SNR Margin Analysis with Updated Link Parameters

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Introduction

- George has provided preliminary PHY analysis for 500m trunk using new proposals from Graber (graber_02_03152023.pdf, graber_01_03152023.pdf), showing that PAM 3, 4, and 5 are all viable with the proposal.
- This presentation further analyses SNR margin for different trunks (300m/400m/500m), 200m spur, as well as 100m motor feedback communication using relaxed PHY AFE parameters.
  - Although spur link is not included in 802.3dg objective yet, it is still worth to investigate and may contribute to the format decision for PHY implementation.

Modeling Parameters

- SNR Margin is analyzed similarly as in Tingting_3dg_01_18_01_2023.pdf. The required SNR for different PAMs at BER of 10^{-10} can be obtained as:

$$SNR_{\text{req}} = 11.44 + 6.02 \times log_2 M \quad (\text{dB}).$$

- PHY parameters: a 2nd-order butterworth filter at Nyquist Frequency, -140 dBm/Hz AWGN, AFE with 10-bit ENOB ADC, 40dB Echo suppression, and 1V V_{pp} for spur only (2.4V for both trunk and motor feedback).
- Link segment parameters include *IL*, *RL*, *PSANEXT*, and *PSAFEXT* or *PSAACR-F*. In terms of the insertion loss:
  - Taking temperature impact and low frequency performance into account, IL for 500m trunk has been suggested to be:

$$IL_{\text{Trunk}} = \left(5.42 \times \sqrt{f} + 0.044 \times f + \frac{1.76}{\sqrt{f}}\right) + 5 \times 0.02 \times \sqrt{f}.$$

  - Consequently, IL for 100m motor feedback is modified with gauge (AWG16, AWG22) and length factor as:

$$IL_{\text{Motor}} = \frac{2}{5} \times \left(5.42 \times \sqrt{f} + 0.044 \times f + \frac{1.76}{\sqrt{f}}\right) + 5 \times 0.02 \times \sqrt{f}.$$

  - For the 200m spur link, IL is given by $IL_{\text{Spur}} = 2.4 \times \left(1.23 \times \sqrt{f} + 0.01 \times f + \frac{0.2}{\sqrt{f}}\right) + 5 \times 0.02 \times \sqrt{f}$.

- For all cases, RL follows:

$$RL = \begin{cases} 9 + 8f, & 0.1\text{MHz} \le f < 0.5\text{MHz} \\ 13, & 0.5\text{MHz} \le f < 20\text{MHz} \\ 13 - 10log_{10}\left(\frac{f}{20}\right), & 20\text{MHz} \le f \le 60\text{MHz} \end{cases}$$

Modeling Parameters – Cont.

- PSANEXT and PSAACRF use the models from Graber (graber_3dg_03_03152023.pdf) with relaxed installation at lower insertion loss, shown as:

$$PSANEXT\ [\mathrm{dB}] = \begin{cases} 55 + 5 \times N & 0.1\mathrm{MHz} \le f < 10\mathrm{MHz} \\ 55 + 5 \times N - 15\log_{10}\left(\frac{f}{10}\right) & 10\mathrm{MHz} \le f \le 60\mathrm{MHz} \end{cases},$$

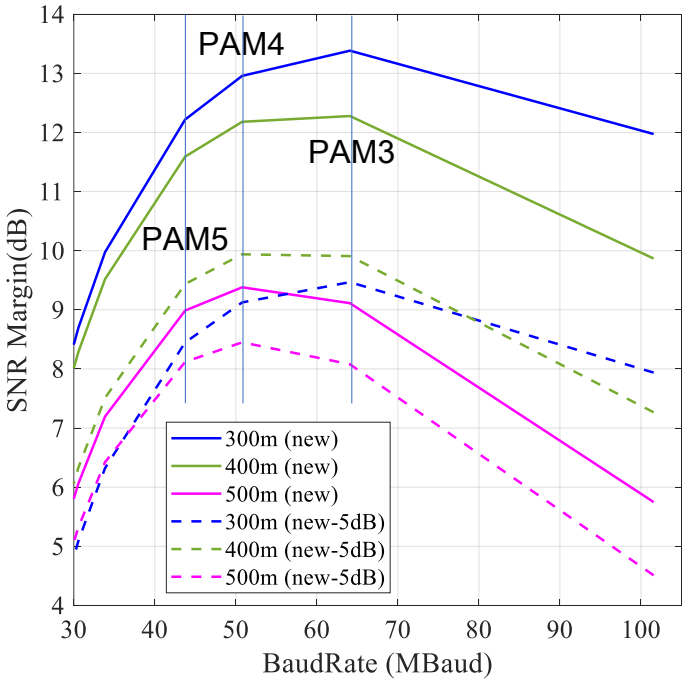
$$PSAACR - F\ [\mathrm{dB}] = \begin{cases} 55 + 5 \times N & 0.1\mathrm{MHz} \le f < 2\mathrm{MHz} \\ 41 + 5 \times N - 20\log_{10}\left(\frac{f}{10}\right) & 2\mathrm{MHz} \le f \le 60\mathrm{MHz} \end{cases},$$

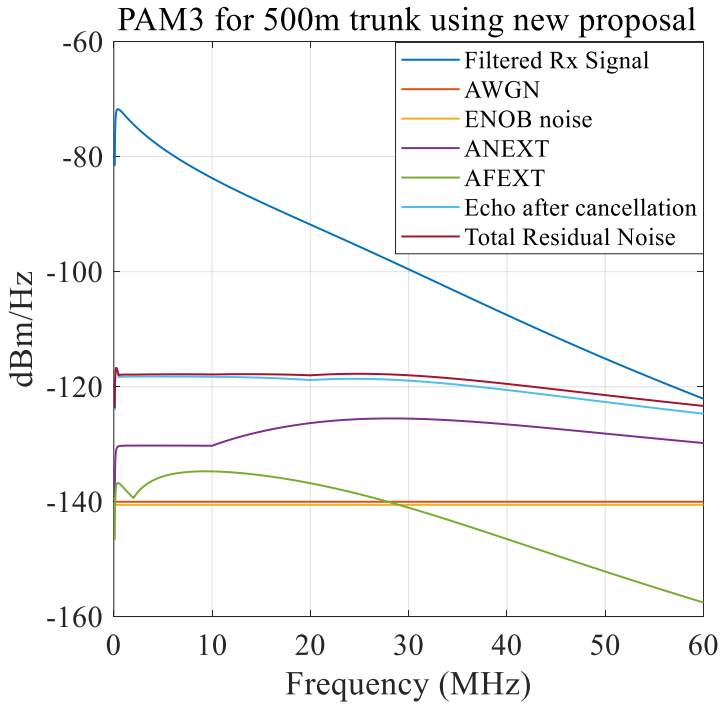
$$\text{where, } N = \begin{cases} 0 & \text{for } IL(20\mathrm{MHz}) < 16\mathrm{dB} \\ 1 & \text{for } 16\mathrm{dB} \le IL(20\mathrm{MHz}) < 21\mathrm{dB}. \\ 2 & \text{for } IL(20\mathrm{MHz}) \ge 21\mathrm{dB} \end{cases}$$

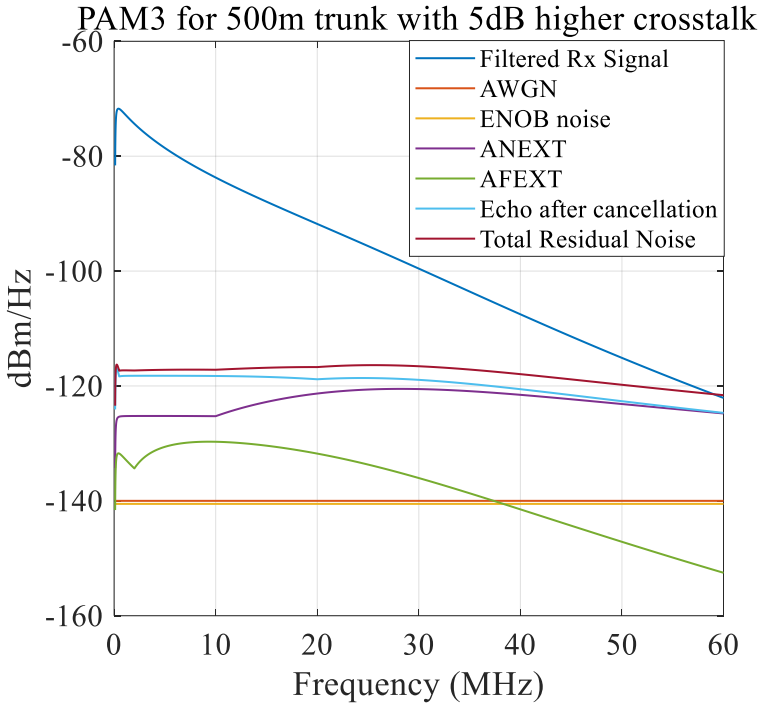
- For motor feedback, alien crosstalk noise is very small (xu_3dg_01a_1116_2022.pdf), therefore, is ignored. For spur link, the IL at 20MHz is lower than 16dB, satisfying *N*=0 condition.

SNR Margin Analysis for Trunk

- Based on Graber's new proposal (**solid** lines in the left figure), the maximum achievable SNR margin decreases with trunk length, giving about 9.3dB for 500m trunk.
- Increasing PSANEXT and PSAACR-F by 5dB (**dashed** lines in the left figure), the maximum SNR margin for 300m trunk is lower than that for 400m trunk, as the relaxed PSANEXT and PSAACR-F limit overtakes the benefit brought by reduced insertion loss. SNR margin of 500m trunk is still the lowest, and is 1dB lower than the case with 5dB lower alien crosstalk.
- In general, PAM3 achieves higher SNR margin except for 500m trunk (but only 0.2dB lower than PAM4).

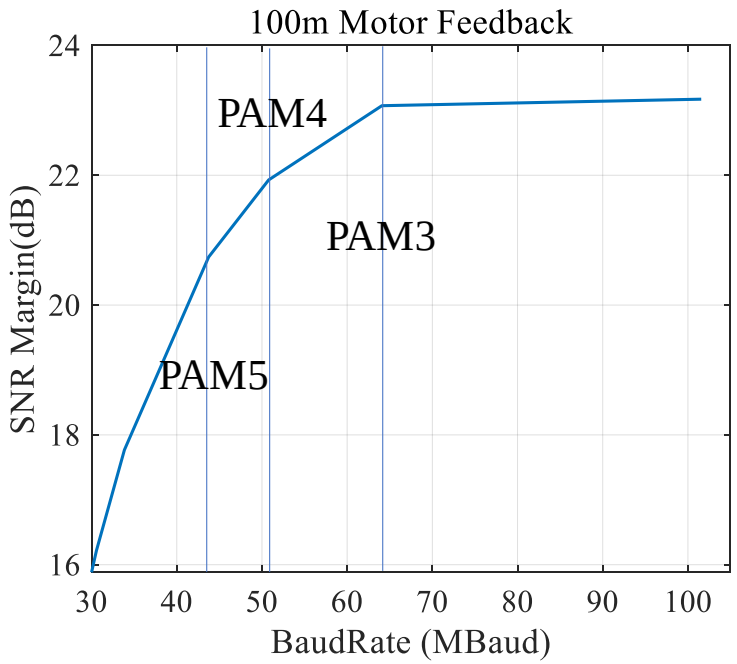


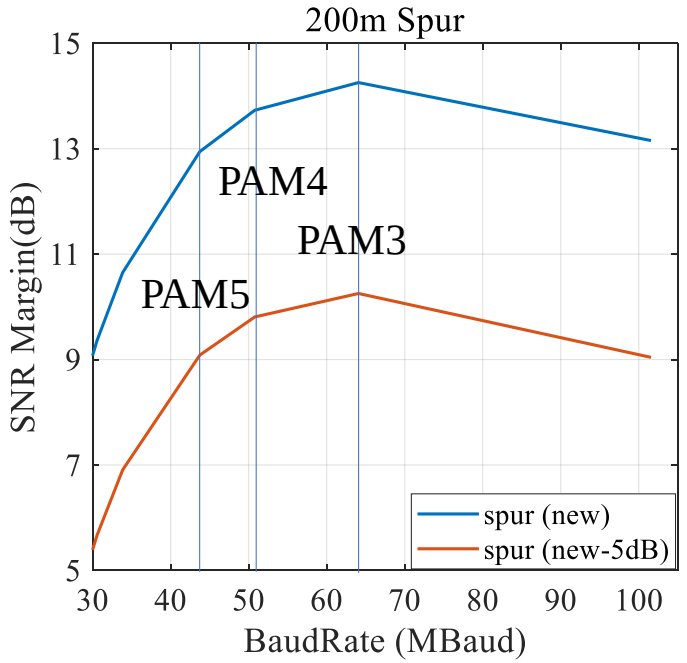




SNR Margin Analysis for Spur and Motor Feedback

- For 100m motor feedback communication with negligible alien crosstalk, SNR margin is over 23 dB and decreases rapidly with PAM order larger than 3.
- For 200m spur, Graber's new proposal with 5dB lower alien crosstalk, achieves 4dB more SNR margin. However, the worse case of 200 spur is still 1.5dB higher than 500m trunk (ref. previous slide).
- For both applications, PAM3 enables highest SNR margin, and may be preferable considering:
  - IEEE always picked the lowest workable PAM.
  - Single symbol error leads to more bit errors for higher PAM levels.
  - DFE error propagation grows exponentially with PAM level.
  - PAM3 is consistent with 10BASE-T1L,100BASE-T1, and 1000BASE-T1.





Conclusion

- Among all applications, the maximum achievable SNR margin for 500m trunk using ENOB of 10bit and echo suppression ratio of 40dB is the smallest. But it is still over 9dB using Graber's new proposal.
- PAM3 to PAM5 are all viable. PAM3 generally gives larger SNR margin, mitigates DFE error propagation (compared with high-order PAM), and provides better compatibility with 10BASE-T1L, 100BASE-T1, and 1000BASE-T1.

Thank you!