COM Parameters Proposal for KR

Mau-Lin Wu, Pei-Rong Li, Yuan-Hao Tung
MediaTek
IEEE 802.3ck Task Force

Outline

- Background and Motivation
- Selected 9 KR Channels Analysis
- COM Sensitivity Analysis & Proposals
  - N_b
  - C_d
  - b_max(1) & b_max(2..N_b)
  - Eta_0
  - TX FIR
- Proposal summary

Supporters

- Chien-Ping Kao, Intel

Background and Motivation

- During 2019 Long Beach interim meeting,
  - Baseline package model was adopted [minutes_3ck_0119_unapproved.pdf, Straw poll #2]
    - However, 'C_d' is TBD
  - 9 KR channels were selected as baseline [kochuparambil_3ck_01c_0119.pdf]
  - COM 2.58 released [mellitz_3ck_01_0119.pdf]
  - The majority prefers DFE as referenced RX in COM [minutes_3ck_0119_unapproved.pdf, Straw poll #5]
- Motivations
  - Performed COM sensitivity by 42 IEEE channels (inc. 9 KR baseline channels)
    - Provide inputs to decide COM settings
- Observations
  - Only 28dB IL KR channels with small enough ICN & ILD can pass 3 dB COM threshold by >= 22-tap DFE
    - COM is sensitive to 'N_b' in the range of 20 to 24
  - COM is sensitive to 'C_d' if N_b <= 20
  - Extending b_max(2..N_b)
    - Error propagation shall not be an concern by b_max(2..N_b) = 0.35
  - Range of TX FIR c(1) shall be extended

Baseline COM Parameters

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	[1.1e-4 1.1e-4]	nF	[TX RX]
z_p select	[1 2]		[test cases to run]
z_p (TX)	[12.32; 1.8 1.8]	mm	[test cases]
z_p (NEXT)	[12.32; 1.8 1.8]	mm	[test cases]
z_p (FEXT)	[12.32; 1.8 1.8]	mm	[test cases]
z_p (RX)	[12.32; 1.8 1.8]	mm	[test cases]
C_p	[0.87e-4 0.87e-4]	nF	[TX RX]
R_0	50	Ohm	
R_d	[50 50]	Ohm	[TX RX]
A_v	0.413	V	sp/vf=.694
A_fe	0.413	V	sp/vf=.694
A_ne	0.608	V	
L	4		
M	32		
filter and Eq			
f_r	0.75	*fb	
c(0)	0.54		min
c(-1)	[-0.34:0.02:0]		[min:step:max]
c(-2)	[0:0.02:0.12]		[min:step:max]
c(-3)	[-0.06:0.02:0]		[min:step:max]
c(1)	[-0.1:0.05:0]		[min:step:max]
N_b	24	UI	
b_max(1)	0.85		
b_max(2..N_b)	0.2		
g_DC	[-20:1:0]	dB	[min:step:max]
f_z	21.25	GHz	
f_p1	21.25	GHz	
f_p2	53.125	GHz	
g_DC_HP	[-6:1:0]		[min:step:max]
f_HP_PZ	0.6640625	GHz	
ffe_pre_tap_len	0	UI	
ffe_post_tap_len	0	UI	
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	0		

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	0	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\100GEL_WG_[date]\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	CR_eval_	
COM_CONTRIBUTION	0	logical
Operational		
COM Pass threshold	3	dB
ERL Pass threshold	10.5	dB
DER_0	1.00E-04	
T_r	6.16E-03	ns
FORCE_TR	1	logical
Include PCB	0	logical
TDR and ERL options		
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	logical
TR_TDR	0.01	ns
N	1000	
TDR_Butterworth	1	logical
beta_x	1.70E+09	
rho_x	0.25	
fixture delay time	0	enter sec
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/V3 parameter		
Parameter	Setting	Units
package_tl_gamma0_a1_a2	[0 0.0009909 0.0002772]	
package_tl_tau	6.141E-03	ns/mm
package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm

Table 92J/V12 parameter		
Parameter	Setting	
board_tl_gamma0_a1_a2	Setting	
board_tl_tau	*[0 0.000599 0.0001022]*	ns/mm
board_Z_c	*6.20E-03*	Ohm
z_bp (TX)	*90*	mm
z_bp (NEXT)	*92.7*	mm
z_bp (FEXT)	*92.7*	mm
z_bp (RX)	*92.7*	mm

Selected 9 KR Channels

- 9 KR channels were selected as baseline in ‘kochuparambil_3ck_01c_0119.pdf’

Contribution	Channel	CH ID
heck_3ck_01_1118	28dB Cabled Backplane/Cable_BKP_28dB_0p575m_more_isi	1
	16dB Cabled Backplane/Cable_BKP_16dB_0p575m_more_isi	2
mellitz_3ck_adhoc_02_081518	24,28,30dB including BGA Via/CaBP_BGAVia_Opt2_28dB	3
tracy_3ck_01_0119	Traditional Backplane Channels/Std_BP_12inch_Meg7	4
	Orthogonal Backplane Channels/DPO_IL_12dB	5
kareti_3ck_01a_1118	Measured Orthogonal Backplane Channels/OAch4	6
	Measured Orthogonal Backplane Channels/Och4	7
	Measured Cabled Backplane Channels/CAch3_b2	8
	Measured Traditional Backplane Channels/Bch2_a7p5_7	9

COM Parameters of 9 KR channels

Selected 9 KR Channels – Small IL

- N_b = 16/20/24/28 for DFE ref. RX
- 802.3ck KR objective : IL up to 28dB [CH 2, 3, 4, 5, 8, 9 meets]
  - CH 2, 3, 5 pass 3dB COM easily – small IL, ICN, or ILD
  - CH 4, 8 pass 3dB COM only when **N_b >= 22** – to cover 'double-reflection' due to package
  - CH 9 can't pass 3dB COM even N_b=32 – too large ICN

CH ID	IL (wo PKG, dB)	ICN (mV)	FOM_ILD (dB)	COM (dB)				Min. N_b for 3dB COM
				N_b=16	N_b=20	N_b=24	N_b=28	
1	29.42	1.571	1.074	1.25	1.27	2.34	2.52	150 - 200
2	16.39	2.151	0.864	3.38	3.68	5.32	5.68	6
3	26.72	0.659	0.514	3.80	3.85	4.54	4.55	2
4	16.49	8.317	0.876	2.11	2.12	3.17	3.21	22
5	13.10	1.750	1.036	3.58	3.76	5.88	5.98	6
6	28.72	0.700	0.899	1.32	1.33	1.87	1.89	200 - 250
7	28.92	0.700	1.122	0.28	0.30	0.79	0.80	>300
8	27.81	0.475	0.274	2.64	2.75	3.70	3.77	22
9	27.09	1.783	0.678	0.66	1.20	1.63	1.67	>300

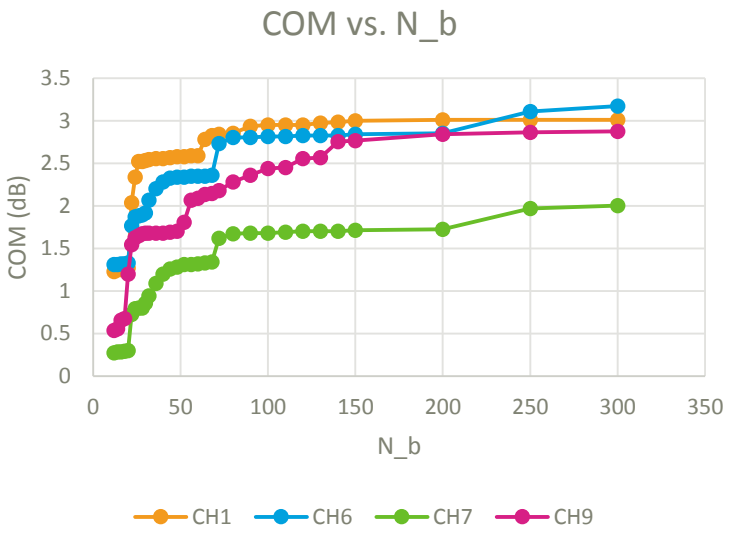
Selected 9 KR Channels – IL ~= 28 dB

- For those IL > 28 dB [CH 1, 6, 7]
  - Impossible to have 3dB COM unless ICN & ILD is small enough
- Correlation to backplane types?
  - Ca = Cabled, Or = Orthogonal, Tra = Traditional
- CH 1 vs. CH 6 [2.34 dB vs. 1.87 dB]
  - CH 1 with larger IL, ICN, & ILD, but larger COM as well
  - CH 6 has far more 'reflection' than CH 1 (see next page)

CH ID	IL (wo PKG, dB)	ICN (mV)	FOM_ILD (dB)	COM (dB)				Min. N_b for 3dB COM	Backplane Type
				N_b=16	N_b=20	N_b=24	N_b=28		
1	29.42	1.571	1.074	1.25	1.27	2.34	2.52	150 - 200	Ca
3	26.72	0.659	0.514	3.80	3.85	4.54	4.55	2	Ca
6	28.72	0.700	0.899	1.32	1.33	1.87	1.89	>200 - 250	Or
7	28.92	0.700	1.122	0.28	0.30	0.79	0.80	>300	Or
8	27.81	0.475	0.274	2.64	2.75	3.70	3.77	22	Ca
9	27.09	1.783	0.678	0.66	1.20	1.63	1.67	>300	Tra

9 KR Channels – Detailed Analysis

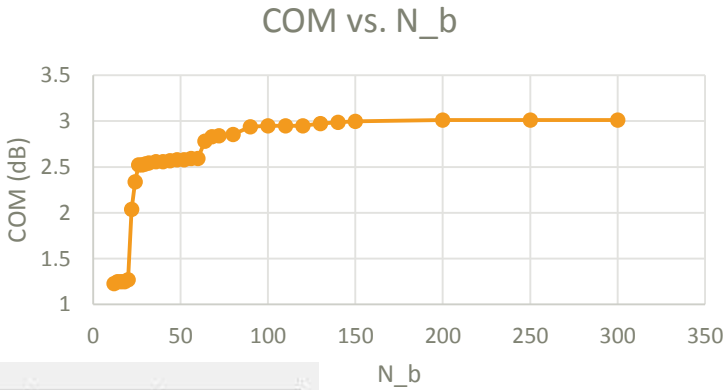
- CH 6 & 7 [Orthogonal]
  - Some far 'reflection' existed at 72-tap & during 200 ~ 250 taps
  - Impedance mismatch due to connector?
  - If these far 'reflection' were removed, CH 6 will outperform CH 1
- CH 9 [Traditional]
  - There are a lot 'reflections' between 50 to 200 taps
- CH 1 [Cabled]
  - Obvious 'reflections' existed between 60 to 100 taps

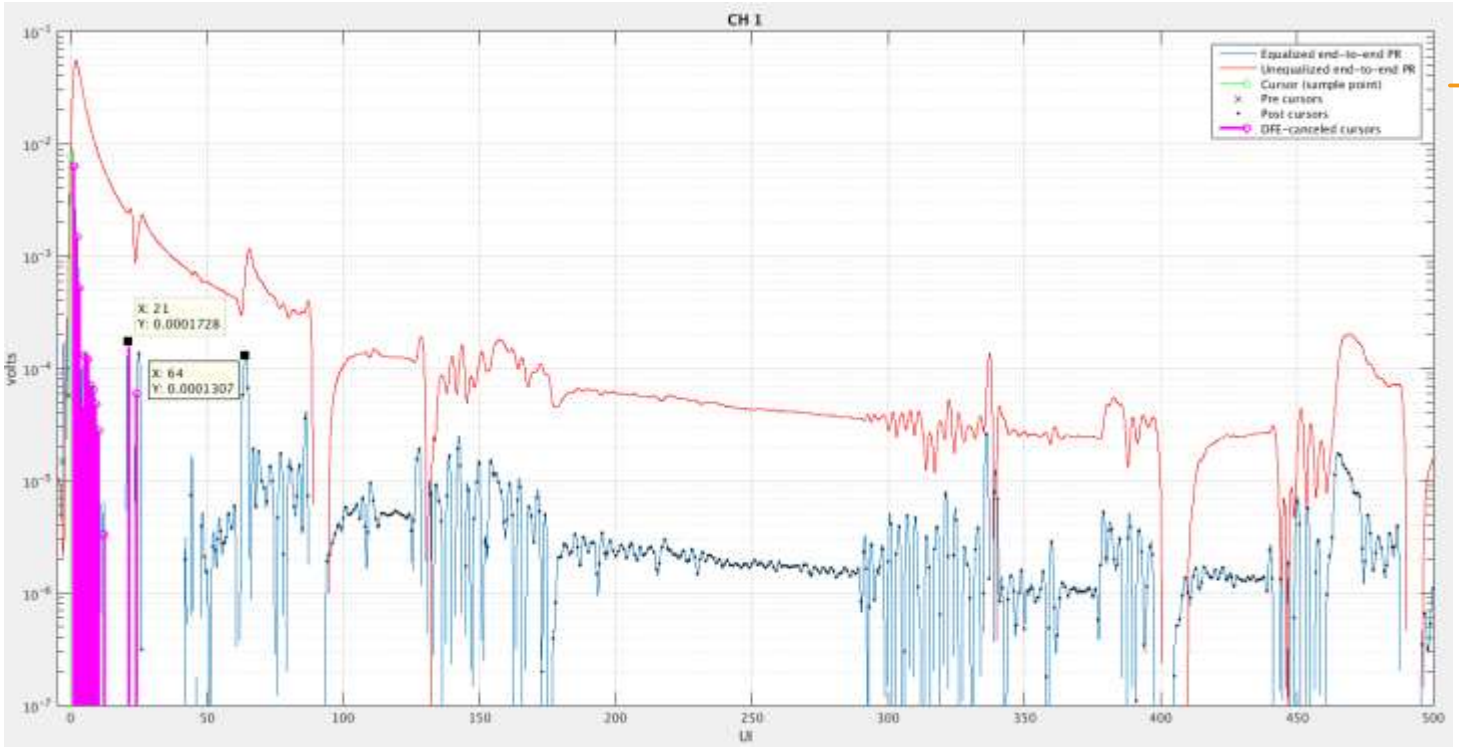


CH ID	IL (wo PKG, dB)	ICN (mV)	FOM_ILD (dB)	COM (dB)				Min. N_b for 3dB COM	Backplane Type
				N_b=24	N_b=72	N_b=150	N_b=250		
1	29.42	1.571	1.074	2.34	2.84	3.00	3.01	150 - 200	Ca
6	28.72	0.700	0.899	1.87	2.73	2.84	3.11	>200 - 250	Or
7	28.92	0.700	1.122	0.79	1.62	1.71	1.97	>300	Or
9	27.09	1.783	0.678	1.63	2.18	2.77	2.87	>300	Tra

Correlations among COM & Reflection

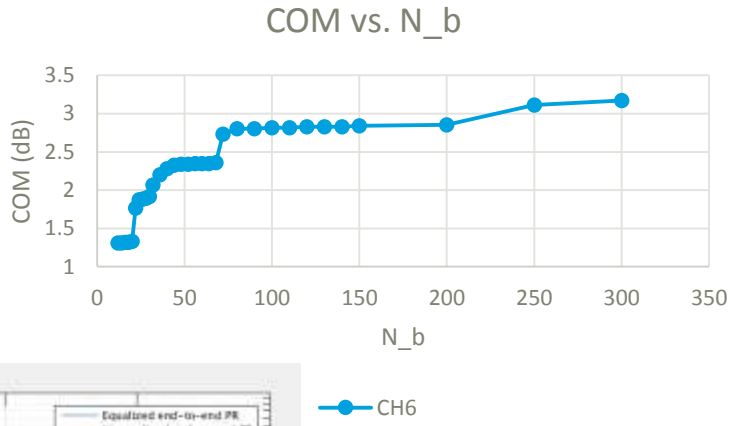
- CH 1: Major reflections at
  - Tap21 : package
  - Tap64: reflection contributed from channel

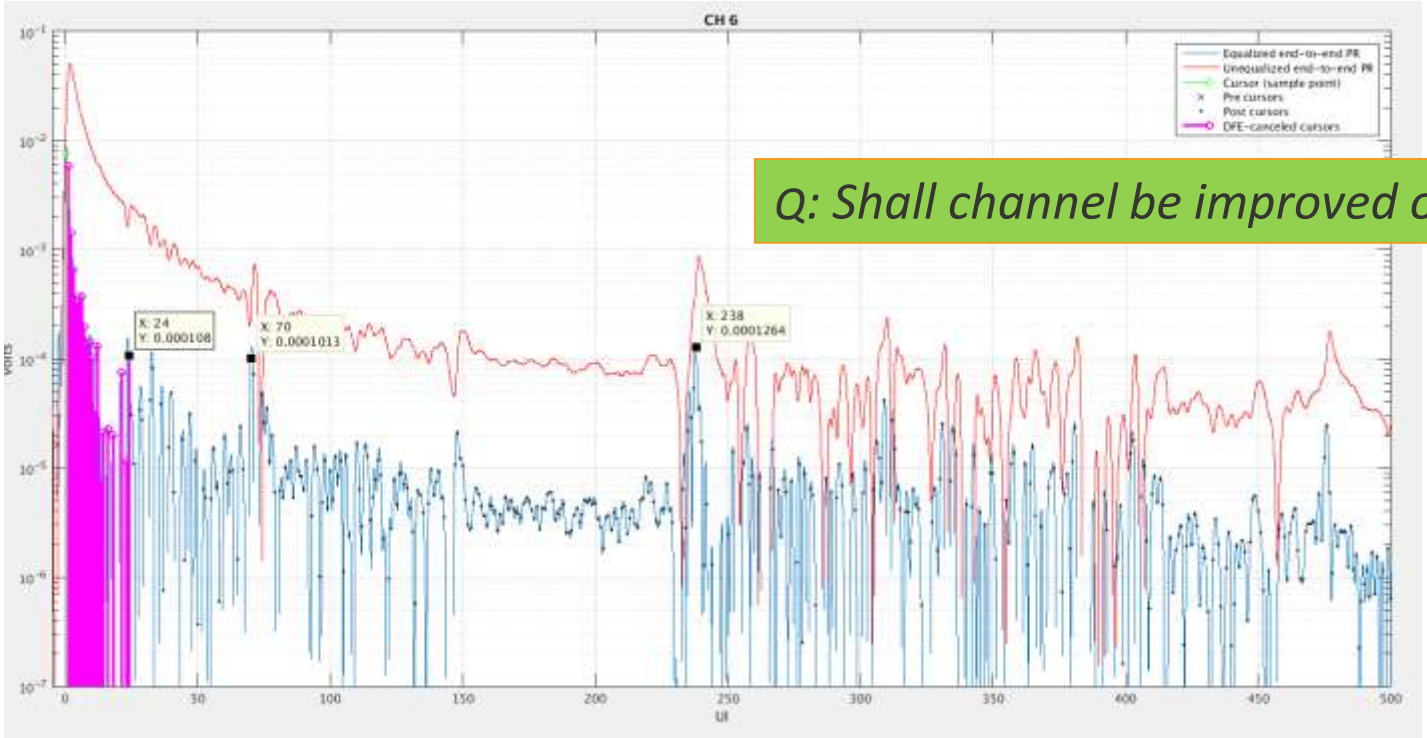




Correlations among COM & Reflection

- CH 6: Major reflections at
  - Tap24 : package
  - Tap70 & 238: reflection contributed from channel





Q: Shall channel be improved or RX shall cover it?

Correlation of CH7

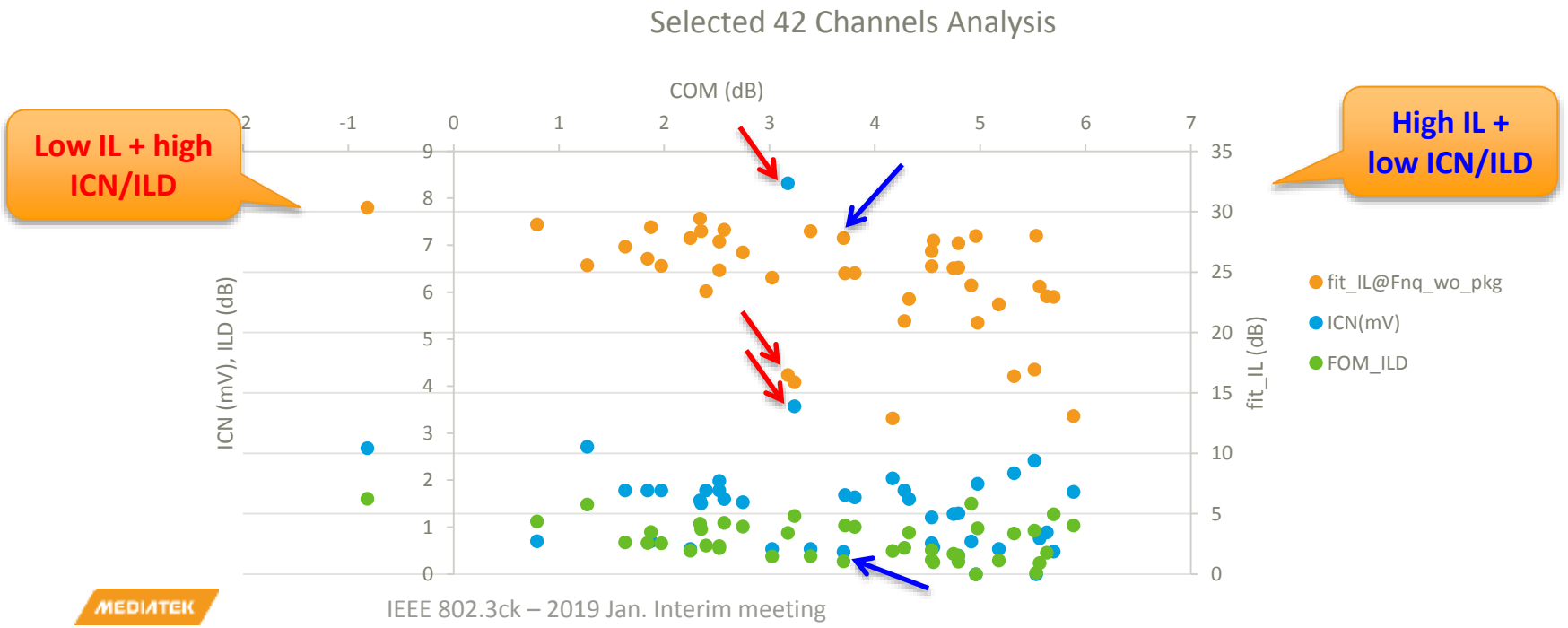
Correlation of CH9

COM Sensitivity – b_max as example

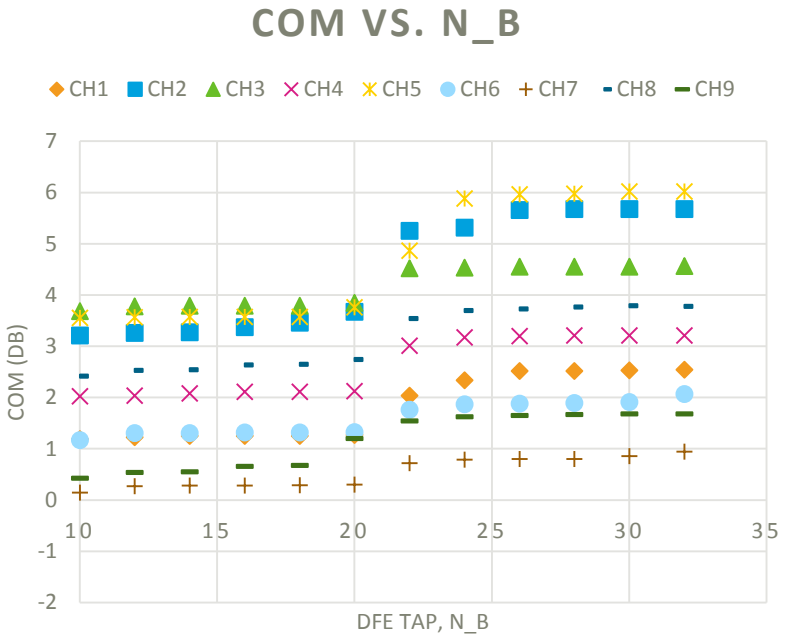
- Simulation conditions
  - Based on COM spread sheet at page 5
  - Including IEEE 42 channels for analysis [Selected 9 KR channels inc.]
  - COM 2.58 with baseline package (C_d = 110 fF)
  - DFE
    - N_b = 24
    - With different 'b_max(1)' & 'b_max(2..N_b)' settings
- Sensitivity analysis
  - Define 'Delta COM(b_1,b_2,CH_i)' = COM(b_1,b_2,CH_i) – COM(0.85,0.2,CH_i)
    - Where b_1 = b_max(1) & b_2 = b_max(2..N_b), & CH_i = the ith channel
  - Analyze COM sensitivity by 'mean of Delta COM' among all channels

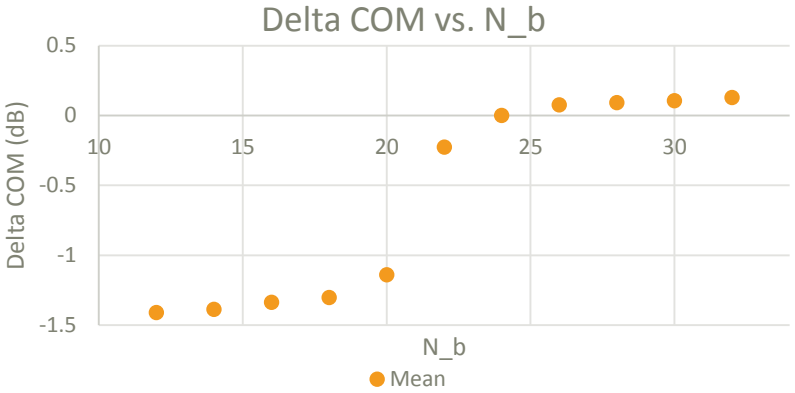
Selected KR Channels Policy

- All 9 KR baseline channels & all 15 KR channels before 2018 Nov.
- Select 18 channels from IEEE 2018 Nov. channels
  - Try to cover wide ranges from different perspectives
  - IL (ball-2-ball): 13 – 30 dB
  - COM: -0.8 – 6.0 dB
- Some low IL with high ICN/ILD channels: IL ~= 16 dB, ICN = 3.6mV & 8.3mV
- Some high IL with low ICN/ILD channels : IL = 27.8 dB, ICN = 0.5mV, ILD = 0.3 dB



COM Sensitivity – 'N_b'



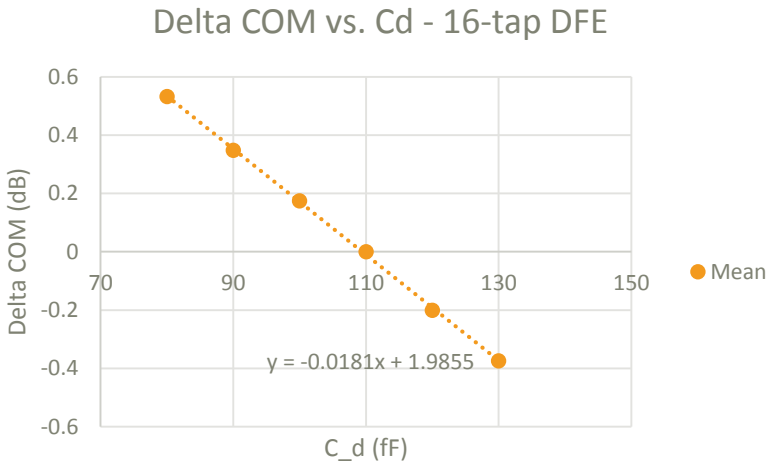


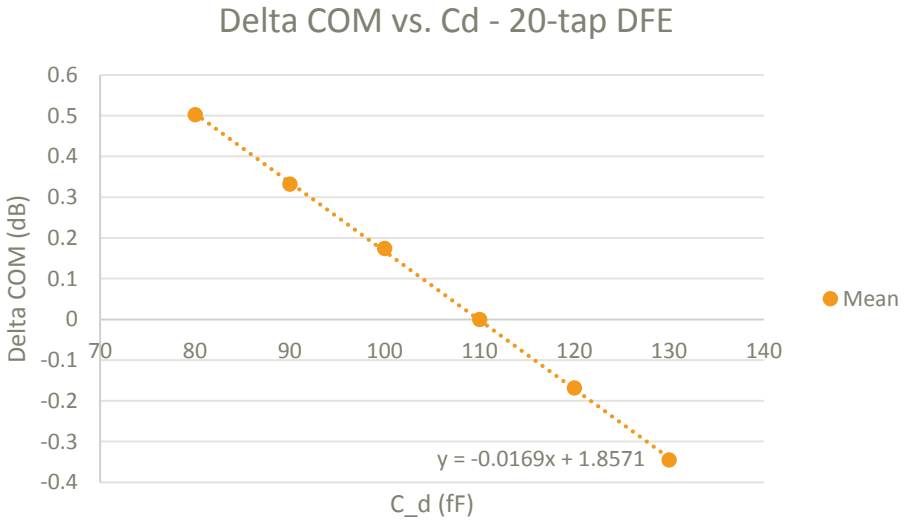
- Obvious gain when N_b = 20 → 22
  - To cover 'double-reflection' due to package model (z_p = 32 mm)
  - 0.9 dB (mean)
- Proposal
  - Adopt N_b = 24

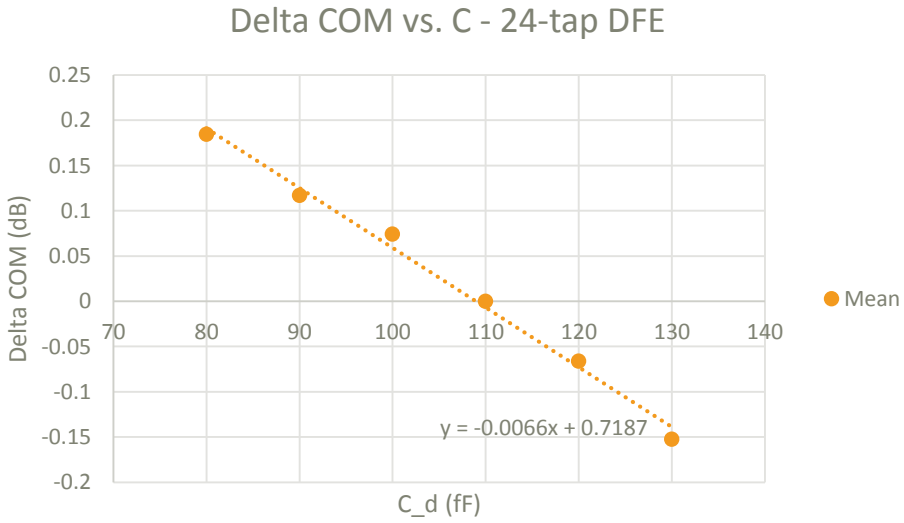
		COM Sensitivity (dB, mean)		
N_b	N_b Range	20~22	18~20, 22~24	Others
	Sen. (COM/tap)	0.46 dB/tap	0.10 dB/tap	0.02 dB/tap

COM Sensitivity – 'C_d'

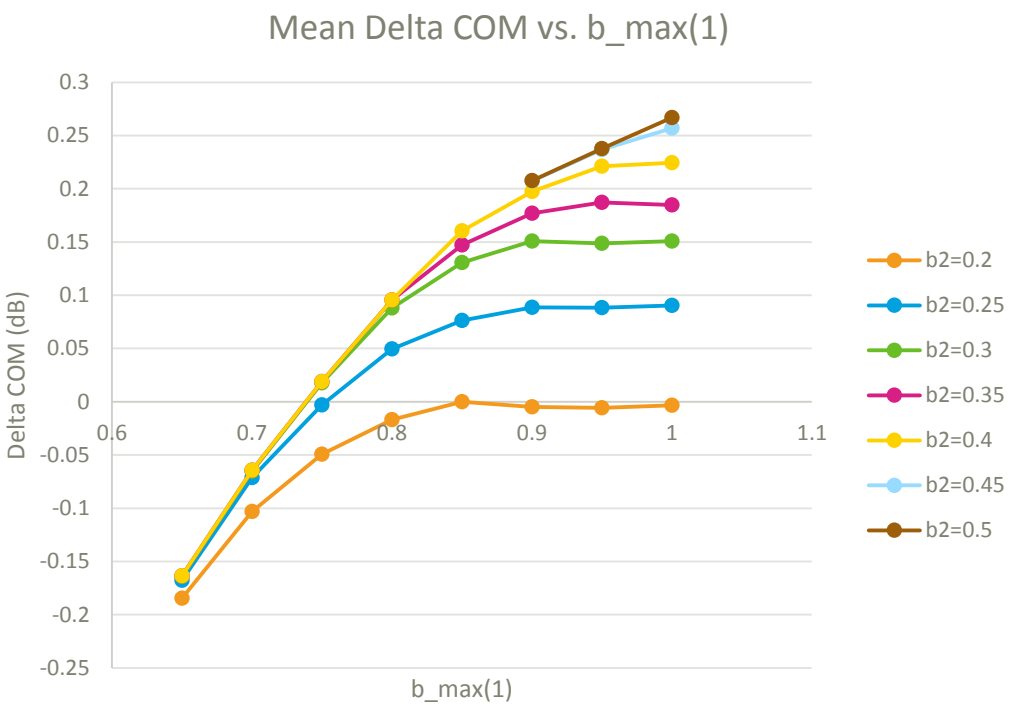
- 16 & 20-tap DFEs
  - Double reflection of package NOT covered by DFE
  - COM sensitivity ~= 0.17~0.18 dB / 10fF
- 24-tap DFE
  - COM sensitivity ~= 0.07 dB / 10fF
- COM is sensitive to 'C_d' if N_b <= 20







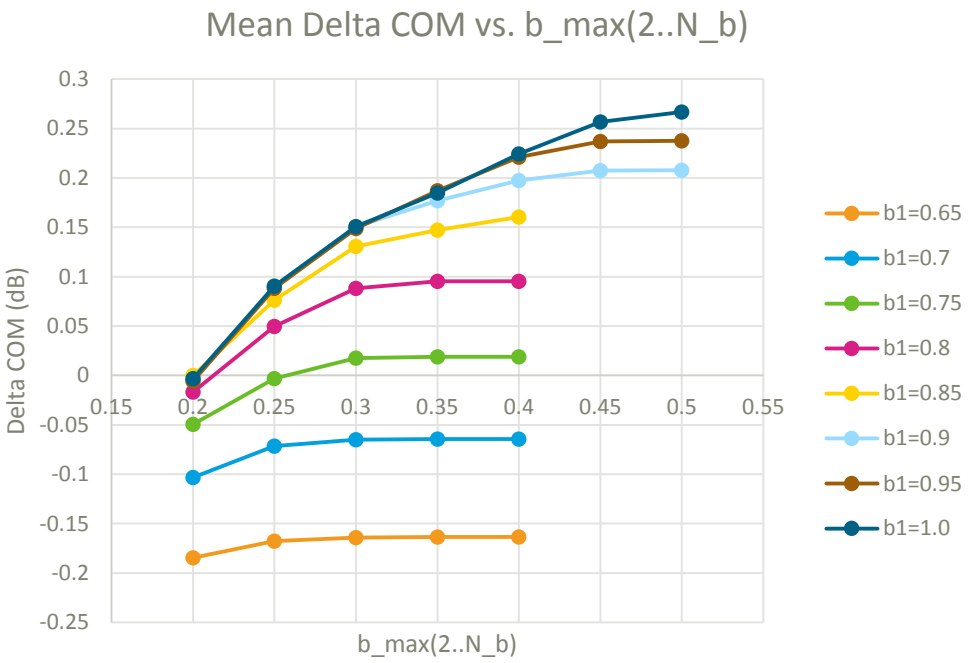
COM Sensitivity – b_max(1)



- For b2<=0.35, COM is NOT sensitive to b1 in the range of b1 = 0.85 to 1.0
  - Within 0.05 dB mean difference
- With larger b2 (>=0.4), larger b1 provides some gains up to 0.1 dB
- Larger b_max(1) raises concerns of error propagation, which is NOT considered in COM model
  - Analysis followed
- Proposal
  - Adopt b_max(1) = **0.85**

@ b_max(2..N_b) = 0.35		COM Sensitivity (dB, mean)	
b_max(1)	b_max(1) Range	0.6~0.85	0.85~1
	Sen. (COM/val)	0.13 dB/0.1	0.02 dB/0.1

COM Sensitivity – b_max(2..N_b)

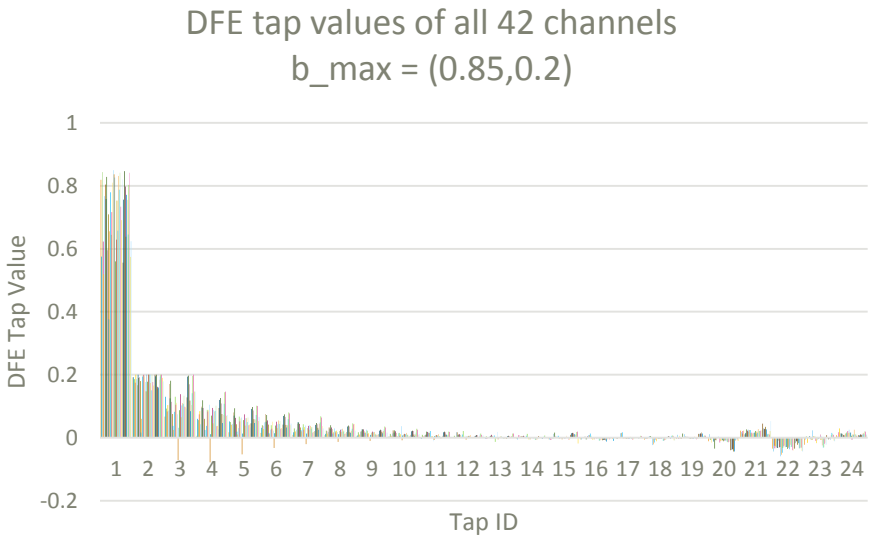


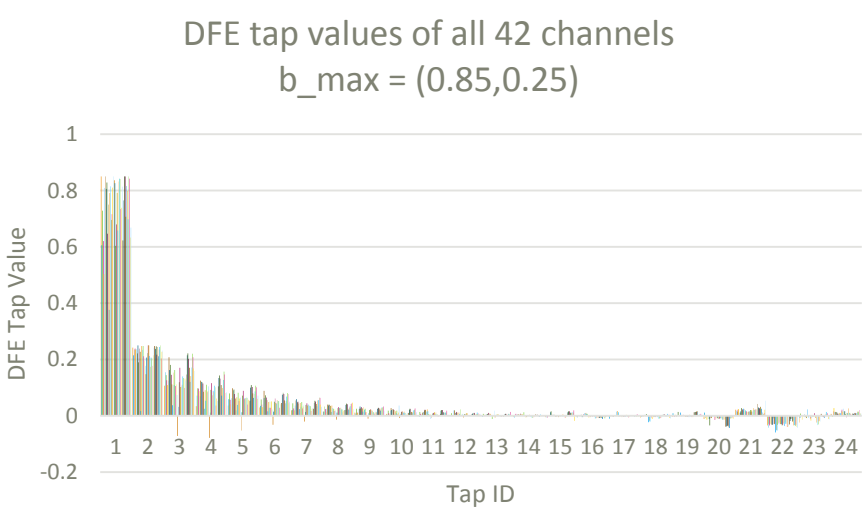
- For b1<=0.9, COM is NOT sensitive to b2 in the range of b2 = 0.35 to 0.5
  - Within 0.05 dB mean difference
- With larger b1 (>=0.95), larger b2 provides some gains up to 0.08 dB
- Proposal
  - Change b_max(2..N_b) from 0.2 to 0.35 gets 0.15 dB
  - Adopt b_max(2..N_b) = **0.35**

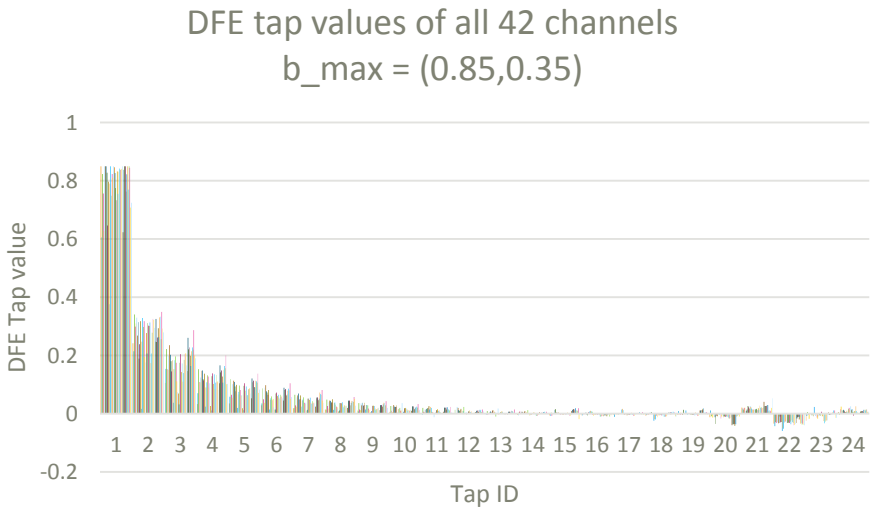
@ b_max(1) = 0.9		COM Sensitivity (dB, mean)	
b_max(2..N_b)	b_max(2..N_b) Range	0.2~0.35	0.35~0.5
	Sen. (COM/val)	0.13 dB/0.1	0.02 dB/0.1

DFE Tap Values Distribution

- Only b1, b2, & b3 reach max limit
  - We don't need to separate max limit for b2 & b3…
- Calculate the 'equivalent 1-tap DFE weight' to evaluate error propagation effect
  - Based on formula ***Post1'(n) = b(1) – b(2) + …(-1)$^{n-1}$b(n)*** in [lu_3ck_adhoc_01a_010219.pdf]

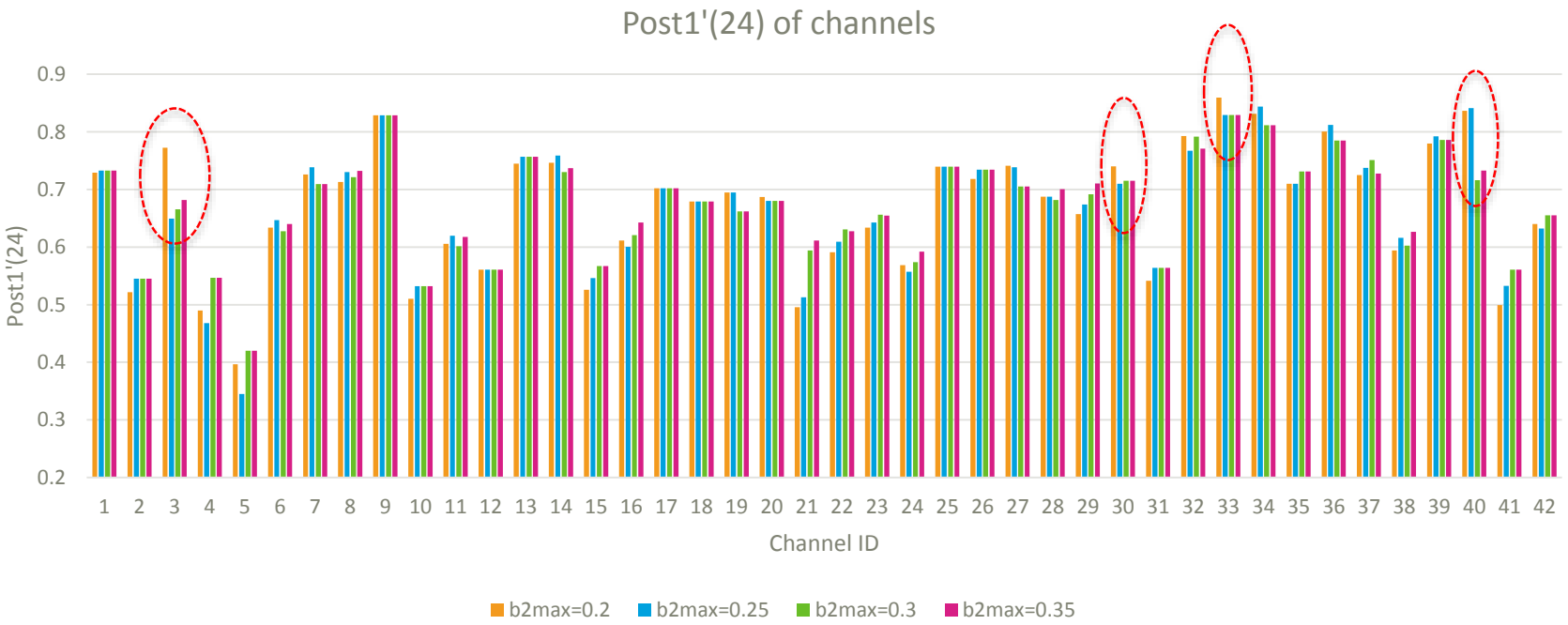






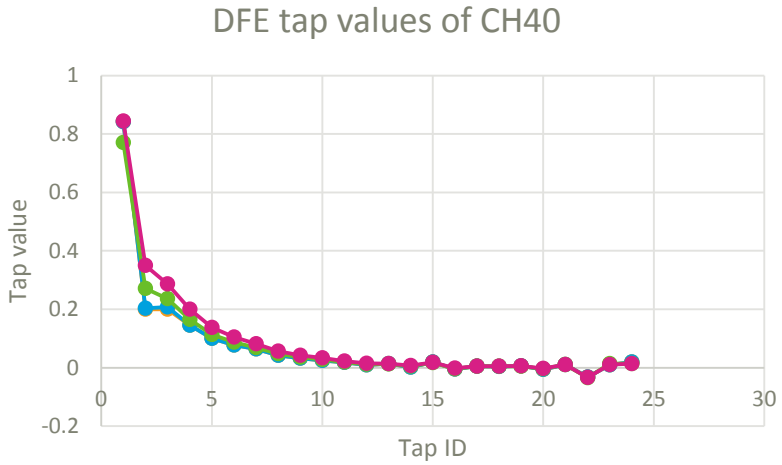
Post1’(24) Distribution

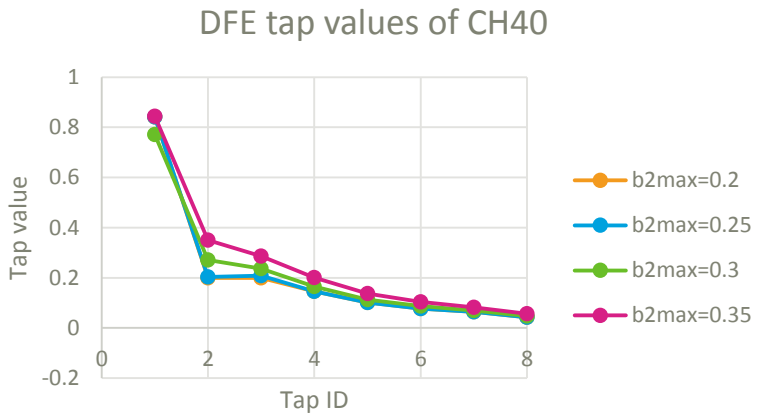
- Post1’(24) shown nearly the same among b2_max from 0.2 to 0.35
  - For some cases (CH3, CH30, CH33, CH40), b2max=0.2 has largest Post1’(24)
    - Higher b2_max increases b2, which reduce Post1’(n) [Details in next page]
  - For those channels with Post1’(24) >= 0.7, Post1’(24) is not sensitive to b2max up to 0.35

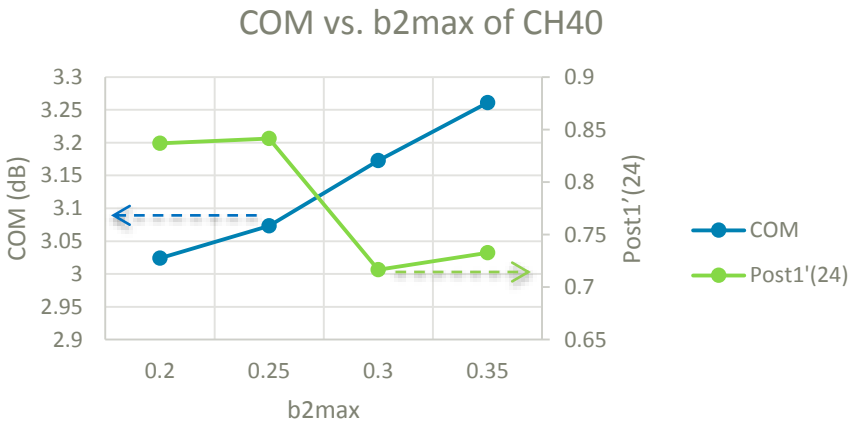


b(n) vs. b(1) for different b_max settings

CH40 Detailed Analysis







- Increasing b2max results in larger b(1), b(2), b(3)…
  - Post1’(24) is smaller (from 0.85 to 0.7x) → larger b(n) doesn’t mean worse error propagation
  - COM increases 0.24 dB

Error Propagation Evaluation

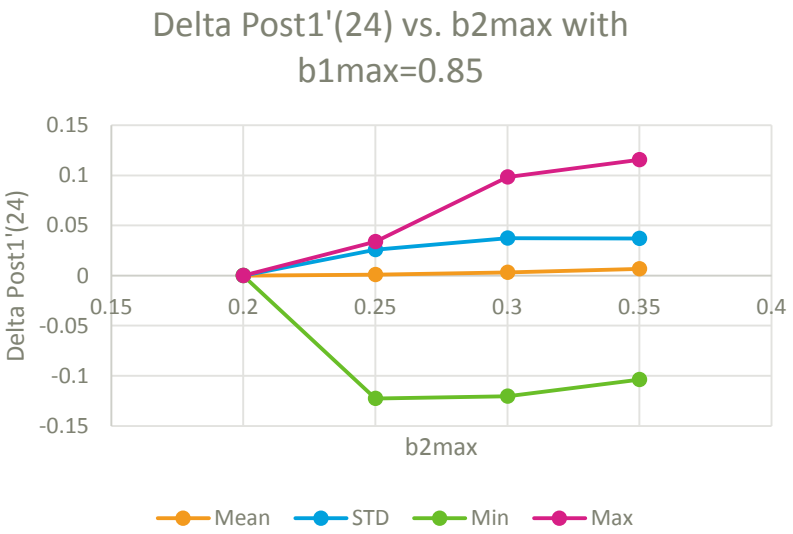
- Thanks to Yuchun's suggestion, we listed DFE tap values (b(1) to b(5)) for all channels with Post1'(5) > 0.7
  - Others can evaluate DFE error propagation effects

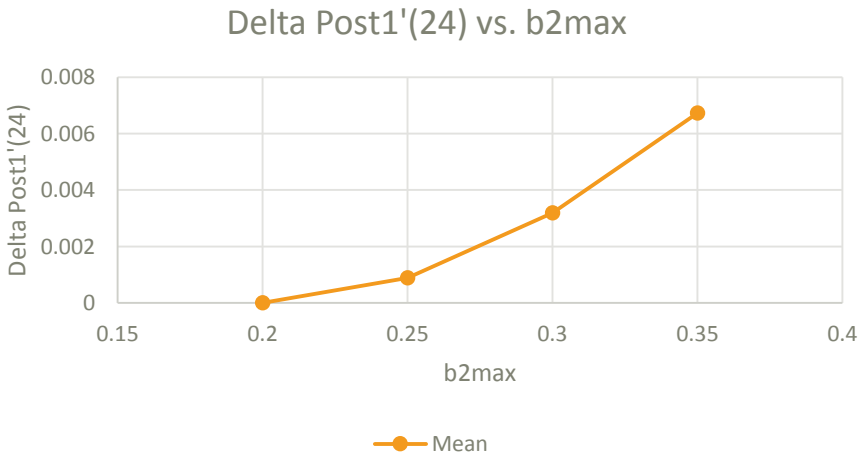
CH ID	1	6	7	8	9	17	18	25	26	29	30	32	33	34	36	37	39	40
COM	2.37	2.15	0.92	3.82	1.63	4.79	2.75	4.54	4.79	3.89	2.73	2.73	2.15	1.99	2.64	3.56	2.41	3.26
IL(ball2ball)	29.4	28.7	28.9	27.8	27.1	27.4	26.6	25.5	25.3	24.9	28.5	23.4	25.5	26.1	27.5	28.4	27.8	24.5
ICN	1.57	0.7	0.7	0.47	1.78	0.4	1.53	1.21	1.28	1.69	1.6	1.78	1.78	1.78	1.78	0.54	0.54	0.54
ILD	1.07	0.9	1.12	0.27	0.68	0.27	1.01	0.3	0.43	1.04	1.09	0.61	0.66	0.66	0.6	0.38	0.5	0.38
b(1)	0.85	0.85	0.85	0.85	0.83	0.81	0.85	0.83	0.84	0.84	0.85	0.84	0.85	0.85	0.82	0.85	0.85	0.84
b(2)	0.24	0.33	0.27	0.31	0.19	0.19	0.18	0.17	0.21	0.32	0.3	0.33	0.25	0.26	0.26	0.33	0.26	0.35
b(3)	0.11	0.2	0.24	0.2	0.18	0.11	0.07	0.11	0.14	0.21	0.17	0.26	0.22	0.23	0.16	0.21	0.22	0.29
b(4)	0.03	0.12	0.15	0.15	0.12	0.09	0.1	0.08	0.11	0.11	0.08	0.17	0.14	0.15	0.11	0.15	0.16	0.2
b(5)	0.04	0.1	0.11	0.11	0.09	0.06	0.06	0.06	0.06	0.09	0.07	0.12	0.11	0.11	0.09	0.11	0.11	0.14
Post1'(5)	0.72	0.7	0.78	0.7	0.79	0.7	0.71	0.75	0.73	0.7	0.71	0.73	0.79	0.78	0.71	0.7	0.76	0.72

Post1’ Sensitivity – b2max

- Post1’(24), which is related to DFE error propagation, is not sensitive to b2max up to 0.35
- It’s worthwhile to set b2max=0.35 to get performance gain (average 0.15 dB) without penalty from DFE error propagation

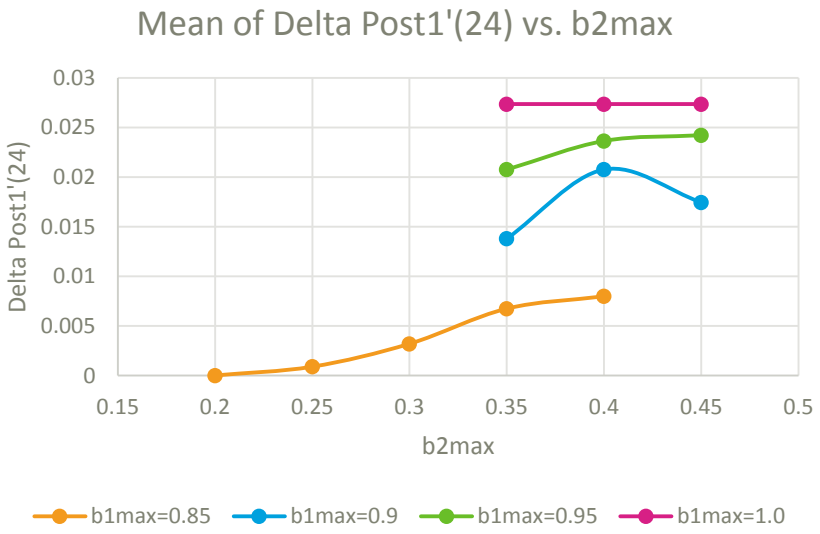
b2max	0.2	0.25	0.3	0.4
mean(Delta Post1’)	0	0.001	0.003	0.007





Post1’ Sensitivity – Different b1max

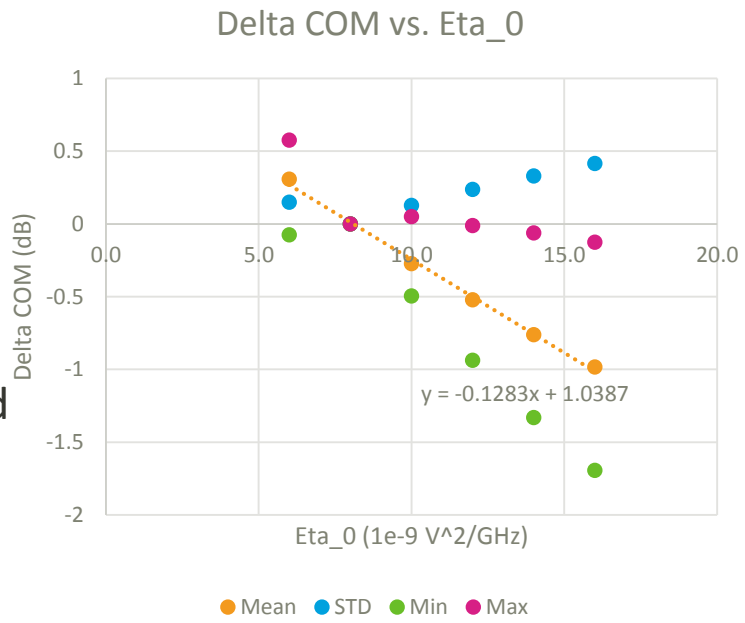
- Check with different b1max
- Other settings with larger b1max show significant increase of Post1’(24)
- Propose to set b_max = **(0.85, 0.35)**



b2max	0.2	0.25	0.3	0.35	0.4	0.45
mean(Delta Post1’)	0	0.001	0.003	0.007	0.008	X
0.9	X	X	X	0.014	0.021	0.017
0.95	X	X	X	0.021	0.024	0.024
1.0	X	X	X	0.027	0.027	0.027

COM Sensitivity – 'Eta_0'

- COM is quite sensitive to 'Eta_0'
  - 0.13 dB loss per extra 1e-9 V^2/GHz Eta_0
  - 1.0 dB COM loss comparing 16e-9 to 8e-9
- How to decide Eta_0 (noise power density)?
  - We adopted 16.4e-9 @ 50Gbps
- If only 'system noise' count in
  - Measured data and/or new model require? [mellitz_3ck_01_0319]
  - Q: How many COM margin shall be reserved for RX noise?
    - Analog noise – CTLE noise, thermal, ADC quantization noise
    - Digital implementation loss
- If both system noise & analog noise considered,
  - Q: Shall we get consensus on methodology to decide Eta_0 first



	COM Sensitivity (dB, mean)	
Eta_0		6.0~16.0e-9 V^2/GHz
	Sen. (COM/Eta_0)	0.13 dB/1e-9

COM Sensitivity – TX FIR

- Three kind of specs
  - **Tap number** – Q: Is every one OK for 5-tap? [c(-3) to c(1)]
  - **Range spec** – min or max values
  - **Step size** – 1.5%, 2%, 2.5%, 5%, …
- We tried to analyze 'Range spec' in this contribution as the 1st step
- Current COM setting in COM2p58 (for KR)

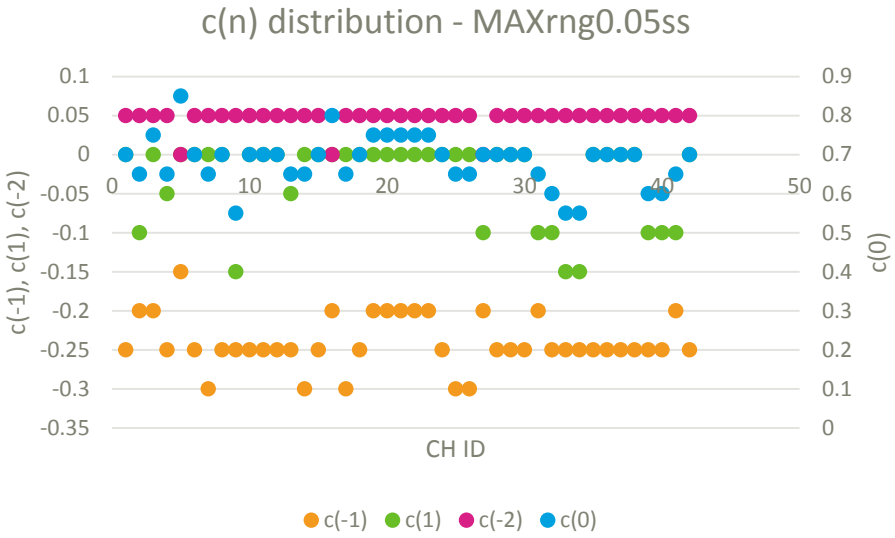
c(0)	0.54		min
c(-1)	[-0.34:0.02:0]		[min:step:max]
c(-2)	[0:0.02:0.12]		[min:step:max]
c(-3)	[-0.06:0.02:0]		[min:step:max]
c(1)	[-0.1:0.05:0]		[min:step:max]

- In order to explore the range, we use the following COM setting [larger range with 5% step size to speed-up, marked as 'MAXrng0.05ss']

c(0)	0.45		min
c(-1)	[-0.4:0.05:0]		[min:step:max]
c(-2)	[0:0.05:0.15]		[min:step:max]
c(-3)	[-0.1:0.05:0]		[min:step:max]
c(1)	[-0.3:0.05:0]		[min:step:max]

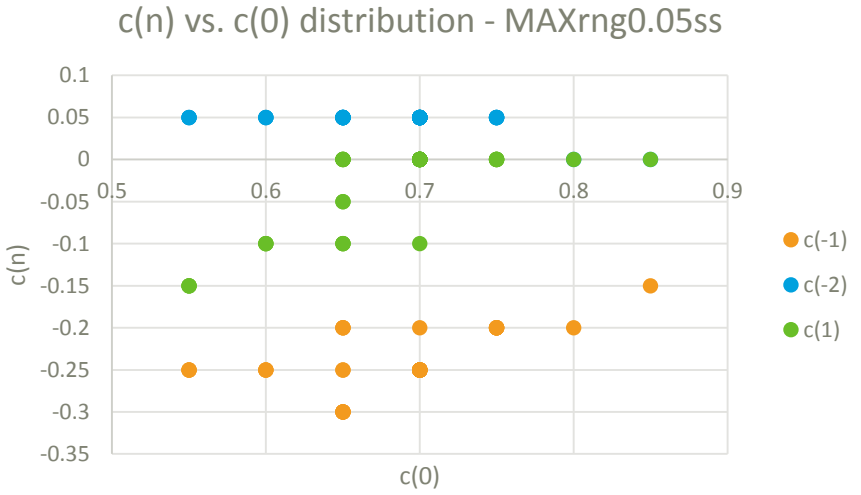
Range of c(n)

Taps	c(0)	c(-1)	c(-2)	c(1)
Min	0.55	-0.3	0	**-0.15**
Max	0.85	-0.15	0.05	0
COM2.58	>=0.54	[-0.34:0]	[0:0.12]	[**-0.1**:0]



- For COM2.58
  - Ranges of c(0), c(-1), c(-2) are suitable
    - Min and max values are within range with margin
  - Min of c(1) is too small
    - Proposed to extend to 0.2
- We may consider setting below

c(0)	0.54		min
c(-1)	[-0.34:TBD:0]		[min:step:max]
c(-2)	[0:TBD:0.12]		[min:step:max]
c(-3)	[-0.06:TBD:0]		[min:step:max]
c(1)	[~~-0.1~~-->**-0.2**:TBD:0]		[min:step:max]



COM Sensitivity – Summary

		COM Sensitivity (dB, mean)		
N_b	N_b Range	20~22	18~20, 22~24	Others
	Sen. (COM/tap)	0.46 dB/tap	0.10 dB/tap	0.02 dB/tap
b_max(1)	b_max(1) Range	0.6~**0.85**	0.85~1	
	Sen. (COM/val)	0.13 dB/0.1	0.02 dB/0.1	
b_max(2..N_b)	b_max(2..N_b) Range	0.2~**0.35**	0.35~0.5	
	Sen. (COM/val)	0.13 dB/0.1	0.02 dB/0.1	
C_d	N_b Range	16	20	24
	Sen. (COM/10fF)	0.18 dB/10fF	0.17 dB/10fF	0.07 dB/10fF
Eta_0		6.0~16.0e-9 V^2/GHz		
	Sen. (COM/Eta_0)	0.13 dB/1e-9		

- Proposals based on COM sensitivity & other analysis
- N_b = 24
- b_max(1) = 0.85 & b_max(2..N_b) = 0.35
- c(1) min = -0.2

Proposal of COM Parameters for KR

- Based on the analysis in this contribution
  - We propose to have update of COM as below
- c(1) min – -0.1 → **-0.2**
- N_b – 16 → **24**
- b_max(2..N_b) – 0.2 → **0.35**

filter and Eq					ERL_ONLY	0	logical
f_r	0.75	*fb			TR_TDR	0.01	ns
c(0)	0.54		min		N	1000	
c(-1)	[-0.34:0.02:0]		[min:step:max]		TDR_Butterworth	1	logical
c(-2)	[0:0.02:0.12]		[min:step:max]		beta_x	1.70E+09	
c(-3)	[-0.06:0.02:0]		[min:step:max]		**rho_x**	**0.25**	
c(1)	[~~-0.1~~ -> **-0.2**:0.05:0]		[min:step:max]		fixture delay time	0	enter sec
N_b	~~16~~ -> **24**	UI			**Receiver testing**		
b_max(1)	0.85				RX_CALIBRATION	0	logical
b_max(2..N_b)	~~0.2~~ -> **0.35**				Sigma BBN step	5.00E-03	V
g_DC	[-20:1:0]	dB	[min:step:max]		**Noise, jitter**		
f_z	21.25	GHz			sigma_RJ	0.01	UI
f_p1	21.25	GHz			A_DD	0.02	UI
f_p2	53.125	GHz			eta_0	8.20E-09	V^2/GHz
g_DC_HP	[-6:1:0]		[min:step:max]		SNR_TX	33	dB
f_HP_PZ	0.6640625	GHz			R_LM	0.95	

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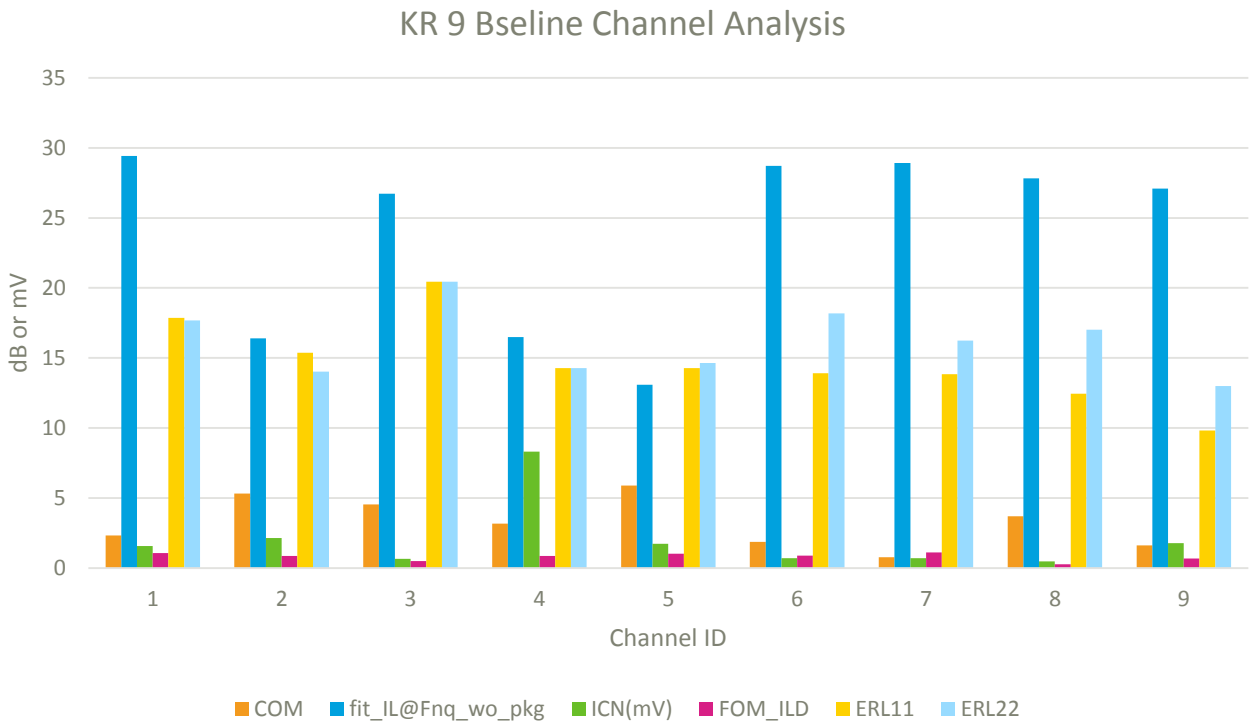
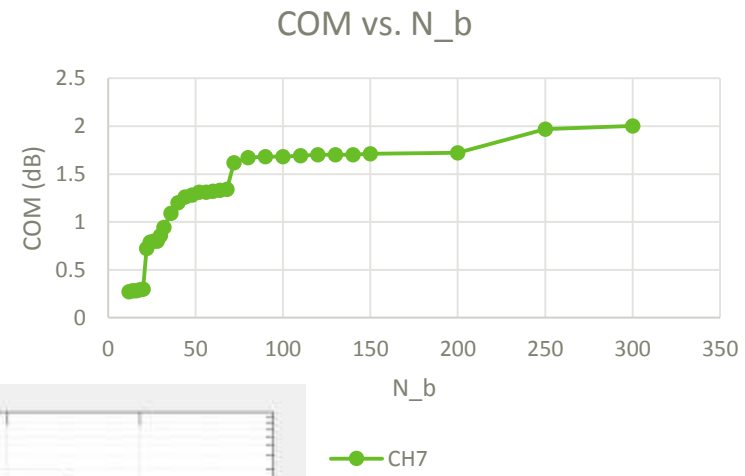
Selected 9 KR Channels – Analysis

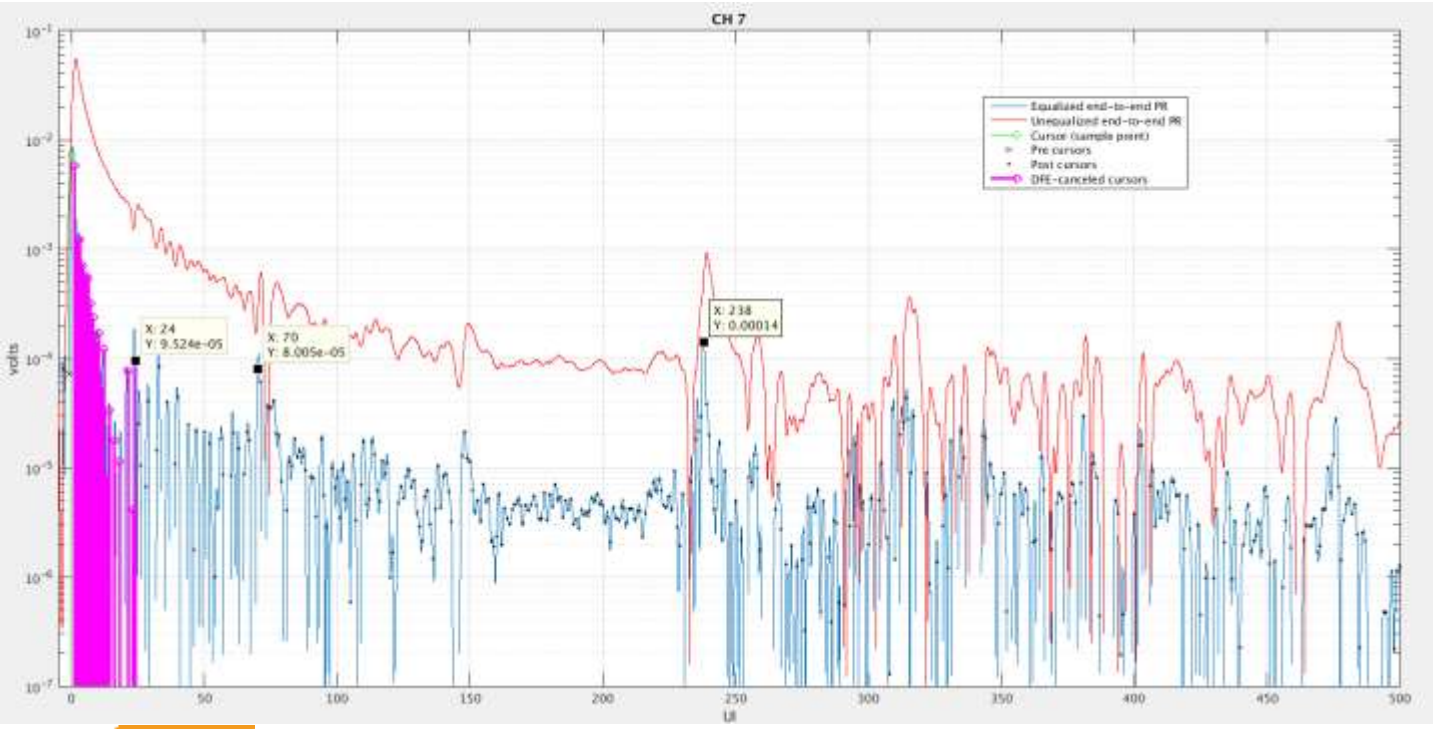
- Show basic COM parameters for 9 KR channels



Correlations among COM & Reflection

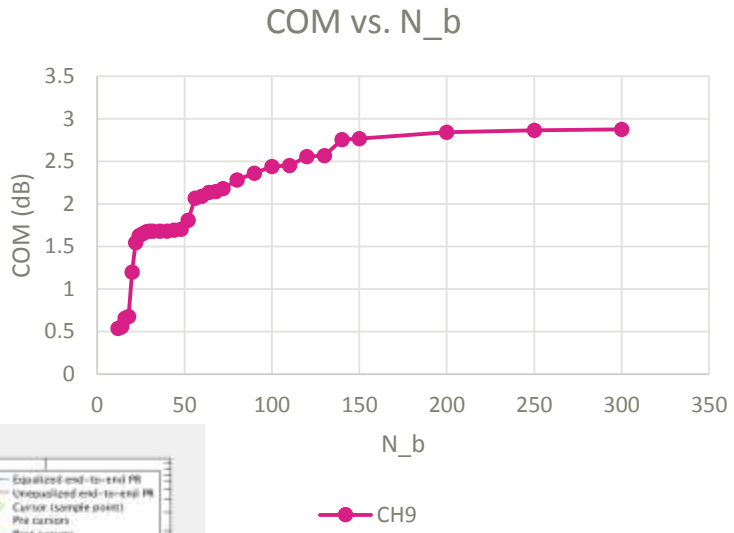
- CH 7: Major reflections at
  - Tap24 : package
  - Tap70 & 238: reflection contributed from channel

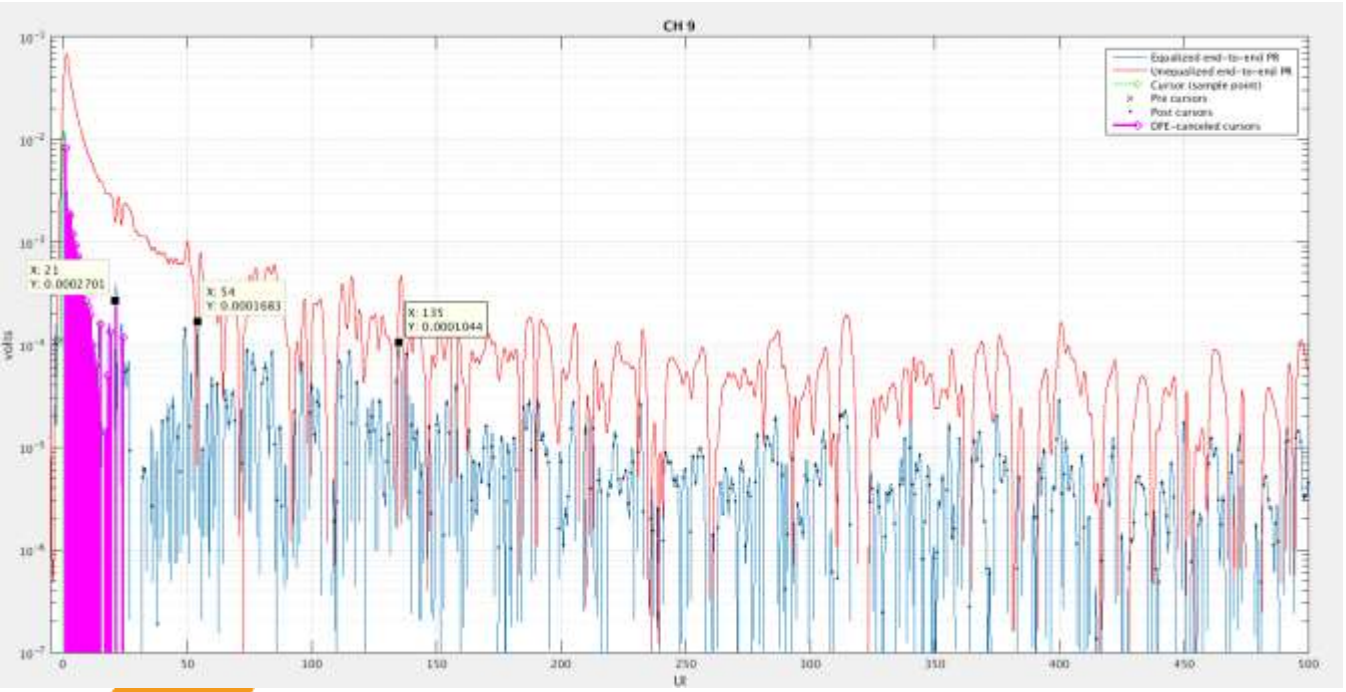




Correlations among COM & Reflection

- CH 9: Major reflections at
  - Tap24 : package
  - Tap54 ~ 135: reflection contributed from channel





b(n) vs. b(1) Distribution