Jitter effect on TDECQ, error rates, and jitter measurements

Adee Ran, Cisco

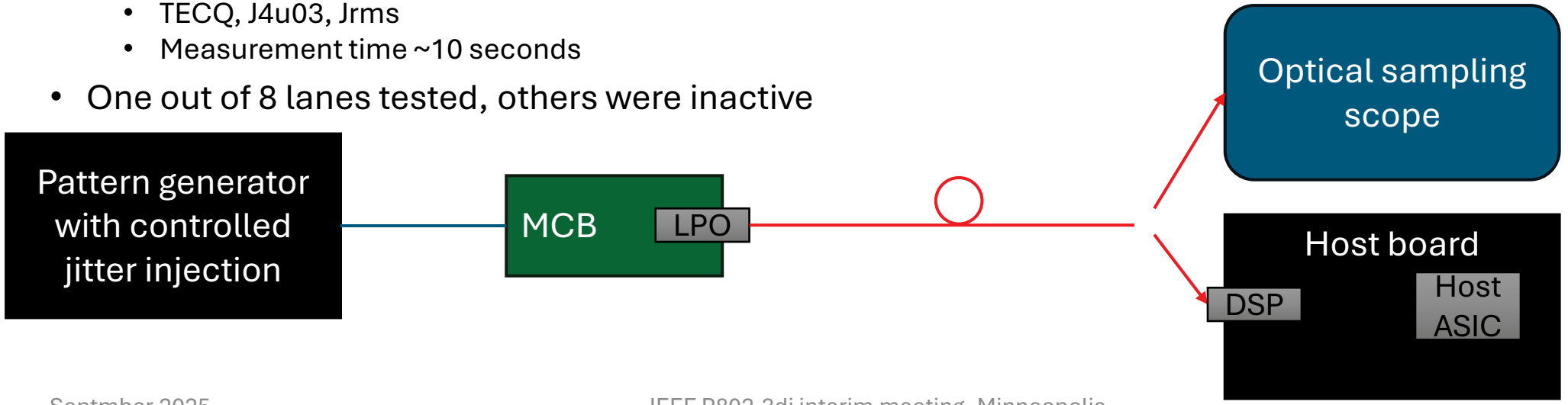
Fabio Bottoni, Cisco

Introduction

- Output jitter in optical PMDs has been a topic of concern for a long time
- Previously reported measurements results include oif2024.449.02 (Marco Mazzini & Yi Tang), summarized with additional simulation results in ran_3dj_optx_01_240829
- There were many subsequent discussions
  - Whether TECQ/TDECQ measurements are sufficient to identify transmitters with jitter that degrades FEC performance
  - Whether jitter measurements or other tests can do better
  - Test times are a concern
- This presentation provides measured data to shed more light on these questions

Test setup

- Transmitter:
  - 100GBASE-R + Clause 91 FEC pattern generator
    - Jitter injected: SJ at 12 MHz / 40 MHz, RJ
  - 8x100GBASE-DR1 LPO module (E/O, assumed to have no jitter contribution)
- Channel: ~1m SMF patch cord
- Receiver:
  - Compliant retimed (DSP) 8x100GBASE-DR1 module
  - Compliant host with 800GAUI-8 C2M
  - FEC statistics collected over 30 seconds (~5e8 codewords)
- TP2 Measurements (Keysight DCA, 4 MHz CRU):
  - TECQ, J4u03, Jrms
  - Measurement time ~10 seconds
- One out of 8 lanes tested, others were inactive



Test details

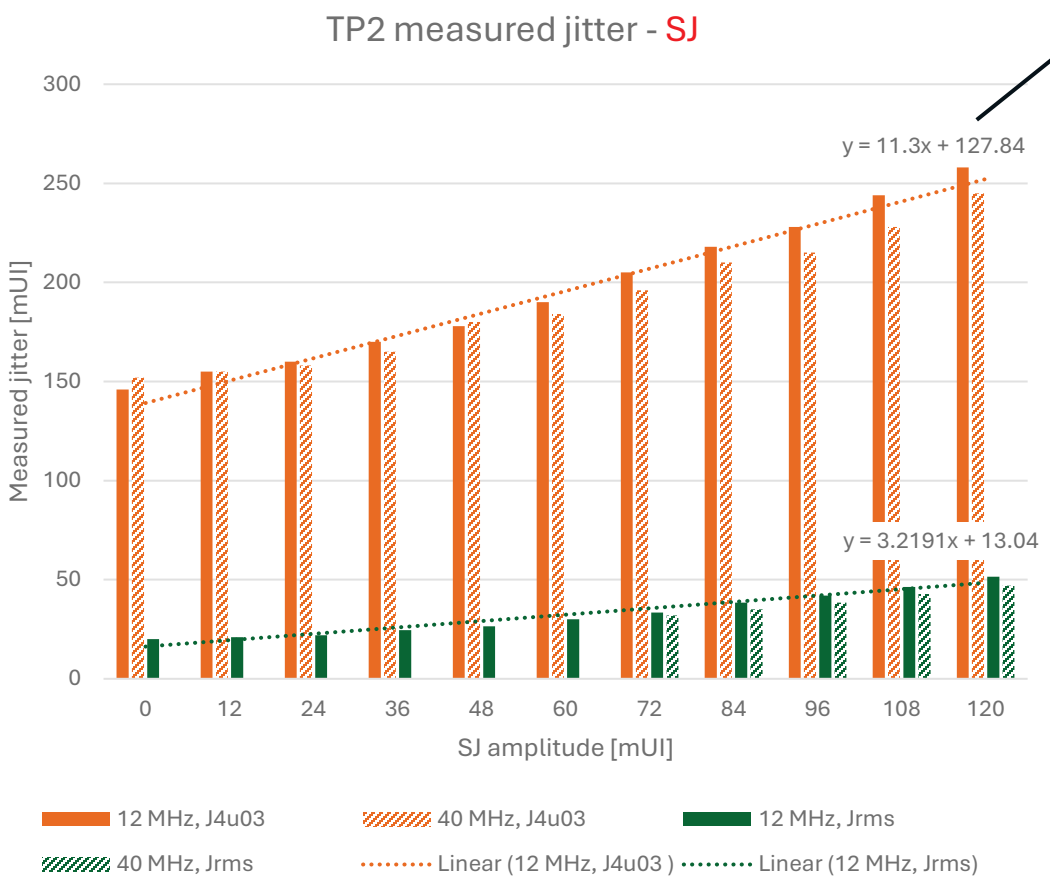
- RJ injected by the pattern generator can be either low-pass filtered to 100 MHz or not
  - The results had only slight differences between these two settings
  - The reported results are without filtering
- BER is estimated from the FEC statistics
  - Assuming each symbol error is one bit error
- With short fiber connection, the scope input signal is much above sensitivity level and should have little dispersion
- Jitter measurements are per 802.3ck:
  - J4u03 measured by “combined R03 and F30” – not their RMS as in 802.3dj
  - Jrms is not using the “phase only jitter” method introduced in 802.3dj

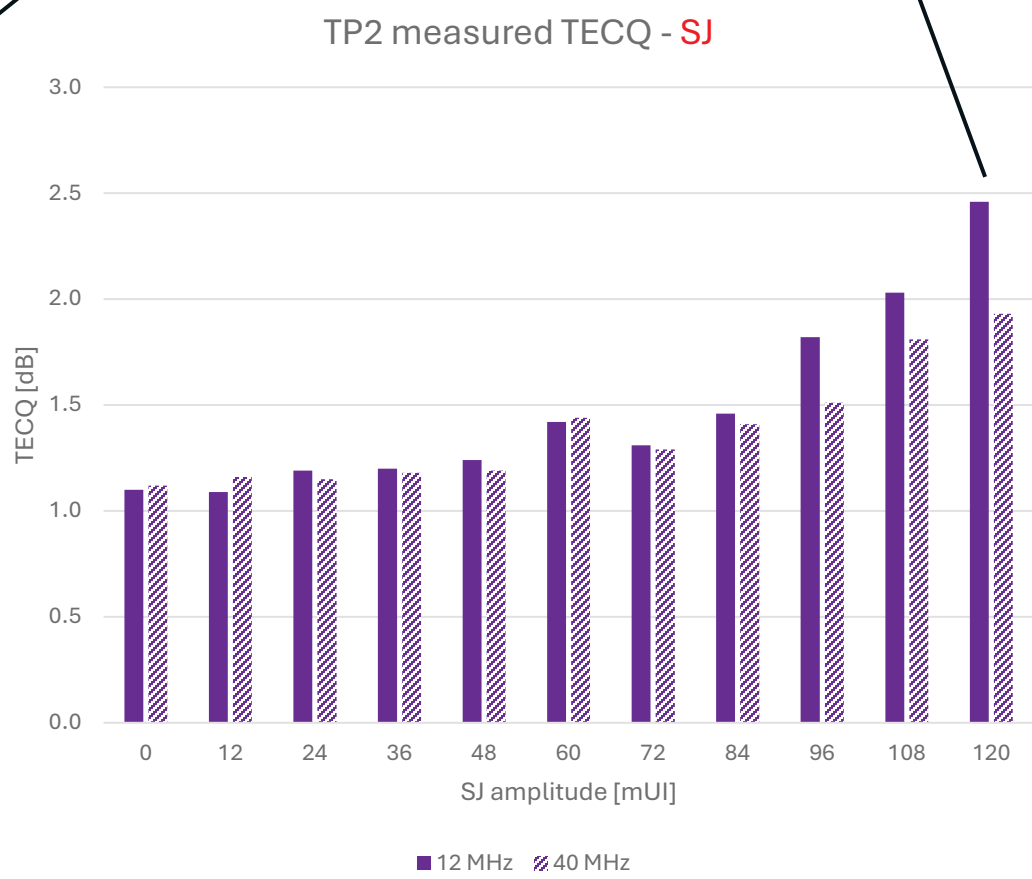
Results

TP2 measurements vs. SJ

Both J4u03 and Jrms are very sensitive to SJ

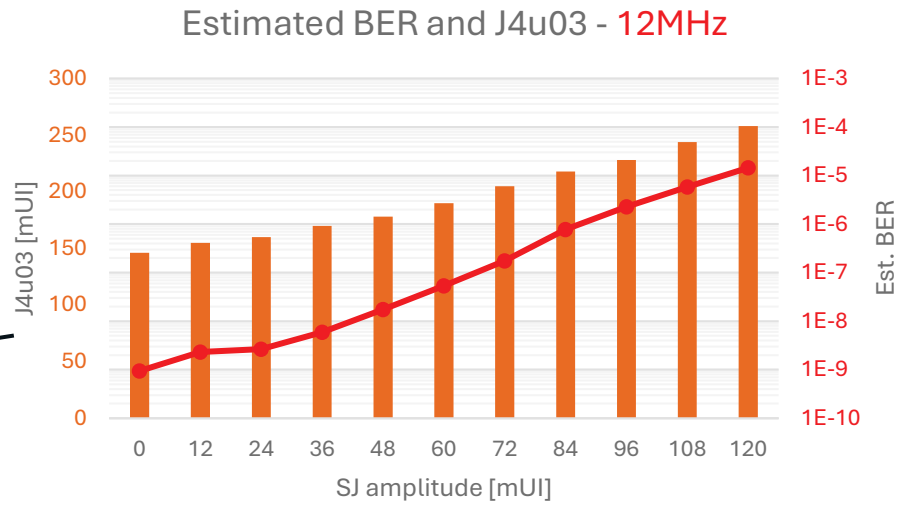
TECQ is affected by SJ but is below the 3.4 dB maximum even at very high values

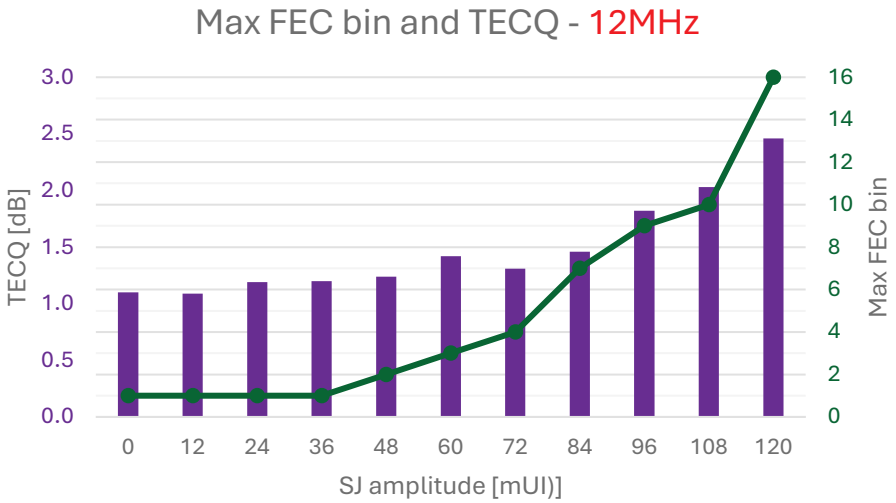




FEC performance vs. 12 MHz SJ

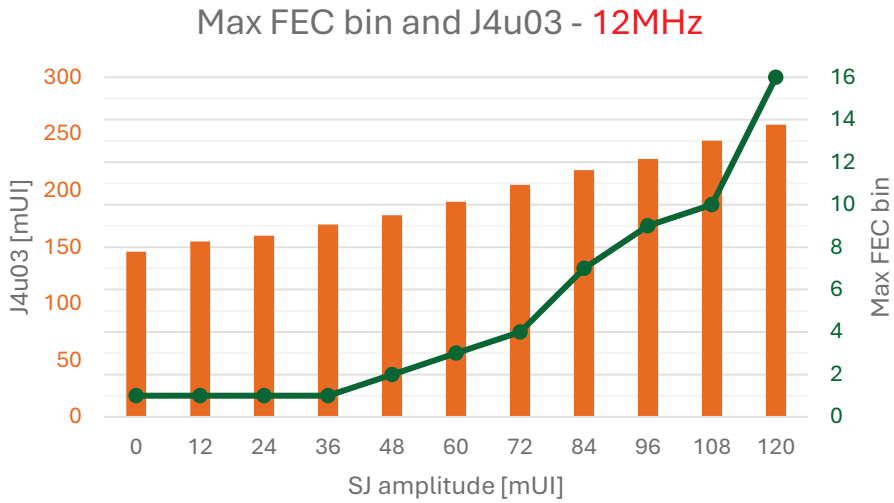
J4u03 is roughly proportional to log(BER); The highest measured BER is still lower than the max BER allowed





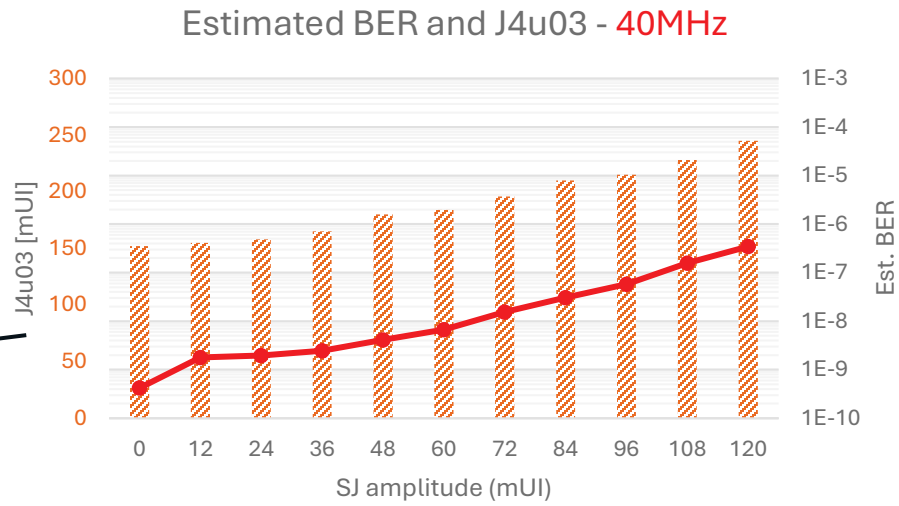
At the highest SJ, uncorrectable codewords observed within 30 seconds (not predicted by BER≈1e-5; errors are correlated).

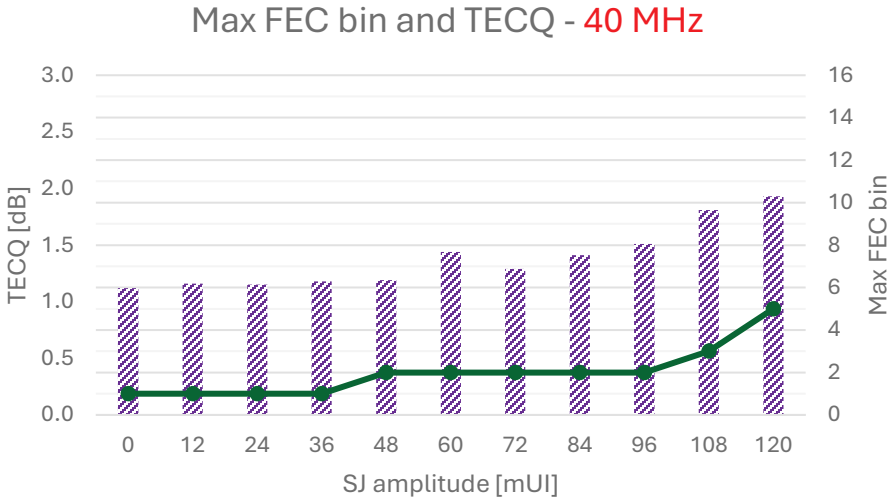
J4u03 seems to predict max FEC bin better than TECQ.



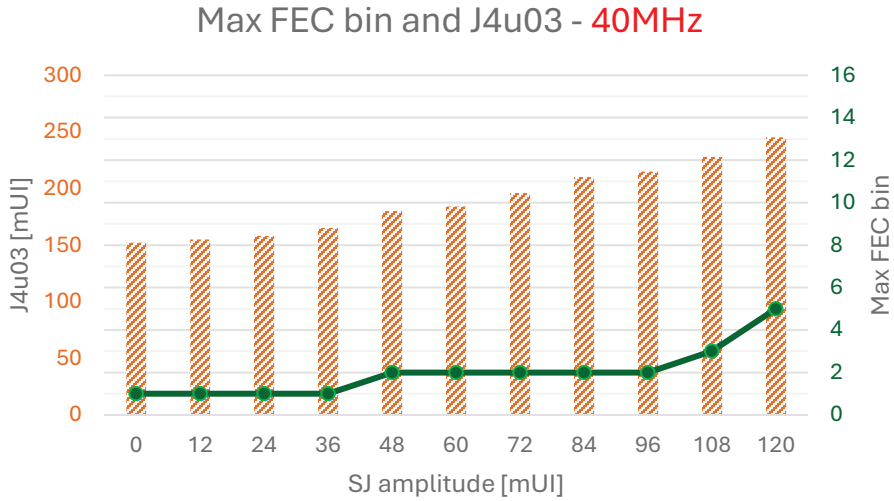
FEC performance vs. 40 MHz SJ

J4u03 is roughly proportional to log(BER). The BER with 40 MHz is considerably lower than with 12 MHz at the same amplitude.





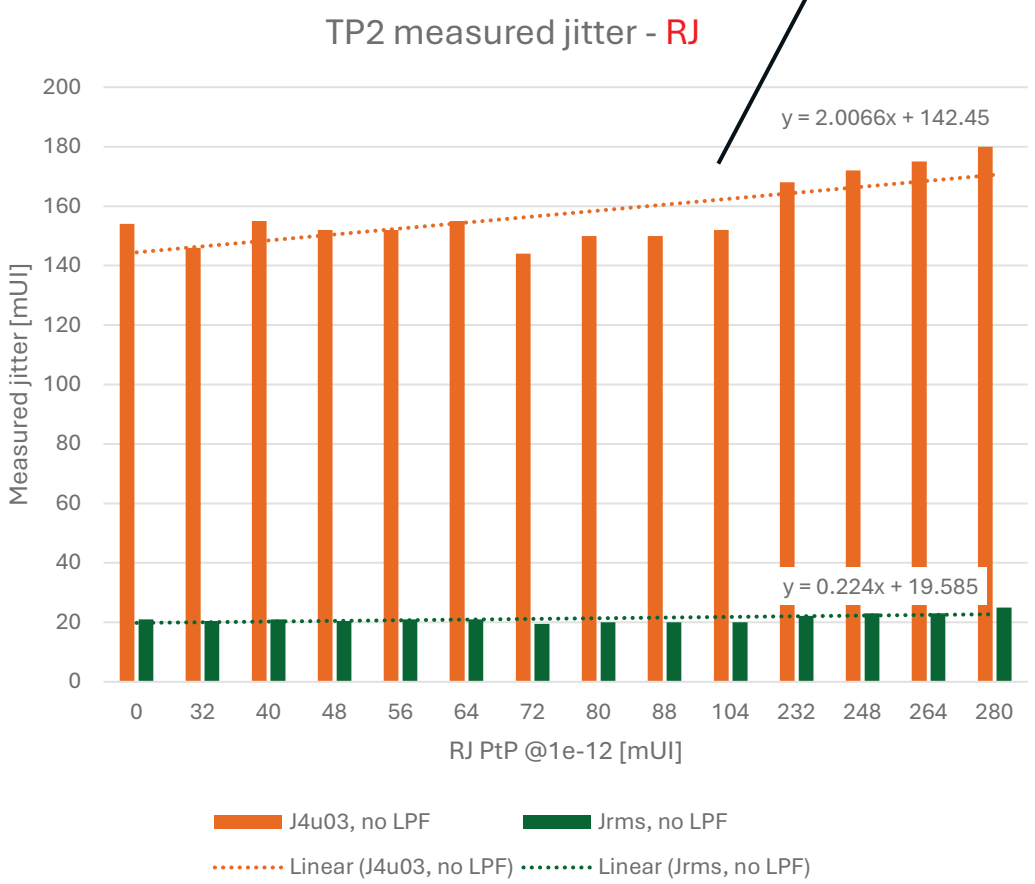
FEC impact is much less severe at 40 MHz; can be explained by the lower BER (~1e-7). TECQ is also lower.

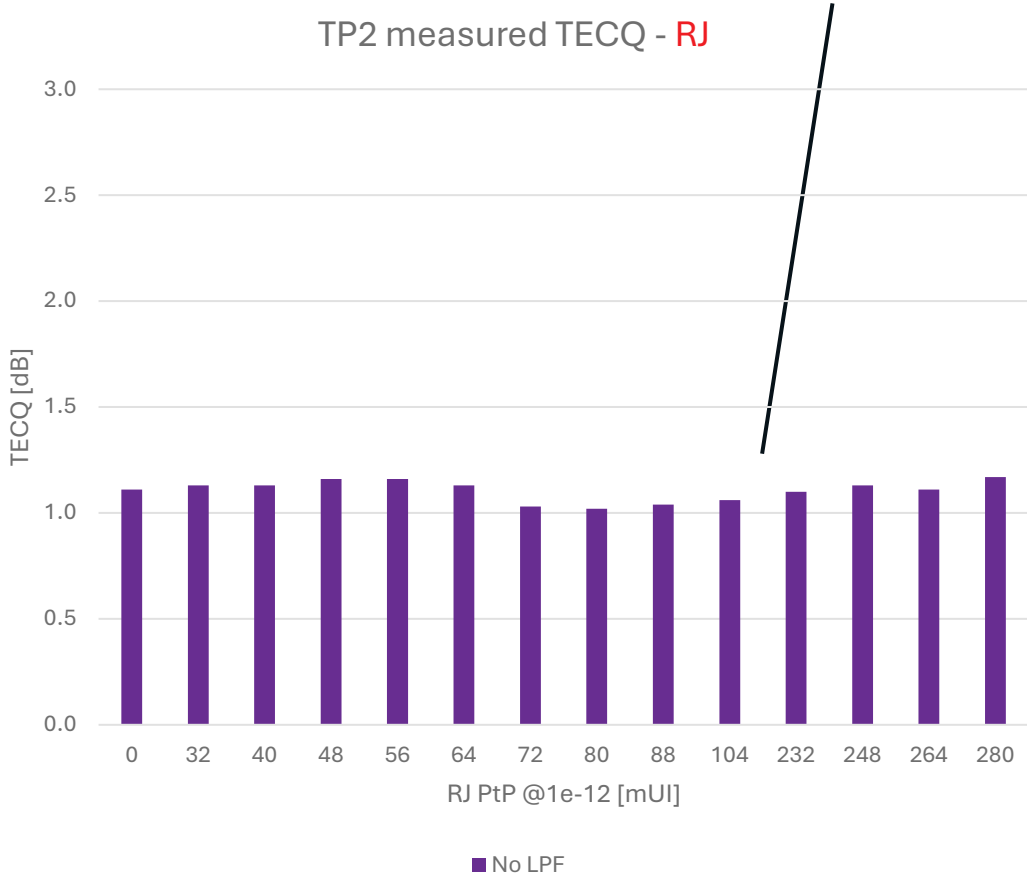


TP2 measurements vs. RJ

J4u03 is mildly sensitive to RJ. Jrms almost not affected by the levels used in the test.

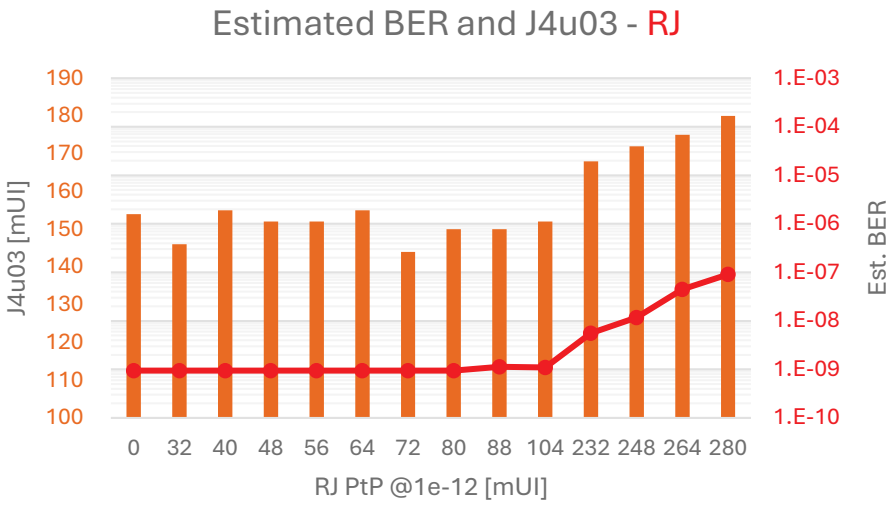
TECQ is not sensitive to RJ and is always way below the 3.4 dB maximum.

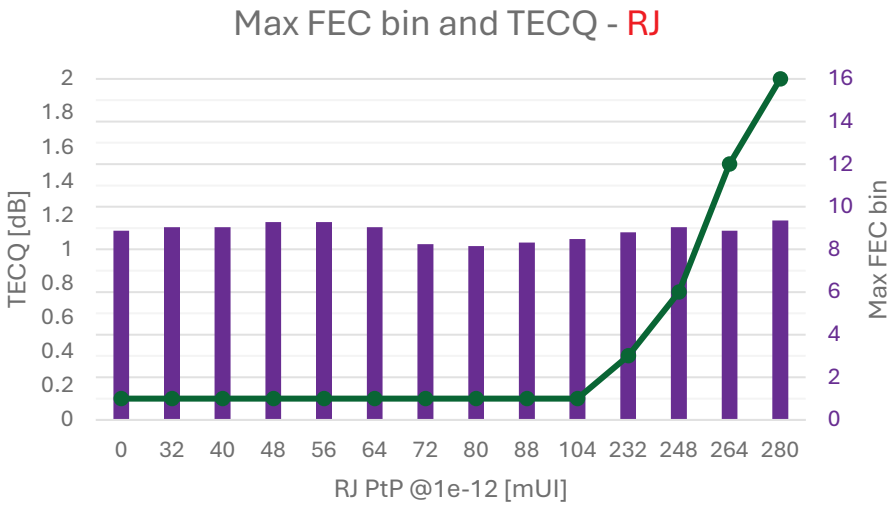




FEC performance vs. RJ

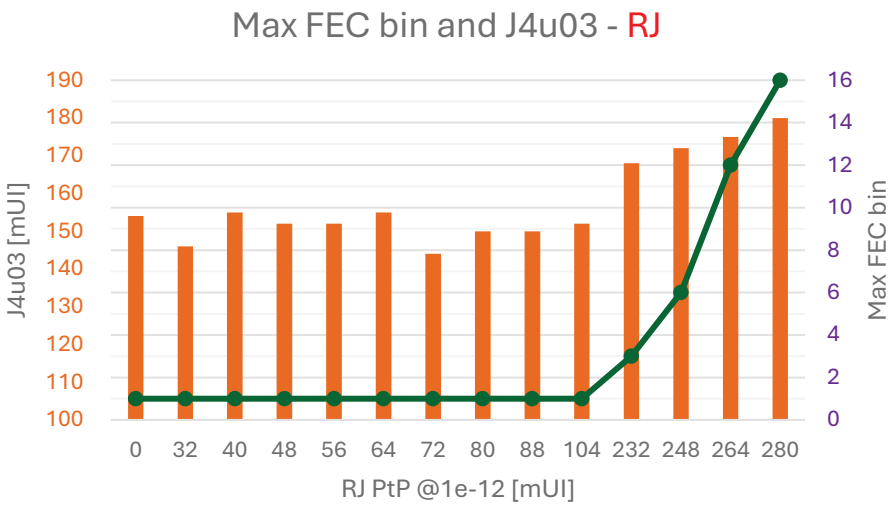
J4u03 is roughly proportional to log(BER).
Low RJ values have no visible effect on BER.





At high RJ levels the FEC performance degrades quickly. uncorrectable codewords observed within 30 seconds (not predicted by BER ≈1e-7; errors are correlated).

J4u03 seems to predict max FEC bin better than TECQ.



Observations

- BER (calculated from the FEC bin counters) is not a good predictor of FEC performance when jitter is present: uncorrectable codewords appear quickly with BER as low as 1e-7
  - Confirming previous reports
- TECQ is not sensitive to RJ and is only weakly sensitive to SJ; value is below the 3.4 dB maximum at levels that create uncorrectable errors
- Optical jitter measurements yield higher values than the electrical PMD specs, even before jitter injection
  - Perhaps due to E/O and O/E noise, or other effects?
  - Worth further examination
  - New 802.3dj methods may improve the situation
- J4u03 is measurable on an optical signal and enables better prediction of FEC performance than TECQ
  - Jrms also measurable but is less correlated with performance

Thoughts

- The experiment was conducted on commercially available 100GBASE-DR parts and test equipment
  - Ideally the experiment should be run with 200G technology, but components are not as easily available
  - The results are conclusive enough to state that 100G optical specs are insufficient
  - Jitter problems are not expected to go away at higher speeds
- Other changed to Tx specs were made in 802.3dj
  - FRx – built upon performance of a physical receiver, whose sensitivity to jitter is not specified; different receivers might be affected differently
  - TDECQ reference receiver with DFE – not related to jitter, and TDECQ still calculated based on “the center of the eye” samples
  - These may prove to address jitter as well, but there is virtually no measurement data at this time, even for 100G technology
- Jitter measurement provides direct transmitter metrics that require less processing, assumptions, and uncertainty
  - Not dependent on a reference equalizer (which is currently a moving target, and does not necessarily match receiver implementations)

Summary

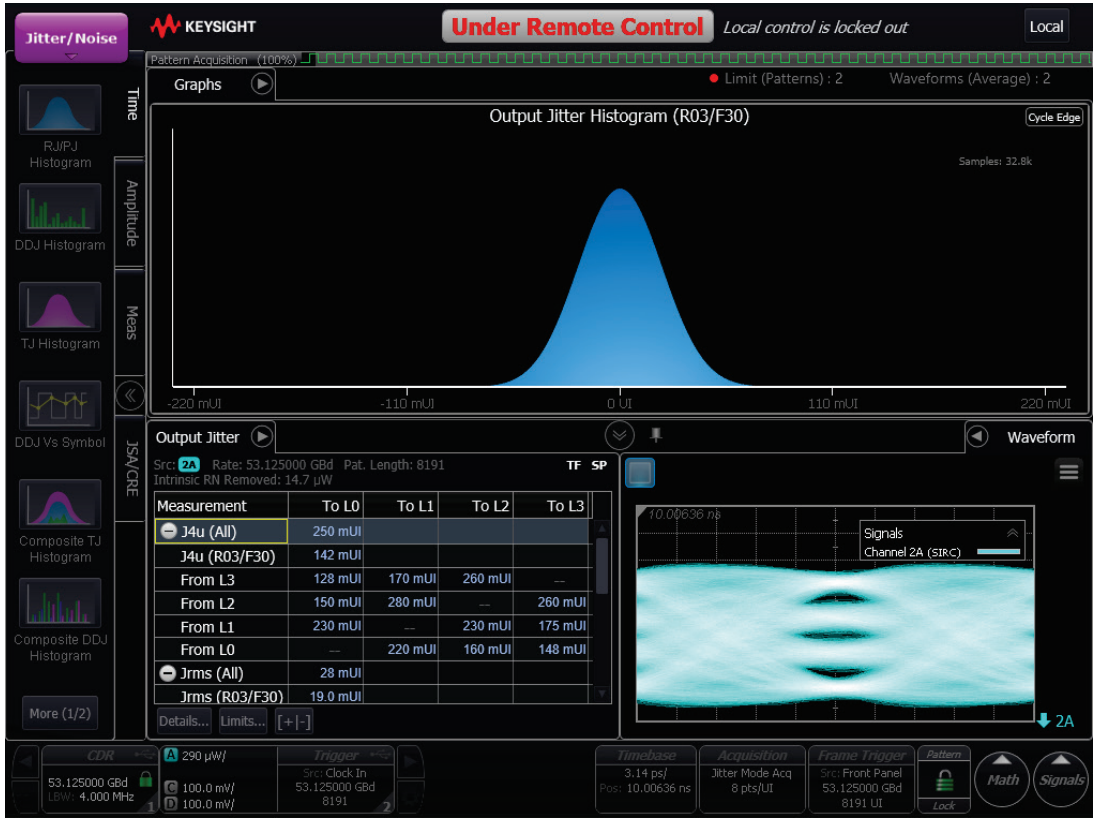
- Jitter affects FEC performance more than what could be predicted by BER
- TECQ/TDECQ is not sensitive enough to high jitter
- Jitter measurement of 10 seconds on a sampling scope can detect high jitter
- Jitter measurements on optical signals using 802.3ck methods yield high values even without jitter injection
  - Using updated 802.3dj methods may improve accuracy
  - We are unable to recommend pass/fail levels for 802.3dj at this time
- Further study with 200G technology is encouraged
  - Whether or not is jitter added as a compliance requirement within 802.3dj depends on consensus
  - If 802.3dj doesn’t add it, other industry players might
  - This may become a de-facto requirement, especially if other tests prove insufficient

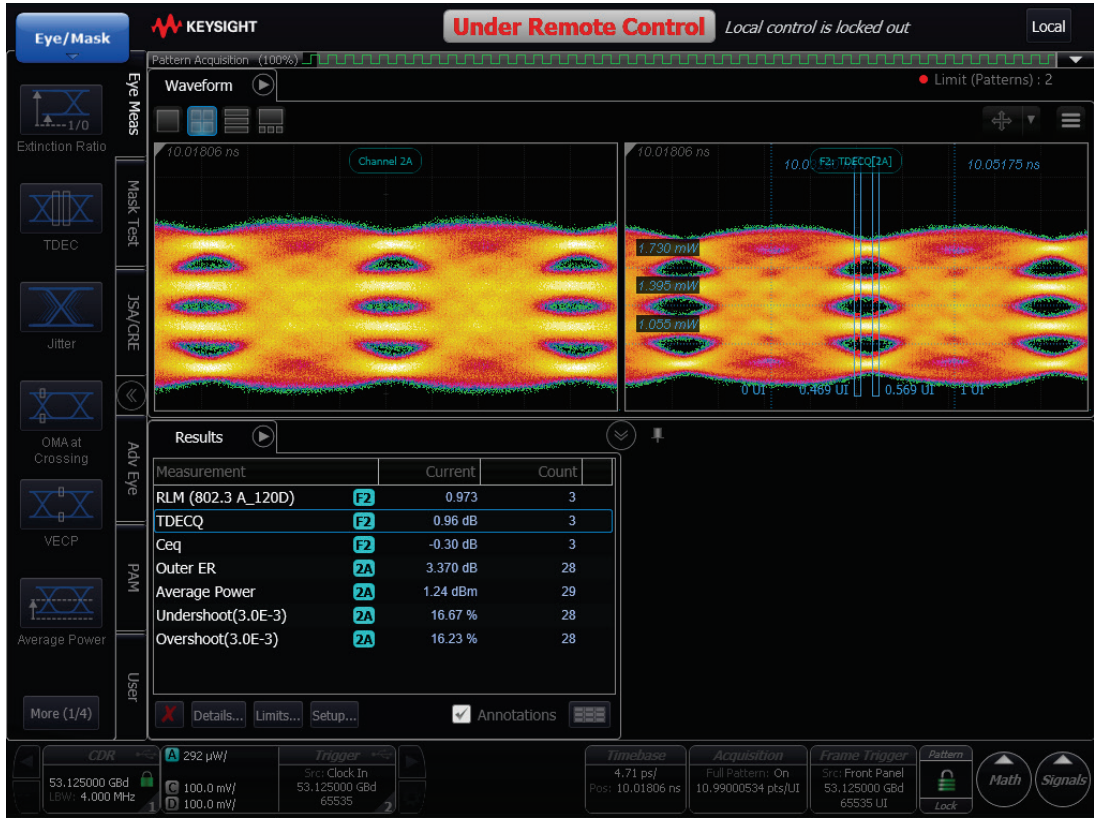
That’s all

Questions?

Backup

TP2 measurement, no SJ/RJ





TP2 measurement, high 12 MHz SJ

(uncorrectable codewords)