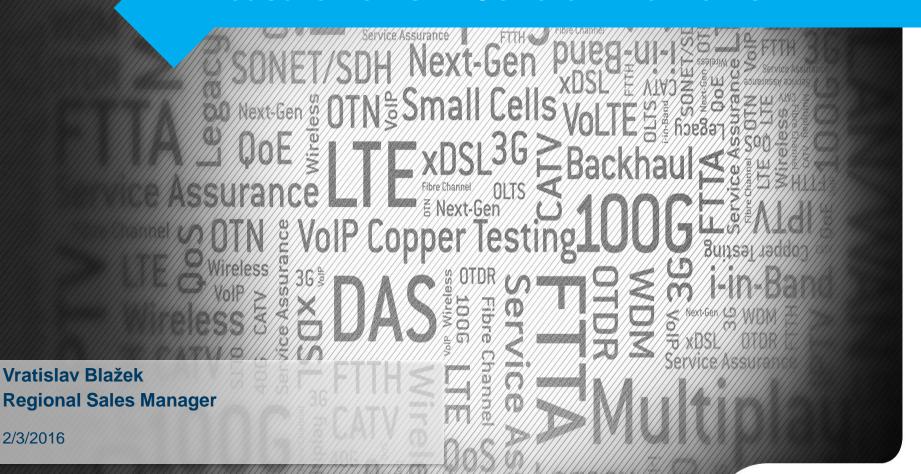
Measurements in Coherent Networks

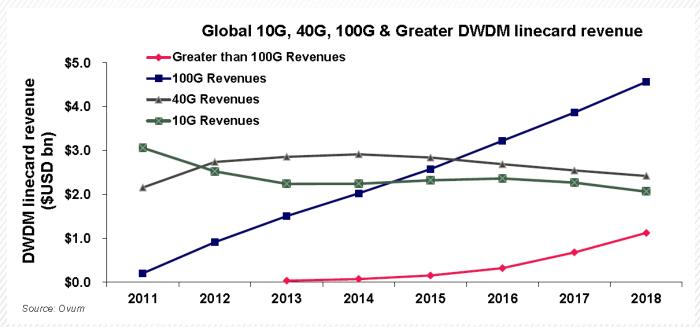


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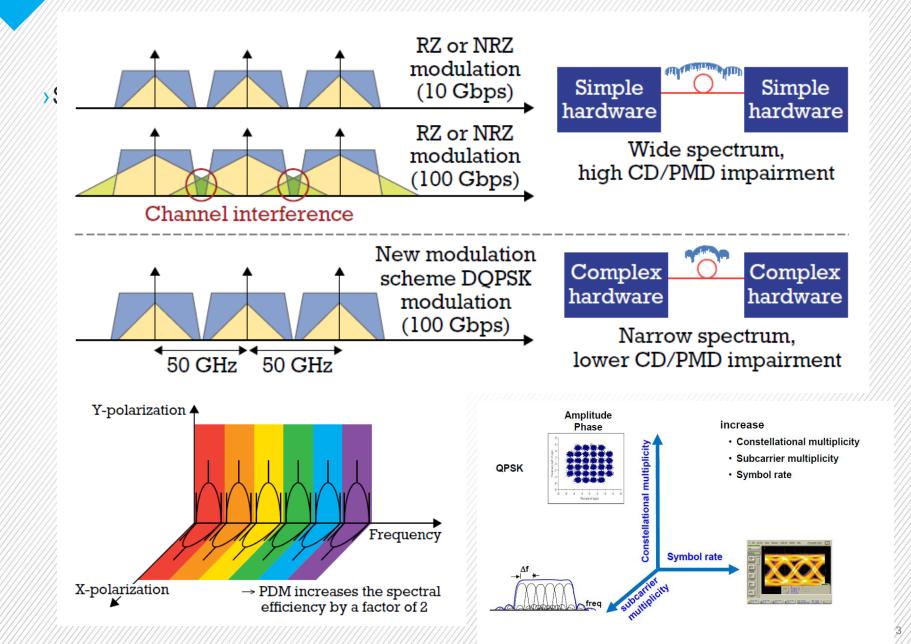
100G Long Term Winner

- Service Providers Port Revenue: 10G Declining, 100G Outgrows 40G
- Service provider high speed ports are predominantly 10G, with some 40G and fewer 100G
- >100G, especially 100GE, will be a long-term winner (2016-2030); expected to contribute well over \$5B in revenue by CY16

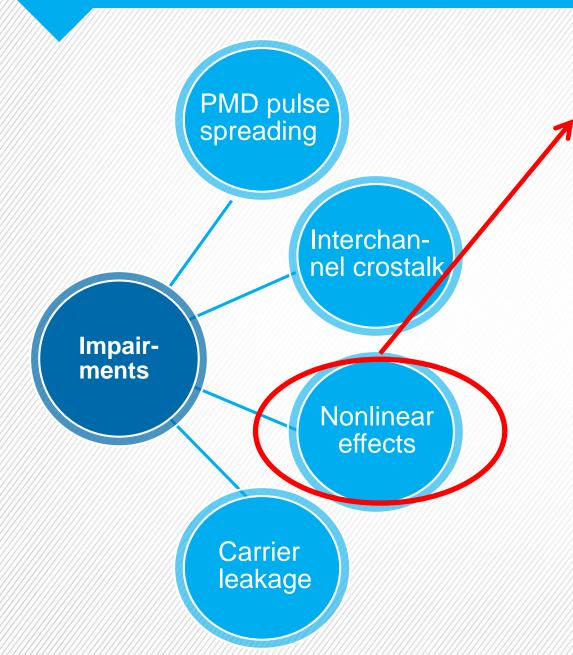


10G and lower rate services are still counting for more than 50% of SPs revenues

Why new modulation schemes

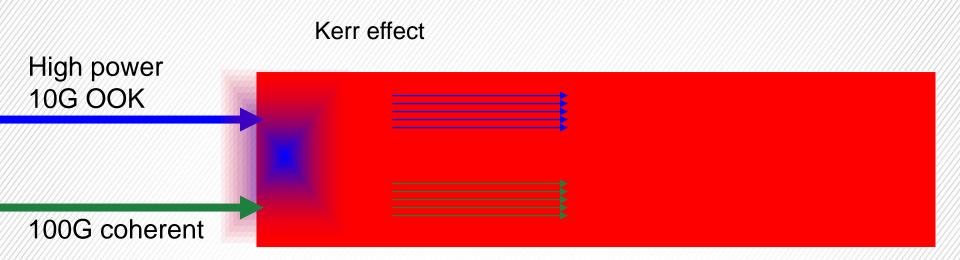


New and "old" impairments in DWDM



- New impairment.
- When signals interact nonlinearly with one another
- i.e. cross-phase modulation: phase variation caused by changing power of neighbour channel
- Typical when mixing 10G with 40G or 100G.

Cross-phase modulation



- 10G OOK: amplitude modulation; 40G coherent: phase modulation
- 10G channel goes on and off, changing locally index of refraction as a function of space and time.
- phase of 100G channel changes. Phase noise! Signal quality degrades.

New impairments: new sources of noise

In summary ...

The old days (10G and below)

$$Noise = N_{ASE}$$

■ Today (40G, 100G)

$$Noise = N_{ASE} + N_{NLE} + N_{x-talk} + N_{CL}$$

ASE: amplified spontaneous emission (noise from amplifiers)

NLE: nonlinear effects like cross-phase modulation

X-talk: cross-talk

CL: carrier leakage

The Solution: WDM Investigator

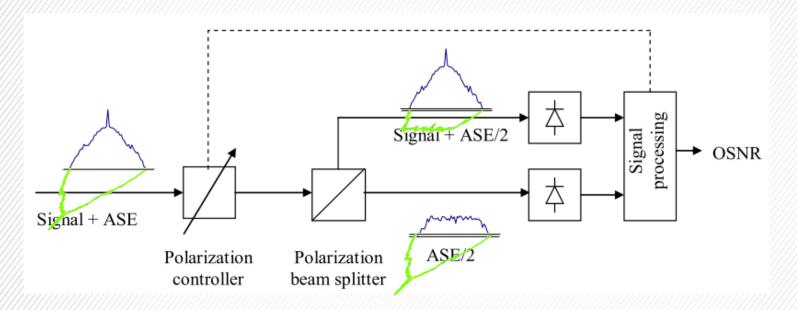


What does an OSA measure



Why in-band fails in coherent networks

ITU-T G.697 Optical Monitoring for DWDM systems



For a polarization 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.

Pol-Mux OSNR: applicable standards

China Communications Standards Association (CCSA)
 YD/T 2147-2010

$$Pol\ Mux\ OSNR = 10\log_{10}\left(\frac{P-N}{n/2}\right)$$

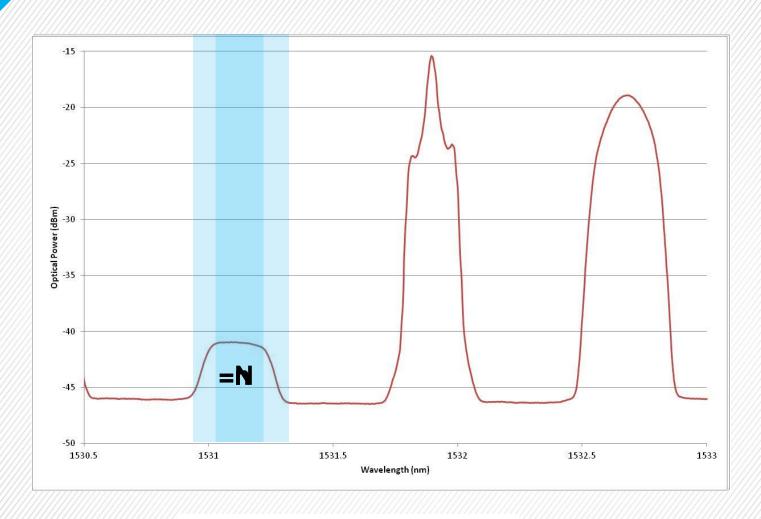
where for a 50 GHz channel

P= integrated power (Signal + Noise) over the 0.4 nm channel bandwidth

N= integrated power (Noise) over 0.4 nm bandwidth

n = integrated power (Noise) inside 0.2 nm, then normalised to 0.1nm

CCSA: Turn On/Turn Off Method



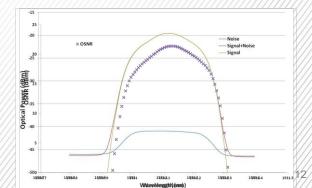
$$Pol\ Mux\ OSNR = 10\log_{10}\left(\frac{P-N}{n/2}\right)$$

Pol-Mux OSNR: applicable standards

- IEC 61282-12
- OSNR = log(R),

$$R = \frac{1}{B_r} \int_{\lambda_1}^{\lambda_2} \frac{s(\lambda)}{\rho(\lambda)} d\lambda$$

- s(λ): time-averaged signal spectral power density, not including ASE, expressed in W/nm;
- ρ(λ): ASE spectral power density, independent of polarization, expressed in W/nm;
- Br: reference bandwidth expressed in nm (usually 0.1 nm)
- λ_1 to λ_2 : signal spectral range.



Standards Summary

Turn On, Turn Off Method

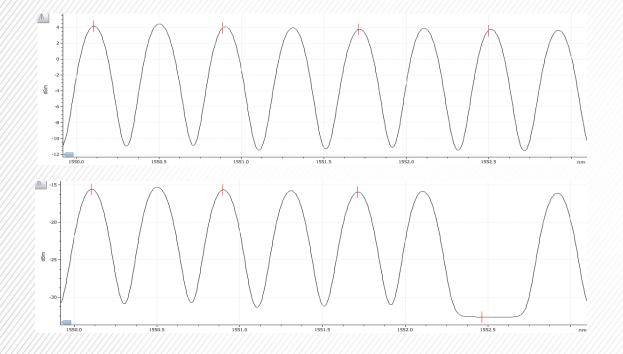
- Easy to do (at commissioning)
- Results dependant on noise bandwidth used (requires consistency)

IEC-61282-12

- Overcome dependency of noise bandwidth
- More complex to implement

Pol-Mux OSA: Commissioning Assistant

- Involves taking traces during commissioning by turning off channels
- -Requires n+1 traces (n= number of channels)



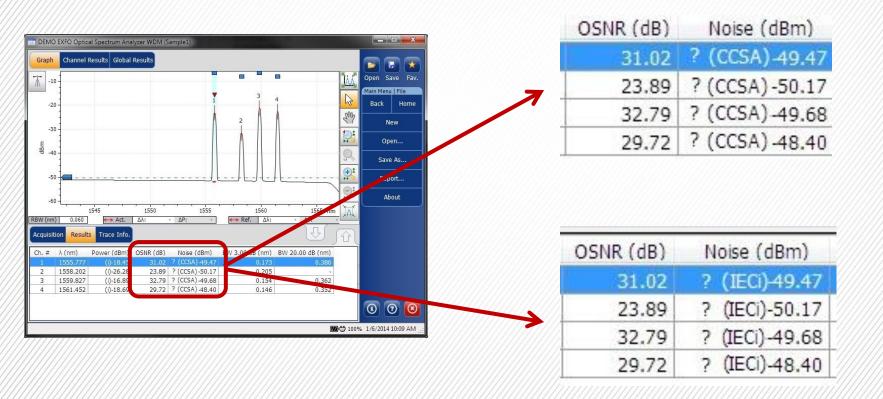
All channels on

Trace with one channel turned off

-Use 'Tool' on OSA or PC to calculate OSNR

Comm. Assistant standards compliance

- China Communications Standards Association (CCSA)
 YD/T 2147-2010
- IEC 61282-12 (IECi) (under revision)



Commissioning Assistant vs manual method

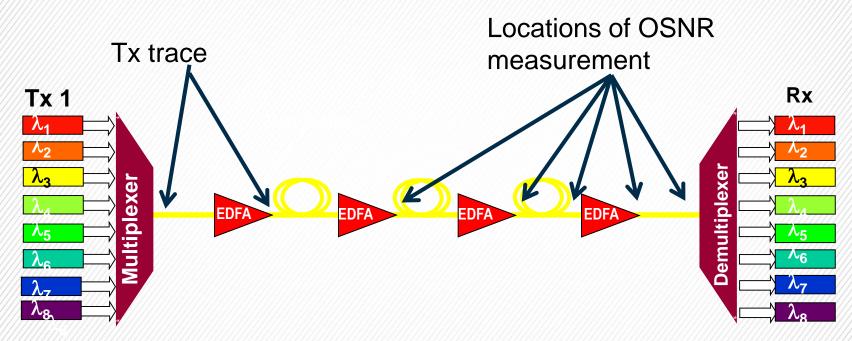
Same acquisition procedure as that of Commissioning Assistant but analysis is different.

Commissioning Assistant benefits:

- Standards Compliance
- Saves time
- Reduce human error
- Facilitates reporting
- Independent third-party solution
- Vendor agnostic: works on all systems

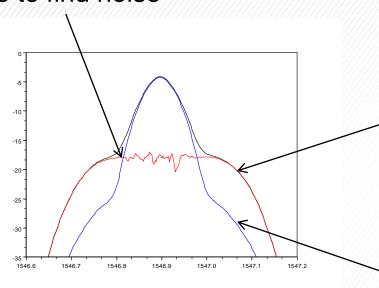
Tx trace method: Overview

- Requires 2 traces. 1 from Tx and 1 from Rx
- Works via taps (monitor ports).
- Use reference-acquired shape to find noise contribution.



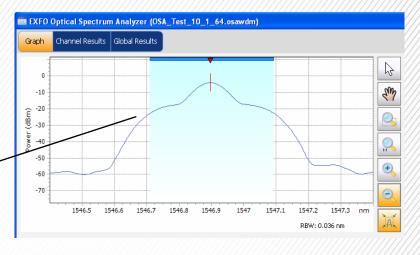
Tx trace method: Overview

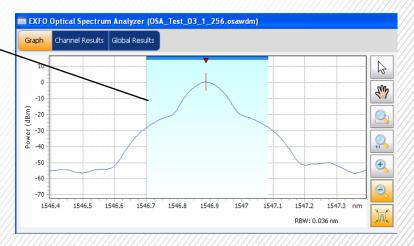
 Use Tx trace measurement as signal shape to find noise





Receiver





Tx Reference

From 10 to 40 to 100G in the Field

Going faster means more pressure on the network. Or does it...?

Speed	Modulation	OSNR	CD	PMD
10Gbps	NRZ - Traditional On- Off Keying	Traditional OSNR (IEC)	Typically around 1100 ps/nm	Typically around 10ps (average PMD)
40Gbps	OOK, DPSK or DQPSK (non coherent)	Requires In-Band, IEC Fails	Typically around 250 ps/nm	Typically below 10ps (average PMD)
40Gbps	DP-QPSK (Coherent)	Requires Pol-Mux ready In-Band (not yet available?)	60.000ps/nm, but likes residual CD	Typically above 30ps, but sensitive to instantenous DGD
100Gbps	DP-QPSK (Coherent)	Requires Pol-Mux ready In-Band (not yet available?)	20'-40.000ps/nm, but likes residual CD	Typically above 20ps, but sensitive to instantenous DGD

The testing needs remain, but for different reasons

THANK YOU

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