White Paper

Measuring the Optical Signal-to-Noise Ratio in Agile Optical Networks

Introduction

The optical signal-to-noise ratio (OSNR) is the key performance parameter in optical networks that predicts the bit error rate (BER) of the system. OSNR measurements and calibration have been performed using an interplation method. In this case, the OSNR is obtained by measuring the total signal power in the channel passband and the amplified spontaneous emission (ASE) noise in the gaps between the optical channels (normalized to a 0.1 nm bandwidth). This method is termed the linear interpolation method since the noise power is averaged from the ASE noise, which is present to the left and to the right of the optical channel (Figure 1).

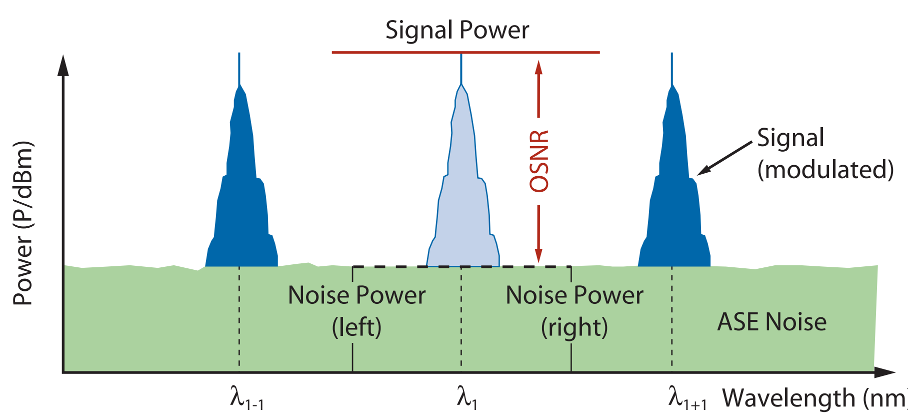

Figure 1 Linear interpolation method

The OSNR is calculated using the following formula:

$$OSNR = \frac{P_{Signal}}{\frac{P_{Noise\,(L)} + P_{Noise\,(R)}}{2}}$$

Written by:

Wolfgang Moench
Communications Test & Measurement
JDSU

Julia Larikova
Optical Transport R&D
Tellabs Inc

The AON Challenge

An agile optical network (AON) is a dynamically reconfigurable dense wavelength division multiplexing (DWDM) network providing add and drop functionality on the optical layer using reconfigurable optical add-drop multiplexers (ROADMs). In AON networks, each channel may traverse through different routes, optical amplifiers, and add-drop filters. Even adjacent channels may have a different noise level. The measurement of the "true" OSNR in these networks is not possible using the conventional linear interpolation technique.

The in-line optical filters which are built into ROADMs suppress the noise between optical channels. The measurement of the noise power in the gaps used by the OSNR linear interpolation method gives no indication of the noise present at the channel wavelength. This is called the *filtered noise*. The noise level will be underestimated resulting in a misinterpretation of the OSNR value.

Figure 2 shows the effect of suppressed and filtered noise, which results in a different noise power within the signal bandwidth than in the gaps between the optical channels.

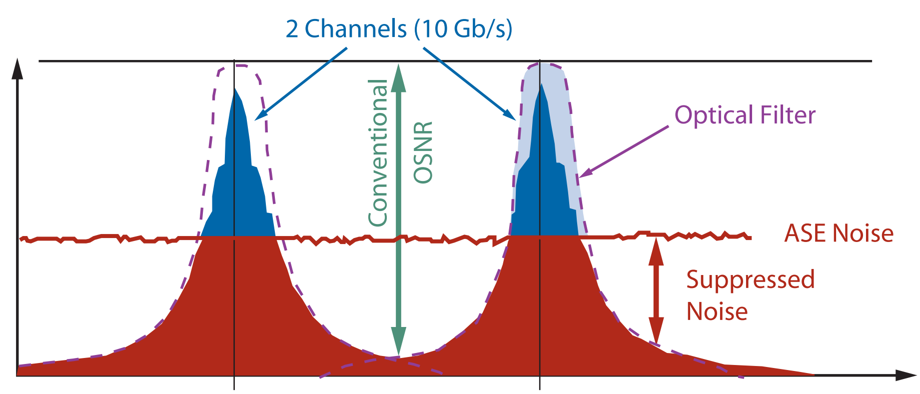

Figure 2 Effect of filtered noise

For accurate OSNR measurement, it is essential to know the ASE noise value in the passband of the optical filters in a system which is shown as the filtered noise. This measurement is called the In-band OSNR measurement. Since the standard interpolation method does not provide this information, the polarization-nulling method is proposed to measure the OSNR in the AON.[1, 2] However, the performance of this technique could suffer from depolarization effects due to polarization mode dispersion (PMD) and nonlinear birefringence.[3]

In this paper, a novel technique is proposed using a setup with an optical spectrum analyzer together with a polarization controller and polarization beam splitter for polarization nulling. This method is called the Optical Polarization Splitting method (OPS method).

Figure 3 shows a simplified block diagram of the OPS method.

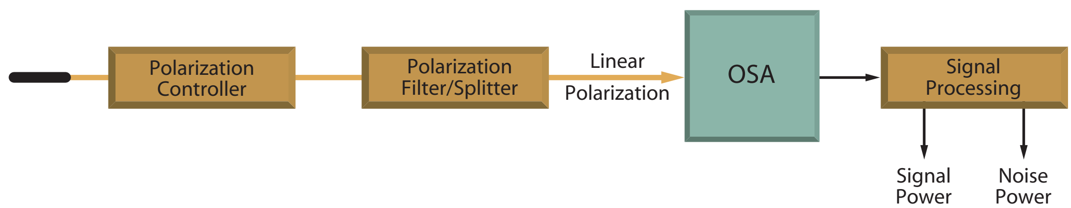

Figure 3 A block diagram of the OPS method

Experiments and results

Most studies and experiments of polarization-nulling based OSNR measurements have been focused on 2.5 Gb/s and 10 Gb/s NRZ signals. This paper demonstrates the results of OSNR measurements using the OPS method in Tellabs' ultra high speed agile optical networks that include different optical filter technologies and 40 Gb/s transponder modules with different modulations (see below).

The sensitivity of the OPS-method against the following effects have been tested.

- PMD
- Filter cascading (1, 4, 8, 15 optical filters)
- Modulation format (CS-RZ, PSBT, DPSK-RZ)
- Modulation speed (43 G and 10.7 G)

Test setup:
The following pictures show the block diagram and the test setup at Tellabs in Chicago.

- 180 km SSMF with 8 optical amplifiers and 4 ROADMs
- 3 optical channels at 43 Gb/s: CS-RZ, PSBT and DPSK-RZ

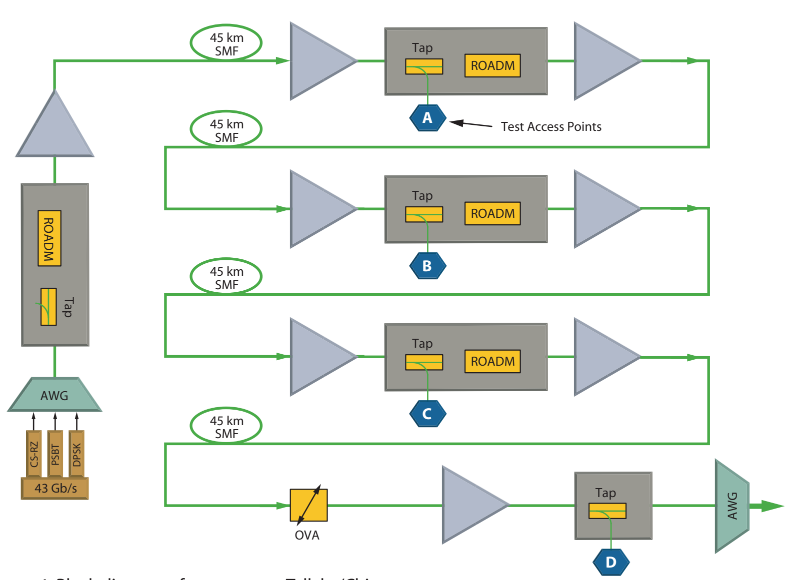

Figure 4 Block diagram of test setup at Tellabs/Chicago

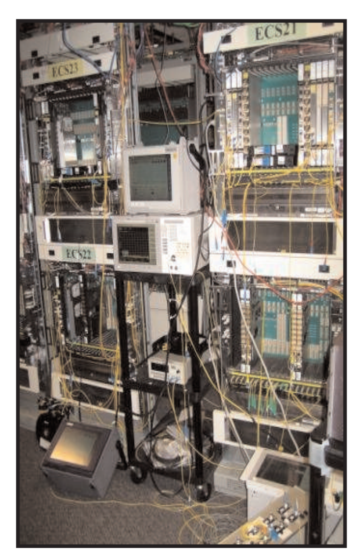

Figure 5 Tellabs test setup

Test Results

The OSNR was measured with a standard optical spectrum analyzer using the linear interpolation method and a new OSA from JDSU using the OPS method. The measurement results at the test access points A to D representing an OSNR range from 33 dB to 22 dB are shown in the following table.

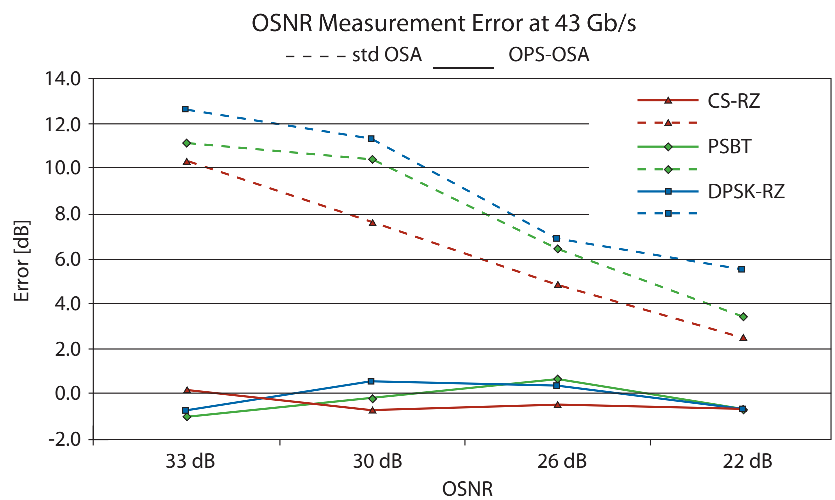

Table 1 OSNR test results

The test results show that the conventional OSA method will always show OSNR values that are too high since this method is based on the noise power in the gaps between the channels. This is suppressed by in-line optical filtering. The error can be as high as 9-10 dB depending on the system configuration. The OPS-OSA method shows very accurate measurements with an error of less than ±1dB.

Additional results showing the robustness against PMD and filter cascading will be presented at OFC/NFOEC 2007.

Summary

An improved OSNR measurement technique called Optical Polarization Splitting based on the polarization-nulling method is proposed. The test results with Tellabs ultra high speed networks showed that the proposed technique could measure the OSNR accurately at all modulation formats even when the signal was significantly depolarized due to PMD and nonlinear birefringence.

References

[1]D. K. Jung, C. H. Kim, Y. C. Chung, *"OSNR monitoring technique using polarization-nulling method"*, in Tech. Dig. OFC2000, Paper WK4, 2000

[2]J. H. Lee, Y. C. Chung, *"Improved OSNR monitoring Technique based on polarization-nulling method"*, Electron. Lett., vol. 37, no. 16, pp. 1032-1033, 2001

[3]M.H. Cheung, L. K. Chen, C. K. Chan, *"PMD-insensitive OSNR Monitoring based on polarization-nulling with off-center narrow-band filtering"*, IEEE Photonics Technology Letters, vol. 16, no. 11, pp. 2562-2564, 2004

All statements, technical information and recommendations related to the products herein are based upon information believed to be reliable or accurate. However, the accuracy or completeness thereof is not guaranteed, and no responsibility is assumed for any inaccuracies. The user assumes all risks and liability whatsoever in connection with the use of a product or its application. JDSU reserves the right to change at any time without notice the design, specifications, function, fit or form of its products described herein, including withdrawal at any time of a product offered for sale herein. JDSU makes no representations that the products herein are free from any intellectual property claims of others. Please contact JDSU for more information. JDSU and the JDSU logo are trademarks of JDS Uniphase Corporation. Other trademarks are the property of their respective holders. ©2007 JDS Uniphase Corporation. All rights reserved. 30149227 000 1007 NFOEC.WP.FOP.TM.AE

Test & Measurement Regional Sales

NORTH AMERICA	LATIN AMERICA	ASIA PACIFIC	EMEA	www.jdsu.com/test
TEL: 1 866 228 3762	TEL: +55 11 5503 3800	TEL: +852 2892 0990	TEL: +49 7121 86 2222	
FAX: +1 301 353 9216	FAX: +55 11 5505 1598	FAX: +852 2892 0770	FAX: +49 7121 86 1222	