Why OSAs are a better choice for spectral analysis than optical channel monitors

white paper

EXFO

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Introduction

Spectral analysis encompasses measurements like channel power, channel central wavelength and optical signal-to-noise ratio (OSNR) which are key performance indicators (KPIs) of network performance and critical to manage in order to prevent network outages. There are two categories of instruments that perform spectral analysis: portable devices like optical spectrum analyzers (OSAs) and spectral analysis capabilities embedded in transport systems and accessible through the element management system (EMS) that are also called optical channel monitors (OCMs) or optical performance monitors (OPMs). These two categories of devices present important differences in terms of performance (accuracy, range of measured values, etc.) and in terms of how they measure power, wavelength and OSNR. This document will highlight these differences and their impact on assessing network performance.

OSAs and EMSs/OCMs/OPMs: a sneak peek at the basics

Optical spectrum analyzers are instruments that measure the optical power energy distribution over the wavelength domain, thereby enabling spectral analyses and monitoring of optical signals and networks. OSAs have become a fundamental device in telecommunications. This is due to its involvement in several applications such as light source characterization, optical amplifier assessment, WDM network analysis and OSNR measurement.

With respect to optical design, optical spectrum analyzers are classified into two categories. The first category consists of devices for measuring optical power after the decomposition of the different wavelengths/frequencies. In this case, the optical core is a diffraction grating or an interferometric system. The second category includes high resolution OSAs because spectral resolution under 1 pm can be achieved. In this case, the ultra-narrow filtering process is caused by a non-linear effect, however this category is not the subject of this white paper.

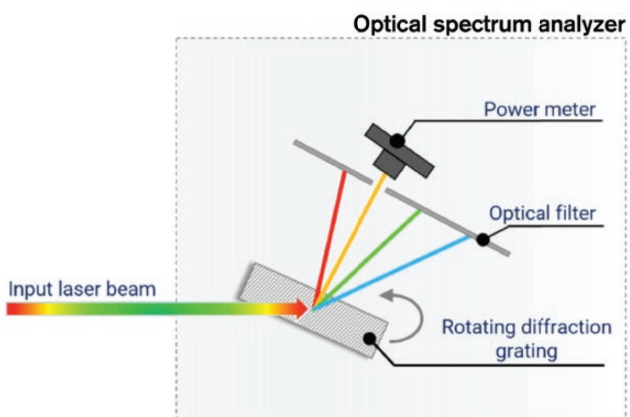

Figure 1. Schematic of a diffraction grating-based optical spectrum analyzer.

> OSAs and EMSs/OCMs/OPMs all claim the ability to achieve accurate results. However, OSAs deliver higher performance, in terms of absolute spectral and power readings, than do EMSs/OCMs/OPMs.

The first class of OSAs, the diffraction grating-based, are certainly the widest employed. In this kind of optical spectrum analyzers, the incoming light passes through a controlled-rotation grating that plays the role of a wavelength-tunable optical filter. The different wavelengths of the beam are then separated and finally, only one component is quantified by a photodetector (Figure 1). The bandwidth resolution of OSAs are then set by a slit.

A grating-based OSA's design might involve multiple passes of the incoming light through this diffraction system to further reduce the spectral bandwidth. For this reason, the spectral performance parameters of grating-based OSAs vary from one manufacturer to another, typically ranging from 20 to 100 pm in terms of resolution bandwidth and between ±10 to ±50 pm of wavelength accuracy. Furthermore, lower spectral resolution bandwidths (given mostly by multi-pass designs) lead to sharper filter edges, thus the dynamic range is increased. As for the detected optical power, it should be considered that every wavelength reading is always associated to a power level for each scan, and a typical value of power accuracy is ±0.5 dBm.

In contrast, perhaps for confidentiality purposes, the working principles of EMSs/OCMs/OPMs are not commonly detailed. Both the physical foundations of the measurements and the internal structure are scarcely accessible by customers. In this way, they behave as black box systems where data processing algorithms are responsible for monitoring, optimization and compensation of the most common impairments. Some system vendors do not even publish these devices' key specifications, making it questionable whether these devices deliver accurate and precise results.

Despite the large variety of solutions and different principles contained in the EMS/OCM/OPM concept, when specifications are published, the accuracy of optical power and wavelength are approximately ±1.5 dB and ±50 to 100 pm, respectively. Likewise, EXFO's experience of side-by-side OSA-EMS tests has revealed that EMS/OCM/OPM accuracy varies widely by brand and model.

OSAs and EMSs/OCMs/OPMs all claim the ability to achieve accurate results. However, it is worth highlighting that OSAs available on the market today deliver higher performance in terms of absolute spectral and power readings than do EMSs/OCMs/OPMs. In addition, several factors might limit the suitability to employ these devices for monitoring and evaluating the performance of optical networks, as is the case with OSNR measurement. This is discussed in the next sections.

OSAs & EMSs/OCMs/OPMs for OSNR measurement

In optical communications, the distortions by channel impairments (fiber non-linearities, inter-channel crosstalk, amplified spontaneous emissions coming from optical amplifiers, filtering effects or issues in fibers associated with mechanical effects) are experimentally unavoidable ultimately affecting quality of transmission. To ensure only marginal errors in data transmission, the distortions by channel must be monitored and quantified throughout the optical network. In this regard, as it provides information per channel, OSNR representing the ratio between amplitude of signal (meaningful information) and the amplified spontaneous emission noise generated by optical amplifiers, is considered a key parameter in the performance of WDM networks.

Modulation formats: the key to evolution in OSNR measurements

As discussed in previous application notes written by EXFO [1, 2], using OSAs to measure OSNR in order to assess the performance of optical networks has become widely accepted in the industry. However, the methods of using OSAs to measure OSNR have continuously evolved as a response to two main factors: the evolution of network architecture and the implementation of new modulation formats.

OSAs were broadly used to measure OSNR in 10G networks through the standard IEC 61280-2-9, also known as the interpolation method. Some years later, when 40G networks took center stage, the new *in-band* method for OSNR measurement was developed to overcome noise filtering caused by wavelength-selectable switches (WSS). WSSs are the core of ROADMs (see application notes listed in footnote below [3, 4]), and rendered the interpolation OSNR method inapplicable. Later on, around 2009, the introduction of coherent 100 Gbit/s signals made the in-band OSNR method obsolete. This obsolescence was due to the polarization multiplexing that quadrature phase shift keying (QPSK) 100 Gbit/s signals use. Accordingly, Pol-Mux OSNR and in-service Pol-Mux OSNR measurement methods were introduced for coherent transmissions (see EXFO application notes for more details [5, 6, 7]). The OSNR measurement methods offered on OSAs for each type of signal are shown in table 1.

Data rate	ROADM present in network?	OSNR method
≤10G	No	IEC 61280-2-9 (interpolation)
≤10G	Yes	In-band
Direct detect 40G	Yes or no	In-band
Coherent 40G/100G/200G/400G	Yes or no	Pol-Mux or in-service Pol-Mux

Table 1. Evolution of the OSNR methods with respect to data rates and network topology

As can be seen above, OSNR measurement methods used in OSAs have evolved to handle new technological advancements, and ample literature is available to explain how each method works. Generally speaking, this is quite the opposite for EMS/OCM/OPM.

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Nestled among the scant information that EMS/OCM/OPM manufacturers provide to customers, the detuning method is eventually mentioned. It is assumed that this method integrates the power in slightly large or shorter wavelengths from center of the channel peak, to determine the noise floor level in the spectral gap between two transmission channels. As discussed earlier, the noise level will be drastically affected by ROADMs and EDFAs in coherent transmissions, which could lead to large errors in OSNR calculations. Since the detuning method is rather similar to the outdated IEC 61280-2-9 standard, it could be considered limited in today's high-speed networks. At first glance, it doesn't seem to make sense to use an OSNR-measuring technique in coherent networks where the background noise is not taken into account or where it is assumed to be linear. However for the sake of transparency, end-users are free to gather in-depth information which helps to understand the EMS/OCM/OPM's principle for OSNR measuring.

[1] Application note 098: Measuring OSNR in WDM systems—effects of resolution bandwidth and optical rejection ratios
[2] Application note 254: How to capitalize on the existing fiber network's potential with an optical spectrum analyzer
[3] Application note 171: The ROADM challenge and the in-band OSNR solution
[4] Application note 235: Optical spectrum analyzers in next-gen networks
[5] White paper 028: 40G/100G/200G OSNR Measurements with a Pol-Mux OSA
[6] White paper: Choosing the best field-based optical spectrum analyzer for analysis of 200G/400G and flexgrid signals
[7] Application note 350: How to perform in-service Pol-Mux OSNR measurements with your FTBx-5255 optical spectrum analyzer

The right tool for OSNR measurement

In order to make an enlightened choice when selecting an OSNR measurement tool (OCM or OSA), EXFO recommends that users ask questions of the vendor. Key points to inquire about are:

- What is the OSNR accuracy of the solution?
- Does it support coherent 100G+ signals?
- How is OSNR measured? Are there any patents or technical/scientific documentation describing the OSNR measurement method?
- Does the OSNR measurement comply with international standards?

Discussion

The development of OSAs has achieved a degree of **maturity** providing a remarkable **flexibility** to deal with the evolution of modulation formats and network topologies. The **reliability** of OSNR readings for any network topology at any data rate using different methods (interpolation, in-band, Pol-Mux and in-service Pol-Mux), has been successfully applied in the field by providing accurate BER predictions. This has lead to the enactment of international standards for OSNR measurement including IEC 61280-2-9, IEC 61282-12 and China Communications Standards Association (CCSA) YD/T2147-2010. Consequently, the optical communications industry accepts and trusts the accuracy of the standard-based OSNR readings.

EMS/OCM/OPM on the other hand, have appeared in the market as modular solutions asserting the capability for measuring OSNR in all types of optical networks. As explained before, it is complicated to encompass all the EMSs/OCMs/OPMs in a unique concept. Accordingly, their accuracy values are quite different depending on the brands and the model, and lastly their working principles are diverse as well.

The main performance indicators of OSAs and EMSs/OCMs/OPMs are summarized in Table 2 below.

Parameter	OSA	EMS/OCM/OPM
Power accuracy	±0.5 dB typically	Varies from ±0.5 dB to ±1.5 dB typically
Wavelength accuracy	±30 pm to ±50 pm typically	Varies from ±50 pm to ±100 pm typically
OSNR accuracy	±0.5 dB typically	Varies widely. Sometimes not quoted.
OSNR measurement methods	IEC 61280-2-9, in-band OSNR, Pol-Mux OSNR, in-service Pol-Mux OSNR	Usually not disclosed
OSNR supports 100G+ signals	Yes, Pol-Mux OSNR and in-service Pol-Mux OSNR	Unclear
Availability of literature describing OSNR measurement methods	Yes, abundant literature	Usually confidential

Table 2. Overview of the typical specifications of OSAs and EMSs/OCMs/OPMs

In summary, this white paper presented a general overview of OSAs and EMSs/OCMs/OPMs, providing the essential information about OSNR measurement capabilities and limitations for current and future optical networks.