Level Setting
Tx Quality Metric

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Disclaimer

- Neither author claims to be an EVM expert, and this presentation is our interpretation of material presented to date and numerous discussions with multiple individuals.

Recap of Events

- Jan 20 – Motion Adopts EVM
  - Move to adopt the EVM measurement methodology defined by Slides 5 -9 of https://www.ieee802.org/3/ct/public/20_01/pittala_3ct_01a_0120.pdf to enable correlation for the definition of a transmitter metric

- Summary of data presented –
  - Initial measurement results on EVM_{RMS} for DP-16QAM presented in https://www.ieee802.org/3/ct/public/19_03/anslow_3ct_02_0319.pdf
  - Initial measurement results on EVM_{RMS} for DP-16QAM presented in https://www.ieee802.org/3/ct/public/19_07/pittala_3ct_01a_0719.pdf
  - 400GBASE-ZR EVM Pass/Fail Criteria - https://www.ieee802.org/3/ct/public/19_11/way_3ct_01b_1119.pdf
  - Other - ????

- IEEE P802.3cw begins Task Force Review

- IEEE P802.3cw EVM Ad hoc formed - charter
  1. Check, and if necessary, update, the Error Vector Magnitude test plan in slides 5 – 9 of pittala_3ct_01a_0120.pdf.
  2. Develop baseline text to describe Error Vector Magnitude, reusing as much as possible information from Recommendation ITU-T G.698.2 and the OIF 400ZR IA.
     a) Expected completion - inclusion in IEEE P802.3cw D1.2
  3. Evaluate (test) data submitted to IEEE P802.3cw, confirm the suitability of EVM as a Tx quality metric for IEEE P802.3cw, update (if necessary) the EVM definition, and recommend values for Error Vector magnitude related parameters.

- Discussion of pittala_3ct_01a_0120 - Questions regarding testing and terminology

- Tx_BER was proposed per way_3cw_01a_210721.pdf as an alternative Tx Quality Metric. No decision made by TF yet.

- Greg LeCheminant / Bernd Nebendahl have offered to work with individuals to provide a path for EVM results to be presented anonymously

Tx Quality Metric (TQM) Recap

- TQM is intended as a single test metric to cover multiple Tx parameters that allows implementers to make tradeoffs in their design

- Error Vector Magnitude
  - Adopted July 2019 (https://www.ieee802.org/3/ct/public/19_07/stassar_3ct_02_0719.pdf)
    - P802.3ct Motion - Move to adopt the parameter list on slides 4 to 6 of stassar_3ct_02_0719 for the 400GBASE-ZR PMD specification.
    - P802.3cw motion reaffirmed - 02 Apr 2020
  - Per https://www.ieee802.org/3/ct/public/19_03/anslow_3ct_02_0319.pdf

    Further work is required to:
    - Measure EVM_{RMS} with I-Q offset to confirm whether this has to be excluded as for QPSK
    - Measure EVM_{RMS} with a wide variety of impairments using other DP-16QAM implementations to confirm that these measurements are reproducible.

- Tx_BER suggested (no formal proposal) as an alternative - https://www.ieee802.org/3/cw/public/adhoc/21_0721/way_3cw_01a_210721.pdf

- This presentation explores the possibility of defining a common approach to obtaining data for both TQM candidates.

TQM Test Setups

- Setup #1 –
  - Defined standardized test method for generating data to submit to TF related to Tx Quality Metric.
  - Two possible options for obtaining the Tx quality metric data
    - Option #1 – "Remote" TQM calculation
    - Option #2 – "Local" TQM calculation
  - **This would not go into the standard.**

- Setup #2 –
  - Test methodology for a single test for Tx Quality Metric
  - **This goes into the standard.**

Terminology & Concepts

- The following terms and concepts will be illustrated in the following pages -
  - Constellation Analyzer
    - This term has been used in multiple presentations. It is really the Tx quality metric (TQM) Reference Rx
  - TQM Reference Rx
    - Used in the standard to define how TQM is measured
    - Approaches to calculating the TQM must be consistent with the definition of the TQM Reference Rx in the standard
  - Test DP-16QAM Transmitter / DP-16QAM Receiver – representative implementations of 400GBASE-ZR Tx / Rx
  - EVM – measured by the TQM Reference Rx when connected to the Test DP-16QAM Transmitter
  - Tx_BER – the BER measured by the TQM Reference Rx when connected directly to the Test DP-16QAM Transmitter
  - RX_BER – the BER measured by the System (real-time) receiver

TQM Reference Rx

Assumed to be common between both approaches.

EVM Approach

| Optical front-end | 4-channel ADC | IQ-offset compensations | Polarization Alignment | Frequency offset Recovery | Carrier Phase Recovery | Clock Recovery | Equalizer | EVM Calculation |

Tx_BER Approach

| Optical front-end | 4-channel ADC | IQ-offset compensations | Polarization Alignment | Frequency offset Recovery | Carrier Phase Recovery | Clock Recovery | Equalizer | Tx_BER Measurement |

Proposal to define standardized approaches for calculating EVM or measuring Tx_BER is necessary.

For EVM calculation -
- Leverage ongoing industry efforts
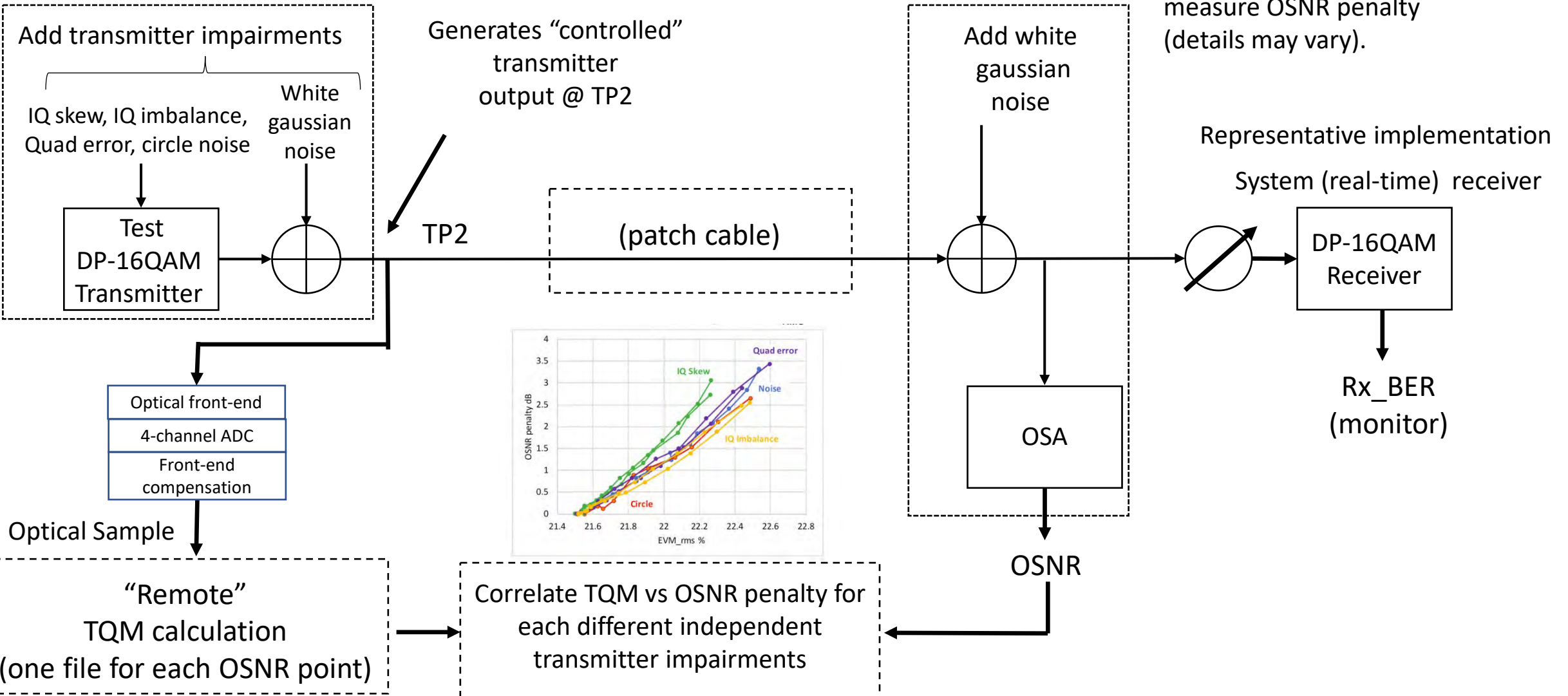- Details to be finalized

For BER Measurement -
What would the sub-blocks be?
- Absolute phase recovery
- Bit Stream Recovery
- Test Pattern alignment
- Comparison of Rx bits with Test pattern
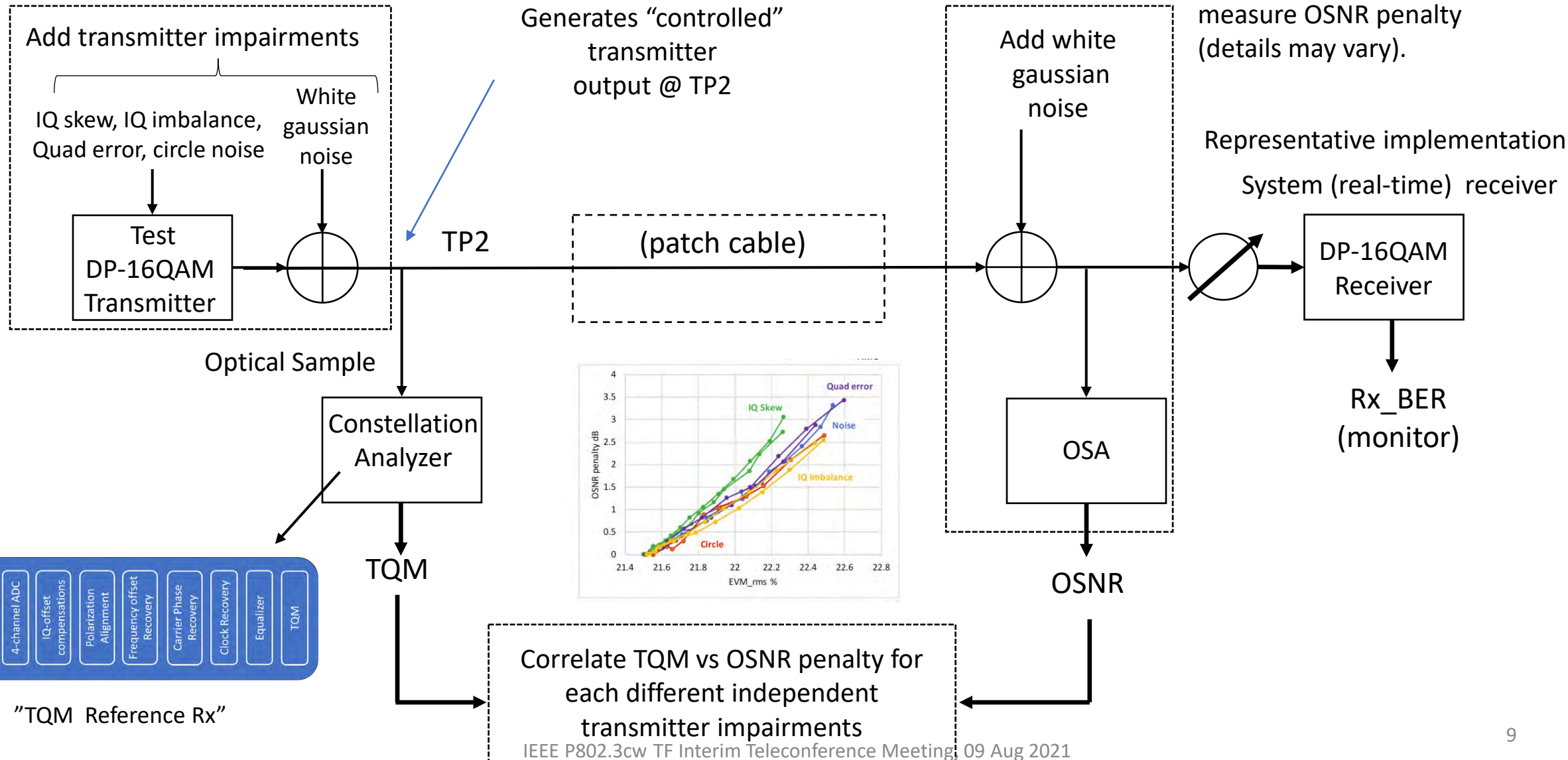
Also need to define test pattern

Setup 1 Option #1 - Measurement setup for "evaluating" TQM - Remote

Representative implementation

Add transmitter impairments

IQ skew, IQ imbalance, Quad error, circle noise

White gaussian noise

Test DP-16QAM Transmitter

Generates "controlled" transmitter output @ TP2

TP2

(patch cable)

Add white gaussian noise

Note: Only to measure OSNR penalty (details may vary).

Representative implementation

System (real-time) receiver

DP-16QAM Receiver

Rx_BER (monitor)

Optical front-end

4-channel ADC

Front-end compensation

Optical Sample

OSA

OSNR

"Remote" TQM calculation (one file for each OSNR point)

Correlate TQM vs OSNR penalty for each different independent transmitter impairments

Setup 1 Option #2 - Measurement setup for "evaluating" TQM - Local

Representative implementation

Add transmitter impairments

IQ skew, IQ imbalance, Quad error, circle noise

White gaussian noise

Test DP-16QAM Transmitter

Generates "controlled" transmitter output @ TP2

TP2

(patch cable)

Add white gaussian noise

Note: Only to measure OSNR penalty (details may vary).

Representative implementation

System (real-time) receiver

DP-16QAM Receiver

Rx_BER (monitor)

Optical Sample

Constellation Analyzer

OSA

TQM

OSNR

Optical front-end | 4-channel ADC | IQ-offset compensations | Polarization Alignment | Frequency offset Recovery | Carrier Phase Recovery | Clock Recovery | Equalizer | TQM

"TQM Reference Rx"

Correlate TQM vs OSNR penalty for each different independent transmitter impairments

Example

DP-16QAM OSNR Penalty vs. EVM$_{RMS}$
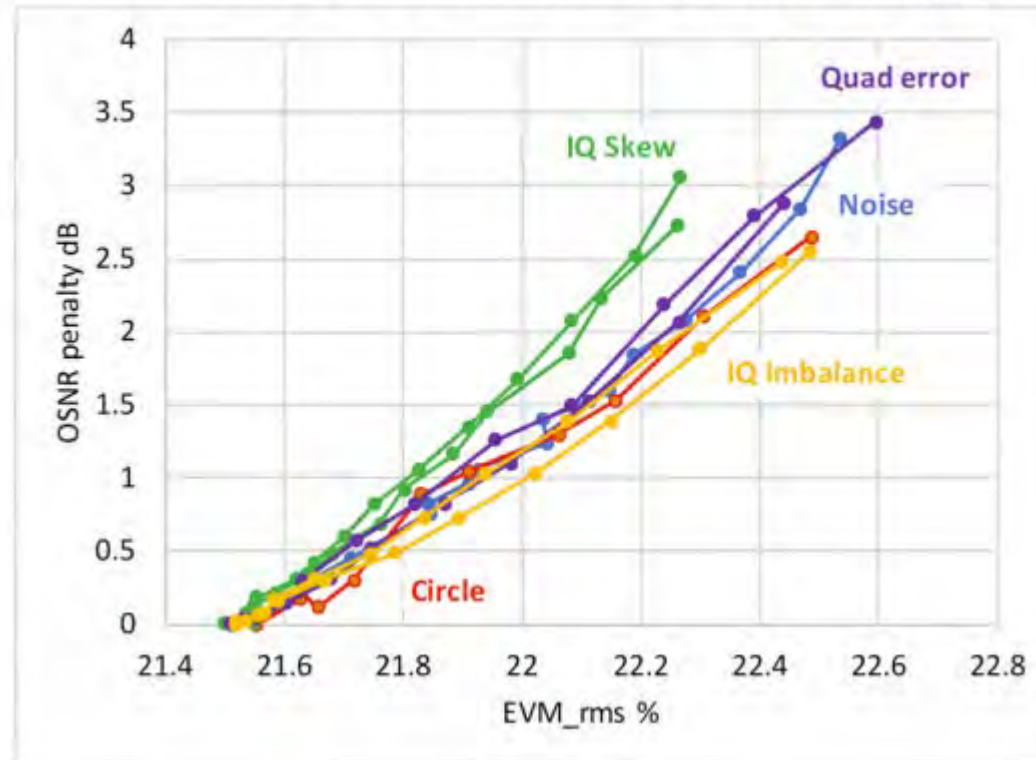
- For the "validation exercise" we need to plot both EVM and Tx_BER versus receiver performance (based on OSNR penalty), as we vary each of the transmitter impairments separately (i.e. plot the curves above).
- This needs to be done for multiple representative implementations of 400GBASE-ZR Tx / Rx.
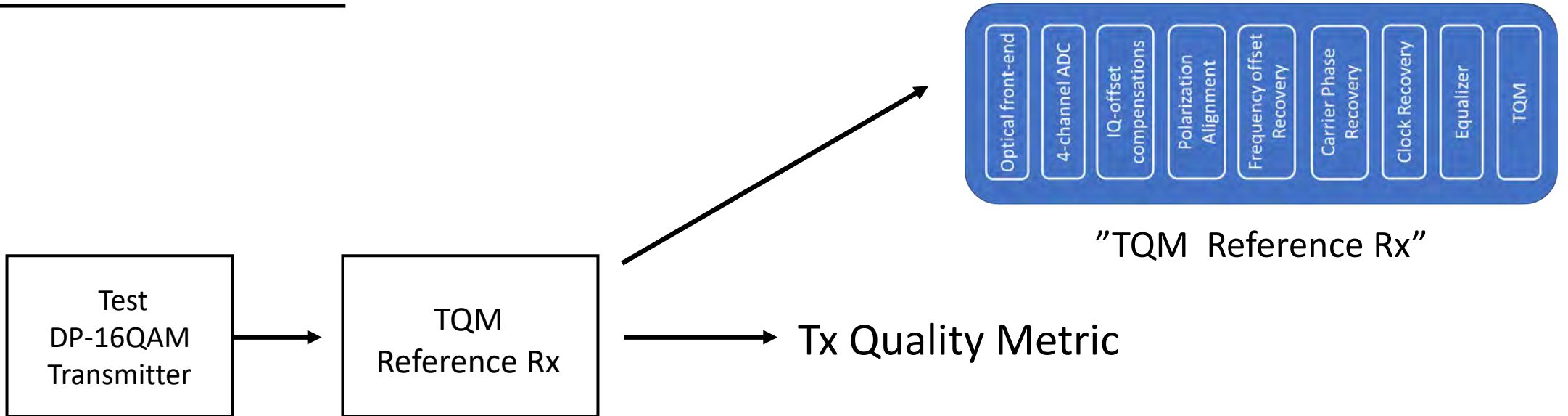
Tx_BER Summary

- Tx_BER suggested as an alternative TQM, but detailed proposal not yet provided.

- The authors of this presentation initially assumed that Tx_BER data could be collected via a common approach, as part of the same testing, and that the description of the "EVM Calculation" block could be simply changed to reflect "BER Measurement"
  - A standardized approach for measuring Tx_BER [or calculating EVM] is necessary.
  - "BER Measurement" description needed for TQM Reference Rx.

- Additional definitions for measuring Tx_BER may also be necessary, such as data pattern.

- A proposal is needed before any testing can begin.

Proposed Updates to pittala_3ct_01a_0120

- Based on current "EVM for TQM" direction
    - For this exercise, it is assumed that the Test DP-16QAM Transmitter and the DP-16QAM Receiver are from the same implementer. We need testing from multiple implementations to confirm observed trends across implementations.
    - Update test steps that as measurements are being taken the optical attenuator is adjusted to maintain a constant optical input power to the receiver
    - Need to modify proposal to allow remote / local EVM calculation
    - Sampled optical data should be captured and stored for future investigation of alternative EVM algorithms
- If there is consensus to also evaluate Tx_BER as a TQM
    - Revisit updating pittala_3ct_01a_0120

Test Setup - 2 : Measurement setup for testing TQM
Goes in the standard

"TQM Reference Rx"

```
┌──────────────┐         ┌──────────────┐
│    Test      │         │    TQM       │
│  DP-16QAM    │ ──────▶ │ Reference Rx │ ──────▶  Tx Quality Metric
│ Transmitter  │         │              │
└──────────────┘         └──────────────┘
```

- TQM is intended as a single test metric to cover multiple Tx parameters that allows implementers to make tradeoffs in their design
- TQM Test methodology is a single test
- TQM is measured by TQM Reference Rx
- OSNR is NOT measured
- Rx_BER is NOT measured

Summary

- Proposed Terminology – See Page 6

- Proposed updates to pittala_3ct_01a_0120 – See Page 12

- Definition of TQM Reference Rx
  - EVM: currently underway, leveraging industry knowledge
  - Tx_BER: needs a proposal

- Evaluation of TQM (using representative DP-16QAM Tx / Rx implementations)
  - Testing could begin now using Setup1 Option 1
  - EVM: based on current industry knowledge
  - Tx_BER: needs a proposal to define TQM Reference Rx