ERL Progress: The KR Channel Cases

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Agenda

- Review ERL equations
- Simplify parameters
- Select interesting channels
- Use very low loss delay to determine ERL to COM tracking
- Effects of DFE and package length
- N_{bx} analysis
- Recommendation

ERL equations

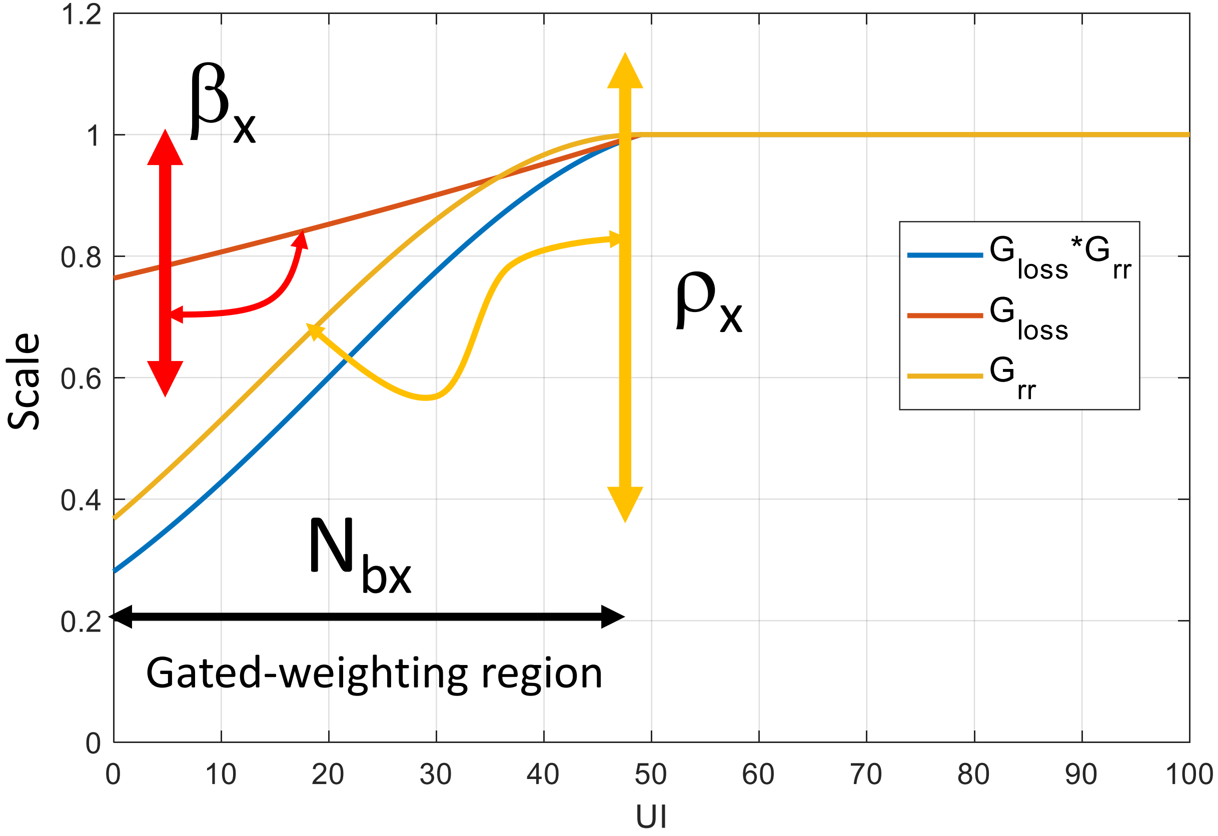
$$G_{rr}(t) = \begin{cases} 0 & t < T_{fx} \\ \rho_x(1+\rho_x)\exp\left(-\frac{[(t-T_{fx})f_b-(N_{bx}+1)]^2}{(N_{bx}+1)^2}\right) & T_{fx} \le t < T_{fx} + \frac{N_{bx}+1}{f_b} \\ 1 & t \ge T_{fx} + \frac{N_b+1}{f_b} \end{cases}$$

$$R_{eff}(t) = PTDR(t) \times G_{rr}(t) \times G_{loss}(t)$$

- Most parameters original had meaning
  - N_{bx} – Equalizer impact in UI based COM degradation
  - T_{fx} – Test fixture delay in seconds
  - β_x – Related to loss of package
  - ρ_x – related to reflection in the gated region
- But are best found with fitting and correlation
- Then once locked down
  - ERL_{mim} may be determined
  - So that really bad reflections are not allowed based on COM delta compared to the reference package

$$G_{loss}(t) = \begin{cases} 0 & t < T_{fx} \\ 10^{\frac{\frac{\beta_x}{f_b}[(t-T_{fx})f_b-(N_{bx}+1)]}{20}} & T_{fx} \le t < T_{fx} + \frac{N_{bx}+1}{f_b} \\ 1 & t \ge T_{fx} + \frac{N_{bx}+1}{f_b} \end{cases}$$

For now, let's consider N_{bx}, ρ_x, β_x spec tuning parameters



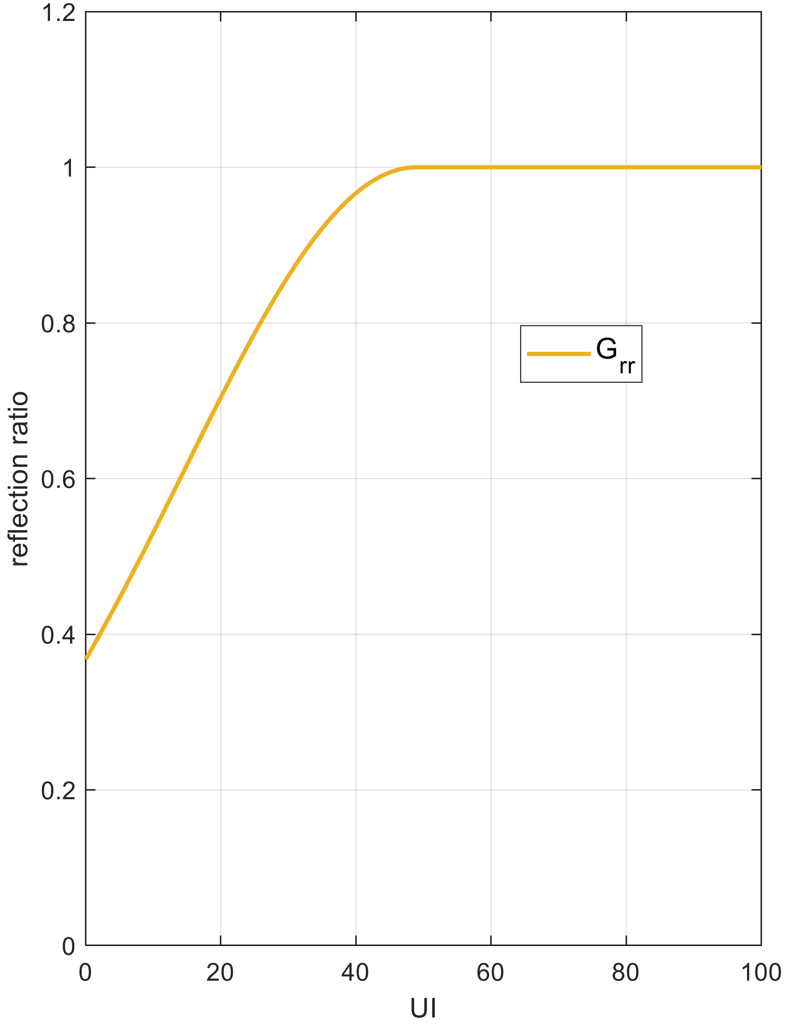
$$G_{rr}(t) = \begin{cases} 0 & t < T_{fx} \\ \rho_x(1+\rho_x)\exp\left(-\frac{[(t-T_{fx})f_b-(N_{bx}+1)]^2}{(N_{bx}+1)^2}\right) & T_{fx} \le t < T_{fx}+\frac{N_{bx}+1}{f_b} \\ 1 & t \ge T_{fx}+\frac{N_b+1}{f_b} \end{cases}$$

$$G_{loss}(t) = \begin{cases} 0 & t < T_{fx} \\ 10^{\frac{\frac{\beta_x}{f_b}[(t-T_{fx})f_b-(N_{bx}+1)]}{20}} & T_{fx} \le t < T_{fx}+\frac{N_{bx}+1}{f_b} \\ 1 & t \ge T_{fx}+\frac{N_{bx}+1}{f_b} \end{cases}$$

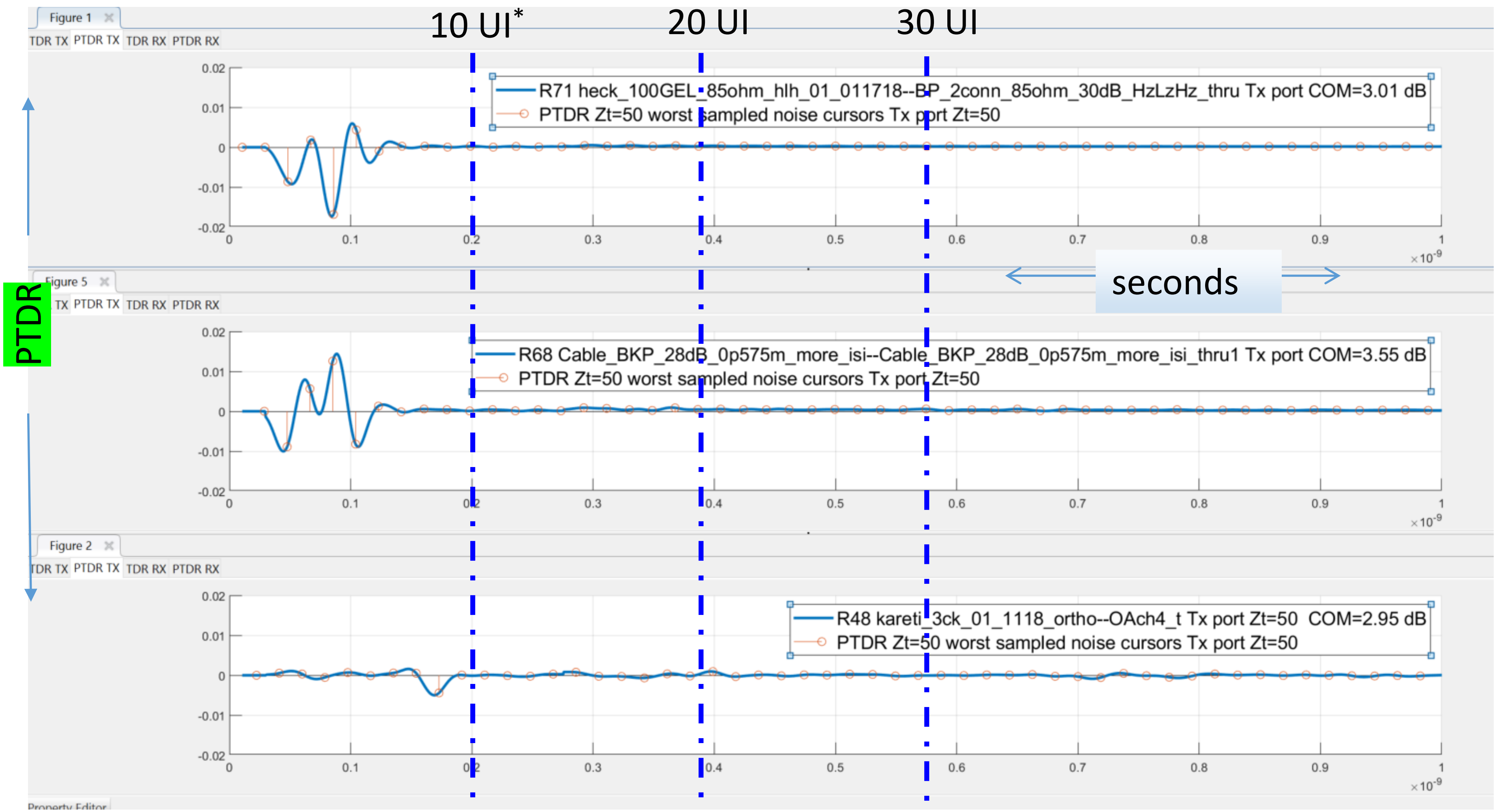
- Setting β_x to zero simplifies the problem by forcing G_{loss} to 1
- One more simplification is to set ρ_x to 0.618 which smooths out the gating function at the end of the gated region

Moving forward

- ☐ Is N_{bx} and the gated weighting yellow shaped line in the graph at right sufficient to:
  - Correlate ERL to COM
  - Allow an ERL to limit Δ COM
  - Eliminate design with extreme reflections
- ☐ Let's see



First: Choose channels with reflections near TP0 and with COM ~ 3 dB (use PTDR)



Larger reflections

Larger reflections

Smaller reflections

*Delay through 30 mm package is ~ 10 UI

File Key: Previous slide

❑ Larger reflections

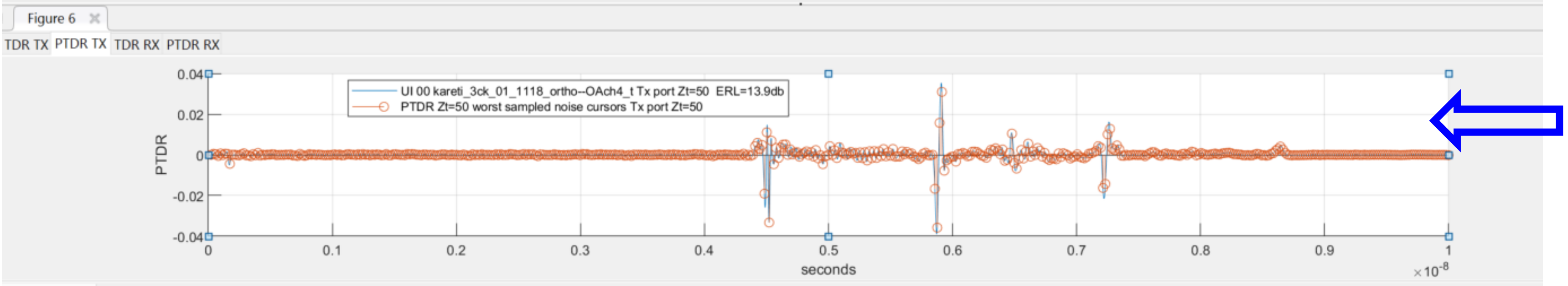
- R71 heck_100GEL_85ohm_hlh_01_011718--BP_2conn_85ohm_30dB_HzLzHz_thru: COM 3.0 dB
- R68 Cable_BKP_28dB_0p575m_more_isi--Cable_BKP_28dB_0p575m_more_isi_thru: COM 3.5 dB

❑ Smaller reflections

- R48 kareti_3ck_01_1118_ortho--OAch4_t:Larger reflections: COM 2.95 dB

PTDR the rest of the story

There are reflection away from TP0



Most all return loss is all comprehended in COM

Use delay line to determine impact of the position of reflection near the test point tp0

- ❑ Add 0 to 90 UI of delay to channel who has large reflection around TP0
- ❑ Hypothesis is
  - COM would get worse as lossless delay gets longer
  - COM would levels out when delay gets even longer
  - Channels with small reflections around TP0 would show less impact from added delay
- ❑ If the Hypothesis is correct
  - This would be basis for channel the N_{bx} value for ERL gating

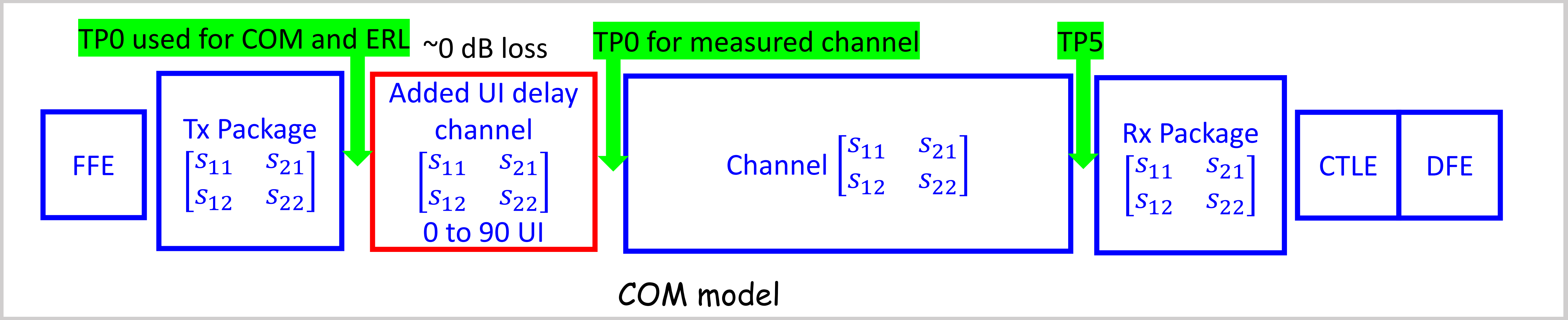
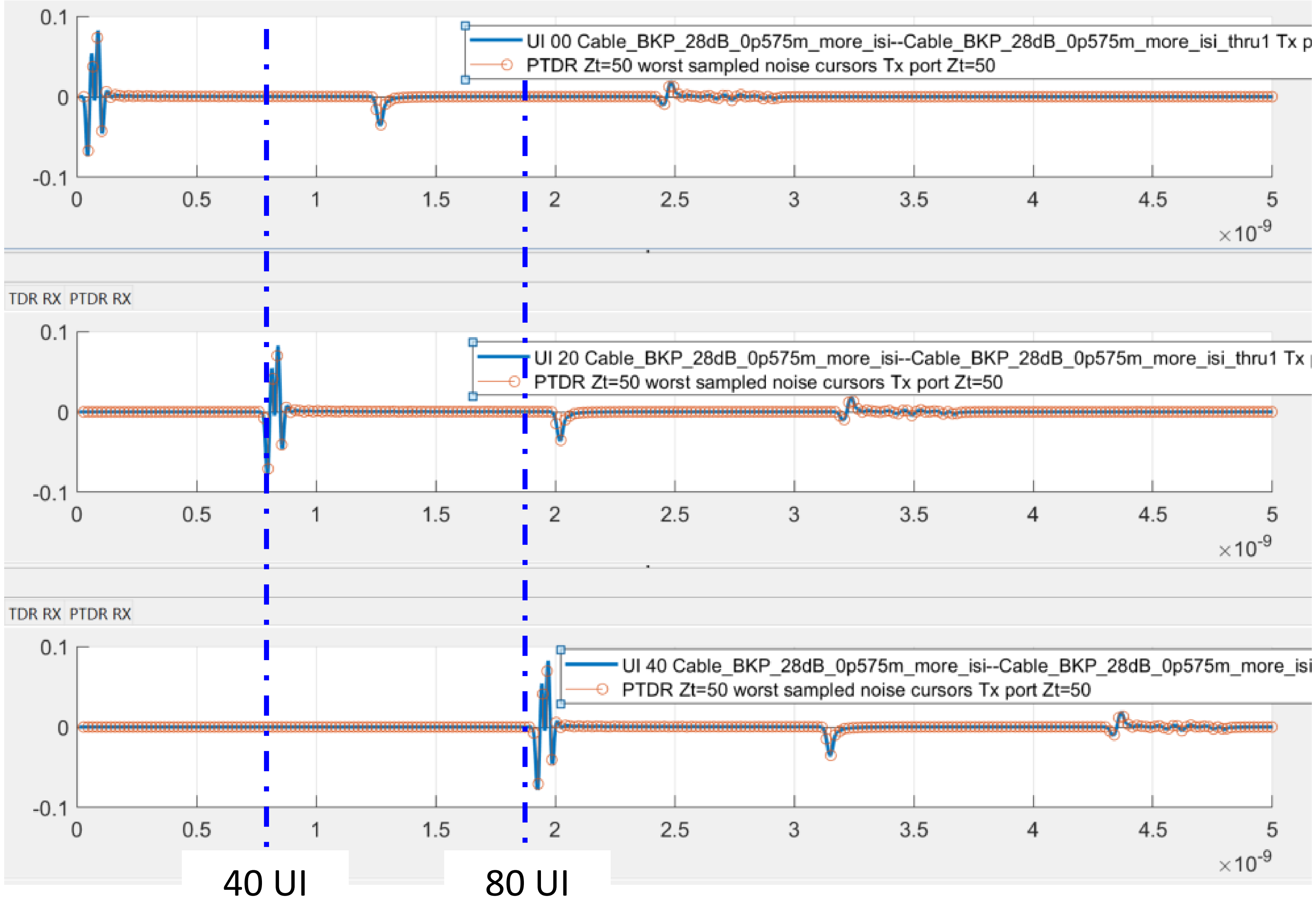
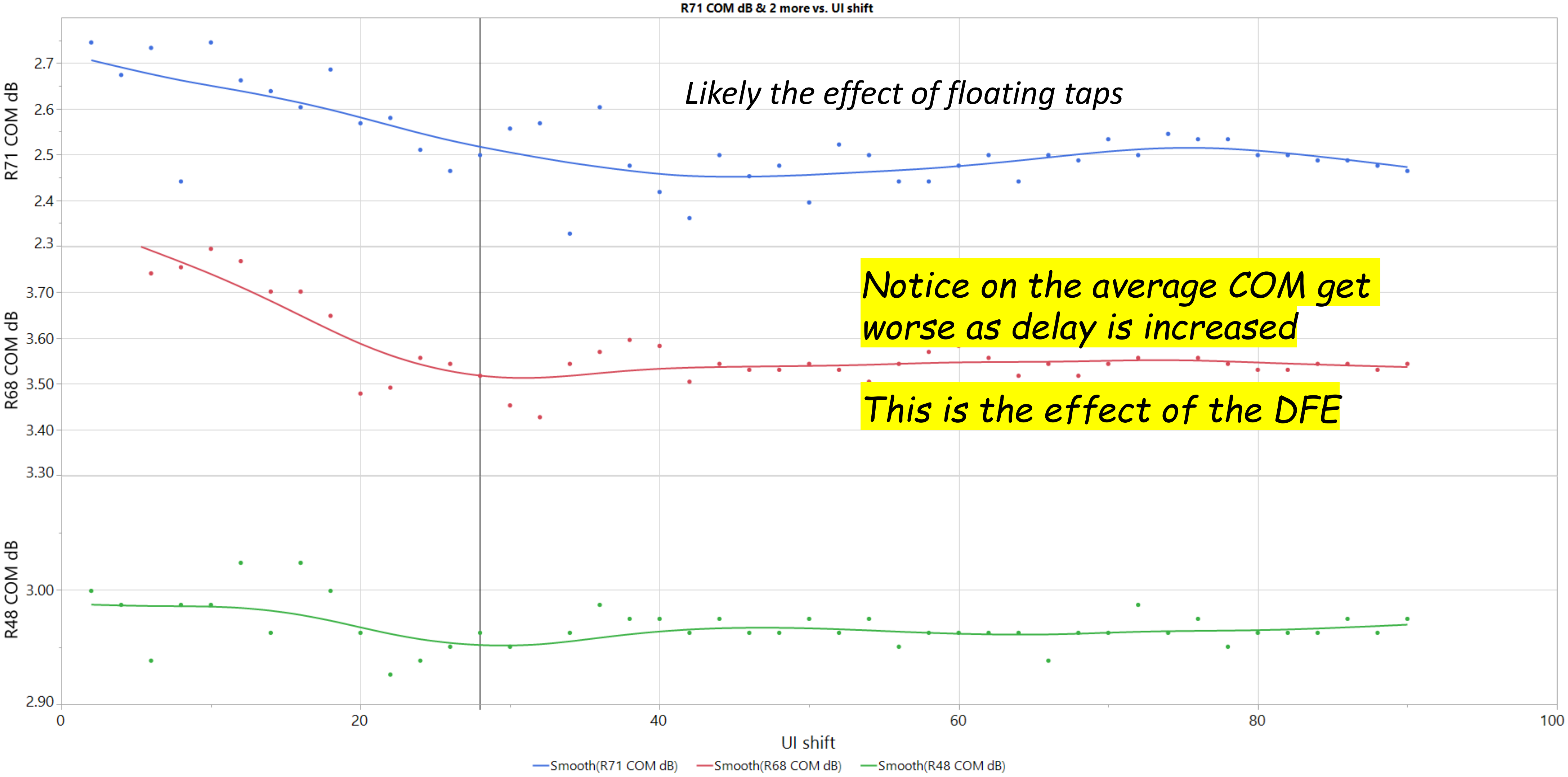


Illustration delaying PTDR (n_{bx}=0) for 0, 20, & 40 UI Delay



Note: TDR delay is twice physical added delay

Clause 163 (D1.1, KR) COM vs added transmission line delays (UI)



Likely the effect of floating taps

Notice on the average COM get worse as delay is increased

This is the effect of the DFE

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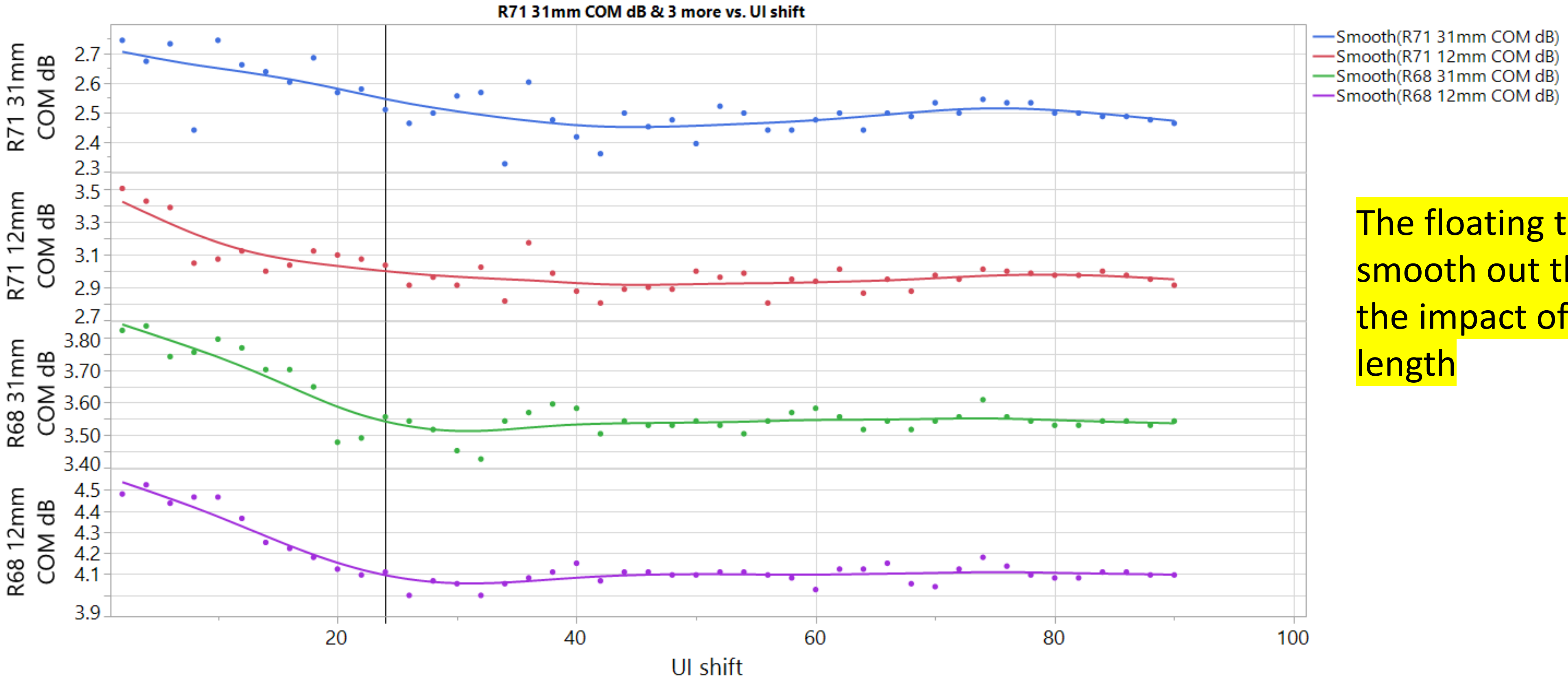
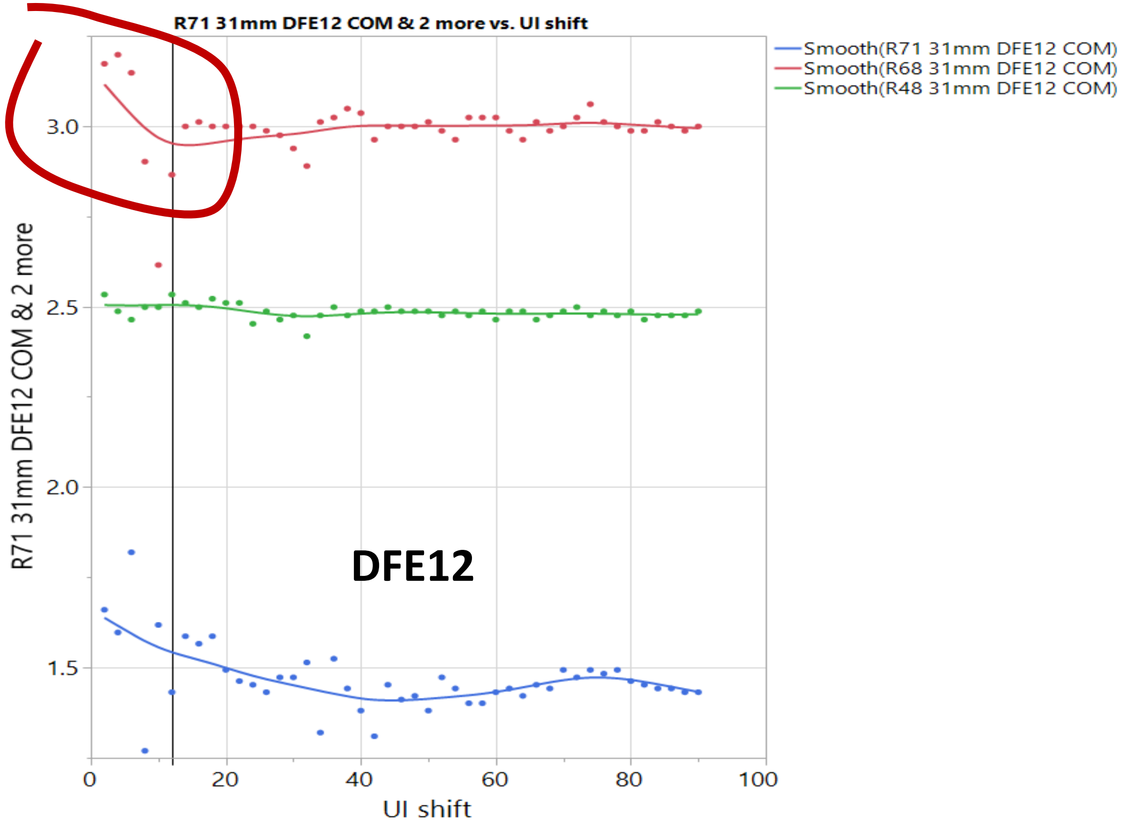
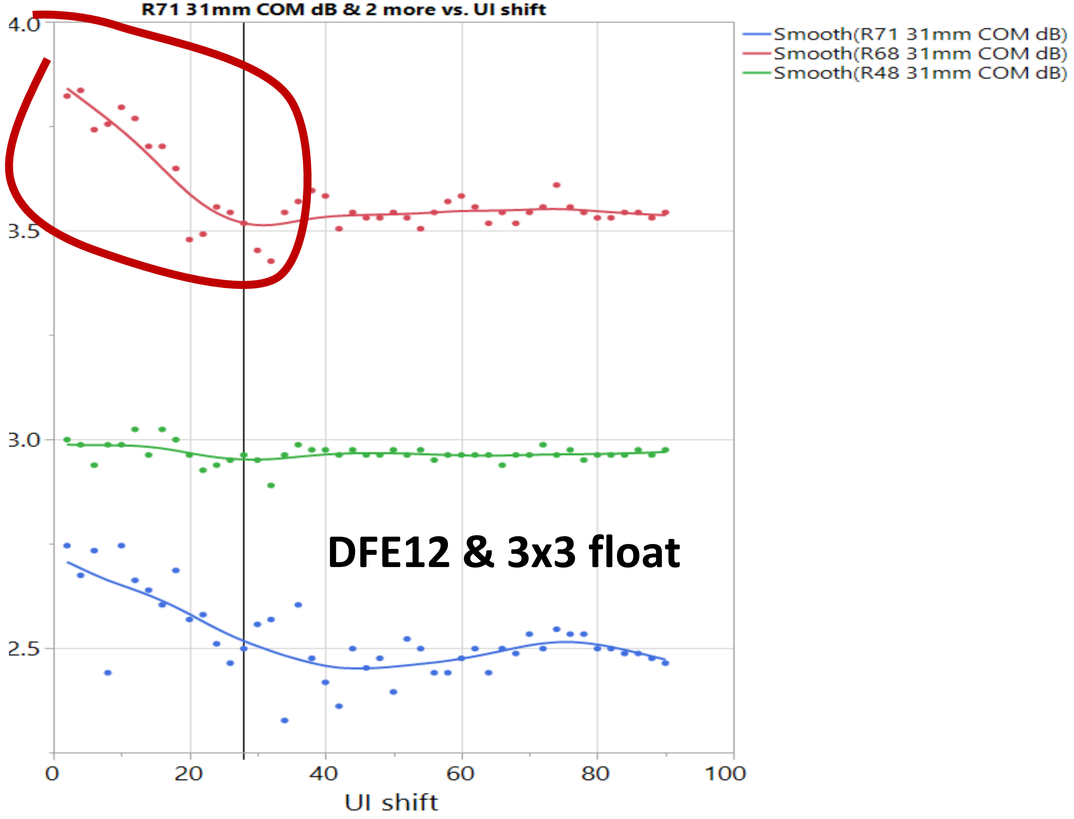
COM vs added transmission line delay (UI) for 31 mm and 12 mm package



The floating taps may smooth out the effect of the impact of package length

COM comparison with DFE show gating region makes some sort of sense



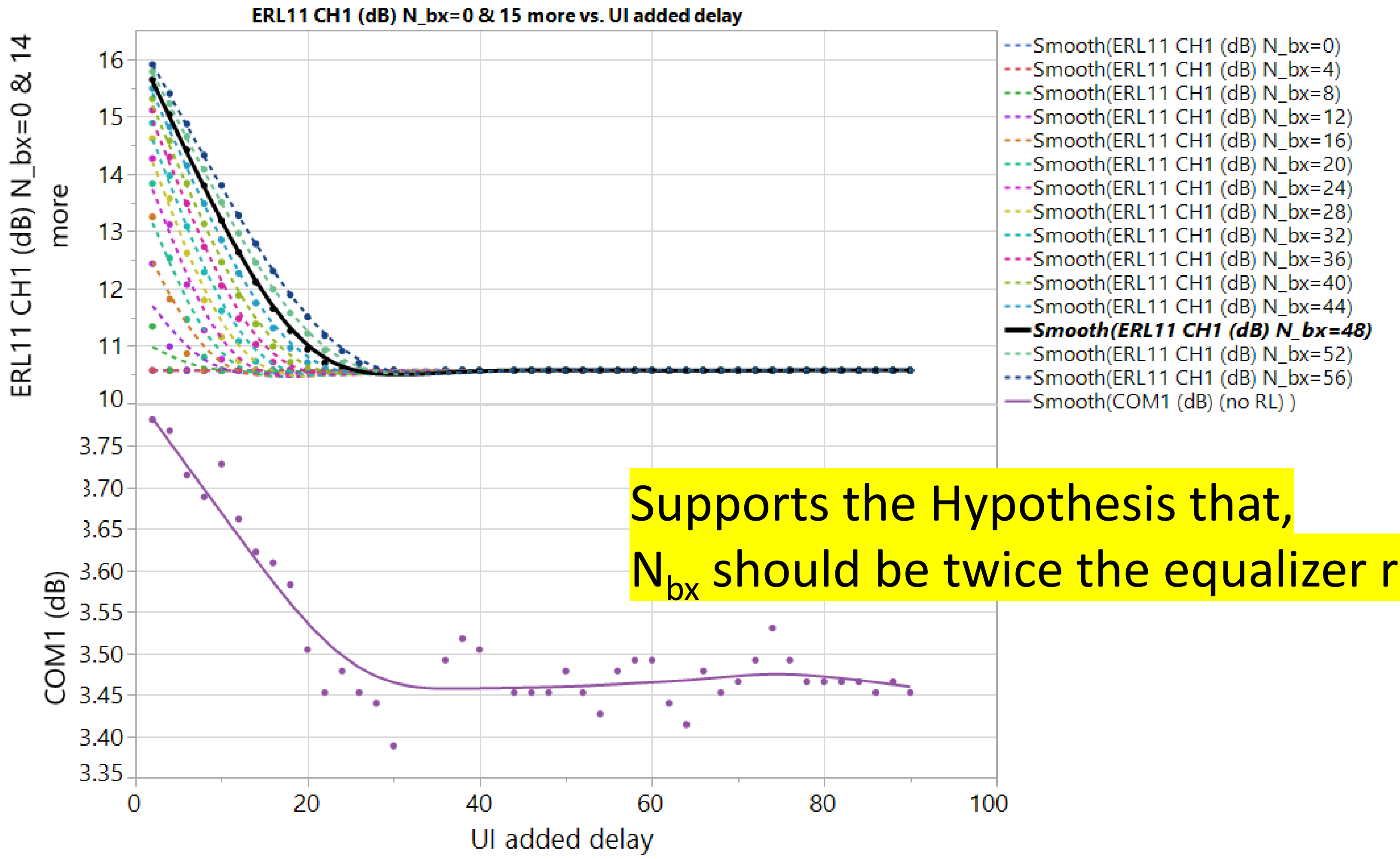


- ❑ Shorter DFE shows less impact from reflection delay
- ❑ Longer DFE shows more impact fro, reflection delay

So Far

- ❑ If channels have large reflections near TP0 they interact with package
- ❑ Longer packages interact for longer time after TP0
- ❑ COM is effected by the receiver equalizer length and position of reflections.
- ❑ If the reflection at TP0 are within the "DFE reach", COM is better.
  - and more or less unaffected by the delayIf delayed reflections are outside the "DFE reach", COM is worse
- ❑ Hypothesis: N_{bx} should be twice the equalizer reach

Added delay vs COM and ERL N_{bx}



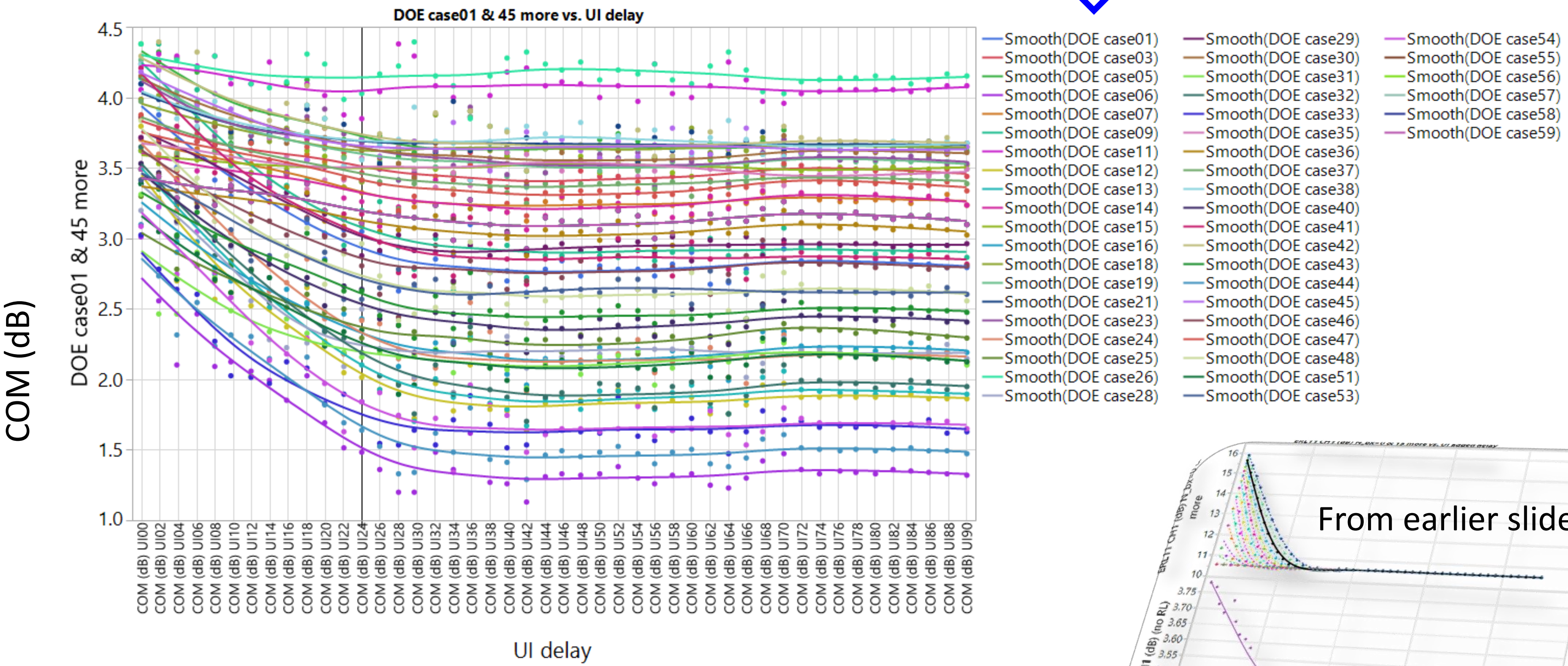
Supports the Hypothesis that,
N_{bx} should be twice the equalizer reach

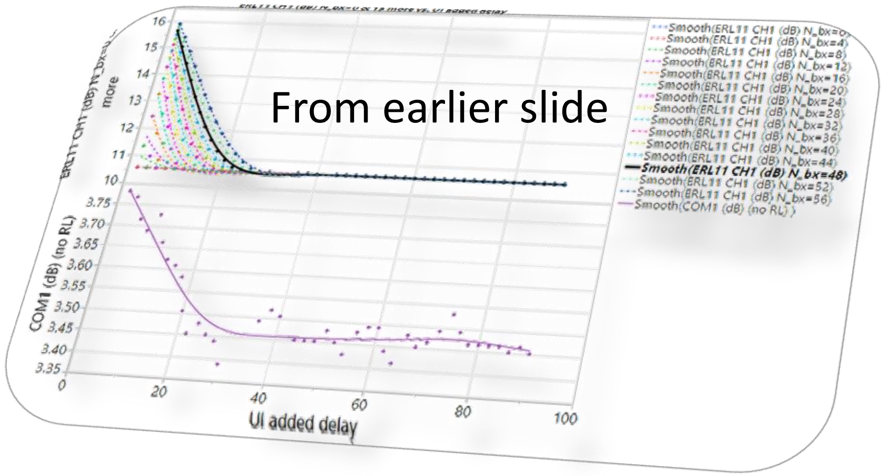
Does this correlation to N_{bx} hold if a wider range of package parameters are chosen?

Cd (ff)	Cp (ff)	Zc (ohms)	Loss scale	Zc1 (ohms)	Zpx1 (mm)	Zpx2 (mm)	Zp (mm)	Zp1 (mm)
90	0	65.625	0.5	67.875	4	0	Zpx1+Zpx2	0
120	90	87.5	1	90.5	11.5	6.5		1.8
150	180	109.375	1.5	113.125	19	13		4.8

Yes!

Package cases (see back up for data)





From earlier slide

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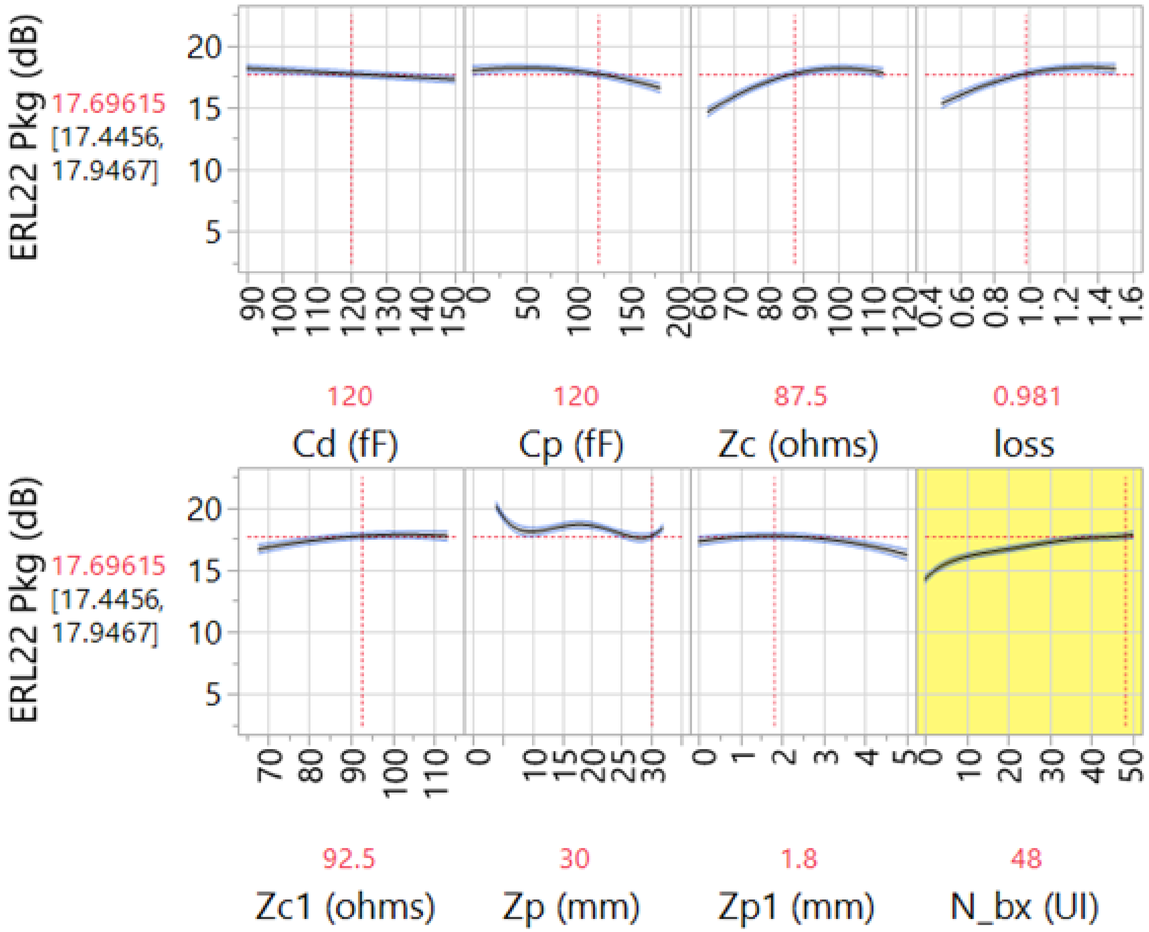
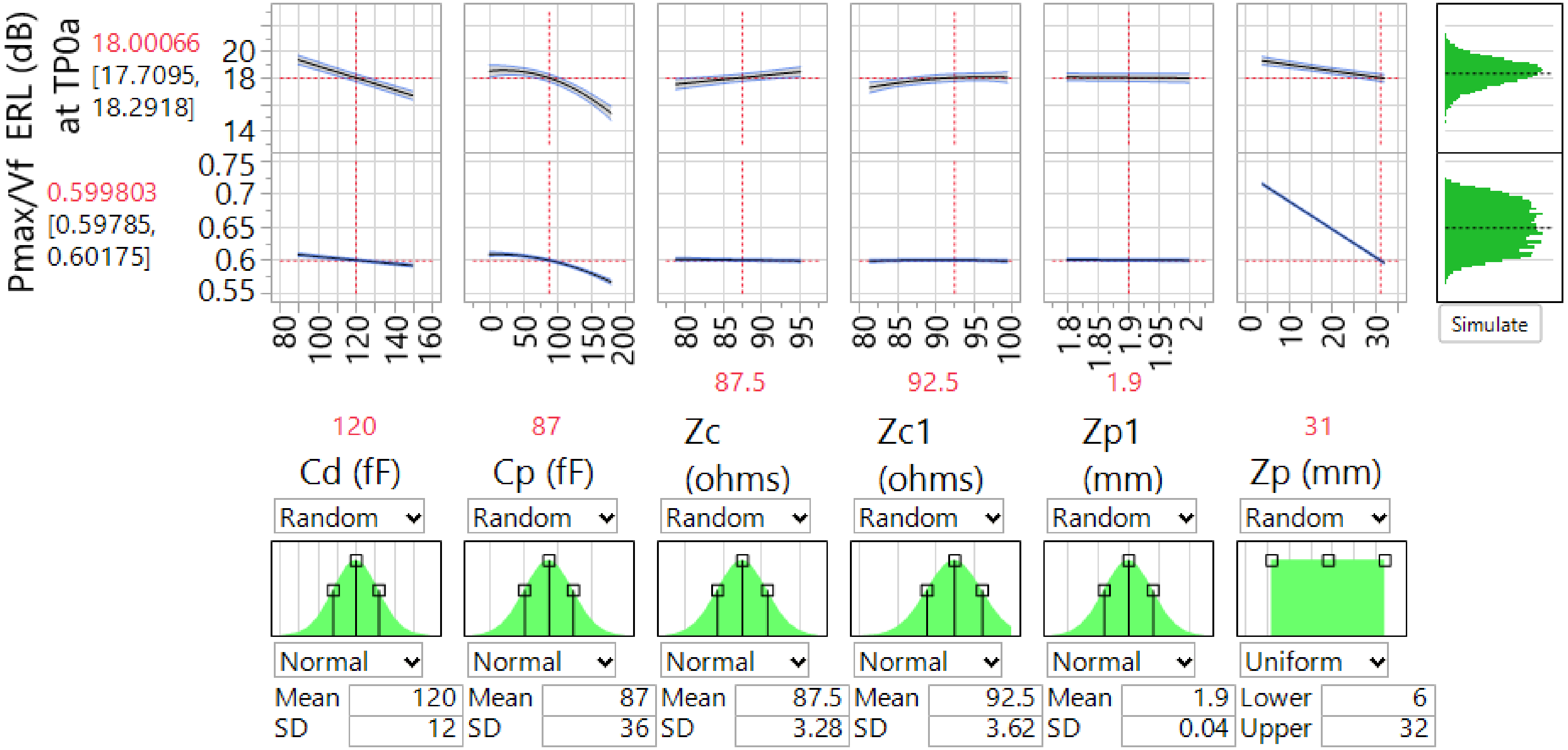
Hypothesis: ERL of the package varies inversely to N_{bx}

* Same experiment as earlier but N_{bx} is swept

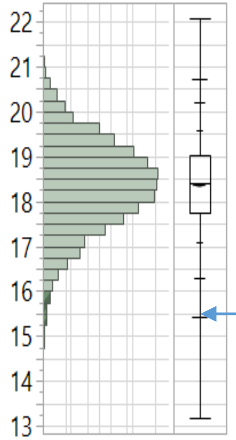


Yes!

Variation on Reference package seem to be limited to 15 dB ERL



120	87				31
Cd (fF)	Cp (fF)	Zc (ohms)	Zc1 (ohms)	Zp1 (mm)	Zp (mm)
Random	Random	Random	Random	Random	Random
Normal	Normal	Normal	Normal	Normal	Uniform
Mean 120	Mean 87	Mean 87.5	Mean 92.5	Mean 1.9	Lower 6
SD 12	SD 36	SD 3.28	SD 3.62	SD 0.04	Upper 32



3 σ is 15.5 dB

All sweeps below 15.5 dB ERL have Pmax/Vf < 0.6

Recommend: For Channels and Packages

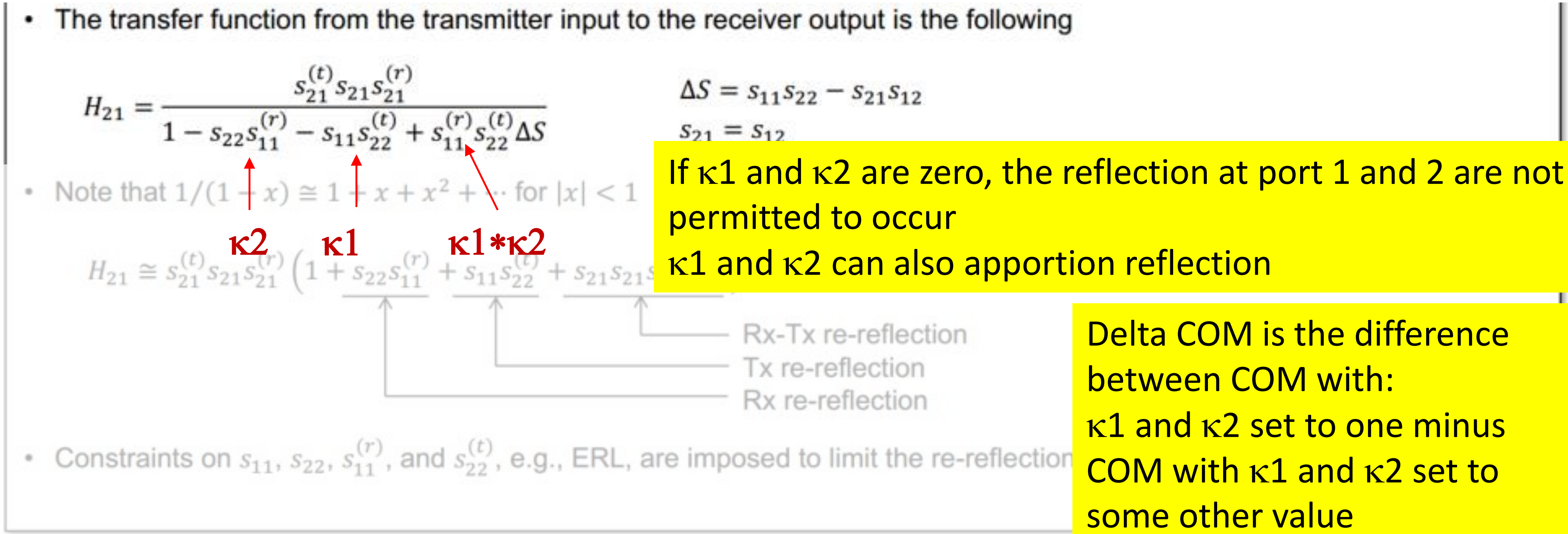
☐ Set β_x=0

☐ Set ρ_x=0.618

☐ Set N_{bx}= 48

Now let's look at Delta COM to help set ERL_{min} limits

Kappa (κ) may be used to determine impact of reflections (from healey_3ck_01a_0120)



- The transfer function from the transmitter input to the receiver output is the following

$$H_{21} = \frac{s_{21}^{(t)} s_{21} s_{21}^{(r)}}{1 - s_{22}s_{11}^{(r)} - s_{11}s_{22}^{(t)} + s_{11}^{(r)}s_{22}^{(t)}\Delta S}$$

$$\Delta S = s_{11}s_{22} - s_{21}s_{12}$$

$$s_{21} = s_{12}$$

- Note that $1/(1-x) \cong 1 + x + x^2 + \cdots$ for $|x| < 1$

$$H_{21} \cong s_{21}^{(t)} s_{21} s_{21}^{(r)} \left(1 + \underline{s_{22}s_{11}^{(r)}} + \underline{s_{11}s_{22}^{(t)}} + \underline{s_{21}s_{21}s}\right.$$

Rx-Tx re-reflection

Tx re-reflection

Rx re-reflection

- Constraints on s_{11}, s_{22}, $s_{11}^{(r)}$, and $s_{22}^{(t)}$, e.g., ERL, are imposed to limit the re-reflection

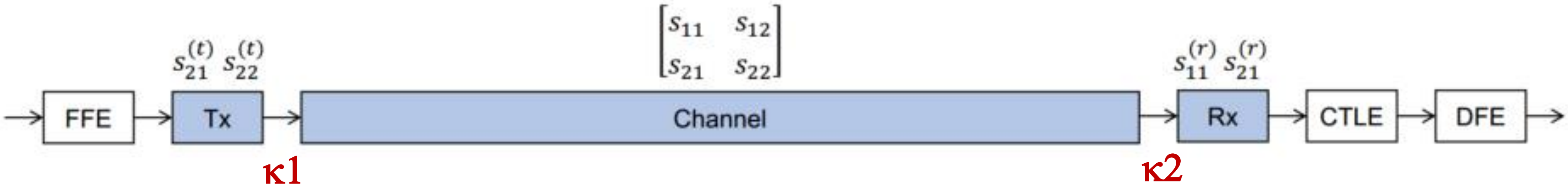
If κ1 and κ2 are zero, the reflection at port 1 and 2 are not permitted to occur

κ1 and κ2 can also apportion reflection

Delta COM is the difference between COM with:

κ1 and κ2 set to one minus

COM with κ1 and κ2 set to some other value



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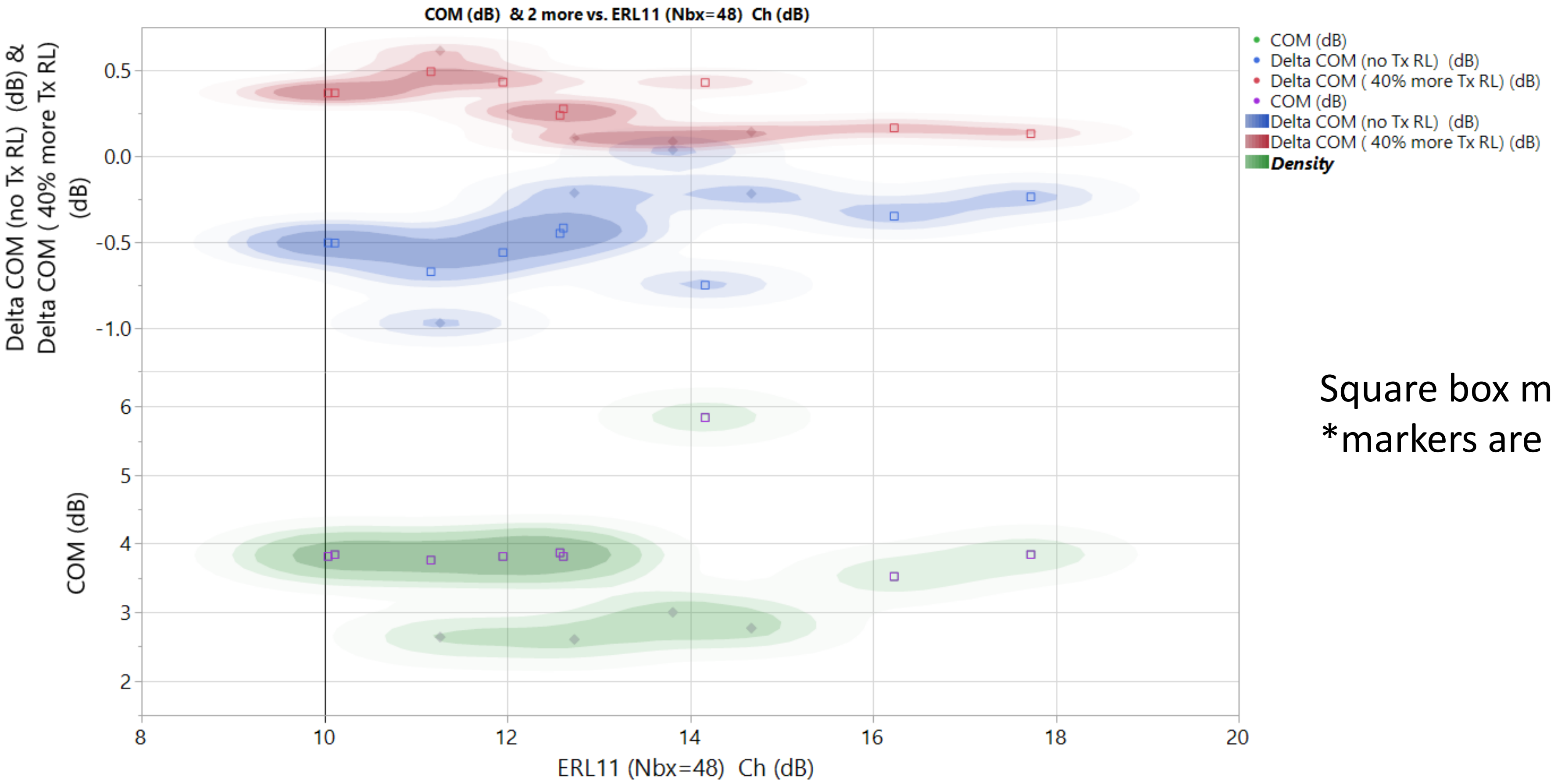
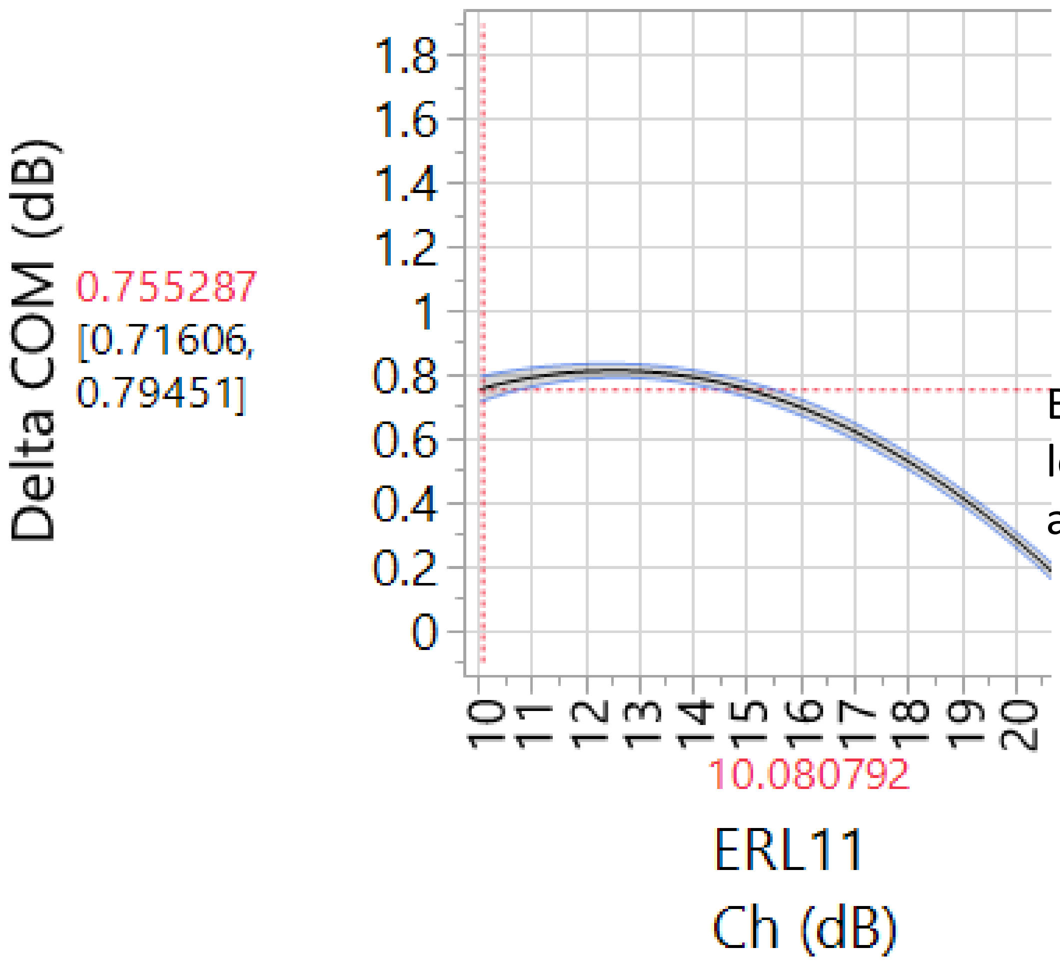
Suggest: ERL$_{min}$ = 10 dB



Square box markers are COM > 3.5 dB
*markers are COM <= 3dB

Is ERL correlated to Delta COM?

Yes!



Better ERL means less COM variability at the receiver

Recommend: ERL_{min}

☐ Channel: 10 dB

☐ Package: 15.5 dB

and …

☐ Pmax/Vf < 0.6

Thank You!

Additional backup data

COM spreadsheet used

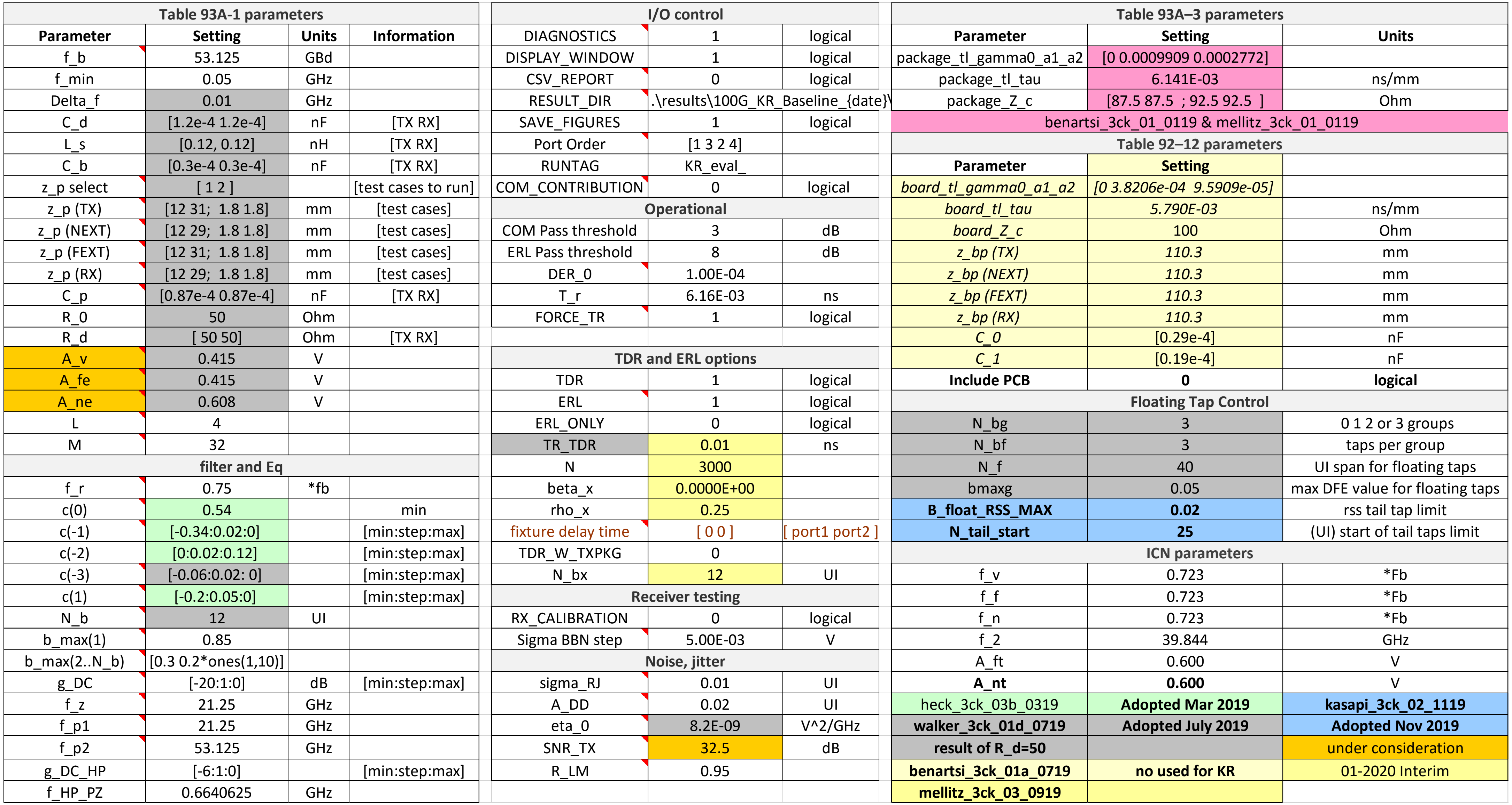


Table 93A-1 parameters			
Parameter	**Setting**	**Units**	**Information**
f_b	53.125	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[1.2e-4 1.2e-4]	nF	[TX RX]
L_s	[0.12, 0.12]	nH	[TX RX]
C_b	[0.3e-4 0.3e-4]	nF	[TX RX]
z_p select	[1 2]		[test cases to run]
z_p (TX)	[12 31; 1.8 1.8]	mm	[test cases]
z_p (NEXT)	[12 29; 1.8 1.8]	mm	[test cases]
z_p (FEXT)	[12 31; 1.8 1.8]	mm	[test cases]
z_p (RX)	[12 29; 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	0.415	V	
A_fe	0.415	V	
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)	[-0.2:0.05:0]		[min:step:max]
N_b	12	UI	
b_max(1)	0.85		
b_max(2..N_b)	[0.3 0.2*ones(1,10)]		
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	

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
CSV_REPORT	0	logical
RESULT_DIR	.\results\100G_KR_Baseline_{date}\	
SAVE_FIGURES	1	logical
Port Order	[1 3 2 4]	
RUNTAG	KR_eval_	
COM_CONTRIBUTION	0	logical
Operational		
COM Pass threshold	3	dB
ERL Pass threshold	8	dB
DER_0	1.00E-04	
T_r	6.16E-03	ns
FORCE_TR	1	logical
TDR and ERL options		
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	logical
TR_TDR	0.01	ns
N	3000	
beta_x	0.0000E+00	
rho_x	0.25	
fixture delay time	[0 0]	[port1 port2]
TDR_W_TXPKG	0	
N_bx	12	UI
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	8.2E-09	V^2/GHz
SNR_TX	32.5	dB
R_LM	0.95	

Table 93A–3 parameters		
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
benartsi_3ck_01_0119 & mellitz_3ck_01_0119		
Table 92–12 parameters		
Parameter	**Setting**	
board_tl_gamma0_a1_a2	*[0 3.8206e-04 9.5909e-05]*	
board_tl_tau	*5.790E-03*	ns/mm
board_Z_c	100	Ohm
z_bp (TX)	*110.3*	mm
z_bp (NEXT)	*110.3*	mm
z_bp (FEXT)	*110.3*	mm
z_bp (RX)	*110.3*	mm
C_0	[0.29e-4]	nF
C_1	[0.19e-4]	nF
Include PCB	**0**	**logical**
Floating Tap Control		
N_bg	3	0 1 2 or 3 groups
N_bf	3	taps per group
N_f	40	UI span for floating taps
bmaxg	0.05	max DFE value for floating taps
B_float_RSS_MAX	**0.02**	rss tail tap limit
N_tail_start	**25**	(UI) start of tail taps limit
ICN parameters		
f_v	0.723	*Fb
f_f	0.723	*Fb
f_n	0.723	*Fb
f_2	39.844	GHz
A_ft	0.600	V
A_nt	**0.600**	V
heck_3ck_03b_0319	**Adopted Mar 2019**	**kasapi_3ck_02_1119**
walker_3ck_01d_0719	**Adopted July 2019**	**Adopted Nov 2019**
result of R_d=50		under consideration
benartsi_3ck_01a_0719	**no used for KR**	01-2020 Interim
mellitz_3ck_03_0919		

Example of added delay parameters (2 UI steps)

param.z_bp_tx	param.z_bp_fext	param.z_bp_rx	param.z_bp_next	param.brd_gamma0_a1_a2
0	0	0	0	[0 3.8206e-08 9.5909e-09]
6.502082698	0	0	0	[0 3.8206e-08 9.5909e-09]
13.0041654	0	0	0	[0 3.8206e-08 9.5909e-09]
19.5062481	0	0	0	[0 3.8206e-08 9.5909e-09]
26.00833079	0	0	0	[0 3.8206e-08 9.5909e-09]
32.51041349	0	0	0	[0 3.8206e-08 9.5909e-09]
39.01249619	0	0	0	[0 3.8206e-08 9.5909e-09]
45.51457889	0	0	0	[0 3.8206e-08 9.5909e-09]
52.01666159	0	0	0	[0 3.8206e-08 9.5909e-09]
58.51874429	0	0	0	[0 3.8206e-08 9.5909e-09]
65.02082698	0	0	0	[0 3.8206e-08 9.5909e-09]
71.52290968	0	0	0	[0 3.8206e-08 9.5909e-09]
78.02499238	0	0	0	[0 3.8206e-08 9.5909e-09]
84.52707508	0	0	0	[0 3.8206e-08 9.5909e-09]
91.02915778	0	0	0	[0 3.8206e-08 9.5909e-09]
97.53124048	0	0	0	[0 3.8206e-08 9.5909e-09]
104.0333232	0	0	0	[0 3.8206e-08 9.5909e-09]
110.5354059	0	0	0	[0 3.8206e-08 9.5909e-09]
117.0374886	0	0	0	[0 3.8206e-08 9.5909e-09]

⋱

check < 3	CASE #	Cd (fF)	Cp (fF)	Zc (ohms)	loss	Zc1 (ohms)	Zpx1 (mm)	Zpx2 (mm)	Zp1 (mm)	ERL22 Pkg (dB)	Pmax_by_ Vf_est	V_f (mV)	N_bx (UI)	COM (dB) UI00
FALSE	1	90	0	62.625	0.5	67.875	19	0	0	10.55072	0.734204	410.9349	48	4.096308
TRUE	2	150	90	113.125	1.5	67.875	4	13	4.8	7.6077	0.531896	406.5272	48	2.315425
FALSE	3	120	90	87.875	1	90.5	4	13	4.8	13.10037	0.645377	408.642	48	3.985658
TRUE	4	120	180	113.125	1.5	113.125	4	13	0	9.551115	0.555105	408.2218	48	2.781268
FALSE	5	120	90	87.875	1	90.5	4	0	1.8	12.11097	0.71728	410.8786	48	4.379261
FALSE	6	150	180	62.625	1.5	67.875	19	0	0	9.690471	0.553069	407.1682	48	3.011612
FALSE	7	120	90	87.875	1	90.5	11.5	13	0	13.85008	0.633708	408.4953	48	3.849299
TRUE	8	150	180	113.125	0.5	113.125	19	13	4.8	8.528645	0.621023	410.6744	48	2.102607
FALSE	9	120	0	62.625	0.5	113.125	4	0	0	10.58885	0.770538	411.7007	48	4.138168
TRUE	10	120	0	62.625	1.5	67.875	19	13	4.8	11.42111	0.498819	402.7845	48	2.418082
FALSE	11	90	0	113.125	0.5	67.875	4	13	0	15.10951	0.756015	411.3386	48	4.054649
FALSE	12	150	180	62.625	0.5	113.125	19	0	0	9.220989	0.683465	411.5966	48	3.79535
FALSE	13	120	180	62.625	0.5	67.875	4	13	0	9.248655	0.694035	411.3718	48	3.622292
FALSE	14	120	90	87.875	1	90.5	19	6.5	1.8	13.81166	0.622585	408.1614	48	3.715048
FALSE	15	90	0	113.125	1.5	67.875	19	0	0	17.18356	0.604681	405.9128	48	3.622292
FALSE	16	90	0	62.625	1.5	113.125	4	13	0	10.94281	0.600955	406.5415	48	3.388227
TRUE	17	90	90	113.125	1.5	113.125	19	13	4.8	14.70364	0.49708	404.2775	48	2.326771
FALSE	18	150	0	113.125	1.5	90.5	4	0	0	10.16996	0.674483	409.4313	48	3.985658
FALSE	19	120	90	87.875	1	90.5	4	6.5	0	12.76922	0.694597	410.4788	48	4.264972
TRUE	20	150	180	113.125	1.5	113.125	19	0	0	8.45706	0.535477	407.9459	48	2.441061
FALSE	21	90	0	87.875	1.5	113.125	4	0	4.8	12.50137	0.675168	408.191	48	4.096308
TRUE	22	90	0	62.625	0.5	113.125	19	13	4.8	6.989964	0.678043	410.1385	48	2.938209
FALSE	23	120	90	87.875	1	90.5	11.5	0	1.8	12.89097	0.681895	410.226	48	4.236633
FALSE	24	150	180	87.875	0.5	67.875	4	0	4.8	7.326592	0.700508	412.023	48	3.701736
FALSE	25	90	0	62.625	1.5	90.5	19	0	4.8	9.360209	0.569598	402.9964	48	3.298878
FALSE	26	90	0	113.125	0.5	113.125	19	0	0	14.52146	0.750575	411.3433	48	4.379261
TRUE	27	150	180	62.625	1.5	113.125	19	13	0	10.08634	0.491039	403.9859	48	2.124765
FALSE	28	90	0	113.125	0.5	67.875	19	13	4.8	8.408901	0.67223	410.2358	48	3.197878
FALSE	29	90	180	113.125	0.5	113.125	4	0	4.8	9.629721	0.705264	411.8495	48	3.715048
FALSE	30	150	90	87.875	0.5	113.125	4	13	0	11.22599	0.725925	411.614	48	4.152166

check < 3	CASE #	Cd (fF)	Cp (fF)	Zc (ohms)	loss	Zc1 (ohms)	Zpx1 (mm)	Zpx2 (mm)	Zp1 (mm)	ERL22 Pkg (dB)	Pmax_by_ Vf_est	V_f (mV)	N_bx (UI)	COM (dB) UI00
FALSE	31	150	90	62.625	0.5	67.875	19	13	4.8	10.60062	0.675453	409.8266	48	3.311586
FALSE	32	90	180	62.625	0.5	113.125	4	13	0	9.21095	0.696813	411.4291	48	3.648693
FALSE	33	150	180	62.625	1.5	113.125	4	0	4.8	4.343384	0.577162	409.202	48	3.023906
TRUE	34	150	180	113.125	1	67.875	19	13	0	9.388323	0.546335	408.5771	48	2.510364
FALSE	35	150	0	113.125	0.5	113.125	19	13	0	11.67718	0.690027	410.9405	48	3.530515
FALSE	36	120	90	87.875	1	90.5	19	13	0	14.45699	0.603307	407.6849	48	3.413925
FALSE	37	120	90	87.875	1	90.5	11.5	6.5	4.8	13.27481	0.640884	408.6234	48	3.971926
FALSE	38	150	0	113.125	0.5	67.875	19	0	0	10.49239	0.721666	411.2391	48	4.236633
TRUE	39	150	0	113.125	1.5	113.125	19	13	4.8	16.76067	0.492803	403.2458	48	2.315425
FALSE	40	150	0	62.625	1	67.875	4	13	0	11.01043	0.656461	409.3898	48	3.530515
FALSE	41	90	90	62.625	0.5	67.875	4	0	4.8	10.41425	0.752631	411.5562	48	4.208386
FALSE	42	120	90	87.875	1	90.5	4	0	0	12.31652	0.72588	411.0703	48	4.293403
FALSE	43	90	180	87.875	1.5	67.875	4	13	0	12.7995	0.578535	407.6657	48	3.388227
FALSE	44	90	180	62.625	1.5	113.125	19	0	0	9.695774	0.558383	407.1783	48	3.098039
FALSE	45	150	0	113.125	0.5	113.125	4	0	4.8	9.978815	0.746956	411.9877	48	4.18023
FALSE	46	150	0	62.625	0.5	90.5	4	13	4.8	8.685404	0.724082	411.009	48	3.862839
FALSE	47	120	90	87.875	1	90.5	19	0	4.8	14.47076	0.636786	408.4645	48	3.876401
FALSE	48	150	0	62.625	1.5	67.875	4	0	4.8	10.52442	0.649206	408.2777	48	3.835781
TRUE	49	90	180	62.625	0.5	113.125	19	0	4.8	4.089351	0.642528	411.2468	48	2.987075
TRUE	50	150	180	113.125	1.5	90.5	19	0	4.8	8.45936	0.517242	406.5672	48	2.135865
FALSE	51	150	0	62.625	1.5	113.125	19	0	0	11.06305	0.582819	406.1769	48	3.388227
TRUE	52	90	180	62.625	1	67.875	19	13	4.8	9.304253	0.55623	406.2889	48	2.781268
FALSE	53	90	180	113.125	0.5	67.875	19	0	0	9.178405	0.681478	411.5637	48	3.413925
FALSE	54	90	180	113.125	1.5	67.875	4	0	4.8	6.758071	0.598912	409.1577	48	3.08564
FALSE	55	120	87	87.5	1	92.5	31	0	1.8	15.11941	0.601653	407.5826	48	3.491478
FALSE	56	120	87	87.5	1	92.5	31	0	1.8	15.11941	0.601653	407.5826	48	3.491478
FALSE	57	120	87	87.5	1	92.5	31	0	1.8	15.11941	0.601653	407.5826	48	3.491478
FALSE	58	120	87	87.5	1	92.5	31	0	1.8	15.11941	0.601653	407.5826	48	3.491478
FALSE	59	120	87	87.5	1	92.5	31	0	1.8	15.11941	0.601653	407.5826	48	3.491478