FIBER OPTIC CABLING REFERENCE GUIDE

Technology eBook Series - #2 of 4

- **Testing Theory - Performance of Optical Fiber Cabling**

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Testing Theory - Performance of Optical Fiber Cabling

Certification is the most complete form of field-testing. As alluded to earlier, the certification test procedure ensures that the installed cabling conforms to the transmission performance standards defined in the industry standards such as the applicable International Organization for Standard/International Electrotechnical Commission (ISO/IEC) and TIA standards.

Industry Performance Standards

Two groups of standards should be considered to obtain a complete specification and ensure that the installed cabling will support the requirements for the intended network applications. The goal of certification testing after all is to gain the confidence that the cabling system will not be the source of any network malfunction even before the network equipment is installed. The two groups of standards recognize each other's requirements but do not provide a perfect overlap.

Generic Installation Standards

The generic standards address the general installation rules and performance specifications. The applicable standards are the ISO std 11801-1:2017(en) and ISO/IEC 14763-3 Edition 2.0, Information Technology – Implementation and operation of customer premises cabling – Part 3: Testing of optical fibre cabling, and the ANSI/TIA 568.3-D, Optical Fiber Cabling and Component Standard. The latter specifies performance and transmission requirements for premises optical fiber cable, connectors, connecting hardware, and patch cords. Transition methods used to maintain optical fiber polarity and ensure connectivity between transmitters and receivers using simplex, duplex, and array connectivity are also described.

These standards address field-test specifications for post-installation transmission performance which depends on cable characteristics, length, connecting hardware, cords, cross-connect wiring, the total number of connections, and the care with which they are installed and maintained. For example, severe cable bends, poorly installed connectors and a very common problem – the presence of dust, dirt and other contaminants on the end-face of fibers in connections – negatively influence link attenuation.

The installation standards specify as a minimum transmission performance that the measured link loss be less than the allowed maximum (loss limit), which is based on the number of connections, splices and the total length of optical fiber cable. This certification must be executed with an accurate Optical Loss Test Set (OLTS) or a Light Source and Power Meter (LSPM). These test tools will be described in more detail later as well as the Optical Time Domain Reflectometer (OTDR). An OTDR provides a good indication of total link loss but is not sufficiently accurate for link loss certification testing. Certification includes the requirement of documentation of the test results; this documentation provides the information that demonstrates the acceptability of the cabling system or support of specific networking technologies.

The link attenuation allowance calculation:

Link Attenuation Allowance (dB) = Cable Attenuation Allowance (dB) + Connector Insertion Loss Allowance (dB) + Splice Insertion Loss Allowance (dB)

Where:

Cable Attenuation Allowance (dB) = Maximum Cable Attenuation Coefficient (dB/km) × Length (km)
Connector Insertion Loss Allowance (dB) = Number of Connector Pairs × Connector Loss Allowance (dB)
Splice Insertion Loss Allowance (dB) = Number of Splices × Splice Loss Allowance (dB)

Table 1 (see eBook #1 of this series) lists the cable attenuation coefficient by cable type; this coefficient is 3.5 dB/km at 850 nm for all multimode optical fiber types recommended for premises cabling systems. Indoor rated singlemode fiber has an attenuation coefficient of 1 dB/km or lower while outdoor rated singlemode fiber has a coefficient of 0.5 dB/km or lower. The standards also specify the maximum connector loss allowance as 0.75 dB and the maximum splice loss allowance as 0.3 dB. Well-executed cabling installations should generally deliver connections that exhibit significantly lower connection losses. The same statement applies to splice losses. Note that the length of the fiber link must be known or must be measured by the test tool to determine the loss limit.

Table 2 shows an example application of the loss limit calculations. The calculation is performed for a 300 meter OM3 fiber link segment with just two end connectors and no splices that is used with an 850 nm light source.

	Max. loss per unit length or per item	Length / number	Calculated loss (dB)
Max. loss in fiber	3.5 dB/km	0.3 km	1.05
Max. loss in connections	0.75 dB	2 connections	1.5
Max. loss in splices	0.3 dB	0 splices	0.0
Link loss limit			**2.55**

Table 2 -Loss limit calculation for a 300 meter multimode link with 850 nm light source.

Wavelength and directional requirements:

1. Horizontal cabling or Cabling Subsystem 1 link segments (TIA-568.3-D) need to be tested in one direction at one wavelength, either 850 nm or 1300 nm for multimode, and either 1310 nm or 1550 nm for single-mode.
2. Backbone/riser cabling (Cabling Subsystem 2 and Cabling Subsystem 3 link segments) shall be tested in at least one direction at both operating wavelengths to account for attenuation differences associated with wavelength. Multimode link segments shall be tested at 850 nm and 1300 nm; singlemode link segments shall be tested at 1310 nm and 1550 nm. Links that use keyed connectors to implement the fiber polarity can only be tested in the direction prescribed by the keying of the connectors.

Network Application Standards

For certification, the network application standards such as the IEEE standard 802.3 for Ethernet or the ANSI standard for Fiber Channel (FC) must also be considered. High throughput applications (Gb/s range and above) require more stringent limits on channel length and channel loss that is depending on the type and bandwidth rating of the optical fiber and the light sources used in the network devices. **Table 3** shows the maximum supported distance and the maximum allowable channel loss for a number of common network applications and for the different fiber types we described earlier in **Table 1**. The maximum channel length (maximum distance supported) is a proxy specification for dispersion. As long as the channel length does not exceed the maximum stated in the standard, dispersion will not cause a communication breakdown.

Field certification shall verify that fiber optic channel length does not exceed the maximum supported distance (the length limit). The installation standards discussed above require the measurement of cable length in order to calculate the 'maximum link attenuation allowance' but the installation standards impose a generic maximum length, which may far exceed the length specified for the application. This means that ANSI/TIA-568.3-D testing may not guarantee that your fiber application will work. ANSI/TIA-568.3-D only guarantees the workmanship of the installation. ANSI/TIA-568.0-D Section 1 cautions the user to consult application standards. In section 5.10.1 it states: "Cabling lengths are dependent upon the application and upon the specific media chosen (see Annex C). The length includes the cords and jumpers used for cross-connections, interconnections, and connections at the equipment outlet."

Tables 3 and 4 document that the length is limited and that it decreases for higher data rate applications depending on the bandwidth rating of each fiber type (a function of the modal dispersion characteristics of the fiber).

		OS1		OS2	
Application	Wave-length	Dist. (m)	Loss (dB)	Dist. (m)	Loss (dB)
10GBASE-L	1310	10000	6.2	10000	6.2
40GBASE-LR4	1310	10000	6.6	10000	6.6
100GBASE-LR4	1310	10000	6.3	10000	6.3

Table 3 – Maximum Channel Distance and Loss for single mode optical fiber application by fiber type.

		OM1		OM2		OM3		OM4		OM5	
Application	Wave-length	Dist. (m)	Loss (dB)	Dist. (m)	Loss (dB)	Dist. (m)	Loss (dB)	Dist. (m)	Loss (dB)	Dist. (m)	Loss (dB)
1000BASE-SX	850	275	2.6	550	3.6	800	4.5	880	4.8	n/a	n/a
10GBASE-S	850	33	2.4	82	2.3	300	2.6	450	3.1	400	2.9
40GBASE-SR4	850	n/a	n/a	n/a	n/a	100	1.9	125	1.9	150	1.5
100GBASE-SR4	850	n/a	n/a	n/a	n/a	70	1.8	100	1.9	100	1.9
100GBASE-SR10	850	n/a	n/a	n/a	n/a	100	1.9	125	1.9	150	1.5
10G Fiber Channel 1200-MX-SN-I (10,512 Mbaud)	850	33	2.4	82	2.2	300	2.6	300	2.6	n/a	n/a
16G Fiber Channel 1600-MX-SN (10,512 Mbaud)	850	n/a	n/a	35	1.6	100	1.9	125	1.9	n/a	n/a

Table 4 – Maximum Channel Distance and Loss for multimode optical fiber application by fiber type.

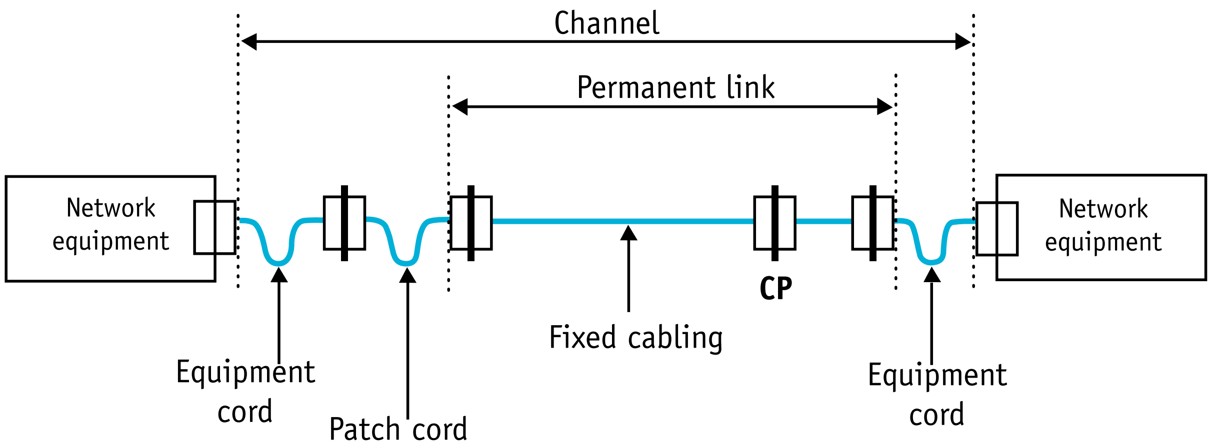

Figure 11 – The channel represents the end-to-end link connecting transmitter and receiver. The fixed cabling – a subsegment of the channel – is called the permanent link. The figure shows a generic horizontal link model that contains optional connections such as the CP (Consolidation Point).

The channel is the total cabling link including all patch cords (also called equipment cords) that link the active devices. **Figure 11** depicts the difference between channel and permanent link. The permanent link describes the link that is considered a permanent part of the building or datacenter infrastructure. The network equipment is connected to the permanent link using patch cords. Care should be taken to select cords made of the same fiber type as the permanent link optical fiber cabling.

Often an optical fiber link is constructed with several segments or sections and the network equipment is often not installed yet when the cabling installation is certified. It is not sufficient to test each segment against the installation standards. Ensuring that the installed cabling system will support the intended network application requires that the installed channels (end-to-end fiber links) meet the length and loss requirements defined in the application specification as shown in **Tables 3 and 4**.

You may select one of two methods to assure that the installed channel meets the application requirements before you turn up the network service:

1. Calculate the channel loss by adding the data for each link segment in the channel and adding the expected loss contribution of the interconnecting patch cords. ISO/IEC 14763-3 Ed2: 2014 makes explicit assumptions about the loss of a TRC connection with a link (0.5 dB for multimode fiber and 0.75 dB for singlemode fiber) versus the maximum loss of connections made with commercial patch cords (0.75 dB for both multimode and singlemode fibers).
2. Measure the channel loss as demonstrated in **figure 12**. The end-connections of the channel – connections made with the network equipment – are now made with TRCs that introduce a negligible loss. This method should be used when total fiber channels are tested and not just

segments thereof. Furthermore the test setup must include the final patch cords as well as the TRCs. Keep in mind that the accuracy of the measurements will depend heavily on a correct fiber reference setting.

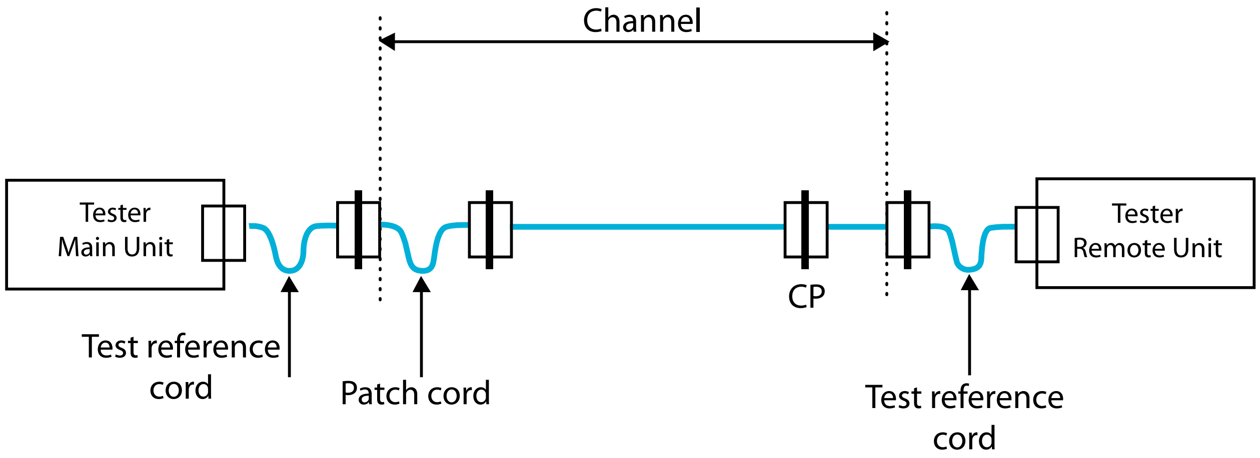

Figure 12 – The end connections in Fig 12 are not part of the channel specification. By replacing the patch cords with the Test Reference Cords (TRCs) for the channel loss and length measurement, the "error" in the loss measurement is represented by the difference in length between one TRC and the sum of the two patch cords used to complete the channel.

Optical fiber link polarity

Local area network installations support bi-directional communication by using separate optical fibers in each direction. The cabling system shall provide means to maintain correct signal polarity so that the transmitter on one end of the channel will connect to the receiver on the other end of the channel. Several methods are used to maintain polarity for optical fiber cabling systems. Guidelines are described and illustrated in Annex B of TIA-568-C.0. Duplex connector types and array connector systems that allow the fiber ordering arrangement to be maintained relative to the plug's keying features should be selected.

Coming Soon

Soon the following eBooks will become accessible:

#3: Optical Fiber Cabling Certification

- Select the performance standard
- Certification- Process and equipment requirements
- Measurement units
- Set the reference - principle
- Launch conditions

#4: Fiber Certification with an OLTS in Practice

Fluke Networks Fiber Test and Troubleshooting Solutions

	Inspection and Cleaning				MPO Testing	Loss Length Testing (Tier 1 Certification)		Plant Characterization and Troubleshooting (Tier 2 Certification)			
											
	FI-500 FiberInspector™ Micro	FI-7000 FiberInspector™ Pro	FI-3000 FiberInspector™ Ultra	Fiber Optic Cleaning Kits	MultiFiber™ Pro MPO Tester	CertiFiber® Pro Optical Loss Test Set	SimpliFiber® Pro Power Tester and Fiber Test Kits	VisiFault™ Visual Fault Locator	Fiber QuickMap™	OptiFiber® Pro OTDR	OptiFiber® Pro PON/FTTx HDR OTDR
Check end-face contamination or damage	✓	✓	✓				✓			✓	✓
End-face inspection grading		✓	✓				✓			✓	✓
Port Illumination	✓		✓								
Auto-focus	✓		✓								
Clean contamination				✓							
Check connectivity					✓	✓	✓	✓		✓	✓
Check polarity					✓	✓	✓	✓			
Verify loss over entire link to ensure loss budget not exceeded					✓	✓	✓				
Dual-fiber loss testing						✓				✓	✓
Singlemode Tier 1 certification					✓	✓	✓				
Multimode Encircled Flux Compliant Tier 1 Certification					EF compliant at the bulkhead	with EF TRC's	✓				
Locate faults								✓	✓	✓	✓
Tier 2 certification										✓	✓
Pass/fail results		✓	✓			✓			✓	✓	✓
Document test results		✓	✓		✓	✓	✓			✓	✓
Fiber types supported	Multimode Singlemode	MPO, Multimode Singlemode	MPO	MPO, Multimode Singlemode	MPO Multimode Singlemode	Multimode Singlemode	Multimode Singlemode	Multimode Singlemode	Multimode	Multimode Singlemode	Singlemode (1310, 1550, 1490 & 1625 nm)
Source type					LED, FP Laser	LED, FP Laser	LED, FP Laser	Laser	Laser	LED, FP Laser	Laser

Other highly technical resources:

To download the Fiber Test & Troubleshooting eBook visit:
www.flukenetworks.com/request/fiber-test-troubleshooting-ebook

To download the Twisted Pair Balance Measurements eBook visit:
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Want to talk to an expert then locate you local contact number on:
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Online Training Videos

These videos provide basic training for the complete Versiv™ Cabling Certification System. For each product, a set of videos cover the following topics:

- Unboxing – what comes with the product and what to do with it
- Setting Up a Test
- Running a Test
- Saving and Managing Results (using LinkWare™ PC and LinkWare™ Live)

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