Server/NIC Chip-to-Chip Channels & Reference Receiver Analysis

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- Recommendations
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Objectives

1. Provide a set of AUI C2C channels to represent common server/NIC configurations.
   - PCB trace range: 2 inches to 14 inches with 1 inch step size
   - Die-die insertion loss range: 9.4 dB to 34.4 dB
2. Provide 1st cut AUI C2C reference RX recommendations.
   - # RXFFE fixed postcursor taps: 4, 8, 12, 16, 20, 24
   - η_0: $4 \times 10^{-9}, 8 \times 10^{-9}, 1 \times 10^{-8}, 1.25 \times 10^{-8}\ {V^2}/{GHz}$
   - TXFFE precursor taps: 3, 2, 1
   - R_d: 40Ω to 60Ω

Initial recommendations are based only upon the channels provided in this contribution.

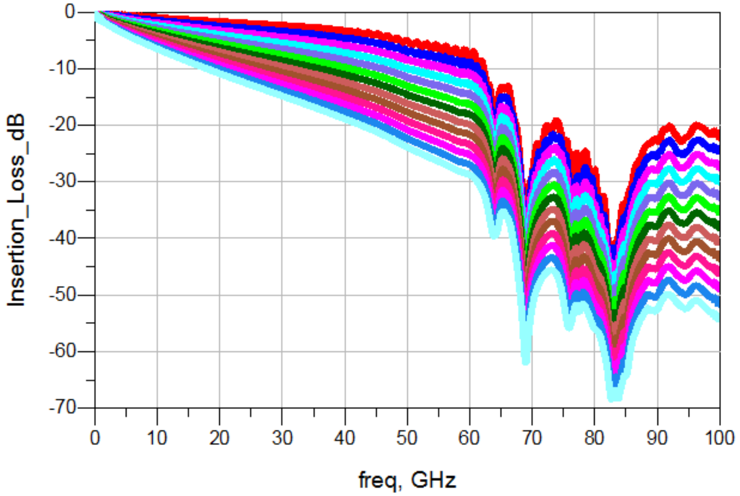
Channels

Physical Channel Description (Simulated)

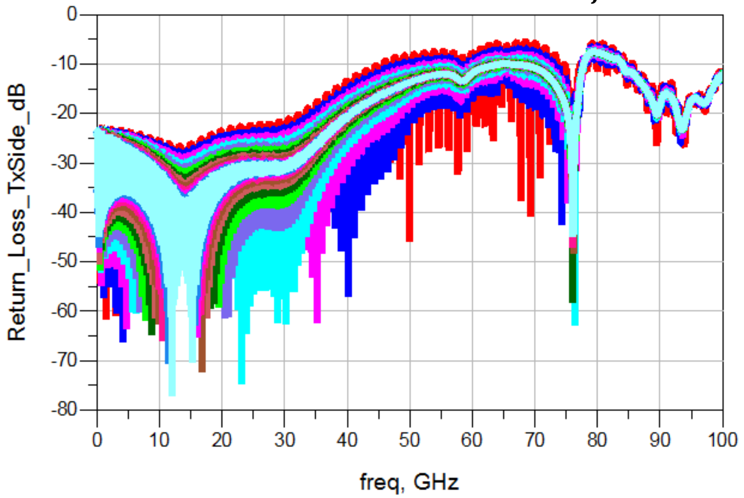
- Number of Aggressors: 3 FEXT and 4 NEXT
- BGA escape model
  - BGA ball not included, 5 mils stub
  - Via Drill Depth:
    - Tx 10 mils, Rx 20 mils
- Host PCB impedance
  - 93 Ω
  - 1.5dB/in @53.125GHz
- Does NOT include package or silicon structures

Channel Response

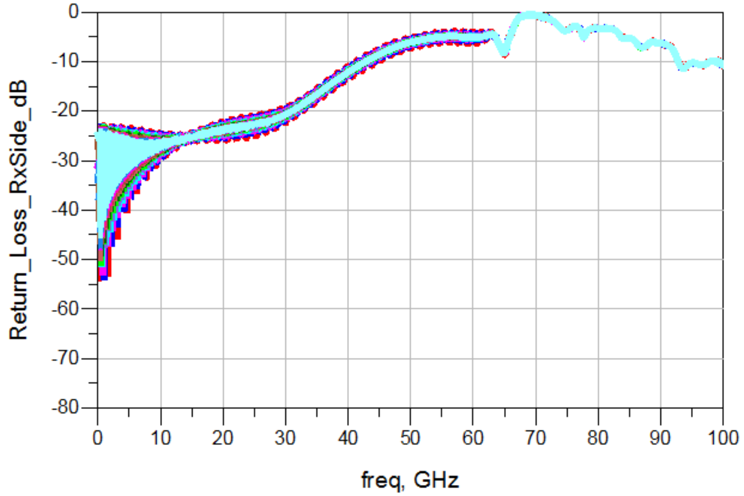
Insertion Loss, Differential, Z_{ref} =100 Ω



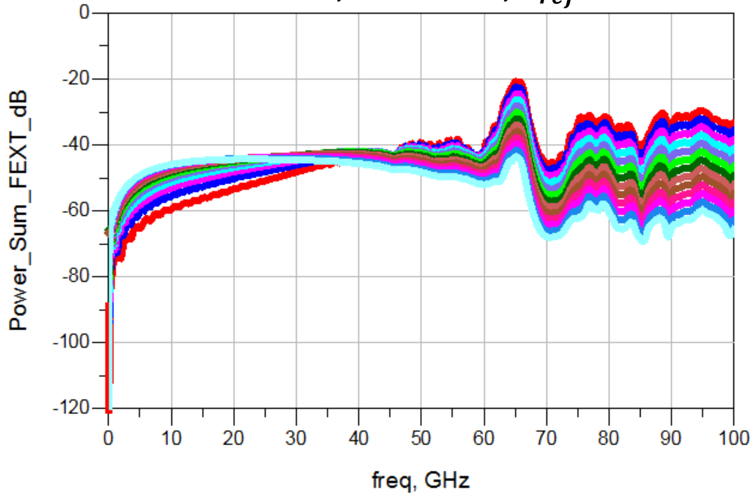
Return Loss (Tx Side), Differential, Z_{ref} =100 Ω



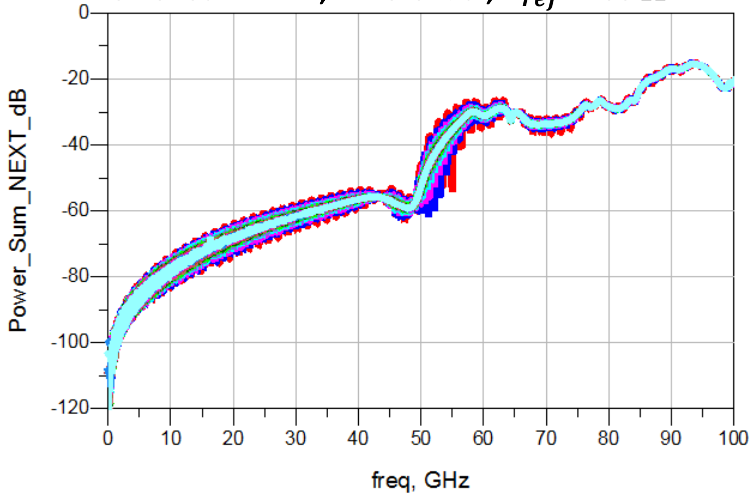
Return Loss (Rx Side), Differential, Z_{ref} =100 Ω



Power Sum FEXT, Differential, Z_{ref} =100 Ω

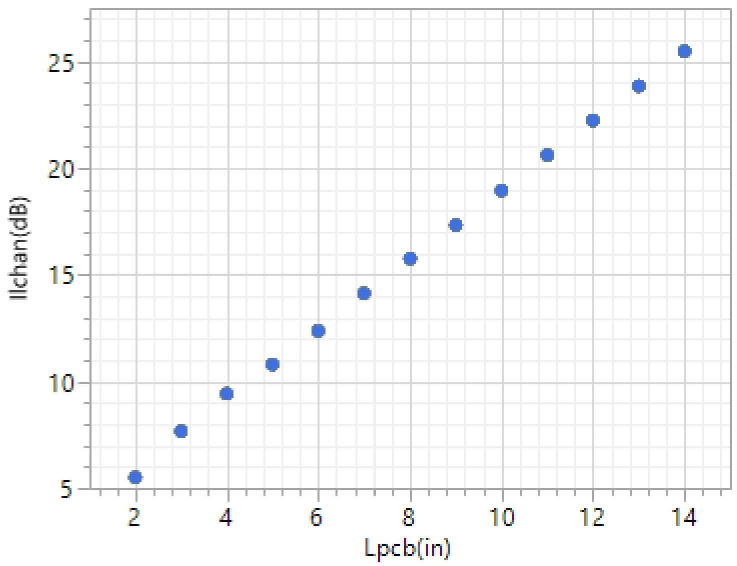


Power Sum NEXT, Differential, Z_{ref} =100 Ω

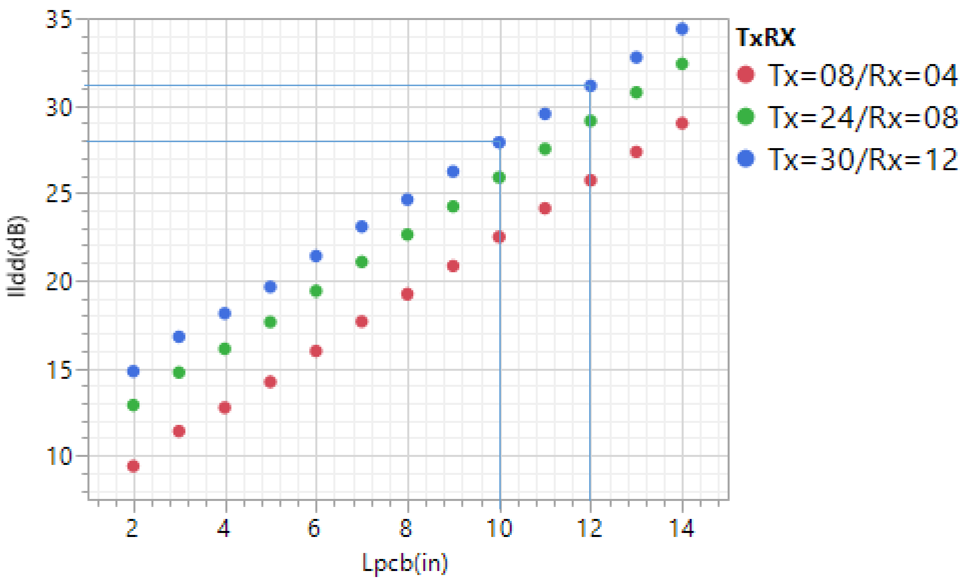


Channel Insertion Loss & PCB Trace Lengths

Ball-Ball Insertion Loss vs PCB Length



Die-Die Insertion Loss vs PCB Length



Analysis considers 9.4-34.4 dB die-die insertion loss range.

We would like to support at least 10-inch PCB trace length (12 would be better).

- 10-inch length needs ~28dB die-die insertion loss ($ILdd$) for the channels in this contribution with Type A packages @ the lengths we considered.
- 12-inch length requires ~31dB

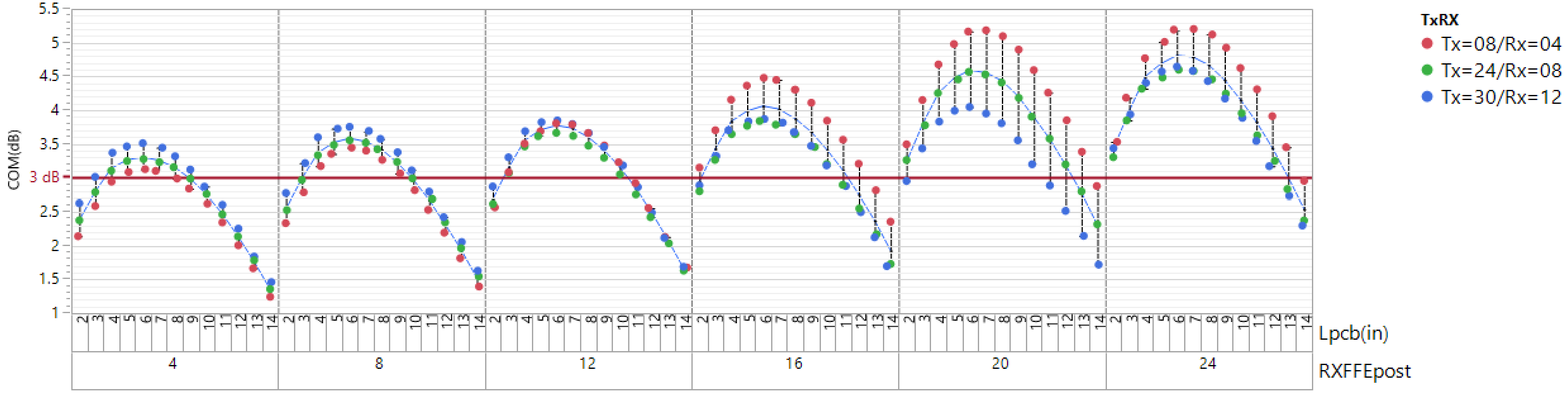
Analysis

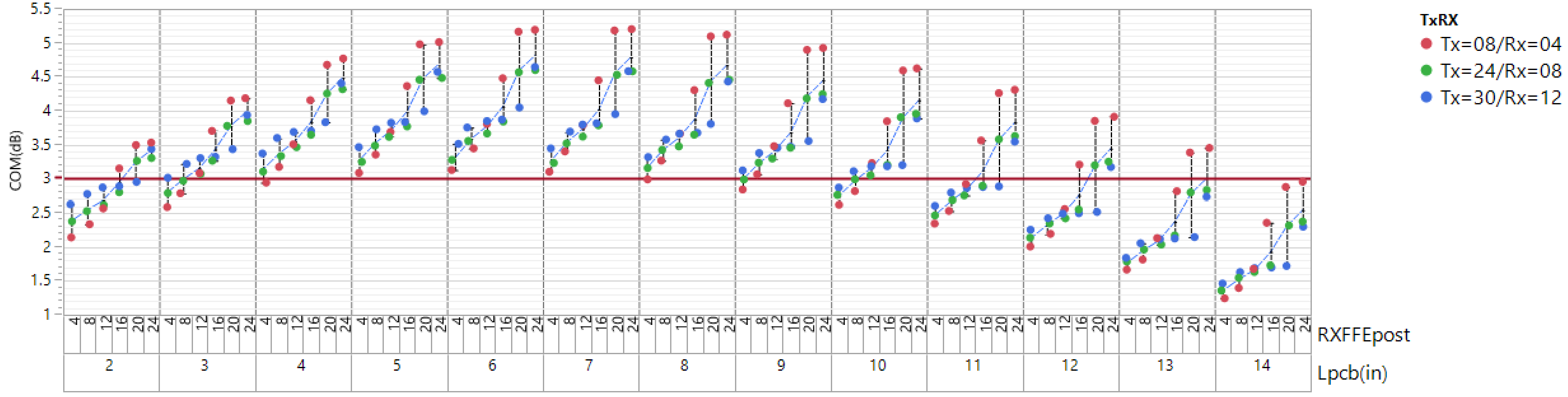
Parameters Studied

- PCB Trace Length: 2 inches to 14 inches in 1 inch steps
- Package: Class A w/ die model from lim_3dj_01_2401 slide 8
  1. Tx = 8mm, Rx = 4mm
  2. Tx = 24mm, Rx = 8mm
  3. Tx = 30mm, Rx = 12mm
- RxFFE: fixed taps, MMSE, no MLSD
  - 6 precursor
  - 4/8/12/16/20/24 post-cursor
- R_d: $40\ \Omega$ to $60\ \Omega$
- TxFFE: 2 pre-cursor, 1 post-cursor
  - Not swept - no COM run resulted in any setting besides [0 0 1 0].

Analysis performed with COM 4.3 @ 0.67e-5 DER in host to retimer direction.

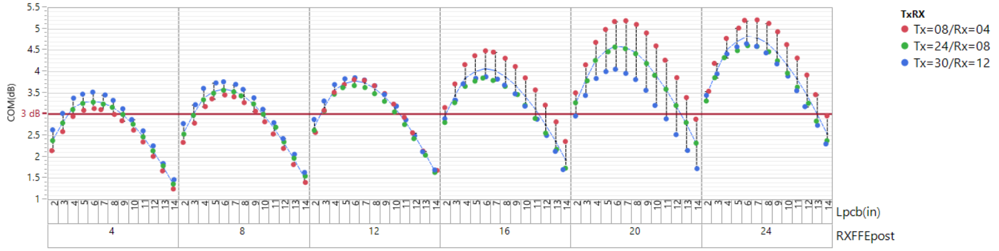
RXFFE Postcursor Tap Count Sensitivity



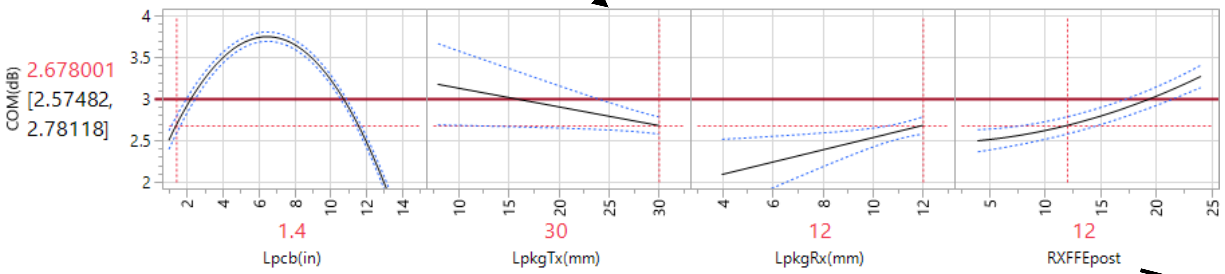


Parameter	Value
TxFFE	2 pre/1 post
η_0	1.25×10^{-8} V^2/GHz
Pkg class	A
DER	0.67×10^{-5}
R_d	50 Ω

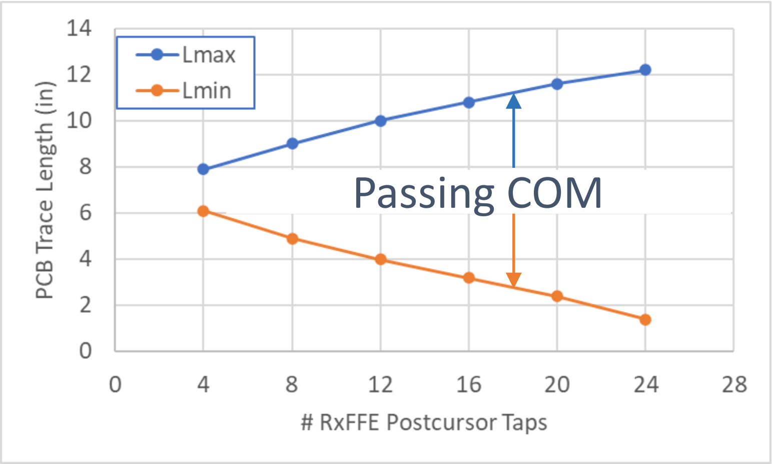
RXFFE Postcursor Tap Count Sensitivity



Fit Model

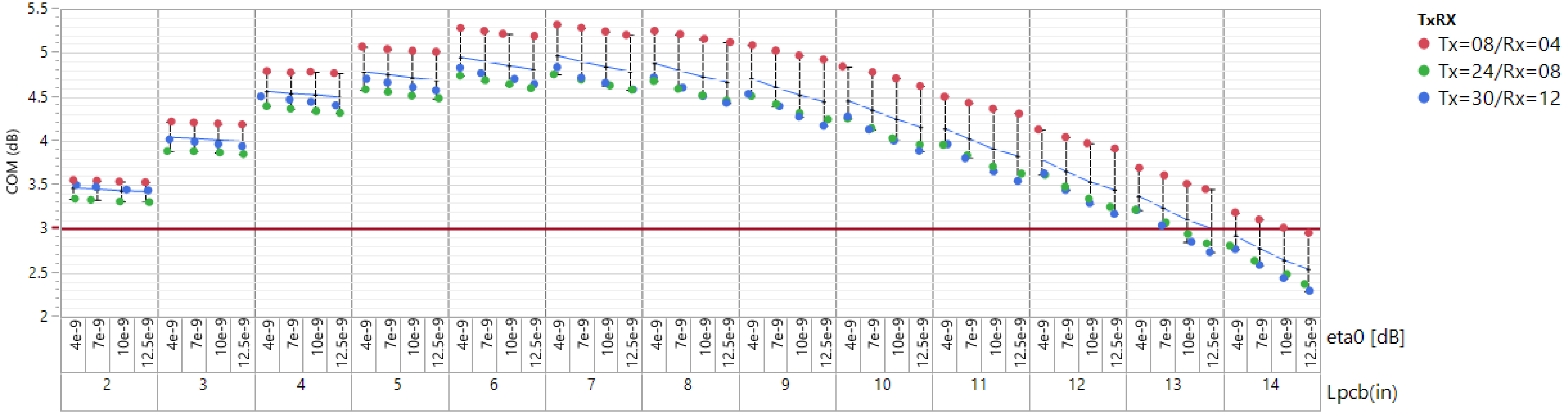


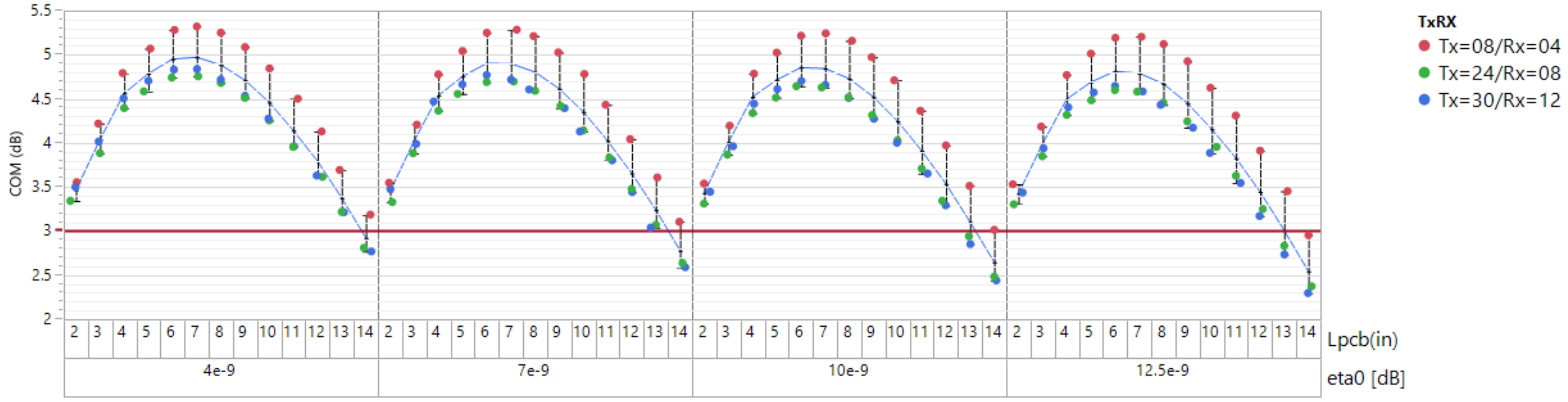
Find min/max PCB length
& WC pkg length corners



Sixteen postcursor FFE taps support 10-inch PCB route.

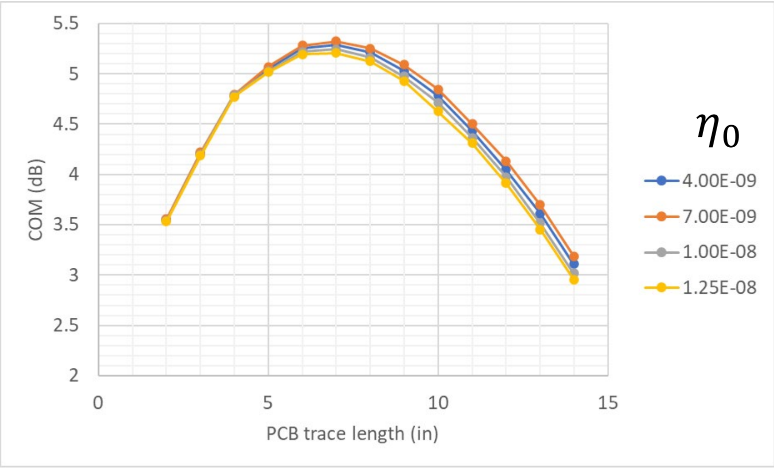
Sweep Results: η_0



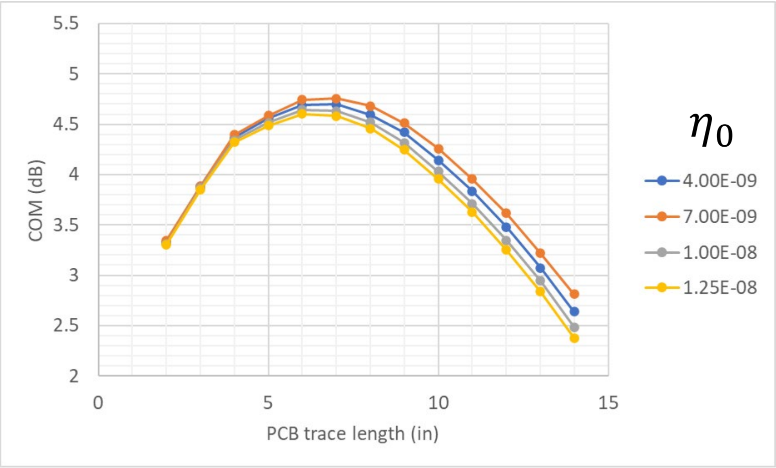


Parameter	Value
# TxFFE	3 pre/1 post
# RXFFe Post taps	24
Pkg class	A
DER	0.67e-5
R_d	50 Ω

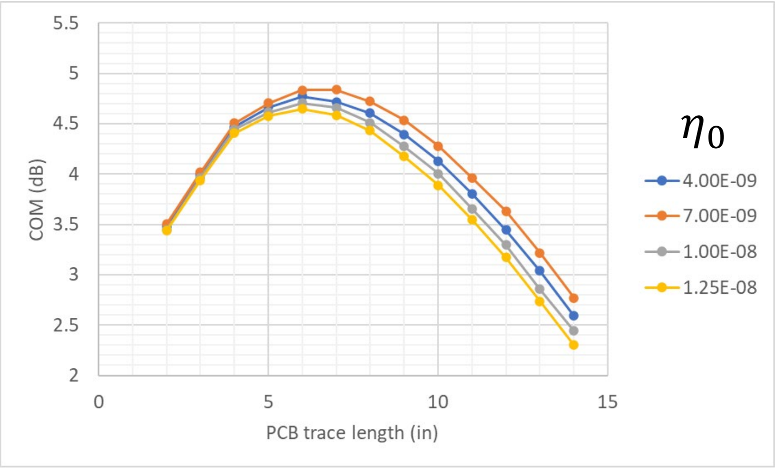
η_0 Impact on Reach



L_{Txpkg}=8mm/L_{Rxpkg}=4mm

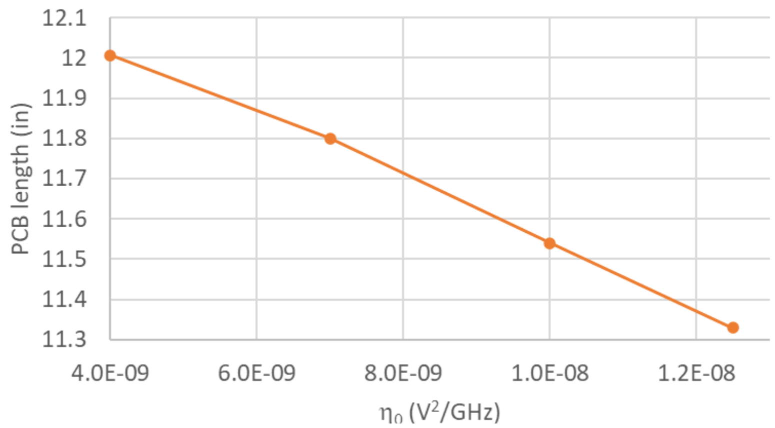


L_{Txpkg}=24mm/L_{Rxpkg}=8mm

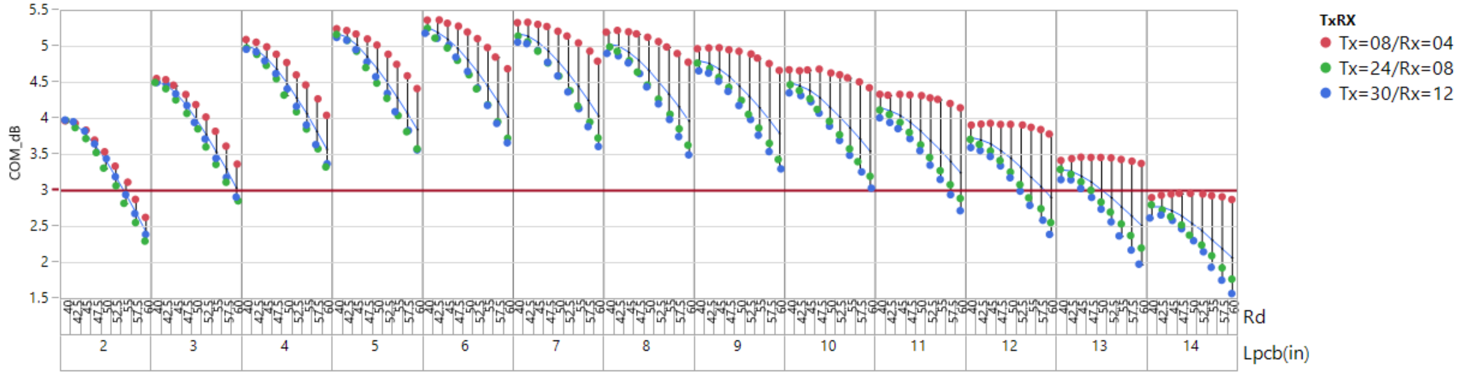


L_{Txpkg}=30mm/L_{Rxpkg}=12mm

- Reducing η_0 from $1.25 \times 10^{-8}\,V^2/GHz$ to $4 \times 10^{-9}\,V^2/GHz$ improves COM by ~0.3dB @ max loss corner.
- Translates to ~0.7 inch length increase.
  - For 24 postcursor FFE taps

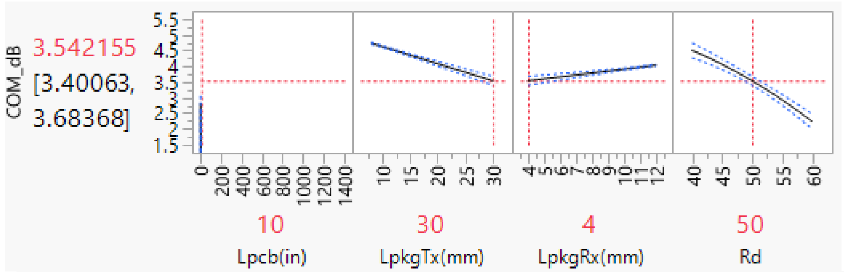


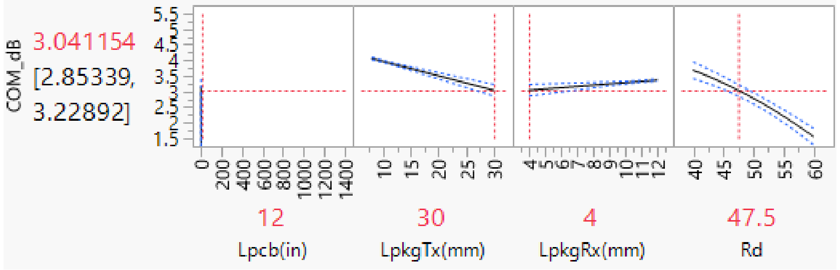
Sweep Results: R_d



Parameter	Value
# TxFFE	3 pre/1 post
# RXFFe Post taps	24
Pkg class	A
DER	0.67e-5
η_0	$1.25 \times 10^{-8}\, V^2/GHz$

- Analysis shown for 24 FFE postcursor taps.
- Trend: lower R_d gives better COM.
- Analysis to be repeated with fewer FFE taps.





Preliminary Conclusions

- RxFFE with 16 fixed postcursor taps can support 10+ inch PCB route:
  - Class A package: 30mm max host length, 12mm max retimer length
  - $\eta_0 = 1.25 \times 10^{-8}\ V^2/GHz$
  - no need for floating taps or MLSD for AUI C2C
  - for the server/NIC-based channels that we are contributing
- Reducing η_0 provides modest increase in PCB routing length.
  - ~0.7in increase w/ 24 RXFFE postcursor taps @ max loss corner for >3-fold reduction in η_0.
  - Not recommending to reduce from $1.25 \times 10^{-8}\, V^2/GHz$.
- Reducing R_d provides benefit but may not be needed.
  - Expect that to depend on the # of RXFFE taps that we choose.
- TxFFE is unused across all channels studied (post-training).
  - for any of the RxFFE and $\eta_0$cases analyzed
- Worst case Tx/Rx package condition
  - tends to favor 30 mm length @ Tx (Host) and 4 mm @ Rx (retimer)

Next Steps

Further analysis:

- Re-examine η_0 & R_d sensitivity with varying # of RXFFE postcursor taps.
  - Propose to consider 12, 16, & 20 taps.
- Vary package trace lengths independently.
  - Verify worst case & develop a more comprehensive statistical model.
- Include PCB Z_0 variation.
- Include prior channel contributions.
  - mellitz_3dj_03_elec_230504.zip
  - mellitz_3dj_04_2303.zip
  - mellitz_3df_02_2207.zip
- Cover retimer-to-host direction.

Additional Info

COM Template

Table 93A-1 parameters			
Parameter	**Setting**	**Units**	**Information**
f_b	106.25	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[0.4e-4 0.9e-4 1.1e-4 ;0.4e-4 0.9e-4 1.1e-4]	nF	[TX RX]
L_s	[0.13 0.15 0.14; 0.13 0.15 0.14]	nH	[TX RX]
C_b	[0.3e-4 0.3e-4]	nF	[TX RX]
R_0	5.00E+01	Ohm	
R_d	[50 50]	Ohm	[TX RX]
PKG_NAME	PKG_HiR_CLASSB PKG_LowR_CLASSA		TX RX
A_v	0.413	V	
A_fe	0.413	V	
A_ne	0.608	V	
z_p select	[1 2 3]		
L	4		
M	32		
filter and Eq			
f_r	0.75	*fb	
c(0)	0.54		min
c(-1)	[-0.4:0.02:0]		[min:step:max]
c(-2)	[0:.02:0.04]		[min:step:max]
c(-3)	0		[min:step:max]
c(-4)	0		[min:step:max]
c(1)	0		[min:step:max]
N_b	1	UI	
b_max(1)	0.85		As/dffe1
b_max(2..N_b)	0.15		As/dfe2..N_b
b_min(1)	0		As/dffe1
b_min(2..N_b)	-0.15	S	As/dfe2..N_b
g_DC	[-13:1:0]	dB	[min:step:max]
f_z	25.16	GHz	
f_p1	40	GHz	
f_p2	56	GHz	
g_DC_HP	[-6:1:0]		[min:step:max]
f_HP_PZ	1.328125	GHz	
Butterworth	1	logical	include in fr

.START	PKG_LowR_CLASSA	[2.44 5.7] db	
Table 93A–3 parameters			
Parameter	**Setting**	**Units**	Information
package_tl_gamma0_a1_a2	[5e-4 6.5e-4 2.93e-4]		
package_tl_tau	0.006141	ns/mm	
package_Z_c	[87.5 87.5 ; 95 95;100 100; 78 78]	Ohm	
R_d	[50 50]	Ohm	[TX RX]
z_p (TX)	[4 8 12 16;2 2 2 2 ; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
z_p (NEXT)	[4 8 12 16;2 2 2 2 ; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
z_p (FEXT)	[4 8 12 16;2 2 2 2 ; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
z_p (RX)	[4 8 12 16;2 2 2 2 ; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
C_p	[0.4e-4 0.4e-4]	nF	[TX RX]
A_v	[0.4057 0.4143 0.4143 0.4143]	V	Vf=0.400
A_fe	[0.4057 0.4143 0.4143 0.4143]	V	Vf=0.399
A_ne	[0.600 0.600 0.600 0.600]	V	Vf=0.400
.END			

.START	PKG_HiR_CLASSB	[2.8 5.6 6.7 9.4] db	
Table 93A–3 parameters			
Parameter	**Setting**	**Units**	Information
package_tl_gamma0_a1_a2	[5e-4 6.5e-4 2.93e-4]		
package_tl_tau	0.006141	ns/mm	
package_Z_c	[87.5 87.5 ; 95 95;100 100; 78 78]	Ohm	
R_d	[50 50]	Ohm	[TX RX]
z_p (TX)	[8 24 30 45;2 2 2 2 ; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
z_p (NEXT)	[8 24 30 45;2 2 2 2 ; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
z_p (FEXT)	[8 24 30 45;2 2 2 2 ; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
z_p (RX)	[8 24 30 45;2 2 2 2 ; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
C_p	[0.4e-4 0.4e-4]	nF	[TX RX]
A_v	[0.4049 0.4114 0.4132 0.4173]	V	Vf=0.400
A_fe	[0.4049 0.4114 0.4132 0.4173]	V	Vf=0.399
A_ne	[0.600 0.600 0.600 0.600]	V	Vf=0.400
.END			

I/O control		
NOSTICS	1	logical
_WINDOW	1	logical
REPORT	1	logical
LT_DIR	.\results\CRKR_{date}\	
SAVE_FIGURES	0	logical
Port Order	**[1 3 2 4]**	
RUNTAG	KR_set1_eval_	
COM_CONTRIBUTION	1	logical
TDR and ERL options		
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	ns
TR_TDR	0.01	
N	4000	logical
TDR_Butterworth	1	
beta_x	0	
rho_x	0.618	
TDR_W_TXPKG	0	UI
N_bx	20	
fixture delay time	[0 0]	
Tukey_Window	1	
Noise, jitter		UI
sigma_RJ	0.01	UI
A_DD	0.02	V^2/GHz
eta_0	1.25E-08	dB
SNR_TX	33	
R_LM	0.95	

.START	PKG_Module		
Table 93A–3 parameters			
Parameter	**Setting**	**Units**	Information
package_tl_gamma0_a1_a2	[0.0005 0.00089 0.0002]		
package_tl_tau	0.006141	ns/mm	
package_Z_c	[87.5 87.5 ; 95 95 ; 100 100; 100 100]	Ohm	
R_d	[50 50]	Ohm	[TX RX]
z_p (TX)	[8 8 8 8 ; 0 0 0 0 ;0 0 0 0 ;0 0 0 0]	mm	[test cases]
z_p (NEXT)	[8 8 8 8 ; 0 0 0 0 ;0 0 0 0 ;0 0 0 0]	mm	[test cases]
z_p (FEXT)	[8 8 8 8 ; 0 0 0 0 ;0 0 0 0 ;0 0 0 0]	mm	[test cases]
z_p (RX)	[8 8 8 8 ; 0 0 0 0 ;0 0 0 0 ;0 0 0 0]	mm	[test cases]
C_p	[0.4e-4 0.4e-4]	nF	[TX RX]
A_v	[0.4057 0.4057 0.4057 0.4057]	V	Vf=0.400
A_fe	[0.4057 0.4057 0.4057 0.4057]	V	Vf=0.399
A_ne	[0.600 0.600 0.600 0.600]	V	Vf=0.400
.END			

.START	PKG_Null		
Table 93A–3 parameters			
Parameter	**Setting**	**Units**	Information
package_tl_gamma0_a1_a2	[5e-4 0.001 0.03]		
package_tl_tau	0.006141	ns/mm	
package_Z_c	[92 92 ; 70 70; 80 80; 100 100]	Ohm	
R_d	[50 50]	Ohm	[TX RX]
z_p (TX)	[0 0 0 0 ;0 0 0 0; 0 0 0 0 ;0 0 0 0]	mm	[test cases]
z_p (NEXT)	[0 0 0 0 ;0 0 0 0; 0 0 0 0 ;0 0 0 0]	mm	[test cases]
z_p (FEXT)	[0 0 0 0 ;0 0 0 0; 0 0 0 0 ;0 0 0 0]	mm	[test cases]
z_p (RX)	[0 0 0 0 ;0 0 0 0; 0 0 0 0 ;0 0 0 0]	mm	[test cases]
C_p	[0 0]	nF	[TX RX]
A_v	0.5	V	Vf=0.400
A_fe	0.5	V	Vf=0.400
A_ne	0.61	V	
.END			

Table 93A–3 parameters			
Parameter	**Setting**	**Units**	Information
package_tl_gamma0_a1_a2	[5e-4 0.00065 0.0003]		
package_tl_tau	0.006141	ns/mm	
package_Z_c	92 ; 70 70; 80 80; 100 1	Ohm	
z_p (TX)	1 1 1 1; 1 1 1 1 ; 0.5	mm	[test cases to run]
z_p (NEXT)	1 1 1 1; 1 1 1 1 ; 0.5	mm	[test cases]
z_p (FEXT)	1 1 1 1; 1 1 1 1 ; 0.5	mm	[test cases]
z_p (RX)	1 1 1 1; 1 1 1 1 ; 0.5	mm	[test cases]
C_p	[0.4e-4 0.4e-4]	nF	[test cases]
Operational			
ERL Pass threshold	10	dB	
COM Pass threshold	3	db	
DER_0	6.70E-06		
T_r	0.00400	ns	
FORCE_TR	1	logical	
PMD_type	C2C		
EW	1		
MLSE	0	logical	
ts_anchor	1		
sample_adjustment	[-8 8]		
Local Search	2		
Filter: Rx FFE			
ffe_pre_tap_len	6	UI	
ffe_post_tap_len	24	UI	
ffe_pre_tap1_max	1		
ffe_post_tap1_max	1		
ffe_tapn_max	1		
FFE_OPT_METHOD	MMSE		FV-LMS or MMSE
num_ui_RXFF_noise	1024		
Floating Tap Control			
N_bg	0	0 1 2 or 3 groups	
N_bf	4	taps per group	
N_f	80	UI span for floating taps	
bmaxg	0.2	max DFE value for floating taps	
B_float_RSS_MAX	1	rss tail tap limit	
N_tail_start	25	(UI) start of tail taps limit	

Channel Naming Convention

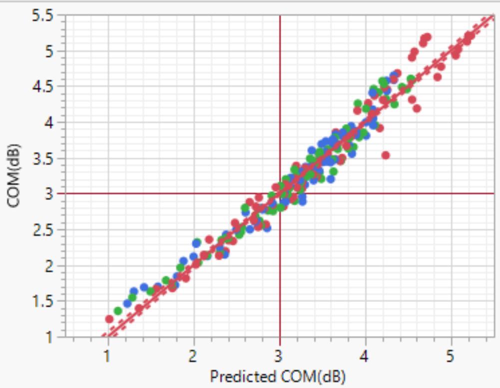
Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7	Channel 8
Tx_2in_Rx_thru1.s4p	Tx_3in_Rx_thru1.s4p	Tx_4in_Rx_thru1.s4p	Tx_5in_Rx_thru1.s4p	Tx_6in_Rx_thru1.s4p	Tx_7in_Rx_thru1.s4p	Tx_8in_Rx_thru1.s4p	Tx_9in_Rx_thru1.s4p
Tx_2in_Rx_xtalk1_Fext.s4p	Tx_3in_Rx_xtalk1_Fext.s4p	Tx_4in_Rx_xtalk1_Fext.s4p	Tx_5in_Rx_xtalk1_Fext.s4p	Tx_6in_Rx_xtalk1_Fext.s4p	Tx_7in_Rx_xtalk1_Fext.s4p	Tx_8in_Rx_xtalk1_Fext.s4p	Tx_9in_Rx_xtalk1_Fext.s4p
Tx_2in_Rx_xtalk2_Fext.s4p	Tx_3in_Rx_xtalk2_Fext.s4p	Tx_4in_Rx_xtalk2_Fext.s4p	Tx_5in_Rx_xtalk2_Fext.s4p	Tx_6in_Rx_xtalk2_Fext.s4p	Tx_7in_Rx_xtalk2_Fext.s4p	Tx_8in_Rx_xtalk2_Fext.s4p	Tx_9in_Rx_xtalk2_Fext.s4p
Tx_2in_Rx_xtalk3_Fext.s4p	Tx_3in_Rx_xtalk3_Fext.s4p	Tx_4in_Rx_xtalk3_Fext.s4p	Tx_5in_Rx_xtalk3_Fext.s4p	Tx_6in_Rx_xtalk3_Fext.s4p	Tx_7in_Rx_xtalk3_Fext.s4p	Tx_8in_Rx_xtalk3_Fext.s4p	Tx_9in_Rx_xtalk3_Fext.s4p
Tx_2in_Rx_xtalk4_Next.s4p	Tx_3in_Rx_xtalk4_Next.s4p	Tx_4in_Rx_xtalk4_Next.s4p	Tx_5in_Rx_xtalk4_Next.s4p	Tx_6in_Rx_xtalk4_Next.s4p	Tx_7in_Rx_xtalk4_Next.s4p	Tx_8in_Rx_xtalk4_Next.s4p	Tx_9in_Rx_xtalk4_Next.s4p
Tx_2in_Rx_xtalk5_Next.s4p	Tx_3in_Rx_xtalk5_Next.s4p	Tx_4in_Rx_xtalk5_Next.s4p	Tx_5in_Rx_xtalk5_Next.s4p	Tx_6in_Rx_xtalk5_Next.s4p	Tx_7in_Rx_xtalk5_Next.s4p	Tx_8in_Rx_xtalk5_Next.s4p	Tx_9in_Rx_xtalk5_Next.s4p
Tx_2in_Rx_xtalk6_Next.s4p	Tx_3in_Rx_xtalk6_Next.s4p	Tx_4in_Rx_xtalk6_Next.s4p	Tx_5in_Rx_xtalk6_Next.s4p	Tx_6in_Rx_xtalk6_Next.s4p	Tx_7in_Rx_xtalk6_Next.s4p	Tx_8in_Rx_xtalk6_Next.s4p	Tx_9in_Rx_xtalk6_Next.s4p
Tx_2in_Rx_xtalk7_Next.s4p	Tx_3in_Rx_xtalk7_Next.s4p	Tx_4in_Rx_xtalk7_Next.s4p	Tx_5in_Rx_xtalk7_Next.s4p	Tx_6in_Rx_xtalk7_Next.s4p	Tx_7in_Rx_xtalk7_Next.s4p	Tx_8in_Rx_xtalk7_Next.s4p	Tx_9in_Rx_xtalk7_Next.s4p

Channel Naming Convention

Channel 9	Channel 10	Channel 11	Channel 12	Channel 13
Tx_10in_Rx_thru1.s4p	Tx_11in_Rx_thru1.s4p	Tx_12in_Rx_thru1.s4p	Tx_13in_Rx_thru1.s4p	Tx_14in_Rx_thru1.s4p
Tx_10in_Rx_xtalk1_Fext.s4p	Tx_11in_Rx_xtalk1_Fext.s4p	Tx_12in_Rx_xtalk1_Fext.s4p	Tx_13in_Rx_xtalk1_Fext.s4p	Tx_14in_Rx_xtalk1_Fext.s4p
Tx_10in_Rx_xtalk2_Fext.s4p	Tx_11in_Rx_xtalk2_Fext.s4p	Tx_12in_Rx_xtalk2_Fext.s4p	Tx_13in_Rx_xtalk2_Fext.s4p	Tx_14in_Rx_xtalk2_Fext.s4p
Tx_10in_Rx_xtalk3_Fext.s4p	Tx_11in_Rx_xtalk3_Fext.s4p	Tx_12in_Rx_xtalk3_Fext.s4p	Tx_13in_Rx_xtalk3_Fext.s4p	Tx_14in_Rx_xtalk3_Fext.s4p
Tx_10in_Rx_xtalk4_Next.s4p	Tx_11in_Rx_xtalk4_Next.s4p	Tx_12in_Rx_xtalk4_Next.s4p	Tx_13in_Rx_xtalk4_Next.s4p	Tx_14in_Rx_xtalk4_Next.s4p
Tx_10in_Rx_xtalk5_Next.s4p	Tx_11in_Rx_xtalk5_Next.s4p	Tx_12in_Rx_xtalk5_Next.s4p	Tx_13in_Rx_xtalk5_Next.s4p	Tx_14in_Rx_xtalk5_Next.s4p
Tx_10in_Rx_xtalk6_Next.s4p	Tx_11in_Rx_xtalk6_Next.s4p	Tx_12in_Rx_xtalk6_Next.s4p	Tx_13in_Rx_xtalk6_Next.s4p	Tx_14in_Rx_xtalk6_Next.s4p
Tx_10in_Rx_xtalk7_Next.s4p	Tx_11in_Rx_xtalk7_Next.s4p	Tx_12in_Rx_xtalk7_Next.s4p	Tx_13in_Rx_xtalk7_Next.s4p	Tx_14in_Rx_xtalk7_Next.s4p

Response Surface Model Fit for RXFFE Postcursor Tap Sweep

Bivariate Fit of COM(dB) By Predicted COM(dB)



Summary of Fit

RSquare	0.957832
RSquare Adj	0.955742
Root Mean Square Error	0.180562
Mean of Response	3.299674
Observations (or Sum Wgts)	234

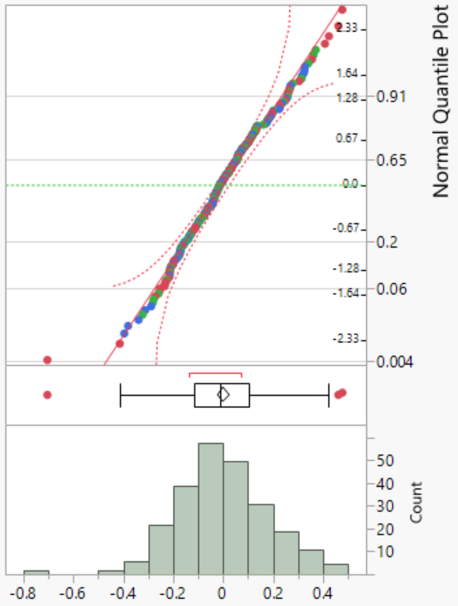
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	11	164.40368	14.9458	458.4216
Error	222	7.23780	0.0326	Prob > F
C. Total	233	171.64148		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.9279086	0.051086	76.89	<.0001*
Lpcb(in)	-0.106818	0.003155	-33.86	<.0001*
LpkgTx(mm)	-0.024664	0.005008	-4.92	<.0001*
LpkgRx(mm)	0.0350701	0.014238	2.46	0.0145*
RXFFEpost	0.0693852	0.001728	40.16	<.0001*
(Lpcb(in)-8)*(Lpcb(in)-8)	-0.041213	0.000951	-43.33	<.0001*
(Lpcb(in)-8)*(LpkgTx(mm)-20.6667)	0.0003282	0.001338	0.25	0.8065
(Lpcb(in)-8)*(LpkgRx(mm)-8)	-0.005105	0.003805	-1.34	0.1811
(Lpcb(in)-8)*(RXFFEpost-14)	0.0001182	0.000462	0.26	0.7983
(LpkgTx(mm)-20.6667)*(RXFFEpost-14)	-0.002179	0.000733	-2.97	0.0033*
(LpkgRx(mm)-8)*(RXFFEpost-14)	-0.002413	0.002084	-1.16	0.2481
(RXFFEpost-14)*(RXFFEpost-14)	0.0013083	0.000296	4.42	<.0001*

Residual COM(dB)



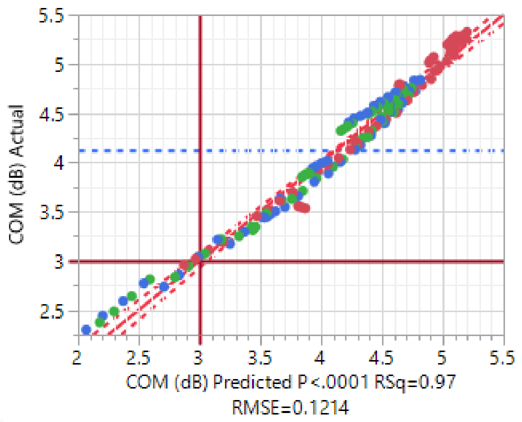
Quantiles

100.0%	maximum	0.4779191999
99.5%		0.4751377473
97.5%		0.3631279867
90.0%		0.2513171224
75.0%	quartile	0.105370962
50.0%	median	-0.013601177
25.0%	quartile	-0.116697986
10.0%		-0.213244671
2.5%		-0.325010387
0.5%		-0.653688174
0.0%	minimum	-0.704478087

Summary Statistics

Mean	-4.59e-16
Std Dev	0.1762485
Std Err Mean	0.0115217
Upper 95% Mean	0.0227001
Lower 95% Mean	-0.0227
N	234

Response Surface Model Fit for Eta0 Sweep



Summary of Fit

RSquare	0.97436
RSquare Adj	0.972401
Root Mean Square Error	0.121402
Mean of Response	4.125739
Observations (or Sum Wgts)	156

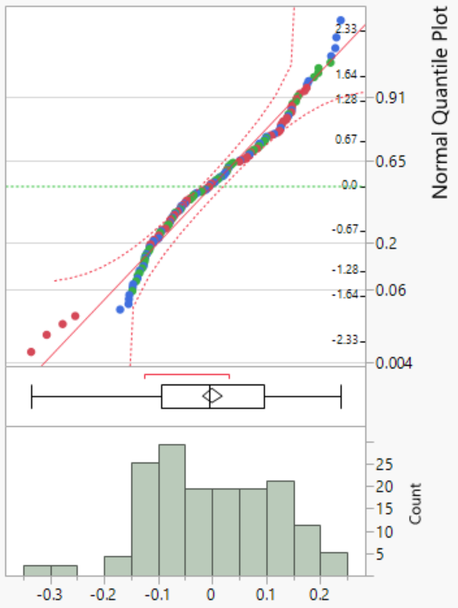
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	11	80.651107	7.33192	497.4721
Error	144	2.122323	0.01474	Prob > F
C. Total	155	82.773430		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	6.1146877	0.046222	132.29	<.0001*
Lpcb(in)	-0.087593	0.002598	-33.72	<.0001*
LpkgTx(mm)	-0.054769	0.004124	-13.28	<.0001*
LpkgRx(mm)	0.0883553	0.011724	7.54	<.0001*
eta0 [dB]	-24912745	3068697	-8.12	<.0001*
(Lpcb(in)-8)*(Lpcb(in)-8)	-0.046925	0.000783	-59.91	<.0001*
(Lpcb(in)-8)*(LpkgTx(mm)-20.6667)	-0.000389	0.001102	-0.35	0.7244
(Lpcb(in)-8)*(LpkgRx(mm)-8)	-0.003815	0.003133	-1.22	0.2254
(Lpcb(in)-8)*(eta0 [dB]-8.38e-9)	-3760500	814512.3	-4.62	<.0001*
(LpkgTx(mm)-20.6667)*(eta0 [dB]-8.38e-9)	-332468.4	1292998	-0.26	0.7974
(LpkgRx(mm)-8)*(eta0 [dB]-8.38e-9)	-1268454	3676149	-0.35	0.7306
(eta0 [dB]-8.38e-9)*(eta0 [dB]-8.38e-9)	2.406e+14	1.23e+15	0.20	0.8454

Residual COM (dB)



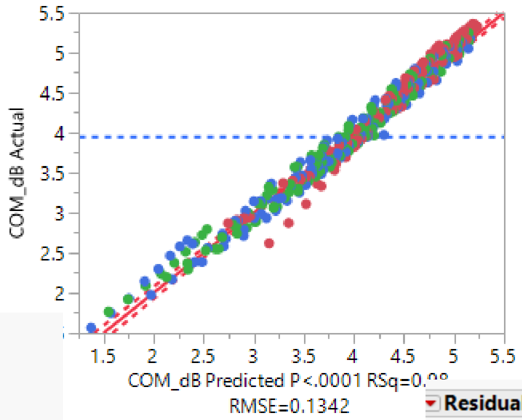
Quantiles

100.0%	maximum	0.2383370841
99.5%		0.2383370841
97.5%		0.2211366121
90.0%		0.1552369043
75.0%	quartile	0.096555244
50.0%	median	-0.004638058
25.0%	quartile	-0.094096009
10.0%		-0.134427372
2.5%		-0.255392739
0.5%		-0.335380187
0.0%	minimum	-0.335380187

Summary Statistics

Mean	6.661e-16
Std Dev	0.1170145
Std Err Mean	0.0093687
Upper 95% Mean	0.0185067
Lower 95% Mean	-0.018507
N	156

Response Surface Model Fit for Rd Sweep



Summary of Fit

RSquare	0.976391
RSquare Adj	0.975625
Root Mean Square Error	0.134233
Mean of Response	3.958853
Observations (or Sum Wgts)	351

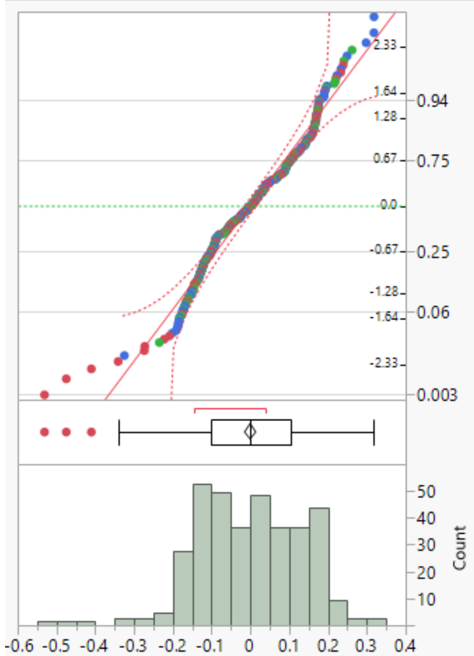
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	11	252.61733	22.9652	1274.532
Error	339	6.10829	0.0180	Prob > F
C. Total	350	258.72561		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	8.8433721	0.061827	143.03	<.0001*
Lpcb(in)	-0.09858	0.001915	-51.48	<.0001*
LpkgTx(mm)	-0.052108	0.00304	-17.14	<.0001*
LpkgRx(mm)	0.0685401	0.008642	7.93	<.0001*
Rd	-0.056846	0.00111	-51.21	<.0001*
(Lpcb(in)-8)*(Lpcb(in)-8)	-0.046834	0.000577	-81.12	<.0001*
(Lpcb(in)-8)*(LpkgTx(mm)-20.6667)	-0.001201	0.000812	-1.48	0.1404
(Lpcb(in)-8)*(LpkgRx(mm)-8)	-0.003218	0.00231	-1.39	0.1645
(Lpcb(in)-8)*(Rd-50)	0.0036302	0.000297	12.24	<.0001*
(LpkgTx(mm)-20.6667)*(Rd-50)	-0.004259	0.000471	-9.04	<.0001*
(LpkgRx(mm)-8)*(Rd-50)	0.0060034	0.001339	4.48	<.0001*
(Rd-50)*(Rd-50)	-0.001663	0.000196	-8.49	<.0001*

Residual COM_dB



Quantiles

100.0%	maximum	0.3188806009
99.5%		0.3187049864
97.5%		0.2328738688
90.0%		0.169084927
75.0%	quartile	0.1047031833
50.0%	median	0.0001083068
25.0%	quartile	-0.100500443
10.0%		-0.151581837
2.5%		-0.224838877
0.5%		-0.488685507
0.0%	minimum	-0.53124601

Summary Statistics

Mean	-6.88e-16
Std Dev	0.1321069
Std Err Mean	0.0070513
Upper 95% Mean	0.0138683
Lower 95% Mean	-0.013868
N	351