Description of the calculation of the extended transmitter constellation closure (ETCC) for IEEE 802.3dj

IEEE P802.3dj Task Force
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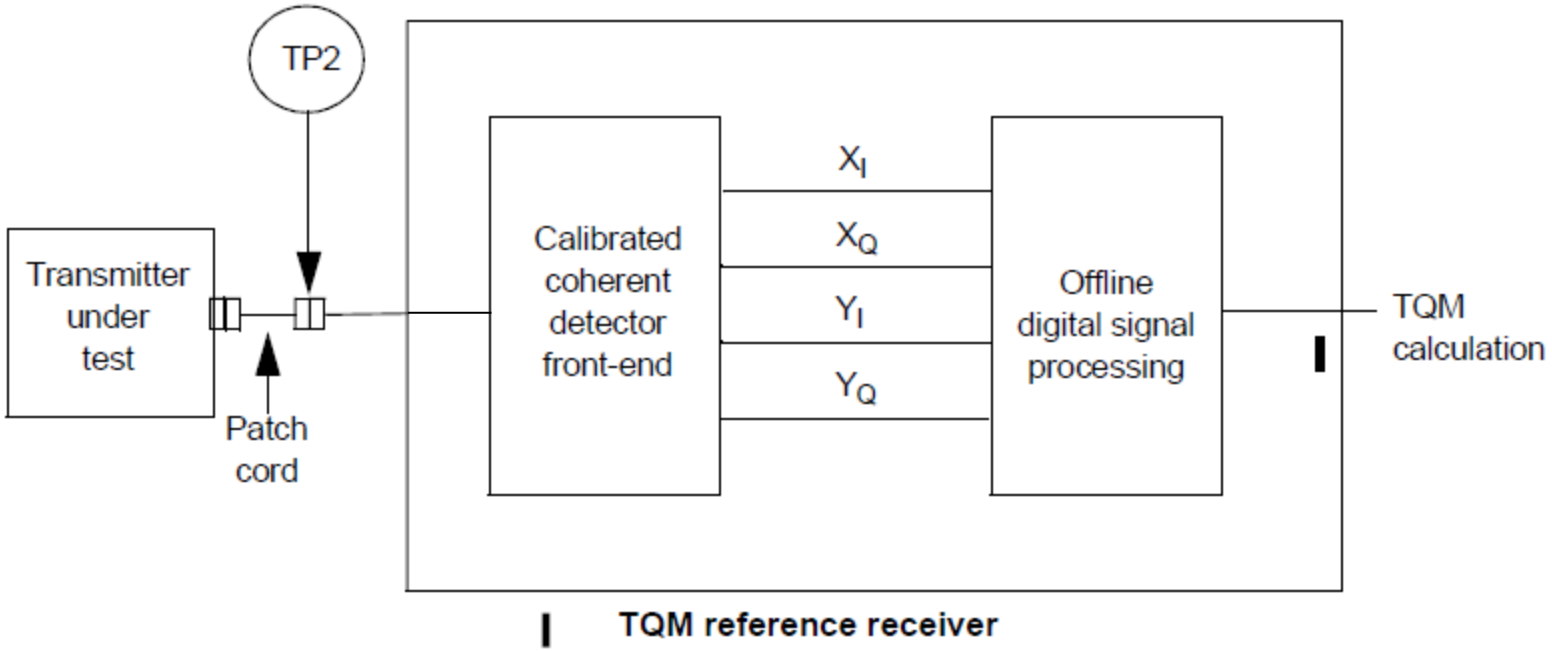
Introduction

- The following presentation addresses the following comments
  - **Comment #259** (SC 185.9) - This subclause "Transmitter quality metric (TQM) test setup and calculation" is incomplete and there is an editors note requesting contributions to help complete
  - **Comment #260** (SC 187.9) - This subclause "Transmitter quality metric (TQM) test setup and calculation" is incomplete and there is an editors note requesting contributions to help complete.
- This presentation will provide a proposed recommendation to address these comments.
- This presentation builds upon
  - "Leveraging IEEE P802.3cw Specification Approach for IEEE P802.3dj" (https://www.ieee802.org/3/dj/public/24_07/dambrosia_3dj_01_2407.pdf)
  - "Reference Receiver Design for Transmitter Constellation Closure (TCC) as a Transmitter Quality Metric (TQM) for coherent transmitters" (https://www.ieee802.org/3/dj/public/24_07/fan_3dj_02a_2407.pdf)
  - SG15-LS125, Liaison Statement – "LS/r on B400G work and EVM"
  - SG15-TD214/WP2 – "Transmitter Quality Metric (TQM) and Reference Receiver for 800G" (https://www.ieee802.org/3/private/liaison_docs/itu/Att-TD214-WP2.pdf, Note – Password needed)
  - "Transmit Quality Metric approach for Coherent Specifications" (https://www.ieee802.org/3/dj/public/24_05/maniloff_3dj_02_2405.pdf)
  - IEEE P802.3cw D3.0
  - "Transmitter Quality Metric (TQM) and Reference Receiver for 800G Being Considered in ITU-T and IEEE 802.3" (https://www.oiforum.com/bin/c5i?mid=4&rid=5&gid=0&k1=54472)
  - "Supporting Material – TQM Related Comments (259, 260) for 800GBASE-LR1, 800GBASE-ER1-20, 800GBASE-ER1" (https://www.ieee802.org/3/dj/public/24_09/issenhuth_3dj_01_2409.pdf)

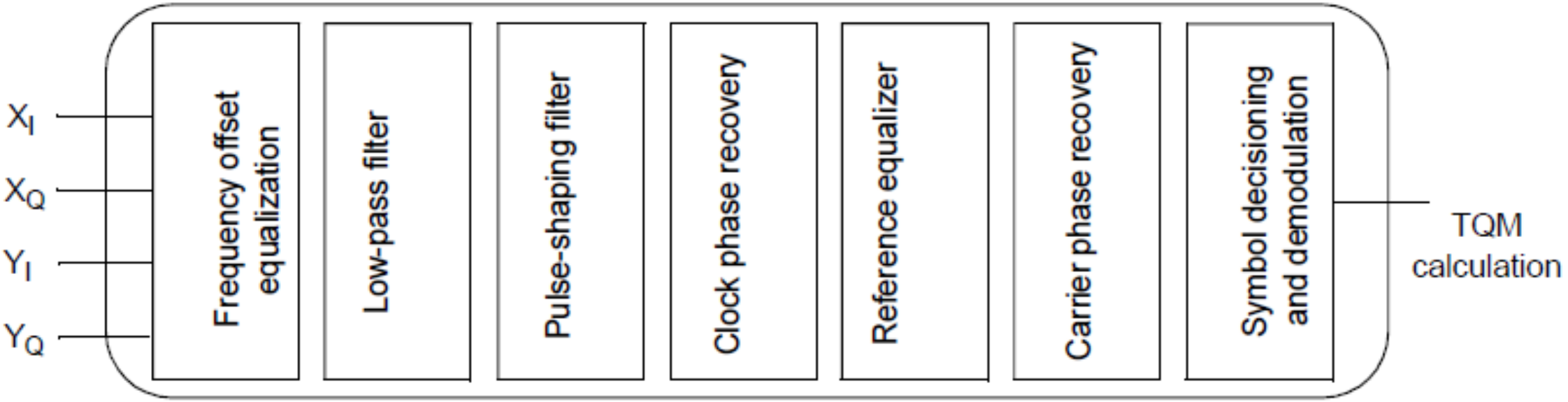
Agreements on ETCC so far (issenhuth_3dj_01_2409)

1. Utilize the document structure proposed in dambrosia_3dj_01_2407.pdf.
   - Calculate TQM Calculation for 800GBASE-LR1, 800GBASE-ER1-20, 800GBAS-ER1, as per SG15-LS125 / SG15-TD214/WP2 and maniloff_3dj_02_2405.pdf:
     a) TQM = ΔRSNRtx, Tx-only RSNR penalty (Renamed as "Extended TCC") in dB (*normative* with a maximum specification)
     b) SNRtx, ECtx in dB (*informative*)
2. Proposed Figures & associated text where appropriate
     a) TQM Test Setup
     b) Calibrated coherent detector Front End
     c) Coherent Detector Front-end
     d) Address IQ offset in coherent detector front-end (reference IEEE P802.3cw D3.0 "IQ offset per polarization")
     e) Offline Digital Signal processing
3. Implement with editorial license
4. Continued liaisons with ITU-T on TQM development efforts recommended.

TQM Test Setup (issenhuth_3dj_01_2409)



Offline digital signal processing (DSP) for TQM calculation (issenhuth_3dj_01_2409)



- Leverage descriptions for each step on Page 7 of fan_3dj_02a_2407.pdf.

ETCC Calculation – Overall flowchart

Definitions

- **The following definitions apply**
- EC_{modem}**: Eye-closure term, representing signal loss**
- S**: Signal power**
- N_{ase}**: ASE (or non-transmitter) noise power (in the signal Nyquist bandwidth)**
- N_{modem}**: Modem implementation noise power**
- NSR_{ase}**: ASE (or non-transmitter) noise-to-signal ratio**
- NSR_{modem}**: Modem implementation noise-to-signal ratio**

Notes:

1) The non-transmitter noise power is introduced digitally by virtual noise loading and includes the intrinsic frontend noise power.
2) To add additional equations to explain terms in a November 2024 contribution.

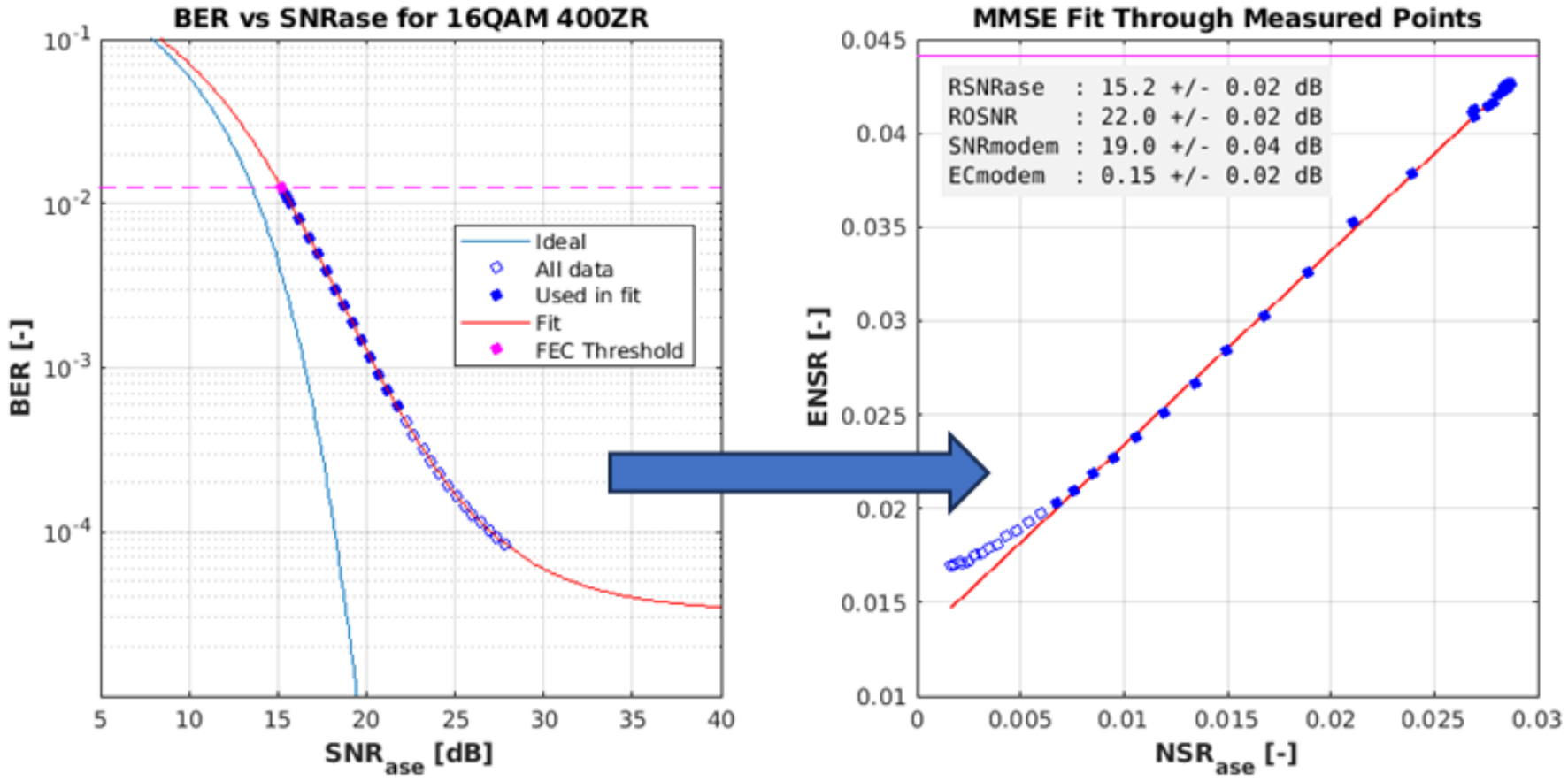
ETCC Calculation – Procedural steps

The ETCC calculation consists of the following eight procedural steps:

1. A coherent receiver frontend and a real-time sampling oscilloscope is used to acquire X_I, X_Q, Y_I and Y_Q digital waveforms.
2. Find the intrinsic frontend noise power NSRref,rx, and ECref,rx via a frontend calibration process, e.g., by using a known transmitter.
3. Estimate the BER_0 of the preconditioned test waveform from a given Tx under test (TUT). Add incremental, controlled amounts of white Gaussian noise (AWGN) with power N_{ase} to the TUT waveform and repeat the processing to estimate BER_i. Repeat N times with small enough noise increments such that $BER_i < BER_{ref}$.
4. Convert the measured BER values (BER_m) to effective noise-to-signal ratios (ENSRs) to obtain the relationship between the measured *ENSR* and NSR_{ase}.
5. Find the two parameters (a and b) that relate *ENSR* and NSR_{ase} in the linear region between BER_{ref} and $0.1 \cdot BER_{ref}$ as
   $$ENSR(BER) = a \cdot NSR_{ase}(BER) + b$$
   by using a minimum mean square error (MMSE) fit.
6. Obtain EC_{modem} and NSR_{modem} by
   $$EC_{modem} = a \text{ and } NSR_{modem} = b/EC_{modem}$$
7. Removing the Rx contribution to determine the Tx NSR and EC
   $$NSR_{tx} = NSR_{modem} - NSR_{ref,rx}\ ,\ EC_{tx} = EC_{Modem}/EC_{ref,rx}$$
8. Obtain the transmitter-only required SNR penalty ($\Delta RSNR_{TX}$) for a given BER as
   $$ETCC(BER) = RSNR_{ase}(BER)/RSNR_{Ref}(BER)$$

ETCC Calculation – An example

Pictorial representation of data collection and parameter extraction during ASE noise loading experiment (SG15-TD214/WP2)



ETCC Specifications

Table 185–13 — ETCC spec for 800GBASE-LR1

BER	ETCC
1.1E-2	≤3.4 dB

Table 185–14 — ETCC spec for 800GBASE-ER1

BER	ETCC
2E-2	≤3.4 dB