RL, ERL, COM, & PTDR investigations update

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How much impact does return loss have on the COM specification?

- Past standards specify a combination of or computation from
  - Magnitude of frequency domain (FD) insertion loss (IL)
  - Magnitude of FD return loss (RL)
  - Magnitude of FD crosstalk (NEXT, FEXT)
  - Much of the analysis is rooted in broadband
- COM is specifies a minimum signal to noise ratio computed in the time domain (TD) from
  - Complex s parameters models of the reference package and the channel
  - These inheritably include return loss and crosstalk
  - COM analysis is rooted in baseband
- Problem: It may be possible for a system using a device and channel which passes individual specifications to fail in practice if the actual test environment or actual device differs greatly in return loss of the reference device.
  - This called a “false positive” system
  - Limiting return loss has been suggested a means to limit false positives

Return loss is more of an issue for PAM-4

- Bandwidth reduces by about 1/2
- Signals goes down by 1/3
- ISI noise only goes down by about 3/5
- The impact of linearly reduces the signal by 5 %
- That means RL parity is 7.4 dB worse for PAM-4 vs NRZ

- Hence the impact can be expect to be more critical and worse the problem of the false positives
- So let look closer at how return loss effects performance

Forthcoming Analysis

- ❑ Focus first on channel return loss
- ❑ Reflection experiment
- ❑ PTRD, IL, and RL
- ❑ Pulse response comparison for reflection choices
- ❑ COM, ERL, gated ERL, and RL comparison

Set up the channel RL experiments

Utilize a channel with just 2 impairment

1) Loss ~27 dB @ 13.3 GHz
2) Two reflection reflections

Determine ISI impact by using a COM computation

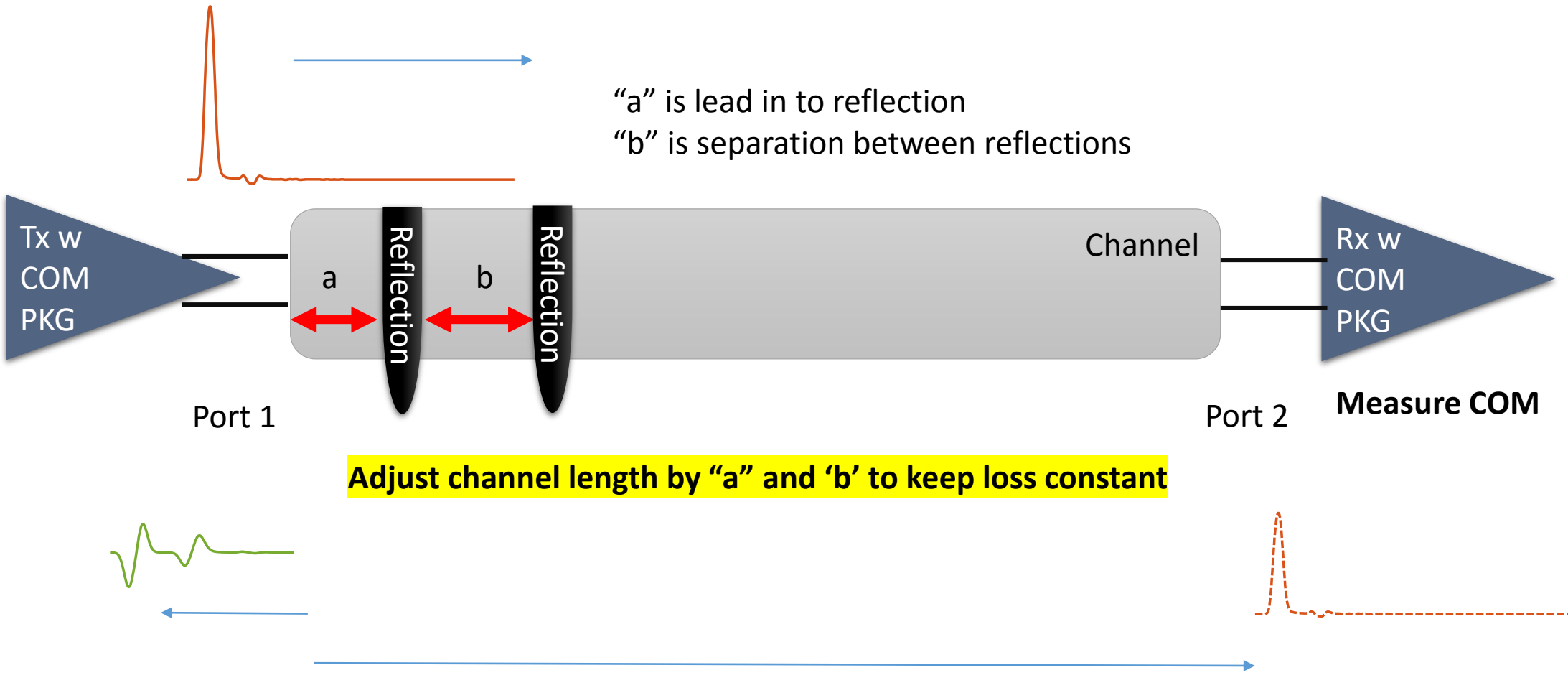
- Signaling: 50Gbs PAM4 – IEEE802.3 cd clause 137 equalization and the 30 mm package
- For COM computation, remove all noise sources and jitter except SNR_Tx
  - Adjust SNR_Tx to achieve just slightly higher than 3 dB COM
  - For these experiments 24 dB was used for SNR_Tx

❑ Investigate for correlations between COM and PTDR computation into a single number

❑ Refine the computation to a single return loss parameter called effective return loss (ERL)

❑ Tie ERL to parameter in the device and channel specifications

Reflection experiment using a 27 dB IL channel and 2 reflections



Details, Keys, and Examples ~ 27 dB @ 13.3 GHz

One side of a differential channel

Similar to IEEE802.3bj CR host board model

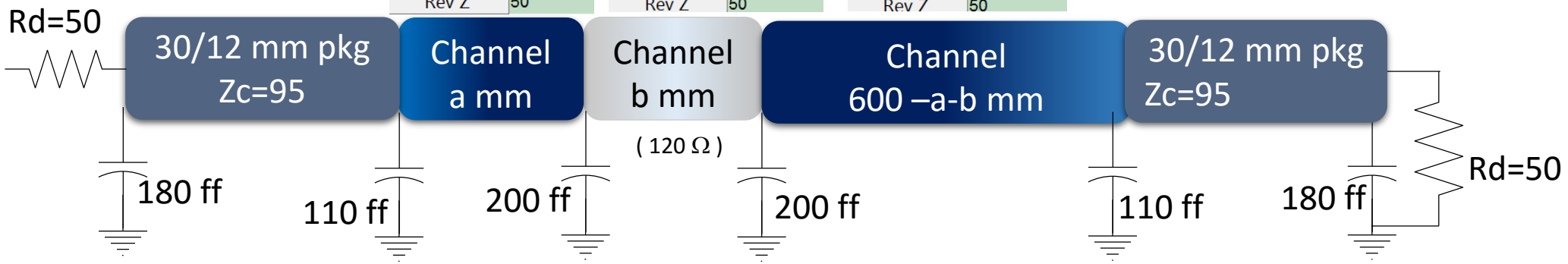
RL11 and ERL11 are associated with Port 1

RL22 and ERL22 are associated with Port 2

Gamma 0	0
Alpha 1	4.114e-4
Alpha2	2.547e-4
Tau	6.191e-03
Z0	100
Rev Z	50

Gamma 0	0
Alpha 1	0.0004114
Alpha2	0.0002547
Tau	0.006191
Z0	120
Rev Z	50

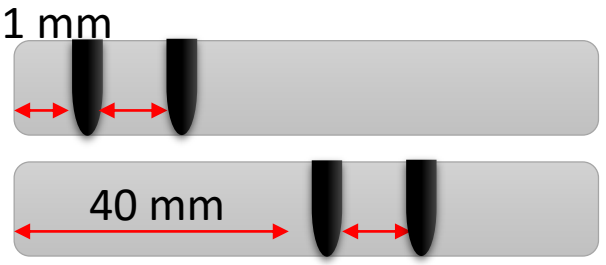
Gamma 0	0
Alpha 1	4.114e-4
Alpha2	2.547e-4
Tau	6.191e-03
Z0	100
Rev Z	50



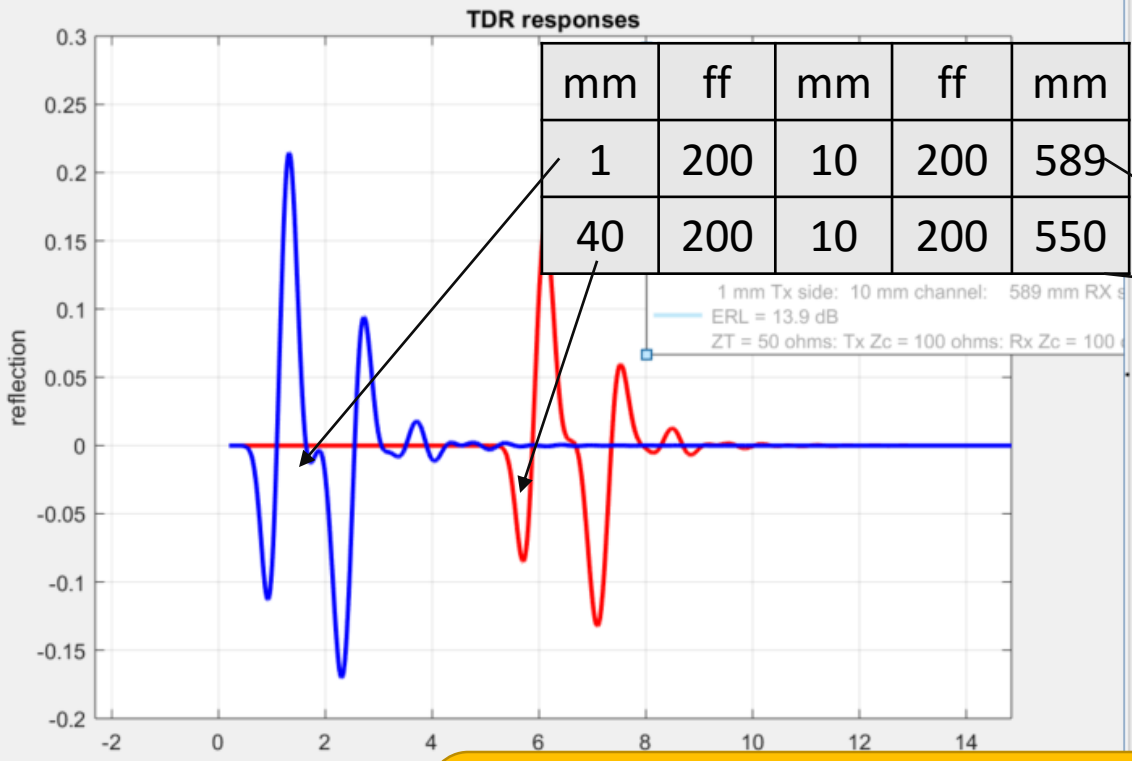
~27 dB @ 13.3 GHz

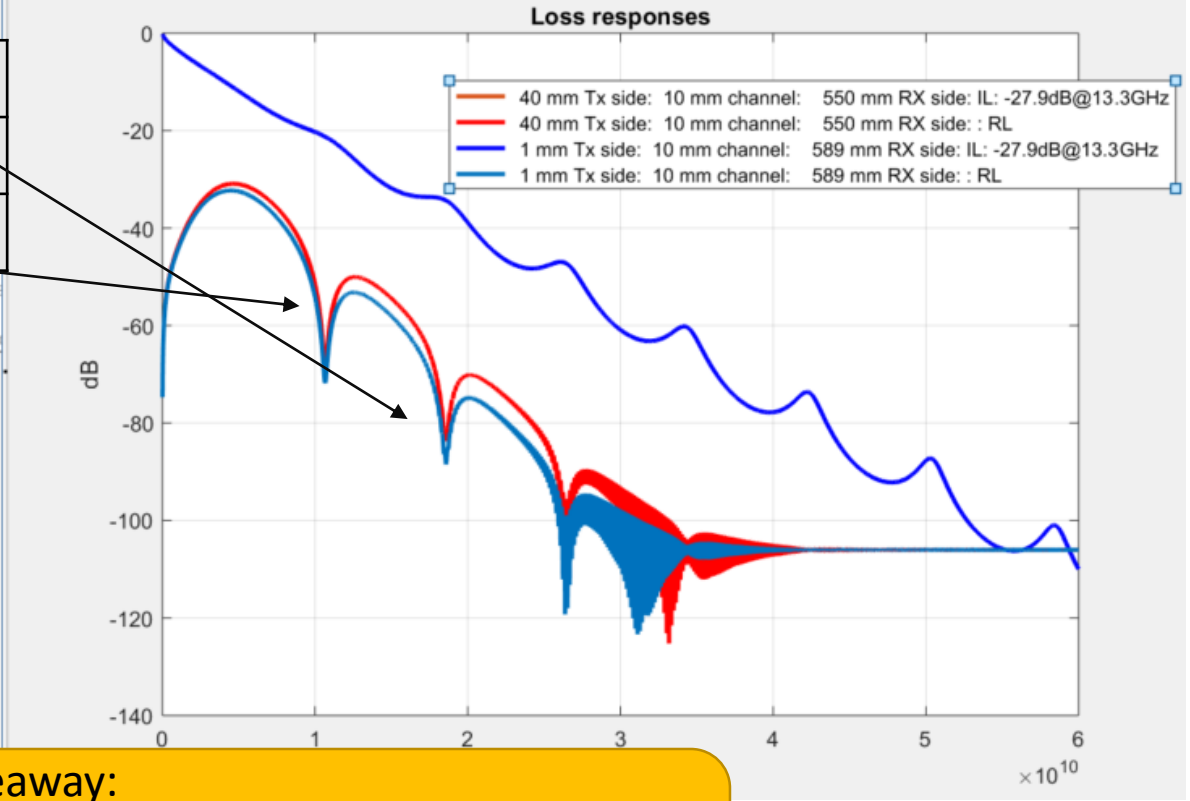
Ω	ff	Ω	mm	ff	mm	ff	mm	ff	mm	ff	mm	Ω	ff	Ω
30	180	95	12	110	a	200	b	200	600 -a-b	110	30	95	180	50

PTDR for 1 mm and 40 mm lead in (a) 10 mm space: (same insertion losses)



mm	ff	mm	ff	mm
1	200	10	200	589
40	200	10	200	550





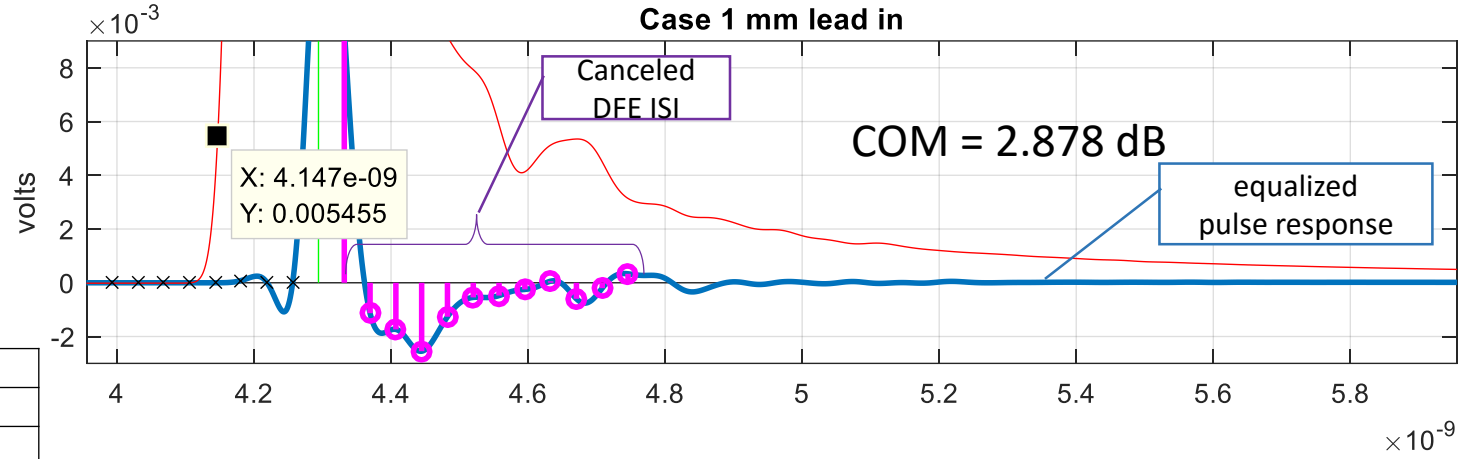
Takeaway:

- As expected the farther the reflection is from the measurement point the higher the return loss.
- The round trip is added to the return loss

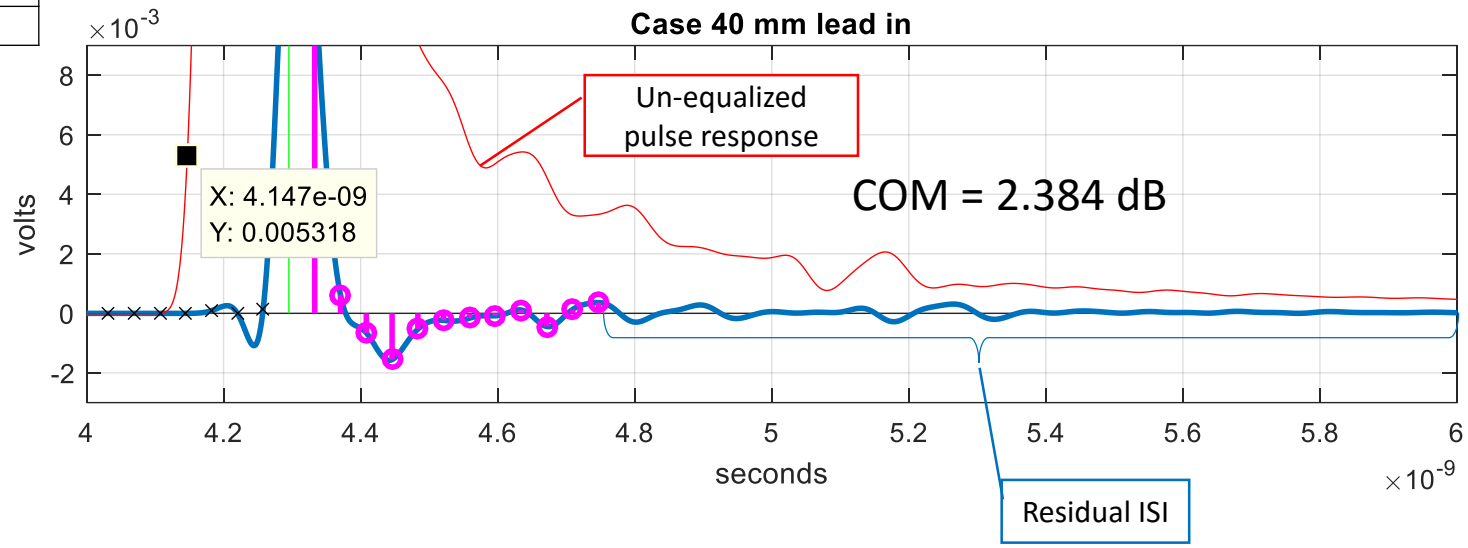
Observation: More post DFE ISI in a=40 mm case, but less ISI in DFE region

Adjusted values to achieve ~ 3 dB COM

sigma_RJ	0
A_DD	0
eta_0	1.64E-99
SNR_TX	24

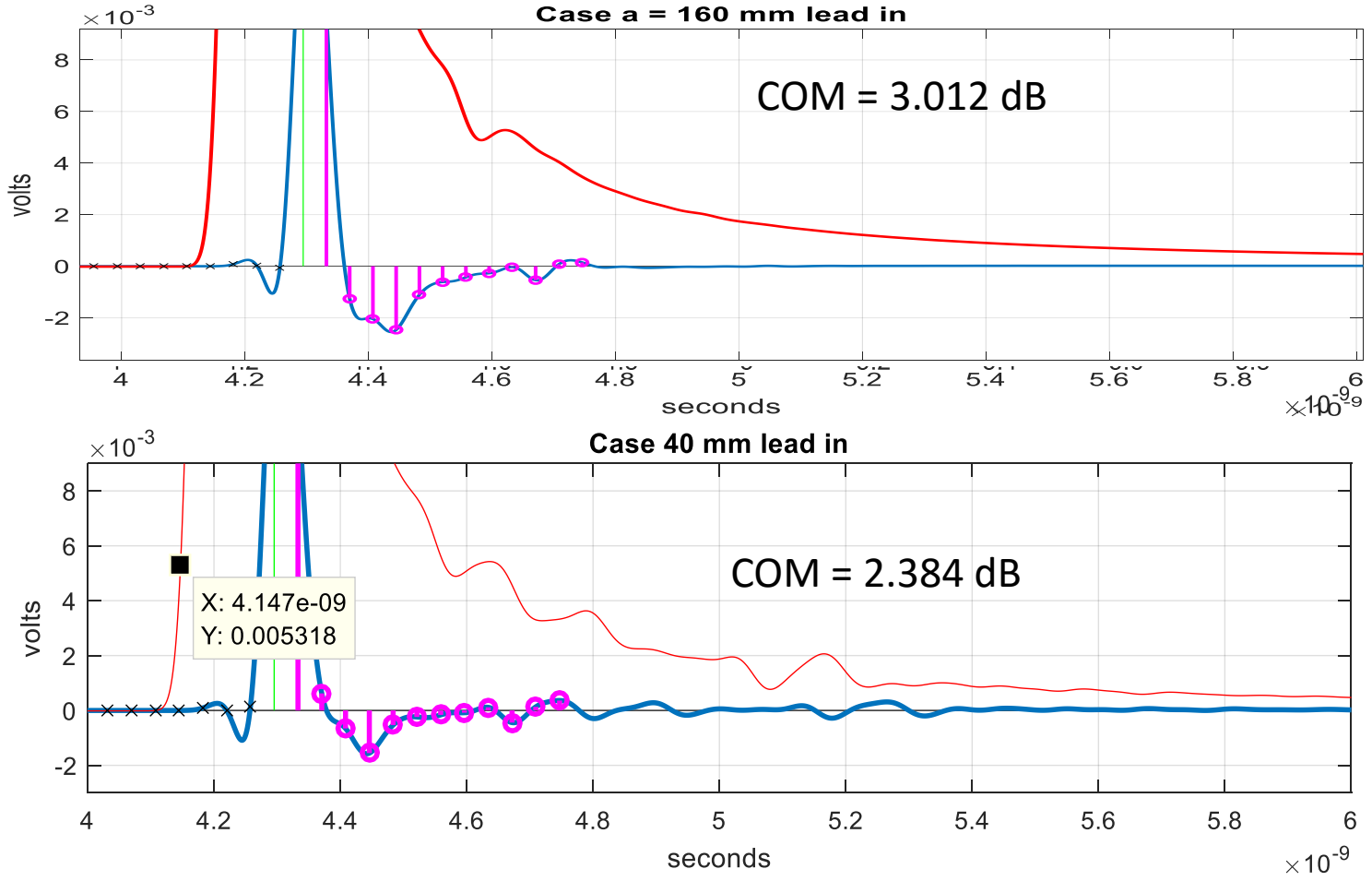


a=1 mm b=10 mm



a=40 mm b=10 mm

When a = 160 mm COM improves, However ISI is worse in DFE region



a=160 mm b=10 mm

a=40 mm b=10 mm

ERL Computation: Weighted Gating Algorithm

- $R_{eff}(t)$ is computed with time gating and weighting of a Pulse TDR waveform, PTDR(t)
- $reff_{I,m}$ is the time sampled waveform of $R_{eff}(t)$
  - Samples per UI is represented by "i"
  - Number of UI is represented by "m"
- Method 1: ERL=RMS($reff_{i,1:m}$)
- Method 2: ERL=Greatest CDF(PDF($reff_{i,1:m}$⊗ [1]Constellation)) @BER
- Method 3: ERL=Greatest RSS($reff_{i,1:m}$) for each i
- Converting ERL to positive dB makes this somewhat similar to RL in the frequency domain

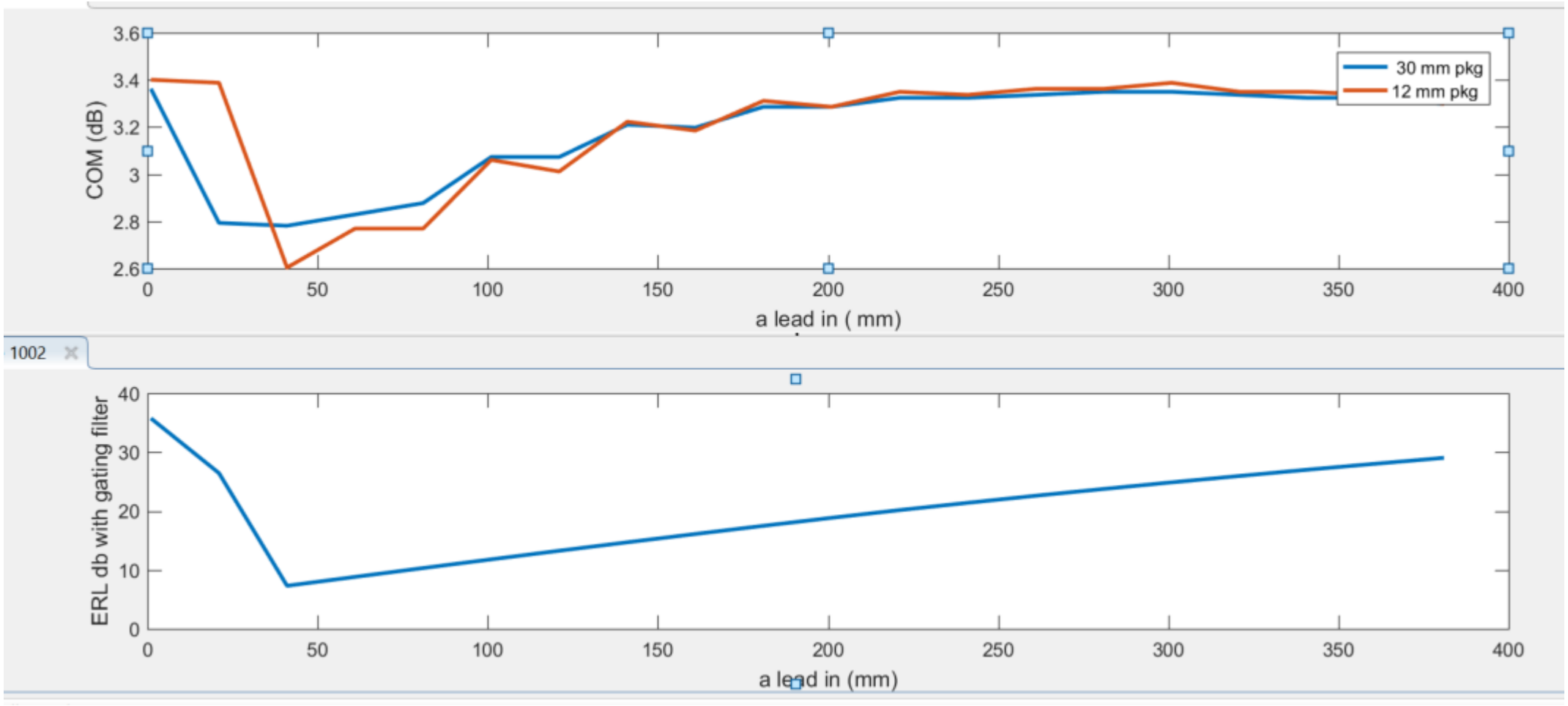
[1]*Constellation for PAM-4 = [-1 -1/3 1/3 1]*

$$R_{eff}(t) = PTDR(t)\left(1 - \rho_x(1+\rho_x)e^{-\left(\frac{t}{T_b}-N_b-1\right)^2}\right)10^{\frac{\beta_x\left(t-T_b(N_b+1)\right)}{20}}$$

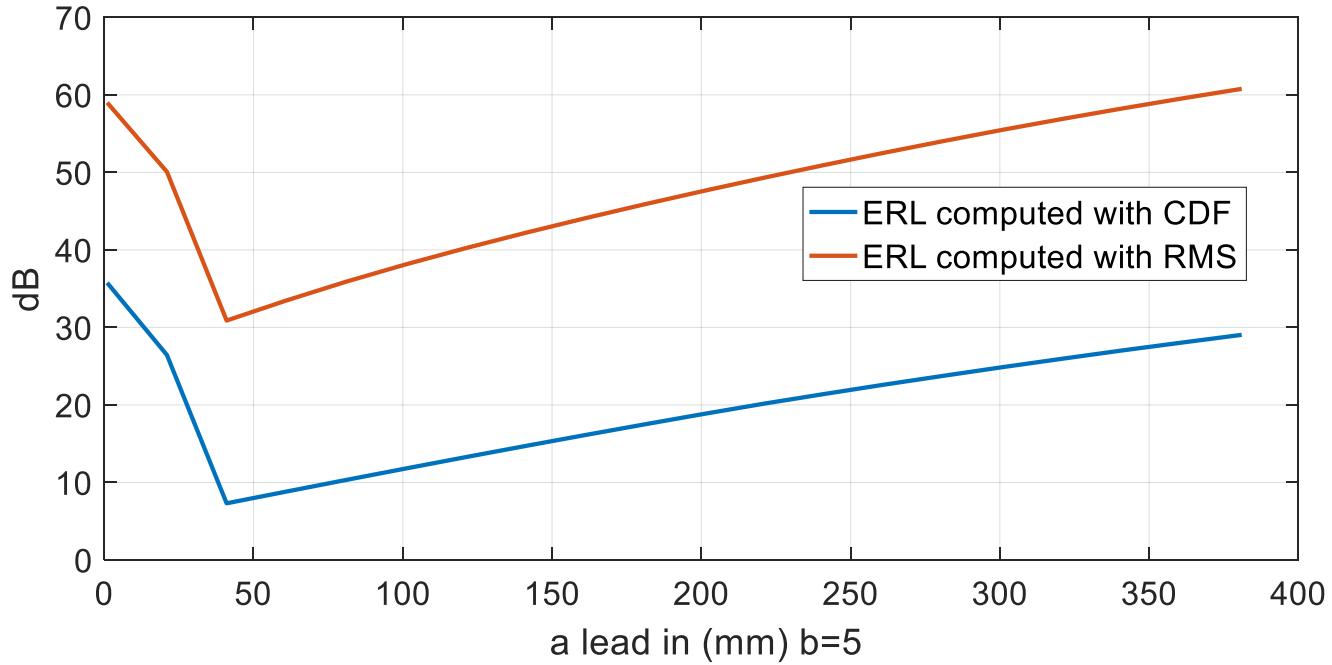
DFE compensation and re-reflection

Loss compensation

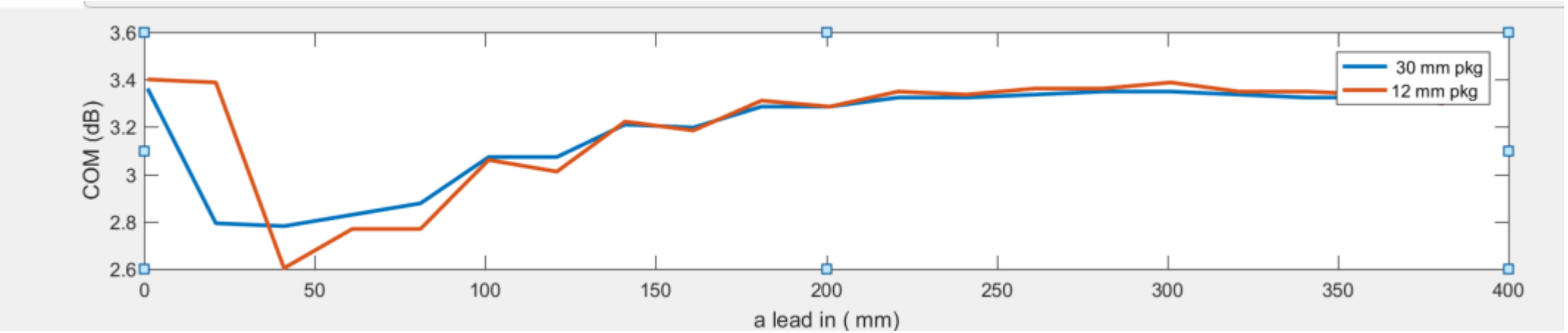
Plot COM, ERL11 gated vs Lead in for b=10 mm and package length = 12 mm and 30 mm

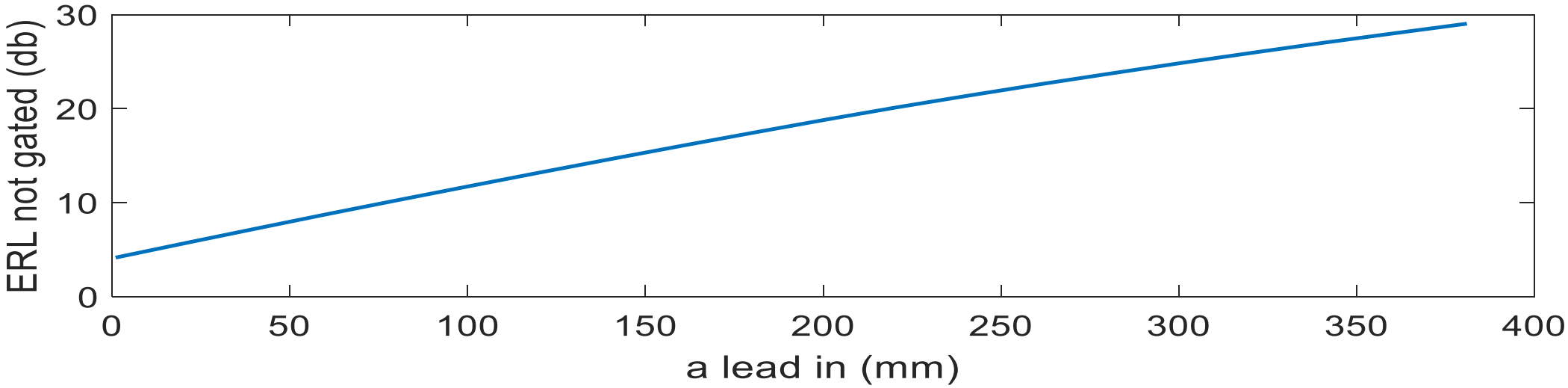


RMS seems to produce the same shape curves but not sure how to tie in high ERL numbers

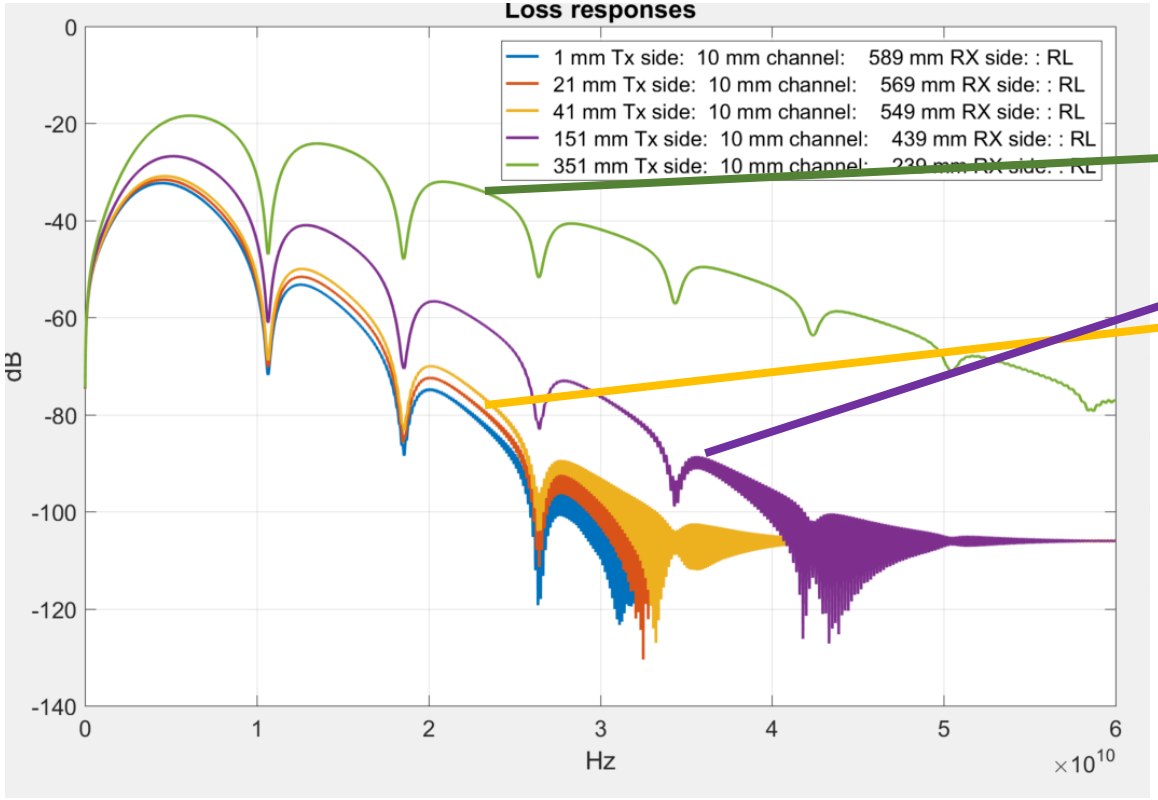


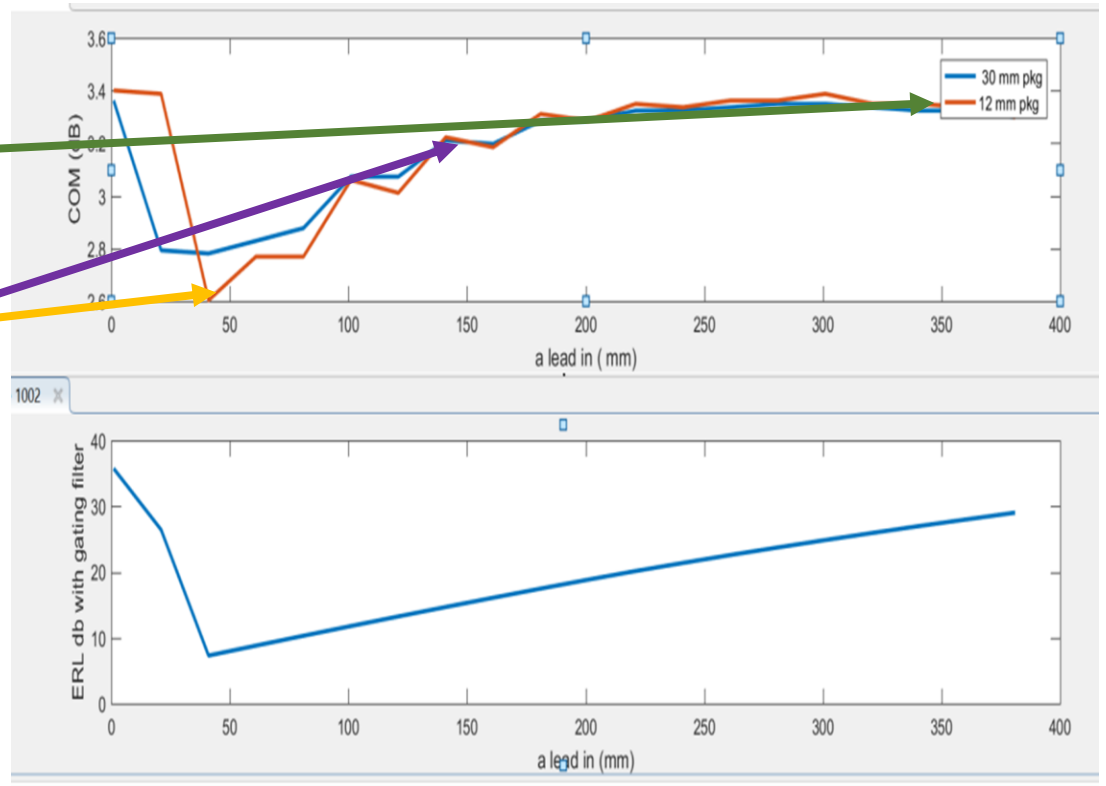
Ungated ERL does not track COM





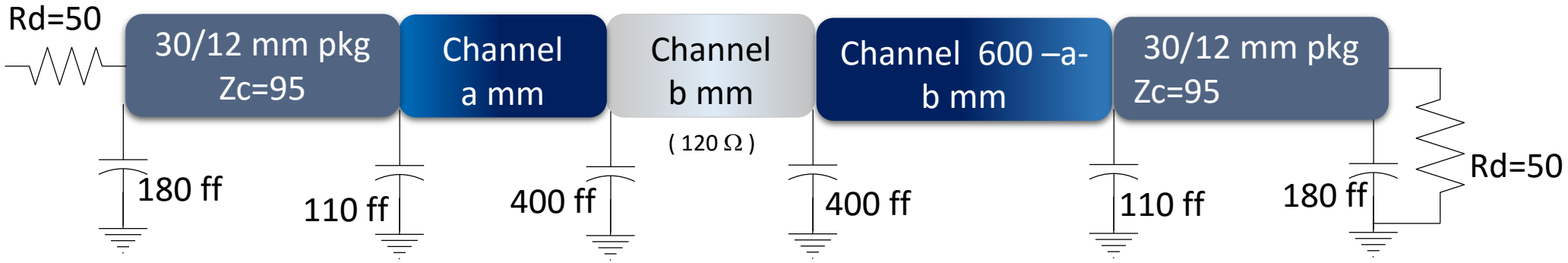
Return Loss does not track COM





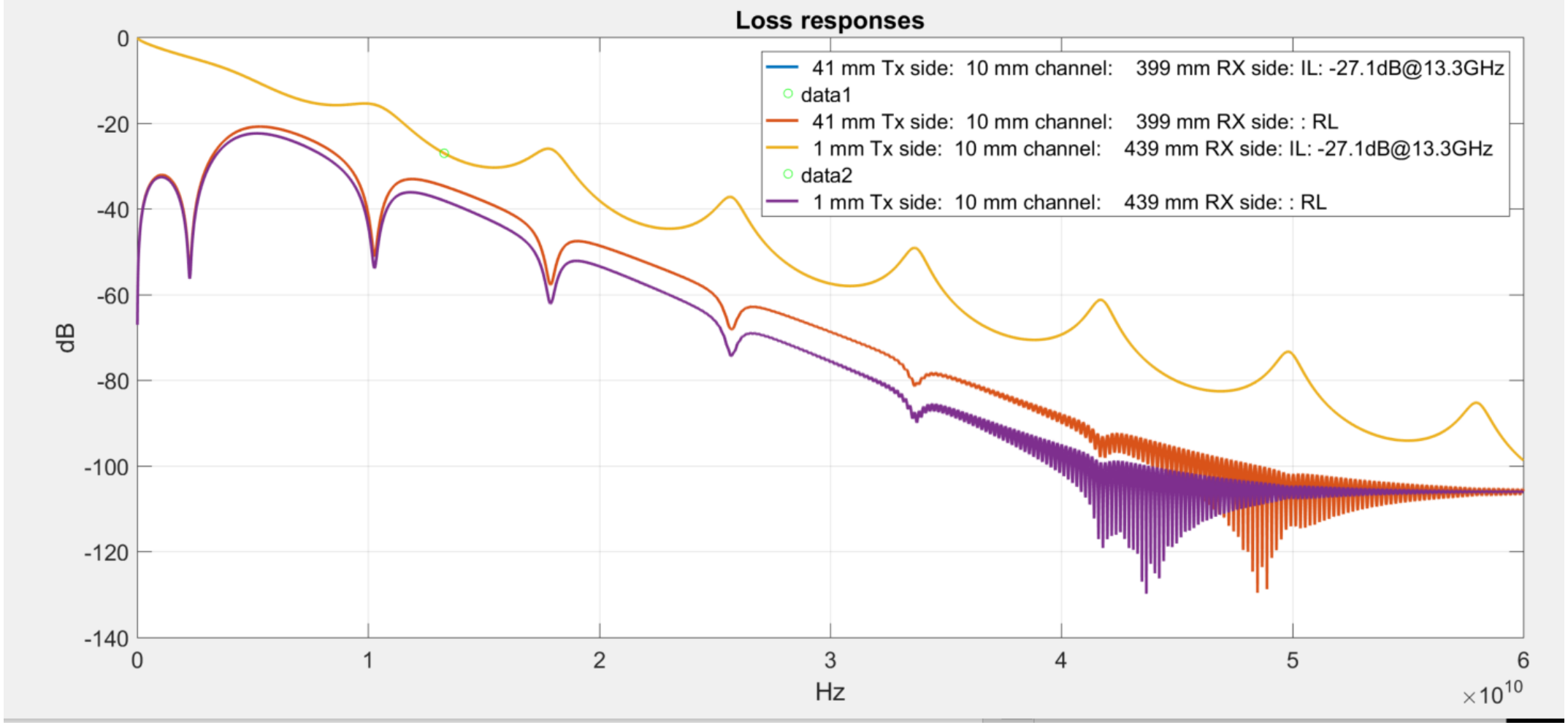
Does changing the amount of reflection alter the trends of the results?

- Change the capacitor to 400 ff from 200 ff
- Shorten the total length to 450 mm from 600 mm to keep around 3 dB of COM

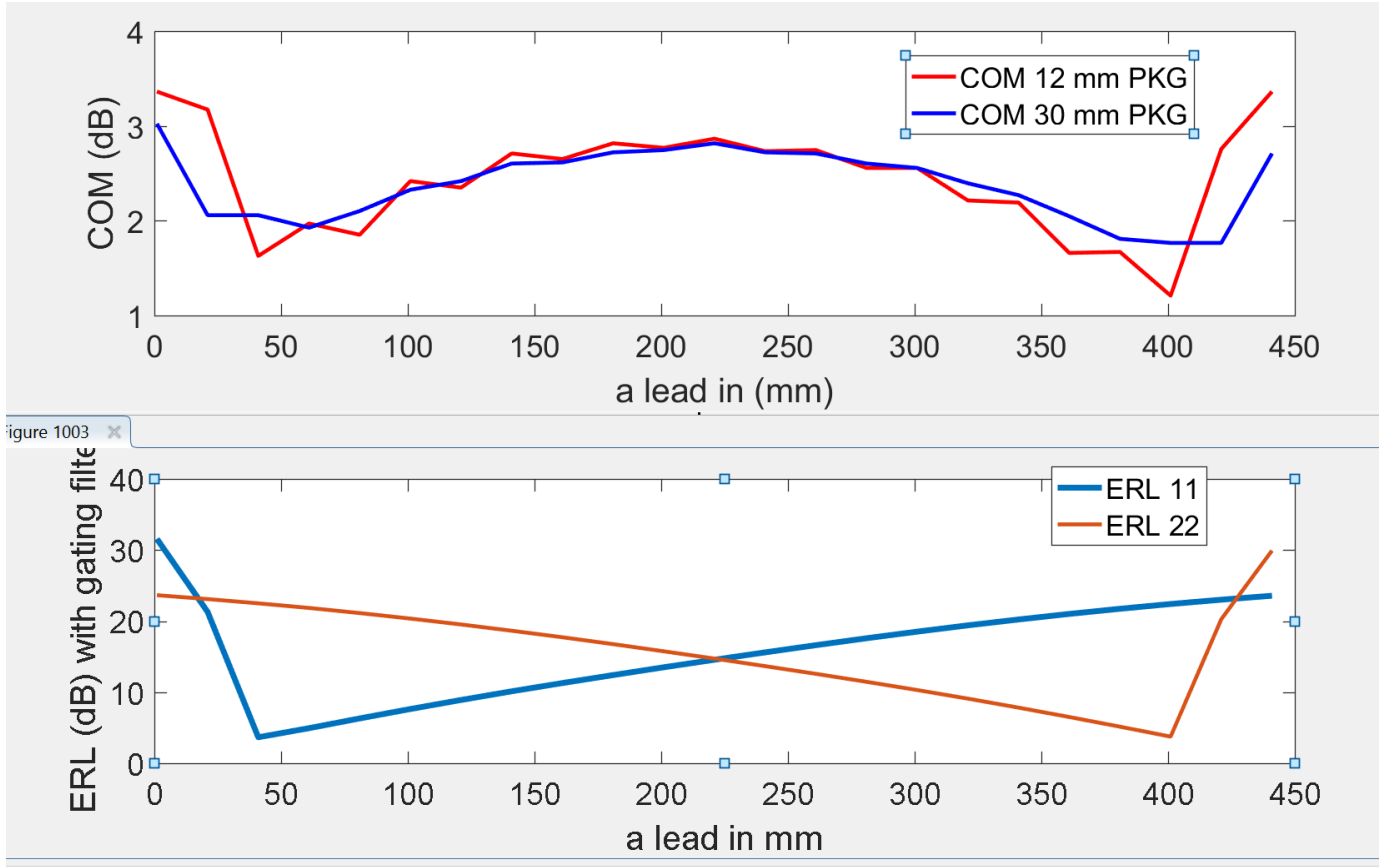


Ω	ff	Ω	mm	ff	mm	ff	mm	ff	mm	ff	mm	Ω	ff	Ω
30	180	95	12	110	a	400	b	400	450 -a-b	110	30	95	180	50

Short total length but still about 27 dB IL at 13.3 GHz



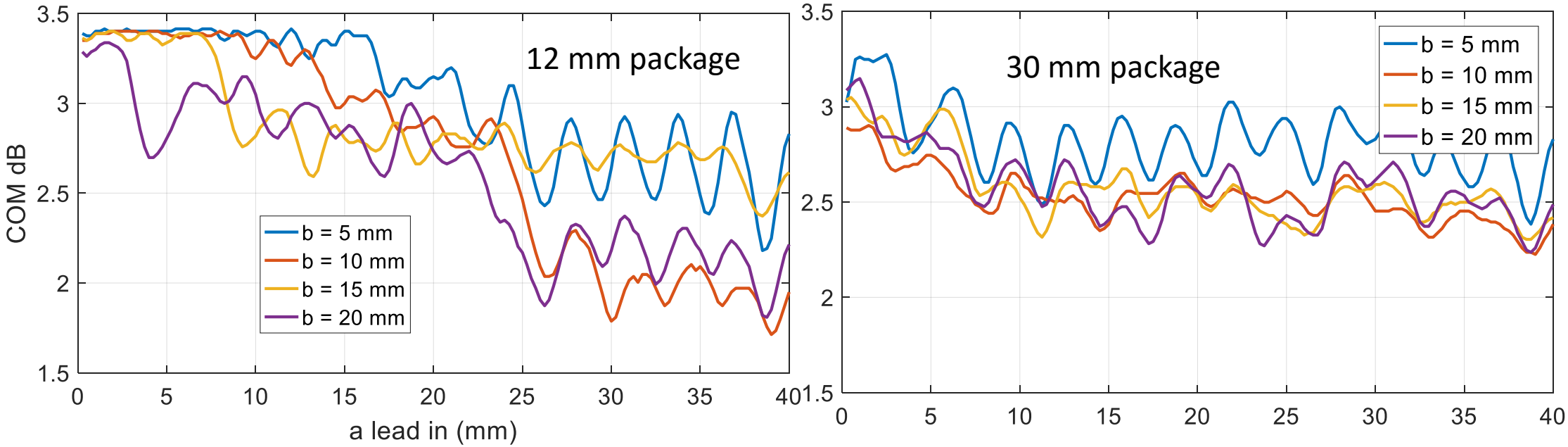
Similar trends regardless of reflection magnitude



Takeaway:

- Similar effects on either end of the channel
- A key factor is the distance a channel reflection is from either Tx or Rx package

Finer lead in step sizes show DFE effects



- COM packages seem somewhat interactive lead in (a) distance
- DFE effect can clearly be seen as COM is constant for b=5,10, and 15 for progressively shorter lead in values of a for the 12 mm package
- This suggest there are two components of package return loss:
  - Loss
  - Reflections