Testing optical systems in coherent era,

Monitoring fronthaul physical layer and RF spectrum

Vratislav Blazek

Regional Sales Manager

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teledatanet experience innovation

EXFO

We are the global network test, data and analytics experts.

90%+

of leading service providers choose us

1500+

employees in 25 countries and clients in 120 countries

30+

years of leadership

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Intelligence

Fiber

High speed

Cloud

5G, IoT, NFV

Analytics

Partnering with you to make your whole network smarter. Our test orchestration and real-time 3D analytics solutions help you adapt, transform, accelerate and excel.

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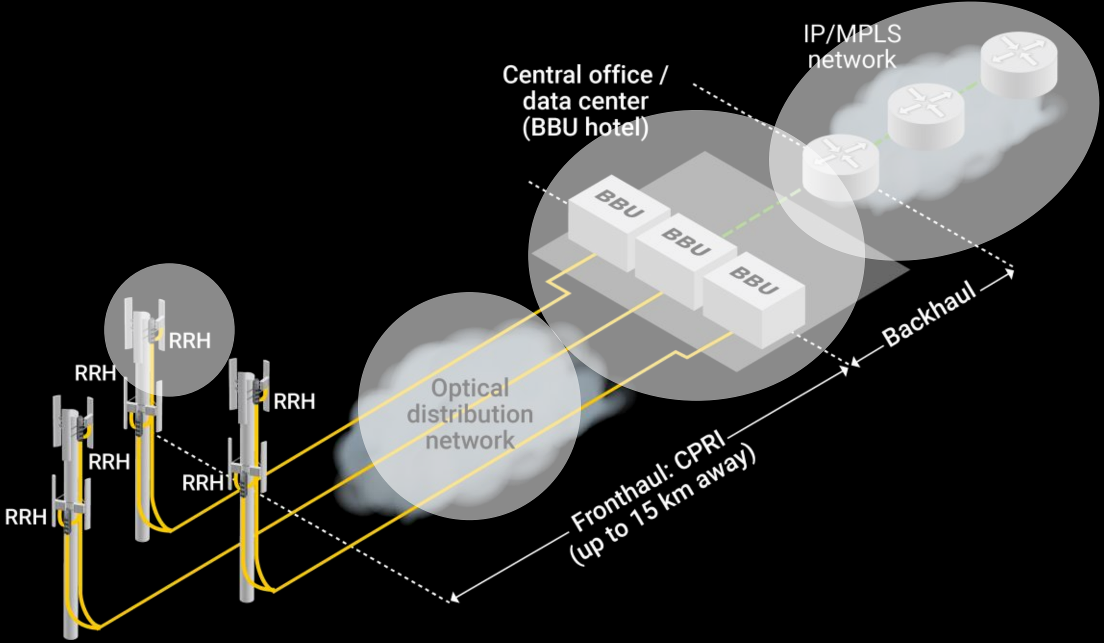
Fronthaul remote access & monitoring test solution

Problems

Resources

Efficiency

Today … problems faced by MNOs



… at the end, it is about **cost** reduction, **QoE** improvement and reducing **churn**

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Mobile Radio Interferences

TV broadcast signals

Power lines

WiFi devices

Lightening

Arc welding

Street lamps

What if . . .

Clear & real-time visibility

High-resolution RF spectrum

Fronthaul fiber monitoring

Remote access & monitoring

Powering ahead with SkyRAN!

Optical switches

iOLM/OTDR modules

RF spectrum modules

MODULAR = FLEXIBLE

Industry's best real-time, high-resolution RF Spectrum Analysis over CPRI

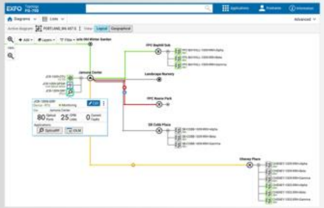
- ✓ Detect any interferer: Transient, sweeping & PIM
- ✓ If there is any RF interference, you will see it with SkyRAN

Fiber Monitoring

- ✓ iOLM : Best in Class OTDR Solution
- ✓ On-Demand & Monitoring Mode

Network Visibility

- ✓ Local Area / City / Sub Market / Market / Territory / National



Actionable Analytics

- ✓ PIM Levels & Trending
- ✓ RSSI / Noise Density Levels & Trending
- ✓ SFP RX Power Trending

KEY FEATURES


EXFO SkyRAN
Power Blazer
8870
RJ45
SFP+
RJ48C
BNC
ACTIVE
From Macro cell sites (1x12, 1x18 and 2x12)
SCALABLE

For C-RAN hubs / BBU hotel:
external optical switch option scalable to 1000s of ports

SCALABLE

Remote access

Now you can troubleshoot from your desk!

Reduce unnecessary travel time to remote cell sites by over 50%

Real-time high resolution spectrum, all from your desk

- ✓ SkyRAN enables 24/7 fiber network monitoring to **pinpoint the exact locations** of fiber-related issues, such as fiber cuts, and when they are resolved.
- ✓ SkyRAN delivers real-time visibility into the mobile spectrum for proactive detection and quick resolution of RF interference and PIM issues.

Remote monitoring
24/7 auto-detection

Fiber Related Issues

RF Interference and PIM

C-RAN operation & maintenance

Reduce operational costs

Time savings

Improve end-user experience

Monitoring from the CRAN hotel

Remote access

OSS integration

RF interference / PIM & OTDR

24x7 Automatic detection

FH/BH Analytics

Enable E2E Network Slicing

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PIM level & RF noise
RRH optical Tx & backhaul
EXFO Xtract
Fronthaul
Backhaul
EXFO

What is coherent detection?

We call “Coherent detection” the reading of the signal phase using a local oscillator at the receiver stage.

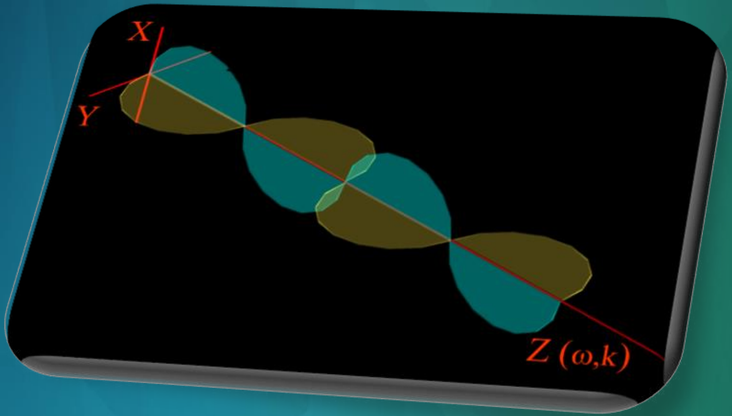
It is also called heterodyne detection.

System vendors sales speetch

There is no need to worry about CD and PMD when deploying 100G and above thanks to the Coherent technology.

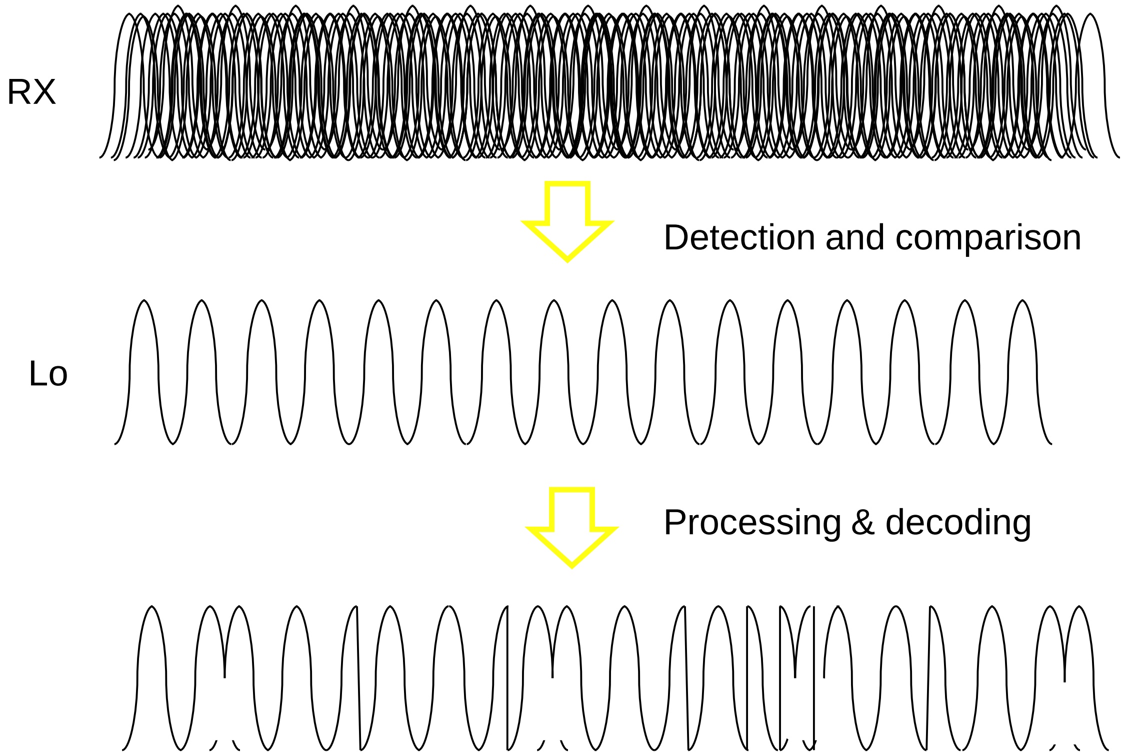
Direct detection versus Coherent

Direct detection : amplitude of the electric field $|E|^2$



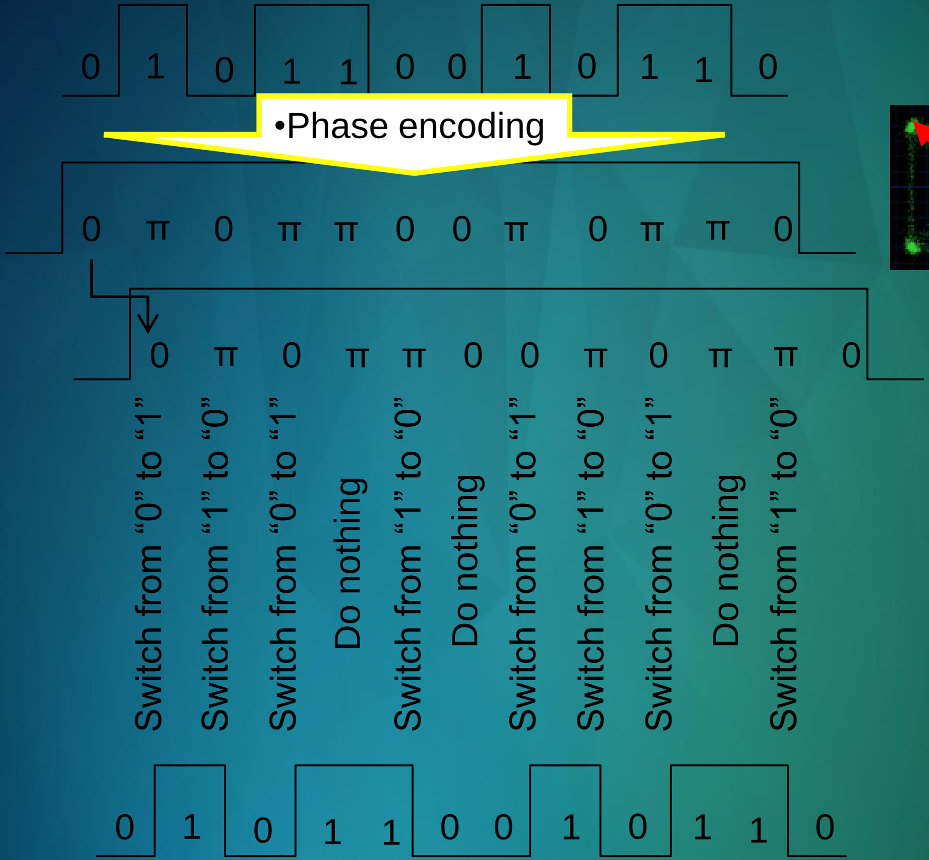
Coherent detection: electric field vector $\vec{E}$

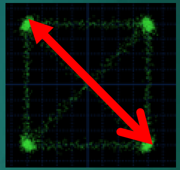
Coherent detection



We can only compensate for effects that are predictable.

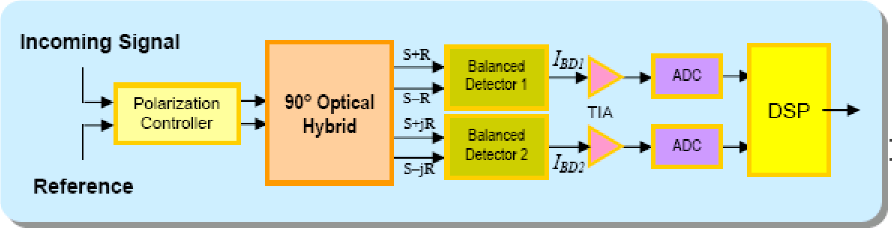
Differential Detection





Coherent detection

What are the promises of Coherent detection:

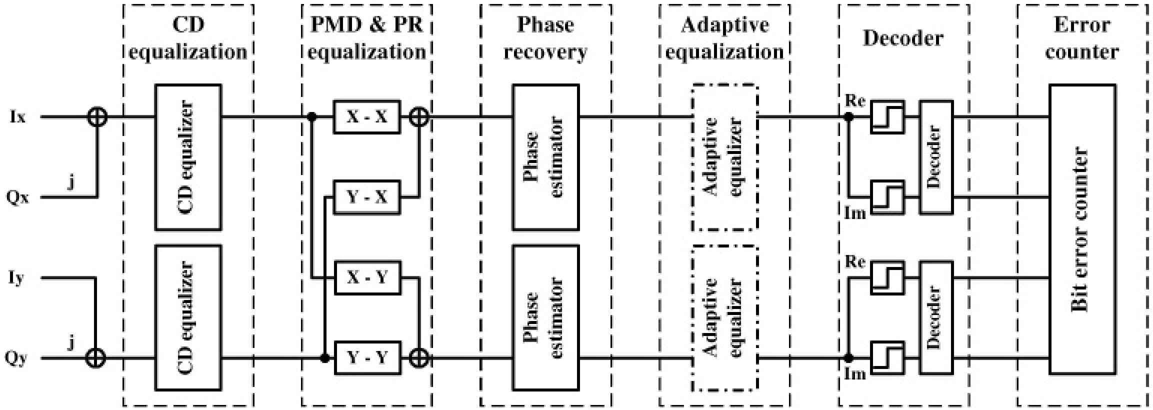
With the appropriate d 

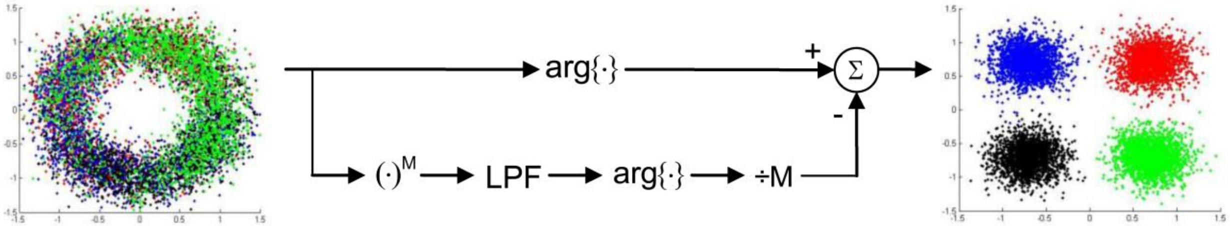
or linear effects such as CD and PMD

Limits:

- Noise (2.0)
- Non Linear effect (4WM, SPM, XPM),
- Polarization Hole burning
- Cross talk
- channel leakage

Digital processing





CD Post compensation using Digital Infinite impulse response (IIR) filter

Dispersion can be approximately considered as a linear operation. So it can be compensated with a linear filter that mimics the inverse chromatic dispersion response.

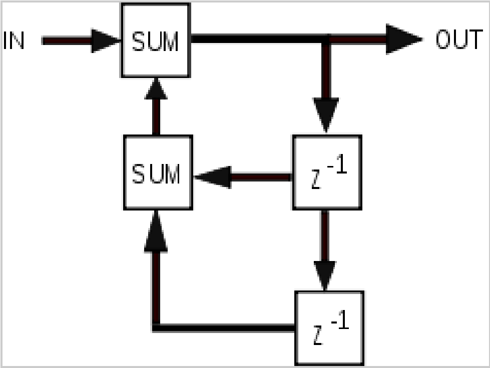
Transfer function derivation [edit]

Digital filters are often described and implemented in terms of the difference equation that defines how the output signal is related to the input signal:

$$y[n] = \frac{1}{a_0}(b_0 x[n] + b_1 x[n-1] + \cdots + b_P x[n-P] - a_1 y[n-1] - a_2 y[n-2] - \cdots - a_Q y[n-Q])$$

where:

- P is the feedforward filter order
- b_i are the feedforward filter coefficients
- Q is the feedback filter order
- a_i are the feedback filter coefficients
- $x[n]$ is the input signal
- $y[n]$ is the output signal.



Simple IIR filter block diagram

PMD compensation in coherent systems

As per Chromatic dispersion, PMD could be compensated by applying a opposite transfer function from a PMD compensator algorithm.

The problem is the complexity of such an algorithm….and the fact that it could change fast…. (up to 10khz…)

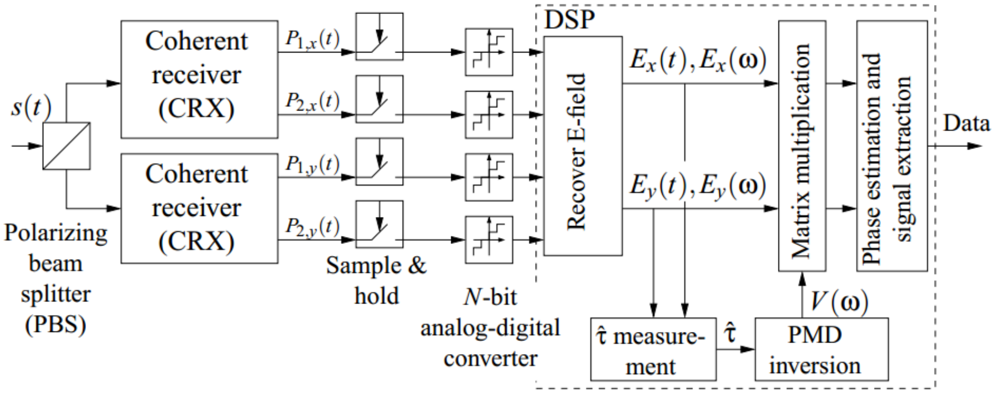
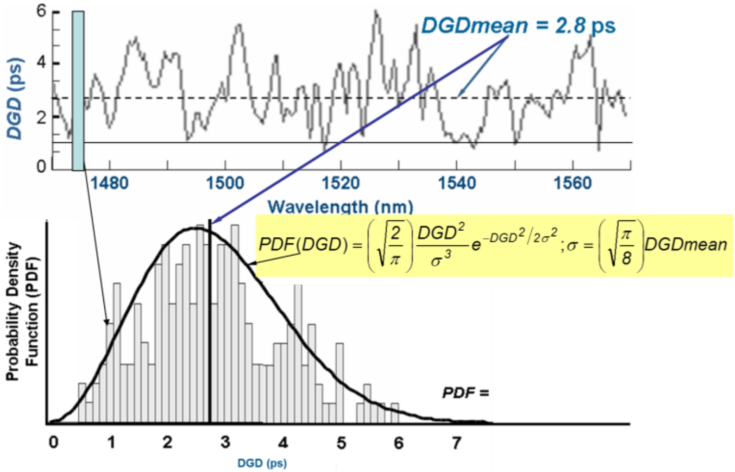
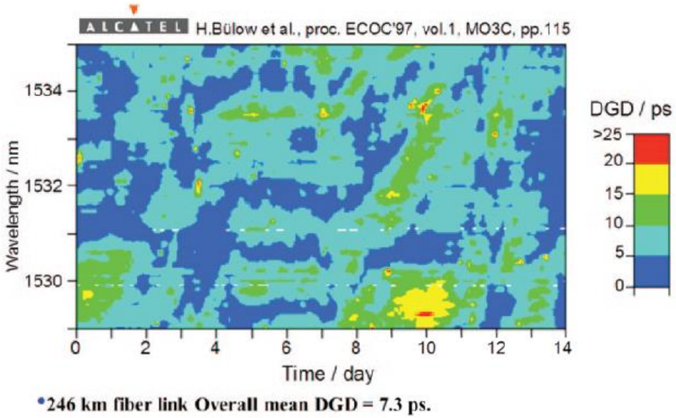


Fig. 1: Coherent receiver with sampling and digital signal processing for PMD compensation. Two CRX are shown to refer to the results of [1] - one CRX can be saved by correct alignment of the local oscillator and placing the PBS behind the CRX.

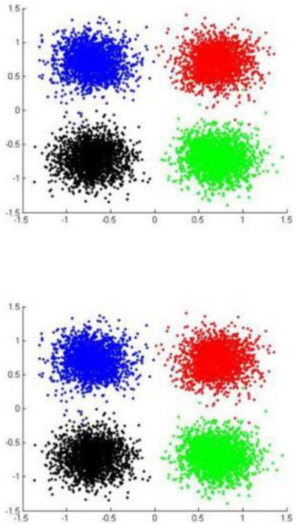
PMD tolerance: Maximum DGD delay

- For the upper limit of CD it doesn't really matter as most of the system could handle a lot of ps/nm!
- For PMD it is a different beast, the best systems will claim to handle hundreds of ps and usually they do… but what they have different hardware versions with different grades of post compensation capabilities.
- They give the spec as DGD MAX not PMD could be 4 times higher…

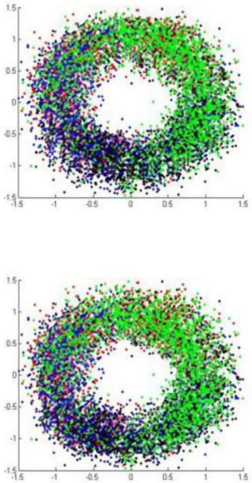




So what will happen if DGD exceed the ability of the algorythm…



Sync loss



For several minute$$$$$$

The Solution: WDM Investigator

Advantages of WDM Investigator

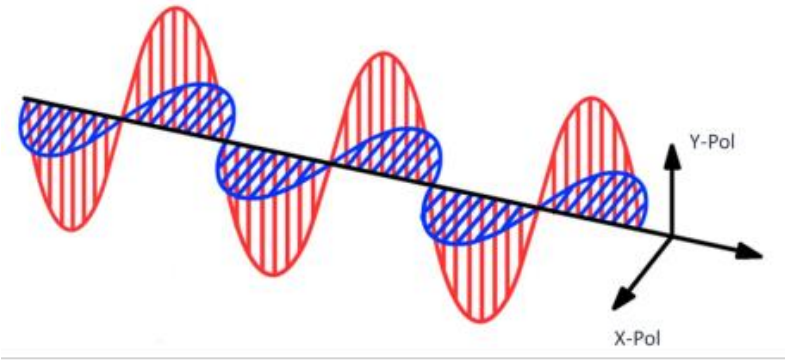
Reduce troubleshooting time and OPEX with unique visibility in WDM network impairments

Provides never seen before assessment of crosstalk, nonlinear effects, carrier leakage

Gives quick (< 5 min) assessment of PMD per channel

Why in-band OSNR method fails in coherent networks

- Coherent signals feature polarization multiplexing: signal along X and Y polarizations at same wavelength.
- E.g., DP-QPSK: dual polarization quadrature phase shift keying.
- In-band methods assume signal is polarized, noise is unpolarized.
- In-band OSNR do not work because signal looks unpolarized (two orthogonal pol's).
  - EXFO's WDM-aware does not work
  - pol. nulling does not work



Pol-Mux OSNR standards

- IEC 61282-12 (adopted in February 2016)

- OSNR = 10log(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;
- B_r: reference bandwidth expressed in nm (usually 0.1 nm)
- λ_1 to λ_2: signal spectral range.

Pol-Mux OSNR standards

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

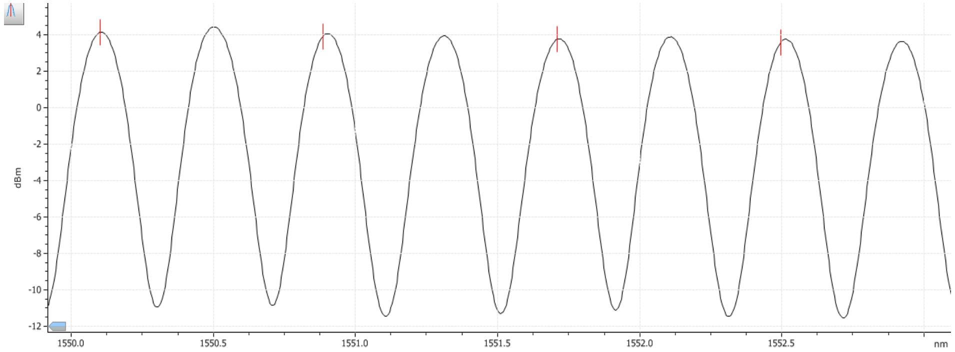
$$Pol\ Mux\ OSNR = 10\log_{10}\left(\frac{P-N}{n/2}\right)$$

where for a 50 GHz channel

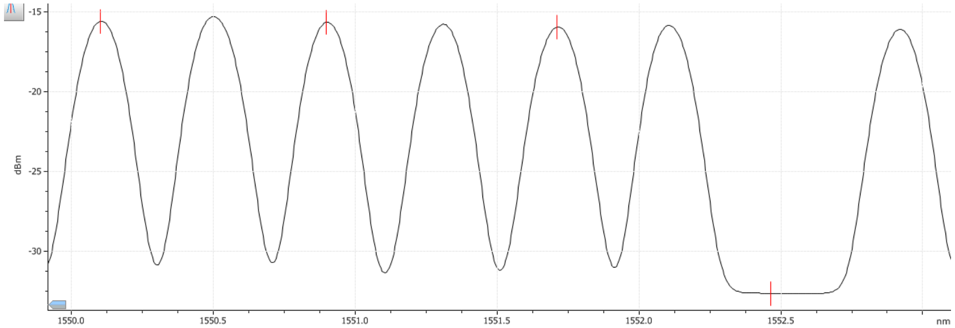
- **P**= integrated power (Signal + Noise) over the 0.4 nm channel bandwidth
- **N**= integrated power (Noise) over 0.4 nm bandwidth
- **n** = integrated power (Noise) inside 0.2 nm, then normalised to 0.1nm

Pol-Mux OSA: commissioning assistant

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

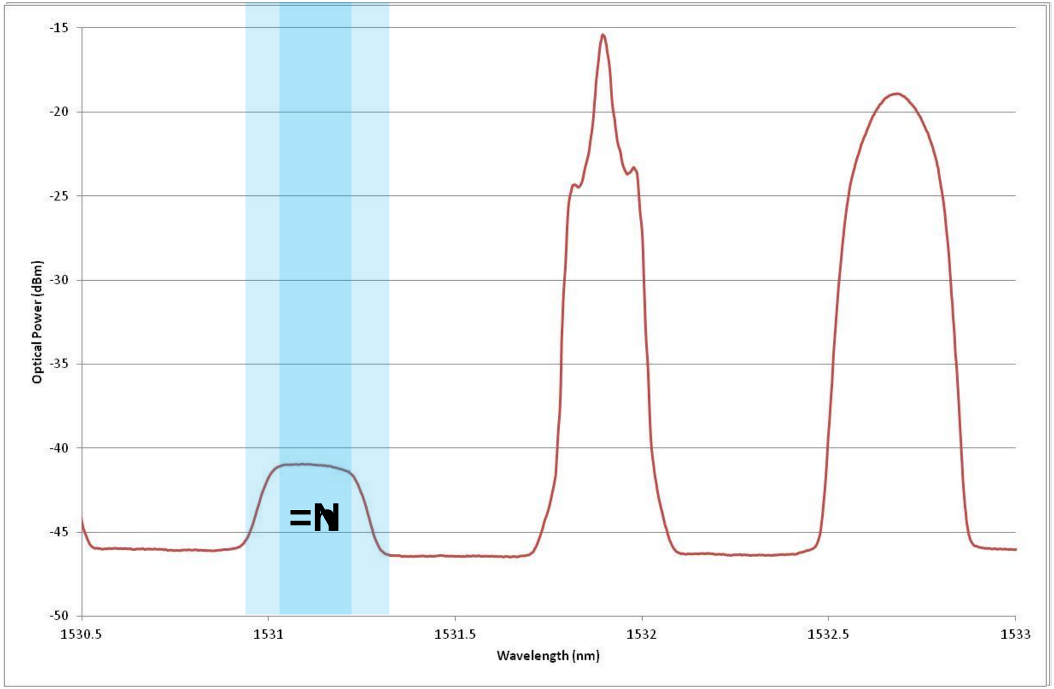


All channels on



Trace with one channel turned off

CCSA standard for Pol-Mux OSNR



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

OSNR stds don’t work on in **live** coherent networks

- Both the CCSA and the IEC 61282-12 standards require turning off channels
- EXFO’s commissioning assistant is perfect for out of service Pol-Mux OSNR measurements at turn-up
- Pol-Mux OSNR method on live coherent networks must be non-intrusive and ideally involve OSA measurements via monitor ports (taps)
- In-service Pol-Mux OSNR comes in!

EXFO’s In-Service Pol-Mux OSNR Method

Benefits of OSNR Testing

- Increase network uptime via preventive maintenance
- Reduce troubleshooting time for noise issues and pinpoint defective ROADMs/amplifers
- Assess upgradability potential of 100G networks to 200G/400G (QPSK to 16-QAM, from 13-15 dB OSNR threshold at Rx to 18-20 dB threshold at Rx)

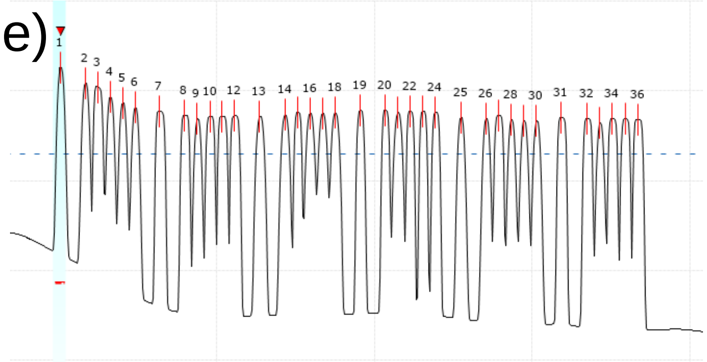
In-Service Pol-Mux OSNR Method

- Method:
  1. Take a first measurement (reference)
  2. Take a second measurement (active trace)
  3. Calculate OSNR of active trace from the 2 measurements

Reference + Active measurement = OSNR

What’s a reference?

- A reference contains two elements:
  1. A spectrum (e.g. an EXFO OSA file)



  2. Knowledge of the Pol-Mux OSNR values of the channels under analysis
     - Pol-Mux OSNR values can either be
       a) contained in OSA file (e.g. using commissionning assistant)
       OR b) known from other source and input manually in the OSA file

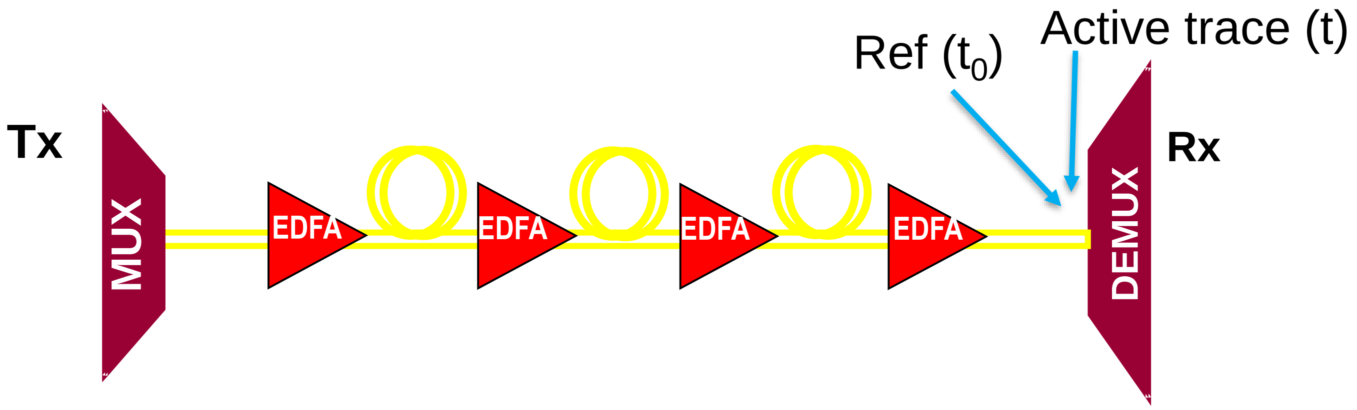
INSPM Method: 2 types of references

- Location Difference Reference (LDREF)
  - Measurements are made at different locations at the ~ same time
  - Measure reference at location 1 (e.g. Tx)
  - Measure at location 2 (e.g. Rx or after N-spans)
  - Calculate OSNR of active trace from the two measurements

- Time Difference Reference (TDREF)
  - Measurements are made at the same location (e.g. Rx) at different time
  - Measure reference at commissioning (using commissioning assistant or other)
  - Measure "later"
  - Calculate OSNR of active trace from the two traces

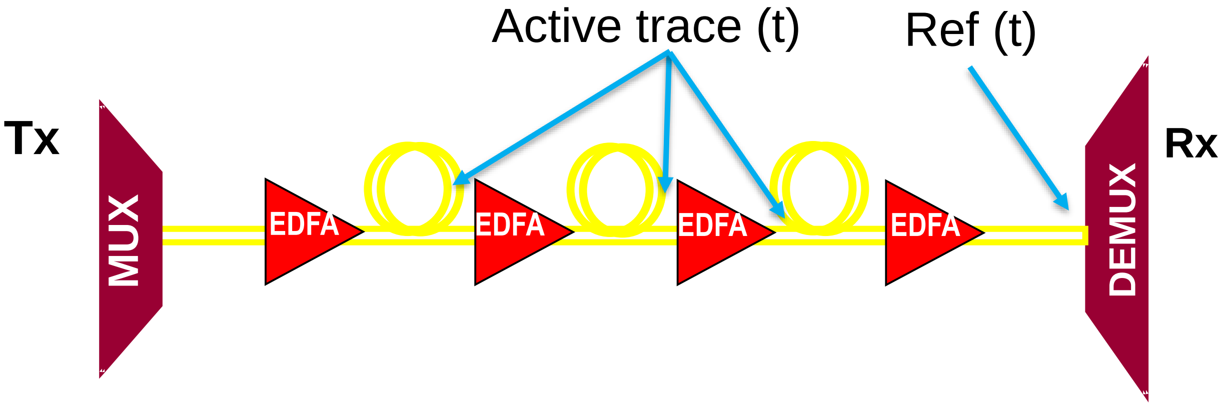
Common use case #1: maintenance at Rx

- Service provider performed commissioning assistant at turn-up at Rx.
- He can also have saved a spectrum + he knows the Pol-Mux OSNR values.
- This is his reference.
- He then performs a measurement (active trace) at Rx on live network at later time and can use INSPM tool applying TD-REF method.



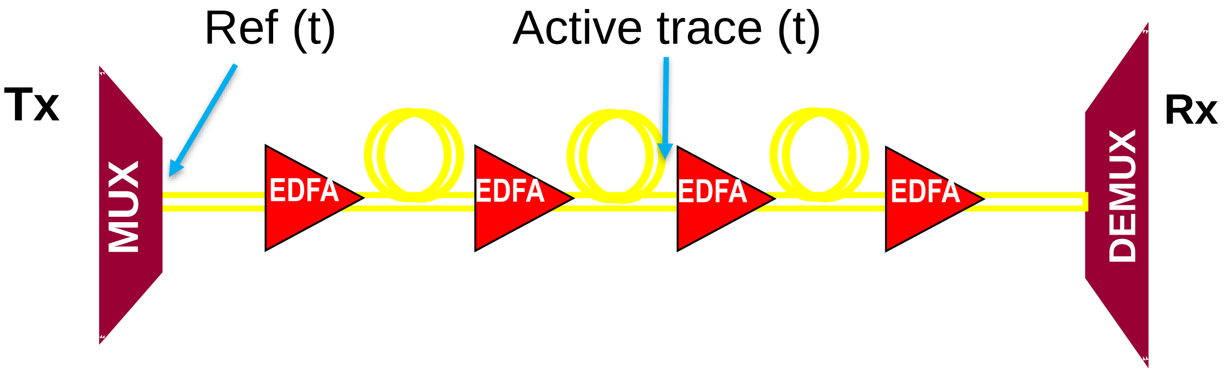
Common use case #2: troubleshooting from Rx

- Service provider just completed use case #1 and finds low Pol-Mux OSNR value at Rx. He wants to identify defective amplifier.
- Active trace from use case #1, at Rx, becomes the reference.
- He then performs a measurement (active trace) at any other location on live network and can use INSPM tool applying LD-REF method.

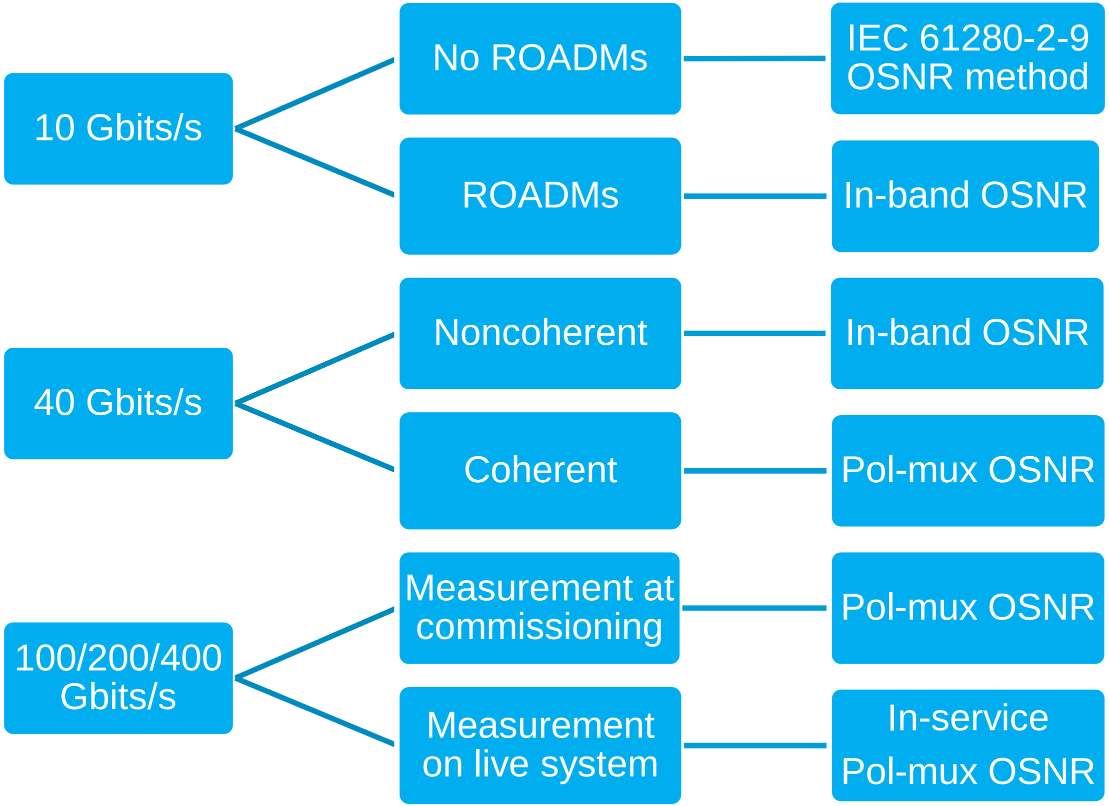


Common use case #3: troubleshooting from Tx

- Network is live and past OSNR values are unknown.
- He first acquires a trace at the Tx, with all channels on, where OSNR is very high because the signal has not passed through any amplifier. This is his reference in which he manually inputs a Pol-Mux OSNR of 35-40 dB.
- He then takes an active measurement at any other location in the network and can use the INSPM method (LD-REF approach).



The right OSNR method for each network



FTBx-5255 Features (Field Focus)

- First third-party 40G/100G/200G Pol-Mux OSNR option on the market; compliant with the IEC 61282-12 standard
- Powerful options: In-band OSNR, WDM Investigator, com. assistant
- Industry’s smallest 100G OSA/transport solution in single platform (FTB-4 PRO)
- Portable solution for DWDM/CWDM networks analysis

Thank you!

EXFO