“OTDR Gainers” - What Are They?
Application Note

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Introduction

Literally speaking, a “gainer” is a perceived increase in power seen when attempting to measure splice loss from one end of an optical fiber/cable with an optical time domain reflectometer (OTDR). They exist because of the way in which OTDRs generate their measurements. As opposed to measuring actual attenuation, an OTDR measures the amount of backscattered light along the length of a fiber. When measuring across splice points, obtaining accurate splice loss representations can be difficult due to small variations in fiber characteristics.

General

An OTDR trace is an integrated sum plot of the magnitude of backscattered light received from locations along the length of the fiber. The OTDR assumes the fiber to be consistent along its length and equates the backscattered light variations to attenuation. The problem with this method is that, at a splice point, it is possible for the amount of backscattered light before the splice to be greater than that after the splice or vice versa. This difference in the amount of backscattered light results primarily from the mismatch in mode-field diameter (MFD) of the two fibers. Specifically, the capture fraction of an optical fiber is inversely proportional to the mode-field diameter squared. Thus, when two fibers of dissimilar mode field diameters are spliced together, measurable differences in back reflected signal will occur. A uni-directional OTDR trace will show these differences either as a “gainer”, an apparent increase in optical power, or as an exaggerated loss, depending on the direction of the measurement. When measuring from a fiber with a larger MFD to one with a smaller MFD, the OTDR measurement may result in a gainer. Conversely, when measuring from the smaller MFD to the larger MFD, the measurement will result in an exaggerated loss. Figures 1 and 2 illustrate “gainers” and “exaggerated losses” as depicted on an OTDR display.

Illustration of a Gainer*
Figure 1

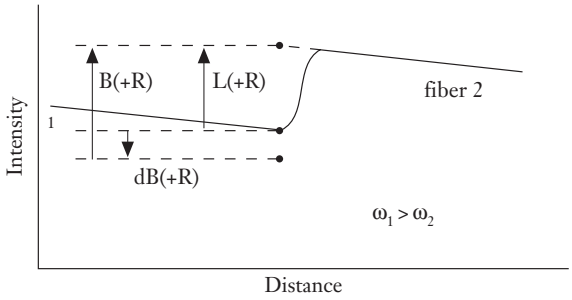
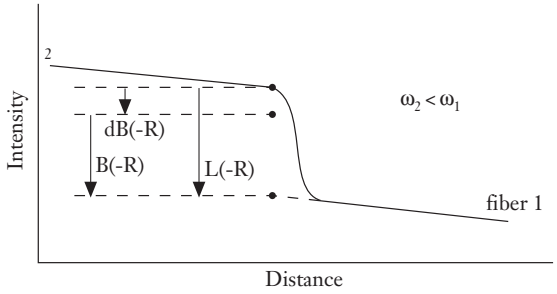


Illustration of an Exaggerated Loss*
Figure 2



*Where dB(±R) represents "true" or "actual" loss, L(±R) represents loss as seen by the OTDR, B(±R) represents loss (backscatter) due to MFD mismatch as seen by the OTDR, and ω_1 and ω_2 represent the respective fiber mode-field diameters.

While these differences in MFD result in "gainers" and "exaggerated losses" in uni-directional OTDR measurements, the effect on actual splice loss is relatively low. Even for a pair of fibers at the extremes of the MFD specification for Corning® SMF-28™ optical fiber (8.8 - 9.6 μm), MFD mismatch contributes ≤0.04 dB to the actual splice loss.

Measurement of an Optical Fiber or Cable Using an OTDR

The Telecommunications Industry Association fiber optical test procedure (TIA-FOTP-61) indicates that splice loss measurements with an OTDR must be conducted from both directions and averaged for accurate results because of gainers and exaggerated losses. In fact, while they may not always be the most practical, bi-directional average of OTDR splice loss measurements provide the most accurate method of measuring individual splice loss. When bi-directional OTDR measurements are not feasible (e.g., poor accessibility to one end of the spliced system), the installer may rely on alternate methods to either measure or estimate splice loss.

One such alternative is a fusion splicer with a resident profile alignment system (PAS) and/or a local injection/detection (LID) system. Profile alignment systems use a combination of the core and/or cladding profiles to align the fibers for splicing. The splicer provides an estimated loss based on the geometry of the spliced fibers. LID systems, on the other hand, use a light optimization method to align and splice the fibers, and the splice loss estimate is based on a power through measurement.

Current industry standard practice for splicer estimation calls for estimates on splices <0.40 dB to be within 0.10 dB of the actual loss 90% of the time. Industry testing with various profile alignment systems shows their ability to meet this specification. As can be seen from the results of testing performed on Corning® SMF-28™ optical fiber listed in Table 1, uni-directional OTDR measurements do not meet these requirements. Table 1 illustrates the differences between uni-directional OTDR measurements and splicing systems with resident splice loss measurement systems.

Splice Loss Estimate Accuracy
Table 1

	% of Splice Loss Estimates Within Range		
Range Between Actual Splice Loss and Estimated Loss	Uni-Directional OTDR Measurements	System 1	System 2
±0.05 dB	54%	85%	88%
±0.10 dB	78%	92%	100%
±0.20 dB	97%	98%	100%
±0.30 dB	99%	100%	100%

If suitable fusion splicer loss estimate systems are not available, and the bi-directional OTDR splice loss measurements are not practical, the installer may consider other options (with uni-directional OTDR): NOTE: Using single directional OTDR measurements is NOT a viable option as evidenced by the Splice Loss Estimate Accuracy in Table 1 and may mask poor splices or invalidate good splices.

None of the following options are deemed to be a good substitute for a proper OTDR splice loss measurement that can only be obtained with bi-directional averaging.

1. If essentially the same splice loss is obtained on two or more successive attempts (break and re-splice) at the same splice, the splice is probably good.
2. The likelihood of a gainer or exaggerated loss may be predicted by comparing with the previous (or next, if necessary) splice.
   - If the previous splice was a gainer from the same direction, this splice would be expected to be an exaggerated loss (or vice versa).
   - If the previous splice was normal, no real prediction can be made for the current splice.
3. "Rules of Thumb" for splicing fibers from different manufacturers (sometimes available from splicer manufacturers):
   - These rules suggest addition or subtraction from the OTDR measurement based on the fiber types and direction of the measurement.

Summary

Uni-directional OTDR measurements lead to inaccuracies due to the method in which the measurements are generated. The inaccuracies usually are in the form of "gainers" or "exaggerated losses". If only uni-directional splice-loss measurement is possible, there are ways to establish reasonable confidence in splices. Also, good splicer PAS and LID systems have proven their reliability in making reasonably accurate estimates within the limits noted. Bi-directional averaging yields accurate splice loss measurement results.

References

1. Felix Kapron, Carrie Kozikowski, and Rick Crotts, "Mode Field Diameter Effects on OTDR Splice Measurements."
2. Mettler, Stephen C., "Monte-Carlo Analysis of the Effect of Mode Field Diameter Mismatch on Single-Mode Fiber Splices."
3. Joseph Schiestle and Marc Stammer, "Fishing for the Perfect Splice," *Telephone Engineer & Management*, February 1, 1993.
4. "Single Fiber Fusion Splicing", Corning Incorporated Application Note AN103.

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