Application Note 076

# Optimizing OTDR Measurement Parameters

*Caroline Hamel and James Barnard, Product Managers, Portable and Monitoring Division*

Over the last several years, telecommunications have become an ever-increasing part of our daily lives. As we constantly rely on these services, ensuring the dependability of optical networks has become imperative. This is where the optical time-domain reflectometer (OTDR) comes in. This instrument is designed to test fiber links by detecting losses and letting technicians know what type of faults have occurred on these links, as well as where they are located, facilitating installation and maintenance and reducing network downtime.

OTDR measurements, however, are affected by several factors, including the OTDR itself. In order to comprehend the importance of parameter optimization, let us examine the measurement process, as well as the key parameters that influence the results.

## OTDR Measurement Process

When light is sent through a glass fiber link, some of the light is reflected back to the transmitter (this is known as backscattering). When characterizing a fiber link using an OTDR, it is this reflected light that is used to calculate the attenuation of the link, the characteristics of loss and the length of the fiber span. The OTDR software displays obvious faults and connections on a generated graph, known as a trace, and provides the loss value in dB as a function of distance. The faults, called events, are listed in a table of events. Figure 1 illustrates a typical OTDR acquisition, displaying a trace and its corresponding table of events.

| Type | No. | Loc. | Loss | Refl. | Att. | Cumul. |
|---|---|---|---|---|---|---|
|  | 5 | 8.038 | 0.147 |  |  | 3.849 |
|  | (2.114 km) |  | 0.745 |  | 0.353 | 4.594 |
|  | 6 | 10.152 | -0.180 |  |  | 4.413 |
|  | (2.508 km) |  | 0.850 |  | 0.355 | 5.263 |
|  | 7 | 12.680 | 0.014 | [illegible] |  | 5.277 |
|  | (1.083 km) |  | 0.622 |  | [illegible] | 5.900 |

*Figure 1. A screenshot of a typical OTDR measurement, displaying both the trace and its table of events*

An OTDR analysis will detect any discrepancy in the fluidity of the light flow. In other words, a near-perfect fiber link would let light through without any loss, but real fiber spans are not perfect; they have impurities that attenuate the light intensity. Furthermore, fiber spans are linked together with splices or connectors, which are additional obstacles to the light flow and, thus, affect the direction of the light. At the precise location where the light encounters these obstacles, the light will either be reflected back to the transmitter (completely or partially) or be forced out of the fiber, or a combination of both. When a significant obstacle is encountered, it is identified as an event.

OTDR analysis software must be well designed to thoroughly locate all possible types of events, such as **reflections**, caused by connectors, fiber breaks or ends; **losses**, caused by splices or macrobends; or **gains**, caused by imperfect core alignments or diameter differences (delta variations in mode-field diameter).

A good-quality OTDR should be able to clearly point out all types of events on the trace to make them easily identifiable to the user. For example, as shown in Figure 1, in addition to locating events, the EXFO OTDR application also numbers the events (on the trace and on the list) so as to allow users to quickly match them with the corresponding measurement information contained in the event table.

As stated previously, measurements can be affected by different factors; therefore, it is important to be aware of the parameters that influence the analysis to better interpret results.

## Key Parameters

Event detection, attenuation and length measurements depend on the signal-to-noise ratio (SNR) the OTDR can reach at any given point of the trace analysis. The SNR is the ratio between the backreflected signal and the noise level, and depends on pulse width, sampling points, measurement distance, receiver bandwidth precision, and averaging number. Therefore, the influence of these factors on event detection, attenuation measurement accuracy and spatial resolution is often difficult to predict by the user. Some OTDR manufacturers have user-definable parameters, while others integrate routines that help the user optimize all parameters in order to get the best results.

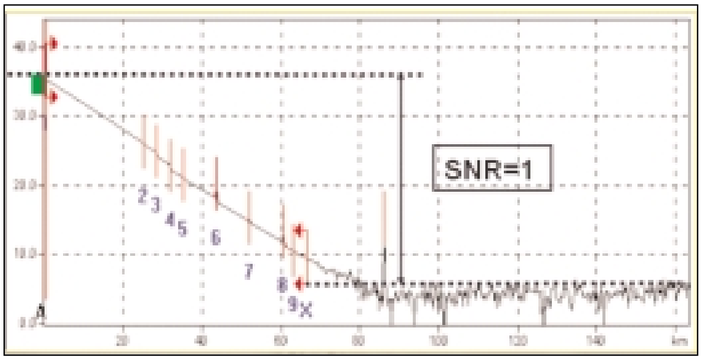

*Figure 2. OTDR Measurement information depends on the signal-to-noise ratio (SNR)*

**Pulse width** determines the power of the backscatter-reflected signal. A long pulse width amplifies the received signal, making it easier to distinguish it from background noise and, therefore, improving the SNR. On the other hand, using a pulse width that is longer than the distance separating two events will lead to inaccurate event detection and measurements. Furthermore, if the pulse width is increased, the attenuation dead zone is also increased, limiting the detection capability of other events after an initial event.

Signal averaging also increases SNR. The noise reduction is proportional to the square root of the averaging number used. This provides improved event detection and measurement as well as spatial resolution, particularly where the signal is weak. The **averaging number** refers to the number of measurements acquired on the same sampling point to obtain an average value. Because of the uneven and arbitrary nature of background noise, increasing the averaging number reduces the noise level, improving the SNR, which, in turn, improves the event measurement accuracy and detection. When studying closely spaced events, the averaging number also improves spatial resolution because it helps to reduce noise during high-bandwidth analysis.

The influence of the **receiver's bandwidth** resides in the fact that low-bandwidth transmission smoothes down curves and attenuates sharp transitions. Although this reduces noise and improves SNR at the far end of long-range measurements, it increases dead zones. A high receiver bandwidth, on the other hand, transmits sharp transitions from the backscattered and reflected signals, but also lets through noise. This shortens dead zones, but may require more averaging in order to reduce noise level. A high receiver bandwidth has a limited range mainly due to the random noise it contains. However, it improves front-end fiber link event measurement accuracy and spatial resolution, especially when measuring closely spaced events.

**Sampling points** have a more complex influence on the end results. Without necessarily going into a detailed description of sampling rates and phases, it is safe to say that the main influences of sampling points may be described as follows:

- Increasing the number of sampling points decreases the distance between the points.
- A high-sampling-point count increases the measurement distance (when not limited by the dynamic range).
- Increasing the number of sampling points improves the spatial resolution of events (when not limited by the pulse width).
- For a given measurement range and averaging time, increasing the number of sampling points decreases averaging on each point.

## Note on Results

OTDR measurements are, of course, an approximation of reality; they are based on statistics and the analysis extrapolates the best possible characterization of a given fiber span. Over the past few years, suppliers have fine-tuned their OTDR equipment and developed technology that allows for very realistic results. However, every OTDR reacts differently to the above-mentioned parameters. Consequently, in order to adequately select parameters for optimum performance, the common outside plant OTDR user must have a thorough understanding of the parameters that generally influence OTDR measurements, as well as their impact on the specific OTDR unit used. For example, using a high-bandwidth analysis and concentrated sampling points while investigating a long pulse width may lead to noisy results, poor SNR and, hence, poor fault detection, as well as erroneous event measurement.

As field technicians do not work in laboratory conditions, they can't afford to waste valuable time determining their OTDR's optimal configuration; nor do they have access to all required knowledge to always select the right parameters. Therefore, the OTDR should be able to optimize all the parameters necessary to meet the user's needs. The impact of the signal-to-noise ratio on the quality of event detection and measurement won't just go away on its own, this is why suppliers like EXFO optimize their OTDR parameters, providing the user with premium results every time.

## Conclusion

Parameters such as the pulse width, the number of sampling points, the measurement distance, the receiver bandwidth and averaging all affect the SNR (ratio of backreflected signal-to-noise level). As a whole, these parameters have a considerable impact on the end results and the influence of these factors on event detection measurement and spatial resolution is very difficult to predict as they interact differently in every OTDR. Changing one parameter will modify others, which is something the user might not be aware of or might not want to do.

EXFO's FTB-7000B/70000C OTDR Series modules avoid unwanted results by enabling an optimal configuration, which provides highly accurate measurements, all the time. Field technicians don’t have to worry about parameter optimization. EXFO does, and that's why the FTB-7000B/70000C OTDR Series is a time-saving, first-rate solution.

*Figure 3. EXFO’s FTB-7000B OTDR series combines with the FTB-100B Mini-OTDR platform, as well as the FTB-400 to provide fast parameter optimization.*

| | | | |
|---|---|---|---|
| CORPORATE HEADQUARTERS | 465 Godin Avenue | Vanier (Quebec) G1M 3G7 CANADA | Tel.: 1 418 683-0211 . Fax: 1 418 683-2170 |
| EXFO AMERICA | 1201 Richardson Drive, Suite 260 | Richardson TX 75080 USA | Tel.: 1 800 663-3936 . Fax: 1 972 907-2297 |
| EXFO EUROPE | Le Dynasteur 10/12, rue Andras Beck | 92366 Meudon la Forêt Cedex FRANCE | Tel.: +33.1.40.83.85.85 . Fax: +33.1.40.83.04.42 |
| EXFO ASIA-PACIFIC | 151 Chin Swee Road, #03-29, Manhattan House | SINGAPORE 169876 | Tel.: +65 333 8241 . Fax: +65 333 8242 |
| TOLL-FREE (USA and Canada) | Tel.: 1 800 663-3936 | www.exfo.com • info@exfo.com | |

www.exfo.com