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Measuring In-Band OSNR on Polarization-Multiplexed Signals

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In-Band OSNR Measurement



- **In-Band OSNR measurement**
 - Measure the optical noise within the spectrum of a transmitted optical signal = **in-band noise**
 - Use the polarization nulling technique to suppress the signal and get access to the noise
- **Assumptions**
 - Optical ASE noise from optical amplifiers is **un-polarized** light
 - Laser-based optical transmitters emit **highly polarized** light
 - Conventional 10-Gb/s transmitters generate single polarized signals
 - Signals remain highly polarized during transmission
 - Signal and noise may be distinguished by simple polarization analysis
- **Polarization nulling method**
 - The polarized optical signal is suppressed by an **adjustable pol-filter**
 - Unpolarized ASE noise is not suppressed by polarization filter
 - Spectrum of ASE noise can be measured by polarization filter and OSA
 - In-band OSNR can be determined from the total signal power and the in-band noise spectral density

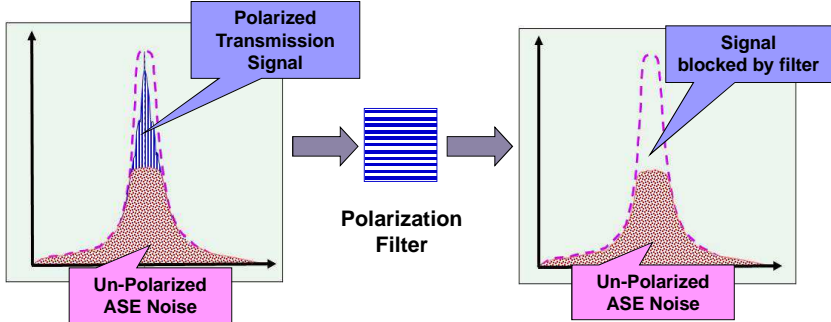
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Principle of In-Band OSNR Measurement



Background:


- ASE noise from the EDFAs is un-polarized light.
- Transmitted signal is highly polarized light.

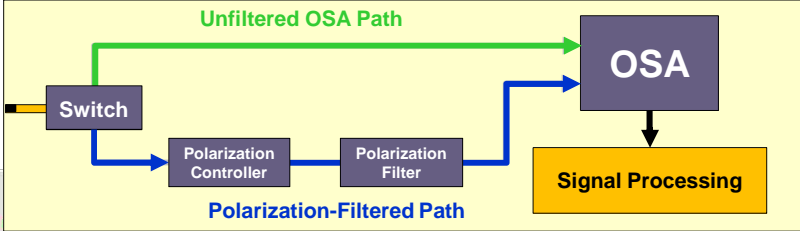
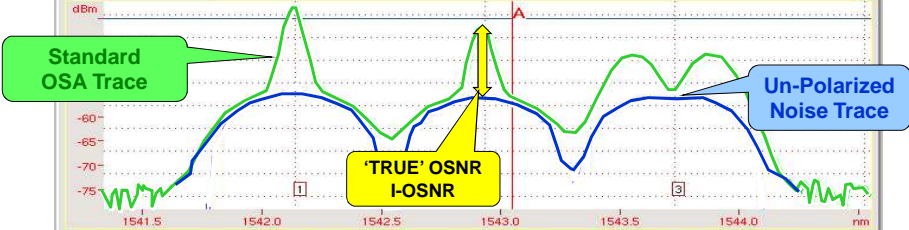


Polarization nulling method:
 A polarization filter is used to suppress the polarized optical transmission signal allowing measurement of the un-polarized ASE noise.
 → This is called in-band noise / in-band OSNR measurement

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JDSU's Polarization-Nulling Technique




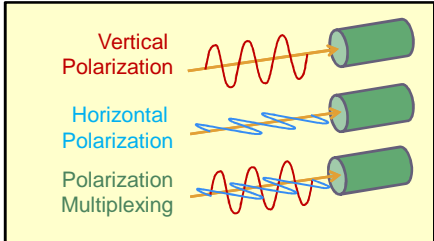
Detect.	Permanent	Splitter: No	Nb: 003/003	Pcomp: -33.51 dBm/ 445.9 nW		
Channel	Wavelen.(nm)	Spacing(nm)	Level(dBm)	Noise(dBm)	I-OSNR(dB)	P/Pcomp(%)
002	1542.830	0.792	-40.34	-53.75	13.40	20.66
003	1543.725	0.795	-40.15	-54.16	14.01	21.62

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Principle of Polarization Multiplexing




- **Polarization Multiplexing**
 - Transmitter emits 2 data streams at the same wavelength but in orthogonal polarization states
 - Polarization multiplexing or polarization-division multiplexing (**PDM**) doubles the spectral efficiency of signal transmission by combining **two orthogonally polarized signals** of the same bit rate into the same wavelength channel.
 - **PDM** is widely used for long-haul 100 Gb/s DWDM transmission (usually in combination with coherent detection).



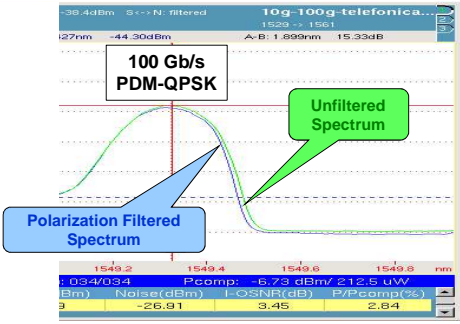
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Polarization Nulling of PDM Signals



- Transmitter emits 2 data streams at the same wavelength but in orthogonal polarization states
 - Polarization multiplexed signals are **not highly polarized**
 - They appear to be un-polarized when measured with a polarization analyzer
- Polarization filter cannot suppress polarization multiplexed signals
- **Un-polarized ASE noise cannot be separated from signal**

Polarization nulling technique does not work with polarization-multiplexed (PDM) signals



	1549.2	1549.4	1549.6	1549.8	nm
034/034					
Power (dBm)					
Noise (dBm)	-26.91		3.45		
OSNR (dB)					
P/Pcomp (%)					

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Single-Polarization vs. Polarization-Multiplexed Signals JDSU

The figure shows an optical spectrum analyzer (OSA) plot. The x-axis represents wavelength in nm, ranging from 1548.4 to 1549.8. The y-axis represents power in dBm, ranging from -50 to -25. Two signals are compared: a Single-Polarization 10 Gb/s NRZ Signal (green line) and a Polarization-Multiplexed 100 Gb/s Signal (red line). For the 10 Gb/s signal, the unfiltered spectrum (top trace) shows a broad peak, while the polarization filtered spectrum (bottom trace) shows a much narrower peak. For the 100 Gb/s signal, the unfiltered spectrum (top trace) shows a broad peak, and the polarization filtered spectrum (bottom trace) also shows a broad peak, indicating that polarization nulling does not work for this signal.

- **Polarization nulling works with single-polarization signals**
 - In-band noise can be extracted from conventional 10 Gb/s NRZ-OOK signal
- **Polarization nulling does not work on polarization-multiplexed signals**
 - In-band noise **cannot** be extracted from 100 Gb/s PM QPSK signal
- **Power, wavelength, and out-of-band OSNR measurements can be performed on polarization-multiplexed signals with conventional OSAs**
 - JDSU OSA-110M/180/500/500R

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Testing 40/100G with an OSA (line side) JDSU

The diagram illustrates a network configuration for testing 40/100G signals. It starts with a transmitter (Tx) connected to a ROADM (Reconfigurable Optical Add-Drop Multiplexer). The signal then passes through another ROADM, which is connected to a Monitor Point. The Monitor Point is connected to an OSA (Optical Spectrum Analyzer), which is connected to a BERT (Bit Error Rate Tester) device. The BERT device is shown with a screen displaying test results.

No difference to legacy 10G testing

- Final acceptance tests during I&M and trouble shooting
- Use system monitor points (Mon) at amplifiers
- Measure power, wavelength and OSNR of each DWDM-channel

Challenges for spectral testing

- New modulation formats create different optical spectra and require new analysis for accurate measurements
- Need for in-band OSNR testing in ROADM networks

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Questions and Answers



- **What are the basic OSA measurements in WDM systems ?**
 - Measure ch-power, ch-wavelength and OSNR (=> OSA-110M, OSA-180/OSA-500)
- **What are the measurement challenges in ROADM networks ?**
 - Standard out-of-band measurements provide wrong OSNR results due to filtered noise distribution induced from ROADM network elements
 - Requires in-band OSNR measurement (use of pol-nulling technique => OSA-500R)
- **What are the measurement challenges in 40G networks ?**
 - Using 40G data transmission at 50GHz channel spacing will create overlapping spectra. Standard out-of-band OSA measurements provide wrong OSNR results.
 - Requires in-band OSNR measurement (use of pol-nulling technique => OSA-500R)
- **What are the measurement challenges in 100G networks ?**
 - 100G networks are using coherent transmission techniques with **polarization multiplexed** (PDM) modulation formats
 - **PDM** signals cannot be analyzed using polarization nulling techniques.
 - It is not possible to perform **in-service in-band** OSNR measurements !
 - **In-band** OSNR measurements can be performed **out-of-service** in a 2 step method:
 1. Perform WDM measurement with all channels activated
 2. Perform WDM channels with 100G PDM channels switched-off
 3. Measure the noise power inside switched-off channels and calculate in-band OSNR
- **What about standard OSA measurements in 100G networks ?**
 - All standard measurements like ch-power, ch-wavelength and **out-of-band** OSNR can be measured with a standard OSA (=> OSA-110M, OSA-180/OSA-500)

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Conclusion



- High Speed Networking (e.g. 43G) is based on new modulation formats creating different spectra than legacy 10G signals
- OSA requires advanced analysis SW to accurately measure the optical channel power, channel wavelength and number of channels.
- Conventional spectrum analyzers do NOT provide accurate results
- All JDSU OSAs (**OSA-110M/180/500/500R**) have advanced analysis-SW to measure systems at 40G, 100G and above
- **ROADM** network topology and the use of high data rates at tight channel spacing (40G@50GHz ch-spg) require new methods to measure the 'TRUE' in-band OSNR.
- **JDSU OSA-500R** provides in-band noise measurement capability to measure the 'TRUE' OSNR in high speed networks with ROADMs or with 40/43G@50GHz ch-spcg
- **In-band OSNR** measurements in 100G networks using polarization multiplexing can only be performed by measuring the noise power when the 100G channel is switched-off



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JDSU's On/Off-OSNR Method



Challenge:

- As it is not possible to use the polarization nulling technique to measure the in-band OSNR in polarization-division multiplexed (PDM) systems, JDSU is using the On/Off-OSNR method

Principle of „On/Off-OSNR Measurement“:

- The On/Off-OSNR method is based on measuring the noise power when the transmission channel is switched-off. This is a 2 step method:
 - Switch-on all channels and perform a standard WDM measurement
 - Take a note of all channel power levels P_{on}
 - Switch-off the channel carrying PDM signals and perform a second measurement
 - The channel power measured at the deactivated channel wavelength will indicate the in-band noise P_{off} = noise power
 - In-band OSNR: $I\text{-OSNR} = P_{on} - P_{off}$ (in dB)

Prepare OSA for First Measurement

Setup:

sweep range: ext. C-band
 resolution: full
 channel detection mode: permanent

ext. C-band
 full
 permanent

1 Acquisition		3 Display	
Sweep	Single	Grid	Manual
Sweep Range	ext. C Band	Alarms	None
Averaging acquisition	No	Wavelength Range	Auto
Resolution	Full	Notes Table	No
Number of sweeps	20	Unit	nm
Long Term	No		
Wait period	5 s		

2 Measurements	
Mode	WDM / OSNR
Channel	Channel detection
OSNR	Signal Threshold: Auto
Splitter CMode	Permanent
Min channel spacing	Std 50 GHz
Min channel elevation	Auto

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Perform First Measurement

Result: WDM table shows all relevant measurement results

NOTE: Channel power is shown in the table as the total channel power = integrated channel power

Example for CH3 (switched on)

P_{3on}: -20.90 dBm

But:

OSNR = 28.04 dB

Channel	Wavelength (nm)	Spacing (nm)	Power (dBm)	Noise (dBm)	OSNR (dB)	P/Pcomp (%)
001	1553.316	---	-21.35	-49.30	27.92	16.56
002	1554.120	0.804	-20.90	-49.14	28.19	18.22
003	1554.919	0.799	-20.90	-48.97	28.04	18.35
004	1555.737	0.818	-22.00	-49.19	27.07	13.94
005	1559.772	4.034	-21.80	-49.48	27.65	14.91
006	1560.589	0.818	-20.99	-49.50	28.49	17.99

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Prepare OSA for Second Measurement

Pre-setup:

- Press “Adopt Grid”
- Set channel detection mode to “Grid”
- Set resolution to “0.1nm”

Note: OSNR is defined as:

$$\text{OSNR} = \frac{\text{total channel power}}{\text{[noise power in 0.1nm bandwidth]}}$$

presets channel grid to identified channels from test 1
 will force the instrument to measure at same channels like test 1

1 Acquisition

Sweep: Single

Sweep Range: ext. C Band

Averaging acquisition: No

Resolution: **0.1 nm**

Number of sweeps: 1000

Long Term: No

Wait period: 5 s

2 Measurements

Mode: WDM / OSNR

Channel: Channel detection

OSNR: Signal Threshold: Auto

Splitter Mode: **Grid**

Min channel spacing: Std 50 GHz

Min channel elevation: Manual

Manual value: 0.5 dB

3 Display

Grid: ITU DWDM

Alarms: None

Wavelength Range: Auto

Notes Table: No

Unit: THz

Test Auto WDM

View Grid

Adopt Grid

Test Auto I-OSNR

Preset multi trace
 Goto “Result” screen

- Select “Advanced” => “Overlay” “Set New Trace” a new empty trace will be generated

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Start Second Measurement

- Switch-off the channel to be measured in in-band OSNR mode (= PDM channel)
- Start measurement: a second trace will be displayed
- Place cursor A to the center of the channel which is switched-off
- On top of the screen the power level at marker A will be shown

This power level = noise power measured with 0.1nm res bandwidth = noise

– Example: CH3 (switched off)
 $P_{\text{3off}} = \text{Noise} = -45.43 \text{ dBm}$

Channel	Wavelen.(nm)	Spacing(nm)	Power(dBm)	Noise(dBm)	OSNR(dB)	P/Pcomp(%)
001	1553.311		-21.03	-49.15	28.09	21.08
002	1554.108	0.797	-20.59	-49.06	28.44	23.29
003	1555.752	1.644	-21.91	-47.36	25.39	17.19
004	1559.793	4.041	-21.75	-49.32	27.53	17.84
005	1560.587	0.794	-21.14	-49.38	28.21	20.55

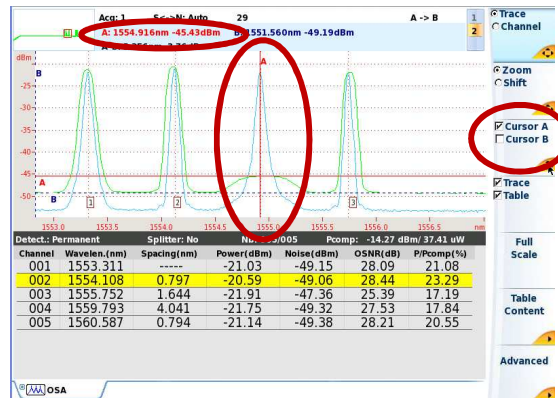
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Calculate In-band OSNR



1. Take power from measurement 1 = P_{3on}
2. Subtract power P_{3off} from measurement 2
In-band OSNR = $P_{3on} - P_{3off}$

Example:
 $I\text{-OSNR} = P_{3on} - P_{3off}$
 $= -20.90 - (-45.43) \text{ dB}$
 $= 24.53 \text{ dB}$

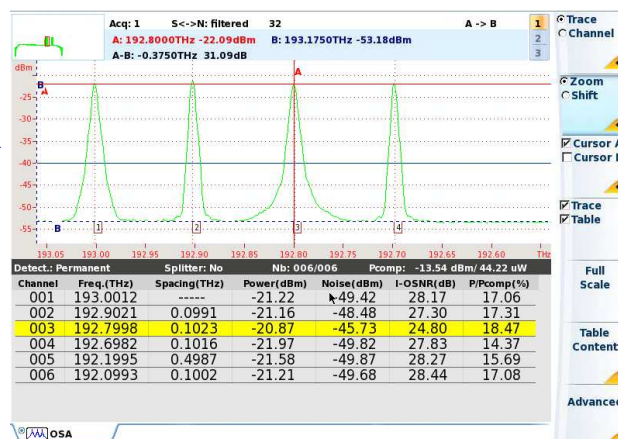


Verification with I-OSNR Measurement



For transmission signals **NOT being modulated with polarization division multiplexing** a verification of the measurement using the OSA-500R in the I-OSNR mode can be used

Example:
 Ch3 analyzed with OSA-500R
I-OSNR = 24.80 dB



Conclusion



- Using the On/Off-OSNR method it is possible to measure the in-band OSNR of all kind of signals including 100G with polarization-division multiplexing (PDM)
- The On/Off-OSNR method is applicable with all kind of JDSU OSAs: OSA-110M/180/500/500R (It is NOT necessary to use the in-band OSA 500R)
- The On/Off-OSNR method requires an intervention into the system as the PDM channel needs to be deactivated
- JDSU is working on an automation to support easy instrument setup and auto calculation of in-band OSNR at 100G systems using polarization-division multiplexing



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