Proposal for CAUI-4 Package, Reference Receiver, and COM Parameters In Support of Comment 105,106, 107,108,111, 112

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Supporters

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Given:

- A channel that passes a channel compliance specification must work for all compliant chips.
- A device that passes a receiver compliance test will work for all compliant channels.

We will illustrate:

- Test instrument and chip-in-a-package are two different worlds
- Eye opening in mV on an ideal termination with a software equalizer cannot predict operation of a chip

Proposal:

- Evaluation with reference package and ideal termination
- Reference DFE
- Look at normalized metric such as COM
  - VEC defined in 83E.4.2.1 is essentially COM of a TX+channel

COM, EYE Diagram, and Clause 83E are Similar

- Figure of merit used to determine equalization.
  - Best ratio of signal at sample point to rms of all appropriate cursors.
- Comparable to Equation 83E–9
  - AV is like the available signal, A_s
  - EH15 is like "A_s – N"
  - COM is an opening and VEC is the closure
    - Essentially they are the same metric
    - COM noise uses an exact statistical calculation while VEC is an extrapolation of measured statistics

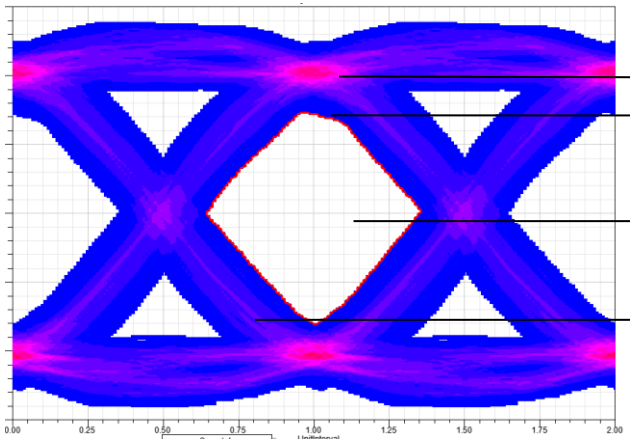
83E.4.2.1 Vertical eye closure

Vertical eye closure is calculated using Equation (83E–9)

$$VEC = 20\log\left(\frac{AV}{EH15}\right) \quad \text{(83E–9)}$$

where

VEC	is vertical eye closure in dB
AV	is the eye amplitude of the equalized waveform. Eye amplitude is defined as the mean value of logic one minus the mean value of logic zero in the central 5% of the eye
EH15	is given in equation Equation (83E–8)



Available Signal, A_s, $\propto AV$

Total_noise, N, $\propto A_s$-*EH15*

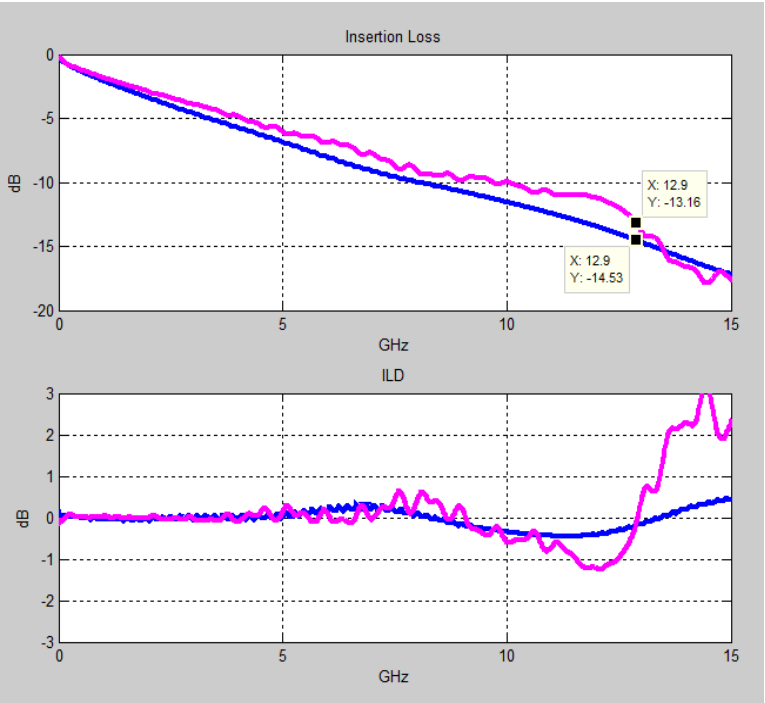
VEO $\propto$ *EH15*

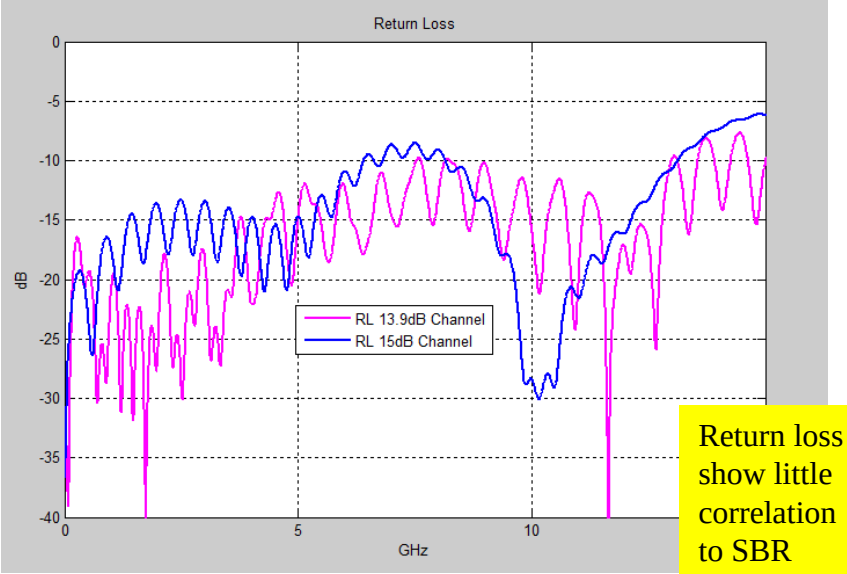
$$COM = 20 * log10\left(\frac{A_s}{N}\right)$$

We will look at COM and Vertical Eye Opening (VEO)

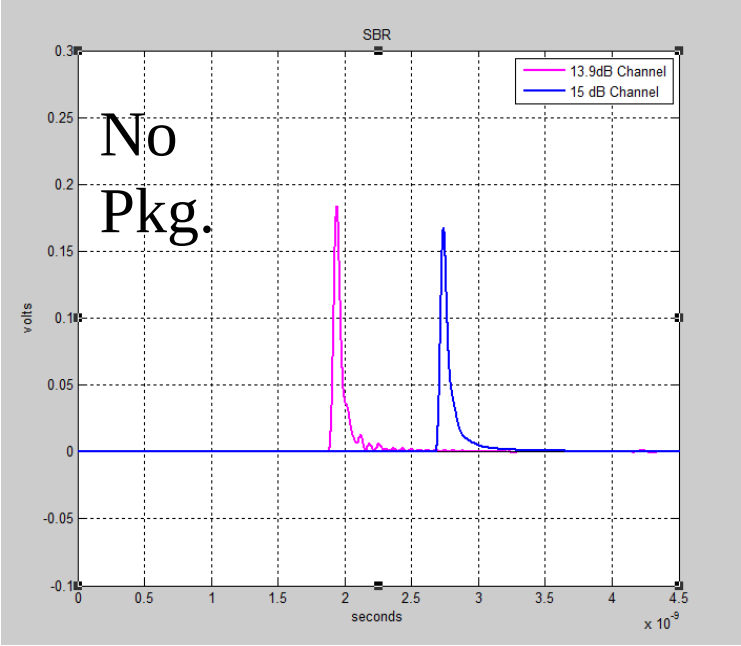
Two Channels Considered

- Two channels considered
  - 15dB ~ one board: fairly clean channel
  - 13.39dB ~ two boards with good connector: somewhat reflective channel



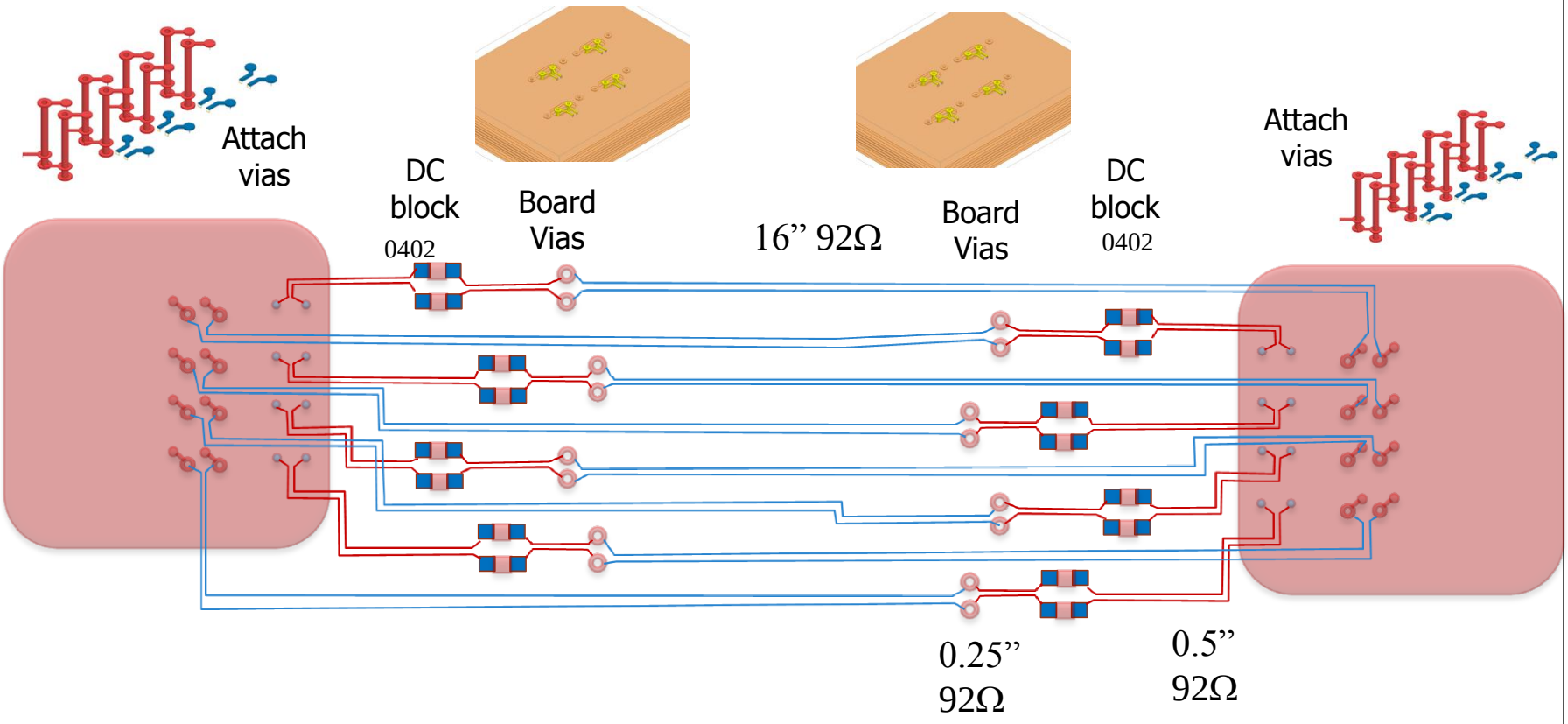


Return loss show little correlation to SBR



15(14.53)dB Channel

15 mils max stub length.
102 mil thick 12 layer board

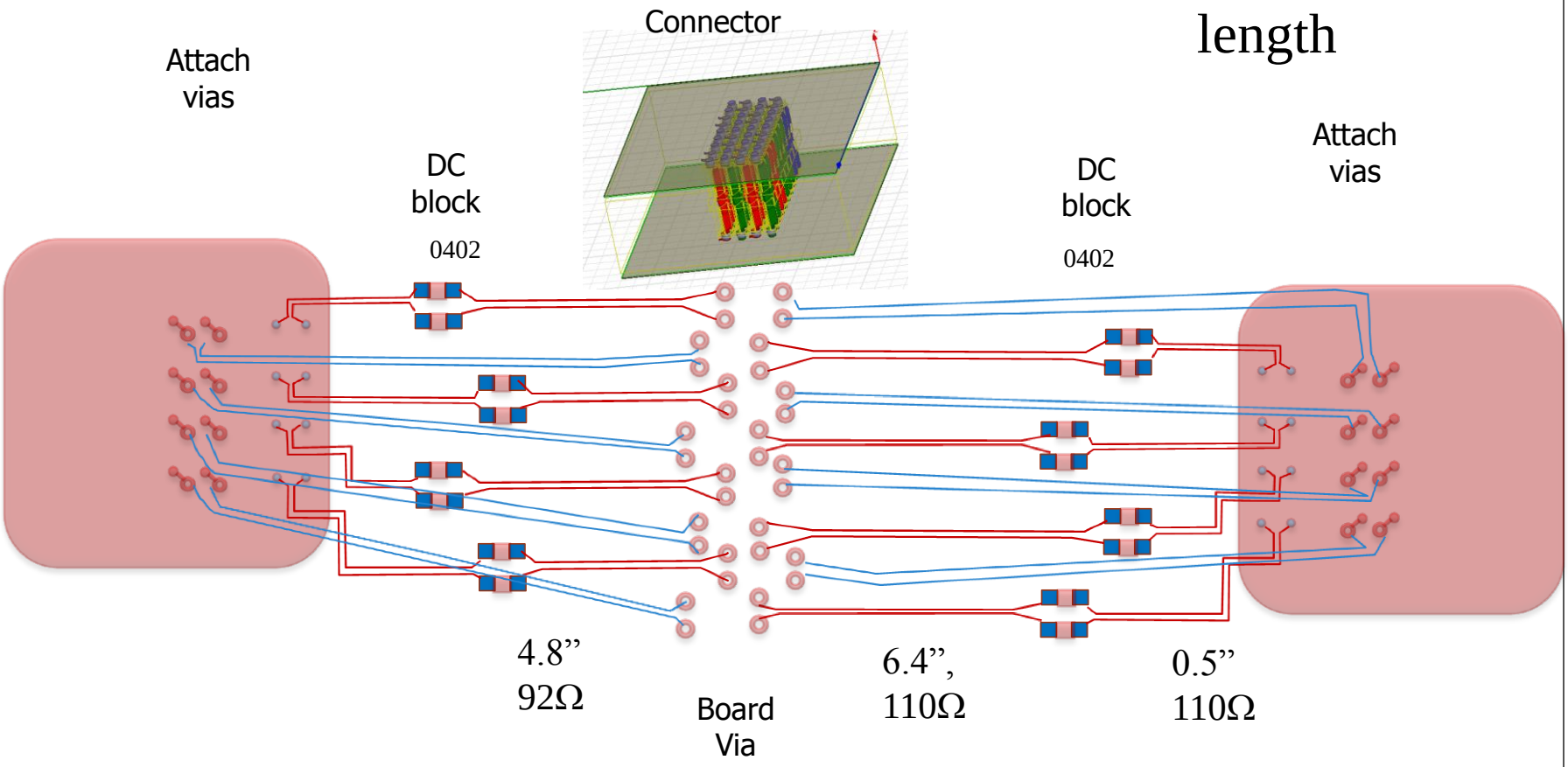


Board Material	Total Length	Loss at 12.9GHz
Meg6_LowSR	16.75”	14.53dB

This is a simple of design using very low loss material. This design need to have good margin.

13.39(13.16) dB Channel

15 mils max stub length



Board Material	Total Length	Loss at 12.9GHz
ImpFR4_LowSR	11.45”	13.16dB

This is a simple of design of a 2 board design using “improved FR4” material with a simple high performing connector.

Terminations

- Two realistic Rx package models (clause 93a)*
  - 12mm and 30 mm PKG
  - Die pad capacitance 250fF
  - Termination 55 ohms single ended
  - Package to board capacitance = 180fF
- Ideal Rx termination
- 12 mm package is used for the transmitter in both cases

** See: moore_3bj_02_0713, mellitz_3bj_01b_0113a, benartsi_3bj_01_0113, benartsi_3bj_01_0912, benartsi_3bj_01a_0113, benartsi_3bj_01a_0513, and benartsi_3bj_02_0912*

COM Parameters Used

Parameter	With packages no DFE	Ideal termination no DFE	With packages DFE	Units	Information
f_b	25.78125	25.78125	25.78125	GBd	
f_min	0.05	0.05	0.05	GHz	
Delta_f	0.01	0.01	0.01	GHz	
C_d	[2.50E-04 2.50E-04]	[2.50E-04 0]	[2.50E-04 2.50E-04]	nF	[TX RX]
z_p select	[1 2]	[1]	[1 2]		[test cases to run]
z_p (TX)	[12 12]	[12]	[12 12]	mm	[test cases]
z_p (NEXT)	[12 12]	[12]	[12 12]	mm	[test cases]
z_p (FEXT)	[12 12]	[12]	[12 12]	mm	[test cases]
z_p (RX)	[12 30]	0	[12 30]	mm	[test cases]
C_p	[1.80E-04 1.80E-04]	1.80E-04 0]	[1.80E-04 1.80E-04]	nF	[TX RX]
R_0	50	50	50	Ohm	
R_d	[55 55]	[55 50]	[55 55]	Ohm	[TX RX]
f_r	0.75	0.75	0.75	*fb	
TX equalizer c(-1)	[-0.18:0.02:0]	[-0.18:0.02:0]	[-0.18:0.02:0]		[min:step:max]
TX equalizer c(+1)	[-0.38:0.02:0]	[-0.38:0.02:0]	[-0.38:0.02:0]		[min:step:max]
g_DC	[-16:1:0]	[-16:1:0]	[-16:1:0]	dB	[min:step:max]
A_v	0.4	0.4	0.4	V	
A_fe	0.4	0.4	0.4	V	
A_ne	0.6	0.6	0.6	V	
L	2	2	2		
M	32	32	32		
N_b	0	0	1,2,3,4	UI	
b_max(1)	1	1	0.5		
b_max(2..N_b)	1	1	0.5		
sigma_RJ	0.01	0.01	0.01	UI	
A_DD	0.05	0.05	0.05	UI	
eta_0	5.20E-08	5.20E-08	5.20E-08	V^2/GHz	
SNR_TX	29	29	29	dB	
R_LM	1	1	1		
DER_0	1.00E-15	1.00E-15	1.00E-15		

COM pass > 2dB

COM and Vertical Eye Opening (VEO)

- Clause 93a COM* parameters used for this comparison.
- Considerations with and without DFE
- Both channels have the same vertical eye opening (VEO) with an ideal Rx and tuned CTLE, but have different COM values.
  - Crosstalk has negligible effect and was omitted from results..

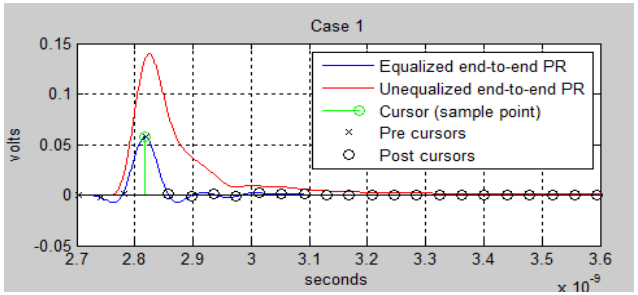
loss	VEO (mV)	COM (dB)	DFE	Rx Pkg len	Tx Pkg len
13.39dB reflective	47.5290	3.8659	0	Ideal termination	12mm
15dB clean	47.5454	4.5777	0	Ideal termination	12mm

- Let's say we use the 15 dB channel for receiver compliance with the 47.5 mv VEO.
- We design a receiver to work for that channel (which includes our package)
- Now we measure the 13.39 dB product channel and get the same eye opening into the ideal load.

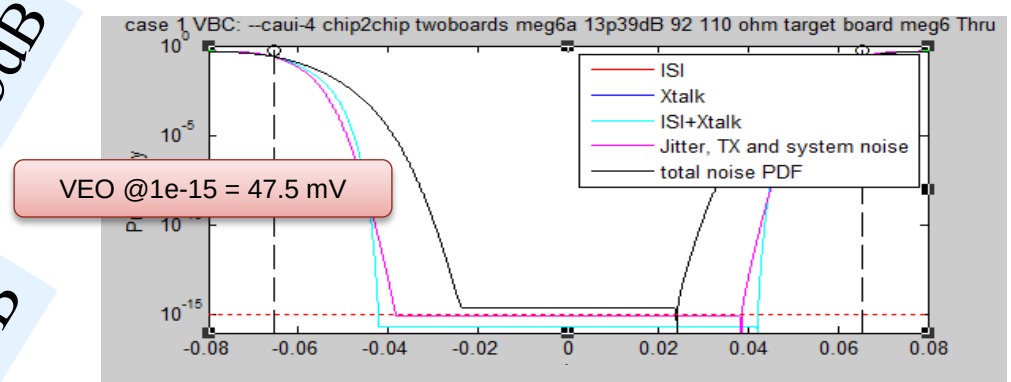
*ran_3bj_com_d2p2_01_0813

On a measurement instrument with ideal Rx termination, both channels look good

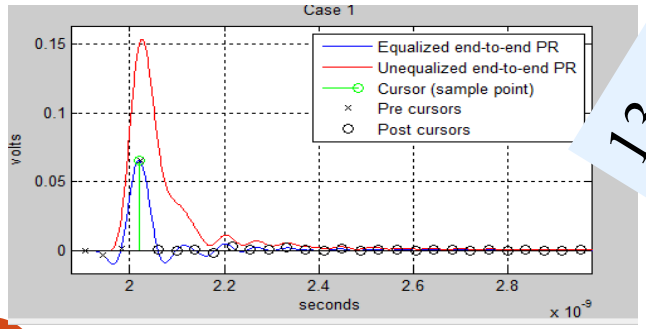
- Very minor ISI effect – seems to have lots of margin
- Suggested as reference receiver, but unrealistic – packages are not transparent
- Those of us who don't have a good package may use other means to compensate… (e.g. DFE?)



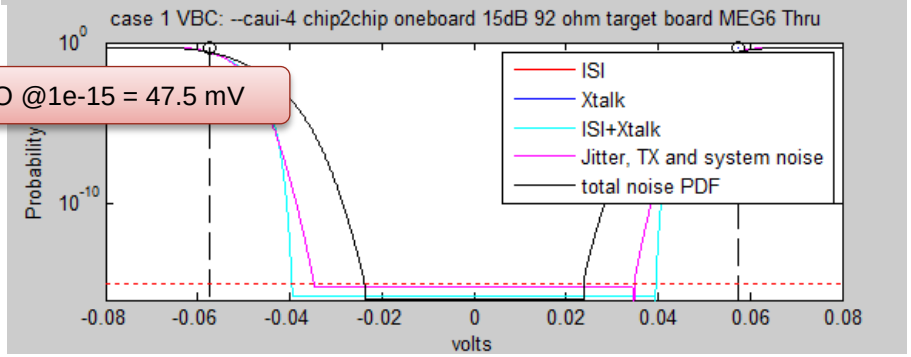
15dB



VEO @1e-15 = 47.5 mV



13.39dB



VEO @1e-15 = 47.5 mV

Results With Reference Packages (CTLE only)

loss	VEO (mV)	COM (dB)	DFE	Rx Pkg len	Tx Pkg len
13.39dB reflective	**5.2617**	**0.4684**	0	12mm	12mm
15dB clean	**10.3430**	**1.0445**	0	12mm	12mm
13.39dB reflective	**3.0993**	**0.3409**	0	30mm	12mm
15dB clean	**9.5027**	**1.2711**	0	30mm	12mm

- Both receiver packages seem to make both channels fail
  - Unacceptable COM and VEO
  - Channels do not have the same VEO any more
- So we decide to add a DFE and make it work with the 15 dB channel.
  - But how many taps would it take?

Each channel Rx package combination requires a different amount of minimum equalization to work acceptably

channel label	Pkg_len_RX	COM (dB)	VEO_mV	COM (dB)	VEO_mV	COM (dB)	VEO_mV	COM (dB)	VEO_mV
		dfe1		dfe2		dfe3		dfe4	
13.39dB reflective	12	1.31	18.20	1.18	17.51	1.24	19.39	2.83	32.78
15dB clean	12	2.73	43.28	2.85	34.51	2.99	37.56	5.31	48.96
13.39dB reflective	30	1.95	21.09	1.96	22.51	1.89	21.65	3.14	30.13
15dB clean	30	3.40	31.87	3.51	30.22	3.54	32.18	4.65	33.21

- For the 15 dB channel we only need a DFE1
- The channel with a connector would not work without DFE4.
- Remember both the channel looked the same with the test instrument… They are not!

What package do we need to work without a DFE?

- Die pad capacitance of 150 fF
- Package to board capacitance to 170 fF
- Package length of 6mm

loss	VEO (mV)	COM (dB)	DFE	Rx Pkg len	Tx Pkg len
13.39dB reflective	25.7476	2.0657	0	6mm	12mm
15dB clean	29.2416	2.7389	0	6mm	12mm

- This may not be consistent with a wide range of products.
  - Challenging to implement and may not be technically feasible.

Conclusion

- Vertical eye opening into an ideal load is not a sufficient receiver design requirement.
- DFE or equivalent is required for realistic packages
  - Clean channels can get away with DFE1
  - A clean channel is unlikely for a one connector design

Proposal

- Update COM tables to parameters in last data column of slide 8
- Suggest DFE4 to accommodate the one connector designs