the enterprise server. This technology remained unchanged until the introduction of the Enterprise Systems Connection (ESCON) architecture was first introduced on the IBM System/390® family in 1990 as an alternative high speed I/O channel attachment. The ESCON interface quickly became the de facto industry standard for large system attachments; the specifications were subsequently published and adopted by other original equipment manufacturers (OEM). In 1996 they were adopted by the ANSI X3T1 committee as the Serial Byte Connection (SBCON) standard.

The ESCON channel is a bi-directional, point-to-point architecture supporting a 1300 nanometer Light Emitting Diode (LED) transceiver with a maximum link rate of 17 Mbytes/s (200 Mbit/s). The physical layer specifications are given in Table 11 on page 82. ESCON supports a maximum unrepeated distance of 3 km using 62.5 micron multi-mode fiber and LED transmitters with an 8 dB link budget, or a maximum unrepeated distance of 20 km using single-mode fiber and laser transceivers with a 14 dB link budget. The single-mode links are also known as the ESCON Extended Distance Feature (XDF), available only on ESCON repeaters (9036) and Directors (9032 and 9033). All of these products have been withdrawn from marketing. IBM can sometimes support ESCON links that do not meet the specified distance and link budget considerations, or that exceed the maximum allowed specifications by a small amount. This support is provided on an individual basis. Interested customers can contact their IBM sales representative to inquire about support for non-standard fiber optic links.

Physical connection to the ESCON link is provided by an ESCON Duplex connector on S/390 servers and in the compatibility I/O cage of zSeries 900. MT-RJ connectors are supported on all System z servers.

The ESCON Duplex connector features a unique spring-loaded retractable dust cover, which protects the ferrules when the connector is not in use and retracts upon insertion into an ESCON receptacle. The connector was designed specifically to provide a low profile, ease of use, consistently low loss, and a rugged, repeatable connection.

Initially, the ESCON duplex connector was offered in both multi-mode and single-mode versions, color coded with black connectors/orange fiber jacket for multi-mode and gray connectors/yellow fiber jacket for single-mode. **The single-mode ESCON links adopted the SC Duplex connector, followed later by the LC Duplex connector as standardized by Fibre Channel. Conversion kits are available to convert from one connector type to another (such as ESCON Duplex to MT-RJ).**

ESCON devices and servers may communicate directly through a channel-to-channel (CTC) attachment, but more commonly attach to a central non-blocking dynamic crosspoint switch. The resulting network topology is a point-to-point star, which provides both effective bandwidth utilization, connectivity, and reduced cabling requirements. This structure also makes it easy to add or reconfigure equipment while maintaining the ability to isolate and partition subdivisions of the network. The switching function is provided by an ESCON Director, a non-blocking circuit switch. With the use of repeaters or switches, an ESCON link can be extended up to greater distances; however, performance of the attached devices typically falls off quickly at longer distances due to the longer round-trip latency of the link, making this approach suitable only for workloads that can tolerate a lower effective throughput, such as remote backup of data for disaster recovery. It is possible for multiple system images to share a common ESCON channel using the Multiple Image Facility (MIF). The same physical layer hardware used on the ESCON channel (ESCON Duplex) also supports the Sysplex Timer (9037-002), which uses the External Time Reference (ETR) architecture that synchronizes the Time-of-Day (TOD) clocks of all attached servers.

FICON

In May 1998, IBM announced FIbre Connection (FICON) on S/390 Generation 5 (G5) servers. FICON began shipping in August 1999. The FICON channels are based on the ANSI Fibre Channel Standard, established in 1994. FICON was introduced to provide higher speed link data rates and to increase the overall I/O capacity of the faster G5 server. Since the higher speed channels provide more efficient use of the channel capacity, IBM was able to offer increased capability without exceeding the 256 channel architecture.

The physical specifications of the FICON channel are given in Table 11 on page 82. The initial link data rate for a FICON channel was 1Gbit/s (100MByte/s). A FICON channel, depending upon the generation of the server and the feature, is designed to support a link data rate of 1, 2, 4 or 8 Gbps auto-negotiated . These link data rates are consistent with the ANSI Fibre Channel Standard. FICON multi-mode (SX) links may allow enterprises to use their existing multi-mode fiber optic cable plant at reduced distances. Cable plants with mixed types of multi-mode fiber (50 and 62.5 micron) are not supported for use in the same link. At introduction, FICON links used the same SC duplex transceiver used by ESCON XDF and ISCs. When zSeries was introduced, the migration to Small Form Factor LC Duplex transceivers occurred for ISCs, FICON, and Gigabit Ethernet.

Parallel Sysplex ISC coupling links

In 1994, IBM announced the Parallel Sysplex architecture for the S/390 servers. This architecture uses high speed fiber optic data links to couple servers together in parallel, thereby increasing capacity and scalability. Servers can be interconnected using a Coupling Facility, which is designed to provide data caching, locking, and queuing services; it may be implemented as a logical partition (LPAR) rather than a separate physical device.

The Inter System Channel (ISC) or Coupling Link uses single-mode fiber and operates at distances up to 10 km with a 7 dB link budget as defined in Table 11 on page 82 (ISC links were originally announced with a maximum distance of 3 km, which was increased to 10 km in May 1998). These links operate at 1 or 2Gbit/s. Initially, these links used the SC duplex connector, but now they use the SFF (Small Form Factor) optics and thus use the LC duplex connector. When ISC links were originally announced, an optional interface at 531 Mbit/s was offered using short wavelength lasers on multi-mode fiber. The 531 Mbit/s ISC links were discontinued in May 1998 for the G5 and follow-ons, consistent with single-mode fiber optic strategy. A feature is available to accommodate operation of 1 Gbit/s ISC adapters on multi-mode fiber, using a Mode Conditioning Patch (MCP) cable at restricted distances. ISC-3 on System z9 supports 2 Gbps link data rates exclusively.

Parallel Sysplex IFB coupling links

In 2008 the IBM System z10 EC introduced InfiniBand® Trade Association coupling link technology designed to provide increased bandwidth at greater cable distances. At introduction, InfiniBand coupling links complement and do not replace the current coupling links (ICB-4, ISC-3) which continue to work with current System z10 EC and zSeries servers.

The IBM System z10 EC will support a 12x (12 lanes of fibre in each direction) InfiniBand-Double Data Rate (IB-DDR) coupling link which is designed to support a total interface link data rate of 6 GigaBytes per second (GBps) in each direction. The maximum distance for this point-to-point link over fibre optic cabling is 150 meters (492 feet). This new InfiniBand coupling link provides improved performance over the current ISC-3 coupling link in data centers where systems are less than 150 meters apart.

A 12x InfiniBand-Single Data Rate (IB-SDR) coupling link is available on System z9 EC and System z9 BC S07 servers configured as internal coupling facilities (ICFs) only. This coupling link is designed to support a total interface link data rate of 3 GigaBytes per second (GBps) in each direction. This new InfiniBand coupling link provides improved performance over the current ISC-3 coupling link in data centers where systems are less than 150 meters apart. When a System z10 EC server is connected to a System z9 server using point-to-point InfiniBand cabling, the link auto-negotiates to the highest common data rate of 3 GBps.

Single-mode versus multi-mode fiber optic cable installation considerations

As link data rates increase, the unrepeated distance decreases when using multi-mode fiber optic cabling. With this paradigm, it is essential that enterprises install a communication media that supports increased link data rates and increased distances. As a general guideline, the maximum distance and link loss budgets of a multi-mode fiber optic link decreases by half each time the link data rate doubles). The use of single-mode fiber for data communications is designed for long distance applications (more than a few hundred meters). The use of single-mode fiber optic cable plants is designed to allow enterprises to take maximum advantage of higher speed fiber optic technology as it becomes available while continuing to maintain the maximum distance capability that fiber optic technology allows. For example, a 2 Gbps fiber optic link using single-mode fiber supports an unrepeated distance of 10 km, while a multi-mode fiber link at 2 Gbps may be limited to 275 meters (depending on the MHz-km rating of the fiber). As the link data rate increases to 4 Gbps and beyond, the unrepeated distance when using multi-mode fiber will continue to decline.

Single-mode fiber is often the preferred fiber of the worldwide telecommunications industry for all links. All current and future fiber optic interfaces are designed to meet international laser and optical safety classifications for inherently safe (class 1) operation. New fiber installations should contain single-mode fiber ‘to take advantage of link data rate increases. Single-mode fiber offers maximum flexibility and extendibility for the future, and is the best way to protect the cable plant investment. Specifications for single-mode fiber are available in fiber optic installation and planning guides or from local fiber suppliers.

References

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"Fiber Transport Services Physical and Configuration Planning" (IBM document number GA22-7234), IBM Corp., Mechanicsburg, PA (1998)

Figures

FICON attachments

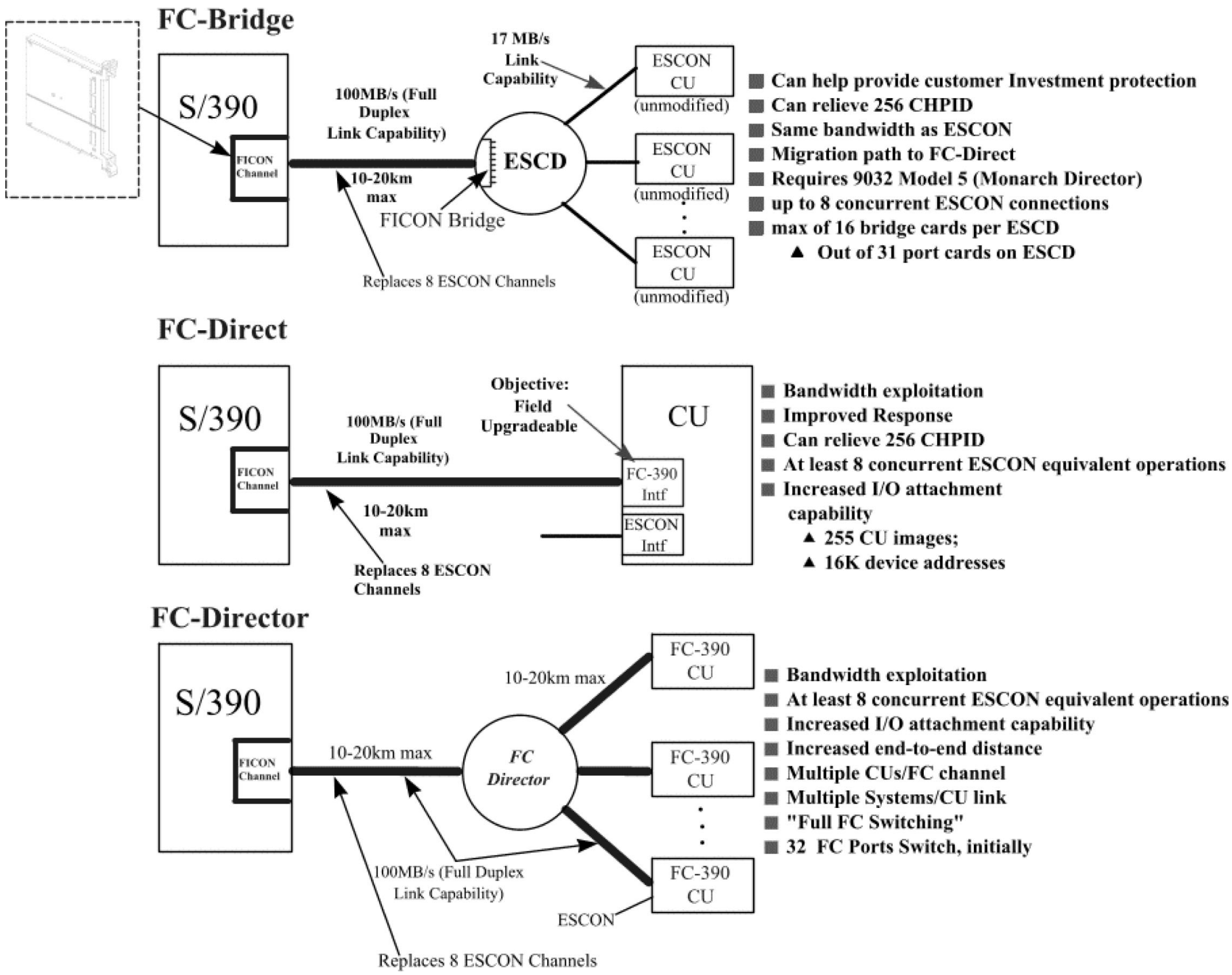

Figure 46. FICON configurations (Including the FICON bridge, direct attach, and attachment via 9032-5 directors)

Geographically dispersed Parallel Sysplex™

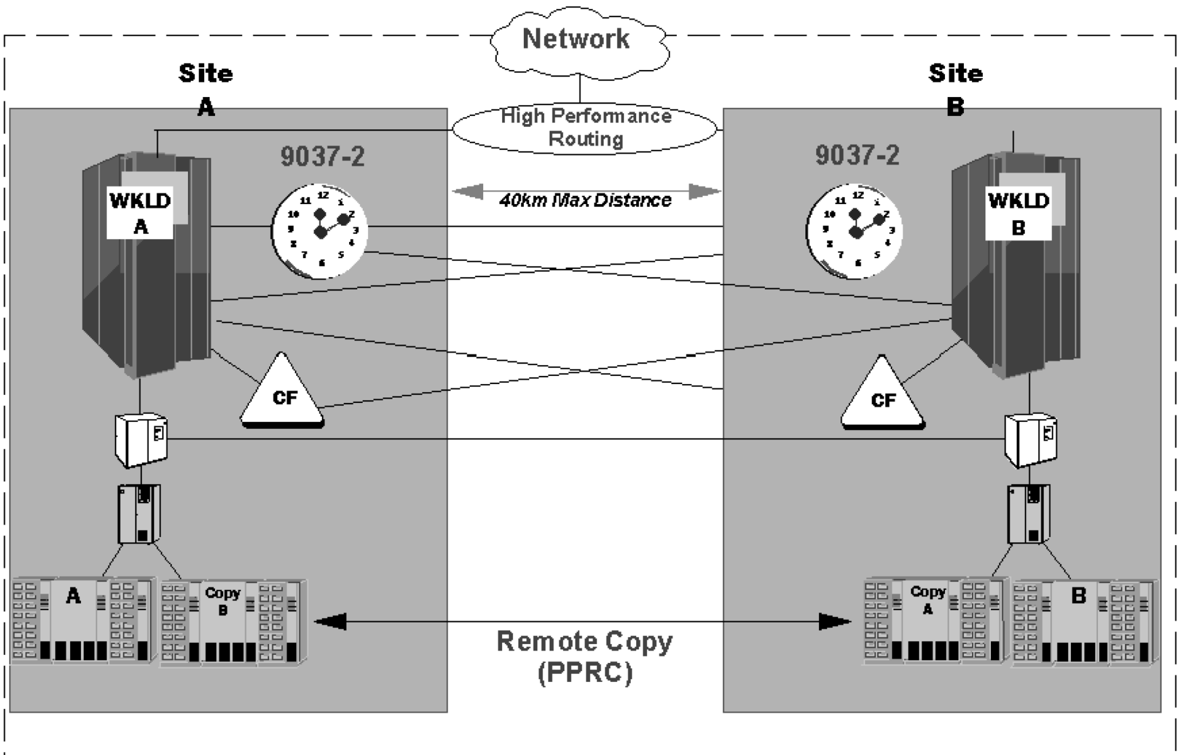

Figure 47. Typical large Parallel Sysplex (Geographically distributed parallel sysplex) using the IBM 9729 and S/390 (from Geographically distributed parallel sysplex paper)

Fiber optic channel attachment options

This table lists maximum unrepeated distance and link budget for each type of channel; longer distances are possible using repeaters, switches, or channel extenders. SBCON is the non-IBM trademarked name of the ANSI industry standard. All industry standard links (ESCON/SBCON) follow published industry standards. Minimum bandwidth requirement to achieve these distances is listed for multi-mode fiber only, this specification does not apply to single-mode fiber. MCP denoted mode conditioning patch cable, which is required to operate some links over multi-mode fiber. Bit rates given below may not correspond to effective channel data rate in a given application due to protocol overheads and other factors. SC duplex connectors are keyed per the ANSI Fibre Channel Standard specifications. Deviations from these specifications, including longer distances, may be possible and are evaluated on an individual basis by submitting a Request for Price Quote (RPQ) to IBM. Various types of non-fiber optic interconnects are also supported, including Token Ring, Ethernet, Fast Ethernet, and Parallel Channel (Bus-and-Tag).

Table 11. Fiber optic channel attachment options

Channel Type	Fiber	Connector	Bit Rate	Distance/Bandwidth	Link Budget
ESCON (SBCON)	Single-mode	SC Duplex	200 Mbit/s	20 km	14 dB
	Multi-mode 62.5	ESCON Duplex or MT–RJ Duplex	200 Mbit/s	2 km/500 MHz-km 3 km/800 MHz-km	8 dB
	Multi-mode 50.0	ESCON Duplex or MT–RJ Duplex	200 Mbit/s	2 km/800 MHz-km	8 dB
	OM3	ESCON Duplex or MT–RJ Duplex	200 Mbit/s	3 km/2000 MHz-km	8 dB
Sysplex Timer® (ETR/CLO)	Multi-mode 62.5	ESCON Duplex	16 Mbit/s	2 km/500 MHz-km 3 km/800 MHz-km	8 dB
FICON (LX)	Single-mode	SC Duplex or LC Duplex	1.06 Gbit/s	10 km	7.8 dB
	Multi-mode 62.5 (With MCP)	SC Duplex	1.06 Gbit/s	550 meters/500 MHz-km	5 dB
	Multi-mode 50.0 (With MCP)	SC Duplex	1.06 Gbit/s	550 meters/400 MHz-km	5 dB
FICON Express2 (LX)	Single-mode	LC Duplex	2.13 Gbit/s	10km	7.8 dB
FICON Express4 (LX)	Single-mode	LC Duplex	4.25 Gbit/s	10 km	7.8 dB
	Single-mode	LC Duplex	4.25 Gbit/s	4 km	4.8 dB
FICON Express8 (LX)	Single-mode	LC Duplex	8.5 Gbit/s	10 km	6.4 dB
FICON (SX)	Multi-mode 62.5 *	SC Duplex or LC Duplex	1.06 Gbit/s	300 meters/200 MHz-km	3.0 dB
	Multi-mode 50.0 *	SC Duplex or LC Duplex	1.06 Gbit/s	500 meters/500 MHz-km 860 meters/2000 MHz-km	3.85 dB 4.62 dB
FICON Express2 (SX)	Mult-imode 62.5	LC Duplex	2.13 Gbit/s	150 meters/200 MHz-km	2.10 dB
	Multi-mode 50.0	LC Duplex	2.13 Gbit/s	300 meters/500 MHz/km 500 meters/2000 MHz-km	2.62 dB 3.31 dB
FICON Express4 (SX)	Multi-mode 62.5	LC Duplex	4.25 Gbit/s	70 meters/200 MHz-km	1.78 dB
	Multi-mode 50.0	LC Duplex	4.25 Gbit/s	150 meters/500MHz/km 380 meters/2000 MHz-km	2.06 dB 2.88 dB
FICON Express8 (SX)	Multi-mode 62.5	LC Duplex	8.5 Gbit/s	21 meters/200 MHz/km	1.58 dB
	Multi-mode 50.0	LC Duplex	8.5 Gbit/s	50 meters/500MHz/km 150 meters/2000 MHz-km	1.68 dB 2.04 dB
Coupling Link (ISC)	Single-mode	SC Duplex or LC Duplex	1.06 Gbit/s	10 km (Increased from 3 km May 1998) RPQ to 20 km	7 dB
	Single-mode	LC Duplex	2.1 Gbit/s	10 km	7 dB
	Multi-mode 50.0 (With MCP)	SC Duplex	1.06 Gbit/s	550 meters/500 MHz-km	5 dB
	Multi-mode 50.0 * (Withdrawn May 1998; RPQ only)	SC Duplex	531 Mbit/s	1 km/500 MHz-km *	8 dB *

Table 11. Fiber optic channel attachment options (continued)

Channel Type	Fiber	Connector	Bit Rate	Distance/Bandwidth	Link Budget
OSA-Express2 (GbE) LX	Single-mode	SC Duplex	1.25 Gbit/s	5 km	4.6 dB
	Multi-mode 62.5 (With MCP)	SC Duplex	1.25 Gbit/s	550 meters/500 MHz-km	2.4 dB
	Multi-mode 50.0 (With MCP)	SC Duplex	1.25 Gbit/s	550 meters/500 MHz-km	2.4 dB
OSA-Express2 (GbE) SX	Multi-mode 62.5	SC Duplex	1.25 Gbit/s	275 meters/200 MHz-km	2.6 dB
	Multi-mode 50.0	SC Duplex	1.25 Gbit/s	550 meters/500 MHz-km	3.6 dB
OSA- Express2 10GbE (LR)	Single-mode	SC Duplex	10.3125 Gbit/s	10km	9.4 dB***
OSA- Express3 (GbE) LX	Single-mode	LC Duplex	1.25 Gbit/s	5 km	4.6 dB
	Multi-mode	LC Duplex	1.25 Gbit/s	550 meters/500 MHz-km	2.4 dB
OSA- Express3 (GbE) SX	Multi-mode	LC Duplex	1.25 Gbit/s	550 meters/500 MHz-km	3.6 dB
	Multi-mode	LC Duplex	1.25 Gbit/s	275 meters/200 MHz-km	2.6 dB
	Multi-mode	LC Duplex	1.25 Gbit/s	200 meters/160 MHz-km	2.6 dB
OSA- Express3 10GbE (LR)	Single-mode	LC Duplex	10.0 Gbit/s	10 km	6.0 dB
OSA- Express3 10GbE (SR)	Multi-mode	LC Duplex	10.0 Gbit/s	OM3	2.6 dB
OSA- Express3 10GbE (SR)	Multi-mode	LC Duplex	10.0 Gbit/s	OM2	1.8 dB
OSA- Express3 10GbE (SR)	Multi-mode	LC Duplex	10.0 Gbit/s	OM1	1.6 dB
PSIFB (1x IFB)	Single-mode	LC Duplex	2.5 / 5.0 Gbit/s	10 km	5.66 dB
PSIFB (12x IFB)	Multi-mode	12x MPO	3.0 GB/s	150 meters/2000 MHz-km	2.06 dB
	Multi-mode	12x MPO	6.0 GB/s	150 meters/2000 MHz-km	2.06 dB

* indicates channels which use short wavelength (850 nm) optics; all link budgets and fiber bandwidths are measured at this wavelength. Unless noted, all other links are long wavelength (1300 nm).

Mbit/s, reduced to an effective data rate of 100 Mbit/s by protocol overhead.

*** See 10GBASE-L link power budget in IEEE 802.3ae standard.

Appendix E. Notices

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Avis de conformlté aux normes du ministère des Communications du Canada

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EC Declaration of Conformity (In German)

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Verantwortlich für die Konformitätserklärung nach Paragraf 5 des EMVG ist die IBM Deutschland GmbH, 70548 Stuttgart.

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update: 2004/12/07

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