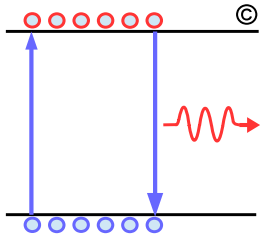


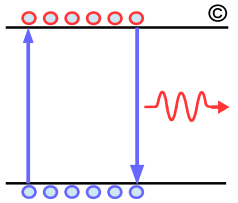
Updated 50G PAM4 C2M Simulations

Ali Ghiasi
Ghiasi Quantum LLC

IEEE 802.3bs Electrical Adhoc Meeting

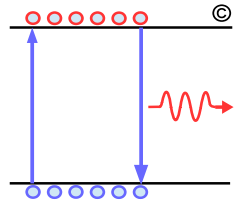
Feb 20th, 2017

Contributor/Supporter



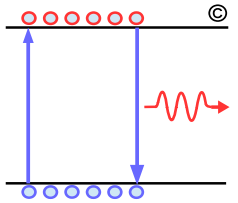
- **Rich Mellitz – Samtec**
- **Yasuo Hidaka – Fujitsu**

Overview



- **Updated simulation evaluates far end eye opening for the TE channels as function of ICN**
- **Updated simulations now include results from Yamaichi QSFP28 connector with significantly lower crosstalk than limits of CL92**
- **The base simulations have consisted of**
  - 6 TE hypothetical channels with crosstalk ~1/6 of MDI definition of clause 92 and referenced by CL 120.E
  - 2 Cisco channels with no crosstalk
- **History of comments on this issue**
  - This issue was first raised with Comment 128 against P802.3bs draft 1.4 that mated board of CL92 crosstalk is excessive in support of 50G Cu cabling
  - Comments 83 and 86 are submitted against D2.0 related to excessive crosstalk not considered in the baseline C2M
  - Comments 135 against D2.1 related to excessive crosstalk not considered in the baseline C2M
- **Clause 120.e specification far end eye opening can't be met as currently defined**
  - A clause 120.d transmitter with max crosstalk as defined by clause 92 MDI can only support about 7.5 dB for good channels and not 10.2 dB!
  - An engineered C2M with improve transmitter coupled with a lower crosstalk MDI can support 10.2 dB objective!

50G Mated Board References Legacy CL92 MCB/HCB Specifications

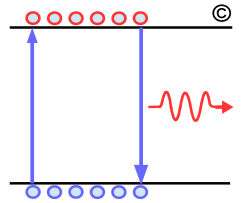


- **Currently CL 120E.4.1 MCB/HCB specifications references**
  - CL 92.11.1 for HCB specifications
  - CL 92.11.2 for the MCB specifications
  - CL 92.11.3.6 defines mated text fixture ICN
    - MDFEXT of 4.8 mV is excessive for 50G PAM4 link!

Table 92–13—Mated test fixtures integrated crosstalk noise

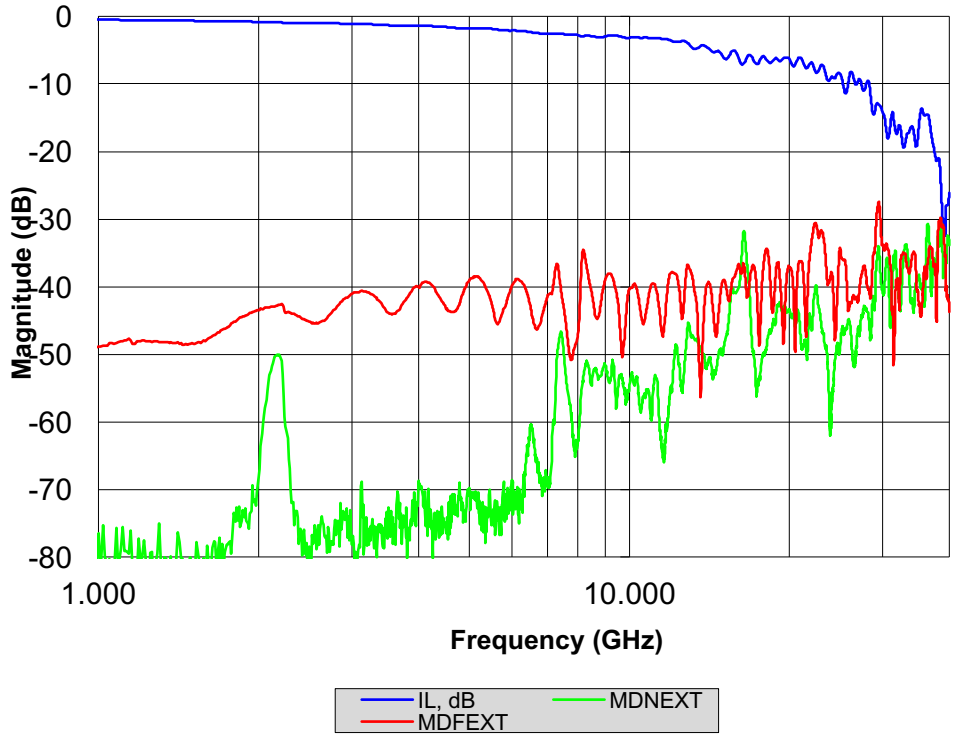
Parameter	100GBASE-CR4	Units
MDNEXT integrated crosstalk noise voltage	Less than 1.8	mV
MDFEXT integrated crosstalk noise voltage	Less than 4.8	mV

Bases for the Mated MCB/HCB MDFEXT/MDNEXT in CL92

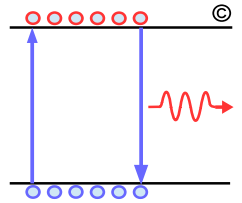


- **QSFP+ connector provided bases for the CL92 MDFEXT and MDNEXT**
  - QSFP28 does provide slight improvement but in 802.3cd decided to stay with these legacy limits
  - http://www.ieee802.org/3/bj/public/sep12/ghiasi_3bj_01a_0912.pdf

MCB-HCB Crosstalk	10.3125 GBd ICN (mV)	25.78 GBd ICN (mV)	28.0 GBd ICN (mV)
Rise Time 20-80% (ps)	24.000	9.600	8.840
MDNEXT	0.323	1.390	1.612
MDFEXT	3.593	4.562	4.673
ICN	3.607	4.769	4.943



Hypothetical Channel Used for C2M Analysis Has Significantly Lower NEXT/FEXT

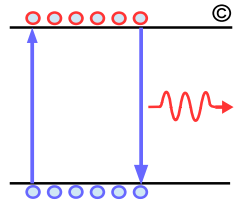


- **CDAUI-8/CCAUI-4 base channels**
  - http://www.ieee802.org/3/bs/public/adhoc/elect/24Aug_15/dallaire_01_082415_elect.pdf

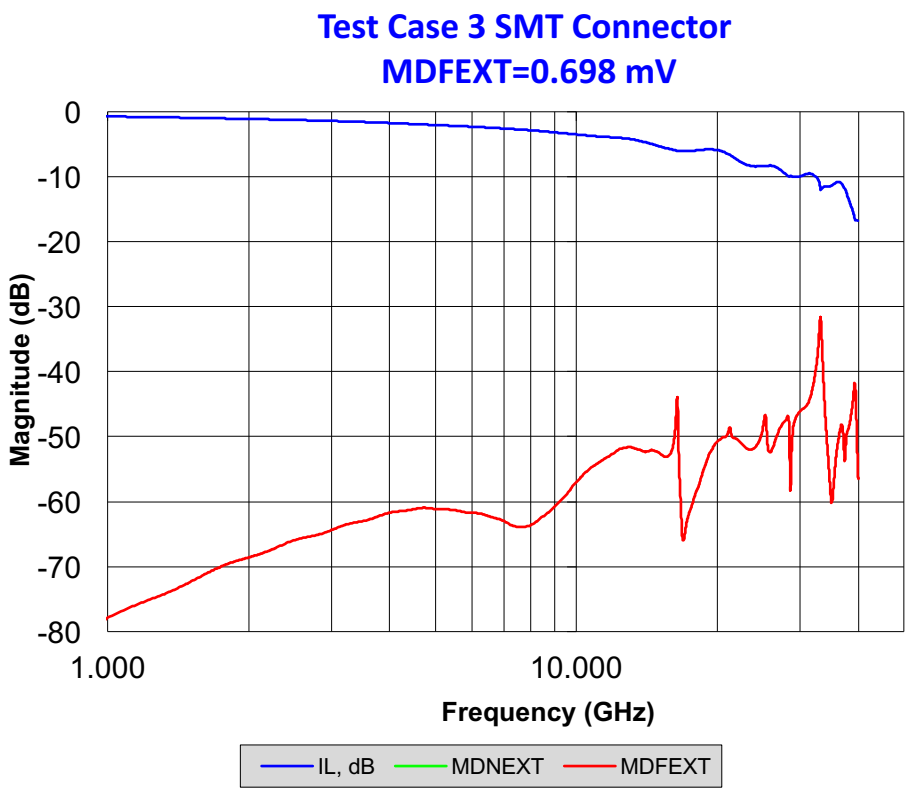
CHANNEL	FEXT	NEXT	IL @ 13.28125 GHz (dB)	ILD (dBrms)
From IEEE 802.3bs shanbhag_3bs_14_0623:				
(1) Nelco 4000-13SI Host PCB + next gen 28Gb/s high density SMT IO	5	0	8.7	0.110
(2) EM-888 Host PCB + next gen 28Gb/s press-fit stacked IO	7	0	8.9	0.051
From IEEE 802.3bs shanbhag_3bs_01_1014:				
(3) 4in Megtron6 Host PCB + next gen 28Gb/s high density SMT IO	5	0	4.3	0.110
(4) 10in Megtron6 Host PCB + next gen 28Gb/s high density SMT IO	5	0	8.8	0.106
(5) 4in Megtron6 Host PCB + next gen 28Gb/s press-fit stacked IO	7	0	4.5	0.051
(6) 10in Megtron6 Host PCB + next gen 28Gb/s press-fit stacked IO	7	0	9.0	0.052
Cisco Channels:				
(7) Cisco 2in Stacked	0	0	8.5	0.237
(8) Cisco 5in Stacked	0	0	11.3	0.245

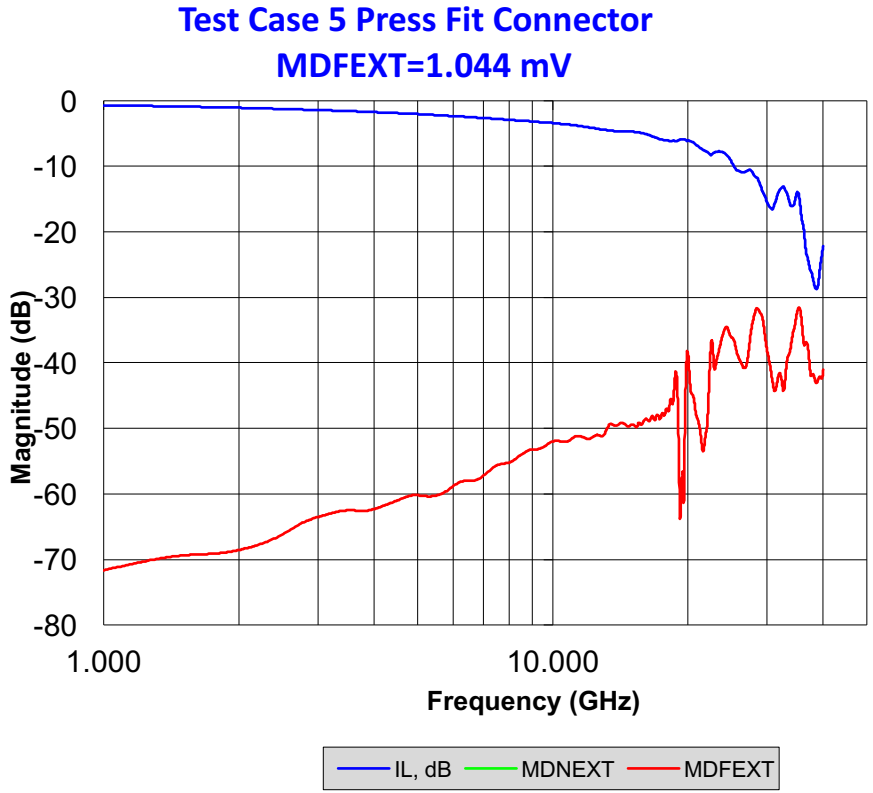
Test case 3 and 5 Having a loss similar to mated board are Used for Crosstalk Analysis

Crosstalk for C2M Test Case 3 and 5

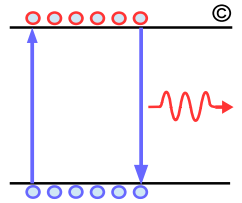


- **Mated board had no NEXT and with excellent FEXT**
  - http://www.ieee802.org/3/bs/public/channel/TEC/shanbhag_3bs_01_1014.pdf
  - C2M are based on channels with 5-7x lower crosstalk than mated board referenced currently!

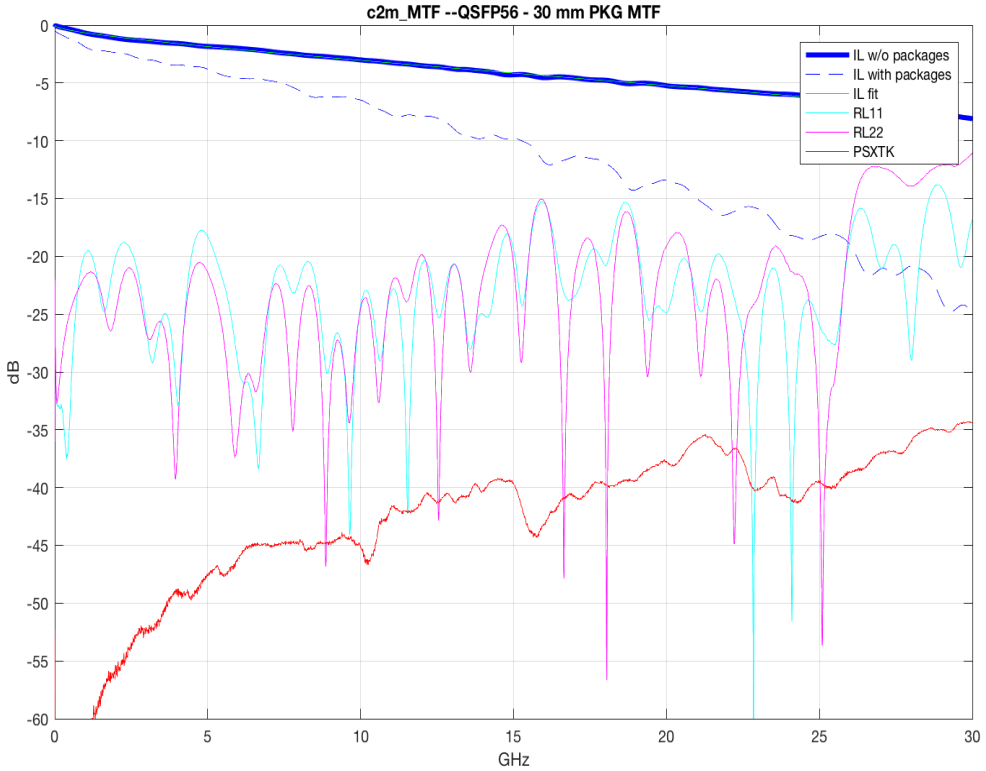


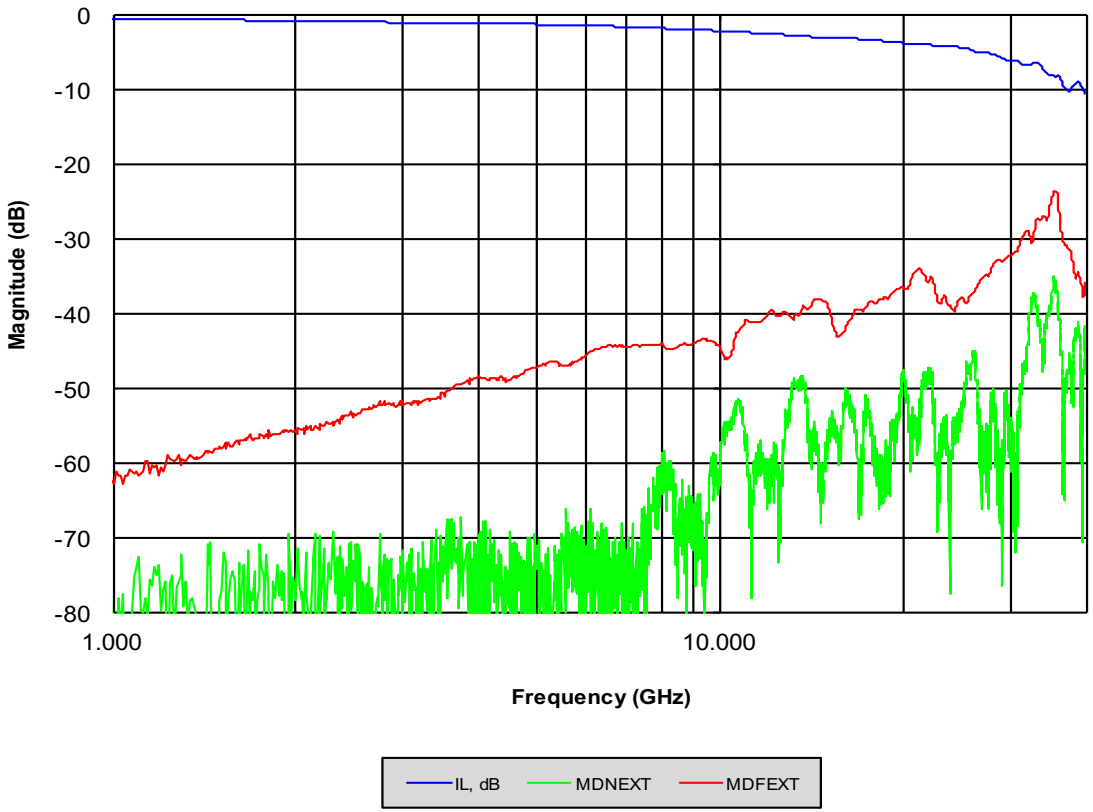


Yamaichi QSFP28

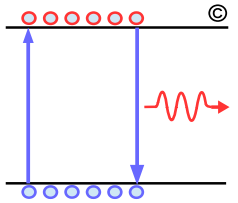


- **Based on measured current generation Yamaichi QSFP28 with lower crosstalk**
  - Mated board loss is only 2.8 dB exasperating the crosstalk value
  - MDNEXT=0.523 mV (RX1-RX4 used 4x) MDFEXT=2.49 mV [FEXT/NEXT aggressor 900/1200 mV]





Baseline C2M Simulation Summary



- **Baseline C2M simulation COM analysis for the hypothetical channels with 5-7x lower crosstalk doesn't even have margin even with CTLE+TXFIR+LFEQ at 1E-5 BER!**
  - Increasing crosstalk by 5-7x on channels below with current link configuration and equalizer will be detrimental!
  - Summary results from http://www.ieee802.org/3/bs/public/adhoc/elect/24Aug_15/dallaire_01_082415_elect.pdf

Channel	1	2	3	4	5	6	7	8
CTLE	-0.07	-0.04	1.01	-0.45	1.24	-0.13	-1.37	-2.65
CTLE + TXFIR	1.47	1.53	1.43	0.84	2.08	1.35	0.84	0.55
CTLE + TXFIR + LFEQ (1E-6)	2.26	2.50	1.99	1.28	2.95	2.14	1.43	0.84
CTLE + TXFIR + LFEQ (1E-5)	3.15	3.39	2.89	2.15	3.87	3.03	2.33	1.72

IEEE COM Rev 165 Parameters

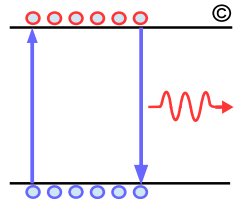


Table 93A-1 parameters			
Parameter	Setting	Units	Information
f_b	26.5625	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[1.8e-4 0]	nF	[TX RX]
z_p select	[2]		[test cases to run]
z_p (TX)	[12 6]	mm	[test cases]
z_p (NEXT)	[12 6]	mm	[test cases]
z_p (FEXT)	[12 6]	mm	[test cases]
z_p (RX)	[0 0]	mm	[test cases]
C_p	[0.9e-4 0]	nF	[TX RX]
R_0	50	Ohm	
R_d	[55 50]	Ohm	[TX RX]
f_r	0.75	*fb	
c(0)	0.6		min
c(-1)	[-0.15:0.05:0]		[min:step:max]
c(-2)	[0:0.025:0.1]		
c(1)	[-0.25:0.05:0]		[min:step:max]
g_DC	3.5 4 4.5 5 5.5 6 6.5	dB	[min:step:max]
f_z	55 5.733 5.353 5.007	GHz	
f_p1	5.6 15.6 15.6 15.6 15	GHz	
f_p2	4.1 14.1 14.1 14.1 14	GHz	
A_v	0.45	V	
A_fe	0.45	V	
A_ne	0.63	V	
L	4		
M	32		
N_b	0	UI	
b_max(1)	0.5		
b_max(2..N_b)	0.2		
sigma_RJ	0.01	UI	
A_DD	0.015	UI	
eta_0	0.00E+00	V^2/GHz	
SNR_TX	33	dB	
R_LM	0.95		
DER_0	1.00E-05		
Operational control		1	
COM Pass threshold	3	dB	
Include PCB	1	Value	0, 1
PHY_type	C2M		
EH_min	32	Value	EH limit
EH_max	1000	Value	EH limit
f_HP_P	2 1.2 1.2 1.2 1.2 1.2 1	GHz	
f_HP_Z	.075 1.05 1.025 1 1 1	GHz	

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
Display frequency domai	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\C2C_{date}\	
SAVE_FIGURES	0	logical
Port Order	[2 4 1 3]	
RUNTAG	c2m_MTF	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
IDEAL_TX_TERM	0	logical
T_r	1.30E-02	ns
FORCE_TR	1	logical

Non standard control options		
INC_PACKAGE	1	logical
IDEAL_RX_TERM	0	logical
INCLUDE_CTLE	1	logical
INCLUDE_TX_RX_FILTER	1	logical
COM_CONTRIBUTION	0	logical

Table 93A–3 parameters		
Parameter	Setting	Units
package_tl_gamma0_a1_a2	0 1.734e-3 1.455e-4]	
package_tl_tau	6.141E-03	ns/mm
package_Z_c	85	Ohm

Table 92–12 parameters		
Parameter	Setting	
board_tl_gamma0_a1_a2	0 4.114e-4 2.547e-4]	
board_tl_tau	6.191E-03	ns/mm
board_Z_c	109.8	Ohm
z_bp (TX)	24	mm
z_bp (NEXT)	24	mm
z_bp (FEXT)	24	mm
z_bp (RX)	0	mm

Host IC [12 30]

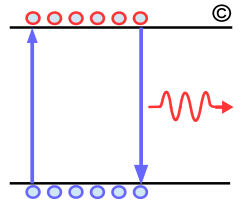
1

Improve transmitter uses A_dd=0.015 UI and SNR_TX=33 dB

1 Adds xyz mm PCB, 0 no extra PCB

http://www.ieee802.org/3/cd/public/channel/mellitz_3cd_01_1116_COM.zip

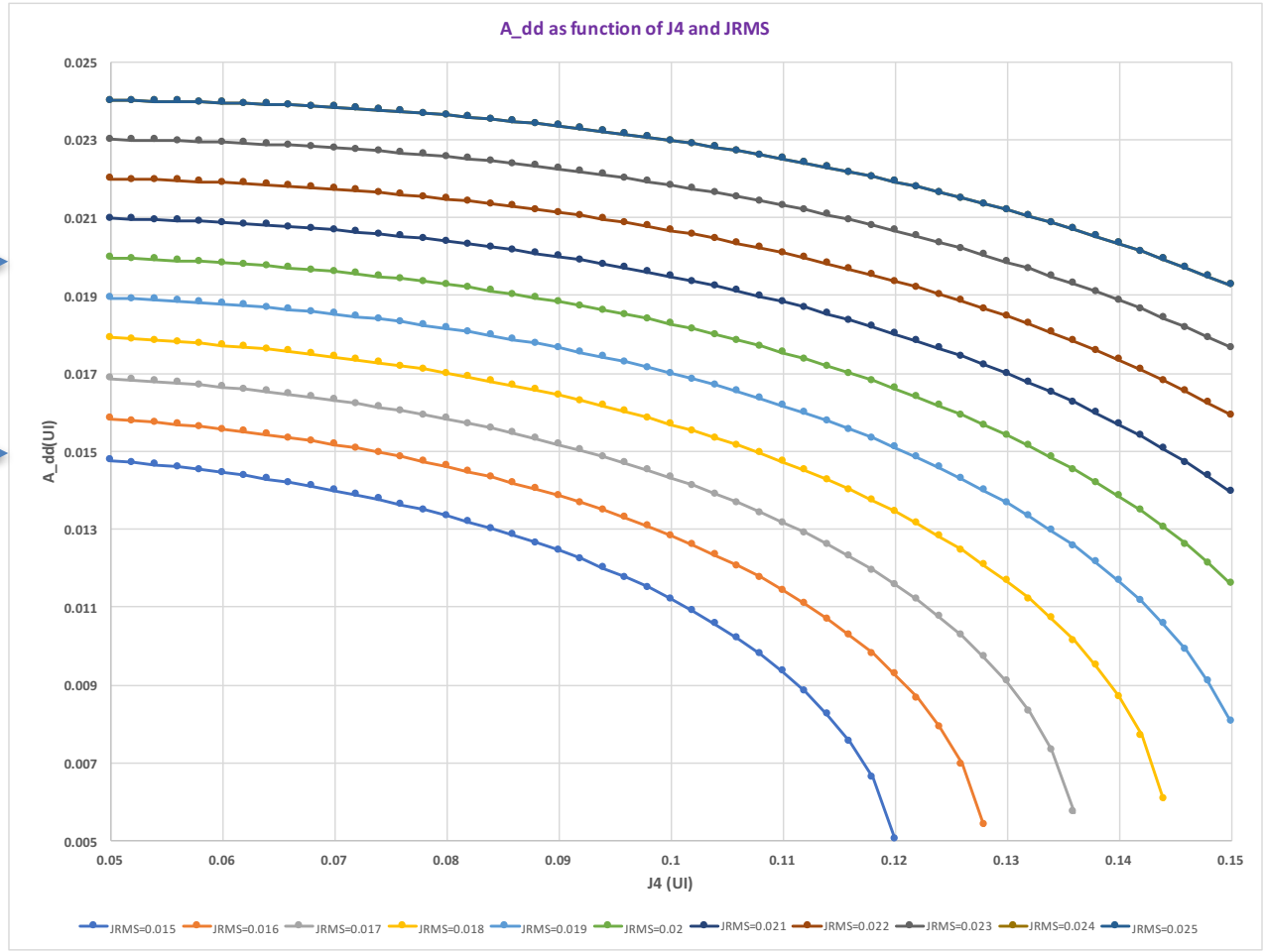
How Realistic is Tighter Transmitter



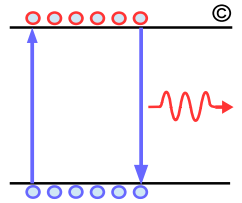
- **Improve transmitter**
  - A_dd=0.015 UI reduced from 0.02 UI
  - Sigma_RJ=0.01 UI unchanged
  - SNR increased to 33 dB
  - Package trace reduced to 24 mm
- **But other combination may also yield the same results**
  - Adding TP0a eye opening test could potentially allow trade off between above parameters as well other parameters.

Cl 120.d limit

Improve TX



TP1a Output as function of Channel IL and ICN



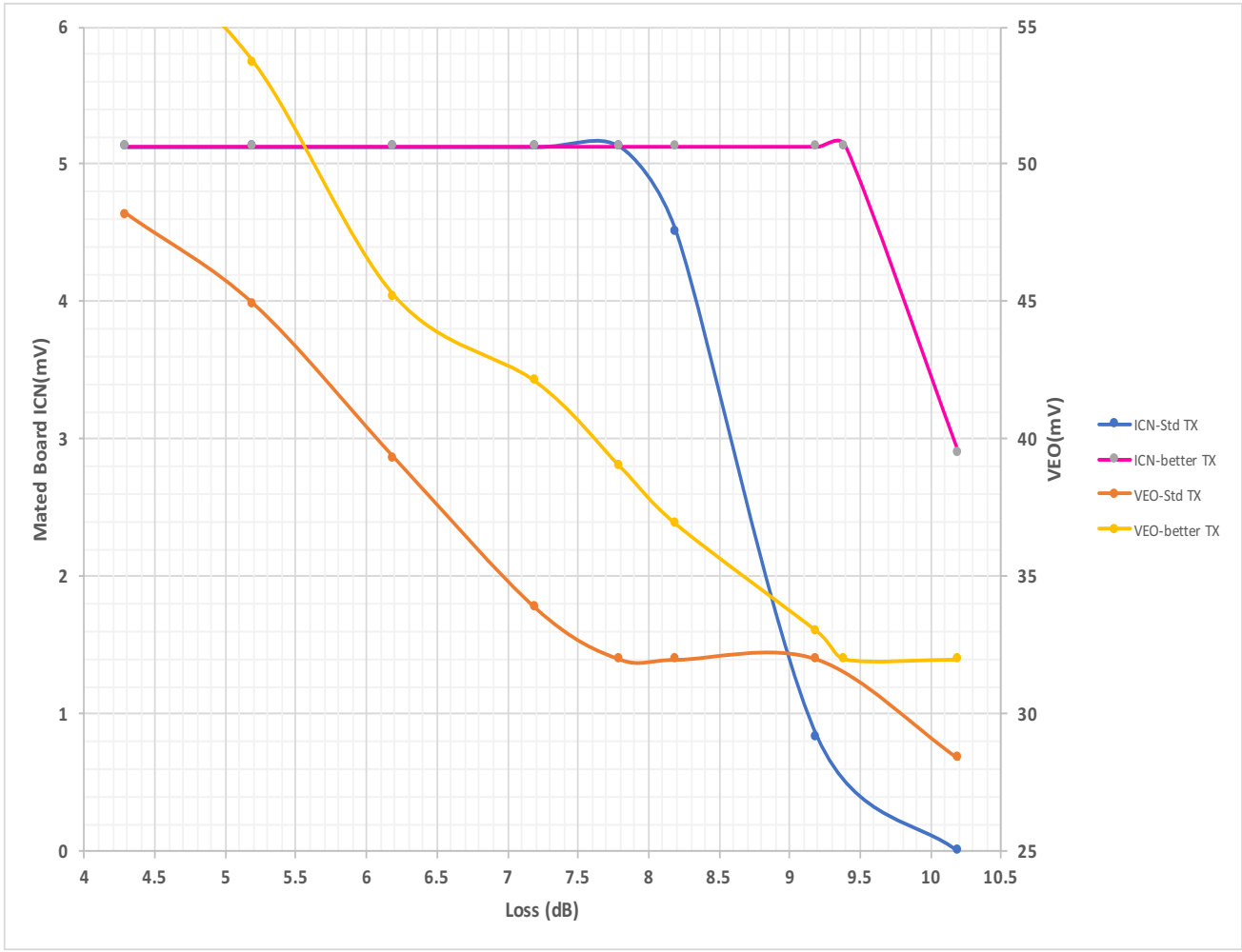
- **Collocation of results with more data points from**

http://www.ieee802.org/3/bs/public/adhoc/elect/30Jan_17/ghiasi_01_013017_elect.pdf

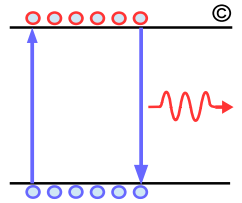
- **Channel for this analysis is the TE 4" stacked hypothetical channels with additional loss added per definition of CL 92**

http://www.ieee802.org/3/bs/public/channel/TEC/shanbhag_3bs_01_1014.pdf

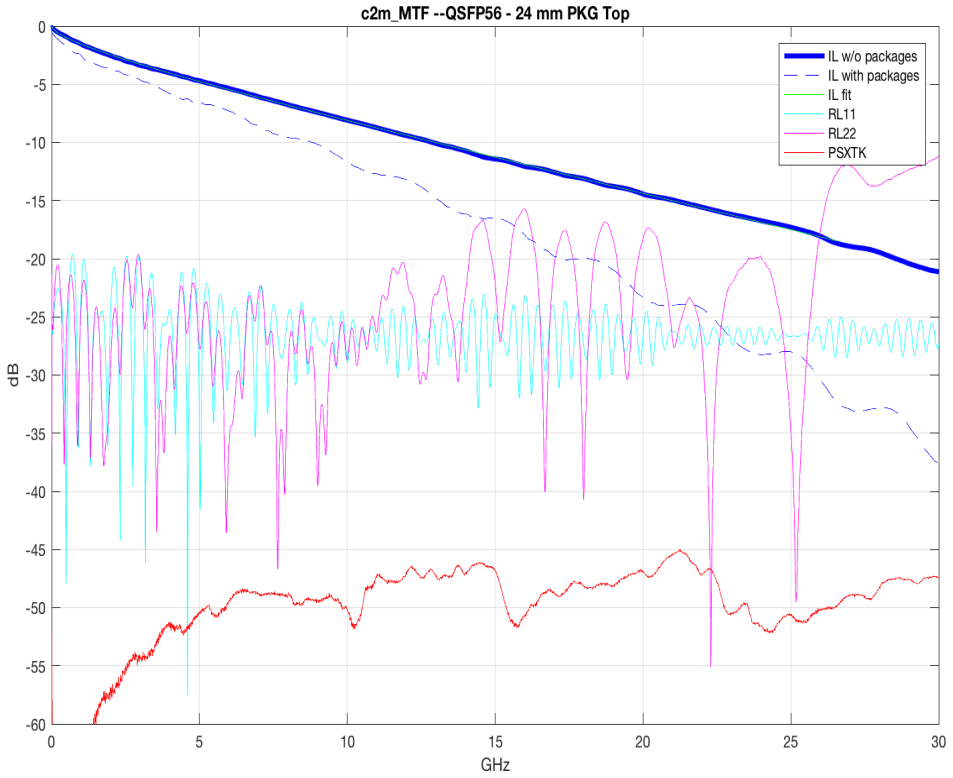
- **Results are for worst case and improved transmitter**
  - Worst TX PKG=30 mm, SNR=31, A_dd=0.02 UI
  - Better TX PKG=24 mm, SNR=33, A_dd=0.015 UI
- **With CL92 mated board and standard TX only 7.8 dB channel can be supported**
- **Improve TX with lower crosstalk mated board ICN of 2.9 mV can support current objective of 10.2 dB**
  - Other configuration may also support 10.2 dB objective
- **Standard TX with CL 92 can't support 10.2 dB and CL120.e should suggest it!**



TP1a Results for Yamaichi QSFP28



- **10.2 dB channels can be supported with next Gen QSFP28 having lower ICN**
  - Std transmitter PKG=30 mm, A_dd=0.02, SNR=31 dB
  - Improve transmitter PKG=24 mm, A_dd=0.015, SNR=33 dB

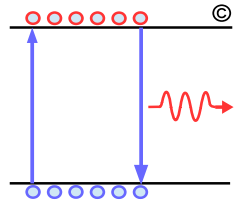


Results with Std TX:
VEO*=26.8 mV (failing), ICN=1.435 mV, Peak ISI=9.77 mV, MDFEXT Peak=2.6 mV, MDNEXT=0.51, ILD(FOM)=0.042, COM=4.97 dB

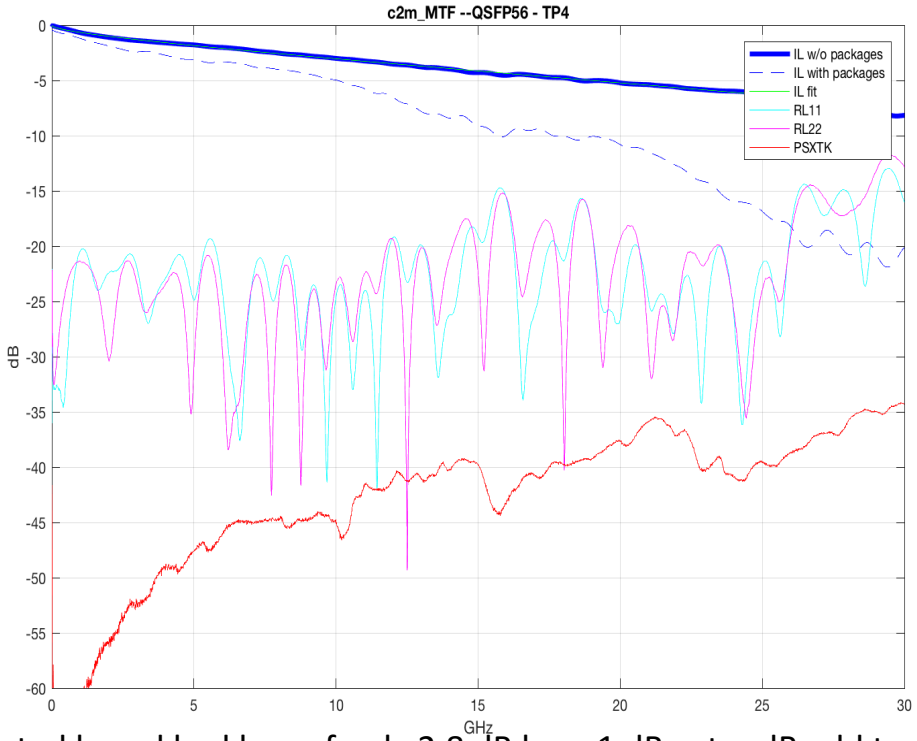
Results with Improve TX:
VEO*=31.58 mV (failing), ICN=1.434 mV, Peak ISI=11.07 mV, MDFEXT Peak=2.6 mV, MDNEXT=0.51, ILD(FOM)=0.042, COM=4.97 dB

By lowering EH at TP1a to 30 mV then 10.2 dB can be supported!

TP4/TP5 Results for Yamaichi QSFP28*



- **10.2 dB channels can be supported with an existing QSFP28 with lower ICN**
  - Std transmitter PKG=[6 12] mm, A_dd=0.02, SNR=31 dB
  - Improve transmitter PKG=[6 12] mm, A_dd=0.015, SNR=33 dB



Results with Std TX:
TP4: VEO*=67.8 mV (failing), ICN=1.435 mV, Peak ISI=22.22 mV, MDFEXT Peak=5.5 mV, MDNEXT=1.28, ILD(FOM)=0.044, COM=4.99 dB
TP5: VEO= 28.3 mV (failing)

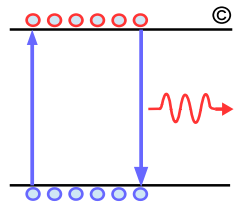
Results with Improve TX:
TP4: VEO*=71.2 mV (failing), ICN=1.434 mV, Peak ISI=11.07 mV, MDFEXT Peak=5.5 mV, MDNEXT=1.28, ILD(FOM)=0.042, COM=5.99 dB
TP5: VEO=33.2 mV

Results for improve transmitter with A_fe=0.9, A_ne=1.26 (double crosstalk):
VEO*=67.5 mV (failing), ICN=2.64 mV, Peak ISI=22.2 mV, MDFEXT Peak=10.54 mV, MDNEXT=2.61, ILD(FOM)=0.045, COM=5.56 dB
TP5: VEO=31.67 mV

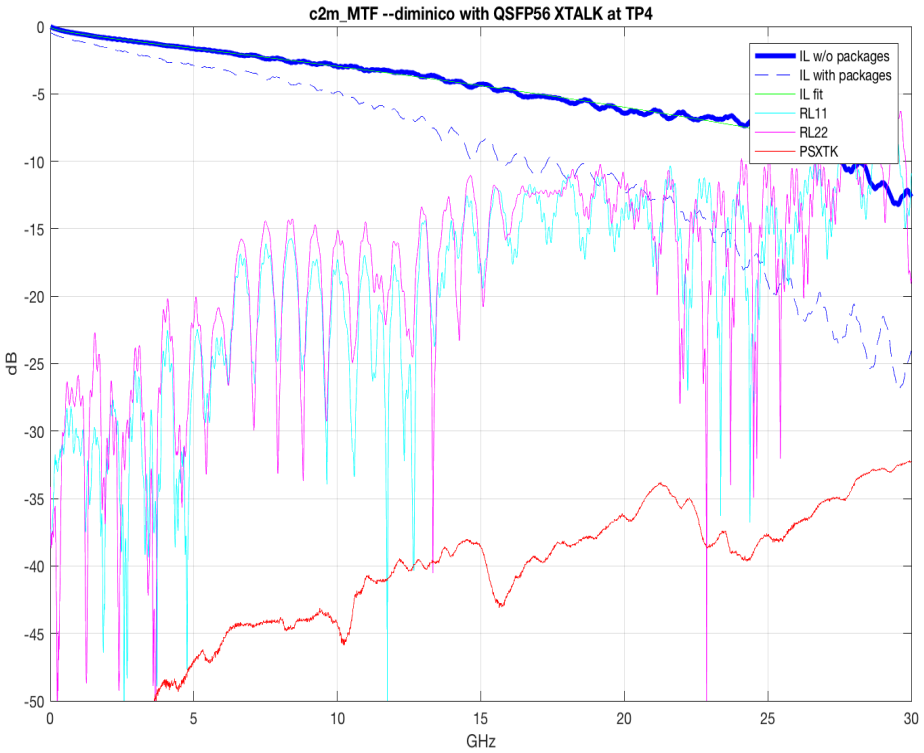
Lowering EH at TP4 from 90 mV to 70 mV should be sufficient for 30 mV at TP5!

* Mated board had loss of only 2.8 dB loss, 1 dB extra dB add to increase loss to 3.8 dB and may result in excess crosstalk.

TP4 Results for diminico MTF with Yamaichi QSFP28 Crosstalk



- **10.2 dB channels can be supported with an existing QSFP28 with lower ICN**
  - Std transmitter PKG=[6 12] mm, A_dd=0.02, SNR=31 dB
  - Improve transmitter PKG=[6 12] mm, A_dd=0.015, SNR=33 dB



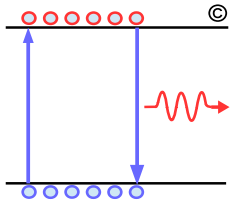
Results for std transmitter with A_fe=0.9, A_ne=1.26:
VEO*=67.7 mV (failing), ICN=2.9 mV, Peak ISI=24.1 mV, MDFEXT Peak=12.2 mV, MDNEXT=2.95, ILD(FOM)=0.055, COM=5.8 dB
TP5: VEO=31.2 mV

Results for improve transmitter:
TP4: VEO*=81.6 mV (failing), ICN=2.927 mV, Peak ISI=11.07 mV, MDFEXT Peak=6.38 mV, MDNEXT=1.47, ILD(FOM)=0.055, COM=6.38 dB
TP5: VEO=38.2 mV

Results for improve transmitter with A_fe=0.9, A_ne=1.26 (double crosstalk):
VEO*=77.3 mV (failing), ICN=2.927 mV, Peak ISI=24.1 mV, MDFEXT Peak=12.2 mV, MDNEXT=2.95, ILD(FOM)=0.055, COM=5.9 dB
TP5: VEO=36.24 mV

Lowering EH at TP4 from 90 mV to 70 mV should be sufficient for 30 mV at TP5!

Summary



- **802.3bs C2M simulation in support of 50G/lane PAM4 were based on a TE hypothetical connector with ~6x lower FEXT and NEXT and does not provided technical feasibility with current MDI definition**
  - Currently 10.2 dB channel can be supported only with no crosstalk!
- **P802.3bs clause 120.E which reference CL92 has excessive amount of MDFEXT (4.8 mV) and MDNEXT (1.8 mV) which does not support 10.2 dB channel assuming clause 120.d transmitter**
- **If we don't want to tighten the crosstalk and transmitter then 10.2 dB limit of C2M should be reduced to 7.5 dB**
- **A representative QSFP28 exist that offers ~40% lower crosstalk than limits of CL 92 MDI**
- **An improve MDI with an improve transmitter can support 10.2 dB in several ways, so we have the following option**
  - Option A: Change 10.2 dB to 7.5 dB for current MDI crosstalk with CL120.d TX
  - Option B: Reduce MDFEXT=2.8 mV and PSXT=2.9 mV and define an improved CL120.d TX to support 10.2 dB
  - Option C: Reduce C2M channel loss to 7.5 dB and leave the current crosstalk limit of CL 92, then add an informative section on engineered link implementation to support up to 10.2 dB using COM analysis.