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-COM tracking
- ☐ Effects of DFE and package length
- ☐ N_{bx} analysis
- ☐ Recommendation
- ☐ Next steps

ERL equations

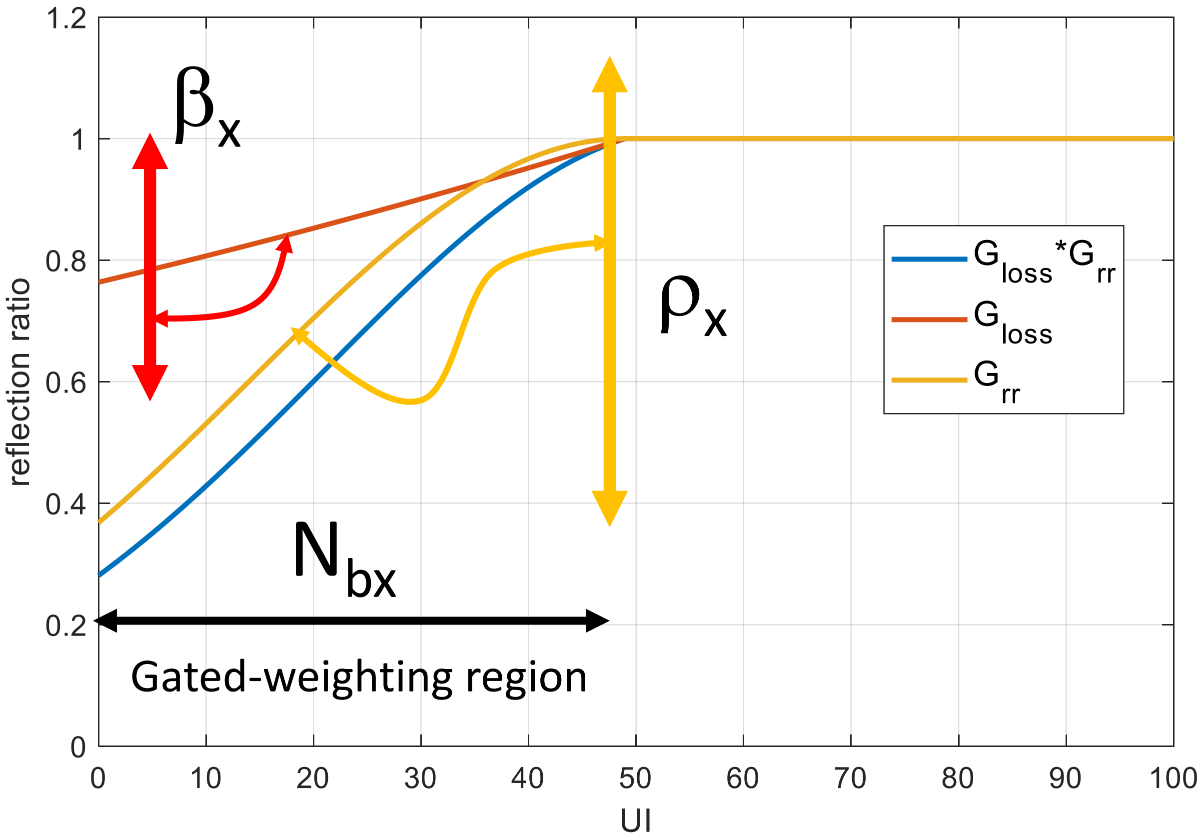
$$G_{rr}(t) = \begin{cases} 0 & t < T_{fx} \\ \rho_x(1+\rho_x)\exp\left(-\dfrac{[(t-T_{fx})f_b-(N_{bx}+1)]^2}{(N_{bx}+1)^2}\right) & T_{fx} \le t < T_{fx} + \dfrac{N_{bx}+1}{f_b} \\ 1 & t \ge T_{fx} + \dfrac{N_b+1}{f_b} \end{cases}$$

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

- ☐ 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

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

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



So is Nbx and the yellow line shape sufficnte to map ERL to COM

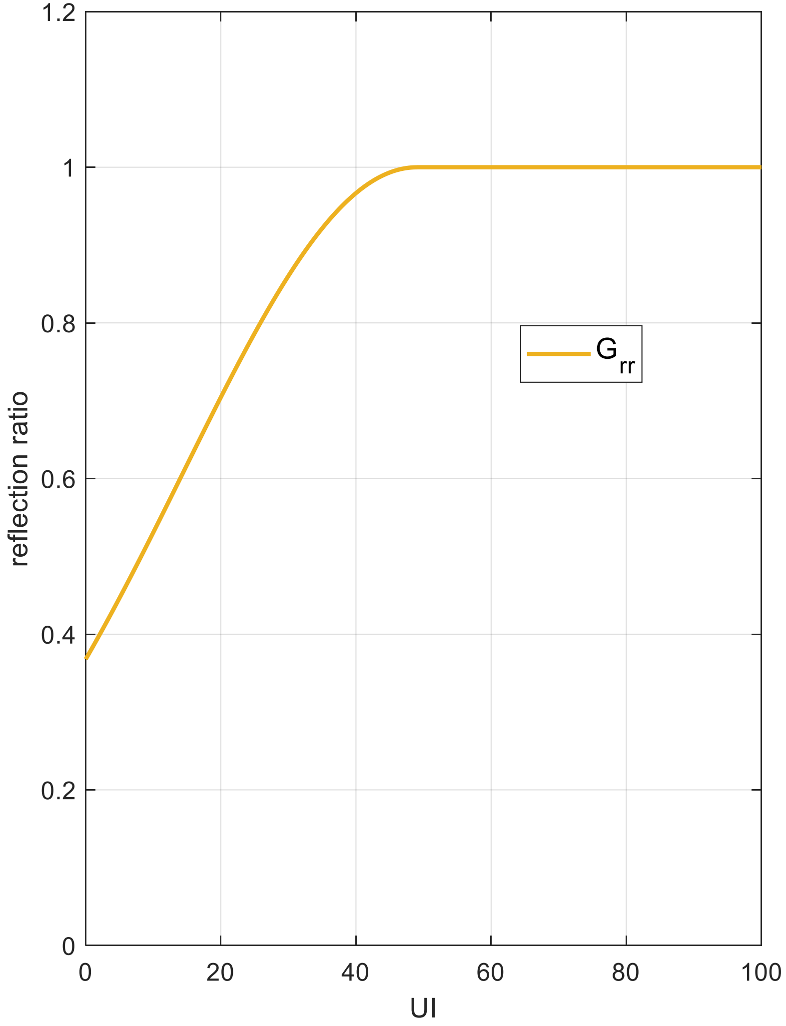
$$G_{rr}(t) = \begin{cases} 0 & t < T_{fx} \\ \rho_x(1+\rho_x)\exp\left(-\frac{[(t-T_{fx})f_b-(N_{bx}+1)]^2}{(N_{bx}+1)^2}\right) & T_{fx} \le t < T_{fx} + \frac{N_{bx}+1}{f_b} \\ 1 & t \ge T_{fx} + \frac{N_b+1}{f_b} \end{cases}$$

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

- 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 line shape 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

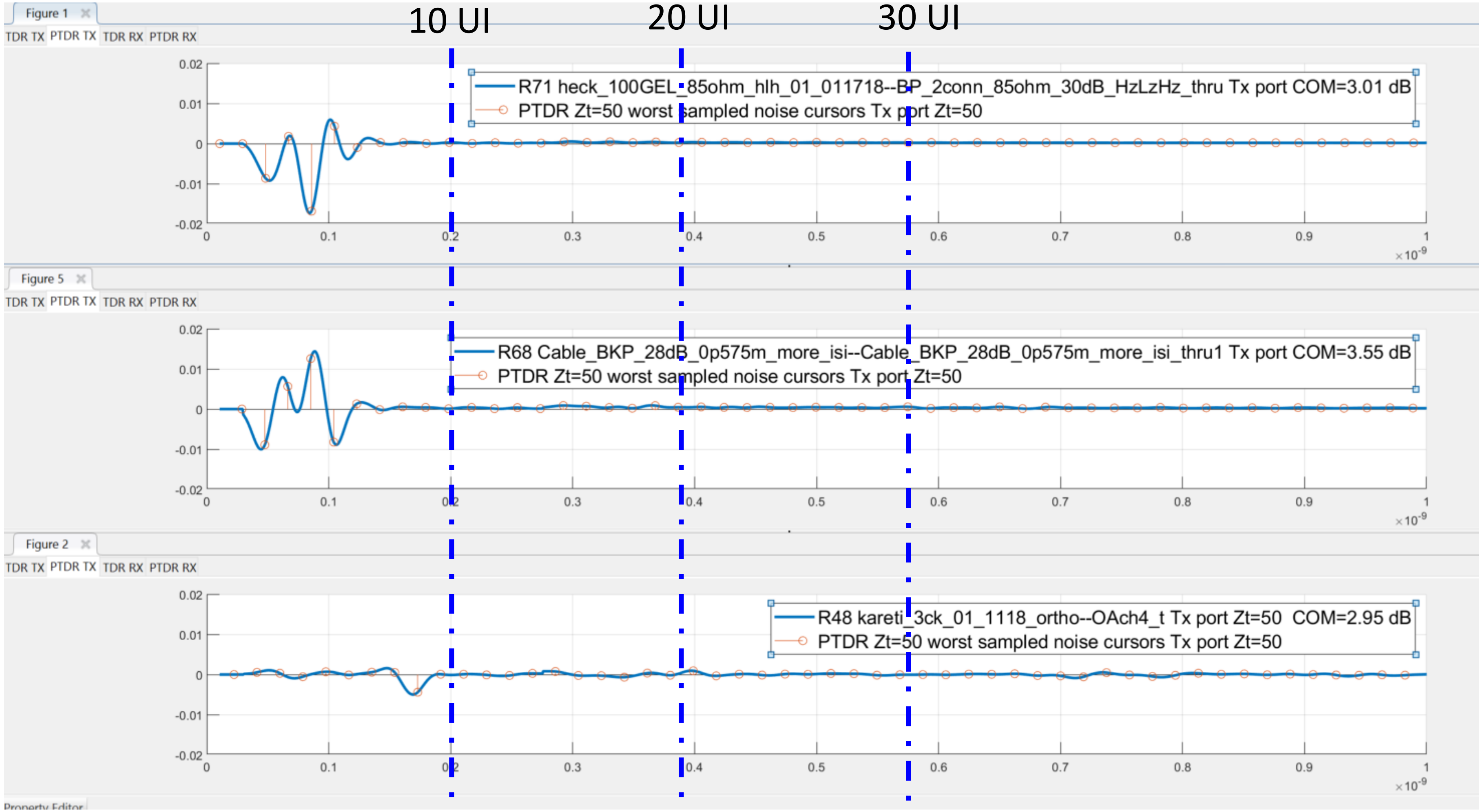


First: Choose channels with reflections near TP0 and with COM ~ 3 dB (use PTDR)

Larger reflections

Larger reflections

Smaller reflections



Delay through 30 mm package is ~ 10 UI

File Key: Previous slide

☐ Larger reflections

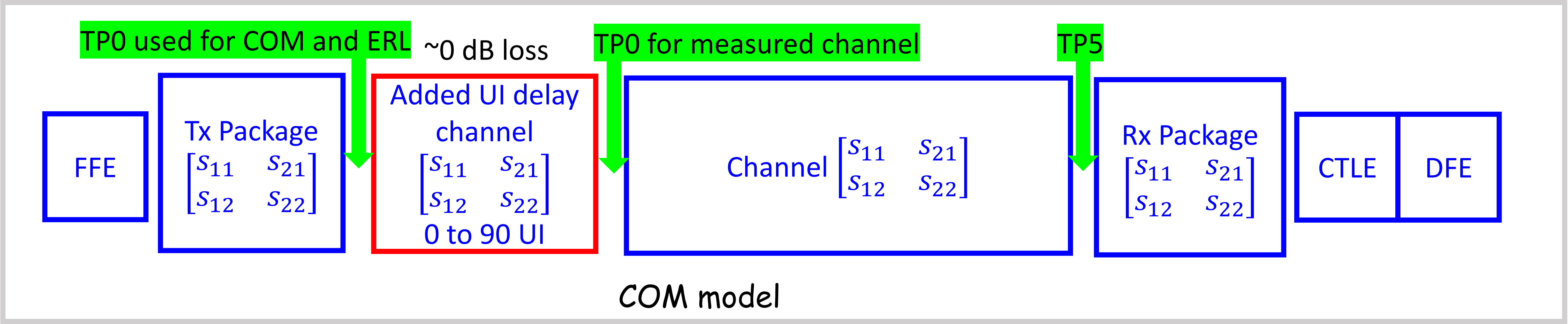
- R71 heck_100GEL_85ohm_hlh_01_011718--BP_2conn_85ohm_30dB_HzLzHz_thru: COM 3.0 dB
- R68 Cable_BKP_28dB_0p575m_more_isi--Cable_BKP_28dB_0p575m_more_isi_thru: COM 3.5 dB

☐ Smaller reflections

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

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



TP0 used for COM and ERL

~0 dB loss

TP0 for measured channel

TP5

FFE

Tx Package $\begin{bmatrix} s_{11} & s_{21} \\ s_{12} & s_{22} \end{bmatrix}$

Added UI delay channel $\begin{bmatrix} s_{11} & s_{21} \\ s_{12} & s_{22} \end{bmatrix}$ 0 to 90 UI

Channel $\begin{bmatrix} s_{11} & s_{21} \\ s_{12} & s_{22} \end{bmatrix}$

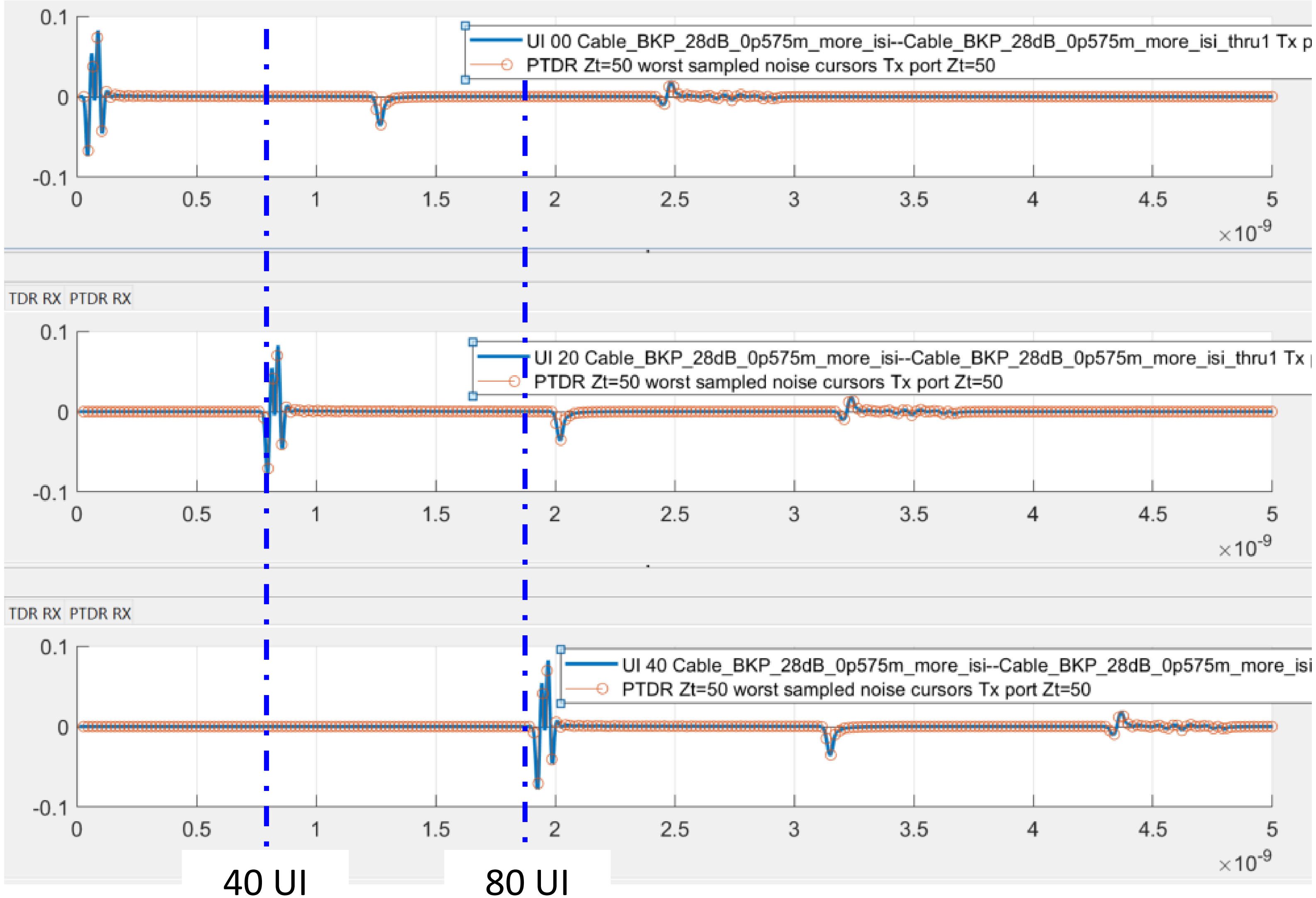
Rx Package $\begin{bmatrix} s_{11} & s_{21} \\ s_{12} & s_{22} \end{bmatrix}$

CTLE

DFE

COM model

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

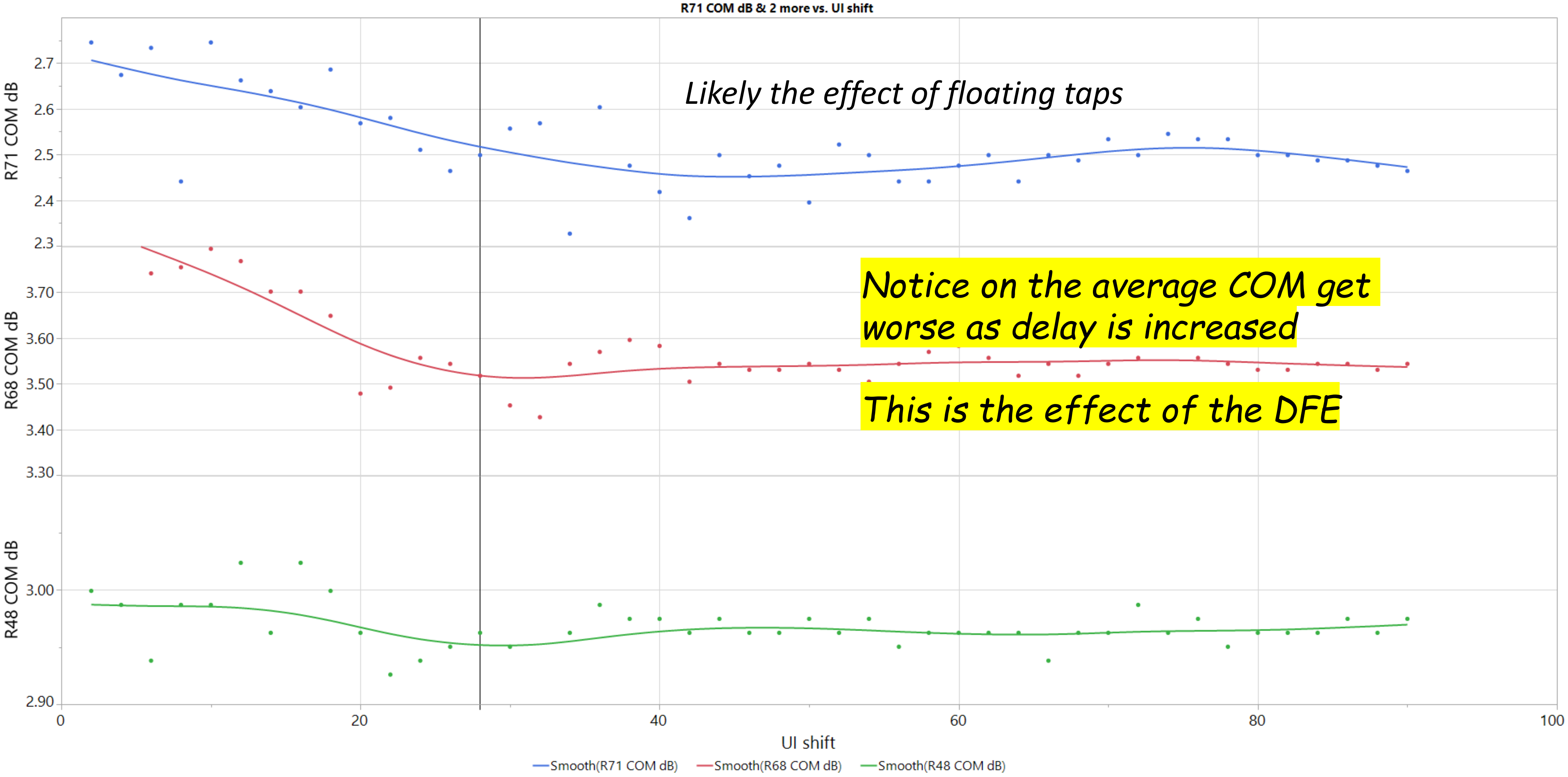


40 UI

80 UI

Note: TDR delay is twice physical added delay

Clause 163 (KR) COM vs added transmission line delays (UI)

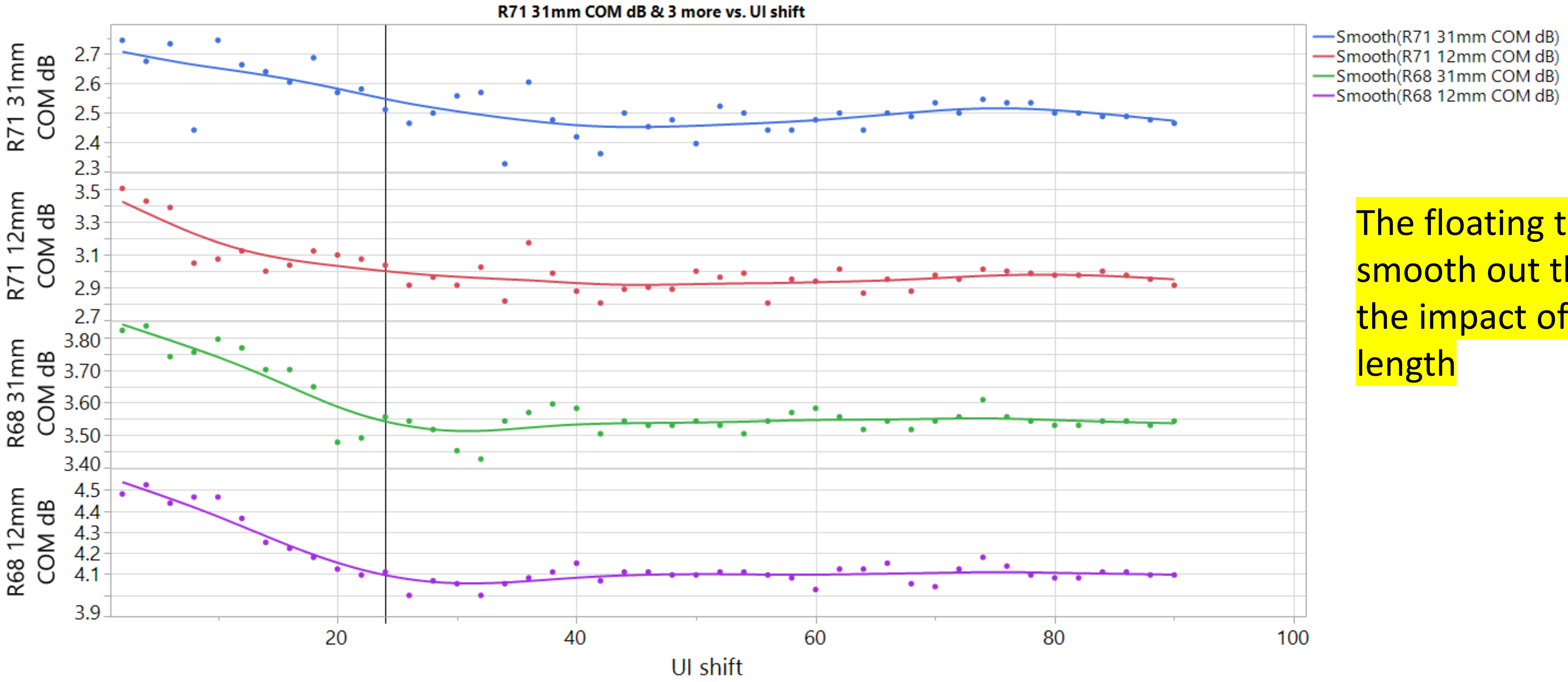


Likely the effect of floating taps

Notice on the average COM get worse as delay is increased

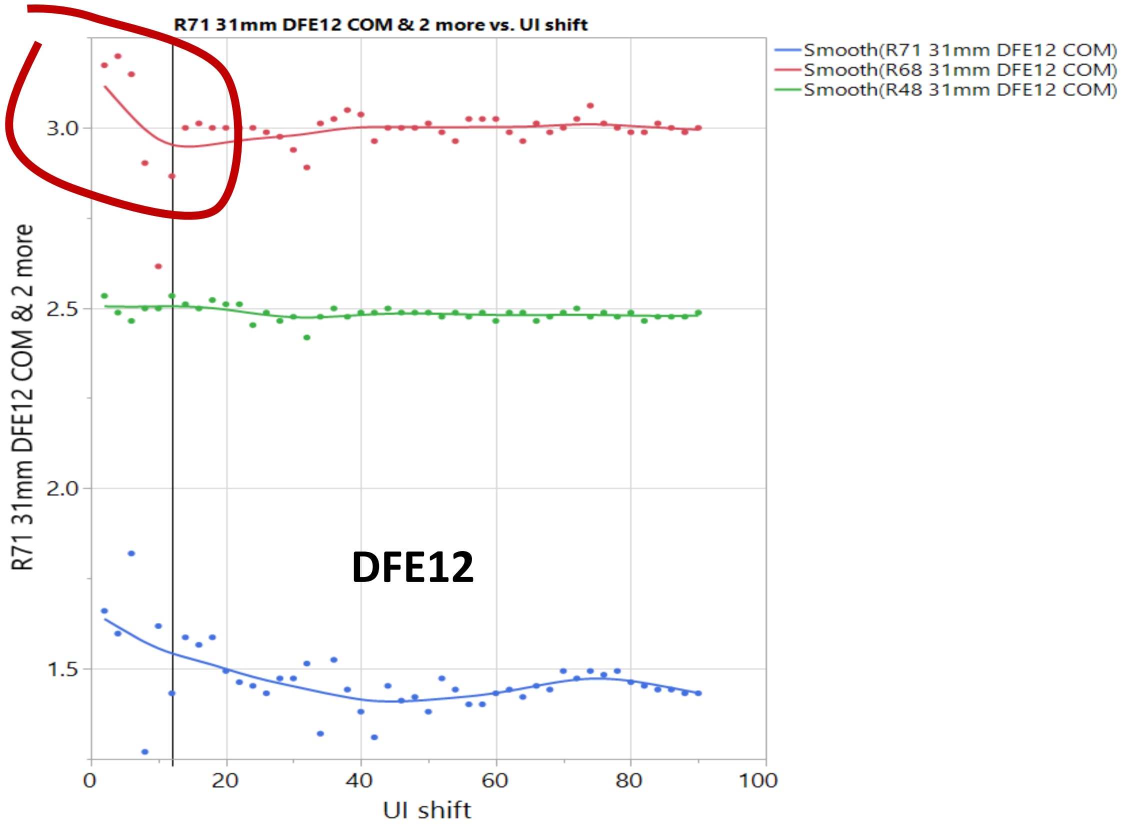
This is the effect of the DFE

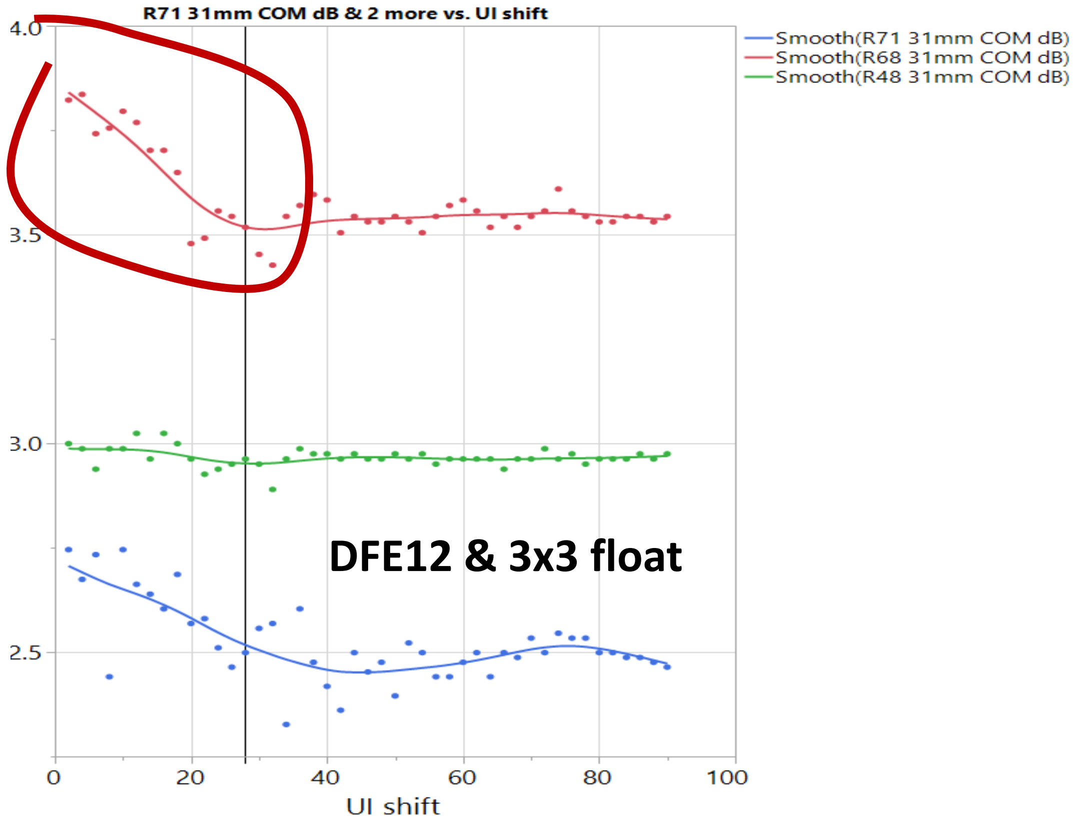
COM vs added transmission line delay (UI) for 31 mm and 12 mm package



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



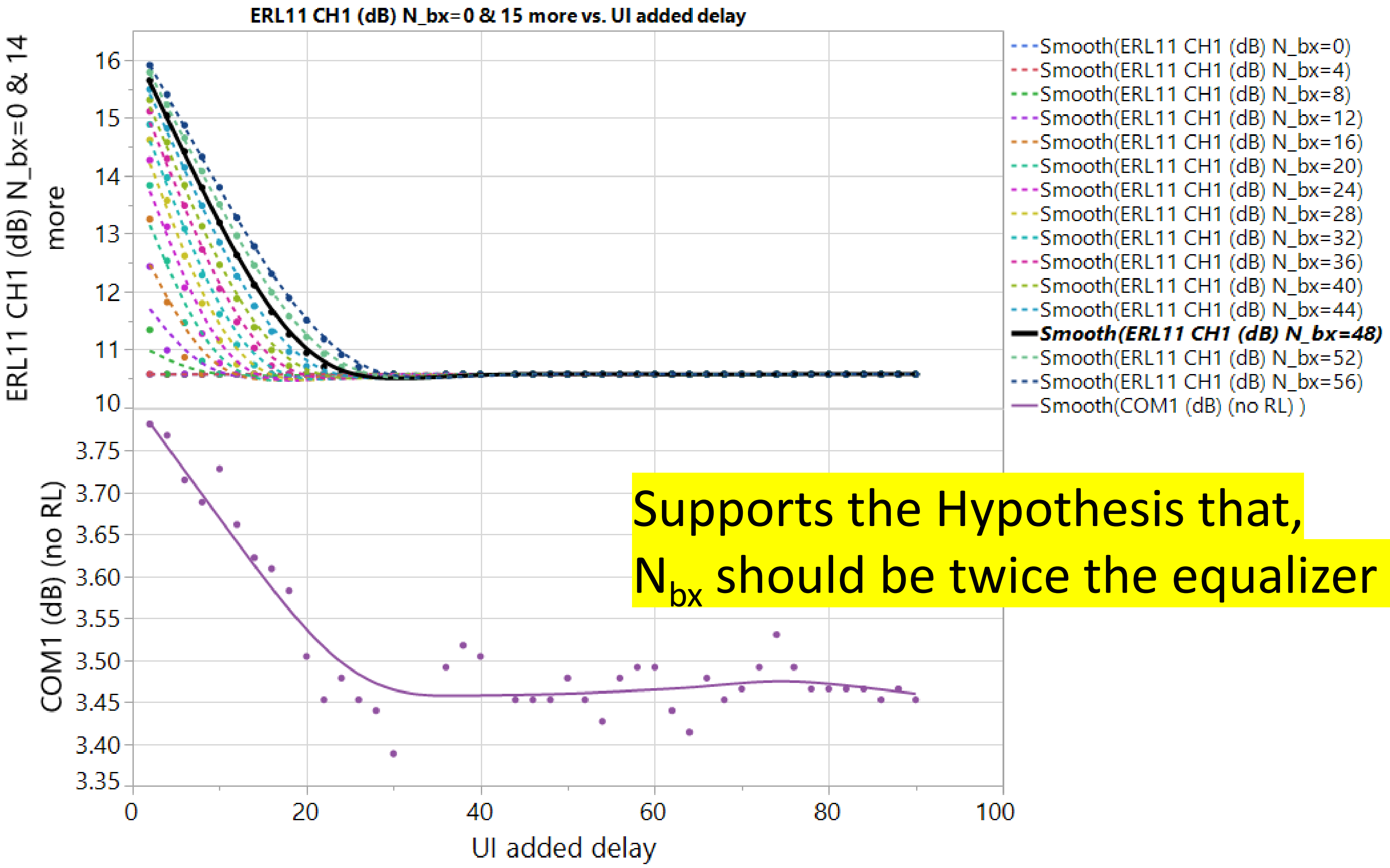


- Shorter DFE shows less impact from reflection delay
- Longer DFE shows more impact fro, reflection delay

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.
  - If delayed reflections are outside the “DFE reach”, COM is worse and more or less unaffected by the delay
- Hypothesis: N_{bx} should be twice the equalizer reach

Added delay vs COM and ERL N_{bx}



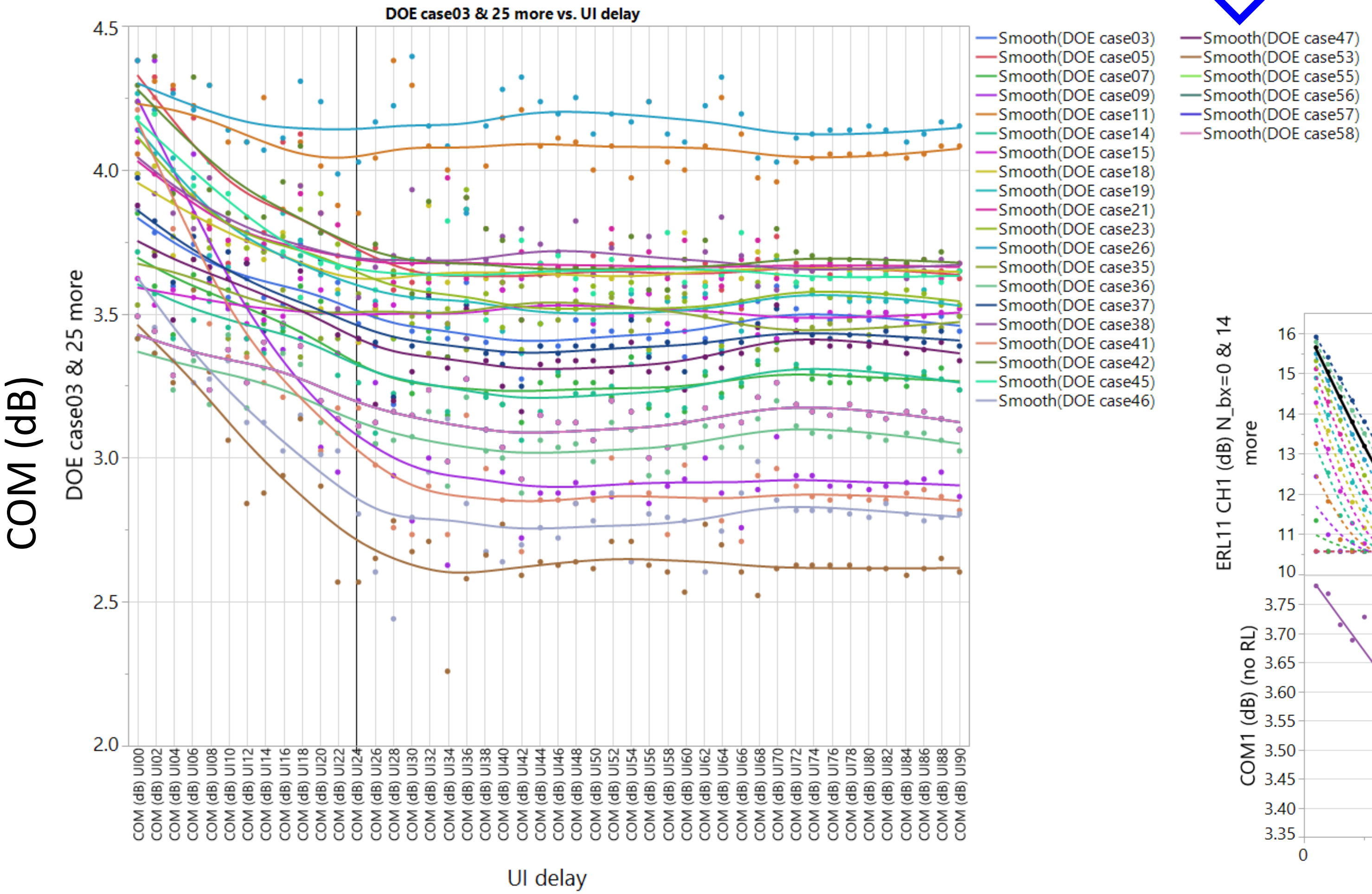
Supports the Hypothesis that,
N_{bx} should be twice the equalizer reach

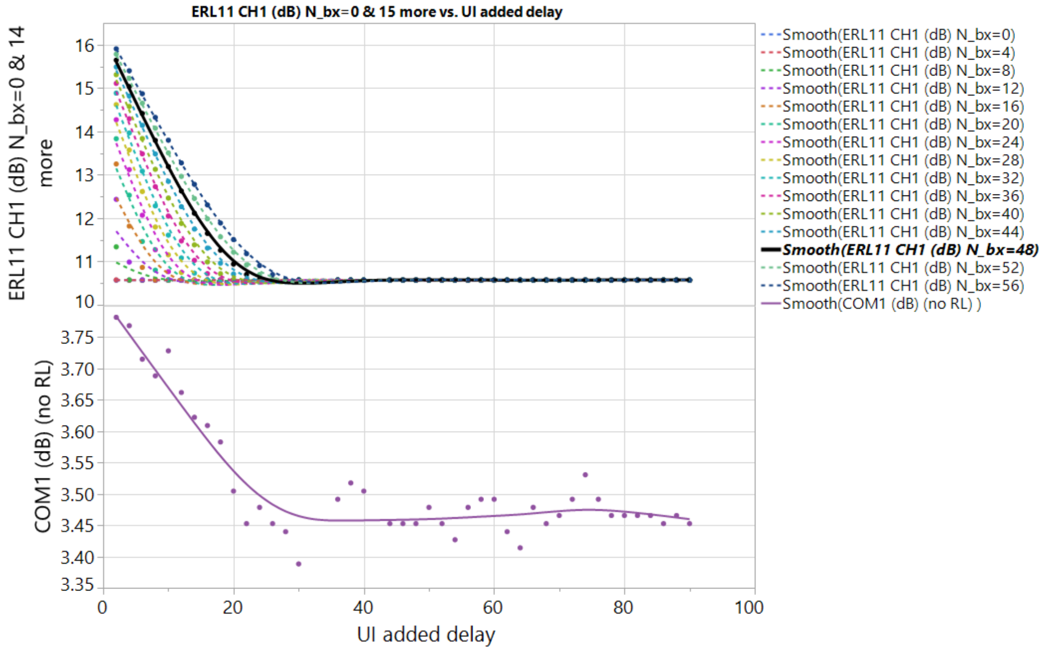
Does this correlation to N_{bx} hold if a wider range of package parameters are chosen

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

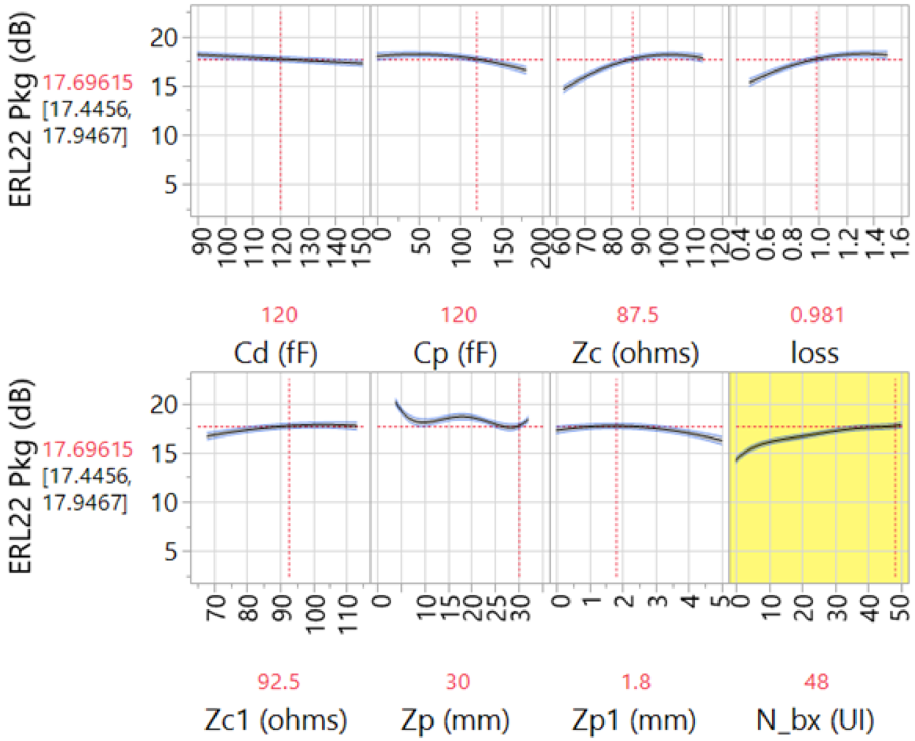
Yes

Package cases





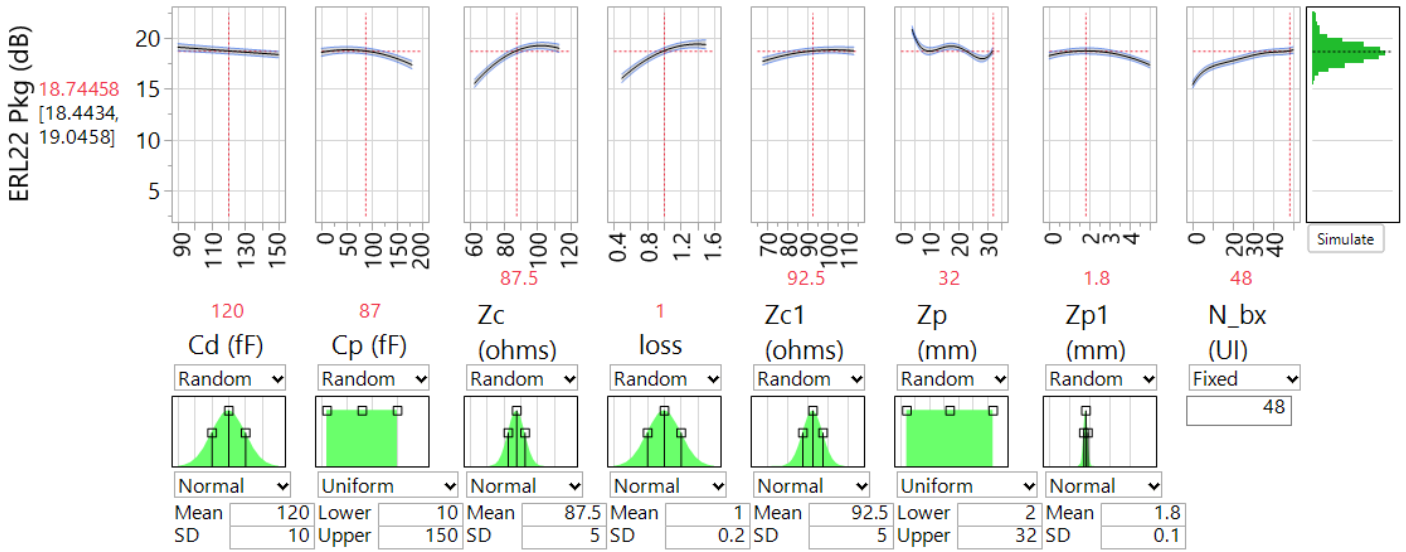
Hypothesis: ERL of the package varies inversely to N_{bx}



Yes!

IEEE 802.3 100 Gb/s, 200 Gb/s, and 400 Gb/s Electrical Interfaces Task Force

Variation on Reference package are limited to 15 dB ERL



Cd (fF)	Cp (fF)	Zc (ohms)	loss	Zc1 (ohms)	Zp (mm)	Zp1 (mm)	N_bx (UI)
Random	Random	Random	Random	Random	Random	Random	Fixed
Normal	Uniform	Normal	Normal	Normal	Uniform	Normal	48
Mean 120	Lower 10	Mean 87.5	Mean 1	Mean 92.5	Lower 2	Mean 1.8	
SD 10	Upper 150	SD 5	SD 0.2	SD 5	Upper 32	SD 0.1	

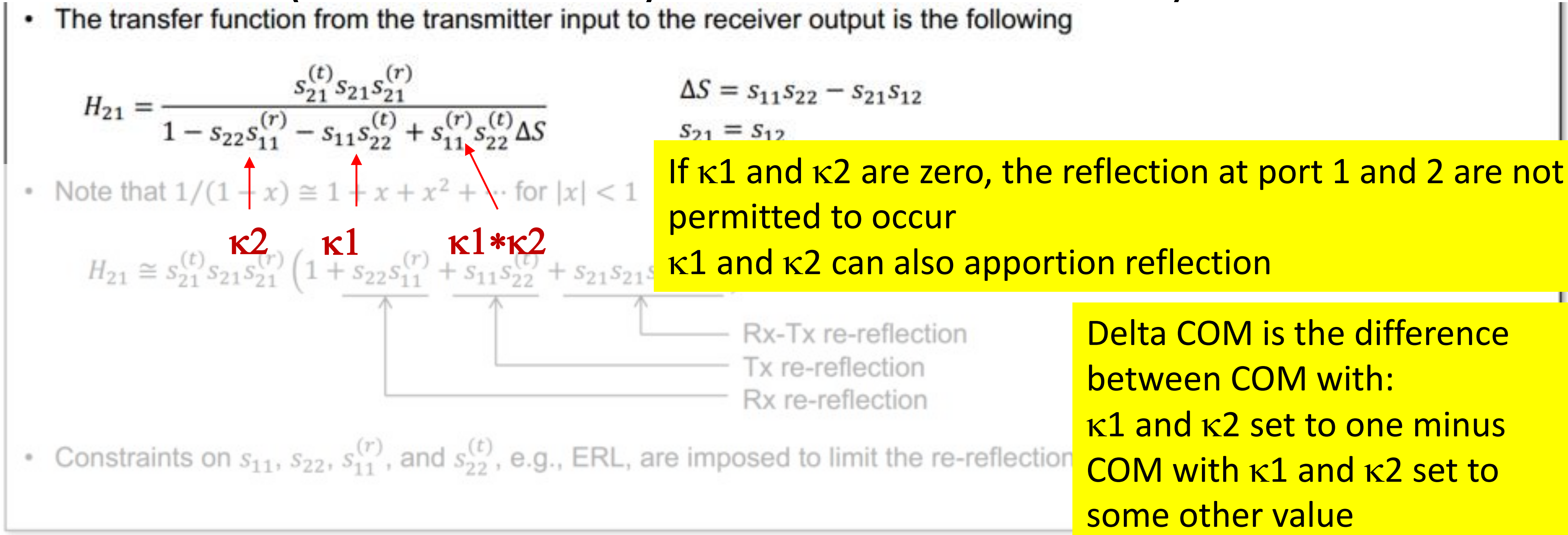
Recommend: For Channels and Packages

☐ Set β_x=0

☐ Set ρ_x=.618

☐ Set N_{bx}= 48

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

$$H_{21} = \frac{s_{21}^{(t)} s_{21} s_{21}^{(r)}}{1 - \underset{\kappa 2}{s_{22} s_{11}^{(r)}} - \underset{\kappa 1}{s_{11} s_{22}^{(t)}} + \underset{\kappa 1 * \kappa 2}{s_{11}^{(r)} s_{22}^{(t)} \Delta S}}$$

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

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

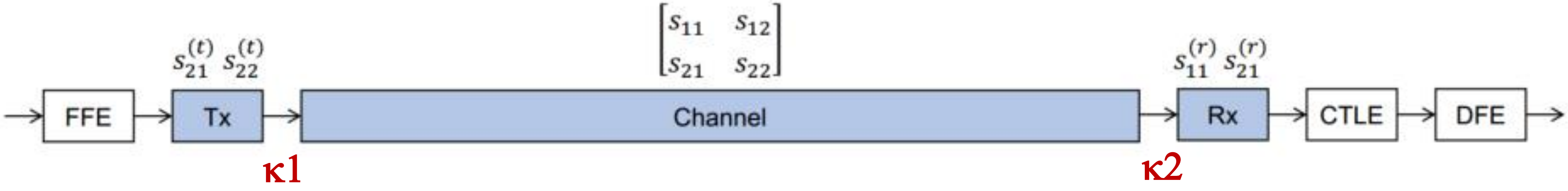
- Note that $1/(1 - x) \cong 1 + x + x^2 + \cdots$ for $|x| < 1$

$$H_{21} \cong s_{21}^{(t)} s_{21} s_{21}^{(r)} \left(1 + \underbrace{s_{22} s_{11}^{(r)}}_{\text{Rx re-reflection}} + \underbrace{s_{11} s_{22}^{(t)}}_{\text{Tx re-reflection}} + \underbrace{s_{21} s_{21} s}_{\text{Rx-Tx re-reflection}}\right.$$

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

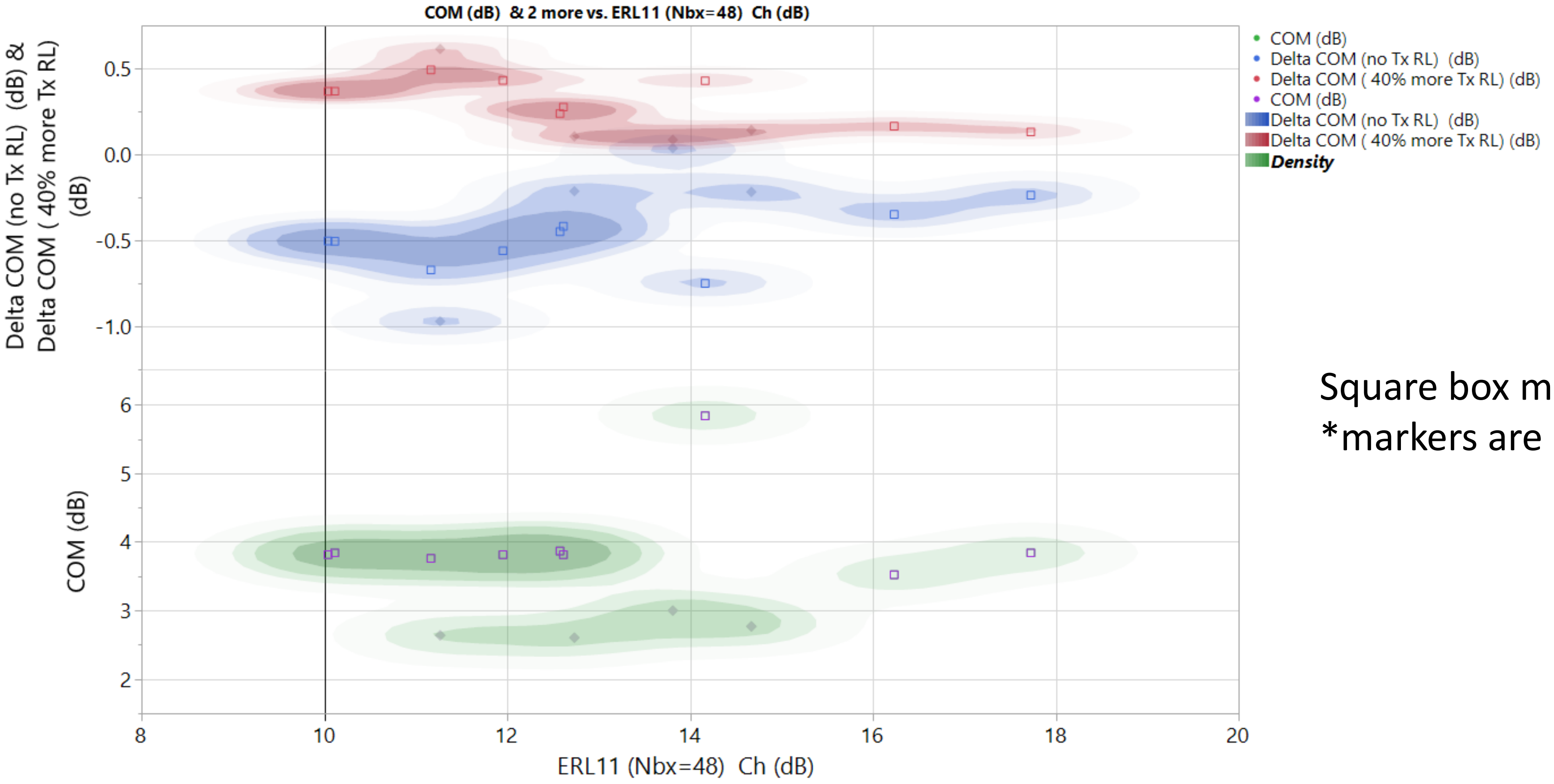
If κ1 and κ2 are zero, the reflection at port 1 and 2 are not permitted to occur
κ1 and κ2 can also apportion reflection

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



IEEE 802.3 100 Gb/s, 200 Gb/s, and 400 Gb/s Electrical Interfaces Task Force

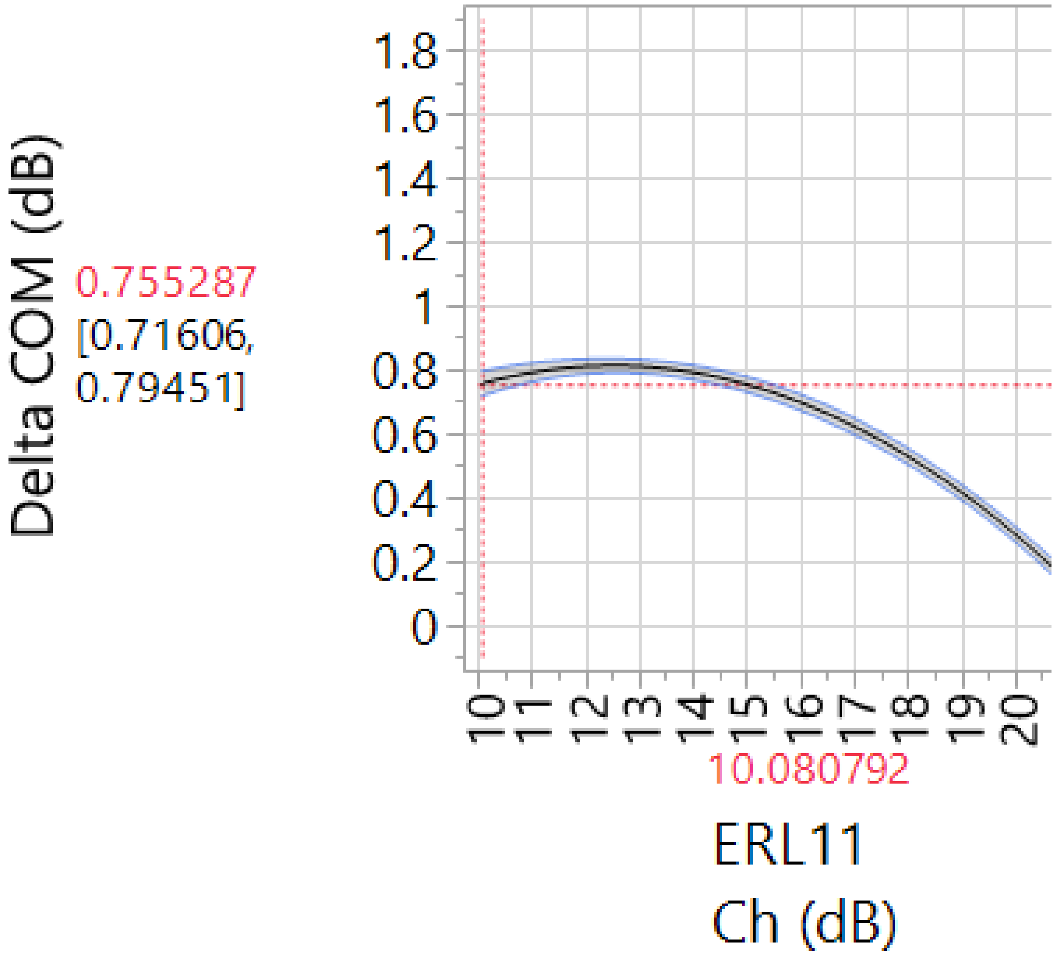
First estimate: ERL$_{min}$ = 10 dB



Square box markers are COM > 3.5 dB

*markers are COM <= 3dB

ERL is correlated to Delta COM



Better ERL means
less COM variability
at the receiver

Recommend: ERL_{min}

- ☐ Channel: 10 dB
- ☐ Package: 15 dB

Next steps look at packages

- ☐ Lock down channel ERL parameters
- ☐ Do similar work for package to see if N_{bx} tracks as well as
- ☐ Used wider range (+/- 25%)of package parameters

Additional backup data

COM spreadsheet used

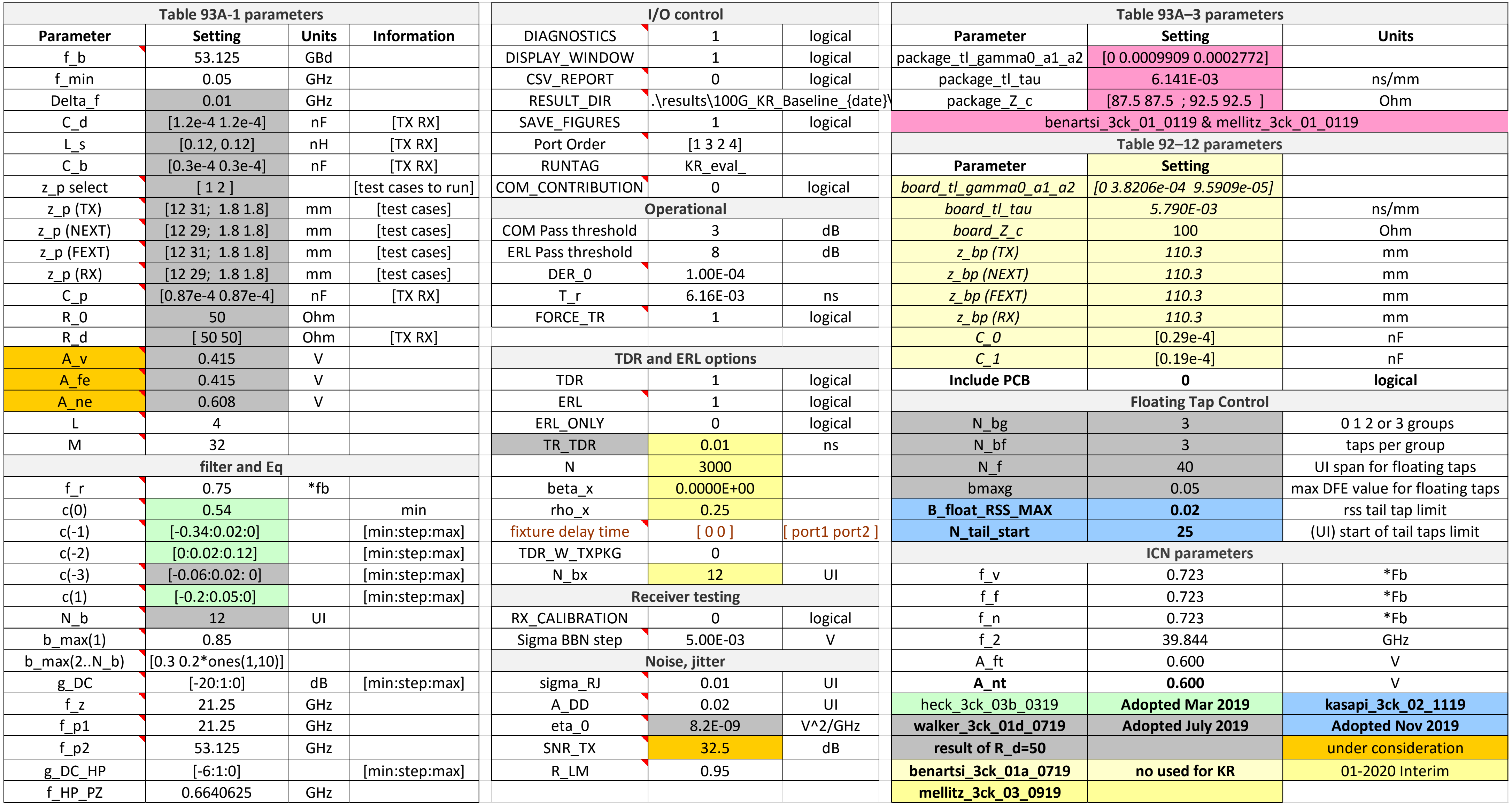


Table 93A-1 parameters			
Parameter	**Setting**	**Units**	**Information**
f_b	53.125	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[1.2e-4 1.2e-4]	nF	[TX RX]
L_s	[0.12, 0.12]	nH	[TX RX]
C_b	[0.3e-4 0.3e-4]	nF	[TX RX]
z_p select	[1 2]		[test cases to run]
z_p (TX)	[12 31; 1.8 1.8]	mm	[test cases]
z_p (NEXT)	[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]

⋱