APPLICATION NOTE
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THE ROADM CHALLENGE AND THE IN-BAND OSNR SOLUTION

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Many high-bandwidth networks are currently being upgraded to include reconfigurable optical add/drop multiplexers (ROADMs) in order to improve efficiency and flexibility. Networks using ROADMs are somewhat different from standard systems: a simple glitch on a live network operating at many wavelengths and at high data rate can cause the system to lose a considerable amount of data, gravely affecting not only overall quality of service (QoS) but costs as well, thus accentuating the importance of accurate measurement of optical signal-to-noise ratio (OSNR).

Traditionally, the standard technique for measuring OSNR was to deduce it from a simple interpolation of the interchannel noise level between dense wavelength division multiplexing (DWDM) channels (as recommended in the IEC subsystem test procedure 61280-2-9); this is referred to as the "out-of-band" technique. However, the out-of-band technique is no longer valid in reconfigurable networks, since the optical filtering in ROADMs removes the noise between channels. Therefore, in-band OSNR measuring techniques become essential to accurately measure the OSNR in reconfigurable networks, and optical spectrum analyzers that base their measurements on the IEC 61280-2-9 procedure make critical errors.

The IEC 61280-2-9 Standard: Not a Practical Solution for the ROADM Challenge

The traditional OSNR measurement technique is based on the standard entitled IEC 61280-2-9 Fiber Optic Communication Subsystem Test Procedures Part 2-9: Digital Systems Optical Signal-to-Noise Ratio Measurement for Dense Wavelength-Division Multiplexed Systems. This standard defines optical signal-to-noise ratio (OSNR) measurement as the average between the left and right OSNRs, which are themselves measured as the difference in power between the peak power and the noise at half the distance between the peaks (as indicated below):

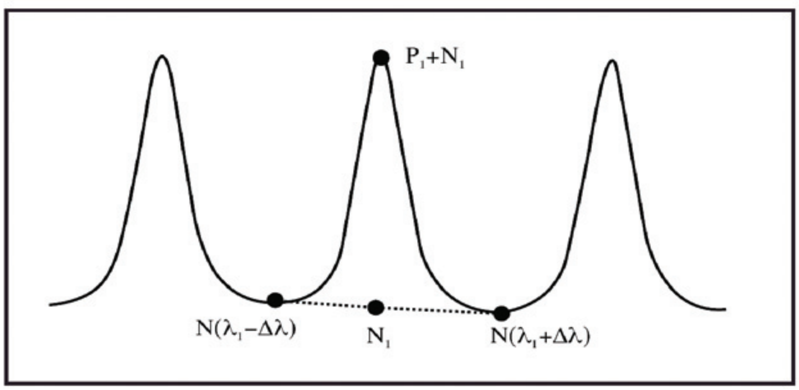

Figure 1: Graphical illustration of IEC 61280-2-9 Fiber Optic Communication Subsystem Test Procedures Part 2-9: Digital Systems optical Signal-to-Noise Ratio Measurement for Dense Wavelength-Division Multiplexed Systems.

The wavelength-selectable switch (WSS) is at the core of the ROADM, due to its capacity to select which lambda goes where at any given time. At the output, wavelengths can come from different network paths, meaning that they exhibit different noise contributions. Additionally, wavelengths are demultiplexed as they enter the ROADM, so that they can be switched to any port. As filters are wider than the DWDM signal, part of the residual noise goes through, which creates a shoulder-like shape on the filtered wavelength and, at the output of the ROADM, the spectrum may look like the one illustrated in Figure 2. The biggest challenge in installing ROADMs is to monitor the impact of the device on the OSNR, and measuring the residual signal-to-noise ratio at the output. The IEC 61280-2-9 OSNR measurement technique is no longer suitable for ROADM-based networks, as it can lead to critical errors.

For example, when examining a 100 GHz ROADM and a 10 Gbit/s transmitter, OSNR can be measured manually (with visual markers), even though the automatic OSNR measurement is incorrect. On a 50 GHz spacing device, the reduced shoulders on either side of the peak can no longer be identified, but noise is still present in the channel (referred to as “in-band noise”). The same remains true for the broader 40 Gbit/s transmission, making the risk of error even greater since the noise and signal cannot be visually discriminated as the spectrum. See Figure 2, which represents a 100 GHz ROADM and a 10 Gbit/s transmitter:

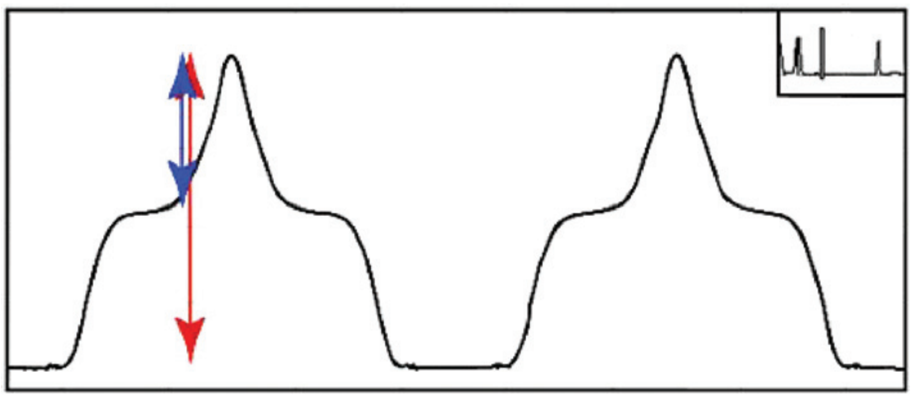

Figure 2: DWDM signal after a ROADM, where the blue arrow represents the true OSNR of the channel, and the red one represents the OSNR according to the IEC 61280-2-9 definition.

Measuring OSNR

OSAs deliver highly accurate optical signal-to-noise ratio (OSNR) measurements for systems where noise fluctuates from channel to channel. The IEC 61280-2-9 defines OSNR measurement as the difference in power between the peak power and the noise at half the distance between the peaks. In ROADM systems, this method may lead to incorrect results.

In the example below, the system under test had 18 active channels with different OSNR levels that depended on the path followed by each channel. The following figure shows the OSA display of the peaks:

The graph indicates that variable OSNR levels were present and ranged from around 14 dB to 30 dB.

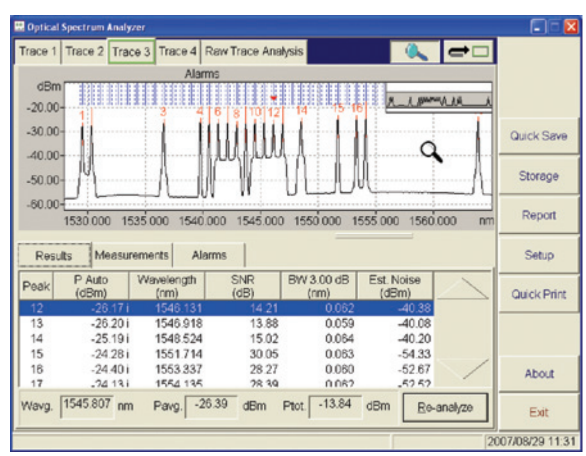

Figure 3: A ROADM display with 18 peaks

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 OSNR.

Comparing Results

In order to compare the results of the standardized IEC OSNR measurement method with the in-band technique, another trace was acquired on the same system with the SNR settings in IEC auto mode. A sharp-spectral-response OSA, such as EXFO's FTB-5240, can perform an excellent OSNR measurement out of band, without using the inter-channel spacing (as standardized by the IEC procedure). This can be done either by placing markers at the shoulder positions, or on some more advanced OSAs (such as the EXFO FTB-5240), by selecting the distance from the peak at which the OSNR is to be calculated (called out-of-band measurements).

It is important to emphasize once again that the out-of-band approach will provide very good results if, and only if, the shoulders are seen on either side of the carrier. On faster modulation, tighter channel spacing or with different modulation formats, this may not always be the case, and thus an experimented user should determine whether or not a custom analysis will be valid. The in-band analysis, on the other hand, does not require a trained-eye decision.

Channel Number	Position (nm)	Peak Power (dBm)	IEC Standard (dB)	Out-of-Band (dB)	EXFO's In-Band Approach (dB)	IEC Approach Measurement Errors
01	1563.870	-24.76	30.9	22.8	22.8	√
13	1554.134	-24.13	29.8	28.4	28.4	
14	1553.337	-24.40	29.7	28.3	28.3	
16	1551.714	-24.28	31.1	30.1	30.1	
20	1548.524	-25.19	28.1	15.0	15.0	√
22	1546.918	-26.13	27.7	14.3	13.9	√
23	1546.130	-26.17	14.4	14.2	14.2	
24	1545.321	-26.27	14.5	14.6	14.3	
25	1544.529	-26.61	31.2	14.2	14.1	√
26	1543.734	-26.09	30.7	29.4	29.4	
27	1542.936	-26.68	31.2	14.7	14.6	√
28	1542.146	-26.72	15.0	15.0	15.0	
29	1541.349	-26.46	31.5	15.3	15.3	√
30	1540.558	-26.19	31.0	29.9	29.9	
31	1539.776	-26.06	30.9	30.7	30.7	
35	1536.605	-25.86	30.8	21.6	21.1	√
43	1530.337	-26.81	30.0	20.6	20.6	√
44	1529.546	-27.31	30.1	20.4	19.8	√

Table 1: Various measurement results with each of the OSNR methods (IEC, out-of-band and in-band).

Closer Analysis of Peaks

In order to evaluate the actual OSNR value of a peak where the inter-channel does not work (e.g., channel 20 at 1548.5 nm), the saved trace is analyzed. Since this in-band measurement relies on polarization-diversity detection, two constituting sub-traces are produced.

Using the sub-traces, a value of 43.2 dBm is obtained for polarization trace B (see Figure 3; lower curve); i.e., an actual noise level of -40.2 dBm for this peak (3 dB higher since the unpolarized noise is split equally between the two polarizations). The peak power was measured at -25.2 dBm (upper curve), which leads to an OSNR value of 15 dB, as compared to 28.1 dB, when measured according to the IEC method.

When comparing these results, it can be seen that the in-band measurement is in agreement with the manually obtained value using an alternate technique (based on partial polarization nulling) while the IEC recommended procedure leads to a false result.

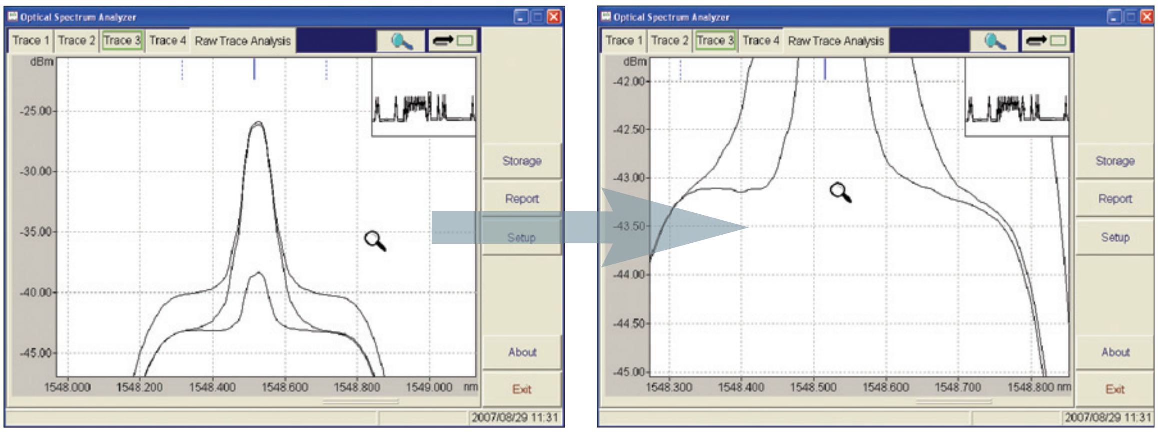

Figure 4: Polarization-diversity traces: A (bottom curve), B (middle curve) and Sum (top curve) of Channel 14.

Conclusion

After examining a Tier-1 network service provider's ROADM-based network, the accurate ROADM OSNR measurement was obtained by using the in-band measurement technique, and not by measuring with the IEC 61280-2-9 standard for inter-channel noise estimation.

Therefore, to ensure an optimal OSNR measurement, the measurement should be performed in-band, since noise contribution can be different for each wavelength. Traditional, out-of-band OSNR measurements are based on the noise level in between the channels, so in this application, the measurements fail. This indicates that traditional OSAs need to evolve, since their automated measurements are typically based on the IEC procedure, which, as demonstrated herein, can lead to critical errors.

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