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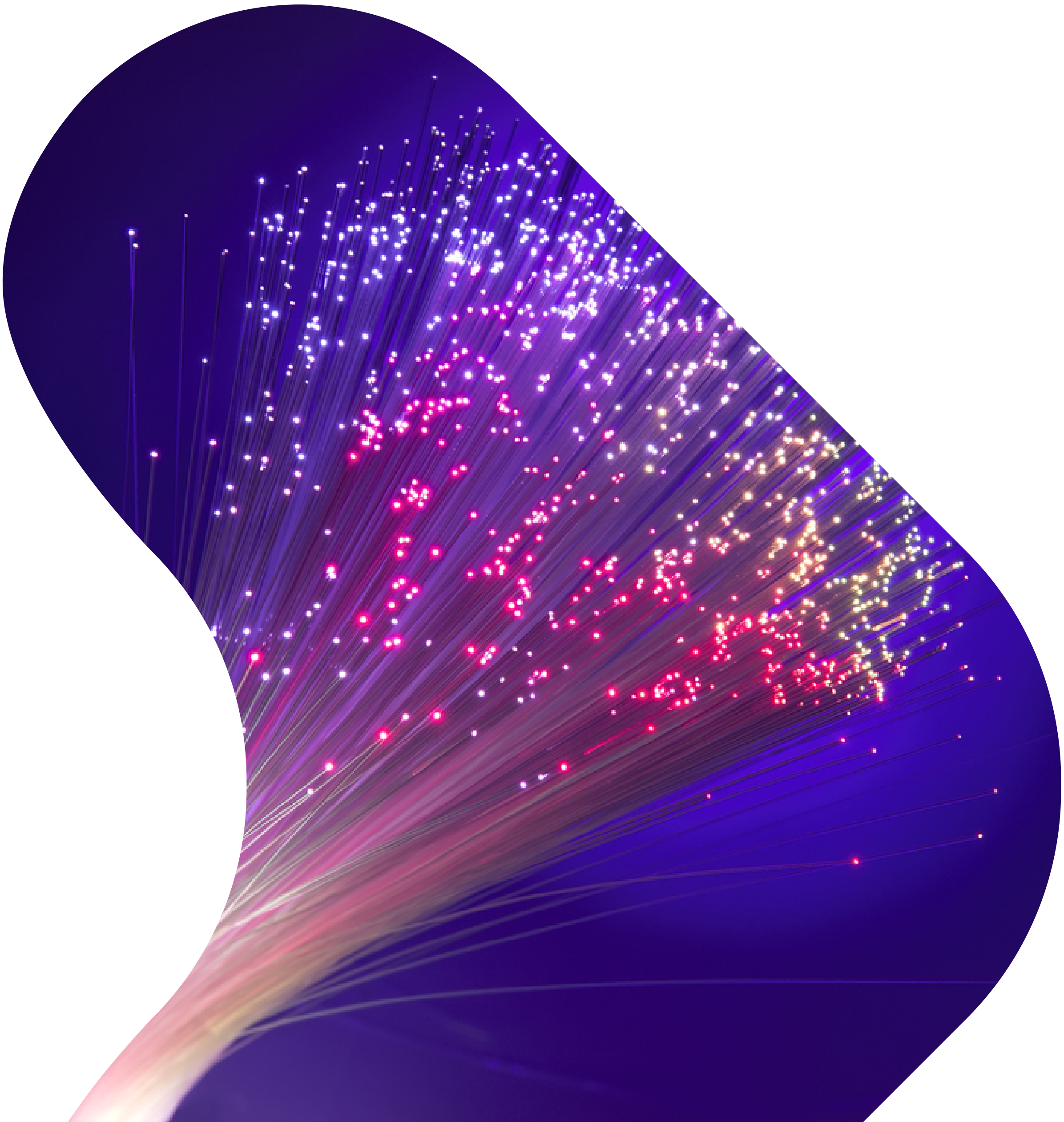
Measurements in New Optical Cables Pre-Construction and Post-Construction Measurements



Abstract
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. Lead-in fibers are useful to locate short distance faults and making loss/attenuation measurement in real time mode. This document explains how to use lead-in fibers.

Keywords
Lead-in fiber, Optical Time Domain Reflectometer (OTDR) accessory, elastomeric lab splice, loss/attenuation measurement, backscatter, dead zone

Introduction

Optical fiber cables are tested for attenuation using the cut back method (TIA 455-78) or back reflection method (TIA 455-8). The cutback method is mainly used in test at the manufacturing facility and the back reflection method is normally used in the field and in the manufacturing facility for some tests. An optical time domain reflectometer (OTDR) is the portable optical test set used in the field for pre- and post construction fiber measurements. The backscatter concept is illustrated in Figure 1

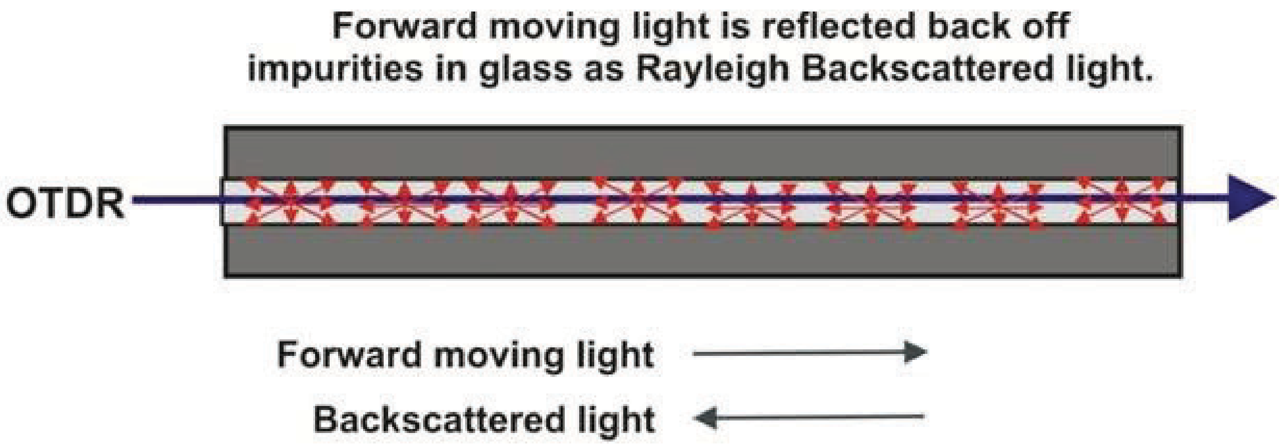


Figure 1- Schematic Drawing of the Backscatter Phenomena Upon Which OTDRs Use to Make Measurements

A lead-in or launch fiber is used to eliminate the effect of dead zone created from the OTDR fiber interface connector. A lead-in fiber is a fiber several hundred meters in length that connects the OTDR to the fiber being measured. It provides a useful fiber trace for the entire length of fiber under test. Since it provides backscatter power leading into and out of the initial fiber connection in the fiber undertest, a more accurate measurement of fiber length and total end-to-end loss can be made. 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 in this case a bare fiber with a mechanical alignment fiber connector, such as an elastomeric lab splice. Lead-in fibers are useful to locate short distance faults and making loss/attenuation measurement in real time mode. This document explains howto use lead-in fibers.

Safety

Laser precaution:
IMPORTANT: Laser beams used In testing optical fiber plant are invisible and can seriously damage the eyes. Viewing these test 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 viewed directly. Therefore,

• Never look into a fiber having a laser coupled to it
• If the eye is accidentally exposed to a laser beam, immediately rush the individual to a medical facilityfor treatment.

Optical Fiber Handling Precaution

- Be careful while handling the fibers.
- Do not stick the broken ends offiber into yourfingers.
- 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 properly.
- Do not eat or drink nearthe installation area.

Measurement Procedure

Block Diagram

This is a schematic diagram of testing optical fibers using an OTDR with a lead-in or a launch fiber.

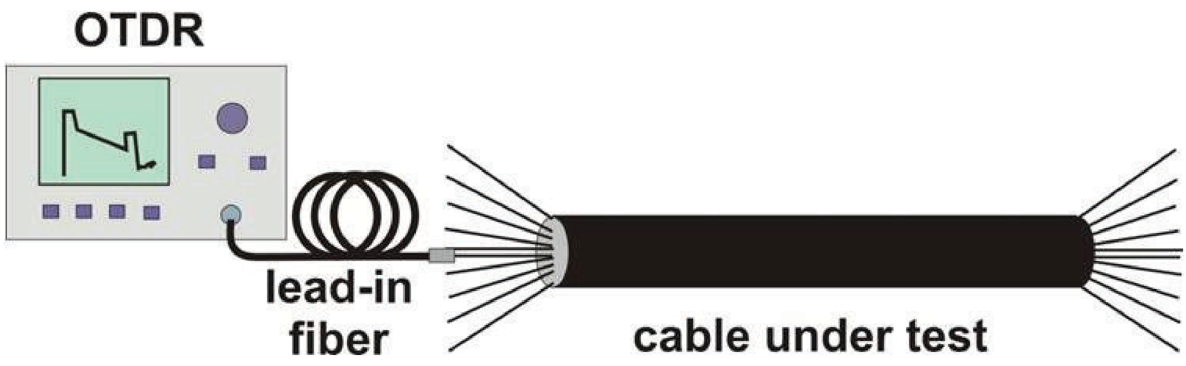


Figure 2 - Schematic Drawing of OTDR Used to Measure Cable Fiber Connected to Lead-in Fiber

Procedure

Connecting Dummy Fibers / Pigtails to OTDR: Clean optical connector in end of lead-in fiber that will mate with the OTDR using isopropanol and lint free wipers. Connect it to the OTDR output so that a fiber trace can be observed. A square peak on the fiber trace (see Figure 3) will mark the start of the trace. Next to this peak OTDR traces should be a smooth with a continuous slope. Adjust the connector to obtain the OTDR trace as shown in Figure3.

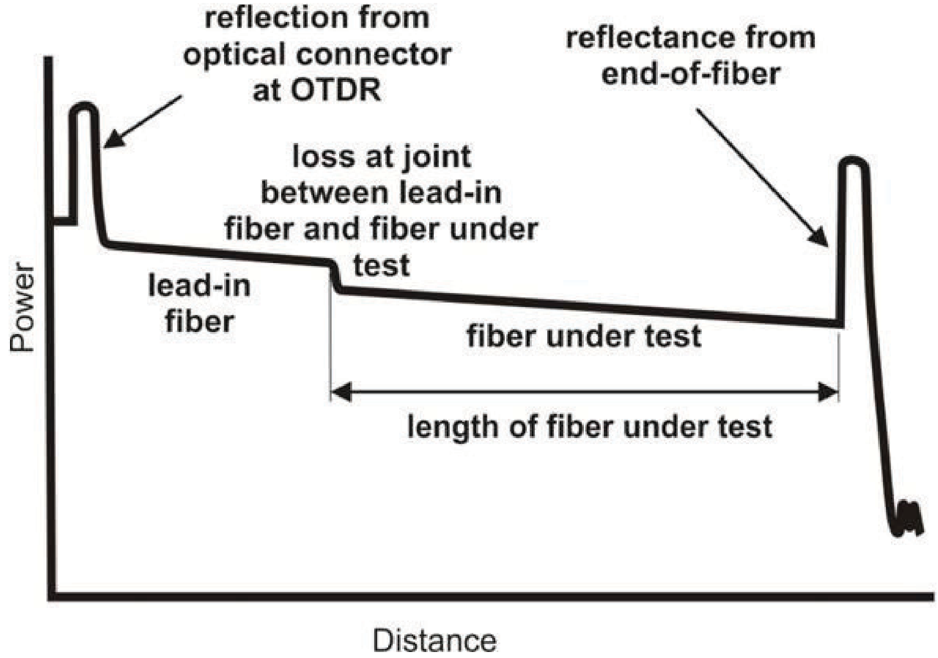


Figure 3 - Typical OTDR Trace Showing Lead-in Fiber Connected to Fiber in Pre- or Post-Construction Cable Testing

NOTE: Clean connectors properly and keep capped when not in use. Dirty connectors can cause permanent damage to the OTDR or the dummyfiber end.

Length Measurement
Once a proper fiber trace is observed on the OTDR, cut a short piece of fiber (1 to 2 cm) from the far end of the cable. Cleave its end to produce a smooth, perpendicular end on the fiber in the cable. Set the OTDR to “real time” testing. The trace should have a square peak at the far end of the fiber (Figure 4). Place OTDR “cursor 2” at the beginning of the peak at the end of the fiber, ensuring that it is on the linear portion of the trace. Connectthefiber undertestto the lead-in fiber using a mechanical connector orfusion splicer.

NOTE: If a fusion splice set is available, its fiber alignment apparatus can be used to align the cleaved bare fiber end of the lead-in fiber with the cleaved bare fiber end of the cable undertest near-end fiber.

The trace shown in Figure 3 will appear on the OTDR. Set “cursor 1” to the splice between lead-in fiber and fiber under test. It shall be positioned at the upper point where the trace begins to drop from the temporary connection loss or if the connection is reflective, it shall be positioned at the upper, left-hand portion of the trace that rises from the reflective connection. Set “cursor 2” at the end of the fiber under test. 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 undertest.

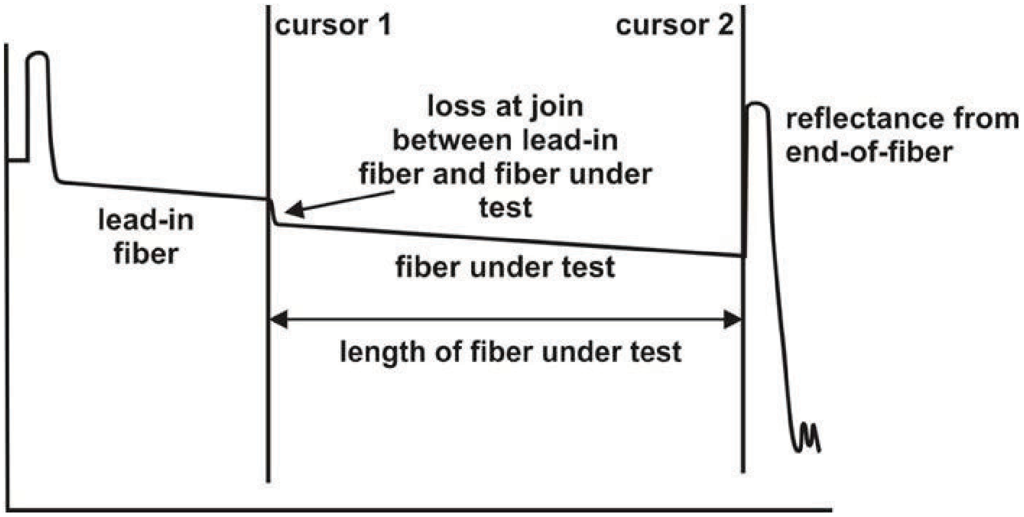


Figure 4 - Typical OTDR trace to determine the fiber length of fiber under test.

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

To measure attenuation coefficient, dB/km, of the fiber under test, connect the fiber using a mechanical or fusion splicer to connect the lead-in fiber and OTDR, see Figure 5. This trace is typical of the trace used to measure the fiber length. This time, however, position “cursor 1” to right of connection between lead-in fiber and the fiber under test.

Make sure that the cursor 1 is on the linear portion of the trace just after the start of the fiber under test. Cursor 2 at the end of the cable can remain at the same location as used for the fiber length measurement. The distance between cursor 1 and 2 should be at least 100 meters or more to assure that the measurement accuracy is acceptable.
The power loss between the two cursor positions is equal to the optical loss between cursor positions. If this loss is divided by the distance between the two cursors, the fiber’s attenuation coefficient is determined in dB/km (or dB/unit distance set on the OTDR).

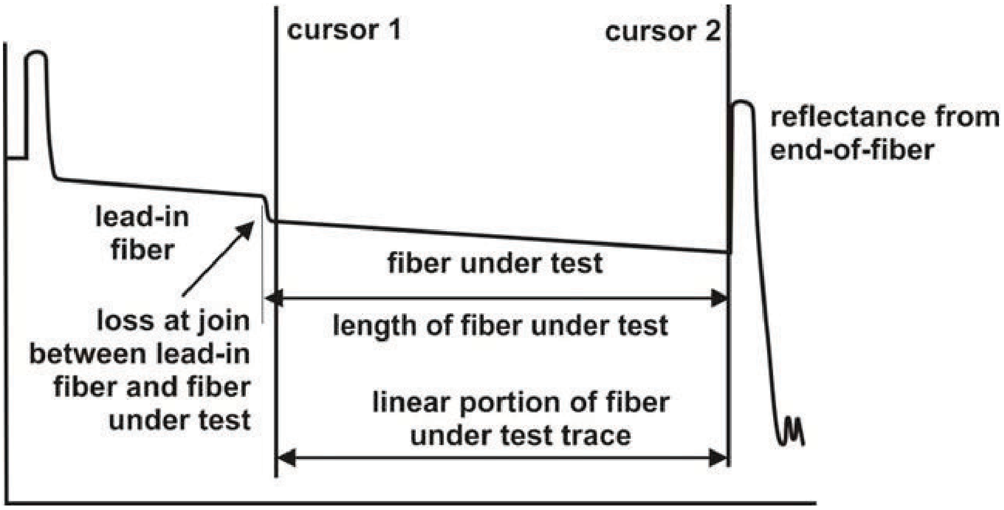


Figure 5 - Typical OTDR Trace to determine the Attenuation Coefficient of Fiber under test.

If the attenuation coefficient is specified at more than one wavelength, the OTDR measurement shall be made at all wavelengths specified in the procurement agreement. Typically the attenuation coefficient at 1310 and 1550 nm are specified for long-haul, single-mode fibers and the attenuation coefficient at 1310, 1550, and 1490 nm are specified for FTTH fibers.

Technical Terms

Please note, this section describes only the most basic operations of OTDR use. There is no substitute for reading the manual provided by the manufacturer ofthe OTDR.

Optical Time Domain Reflectometer (OTDR):
Optical test set used to measure fiber attenuation, loss, length, splice loss, reflectance, and distance to an event. It is a unique fiber test set in that it measures fiber with access to only one end of the fiber. It also measures the distance to a point along the fiber. OTDRs use a phenomenon called backscatter as the basis for their operation. An OTDR sends a pulse out into the fiber and impurities in the fiber cause a small amount of power from the pulse to be returned to the OTDR in a process called backscatter. By timing the returned energy to the OTDR, the distance into the fiber can be determined. The result is a power versus distance plat provided as output bythe OTDR.

Attenuation Coefficient:
Attenuation coefficient is the parameter that characterizes the fiber loss per unit length. If is typically expressed as dB/km or dB/kft. The slope of the linear portion of the OTDR fiber trace is equal to the attenuation coefficient of the fiber being measured.

Splice:
A splice is a connection between two optical fibers. Splices typically exhibit some optical loss. On an OTDR, a non-reflective splice, such as what you would get from a fusion splice, looks like a sudden drop off in optical power. The OTDR fiber trace of a non-reflective spice appears similar to a water fall. The OTDR fiber trace of a reflective splice, typical of what one might get from a mechanical connector, is a spike equivalent in height to the reflectance of the connection followed by a trace that curve asymptotically to the linear slope of the fiber following the mechanical connector.

Dead Zone:
OTDRs exhibit a phenomenon that results from having their receiver over driven by the reflective power that returns from a reflective event and from the fact that the fiber pulse has a finite length that takes a finite amount of time to pass over a fiber event. There are two types of dead zones that are often discussed:

• **Event dead zone:** The minimum distance required for adjacent reflective events to be identified by an OTDR as two distinct events. If the two events are within the event dead zone, they appear as one event, an elongated version of the first event. Two versions of the event dead zone are often used, non-reflective and reflective event dead zone, depending upon the reflectance of the event being discussed.

• **Attenuation dead zone:** The minimum distance required, after a reflective event, for an OTDR to recover sufficiently to measure a reflective or non-reflective event loss accurately. If an event occurs within the within the attenuation dead-zone, it may be detected as a second event, but its distance or its loss cannot be accurately determined because it is within the zone in which the fiber trace is recovering from the first event to asymptotically approach the backscatter level of the fiber beyond the second event in question.

The dead-zone of an event depends upon:

• **The loss of the event-** the greaterthe loss the greater the dead zone.
• **The reflectance of the event-** the greaterthe reflectance of the event used, the greaterthe dead zone.
• **Energy within the OTDR pulse-** the greater the energy (pulse width) of the event selected to be used by the OTDR, the greaterthe dead zone.

How the OTDR Measures Splice Loss:
OTDRs launch short duration light pulses into a fiber and then measures the optical power returned from this pulse as it travels down the fiberversustime from the original launching of the pulse much like radar.
All measurements are made from the launch end of the fiber being tested. The returned optical signal is digitized, converted to logarithmic units of power (dBs), and then, displayed with the time base translated to fiber distance. To improve the signal-to-noise ratio of the received signal, the returned signal from many consecutive pulses is averaged. The returned signal consists of backscattered light from along the fiber, and reflected light from "events" such as refractive index discontinuities at fiber joints, breaks, and ends. Optical loss between two points on the fiber can be indirectly determined by measuring the difference in the returned backscatter power between the two points in question.

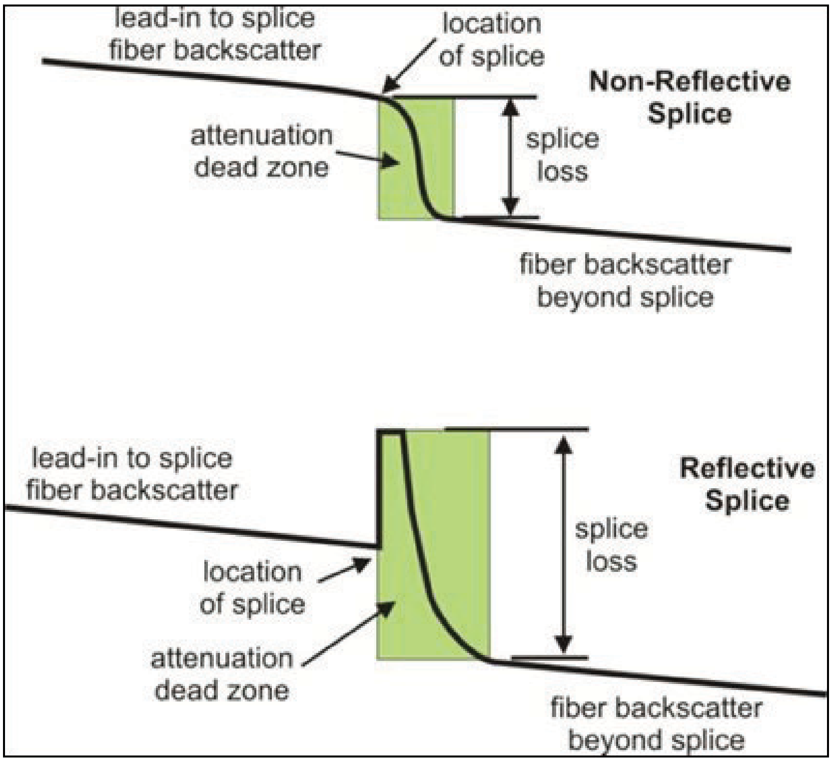


Figure 6 - Measuring Splice Loss from the OTDR fiber trace.

The OTDR uses the backscatter level before and after a splice to determine the level of the splice loss. Backscattering is the scattering of light in a direction generally opposite to the original launched pulse. It is well known that an OTDR will erroneously determine the value of a splice loss if the two mating fibers have significantly different mode field diameters resulting in a difference in backscatter propensity.

Figure 7, below provides an insight into this situation. Consider a situation in which light is traveling through a single-mode fiber with a small backscatter coefficient and it is spliced to a second fiber with a significantly larger backscatter coefficient. The result is a fiber splice that when measured with an OTDR on the fiber with the lower backscatter coefficient appears as a gainer. When the OTDR is moved to the opposite end (the fiber with the greater backscatter coefficient), the same splice appears as a loss. In actuality, neither measurement is correct because OTDRs don't measure forward moving power directly, but rely on backscattered power measurements as the source of information upon which they base their measurements. If both OTDR measurements are averaged (bidirectional average) the resulting average loss agrees with the true fiber attenuation of the splice.

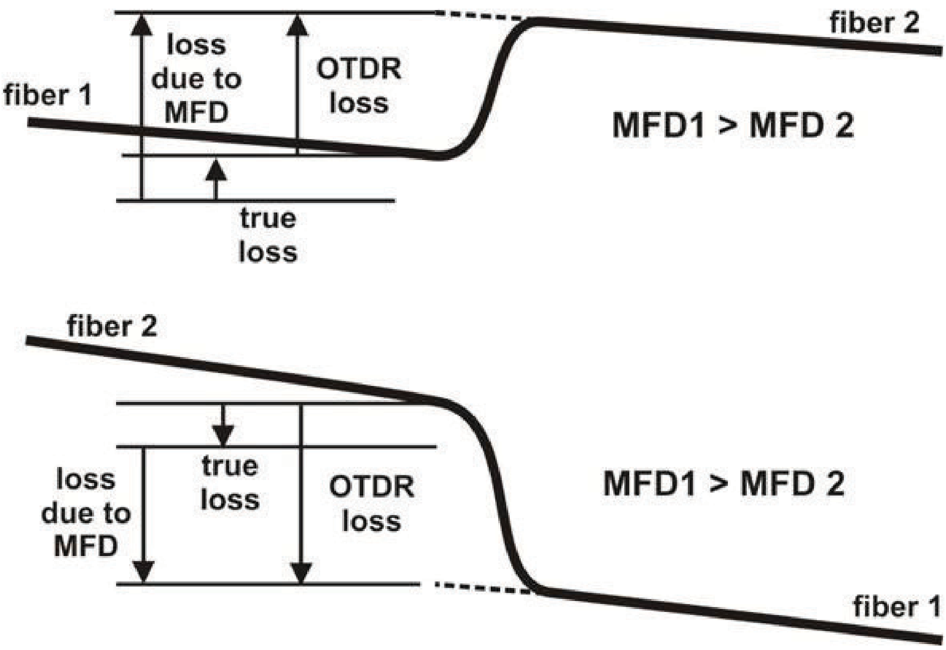


Figure 7 - Splice Loss as Measured from Both Fiber Ends

NOTE: Most fiber splices are made between cables ordered at the same time and as a result the fibers all have very similar optical properties. When these cables are spliced together they produce splice loss results which have much smaller directional sensitivity and a one direction measurement is often quite accurate. If the one direction splice loss is measures as a loss that meets the normal fusion splice acceptance threshold, it is extremely likelythat the splice is acceptable.

Post-Construction Measurements

After an optical cable link is constructed, the overall optical performance of each fiber pathway should be characterized to assure that the cable has been placed without damage, that all splices have been made properly, and the completed fiber link will meet the intended service objectives. The quality of the new fiber system can be determined by making a series of measurements on each fiber. As long as splices between cables have been made using a profile alignment style fusion splicer, each of the fusion splices should be acceptably low-loss and the post-construction measurements can be made between the two terminating fiber distribution frames (FDFs).

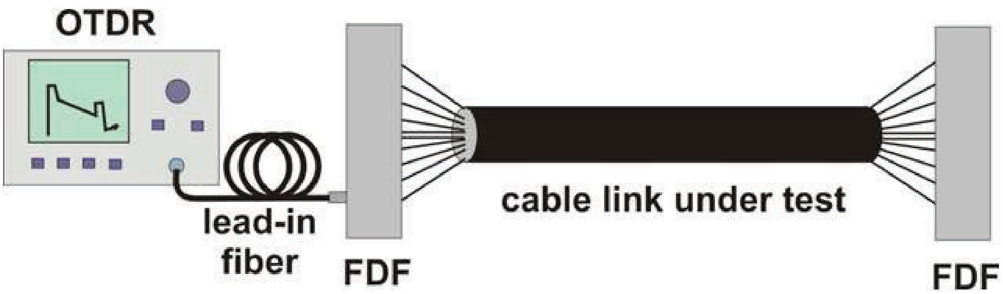


Figure 8 - Making Post-Construction Measurements of the Fiber Pathway Using an OTDR

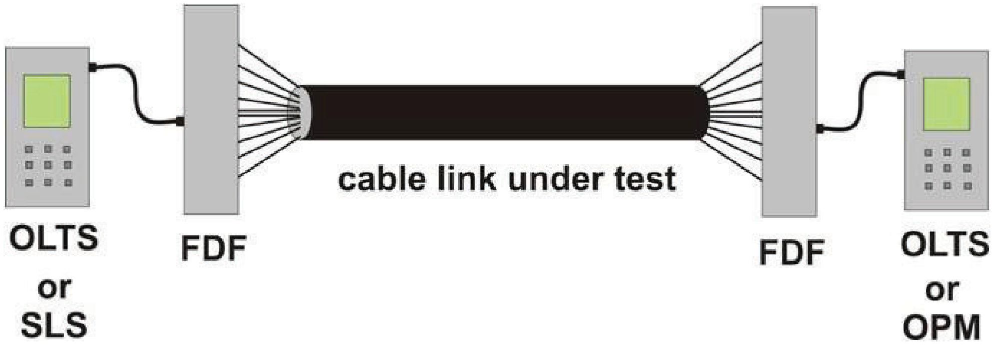


Figure 9 - Making Post-Construction Measurements of the Fiber Pathway Using an OLTS or a SLS and OPM

This type measurement will check each concatenated fiber pathway and each splice in the cable link. The following measurements should be made:

End-to-end link loss-
Can be measured with a stabilized light source (LED or laser) or an optical loss test set (OLTS) at the intended service wavelength. The measurement can also be made with an OTDR with sufficient accuracyto satisfy most post-construction requirements.

Splice loss-
Must be measured with an OTDR at the intended service wavelength. Be aware of the phenomenon of OTDR splice gainers. If necessary a two directional measurement should be made and averaged. Each fiber pathwaytrace should be saved for future use if maintenance is required.

Fiber reflectance-
Will be located with the OTDR measurements of each fiber pathway, see splice loss. Normally, fiber reflectance limits require that events have a reflectance equal to or less than a -55 dB; however, some systems require reflectance to be less than or equal to -65 dB. Fiber reflectance occurs at fiber connections and from the endface 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." However, if it is required, it can be determined with an OTDR measurement for each fiber pathway.

Fiber continuity-
Fiber length will be determined when the OTDR measurements are made. This 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.

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 (OLTSs).

• To minimize measurement error, the optical jumper attached to the output port of the SLS or OLTS for the reference power measurement should remain attached for all link loss measurements.

• To minimize measurement error, the optical jumper attached to the output port of the SLS or OLTS for the reference power measurement should remain attached for all link loss measurements.

• Always make measurements with clean connectors. Use an alcohol dampened wiper to clean the end of the connector usedto connectto and from the test sets andthe fiber link. Canned air can also be used to blow off any link or dirt both before and after cleaning with the wiper.

• Avoid kinking or inducing sharp bends (smallerthan a golf ball) into test jumpers.
• If no wavelengths are for the post-construction measurements, measurements should be made at 1310 nm and 1550 nm.

beyond tomorrow

About STL - Sterlite Technologies Ltd

STL is a leading global optical and digital solutions company providing advanced offerings to build 5G, Rural, FTTx, Enterprise and Data Centre networks. The company, driven by its purpose of 'Transforming Billions of Lives by Connecting the World', designs and manufactures in 4 continents with customers in more than 100 countries. Telecom operators, cloud companies, citizen networks, and large enterprises recognize and rely on STL for advanced capabilities in Optical Connectivity, Global Services, and Digital and Technology solutions to build ubiquitous and future-ready digital networks.
STL's business goals are driven by customer-centricity, R&D and sustainability.

Championing sustainable manufacturing, the company has committed to achieve Net Zero emissions by 2030.
With top talent from 30+ nationalities, STL has earned numerous 'Great Place to Work' awards and been voted as the 'Best Organisation for Women'.

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