LUNA Engineering Note EN-FY1306

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Using a Circulator to Make Insertion Loss Measurements in Transmission with the Optical Backscatter Reflectometer

Introduction

Luna Technologies' Optical Backscatter Reflectometer (OBR) is well suited for making localized insertion loss (IL) measurements in reflection using the differences in fiber Rayleigh backscatter amplitude on either side of a loss event. The principle is similar to making IL measurements with an OTDR, except that the OBR's superior spatial resolution and lack of a dead zone enables the user to measure IL for events that are in some cases spaced only centimeters apart. However, if the accumulated loss along the test fiber path causes the fiber Rayleigh backscatter level to drop below the noise floor, accurate IL measurements can no longer be made. Thus, the difference in reflection amplitude between the Rayleigh backscatter level at the instrument front panel to the noise floor limits the dynamic range for these IL measurements. For the OBR 4600 using Corning SMF-28 fiber, the single pass IL dynamic range is specified to be at least 18 dB, or 9 dB for a double-pass loss.

For situations in which the device under test (DUT) exhibits a total IL that exceeds the IL dynamic range of the OBR, it is still frequently possible to measure the accumulated IL by using a circulator. The circulator is used to route light transmitted through the DUT back to the OBR, enabling the OBR to measure the transmission amplitude. If this result is compared to the transmission amplitude for the circulator alone, the total IL for the device can be computed with a dynamic range in excess of 60 dB.

Measurement Example: Measuring the loss of a Mandrel Wrap in both Reflection and Transmission

To demonstrate how to measure IL in transmission with a circulator, and to show the differences between measuring IL in reflection and transmission, set-up diagrams and OBR scans taken both in reflection and transmission are presented. The test DUT consists of a 3 m patch cord with a mandrel wrap near the center.

An IL measurement of the test network is first acquired in reflection using the OBR and a conventional set-up, which is shown in Figure 1. The DUT, consisting of a 3 m patch cord with a mandrel wrap near the center, is connected to the OBR front panel with 0.25 m long jumpers on either end.

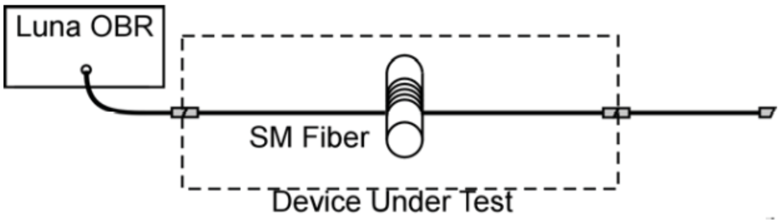

Figure 1: Set-up for measuring DUT IL in reflection.

Figure 2 shows the delay-domain amplitude plot resulting from scanning this set-up using an OBR configured to perform a 10 nm wide wavelength scan. The yellow cursor is used to integrate the Rayleigh backscatter over the length of fiber located before the first DUT connector. The red cursor integrates the Rayleigh backscatter over the length of fiber located before the final DUT connector. These cursor positions measure the combined IL of one connector pair and the mandrel wrap: 6.05 dB. Only one of the connector pairs is included in this measurement, as the transmission measurement effectively includes the IL of a single pair.

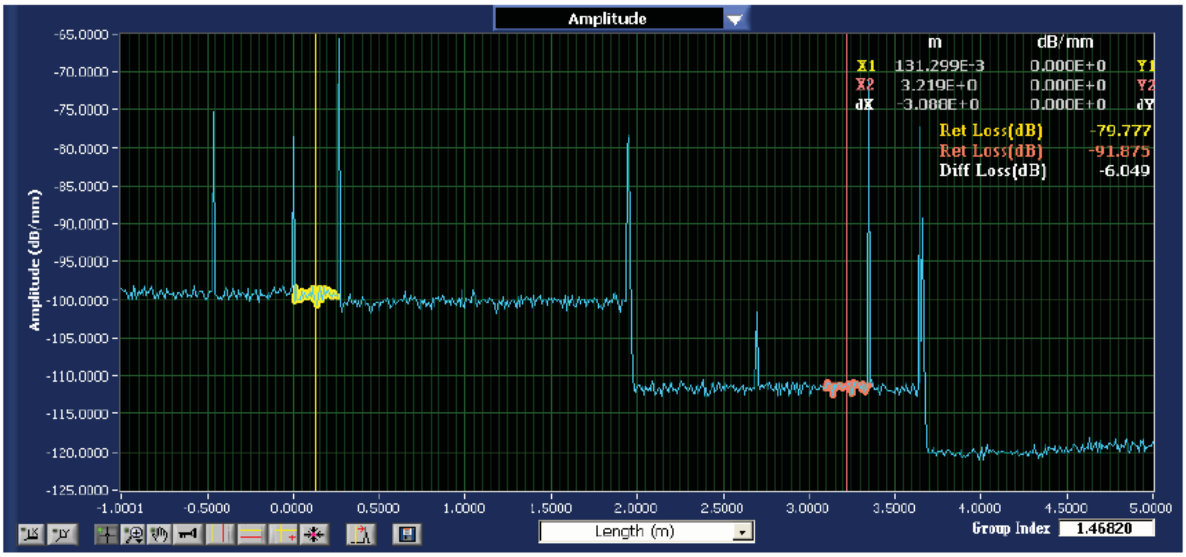

Figure 2: OBR scan of the DUT showing a IL measurement using the top graph cursors.

To make a similar IL measurement in transmission, a circulator is attached to the OBR and the DUT as depicted in Figure 3. Circulators typically have three ports, and light is constrained to travel in the direction indicated by the arrows in the top image. Light that enters one port, for example port 2, is routed so that it exits the next port in the direction of the arrows, which is port 3 in this scenario. Continuing this example, light reflected back to port 3 is routed so that it exits port 1; this light is not routed to port 2. Thus, if the OBR is attached to port 2 of the circulator, the DUT input is attached to port 3, and the DUT output is attached to port 1, the circulator routes only the light transmitted in a single pass from the OBR, through the DUT, and back into the OBR. In this way, a circulator can be used to enable the OBR to measure the relative power of the light transmitted through the DUT, yielding the single pass IL for the DUT.

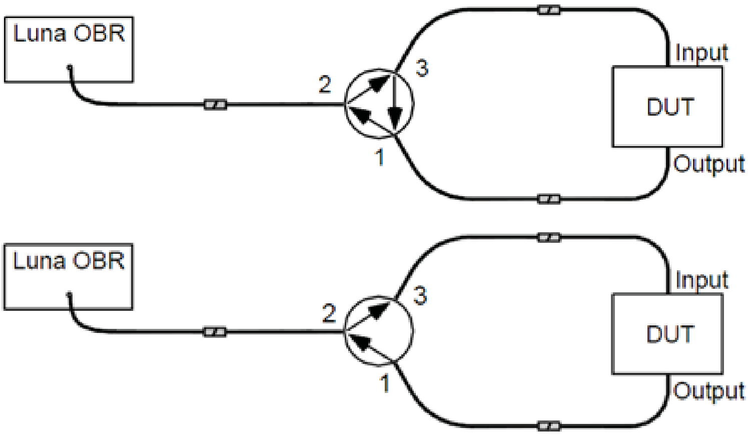

Figure 3: Configuration which allows the OBR to monitor transmitted power through the DUT.

The result of a 10 nm wide wavelength OBR scan of the DUT and circulator in this configuration is shown in Figure 4. In this transmission measurement, the light emitted from the OBR travels through the DUT and back into the OBR in a relatively compact packet. The detection of this transmitted packet results in a strong peak in the delay domain.

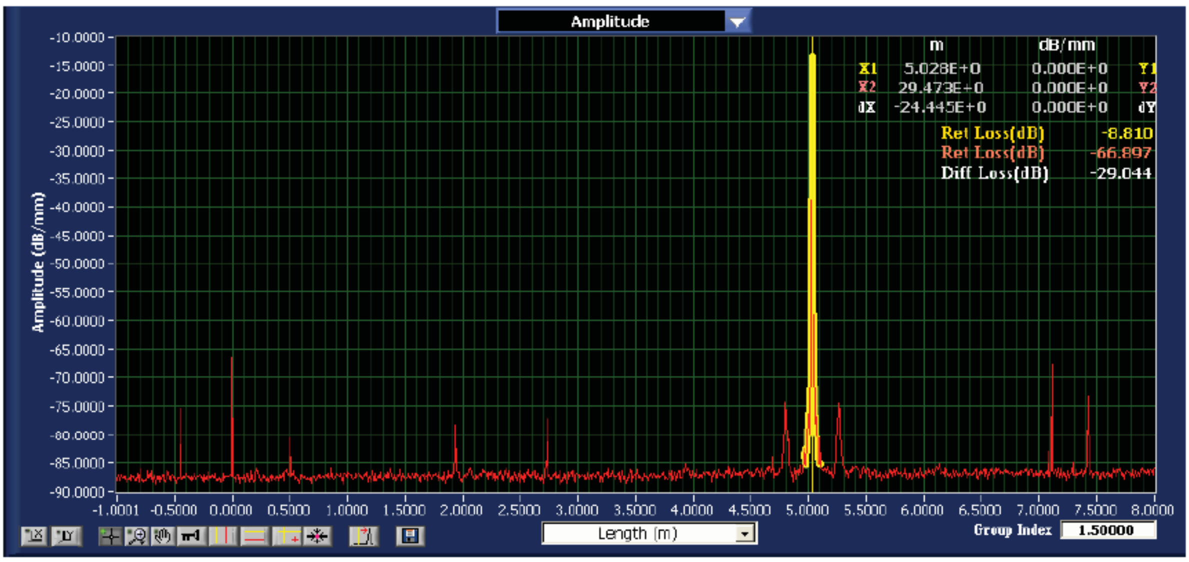

Figure 4: OBR scan of the circulator and DUT in the configuration depicted in Figure 3 showing a strong transmission peak at 5 m.

The position of the peak is a measurement of the time it takes the light packet to travel from the OBR front panel, through the circulator, through the DUT, back through the circulator, and then return to the OBR front panel. The peak appears around 5 m, but actual path length is twice this distance, ~10 m, because the OBR software scales the x-axis using the assumption that a reflection measurement was performed; reflection measurements are double-pass, while transmission measurements are single-pass.

The integrated amplitude of the peak records the effects of the insertion loss the light packet suffered when it traveled from the front panel, through the DUT, and then back to the front panel. The insertion loss can be assessed by placing the yellow cursor over the strong transmission peak, as is shown in Figure 4. The OBR measures a “return loss” of 8.81 dB. When the set-up is configured to make a transmission measurement, as it is in this case, this reading is actually the IL of the entire path through both of the circulator and the DUT. If there were no IL, the reading would be ~ 0 dB.

This measurement of IL includes the IL of the circulator, which possesses a non-negligible amount of IL. The set-up configuration depicted in Figure 5 is used to measure the IL of the circulator. This IL measurement also includes the IL associated with the two connector pairs.

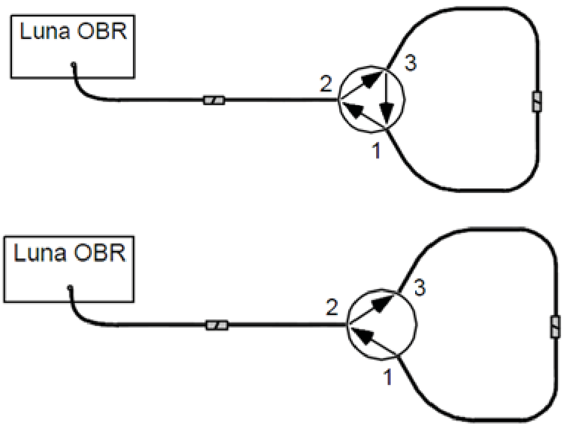

Figure 5: Configuration used to measure the IL through the circulator alone.

The resulting transmission OBR scan is shown in Figure 6. The location of the transmission peak has shifted from 5 m to 3.5 m. The difference is half the DUT length, which is in keeping with the automatic scaling of the x-axis that assumes double-pass measurements. The cursor is centered over the transmission peak, which calculates an IL of 2.79 dB.

The IL of the DUT, which includes the contribution of a connector pair, is calculated by subtracting the second transmission IL measurement from the first: 8.81 – 2.79 dB = 6.02 dB. Comparing this calculation of the IL of the DUT with the IL measured when the DUT was scanned in reflection reveals that the two differ by 0.03 dB. This small difference is attributed to the differences in IL among different connector pairs. These measurements would be expected to produce equal values of IL if the IL of every connector pair is the same. In actuality, the uncertainty in IL, when using well-polished and well-cleaned connectors, is expected to be a few tenths of a dB.

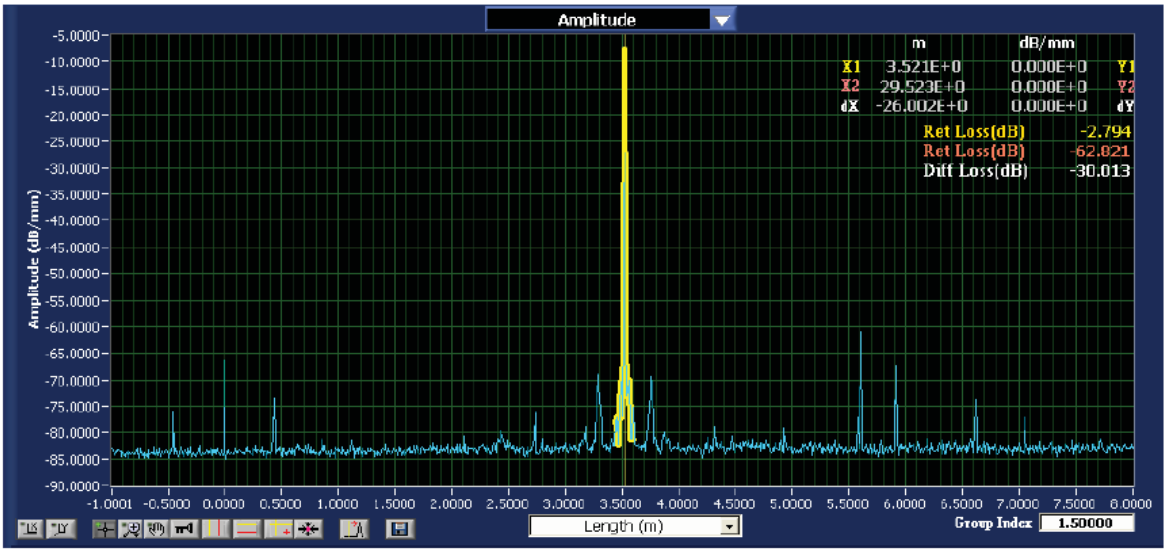

Figure 6: OBR scan of the circulator in the configuration depicted in Figure 5 showing a strong transmission peak at 3.5 m.

Summary

When the IL of a DUT scanned in reflection exceeds the dynamic range of the OBR, a circulator may be used to implement a transmission measurement technique capable of finding the total IL of the DUT. The measurement signal consists of a peak whose position correlates with the length of the transmission path though the DUT; the integrated amplitude of the peak records the total loss incurred by traversing the transmission path. The transmission measurement, in contrast to the reflection measurement, cannot resolve separate events within the device. Using this transmission approach, the measurable IL range is limited only by the directivity of the circulator and the OBR’s return loss dynamic range, both of which typically exceed 60 dB. The added functionality achieved using this technique eliminates the need for a traditional transmission loss test set, which saves time, space, and expense.

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