Discrepancies between SNDR/SNR_TX in Tx specification, Rx test calibration, and COM

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(supplement to comment I-53)

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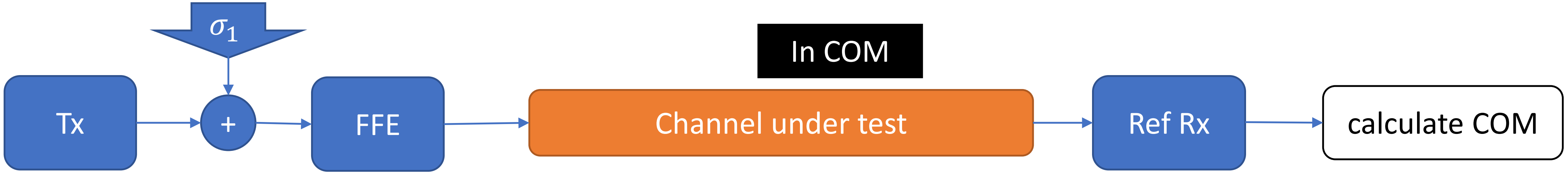
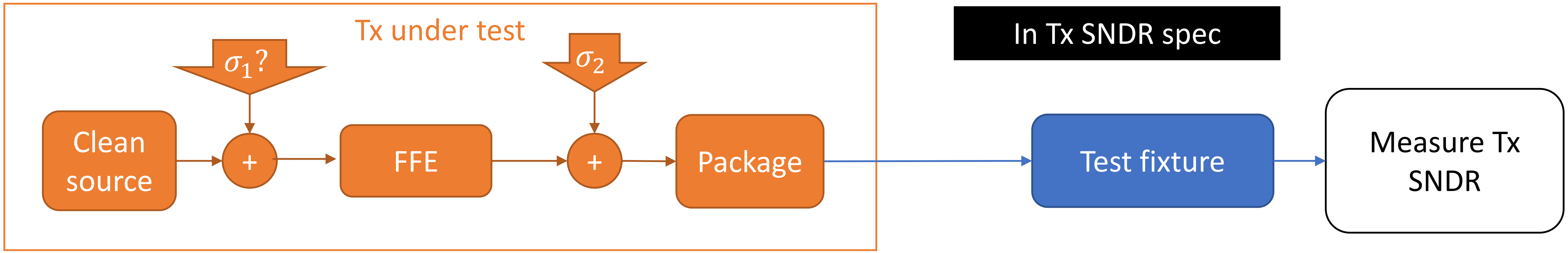
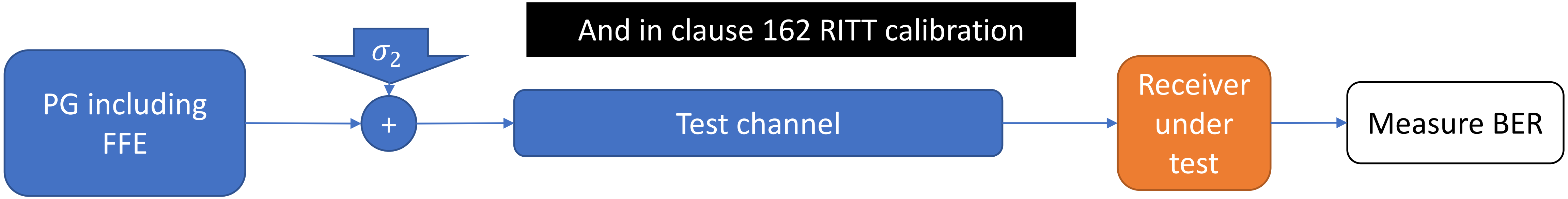
We have different Tx noise models…







A simple question started the quest:

- At what Tx equalization state should SNDR be measured?
  - Not stated explicitly – both 162 and 163 use 162.9.3.3 as a definition; 162.9.3.3 points to 120D, which just says "with transmitters on all lanes enabled, with identical transmit equalizer settings"
- Looking back at the original SNDR definition, in 92.8.3.7, it said "SNDR shall be greater than 26 dB regardless of the transmit equalizer setting."
  - This smaller value may have been easier to pass even with the strongest equalization assumed for NRZ…
- Now we require 32.5 dB!
  - At strong equalization settings, c(0) can go as low as 0.5, directly reducing the pulse peak, but not the noise
  - To meet 32.5 dB under this condition, un-equalized SNDR needs to be ~38.5 dB, which may be more difficult than people expect…
  - Also, measuring SNDR with all possible equalizer settings may be impractical or impossible!

SNR_{TX} effect in COM

$$\sigma_{TX}^2 = [h^{(0)}(t_s)]^2 10^{-SNR_{TX}/10} \quad (93A\text{–}30)$$

- This models approximately[1]:
  - A noise source which has the same spectrum as the victim (flat, pulse-shaped)
  - with power attenuated by a flat SNR_{TX}
  - that passes the end-to-end channel, *which includes Tx equalization*
- This matches a noise source before the Tx equalizer (σ_1) but not after it (σ_2)
  - With σ_1 only, if equalization is changed, it affects both noise and signal, so their power ratio is (arguably) maintained
  - With σ_2, it does not hold at all; the pulse peak is attenuated, the noise is not

[1] Approximately, because if the end-to-end channel has residual ISI, then the noise will be amplified by the RSS of the sampled pulse response; but we assume this ISI is very small and neglect noise amplification

SNDR in Tx specifications

- Modern transmitters likely have mainly noise sources after the equalizer (σ_2)
    - Examples: DAC noises, crosstalk, …

    (Noise source before the equalizer (σ_1) may better match analog Tx equalization?)
- Changing Tx equalization does not reduce σ_2
    - But it can reduce the pulse peak, both in Tx measurement at TP2 and in the Rx signal
- For σ_2 can we assume the same spectrum as the victim at TP2?
    - Noise from the same lane is colored by the “thru” channel to TP2 ⇒ same spectrum
    - Noise from other lanes is colored by the FEXT channel to TP2 ⇒ more attenuation at low frequencies
    - … justification is incomplete, but it will simplify things
- When SNDR is measured with a σ_2 noise source and variable equalization…
    - Pulse peak is multiplied by c(0)
    - Noise RMS is not affected by equalization (it is added after the equalizer)
    - Thus, SNDR is degraded by the dB equivalent of c(0), compared to the no-equalization state

SNDR in Receiver ITT calibration (clause 162)

- In the clause 162 test, noise is injected at the Tx reference, after the Tx equalization $\Rightarrow \sigma_2$
  - This matches modern transmitters
- The noise is calibrated by measuring SNDR and using the result as SNR_{TX} in COM
  - Although, as discussed above, SNR_{TX} in COM represents a white noise source *before* the Tx equalization $\Rightarrow \sigma_1$
  - The effect of the injected noise does not match the COM model

- In summary, the COM calculation has an incorrect Tx noise model!

A possible solution

- Specify SNDR at no-equalization state, so that c(0)=1
- Account for the effect of Tx equalization (lower c(0)) in COM by modifying the calculated σ_{TX}
  - That would result in degradation of COM for existing channels if SNR_{TX} is kept at its current value.
  - If we don't want to increase the burden on channels, SNR_{TX} should be increased according to the effect of a reasonable Tx equalizer; say, c(0)=0.6 ⇒ 4.4 dB.
  - SNDR (min) should also be increased to match SNR_{TX}.
- The injected noise in the Rx test will still be calibrated by its effect on SNDR (Tx without equalization).

How about KR, C2C

- The main difference is that the Rx test is defined with noise added at the Rx side. This noise does not affect σ_{TX} and is naturally independent of Tx equalization.
- However, σ_{TX} (a function of SNR_{TX}) is still included in the noise calibration (Equation 93A–49). So the attenuation of the peak by equalization is still not accounted for.
- The changes in Clause 162 (where SNDR is measured at TP2) should also be applied in Clause 163 and Annex 120F (where SNDR is measured at TP0v).

Possible changes to the draft

1. Use a modified Equation 93A-30:

$$\sigma_{TX}^2 = \left[H^{(0)}(t_s)\right]^2 10^{-\frac{SNR_{TX}}{10}} \quad \rightarrow \quad \sigma_{TX}^2 = \left[\frac{H^{(0)}(t_s)}{c(0)}\right]^2 10^{-\frac{SNR_{TX}}{10}}$$

   This change amplifies the noise by the reciprocal of c(0) – similar to the effect of c(0) on measured SNDR.

2. Specify SNDR to be measured with equalization off (c(0)=1, to match the definition above).

3. SNDR and SNR_{TX} per case:
   - In Table 162–19, change the value of SNR_{TX} from 32.5 dB to 36.9 dB.
   - In Table 163–11 and Table 120F–8, change the value of SNR_{TX} from 33 dB to 37.4 dB.
   - In Table 162–10, change the value of SNDR (min) from 31.5 dB to 35.9 dB.
   - In Table 163–5 and Table 120F–1, change the value of SNDR (min) from 32.5 dB to 36.9 dB.

Editorial license to be provided for implementing the above in a clean way.

That’s all folks!

Comments? Improvements?