Transmitter Metric for 400GBase-ZR Interoperability

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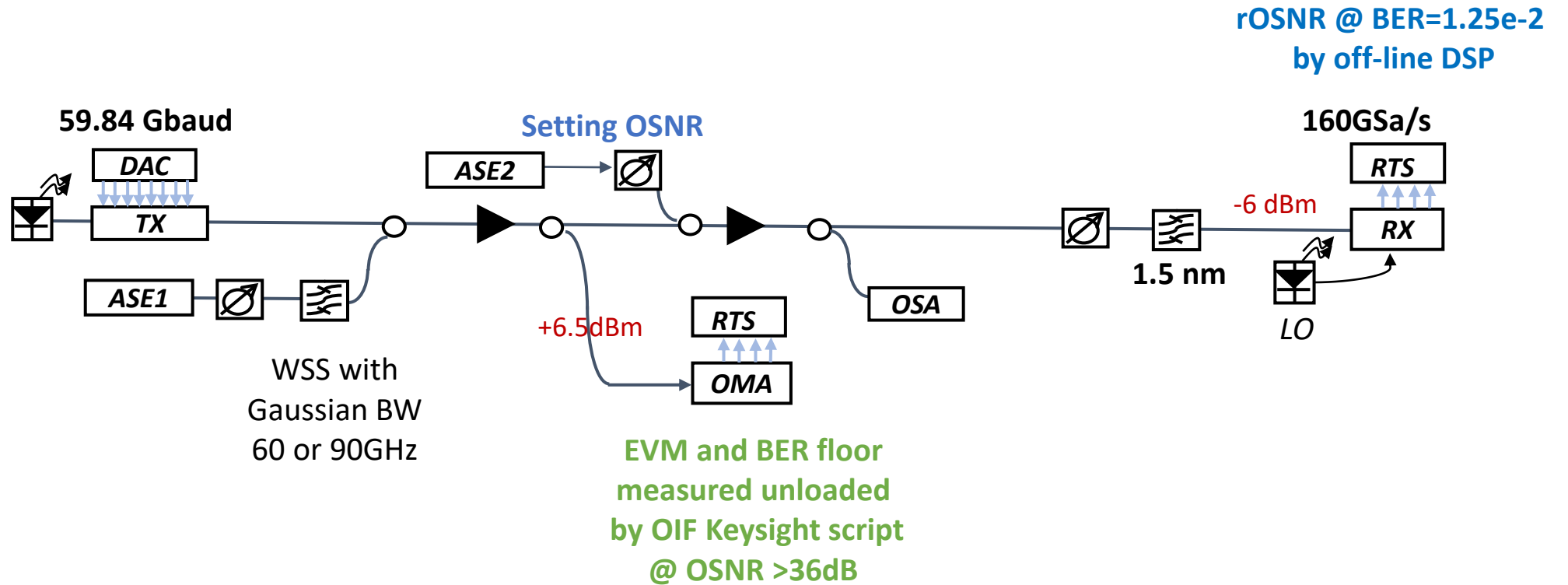
IEEE 802.3cw

*Now with MediaTek

Background

- Rahn_3cw_01a_220223.b showed that by interoperating 3 vendors' modules, loopback ROSNR is a good prediction of paired ROSNR *(EVM 8.7~10.2% (RRC 0.2), 10~11.4% (no filter))*

- Maniloff_3cw_01_220314 measured ROSNR vs EVM for TX IQ transmitter impairments *(EVM baseline ~12% and 10~11% in two different slides)*

- Williams_3cw_01_220516 measured ROSNR penalty vs EVM for TX IQ transmitter impairments *(EVM baseline 9.5-10.5% for 7 taps with no RRC, and 5-6% for 35 taps RRC=0.2)*

- For the above two references, a reference receiver based on OMA and OIF Keysight DSP script was used

- Way_3cw_01_210721 proposed BER floor as a TX metric for interoperability

- Nicoll_3cw_01a_210809.pdf asked for a reference receiver for TX_BER

Measurement Setup

rOSNR @ BER=1.25e-2
by off-line DSP

59.84 Gbaud

160GSa/s

DAC

RTS

TX

RX

ASE1

Setting OSNR

ASE2

-6 dBm

LO

WSS with
Gaussian BW
60 or 90GHz

+6.5dBm

RTS

OMA

OSA

1.5 nm

EVM and BER floor
measured unloaded
by OIF Keysight script
@ OSNR >36dB

TX Impairments Tested

- IQ skew [0-2.5] ps

- IQ imbalance [0-1.5] dB

- IQ quadrature error: [0-10] degrees

- AWGN

- Driver nonlinearity with optimum driver setting

- Each impairment is measured with all other impairments minimized*
- EVM and BER floor** are measured using OIF Keysight script* with 15 AE taps
- ROSNR was obtained via an off-line DSP (which closely emulate actual 400ZR modules) without TX IQ impairment compensations

*TX IQ impairments were measured when TX output power is set to -15.5dBm to ensure drivers are in the linear operating range.
  TX nonlinearity and TX IQ impairments were measured with ASE1 turned off. Gaussian noise was measured with all TX IQ impairments
  tuned to minimum and TX output power set to -15.5dBm.
**To evaluate BER from the OIF Keysight script, the reference file (contains repeated 38400 random symbols) for calculating BER should
be correlated with each output block of the **removeImpairments(…,** blockSize**, …)** function within the OIF Keysight script.
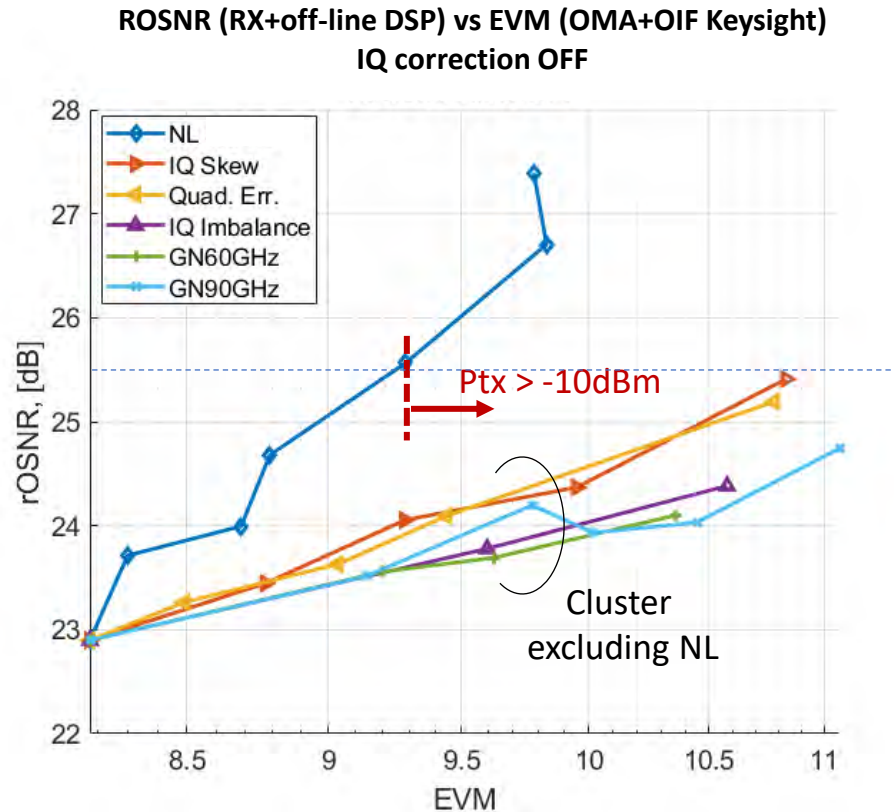Note: Actual output block is shorter than specified by the block-size parameter.
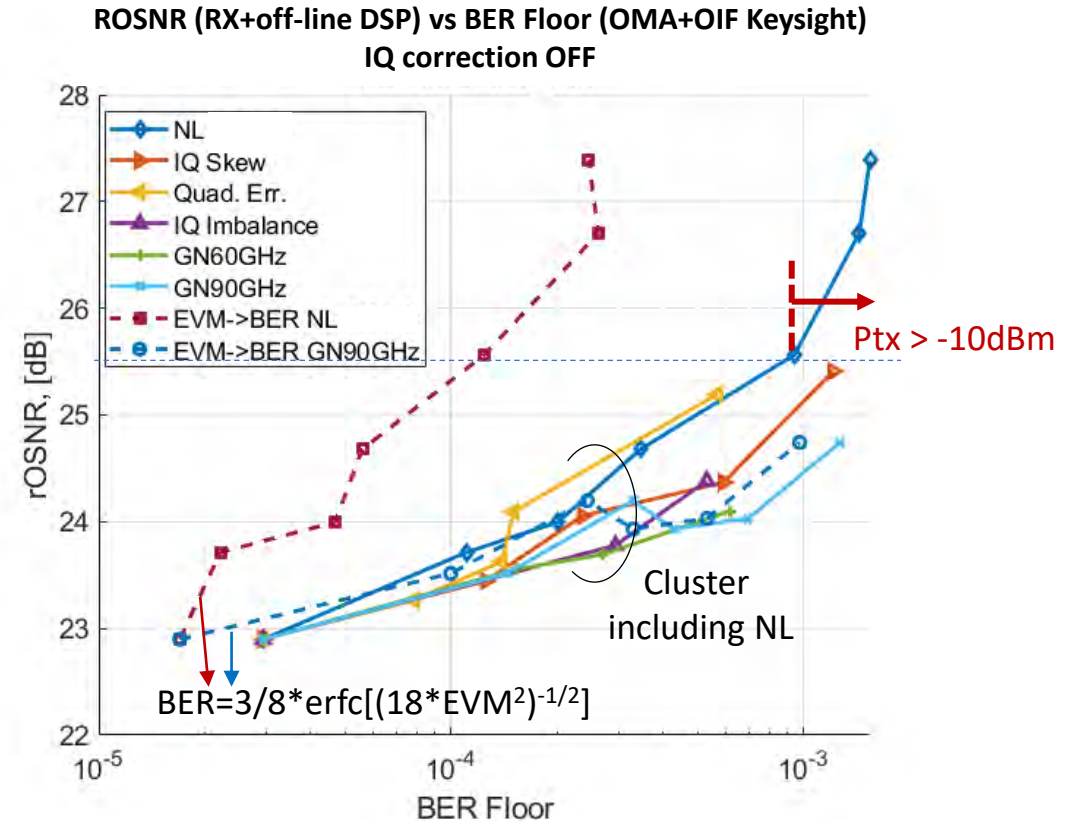
Overview of Measured Results

- Both <u>unloaded</u> EVM and BER floor* are linearly proportional to ROSNR for receivers with or without TX IQ impairment compensations. If ROSNR is a good indicator for interop (Rahn_3cw_01a_220223.b), both EVM and BER floor should be good metrics to qualify TX.

- However, for a silicon photonics-based 400GBase-ZR transmitter (TX) with an optical output power (Ptx) ≥ -10dBm, driver nonlinearity dominates the EVM performance. For the same EVM, driver nonlinearity causes much higher ROSNR than TX IQ impairments or Gaussian noise.

- Using BER floor* as the TX metric to replace EVM allows more converged results with TX IQ/GN impairments. This is due to the fact that unloaded BER is less sensitive to nonlinearity-induced constellation displacement than EVM. The converged results make a single pass/fail BER floor value feasible.

*BER floor is defined as the BER for a back-to-back TX and an OMA-based reference receiver.

ROSNR vs EVM/BER Floor (SiP PMQ modulator)

**ROSNR (RX+off-line DSP) vs EVM (OMA+OIF Keysight)
IQ correction OFF**

Curves due to TX IQ/GN impairments are clustered together, while the curve due to NL is distinct and shows much higher ROSNR for the same EVM. For example, if one requires ROSNR=25.5dB, Ptx > -10dBm, the pass/fail EVM thresholds for NL and TX IQ impairments are very different: 9.25% vs 11.5%.

**ROSNR (RX+off-line DSP) vs BER Floor (OMA+OIF Keysight)
IQ correction OFF**

The NL curve moves to within the cluster of TX IQ/GN impairment curves, which makes it possible the selection of a single pass/fail BER. This is due to the fact that unloaded BER is less sensitive to nonlinearity-induced constellation displacement than EVM, and is evidenced by the BER directly converted from EVM (dashed lines, based on AWGN).
If one requires ROSNR=25.5dB, Ptx > -10dBm, the pass/fail BER floor for all impairments are within a small range of ~1e-3 to ~2e-3.

400ZR BER Floors of Multiple Vendors Tested by End Users

- ## Google (Mark Filer, OIF Panel, OFC'22)

  Full C-band TX/RX frequencies, received optical power -12 to 0dBm, full TX power range

  0km: BER= 10^{-4} ~ 3×10^{-3} @ OSNR=40dB

  100km: BER= 10^{-3} ~ 6×10^{-3} @ OSNR=40dB

- ## Microsoft (B. Guan and Y. Yin, "400ZR: A view from the "Clouds"", LightReading Optical Networking Digital Symposium, Feb 16 2021)

  80km: 5×10^{-4} ~ 2×10^{-3} @ OSNR~37dB

Summary

- To qualify 400GBase-ZR TX with a single pass/fail metric value, pre-FEC BER floor is shown to be a more suitable metric than EVM for interoperability. This is especially true when driver/MZM nonlinearity plays a dominant role.

- We have used the same OMA and OIF Keysight DSP to obtain both EVM and pre-FEC BER floor. The Keysight EVM estimation can be modified to get pre-FEC BER floor by comparing the received data to a reference data with repeated 38400 random symbols.

- Exact pass/fail BER floor number needs more discussion and should consider the performance of the modules on the market today.