White Paper

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Permanent Link Testing of MPO Cable Plant for Higher Speed Channels

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Introduction

For new high-speed optical networks supporting 40Gb/s and 100Gb/s Ethernet over multimode fiber (MMF), it is critical to have accurate data indicating the performance of the permanent links deployed in the network. Links built to support these higher speed protocols require compliance with tight customer and industry specifications, therefore, very accurate/capable insertion-loss measurement processes are necessary to accommodate these specifications. It is also important to assure that the links deployed by end-users can meet the manufacturer's warranty requirements.

New higher speed LAN and SAN standards such as 40Gb/s and 100Gb/s Ethernet (IEEE-802.3ba) and 16Gb/s Fiber Channel (ANSI FC-PI-5) have increased data rates at the expense of reduced optical power budgets. Since the standardization of 1Gb/s Ethernet (1000BASE-SX) in 1998, the total Channel Insertion Loss (CIL) for these applications has been reduced from 3.56dB, to 1.9dB for 40GBASE-SR4 and 100GBASE-SR10. Consequently, for 40GBASE-SR4 and 100GBASE-SR10, a maximum connector insertion loss of 1.0dB is required for a 150m OM4 "engineered link" which may contain multiple connector interfaces. As a result, the need to accurately measure CIL is of vital importance.

The most widely accepted method of measuring the loss of a permanent link is the one reference patch cord method. Similar to component testing per TIA-FOTP 171, this method involves a single well-controlled, nearly ideal patch cord used as the test interface. Single reference cord methods for permanent link qualification yield a high degree of internal measurement repeatability and reproducibility between multiple test sets, Light Source/Power Meters (LSPM), and across many operators.

The current methodology for testing an MPO-based cable plant is to use reference grade MPO to LC or SC, fan-out harnesses. This is because up until recently, test equipment was delivered only with LC or SC connectors. Unfortunately, using reference fan-outs to test parallel optics MPO cable plant prevents using the single reference patch cord method.

To reliably measure the loss of a 30 meter OM4 permanent link and comply with the TIA and IEC standards requirements, one would expect a total loss to be a little over 1.5 dB. Typically, the capability of the test system should be 1/10 of the acceptance limits. This requires the test equipment's repeatability and reproducibility to be a small fraction of 1.5dB. Important questions to ask during testing are:

- What is the most capable and accurate measurement methodology for higher speed multimode links?
- What are the industry's best practices to assure that the number of measurement errors are reduced, saving time and money?

This white paper explores various test methods and best practices, and their impact on measurement accuracy, repeatability and reproducibility to enable installers to decide on the most effective methods for their needs. Use cases for testing MPO-based cable plant supporting higher speed applications are presented, highlighting a new and recently introduced MPO test set from Fluke Networks and new reference MPO connector systems from Panduit. This white paper also identifies how the combined technologies from Fluke Networks and Panduit address the issues surrounding permanent link testing.

Cable and Application Standards

Polarity and Gender Maintenance in Parallel Optics Systems

Responding to the growing adoption of fiber cabling based on multi-fiber connectivity, the TIA/EIA developed and published an addendum to the standards governing cabling systems. TIA/EIA-568-B.1 Addendum 7, *Guidelines for Maintaining Polarity Using Array Connectors*, is now formalized as TIA/EIA-568-C.1. TIA/EIA-568-C.1 also details a migration path from the cable plant that supports serial channels based on single fiber LC or SC connectors to the parallel optics plant that is based on array connectivity, or the MPO connector. This standard outlines three recommended methods for assuring correct transmit-to-receive polarity over serial duplex fiber networks using ribbon cables and MPO connectors. This document serves as a guideline and does not promote one method over another. It also states that other methods may be available to establish correct polarity throughout installation and during subsequent maintenance, upgrades, and additions.

Currently, there are two distinct types of cable plant for parallel optics. The first type is a cable plant originally built to support serial duplex communications. These permanent links are upgraded to parallel optics by replacing the male fan-outs or cassettes with MPO coupler panels. This leaves the female MPO trunks in place for connection to parallel optics electronics with female to male equipment cords. The female end is connected to the optical module and the male end is connected to the fiber trunk using the MPO coupler panel. The second type is a cable plant which is built with male trunks. This allows the use of equipment cords that are female on both ends. See Figure 1 for an illustration of both types of cable plant.

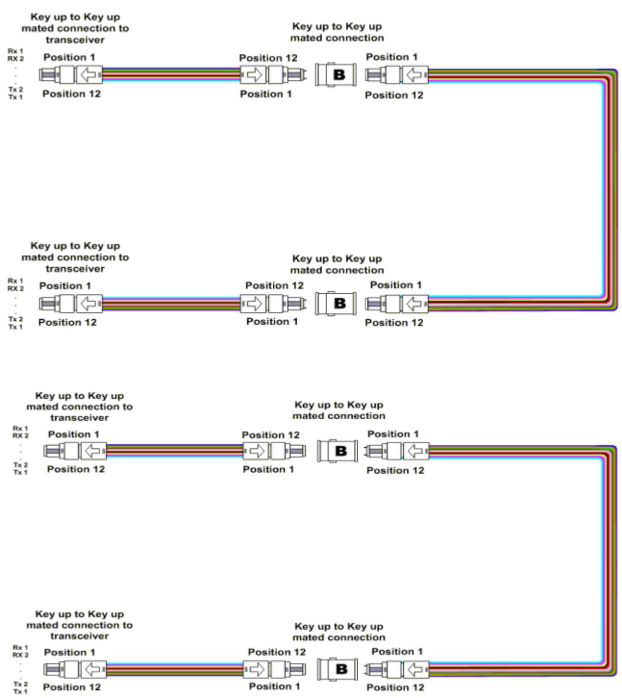

Figure 1. Legacy "migrated" cable plant (female trunks, hybrid cords) (top); "optimal" parallel optics cable plant (male trunks, standard cords) (bottom).

Permanent Link vs. Channel

ISO/IEC and TIA standards define the permanent link as the non-moveable fiber cabling infrastructure. Since the permanent link is non-moveable, this does not include equipment patch cords connecting to active network devices.

ISO/IEC and TIA standards define tests to verify the performance of the permanent links of installed cabling as accurately as possible. These tests provide assurance that permanent links can be reliably configured using quality patch cords to connect the permanent link to the active equipment.

ISO/IEC and TIA standards define the channel as an end-to-end link including equipment patch cords to connect the active network devices to the permanent link.

The application link power budget for Ethernet and Fiber Channel does not include the connectors that are attached to equipment on either end of the link. These are built into the link power budget as the difference between the minimum transmitter power into the fiber and receiver minimum sensitivity. As a result, the number of connectors in the channel is the total number of “mated pairs.” Connectors that are mated to the optical transceivers are not considered “mated pairs.”

Application Standards Power Budgets

The overall power budget for an optical channel is determined by the application standard, such as Ethernet, and is based on the magnitude of many power penalties, or impairments, as well as the maximum length of the channel. Typically, most of these optical impairments are small, under 0.3dB. However, Inter-symbol Interference (ISI) which is a function of the fiber’s bandwidth, and connector insertion loss, contribute large optical penalties and are the two primary impairments that limit the reach of the channel. The impact of these impairments is strongly influenced by the quality and practices used in the construction and testing of the channel.

There are two sources of loss: loss in the mated connectors which is Insertion Loss (IL) and loss of the laser energy within the fiber itself, or attenuation. IL is a critical parameter that determines the performance of a channel.

In principle, one can trade off cable attenuation for connector IL, or ISI power penalties for IL, however this must be done with caution. “Engineered links” are those channels designed making tradeoffs of parameters. As an example, consider an OM4 (M5F in Fiber Channel), 16Gb/s Fiber Channel link with an installed reach of 50m; this is a third of the maximum specified reach of an 150m engineered link (see Table 1).

Table 1. 16Gb/s fiber channel reach/power budget vs. total connector insertion loss.

Distance (m) / Loss Budget (dB)					
Fiber Type	**Connection Loss**				
	3.0 dB	**2.4 dB**	**2.0 dB**	**1.5 dB**	**1.0 dB**
M5F (OM4)	NA	50 / 2.58	100 / 2.36	125 / 1.95	150 / 1.54
M5E (OM3)		40 / 2.54	75 / 2.27	100 / 1.86	120 / 1.43
M5 (OM2)		NA	25 / 2.09	35 / 1.63	40 / 1.14

ISI for this channel is significantly less than when it is at 150m. As a result, a larger connector IL of 2.4dB can be tolerated. Alternatively, the ISI penalty can be reduced by using the increased fiber bandwidth of OM4.

It is important to understand and quantify the permanent link certification limits within the LSPM test procedure. The setup values for connector loss for “engineered links” in particular must be selected to be in compliance with the application standard if these limits are tighter than the relevant cabling standard. For example, the TIA/ISO typically states 0.75dB maximum per connector pair, but an “engineered link” may call for 0.5dB maximum, therefore the application standard takes precedence.

Link Certification

Several Permanent Link (PL) test configurations exist as defined by both TIA and IEC cabling standards. The goal of testing any permanent link should be to minimize the impact of the tester referencing cables so the test results are not biased.

Current Methods for Tier 1 Certification

There are three standard methods of completing a link loss test:

- One Reference Patch Cord Method (TIA Method ‘B’)
- Two Reference Patch Cord Method (TIA Method ‘A’)
- Three or “Golden” Reference Patch Cord Method (TIA Method ‘C’)

All of the methods use “reference quality” patch cords and adapters. This ensures accurate, repeatable and reproducible measurements.

Reference Patch Cords

Reference patch cords use high performance connectors which have optimal optical and geometrical characteristics such as Numerical Aperture (NA) and Core/Ferrule concentricity that produce near zero insertion loss when mated with other reference patch cords.

Figure 2. Reference patch cords.

Use of reference grade patch cords is a necessity to assure testing accuracy and repeatability, (replication of link tests under same reference) and reproducibility (across multiple test sets and references, as shown in Figure 2). These cords are viewed as consumable items in the commissioning and qualification of links after the initial installation. Reference-grade patch cords minimize total installed cost by providing excellent measurement capability in the face of tight application power budgets required by higher speed channels.

Reference patch cords are required in the measurement of fiber connectors and cable assemblies (TIA/EIA-455-171A) and are defined in terms of geometry and optical performance in other standards (ISO/IEC 14763-3 and TIA/EIA-455-171A Annex ‘A’). Reference patch cords should display the following characteristics:

- Core true position of <1 micron
- Exit angle <0.2 degrees
- Mated reference connector IL <0.10dB

One Reference Patch Cord Method – TIA Method ‘B’

The one reference patch cord method calculates link loss as the loss of the two adapters and the link under test. Key features include the following:

- Preferred method outlined in TIA/EIA 568-C.3 (Method ‘B’), secondary method as outlined in ISO/IEC 11801
- Meter test head must have the same connector type as the link under test
- Most accurate, repeatable and reproducible link measurement method
- Similar to component insertion loss test (FOTP 171) used by manufacturers to qualify component insertion loss

Two Reference Patch Cord Method – TIA Method ‘A’

The two reference patch cord method calculates link loss as the loss of the adapter in the original reference setup subtracted from the sum of the two adapters and the link under test. This method is chosen by contractors due to lack of fully understanding referencing methods and implications of using the wrong method. This method also assumes that a majority of the loss is in the fiber cable and not the connectors. Key features include the following:

- Preferred method for convenience by Domestic (N. American) contractors, although not referenced in ISO/IEC 11801
- Test head does not need to have the same connector type as the link under test
- Typically used on links where media loss dominates (over connectors)
- Slightly underestimates link loss
- High variability - bias due to propagation of referencing error, and the potential for erroneous “negative losses” is high

Three Reference Patch Cord Method – TIA Method ‘C’

The three reference patch cord method calculates link loss as the loss of the adapters (2) in the original reference setup subtracted from the sum of the two adapters and the link under test. Key features include the following:

- Preferred method in ISO/IEC 11801, although not referenced in TIA/EIA 568-C.3.
- Test head does not need to have the same connector type as the link under test
- Underestimates link loss
- Highest variability & bias - Measurement error can be substantial, and the potential for erroneous “negative losses” is high

Parallel Optics Field Testing With Fluke Networks’ Multi-Fiber™ Pro LSPM

End-users deploying a parallel optics cable plant should “future proof” their network infrastructure and require LSPM testing (see Figure 3). This method has historically used single fiber connector test units with reference grade LC or SC to MPO harnesses.

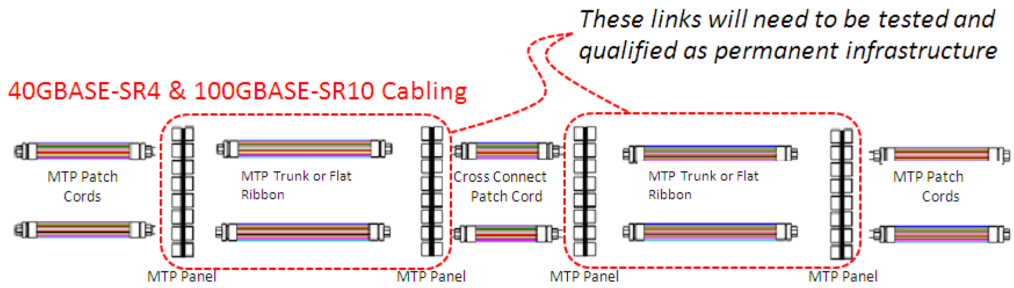

Figure 3. Cross-connect parallel optics cable plant.

Fluke Networks has simplified the testing of the multi-fiber parallel optics cable plant with the introduction of the MultiFiber™ Pro optical power meter and fiber test kit (see Figure 4). With an on-board female MPO connector, it is the first tester to automate the MPO fiber-trunk testing process. This LSPM automatically scans all the fibers and displays the test results in an easy-to-read bar graph.

Figure 4. Multi-Fiber™Pro power meter and light source.

The MultiFiber™ Pro power meter and light source has the following key features:

- Automatic scanning and testing of all MPO fibers
- Built-in polarity verification to validate end-to-end connectivity
- On-board MPO connector eliminates need for reference fan-out patch cords
- Easy-to-read test results with minimal navigation
- Ability to look at single fiber results
- Integrated shutters keep the integrated MPO connector clean
- Encircled flux compliant source

These innovative features allow MultiFiber™ Pro test kits to eliminate the complexity of testing MPO permanent links, making it up to 90% faster than the traditional test methods. Fluke Networks has a simple ROI/Payback calculator that highlights the cost differences between testing with reference fan-out methods and testing with the MultiFiber™ Pro when certifying an MPO-based cable plant. Refer to the following link for more information: http://www.flukenetworks.com/content/roi-calculator.

Testing the Legacy MPO Cable Plant with MultiFiber™ Pro

Figure 5 shows the MultiFiber™ Pro testing TIA-568C.1 compliant female MPO legacy trunks. This method allows for the use of the single male-to-male MPO reference patch cord to produce the reference level. The addition of a second male-to-male reference patch cord produces and completes the most capable measurement possible of the MPO link.

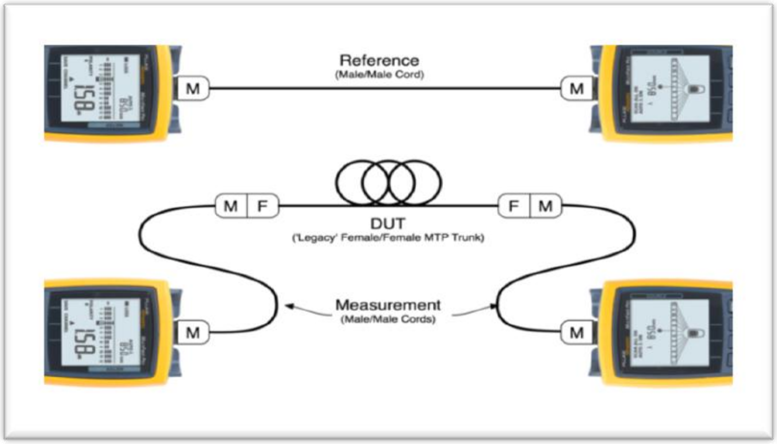

Figure 5. Brownfield migrated cable plant re-certification. This is the current Fluke Networks measurement technique with MultiFiber™ Pro.

Testing the Greenfield MPO Cable Plant with MultiFiber™ Pro

As shown in Figure 6, it is also possible to use the MultiFiber™ Pro for testing TIA-568 C.1 compliant male MPO trunks. This approach uses the two reference patch cord method: a male-to-female MPO reference patch cord and a male-to-male bucket cord, which is a receive cord that has nominal core size and numerical aperture greater than the device under test. The bucket cord, which is typically a 62.5/125 □m fiber, simulates a detector at the test connector surface, and performs the gender change of this new “detector” surface to male. The addition of a second female-to-male reference cord allows the trunk to be certified.

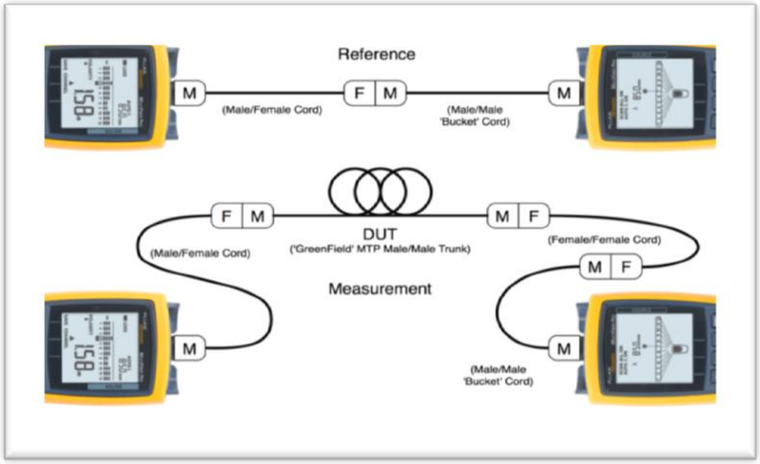

Figure 6. Greenfield cable plant certification. This is the current Fluke Networks measurement technique with MultiFiber™ Pro.

Panduit PanMPO™ Connectors

Migrating from 10Gb/s Ethernet networks to 40Gb/s networks has been a complicated process for end-users. An existing10Gb/s installation might require two different MPO patch cords to transition to 40Gb/s and could lead to confusion over which patch cord to use. Due to the complex construction of the connector, changing the polarity of standard MPO connectors in the field is not recommended. It could lead to damage of the exposed fibers exiting the rear of the MPO ferrule. In addition, gender on standard MPO connectors cannot be changed in the field.

The PanMPO™ Connector allows end-users to change the polarity and gender of the MPO fiber connector in the field, with no risk of damaging the internal fiber ribbon or the connector's endface. Using reference patch cords terminated with the PanMPO™ Connector simplifies the process of both testing and certifying existing cable plant and new installations, which helps ease the migration from 10Gb/s Ethernet to 40Gb/s Ethernet, while keeping the installation compliant with standards and industry best practices. For more information, visit: http://www.panduit.com/wcs/Satellite?pagename=PG_Wrapper&friendlyurl=/en/landing-pages/mpo-fiber-connector

PanMPO™ Reference Cable Assemblies are pre-terminated 12-fiber reference grade MPO-compatible assemblies that perform permanent link testing to commission and certify MPO-based structured cabling to international and domestic cabling standards. These reference cable assemblies are terminated with reference grade PanMPO™ Connectors on both ends that allow for any combination of gender and polarity cable plant to be tested using single reference patch cord methods. PanMPO™ reference cords contain connectors that display nominal optical and geometrical characteristics.

For testing the MPO-based cable plant in support of 40GBASE-SR and 100GBASE-SR10 applications, reference quality MPO cords must be used to ensure accurate, repeatable and reproducible measurements for permanent link certification. Reference Cable Assemblies with PanMPO™ Connectors provide contractors the capability to maintain high measurement integrity over time through the ability to retract the alignment pins in the connector for effective cleaning of the complete MPO connector surface. The PanMPO™ Connector is a multiple-fiber push-on/pull-off connector fully compliant with all appropriate standards (see Figure 7). Its gender can be changed to either male or female and with key up or key down polarity. This unique connector helps ease the fiber infrastructure transition from 10Gb/s Ethernet to 40Gb/s Ethernet while keeping the installation compliant with standards and industry best practices (see Figure 8).

Figure 7. PanMPO™ connector detail.

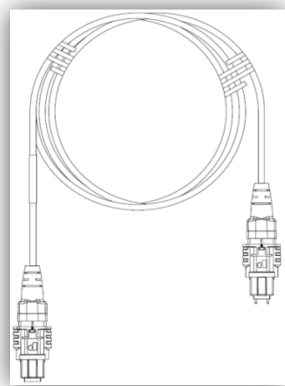

Figure 8. PanMPO™ cable assembly detail.

PanMPO™ reference patch cord assemblies:

- Provide superior measurement accuracy
- Maximize the flexibility for all gender and polarity links and test equipment
- Contain controlled MPO ferrule endface geometry that assures repeatable high performance
- Include reference quality connectors on both ends of the cable assembly that allow it to be used to mate to the permanent link for test

Changing Polarity

The interchangeable housing of the PanMPO™ Connector enables end-users to change the position of the key between key up and key down, as shown in Figure 9. This capability can make the reference patch cord either a Method A or Method B MPO cord. The yellow keys on the side of the connector identify which way the connector is keyed with respect to "fiber one" in the MPO ferrule.

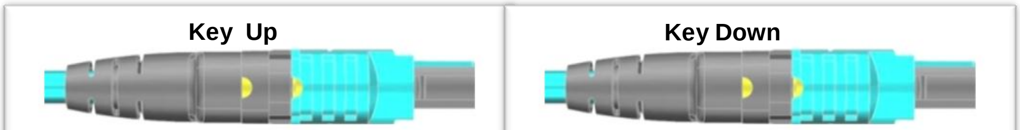

***Figure 9. Reference cord polarity change*.**

Changing Gender

The gender of the connector can be changed by removing the housing and using the gender-changing tool to either extend or retract the pins. The tool is used to slide a tab back and forth to either extract the alignment pins or retract them (see Figure 10).

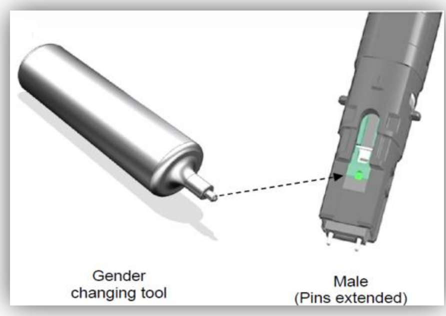

Figure 10. Reference cord gender change.

Tier 1 Certification Using the MultiFiber™ Pro and the PanMPO™ Reference Patch Cords

Using reference patch cords terminated with PanMPO™ Connectors offers several advantages over the typical reference cord. When used as a reference patch cord with the MultiFiber™ Pro test kit, the PanMPO™ Connector allows a single reference patch cord test method for new cable plant certification as opposed to the two reference patch cord method. As shown in Figure 11, a reference is first obtained with the female equipped MultiFiber™ Pro power meter and light source. To test the permanent link, the gender of the PanMPO™ reference patch cord must be female to test male-to-male trunks. As in the single reference patch cord method, the addition of a second female-to-male reference patch cord allows for the most capable means of testing and certifying the trunks. The gender change capability of this connector facilitates easy checking of the reference cords against "known good" reference cords.

The extend and retract feature of the alignment pins provides the ability to effectively clean the whole endface of the MPO connector. The connector is cleaned while configured with the pins retracted and the pins are extended for occasional re-referencing. This is not possible with typical MPO reference patch cords where installers must resort to frequent and tedious wet cleaning around the base of the alignment pins.

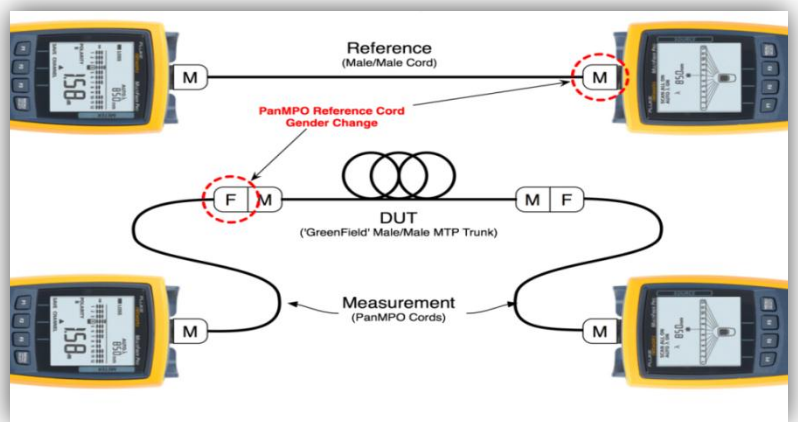

Figure 11. Greenfield cable plant certification. This is the current Fluke Networks measurement technique with MultiFiber™ Pro Power Meter and Light Source and PanMPO™ Connectors.

Conclusion

Reducing the Variability in Measurements

The type of reference patch cord that is used, the quality of the reference patch cords, and the cleaning and inspecting practices of the connector endfaces directly impact the integrity of the link loss measurement. Using standard quality jumpers instead of reference-grade, multiple reference patch cord methods (TIA-526-14-B Annex 'B' and Annex 'C') or poor test/measurement cleanliness can produce false failures (links that fail but are truly passing) and false passes (links that pass but are truly failing). False failures immediately impact the installation costs to fix the permanent link and retest can be significant. Such costs are usually absorbed by the contractor and then passed on to the end-user. False passes may cause link performance issues when the permanent links are in service. This costs both the end-user troubleshooting time and the installer may have to return to correct the issue.

PanMPO™ Cleaning Functionality

Proper cleaning of the MPO connector is needed to maintain its optical performance. However, it can be a challenge to keep the MPO connector endface clean, especially in highly active patch field applications or in high volume testing. The area around the base of the alignment pins used in the male connector becomes contaminated to the point where standard reeled dry tape type cleaning tools are ineffective. When that happens, the installer must resort to wet cleaning with alcohol and swabs which poses its own set of problems.

Reference patch cords terminated with PanMPO™ Connectors allow the complete endface to be cleaned with standard single fiber connector reeled dry tape type cleaning tools because the alignment pins can be retracted. After cleaning, the alignment pins can be extended if the installer needs a male MPO connector. Refer to the Panduit Best Practice document for inspection and cleaning methods: *Visual Inspection and Cleaning of MM and SM SCS Interconnect Components* at http://www.panduit.com/heiler/InstallInstructions/PN446.pdf

Cost Reduction

Costs involved in the installation of fiber structured cable systems can quickly escalate if best practices in preparation, installation, test/measurement, troubleshooting and remediation are not followed. Certifying links with the Fluke MultiFiber™ Pro power meter and light source and using reference patch cords equipped with the PanMPO™ Connectors are essential tools that minimize the total installed cost.

For more information on PanMPO™ visit: http://www.panduit.com/panmpo

Referenced Resources

- ANSI-FC-PI-5-Fibre Channel-Physical Interface-5
- IEEE-802.3ba-40Gb/s and 100Gb/s over 1m Backplane
- TIA-FOTP 171-Attenuation by Substitution Measurement for Short Length Multimode Graded-Index and Single-Mode Optical Fiber Cable Assemblies (ANSI/IA/EIA-455-171-A-2001)
- TIA/EIA-568-B.1 Addendum 7-Guidelines for Maintaining Polarity Using Array Connectors
- TIA/EIA-568-C.1-Commercial Building Telecommunications Cabling Standard. Part 1: General Requirements
- TIA/EIA-455-171A-Attenuation by Substitution Measurement for Short Length Multimode Graded-Index and Single-Mode Optical Fiber Cable Assemblies (ANSI/IA/EIA-455-171-A-2001)
- TIA/EIA 568-C.3 (Method B) – Optical Fiber Cabling Components
- TIA-526-14-B Annex B and Annex C – Optical Power Loss Measurements of Installed
- Multimode Fiber Cable Plant; IEC 61280-4-1 edition 2, Fiber-Optic Communications Subsystem
- Test Procedure – Part 4-1: Installed Cable Plant – Multimode Attenuation Measurement
- ISO/IEC 14763-3-Information Technology-Implementation and Operation of Customer Premises Cabling—Part 3: Testing of Optical Fibre Cabling
- ISO/IEC 11801-Information Technology – General Cabling for Customer Premises

About Fluke Networks

Fluke Networks provides innovative solutions for the installation and certification, testing, monitoring, and analysis of copper, fiber, and wireless networks used by enterprises and telecommunications carriers. The company's comprehensive line of Network SuperVision™ Solutions provide network installers, owners, and maintainers with superior vision, combining speed, accuracy and ease of use to optimize network performance. Headquartered in Everett, Washington, the company distributes its products in more than 50 countries.

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About Panduit

Panduit is a world-class developer and provider of leading-edge solutions that help customers optimize the physical infrastructure through simplification, increased agility and operational efficiency. Panduit Unified Physical Infrastructure℠ (UPI)-based solutions give enterprises the capabilities to connect, manage and automate communications, computing, power, control and security systems for a smarter, unified business foundation. Panduit provides flexible, end-to-end solutions tailored by application and industry to drive performance, operational and financial advantages. Panduit global manufacturing, logistics, and e-commerce capabilities along with a global network of distribution partners help customers reduce supply chain risk. Strong technology relationships with industry leading systems vendors and an engaged partner ecosystem of consultants, integrators and contractors together with its global staff and unmatched service and support make Panduit a valuable and trusted partner.

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