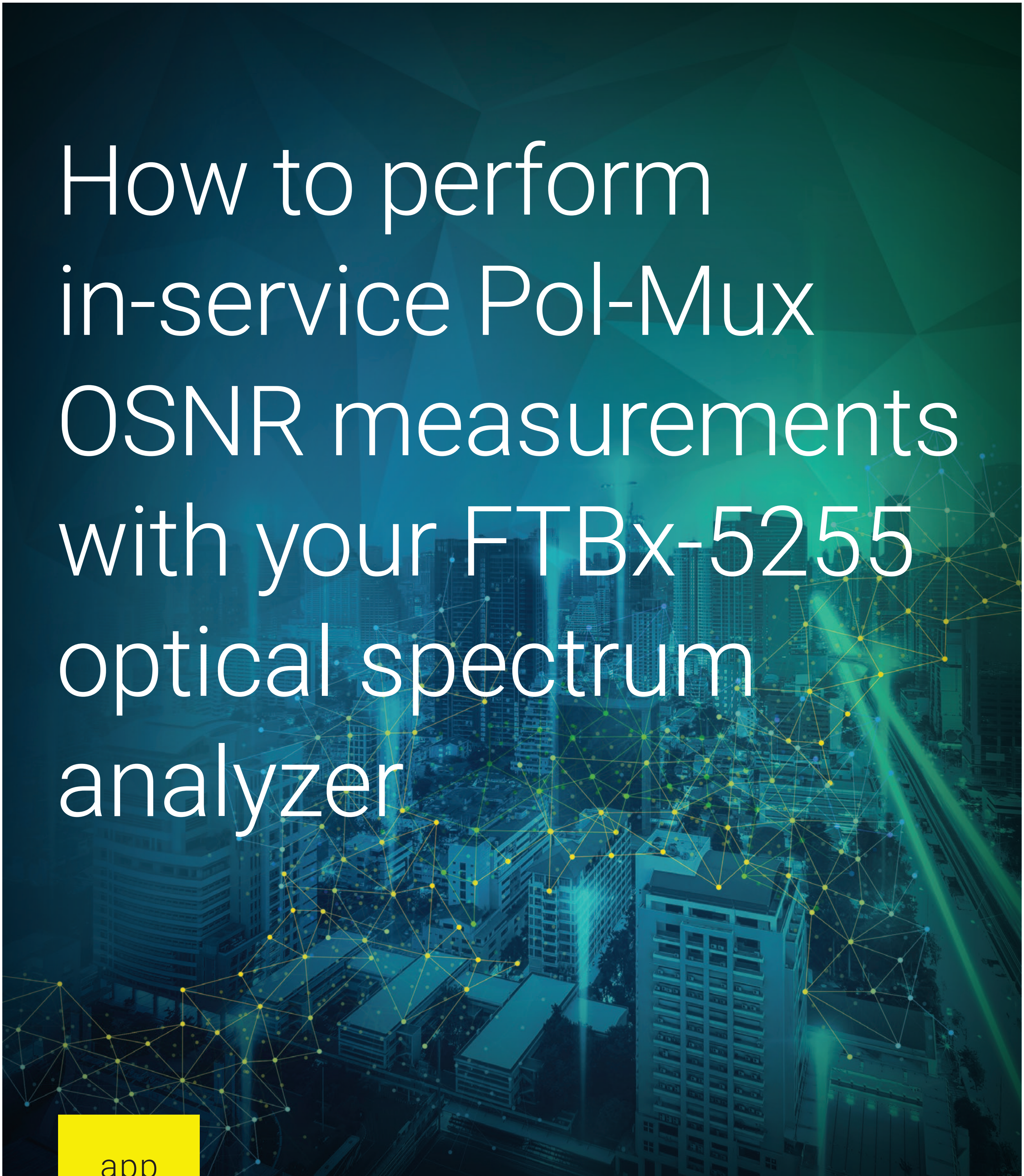
# How to perform in-service Pol-Mux OSNR measurements with your FTBx-5255 optical spectrum analyzer



app note

EXFO

# How to perform in-service Pol-Mux OSNR measurements with your FTBx-5255 optical spectrum analyzer

app note

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## Introduction

Your EXFO FTBx-5255 optical spectrum analyzer (OSA) is a precise instrument that uses a unique approach to perform in-service Pol-Mux optical signal-to-noise ratio (OSNR) measurements. Although the process is relatively simple, in-service Pol-Mux analysis does require knowledge of your network and of the signal spectra it conveys.

This application note provides some background concerning state of the art OSNR measurement methods in today's networks. First, we explain why classical OSNR measurement methods no longer constitute workable solutions. Then, we lay out EXFO's in-service Pol-Mux OSNR method (Figure 1) and explain how it is performed. Finally, we describe the conditions under which reference-based OSNR measurement is sound and how to generate valid reference trace measurements and keep them healthy.

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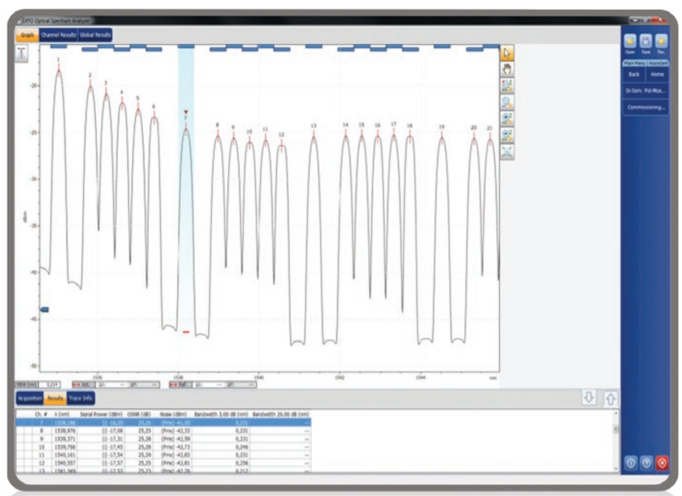


*Figure 1. EXFO's in-service Pol-Mux OSNR*

# Challenges in measuring OSNRs for polarized multiplexed signals on today's networks

## Why IEC and in-band OSNR methods fail in coherent networks

The traditional method of measuring OSNR is defined by the International Electrotechnical Commission (IEC) in the IEC 61280-2-9 standard and is known as the interpolation or out-of-band method (Figure 2).

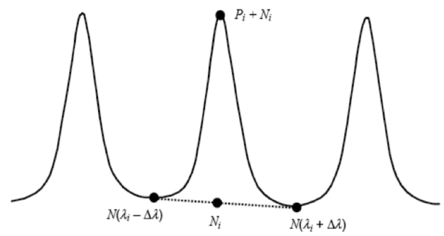



***Figure 2. IEC OSNR method***

The IEC method applied to 40G/100G/200G Pol-Mux signals will lead to an overestimation or underestimation of noise.

This method consists of measuring the noise level at the mid-points between the channel of interest and its two adjacent neighbors—(N(λi-Δλ) and N(λi+Δλ)—then computing the average of the two noise values to obtain $N_i$ (Figure 1), thus performing a linear interpolation. The OSNR can then be calculated by dividing the signal power by this interpolated noise value, after normalization. This method works well for networks up to 10 Gbits/s that don't have any reconfigurable optical add/drop multiplexers (ROADMs). For noncoherent 40 Gbits/s networks or networks that include ROADMs, OSNR approaches relying on polarization analysis were introduced commercially around 2009. These are known as in-band OSNR methods. We will now explore why the IEC 61280-2-9 and the in-band methods fail for Pol-Mux signals.

Figure 3 shows 100G channels that are spaced at 50 GHz, a common spacing in modern networks. Pol-Mux 40G/100G/200G signals are typically a lot wider than 10G, which means that they will overlap with neighboring channels—a phenomenon known as interchannel crosstalk. This means that the midpoint between channels no longer consists solely of noise, but rather of signal plus noise. The IEC method applied to 40G/100G/200G Pol-Mux signals will therefore lead to an overestimation of noise.

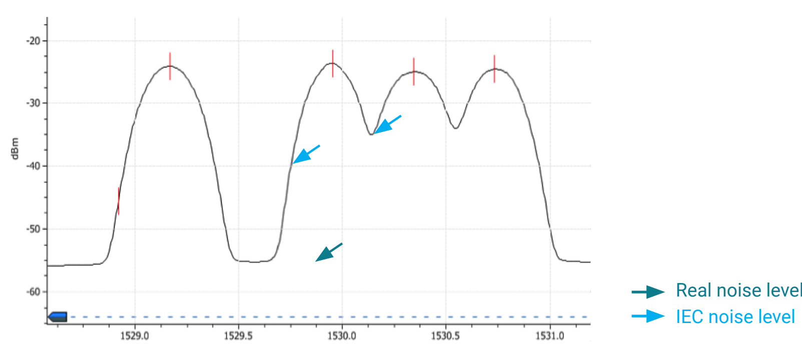



***Figure 3. IEC method fails with dense Pol-Mux 40G/100G signals***

Figure 4 illustrates a 100G signal that has gone through a ROADM, with the green area showing the channel bandwidth. Given that there are filters inside the ROADM, the noise at the midpoint between channels will be carved (or filtered), leading to an underestimation of the noise level if the IEC method is used. Hence, ROADMs also cause the IEC method to fail in coherent networks.

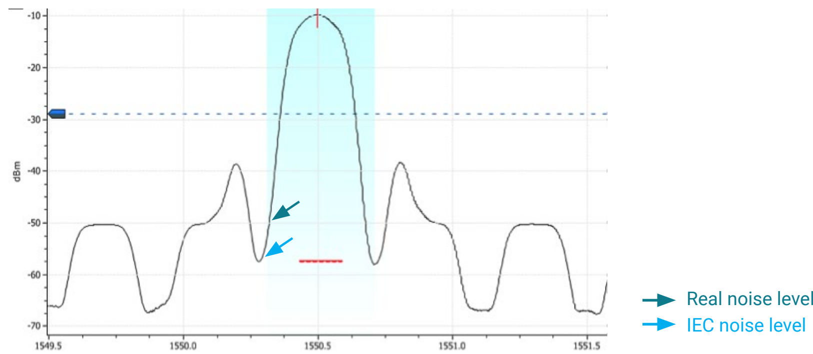



***Figure 4. IEC method fails in ROADM 40G/100G Pol-Mux networks***

The IEC method fails for 40G/100G signals due to the width of the channels and to the presence of ROADMs. What about in-band OSNR? The basic setup of an in-band OSA, shown in Figure 5, consists of a polarization controller followed by a polarization beam splitter. With non-Pol-Mux signals, given the signal is polarized and the noise unpolarized, adjustments to the polarization controller will change the proportion of signal that goes in each of the two branches, SOP-1 and SOP-2. To compute the in-band OSNR, complex algorithms can then be applied to the OSA traces found in branches 1 and 2. Therefore, in-band OSNR methods will work perfectly for single polarization signals like 10G with ROADMs or noncoherent 40G.

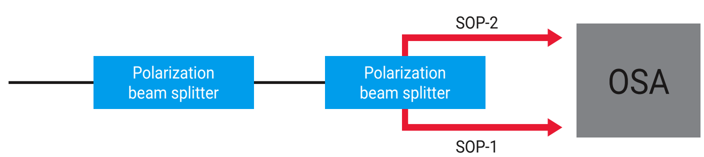



***Figure 5. Polarization-based, in-band OSA setup***

For Pol-Mux signals, in-band approaches like polarization nulling or EXFO's WDM-aware will not work because the signal, which consists of two orthogonal polarizations, appears to be unpolarized. The ITU-T G.697 recommendation regarding such in-band methods is as follows: "For a polarized multiplexed signal, there is a separate signal on each of the two orthogonal polarizations so it is not possible to extinguish the signal using a polarization beam splitter. Hence, it is not possible to use this method of OSNR measurement for these signals."

Since both IEC and in-band methods are inappropriate for OSNR measurements of Pol-Mux 40G/100G signals, a third method called Pol-Mux OSNR is necessary using a Pol-Mux OSA.

## EXFO's in-service Pol-Mux OSNR measurement method

Given the non-suitability of the above methods for in-service Pol-Mux OSNR measurements, we developed a non-intrusive in-band OSNR measurement technique based on spectral analysis that utilizes widely deployed conventional optical spectrum analyzers. The technique is reference-based in that it relies on a detailed spectral comparison of a reference measurement trace against an active measurement trace (the signal of interest). The reference measurement trace may have been acquired some time ago and/or at another location via the available taps (monitor ports) in the transmission system.

For a simple way of looking at things, consider the case where the signal power of the active trace and the reference trace are equal. The optical noise difference between the reference and the active trace can then be calculated directly as:

*Optical noise difference = active measurement trace – reference measurement trace*

Furthermore, when the reference measurement trace is free of noise, for example at the transmitter, then the calculated noise difference allows for direct calculation of the OSNR for the active measurement trace.

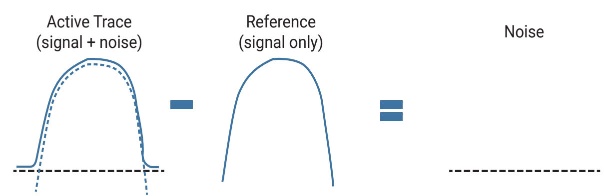



***Figure 6. Reference-based noise measurement***

In general, a normalization step is needed when the power of the active and the reference traces are different.

## Obtaining a noise-free reference measurement trace

In practice, a noise-free reference is only available at the transmitter location. However, it is possible to compute a noise-free reference from any location provided that the OSNR or noise level at this location is known. This can be achieved in **three steps**:

- **Step 1:** compute the noise level of the reference from the OSNR value
- **Step 2:** subtract the reference noise level from the reference spectrum
- **Step 3:** obtain a noise-free reference

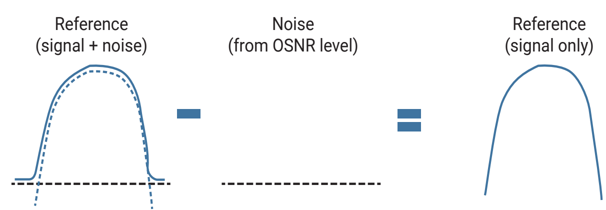



***Figure 7. Computing a noise-free reference***

As we will see below, this provides a valid reference trace as long as the signal shape of the reference is representative of its shape at the OSNR measurement location.

## How to perform an in-service Pol-Mux measurement

This section presents a high-level overview of how to perform an in-service Pol-Mux measurement with the FTBx-5255 OSA. For detailed instructions, please refer to your FTBx-5255 OSA User Guide. The reference-based approach described previously is valid for traces in which signal spectral shapes are highly correlated, for example in successive traces taken at a single location, and traces taken simultaneously at different locations in the system. The following section explains the conditions under which this hypothesis is valid. For the sake of clarity, we will describe how to perform in-service Pol-Mux measurements at a single node.

In-service Pol-Mux analysis is performed in two steps:

- **Step 1:** define one or several reference measurement traces that will be used later to perform multiple in-service Pol-Mux analyses.
- **Step 2:** perform in-service Pol-Mux analysis on one or more active measurement traces in light of the reference measurement traces defined in step 1.

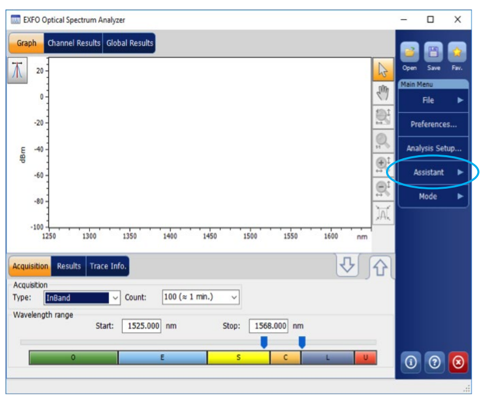
The FTBx-5255 OSA application guides you through both steps using the In-Service Pol-Mux Assistant.

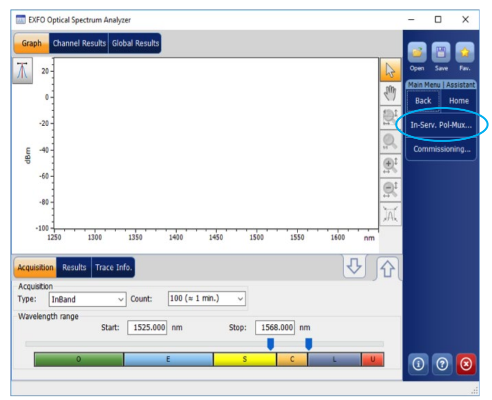
The FTBx-5255 OSA application guides you through the two-step Pol-Mux analysis process using the In-Service Pol-Mux Assistant

## Defining reference measurement traces with the In-Service Pol-Mux Assistant

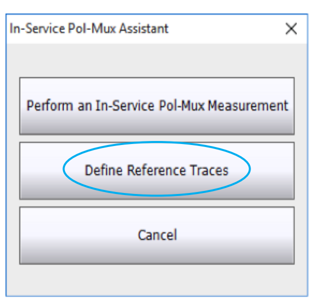
To define reference measurement traces, perform the following steps:

- **Step 1:** open the In-Service Pol-Mux Assistant.



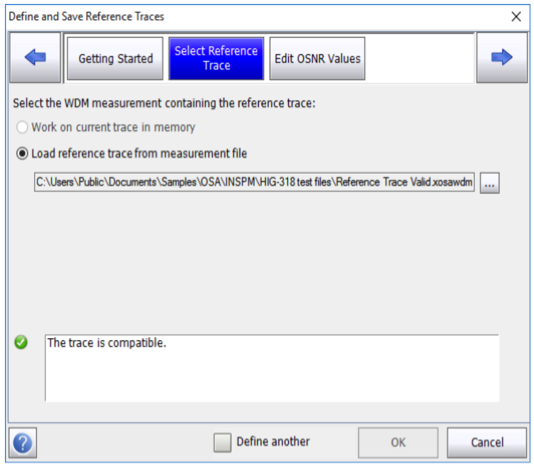




- **Step 2:** select 'Define Reference Traces'.



– **Step 3:** select a measurement trace to define as a reference.




– **Step 4:** for the channels of your choice, you can define OSNR values in the following ways:

a. Edit single values in the Reference OSNR (dB) column or the Reference noise (dBm) column. Both columns are updated once values are entered.

b. Edit multiple reference OSNR values by selecting channels and doing one of the following:

– i. Importing the OSNR values from the measurement trace.

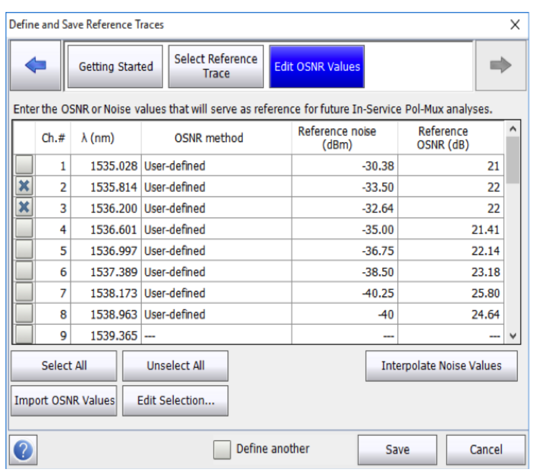
– ii. Selecting 'Edit Selection' and applying an OSNR value for all selected channels.

c. Edit multiple reference noise (dBm) values (and by ricochet reference OSNR values) by doing the following:

– i. Enter two or more reference noise (dBm) values for non-contiguous channels.

– ii. Select 'Interpolate Noise Values'. All the values between the defined boundaries will be linearly interpolated. (This interpolation approach will only be valid if the channels between the boundaries come from the same transmitter location and have traveled along the same path.)

– **Step 5:** save the reference measurement trace.

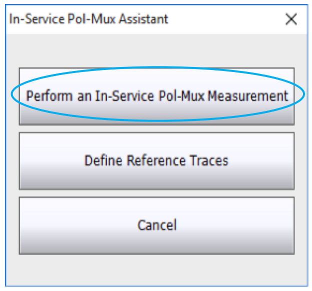


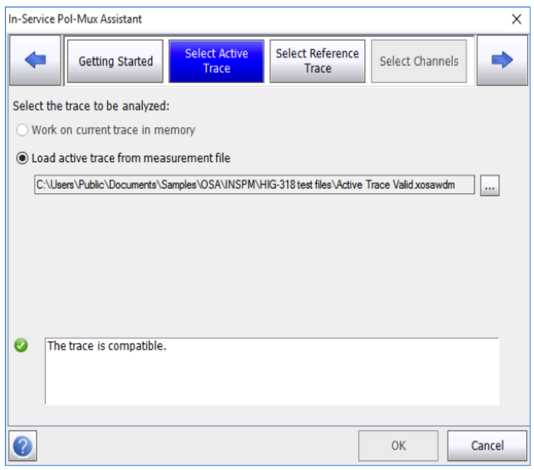
## Performing an in-service Pol-Mux analysis

To perform an in-service Pol-Mux analysis, perform the following steps:

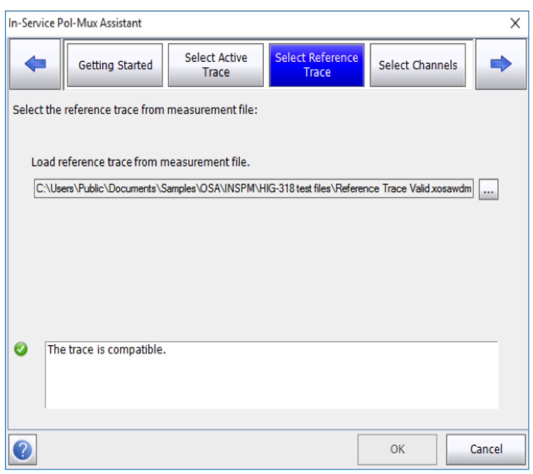
- **Step 1:** open the In-Service Pol-Mux Assistant.
- **Step 2:** select 'Perform an In-Service Pol-Mux Measurement'.




- **Step 3:** select a measurement trace for which an in-service Pol-Mux analysis is required.



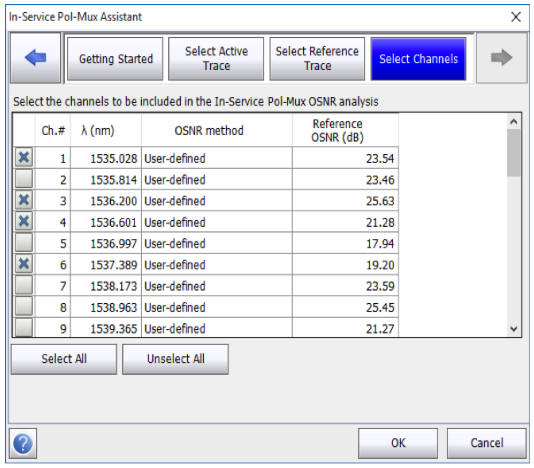

- **Step 4:** select a corresponding reference measurement trace.



– **Step 5:** select the channels for which an in-service Pol-Mux analysis is required and select 'OK'.

(In order to obtain valid OSNR results, only the channels for which the same signal appears in both the active and reference traces should be selected.)




– **Step 6:** view results.

## Reference-based method validity for an in-service Pol-Mux measurement

We mentioned above that EXFO's in-service Pol-Mux measurement method relies on the assumption that reference and active signal shapes are correlated, therefore enabling the calculation of corresponding OSNR values in the active trace measurement. This section explores the conditions under which this hypothesis holds true.

To support our discussion, let's consider a trivial case where two immediately successive measurements are made at a single node within a system. All other things being equal, the two measurements are essentially spectrally identical, i.e., their respective signal and ASE noise levels are identical, and thus their OSNR values, too. One could therefore use the ASE noise levels of the first trace and the signal levels of the second trace to determine the OSNR values and obtain valid results. This is the basis for EXFO's reference-based in-service Pol-Mux measurement.

From here on, let's imagine that our two measurements are each spaced at a different time and location (i.e., different nodes in the system). These two measurements still bear sufficient spectral correlation to enable a reference-based in-service Pol-Mux measurement. However, when spectral correlation decreases due to systemic factors mentioned below, the absolute OSNR value calculation is less precise. Therefore, EXFO recommends that the following essential conditions be met to ensure valid reference measurements when performing in-service Pol-Mux OSNR measurements:

– The reference and active measurement traces come from the same transmitter

– The reference and active measurement traces are obtained either

  – a) at the same location OR

  – b) at two locations between which there are no elements that change the signal's spectral shape, such as filters or ROADMs

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40G/100G/200G OSNR measurements with a Pol-Mux OSA

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- Spectrum variations induced by the transmitter are within an acceptable range (stable transmitter settings)
- Relative central wavelength drift of transmitter or ROADM is within a given range (typically ±1 GHz)
- System topology reconfiguration (e.g., through Flexgrid) should prompt the acquisition of fresh reference measurement traces

Given these considerations, new reference measurement traces should be taken when the following occurs:

- Change of transmitter or excessive variation in transmitter spectrum
- Reconfiguration of ROADM in the light path
- Signal rerouting
- Addition or removal of ROADM
- Significant drift (e.g., > 2GHz) in central wavelength of the transmitter or ROADM

## Conclusion

This application note explained why today's coherent networks cause existing OSNR measurement methods to fail and presented EXFO's reference-based OSNR method to circumvent the difficulties inherent to conventional approaches. We have shown how—and under which conditions—EXFO's breakthrough in-service Pol-Mux OSNR approach can be used to measure OSNR of 100G/200G/400G signals, and how it is now possible for service providers to solve a key challenge they've been facing to reduce network outages.

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