Equalization effects on Transmitter specifications

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Outline

- Discuss meaning of specification and measurement
- Examine which Tx parameters are dependent on equalization
- Some experimental results

Meaning of specification and measurement

- When we define a specification, it has to be measurable
  - It is not required to measure all devices in all settings and modes… (or any)
  - But a single port should be possible to fully measure to spec with a reasonable effort
- Some specifications characterize the device only at specific settings (e.g. v_f ⇒ equalization off)
- Some are defined allowing settings that optimize the result (e.g., C2M output specs)
- For specifications that are inherently dependent on some setting, we should make it clear whether the definition holds for “any setting” or just specific ones
  - “any setting” may be impractical to measure, impossible to meet, or meaningless

Tx specifications – the good part

Parameter	Dependence on equalization (if not specified)	Defined with specific equalization?
Differential pk-pk voltage, v_{di} (max)	Strong	No, but measurement with equalization off is natural
DC Common mode (min, max)	Unlikely	No
Transmitter steady-state voltage, v_f (min) (max) $+dv_f$	Strong	Equalization off
Linear fit pulse peak ratio, R_{peak} (min) $+dR_{peak}$	Strong	Equalization off
Transmitter output waveform: Absolute step size for each tap Minimum/maximum values	Inherent	No (all specs are relative)
Jitter parameters	Weak (measurement)	“chosen to minimize any or all of the jitter parameters”
ERL/dERL, RLcc, RLdc	Unlikely	No

Tx specifications – the not-so-good part

Parameter	Dependence on equalization (if not specified)	Defined with specific equalization?
RLM (min)	Possible	No
ISI_RES (max)	Strong	No (but some discussion is going on)
SCMR (max)	Strong	No
SNDR (min)	Strong	No

Meeting these specs with all possible equalization settings may be impossible.
Measuring at all possible settings is impractical.
This creates problems for both design and validation.

RLM

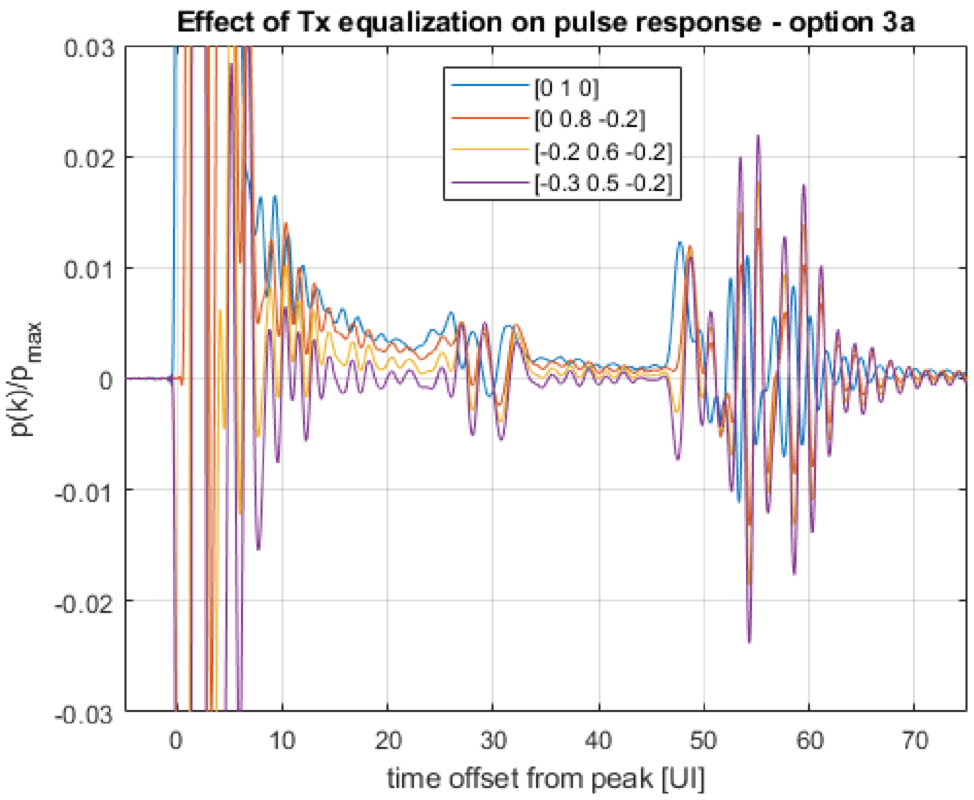
- Nonlinearity in the transmitter after the FFE calculation (e.g. DAC nonlinearity) can degrade the RLM
- How bad is it?
  - In many cases, RLM is improved by applying equalization, since the nominal levels are obtained with a smaller signal.
  - For short channels requiring low equalization, the receiver will likely attenuate the signal via training.

  ⇒ The practical equalization settings will likely improve RLM compared to measurement.
- Still, unspecified equalization is a problem for testing and validation.
- How about: specify SNDR with any of the 5 preset settings defined in Table 162–11.

ISI_RES

- As discussed in li_3ck_adhoc_01_030922, with the current definition, ISI_RES measures not only the reflections we want to limit, but also some dispersion-related ISI
- In a side discussion it was suggested that this ISI can be mitigated using Tx equalization
  - This is easier to specify than other solutions, e.g. use a reference receiver
- Tx equalization reduces the dispersive ISI and emphasizes the reflections (see next slide)

ISI_RES experiment



- The effect of equalization is shown in the plot on the left
  - The pulse response is normalized such that the peak is 1 (since ISI_RES is the ratio $\frac{\sigma_e}{p_{max}}$)
  - Zoomed in vertically for emphasis.
- Clearly, equalization mitigates the dispersion ISI and emphasizes the reflections.
- How about: adding the following to the definition of ISI_RES

ISI_RES is calculated from measurements with a single transmit equalizer setting to compensate for the loss of the transmitter package and host channel. The equalizer setting is chosen to minimize *ISI_RES*.

Channel: C2M__Z100_IL12_WC-BOR_H_L_H_THRU from mellitz_3ck_01_0518_C2M

SCMR

- The SCMR definition says "The procedure in 162.9.4.1.1 is used to determine the differential-mode linear fit pulse response p(k).“
  - The numerator p_{max} is defined as the maximum of p(k), which clearly depends on equalization.
  - The denominator, $V_{CMPP-HF}$ is mostly independent of equalization setting.
  - ⇒ SCMR strongly depends on equalization setting – and unspecified equalization is a problem for testing and validation.
- How about: Change the equation to use v_{peak} instead of p_{max}, where v_{peak} is defined with equalization off.
  - This will remove the dependence on equalization setting.

SNDR

- Already discussed, see ran_3ck_01_0122, ran_3ck_03a_0122
- As in the other parameters discussed above, unspecified equalization is a problem; the usable setting is likely with equalization, so it's preferable to measure with equalization, but compensate for its effect.
- The proposal in the presentations above was
  - Define SNDR as $10\log_{10}\frac{\left(v_{peak}/c(0)\right)^2}{\sigma_e^2+\sigma_n^2}$ where v_{peak} is defined with equalization off (as in 162.9.4.1.2), and c(0) is calculated from the linear fit procedure (equation 162–2); calculated with a single transmit equalizer setting to compensate for the loss of the transmitter package and host channel, where the equalizer setting is chosen to maximize SNDR.
- Measurement data:
  - Product board meets CR spec (31.5 dB) with equalization on (preset 3: [0, 0, -0.075, 0.75, 0])
  - With the proposed change of scaling p_{max} by $c(0)$, the SNDR would increase by $20\log_{10}\left(\frac{1}{0.75}\right)$ = 2.5 dB (with the same measurement!)
  - This is not necessarily the optimized SNDR across all equalization settings.
- Consider: increase the minimum SNDR by 2.5 dB (e.g. in clause 162 to 34 dB) to keep the effective limit.

SNDR

- The other part of the proposal was to close the gap in COM by replacing equation 93A-30 with

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

  where c(0) is based on the chosen Tx equalizer, and SNR_{TX} is increased by 4.4 dB (1/0.6) from its current values.
  - This would have zero effect if c(0) is indeed 0.6, e.g. high loss channels
  - With channels that require less equalization, σ_{TX} would becomes smaller, and improve COM.
- This is effectively keeping things as they are; the change is unnecessary. We can keep the value of SNR_{TX} as it is without increasing it.

That’s all!

Discussion?