

Effect of AUI error propagation on optical error rate for 200Gb/s lanes.

802.3dj Sept Interim 2023

Mike Dudek Marvell

Introduction

- A DER of $2.67e-5$ was adopted for the AUI's at each end of the link with the following vote in the interim meeting in May 2023
 - adopt a DER0 value of $2.67e-5$ (equivalent to measured BER of $4e-5$ with precoding ON) as the total allocation for higher-loss AUIs within a PHY (BER division between C2C and C2M as well as the measurement method to be determined later).
- The effect of this and methods for specifying the optical link have been studied in the below presentations assuming the DER creates random errors
 - [Specifying BER in PMD clauses \(ieee.org\)](#) (RAN_3dj_optx_01_230815)
 - [AUI error rate specifications \(ieee.org\)](#) (RAN_3dj_01_230817)
- This presentation explores the effect of error propagation on the link performance.

Assumptions

- The link performance (Frame Loss Ratio) is set by the number of errored FEC symbols within FEC codewords.
- With the adopted Symbol muxing PMA each FEC symbol contains 5 consecutive PAM4 symbols.
- The FEC symbols are distributed within a codeword such that the minimum “distance” between FEC symbols from the same codeword is 3 (i.e. every 4th FEC symbol is from the same codeword).
- A worst case DFE error propagation model with $a=0.75$ is assumed.
- Pre-coding will result in one PAM4 symbol error at the original error and one PAM4 symbol error at the end of the burst.
- Random errors produce one errored FEC symbol.

Analysis with pre-coding.

- With 5 PAM4 symbols in each FEC symbol there is a 20% probability of the first error being in each position within the FEC symbol and the probability of the error propagating into another FEC symbol is shown in the table below.

Position within FEC symbol	Probability of error propagating to another FEC symbol with pre-coding	
1	0.75^4	0.316
2	0.75^3	0.422
3	0.75^2	0.563
4	0.75	0.750
5	1	1
Average probability	0.61015625	

- The probability of the FEC symbol this propagates to being in the same codeword 3 words later is $0.75^{15} - 0.75^{20} = 0.010$. This gives a probability that there will be a second FEC symbol errors in the same codeword of $2.67e-7$ which is much smaller than the $2.8e-3$ probability of errors in any FEC symbol that the RS544,514 code can stand.

Analysis without pre-coding.

- The probability of the error propagating into a second FEC symbol is shown in the table below.

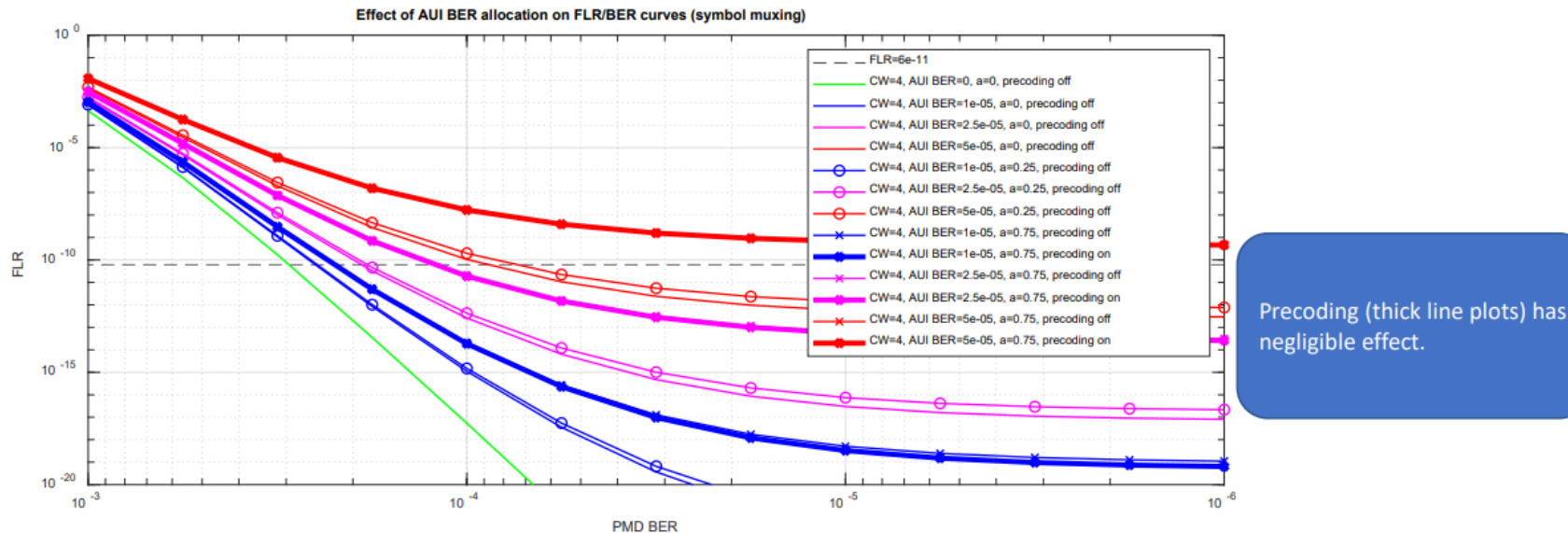
Position within FEC symbol	Probability of error propagating to 2nd FEC symbol without pre-coding.	
1	0.75^5	0.237
2	0.75^4	0.316
3	0.75^3	0.422
4	0.75^2	0.563
5	0.75	0.750
Average probability of 2 or more FEC symbol errors		0.458

- The burst does not stop at the second FEC symbol however. The probability of there being 3 FEC symbol errors is $0.458 \cdot 0.75^5$. The probability of there being 4 FEC symbol errors is $0.458 \cdot (0.75^5)^2$. etc. i.e. average error probability = $0.458 \cdot (1 + 0.75^5 + (0.75^5)^2 + (0.75^5)^3 \dots) = 0.458 \cdot (1/(1 - 0.75^5)) = 0.600$
- There is again a probability of there being multiple FEC symbol errors in the same codeword but again it is not that significant with the probability of there being 5 codewords in error being $0.458 \cdot 0.75^95 = 6.2e-13$.

Simulation confirmation.

- These results are confirmed with the simulations in https://www.ieee802.org/3/dj/public/adhoc/electrical/23_0420/ran_3dj_elec_01_230420.pdf where slide 10 is reproduced below.

Effect of precoding with 4-CW interleaving



- The blue curves are showing the effect of this error extension and also showing that the results with and without pre-coding are similar.

Conclusion.

- The suggestions on slide 8 of [Specifying BER in PMD clauses \(ieee.org\)](#) (RAN_3dj_optx_01_230815) for the allowed optical segment error performance is optimistic.
- We need to use a “BER budget” for the optical link of $2.8e-4 - 4 \times 1.6e-5$ equals $2.16e-4$ (instead of $2.4e-4$) or alternatively specify that with additional random BER of $6.4e-5$ ($1.6 \times (4e-5)$) (from other segments in a full link), the errors shall enable FLR lower than $6.2e-11$.
- If this is not done then we need to revisit the value of DER0 allocated to the AUIs or somehow limit the error propagation factor.