PHY Analysis Relative to Link Segment

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Introduction

- Suggested Link Segment Parameters have been presented in graber_3dg_01_08302022.pdf and Schicketanz_3dg_01a_10122022.pdf
- The Task Force can help progress cabling standards work by providing guidance on frequencies used and identifying parameters to be improved or mitigated
- This presentation provides preliminary PHY analysis to identify bandwidth needs and limiting parameters
  - It is NOT a PHY baseline proposal at this time

PHY Modeling

- Desire to be implementation independent – use theoretical limitations, established, proven technique for Salz modeling
  - Extensible to PAM/QAM, shown to be equivalent to geometric SNR for multicarrier
  - Experience shows > 6 dB SNR margin needed, 8 dB reasonable, more than 10 dB often not realized
    - Relative to uncoded SNR (12.27 dB SNR gap)
      - Coding Gain does not change shape of margin curve
    - Good indication that a system can be designed provided implementation-specific issues satisfied – not necessarily that any given PHY design with a given modulation works on a link segment
- Model includes residual components from echo & receiver noise
  - Assume high degree of echo cancellation, good AFE
  - For this presentation use receiver parameters within technology, but high enough not to limit performance – focus on link segment - 50 dB echo, 12 bits ENOB (overkill)

Link Segment Transmission Models - Graber

- Insertion Loss: (Graber slide 5)

  $5*(0.98*SQRT(f_{MHz})+0.01*f_{MHz}+0.2/SQRT(f_{MHz}))+5*0.02*SQRT(f_{MHz})$

- Return Loss (Graber slide 10, secondary factor - choices of receiver parameters)

  $9+8*f_{MHz}$ dB ($f_{MHz} < 0.5$ MHz) , 13 dB ($0.5 \le f_{MHz} < 20$ MHz)

  $13-10*LOG10(f_{MHz}/20)$ ($20 \le f_{MHz} \le 100$ MHz)

- Alien NEXT: (Graber slide 13)

  $-10*LOG10(6*10^{(-7+LOG10(f_{MHz}/10))}+5*2*10^{(-7.3+1.7*LOG10(f_{MHz}/10))})$

  - Note – Clause 146 PSANEXT loss was 37-17log10(f/20) dB, 18.5 dB higher

- Alien FEXT: (Clause 146, Eqn 146-16)

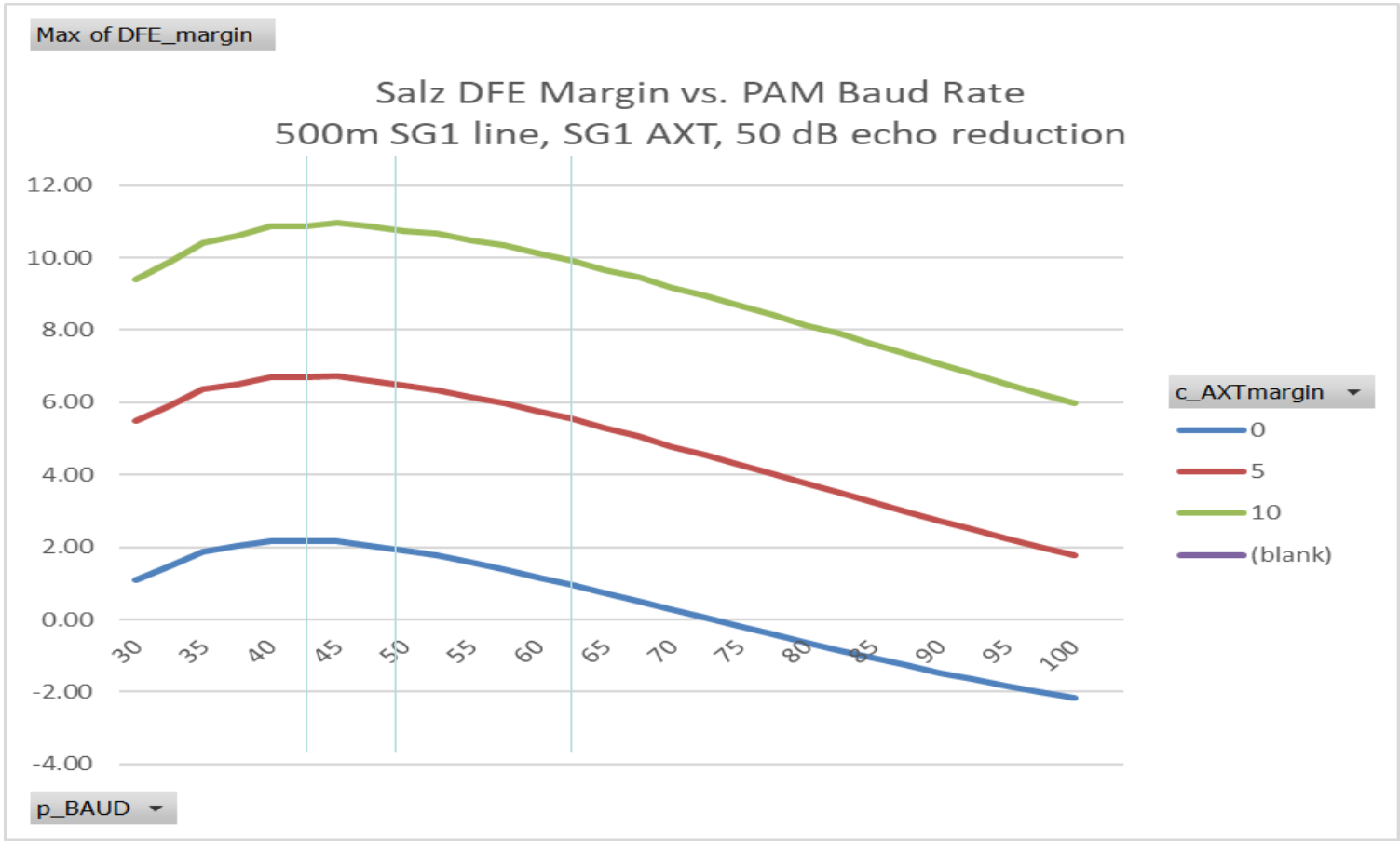
  $IL(f_{MHz})+ 38-18*LOG10(f_{MHz}/20)$

Suggest contributions on scaling alien FEXT for length and connector count on links targeted for 100BASE-T1L.

Likely different from unshielded twisted pair LAN or telephony behavior, due to reported dominant coupling at connectors and mode conversion due to spring connector untwist

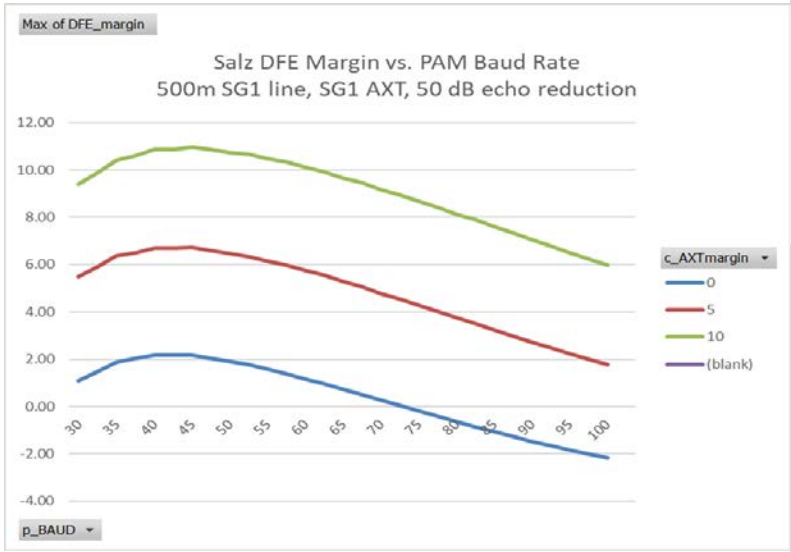
Optimal PHY bandwidth ~ 20 to 30 MHz

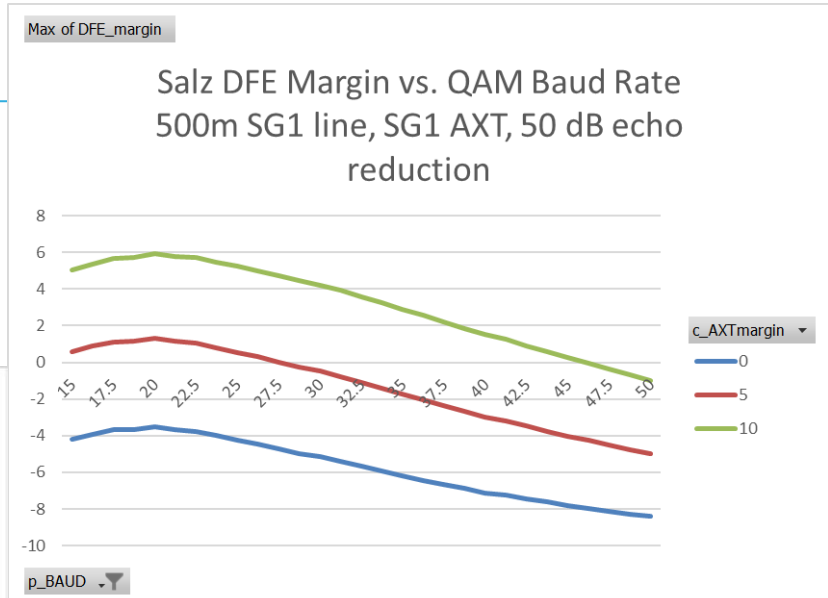
- PAM4 to PAM 5
  - PAM 3 pinched off by ANEXT
- Between 5 dB and 10 dB improvement on alien crosstalk + coding gain needed

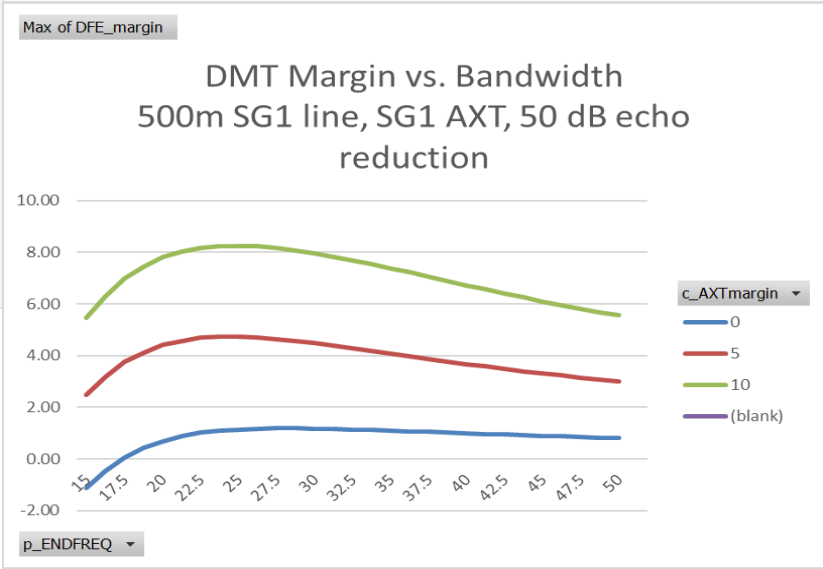


PAM/QAM/Multicarrier: No Magic in Line Codes

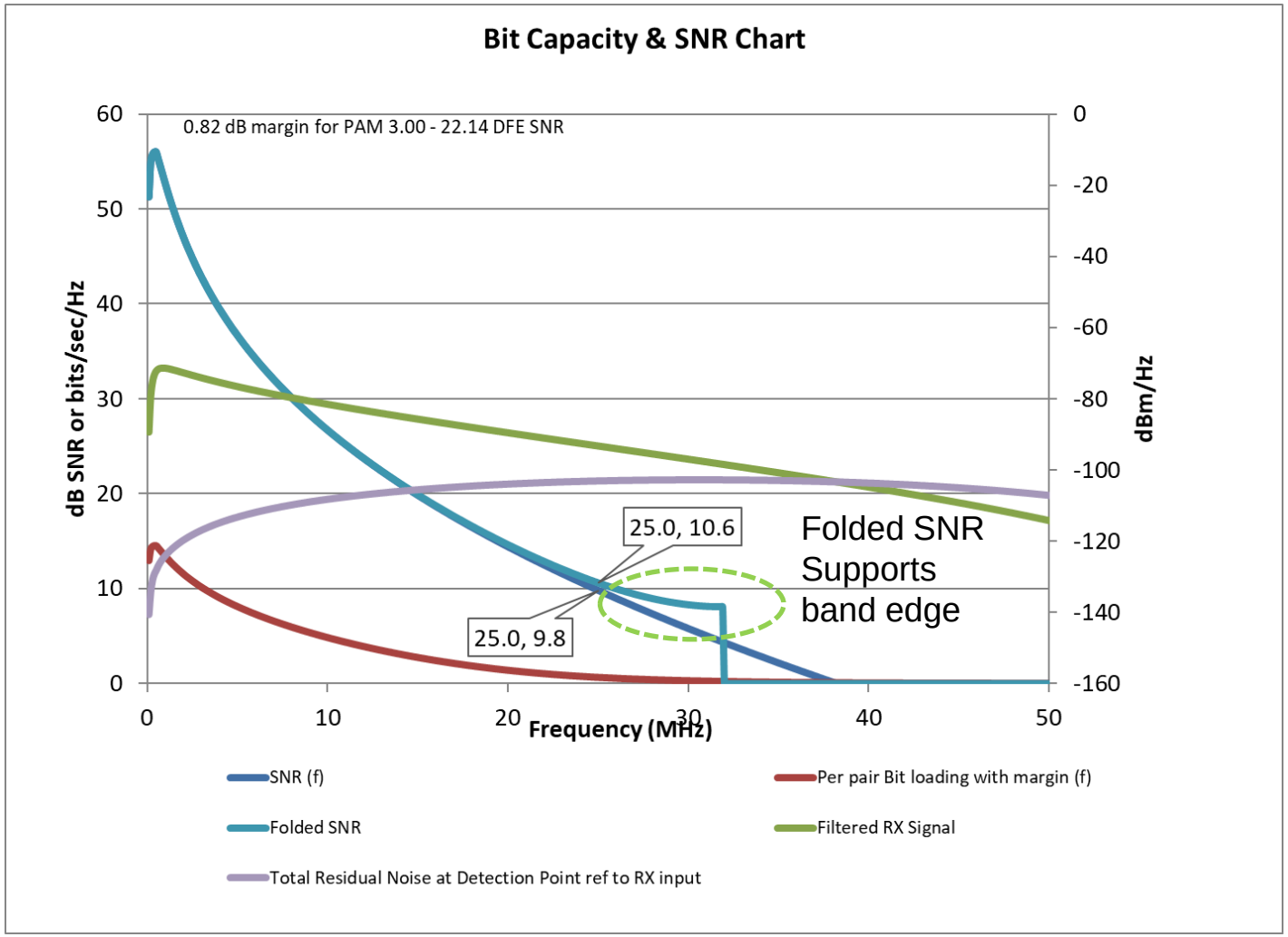
- Likely to want to enable 10BASE-T1L/100BASE-T1L PHYs
  - Implementation advantage to PAM
- PAM provides best use of baseband, lowest complexity for low number of levels
  - PAM 2, 3, 4, 5 can be “multiplier free” echo cancellation, DFE structures
  - Well-known, well-optimized for Ethernet
  - Low Latency
  - Low peak-to-average ratio (good for intrinsic safety applications)







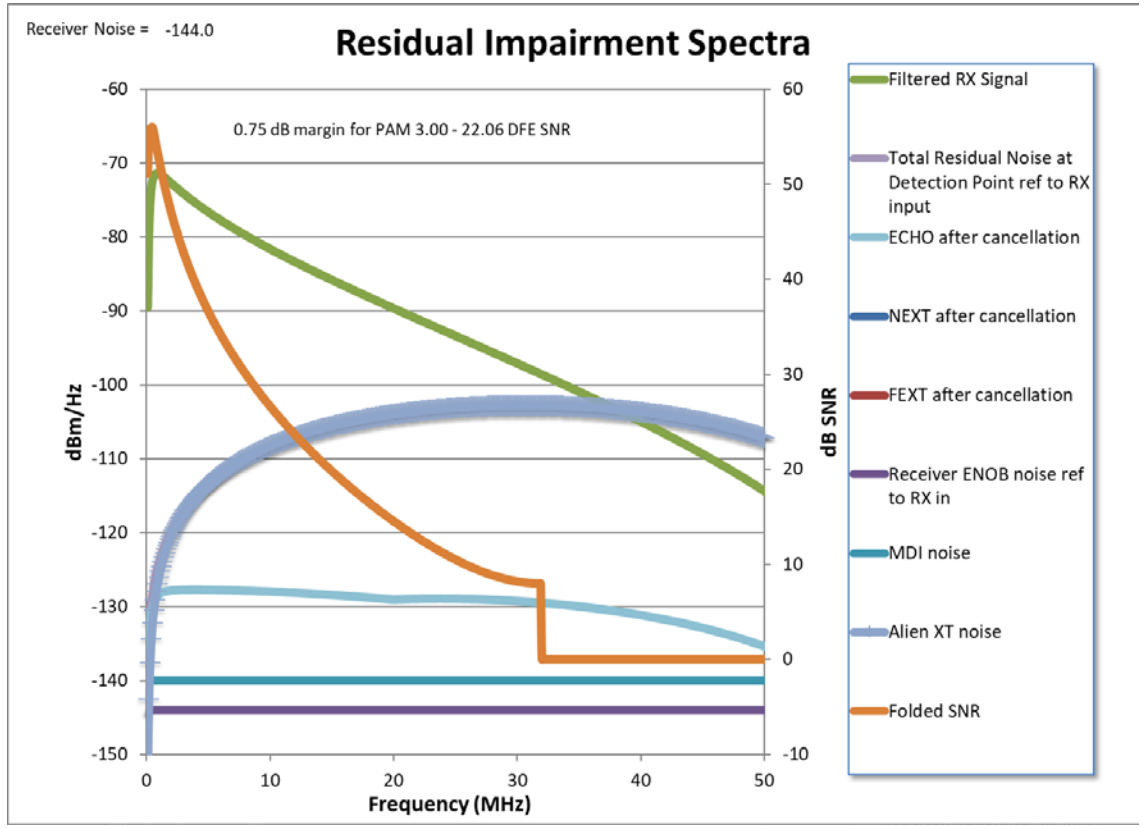
PAM Cabling Bandwidth beyond Nyquist Supports SNR



Alien Crosstalk limits Performance and Bandwidth

- Potential Improvement:
  - Reduction in Alien Crosstalk (see Graber suggestions)
  - Addition of coding gain (PHY complexity, more levels at the same baud rate)
  - Reduction in Insertion Loss

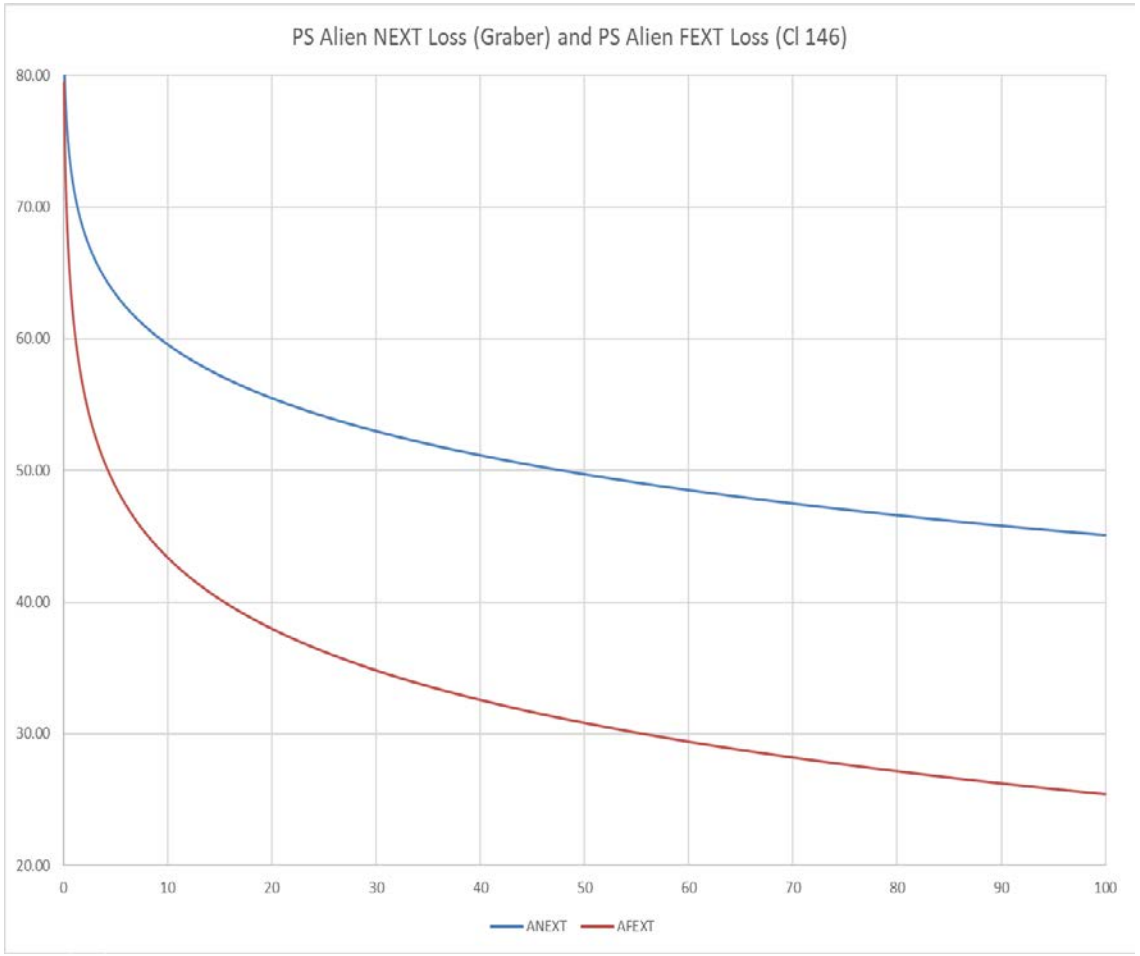
(or combination) is needed to reach our objectives



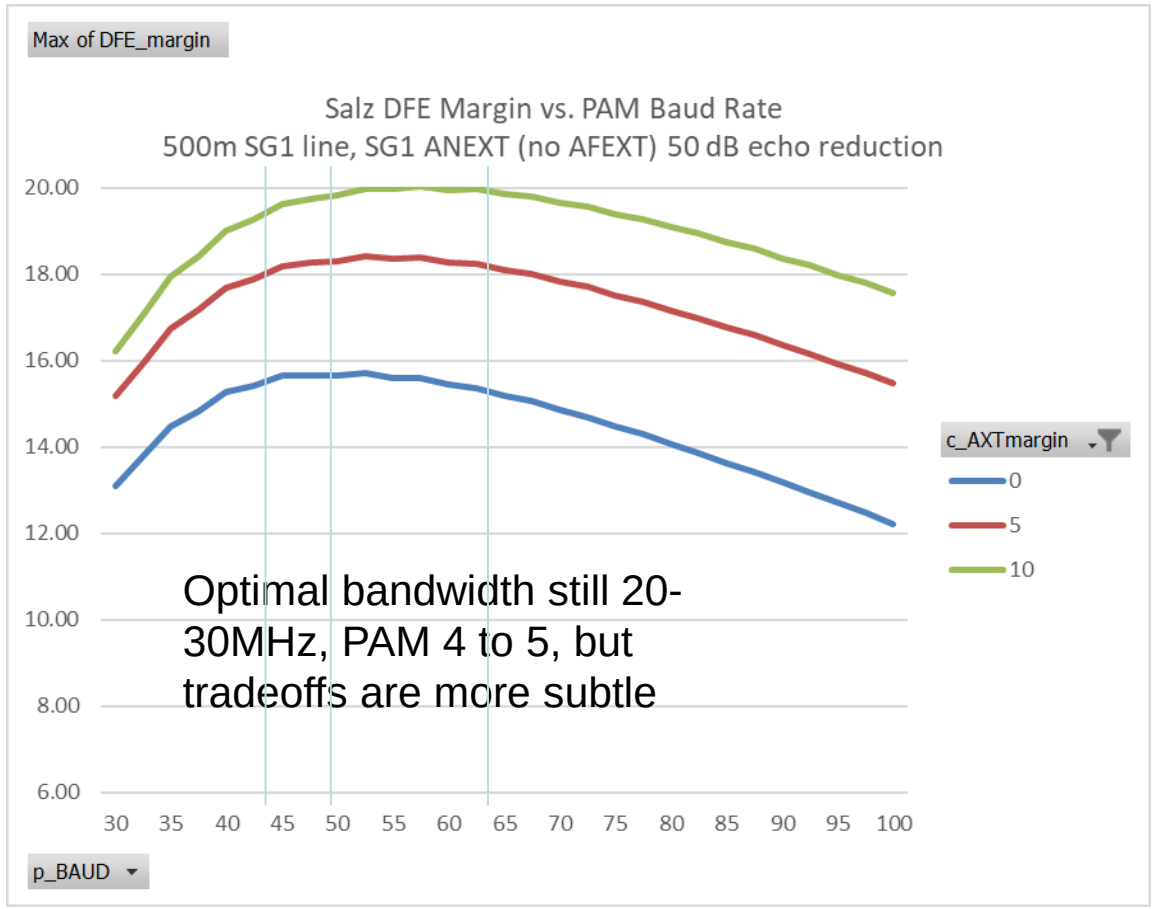
(PHY AFE parameters, voltage levels, or return loss/echo cancellation won't do it)

AFEXT Dominates, Data Needed

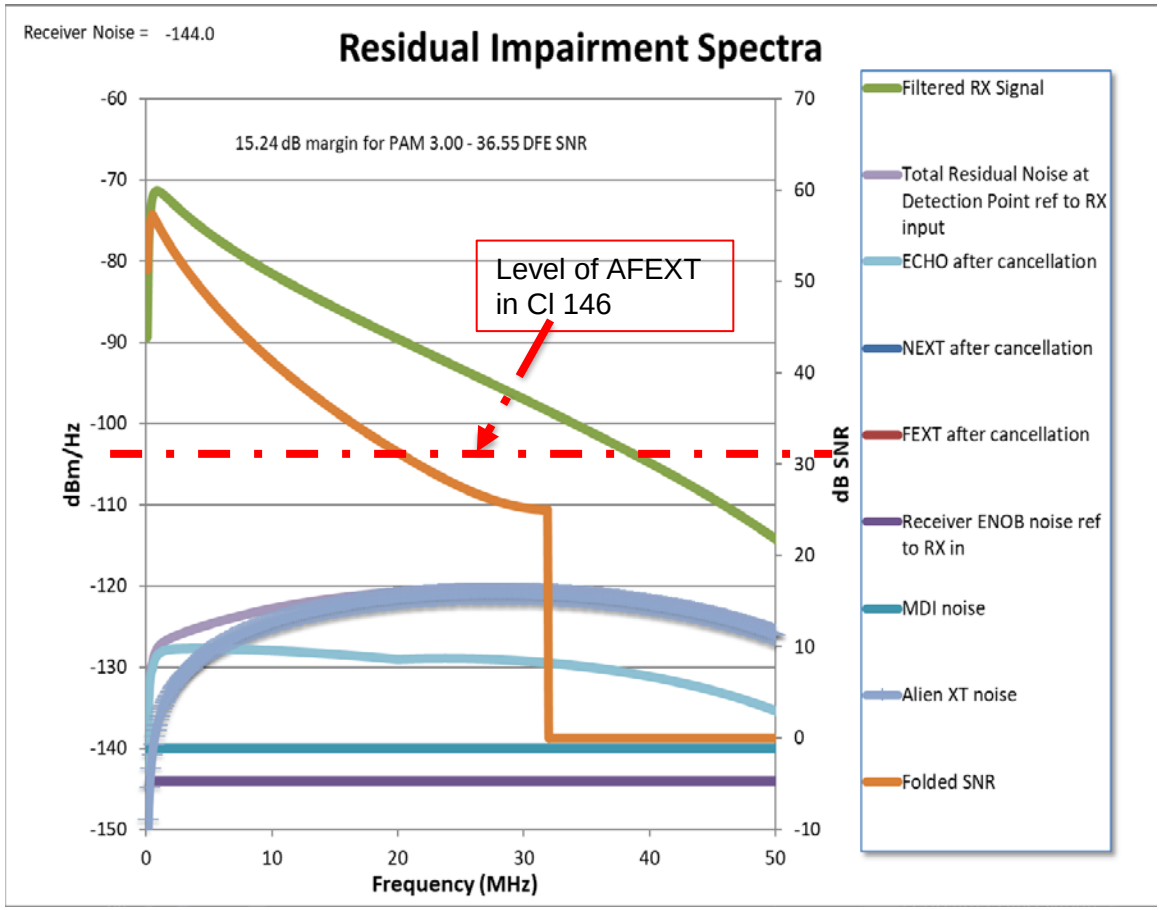
- AFEXT, if like clause 146, dominates AFEXT
  - 17.5 dB higher at 20 MHz
  - Likely unrealistic due to shorter link, fewer connections
- Need AFEXT contributions
  - Equal length links, 500m,
  - 5 connectors
- May need near/far AFEXT mitigation

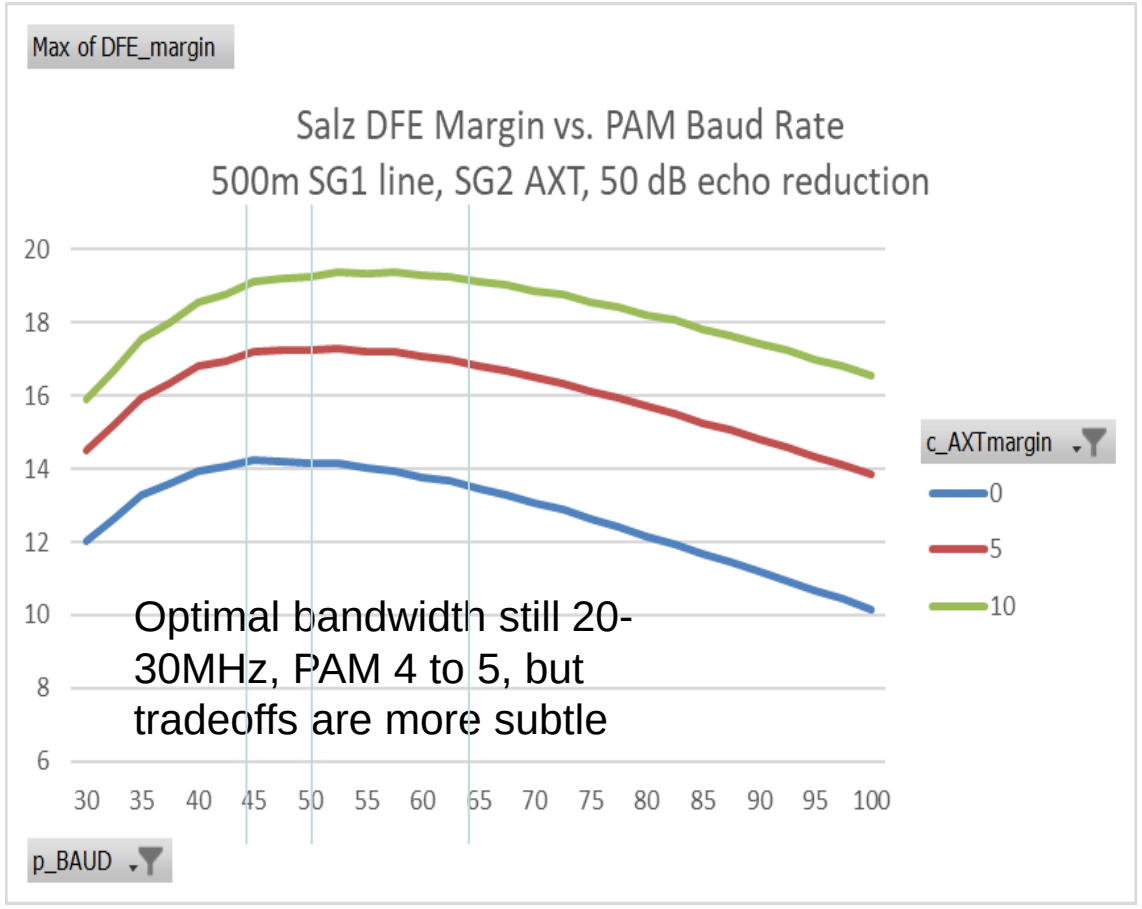


Without AFEXT, it's a little different story



Possible Scenario – AFEXT similar in level to ANEXT (reduce AFEXT 18.5 dB, like ANEXT rel to Cl 146)





Conclusions

- Insertion loss & Alien Crosstalk functions will determine baseline PHY specifications
  - Proposals from graber_3dg_01_08302022.pdf are a good start
  - Need to get consensus on ANEXT/AFEXT models
    - Determines whether FEC is needed for crosstalk noise
    - Validating measurements will important
- Regardless, optimal Nyquist bandwidths are between 20 and 30 MHz used
  - ‘Rule of thumb’ would then specify out to at least 40 MHz (25% beyond Nyquist)
- Optimal noise performance is in favor of PAM 4
  - In low noise, PAM 3 could be used, and long reach/high freq noise, PAM 5

THANK YOU