Impact of Tx Overshoot on Link Performance and TDECQ

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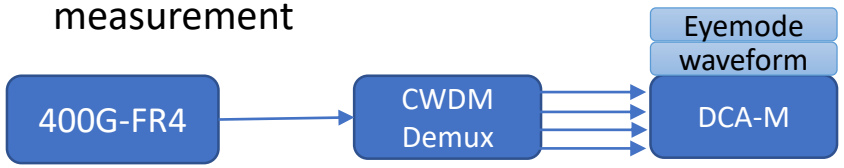
Introduction

- 802.3cu draft 2.0 introduced overshoot transmitter spec to protect receivers from harmful transmitters
- There is currently a discussion on how overshoot impacts real receivers
- This presentation intentionally creates different values of overshoot to analyze Rx performance at sensitivity , mid range power and overload.
- We propose absolute and relative overshoot specs based on the analysis
- Last slides address our view on TDECQ-10*log(Ceq)

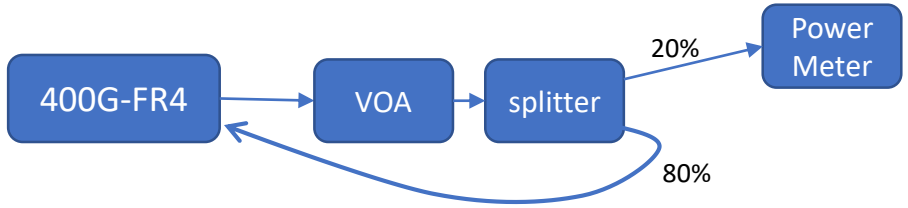
Analysis Setup

- In setup A, transmitter is connected to DCA to capture square wave for offline overshoot, and to measure TDECQ (TECQ) and Ceq with SSPRQ
- In Setup B, transmitter is connected to receiver for BER waterfall measurements
- In Setup C, same than previous setup with the addition of a PDFA to cover overload powers. Single lane measurement

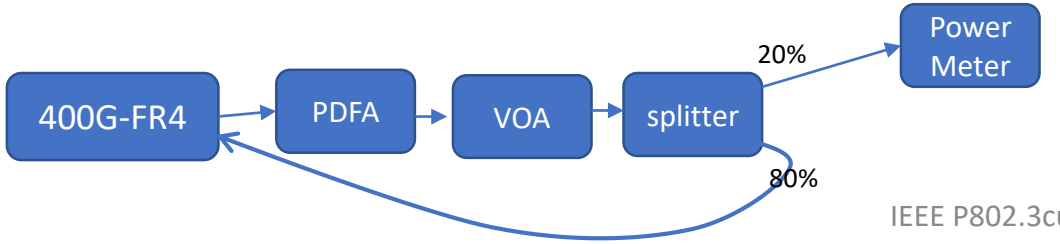
A)



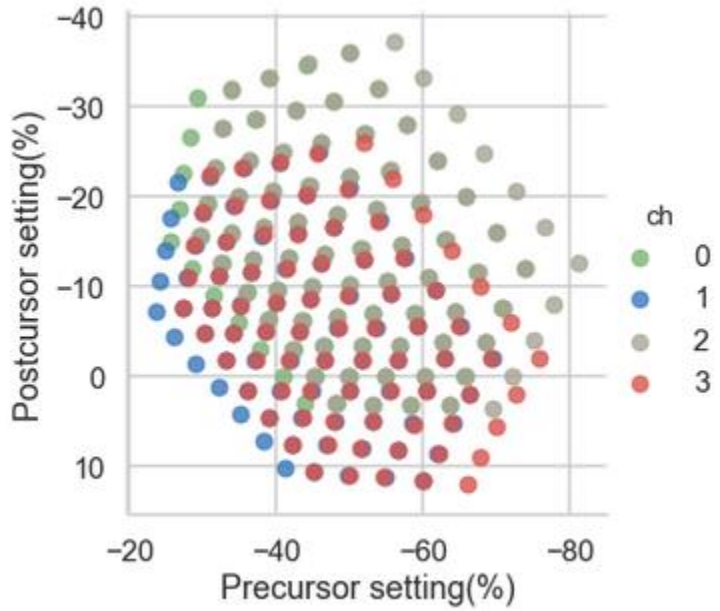
B)



C)

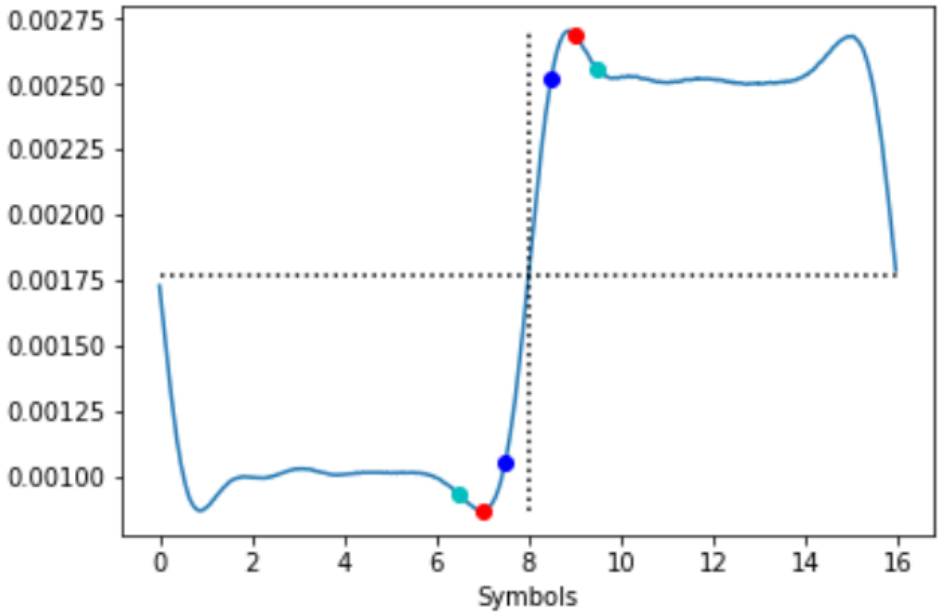


- Tx Postcursor and precursors settings on a 400G module are swept to generate 79 different values of overshoot per channel
- Main tap is changed accordantly to maintain FIR taps sum value constant for minimal ER variation

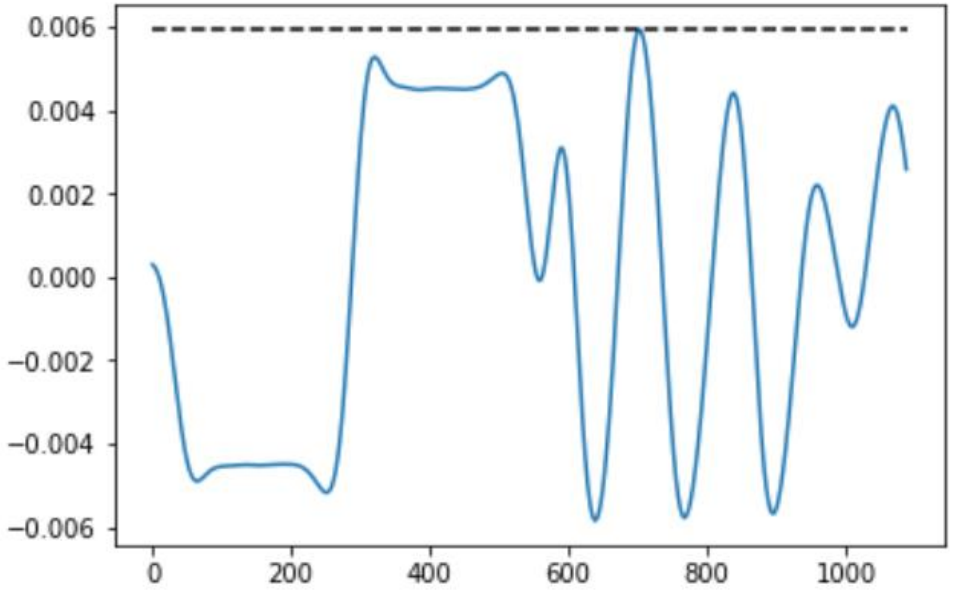


Tx parameters – overshoot extraction

- Overshoot values were extracted by offline processing a square wave.
- Independent pre & post for rising and falling edge were extracted. However, only maximum value was used on this analysis

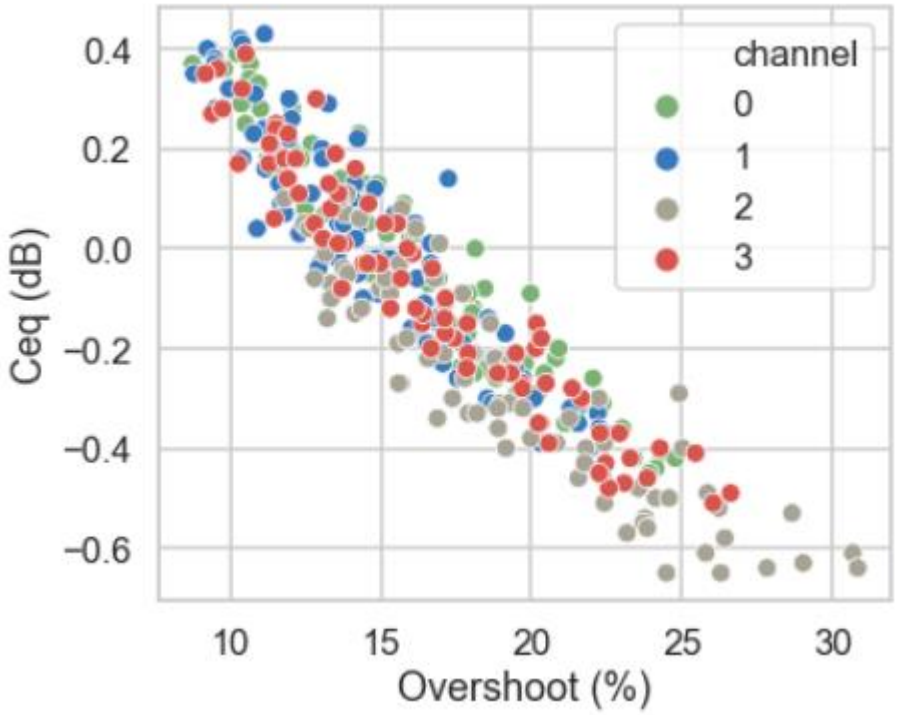


- The impulse response is calculated from the step response
- The overshoot was measured from the maximum value of the convolution of a SSPRQ sequence with the impulse response

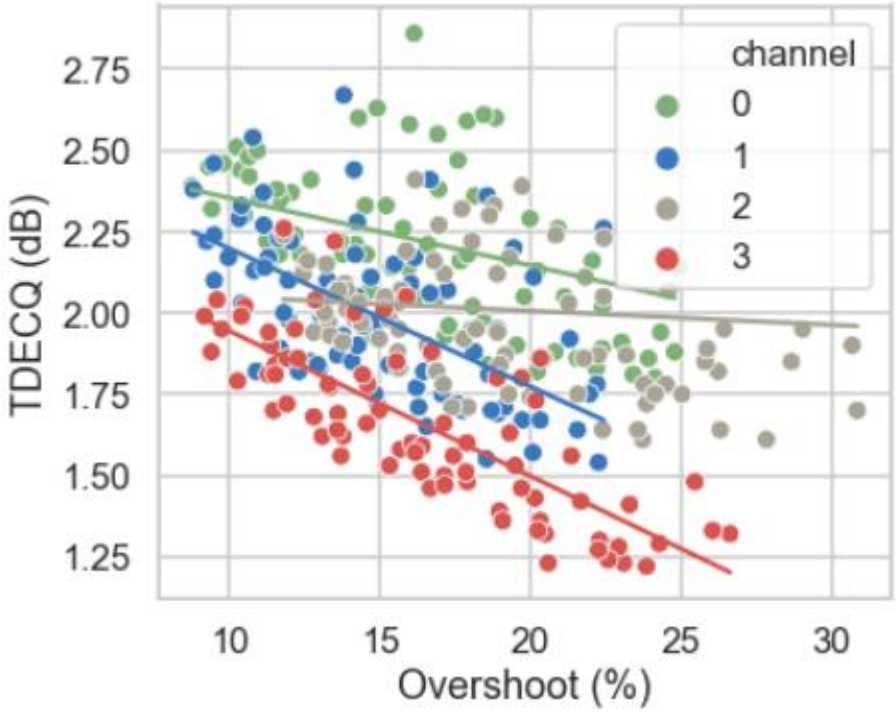


Tx parameters relations

- Overshoot has good correlation with Ceq, at least on EMLs. It might not be the case for DMLs
- Ceq saturates with overshoot higher than 25%

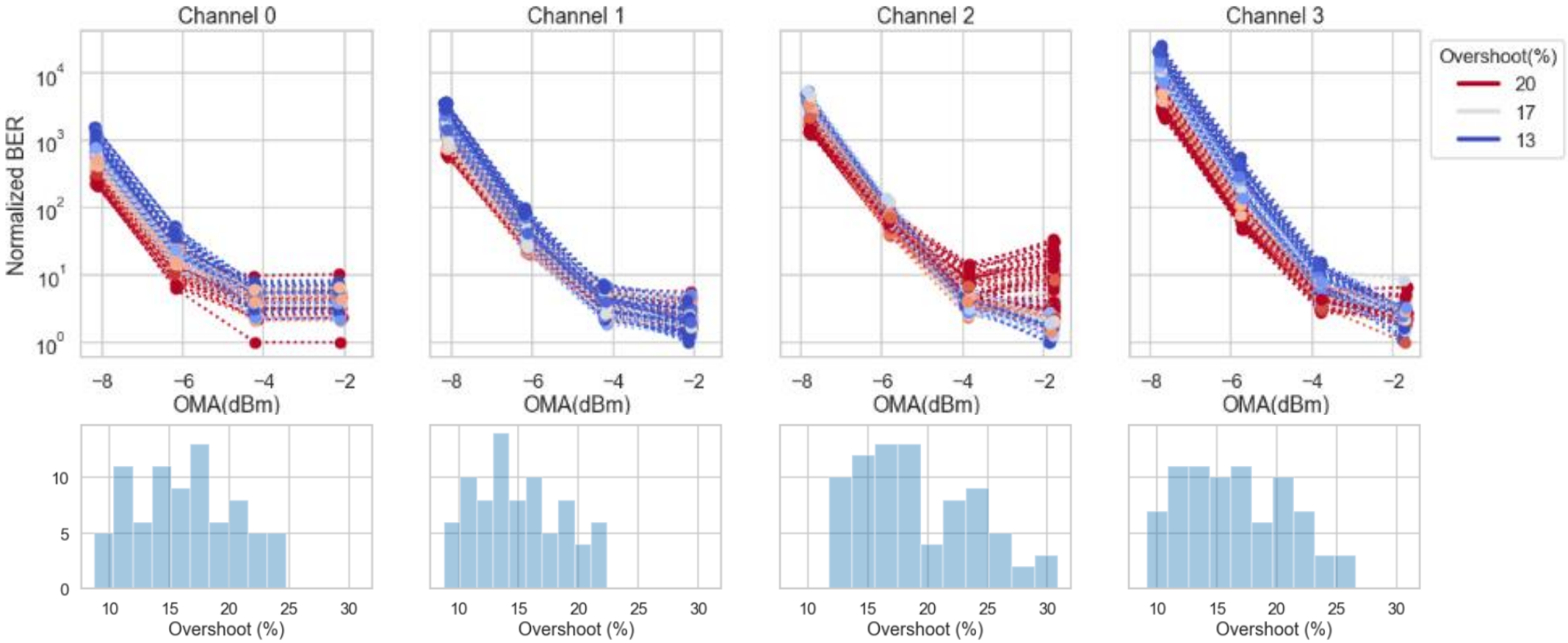


- Higher overshoot tends to improve TDECQ up to certain limit.
- Transmitters that significantly add noise or distortion when adding overshoot tend to degrade TDECQ (see backup).

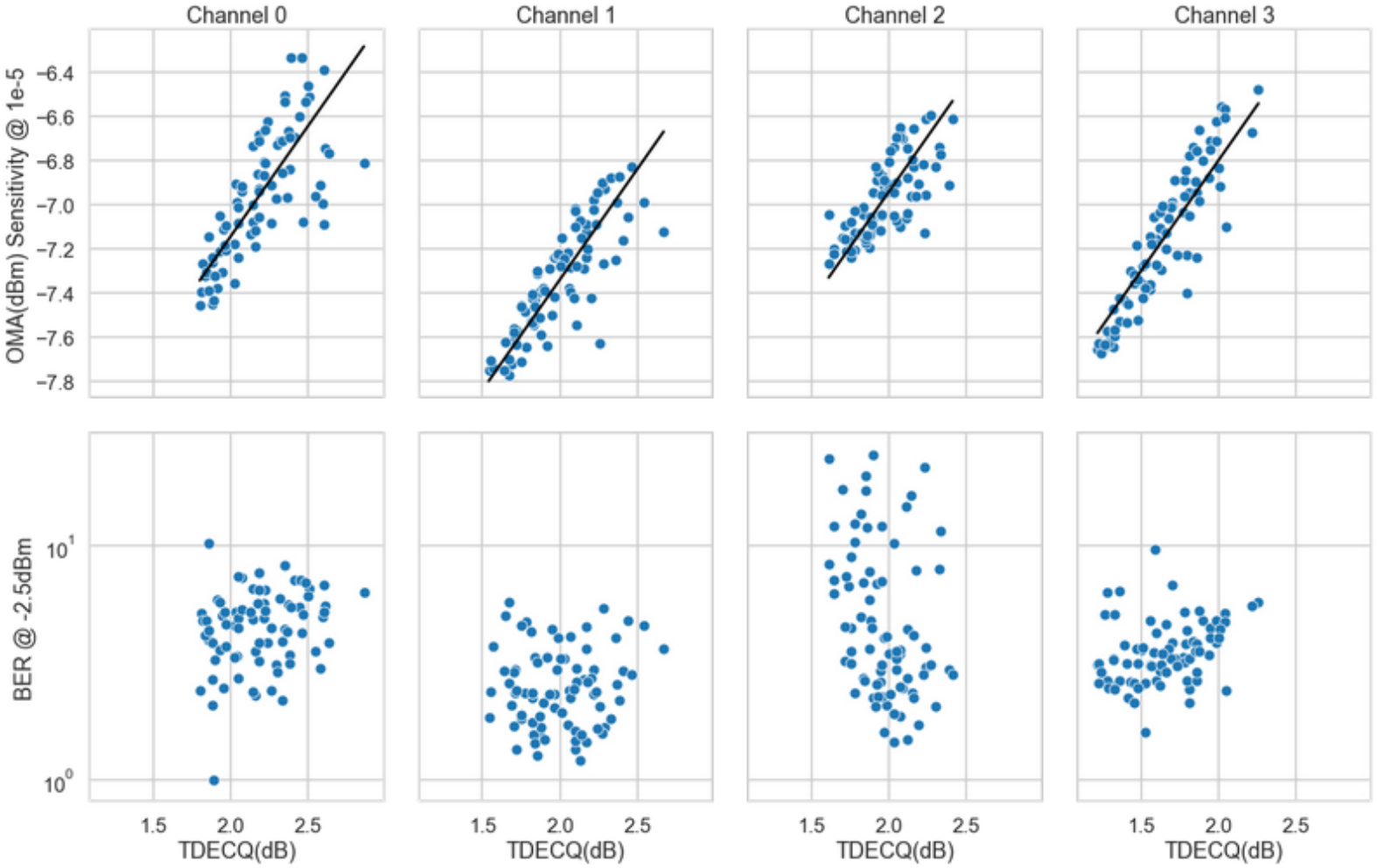


Measured Link performance

- ❑ We used setup B to measure BER versus receiver OMA for all different settings
- ❑ High overshoots (red) tend to have better sensitivity
- ❑ Channel 2 shows significant error floor penalty with larger overshoot settings
- ❑ More details in next 2 slides

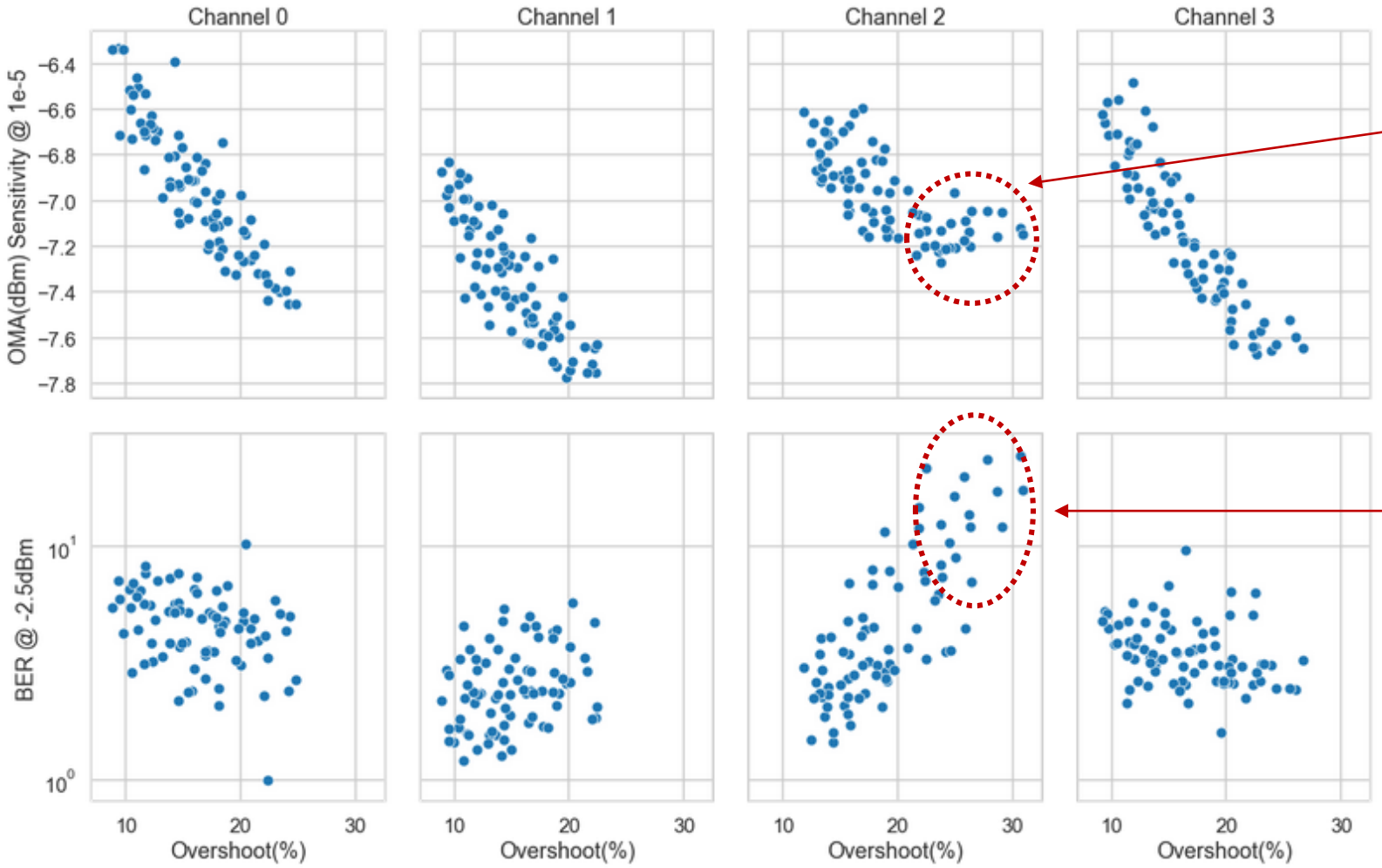


TDECQ vs Rx performance



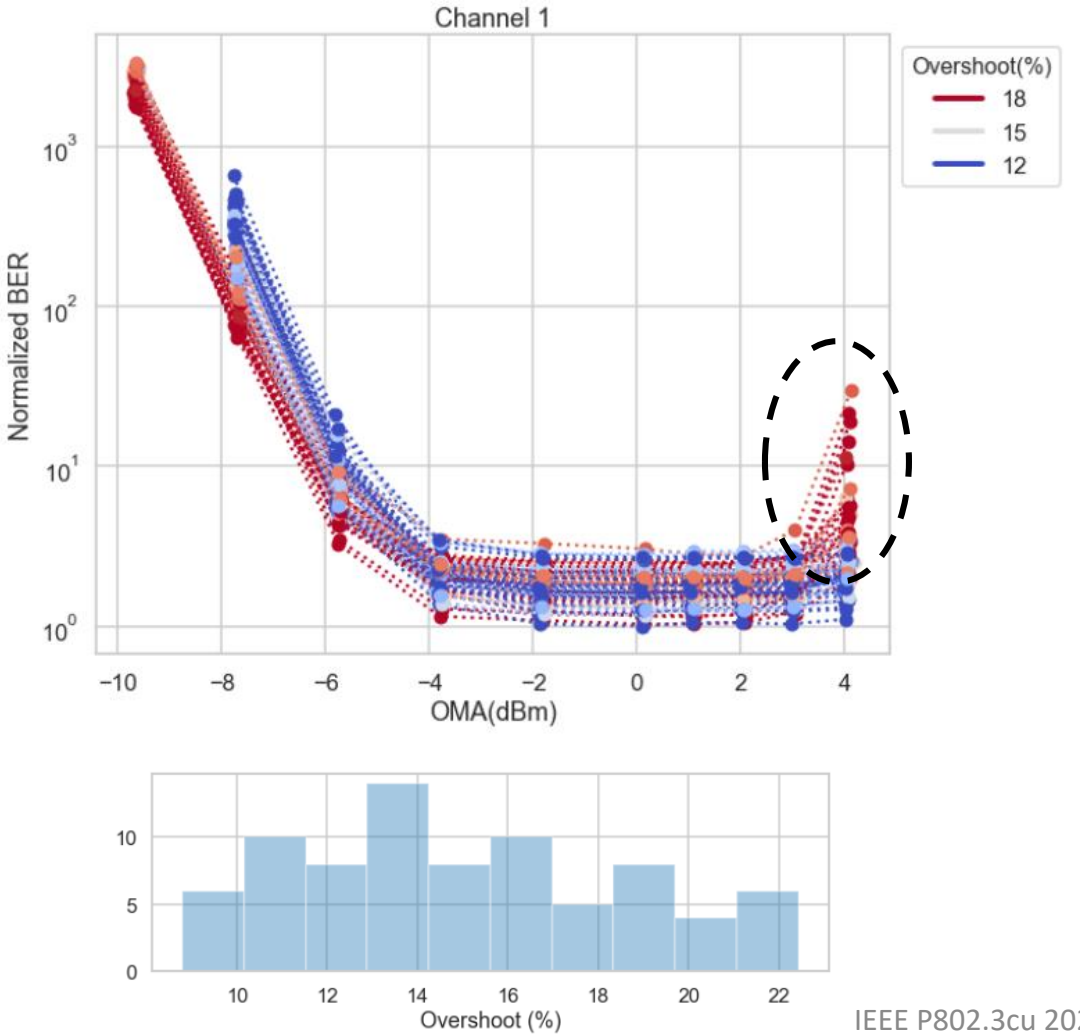
- TDECQ vs Sensitivity shows good agreement with 1:1 linear fit

Overshoot vs Rx performance



- Overshoot tends to improve sensitivity. It saturates for values larger than 22%
- **Overshoot values larger than 22% increase error floor significantly**

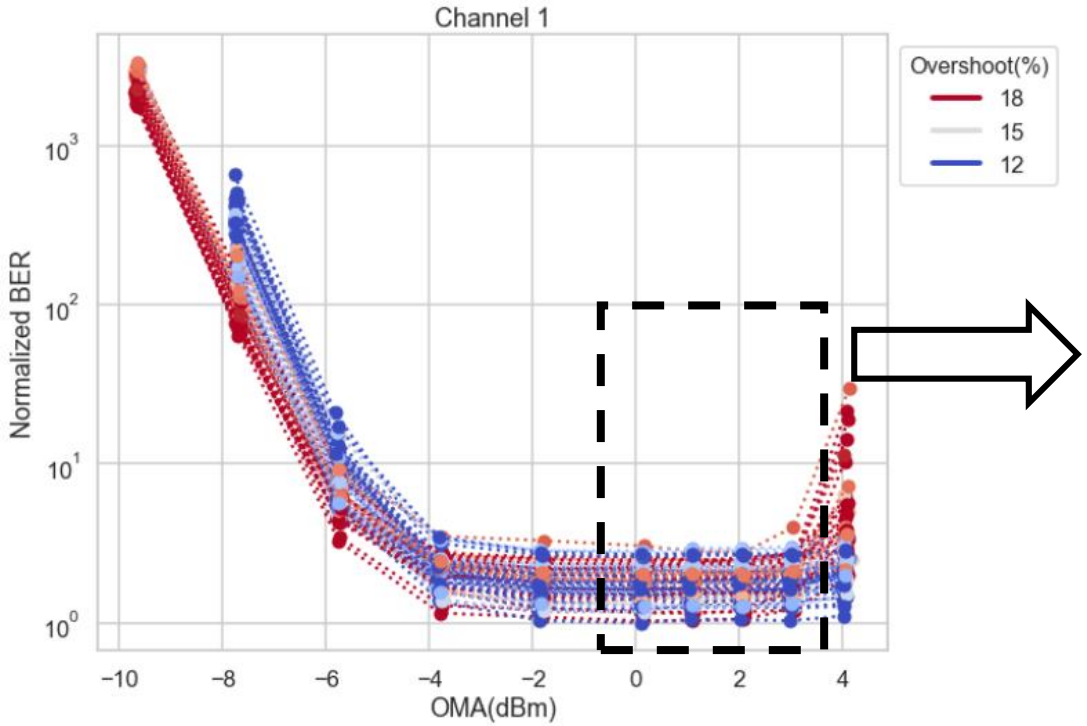
Optical amplification to reach overload

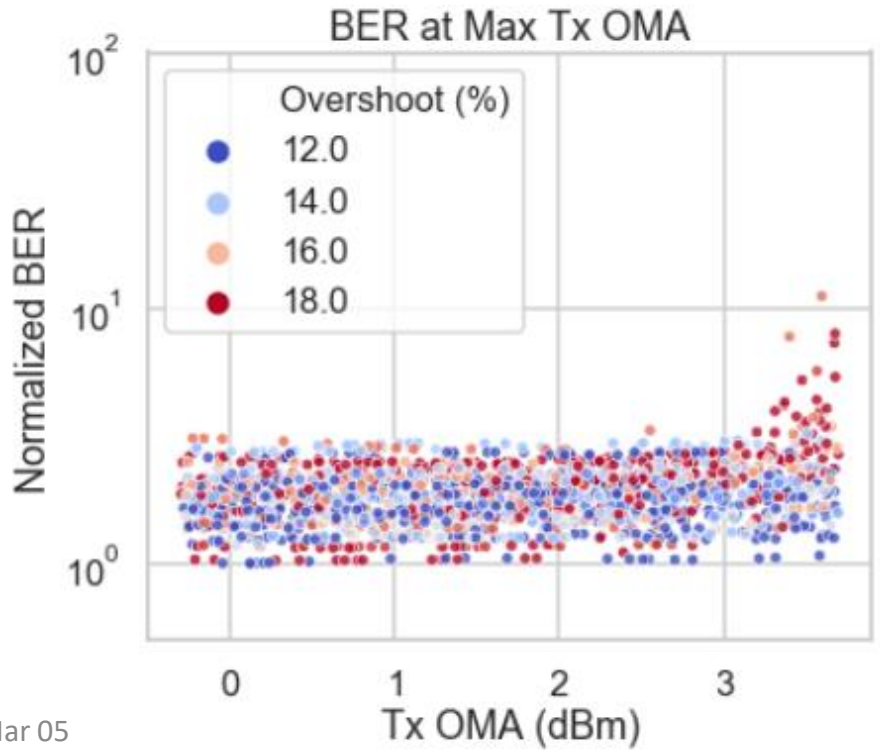


- We used setup C to measure BER versus receiver OMA for all different settings for channel 1.
- Overshoots impacts Rx performance at higher OMA
- What is the best way to protect Rx with minimum penalty on Tx yield?

Best Rx protection with min. Tx yield impact?

- ❑ We perform a Monte Carlo (MC) analysis with measured data
- ❑ MC allow us to compare specs counting over-rejected modules
- ❑ Randomly generate 20 different Tx OMAs (from allowed spec range) for each of the 79 settings
- ❑ 1580 valid transmitters



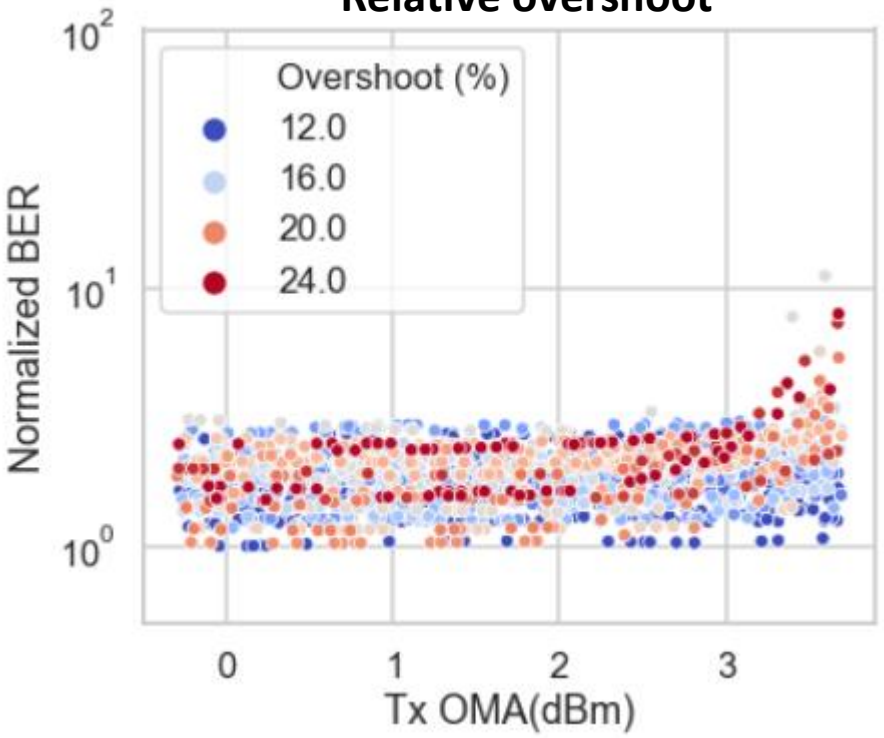


Relative or absolute overshoot?

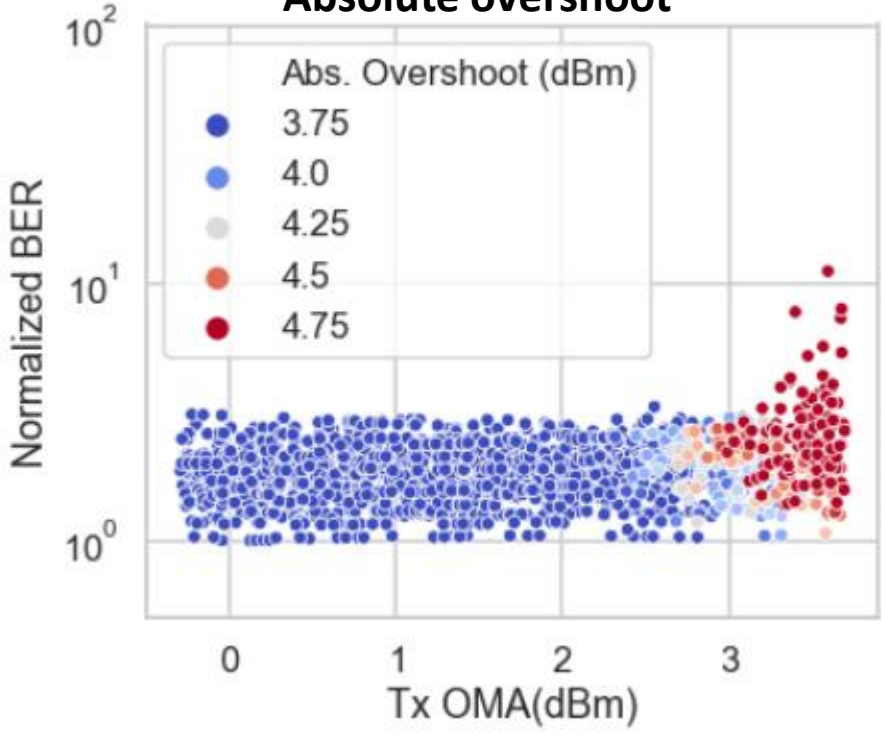
- Relative overshoot should set a limit ~17% to catch harmful Tx's. It will over-reject many Tx not casing problems to receivers

- Absolute overshoot would need to set a limit ~4.5dBm to catch harmful Rx. It will over-reject much less Tx's

Relative overshoot

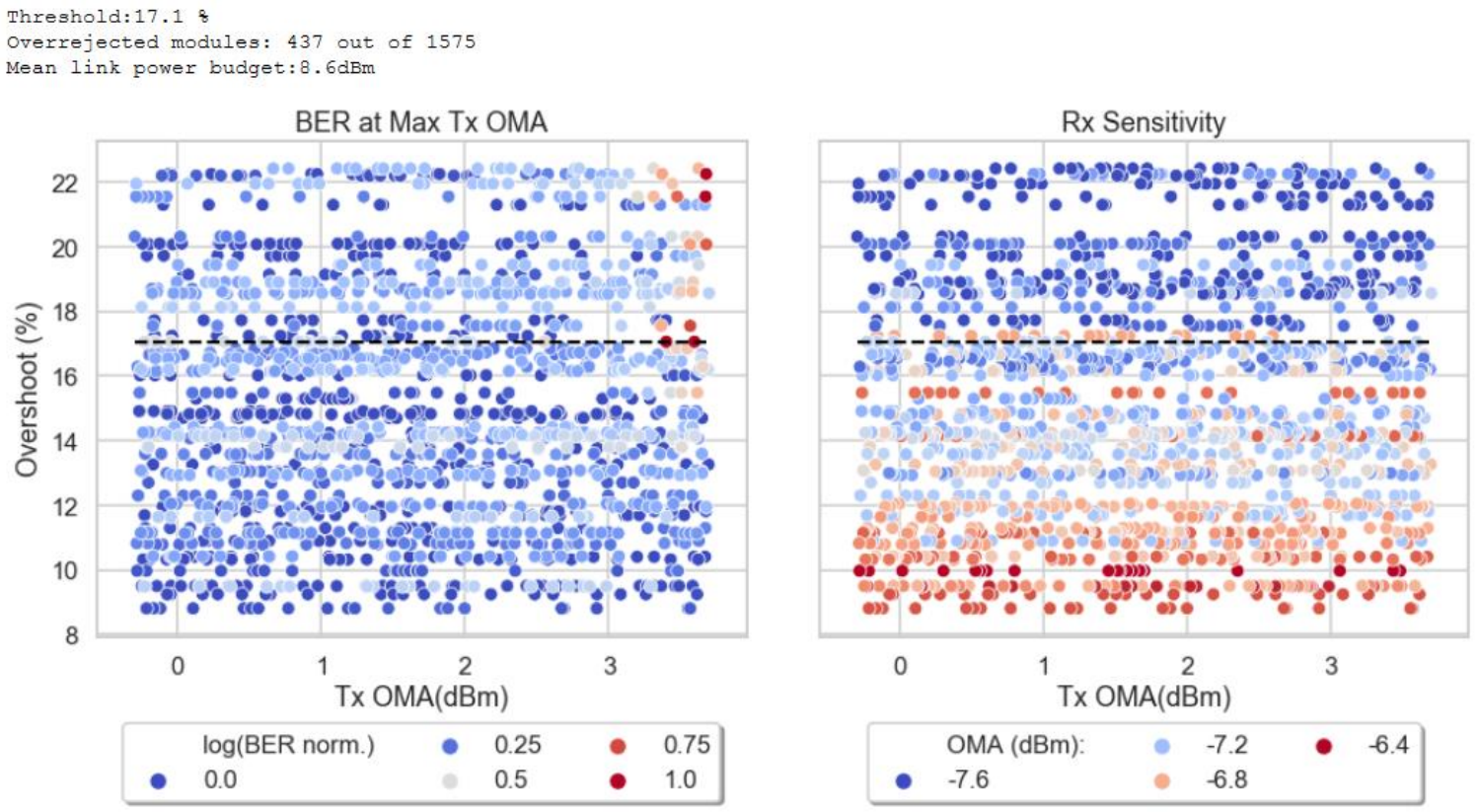


Absolute overshoot



Relative or absolute overshoot?

- We count over-rejected modules setting a limit for each spec that protects for BER penalty higher than 0.75 of a decade
- Relative overshoot would over-reject 437 Tx's
- The spec will reject mainly good sensitivity module



Relative or absolute overshoot?

- ❑ Absolute overshoot would over-reject 69 Tx's
- ❑ We do not over-reject most of the good sensitivity Tx's

```
Threshold:4.7 dBm
Overrejected modules: 69 out of 1575
Mean link power budget:8.7dBm
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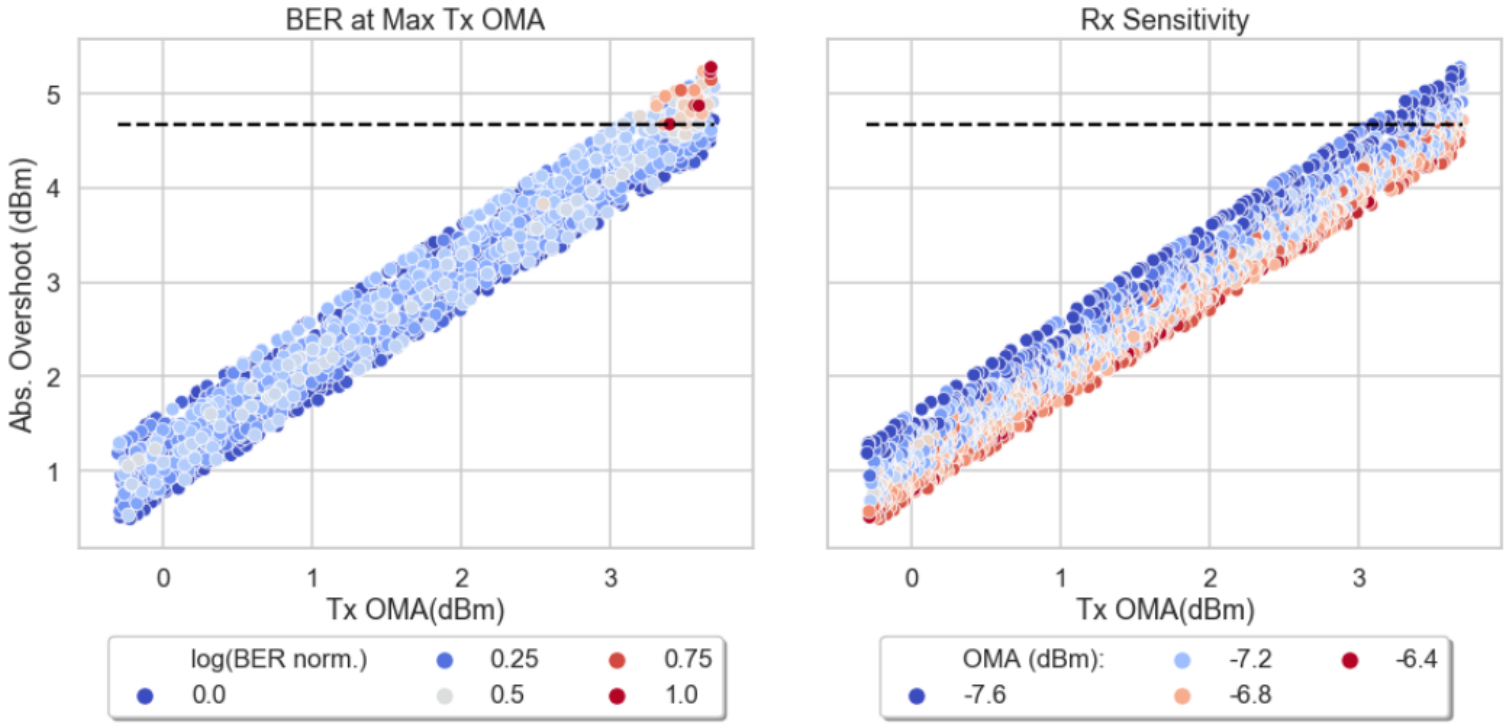
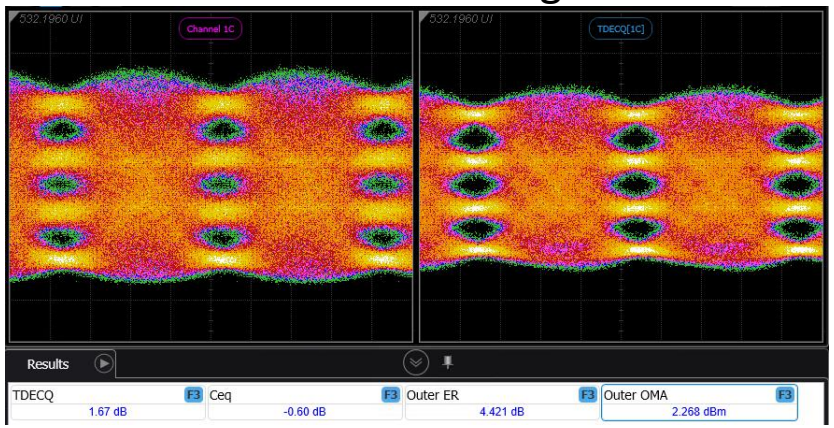


Absolute overshoot spec of 4.5dBm protects Rx from overload with lower impact on Tx yield than relative overshoot

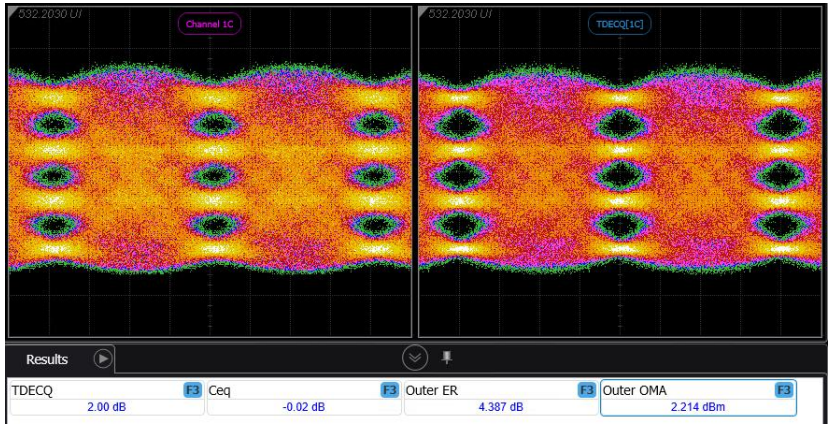
What if we push to very large overshoot?

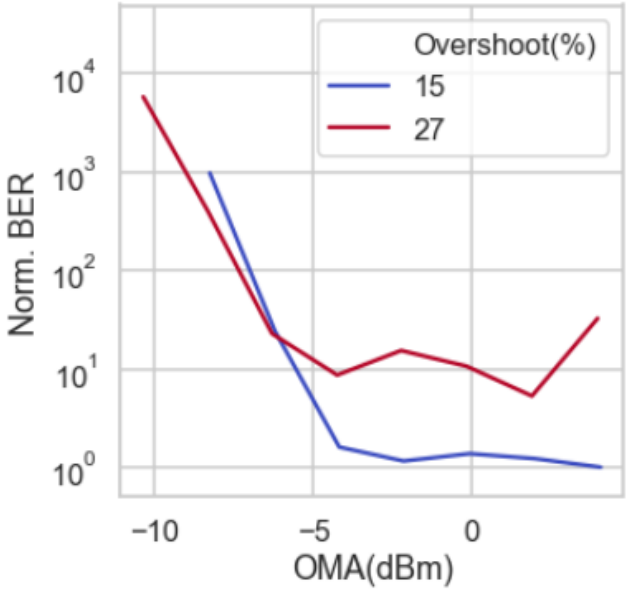
- ❑ New experiment (different module) pushing overshoot above 25% and measuring waterfall from sensitivity to overload.
- ❑ Similar approach than previous analysis: Modify first precursor and first postcursor to generate 27% overshoot

27% overshoot signal



15% overshoot signal

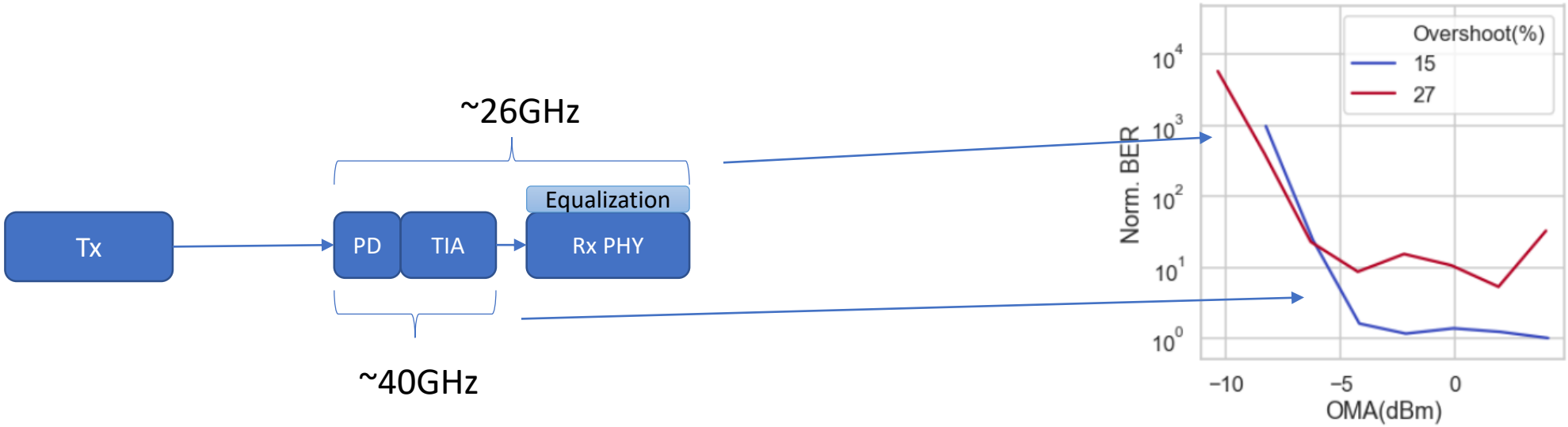




- ❑ Large overshoot shows error floor ‘bump’
- ❑ We think the ‘bump’ is associated with <u>nonlinear distortion on the TIA</u>

Comments and proposal

- ❑ TDECQ assumes a linear Rx with 26G BW and 5-tap equalization that ends up been limited by noise. This is consistent with real receiver situation at sensitivity levels
- ❑ Error floor penalty and overload are more related to nonlinear distortion on the TIA, before any Rx equalization, and probably seen higher BW.

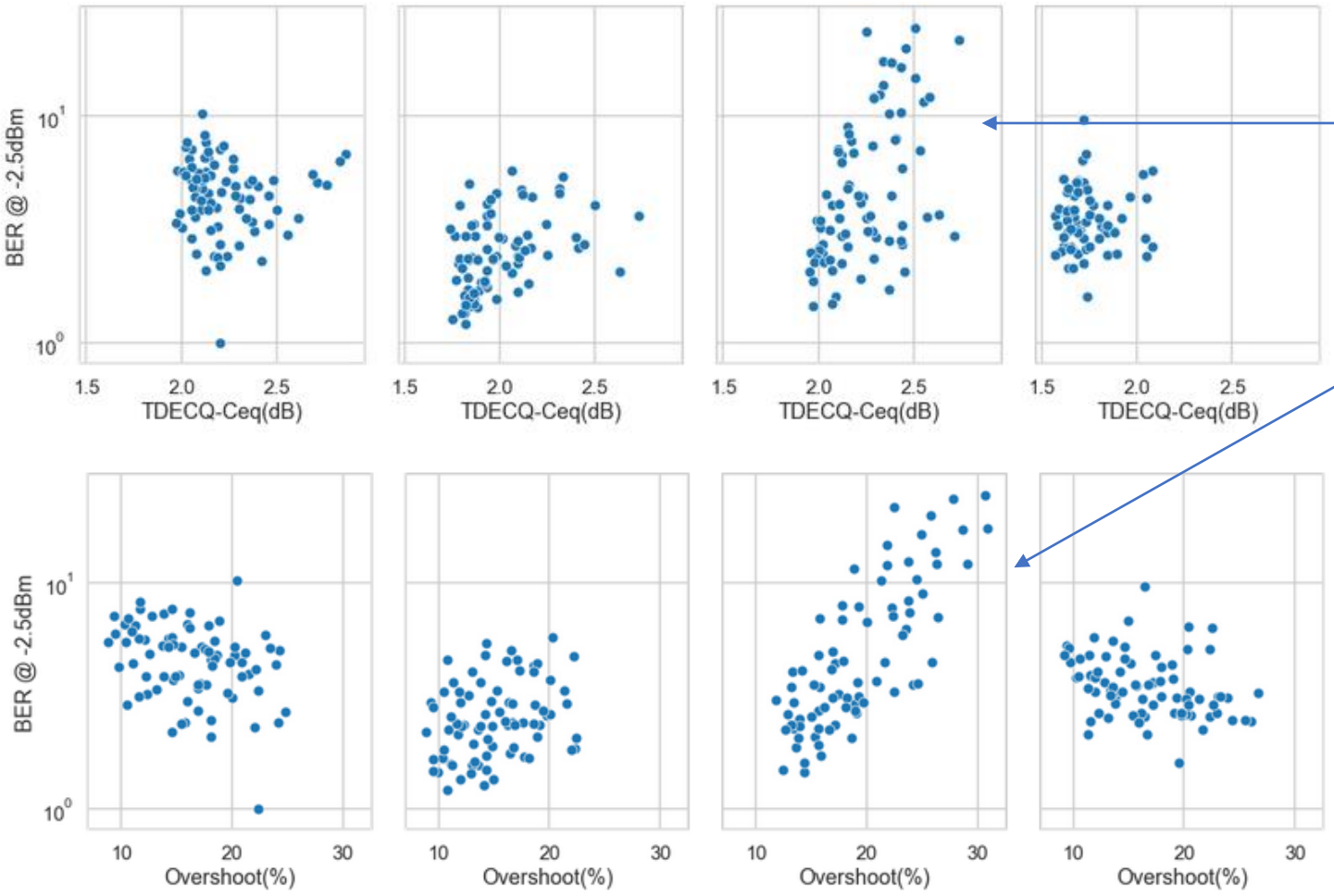


We propose:

- ❑ Keep TDECQ for what it is: guarantee Sensitivity
- ❑ Decouple error floor & overload protection from TDECQ equalization
- ❑ Set maximum 22% overshoot specs to protect Rx error floor
- ❑ Set maximum 4.5dBm absolute overshoot spec to protect Rx at overload

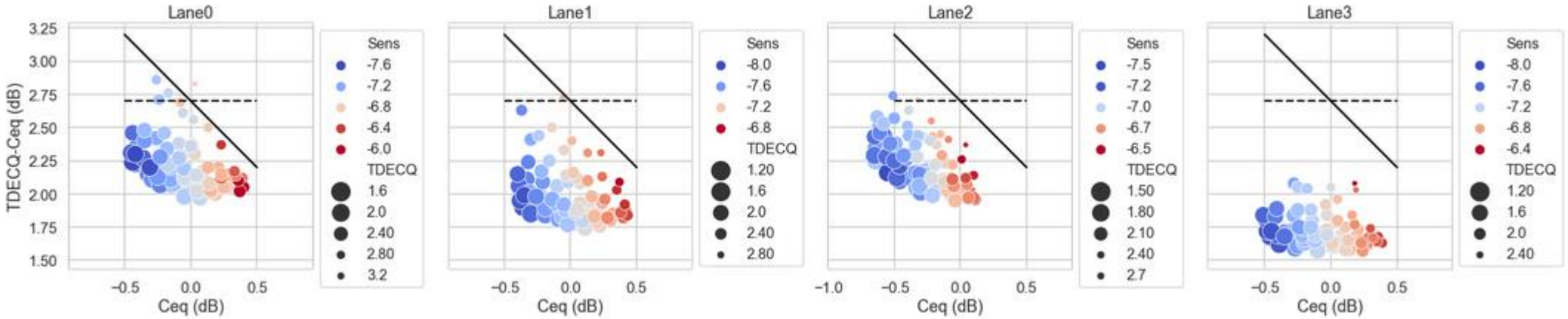
What about TDECQ- 10*log(Ceq)?

TDECQ-10*log(Ceq) for error floor protection?

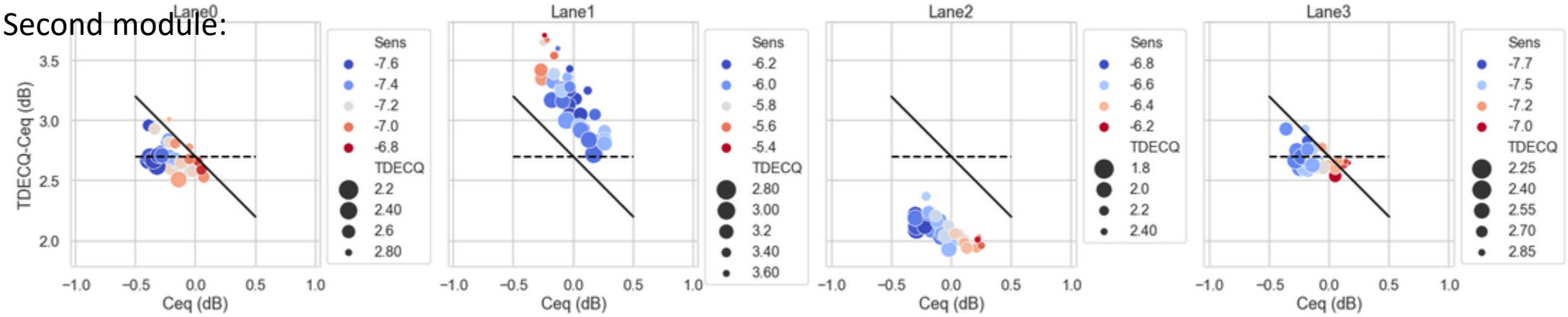


- TDECQ-10*log(Ceq) shows correlation with error floor
- Relative overshoot shows better correlation

TDECQ-10*log10(Ceq) vs Sensitivity?



Second module:



- For sensitivity is the relative position to the TDECQ diagonal line what matters, not your vertical position

TDECQ-10*log(Ceq) for Overload protection?

```
Threshold:1.9 dB
Overrejected modules: 876 out of 1575
Mean link power budget:8.7dBm
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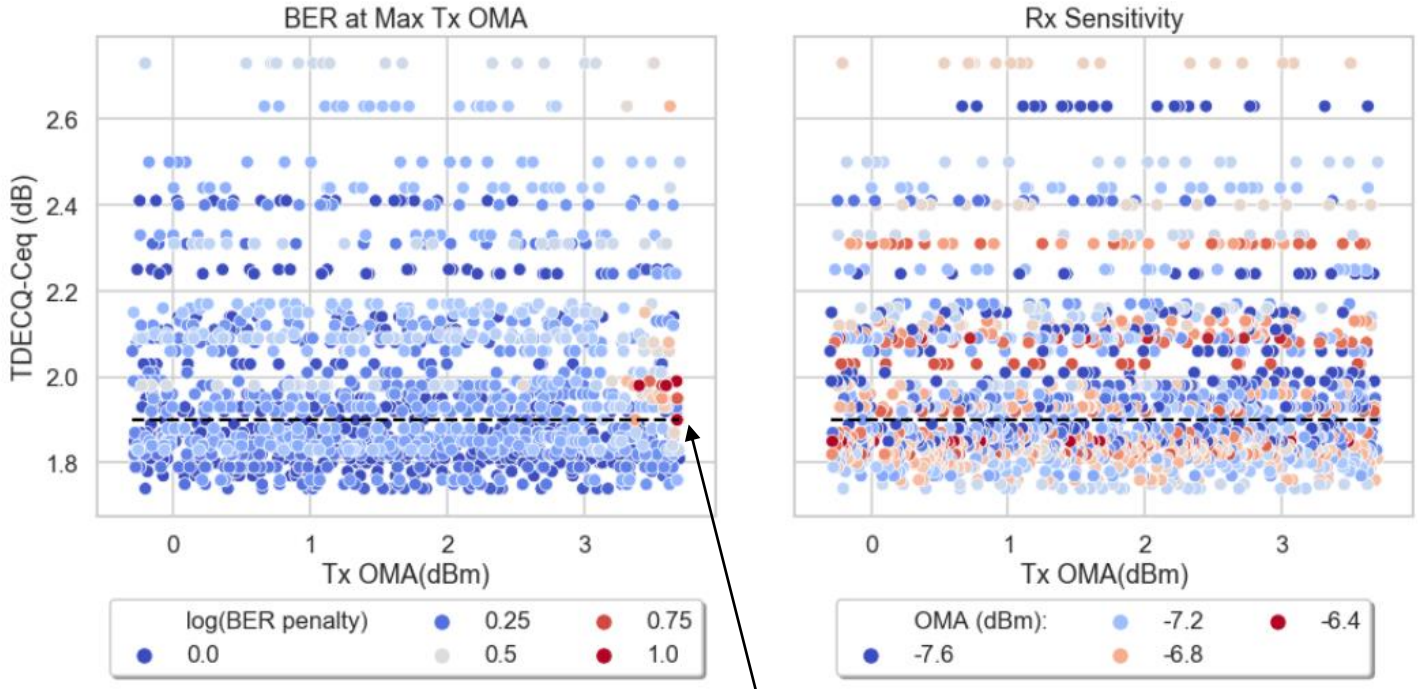

TDECQ-Ceq	log(BER penalty)	TDECQ(dB)	Ceq(dB)	Overshoot(%)	Tx OMA(dBm)	Overshoot(dBm)
1.98	0.753083	1.72	-0.26	17.554593	3.567422	4.874271
1.98	1.046035	1.75	-0.23	17.062073	3.596510	4.871580
1.98	0.887448	1.75	-0.23	17.062073	3.400251	4.675321
1.90	0.899022	1.54	-0.36	22.260447	3.677540	5.276846
1.99	0.862920	1.64	-0.35	21.559264	3.673486	5.230444

- TDECQ-10*log(Ceq) would over-reject 876 Tx's
- Harmful Transmitters with low TDECQ and significant overshoot would be hard to catch with TDECQ-10log(Ceq) spec.
- Absolute Overshoot seems a better metric

Conclusion on TDECQ-10*log(Ceq)

- It shows some correlation with error floor. However, we think it is better protected with overshoot
- If error floor is determined by TIA nonlinearity (before Rx EQ), TDECQ equalization should not be part of the spec protecting for error floor. Overshoot is more relevant for TIA nonlinearity
- Poor correlation with BER penalty at overload and Sensitivity

Backup

Does overshoot always improve TDECQ?

- On this module, channel 1 seems to add more noise or unequalizable distortion when adding overshoot on the Tx

Well behaved Tx