Updates on ETCC Specification for 802.3dj

Addressing comment # 246

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Overview / Related Comment

Cl **185** *SC* **185.9** *P* **537** *L* **45** *#* 246

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Comment Type **T** *Comment Status* **X**

TQM should be replaced with ETCC. More details on the implementation are needed.

SuggestedRemedy

A contribution with more details on the ETCC measurement methodology will be provided.

Proposed Response *Response Status* **O**

This contribution provides details on the TQM strategy to be implemented for the coherent PMD's in 802.3dj

Focus is on 800GBASE-LR1, however the same approach can be applied to the additional coherent specifications

TQM/ETCC Updates

Moving from the EVM approach adopted in 802.3ct & 802.3cw to a new TQM was discussed in dambrosia_3dj_01_2407.pdf

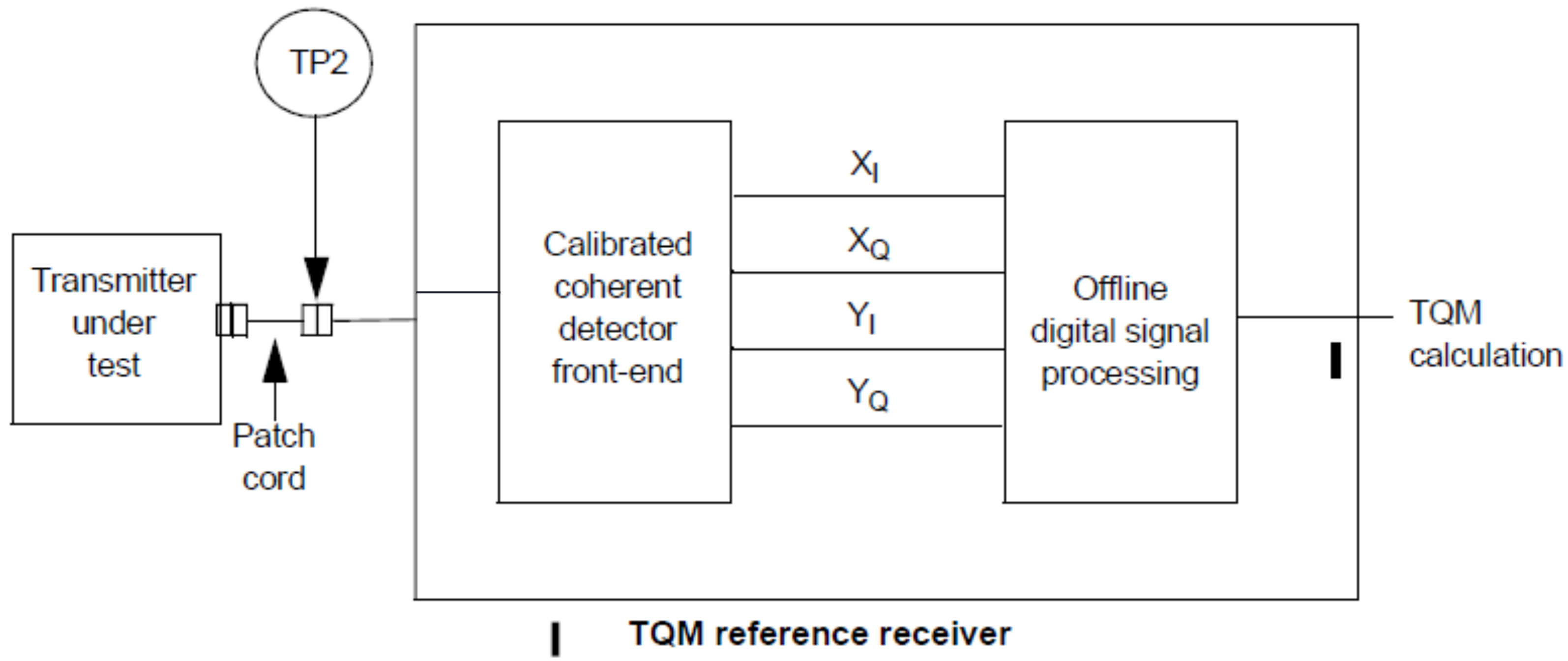
An approach to using ΔRSNR as a TQM was presented in maniloff_3dj_02_2405.pdf

- This approach has been discussed both in 802.3dj and in ITU-T Q6, and has been renamed ETCC
  - See: https://www.ieee802.org/3/dj/public/24_05/maniloff_3dj_02_2405.pdf and https://www.ieee802.org/3/dj/public/adhoc/optics/1024_OPTX/liu_3dj_optx_01_241017.pdf

This contribution provides the key information that can be included (with editorial license) in 802.3dj

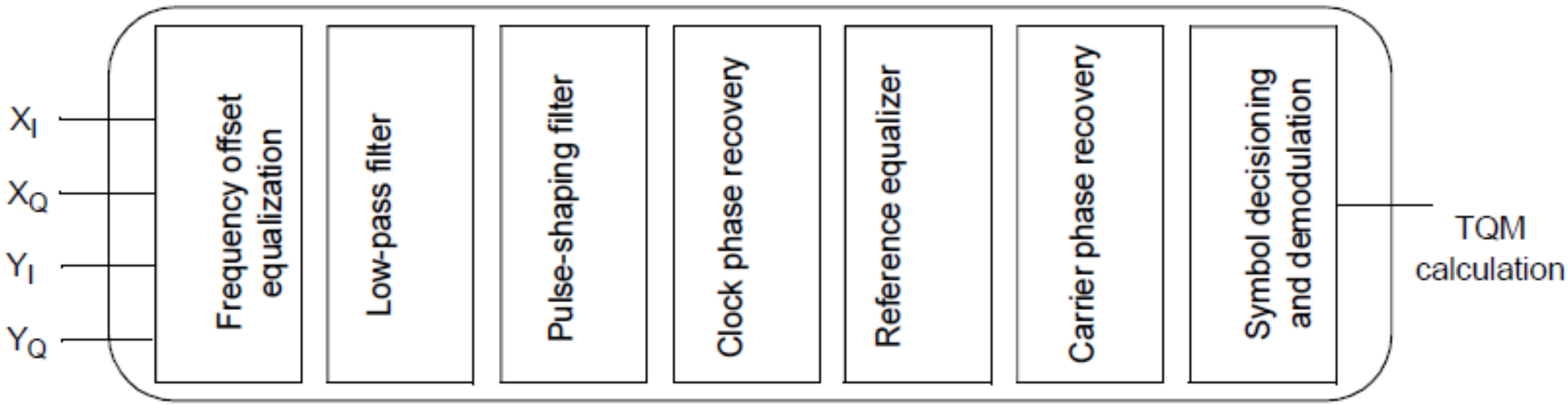
The approach described include providing sufficient detail to describe the ETCC calculation as well as the steps for ETCC measurement

TQM Test Setup (issenhuth_3dj_01_2409)



TQM will be implemented by ETCC, references to TQM will be replaced by ETCC for clause 185

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



The basic blocks that are required for a reference receiver implementation are illustrated

ETCC Calculation – Overall flowchart

Details of the procedure are presented in the following slides

In $ETCC(BER_{Ref})$, BER_{Ref} refers to the FEC threshold

BER_{ref} = 1.1E-2 for 800GBASE-LR1
BER_{ref} = 2.0E-2 for 800GBASE-ER1

ETCC-related term glossary

BER: Bit error ratio
BER_{ref}: Reference BER at the FEC input BER threshold
EC: Eye-closure term representing signal loss
EC_{TX}: Eye-closure term representing signal loss due to transmitter (TX) imperfections
EC_{RX}: Eye-closure term representing signal loss due to receiver (RX) imperfections
EC_{TRX}: Eye-closure term representing signal loss due to transmitter and receiver (TRX) imperfections
$ESNR$: Signal-to-noise ratio for the modulation format used, at the FEC input
$ESNR_{ref}$: Theoretical signal-to-noise ratio at the FEC BER threshold for the modulation format being used
N_{ASE}: Amplified spontaneous emission (ASE) noise power, or more generally non-transmitter-related noise power, in the signal Nyquist bandwidth
N_{vase}: Virtual Amplified spontaneous emission (ASE) noise power
N_{TX}: Tx noise power, including contributions from the TX implementation and physical noise sources
NSR: Noise-to-signal ratio
NSR_{ASE}: ASE (or non-transmitter) noise-to-signal ratio
NSR_{RX}: Intrinsic frontend noise power
NSR_{TX}: Tx Noise-to-signal ratio, including contributions from the TX implementation and physical noise sources
$RSNR_{(v)ASE}$: The Required SNR to meet a specified BER threshold of a device in the presence of (virtual) ASE
S: Signal power
SNR: Signal-to-noise ratio
$\Delta RSNR_{TX}$: TX-only required SNR penalty, or ETCC

ETCC Derivation

The ESNR for a Signal is related to its EC and Noise terms by:

$$\boldsymbol{ESNR} = \frac{\boldsymbol{EC_{TRX}^{-1} \times S}}{\boldsymbol{N_{ASE} + N_{TRX}}} = \frac{\boldsymbol{EC_{TRX}^{-1}}}{\boldsymbol{NSR_{ASE} + NSR_{TRX}}} \qquad (1)$$

The RSNR is related to the ESNR by:

$$RSNR_{ase} = \left(\left(EC_{\boldsymbol{TRX}} \cdot ESNR_{ref} \right)^{-1} - NSR_{\boldsymbol{TRX}} \right)^{-1} \qquad (2)$$

For an ideal device (NSR_{TRX}=0 and EC_{TRX}=1) the theoretical RSNR, is equal to the reference ESNR, $ESNR_{ref}$:

For typical modem implementations, $RSNR_{ase} > ESNR_{ref}$. Thus, the quality of a device (Transmit + Receive) may be quantified by the RSNR penalty, $\Delta RSNR_{TRX}$, due to implementation noise and eye-closure.

ETCC Derivation (continued)

ΔRSNR can be related to the EC, RSNR, and NSR_{TRX} by:

$$\Delta RSNR_{TRX} = 10 * \log 10(RSNR_{ASE}(EC_{TRX}, NSR_{TRX})/ESNR_{ref}) \quad \text{[dB]} \qquad (3)$$

$\Delta RSNR_{TRX}$ includes contributions from both the Tx and Rx. ETCC is defined by the Tx Contribution $\Delta RSNR_{Tx}$. The Tx only contributions are:

$$RSNR_{\boldsymbol{ASE},\boldsymbol{Tx}} = \left(\left(EC_{\boldsymbol{TX}} \cdot ESNR_{ref}\right)^{-1} - NSR_{\boldsymbol{TX}}\right)^{-1} \qquad \textbf{(4)}$$

$$\mathbf{ETCC} = \Delta RSNR_{\boldsymbol{TX}} = 10 * \log 10(RSNR_{\boldsymbol{ASE},\boldsymbol{Tx}}/\boldsymbol{E}SNR_{\boldsymbol{ref}}). \quad \textbf{[dB]} \qquad \textbf{(5)}$$

EC_{TRX} and NSR_{TRX} are measured using a noise loading procedure, based on captured waveforms, as described in slide 11. A set of data relating ESNR to NSR_{ASE} is created, allowing a linear fit:

$$ENSR = EC_{\boldsymbol{TRX}} NSR_{\boldsymbol{ASE}} + EC_{\boldsymbol{TRX}} NSR_{\boldsymbol{TRX}} = a \cdot NSR_{\boldsymbol{ASE}} + b \qquad \textbf{(6)}$$

ETCC Measurement

The ETCC calculation consists of the following procedural steps:

1. **A reference coherent receiver and a real-time sampling oscilloscope are used to acquire X_I, X_Q, Y_I and Y_Q digital waveforms.**
2. **The sampled waveforms are processed using the reference receiver DSP algorithm described in section 185.9 to estimate the BER with no added noise power, BER_0, of the preconditioned test waveform from a given Tx under test (TUT).**
3. **Add incremental, controlled amounts of white Gaussian noise (AWGN) with power $N_{vase,i}$ to the TUT waveform and repeat the processing to estimate BER_i. Repeat > 10 times with small enough noise increments such that $BER_i < BER_{ref}$.**
4. **For each BER_i, calculate the $ENSR_i$ and $NSR_{vase,i} = N_{vase,i}/S$, where S is the signal power of the captured dual-polarization digital waveform.**
5. **Perform a linear fit to $ENSR_i(NSR_{vase,i})$:**

   $ENSR_i = a \cdot NSR_{vase,i} + b$ **resulting in *a* and *b*.**
6. **From this fit, using Eq. 6**

   $EC_{\boldsymbol{TRX}} = \mathrm{a}$

   $NSR_{\boldsymbol{TRX}} = \mathrm{b} / EC_{\boldsymbol{TRX}}$

ETCC Measurement (2)

7. Determine the intrinsic Receiver noise power NSR_{RX}, and EC_{RX} of the calibrated coherent detector front-end via a measurement/calibration process, e.g., by using a known transmitter.

8. Determine NSR_{TX} and EC_{TX}:

$$NSR_{TX} = NSR_{TRX} - NSR_{RX}$$

$$EC_{TX} = EC_{TRX} / EC_{RX}$$

9. Using Equations 4 and 5, ETCC can be determined.

ETCC Calculation – Overall flowchart

Details of the procedure are presented in the following slides

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BER_{ref} = 1.1E-2 for 800GBASE-LR1
BER_{ref} = 2.0E-2 for 800GBASE-ER1

Summary

This contribution provides details of ETCC, intended for inclusion in 802.3dj D1.3

Additional details/definitions in the referenced contributions can be added with editorial license

Thanks!