

# **Quantization Noise in COM – Direct Model or Proxy?**

**Hossein Shakiba**

**Huawei Technologies Canada**

**April 2025**

# Background

- In contribution [shakiba\\_3dj\\_02\\_2405.pdf](#) the impact of quantization noise on COM channel compliance verification was analyzed and a direct method for modeling it was proposed
- Contribution [healey\\_3dj\\_01b\\_2405.pdf](#) considered using existing means (e.g. scaling eta\_0) as a proxy to represent quantization noise
- At the time, there was more support for using the simpler proxy method
  - ❖ Still considerable Y's and a lot of undecideds
- The “N” outcome was mostly motivated by the argument of “reference receiver trap”
- Eta\_0 was elevated to  $1\text{E-}8\text{V}^2/\text{GHz}$  to include the effect of quantization noise
- While the argument of proxy is generally understandable and in many cases applicable, quantization noise is too important to be ignored or represented by a simple proxy
- Also, it would have helped if the theoretical basis of the direct modeling approach and its calculation overhead were better understood, justified, and quantified

May 2024

Straw Poll #1

I support adding a new noise term (such as 'eta\_1' in healey\_3dj\_01a\_2405, slide 6) to the COM reference receiver.

Results (all) Y: 13, N: 37, A: 31

# Facts to Consider

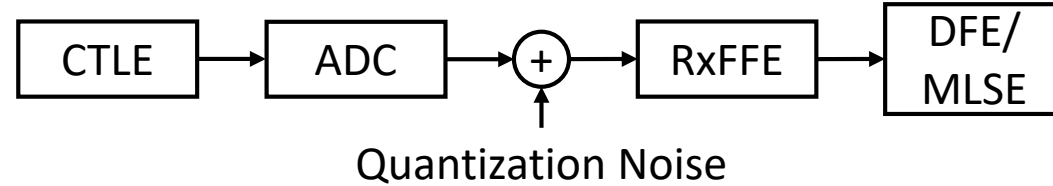
- A big part of the “reference receiver trap” was to avoid features that are implementation-specific and could cause unreasonable complication
- Vast majority to almost all receiver implementations nowadays use ADC, making this architecture generic and de-facto, and the natural baseline for the reference receiver
- Shift in paradigm to consider the non-ADC-based receiver implementation-specific
- Direct modeling of quantization noise stands on a solid theoretical foundation and can be simply embedded with reasonable overhead
- Quantization noise has some unique and specific attributes that makes it not a good candidate to be replaced by a proxy as simple as a fix scaled and uncorrelated  $\eta_0$  noise term
- Several other attributes of the current reference receiver and existing noise terms are likely less important and arguably more implementation-specific
- Uncertainty around TxFFE optimization in the absence of a realistic quantization noise

# Motivation

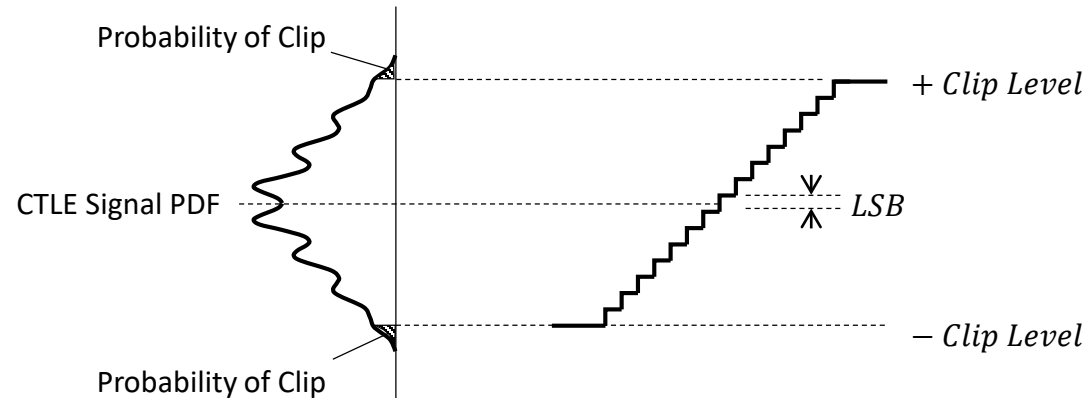
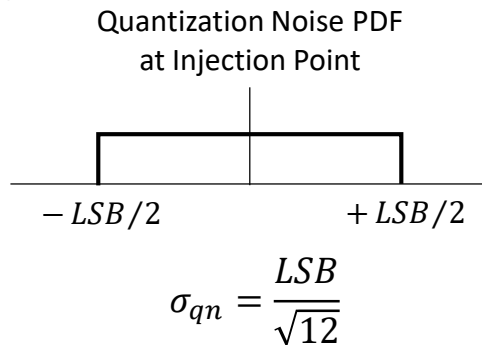
- Some observations and developments since then:
  - ❖ There was a lack of enough data and clarity on the extend of the overhead of adding the quantization noise model to the COM flow
  - ❖ Noticeable ongoing interests and requests to further follow up on this topic
  - ❖ Several direct requests for having access to the COM Matlab function with the capability
  - ❖ More data have been generated and some presented by others since then
  - ❖ Recent changes in the COM code motivates an attempt to re-quantify the effect of quantization noise
  - ❖ The latest released version (480) of the COM Matlab function incorporates the feature
    - Demonstrates a reasonable run time overhead for the added value (also see [shakiba\\_3dj\\_COM\\_03\\_2505.pdf](#))
    - Provides a wider access
    - There are few COM commit requests in recent COM ad hoc meetings that affect the COM results (bug fixes)
- Hopefully consensus will be built and a move in the right direction will be made:
  - 1) Enough support for adding quantization noise to the COM flow
  - 2) ... or use the presented material as a reference for people who wish to use the feature for further exploration

# Quantization Noise Model

- Quantization noise is a new noise term added between CTLE and RxFFE



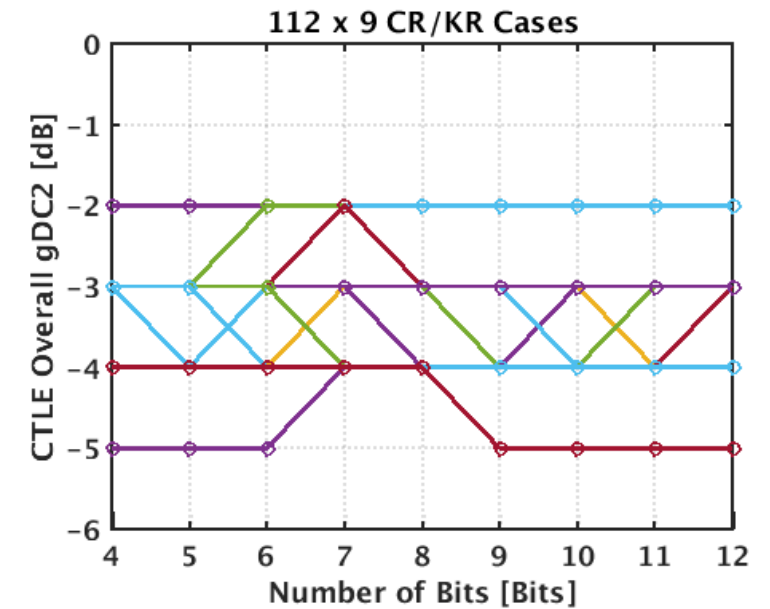
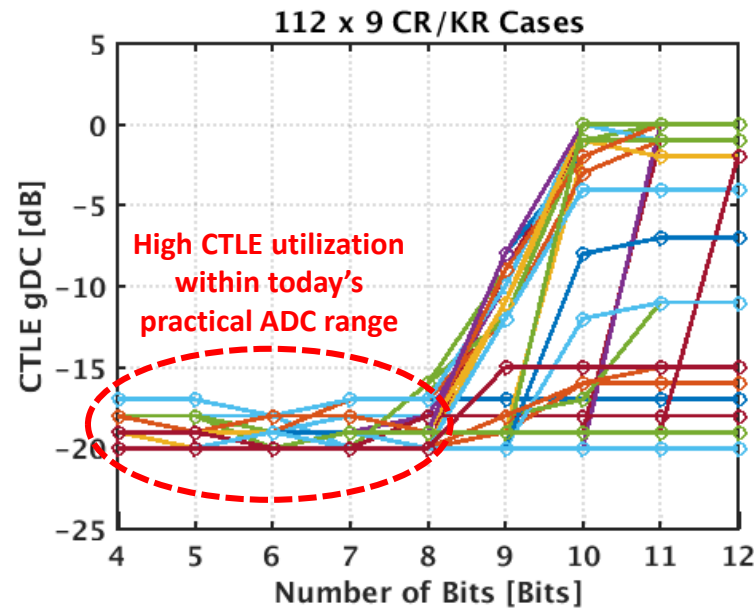
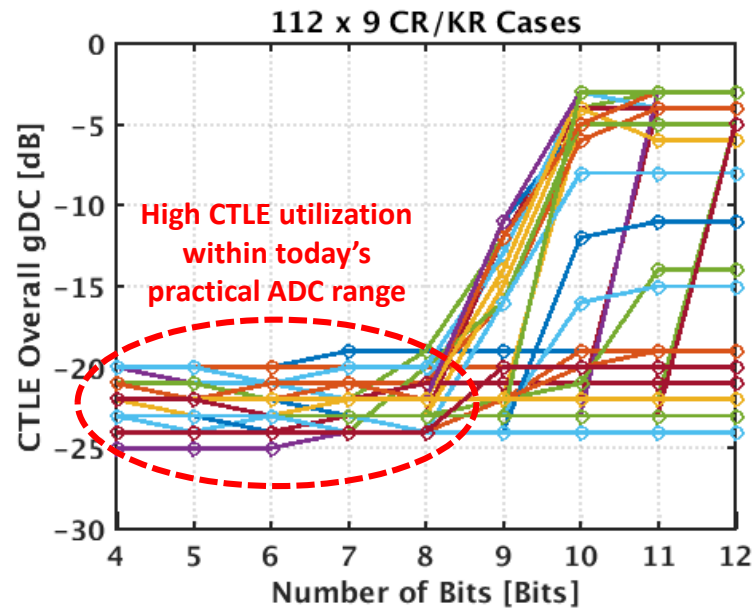
- It can be modeled by a white random noise with uniform distribution over  $-LSB/2$  to  $+LSB/2$  at the injection point



- Quantization clip level can be calculated from the desired probability of signal clipping
- LSB, quantization step size, can be calculated from the desired number of bits and clip level
- Note that modeling quantization functionality is outside the scope, it is only its noise

# Impact of Quantization Noise on CTLE Utilization

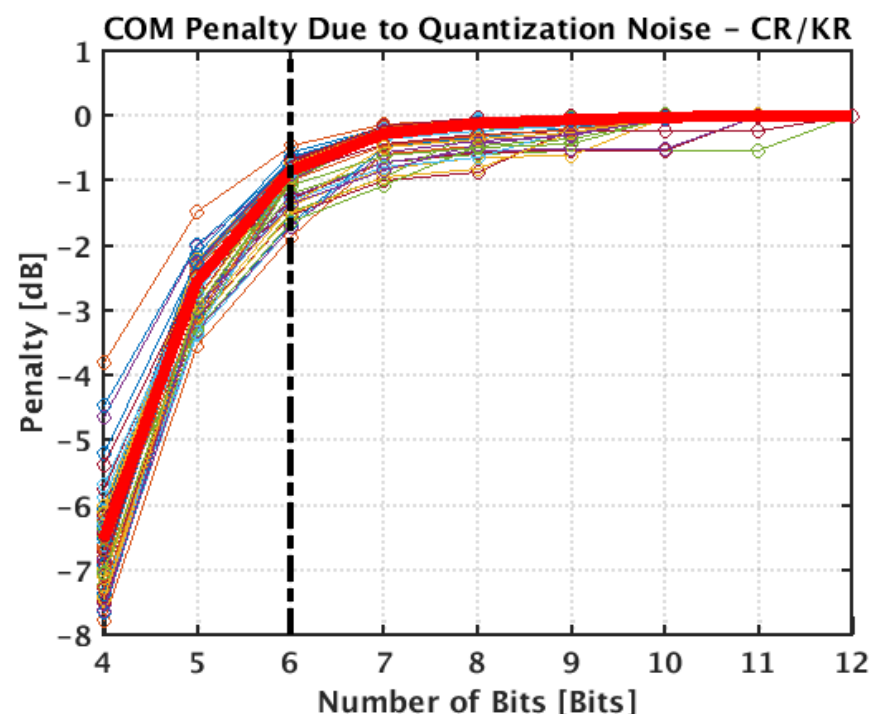
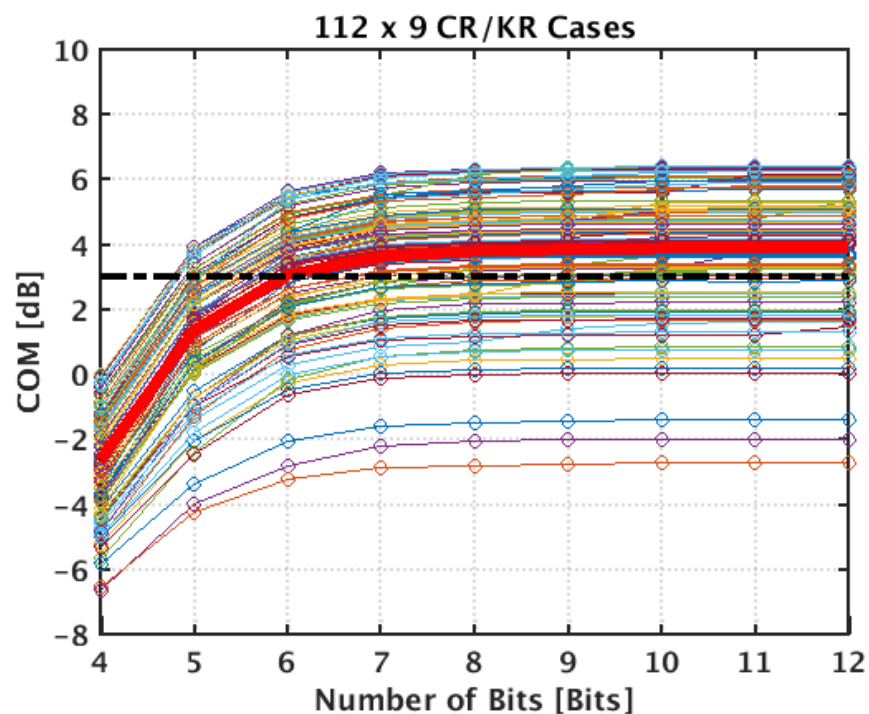
- Quantization noise has a prominent impact on the equalizer distribution and optimization



- CTLE high-frequency gain (gDC) utilization increases with increasing quantization noise
  - ❖ CTLE search range can not be generally reduced (fixing gDC to speed up optimization is not a choice)
- CTLE high-frequency utilization is unrealistically minimal when eta\_0 is used as a proxy
- As expected, CTLE low-frequency boost (gDC2) utilization is not impacted

# Impact of Quantization Noise on COM

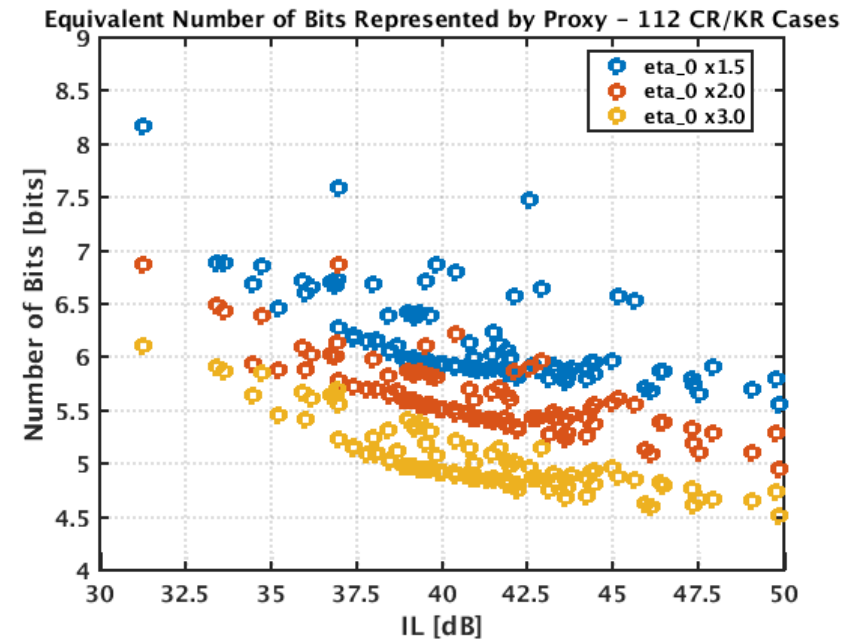
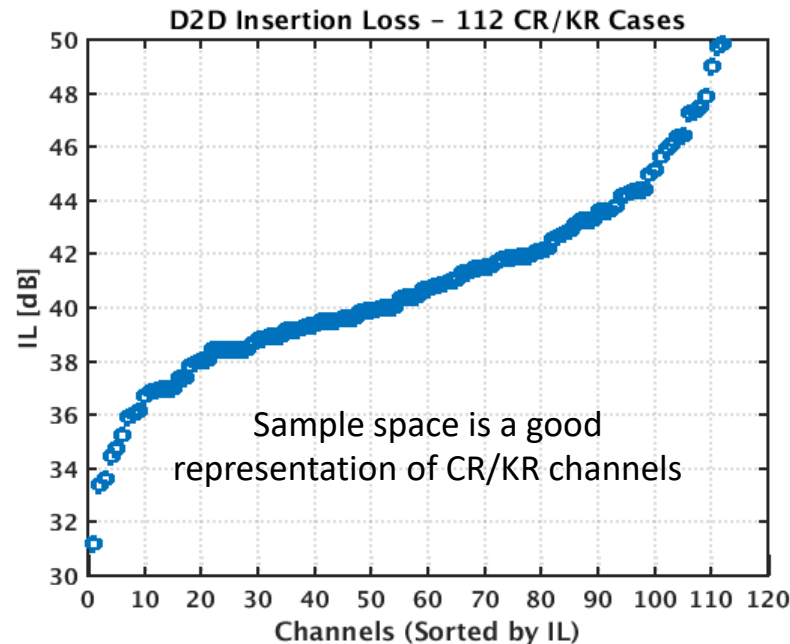
- With direct modeling, the impact of quantization noise on COM can be quantified accurately, predictively, and realistically



- For the test channels, at least 6 bits is needed to contain the quantization noise
- Even with 6 bits, the test channels suffer anywhere between 0.47dB to 1.86dB of COM penalty

# The Concern with eta\_0 Proxy Approach

- With  $\eta_0 = 5\text{E-}9$  and three scale values of 1.5, 2, and 3 COM was calculated for the test cases
- For each individual channel and using data from the plot on the previous slide, the calculated COM was mapped to an equivalent number of bits that would result in the same COM

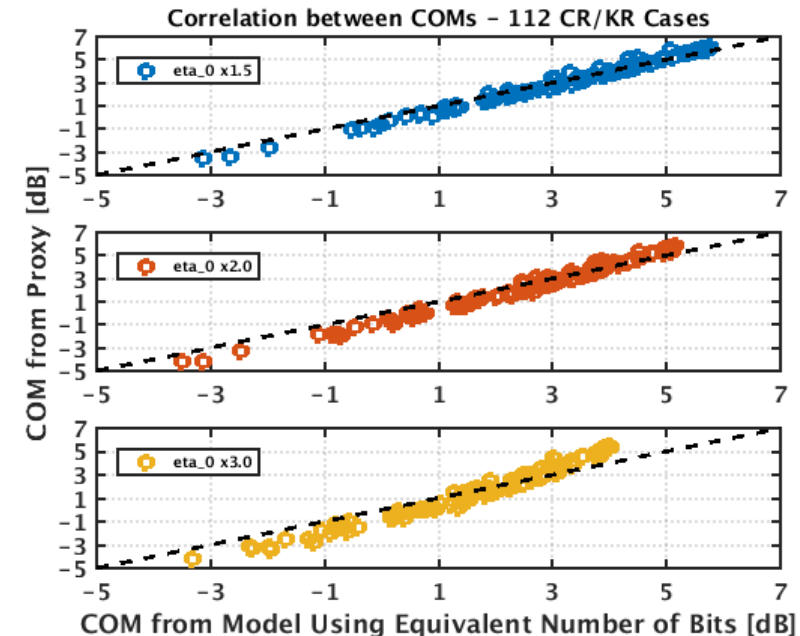
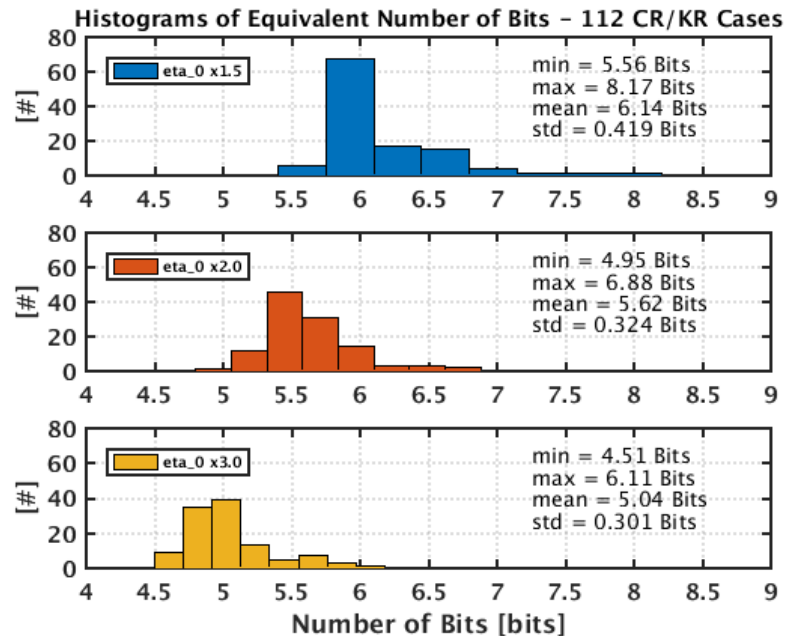


- Ideally, it is expected that the equivalent number of bits be independent of channel loss
- The variation and dependency/correlation to channel loss is evident



# COM Results Comparison

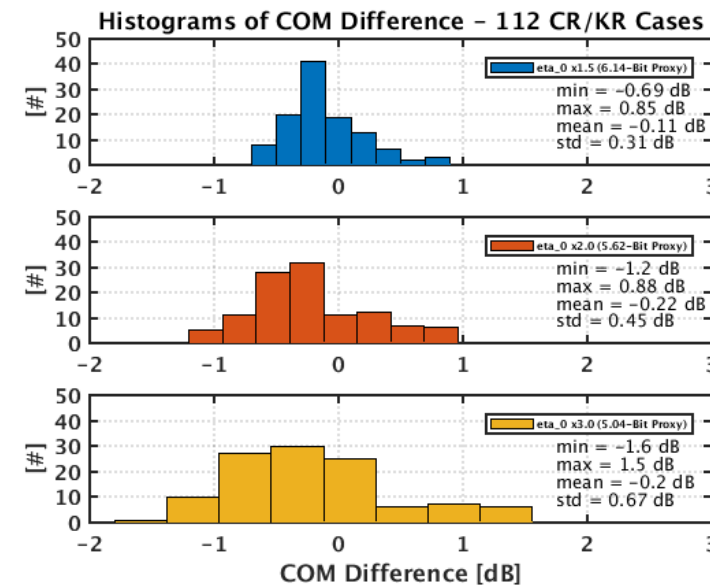
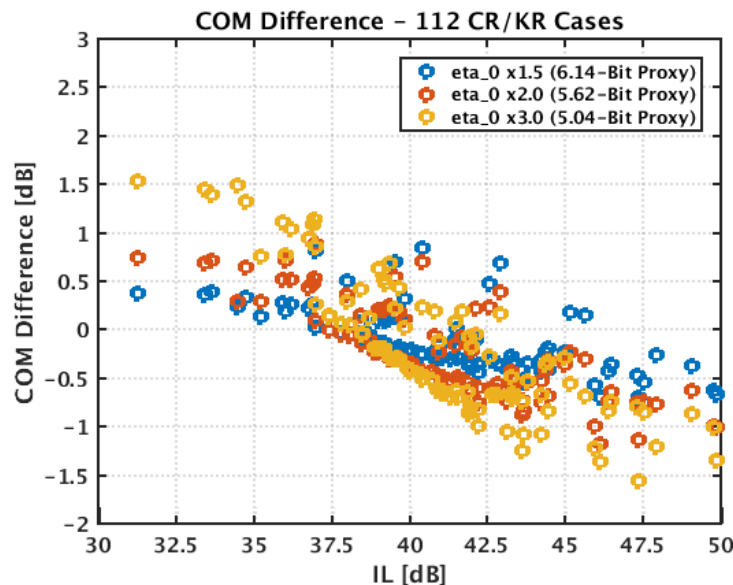
- As a result, the best estimate of the equivalent number of bits that each scale value reflects is its average over channels
- These averages are used to calculate COM that direct model of quantization noise yields
- COM values obtained from two methods (eta\_0 proxy and direct model) now can be compared for the test channels



# COM Difference

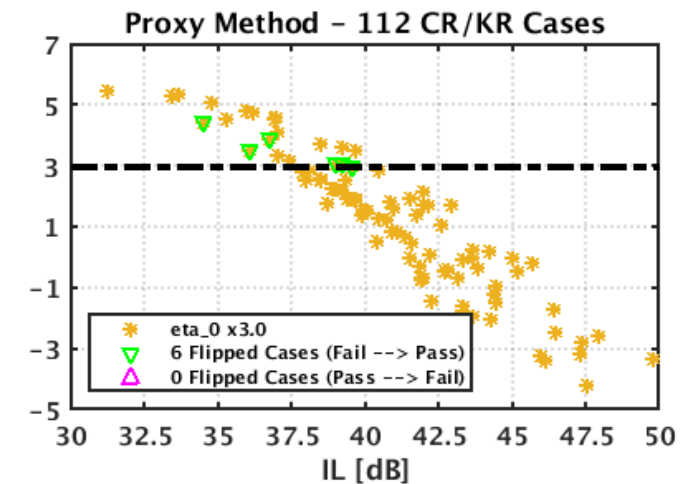
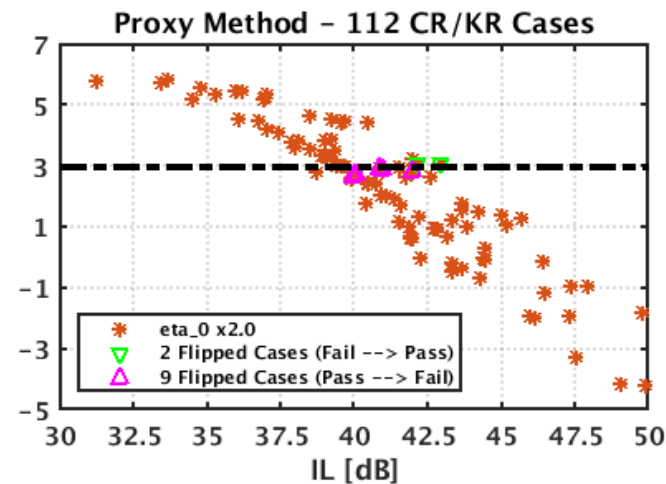
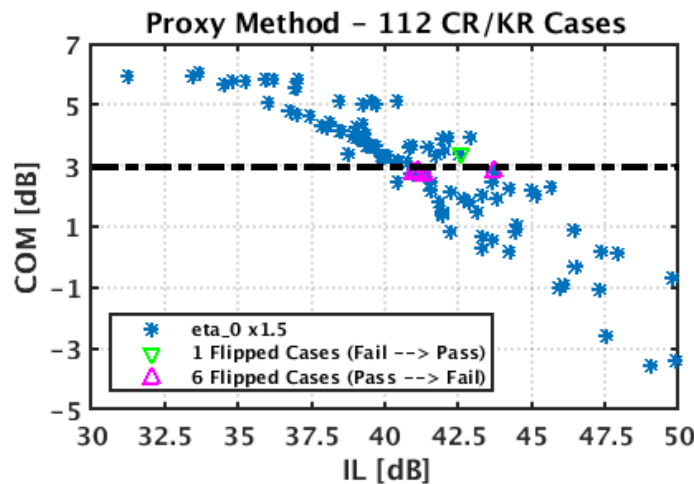
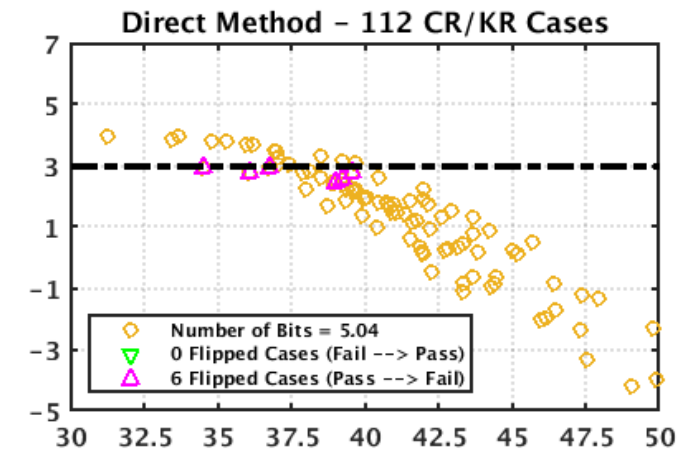
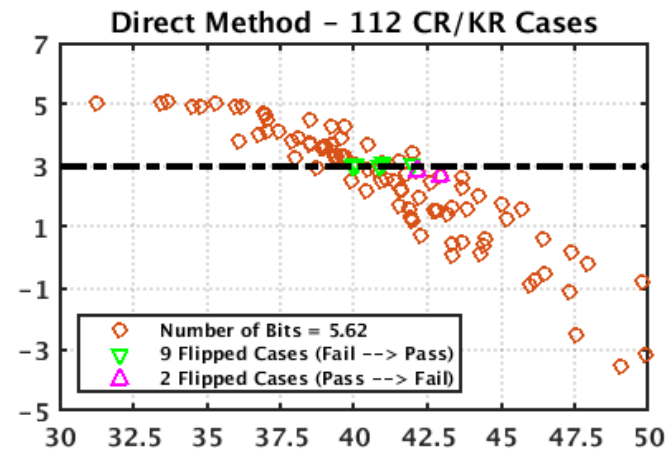
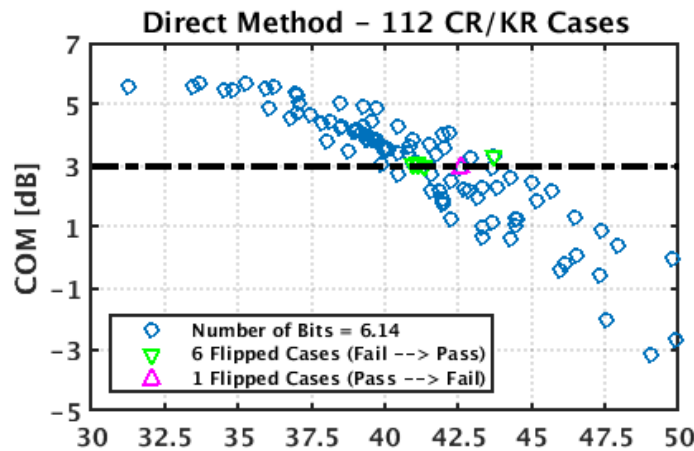
- Closer observations:

- ❖ For channels with IL  $> \sim 40$  dB the proxy method generally under-estimates COM
- ❖ For channels with IL  $< \sim 40$  dB the proxy method generally over-estimates COM
- ❖ Many channels with similar IL can exhibit large COM differences (even more than 1 dB)
- ❖ Correlation in general is not tight enough
- ❖ Depending on the number of quantization bits (even in a practical range), channel, and insertion loss, the difference could be as much as  $\pm 1.5$  dB, which is unacceptable and could flip pass/fail cases



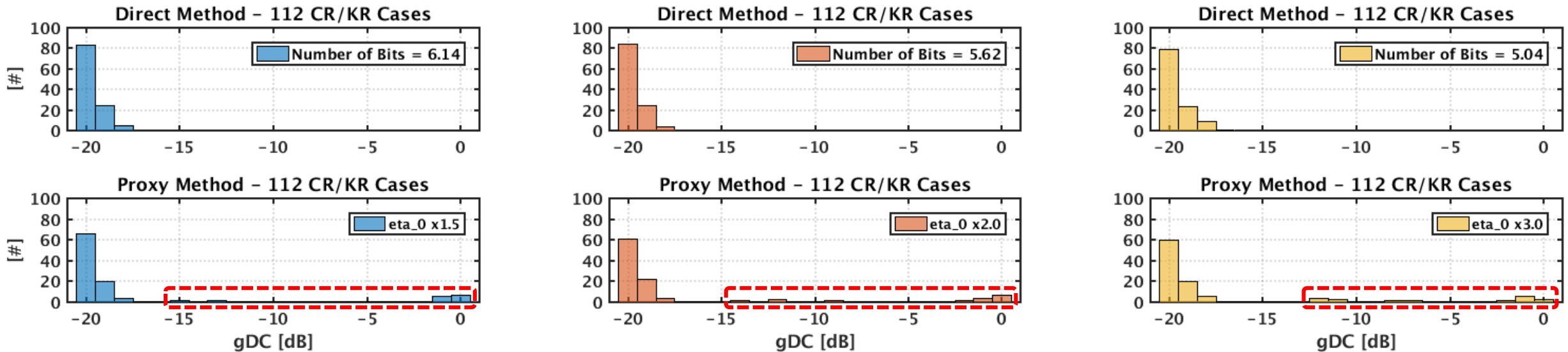
# Pass/Fail and Flipping Cases

- The difference between COMs from two methods causes some cases to flip the pass/fail test



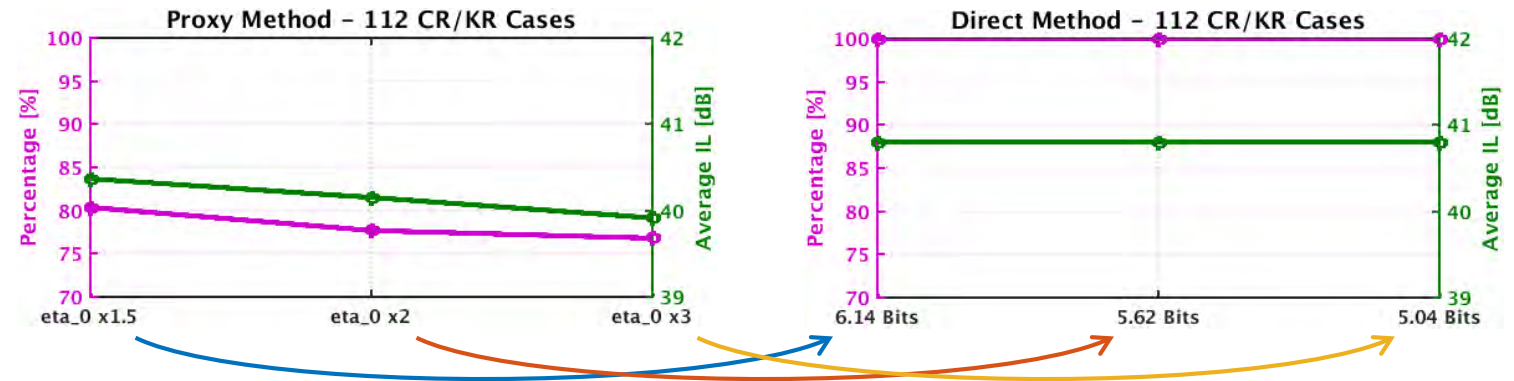
# CTLE Utilization Comparison

- A noticeable population of cases do not properly utilize CTLE with the proxy method



- The trend of CTLE under-utilization as quantization noise increases is against expectation

❖ Percentage of cases that utilize more than 16dB (out of 20dB or more than 80%) of CTLE:



# On the COM Simulation Run Time

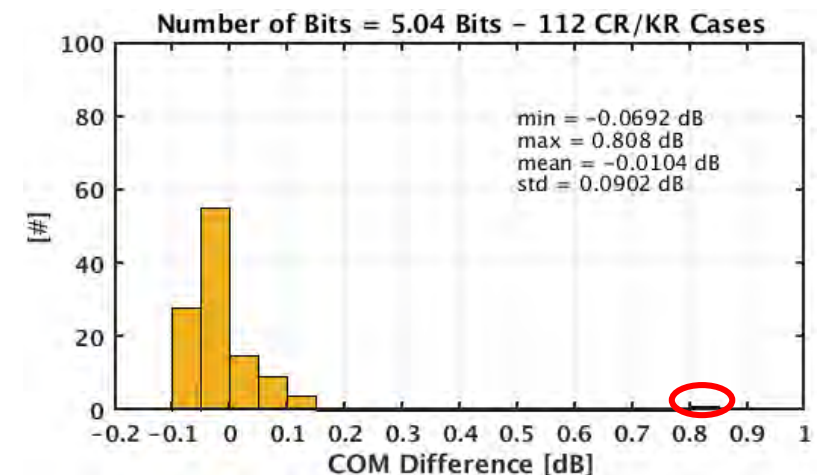
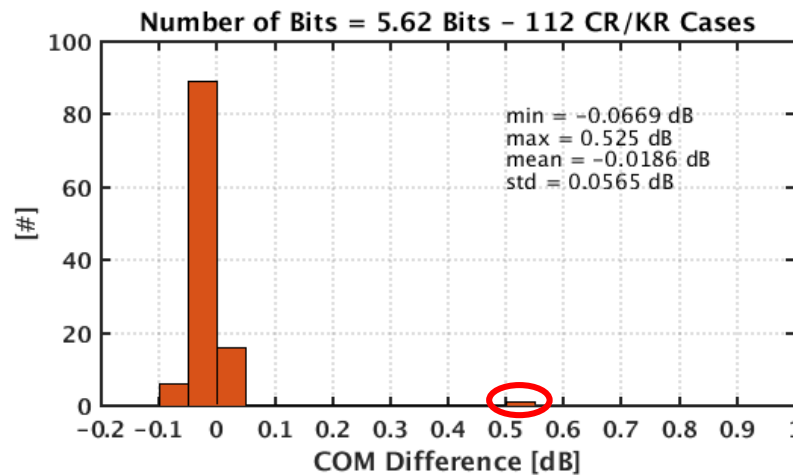
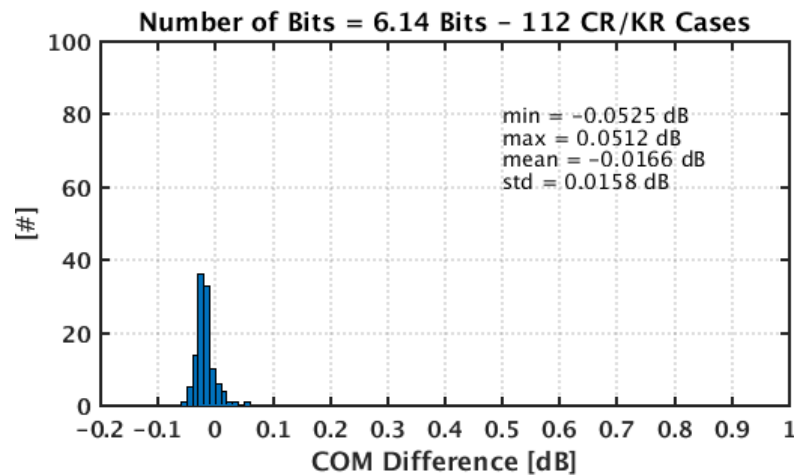
- A recent review of one of the changes in COM version 480 revealed that a part of one of the earlier commit requests was not properly implemented
- This change has to do with the method for calculating quantization noise during optimization iterations
  - ❖ Method 1 is less accurate, but runs faster (3% run time overhead)
  - ❖ Method 2 is more accurate but runs slower (106% run time overhead or 2X slower than method 1)
- Currently, due to a bug both methods are executed but ultimately method 1 overrides the new method
- Consequently, less accurate result of method 1 is yielded with slow run time of method 2 😞
- A COM commit request will be presented in the COM ad hoc meeting this week to address this issue ([shakiba\\_3dj\\_COM\\_03\\_2505.pdf](#))

# On the COM Simulation Run Time

- Run time results without quantization noise and with quantization noise and for both methods across 112 test cases and 3 number of quantization bits:

Average Run Time [s] without Quantization Noise	Average Run Time [s] with Quantization Noise (Method 1)	Average Run Time [s] with Quantization Noise (Method 2)
195	201 (3% Overhead)	401 (106% Overhead)

- The penalty in COM for the above test cases is less than a fraction of a dB except for two cases



# Summary and Conclusion

- Same study and data generation and analysis process was carried on a set of 110 C2C and a set of 208 C2M channels and similar results and trends were observed (see Appendix)
- To include the direct model of quantization noise in the COM flow, a candidate proposal could look like the following:
  - ❖ Scale back  $\eta_0$  from  $1\text{E-}8\text{V}^2/\text{GHz}$  to  $5\text{E-}9\text{V}^2/\text{GHz}$
  - ❖ Add direct model of quantization noise based on this presentation
  - ❖ Set probability of clip,  $P_{qc}$ , to its default value of  $2 \times \text{DER}_0$
  - ❖ Choose number of quantization bits,  $N_{qb}$ , to match the average COM obtained when  $\eta_0$  was  $1\text{E-}8\text{V}^2/\text{GHz}$

Channel	$\eta_0$ [V <sup>2</sup> /GHz]	$P_{qc}$ ( = $2 \times \text{DER}_0$ )	$N_{qb}$
CR / KR	5E-9	2 x 2E-4	5.62
C2C	5E-9	2 x 0.67E-5	6.31
C2M	5E-9	2 x 2E-5	6.56

# Thank You 😊

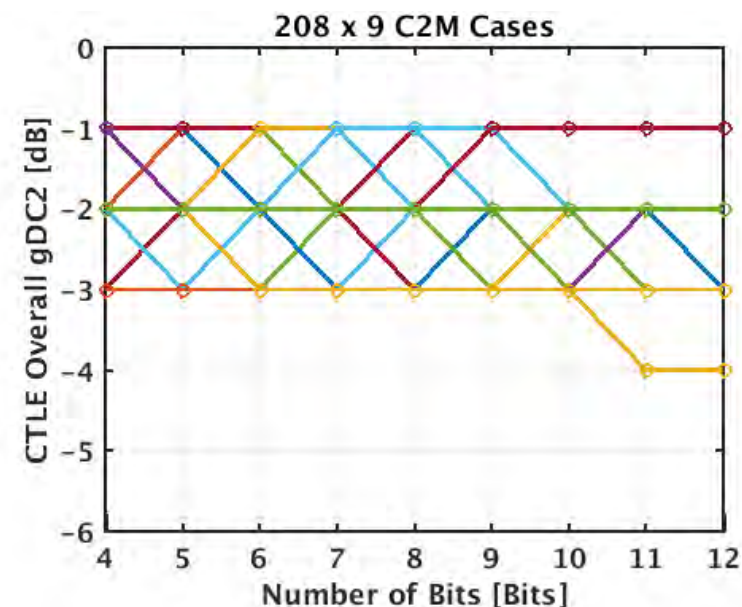
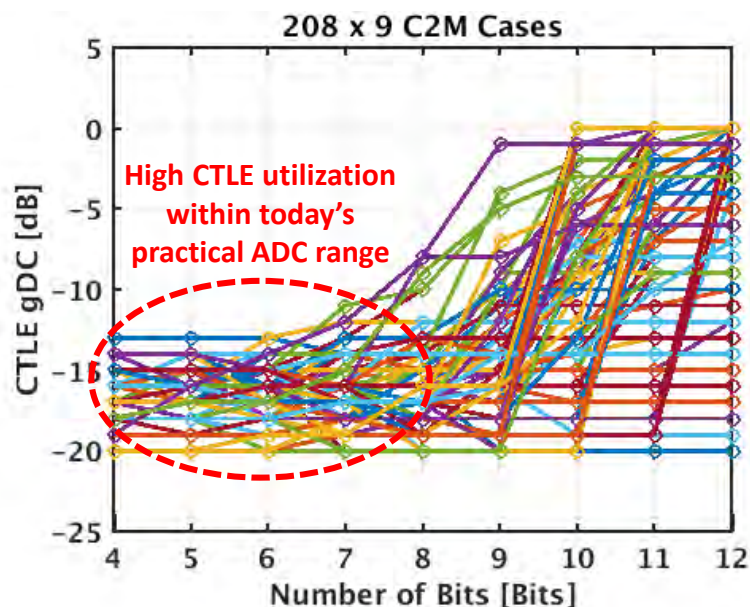
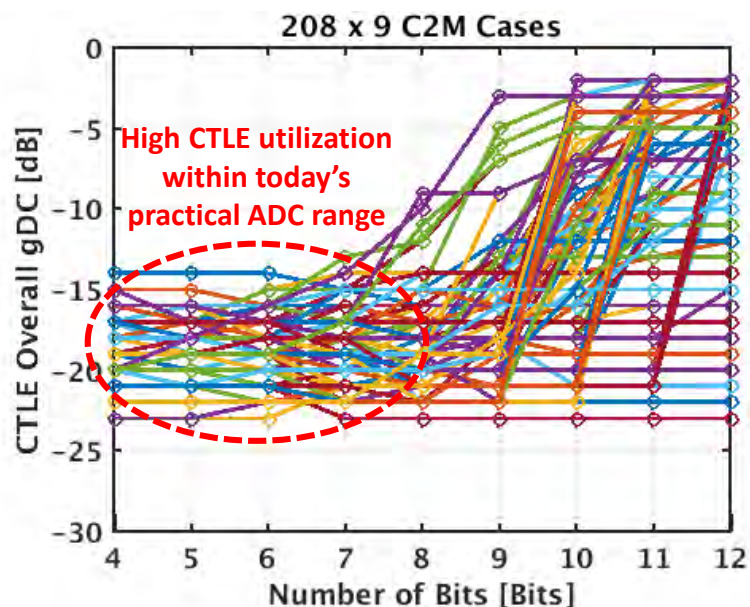
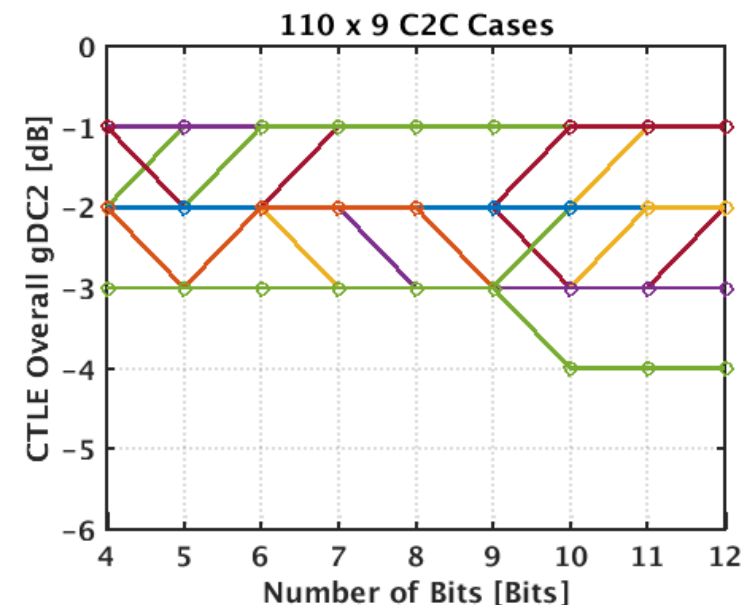
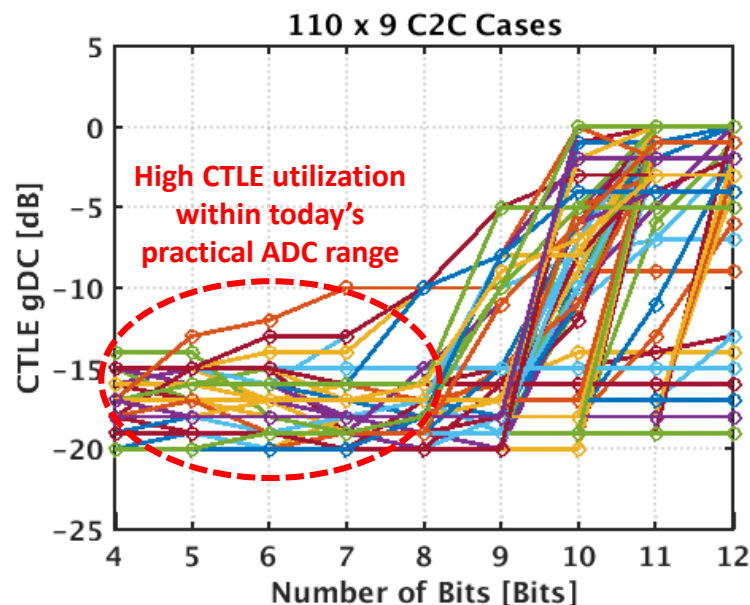
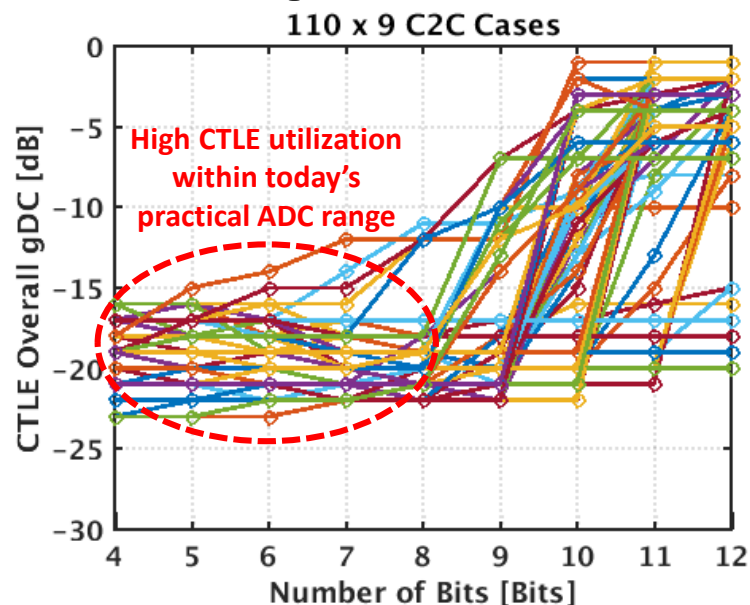
**Hossein Shakiba**  
**Huawei Technologies Canada**



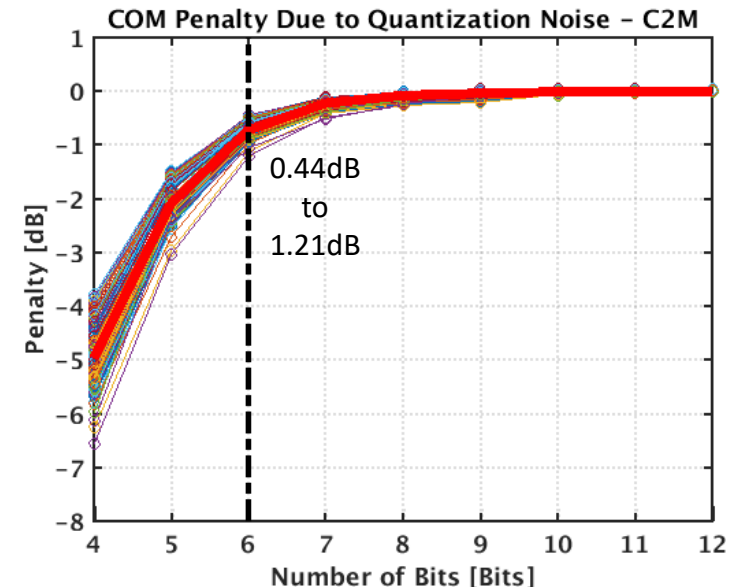
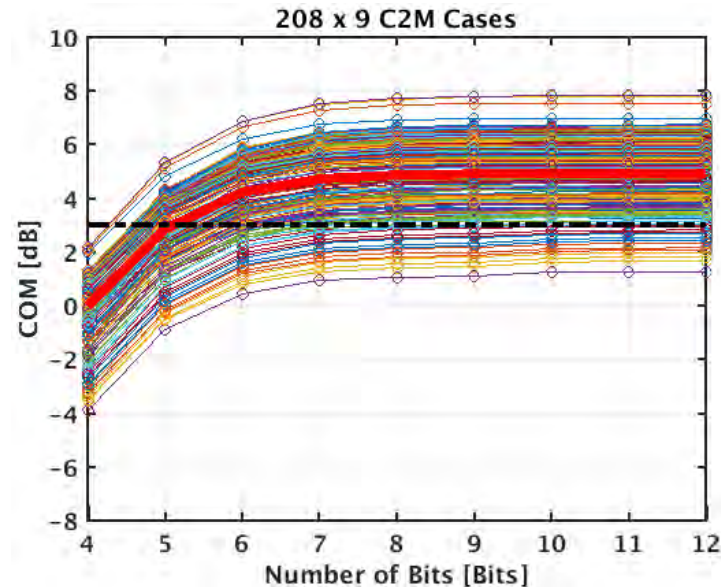
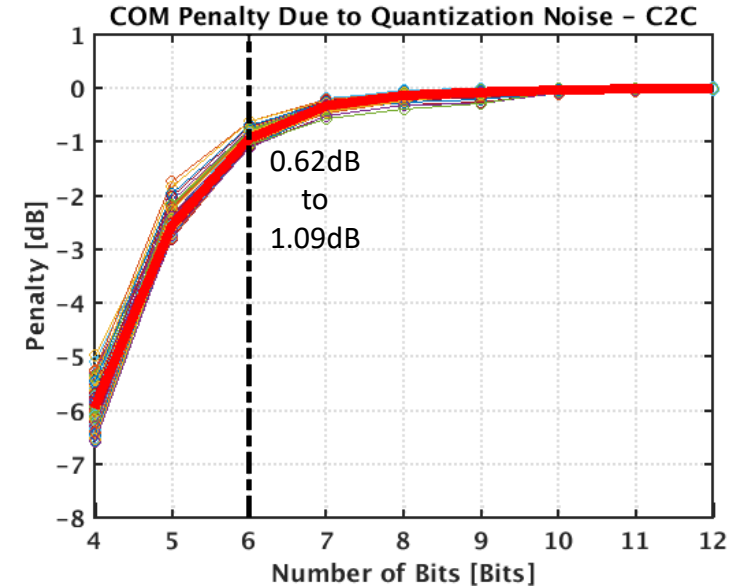
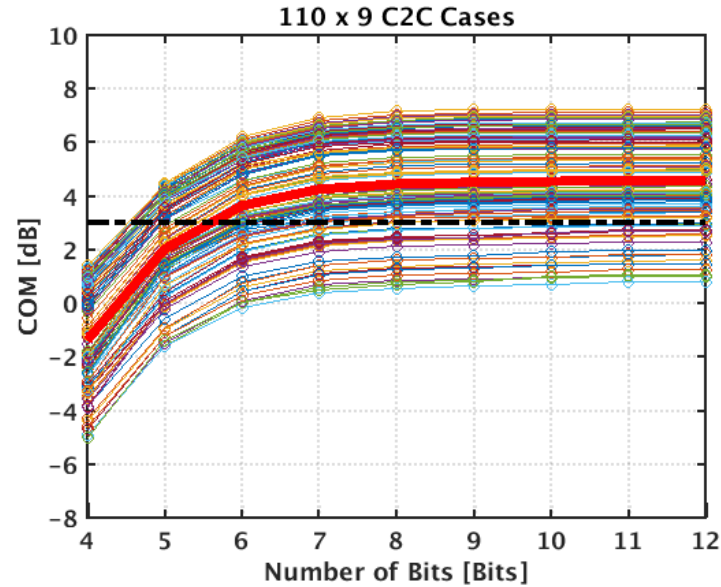
# Appendix

## C2C and C2M Test Case Results

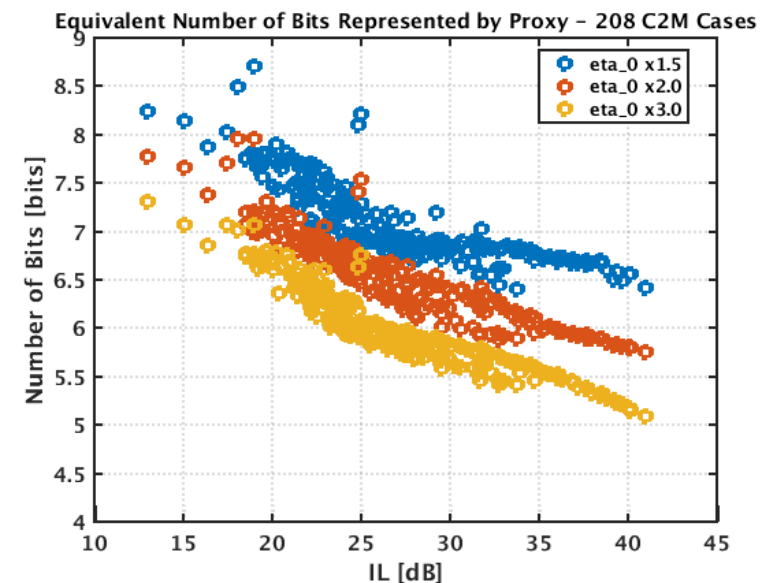
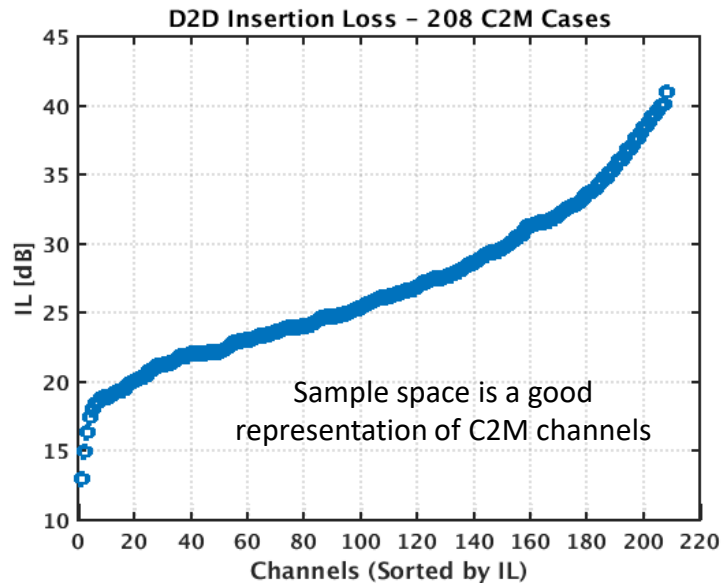
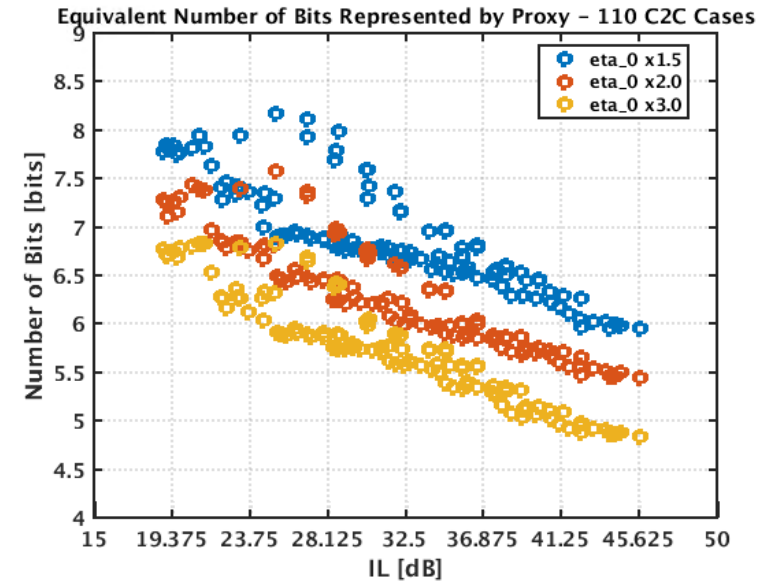
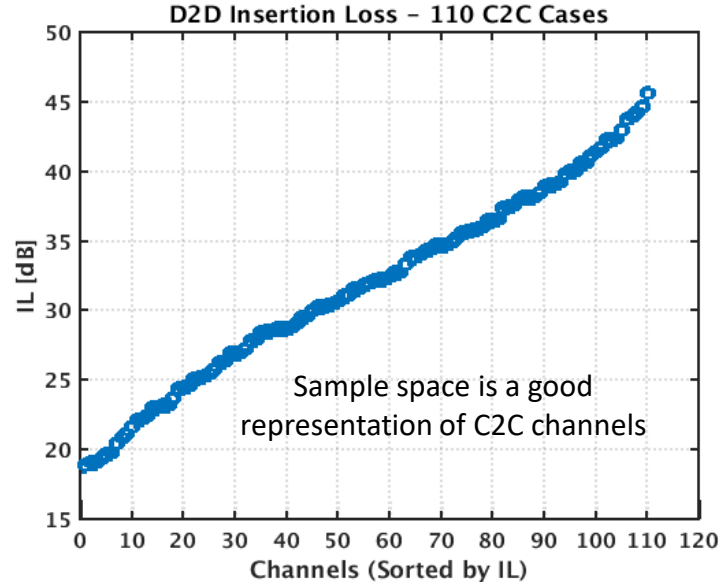
# Impact of Quantization Noise on CTLE Utilization



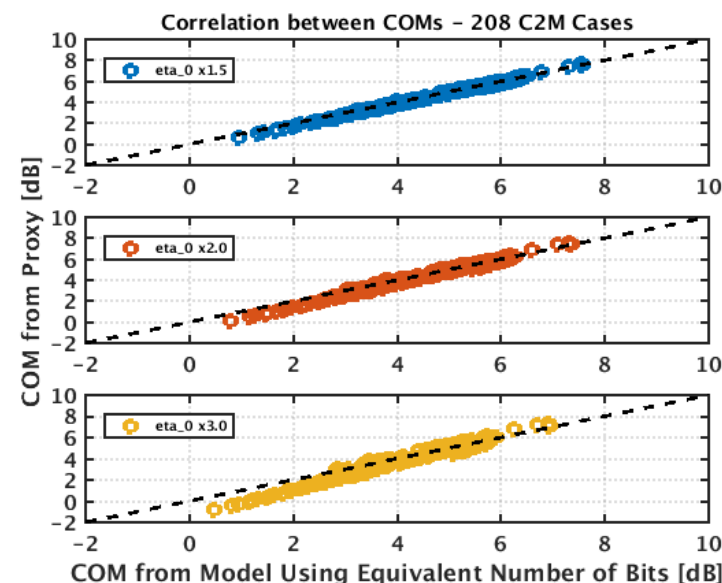
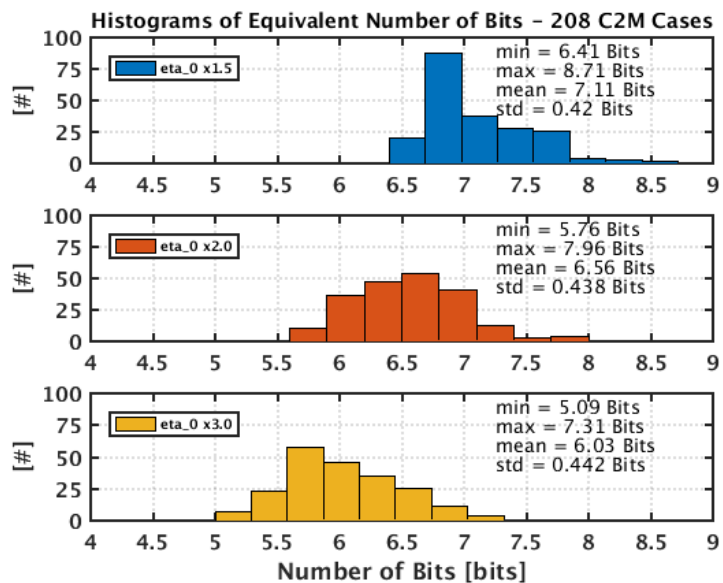
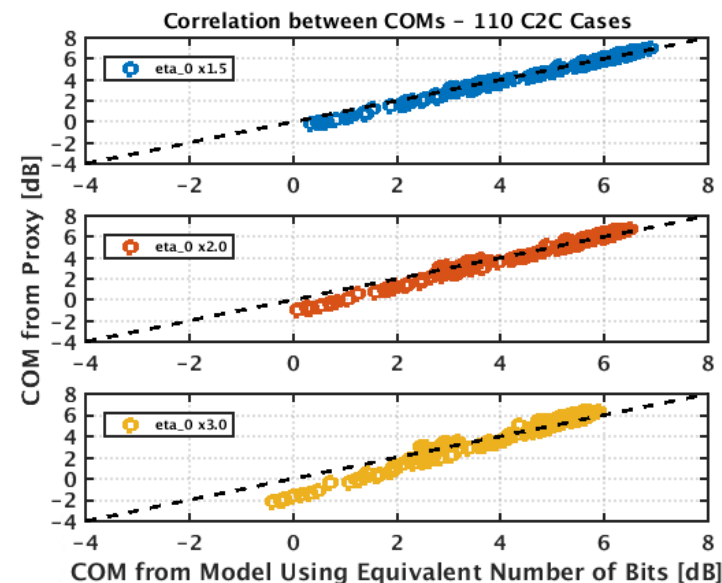
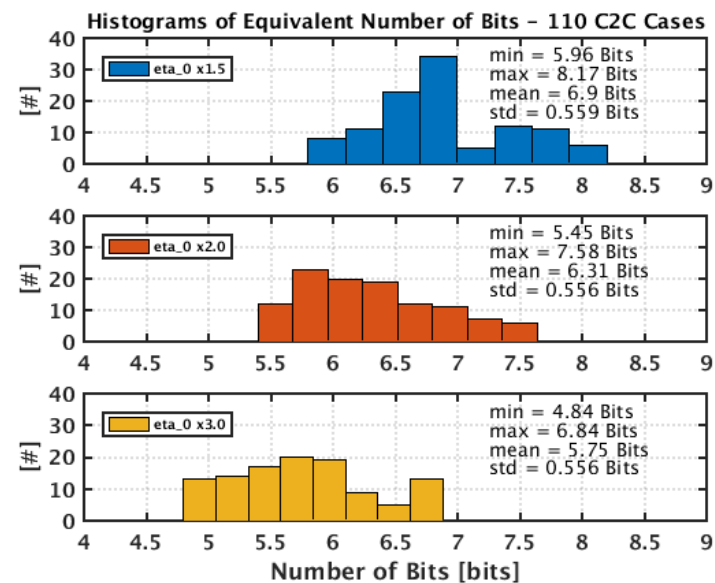
# Impact of Quantization Noise on COM



# The Concern with eta\_0 Proxy Approach

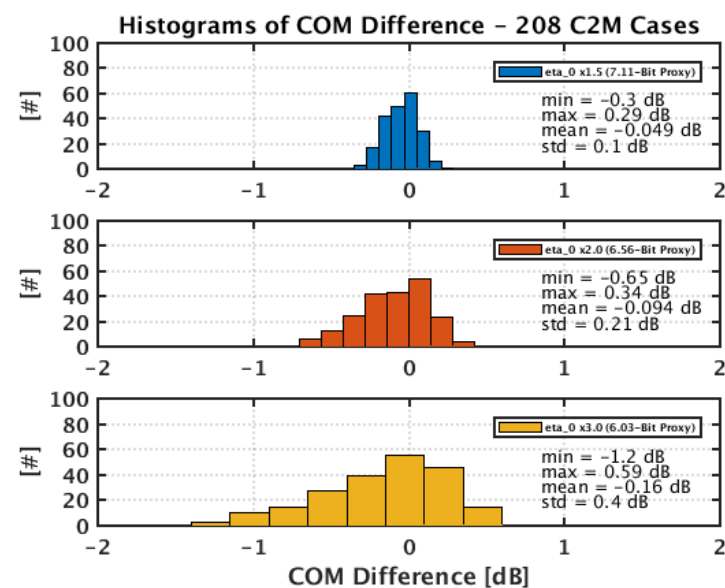
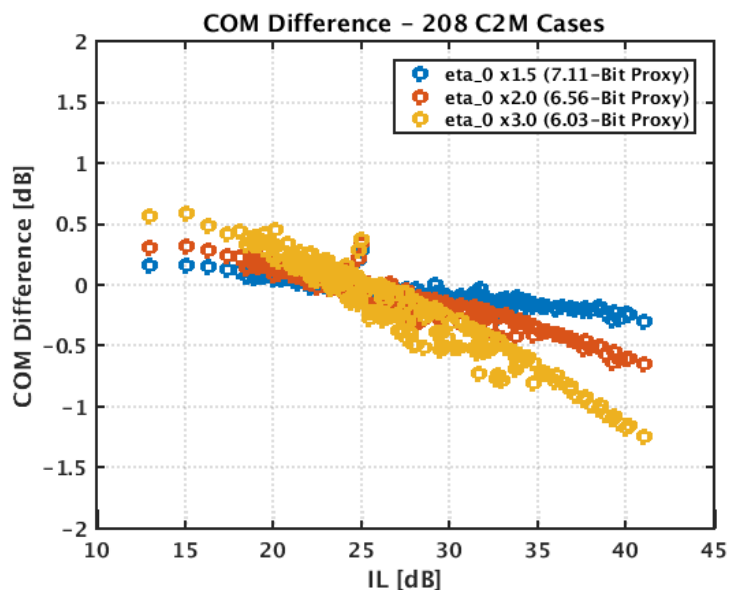
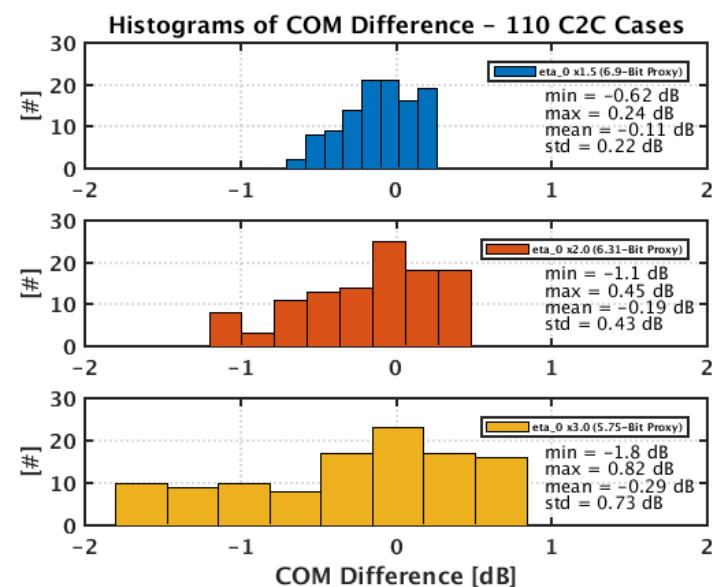
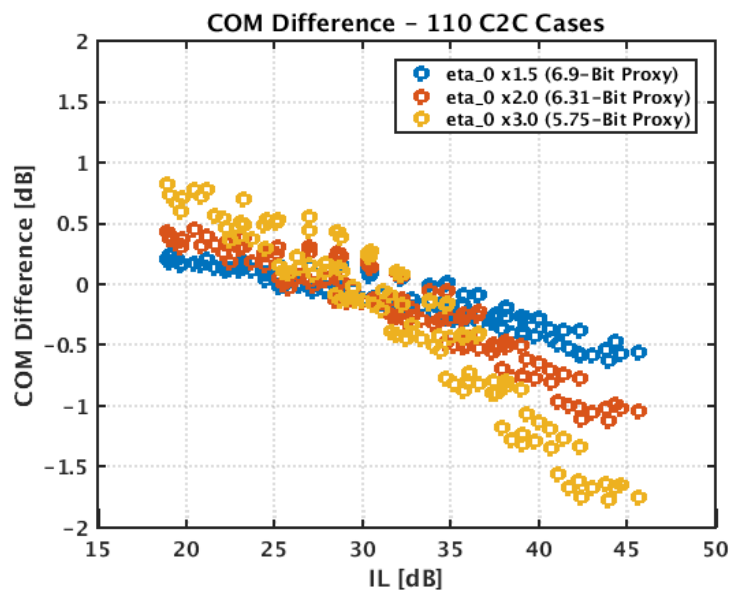


# COM Results Comparison

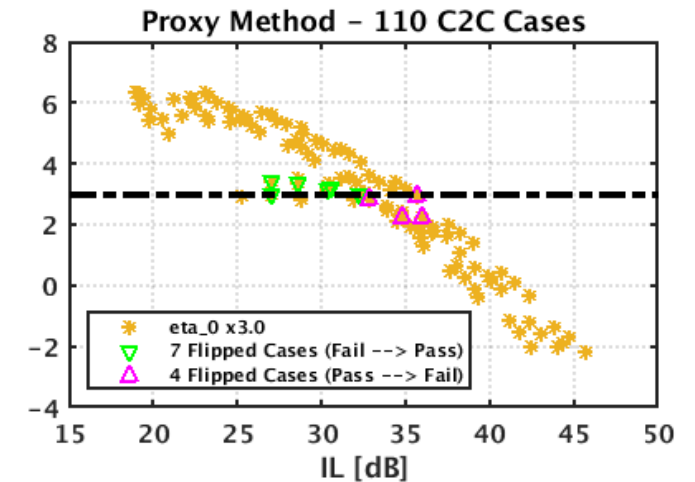
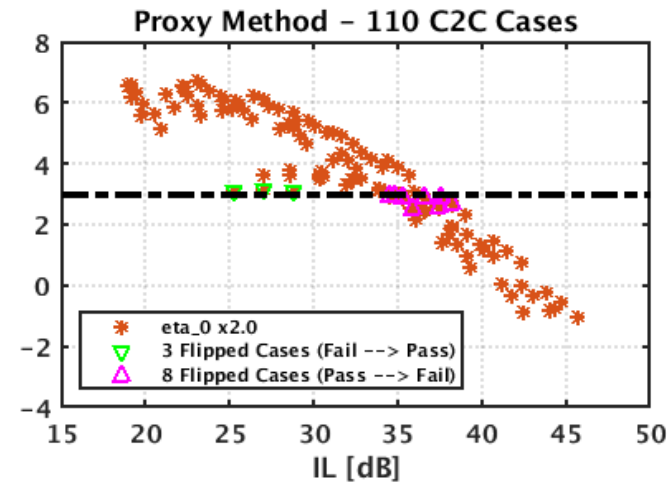
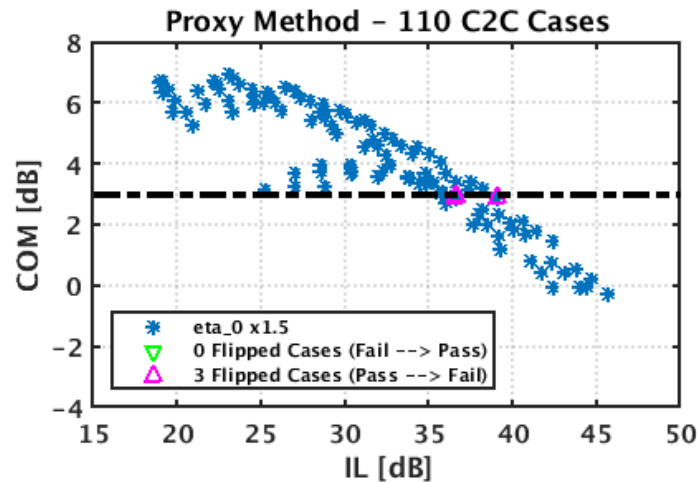
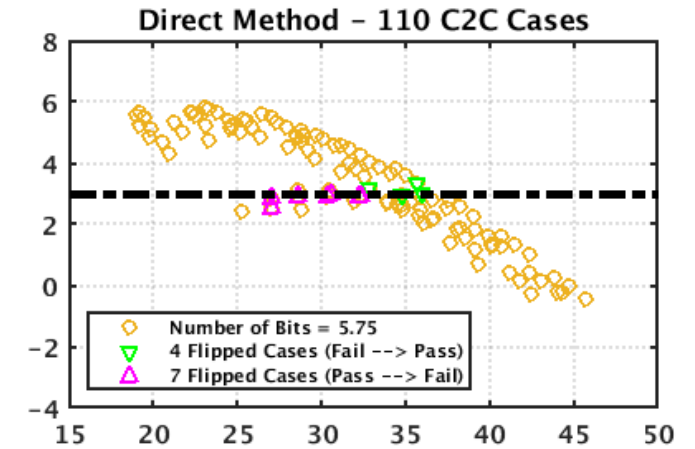
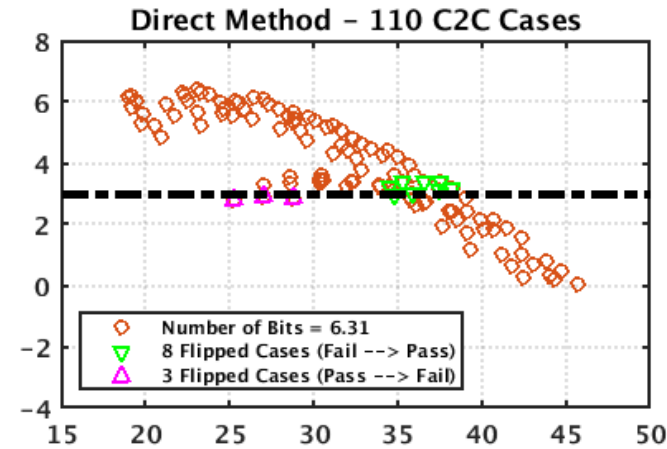
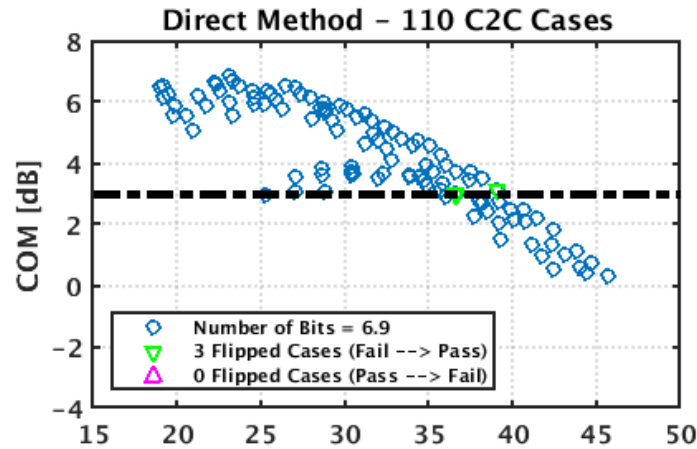




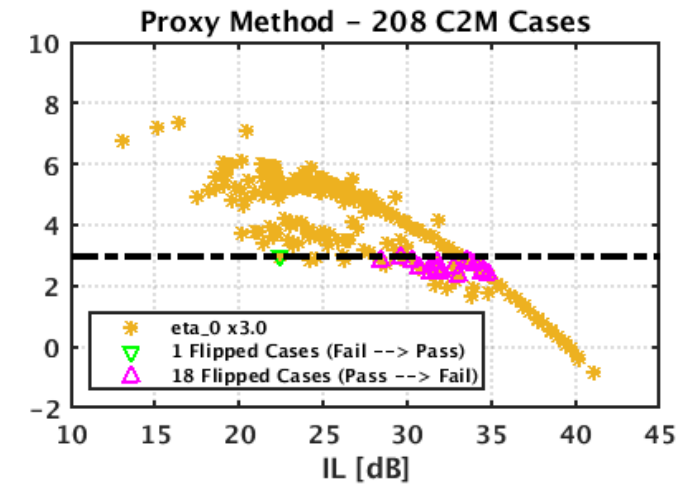
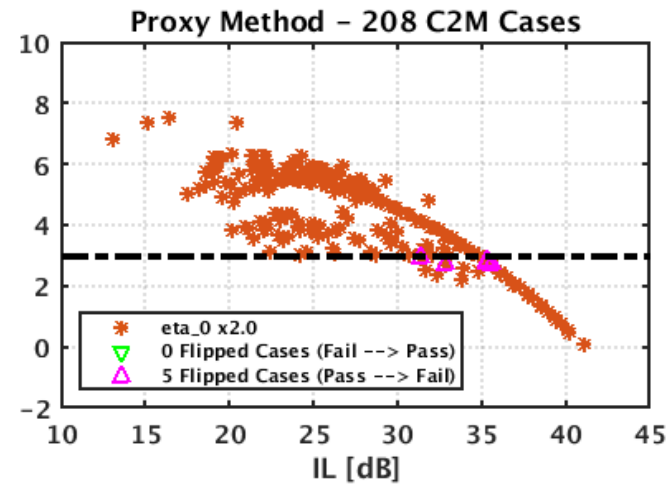
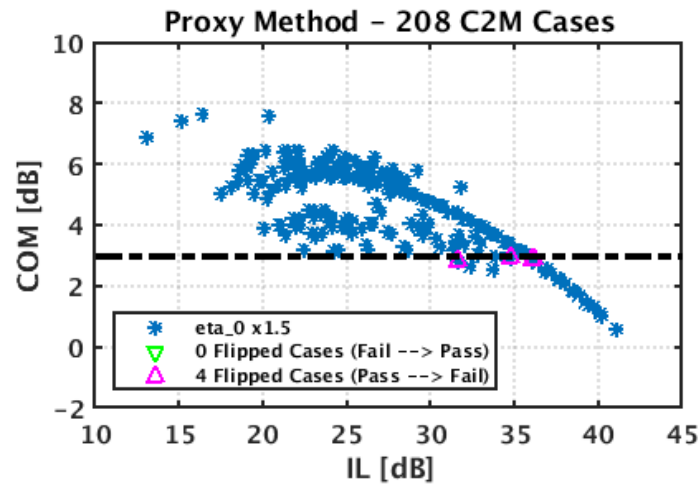
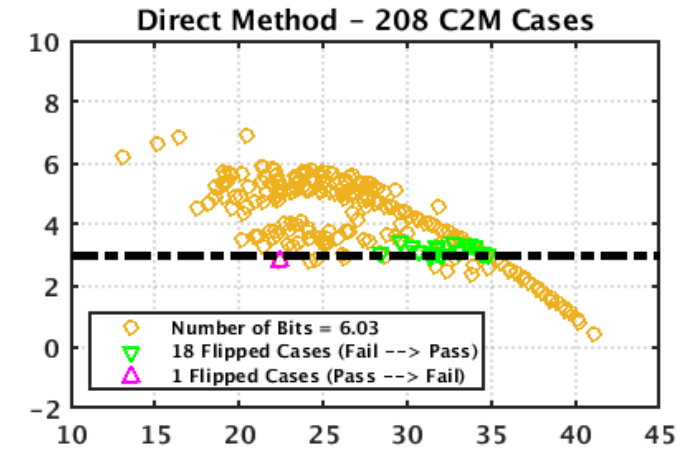
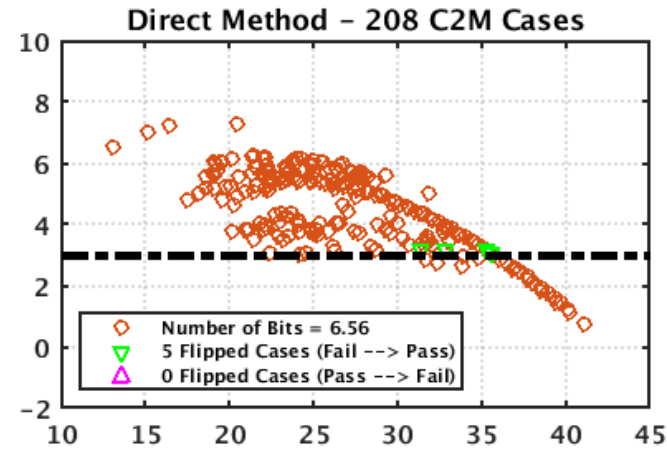
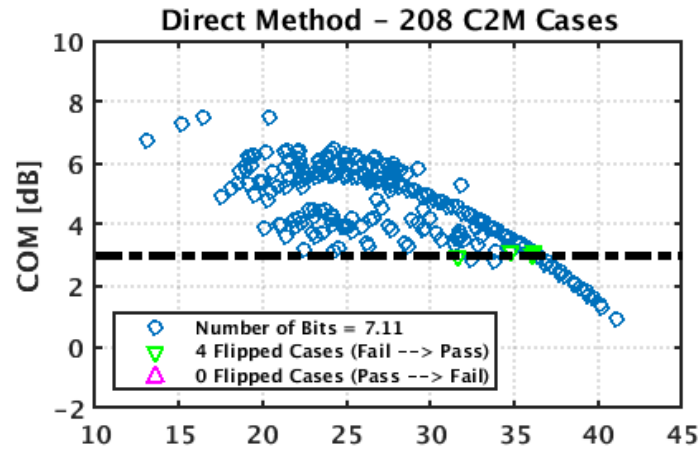
# COM Difference



# Pass/Fail and Flipping Cases

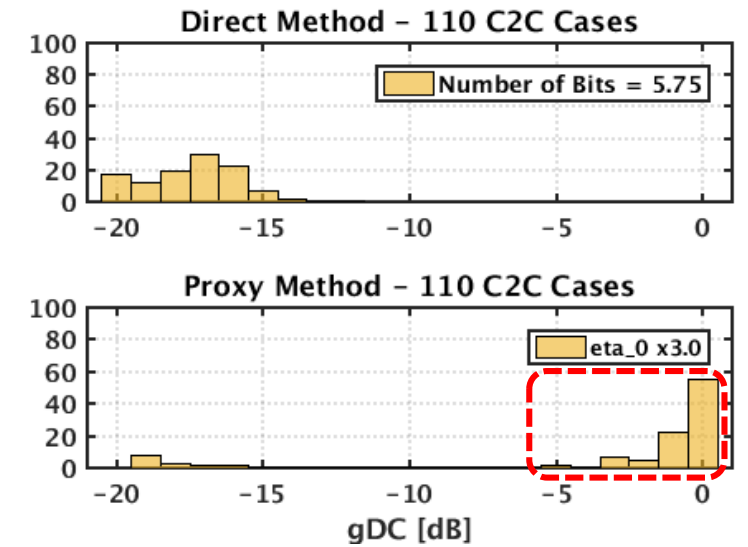
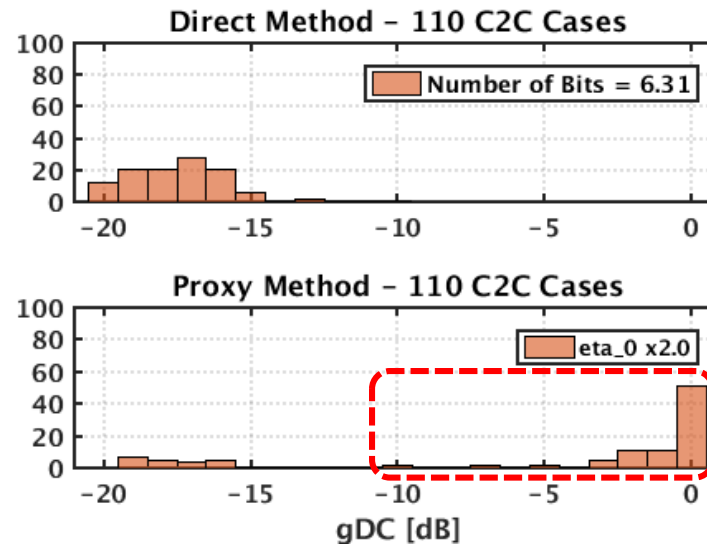
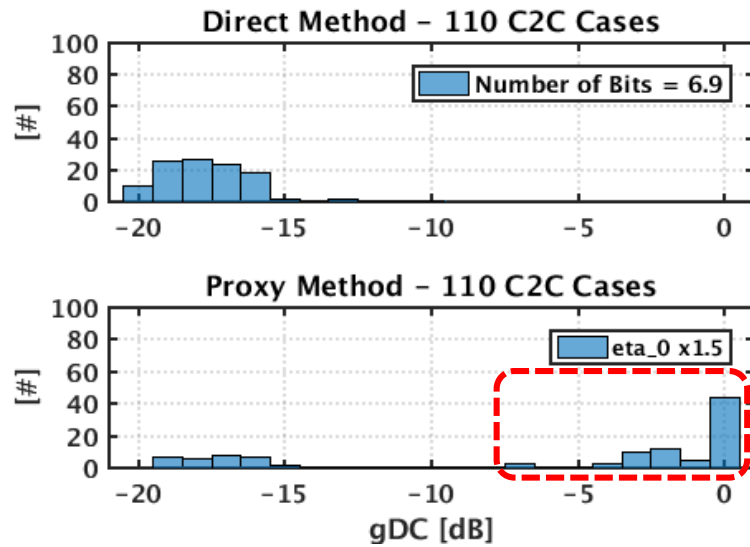


# Pass/Fail and Flipping Cases

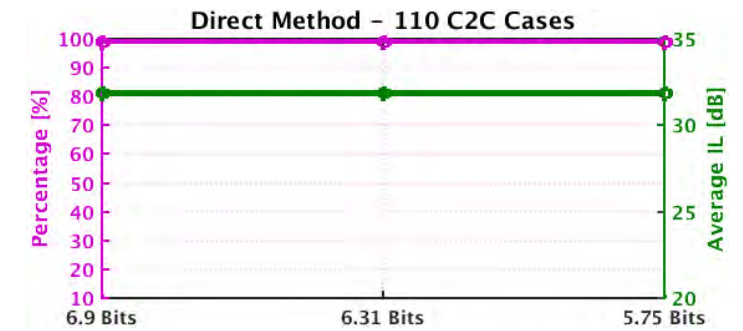
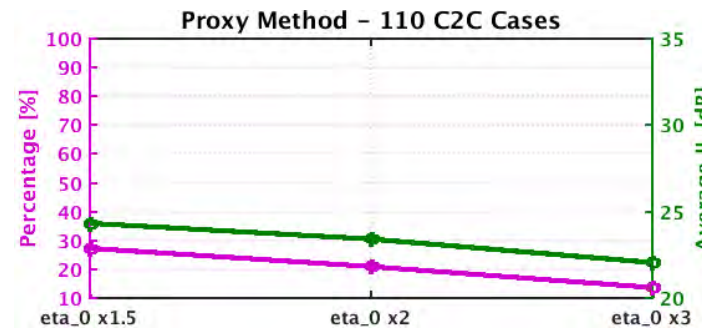




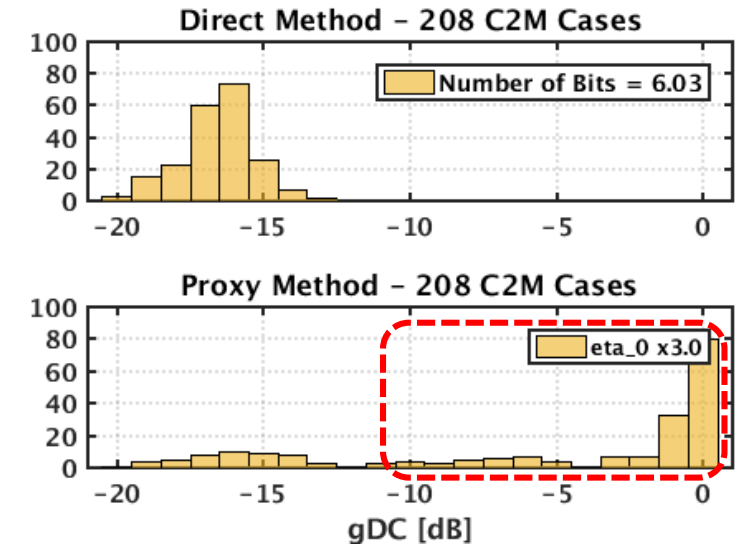
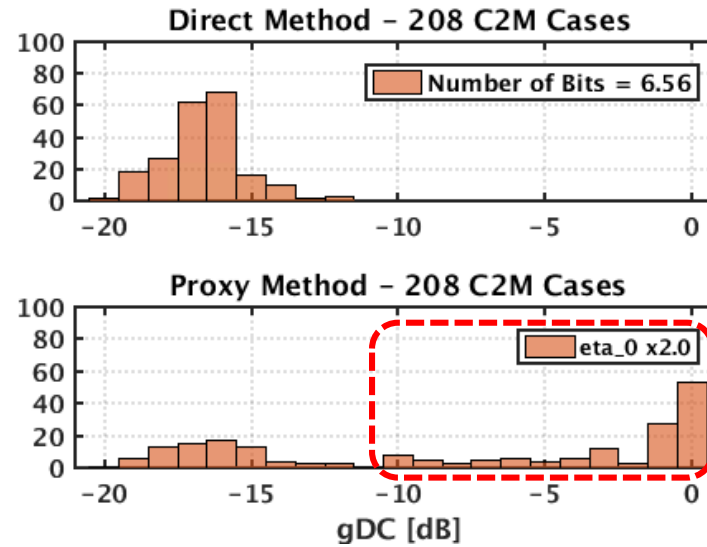
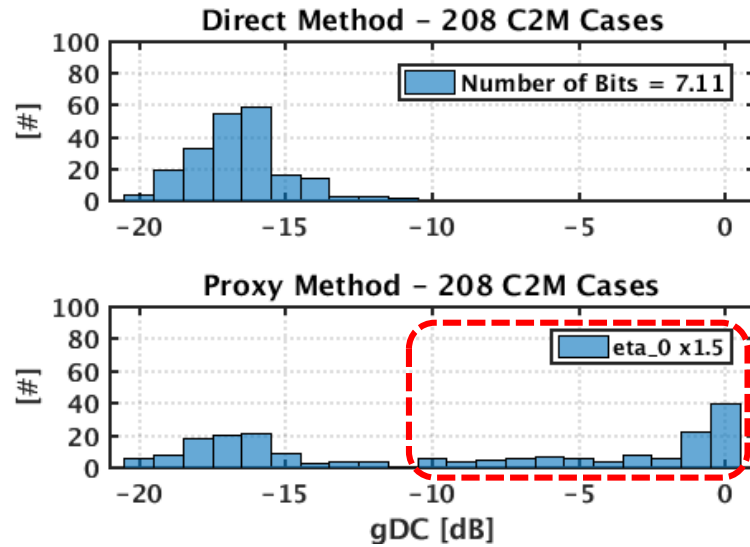
# CTLE Utilization Comparison



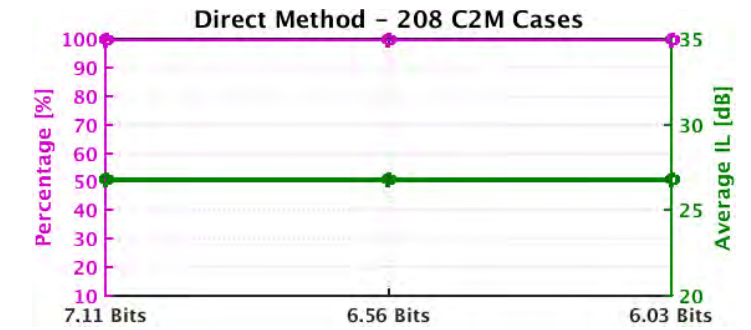
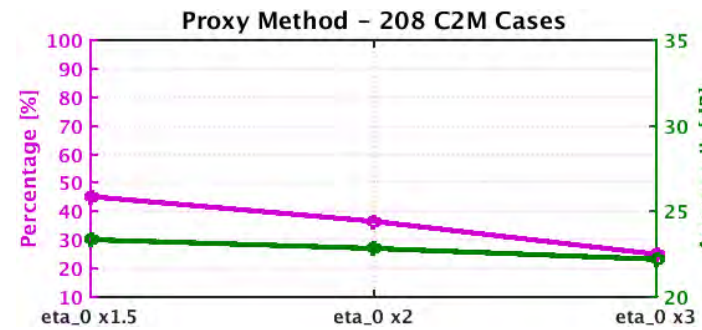
- ❖ Percentage of cases that utilize more than 12dB (out of 20dB or more than 60%) of CTLE:



# CTLE Utilization Comparison



- ❖ Percentage of cases that utilize more than 10dB (out of 20dB or more than 50%) of CTLE:



# Backup Slides

**Channel and COM Info**

# CR/KR Test Channels

Channel #	Channel Source
1	<a href="https://www.ieee802.org/3/dj/public/tools/CR/lim_3dj_03_230629.zip">https://www.ieee802.org/3/dj/public/tools/CR/lim_3dj_03_230629.zip</a>
2	<a href="https://www.ieee802.org/3/dj/public/tools/CR/lim_3dj_04_230629.zip">https://www.ieee802.org/3/dj/public/tools/CR/lim_3dj_04_230629.zip</a>
3 – 7	<a href="https://www.ieee802.org/3/dj/public/tools/CR/kocsis_3dj_02_2305.zip">https://www.ieee802.org/3/dj/public/tools/CR/kocsis_3dj_02_2305.zip</a>
8 – 34	<a href="https://www.ieee802.org/3/dj/public/tools/KR/mellitz_3dj_02_elec_230504.zip">https://www.ieee802.org/3/dj/public/tools/KR/mellitz_3dj_02_elec_230504.zip</a>
35 – 40	<a href="https://www.ieee802.org/3/dj/public/tools/CR/shanbhag_3dj_01_2305.zip">https://www.ieee802.org/3/dj/public/tools/CR/shanbhag_3dj_01_2305.zip</a>
41 – 44	<a href="https://www.ieee802.org/3/dj/public/tools/KR/shanbhag_3dj_02_2305.zip">https://www.ieee802.org/3/dj/public/tools/KR/shanbhag_3dj_02_2305.zip</a>
45 – 80	<a href="https://www.ieee802.org/3/dj/public/tools/KR/weaver_3dj_02_2305.zip">https://www.ieee802.org/3/dj/public/tools/KR/weaver_3dj_02_2305.zip</a>
81 – 88	<a href="https://www.ieee802.org/3/dj/public/tools/KR/weaver_3dj_elec_01_230622.zip">https://www.ieee802.org/3/dj/public/tools/KR/weaver_3dj_elec_01_230622.zip</a>
89	<a href="https://www.ieee802.org/3/dj/public/tools/CR/lim_3dj_07_2309.zip">https://www.ieee802.org/3/dj/public/tools/CR/lim_3dj_07_2309.zip</a>
90 – 96	<a href="https://www.ieee802.org/3/dj/public/tools/KR/akinwale_3dj_01_2310.zip">https://www.ieee802.org/3/dj/public/tools/KR/akinwale_3dj_01_2310.zip</a>
97 – 100	<a href="https://www.ieee802.org/3/dj/public/tools/CR/akinwale_3dj_02_2311.zip">https://www.ieee802.org/3/dj/public/tools/CR/akinwale_3dj_02_2311.zip</a>
101 – 112	<a href="https://www.ieee802.org/3/dj/public/tools/CR/weaver_3dj_02_2311.zip">https://www.ieee802.org/3/dj/public/tools/CR/weaver_3dj_02_2311.zip</a>

# C2C Test Channels

Channel #	Channel Source
1 – 72	<a href="https://www.ieee802.org/3/dj/public/tools/c2c/heck_3dj_02_2405.zip">https://www.ieee802.org/3/dj/public/tools/c2c/heck_3dj_02_2405.zip</a>
73 – 85	<a href="https://www.ieee802.org/3/dj/public/tools/c2c/heck_3dj_02_2403.zip">https://www.ieee802.org/3/dj/public/tools/c2c/heck_3dj_02_2403.zip</a>
86 – 110	<a href="https://www.ieee802.org/3/dj/public/tools/c2c/mellitz_3dj_03_elec_230504.zip">https://www.ieee802.org/3/dj/public/tools/c2c/mellitz_3dj_03_elec_230504.zip</a>

# C2M Test Channels

Channel #	Channel Source
1 – 4	<a href="https://www.ieee802.org/3/dj/public/tools/c2m/mellitz_3dj_02_2409.zip">https://www.ieee802.org/3/dj/public/tools/c2m/mellitz_3dj_02_2409.zip</a>
5 – 64	<a href="https://www.ieee802.org/3/dj/public/tools/c2m/kareti_3dj_elec_02_240111.zip">https://www.ieee802.org/3/dj/public/tools/c2m/kareti_3dj_elec_02_240111.zip</a>
65 – 82	<a href="https://www.ieee802.org/3/dj/public/tools/c2m/gore_3dj_elec_02_231026.zip">https://www.ieee802.org/3/dj/public/tools/c2m/gore_3dj_elec_02_231026.zip</a>
83 – 85	<a href="https://www.ieee802.org/3/dj/public/tools/c2m/lim_3dj_01_230629.zip">https://www.ieee802.org/3/dj/public/tools/c2m/lim_3dj_01_230629.zip</a> <a href="https://www.ieee802.org/3/dj/public/tools/c2m/lim_3dj_02_230629.zip">https://www.ieee802.org/3/dj/public/tools/c2m/lim_3dj_02_230629.zip</a> <a href="https://www.ieee802.org/3/dj/public/tools/c2m/lim_3dj_06_2309.zip">https://www.ieee802.org/3/dj/public/tools/c2m/lim_3dj_06_2309.zip</a>
86 – 101	<a href="https://www.ieee802.org/3/dj/public/tools/c2m/weaver_3dj_elec_02_230831.zip">https://www.ieee802.org/3/dj/public/tools/c2m/weaver_3dj_elec_02_230831.zip</a>
102 – 117	
118 – 123	<a href="https://www.ieee802.org/3/dj/public/tools/c2m/shanbhag_3dj_03_2305.zip">https://www.ieee802.org/3/dj/public/tools/c2m/shanbhag_3dj_03_2305.zip</a>
124 – 206	<a href="https://www.ieee802.org/3/dj/public/tools/c2m/akinwale_3dj_02_2307.zip">https://www.ieee802.org/3/dj/public/tools/c2m/akinwale_3dj_02_2307.zip</a> <a href="https://www.ieee802.org/3/dj/public/tools/c2m/akinwale_3dj_03_2307.zip">https://www.ieee802.org/3/dj/public/tools/c2m/akinwale_3dj_03_2307.zip</a> <a href="https://www.ieee802.org/3/dj/public/tools/c2m/akinwale_3dj_04_2307.zip">https://www.ieee802.org/3/dj/public/tools/c2m/akinwale_3dj_04_2307.zip</a>
207- 208	<a href="https://www.ieee802.org/3/dj/public/tools/c2m/rabinovich_3dj_02_230116.zip">https://www.ieee802.org/3/dj/public/tools/c2m/rabinovich_3dj_02_230116.zip</a> <a href="https://www.ieee802.org/3/dj/public/tools/c2m/rabinovich_3dj_03_230116.zip">https://www.ieee802.org/3/dj/public/tools/c2m/rabinovich_3dj_03_230116.zip</a>



# CR/KR COM Config

- COM version 480\_**hs2p3** (customization **\_hs2p3** applies commit requests 4p8\_1 to 4p8\_5)

Table 93A-1 parameters				sds ref.	V/O control	sds ref.	Table 93A-3 parameters (Table Not Used with Class A and B Packages)				sds ref.	SAVE_D01(FIG2.MAT)	o
Parameter	Setting	Units	Information			Parameter	Setting	Units	Information		Receiver testing		
f_b	106.25	GHz				DIAGNOSTICS	0	logical			RX_CALIBRATION	0	logical
f_min	0.05	GHz				DISPLAY_WINDOW	0	logical			Sum(BB) steps	5.00E+03	V
Delta_f	0.01	GHz				CSV_REPORT	0	logical			CNP parameters		
C_d	[0.4e-4 0.9e-4 1.1e-4 0.4e-4 0.9e-4 1.1e-4]	nF	(TX RX)	d1.0		RESULT_DIR	y:\src\PC2M_data\				f_v	0.275	Fb
L_s	[0.13 0.13 0.14; 0.13 0.13 0.14]	nH	(TX RX)	d1.0		SAVE_FIGURES	0	logical			f_f	0.278	Fb
C_b	[0.3e-4 0.3e-4]	nF	(TX RX)	d1.0		Port Order	[1 1 3 2 4]	input			f_n	0.279	Fb
R_0	30	Ohm	(TX RX)	d1.0 cmg 396		BUTTING	C2M_				f_2	58.438	GHz
R_d	[46.25 46.25]	Ohm	(TX RX)			COM_CONTRIBUTION	1	logical			A_ft	0.450	V
PNG_NAME	PNG_HIR_CLASSB PNG_lowR_CLASSA		TX RX								A_nt	0.450	V
A_w	0.387	V				TDR and ERL options							
A_te	0.387	V				TDR	1	logical			Parameter Setting		
A_ne	0.482	V				ERL	1	logical			board_id_param0_at_1_2	(0 5.95e-4 2.6e-05)	1.4 dB/cm @ 53.125G
z_p select	{1}					ERL_ONLY	0	logical			board_id_tau	5.790E+3	dB/mm
L	4					TR_TDR	0.005	N			board_z_c	92.5	Ohm
M	32					FORCE_TR	1	U			z_b (TX)	32	mm
filter and eq						TDR_Buttermouth	1	U			z_b (NEXT)	32	mm
f_r	0.500	Hz				beta_x	0	U			z_b (EXT)	32	mm
c[0]	0.54	min				rhc_x	0.618	U			z_b (RX)	32	mm
c[-1]	0	(min:step:max)				TDR_VV_TPNG	1	U			C_0	(0.29e-4 0)	nF
c[-2]	0	(min:step:max)				FLTx	16	U			C_1	[0.1e-4 0]	nF
c[-3]	0	(min:step:max)				fixtue delay time	{ 0 0 }	S			Include PCB	0	logical
c[-4]	0	(min:step:max)				Legacy Window	1				Selections (rectangle, gaussian, dual, triangle)		
c[1]	0	(min:step:max)				Noise filter					Histogram_Window_Width	0.0001	selection
r_n	1	U				signal_RJ	0.01	U			eq	0.02	U
b_max(1)	0.85	As/dBct				A_DD	0.02	U			Filter Rx FFT		
b_max(2_N_b)		As/dBct_N_b				da_0	1.00E+08	V^2/GHz			ff_gm_bop_len	6	U
b_min(1)	0	As/dBct				SR_TX	33.5	dB			ff_gm_bop_jst	8	U
b_min(2_N_b)	-0.15	U	YAW/YRB+1			RLM	0.95				ff_gm_bop1_max	0.7	interpreted as +/-
e_DC	(-20 1.0)	dB	(min:step:max)	d1.0 (Max value -20)							ff_gm_bop1_min	0.7	interpreted as +/-
f_z	-42.50	GHz				bandwidth	0	bandwidth			ff_gm_bop1_max	0.7	interpreted as +/-
f_p1	-42.50	GHz				bandwidth	1.00E+08	bandwidth			FFS_OPTION_METHOD	MUSE	
f_p2	106.25	GHz				bandwidth	1.00E+08	bandwidth			num_Ultra_XRF_nodes	2048	
e_DC_HP	(-0.1 0)		(min:step:max)	d1.0							Floating tap Control		
LHP_PZ	1.328125	GHz				bandwidth	1.00E+08	bandwidth			N_bop	2	0 1 2 or 3 groups
Butterworth	1	logical	include in fr			bandwidth	1.00E+08	bandwidth			N_H	4	taps per group
						bandwidth	1.00E+08	bandwidth			N_F	30	U/skip for floating taps
						bandwidth	1.00E+08	bandwidth			max_DFS	0.2	max DFS value for floating taps
						bandwidth	1.00E+08	bandwidth			B_flow_RSS_MAX	1	as tap limit
						bandwidth	1.00E+08	bandwidth			N_tap_start	9	(U) start of tap limit

START	PKG_LowR_CLASSA	[2.44 5.7] dB	
Table 93A-3 parameters			
Parameter	Setting	Units	Information
package_tj_gamma0_a1_a2	[ 0.0005 0.00089 0.0002 ]		d1.0
package_tj_tau	0.006141	ng/mm	d1.0
package_Z_c	[87.5 87.5 ; 92.5 92.5 ; 100 100; 100 100]	Ohm	d1.0
R_d	[46.25 46.25]	Ohm	[TX RX] d1.0 gmt.196
z_p (TX)	[ 33 12 33 33 ; 1.8 1.8 1.8 1.8 ; 0.0 0.0 ; 0.0 0.0 ]	mm	[test cases] d1.0
z_p (NEXT)	[ 33 12 33 33 ; 1.8 1.8 1.8 1.8 ; 0.0 0.0 ; 0.0 0.0 ]	mm	[test cases] d1.0
z_p (FEED)	[ 33 12 33 33 ; 1.8 1.8 1.8 1.8 ; 0.0 0.0 ; 0.0 0.0 ]	mm	[test cases] d1.0
z_p (RX)	[ 33 12 33 33 ; 1.8 1.8 1.8 1.8 ; 0.0 0.0 ; 0.0 0.0 ]	mm	[test cases] d1.0
C_p	[0.4e-4 0.4e-4]	nF	[TX RX] d1.0
A_v	[0.385 0.385 0.385 0.385]	V	Vf=0.400 d1.2
A_fe	[0.385 0.385 0.385 0.385]	V	Vf=0.399 D1.2
A_re	[0.481 0.481 0.481 0.481]	V	Vf=0.400 D1.2
END			

START	PKG_HIR_CLASS5B	[2 8 5 6 6 7 4 4] db	
Table 93A-3 parameters			
Parameter	Setting	Units	Information
package_tf_gamma0_a1_a2	[ 0.0005 0.00065 0.000293 ]		d1.0
package_tf_tau	0.006141	ng/mm	d1.0
package_Z_c	[87.5 87.5 ; 95.95 ; 100 100; 78 78]	Ohm	d1.0
R_d	[ 46.25 46.25 ]	Ohm	[TX RX] d1.0 cmt 396
z_p (TX)	[ 45 30 8 24 ; 2 2 2 2 ; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5 ]	mm	[test cases] d1.0
z_p (NEXT)	[ 44 29 8 24 ; 2 2 2 2 ; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5 ]	mm	[test cases] d1.0
z_p (FEET)	[ 45 30 8 24 ; 2 2 2 2 ; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5 ]	mm	[test cases] d1.0
z_p (RX)	[ 44 29 8 24 ; 2 2 2 2 ; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5 ]	mm	[test cases] d1.0
C_p	[0.4e-4 0.4e-4]	nF	[TX RX] d1.0
A_v	[0.385 0.385 0.385 0.385]	V	Vf=0.400 d1.0 cmt 434
A_fe	[0.385 0.385 0.385 0.385]	V	Vf=0.399 d1.0 cmt 434
A_re	[0.481 0.481 0.481 0.481]	V	Vf=0.400 d1.0 cmt 434
END			



# C2C COM Config

- COM version 480\_**hs2p3** (customization **\_hs2p3** applies commit requests 4p8\_1 to 4p8\_5)

Table 93A-1 parameters				sds ref.	I/O control				sds ref.	Table 93A-3 parameters (Table Not Used with Class A and B Packages)				sds ref.	SAVE_CONFIG2.MAT	0	
Parameter	Setting	Units	Information		DIAH/OSTICS	0	logical			Parameter	Setting	Units	Information			Receiver testing	
f_b	106.25	GHz			DISPLAY_WINDOW	0	logical			package_t_gamma0_a1_a2	[5e-4 0.00065 0.0003]					RX_CALIBRATION	0
f_min	0.05	GHz			CSV_REPORT	0	logical			package_t_gamma0_a1_a2	0.006141	ns/mm				SignalBBI dep	0.00E-03
Delta_f	0.01	GHz			RESULT_DIR	_results\VC2M_1\data\				package_Z_c	[87.5 87.5; 92.5 92.5; 100 100; 100 100]	Ohm				C.N.p parameters	
C_d	[0.4e-4 0.9e-4 1.1e-4 0.4e-4 0.9e-4 1.1e-4]	nF	[TX RX]	d1.0	SAVE FIGURES	0	logical			z_p [TX]	[1 1 1; 1 1 1; 0.5]	mm	[test cases to run]			I_v	0.278
L_p	[0.13 0.13 0.14; 0.13 0.13 0.14]	nH	[TX RX]	d1.0	Port Order	[1 3 2 4]	input			z_p [NEXT]	[1 1 1; 1 1 1; 1.0]	mm	[test cases]			I_1	0.278
C_b	[0.3e-4 0.3e-4]	nF	[TX RX]	d1.0	BUTTING	C2M_				z_p [EXT]	[1 1 1; 1 1 1; 1.0]	mm	[test cases]			I_2	0.278
R_d	50	Ohm	[TX RX]	d1.0 cmt 396	COM_CONTRIBUTION	1	logical			z_p [RX]	[1 1 1; 1 1 1; 1.0]	mm	[test cases]			A_h	58.438
R_d	[46.25 46.25]	Ohm	[TX RX]		C_p					C_p	[0.4e-4 0.4e-4]	nF	[test cases]			A_h	0.450
PNG_NAME	PNG_HIR_CLASSB PNG_LowR_CLASSA		TX RX													A_ne	0.450
A_v	0.385	V			TDR and ERL options					ERL Pass threshold	10	dB					
A_je	0.385	V			TDR	1	logical			COM Pass threshold	3	dB					
A_ne	0.481	V			ERL_ONLY	0	logical			Q ERD	6.70E-05						
z_p select	[1]				TR_TDR	0.005	nF			FORCE_TR	0.00400	ns					
L	4				TDR Butterworth beta_x	7000	UI			EMD_type	C2C						
M	32				TDR Butterworth beta_x	0				samples_for_C2M	100						
					TDR Butterworth beta_x	0				T_C	50						
f_p	0.550	nF		d1.0 cmt 60 (60 GHz)	rho_x	0.618				BV	1						
c[0]	0.54	min		d1.0 cmt 37	TDR_W_TDRPKG	1	UI			MUSE	1	logical					
c[-1]	0	(min:step:max)		d1.0 max value -0.34	HL_tx	16	UI			ts_anchor	1						
c[-2]	0	(min:step:max)		d1.0 max value 0.16	fixturedelay time	[0 0]	S			sample_adjustment	(-19 16)						
c[-3]	0	(min:step:max)			TDR Window	1				Local Search	2						
c[-4]	0	(min:step:max)															
c[1]	0	(min:step:max)		d1.0 cmt 37	signal_RU	0.01	UI										
R_b	1	UI		d1.0	A_DD	0.02	UI										
b_max[1]	0.85	As/dB[1]		d1.0 cmt 279	da_0	1.00E+08	V^2/GHz										
b_max[2_N_b]	0	As/dB[2_N_b]			SIR_TX	33.5	dB										
b_min[1]	0	As/dB[1]		d1.0 cmt 279	R_LM	0.95											
b_min[2_N_b]	-0.45	UI															
z_DC	(-20:10)	dB	(min:step:max)	d1.0 (Max value -20)													
f_p1	42.50	GHz		d1.0													
f_p1	42.50	GHz		d1.0													
f_p2	106.25	GHz		d1.0													
z_DC_HP	[-6:10]		(min:step:max)	d1.0													
L_HP_PZ	1.328125	GHz		d1.0													
Butterworth h	1	logical	include in fr	d1.0													

START	PNG_LowR_CLASSA	[2.44 5.7] db	
Table 93A-3 parameters			
Parameter	Setting	Units	Information
package_t_gamma0_a1_a2	[ 0.0005 0.00089 0.0002 ]		d1.0
package_t_gamma0_a1_a2	0.006141	ns/mm	d1.0
package_Z_c	[87.5 87.5; 92.5 92.5; 100 100; 100 100]	Ohm	d1.0
R_d	[ 46.25 46.25 ]	Ohm	[TX RX] d1.0 cmt 396
z_p [TX]	[ 33 12 33 33; 1.8 1.8 1.8 1.8; 0.0 0.0; 0.0 0.0 ]	mm	[test cases] d1.0
z_p [NEXT]	[ 33 12 33 33; 1.8 1.8 1.8 1.8; 0.0 0.0; 0.0 0.0 ]	mm	[test cases] d1.0
z_p [EXT]	[ 33 12 33 33; 1.8 1.8 1.8 1.8; 0.0 0.0; 0.0 0.0 ]	mm	[test cases] d1.0
z_p [RX]	[ 33 12 33 33; 1.8 1.8 1.8 1.8; 0.0 0.0; 0.0 0.0 ]	mm	[test cases] d1.0
C_p	[0.4e-4 0.4e-4]	nF	[TX RX] d1.0
A_v	[0.385 0.385 0.385 0.385]	V	VF=0.400 d1.2
A_je	[0.385 0.385 0.385 0.385]	V	VF=0.399 d1.2
A_ne	[0.481 0.481 0.481 0.481]	V	VF=0.400 d1.2
END			

START	PNG_HIR_CLASSB	[2.8 5.6 6.7 4] db	
Table 93A-3 parameters			
Parameter	Setting	Units	Information
package_t_gamma0_a1_a2	[ 0.0005 0.00065 0.000293 ]		d1.0
package_t_gamma0_a1_a2	0.006141	ns/mm	d1.0
package_Z_c	[87.5 87.5; 95 95; 100 100; 78 78]	Ohm	d1.0
R_d	[ 46.25 46.25 ]	Ohm	[TX RX] d1.0 cmt 396
z_p [TX]	[ 45 30 8 24; 2.2 2.2; 1.3 1.3 1.3; 1.5 1.5 1.5 ]	mm	[test cases] d1.0
z_p [NEXT]	[ 44 29 8 24; 2.2 2.2; 1.3 1.3 1.3; 1.5 1.5 1.5 ]	mm	[test cases] d1.0
z_p [EXT]	[ 45 30 8 24; 2.2 2.2; 1.3 1.3 1.3; 1.5 1.5 1.5 ]	mm	[test cases] d1.0
z_p [RX]	[ 44 29 8 24; 2.2 2.2; 1.3 1.3 1.3; 1.5 1.5 1.5 ]	mm	[test cases] d1.0
C_p	[0.4e-4 0.4e-4]	nF	[TX RX] d1.0
A_v	[0.385 0.385 0.385 0.385]	V	VF=0.400 d1.0 cmt 434
A_je	[0.385 0.385 0.385 0.385]	V	VF=0.399 d1.0 cmt 434
A_ne	[0.481 0.481 0.481 0.481]	V	VF=0.400 d1.0 cmt 434
END			



# C2M COM Config

- COM version 480 **\_hs2p3** (customization **\_hs2p3** applies commit requests 4p8\_1 to 4p8\_5)

Table 93A-1 parameters				sds ref.	I/O control			sds ref.	Table 93A-3 parameters (Table Not Used with Class A and B Packages)				sds ref.	SAVE_CONFIG2.MAT	0	Receiver testing
Parameter	Setting	Units	Information		DIAGNOSTICS	0	logical		Parameter	Setting	Units	Information				
f_b	106.25	GBd			DISPLAY_WINDOW	0 <td>logical</td> <td></td> <td>package_tj_gamma0_a1_a2</td> <td>[5e-4 0.00065 0.0003]</td> <td></td> <td></td> <td></td> <td>RX_CALIBRATION</td> <td>0</td> <td>logical</td>	logical		package_tj_gamma0_a1_a2	[5e-4 0.00065 0.0003]				RX_CALIBRATION	0	logical
f_min	0.03	GHz			CSV_REPORT	0 <td>logical</td> <td></td> <td>package_tj_tau</td> <td>0.006141</td> <td>ns/mm</td> <td></td> <td></td> <td>SigmaBB1_steps</td> <td>5.00E+01</td> <td>V</td>	logical		package_tj_tau	0.006141	ns/mm			SigmaBB1_steps	5.00E+01	V
Delta_f	0.01	GHz			RESULT_DIR	yes/no C2M, [date]			package_Z_c	[87.5 87.5 ; 92.5 92.5 ; 100 100 ; 100 100]	Ohm			C_N parameters		
C_d	[0.4e-4 0.9e-4 1.1e-4 0.4e-4 0.9e-4 1.1e-4]	nF	[TX RX]	d1.0	SWE_FIGURES	0	logical		z_bp (TX)	[1 1 1 1 ; 1 1 1 1 ; 0.5]	mm	[test cases]	d1.0	f_y	0.278	Fb
L_s	[0.13 0.13 0.14 ; 0.13 0.13 0.14]	nH	[TX RX]	d1.0	Port Order	[1 3 3 4]	input [1]		z_bp (NEXT)	[1 1 1 1 ; 1 1 1 1 ; 0.5]	mm	[test cases]	d1.0	f_f	0.278	Fb
C_b	[0.3e-4 0.3e-4]	nF	[TX RX]	d1.0	BUFLAG	C2M			z_bp (EXT)	[1 1 1 1 ; 1 1 1 1 ; 0.5]	mm	[test cases]	d1.0	f_n	0.278	Fb
R_d	50	Ohm	[TX RX]	d1.0 cmt 396	COM_CONTRIBUTION	1	logical		z_bp (RX)	[1 1 1 1 ; 1 1 1 1 ; 0.5]	mm	[test cases]	d1.0	f_2	58.438	GHz
R_d	[46.25 46.25]	Ohm	[TX RX]						C_p	[0.4e-4 0.4e-4]	nF	[test cases]	d1.0	A_ft	0.450	V
PNG_NAME	PNG_HR_CLASSB.PNG_Matule		TX RX		TDR and ERL options					Operational				A_nt	0.450	V
A_v	0.387	V			TDR	1	logical		ERL Pass threshold	10	dB			Parameter		
A_e	0.387	V			ERL	1	logical		COM Pass threshold	3	dB			Setting		
A_ue	0.482	V			ERL_ONLY	0	logical		QBL_D	2.00E+03				board_tj_gamma0_a1_a2	[0 3.95e-4 2.6e-03]	1.4 dB/m @ 33 125G
z_p select	[2]				TR_TDR	0.005	ns		T_j	0.00400	ns			board_tj_tau	5.790E-03	ns/mm
L	4				IT	7000	UI		FORCE_TR	1	logical	required for backward compatibility		board_Z_c	92.5	Ohm
M	32				TDR_Buttenworth	1			EMD_type	C2C				z_bp (TX)	32	mm
f_r	0.530	Hz			beta_x	0			samples_for_C2M	100				z_bp (NEXT)	32	mm
c[0]	0.54				rho_x	0.618			T_O	50				z_bp (EXT)	32	mm
c[1]	0				TDR_W_DrPkg	1	UI	ERL computation at TP is	BV	1				z_bp (RX)	32	mm
c[2]	0				HLba	16	UI		MUSE	1	logical			C_0	[0.29e-4 0]	nF
c[3]	0				fixtue delay time	[0 0]	S		ts_anchor	1				C_1	[0.1e-4 0]	nF
c[4]	0				Rules Window	1			sample adjustment	[-16 16]				Include PCB		
c[1]	0				Noise filter					Local Search	2			0=full grid search, 2=local search		
H_b	1				sigma_RJ	0.01	UI		Filter KAFFE					Histogram_Window_Weight		
b_max(1)	0.03				A_OD	0.02	UI		fb_pre_top_en	5	UI			0=none, 1=rectangle, 2=gaussian, dual=right triangle		
b_max(2_N_b)	0				du_0	1.00E+08	V^2/GHz		fb_pre_bot_en	8	UI			position		
b_min(1)	0				du_1	33.3	dB		fb_pre_bot_max	0.7		interpreted as +/-		0.02		
b_min(2_N_b)	-0.12				RL_QM	0.93			fb_pre_bot_min	0.7		interpreted as +/-		selection		
g_DC	[-20 1.0]	dB			fb_bot_max	0.7			fb_bot_min	0.7		interpreted as +/-		UI		
f_z	42.50	GHz			FFI_OPT_METHOD	MMSE			FFI_MAX_GAIN	2048				COM to change to Vmax/min		
f_p1	42.50	GHz			search thresholds	0	logical		search thresholds	0	logical			COM to change to Vmax/min		
f_p2	106.25	GHz			du_0_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
g_DC_HP	[-6 1.0]	dB			du_1_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
f_HP_PZ	1.328125	GHz			du_2_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
Butterworth	1	logical	include in fr		du_3_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_4_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_5_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_6_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_7_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_8_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_9_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_10_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_11_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_12_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_13_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_14_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_15_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_16_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_17_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_18_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_19_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_20_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_21_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_22_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_23_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_24_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_25_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_26_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_27_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_28_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_29_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_30_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_31_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_32_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_33_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_34_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_35_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_36_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_37_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_38_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_39_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_40_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_41_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_42_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_43_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_44_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_45_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_46_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_47_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_48_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_49_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_50_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_51_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_52_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_53_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_54_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_55_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_56_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_57_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_58_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_59_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_60_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_61_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_62_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_63_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_64_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_65_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_66_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_67_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_68_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_69_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_70_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min		
					du_71_max	1.00E+08			search thresholds	0	logical			COM to change to Vmax/min</		