VITESSE

Lucent Technologies
Bell Labs Innovations

Simulation Results for 10 Gb/s Duobinary Signaling

Populating the Signaling Ad Hoc Spreadsheet

IEEE 802.3ap Task Force
Atlanta
March 15-17, 2005

Contributors

Vitesse

Majid Barazande-Pour

Badri Gomatam

Lucent

Jeffrey H. Sinsky

Supporters

- *Mary Mandich, Lucent*
- *Andrew Adamiecki, Lucent*
- *Marcus Duelk, Lucent*
- *Nitish Amin, Vitesse*

Talk Outline

- Overview
- Description of the Modeled Architecture
- Simulation Assumptions
- Simulation Results
- Conclusion

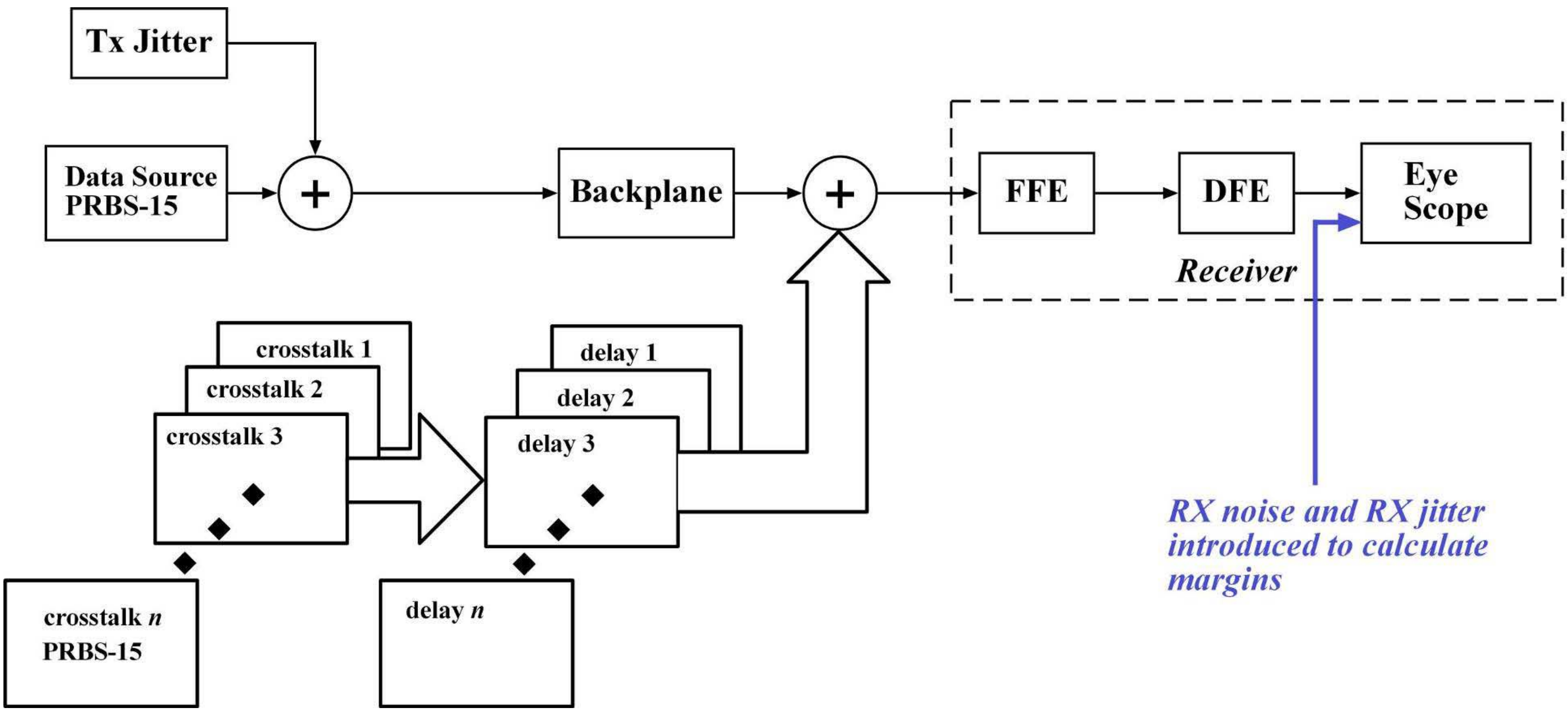
Overview

- Introduction
- Simulation model will be explained
  - Block Diagram
  - Parameters
  - Assumptions
- Simulation results for duobinary signaling will be presented for 16 channels
- Conclusion

Duobinary Signaling for 802.3ap

- Has been suggested as one of the possible formats for use in this standards body
- Contingent on the decision of the group…
  - Duobinary ***may*** be selected as a stand alone solution
  - Duobinary ***may*** be selected as part of the Unified Signaling Proposal for the 10G PHY
- *Either way, a complete understanding of the performance of duobinary signaling is necessary.*

System Topology used in Simulations



Simulation System Parameters

Basic Signaling Properties		
Parameter	Value	Units
Line code	Duobinary	
Bit Rate	10	Gb/s
Symbol Rate	10	Gb/s
Number of Levels	3	
Bits/symbol	1	

Source Data Parameters		
Parameter	Value	Units
Data Pattern	PRBS15	
Launch Amplitude	0.8	volts (p-p) diff.
TX jitter DJ (p-p)	10	Gb/s
Tx Jitter - DCD (p-p)	0.15	UI
Tx Jitter - Rj (rms)	0.0107	UI
AC/DC coupling	DC	

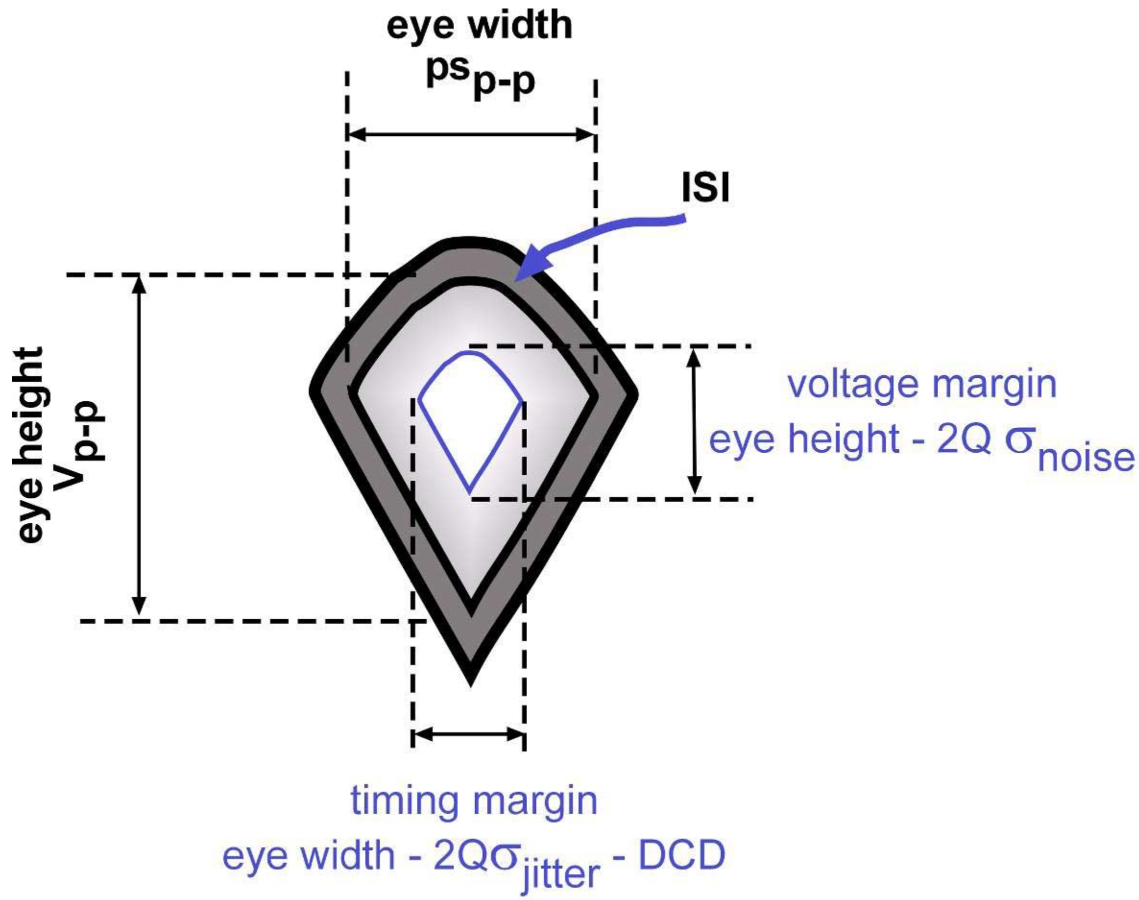
Receiver Parameters		
Parameter	Value	Units
Random noise	1.46	mv_{rms}
Cross-talk type	Random	Random/deterministic
Crosstalk scaling	No	NEXT Scaled to the mask? Yes or no
Rx input Dj	0.15	UI(p-p)
Rx input Rj	0.15	UI(p-p)

Simulation Parameters	
Parameter	Value
Number of bits simulated	15,000
Samples/symbol	120
Simulation tool	Matlab

Simulation Assumptions

- The number of crosstalk aggressors depends on available data from vendor
- Measured 4-port S-Parameters are used to represent transmission and cross-talk characteristics
- Crosstalk data streams are delayed in such a way as to provide a worst case scenario and are identical to the thru channel data stream
- The FFE gain is normalized so that it is PASSIVE
- The RX Noise and RX jitter are modeled by reducing the eye opening by the amount …
  - Vp-p – 2 Q σ_{noise}
  - ps(p-p) – 2 Q σ_{jitter} -DCD
  - where Q = 7.03, 7.94, and 8.75 for BERs of 10^{-12}, 10^{-15}, and 10^{-18} respectively

Explanation of Eye Margins



Q	BER
7.03	10^{-12}
7.94	10^{-15}
8.75	10^{-18}

Simulation Results

Tyco ATCA Backplanes

Channel ID	FFE Taps	DFE Taps	Simulated eye opening for data stream		Margin for BER=10^{-12}		Margin for BER=10^{-15}		Margin for BER=10^{-18}	
			Voltage mVp-p(diff.)	Timing ps(p-p)	Voltage mVp-p(diff.)	Timing ps(p-p)	Voltage mVp-p(diff.)	Timing ps(p-p)	Voltage mVp-p(diff.)	Timing ps(p-p)
Tyco Case1	*3*	*3*	50	37	31.68	6.80	29.02	4.86	26.64	3.12
Tyco Case2	*5*	*3*	76	37	77.36	7.3	74.7	5.36	32.34	3.62
Tyco case3	*5*	*3*	122	41	104.08	11.29	101.42	9.35	99.06	7.62
Tyco Case4	*3*	*5*	76	45	57.54	15.44	54.9	13.49	52.52	11.76
Tyco Case5	*3*	*5*	112	51	92.86	21.27	90.22	19.32	87.84	17.59
Tyco Case6	*5*	*3*	74	38	55.36	8.57	52.7	6.63	50.34	4.89
Tyco Case7	*3*	*3*	76	37	56.7	6.8	54.04	4.8	51.68	3.13

Note: 15,000 bits used to obtain these results

Simulation Results

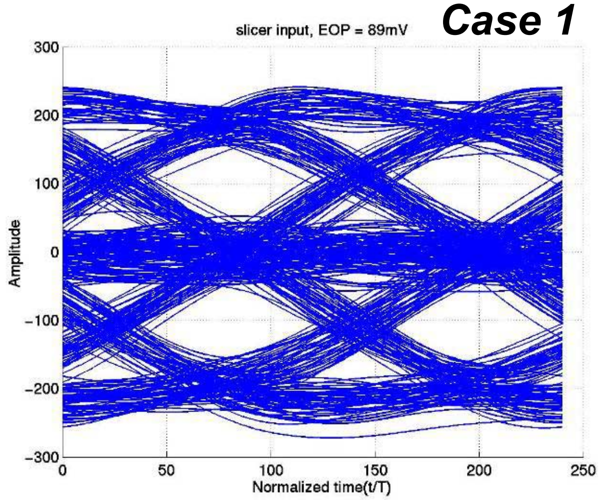
Intel ATCA Backplanes

Channel ID	FFE Taps	DFE Taps	Simulated eye opening for data stream		Margin for BER=10^{-12}		Margin for BER=10^{-15}		Margin for BER=10^{-18}	
			Voltage mVp-p(diff.)	Timing ps(p-p)	Voltage mVp-p(diff.)	Timing ps(p-p)	Voltage mVp-p(diff.)	Timing ps(p-p)	Voltage mVp-p(diff.)	Timing ps(p-p)
Intel B01	3	3	88	49	68.72	19.10	66.06	17.15	63.68	15.41
Intel B12	3	3	84	52	65.76	21.69	63.1	19.75	60.74	18.02
Intel B20	3	3	82	45	62	15.22	59.34	13.28	56.98	11.55
Intel M1	3	3	56	48	37.32	18.36	34.64	16.42	32.28	14.68
Intel M20	3	3	72	39	52.62	9.15	49.96	7.21	47.6	5.47
Intel T1	9	5	54	35	55.24	4.58	52.58	2.63	50.2	0.90
Intel T12	7	3	72	35	52.2	4.97	49.54	3.02	47.18	1.29
Intel T20	7	3	72	37	52.58	7.40	49.92	5.46	47.54	3.73
Intel T32	7	3	66	39	47.94	9.09	45.28	7.14	42.92	5.41

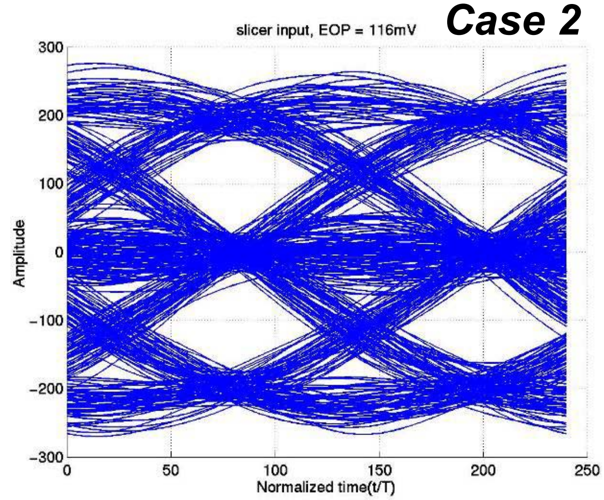
Note: 15,000 bits used to obtain these results

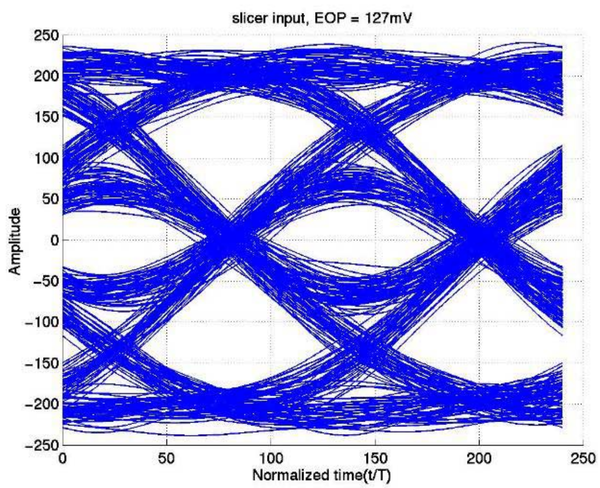
Tyco Cases 1-4

Case 1

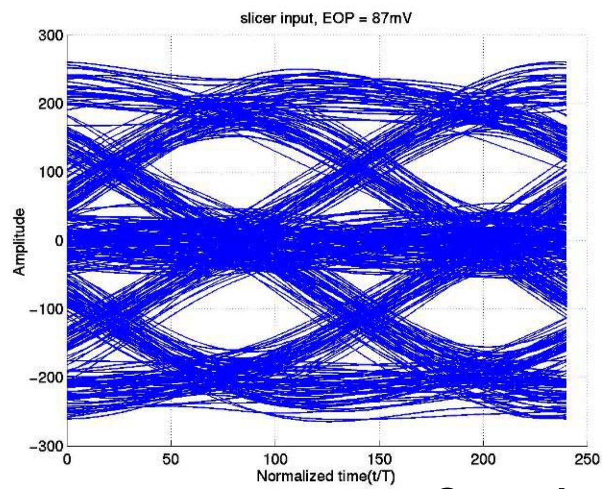


Case 2





Case 3



Case 4

Notes:

- ***Vertical Axis***

  Units = mV

- ***Horizontal Axis***

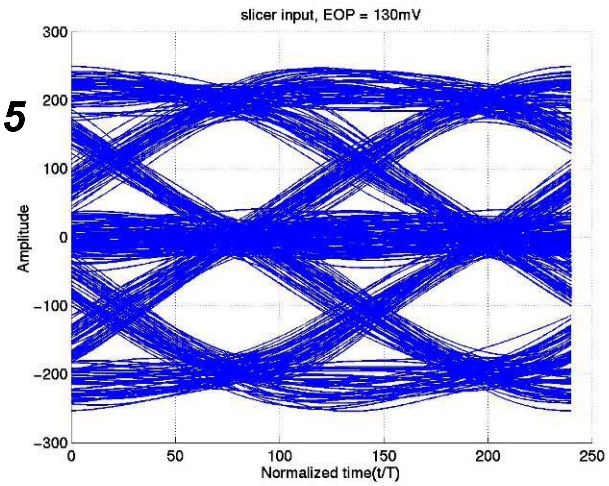
  120 units = 100ps

- ***EOP= eye opening***

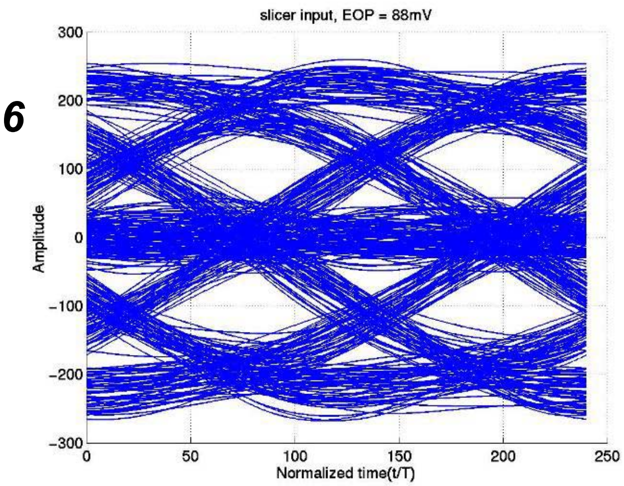
- ***1200 bits are plotted***

Tyco Cases 5-7

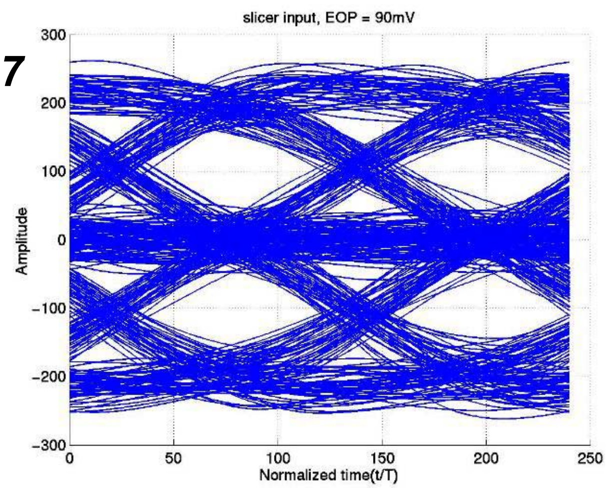
Case 5



Case 6



Case 7



Notes:

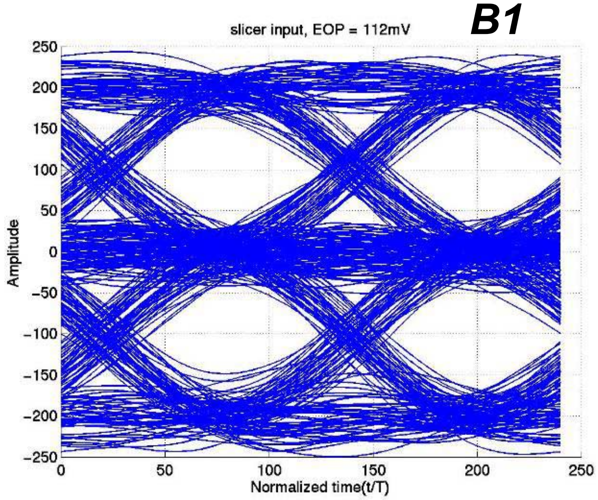
- ***Vertical Axis***

  Units = mV
- ***Horizontal Axis***

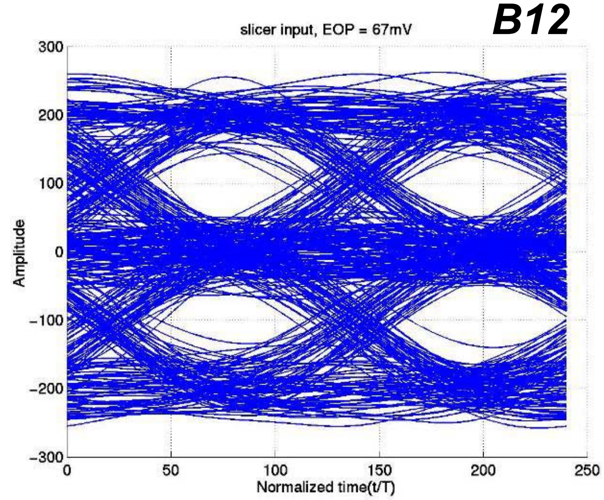
  120 units = 100ps
- ***EOP= eye opening***
- ***1200 bits are plotted***

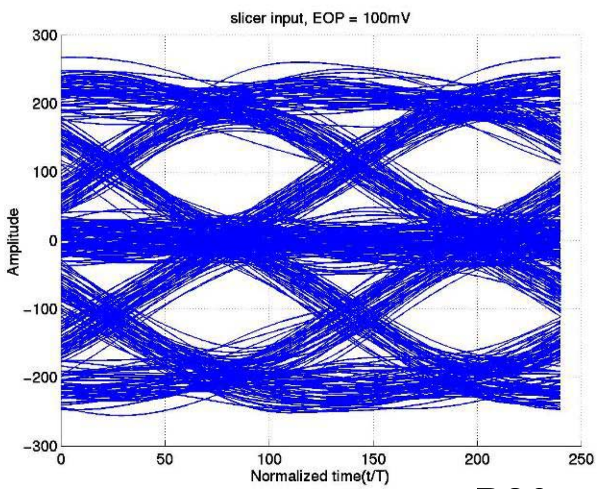
Intel B1, B12, B20, M1

B1

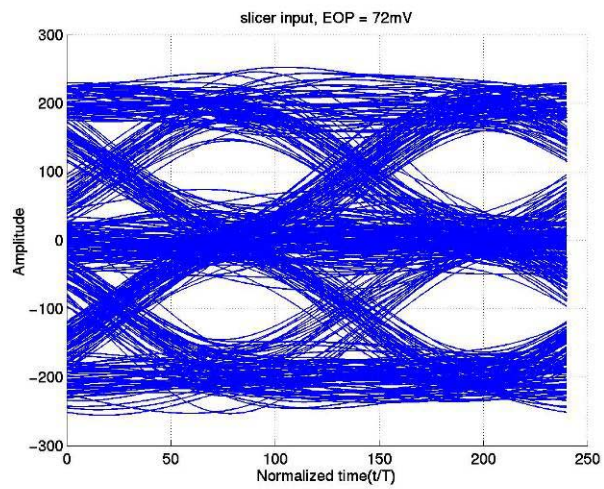


B12





B20



M1

Notes:

- ***Vertical Axis***

  Units = mV

- ***Horizontal Axis***

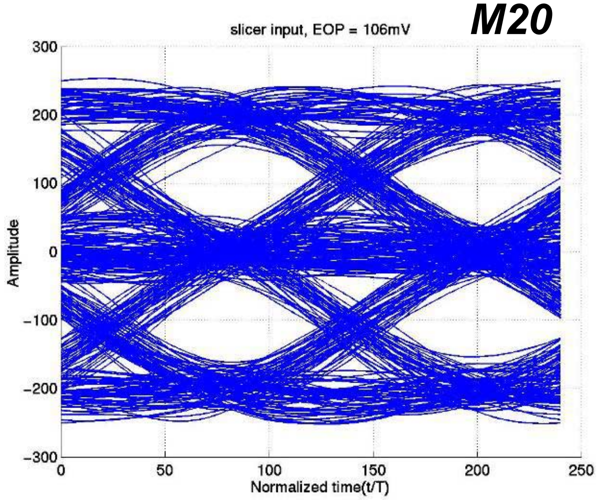
  120 units = 100ps

- ***EOP= eye opening***

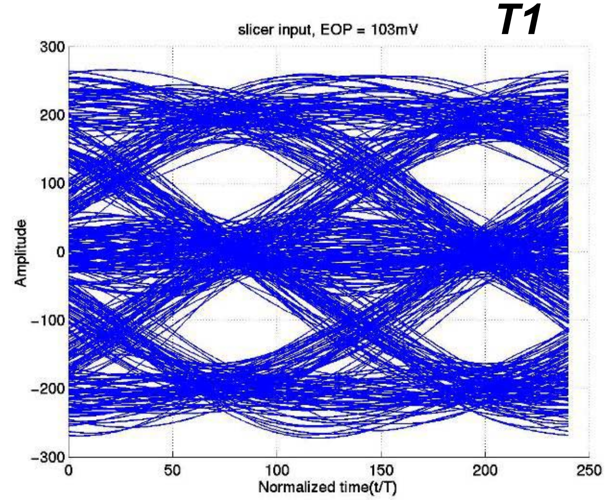
- ***1200 bits are plotted***

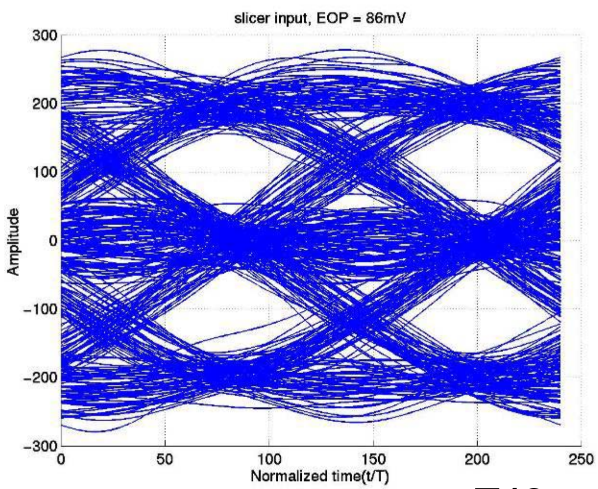
Intel M20 T1 T12 T20

_M20_

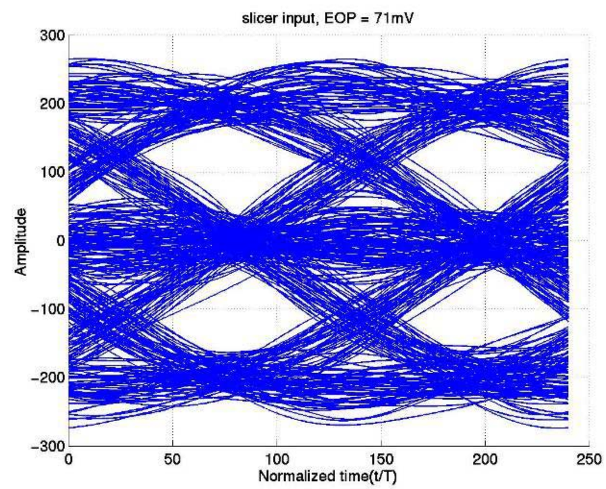


_T1_





_T12_



_T20_

Notes:

- ***Vertical Axis***

  Units = mV

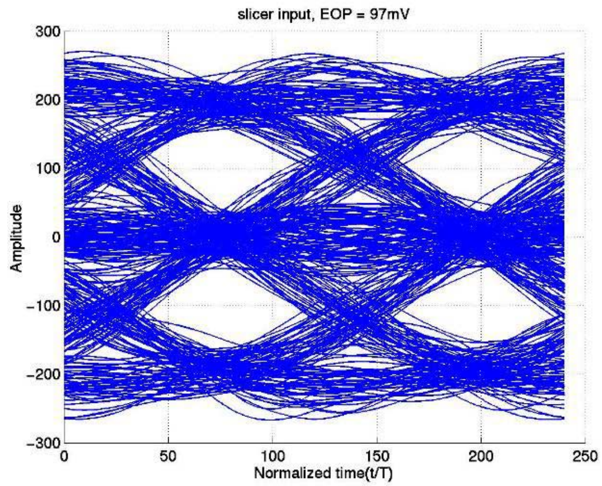
- ***Horizontal Axis***

  120 units = 100ps

- ***EOP= eye opening***

- ***1200 bits are plotted***

Intel T32



Notes:

- ***Vertical Axis***

  Units = mV

- ***Horizontal Axis***

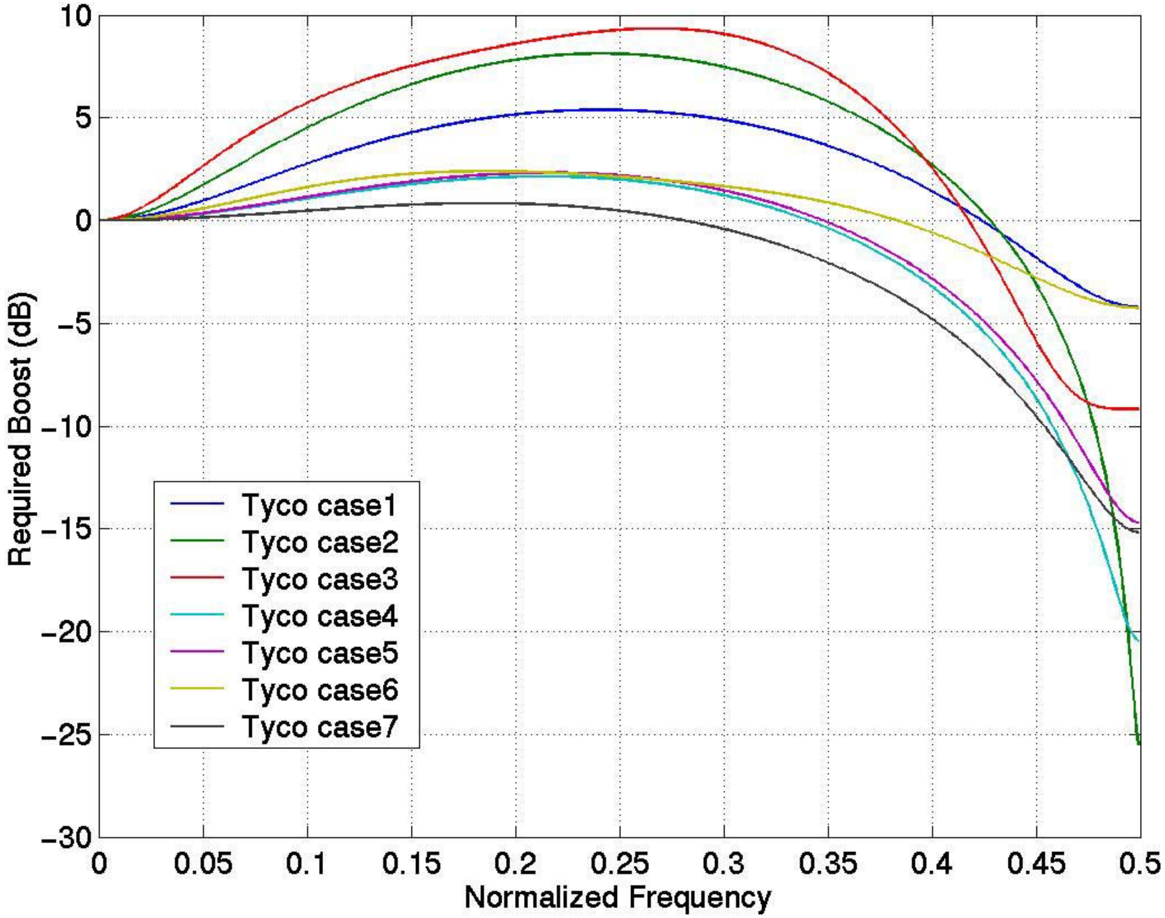
  120 units = 100ps

- ***EOP= eye opening***

- ***1200 bits are plotted***

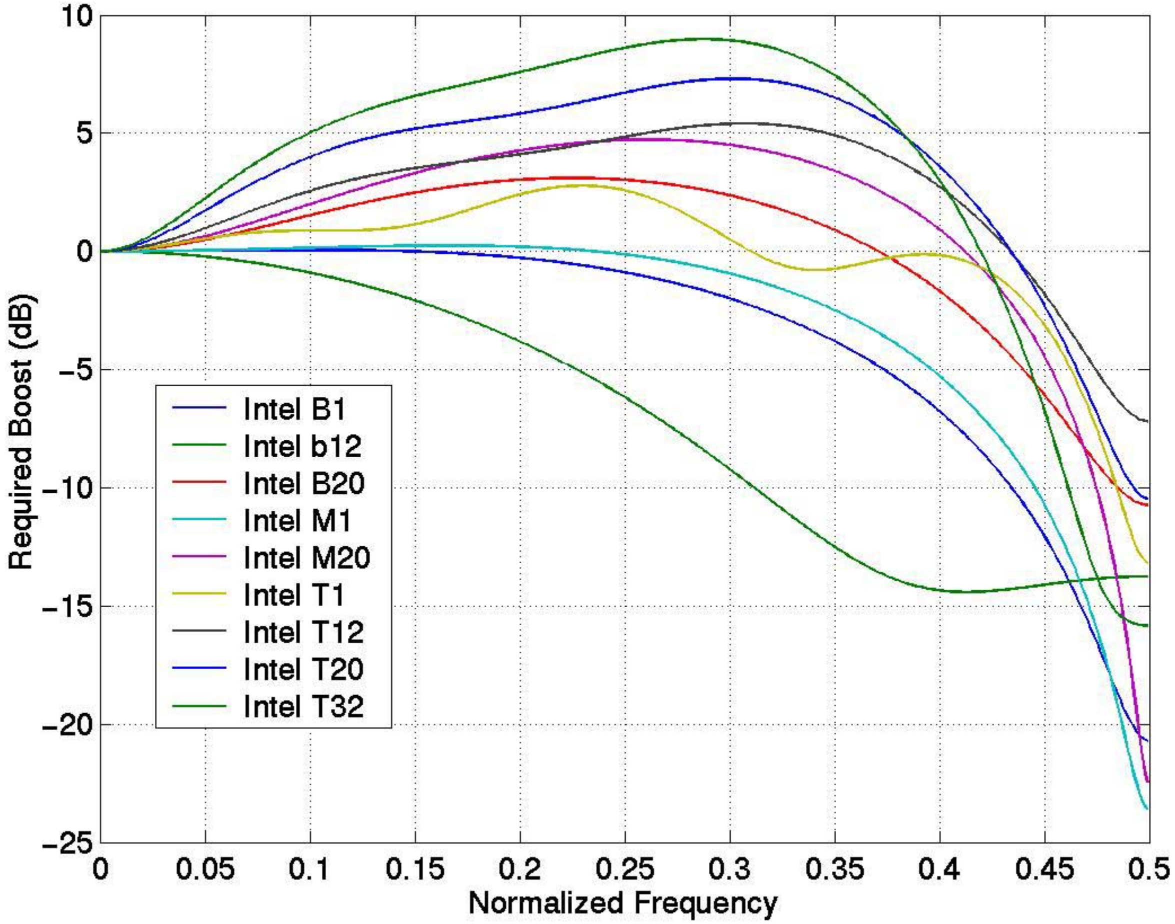
FFE Boost required for each channel

Tyco Backplanes



FFE Boost required for each channel

Intel Backplanes



Discussion of Findings

- We were able to achieve open eyes on ***all*** of the channels analyzed.
- Less than 10 dB of boost is required in the FFE for ***all*** channels analyzed
  - Important for crosstalk sensitivity
  - Reduces required power consumption
  - Reduces complexity of FFE design
- Tyco channels required from 3-5 FFE taps and 3-5 DFE taps
- Intel channels were more challenging – required from 3-9 FFE taps and 3-5 DFE taps.

Conclusion

- A comprehensive simulation of duobinary signaling has been carried out.
- Using Duobinary, we were able to achieve margin, even at a BER=10^{-18}, on ALL CHANNELS.
- FFE boost was < 10 dB which will help us to achieve a signaling solution that has relatively low complexity and power requirements.
- Clearly duobinary signaling provides an attractive solution for the 10G PHY.