C2M Simulation and Methodology

Ali Ghiasi

Ghiasi Quantum LLC

IEEE 802.3ck Task Force

Long Beach

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Contributors

- **Mike Dudek – Marvel**
- **Rich Mellitz - Samtec**

Overview

- **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
- **COM 2.5.7 produces nearly identical results to COM 2.5.1 if one uses BJ package**
  - eta0=8.2e-9 added and reduces COM by ~0.2 dB
  - To have consistency with results from Sept/Nov fr=1.0 but based on feedback received and low cost better to reduce fr to 0.75
  - If we choose to reduce fr=0.75 on a channel with COM of ~3 dB on channel with low ICN ~0.2 dB COM penalty but ~0.1 dB gain on channel with high ICN
- **The new CK proposed packaged has significant penalty for C2M applications**
  - Using CK package over BJ package has ~1.5 dB COM penalty on high ILD channels
  - For detail of BJ package used here with Cp/Cd caps with improved impedance see COM 2.5.1 spreadsheet
  - For detail of CK packaged used here see COM 2.5.7 spreadsheet
- **Short channels combined with CK proposed packaged may require much more capable equalizer such as 12T FFE or 5T FFE+1T DFE**
  - Complexity/power such class of equalizer could be an issue for 800G modules.

COM Code 2.51

- **Filter coefficient selected to have the improved CL120E response scaled for 53.1 GBd**
  - http://www.ieee802.org/3/ck/public/tools/tools/mellitz_3ck_adhoc_01_100318_COM2p51.zip

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	[0.9e-4 0]	nF	[TX RX]
z_p select	[1 2 3]		[test cases to run]
z_p (TX)	[14 15 30]	mm	[test cases]
z_p (NEXT)	[14 15 30]	mm	[test cases]
z_p (FEXT)	[14 15 30]	mm	[test cases]
z_p (RX)	[0 0 0]	mm	[test cases]
C_p	[0.9e-4 0]	nF	[TX RX]
R_0	50	Ohm	
R_d	[45 45]	Ohm	[TX RX]
A_v	0.45	V	
A_fe	0.45	V	
A_ne	0.63	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	1.2	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	3		

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	3	dB
ERL Pass threshold	10.5	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 1.734e-3 1.455e-4]	
package_tl_tau	6.141E-03	ns/mm
package_Z_c	[90 90]	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	90	Ohm
z_bp (TX)	*50*	mm
z_bp (NEXT)	*50*	mm
z_bp (FEXT)	*50*	mm
z_bp (RX)	*0*	mm

COM Code 2.5.7

- **Filter coefficient selected to have the improved CL120E response scaled for 53.1 GBd**
  - http://www.ieee802.org/3/ck/public/tools/tools/mellitz_3ck_adhoc_01_121918_COM2p57.zip

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	[0.9e-4 0]	nF	[TX RX]
z_p select	[1 2 3]		[test cases to run]
z_p (TX)	[14 15 30; 1.8 1.8 1.8]	mm	[test cases]
z_p (NEXT)	[14 15 30; 1.8 1.8 1.8]	mm	[test cases]
z_p (FEXT)	[14 15 30; 1.8 1.8 1.8]	mm	[test cases]
z_p (RX)	[0 0 0; 0 0 0]	mm	[test cases]
C_p	[0.9e-4 0]	nF	[TX RX]
R_0	50	Ohm	
R_d	[45 45]	Ohm	[TX RX]
A_v	0.45	V	
A_fe	0.45	V	
A_ne	0.63	V	
L	4		
M	32		
filter and Eq			
f_r	1	*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	1.2	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	3		

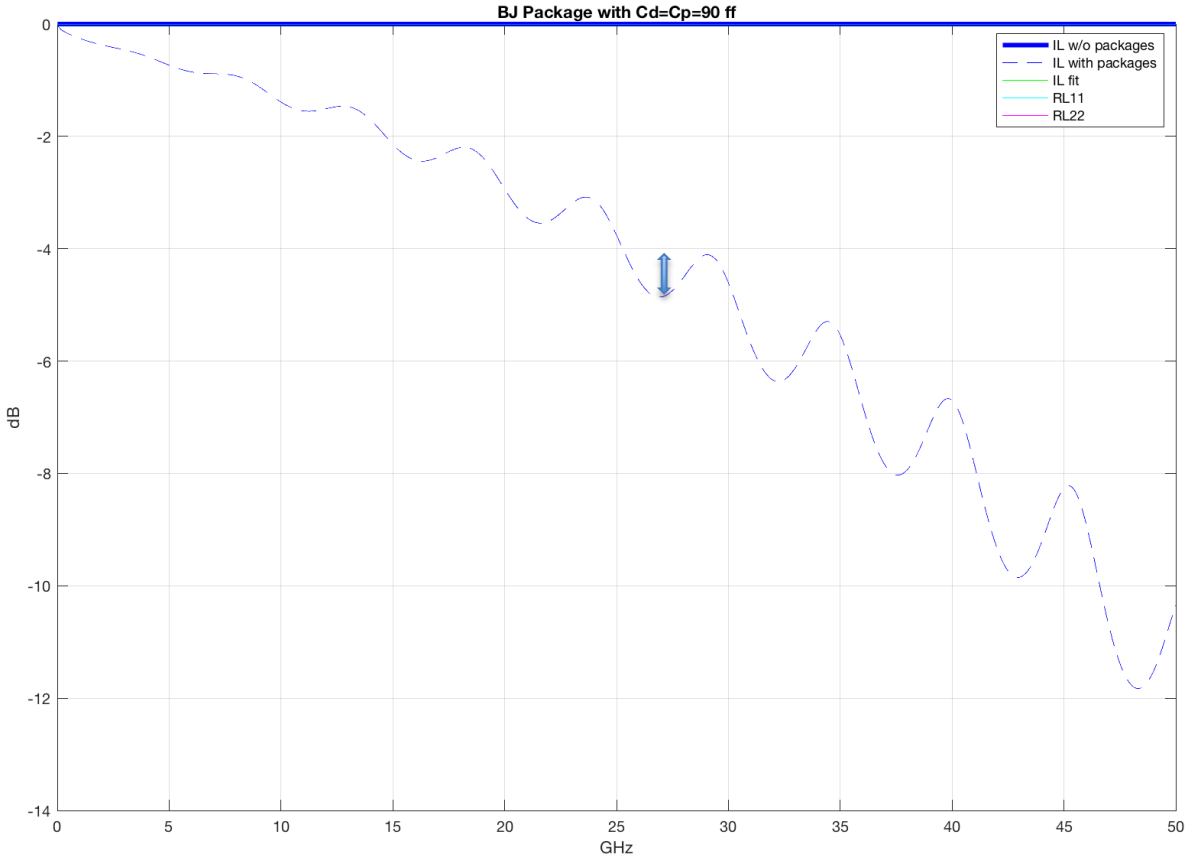
I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\100GEL_WG_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	C2M_1218	
COM_CONTRIBUTION	0	logical
Operational		
COM Pass threshold	3	dB
ERL Pass threshold	10.5	dB
DER_0	1.00E-05	
T_r	6.16E-03	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	

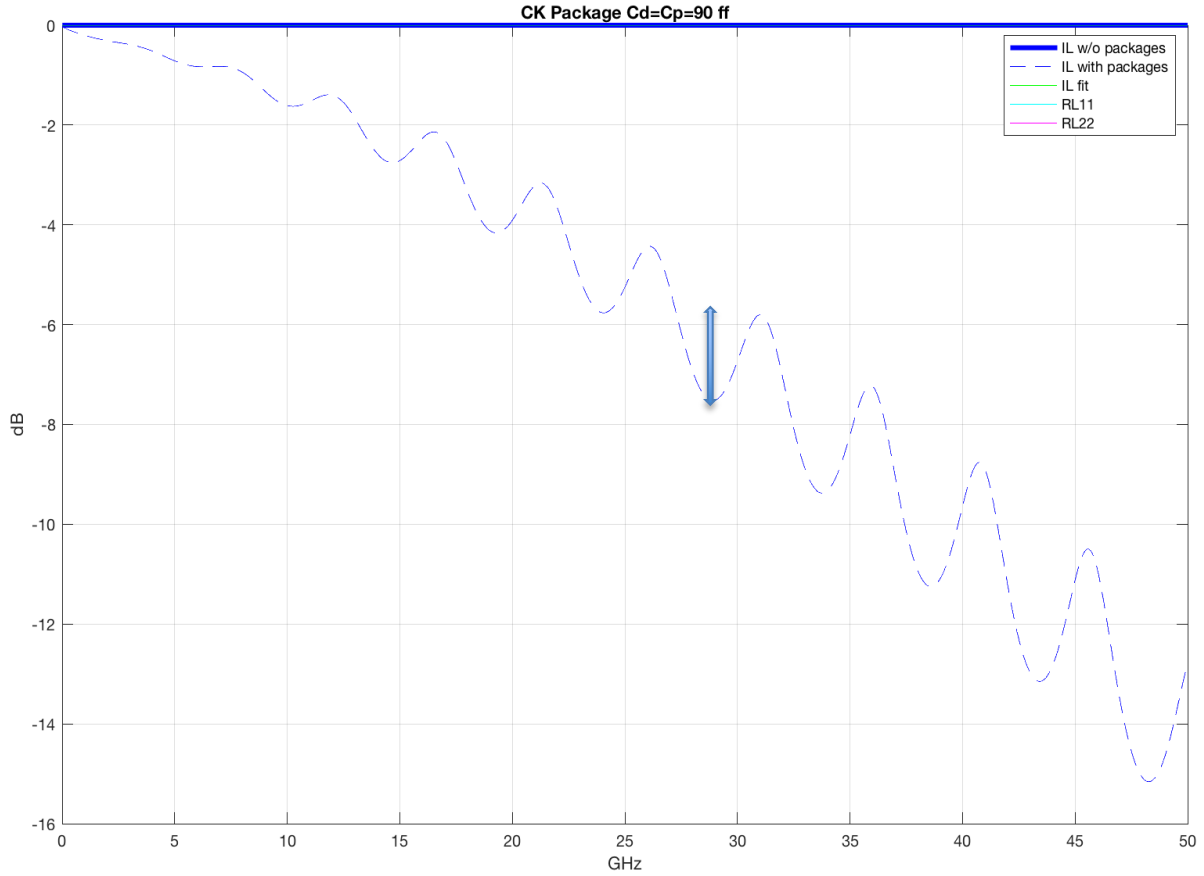
Table 93A–3 parameters		
Parameter	**Setting**	**Units**
package_tl_gamma0_a1_a2	[0 0.0009909 0.0002772]	
package_tl_tau	6.1400E-03	ns/mm
package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm

Table 92–12 parameters		
Parameter	**Setting**	
board_tl_gamma0_a1_a2	*[0 3.8206e-04 9.5909e-05]*	
board_tl_tau	*5.790E-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

15 mm BJ vs CK Package for Cd=Cp=90 ff

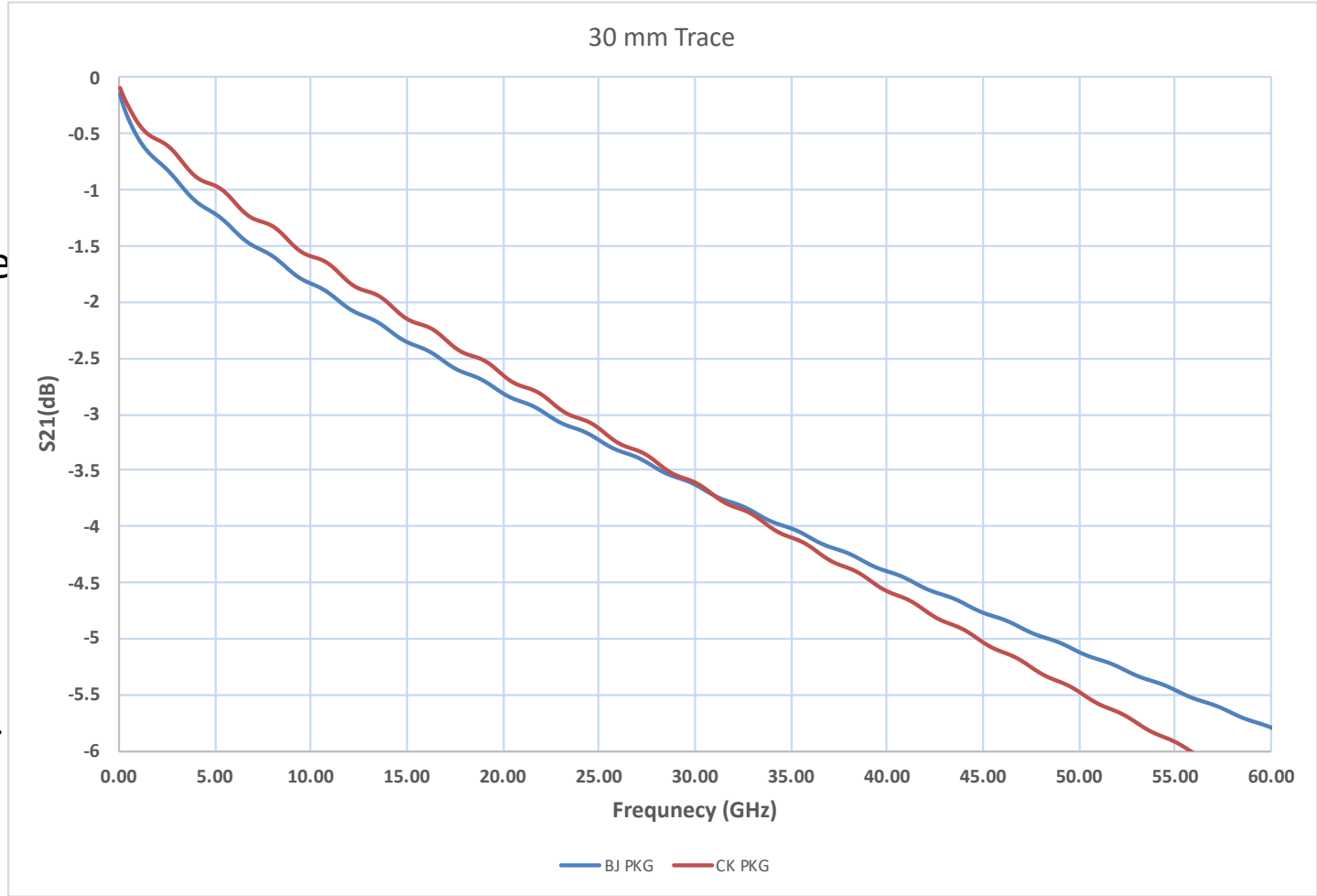
- **CK package has ~2x higher ILD at Nyquist compare to BJ package!**





BJ vs CK Trace Losses

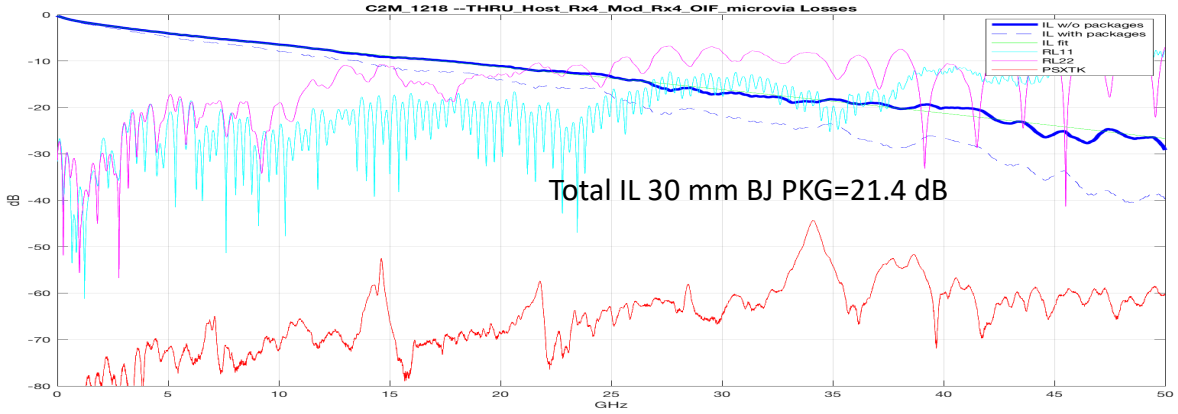
- **Comparisons of BJ vs CK 30 mm trace excluding CK 0.18 mm via**
  - The BJ package generally performs ~0.5 dB worse than well designed packages but new CK package even perform worse than BJ package
  - Both BJ and CK 30 mm traces have similar losses at Nyquist
  - Higher ILD associated with CK package likely as result of 0.18 mm via section
  - The CK package double reflections on short traces are cancelled in case of CR/KR having equalizer with length >=32 UI but C2M link must live with double reflections!

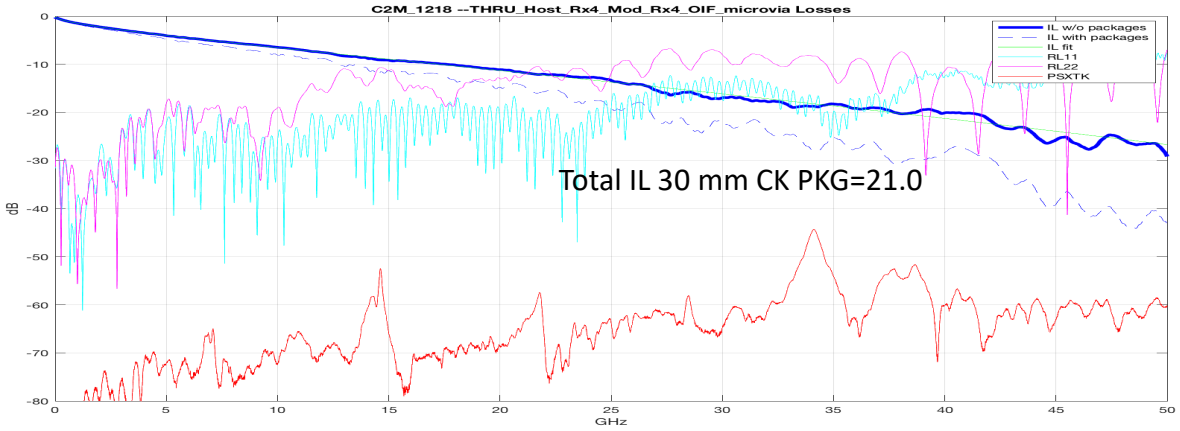


COM Analysis of Tracy Channels

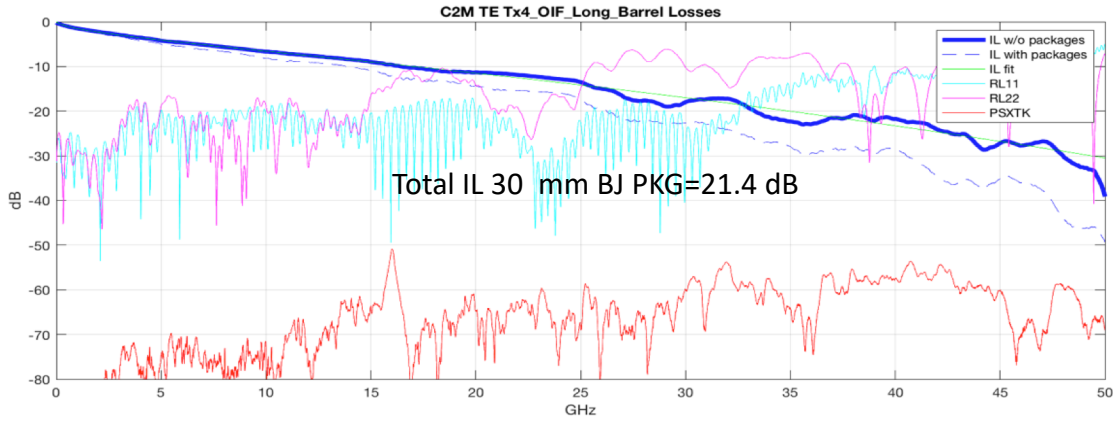
- **8.5” OSFP (16 dB) channels, CK package reduces loss but increases ILD at significant COM penalty!**
  - http://www.ieee802.org/3/100GEL/public/tools/c2m/tracy_100GEL_02_0118.zip (long barrel)
  - http://www.ieee802.org/3/100GEL/public/tools/c2m/tracy_100GEL_06_0118.zip (Micro Via).

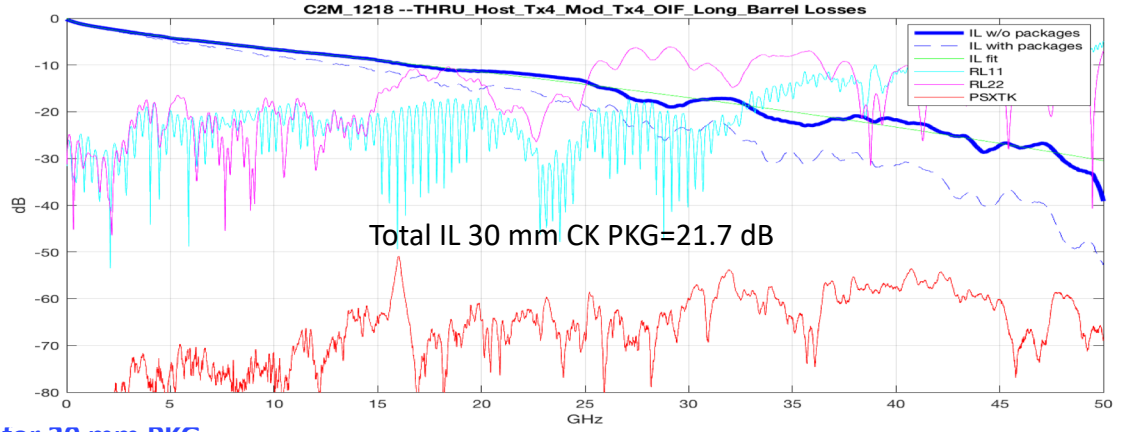
Tracy T4 MicroVia, FOM_ILD=0.23, ICN=0.67 mV, ICR=48, ERL11=14.0, ERL22=7.8
BJ PKG: COM=3.90 (5.96) dB, EH=13.75 (16.6) mV, VEC=8.83 (6.09) dB
CK PKG: COM=3.54 (3.87) dB, EH=12.75 (11.74) mV, VEC=9.52 (8.87) dB





Tracy T4 LongBarrel, FOM_ILD=0.42, ICN=0.54 mV, ICR=46, ERL11=13.4, ERL22=8.6
BJ PKG: COM=3.02 (3.24) dB, EH=9.63 (8.9) mV, VEC=10.64 (10.14) dB
CK PKG: COM=1.58 (2.34) dB, EH=5.30 (6.64) mV, VEC=15.58 (12.52) dB



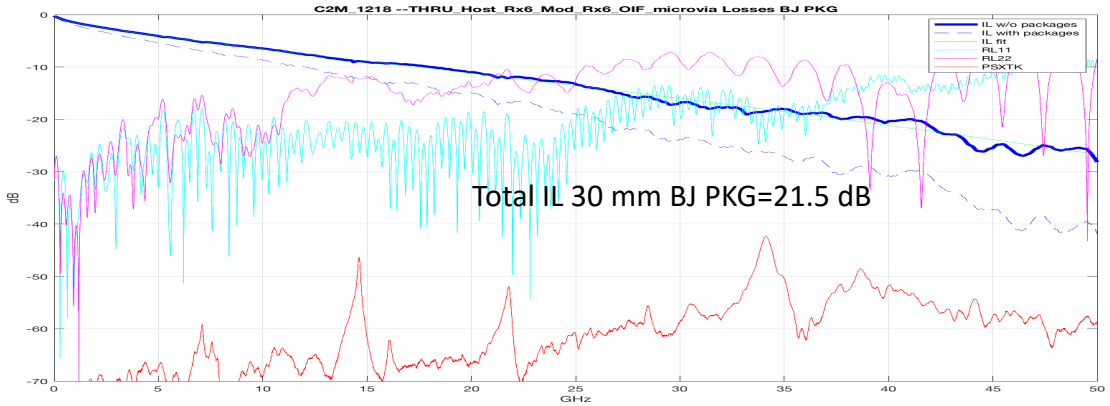


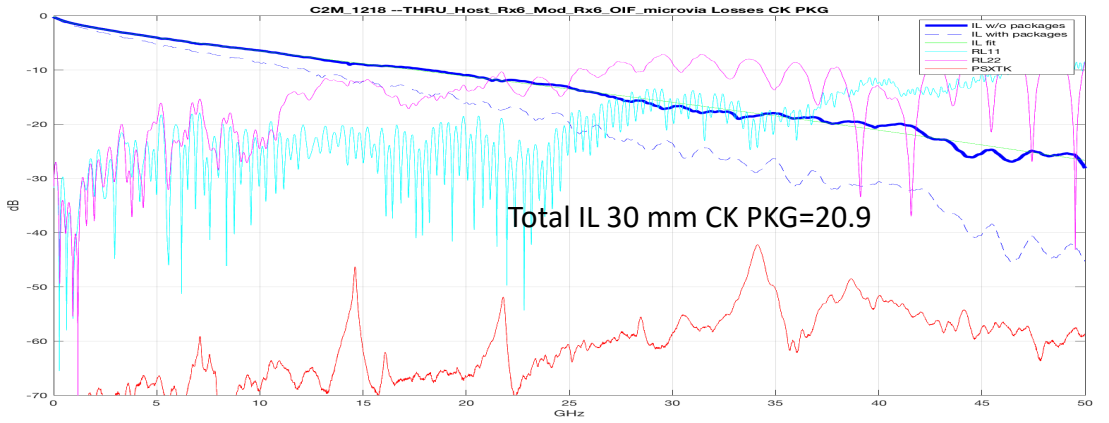
Result in (x) are for 30 mm PKG.

COM Analysis of Tracy Channels

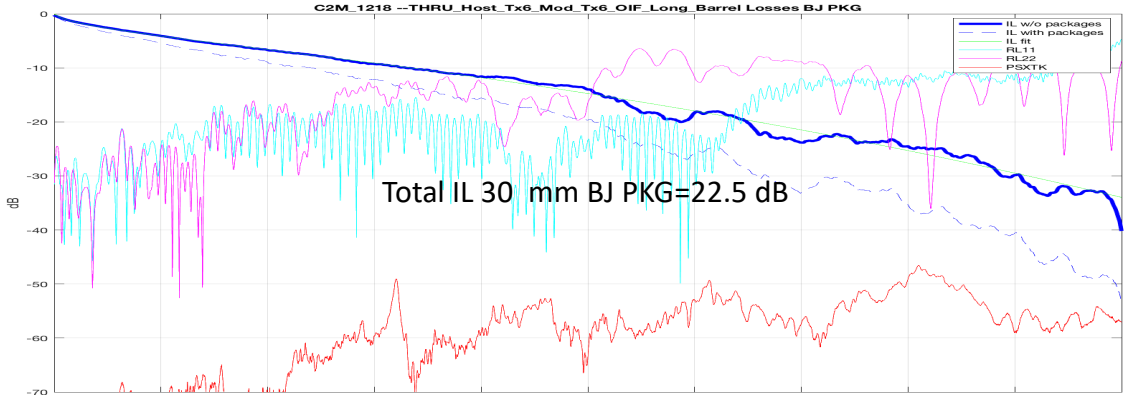
- **8.5” OSFP (16 dB) channels, CK package reduces loss but increases ILD at significant COM penalty!**
  - http://www.ieee802.org/3/100GEL/public/tools/c2m/tracy_100GEL_02_0118.zip (long barrel)
  - http://www.ieee802.org/3/100GEL/public/tools/c2m/tracy_100GEL_06_0118.zip (Micro Via).

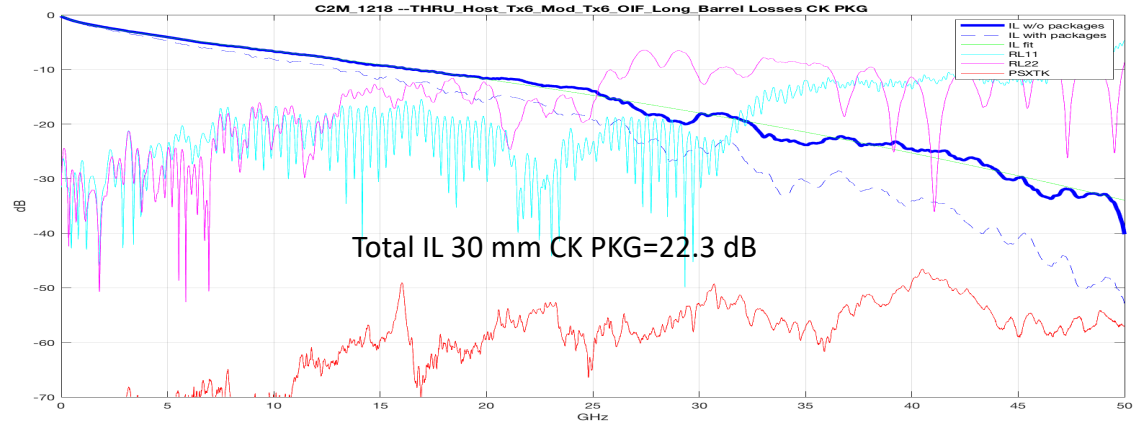
Tracy T6 MicroVia, FOM_ILD=0.23, ICN=0.98 mV, ICR=46, ERL11=15.4, ERL22=8.3
BJ PKG: COM=3.90 (5.4) dB, EH=14 (14) mV, VEC=8.8 (6.7) dB
CK PKG: COM=3.8 (4.6) dB, EH=13.2 (14.2) mV, VEC=9.0 (7.7) dB





Tracy T6 LongBarrel, FOM_ILD=0.39, ICN=1.0 mV, ICR=40.2, ERL11=11.1, ERL22=9.1
BJ PKG: COM=4.9 (4.3) dB, EH=14.6 (12.6) mV, VEC=7.3 (8.2) dB
CK PKG: COM=1.8 (2.6) dB, EH=6.4 (7.5) mV, VEC=14.7 (11.7) dB



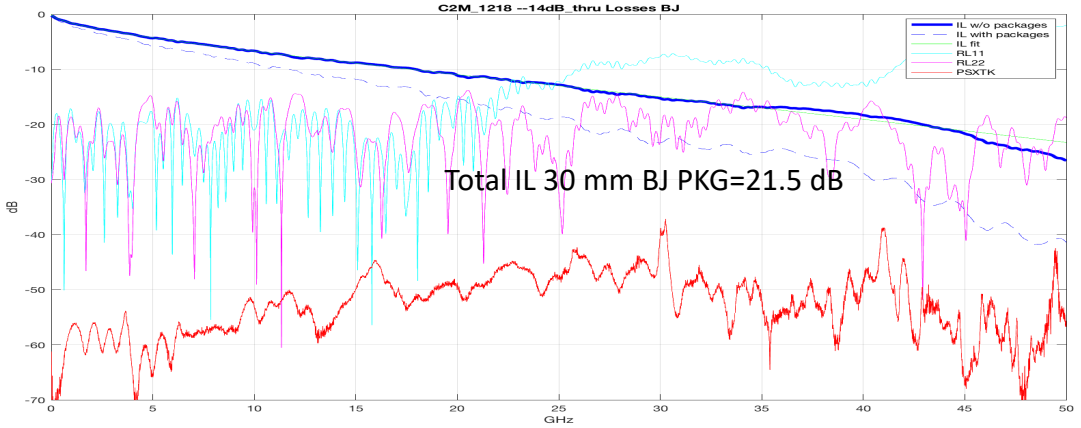


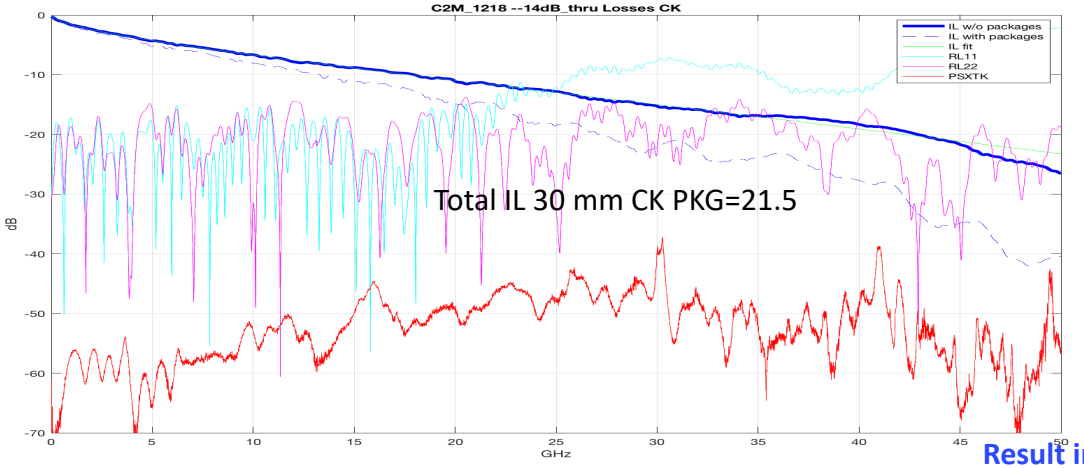
Result in (x) are for 30 mm PKG.

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

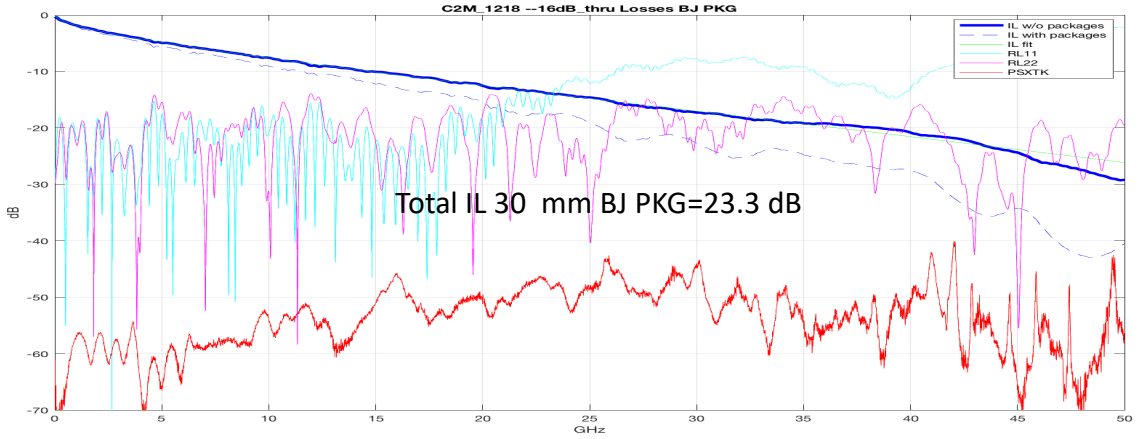
- **Lim Nov-2018 channel ICR still pretty low ~30 dB and with high ICN, but the crosstalk peak at 15 GHz eliminated, with this improvement passes with good margin on 30 mm package**
  - http://www.ieee802.org/3/ck/public/tools/c2m/lim_3ck_01_0918_QDD_legacy_pairs.zip

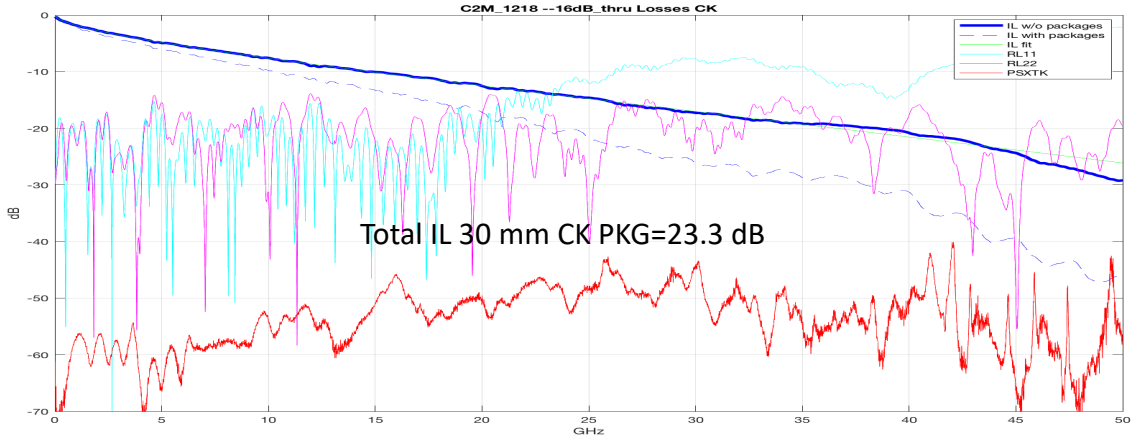
Lim 14 dB FOM_ILD=0.129, ICN=2.79 mV, ICR=31.5, ERL11=9.1, ERL22=12.2
BJ PKG: COM=2.58 (4.44) dB, EH=15.3 (15.9) mV, VEC=11.8 (8.0) dB
CK PKG: COM=2.74 (3.86) dB, EH=14.7 (15.4) mV, VEC=11.4 (8.9) dB





Lim 16 dB, FOM_ILD=0.127, ICN=2.37 mV, ICR=30.8 dB, , ERL11=8.8, ERL22=11.6
BJ PKG: COM=2.63 (4.16) dB, EH=12.1 (12.1) mV, VEC=11.6 (8.4) dB
CK PKG: COM=2.60 (4.31) dB, EH=9.9 (12.6) mV, VEC=11.7 (8.2) dB



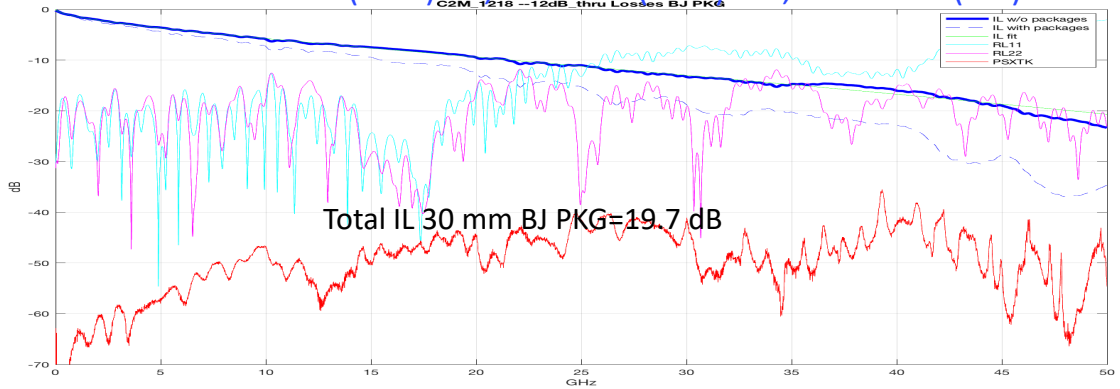


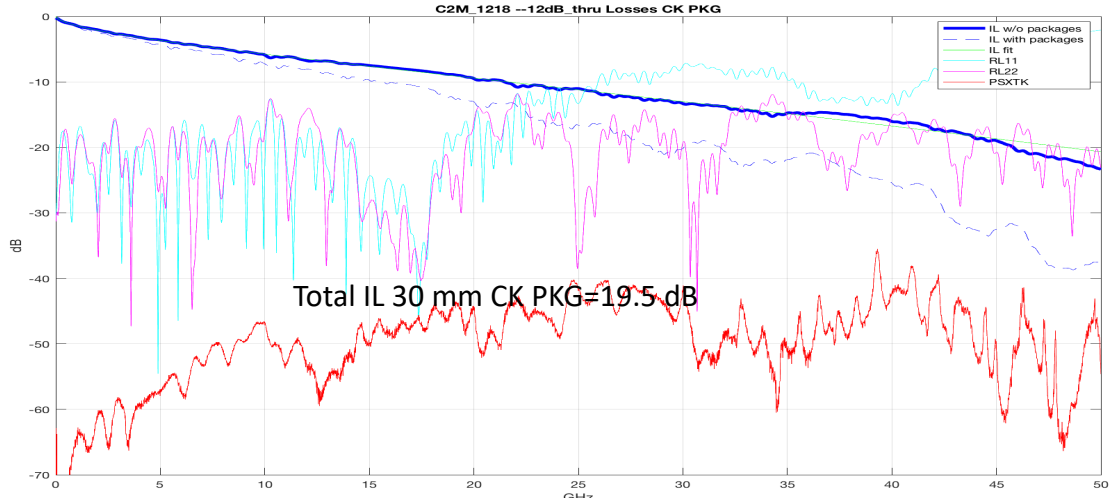
Result in (x) are for 30 mm PKG.

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

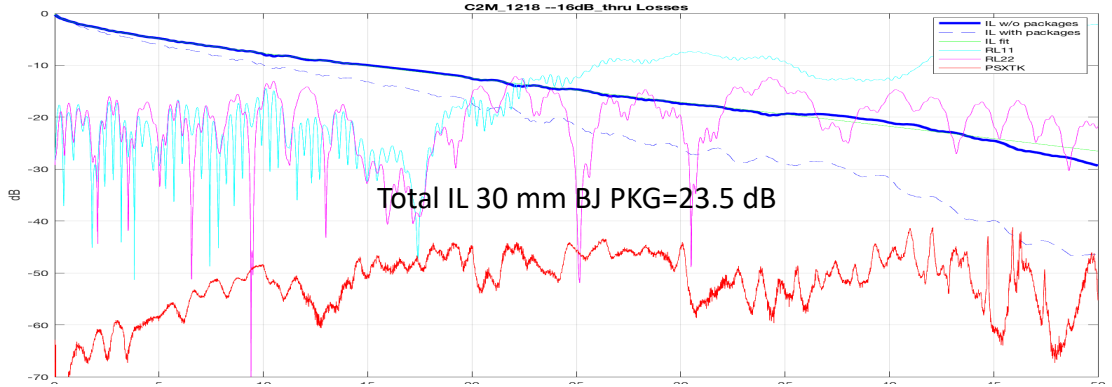
- **Lim Nov-2018 channel ICR still pretty low ~30 dB and with high ICN, but the crosstalk peak at 15 GHz eliminated, with this improvement passes with good margin on 30 mm package**
  - **http://www.ieee802.org/3/ck/public/tools/c2m/lim_3ck_01_0918_QDD_new_pairs.zip**

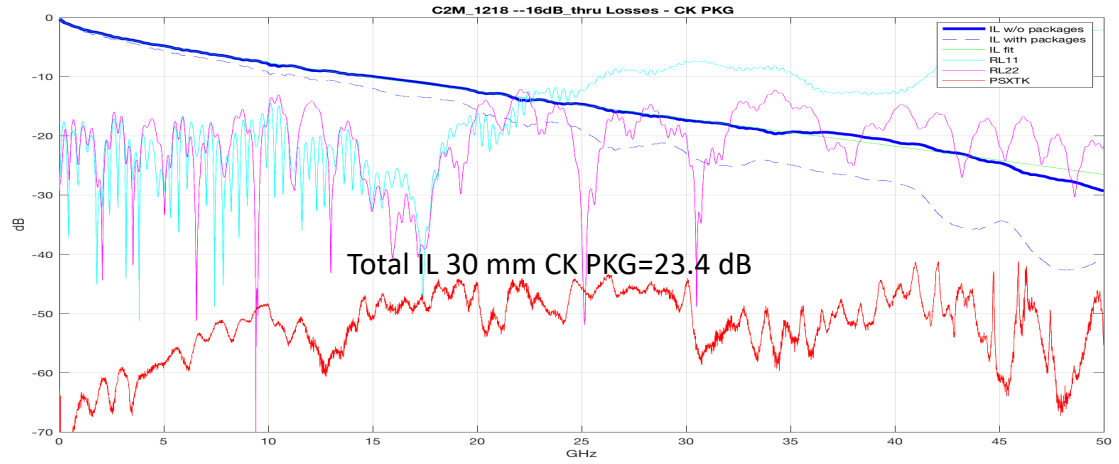
Lim 12 dB, FOM_ILD=0.145, ICN=3.76 mV, ICR=30.2 dB, , ERL11=8.3, ERL22=11.5
BJ PKG: COM=2.6 (4.3) dB, EH=15.9 (19.2) mV, VEC=11.7 (8.1) dB
CK PKG: COM=3.02 (3.84) dB, EH=15.8 (19.4) mV, VEC=10.6 (8.9) dB





Lim 16 dB, FOM_ILD=0.142, ICN=2.92 mV, ICR=30.8 dB, , ERL11=8.8, ERL22=11.6
BJ PKG: COM=2.47 (3.9) dB, EH=11.6 (13.3) mV, VEC=12.1 (8.8) dB
CK PKG: COM=2.57 (3.6) dB, EH=9.9 (10.8) mV, VEC=11.8 (9.4) dB



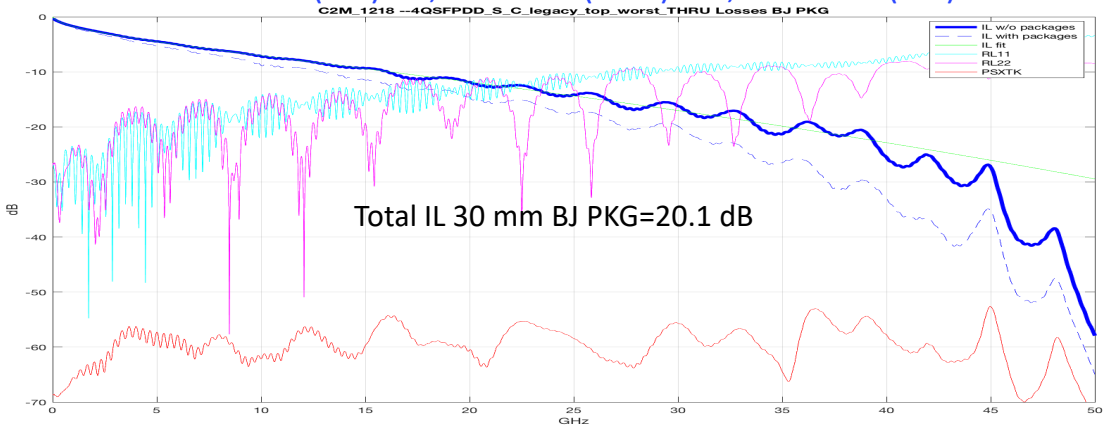


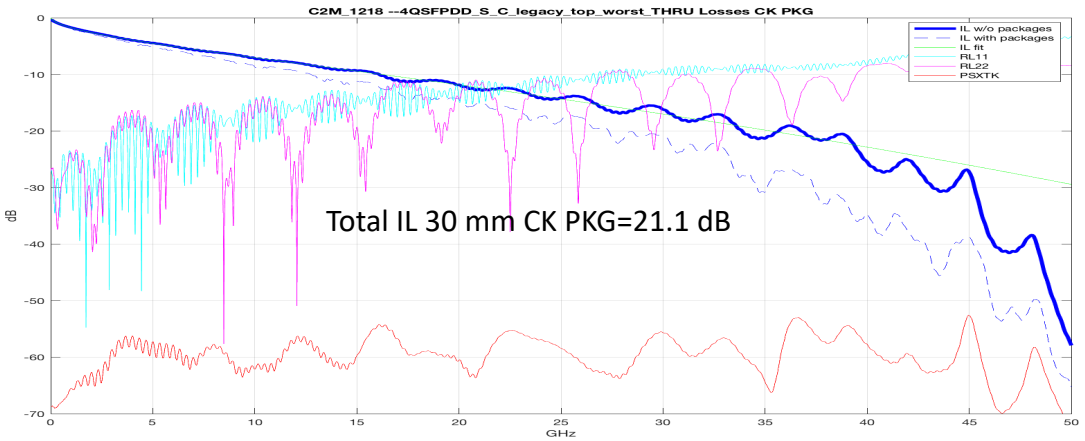
Result in (x) are for 30 mm PKG.

Yamaichi Improved QSFP-dd on Host Channel with 2x7 mils Via stubs

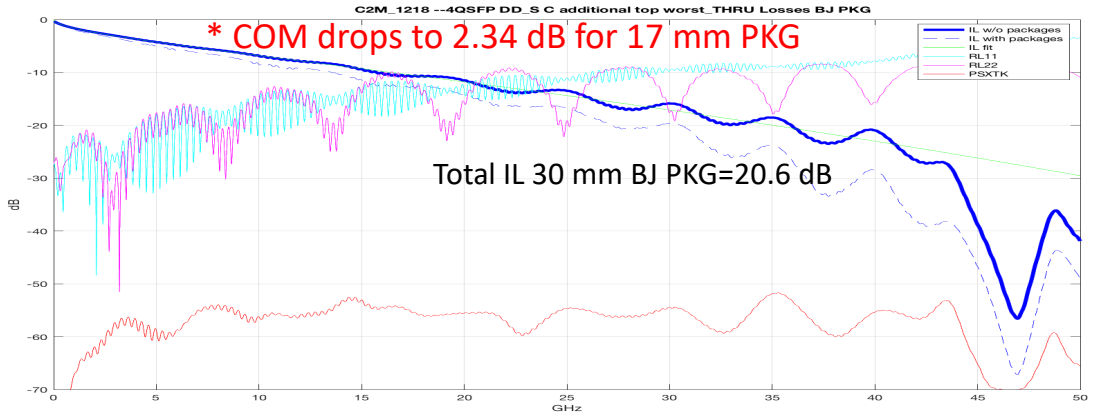
- **These board have dramatically improved ICN (Include 7 FEXT+ 8 NEXT) but ILDs are high**
  - Top-contact legacy channel loss 15.17 dB and top contact-dd channel loss is 15.21 dB.

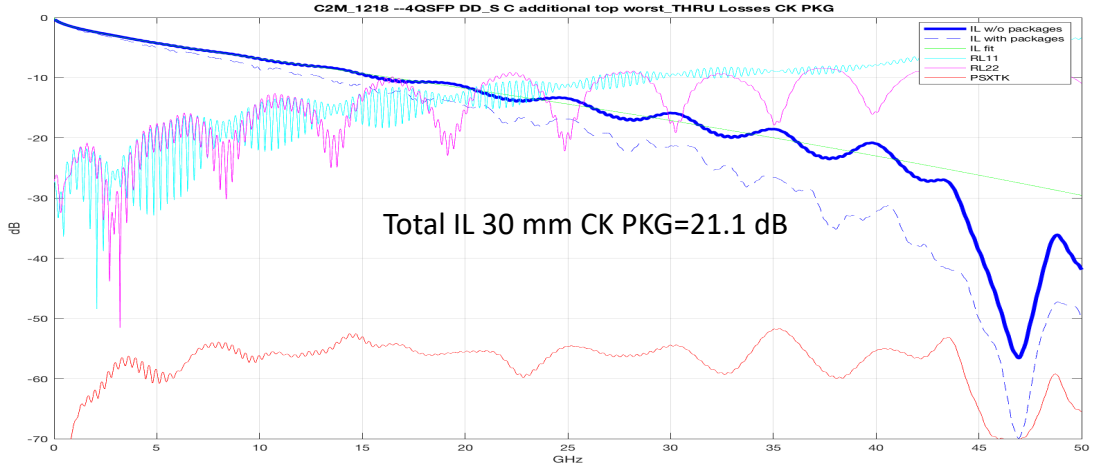
Top-Legacy Contact (worst mating)
FOM_ILD=0.557, ICN=1.07 mV, ICR=43 dB, , ERL11=9.8, ERL22=9.6
BJ PKG: COM=4.6 (5.0) dB, EH=15.9 (14.6) mV, VEC=7.6 (7.2) dB
CK PKG: COM=4.2 (3.9) dB, EH=12.5 (10.4) mV, VEC=8.3 (8.7) dB





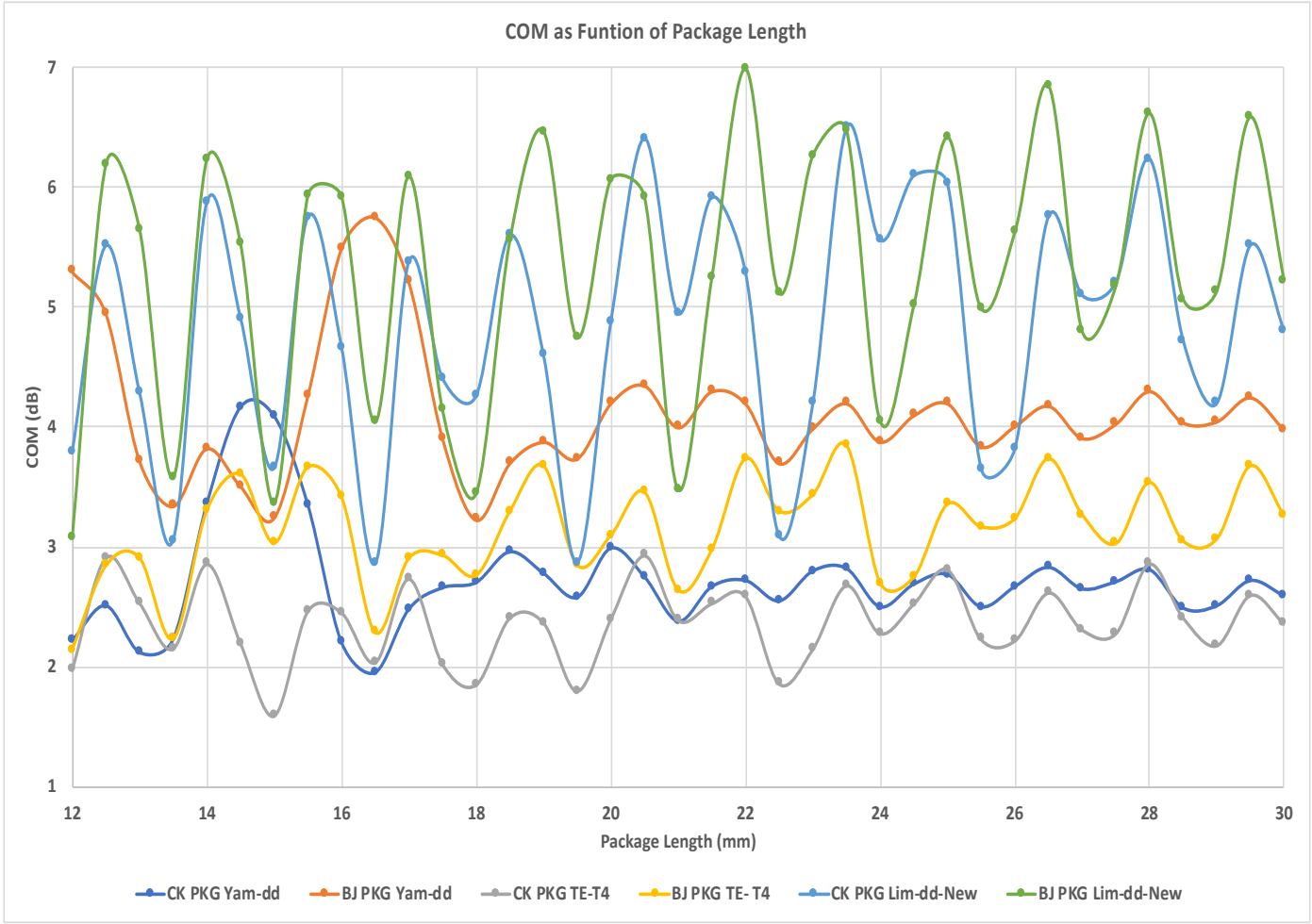
Top-dd Contact (worst mating)
FOM_ILD=0.739, ICN=1.46 mV, ICR=40 dB, , ERL11=9.8, ERL22=9.4
BJ PKG: COM=3.08 (3.80) dB, EH=10.4 (10.6) mV, VEC=10.5 (9.0) dB
CK PKG: COM=3.91* (2.46) dB, EH=11.3 (7.4) mV, VEC=8.8 (12.1) dB





COM As Function of Package Trace Length

- **COM reported for short package trace may not account for worst interreferences**
  - COM results without crosstalk
  - Result indicate both package and channel dependency with > 2 dB of COM variation
  - ASIC Double reflection period is ~3.5 mm
    - Yamaichi channel possibly due to high ILD may have 2nd order interference
  - One method to improve short package ASIC COM is by optimizing traces length/PTH to avoid double reflection landing in middle of the eye.



Study of Lim QSFP-dd Channels as Function of Equalizer and Package

- **QSFP-dd new contacts**
  - Unless short ASIC packages could be tuned either 12 tap FFE or 5 tap FFE+1DFE would be necessary!

Channel	EQ	14 mm Package			15 mm Package			30 mm Package		
		COM (dB)	EH (mV)	VEC (dB)	COM (dB)	EH (mV)	VEC (dB)	COM (dB)	EH (mV)	VEC (dB)
Lim 16 dB dd CK Package ILD=0.14, ICN=2.9 ERL11=8.8 ERL22=11.6	5T FFE	4.4	15.9	8.0	2.6	9.9	11.8	3.6	10.8	9.4
	7T FFE	4.39	17.2	8.0	2.54	10.1	11.9	3.6	11.0	9.4
	9T FFE	4.4	17.2	8.0	2.6	10.2	11.8	3.6	11.0	9.4
	12T FFE	3.7	12.0	9.2	3.7	12.0	9.1	3.6	11.0	9.4
	5T FFE+1DFE	4.2	20.6	8.2	5.3	23.2	6.8	4.8	18.4	7.5
Lim 16 dB dd BJ Package ILD=0.14, ICN=2.9 ERL11=8.8 ERL22=11.6	5T FFE	4.7	19.5	7.5	2.5	11.6	12.1	3.9	13.3	8.8
	7T FFE	4.7	19.4	7.6	2.5	11.6	12.1	4.0	13.5	8.7
	9T FFE	4.8	16.0	7.5	2.5	11.6	12.1	4.0	13.5	8.7
	12T FFE	5.3	20.8	6.8	4.6	14.7	7.7	4.0	13.5	8.7
	5T FFE+1DFE	5.5	23.4	6.6	4.1	20.5	8.5	5.0	19.4	7.2

Tracy Channels with Long Barrel Via

- **Tracy T4 and T6 both have high ILD**
  - With BJ package both T4 and T6 works fine with 5T FFE but incase of CK package 7-9 taps FFE would be needed!

Channel	EQ	14 mm Package			15 mm Package			30 mm Package		
		COM (dB)	EH (mV)	VEC (dB)	COM (dB)	EH (mV)	VEC (dB)	COM (dB)	EH (mV)	VEC (dB)
TE T6 Channel CK Package ILD=0.39, ICN=1.0 ERL11=11.1 ERL22=9.1	5T FFE	3.0	9.2	10.7	1.8	6.4	14.7	2.6	7.5	11.7
	7T FFE	4.0	12.5	8.7	2.7	9.3	11.4	3.5	9.5	9.6
	9T FFE	4.7	14.3	7.5	3.6	12.9	9.4	4.2	11.2	8.4
TE T6 Channel BJ Package ILD=0.39, ICN=1.0 ERL11=11.1 ERL22=9.1	5T FFE	5.4	17.6	6.7	4.9	14.6	7.3	4.3	12.6	8.2
	7T FFE	4.7	19.4	7.6	2.5	11.6	12.1	4.0	13.5	8.7
	9T FFE	5.4	16.4	6.7	3.9	11.9	8.7	4.8	11.9	7.5
TE T4 Channel CK Package ILD=0.15, ICN=0.54 ERL11=8.8,ERL22=11.6	5T FFE	2.8	9.3	11.1	1.58	5.3	15.6	2.5	6.6	12.5
	7T FFE	4.5	13.4	7.9	3.2	10.5	10.3	3.8	10.1	9.0
	9T FFE	5.5	17.6	6.6	4.3	14.1	8.2	4.7	13.7	7.6
TE T4 Channel BJ Package ILD=0.15, ICN=0.54 ERL11=8.8,ERL22=11.6	5T FFE	3.3	12.1	10.0	3.0	9.6	10.6	3.2	8.9	10.1
	7T FFE	5.1	15.3	7.1	4.6	13.5	7.8	4.9	12.4	7.3
	9T FFE	6.2	19.2	5.8	5.0	15.8	7.2	3.2	8.9	10.1

50G C2M Specifications

- **50G CL135E C2M specifications is based on C2M CL83E**
  - Does anyone believe elementary loss specifications is sufficient for 100G specifications!

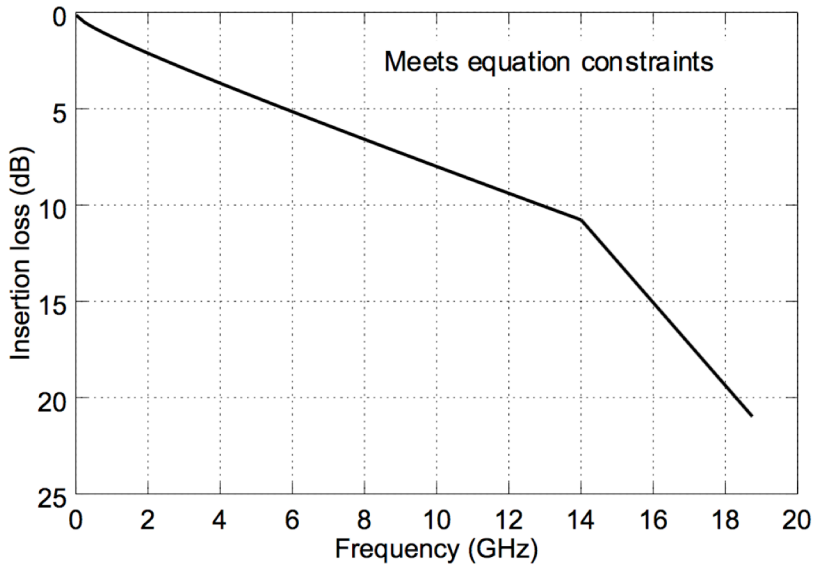


Figure 83E–3—CAUI-4 chip-to-module channel insertion loss

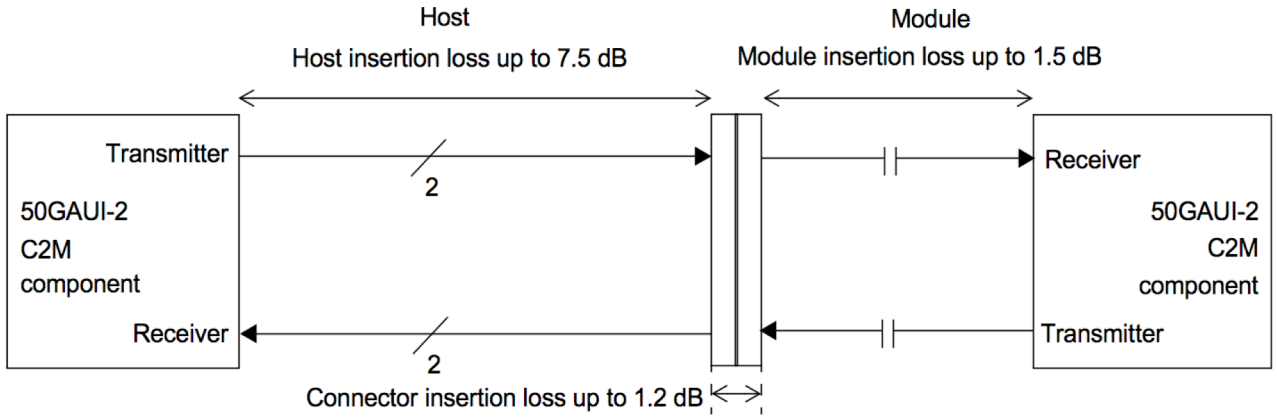


Figure 135E–2—50GAUI-2 C2M insertion loss budget at 13.28 GHz

Improving C2M Methodology

- **The normative specifications are at TP1a and TP4**
  - Any host package/channel combination delivering TP1a EH/EW/VEC is a compliant host
  - Any module delivering TP4/farend EH/EW/VEC is a compliant module
- **As we move from 50G to 100G with ever expanding connector option more robust specifications in addition to max insertion loss**
  - It has been suggested to add limit on ICN, ILD, ERL, and IL but adding these hard limit potentially may outlaw some channel which are compliant at TP1a/TP4
  - COM is now being used as the tool to study C2M equalizers and channel compliance
  - COM can be utilized as a tool to trade-off ICN, ILD, ERL, IL instead of defining hard limits
  - An informative COM annex will provide significant benefit to the industry given the complexity of 100G
- **In addition we should also explore use of COM for mated boards.**

Summary

- **The 5 tap low power FFE equalizer may not be sufficient unless ILD, ICN, and channel reflections are better controlled**
  - The source of problems are long barrel vias and connector crosstalk which is improving
- **The new CK proposed package with higher ILD and lower loss penalizes C2M applications where the C2M equalizers are not capable to cancel the package double reflections**
  - Need to consider limitations of C2M interface as we develop a common package for CK
  - Otherwise C2M will get the short end and get forced to higher power class equalizer such as 12 tap FFE or 5 tap FFE+1 DFE
  - These more capable equalizer with higher power will make it difficult to build 800G modules
- **Combination of new proposed CK package with higher ILD, channels with long barrel via/stubs, and QSFP-dd new contacts may drive C2M equalizer complexity to 12 tap FFE or 5 tap FFE+1DFE**
  - 5 Tap FFE might be sufficient if we could improve CK package ILD, tune short package traces, or use blind vias
  - Alternatively we can explore two C2M receivers a 5 taps FFE for connectors with improved SI and a more capable receiver for connector with more challenging SI – not the best option
- **Instead of defining hard limit on ILD, ICN, IL, or ERL, COM can be used as the tool for channel goodness but first we need to agree on complexity of equalizer**
  - Purpose to add a C2M COM informative annex instead of adding hard limits on ILD, ICN, IL, or ERL.