What Problem Jitter Solves for Optical Transmitters

(Comments 256, 257, 258, 259)

Ali Ghiasi - Ghiasi Quantum/Marvell

Fred Tang – Broadcom

Karl Muth – Broadcom

Marco Mazzini – Cisco

Vasu Parthasarathy – Broadcom

IEEE 802.3dj Plenary Meeting

Bangkok

November 10, 2025

Overview

- **Section – I**
  - Background
  - Concern with transmitter block errors
- **Section – II**
  - EECQ/TDECQ as function of input jitter
- **Section – III**
  - FRx results
- **Section – IV**
  - Ailments and remedies
- **Summary.**

Section I – Problem Statement

Background on Improving Optical Transmitters Quality Metric

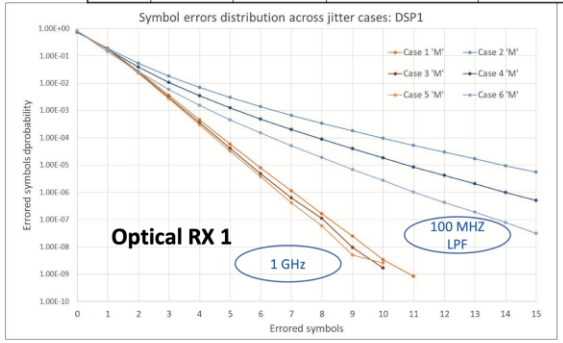
- **Ghiasi_3dJ_01_2501 proposes several enhancements to TDECQ method**
  - Testing TDECQ in mission mode – added to D1.5
  - Adding counter propagating traffic during TDECQ test – added to D1.5
- **Mazzini OIF 2024.449.02 showed due to bandlimited RJ later presented some of the same material in 802.3dj by ran_3dj_elec_01_240822 may result in block errors for compliant transmitters**
  - Mazzini had to use Functional Rx to determine bad transmitter that had good average TDECQ
    - Jitter and phase noise measurement wouldn't identify the smoking gun
  - The fundamental issue with current TDECQ test method is that provides average TDECQ penalty over ~ 1 seconds where jitter perturbations are averaged out
  - Block TDECQ proposed by ghiasi_3dj_03_2501 would be able to identify any problematic transmitters but due to cost of real time scope task force voted for FRx in Madrid
  - CER TDECQ chayeb_3dj_01b_2509 based on the concept of Block TDECQ enhances TDECQ by accurately computing code word error rate and works for both sampling and real time scopes
- **In Minneapolis meeting ran_3dj_04_2509 jitter proposal was accepted to supplement TDECQ!**

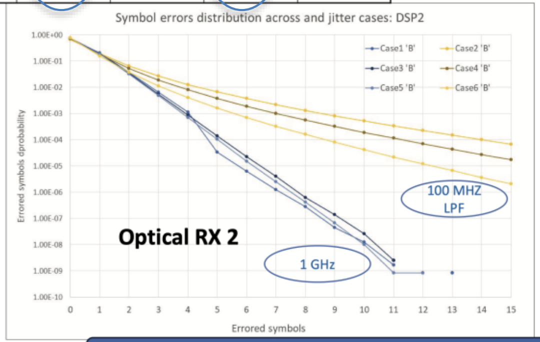
Concern Raised on Optical Transmit Jitter

- **Concern raised that high phase noise in the 4-100 MHz may cause error floor, see ran_3dj_elec_01_240822**
  - What is not clear if receive DSP/modules were operated at min designed OMA or at levels lower to get a BER floor then pump concentrated RJ or SJ in the 4-100 MHz band to further degrade the error floor
  - Comparing Odd (LPF off good) vs Even (LPF on bad) cases even the use of integrated phase would be difficult to identify bad from good transmitters
  - There seem to be an issue with the measurement as the reported SNR of ~22.5 dB for filter on/off should result in much better BER than ~4E-5 irrespective of jitter!

Symbol Error Distribution SKU: NA21G

CASE	Frequncy [MHz]		Random Jitter Relative Power Density	SECQ [dB]	Optical RX 1		Optical RX 2	
	HPF	LPF			BER	Symbol Error	BER	Symbol Error
1	OFF	OFF	1	3.33	4.61E-05	13	3.94E-05	11
2	OFF	100	~10	3.33	5.83E-05	> 16	5.02E-05	> 16
3	20	OFF	~1	3.27	4.36E-05	11	3.77E-05	10
4	20	100	~10	3.39	4.94E-05	> 16	4.11E-05	> 16
5	10	OFF	~1	3.33	4.22E-05	12	3.64E-05	10
6	10	100	~10	3.4	3.96E-05	> 16	3.29E-05	> 16

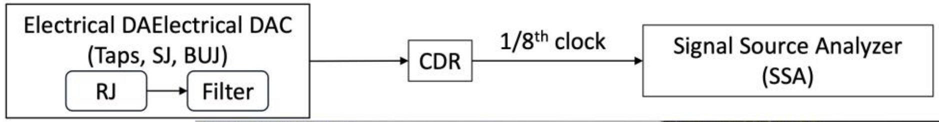




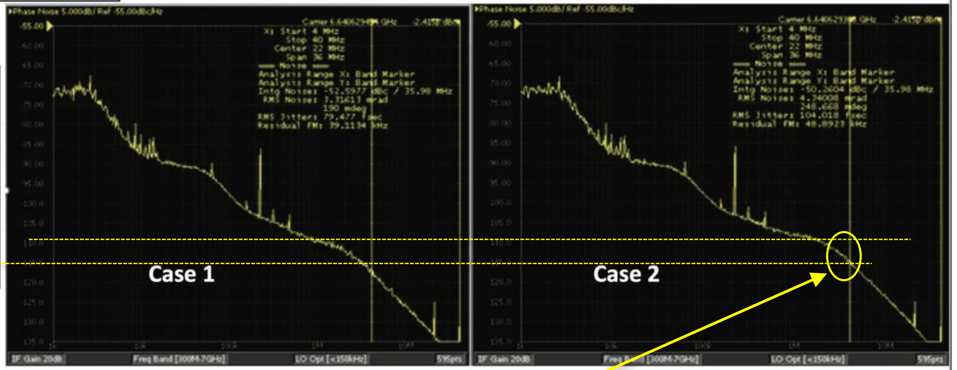
Content provided by Marco Mazzini and Yi Tang

2024-08-22 IEEE P802.3dj Electrical ad hoc 5

Jitter Characterization of Test Cases



CASE	Frequency [MHz]		RJ_{RMS} [fs]
	HPF	LPF	(4MHz - 40MHz)
1	OFF	OFF	79.5
2	OFF	100	104
3	20	OFF	76
4	20	100	93.5
5	10	OFF	75.7
6	10	100	87



Content provided by Marco Mazzini and Yi Tang

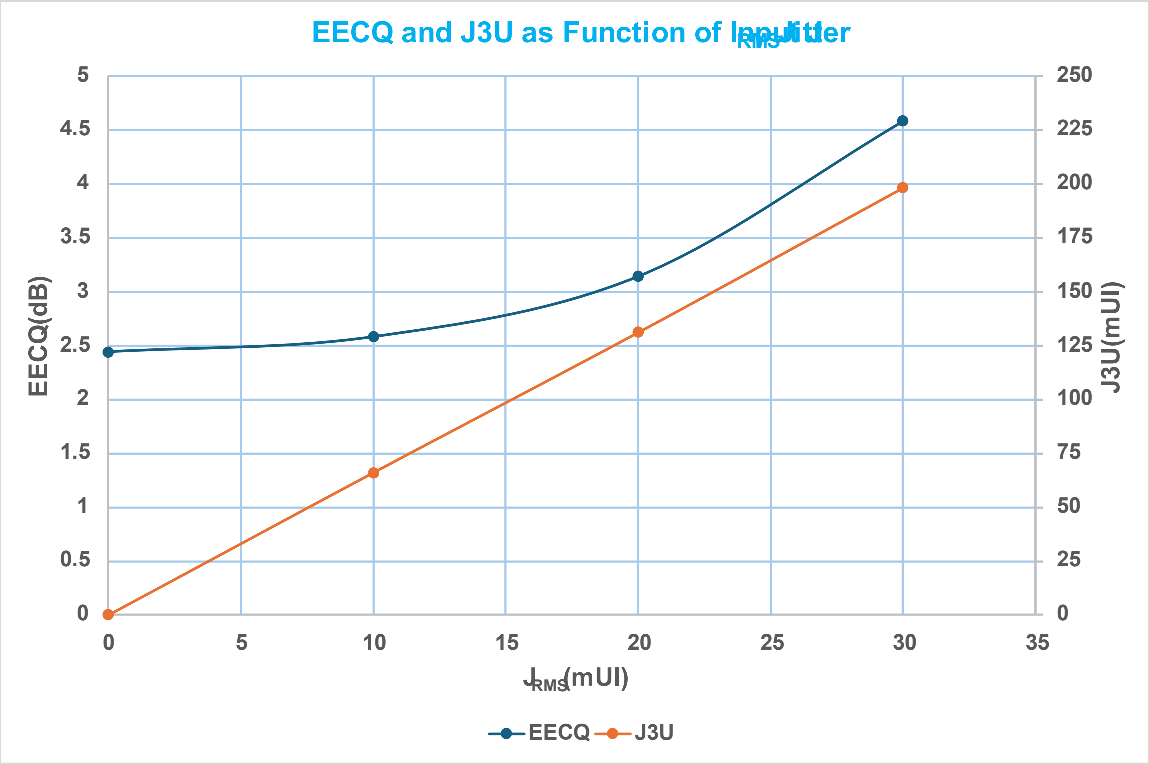
2024-08-22 IEEE P802.3dj Electrical ad hoc 6

Tiny amount of phase noise increase results in error floor

Section II – Jitter Measurements

EECQ/TDECQ Correlation to Input Jitter

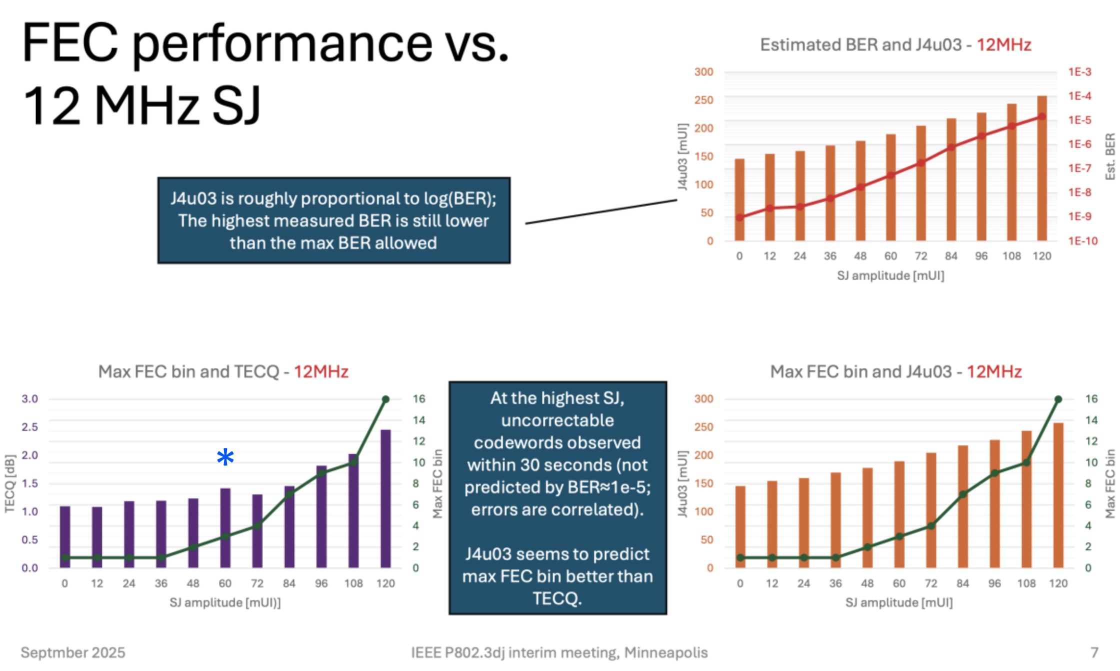
- **For full simulation results, see [ghiasi_3dj_01a_2409]**
- **Simulation show that there is strong correlation between EECQ/TDECQ and J3U as function of input JRMS**
  - J3U is a redundant measurement that is less effective than EECQ/TDECQ measured with a more representative SSPRQ pattern
  - For TDECQ>1.5 dB, TDECQ and J3U have 1-to-1 relationship
- **EECQ/TDECQ are very effective to capture average jitter/noise**
  - However neither TDECQ (except CER_TDECQ with Realtime Scope) or J_{RMS}/EOJ/J4u will identify problematic transmitter reported by [Mazzini OIF 2024.449.02] !

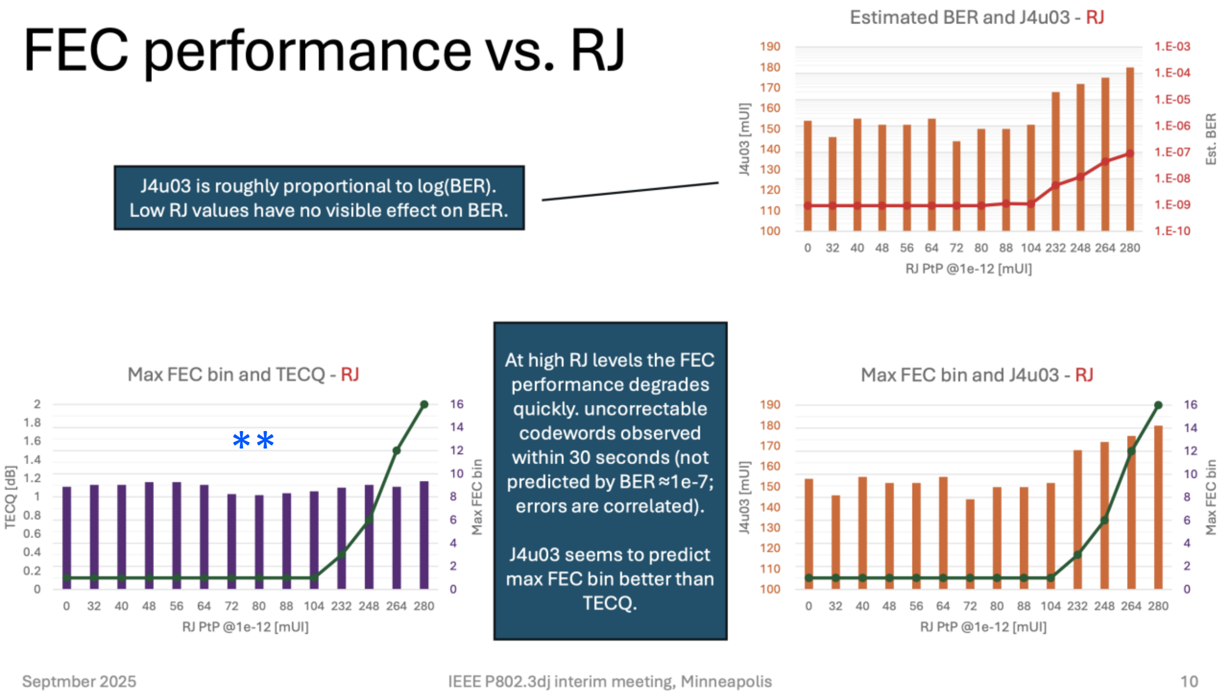


TDECQ=1/2 of EECQ

TECQ and Jitter Measurements

- **[ran_3dj_04_2509] used an 8x100GBASE-DR1 LPO module plugged in to an MCB and driven from a pattern generator with jitter injection to determine if jitter is better metric than TECQ**
  - TECQ at ~1.3 dB start having correlation with input SJ which is as expected given fairly open eye, see *
  - TECQ with low probability (1E-12) RJ is flat with increasing RJ as expected, see **
    - The main reason FRx was added to identify failing transmitter that may have low probability events
  - With combination of TDECQ and FRx not clear what problem output jitter tests (J_{RMS}, EOJ_{03}, and $J4u_{03}$) are solving!

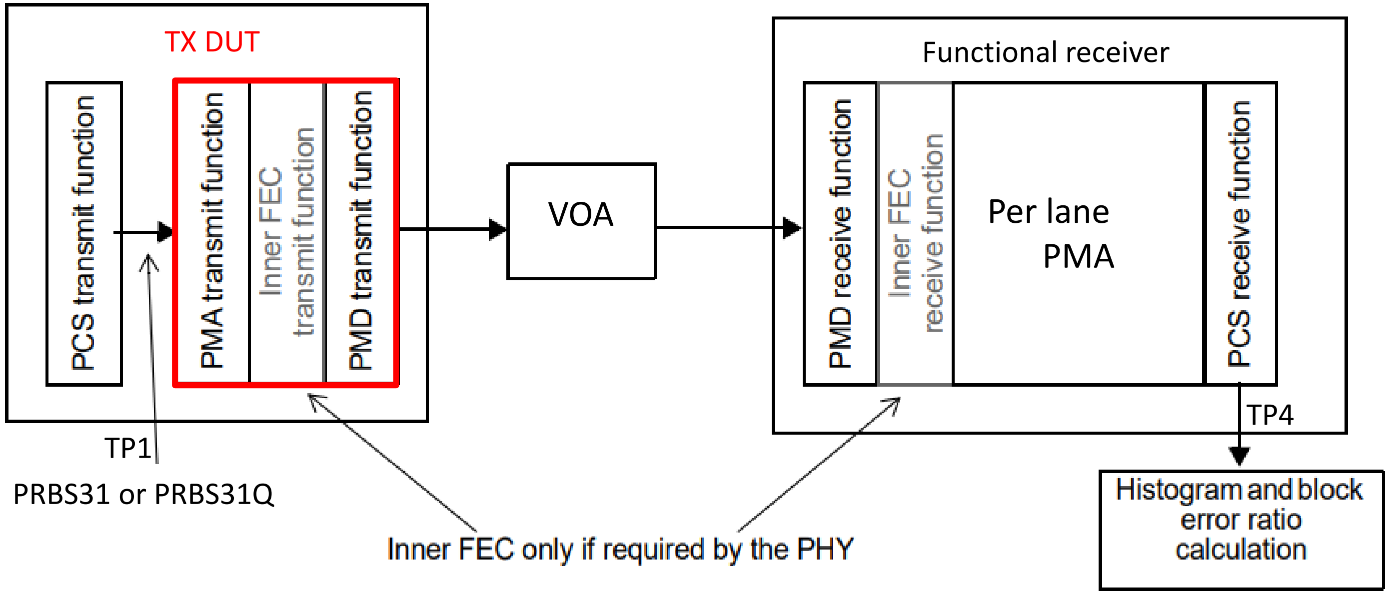


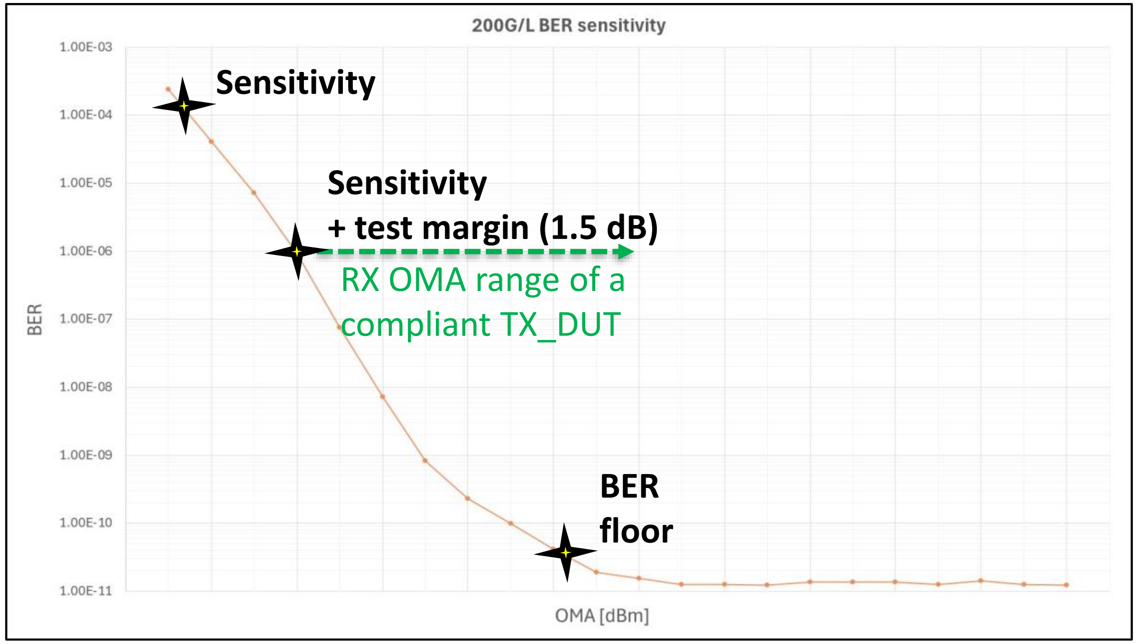


Section III – Functional Receiver

FRX Definition

- Following cole_3dj_01e_2507 proposal, Transmitter functional symbol error mask test were adopted 802.3dj
- Due to concerns that functional RX hardware should not introduce intrinsic errors the VOA adjusted at +1.5 dB above the RxS sensitivity
  - Given that FRx operating 1.5 dB above the sensitivity it may not do well discriminating between shades of gray but is very effective to identify bursts and high block errors!





Functional Receiver Mask

- **Production 200G-DR8 modules operated in loopback mode**
  - SiPho Module with TECQ of 1.2 dB (DFE on)
  - EML Module tuned to have TECQ of 3.8 dB (DFE on)
- **Transmitter functional error histogram 180.9.9**
  - FRx operated at +1.5 above RxS
  - Pre-FEC BER=2.4E-5 with P=1
  - Use equation 180-27, 180-28, 180-29, and 18—30 to calculate the VOA attenuation, see table on the next page
- **A compliant transmitter must meet the FRx mask in table 180-18**

Table 180–18—Transmitter functional symbol error mask

Test symbol errors per test block, *k* (see 174A.9.5)	Probability $H_{max}(k)^{a,b}$
1	1.15×10^{-1}
2	7.47×10^{-3}
3	3.24×10^{-4}
4	1.05×10^{-5}
5	2.73×10^{-7}
6	5.88×10^{-9}
7	1.08×10^{-10}
8	1.75×10^{-12}
9	3.5×10^{-13}
10	3.5×10^{-13}
11	3.5×10^{-13}
12	3.5×10^{-13}
13	3.5×10^{-13}
14	3.5×10^{-13}
15	3.5×10^{-13}
16	3.5×10^{-13}

Functional Receiver FRx Testing with 200G-DR8 Production Optics

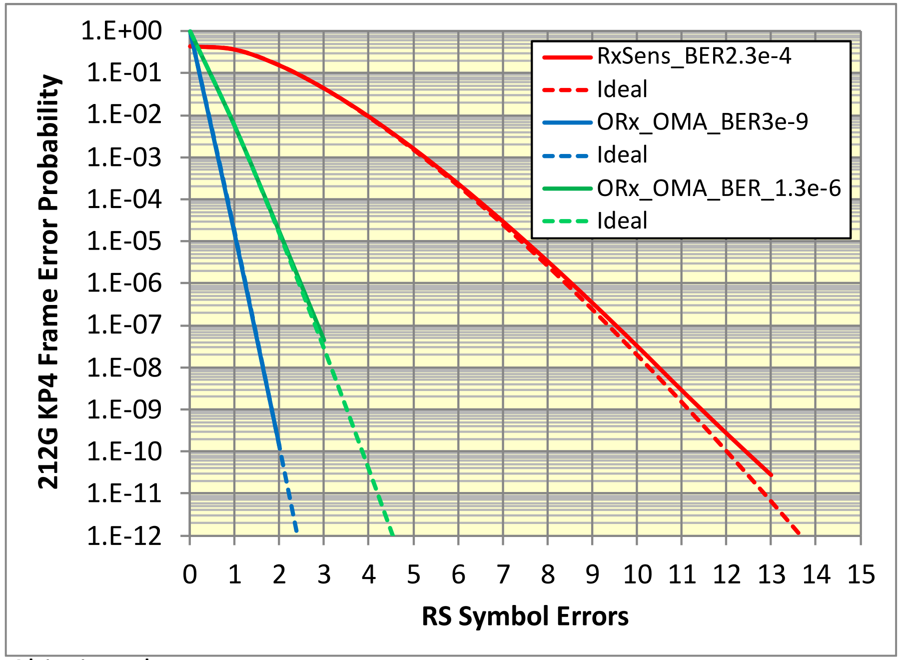
- **Reference transmitter had TECQ of 1.2 dB then FRx was configured to operate +1.5 dB above RXs**
  - For details see the table below

DR8 Optics	TECQ	TDECQ	max(TECQ, TDECQ)	margin	OMA dBm	actual			estimated			ORx_RxS @DUT _TECQ	Test _margin	VOA _level	ORx _OMA dBm	Test _margin _error
						loss	MPI+DGD	DUT_CD	loss	MPI+DGD	DUT_CD					
Sipho Tx	1.2	n/a	1.2	1.5	1.7	0.0	0.0	0.0	0.0	0.0	0.0	-6.8	1.5	5.5	-3.8	0.0
EML Tx	3.9	n/a	3.9	1.3	4.1	0.0	0.0	0.0	0.0	0.0	0.0	-4.3	1.5	5.7	-1.5	0.0

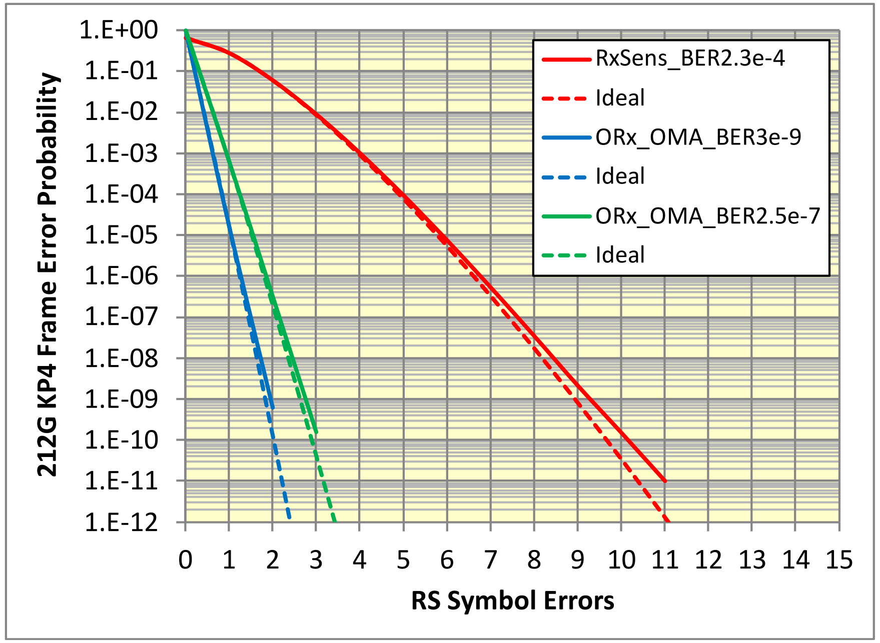
Test_margin_error = (ORx_OMA = Tx_DUT_OMA - Test_SMF_actual_loss - VOA_level) - (ORx_RxS@actual_TECQ + Test_SMF_actual_MPI+DGD+DUT_CD_penalty + Tx_margin + Test_margin)

Data courtesy of Fred Tang Broadcom

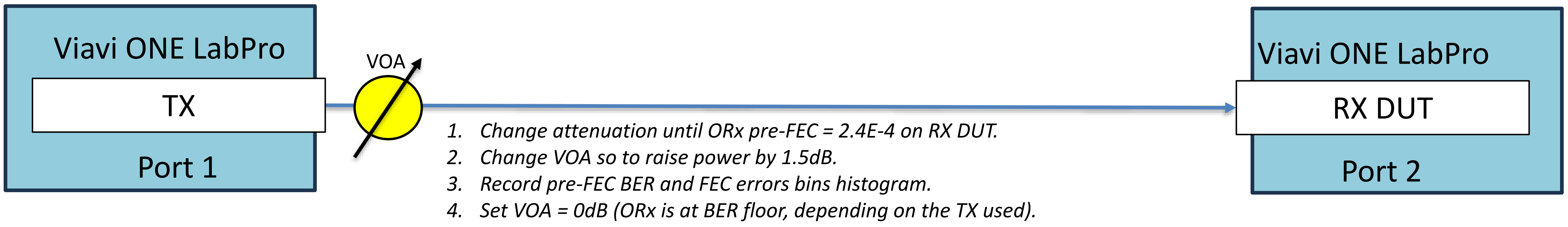
Sipho Tx



EML Tx



Transmitter functional symbol error test Setup-2nd set of Data

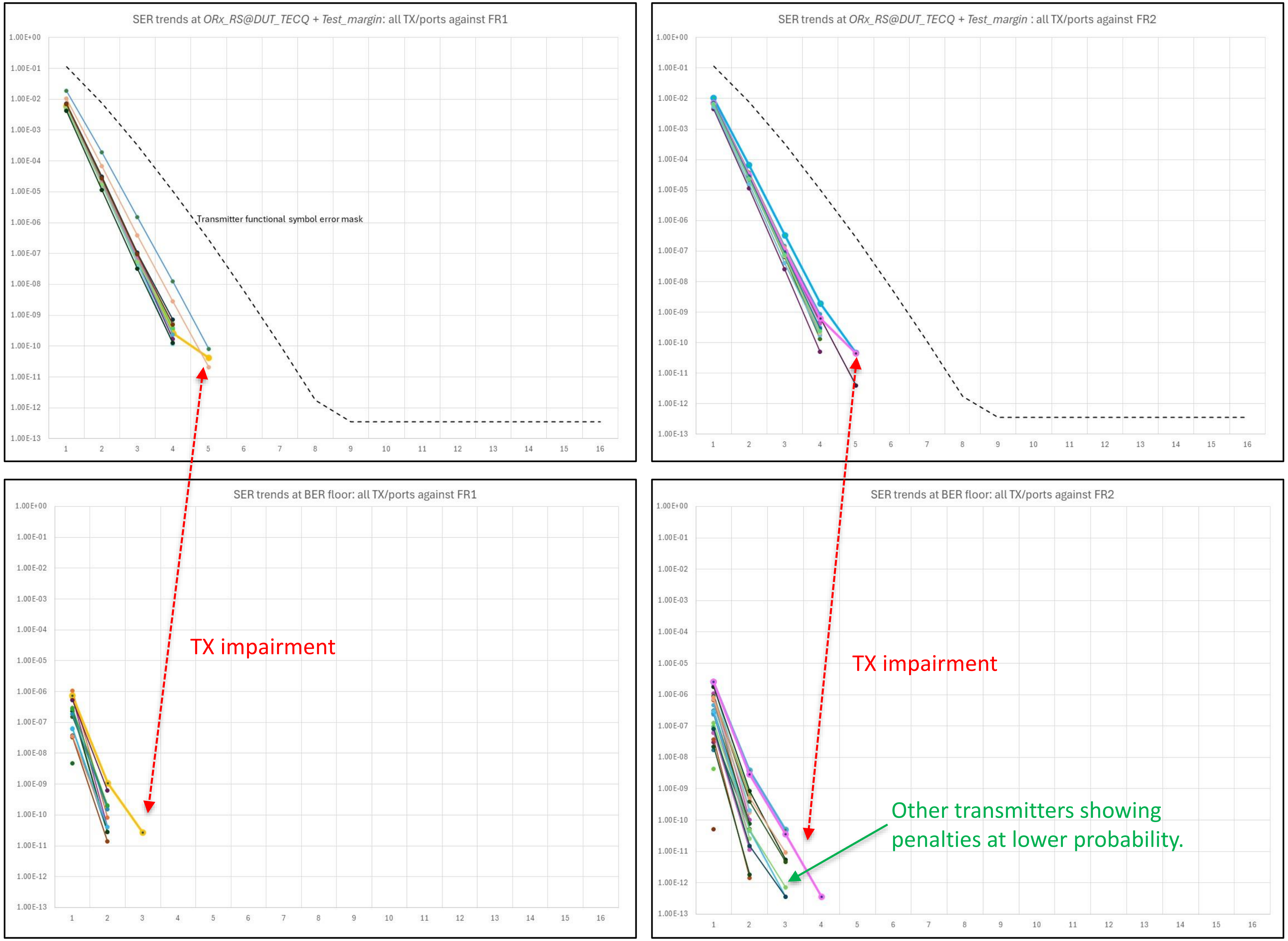


Viavi ONE LabPro used to test individual lanes of different 1.6T modules in 8x200G mode.
Configured duplex mode with variable optical attenuation between the TX and the RX DUT lane.

Checking RX DUT operation at ORx_RS@DUT_TECQ + Test_margin against all permutation of available TXs.
Normalized to sensitivity @pre-FEC = 2.4E-4 + 1.5dB: despite this can be considered as worst-case scenario for Transmitter functional symbol error histogram test, the need to calibrate against TX TECQ is removed.

Further test RX DUT tested at BER floor are here presented too

Functional RX Results



Across all test cases, two receivers were selected as reference ones.
Left charts showing permutation against all available transmitters at *ORx_RS@DUT_TECQ + Test_margin.*

All transmitters DUT pass the TFSEH mask under this worst-case conditions.
Longer observations are helpful to discriminate lower probability trends.

Same worst-cases transmitter cases are identified when measuring the ORx at BER floor (input OMA > 0 dBm) on the two functional receivers taken as reference .

In case of BER floor, one can set a dedicated mask (e.g. corresponding to 5E-8 BER) to further screen parts.

Data courtesy of Marco Mazzini, Cisco

Section IV – Ailments and remedies

Pro and Cons of Various Methods to Supplement TDECQ

- **TDECQ is an average penalty using an ideal receiver and wasn't designed to captured block error penalty!**

Additional Test	Pro	Cons
J3U/JRMS	Depending on the jitter frequency and probability may identify a failing transmitter that TECQ may not	Measurement redundant per Ghiasi and Anil Mehta (T11-2025-00114-v000) results presented in FC, may result in additional yield loss, and FRx is a direct measurement if there are any block errors
Phase noise measurement	Can limit transmitter with an integrated high phase noise over a band	Better than J3U/JRMS but this measurement is average and may not isolate transmitter with block errors
Overshoot/Peak to Average Penalty	TDECQ detector is ideal signal not penalized with increase overshoot and reducing overshoot is a good option (TDECQ with DFE doesn't rely on overshoot)	TDECQ can enhanced by incorporating Overshoot/PAR penalty if needed longer term
Limiting Weird Tap settings	Will address issue brought by chayeb_3dj_01_2505 which is related to timing recovery	Will address this issue but another DSP may have a different weakness
Adding DFE to TDECQ	Make reference receiver more like actual receiver and shifts margin from RX to TX	May add burst errors for Bmax>0.35 and can make LPO/RTLR implementations harder
Functional hardware receiver FRx	Catch block errors and to reduce HW receiver block errors contribution must operate 1-2 dB above sensitivity	Can only catch growth block errors rather than quality of transmitter, may see different result with different DSP's
CER TDECQ	Address Mazzini high jitter case and will provide CER TDECQ instead of average TDECQ	To capture asynchronous effects and jitter requires real time scope

Key Issues and Optimum Solution

- **Some may have given up on TDECQ because some compliant transmitters may fail block BER and in some cases transmitters with higher TDECQ may have better block BER**
  - TDECQ is doing what it should do but can be enhanced and any other test will have its own limitation
    - Mazzini OIF 2024.449.02 raised issue is due to bandlimited transmit RJ that affect certain blocks unproportionally
    - chayeb_3dj_01_2505 raised issue with weird tap settings affecting certain DSP Timing Recover (TR) but neither TDECQ or jitter will address the issue but the combination limiting taps and FRx is the best solution
    - TDECQ doesn't include any compression or Peak-to-Average Ratio (PAR) Penalty, ghiasi_3dj_04a_2507, effects and given overshoot driving TDECQ lower without considering penalty due to ADC clipping!

4 Key Issues Raised in DJ TF	**J3U/JRMS**	**Phase noise measurement**	**Reduce Overshoot**	**Limiting Weird Taps**	**Adding DFE**	**Hardware Functional RX**	**CER TDECQ**
Mazzini Raised Issue Passing TDECQ but failing Block BER	Maybe	Maybe	No	No	No	**Yes**	Yes (with real time scope)
Chayeb Raised Issue Passing TDECQ fail block BER	No	No	No	**Yes**	No	Maybe	No
TDECQ>3.4 dB has Better block BER	No	No	**Yes**	No	**Yes**	Maybe	No
PAR/ADC clipping	No	No	**Yes**	No	No	Yes (if tested at Max Overshoot)	No

Summary

- **Mazzini OIF 2024.449.02 showed due to bandlimited RJ later presented some of the same material in 802.3dj by ran_3dj_elec_01_240822 may result in block errors for compliant transmitters**
  - Block TDECQ (CER TDECQ) and Functional receiver were investigated to identify transmitters with potential block errors
    - TF added Functional receiver FRx was added in Madrid to supplement TDECQ and address potential block errors
    - CER TDECQ improves TDECQ methodology by relating penalty to CER but may not address block errors
- **TDECQ as was shown by ghiasi_3dj_01a_2409 can capture J3U jitter and ran_3dj_04_2509 showed that SJ is captured also by TDECQ but low probability RJ is not captured by TDECQ**
  - Ran uses FRx to identify block errors as function of increasing RJ
  - This is exactly the reason FRx was added to supplement TDECQ
  - Adding jitter would be redundant measurement but inferior to direct block error measurement with FRx
    - If we still believe a jitter test is required for optical transmitters let's not reinvent and instead consider SONET jitter generation that is proven
- **Unless it can be shown that the combination of TDECQ and FRx are insufficient to guarantee interoperability per comments 256, 257, 258, and 259 recommend removing jitter test from clause 180-183.**

Thank You!