OMAouter measurement with SSPRQ

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Summary

- OMA_{outer} measurement per SC180.9.5 is specifically tailored to a PRBS13Q sequence. However, for TDECQ, computation of both OMA_{outer} and OMA_{TDECQ} is done with SSPRQ. The various possible interpretations of SC180.9.5 for an SSPRQ signal may lead to different results, unless specified unambiguously.

- This presentation specifically selects one possible way to compute OMA_{outer} with SSPRQ.

Outline

- IEEE definitions of OMA_{outer} per SC180.9.5
- Difference of PRBS13Q and SSPRQ sequences
- OMA_{outer} measurement interpretation
- Results for 3 modules reported in https://www.ieee802.org/3/dj/public/25_09/alloin_3dj_01b_2509.pdf
- Impact of different averaging schemes on SSPRQ
- Proposed editorial changes
- Conclusion / recommendation

OMA_{outer} measurement

OMA_{outer} is measured on a PRBS13Q or SSPRQ per Table 180–14

However, SC180.9.5 is tailored around the PRBS13Q signal structure !

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.

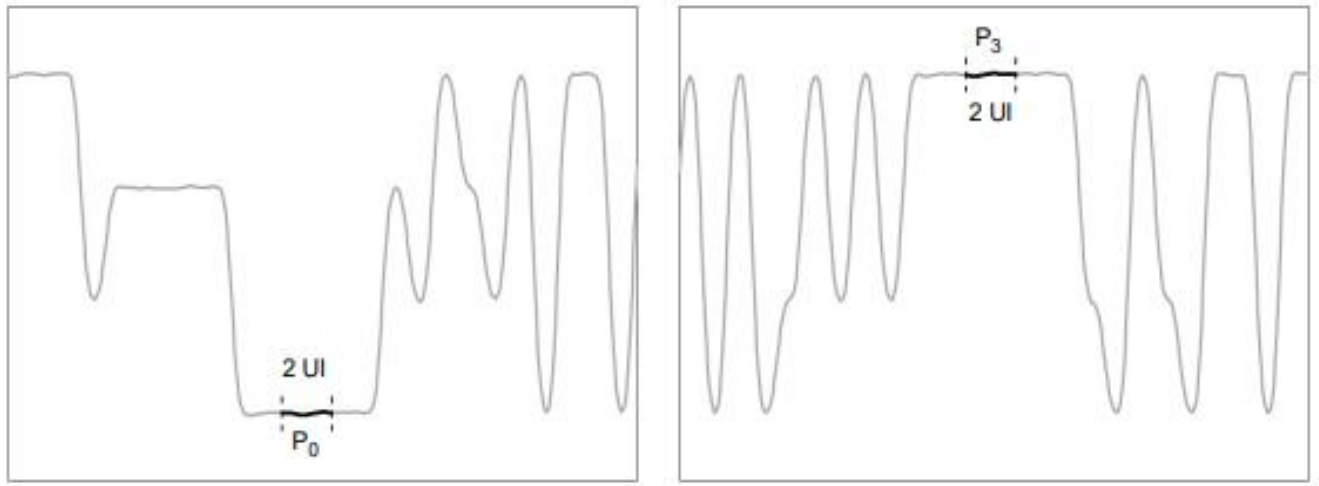


Figure 180–8—Example power levels P_0 and P_3 from PRBS13Q test pattern

PRBS13Q vs SSPRQ

OMA_{outer} is measured on a PRBS13Q or SSPRQ per Table 180–14 , looking for runs of 6 zeros and 7 ones

- PRBS13Q is asymmetrical and has only 1 run of 6 zeros, and 1 run of 7 ones
- SSPRQ is symmetrical and has the following run length distribution of both zeros and ones:

run length	14	13	12	11	10	9	8	7	6
# runs	1	3	1	3	4	3	8	16	20

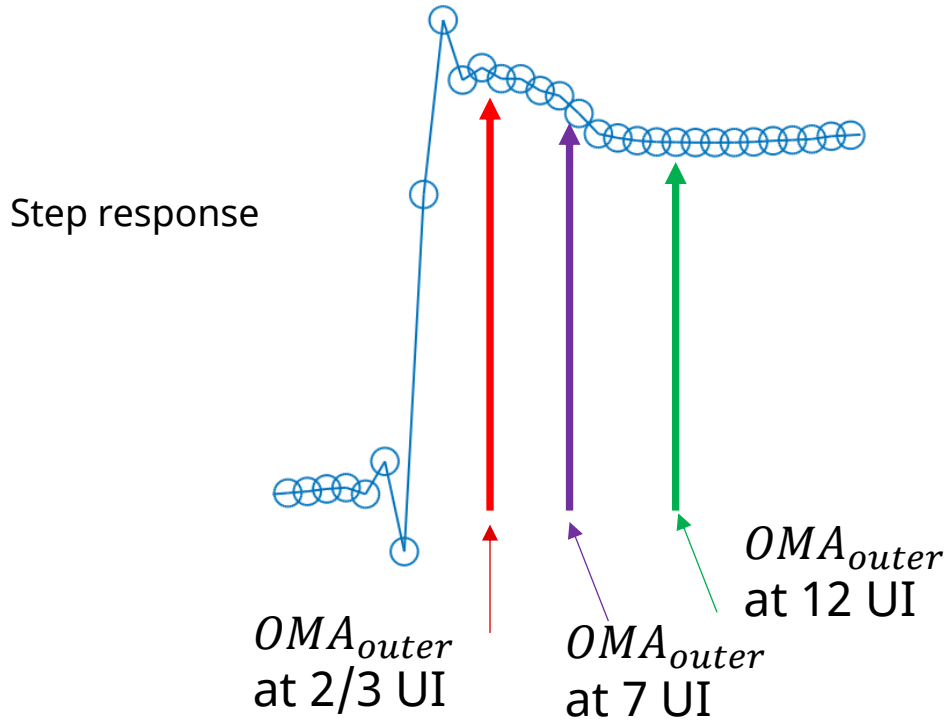
Averaging OMA_{outer} on multiple runs of PRBS13Q, or using multiple points of the SSPRQ sequence that satisfies the minimum run length condition is desirable to average the impact of additive noise in the estimate.

However, considering different runs of the SSPRQ or applying different averaging schemes may lead to slightly different OMA estimates.

OMA_{outer} measurement interpretation

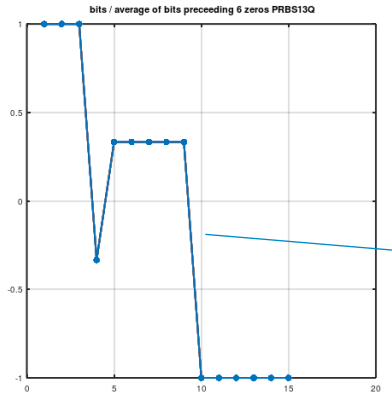
Measuring OMA_{outer} is to a first order equivalent to evaluating the step response of a module

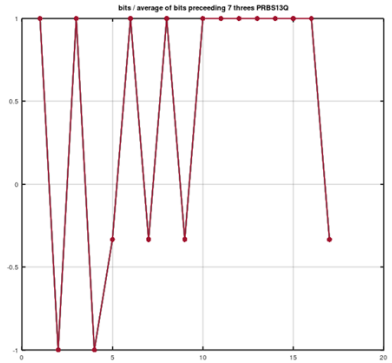
Evaluating it systematically after 2 or 3 UI of a given pattern length (red arrow) will give us a different result than if we average only the position 7 (purple arrow) of all patterns of length > 9, or at position 12 (green arrow) of the longest run length of 14 of the SSPRQ sequence, or yet an average of these estimates. All positions are valid and can be understood as compliant to SC 180.9.5. or not depending on its various possible interpretations!



- Should we use only runs of 6 zeros, and 7 ones excluding all others?
- Should we use all runs > 6 for both zeros and ones (SSPRQ is symmetrical) and all the symbols in those runs excluding the first 2UI and last 2UI?
- Should we use all runs > 6, but only averaging symbols of those runs at the 3rd and 4thUI after the transition?

OMA_{outer} measurement with PRBS13Q





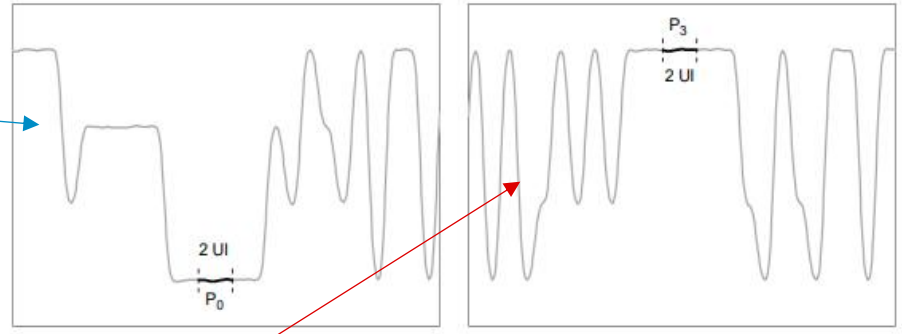


Figure 180–8—Example power levels P_0 and P_3 from PRBS13Q test pattern

OMA_{outer} measured on a PRBS13Q benefits from some “alternating” patterns that break the impact of a long tail impulse response on the OMA_{outer} estimate, especially when a reflection is constructive (systematic tail >0) or destructive (systematic tail <0)

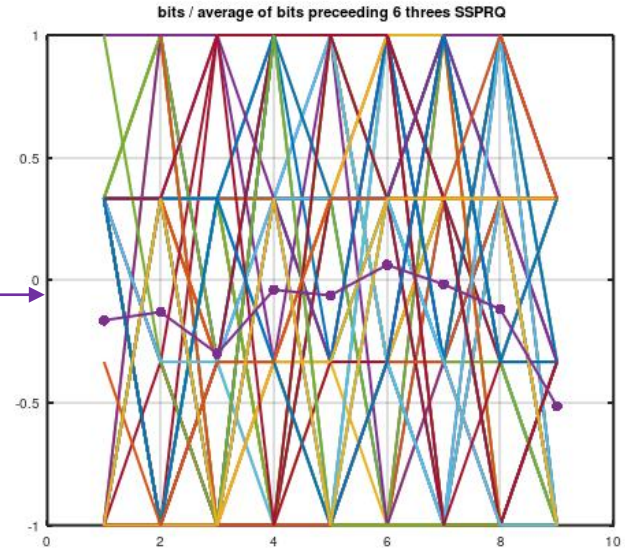
However, the PRBS13Q pattern is fixed; averaging across sequences will not further reduce the residual impact of the long tail in the OMA_{outer} estimate.

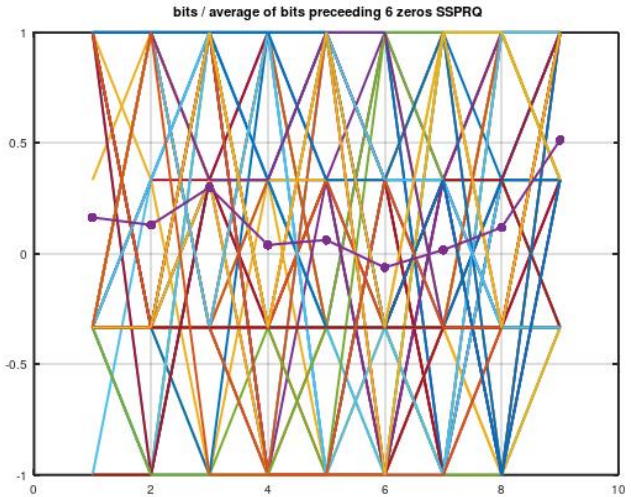
OMA_{outer} measurement with SSPRQ

With SSPRQ, patterns preceding runs of length 6/7 of threes and zeroes are not only alternating, but they vary across a full SSPRQ sequence length

Number of runs of length 6 or more in SSPRQ: 59

Average is close to zero mean



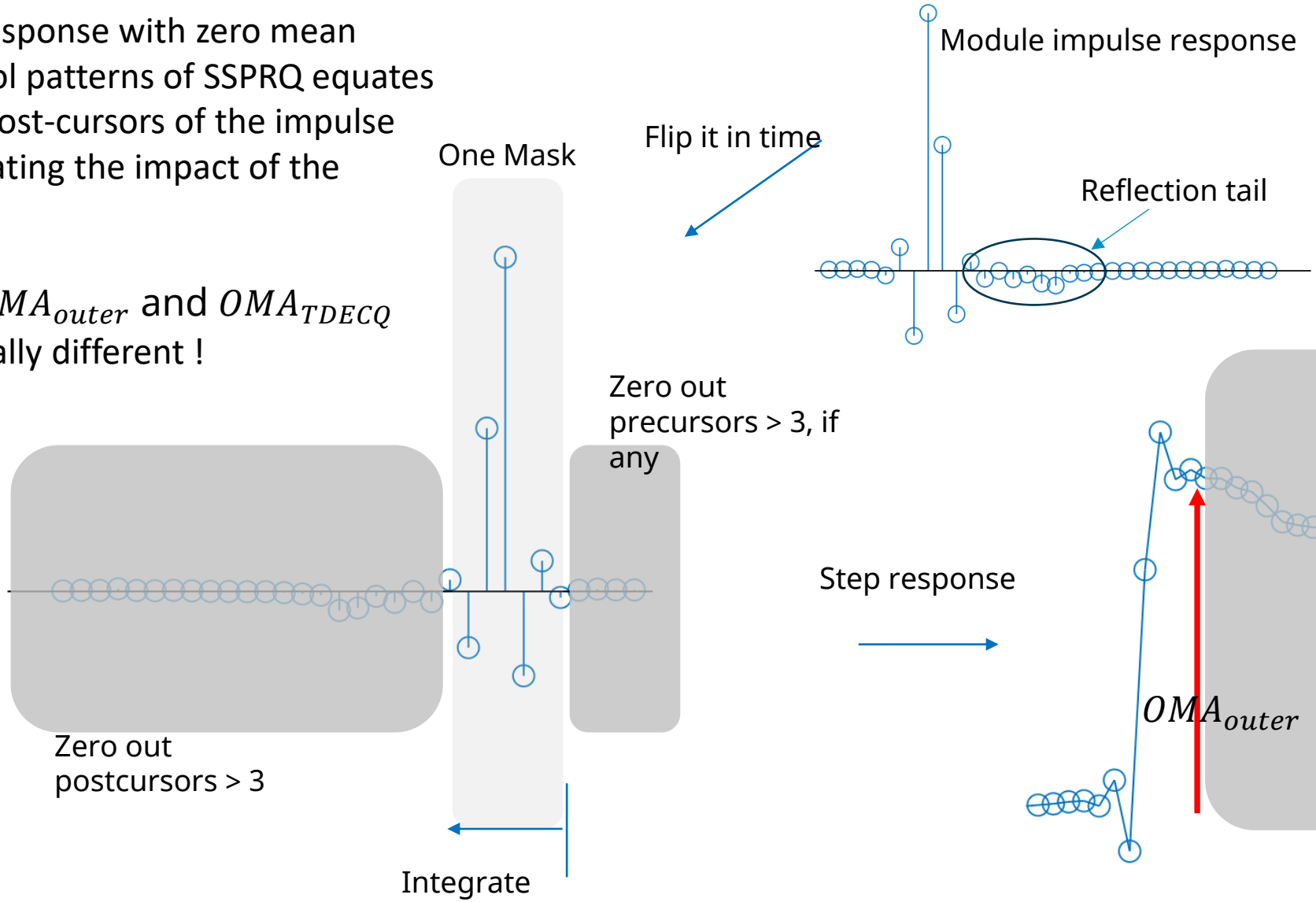


OMA_{outer} measured on a SSPRQ benefits from truly "alternating" patterns that break the impact of a long tail impulse response on the OMA_{outer} estimate, especially when a reflection is constructive (tail >0) or destructive (tail <0)

OMA_{outer} measurement interpretation

Convolving an impulse response with zero mean random preceding symbol patterns of SSPRQ equates to zeroing out pre- and post-cursors of the impulse response thereby eliminating the impact of the reflections altogether!

Which is what leads to OMA_{outer} and OMA_{TDECQ} being eventually potentially different !



OMA_{outer} estimate with SSPRQ / PRBS13Q

For 3 modules reported in https://www.ieee802.org/3/dj/public/25_09/alloin_3dj_01b_2509.pdf

OMA_{outer} estimate based on PRB13Q remains close to the SSPRQ estimate, despite its pattern being non-random. The OMA_{outer} estimate deviates significantly for module # 1 and #3 from the OMA_{TDECQ}

Module	#1	#2	#3	
Txpower	4.10	4.10	4.10	dBm
OMA_{outer} (SSPRQ)	3.13	3.28	3.37	dBm
OMA_{outer}(PRBS13Q)	3.18	3.30	3.37	dBm
OMA_{TDECQ} (SSPRQ)	2.49	3.25	3.93	dBm
OMA_{outer} (SSPRQ) - OMA_{TDECQ} (SSPRQ)	0.64	0.02	-0.56	dBm

Note: OMA_{TDECQ} is measured here after the FFE with DFE tap b = 0

Note: OMA with SSPRQ is measured using all runs > 6, but only averaging symbols of those runs at the 3rd and 4thUI (C1 option –next slides)

Impact of different averaging of runs of SSPRQ

Applying different averaging schemes on the SSPRQ sequence may yield slightly different estimates:

- Column 1 (C1): average of 3rd& 4th UI OMA estimate of all runs of 6+ consecutive symbols
- C3 to C11: average of all runs of a given length, with all symbols within the run except the first & last 2 UIs
- C12 (avg of runs): the average of the averages of all runs of C3 to C11
- C13 (avg of all seq) : the average of the averages of all runs of C3 to C11 weighted by the number of run occurrences of each length in the SSPRQ pattern

OMAouter [dBm]	run length	14	13	12	11	10	9	8	7	6	avg of runs	avg of all seq	OMAFFE
avg runs6+(3rd,4thUI only)	# runs	1	3	1	3	4	3	8	16	20			
3.14	Mod#1	2.81	2.92	3.02	2.95	2.96	2.99	3.02	3.08	3.11	2.99	3.01	2.50
3.25	Mod#2	3.14	3.21	3.27	3.16	3.20	3.22	3.18	3.24	3.25	3.21	3.21	3.11
3.33	Mod#3	3.48	3.45	3.40	3.39	3.38	3.44	3.33	3.38	3.39	3.40	3.39	3.93

C1: strict interpretation of CL 180.9.5 looking at the 3rd and 4th UI only of each run, regardless of the run length of the SSPRQ sequence = windowing channel impulse response to ~6UI

C12 (avg of runs) or alternatively C13 (avg of all seq) does not yield a too much different estimate, even though they do take into account, in the average, symbols that fall outside of this window.

OMA_{TDECQ} differs from all these results by a large amount and is closest to OMA_{outer} estimate on the longest run (14), with the exception that it discards the first 12 UI or so in the average

Proposed editorial changes

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.

Proposed exception:

"When measured with SSPRQ, 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."

Conclusion / Recommendation

Even though different averaging schemes yield a similar result in this case, it probably is worth clarifying what the expectation should be when applying SC 180.9.5 onto an SSPRQ sequence, since it is left to the implementer's interpretation.

A proposal is formulated to consider looking at around the 3rd and 4th UI only of all runs of length of 7 threes or more, and all runs of 6 zeros or more.

The strict interpretation of CL 180.9.5 looking at around the 3rd and 4th UI only of each run, regardless of the run length of the SSPRQ sequence, precisely yields the desired outcome of eliminating the reflections that may impact the OMA estimate of the ideal PAM4 signal against which we need to derive the TECQ penalty.

It may not have been what was initially intended, but as baud rates increase and channel impairments with long ISI tail become more determinant, it appears to be a practical way of dealing with its impact.

Thank you