Engineering Note EN-FY1306

Revision 5 –April 23, 2013

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 scatter 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 scatter level to drop below the noise floor, accurate IL measurements can no longer be made. Thus, the difference in reflection amplitude between the Rayleigh scatter level at the instrument front panel to noise floor limits the dynamic range for these IL measurements. For the OBR 4600 using 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 commonly still possible to measure the accumulated IL by using a circulator. The circulator is used to route light which transmits through the DUT back to the OBR, so that the OBR can measure the transmission amplitude. If this result is compared to the transmission amplitude for the circulator alone, the total IL for the device can easily 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, we will show OBR scans taken both in reflection and transmission for a DUT that consists of a 3 m patch cord with a mandrel wrap near the center.

First we will show an IL measurement taken in reflection using the OBR. The measurement set up 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.

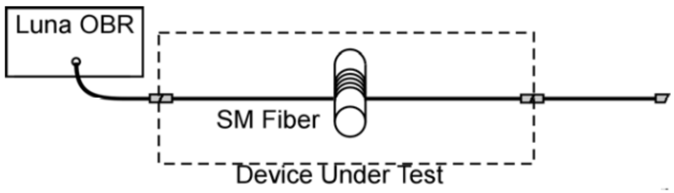

Figure 1: Set-up for measuring DUT IL in reflection.

A 10 nm wide OBR scan of this network is shown in Figure 2. The yellow and red cursors are used in the top graph to integrate over fiber Rayleigh scatter before the first DUT connector and before the final DUT connector so that the IL of one connector pair and the mandrel wrap is measured. The measured IL is 6.05 dB. We only measure over one of the connector pairs because the transmission measurement will effectively do the same.

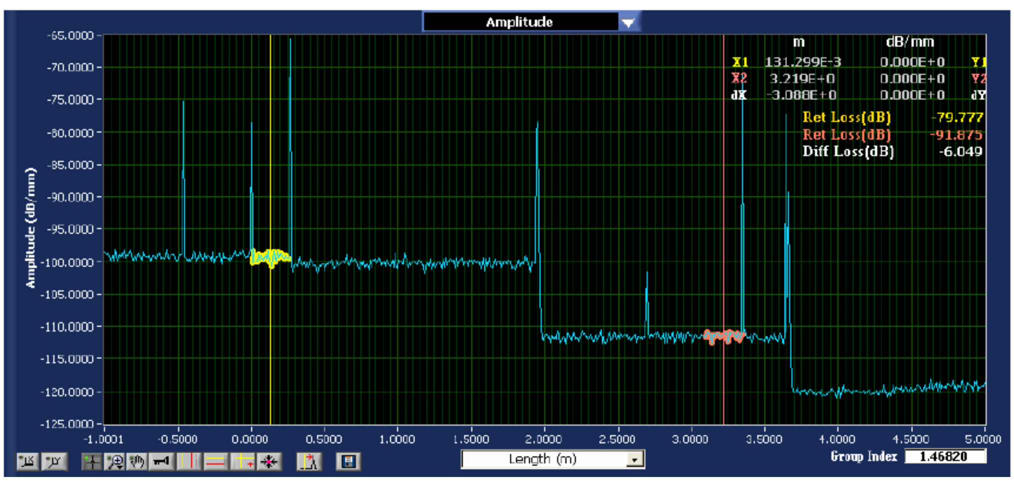

Figure 2: OBR scan of the DUT showing a IL measurement using the top graph cursors.

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: light which enters port 2 is routed to the output of port 3 and light which enters port 1 is routed back 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, light from the OBR transmits through the DUT in a single pass and is routed back through the circulator into the OBR. In this way, a circulator attached to the OBR and DUT will enable the OBR to measure the relative power of the light transmitted through the DUT, yielding the single pass IL for the DUT.

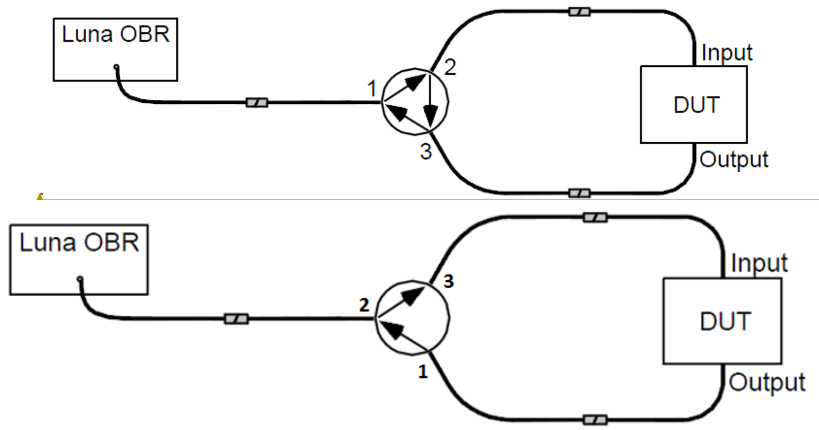

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Figure 3: Configuration which allows the OBR to monitor transmitted power through the DUT.

A 10 nm wide scan of the DUT and circulator in this configuration is shown in Figure 4. There is a very strong peak at 5 m which corresponds to the transmission path from the OBR front panel to the circulator, from the circulator through the DUT, through the circulator again, and back to the OBR. The actual path length is twice this distance (10 m), because the OBR scaling assumes that the distance is a double pass measurement, but the transmission path is in fact a single pass measurement. By placing the yellow cursor over the strong transmission peak, the OBR measures a “Return Loss” of 8.81 dB. When used in this manner, this reading is actually the IL of the entire path through both of the circulator and the DUT.

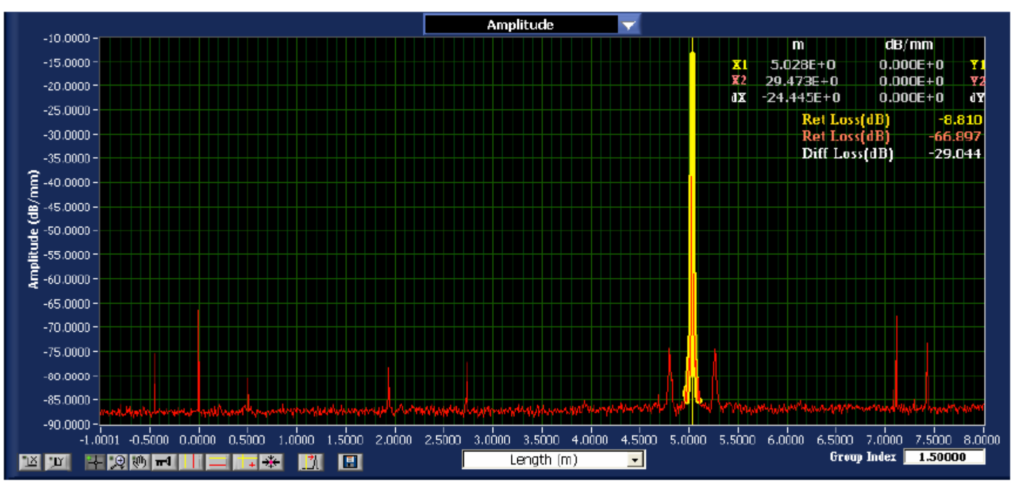

Figure 4: OBR scan of the circulator and DUT in the configuration depicted in Figure 3 showing a strong transmission peak at 5 m.

The circulator, however, has a significant amount of IL by itself. To measure this IL, we use the connection configuration depicted in Figure 5.

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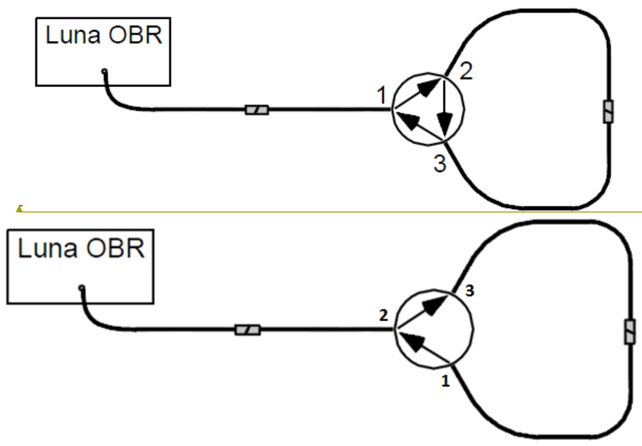

Figure 5: Configuration used to measure the IL through the circulator alone.

The resulting OBR scan of the circulator alone is depicted in Figure 6. The transmission peak has shifted from 5 m to 3.5 m, a reduction of half of the DUT length (remember that measurements made in transmission are half the actual distance, since the OBR x-axis scaling assumes measurements are double-pass). By placing the cursor over the transmission peak, we observe that the IL of the circulator alone is 2.79 dB. Thus the IL measured in transmission for the DUT is 8.81 – 2.79 dB = 6.02 dB. This result is only 0.03 dB below the result obtained for one connector pair and the loss of the mandrel wrap measured in reflection. In general, the uncertainly of the transmission measurement will be dominated by the variation in IL of the connectors used to connect the DUT to the circulator, as the IL of the port 3 connector attached to the port 1 connector will not generally be identical to the connector pairs formed when connecting ports 3 and 1 to the DUT input and output. Thus we expect the uncertainty to be a few tenths of a dB when using well-polished and well-cleaned connectors.

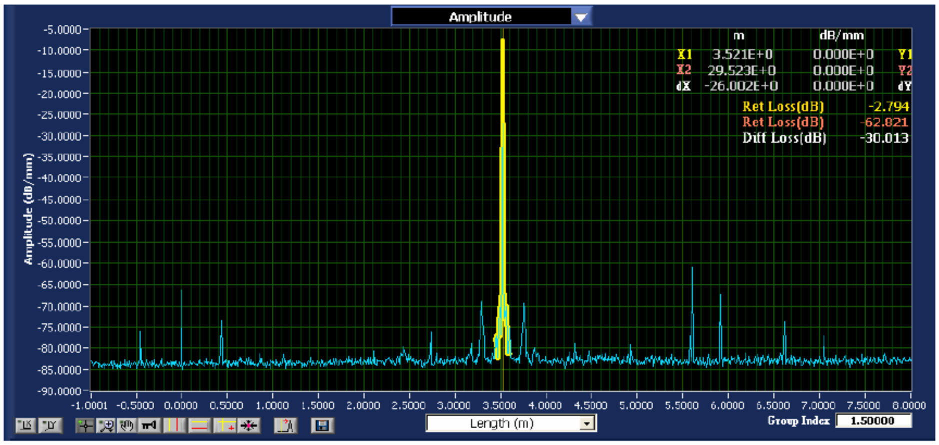

Figure 6: OBR scan of the circulator in the configuration depicted in Figure 5 showing a strong transmission peak at 3.5 m.

Summary

Careful use of a circulator allows the user to measure the total IL of their DUT in transmission. Unlike in reflection, this IL measurement cannot be resolved to separate events within the device, but is the total IL from the input to output ports. However, the IL range which the OBR may accurately measure in transmission is limited by the directivity of the circulator and the OBR's RL dynamic range, both of which typically exceed 60 dB. This added functionality eliminates the need for a traditional transmission loss test set, saving time, space, and expense.

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