AUI Chip-to-Chip Reference Receiver Parameter Analysis

(Comment #504 against D1.0)

Howard Heck, Intel
Femi Akinwale, Intel

Supporters

- Rich Mellitz, Samtec

Contents

- Objective
- Channels
- Analysis
  - Experiment
  - Raw Data & Statistical Model
  - FFE Tap Count
  - DFE Limits
  - FFE Limits
- Summary

Objective

Provide recommended values & supporting analysis for the TBDs in Table 176D-6 and Table 176D-7.

from Table 176D-6

Parameter	Symbol	Value	Units
…	...	...	...
Single-ended reference resistance	R_0	TBD	Ω
Single-ended transmitter termination resistance	$R_d^{(t)}$	TBD	Ω
Single-ended receiver termination resistance	$R_d^{(r)}$	TBD	Ω

from Table 176D-6

Parameter	Symbol	Value	Units
…	...	...	…
Receiver 3 dB bandwidth	f_r	TBD × f_b	GHz
…	...	…	…
Continuous time filter zero frequency 2	f_{z2}	TBD	GHz
…	...	…	…
Differential peak output voltage, victim transmitter	A_v	TBD	V
Differential peak output voltage, far-end aggressor	A_fe	TBD	V
Differential peak output voltage, near-end aggressor	A_ne	TBD	V
Transmitter transition time	T_r	TBD	ns

Objective (2)

from Table 176D-7

Parameter	**Symbol**	**Value**	**Units**
…	...	...	...
Transmitter signal-to-noise ratio	SNR_{TX}	TBD	dB
Dual-Dirac jitter, peak	A_{DD}	TBD	UI
Level separation mismatch ratio	R_{LM}	TBD	
One-sided noise spectral density	η_0	TBD	V^2/GHz
Number of samples per unit interval	M	TBD	
Receiver discrete-time equalizer parameters			
Number of pre-cursor taps	d_w	TBD	—
Number of fixed-position taps	N_{fix}	TBD	—
Number of floating tap groups	N_g	TBD	—
Number of taps per floating tap group	N_f	TBD	—
Highest allowed tap index	N_{max}	TBD	—
Normalized upper limit on feed-forward coefficient $w(j)$	$w_{max}(j)$	TBD	—
Normalized lower limit on feed-forward coefficient $w(j)$	$w_{min}(j)$	TBD	—
Number of feedback taps	N_b	1	—
Normalized upper limit on feedback coefficient $b(j)$	$b_{max}(j)$	TBD	—
Normalized lower limit on feed-forward coefficient $b(j)$	$b_{min}(j)$	TBD	—
Random jitter, RMS	σ_{RJ}	TBD	UI

Channels

Physical Channel Description (Simulated)

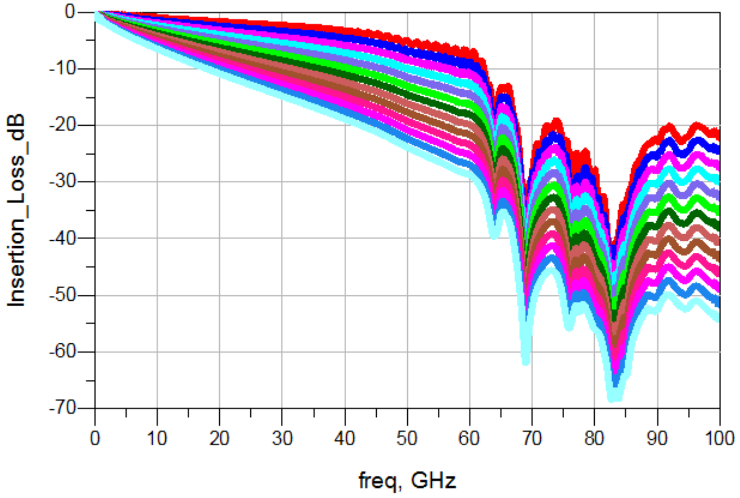
- Number of Aggressors: 3 FEXT and 4 NEXT
- BGA escape model
  - BGA ball not included, 5 mil stub
  - Tx/RX via drill depths: 10/20, 35/45, 60/70
- Host PCB
  - Impedance: 85, 93, 100 Ω
  - Insertion loss: 1.5dB/in @53.125GHz
- Does not include package or silicon structures

Channels based on heck_3dj_01b_2403 w/ the addition of longer via lengths & PCB impedance corners.

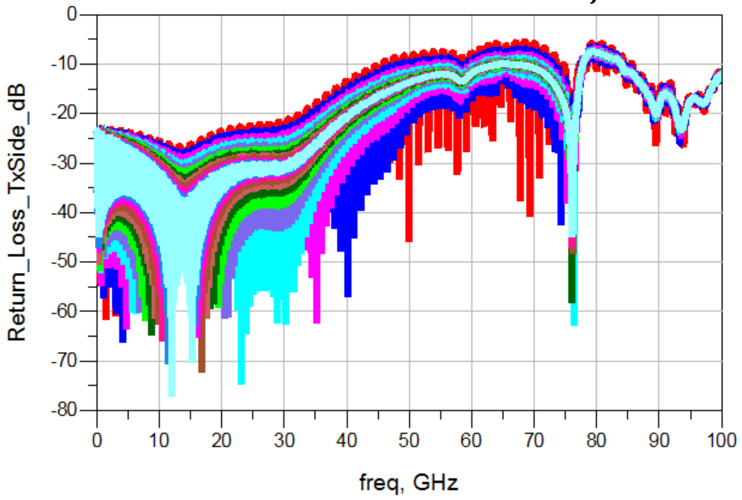
We also analyze contributed channels in mellitz_3dj_elec_01_230504.

Channel Response

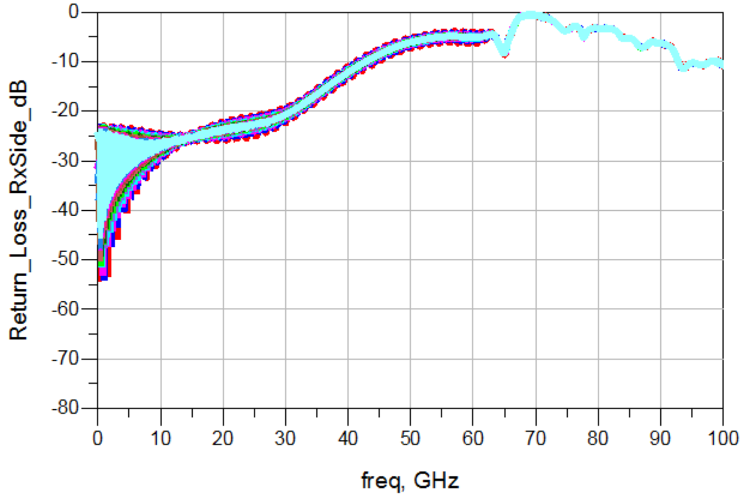
Insertion Loss, Differential, Z_{ref} =100 Ω



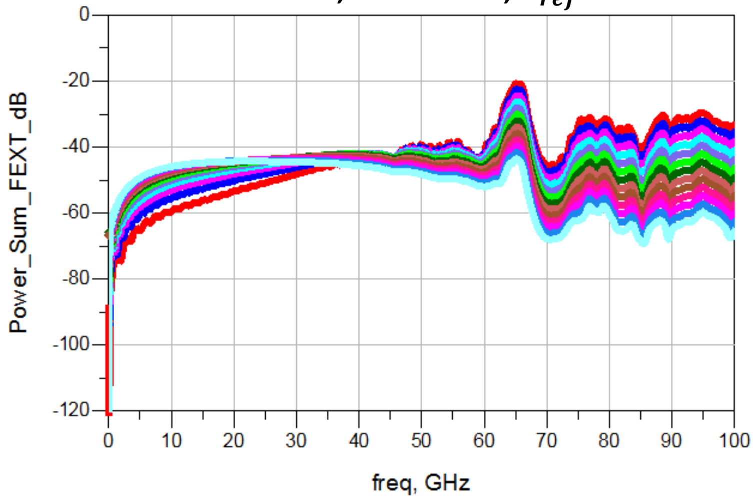
Return Loss (Tx Side), Differential, Z_{ref} =100 Ω



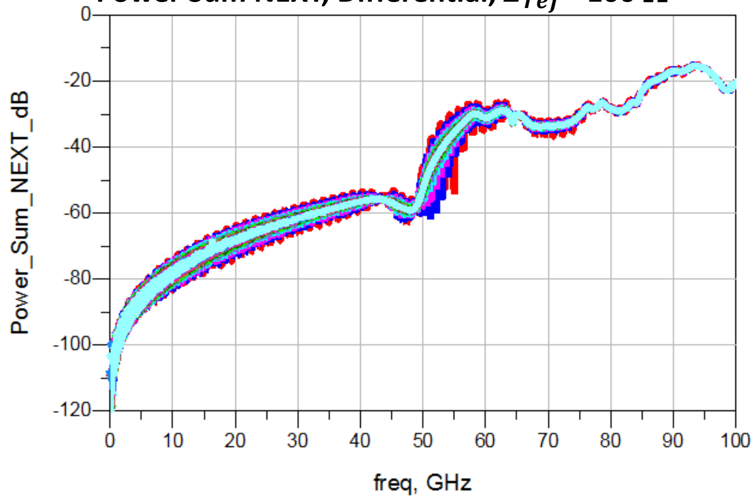
Return Loss (Rx Side), Differential, Z_{ref} =100 Ω



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

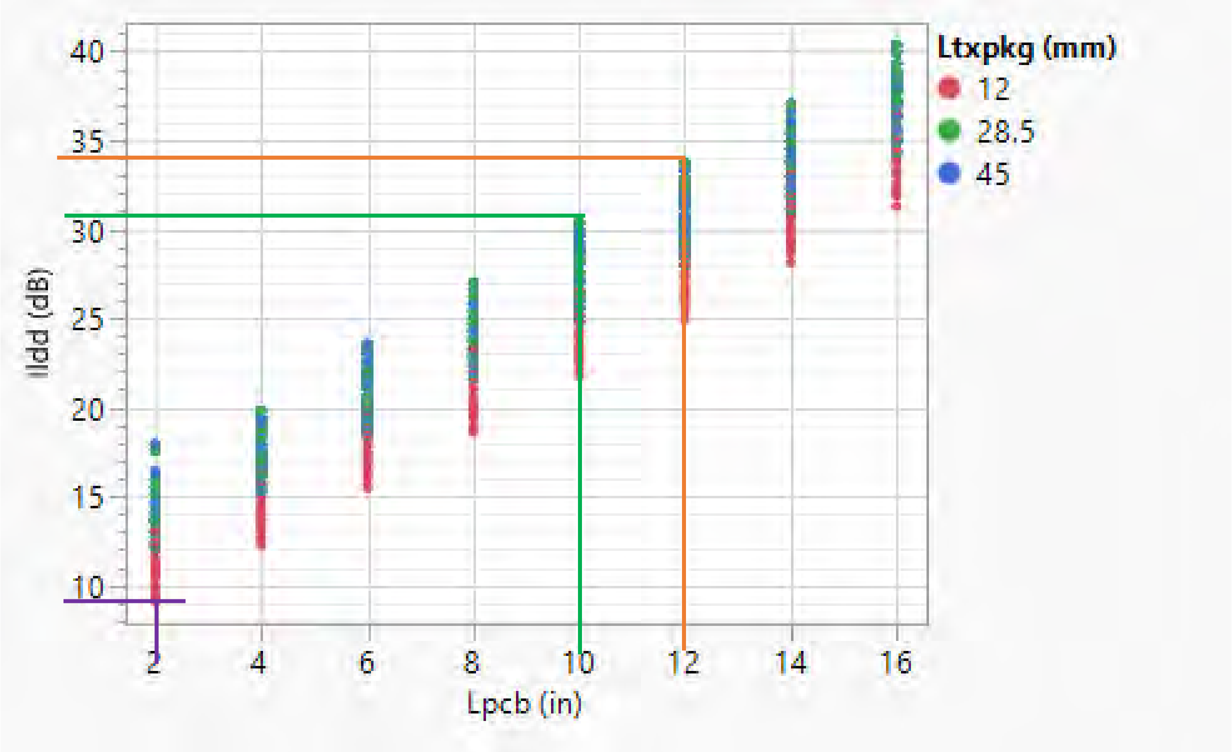


Power Sum NEXT, Differential, Z_{ref} =100 Ω



Channel Insertion Loss & PCB Trace Lengths

Die-Die Insertion Loss vs PCB Length



Loss/Length Goals

Case	L_{pcb} (in)	IL_{dd} (dB)	
Max	10	31	
	12	34	(desired)
Min	2	9	

Analysis

COM Setup

- COM 4.5b3
- Die model per lim_3dj_01_2401, slide 8.
- Static values:

Parameter	Value
DER	0.67×10^{-5}
R_d	50 Ω
f_r	$0.75\times f_b$
A_v	0.413 V
A_{fe}	0.413 V
A_{ne}	0.608 V
T_r	0.04 ns

Parameter	Value
η_0	1.25×10^{-8} V^2/GHz
SNR_{TX}	33 dB
A_{DD}	0.02 UI
R_{LM}	0.95
M	32
σ_{RJ}	0.01 UI

Propose to replace TBDs with these values in Tables 176D-6 & 176D-7.

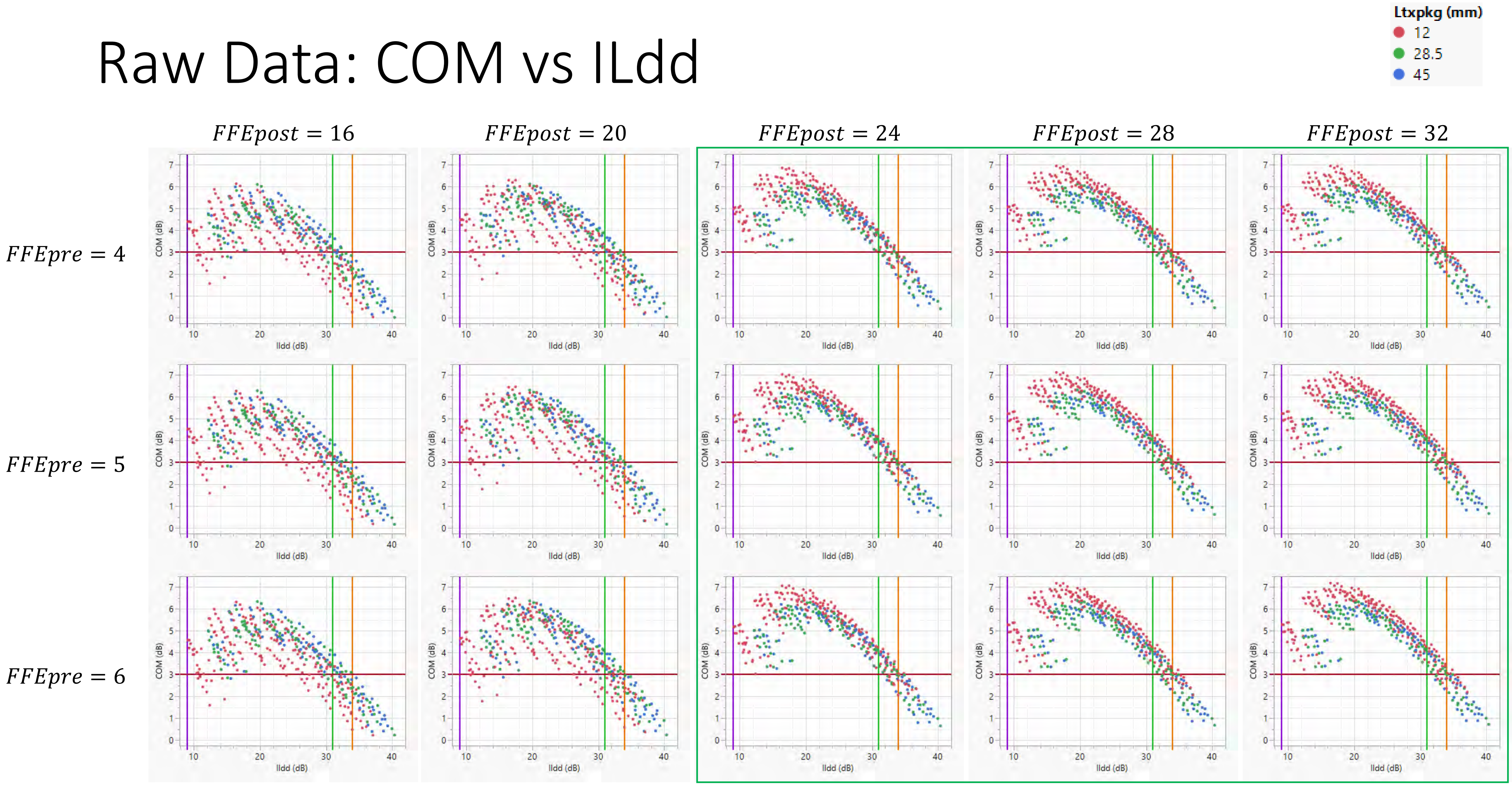
- Experiment design on next slide.

Experiment Definition

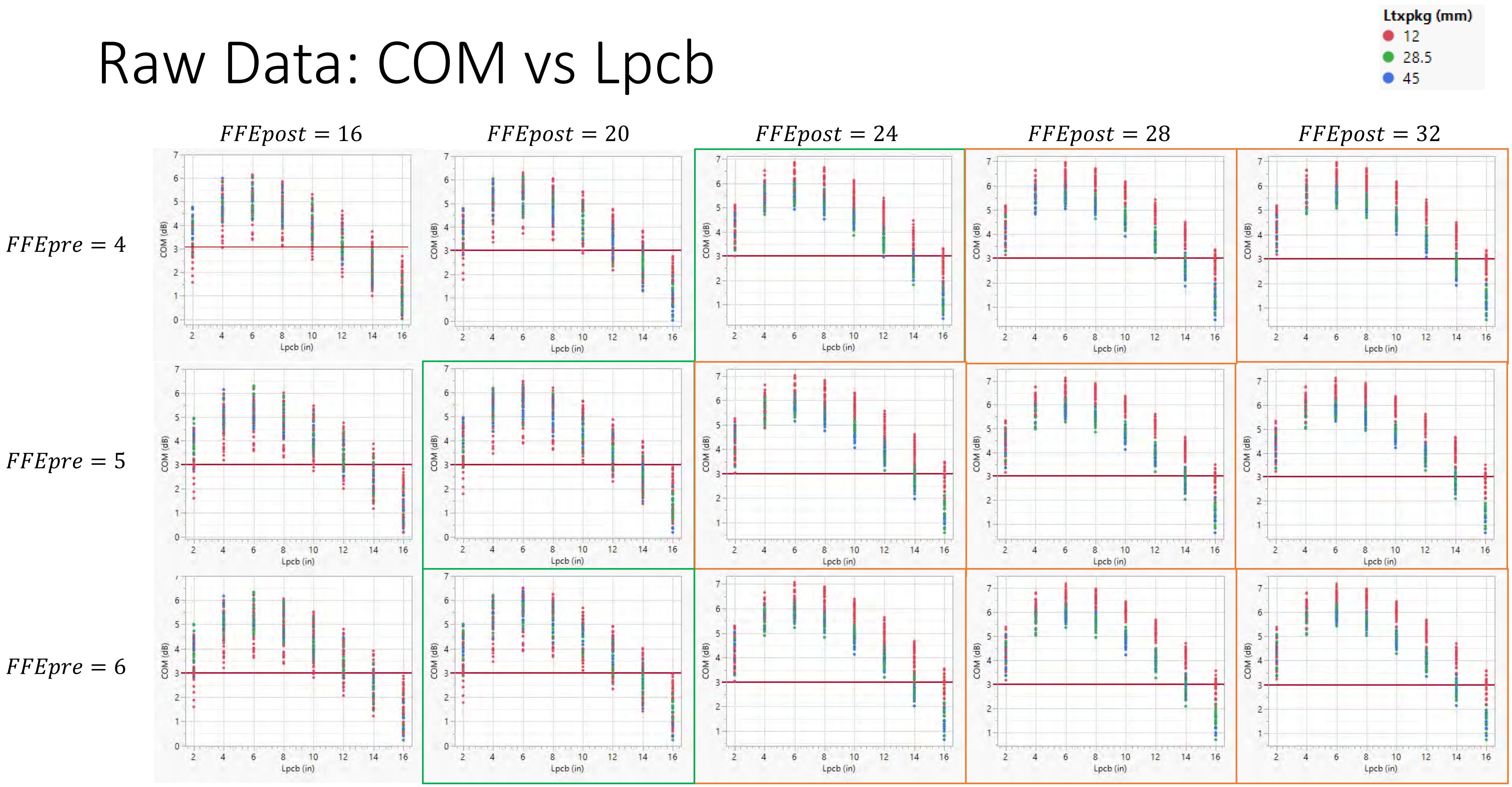
Component	Variable	Values	units	# points
TX pkg trace length	*Ltxpkg*	12, 28.5, 45	mm	3
RX pkg trace length	*Lrxpkg*	4, 8, 12	mm	3
# FFE precursor taps	*FFEpre*	4, 5, 6		3
# FFE postcursor taps	*FFEpost*	12, 16, 20, 24, 28, 32		6
PCB trace length	*Lpcb*	2, 4, 6, 8, 10, 12, 14, 16	in	8
PCB Impedance	*Zpcb*	85, 92.5, 100	Ω	3
TX/RX via length	*Ltxvia/Lrxvia*	10/20, 35/45, 60/70	mil	3

- Full factorial design: 11,664 cases
- Analysis performed with COM 4.5b3 @ 0.67e-5 DER in host to retimer direction.
  - Spot check on retimer to host direction
- Use the results to fit a 2^{nd} order response surface model for COM as a function of the variables in the table.

Raw Data: COM vs ILdd



Raw Data: COM vs Lpcb



Statistical Model

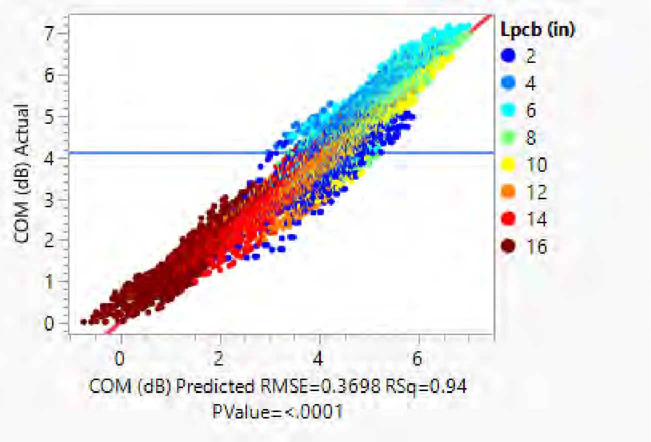
Fit metrics

Summary of Fit

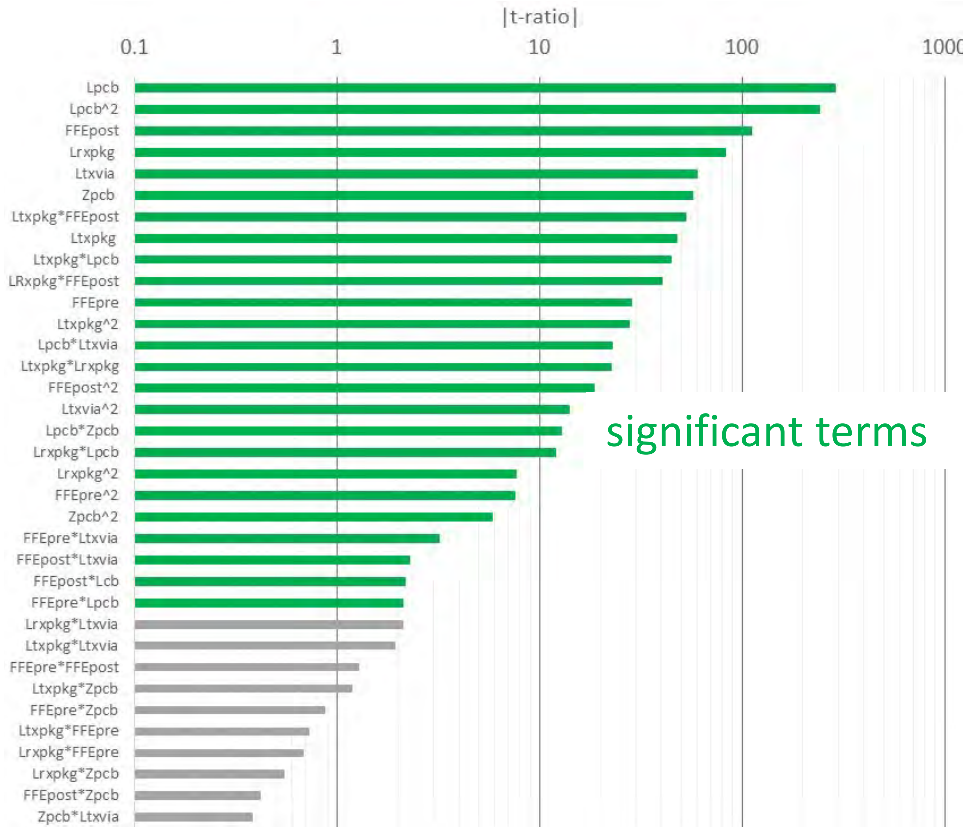
RSquare	0.939396
RSquare Adj	0.939214
Root Mean Square Error	0.369796
Mean of Response	4.133654
Observations (or Sum Wgts)	11664

Analysis of Variance

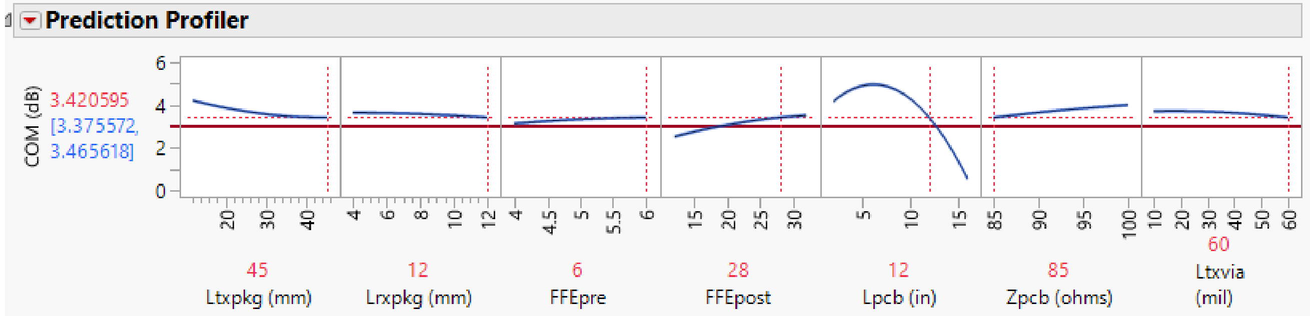
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	35	24647.830	704.224	5149.751
Error	11628	1590.118	0.137	Prob > F
C. Total	11663	26237.948		<.0001*



Model terms

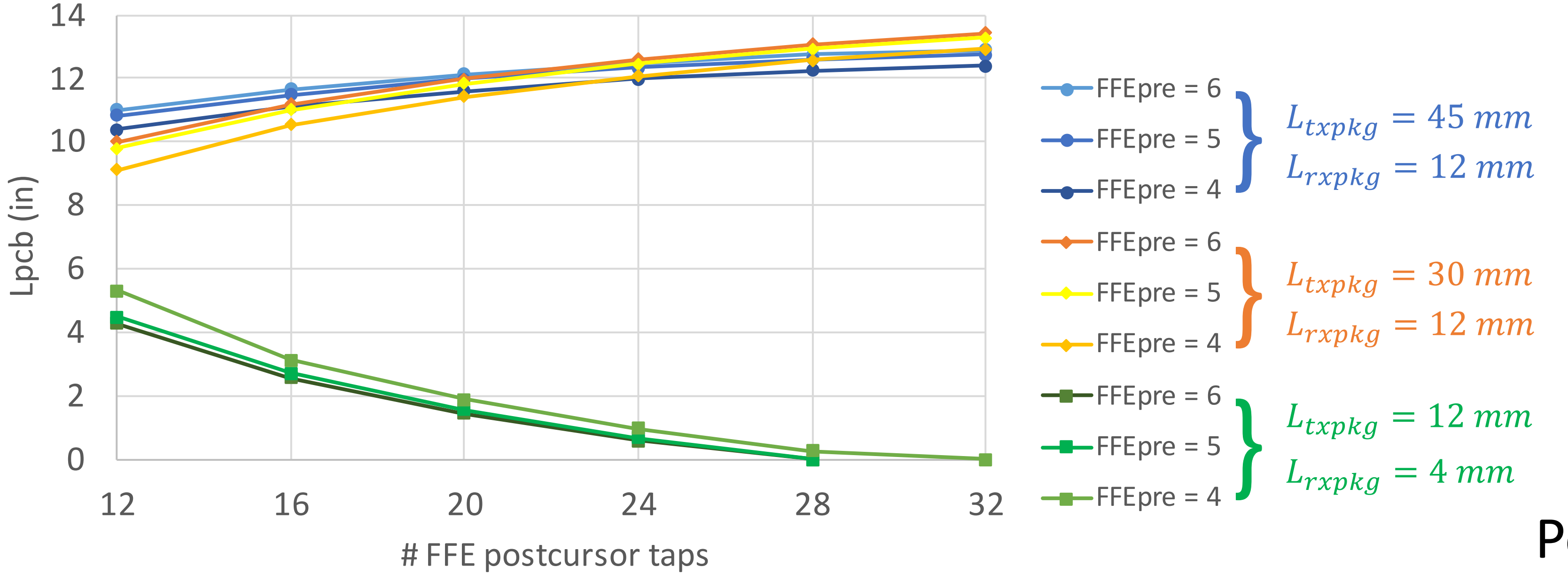


Predictions



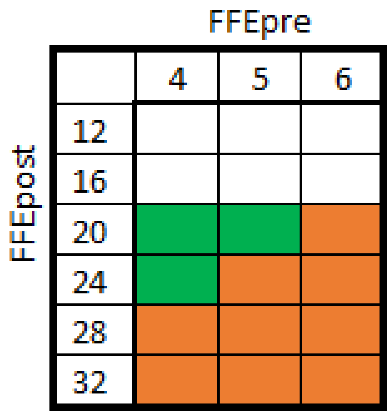
~±0.05 dB confidence interval on predictions

FFE Precursor/Post-cursor Taps



Z_{pcb}	85 Ω
L_{txvia}/L_{rxvia}	60/70 mil

Potential Solutions



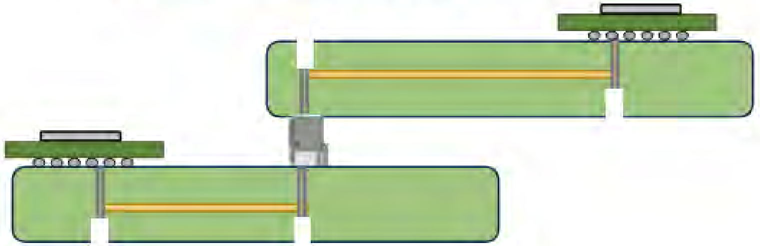
Method:

1. Set all variables except L_{pcb} to give worst case COM prediction.
2. Find the value of L_{pcb} that just passes 3 dB COM.

Analysis w/ Other Contributed Channels

Channel contribution from mellitz_3dj_elec_01_230504.

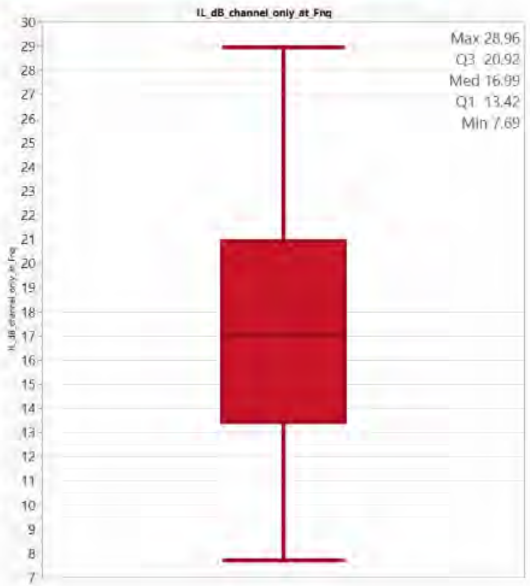
Chip to Chip (C2C) Mezzanine



C2C Loss vs channel (TP0 TP5)

IL: 7.7 dB and 29 dB

Channel	TP0-TP5 Loss (dB)
C2C_withXtalk_Mezz_9_PCB-130mm_60mm_thru.s4p	7.7
C2C_withXtalk_Mezz_10_PCB-200mm_60mm_thru.s4p	10.2
C2C_withXtalk_Mezz_11_PCB-25mm_95mm_thru.s4p	12.3
C2C_withXtalk_Mezz_12_PCB-60mm_95mm_thru.s4p	14.3
C2C_withXtalk_Mezz_13_PCB-95mm_95mm_thru.s4p	18.3
C2C_withXtalk_Mezz_14_PCB-130mm_95mm_thru.s4p	10.0
C2C_withXtalk_Mezz_15_PCB-200mm_95mm_thru.s4p	12.5
C2C_withXtalk_Mezz_16_PCB-25mm_130mm_thru.s4p	14.7
C2C_withXtalk_Mezz_17_PCB-60mm_130mm_thru.s4p	16.7
C2C_withXtalk_Mezz_18_PCB-95mm_130mm_thru.s4p	20.7
C2C_withXtalk_Mezz_19_PCB-130mm_130mm_thru.s4p	12.3
C2C_withXtalk_Mezz_20_PCB-200mm_130mm_thru.s4p	14.8
C2C_withXtalk_Mezz_21_PCB-25mm_200mm_thru.s4p	17.0
C2C_withXtalk_Mezz_22_PCB-60mm_200mm_thru.s4p	19.0
C2C_withXtalk_Mezz_23_PCB-95mm_200mm_thru.s4p	22.9
C2C_withXtalk_Mezz_24_PCB-130mm_200mm_thru.s4p	14.3
C2C_withXtalk_Mezz_25_PCB-200mm_200mm_thru.s4p	16.8
C2C_withXtalk_Mezz_1_PCB-25mm_25mm_thru.m4p	19.1
C2C_withXtalk_Mezz_1_PCB-25mm_25mm_thru.s4p	21.0
C2C_withXtalk_Mezz_2_PCB-60mm_25mm_thru.s4p	25.0
C2C_withXtalk_Mezz_3_PCB-95mm_25mm_thru.s4p	18.3
C2C_withXtalk_Mezz_4_PCB-130mm_25mm_thru.s4p	20.8
C2C_withXtalk_Mezz_5_PCB-200mm_25mm_thru.s4p	23.0
C2C_withXtalk_Mezz_6_PCB-25mm_60mm_thru.s4p	25.0
C2C_withXtalk_Mezz_7_PCB-60mm_60mm_thru.s4p	29.0



IEEE P802.3dj Ethernet Task Force

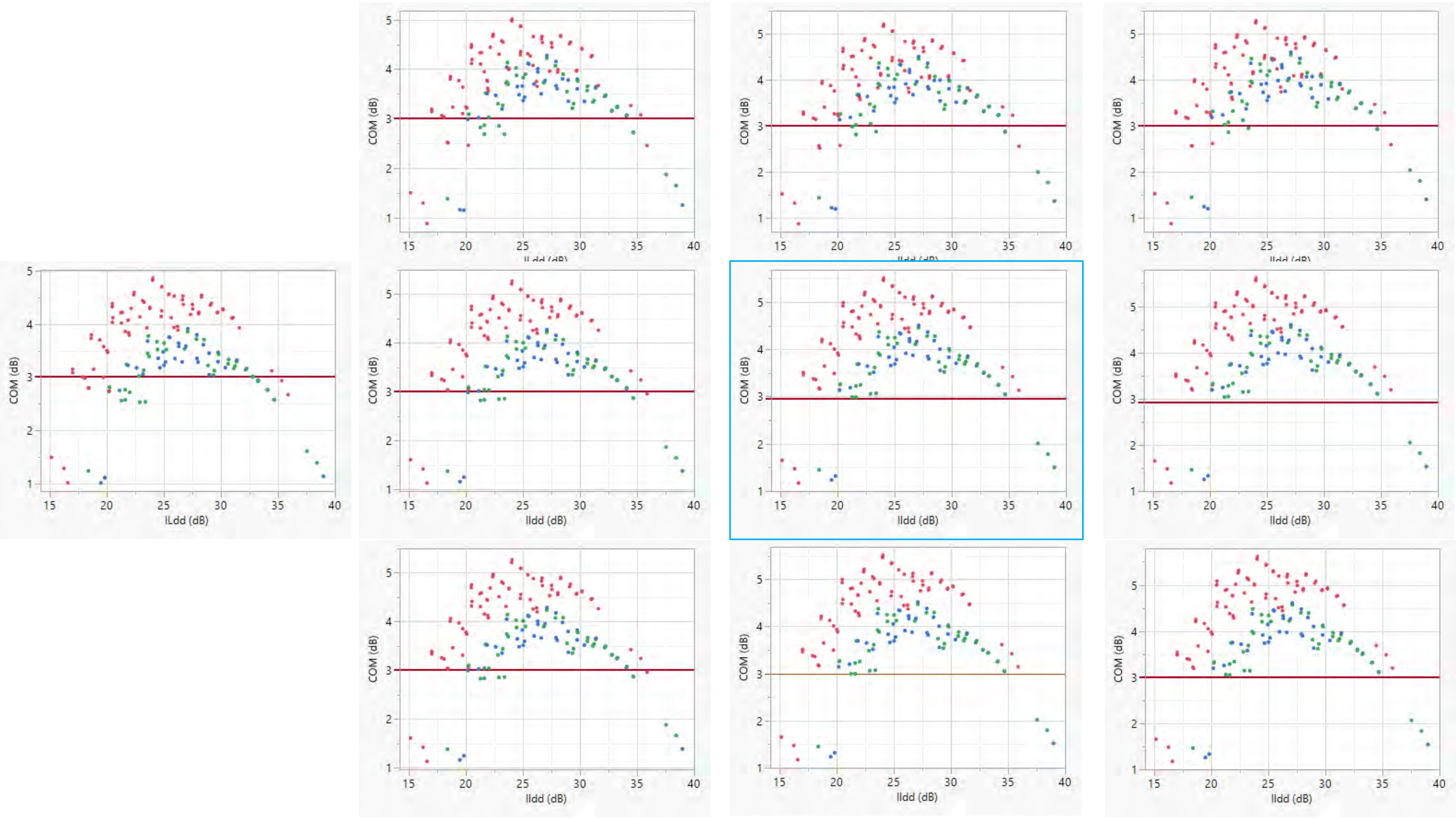
11

COM vs ILdd

Results for channel contribution from mellitz_3dj_elec_01_230504.

Ltxpkg (mm)
- 12
- 28.5
- 45

	$FFEpre = 4$	$FFEpre = 5$	$FFEpre = 6$	$FFEpre = 7$
$FFEpost = 24$				
$FFEpost = 28$				
$FFEpost = 32$				

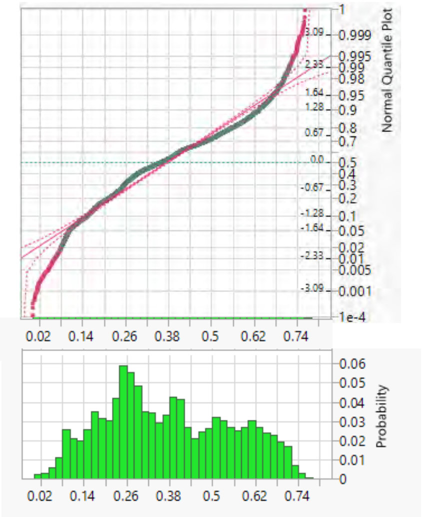


Recommendation: FFEpre = 6, FFEpost = 28

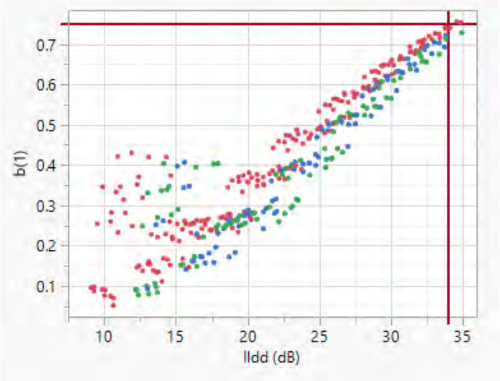
DFE b(1) Limits

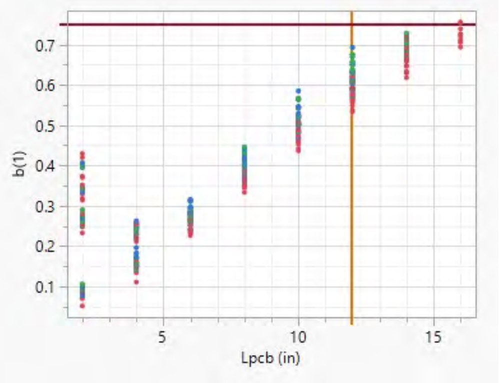
Data for channels with $COM \geq 3\ dB$ for $FFE\text{pre} = 6$, $FFE\text{post} = 28$.

heck_3dj_01a_2405



$b(1)$

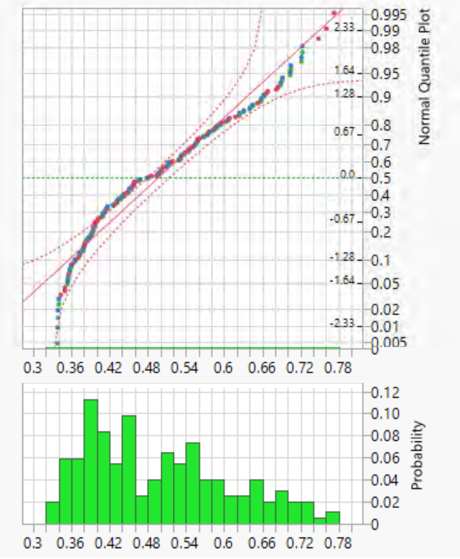


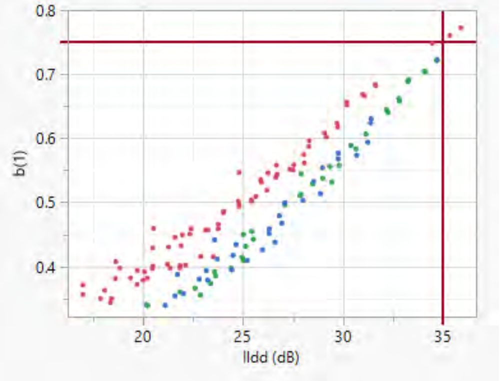


Quantiles		
100.0%	maximum	0.76213
99.5%		0.7294133
97.5%		0.7000503
90.0%		0.633435
75.0%	quartile	0.522115
50.0%	median	0.35688
25.0%	quartile	0.24171
10.0%		0.152591
2.5%		0.084642
0.5%		0.0444859
0.0%	minimum	0

Summary Statistics	
Mean	0.3755171
Std Dev	0.1767743
Std Err Mean	0.0018644
Upper 95% Mean	0.3791717
Lower 95% Mean	0.3718624
N	8990
N Missing	0

mellitz_3dj_elec_01_230504





Quantiles		
100.0%	maximum	0.77251
99.5%		0.7720883
97.5%		0.7226798
90.0%		0.66219
75.0%	quartile	0.57358
50.0%	median	0.47918
25.0%	quartile	0.399845
10.0%		0.36619
2.5%		0.34054
0.5%		0.33885
0.0%	minimum	0.33885

Summary Statistics	
Mean	0.4964045
Std Dev	0.1094149
Std Err Mean	0.0076233
Upper 95% Mean	0.5114346
Lower 95% Mean	0.4813743
N	206
N Missing	0

Recommended specification:

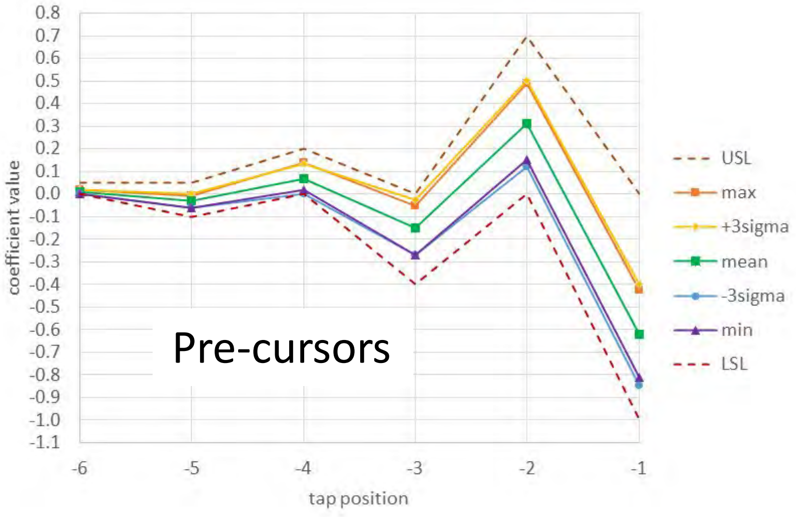
- Min: 0.0
- Max: 0.75

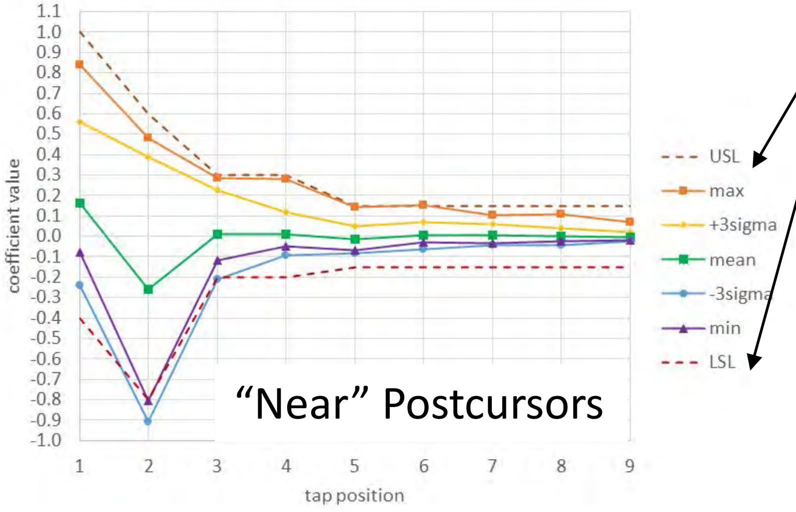
Note: Recommendation is independent of $FFEpre/FFEpost$.

Recommended Reference RX Specifications

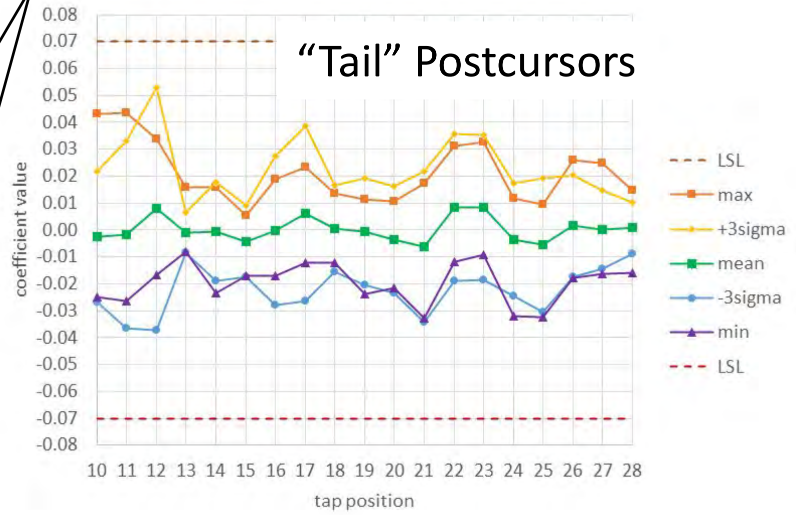
Parameter	Symbol	Value	Units
…	...	…	…
Receiver discrete-time equalizer parameters			
Number of pre-cursor taps	d_w	6	—
Number of fixed-position taps	N_{fix}	28	—
Number of floating tap groups	N_g	0	—
Number of taps per floating tap group	N_f	NA	—
Highest allowed tap index	N_{max}	NA	—
Normalized upper limit on feed-forward coefficient $w(j)$	$w_{max}(j)$	TBD	—
Normalized lower limit on feed-forward coefficient $w(j)$	$w_{min}(j)$	TBD	—
Number of feedback taps	N_b	1	—
Normalized upper limit on feedback coefficient $b(j)$	$b_{max}(j)$	0.75	—
Normalized lower limit on feed-forward coefficient $b(j)$	$b_{min}(j)$	0	—

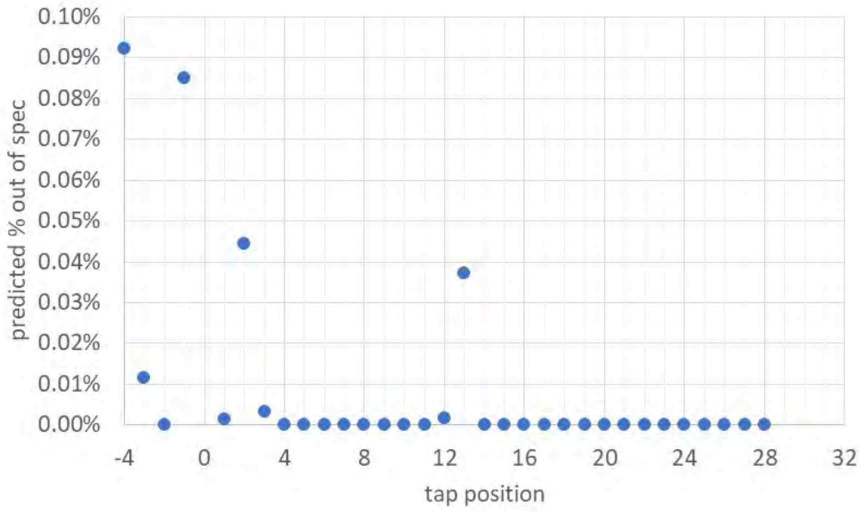
FFE w(j) Limits





Recommended specifications



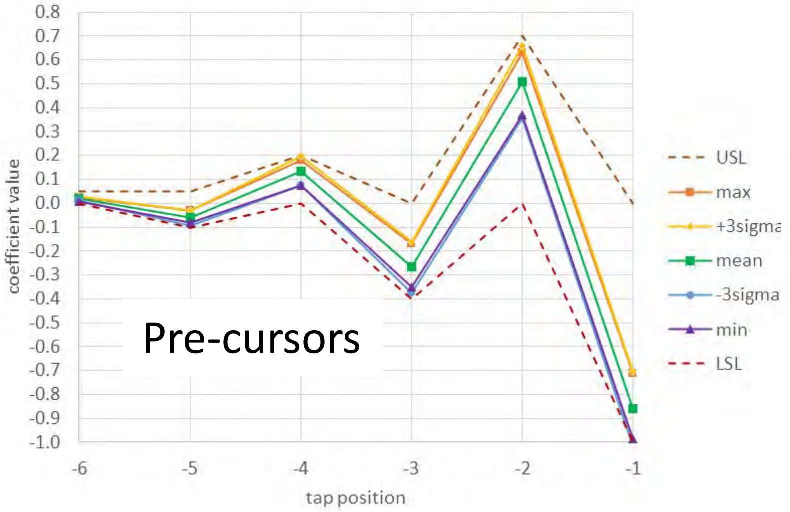


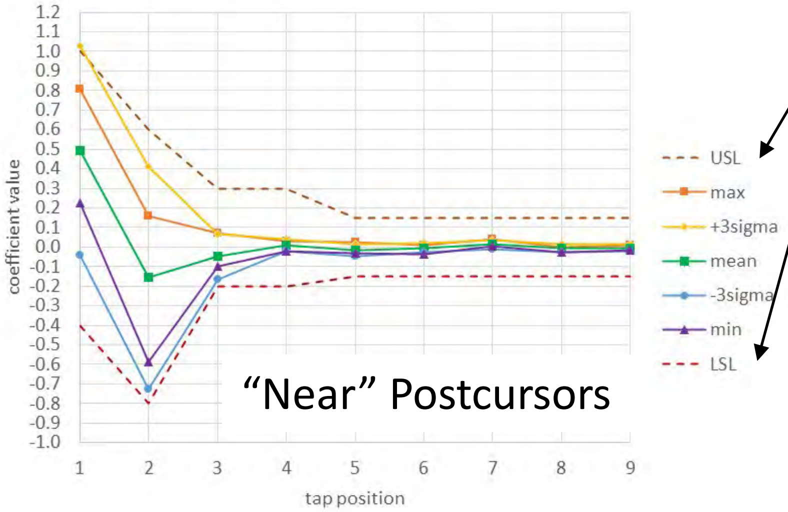
FFE data for 6 pre-cursors, 28 postcursors.

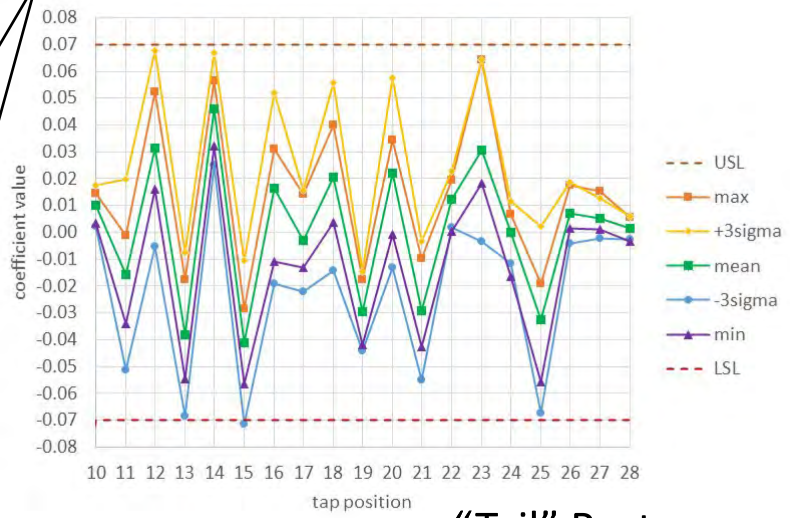
Data in tabular form provided in backup.

FFE w(j) Limits (2)

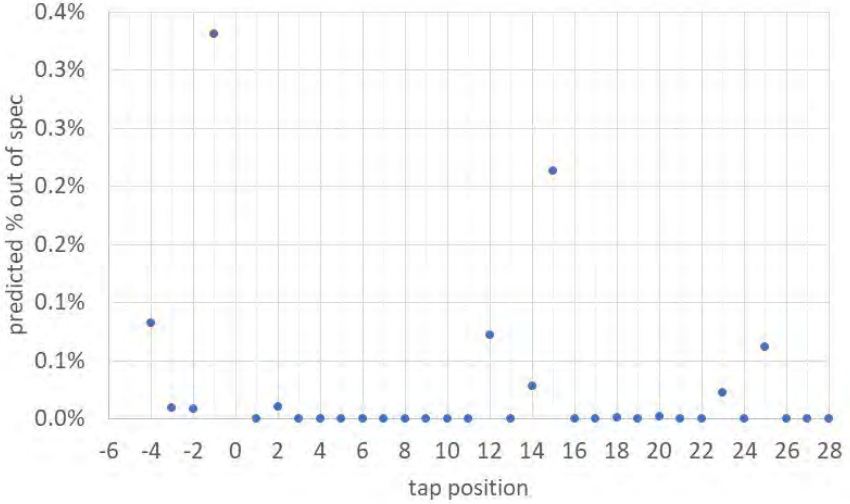
Recommended specifications







“Tail” Postcursors



Data for channels from mellitz_3dj_elec_01_230504.

Recommended Ref RX FFE Coefficient Limits

Parameter	Symbol	Value	Units
…	…	…	…
Receiver discrete-time equalizer parameters			
…	…	…	…
Normalized upper limit on feed-forward coefficient *w*(*j*)	$w_{\max}(j)$		
for *j* = -6		0.05	
for *j* = -5		0.05	
for *j* = -4		0.2	
for *j* = -3		0	
for *j* = -2		0.7	
for *j* = -1		0	—
for *j* = 1		1	
for *j* = 2		0.6	
for *j* = 3 to 4		0.3	
for *j* = 5 to 9		0.15	
for *j* = 10 to 28		0.07	
Normalized lower limit on feed-forward coefficient *w*(*j*)	$w_{\min}(j)$		
for *j* = -6		0	
for *j* = -5		-0.1	
for *j* = -4		0	
for *j* = -3		-0.4	
for *j* = -2		0	
for *j* = -1		-1	
for *j* = 1		-0.4	—
for *j* = 2		-0.8	
for *j* = 3 to 4		-0.2	
for *j* = 5 to 9		-0.15	
for *j* = 10 to 28		-0.07	

Summary of Recommended Values

Parameter	Symbol	Value	Units
…	…	…	…
Single-ended reference resistance	R_0	50	Ω
Single-ended transmitter termination resistance	$R_d^{(t)}$	50	Ω
Single-ended receiver termination resistance	$R_d^{(r)}$	50	Ω

from Table 176D-6

Parameter	Symbol	Value	Units
…	…	…	…
Receiver 3 dB bandwidth	f_r	$0.75 \times f_b$	GHz
…	…	…	…
Differential peak output voltage, victim transmitter	A_v	0.4	V
Differential peak output voltage, far-end aggressor	A_fe	0.4	V
Differential peak output voltage, near-end aggressor	A_ne	0.6	V
Transmitter transition time	T_r	0.04	Ns
…	…	…	…
Transmitter signal-to-noise ratio	SNR_{TX}	33	dB
Dual-Dirac jitter, peak	A_{DD}	0.02	UI
Level separation mismatch ratio	R_LM	0.95	
One-sided noise spectral density	η_0	1.25×10^{-8} V^2/GHz	V^2/GHz
Number of samples per unit interval	M	32	

from Table 176D-7

Summary of Recommended Values (2)

from Table 176D-7

Parameter	Symbol	Value	Units
Receiver discrete-time equalizer parameters			
Number of pre-cursor taps	d_w	4	—
Number of fixed-position taps	N_{fix}	28	—
Number of floating tap groups	N_g	0	—
Number of taps per floating tap group	N_f	NA	—
Highest allowed tap index	$N_{\max}$	NA	—
Normalized upper limit on feed-forward coefficient *w*(*j*)	$w_{\max}(j)$		
for *j* = -6		0.05	
for *j* = -5		0.05	
for *j* = -4		0.2	
for *j* = -3		0	
for *j* = -2		0.7	
for *j* = -1		0	—
for *j* = 1		1	
for *j* = 2		0.6	
for *j* = 3 to 4		0.3	
for *j* = 5 to 9		0.15	
for *j* = 10 to 28		0.07	
Normalized lower limit on feed-forward coefficient *w*(*j*)	$w_{\min}(j)$		
for *j* = -6		0	
for *j* = -5		-0.1	
for *j* = -4		0	
for *j* = -3		-0.4	
for *j* = -2		0	
for *j* = -1		-1	
for *j* = 1		-0.4	—
for *j* = 2		-0.8	
for *j* = 3 to 4		-0.2	
for *j* = 5 to 9		-0.15	
for *j* = 10 to 28		-0.07	

Summary of Recommended Values (3)

from Table 176D-7

Parameter	Symbol	Value	Units
…	...	…	…
Receiver discrete-time equalizer parameters			
…	...	…	…
Number of feedback taps	N_b	1	—
Normalized upper limit on feedback coefficient $b(j)$	$b_{max}(j)$	0.75	—
Normalized lower limit on feed-forward coefficient $b(j)$	$b_{min}(j)$	0	—
Random jitter, RMS	σ_{RJ}	0.01	UI

Summary

Proposal: Adopt the values on the previous two slides to replace the TBDs in Tables 176D-6 and 176C-7.

Thank you

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	[-20:1:0]	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

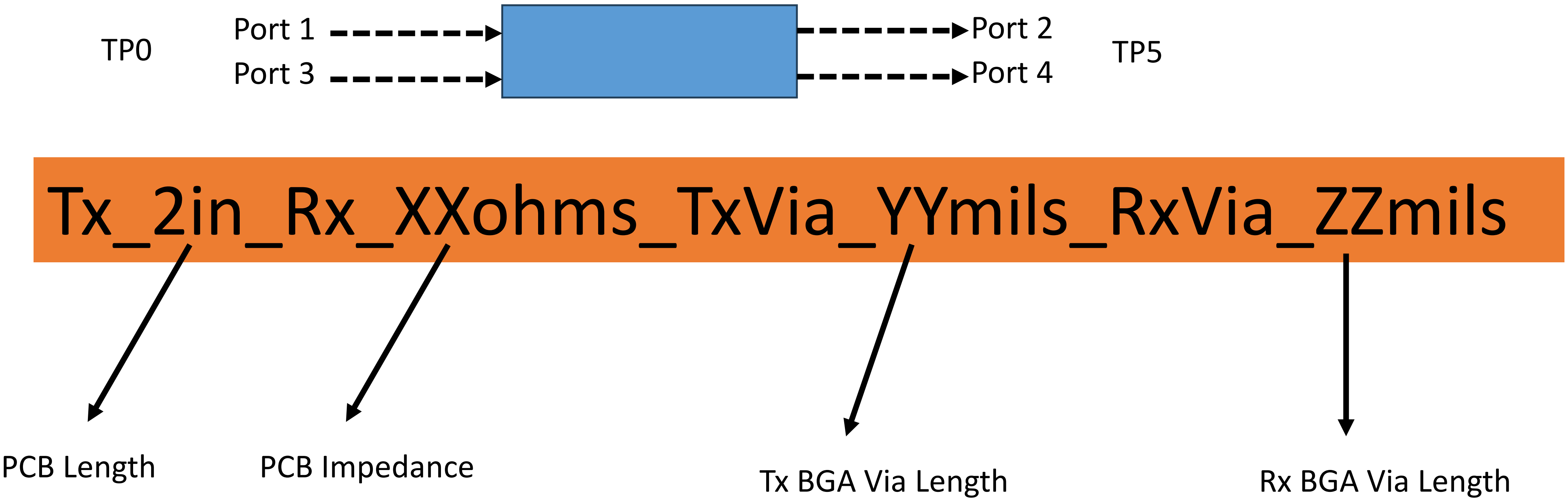
Noise, jitter		UI
sigma_RJ	0.01	UI
A_DD	0.02	V^2/GHz
eta_0	1.25E-08	dB
SNR_TX	33	
R_LM	0.95	

.START	PKG_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 12;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 12;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 12;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 12;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)	[12 12 12 12;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)	[12 12 12 12;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)	[12 12 12 12;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)	[12 12 12 12;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			

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	4	UI	
ffe_post_tap_len	28	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	

AUI C2C Channels – File Naming Convention



XX: 85 ohms, 93 ohms, and 100 ohms
YY: 10 mils, 35 mils , 60 mils
ZZ: 20 mils, 45 mils , 70 mils

Channel Naming Convention

XX: 85 ohms, 93 ohms, and 100 ohms
YY: 10 mils, 35 mils , 60 mils
ZZ: 20 mils, 45 mils , 70 mils

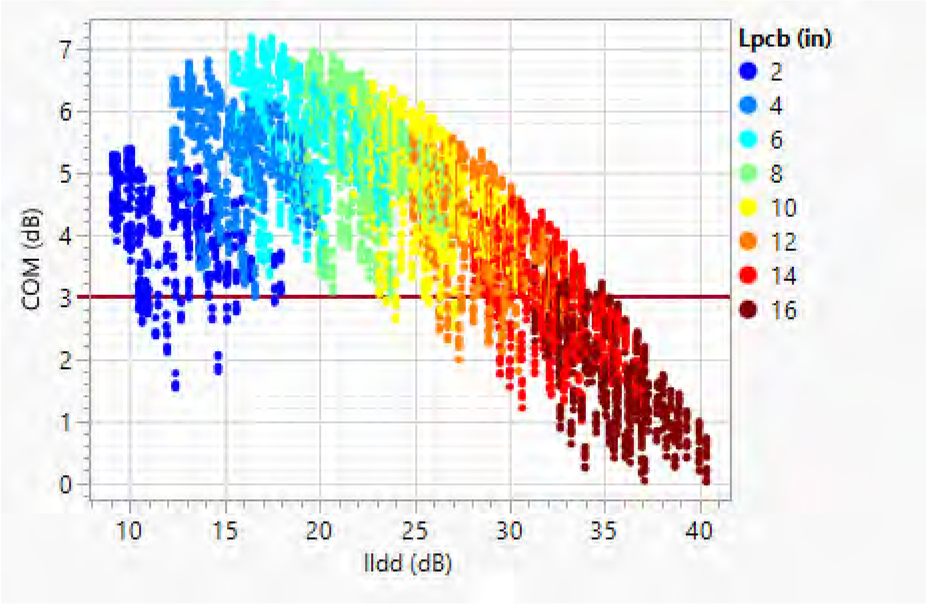
el 1	Channel 2	Channel 3	Channel 4
_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_thru1.s4p	Tx_4in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_thru1.s4p	Tx_6in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_thru1.s4p	Tx_8in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_thru1.s4p
_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk1_Fext.s4p	Tx_4in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk1_Fext.s4p	Tx_6in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk1_Fext.s4p	Tx_8in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk1_Fex
_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk2_Fext.s4p	Tx_4in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk2_Fext.s4p	Tx_6in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk2_Fext.s4p	Tx_8in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk2_Fex
_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk3_Fext.s4p	Tx_4in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk3_Fext.s4p	Tx_6in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk3_Fext.s4p	Tx_8in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk3_Fex
_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk4_Next.s4p	Tx_4in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk4_Next.s4p	Tx_6in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk4_Next.s4p	Tx_8in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk4_Ne
_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk5_Next.s4p	Tx_4in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk5_Next.s4p	Tx_6in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk5_Next.s4p	Tx_8in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk5_Ne
_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk6_Next.s4p	Tx_4in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk6_Next.s4p	Tx_6in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk6_Next.s4p	Tx_8in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk6_Ne
_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk7_Next.s4p	Tx_4in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk7_Next.s4p	Tx_6in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk7_Next.s4p	Tx_8in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk7_Ne

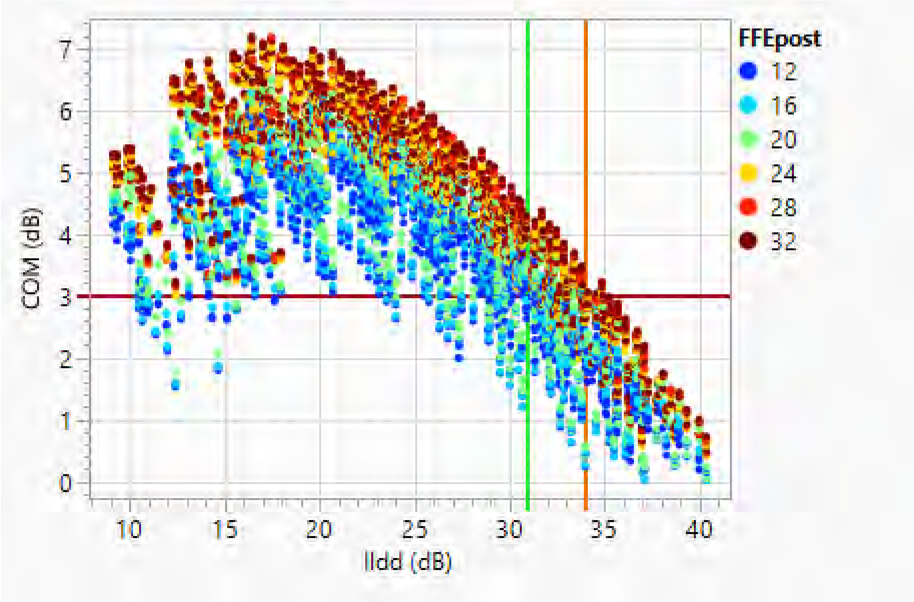
Channel Naming Convention

XX: 85 ohms, 93 ohms, and 100 ohms
YY: 10 mils, 35 mils , 60 mils
ZZ: 20 mils, 45 mils , 70 mils

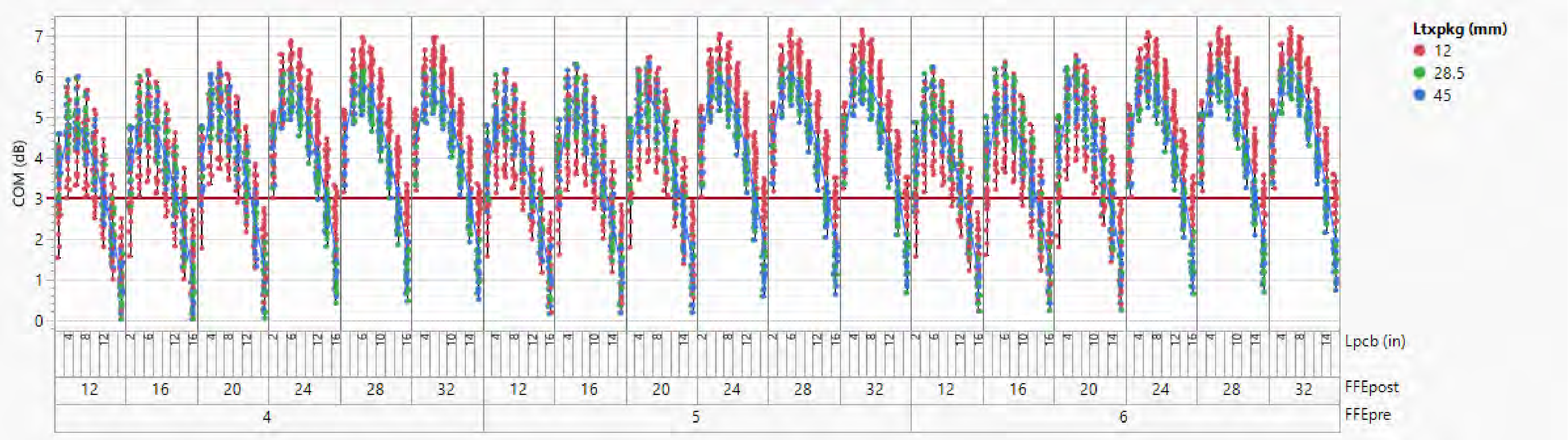
	Channel 2	Channel 3	Channel 4
_XXohms_TxVia_YYmils_RxVia_ZZmils_thru1.s4p	Tx_12in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_thru1.s4p	Tx_14in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_thru1.s4p	Tx_16in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_thru1.s4p
_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk1_Fext.s4p	Tx_12in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk1_Fext.s4p	Tx_14in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk1_Fext.s4p	Tx_16n_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk1_Fext
_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk2_Fext.s4p	Tx_12in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk2_Fext.s4p	Tx_14in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk2_Fext.s4p	Tx_16in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk2_Fex
_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk3_Fext.s4p	Tx_12in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk3_Fext.s4p	Tx_14in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk3_Fext.s4p	Tx_16in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk3_Fex
_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk4_Next.s4p	Tx_12in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk4_Next.s4p	Tx_14in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk4_Next.s4p	Tx_16in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk4_Ne
_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk5_Next.s4p	Tx_12in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk5_Next.s4p	Tx_14in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk5_Next.s4p	Tx_16in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk5_Ne
_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk6_Next.s4p	Tx_12in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk6_Next.s4p	Tx_14in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk6_Next.s4p	Tx_16in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk6_Ne
_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk7_Next.s4p	Tx_12in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk7_Next.s4p	Tx_14in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk7_Next.s4p	Tx_16in_Rx_XXohms_TxVia_YYmils_RxVia_ZZmils_xtalk7_Ne

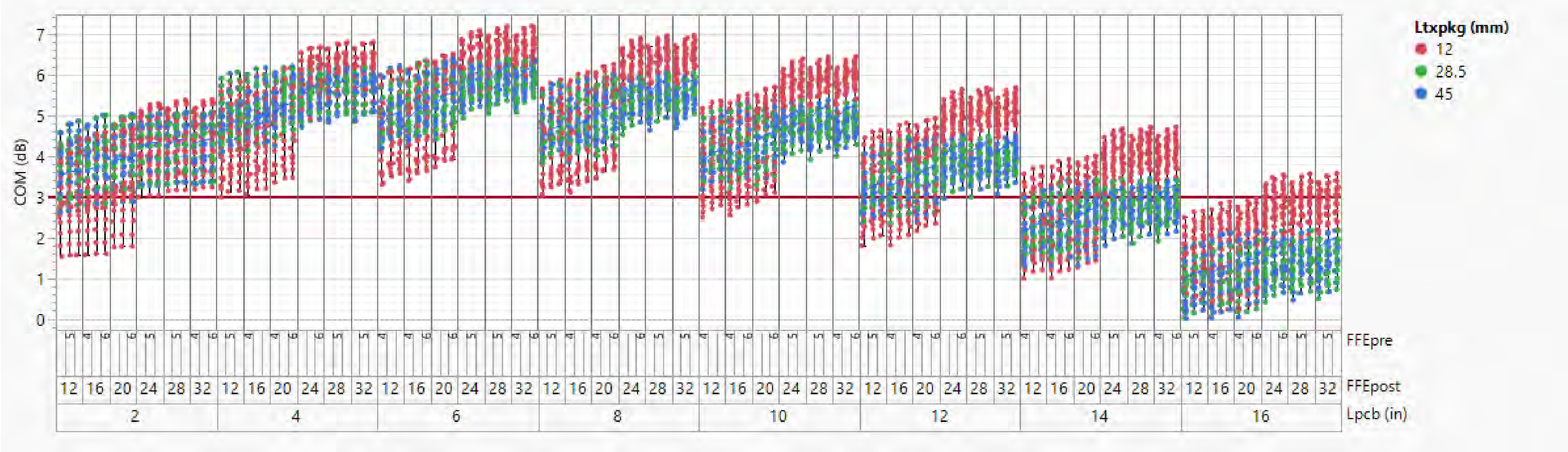
Raw Data: COM vs ILdd





Raw Data: COM vs Lpcb/FFEpre/FFEpost





PCB Length Analysis

Same data as shown on slide 15.

Max length for Ltxpkg = 45 mm

FFEpre	FFEpost	Lpcb
4	12	10.39
4	16	11.10
4	20	11.61
4	24	11.99
4	**28**	**12.25**
4	32	12.41
5	12	10.84
5	16	11.49
5	20	11.98
5	24	12.34
5	28	12.59
5	32	12.75
6	12	11.00
6	16	11.65
6	20	12.13
6	24	12.49
6	28	12.74
6	32	12.90

Ltxpkg	45 mm
Lrxpkg	12 mm
Zpcb	85 ohm
Ltxvia	60 mil
Lrxvia	70 mil

Max length for Ltxpkg = 30mm

FFEpre	FFEpost	Lpcb
4	12	9.13
4	16	10.53
4	20	11.43
4	24	12.08
4	**28**	**12.58**
4	32	12.94
5	12	9.80
5	16	11.00
5	20	11.83
5	24	12.45
5	28	12.92
5	32	13.27
6	12	10.02
6	16	11.18
6	20	11.99
6	24	12.60
6	28	13.07
6	32	13.42

Ltxpkg	30 mm
Lrxpkg	12 mm
Zpcb	85 ohm
Ltxvia	60 mil
Lrxvia	70 mil

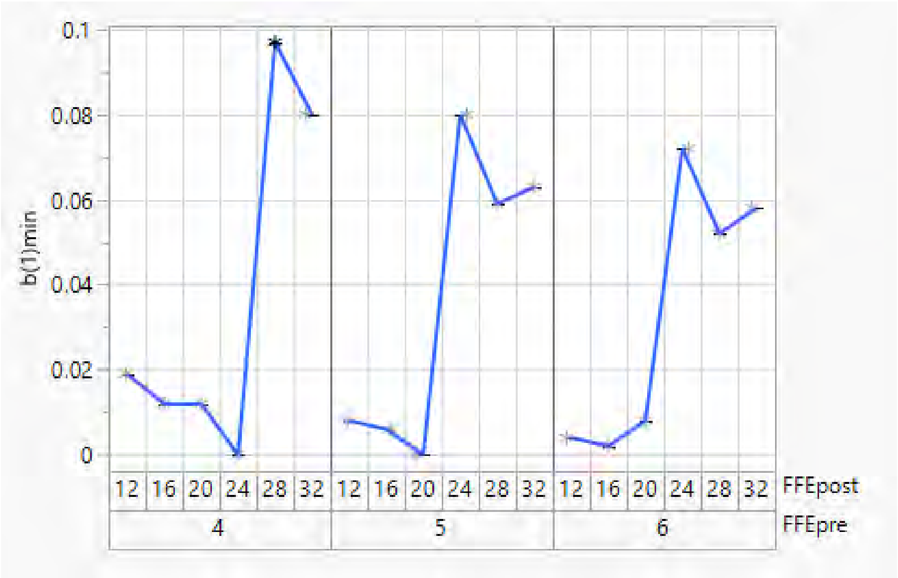
Min length

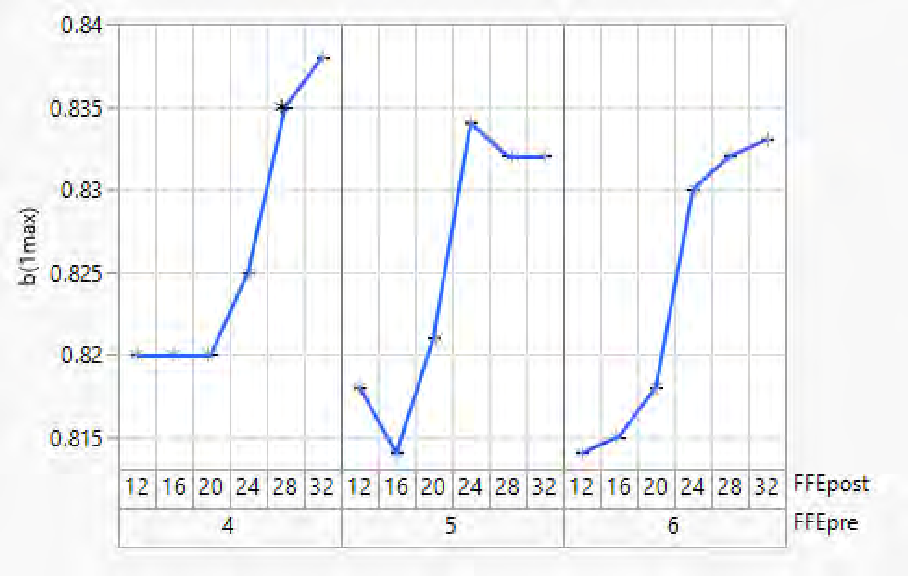
FFEpre	FFEpost	Lpcb
4	12	5.31
4	16	3.14
4	20	1.89
4	24	0.99
4	28	0.28
4	32	0.00
5	12	4.49
5	16	2.71
5	20	1.56
5	24	0.70
5	28	0.01
5	32	0.00
6	12	4.28
6	16	2.58
6	20	1.45
6	24	0.60
6	28	0.00
6	32	0.00

Ltxpkg	12 mm
Lrxpkg	12 mm
Zpcb	85 ohm
Ltxvia	60 mil
Lrxvia	70 mil

DFE b(1) Limits

- Recommended limits appear to apply for all FFEpre/FFEpost combinations.
  - Min: 0.0
  - Max: 0.85





FFE Coefficient Data: 6 precursor, 28 postcursor

Tap	μ	σ	min	max	μ-3σ	μ+3σ	LSL	USL	%OL	%OH
-6	0.0089	0.0028	0.0013	0.0175	0.0004	0.0173	0.00	0.05	0.0008	0.0000
-5	−0.0295	0.0101	-0.0628	-0.0060	-0.0598	0.0007	-0.10	0.05	0.0000	0.0000
-4	0.0691	0.0222	0.0177	0.1401	0.0025	0.1357	0.00	0.20	0.09%	0.00%
-3	-0.1491	0.0405	-0.2704	-0.0524	-0.2706	-0.0276	-0.40	0.00		0.01%
-2	0.3126	0.0638	0.1530	0.4901	0.1213	0.5039	0.00	0.70	0.00%	0.00%
-1	-0.6226	0.0743	-0.8140	-0.4246	-0.8454	-0.3998	-1.00	0.00	0.09%	0.00%
0	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000				
1	0.1620	0.1335	-0.0761	0.8390	-0.2385	0.5625	-0.40	1.00	0.00%	0.00%
2	-0.2585	0.2161	-0.8053	0.4822	-0.9067	0.3897	-0.80	0.60	0.04%	0.00%
3	0.0081	0.0732	-0.1173	0.2869	-0.2114	0.2276	-0.20	0.30	0.00%	0.00%
4	0.0126	0.0350	-0.0474	0.2822	-0.0923	0.1175	-0.20	0.30	0.00%	0.00%
5	-0.0165	0.0225	-0.0679	0.1436	-0.0840	0.0510	-0.15	0.15	0.00%	0.00%
6	0.0036	0.0217	-0.0288	0.1547	-0.0615	0.0687	-0.15	0.15	0.00%	0.00%
7	0.0067	0.0168	-0.0320	0.1018	-0.0436	0.0571	-0.15	0.15	0.00%	0.00%
8	-0.0003	0.0139	-0.0230	0.1108	-0.0419	0.0412	-0.15	0.15	0.00%	0.00%
9	-0.0021	0.0080	-0.0204	0.0668	-0.0261	0.0218	-0.15	0.15	0.00%	0.00%
10	-0.0024	0.0081	-0.0249	0.0430	-0.0267	0.0220	-0.07	0.07	0.00%	0.00%
11	-0.0018	0.0116	-0.0264	0.0434	-0.0365	0.0330	-0.07	0.07	0.00%	0.00%

Tap	μ	σ	min	max	μ-3σ	μ+3σ	LSL	USL	%OL	%OH
12	0.0078	0.0150	-0.0166	0.0338	-0.0373	0.0529	-0.07	0.07	0.00%	0.00%
13	−0.0009	0.0025	-0.0081	0.0157	-0.0085	0.0067	-0.07	0.07	0.0000	0.0004
14	−0.0006	0.0061	-0.0233	0.0158	-0.0190	0.0178	-0.07	0.07	0.0000	0.0000
15	-0.0042	0.0044	-0.0169	0.0053	-0.0175	0.0091	-0.07	0.07	0.00%	0.00%
16	-0.0002	0.0092	-0.0169	0.0189	-0.0279	0.0275	-0.07	0.07	0.00%	0.00%
17	0.0062	0.0108	-0.0120	0.0234	-0.0263	0.0387	-0.07	0.07	0.00%	0.00%
18	0.0005	0.0054	-0.0123	0.0138	-0.0157	0.0167	-0.07	0.07	0.00%	0.00%
19	-0.0006	0.0066	-0.0237	0.0114	-0.0203	0.0191	-0.07	0.07	0.00%	0.00%
20	-0.0035	0.0066	-0.0214	0.0106	-0.0233	0.0162	-0.07	0.07	0.00%	0.00%
21	-0.0061	0.0094	-0.0329	0.0174	-0.0342	0.0220	-0.07	0.07	0.00%	0.00%
22	0.0083	0.0091	-0.0118	0.0312	-0.0190	0.0356	-0.07	0.07	0.00%	0.00%
23	0.0083	0.0089	-0.0092	0.0329	-0.0185	0.0351	-0.07	0.07	0.00%	0.00%
24	-0.0037	0.0070	-0.0320	0.0119	-0.0246	0.0173	-0.07	0.07	0.00%	0.00%
25	-0.0056	0.0083	-0.0323	0.0095	-0.0305	0.0194	-0.07	0.07	0.00%	0.00%
26	0.0015	0.0063	-0.0177	0.0259	-0.0174	0.0204	-0.07	0.07	0.00%	0.00%
27	0.0003	0.0049	-0.0165	0.0249	-0.0144	0.0149	-0.07	0.07	0.00%	0.00%
28	0.0008	0.0031	-0.0160	0.0149	-0.0087	0.0102	-0.07	0.07	0.00%	0.00%