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Channel Simulation Platform Creation in Matlab and IBIS-AMI Simulation Verification

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Outline

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- As serial signal rates are rising to the 10+ Gbps, the eye is closed without equalization. Equalization (FFE, CTLE and DFE) can improve the quality of eye at receiver side.

- For a system-level high speed designer, the key to choosing an equalizer is not just to evaluate the characteristic of a lossy channel, but also to determine capability of the equalizers.

- A platform in Matlab is set up and introduced to perform channel simulation with FFE, CTLE and DFE equalization.

- The verification is done based on IBIS-AMI simulation in EDA tool, both results from EDA Tool and from the channel simulation platform are compared.

Channel Simulation Platform Flow

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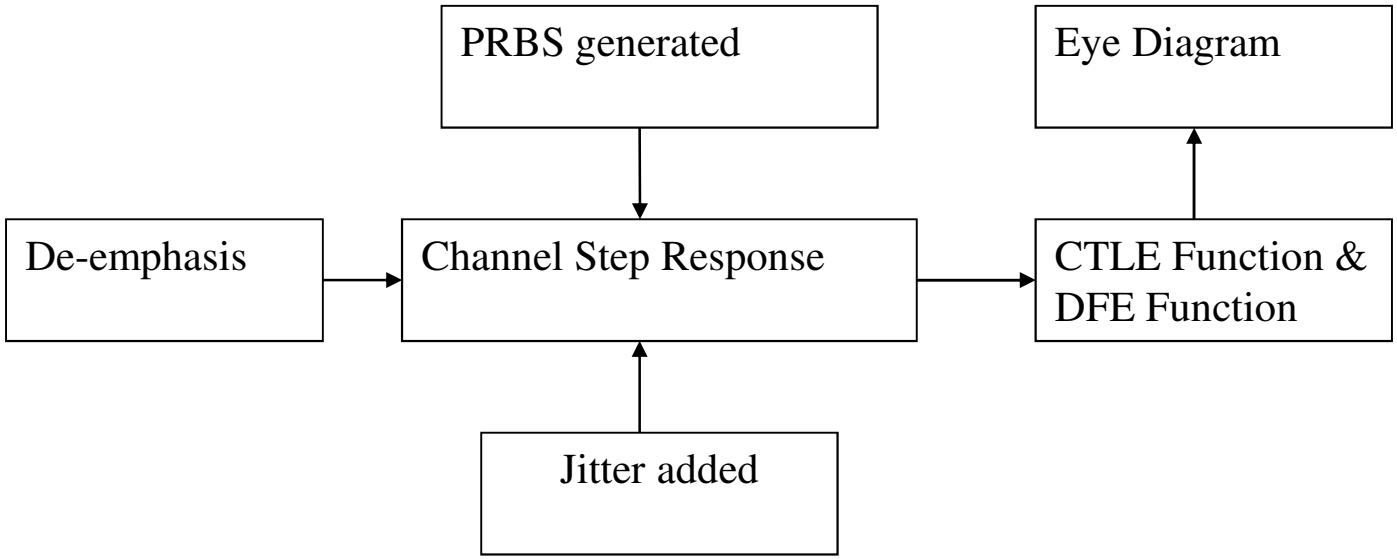
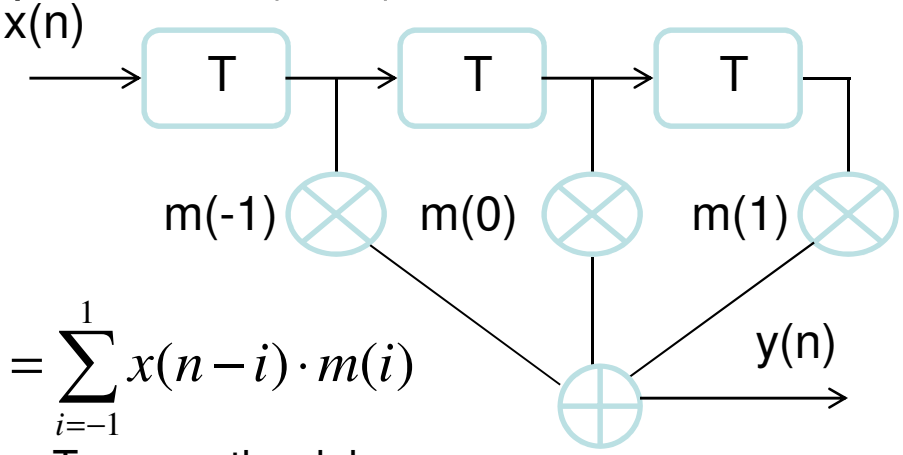


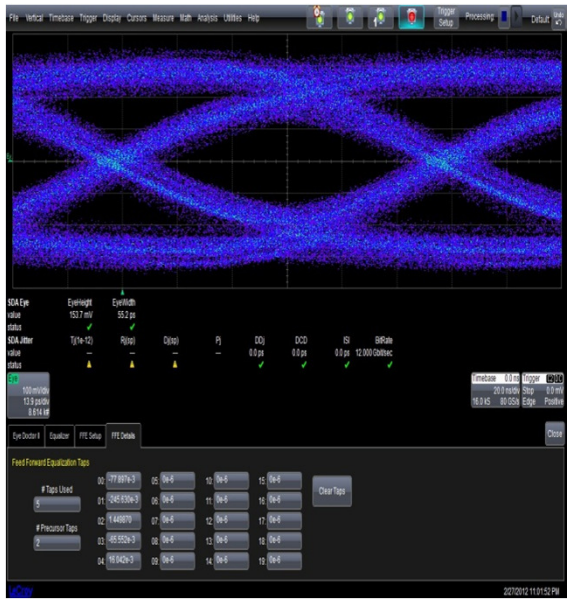
FFE Modeling

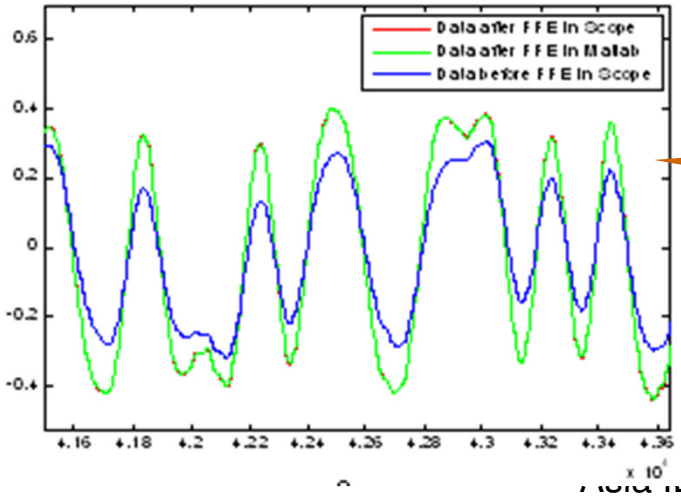
- 3 taps emphasis is modeled as feed-forward equalization (FFE),



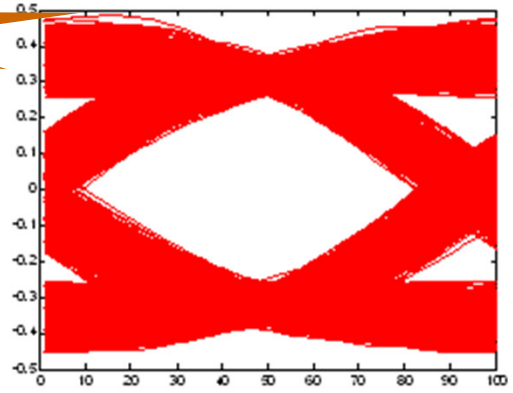
$$y(n) = \sum_{i=-1}^{1} x(n-i) \cdot m(i)$$

Where : T means the delay.





Matched!



Decision Feedback Equalization (DFE) Modeling

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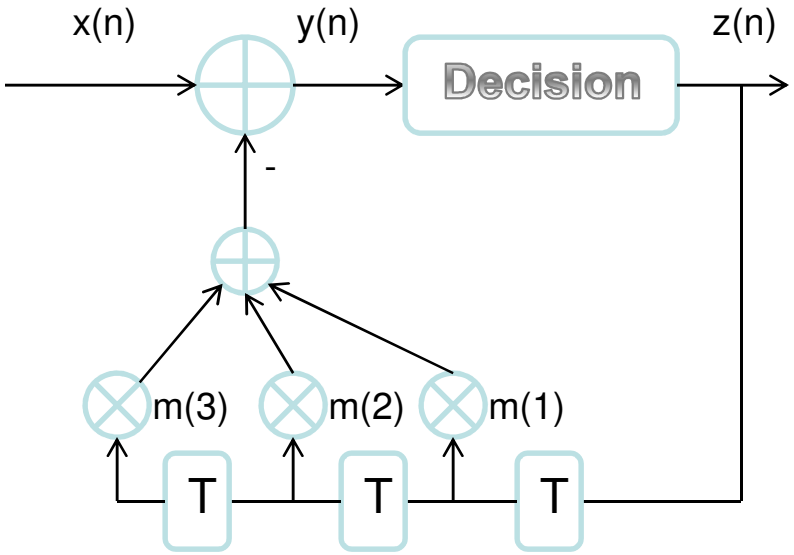
- 3 taps DFE modeling is shown below,



$$y(n) = x(n) - \sum_{i=1}^{3} z(n-i) \cdot m(i)$$

Where : T means the delay.

$$z(n) = \begin{cases} 1 & if\ y(n) >= threshold \\ -1 & if\ y(n) < threshold \end{cases}$$

- DFE tap parameters can be optimized by the equalization algorithm;

Continuous Time Linear Equalization (CTLE) modeling

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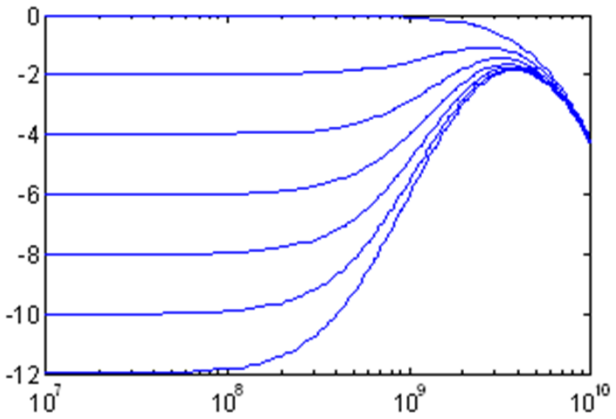
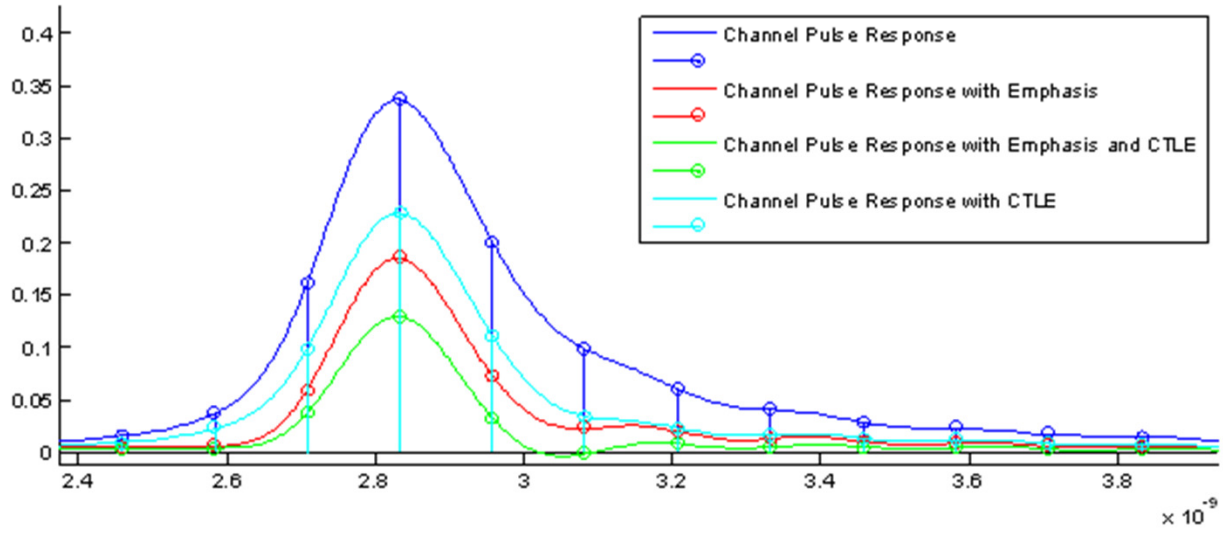
- CTLE is defined in high speed interface specifications to improve the quality of eye before DFE or at Rx side.

- It can be transformed to time domain for convolution.

$$H(s) = 2 \cdot pi \cdot 8e9 \cdot \frac{s + 2 \cdot pi \cdot 2e9 \cdot Adc}{(s + 2 \cdot pi \cdot 2e9) \cdot (s + 2 \cdot pi \cdot 8e9)}$$ where : Adc is DC Gain



Channel Pulse Response (CPR)

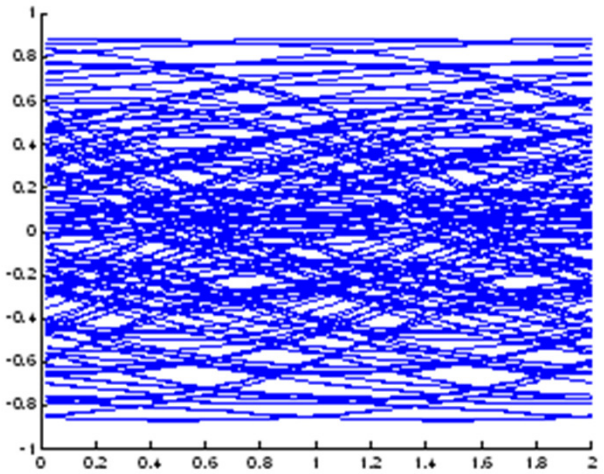


- Channel Pulse Response can not only be used to evaluate channel performance , but also to determine which equalization should be used in the channel.
- An equation is created to evaluate the performance of CPR:

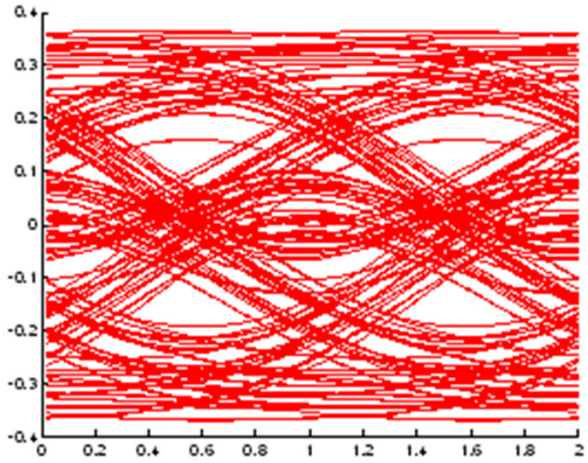
$$M = \frac{P_{main} - \sum_{i \neq main} abs(P_i)}{\sum_{i} abs(P_i)}$$

where: P_{main} is the value of main cursor,

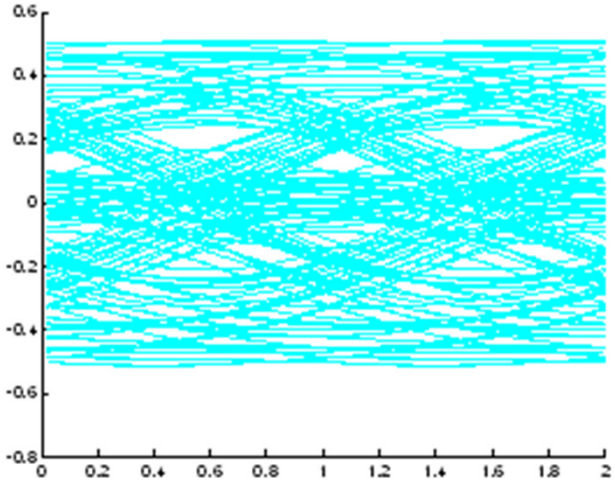
$\sum_{i \neq main} abs(P_i)$ is the sum of rest cursors.



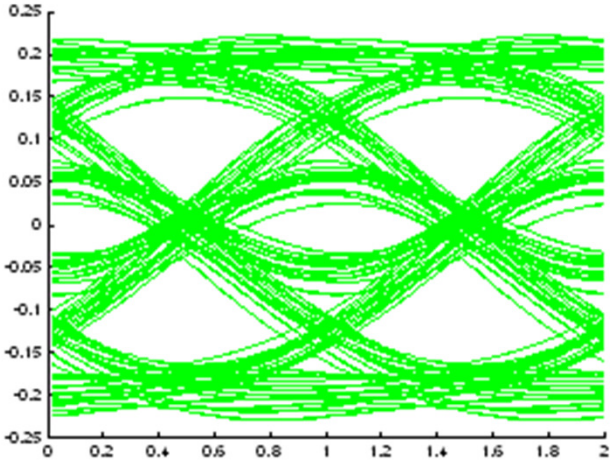
(a) Eye without equalization



(b) Eye with Emphasis



(c) Eye with CTLE



(d) Eye with Emphasis and CTLE

Jitter modeling

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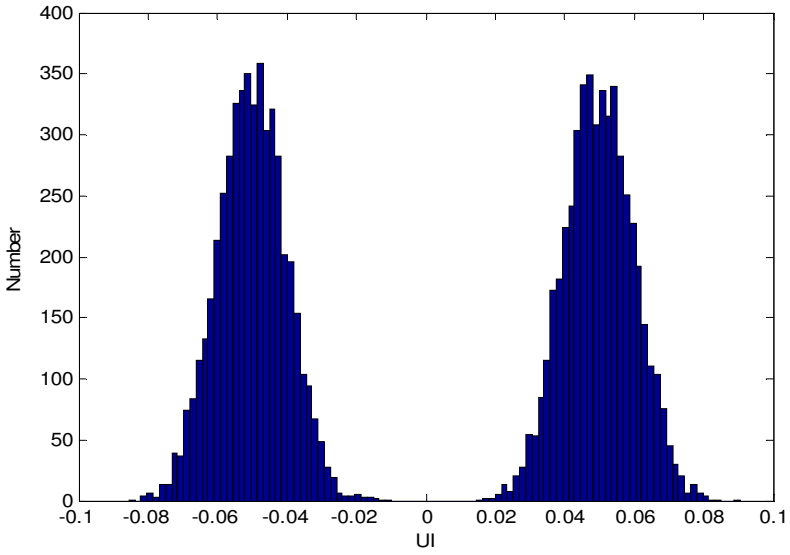
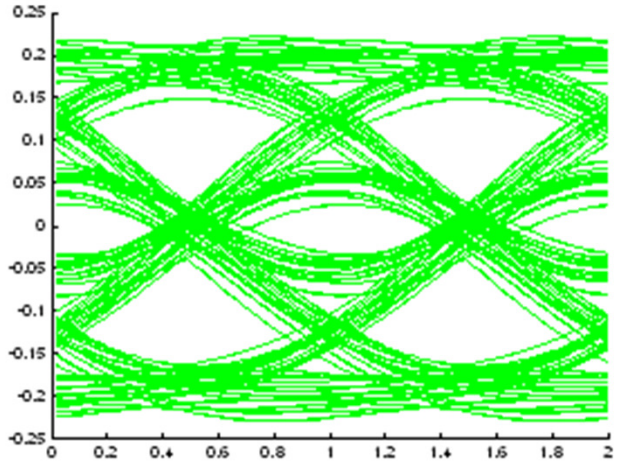
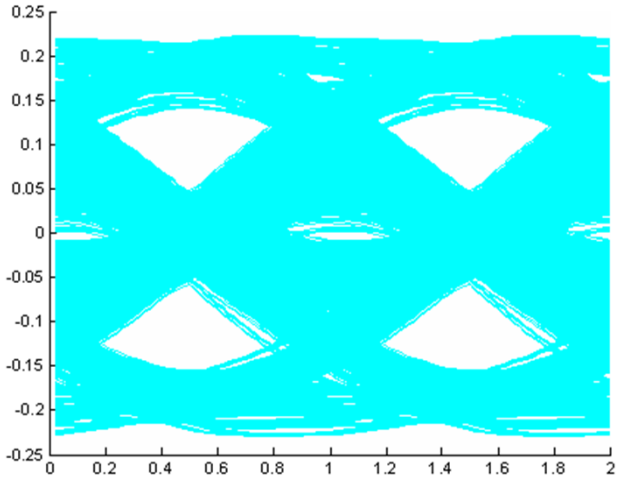
- Total Jitter (TJ) can be modeled as the random jitter (RJ) convolved with deterministic jitter (DJ).
- DJ can be modeled as Dual-Dirac model.





(d) Eye without TX Jitter

(e) Eye with TX jitter



IBIS-AMI Correlation between Matlab and EDA Tool

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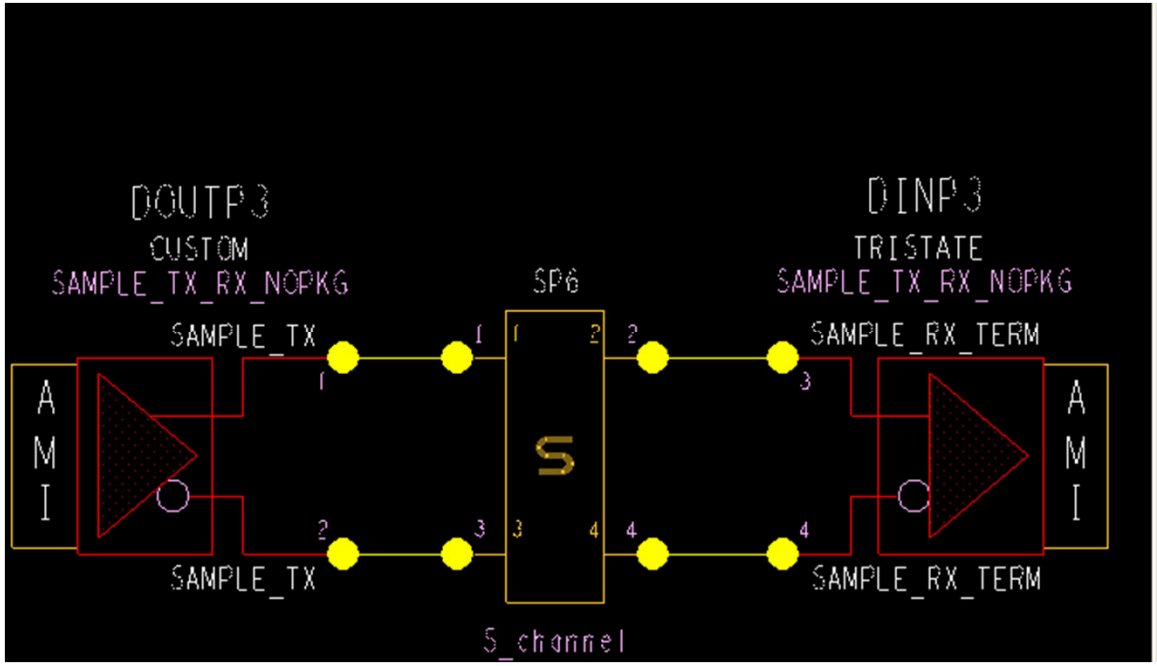
Table 1: EDA tool simulation condition

Pattern	Bits	Signal Rate	Ignore bits	Jitter
PRBS31	2000	5Gbps	250	0



CIRCUIT	
autoSolve	On
tlineDelayMode	length
userRevision	1.0
DESIGN	
DINP3	
bufferModelInverting	SAMPLE_RX_TERM
bufferModelNonInverti	SAMPLE_RX_TERM
sample_rx	AmiModel
tap4	-0.008
tap3	-.04
tap2	-.04
tap1	-.14
filter_on	False
DOUTP3	
bufferModelInverting	SAMPLE_TX
bufferModelNonInverti	SAMPLE_TX
sample_tx	AmiModel
filter_on	False
deemphasis	-3
SP6	

Channel Characteristic and Simulation Settings

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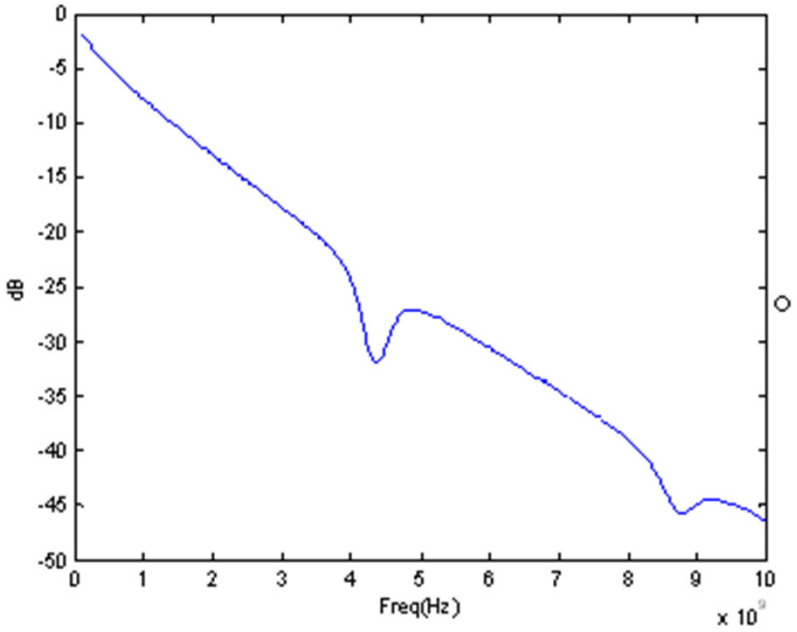

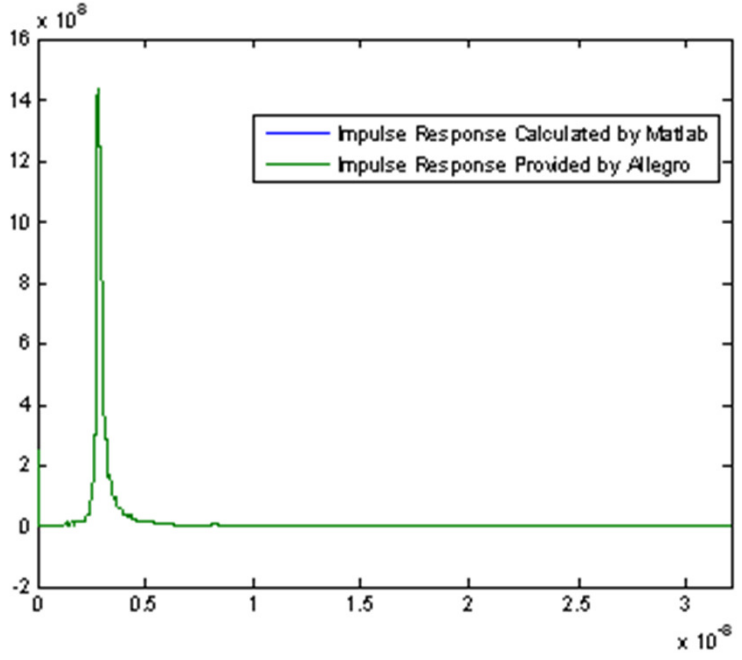

- The figure above is the magnitude of sdd21.
- The figure at above right is the impulse correlation between EDA tool and Matlab calculated from the step response which is obtained from EDA tool.
- Table at below right is the simulation settings.

Case	TX De-emphasis setting:	RX DFE setting:
Case 1	0dB (2 taps)	Off
Case 2	0dB (2 taps)	[0.2 0.05 -0.02 0.01]
Case 3	-3.5dB (2 taps)	Off
Case 4	-3.5dB (2 taps)	[0.1 -0.04 0.01 0.002]
Case 5	-6dB (2 taps)	Off
Case 6	-6dB (2 taps)	[0.05 -0.01 0.003 0.001]

Simulation Correlation Results

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Case No.		#1	#2	#3	#4	#5	#6
EDA tool	Vertical Eye:(mV)	0	181.8	128.3	249.9	275.1	295.5
	Horizontal Eye:(UI)	0	0.451	0.395	0.581	0.688	0.729
Matlab	Vertical Eye:(mV)	0	188	114	267	262	280
	Horizontal Eye:(UI)	0	0.478	0.393	0.556	0.707	0.721
Difference Ratio	Vertical Eye:(%)	0	3.41	12.54	6.40	5.00	5.54
	Horizontal Eye:(%)	0	5.99	0.51	1.07	2.76	1.11

EDA Tool Simulation results

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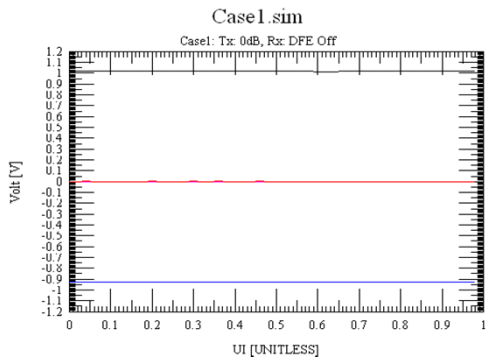
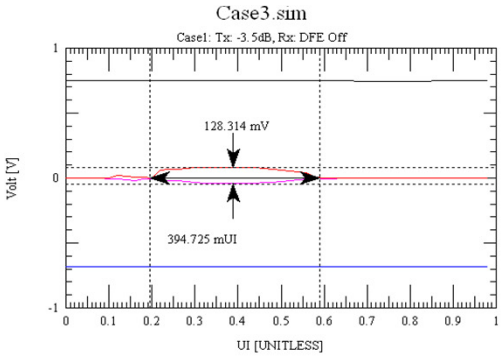
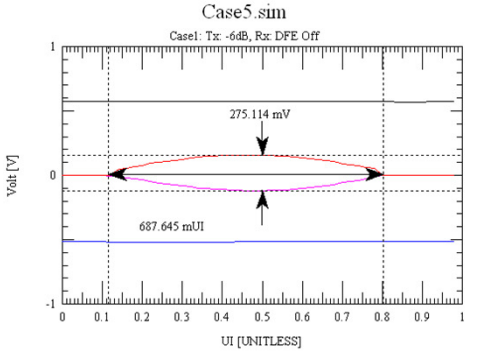


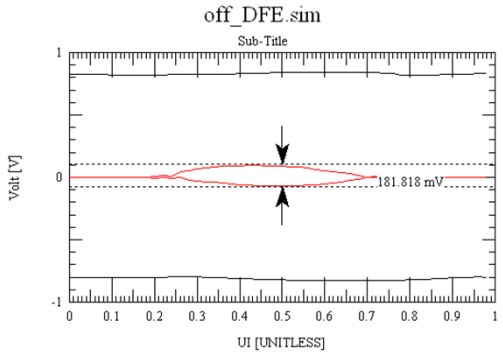
case1



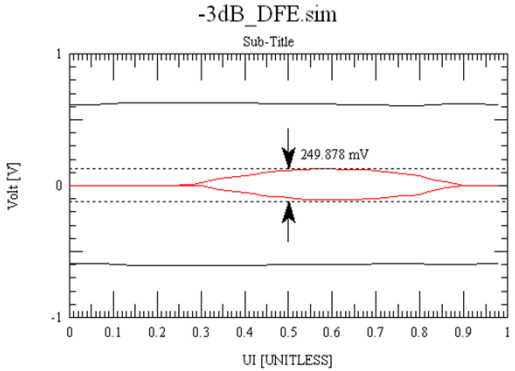
case3



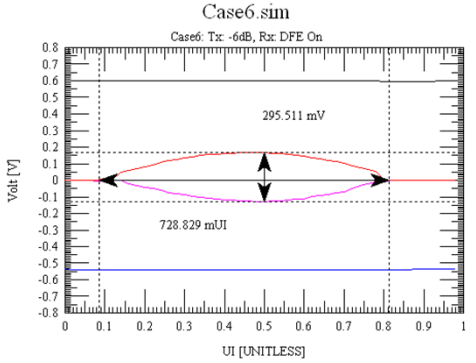
case5



case2



case4



case6

- The eye is closed when both de-emphasis and DFE are off, and the eye is much larger when the two equalization methods are applied.

Matlab Simulation results

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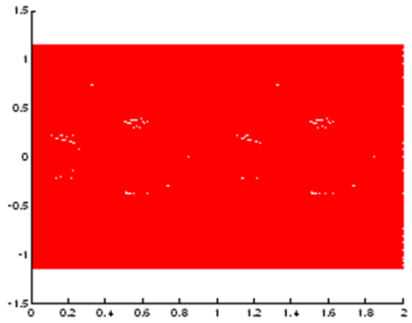
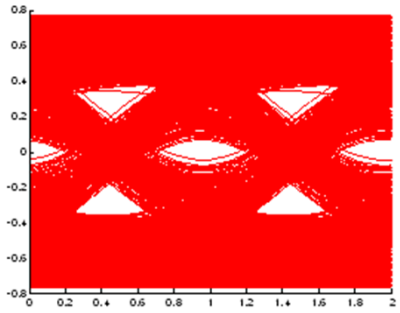
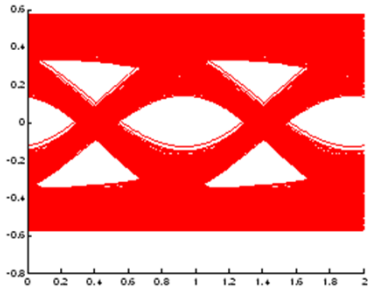


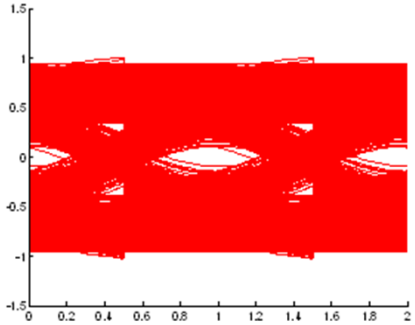
case1



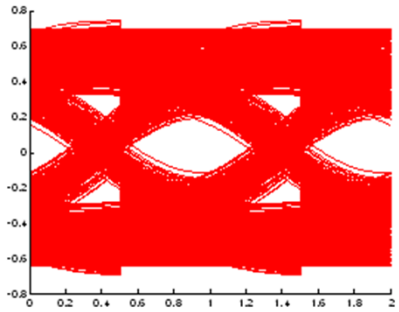
case3



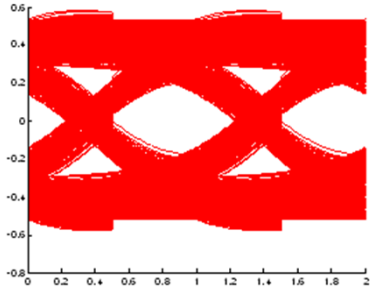
case5



case2



case4



case6

- The eye is closed when both de-emphasis and DFE are off, and the eye is much larger when the two equalization methods are applied. They are identical with the EDA tool simulation results.

Conclusion

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- This channel simulation platform based on Matlab is created, which can do system level high speed simulation with FFE, CTLE, DFE and jitter analysis.
- The simulation results show that channel simulation platform based on Matlab is aligned well with EDA tool, the difference is caused by the different seeds of PRBS and different rise/fall time definitions.
- The platform can not only be used to evaluate the performance of a Channel, but also to determine the capability of an equalizer when choosing the equalizer in system-level high speed design.

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Thanks!