FIBER OPTIC CABLING REFERENCE GUIDE

Practical technology eBook

FLUKE networks®

Table of contents

FLUKE networks

Introduction

Fiber optics is a fascinating and somewhat mysterious industry. The need for higher data transmission capacity continues to grow as network applications grow and expand. These higher transmission speeds demand cabling that delivers higher bandwidth support and fiber optic infrastructure is increasingly the preferred medium.

The intent of this eBook is to provide a very practical look at the technology. In a sense, it is an attempt to present a very technical subject in the most straightforward and intuitive manner possible.

This eBook will appeal to those that are newcomers to the field or those who cannot get past the techno-jargon that seems to go with every technology. It presents the essential concepts of the fiber optic industry and gives the reader a good feeling about how the technology really works rather than presenting mind-numbing equations.

Fiber optics is a reliable and cost effective transmission medium, but due to the need for precise alignment of very small fibers, problems ranging from end-face contamination to link damage can occur. Regardless, narrowing down the source(s) of failure is often a time-consuming and resource-intensive task.

FLUKE networks

For this reason, Fluke Networks has also created an enterprise-focused Fiber Optic Test and Troubleshooting eBook to assist you in ensuring: 1) proper assessment of cable installation quality, and 2) efficient troubleshooting to reduce the time spent identifying the root cause of a problem before taking corrective action to fix it. You can download this eBook from the Fluke Networks web site as well.

FLUKE networks

An Overview of the Principles of Transmission over Optical Fiber

Construction

Optical fiber cable consists of extremely thin strands of ultra-pure glass designed to transmit light signals. **Figure 1** depicts the construction of the buffered glass strand that is the basic component in many optical fiber cable constructions. The center of the fiber strand is called the 'core'. The core actually contains the light signals to be transmitted. A glass layer called the 'cladding' surrounds the core. The cladding confines the light in the core. The outer region of the optical fiber is the coating or 'buffer'. The buffer, typically a plastic material, provides protection and preserves the strength of the glass fiber.

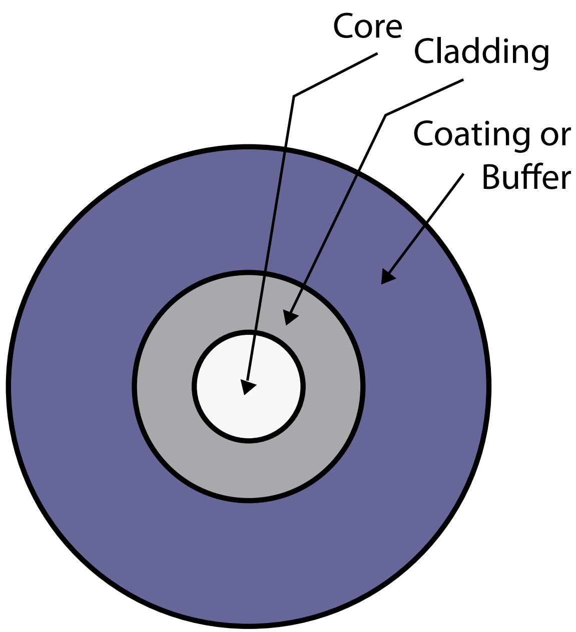


Figure 1 – Cross section of an optical fiber.

A common outer diameter for the cladding is 125 micron (µm) or 0.125 mm. The diameter of the core for optical fiber cable commonly used in premises infrastructures is either 62.5, 50 or 9 µm. The larger 62.5 and 50 µm diameter defines multimode fiber types; singlemode fiber has the smaller diameter with a nominal value of 9 µm.

Reflection and refraction

The operation of optical fiber is based on the principle of total internal reflection. **Figure 2** illustrates this principle when light travels from air into water. When light arrives at the water surface at an incident angle θ_i less than the critical angle $\theta_{critical}$, it travels into the water but changes direction at the boundary between air and water (refraction). When a light beam strikes the water surface at an angle greater than the critical angle, the light reflects on the water surface. Each material is characterized by an index of refraction, which is represented by the symbol ***n***. This index, also called refractive index, is the ratio of the velocity of light in vacuum ***(c)*** to its velocity in a specific medium ***(v)***.

$$n = c/v$$

The refractive index in vacuum (outer space) is 1 ***(v = c)***. The refractive index for air (n_1) is 1.003 or slightly higher than that of a vacuum while the refractive index for water is 1.333. A higher value of the refractive index ***n*** of a material indicates that the light travels slower in that material. Light travels faster through the air than in water. The core of an optical fiber has a higher refractive index than the cladding. The light that strikes the boundary between the core and the cladding at an incident angle greater

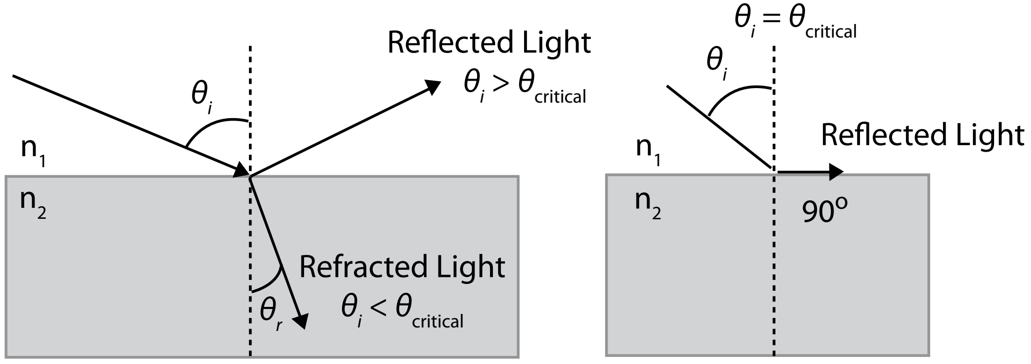


Figure 2 – Principle of total reflection. The amount of light that is bent away is given by: $n_1 \sin\theta_i = n_2 \sin\theta_r$ (Snell's Law).

than the critical angle reflects and continues to travel within the core. This principle of total reflection is the basis for the operation of optical fiber. The critical angle is a function of the refractive index of the two media, in this case the glass in the core and the glass in the cladding. The refractive index for the core typically is around 1.47 while the refractive index for the cladding is approximately 1.45.

Numerical Aperture

Because of this principle, we can describe an imaginary cone with an angle α_i which is related to the critical angle (see **figure 3**). If the light is launched into the fiber end from within this cone, it is subject to total reflection and travels in the core. The notion of this cone is related to the term Numerical Aperture (NA), the light gathering ability of the fiber. Light launched into the fiber end outside of this cone will refract into the cladding when it meets the core-cladding boundary; it does not stay within the fiber.

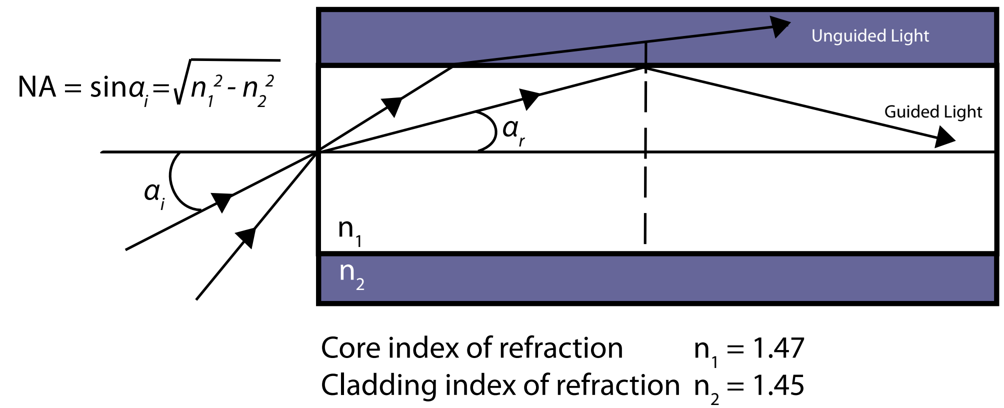


Figure 3 – Numerical aperture and total reflection: Light that enters the fiber with an angle α_i smaller than the critical angle travels in the core.

Signaling

Local area networks like Ethernet and Fibre Channel transmit pulses that represent digital information. The bit – short for binary digit – is the basic unit of digital information. This unit can only take one of two values: 0 or 1. Numeric data is transformed into a digital number. Other data such as characters are coded in a string of bits. An 'On' or an 'Off' state electronically represents the value of a bit. Similarly, a serial string of light pulses represents the digital information transmitted over an optical fiber link. The 'On' state represents a bit with value 1 and the 'Off' state represents a bit with value 0. **Figure 4** represents such a sample of digital information as transmitted over an optical fiber cable.

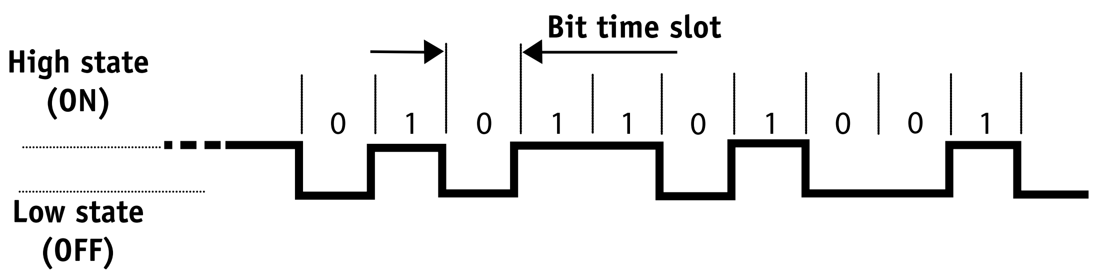


Figure 4 – A typical pulse train that represents the digital data.

The representation of the pulses in **figure 4** is "idealized". In the real world, pulses have limited rise and fall times. **Figure 5** describes the main characteristics of a pulse. Rise time indicates the amount of time required to turn the light to the 'On' state; it is typically characterized by the time required to transition from 10% to 90% of the amplitude. Fall time is the opposite of rise time and represents the duration to turn the light from 'On' to 'Off'. Rise time and fall time are critical parameters; they determine the upper limit for the rate at which the system can create and transmit pulses.

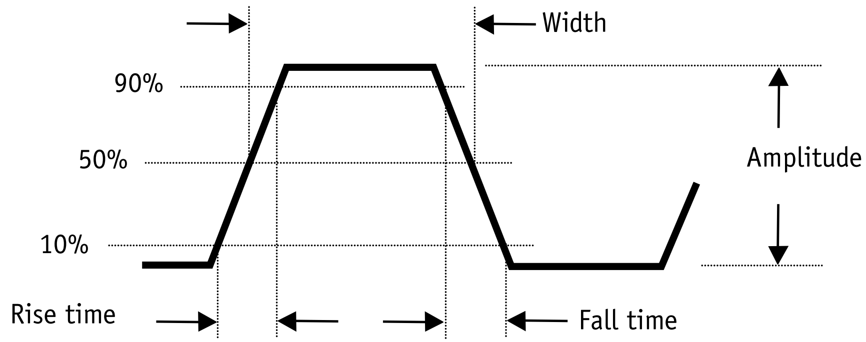


Figure 5 – Analysis of a pulse.

When transmitting one billion or more bits per second (data rate of 1 Gb/s or more), LED light sources can no longer be used due to the rise and fall time of the LED light sources. These higher-speed systems only use laser light sources. A very common light source in premises networks is the VCSEL (Vertical Cavity Surface Emitting Laser) that transmits light at the 850 nm wavelength.

Requirements for reliable transmission

When the light source in the transmitting device generates a pulse train like the one depicted in **figure 4**, the optical fiber link must transmit this pulse train with sufficient signal fidelity so that the detector at the receiving device can detect each pulse with its true value of 'On' or 'Off'.

Minimally, two things are required to ensure reliable reception and transmission:

Channel insertion loss: the maximum signal loss or signal attenuation allowed over the transmission medium from the transmitting device to the receiving device. The term ‘channel’ defines the end-to-end transmission medium between transmitter and receiver. The signal loss consists of the cumulative losses in the optical fiber cabling and in each connection or splice.

Signal dispersion: As we will discuss, the light pulses have a tendency to spread out as they are traveling along the fiber optical link due to dispersion. The spreading must be limited to prevent the pulses from running together or overlapping at the receiving end. Both of these parameters – channel loss and signal dispersion – play a critical role in establishing reliable and error-free transmission. Dispersion cannot be measured in the field. The network standards define a maximum channel length for an optical fiber channel; the maximum length is a function of data rate and the bandwidth rating of the optical fiber. The bandwidth rating, in turn, is based on laboratory measurements to characterize the modal dispersion in multimode optical fibers.

Loss

Loss or attenuation has been a well-established performance parameter in the cabling and network application standards. The signal must arrive at the end of the fiber optic link – the input to the detector at the receiving device – with sufficient strength to be properly detected and decoded. If the detector cannot clearly “see” the signal, transmission certainly has failed.

Attenuation or signal loss in optical fiber is caused by several intrinsic and extrinsic factors. Two intrinsic factors are scattering and absorption. The most common form of scattering, called 'Rayleigh Scattering', is caused by microscopic non-uniformities in the optical fiber. These non-uniformities cause rays of light to partially scatter as they travel along the fiber core and thus some light energy is lost. Rayleigh scattering is responsible for roughly 90% of the intrinsic loss in modern optical fibers. It has a greater influence when the size of the impurities in the glass is comparable to the wavelength of the light. Longer wavelengths are therefore less affected than shorter wavelengths and longer wavelengths are subject to less loss than the shorter wavelengths.

Extrinsic causes of attenuation include cabling manufacturing stresses and bends in the fiber. Bends can be distinguished in two categories: microbending and macrobending. Microbending is caused by microscopic imperfections in the geometry of the fiber resulting from the manufacturing process such as rotational asymmetry, minor changes in the core diameter, or rough boundaries between the core and cladding. Mechanical stress, tension, pressure or twisting of the fiber can also cause microbending. **Figure 6** depicts microbending in a fiber and its effect on the light path.

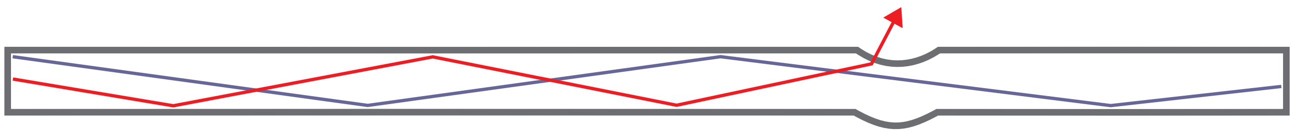


Figure 6 – A microbend in an optical fiber causes some light to escape the core which adds to the signal loss.

The primary cause of macrobending is a curvature with a small radius. The standards describe the bend radius limits as follows: “Cables with four or fewer fibers intended for Cabling Subsystem 1 (horizontal or centralized cabling) shall support a bend radius of 25 mm (1 in) when not subject to tensile load. Cables with four or fewer fibers intended to be pulled through pathways during installation shall support a bend radius of 50 mm (2 in) under a pull load of 220 N (50 lbf). All other optical fiber cables shall support a bend radius of 10 times the cable outside diameter when not subject to tensile load, and 20 times the cable outside diameter when subject to tensile loading up to the cable’s rated limit.”

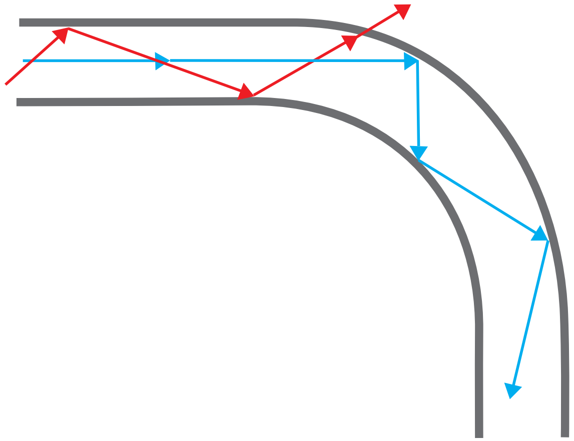


Figure 7 – A macrobend or bend with a tight bending radius causes higher order mode light to escape the multimode core and thuis causes loss.

Figure 7 shows the effect of a bend with smaller radius on the path of the light in the fiber. Some light in the higher order mode groups is no longer reflected and guided within the core.

The length of the fiber and the wavelength of the light traveling through the fiber primarily determine the amount of attenuation. The loss in an installed optical fiber link consists of the loss in the fiber plus the loss in connections and splices. The losses in connections and splices represent the majority of the losses in shorter fiber optical links typical in the premises network application. A troubleshooting tool like an Optical Time

Domain Reflectometer (OTDR) will allow you to gauge and inspect the loss at each connection or splice.

Dispersion

Dispersion describes the spreading of the light pulses as they travel along the optical fiber. Dispersion limits the bandwidth of the fiber, thereby reducing the amount of data the fiber can transmit. We will limit the discussion of dispersion to modal dispersion in multimode fiber.

The term 'multimode' refers to the fact that numerous modes of light rays propagate simultaneously through the core. **Figure 8** shows how the principle of total internal reflection applies to multimode step index optical fiber. The term 'step index' refers to the fact that the refractive index of the core is a step above the index of the cladding. When the light enters the fiber, it separates in different paths known as 'modes'. The principle of total internal reflection described above and shown in **figure 3** guides each path or mode through the fiber core. One

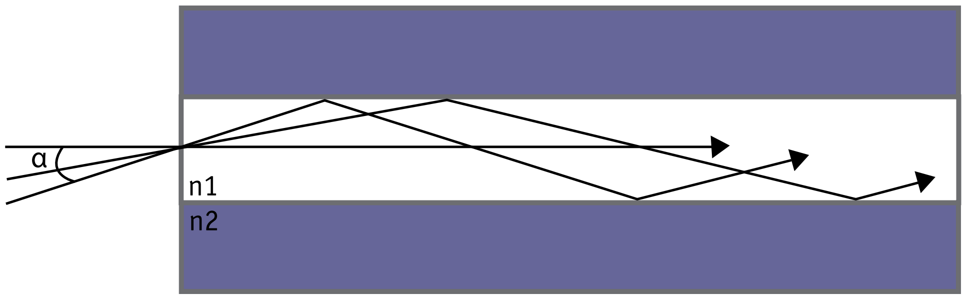


Figure 8 – The optical fiber gathers all the light that enters within the angle determined by the Numerical Aperture. The light reflects at the boundary between the core and the cladding and travels along different paths. A path is also called a mode. Multimode optical fiber guides the light along multiple paths or modes. The light that enters at the wider angle takes more bounces and travels a longer way. It represents the higher order modes.

mode travels straight down the center of the fiber. Other modes travel at different angles and bounce back and forth due to the internal reflection. The modes bouncing the most are called the 'higher order modes'. The modes bouncing very little are the 'lower order modes'. The shortest path is the straight line. All other paths taken by the light (modes) are longer than the straight line path – the steeper the angle, the more bounces taken, and the longer the path traveled. As the path length varies, so varies the travel time to reach the end of the fiber link. The disparity between arrival times of the different light rays also known as differential mode delay (DMD), is the reason for dispersion or spreading of the light pulse as it travels along the fiber link.

The effect of dispersion, see **figure 9**, increases with the length of the optical fiber link. As pulses travel farther, the difference in the path length increases, therefore the difference in arrival times increases and the spreading of the pulses continues to grow. The effect is that the light pulses arriving at the end of the longer fiber link run into each other and that the receiver can no longer distinguish them, let alone decode their state (value). Higher data rates are achieved by sending shorter pulses at rapid succession. Dispersion limits the rate at which pulses can be transmitted. In other words, dispersion limits the bandwidth of the cabling.

Figure 9 – The net effect of dispersion causes the transmitted pulses to run together and overlap at the end of the link (input to the detector). The detector can no longer recognize and decode the state of individual pulses.

To compensate for the dispersion inherent in multimode step index fiber, multimode graded index fiber was developed. 'Graded index' refers to the fact that the refractive index of the core gradually decreases farther away from the center of the core. The glass in the center of the core has the highest refractive index which causes the light in the center of the core to travel at the slowest speed. The light that takes the shorter path through the fiber is traveling at a slower speed. This core construction allows all the light rays to reach the receiving end in approximately the same time, reducing the modal dispersion in the fiber. As **figure 10** depicts, the light in graded index multimode fiber no longer travels in straight lines from edge to edge but follows a helix path; it is gradually reflected back toward the center of the core by the continuously declining refractive index of the glass in the core.

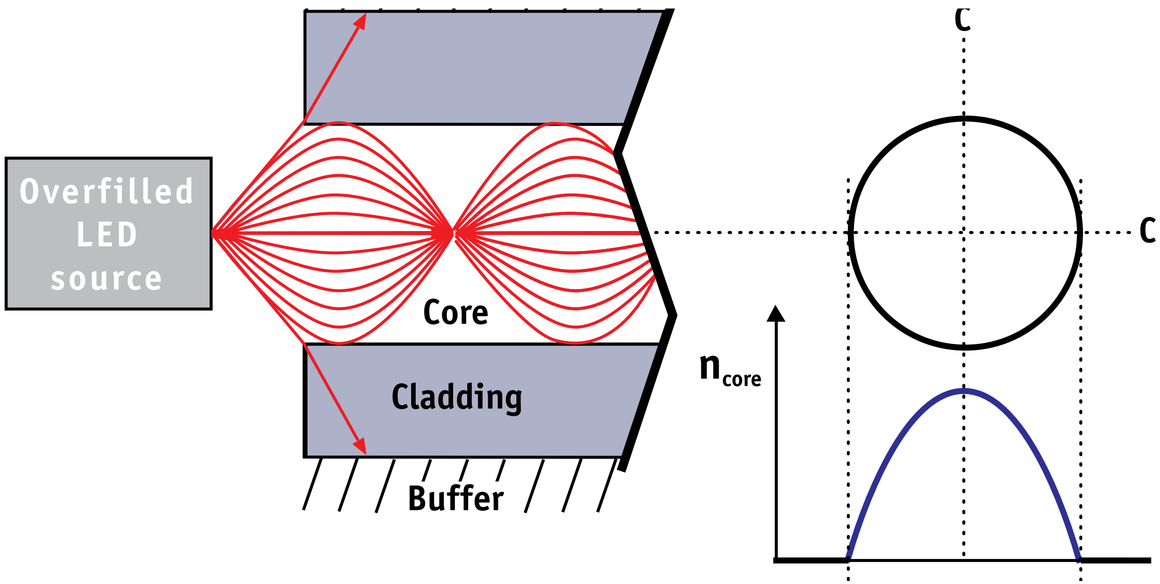


Figure 10 – Light paths (modes) follow a helix path as shown in the left panel of this figure. In graded index multimode fiber the refraction index of the core changes throughout the core. It is highest in the center and gradually decreases toward the boundary with the cladding. The lower modes light (center of the core) advance slowest while the modes in the outer regions travel the longer distances faster to compensate for some of the extra time the longer path takes to complete. Graded index multimode fiber therefore provides better bandwidth.

Laser-optimized multimode fiber that is to be used for the newer high-speed network application (data rates in the Gigabit per second range) is constructed as graded index multimode fiber. This laser-optimized multimode fiber also uses the smaller 50 µm core diameter. The smaller core diameter also decreases the dispersion effect in the fiber by limiting the number of modes.

'Singlemode' fiber, as the name implies, only allows one mode of propagation at wavelengths longer then the cutoff wavelength[1]. The 1310 nm wavelength that is used by most premises network application over singlemode fiber (9 µm core diameter) is well above the cutoff wavelength which is between 1150 nm and 1200 nm. Singlemode fibers using the longer wavelengths retain the fidelity of each light pulse over longer distances since they exhibit no modal dispersion (caused by multiple modes). Thus, more information can be transmitted per unit of time over longer distances (intrinsic loss is less at the higher wavelengths). This gives singlemode fibers higher bandwidth compared to multimode fiber.

Singlemode fiber design has evolved over time as well. Other dispersion mechanisms and non-linearities exist which we will not cover since they play a much less important role in the optical fiber application in premises networks. Singlemode fiber has some disadvantages. The smaller core diameter makes coupling light into the core more difficult. The tolerances for singlemode connectors and splices are more demanding to achieve good alignment of the smaller core. Furthermore, the longer wavelength laser light sources are more expensive than the VCSEL operating at 850 nm.

---

1) **Cutoff Wavelength:** The wavelength below which a singlemode optical fiber ceases to transmit in a singlemode.

Bandwidth

A key fiber performance characteristic is bandwidth, or information-carrying capacity of the optical fiber. In digital terms, bandwidth is expressed in a bit rate at which signals can be sent a given distance without one bit interfering with the bit before it or following it. Bandwidth is expressed in the product MHz•km. The interference occurs because of the dispersion phenomenon we discussed above.

Bandwidth can be defined and measured in a variety of ways. The three standardized bandwidth specifications and applicable measurements are Overfilled Bandwidth, Restricted Modal Bandwidth and Laser Bandwidth or Effective Modal Bandwidth (EMB). The reason for these different methods stems from the differences in the characteristics of the light sources used to transmit information.

The traditional light source for 10 Mb/s and 100 Mb/s Ethernet has been the Light Emitting Diode (LED), an excellent option for applications operating up to speeds of 622 Mb/s. LEDs produce a uniform light output that fills the entire core of the optical fiber and excites all of its modes. To best predict the bandwidth of conventional multimode fibers when used with LED light sources, the industry uses a method called Overfilled Bandwidth (OFL) and testing by using Encircled Flux (EF) launch conditions. EF further reduces loss measurement uncertainty and will be discussed in more detail in the 3rd section of this eBook.

As mentioned above, LEDs cannot be modulated fast enough to transmit the one billion or more pulses per second required for Gb/s data rates. A common light source to support the gigabit transmission speeds in premises network applications is the VCSEL (Vertical Cavity

FLUKE networks

Surface Emitting Laser) at 850 nm wavelength. Unlike an LED, the light output of a VCSEL is not uniform and therefore not suitable for use in test equipment. It changes from VCSEL to VCSEL across the end-face of the optical fiber. As a result, lasers do not excite all the modes in multimode fiber but rather a restricted set of modes. And what may be more important, each laser fills a different set of modes in the fiber and with differing amounts of power in each mode.

A superior method of ensuring bandwidth in optical fiber links for the deployment of Gigabit speeds is the measurement of DMD (differential mode delay – see the prior discussion on dispersion). This measurement technique is the only bandwidth specification mentioned in the standards for 10 Gb/s data rates. The Laser Bandwidth or EMB is mathematically derived from the DMD measurements.

Fiber Types

The ISO/IEC 11801 standard defines several types of optical fibers to support various classes of premises network applications. The ISO/IEC std 11801 defines five multimode optical fiber types (OM1, OM2, OM3, OM4 and OM5) and two singlemode types (OS1 and OS2). These type designations are finding acceptance in the North American market as well and are listed in the ANSI/TIA-568.3-D document[2)]. The following table provides a short overview of the main characteristics of these fiber types.

[2)] Telecommunications Industry Association (TIA). TIA represents the telecommunication industry in association with the Electronic Industries Association. TIA is accredited by the American National Standards Institute (ANSI) as a major contributor to voluntary standards. Standard ANSI/EIA/TIA 568 Commercial Building Telecommunications Cabling Standard is the primary standard related to structured cabling systems in North America.

		Cable attenuation coefficient (dB/km)		Minimum modal bandwidth (MHz•km)		
				Overfilled		Laser
Wavelength (nm)		850	1300	850	1300	850
Optical fiber type	Core diameter (µm)					
OM1	62.5	3.5	1.5	200	500	n/a
OM2	50	3.5	1.5	500	500	n/a
OM3	50	3.5	1.5	1,500	500	2,000
OM4	50	3.0	1.5	3,500	500	4,700
OM5	50	3.0	1.5	3,500	500	4,700

Table 1 – Multimode optical fiber types (ISO designations).

Note that older or legacy multimode fibers with an overfilled bandwidth rating below 200 MHz•km are not included in this table and are no longer recommended in the design of any new installations. The OM3 designation describes the high-bandwidth laser-optimized multimode optical fiber cable. Among the different fiber optic based transmission standards for 10 Gb/s Ethernet, 10GBASE-SR (the serial transmission of 10 Gigabits per second using the short wavelength VCSEL [850 nm]) is the most economical implementation of this high-speed network application in the premises local area network, the datacenter or the storage area network. And for this application, OM3 is the preferred fiber optic cable type.

Manufacturers of optical fiber have developed laser optimized multimode fiber with modal bandwidth characteristics that are better than the OM3 type specifications. This has led to the adoption of the OM4 and OM5 rating with an effective laser bandwidth of 4,700 MHz•km.

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 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.

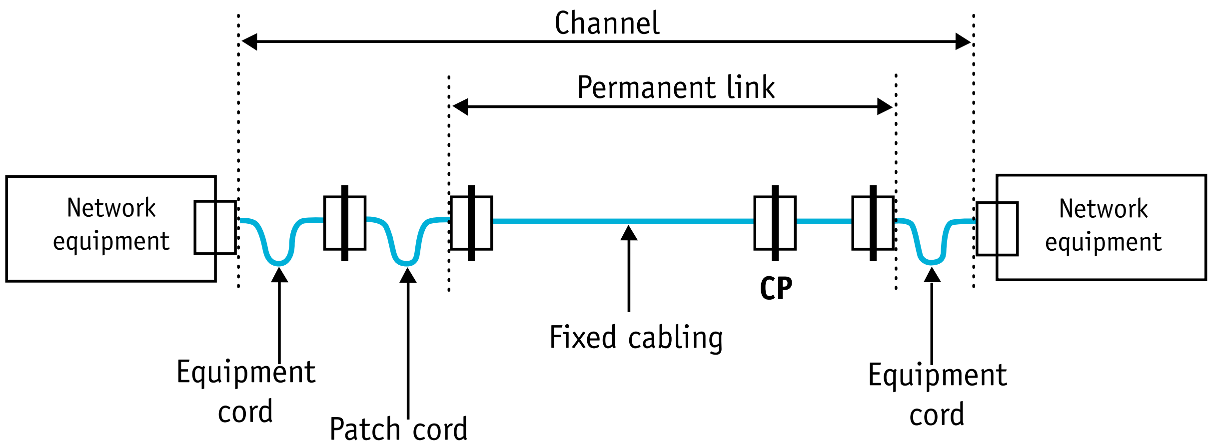


Figure 11 – The channel represents the end-to-end link connecting transmitter and receiver. The fixed cabling – a subsegment of the channel – is called the permanent link. The figure shows a generic horizontal link model that contains optional connections such as the CP (Consolidation Point).

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.

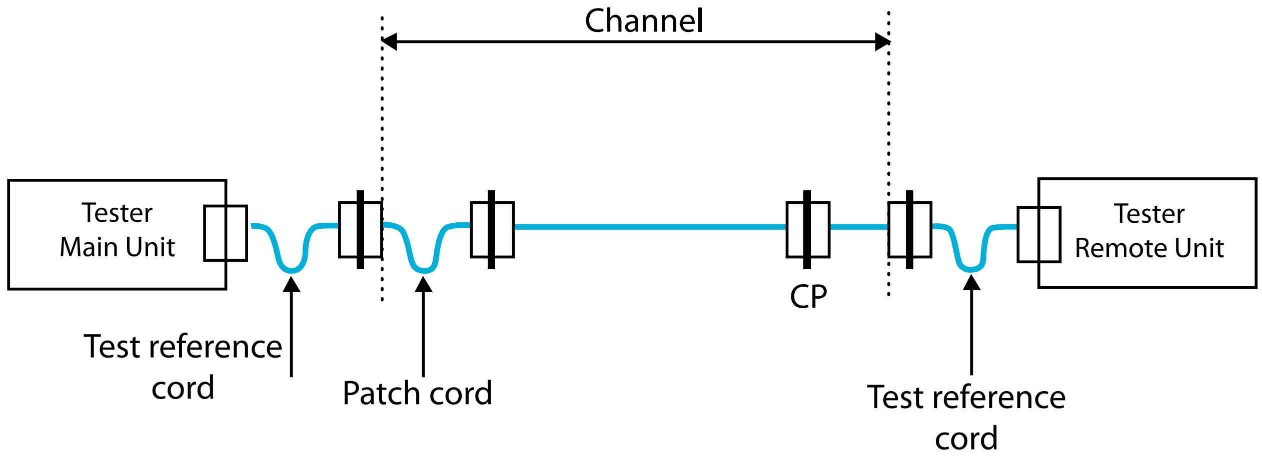


Figure 12 – The end connections in Fig 12 are not part of the channel specification. By replacing the patch cords with the Test Reference Cords (TRCs) for the channel loss and length measurement, the "error" in the loss measurement is represented by the difference in length between one TRC and the sum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

Optical Fiber Cabling Certification

Select the performance standard

The standards define a minimum test procedure consisting of:

1. Measurement and evaluation of the link loss using an 'optical loss test set' (OLTS) – some standards refer to this test tool as a 'Light Source and Power Meter' (LSPM). OLTS and LSPM tend to be used interchangeably. In this document we will choose the terminology OLTS for certification test tools that automatically measure the length of the link-under-test whereas we will use the term LSPM to designate test sets that do not measure the link length – and therefore may require some manual calculations to interpret the measured values. The light source is connected to one end of the fiber-under-test while the power meter is connected at the other end.

2. Measurement and evaluation of the link length. The length must be known to calculate the loss test limit for many installation standards – the maximum loss to be contributed by the optical fiber in the link loss limit value.

   Length also plays an important role when certifying a link for a specific network application. As shown in **Tables 3 and 4**, the maximum length of a fiber channel for a given network application depends on the fiber type and bandwidth rating of the fiber.

3. Verification of link polarity.

Steps 1 through 3 constitute the minimum certification testing requirement, also referred to as "Basic Certification" or "Tier 1" testing. The "Tier 2" test, also known as the "Extended Certification" test, is optional and includes the Tier 1 tests plus the addition of an OTDR link analysis (with trace and/or event table). The OTDR analysis can be used to characterize the components within the installed fiber link resulting in an indication of the uniformity of cable attenuation and individual connector insertion loss, individual splice insertion loss and other "events" that may be detected. An OTDR analysis provides an overall loss measurement for the link. The standards define that the basic certification (Tier 1) loss measurement must be executed using OLTS (Optical Loss Test Set) or LSPM (Light Source Power Meter) equipment which when properly used provides a higher accuracy loss analysis.

The end-user should specify the test standard to be chosen for the optical fiber certification test procedure. A test standard defines the tests to be executed and the limits or maximum allowable values for the tests. As we have discussed, when testing or certifying links that must support high-throughput applications (data rates in the Gb/s range), the application standards impose exacting limits for channel length and channel loss. When you need to certify the cabling to support such applications it is important that (a) you select the corresponding application standard in the OLTS setup and (b) certify the channel configuration.

Certification - Process and equipment

Table 3 illustrates that the channel loss limits for high-throughput network applications are relatively small. In order to make the Pass/Fail decisions with confidence, the test procedure must be executed with precision and with accurate OLTS or LSPM equipment. When the loss limit value is 2.6 dB (10GBASE-S), a measurement error of even 0.25 dB constitutes an error approaching 10% of the limit value. This section will review the procedural steps and equipment requirements to achieve accurate and repeatable measurements.

Two issues have proven to make a critical contribution to the topic of measurement accuracy:

FLUKE networks

(1) The reference for the loss measurement
(2) The launch condition of the light source into the link-under-test

Measurement Units

The dB or decibel expresses a ratio of power levels using a logarithmic function. If we represent the input power into a black box as P_{in} and the output power as P_{out}, we calculate the amplification or attenuation of the signal processed through the black box in dB using the following function:

$$10 \times \log10(P_{out} / P_{in})$$

Note that when P_{out}, is greater than P_{in} , the black box has amplified the signal and the mathematical formula above yields a positive number. If on the other hand P_{out} is lower than the P_{in}, the signal has been attenuated and the formula produces a negative number. Since the latter is always the case when we measure passive cabling and since the standards use the name "Loss", the negative sign is omitted in reporting the cabling loss in dB.

An absolute power level is typically expressed in watt (and its multiples like megawatt in the electrical power generation world or fractions of a watt like milliwatt or even microwatt in electronics). In the communication field, an absolute power level P is often expressed as a ratio to one milliwatt (mW) using the decibel. We apply the formula stated above but replace the reference (input power level) with the absolute power level of 1 mW.

$$1 \text{ dBm} = 10 \times \log10(P/\text{mW})$$

The 'm' in the symbol dBm indicates a power level referenced to one milliwatt.

Note: the dB scale is not a linear scale as the numbers in table 5 demonstrate:

dB loss	Power output as a % of the power input	% of power lost	Ratio P_{out}/P_{in}
1	79%	21%	
2	63%	37%	
3	50%	50%	1/2
5	32%	68%	
6	25%	75%	1/4
7	20%	80%	1/5
10	10%	90%	1/10
15	3.2%	96.8 %	~1/30
20	1%	99%	1/100
30	0.1 %	99.9%	1/1000

Table 5 – Decibel expresses a ratio between two power levels. The logarithm of the ratio turns this unit non-linear.

Set the reference - principle

The principle of the loss measurement is based on the difference of two power measurements. **Figures 13 and 14** show the principle of the fiber loss measurement of a link. In **figure 13** the light source is connected to the power meter with one 'test reference cord' (TRC). A TRC is a high-quality fiber cord between 1 to 3 m with high performance connectors at either end. The end-faces of the connectors should be treated by the manufacturer to provide scratch resistant hardened surfaces that support a multitude of insertions without degradation in performance. It is critically important that the end-faces of TRCs are kept very clean and are inspected regularly – and cleaned if necessary – throughout the day when certifying optical fiber links.

The light source in **figure 13** launches the light into the TRC which directs the light into the power meter. The power meter measures the light energy level and typically expresses it in dBm (refer to sidebar). The reference power reading (for multimode fiber 50 µm) with LED light sources falls in the range of -19.4 dBm to -26.5 dBm. The typical -23 dBm level corresponds to 0.005 mW. When testing a singlemode fiber link with a laser light source, the reference power measurement may yield -4 dBm (typical), which corresponds to approximately 0.4 mW, a power level that is about 80 times stronger than the LED light output. Therefore, always use caution that you do not look into an active fiber link – light used for data communication falls outside the visible spectrum but can cause permanent harm to your eye!

The reference power measurement compensates for uncertainties that could translate into measurement errors (inaccuracies). The exact power output level of the light source is unknown and the amount of light coupled into the TRC varies every time we make a connection. We must accept that there is some loss in the connection between the light source and the TRC. Because of the reference measurement, we do not need to know exactly how much this coupling loss is as long as it remains unchanged throughout the testing job. Therefore, the TRC shall not be removed from the light source until we quit or set a new reference.

The coupling of light from the TRC into the power meter is less variable since the power meter should be equipped with a wide angle input to capture all of the light from the TRC. This coupling must be clean and the connectors must be properly seated to ensure that the reference measurement truly establishes “the reference”. Many testers like the CertiFiber® Pro automatically verify that the measured reference power level is within the acceptable range for the light source. This provides some level of assurance that the reference is valid but it does not alleviate the need to make sure you use high-quality TRCs that have been inspected to be clean.

After we have established this reference power level, we move to the measurement connections as shown in **figure 14** with the following actions:

1. First, do NOT tamper with the connection between the light source and the TRC in any way.

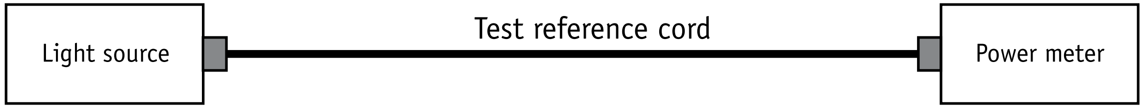


Figure 13 – Principle for connections to set the reference for an optical loss measurement.

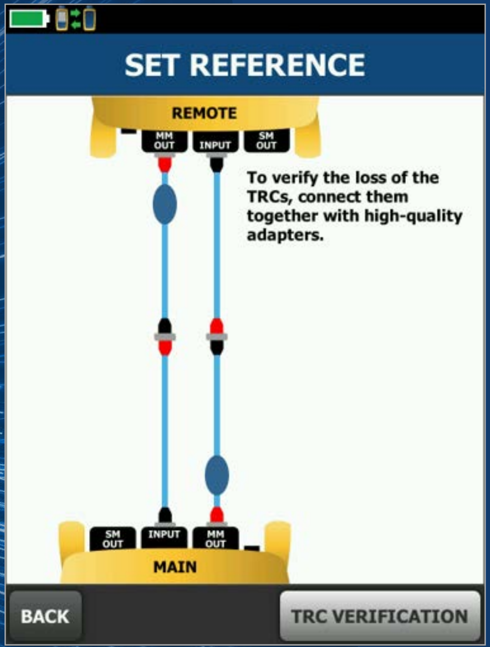
2. Connect the light source and TRC at one end of the link-under-test (connector C1).
3. Connect a second TRC (“Added TRC”) between the other end of the link-under-test (C2) and the power meter. This second TRC should exhibit the same quality as the first one (used to set the reference). It too must be inspected to ensure that both end connections are clean.
4. Make a power measurement while the light source transmits the light through the link-under-test to the power meter.
5. The power meter measures the light energy through the link-under-test and produces a result in dBm.

Assume that the power measurement through the link under test is -23.4 dBm and the reference power level is -20 dBm. By subtracting these two measurement readings, we find the loss caused in the link-under-test. In this example, the loss is -20 –(-23.4) or 3.4 dB. Note that a loss is expressed in dB (in contrast with absolute power measurements expressed in dBm). An OLTS automatically calculates the difference in power levels (the loss of the link-under-test) in dB and compares the result to the limit for the link-under-test. If the measured loss is less than or equal to the limit, the test passes.

Different methods to set the reference

The implementation of the loss measurement principle shown in Figures 13 and 14 is the 'one-jumper' method. One jumper or one TRC is used to set the reference. This method is preferred for the loss test of all premises wiring cabling. These cabling systems are characterized by relatively short fiber lengths but may contain several connections. As the example loss calculation in Table 2 demonstrates, the maximum loss allowed in a short 300 m link by the two connectors is 1.5 dB out of the total budget of 2.55 dB; the connecting hardware loss constitutes 59%. This underscores the need to make sure that all connection losses must be properly included in the loss measurement.

When we analyze the reference method shown in **figure 13**, the TRC does not introduce a connection between the light source and power meter. The TRC connects to each device but does not add any connections. Follow the light path between light source and power meter in Figure 14 to realize that the loss in connection C1, the loss in the link-under-test and the loss in connection C2 are fully accounted for in the measurement. The loss measurement also includes the loss of the "Added TRC." The maximum loss represented in a 2 m TRC is 0.007 dB (**Table 1** shows that the maximum loss for the fiber types used in premises wiring is 3.5 dB/km or 0.0035 dB/m). Another difference between the reference measurement and the link loss measurement is a new connection between the 'Added TRC' and the power meter. This difference is also very small (assuming the end-faces of the 'Added TRC' are indeed clean) since the meter is equipped with a wide-angle lens to capture all the light transmitted by the link-under-test. We judge the



The CertiFiber Pro is equipped with a "Set Refernce Wizard" that ensures reference setting is done right first time.

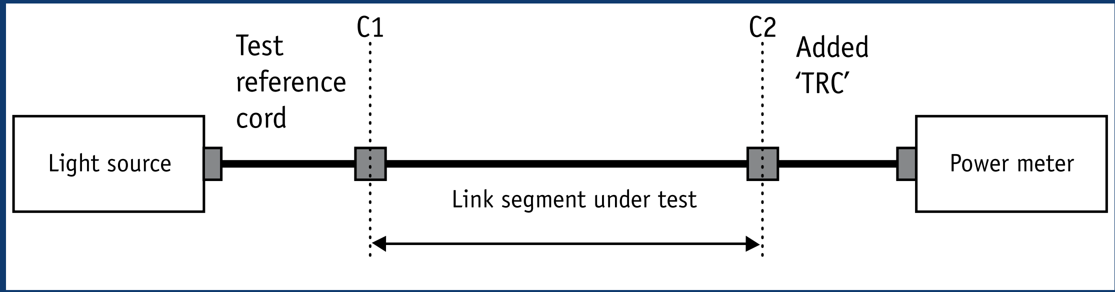


Figure 14 – Connection of "Light Source" and "Power Meter" for an optical loss measurement.

measurement error due to the 'Added TRC' to be less than 0.01 dB which also happens to be the resolution of a power meter.

The one-jumper method can only be applied if the connector in the power meter and the end-connectors of the link-under-test are the same type (for example, SC connectors). After setting the reference, we disconnect the TRC from the power meter and are only able to connect this TRC to the link-under-test if the end-connector of the link (C1 in **figure 14**) properly mates with this TRC.

To be able to use the preferred one-jumper method with different connector types, many of Fluke Networks' power meters, including the CertiFiber® Pro and SimpliFiber® Pro, are equipped with a removable adapter. A set of hybrid TRCs assures proper measurement connections while taking full advantage of the accuracy of the one-jumper method.

There are multiple methods to set the reference for an optical fiber loss test. The following names are used in Fluke Networks documents: one-jumper method, the two-jumper method, the three-jumper method and the enhanced three-jumper method. In ISO/IEC 14763-3 Ed. 2 the enhanced three-jumper method actually replaced the three-jumper method. While the enhanced method is highly accurate to test channels (not for permanent links), it is not practical for field testing as it involves the process of setting the reference for every channel that is being tested and requires the meter or source to be moved to the other end of a link.

Launch Conditions

The goal of any certification measurement is to provide Pass/Fail indications the end-user and the installation contractor can rely on. The chosen "launch conditions", that is how optical power is injected into the fiber core, have proven to have a major impact on the accuracy and consistency of optical fiber loss measurements. Failing to specify the launch conditions correctly can result in a measurement uncertainty as high as 60%.

We reviewed that the light in graded-index multimode fiber propagates in many modes. The number of modes that are excited by the launch and the energy level in each mode affects the power measurements. If the launch conditions are not controlled from test tool to test tool, each tool may provide a different measurement and test results; this is a certain indication that none of them are correct or trustworthy.

The goal is to control the launch conditions such that compliant test tools produce results that fall within a narrow range around the true loss value.

Factors that influence the launch conditions. LEDs are the preferred light sources to test the link loss for multimode fiber links. We discussed how VCSELs have become the light source of choice for all higher-throughput network applications using multimode fiber because VCSELs meet the modulation capability to provide short pulses in rapid succession to support the data rate for the 1 and 10 Gb/s applications. But VCSELs are not well suited for loss testing because each VCSEL may excite a different set of modes with varying energy levels in these modes. In other words, the light output of a VCSEL is not uniform. It changes from VCSEL to VCSEL across the end-face of the optical fiber.

Furthermore, loss testing is performed with a constant light wave rather than a modulated signal.

LEDs produce a cone of light that is evenly spread over the end-face of the fiber, even beyond the core. LEDs create an “overfilled launch” condition. The degree of overfill, however, produces significant variations in the loss measurement. A laser light source including a VCSEL creates an “underfilled launch” condition. These sources shine a narrow cone of light in the center of the core. An underfilled launch condition may not properly detect problems in the fiber link and

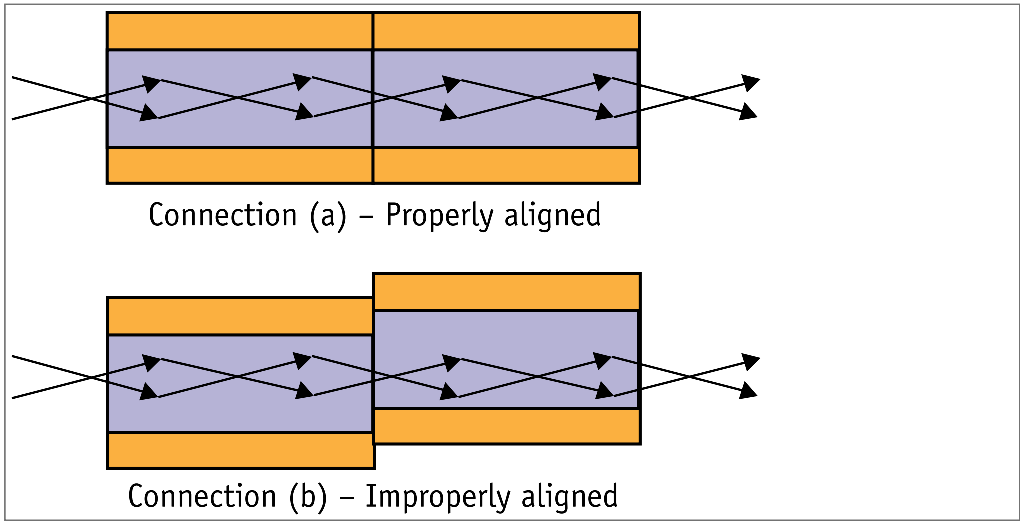


Figure 15. Testing the two connections shown with underfilled launch conditions may not detect the misalignment problem in the optical cable.

may consequently provide a more optimistic test result.

The misaligned connection in **figure 15** provides an example in which the loss measurement with an underfilled launch cannot detect the full impact of the misalignment. It reports a lower loss value (optimistic loss value) than a test executed with an overfilled light source (pessimistic loss value), see **figure 16**.

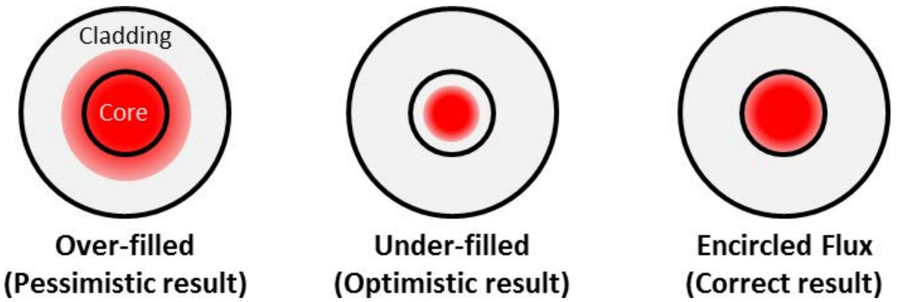


Figure 16. Three different launch conditions.

Encircled Flux (EF) truly controls how the light is launched into the fiber under test from a multimode source. Prior to EF, ANSI/TIA defined the launch condition using a technique called Coupled Power Ratio or CPR. This method turned out to be inadequate and was replaced with EF in 2010. ISO/IEC replaced CPR with Modal Power Distribution or MPD in 2006. Whilst better than CPR, it too was deemed not adequate for measuring low loss multimode fiber optic systems.

EF is the final part to the story in reducing measurement uncertainty. It tightly defines optical power, reducing to a minimum the variation in measurement results between those made using different EF compliant light sources. It basically defines the light output as if it were coming from an ideal VCSEL source. Given the fact that a VCSEL is a non-uniform light source, this means that in the EF light all VCSELs are "represented".

As a result, you do not need to worry about the launch conditions if you use Encircled Flux (EF) compliant sources with matching test reference launch cords.

EF compliance has become a requirement in many test specifications making it important to certify with EF compliant instrumentation.

Fiber Certification with an OLTS in Practice

An Optical Loss Test Set (OLTS) is a highly accurate instrument that combines a power meter and source in both the main and remote unit. It is best tool to determine the total loss or attenuation of fiber links. In order to ensure accuracy, it is important to first set up the OLTS correctly. This is described in detail in the "Fiber Test & Troubleshooting" eBook. Summarizing one must:

Figure 17 – The CertiFiber® Pro highlighting the SYSTIMAX Fiber Performance Calculator

- Allow sources to stabilize by turning on both the main and remotes units about 5 minutes before starting to make any measurements. It is key to allow extra time for the sources to stabilize if the change in environmental temperature is significant. If the sources do not stabilize there will be issues with setting the reference or as the source warms up, its output power will increase resulting in optimistic or negative loss readings.
- Establish and enter the correct Pass/Fail test limits for the links that are being tested. If you're installing SYSTIMAX links, leverage the SYSTIMAX Fiber Performance Calculator that can be found on-board the CertiFiber® Pro OLTS shown in **figure 17**. By chosing it you can quickly and easily calculate maximum attenuation performance for a proposed SYSTIMAX cabling channel, know which applications the

channel will support, and receive Commscope's guarantee of support-in writing.

- "Set the reference" correctly in order to remove the impact of the various connections between the tester and the links under test. Preferably this should be done by using the 1-jumper method. If reference setting is done incorrectly, highly undesirable negative loss measurements will typically occur. A negative loss is often referred to as a gainer and should not be possible on a passive link. When setting the reference ensure this is done with clean, high quality Test Reference Cords (TRCs) as required by ANSI/TIA and ISO/IEC. Dirty or defective TRCs will result in links not passing! Keep in mind that TRCs can wear out or be damaged if not treated correctly. Therefore always replace dust caps to protect end-faces an do not set bare end-faces on surfaces.
- Ensure the connectors on the test instruments themselves are clean. This is often overlooked and feedback from Fluke Service Centers indicates that a very high percentage of instruments sent in for repair were only suffering from dirty fiber optic connectors. Inspecting and cleaning of instrument connectors can be carried out in the field with the very same equipment that is used to inspect and clean TRCs and connectors in patch panels.

Since contamination can have a significant impact on optical power, the critical initial step in the certification process, before connecting fiber links to the tester, is to inspect and clean if necessary, both ends of the links under test. The best way to do this is with an OLTS that has the ability to inspect and certify fiber optic end-faces at both ends.

Traditional OLTS's have one main unit with a display and a remote unit. This means that a separate inspection tool must be carried to the remote end to view and document the end-face. With systems like the one shown in **figure 18**, the 2nd main unit can be configured to function as a remote unit. Users simply select “Main as Remote” in the setup menu. While the main unit is always in control of the OLTS test, the technician at the far end can now access the fiber inspection tool by selecting "FiberInspector", see **figure 19**. The same inspection features as on the main unit are then also available on the remote. Once the inspection and certification of the end-face has occurred, data is stored in the remote unit. Inspection results and images from both the main and remote can later be merged at the time the certification report is being worked on in the LinkWare™ PC Cable Test Management Software or with the LinkWare™ Live Cloud cloud-based service.

Figure 18 – The CertiFiber Pro CFP-100-Qi with dual-ended inspection capability.

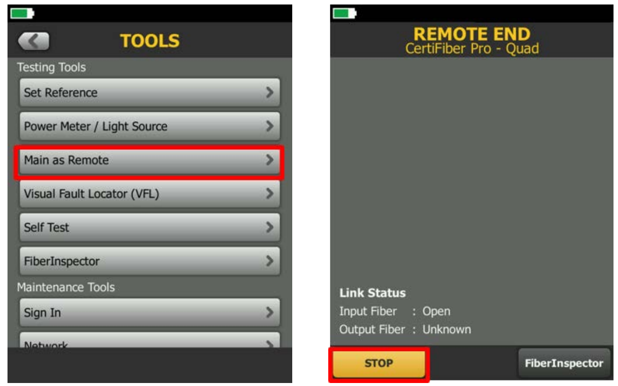


Figure 19 – Setting up the tester for inspection at the remote end.

The actual certification can now take place and the OLTS can be connected to the links under test. Keep in mind that bi-directional tests will be executed and that basically two links are being tested simultaneously: an "input" fiber and an "output" fiber. While the main unit is executing the OLTS test and storing the loss results, the remote unit will flash messages to inform the remote user about progress, see **figure 20**.

Understanding the duplex fiber measurement results

In this eBook we focus on bi-directional, dual wavelength fiber link certifications as results of measurements made in both directions can differ from one another. In case multimode fiber is being tested, the CertiFiber Pro in only 3 seconds does the following:

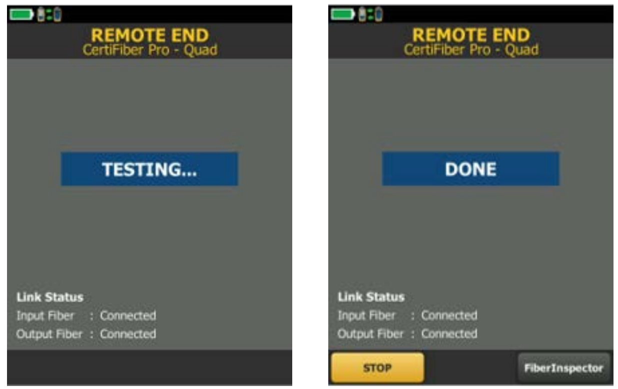


Figure 20 – User at the remote end being kept informed about test progress.

- Measure the optical loss of Fiber A at 850/1300 nm
- Measure the optical loss of Fiber B at 850/1300 nm
- Determine the length of the fiber by using the round trip propagation delay
- Compare the losses to the chosen test limit and provide a PASS or FAIL

In some cases testing in only one direction may suffice. However, testing in both directions is in any case required to:

- Determine length
- Find fiber core mismatches in splices and
- Detect links in which fibers of different core sizes are mixed.

Thanks to the test speed of the OLTS it is almost a no-brainer to certify bi-directionally, dual wavelength. Not only does it prove good workmanship but ideally measurements must also made at multiple wavelengths as the fiber should be tested using the same wavelength that will be used for transmission. Therefore, multimode links are tested using 850 nm and 1300 nm wavelengths and singlemode links using 1310 nm and 1550 nm wavelengths. Keep in mind that there could be significant attenuation differences caused by wavelengths especially in longer links as the loss per km in fiber is not the same at every wavelength. For example, for multimode fiber, the loss is about 3 dB per km at 850 nm and 1 dB per km at 1300 nm.

Interesting detail is also that when testing singlemode links, the 1310 nm wavelength is more sensitive to alignment problems (i.e. loss events), and the 1550 nm wavelength is more sensitive to issues caused by bends and cracks in the fiber link under test. Comparing the 1310 nm wavelength loss with the 1550 nm wavelength loss can indicate a bend or crack is present if there is more loss at the 1550 nm than at the 1310 nm wavelength.

Duplex fiber measurement results

See the result summary screen in **figure 21**. Notice first the green "PASS". The screen highlights the measurements were already saved as the tester is ready to test a new set of links, hence "TEST" at the bottom right of the screen. The label IDs of the input fiber and the output fiber are also visible in the boxes showing the loss and Length measurement results.

If a fiber should fail, two options will appear:

- FIX LATER where it saves the result and
- TEST AGAIN where you simply retest.

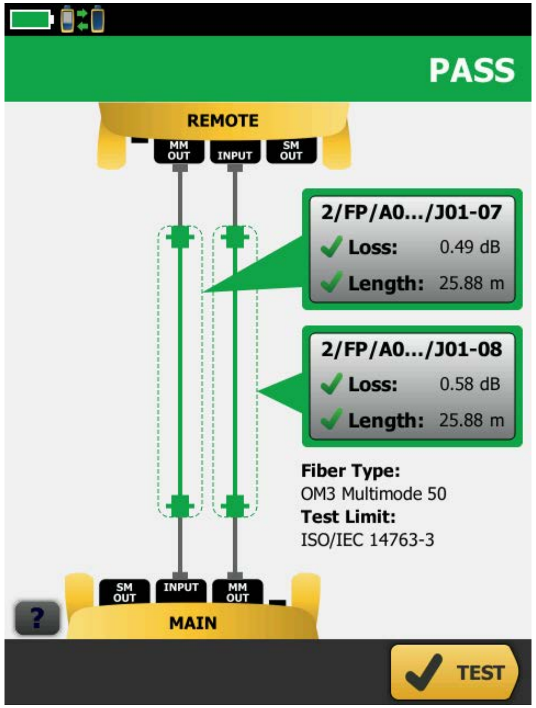


Figure 21 – CertiFiber Pro duplex fiber measurement result screen.

FIX LATER creates a punch list of all links with issues that the crew that was executing the tests did not solve. The "expert" can now come in and he will know immediately which links needing fixing. Results can be recalled and the option to retest the link is provided.

Should fixing an issue be extremely problemanic, users have the possibility involve the Fluke Technical Assistance Center (TAC). By directly uploading test results to the LinkWare™ Live Cloud Service and inviting a TAC agent to view the project which contains the results in question, the TAC agent will be able to log in to your Organization and import results. In Linkware™ PC these results can then be analyzed in detail and fixes suggested. Keep in mind that when the support case is closed you have the ability in the INTERNAL USERS tab of LinkWare™ Live, to edit (reset password) or delete the account of the TAC agent from your Organization.

Labeling the link

Several tools are available that allow you to print multiple cable ID's stored in Linkware™ Live projects onto labels. This reduces errors and saves you time over manually typing each individual cable ID on the label printer's keypad. The workflow is typically as follows:

- Connect to your Linkware™ Live account within the app or software provided by either Brady, Brother, Dymo or Epson.
- Select your project, then the range of cable ID's required and download to either a SmartPhone or PC (is printer vendor dependant).
- Then upload these cable ID's to the printer's built-in database.
- Finally choose your required label type using the printer's keyboard and select the range of cable ID's to print each label automatically.

Image courtesy of Brother Europe Ltd.

Interpreting a fiber measurement report

Below is a measurement report as generated by LinkWare™ PC. This first thing to notice is

Insert your
Company logo here

Cable ID: Of the Fiber that was tested — **Test Summary: PASS**

Date / Time: 05/31/2016 11:16:47 AM
Cable Type: affects supported apps
n = 1.482500 (850 nm)
n = 1.477800 (1300 nm)

Modal Bandwidth: 4700MHz-km (850 nm)
Modal Bandwidth: 500MHz-km (1300 nm)
Backscatter Coefficient: -67.0dB (850 nm)
Backscatter Coefficient: -74.0dB (1300 nm)

Loss (M->R)
PASS
Date / Time: 05/31/2016 11:16:47 AM
Test Limit: TIA-568.3-D Multimode
Limits Version: 4.6
Operator: of the test equipment
CertiFiber Pro (2931763 V4.6 Build 2)
Module: CFP-MM(3007003)
Calibration Date: 11/17/2015
certifiber pro remote (2930165 v4.6 build 2)
Module: CFP-MM(3007006)
Calibration Date: 11/17/2015

Propagation Delay (ns)	2426	
Length m	492.2	PASS
Limit 2000.0		
	850 nm	1300 nm
Result	PASS	PASS
Loss (dB)	1.88	1.02
Limit (dB)	3.22	2.24
Margin (dB)	1.34	1.22
Reference (dBm)	-23.26	-23.76

Number of Adapters: 2
Number of Splices: 0
Connector Type: LC
Patch Length1 (m): 2.0
Reference Date: 05/31/2016 08:57:49 AM
1 Jumper

Compliant Network Standards:

1000BASE-LX	1000BASE-SX	100BASE-FX
10BASE-FL	ATM155	ATM155SWL
ATM52	ATM622 Fiber Optic	FDDI Fiber Optic

the "PASS". This means that the measured loss (1.88 dB at 850 nm) is less than the limit (3.22 dB at 850 nm). This needs to be immediately followed by a check against which test limit the "PASS" was achieved: in this case "TIA Length Based Limit for Multimode Fiber". If this is in line with the requested test limit, then you're done, otherwise re-testing may be necessary.

Other important things to check are:

- If the testing was executed with an instrument that has a valid calibration. In above

FLUKE networks

document calibration was valid until 1-year after November 17th, 2015.

- The type of reference setting that was used and how much time elapsed between the time the reference was set and when the measurement was made. In the document 1-jumper reference setting was used and about 2 hours and 19 minutes have elapsed.
- If the firmware of the tester was up-to-date (LinkWare™ PC will actually tell you if firmware upgrades are available).
- The supported applications (see "Compliant Networks Standards" in the document).
- Fiber link characteristics like number of splices, connector type, length, etc.

Important

- Certification is the best way to assure that installed links will meet performance expectations.
- Be sure to inspect ALL connections before installing, clean them if necessary.
- Know how to read your test results to be sure they are acceptable.
- Make sure you always have access to the "raw" measurement data: the ".flw" data from LinkWare™ PC. It is often requested by project consultants and leading cabling manufacturers.

Conclusion

With the introduction of low loss fiber optic components such as LC/MPO cassettes, loss budgets (test limits) are becoming increasingly smaller. As a result, installers are finding out that previous methods and assumptions about fiber testing no longer hold true. IEC and other organizations, such as the Telecommunications Industry Association (TIA), routinely reaffirm standards every few years. Reaffirmation is a way for subcommittees to decide if a standard is "dated" or still applicable to current times. Technology and market needs change often which drive standards to change. Standards take time to complete however, usually 2 to 3 years, for several reasons. One reason is because it is difficult for a diverse group of participants representing the fiber industry for components and testing to reach consensus.

While the TIA still allows 0.75 dB per connector, factory polished connectors are closer to 0.2 dB. So when testing to TIA limits, installers are afforded quite a bit of measurement uncertainty. In other words, their testing practices need to be reasonable but not perfect. However, consultants and cabling vendors alike are now starting to specify loss budgets and custom test protocols based on component performance, not standards. As a result, the allowable slack in testing practices has disappeared.

To stay current, installers need to re-evaluate their test equipment and procedures.

Setting a reference through a bulkhead adapter is no longer an option; the reference has to be continuous from the source to the meter using one test reference cord (1-jumper). On top of that the custom test protocols may specify that fiber reference setting is required multiple times per day. Some vendors already specify a fiber reference validity of 2 hours only. This means it needs to be really easy to set the reference right first time. For some, that means investment in new test equipment and the inevitable training that goes along with it.

The test reference cords must also have reference grade connectors, which ISO/IEC 14763-3 defines as being ≤0.1 dB for multimode and ≤0.2 dB for singlemode. When the low-loss cassette has a 0.15 dB LC connector, testing it with anything worse than a 0.15 dB LC connector is going to result in a pessimistic result or potential failure.

For an overview of the best fiber optic test and troubleshooting practices we suggest you download the Fiber Optic Test and Troubleshooting eBook.

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:

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

For the Twisted Pair Balance Measurements eBook visit:
https://www.flukenetworks.com/request/free-e-book-balance-measurements-handbook

Want to talk to an expert then locate you local contact number on:
www.flukenetworks.com/contact

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)

www.youtube.com/FlukeNetworksVideo

Cabling Chronicles Blog

Find out what's new in the world of testing and standards with articles written by Fluke Networks' experts.

www.flukenetworks.com/blog/cabling-chronicles

Knowledge Base

Get the most out of your Fluke Networks investment with tips and tricks plus product updates from our team of support experts.

www.flukenetworks.com/knowledge-base

FLUKE networks

P.O. Box 777, Everett, WA USA 98206-0777

Fluke Networks operates in more than 50 countries worldwide. To find your local office contact details, go to **www.flukenetworks.com/contact**.

11/2020 19086-RL