COM Parameter Refinements for CDAUI Chip to Chip 8x50Gbs PAM4

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July, 2015
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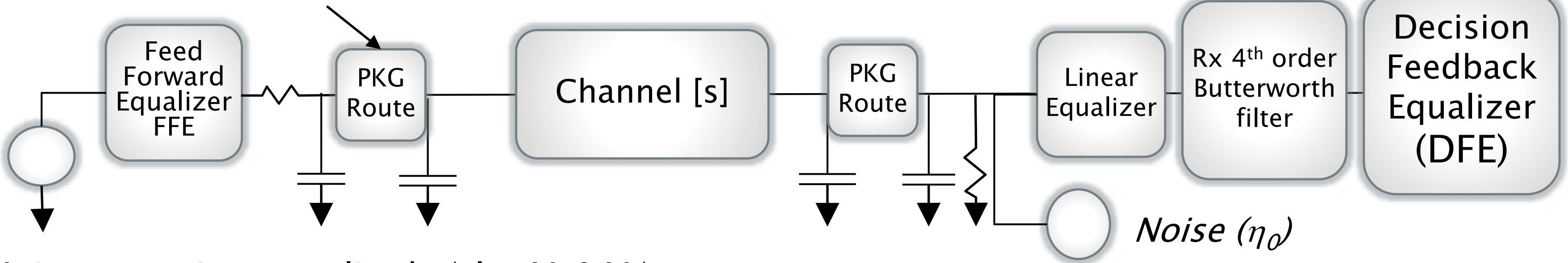
Review of Annex 93a Reference Model

simplified

12mm = 0.88 dB @12.89GHz 78Ω
30mm = 2.22dB @12.89GHz 78Ω



- **V_a** [1] – transmitter amplitude (also V_f & V_n)
- Tx FFE – 1 pre, 1 cursor, 1 post
- **SNR_{tx}** – Signal to noise distortion ratio at Tx. Include transmitter noise, package and Tx induced distortion (In Tx table, called SNDR)
- Package – Tx and Rx same
  - **Z_c , Z_p**, – package impedance, length
  - **C_c, C_p** - device capacitance, bga capacitance in pkg (not inc. board)

- **A_{dd}** – Tx dual Dirac jitter
- **σ_r** – rms random jitter
- **η_0** – Rx noise floor includes ambient system noise
- Continuous Time Linear Equalizer– CTLE
  - **G_{dc}** - AC-DC gain for passive CTLE

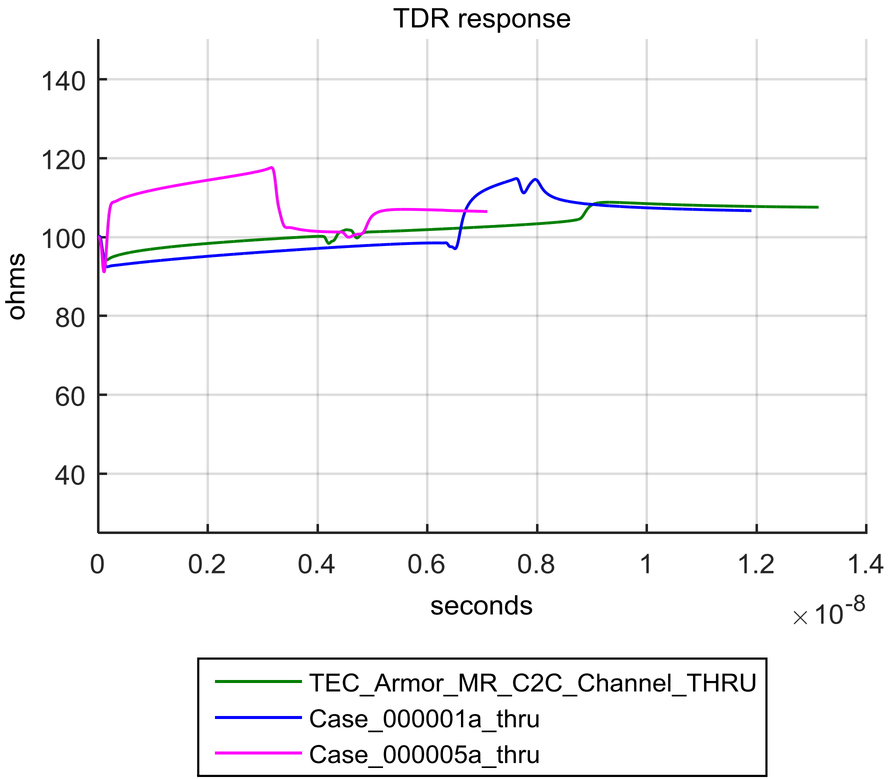
[1] **Bold** is IEEE COM terminology

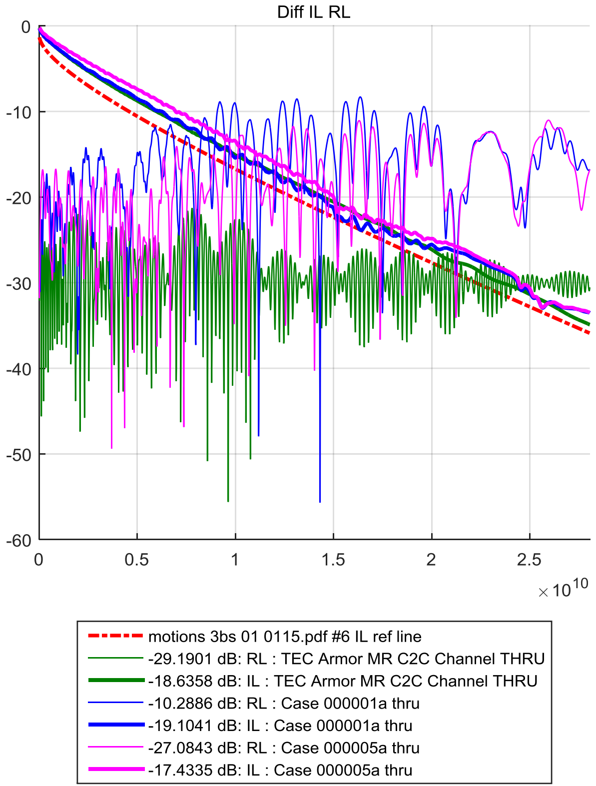
3 Posted C2C Channels Seem to Bound Some 50Gb/s per Lane Challenges

- shanbhag_01_0914--TEC_Armor_MR_C2C
  - Best of the best
    - seems to be room temp and wide Cu trace route
  - 100 ohm traces
    - No impedance variation and BGA escape routing (18.6dB @[1]13.28GHz)
  - No Next
- mellitz_3bs_03a_0315--Case_000001a
  - Better than many 25G boards
  - 25” of exceptional material (0.75dB/in @12.89GHz)
  - Crosstalk is mainly board via coupling
  - 92/108 ohm impedances plus BGA escape routing and 0201 AC cap (19.1dB @[1]13.28GHz)
  - 5 mil, 1oz trace routing @ 65 deg. C
- mellitz_3bs_06a_0315--Case_000005a
  - Better than many 25G boards
  - 15” of good material (1.1dB/in @12.89GHz)
  - Crosstalk is mainly board via coupling
  - 108/92 ohm impedances plus BGA escape routing and 0201 AC cap (17.4dB @[1]13.28GHz)
  - 5 mil, 1oz trace routing @ 65 deg. C

[1] frequency derived from data rate in li_3bs_01_0315

TDR and Loss Plots Illustrate Manufacturing Variations: All Above IL Loss Guideline





Baseline Used for First Computions[2]

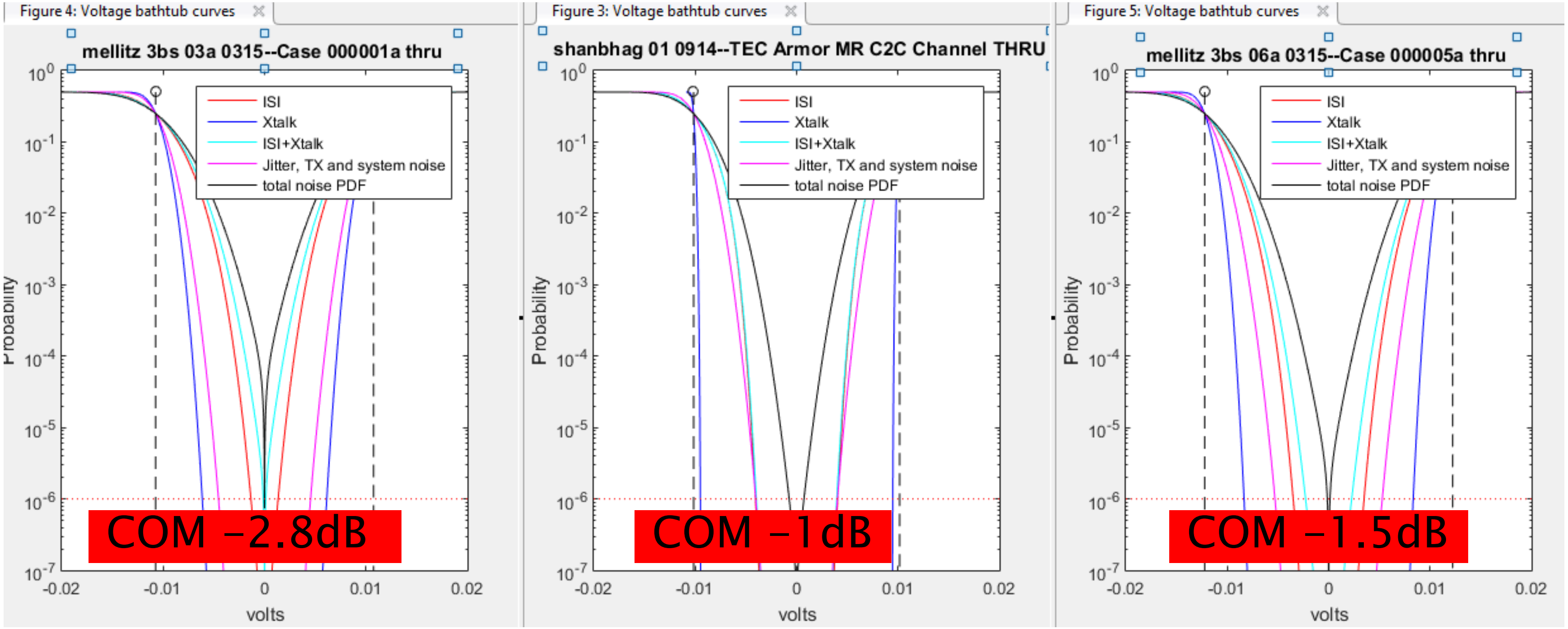
Parameter	Symbol	Value	Units
Signaling rate	f_b	26.5625	GBd
Maximum start frequency	f_{min}	0.05	GHz
Maximum frequency step	Δf	0.01	GHz
Device package model Single-ended device capacitance Transmission line length, Test 1 Transmission line length, Test 2 Single-ended package capacitance at package-to-board interface	 C_d z_p z_p C_p	 ~~TBD~~ → 2.5e-4 12 30 ~~TBD~~ → 1.8e-4	 nF mm mm nF
Single-ended reference resistance	R_0	50	Ω
Single-ended termination resistance	R_d	~~TBD~~ → 52	Ω
Receiver 3 dB bandwidth	f_r	0.75 × f_b	
Transmitter equalizer, minimum cursor coefficient	$c(0)$	0.60	—
Transmitter equalizer, pre-cursor coefficient Minimum value Maximum value Step size	$c(-1)$	 –0.15 0 0.05	 — — —
Transmitter equalizer, post-cursor coefficient Minimum value Maximum value Step size	$c(1)$	 –0.25 0 0.05	 — — —
Continuous time filter, DC gain Minimum value Maximum value Step size	g_{DC}	 –15 0 1	 dB dB dB
Continuous time filter, zero frequency	f_z	f_b / 4	GHz
Continuous time filter, pole frequencies	f_{p1} f_{p2}	f_b / 4 f_b	GHz
Transmitter differential peak output voltage Victim Far-end aggressor Near-end aggressor	 A_v A_{fe} A_{ne}	 0.4 0.4 0.6	 V V V

Number of signal levels	L	4	—
Level separation mismatch ratio	R_{LM}	0.92	—
Transmitter signal-to-noise ratio	SNR_{TX}	31	dB
Number of samples per unit interval	M	32	—
Decision feedback equalizer (DFE) length	N_b	5	UI
Normalized DFE coefficient magnitude limit for n = 1 for n = 2 to N_b	$b_{max}(n)$	1 0.2	—
Random jitter, RMS	σ_{RJ}	0.01	UI
Dual-Dirac jitter, peak	A_{DD}	0.02	UI
One-sided noise spectral density	η_0	5.2×10^{-8}	V^2/GHz
Target detector error ratio	DER_0	10^{-6}	—

[2]li_3bs_01_0315.pdf plus TBD's filled in from CAUI-4

Bath Tub Plots Show Work Needed on ISI, and Jitter, and Noise (only 30 mm package case considered)

http://www.ieee802.org/3/bs/public/channel/TEC/shanbhag_02_0914.pdf
http://www.ieee802.org/3/bs/public/15_03/mellitz_3bs_01_0315.pdf



(COM table used from previous slide)

Package Parameter Alignment: Address Double Counting

- SNDR and voltage amplitudes not consistent with COM package
  - http://www.ieee802.org/3/by/public/adhoc/architecture/mellitz_040815_25GE_adhoc.pdf
  - V_a, V_f , and V_n COM parameter require adjustments of 3.6% per mm COM package trace routing
  - For 20mm package V_a, V_f , and V_n = 0.42v,0.42v, and 0.63v
  - SNDR should be adjusted for at least σ_e from COM package.
- Does σ_n affects jitter since the package results in a slow edge transition time of ~ 0.46 UI
- Recommended SNR_{TX} of 31dB seems plausible

Re-evaluating eta_0 (η_0)

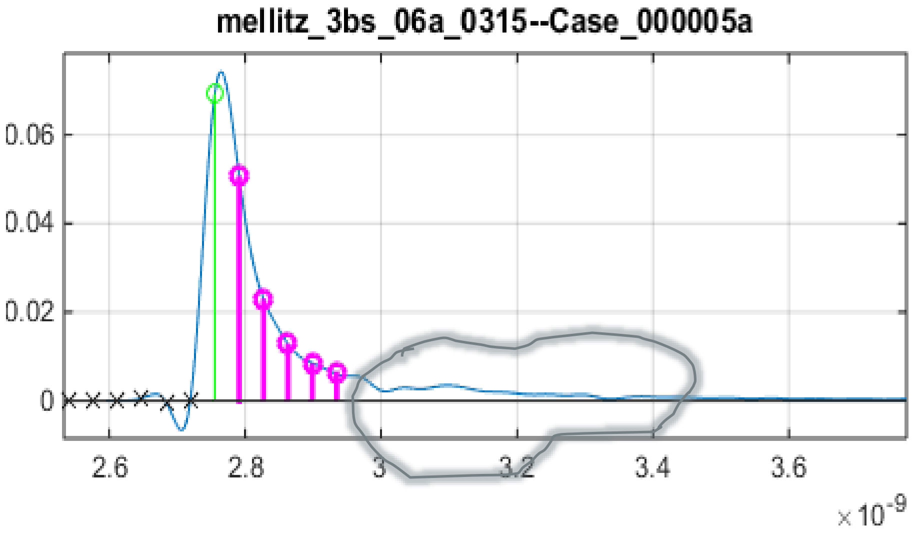
From Clause 92,93 etc.

- $\eta_0 = \frac{{V_{noise\_floor}}^2}{GHz}$ =5.2e-8
- Based on desire to keep 1mV rms as receiver noise

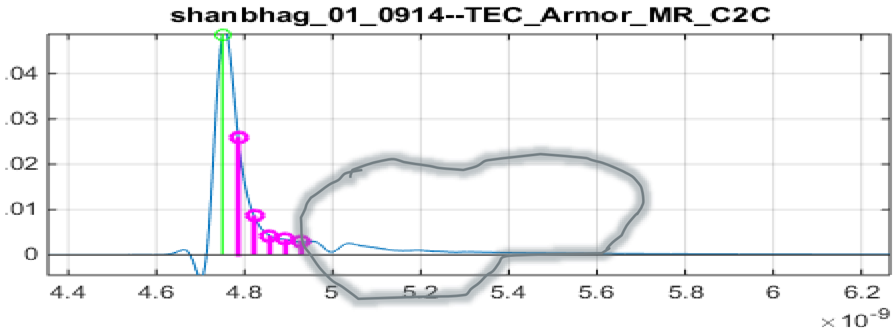
For 2 dB COM limit

- Assume system noise and some Rx noise floor is not in COM Rx budget
- $\eta_r = \frac{{V_{noise\_floor}}^2}{GHz}$=9.5593e-09, for 16 dB receiver noise floor
  - ${V_{noise\_floor}}^2 = 10^{\left(\frac{NF}{10}+log10(T0_K*k_b)+log10(BW)\right)} * \frac{R}{1000}$
- η_s = 9.4115e-9 (½ mV RMS)
  - This is associated with the Channel
  - Recommend is new parameter to be supplied by channel providers
- For COM use $\eta_0 = \eta_r + \eta_s$ =1.8971e-8
  - Unless channel provides η_s

Decaying ISI After 5 DFE Taps (Equalized SBR) Persists



Addition of a c(−2) Tx FFE tap would help keep the available signal larger (0:0.04:0.04) and yield a higher COM



Recommend weak extra DFE taps:

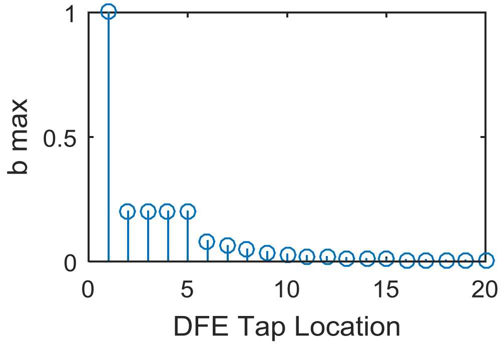
$V(t) = A * e^{B(t-t_{start})}$

Weak DFE taps

$DFE(n) = \frac{V(t_n)}{Asd}$

$tn = t_{start} + n * UI$

$A = 7.9459e\text{-}04$
$B = -2.2084e{+}09$
$Asd = 18.5096$



Hypothetical Suggestions for Addressing ISI

- Add a c(-2) precursor tap with range [0:0.01:0.04]
- Change DFE capability to 5 stronger taps and 15 very weaker taps
  - Set b_{max}= [1 0.2 0.2 0.2 0.2 0.0809 0.0623 0.0480 0.0370 0.0285 0.0220 0.0169 0.0131 0.0101 0.0078 0.0060 0.0046 0.0035 0.0027 0.0021]
  - There are other ways to address this, but this is within the Annex 93A construct
- Change R_d to 52 ohms to better match package
- Change package impedance (Z_c) to 85 ohms to align to a realistic 93 ohm package target minus 10%
- Change package length/loss from 30mm/2.2 dB @ 12.89GHz to 20mm/1.5 dB @ 12.89GHz

Hypothetical Changes Used for Computations

Parameter	Symbol	Value	Units
Signaling rate	f_b	26.5625	GBd
Maximum start frequency	f_{min}	0.05	GHz
Maximum frequency step	Δf	0.01	GHz
Device package model Single-ended device capacitance Transmission line length, Test 1 Transmission line length, Test 2 Single-ended package capacitance at package-to-board interface	 C_d z_p z_p C_p	 ~~TBD~~ → 2.0e−4 12 ~~30~~ → 20 ~~TBD~~ → 1.0e−4	 nF mm mm nF
Single-ended reference resistance	R_0	50	Ω
Single-ended termination resistance	R_d	~~TBD~~ → 52	Ω
Receiver 3 dB bandwidth	f_r	0.75 × f_b	
Transmitter equalizer, minimum cursor coefficient	c(0)	0.60	—
Transmitter equalizer, pre-cursor coefficient Minimum value Maximum value Step size	c(−1)	 −0.15 0 0.05	 — — —
Transmitter equalizer, post-cursor coefficient Minimum value Maximum value Step size	c(1)	 −0.25 0 0.05	 — — —
Continuous time filter, DC gain Minimum value Maximum value Step size	g_{DC}	 −15 0 1	 dB dB dB
Continuous time filter, zero frequency	f_z	f_b / 4	GHz
Continuous time filter, pole frequencies	f_{p1} f_{p2}	f_b / 4 f_b	GHz
Transmitter differential peak output voltage Victim Far-end aggressor Near-end aggressor	 A_v A_{fe} A_{ne}	 ~~0.4~~ → .42 ~~0.4~~ → .42 ~~0.6~~ → .63	 V V V

η_s = 9.4115e−9
η_r = 9.5593e−9

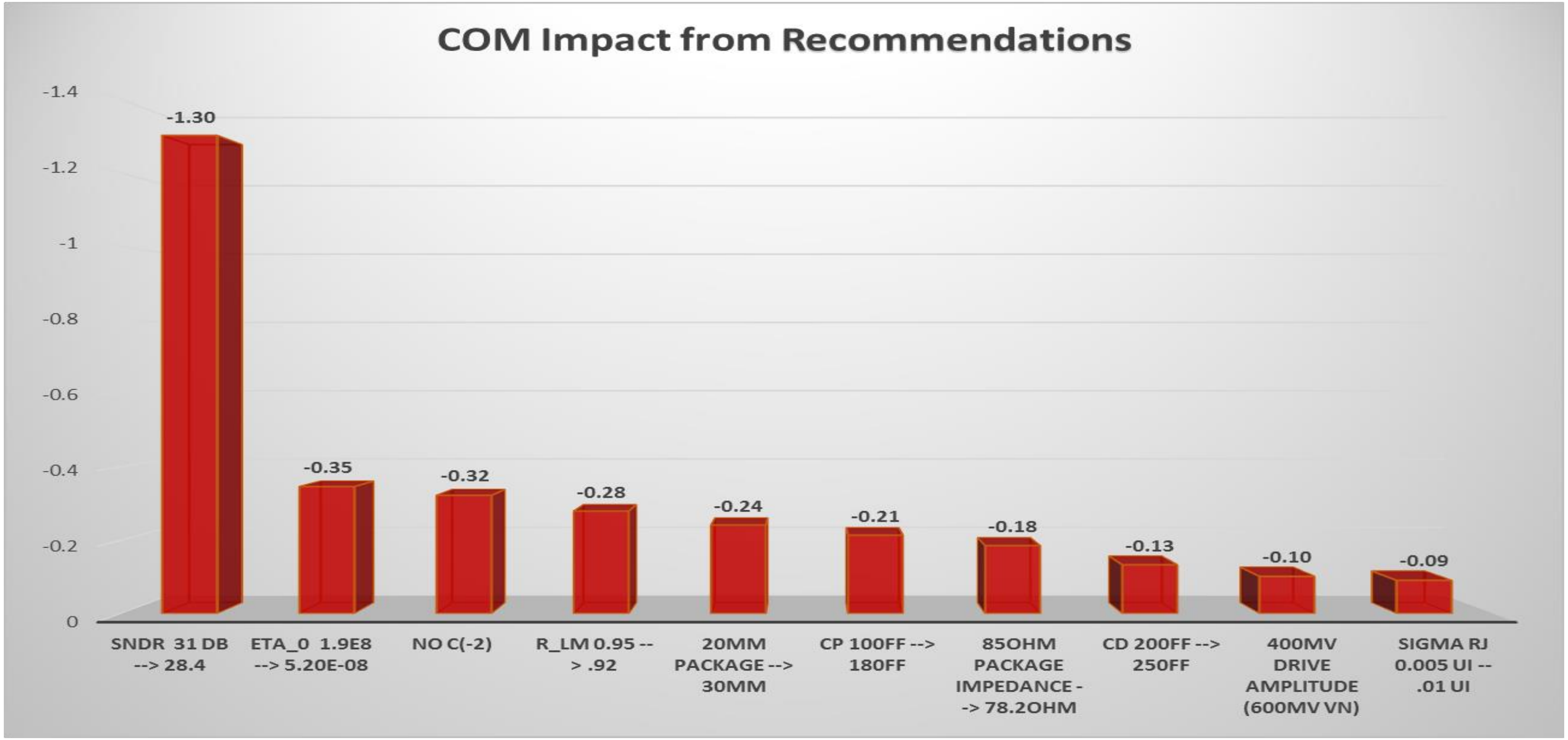
Number of signal levels	L	4	—
Level separation mismatch ratio	R_{LM}	~~0.92~~ → 0.95[1]	—
Transmitter signal-to-noise ratio	SNR_{TX}	31	dB
Number of samples per unit interval	M	32	—
Decision feedback equalizer (DFE) length	N_b	~~5~~ → 20	UI
Normalized DFE coefficient magnitude limit for n = 1 for n = 2 to N_b	$b_{max}(n)$	1 0.2	—
Random jitter, RMS	σ_{RJ}	~~0.01~~ → .005	UI
Dual-Dirac jitter, peak	A_{DD}	0.02	UI
One-sided noise spectral density	η_0	~~5.2 × 10~~ → $\eta_0=\eta_s+\eta_r$	V²/GHz
Target detector error ratio	DER_0	10^{-6}	—

[1 0.2 0.2 0.2 0.2 0.0809 0.0623 0.0480 0.0370 0.0285 0.0220 0.0169 0.0131 0.0101 0.0078 0.0060 0.0046 0.0035 0.0027 0.0021]

c(−2) → (0: 0.01 :0.04)

[1] healey_3bs_01_0315.pdf but more said more data need

COM Parameter Pareto from Hypothetical Changes Shows Impact of Tradeoffs



Results Enable mellitz_3bs_03a_0315--Case_000001a to Exceed 2.0 dB COM

Channels (crosstalk included)	COM	
shanbhag_01_0914--TEC_Armor_MR_C2C	5.27dB	PASS
mellitz_3bs_03a_0315--Case_000001a	2.21dB	PASS
mellitz_3bs_06a_0315--Case_000005a	3.48dB	PASS

Proposal

There seems to a path to success with modification and tradeoffs between a number of parameters.

All of which will require some lengthy consensus building.

With at in mind the proposal is to:

Create a CDAUI-8 C2C electrical ad-hoc to modify COM specification parameters and associated Tx and Rx specifications.