C2M Simulation

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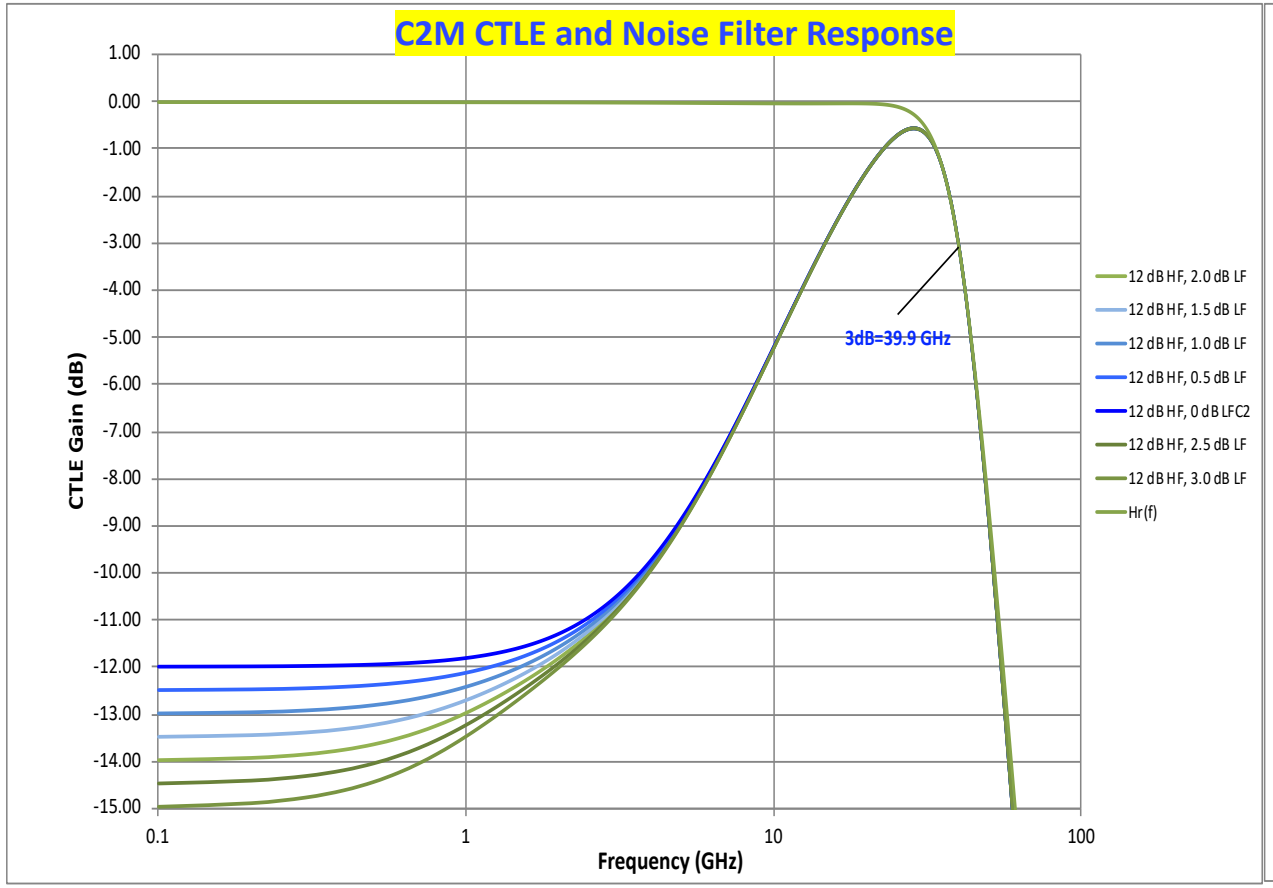
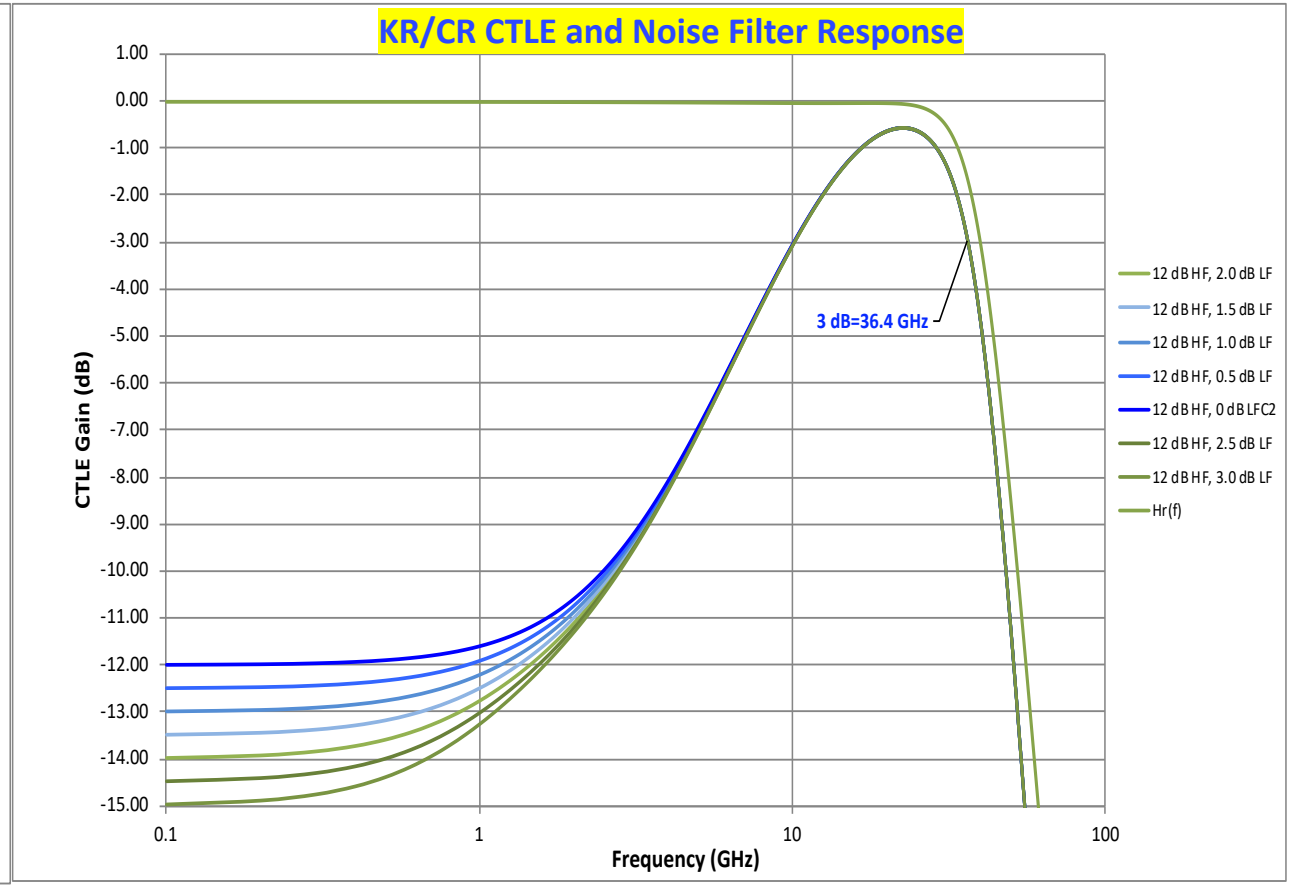
Overview

- **Improved C2M/VSR CTLE response cascaded with noise filter response**
- **Results are based on COM 2.5.8 with improved C2M CTLE and post filter fr=0.75**
- **Channel investigated for C2M at TP1a and M2C simulation at TP4/TP5**
  - TE/Tracy OSFP micro-via channels exceed 3 dB COM with 5 T FFE
  - TE/Tracy OSFP Long Barrel Via some channels do not meet 3 dB COM with 5 T FFE
  - Cisco/Lim QSFP-dd channels do not pass 3 dB COM with 5T FFE after Cd increased from 90 ff to 110 ff
- **The TP1a/TP5 is a weak generic equalizer to observe and sampler the signal**
  - The actual equalizer may need additional capability to recover the signal at slicer.

Response of C2M and KR/CR CTLE and Noise Filters

- **Response of C2M and KR/CR CTLE with 12 dB and LF from 0 to 3 dB**
  - C2M CTLE has higher BW and designed to perform better with no DFE receiver
  - Response below is noise filter and cascaded the CTLE+Hr(f) filters.





112G CTLE

- **IEEE Proposed 112G KR/CR CTLE Coefficients**
  - Low frequency gain sum of g_{DC}+g_{DC2}
  - Low frequency zero/pole adjustable
  - g_{DC} 0 to -15 dB in 1 dB step
  - g_{DC2} 0 to -4 dB in 1 dB step
  - F_z=Fbaud/4.25
  - F_{p1}=Fb/1.8839
  - F_{p2}=Fbaud
  - F_{lF}=Fbaud/40
  - f_r=0.75*Fbaud

Common CTLE Filter for KR/CR/C2M

$$H_{ctf}(f) = \frac{\left(10^{\frac{g_{DC}}{20}} + j\frac{f}{f_z}\right)\left(10^{\frac{g_{DC2}}{20}} + j\frac{f}{f_{LF}}\right)}{\left(1 + j\frac{f}{f_{p1}}\right)\left(1 + j\frac{f}{f_{p2}}\right)\left(1 + j\frac{f}{f_{LF}}\right)}$$

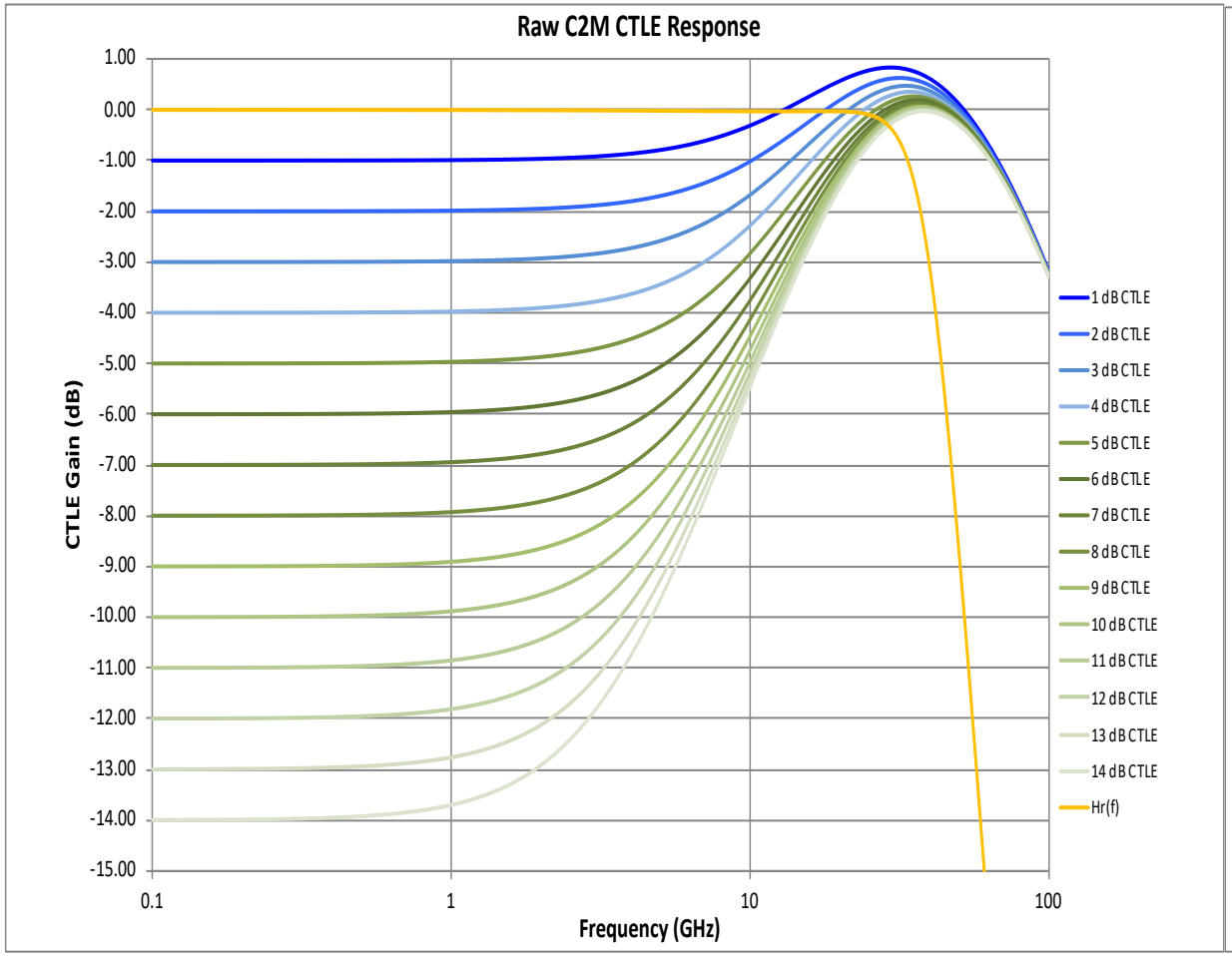
- **Proposed 112G C2M CTLE Coefficients are based on CL120E CTLE with enhance performance for non-DFE receiver**
  - Low frequency gain sum of g_{DC}+g_{DC2}
  - Low frequency zero/pole adjustable
  - g_{DC} 0 to -14 dB in 0.5 dB step
  - g_{DC2} 0 to -3 dB in 0.5 dB step
  - F_z=Fbaud/2.862
  - F_{p1}=Fbaud/1.8839
  - F_{p2}=Fbaud
  - F_{lF}=Fbaud/40
  - f_r=0.75*Fbaud

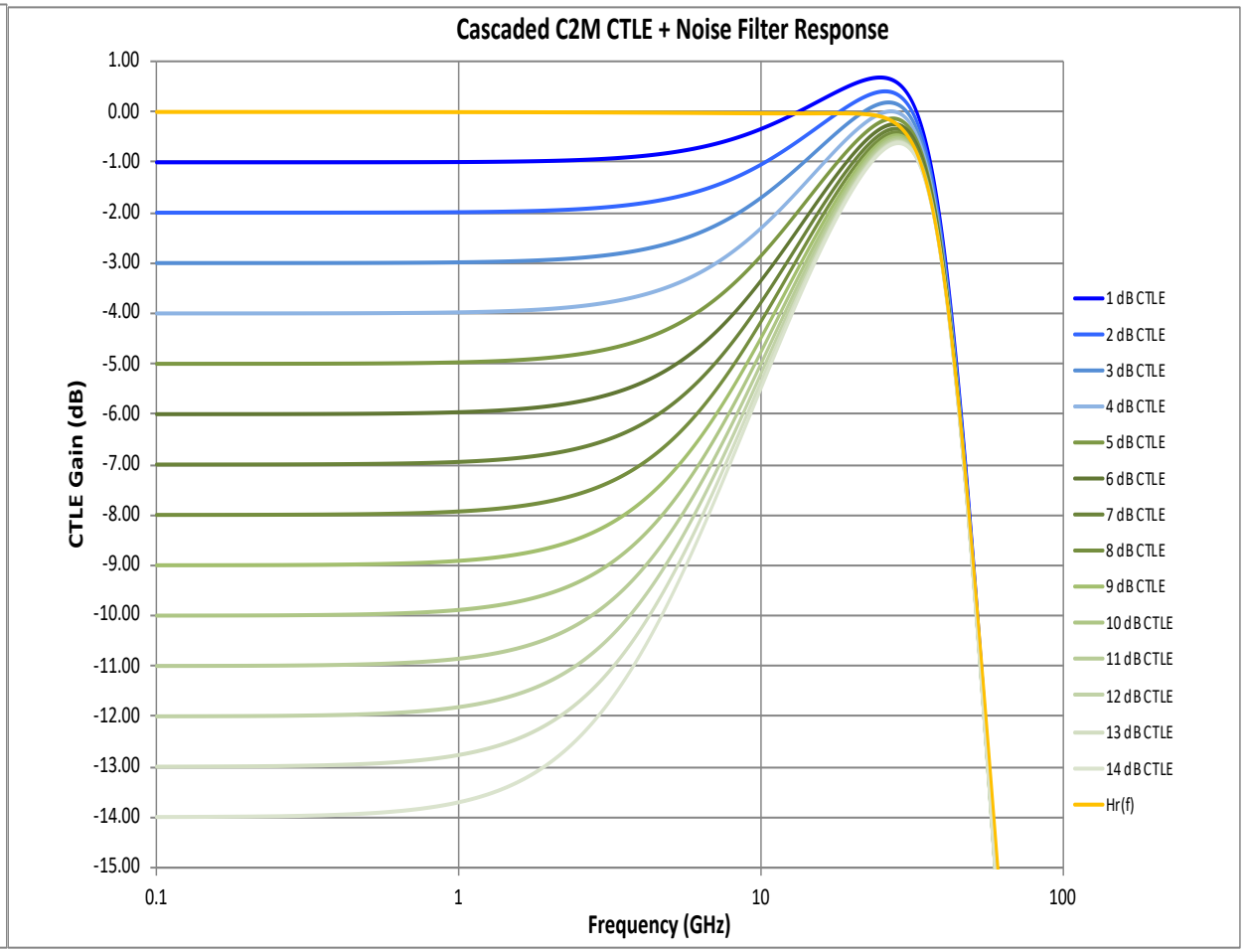
Post CTLE Noise/Technology 4th Order Butterworth Filter

$$H_r(f) = \frac{1}{1 - 3.414214(f/f_r)^2 + (f/f_r)^4 + j2.613126(f/f_r - (f/f_r)^3)}$$

Proposed C2M CTLE Response and cascaded CTLE with Noise Filter

- **Raw CTLE response shown from 1-12 dB for LF=0 dB and cascaded with noise filter fr=0.75**
  - Raw CTLE gain at peak varies from 0 to +0.83 dB and cascaded response gain varies from +0.68 to -0.57 dB
  - TP1a measurement should be made with cascaded CTLE + Noise/Technology filter.





COM Code 2.5.8 Host-Module (2 Segments PKG 15-30 mm)

- **Filter coefficient selected to have the improved CL120E response scaled for 53.1 GBd**

Table 93A-1 parameters			
Parameter	**Setting**	**Units**	**Information**
f_b	53.1	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[1.1e-4 0]	nF	[TX RX]
z_p select	[1 2]		[test cases to run]
z_p (TX)	[15 30; 1.8 1.8]	mm	[test cases]
z_p (NEXT)	[15 30; 1.8 1.8]	mm	[test cases]
z_p (FEXT)	[15 30; 1.8 1.8]	mm	[test cases]
z_p (RX)	[0 0 ; 0 0]	mm	[test cases]
C_p	[0.87e-4 0]	nF	[TX RX]
R_0	50	Ohm	
R_d	[45 50]	Ohm	[TX RX]
A_v	0.41	V	
A_fe	0.41	V	
A_ne	0.6	V	
L	4		
M	32		
filter and Eq			
f_r	0.75	*fb	
c(0)	0.65		min
c(-1)	[-0.2:0.02:0]		[min:step:max]
c(-2)	[0:.02:0.1]		[min:step:max]
c(1)	[-0.1:0.02:0]		[min:step:max]
N_b	0	UI	
b_max(1)	0.5		
b_max(2..N_b)	0.2		
g_DC	[-14:0.5:-4]	dB	[min:step:max]
f_z	18.55345912	GHz	
f_p1	53.1	GHz	
f_p2	28.2	GHz	
g_DC_HP	[-3:0.5:-1]		[min:step:max]
f_HP_PZ	1.3275	GHz	
ffe_pre_tap_len	**0**	UI	
ffe_post_tap_len	6	UI	
Include PCB	0	logical	
ffe_tap_step_size	0		
ffe_main_cursor_min	0.7		
ffe_pre_tap1_max	0.3		
ffe_post_tap1_max	0.3		
ffe_tapn_max	0.125		
ffe_backoff	1		

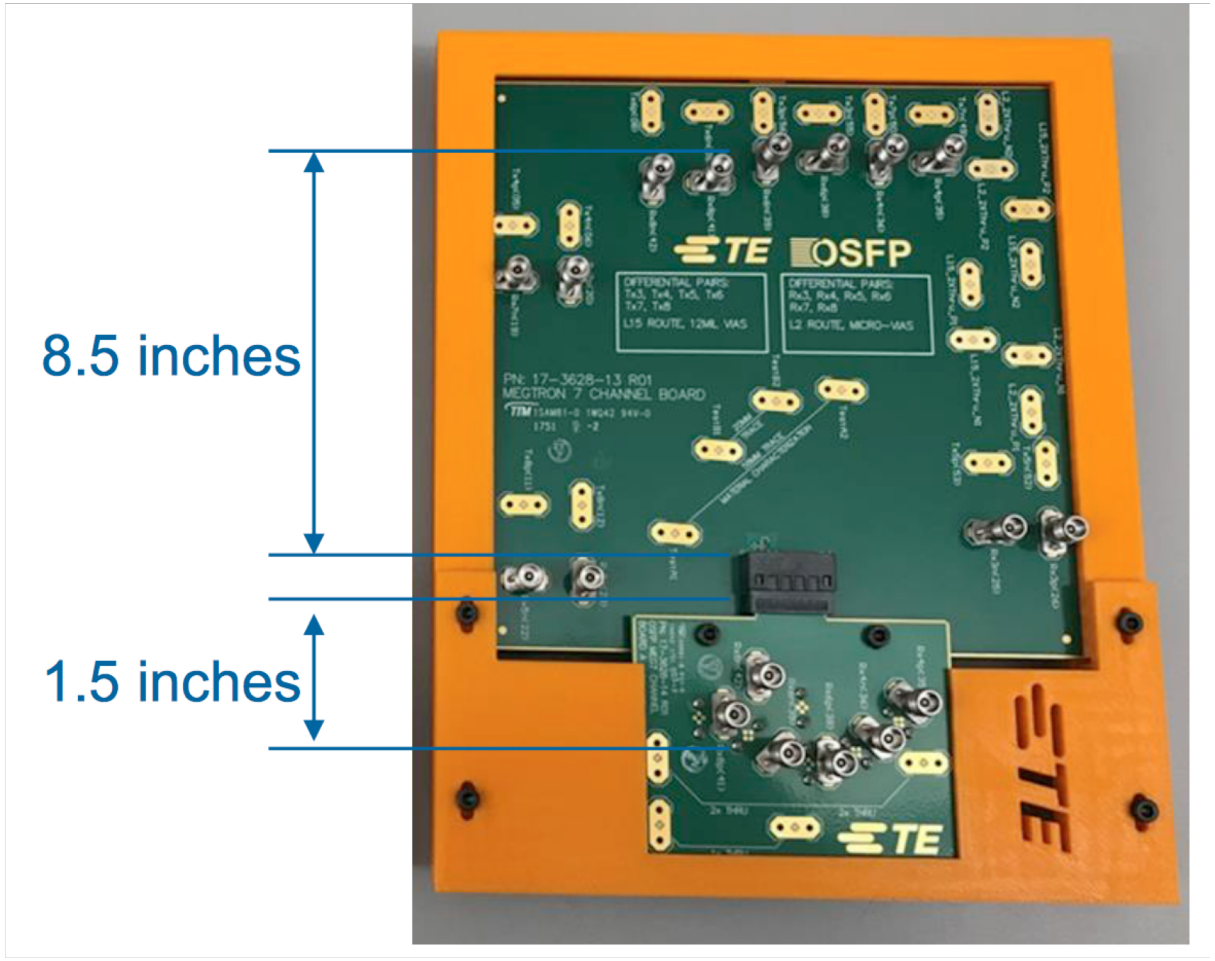
I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\100GEL_WG_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	C2M_1218	
COM_CONTRIBUTION	0	logical
Operational		
COM Pass threshold	1	dB
ERL Pass threshold	5	dB
DER_0	1.00E-05	
T_r	6.16E-03	ns
FORCE_TR	1	logical
TDR and ERL options		
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	logical
TR_TDR	0.01	ns
N	300	
TDR_Butterworth	1	logical
beta_x	1.70E+09	
rho_x	**0.18**	
fixture delay time	0	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
Noise, jitter		
sigma_RJ	0.01	UI
A_DD	0.02	UI
eta_0	8.20E-09	V^2/GHz
SNR_TX	33	dB
R_LM	0.95	

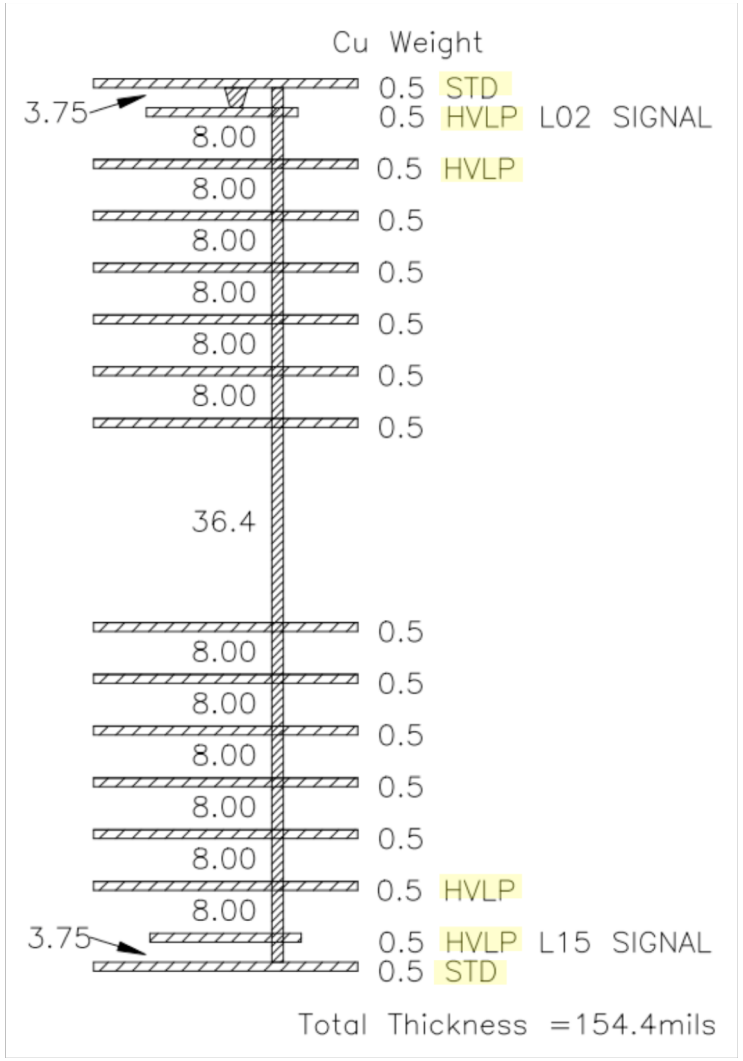
Table 93A–3 parameters		
Parameter	**Setting**	**Units**
package_tl_gamma0_a1_a2	[0 0.0009909 0.0002772]	
package_tl_tau	6.1400E-03	ns/mm
package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm

Table 92–12 parameters		
Parameter	**Setting**	
board_tl_gamma0_a1_a2	*[0 0.000599 0.0001022]*	
board_tl_tau	*6.200E-03*	ns/mm
board_Z_c	90	Ohm
z_bp (TX)	*50*	mm
z_bp (NEXT)	*50*	mm
z_bp (FEXT)	*50*	mm
z_bp (RX)	*0*	mm

Tracy OSFP Board

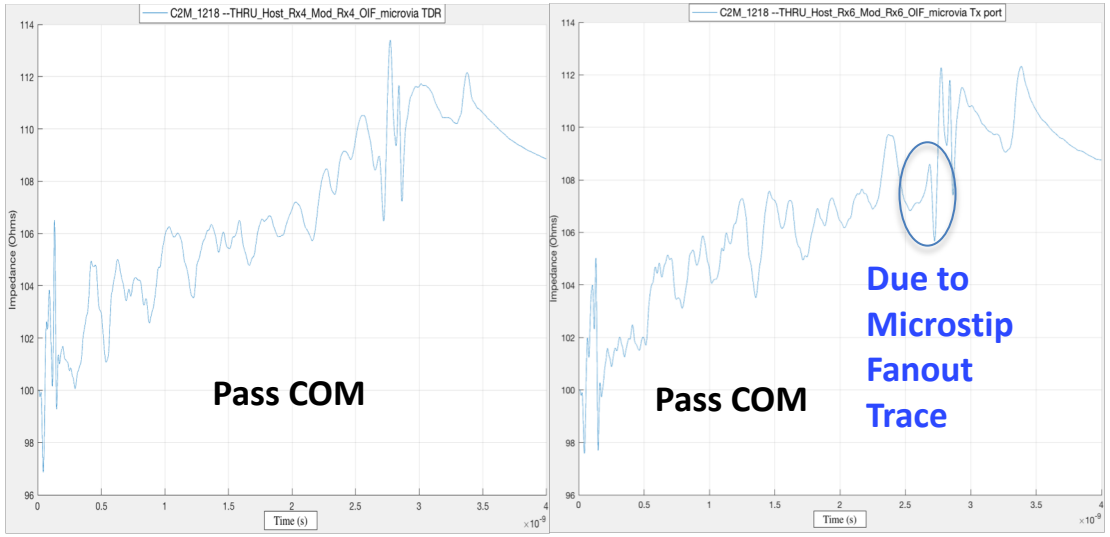
- **Board uses microvias as well as long barrel 154.4 mils vias with 3.75 mils stub.**





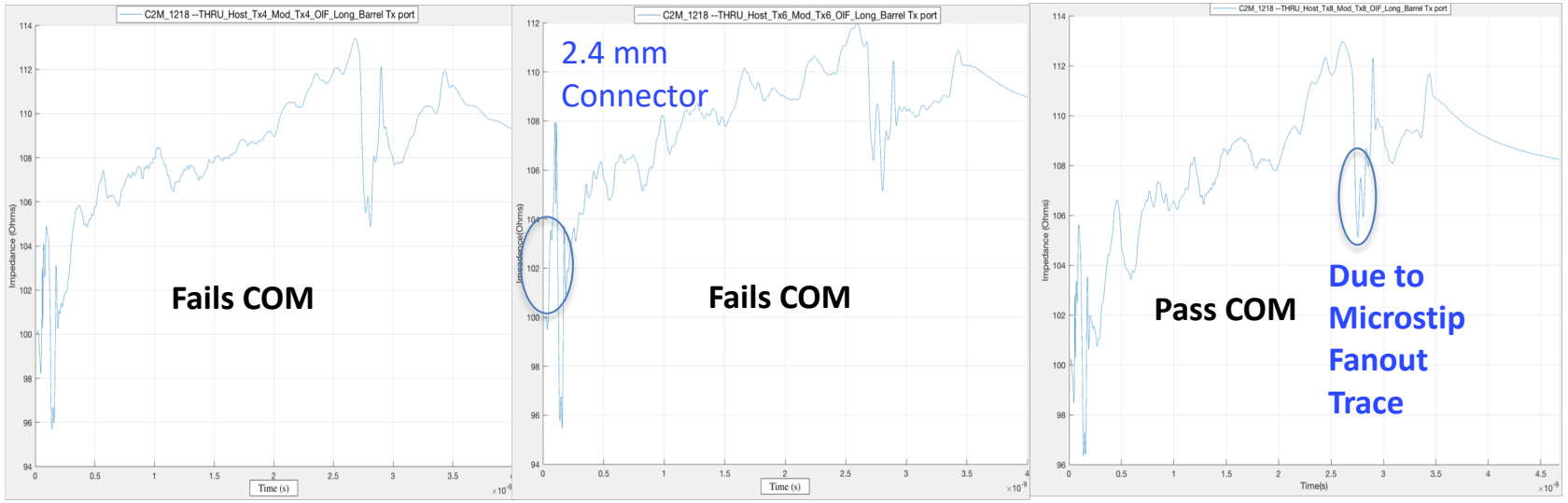
Tracy Microvia and Long Barrel Via Channels TDR T4 and T6

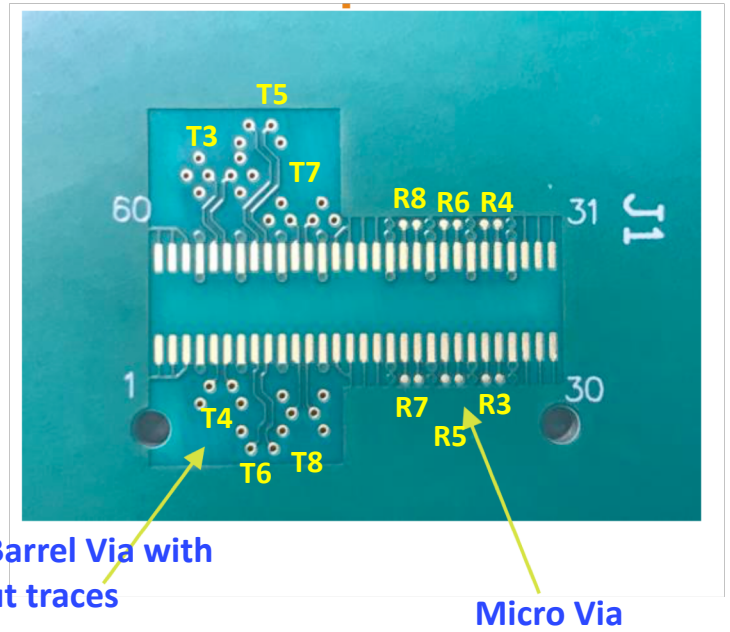
Microvia TE RX4 and RX6 Channels.



- 3.75 mils via stub is unlikely as the source of degradation.
- 154.4 mils long via likely one source of degradation.
- Microstrip fanout trace likely source of degradation
- 2.4 mm connector on T6 has 20 Ω swing.
- Tracy channels include connector and may double count Cp.

Microvia TE TX4, TX6, and TX8 Long barrel via channels.

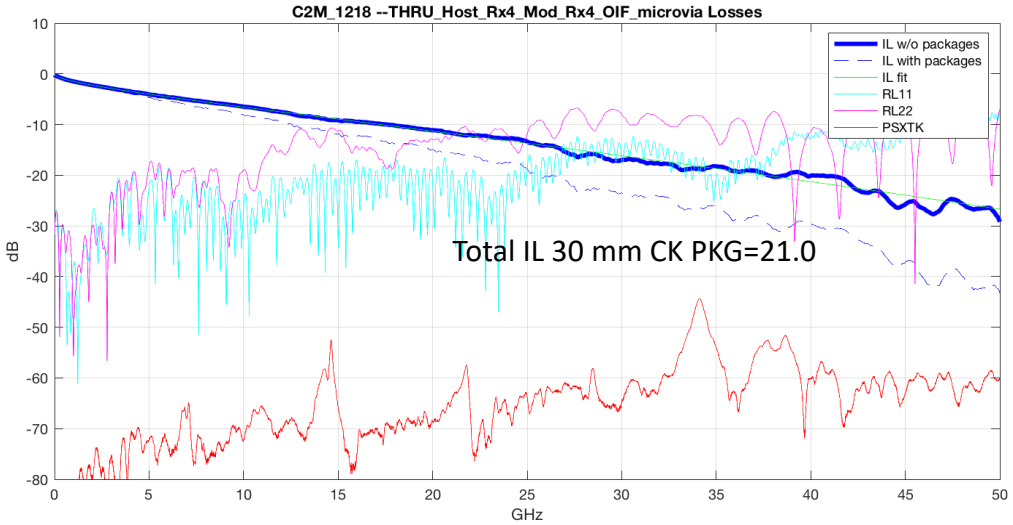


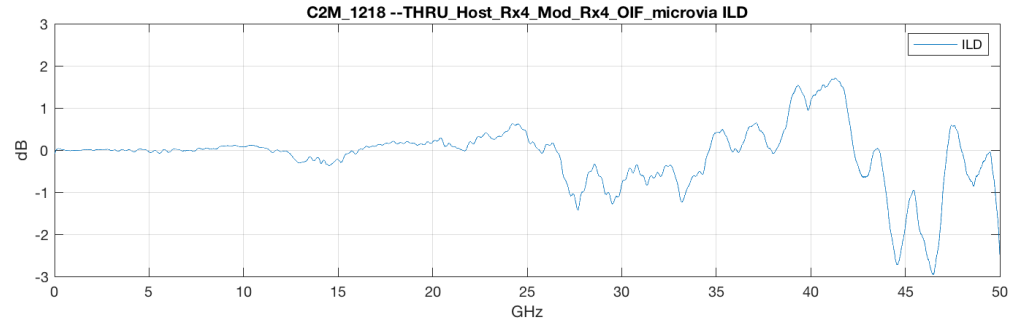


COM Analysis of Tracy Channels

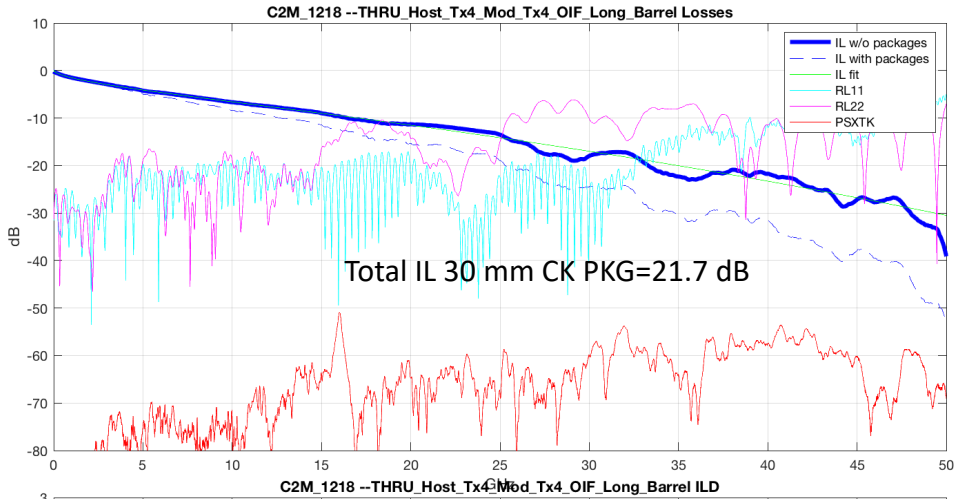
- **8.5” OSFP (16 dB) channels, with 2 segment CK package with increased ILD and COM penalty!**
  - http://www.ieee802.org/3/100GEL/public/tools/c2m/tracy_100GEL_02_0118.zip (long barrel)
  - http://www.ieee802.org/3/100GEL/public/tools/c2m/tracy_100GEL_06_0118.zip (Micro Via).

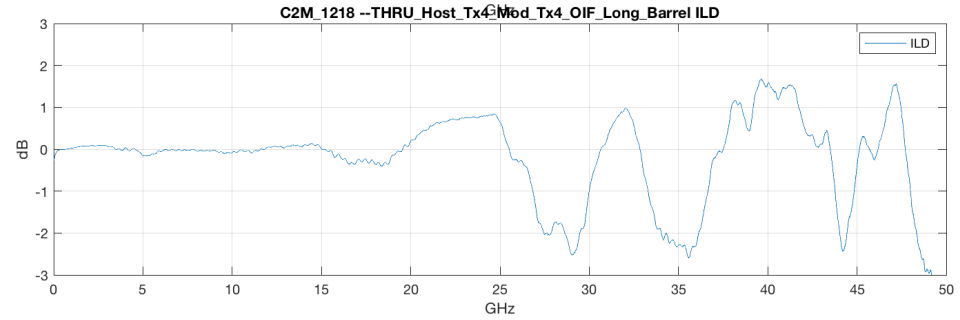
Tracy T4 MicroVia, FOM_ILD=0.20, ICN=0.62 mV, ICR=48, ERL11=14.1, ERL22=7.9
COM=4.18 (4.74) dB, EH=13.3 (11.8) mV, VEC=8.4 (7.5) dB





Tracy T4 LongBarrel, FOM_ILD=0.38, ICN=0.51 mV, ICR=46, ERL11=14.7, ERL22=8.9
5T FFE - CK PKG: COM=1.9 (2.8) dB, EH=6.3 (7.9) mV, VEC=14.1 (11.3) dB
7T FFE - CK PKG: COM=3.4 (4.1) dB, EH=10.3 (10.4) mV, VEC=9.8 (8.4) dB





Result in x(y) are for 15(30) mm PKG.

COM Analysis of Tracy Channels

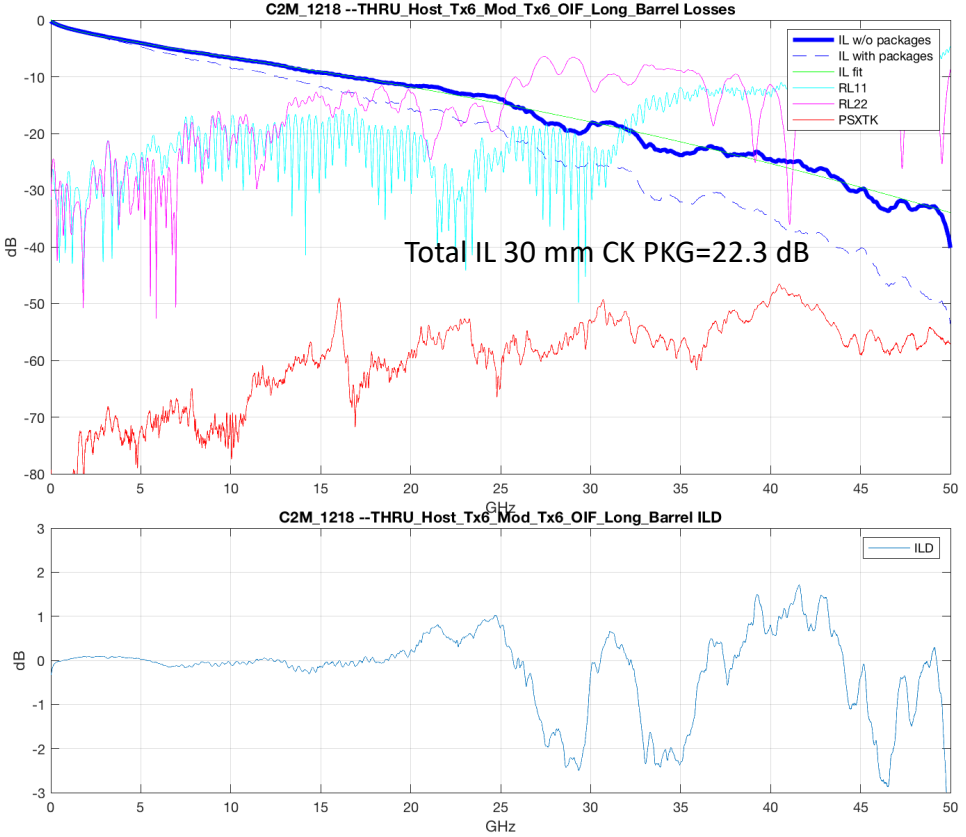
- **8.5” OSFP (16 dB) channels, with 2 segment CK package with increased ILD and COM penalty!**

  http://www.ieee802.org/3/100GEL/public/tools/c2m/tracy_100GEL_02_0118.zip (long barrel)

  http://www.ieee802.org/3/100GEL/public/tools/c2m/tracy_100GEL_06_0118.zip (Micro Via).

Tracy T6 MicroVia, FOM_ILD=0.21, ICN=0.91 mV, ICR=46, ERL11=15.4, ERL22=8.3
5T FFE: COM=4.6 (5.7) dB, EH=16.7 (15.8) mV, VEC=7.6 (6.3) dB
7T FFE: COM=4.8 (5.8) dB, EH=18.1 (17.6) mV, VEC=7.5 (6.3) dB

Tracy T6 LongBarrel, FOM_ILD=0.39, ICN=0.98 mV, ICR=40.2, ERL11=14.0, ERL22=9.3
5T FFE: COM=2.2 (3.0) dB, EH=7.4 (8.1) mV, VEC=12.9 (10.6) dB
7T FFE: COM=3.1 (3.9) dB, EH=9.8 (9.8) mV, VEC=10.5 (8.8) dB

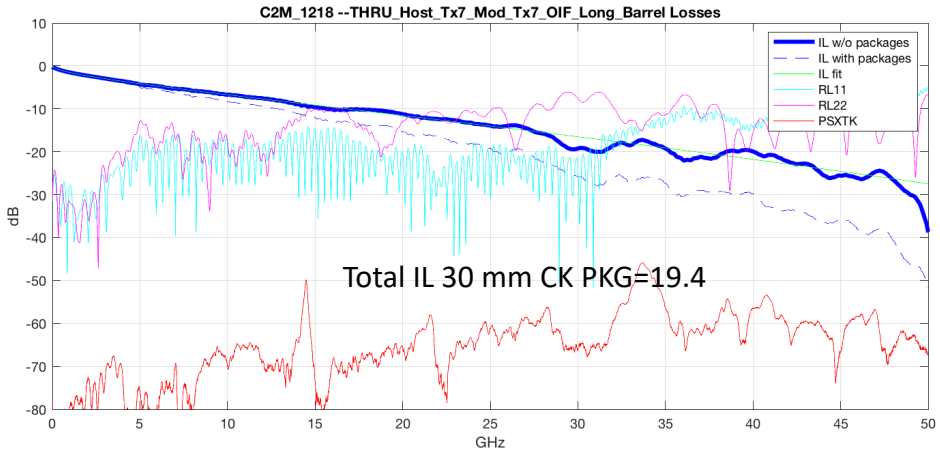


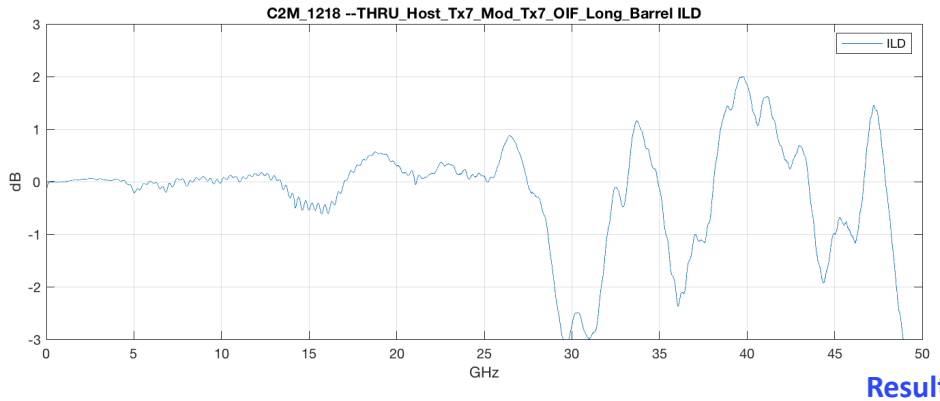
Result in x(y) are for 15(30) mm PKG.

COM Analysis of Tracy Channels

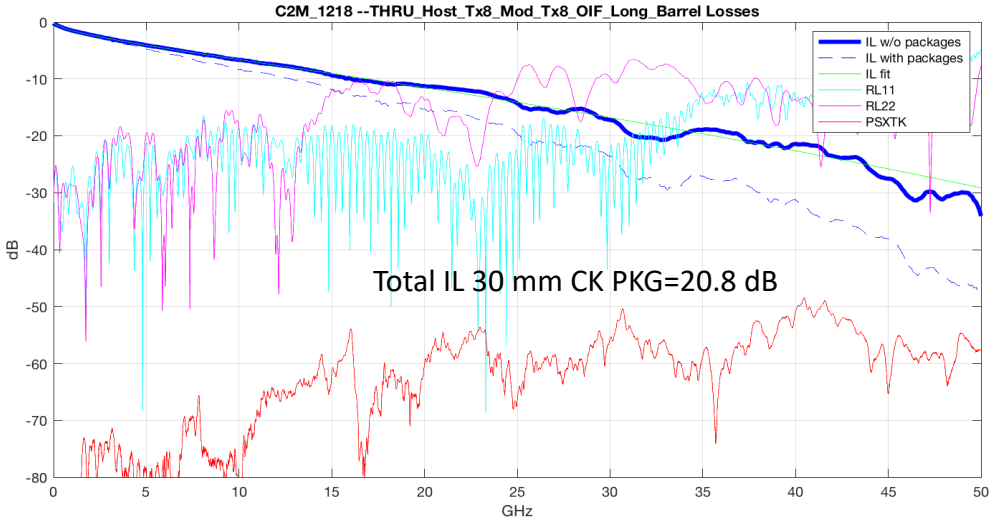
- **8.5” OSFP (16 dB) channels, CK package reduces loss but increases ILD at significant COM penalty!**
  - http://www.ieee802.org/3/100GEL/public/tools/c2m/tracy_100GEL_02_0118.zip (long barrel)
  - http://www.ieee802.org/3/100GEL/public/tools/c2m/tracy_100GEL_06_0118.zip (Micro Via).

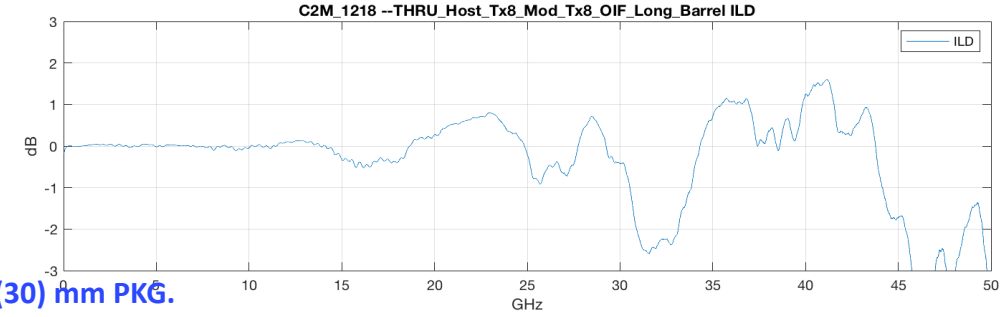
Tracy T7 LongBarrel, FOM_ILD=0.39, ICN=0.66 mV, ICR=48, ERL11=13.0, ERL22=7.3
5T FFE: COM=2.4 (3.5) dB, EH=8.6 (10.2) mV, VEC=12.3 (9.6) dB
7T FFE: COM=2.6 (3.7) dB, EH=8.3 (9.7) mV, VEC=11.7 (9.2) dB





Tracy T8 LongBarrel, FOM_ILD=0.32, ICN=0.76 mV, ICR=43, ERL11=14.9, ERL22=8.7
5T FFE: COM=4.6 (4.0) dB, EH=14.8 (11.2) mV, VEC=7.8 (8.6) dB



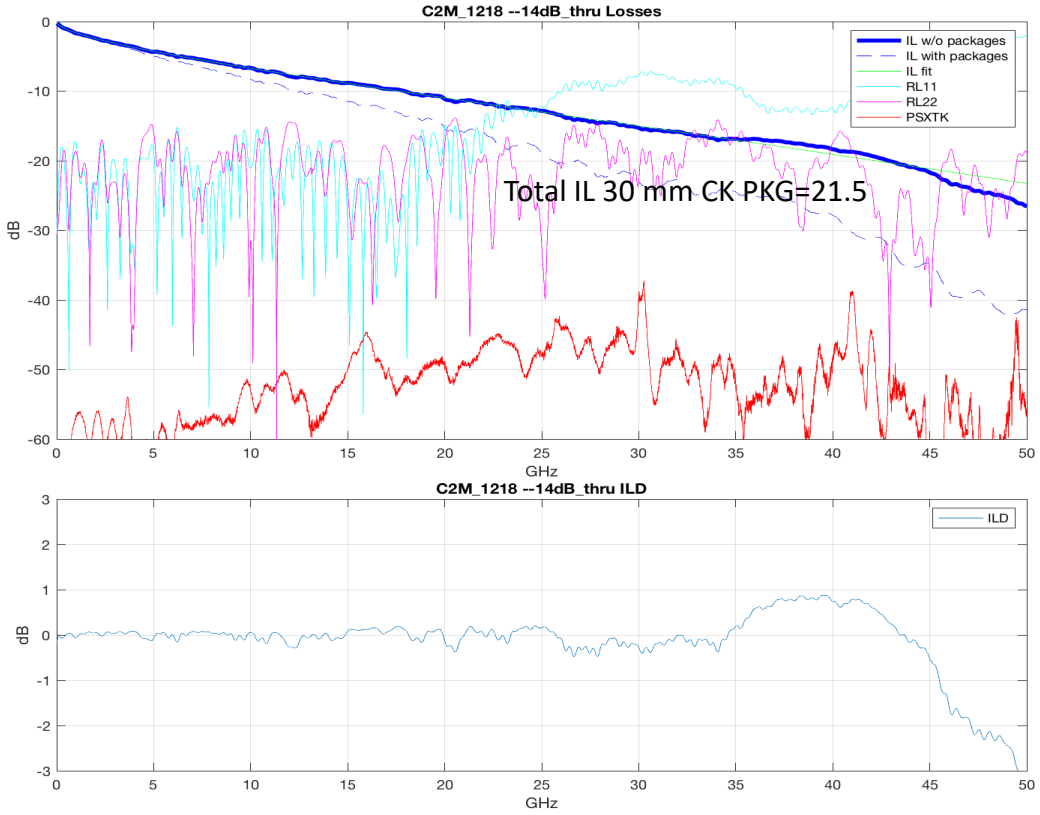


Result in x(y) are for 15(30) mm PKG.

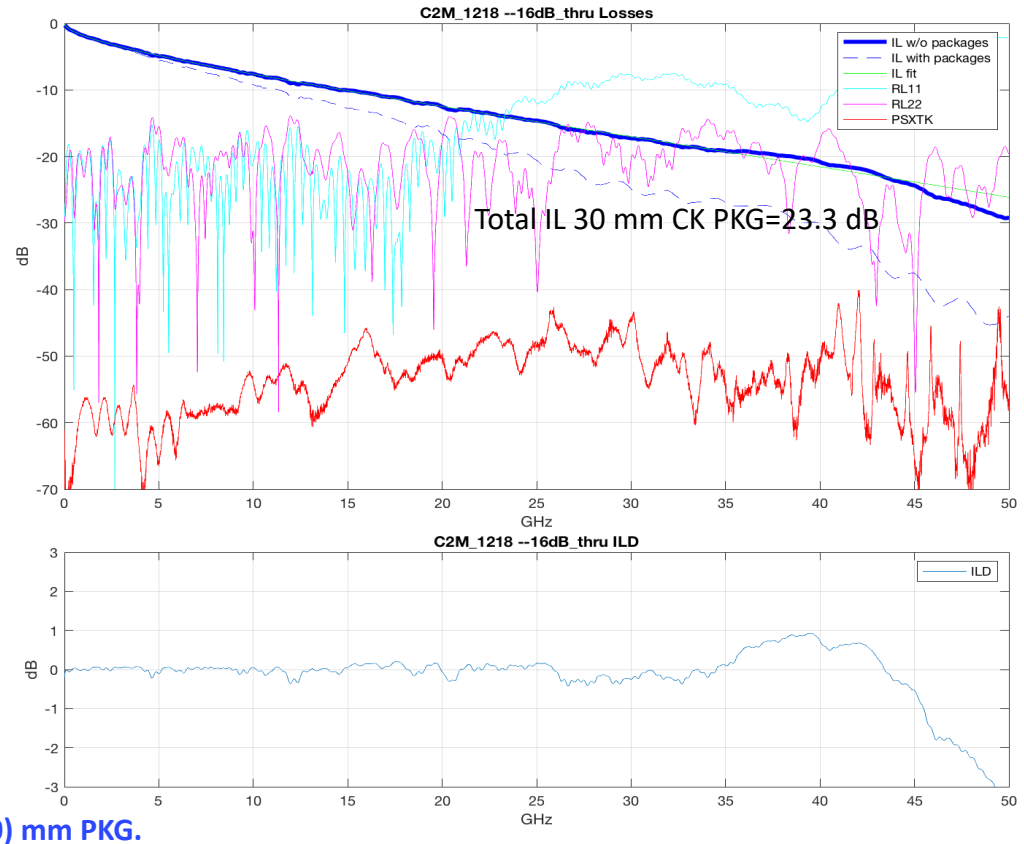
COM Analysis on Lim Nov-18 Channels (Legacy Contacts)

- **Lim Nov-2018 channel ICR still pretty low ~30 dB and with high ICN, with 2 segment CK package with increased ILD and COM penalty!**
  - http://www.ieee802.org/3/ck/public/tools/c2m/lim_3ck_01_0918_QDD_legacy_pairs.zip

Lim 14 dB FOM_ILD=0.11, ICN=2.72 mV, ICR=31.5, ERL11=9.1, ERL22=12.2
5T FFE: COM=2.6 (4.0) dB, EH=10.6 (13.2) mV, VEC=11.7 (8.7) dB
7T FFE(6 post): COM=2.6 (4.0) dB, EH=12.1 (12.0) mV, VEC=11.8 (8.7) dB
5T FFE(4 post)+1DFE: COM=4.4 (4.9) dB, EH=23.1 (21.5) mV, VEC=8.1 (7.3) dB



Lim 16 dB, FOM_ILD=0.10, ICN=2.14 mV, ICR=30.8 dB, , ERL11=9.4, ERL22=12.3
5T FFE(4 post): COM=2.60 (4.4) dB, EH=9.5 (11.3) mV, VEC=11.8 (8.0) dB
7T FFE(6 post): COM=2.4 (4.4) dB, EH=9.2 (13.2) mV, VEC=12.4 (8.0) dB
5T FFE(4 post)+1DFE: COM=4.3 (5.3) dB, EH=18.5 (18.4) mV, VEC=8.2 (6.8) dB

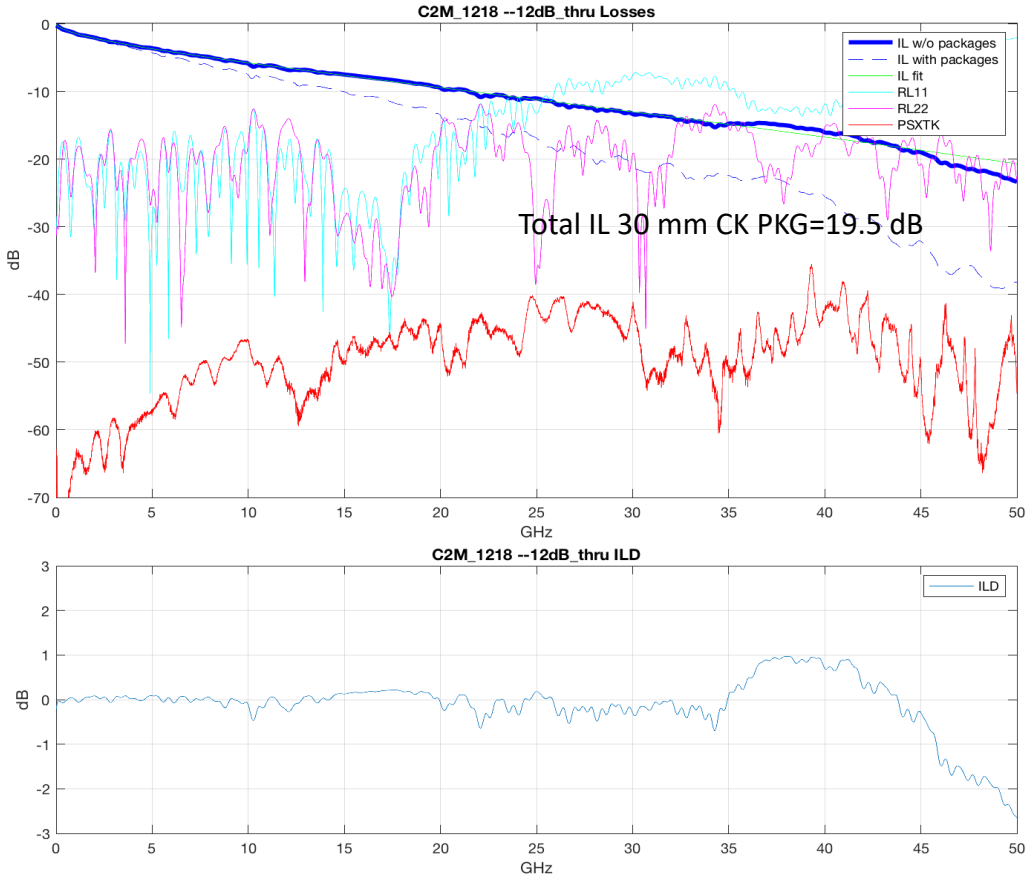


Result in x(y) are for 15(30) mm PKG.

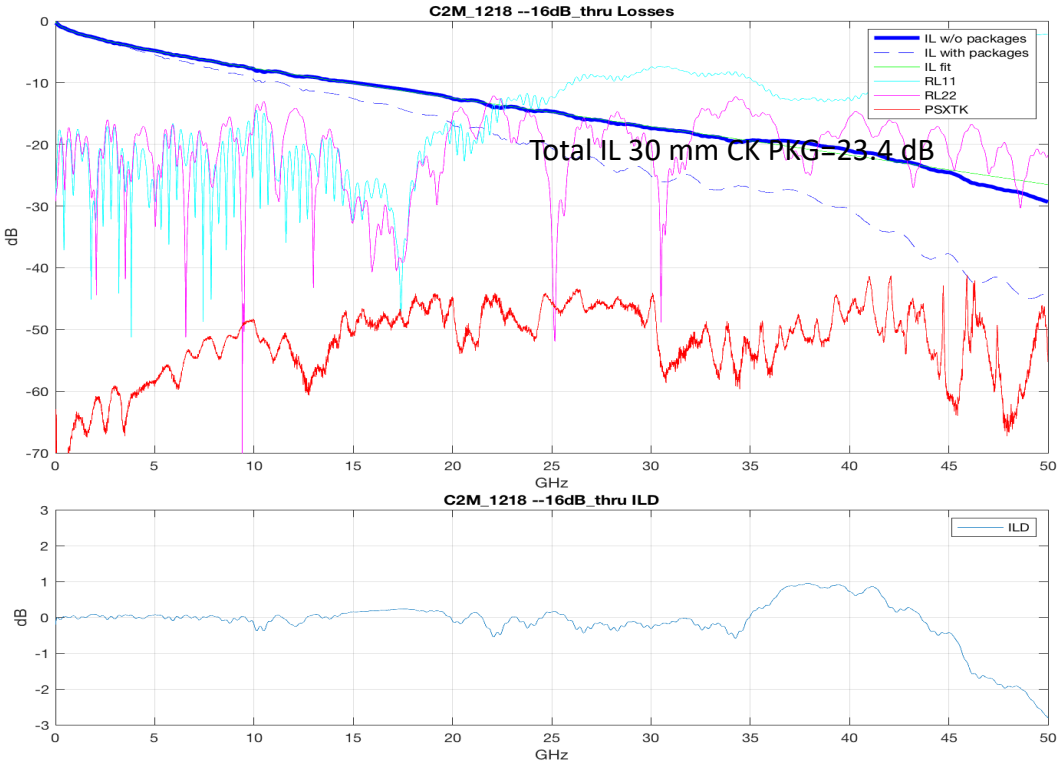
COM Analysis on Lim Nov-18 Channels (new contacts)

- **Lim Nov-2018 channel ICR still pretty low ~30 dB and with high ICN, with 2 segment CK package with increased ILD and COM penalty!**
  - **http://www.ieee802.org/3/ck/public/tools/c2m/lim_3ck_01_0918_QDD_new_pairs.zip**

Lim 12 dB, FOM_ILD=0.126, ICN=3.65 mV, ICR=30.2 dB, , ERL11=8.7, ERL22=11.5
5T FFE: COM=3.2 (4.3) dB, EH=18.3 (17.7) mV, VEC=10.3 (8.2) dB



Lim 16 dB, FOM_ILD=0.122, ICN=2.85 mV, ICR=30.8 dB, , ERL11=9.3, ERL22=11.6
5T FFE(4 post): COM=2.9 (4.0) dB, EH=10.9 (11.2) mV, VEC=11.1 (8.7) dB
7T FFE(6 post): COM=2.9 (4.0) dB, EH=11.0 (11.3) mV, VEC=10.9 (8.6) dB
5T FFE(4 post)+1DFE: COM=4.4 (4.8) dB, EH=18.8 (17.2) mV, VEC=8.0 (7.4) dB



Result in x(y) are for 15(30) mm PKG.

COM 2.5.8 Module-Host (Single Segment PKG 2-10 mm)

Table 93A-1 parameters			
Parameter	**Setting**	**Units**	**Information**
f_b	53.1	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[0.85e-4 0]	nF	[TX RX]
z_p select	[1 2]		[test cases to run]
z_p (TX)	[2 10]	mm	[test cases]
z_p (NEXT)	[2 10]	mm	[test cases]
z_p (FEXT)	[2 10]	mm	[test cases]
z_p (RX)	[0 0]	mm	[test cases]
C_p	[0.87e-4 0]	nF	[TX RX]
R_0	50	Ohm	
R_d	[45 50]	Ohm	[TX RX]
A_v	0.41	V	
A_fe	0.41	V	
A_ne	0.6	V	
L	4		
M	32		
filter and Eq			
f_r	0.75	*fb	
c(0)	0.72		min
c(-1)	-0.2		[min:step:max]
c(-2)	57:36.0		[min:step:max]
c(1)	-0.04		[min:step:max]
N_b	∞	UI	
b_max(1)	0.5		
b_max(2..N_b)	0.2		
g_DC	[-14:0.5:-4]	dB	[min:step:max]
f_z	18.55345912	GHz	
f_p1	53.1	GHz	
f_p2	28.2	GHz	
g_DC_HP	[-3:0.5:-1]		[min:step:max]
f_HP_PZ	1.3275	GHz	
ffe_pre_tap_len	**0**	UI	
ffe_post_tap_len	4	UI	
Include PCB	0	logical	
ffe_tap_step_size	0		
ffe_main_cursor_min	0.7		
ffe_pre_tap1_max	0.3		
ffe_post_tap1_max	0.3		
ffe_tapn_max	0.125		
ffe_backoff			

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\100GEL_WG_{date}\	
SAVE_FIGURES	0	logical
Port Order	[2 4 1 3]	
RUNTAG	C2M_1218	
COM_CONTRIBUTION	0	logical
Operational		
COM Pass threshold	1	dB
ERL Pass threshold	5	dB
DER_0	1.00E-05	
T_r	6.16E-03	ns
FORCE_TR	1	logical
TDR and ERL options		
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	logical
TR_TDR	0.01	ns
N	300	
TDR_Butterworth	1	logical
beta_x	1.70E+09	
rho_x	**0.18**	
fixture delay time	0	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
Noise, jitter		
sigma_RJ	0.01	UI
A_DD	0.02	UI
eta_0	8.20E-09	V^2/GHz
SNR_TX	33	dB
R_LM	0.95	

Table 93A–3 parameters		
Parameter	**Setting**	**Units**
package_tl_gamma0_a1_a2	[0 0.0009909 0.0002772]	
package_tl_tau	6.1400E-03	ns/mm
package_Z_c	[87.5 87.5]	Ohm

Table 92–12 parameters		
Parameter	**Setting**	
board_tl_gamma0_a1_a2	*[0 0.000599 0.0001022]*	
board_tl_tau	*6.200E-03*	ns/mm
board_Z_c	90	Ohm
z_bp (TX)	*50*	mm
z_bp (NEXT)	*50*	mm
z_bp (FEXT)	*50*	mm
z_bp (RX)	*0*	mm

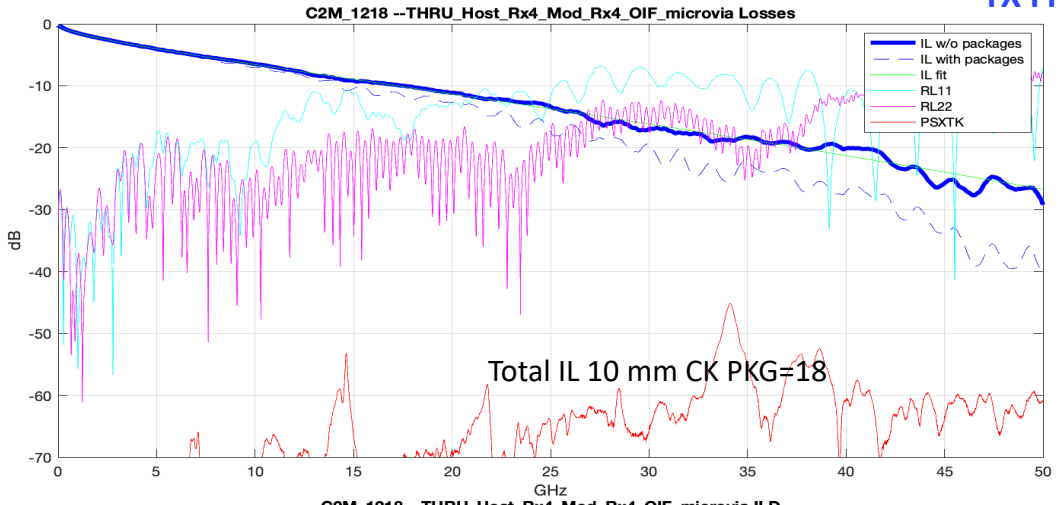
COM Analysis of Tracy Channels Module-ASIC (Single Segment PKG)

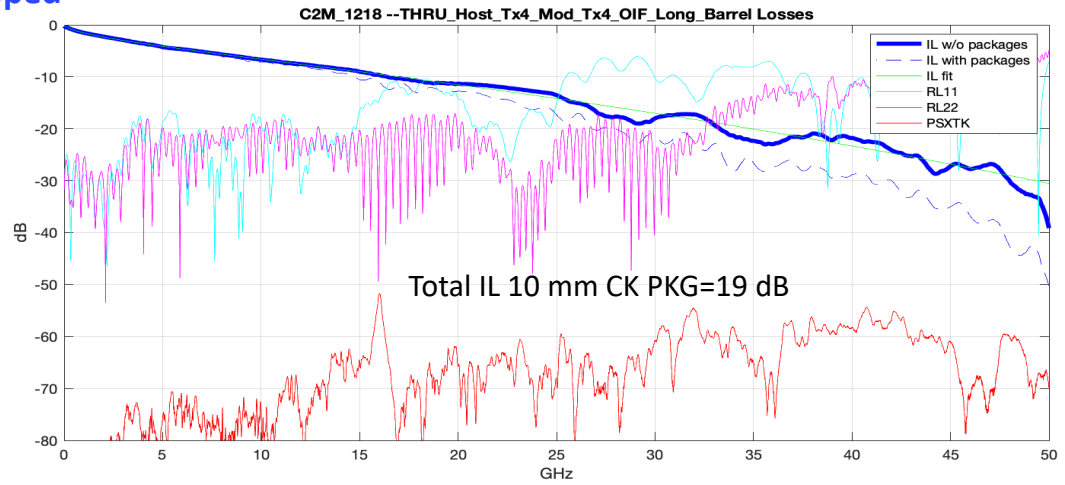
- **Swapping optimum TX FFE for TE T4 microvia with long barrel channel there is as much as 1.3 dB COM penalty and 35% eye height reduction!**

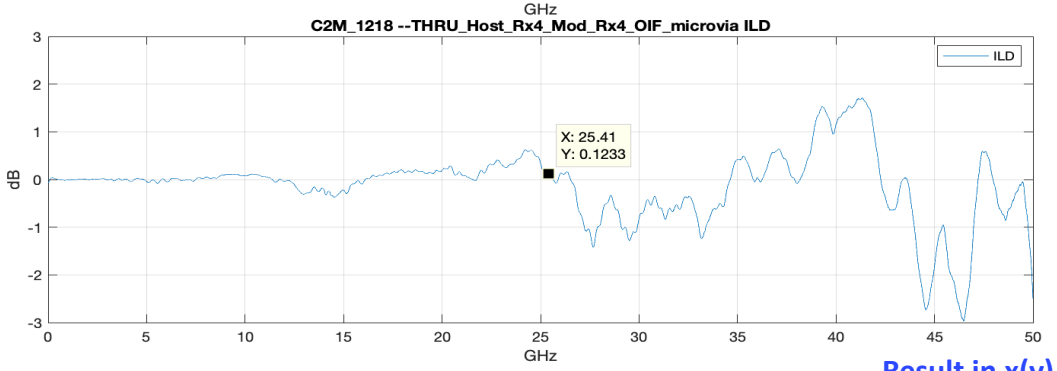
Tracy T4 MicroVia, FOM_ILD=0.20, ICN=0.57 mV, ICR=48, ERL11=7.9, ERL22=14.1
COM=4.2 (4.6) dB, EH=15.8 (15.6) mV, VEC=8.4 (7.7) dB
TX FFE[0.02, -0.14, 0.76,-0.08] Optimum
COM=3.5 (3.9) dB, EH=14.2 (15.6) mV, VEC=9.6 (8.8) dB

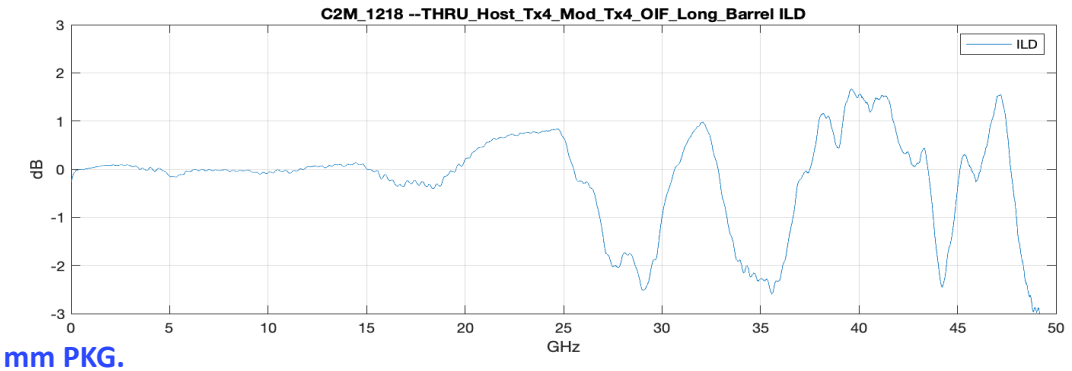
Tracy T4 LongBarrel, FOM_ILD=0.38, ICN=0.47 mV, ICR=46, ERL11=8.9, ERL22=14.7
5T FFE - CK PKG: COM=2.6 (3.1) dB, EH=9.9 (10.6) mV, VEC=11.8 (10.4) dB
TX FFE[0.04, -0.2, 0.72,-0.04] Optimum
5T FFE - CK PKG: COM=1.4 (2.5) dB, EH=6.4 (9.5) mV, VEC=16.4 (12) dB

TX FFE Taps Swapped









Result in x(y) are for 2(10) mm PKG.

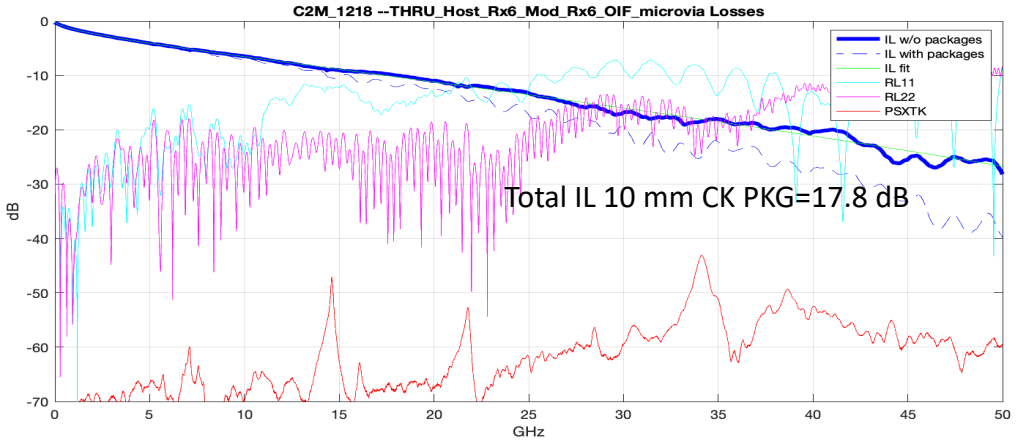
COM Analysis of Tracy Channels Module-ASIC with Single Segment PKG

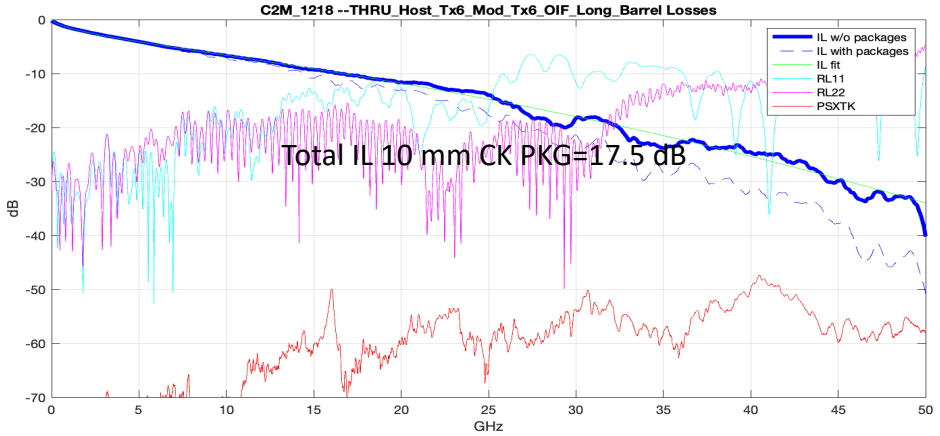
- **Swapping optimum TX FFE for TE T6 microvia with long barrel channel there is as much as 0.7 dB COM penalty and no eye height reduction!**

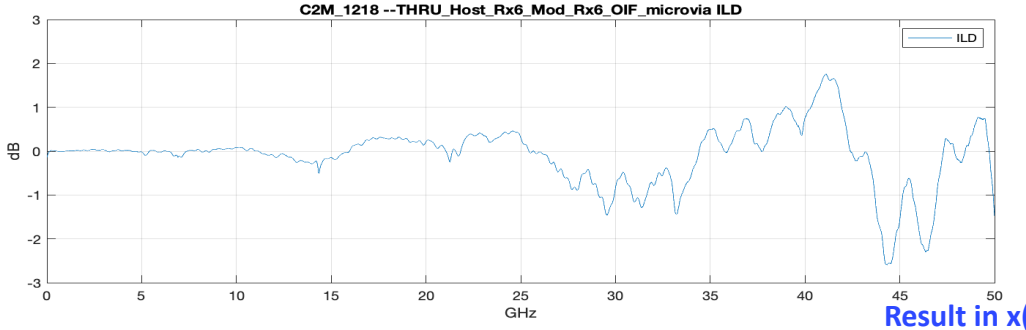
Tracy T6 MicroVia, FOM_ILD=0.21, ICN=0.83 mV, ICR=46, ERL11=8.3, ERL22=15.4
5T FFE: COM=4.8 (4.7) dB, EH=19.0 (17.1) mV, VEC=7.5 (7.6) dB
TX FFE[0.04, -0.18, 0.76, -0.02] Optimum Setting
5T FFE: COM=4.1 (4.5) dB, EH=19.1 (14.3) mV, VEC=8.4 (7.9) dB

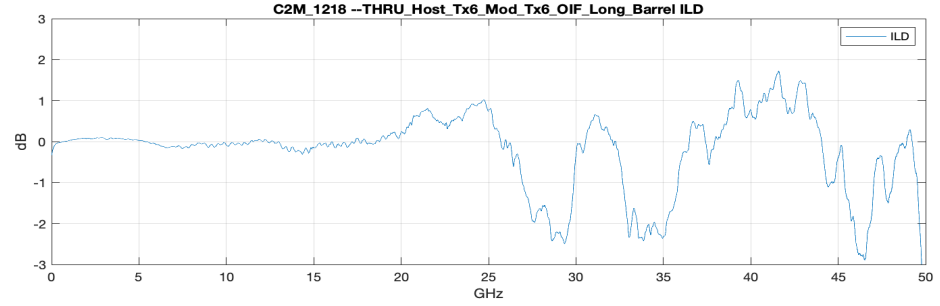
Tracy T6 LongBarrel, FOM_ILD=0.37, ICN=0.90 mV, ICR=40.2, ERL11=9.3, ERL22=14
5T FFE: COM=3.2 (3.7) dB, EH=10.8 (12.3) mV, VEC=10.3 (9.2) dB
TX FFE[0.04, -0.18, 0.68, -0.1] Optimum TX FFE
5T FFE: COM=2.9 (3.6) dB, EH=11.8 (12.4) mV, VEC=11.0 (9.3) dB

TX FFE Taps Swapped







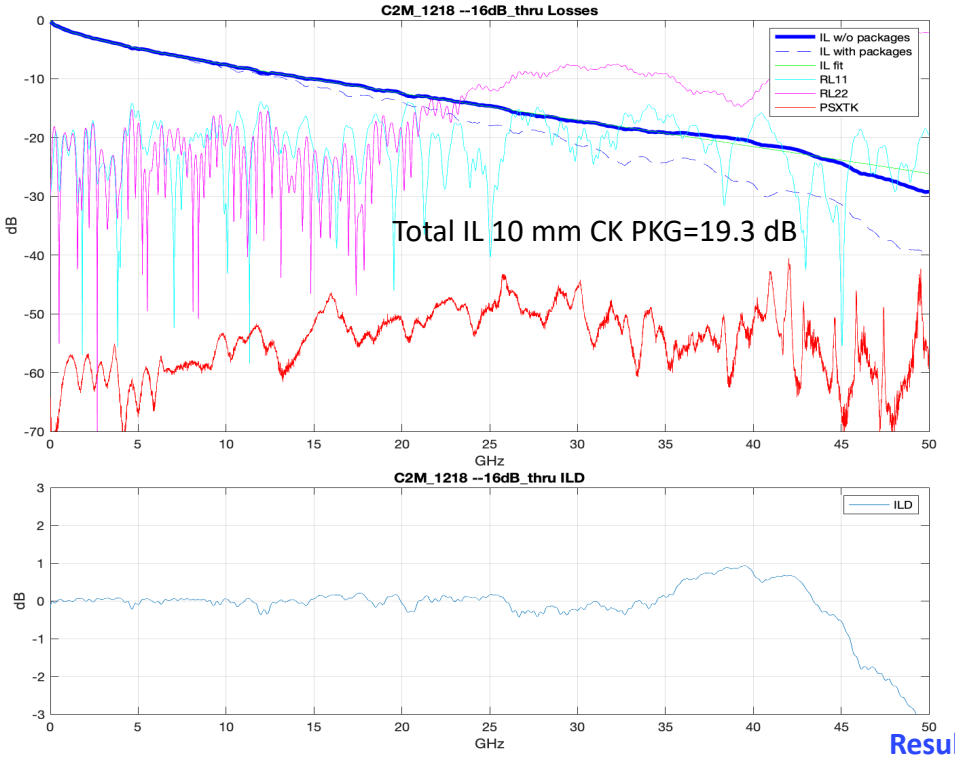


Result in x(y) are for 2(10) mm PKG.

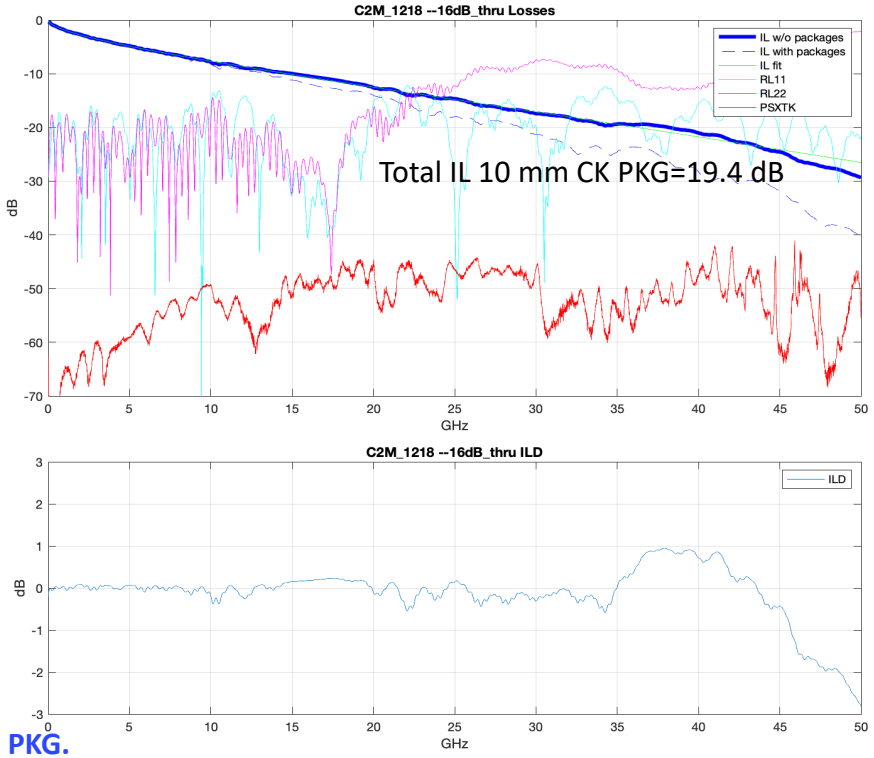
COM Analysis on Lim Nov-18 Channels (new contacts) Module-ASIC with Single Segment PKG

- **Using TX FFE for TE T4 microvia for Lim channels there is as much as 1.0 dB COM penalty and 21% eye height reduction!**

Lim 12 dB, FOM_ILD=0.105, ICN=2.1 mV, ICR=30.2 dB, , ERL11=12.3, ERL22=9.4
5T FFE: COM=5.1 (5.5) dB, EH=21.7 (17.5) mV, VEC=6.6 (7.1) dB
TX FFE [0.02, -0.14, 0.84, 0] Optimum
5T FFE(4 post): COM=4.6 (4.3) dB, EH=19.9 (17.8) mV, VEC=7.7 (8.1) dB
TX FFE[0.04, -0.2, 0.72,-0.04] with TE T4 Settings



Lim 16 dB, FOM_ILD=0.122, ICN=2.66 mV, ICR=30.8 dB, , ERL11=11.7, ERL22=9.3
5T FFE(4 post): COM=5.2 (4.7) dB, EH=22.9 (17.3) mV, VEC=6.9 (7.6) dB
TX FFE [0.02, -0.14, 0.82, -0.02] Optimum
5T FFE(4 post): COM=4.1 (3.7) dB, EH=18.2 (15.7) mV, VEC=8.5 (9.1) dB
TX FFE[0.04, -0.2, 0.72,-0.04] with TE T4 Settings

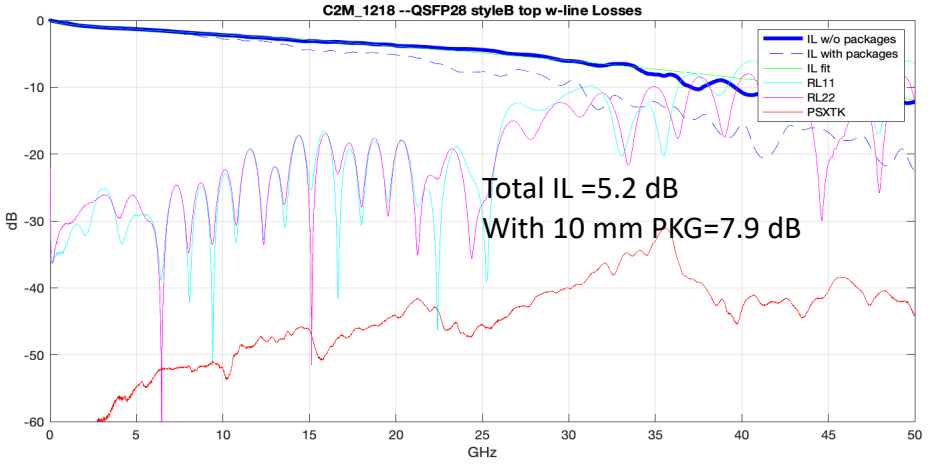


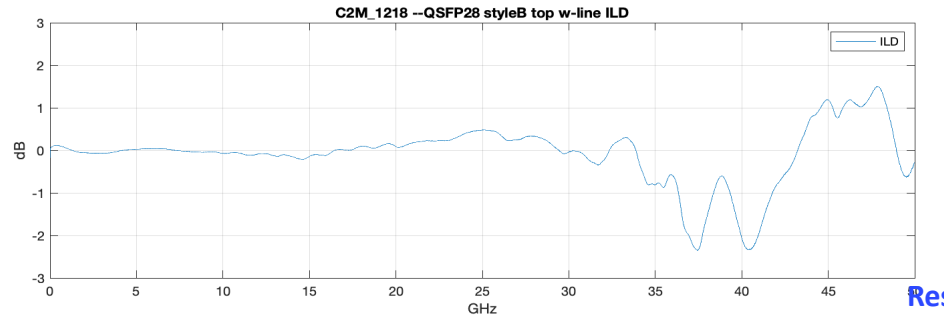
Result in x(y) are for 2(10) mm PKG.

Yamaichi QSFP28 MCB/HCB TP4 Simulations with Single Segment PKG

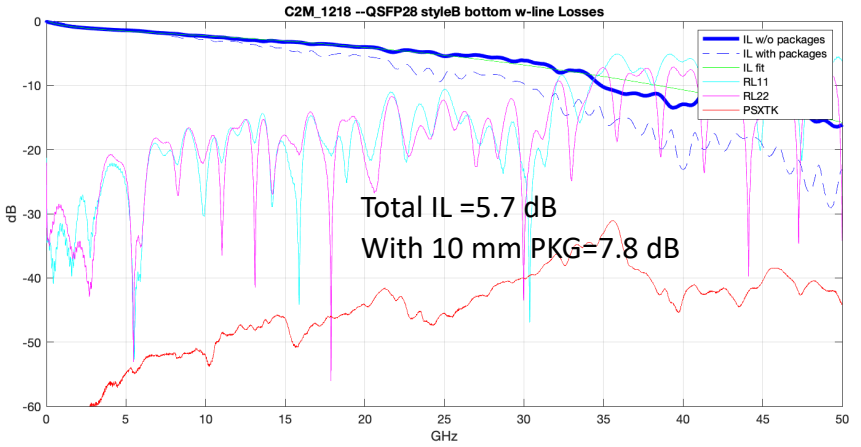
- **Using TX FFE for TE T4 microvia for Yamichi MCB/HCB channels there is as much as 0.9 dB COM penalty and 20% eye height reduction at TP4!**

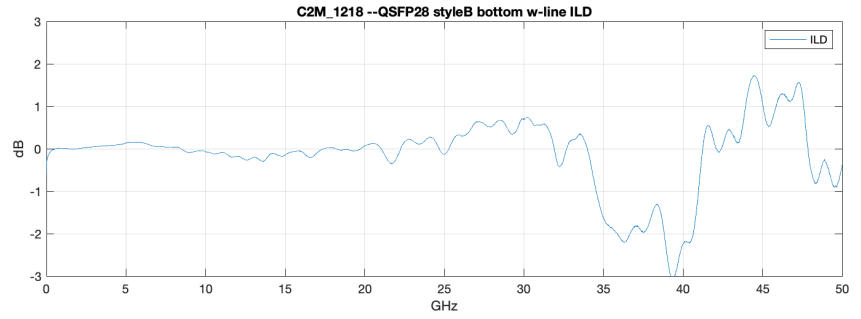
Top, FOM_ILD=0.18, ICN=5.2 mV, ICR=40 dB, , ERL11=14.5, ERL22=14.4
5T FFE: COM=5.4 (5.2) dB, EH=49.7 (43.8) mV, VEC=6.7(6.9) dB
TX FFE [0.04, -0.18, 0.78, 0] Optimum
5T FFE(4 post): COM=4.5 (4.4) dB, EH=42.3 (37.9) mV, VEC=7.9 (8.0) dB
TX FFE[0.04, -0.2, 0.72,-0.04] with TE T4 Settings





Bottom, FOM_ILD=0.23, ICN=5.2 mV, ICR=39 dB, , ERL11=10.9, ERL22=11.9
5T FFE(4 post): COM=5.8 (4.8) dB, EH=53.9 (38.9) mV, VEC=6.3 (7.4) dB
TX FFE [0.04, -0.18, 0.78, 0] Optimum
5T FFE(4 post): COM=4.8 (4.6) dB, EH=43.1 (38.1) mV, VEC=7.4 (7.7) dB
TX FFE[0.04, -0.2, 0.72,-0.04] with TE T4 Settings





Result in x(y) are for 2(10) mm PKG.

Summary

- **The 5 tap low power FFE equalizer can be sufficient if ILD, ICN, and channel reflections are better controlled**
  - The key source of problems are long barrel vias and connector fan-in/transitions traces
- **Updated results on Tracy and Lim channels are promising to assume 5T FFE for TP1a test point equalizer as the channels will improve with 112G generation of connectors**
  - Tracy OSFP micro-via channels all exceed 3 dB COM with 5 T FFE
  - Tracy OSFP Long Barrel Via some channels do not meet 3 dB COM with 5 T FFE but pass 3 dB COM with 7T FFE
  - Some of Lim QSFP-dd channels do not meet 3 dB COM with 5T FFE
  - But in every case Tracy Long Barrel and Lim channels which has long barrel via pass with 30 mm PKG
  - One option is to restrict connecting short package traces to long barrel vias
- **Limited simulation at TP4/TP5 using Tracy and Lim channels are promising with the assumed 2 and 10 mm single segment package**
  - One key observation is that fixed module TX FFE may result in as much as 1 dB of COM penalty at TP5 due to non optimum pre cursor setting
  - We may need to consider host receiver with 7 Tap FFE with 2 pre-cursor large penalty associated with fix module TX pre-cursor!