



# 100Gb/s Backplane Channel Simulation (update)

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IEEE802.3ck

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**Socionext Inc.**

# Agenda

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- 1. Overview**
- 2. Channels for Simulation**
- 3. Backplane Channel Simulation (proprietary tool)**
- 4. Backplane Channel COM Simulation**
- 5. Observation and Future Work**

# 1. Overview

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- ✓ **Update of 100Gb/s backplane channel simulation with PKG parameters and equalizer configurations.**
  - mid-PKG trace PTH effect with Rx FFE tap skewed
- ✓ **PKG and equalizer analysis using COM (v2.41)**
  - Rx FFE pre/post-taps
  - Tx and Rx PKG trace length

## 2. Backplane Channels for Simulation

#	contributor	type	IL[dB]*	ERL[dB]	ICN[mV]	note	name in graph	reference	
1	Mellitz	legacy	15.88	12.02	3.53	Tachyon_3"	ST3	[1][2]	
2			25.55	12.89	2.68	Tachyon_13"	ST13	[1][3]	
3			30.34	13.07	2.65	Tachyon_18"	ST18	[1][4]	
4			28.01	52.77	0.00	"smooth" PCB Megtron-6	Sm	[7][8]	
5		cabled	23.79	19.85	0.76	24dB_opt1	S241	[5][6]	
6			22.98	17.53	0.88	24dB_opt2	S242		
7			27.59	20.85	0.56	28dB_opt1	S281		
1			26.72	18.35	0.65	28dB_opt2	S282		
9			31.36	21.80	0.44	32dB_opt1	S321		
10			30.42	19.08	0.50	32dB_opt2	S322		
11			27.98	73.98	0.00	"smooth" twinax cabled	St		[7][8]
12			27.9		0.73	2m, cabled	2m		[9][10]
13	Zambell	ortho	26.64	14.55	1.52	20" orthogonal	Ao	[10][11]	
14	Heck	legacy	29.74	9.51	2.05	30dB, nominal, 85-ohm	In	[12][13]	
15			29.62	8.80	2.03	30dB, high-low-high, 85-ohm	lhlh	[12][14]	
16			29.85	8.04	2.05	30dB, low-high-low, 85-ohm	llhl	[12][15]	

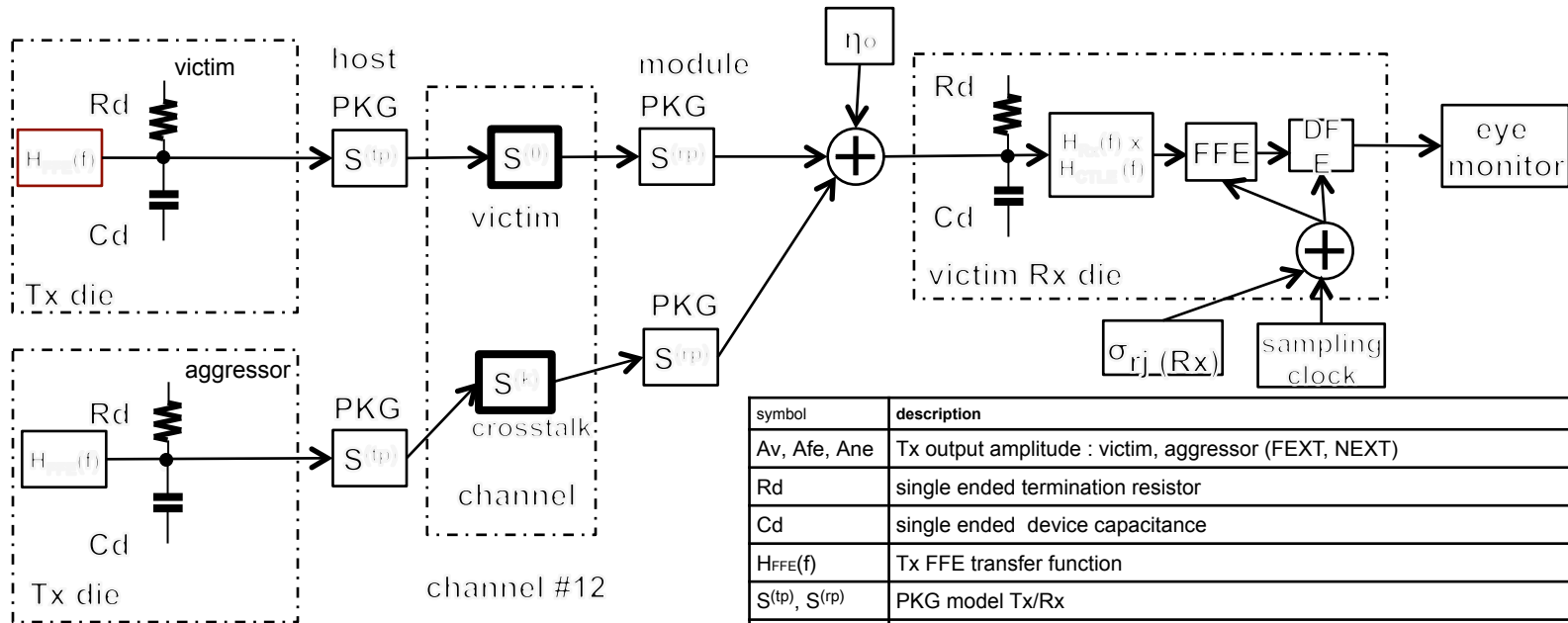


# **3. Backplane Channel Simulation**

## **(proprietary tool)**

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# 3.1.1 Simulation Model



PKG : 30mm  
simulated model

symbol	description
Av, Afe, Ane	Tx output amplitude : victim, aggressor (FEXT, NEXT)
Rd	single ended termination resistor
Cd	single ended device capacitance
H <sub>FFE</sub> (f)	Tx FFE transfer function
S <sup>(tp)</sup> , S <sup>(rp)</sup>	PKG model Tx/Rx
S <sup>(0)</sup>	channel under test
H <sub>Rx</sub> (f)	Rx noise filter
H <sub>CTLE</sub> (f)	Rx CTLE transfer function
η <sub>0</sub>	one-sided noise spec
Add	Dual-Dirac jitter, peak to peak Tx : before FFE Rx : considered as eye margin
σ <sub>j</sub>	random jitter, RMS Tx : before FFE Rx : before FFE/DFE

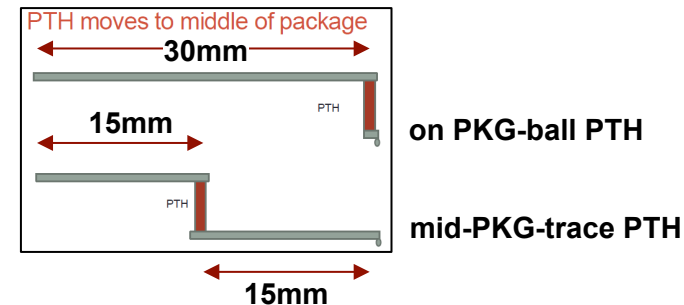
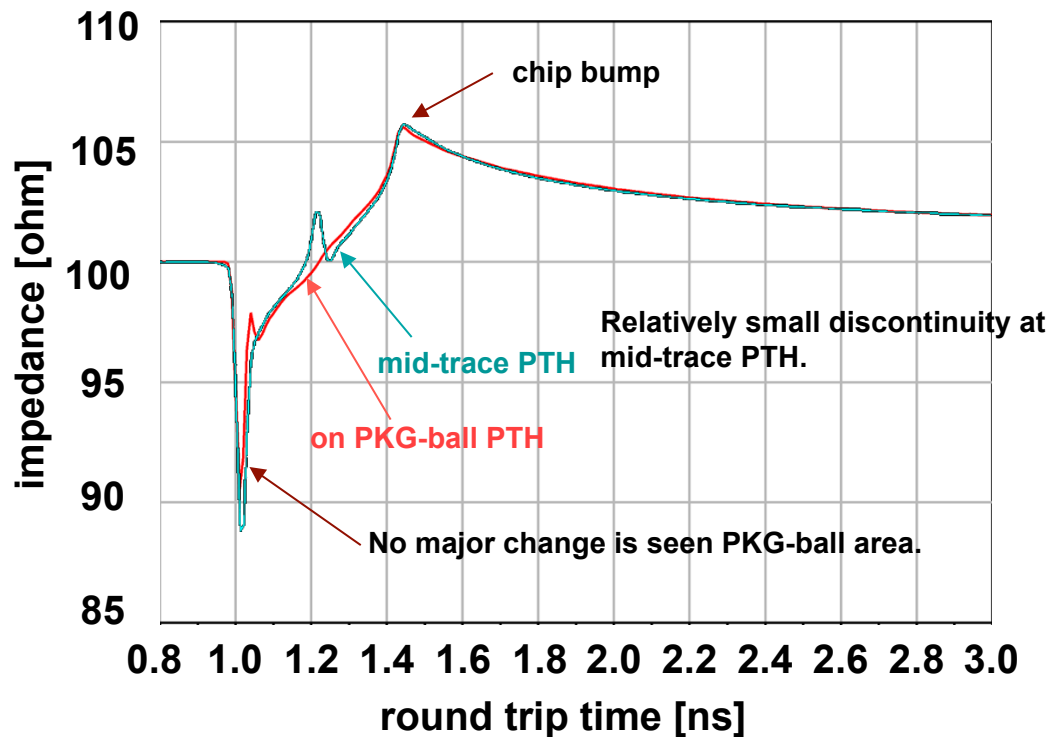
- ✓ The same as previous ones in Study Group.
- [http://www.ieee802.org/3/100GEL/public/18\\_01/sakai\\_100GEL\\_01b\\_0118.pdf](http://www.ieee802.org/3/100GEL/public/18_01/sakai_100GEL_01b_0118.pdf)
- [http://www.ieee802.org/3/100GEL/public/18\\_03/sakai\\_100GEL\\_01\\_0318.pdf](http://www.ieee802.org/3/100GEL/public/18_03/sakai_100GEL_01_0318.pdf)

## 3.1.2 Simulation Set Up

- ✓ Static Channel Model Simulation (proprietary)
- ✓ Behavior model using MatLab
- ✓ PAM4 at 58.0Gbd to see margin and other applications. (conservative)
- ✓ Rx/CDR jitter (DJ) are considered as eye opening margin. (EW4, EH4)
- ✓ Crosstalk noise in channel S-parameter
- ✓ Impedance are nominal : 50-ohm single ended
  
- ✓ T-spaced FFE
  - ✓ Rx FFE parameters are set to minimize ISI.
- ✓ CTLE coefficients are optimized for each channel.
- ✓ PKG model is based on current design, modified PTH location.
  - PKG material : “GZ41”.

item	value	unit
modulation	PAM4	
pattern	PRBS13Q	
baud rate	58	Gbd
DJ_Tx	60	mUIpk-pk
RJ_Tx	10	mUI_rms
EOJ_Tx	0	UI
SNR_Tx	32.5	dB
Rt_Tx	50	ohm
Tx_FFE	4/2	tap/pre
Cd_Tx/Rx	160	fF
Cp Tx/Rx	110	fF
Rx FFE + DFE		FFE tap/pre + DFE tap
Rx fr	3/4 fb	
Av	0.8	Vppd
AVx	1.2	Vppd
BER	1.0E-4	
$\eta_0$ eta0	8.2E-09	V <sup>2</sup> /GHz
DJ_Rx	0	UI
RJ_Rx	10	mUI_rms
Rt_Rx	50	ohm

## 3.2.1 TDR : PKG PTH location



[http://www.ieee802.org/3/ck/public/adhoc/aug15\\_18/mellitz\\_3ck\\_adhoc\\_03\\_081518.pdf](http://www.ieee802.org/3/ck/public/adhoc/aug15_18/mellitz_3ck_adhoc_03_081518.pdf) (page-14)

- ✓ At ad hoc meeting on Aug/15/2018, mid-PKG-trace PTH was suggested.
- ✓ To check the effect, model parameter extraction (HFSS) was done for channel simulation.
- ✓ TDR result shows no significant discontinuity changes at PKG ball.

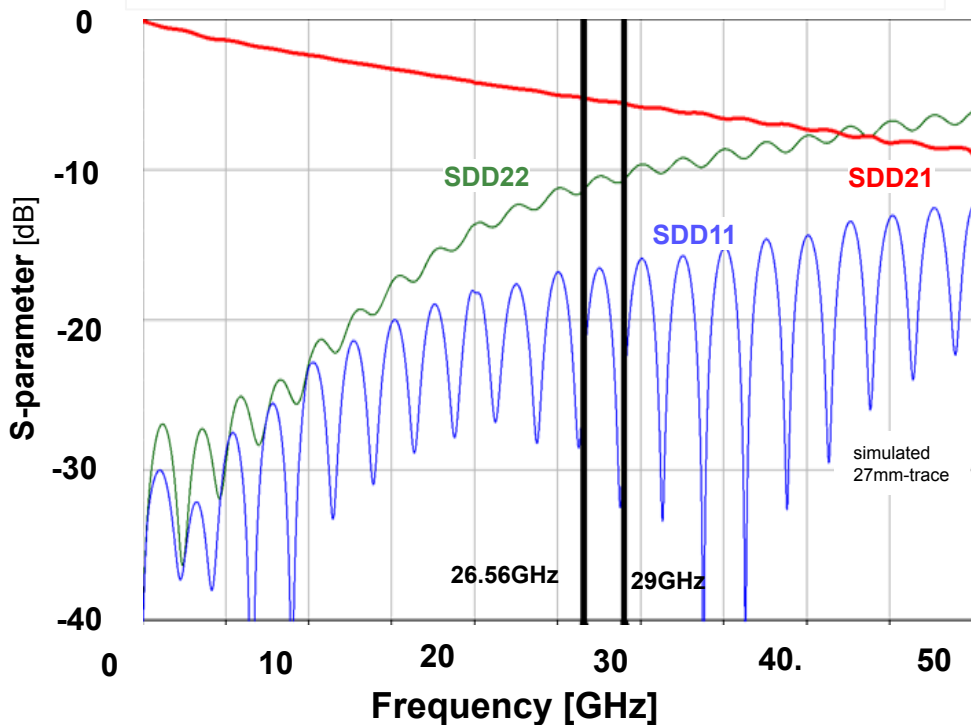


## 3.2.2 PKG Characteristics

**30mm PKG (FCBGA, extracted, on-PKG-ball PTH)**

SDD21: -5.24 / -5.62 dB @26.56 / 29 GHz

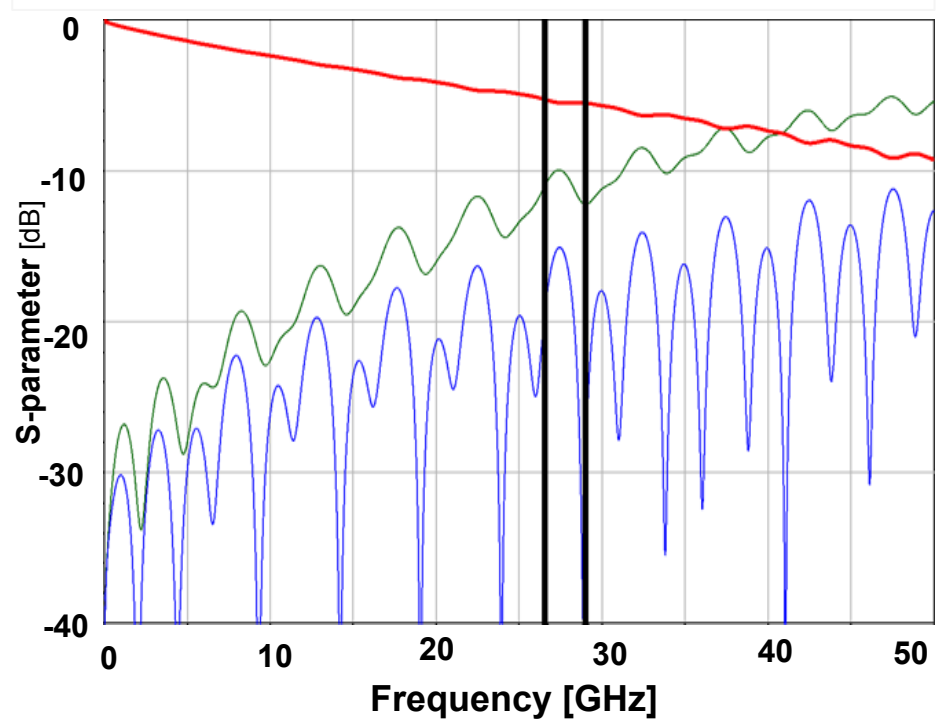
SDD22: -11.4 / -10.7 dB @26.56 / 29 GHz



**15/15mm PKG (FCBGA, extracted, mid-PKG-trace PTH)**

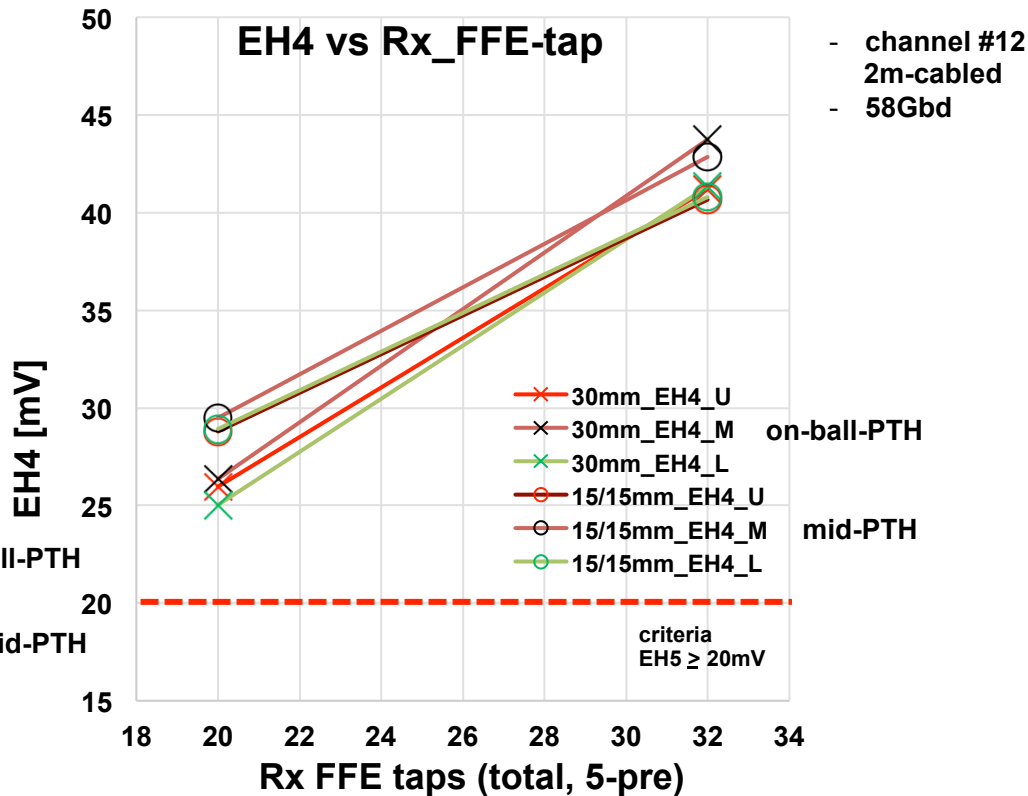
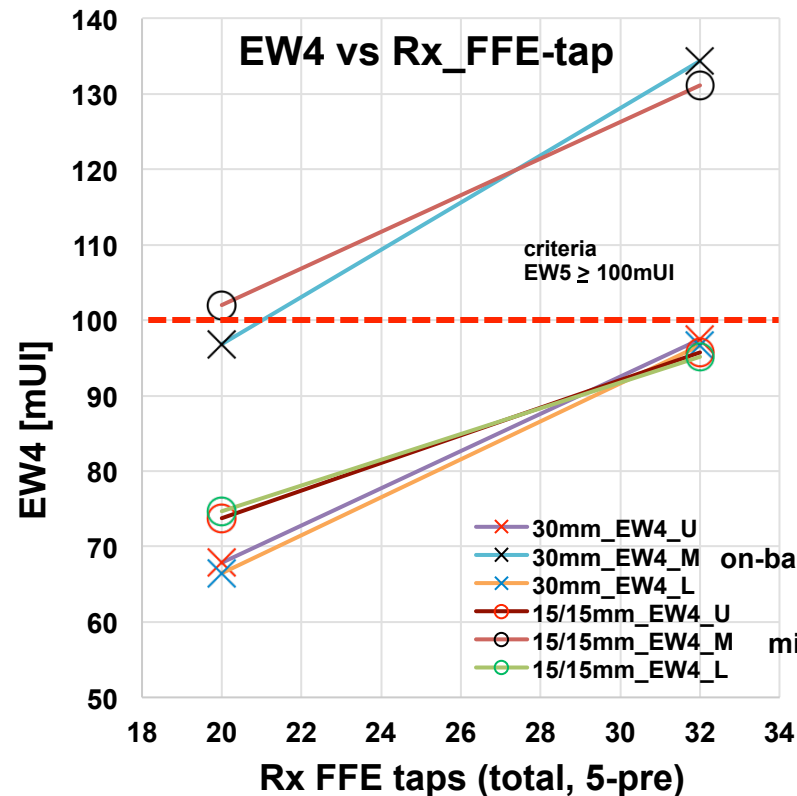
SDD21: -5.28 / -5.51 dB @26.56 / 29 GHz

SDD22: -11.0 / -10.7 dB @26.56 / 29 GHz



note : No xtalk is considered in these PKG models.

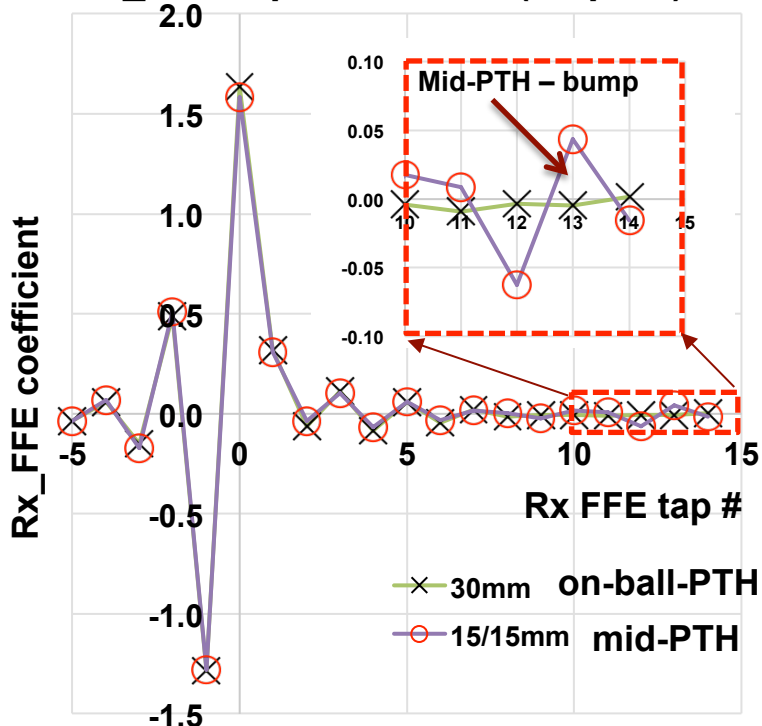
### 3.2.3 EW4/EH4 vs Rx FFE tap : PKG PTH location



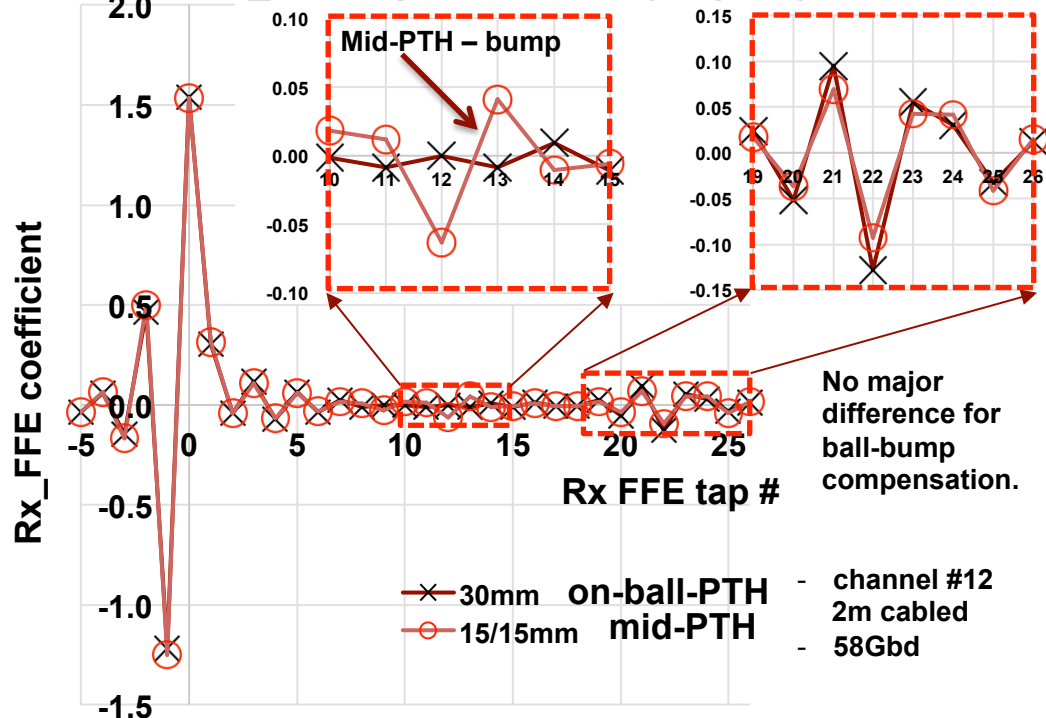
✓ Mid-PTH has some gain with shorter (20-tap) Rx FFE-taps, however, no gain with longer (32-tap) Rx FFE-taps. So, in case of limited Rx FFE tap cases, mid-trace PTH has benefit.

### 3.2.4 Rx FFE-tap coefficient : PKG PTH location

Rx\_FFE-tap coefficient (14-post)

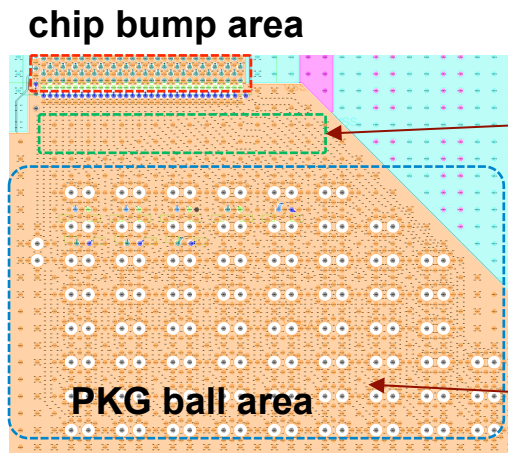
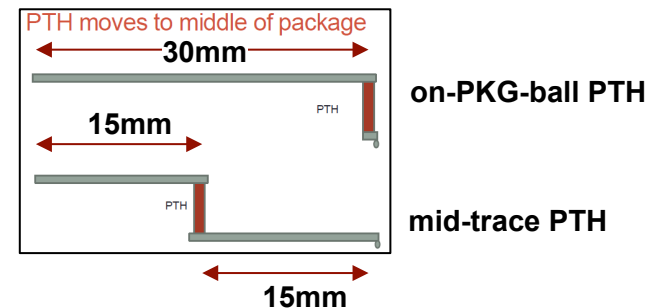
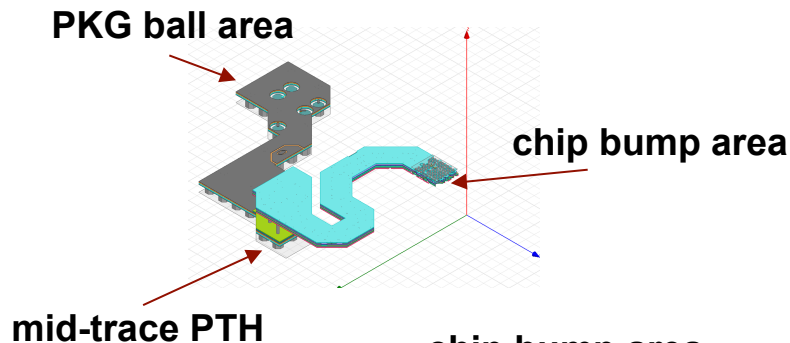


Rx\_FFE-tap coefficient (26-post)



- ✓ Mid-PTH has some benefit with shorter (14-post) Rx FFE-taps, however, almost no difference with longer (26-post) Rx FFE-taps.

## 3.2.5 PKG PTH layout issue



✓ Mid-trace PTH case, PTH area needs to be between bump and PKG ball.  
- Limited space, and may not be suitable for high density routing.

✓ On-PKG-ball PTH case, PTH area is the same as PKG ball.

PKG bump/trace/ball layout (example)



## 4. Backplane Channel COM Simulation

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## 4.1 COM parameters (COM 2.41 with Rx FFE)

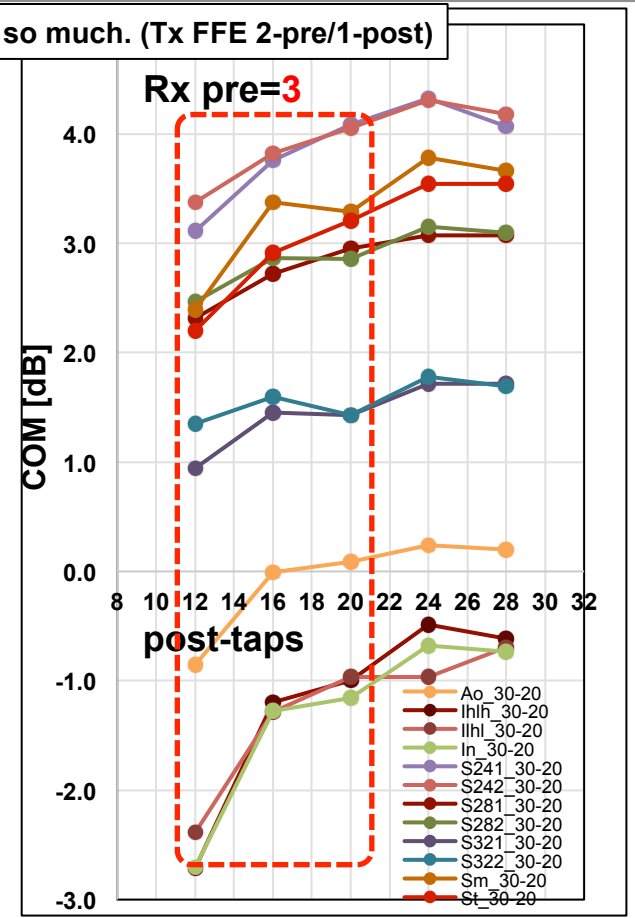
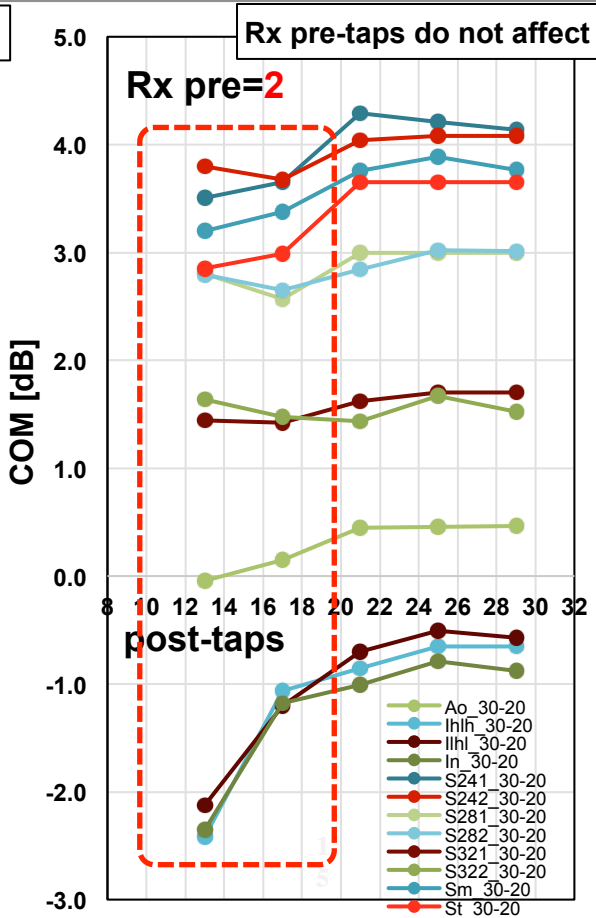
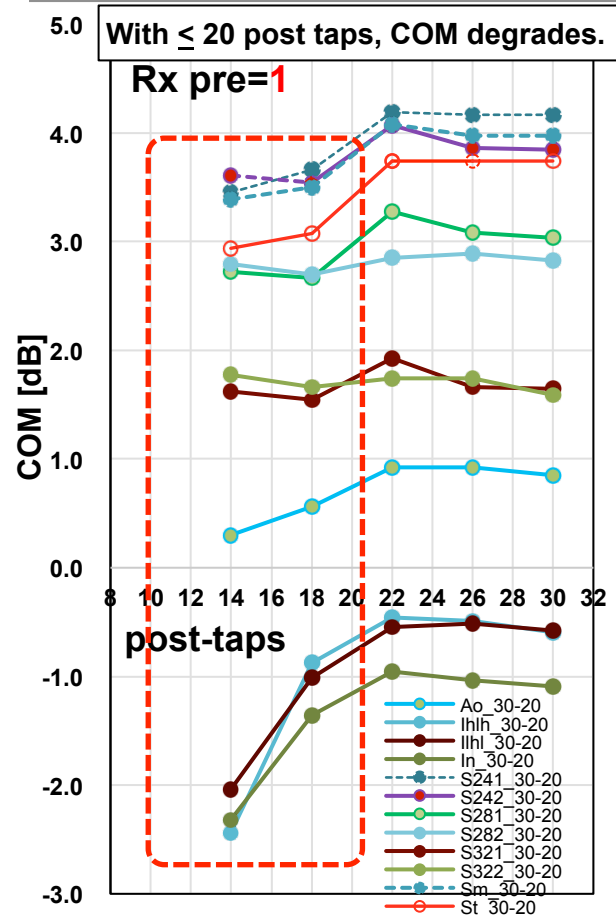
Table 93A-1 parameters			
Parameter	Setting	Units	Information
f_b	53.125	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	1.3e-4 1.3e-4	nF	[TX RX]
z_p select	[ 1 2]		[test cases to run]
z_p (TX)	[12 30]	mm	[test cases]
z_p (NEXT)	[12 30]	mm	[test cases]
z_p (FEXT)	[12 30]	mm	[test cases]
z_p (RX)	[12 30]	mm	[test cases]
C_p	[1.1e-4 1.1e-4]	nF	[TX RX]
R_0	50	Ohm	
R_d	[ 50 50]	Ohm	[TX RX] or selected
f_r	0.75	*fb	
c(0)	0.6		min
c(-1)	[-0.3:0.05:0]		[min:step:max]
c(-2)	[0:0.025:0.1]		[min:step:max]
c(-3)	0		[min:step:max]
c(-4)	0		[min:step:max]
c(1)	[-0.2:0.05:0]		[min:step:max]
g_DC	[-20:1:10]	dB	[min:step:max]
f_z	21.25	GHz	fb/2.5
f_p1	21.25	GHz	fb/2.5
f_p2	53.125	GHz	fb
A_v	0.41	V	tdr selected
A_fe	0.41	V	tdr selected
A_ne	0.6	V	tdr selected
L	4		
M	32		
N_b	1	UI	1-tap DFE
b_max(1)	0.7		
b_max(2..N_b)	0.2		
sigma_RJ	0.01	UI	
A_DD	0.02	UI	
eta_0	8.2E-09	V^2/GHz	
SNR_TX	32.5	dB	tdr selected
R_LM	0.95		
DER_0	1.E-04		

I/O control			
DIAGNOSTICS	0	logical	
DISPLAY_WINDOW	0	logical	
CSV_REPORT	1	logical	
RESULT_DIR	.\results\100G(date)\		
SAVE_FIGURES	0	logical	
Port Order	[1 3 2 4]		
RUNTAG	100G-KR		
Receiver testing			
RX_CALIBRATION	0	logical	
Sigma BBN step	5.00.E-03	V	
IDEAL_TX_TERM	0	logical	
T_r	6.161.E-03	ns	
FORCE_TR	1	logical	
Non standard control options			
COM_CONTRIBUTION	0	logical	
TDR	1	logical	
ERL	1	logical	
ERL_ONLY	0	logical	
TR_TDR	0.01	ns	
N	1000		
TDR_Butterworth	1	logical	
beta_x	1.70.E+09		
rho_x	0.18		
fixture delay time	0		
Operational control			
COM Pass threshold	3	dB	
Include PCB	0	Value	0, 1, 2
g_DC_HP	[-6:1:0]		[min:step:max]
f_HP_PZ	0.6640625	GHz	
ffe_pre_tap_len	3	UI	Rx FFE taps
ffe_post_tap_len	16	UI	
ffe_tap_step_size	0.01		
ffe_main_cursor_min	1		
ffe_pre_tap1_max	0.5		
ffe_post_tap1_max	0.5		
ffe_tapn_max	0.125		

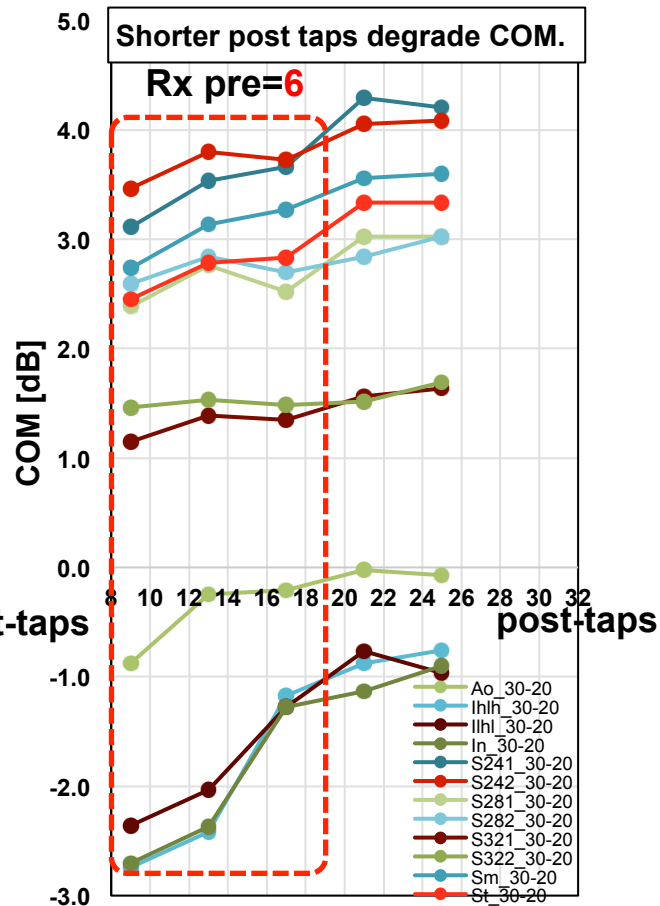
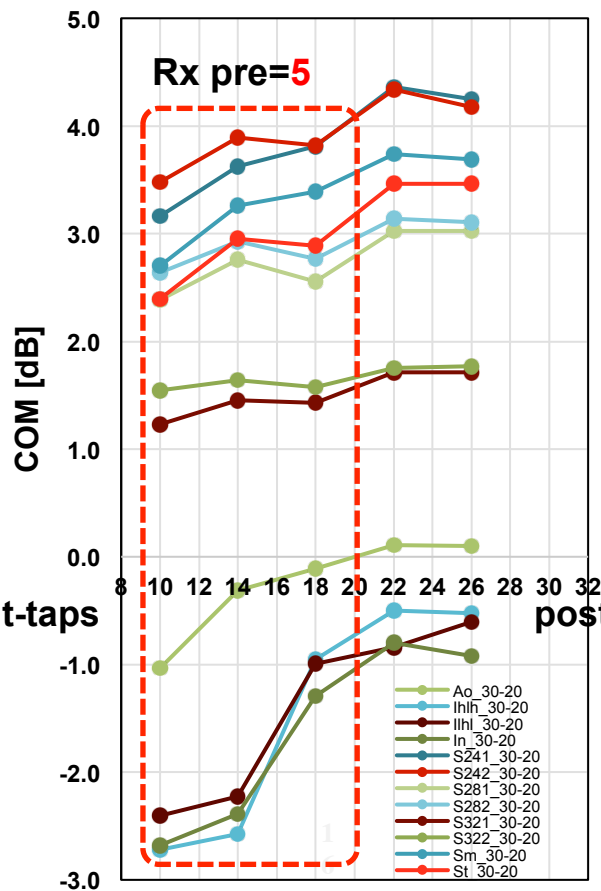
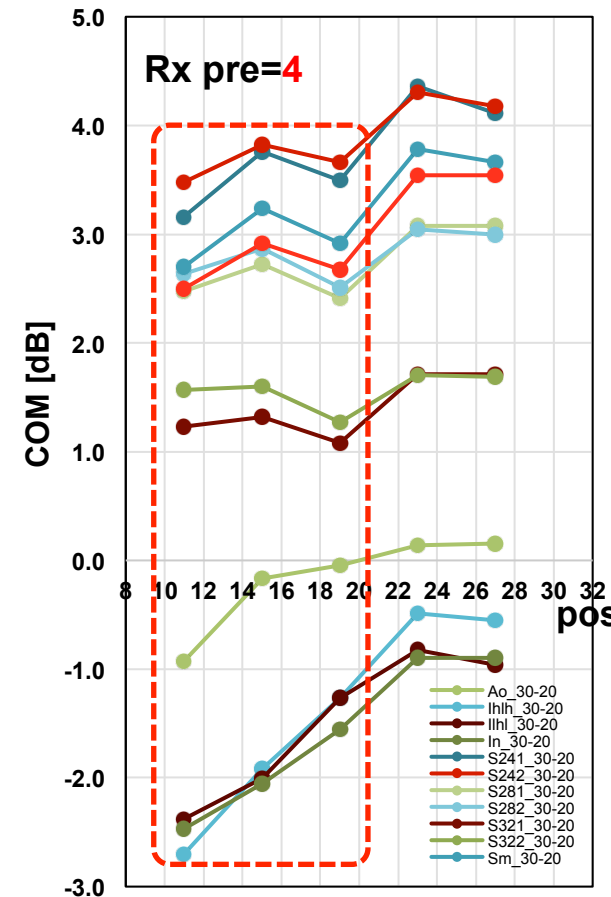
Table 93A * parameters		
Parameter	Setting	Units
package_tl_gamma0_a1_a2	[0 1.734e-3 1.455e-4]	
package_tl_tau	6.141.E-03	ns/mm
package_Z_c	90	Ohm (tdr sel)
Table 92 * 2 parameters		
Parameter	Setting	Units
board_tl_gamma0_a1_a2	[0 4.114e-4 2.547e-4]	
board_tl_tau	6.191.E-03	ns/mm
board_Z_c	110	Ohm
z_bp (TX)	151	mm
z_bp (NEXT)	72	mm
z_bp (FEXT)	72	mm
z_bp (RX)	151	mm

- ✓ fb : 53.125Gbd (fixed, PAM4)
- ✓ Tx FFE : 2-pre/1-post (fixed)
- ✓ CTLE pole/zero frequencies : fixed
- ✓ Rx DFE : 1-tap (fixed)
- ✓ Cp : 110fF (fixed)
- ✓ sigma\_RJ : 0.01UI
- ✓ A\_DD : 0.02UI
- ✓ SNR\_TX : 32.5dB
- ✓ DER\_0 : 1E-4

# 4.2 COM vs IL w/PKG and Cd : Rx\_FFE-taps (pre/post)

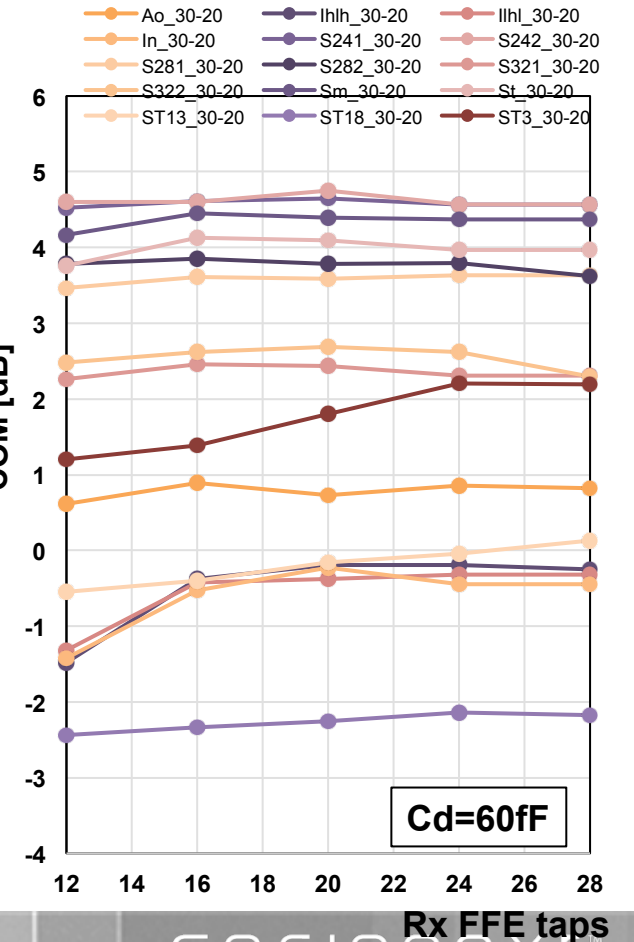
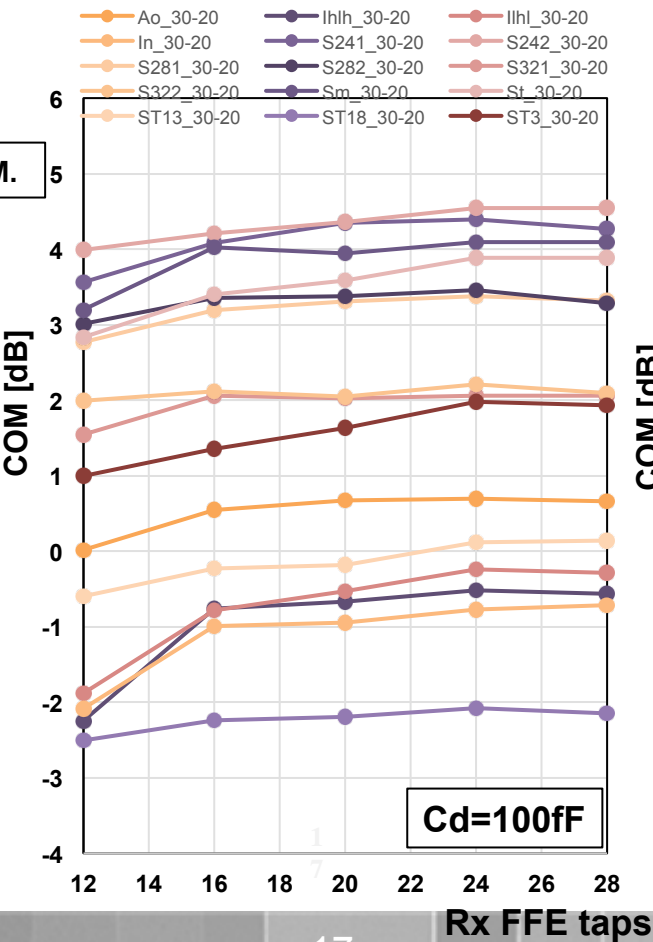
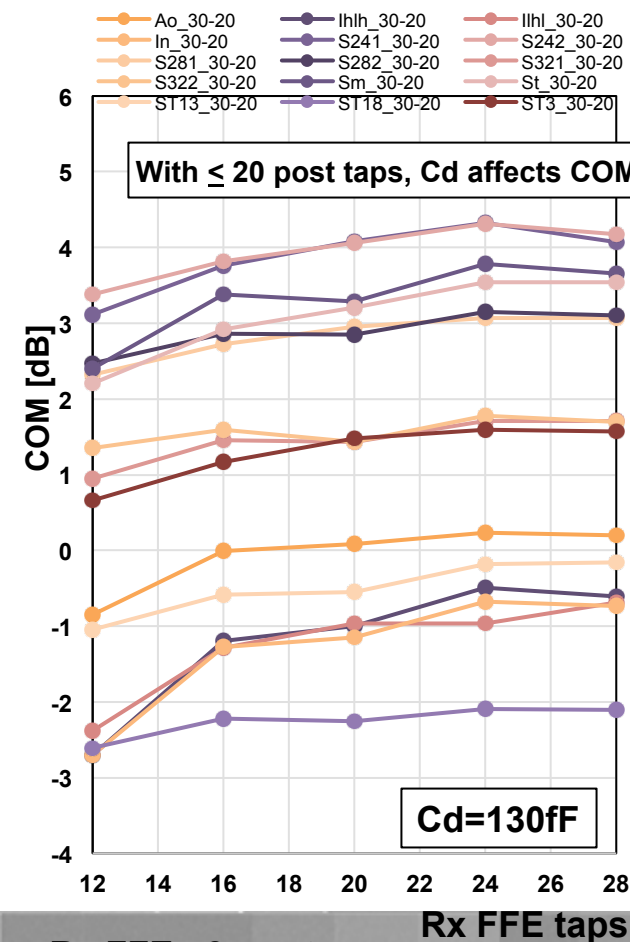


# 4.2 COM vs IL w/PKG and Cd : Rx\_FFE-taps (pre/post)

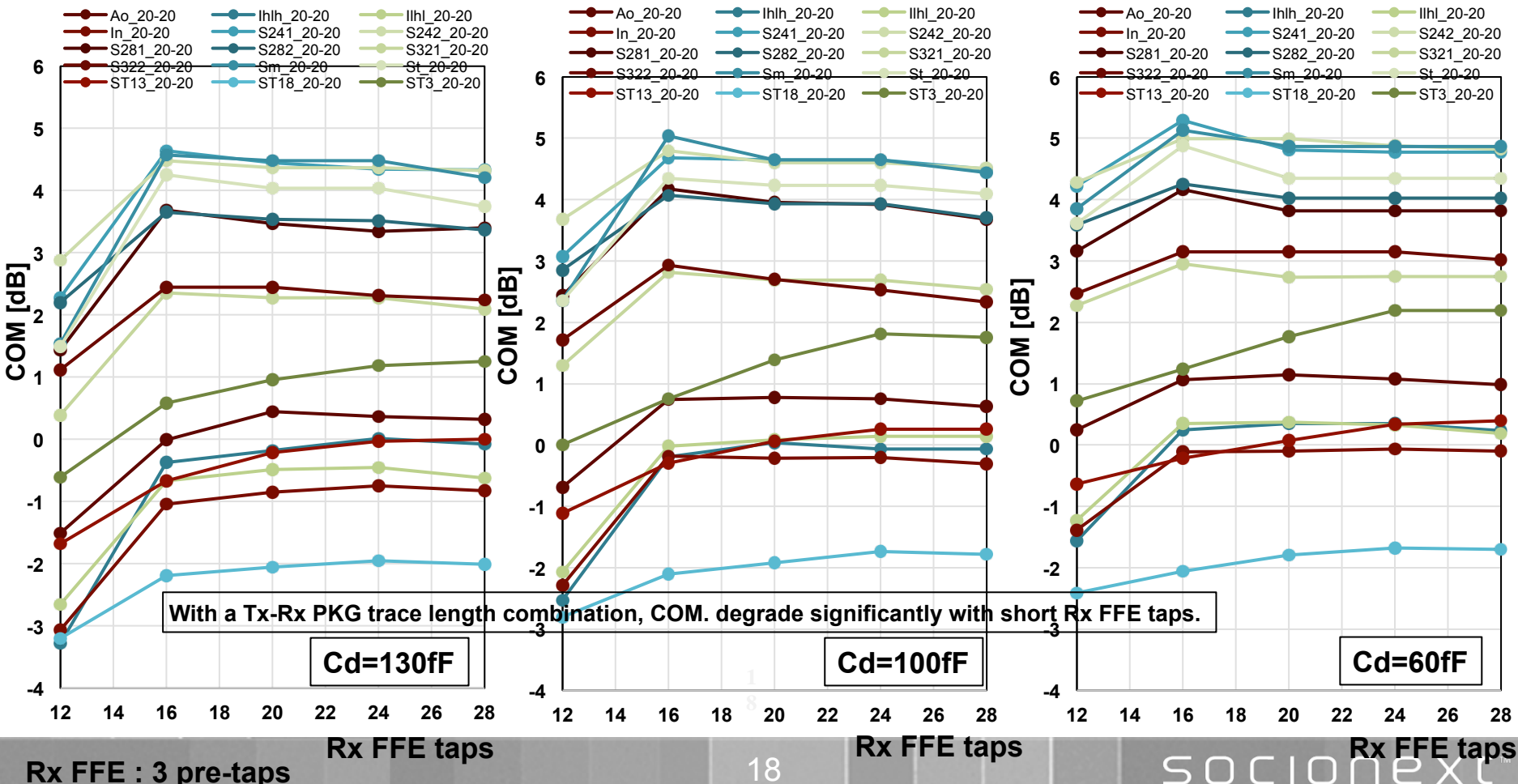




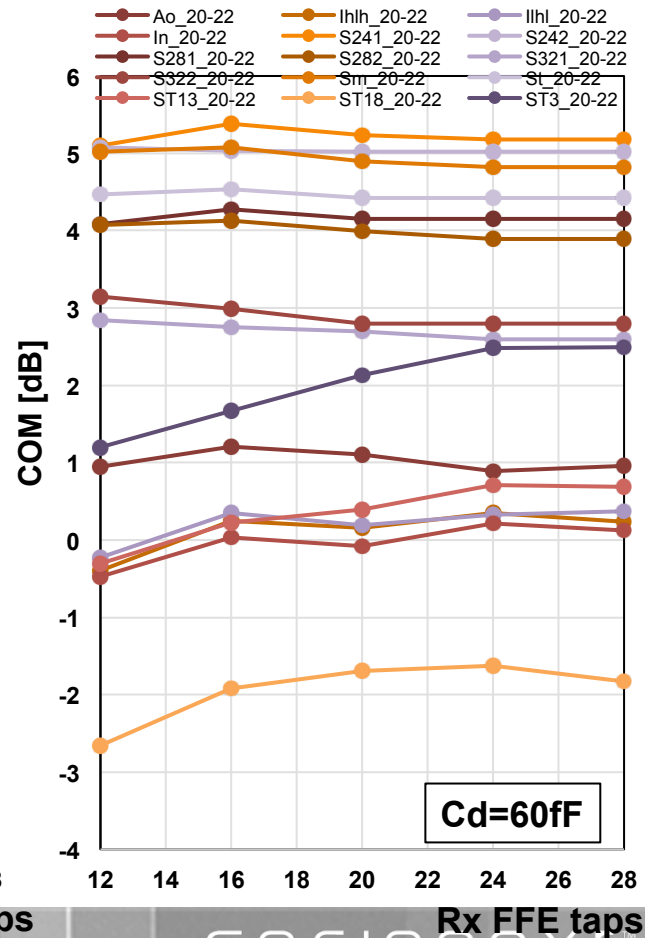
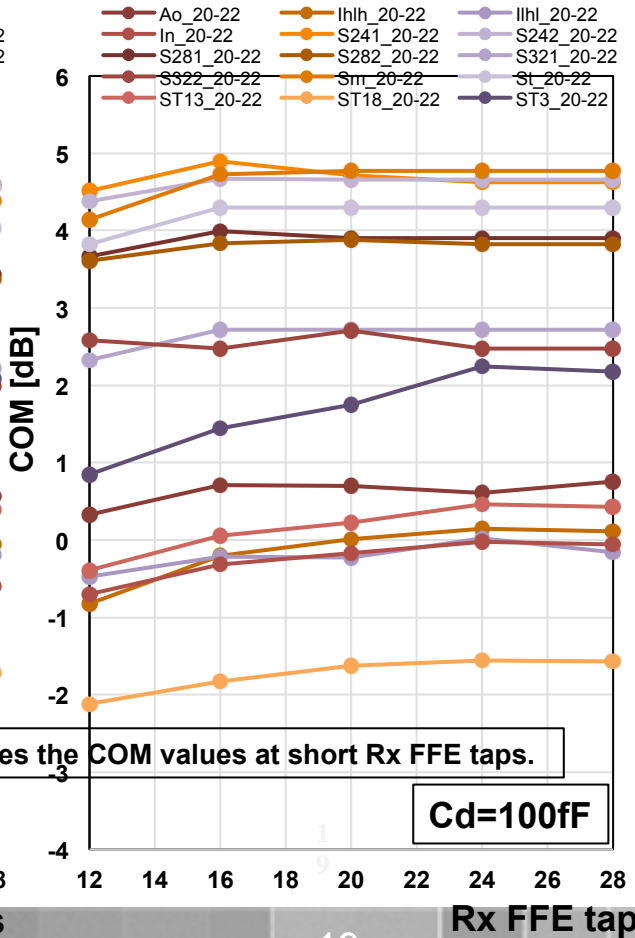
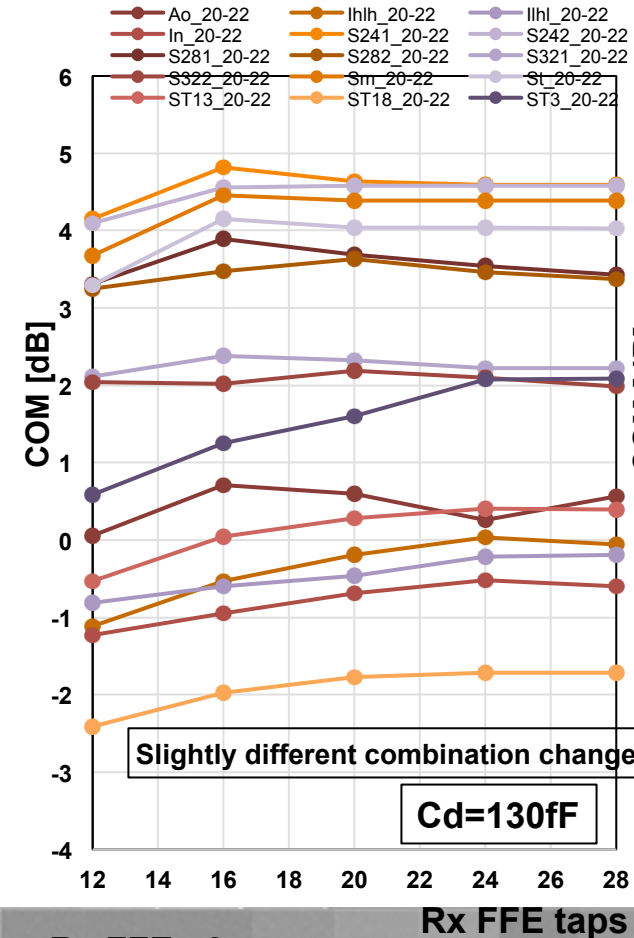
# 4.3 COM vs Rx FFE taps, PKG Tx 30mm/Rx 20mm



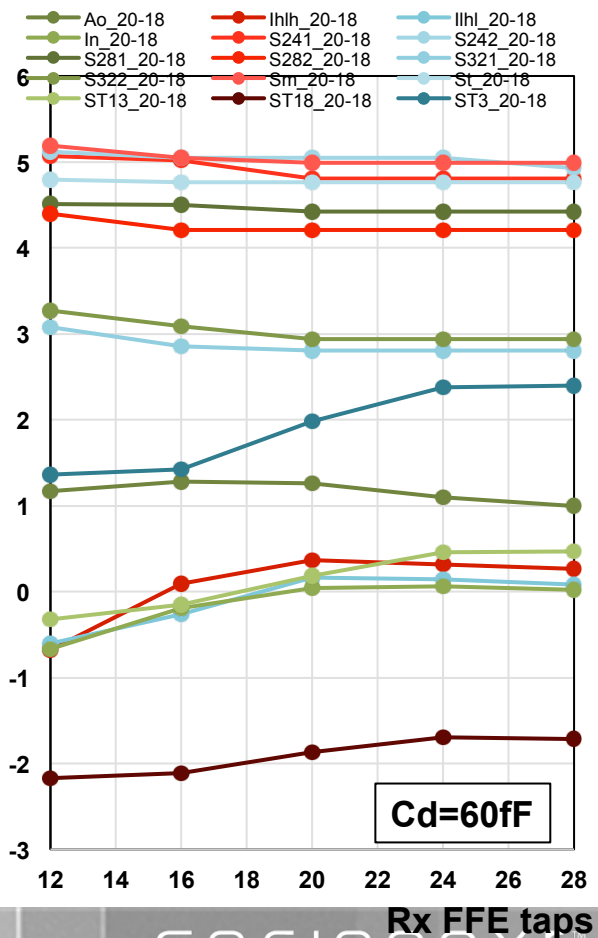
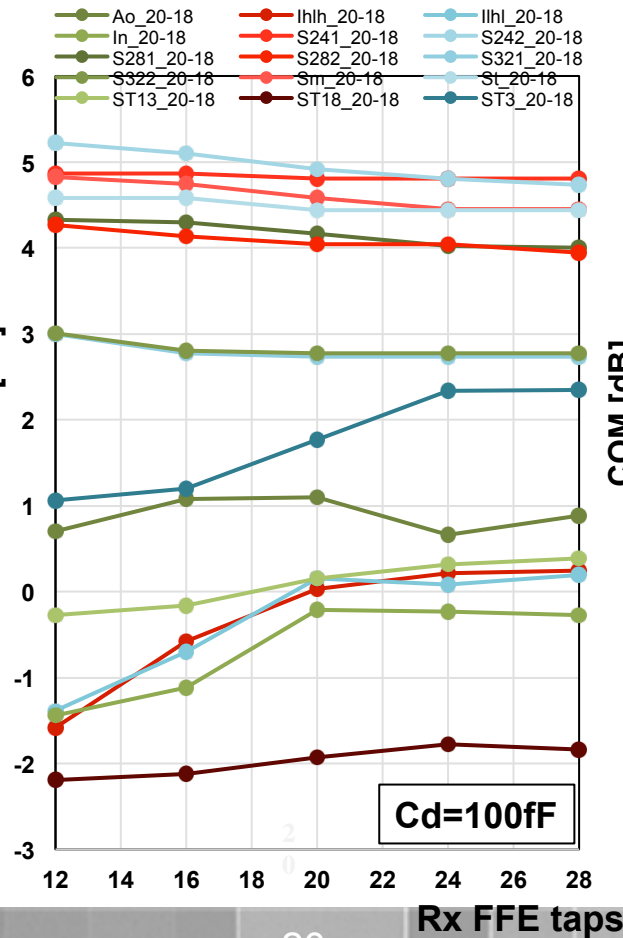
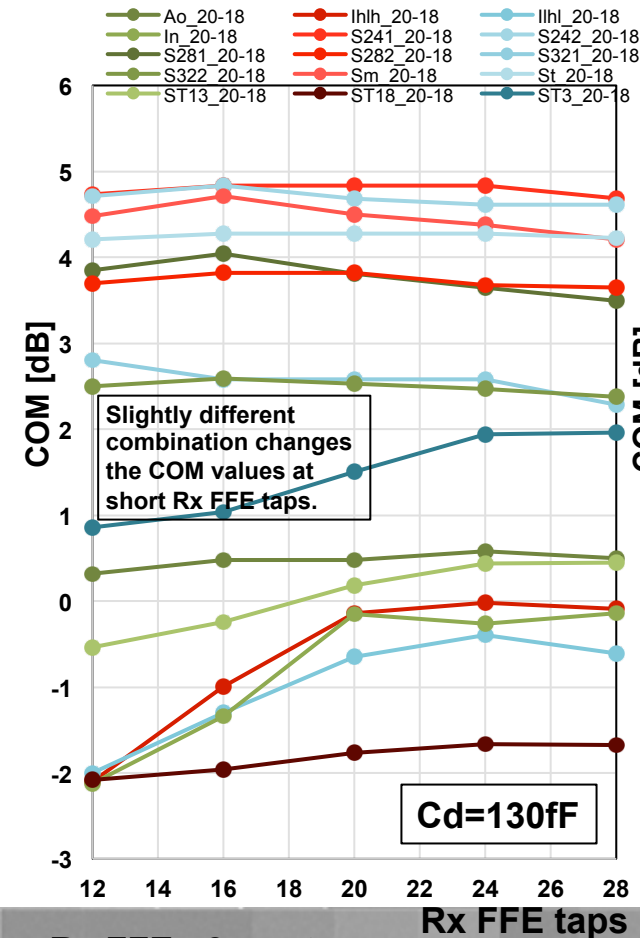
# 4.3 COM vs Rx FFE taps, PKG Tx 20mm/Rx 20mm



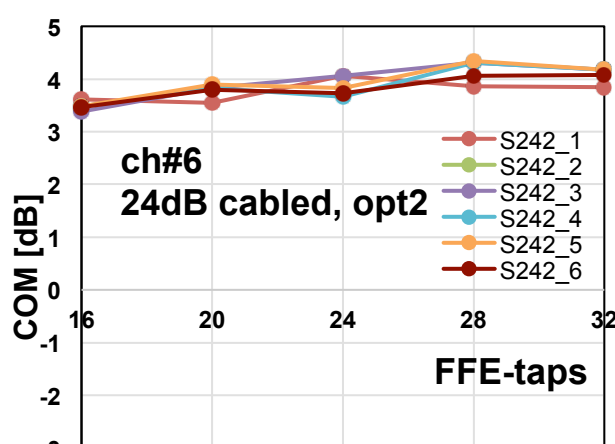
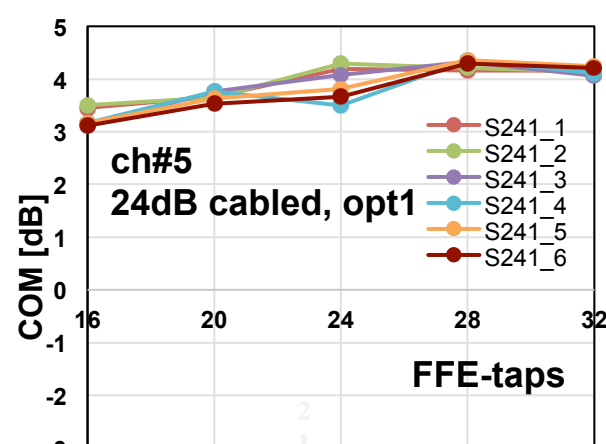
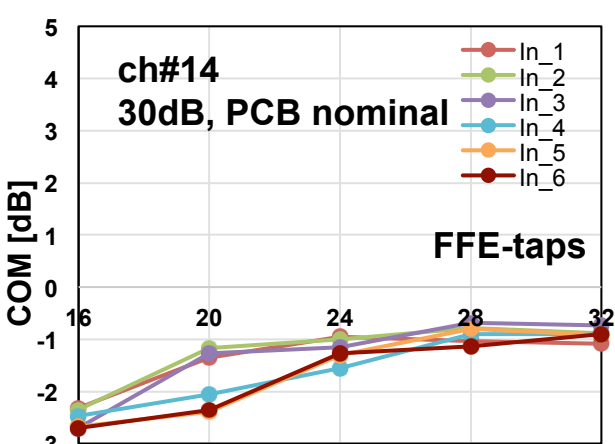
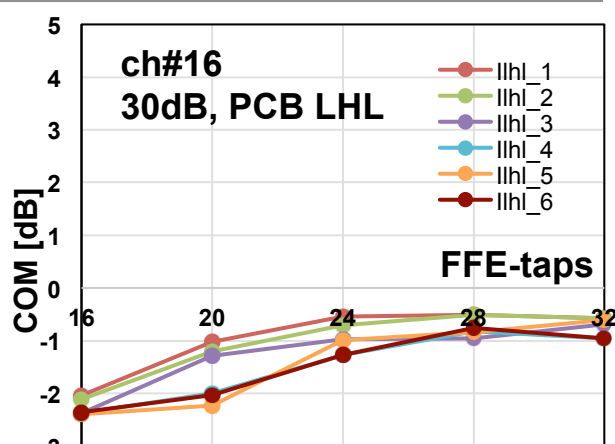
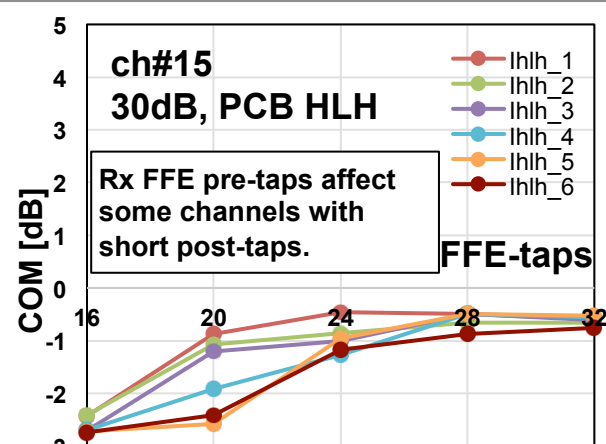
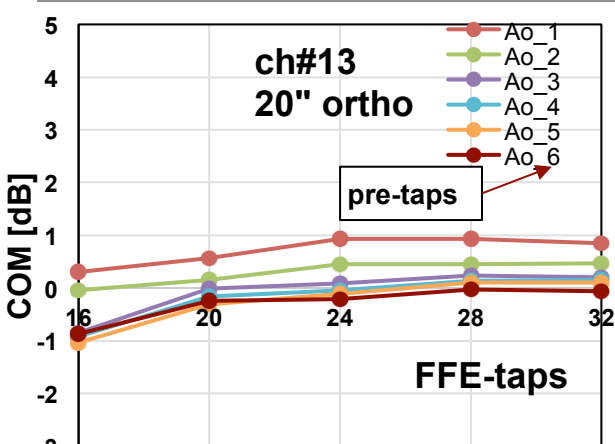
# 4.3 COM vs Rx FFE taps, PKG Tx 20mm/Rx 22mm



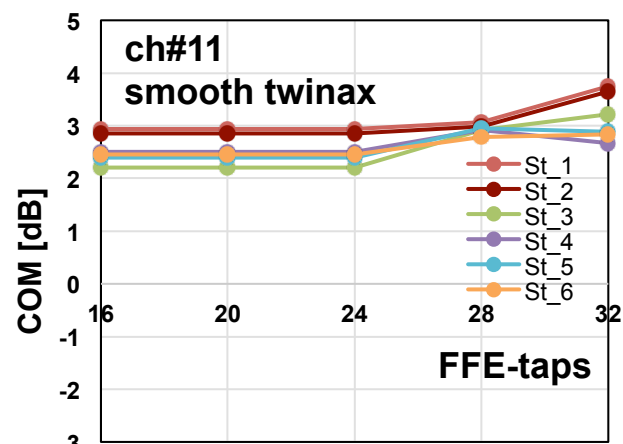
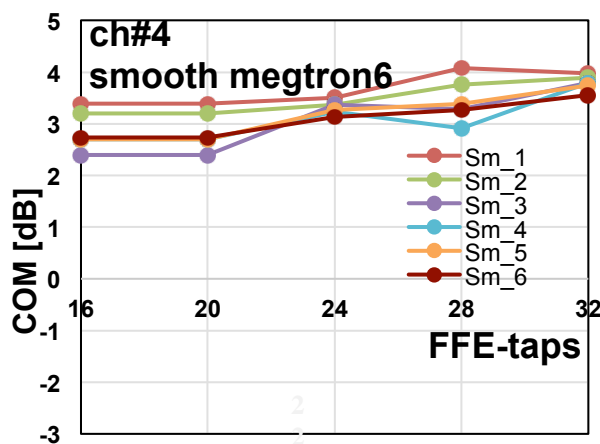
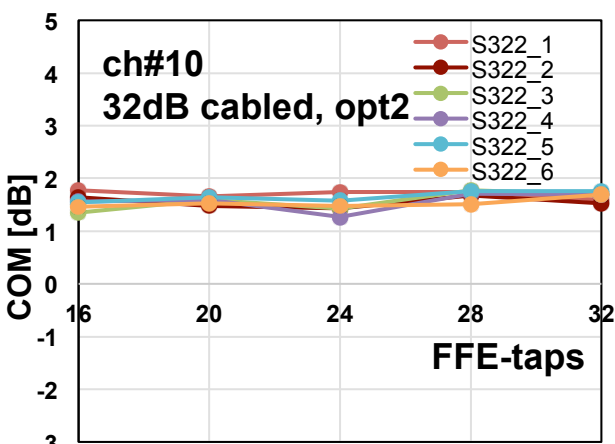
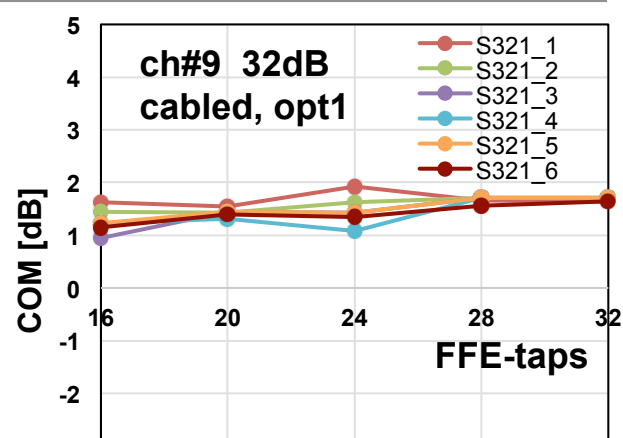
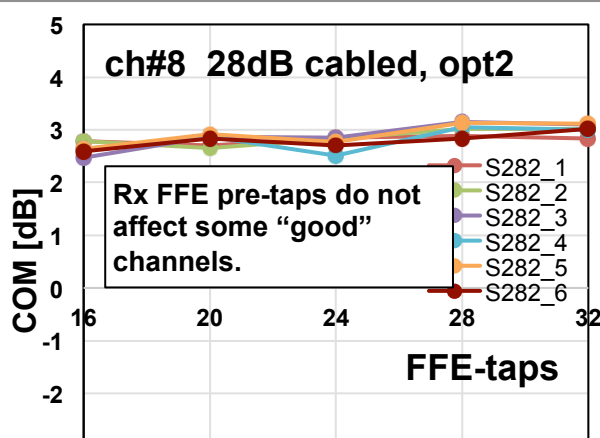
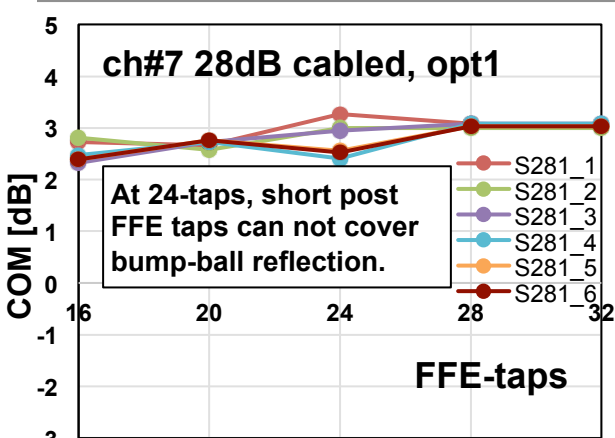
# 4.3 COM vs Rx FFE taps, PKG Tx 20mm/Rx 18mm



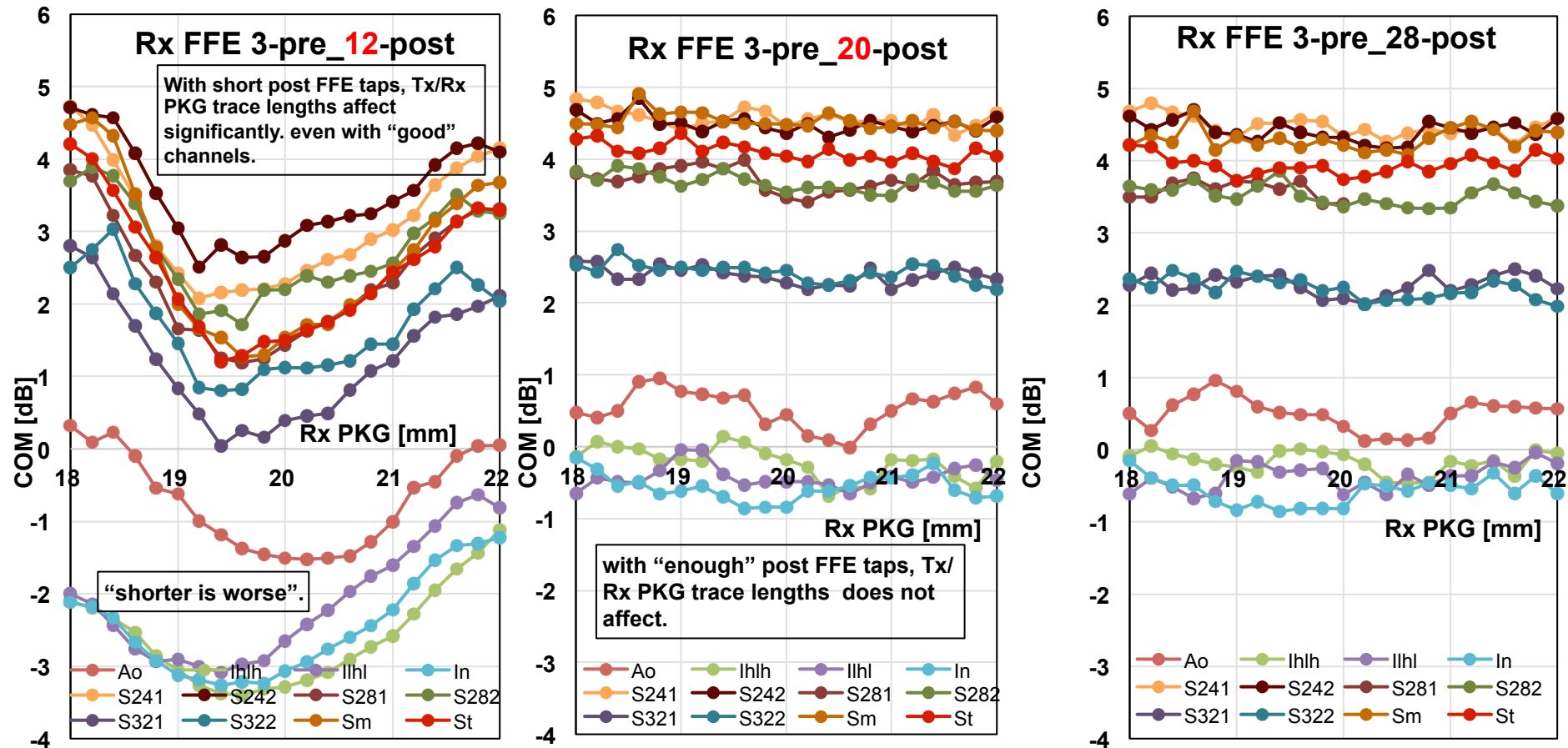
# 4.4 COM vs Rx\_FFE-taps / pre-taps (post+pre+1=total)



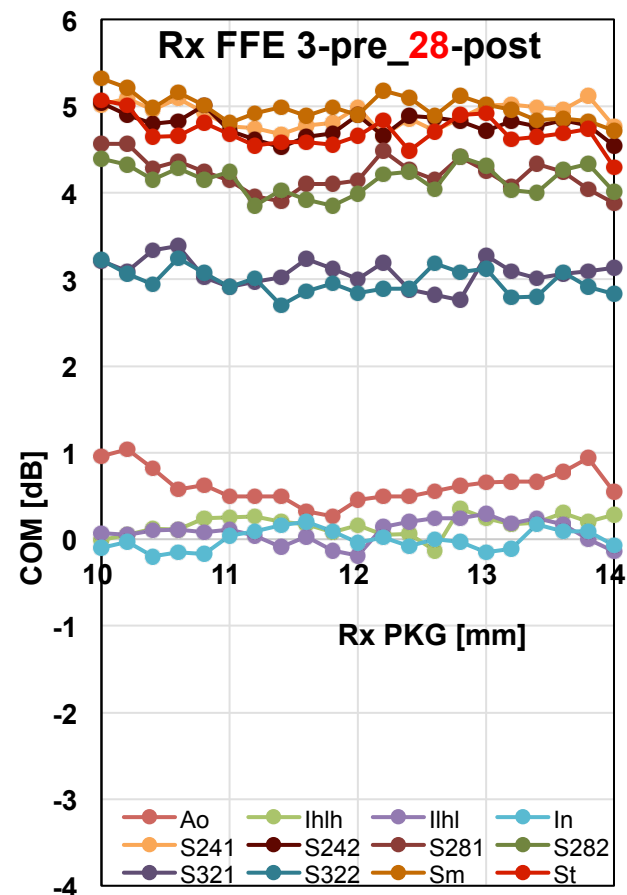
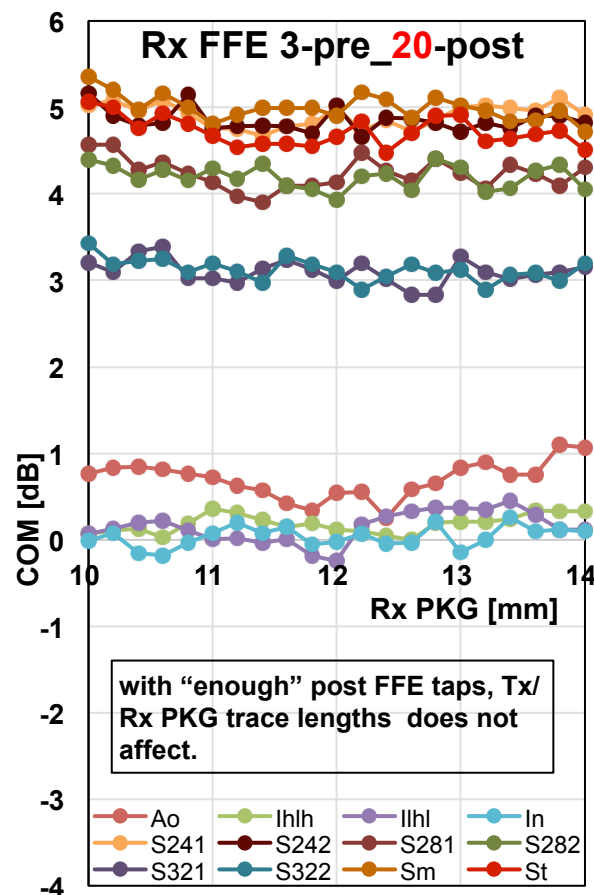
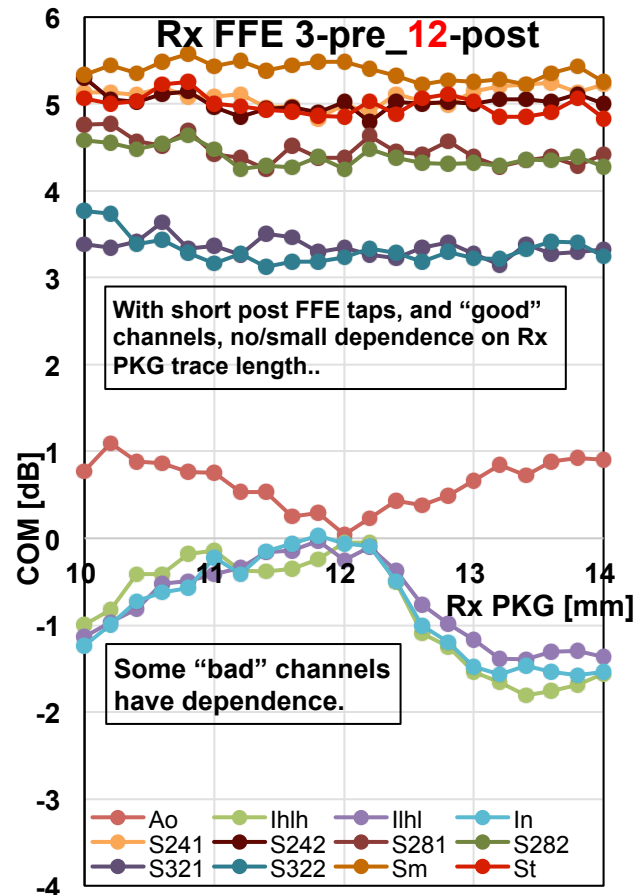
# 4.4 COM vs Rx\_FFE-taps / pre-taps (post+pre+1=total)



# 4.5 COM : Rx PKG trace length (Tx PKG : 20mm)

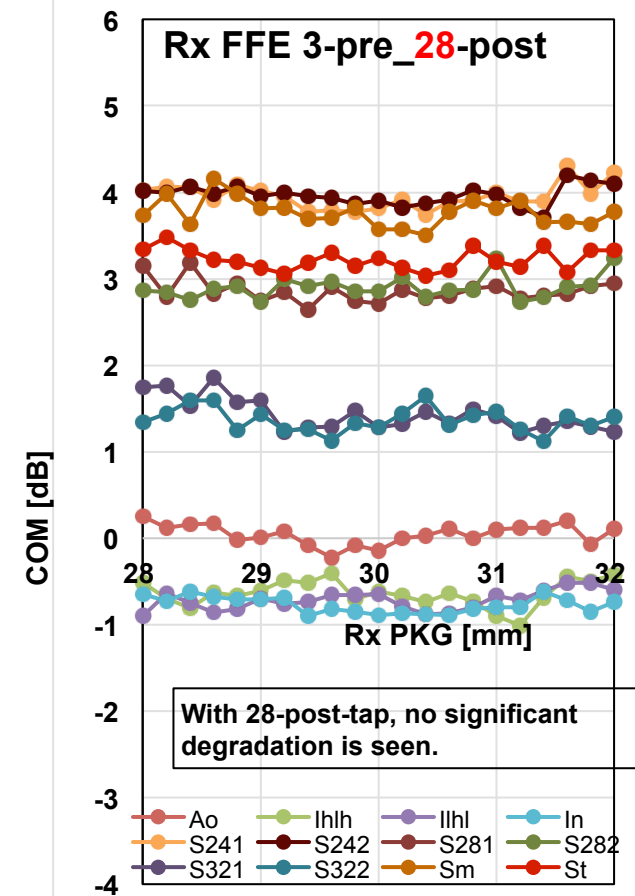
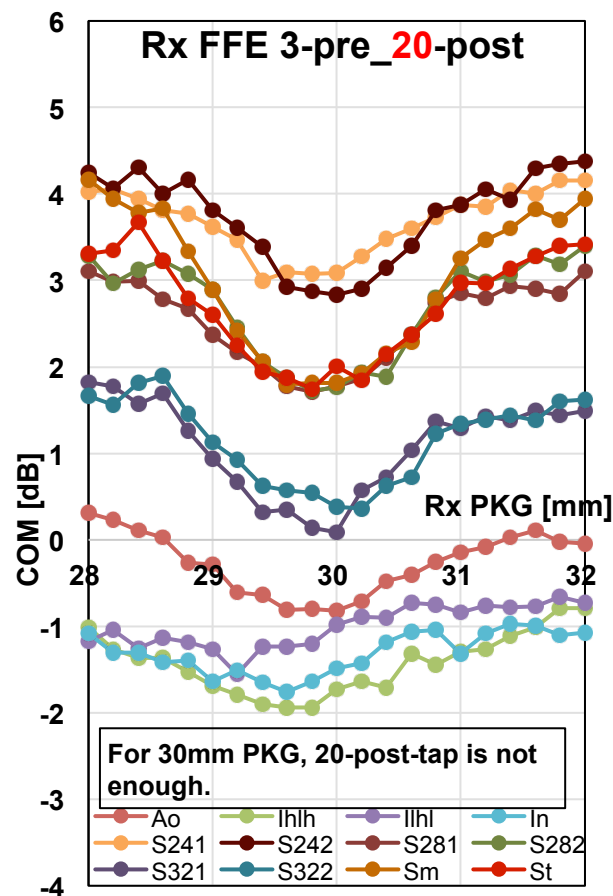
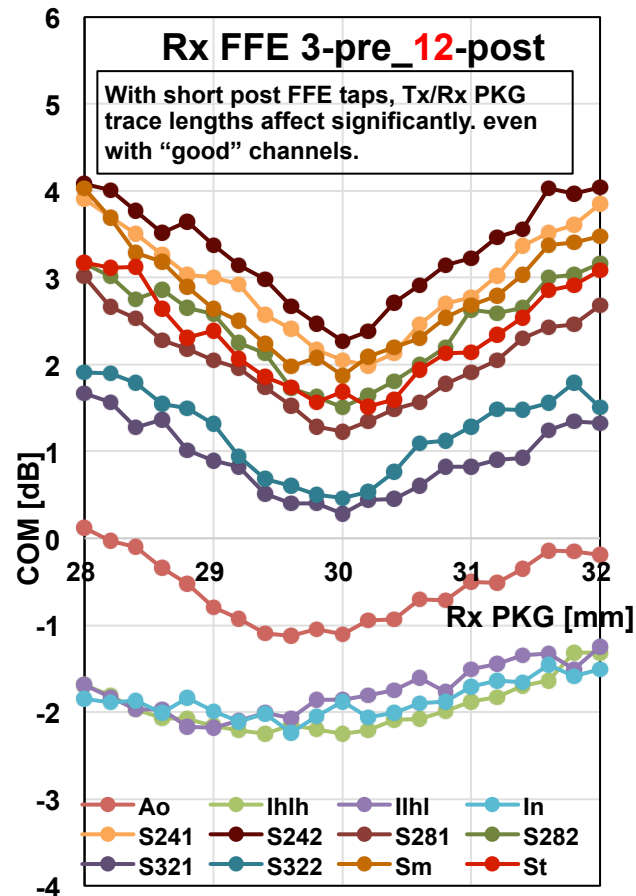


# 4.5 COM : Rx PKG trace length (Tx PKG : 12mm)

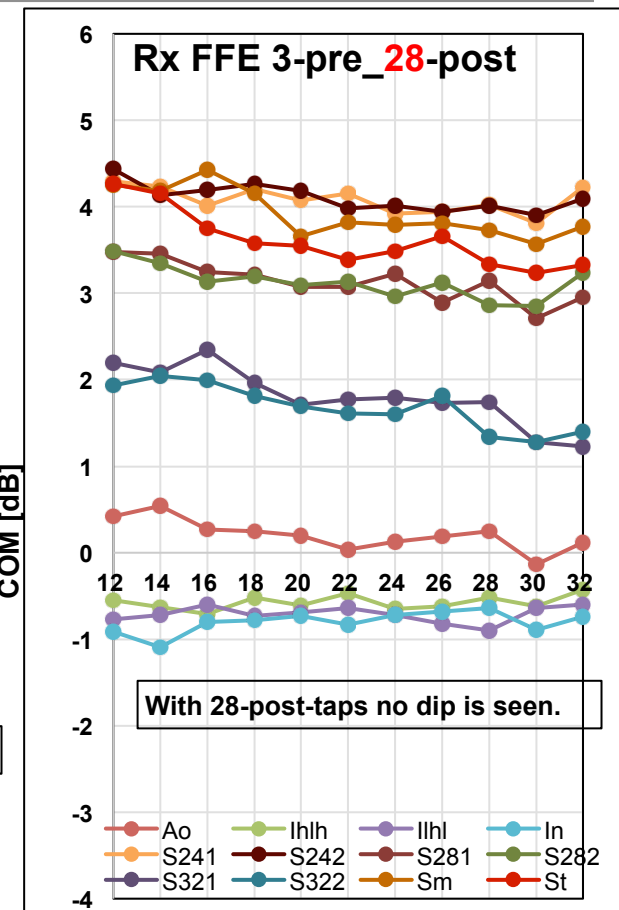
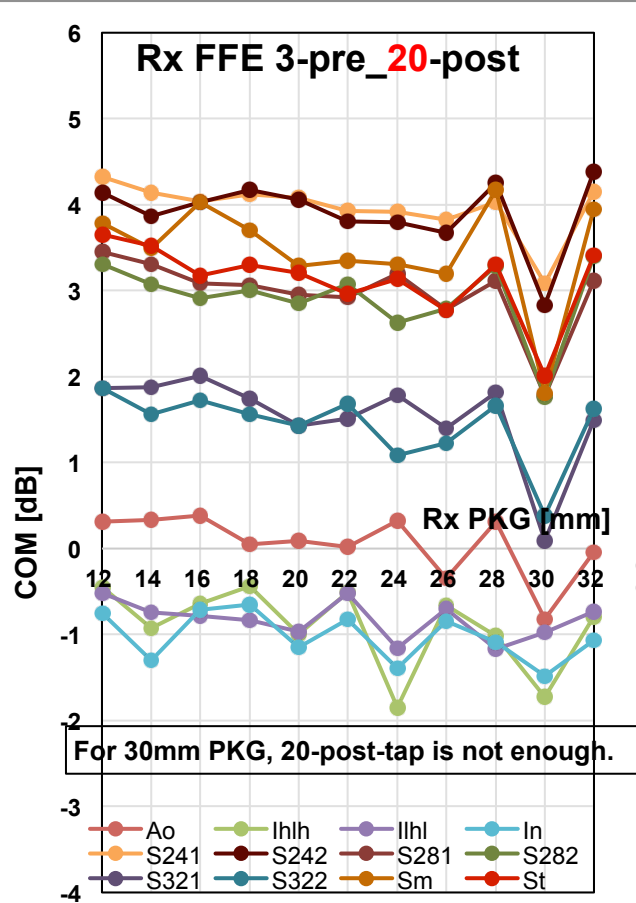
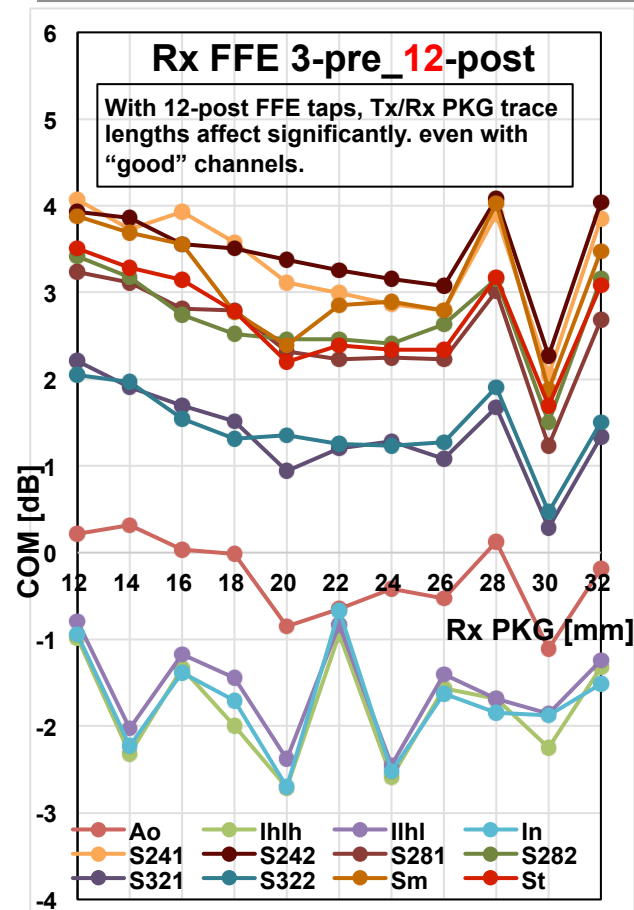




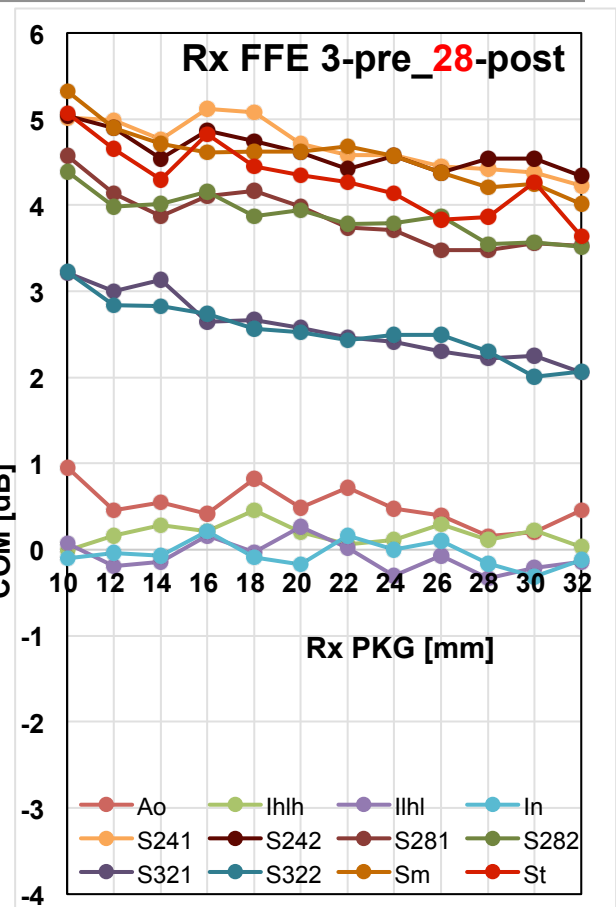
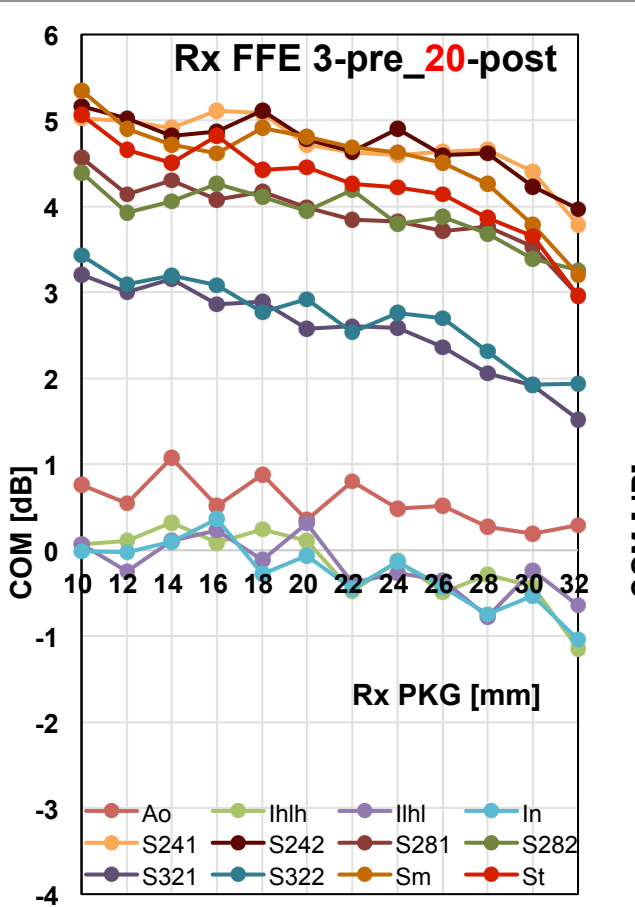
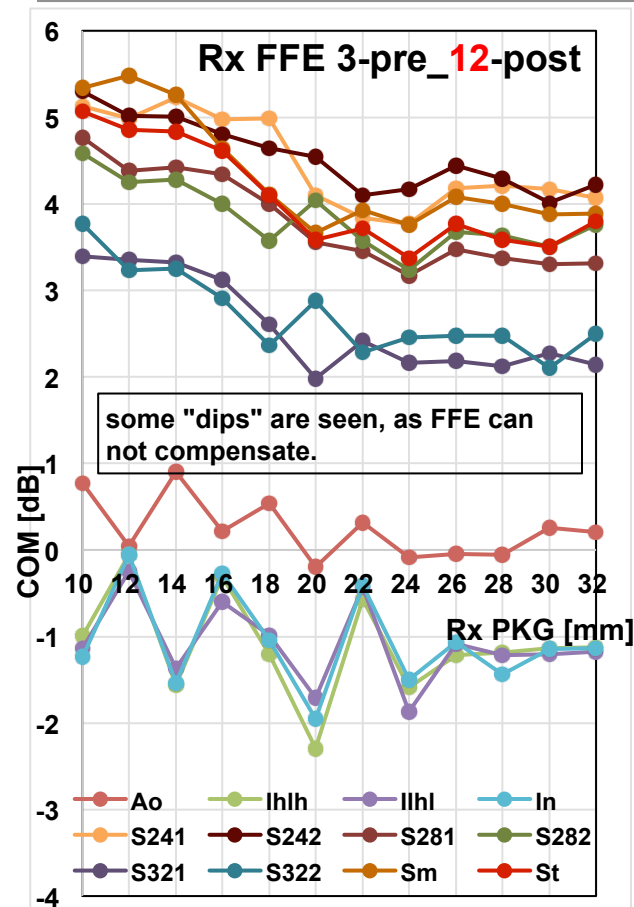
# 4.5 COM : Rx PKG trace length (Tx PKG : 30mm)



# 4.5 COM : Rx PKG trace length (Tx PKG : 30mm)



# 4.5 COM : Rx PKG trace length (Tx PKG : 12mm)



## 5. Observation and Future Work

1. **PKG trace affects long reach transmission.**
  - Mid-PKG trace helps some in case of short Rx-FFE.
2. **Rx PKG trace length together with Tx trace length affects COM values.**
  - In case of short Rx FFE taps, it is significant with some combinations.
  - However, with longer ( $\geq 20$ , 20mmPKG case) taps, the effect is limited or none.
  - With long enough Rx FFE taps for a PKG, channel and PKG characteristics is affected less.
3. **“Good” (less XT, less reflection) channels are also required for transmission, anyway.**
4. **Further investigation needed.**
  - PKG parameters (COM PKG model or need to consider “standard” PKG S-parameter, like "JCOM"(JESD204C) introduced.)
  - Other channel models, compensation parameters/method

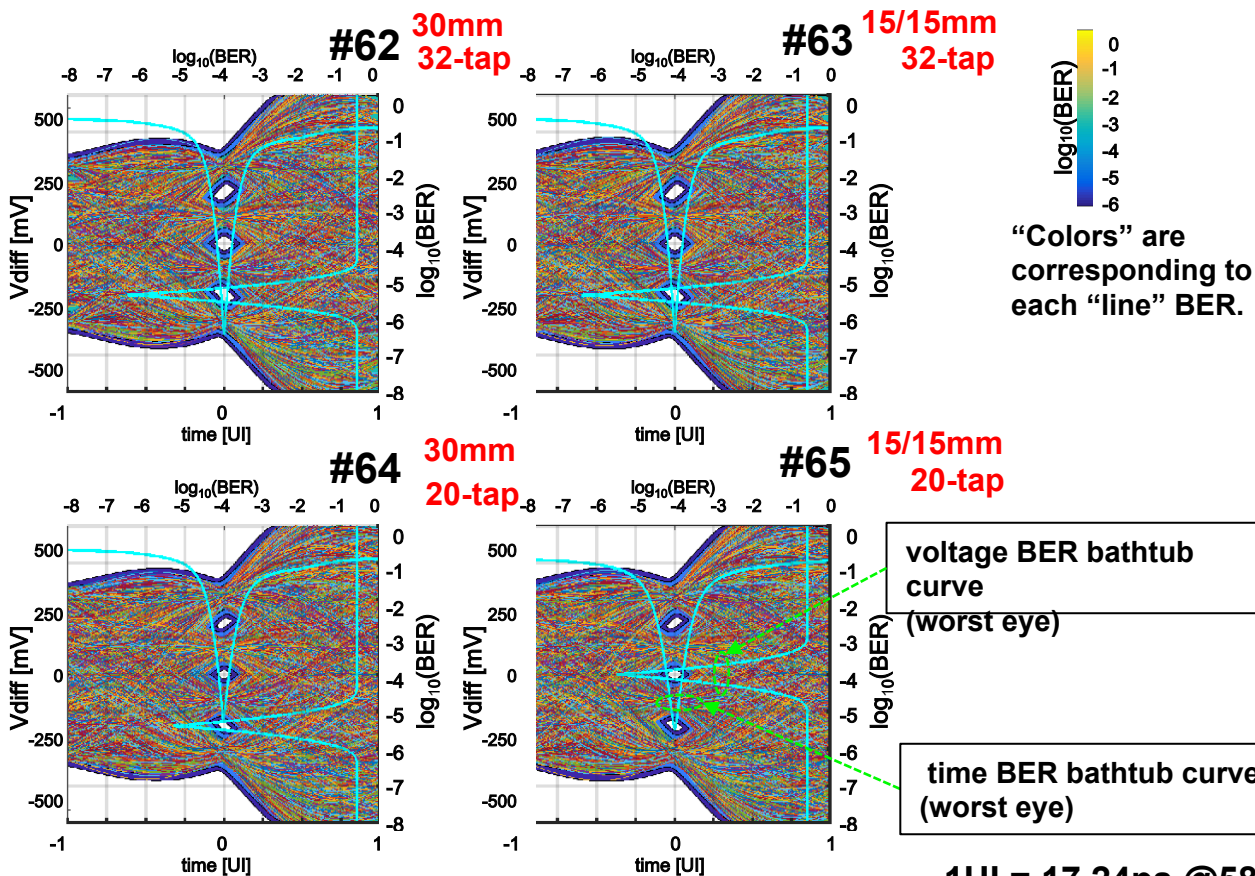
# Thank you!

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for better quality of experience

# backup slides

3  
0

# A. Simulation Result (ch#12, PKG trace)



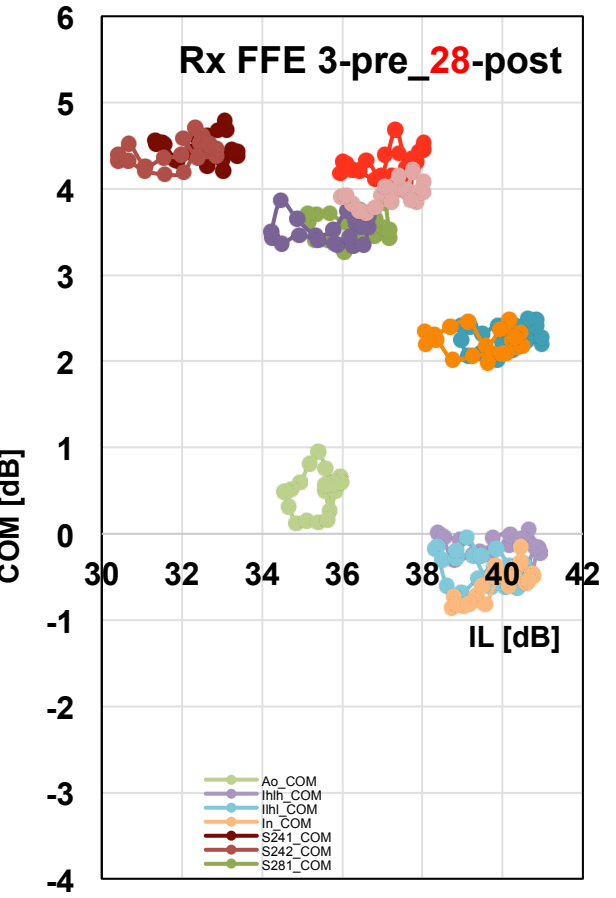
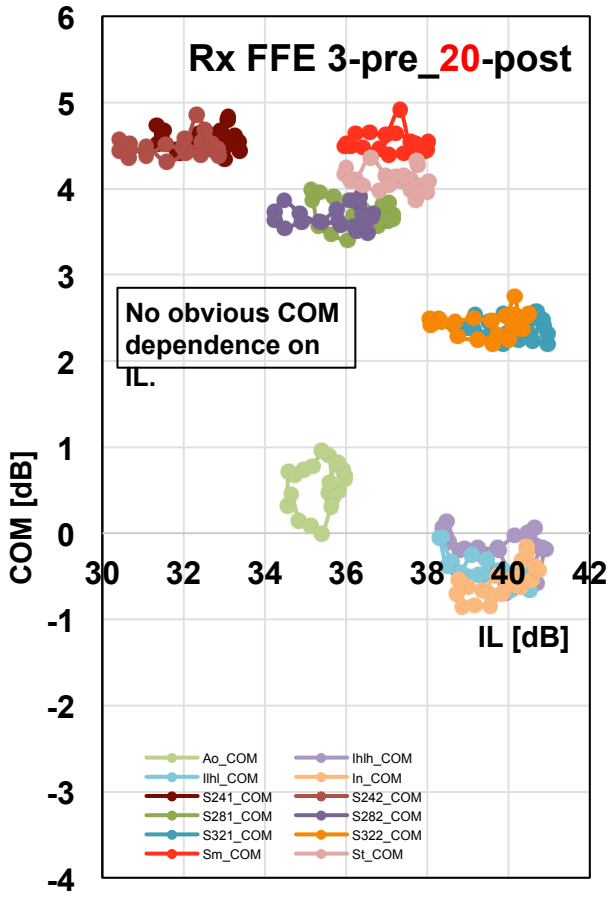
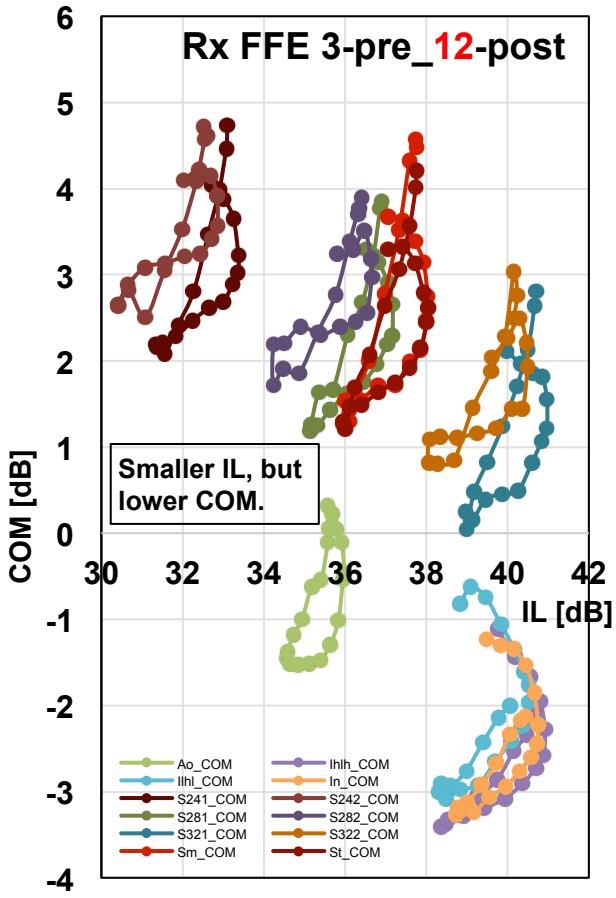
item	unit	#62	#63	#64	#65		
baud rate	GSym/s	58					
channel	type		ch#12, cabled 2m				
	IL	no PKG <sup>*1</sup>	dB			30.5	
		w/ PKG <sup>*2</sup>	dB	43.7	43.9	43.7	43.9
	ICN		mV			0.348	
Tx	FFE	tap/pre		1/0			
	RJrms	mUI		10			
	SNR	dB		32.5			
Tx/ Rx	PKG trace <sup>*3</sup>	mm	30	15/15	30	15/15	
	Cd	fF	160				
	Cp	fF	extracted				
	CTLE	HF/LF	2p-1z/1p-1z				
Rx	eta0	V <sup>2</sup> /GHz	8.2E-9				
	fr	x fb	GHz			3/4	
	FFE	tap/pre	32/5		20/5		
	RJrms	mUI	10				
	eye	EW4	upp	mUI	97	96	68
mid			mUI	134	131	97	102
low			mUI	97	95	66	75
EH4		upp	mV	41	41	26	29
		mid	mV	44	43	26	29
		low	mV	41	41	25	29

criteria  
EW4 ≥ 100mUI  
EH4 ≥ 20mV

\*1 : no PKG @29GHz  
\*2 : with PKG, Cd @29GHz  
\*3 : 30mm : on-PKG-ball PTH  
15/15mm : mid-trace PTH

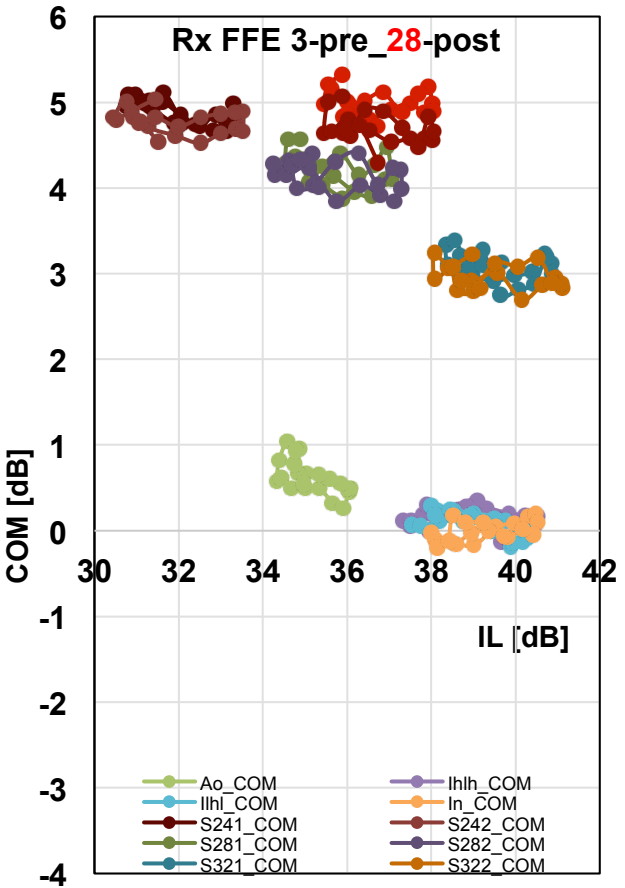
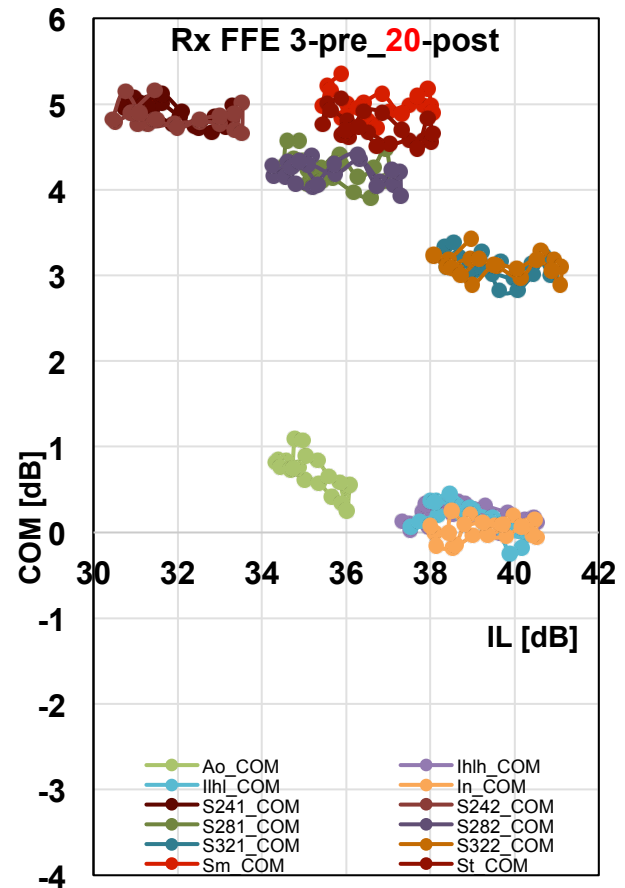
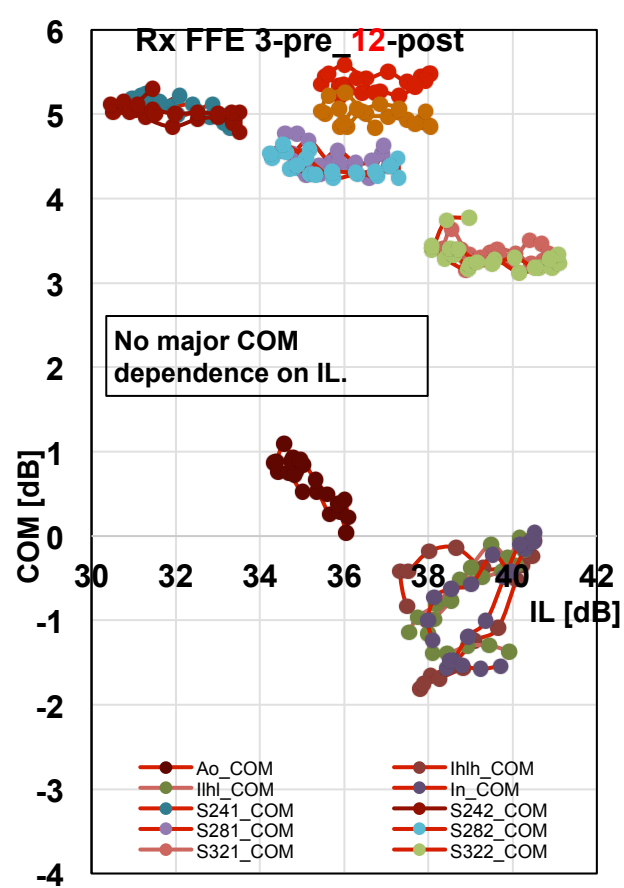
1UI = 17.24ps @58Gbd

# B.1 COM vs IL (with PKG), PKG : Tx 20mm, Rx 18~22mm

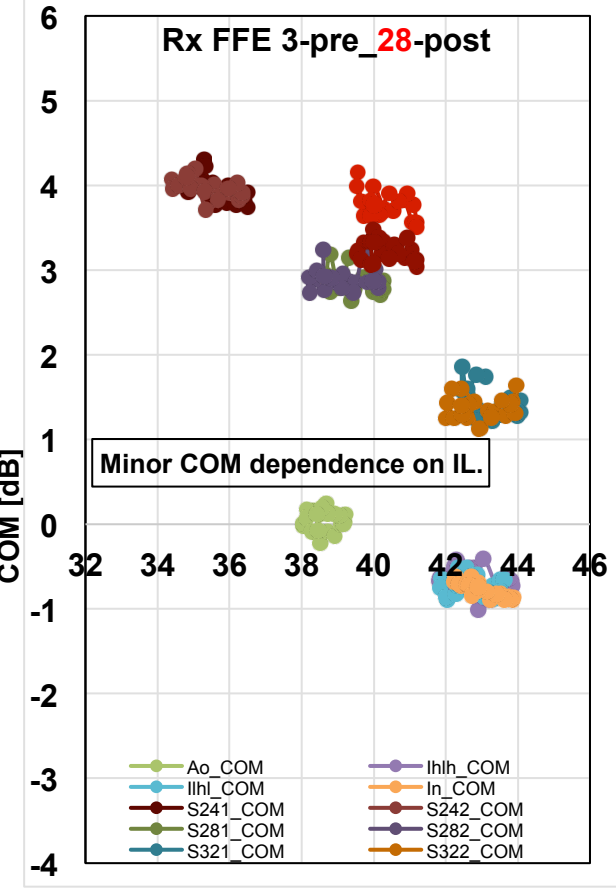
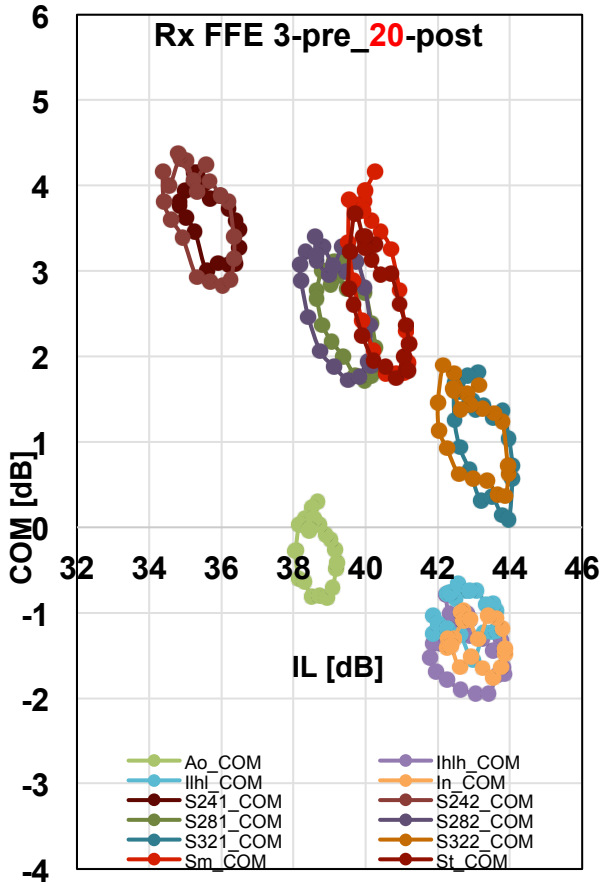
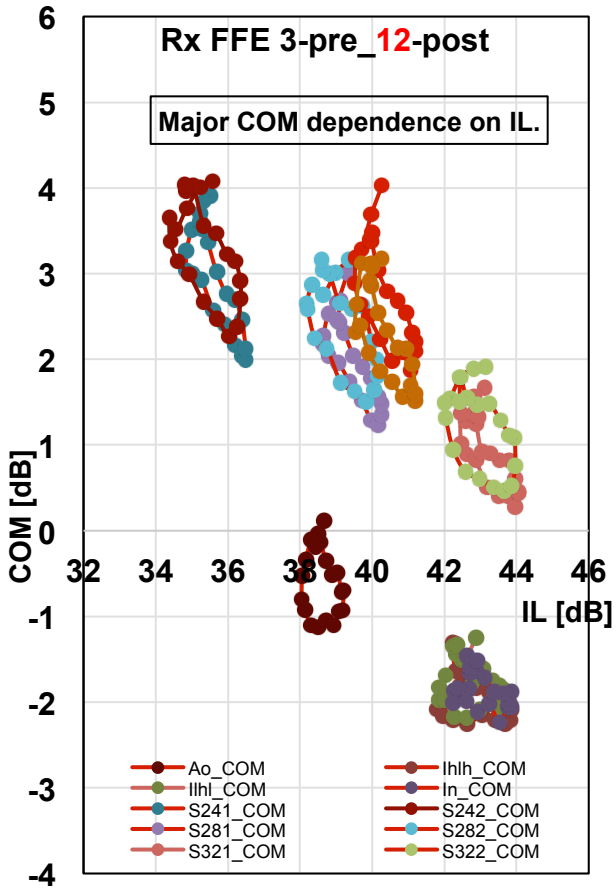




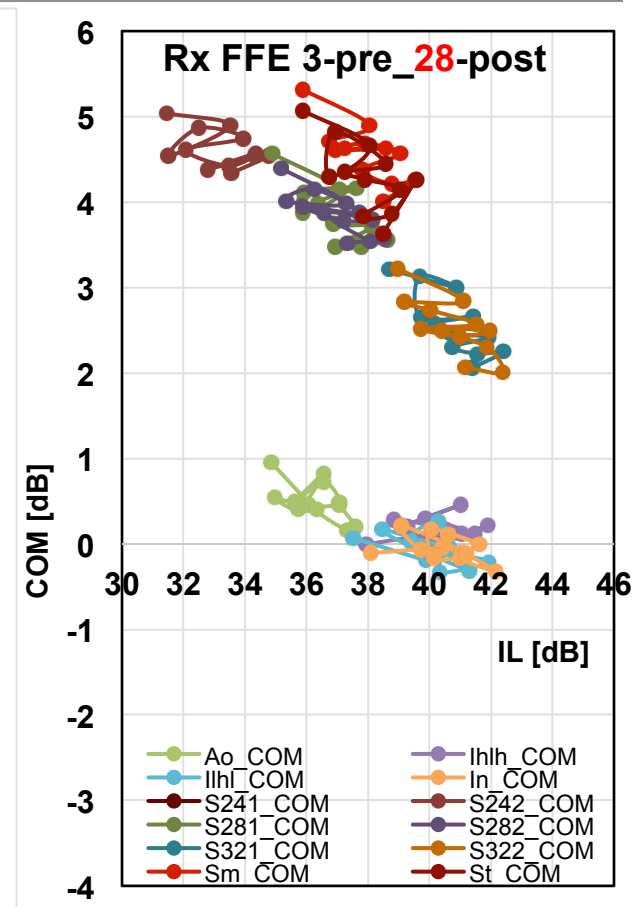
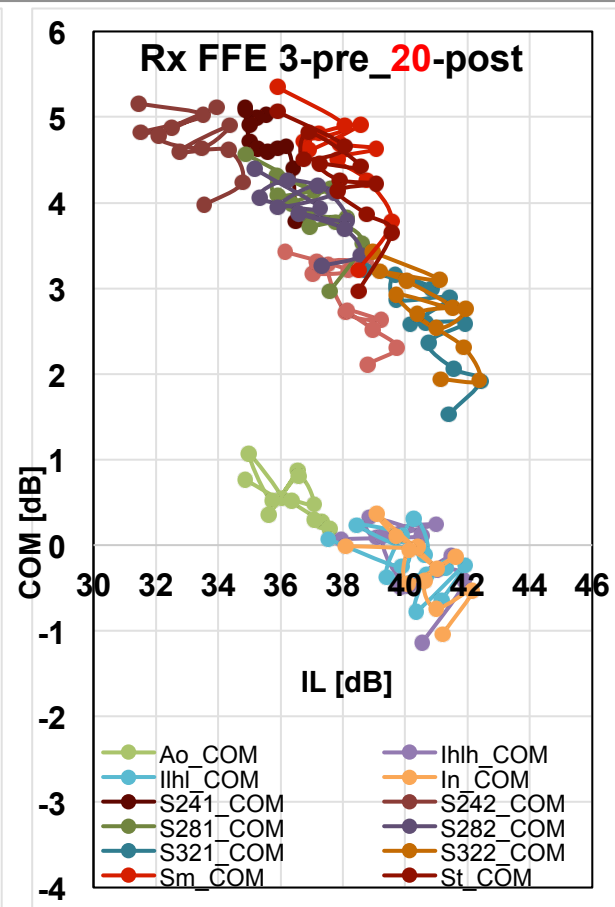
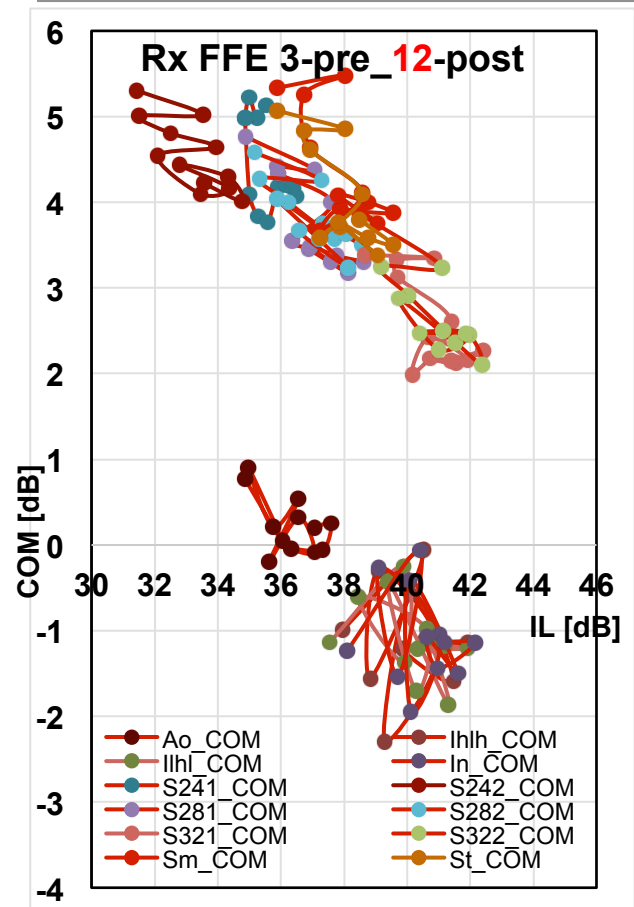
# B.2 COM vs IL (with PKG), PKG : Tx 12mm, Rx 10~14mm

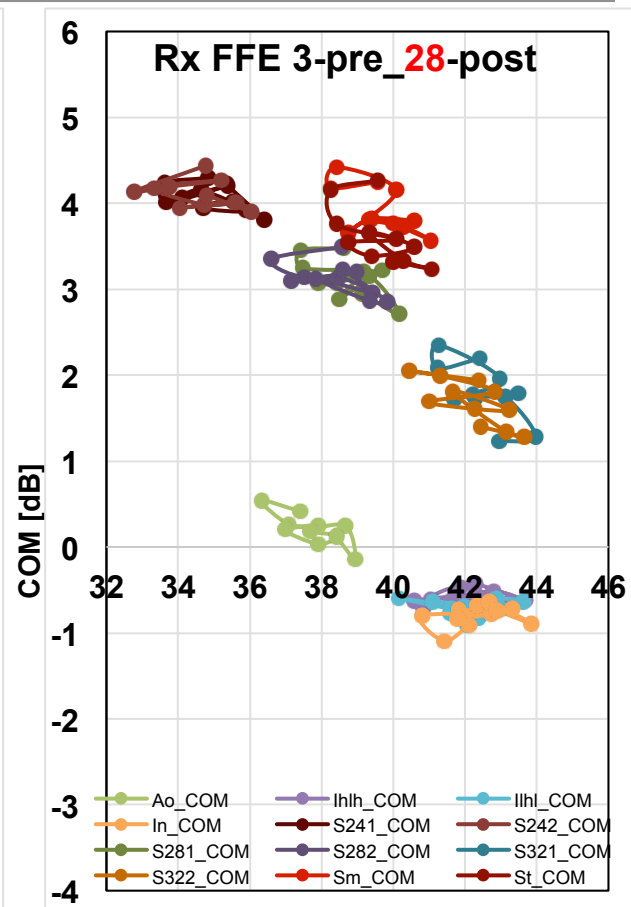
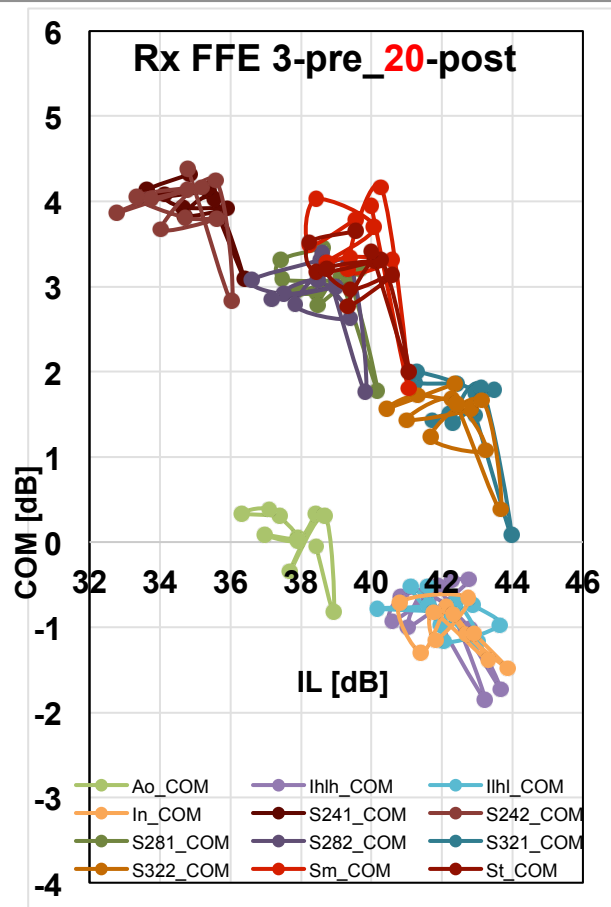
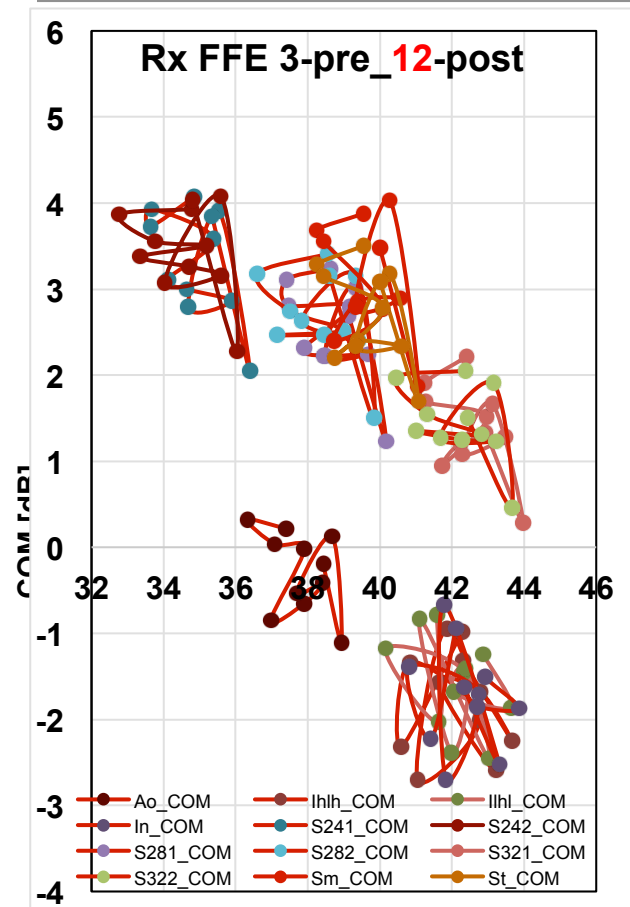


# B.3 COM vs IL (with PKG), PKG : Tx 30mm, Rx 28~32mm



# B.4 COM vs IL (with PKG), PKG : Tx 12mm, Rx 12~32mm





# B. references (backplane channels)

Mellitz

- [1] [http://www.ieee802.org/3/100GEL/public/adhoc/jan03\\_18/mellitz\\_100GEL\\_adhoc\\_01\\_010318.pdf](http://www.ieee802.org/3/100GEL/public/adhoc/jan03_18/mellitz_100GEL_adhoc_01_010318.pdf)
- [2] [http://www.ieee802.org/3/100GEL/public/tools/backplane/mellitz\\_100GEL\\_adhoc\\_03\\_010318.zip](http://www.ieee802.org/3/100GEL/public/tools/backplane/mellitz_100GEL_adhoc_03_010318.zip)
- [3] [http://www.ieee802.org/3/100GEL/public/tools/backplane/mellitz\\_100GEL\\_adhoc\\_02\\_010318.zip](http://www.ieee802.org/3/100GEL/public/tools/backplane/mellitz_100GEL_adhoc_02_010318.zip)
- [4] [http://www.ieee802.org/3/100GEL/public/tools/backplane/mellitz\\_100GEL\\_adhoc\\_04\\_010318.zip](http://www.ieee802.org/3/100GEL/public/tools/backplane/mellitz_100GEL_adhoc_04_010318.zip)
  
- [5] [http://www.ieee802.org/3/ck/public/adhoc/aug15\\_18/mellitz\\_3ck\\_adhoc\\_02\\_081518.pdf](http://www.ieee802.org/3/ck/public/adhoc/aug15_18/mellitz_3ck_adhoc_02_081518.pdf)
- [6] [http://www.ieee802.org/3/ck/public/tools/backplane/mellitz\\_3ck\\_adhoc\\_02\\_081518\\_cabledbackplane.zip](http://www.ieee802.org/3/ck/public/tools/backplane/mellitz_3ck_adhoc_02_081518_cabledbackplane.zip)
  
- [7] [http://www.ieee802.org/3/ck/public/adhoc/july25\\_18/mellitz\\_3ck\\_adhoc\\_02\\_072518.pdf](http://www.ieee802.org/3/ck/public/adhoc/july25_18/mellitz_3ck_adhoc_02_072518.pdf)
- [8] [http://www.ieee802.org/3/ck/public/tools/backplane/mellitz\\_3ck\\_adhoc\\_02\\_072518\\_channels.zip](http://www.ieee802.org/3/ck/public/tools/backplane/mellitz_3ck_adhoc_02_072518_channels.zip)
  
- [9] [http://www.ieee802.org/3/ad\\_hoc/ngrates/public/17\\_05/mellitz\\_nea\\_01a\\_0517.pdf](http://www.ieee802.org/3/ad_hoc/ngrates/public/17_05/mellitz_nea_01a_0517.pdf)
- [10] [http://www.ieee802.org/3/ad\\_hoc/ngrates/public/17\\_05/mellitz\\_nea\\_03\\_0517.zip](http://www.ieee802.org/3/ad_hoc/ngrates/public/17_05/mellitz_nea_03_0517.zip)

Zambell

- [11] [http://www.ieee802.org/3/100GEL/public/18\\_03/zambell\\_100GEL\\_01a\\_0318.pdf](http://www.ieee802.org/3/100GEL/public/18_03/zambell_100GEL_01a_0318.pdf)
- [12] [http://www.ieee802.org/3/100GEL/public/tools/backplane/zambell\\_100GEL\\_02\\_0318.zip](http://www.ieee802.org/3/100GEL/public/tools/backplane/zambell_100GEL_02_0318.zip)

Heck

- [13] [http://www.ieee802.org/3/100GEL/public/18\\_01/heck\\_100GEL\\_01\\_0118.pdf](http://www.ieee802.org/3/100GEL/public/18_01/heck_100GEL_01_0118.pdf)
- [14] [http://www.ieee802.org/3/100GEL/public/tools/backplane/heck\\_100GEL\\_85ohm\\_hlh\\_01\\_011718.zip](http://www.ieee802.org/3/100GEL/public/tools/backplane/heck_100GEL_85ohm_hlh_01_011718.zip)
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