Optical PAM4 RX SRS Results Update*

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* Thanks to UCSB for support during the test, and Mike Dudek and David Lewis for fruitful discussions
Problem Statements

- There exists Interoperability concerns/risks associated with SRS
  - Lack of correlation between TDECQ vs. Sensitivity
  - Lack of Rx validation with SRS testing

- This is the first time ever to do such PAM4 SRS tests in industry
  - 26Gbaud SRS is just in final stage of developments by test equipment vendors
  - 53Gbaud SRS is not yet available in any form
  - No SRS data available so far during 802.3bs spec definition

- Schedule optical SRS tests jointly with Source
  - From Week of 10/16th with Keysight at Inphi WVL lab

- Purpose:
  - To validate the existing SRS testing methodology
  - To help define SRS spec at 26GBd (and 53GBd due to similarity).
What’s in mind to validate SRS?

- Pattern comparison
  - SSPRQ vs PRBS31

- Interplay between S.I. vs. G.N (and S.J.)

- Different ROSA behavior
  - Various prevailing product-grade PAM4 ROSAs

- Critical contributing parameters affecting SECQ
  - Redefine calibration procedures

- ER impact on SECQ

- Impact of number of taps for un-stressed and stressed

- Impact of TX filter BW

- Impact of RX filter BW

- Different DSP modes
Optical SRS Reqs for compliance tests

- Optical SRS is critical pass/fail specs on optical RX at TP3
- SECQ=Stressed eye closure for PAM4

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>200GBASE-DR4</th>
<th>200GBASE-FR4</th>
<th>200GBASE-LR4</th>
<th>200GBASE-FR8</th>
<th>400GBASE-LR8</th>
<th>50GBASE-FR</th>
<th>50GBASE-LR</th>
<th>100GBASE-DR</th>
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<tbody>
<tr>
<td>Reference Rx equalizer</td>
<td>Taps, Spacing</td>
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<td>5, T</td>
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<tr>
<td>TDECQ (max)</td>
<td>dB</td>
<td>3.4</td>
<td>3.3</td>
<td>3.4</td>
<td>3.1</td>
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<tr>
<td>SRS</td>
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<td>-6.4</td>
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<td>ps/nm</td>
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<td>6.7</td>
<td>9.5</td>
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<td>9.5</td>
<td>3.2</td>
<td>16</td>
<td>0.8</td>
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<tr>
<td>Dispersion (min)</td>
<td>ps/nm</td>
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<td>-11.9</td>
<td>-28.4</td>
<td>-10.2</td>
<td>-50.8</td>
<td>-3.7</td>
<td>-18.6</td>
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<td>-0.93</td>
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<td>ΔTdisp / Tsymbol (GVD max)</td>
<td>%</td>
<td>0.3%</td>
<td>2.7%</td>
<td>3.8%</td>
<td>0.8%</td>
<td>3.8%</td>
<td>1.3%</td>
<td>6.4%</td>
<td>1.3%</td>
<td>1.3%</td>
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<tr>
<td>ΔTdisp / Tsymbol (GVD min)</td>
<td>%</td>
<td>0.4%</td>
<td>4.7%</td>
<td>11.3%</td>
<td>4.1%</td>
<td>20.2%</td>
<td>1.5%</td>
<td>7.4%</td>
<td>1.5%</td>
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<td>Draft</td>
<td></td>
<td>P802.3cd D2.1</td>
<td>P802.3bs D3.3</td>
<td>P802.3bs D3.3</td>
<td>P802.3bs D3.3</td>
<td>P802.3bs D3.3</td>
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<td>P802.3bs D3.3</td>
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Optical SRS Testing Setups

- Complex and expensive test setups
  - Establish hard/solid correlation between URS and SRS

Key calibration procedures:
- Select SSPRQ pattern
- Ideal LN MZM TX with SECQ~0.9dB
- Set ER=3.5dB
- TX E/O+LPF generate half of the SECQ
- S.J. 0.05mUI @100MHz
- S.I.+ G.N to meet SECQ=3.4dB
Generate stressed eyes – Ideal TX eye (SSPRQ)
Generate stressed eyes – ideal TX w/ LPF (SSPRQ)
Generate stressed eyes – Fully stressed (SSPRQ)
Generate stressed eyes – Fully stressed with TX Filtering by 12GHz Cable (SSPRQ)
SECQ behave differently under full or no stress
- ER is varied with changing RF modulation amplitude (Vpp) only

Note: Refer to DCA-M N1092B RX BW ~33GHz.
**TX and Rx BW on SECQ (SSPRQ)**

- RX filtering impact differently for higher stressed cases.
  - Also look into the scenarios when TX is highly BW limited (next 2 slides).

Note: Refer to DCA-M N1092B RX BW ~33GHz.
TX and Rx BW on SECQ (SSPRQ)

- RX filtering impact differently for higher stressed cases.
  - Under TX filtering at ~12GHz BW LPF cable

Note: Refer to DCA-M N1092B RX BW ~33GHz.
RX filtering impact differently for higher stressed cases.

- Under TX filtering at ~9GHz BW LPF cable

Note: Refer to DCA-M N1092B RX BW ~33GHz.
The Number of Taps on SECQ (SSPRQ)

- More taps help the most for higher or full stress
  - Also look into the scenarios when TX is highly BW limited (next 2 slides).
The Number of Taps on SECOQ (SSPRQ)

- More taps help the most for higher or full stress
  - Under TX filtering at ~12GHz BW LPF cable

Note: Refer to DCA-M N1092B RX BW ~33GHz at RX 13.28GHz filtering
The Number of Taps on SECQ (SSPRQ)

- More taps help the most for higher or full stress
  - Under TX filtering at ~9GHz BW LPF cable

Note: Refer to DCA-M N1092B RX BW ~33GHz at RX 13.28GHz filtering
SSPRQ vs. PRBS31Q Pattern Comparison

SSPRQ

No stress

Full stress

PRBS31Q

No stress

Full stress
RX SRS Tests with PRBS31Q – Case 1

- Case 1 with S.I. dominance

Optical SRS tests for 26GBd ROSA+PAM4 Receiver

- Error free (<1E-12)
Case 2 with G.N. dominance
Compare Two Cases with PRBS31Q

- Same SECQ=3.4dB but with different BER behavior

<table>
<thead>
<tr>
<th>Case1</th>
<th>S.I. dominance</th>
<th>SECQ</th>
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<tr>
<td>Ideal Tx</td>
<td>0.87</td>
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<tr>
<td>TX+LPF</td>
<td>1.66</td>
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<tr>
<td>S.J. only</td>
<td>1.74</td>
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<tr>
<td>S.J+G.N.</td>
<td>1.78</td>
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<tr>
<td>S.J.+ S.I.</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>S.J.+ G.N.+S.I.</td>
<td>3.4</td>
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<table>
<thead>
<tr>
<th>Case2</th>
<th>G.N. dominance</th>
<th>SECQ</th>
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<tbody>
<tr>
<td>Ideal Tx</td>
<td>0.87</td>
<td></td>
</tr>
<tr>
<td>TX+LPF</td>
<td>1.66</td>
<td></td>
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<tr>
<td>S.J. only</td>
<td>1.74</td>
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</tr>
<tr>
<td>S.J.+S.I.</td>
<td>2.1</td>
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<tr>
<td>S.J.+ G.N.</td>
<td>2.75</td>
<td></td>
</tr>
<tr>
<td>S.J.+ G.N.+S.I.</td>
<td>3.4</td>
<td></td>
</tr>
</tbody>
</table>

Optical SRS tests for 26GBd ROSA+ PAM4 Receiver

- Error free (<1E-12)

Graph showing SECQ values for different stress cases.
Summary & Recommendation

- Optical SRS are investigated extensively, major observations from preliminary results:
  - SRS setup is pretty complex, but stable and repeatable once well calibrated.
  - SSPRQ seems to show good representative of PRBS31 pattern.
  - More Ref equalizer taps help the most for higher and full stress situation.
  - Lower ER does not help high stressed signals due to small eye opening.
  - There exists strong interplay between G.N and S.I (with S.J.). G.N. impact most the BER degradation in SRS.
  - Ref transmitter used for SRS may not be able to represent “Non-ideal” product grade transmitters.
  - Data repeatedly show SECQ correlates well with BER flooring (or equivalently SNR).

- Recommendations:
  - Production implementation could possibly induce interop risks.
  - Each contributing items (and ratio) in setting SRS should be well defined in specs.
Thank You!

QUESTIONS?