Chip-to-module far-end TX eye measurement proposal

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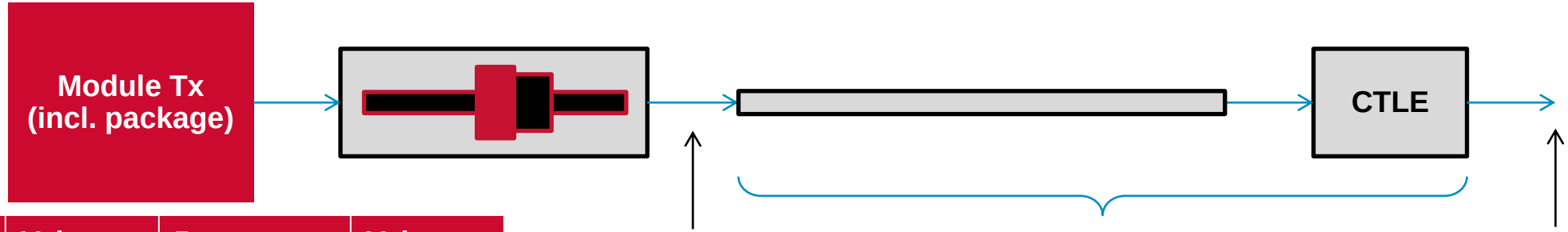
Background

- In smith_3bs_01a_0915, it was shown that the module transmitter needs to provide fixed pre-cursor de-emphasis to close the link budget for a number of chip-to-module channels
- This need also motivated hegde_3bs_01_0116, hegde_01_042516_elect and hegde_3bs_02_0516. These contributions formed the basis for the content in 120E.3.2.1.1.
- It was assumed that including a loss channel in the far-end eye measurement methodology would capture the pre-cursor component requirement
- **Was this assumption correct?**

Questions

- Is it possible for the module transmitter to pass the far-end eye requirements without fixed pre-cursor equalization? **Answer: Yes**
- If the far-end eye opening requirements are met, does it matter if pre-cursor equalization is provided or not? **Answer: Yes**
- How might we better enforce the pre-cursor equalization requirement?

Far-end eye with hypothetical module transmitter



Parameter	Value	Parameter	Value
T_r ($\beta = 2$)	13 ps	R_d	45 Ω
A_v	0.45 V	C_d	90 fF
SNR_{TX}	35 dB	z_p	10 mm
R_{LM}	0.98	Z_c	90 Ω
A_{DD}	20 mUI	C_p	90 fF
σ_{RJ}	10 mUI		

$$VEO = 2A_s\left(1 - 10^{-COM/20}\right)$$

Procedure (using COM):

- Measure the waveform at the output of module compliance board
- Apply Bessel-Thomson low-pass response with 33 GHz bandwidth
- Apply “loss channel” (151 mm PCB) and reference CTLE
- Search over all CTLE gain settings to obtain the best eye opening

- With [c(−1), c(0), c(1)] = [0, 1, 0], the vertical eye opening (VEO) is 35.7 mV
- COM-based example supports lab findings (note that eye width and ESMW requirements also met)

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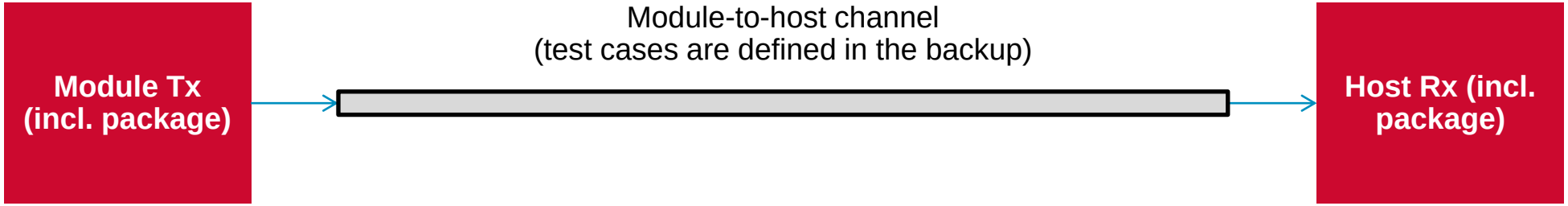
Emulate full module-to-host link



Parameter	Value	Parameter	Value
T_r (β = 2)	13 ps	R_d	45 Ω
A_v , A_{fe}	0.45 V	C_d	90 fF
SNR_{TX}	35 dB	z_p	10 mm
R_{LM}	0.98	Z_c	90 Ω
A_{DD}	20 mUI	C_p	90 fF
σ_{RJ}	10 mUI		

Parameter	Value	Parameter	Value
R_d	55 Ω	η_0	2.6 x 10^{-8} V2/GHz
C_d	280 fF		
z_p	30 mm		
Z_c	90 Ω		
C_p	110 fF		

- Two equalizers are considered:
  - Reference CTLE defined in 120E.3.1.7 (plus 33 GHz Bessel-Thomson low-pass filter)
  - 2-stage CTLE and decision feedback equalizer (DFE) as defined in 120D.4

Summary of results

Chip-to-module reference receiver (120E.3.1.7)

* [c(-1), c(0), c(1)]

Test case		1	2	3	4	5	6	7	8	9
IL at 13.28 GHz, dB		8.74	8.94	4.29	8.81	4.5	9.01	9.28	10.29	11.61
COM, dB	[0, 1, 0] *	0.89	1.11	2.14	0.39	3.25	0.6	−0.22	−0.77	−1.42
	[−0.1, 0.9, 0]	3.27	4.39	4.27	3.11	5.05	4.19	2.84	2.56	1.25
Penalty for no precursor, dB		2.38	3.28	2.13	2.72	1.8	3.59	3.06	3.33	2.67

Chip-to-chip reference receiver (120D.4)

Test case		1	2	3	4	5	6	7	8	9
IL at 13.28 GHz, dB		8.74	8.94	4.29	8.81	4.5	9.01	9.28	10.29	11.61
COM, dB	[0, 1, 0]	4.83	4.76	4.72	4.99	5.04	5.17	4.02	4.18	4.22
	[−0.1, 0.9, 0]	8.39	8.9	6.8	7.63	7.5	8.17	6.99	7.73	7.36
Penalty for no precursor, dB		3.56	4.14	2.08	2.64	2.46	3	2.97	3.55	3.14

- Significant reduction in margin without the fixed pre-cursor de-emphasis
- Test cases 1 to 6 have low FEXT and 7 to 9 have no crosstalk

Is there a better way to enforce the requirement?

- Capture the PRBS13Q waveform and calculate the linear fit pulse as defined in 120D.3.1.3
- The linear fit pulse should include the impact of the loss channel and [optimized] CTLE
- Find the amplitude of the pulse peak
- Find the magnitude of the pulse response 1 UI prior to the peak. Call this the pre-cursor value.
- Define the pre-cursor ratio as the pre-cursor value divided by the pulse peak

Pre-cursor ratio results

Chip-to-module reference receiver (120E.3.1.7)

Test case		1	2	3	4	5	6	7	8	9
IL at 13.28 GHz, dB		8.74	8.94	4.29	8.81	4.5	9.01	9.28	10.29	11.61
Pre-cursor ratio	[0, 1, 0]	0.18	0.202	0.083	0.19	0.089	0.179	0.224	0.271	0.311
	[−0.1, 0.9, 0]	0.048	0.063	0.001	0.065	0.025	0.02	0.027	0.099	0.146

Note: Red text indicates cases with less than 3 dB COM.

Chip-to-chip reference receiver (120D.4)

Test case		1	2	3	4	5	6	7	8	9
IL at 13.28 GHz, dB		8.74	8.94	4.29	8.81	4.5	9.01	9.28	10.29	11.61
Pre-cursor ratio	[0, 1, 0]	0.08	0.089	0.069	0.09	0.064	0.092	0.091	0.099	0.103
	[−0.1, 0.9, 0]	0.004	0	0.016	0.004	0.003	0	0.004	0.002	0.002

- Propose a pre-cursor ratio limit of 7%

Summary

- The far-end eye opening is not sufficient to ensure that the module transmitter provides fixed pre-cursor compensation
- Pre-cursor equalization can have a significant impact on link performance
- A supplemental test is proposed to ensure that pre-cursor ISI is compensated
- The proposed test is relatively simple and based on established techniques
- Draft text to be provided

Backup slides

Test case descriptions

Test case	Channel	No. of FEXT	No. of NEXT	IL at 13.28 GHz, dB
From shanbhag_3bs_14_0623				
1	Nelco 4000-13SI Host PCB + next gen 28Gb/s high density SMT IO	5	0	8.74
2	EM-888 Host PCB + next gen 28Gb/s press-fit stacked IO	7	0	8.94
From shanbhag_3bs_01_1014				
3	Next-gen 28Gb/s high density SMT IO + 4 inch host	5	0	4.29
4	Next-gen 28Gb/s high density SMT IO + 10 inch host	5	0	8.81
5	Next-gen 28Gb/s press-fit stacked IO + 4 inch host	7	0	9.01
6	Next-gen 28Gb/s press-fit stacked IO + 10 inch host	7	0	4.5
Cisco channels				
7	HCB_MCB + 3” passive	0	0	9.28
8	HCB_MCB + 4” passive	0	0	10.29
9	HCB_MCB + 5” passive	0	0	11.61