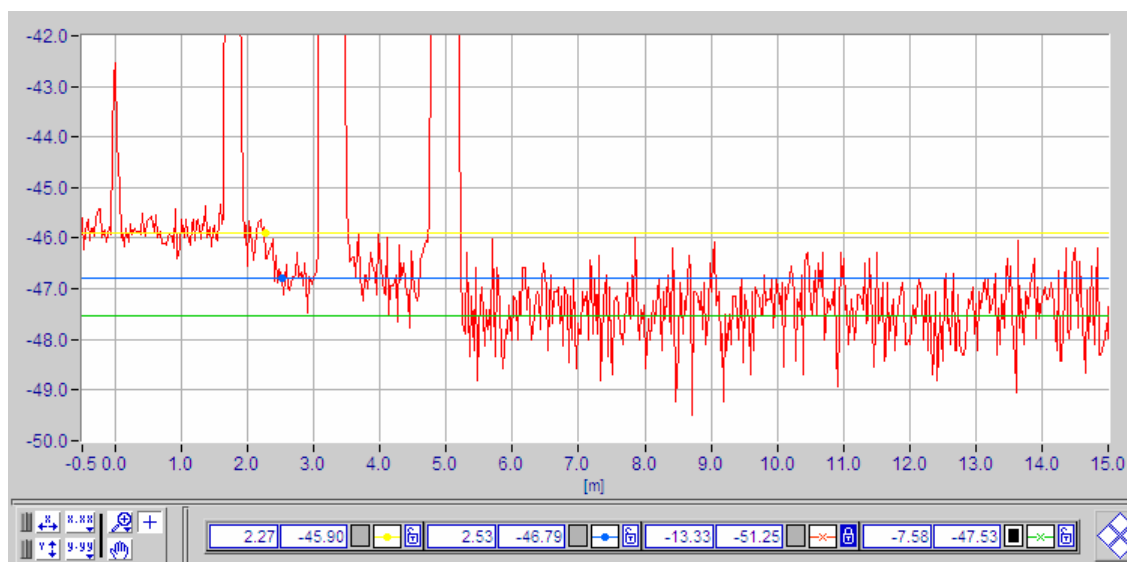




## n-OTDR - High resolution OTDR

### Application note 5: Dark counts correction

The n-OTDR is based on photon-counting. Each time one pulse is sent through the Device Under Test (DUT), only one photon is expected to come back, at a random time. The final trace is obtained by integrating many of these pulses. Unfortunately, photon-counting detectors have some noise: even in the absence of a photon, they will sometime give a spurious count. These counts are known as “dark counts”, and add some noise to the trace. This is shown in Figure 1 below, which represents a fiber with an optical coupler at 2.3 m and various connectors. The end of the fiber is at 5 m, seen as a large reflection. In order to show the influence of the dark counts more clearly, Figure 1 is a zoom on the vertical scale. The reflection peaks are therefore cut out in the picture, except for the initial reflection at 0 m, which is the APC connector on the front panel.



**Figure 1: Loss at a coupler at 2.3 m; influence of dark counts**

In order to measure the intensity level inside the DUT and outside, it is useful to transform the cursors to horizontal lines. This can be done by selecting the proper CURSOR STYLE, in the cursor boxes, such as  for the yellow cursor (see User's Manual for details). It is also best to uncheck the lock button, , to move the cursors freely on the display. It is now easy to move the cursors to the right level. Here we see three levels; one immediately after the front panel connector (yellow cursor); one after the coupler at 2.3 m (blue cursor); and one after the end of the fiber (green cursor). The position of each cursor is given in the cursor boxes, for example -47.5 for the green cursor. On this trace, the noise level (green cursor), given by the dark counts of the detector, is only marginally below the signal in the

**Luciol Instruments S.A**  
7b Route Suisse  
CH 1295 MIES  
Switzerland

Tel : (+41).22.755.56.50  
Fax : (+41).22.755.56.67  
Email: bruno.huttner@luciol.com  
On the web: www.luciol.com

fiber (-46.8 for the blue cursor and -45.9 for the yellow one). This is due to the dynamic range of about 40 dB, and the strong reflection at the coupler output at -5 dB (not seen on this zoom). In addition, the drop at the coupler is seen here as 0.9 dB (distance between blue and red cursors). As the signal value is contaminated by noise, this value is not correct. In order to get the real value of the drop at the coupler, it should be corrected for the dark counts.

After the end of the DUT (5 m), the trace represents only the noise created by the dark counts. Inside the DUT, the same noise is of course present, added to the real signal. At each point in the fiber, we can thus write:

$$S_{meas} = S_{real} + N ;$$

where  $S_{meas}$  is the measured signal,  $S_{real}$  is the real signal, which we want to calculate, and  $N$  is the noise. If we denote by  $X_{dB}$  the height between the measured signal and the noise in dBs, we can easily calculate  $S_{real}$  as a function of  $X_{dB}$  :

$$S_{real} = C \times S_{meas}$$

where  $C$  is the correction factor, given by:

$$C = \left(1 - 10^{-X_{dB}/10}\right).$$

It may be best to work directly in dB, so that the correction factor is simply added to the measured value in dB:

$$C_{dB} = 10 \times \log\left(1 - 10^{-X_{dB}/10}\right). \quad (1)$$

It is possible to use directly the above Formula (1), or to use the following Figure 2, where we give the correction factor in dB as a function of  $X_{dB}$ . We estimate that, in order to get meaningful results, the signal level should be at least about 1 dB above noise, corresponding to a correction of -7 dB. On the other hand, if  $X_{dB}$  is larger than about 10 dB, the correction is less than 0.5 dB, which corresponds roughly to the uncertainty in the measurements. The correction procedure is therefore useful when the signal level is between 1 dB and 10 dB above the noise.

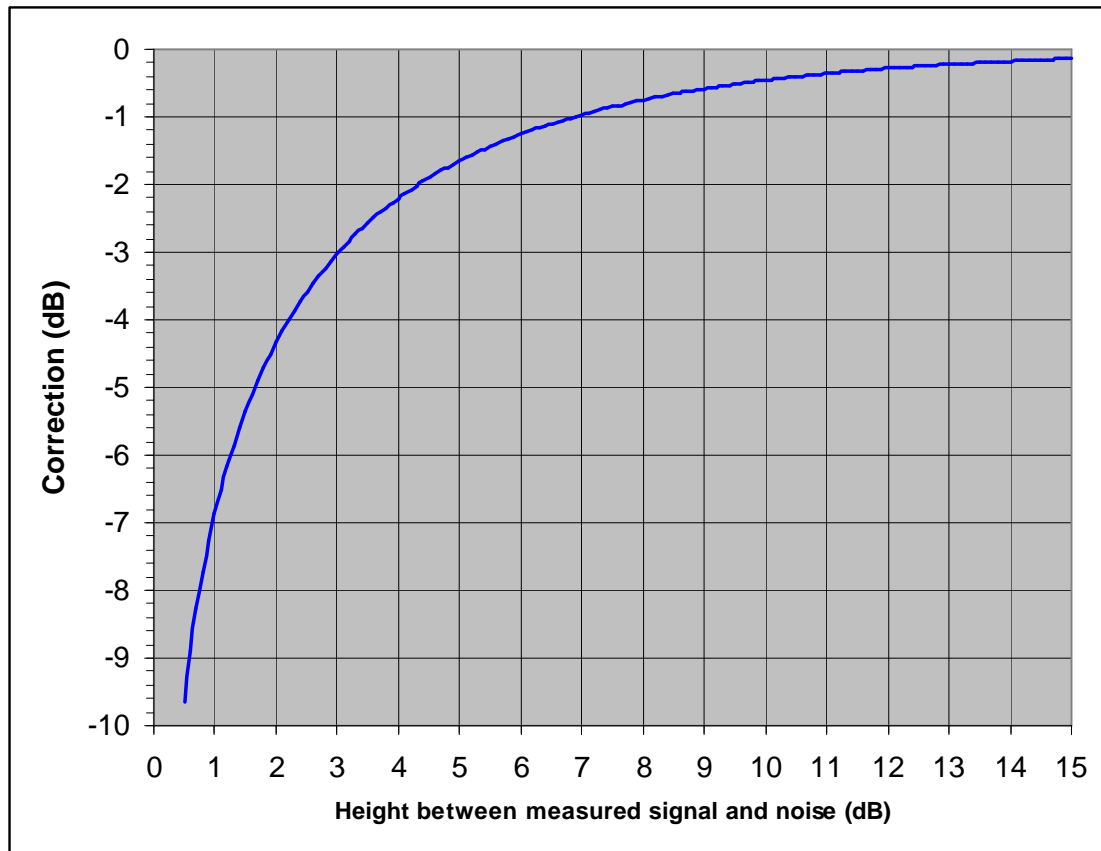


Figure 2: Dark counts correction factor:  $C_{dB}$  as a function of  $X_{dB}$

The dark counts correction procedure is thus simply the following:

1. Find the noise level, which is the level after the end of the fiber;
2. For each value of the signal find the height above the noise, denoted by  $X_{dB}$ . For meaningful results,  $X_{dB}$  should be between 1 dB and 10 dB.
3. Calculate the correction factor  $C_{dB}$ , or find it on Figure 2, and add it to the measured value (this will always be a negative value).

As an example, let us calculate the correction for Figure 1.

- Noise level is at -47.5 dB (green cursor);
- Signal after the coupler is at -46.8 dB (blue cursor), or 0.7 dB above noise. This gives a correction of -8.3 dB;
- Signal before the coupler is at -45.9 dB (yellow cursor), or 1.6 dB above noise. This gives a correction of -5.1 dB.

Therefore the real drop at the coupler is 4.1 dB, which is consistent with a 3 dB coupler. Note that in this case, since the signal is so close to the noise level (only 0.7 dB above), the precision of the correction is not very good (less than 1 dB).