OTDRs: END OF NON-LINEARITY ISSUES

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Optical time-domain reflectometers (OTDRs) characterize signals by sending short pulses of light into a fiber and measuring how long it takes for them to travel back to the device's detector.

As the signal travels along the fiber, light scattering occurs due to discontinuities such as connectors, splices, bends and faults, which induce power loss. It is the remaining signal that makes its way back to the OTDR's detector, which allows the instrument to determine how far the signal traveled, as well as characterize the signal and events along the fiber, based on the time lapse between launch and detection. These characterizations are displayed as traces, and the quality of the traces are dependent upon the linearity of the instrument.

Linearity

In the context of test and measurement, linearity can be defined as the ability of the instrument to measure the strength of an input signal and report its value with fidelity on a given range of signal strength.

For example, in an OTDR that is used to test a long and uniform fiber, the OTDR trace displays a straight line with a slope that is related to fiber attenuation. Any curvature on this trace would be considered as a non-linearity (assuming that it is not the fiber itself that has a fluctuation in its attenuation).

OTDR linearity is normally specified for trace regions with very low noise. As the OTDR trace gets closer to its noise floor, the trace gets noisier and will often exhibit non-linear behavior.

Effects of Linear vs. Floating (Non-Linear) Traces

A trace can deviate from the ideal behavior in two ways: a) the trace is higher than it should be–known as a floating trace; or b) the trace is lower than it should–known as a diving trace). Both of these behaviors will induce errors in loss and attenuation measurements. In this article, we will illustrate the non-linearity issue caused by a floating trace.

To begin, consider the following figure, which illustrates OTDR traces with and without non-linearity issues.

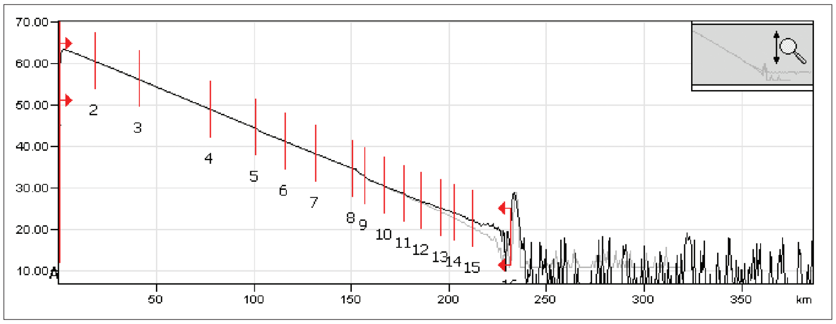

Figure 1a. OTDR traces with and without non-linearity issues.

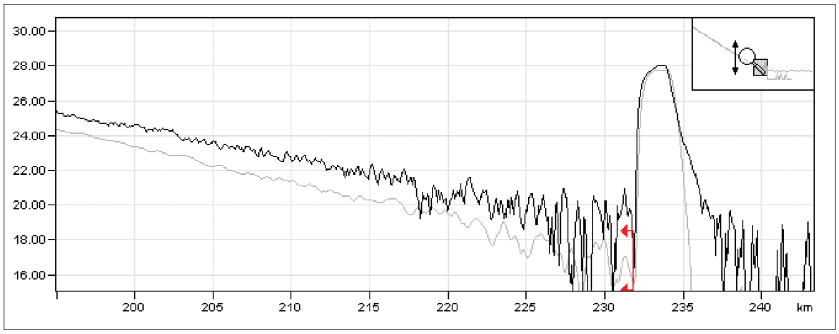

Figure 1b. Illustration of non-linearity issue on floating OTDR trace (black), compared to a trace without non-linearity issues (grey).

At first glance, both traces (taken individually) appear to be fine. However, when they are displayed together, it is clear that they differ from each other considerably after 175 km, and at 215 km, there is a deviation of about 1.5 dB between the two.

The non-linear trace (floating) will underestimate the loss of all events located after 175 km. Similarly, the floating trace will underestimate the attenuation of all fiber sections after 175 km.

In the end, the actual cumulative link loss may be several dB higher than estimated. In the example shown in Figure 1, the link loss found on the non-linear trace will be estimated at about 2 dB lower than it actually is. This is a serious issue.

Let us look at an exaggerated non-linearity case to illustrate some other issues associated with floating traces.

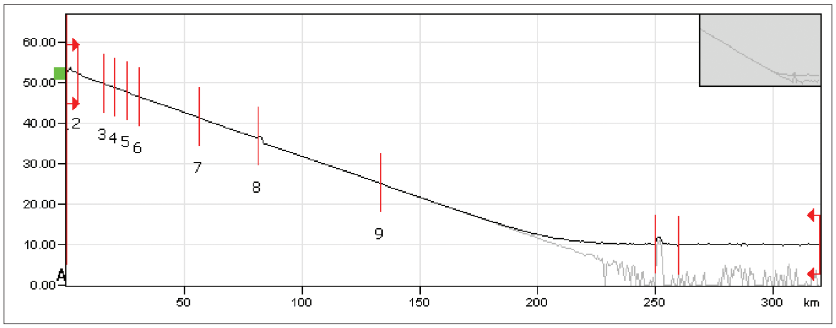

Figure 2: Illustration of severe non-linearity issue on floating OTDR trace (black), compared to linear trace (grey).

The trace that exhibits the floating problem will appear to have less noise than a non-floating trace (for the same km location). Due to this behavior, OTDRs with a slight floating-trace problem may mistakenly be perceived as being better (less noise for the same distance, ability to detect fiber end farther away). However, as you can see in the example shown in Figure 2, the link loss gets dramatically faulty.

Dynamic Range

Verification of dynamic range will become tricky when looking at OTDR traces with non-linearity issues. Depending on the method used to determine noise-floor level, noise-floor estimation will be biased by the non-linearity. Floating traces tend to exhibit noise floors that are higher than normal (reducing apparent dynamic range). In contrast, traces that dive (another very frequent problem) will underestimate the noise floor (artificially increasing the apparent dynamic range).

Conclusion

In brief, linearity at the far end of an OTDR trace is very important to guarantee proper link loss, event loss and attenuation readings. Moreover, dynamic range estimation is affected by non-linearity issues and may be too optimistic or too pessimistic.

If you are experiencing such misreadings, be sure to take a look at EXFO's latest series of OTDRs, which were specially designed to prevent these effects. Thanks to their unmatched linearity of ±0.03 dB/dB, the FTB-7400E/7500E/7600E OTDRs accurately locate faults on long links—without compromising on resolution and distance.

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