Ensuring the Health of Tomorrow's Fiber LANs

OTDR Trace Analysis – Become an Expert Troubleshooter with Advanced OTDR Trace Analysis

Experience designing cable and network testers has enabled a breakthrough in automated fiber trace analysis.

Automated OTDR trace analysis improves a user's ability to determine the health of the fiber LAN by translating raw data into simple PASS/FAIL results.

This white paper discusses how an OTDR detects and analyzes test results, and explains expected, as well as unexpected, trace data from fiber networks.

Table of contents

FLUKE networks

Ensuring the Health of Tomorrow's Fiber LANs *Part II – OTDR Trace Analysis – Become an Expert Troubleshooter with Advanced OTDR Trace Analysis*

What can OTDR analysis do for you?

Part I of the series *Ensuring the Health of Tomorrow's Fiber LANs*, Choosing an OTDR, explained what an optical time domain reflectometer (OTDR) is and what is important when choosing one for use on your network. An OTDR can be a very effective single-ended testing and troubleshooting tool, requiring equipment and an operator at only one end. OTDRs have an advantage over Loss/Length meters in that an OTDR can pinpoint the locations of faults, reflective and loss events on the fiber cabling. Choosing an OTDR with the most appropriate features and specifications for the premises environment is important to capitalize on these advantages.

Equally important to choosing the right OTDR is the ability to correctly analyze and interpret OTDR test results. This white paper provides information on how an OTDR detects and analyzes test results in fiber optic networks. It discusses typical events detected and how to interpret the data into what is important to ensure the health of fiber optic LANs.

Events, backscatter, and other unfamiliar terms

There are many unfamiliar terms used when describing how an OTDR works and how it analyzes test results. These terms are easy to understand when properly explained. OTDRs are used to find and analyze instances of disturbance to a fiber optic signal. These instances are often called "events". Some events are expected and others are unexpected in a fiber link. These events are categorized into reflective and non-reflective. The following sections of this paper explain types of events seen when using an OTDR.

OTDRs work by sending a series of very short high-power light pulses into a fiber and recording the light reflected as each pulse travels down the fiber. OTDRs use specialized pulsed laser diodes to generate these high-power light pulses and special high-gain light detectors to measure the light power reflected or backscattered. This is referred to as "shooting a trace." A "trace" is the graphical plot of the fiber being tested where power is on the Y axis and distance is on the X axis as shown in Figure 1.

The optical fiber acts as a waveguide for the light pulse. As the source pulse travels down the fiber, most of the light travels in the direction of the fiber. A small fraction of the light is scattered in different directions, due to the normal structure of (and small defects in) the glass that makes up the fiber. "Backscatter" is the tiny portion of the scattered light that is directed back toward the OTDR and can be detected. The OTDR uses backscatter changes to detect events in the fiber that reduce or reflect the power in the source pulse. Thus the portion of an OTDR trace between events is called the "backscatter line."

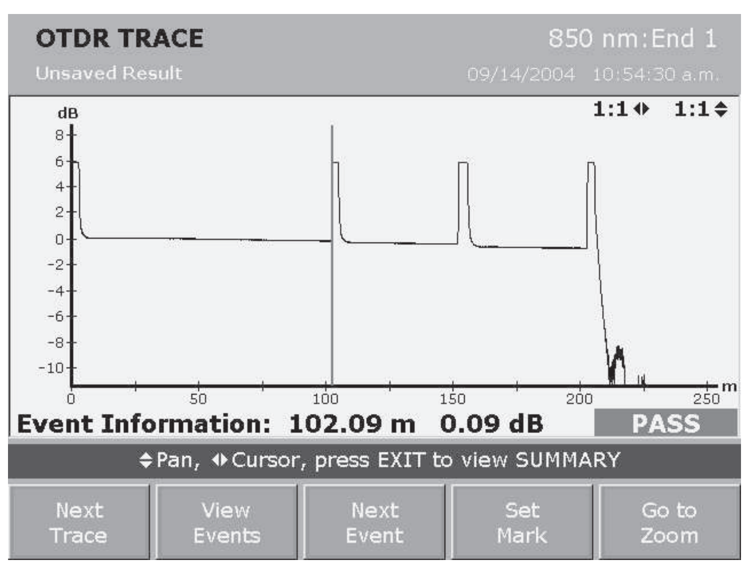
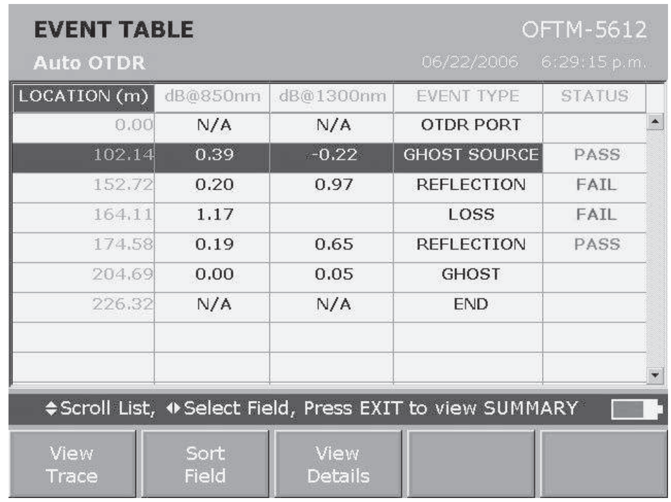


Figure 1. An OTDR trace

The power of a light pulse decreases because of loss from scattering, and at events such as connections and splices. At the same time, reflections are caused by connections, breaks, cracks, splices, sharp bends, and the end of the fiber. An OTDR is able to determine both the loss and "reflectance" of individual events as well as total loss and total reflectance or "optical return loss" of a section of fiber.

The rise of the event analyzer

Historically, OTDRs relied on expert users to interpret the results shown on a trace. For example, a technician would determine what was noise on the trace, what were events, and what type of events he was looking at based on his experience and familiarization with OTDR traces. As embedded processors became more capable, software was added to help users interpret the results. OTDRs can now distinguish certain types of events from others and compare to user defined limits. As software has become more sophisticated, it has further reduced the need for users to interpret results. Most OTDRs also extract event information from the trace data and can display text tables showing the location and characteristics such as the loss and reflectance of the events found. This is often called an "event table." See Figure 2.


EVENT TABLE OFTM-5612
Auto OTDR 06/22/2006 6:29:15 p.m.

LOCATION (m)	dB@850nm	dB@1300nm	EVENT TYPE	STATUS
0.00	N/A	N/A	OTDR PORT	
102.14	0.39	-0.22	GHOST SOURCE	PASS
152.72	0.20	0.97	REFLECTION	FAIL
164.11	1.17		LOSS	FAIL
174.58	0.19	0.65	REFLECTION	PASS
204.69	0.00	0.05	GHOST	
226.32	N/A	N/A	END	

Scroll List, Select Field, Press EXIT to view SUMMARY

View Trace | Sort Field | View Details

Figure 2. Event table

Certain events – such as connectors, splices and the end of a fiber – are expected on an OTDR trace and are factored into loss budgets. A mated pair of fiber optic connectors is a "reflective event," and a fiber splice is considered a "loss event," since it exhibits very little reflectance. Connections and splices must exhibit loss and reflectance that conform to specifications required by industry standards for applications running over the fiber optic network. With Fluke Networks' OptiFiber Certifying OTDR, users can assign test limits to event characteristics. These limits for loss and reflectivity can be set based on industry standards, or for specific job requirements. OptiFiber's analyzer compares the event characteristics to the user-selected set of test limits and gives the user a PASS/FAIL indication that can be stored in a test record. This feature, which depends on accurate extraction of event characteristics by the event analyzer software, eliminates the need for both novice and expert OTDR users to analyze traces of fibers that meet or exceed expectations for loss and reflectivity enabling technicians to perform efficiently.

Unexpected events

In addition to expected events such as connectors and splices, OTDRs also locate and characterize unplanned events on fibers. These events include ghosts, gainers, hidden and unplanned loss events. Refer to Figure 3 for examples of events on an OTDR trace. These events usually accompany something occurring in the fiber link that is not optimal. Dirty connectors, sharp bends, and mismatched fiber core sizes are examples of causes of unplanned events.

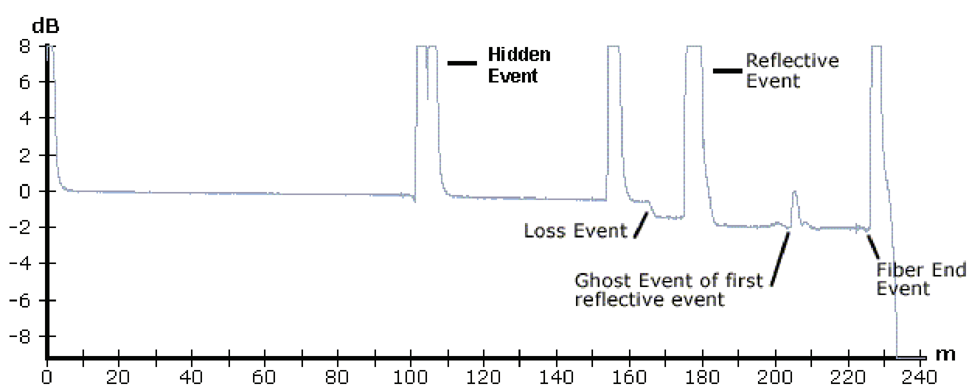


Figure 3. A complex OTDR trace

Ghost events

One of the most interesting events seen on an OTDR trace is a ghost. This type of event can be difficult to distinguish from actual events because it is a non-existent event that shows up on an OTDR trace. Ghosts can be generated in two ways.

One way a ghost is created is from insufficient delay between laser firings. In this case, the energy from one laser firing gets mixed with the energy from another. The ghosts in Figure 4 are examples caused by light pulses being too close together. These are the four large pulses after the end of the fiber, with the first pulse just after 250 m. The even spacing of these events and the fact that pulses generally decrease in height is an indication these are ghosts. In this case, the energy from one laser firing gets mixed with the energy from another. But the most common cause of ghosts in LANs is an "echo" of light bouncing multiple times between events. An echo is typically caused by a poor connection between fibers. Reflective events act as translucent mirrors, where most of the light passes through, but a percentage is reflected back toward the OTDR. Not only will it reflect light back towards the OTDR, it will also reflect in the opposite direction, reflecting the returning light back towards the far end. The OTDR trace in Figure 3 shows a ghost event generated by a reflection off the first large reflective event at 100 m, then off the instrument bulkhead (OTDR Port) event, then again reflected from that first event. Note that the ghost is located at about 200 m into the fiber, which is twice the distance to the first large reflective event and that there is little or no loss across the ghost event.

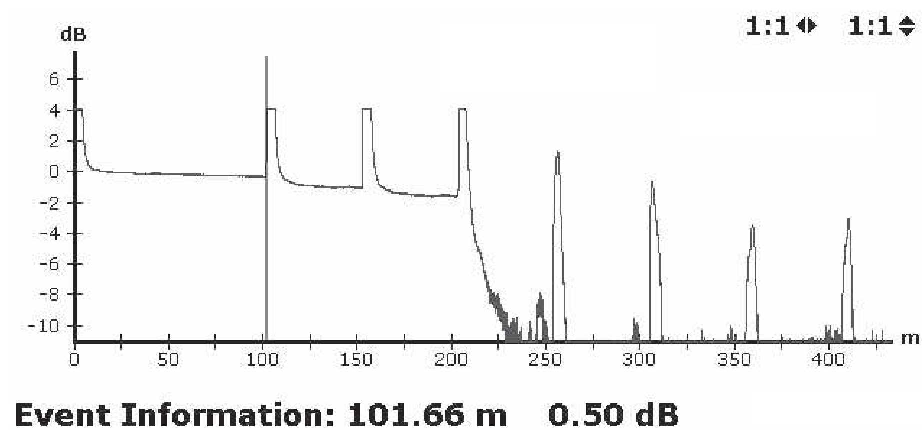
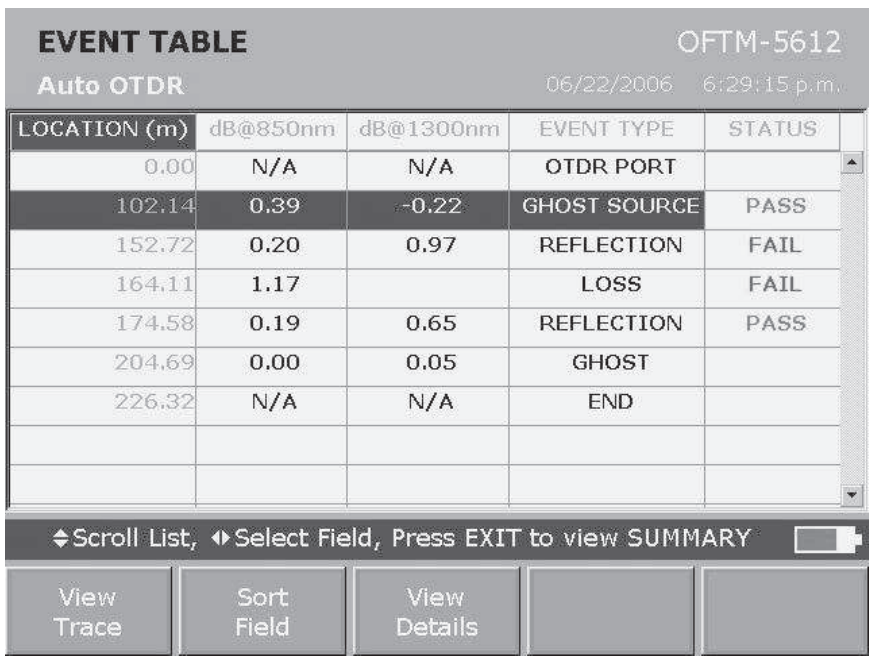


Figure 4. Example of ghost events

There are several ways to identify a ghost and distinguish it from a real event. An expert OTDR user will look for several things when analyzing a trace. Events that show much more dispersion (pulse broadening) than other events or change location if additional fiber is inserted after the location are suspected of being ghosts. Also, events that exhibit no loss, and show repetition an equal distance down the trace are probably ghosts. Only a very experienced fiber technician can effectively identify ghosts using these trial-and-error methods.

When using OptiFiber, identifying ghosts is a simple process. Ghost events and ghost sources are identified by the analyzer software and labeled “ghost” and “ghost source” in the event table as seen in Figure 5. To minimize the disruption caused by ghosts, make sure all connections in the fiber link are cleaned, properly mated, and are of good quality before starting a test. This minimizes the reflected energy, which reduces the chance a significant ghost will be generated. Also make sure all launch, receive, and patch cables are the same fiber type and have the same core size.



LOCATION (m)	dB@850nm	dB@1300nm	EVENT TYPE	STATUS
0.00	N/A	N/A	OTDR PORT	
102.14	0.39	-0.22	GHOST SOURCE	PASS
152.72	0.20	0.97	REFLECTION	FAIL
164.11	1.17		LOSS	FAIL
174.58	0.19	0.65	REFLECTION	PASS
204.69	0.00	0.05	GHOST	
226.32	N/A	N/A	END	

Figure 5. Event table with ghost and ghost source identified

Hidden events

Hidden events are events that follow so closely after a preceding event, the signal from the preceding event does not have time to get down to the backscatter level before the hidden event is detected. Hidden events often occur as a result of patch cords that are installed in a fiber link. The hidden events shown in figures 3 and 6 are from a short patch cord connected between the OTDR launch fiber and the fiber link.

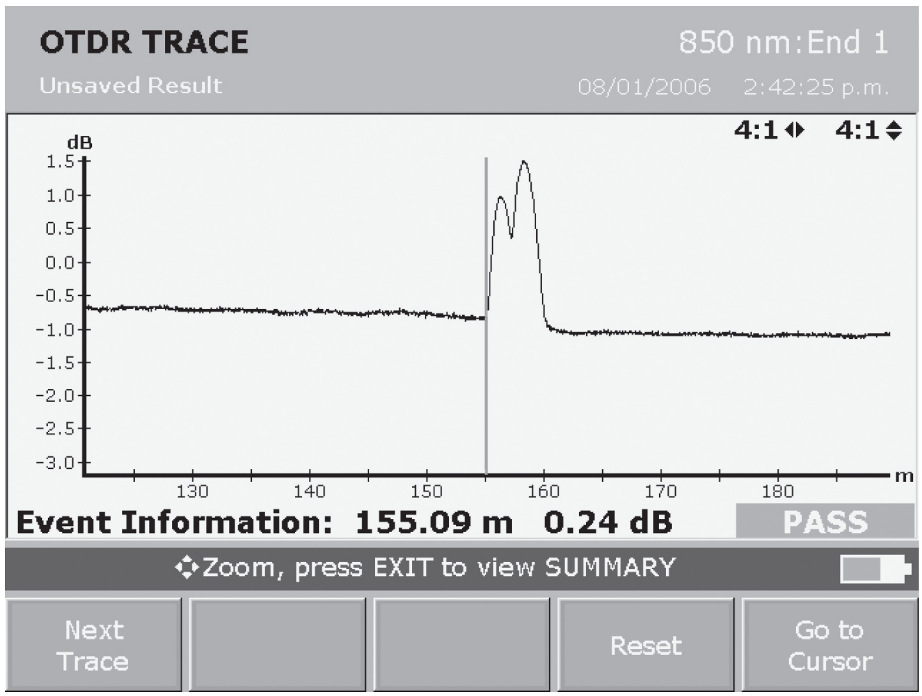


Figure 6. Hidden event

Many OTDRs will not display hidden events because their event deadzones are not sufficient for determining events so close together. However, OTDRs that have been designed for LAN and campus applications exhibit short event deadzones. But it is possible that very short patch cords can appear as a hidden event, instead of two distinct reflective events in OTDR traces. When viewing a trace such as the one in Figure 6, it can be difficult for many technicians to determine the location of connectors and short patch cords. To make it easier the OptiFiber Certifying OTDR has a special capability called ChannelMap.

The OptiFiber ChannelMap test uses special OTDR and analyzer setup and processing to extract only reflective events from the trace data. Loss events such as splices are not included in the results. This test is optimized to locate closely spaced reflective events. Figure 7 shows an example of a ChannelMap diagram. ChannelMap provides the best resolution in OptiFiber; it can detect and display multimode patch cords as short as 1 meter and singlemode patch cords as short as 2 meters.

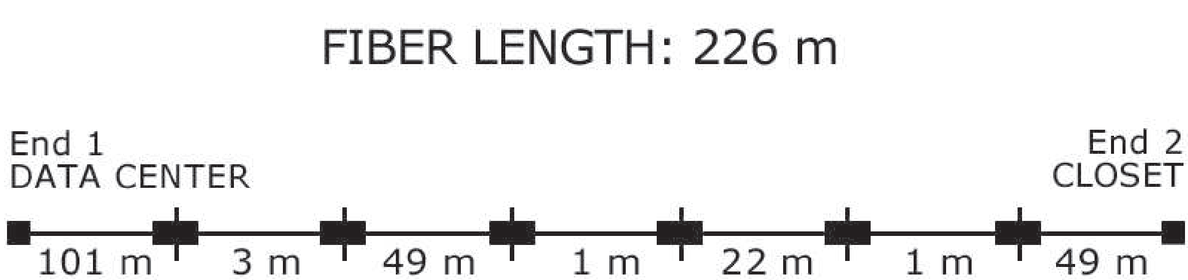


Figure 7. ChannelMap with six connections

Gainer events

When the backscatter level measured after an event is higher than that measured before the event, the event is called a gainer. This can happen when two sections of dissimilar fiber are connected together. For example, Figure 8 shows a large gainer in an OTDR trace where 100 meters of 50 µm fiber is connected to 100 meters of 62.5 µm fiber.

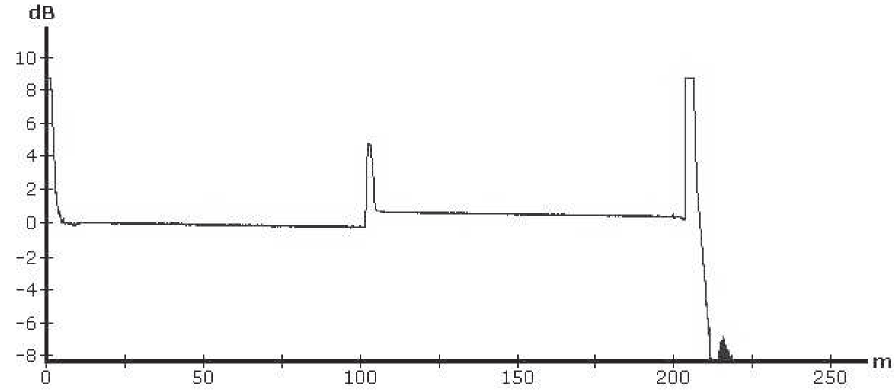


Figure 8. Example of a gainer event

A gainer can also happen after a highly reflective event. It is obviously impossible to introduce a real "gain" or increase in power from a passive device such a connector. So a gainer is an indication a mistake has been made when terminating or connecting fibers. OptiFiber will enable a technician to quickly identify "gainers," and make the necessary changes to fix the problem. Typically, a broken connector or a patchcord with the wrong core size must be replaced to resolve this.

Unplanned loss events

When a fiber optic network is designed, the quantity and quality of connections and splices is planned for. An OTDR can find additional loss events that were not planned for. These are typically caused by sharp bends in the fiber. A tight tie wrap or poor cable management as shown in Figure 9 will cause loss of light from the fiber. Since there is little or no reflection from this event, it will appear as a non-reflective event on an OTDR trace. This type of event is detected by a sudden change in the backscatter level across the event site. For the OTDR to measure loss, it must generate and detect backscatter at this loss event that is above the noise level at the OTDR detector.

If you have such a loss event and you didn't plan for it, only an OTDR will locate it for you. The OptiFiber Certifying OTDR's automatic test limits will ensure unplanned loss events don't slip through unnoticed. Often removing a tight tie wrap will resolve the problem and ensure your network is unencumbered with excess loss.

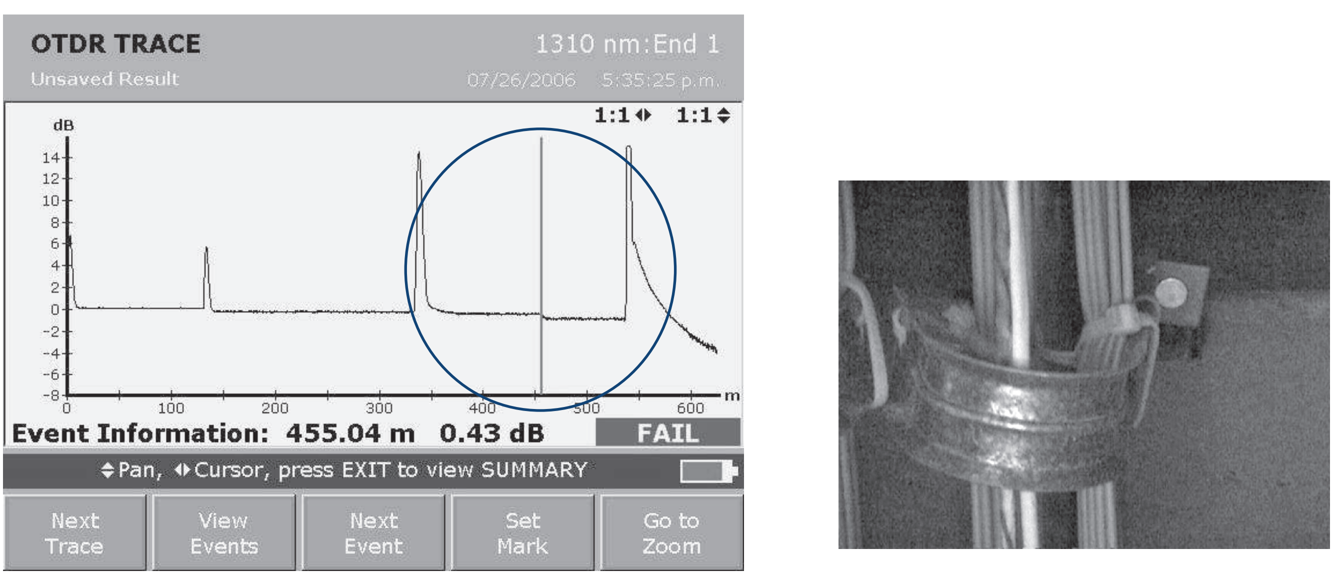


Figure 9. Bending loss event

OptiFiber Certifying OTDR – the complete trace analysis solution

OTDRs are an important documentation and troubleshooting instrument used by organizations to install and maintain optical fiber. In addition to troubleshooting, OTDRs can examine the performance of each connection rather than only the sum of all losses. In this way, it can complement the power meter and light source test, improving the quality of an installation and ensuring poor connections are detected and not masked by other very good connections in the fiber link.

Identifying and understanding events that occur within a fiber optic link is important in ensuring the health of fiber LANs. An OTDR is the only tool that will give visibility of these events. An OTDR's ability to detect connectors, splices, and faults in an optical fiber run depends mainly on its key features and specifications such as deadzone, dynamic range, maximum range, distance accuracy, loss threshold, linearity, and sampling resolution specifications.

In some cases, OTDRs can misinterpret events, or miss them altogether, due to improper test parameter set up, or improper choice of an OTDR for the application. In other cases, technicians are unable to correctly interpret OTDR traces. Understanding how the OTDR and its analyzer work and how an OTDR's specifications affect its performance can help users get maximum performance from their OTDR.

An OTDR's ability to identify and characterize the events is critical. Of equal importance is its capability to identify both expected events such as connectors and splices and unexpected events such as ghosts, gainers, hidden and unplanned loss events. The OptiFiber Certifying OTDR offers an unmatched trace analysis capability. In addition to analyzing the trace and identifying ghosts, ghost sources, hidden events, reflective events, gainers, loss events, and fiber ends, OptiFiber provides a help menu which guides a technician through resolving unexpected events that result during testing and troubleshooting. Its unique ability to establish trace and event limits makes this a productive experience. In summary, OptiFiber enables technicians to perform at an expert level to increase the quality and health of their fiber network. Visit our fiber best practices solution center at **www.flukenetworks.com/fiberbestpractices** to learn more about OTDR testing with OptiFiber.

NETWORKSUPERVISION

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**.

Printed in U.S.A. 10/2006 2527518 A-ENG-N Rev A