

Field Test Procedure for Optical Fibre Link Measurements

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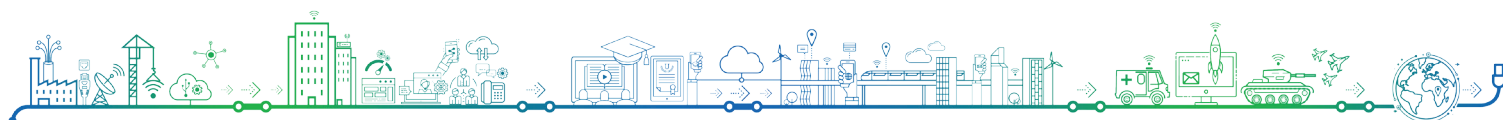
Abstract

After fiber optic cables are installed, spliced and terminated, they must be tested. For every fiber optic cable plant, you need to test for continuity and polarity, end-to-end insertion loss and then troubleshoot any problems. If it's a long outside plant cable with intermediate splices, you will probably want to verify the individual splices with an OTDR test also, since that's the only way to make sure that each splice is good. If you are the network user, you may also be interested in testing transmitter and receiver power, as power is the measurement that tells you whether the system is operating properly.

This document includes basic testing procedures for verifying horizontal optical fiber cabling after initial installation

Keywords

OTDR, OLTS, SLS/OPM, Attenuation



1. Introduction

Optical cables are tested by their manufacturer at the factory during and after manufacture, again after delivery to the staging area for the construction project by the contractor or his agent, and finally after construction by the contractor, his agent, or the end-user. A summary of the factory tests are usually provided by the cable manufacturer as part of a cable characterization packet accompanying each cable shipped. Pre-construction measurements at the fiber staging area assure the contractor that there has been no damage done to the cables during shipping and handling. Each fiber in all new cable reels should be measured to assure the fiber possesses the optical properties originally ordered and hasn't been damaged during shipment and storage:

1. Optical continuity in all fibers¹.
2. Length of each fiber.
3. Optical attenuation coefficient of each fiber at user specified wavelengths.

Post-construction measurements provide assurance that cable placing, splicing, and link construction activities have been completed that will enable the intended transmission system to function properly and to provide support for any future maintenance activities on the link. The most common post-construction measurements include the following:

Table 1 – Typical Post-Construction Fiber Link Measurements and Equipment Used

Post-Construction Link Measurement	Test Equipment
Length of the fiber link	OTDR
End-to-end fiber attenuation for link	OTDR, OLTS, SLS ² /OPM
Attenuation for each installed fiber	OTDR
Loss, location and reflectance of each splice	OTDR
Optical return loss of link	OTDR
Any reflective or high loss event in link: record loss and location	OTDR

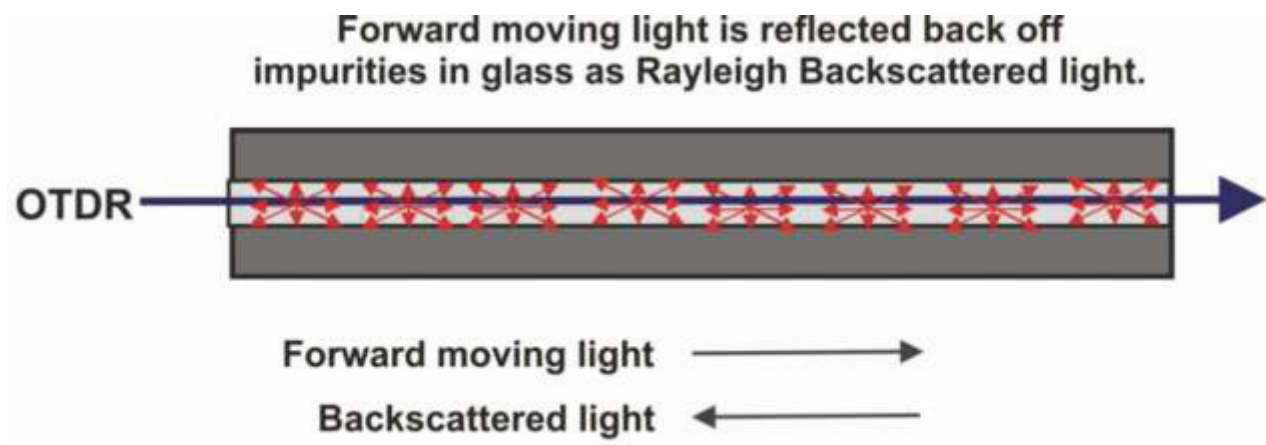
Note: Chromatic dispersion (CD) and polarization mode dispersion (PMD) measurements are not usually made as part of the post-construction measurement program. Both characteristics are normally issues for high-volume, long fiber lengths as would be encountered in long haul fiber routes. Chromatic dispersion measurements made at the factory are stable and generally not considered sensitive to installation handling, therefore factory supplied chromatic dispersion is normally used for field installed fibers. PMD is an optical phenomenon that varies from fiber to fiber and with respect to time and must be combined statistically for the respective fibers concatenated to form the fiber link. PMD can be measured using a PMD test set, but is normally not an issue unless transmission rates exceed several Gb/sec and fiber link lengths are very long.

Most post-construction optical fiber loss measurements use the cut back method (TIA 455-78) or the back reflection method (TIA 455-8) to determine their measured quantity. The cutback method and the back

¹ Fiber continuity will be verified by the fiber length measurements and fiber attenuation measurements. ² Stabilized Light Sources



reflection method are mainly used for testing at the manufacturing facility and the back reflection method is normally used in the field for most tests. An optical time domain reflectometer (OTDR) is the back reflection, portable optical test set used in the field for pre and post-construction fiber measurements. The backscatter concept is illustrated in **Figure 1**.



**Figure 1 – Schematic of the Backscatter Phenomena
Which OTDRs Use to Make Measurements**

Note: Following the OTDR manufacturer's instructions, set the fiber group index to 1.4670 for measurements at 1310 nm and 1.4675 for measurements at 1550 nm. The group index is used by the OTDR to convert time-of-flight of OTDR pulse to distance.

2. Safety

2.1 Laser precaution:

IMPORTANT: Laser or LED beams used in testing optical fiber plant are invisible and can seriously damage the eyes. Viewing these signals directly does not cause any pain and the iris of eye does not close automatically as it would when viewing bright lights. Communications lasers can cause serious damage to the retina of eye if view directly. Therefore,

- Never look directly into a fiber having a laser or LED coupled to it.
- If the eye is accidentally exposed to a laser or LED beam, immediately take the individual to a medical facility for treatment.

2.2 Optical Fiber Handling Precaution

Broken fiber ends (splinters) created during termination and splicing can easily penetrate the skin and can be dangerous. Fiber splinters will result as the fiber is cleaved. Fiber splinters are hard to find and remove once imbedded in the skin. Tweezers and an eye loupe are needed to remove the splinters. Any delay in



removing fiber splinters from the body could lead to infection. Hence:

- Be careful while handling the fibers.
- Do not drop fiber pieces on the floor where they will stick in carpets or shoes and be carried elsewhere.
- Dispose of all splinters and scraps safely and properly.
- Do not eat or drink near the installation area.

3 Post-Construction Measurements Setup

Figure 2 and Figure 3 provide schematic drawings of the two primary setups that are commonly used to test new fiber links: first, using an OTDR with a lead-in fiber and second, using two optical loss test set or a stabilized light source and optical power meter.

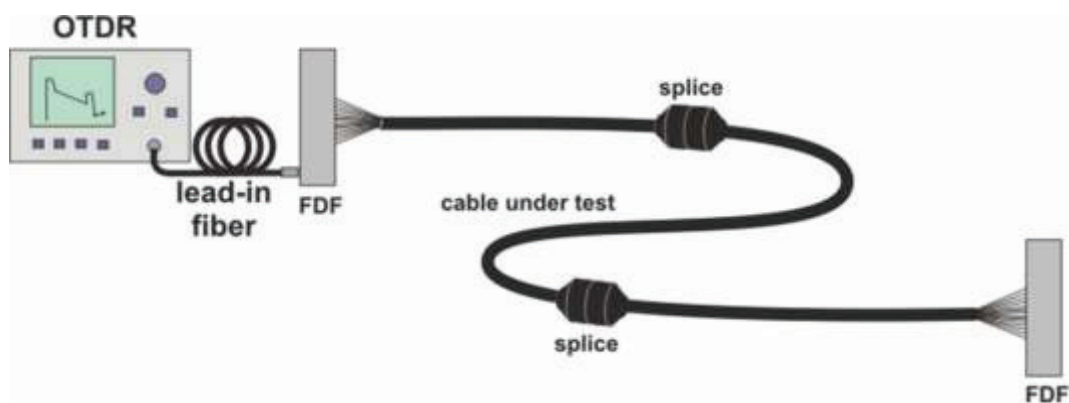


Figure 2 – Schematic Setup of OTDR Used to Measure Link Loss of Fiber Connected to Lead-in Fiber

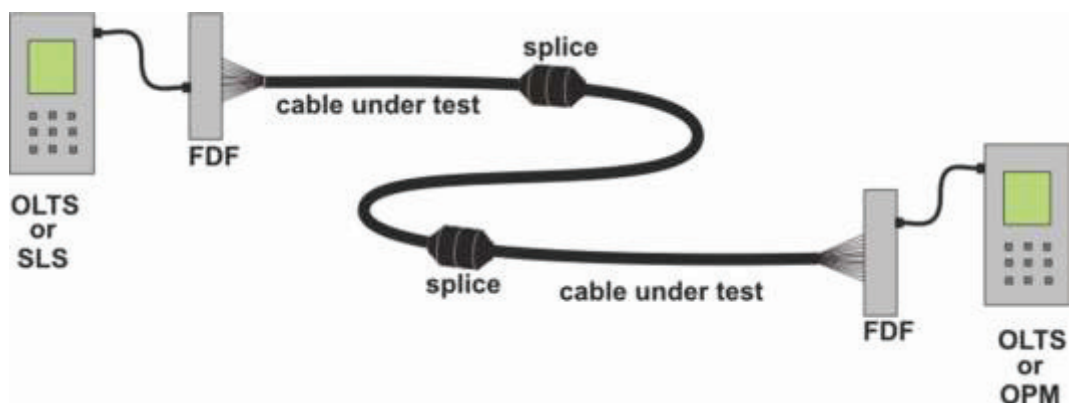


Figure 3 – Schematic Setup of OLTS or SLS/OPM Used to Measure Fiber Link Loss



3.1 Post-Construction Measurement Procedure

Post-construction testing can be seen as an expensive and time consuming operation. It is, however, a necessary operation to verify the quality of the construction operation that just has been completed and to provide a data base that will provide useful information if and when future maintenance is required on the fiber link. The post-construction testing procedure will be optimized with respect to time and cost using the test procedures described in this testing note.

Connecting the OTDR with Lead-In Fiber to the FDF and New Fiber Link

A lead-in or launch fiber should be used to eliminate the effect of the dead zone created from the OTDR's fiber interface connector and to enable the loss of the near-end, lead-in fiber/FDF/fiber-under-test connection to be determined. A lead-in fiber is several hundred meters in length. It connects the OTDR to the fiber being measured. When fiber measurements are made, it enables an accurate measurement of the connection between the lead-in fiber and the new fiber, a more accurate measurement of the new fiber length, and the total end-to-end loss of the new fiber link. The lead-in fiber is a commercially available OTDR accessory with a connector on one end to match the OTDR network interface and a connector on the other end to match the connector encountered on the fiber-under-test or FDF. Lead-in fibers are useful to locate faults at short distances into the link.

Using isopropanol and a lint free wiper, clean the optical connectors at both ends of the lead-in fiber. Connect the lead-in-fiber to the OTDR output port to observe the fiber measurement trace and FDF port to which the fiber-under-test is connected. A spike in the left end of the fiber trace with a rounded or flattened peak (see Figure 4)) will mark the connection to the lead-in fiber at the OTDR and the start of the trace. To the right of this peak the fiber trace should be smooth with a continuous linear slope of the lead-in fiber. If necessary, re-clean the mating ends of the lead-in fiber/FDF connector to obtain the OTDR trace as shown in Figure 4 .

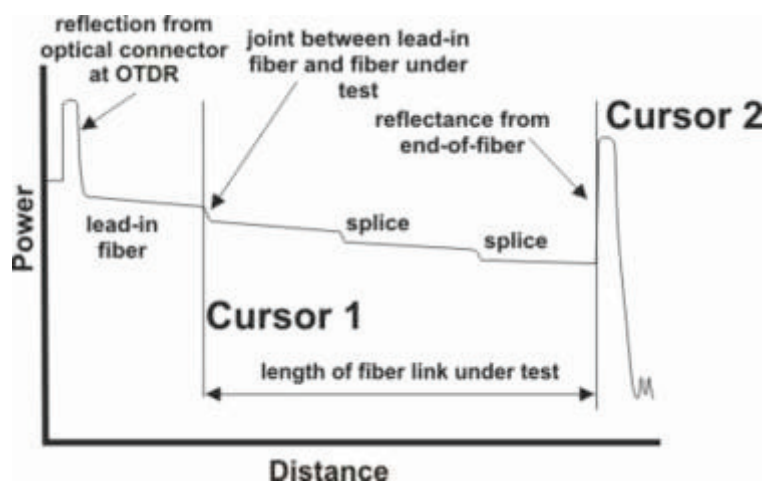


Figure 4 – Typical OTDR Trace Showing Lead-in Fiber Connected to the Post-Construction FiberLink

The connection at the FDF is shown as non-reflective in Figure 4. It may be somewhat reflective, depending upon the connector used at this location, see Figure 5.



NOTE: Clean all connectors properly and keep FDF ports and lead-in fiber connector endscapped when not in use. Dirty connectors can cause permanent damage to the OTDR or the connecting fiber end and will usually be the cause of OTDR measurement problems.

Each fusion splice in the fiber link will appear as small steps in the linear down slope of the fiber trace (see **Figure 4**). The vertical height of the splice offset is equal to the optical attenuation of the splice. The reflectance of a reflective connection is proportional to the height of the spike of its OTDR fiber trace. Its loss is the same as for a fusion splice: the vertical offset of the fiber trace. **Figure 5** illustrates these issues when measuring splice or event loss and reflections.

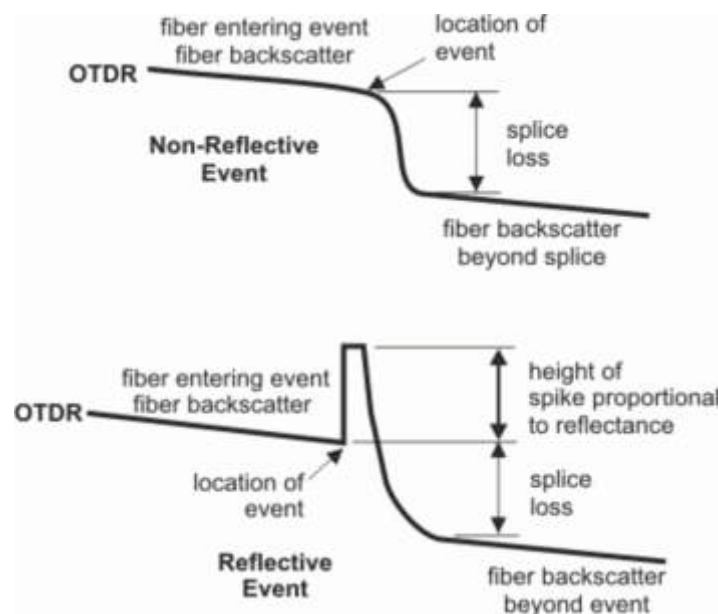


Figure 5 – Key Portions of an OTDR Trace for Non-Reflective and Reflective Fiber Events

3.2 Length Measurement

Connect the lead-in fiber to the fiber-under-test at its FDF port.

1. Set the OTDR to “auto” testing³ and verify that the OTDR's group index is set to the appropriate value to match that of the fiber-under-test (see Section). The fiber link trace shown in will appear on the OTDR.

Once a clean, proper fiber connection is made, electronically record and observe the OTDR fiber trace.

³ “Auto” testing will cause the OTDR to automatically select the appropriate measurement range and pulse width to optimally measure the fiber link under test. Otherwise, consult the OTDR manual to manually select the correct measurement parameters for the fiber measurement.



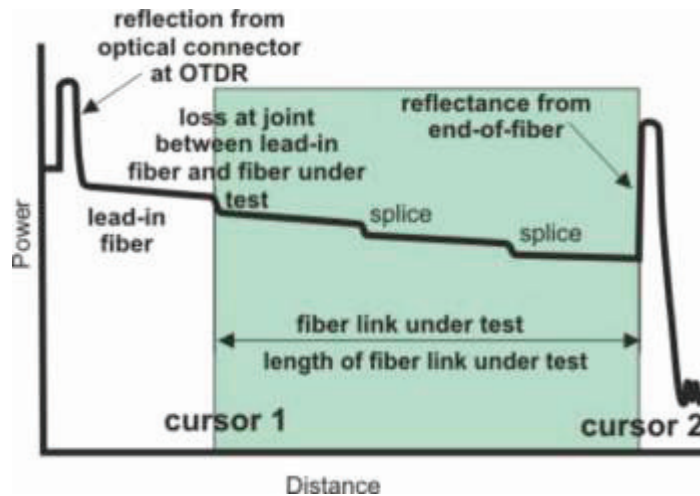


Figure 6 - Typical OTDR trace to determine the fiber length of fiber link under test.

Figure 6 and Figure 7 show the key cursor positions on the fiber trace to measure the fiber length. Set “cursor 1” to the connection at the FDF port between the lead-in fiber and fiber-under-test. It should be positioned at the entry point to the connection where the trace begins to drop from the lead-in, linear backscatter level through the attenuation of the temporary connection at the FDF or if the connection is reflective, it shall be positioned at the entry point to the FDF connection where the trace begins to rise from the reflective connection.

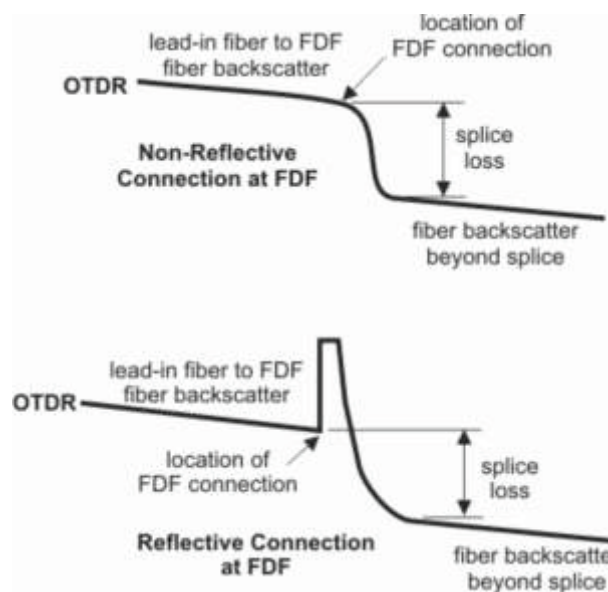


Figure 7 – Key Cursor Locations on OTDR Trace to Measure Fiber Length

The trace should have a slightly rounded or square peak at the far end of the fiber (see). Since the fiber end is reflective, “cursor 2” shall be positioned at the last point on the linear lead-in to the reflective spike at the end of the fiber trace. The difference between the two cursor positions is the length of fiber in the cable under test.



NOTE: The cable sheath length will be several percent shorter than the fiber length because of the fiber stranding used within the cable core.

If available on the OTDR, activate the algorithm that automatically summarizes the entire fiber link trace (fiber lengths, splice loss, event reflectance, end-to-end link loss, and optical return loss) in tabular form. Save this table and the fiber trace electronically, for future reference.

3.3 Fiber Attenuation

3.3.1 OTDR Measurement

While the OTDR is still attached to the fiber just measured for length, it should be measured with the OTDR to determine its attenuation at the working wavelengths for which it was specified. Set the OTDR to the first wavelength to be measured and obtain the fiber trace shown in **Figure 8**. The vertical offset between the intersection points on the fiber trace between cursor 1 and cursor 2, respectively, is equal to the fiber link loss. This vertical offset is equal to the fiber link loss including the loss of the FDF connection at the beginning of the fiber. While the FDF connector is a loss that the transmission signal will experience, many definitions of link loss include only the fiber between FDFs, not the loss of either FDF connector. This loss is shown by the height of the yellow box in **Figure 8**.

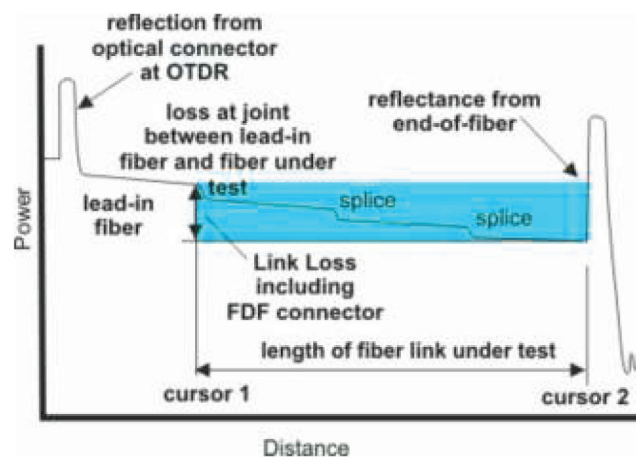


Figure 8 – Typical OTDR trace to determine the attenuation of fiber link under test.

To determine the fiber link loss without including the FDF connectors, the link loss determined above in **Figure 8** must be decreased by the calculated loss of the near-end FDF connection (lead-in fiber/FDF/fiber-under-test connection) calculated using the splice loss routine of the OTDR (see OTDR manual).

The near end FDF connector loss is calculated as is shown in **Figure 9**. Generally, a more accurate determination of splice or connector loss is achieved using the OTDR's least square method as compared to its two point method.



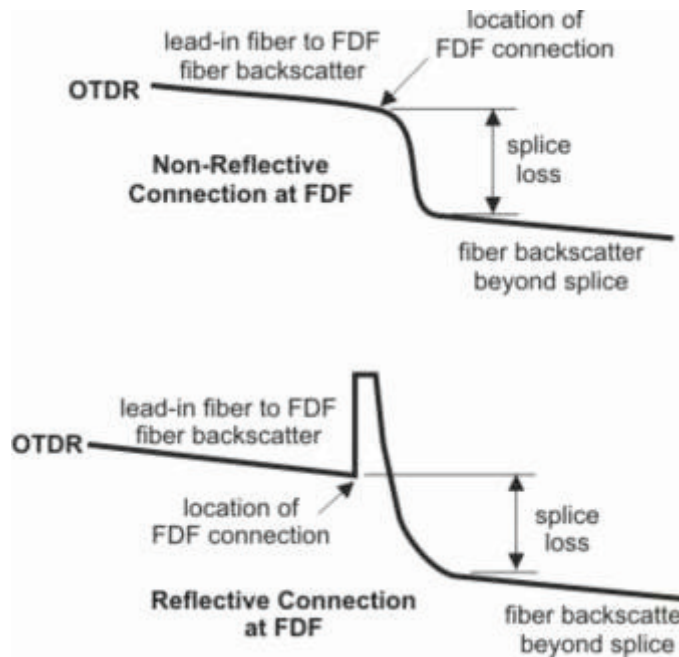


Figure 9 – Measure the splice loss at FDF between lead-in fiber and fiber link being measured.

The fiber-link, end-to-end loss is determined by subtracting the near-end FDF connector loss from the fiber link loss that includes the FDF connector loss (shown in Figure 8), using the principles of Figure 9.

The fiber attenuation coefficient is often characterized by reporting the attenuation coefficient of the fiber at a specific wavelength. The attenuation coefficient is defined as the optical power loss in the fiber per unit length, dB/km, and is equal to the slope of the linear, backscatter portion of the OTDR fiber trace when the optical power is at the specified wavelength.

If the fiber link loss is specified at more than one wavelength, the OTDR measurement shall be made one at a time at each wavelength specified in the work plan. Typically, the attenuation thresholds at both 1310 and 1550 nm are specified for long-haul, single-mode fibers; attenuation thresholds at 1310, 1550, and 1490 nm, respectively, are frequently specified for FTTH fibers.

3.3.2 OLTS or SLS/OPM Measurement

While OTDRs may provide the most economical solution to post-construction measurement issues, many experts may argue that the end-to-end loss using an OTDR is an estimate of the actual end-to-end loss of the fiber link. Many companies may prefer to use a pair of optical loss test sets (OLTSS) or a stabilized light source (SLS) and an optical power meter (OPM) to make this measurement. **Figure 10** shows a typical setup to measure the link loss of fiber using an OLTS or SLS/OPM.

OLTS testing requires access to both ends of the fiber link. A single unit has both a transmitter and receiver. It works with its partner unit positioned at the opposite end of the link to make loss measurements between units. The units communicate with each other and make measurements at several preselected wavelengths in both directions along the fiber link. They also provide a bidirectional average of the link-loss at each respective measurement wavelength. As part of the initial setup procedure for each measurement, the mating OLTS units need to be zeroed to each other's output power levels. Some OLTSs provide automatic zeroing; others require the users to perform this operation (see the OLTS operating manual).



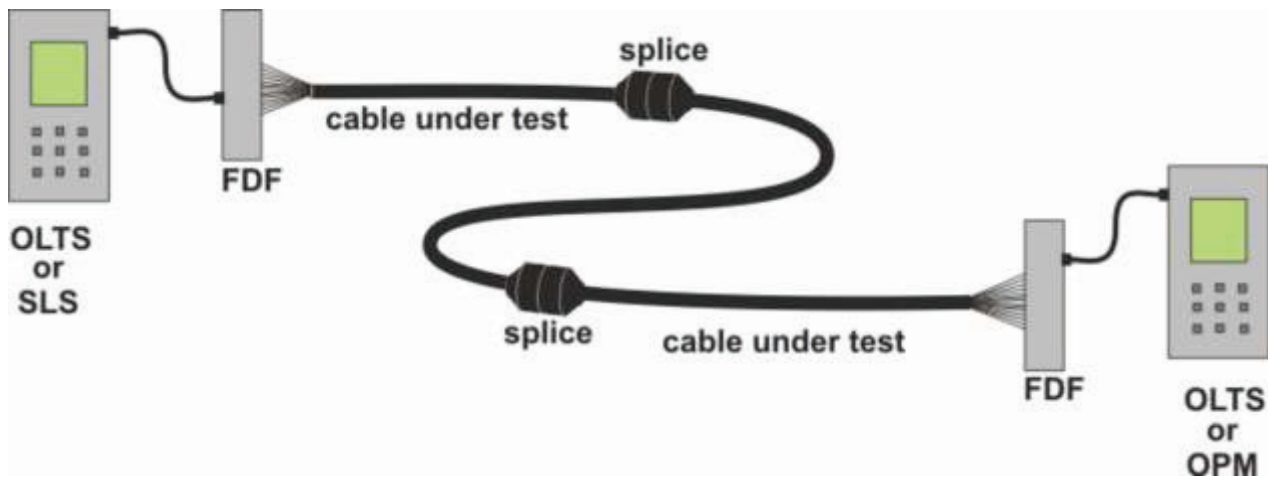


Figure 10 – Fiber Link End-to-End Measurements Using an OLTS or SLS/OPM

This same measurement can be made between a SLS and an OPM at the preselected wavelengths that represent the working transmission wavelengths. These units must be zeroed at the start of the measurement process.

NOTE: To improve measurement accuracy, keep the fiber jumper used for the measurements installed in the transmitter (OLTS or SLS) for the duration of the measurement session. All connections need to be thoroughly cleaned using a lint-free wiper and isopropyl alcohol.

3.4 Remaining OTDR Fiber Measurements

The remaining measurements described in this section are made at the same time as the OTDR fiber length measurements and attenuation measurement discussed in the preceding two sections.

Activate the OTDR algorithm that automatically summarizes in tabular form the fiber link characteristics found by the OTDR after it produced the fiber link trace shown (fiber lengths, splice loss, reflectance, end-to-end link loss, and optical return loss). Save this table and the fiber trace electronically, for future reference.

Fiber reflectance – Will be located with the OTDR measurements of each fiber pathway, see splice loss. Normally, fiber reflectance limits require that all events have a reflectance. Fiber reflectance occurs at fiber connections and from the end face of a broken fiber. Fusion splices will not be reflective.

Optical return loss of link – This may not be a measurement that will be required as part of the placing “proof-of-compliance measurements.” If it is required, it can be determined with an OTDR measurement for each fiber pathway.

Fiber continuity – Fiber continuity will be determined when the OTDR measurements are made. These measurements will confirm continuity. If a light source and power meter are used, the receipt of light at the power meter (located at the far FDF) will assure the continuity of the fiber pathway.



A.6 Measurement Tips

- If a stabilized light source (SLS) is used with an optical power meter (OPM) to make link loss measurements, the OPM must be referenced to the SLS output power before the loss measurement is made. The same referencing operation is required for most optical power loss test sets (OLTSSs).
- To minimize measurement error, the optical jumper attached to the output port of the SLS or OLTSS for the reference power measurement should remain attached for all link loss measurements for the complete session (until the next equipment zeroing).
- Always make measurements with clean connectors. Use an alcohol dampened wiper to clean the end of the mating connector ferrules used to connect the test sets to and from the fiber link. Canned air can also be used to blow off any ferrule or connector housing for dust both before and after cleaning with isopropyl alcohol and a lint-free wiper.
- Avoid kinking or inducing sharp bends (smaller than a golf ball) into fiber test jumpers.
If no wavelengths are specified for the post-construction measurements, measurements should be made at 1310 nm and 1550 nm.

4 Conclusions

If the post-construction measurements confirm the fiber link's ability to provide a physical transport medium that will match or exceed the proposed transmission system's performance requirements, the construction has been confirmed and the measurements are complete. Otherwise the fiber link must be trouble-shot to locate the problem and repairs must be made. All OTDR fiber traces and OLTSS test results determined during the post-construction measurement program should be saved for future reference if problems develop during the fiber's service life. If the post-construction measurements indicate some inherent fiber damage or noncompliance with respect to performance, the cable manufacturer should be notified immediately, so the problem can be investigated and rectified.

5 Additional Information

If there are additional questions on this topic or other fiber optic issues, please contact Sterlite Technologies at:

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