Issues with SNDR specification in clauses 92 and 93

Adee Ran, Intel

Background

- We recently adopted two package models, and BUJ and SNDR specifications, for clauses 92 & 93.
- These changes also affect channel specs (COM) and Receiver Interference Tolerance Test (RITT).
- Some people questioned whether these spec are compatible with each other, and whether we are double counting noise contributions?

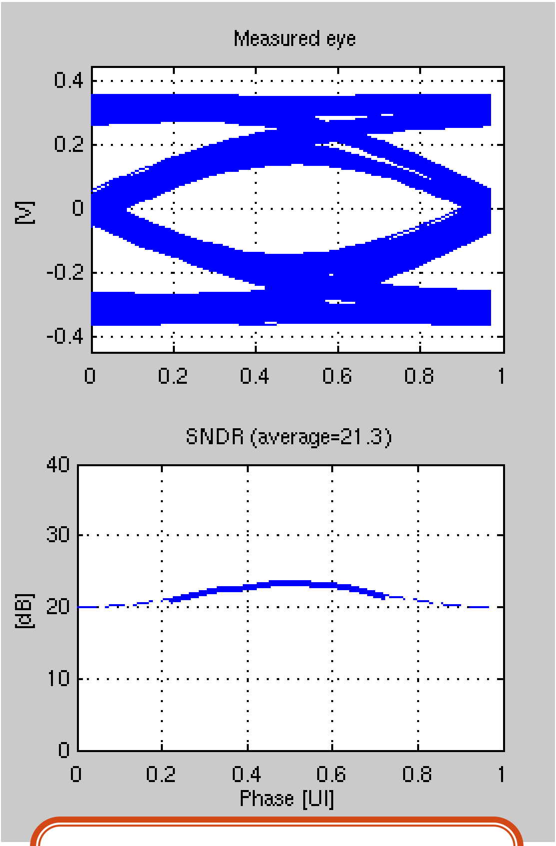
Abstract

- I will show below that
  - SNDR>29 dB can't be met with 30 mm package unless fitted pulse is longer than D2.2 specifications.
  - The combination of package ISI and maximum allowed jitter prevents meeting SNDR specifications.
  - Current fitting method is not good for limiting ISI beyond assumed receiver reach.
- Implications:
  - Additive noise in the TX per the COM parameter σ_{TX} can be hidden by jitter and unmeasurable.
  - To limit TX noise we must measure it without jitter effect.
  - To limit ISI we must measure it without jitter and noise effects.
- Possible remedies and proposals.

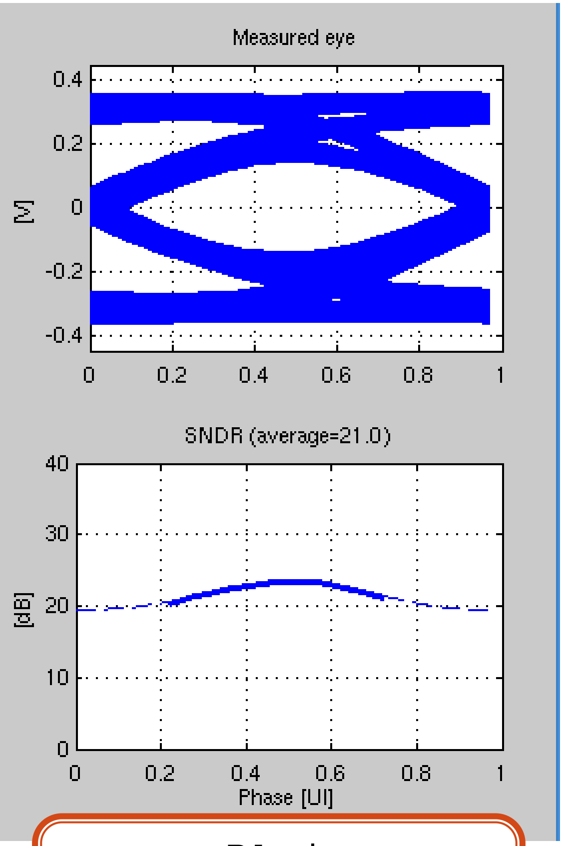
Simulation performed

- NRZ transmission at 25.78 GBaud
- TX: 12 mm and 30 mm Package models
- Board: 1.5 dB from TP0 to TP0a
- RX: ideal termination, reference RX filter
- Pattern: PRBS9
- Jitter test cases: None, max RJ only, and max BUJ only (as SJ)
- SNDR calculated per D2.2 specification

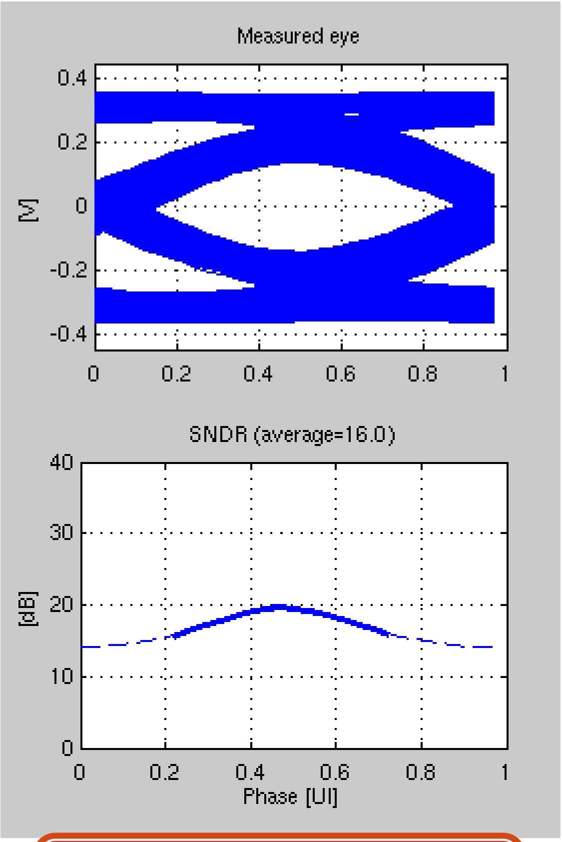
30 mm package results



No jitter
With N_p=8: SNDR=21 dB
With large N_p: >40 dB

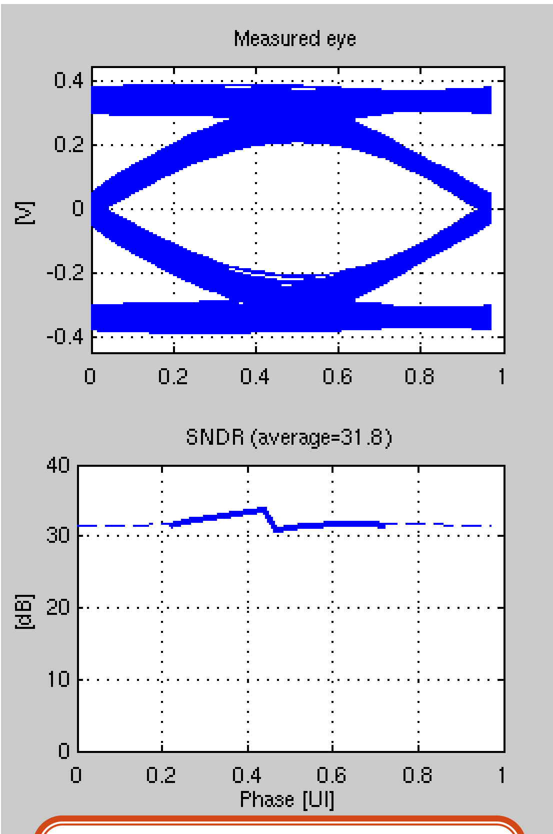


RJ only
With N_p=8: SNDR=20 dB
With large N_p: 28 dB

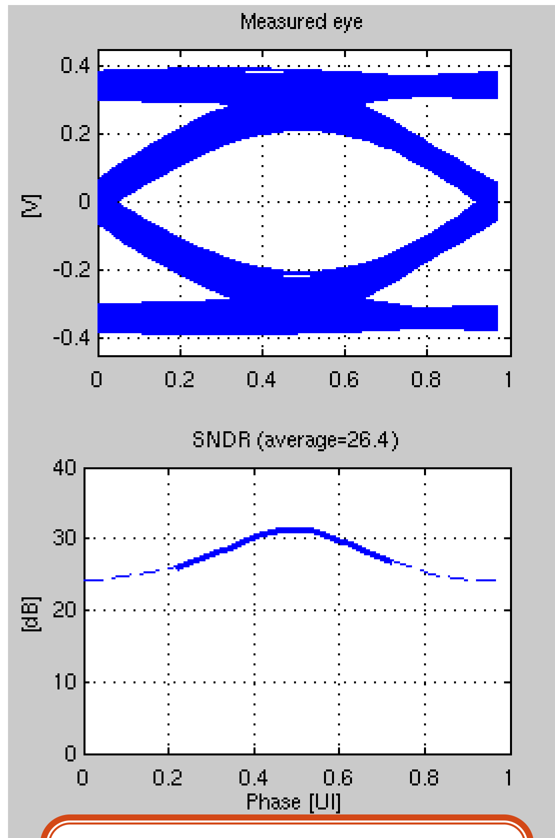


SJ only
SNDR=15.7 dB

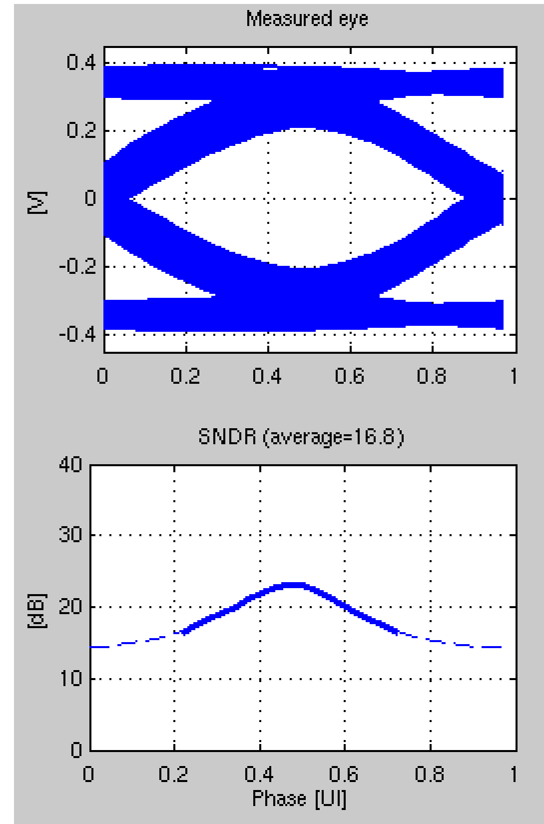
12 mm package results



No jitter
With N_p=8: SNDR=31 dB
With large N_p: >40 dB



RJ only
With N_p=8: SNDR=27 dB
With large N_p: ~29 dB



SJ only
SNDR=16.3 dB

Problem statement

- Linear fitting is used for calculation of both “normalized fitting error” (averaged across measurement) and SNDR (max RMS around middle of eye)
- SNDR specification for clauses 92 and 93 is >29 dB; normalized fitting error spec was <0.037, equivalent to >28.6 dB
  - Neither of these can be met with a 30 mm reference package and/or allowed jitter levels.
  - Increasing fitted pulse length could help meet SNDR, but the noise we want to measure may still be “drowned” by jitter effects.
  - “Averaging multiple waveform captures” could possibly mitigate some of the jitter effects, but would hide the noise that we want to measure.
  - Limit was based on simulation with jitter; this was double counting jitter effect and not counting noise.
- SNDR as currently defined is not a valuable TX parameter!

Possible remedies

- **Do nothing**
  - Passing SNDR may be very challenging for TX design (e.g. very low jitter); this actually leaves margin we could use in channel and RX specs
  - May lead to ignoring SNDR specification and hiding real problems.
- **Relax the SNDR spec, to allow passing even with package and jitter**
  - But what TX noise do we use in COM and RITT calibration? we already have package ISI and jitter budgeted, and should not double count them as additive noise
  - May also enable very noisy transmitters to be compliant (and not work)
  - What does a relaxed spec actually limit?
- **Proposal:**
  - Measure TX noise in a different way that excludes jitter and package ISI
  - Measure package ISI in a different way that isolates it from other effects

Spectrum and distribution of TX noise
(excluding jitter and ISI)

- **Suggest keeping the assumption that noise spectrum is similar to that of desired signal**
  - Holds e.g. for AM due to imperfect power integrity
  - Conservative for additive coupled noises
  - Results in similar attenuation for signal and noise
- **What distribution should we assume?**
  - With jitter excluded, noise is usually bounded; but passing through the channel can make it close to Gaussian (at probabilities down to 1e-6)
  - A Gaussian model will keep COM model stable
  - Suggest keeping a Gaussian distribution

How about clause 94?

- PAM4 is not as sensitive to package and jitter due to the larger UI (results are better and required SNDR is lower).
- But for consistency it is may be desirable to use a common method for all clauses.
- Next slide can be applied to either clauses 92 and 93, or to all three PMDs.

Proposal for modified SNDR measurement

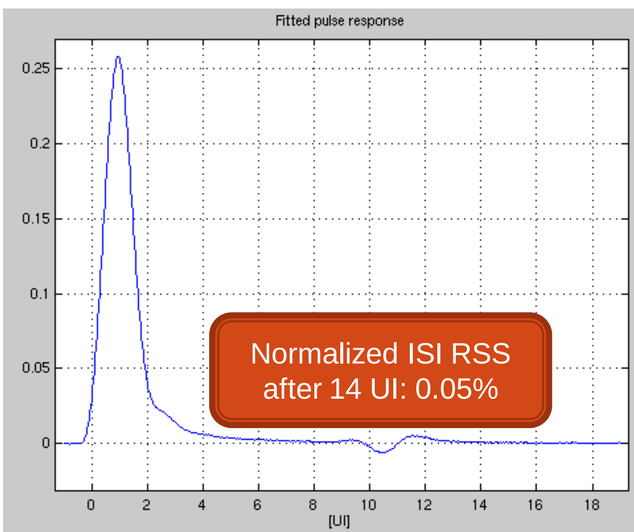
- **Transmit a low-frequency into an AC-coupled test instrument**
  - For clauses 92 & 93 use a square wave (e.g. PMA test pattern, 8 ones followed by 8 zeros)
  - For clause 94 use the transmitter linearity pattern
- **Collect statistics of the voltage in the flat regions**
  - N samples for each level N≥20,000; denote as $V_n^l, l \in \{0,1\}, n \in \{1 \ldots N\}$
  - If clause 94 uses this method, capture only on outer levels i.e. $l \in \{0,3\}$
  - Captures noise frequencies down to 1 MHz with good confidence level
- **Define $SNDR = S_{min}/\sigma_{TX}$; use existing limits**
  - Options for S_{min} for clauses 92 and 93 (for the task force to choose between)
    1. Use v_f as in D2.2 (taken from the linear fit procedure)
    2. Use the average measured amplitude $\frac{1}{2N}\sum_n \sum_l \left|V_n^l\right|$ – dependent on equalization setting
  - Options for σ_{TX} (for the task force to choose between)
    1. Define σ_{TX}^l as the standard deviation of V_n^l , and $\sigma_{TX} = \sqrt{\sum_l \left(\sigma_{TX}^l\right)^2}$
    2. Construct a Dual-Dirac model from V_n^l, extrapolate to DER_0, and define σ_{TX} as the Gaussian parameter that would yield the same DER_0 quantile (i.e. cross the bathtub curve at DER_0).

Limiting ISI in the TX signal

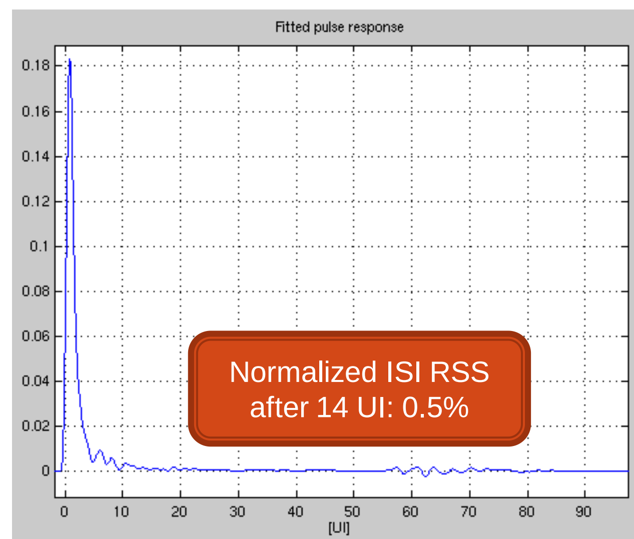
- One motivation for fitting error or SNDR is to limit ISI span; but fitting error due to ISI may be drowned by jitter effect.
- Linear fitting can still be utilized in a different manner:
  - Using a larger length will make the ISI appear of the fitted pulse
  - Specify that the RSS of samples starting N_b UI after the peak (where N_b is the COM DFE parameter), divided by M, is less than 1% of the pulse peak
    - Stricter than the current normalized fitting error 0.037
  - Receiver is supposed to handle ISI up to N_b UI after the peak.

Limiting ISI in the TX signal

- For cause 93 the reference 30 mm package plus test fixture create ISI within the DFE range. Suggest setting Np to at least 20 to verify no additional reflections.
- Clause 92 should use an even longer fitted pulse due to the larger delay:
  - For the 8.25” channel, capturing triple-transit reflections require at least N_p=70
  - Suggest Np at least 100 to capture possible additional reflections
- **Results of fitting are quite immune to jitter and noise; even with noise that creates SNDR<17 dB, the pulse generated is virtually the same**



KR4: 1.5 dB from TP0 to TP0a, N_p=20



CR4: 8.25” host board, N_p=100

Thank you