Further analysis of synthesized 100G C2M short channels

Mark Kimber, Ed Frlan, Sameh Elnaggar, Bill Kirkland, Semtech

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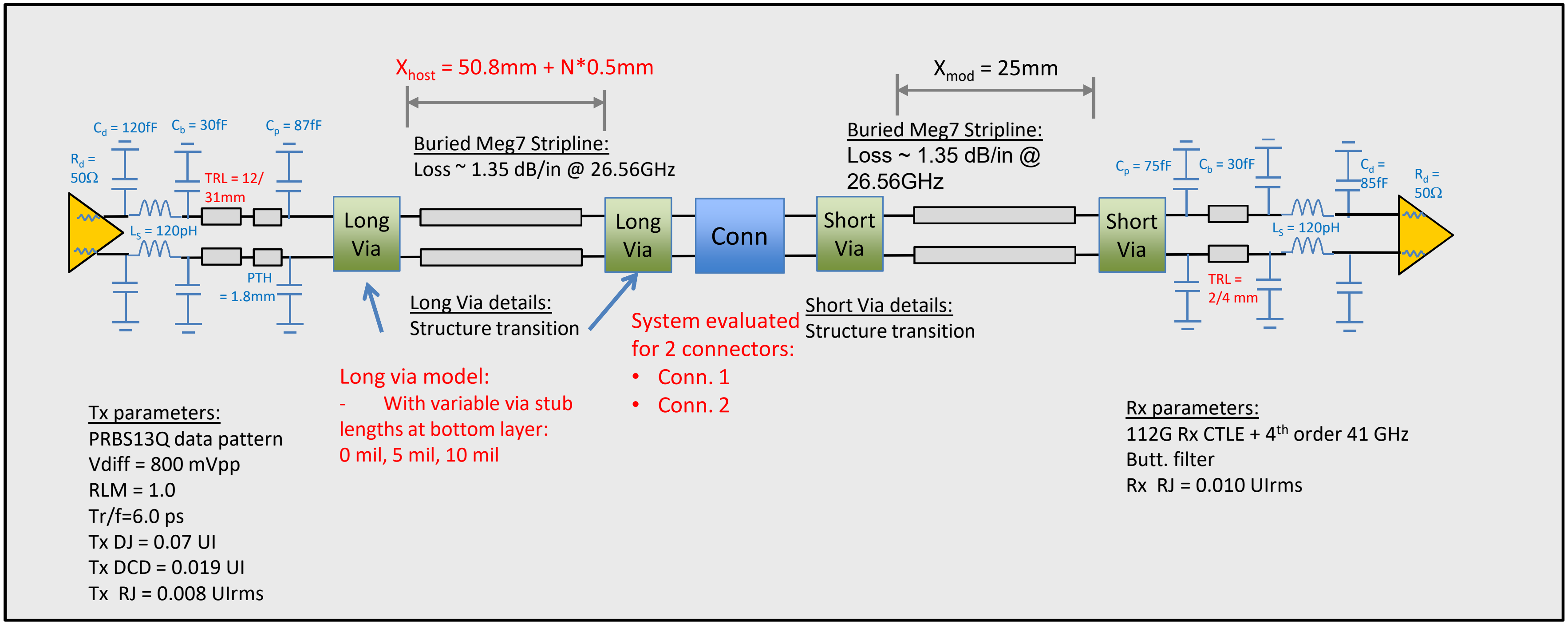
Overview

- Sameh 2” channel
  - System/channel descriptions
  - End-to-end channel simulations
- Lim 2” channel
  - Based on Channel 5a from lim_3ck_C2m_0731_adhoc
  - End-to-end channel simulations
- Observations on COM equalization for short channels

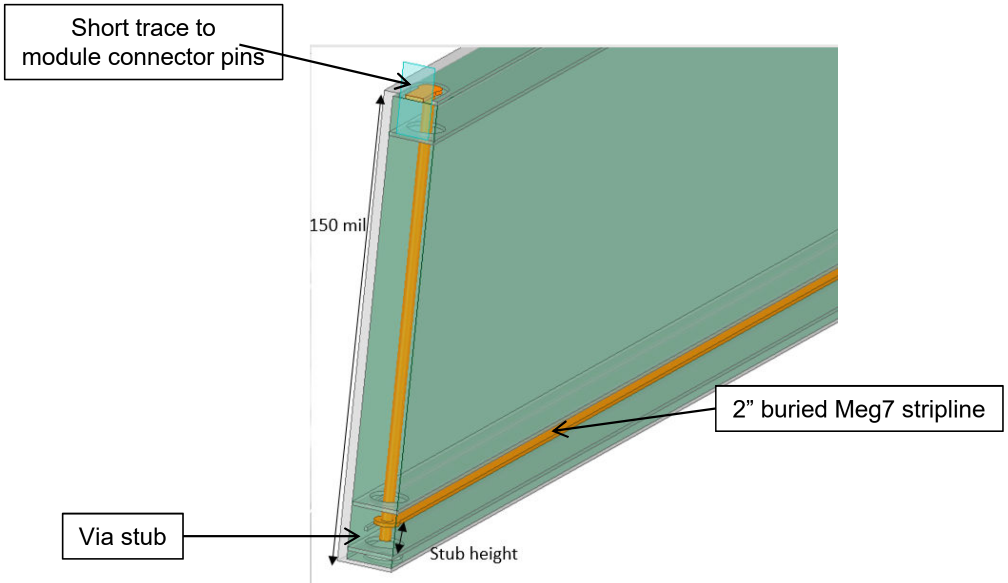
System/Channel description



- For this contribution system parameters that were adjusted included:
  - X_{host} trace lengths (adjusted in steps of 1mm around 2”)
  - Connector type (two main connector types, Conn. 1 and Conn. 2, resulted in overall System 1 and System 2 test benches)
- Items that were fixed for the moment included:
  - Host package TRL length = 12mm
  - Module CDR package TRL length = 2mm

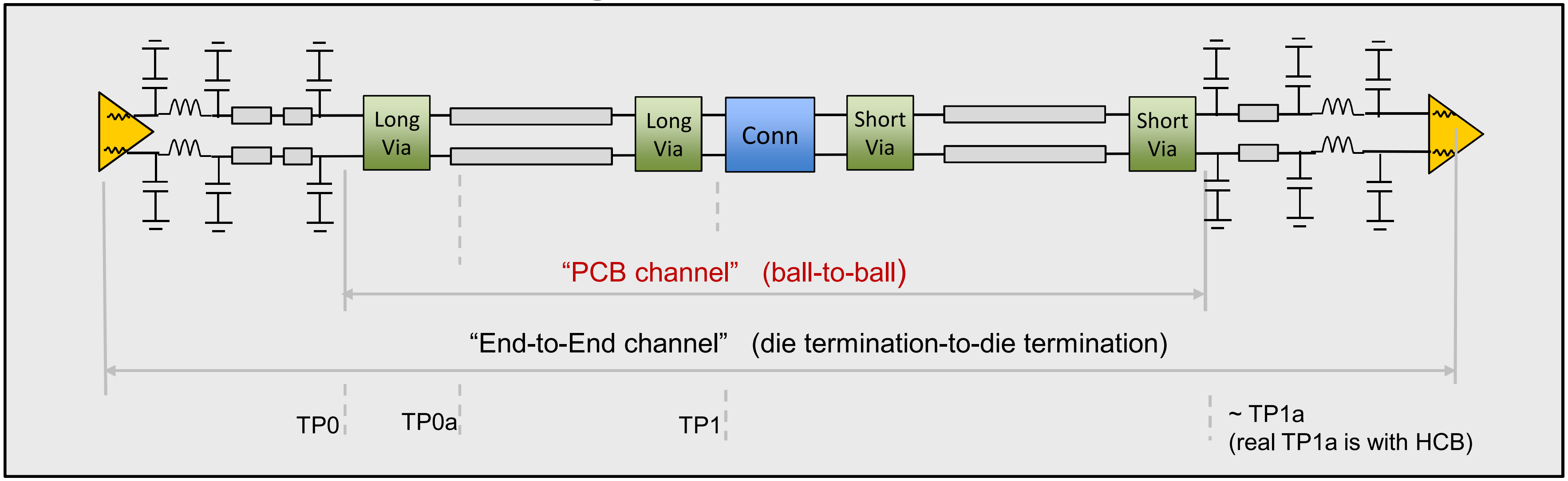
Sameh host via transition/trace model

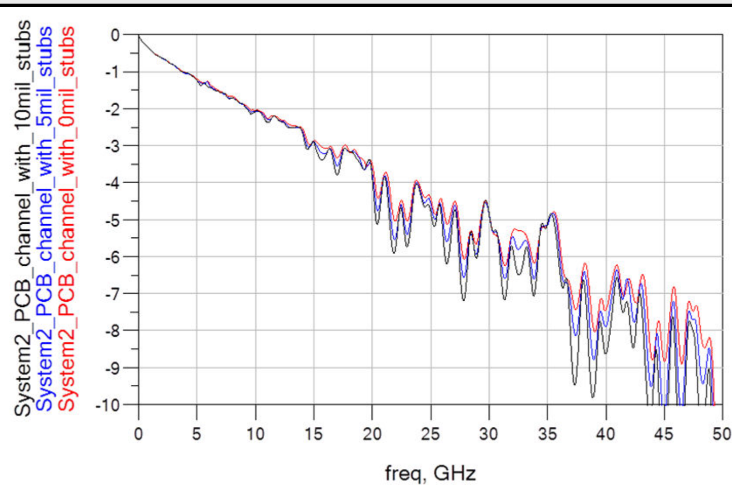
- Differential matched via host interconnect model



- Host interconnect consisted of Host long via + Megtron-7 buried stripline + connector long via + a very short trace on PCB primary to connector pins

Effect of long via stubs on “PCB channel”

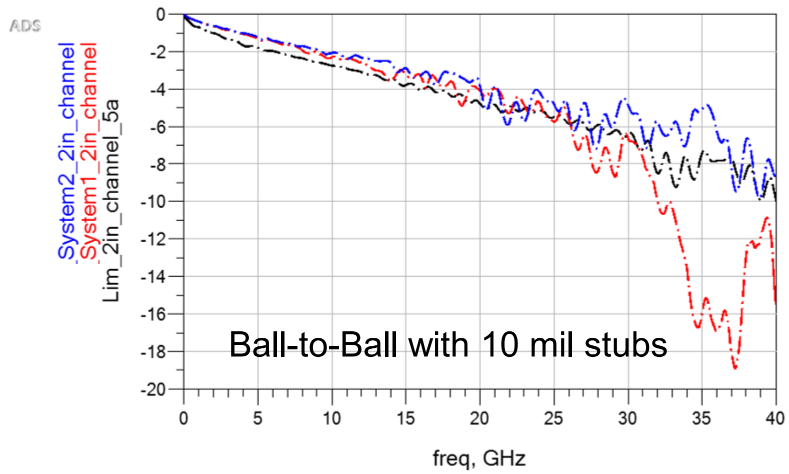


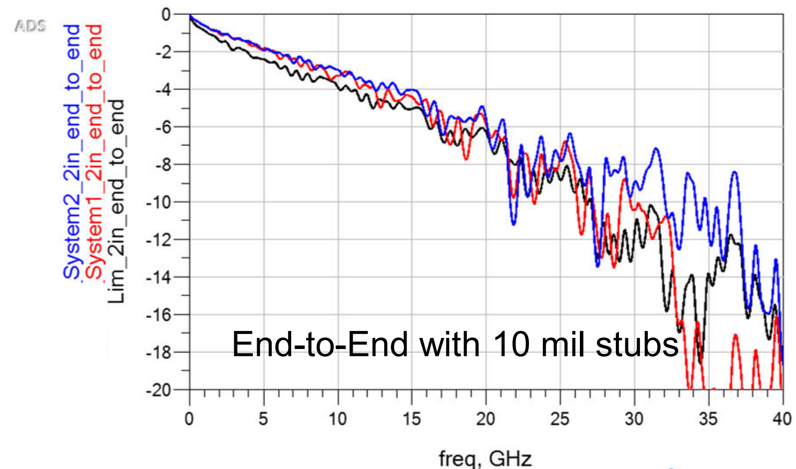


- “PCB channel” response as a function of long via stub lengths for System 2:
- Effect of via stub lengths is subtle when observed in the frequency domain but overall effect on system can be significant
- Shows up as an increased ILD penalty when capturing insertion loss curves (stubs up to 10mil are not long enough to create suck-outs in the channel)

Sameh channels

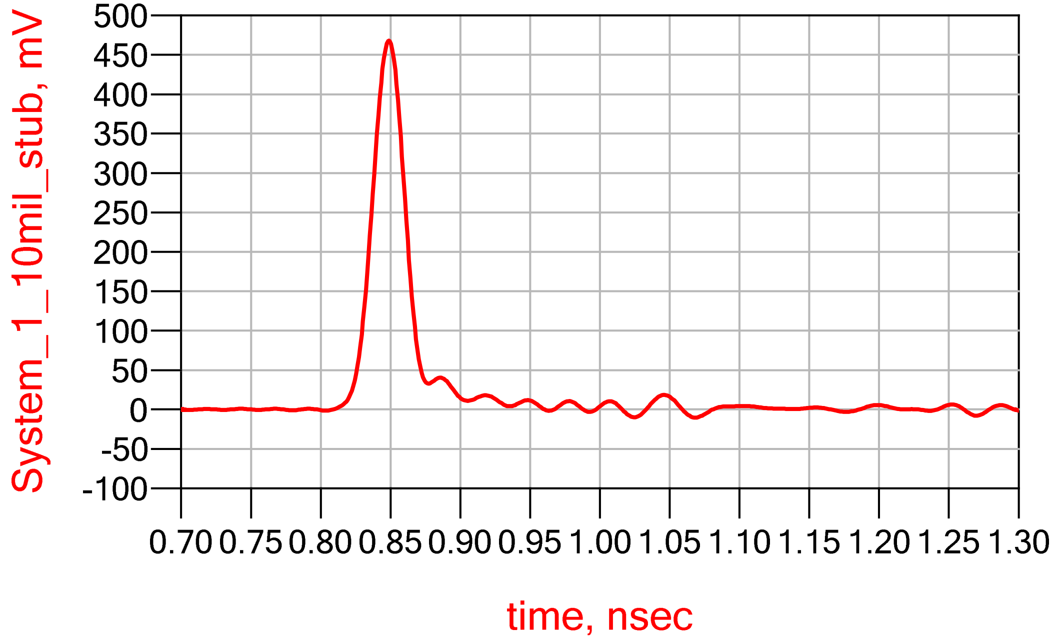
- First investigated end-to-end channels included the combination of a short host package (12mm TRL) with a short CDR package (2mm TRL)
- Various cases included host trace/via interconnect modeling based on HFSS for host lengths of approximately 2 inches and for long vias (150 mil) having stub lengths of 0, 5 and 10 mil
- Two different connectors were integrated into the channel resulting in ‘System 1’ and ‘System 2’
  - System 1 is a 50Gb/s class connector
  - System 2 is a 100Gb/s class connector
- As an example the ball-to-ball and end-to-end (i.e. including package and die effects) channel characteristics for the case of 10-mil via stubs:





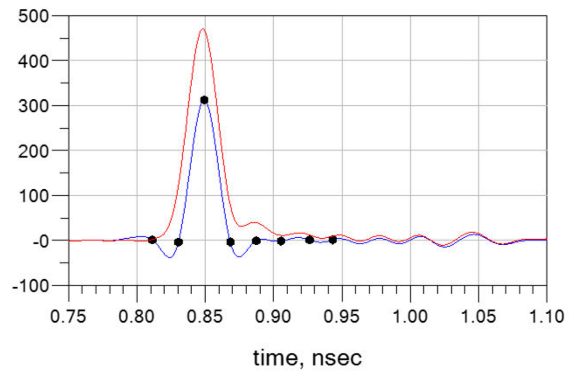
System 1 unequalized pulse responses

- System 1 end-to-end channel un-equalized pulse response with vias having 10-mil stubs



System 1 simulation results (1/4)

- End-to-end unequalized/equalized SBRs (0-mil via stub)

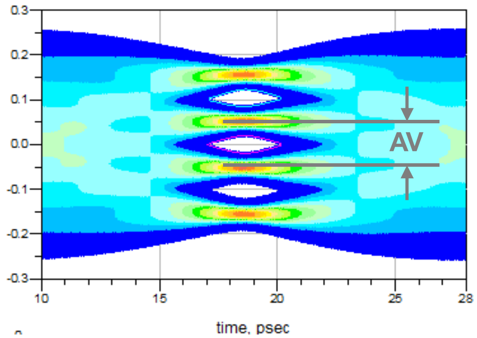


- Short channels do not require significant CTLE high-frequency peaking (i.e. large G_{DC} values)
  - CTLE was manually optimized
- 5-tap equalizer cannot deal with post-cursors in 5-11 UI range

Case	With crosstalk	Host trace length (inches)	Tx FFE [pre2, pre1, main, pst1]	CTLE G_{DC}, G_{DC2}	Rx FFE [main, pst1, pst2, pst3, pst4]
System 1	No	2	[0.04 -0.18 0.76 -0.02]	-2dB, -1.5dB	[1 -0.01 -0.04 0.01 0.00]

System 1 simulation results (2/4)

- For System 1 channel having 0-mil long via stub

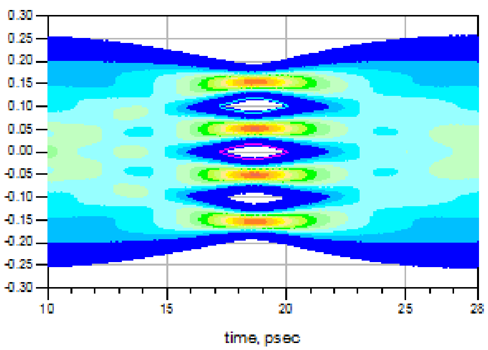


measurement	Summary
WidthAtBER0	3.106E-12
WidthAtBER1	3.200E-12
WidthAtBER2	3.106E-12
HeightAtBER0	0.039
HeightAtBER1	0.039
HeightAtBER2	0.039

AV = 104.2 mV
EH5 = 39 mV
EW5 = 0.165 UI
VEC = 8.54 dB
Equivalent 'COM' = 4.07 dB

Definitions:
VEO = EH5/AV
VEC = $20\log_{10}(1/VEO)$
COM = $20\log_{10}(1/(1-VEO))$

- For System 1 channel having 5-mil long via stub



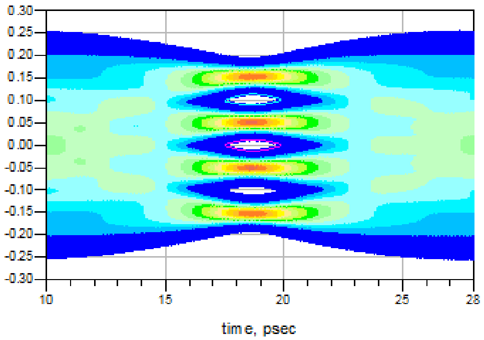
measurement	Summary
WidthAtBER0	2.918E-12
WidthAtBER1	2.918E-12
WidthAtBER2	2.918E-12
HeightAtBER0	0.033
HeightAtBER1	0.033
HeightAtBER2	0.033

AV = 104.2 mV
EH5 = 33 mV
EW5 = 0.155 UI
VEC = 9.99 dB
Equivalent 'COM' = 3.31 dB

- *Note: All quoted 'COM' values in this presentations are those based on ADS simulation results according to the above definition.*

System 1 simulation results (3/4)

- For System 1 channel having 10-mil long via stub



measurement	Summary
WidthAtBER0	2.447E-12
WidthAtBER1	2.447E-12
WidthAtBER2	2.447E-12
HeightAtBER0	0.025
HeightAtBER1	0.026
HeightAtBER2	0.025

AV = 104.2 mV
EH5 = 26 mV
EW5 = 0.130 UI
VEC = 12.06 dB
'COM' = 2.49 dB

System	With crosstalk	Host trace length (inches)	Host via stub length (mils)	VEC (dB)	EH5 (mV)	EW5 (UI)	'COM' (dB)
System 1	No	2	0	8.54	39	0.165	4.07
System 1	No	2	5	9.99	33	0.155	3.31
System 1	No	2	10	12.06	26	0.130	2.49

- System performance is quite sensitive to via stub length
- 10-mil via stubs have significant impact in System 1

System 1 varying host trace lengths (4/4)

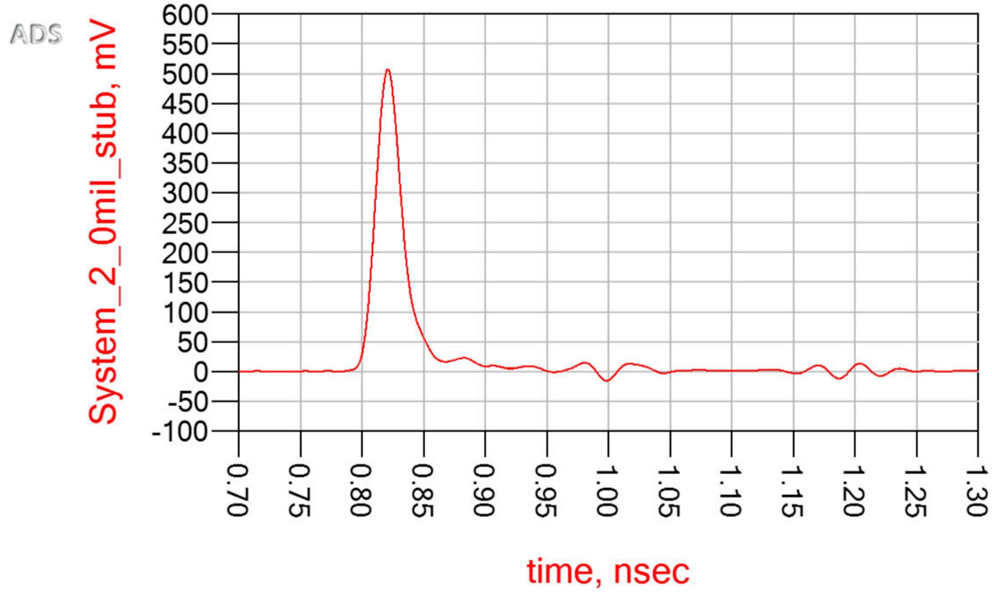
- Varying System 1 host trace lengths in steps of 1mm for the 5-mil via stub case we get the following

System	With crosstalk	Host trace length (mm)	Host via stub length (mils)	VEC (dB)	EH5 (mV)	EW5 (UI)	'COM' (dB)
System 1	No	47.8	5	9.48	35	0.160	3.56
System 1	No	48.8	5	8.99	37	0.165	3.81
System 1	No	49.8	5	9.73	34	0.155	3.43
System 1	No	50.8 (2.0")	5	9.99	33	0.155	3.31
System 1	No	51.8	5	10.25	32	0.155	3.19
System 1	No	52.8	5	9.23	36	0.160	3.68
System 1	No	53.8	5	9.73	34	0.160	3.43

- Variability
  - VEC: 9 - 10.3 dB
  - EH5: 32 - 37 mV
  - COM: 3.3 – 3.8 dB
- Some variability in performance is observed as a function of host trace length, but does not appear significant

System 2 unequalized pulse responses

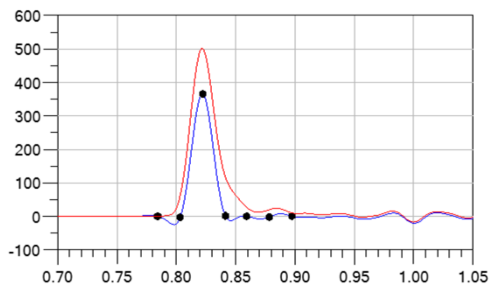
- System 2 end-to-end channel un-equalized pulse response with vias having 10-mil stubs



- System 2 shows significantly less ringing than System 1 in region within several UI of main cursor
- > 10 UI from the main cursor both systems have a similar profile

System 2 simulation results (1/4)

- End-to-end unequalized/equalized SBRs (0-mil via stub)



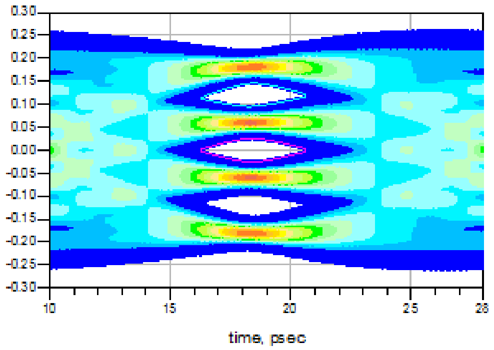
- System 2 does not require high CTLE gain settings either

Case	With crosstalk	Host trace length (inches)	Tx FFE [pre2, pre1, main, pst1]	CTLE G_{DC}, G_{DC2}	Rx FFE [main, pst1, pst2, pst3, pst4]
System 1	No	2	[0.01 -0.09 0.87 -0.02]	-3dB, -2dB	[1 -0.02 0.03 -0.01 0.01]

- Also, Rx FFE post-taps 3 and 4 are not doing much work

System 2 simulation results (2/4)

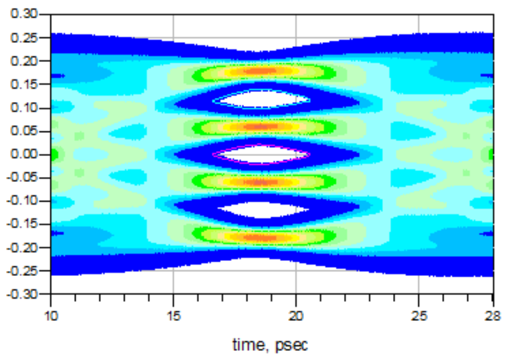
- For System 2 channel having 0-mil long via stub



measurement	Summary
WidthAtBER0	4.424E-12
WidthAtBER1	4.424E-12
WidthAtBER2	4.424E-12
HeightAtBER0	0.051
HeightAtBER1	0.051
HeightAtBER2	0.051

AV = 119.6 mV
EH5 = 51 mV
EW5 = 0.235 UI
VEC = 7.40 dB
'COM' = 4.83 dB

- For System 2 channel having 5-mil long via stub

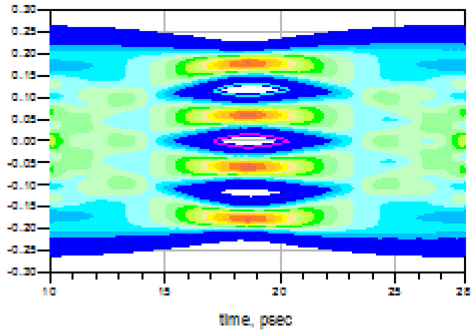


measurement	Summary
WidthAtBER0	4.047E-12
WidthAtBER1	4.047E-12
WidthAtBER2	4.047E-12
HeightAtBER0	0.042
HeightAtBER1	0.042
HeightAtBER2	0.042

AV = 119.6 mV
EH5 = 42 mV
EW5 = 0.215 UI
VEC = 9.09 dB
'COM' = 3.76 dB

System 2 simulation results (3/4)

- <u>For System 2 channel having 10-mil long via stub</u>



measurement	Summary
WidthAtBER0	3.294E-12
WidthAtBER1	3.294E-12
WidthAtBER2	3.294E-12
HeightAtBER0	0.028
HeightAtBER1	0.029
HeightAtBER2	0.028

AV = 119.6 mV
EH5 = 28 mV
EW5 = 0.175 UI
VEC = 12.61 dB
'COM' = 2.32 dB

- Summary:

System	With crosstalk	Host trace length (inches)	Host via stub length (mils)	VEC (dB)	EH5 (mV)	EW5 (UI)	COM (dB)
System 2	No	2	0	7.40	51	0.235	4.83
System 2	No	2	5	9.09	42	0.215	3.76
System 2	No	2	10	12.61	28	0.175	2.32

- System performance is very sensitive to via stub length
- 10-mil via stubs have significant impact in System 2 as well

System 2 varying host trace lengths (4/4)

- Varying System 2 host trace lengths in steps of 1mm for the 5-mil via stub case we get the following

System	With crosstalk	Host trace length (mm)	Host via stub length (mils)	VEC (dB)	EH5 (mV)	EW5 (UI)	'COM' (dB)
System 2	No	47.8	5	9.51	40	0.205	3.54
System 2	No	48.8	5	9.09	42	0.210	3.76
System 2	No	49.8	5	8.69	44	0.225	3.98
System 2	No	50.8 (2.0")	5	8.54	42	0.215	3.76
System 2	No	51.8	5	9.09	42	0.220	3.76
System 2	No	52.8	5	9.51	40	0.210	3.54
System 2	No	53.8	5	8.49	45	0.225	4.10

- Variability
  - VEC: 8.5 – 9.5 dB
  - EH5: 40 - 45 mV
  - COM: 3.5 – 4.1 dB
- Similar variability as for system 1 where excessive excursions in performance are not evident
- End-to-End channel with 5 mil stubs appears to reasonably behaved
- Further work required to model End-to-End behaviour for the case with 10-mil via stubs

Comparison of Systems 1 and 2

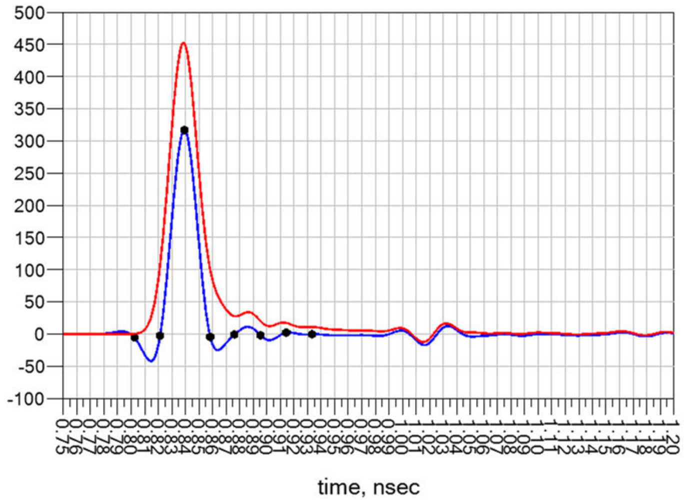
System	With crosstalk	Host trace length (inches)	Host via stub length (mils)	VEC (dB)	EH5 (mV)	EW5 (UI)	'COM' (dB)
System 1	No	2	0	8.54	39	0.165	4.07
System 1	No	2	5	9.99	33	0.155	3.31
System 1	No	2	10	12.06	26	0.130	2.49
System 2	No	2	0	7.40	51	0.235	4.83
System 2	No	2	5	9.09	42	0.215	3.76
System 2	No	2	10	12.61	28	0.175	2.32

- For 0-mil and 5-mil via stubs System 2 provides significantly better eye height metrics
- In all cases System 2 provides significantly more horizontal eye opening (this is extremely important in real systems!!)
- In either case 10-mil via stubs provide similar EH5 eye openings

- Further work required to model additional eye closure due to system crosstalk

Lim 2” end-to-end simulation results (1/2)

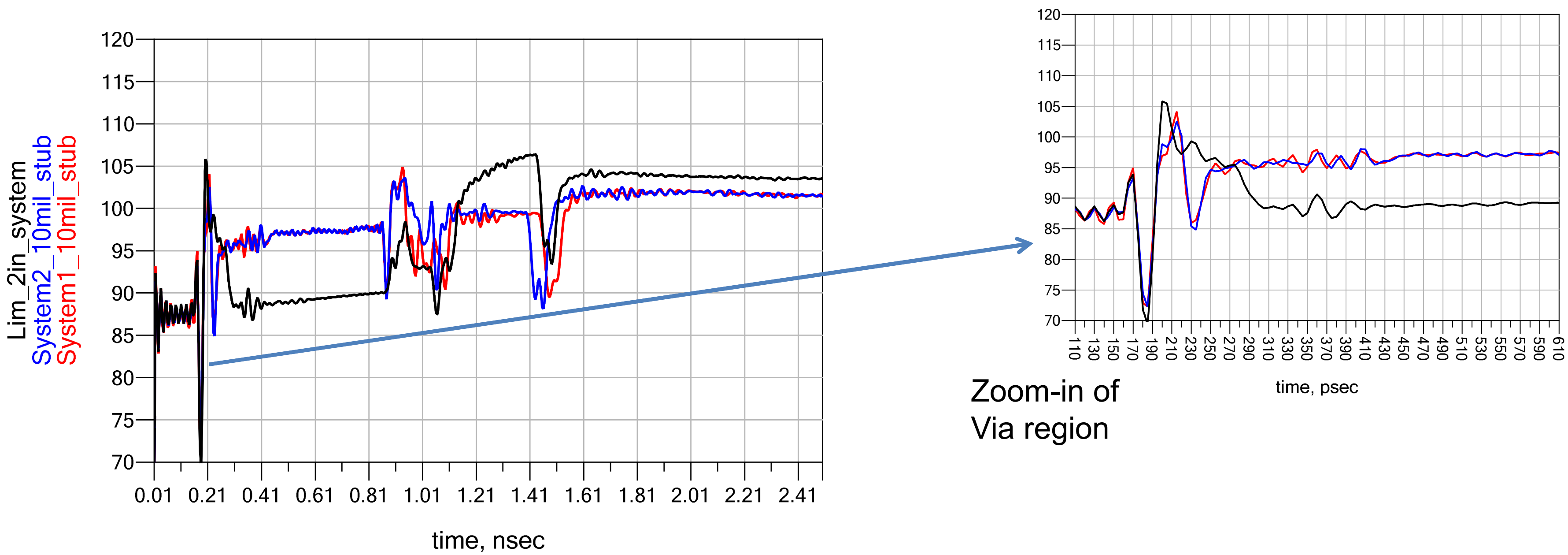
- End-to-end unequalized/equalized SBRs for Lim 2” channel with 12mm host package and 2mm CDR package



Case	With crosstalk	Host trace length (inches)	Tx FFE [pre2, pre1, main, pst1]	CTLE G_{DC}, G_{DC2}	Rx FFE [main, pst1, pst2, pst3, pst4]
Lim 2” end-to-end channel	No	2	[0.02 -0.17 0.80 -0.01]	-2dB, -2dB	[1 -0.08 0.02 -0.02 0.00]

- Also, Rx FFE post-taps 2 through 4 are not doing much work

Comparison of System 1, System 2 and Lim 2” system TDR responses

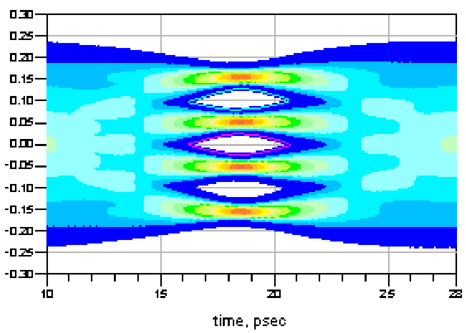


- The level of the 10-mil via transition impedance discontinuities between the Lim and Sameh System 1/2 channels are very similar
- Sameh host trace channel impedance is ~ 97Ω whereas Lim is ~ 88Ω

Lim 2” end-to-end simulation results (1/4)

- <u>Lim 2” channel using ‘Ed’ derived equalization parameters (see Backup section for more details)</u>

Case	With crosstalk	Tx FFE [pre2, pre1, main, pst1]	CTLE G_{DC}, G_{DC2}	Rx FFE [main, pst1, pst2, pst3, pst4]
Lim 2”	No	[0.02 -0.17 0.80 -0.01]	-2dB, -2dB	[1 -0.08 0.02 -0.02 0.00]



AV = 103.6 mV
EH5 = 47 mV
EW5 = 0.235 UI
VEC = 6.87 dB
Equivalent ‘COM’ = 5.25 dB

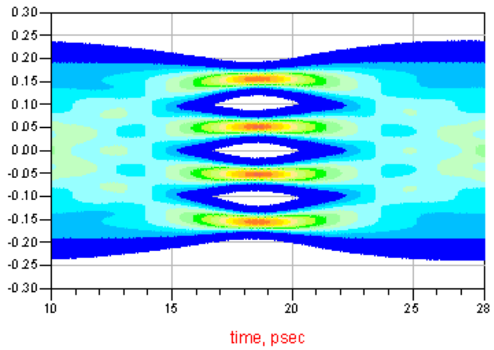
measurement	Summary
WidthAtBER0	4.424E-12
WidthAtBER1	4.518E-12
WidthAtBER2	4.424E-12
HeightAtBER0	0.047
HeightAtBER1	0.048
HeightAtBER2	0.047

System	With crosstalk	VEC (dB)	EH5 (mV)	EW5 (UI)	‘COM’ (dB)
Lim 2” end-to-end channel (‘Ed’ equal)	No	6.87	47	0.235	5.25

- Lim 2” channel performance is similar to System 2 with 0-mil via stubs

Lim 2” end-to-end simulation results (2/4)

- Lim 2” channel using ‘Ed’ derived equalization parameters with crosstalk



AV = 103.6 mV
EH5 = 38 mV
EW5 = 0.210 UI
VEC = 8.71 dB
‘COM’ = 3.97 dB

measurement	Summary
WidthAtBER0	3.953E-12
WidthAtBER1	4.047E-12
WidthAtBER2	3.953E-12
HeightAtBER0	0.038
HeightAtBER1	0.039
HeightAtBER2	0.038

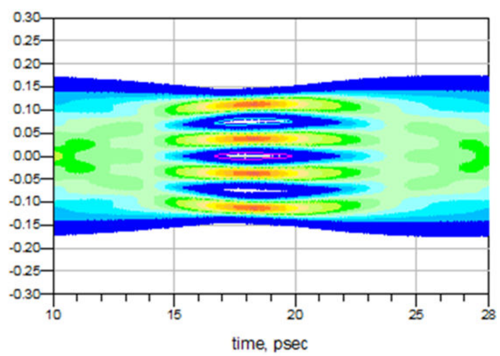
System	With crosstalk	VEC (dB)	EH5 (mV)	EW5 (UI)	‘COM’ (dB)
Lim 2” end-to-end channel (‘Ed’ equal)	Yes	8.71	38	0.210	3.97

- Lim 2” end-to-end performance with crosstalk (using ‘Ed’ equalization settings) increases VEC by almost 2dB

Lim 2” end-to-end simulation results (3/4)

- <u>Lim 2” channel using ‘COM’ derived equalization parameters with crosstalk</u>

Case	With crosstalk	Tx FFE [pre2, pre1, main, pst1]	CTLE G_{DC}, G_{DC2}	Rx FFE [main, pst1, pst2, pst3, pst4]
Lim 2” (using COM equal)	Yes	[0.01 -0.12 0.82 -0.05]	**-9dB**, -1dB	[1 0.2061 0.1149 0.0196 0.0047]



AV = 75 mV
EH5 = 13 mV
EW5 = 0.175 UI
VEC = 15.22 dB
‘COM’ = 1.65 dB

measurement	Summary
WidthAtBER0	3.294E-12
WidthAtBER1	3.294E-12
WidthAtBER2	3.294E-12
HeightAtBER0	0.013
HeightAtBER1	0.014
HeightAtBER2	0.013

System	With crosstalk	VEC (dB)	EH5 (mV)	EW5 (UI)	‘COM’ (dB)
Lim 2” end-to-end channel (COM equal)	Yes	15.22	13	0.175	1.65

- Lim 2” system equalized using COM settings is not optimal

Lim 2” end-to-end simulation results (4/4)

- Summary

System	With crosstalk	VEC (dB)	EH5 (mV)	EW5 (UI)	‘COM’ (dB)
Lim 2” end-to-end channel (using ‘Ed’ equalization)	No	6.87	47	0.235	5.25
Lim 2” end-to-end channel (using ‘Ed’ equalization)	Yes	8.71	38	0.210	3.97
Lim 2” end-to-end channel (using COM equalization)	Yes	15.22	13	0.175	1.65

Summary

- 10-mil via stubs do impact system performance (creates ILD plus other penalties)
- Connectors with higher performance can show similar or worse overall system margins due to the effect of host via transitions
- It is recommended that smaller CTLE equalization settings be used to equalize short channels
  - COM appears to optimize with maximum CTLE and then the other equalizer has to undo most of it
  - Eye height can be significantly improved but at the expense of a small additional amount of VEC!

- Future work:
  - Short channel analysis for packages other than 12mm host and 2mm CDR
  - System benefit of possible via tuning approaches
  - Inclusion of Crosstalk penalty for the Sameh System 1 and 2 channels

Backup

Comment on COM equalization (1/2)

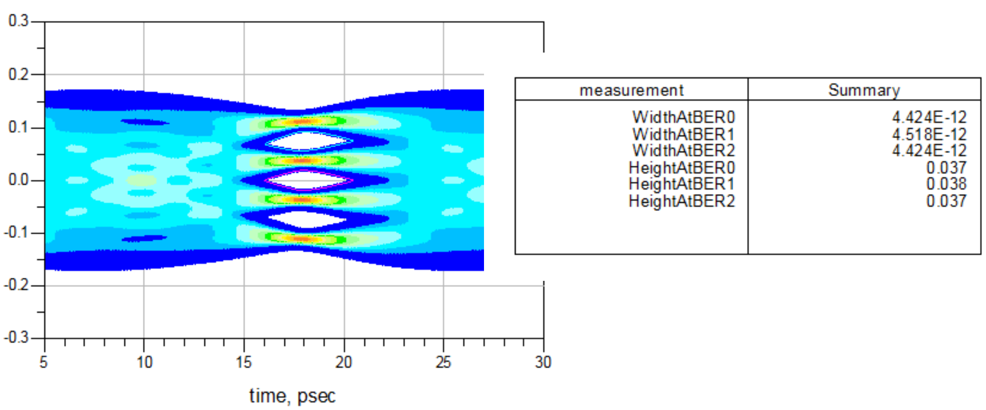
- COM optimizes channel equalization based strictly on SNR
  - VEO can go down to very small voltages
  - For typical short 2” channels having ~ 10dB loss at Nyquist frequency COM will optimize to higher CTLE gain settings (e.g. 9dB)
  - C2M TP1a is not only about VEC (or COM) but also meeting the EH5 requirement
  - Significantly smaller CTLE settings will create pulse responses with larger peaks at a small expense in COM margin

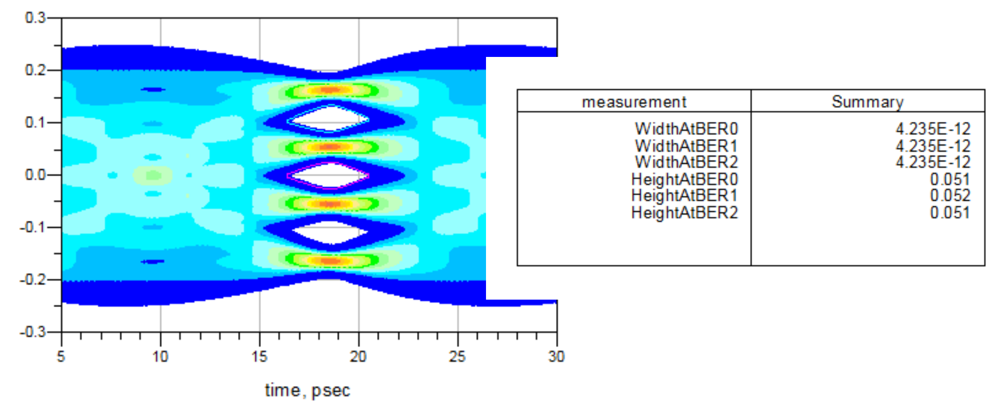
- For example equalizing the Lim 2” channel (no crosstalk aggressors) can lead to two scenarios
  - Case 1. Channel equalization based on COM’s optimized settings
  - Case 2. Channel equalization based on lower CTLE gain settings in order to maintain signal swing

Comment on COM equalization (2/2)

- For example using Lim 2" channel with 12mm host package and 2mm CDR package end-to-end as an example we have the following:

Case	Tx FFE [pre1, main, pst1]	CTLE G_{DC}, G_{DC2}	Rx FFE [main, pst1, pst2, pst3, pst4]
1 – COM derived equalizer settings	[-0.12 0.83 -0.05]	**-9dB**, -1dB	[1 0.2061 0.1149 0.0196 0.0047]
2 – Ed derived equalizer settings	[-0.16 0.84 -0.00]	**-2dB**, -2dB	[1 -0.08 0.02 -0.02 0.00]





Case 1 – COM settings

AV = 75.2 mV
EH5 = 38 mV
VEC = 5.93 dB
COM = 6.11 dB

Case 2 – 'Ed' settings

AV = 108 mV
EH5 = 52 mV
VEC = 6.35 dB
COM = 5.70