C_{eq} report in TDECQ penalty computation

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Supporter List

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Summary

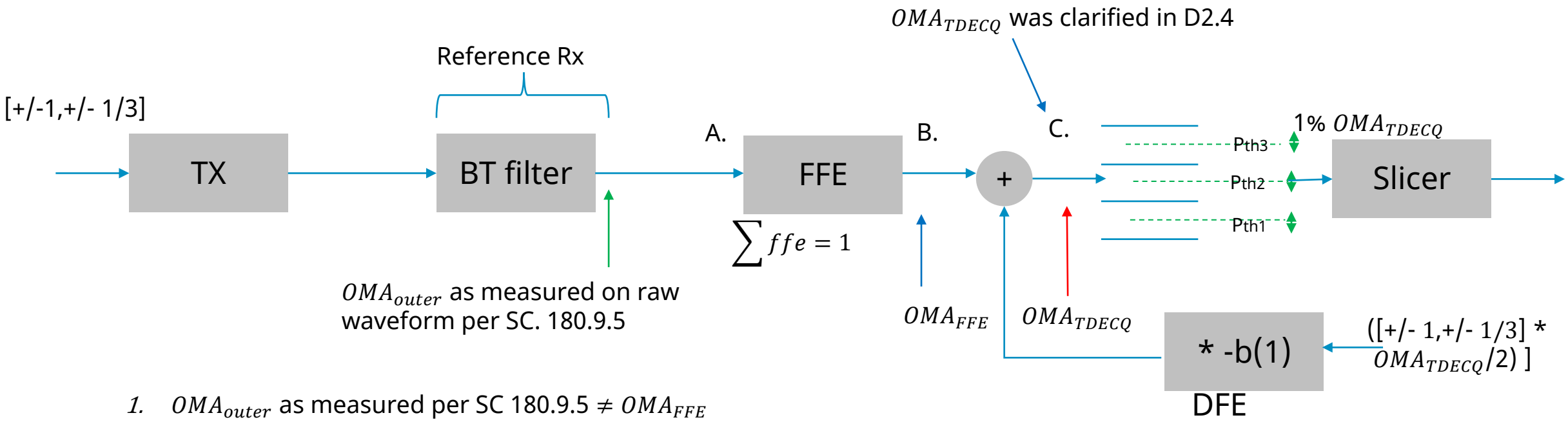
- DFE was added in the IEEE 802.3 dj draft 2.0, as part of the TDECQ reference equalizer, thereby impacting the interpretation of C_{eq}, as a bandwidth limitation metric of the transmitter. Also considering the recent analysis of OMA_{outer} and TDECQ results discussed in the lead to the adoption of draft 2.4, it is preferable to align the report of C_{eq} to the same reference as the one used for the TDECQ report (i.e. OMA_{outer}), such that the quantity TDECQ – C_{eq}retains a meaningful interpretation, such as that of un-equalizable impairment term.

- The current presentation proposes to align the report of the C_{eq} to the OMA_{outer} reference and to consider in its report the inclusion of the DFE in the reference receiver.
  - $\boldsymbol{C_{eq}}$, currently defined as the noise enhancement factor of the FFE, of which the sum of all taps is normalized to unity, is kept unchanged for the computation of the histograms in the TDECQ calculation
  - A new $\boldsymbol{C_{eq\_DFE}}$ term is added as a report of the penalty of equalizable ISI with a reference DFE receiver. This term can be subtracted from the TDECQ metric referenced to OMA_{outer} to yield the quantity TDECQ – C_{eq_DFE}
  - A new $\boldsymbol{C_{eq\_FFE}}$ term is also introduced as the equivalent penalty of equalizable ISI of an equivalent FFE reference receiver, which also translates to a bandwidth limitation metric that can be used for characterizing the transmitter bandwidth.

Outline

- Definition of various OMA quantities at different reference points in the receiver/equalizer
- Example of impact of a reflection on the C_{eq} report (FFE only)
- Consequence for TDECQ- C_{eq} computation (FFE only)
- C_{eq} evolution with DFE tap introduction
- Proposed editorial changes to draft D3.0
- Conclusion and recommendation

Various OMA quantities @ reference receiver in D3.0

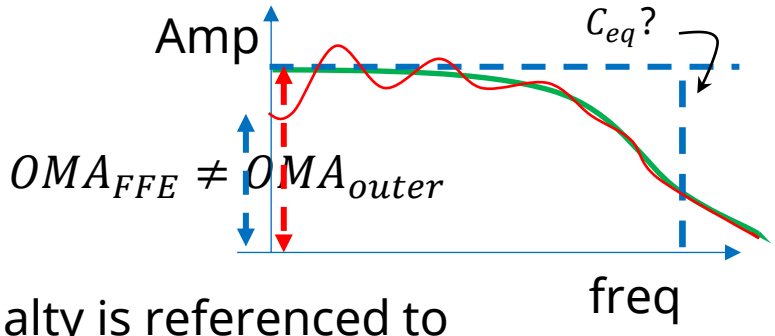


1. OMA_{outer} as measured per SC 180.9.5 ≠ OMA_{FFE}
2. OMA_{FFE} tracks the low frequency level signal and goes up and down based on reflection type , while OMA_{outer} tracks more an averaged level
3. OMA_{FFE}=OMA_{TDECQ} ∗ (1+b)

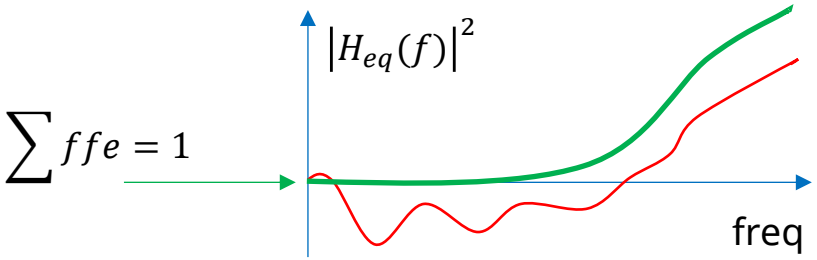
⇒ OMA_{FFE} goes up and down accordingly based on reflection type

Example of impact of a reflection –FFE only

In case of a destructive reflection $OMA_{FFE} < OMA_{outer}$, as OMA_{outer} measured per SC 180.9.5 is equivalent to the OMA of a transmitter without the impact of the reflection.



However, C_{eq} is assessed with respect to OMA_{FFE}, while the TDECQ penalty is referenced to OMA_{outer} to remain independent of the impact of the reflection.



$$C_{eq} = \sqrt{\int_f N(f) \times |H_{eq}(f)|^2 df} \qquad (180\text{–}9)$$

The C_{eq} value appears different for modules of same bandwidth but with different reflections

When considering TDECQ – C_{eq}, both quantities need to be referenced to the same OMA_{outer} level. Since OMA_{FFE} varies with the type of reflection (constructive vs destructive), while OMA_{outer} is independent of the reflection, TDECQ – C_{eq} may not be correct for modules that have a same bandwidth and a same OMA_{outer}.

Consequence for TDECQ-CEQ computation – FFE only

In case of a destructive reflection $OMA_{FFE} < OMA_{outer}$,C_{eq}will be lower. If constructive interference OMA_{FFE} will be higher andC_{eq}will be higher, thereby suggesting that the modulators have different bandwidth (i.e. different OMA @ Nyquist)

For 3 modules reported in https://www.ieee802.org/3/dj/public/25_09/alloin_3dj_01b_2509.pdf

refpoint	FFE only	Mod#1	Mod#2	Mod#3
C	OMAtdecq[dBm]	2.47	3.25	3.93
B	OMAffe [dBm]	2.47	3.25	3.93
A	OMAouter [dBm]	3.12	3.23	3.29
	Ceq [dB]	0.61	1.38	2.06
	Ceq_FFE [dB]	1.25	1.36	1.42
	TECQ [dB]	2.67	2.74	2.86
	TECQ [dB] -Ceq [dB]	2.06	1.37	0.80
	TECQ [dB] -Ceq_FFE [dB]	1.41	1.39	1.44

Inconsistent BW metric

Consistent BW metric

Inconsistent un-equalizable terms

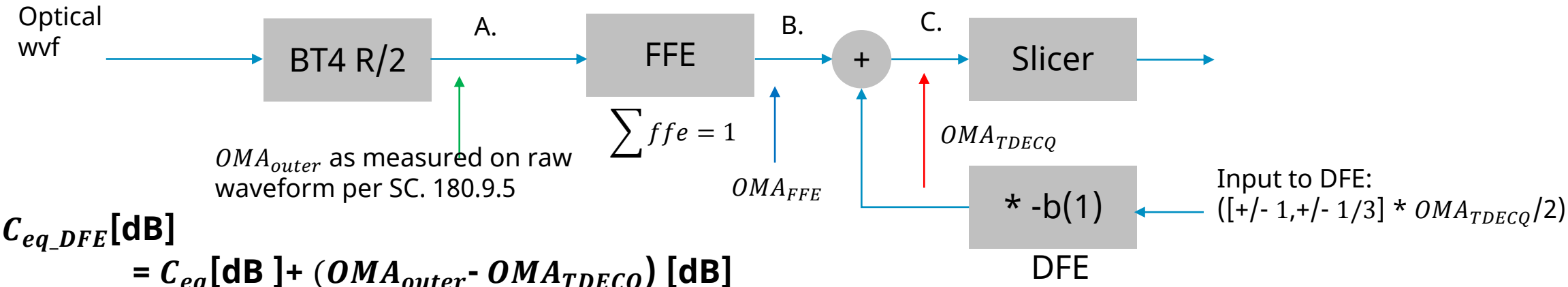
Consequences:

Mod #3 will be flagged as undershooting
Mod #1 will be flagged for overshooting
But all 3 modules offer very similar bandwidth !

Whereas $\boldsymbol{C_{eq\_FFE}}$**[dB]=** $\boldsymbol{C_{eq}}$ **[dB]+** $\boldsymbol{(OMA_{outer}\text{-}OMA_{TDECQ})}$ **[dB]** shows that all 3 modules are similar. Hence, TDECQ - C_{eq_FFE} estimates are now consistent, while TDECQ- C_{eq} estimates are not

CEQ evolution with DFE tap

In the following model, where the DFE tap b is normalized wrt.$OMA_{TDECQ}/2$, as proposed in https://www.ieee802.org/3/dj/public/26_03/alloin_3dj_02a_2603.pdf



$\boldsymbol{C_{eq\_DFE}}$**[dB]**

= $\boldsymbol{C_{eq}}$**[dB]+** $(\boldsymbol{OMA_{outer}}$**-** $\boldsymbol{OMA_{TDECQ}})$ **[dB]**

= C_{eq} [dB]+ $(OMA_{outer}$- OMA_{FFE}+ OMA_{FFE}-$OMA_{TDECQ})$ [dB]

= C_{eq_FFE} [dB]+ $(OMA_{FFE}$-$OMA_{TDECQ})$ [dB]

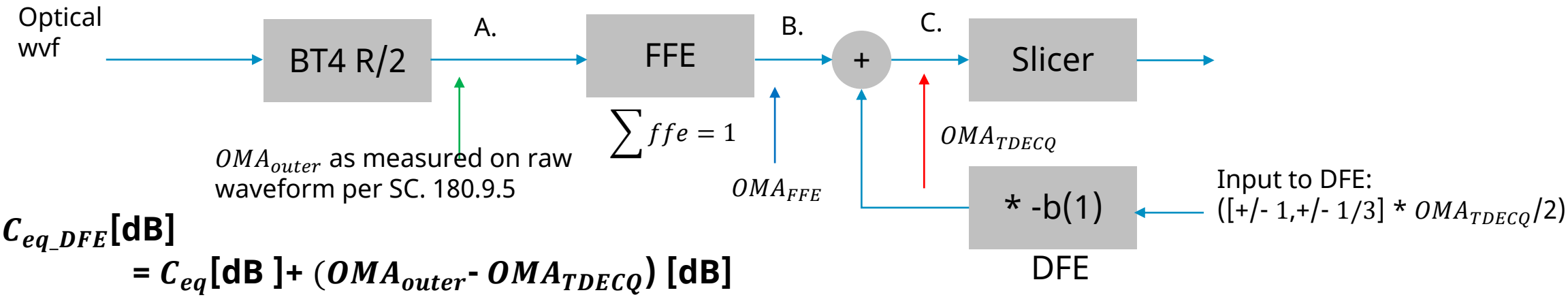
From the relationship : $(OMA_{FFE}\ /OMA_{TDECQ})$ = (1+b) when b is normalized to $OMA_{TDECQ}/2$

=> C_{eq_DFE} [dB]= C_{eq_FFE} [dB]+10*log10(1+b) [dB]

While C_{eq_DFE} can now be used in TDECQ - C_{eq_DFE} to derive an un-equalizable impairment quantity, $\boldsymbol{C_{eq\_FFE}}$**[dB] =** $\boldsymbol{C_{eq\_DFE}}$ **[dB] -10*log10(1+b) [dB]** still can be used as a TX bandwidth limiting metric.

CEQ evolution with DFE tap

In the following model, where the DFE tap b is normalized wrt.$OMA_{TDECQ}/2$, as proposed in https://www.ieee802.org/3/dj/public/26_03/alloin_3dj_02a_2603.pdf



$\boldsymbol{C_{eq\_DFE}}$**[dB]**

= $\boldsymbol{C_{eq}}$**[dB]+** $(\boldsymbol{OMA_{outer}}$**-** $\boldsymbol{OMA_{TDECQ}})$ **[dB]**

= C_{eq} [dB]+ $(OMA_{outer}$- OMA_{FFE}+ OMA_{FFE}-$OMA_{TDECQ})$ [dB]

= C_{eq_FFE} [dB]+ $(OMA_{FFE}$-$OMA_{TDECQ})$ [dB]

From the relationship : $(OMA_{FFE}\ /OMA_{TDECQ})$ = (1+b) when b is normalized to $OMA_{TDECQ}/2$

=> C_{eq_DFE} [dB]= C_{eq_FFE} [dB]+10*log10(1+b) [dB]

While C_{eq_DFE} can now be used in TDECQ - C_{eq_DFE} to derive an un-equalizable impairment quantity, $\boldsymbol{C_{eq\_FFE}}$**[dB] =** $\boldsymbol{C_{eq\_DFE}}$ **[dB] -10*log10(1+b) [dB]** still can be used as a TX bandwidth limiting metric.

Comparison of CEQ_FFE for FFE and FFE+DFE

In case of a destructive reflection $OMA_{FFE} < OMA_{outer}$,C_{eq}will be lower. If constructive interference OMA_{FFE} will be higher andC_{eq}will be higher, thereby suggesting that the modulators have different bandwidth (i.e. different OMA @ Nyquist)

refpoint	FFE +DFE	Mod#1	Mod#2	Mod#3
C	dfe [b]	0.20	0.21	0.22
C	OMAtdecq[dBm]	1.64	2.38	3.05
B	OMAffe [dBm]	2.47	3.24	3.93
A	OMAouter [dBm]	3.12	3.23	3.29
	Ceq [dB]	-0.39	0.33	0.98
	Ceq_DFE [dB]	0.26	0.31	0.34
	Ceq_FFE [dB]	1.24	1.34	1.40
	TECQ [dB]	2.40	2.48	2.51
	TECQ [dB] -Ceq [dB]	2.78	2.16	1.53
	TECQ [dB] -Ceq_DFE [dB]	2.14	2.17	2.17

Consistent BW metric

Consistent un-equalizable terms

Consequences:

Mod #3 will be flagged as OK
Mod #1 will be flagged for overshooting
But all 3 modules offer same bandwidth !

Whereas C_{eq_DFE} [dB]= C_{eq} [dB]+ (OMA_{outer}-OMA_{TDECQ}) [dB] shows that all 3 modules are similar. Hence, TDECQ-C_{eq_DFE} estimates are now consistent

Proposed edits to D3.0

Appending to TDECQ definition in line 39 thru. 48, p483, the following new metric definitions

"C_{eq_DFE} [dB]= $10log10(C_{eq})$ + $10log10(OMA_{outer})$ – $10log10\left(OMA_{TDECQ}\right)$

represents the equalizable ISI penalty associated with the reference DFE receiver, which can be subtracted from TDECQ

C_{eq_FFE} [dB] = C_{eq_DFE} -10*log10(1+b) where b is the normalized DFE coefficient defined in Table 180-16

represents the bandwidth limiting metric of the transmitter"

Conclusion / Recommendation

We recommend adding two quantities $\boldsymbol{C_{eq\_FFE}}$ and $\boldsymbol{C_{eq\_DFE}}$ to complement the $\boldsymbol{C_{eq}}$ value currently used in the TDECQ computation.

$\boldsymbol{C_{eq\_DFE}}$ addresses an erroneous interpretation of the C_{eq} value for modules where $OMA_{outer} \neq OMA_{FFE}$ and it allows the quantity to become consistent with the TDECQ report, such that the quantity (TDECQ - C_{eq_DFE}) can be derived that represents an un-equalizable impairment term.

$\boldsymbol{C_{eq\_FFE}}$ which is directly related to C_{eq_DFE} through the DFE tap value b (normalized to OMA_{TDECQ} /2), can also be reconstructed and can serve as a TX bandwidth metric, as previously considered for characterizing transmitter overshoot and undershoot using an FFE only reference receiver.

Formalizing those two quantities would help avoid ambiguities in interpreting the metric (TDECQ- C_{eq}) for modules where $OMA_{outer} \neq OMA_{FFE}$, as well as reinstating the original C_{eq} report as a transmitter bandwidth metric prior to the introduction of the DFE tap in the reference receiver.

Thank you