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06-419r1 SAS-2 Reference Transmitter and Receiver Specification Proposal

Serial Attached SCSI

Kevin Witt

SAS-2 Phy Working Group

9/14/06

YOUR PARTNER FOR SUCCESS

Outline

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- Present an Evaluation of all Published SAS-2 Channels
  - Clarify the Definition of Transmit De-Emphasis
- Provide a Basis for the Selection of the Transmit De-Emphasis Specification
- Provide a Basis for the Selection of the Reference Transmitter & Receiver
- Propose Initial Transmitter and Receiver Specifications
- References:
  - 06-206R2 SAS-2 Data Eyes vs. De-Emphasis
  - 06-053R0 Roadmap to SAS-2 Physical Layer Specification
  - 06-052R0 Enhanced SFF-8470, SFF-8086 and SATA Cable at 6Gbps
  - 05-204R1 Towards a SAS-2 Physical Layer Specification
  - 05-426R0 SAS-2 Cable Reach Objective and Crosstalk
  - 05-425R1 SAS-2 Channel Model Simulations
  - 05-342R0 SAS-2 Adaptive Equalizer Physical Layer Feasibility
  - 05-341R1 Updated Test and Simulation Results in Support of SAS-2
  - 05-203R0 SAS-2 6Gbps Test Results

SAS-2 Channels Analyzed

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- 28 Channels Submitted
- 0→10 dB De-Emphasis
- 0→10 Taps DFE
- 3,388 Simulation Cases
- Behavior Simulation

ID Used in Plots

ID	T10 Doc #	Source	Description	Type
1	05-398r0	Molex	0.5m MiniSAS	Measured
2	05-398r0	Molex	1 m MimiSAS	Measured
3	05-398r0	Molex	3 m MimiSAS	Measured
4	05-398r0	Molex	3 m MimiSAS	Measured
5	05-398r0	Molex	10 m MimiSAS	Measured
6	05-384r0	HP1	3 Connector Board 2 board	Measured
7	05-384r0	HP2	3 Connector Board 2 board	Measured
8	05-384r0	HP3	3 Connector Board 2 board	Measured
9	05-384r0	HP4	3 Connector Board 2 board	Measured
10	05-384r0	HP5	3 Connector Board 2 board	Measured
11	05-384r0	HP6	3 Connector Board 2 board	Measured
12	05-384r0	HP7	3 Connector Board 2 board	Measured
13	05-384r0	HP8	3 Connector Board 2 board	Measured
14	05-389r0	HP9	4 connector Board to Board	Measured
15	05-389r0	HP10	4 connector Board to Board	Measured
16	05-389r0	HP11	4 connector Board to Board	Measured
17	05-390r0	HP12	Board 1m Cable Backplane Drive	Measured
18	05-390r0	HP13	Board 6" Cable Backplane Drive	Measured
19	05-390r0	HP14	Board 6" Cable Backplane Drive	Measured
20	06-017r0	HP24	4 connector Board to Board	Measured
21	06-017r0	HP25	4 connector Board to Board	Measured
22	06-017r0	HP26	4 connector Board to Board	Measured
23	05-384r2	HP27	Board to board 3 connector	Measured
24	05-384r2	HP28	Board to board 3 connector	Measured
25	05-393r0	Dell 1	Bottom Trace 19"	Model
26	05-393r0	Dell 2	Bottom Trace 8"	Model
27	05-393r0	Dell 3	Top Trace 8"	Model
28	05-393r0	Dell 4	Top Trace 19"	Model

Behavior Simulation Methodology

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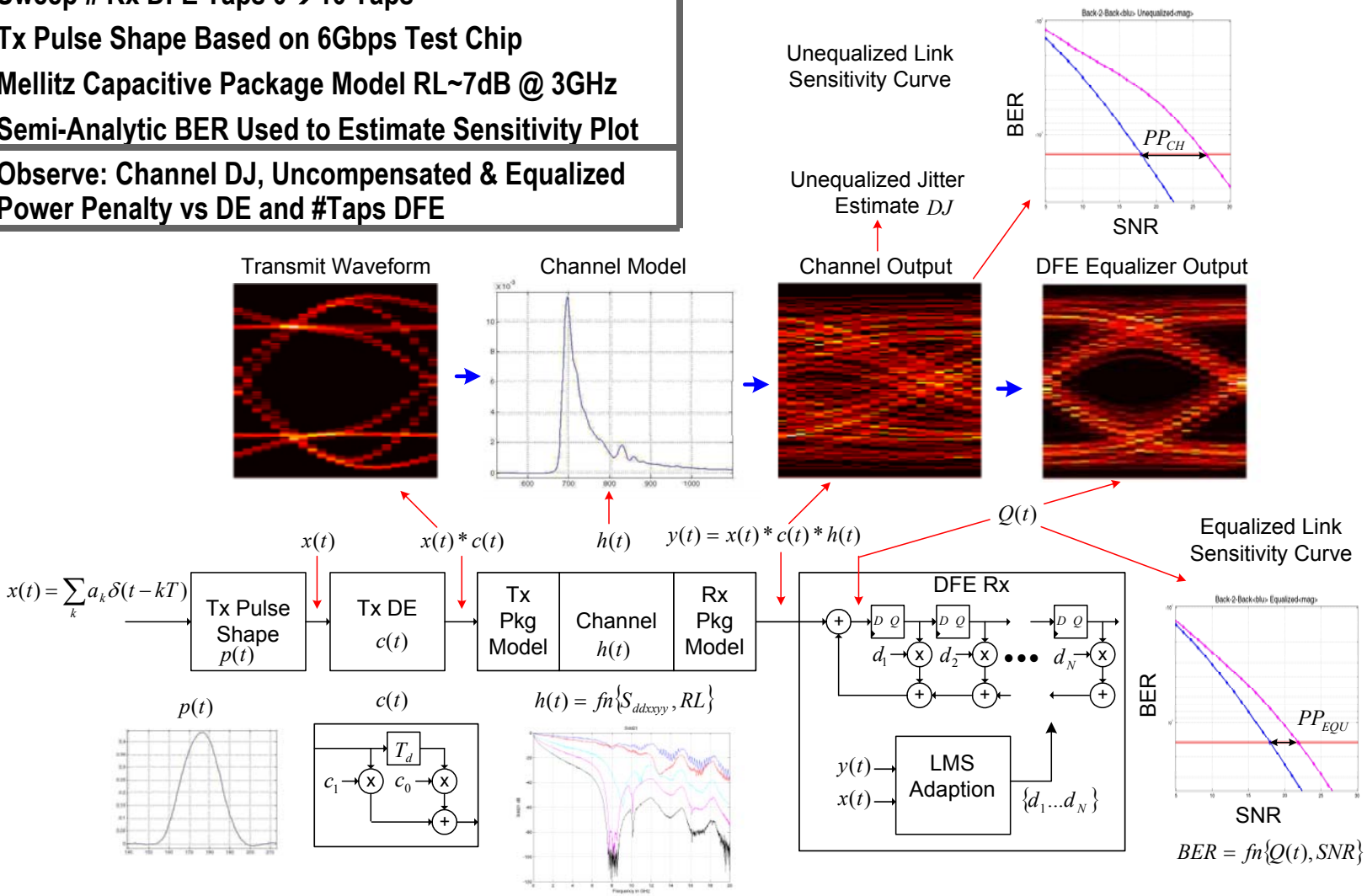
- S-Parameter Channel Models (28 Channels)
- Sweep Tx De-Emphasis 0→10dB
- Sweep # Rx DFE Taps 0→10 Taps
- Tx Pulse Shape Based on 6Gbps Test Chip
- Mellitz Capacitive Package Model RL~7dB @ 3GHz
- Semi-Analytic BER Used to Estimate Sensitivity Plot
- Observe: Channel DJ, Uncompensated & Equalized Power Penalty vs DE and #Taps DFE



Tx De-Emphasis Details

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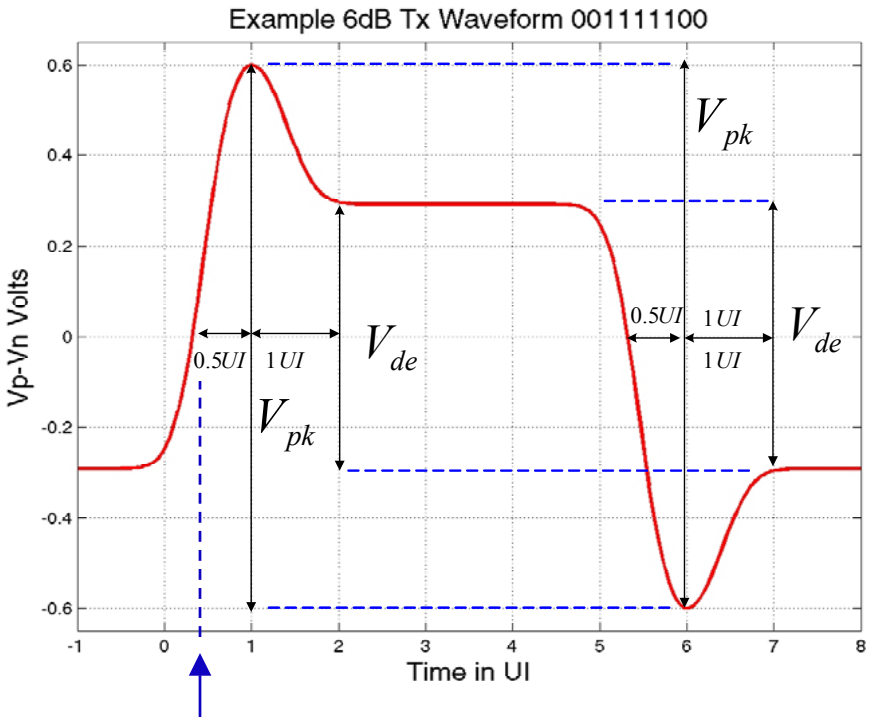
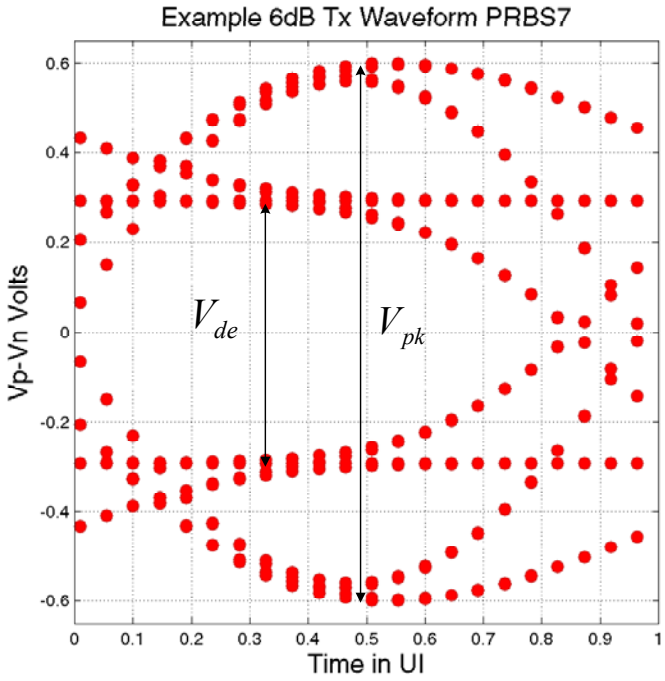
- De-Emphasis Can Be Measured From 00000111110000011111 Waveform





All Voltage Measurements Referenced to Zero Crossing

$$DE_{dB} = 20Log_{10}\left(\frac{V_{pk}}{V_{de}}\right)$$

$$Cutback = \frac{V_{pk} - V_{de}}{V_{pk}}$$

Example

Vpk mV	Vde mV	DE (dB)	CutBack (%)
1200	850	3	29
1200	757	4	37
1200	675	5	44
1200	601	6	50
1200	536	7	55
1200	478	8	60

Power Penalty is Metric Used For Comparison

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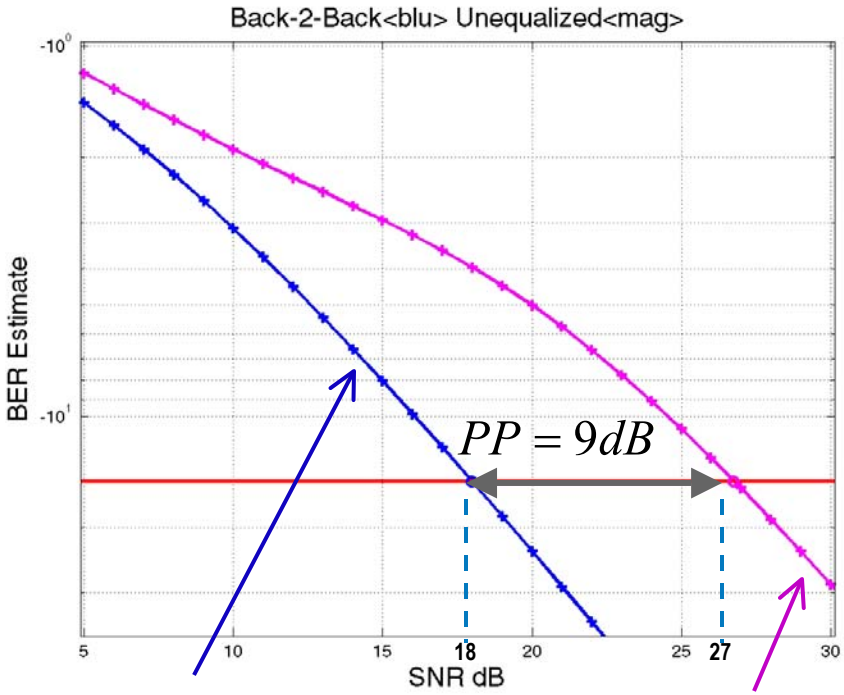
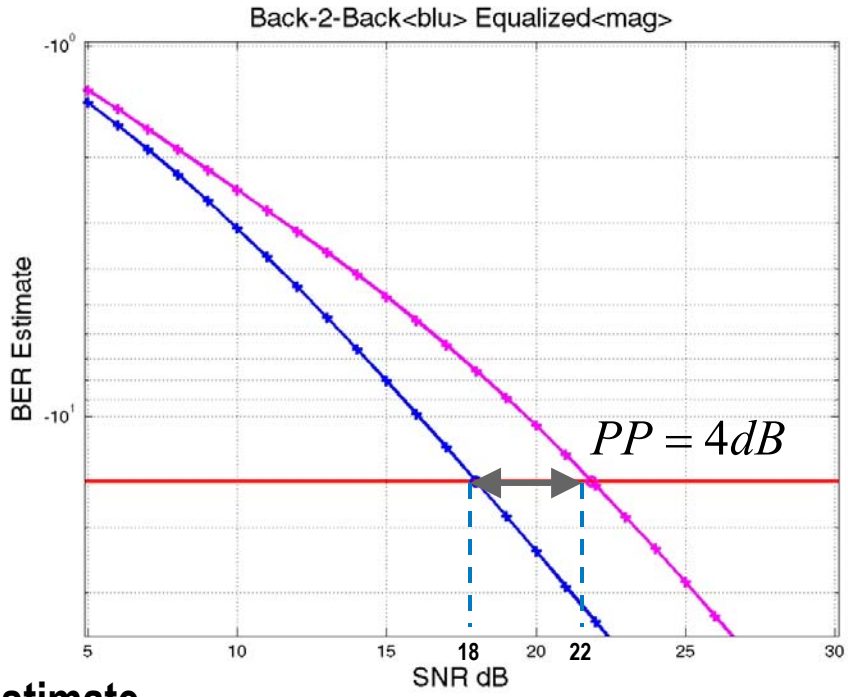
- The Power Penalty Indicates How Much Additional SNR is Required to Overcome the Residual ISI After Equalization to Operate at the Target BER of 1e-15.
- Example





Theoretical for NRZ Link

Semi-Analytic BER Estimate

Reference: Simulation of Communication Systems Modeling, Methodology and Techniques, M. C. Jeruchim, 2000

Visual Check of Simulation Methodology

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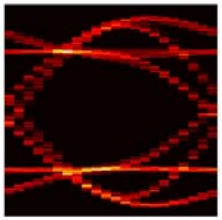
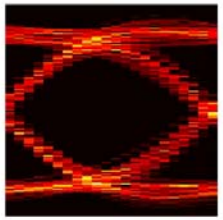
- Simulation vs. Measured
  - 6 Gbps Output Driver Test Chip
  - 6dB 2 Tap De-Emphasis
- Good Agreement With Measured
  - Eye Opening and Eye Shape
  - Jitter at Zero Crossing

6dB De-Emphasis Simulated Eyes

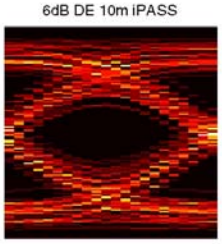
1m



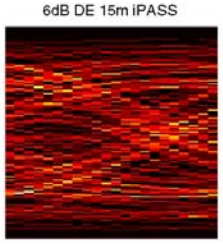
6m



10m

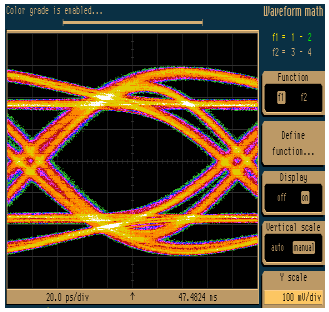


15m

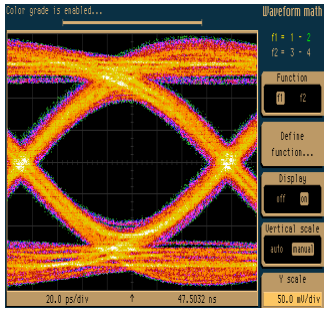


6dB De-Emphasis Measured Eyes

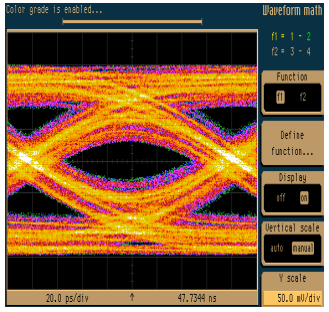
1m



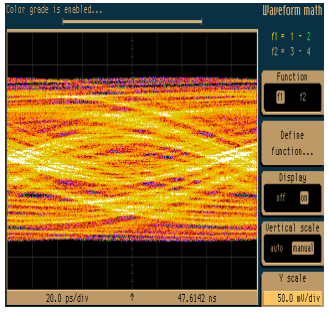
6m



10m



15m



What is the Optimal De-Emphasis Setting?

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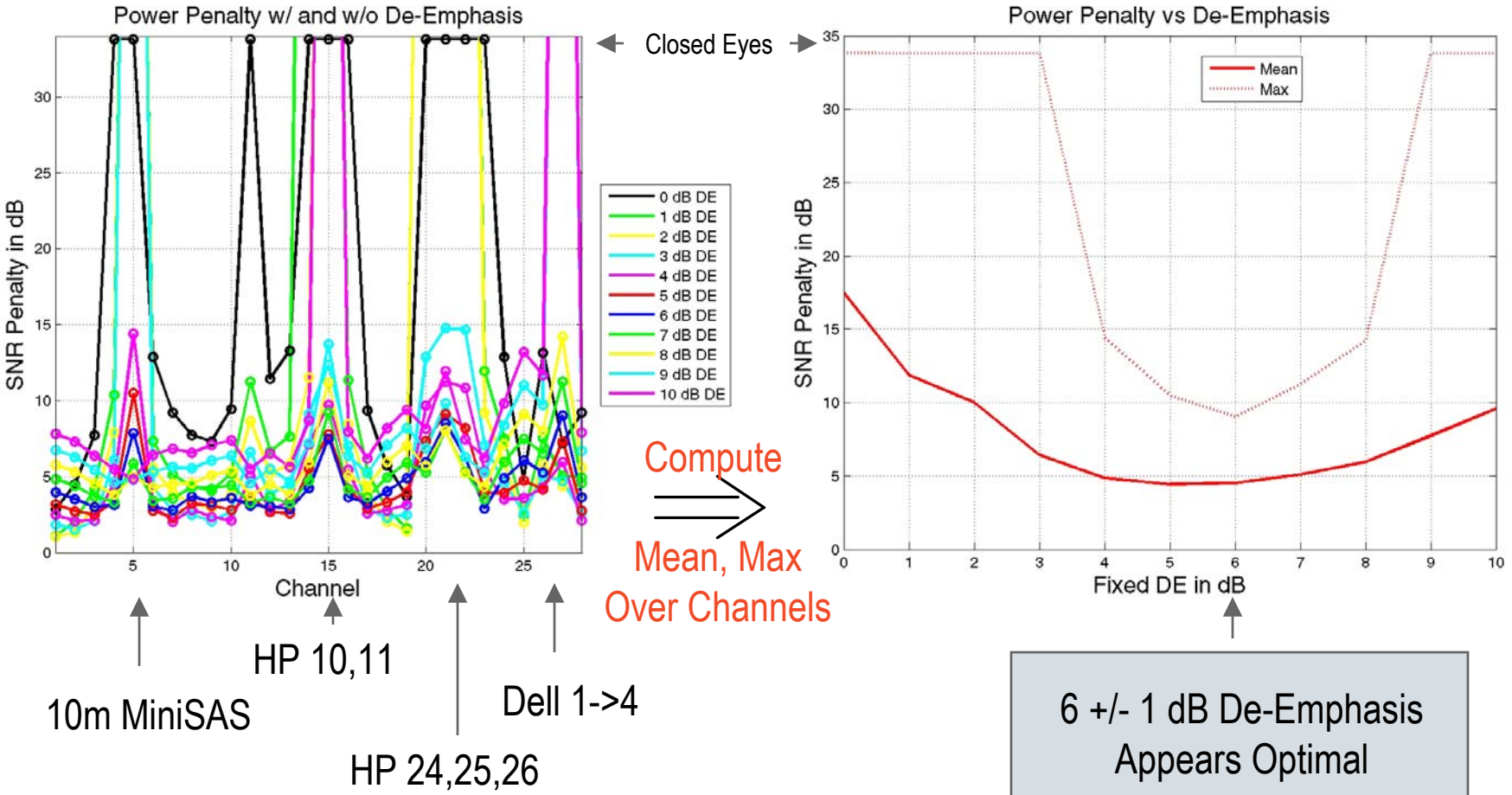
- SNR Penalty vs. De-Emphasis (no DFE)
  - What is the Best De-Emphasis Setting to Minimize SNR Power Penalty
  - Look at Average & Max Penalty vs DE Setting



What is the Optimal De-Emphasis Setting?

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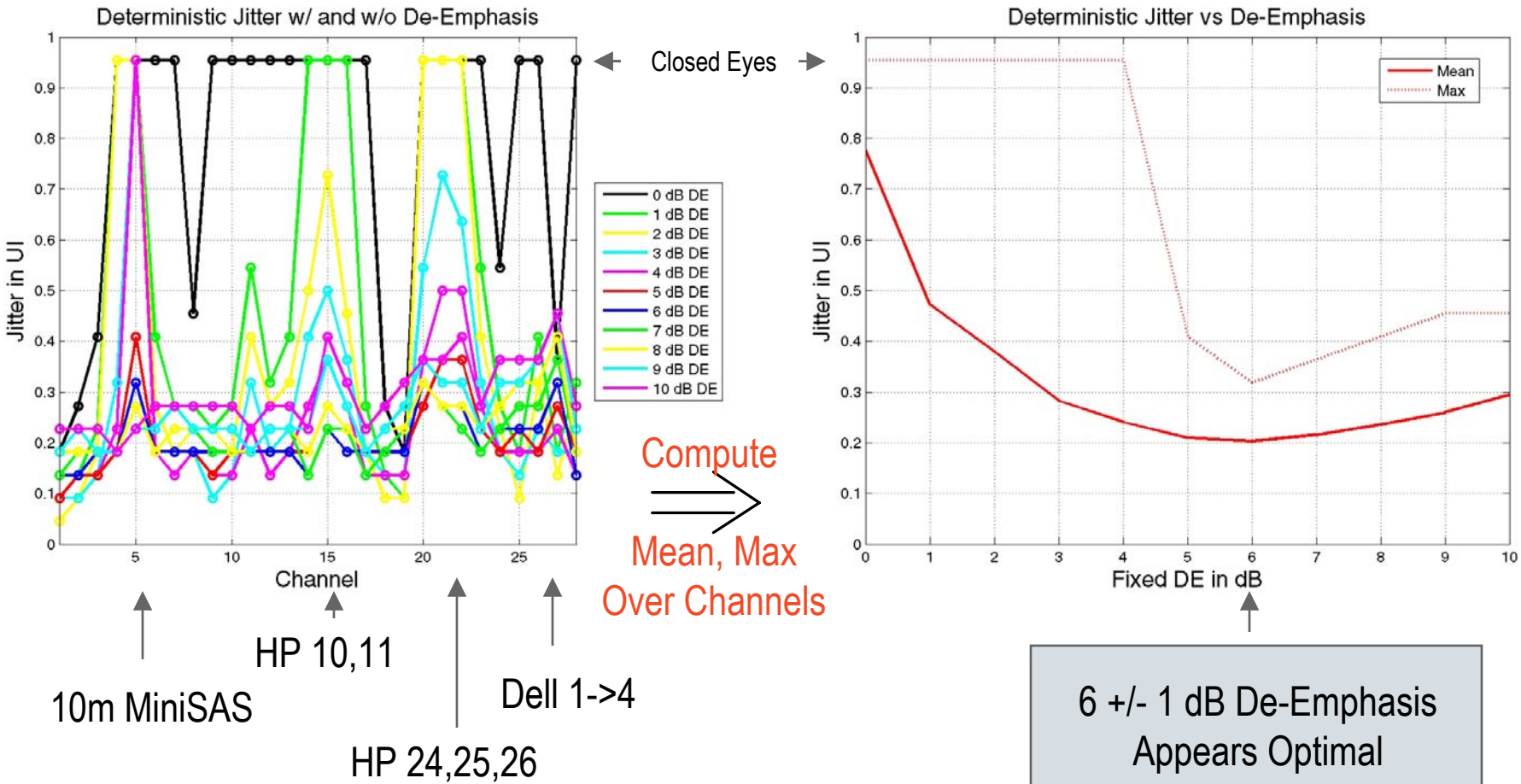
- Deterministic Jitter vs. De-Emphasis (no DFE)
  - What is the Best De-Emphasis Setting to Minimize Jitter Generation
  - Look at Average & Max Jitter Generation vs. DE Setting



What is the Optimal # DFE Taps?

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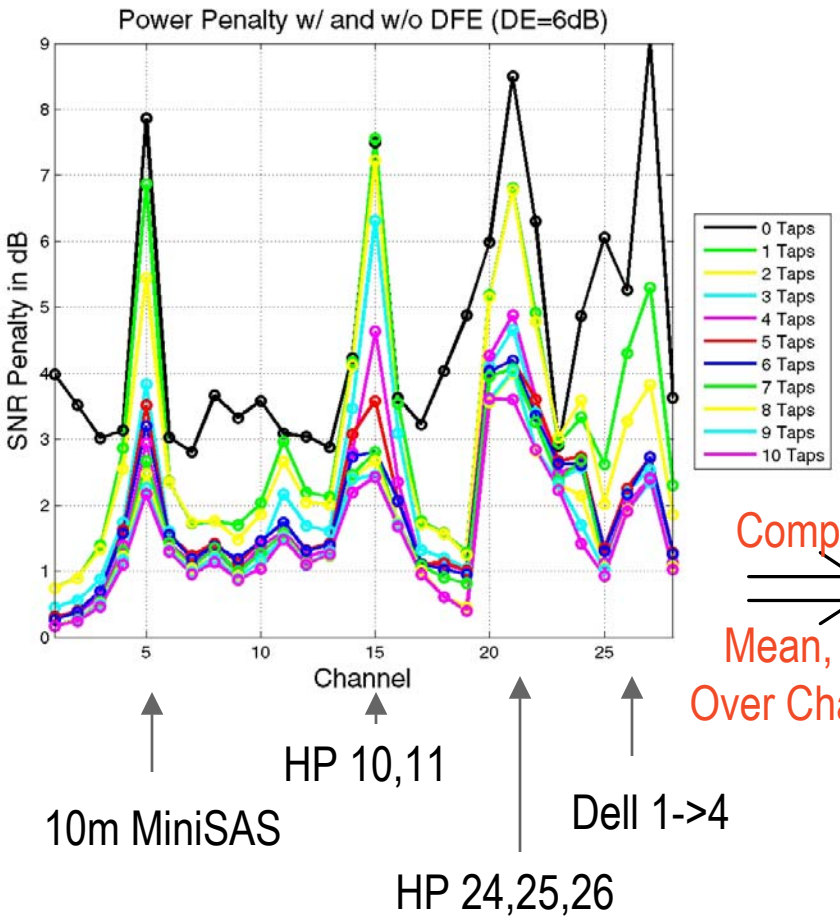
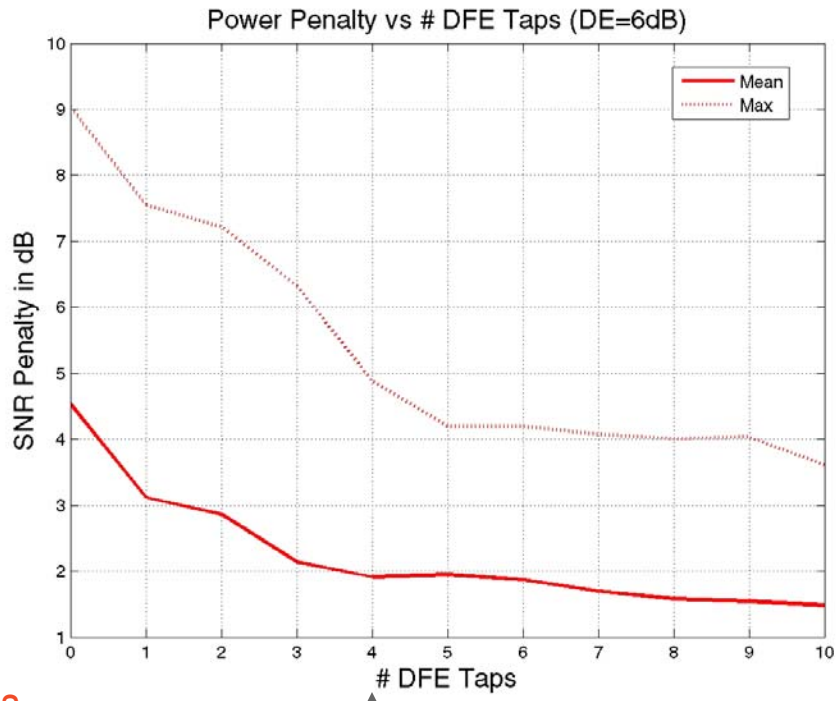
- SNR Penalty vs. # DFE Taps (With 6 dB De-Emphasis)
  - What is the Best De-Emphasis Setting to Minimize SNR Power Penalty
  - Look at Average & Max Penalty vs. DE Setting



Compute

Mean, Max
Over Channels



4 +/- 1 Tap DFE
Appears Near Point Of
Diminishing Return

What is the Optimal # DFE Taps & DE Setting?

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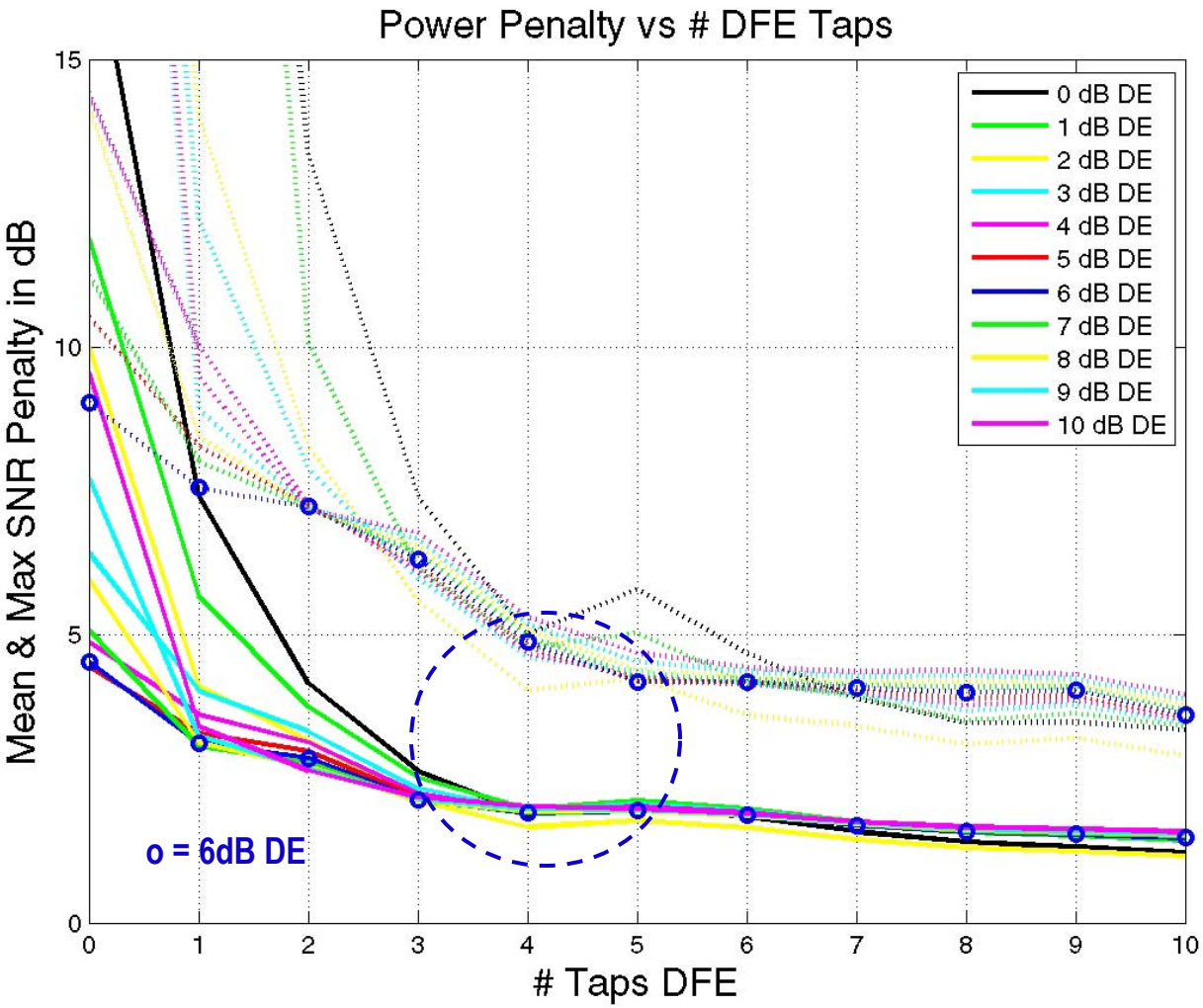
- Look at all 3388 Power Penalty Results as a Family of Curves vs. # DFE Taps



3 or 4 Tap DFE
6 dB DE
Appears to Be a
Reasonable
Reference Rx/Tx

Max (dash)

Mean (solid)

Slice the Results the Other Way

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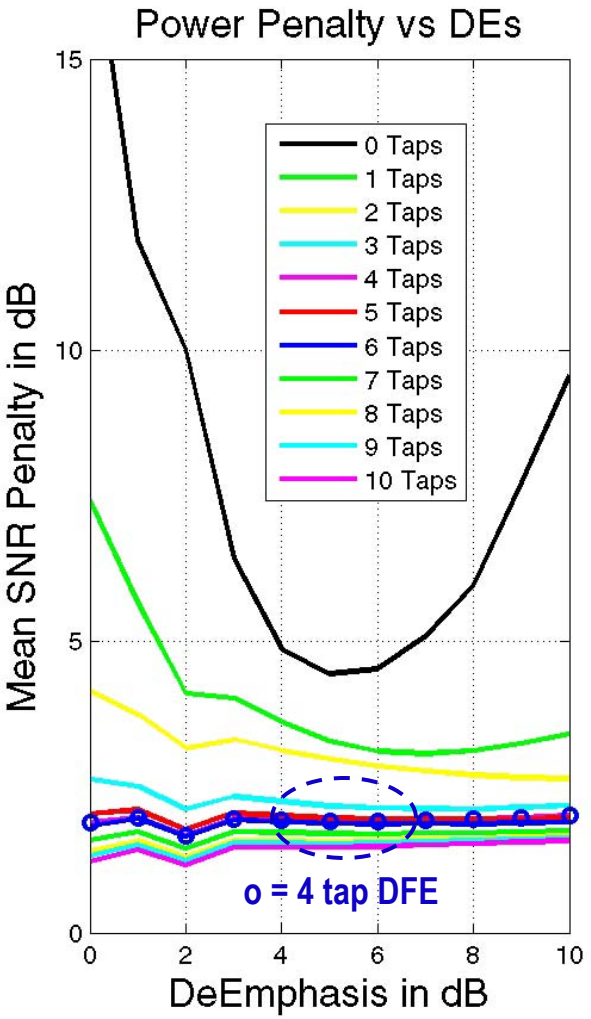
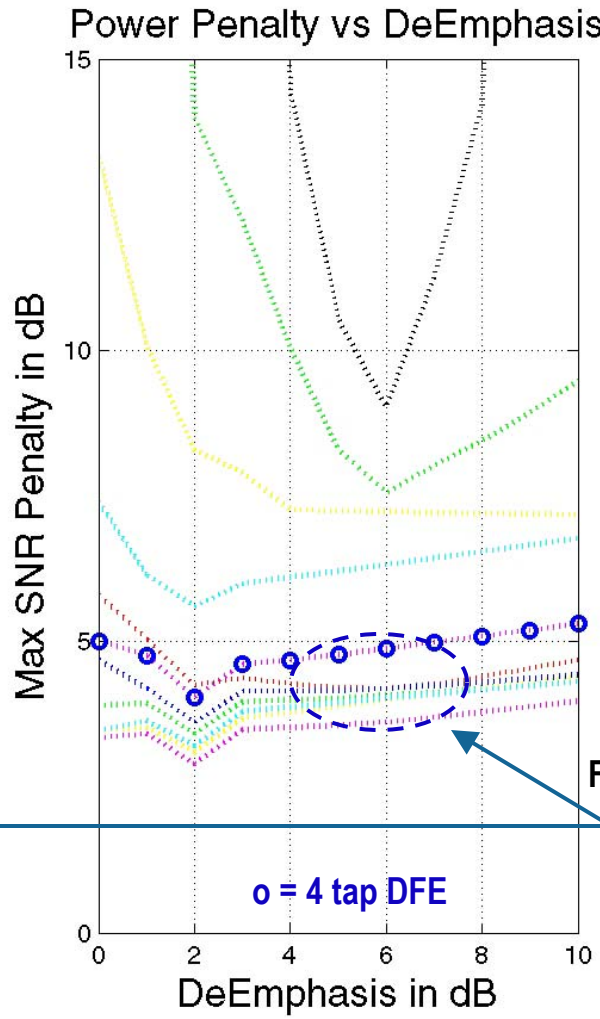
- Look at all 3388 Power Penalty Results as a Family of Curves vs. De-Emphasis

With Enough DFE We Do Not Need De-Emphasis
But the Link Would Be More Susceptible to DFE Error Propagation

Increasing # DFE Taps





3 or 4 Tap DFE
6 dB DE
Appears to Be a
Reasonable
Reference Rx/Tx

Flatness Indicates No Need to Over Constrain the De-Emphasis

Reference Transmitter and Receiver Architecture Proposal

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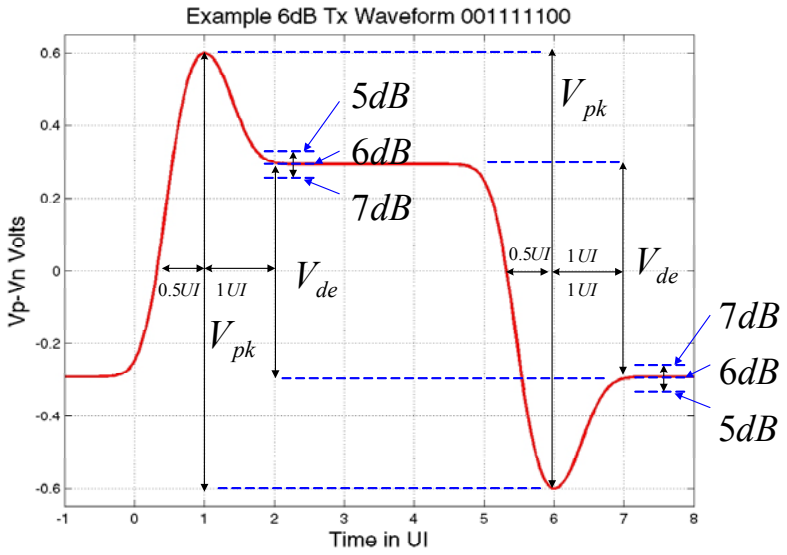
Reference Transmitter De-Emphasis (1)

- **2 Tap De-Emphasis**
- **6dB (per Proposed Measurement Technique)**

1) **Transmitter Implementation is Not Limited to a two tap De-Emphasis Driver Architecture, However, its' Pre-Equalization Capability Shall Be Equivalent to the Reference Transmitter when combined with the Reference Receiver.**



Reference Receiver (2)

- **3 Tap DFE**

2) **Receiver Implementation is Not Limited to a DFE Architecture, However, its' Equalization Capability Shall Be Equivalent to the Reference Receiver.**

Vpk mV	Vde mV	DE (dB)	CutBack (%)
1200	850	3	29
1200	757	4	37
1200	675	5	44
1200	601	6	50
1200	536	7	55
1200	478	8	60
800	566	3	29
800	505	4	37
800	450	5	44
800	401	6	50
800	357	7	55
800	318	8	60

SAS-2 Specification Proposed Numbers

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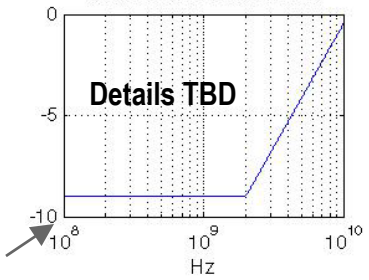
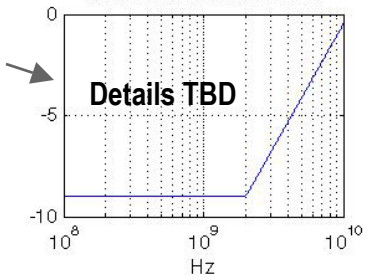
Transmitter

	SAS-2			
Transmitter	Min		Max	Units
Differential Voltage (pk-pk)	800		1200	mV
Transition Time (20%-80%)	50		90	ps
DC Output Impedance	60		115	ohm
DC Output Impedance Mismatch			5	ohm
Differential Return Loss			see Plot	dB
DC Common Mode Impedance	15		40	ohm
Common Mode Return Loss			see Plot	dB
Max. Intra-Pair Skew			15	ps
Random Jitter			0.15	UI
Deterministic Jitter			0.15	UI
Total Jitter			0.3	UI
Ref Tx # Taps De-Emphasis		2		Taps
Ref Tx De-Emphasis		6		dB

What is Missing?

Differential Return Loss
(Similar to 10G Base-KR)





Common Mode Return Loss
Like above but -6dB and TBD Frequency Dependency

SAS-2 Specification Proposed Numbers

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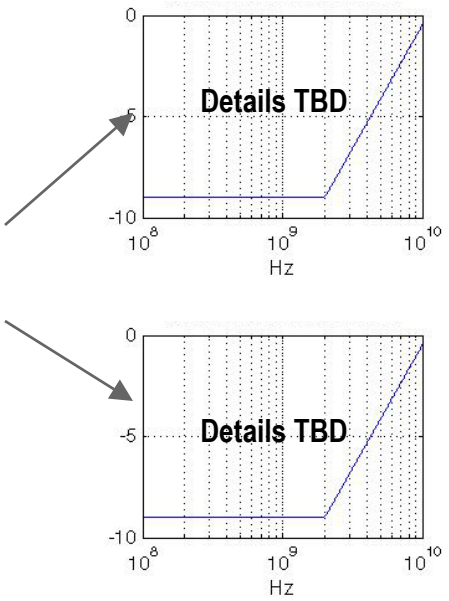
Reference Receiver

	SAS-2			
Receiver	Min		Max	Units
Reference Rx # DFE Taps (See Note 1)		3		taps
Refernece Differential Impedance		100		ohm
Differential Return Loss			See Plot	
Common Mode Impedance	20		40	ohm
Common-Mode Tolerance (2-200MHz)	150			mV
Common Mode Return Loss			See Plot	
Max Operational Input Voltage	1200			mV
Max Non-Operational Input Voltage	2000			mV

Differential Return Loss (Similar to 10G Base-KR)



What is Missing?

Notes:

1) Receiver Implementation is Not Limited to a DFE Architecture, However, its' Equalization Capability Must at Least Be Equivalent to the Reference Receiver.

Summary

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- Evaluation of all Published SAS-2 Channels Provided
  - Definition of Transmit De-Emphasis Clarified.
- Basis for the Selection of Transmit De-Emphasis Specification Provided
  - 2-Tap De-Emphasis w/ 6 dB
- Basis for the Selection of a Reference Receiver Provided
  - 3 Tap DFE
- Propose Reference Transmitter and Receiver Specifications
  - Starting / Discussion Tables Provided for Development