KEYSIGHT

TDECQ Reference Equalizer Definition

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Addressing comments #187, #171, #172, #173, #174, #175, #176, #177, #183, #184, #185 and #186 against IEEE P802.3dj D2.1

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AGENDA

1. Introduction
2. Changes to TDECQ Ref EQ in IEEE 802.3dj Draft 2.1
3. TDECQ Reference Point
4. DFE Coefficient Reference
5. Pre-Post FFE Equalizer Coefficient Difference Limit
6. Summary

Introduction

- The 802.3dj task force adopted significant changes to the TDECQ reference equalizer in draft 2.1 by adding a 1T DFE equalizer as well as a new differential tap limit for the FFE equalizer.
- The changes adopted in draft 2.1 aim to bring the reference equalizer closer to the real receiver implementation which has higher equalization capabilities.
- TDECQ uses a well-defined reference receiver and reference equalizer to make sure all transmitters are measured against the same minimum viable receiver to ensure interoperability.
- The new changes adopted in draft 2.1 lack the specificity required and open the door for interpretation jeopardizing measurement repeatability and interoperability.
- This presentation proposes changes to the draft that explicitly define the reference equalizer to guarantee measurement repeatability and interoperability.
- This presentation addresses comments #187, #171, #172, #173, #174, #175, #176, #177, #183, #184, #185 and #186 against IEEE P802.3dj D2.1.

Changes to TDECQ Ref EQ in IEEE P802.3dj Draft 2.1

- The IEEE 802.3dj task force added a new pre-post equalizer coefficient difference limit for the FFE equalizer:

$$|w(1) - w(-1)|, \text{ for } w(1) > 0$$

- The IEEE 802.3dj task force also added a 1T DFE to the reference equalizer with a coefficient limits of

$$0 < b(1) < 0.3$$

Table 180–15—Reference equalizer tap coefficients

Parameter	Symbol	Value	
		Minimum	Maximum
Feed-forward equalizer (FFE) length	N_w	15	
Number of equalizer pre-cursor taps	—	0	3
Main tap coefficient limit	$w(0)$	0.9	2.5
Normalized equalizer coefficient limits:	$w(i)/w(0)$		
$i = -3$		–0.15	0.1
$i = -2$		–0.1	0.25
$i = -1$		–0.5	0.1
$i = 1$		–0.6	0.2
$i = 2$		–0.2	0.3
$i = 3$		–0.15	0.15
$i = 4$		–0.15	0.15
$i = 5$		–0.15	0.15
$i = 6$		–0.15	0.15
$i \geq 7$		–0.1	0.1
Pre-post equalizer coefficient difference limit: $\lvert w(1) - w(-1) \rvert$, for $w(1) > 0$	—	—	0.25
Equalizer DC gain[a]	—	1	
Decision feedback equalizer (DFE) length	N_b	1	
DFE coefficient limit	$b(1)$	0	0.3

[a] The sum of all 15 equalizer coefficients, $w(i)$.

IEEE P802.3dj ™ – Draft 2.1 – Clause 180.9.5

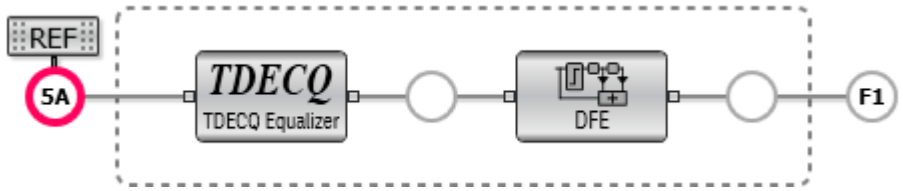
TDECQ Reference Point

- The TDECQ reference point defines where the measured OMA and added noise are referenced to.
- The DFE will change the OMA of the signal, so OMA should be measured before the DFE.
- The FFE equalizer is defined to have unity gain so OMA can be measured either at the input or output of the FFE.

Suggested Remedy: Explicitly specify the TDECQ reference point at the input of the reference equalizer. Add the sentence below after the definition of the reference equalizer.

> The reference equalizer is a 15-tap, T-spaced, feed-forward equalizer (FFE), followed by a 1-tap decision feedback equalizer (DFE), where T is the symbol period, with equalizer coefficient constraints as shown in Table 180–15. The reference equalizer may be implemented in the oscilloscope, but it is not considered part of the reference receiver.

IEEE P802.3dj ™ – Draft 2.1 – Clause 180.9.5



TDECQ Reference Equalizer

"The TDECQ reference point where OMA is referenced to and noise is added is at the input of the FFE equalizer."

DFE Tap Weight Reference

- FFE taps get applied directly to waveform values, so the effect of their taps naturally scales with OMA. The tap limits are based on a clear reference (the main tap value).
- DFE taps get applied to symbol values [-1,-1/3,+1/3,+1], so their normalized tap values need an amplitude reference to convert to a correction amount in watts.
- Using OMA/2 measured at the input to the reference equalizer is equivalent to applying the DFE tap directly to [-OMA/2, -OMA/6, +OMA/6, +OMA/2].
- The maximum correction range for a DFE tap of 1 would be [-OMA/2, +OMA/2]; total range = OMA.
- **<u>Suggested Remedy:</u>** Reference the DFE coefficient to OMA/2 measured at the input of the FFE equalizer. Add a footnote to the reference equalizer tap coefficients table.

Table 180–15—Reference equalizer tap coefficients

Parameter	Symbol	Value	
		Minimum	Maximum
Feed-forward equalizer (FFE) length	N_w	15	
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Pre-post equalizer coefficient difference limit: $\lvert w(1) - w(-1) \rvert$, for $w(1) > 0$	—	—	0.25
Equalizer DC gain[a]	—	1	
Decision feedback equalizer (DFE) length	N_b	1	
DFE coefficient limit	$b(1)$	0	0.3

[a] The sum of all 15 equalizer coefficients, $w(i)$.

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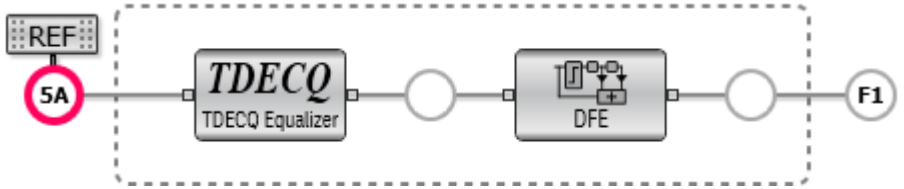

TDECQ Reference Equalizer

"The DFE coefficient $b(1)$ is referenced to OMA/2 measured at the input of the FFE equalizer"

Pre-Post FFE Equalizer Coefficient Difference Limit

- The pre-post equalizer coefficient limit was added to penalize transmitters with poor group delay variation. Restricting the first pre-post tap difference will keep the phase close to linear.
- The spec does not currently specify what the optimization algorithm should do when the w(1) > 0 condition is satisfied which could potentially lead to different answers.

Suggested Remedy:

Remove the condition "for w(1) > 0" to limit asymmetry for all cases

$$|w(1) - w(-1)| < 0.25$$

To address the higher sensitivity when w(1) > 0 demonstrated in chayeb_3dj_01_2505, we can use different limits on both sides:

$$-0.3 \leq w(1) - w(-1) \leq 0.15$$

Table 180–15—Reference equalizer tap coefficients

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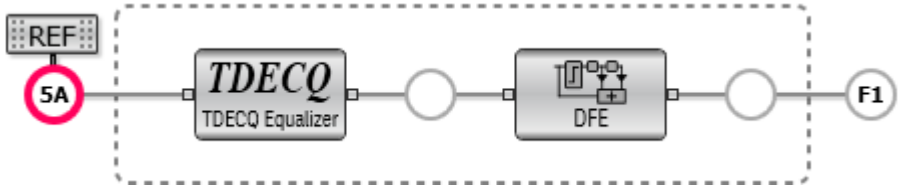

TDECQ Reference Equalizer

Remove the "w(1) > 0" condition from the pre-post equalizer coefficient difference limit

Pre-Post FFE Equalizer Coefficient Difference Limit

- The DFE equalizer can compensate for some of the post cursor effects, so it should be factored in the pre-post difference limit.
- In this experiment, we used the optimized FFE taps for 3 DFE coefficients (0, 0.2, -0.2).
- The bottom right corner (w(1) – b(1) – w(-1)) is fairly stable when calculated based on FFE taps that were normalized to have a main tap of 1 (0.271, 0.278, 0.306).
- The equalizer is compensating in this case for a consistent difference between the first pre/post cursors, regardless of whether FFE or DFE is used.
- FFE taps normalized by the main tap should be used for the pre-post difference limit

FFE Taps, DC gain = 1							
w(-1)	w(0)	w(1)	w(2)	w(1) - w(-1)	w(1) + b(1) - w(-1)	w(1) - b(1) - w(-1)	b(1)
-0.068	0.8669	0.167	0.0341	0.234911	0.234911	0.234911	0
-0.0413	0.6977	0.2924	0.0511	0.333661	0.533661	0.133661	0.2
-0.0828	1.0465	0.0284	0.0079	0.111282	-0.088718	0.311282	-0.2
FFE Taps, normalized by main tap				w(1) - w(-1)	w(1) + b(1) - w(-1)	w(1) - b(1) - w(-1)	b(1)
-0.0784	1	0.1926	0.0393	0.270965383	0.270965383	0.270965383	0
-0.0591	1	0.4191	0.0733	0.4782251	0.6782251	0.2782251	0.2
-0.0792	1	0.0272	0.0076	0.106338636	-0.093661364	0.306338636	-0.2

Suggested Remedy:

The pre-post equalizer coefficient difference limit should use FFE taps normalized to the main tap and account for the DFE (exact limits can be refined based on more data)

$$-0.3 \leq w(1)/w(0) - b(1) - w(-1)/w(0) \leq 0.15$$

Change the pre-post equalizer coefficient difference limit to "$-0.3 \leq w(1)/w(0) - b(1) - w(-1)/w(0) \leq 0.15$"

Summary

- The 802.3dj task force adopted significant changes to the TDECQ reference equalizer in draft 2.1 by adding a 1T DFE equalizer as well as a new differential tap limit for the FFE equalizer.
- TDECQ uses a well-defined reference receiver and reference equalizer to make sure all transmitters are measured against the same minimum viable receiver to ensure interoperability.
- This presentation proposes explicitly defining the TDECQ reference point where measured OMA and added noise are referenced to be at the input of the FFE equalizer and referencing the DFE coefficient to OMA/2 .
- This presentation also proposes adopting a pre-post equalizer coefficient difference limit that factors in the effect of the DFE equalizer and uses normalized FFE taps to penalize transmitter with poor GDV. The proposed pre-post difference limit is: "$-0.3 \leq w(1)/w(0) - b(1) - w(-1)/w(0) \leq 0.15$"
- The proposed changes to the draft would explicitly define the reference equalizer and guarantee measurement repeatability and interoperability.

KEYSIGHT

Thank you