Specifications for coherent 100 Gbit/s DP-DQPSK optical interfaces in a revision of ITU-T G.698.2

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

Fabio Pittalà – on behalf of ITU-T SG15/Q6

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

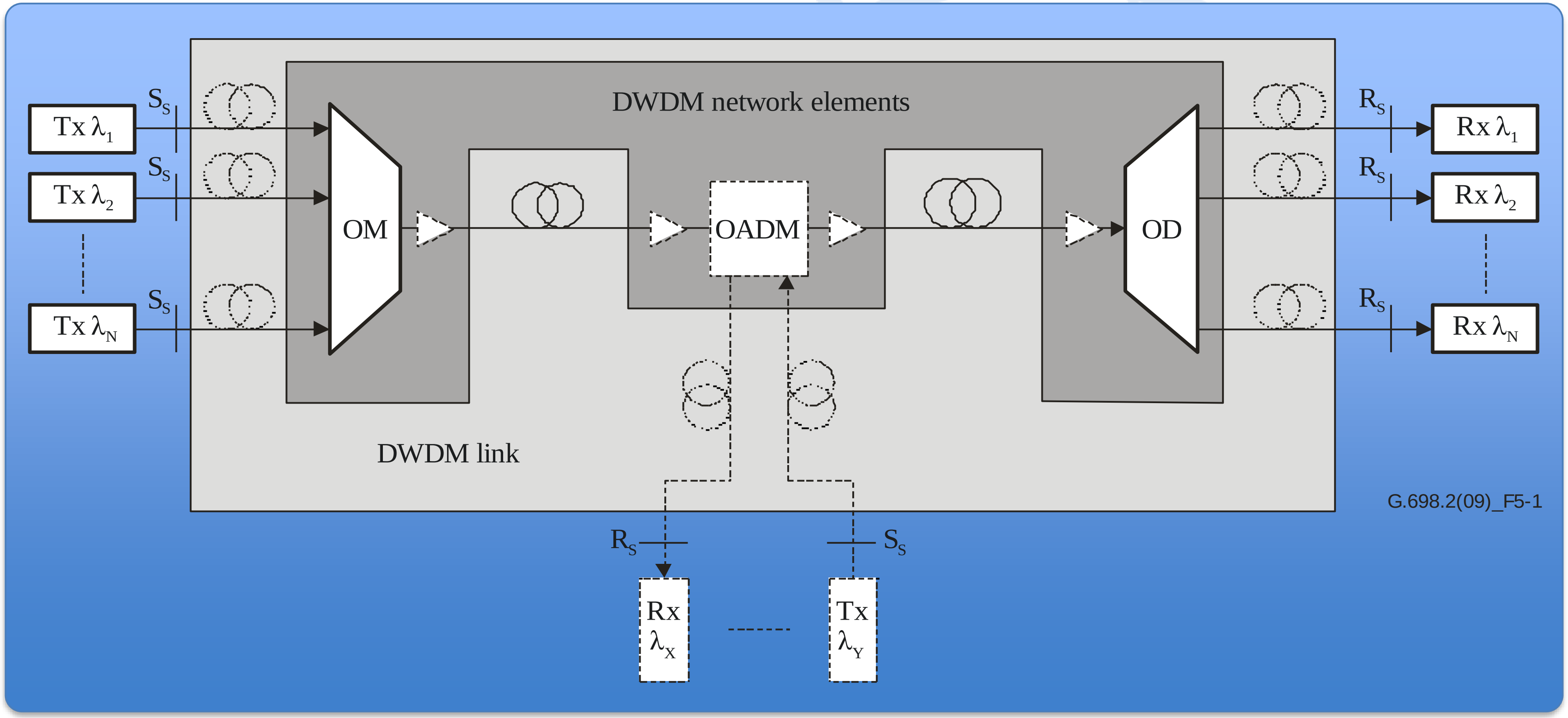
What’s so special about this work in ITU-T?

- **2.5 Gbit/s and 10 Gbit/s specifications** in **in-force G.698.2** have been **widely serving the industry for more than a decade.**
- **First global standard for coherent 100 Gbit/s DP-DQPSK** optical interface specifications.
- **New specification methodologies** and **optical parameter definitions** on basis of established “**black link” specification methodology**.
- Q6/15 is developing **100 Gbit/s specifications** appropriate for **metro applications**:
  - Over **200 – 450 km** distances, **2 – 3 OADMs**, not precluding 6 – 7.
  - Over **80 km** distances, not precluding 120 km, no OADMs.
- Targeted for **completion** (consent) **October 2018**.

The fundamental approach in G.698.2

- **G.698.2 specifications are separated into three parts:**
  - **Optical interface specification @ single-channel Tx output.**
  - **The DWDM network in between Tx and Rx**, containing optical multiplexers & demultiplexers, optical amplifier(s), single-mode optical fibres and OADMs.
  - **Optical interface specification @ single-channel Rx input.**
- The **multi-channel DWDM network** (from input to the optical multiplexer to the output of the optical demultiplexer) is kept **intentionally “BLACK”**:
- **Flexibility for users**, supporting a variety of applications without specs for 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**.
- **Enables the elimination of transponders in multi-vendor DWDM optical transmission networks**.

The black link approach in G.698.2



Reference points

- S_S is a single-channel reference point at the DWDM network element tributary input;
- R_S is a single-channel reference point at the DWDM network element tributary output.

- Every path from S_S to its corresponding R_S must comply with the parameter values of the application code.

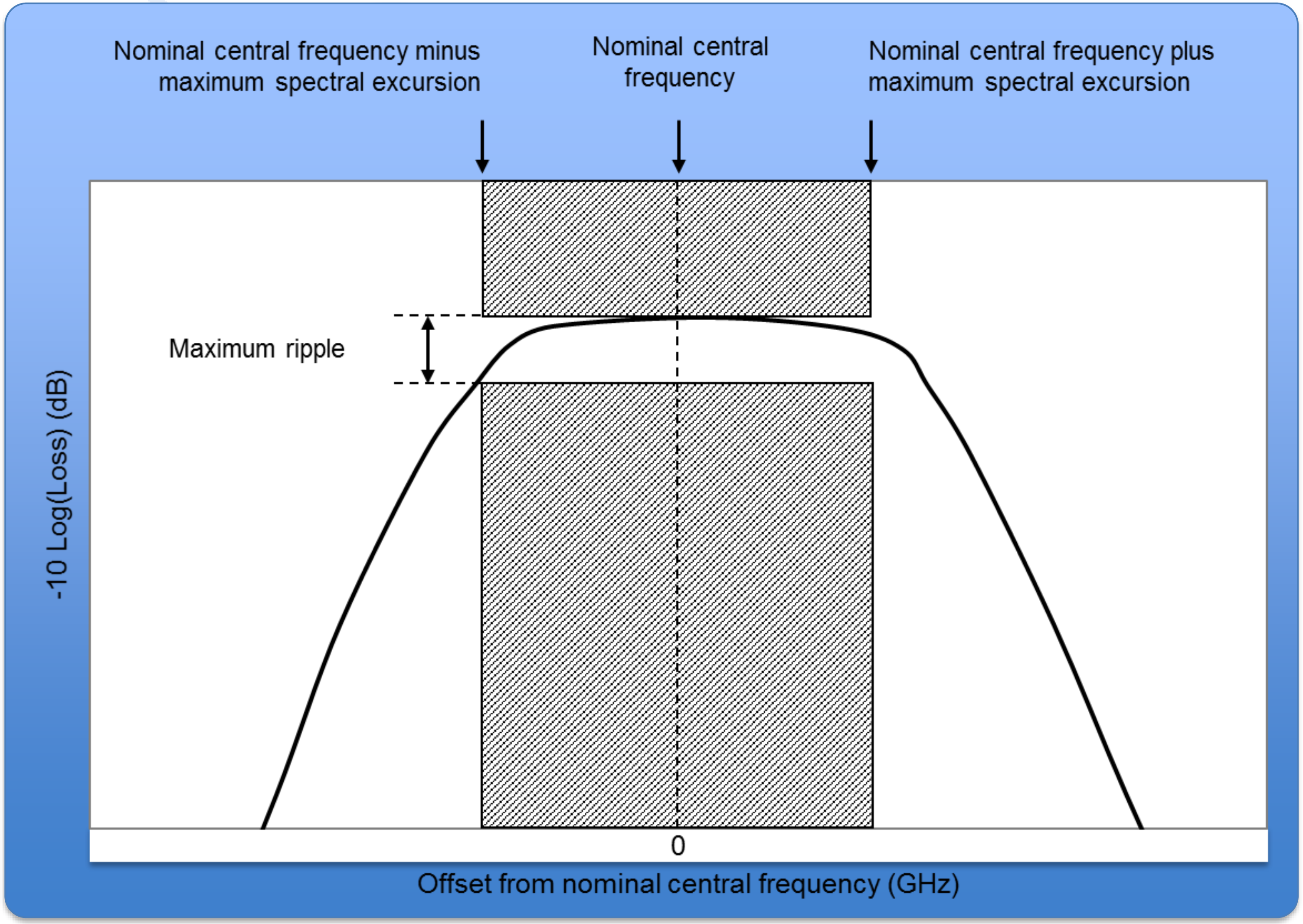
How to characterize the Black Link?

- **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**.
- "**Tunnel" degradation parameters**:
  - Max & Min (residual) chromatic dispersion;
  - Maximum DGD;
  - Maximum inter-channel crosstalk at output demux;
  - Maximum interferometric crosstalk at output demux;
  - Maximum optical path OSNR penalty.

Maximum Ripple

Defined in G.671.

Applied to entire black link from Tx output to the corresponding Rx input.



Interoperable coherent 100 Gbit/s Tx and Rx

Interoperability between Tx and Rx from same vendor via black link not uncommon.

HOWEVER

When Tx and Rx are from different vendors, crucial to unambiguously separate the burden on the transmitter from the burden on the receiver.

Crucial to define Transmitter Quality Metrics that directly relate to overall system (OSNR) performance.

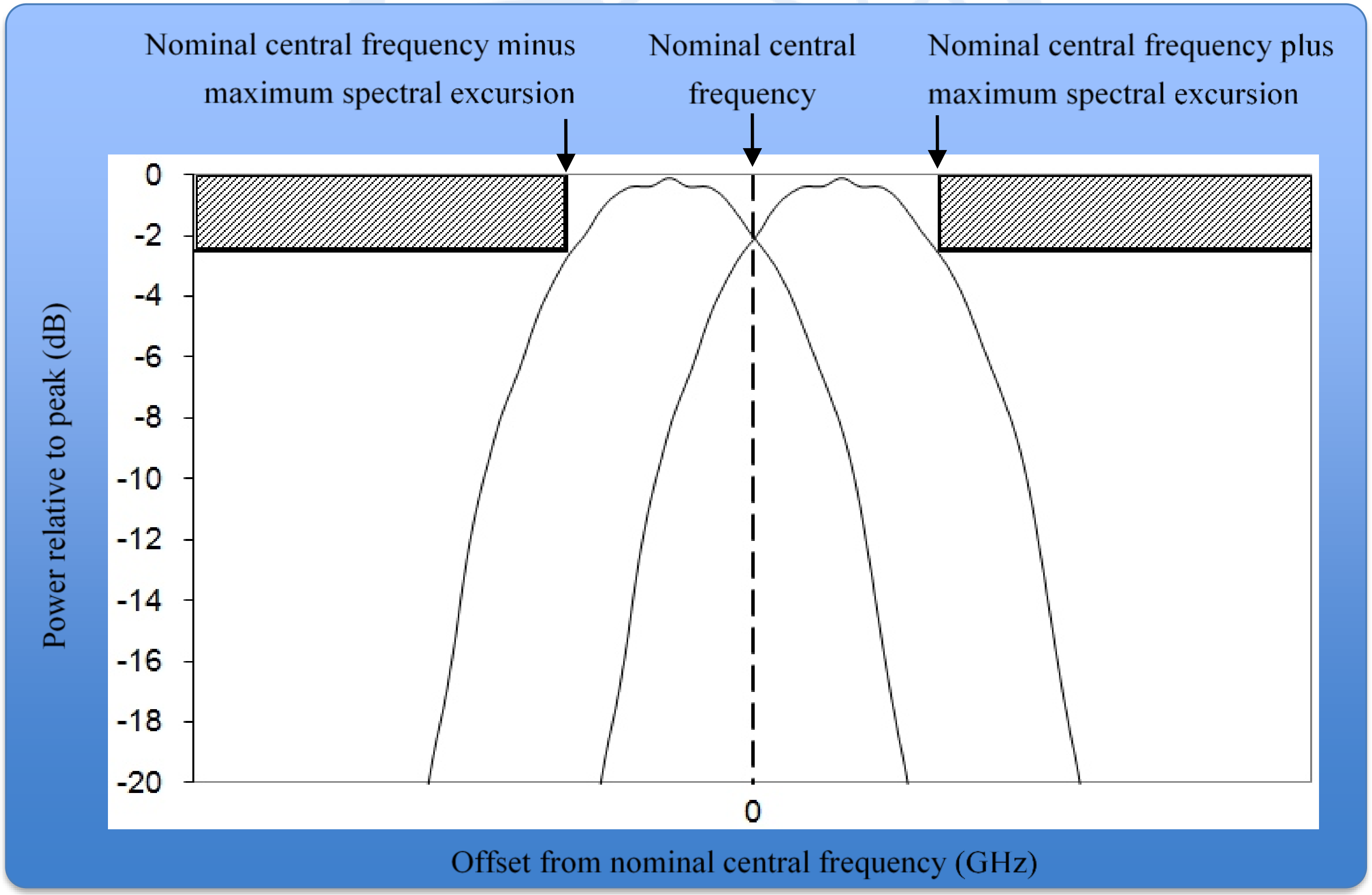
Transmitter Quality Metrics coherent 100 Gbit/s

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

- **Specifically for coherent 100 Gbit/s DP-DQPSK:**
  - **Maximum spectral excursion** (matching the passband through the DWDM network);
  - **Maximum Error Vector Magnitude (EVM_{RMS})**, including definition of 7-tap T-spaced equalizer for the reference receiver to test EVM_{RMS}.
  - **Maximum IQ offset**.

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

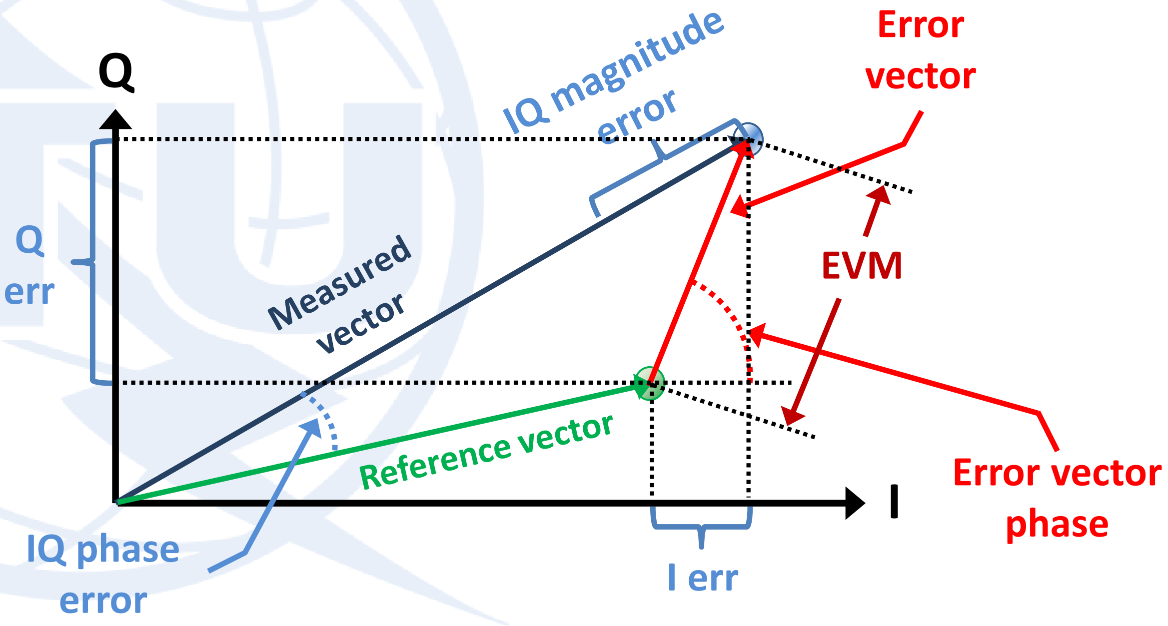
$I_{err} = I_{meas} - I_{ref}$

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

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

where: N= number of EVM points

A= normalization factor



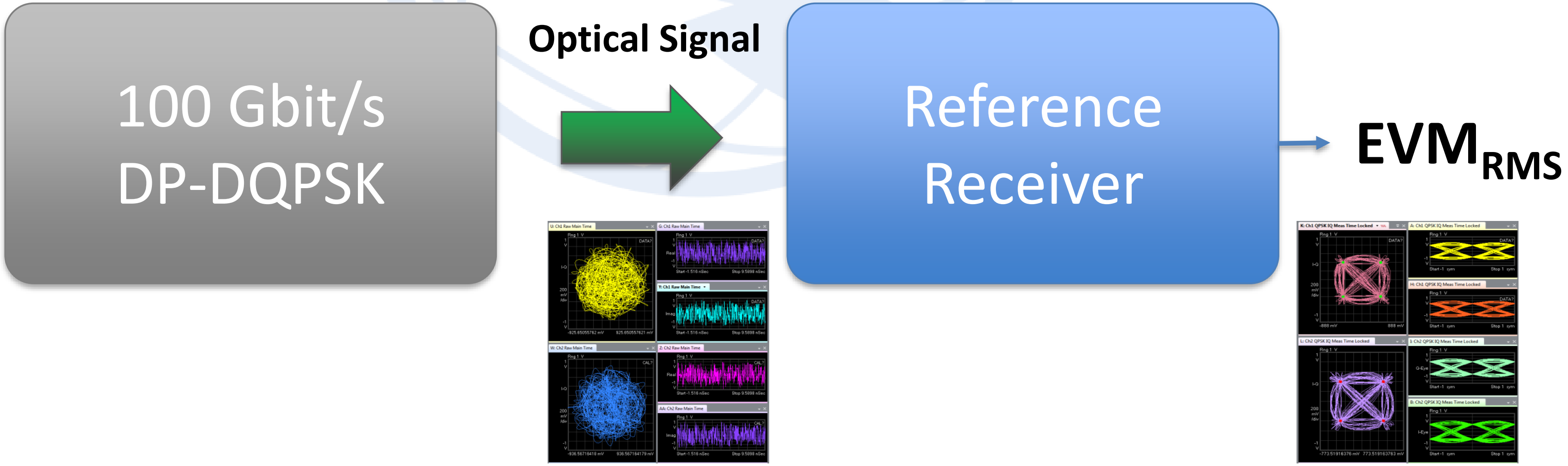
If **EVM = 0** then we have measured an **ideal signal**!

How to Measure EVM_{RMS}?

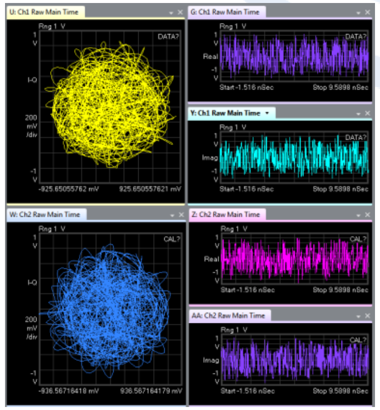
The **EVM_{RMS} metric** should consistently **predict the OSNR penalty due to a variety of transmitter impairments**.

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

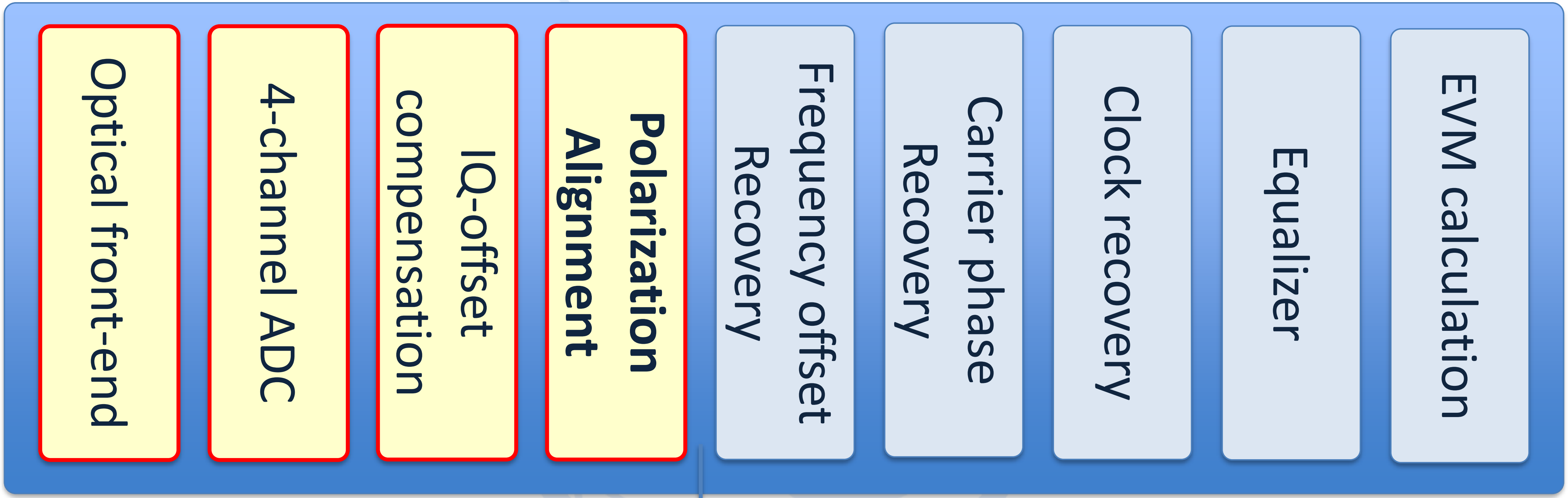


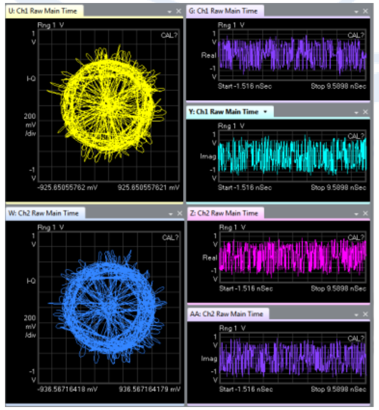
The opto-electronic converter needs to be calibrated over wavelength for: frequency response, channel imbalances, IQ phase angle errors and timing skew.

IQ-offset needs to be removed.

The execution order of the digital processing blocks might be different from that shown.

Reference Receiver

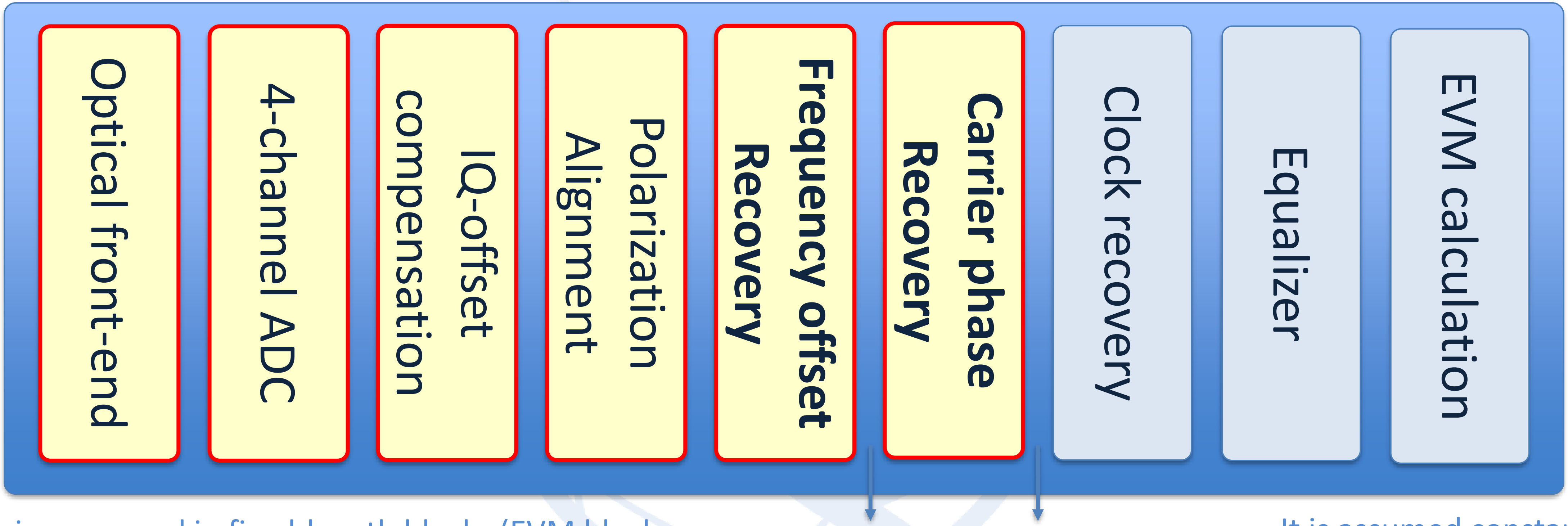




The polarization alignment should neither improve (devices could fail in field) nor impair (lowers the yield) the signal quality.

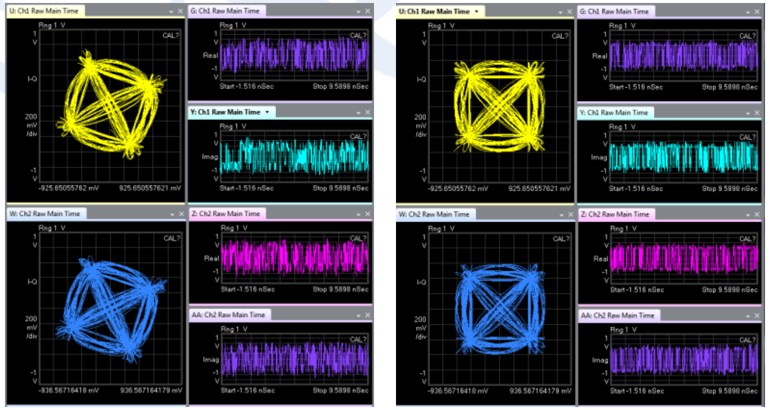
The execution order of the digital processing blocks might be different from that shown.

Reference Receiver



The data is processed in fixed-length blocks (EVM block size):

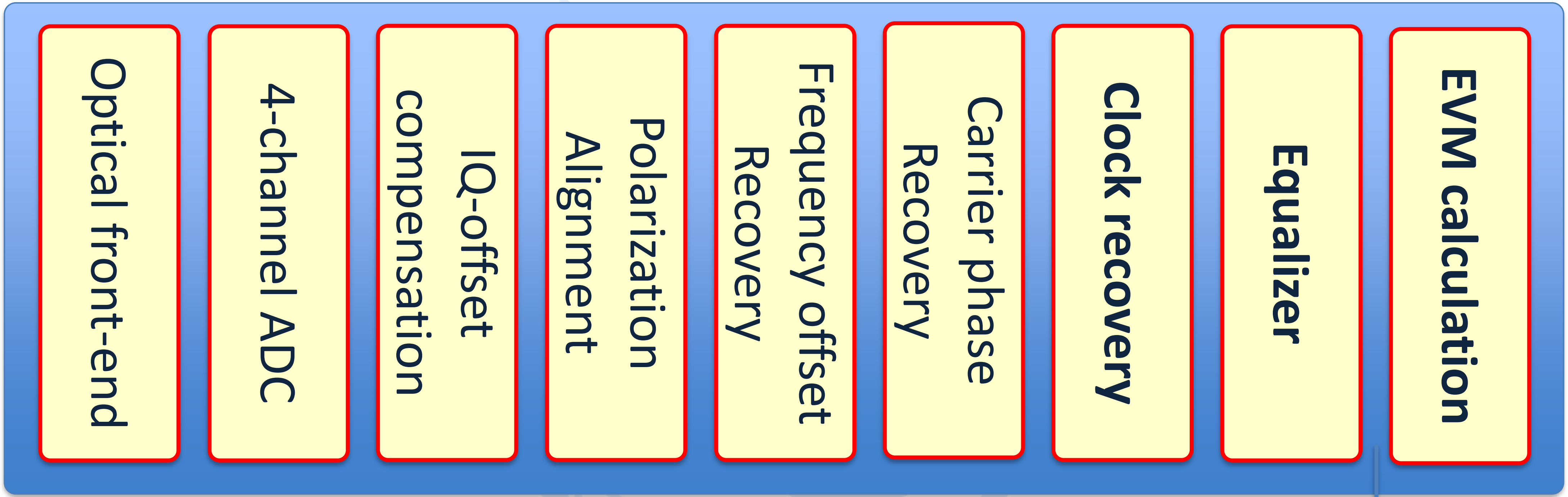
- Too small block size results in higher standard deviation of results;
- Too big block size will overemphasize laser phase noise and increase measurement time;
- Optimum is in the range between 1k and 4k symbols.



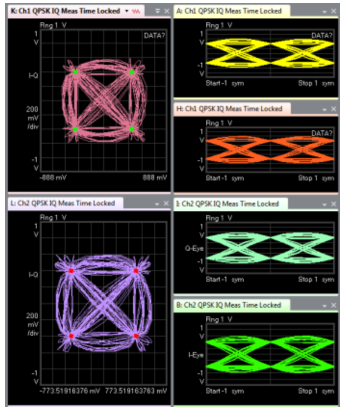
It is assumed constant frequency offset (linear phase over time) for each block.

The execution order of the digital processing blocks might be different from that shown.

Reference Receiver



- The clock recovery retimes and resamples the signal to one sample per symbol.
- The equalizer applies a 7-tap T-spaced FIR filter with the tap coefficients optimized for the lowest EVM.
- The EVM can then be calculated.



The execution order of the digital processing blocks might be different from that shown.

Future revisions of G.698.2

ITU-T Q6/15 has agreed to add specifications for coherent 200 Gbit/s and 400 Gbit/s applications in a further revision of G.698.2 after October 2018.

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.

Depending on choice of modulation format definitions of EVM_{RMS} for 200 Gbit/s and 400 Gbit/s may need to be modified.

ITU