Technical Note

AON – Agile Optical Networks

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

Introduction

The mainstreaming of consumer broadband and the accelerated growth of enterprise traffic have introduced new networking challenges. These challenges demand optical communication innovation that replaces slow, manual processes with solutions, enabling simplified, dynamic network configuration and automated service provisioning.

An agile optical network (AON) is a dynamically reconfigurable DWDM network that is designed to accelerate triple-play service deployment, simplify network management, and enable advanced wavelength applications at significantly reduced costs. Figure 1 shows the topology of a typical AON.

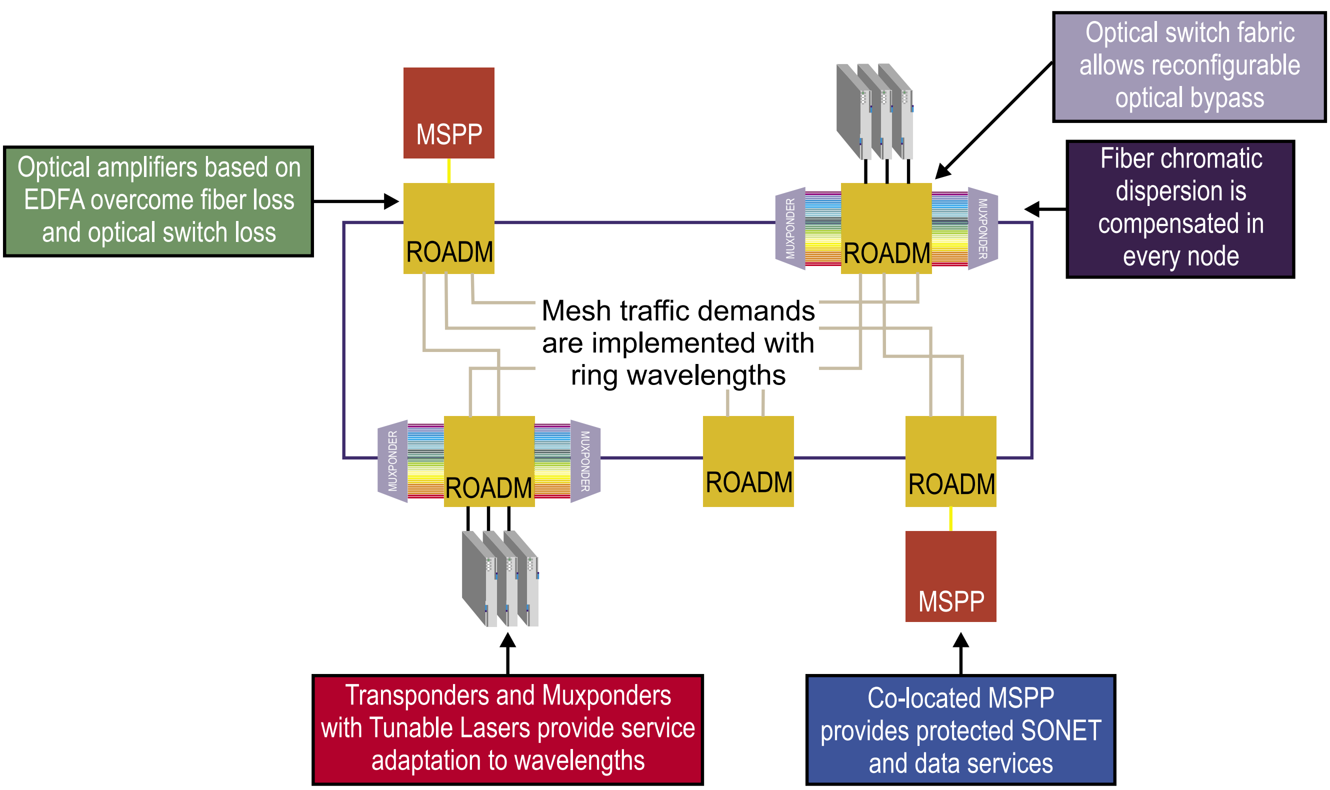


Figure 1. Topology of an agile optical network

AON Benefits

Increased service velocity via a dynamically reconfigurable topology
– Provision new services
– Reconfigure the topology using a "point-and-click" remote network management system (NMS)

Advanced wavelength services
– Private line services at dedicated bandwidths and wavelengths
– Bandwidth on demand
– Wavelength on demand

Accelerated triple-play services
– Flexible
– Scalable
– Simplified management

Reduced operating and capital expenses
–Reduction of expensive O-E-O
– Optimized capacity
– Fewer truck rolls
– Reduction of sparing/inventory
– Increased the supply chain velocity and simplicity
– Increased quality of service through performance monitoring, fault detection, and automatic healing

AON Challenges

The migration from fixed point-to-point networks toward dynamic wavelength switching meshed networks has created a number of challenges.

Wavelength management
– Wavelength ID (pilot tones)
– Wavelength route loss and continuity

Intensity management
– Transient, dynamic wavelength switching testing (OAM transient response)
– Power levels and gain equalization testing

Performance management
– OSNR testing (in-band OSNR)
– Dispersion testing (in-service, in channel CD and PMD)
– Electrical and optical amplification sampling (Q-factor)

Fiber characterization
– Continuity and loss testing (tunable OTDR)
– CD and PMD testing (through ROADMs, for example)

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

Basics

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. Until now, OSNR measurements and calibration have been performed using an interpolation method. In this case, the OSNR is obtained by measuring the total signal power in the channel passband and the noise power (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 2).

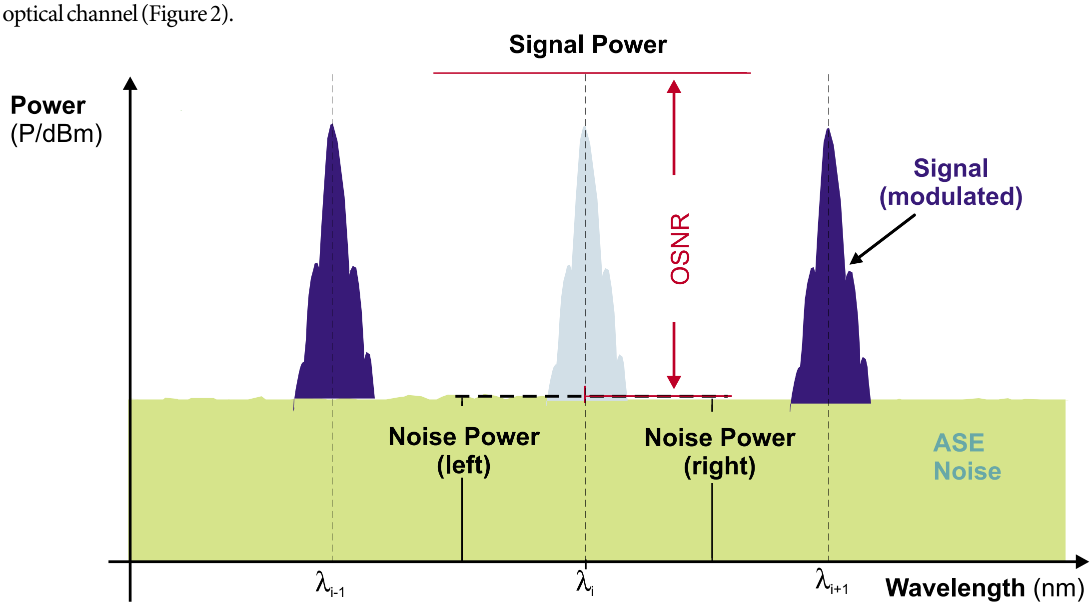


Figure 2. Linear interpolation method

The OSNR is calculated using the following formula:

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

AON Challenge

In the AON, each channel may traverse through different routes, optical amplifiers, and add-drop filters. Even adjacent channels may have a different noise level. Therefore, the measurement of the OSNR in these networks is not possible using the conventional linear interpolation technique.

Problem

The in-line optical filters which are built into ROADMs suppress the noise in 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 which is called the "filtered noise". Thus the noise level will be underestimated resulting in a misinterpretation of the OSNR value.

Therefore, the formula for the calculation of the OSNR at a receiver is no longer valid.

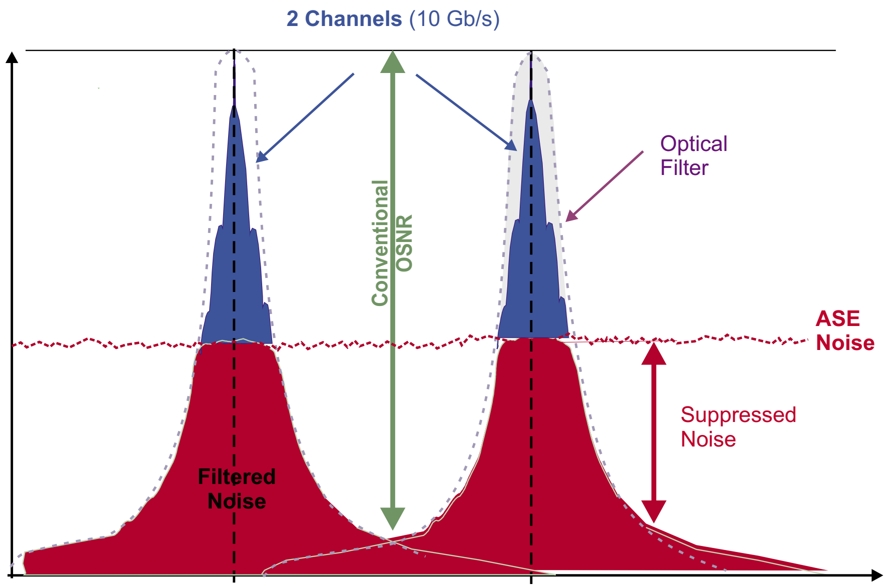


Figure 3. Effect of "filtered noise"

Figure 3 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.

Methods

The in-band OSNR

For OSNR measurement, it is essential to know the filtered noise value in the passband of the optical filters in a system. This measurement is called the 'in-band' OSNR measurement. Since the standard interpolation method does not provide this information, there is a need for alternative ways to measure the OSNR.

On the optical layer there are two principles that are involved in measuring the noise power within the optical channel bandwidth.

1. Signal deactivation

Involves turning off the signal in order to measure the noise power level.

Drawbacks:

- Cannot be performed on a live system without service interruption.
- Instability of ASE noise.
  Automatic gain control in the optical amplifier will change the ASE noise level when the signal is switched off.

Alternative:

- High-speed optical gating can be used to overcome EDFA gain equalization. This technique is used in JDSU's time resolved optical gating (TROG) reference method.

2. Signal elimination

Involves suppressing the optical signal in order to measure the noise power at the signal wavelength. Several polarization-assisted methods like the polarization nulling method have been proposed to measure the in-band OSNR by signal elimination.

Advantage:

- Suitable for live signal monitoring.

Solution

JDSU provides a new method for measuring the in-band OSNR using optical polarization controlling and splitting. This method is called the Optical Polarization Splitting method (OPS method).

Figure 4 shows a simplified block diagram of the OPS method.

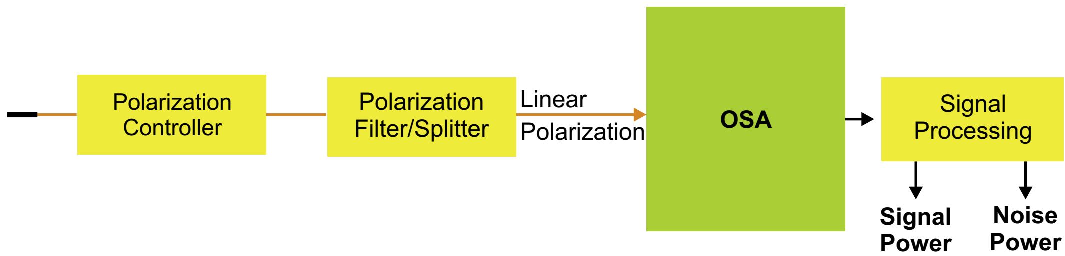


Figure 4. A block diagram of the OPS method

Principle

The OPS-method using optical polarization controlling is based on the fact that the optical transmission signal consists of arbitrarily polarized light; whereas the ASE noise consists of only unpolarized light. A variable polarization controller and splitter separates the polarized signal from the unpolarized noise. Depending on the setting of the polarization controller, the polarization filter/splitter either blocks or passes the optical signal (channel). On the other hand, the polarization filter/splitter always passes the unpolarized noise.

Special signal processing evaluates the ASE noise power and signal power. The measurement of the total channel power and the calculation of the ASE noise power inside the optical system filter bandwidth provide the in-band OSNR.

Figure 5 shows JDSU's OPS-OSA.

Figure 5. JDSU's OPS-OSA

Reference method

The reference OSNR values are measured using JDSU's time-division multiplexing measurement technique, which is called the time resolved optical gating (TROG) reference method. This method can be used for spectral measurements in active WDM loaded links. Similarly to traditional TDM technique, the TROG measurement method is multiplexing time slots with data in WDM and probe signal. At the output of the link, WDM data and probe signal are optically demultiplexed and independently analyzed.

Experimental setup for TROG measurement technique is presented in Figure 6.

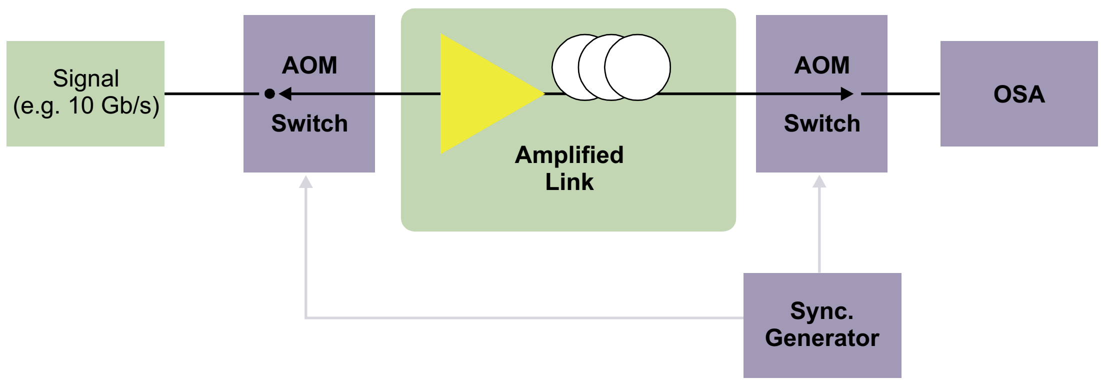


Figure 6. TROG-measurement principle of operation diagram.

To perform TDM measurements, two acousto-optical switches (AOM) are required at input and output of the link under test. The first AOM is switching the signal on and off with frequency of about 1 MHz. This frequency is high enough to prevent the amplifiers from automatic gain control and amplifier relaxation effects. The second AOM is synchronously triggered in front of a standard optical spectrum analyzer (OSA). Synchronizing the AOM at the standard OSA to the ON state will indicate the signal power (P_{Signal}); whereas synchronizing to the OFF state will indicate the noise power. The noise power is equivalent to the in-band noise power ($P_{Noise(in\text{-}band)}$). A time diagram is presented in figure 7.

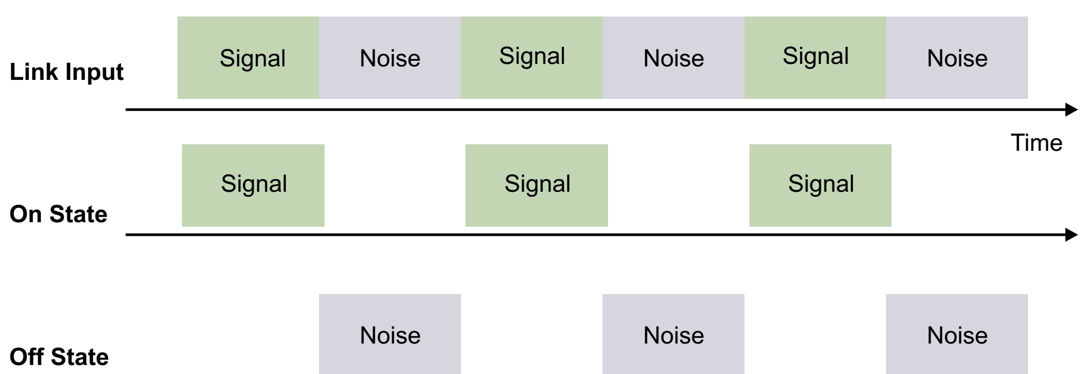


Figure 7. Time diagram for TROG measurement technique.

With this method, accurate OSNR measurements can be achieved according to the following formula:

$$OSNR = \frac{P_{Signal}}{P_{Noise\,(in-band)}}$$

Verification of JDSU's OPS-OSA method

Test Setup

To verify the functionality and accuracy of the new OPS-OSA method, extensive tests have been conducted in JDSU's test lab in Ewing, NJ. Figure 8 shows the test setup in the JDSU test lab.

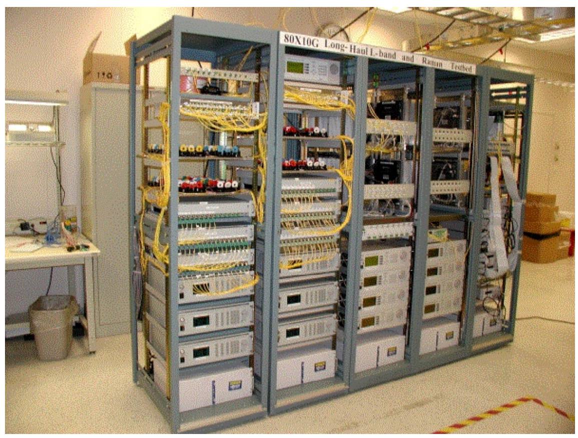


Figure 8. JDSU's test lab located in Ewing, NJ

Configuration of the test setup

- 32 channels modulated at 10 Gb/s, C-band, 100 GHz channel spacing
- 5 fiber segments (80 km) for a total length of 400 km
- 9 optical amplifiers (C-band OAM)
- 3 ROADMs (JDSU) embedded between the OAMs

Figure 9 shows a simplified block diagram of the test access points (A-G) after each amplifier section.

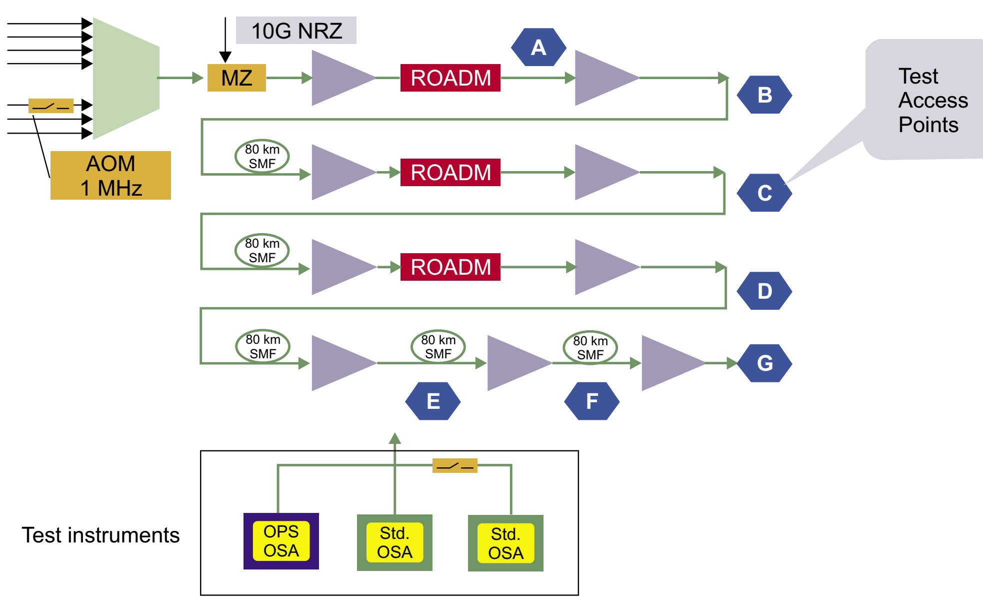


Figure 9. A block diagram of the test setup

Test Results

Figure 10 shows the measurement results performed at each test access point using:

- Standard OSA interpolation method
- TROG reference method with a standard OSA
- OPS-method with JDSU's OPS-OSA prototype

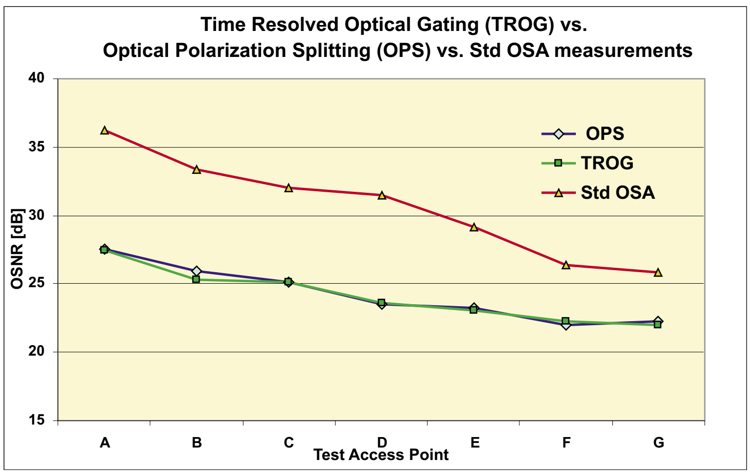


Figure 10. OSNR test results

The TROG reference method is considered as the reference for the in-band OSNR value. It is important to note that this method can only be used in systems that are out of service.

Accuracy

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, which is suppressed by in-line optical filtering. The error can be as high as 9-10 dB depending on the system configuration (Figure 11).

The OPS-OSA method shows very accurate conformance to the TROG reference method. The typical error for this method is in the range of less than ±0.5 dB.

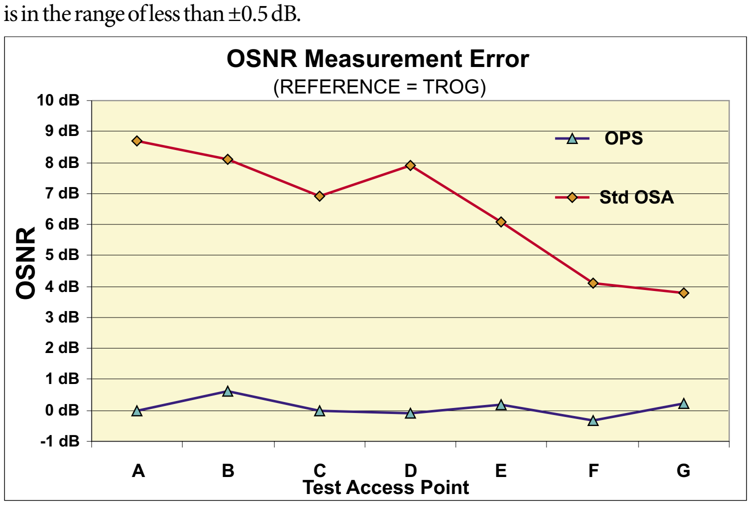


Figure 11. OSNR measurement error

Summary

Measurements of OSNR using the conventional interpolation method, which is used by standard OSAs, is no longer valid for providing accurate measurement results. The error in an agile optical network with in-line optical filters (ROADM or OXC) can be as high as 10 dB.

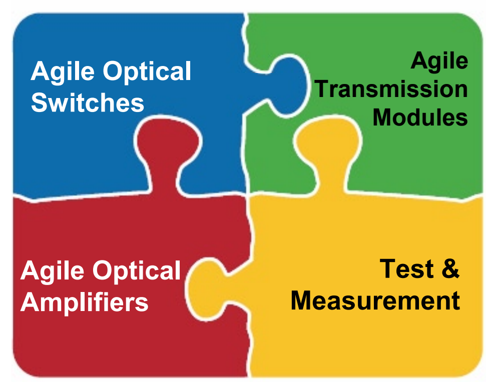
JDSU's new OPS-OSA method using the principle of signal elimination has proven OSNR measurements with a high accuracy. The greatest advantage of this method is that it can be used in live optical systems without the need for service interruption. Therefore, the JDSU OPS-OSA method can be utilized in measuring optical performance in the AON.

JDSU Offers the Broadest AON Portfolio

The dynamically reconfigurable nature of the AON offers many unique competitive and cost advantages, enabling communications service providers to more efficiently use and scale network capacity, streamline service provisioning, and modify network topology through simple "point and click" network management systems.

JDSU offers an end-to-end portfolio of AON-enabling solutions:

- Agile optical switches
  - Reconfigurable optical add/drop multiplexers (ROADMs)
- Agile transmission modules
  - Tunable transponders
- Agile optical amplifiers
  - Fast transient and gain flattened
- Test and mesurement solutions for R&D, manufacturing, I&M, SVT, and troubleshooting
  - Swept wavelength systems (SWS) for testing ROADMs in production
  - Optical spectrum analyzers (OSA-16x, OSA-30x)
  - OTDR, CD, and PMD analyzers
  - Handheld optical attenuators and power meters (SmartClass)



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