25Gb/s Signaling for 100G Backplanes: Channel Loss vs. Equalization

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Introduction

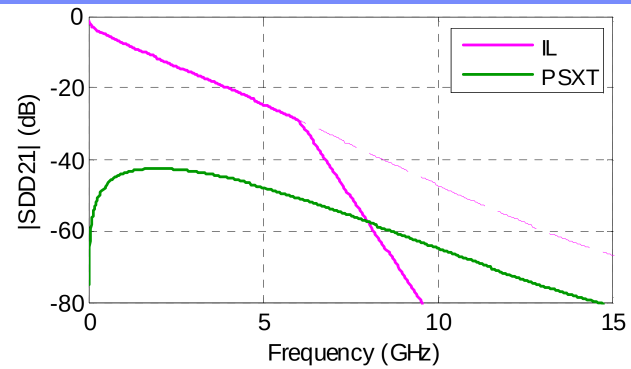
- **Backplane reach objective influenced by technical and economic feasibility**

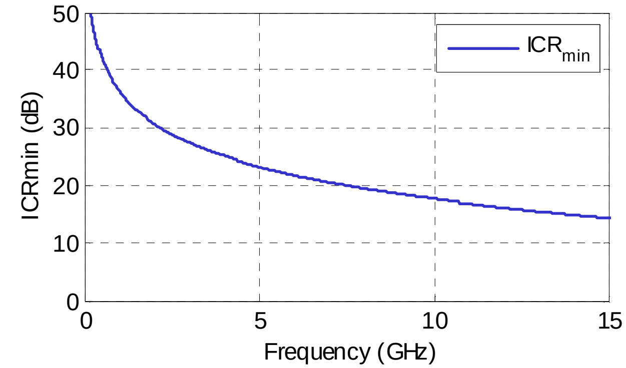
- **MMSE-DFE SNR analysis**
  - Slightly more complex than Salz SNR
  - Still highly ideal analysis

- **Compare SNR across different types of hypothetical channels**
  - 10GBASE-KR
  - CEI 25G-LR

25Gb/s on "KR-like" Channels

- **Use Annex 69B recommendations**
  - Extrapolate ICRmin without change
  - Extrapolate PSXT assuming no breakpoint in insertion loss curve
- **SNR calculations**
  - Salz SNR with crosstalk only
  - Salz SNR with additional white noise
    - Assume –147 dBm/Hz AWGN (10 nV/√Hz)
  - SNR of ideal, finite-complexity, MMSE-DFE
    - 3 T-spaced forward taps + 20 feedback taps (3T1-20)
    - 5 T-spaced forward taps + 10 feedback taps (5T1-10)
  - No FEC coding gain included in margin calculations





Channel Loss (dB)	6.45 GHz	12.9 GHz
KR Channel (solid)	35.3	127
Extrapolated KR (dashed)	31.0	59.3

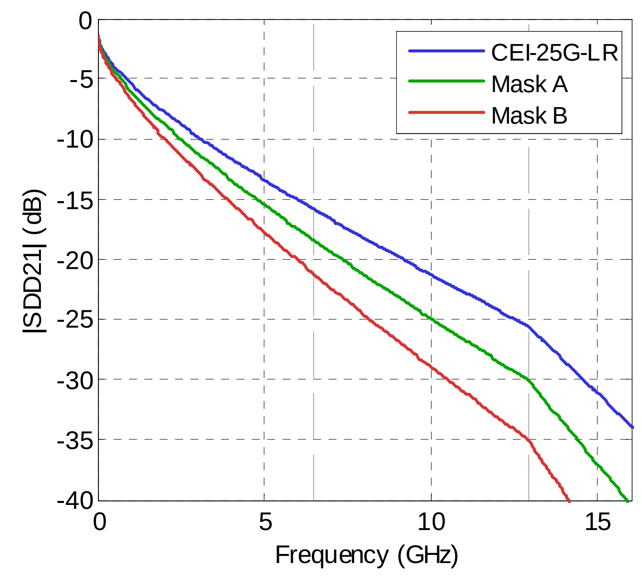
- **25Gb/s transmission on KR channels does not seem technically feasible for either 2 or 4 level PAM encoding.**

Margin @ 10^{-12}	SNR		SNR Margin		SNR Margin	
	KR Channel		KR Channel		Extrapolated KR	
SNR margin	2-PAM	4-PAM	2-PAM	4-PAM	2-PAM	4-PAM
Salz SNR with xtalk only	15.8	29.2	–1.1	5.3	7.2	5.6
Salz SNR (xtalk + AWGN)	14.2	26.8	–2.7	2.8	-0.6	2.5
5T1-10 SNR (xtalk + AWGN)	10.3	22.6	-6.6	-1.4	-3.9	-0.1
3T1-20 SNR (xtalk + AWGN)	7.6	20.1	–9.3	–3.9	-6.6	-3.3

- Data rate: 25.781 Gb/s
- TX risetime: 0.25 UI 20% – 80% 2nd-order Butterworth filter
- RX filter: 4th-order Butterworth at 0.75x symbol rate
- Av = 1Vppd, Aa = 1Vppd
- No CTLE
- No package
- No reflections

25Gb/s on “CEI LR-like” Channels

- **Use Annex 69B ICRmin recommendation**
  - Same ICR used for all masks
- **IL Masks**
  - CEI-25G-LR from oif2008.161.11
  - Mask A & Mask B simple extrapolations based on loss at 12.9 GHz
- **Observations**
  - Appears to be a breakpoint above ~30dB – independent of signaling
  - To achieve equivalent margin to 10GBASE-KR,
    25Gb/s will require some trade-off between
    - Lower loss
    - Lower crosstalk
    - FEC
    - EQ complexity



Channel Loss (dB)	6.45 GHz	12.9 GHz
CEI-25G-LR	15.8	25.5
Mask A	18.3	30.0
Mask B	21.1	35.0

SNR Margin @ 10^{-12} (dB)	CEI 25G-LR		Mask A		Mask B		10Gb/s KR
	2-PAM	4-PAM	2-PAM	4-PAM	2-PAM	4-PAM	NRZ
Salz SNR crosstalk only	7.8	6.4	7.8	6.4	7.8	6.4	15.3
Salz SNR with -147dBm/Hz white noise	6.6	5.4	6.1	5.3	5.3	5.0	13.5
5T1-10 DFE SNR with white noise	4.1	3.0	3.5	2.8	2.6	2.5	7.0 *
3T1-20 DFE SNR with white noise	4.6	4.4	3.0	4.4	1.3	3.2	

** 3-tap FFE + 5-tap DFE*

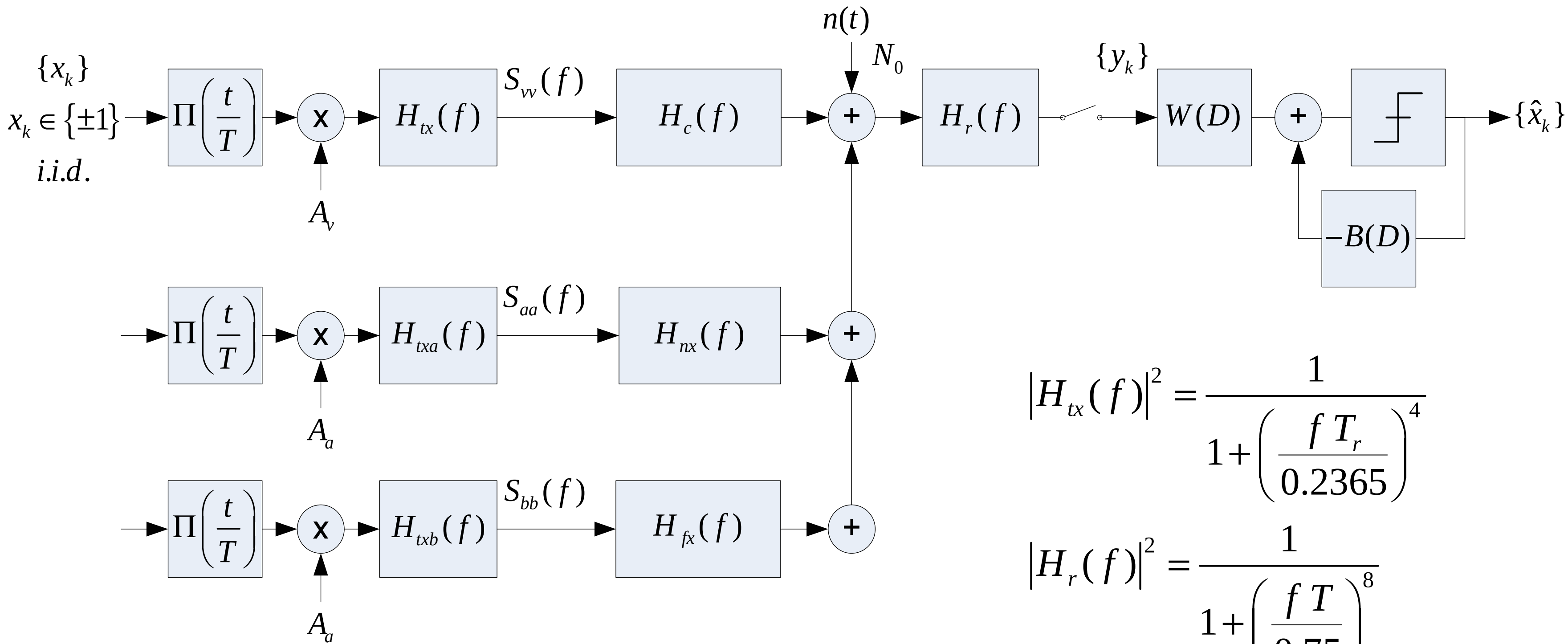
Summary

- **Backplane reach objective requires consideration of:**
  - Improved FR-4 (loss, crosstalk, reflections, …)
  - Equalization complexity (area, power, …)
  - FEC (block, trellis, …)
  - Other?

- **Propose 25dB – 30dB loss @ 12.9GHz as starting point:**
  - Crosstalk similar or better than 10GBASE-KR
  - Launch amplitudes ~ 1Vppd
  - MMSE-DFE
  - Some form of FEC for additional margin

Backup

Simulation Model



$$\left|H_{tx}(f)\right|^2 = \frac{1}{1+\left(\frac{f\,T_r}{0.2365}\right)^4}$$

$$\left|H_r(f)\right|^2 = \frac{1}{1+\left(\frac{f\,T}{0.75}\right)^8}$$

$$\left|H_{nx}(f)\right|^2 = 10^{-MDNEXT(f)/10}$$

$$\left|H_{fx}(f)\right|^2 = 10^{-MDFEXT(f)/10}$$

$$MDNEXT(f) = -10\log_{10}\left(\sum_k 10^{-NEXT_k(f)/10}\right)$$

$$MDFEXT(f) = -10\log_{10}\left(\sum_k 10^{-FEXT_k(f)/10}\right)$$

- *Notes:*
  - *Salz SNR computed using 2-folds*
- *References*

  - *[1] J. Salz, "Optimum mean-square decision feedback equalization," Bell Syst. Tech. J., vol. 52, no. 8, p. 1342, Oct. 1973.*
  - *[2] J. M. Cioffi, G. P. Dudevoir, M. V. Eyuboglu, and G. D. Forney, Jr., "MMSE decision-feedback equalization and coding – Part 1: Equalization results," IEEE Trans. Commun., 1995.*
  - *[3] N. Al-Dhahir and J.M. Cioffi, "MMSE Decision-Feedback Equalizers: Finite-Length Results," IEEE Trans. Information Theory, vol. 41, no. 4, 1995.*