RS(544,514) FEC performance for KR/CR 100G (updated)

Pete Anslow, Ciena

IEEE P802.3ck Task Force, 10 April 2019

Introduction

wu_3ck_adhoc_01_022719 proposed to set:

“b_max(1) = 0.85 & b_max(2..N_b) = 0.35”

and asked whether this would cause issues with error propagation.

sun_3ck_02a_0119.zip contained a spreadsheet that included tap settings for 115 channels with the limits of:

b_max(1) = 0.85 and b_max(2..N_b) = 0.3

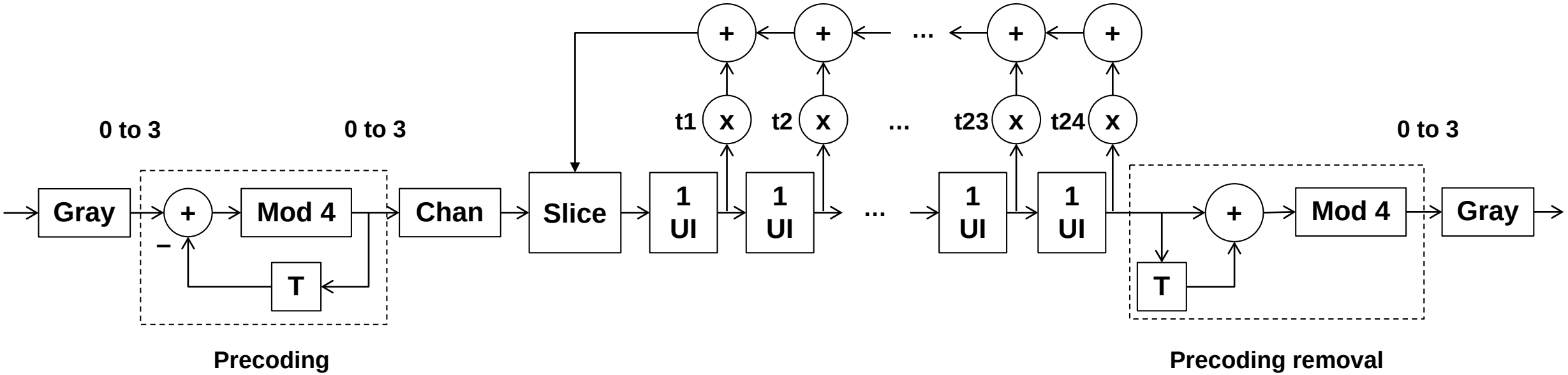
anslow_3ck_01_0319 contained analysis using a 5-tap DFE, but the tap settings were viewed by some as too unrealistic.

This contribution still uses the data from sun_3ck_02a_0119.zip but with a 24-tap DFE model and CH78 for the starting tap values.

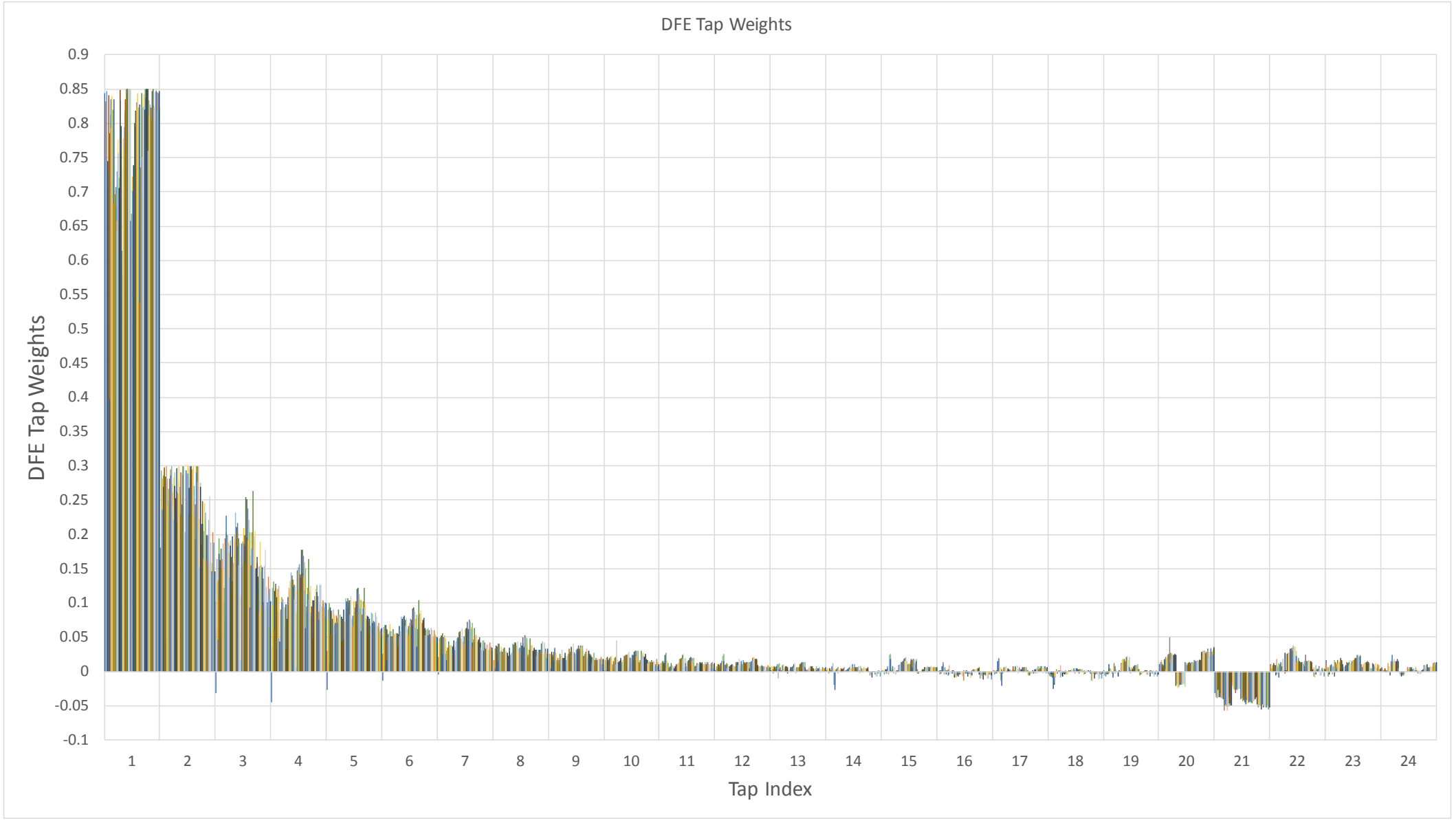
It also contains some investigation of End of Burst Detection (EoBD).

Precoding and 24-tap DFE model

The multi-tap DFE results with precoding in anslow_3ck_01_0319 were for a 5-tap DFE. To investigate the effect of the later taps, this model has been extended to a 24-tap DFE as below.



Tap settings from sun_3ck_02a_0119.zip



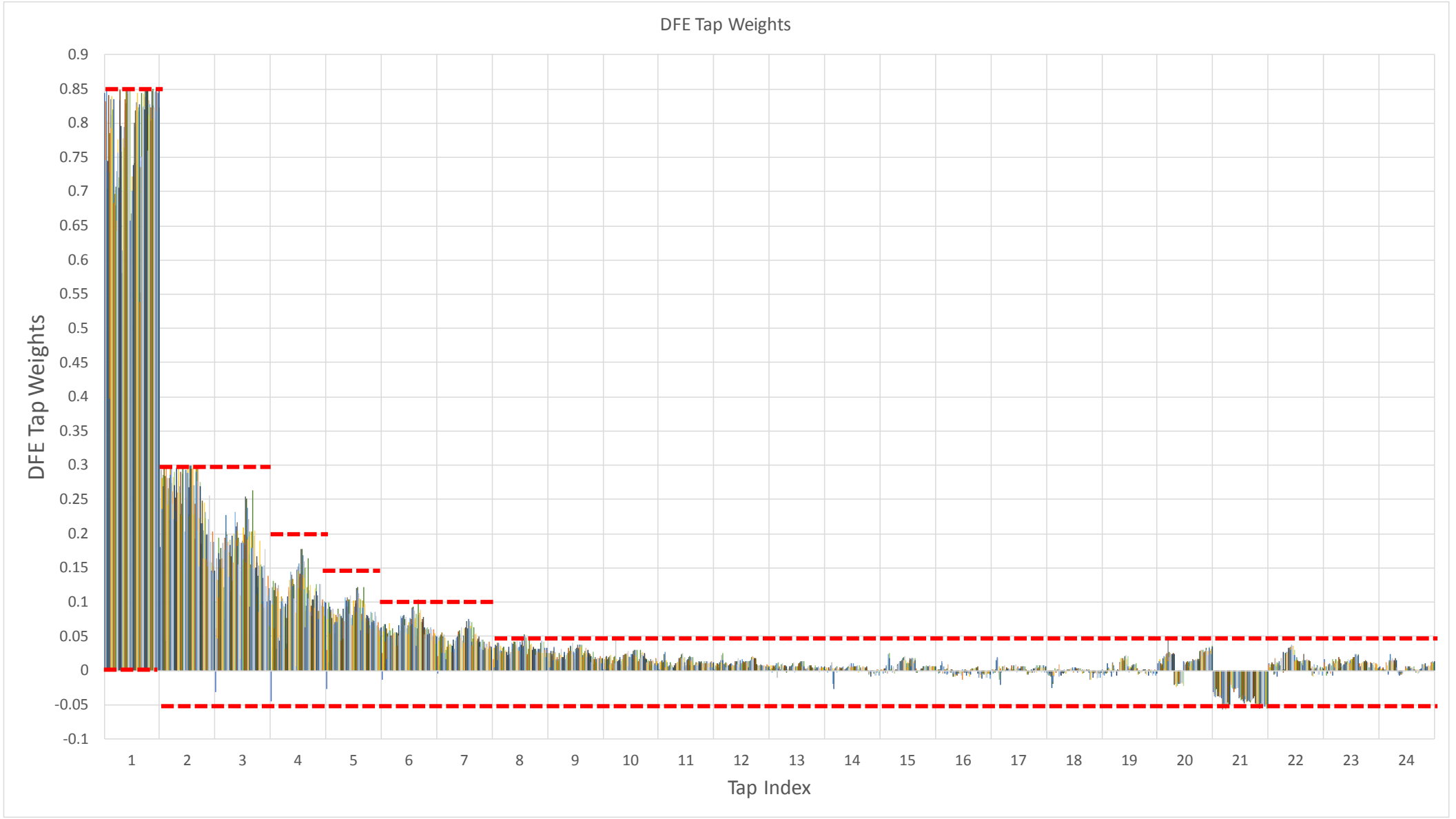
Candidate DFE tap limits 1

A set of DFE tap constraints that would not exclude these tap settings is:

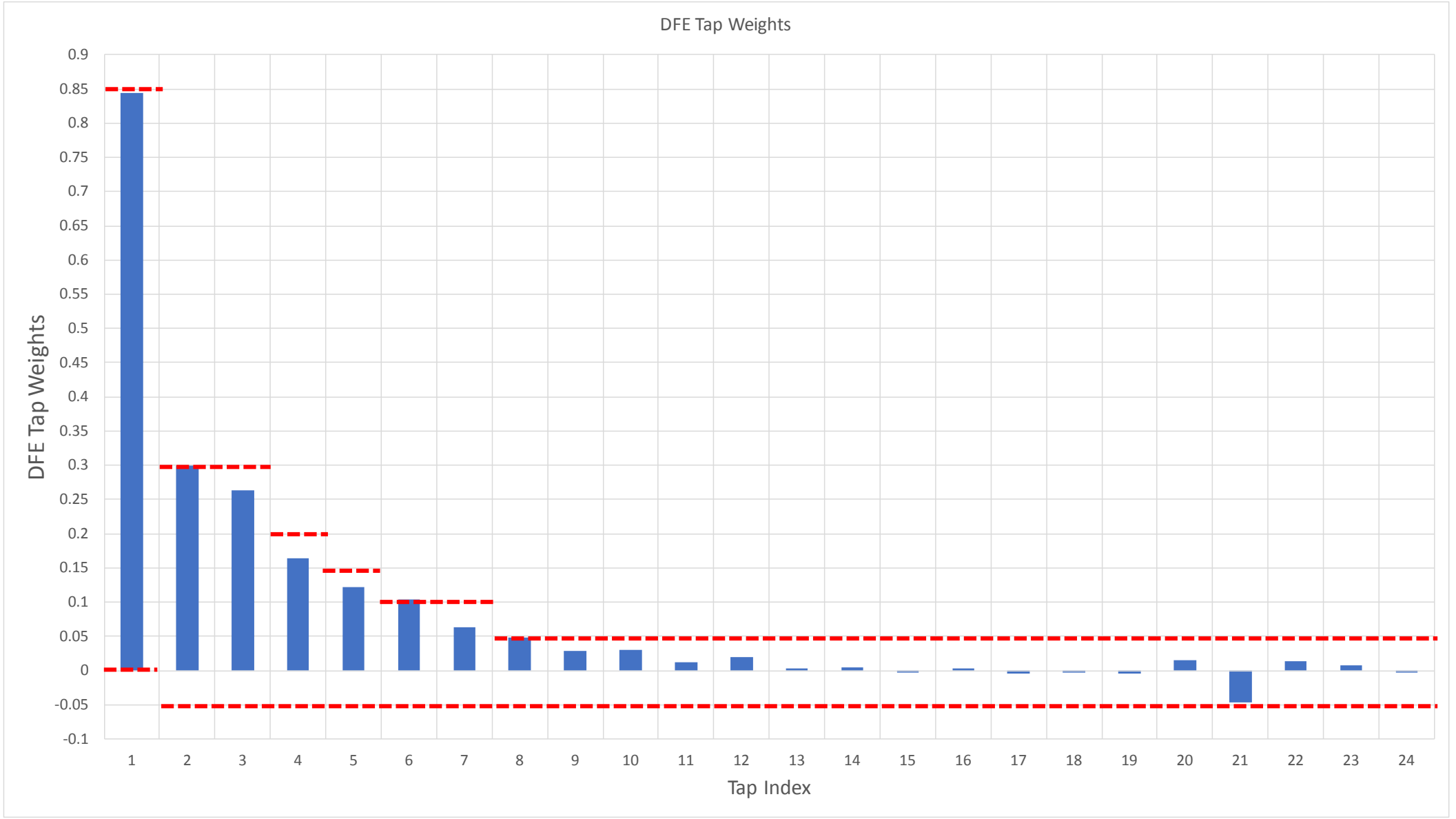
$$0 \le t1 \le 0.85$$
$$-0.05 \le t2 \le 0.3$$
$$-0.05 \le t3 \le 0.3$$
$$-0.05 \le t4 \le 0.2$$
$$-0.05 \le t5 \le 0.15$$
$$-0.05 \le t6 \le 0.1$$
$$-0.05 \le t7 \le 0.1$$
$$-0.05 \le t8 \ldots t24 \le 0.05$$

These constraints are illustrated on page 6.

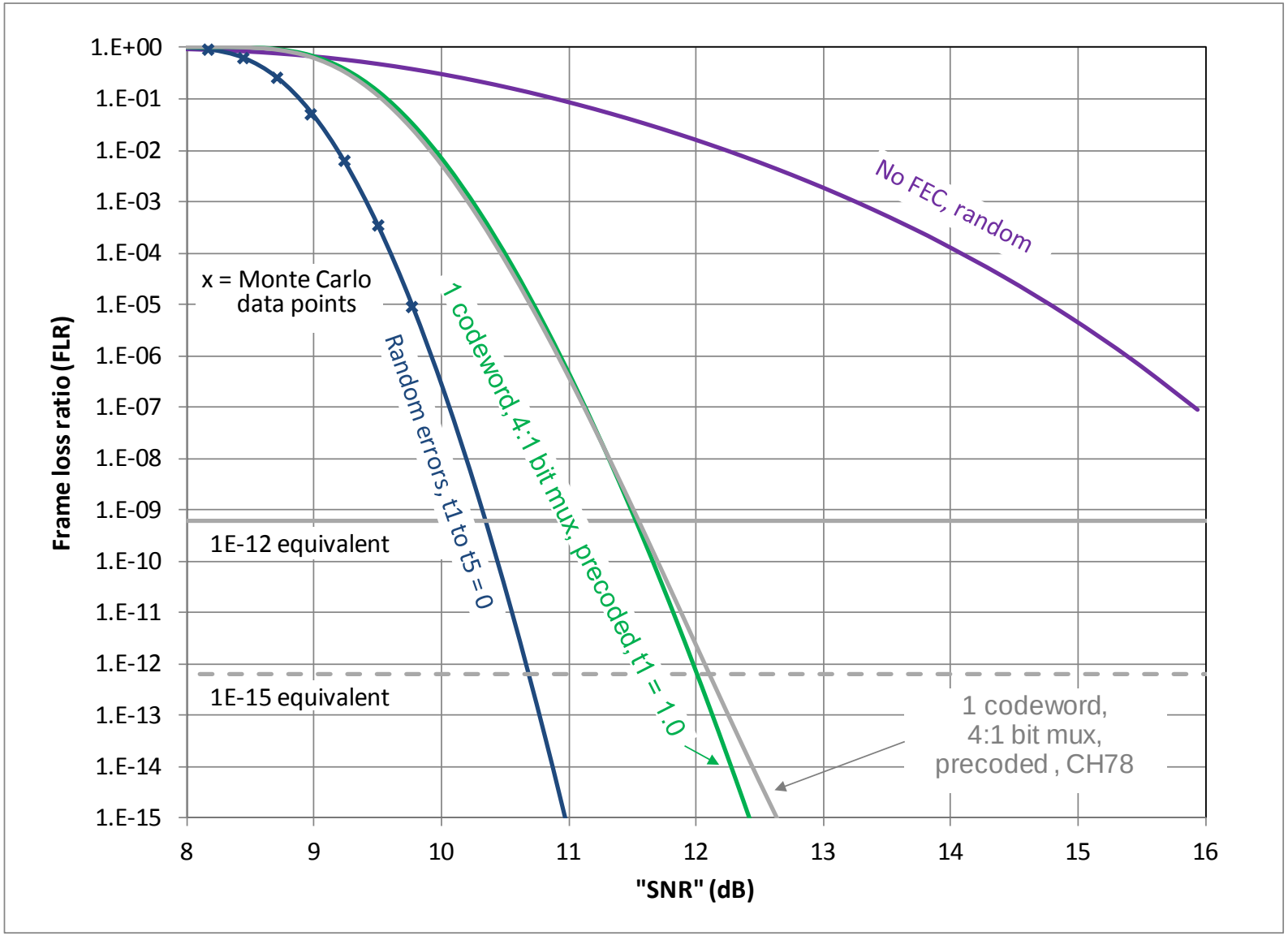
Illustration of candidate tap limits 1



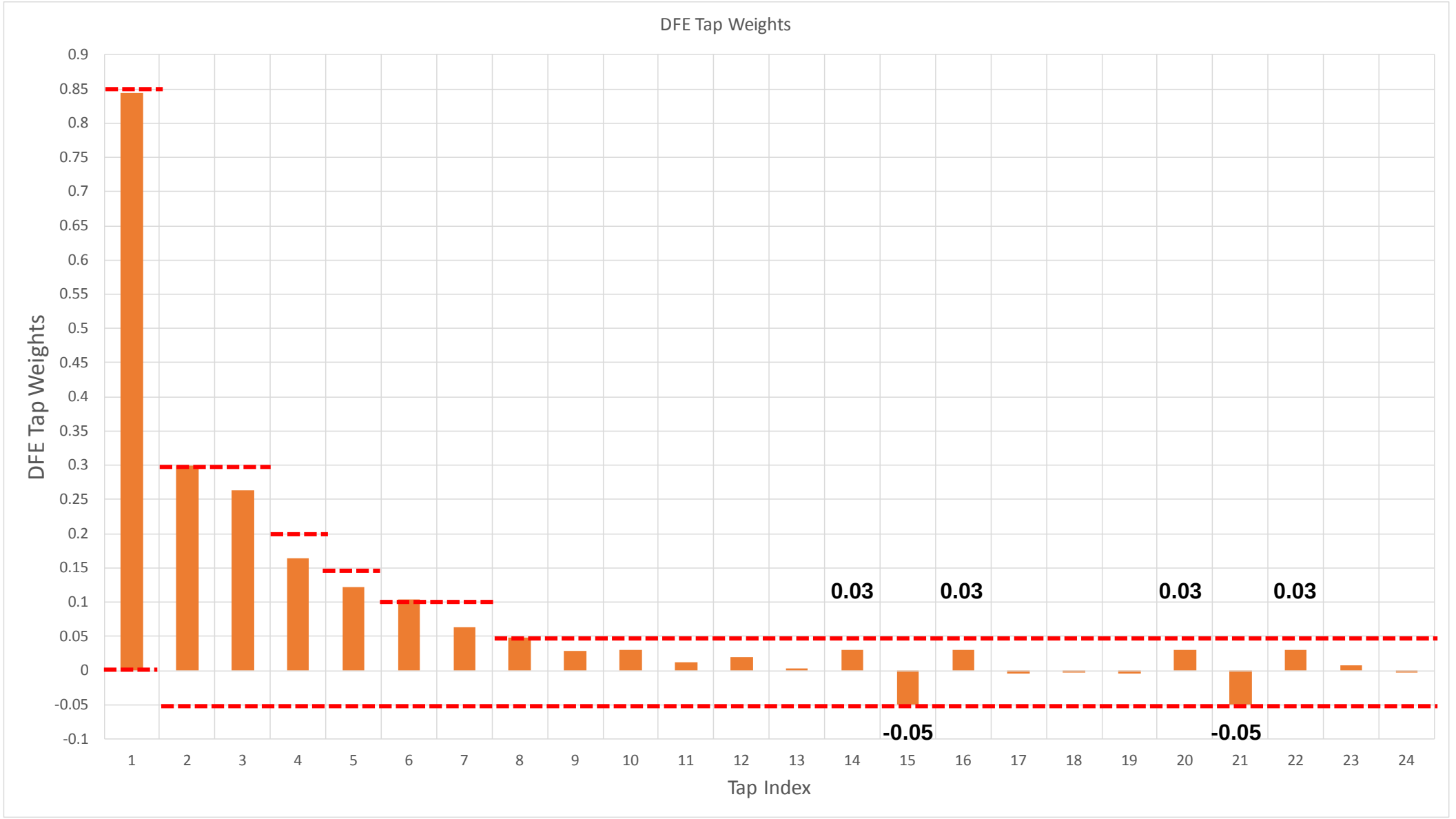
CH78


DFE Tap Weights
DFE Tap Weights
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Tap Index

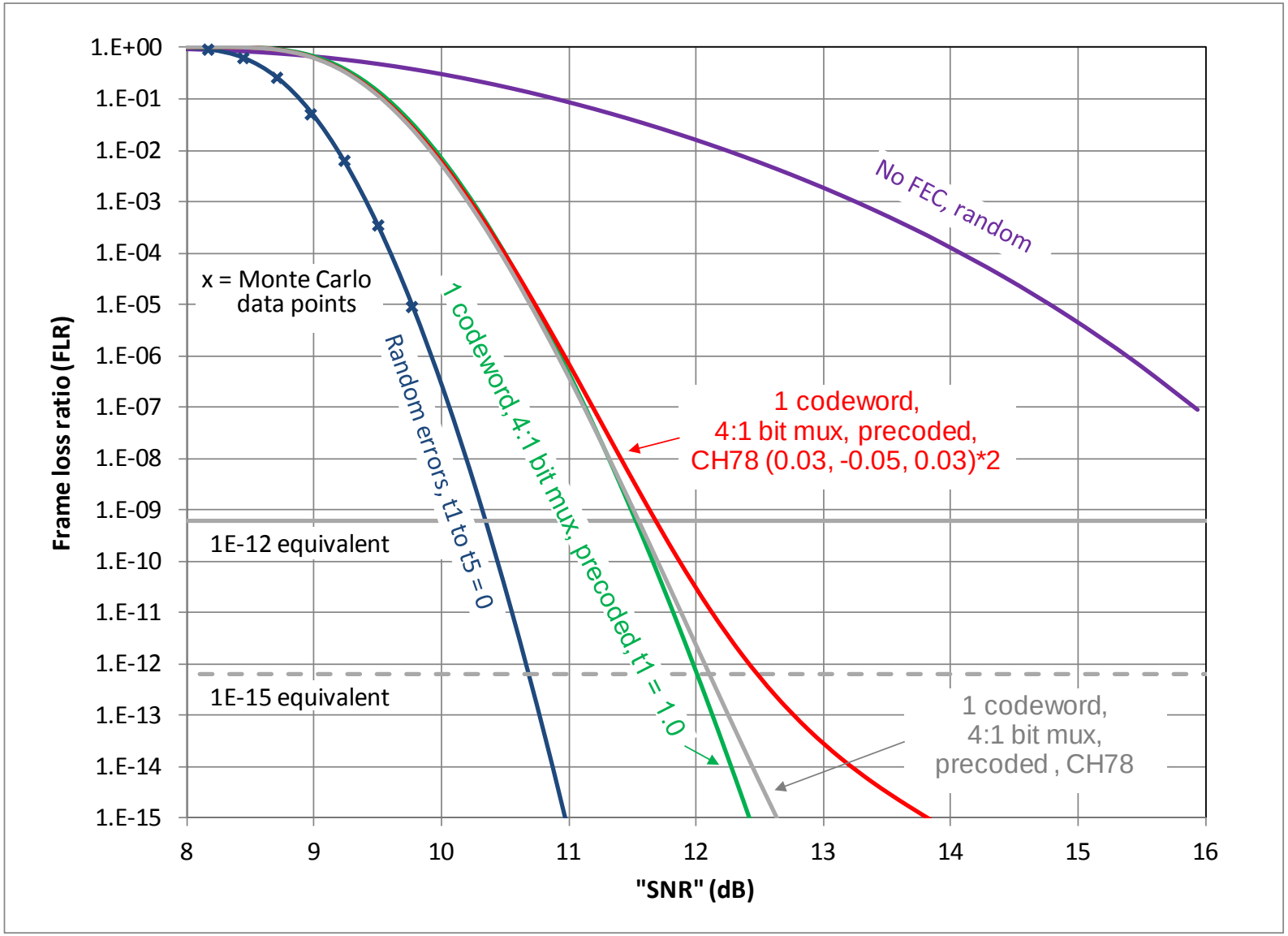
100G with 24-tap DFE CH78 with precoding



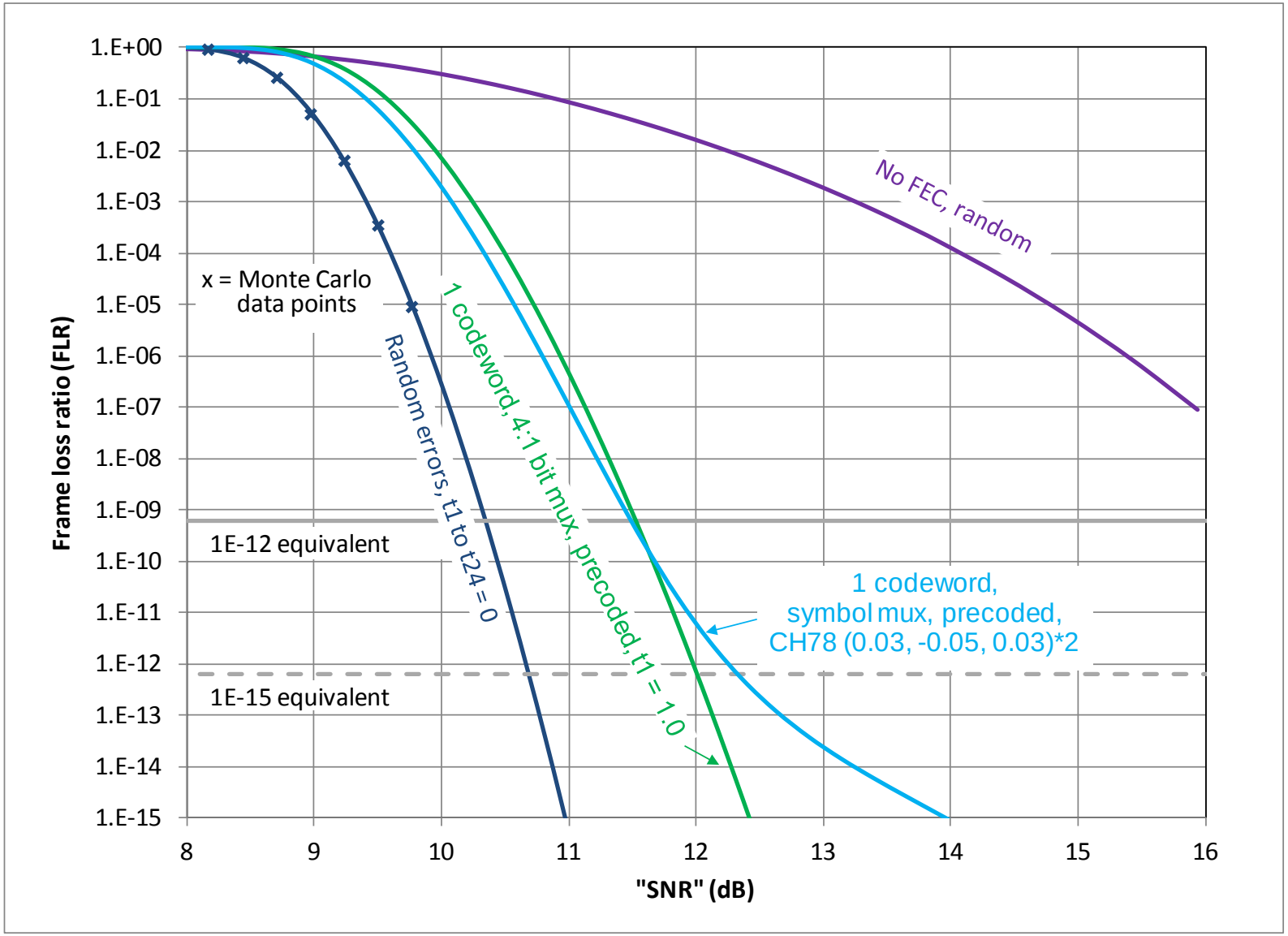
CH78 with modified late taps



100G with 24-tap DFE CH78 (0.03, -0.05, 0.03)*2 with precoding



100G with 24-tap DFE CH78 (0.03, -0.05, 0.03)*2 with symbol mux



24-tap DFE conclusion

The modifications made to the CH78 tap settings to try to find a realistic worst case set of taps were modest and probably underestimate the actual worst case set of taps that would pass the other specifications.

The 24-tap DFE model used here assumes that the combination of FFE and DFE used is able to create a completely open eye in the absence of any errors. This means that the penalties predicted by this model are an underestimate of the actual penalties far a given set of taps.

Given the two considerations above, there is still a concern that even if the taps are constrained to be within the bounds on page 5, the worst case performance may lead to an excessive FLR in practice.

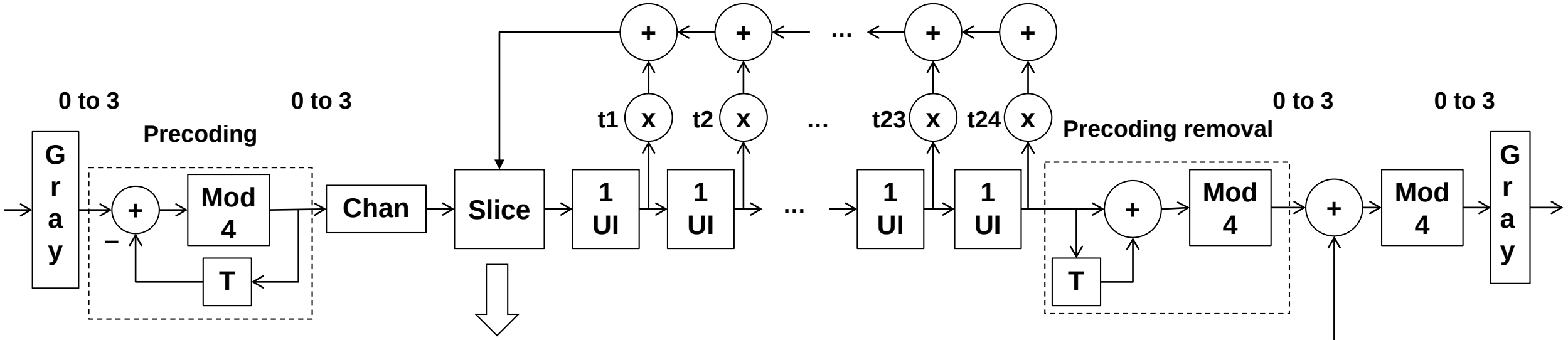
Symbol interleaving in the PMA has slightly better performance than bit interleaving, but changing the PMA for 100G KR/CR in this way is a significant change for a small gain.

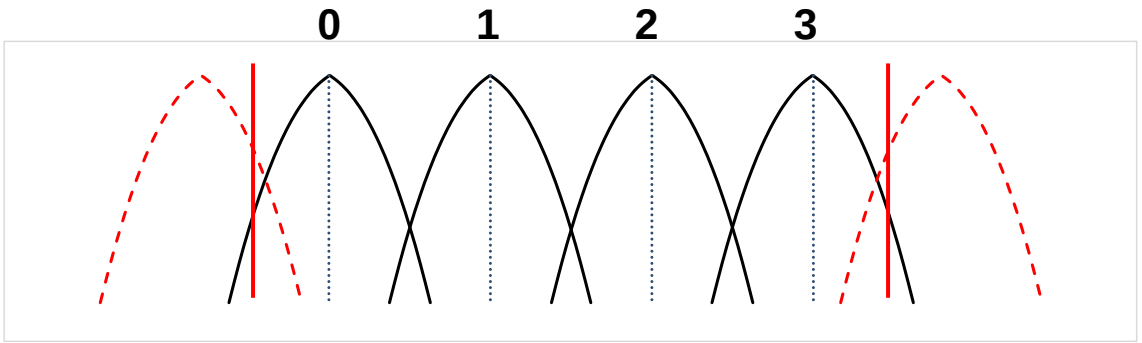
End of Burst Detection

Called “Precoding 2.0” in lu_3ck_01_0319

End of Burst Detection (EoBD) model

lu_3ck_01_0319 proposed that End of Burst Detection (EoBD) could be used to improve performance in precoded systems. The model used to investigate this was as below.





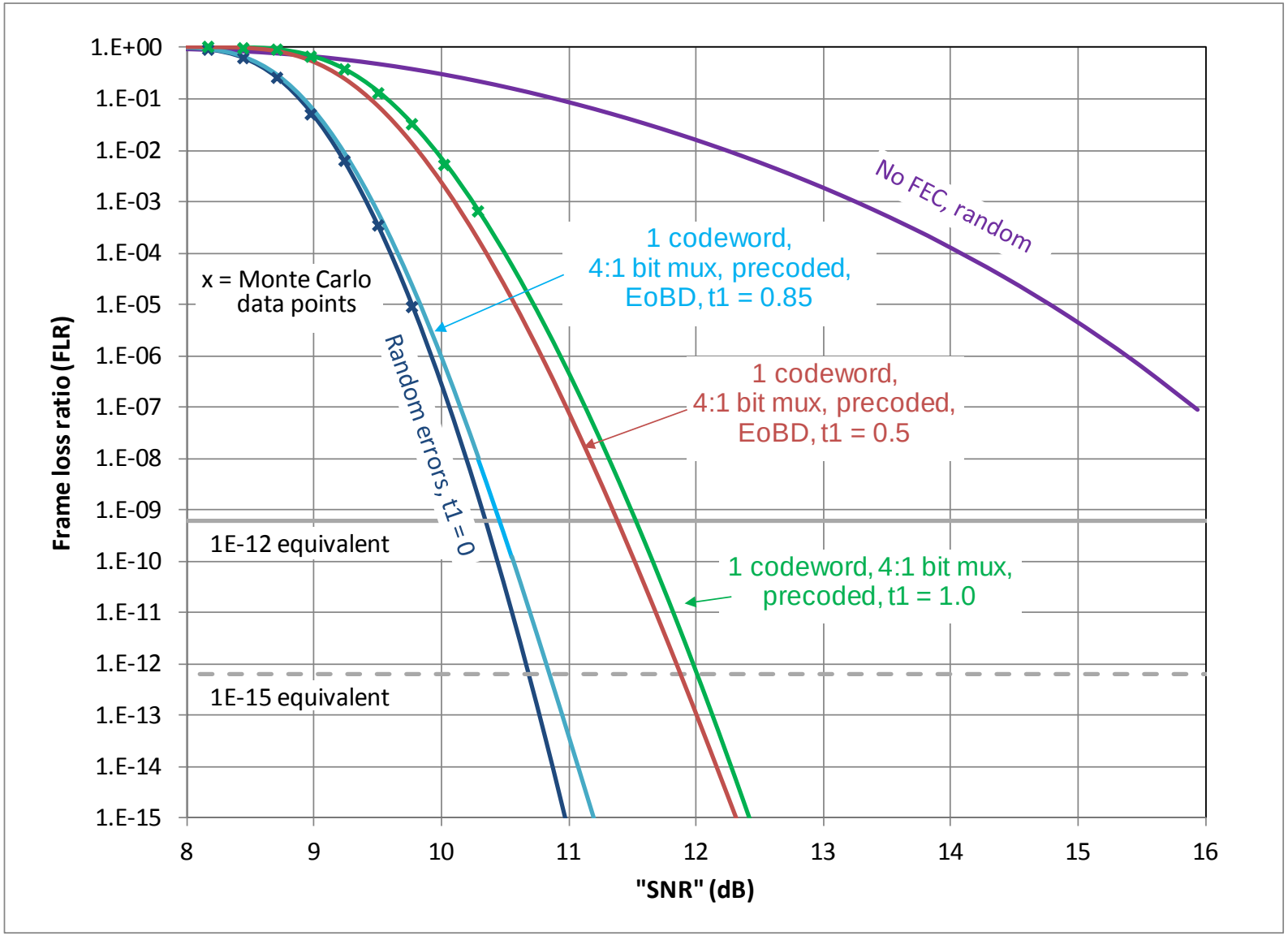
Above upper threshold = 1
In between thresholds = 0
Below lower threshold = -1

EoBD characteristics for a 1-tap DFE

For a 1-tap DFE with a large tap value, samples at the end of an error burst are generally outside the range of samples seen at other times (red dashed curves on previous page). Consequently, thresholds can be set so that the probability of falsely detecting an end of burst is low and the probability of failing to detect an end of burst is also low. In this case, the end of burst detector is able to convert the normal precoding case of two symbol errors per burst to close to one symbol error per burst. See next page for a plot of the case of t1 = 0.85.

As the tap value for a 1-tap DFE is reduced, the samples at the end of an error burst move closer to the range of samples for the 0 and 3 levels (the red dashed curves on previous page move inwards). This makes it more difficult to reliably detect the end of a burst and the optimum positions for the two detection thresholds move inwards also. Consequently, the performance curve for this case is worse than for a high tap value. The limiting case is when the tap value is small enough that the curve without precoding becomes better than the one for precoding with EoBD. See next page for a plot of the case of t1 = 0.5.

100G with 1-tap DFE and EoBD

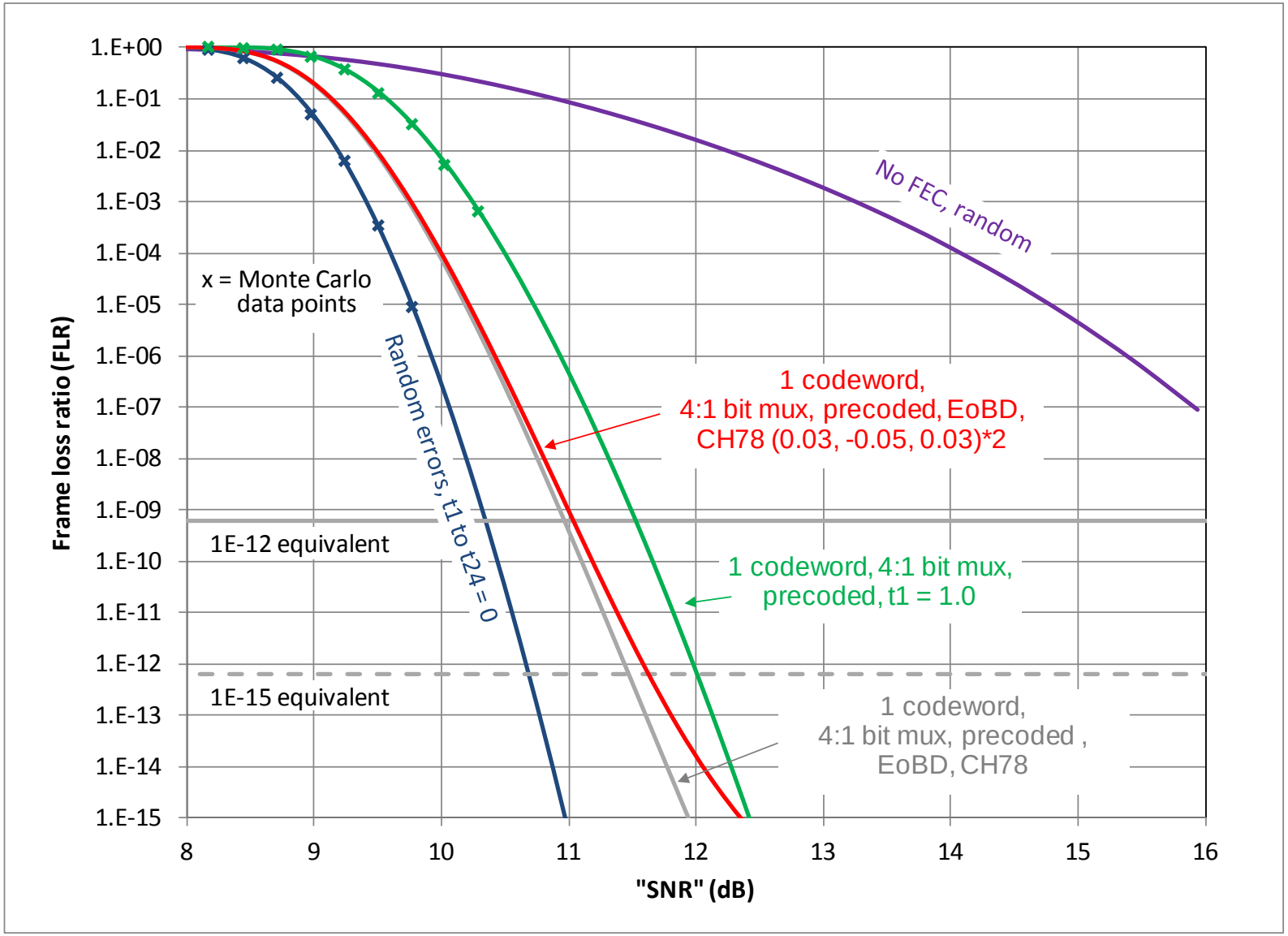


EoBD characteristics for a multi-tap DFE

For a multi-tap DFE, the situation is more complex as the sample at the end of a burst has an offset due to the pattern of errors that is propagating through the DFE structure multiplied by the tap weights.

However, there still seems to be a significant improvement in performance for CH78 and CH78 with modifications as shown on the next page.

100G with 24-tap DFE and EoBD



End of Burst Detection (EoBD) conclusion

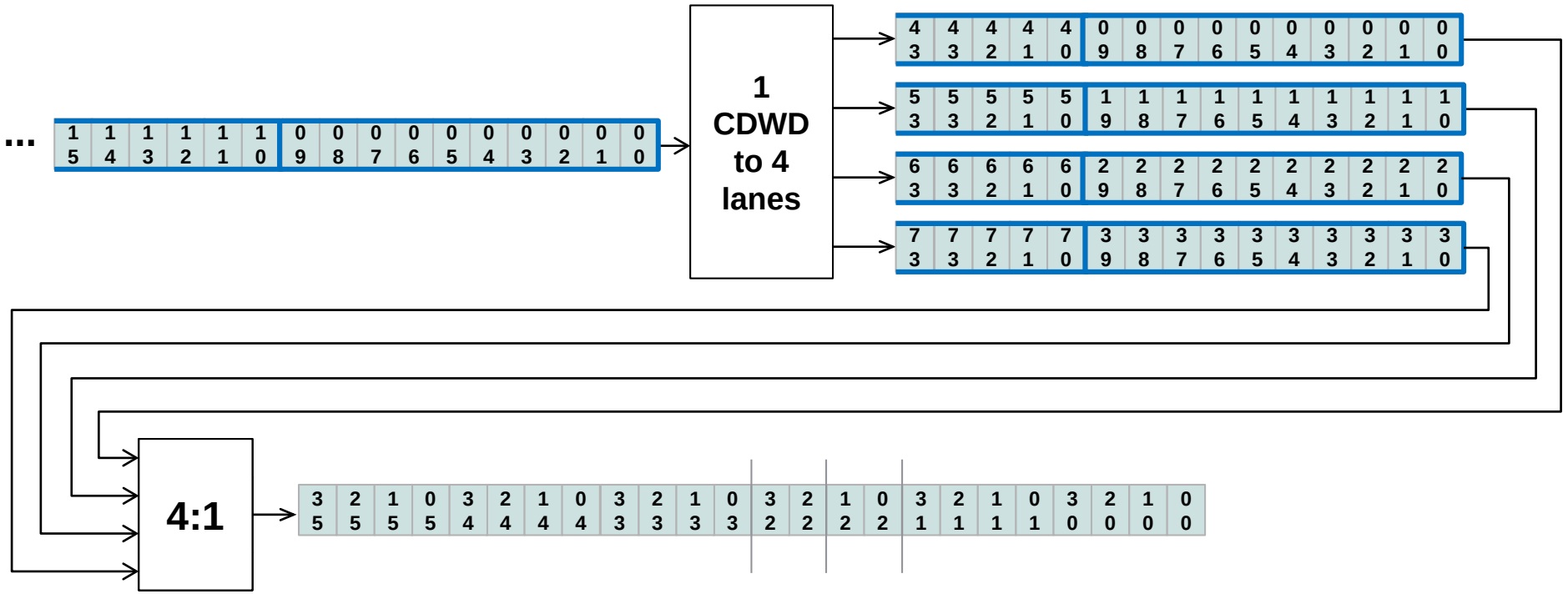
End of Burst Detection (EoBD) improves the performance in the two multi-tap cases simulated, with 0.85 dB improvement for CH78 with modified late taps at an FLR equivalent to 1E-15 BER.

Assuming that there are no barriers to practical implementation of this technique, does this offer sufficient improvement in all cases that FEC interleaving is not required?

Annex

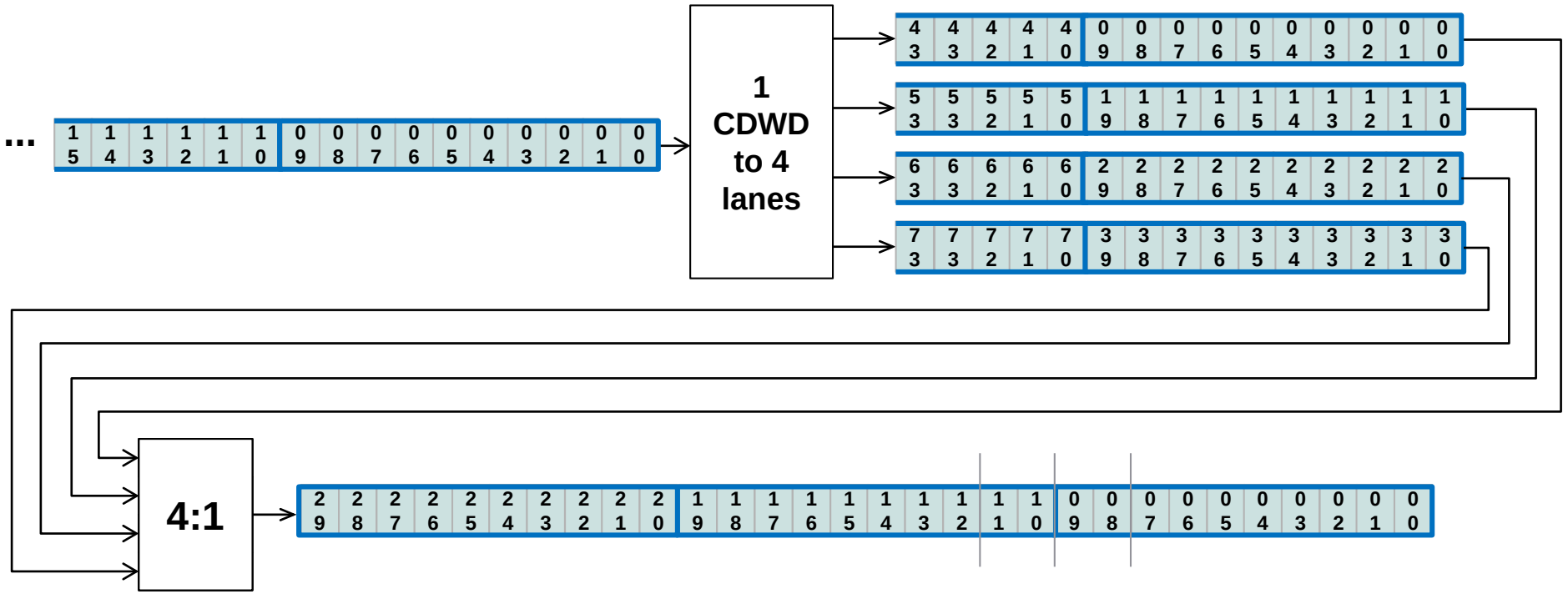
Clause 91 100G with bit mux PMA

Round robin distribution of FEC symbols to the FEC lanes. Bit multiplex in the PMA.



Clause 91 100G with symbol mux PMA

Round robin distribution of FEC symbols to the FEC lanes. Symbol multiplex in the PMA.



Thanks!