Comparison of PAM-N for RTPGE

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Agenda

- Assumptions
- Infinite-Length DFE Results
- Tx Shaping
- Finite-Length DFE Results
- Discussions
- Example Jitter Effects
- Conclusions & Recommendation

Assumptions

- IL limit from 802.3bp [Link Segment Baseline-02].
- PSANEXT and PSAACRF as per [herman_3bp_01_0713].
- Background noise at -140dbm/Hz.
- 10% bandwidth overhead.
- Tx PSD mask based on [Tazebay_3bp_01_0626 13] and modified versions for ease of implementation.

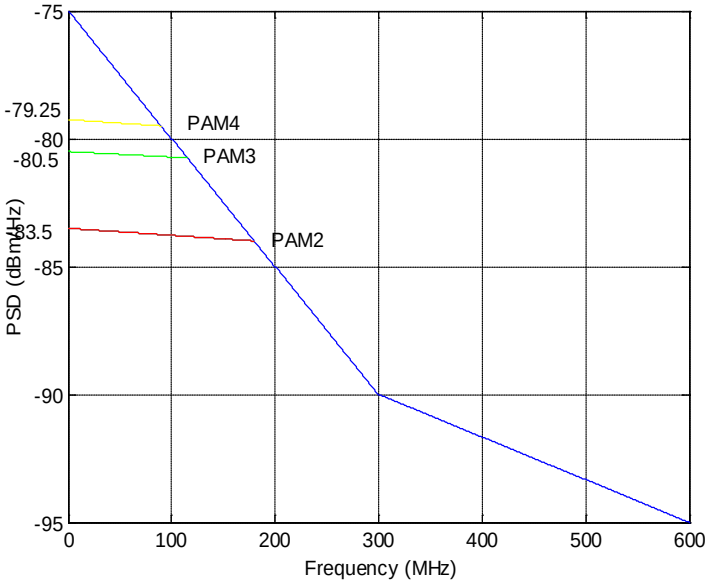


Table - Launch amplitude of modified TX PSD masks.

Modulation	PAM-2	PAM-3	PAM-4
Tx P-P Amplitude (V)	1	1.37	1.55

Infinite-Length DFE Results

Table - Results of Original Tx PSD Mask (15m/2m*) .

Modul.	SNR (dB)	Raw Eye Height (mV)	Eye Height @1e-10 (mV)	First FB Tap
PAM-2	35.1/37.0	225/603	200/549	1.33/1.13
PAM-3	39.9/40.9	205/456	183/413	1.17/1.10
PAM-4	42.0/42.9	179/373	159/335	1.11/1.07

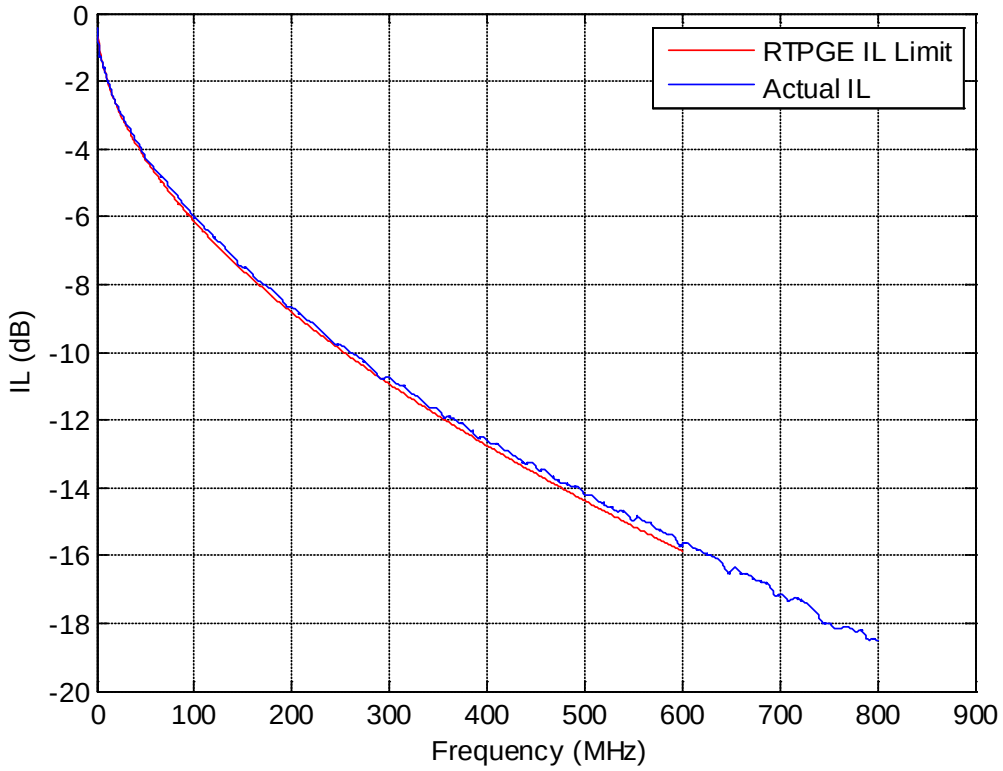
Table - Results of Modified Tx PSD Masks (15m/2m).

Modul.	SNR (dB)	Raw Eye Height (mv)	Eye Height @1e-10 (mv)	First FB Tap
PAM-2	34.7/36.7	192/544	169/493	1.24/1.06
PAM-3	39.5/40.7	188/430	167/389	1.11/1.04
PAM-4	41.8/42.7	168/358	148/320	1.05/1.03

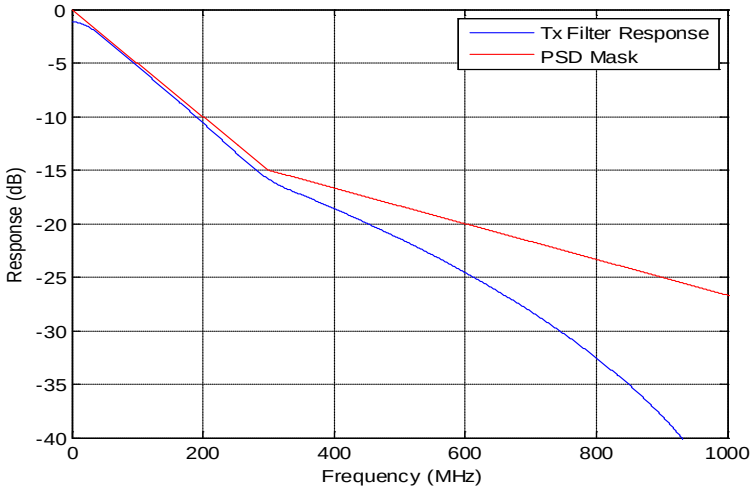
*2m channel at 125C without connectors.

A “Real” Channel

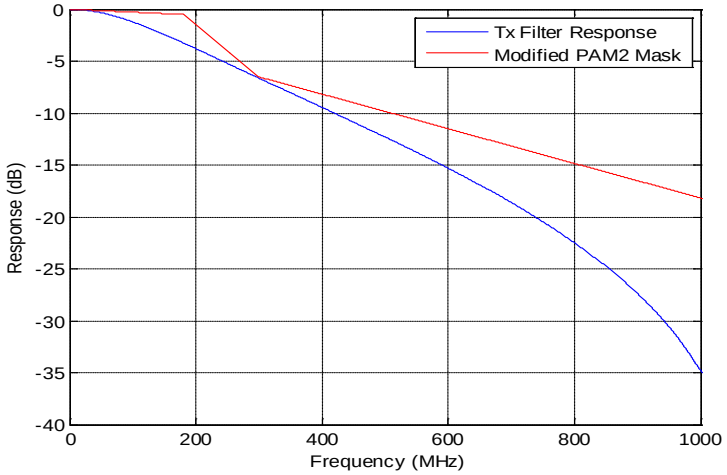
- Created a channel to fit the IL limit from a real channel measured by Commscope.

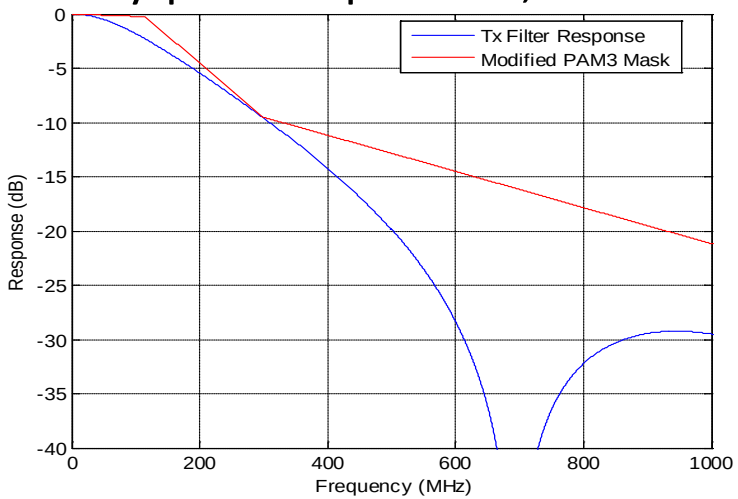


Tx PSD Shaping



- A digital FIR filter to fit the original Tx PSD mask.
- Ist order Butterworth filter with cutoff frequencies optimized to fit the modified Tx PSD masks.
- The gaps between the mask and actual filter responses, particularly at Nyquist frequencies, indicate loss.





Finite-Length DFE Results

Table - Results of Original Tx PSD Mask.

Modul.	SNR (dB)	Raw Eye Height (mV)	Eye Height @1e-10 (mV)	First FB Tap	Max FFE Gain (dB)
PAM-2	33.6	209	181	1.54	0.075
PAM-3	38.7	197	174	1.22	0.002
PAM-4	40.9	171	147	1.11	0.001

Table - Results of Modified Tx PSD Masks.

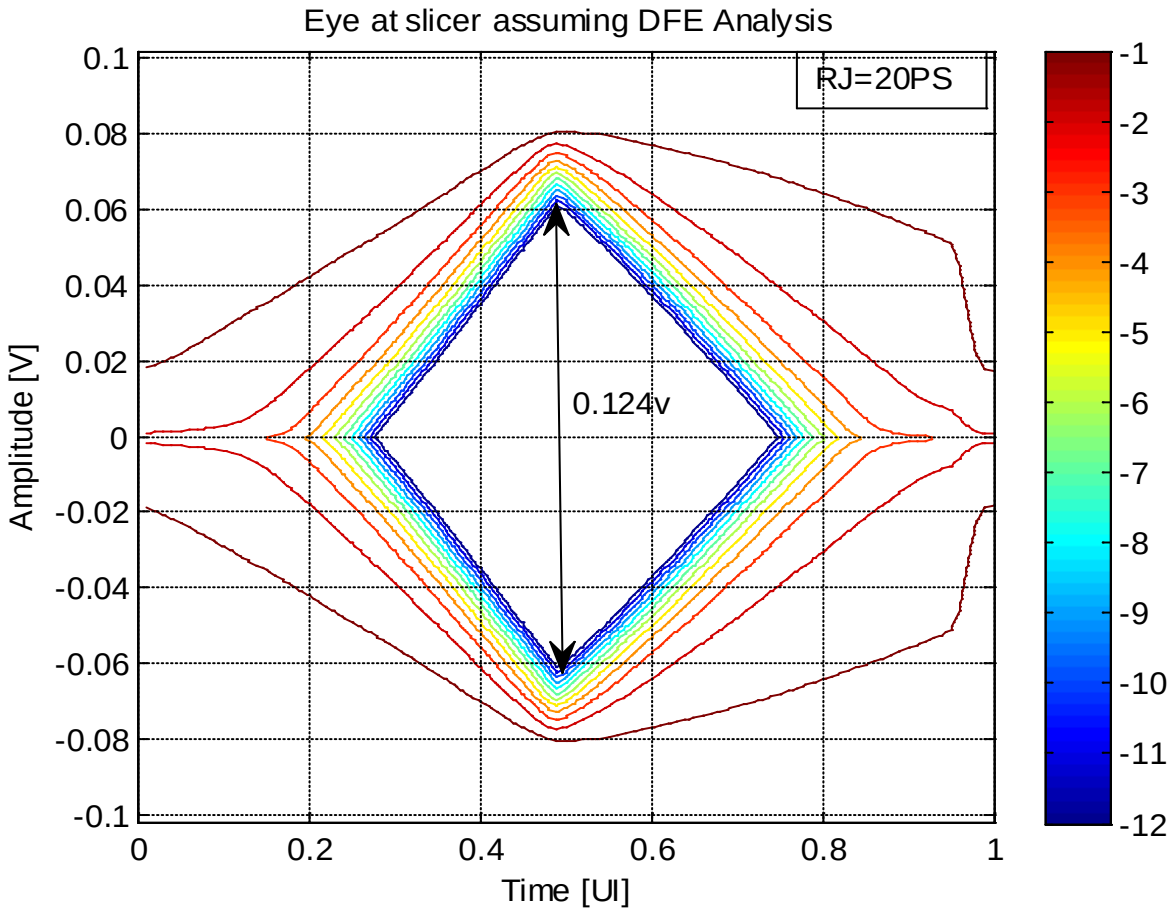
Modul.	SNR (*dB*)	Raw Eye Height (mV)	Eye Height @1e-10 (mV)	First FB Tap	Max FFE Gain (dB)
PAM-2	32.1	165	136	1.17	1.4
PAM-3	38.4	183	161	0.89	0.01
PAM-4	40.2	163	140	0.77	0.001

Discussions

- With 2m cable, all 3 modulation schemes can provide immunity more than 300mv.
- How much RFI immunity is required for the worst-case channel?
  - It's possible to support the most strict BCI test with 2m cables and 100mv RFI immunity for 15m cables.
- Only background noise and Xtalks were considered in the simulations. Other implementation losses/impairments such as ADC, jitter, non-ideal equalizer settings could be more dominant factors.
- Even with ENOB 6 in PAM2, ADC quantization noise will be at least comparable to Xtalks and background noise combined.
- Since RFI can come at any frequency, eye opening needs to be bigger than the RFI amplitude multiplied by the maximal FFE gain in frequency.

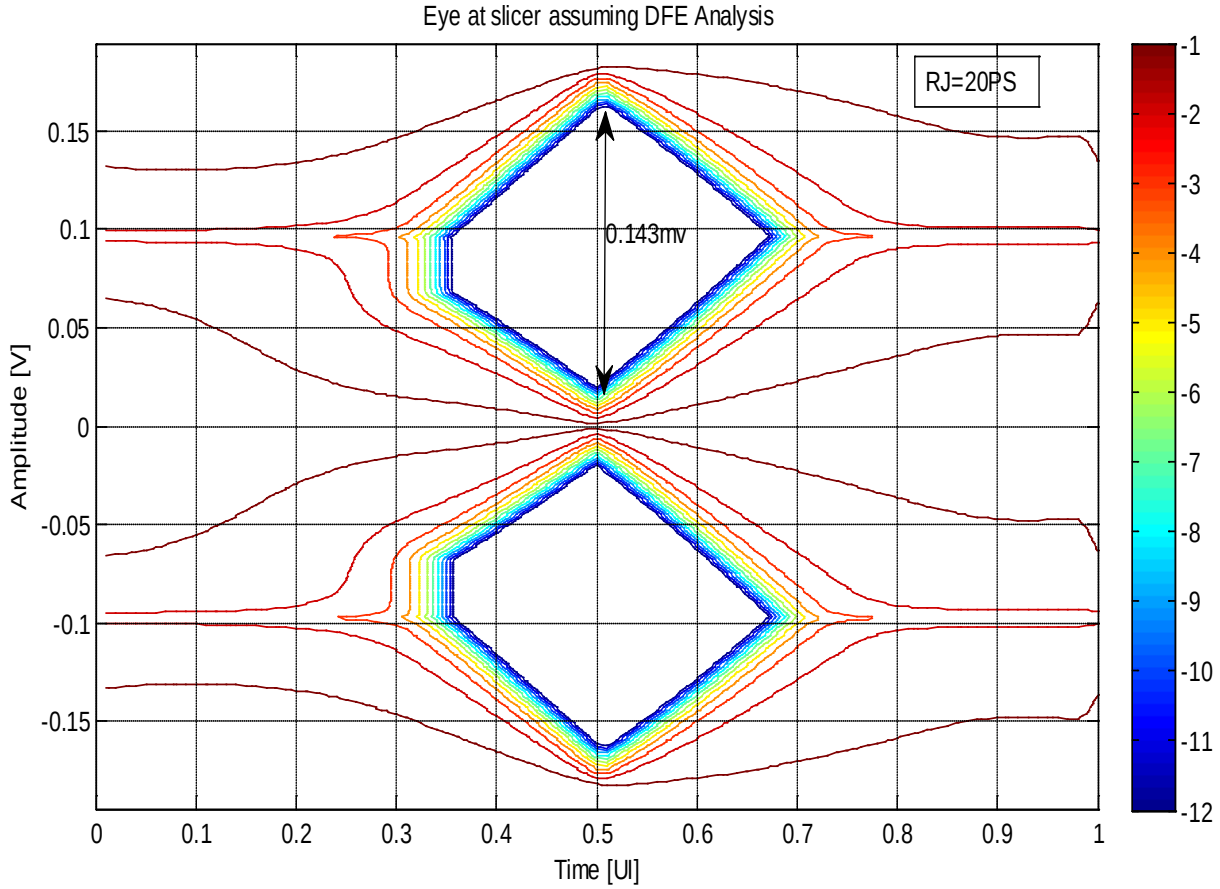
  $Eyeheight_{pp} > RFI_{pp} * Gffe\_max$
- Jitter can increase residual echo and reduce the eye opening.
- When all above considered, PAM2 implementation with modified PSD mask and Butterworth Tx filter is marginal to provide 100mv RFI immunity for 15m channels.

Example Jitter Effects



Eye height =124mv with 20 ps rms RJ, modified PSD mask (vs 136 mv w/o jitter).

Example Jitter Effects



Eye height =143mv with 20 ps rms RJ, modified PSD mask (vs . 161mv w/o jitter)

Conclusions & Recommendation

- With ideal DFE and TX psd masking, PAM2, 3 and 4 all provide good margin with PAM2 having the highest eye opening.
- PAM2 is most sensitive to effects of finite length equalization and Tx filtering.
- PAM3 provides the best compromise in terms of achievable performance and robustness to practical implementation loss.
- Recommend to adopt PAM3 as the modulation scheme.