Reflection Amplitude Scaling Utilized by the Optical Backscatter Reflectometer 4600

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Objective:

This engineering note explains the difference between the forms of reflection amplitude displayed in the Optical Backscatter Reflectometer's (OBR) user interface upper and lower graphs and spreadsheet text file output: linear, decibels (dB), and decibels per millimeter (dB/mm).

Measurement Data

A laser sweep on the OBR results in the production of two arrays of complex reflection coefficients as a function of time delay, from which the OBR software calculates the data traces seen in the upper and lower graph of the OBR user interface display. These reflection coefficients may also be saved to a binary file (with a .obr extension) to fully record the data captured for archival and subsequent retrieval and reprocessing, or the calculated results based on these coefficients may be saved to text spreadsheet files. The two reflection amplitude coefficient arrays result from the output of a polarization diverse receiver with "S" and "P" orthogonal polarization state outputs, and are stored in the binary .obr file in 4 columns, (s_{real}, $s_{imaginary}$, p_{real}, $p_{imaginary}$). The S & P values found in the OBR binary data file are processed to give the following forms of reflection amplitude as a function of time delay (or distance) along the test fiber: linear, decibels (dB), and decibels per millimeter (dB/mm).

Linear Amplitude

The "S" and "P" detector voltages result from interferometer fringes that mix light from a reference path inside the instrument and the device under test, and are proportional to the square root of the power reflected by the Device Under Test (DUT). Thus these terms are squared before they are displayed, as shown below:

$$S = s_{real}^2 + s^2{}_{imaginary}$$
$$P = p_{real}^2 + p^2{}_{imaginary}$$

The Linear Amplitude is adjusted to account for data sampling by dividing the sum of S and P by the sample step size, and is given by:

$$Linear\ Amplitude\left(\frac{1}{mm}\right) = \frac{S+P}{dX}$$

The spatial sample spacing *dX* is given by:

$$dX = \frac{c\ d\tau}{2\ n}$$

In the above equation, c is the speed of light in a vaccum, n is the group index of refraction, and dτ is the time delay increment step size. The spatial sample spacing dX in mm is included in the header of saved time delay domain text files. The time delay increament step size dτ in ns is included in the header file of the binary .obr file, and is equal to the inverse of the difference between the laser scan stop and start optical frequencies.

Amplitude in Decibels

Amplitude in decibels (dB) is computed by taking the Log base 10 of the sum of the S and P. The result is multiplied by a factor of 10.

$$Amplitude\ (dB) = 10\ \log_{10}(S+P)$$

This is the form of Amplitude that is most familiar to many users. The reflection coefficients have been calibrated so that the reflection amplitude (dB) is directly related to Return Loss in dB, so that for a given reflection event, the linear amplitude terms can be integrated over that spatial extent that the reflection event covers, and converted to dB scale to give the Return Loss associated with that event. For example, if a connector interface reflected back 0.1% of the incident light back to the instrument, we would expect that the sum of the S and P terms associated with the reflection event would sum to 0.001, and painting the reflection event with a top graph cursor would result in a Return Loss measurement of -30 dB.

Amplitude in Decibels per mm

Amplitude in decibels per millimeter (dB/mm) is a variant of the Amplitude in decibels with the reflection per unit length adjusted to account for data sample spacing. The Amplitude (dB/mm) is given by:

$$Amplitude\ (dB/mm) = 10\ \log_{10}\left(\frac{S+P}{dX}\right) = 10\ \log_{10}(Linear\ Amplitude)$$

$$Amplitude\ (dB/mm) = Amlitude\ (dB) - \ 10\ \log_{10}(dX)$$

Amplitude (dB/mm) is best suited for displaying reflections associated with distributed reflectors, like Rayleigh Scatter, because if the user changes the laser scan range, and thus changes the value of dX, the scatter level will remain unchanged. For example, Luna has determined the Return Loss of a 1 m length of Corning SMF28E+ fiber (the fiber used inside of the instrument) at 1550 nm to be -73.5 dB, so we expect that the mean Amplitude (dB/mm) level of the fiber inside the instrument front panel after calibration to be -103.5 dB/mm.

Measurement Example

Below we show the top graph display of scans of a 1.1 jumper attached to the front panel of an OBR 4600. Scans were taken with a wavelength range of 21 nm (blue), 43 nm (red), and 88 nm (green). In Figure 1, we see that when viewing the reflection amplitudes in the default Amplitude (dB/mm) scaling, the Rayleigh scatter level of all three traces is identical. However, when we view the reflection amplitudes in the Amplitude (dB) scaling in Figure 2, the Rayleigh scatter levels are separated by roughly 3 dB, due to the different sample spacing of the three scans.

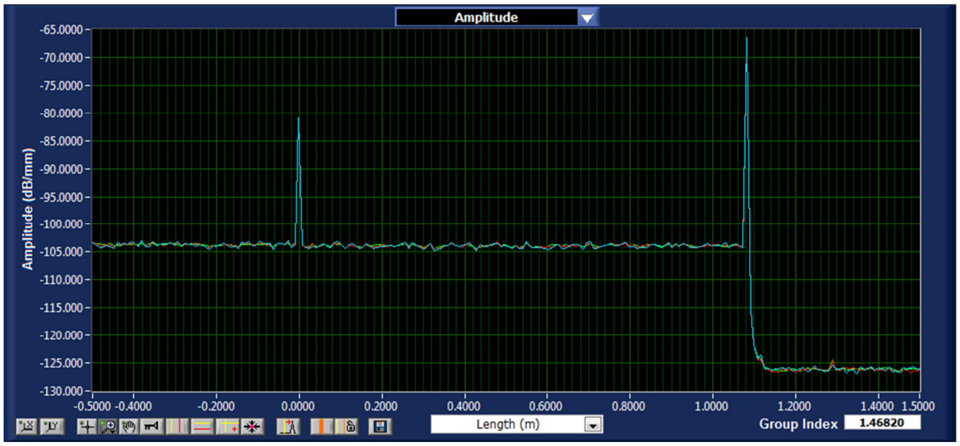

Figure 1. OBR scans of a 1.1 jumper, Amplitude (dB/mm) scaling, taken with a wavelength range of 21 nm (blue), 43 nm (red), and 88 nm (green).

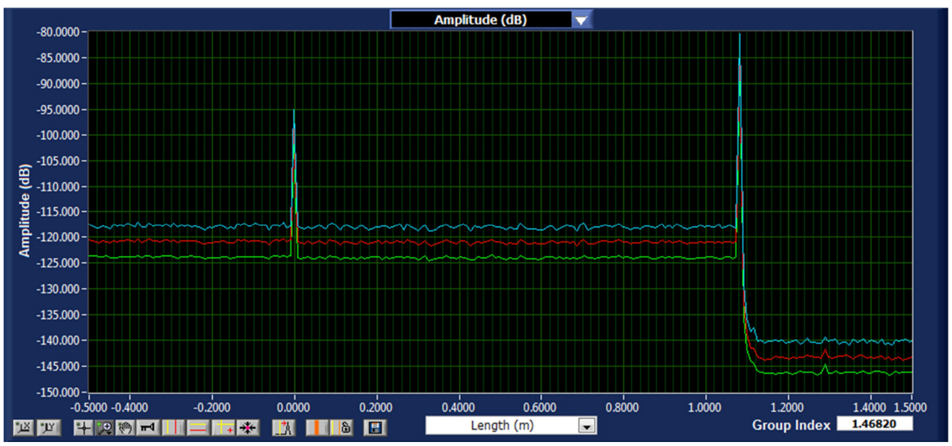

Figure 2. OBR scans of a 1.1 jumper, Amplitude (dB) scaling, taken with a wavelength range of 21 nm (blue), 43 nm (red), and 88 nm (green).

On the other hand, if we use a cursor in the top OBR graph to highlight the jumper end connector at 1.1 m and view connector reflection at full resolution in the bottom graph, we see that the Amplitude (dB) scaling produces a more intuitive result. In Figure 3, we see that when viewing the reflection amplitudes for the connector in the default Amplitude (dB/mm) scaling, the peak reflection value differs with the scan width, with wider scans (finer sample spacing) producing a higher peak. However, when we view the reflection amplitudes on the connector reflection in the Amplitude (dB) scaling in Figure 4, we see that the peak reflection value is consistent between scans, with a peak value close to the Return Loss for this event, at roughly -58 dB.

Figure 3. Close-up of the jumper connector reflection shown in Figure 1, Amplitude (dB/mm) scaling, taken with a wavelength range of 21 nm (blue), 43 nm (red), and 88 nm (green).

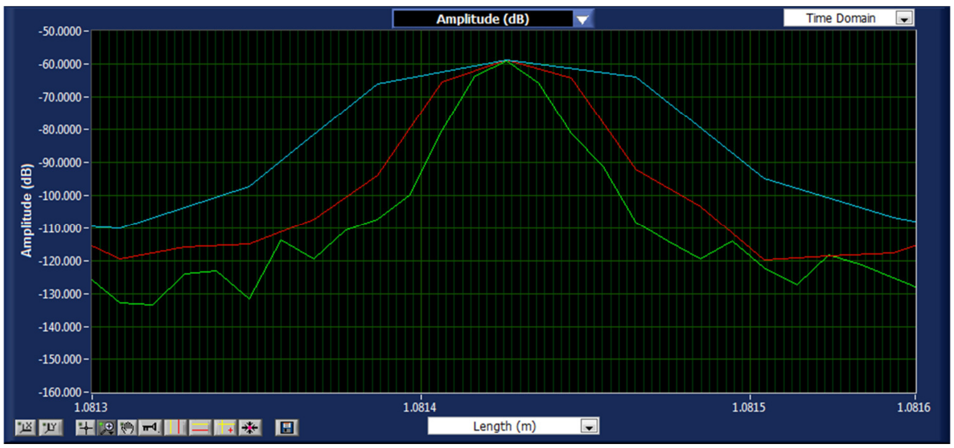

Figure 4. Close-up of the jumper connector reflection shown in Figure 2, Amplitude (dB) scaling, taken with a wavelength range of 21 nm (blue), 43 nm (red), and 88 nm (green).

OBR Software Revisions

This note describes reflection amplitude calculations valid for OBR software revisions v.3.10.0 (released in June 2013) through the most recent v3.13.0 (June 2017). Before that time, an incorrect scaling factor was applied to the value for dX, so that Linear Amplitude values were scaled incorrectly, and Amplitude (dB/mm) values had an incorrect fixed offset to Amplitude (dB) values.

Conclusion

This note reviews the difference between the forms of reflection amplitude in the OBR 4600's measurement output (linear per mm (1/mm), decibels (dB), and decibels per millimeter (dB/mm) and shows how these values are calculated from the raw S and P reflection coefficient values stored in the binary .obr files.

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