White Paper

Automated test limits:

The key to efficient, profitable fiber certification

The quality of an enterprise fiber optic network depends on the test equipment used during its installation. Greater precision and depth of test coverage make it possible to build and certify higher-quality networks.

Unfortunately, early generations of test equipment provided excellent test coverage, but at the cost of being labor-intensive, dependent on skilled technicians, and vulnerable to human error. This resulted in a trade-off between high quality or low cost and network installers had to choose which was more important.

With advances in test-equipment capability, including automatic data analysis and automatic data assessment relative to standard and customized test limits, it has become possible to achieve high quality and depth-of-test coverage at the same time as lowering the test costs.

Table of contents

FLUKE networks

Technologies and standards for fiber optics test

There are two primary technologies for testing fiber optic cabling. Optical loss test sets (OLTS) measure the absolute end-to-end loss of light with a power meter and source for each link. Optical time domain reflectometers (OTDR) analyze the loss and reflectance of light along each link. Together, they provide complete test coverage for installing enterprise fiber optic networks.

Standards for the use of these two technologies are addressed in published guidelines [7] from the Telecommunications Industry Association (TIA). The guidelines specify two levels of testing, Tier 1 and Tier 2, which govern the use of OLTS and OTDR technologies.

- Tier 1 testing is required in all fiber optic cabling links. In Tier 1, an OLTS is used to measure the total attenuation on each link. Fiber length and polarity are also determined, either by measurement or calculation. However, while Tier 1 testing does certify the overall performance of each link, it does not provide any direct information as to the quality of the link's components and construction.
- Tier 2 testing provides the additional depth that Tier 1 does not. This additional testing is optional per industry standards, but extremely important. Tier 2 tests each link with an OTDR and analyzes the connectors, splices and the fiber itself by capturing and measuring the light that is reflected back from them.

Together, Tier 1 and Tier 2 testing provide full test coverage for enterprise fiber optic networks. However, traditional test instruments generally require the time and attention of a skilled technician. This makes the process expensive, time-consuming, and vulnerable to human error.

To solve this problem, OLTS equipment manufacturers began to build functionality for automatically performing the evaluation of test results. This was done through the use of test limits, entered by the operator. The OLTS would apply the limits to each test result, automatically comparing it against performance standards, give a PASS/FAIL result, and record all the test data.

For Tier 1 testing, this has led to increased productivity, lower costs, and the elimination of human error, but only for Tier 1 testing. Tier 2 test results, using an OTDR, still have to be evaluated by a skilled technician and Tier 2 testing continues to be expensive and difficult. Now a new generation of OTDR test equipment has been developed that includes automated test limit analysis capability, and the result is a significant reduction in Tier 2 certification cost and time.

Testing exterprise fiber optic networks

Test method	Applicable standards	Coverage	Results
OLTS	**TIA/EIA Tier 1** **ISO/IEC Basic**	"Black box" test of each fiber's total end-to-end optical loss	Yes/No test that identifies whether each fiber meets the optical loss budget, but does not identify the cause of any failures and does not detect any marginal components or faulty workmanship
OTDR	**TIA/EIA Tier 2** **ISO/IEC Extended**	Analyze splices, connections, cracks, breaks and sharp bends in the fiber by measuring the light that is reflected back from them	Identify and locate the cause of any links that fail OLTS Identify and locate — even on links that pass OLTS — marginal components and faulty workmanship that may cause problems later
Automated OTDR test limits	**TIA/EIA Tier 2** **ISO/IEC Extended**	Make automated pass/fail determinations by comparing the measurements to preset limits and recording the results	Certify the quality of the install, including readiness for future demands such as gigabit or 10 gigabit speeds Provide a documentary record for determining when future callbacks are chargeable Improve profitability by increasing productivity, decreasing errors, and minimizing the need for specialized skill sets or training

Automated OTDR test limits

Complementary Tier 1 and Tier 2 fiber tests provide thorough and in-depth test coverage, as shown above. However, analyzing and evaluating test results requires time and expertise, and even with the most expert technicians, there is the risk of errors. Historically, high test coverage also meant high cost.

(For more information about Advanced OTDR Trace Analysis, download the whitepaper here: ***www.flukenetworks.com/trace****).*

The solution to this problem was the use of automated test limits. Test limits have long been available with OLTS equipment, and the industry has come to expect and rely on them for Tier 1 testing. This same capability was not available in earlier generations of OTDR testers, yet is even more important for Tier 2 because the test results contain more information and are more difficult to evaluate.

Some of today's newest generation of OTDR testers include automated test-limit capability. They perform many of the functions that would otherwise require a skilled technician, and the benefits are significant.

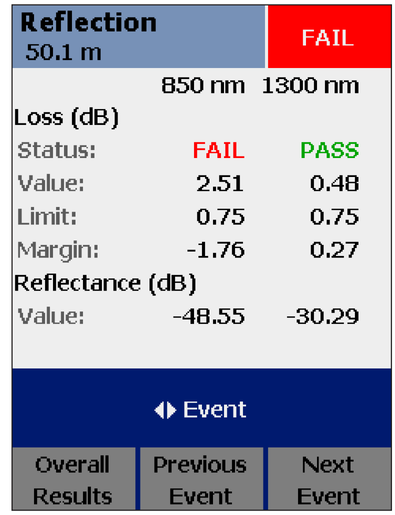


Figure 1. *An OTDR can automatically evaluate connectors and splices against test limits, and generate PASS or FAIL results.*

Benefits of using automated OTDR test limits

Rapid, accurate testing

With automated test limits, an OTDR can analyze a trace much faster than even a skilled technician can. Manual testing requires moving the cursor to each of the many peaks and drops in the OTDR trace, measuring them on-screen and saving the results. The technician also has to read and evaluate every connector and every splice on every trace. With automated test limits, the entire process happens in seconds and the technician only has to look at anything that fails.

Custom limits, per project specifications

A tremendous advantage of test limits is that they can be set directly to the project's contract specifications.

Network designers write specifications that reference various standards [9] and dictate what testing must be performed. The specifications typically include performance limits such as those shown in the example below. Once the limits are entered into the OTDR, every test result will automatically be evaluated and documented against these limits — allowing the technician to do rapid, accurate testing, even without necessarily knowing the project specifications.

1.2 OTDR test specifications

1. Reflective events (connections) shall not exceed 0.75 dB.

2. Non-reflective events (splices) shall not exceed 0.3 dB.

A. All installed cabling links and channels shall be field-tested and pass the test requirements and analysis as described. Any link or channel that fails these requirements shall be diagnosed and corrected. Any corrective action that must take place shall be documented and followed with a new test to prove that the corrected link or channel meets performance requirements.

Figure 2. *Test limits, from a network design specification*

Increased profitability

Automated test limits increase profitability by making OTDR testing faster, error-free, and by reducing the need for specialized skills or training.

Verifying fitness for future usage demands

Completely certifying a network requires testing the performance of all the components, not just the end-to-end optical loss. OTDR testing can certify that the network is ready for future demand such as gigabit or 10-gigabit speed.

Documentation for chargeable future callbacks

The question of who pays for a callback can be troublesome if it is not clear whether the original work was at fault or if the failure occurred after the project was signed off. The automated test records provide a sound basis for determining whether a callback is actually rework from a faulty install or if it is a chargeable service call instead.

Certification

The OTDR stores the results of each test. Those stored results show that the installation is certified — that it has been tested against the design parameters for the project. Also, the certification is objective because each test is evaluated by the OTDR rather than by the technician.

Tier 1 testing: Methodology using an OLTS

An OLTS determines the total light loss along the fiber link, using a known light source at one end of the fiber and a light meter at the other end. The total loss is compared to the test limits, and if the loss is within specified limits, the link passes.

This method gives a PASS/FAIL result for each fiber link, but treats each link as a black box and does not provide information on anything internal to the black box. Paradoxically, this is acceptable when a link fails but can be a liability when a link passes. The reason is that if a link fails Tier 1 testing, the technician knows there is a problem and can work to repair it. But when a link passes Tier 1, the technician doesn't know whether or not there potential problems. A passing link might have marginal connectors, bad splices, or other problems that are not revealed, so relying on Tier 1 alone can give a false sense of security. For example, a link might have a dirty connector with a relatively high loss. As long as the total loss is within limits, the link would pass Tier 1 testing. That dirty connector, however, could cause problems later, leading to downtime or callbacks.

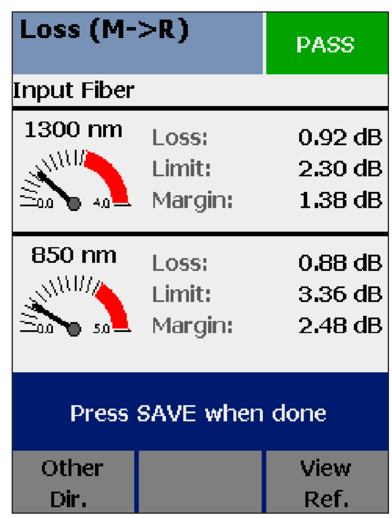


Figure 3. *Tier I test result, showing a fiber that passes OLTS: it is within the specified loss limit (2.00 dB) at both 850 nm and 1300 nm.*

Another limitation of Tier 1 is that it cannot verify whether requirements are being met for the performance of connectors and splices. Most projects now have such specifications, not just specifications for the total loss on each link. Going beyond the limitations of Tier 1 testing requires Tier 2 testing, which captures an OTDR trace of each link.

Tier 2 testing: Methodology using an OTDR

An OTDR sends a known light pulse into the fiber link and measures the strength and timing of light that is reflected back. The OTDR then creates a trace of the strength of the reflected light as a function of distance along the fiber. This trace provides detailed information about the link and its fiber, connectors, splices, bends, and breaks.

Tier 2 testing with an OTDR is valuable both for troubleshooting and for preventing future problems. For links that fail Tier 1 testing, the OTDR can troubleshoot and isolate the cause. For links that pass Tier 1, an OTDR may reveal latent problems, including sub-par splices, dirt, or marginal connectors.

Latent problems that Tier 2 testing can prevent

Marginal components

Figure 4 shows a link with a marginal connector. An OLTS may have found that the overall loss was within the loss budget and the link would have passed Tier 1. However, the OTDR trace reveals that the connector exhibits high loss and is highly reflective.

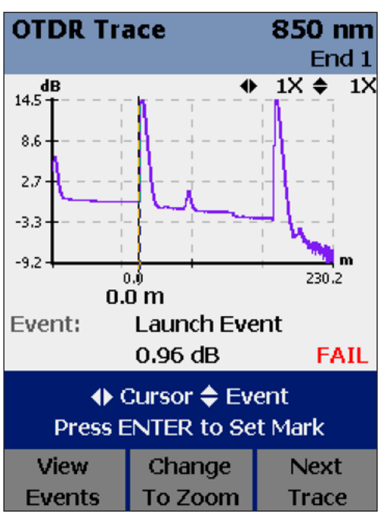


Figure 4*. OTDR trace showing a marginal connector.*

A drop in performance when utilization increases

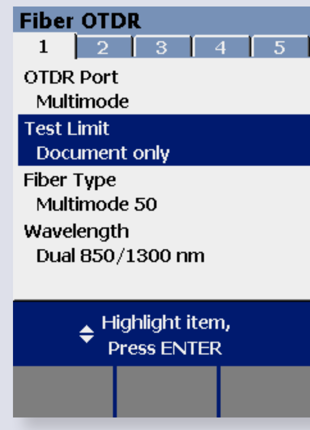
Marginal components can raise the TCP/IP bit error rate and the packet retransmission rate, creating a hidden drain on performance. This may not even be noticeable on a lightly loaded network but it will come to matter more and more as network utilization goes up.

Setting OTDR Limits

OTDR test limits are beneficial because they remove the subjectivity from OTDR testing and allow you to certify individual events that your power meter can't see. Using the DTX Compact OTDR, you can choose a preset limit or create a custom limit in three easy steps.

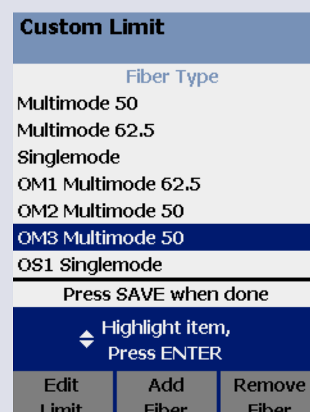
Step 1

- Turn knob to "Set Up"
- Select "Fiber OTDR"
- Select "Test Limit"



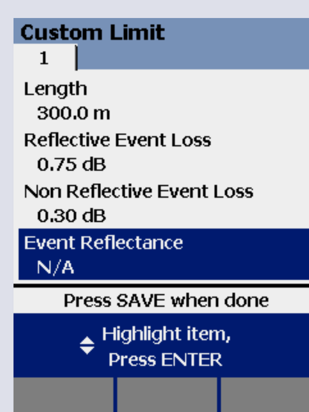
Step 2

- Choose "Custom" test limit
- Create & name the new limit
- Select appropriate fiber type



Step 3

- Create limits for each fiber type
- Select and save each custom test limit you've created
- When you want to test, simply select your saved limit from "Custom Limit" list



The bit error rate (BER) is the probability that a bit is incorrectly detected by the receiver [3]. The receiver compares the amount of optical energy received to some threshold level. If the transmitted energy is well above that level and well above the system noise, then the probability of incorrectly detecting a bit is very low, as shown in *Figure 5A*. The threshold level is the line running through the middle of the eye diagram and the probability distributions of the bit levels are shown to the right of the diagram. There is a good margin between the bit distribution and the threshold level, so there is low probability that a bit will be incorrectly detected.

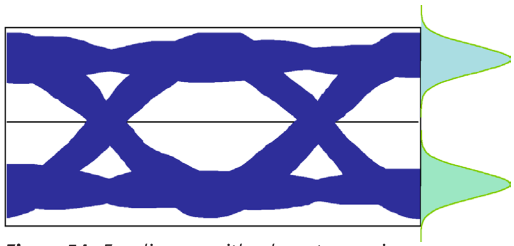


Figure 5A. *Eye diagram with adequate margin*

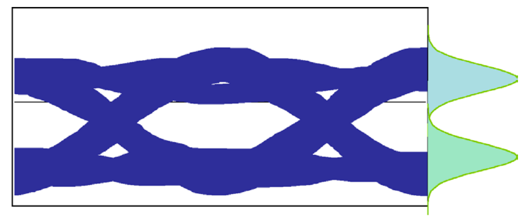


Figure 5B. *Eye diagram with inadequate margin*

If the optical energy received is not well above the threshold level, the probability of incorrectly detecting a bit increases; see *Figure 5B*. This in turn will cause an increase in packet retries and overall sluggish network performance.

A high BER, and poor system performance, can arise in several ways.

- ***Low power.*** Dirty, contaminated, or damaged connectors can be a major problem; they cause the majority of all network failures [10]. Sensitivity analysis of optical communication links shows that the three major contributors to a link's robustness are the amount of power the laser couples into the fiber, the receiver's optical sensitivity, and the amount of connector loss within the link [4]. These three can determine how much optical power gets to the receiver. If a marginal connector reduces the power getting to the receiver, the robustness of the link is diminished.
- ***Mode selective loss.*** Marginal components can create mode selective loss, which discriminates the various modes propagating within the fiber. As mode selective losses increase, the bit error rate degrades [1], [2].
- ***Reflections.*** Contamination on a connector's surface may cause a small air gap that in turn causes high reflection. The reflected light travels back into the laser cavity, causing its output power to fluctuate [5].
- ***Multipath interference.*** This occurs when light is reflected back from an air gap in a connector and interferometrically combines with the rest of the incoming light to cause constructive or destructive interference. The net result is that the transmitted power can vary by 0.7 dB [6].

Failures during moves/adds/changes

Poor splices or connectors on two different links can cause failure — even when each link passes Tier 1 testing — if they're later brought together onto the same link through moves, adds, or changes.

Failures can also occur during changes if connectors are dirty. Each time a dirty connector is moved, the dirt itself can move towards the core and block the light. Even worse, dirt can be ground into the glass when the connector is mated/remated and damage the glass itself with nicks, scratches, or chips. The result is progressive degradation of the fiber face and eventual failure of the link.

Failures from component degradation

A dirty connector can degrade over time while sitting in place. Even without the effects of mating and remating, a fiber that passes optical test at the time of installation can fail in the future: *"Certain types of defects on the optical surface of the connector may not hamper initial performance, particularly if the defects are not in the light-carrying area, but over a period of time…the defect may change, eventually resulting in a network failure. Under pressure from the connector springs and over a period of time of varying temperatures, humidity levels, movement, and vibration, defects may grow to a magnitude that interferes with optical performance."* [8]

Conclusion

As enterprise fiber optic networks become more widespread, and as network utilization continues to grow, in-depth test coverage becomes essential. If not eliminated, latent problems will become a major problem. Complete certification testing of fiber optic cabling is now more important than ever before. Performing both Tier 1 and Tier 2 testing, using an OLTS and an OTDR, provides the necessary depth of coverage. The use of automated test limits keeps costs down, reduces human errors, and shortens the time required.

Citations

[1] Cunningham, D.G., Lane, William G. (1999). Gigabit Ethernet Networking. *Macmillan Technical Publishing*, 237-238.

[2] Guenter, J.K., Johnson, R.H., Smith, D., Tatum, J. A (1997). High-speed characteristics of VCSELs. *SPIE Proceedings: Fabrication, Testing, and Reliability of Semiconductor Lasers II*, Vol. 3004, 151-159.

[3] Walrand, J (1991). Communication Networks: A First Course. *Aksen Associates Incorporated Publishers*, 94-95.

[4] Schell, J.D. (1999). Application of Monte Carlo Simulation Techniques to Optical Fiber Communication Link Models. *48th International Wiring and Cabling Symposium*.

[5] Lasky, R.C., Osterberg U.L., Stigliani, D.P. (1995). Optoelectronics for Data Communication. *Academic Press*, 240.

[6] Sandahl, C.R., Wagner, R.E. (1982). Interference effects in optical fiber connections. Retrieved June 2008 from Optics Interface, 21, 1381. Website: *http://www.opticsinfobase.org/abstract.cfm?URI=ao-21-8-1381*.

[7] TIA Bulletin TSB-140: Additional Guidelines for Field-Testing Length, Loss and Polarity of Optical Fiber Cabling Systems.

[8] Ditto, K. (2000). Connector quality: Are standards enough to eliminate the weak link? *Lightwave*.

[9] The IEEE defines specifications, such as power levels, that are adequate for supporting a specific technology (for example, 10GBASE-SR). In turn, TIA and ISO provide related standards that define generic performance guidelines for enterprise fiber optic cabling networks. Together, these standards are designed to ensure that the cabling infrastructure will actually be capable of supporting the specific technology and the intended applications.

[10] Research commissioned by Fluke Networks, conducted by Martin Technical Research to find out the most common causes of fiber failures. The study began by evaluating a list of 800 installation companies that have a focused 20 percent workload on just installing fiber. Of those companies installing fiber, fifty were randomly interviewed and yet another fifty private network owners were asked for their side of the story.