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Performance Analysis of PAM4 Receivers over Long Backplane Channels

for IEEE 802.3bj 100Gb/s Backplane and Copper Cable Assemblies

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Supporters and Contributors

- Vasudevan Parthasarathy, Broadcom
- Sanjay Kasturia

Introduction

- Goal is to show feasibility of PAM4 signaling over two rather difficult backplane channels.

Agenda

- Assumptions
- Models
- Tyco 42.8” Analysis
- Emerson Long Link
- Summary and Discussions

Assumptions

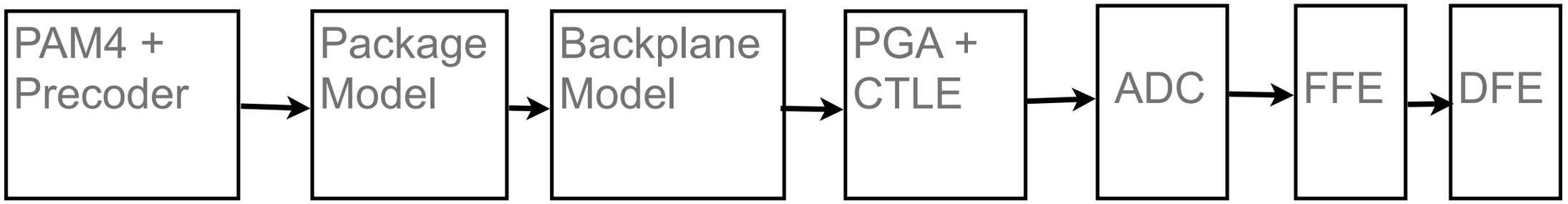
- Two different backplane models:
  - Tyco 42.8” channel with Nelco 4000-6 material:
    - http://grouper.ieee.org/groups/802/3/100GCU/public/ChannelData/TEC_11_0428/shanbhag_03_0411.pdf
  - Emerson’s ‘longest link’:
    - http://www.ieee802.org/3/100GCU/public/ChannelData/emerson_11_0928/meier_01_1011.pdf
- Package:
  - 40G package model:
    - http://www.ieee802.org/3/ba/public/tools/PkgModelProposal_rev.pdf
    - Pkg35mm_T21mm115ohmHiXtalk_BGAHiXtalk.s8p
- Cascade the two models to construct an end-to-end channel model.

Assumptions

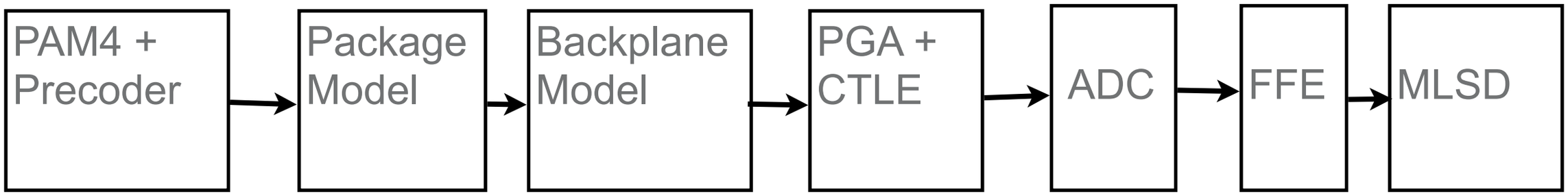
- We equalize to 1+D channel in order to limit the peaking requirement at CTLE:
  - More jitter tolerance.
  - Less cross talk enhancement.
  - No error propagation with either DFE or MLSD receivers.
- All sources of xTalk are alien:
  - Pre-emphasis results in a loss of SNR proportional to sum(abs(h_k)).
  - Clearly too pessimistic.
  - We do not assume any pre-emphasis filter in the transmitter.
- Symbol rate 14GHz: includes FEC overhead.
- 4.5 dB FEC gain with correlated noise:
  - http://www.ieee802.org/3/bj/public/sep11/parthasarathy_01_0911.pdf

Models

DFE with constrained coefficients



MLSD: http://www.ieee802.org/3/bj/public/sep11/dabiri_01_0911.pdf

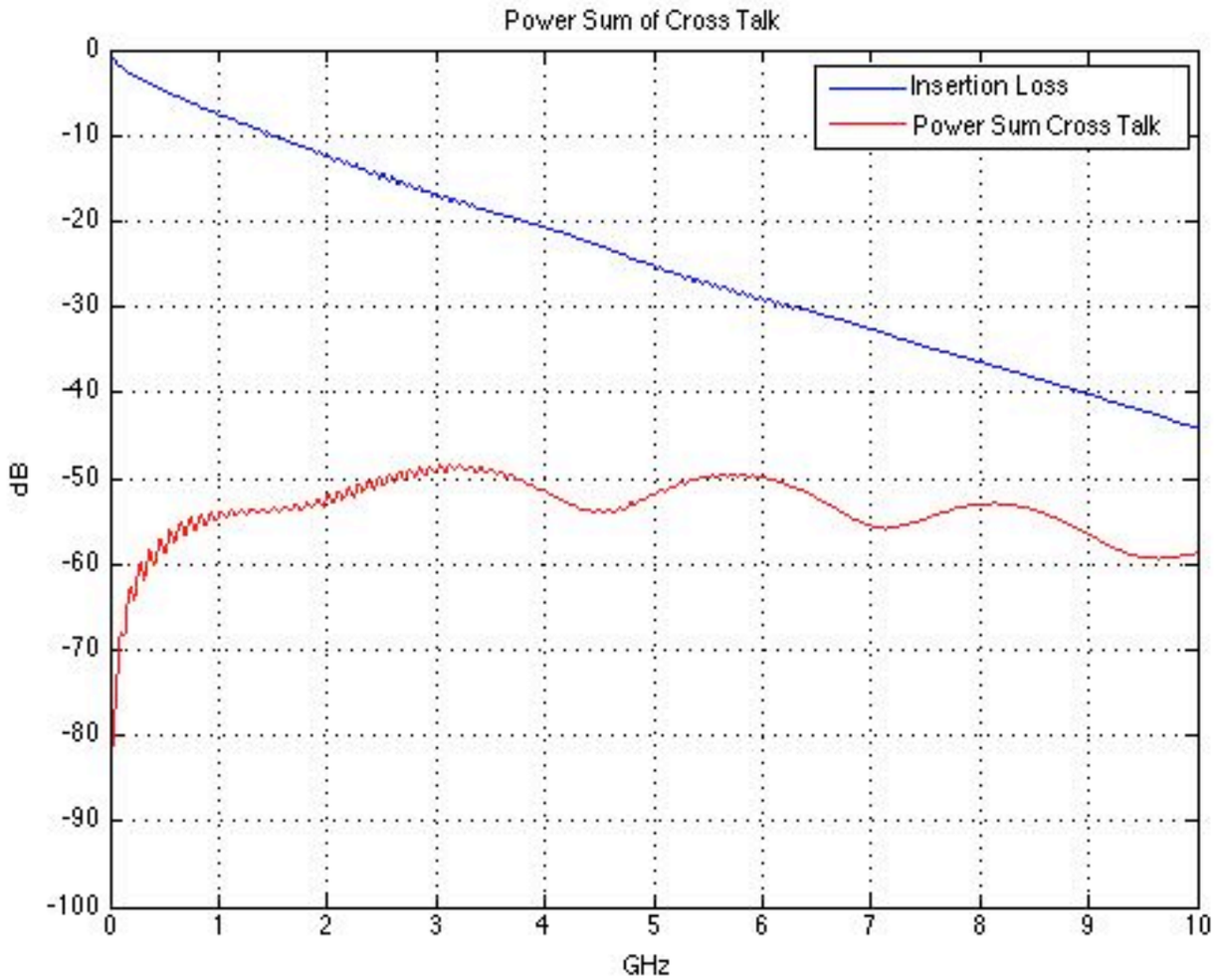


Tyco 42.8”

Nelco 4000-6

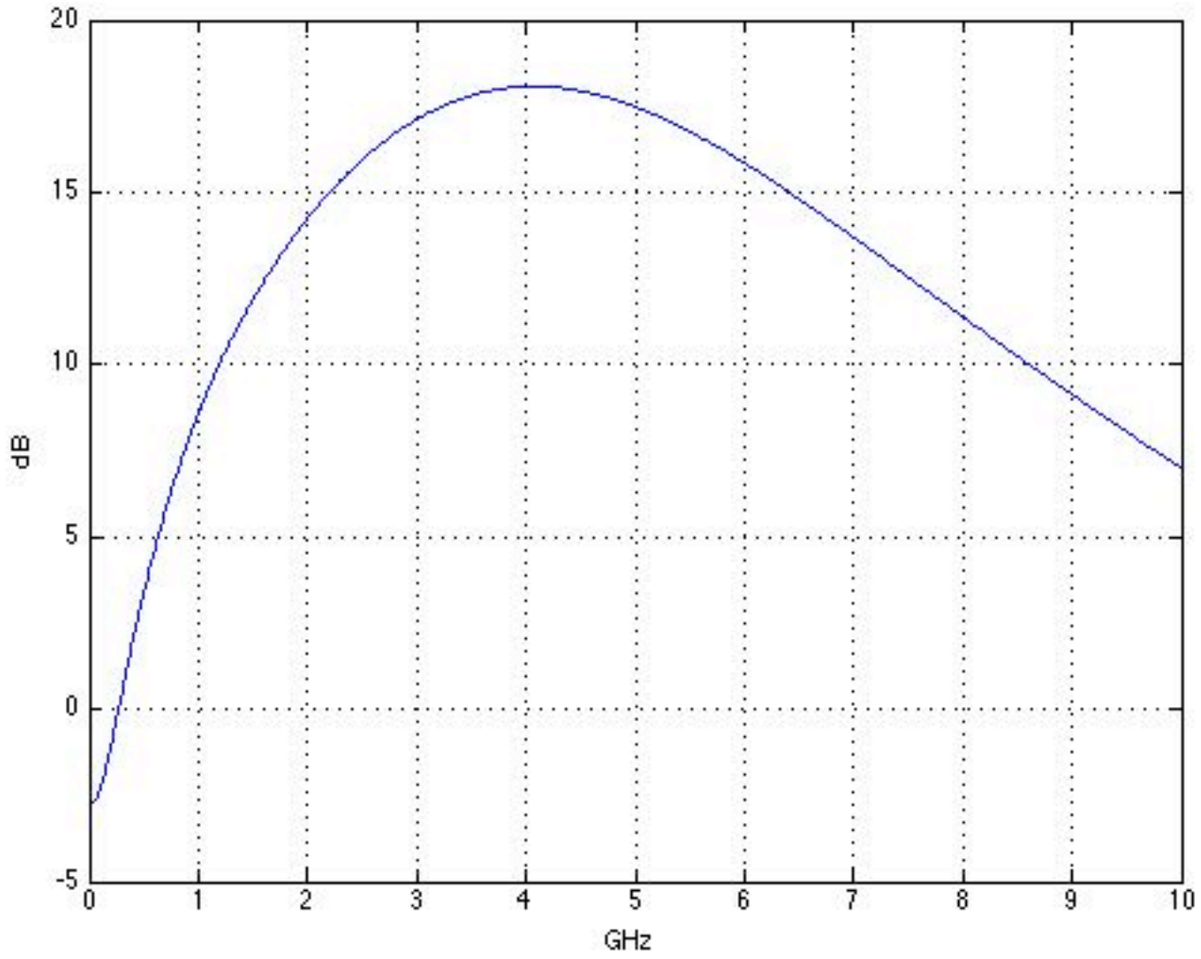
Tyco Channel

- All sources of cross talk are assumed to be alien.
- Power sum of Cross Talk at the ADC input with respect to the transmit level:



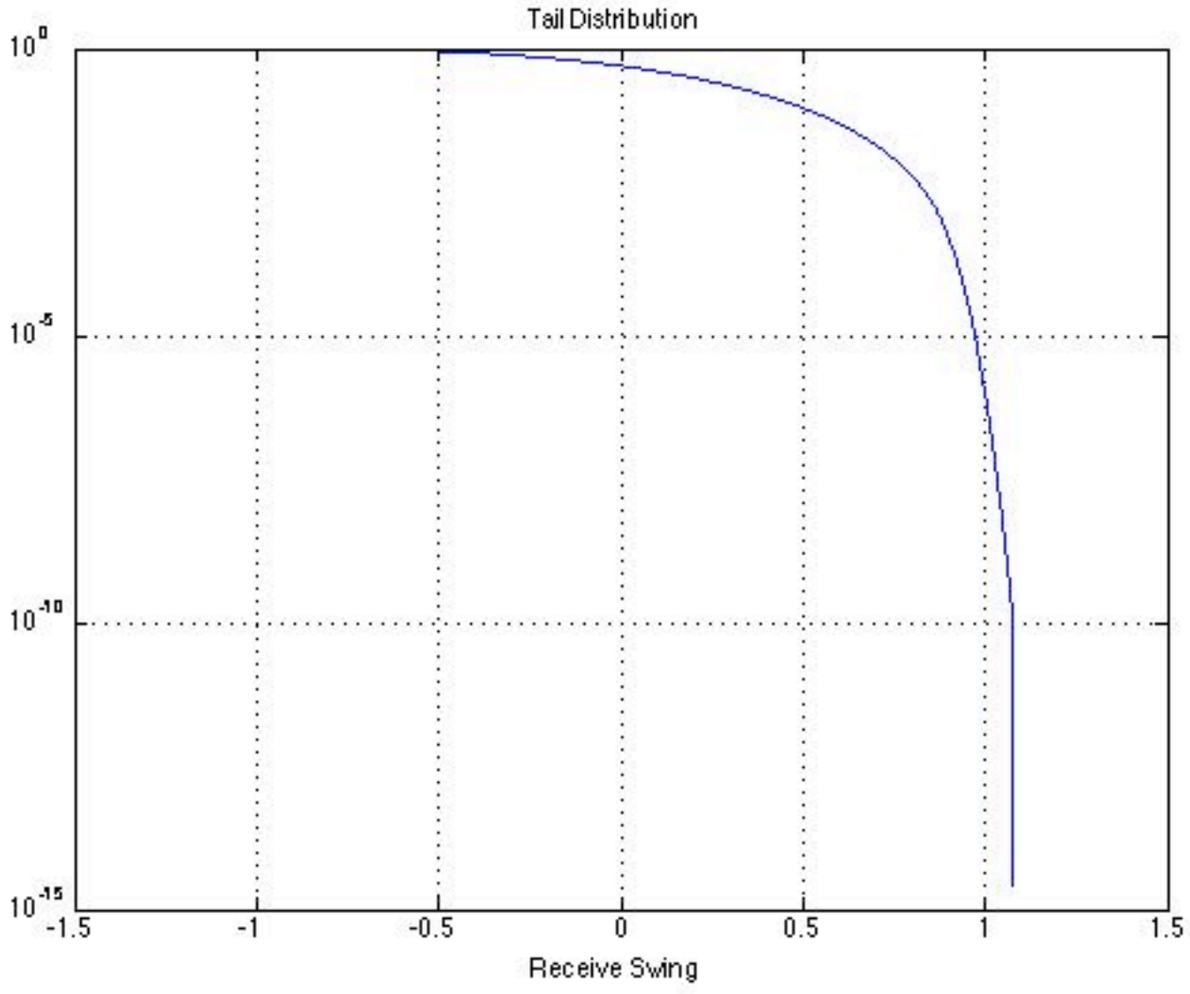
CTLE

- We use a second order band pass filter followed by a second order low pass to model the continuous time analog portion of the receiver:



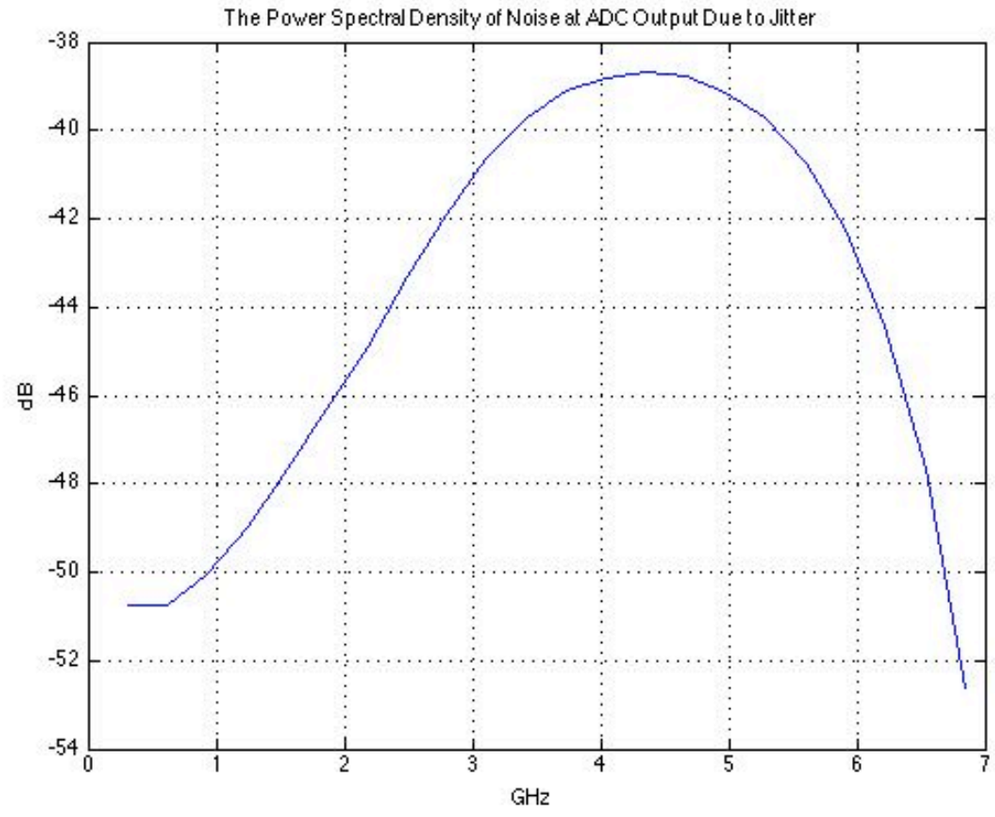
Receive Swing Analysis

- PGA gain is set such that clipping probability at the ADC is 1e-6:



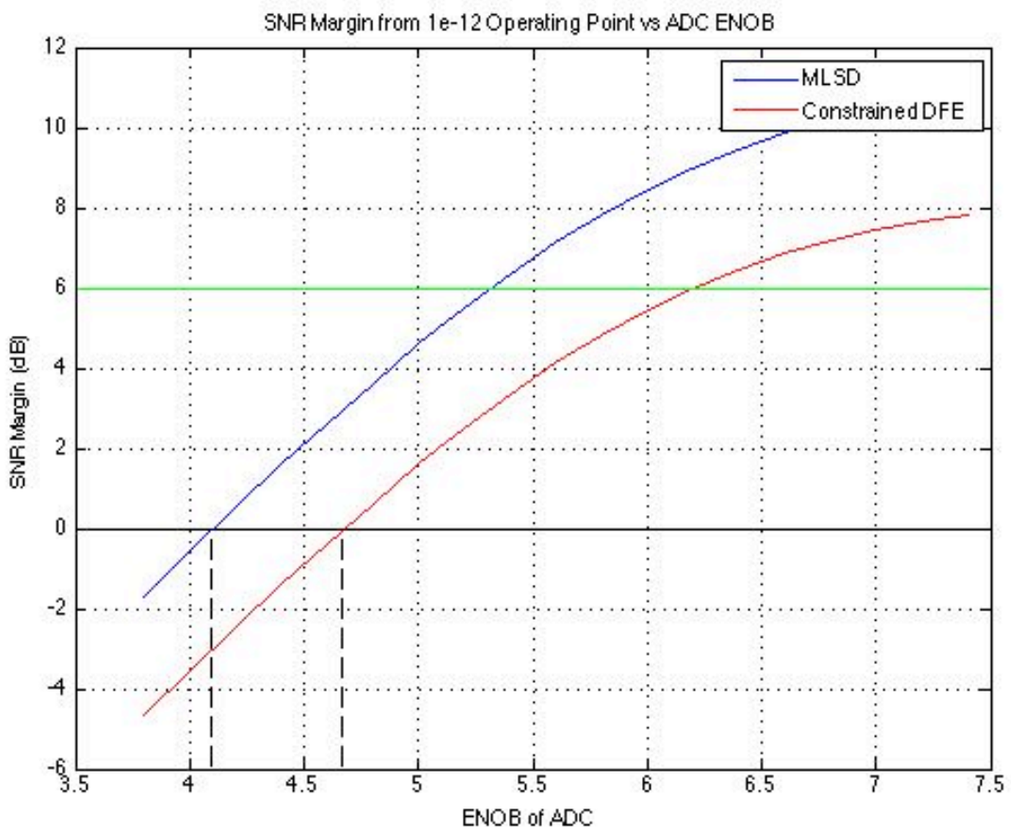
Jitter

- We assume 10mUI rms of wide-band jitter at transmitter and receiver (total 0.2 UI p-p at 1e-12)
- The two source of jitter are assume to be independent of each other.
- Jitter converted to noise by an 8x oversampled frequency domain analysis with folded spectrums.



Link Budget Analysis

- Constrained DFE
- We assume an MLSD receiver (3dB gain) and an RS code with 4.5 dB raw coding gain
  - http://www.ieee802.org/3/bj/public/sep11/dabiri_01_0911.pdf
  - http://www.ieee802.org/3/bj/public/sep11/parthasarathy_01_0911.pdf
- Target SNR of 24dB SNR for BER ~1e-12.

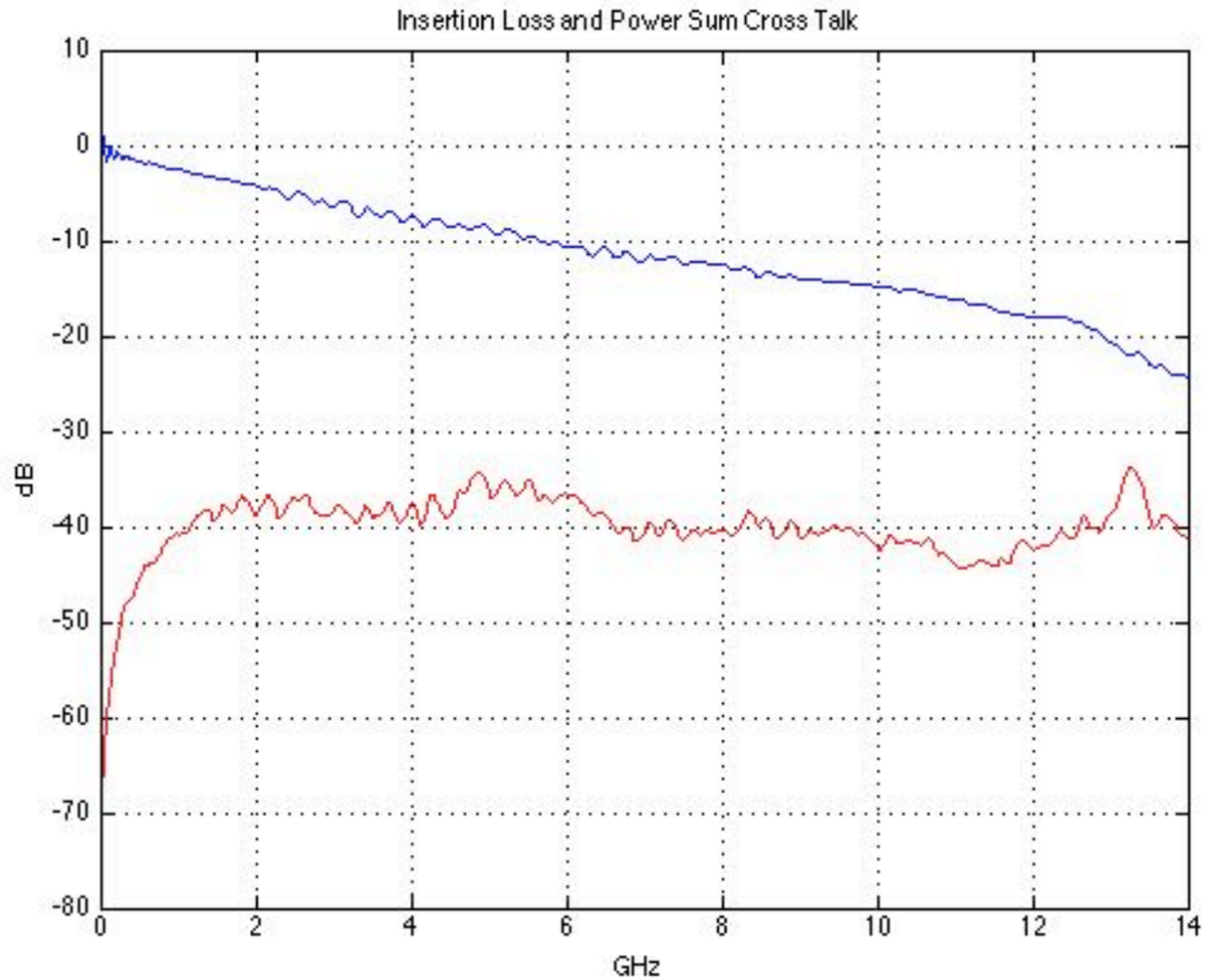


Emerson

Long Link

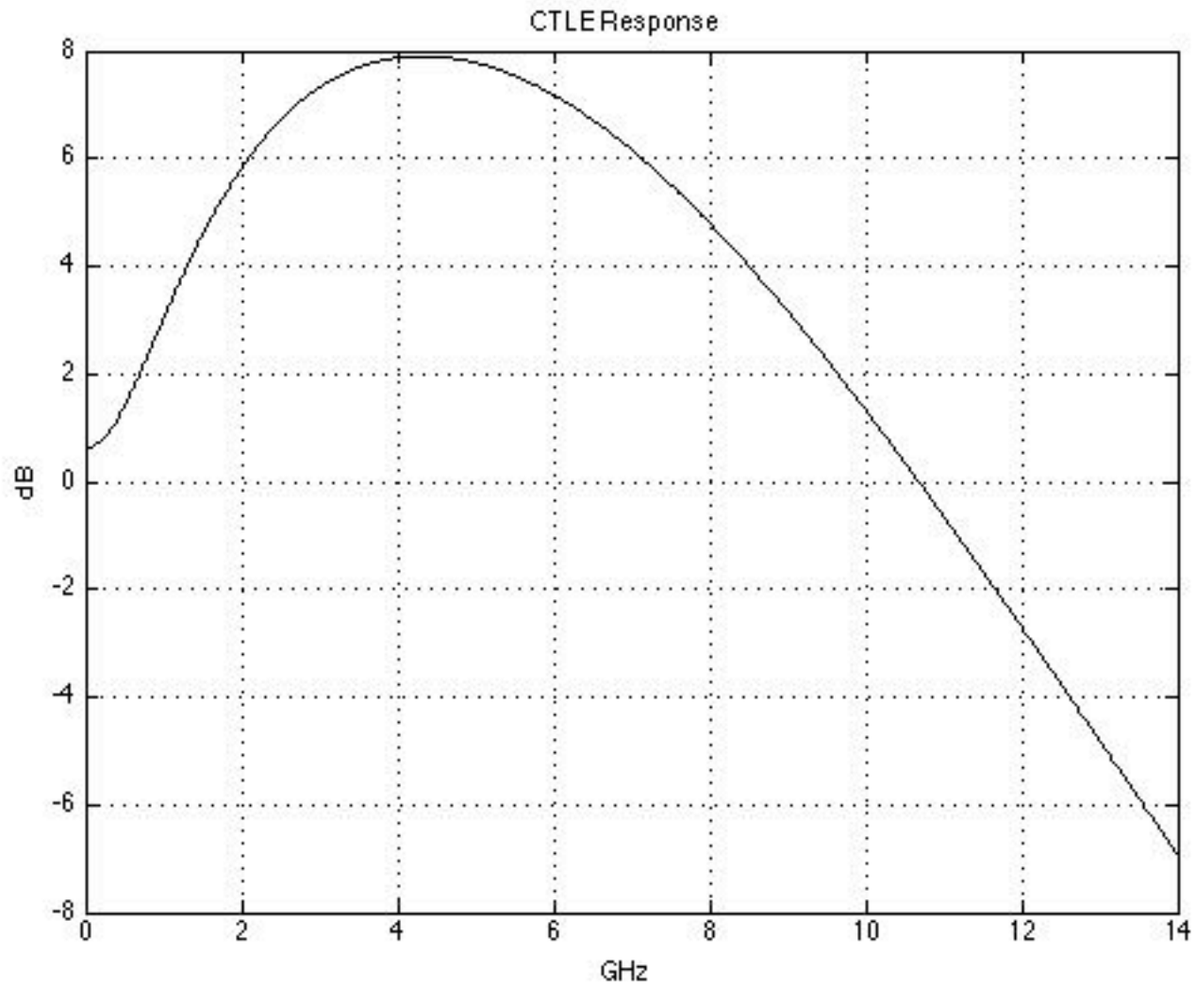
Emerson Channel

- Has significantly higher ILD.
- Has significantly higher xTalk.



CTLE

- Requires significantly less boosting:



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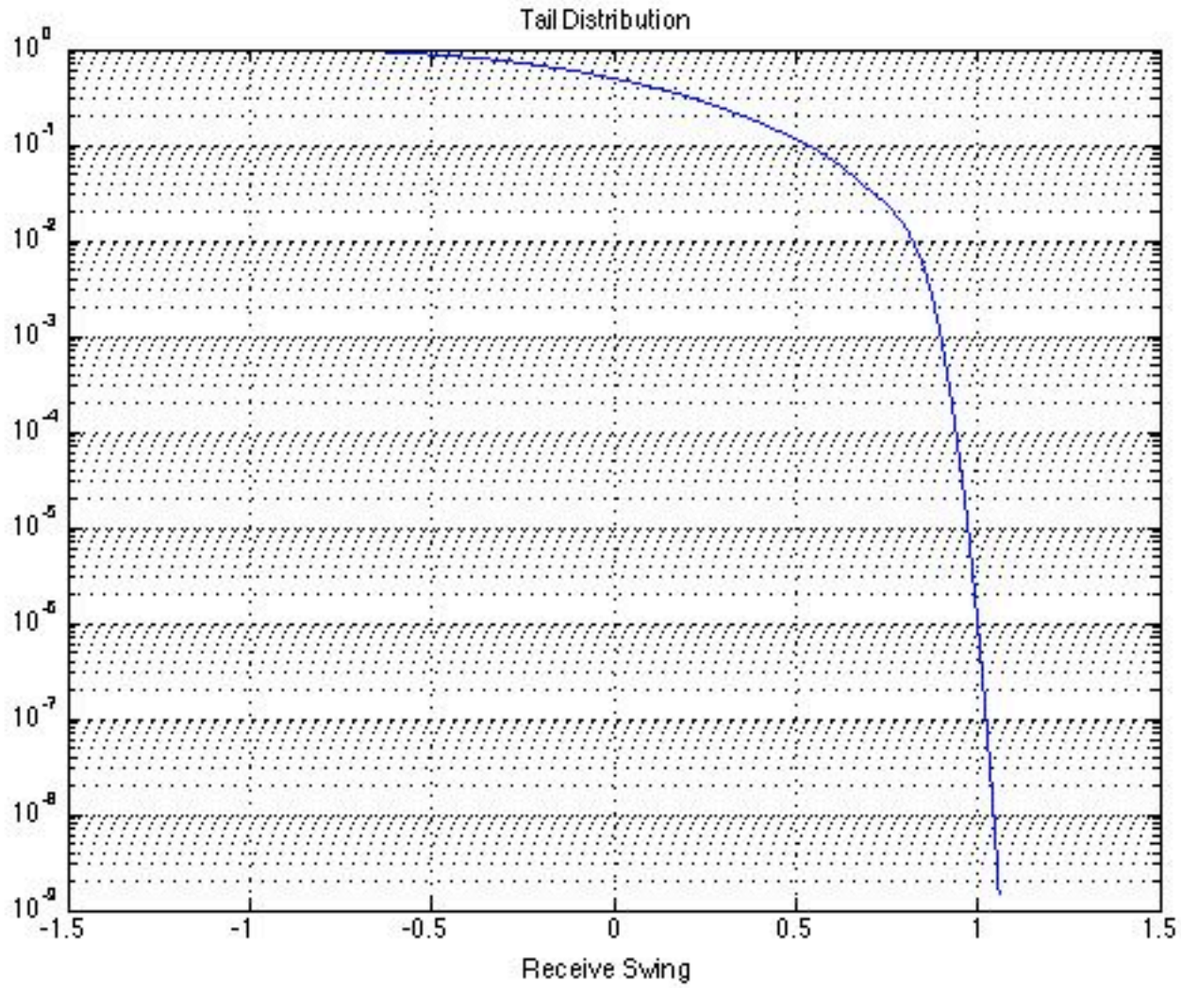
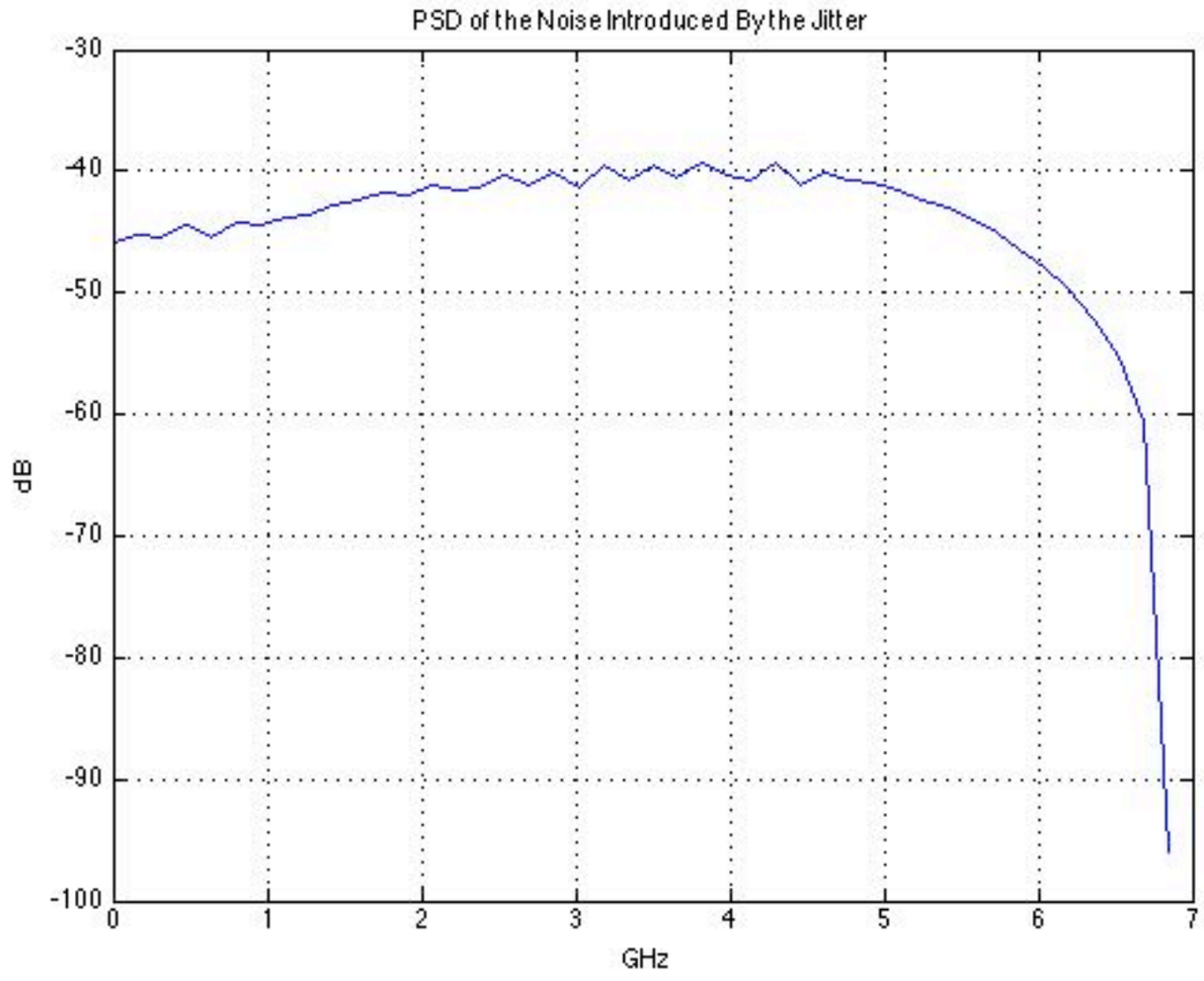


Jitter Analysis

- Assuming 10mUI (0.2 UI p-p) wide-band jitter:



Link Budget Analysis

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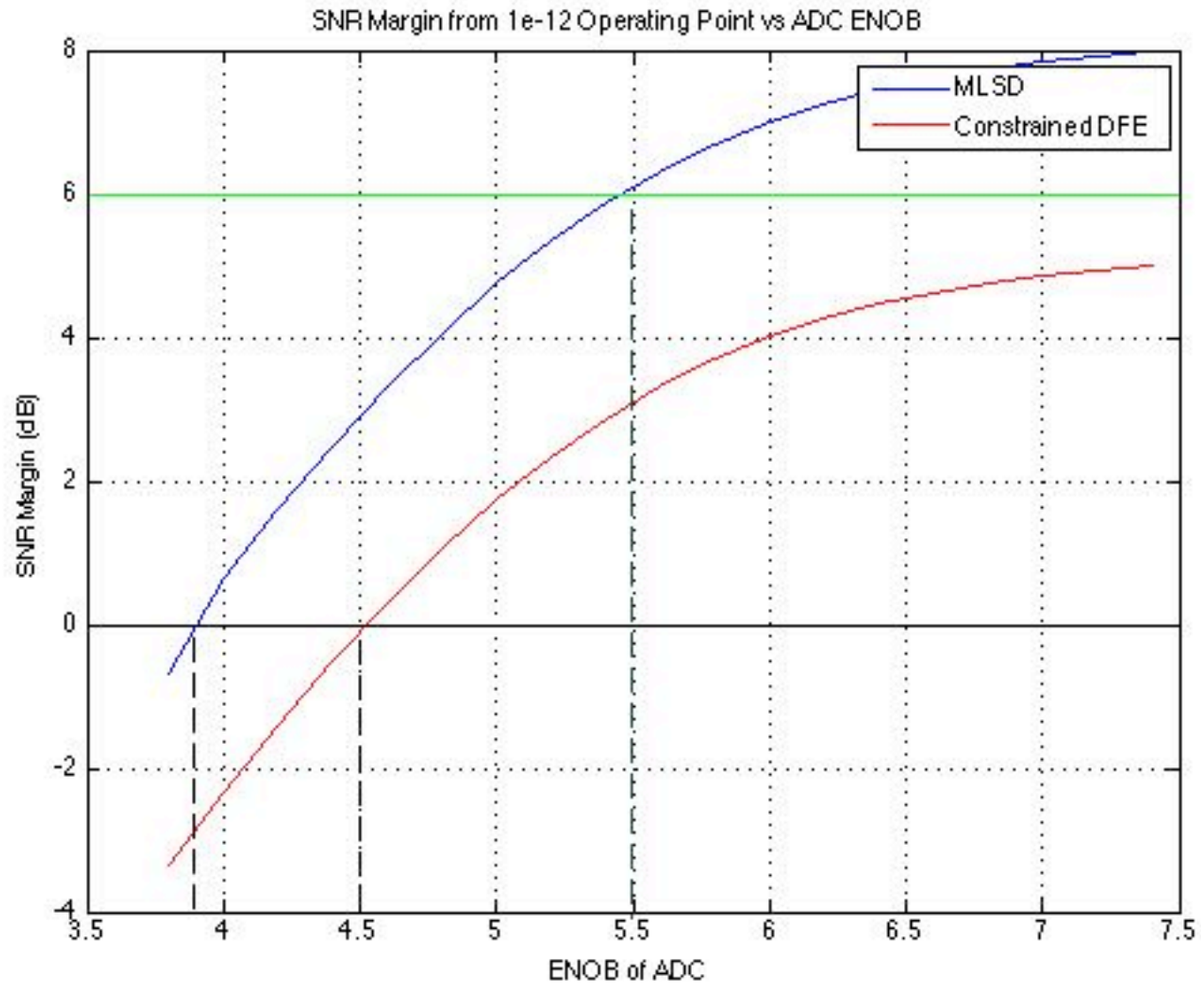

Discussions

- Using MLSD, it is possible to achieve 6 dB total SNR margin with ENOB = 5.5:
  - This means that one can simultaneously quadruple all noise sources (including xTalk) and still meet the target.
- If the design target is to work with 6 dB extra noise than the ADC noise floor:
  - MLSD requires ENOB = 5.2
  - DFE requires ENOB = 5.7
- On Tyco channel both MLSD and DFE can operate with 6 dB total SNR margin:
  - MLSD requires ENOB = 5.5
  - DFE requires ENOB = 6.5
- Different CTLE design targets could change the results.

Conclusion

- The ENOB of 5.5b provides enough margin for robust signaling over long and difficult legacy backplane channels.
- Feasibility of designing low complexity receivers is demonstrated with PAM4 signaling over legacy backplane with MLSD and DFE.