Baseline wander with FEC

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Introduction

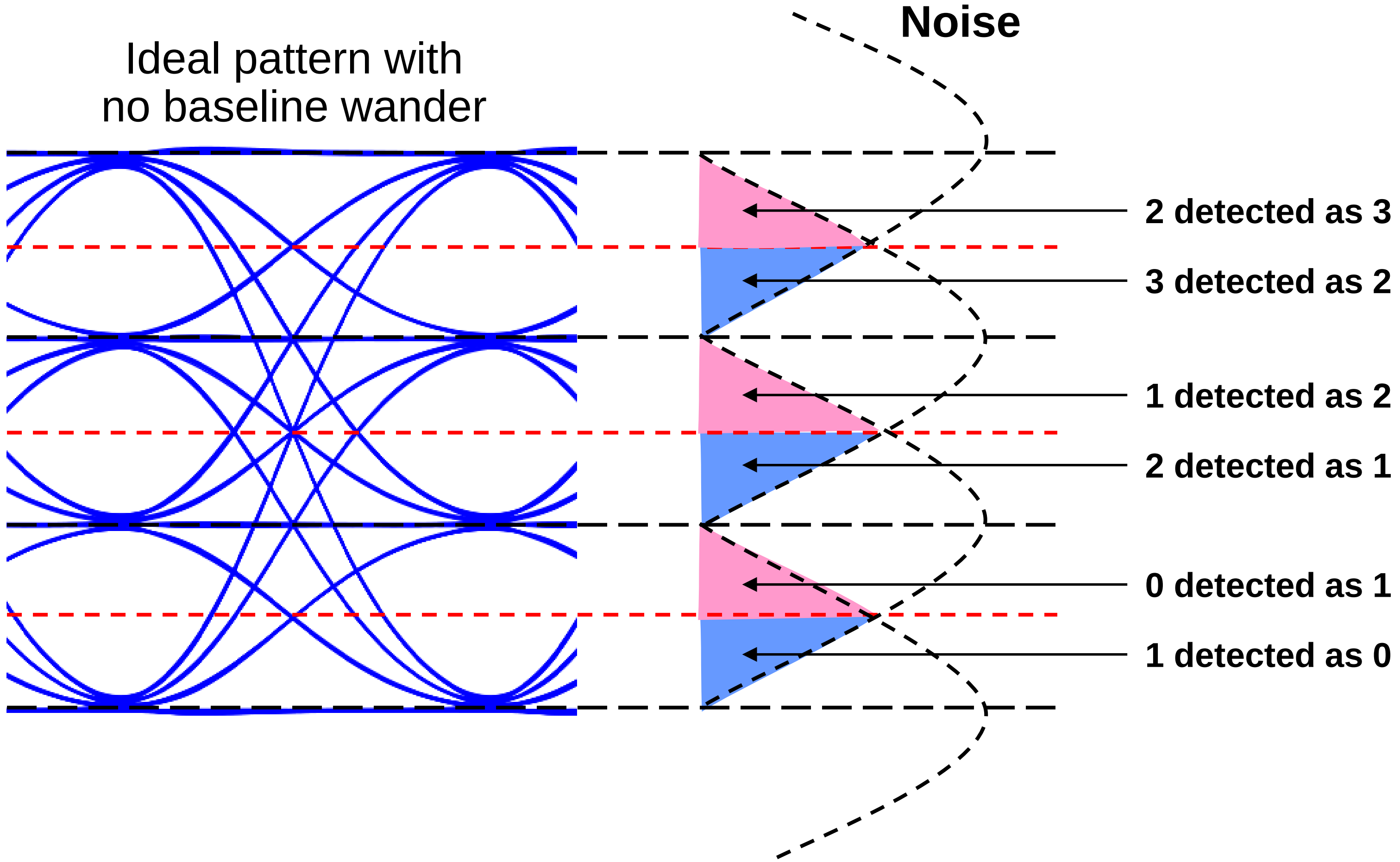
dawe_3bs_01a_0317 used the average BER caused by baseline wander as a metric to judge whether the SSPRQ test pattern is too onerous or not.

This contribution looks at the performance of links that would be allowed if this metric were used.

LF cut frequency analysis 1

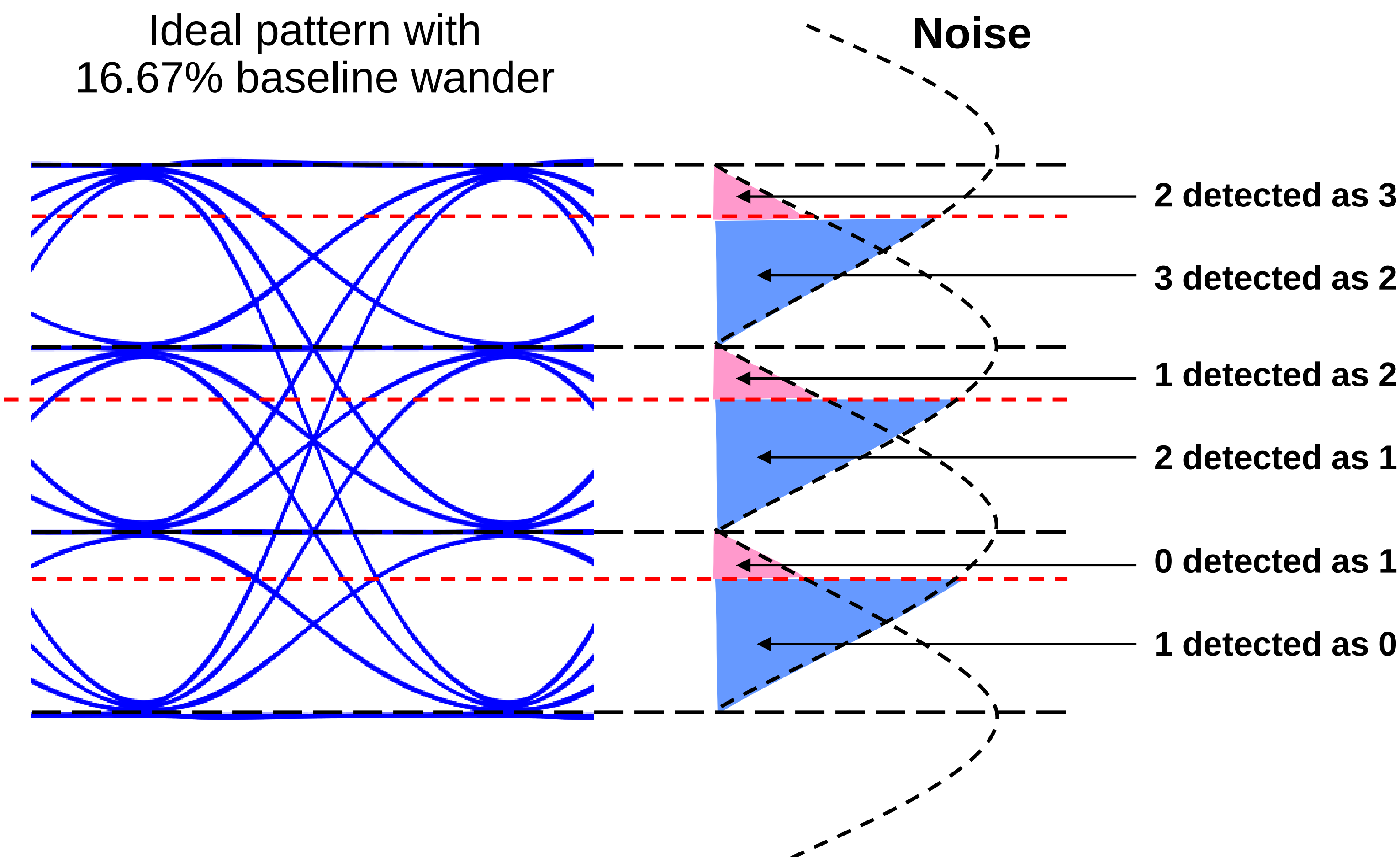
dawe_3bs_01a_0317 slide 3 showed an average optical penalty for patterns up to PRBS23Q of 0.2 dB.

To analyze this, for Gray coded PAM4 there are six possible error types:



LF cut frequency analysis 2

Baseline wander causes an offset between the eyes and the decision points. Three of the error types become more probable and three become less probable:



LF cut frequency analysis 3

For each error type we have:

$$SER = \frac{1}{4} \times \frac{1}{2} erfc\left(\frac{Q_{BW}}{\sqrt{2}}\right)$$

Where Q_{BW} is the Q taking baseline wander into account (3 higher and 3 lower than without BW) and the factor 1/4 comes from each level occurring with a probability of one in four symbols. If there is no baseline wander, then all 6 SERs are equal and the formula contracts to:

$$BER = \frac{1}{2} SER = \frac{1}{2} \times 6 \times \frac{1}{4} \times \frac{1}{2} erfc\left(\frac{Q}{\sqrt{2}}\right) = \frac{3}{8} erfc\left(\frac{Q}{\sqrt{2}}\right) = 2.4\mathrm{E}-4 \text{ for } Q = 3.414$$

Now simulate the entire PRBS23Q sequence, calculating the BER symbol-by-symbol and thereby calculate the average BER over the sequence. For an optical penalty of 0.2 dB, increase the Q value before BW is applied to 3.575 and find the LF cut frequency that returns the average BER to 2.4E-4.

To give an optical penalty of 0.2 dB, the LF cut frequency has to be about Baud/2400.

PRBS31Q with LF cut of Baud/2400

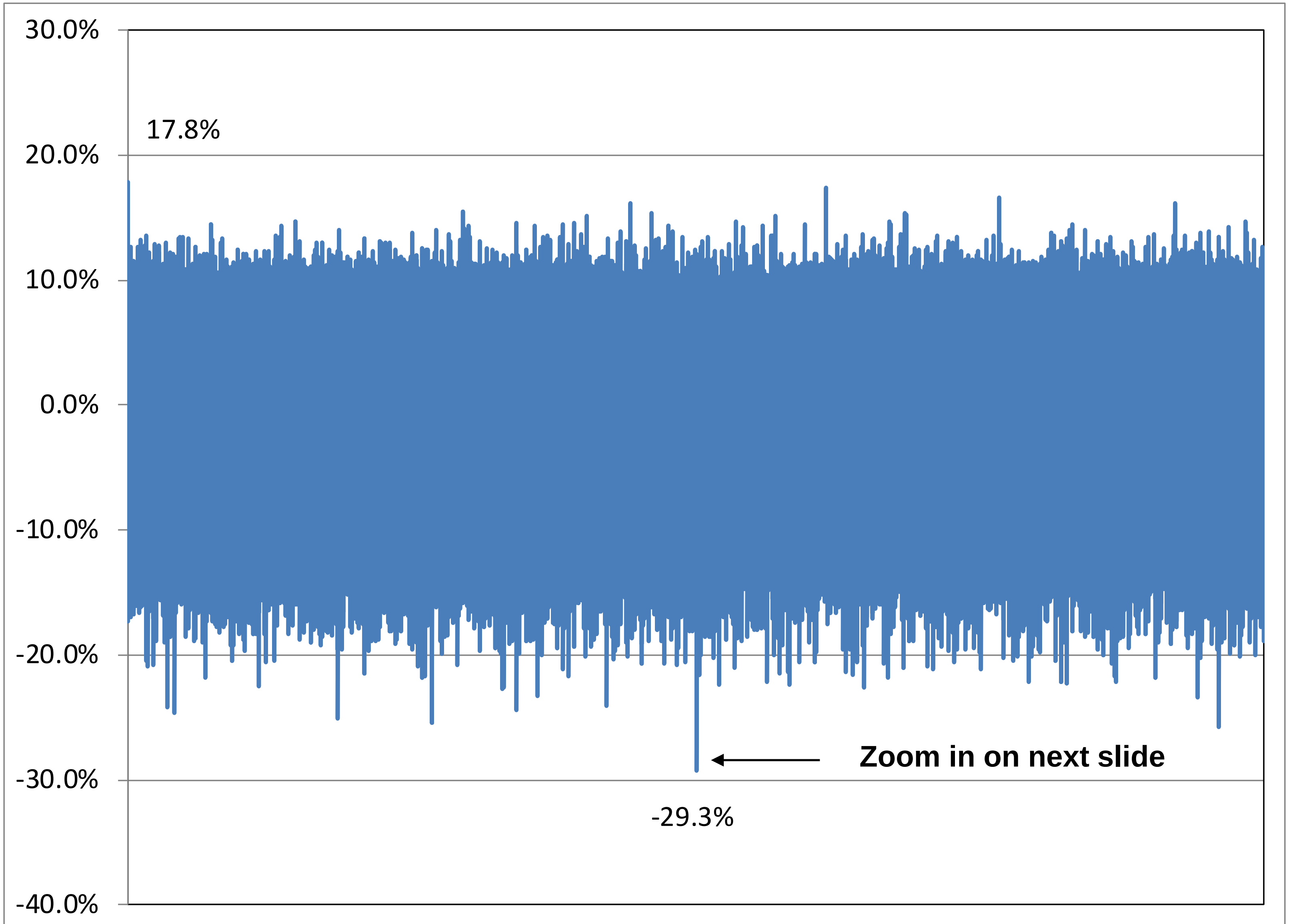
What happens if the transmitter has an LF cut frequency of Baud/2400 and is tested with PRBS31Q?

The next slide shows the time evolution of baseline wander over the entire PRBS31Q sequence.

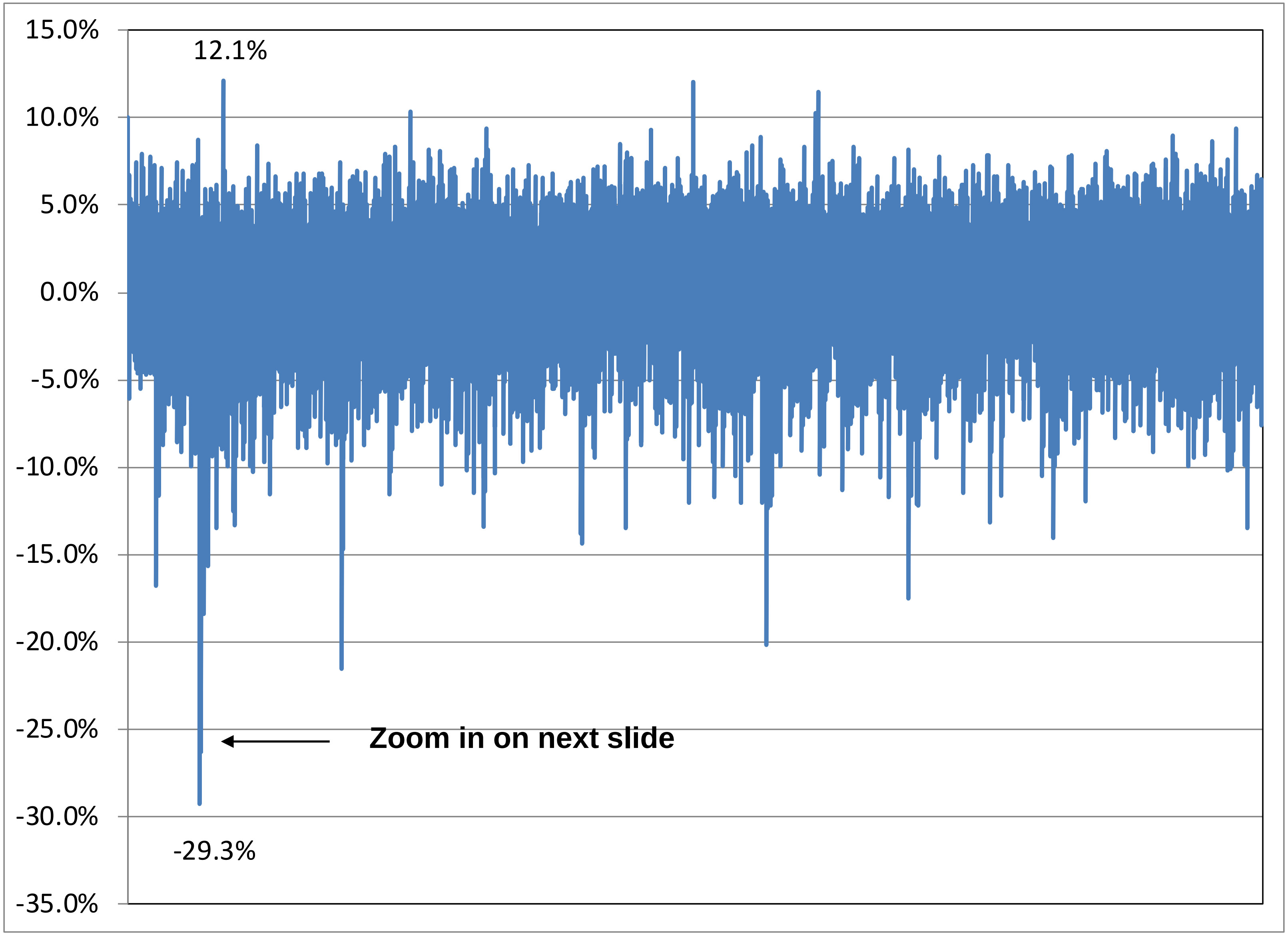
The slide following that shows 1/1024 of the sequence (2,097,152 symbols) around the point of the largest spike.

The slide after that zooms in again to show 10,240 symbols around the largest spike. Superimposed on this is a diagram showing parts of three codeword pairs and also the BER that signals with particular baseline wander values would have.

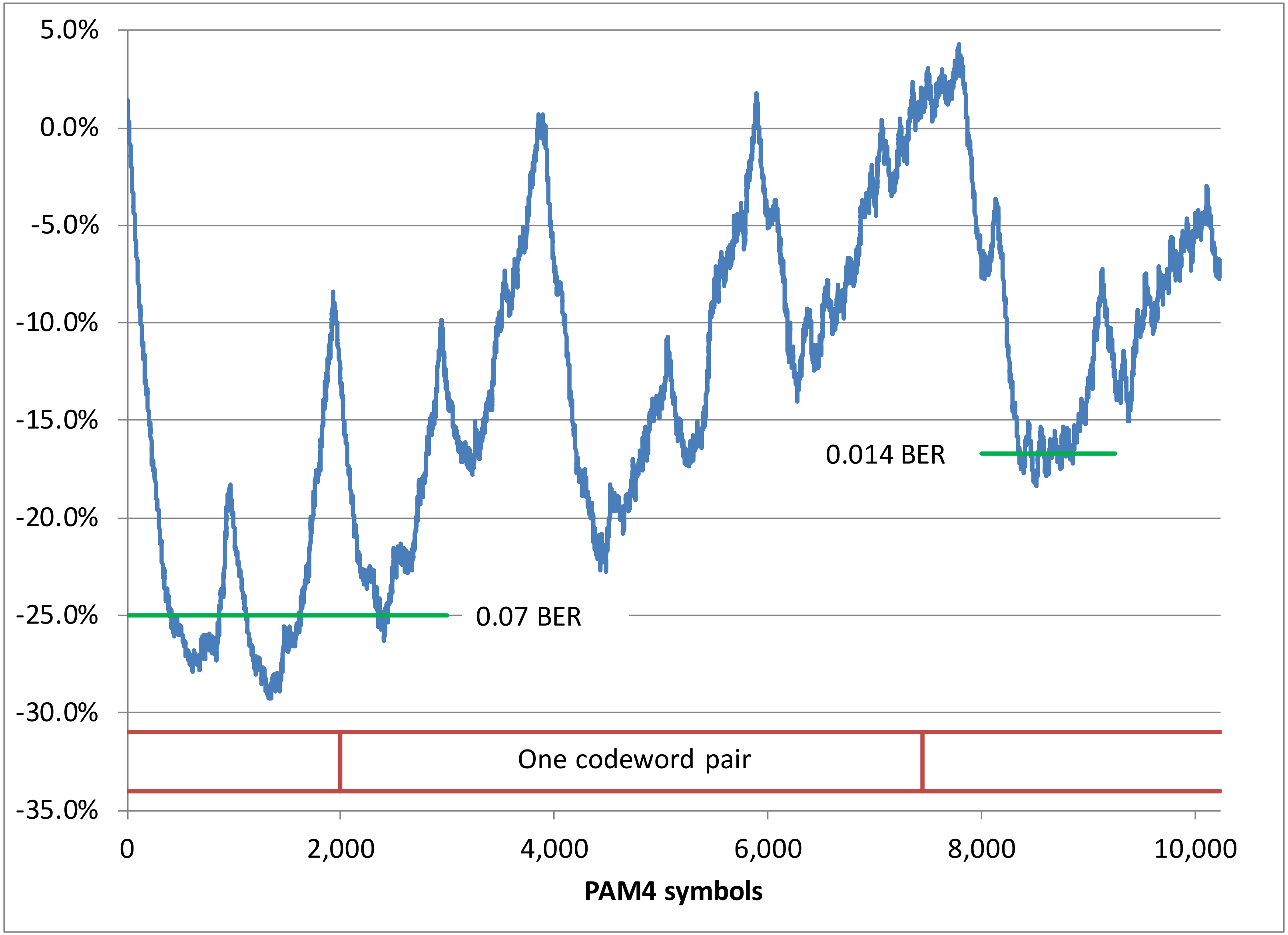
PRBS31Q with LF cut of Baud/2400, all



PRBS31Q with LF cut of Baud/2400, 1/1024



PRBS31Q with LF cut of Baud/2400 10,240 sym



Lane performance

What would happen if a PAM4 lane with an LF cut frequency of Baud/2400 was driven with a FEC encoded signal that had the same baseline wander characteristics as the PRBS31Q sequence?

To find out, a simulation was performed that divided the PRBS31Q sequence into blocks of 5440 symbols (sized to contain one codeword pair) and, taking into account the 10-bit FEC symbols and the chequerboard FEC symbol distribution, calculated the probability of at least one of the two FEC codewords being uncorrectable.

The result was that instead of an FLR of 1.7E-12 as required for the PMD clauses, the FLR is 2.8E-4 (8 orders of magnitude too high).

Loss of synchronization

As can be seen on an earlier slide, the worst part of the PRBS31Q sequence has a duration that is long enough to affect 3 codeword pairs in a row if the alignment between the 5440 symbol blocks and the PRBS31Q pattern is unfortunate. To investigate this simulations were done with a range of offsets between the codeword start and the sequence start.

Offset (symbols)	Frame loss ratio	Time to loss of synch
0	2.8E-4	4.3 hours
1000	3.0E-4	1.6 seconds
2000	2.9E-4	0.2 seconds
3000	2.9E-4	0.18 seconds
4000	3.0E-4	39 seconds

Conclusion

Choosing a short stress pattern on the basis of causing the same average baseline wander BER penalty as a long PRBSQ sequence has been proposed. This would result in a test pattern that would allow a transmitter to have sufficient baseline wander to cause the FLR to be 8 orders of magnitude outside the limit and to declare loss of sync when tested with a FEC encoded sequence with the same baseline wander as PRBS31Q.

Thanks!