Addressing J3u measurement issues
(comments i-156 and i-171)

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Background

- J3u measurement seems to be susceptible to oscilloscope noise, as demonstrated in rysin_3ck_01b_0122.
- The following directions have been discussed:
  - Relax the specification (e.g., per the suggested remedy of comments i-156 and i-171: “Change J3u max from 0.115 UI to 0.125 UI”)
  - Measure only on transitions between levels 0 and 3 (proposed in the presentation)
  - specify (in a non-prescriptive way) that measurement noise effects should be factored out
  - … and combinations of the above
- Although there was consensus that the issue should be addressed, discussion and straw polls during the February 16 2022 meeting did not show a clear path for decision.
- This presentation attempts to summarize the discussion and provide three options for resolution, with detailed changes.

Relaxing the spec?

- rysin_3ck_01b_0122 showed results measured at TP2 “for a combination of COM package with recommended TP0-TP2 PCB loss” with IL of 14.8 dB.
- Measurements at TP2 are more sensitive to noise than at Tp0v (slope degradation is more severe).
  - Note that the J3u spec at TP2 (115 mUI) is relaxed compared to TP0v (106 mUI), to account for the higher loss
    - The numbers above are the same as in C136 and C137 respectively
    - But the slope degradation in C162 is expected to be more severe than in C136; compare to R_{peak} (min) which is 0.397 in C162 vs. 0.49 in C136!
  - It makes sense to relax the TP2 J3u spec further in C162, compared to 163/120F.
    - There are three separate tables, so change only one (Table 162–10).
    - Suggested remedy provides the value 0.125 UI.

Option A1: Relax max J3u at TP2

- Change the value of J3u (max) in Table 162–10 from 0.115 UI to 0.125 UI.

Output jitter (max)			
JRMS	162.9.3.4	0.023	UI
J3u	162.9.3.4	~~0.115~~0.125	UI
Even-odd jitter, pk-pk	162.9.3.4	0.025	UI

Measure only on 0/3 transitions?

- rysin_3ck_01b_0122 showed lower J3u on the large transitions, and provided a reasonable explanation
  - Smaller transitions have lower slopes ⇒ noise to timing error conversion is larger
  - Noise can be introduced by either the scope (measurement inaccuracy) or the DUT (e.g., crosstalk, which would be falsely attributed to jitter)
- In jitter measurement, we are interested in the timing error of the clock driving the signal, not in the transition times per se.
  - In any reasonable design, all transitions are driven by the same clock (possibly with small differences due to clock distribution network)
  - Taking the $5 \cdot 10^{-4}$ quantile of the joint distribution for J3u (or $5 \cdot 10^{-5}$ for J4u) makes the worst-case transition dominate the result
- However, the effect of timing error on voltage noise is smaller for the smaller transitions (see backup slides for details)
  - Thus, the receiver's SNR and performance is dominated by jitter from the large transitions!
- We can have a spec for a modified J3u with only the large transitions, and a more relaxed spec for J3u with all transitions.
  - This makes sense for all interfaces.

Option A2: Specify 0/3 transitions separately

- Change the second paragraph of 162.9.3.4 as follows:

  J3u and J_{RMS} are calculated using the measurement method specified in 120D.3.1.8.1. J3u is defined as the time interval that includes all but 10^{-3} of $f_J(t)$, from the 0.05th to the 99.95th percentile of $f_J(t)$. $J3u_{03}$ is defined as the time interval that includes all but 10^{-3} of $f_{J03}(t)$, from the 0.05th to the 99.95th percentile of $f_{J03}(t)$, where $f_{J03}(t)$ is the estimated probability distribution created from the sets $S0_1$ and $S0_2$, that is, the R03 and F30 transitions.

- Change the last row of Table 162–10 as shown on the right.
- Apply a similar change in Table 163–5, keeping the existing value 0.106 UI for $J3u_{03}$, and 0.115 UI (~9% higher) for J3u.
- Implement similar changes in Annex 120F for J4u/$J4u_{03}$, with values 0.128 UI and 0.118 UI respectively.
- Implement with editorial license.

last row of Table 162–10

Output jitter (max)			
JRMS	162.9.3.4	0.023	UI
$J3u_{03}$	162.9.3.4	0.115	UI
J3u	162.9.3.4	0.125	UI
Even-odd jitter, pk-pk	162.9.3.4	0.025	UI

Measurement noise effects should be factored out?

Straw poll #19:
I support specifying for CR and KR J3u that measurement noise effects should be factored out
(non-prescriptive)
● A: Yes
● B: No
Results: A: 28, B: 2
(See comment i-156)
While taking this straw poll it was noted that it is for CR/KR j3u measurement only, but would not preclude expanding this action to other clauses, should there be consensus to do so.

- Straw poll #19 taken during the February 16th session was quite decisive.
- The discussion suggested that phrasing is important
  - Should be non-prescriptive
  - … and not rule out similar adjustment in other measurements
  - … and not allow high measurement noise to mask bad results.
- It is proposed to use the phrase “proper accounting for measurement noise effects”.
  - Or alternatively, “appropriate”

Option B: Recommend accounting for noise

- In 162.9.3.4, change “Note” to “Note 1”, and add Note 2 as follows:

  NOTE 2—J3u may be sensitive to measurement noise being converted to timing errors. Hence, proper/appropriate accounting for measurement noise effects is recommended.

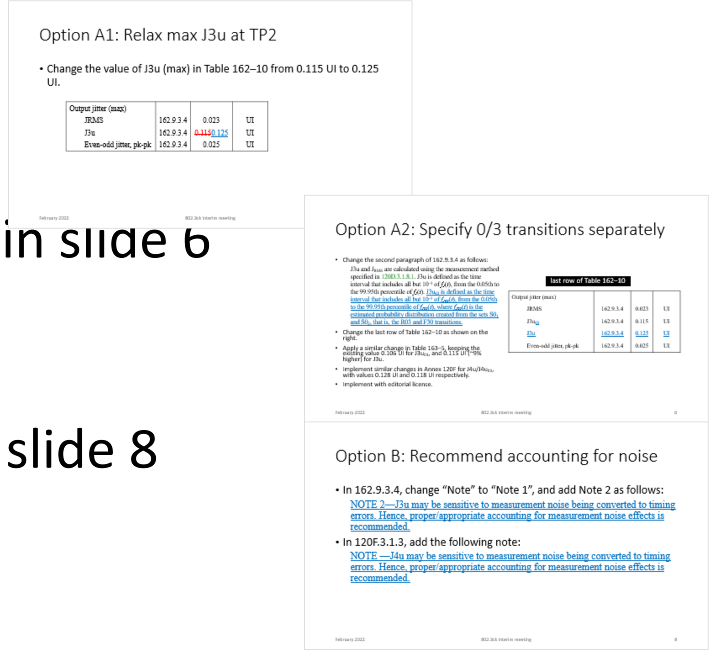
- In 120F.3.1.3, add the following note:

  NOTE —J4u may be sensitive to measurement noise being converted to timing errors. Hence, proper/appropriate accounting for measurement noise effects is recommended.

Summary

- Option A1
  - Relax the spec for J3u at TP2 – as in slide 4
- Option A2
  - Keep J3u as is, and specify $J3u_{03}$ in addition – as in slide 6
  - This encompasses option A
- Option B
  - Recommend accounting for noise effects – as in slide 8

- Questions:
  - A1 or A2 or no change?
  - B or not B?
- Recommended: A2 and B



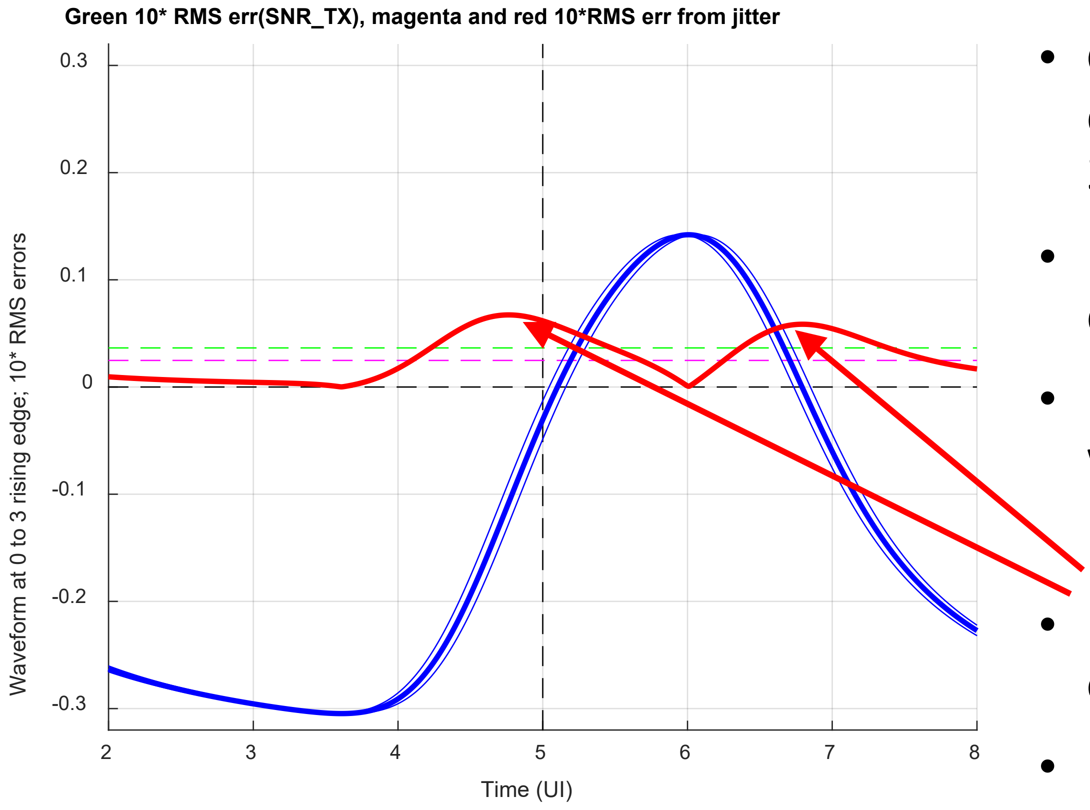
Backup

Correlation between uncorrelated jitter measurement and COM noise model

PM-AM conversion Simulation of PRBS13Q

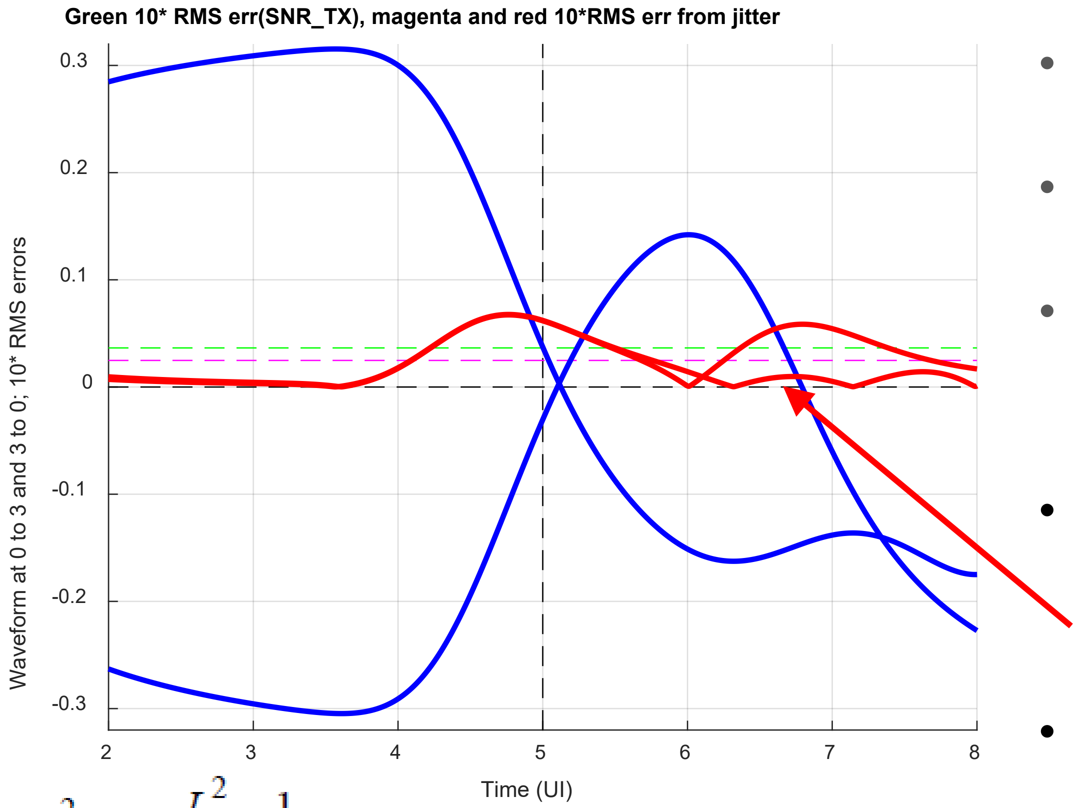
- Signal at TP2 with σ_{RJ} = 0.01 UI, A_{DD} =0.02 UI
- 7.5 ps Gaussian Tx, reference mated test fixtures, lossy transmission line and BT4 observation filter bring Rpeak to 0.397

Example: 0 to 3 edge of the set of 12



- Blue: waveform
- Green: RMS noise and distortion allowed by SNR_{TX} of 32.5 dB
- Red: apparent noise or distortion caused by jitter
- Magenta; same, RMS over the whole PRBS13Q pattern
- Red line has maxima at times of 0 to 3 and 3 to 0 transitions
- Receiver can sample ~1/2 UI away from the maxima or crossing times

Example: 0 to 3 and 3 to 0 edges of the set of 12



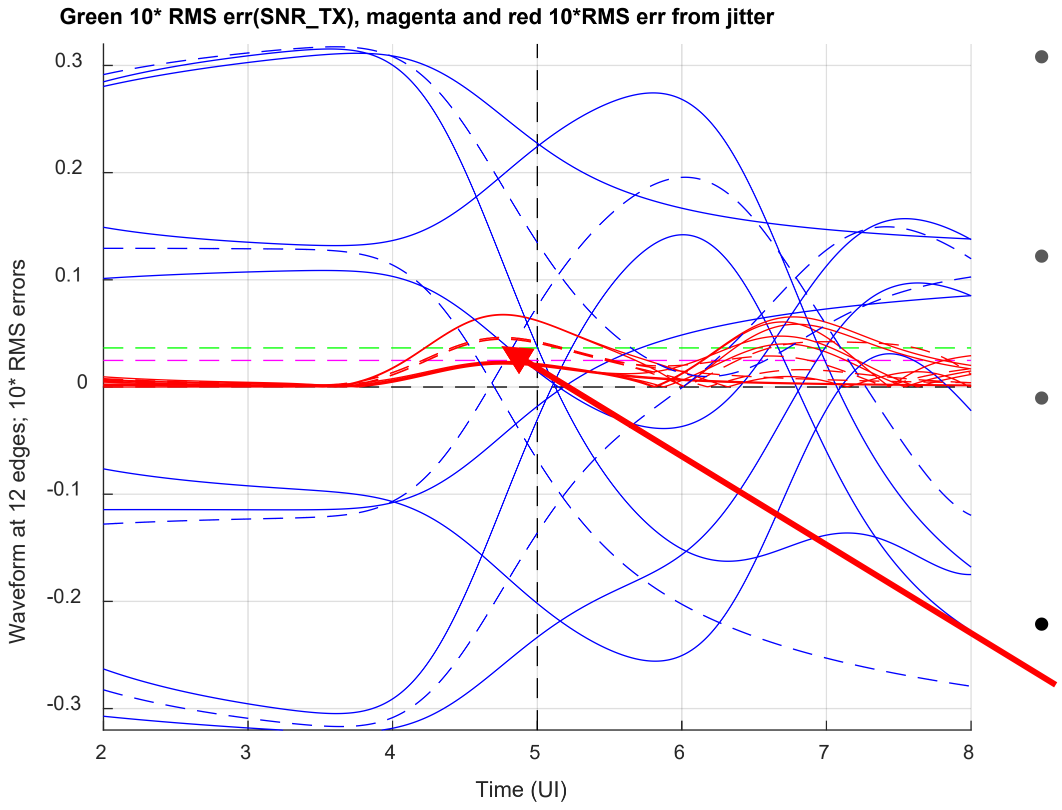
$$\sigma_X^2 = \frac{L^2 - 1}{3(L-1)^2} \qquad (93A\text{–}29)$$

$$p_n(y) = \frac{1}{L}\sum_{l=0}^{L-1} \delta\left(y - \left(\frac{2l}{L-1} - 1\right)h(n)\right) \qquad (93A\text{–}39)$$

- Blue: waveform
- Green: RMS noise and distortion allowed by SNR_{TX} of 32.5 dB
- Red: apparent noise or distortion caused by jitter
- Magenta; same, RMS over the whole PRBS13Q pattern

- The falling 3 to 0 transition is followed by a 0 to 1 transition which causes little vertical impairment
- COM knows that some transitions are less important than others; it calculates PM to AM conversion with factors for PAM4 as on the left

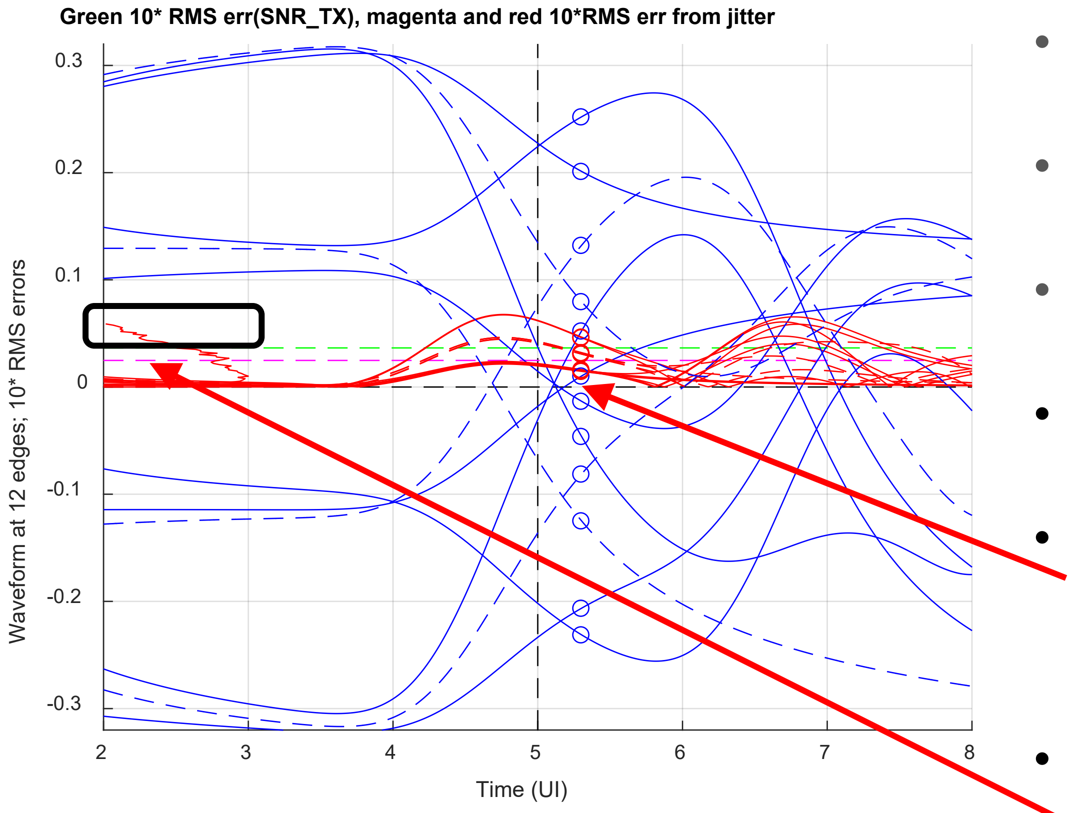
All 12 edges



- Blue: waveform
- Green: RMS noise and distortion allowed by SNR_{TX} of 32.5 dB
- Red: apparent noise or distortion caused by jitter
- Magenta; same, RMS over the whole PRBS13Q pattern

- Vertical impairment of 1-high and 2-high (dashed) edges is 2/3 and 1/3 of 3-high edges

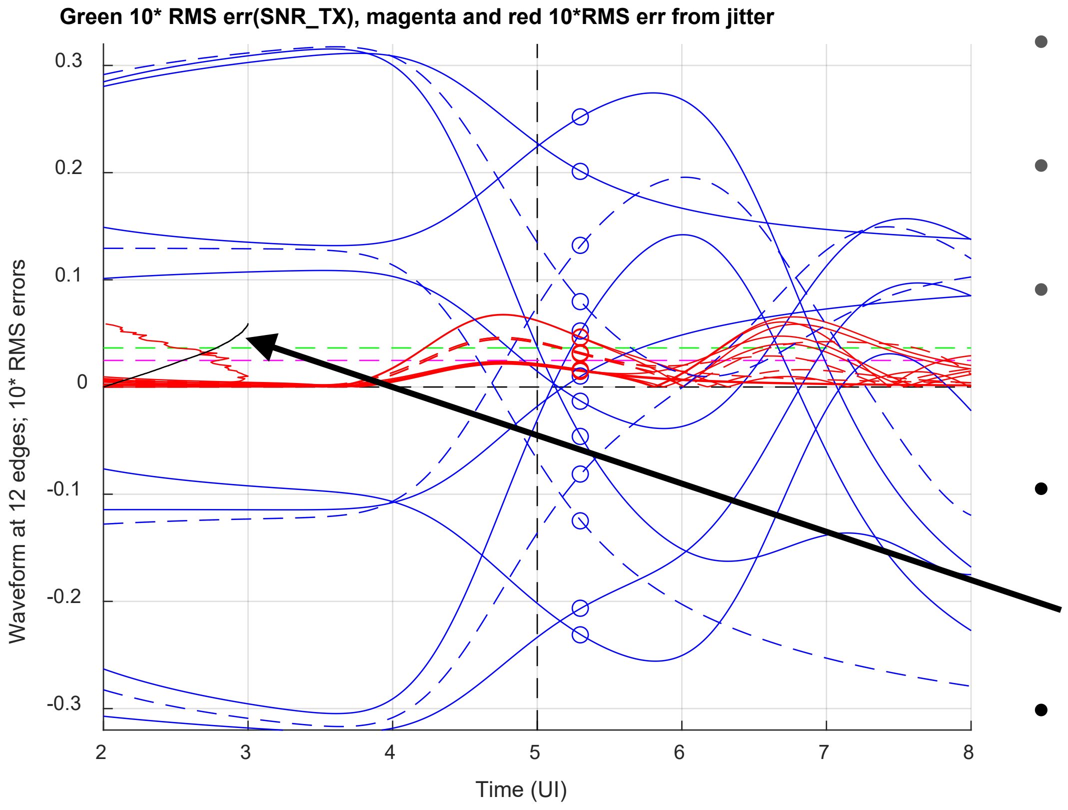
All 12 edges with example sampling and histogram of whole pattern



Top 1/6 of edges in the black box

- Blue: waveform
- Green: RMS noise and distortion allowed by SNR_{TX} of 32.5 dB
- Red: apparent noise or distortion caused by jitter
- Magenta; same, RMS over the whole PRBS13Q pattern
- Sampling time can be away from the red peak
- The equalization in a real link will reduce the peak but the 3-high edges still dominate the distribution
- Histogram of RMS errors at this example sampling time, for the whole PRBS13Q pattern, is shown on left

All PRBS13Q
The 3-high edges dominate



- Blue: waveform
- Green: RMS noise and distortion allowed by SNR_{TX} of 32.5 dB
- Red: apparent noise or distortion caused by jitter
- Magenta; same, RMS over the whole PRBS13Q pattern

- Black curve shows the RMS error from an increasing portion of the edges starting with the shallowest
- Curving upwards: even though they occur on average only once in six edges, the 3-high edges dominate the RMS error

Summary

- Timing errors ("true" jitter) cause voltage deviations that can be investigated by the SNDR method
- The biggest edges with the highest slew rate create the biggest error
  - This is known, and included in COM
- Even though they are the least numerous type, the 3-high edges dominate the RMS error over the whole pattern
  - If the other edges are somewhat more or less jittered, it won't affect link performance significantly
  - But the measurement error is much larger on the smaller edges
- Our measurement method should align to the effect on the link
  - Focus on edges from 0 to 3 and 3 to 0