

RS(544,514) FEC performance for C2M 400G and 100G without interleaving

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Introduction

[anslow_3ck_01_0918](#) showed that for 100G using a Clause 91 FEC sublayer, 4:1 bit muxing and precoding, the performance expected with a multi-tap DFE with a large first tap and medium sized subsequent taps is likely to be unacceptable.

This presentation provides curves for smaller first tap and smaller subsequent tap values that may be appropriate for a chip-to-module (C2M) interface.

Slides defining the DFE model used and the assumed FEC interleaving schemes are contained in an Annex.

Candidate C2M DFE tap limits 1

It has been proposed to limit the C2M Rx to be a four tap DFE with constraints:

$$\begin{aligned}0 &\leq t_1 \leq 0.5 \\ -0.05 &\leq t_2 \leq 0.2 \\ -0.1 &\leq t_3 \leq 0.1 \\ -0.05 &\leq t_4 \leq 0.05\end{aligned}$$

Assuming that a worst case tap set will have all tap values at one limit or the other, the following 8 cases were examined:

0.5, 0.2, 0.1, 0.05

0.5, 0.2, 0.1, -0.05

0.5, 0.2, -0.1, 0.05

0.5, 0.2, -0.1, -0.05

0.5, -0.05, 0.1, 0.05

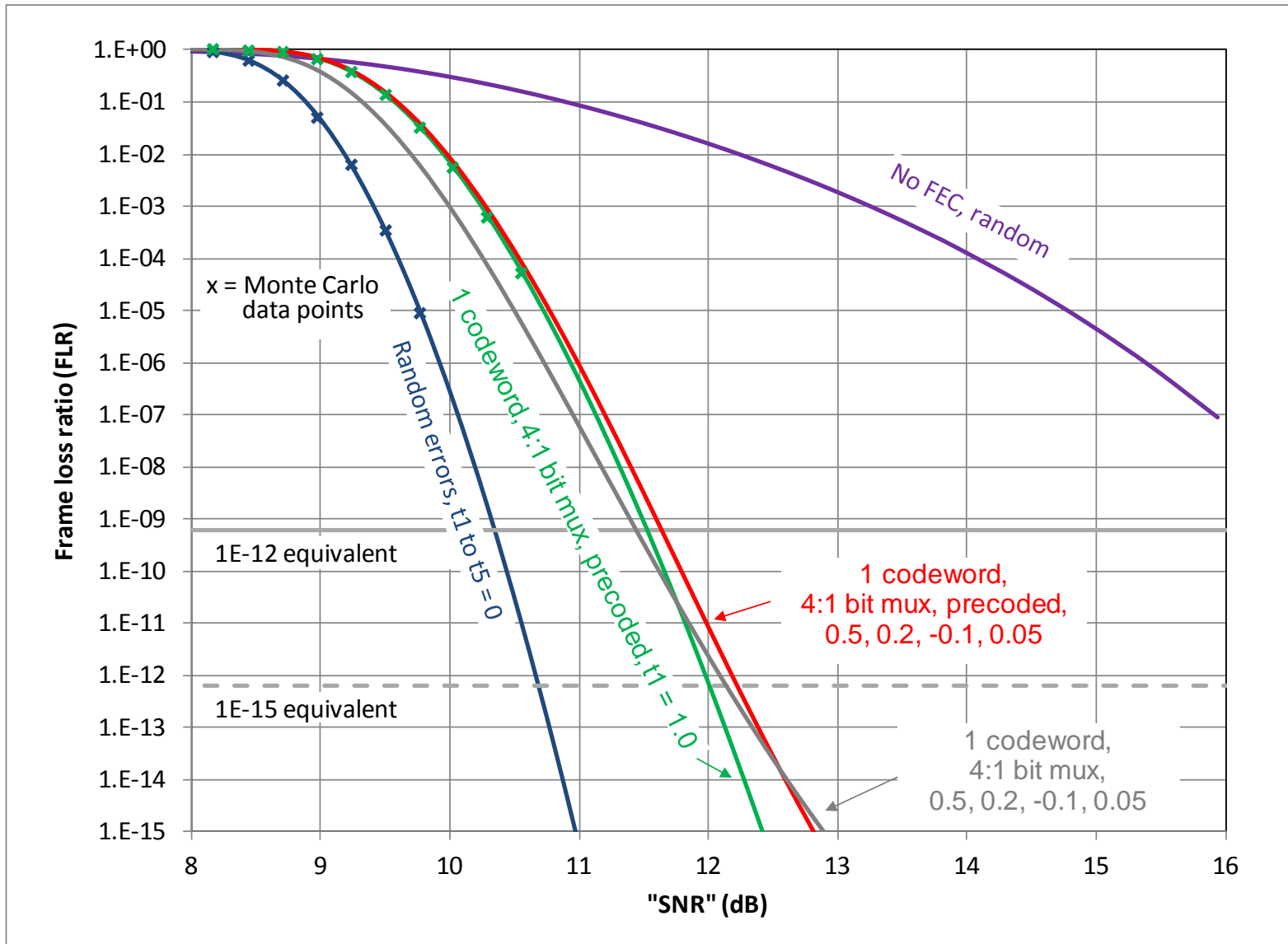
0.5, -0.05, 0.1, -0.05

0.5, -0.05, -0.1, 0.05

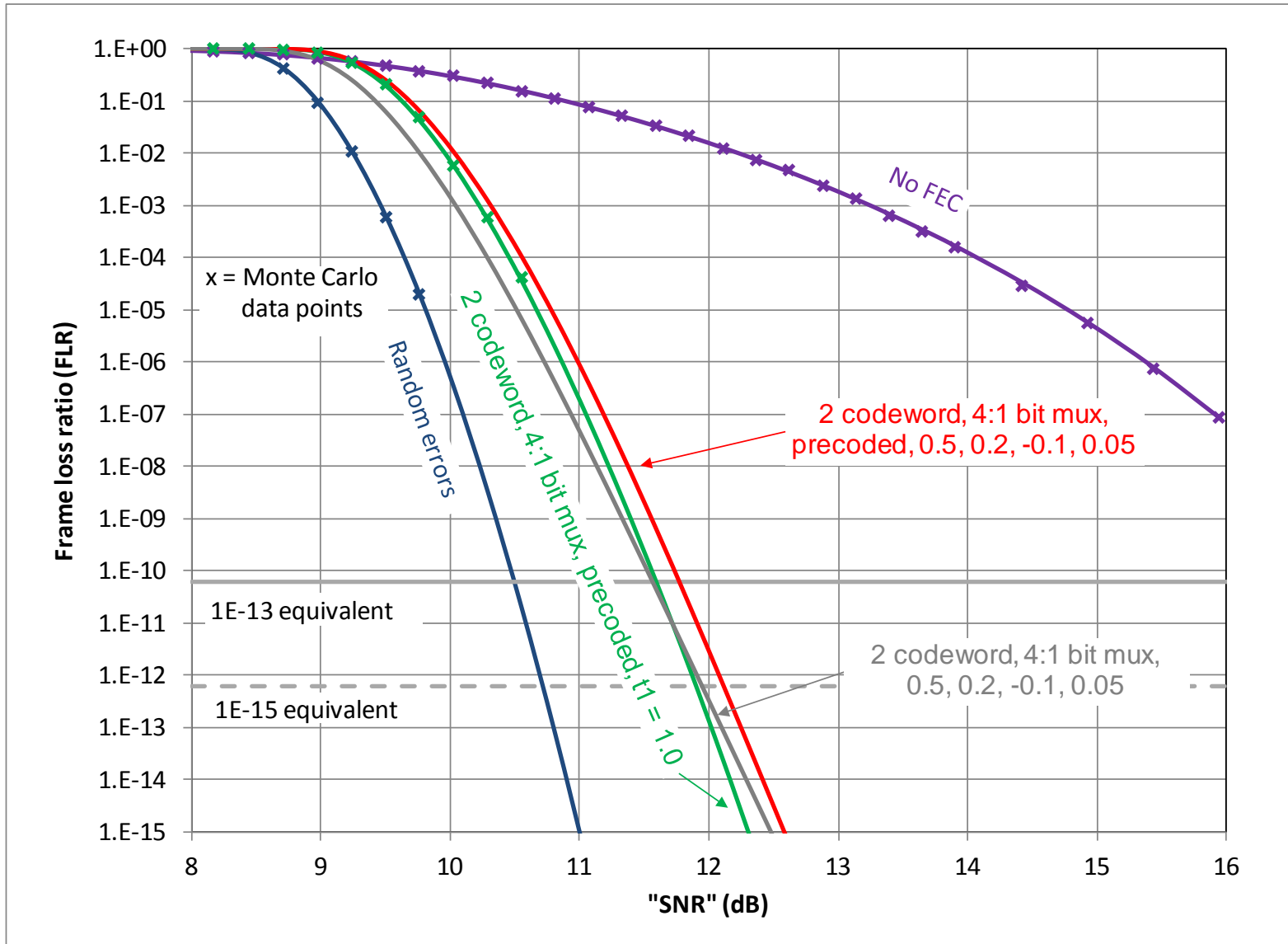
0.5, -0.05, -0.1, -0.05

The worst set out of these with precoding was 0.5, 0.2, -0.1, 0.05

100G with 4-tap DFE (0.5, 0.2, -0.1, 0.05)



400G with 4-tap DFE (0.5, 0.2, -0.1, 0.05)



Multi-part link results 1

For a multi-part link, the BER of the electrical sub-links for a BER of $2.4E-4$ in the optical sub-link are shown in the table below.

100G	RS(544,514) for FLR = $6.2E-10$							
	Electrical					Optical		
	Stats	Slicer out	FEC in	DER ₀	SNR (dB)	Stats	FEC in	
1 codeword, 4:1 bit mux, precoded, t1 = 1.0	Burst	8.4E-5*	4.2E-5	4.2E-5	12.1	Random	2.4E-4	
1 codeword, 4:1 bit mux, precoded, 0.5, 0.2, -0.1, 0.05	Burst	2.3E-5*	3.2E-5	3.1E-5	12.3	Random	2.4E-4	
1 codeword, 4:1 bit mux, 0.5, 0.2, -0.1, 0.05	Burst	3.0E-5*	same	4.1E-5	12.1	Random	2.4E-4	
400G	RS(544,514) for FLR = $6.2E-11$							
	2 codeword, 4:1 bit mux, precoded, t1 = 1.0	Burst	5.4E-5*	2.7E-5	2.7E-5	12.3	Random	2.4E-4
	2 codeword, 4:1 bit mux, precoded, 0.5, 0.2, -0.1, 0.05	Burst	1.4E-5*	1.9E-5	1.8E-5	12.5	Random	2.4E-4
	2 codeword, 4:1 bit mux, 0.5, 0.2, -0.1, 0.05	Burst	1.9E-5*	same	2.6E-5	12.3	Random	2.4E-4

Note – these values are the BER **including** the additional errors due to the bursts. To account for burst errors, the values marked with “*” have been multiplied by 4 for a 1-tap DFE and 1.47 for the 0.5, 0.2, -0.1, 0.05 case.

Candidate C2M DFE tap limits 2

Following an analysis of tap weights used for “reasonable” C2M channels performed by Phil Sun and in order to reduce the worst case penalty, the proposed limits were modified as below:

$$\begin{aligned}0 &\leq t_1 \leq 0.5 \\-0.05 &\leq t_2 \leq 0.2 \\-0.05 &\leq t_3 \leq 0.1 \\-0.05 &\leq t_4 \leq 0.05\end{aligned}$$

Assuming that a worst case tap set will have all tap values at one limit or the other, the following 8 cases were examined:

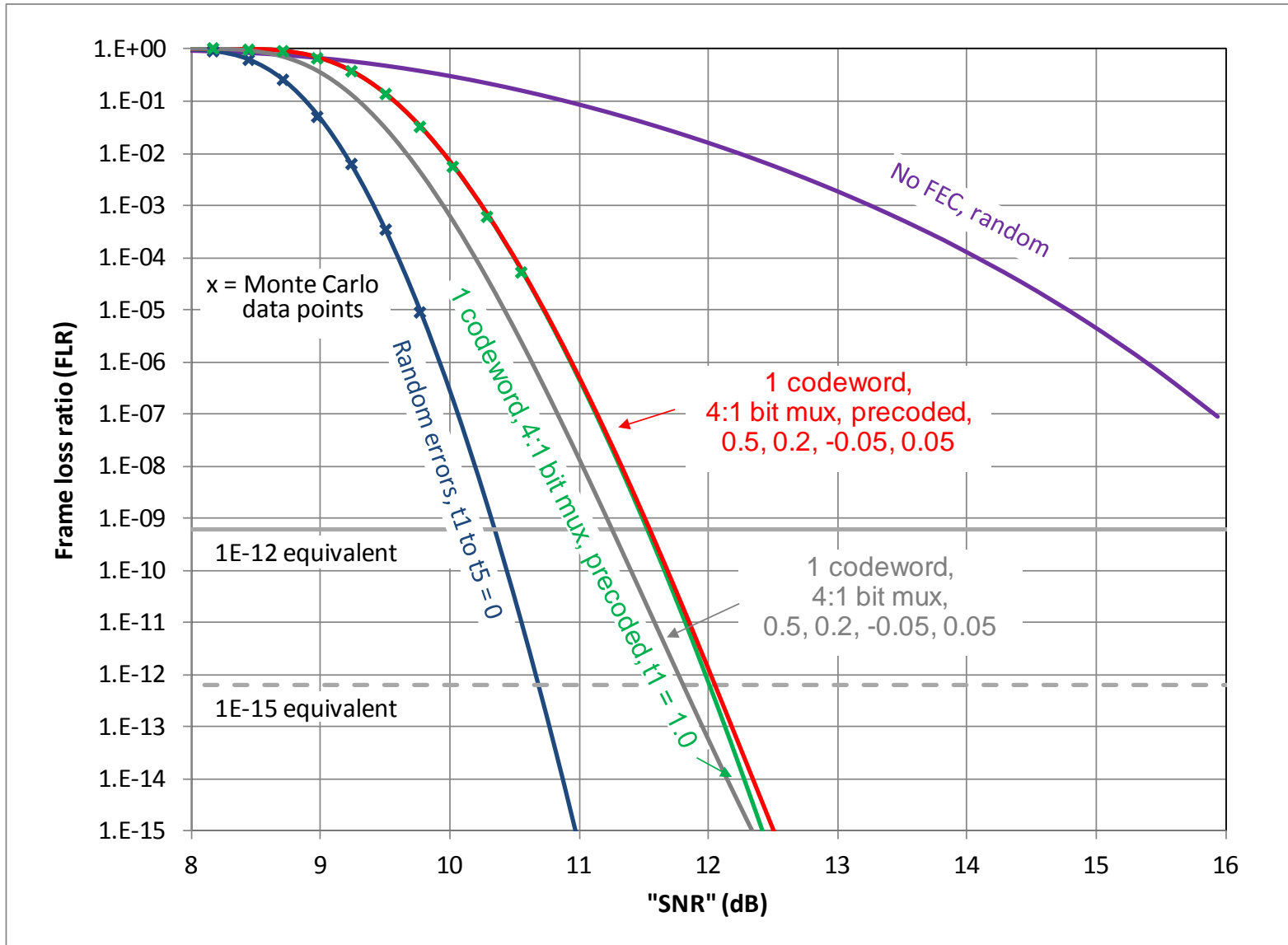
0.5, 0.2, 0.1, 0.05	0.5, 0.2, 0.1, -0.05	0.5, 0.2, -0.05, 0.05
0.5, 0.2, -0.05, -0.05	0.5, -0.05, 0.1, 0.05	0.5, -0.05, 0.1, -0.05
0.5, -0.05, -0.05, 0.05	0.5, -0.05, -0.05, -0.05	

The worst sets out of these were:

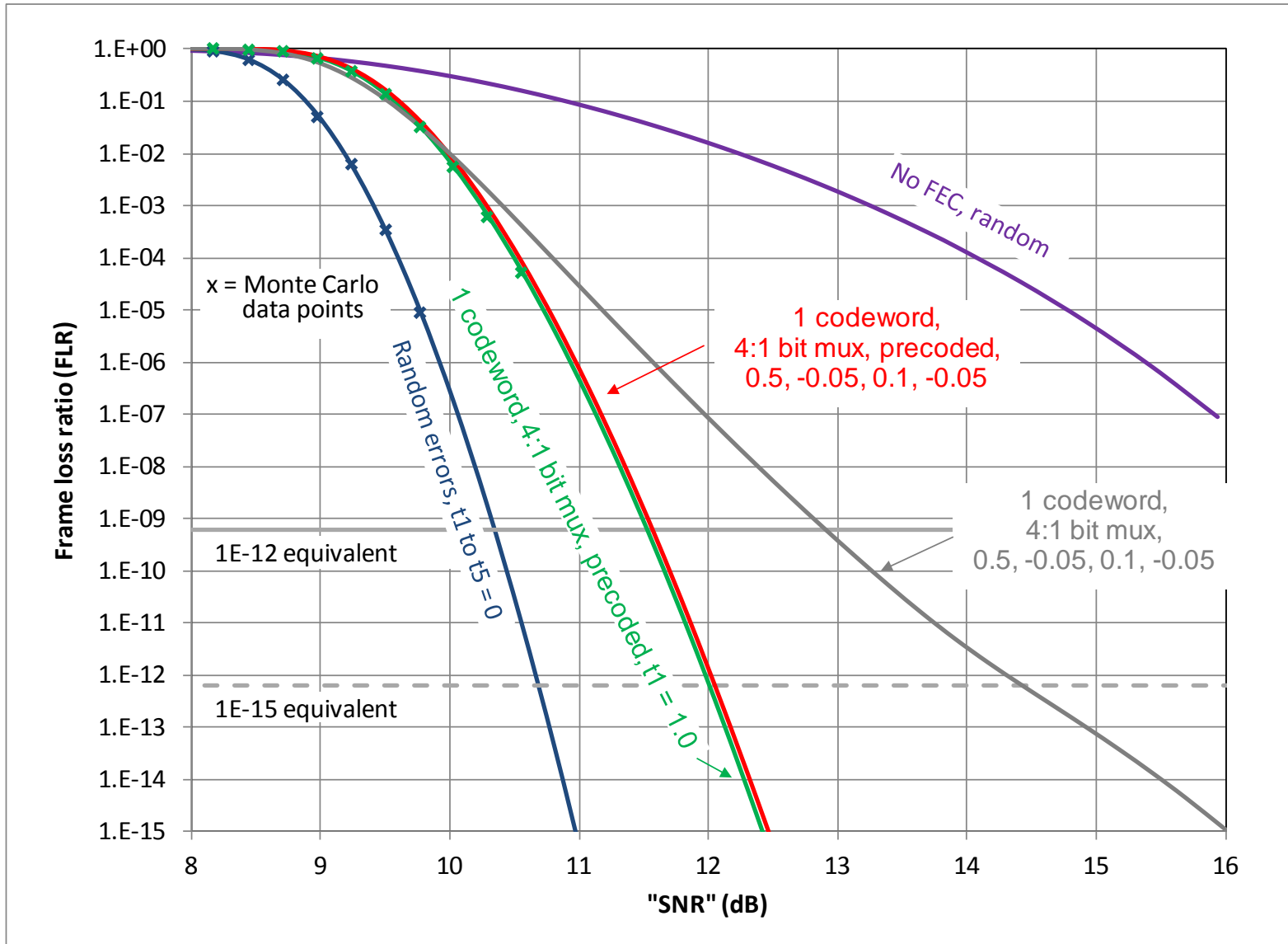
0.5, 0.2, -0.05, 0.05 with precoding

0.5, -0.05, 0.1, -0.05 without precoding

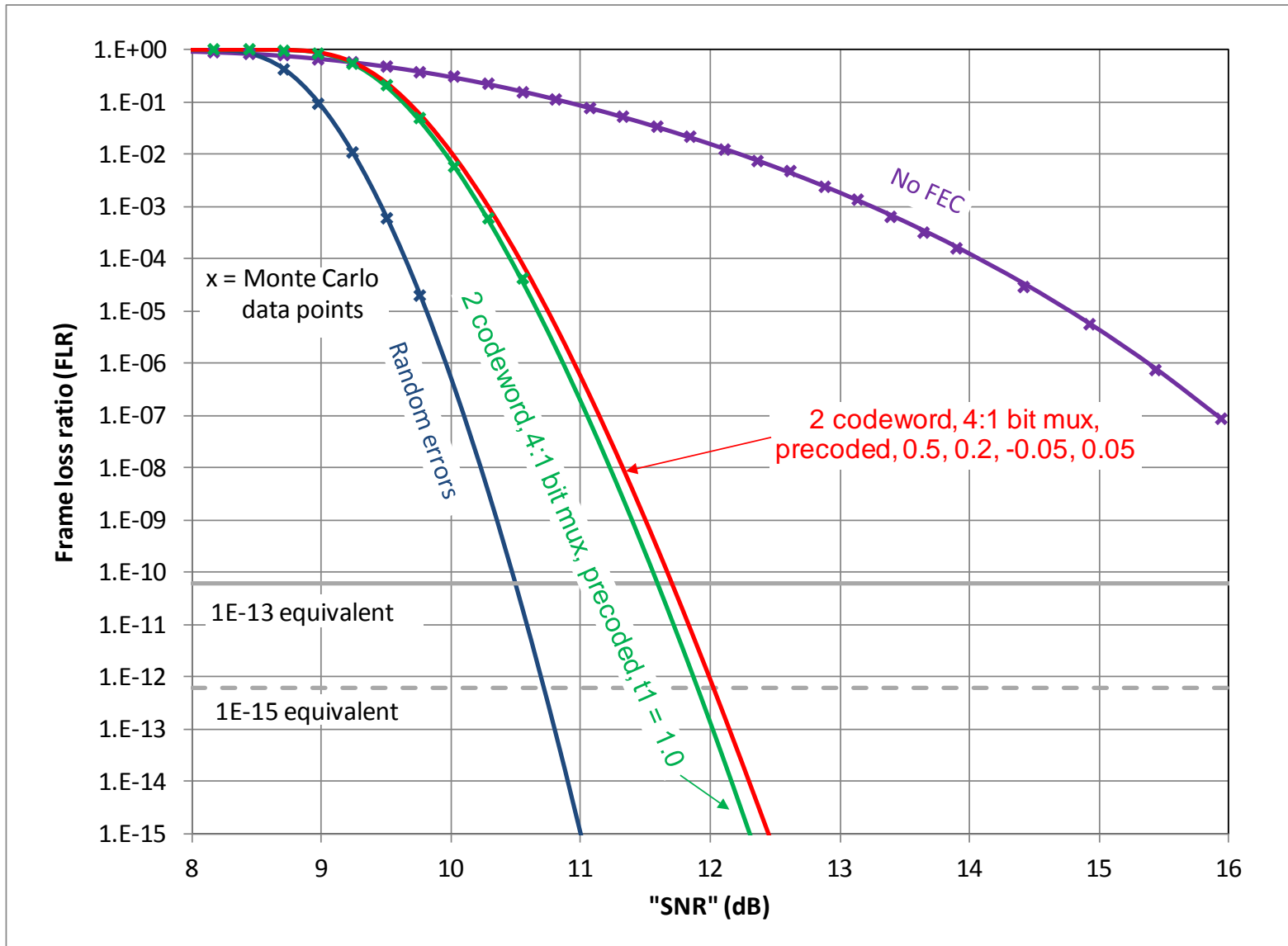
100G with 4-tap DFE (0.5, 0.2, -0.05, 0.05) worst with precoding



100G with 4-tap DFE (0.5, -0.05, 0.1, -0.05) worst without precoding



400G with 4-tap DFE (0.5, 0.2, -0.05, 0.05)



Candidate C2M DFE tap limits 3

It has been stated that as long as the subsequent taps are small, the first tap can be large without much impact, to explore this try:

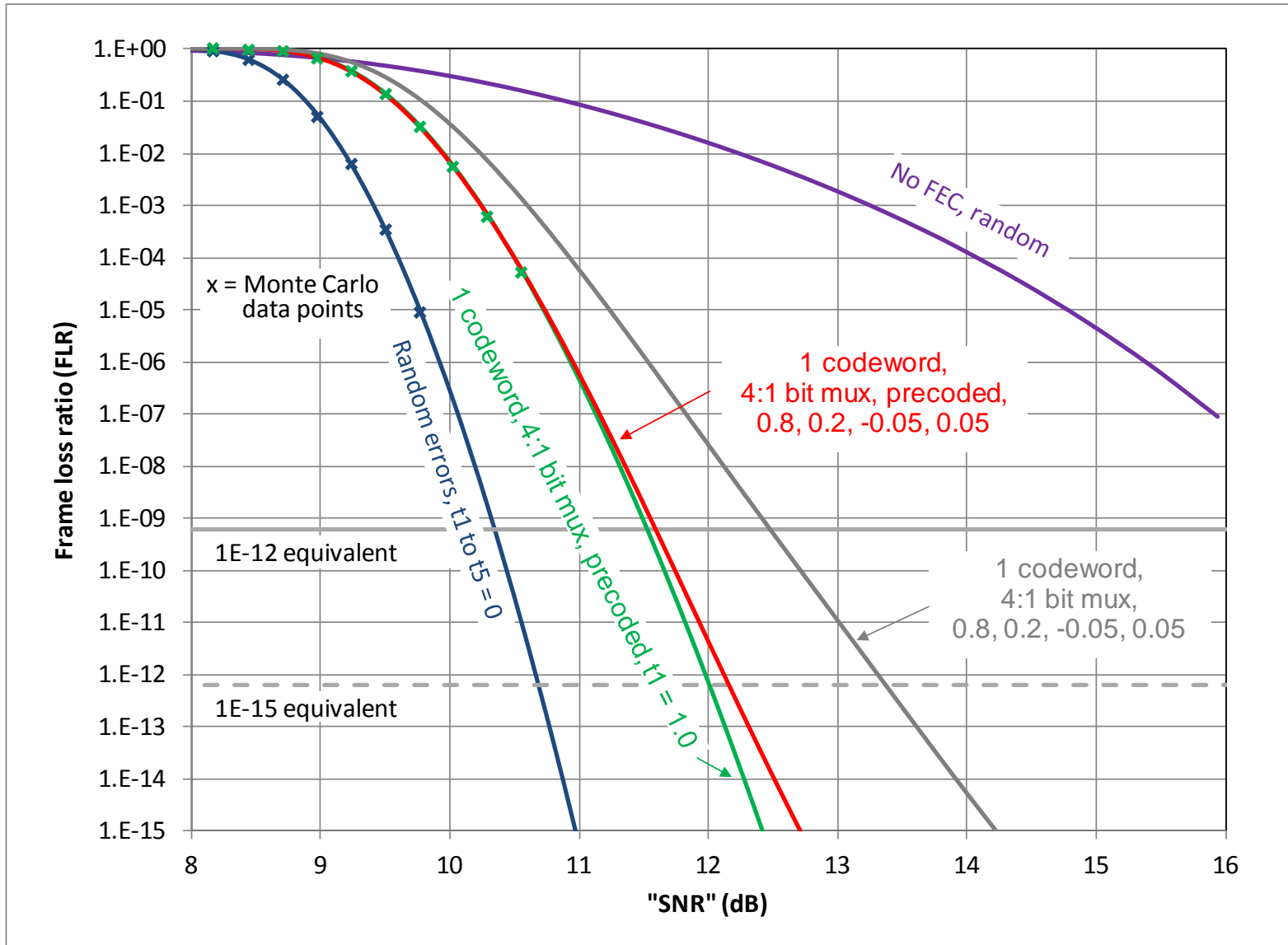
$$\begin{aligned}0 &\leq t_1 \leq 0.8 \\-0.05 &\leq t_2 \leq 0.2 \\-0.05 &\leq t_3 \leq 0.1 \\-0.05 &\leq t_4 \leq 0.05\end{aligned}$$

Assuming that a worst case tap set will have all tap values at one limit or the other, the following 8 cases were examined:

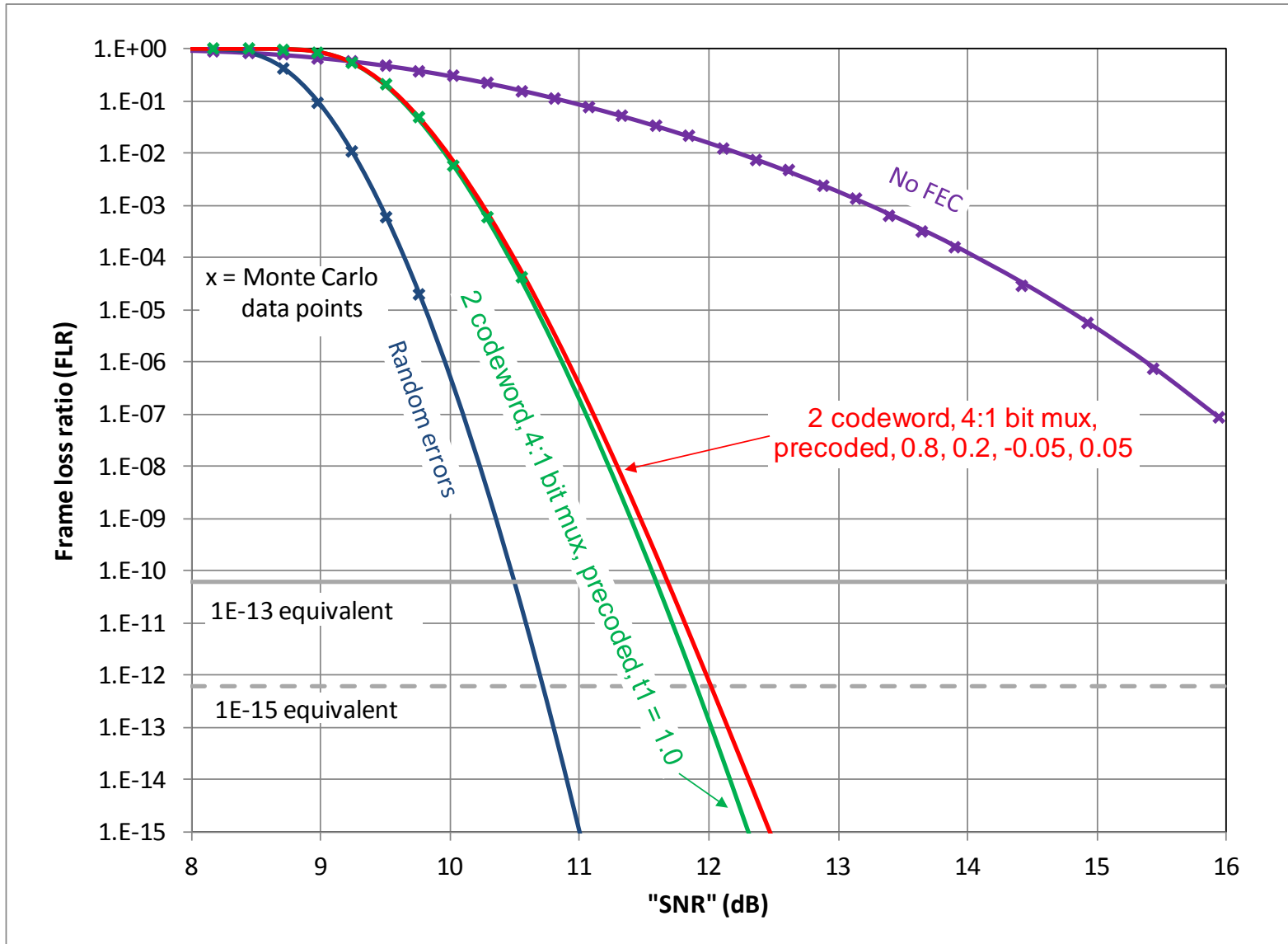
0.8, 0.2, 0.1, 0.05	0.8, 0.2, 0.1, -0.05	0.8, 0.2, -0.05, 0.05
0.8, 0.2, -0.05, -0.05	0.8, -0.05, 0.1, 0.05	0.8, -0.05, 0.1, -0.05
0.8, -0.05, -0.05, 0.05	0.8, -0.05, -0.05, -0.05	

The worst set out of these was: 0.8, 0.2, -0.05, 0.05 with precoding

100G with 4-tap DFE (0.8, 0.2, -0.05, 0.05) worst with precoding



400G with 4-tap DFE (0.8, 0.2, -0.05, 0.05) worst with precoding



Multi-part link results 2

For a multi-part link, the BER of the electrical sub-links for a BER of $2.4E-4$ in the optical sub-link are shown in the table below.

100G	RS(544,514) for FLR = $6.2E-10$						
	Electrical					Optical	
	Stats	Slicer out	FEC in	DER ₀	SNR (dB)	Stats	FEC in
1 codeword, 4:1 bit mux, precoded, t1 = 1.0	Burst	8.4E-5*	4.2E-5	4.2E-5	12.1	Random	2.4E-4
1 codeword, 4:1 bit mux, precoded, 0.5, 0.2, -0.05, 0.05	Burst	2.8E-5*	4.0E-5	3.9E-5	12.1	Random	2.4E-4
1 codeword, 4:1 bit mux, precoded, 0.8, 0.2, -0.05, 0.05	Burst	4.4E-5*	3.6E-5	3.4E-5	12.2	Random	2.4E-4
400G	RS(544,514) for FLR = $6.2E-11$						
2 codeword, 4:1 bit mux, precoded, t1 = 1.0	Burst	5.4E-5*	2.7E-5	2.7E-5	12.3	Random	2.4E-4
2 codeword, 4:1 bit mux, precoded, 0.5, 0.2, -0.05, 0.05	Burst	1.6E-5*	2.2E-5	2.2E-5	12.4	Random	2.4E-4
2 codeword, 4:1 bit mux, precoded, 0.8, 0.2, -0.05, 0.05	Burst	2.8E-5*	2.3E-5	2.2E-5	12.4	Random	2.4E-4

Note – these values are the BER **including** the additional errors due to the bursts. To account for burst errors, the values marked with “*” have been multiplied by 4 for a 1-tap DFE, 1.44 for the 0.5, 0.2, -0.05, 0.05 case, and 2.57 for the 0.8, 0.2, -0.05, 0.05 case.

Conclusion

Candidate C2M DFE tap limits 2:

$$\begin{aligned}0 &\leq t_1 \leq 0.5 \\-0.05 &\leq t_2 \leq 0.2 \\-0.05 &\leq t_3 \leq 0.1 \\-0.05 &\leq t_4 \leq 0.05\end{aligned}$$

give a worst case penalty with precoding that is about the same as that for a 1-tap DFE with precoding.

Relaxing the t_1 upper limit to 0.8, giving Candidate C2M DFE tap limits 3:

$$\begin{aligned}0 &\leq t_1 \leq 0.8 \\-0.05 &\leq t_2 \leq 0.2 \\-0.05 &\leq t_3 \leq 0.1 \\-0.05 &\leq t_4 \leq 0.05\end{aligned}$$

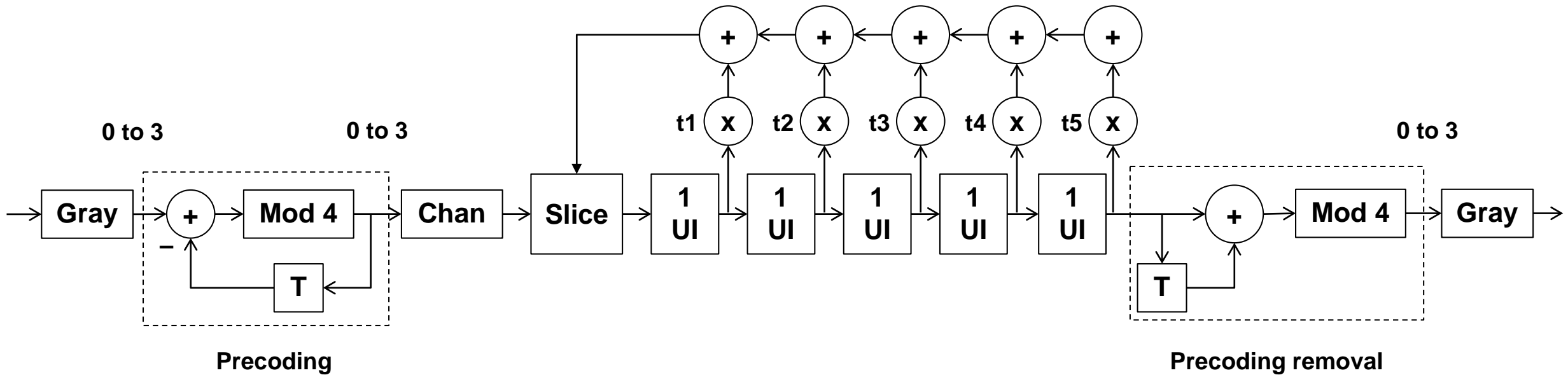
gives worst case penalties that are only slightly higher.

Annex

Precoding and 5-tap DFE model

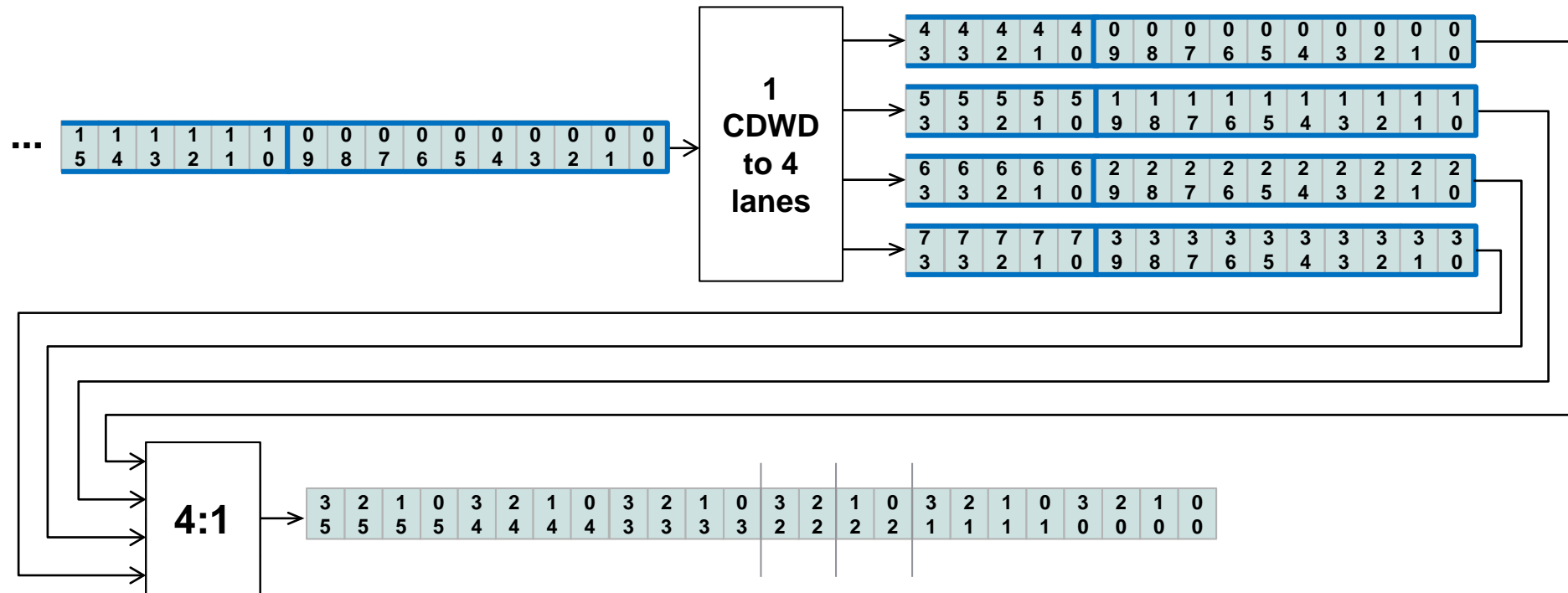
The results with precoding in [anslow_3ck_adhoc_01_072518](#) were for a 1 tap DFE where it is expected that precoding will have the effect of converting an error burst of any length into just two PAM4 symbol errors.

To try to help answer the question of what the performance will be for a realistic multi-tap DFE with precoding, the Monte Carlo model used for previous presentations was extended to include a 5-tap DFE as below.



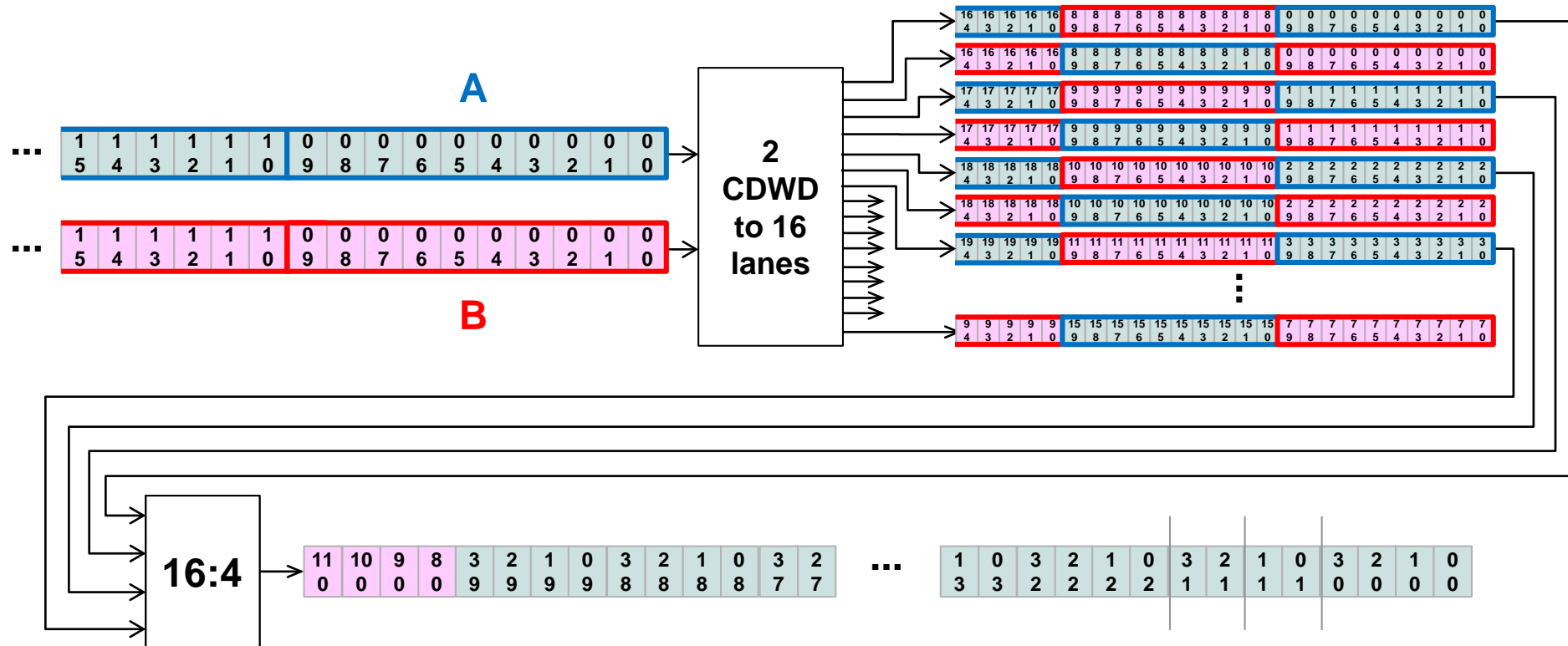
Clause 91 100G with bit mux PMA

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



Clause 119 400G with bit mux PMA

Symbol interleave from 2 FEC codewords. Bit multiplex in the PMA.



If one codeword is uncorrectable, the other is marked bad also.

Thanks!