Floating Tap Incorporation Proposal for Annex 93A

Richard Mellitz

Samtec

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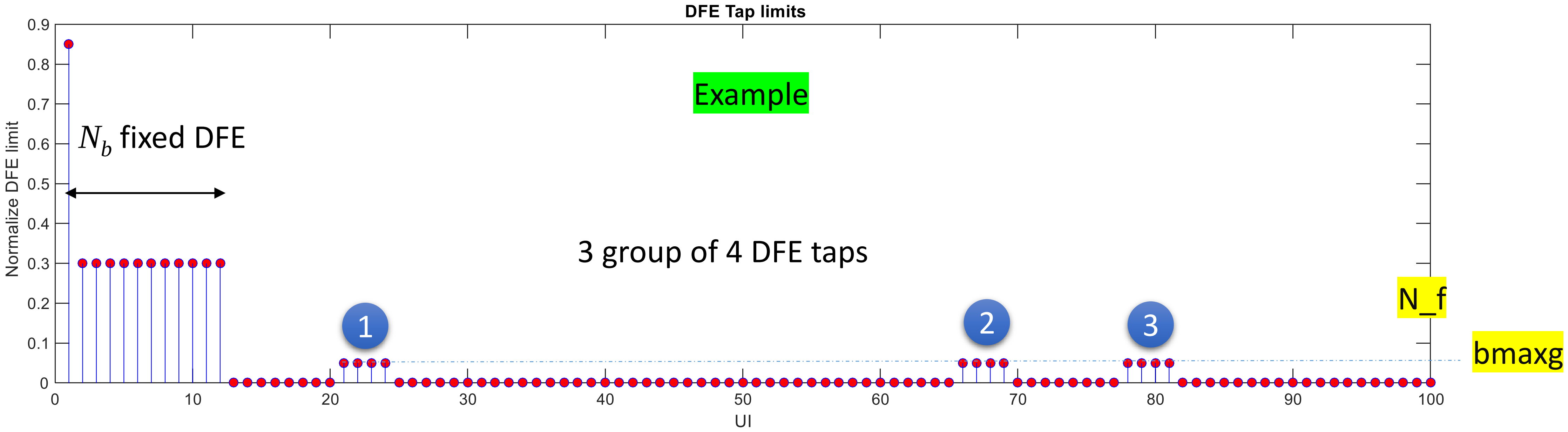
Problem

- Many channels have significant, but deterministic, ISI at timing locations outside of the temporal reach of a fixed tap DFE.

Introduction to Parameters for Floating Tap and Example Values

Floating Tap Parameters in spreadsheet	Example Value	Information
N_bg	3	0, 1, 2 … N_{bg} groups
N_bf	4	taps per group (UI)
N_f	100	UI span for floating taps
bmaxg	0.05	max DFE value for floating taps



Annex 93A Change Overview

Implementation of floating DFE taps in Annex 93A

- ❑ Add a few parameters which represent aspects of floating taps in a DFE
- ❑ Small change to equation 93A-27
- ❑ Add a few lines describing how to determine the location of the floating DFE taps in 93A.1.6
    - Based on the few added parameters
- ❑ Referring section calls out these parameters

Add parameter N_f which is the total reach of the DFE including floating taps

93A.1.6 Determination of variable equalizer parameters

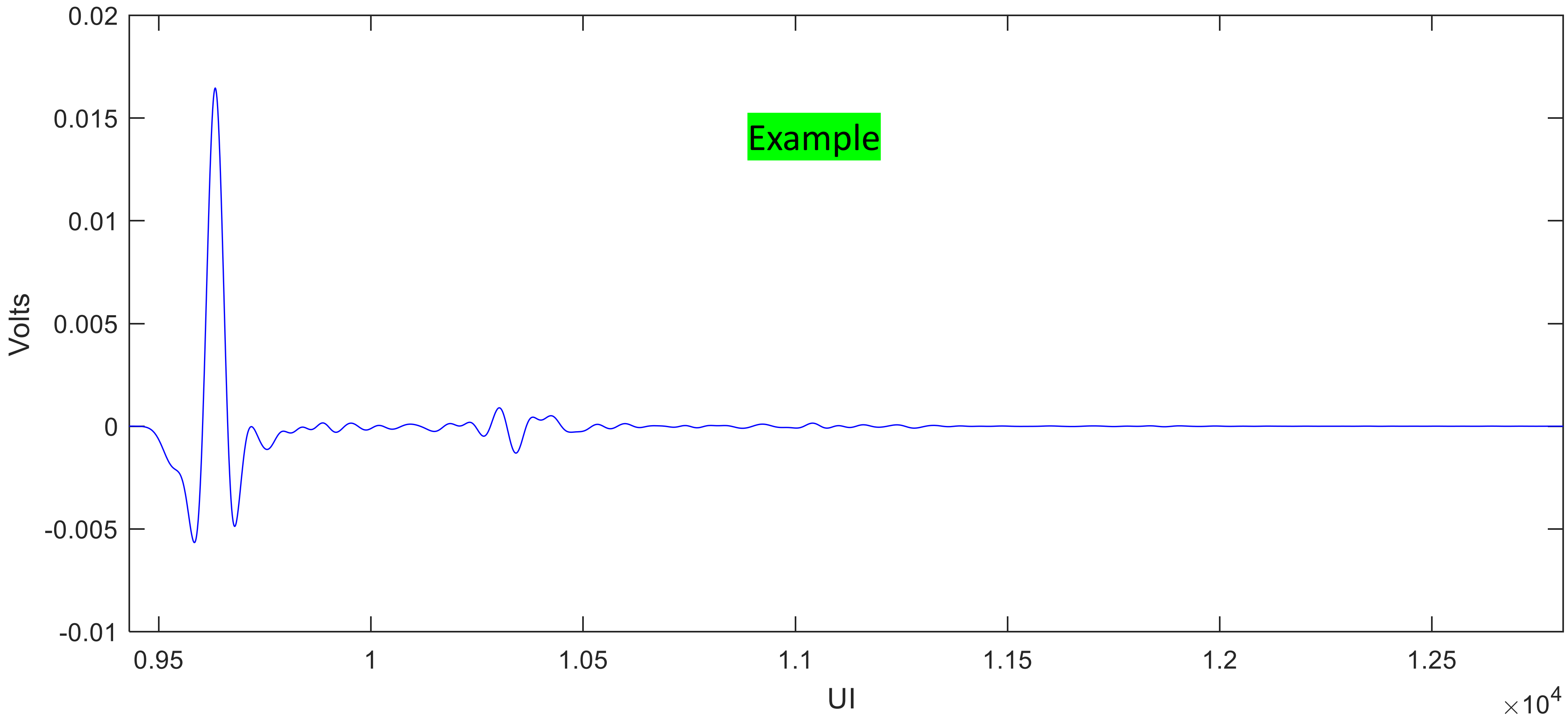
COM is a function of the variables $c(-1)$, $c(1)$, g_{DC}, and g_{DC2}. The following procedure is used to determine the values of these variables that are used to calculate COM.

a) Compute the pulse response $h^{(k)}(t)$ of each signal path k for a given $c(-1)$, $c(1)$, 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 coefficients of the decision feedback equalizer $b(n)$ 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 N_f is not defined in the referring section then considered $N_f = N_b$.**

$h^{(0)}(t)$ is the Pulse Response, PR (Reference Background)

- With all the linear filters applied



Adjust h_{isi} equation 93A-27

We will leverage b_{max}

The DFE action is controlled by vector $b(n)$

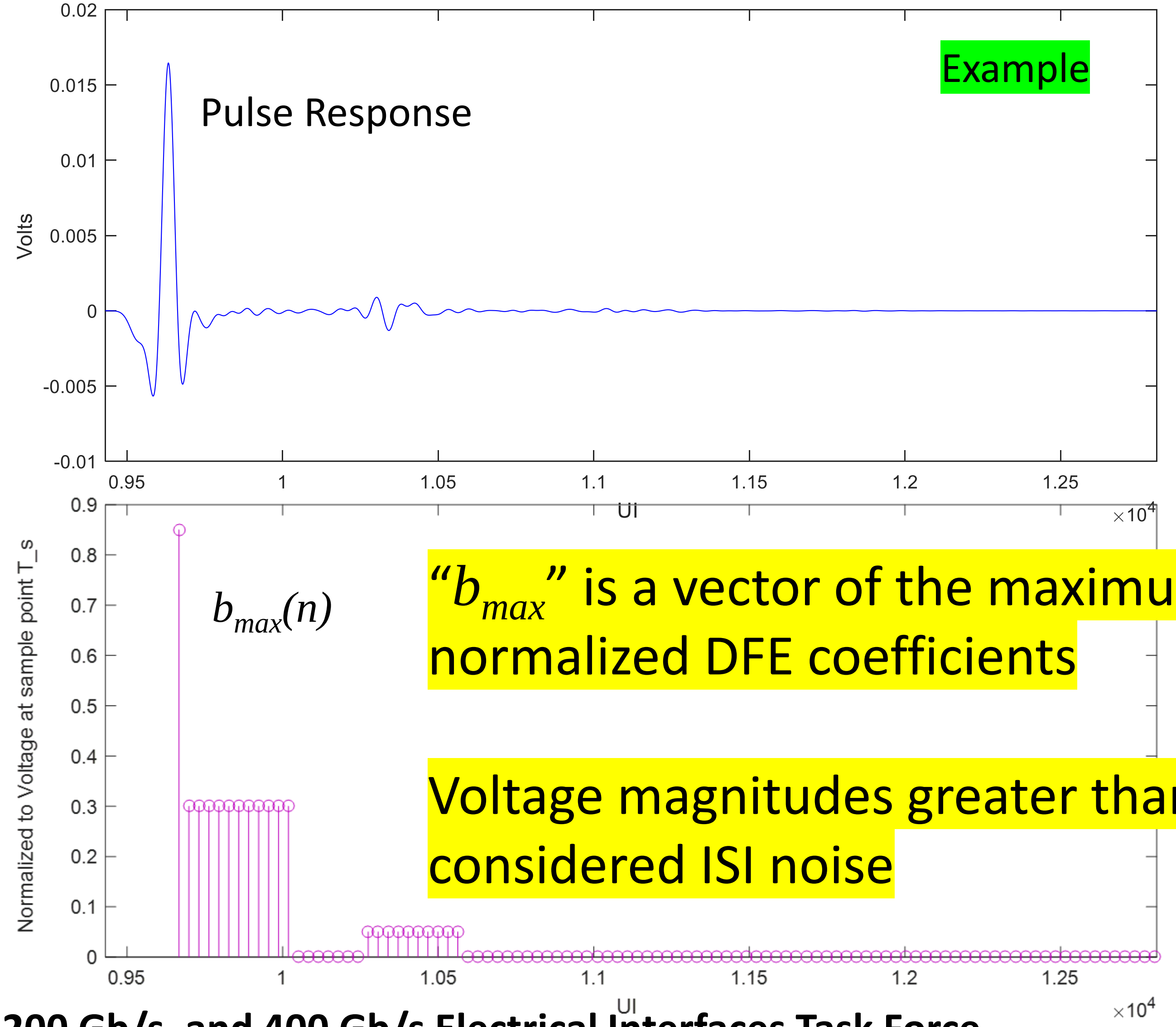
IEEE Std 802.3-2018, IEEE Standard for Ethernet
SECTION SIX

$$b(n) = \begin{cases} -b_{\max}(n) & h^{(0)}(t_s + nT_b)/h^{(0)}(t_s) < -b_{\max}(n) \\ b_{\max}(n) & h^{(0)}(t_s + nT_b)/h^{(0)}(t_s) > b_{\max}(n) \\ h^{(0)}(t_s + nT_b)/h^{(0)}(t_s) & \text{otherwise} \end{cases} \qquad (93A\text{–}26)$$

$$h_{ISI}(n) = \begin{cases} 0 & n = 0 \\ h^{(0)}(t_s + nT_b) - h^{(0)}(t_s)b(n) & 1 \le n \le \overset{N_f}{\cancel{N_b}} \\ h^{(0)}(t_s + nT_b) & \text{otherwise} \end{cases} \qquad (93A\text{–}27)$$

From here, $h_{isi}(n)$ is used to compute ISI noise for computing COM for every combination of linear filter settings

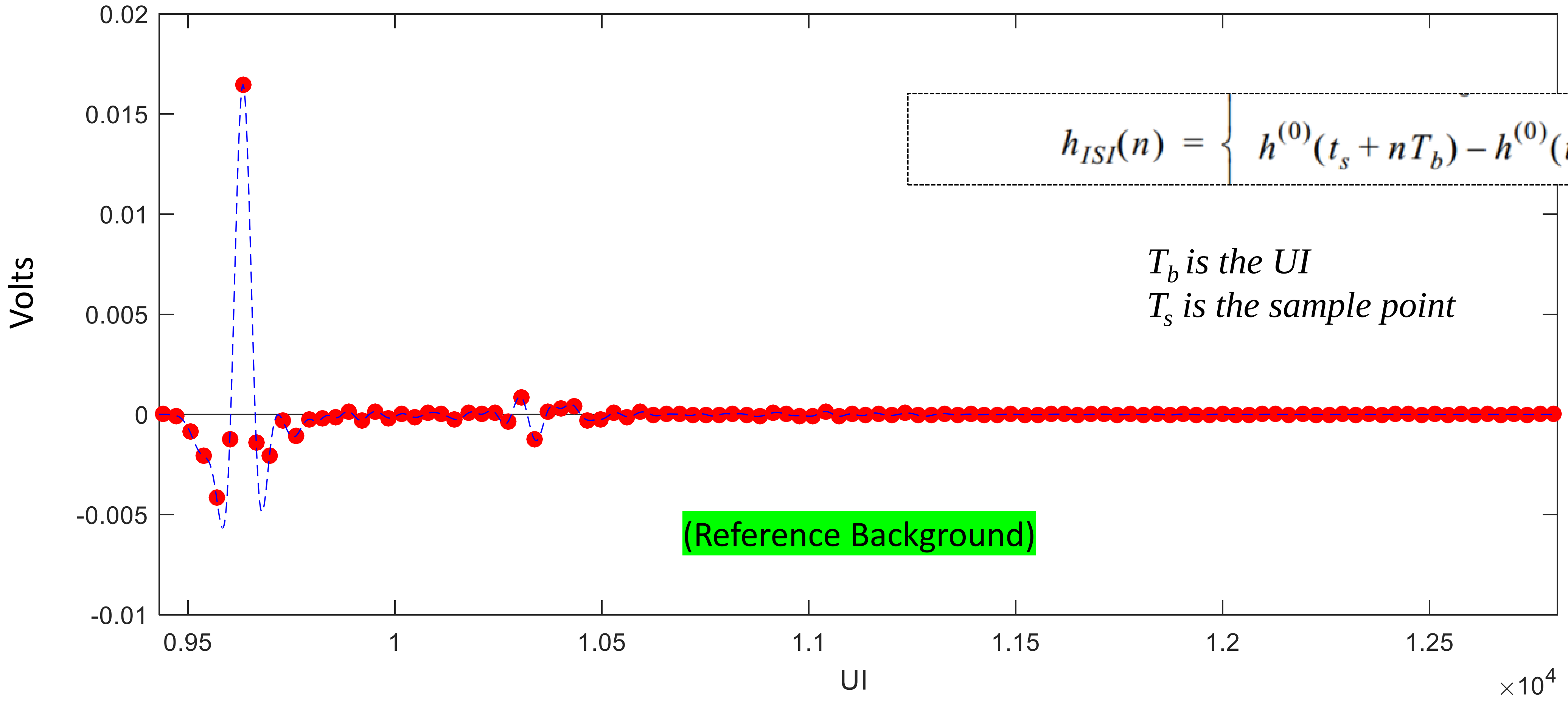
The “n” in $b_{max}(n)$ is in reference to the PR



“b_{max}” is a vector of the maximum allowable normalized DFE coefficients

Voltage magnitudes greater than “$bmax$” are considered ISI noise

$h^{(0)}(t_s + n\,T_b)$ is the sampled pulse response (red dots)

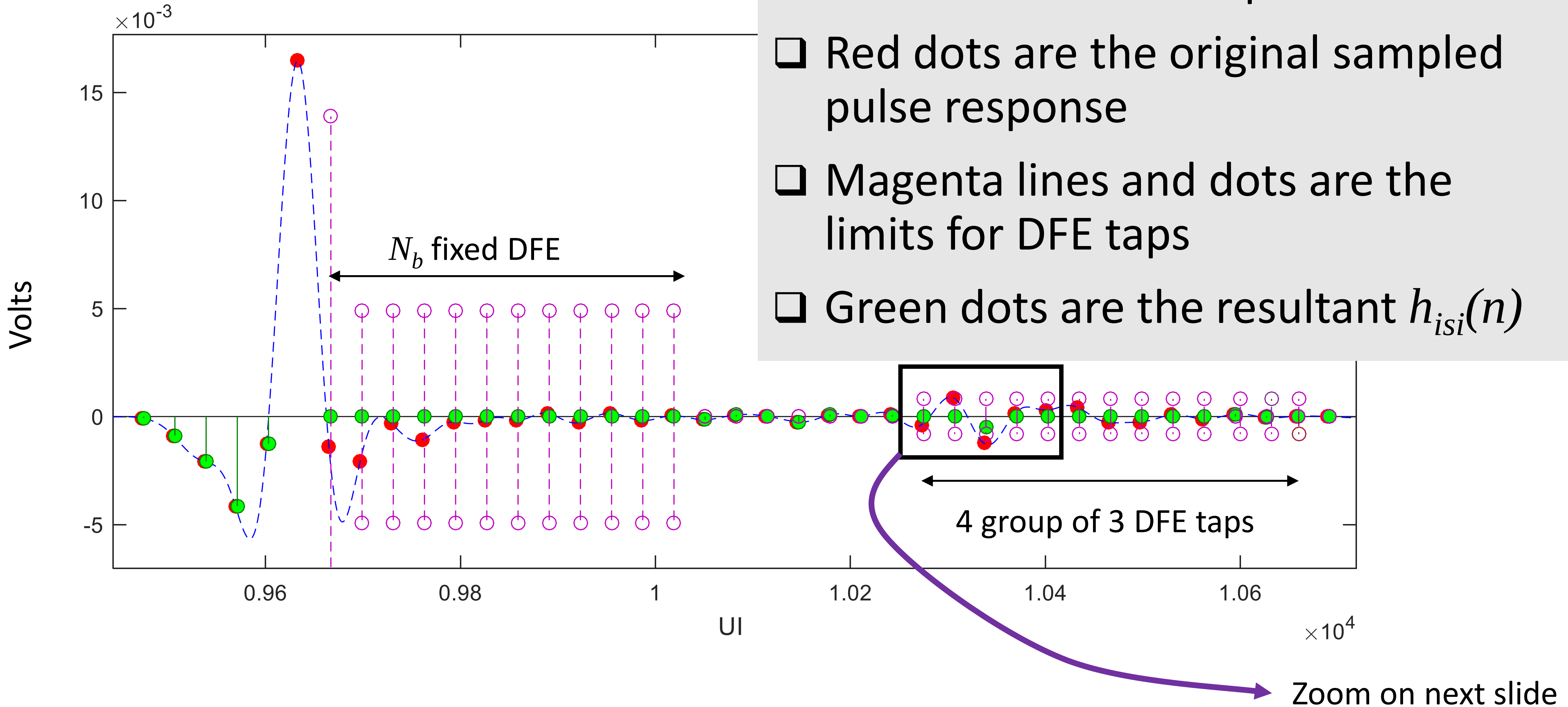


$$h_{ISI}(n) = \left\{ h^{(0)}(t_s + nT_b) - h^{(0)}(t_s)b(n) \right.$$

T_b *is the UI*

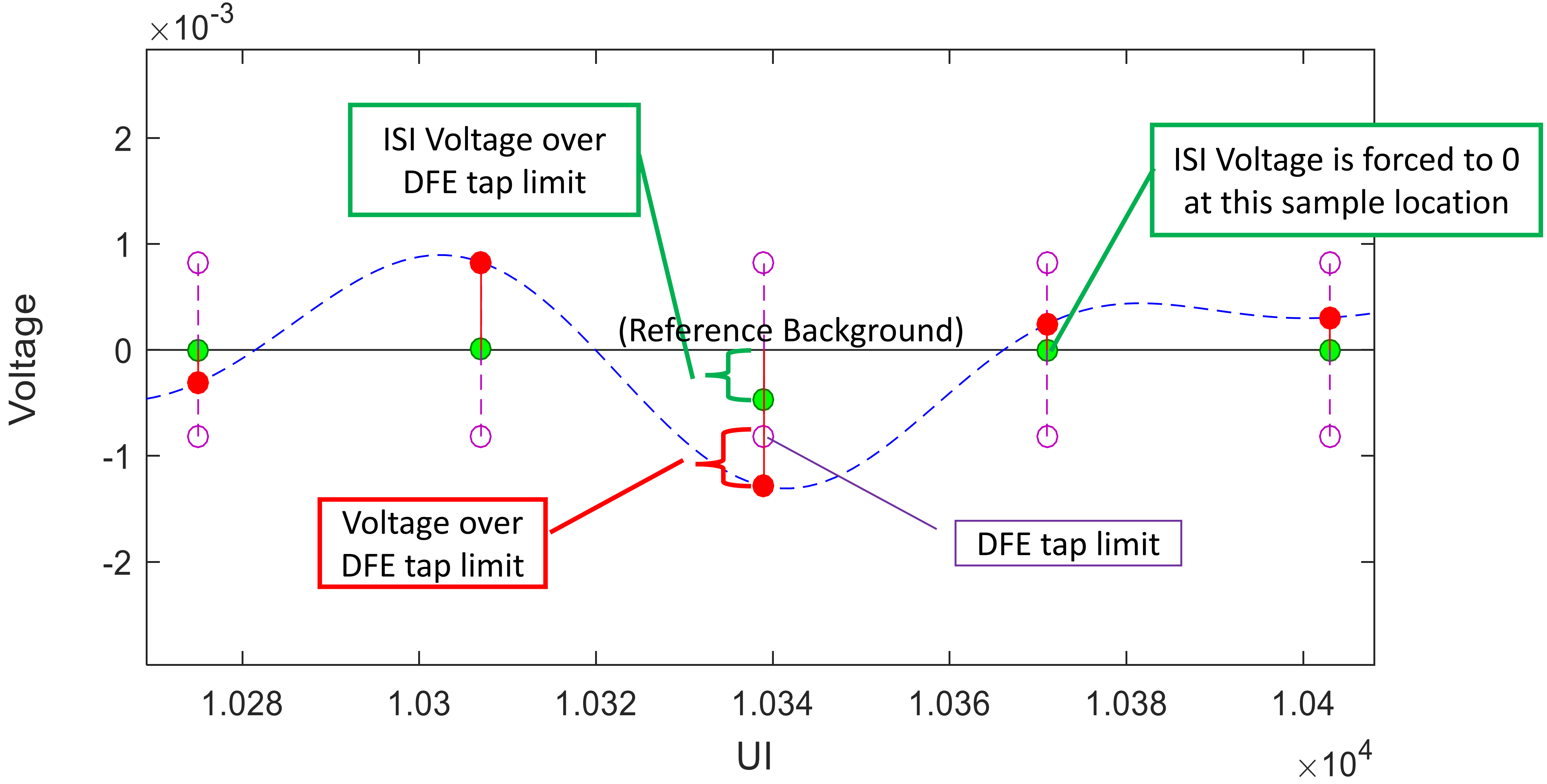
T_s *is the sample point*

Example of 3 groups of 4 DFE taps



- ❑ Blue dashed is the equalize PR
- ❑ Red dots are the original sampled pulse response
- ❑ Magenta lines and dots are the limits for DFE taps
- ❑ Green dots are the resultant $h_{isi}(n)$

Example of Residual ISI over the b_{max} limit (Reference Background)



Insert steps for adjusting $b_{max}(n)$ in 93A.1.6

Insert rules to determine $b_{max}(n)$ here

93A.1.6 Determination of variable equalizer parameters

COM is a function of the variables $c(-1)$, $c(1)$, g_{DC}, and g_{DC2}. The following procedure is used to determine the values of these variables that are used to calculate COM.

a) Compute the pulse response $h^{(k)}(t)$ of each signal path k for a given $c(-1)$, $c(1)$, 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 coefficients of the decision feedback equalizer $b(n)$ 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.

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

d) Compute σ_{TX}^2 per Equation (93A–30) and Equation (93A–29). This represents the noise output from the transmitter.

e) Compute $h_{ISI}(n)$ per Equation (93A–27). This represents the residual intersymbol interference (ISI) after decision feedback equalization. The corresponding ISI amplitude variance σ_{ISI}^2 is computed per Equation (93A–31) and Equation (93A–29).

f) Compute the slope of the pulse response of the victim path $h_J(n)$ as shown in Equation (93A–28). The variance of the amplitude error due to timing jitter σ_J^2 is computed per Equation (93A–32) and Equation (93A–29).

g) The variance of the amplitude for path k is given by Equation (93A–33) where the phase index m can assume any integer value from 0 to M–1. Denote the value of m that maximizes the variance for path k as i. The variance of the amplitude for the combination of all crosstalk paths σ_{XT}^2 is then computed using Equation (93A–34), which is the sum of the maximum variances for the individual paths k=1 to K–1.

h) Compute the variance of the noise at the output of the receive equalizer σ_N^2 based on the one-sided spectral density η_0 referred to the receiver noise filter input per Equation (93A–35).

i) Compute the figure of merit (FOM) per Equation (93A–36).

$$h^{(0)}(t_s - T_b) = h^{(0)}(t_s + T_b) - h^{(0)}(t_s)b(1) \qquad (93A\text{–}25)$$

Rules for Floating Tap Determination of $b(n)$

$$h_{ISI}(n) = \begin{cases} 0 & n = 0 \\ h^{(0)}(t_s + nT_b) - h^{(0)}(t_s)b(n) & 1 \le n \le \cancel{N_b}\ N_f \\ h^{(0)}(t_s + nT_b) & \text{otherwise} \end{cases} \longrightarrow h_{nf}(n)$$

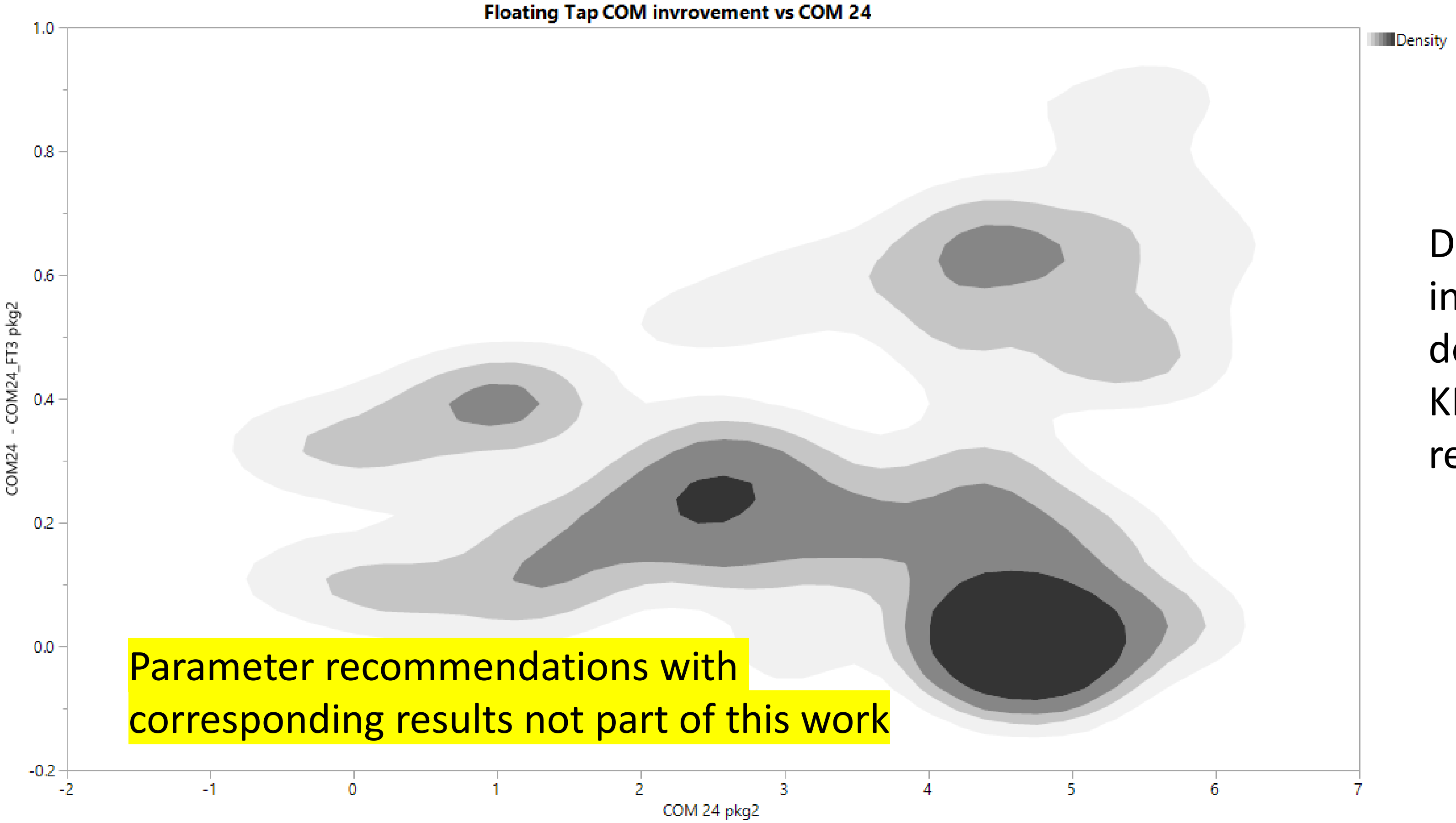
- Define post cursor ISI vector as $h_{nf}(n) = h_{ISI}(n),\ 1 \le n \le N_f$
- $b(1 \ldots N_b)$ *is* as specified in referring section *(no change from prior)*

Determine the location of non-zero $b(n)$ corresponding to each of N_{bg} groups

1. Initially *set* $b(N_b+1 \ldots N_f) = 0$
2. Determine the value for N_{gx} which "minimizes" the $\sum h_{nf}(n)^2$
   - Where $b(N_{gx} \ldots N_{gx}+N_{gf}) = b_{maxg}$ and $N_b+1 \le N_{gx} \le N_f - N_{gx}$
   - I.e. set b_{max} for all the taps in the group
3. Find N_{gx} for each of N_{bg} groups by repeating step 2

Floating taps can improve COM up to to ½ dB compared to channels with DFE24 (fixed) COM which are near 3 dB

COM Floating Tap improvement (dB) Tap 12 fixed, 3 groups of 4 taps



COM using 24 fixed tap (dB)

Darker contours indicates population density of the 118 KR channels in the region

Summary

- ❑ Floating can be added to Annex 93A (COM)
- ❑ Only a few simple alterations to Annex 93A (COM) are required to implement floating DFE taps.
- ❑ Referring sections need only to specify 4 parameters, N_{bg}, N_{bf}, N_f and b_{maxg}

Thank You!