IBM STG

SI Analysis of 25Gb/s Transmission over Backplane and Copper Cables Links

IEEE 802.3 100 Gb/s Backplane and Cable Task Force
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Introduction

- Proposals for transmission signaling and maximum link loss consistent with the task force objectives:
  - *"Define a 4-lane 100 Gb/s backplane PHY for operation over links consistent with copper traces on "improved FR-4" (as defined by IEEE P802.3ap or better materials to be defined by the Task Force) with lengths up to at least 1m."*
  - *"Define a 4-lane 100 Gb/s PHY for operation over links consistent with copper twin-axial cables with lengths up to at least 5m."*

Scope of the Analysis

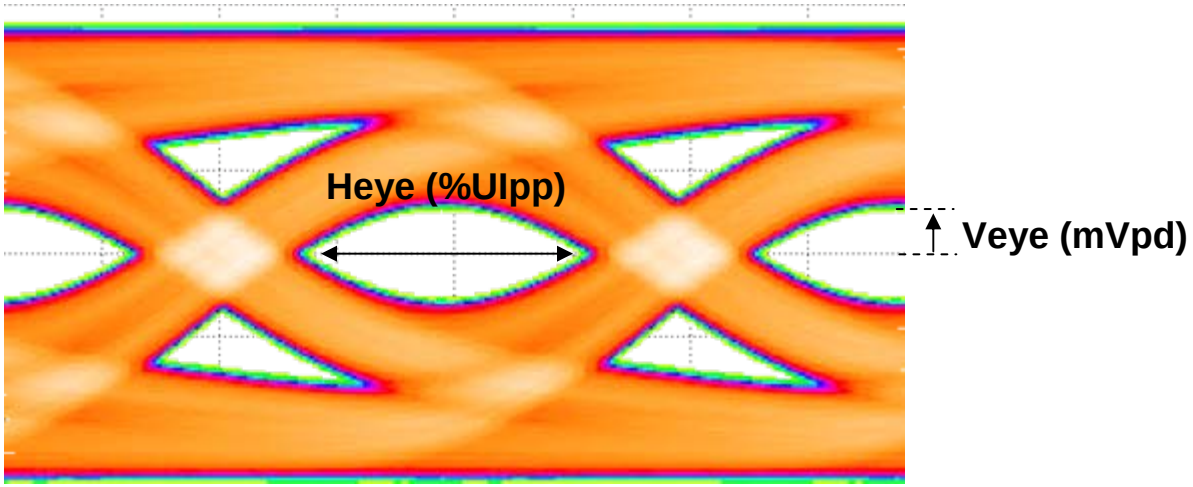
- Time domain based signal integrity simulations performed on backplane links and copper cable links
  - Simulated Backplane links*:
    - ✓ IBM measured 1m channel, Megtron6 material (patel_02_0911.pdf)
    - ✓ Qlogic simulated 1m channel, Megtron6 material (dudek_01_0911.pdf)
    - ✓ TE Connectivity simulated 1.09m channel, Megtron6 material (shanbhag_03_0411.pdf)
  - Simulated 3m and 5m Copper Cable links*:
    - ✓ Measured next generation cable assemblies (bugg_01_0111.pdf, bugg_02_0511.zip)
  - Reference model I/O core parameters are described in details in the back-up slides

*http://grouper.ieee.org/groups/802/3/100GCU/public/ChannelData

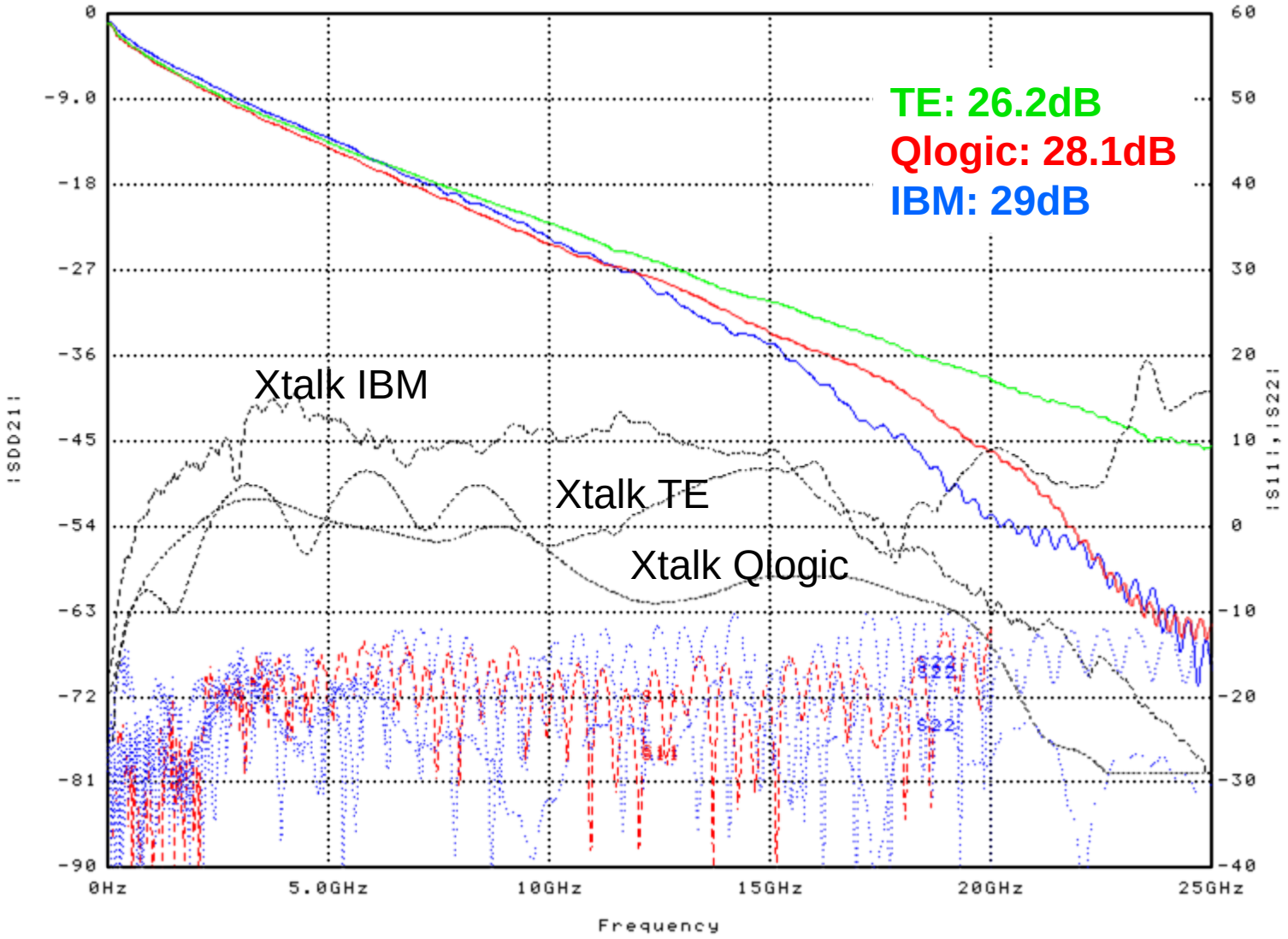
Reported Simulation Results

- NRZ signaling simulation results reported at the Rx slicer input
  - Net vertical eye opening (Veye) at 1e-15 BER
  - Net horizontal eye opening (Heye) at 1e-15 BER
  - BER floor (minimum BER)
  - SNR and SNR margin at the minimum BER (assuming Gaussian noise at low BER)
  - 10M bits simulated, randomly generated,
  - Default data rate 25.78125Gb/s (no FEC)

Equalized differential eye as seen at the Rx slicer



Simulated 1m Backplane Links: Insertion Loss



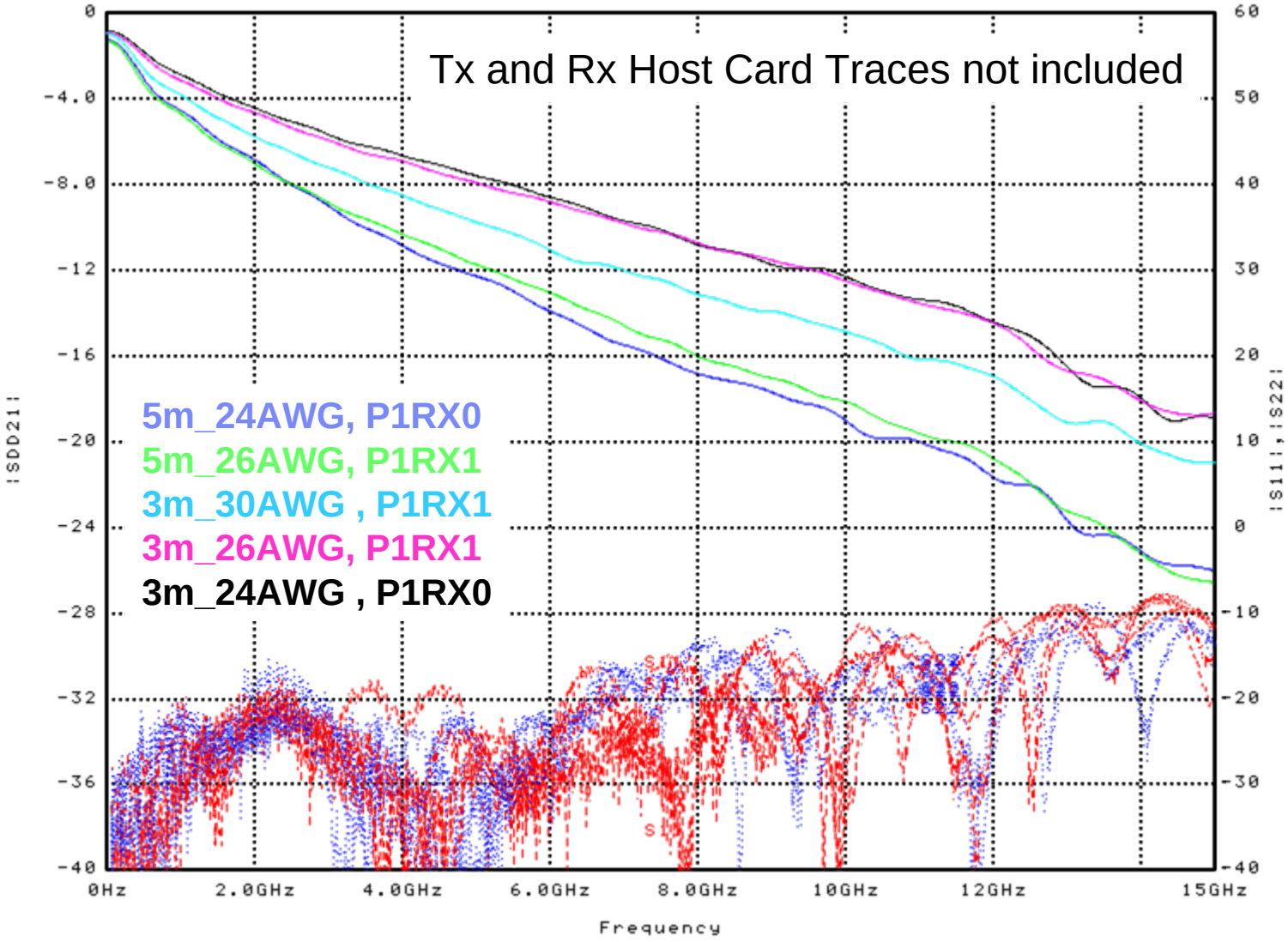
1m Backplane Channels: Simulation Results

Channel	Loss at baud/2 (dB)	Vert. Eye Margin (mVpd)	Horz. Eye Margin (%UIpp)	BER Floor	SNR (dB)	SNR Margin* (dB)
IBM, Meg6, 8 FEXT (patel_01_0911)	30.2	34	26	2e-46	23.4	5.4
Qlogic, Meg6, 8 FEXT (dudek_01_0911.pdf)	28.8	37	23	3e-46	23	5
TE 46" STRADA Whisper, Meg6, 8 NEXT (shanbhag_02_0411)	26.9	36	22	5e-44	22.8	4.8

- 25Gb/s NRZ signaling across 1m backplane with low loss material (i.e. Megtron6) allow for sufficient transmission margins at 1e-15 BER (no FEC applied)
  - >20% horizontal and >30mVpd vertical eye opening margins
  - ~5dB SNR margin
- These margins will allow for more channel impairments
  - higher insertion loss and/or insertion loss deviation and/or cross-talk

* At 1e-15 BER

Simulated Cable Assembly: Measured Insertion Loss (xtalk not shown – see bugg_01_0111.pdf)

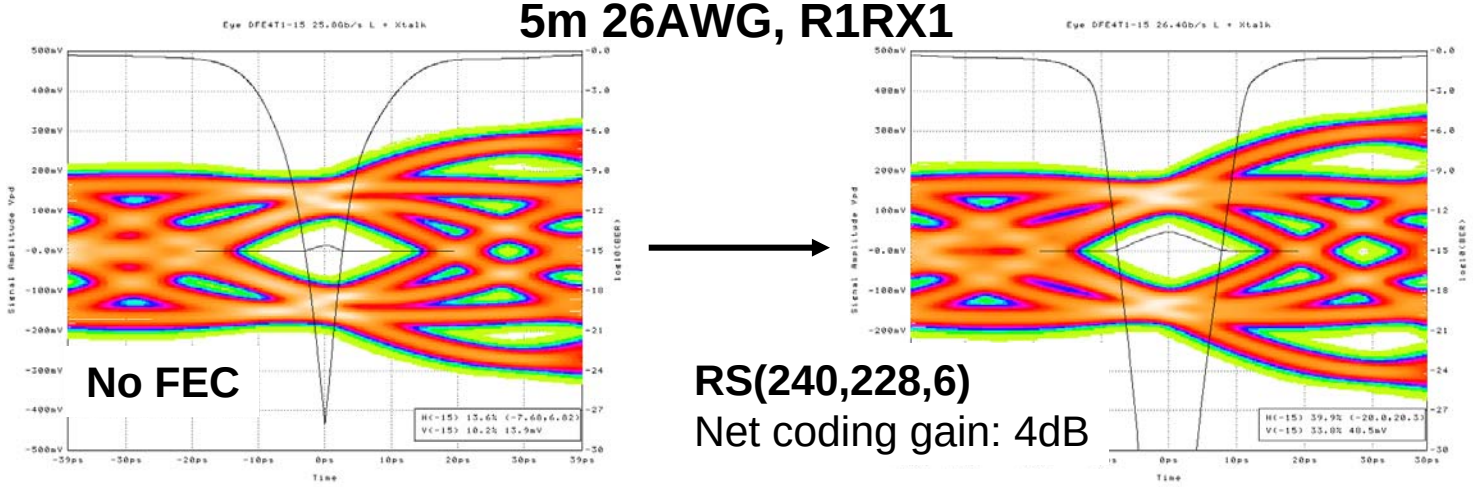


3m and 5m Copper Cable Links – NRZ Simulation Results

Cable Assembly	Cable Assembly Loss (dB)	Total Loss[1] baud/2 (dB)	FEC	Vert. Eye Margin (mVpd)	Horz. Eye Margin (%UIpp)	BER Floor	SNR / SNR margin* (dB)
3m 24AWG, P1RX0	16	26.5	No	33	26	3e-48	23.3/5.3
3m 26AWG, P1RX1	16.2	26.8	No	35	25	6e-51	23.5/5.5
3m 30AWG, P1RX1	18.6	29.2	No	32	25	2e-45	23/5
5m 24AWG, P1RX0	23.1	35.1	No	24	19	3e-35	21.8/3.8
5m 26AWG, P1RX1	22.7	34.5	No	14	14	1e-28	20.9/2.9
5m 26AWG, P1RX1	23.3	35.3	RS(240,228,6)[2]	48	40	6e-69	24.9/6.9

(1) Includes ~5dB loss per Tx / Rx PCB trace
(2) cideciyan_01_0911.pdf. Line rate is 26.37Gb/s

5m 26AWG, R1RX1

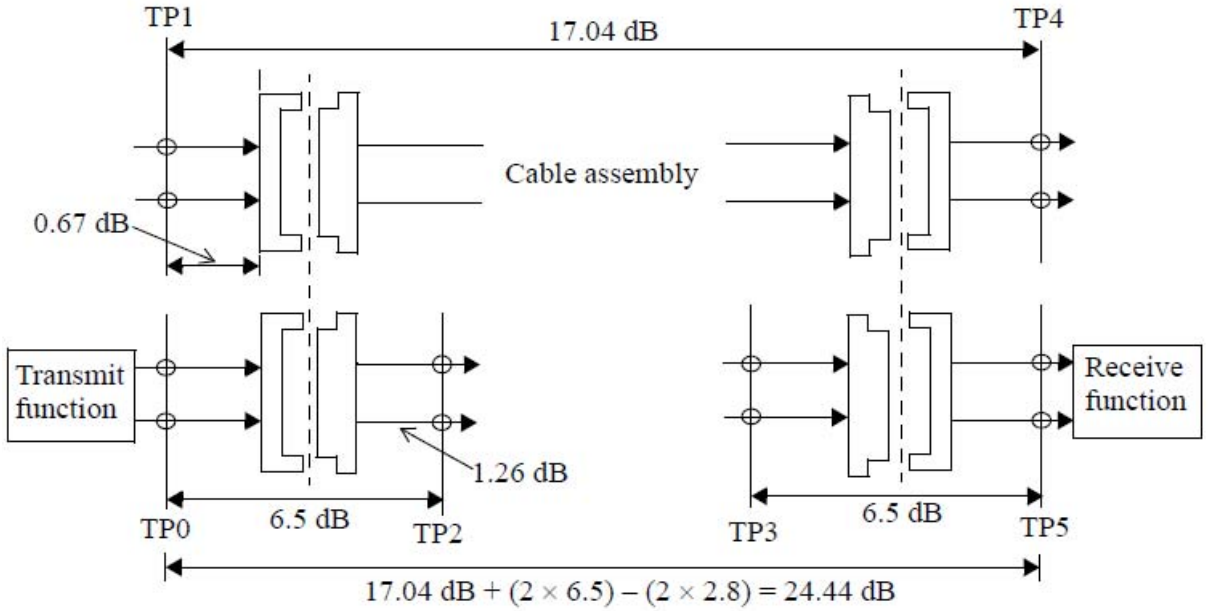


No FEC

RS(240,228,6)
Net coding gain: 4dB

* At 1e-15 BER

Copper Cable Link: Loss Budget Examples



Next generation cable assemblies loss (bugg_01_0111.pdf)

Loss at 12.9GHz	Loss (dB)
3m 24AWG cable	10.82
5m 24AWG cable	18
Connector	2

Link Component	802.3ba Annex 85-A (5.15625GHz)	802.3bj Loss Budget Example (12.9GHz) w.o. FEC	802.3bj Loss Budget Example (12.9GHz) FEC (e.g. RS(248, 224,6))
Tx_PCB + Connector (TP0 – TP2)	6.5dB	9.5dB	8.5dB
Bulk Cable (TP2 – TP3)	11.44dB	11dB (i.e. 3m 24AWG)	18dB (i.e. 5m 24AWG)
Rx_PCB + Connector (TP3 – TP5)	6.5dB	9.5dB	8.5dB
Total Loss (TP0 – TP5)	24.44dB	30dB	35dB

Final loss budget will depend on actual system implementation needs

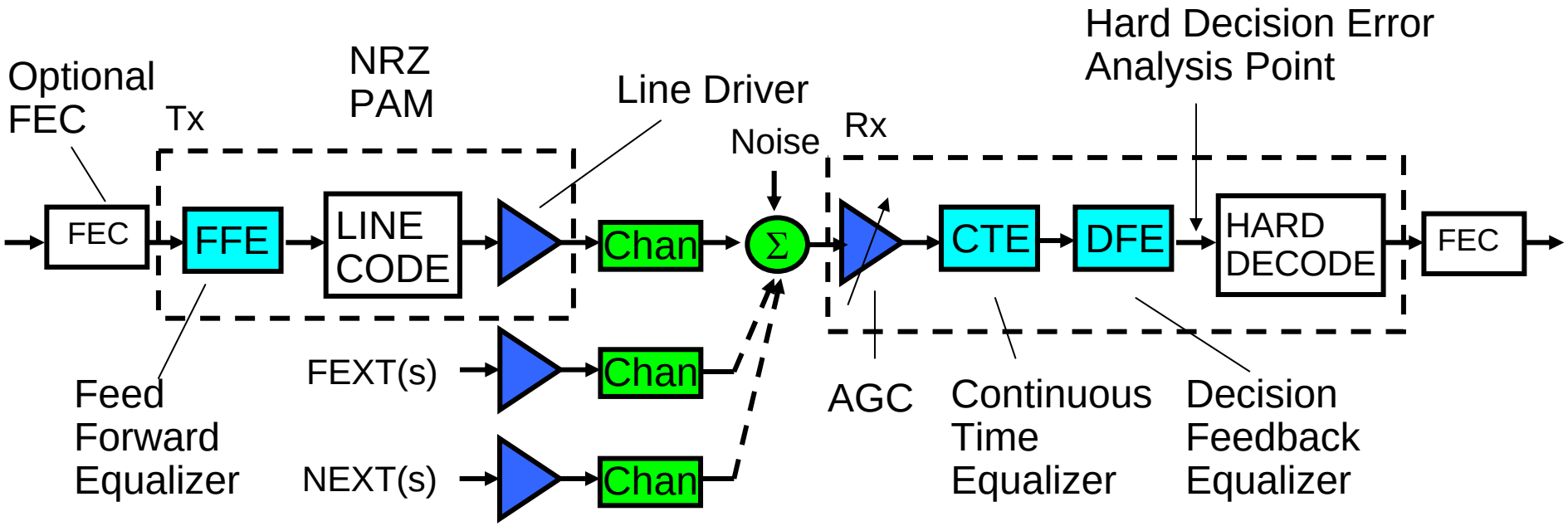
Summary of Proposals

NRZ signaling supports a total loss of 35dB at 12.89GHz over backplane and copper cable links

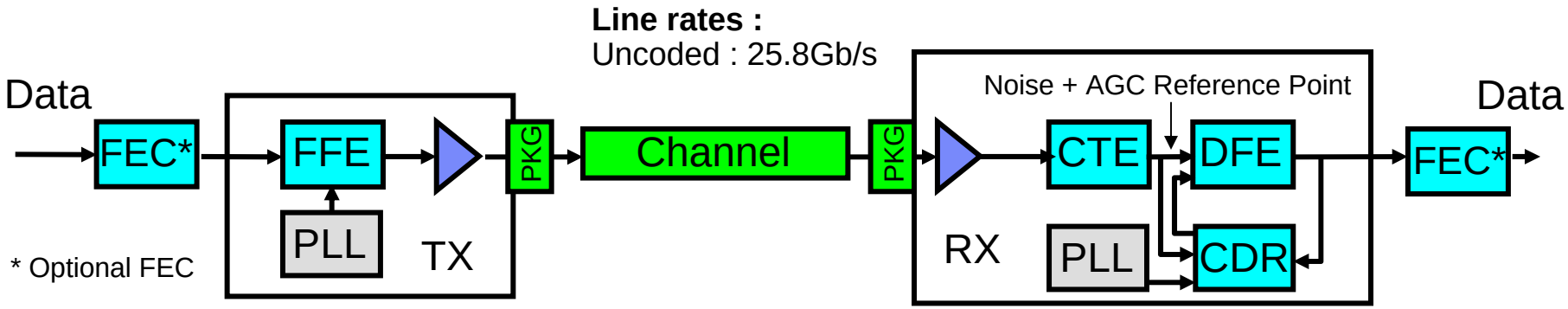
- **A total loss of ~30dB is achievable without the use of FEC**
  - ✓ Supports a reach of at least 1m on backplane links using low loss materials (Tier3 materials, goergen_02b_0311.pdf)
  - ✓ Supports a reach of at least 3m on 30AWG copper cable links
  - ✓ Possibly supports a reach of at least 5m on 24AWG copper cable links
  - ✓ FEC should be considered to increase link operating margins
- **A FEC option (e.g. RS(248,224,6)) extends the total link loss to ~35dB**
  - ✓ Supports a reach of at least 1m on backplane links using a mix of low and medium loss materials (Tier 2 and Tier3 materials, goergen_02b_0311.pdf)
  - ✓ Supports a reach of at least 5m on 26AWG copper cable links
- **NRZ signaling allows backward compatibility and is consistent with other 25Gb/s emerging standards**

Backup

I/O System Model



Reference Model I/O Core Parameters

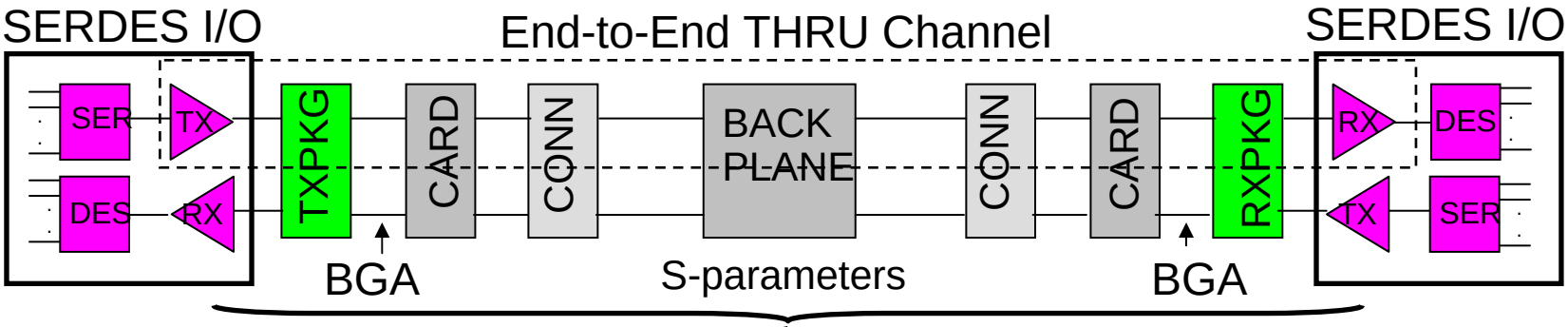


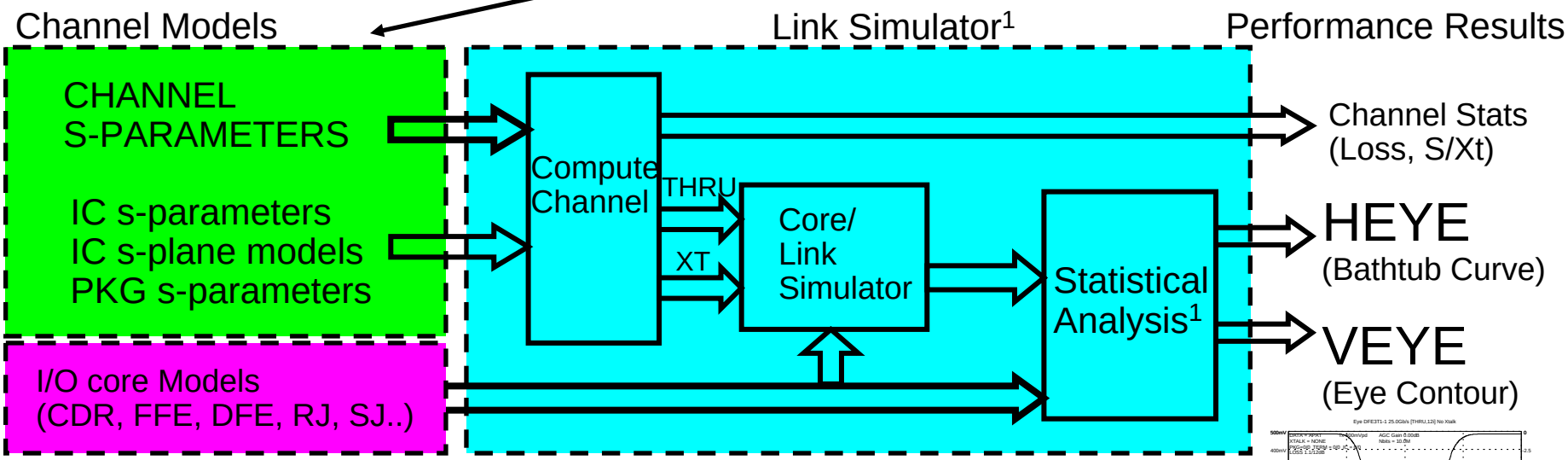
PARAMETER	VALUE NRZ	VALUE PAM4
PEAK SWING	1000mVppd	1000mVppd
RJ	350fs RMS	350fs RMS
DCD	1.6% (49.2:50.8)	0
SJ	5% UI	5%
BW	-1.5dB@13GHz 2 pole Bessel	-1.5dB @13GHz 2 pole Bessel
PKG	-2.6dB@13GHz	-2.6dB @13GHz
FFE	4 tap 2 precursor	4 tap 2 precursor

- Simplified T & R model
- Parameters selected to approximate "real" hardware realization performance
- Set up to "favor" PAM4 : 2x complex DFE
- Target BER = 1E-15
- E/L CDR active for NRZ & PAM4

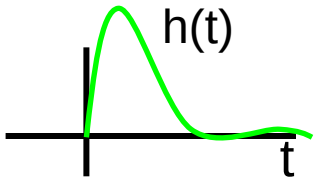
PARAMETER	VALUE NRZ	VALUE PAM4
NOISE@ SLICER	2.75mV RMS	2mV RMS
Sensitivity@ SLICER	20mVpd	20mVpd
AGC LEVEL	280mVpd	280mVpd
AGC GAIN MAX	3	3
RJ	350fs RMS	350fs RMS
SJ	5% UI	0%
BW	-1.5dB @13GHz 4 pole Bessel	-1.5dB @13GHz 4 pole Bessel
PKG	-2.7dB @ 13GHz	-2.7dB @ 13GHz
CTE	12dB peak @ 13GHz 3 pole 2 zero	12dB peak @ 13GHz pole 2 zero
DFE	15 tap	15 tap (2X NRZ)

Link Performance Analysis

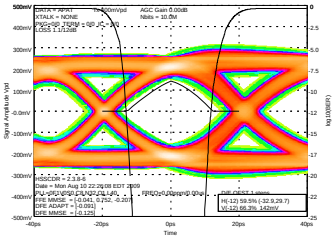




1) Compute Channel Impulse Response



2) Generate EYE



[1]see appendix for further detail