802.3cw D1.4 Comments #30-#39
Interoperable Transmitter Metrics

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Observations

- No single metric can fully qualify a Transmitter as being compliant to the 400GBASE-ZR specification, nor determine its ability to interoperate with another vendor’s modules.
- In October 2021 the 802.3cw TF passed a motion adopting EVM Measurement Methodology for correlation for EVM TQM. https://www.ieee802.org/3/cw/tools/EVMTQM_211025.pdf
  - For this methodology, it is assumed that the DUT DP-16QAM Transmitter and the DP-16QAM Receiver are from the same implementer.
    - Requires Module vendor access to skew TX parameters independently.
  - For this methodology an EVM reference Rx is defined.
  - Test Objective is to provide correlation between the transmitter’s EVM to ROSNR penalty.
  - i.e., Transmitter EVM measured by a well-defined constellation analyzer correlates with measured ROSNR
- EVM’s expected results
  - Converge multiple TX spectral parameters into a single measurement for TX Spectral quality. EVM(max) threshold for guaranteed Interoperability.
  - Ability for manufacturer to trade-off TX parameters for maximum yield/lowest cost.
  - Identify TX parameters that are required to be independently specified. These parameters would need to be compensated by RX or Limited at TX.
  - All non-EVM parameters would be independently verified.

Current State

- EVM Status – Not qualified as a TX spectral Quality metric for 400G DP-16QAM- Limited test results submitted to date

  https://www.ieee802.org/3/ct/public/19_03/anslow_3ct_02_0319.pdf

  https://www.ieee802.org/3/ct/public/19_07/pittala_3ct_01a_0719.pdf

  https://www.ieee802.org/3/cw/public/adhoc/22_0223/rahn_3cw_01a_220223.pdf

    - ROSNR values show little correlation with EVM

  https://www.ieee802.org/3/cw/public/22_03/maniloff_3cw_01_220314.pdf

    - EVM measurements are performed unloaded
    - Required OSNR was determined using ASE noise loading
    - RX compensation loops intentionally disabled to measure impact of TX impairments on ROSNR.

  Maniloff_3cw_01_220314 does demonstrate:

  - The impact of each impairment on EVM.
  - I/Q Skew, I/Q imbalance, and Quadrature Error result in performance penalties vs Tx EVM, similar to AWGN.
    - RX OSNR penalty based on these TX values may vary by receiver
    - Correlation of EVM to ROSNR may not be feasible - Unless it is the well defined reference receiver.

  Crux of EVM as a TX Quality Metric is that the ROSNR performance is still a combination of the TX/RX performance. Vendor to vendor performance will vary. As a result, where do you define the limit?

TQM proposal:

1. Goal of P802.3cw is to define a multi-vendor interoperable specification.
2. Currently, the lack of EVM qualification as a TQM is limiting P802.3cw progress
3. Other Standards Organizations that have specified and released 400G 16QAM specifications with demonstrated interoperability by:
   - Taking a parametric approach - Fully specifying ALL Tx parameters.
   - Identifying a common set(s) of Test vectors and test methodologies.
   - Private and Independent verification of the specified parameters have occurred.
   - Public multi-vendor interop demonstrations – e.g., OFC
4. Benefits include:
   - Completely specified TX. No ambiguity on parameters required for interoperability.
5. EVM qualification can proceed in parallel.
   - EVM remains a promising approach that would allow a TQM to be measured while allowing greater design flexibility.
   - Eventual Realization of EVM as a TX quality Metric, along with its benefits and goals.

Recommendation:

- Progress the 802.3cw specification by fully specifying the TX as outlined in this presentation.
  - This proposal removes EVM methodology as a hurdle to progressing the 802.3cw draft.
  - Adoption of this proposal may accelerate EVM definition by fully defining TX parameters.
- Include clear TX Metric definitions and Test Methodologies for the following TX parameters:
  - TX Clock Phase Noise – (See 802d3cw_D1.4 review comment #30-33 and details on pgs. 7-10).
  - Specify I/Q parameters – (See 802.3cw_D1.4 review comments #34-37 and details on pg. 11
- Recommendation: Adopt TX parameters specified on pgs. 8-11.
- Maintain EVM test and measurement methodology in 802.3cw as informational/directional.
  - Adoption of EVM remains possible at a later stage with more contributions and consensus building.

Comment #30: Error Vector Magnitude

Remove from Table 156-6 400GBASE-ZR transmit characteristics: Error Vector Magnitude (max)

~~Error vector magnitude (max)~~	~~TBD~~	~~%~~

Alternative to removal - Table 156-6 400GBASE-ZR transmit characteristics: Error Vector Magnitude (max)

Error vector magnitude (max)[1]	<under study> (See 156.9.10)	%

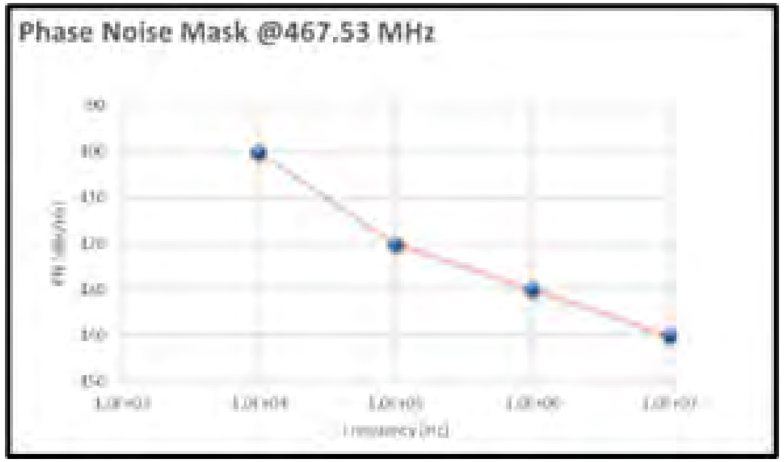
[1]Error Vector Magnitude (max) is an informative Tx quality metric that is under study for future consideration. EVM is not a requirement for compliance.

Comment #31: TX Clock Phase Noise

Add to Table 156-6 400GBASE-ZR transmit characteristics: Tx Clock Phase Noise – Maximum PN mask

Tx Clock Phase Noise - Maximum PN mask	See mask	dBc/Hz

Add Mask and definition to 156.9.x: Tx Clock Phase Noise – Maximum PN mask



PN [dBc/Hz]	Frequency [Hz]
-100	1.00E+04
-120	1.00E+05
-130	1.00E+06
-140	1.00E+07

Phase noise, $\mathcal{L}(f)$, $\mathrm{f_c} = \frac{\mathrm{f_{baud}}}{128} = {\sim}467.53\ \mathrm{MHz}$ Mask does not apply to spurs, broadband phase noise only. Spurs are considered separately.

Comment #32: TX Clock Phase Noise (cont.)

Add to Table 156-6 400GBASE-ZR transmit characteristics: TX Clock Phase Noise – Maximum Total Integrated RMS phase jitter between 10Khz and 10 MHz

TX Clock Phase Noise- Total Integrated RMS phase jitter between 10KHz and 10 MHz (max)	600	fs

Add Definition to 156.9.x: TX Clock Phase Noise – Maximum Total Integrated RMS phase jitter between 10Khz and 10 MHz:

rms random jitter: $\sigma_{rj} = \frac{1}{2\pi f_c}\sqrt{2 \cdot \int_{f_1}^{f_2} 10^{\frac{\mathcal{L}(f)}{10}} df}$ rms periodic jitter (spurs): $\sigma_{pj,i} = \frac{1}{\sqrt{2}\pi f_c} \cdot 10^{\frac{s_i}{20}}$

where, $\mathrm{f_1} = 10\mathrm{kHz}$, $\mathrm{f_2} = 10\mathrm{MHz}$, $\mathrm{f_c} = \frac{\mathrm{f_{baud}}}{128} = \sim 467.53\mathrm{MHz}$, $\mathcal{L}(\mathrm{f}) = \text{phase noise (PN)}$,

$s_i = \text{individual spur in [dBc]}$rms total jitter: $\sigma_{tj} = \sqrt{{\sigma_{rj}}^2 + \sum_{i=1}^{N} {\sigma_{pj,i}}^2}$

where, $\mathrm{N} = \text{total number of spurs.}$

Comment #33: TX Clock Phase Noise (cont.)

Add to Table 156-6 400GBASE-ZR transmit characteristics: TX Clock Phase Noise – Maximum Total Integrated RMS phase jitter between 1MHz and 200MHz

TX Clock Phase Noise- Total Integrated RMS phase jitter between 1MHz and 200 MHz (max).	250	fs

Add Definition to 156.9.x: TX Clock Phase Noise – Maximum Total Integrated RMS phase jitter between 1MHz and 200MHz.

rms random jitter: $\sigma_{rj} = \frac{1}{2\pi f_c}\sqrt{2 \cdot \int_{f_1}^{f_2} 10^{\frac{\mathcal{L}(f)}{10}} df}$

rms periodic jitter (spurs): $\sigma_{pj,i} = \frac{1}{\sqrt{2}\pi f_c} \cdot 10^{\frac{s_i}{20}}$

where, $\mathrm{f}_1 = 1\mathrm{MHz}$, $\mathrm{f}_2 = 200\mathrm{MHz}$, $\mathrm{f_c} = \frac{f_{baud}}{128} = 467.53MHz$, $\mathcal{L}(\mathrm{f}) = \text{phase noise (PN)}$, $s_i = \text{individual spur in [dBc]}$

rms total jitter: $\sigma_{tj} = \sqrt{{\sigma_{rj}}^2 + \sum_{i=1}^{N} {\sigma_{pj,i}}^2}$

where, $\mathrm{N} = \text{total number of spurs.}$

Comments # 34-37 I/Q Parameters

Add to Table 156-6 400GBASE-ZR transmit characteristics:

I/Q Phase error (min)	-5	deg
I/Q Phase error (min)	+5	deg
I/Q Quadrature Skew (max)	0.75	ps
I/Q Amplitude Imbalance (mean)	1	dB

Add Definitions to 156.9.x:

I/Q Phase error – The difference in phase of a measured I/Q signal and a reference IQ signal. E.g., as determined by a VSA

I/Q Quadrature skew –

I/Q Amplitude Imbalance – To be added