BER for 100GBASE-SR4

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Introduction

If the specification for 100GBASE-SR4 (proposed to fulfil the IEEE P802.3bm objective to “Define a 100 Gb/s PHY for operation up to at least 100 m of MMF”) includes mandatory FEC, then there is a desire to specify the BER at the module output that would be required to give a certain MAC frame error ratio (FER).

In order to do this some assumptions are required as to the error statistics. The calculations in anslow_01a_1112_mmf, assumed a random error distribution and the RS(528,514) FEC scheme defined in Clause 91 of IEEE P802.3bj D 1.2 for 100GBASE-CR4/KR4 to propose:

- BER at the PMA service interface should be less than 5×10^{-5}
- “For a complete Physical Layer, this specification is considered to be satisfied by a frame error ratio less than 5.12×10^{-10} for 64 octet frames with minimum inter-packet gap.”

This contribution looks at the consequences of non-random errors on the relationship between BER at the module output and the FER after FEC decoding.

Decision point instability

What would happen if the position of the threshold in the decision circuits are influenced by a square wave due to inadequate decoupling?

Assume that the period of the square wave is long compared to the ~50 ns FEC codeword duration and during one state of the square wave the threshold is near optimum. In the optimum state the BER might be as low as say 1E-5. When the square wave is in the other state, the BER can be as high as 9E-5 and still maintain an average BER of 5E-5.

Using the equations from anslow_01a_1112_mmf, for codewords with an input BER of 1E-5 and 9E-5, the FER after FEC decoding will be 1.5E-15 and 4.5E-8, respectively, so the average output FER will be 2.3E-8 rather than the 5.12E-10 we expect.

This scenario is not too bad as a modest reduction in the average BER at the input to 2.5E-5 would restore the expected FER at the output.

Transient effects

What if the degraded BER is due to a repeated transient effect?

If the period of time that the input BER is degraded becomes short compared to the time between occurrences, then the degraded BER can become very high while still meeting the average BER target of 5E-5.

For example, if the input BER is 1E-5 most of the time and the degraded BER lasts for 1/100 of the time, the degraded BER can be as high as 4E-3 while still meeting an average input BER of 5E-5.

For codewords with an input BER as high as 4E-3 it is nearly certain that they will contain more than 8 symbol errors and hence be uncorrectable, which leads to an FER of about 1E-2.

If things get this bad, then the chance becomes high of getting 3 consecutive uncorrected codewords which results in the RS-FEC sublayer declaring loss of codeword alignment.

Is there a “safe” input BER?

If an input BER of 5E-5 can turn in to a FER of 1E-2, is there an input BER that is guaranteed to give an FER of 5.12E-10?

If we don’t know the statistics of the error distribution, then we don’t know whether the FEC will improve the BER or not. In that case, the only input BER that we can be reasonably sure will lead to an output BER of 1E-12 is 1E-12.

For any input BER above 1E-12, there is at least some risk that a receiver could have that BER at its output and the FER after FEC decoding could be worse than 5.12E-10.

For this reason, simply setting the required BER at the FEC input to be some arbitrary amount below 5E-5 does not seem adequate.

Conclusion

The expectation for reasonable 100GBASE-SR4 implementations is that the errors will be sufficiently random that a BER of 5×10^{-5} will result in a FER of less than 6.2×10^{-10} for 64 octet frames with minimum inter-packet gap.

It is therefore proposed to make the normative requirement to be that the BER shall be less than 5×10^{-5} provided that the error statistics are sufficiently random that this results in an FER of less than 6.2×10^{-10} for 64 octet frames with minimum inter-packet gap when processed according to Clause 91.

If the error statistics are not sufficiently random to meet this requirement, then the BER shall be less than that required to give FER of less than 6.2×10^{-10} for 64 octet frames with minimum inter-packet gap when processed according to Clause 91.

The PICS could then be written with an option for each of these two cases.

Thanks!