A Proposal for Updating Annex 93A.1 Channel Operating Margin (COM) with a FFE Reference Receiver for IEEE P802.3dj

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Supporters

- **Richard Mellitz, Samtec**

Background and Goals

- **802.3dj COM RX trending**
  - RX EQ will be equipped with CTLE, +long FFE, +short (1-tap) MLSD or DFE
- **802.3dj July plenary straw poll showed**
  - Strong interest to support FFE in COM reference RX
- **Proposals for RX FFE (both fixed and floating) determination methodology and descriptions had been presented [1]**
- **Goals**
  - Propose specific RX FFE (both fixed and floating) coefficient determination methodology and descriptions for Annex 93A

Outline of Proposed Modifications to Annex 93A.1

i. Update 93A.1

a) Modify Figure 93A-1

b) Modify Table 93A-1

ii. Update 93A.1.4

a) Modify Eq. 93A-19

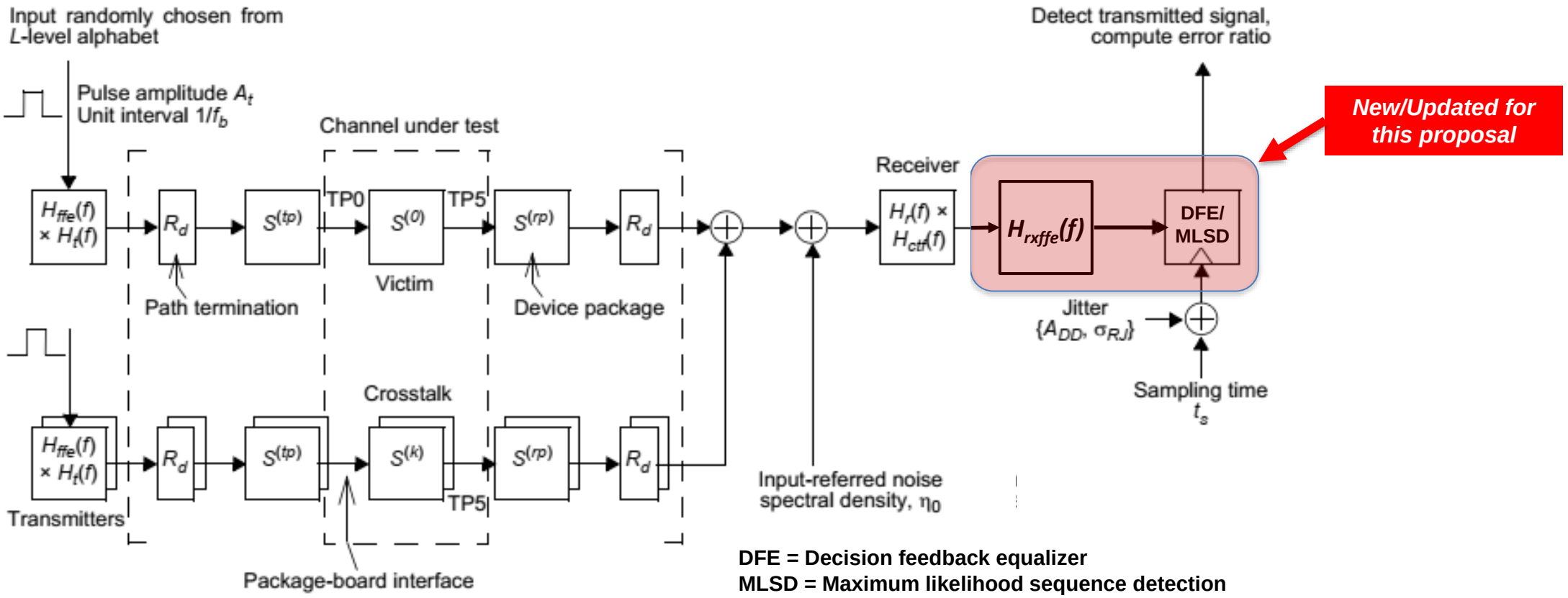
b) Add 93A.1.4.4 Receiver feed forward equalizer

iii. Update 93A.1.6

a) Adding RX FFE coefficient and floating tap location determination

i. a) Update 93A.1 Channel Operating Margin

- Modify Figure 93A-1



DFE = Decision feedback equalizer
MLSD = Maximum likelihood sequence detection

i. b) Update 93A.1 Channel Operating Margin

- Modify Table 93A-1 by adding the following COM parameters

Parameter	Reference	Symbol	Units
Receiver feed forward equalizer (RX FFE) pre-tap length	93A.1.6	ffe_pre_len	UI
RX FFE post-tap length	93A.1.6	ffe_post_len	UI
RX FFE coefficient limit	93A.1.6	ffen_max	
Number of RX FFE floating tap banks	93A.1.6	ffe_bg	UI
Number of RX FFE floating taps per bank	93A.1.6	ffe_bn	UI
RX FFE maximum span including FFE floating taps	93A.1.6	ffe_Nf	UI

ii a) and b) Update 93A.1.4 Filters

- Update 93A.1.4
  - Modify Equation 93A-19

$$H^{(k)}(f) = H_{ffe}(f)\, H_t(f)\, H_{21}^{(k)}(f)\, H_r(f)\, H_{ctf}(f)\, H_{rxffe}(f)$$

  - Modify description
    - … *"the transmitter equalizer $H_{ffe}(f)$ is defined in 93A.1.4.2, the receiver equalizer $H_{ctf}(f)$ is defined in 93A.1.4.3, and the receiver feed forward equalizer $H_{rxffe}(f)$ is defined in 93A.1.4.4."*
- Add *93A.1.4.4 Receiver feed forward equalizer*
  - *"$H_{rxffe}(f)$ is defined by Equation (93A–23) and is intended to represent the receiver feed forward equalizer (RX FFE) where pre_len is the pre-tap length of RX FFE and post_len is the post-tap length of RX FFE. If the value of c(i) is larger than the specified maximum values, the RX FFE coefficients are considered invalid and is not used to calculate COM."*

$$H_{rxffe}(f) = \sum_{i=-1*pre\_len}^{post\_len} c(i)\exp(-j2\pi(i + pre\_len)\frac{f}{f_b}) \qquad \text{(93A-23)}$$

iii Update 93A.1.6

- Modify 93A.1.6 Determination of variable equalizer parameters
  - Currently in 802.3ck_D3p3

To be modified for use RX FFE option

a) Compute the pulse response $h^{(k)}(t)$ of each signal path k for a given $c(-3)$, $c(-2)$, $c(-1)$, $c(1)$, g_{DC}, and g_{DC2} using the procedure defined in 93A.1.5.

b) Define t_s to be the time that satisfies Equation (93A–25). If there are multiple values of t_s that satisfy the equation, then the first value prior to the peak of $h^{(0)}(t)$ is selected. The fixed-tap coefficients of the ~~decision feedback equalizer~~DFE $b(n)$ are computed as shown in Equation (93A–26). If N_b is 0, then the $b(n)$ is considered to be zero for all n. If $bb_{min}(n)$ and $bb_{max}(n)$ are not provided by the clause that invokes this method then $bb_{min}(n)$ is set to $-b_{max}(n)$ and $bb_{max}(n)$ is set to $b_{max}(n)$.

c) Compute the location and coefficients of floating-tap coefficients of the DFE to minimize the residual ISI using the method described in 93A.1.6.1. If N_{bg}, N_{bf}, N_f, b_{gmax} are not specified then no floating taps are used and N_f takes the value of N_b from the referring clause.

d) ~~c)~~ Define A_s to be $R_{LM}h^{(0)}(t_s)/(L-1)$.

iii Update 93A.1.6 *(cont.)*

- Update 93A.1.6 Determination of variable equalizer parameters step b) and c)
  - b) If the receiver has feed forward equalizer (FFE), follow step b1) to b6). If no FFE, skip to step c)
    - **b1)** *Define ts to be the time that satisfies Equation (93A–25). If there are multiple values of ts that satisfy the equation, then the first value prior to the peak of $h^{(0)}(t)$ is selected. The partial response coefficient pr = $b(1)/h^{(0)}(ts)$ is computed as shown in Equation (93A–26). If Nb is 0, then the b(1) is considered to be zero. If $bb_{min}(1)$ and $bb_{max}(1)$ are not provided by the clause that invokes this method then $bb_{min}(1)$ is set to $–b_{max}(1)$ and $bb_{max}(1)$ is set to $b_{max}(1)$.*
    - **b2)** *Using the linear fitting (LF) method as in 85.8.3.3.5 and 85.8.3.3.6, compute FFE coefficients w(n), where n is from –1*ffe_pre_len to -1 and 0 to ffe_Nf, if FFE floating taps exist, or 0 to ffe_post_len, if no FFE floating tap, with the following conditions:*
      - *Create P (Nw x Nw matrix) from CTLE Output $h^{(0)}(t)$ where Nw is the number of FFE taps. Nw = ffe_pre_len + 1 + ffe_Nf, if FFE floating taps exist, or Nw = ffe_pre_len + 1 + ffe_post_len, if no FFE floating tap.*
      - *Create x vector (Nw x1 vector) with:*
        - *x(ffe_pre_len + 1) = 1*
        - *x(ffe_post_len + 2) = pr*
        - *All other components = 0*
      - *Normalize the resultant w(n) so that w(ffe_pre_len + 1) = 1. If w(n) exceed ffen_max, FFE will not be used.*
    - **b3)** *If FFE floating taps exist, compute pulse response $h_{fix}^{(0)}(t)$ for the given transmitter equalizer coefficients c(n), g_{DC}, g_{DC2}, and partial receiver FFE coefficients $w_{fix}(n) = w(1 : 1 + ffe\_pre\_tap\_len + ffe\_post\_len)$ using the procedure defined in 93A.1.5.*
    - **b4)** *if FFE floating taps exist, compute the location and coefficients of floating-tap coefficients of the FFE using $h_{fix}^{(0)}(t)$ to minimize the residual ISI using the method described in 93A.1.6.1. If ffe_bg, ffe_bf, ffe_Nf, ffe_bgmax are not specified then no floating taps are used and ffe_Nf takes the value of ffe_post_len from the referring clause. Update w(n) so that not-selected floating tap locations are set to 0.*
    - **b5)** *Follow step b1) and re-compute ts using $h_{new}^{(0)}(t)$ for the given transmitter equalizer coefficients c(n), g_{DC}, g_{DC2}, and receiver FFE coefficients w(n).*
    - **b6)** *Recompute $h^{(k)}(t)$ for the given transmitter equalizer coefficients c(n), g_{DC}, g_{DC2}, and receiver FFE coefficients w(n).*

iii Update 93A.1.6 *(cont.)*

- Update 93A.1.6 Determination of variable equalizer parameters
  - c) is the original step b) as in 802.3ck
    - c1) is the original step c) as in 802.3ck

Summary and Next Steps

- Detailed/specific changes/updates for Annex 93A in supporting RX FFE (both fixed and floating) coefficient determination are presented.
- Expecting 802.3dj members review and adoption to enable the specification development.

References

[1] M. Li et al, https://www.ieee802.org/3/dj/public/23_09/lim_3dj_05_2309.pdf, Nov, 2023