Impact of Tx Overshoot on Link Performance and TDECQ

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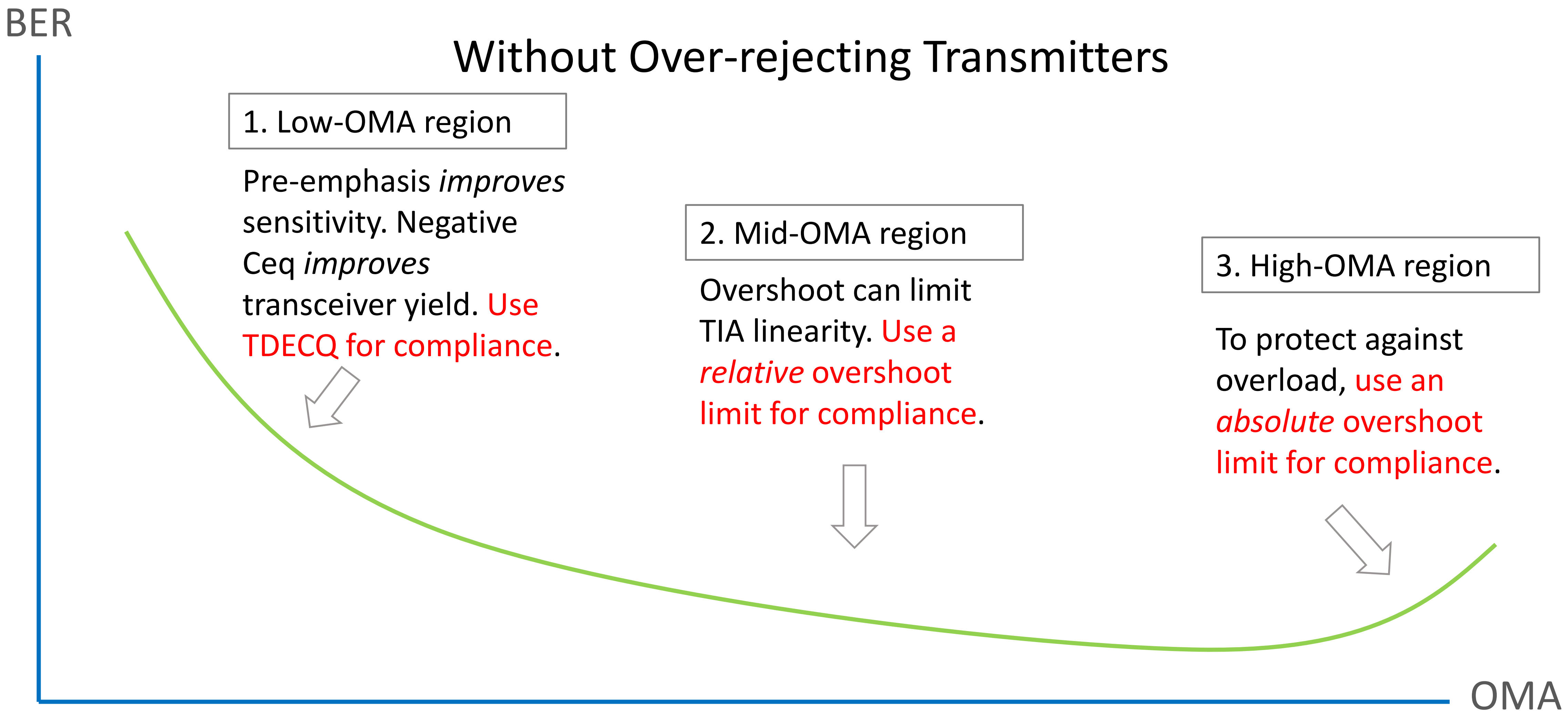
Introduction

- 802.3cu draft 2.0 introduced overshoot transmitter spec to protect receivers from harmful transmitters
- During March ad-hoc meeting we presented many experimental data analyzing overshoot vs Rx sensitivity, error floor and overload
  http://www.ieee802.org/3/cu/public/cu_adhoc/cu_archive/rodes_3cu_adhoc_030520_v2.pdf
- We received comments about clarification of our recommendation
- This presentation tries to clarify our recommendation based on the previously presented data

Achieving Robust Transmitter Compliance



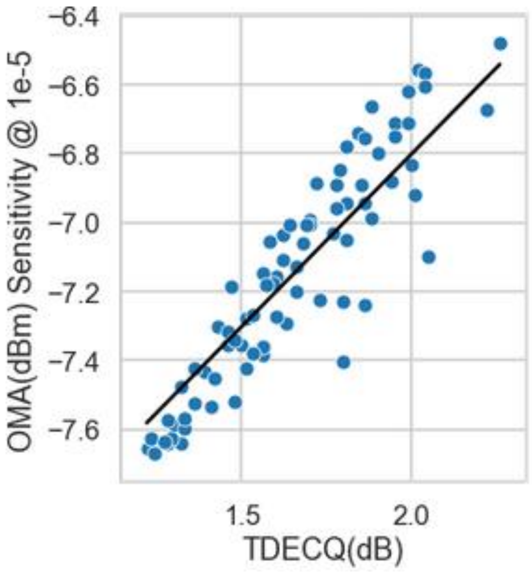
Low-OMA region: use TDECQ for compliance

Why TDECQ?

It is meant to simulate sensitivity. Instead of reducing Tx signal until the Rx noise limits BER to 2.4e-4, we add simulated noise to a fixed Tx signal until we hit the same BER.

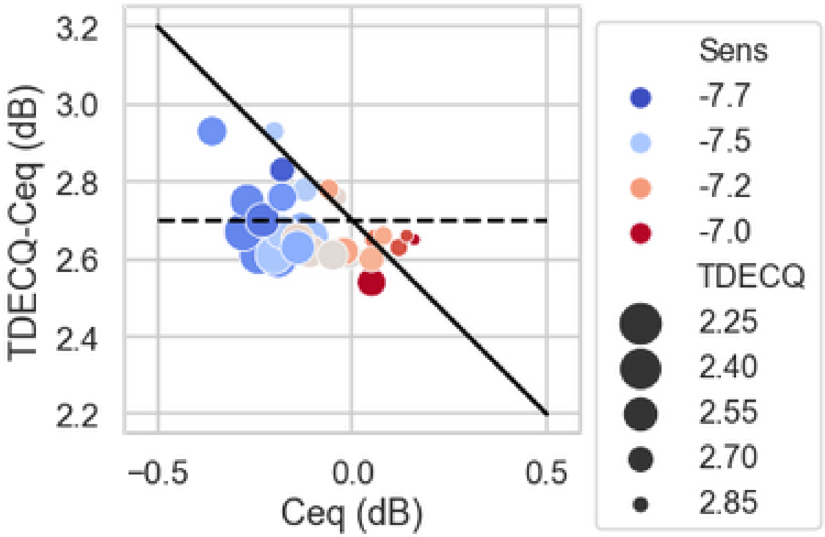
Is TDECQ reliable?

Yes. TDECQ vs Sensitivity shows decent agreement with 1:1 linear fit



Does TDECQ-10log(Ceq) help, or could harm?

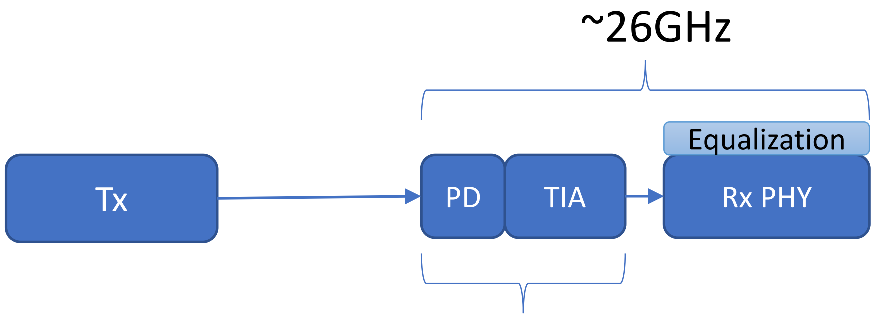
Transmitters could fail TDECQ-10log(Ceq) even with good sensitivity



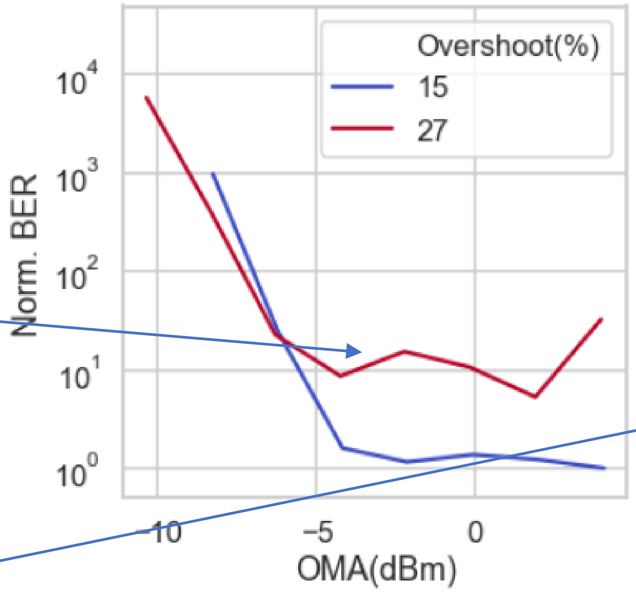
Mid-OMA region: use overshoot for compliance

Why control relative overshoot?

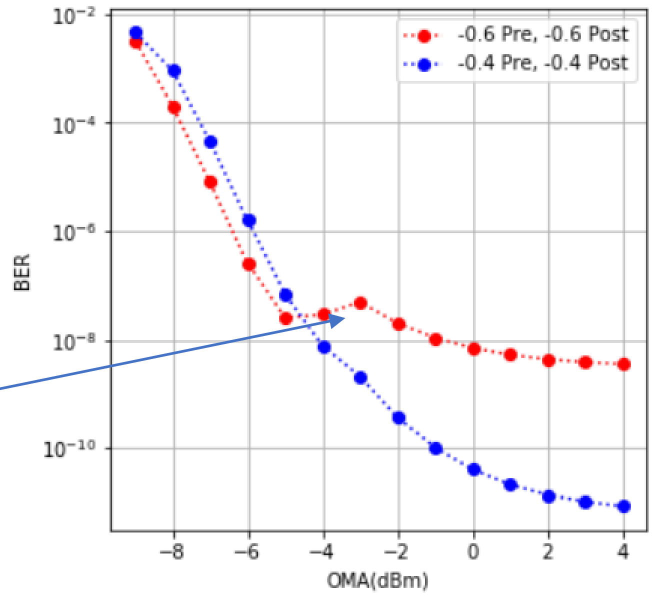
Overshoot triggers TIA nonlinearities that limit Error floor



Measured real Rx



TIA THD simulation



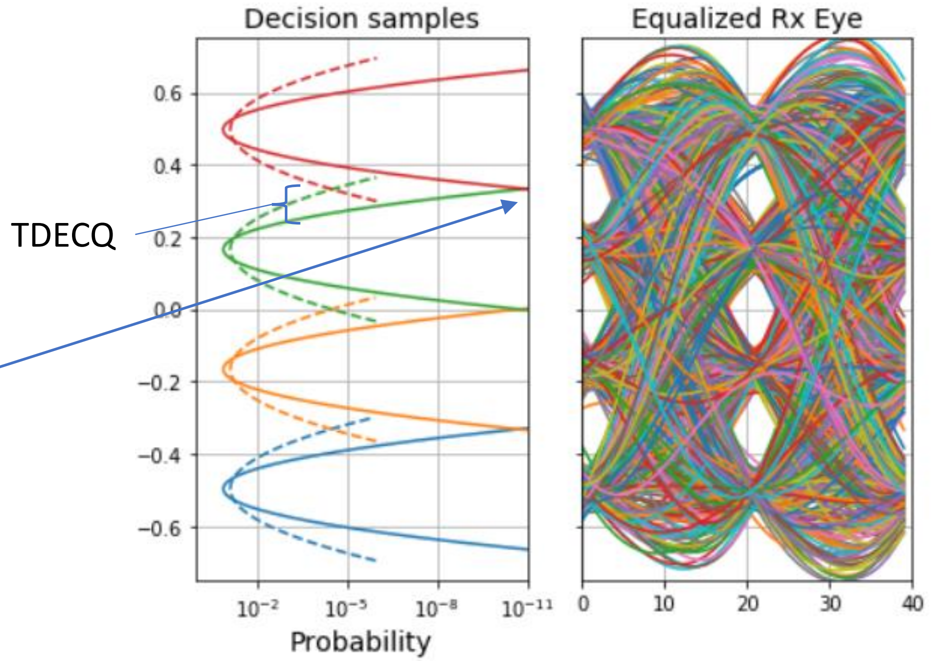
Why do we think this is TIA related?

1. We can simulate a similar error bump with a simple logistic function (S-shaped) to model TIA saturation
2. Manual gain control of TIA eliminates the error bump

Mid-OMA region: use relative overshoot for compliance

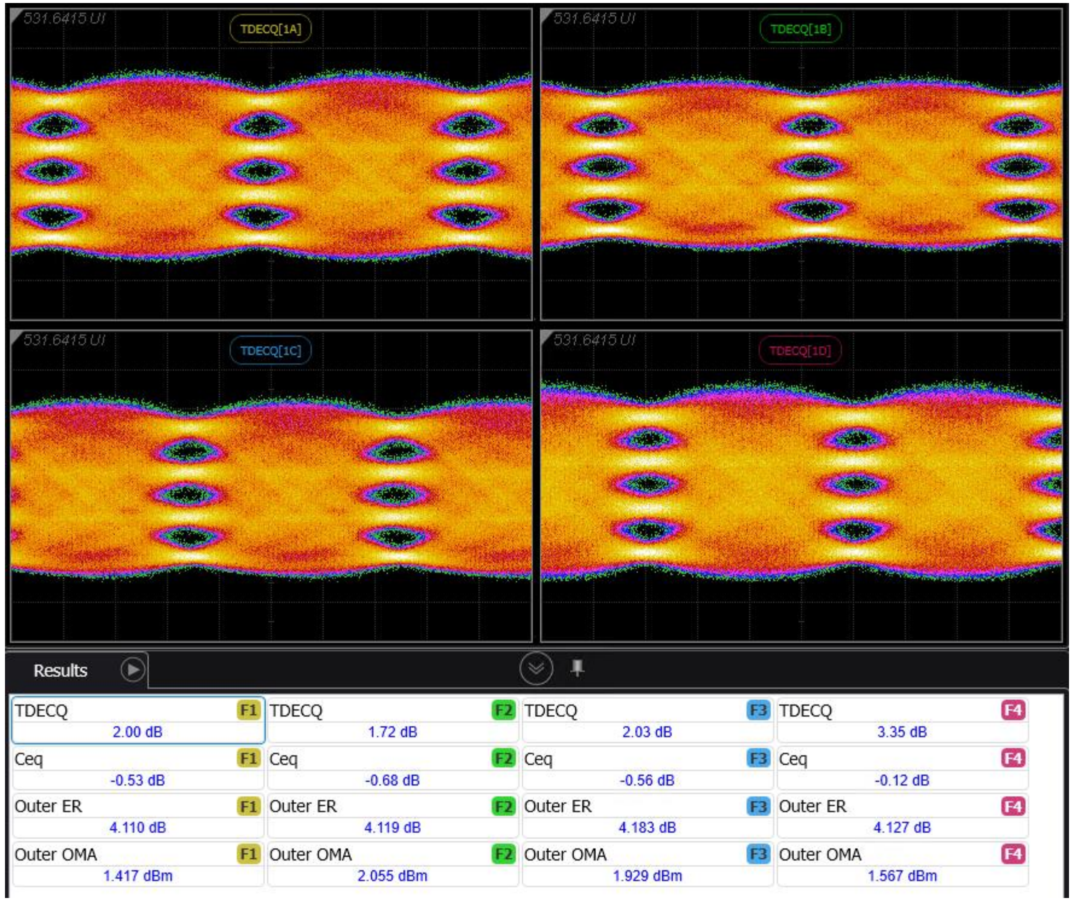
Why not use TDECQ-10*log(Ceq) to control error floor?

- TDECQ works adding noise to hit 2.4e-4 BER(dashed line). We shouldn't expect the same spec to predict BER performance at 1e-7, 1e-8 or lower.
- Error floor is not about how much noise you can add (like TDECQ), but about how low your error probability is
- "What should the spec **NOT** do:
  - Fail devices that would work in the field (yield reduction and cost increase)
  - Pass devices that would not work in the field (unhappy customers and returns that will pass again)" by Peter Stassar. Next 2 slides shows data on this.



Mid-OMA region: use overshoot for compliance

Why not use TDECQ-10*log(Ceq) for controlling error floor?



Measurements:

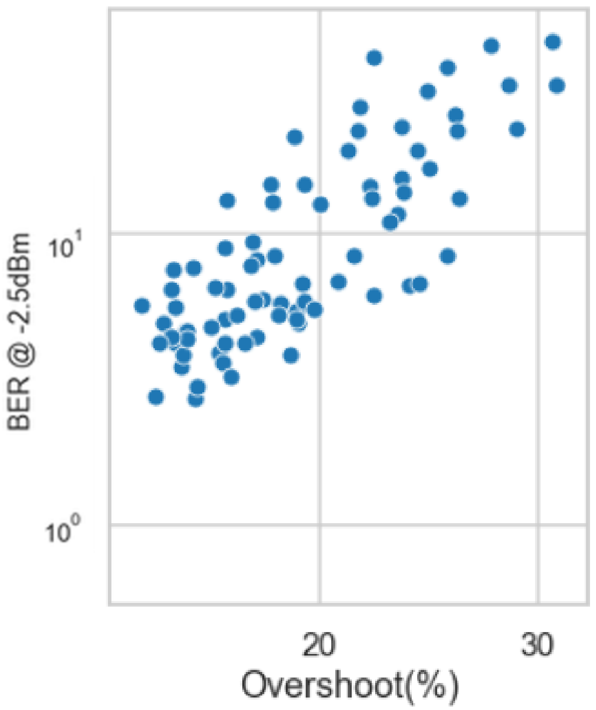
Lane	TDECQ(dB)	Ceq(dB)	TDECQ-Ceq(dB)	error floor
1	2.00	-0.53	2.53	1.06E-06
2	1.72	-0.68	2.4	2.98E-07
3	2.03	-0.56	2.59	4.15E-07
4	3.35	-0.12	3.47	7.27E-09

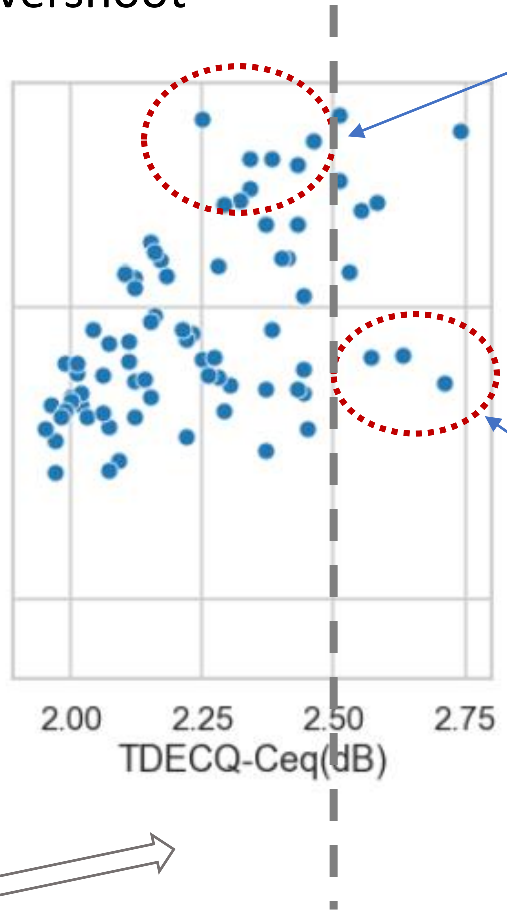
Purposely modified FR4 module to show:

- ❑ TDECQ-10log(Ceq) spec would fail the Tx that has the best error floor (by more than 1 decade)
- ❑ TDECQ-10log(Ceq) spec will pass transmitters that will show very poor error floor in the field

Mid-OMA region: use relative overshoot for compliance

Data presented on March ad-hoc meeting shows stronger correlation of error floor with overshoot





Passing devices that would 'not work' in the field

	TDECQ	Ceq	ER	TDECQ-Ceq
168	1.61	-0.64	4.212	2.25
161	1.70	-0.64	4.217	2.34
214	1.85	-0.53	4.231	2.38
162	1.82	-0.52	4.236	2.34
169	1.78	-0.54	4.232	2.32

Failing devices that would work in the field

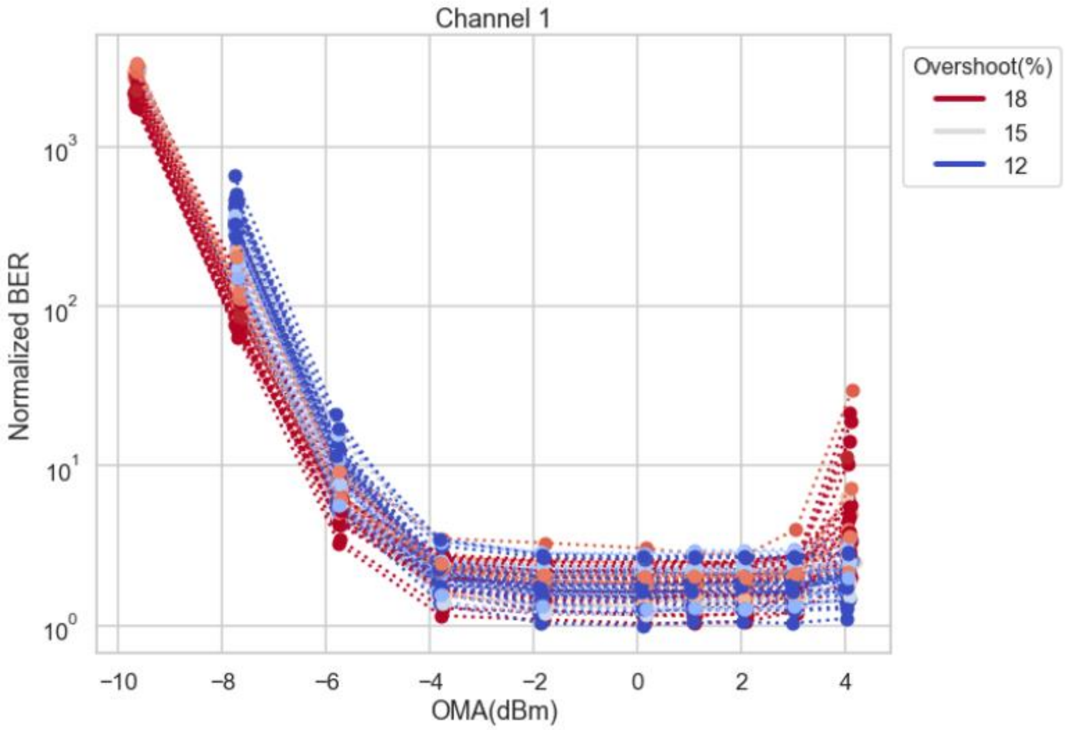
	TDECQ	Ceq	ER	TDECQ-Ceq
230	2.39	-0.32	4.256	2.71
216	2.07	-0.50	4.242	2.57
223	2.24	-0.39	4.274	2.63

This example is based on the implementer's requirement of 0.9 dB manufacturing margin

High-OMA region: absolute overshoot for compliance

Why absolute overshoot?

Transmitters with maximum allowed overshoot(%) can still overload TIA when in conjunction with maximum Tx OMA spec.



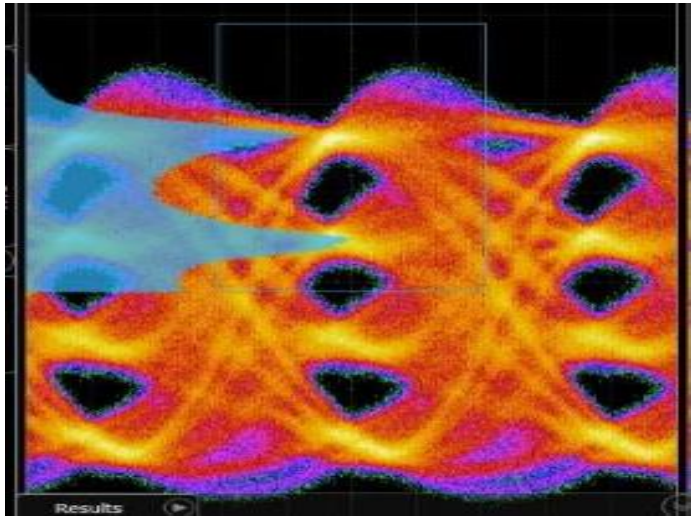
Why not just use a tighter relative overshoot (%) spec instead?

Protecting Rx at overload with overshoot(%) would require a much tighter spec value. This would harm sensitivity for all Transmitters just to protect from the few with high Tx OMA

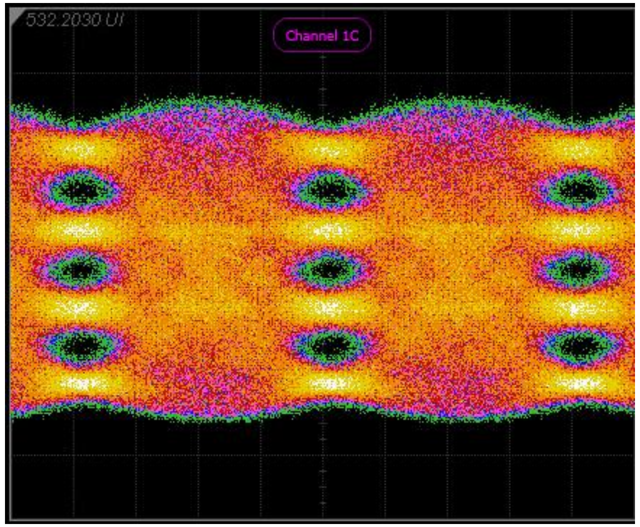
Overshoot measurement guidelines

- 50G PAM4 DML-based and 100G PAM4 EML-based modules show overshoot on different part of the UI.
- We recommend overshoot measurement over the whole UI to cover all Tx types
- Maximum overshoot should be satisfied at TP2 and TP3:
    - Absolute overshoot will be worst at TP2, Relative overshoot could be worst at TP3 (to account for dispersion)
- Eye Mode SSPRQ vs Oscilloscope Mode Square wave
    - Square wave more fundamental, SSPRQ more practical
- For further investigation

50G PAM4 DML



100G PAM4 EML



Summary

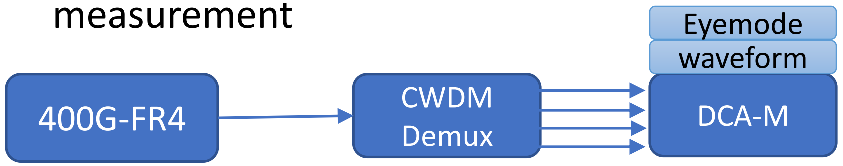
- Keep TDECQ for what it is: guarantee Sensitivity
- Decouple error floor & overload protection from TDECQ equalization
- Set maximum 22% overshoot specs to protect Rx error floor
- Set maximum 4.5 dBm absolute overshoot spec to protect Rx at overload
- Do not impose (TDECQ – 10logCeq) constraint
  - It results in over-rejection of transmitters, which will raise cost
  - A better way of ensuring transmitter compliance is thru overshoot control

Backup

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)



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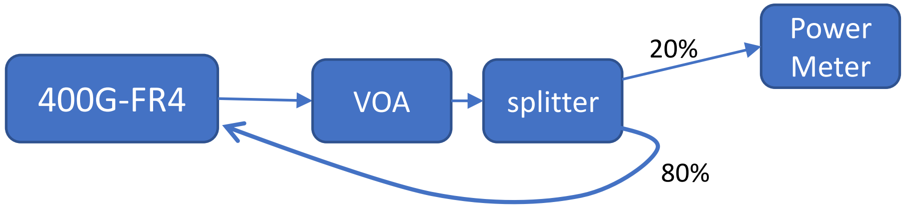
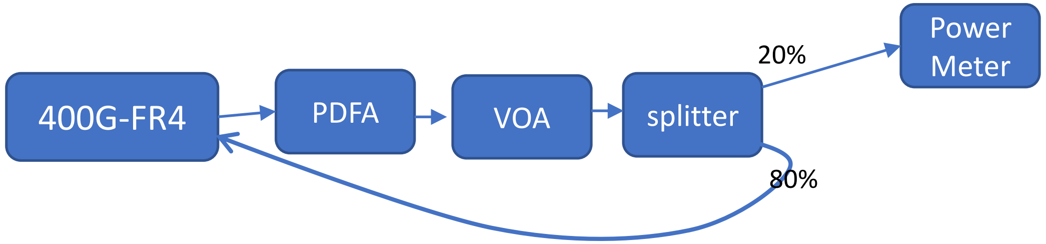
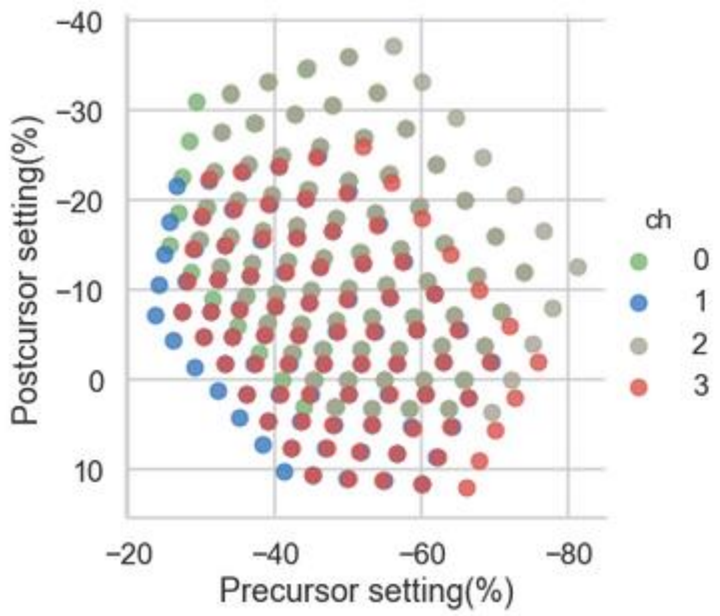


C)



- ❑ 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