ERL and Termination effect on COM
(in support of r02-30)

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May 2018

With contributions from Rich Mellitz

Comment

Cl **136** *SC* **136.11.8** *P* **233** *L* **7** # r02-30

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Comment Type **TR** *Comment Status* **X**

The COM parameters for clause 136 correspond to very well-matched channel terminations. The device single-ended termination resistance is 50 Ohm, the package model characteristic impedance is 95 Ohm, and the host board impedance (136.11.8.1) is 100 Ohm.

This creates a smooth channel with no reflections outside of the cable, except for the package capacitors (which are within the DFE reach).

In reality things will not be so nice. Actual devices and NICs will have reflections outside of the DFE reach (limited by ERL, not not zero). These reflections are not accounted for in the COM budget - leaving a deficit.

The effect of far-end reflections is not accounted for in the receiver interference tolerance test COM calibration. So receivers may perform well in the test but fail in real life scenarios.

I am planning a presentation with more details of the problem and proposed solutions.

SuggestedRemedy

Upcoming presentation.

A look at a transmitter

This is the MDI for clause 137 PHYs

This is the MDI for clause 136 PHYs

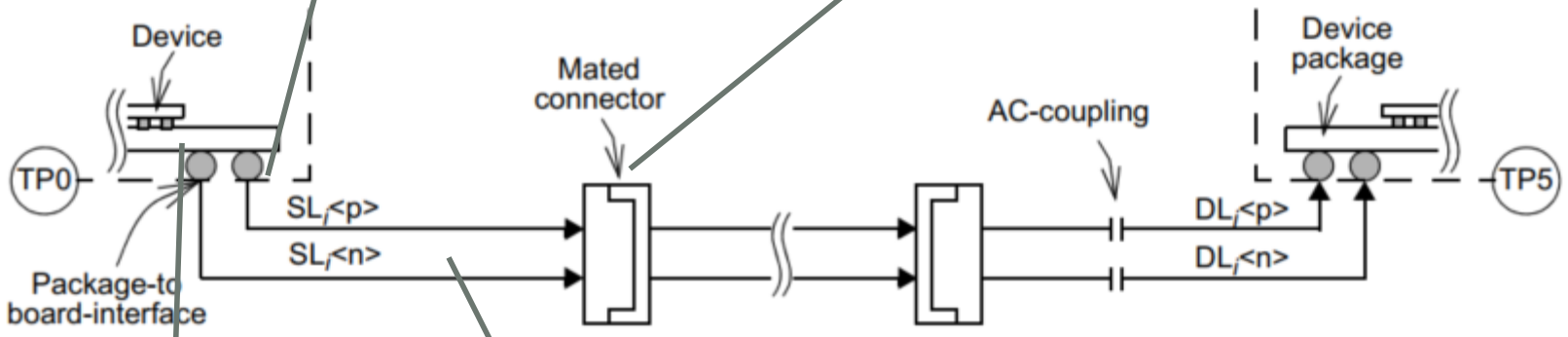


Figure 137–2—50GBASE-KR, 100GBASE-KR2 or 200GBASE-KR4 link (one direction for one lane is illustrated)

COM for clause 136 uses 30 mm of package trace, 95 Ohm

COM for clause 136 uses 151 mm of PCB trace, 100 Ohm

Changes in this project compared to 802.3bj (clause 92)

136.11.8.1 Channel signal and crosstalk path calculations

The channel paths between TP0 and TP5 used for calculation of the cable assembly COM consist of measured cable assembly signal and crosstalk paths, representative transmitter PCB signal paths, and representative receiver PCB signal paths.

The transmitter and receiver PCB signal paths are calculated using the method defined in 93A.1.2.3. The scattering parameters for a PCB are defined by Equation (93A–13), Equation (93A–14), and the parameter values given in Table 92–12, with the exception that Z_c is 100 Ω. The PCB trace length parameter z_p has different value for each specific signal path, as specified in 136.11.8.1.1 and 136.11.8.1.2.

Table 92–12—Transmission line model parameters

Parameter	Value	Units
γ_0	0	1/mm
a_1	4.114×10^{-4}	$ns^{1/2}/mm$
a_2	2.547×10^{-4}	ns/mm
τ	6.191×10^{-3}	ns/mm
Z_c	109.8	Ω

Clause 136 COM parameters

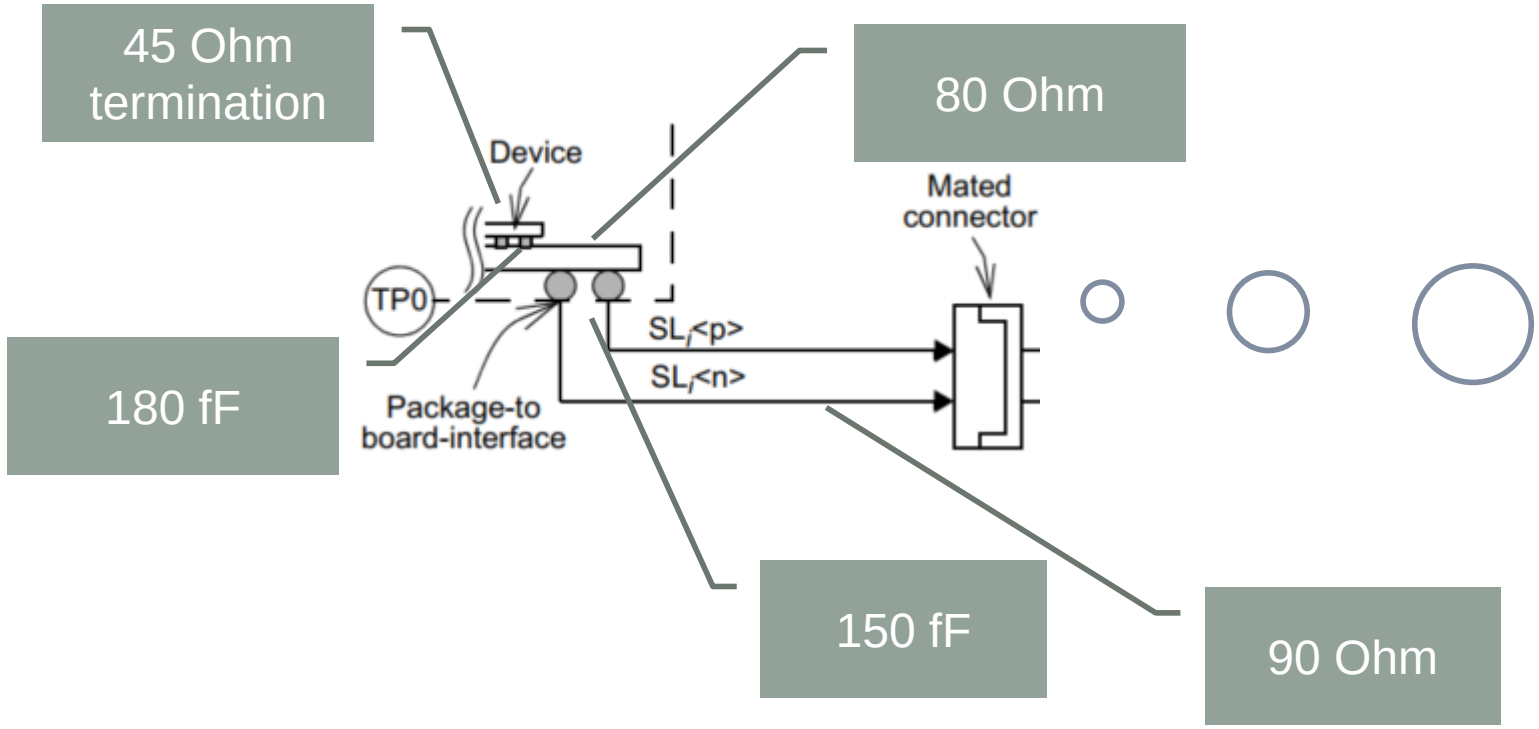
Device package model			
Single-ended device capacitance	C_d	1.8×10^{-4}	nF
Transmission line length, Test 1	z_p	12	mm
Transmission line length, Test 2	z_p	30	mm
Single-ended package capacitance at package-to-board interface	C_p	1.1×10^{-4}	nF
Package transmission line characteristic impedance	Z_c	95	Ω
Single-ended termination resistance	R_d	50	Ω

Device package model			
Single-ended device capacitance	C_d	2.5×10^{-4}	nF
Transmission line length, Test 1	z_p	12	mm
Transmission line length, Test 2	z_p	30	mm
Single-ended package capacitance at package-to-board interface	C_p	1.8×10^{-4}	nF
Single-ended termination resistance	R_d	55	Ω

defined in Table 93A–3. Where a value for Z_c is not provided by the clause that invokes this method, it takes the value 78.2 Ω. The units of f are GHz.

Are these improvement expectations realistic?

More realistic device, package and board models



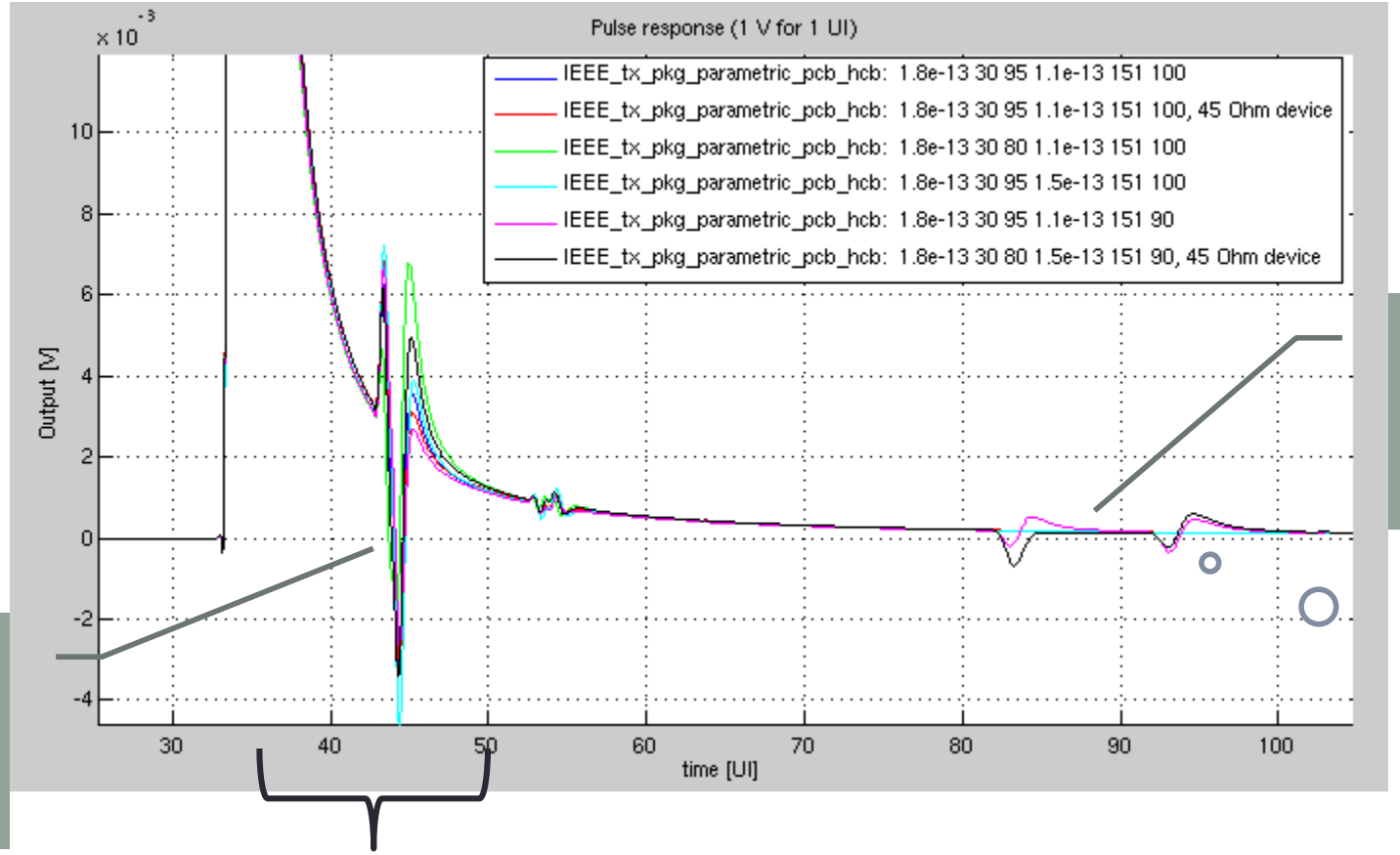
Taking into account actual design limitations, Manufacturing variations of boards, connectors, devices, assembly...

These numbers are not too pessimistic

Update:

Case	ERL TP0a	ERL TP2
COM 30 mm Reference package	17.3 dB	17.8 dB
Modified package parameters above	15.5 dB	14.8 dB

ISI from a mismatched host board - visualized



Reflections from package discontinuity – magnitude depends on package impedance and Cp.

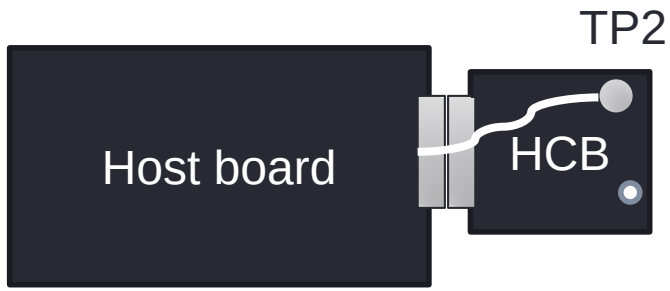
These are within the DFE reach!

DFE expected reach

Secondary reflections appear when the board impedance is 90 Ω – not matched to the cable assembly. These are outside of the DFE reach.

Does ERL catch this?

ERL measurement of host



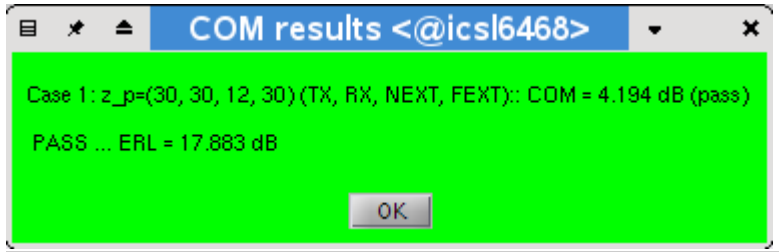
Any reflection from the host board appears in TDR right after the “test fixture delay” so within the DFE reach – therefore it is discounted

Cable assembly measurement has a similar problem – impedance mismatch is not counted

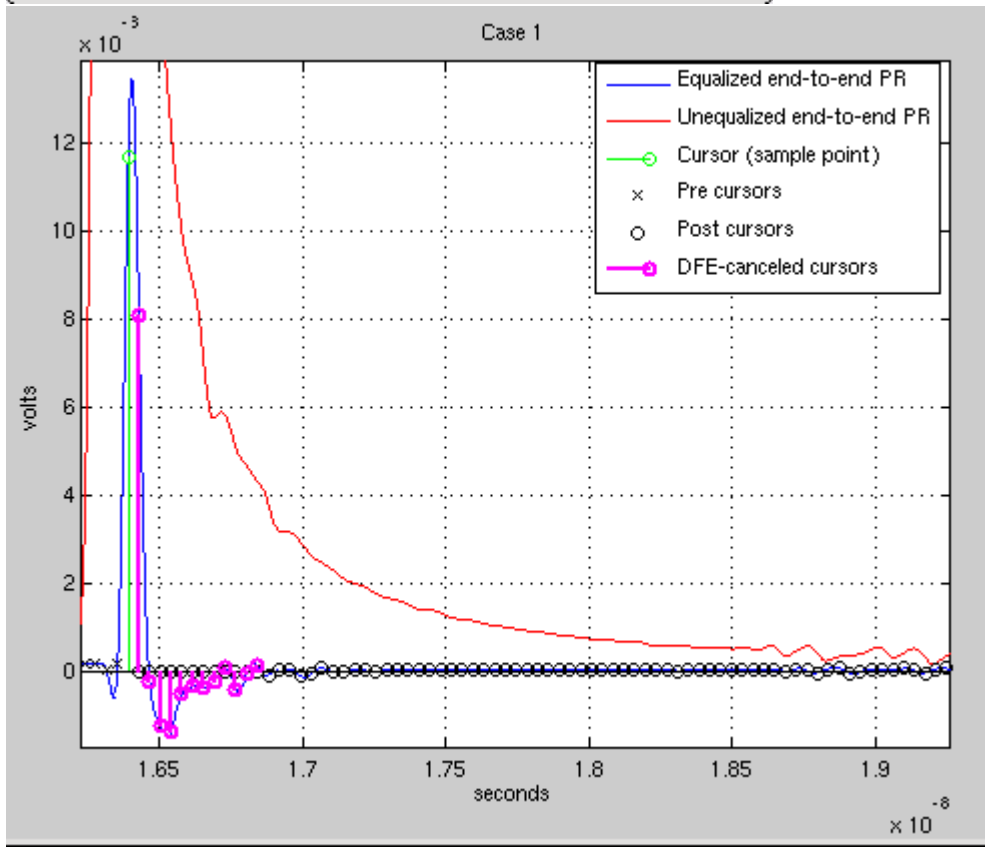
How bad is it? – rough estimate

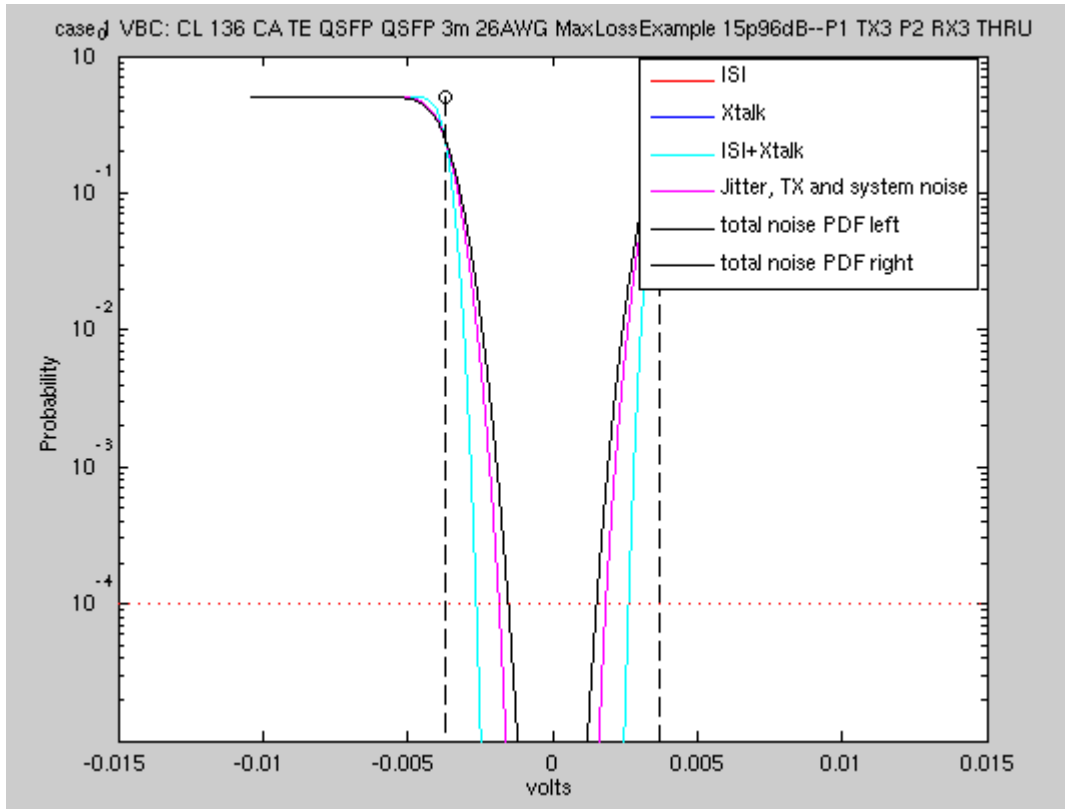
- In the example – 3 ISI terms, each ~0.05% of the unequalized pulse peak
- Assume similar ISI on the receiver side
- Total (RSS) is 1.2% of unequalized pulse, assumed Gaussian
- Tx equalization reduced “signal” amplitude to ~70%
  - This reflection noise is not equalized
  - Effect becomes 1.7% of the signal ➔ COM of 3 dB would be reduced to 2.79 dB

Actual COM test with a cable assembly

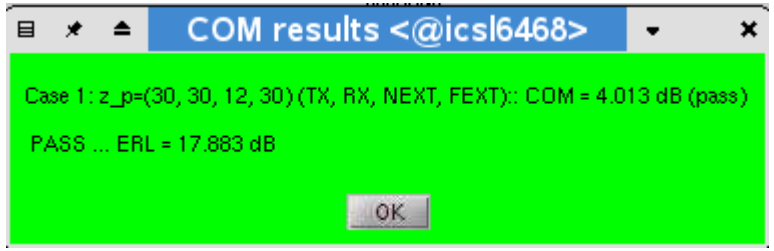


TE_QSFP_QSFP_3m_26AWG_MaxLossExample_15p96dB
Thru only
Current parameters

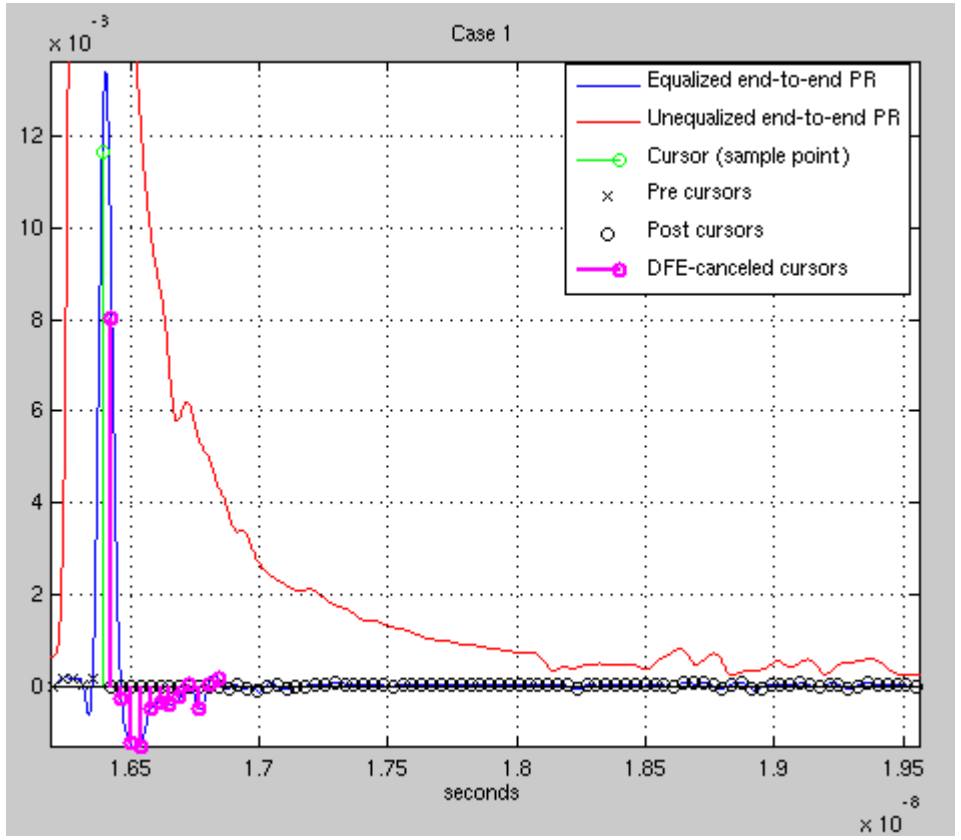


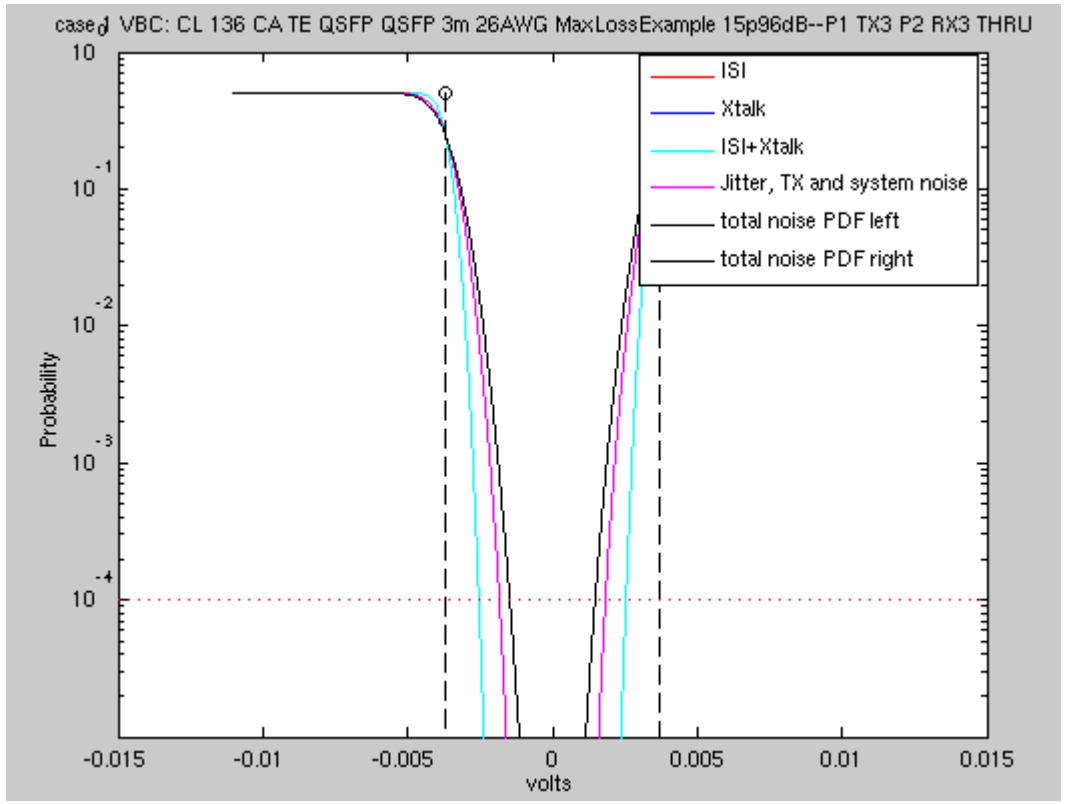


Actual COM test with a cable assembly



TE_QSFP_QSFP_3m_26AWG_MaxLossExample_15p96dB
Thru only
Modified parameters as in the example - ~0.18 dB loss





Notes to consider

- During working group ballot there was significant work done by Yasuo Hidaka, examining effect of variations of termination parameters on performance
  - At the time, COM parameters modeled non-ideal terminations, but not all possible combinations
  - The attempted change was to add a guard band to cover for possible lack of coverage of COM – as an alternative to adding more test cases
  - A 0.5 dB gap between COM channel compliance and Rx ITT calibration was proposed
  - There was no consensus and the proposal was not adopted
- In the January 2018 interim, dudek_3cd_01_0118 proposed a set of changes to termination parameters (improved matching, nominal instead of pessimistic) and a gap of 0.3 dB between cable test and Rx ITT as a guard band
  - The more optimistic parameters were adopted, but the guard band was not… ???!!!
  - Implemented in Draft 3.1
- We introduced a hole in the budget!

Possible solutions

- Revert the parameters to worse values
  - Will takes us back into the old discussions
  - Not likely
- Leave a hole in the budget
  - 50 Gb/s in PAM4 is not in wide deployment yet, unlike 25G days we don't have evidence of margins
  - This will hurt interoperability
  - This will haunt us again in 100G
- Apply the guard band as proposed in dudek_3cd_01_0118
  - Or perhaps a smaller one – 0.2 dB?
  - Note that COM results were improved by the changes in D3.1 by about 0.2 dB so this is not a dangerous change

Proposal - #1

- Change the COM minimum for cable assemblies, creating a guard band
  - Rx ITT is calibrated to 3 dB COM (Table 136–15) – no change
  - In 136.11.8, “COM for any channel within the cable assembly shall be greater than or equal to 3 dB” **– change 3 to 3.3**

Proposal - #2

- Change the COM minimum for backplane, creating a guard band
  - Rx ITT is calibrated to 3 dB COM (Table 120D–6) – no change
  - In 137.10, “COM shall be greater than or equal to 3 dB” – **change 3 to 3.3**

THANK YOU