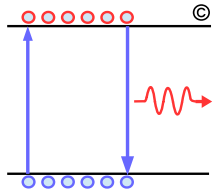


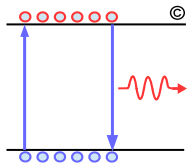
Updated 50G PAM4 C2M Simulations

Ali Ghiasi
Ghiasi Quantum LLC

IEEE 802.3bs Electrical Adhoc Meeting

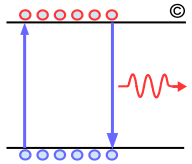
Jan 30th, 2017

Contributor/Supporter



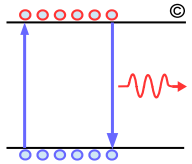
- **Rich Mellitz – Samtec**
- **Yasuo Hidaka – Fujitsu**

Overview



- **The updated contribution adjust for effect of Sigma_x**
  - Updated result adjust for PAM4 Sigma_x =sqrt(5/9) to calibrate COM MDFEXT output with A_fe=3.09
  - Updated results one set represent host to module and another set represent module to host
    - Host ASIC assumed package [6 30] mm
    - Module IC assumed packaged [6 12] mm
  - Updated result with host IC with higher loss is almost a wash with module IC having lower loss but higher crosstalk
- **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 92 MDI data without crosstalk show just about passes vertical eye opening**
  - There is very strong indication that clause 120.e fails badly far end eye opening
  - Having MDI data which include crosstalk data will improve the simulation results and accuracy
- **Several times have requested representative clause 92 MDI data for more accurate simulation but no new data has yet been provided.**

50G Mated Board References Legacy CL92 MCB/HCB Specifications

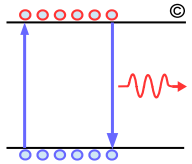


- **Currently CL 120E.4.1 MCB/HCB specifications references**
  - CL 92.11.1 for HCB specifications
  - CL 92.11.2 for the MCB specifications
  - CL 92.11.3.6 defines mated text fixture ICN
    - MDFEXT of 4.8 mV is excessive for 50G PAM4 link!

Table 92–13—Mated test fixtures integrated crosstalk noise

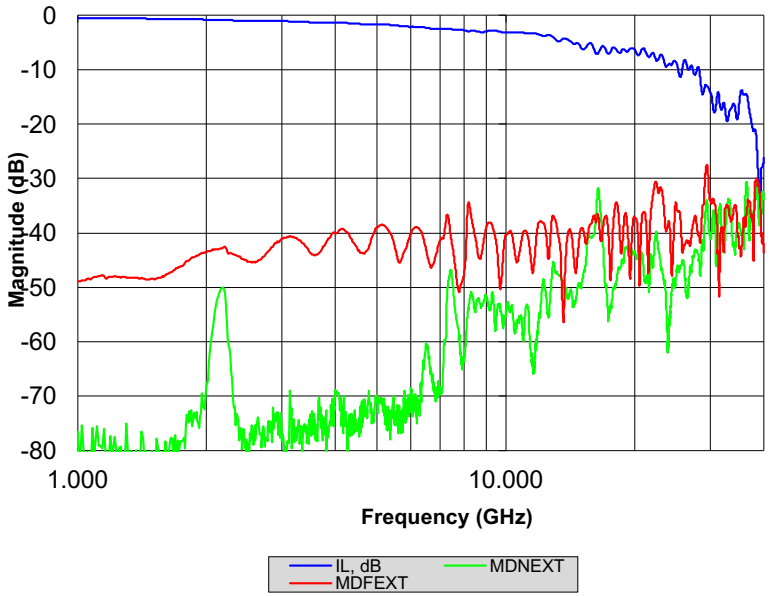
Parameter	100GBASE-CR4	Units
MDNEXT integrated crosstalk noise voltage	Less than 1.8	mV
MDFEXT integrated crosstalk noise voltage	Less than 4.8	mV

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

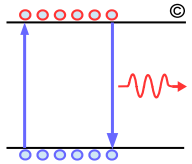


- **QSFP+ connector provided bases for the CL92 MDFEXT and MDNEXT**
  - QSFP28 does provide slight improvement but in 802.3cd decided to stay with these legacy limits
  - http://www.ieee802.org/3/bj/public/sep12/ghiasi_3bj_01a_0912.pdf

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

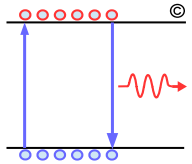


- **CDAUI-8/CCAUI-4 base channels**
  - http://www.ieee802.org/3/bs/public/adhoc/elect/24Aug_15/dallaire_01_082415_elect.pdf

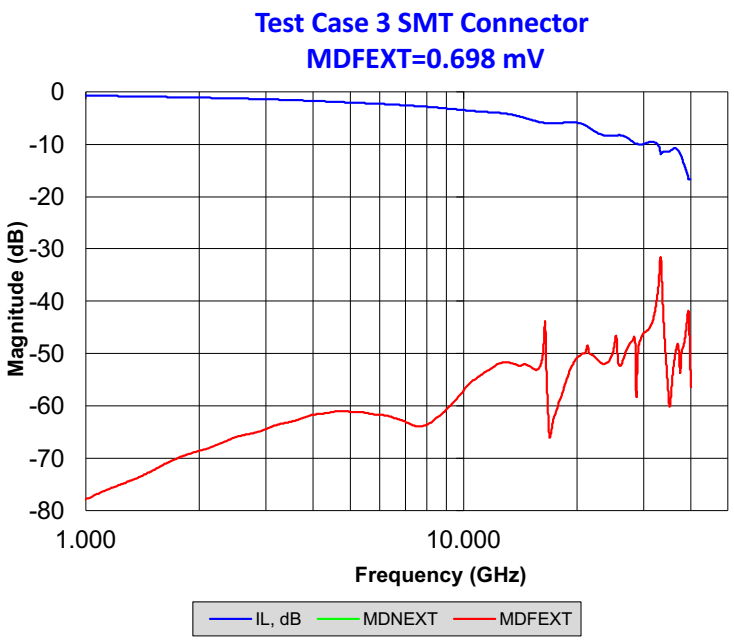
CHANNEL	FEXT	NEXT	IL @ 13.28125 GHz (dB)	ILD (dBrms)
From IEEE 802.3bs shanbhag_3bs_14_0623:				
(1) Nelco 4000-13SI Host PCB + next gen 28Gb/s high density SMT IO	5	0	8.7	0.110
(2) EM-888 Host PCB + next gen 28Gb/s press-fit stacked IO	7	0	8.9	0.051
From IEEE 802.3bs shanbhag_3bs_01_1014:				
(3) 4in 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

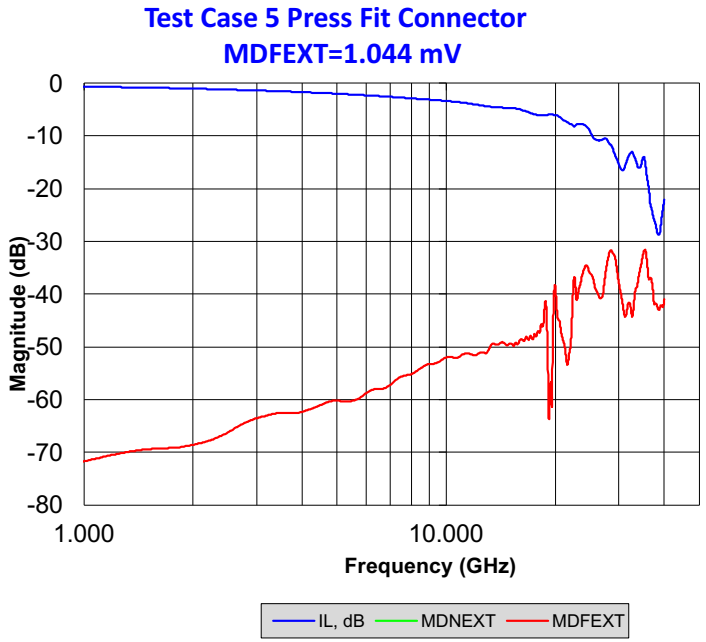
Test case 3 and 5 Having a loss similar to mated board are Used for Crosstalk Analysis

Crosstalk for C2M Test Case 3 and 5

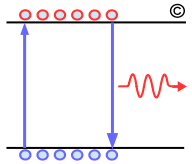


- **Mated board had no NEXT and with excellent FEXT**
  - http://www.ieee802.org/3/bs/public/channel/TEC/shanbhag_3bs_01_1014.pdf
  - C2M are based on channels with 5-7x lower crosstalk than mated board referenced currently!





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

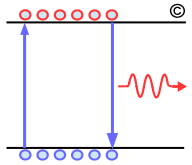


Table 93A-1 parameters			
Parameter	**Setting**	**Units**	**Information**
f_b	26.5625	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[1.8e-4 0]	nF	[TX RX]
z_p select	[2]	[test cases to run]	
z_p (TX)	[6 30]	mm	[test cases]
z_p (NEXT)	[6 30]	mm	[test cases]
z_p (FEXT)	[12 0]	mm	[test cases]
z_p (RX)	[0 0]	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	.5 4 4.5 5 5.5 6 6.5 7	dB	[min:step:max]
f_z	.733 5.353 5.007 4.69	GHz	
f_p1	15.6 15.6 15.6 15.6 1	GHz	
f_p2	14.1 14.1 14.1 14.1 1	GHz	
A_v	0.45	V	
A_fe	3.09	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	0.02	UI	
eta_0	0.00E+00	/^2/GHz	
SNR_TX	31	dB	
R_LM	0.95		
DER_0	1.00E-05		
Operational control	**1**		
COM Pass threshold	3	dB	
Include PCB	0	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	GHz	
f_HP_Z	75 1.05 1.025 1 1 1 1	GHz	

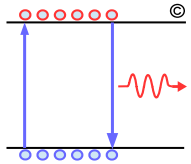
I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
Display frequency domain	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\C2C_{date}\	
SAVE_FIGURES	0	logical
Port Order	[2 4 1 3]	
RUNTAG	c2m_MTF	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
IDEAL_TX_TERM	0	logical
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	[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	[4.114e-4 2.547e-4]	
board_tl_tau	6.191E-03	ns/mm
board_Z_c	109.8	Ohm
z_bp (TX)	150	mm
z_bp (NEXT)	150	mm
z_bp (FEXT)	150	mm
z_bp (RX)	0	mm

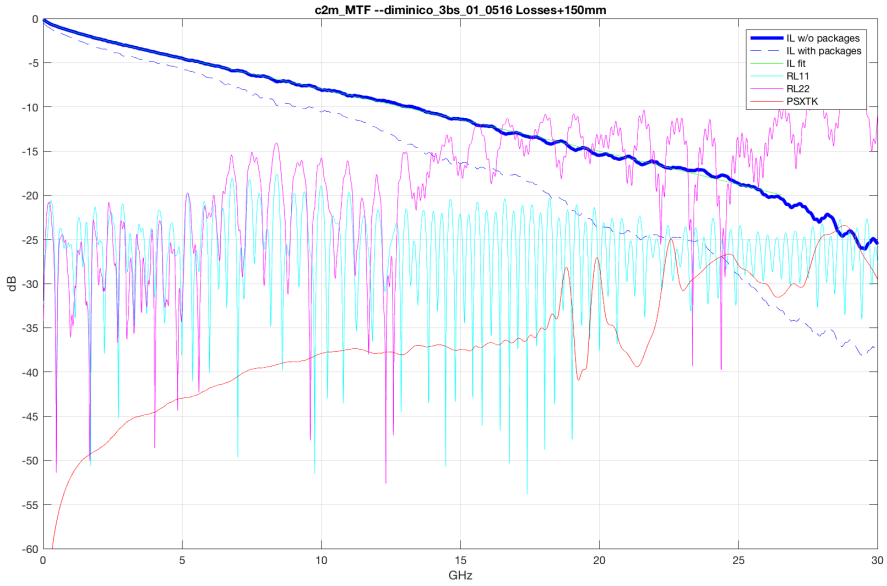
1 Adds 150 mm of PCB, 0 no extra PCB

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

Results with MTF Test Board

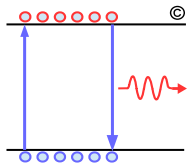


- **TP1a response of the MTF test board + 150 mm (10.2 dB loss) has output VEO=28.7 mV without any crosstalk failing CL 120.E TP1a limit even without crosstalk!**
  - MTF board http://www.ieee802.org/3/bs/public/channel/mccom/diminico_3bs_01_0516.s4p

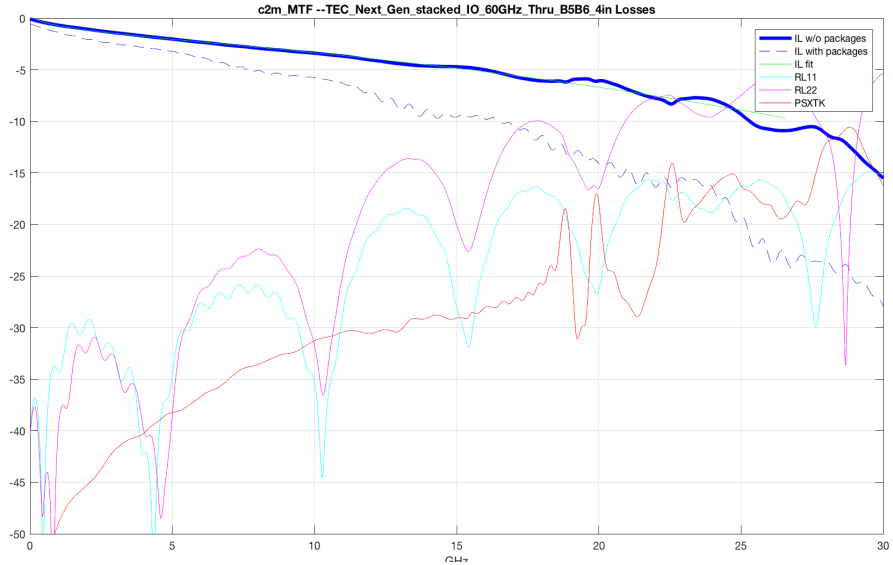


Using COM version 165
Results for MTF like channel with IL_fit=10.25 dB
VEO=28.7 mV, ICN=0 mV, Peak ISI=9.31 mV, MDFEXT Peak=0 mV, ILD(FOM)=0.062, COM=5.34 dB

4” TE Stacked 50G Channel Meeting MTF (Host Output TP1a)



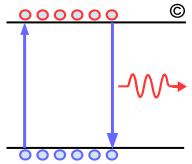
- **Based on TE hypothetical connector with IL_Fit of 4.3 dB but having MDFEXT p-p=2.37 mV (MDFEXT RMS for BER 1E-5=2.37/4.26=0.56 mV)**
  - To account for worst case MDFEXT=4.8 mV and MDNEXT=1.8 mV (PSXT=5.13 mV RMS) A_fe in in COM was adjusted from 0.45 to 3.09 in order to get MDFEXT p-p of 16.31 mV equivalent to PSXT of 5.13 mV RMS per table 92-13
  - http://www.ieee802.org/3/bs/public/channel/TEC/shanbhag_3bs_01_1014.pdf



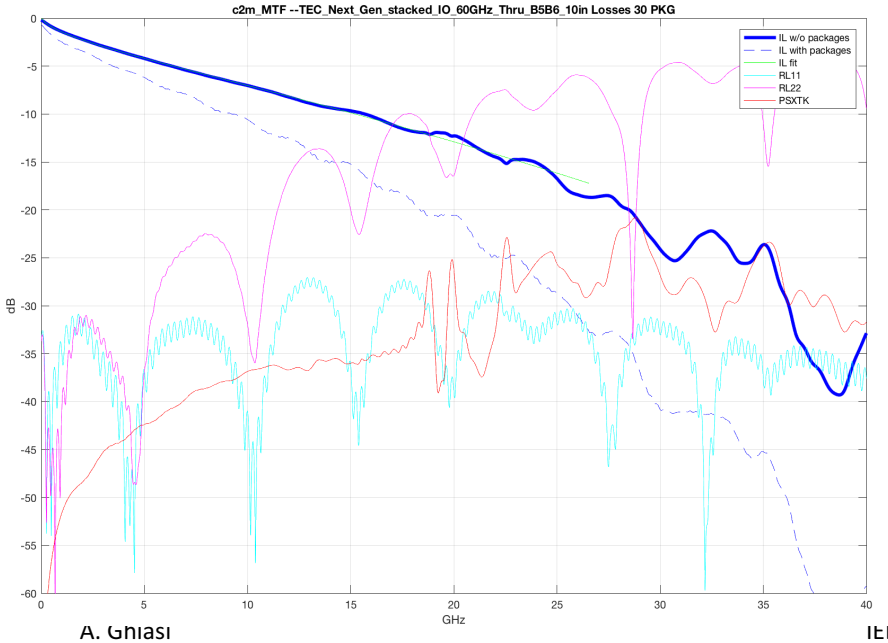
Results for A_fe=0.45:
VEO=59.29 mV, ICN=1.237 mV, Peak ISI=12.38 mV, MDFEXT Peak=2.36 mV, ILD(FOM)=0.0675, COM=5.01 dB

Results with A_fe=3.09:
VEO=48.17 mV, ICN=1.237 mV, Peak ISI=21.5 mV, MDFEXT Peak=16.24 mV, ILD(FOM)=0.0675 COM=4.69 dB

10” TE Stacked 50G Channel (Host Output TP1a)



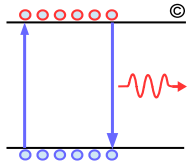
- **Based on TE hypothetical connector with IL_Fit of 8.8 dB shy of clause 120.E loss of 10.2 dB**
  - Since the 4” and 10” TE stack boards have similar construction with exception of one with longer trace, the calibrated A_fe crosstalk of the 4” board is used for the 10” board
  - http://www.ieee802.org/3/bs/public/channel/TEC/shanbhag_3bs_01_1014.pdf



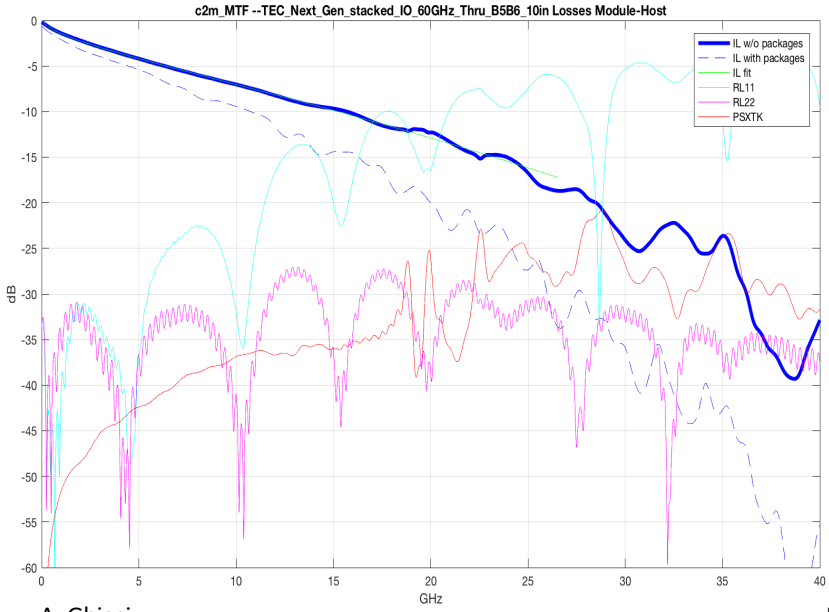
Using COM version 165
Results for MTF like channel with IL_fit=4.3 dB
Results for A_Fe=0.45:
VEO=34.95 mV, ICN=0.759 mV, Peak ISI=8.92 mV, MDFEXT Peak=1.38 mV , ILD(FOM)= 0.0572, COM=5.28 dB

Results with A_Fe=3.09 (updated):
VEO=28.87 mV (failing), ICN=0.759 mV, Peak ISI=8.92 mV, MDFEXT Peak=9.52 mV, ILD(FOM)= 0.0572, COM=4.46 dB

10” TE Stacked 50G Channel (Module Output TP5)



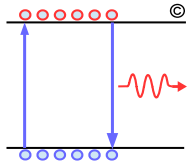
- **Based on TE hypothetical connector with IL_Fit of 8.8 dB shy of clause 120.E loss of 10.2 dB**
  - Since the 4” and 10” TE stack boards have similar construction with exception of one with longer trace, the calibrated A_fe crosstalk of the 4” board is used for the 10” board
  - http://www.ieee802.org/3/bs/public/channel/TEC/shanbhag_3bs_01_1014.pdf



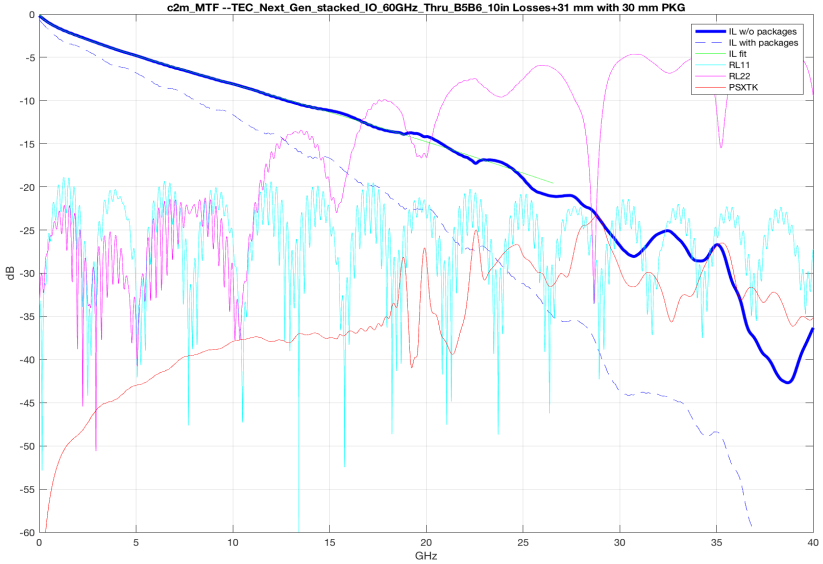
Using COM version 165
Results for A_Fe=0.45:
VEO=32.27 mV, ICN=0.759 mV, Peak ISI=16.3 mV, MDFEXT Peak=1.40 mV , ILD(FOM)= 0.0572, COM=4.33 dB

Results with A_Fe=3.09 (updated):
VEO=27.23 mV (failing), ICN=0.759 mV, Peak ISI=9.7 mV, MDFEXT Peak=16.3 mV, ILD(FOM)= 0.0572, COM=3.5 dB

10” TE Stacked 50G Channel (Host Output TP1a)

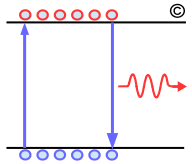


- **Based on TE hypothetical connector with IL_Fit of 8.8 dB shy of clause 120.E loss of 10.2 dB, 31 mm of PCB trace added to increase the loss to 10.2 dB**
  - Since the 4” and 10” board are similar with exception of the longer trace

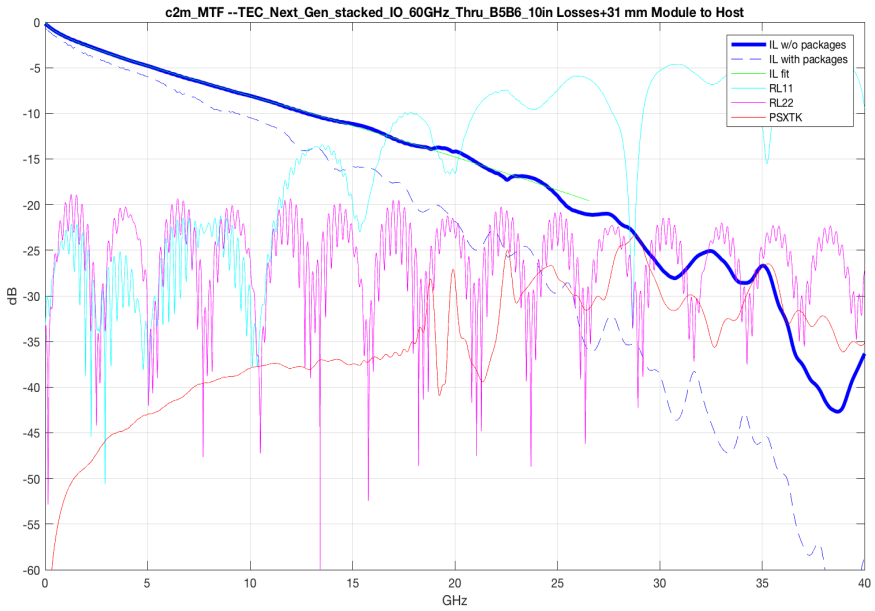


Results with A_fe=3.0:
VEO=23.89 mV (failing), ICN=0.663 mV, Peak ISI= 9.11 mV, MDFEXT Peak=8.19 mV, ILD(FOM)=0.0558, COM=4.2 dB

10” TE Stacked 50G Channel (Module Output TP5)

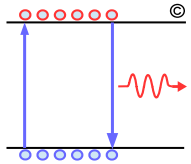


- **Based on TE hypothetical connector with IL_Fit of 8.8 dB shy of clause 120.E loss of 10.2 dB, 31 mm of PCB trace added to increase the loss to 10.2 dB**
  - Since the 4” and 10” board are similar with exception of the longer trace

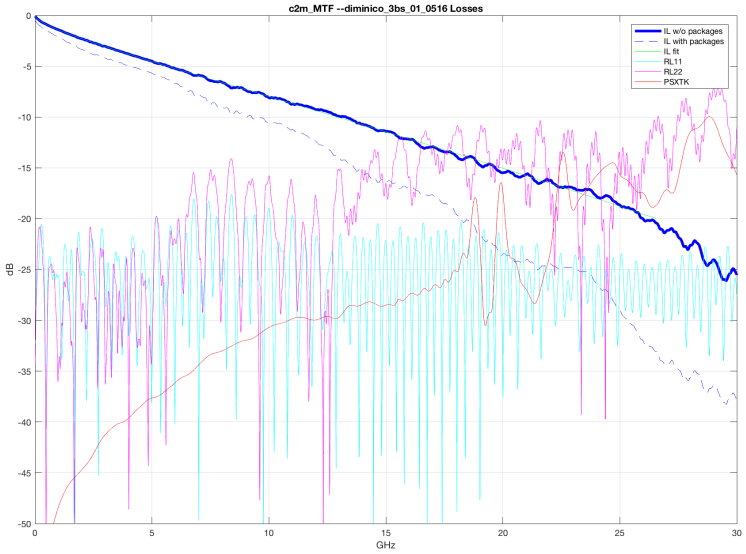


esults with A_fe=3.0:
EO=23.15 mV (failing), ICN=0.663 mV, Peak ISI= 15.01 mV, MDFEXT eak=8.36 mV, ILD(FOM)=0.0558, COM=3.65 dB

QSFP MTF + Crosstalk from TE 4” Stacked (Host Output TP1a)

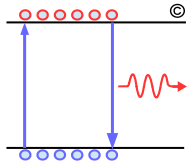


- QSFP MTF (diminico_3bs_01_0516.s4p) does not have any crosstalk data
  - TE 4” stacked with IL_Fit of ≃4.3 is used as the crosstalk source
  - 150 mm of PCB trace is added per clause 92 to the MTF to increase channel loss to 10.2 dB
  - 138 mm of PCB trace was added for FEXT aggressor as the TE 4” board has 0.5 dB higher loss than QSFP MTF.



Results with A_fe=3.09 :
VEO=23.67 mV (failing), ICN=0.6634 mV, Peak ISI=9.31 mV, MDFEXT Peak=8.06 mV, ILD(FOM)=0.0621, COM=4.14 dB

Summary



- **P802.3bs clause 120.E which reference CL92 has excessive amount of MDFEXT (4.8 mV) and MDNEXT (1.8 mV)**
  - Above crosstalk limits results in ~24 mV at TP1a instead of current limit of EH1E-5=32 32 mV
  - Above crosstalk limits results in ~23 mV at TP5 instead of current limit of EH1E-5=32 32 mV
- **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**
- **IEEE P802.3bs and cd need to collectively work together to resolve this issue sooner than later to minimize the impact**
  - Having updated representative MDI data with crosstalk will be very helpful to improve the analysis and trade offs
- **Potential area need to be considered in order to close the major hole in clause 120.E specification**
  - Clause 92 MDI crosstalk was based on the data I presented in 802.3bj over 5 years ago need to be tighten by ~3x for robust PAM4 operation
  - TE hypothetical connector with superior crosstalk s proof that improved connector can be developed
  - Current far end eye opening of EW1E-5=0.22 and EH1E-5=32 mV has very little room for further tightening
  - Tighten transmitter parameters such as jitter and rise time can provided some relief but not enough to close the link budget
  - Use COM as the tool to trade off loss, crosstalk, and ISI now that there are several MDI's each with somewhat different characteristics are targeted for 802.3bs/cd implementation
  - Define a more powerful equalizer for the chip-to-module
- **The facts are clear 10.2 dB channel is only feasible with no crosstalk with CL120.e assumtions!**