Trying to understand TDECQ and TDECQ-10LogCeq

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Disclaimer

- This presentation is not taking a position on the topic of "TDECQ-10LogCeq"
- This presentation is purely an attempt to raise the level of understanding of the topic (for non-experts like myself), with the hope that it leads to a more informed decision by the broader Task Force (or at the very least allows more people to follow the discussions)
- The author claims no extensive expertise in TDECQ

Background

During the January Interim meeting of 802.3cu, “TDECQ-10logCeq” was removed from the transmitter specs:

- Having the effect of increasing the potential range of compliant transmitters

However “SECQ-10LogCeq” was not removed from the receiver specs:

- Meaning that receivers are only required to operate with (and be tested against) a more restricted range of transmitters

Therefore by making this change in D2.0 we introduced a potential interoperability gap (where a fully compliant transmitter and a fully compliant receiver might not interoperate).

There are two ways to address this:

- Reinstate “TDECQ-10LogCeq” on the transmitter
- Remove “SECQ-10LogCeq” from the receiver

TDECQ Overview

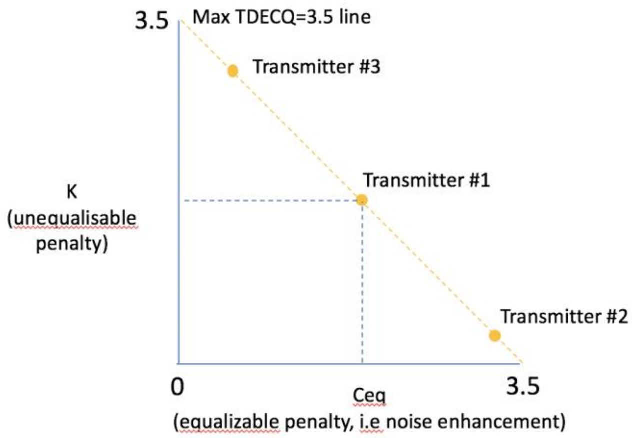
TDECQ can be viewed as a component penalty comprising the sum of two individual penalties*:

TDECQ = K + C

K=unequalizable penalty (penalty from impairments on the link that cannot be equalized, i.e. random noise)

C=equalizer penalty (penalty introduced by the equalizer itself, often called "noise enhancement", and the harder the equalizer has to work to compensate for equalizable impairments on the link the higher the penalty)

C=0: equalizer is doing nothing
C>0: working as traditional linear equalizer (HPF), and the higher the number the harder it is working
C<0: probably atypical situation where the equalizer is really operating as a LPF (restricting bandwidth)



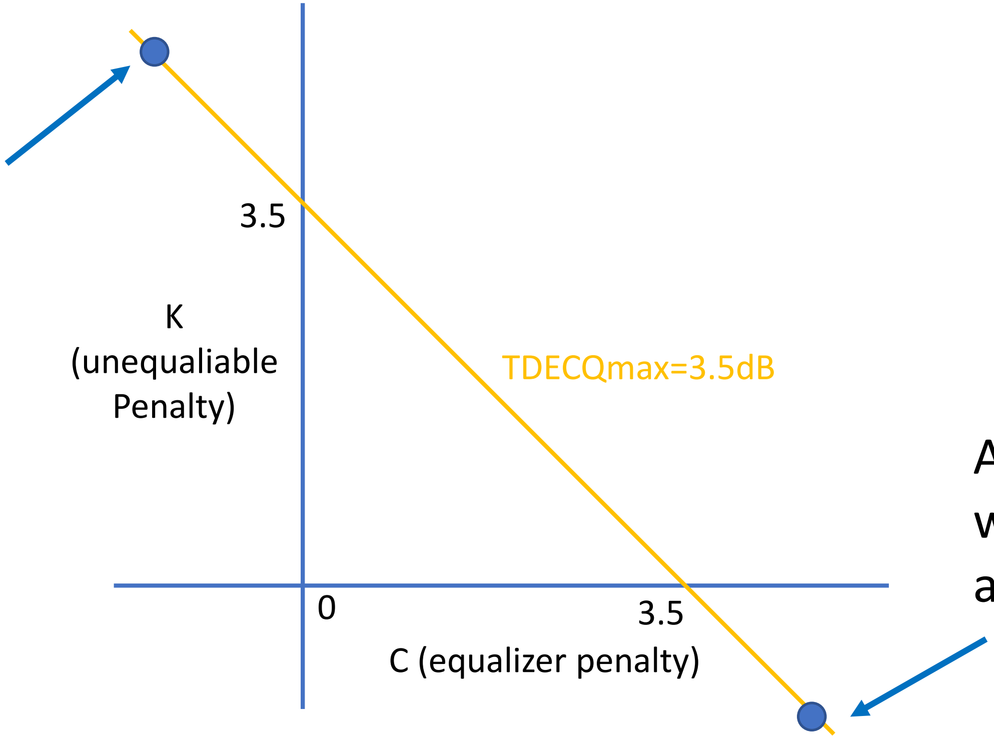
- TDECQ can therefore be plotted on a 2D graph as shown
- Transmitters #1,#2,#3 all have the same TDECQ value, but are very different.
- Transmitter #3 has a lot of unqualizable penalty
- Transmitter #2 has a lot of equalizable penalty
- A receiver has to work with all these transmitters
- A receiver therefore cannot be simply tested at a single TDECQ point

** Ref: "Transmitter and Dispersion Eye Closure Quaternary (TDECQ) and Its sensitivity to Impairments in PAM4 waveforms", Journal of Lightwave Technology, Vol 37, No 3, Feb 1, 2019*

TDECQ as a point constraint ?

- A single TDECQmax spec by itself itself dos not constrain where on the TDECQmax line that a given transmitter resides
- Therefore, theoretically, the range over which a receiver has to work is unbounded

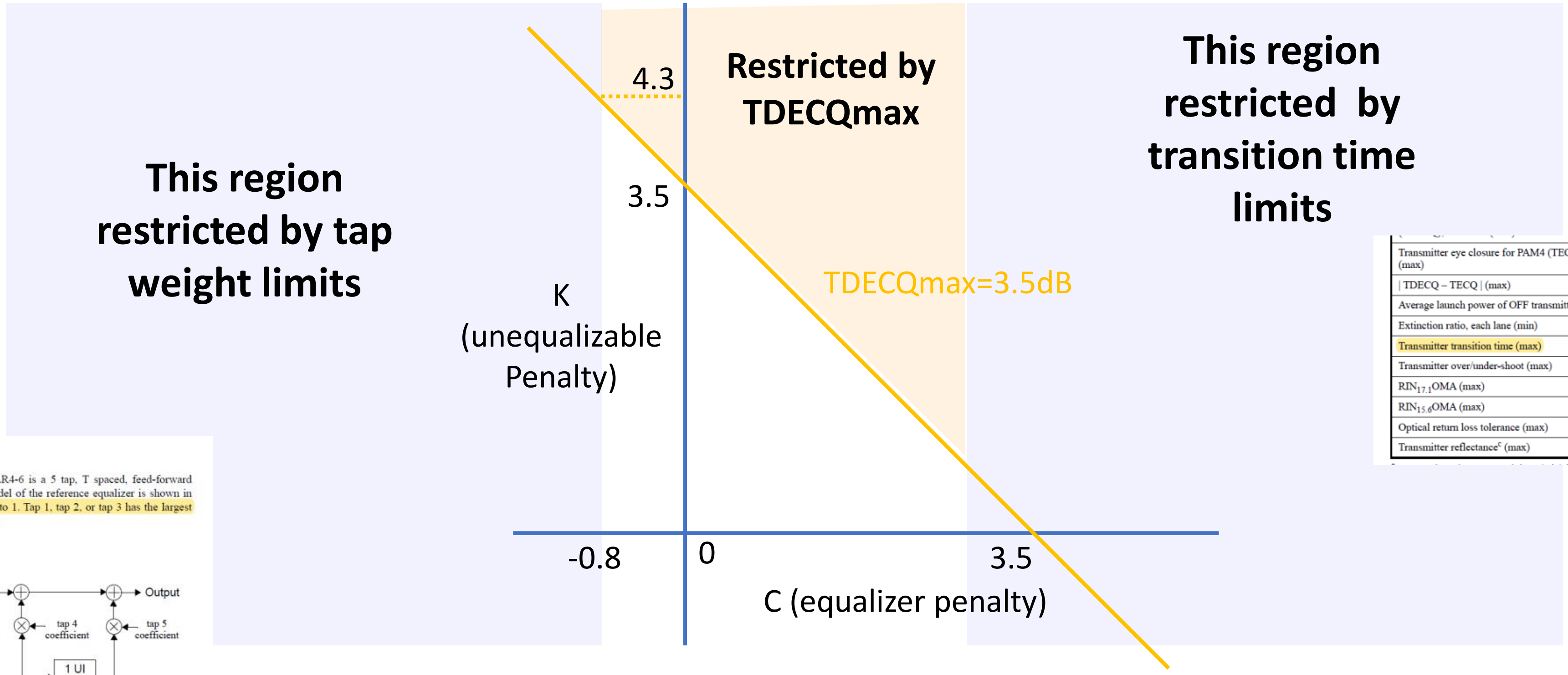
A transmitter could sit up here:
with K >> 3.5dB
as long as C << 0



A transmitter could sit down here:
with C >> 3.5dB
as long as K << 0

TDECQ – Additional constraints

- Additional constraints are necessary to bound the range over which a receiver has to operate
- These were added in 802.3cd (tap weight limits and transition time)



Transmitter eye closure for PAM4 (TECQ), each lane (max)	3.4	3.5	dB
| TDECQ – TECQ | (max)	2.5	2.5	dB
Average launch power of OFF transmitter, each lane (max)	–16	–16	dBm
Extinction ratio, each lane (min)	3.5	3.5	dB
Transmitter transition time (max)	17		ps
Transmitter over/under-shoot (max)	12	12	%
$RIN_{17.1}OMA$ (max)	–136	—	dB/Hz
$RIN_{15.6}OMA$ (max)	—	–136	dB/Hz
Optical return loss tolerance (max)	17.1	15.6	dB
Transmitter reflectance[c] (max)	–26		dB

151.8.5.4 TDECQ reference equalizer

The reference equalizer for 400GBASE-FR4 and 400GBASE-LR4-6 is a 5 tap, T spaced, feed-forward equalizer (FFE), where T is the symbol period. A functional model of the reference equalizer is shown in Figure 151–5. The sum of the equalizer tap coefficients is equal to 1. Tap 1, tap 2, or tap 3 has the largest magnitude tap coefficient, which is constrained to be at least 0.8.

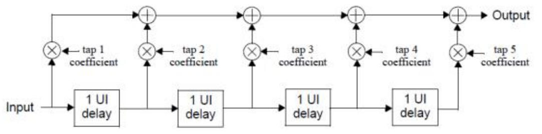
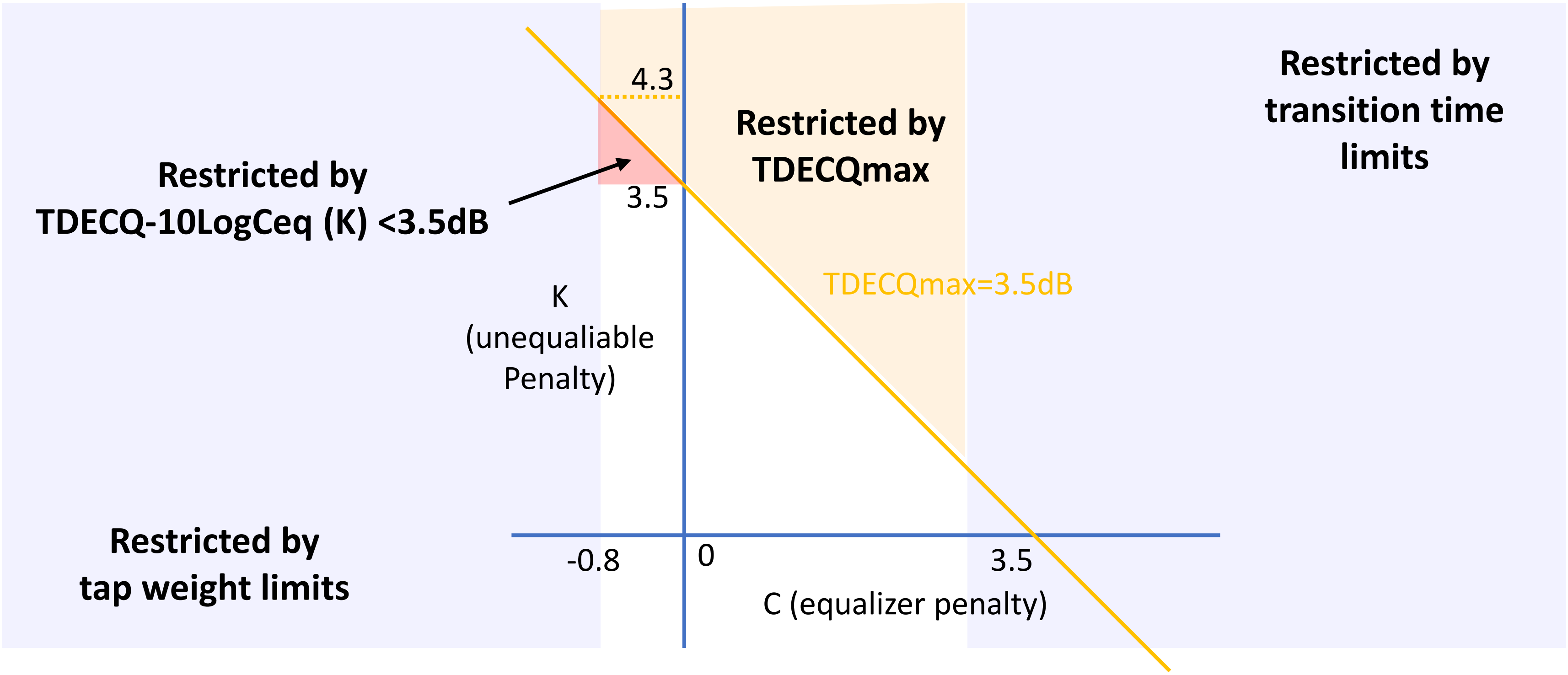


Figure 151–5—TDECQ reference equalizer functional model

TDECQ-10LogCeq

- An additional incremental constraint on transmitters (red shaded area) and therefore the range over which a receiver has to operate
- It essentially bounds the unequalizable penalty (K) at 3.5dB rather than 4.3 dB

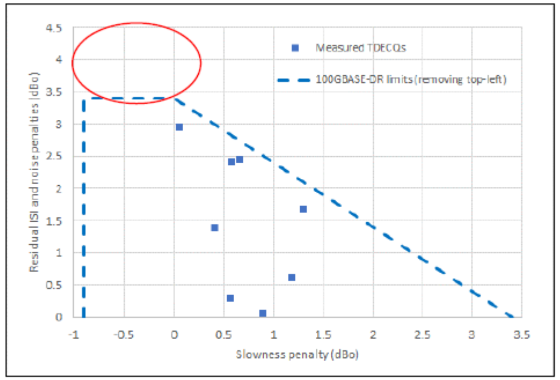


TDECQ-10LogCeq – why add this constraint?

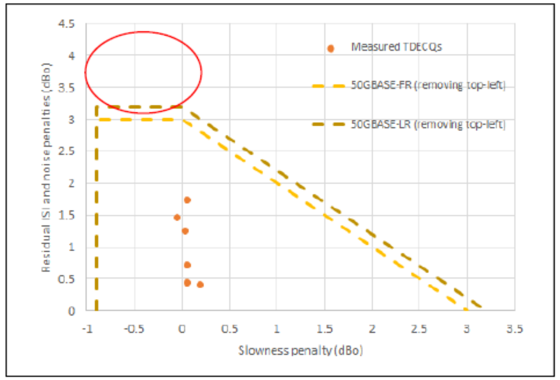
2. Constraining $TDECQ_{max}$ in upper left region

Propose to bound the top-left region by adding a limit equivalent to TDECQ -10*log10(Ceq)
- Aligned with the proposed $TDECQ_{max}$ increase in previous slide

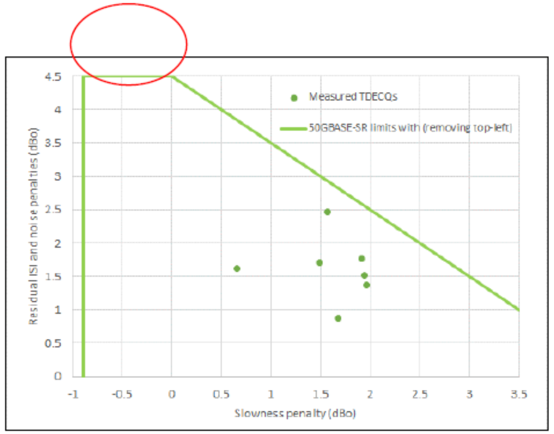
Negligible impact to Tx yield



100GBASE-DR: limit to 3.4dB



50GBASE-FR: limit to 3dB
50GBASE-LR: limit to 3.2dB



50GBASE-SR, 100GBASE-SR2 and 200GBASE-SR4: limit to 4.5dB

Why add this constraint?
- Very difficult region to verify SRS compliance
- Adds additional equalizer power and design complexity to receiver
- Real transmitters not expected to be realizable in this region

mazzini_3cd_01_0718 (Achieving closure on TDECQ/SRS) 11

Source: http://www.ieee802.org/3/cd/public/July18/mazzini_3cd_01d_0718.pdf

TDECQ-10LogCeq – why add this constraint?

- One of the primary reasons (based on mazzini_3cd_01d_0718) appears to have been to reduce the range over which a receiver has to operate
  - Simplifying receiver design and testing
- Were there additional reasons for adding TDECQ-10LogCeq, e.g. an attempt to screen out other transmitter characteristics, unrelated to the point above ?
  - A clear case has not been made

Final Thoughts ….

Adding a TDECQ-10LogCeq (K) limit clearly provides an incremental benefit (albeit unquantified) to the receiver:

- Restricts the range over with a receiver has to operate and be tested
- Simplifies SRS testing

Adding a TDECQ-10LogCeq (K) limit appears to have minimal impact on the transmitter:

- Minimal impact on yield (not expect to see any real transmitters in this region)
- Minimal impact on test time (since Ceq is calculated as part of the TDECQ test)

If the above assumptions are correct, then we can certainly argue about the absolute usefulness of TDECQ-10LogCeq, but on the contrary it doesn't do significant harm.