Understanding OMA_{outer} and its requirements

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Supporter list

- Piers Dawe, Nvidia
- Mike Dudek, Marvell

In reference to comment # I-218

Cl **180** *SC* **180.9.5** *P* **476** *L* **42** # I-218

Maniloff, Eric Ciena Corporation

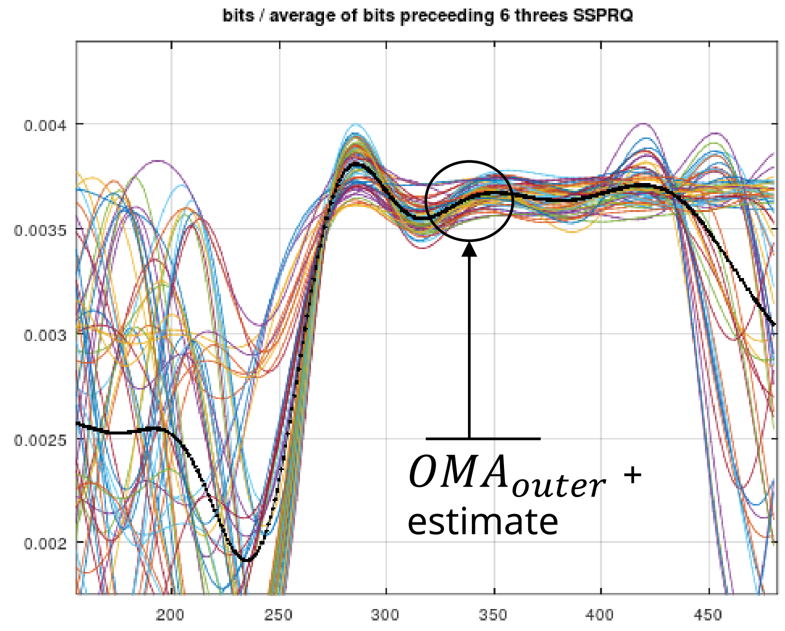
Comment Type **TR** *Comment Status* **X**

OMA_Outer with pattern 6 (SSPRQ) has multiple runs of ≥ 7 threes and ≥ 6 zeroes. In order to obtain consistent measurements, all runs of 7's and 3's should be measured.

SuggestedRemedy

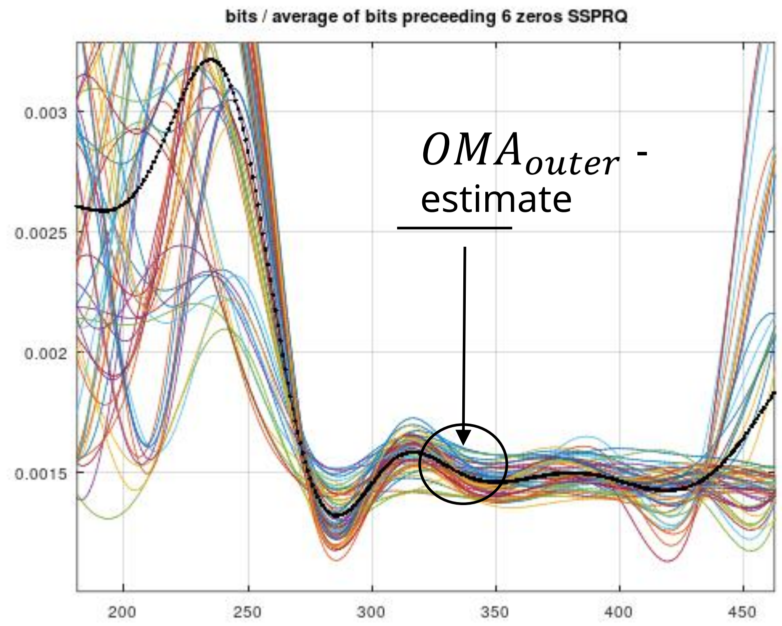
Change text to: "When measured with pattern 6, OMA_outer is measured as the difference between the average optical launch power level P3, measured over the central 2 UI of the first 7 UI of
all runs of 7 threes or more, and the average optical launch power level P0, measured over the central 2 UI of the first 6 UI of all runs of 6 zeroes or more.". Make similar change in clause 181.9.5, 182.9.5, and 183.9.5

Proposed Response *Response Status* **O**



Resolution: Approve remedy suggested in
https://www.ieee802.org/3/dj/public/26_03/alloin_3dj_01a_2603.pdf

and supported by directional Straw Poll #6 vote results in:
https://www.ieee802.org/3/dj/public/26_03/motions_3dj_2603.pdf



Straw Poll # 6

I support the addition of the proposed clarification to the OMA_outer definition when measured using a SSPRQ as outlined in alloin_3dj_01a_2603 slide 13.

Yes

No

Result: Y: 61 N: 11

Summary

- OMA_{outer} measurement may seem an ambiguous quantity. While previously associated with the settled OMA value of a transmitter, the quantity as defined per SC180.9.5 represents a more complex quantity that effectively attempts to represent the useful signal variance of the transmitter that it characterizes, while still being the amplitude of an equivalent step response. As defined, it is resilient to bandwidth limitation and optical fiber impairments, as well as to reflections within the transmitter.

- We analyze OMA_{outer} measured per SC180.9.5 and reaffirm that these are the key attributes that make the OMA_{outer} metric the proper reference for the computation of the TDECQ penalty, and its usage in the link budget. With this objective in mind, we argue that when applied to an SSPRQ sequence, the method described in SC180.9.5 should measure OMA_{outer} at the same locations as those defined for the PRBS13Q sequence to preserve those attributes. This is on support of comment # I-218 against Draft D3.0.

- If required, we propose that any redefinition of the OMA_{outer} method as per SC180.9.5 takes into consideration the intrinsic features of the metric and its associated objectives.

Outline

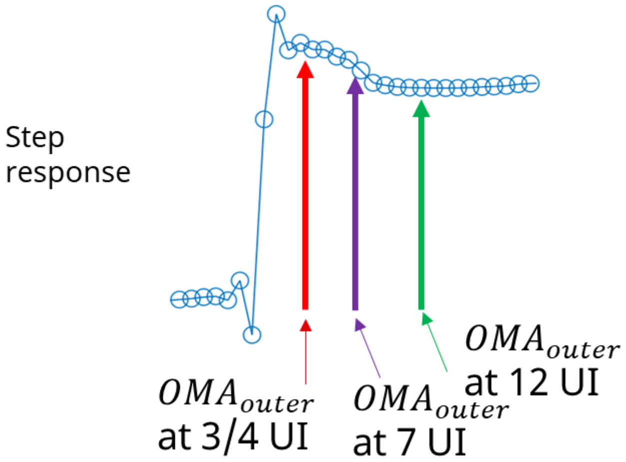
- IEEE definitions of OMA_{outer} per SC180.9.5
- OMA_{outer} measurement interpretation
- How does the OMA_{outer} windowing work exactly?
- Case of a pre-emphasized or de-emphasized TX vs case of a TX with unintended reflections
- Requirements of an “ideal” OMA_{outer} reference
- Conclusion and recommendation

- Backup slides : Confirmation and interpretation of results reported in https://www.ieee802.org/3/dj/public/adhoc/electrical/26_0421/el-chayab_3dj_adhoc_01_260421.pdf
  - Scenarios evaluated and results
  - Evolution of OMA_{outer} and TDECQ with reflections of various delays : (dj Draft 3.0)
  - Evolution of OMA_{outer} and TDECQ with reflections of various delays : (clause 121)
  - Examples of step responses of 100G & 200G commercial modules

OMA_{outer} measurement per SC180.9.5

OMA_{outer} is measured on the 2 middle UIs of a window of runs of 6 or 7 consecutive zeros or threes.

This corresponds to evaluating the step response of the equivalent underlying module impulse response at the 3rd or 4th UI into the step



180.9.5 Outer optical modulation amplitude (OMA_{outer})

The OMA_{outer} of each lane shall be within the limit given in Table 180–7. The OMA_{outer} is measured using a test pattern specified for OMA_{outer} in Table 180–14 as the difference between the average optical launch power level P_3, measured over the central 2 UI of a run of 7 threes, and the average optical launch power level P_0, measured over the central 2 UI of a run of 6 zeros, as shown in Figure 180–8. OMA_{outer} is measured using the waveforms captured at the output of the reference receiver defined in 180.9.2.

Draft Amendment to IEEE Std 802.3-2022 | IEEE *Draft* P802.3dj/D3.0
IEEE P802.3dj 200 Gb/s, 400 Gb/s, 800 Gb/s, and 1.6 Tb/s Ethernet Task Force | 16 February 2026

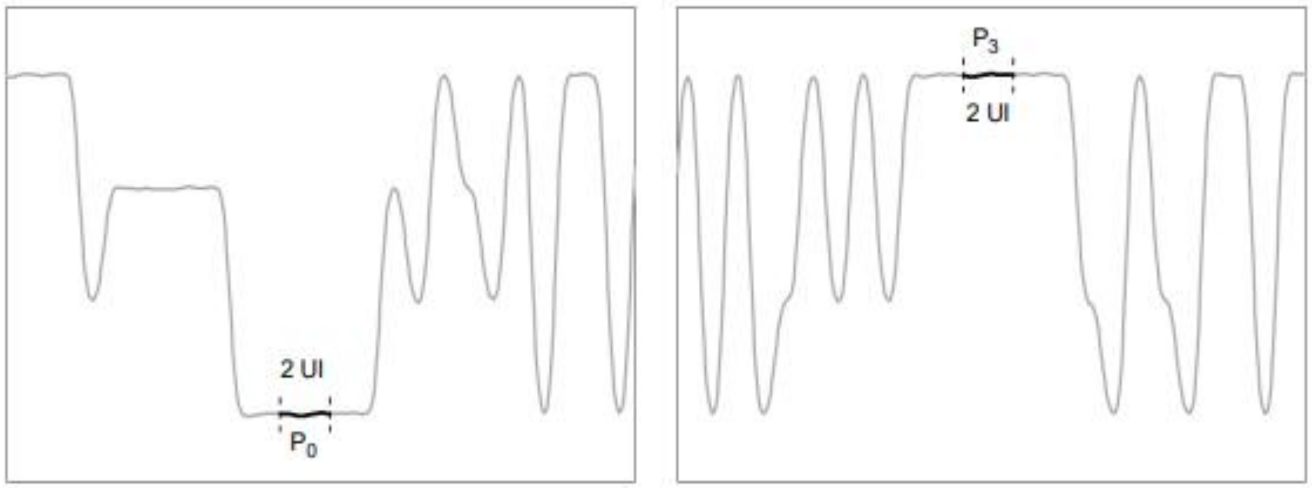
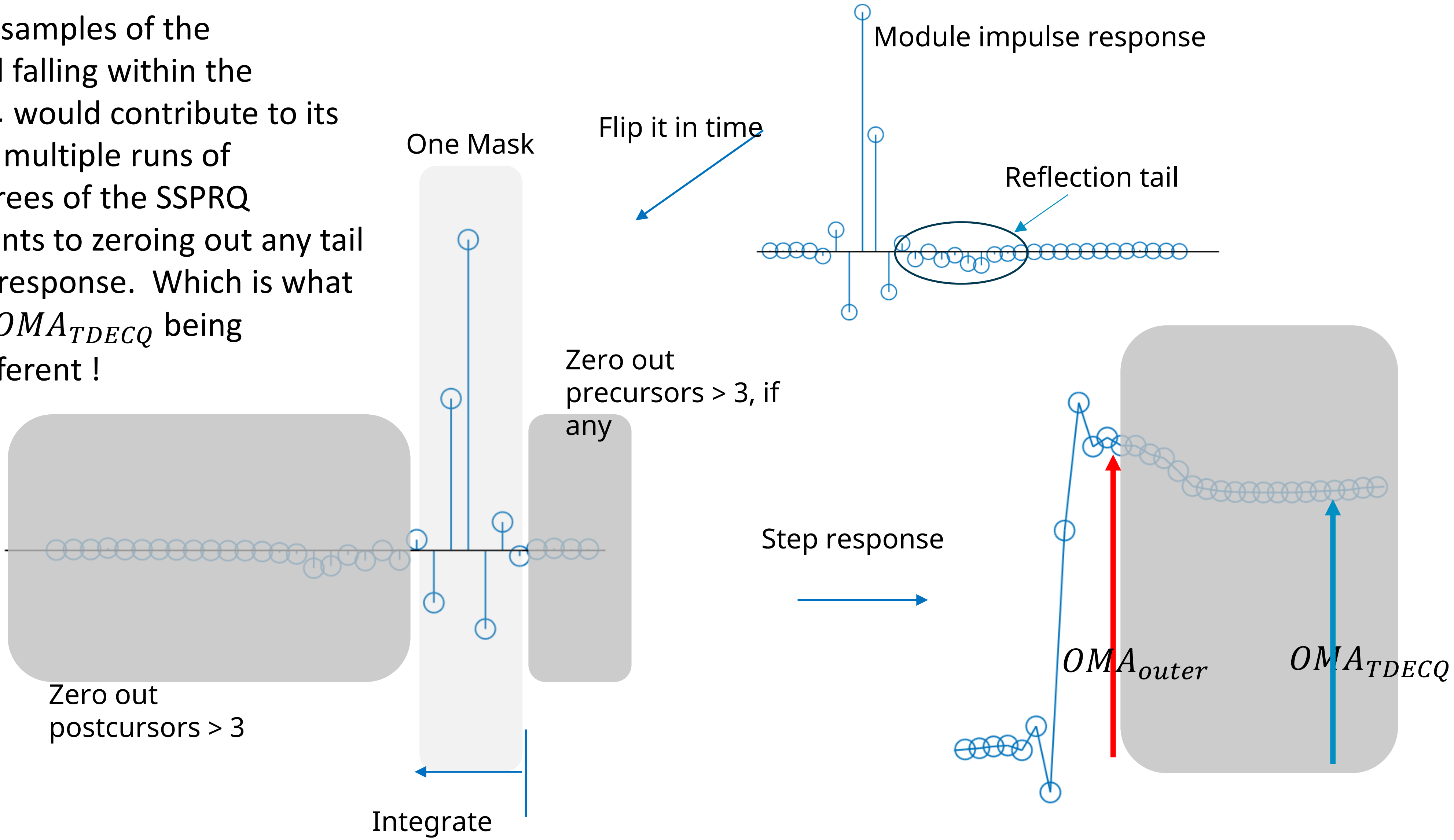


Figure 180–8—Example power levels P_0 and P_3 from PRBS13Q test pattern

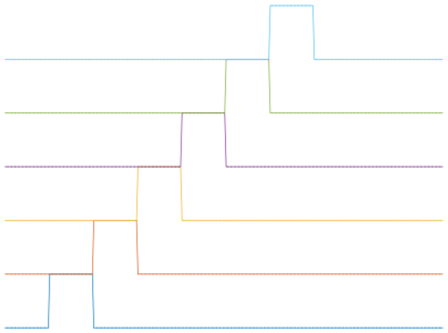
OMA_{outer} measurement interpretation

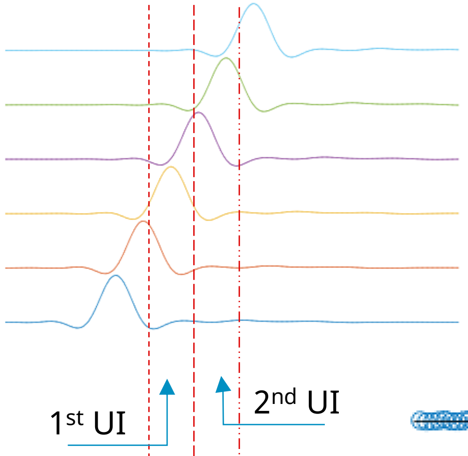
In SC 180.9.5, only those samples of the underlying impulse signal falling within the window of the OMA_{outer} would contribute to its estimate. Averaging over multiple runs of consecutive zeros and threes of the SSPRQ pattern, effectively amounts to zeroing out any tail and head of the impulse response. Which is what leads to OMA_{outer} and OMA_{TDECQ} being eventually potentially different !



How does the windowing exactly work?

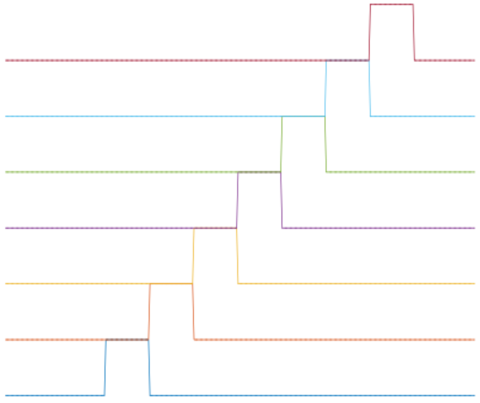
The exact window applied as per the definition of SC180.9.5 is the results of an average across 2 UIs and on two runs of 6 and 7 consecutives pulses

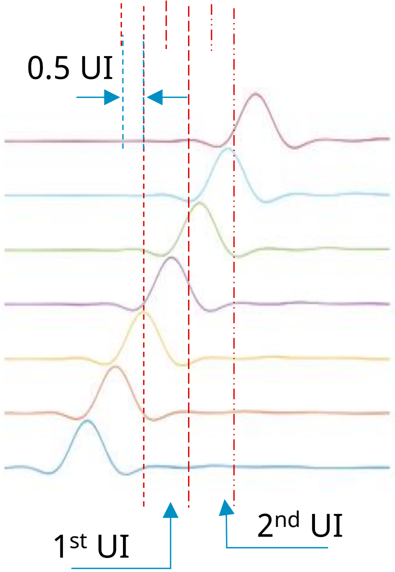




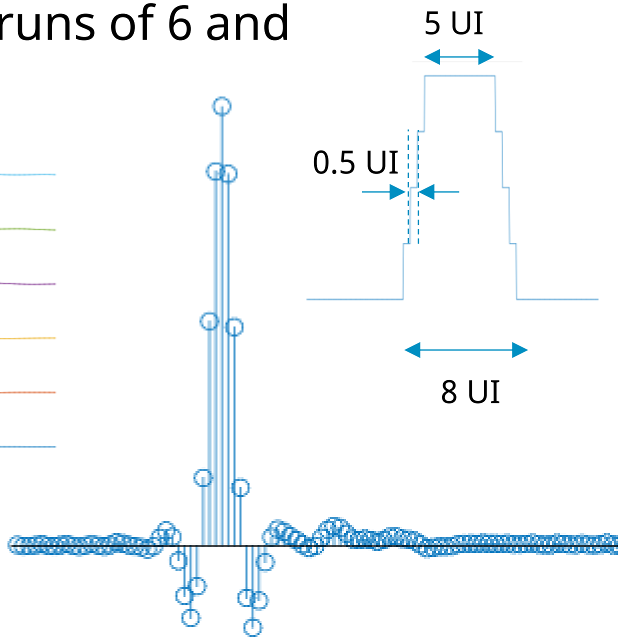
6 consecutive negative Pulses

7 consecutive positive Pulses

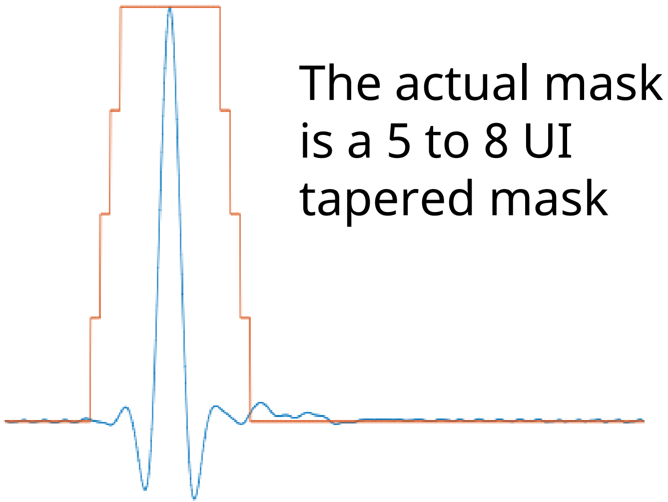




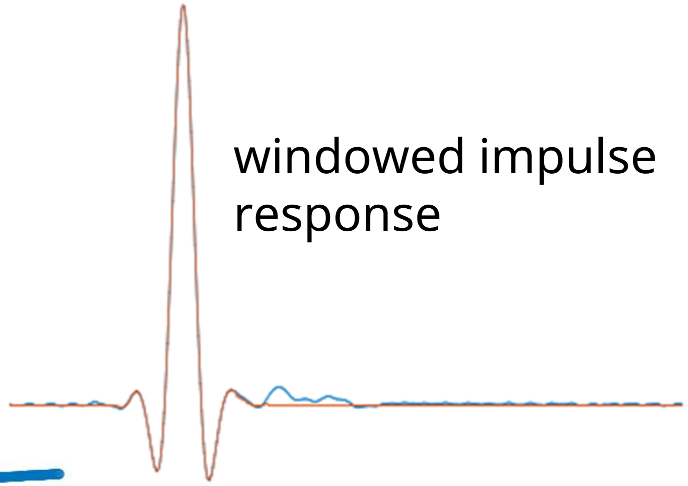
actual mask



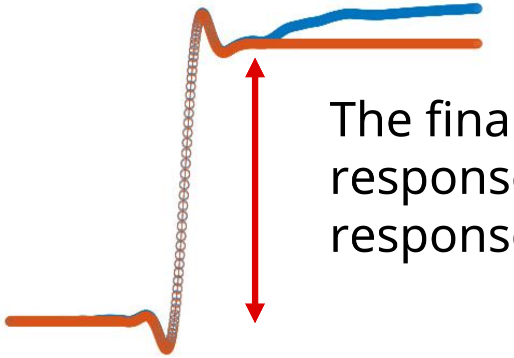
Impulse response



The actual mask is a 5 to 8 UI tapered mask



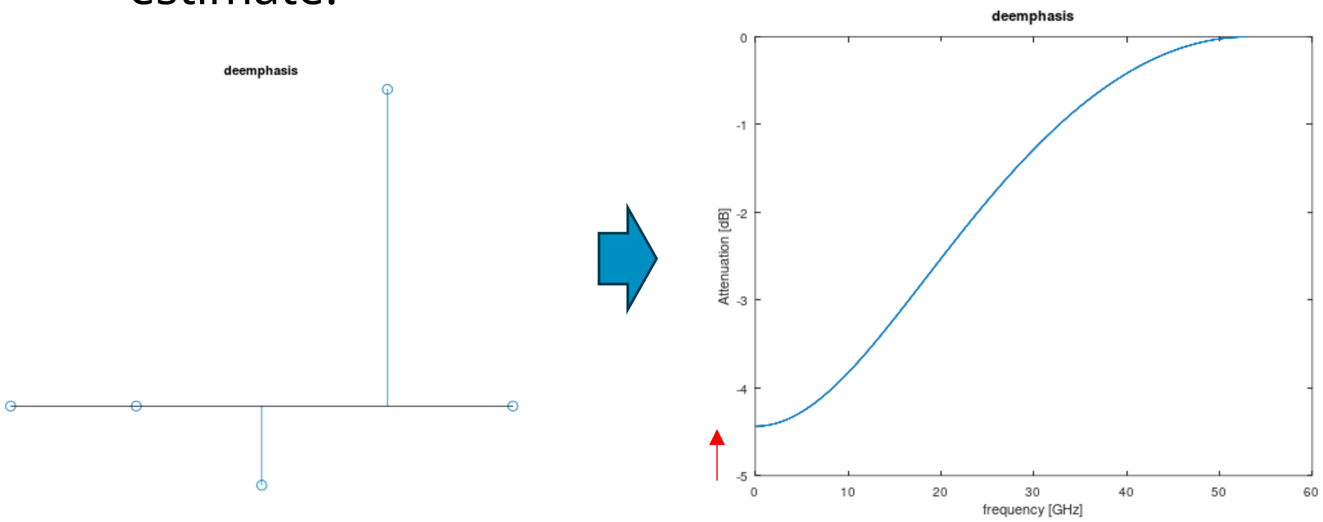
windowed impulse response

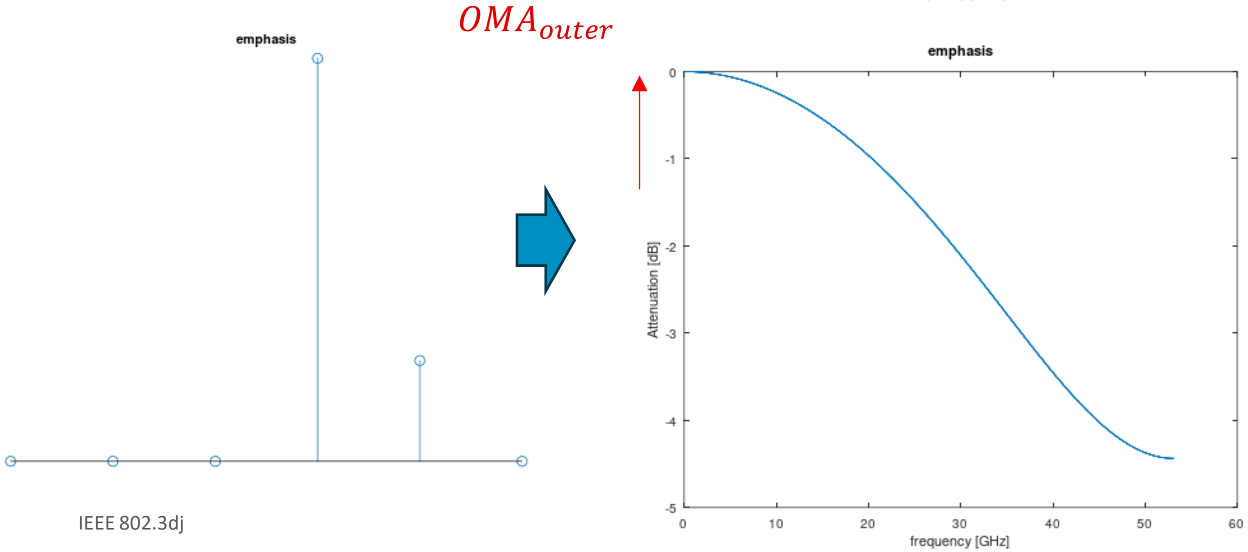


The final height of the step response of the windowed impulse response yields OMA_{outer}

Tx with emphasis or de-emphasis

- Since all taps fall within the OMA_{outer} window, their contribution will be considered in the OMA_{outer} estimate:





Case LF de-emphasis / HF emphasis:

=> OMA_{outer} is lower

TDECQ is assessed wrt. a lower OMA_{outer} ideal TX => TDECQ will be low due to overshoot 👍

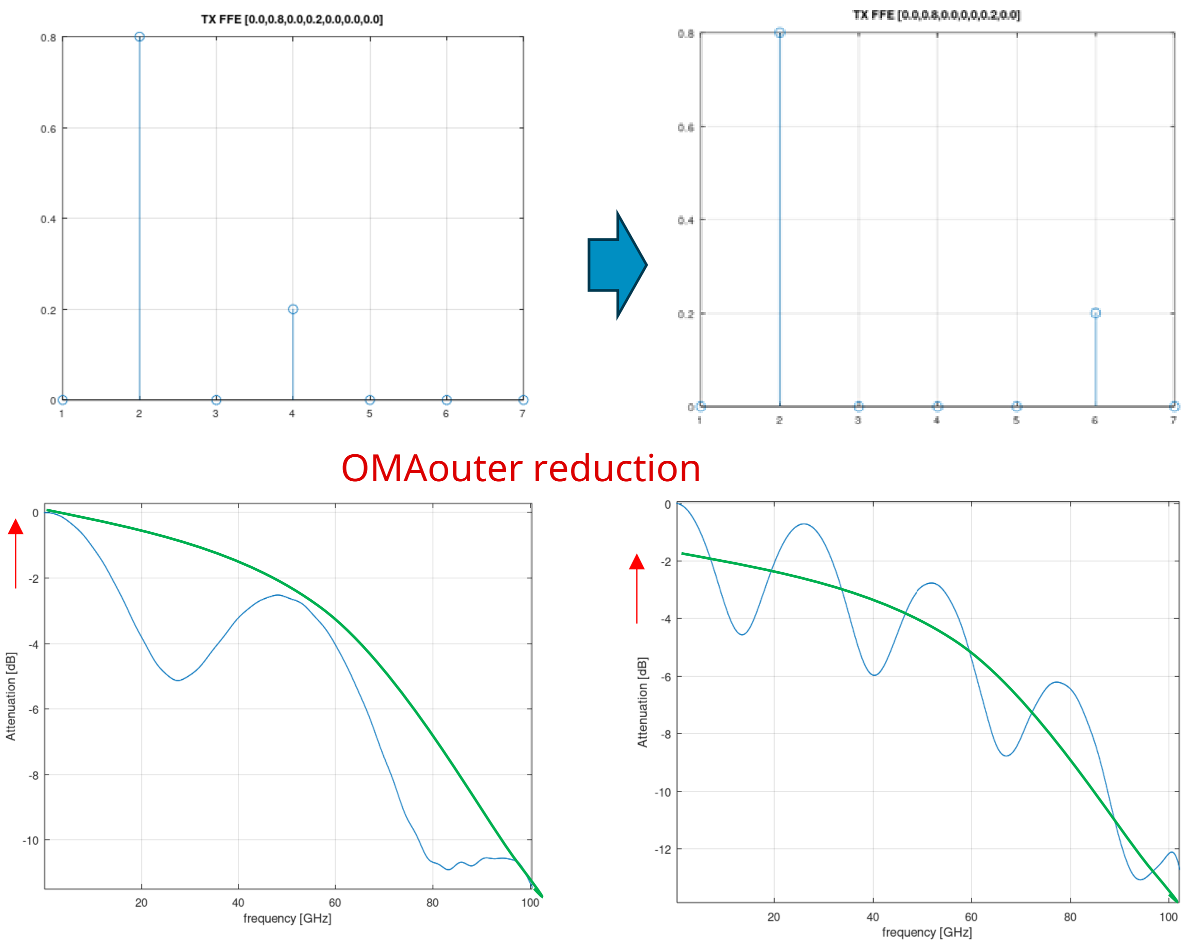
Case LF emphasis / HF droop:

=> OMA_{outer} is higher

TDECQ is assessed wrt. a higher OMA_{outer} ideal Tx => TDECQ will be high due to bandwidth droop 👍

TX with reflections

- As the TX FFE tap, emulating the impact of a reflection moves away form the main tap, it is no longer viewed as part of a natural TX shape, but instead it is considered as an undesirable impairment, which may or may not be dealt with properly by the reference Rx



Case LF emphasis / HF droop / positive reflection:

=> With a delayed reflection, OMA_{outer} is projected lower than the expected OMA level that was part of the natural LF emphasis

TDECQ is assessed wrt. an OMA_{outer} of an ideal Tx (without reflection) => TDECQ will be moderately low due to the bandwidth droop, but it will not be increased due to the impact of the reflection if properly dealt with by the RX ref. equalizer 👍

Interpretation of OMA_{outer} quantity

In summary, the OMA_{outer} quantity reflects our intuitive interpretation of the signal level:

1. A LF de-emphasized TX has lower OMA_{outer} and will have lower TDECQ
2. A HF de-emphasized TX may have higher OMA_{outer} and possibly a higher TDECQ
3. A transmitter impacted by an unwanted reflection will not be given credit for the reflection for its OMA_{outer} estimate. It will be assessed wrt. a transmitter of identical OMA_{outer} level leading to a moderate TDECQ, if it is dealt with by the ref. RX equalizer

In conclusion, OMA_{outer} is appreciated as a proxy for the useful signal amplitude of a given TX:

- Any signal within the OMA_{outer} window will be considered as legitimate signal component that can contribute to the OMA_{outer} estimate.
- Any signal falling outside of the window is considered as unintended and will be accounted for in the TDECQ penalty, if it is not dealt with by the reference equalizer. However, it is currently not credited towards the OMA_{outer} estimate.

Requirements of OMA_{outer} quantity

The desirable features of OMA_{outer} are:

1. Resilience to TX bandwidth limitation
2. Resilience to optical impairment (a.o. to Chromatic Dispersion)
3. Resilience to long tail reflections

Link budget assumptions:
All uncompensated impairments at the reference receiver will be lumped into a TDECQ penalty.
The TX can then be abstracted as an equivalent Ideal Transmitter of similar OMA_{outer} level to which a TDECQ penalty is associated, making it usable in the link budget

Wrt. 1/2. : The bandwidth limitation and CD resilience is ensured by measuring the amplitude of a step response after a minimum settling time of 2 UI. Still taking any natural pre-emphasis or de-emphasis of the transmitter into account, as part of the legitimate signal energy.

Wrt. 3. : The long tail resilience is ensured by limiting the measurement after a settling time of maximum 3 UI. The average across multiple runs of SSPRQ ensures by design a zero net contribution of the tail.

Conclusion / Recommendation

OMA_{outer} as defined per SC180.9.5 represents the signal amplitude of the transmitter that it characterizes, captured by a 5-8 UI tapered window, as the amplitude of an equivalent step response.

The tapering of the window determines whether a signal component is part of the natural shape of the transmitter or whether it should be interpreted as an impairment that will not be credited towards the OMA_{outer} estimate. As currently defined, the OMA_{outer} quantity reflects an intuitive interpretation of what the signal level is expected to be, for different TX configurations.

We laid out the desirable features of OMA_{outer}, if it had to be refined : it is resilient to bandwidth limitation and optical fiber impairments, as well as to reflections within the transmitter.

We therefore recommend confirming the OMA_{outer} measurement with SSPRQ, as captured in comment # I-218, to preserve the desirable features of the estimate. Alternatively, if required, we propose that any redefinition of the OMA_{outer} method as per SC180.9.5 takes into consideration the intrinsic features of the metric and its associated objectives.

Backup

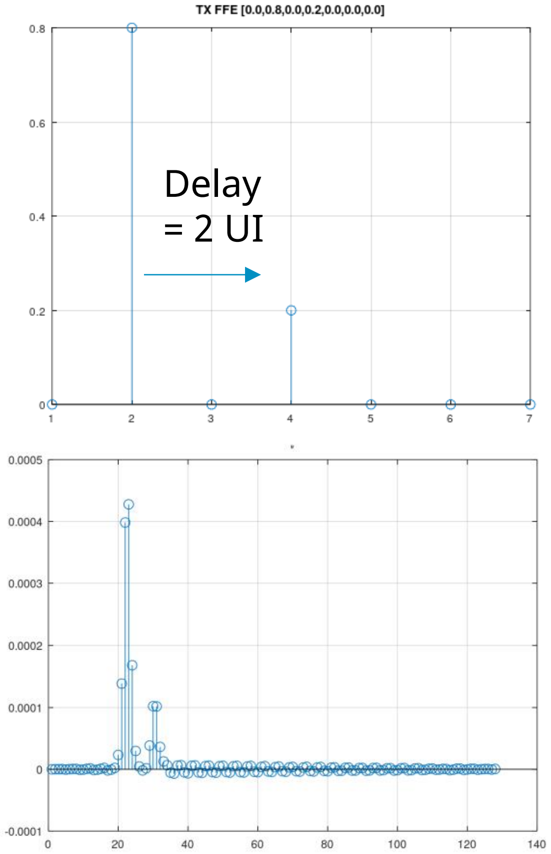
Backup outline

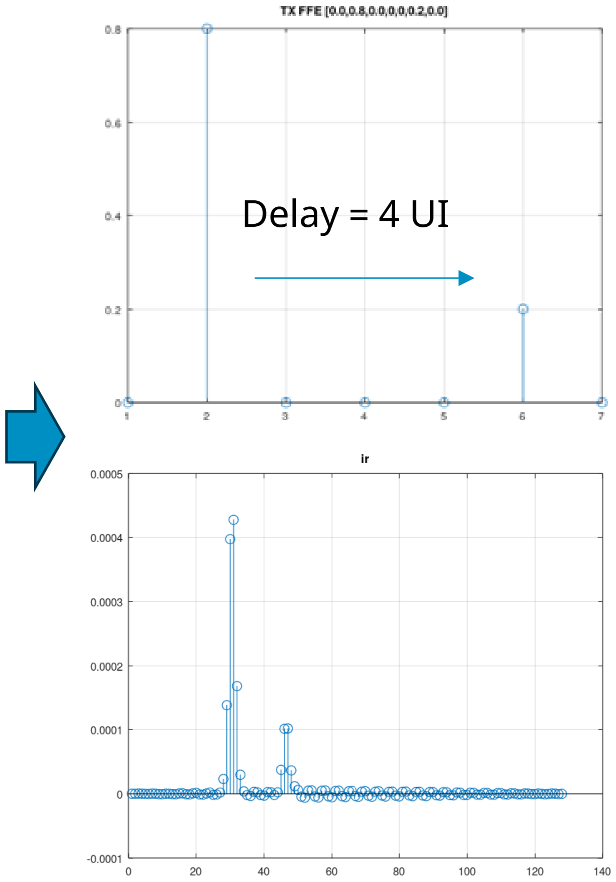
Evaluation of the impact of an emulated delayed reflection on OMA_{outer} and TDECQ.
Confirmation and interpretation of results reported in
https://www.ieee802.org/3/dj/public/adhoc/electrical/26_0421/el-chayab_3dj_adhoc_01_260421.pdf

- Description of scenarios evaluated
- TX eye diagram with reflections of various delay and different amplitudes
- Evolution of OMA_{outer} and TDECQ with reflections of various delay : (dj Draft 3.0)
- Evolution of OMA_{outer} and TDECQ with reflections of various delay : (clause 121)
- Examples of step responses of 100G & 200G commercial modules
- Observations and recommendations

Scenarios evaluated

Vary TX FFE to emulate impact of a reflection : the main tap is followed by a delayed tap of 1 to 5 UI away, progressively crossing the boundary of the OMA_{outer} window. The sign of the delay tap is + or -, results are compared.

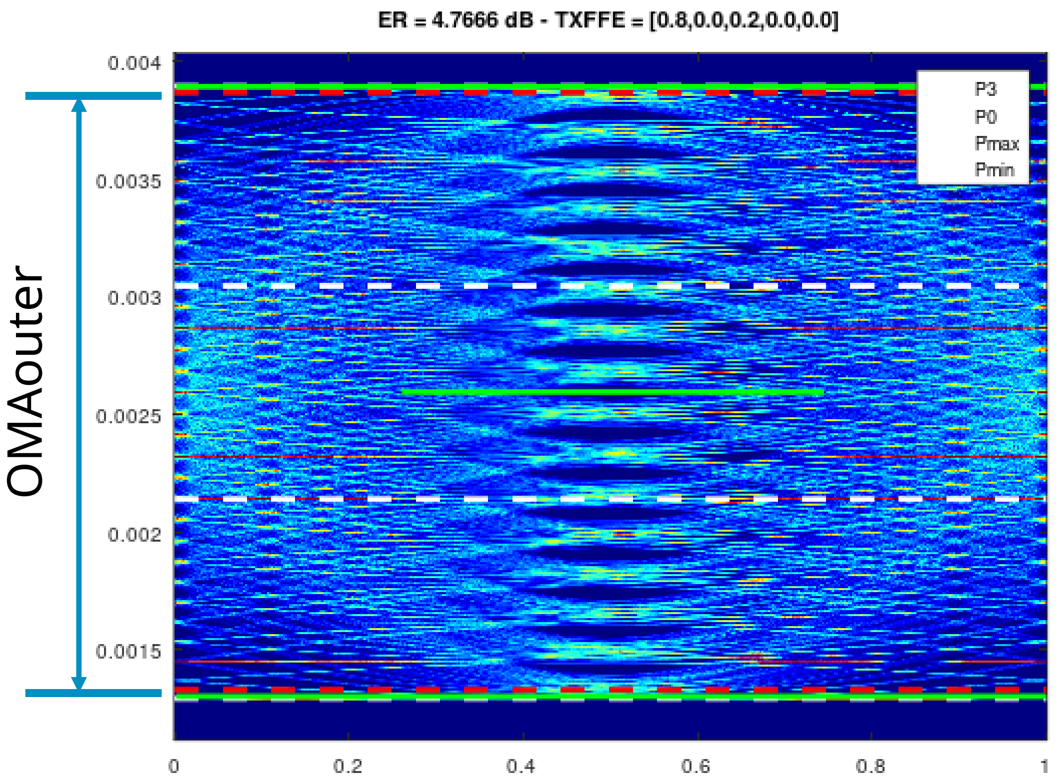




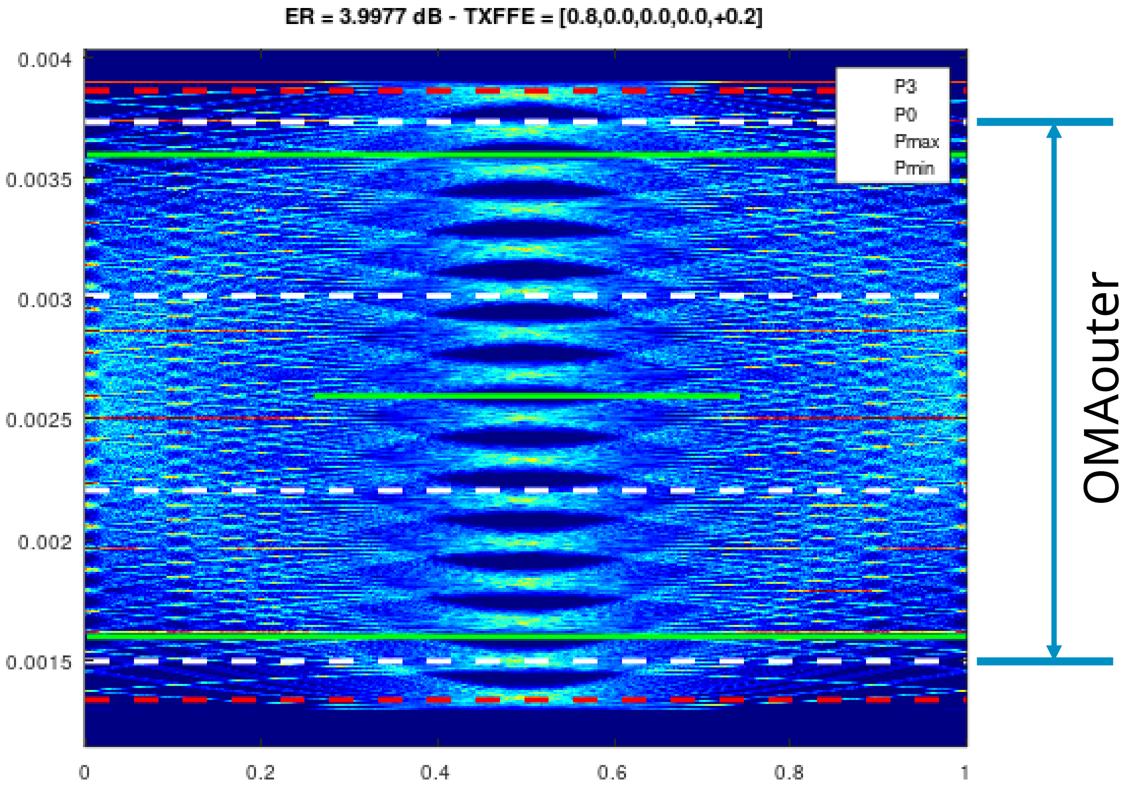
- Transmitter emulated with a TX FFE and rise time and measured at the output of the reference receiver (BT4 R/2 low pass filter)
- Eye diagrams are produced
- Impulse and step responses are evaluated.
- OMA_{outer} and OMA at FFE are compared per SC180.9.5
- TDECQ is computed

TX eye diagram with different "+" reflections

a) TX FFE [0.0,0.8,0.0,0.2,0.0,0.0]



b) TX FFE [0.0,0.8,0.0,0.0,0.0,0.2]

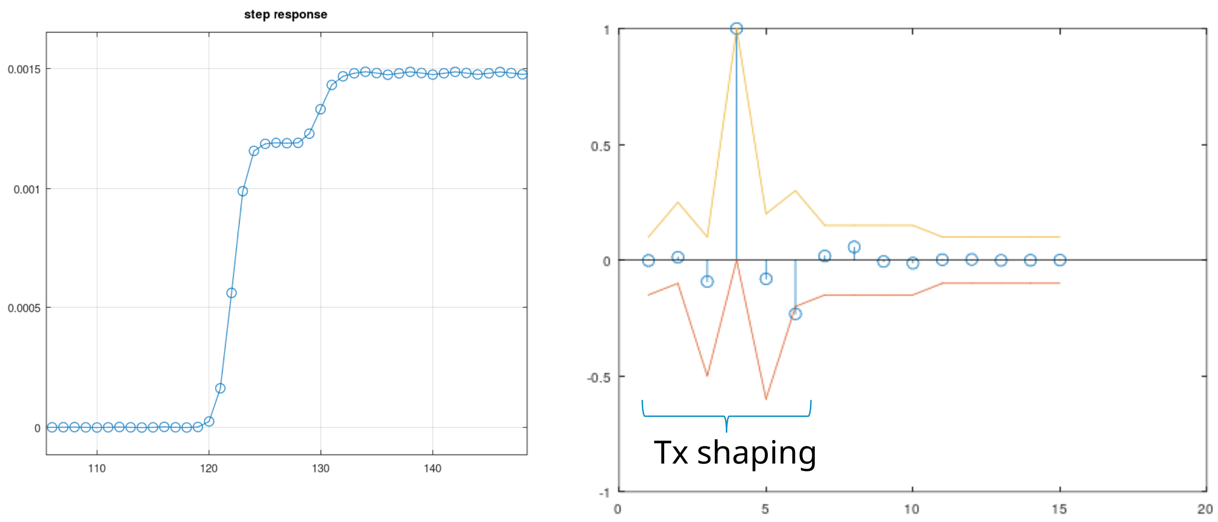


Examples of eye diagrams with reflection of amplitude [+0.2] affected by a delay of a) 2UI and b) 4UI

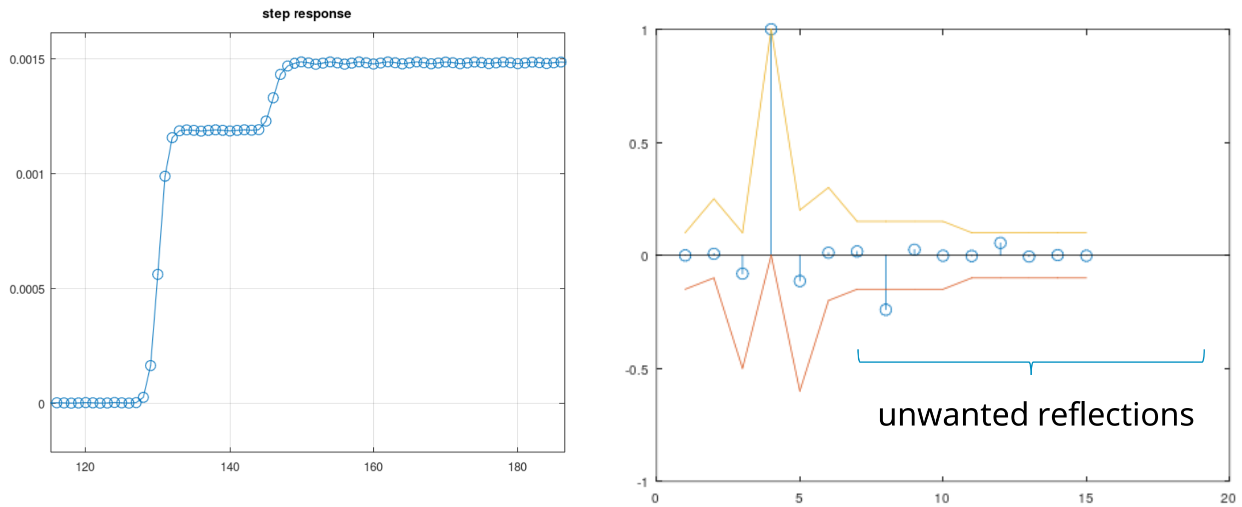
- In a) estimated OMA_{outer} = peak to peak signal : i.e. effect of reflection is undistinguishable from natural TX shaping - overshoot = 0% !
- In b) OMA_{outer} = peak to peak signal : reflection is independent of the TX shaping and is seen as contributing to the overshoot

Step responses and TDECQ ref eq taps for “+” reflection

a) TX FFE [0.0,0.8,0.0,0.2,0.0,0.0]



b) TX FFE [0.0,0.8,0.0,0.0,0.0,0.2]

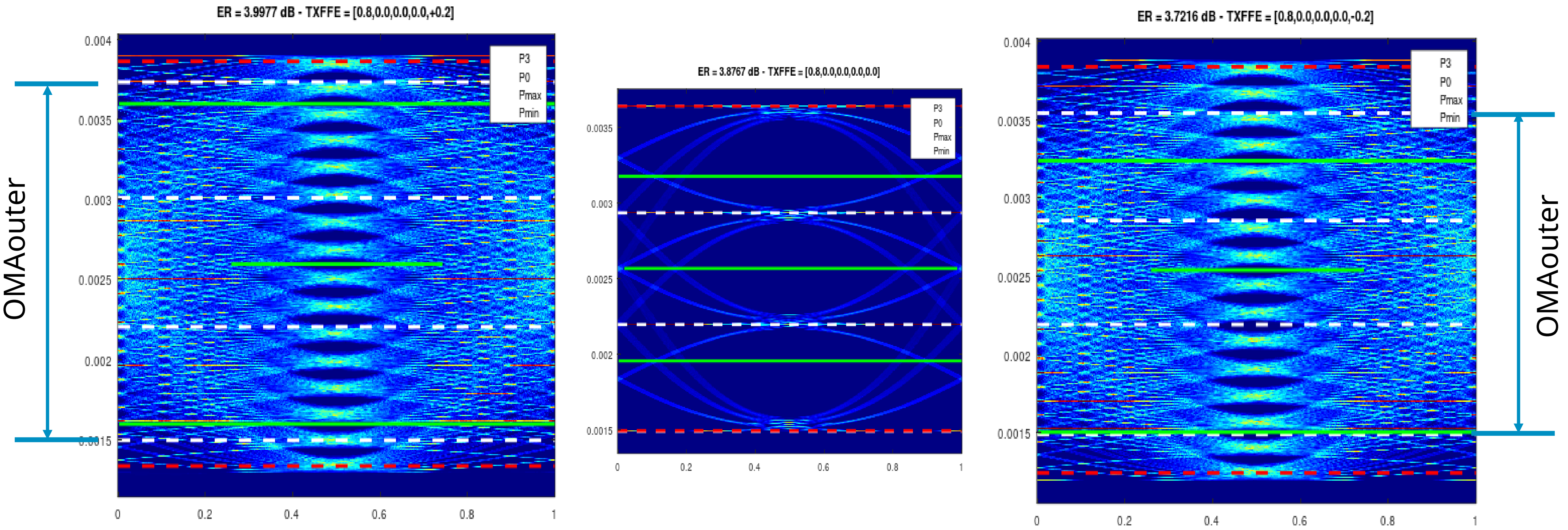


Examples of step responses and associated TDECQ reference equalizer taps with reflection of amplitude [+0.2] affected by a delay of a) 2UI and b) 4UI

- The 8ps transition time of both waveforms is met
- Tap weight boundaries reflect that TX shaping should be limited to Maintap-1 to Maintap+2
- In b) postcursor taps may exceed the limit but TX FFE TX FFE [0.0,0.85,0.0,0.0,0.0,0.15] would not !

⇒ Legitimate use cases

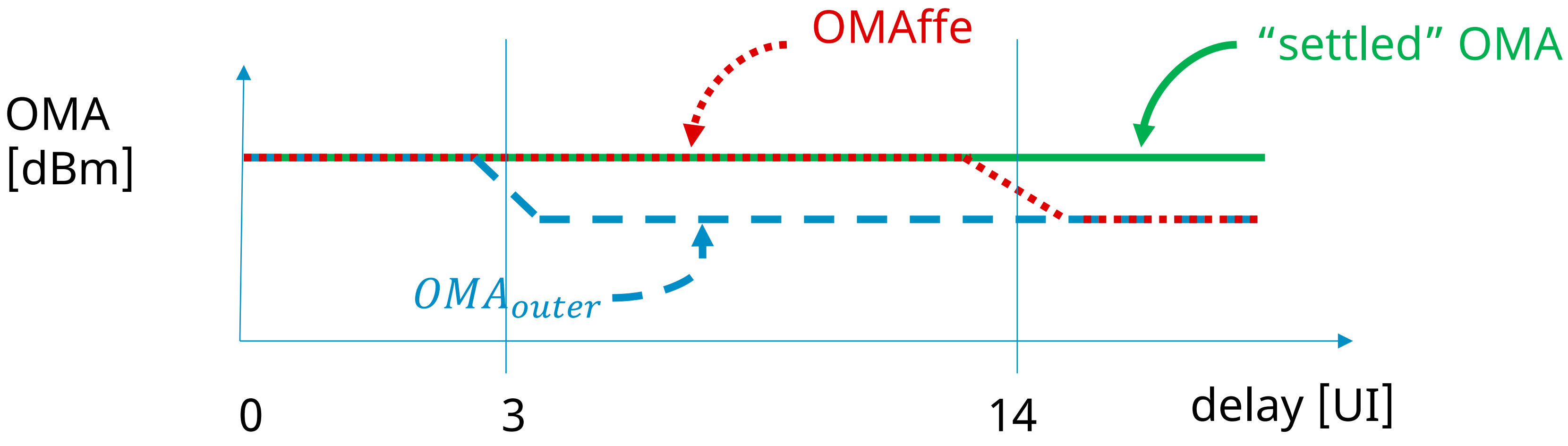
TX eye diagrams with different reflection polarity



Examples of eye diagrams with reflection modulated with amplitude [+0.2,0.0,-0.2].

- Intuitively, we can appreciate the transmitter as a transmitter of a given OMA_{outer} corresponding to the reflection free scenario affected by an uncontrolled reflection of either polarity

Evolution of OMA with delay of reflection "+" reflection



Notes:

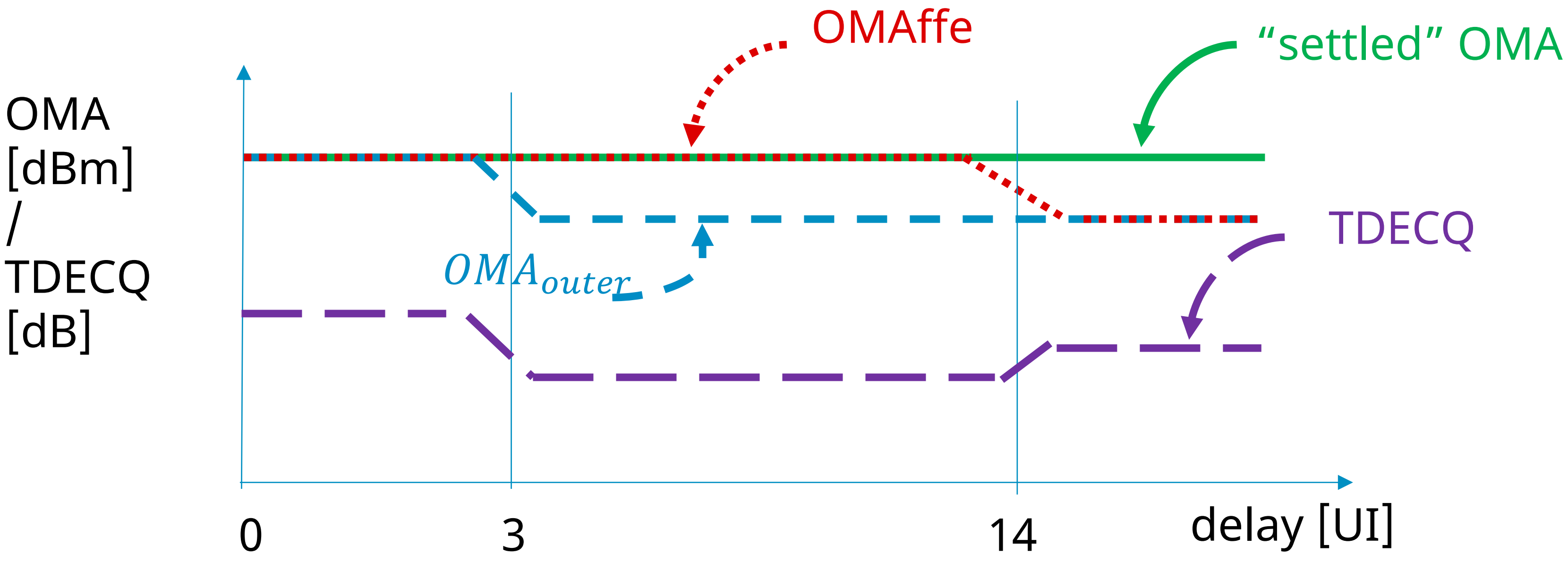
With a positive "+" reflection delay swept from 0 to 14+ UI:

1. Below 3 UI (within the OMA_{outer} window of 6-7UI), OMA_{outer} = OMAffe = settled OMA
2. Above 3 UI, OMA_{outer} != OMAffe, and OMAffe = "settled OMA"
3. Above ~14 UI, again OMA = OMAffe and both differ from the illusive "settled OMA"

Interpretation:

- Below 3 UI, reflection is part of module TX shape; from 4 to 14 UI, reflection is equalizable ISI; beyond 14 UI, reflection is unequalizable ISI even with a 15-3 tap equalizer !
- Even though OMA at the equalizer output, "OMAffe", looks like the "settled" OMA, it actually is not beyond 14 UI => are we really interested in this elusive "settled OMA", that we are not sure of capturing ?

Evolution of OMA and TDECQ with delay of "+" reflection



Notes:

- TDECQ will actually be lower when OMA_{outer} is lower
- OMA_{outer} – TDECQ will remain ~ constant below 14 UI

TXffe	OMAouter (BT)	OMAffe	TDECQ	TDECQeq	Ceq	Ceqmod	OMAouter-TDECQ	OMAffe-TDECQ	OMAffe-TDECQeq
[0.8,0.2]	4.16	4.16	2.55	2.56	2.14	2.14	1.60	1.61	1.60
[0.8,0.0,0.2]	4.10	4.15	2.23	2.28	1.92	1.87	1.87	1.92	1.87
[0.8,0.0,0.0, 0.2]	3.48	4.19	1.84	2.56	1.98	1.32	1.63	2.35	1.63
[0.8,0.0,0.0,0.0,0.2]	2.95	4.16	1.66	2.87	1.95	0.74	1.30	2.51	1.30
[0.8,0.0,0.0,0.0,0.0,0.2]	3.16	4.16	1.42	2.42	1.93	1.26	1.74	2.74	1.74

Evolution of OMA and TDECQ with sign of reflection

OMAs and TDEQC are computed for a positive/constructive (+) reflection or negative/destructive (-) reflection

a. Positive (+)

TXffe	OMAouter (BT)	OMAffe	TDECQ	TDECQeq	Ceq	Ceqmod	OMAouter-TDECQ	OMAffe-TDECQ	OMAffe-TDECQeq
[0.8,0.2]	4.16	4.16	2.55	2.56	2.14	2.14	1.60	1.61	1.60
[0.8,0.0,0.2]	4.10	4.15	2.23	2.28	1.92	1.87	1.87	1.92	1.87
[0.8,0.0,0.0, 0.2]	3.48	4.19	1.84	2.56	1.98	1.32	1.63	2.35	1.63
[0.8,0.0,0.0,0.0,0.2]	2.95	4.16	1.66	2.87	1.95	0.74	1.30	2.51	1.30
[0.8,0.0,0.0,0.0,0.0,0.2]	3.16	4.16	1.42	2.42	1.93	1.26	1.74	2.74	1.74

b. Negative (-)

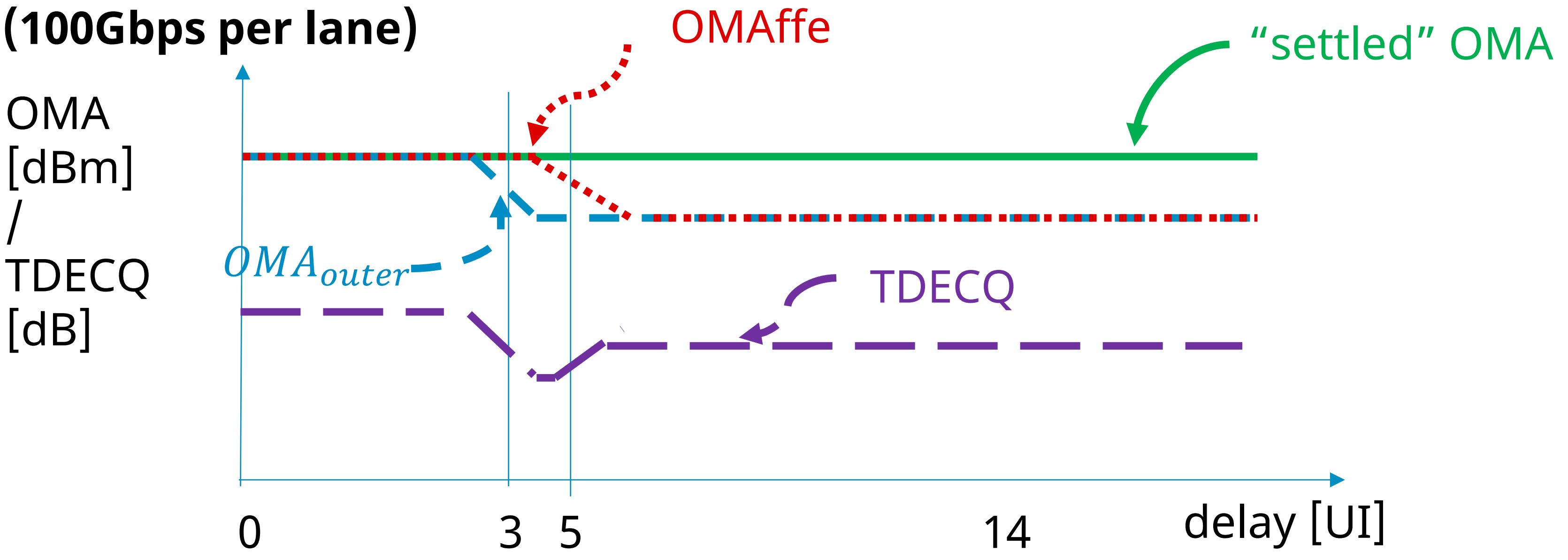
TXffe	OMAouter (BT)	OMAffe	TDECQ	TDECQeq	Ceq	Ceqmod	OMAouter-TDECQ	OMAffe-TDECQ	OMAffe-TDECQeq
[0.8,-0.2]	2.21	2.20	0.04	0.03	-0.39	-0.37	2.17	2.16	2.17
[0.8,0.0,-0.2]	2.31	2.20	0.49	0.37	-0.15	-0.04	1.83	1.71	1.83
[0.8,0.0,0.0,-0.2]	3.14	2.20	1.17	0.23	-0.18	0.76	1.97	1.03	1.97
[0.8,0.0,0.0,0.0,-0.2]	3.66	2.24	1.74	0.32	0.15	1.28	1.92	0.49	1.92
[0.8,0.0,0.0,0.0,0.0,-0.2]	3.48	2.26	1.57	0.36	-0.13	1.08	1.91	0.69	1.91

Observations:

- OMA_{outer} values in b. evolve as we expect for the application of a de-emphasis filter
- Last rows of both tables exhibit similar OMA_{outer} -TDECQ , but large discrepancy in TDECQ if referenced to OMAffe (up to 2dB of difference)

Evolution of OMA and TDECQ with delay of "+"reflection

Clause 121 (100Gbps per lane)



Notes:

- In clause 121 (100Gbps per lane), there may be a small region where OMA_{outer} differs from OMAffe, but region is limited due to the limited equalizer span (5-2)

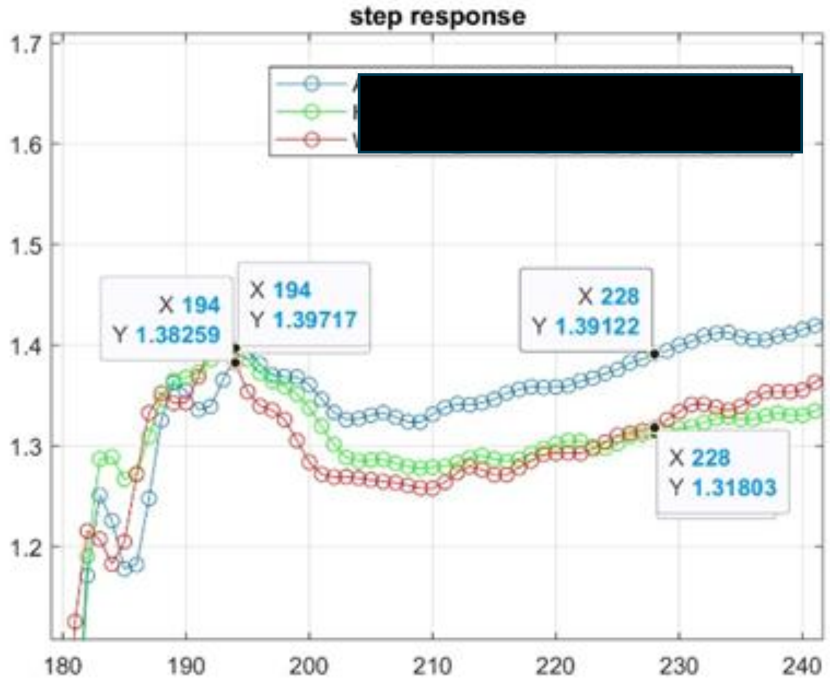
- On many measured modules, OMA_{outer} is not identical to the "settled" OMA

$\Rightarrow$ Even so, we did not need to resort to measuring the "settled" OMA as a reference to TDECQ; instead, we kept OMA_{outer} and we did not think of using OMAffe

Examples of commercially available 100G modules

Step response measurement of commercially available 100G modules at oversampling 4 sps/UI

Settled OMA?
Delta : 0.5dB

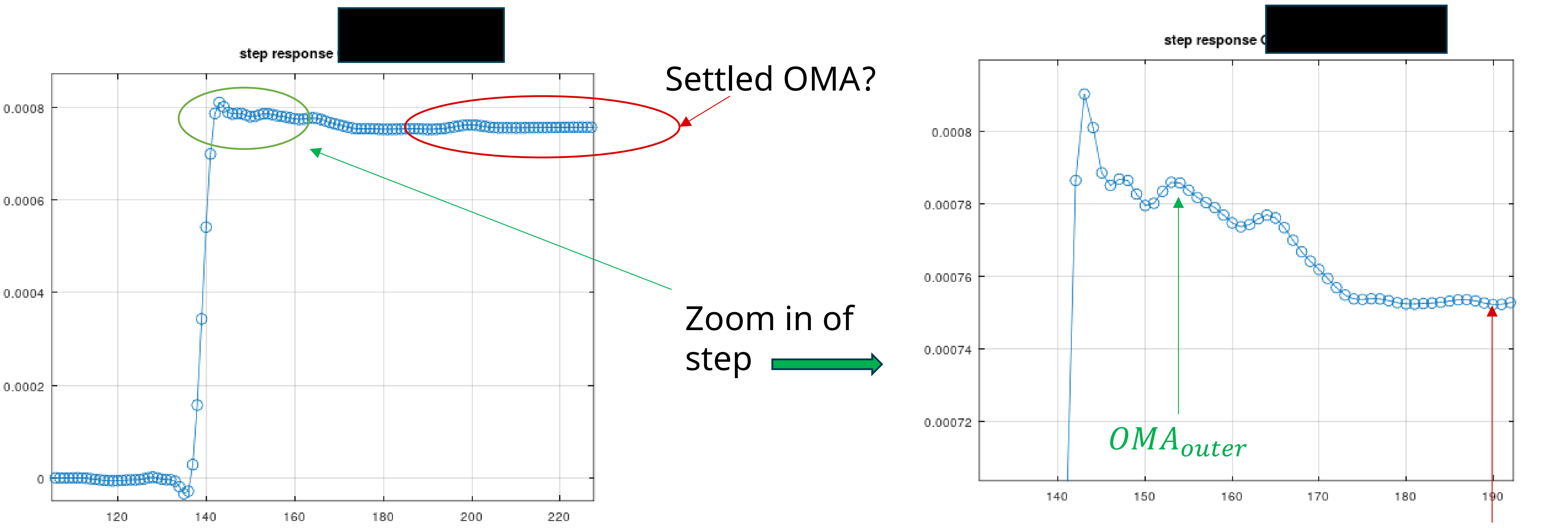


- Step response continues to rise as an "illusive" or "elusive" OMA value

- Projection of OMA_{outer} quantity if measured at UI 12 after step as compared to 3/4 UI after step => delta = 0.23dB for module #2 & #3

Example of commercially available 200G module

Step response measurement of commercially available 200G module at oversampling 4 sps/UI



OMA_{outer} – OMAffe = 10*log10(step_resp(153)/step_resp(190)) = ~ 0.19dB

TDECQ referenced t the equalizer output will be ~0.2dB lower than when referenced to OMA_{outer}

Observations / Recommendation

OMA_{outer} measurement results are shown to vary as expected when a reflection is emulated in a module with a varying delay.

The appreciation of whether the emulated reflection is part of the natural shape of the transmitter or whether it is interpreted as a harmful impairment is determined by the 5-8 UI tapered window associated with the OMA_{outer} measurement in SCL 180.9.5.

If anything, this boundary should be made consistent with the tap weight limits currently defined for the reference equalizer in the TDECQ penalty computation

It is shown that the “settled OMA” remains an illusive quantity against which to align the reference for the TDECQ penalty report. In clause 121, a possible similar discrepancy between OMA_{outer} and OMAffe may exist for some modules, and it is also to be expected that those two quantities do not even match the “settled” OMA value either.

For 802.3 dj, we therefore recommend continuing using OMA_{outer} as the reference quantity to characterize the TX in isolation of the receiver equalizer, as opposed to using the “settled OMA” value as the desired reference.

Thank you