# Measurement of Tx specs and alignment with COM

Adee Ran, Intel

Oran Gafni, Intel

# Background

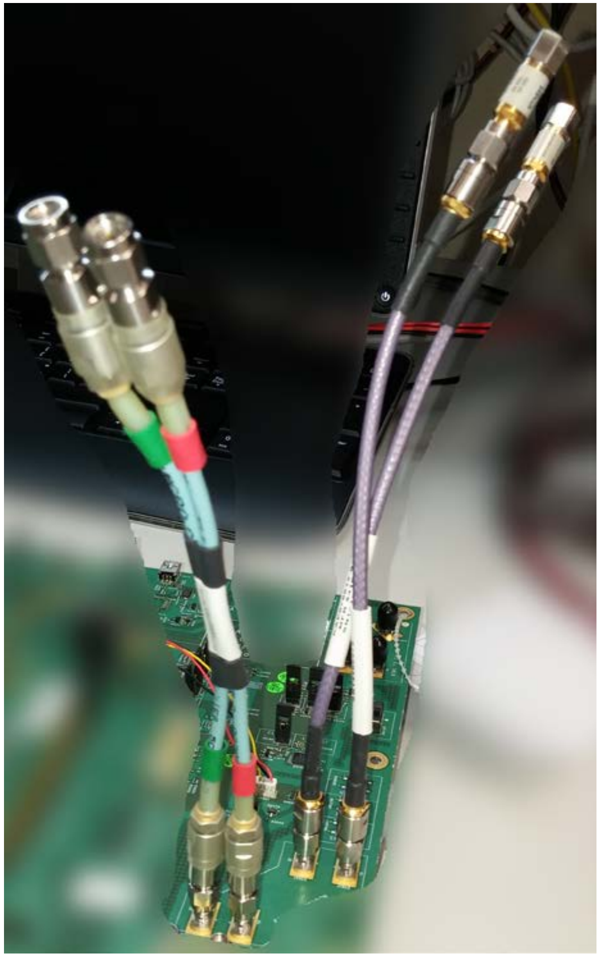
- As shown in the January interim meeting (dudek_3by_01_0116) there is a misalignment between Tx specifications and COM parameters…
  - "linear fit pulse peak" $P_{max}$ to $v_f$ ratio: 0.71 for KR
  - Simulation with COM Package model and TP0-TP0a trace suggests ratio of a fast transmitter is ~0.81
- So Tx specs allow for slower transmitter than COM assumes; budget is in deficit

# What should we do?

- Can the Tx specs be made tighter?
  - We contend that there's little or no margin in practical transmitters
    - Based on lab measurements and simulations
- Increase transition time in COM?
  - Would impact cables and possibly receivers
- There may be other ways to change specs
  - Exploit hidden margins…
- Or we can leave things as they are

# What do we get in practice?

- We measured the Tx specified parameters (at TP0a) with instrument-grade pattern generator
  - First with a direct low-loss connection to a scope
  - Then with a TP0-TP0a fixture inserted

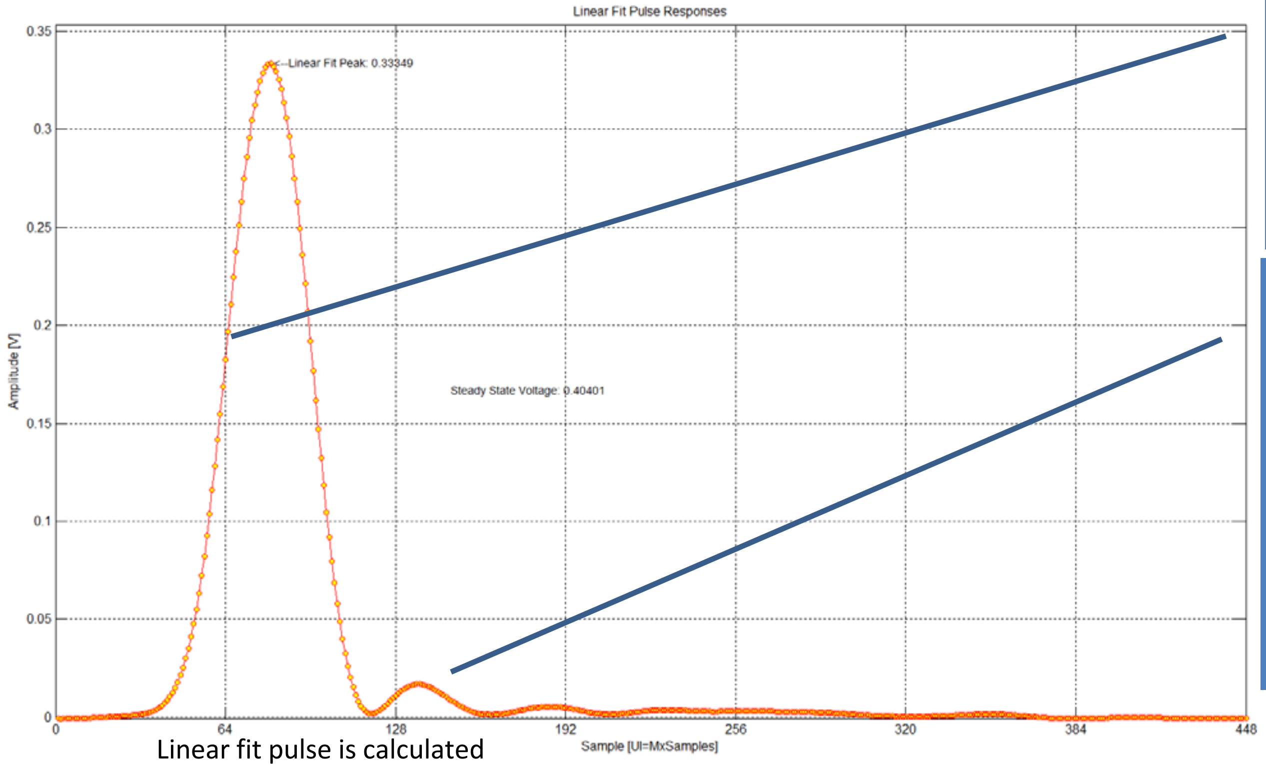


# Lab measurements

- PG set to 800 mV PtP
- Connected to scope using a high quality cable – <u>without TP0-TP0a trace</u>

- Results: $P_{max}/V_f$=0.81; SNDR=35.1 dB

We estimate that de-embedding the cables would make $P_{max}/V_f$=0.82




Linear fit pulse is calculated with oversampling M=32

Transition time was not measured, but it is obviously significant; estimated ~20 ps;

Mostly due to the PG

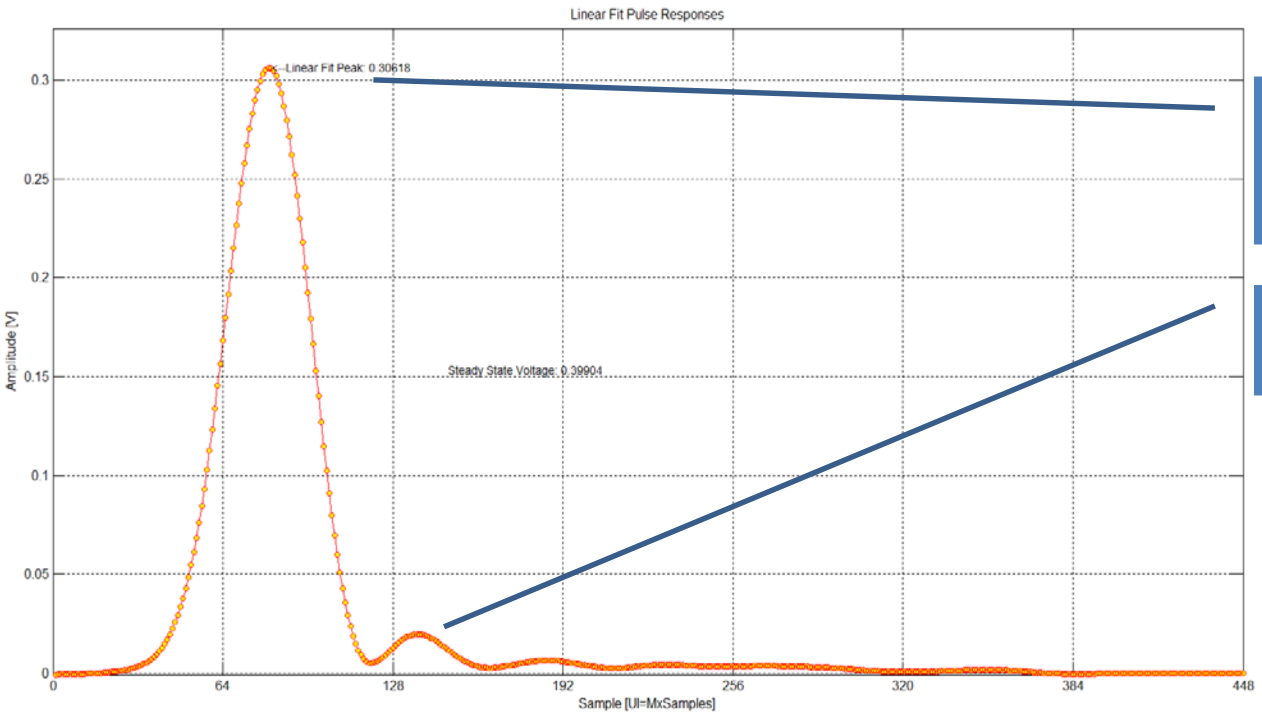
A close reflection (a few mm) is noticeable

Its energy goes off the pulse peak

High SNDR suggests this reflection and the transition time are the main causes for the reduced peak (very little energy after 12 UI)

# Lab measurements

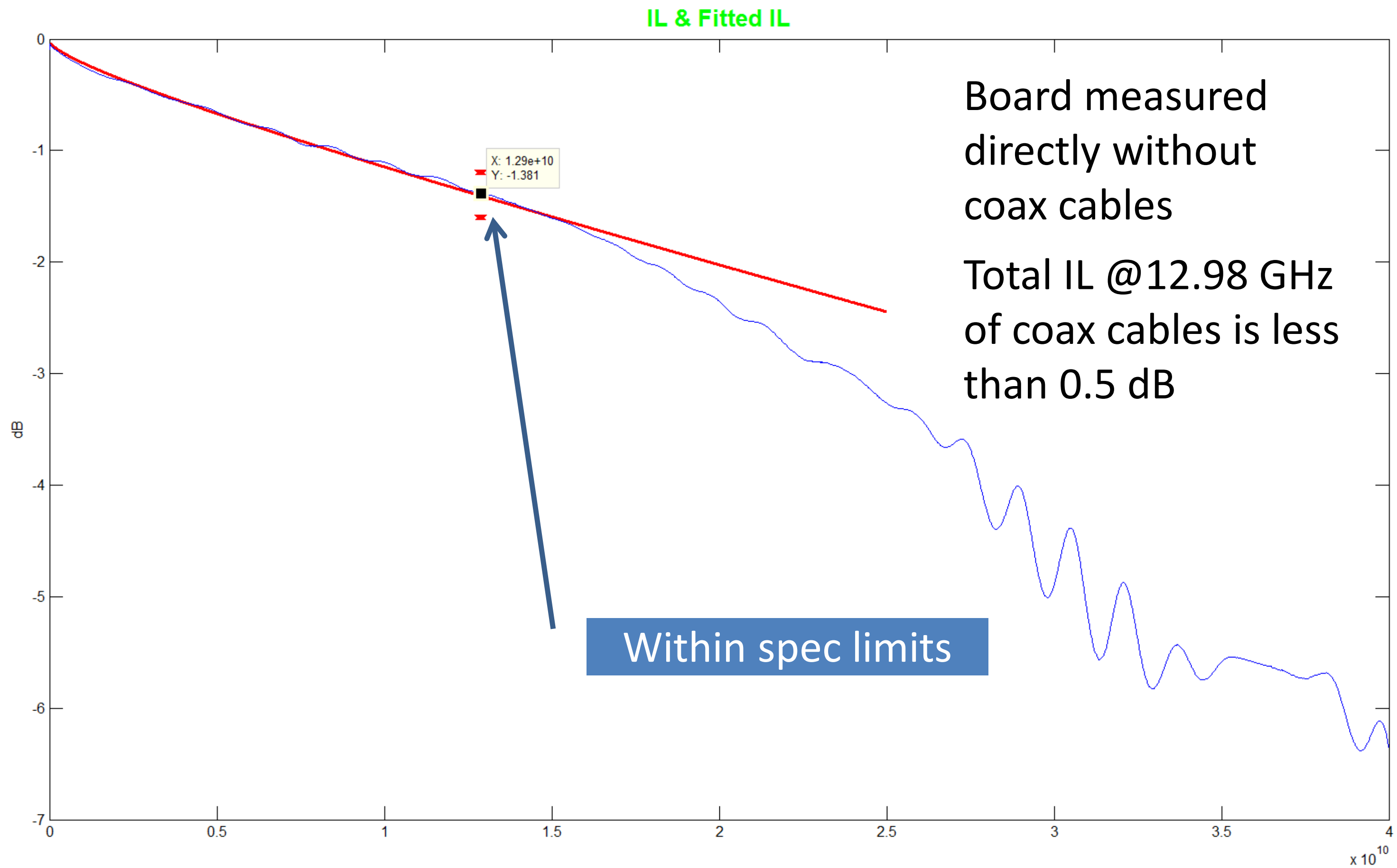
- Repeated measurement with TP0-TP0a trace between pattern generator and scope
- Now $P_{max}/V_f$=0.77
  - Compare to 0.806 under similar conditions in [dudek_3by_01_0116]
- SNDR=34.5 dB



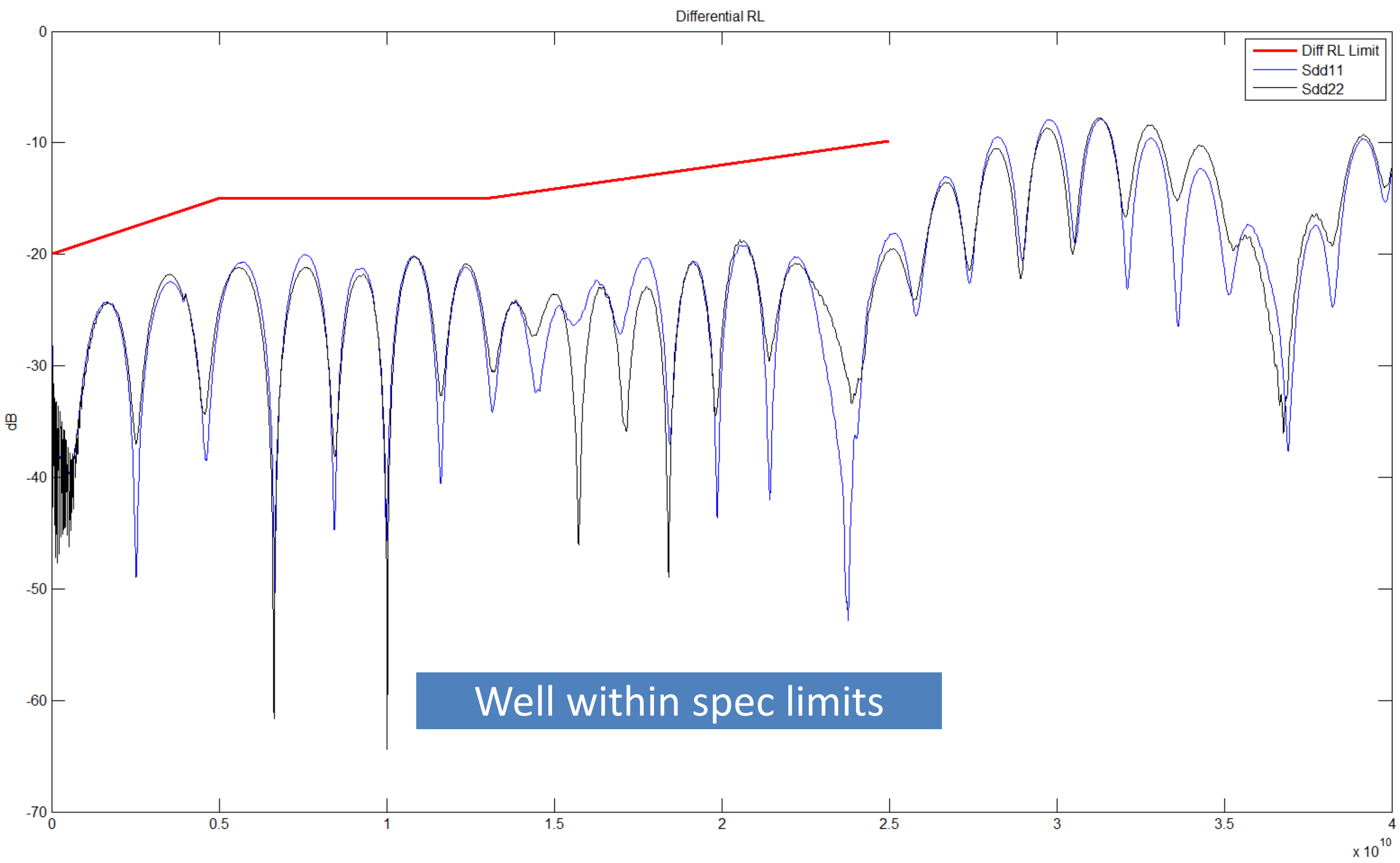

Pulse peak is reduced compared to the previous result

Reflection and ISI seem slightly higher

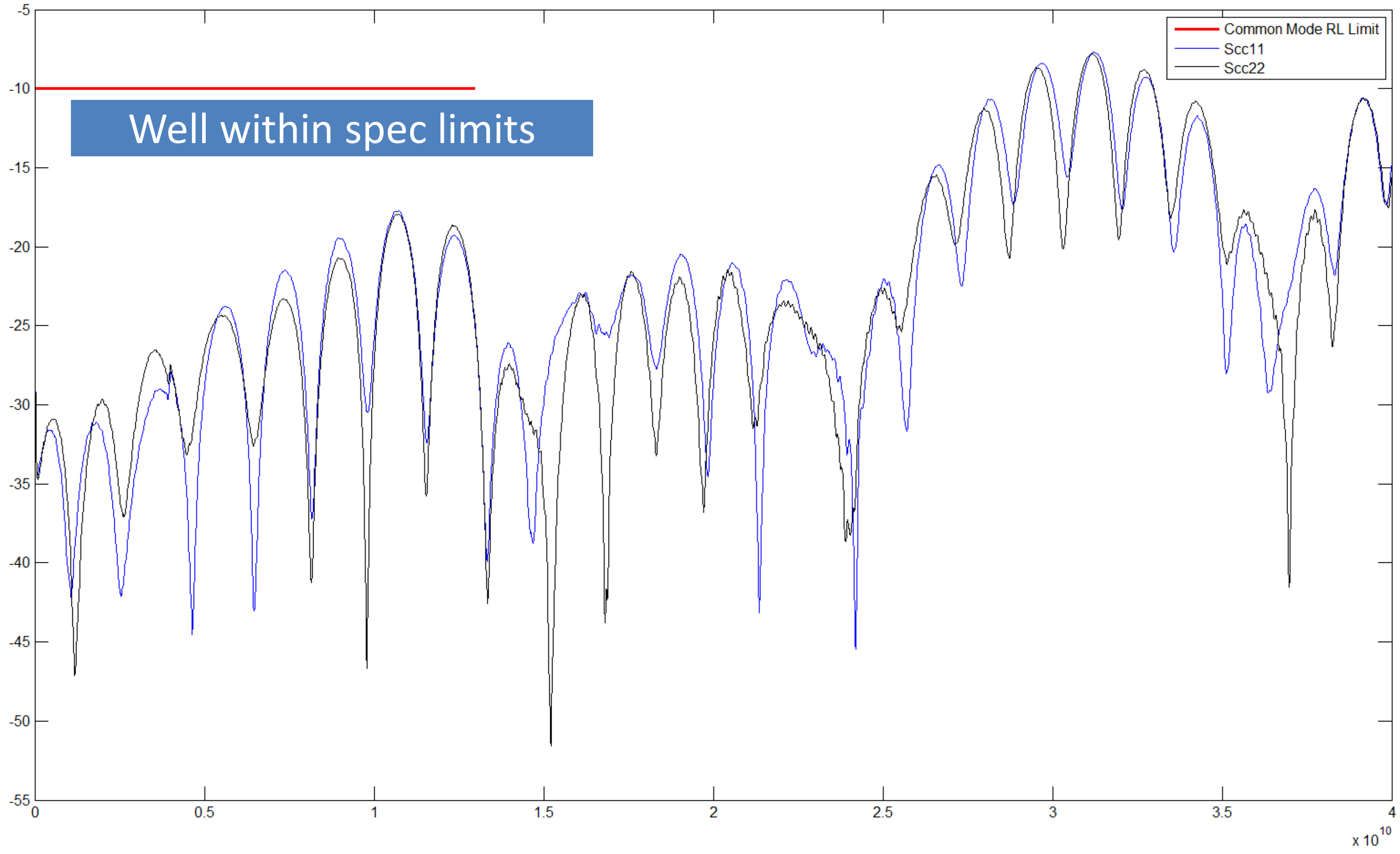
# TP0-TP0a trace measurements



# TP0-TP0a trace measurements



# TP0-TP0a trace measurements

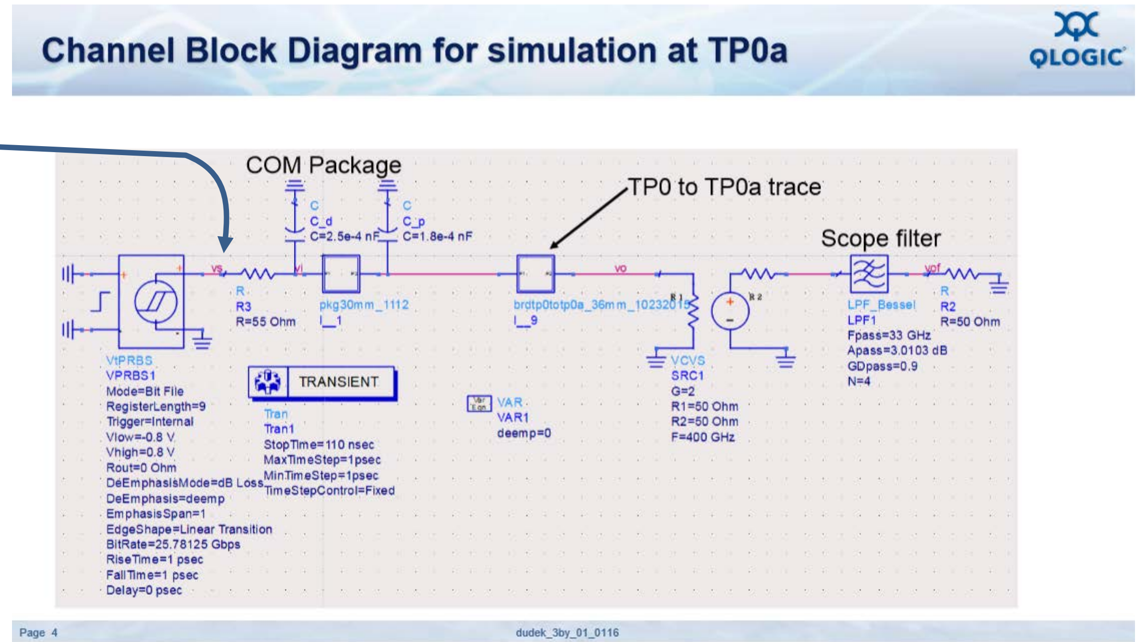


# Interim conclusion

- SNDR is much better than spec in both cases
  - Suggesting good setup
- An instrument-grade transmitter $P_{max}/V_f$ ratio (0.77) is significantly lower than “1 ps rise time” simulation results in dudek_3by_01_0116 (0.81)
- Slightly above the $P_{max}/V_f$ spec @TP0a (>0.71)
  - There is no “margin on the table” here

# Internal transition time

- Circuit simulations of a real Tx design
- $T_r$ at "VS" (without any load): 12 to 15 ps
- Can be attributed to
  - Internal clock transition times
  - Parasitic capacitance and resistance




Faster transmitters consume more power…
Designers try to minimize power

- This non-zero transition time is not taken into account in COM
- It could be addressed by adding a transition time filter or increasing $C_d$ value in COM calculation…
  - But that would degrade COM for channels we target

# Another look at SNDR

- $SNDR = 10\log_{10}\frac{p_{max}^2}{\sigma_e^2+\sigma_n^2}$ is a significant component of COM
- SNDR is specified "regardless of the transmit equalizer setting"
  - $\sigma_e$ and $\sigma_n$ are typically independent of equalization setting
  - $p_{max}^2$I s strongly dependent on equalization setting (and is measured separately for each setting)
  - Typically the worst SNDR is with the "strongest" equalization; other settings are better (up to ~4 dB difference!)
- COM for a specific channel might not need the strongest equalization
  - Especially with lower-than-maximum-length channels, e.g. those used without RS-FEC
  - So for these channels the effective SNDR is expected to be better than $SNR_{TX}$
    - We already took some advantage of that with the higher $SNR_{TX}$ used for CA-25G-N
- We can find some extra margin here…
  - In COM:
    - Include $T_r$ filter equivalent to 20 ps
    - Use higher value for $SNR_{TX}$ than SNDR spec in short channels, e.g. 29 dB
  - No change in Tx specs

# BACKUP

# Initial suspect: Reflections across the test setup

- The test setup includes connectors at TP0 and TP0a and low-loss cables. Additionally, pattern generator and scope are not ideal terminations (and this is not modeled).
- Any reflections in this setup
  - will always decrease the linear fit pulse peak
  - may also reduce $v_f$ to some extent, depending on cable length
  - will show up as ISI beyond the linear fit length.
  - $P_{max}/V_f$ and SNDR degradation are expected.
- In the actual link (TP0 to TP5)
  - there is no reflection at TP0a
  - the non-ideal terminations are modeled (COM package).
- Therefore some degradation of $P_{max}/V$ could be a measurement artifact.
- However, measurement results don't support this hypothesis…

# Can we discount some ISI after 12 UI?

- A significant part of the noise (SNDR denominator) is caused by the fitting error $\sigma_e$
- $\sigma_e$ includes all the ISI energy which is not within $N_p - D_p = 14 - 2$ =12 UI after the pulse peak
- Part of this ISI is handled by the reference receiver
  - 14 DFE taps – so at least the 14.5 UI after the peak are assumed to be zeroed
  - CTLE has effect even further, assuming ISI is smooth (dispersion)
- If we change the fitting, so that ISI after 12 UI would not be counted as noise – the denominator of SNDR would become lower – SNDR would improve…
- Increasing $N_p$ to from 14 to 16 is easily justified
- After 14 UI: we can fit to a longer pulse and rely on the CTLE to handle far ISI
  - What would guard against non-smooth pulse that the CTLE can't mitigate?
  - We could apply the reference CTLE in the Tx measurement
    - Complex change
    - conflicts with the CTLE's use for equalizing the channel
  - Or, we can assume that any ripple in the far ISI would also be seen as peaks in the return loss – and we have RL specs to protect us
    - Difficult to validate
- Note that a longer fit would
  - Improve SNDR (sometimes significantly)
  - Increase $V_f$ (to some extent) but without affecting the pulse peak ➔ decrease $P_{max}/V_f$ ratio
- With improved SNDR, some channels may be able to assume higher $C_d$ or slower Tx and still pass COM

# A possible solution

- Increase $N_p$ to 32 (practically catch all linear effects)
- Tighten Tx $v_f$ specs: from 0.34 to 0.36 in clause 110, and from 0.4 to 0.42 in clause 111
- Relax Tx $P_{max}/V_f$ specs: from 0.45 to 0.42 in clause 110, and from 0.71 to 0.67 in clause 111
- Change COM parameters:
  - $A_v$ – from 0.4 to 0.42 (increases COM)
  - SNDR from 27 to 30 dB (increases COM)
  - $C_d$ from 2.5e-4 to 3.5e-4 nF (decreases COM)
- Expected end result: no significant change to current COM results
  - So we can consider not doing anything

Red: TBD