PMD Measurements Using Fixed-Analyzer Technique on a 1000 km Amplified Link That Includes ROADMs

Vincent Lecœuche, Fabien Sauron and André Champavère, JDSU Commtest Division, Saint-Etienne, France

Alexey Turukhin and Enrico Gonzales , JDSU Optical Network Research, Eatontown, New Jersey

Presented at National Institute of Standards & Technology (NIST) Symposium for Photonic & Fiber Measurements (SOFM) 2006

Summary

We report PMD measurements, performed on an amplified network with reconfigurable optical add drop multiplexers (ROADMs) and a total fiber length exceeding 1000km, using a commercially available setup based on the Fixed Analyzer Fourier Transform (FA-FT) technique. We have implemented straightforward numerical filtering that removes the inter-channel spectral data as well as dropped channels and demonstrated the improvement brought to the SNR. We show that this enhancement would allow one to maintain reliable PMD readings in Agile Optical Networks with transmission pass-bands affected by ROADMs.

Introduction

Measurement of the polarization mode dispersion (PMD) of the Agile Optical Network represents new challenges for test and measurement equipment. Not only do the signal paths depend on wavelength and time, but the wavelength span available for actually performing the PMD measurement into channels may get so limited that measurement accuracy is compromised. This latter fundamental limitation, associated with the statistical nature of PMD, applies to any of the available measurement techniques.[1] Some methods would indeed allow a precise measurement of the instantaneous differential group delay (DGD) at the exact channel wavelength, but this information alone is not really valuable as the DGD varies over time, even with relatively short spans of buried cables.[2] In this context, we focused our attention on the only truly representative parameter that can be measured, i.e., the most stable over time, which is the average DGD over the available wavelength span.

We have conducted laboratory experiments on an amplified network that includes commercial ROADMs, using the FA-FT technique implemented into our field test mainframe. We showed that this method provides a meaningful reading of the mean DGD over the available wavelength span, provided that a sufficient number of channels are passing through the link under test.

In section 1 (experimental arrangement), we will first briefly describe our experimental setup. In section 2 (measurements), we will describe our experimental results, observed both on a "regular" amplified link and one that does include ROADMs.

Experimental arrangement

The FA-FT technique is a well documented measurement tool and JDSU's implementation of it strictly follows the recommendations of the standards on PMD measurements.[3] The measurement block diagram is shown in Figure 1. A broadband polarised source (BBS) is launched into the Device Under Test (DUT), and the transmitted signal is analysed spectrally through a polarizer, integrated into the OSA and commutable. Manual polarisation controllers are added before and after the DUT in order to improve measurement accuracy.

Note that a reference spectrum is first performed without the polarizer, and the signal through the polarizer is normalized to this reference signal before performing the FFT, so that the FA-FT is intrinsically immune to any source/amplifier spectral shape features. This direct normalization procedure in the frequency domain is mathematically equivalent to other means that have been proposed in order to compensate for the corresponding auto-correlation peak in the time domain, as observed on interferometric setups. We will see hereafter that the direct access to the spectral data also allows the analysis of the ROADM passing channels information, yielding an improvement on the measurement accuracy.

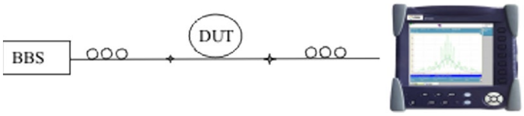

Figure 1: Measurement equipment

The link under test is described in Figure 2. This C-band link is fully functional and normally populated with 40 WDM channels with 100GHz spacing, modulated at 10Gb/s using NRZ format. The Multi-port Wavelength Switches, used as ROADMs have been configured to allow traffic for all channels through the express port. Measurements have been performed both on the whole link, i.e. from launch point A to detection point C, including the 3 ROADMs to imitate a fragment of AON, and from point B to C to consider the case of a regular point-to-point amplified network.

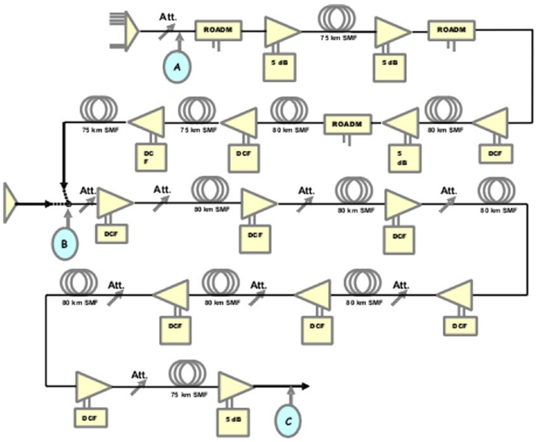

Figure 2: Link under test, including 3 ROADMs (MWS1X6+2), 14 EDFAs (OA3500), 940 kms of SMF and 140 kms of dispersion compensating fiber

Measurements

PMD measurements on a regular amplified link

The first test was performed on the link from point B to C. The value of the mean DGD, averaged over 50 successive measurements while manually changing the input/output polarisation launch conditions between successive scans, was found to be 1.32 ps with a standard deviation of 0.16 ps.

Figure 3-a) shows the measurement distribution, while Figure 3-b) shows a typical Fourier transform.

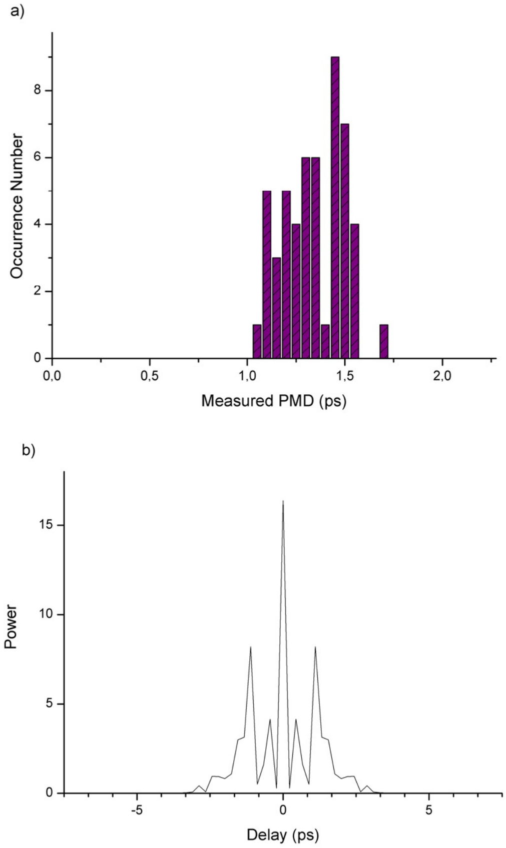

Figure 3: a) Histogram of the 50 measurements recorded while changing input/output polarisation launch conditions and b) typical FFT measured from point B to C.

For comparison, we used a commercial bench top instrument based on the Jones Matrix Eigenanalysis (JME) method. The use of a JME on WDM amplified network brings some difficulties associated with transmitting a single test channel, which is using the total power of the amplifiers. To avoid nonlinear issues, the amplifiers must somehow be loaded with an additional signal. To do so we used a broadband ASE source combined with the tunable laser. While the degree of polarisation at the output of the network was of only 10%, which is low to conduct reliable polarimetric measurements, the JME instrument was robust enough to take a reading. We ran 3 successive measurements without changing the launch conditions (the JME method being mostly insensitive to these changes), and the mean DGD over 1527-1563 band was found to be 1.33, 1.23 and 1.38 ps.

PMD measurements through a ROADM

The second experiment was performed on the total link represented in figure 2 from point A to C. The 3 ROADMs are set to let all the channels pass through. The spectrum of the BBS transmitted by the network is shown in Figure 4.

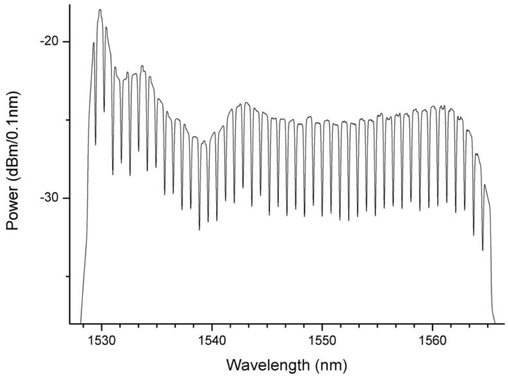

Figure 4: spectral transmission of the BBS from A to C, with ROADMs set in passing mode for all 45 channels.

The mean DGD was found to be 1.63 ps, averaged over 50 successive measurements while manually changing the input/output polarisation launch conditions between successive scans, with a standard deviation of 0.18 ps. With the JME setup, we have obtained a mean DGD of 1.71 ps after manually removing the inter-channel DGD points that were totally wrong as one could expect. Figure 5-a) shows the measurement distribution, and Figure 5-b) shows a typical Fourier transform.

We would like to emphasize that our standard test tool without any modification was able to provide reliable PMD measurements despite the peculiar shape of the transmission associated with ROADM's pass-bands. However, we must consider that conditions were quite favourable, and in particular the value of the PMD of the link was quite advantageous here. A close look at Figure 5-b) reveals the presence of signals at several harmonics of 10 ps which directly arises from the 100 GHz spacing of the ROADM channels. If the PMD of the link had been slightly higher with components close or above 10 ps, these perturbations would have been integrated into the width calculation and the result would probably have been overestimated. The signal to noise ratio would also decrease if some channels are dropped on the line or if the output Degree Of Polarization decreases.

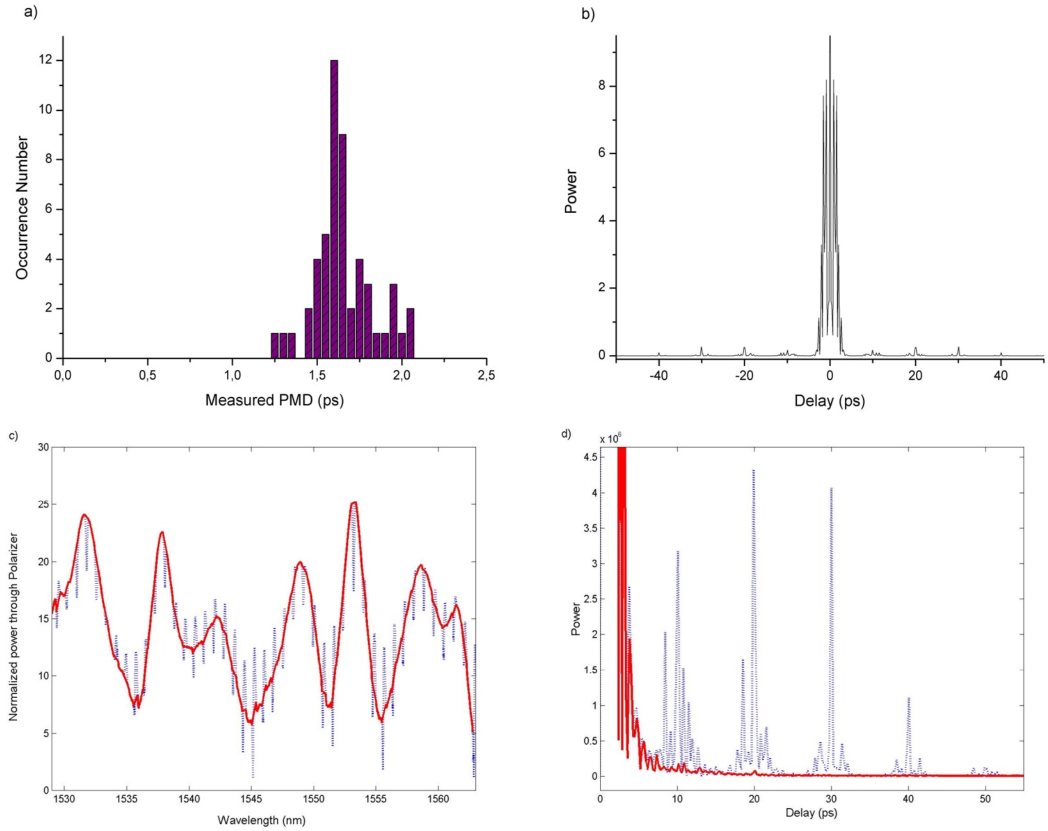

Figure 5: a) Histogram of the 50 measurements recorded while changing input/output polarisation launch conditions. b) typical FFT measured from point A to C. c) Normalized spectrum through polarizer (dotted line), with inter-channel filtering applied (solid line). d) zoom on the ROADM perturbations in the FFT (dotted line) removed with the inter-channel filtering applied (solid line).

As the FA-FT does a reference signal similar to the one shown in Figure 4) at every scan, we can use this information to locate the passing channels and simply remove the inter-channel signals. Channels are on the ITU grid, and we have located the passing bands with a power drop criteria of 0.3 dB compared to the channel centre value. The second step is to replace the inter-channel signals with straight lines as shown in Figure 5-c). By doing so the 10 ps component and its harmonics are clearly removed on the FFT as can be seen in Figure 5-d). Without filtering, the reading on this scan was 1.54 ps, with filtering, the reading was 1.48 ps, confirming that the ROADM influence on our measurement remains minor in this experiment.

Conclusions

We have demonstrated PMD measurement capability on an amplified network using the FA-FT technique. We showed that for this particular setup the measurements were not significantly affected by the presence of ROADMs in-line, and we proposed a software enhancement that would allow one to maintain valuable readings in more critical conditions. While this method is not meant to replace polarimetric methods that allow high-resolution DGD readings, it provides a simple, cost effective and field dedicated alternative when a sufficient number of passing channels are available.

References

[1] Gisin et al, IEEE Photonics Technology Letters 8, n°12, p. 1671 (1996)

[2] Allen et al, Journal of Lightwave Technology 21, n°1, p. 79 (2003)

[3] see for example IEC 60793-1-48, IEC61280-4-4, ITU-T G.650.2 or TIA 455-113

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