200G PAM4 per Lane C2M Channel Technical Feasibility

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KEYSIGHT TECHNOLOGIES

200G PAM4 C2M Technical Feasibility

Contributors and Supporters

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200G PAM4 C2M Technical Feasibility

Objectives

- Determine the C2M Channel Technical Feasibility Using COM
- The purpose of this presentation is NOT to offer “the” solution
- The intention is to OPEN the conversation and identify the variables that will need to be adjusted to arrive at a solution
- It will be shown that incremental changes to the .ck project parameters may not be enough and that a more thorough alternative will be necessary.
  - ❖ COMPREHENSIVE rather than INCREMENTAL solution

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C2M Channel Highlights

- Traditional Topology, i.e., medium PCB material between ASIC and Connector
  - ❖ Short Channel - Ex. NIC card
- Short Host Channel – IL ~ 7 dB @ Nyquist
- Channel with IMPAIRMENTS
  - ❖ ASIC/Connector vias/Insert module finger transition
  - ❖ Layout Turns
  - ❖ Skew Compensation
  - ❖ Full Channel Crosstalk
- MDI is an OSFP Connector
- Assume ASIC Parallel Fan-Out
- Two HCB losses 2.5 dB and 4.0 dB @ Nyquist
- COM rev. 3.4

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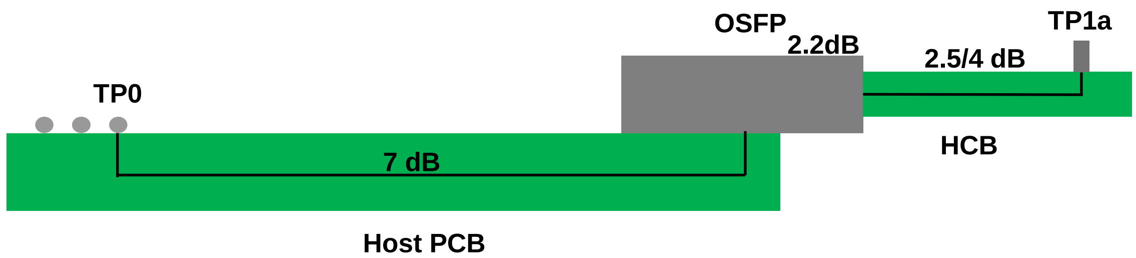
Structure View & Insertion Losses



- **Vias = 40 mil long**
- **Blind Vias**
- **Frequency Sweep Range = 10 MHz to 120 GHz**

IL @ Nyquist (53.125 GHz)

IL_{HCB} = 2.5 dB	IL_{HCB} = 4 dB
• IL_{PCB} = 7 dB	• IL_{PCB} = 7 dB
• IL_{Conn} = 2.2 dB	• IL_{Conn} = 2.2 dB
• IL_{HCB} = 2.5 dB	• IL_{HCB} = 4 dB
• IL_{C2M} = 11.4 dB	• IL_{C2M} = 12.9 dB

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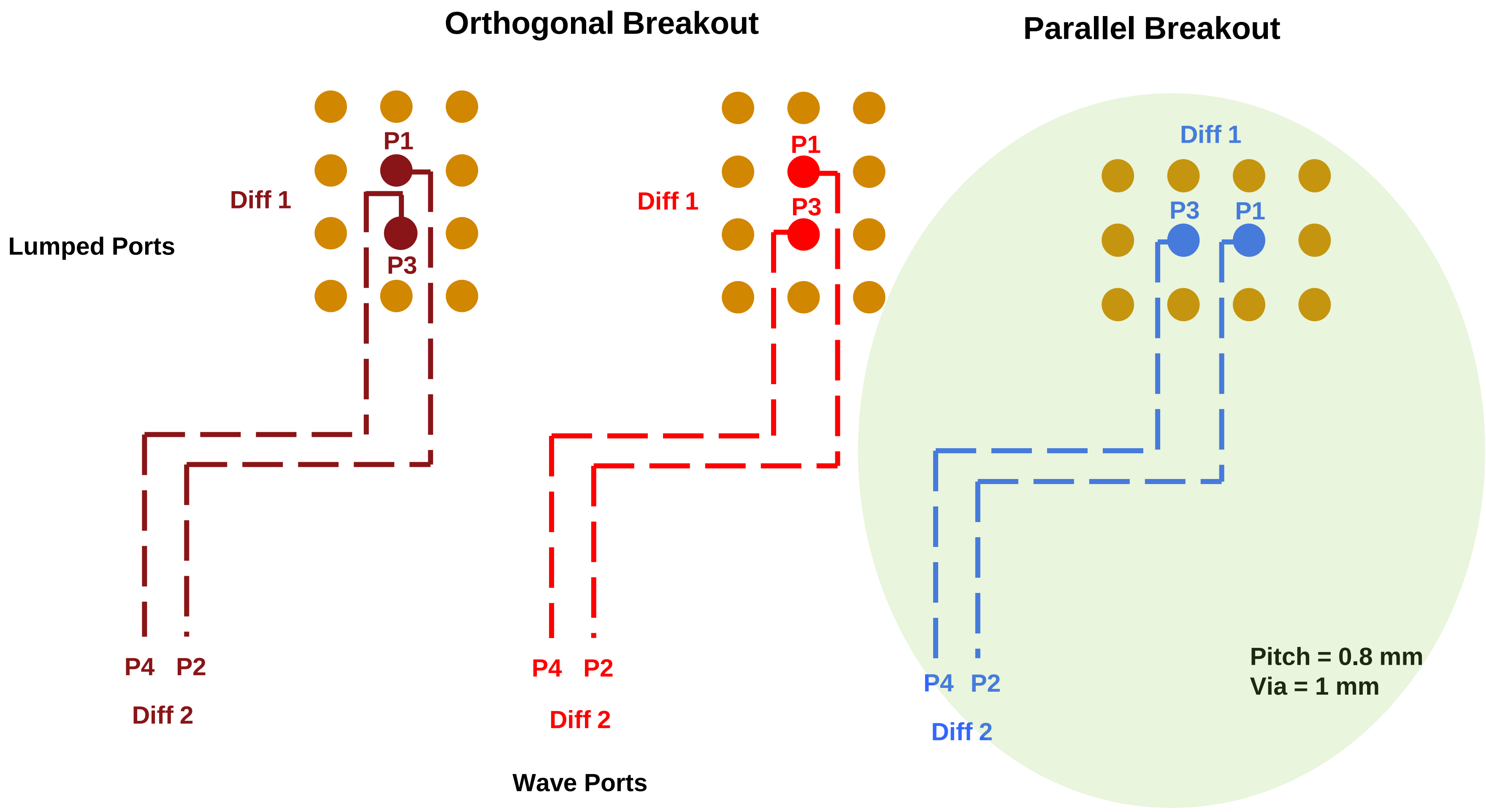
Orthogonal vs. Parallel Fanouts



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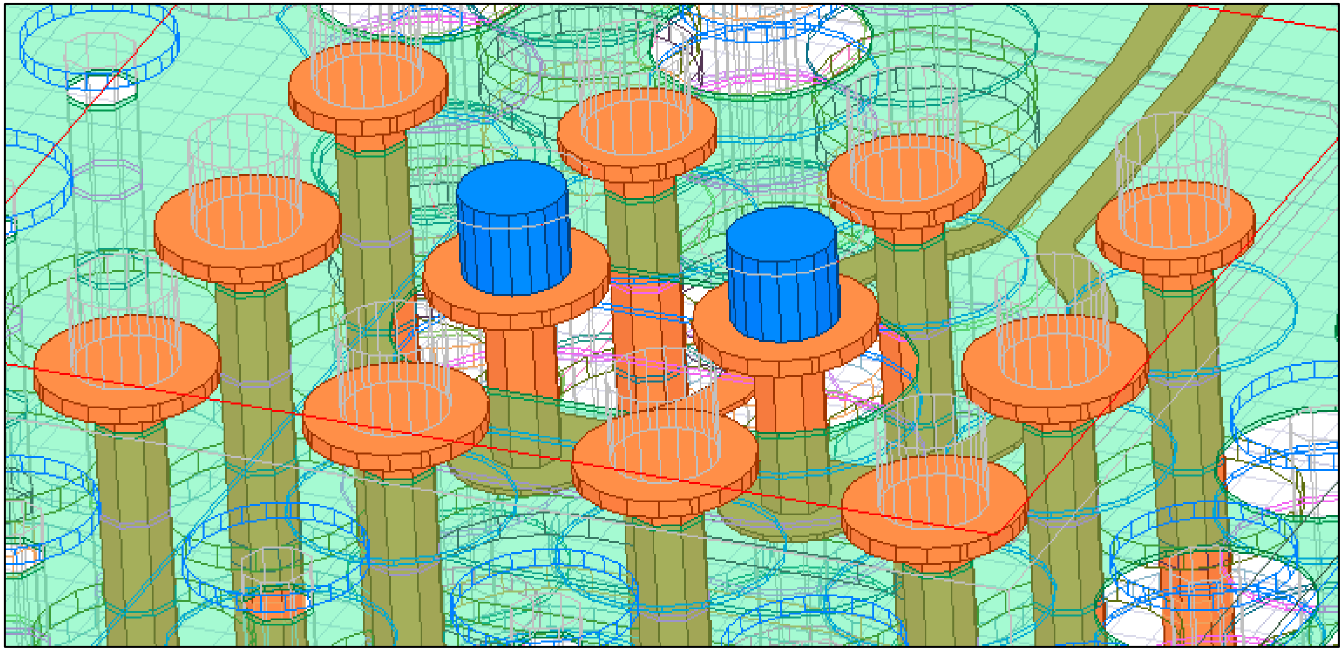
ASIC Ball Model Example



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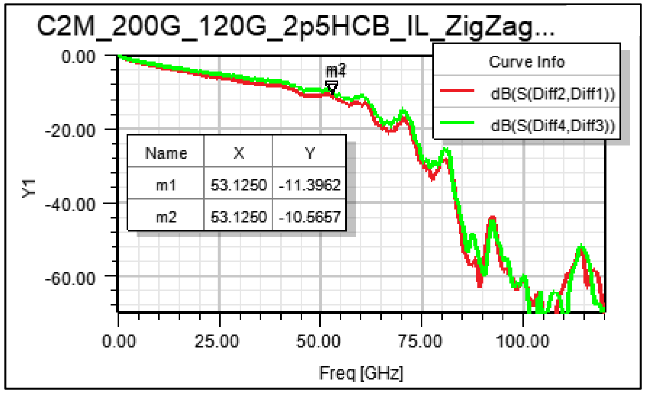
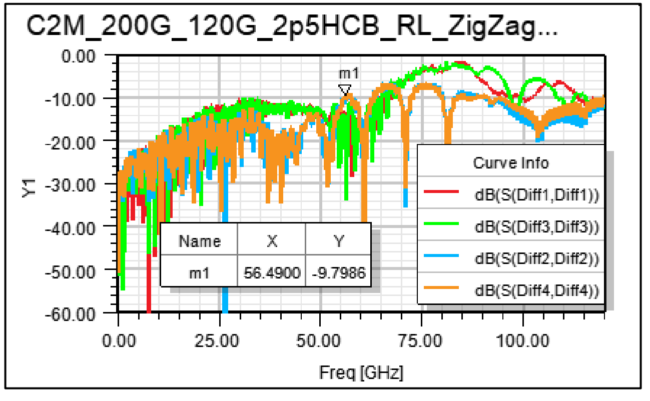
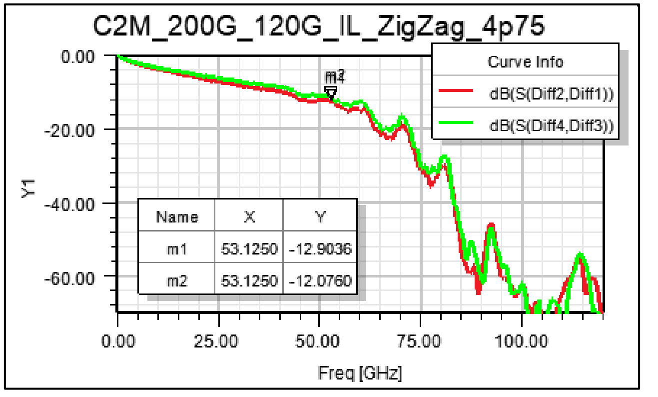
IL/RL Performance

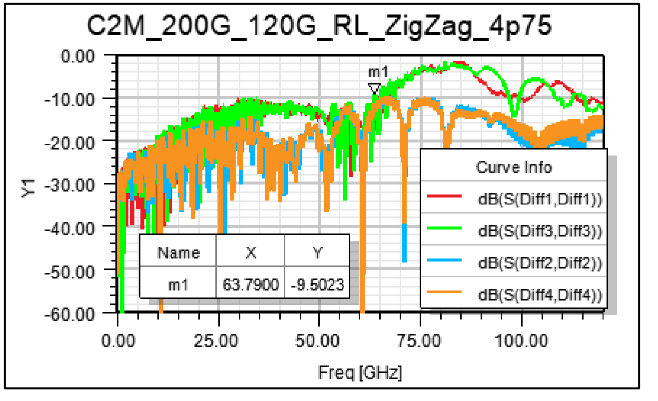
IL_{HCB} = 2.5 dB





IL_{HCB} = 4 dB





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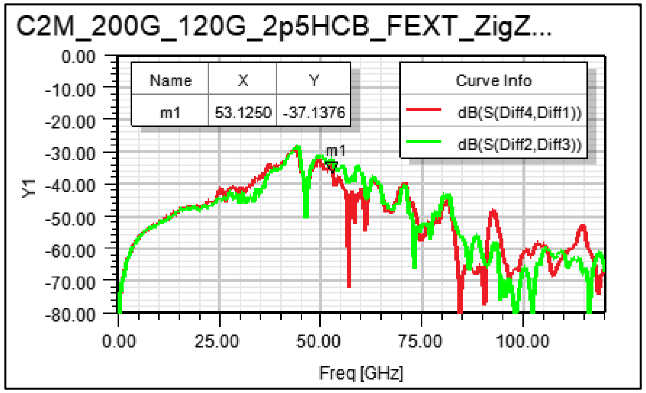
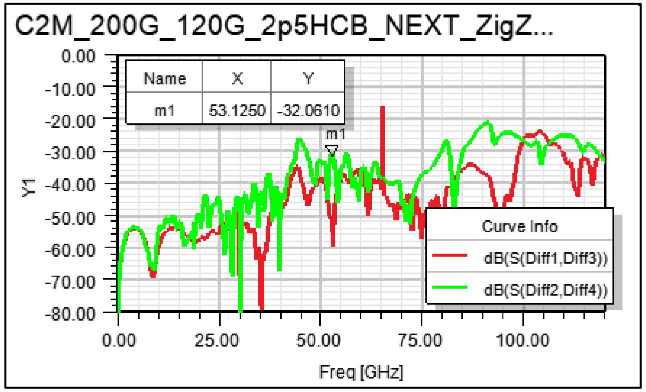
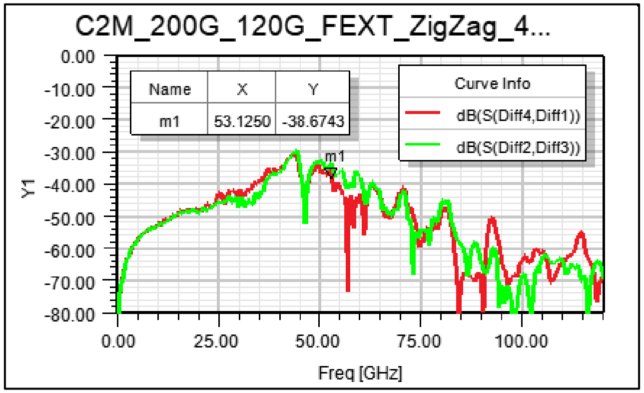
FEXT/NEXT Performance

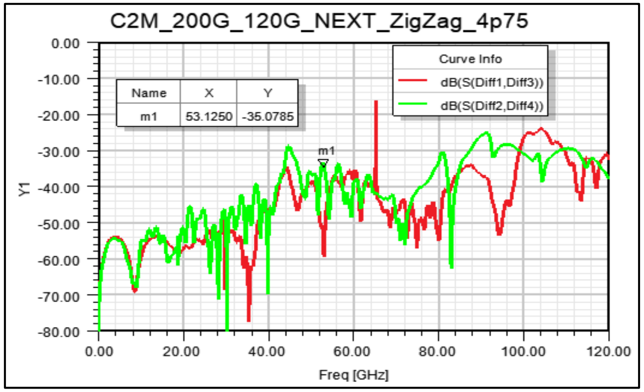
IL_{HCB} = 2.5 dB





IL_{HCB} = 4 dB





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COM Results – “Incremental” Changes

	P802.3.ck	P802.3df
f_b	53.125	106
C_d	[1.2e-4 0]	[0.7e-4 , 0]
L_s	[0.12 0]	[0.1,0]
C_b	[0.3e-4 0]	[0.23e-4 0]
N_b	4	9
eta_0	4.10E-08	4.10E-09
SNR_TX	32.5	33
package_tl_gamma0_a1_a2	[0 0.0009909 0.0002772]	[0 0.000644085 0.00018018]
package_tl_tau	6.141E-03	0.0057
package_Z_c	[87.5 87.5 ; 92.5 92.5]	[87.5 87.5 ; 92.5 92.5]

IL_{HCB} = 2.5 dB

COM r3.40 results

: Case 1: z_p=(15:1.8, 0:0, 0:0, 15:1.8) (TX, RX, NEXT, FEXT):
: EH = 6.170 mV (FAIL)
: VEC = 18.041 dB (FAIL)
: FAIL ... ERL = 9.712 dB (NaN dB,9.712 dB)
: Case 2: z_p=(31:1.8, 0:0, 0:0, 31:1.8) (TX, RX, NEXT, FEXT):
: EH = 6.880 mV (FAIL)
: VEC = 14.833 dB (FAIL)
: FAIL ... ERL = 9.712 dB (NaN dB,9.712 dB)

OK

1 FEXT

IL_{HCB} = 4 dB

COM r3.40 results

: Case 1: z_p=(15:1.8, 0:0, 0:0, 15:1.8) (TX, RX, NEXT, FEXT):
: EH = 6.060 mV (FAIL)
: VEC = 16.963 dB (FAIL)
: PASS ... ERL = 11.818 dB (NaN dB,11.818 dB)
: Case 2: z_p=(31:1.8, 0:0, 0:0, 31:1.8) (TX, RX, NEXT, FEXT):
: EH = 5.940 mV (FAIL)
: VEC = 14.083 dB (FAIL)
: PASS ... ERL = 11.818 dB (NaN dB,11.818 dB)

OK

No FEXT

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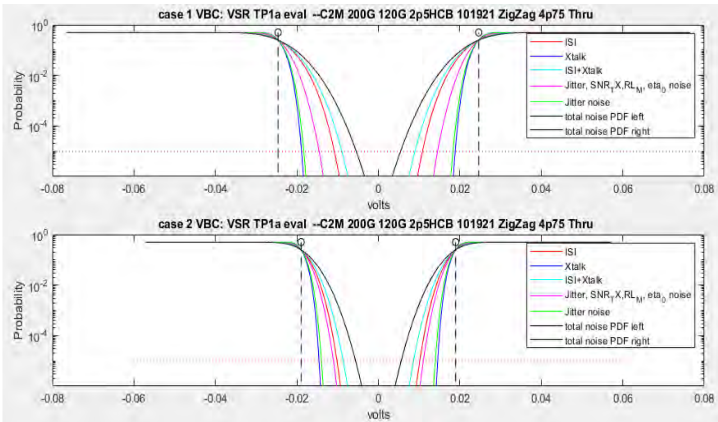
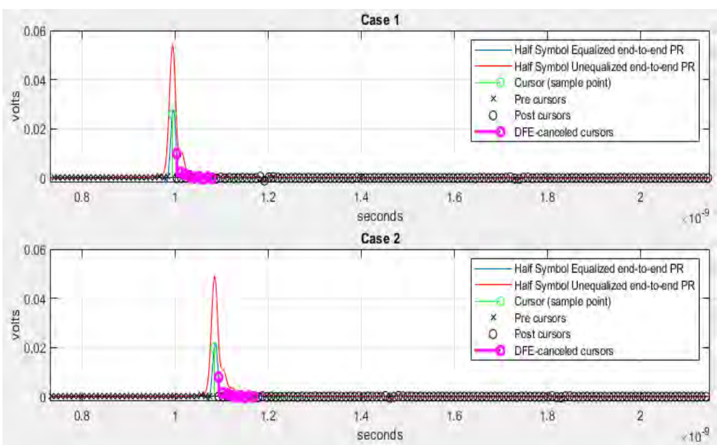
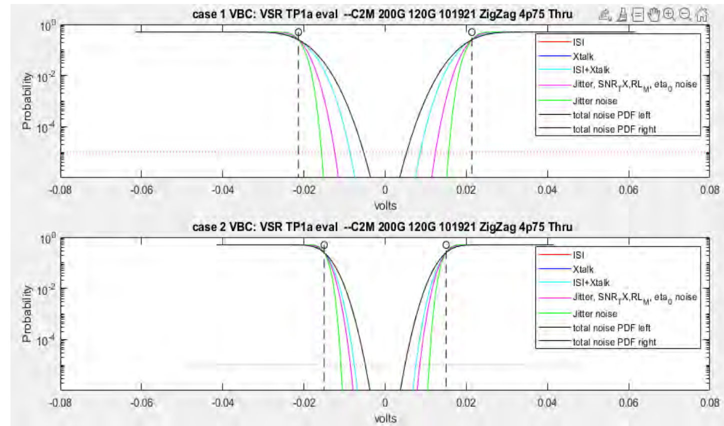
Bathtub and Pulse Response – Incremental Changes

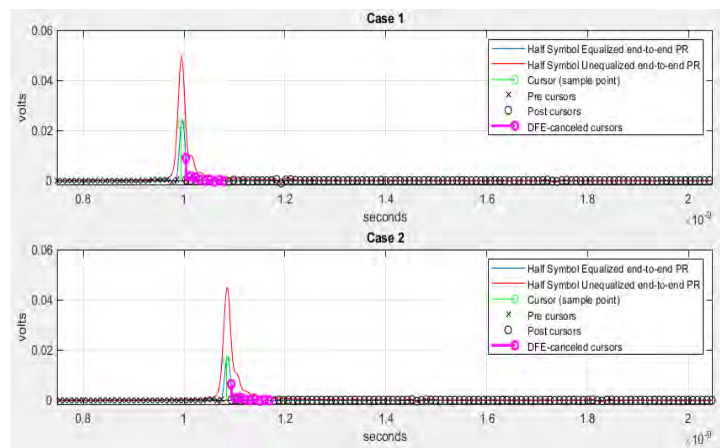
IL_{HCB} = 2.5 dB





IL_{HCB} = 4 dB





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COM Results – Comprehensive Changes

IL_{HCB} = 2.5 dB

COM r3.40 results

: Case 1: z_p=(15:1.8, 0:0, 0:0, 15:1.8) (TX, RX, NEXT, FEXT):
: EH = 17.710 mV (pass)
: VEC = 10.802 dB (pass)
: PASS ... ERL = 11.993 dB (NaN dB,11.993 dB)
: Case 2: z_p=(31:1.8, 0:0, 0:0, 31:1.8) (TX, RX, NEXT, FEXT):
: EH = 16.130 mV (pass)
: VEC = 10.734 dB (pass)
: PASS ... ERL = 11.993 dB (NaN dB,11.993 dB)

OK

4 FEXTs

IL_{HCB} = 4 dB

COM r3.40 results

: Case 1: z_p=(15:1.8, 0:0, 0:0, 15:1.8) (TX, RX, NEXT, FEXT):
: EH = 13.760 mV (pass)
: VEC = 11.672 dB (pass)
: PASS ... ERL = 14.213 dB (NaN dB,14.213 dB)
: Case 2: z_p=(31:1.8, 0:0, 0:0, 31:1.8) (TX, RX, NEXT, FEXT):
: EH = 11.450 mV (pass)
: VEC = 11.765 dB (pass)
: PASS ... ERL = 14.213 dB (NaN dB,14.213 dB)

OK

4 FEXTs

		Incremental	Comprehensive
	P802.3.ck	P802.3df	P802.3df
f_b	53.125	106	106
C_d	[1.2e-4 0]	[0.7e-4 , 0]	[0.7e-4 , 0]
L_s	[0.12 0]	[0.1,0]	[0.1,0]
C_b	[0.3e-4 0]	[0.23e-4 0]	[0.23e-4 0]
N_b	4	9	9
eta_0	4.10E-08	4.10E-09	4.10E-09
SNR_TX	32.5	33	33
package_tl_gamma0_a1_a2	[0 0.0009909 0.0002772]	[0 0.000644085 0.00018018]	[0 0.000644085 0.00018018]
package_tl_tau	6.141E-03	0.0057	0.0057
package_Z_c	[87.5 87.5 ; 92.5 92.5]	[87.5 87.5 ; 92.5 92.5]	[87.5 87.5 ; 92.5 92.5]
b_max(1)	0.4	0.4	0.85
DER_0	1.00E-05	1.00E-05	1.00E-04
N_bg	0	0	3
N_bf	3	3	3
N_f	40	40	40
C_p	[0.87e-4 0]	[0.87e-4 0]	[0 0]*

*** Note: C_p already included in simulation model**

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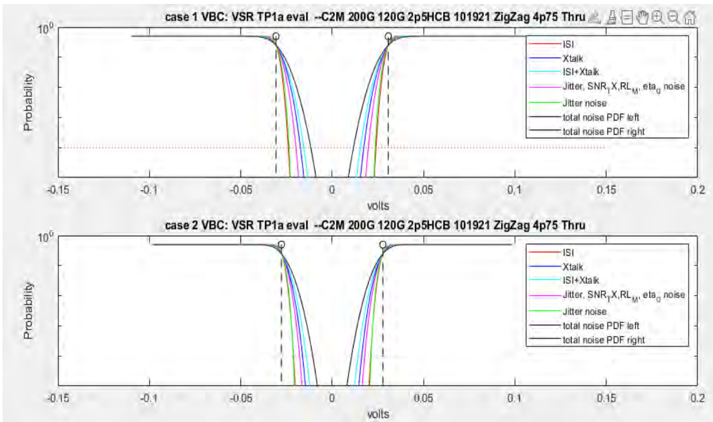
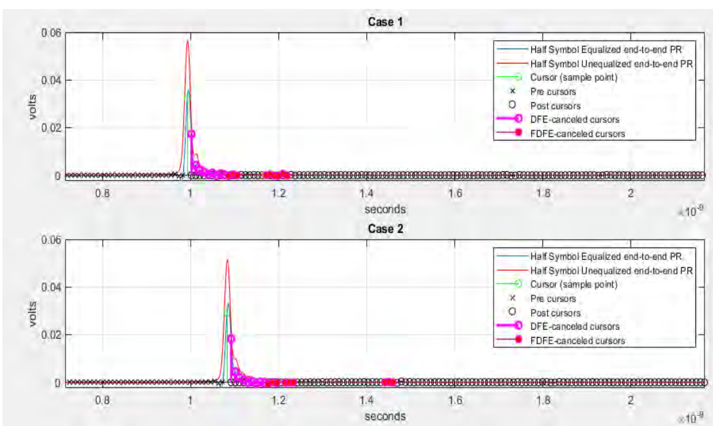
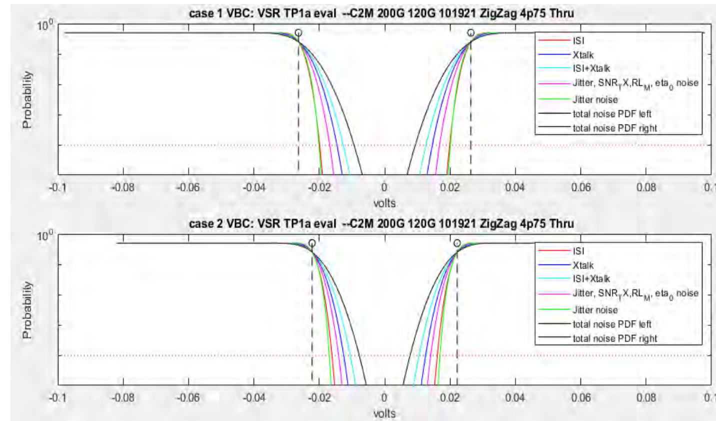
Bathtub and Pulse Response – Comprehensive Changes

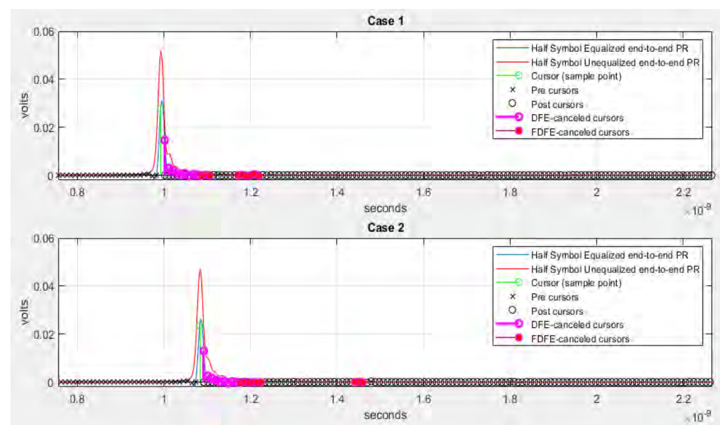
IL_{HCB} = 2.5 dB





IL_{HCB} = 4 dB





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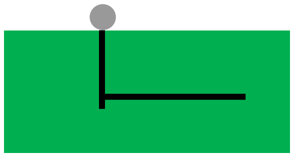
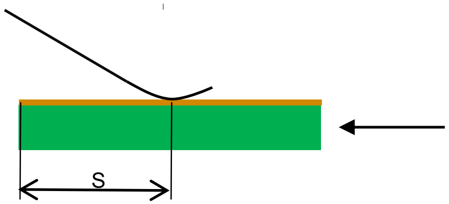
Nemesis – Channel Transitions

Vias and Stubs

1. ASIC to PCB and PCB to Connector
   - Are we reaching the end of life for transition vias?
     - Although blind vias was is used in this study



2. Paddle board finger to connector spring
   - Are we reaching the end of life for paddle board finger connectivity?



Comments?

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Summary

"Equal Distribution of *PAIN*" to make C2M a viable interface:

1. **Need to improve transition technology at both ends of connectors and ASIC**
   - **Other media rather than PCB, i.e., co-package, pigtail connector, etc.**
   - **Improve connector performance**

2. **Stronger FEC , i.e.,**
   - **DER_0 to be 1e-4 (one order of magnitude better than it is today)**
   - **Segmented FEC (?)**

3. **Stronger Equalization at Tx and Rx, i.e.,**
   - **Enable three groups of three floating taps (similar to .ck backplane)**
   - **b_max(1) = 0.85 and as an example of strong equalization for this specific channel**

4. **Reduce Intrinsic Chip Noise by one order of magnitude (from 4.10e-08 to 4.10e-09)**

5. **IL_{HCB} range 2.5 dB to 4 dB**

6. **Improve Interpretation of some COM parameters**
   - **Cp = 0 to avoid double capacitive counting if model already includes ball elements**
     - **Ex.: Lumped ports already include the equivalent to solder balls**

Q & A

Additional Data

200G PAM4 C2M Technical Feasibility

Working Spreadsheet

	A	B	C	D	E
1	Table 93A-1 parameters				
2	Parameter	Setting	Units	Information	
3	f_b	106.00	GBd		
4	f_min	0.05	GHz		
5	Delta_f	0.01	GHz		
6	C_d	[0.7e-4 , 0]	nF	[TX RX]	
7	L_s	[0.1,0]	nH	[TX RX]	
8	C_b	[0.23e-4 0]	nF	[TX RX]	
9	z_p select	[1 2]		[test cases to run]	
10	z_p (TX)	[15 31; 1.8 1.8]	mm	[test cases]	
11	z_p (NEXT)	[0 0; 0 0]	mm	[test cases]	
12	z_p (FEXT)	[15 31; 1.8 1.8]	mm	[test cases]	
13	z_p (RX)	[0 0; 0 0]	mm	[test cases]	
14	C_p	[0 0]	nF	[TX RX]	
15	R_0	50	Ohm		
16	R_d	[50, 50]	Ohm	[TX RX]	
17	A_v	0.415	V		
18	A_fe	0.415	V		
19	A_ne	0.45	V		
20	L	4			
21	M	32	Samp/UI		
22	samples_for_C2M	100	Samp/UI		
23	T_O	50	mUI		
24	AC_CM_RMS	0	V	[test cases]	[0.0235 0.0256
25	filter and Eq				
26	f_r	0.75	*fb		
27	c(0)	0.65		min	
28	c(-1)	[-0.2:0.02:0]		[min:step:max]	
29	c(-2)	[0:.02:0.1]		[min:step:max]	
30	c(-3)	[0]		[min:step:max]	
31	c(1)	[-0.1:0.02:0]		[min:step:max]	
32	N_b	9	UI		
33	b_max(1)	0.85		As/dffe1	
34	b_max(2..N_b)	0.15 0.15 0.1 0.1 0.1 0.1 0.1 0.1]		As/dfe2..N_b	
35	b_min(1)	0		As/dffe1	
36	b_min(2..N_b)	0.1 -0.05 -0.05 -0.05 -0.05 -0.05 -0.05]		As/dfe2..N_b	
37	g_DC	[-13:1:-0]	dB	[min:step:max]	
38	f_z	42.4	GHz		
39	f_p1	42.4	GHz		
40	f_p2	106	GHz		
41	g_DC_HP	[-3.5:0.5:0]		[min:step:max]	
42	f_HP_PZ	2.65	GHz		
43					
44					

	F	G	H
1	I/O control		
2	DIAGNOSTICS	1	logical
3	DISPLAY_WINDOW	1	logical
4	CSV_REPORT	1	logical
5	RESULT_DIR	.\results\200GEL_VSR_host_TP1a	
6	SAVE_FIGURES	0	logical
7	Port Order	[1 2 3 4]	
8	RUNTAG	VSR_TP1a_eval_	
9	COM_CONTRIBUTION	0	logical
10	Local Search	2	
11	Operational		
12	VEC Pass threshold	12	db
13	EH_min	10	mV
14	ERL Pass threshold	10	dB
15	Min_VEO_Test	8	mV
16	DER_0	1.00E-04	
17	T_r	3.25E-03	ns
18	FORCE_TR	1	logical
19	PMD_type	C2M	
20	BREAD_CRUMBS	0	logical
21	SAVE_CONFIG2MAT	1	logical
22	PLOT_CM	0	logical
23	TDR and ERL options		
24	TDR	1	logical
25	ERL	1	logical
26	ERL_ONLY	0	logical
27	TR_TDR	0.005	ns
28	N	800	
29	beta_x	0	
30	rho_x	0.618	
31	fixture delay time	[0 0]	port1 port2]
32	TDR_W_TXPKG	1	
33	N_bx	0	UI
34	Tukey_Window	1	
35	Receiver testing		
36	RX_CALIBRATION	0	logical
37	Sigma BBN step	5.00E-03	V
38	Noise, jitter		
39	sigma_RJ	0.01	UI
40	A_DD	0.02	UI
41	eta_0	4.10E-09	V^2/GHz
42	SNR_TX	33	dB
43	R_LM	0.95	
44	Impulse response tru	0.0001	

	J	K	L
1	Table 93A–3 parameters		
2	Parameter (ms)	Setting	Units
3	package_tl_gamma0_a1_a2	0 0.000644085 0.00018018]	
4	package_tl_tau	0.0057	ns/mm
5	package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm
6	ICN & FOM_ILD parameters		
7	f_v	0.469	*Fb
8	f_f	0.469	Hz f_r specified in first column
9	f_n	0.469	GHz
10	f_2	79.5	GHz
11	A_ft	0.450	V
12	A_nt	0.450	V
16	Histogram_Window_Weight	gaussian	ectangle, gaussian,dual_rayleigh,triangle
17	QL	2.5	
26	Table 92–12 parameters		
27	Parameter	Setting	
28	board_tl_gamma0_a1_a2	0 0.000567732 2.90358e-05	1.3 db/in at 56GHz
29	board_tl_tau	0.0058	ns/mm
30	board_Z_c	100	Ohm
31	z_bp (TX)	130	mm
32	z_bp (NEXT)	0	mm
33	z_bp (FEXT)	0	mm
34	z_bp (RX)	0	mm
35	C_0	0	nF
36	C_1	0	nF
37	Include PCB	0	logical

	N	O	P	Q
1	Floating Tap Control			
2	N_bg	3	0 1 2 or 3 groups	
3	N_bf	3	taps per group	
4	N_f	40	pan for floating taps	
5	bmaxg	0.2	E value for floating taps	
7	for TP4-->	[1.2e-4 0]	nF	[TX RX]
8		[0.12 0]	nH	[TX RX]
9		[0.3e-4 0]	nF	[TX RX]
10		[1 2 3]		[test cases to run]
11		[2 7 8]	mm	[test cases]
12		[0 0 0]	mm	[test cases]
13		[2 7 8]	mm	[test cases]
14		[0 0 0]	mm	[test cases]
15		[0 0.87e-4]	nF	[TX RX]

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Channel Contribution

- rabinovich_3df_with_impairments_01_022422.zip
  - ❖ KEY_C2M_200G_120G_2p5HCB_022422_FEXT.s4p
  - ❖ KEY_C2M_200G_120G_2p5HCB_022422_NEXT.s4p
  - ❖ KEY_C2M_200G_120G_2p5HCB_022422_Thru.s4p
  - ❖ KEY_C2M_200G_120G_4p0HCB_022422_FEXT.s4p
  - ❖ KEY_C2M_200G_120G_4p0HCB_022422_NEXT.s4p
  - ❖ KEY_C2M_200G_120G_4p0HCB_022422_Thru.s4p
  - ❖ C2M_212G_P802p3bj_PAM4_022422.xls