Coherent Multi-Vendor Interoperable Specifications in Recommendation ITU-T G.698.2

G.698.2: Amplified multichannel dense wavelength division multiplexing applications with single channel optical interfaces

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The preparation of this slide-set is a joint work of the SG15/Q6 contributors

100 Gbit/s DP-DQPSK optical interface specifications (**OTL4.4-SC or FOIC1.4-SC tributary signals), for**:

- **200 – 450 km** distances, **2 – 3 OADMs**, not precluding 6 – 7;
- **80 km** distances, not precluding 120 km;
- 50GHz and 100GHz minimum channel spacing in G.652, G.653, G.655 optical fiber types.

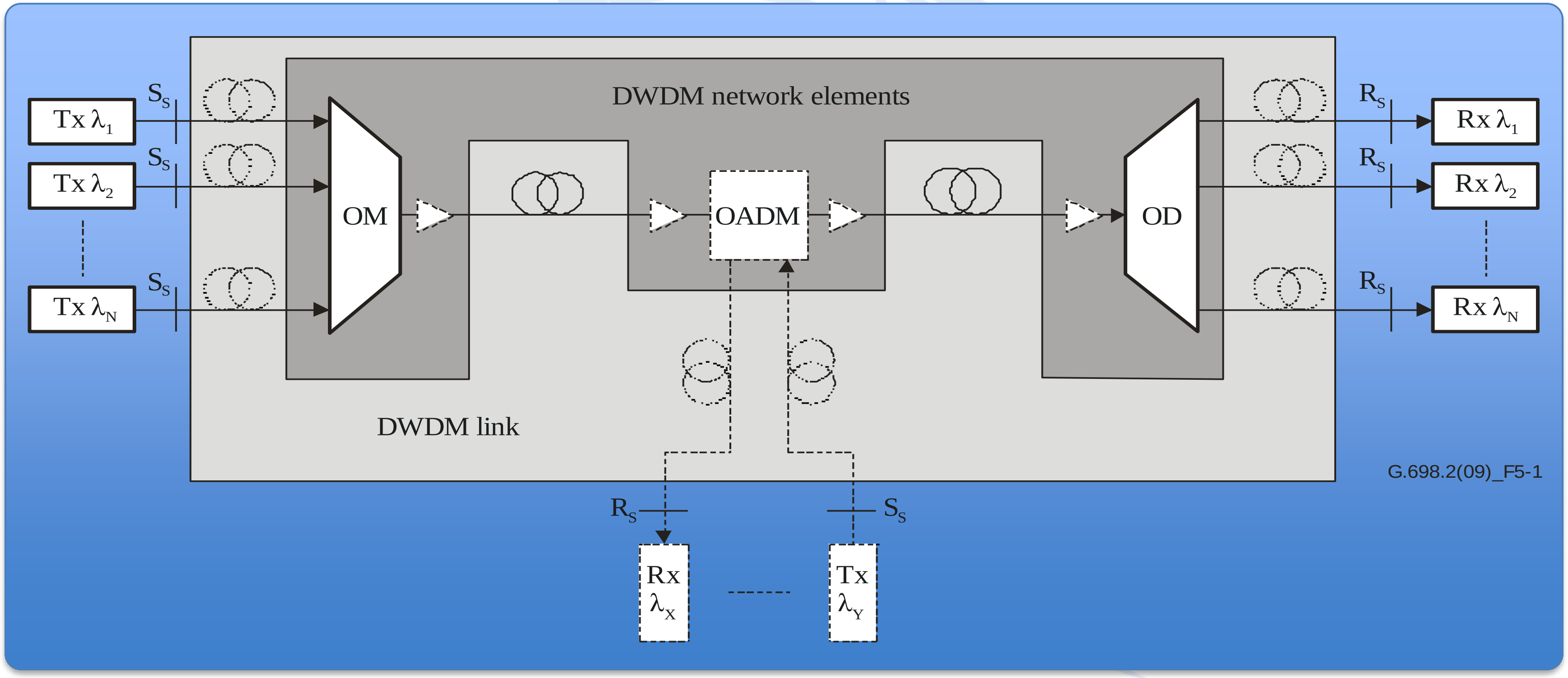
What’s so special about this work in ITU-T?

- **Specifications** and **optical parameter definitions** on basis of established “**black link” methodology**:
  - Flexibility for users, supporting a variety of applications without defining its details.
  - Removes complexity of engineering of non-linear performance of the black link (gain tilt OAs, Cross-Phase mixing, Four Wave Mixing, etc.) from the standard.

- **Coherent multi-vendor interoperability** by defining the **quality of an optical signal, with the data encoded in the phase, using the ‘Error Vector Magnitude’:**
  - The metric defines the **quality of a transmitter**, a consideration **fundamental to multi-vendor interoperability**.

The black link approach in G.698.2

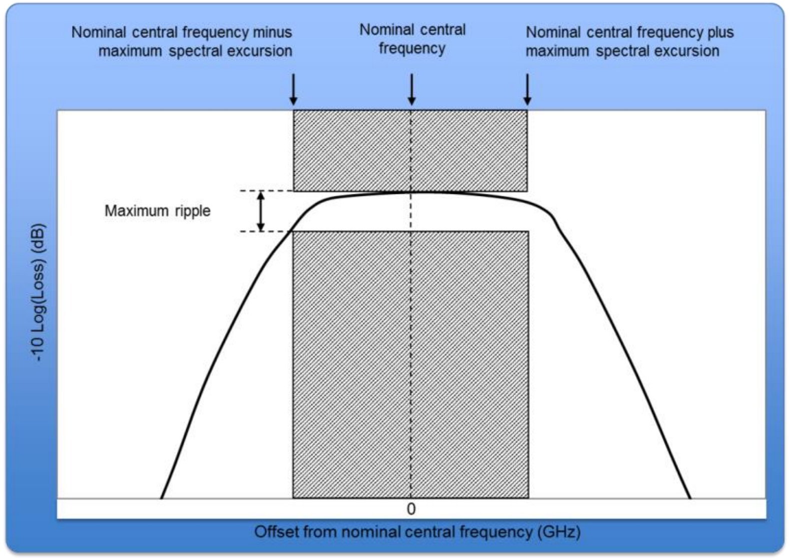
- **The multi-channel DWDM network (from input to the optical multiplexer to the output of the optical demultiplexer) is kept intentionally “BLACK”:**



- **S_s** and **R_s** are **single-channel reference points** at the **DWDM network element** tributary **input** and **output**, respectively;
- **Every path from S_s to its corresponding R_s must comply with the parameter values of the application code.**

How to characterize the Black Link?

- **Transfer characteristics only.**
- **Maximum Ripple specification as** main "tunnel" parameter:
  - **"Tunnel flatness"**;
  - **"Tunnel width"**, with 1-to-1 relation with the **transmitter maximum spectral excursion**.



Parameter	Units	200 – 450 km distances, 2 – 3 OADMs, not precluding 6 – 7	80 km distances, not precluding 120 km
Optical path from point S_S to R_S			
Maximum ripple	dB	2.5	2.5
Maximum (residual) chromatic dispersion	ps/nm	10 000	2 400
Minimum (residual) chromatic dispersion	ps/nm	–820	–200
Minimum optical return loss at S_S	dB	24	24
Maximum discrete reflectance between S_S and R_S	dB	–27	–27
Maximum differential group delay	ps	50	20
Maximum polarization dependent loss	dB	2	1.5
Maximum polarization rotation speed	krad/s	50	50
Maximum inter-channel crosstalk	dB	–16	–16
Maximum interferometric crosstalk	dB	–25	–25
Maximum optical path OSNR penalty	dB	5	5

Coherent Multi-Vendor Interoperable 100 Gbit/s

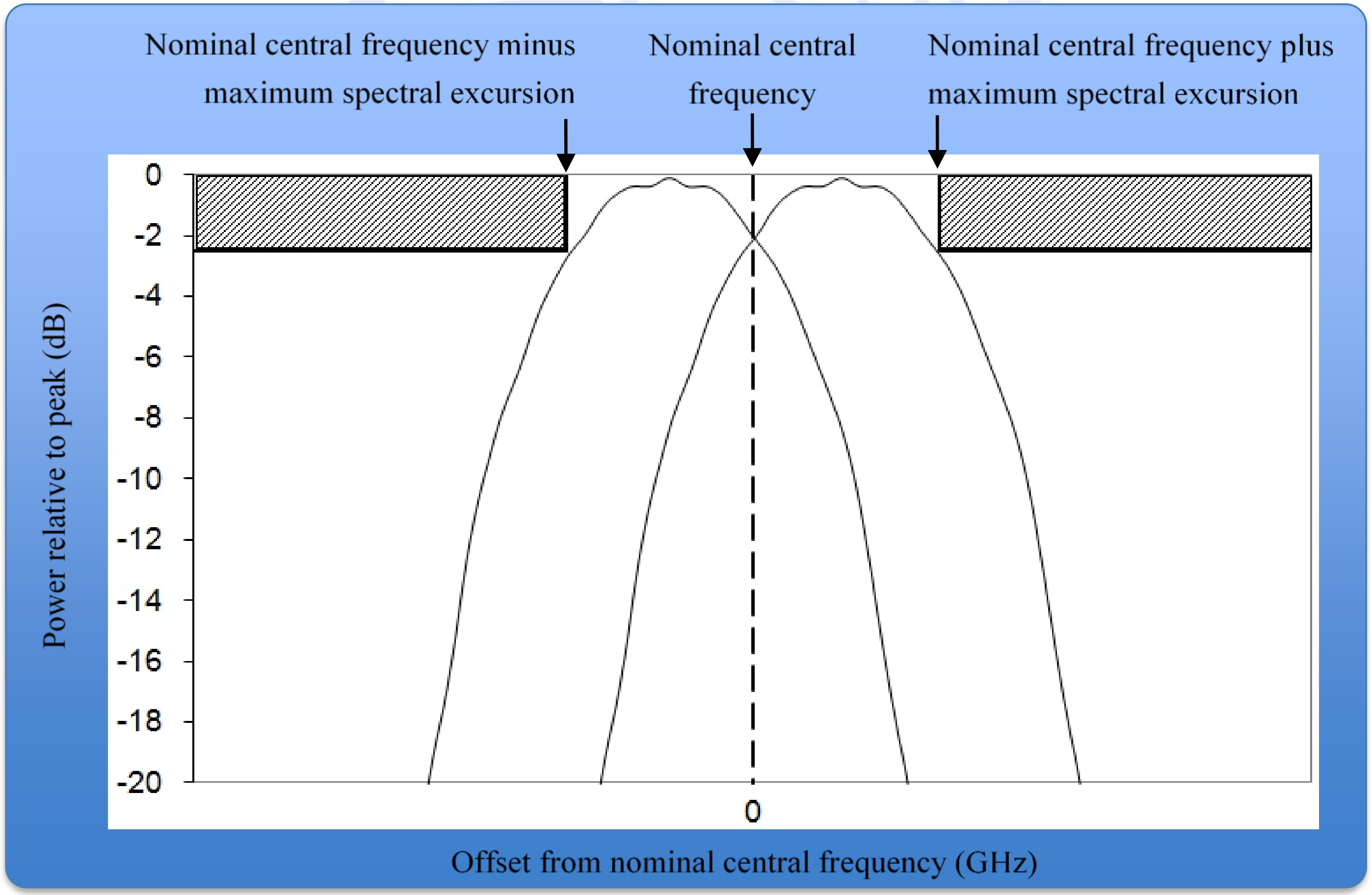
- In **multi-vendor scenarios** it is **crucial to unambiguously separate the burden on the transmitter from the burden on the receiver**.

- **ITU-T Q6/15 has developed a set of Transmitter Quality Metrics.**
  - **Via multi-company contributions and extensive testing efforts.**

- **Specifically for coherent 100 Gbit/s DP-DQPSK:**
  - **Maximum spectral excursion** (placing limits on the passband through the DWDM network);
  - **Maximum Error Vector Magnitude (EVM_{RMS})**, including definition of a reference receiver leading to EVM_{RMS} testing.

Maximum Spectral Excursion

Maximum spectral excursion is the maximum acceptable **difference between the nominal central frequency of the channel** and **the –2.5 dB points of the transmitter spectrum furthest from the nominal central frequency** measured at **Tx output**.



Error Vector Magnitude

The EVM is the length of the vector - at the detected symbol location - **which connects the I/Q reference-signal vector to the I/Q measured-signal vector.**

$$EVM[n] = \sqrt{I_{err}^2[n] + Q_{err}^2[n]}$$

where: n = symbol index

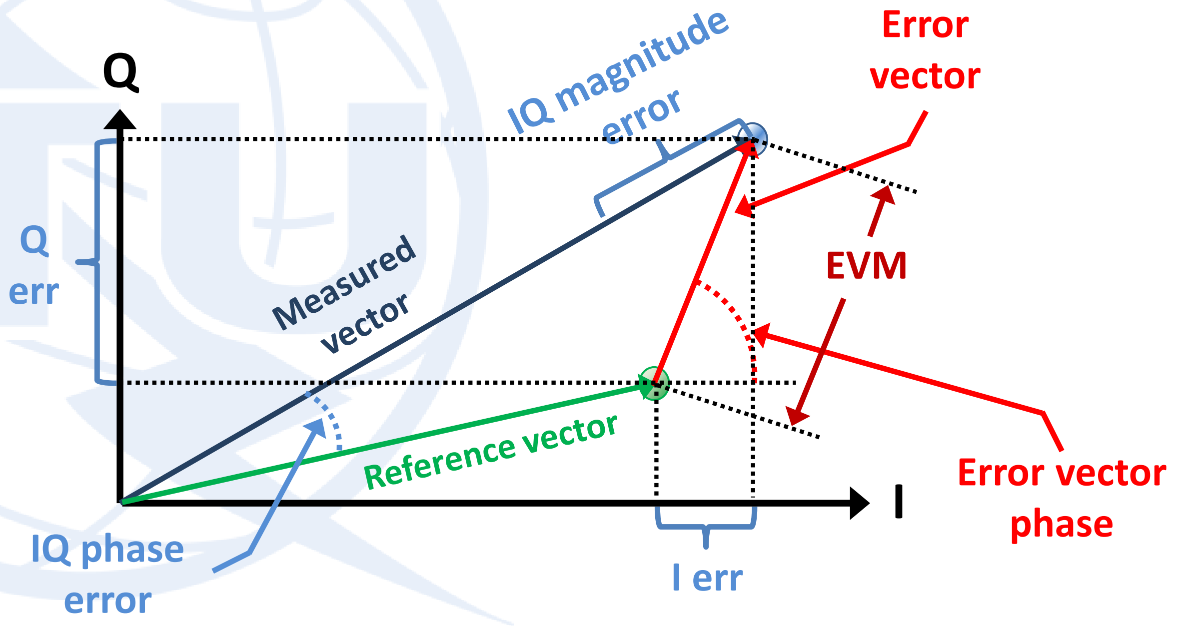
$$I_{err} = I_{meas} - I_{ref}$$

$$Q_{err} = Q_{meas} - Q_{ref}$$

$$EVM_{RMS} = \frac{\sqrt{\frac{1}{N}\sum_{n=1}^{N} EVM^2[n]}}{|A|}$$

where: N= number of EVM points

A= normalization factor



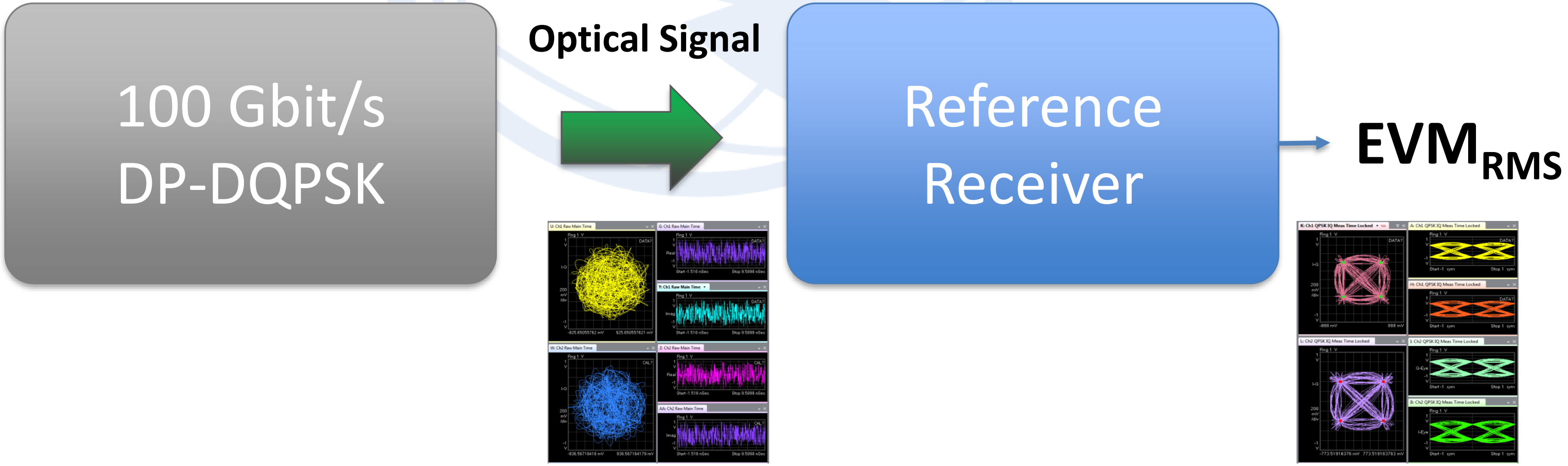
If **EVM = 0** then we have measured an **ideal signal**!

How to Measure EVM$_{RMS}$?

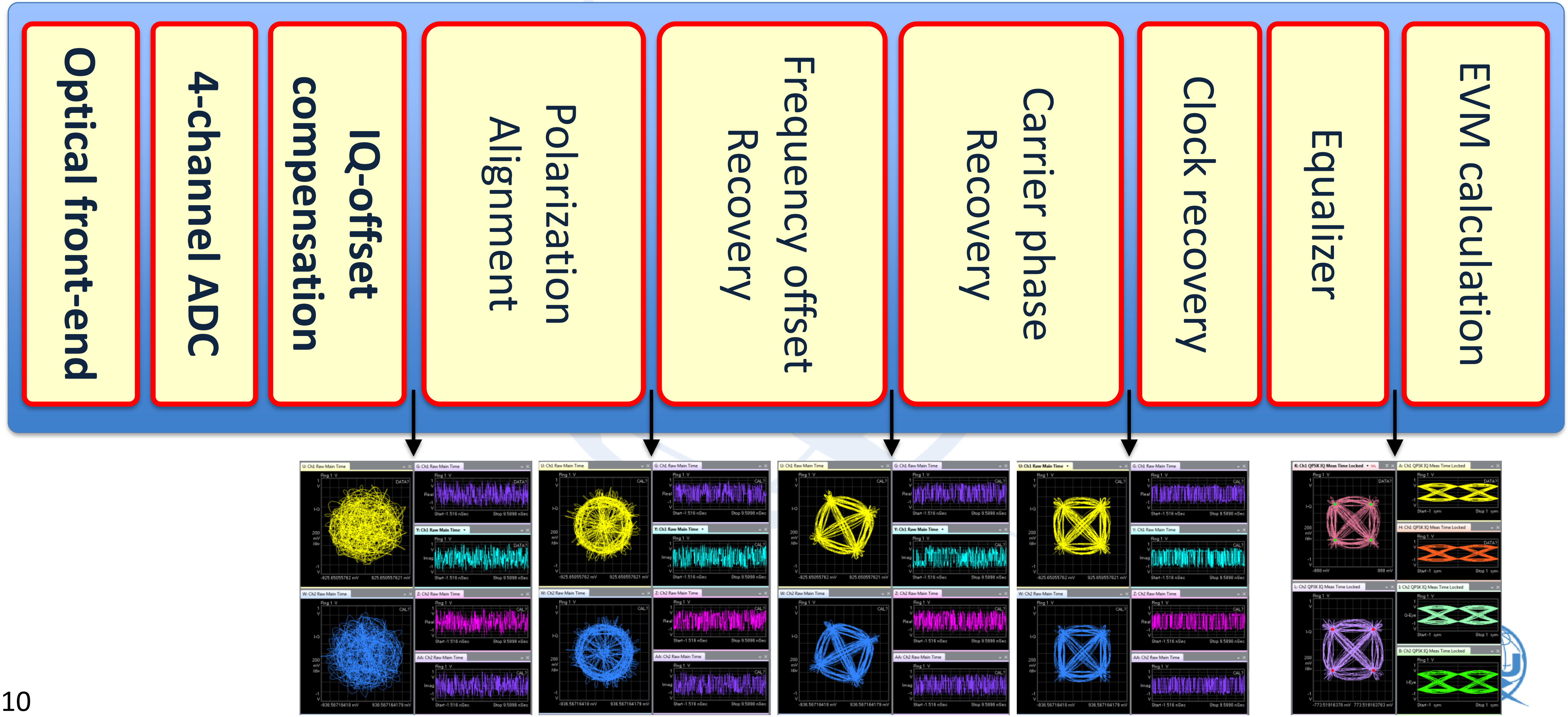
The **EVM$_{RMS}$ metric** should consistently **predict the OSNR penalty due to a variety of transmitter impairments**.

Since the **EVM$_{RMS}$** is **measured from a “clean” constellation plot**, a **reference receiver with defined processing blocks** is needed for consistent results.

Multi-company testing on **representative hardware was required** to support the **definition of appropriate parameters and associated values for multi-vendor interoperable optical specs**.



Reference Receiver



Transmitter and Receiver Specifications

Parameter	Units	200 – 450 km distances, 2 – 3 OADMs, not precluding 6 – 7	80 km distances, not precluding 120 km
Interface at point S_S			
Maximum mean channel output power	dBm	0	–3
Minimum mean channel output power	dBm	–5	–8
Minimum central frequency	THz	191.5 for (C) 186.0 for (L)	191.5 for (C) 186.0 for (L)
Maximum central frequency	THz	196.2 for (C) 191.5 for (L)	196.2 for (C) 191.5 for (L)
Maximum spectral excursion	GHz	±15	±15
Minimum side mode suppression ratio	dB	30	30
Maximum laser linewidth	kHz	500	500
Maximum offset between the carrier and the nominal central frequency	GHz	1.8	1.8
Maximum power difference between polarizations	dB	1.5	1.5
Maximum skew between the two polarizations	ps	5	10
Maximum error vector magnitude	%	26	23
Maximum I-Q offset	dB	–25	–25
Interface at point R_S			
Maximum mean input power	dBm	0	0
Minimum mean input power	dBm	–18	–18
Minimum OSNR(193.6) (Note 2)	dB (0.1 nm)	21	24
Receiver OSNR tolerance(193.6) (Note 3)	dB (0.1 nm)	16	19
Maximum reflectance of receiver	dB	–27	–27
ITU-T has defined a frequency dependent OSNR. Values referring to OSNR are specified at a channel frequency of 193.6 THz.			

Work in progress

ITU-T Q6/15 is investigating whether it is useful to define further 100 Gbit/s application codes, optimized for significantly shorter distances than 80 km (e.g. 40km or 20km).

ITU-T Q6/15 is currently developing specifications for coherent multi-vendor Interoperable 200 Gbit/s and 400 Gbit/s applications in a further revision of G.698.2.

Terms of reference:

- Specifications appropriate for 80 km distances, not precluding 120 km, without OADMs;
- Specifications appropriate for 200 – 450 km distances, for 3 – 4 OADMs, not precluding 6 – 7;

Modulation Format for 200 Gbit/s and 400 Gbit/s

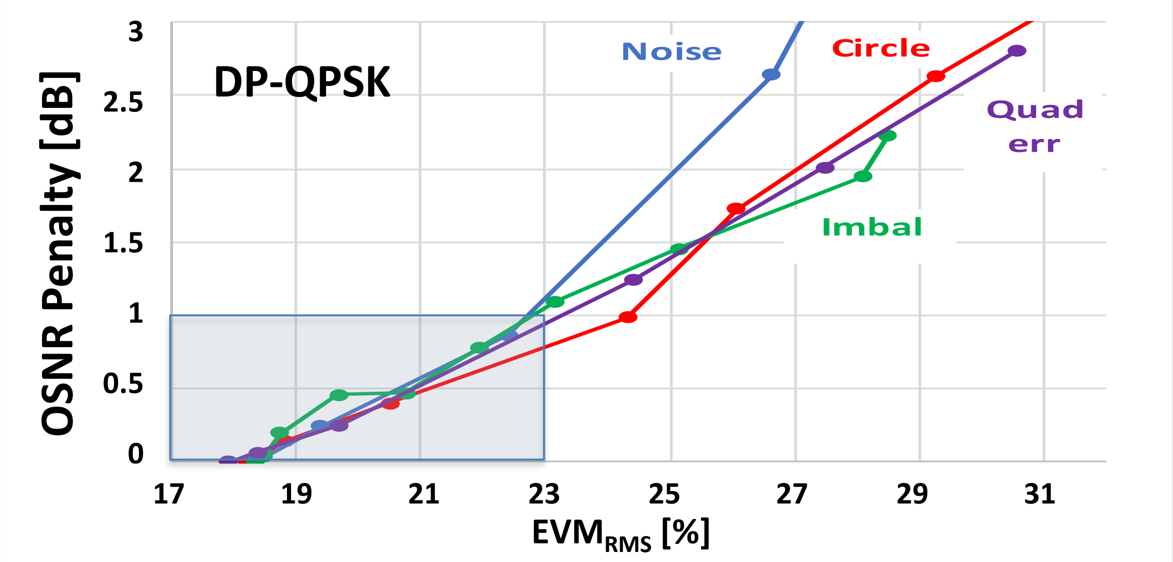
400Gbit/s:

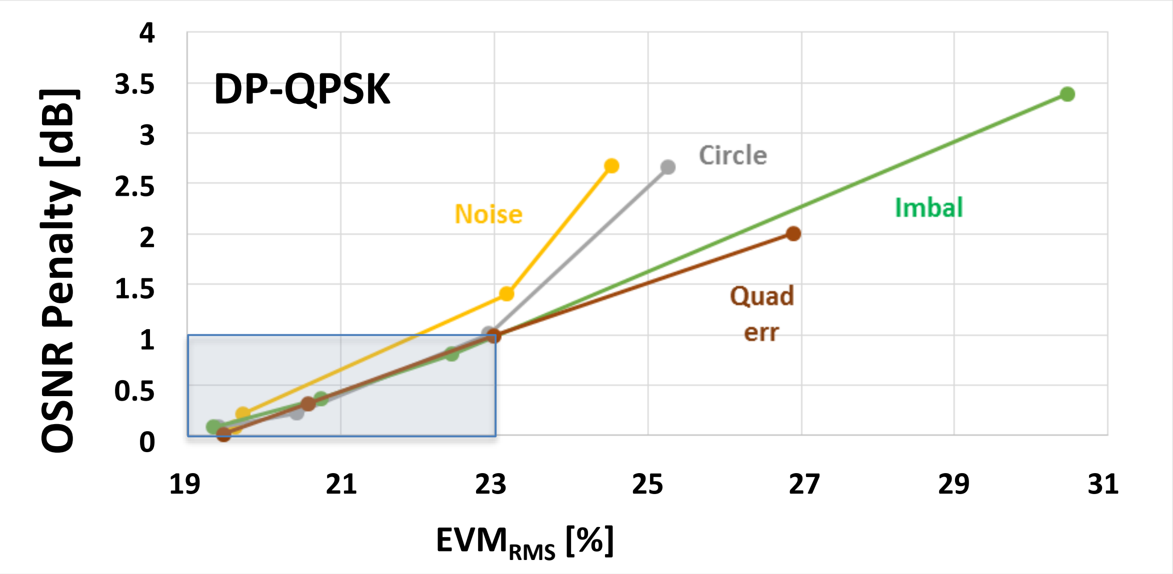
- DP-16QAM is currently the only candidate format for both 80km and 450km application spaces.

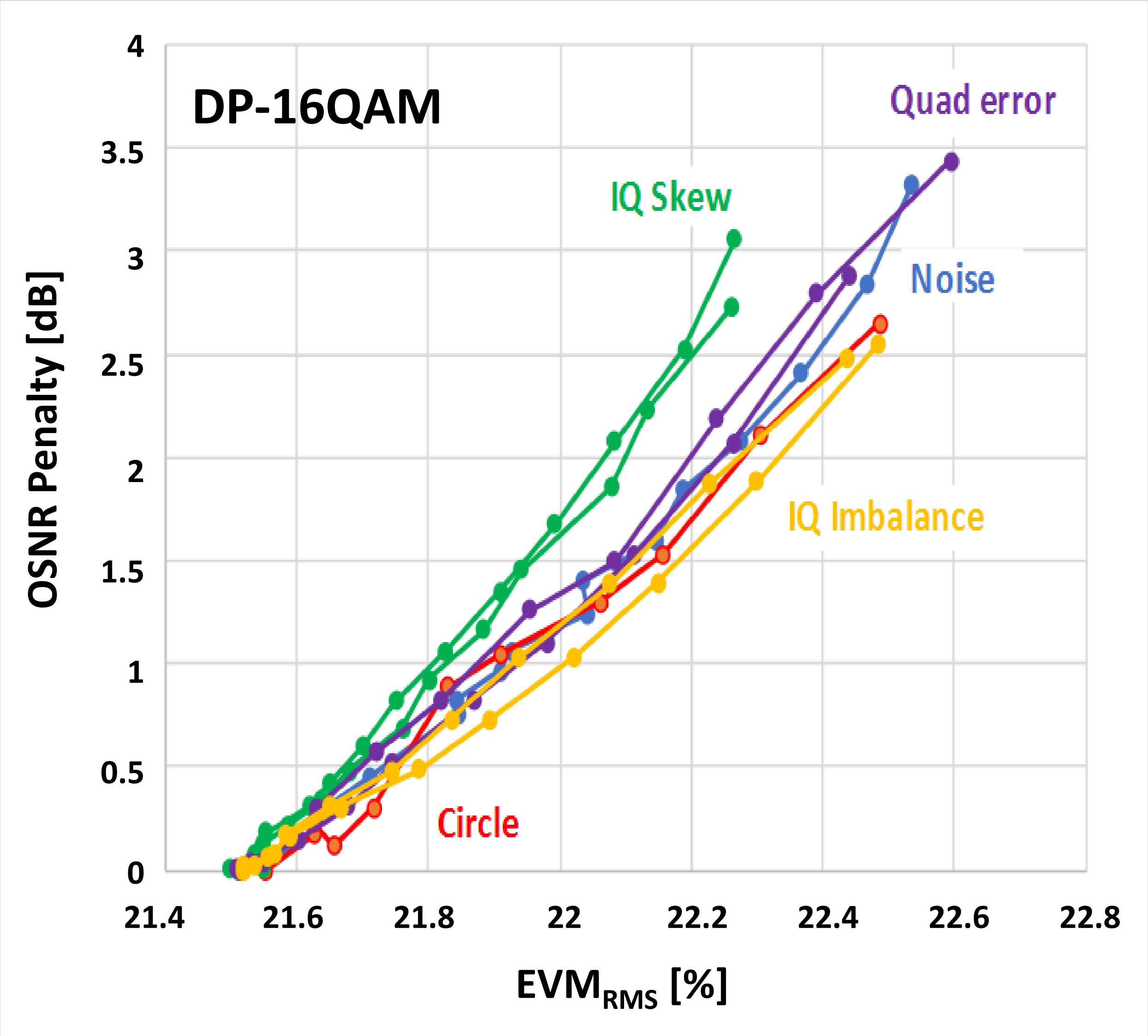
200Gbit/s:

- Both DP-QPSK and DP-16QAM are still under consideration.
- Operators inputs on the trade-off channel density versus distance are required.

EVM_{RMS} test results for DP-16QAM, compared with DP-QPSK







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