

n-OTDR - High resolution OTDR

Application Note 3: Loss measurements

1. Rayleigh Back scattering measurement

In optical fiber networks, one can distinguish between two different loss mechanisms. One is the distributed loss along the fiber, due to absorption in the fiber itself; and the second is the additional attenuation introduced by a connection between fibers or an optical component. Both can be measured by the n-OTDR, using the Rayleigh Back Scattering (RBS) level. The former is given by the slope of the RBS, while the latter is the jump in the RBS, which can be seen at the connection.

Therefore, when performing a loss measurement, you need to check first that the signal corresponds indeed to the RBS. This is shown in the following figure.

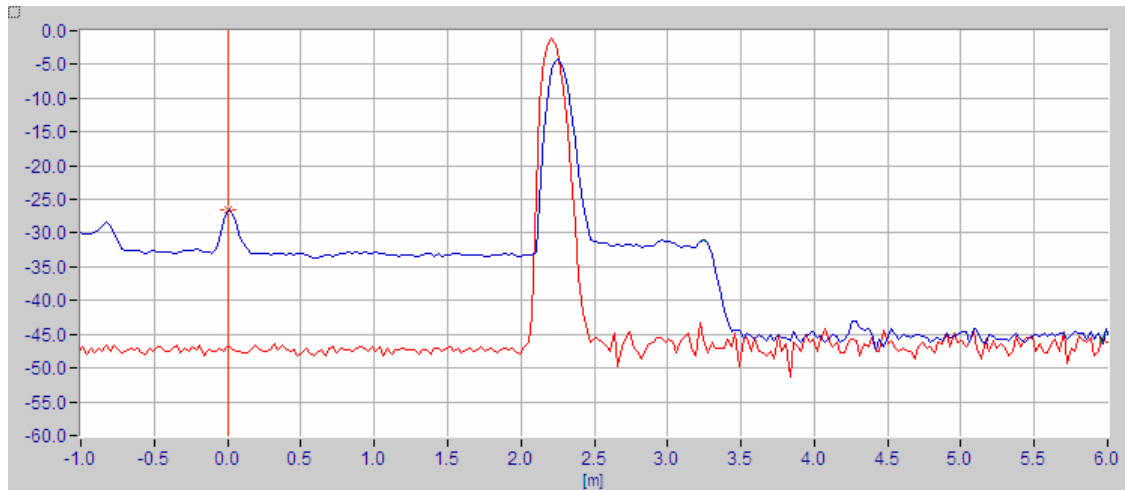


Figure 1: RBS versus noise

The red curve is a 2.2 m-long fiber, connected to the OTDR with an APC connector (low reflection). The end of the fiber has a polished FC/PC connector, corresponding to a Fresnel reflection (-14.5 dB). Note that the horizontal trace is at the same height, both in the fiber (before the peak) and after the end of the fiber (after the peak). This demonstrates that this trace does not represent RBS, but is in fact only noise (same value inside and outside the fiber). The blue curve represents the same fiber, which is now connected to another piece of fiber, with an FC/PC at one end, and a non-reflecting reflection at the other end (3.3 m). The FC/PC reflection from the mated connector is now low enough, to see the RBS inside the fibers. This is demonstrated by the jump above 12 dB at the end of the second fiber: inside the fiber the signal is the RBS, outside it is the noise, due to the dark counts of the detector. Note that, now that the signal in the fiber is RBS, the front panel APC connector is clearly seen. This reflection was hidden by noise in the previous trace.

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The important conclusion is thus the following:

In order to see the RBS in the fibers under test, it is essential to verify that there is a clear jump in the signal at the end of the fiber.

If the jump is weak, below 10 dB in backreflection mode say, the signal is contaminated by noise. What is seen is a combination of RBS and noise. It is however possible to correct this noise, as explained in AN 5: dark counts correction. In the cases, where the end of the fiber is not visible, one can introduce loss in the fiber at a known place (for example by bending the fiber in a small loop), and verify that the trace decreases at this point.

2. Distributed loss

Distributed loss in a fiber is shown in the following trace (taken in the loss setting, to get directly the value of the loss coefficient).

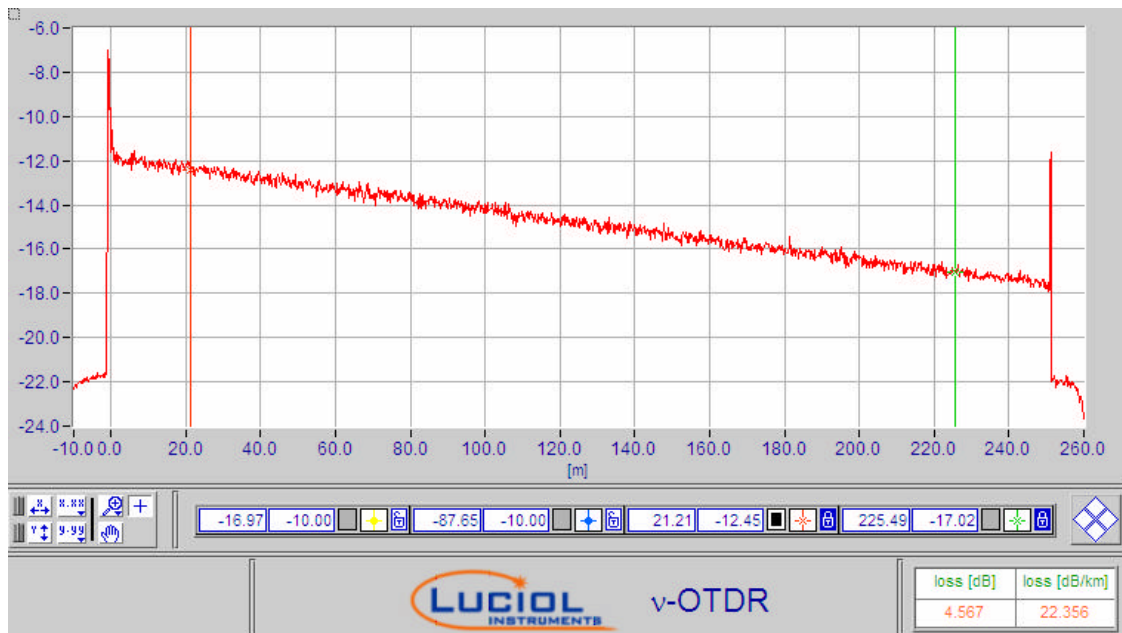


Figure 2: Distributed loss in a speciality fiber

Figure 2 represents a speciality fiber, at 1550 nm, with a large attenuation, as seen in the slope of the RBS. In order to measure the attenuation, one can use the LOSS application of the MEASUREMENT menu: bring the red and the green cursors at the desired points, and the software calculates both the absolute loss between the cursors and the loss coefficient (dB per km). Note that in this trace, the jump between the RBS and the noise after the fiber is about 4 dB. Since we are using the loss setting, this corresponds to 8 dB in backreflection setting (i.e. in terms of the power at the detector). This is enough to be negligible.

In most cases, attenuation in a single mode fiber at 1550 nm is so low (less than 0.3 dB/km), that the RBS is completely flat on the scale we investigate (up to two hundred meters in one window). However, RBS is still useful to analyse additional attenuation at connectors or components.

3. Insertion loss

In addition to distributed loss, there may be point-like events in the fiber generating extra losses. This is typically the case at connectors (reflecting events) or at splices between fiber (generally reflectionless events). This is shown in the following figure.

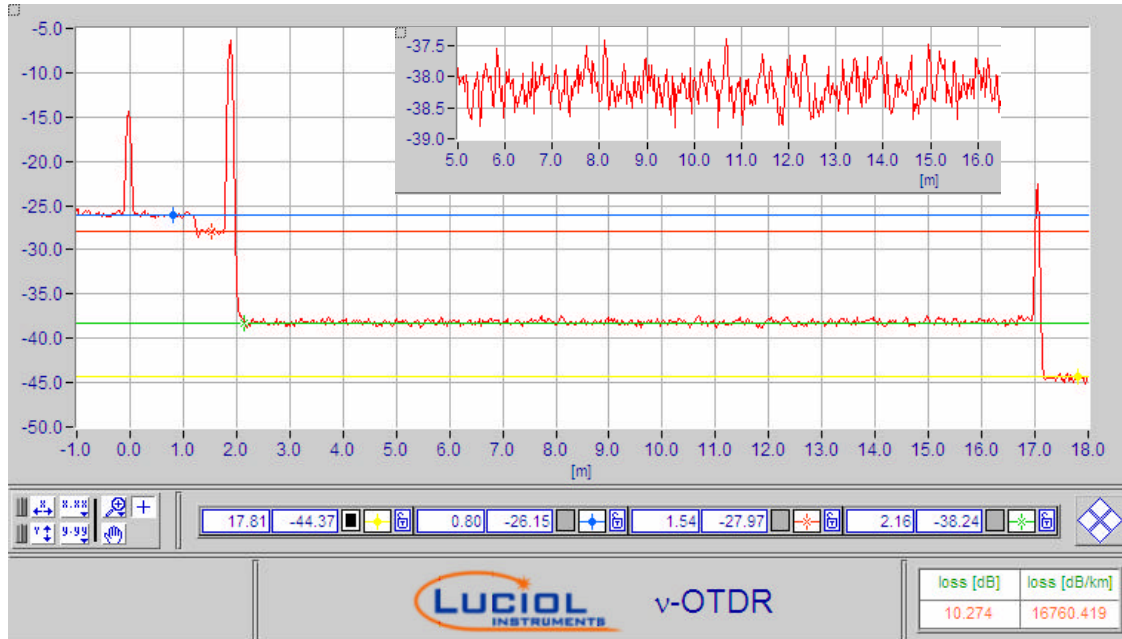




Figure 3: Loss at splices and connectors

Figure 3 shows the front panel APC connector at 0 m, followed by a lossy splice around 1.2 m, another APC at 1.9 m, which was voluntarily misplaced, to create a lossy connection, and the end reflection at 17 m. In order to measure insertion loss easily, the CURSORS STYLE (click on  to modify it) can be modified, to obtain a horizontal line. In addition, to move the cursors freely, it may be best to unlock them, using the  button. The yellow cursor is set on the noise (trace after the end of the fiber). The other cursors are the RBS level in the various sections. Note that you can use the measurement menu and loss parameter to obtain directly the loss between red and green cursors: here 10.27 dB.

The inset of Figure 3 shows a zoom on one section of the trace, to emphasize the RBS signal. The noise on the RBS signal is typically 0.5 dB, which limits the precision for any insertion loss measurement. It is however possible to use a specially designed v-OTDR (patent pending) to improve the signal.

4. Splice loss

As shown above in Figure 3, the RBS on the trace of a high resolution OTDR is quite noisy. This is a physical effect, due to the fact that RBS is a random process: light is scattered by microscopic inhomogeneities in the fiber. It is therefore intrinsically noisy on a small scaleⁱ. The very smooth line, seen on standard OTDRs is due to the large spatial averaging. For higher spatial resolution, the RBS gets noisier. Therefore, there is a trade-off between spatial resolution and reflectivity resolution. This will limit the precision in reflectivity measurements with high resolution OTDRs.

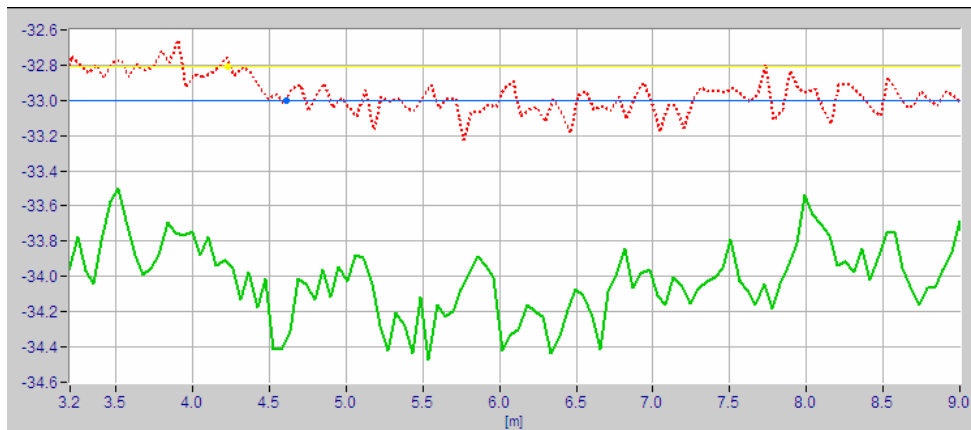


Figure 4: Small splice-loss measurement

Figure 4 shows the trace of a fiber with a splice at 4.3 m. This splice has a loss of 0.1 dB. The lower trace is obtained with a standard high resolution OTDR. The loss at the splice is not clearly visible, due to the noise on the RBS. The upper trace (dotted line) is the trace of the same fiber, obtained with a specially devised high resolution OTDR. The new design (patent pending) allows reducing the noise on the RBS, with the same spatial resolution. With this instrument, the 0.1 dB loss is clearly visible at 4.3 m. Note that, since we used the BACKREFLECTION settings, the 0.1 dB loss at the splice is seen as a 0.2 dB jump on the trace (0.1 dB loss in each direction). For more information on this special OTDR contact Luciol.

ⁱ This effect can also be seen on Optical Low Coherence Reflectometers (OLCRs), where the spatial resolution is even higher (tens of microns). Here the noise on the RBS can be as high as several dBs.