Modal noise in 100GBASE-SR4

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Summary

- A reduced extinction ratio increases modal noise penalty; we have to find room in the budget for this
- To quantify the amounts, this analysis is based on the link model spreadsheet and specifications for 10GBASE-SR
- By rescaling that scenario for BER and extinction ratio we can predict the effect on 100GBASE-SR4
- At 2 dB extinction ratio, lower than previous specs, the modal noise penalty is starting to increase rapidly
- We need to e.g. find 0.2 dB in the budget for additional modal noise penalty and/or increase the minimum extinction ratio
- Either change is feasible, or some of each

Introduction

- This presentation investigates the consequences of allowing a reduced extinction ratio in the 100GBASE-SR4 specification
- A lower extinction ratio could affect the signal-to-noise ratio in three ways:
  - Relative intensity noise
  - Mode partition noise
  - Modal noise
- Relative intensity noise
  - If expressed as RIN_OMA, is expected to get worse with lower extinction ratio
  - See mmfadhoc/meetings/oct8_13/100GBASE-SR4-penalties-v-ER.pdf
  - However, the worse RIN penalty is part of what's measured in the TDP test. A transmitter implementer is not required to use an allowed low extinction ratio if it doesn't help him
- Mode partition noise
  - The large majority of mode partition noise is caused by a changing transmitted signal (among other factors)
  - See e.g. slides 11, 12 of 100GNGOPTX/public/mfadhoc/meetings/pepeljugoski_01_0612_mmf.pdf
  - A lower extinction ratio has a higher non-changing component of the signal, which is expected to make very little difference
- Modal noise
  - Is not measured in the TDP test
  - It is included by estimation in the budget
  - If it can get worse, ALL receivers have to pay for it, whether transmitters use an allowed low extinction ratio or not

Modal noise penalty

- Modal noise and modal noise penalty are not the same thing
  - In the absence of any other penalty, modal noise penalty would be 1/sqrt(1-(Qmin*sigma)^2)
    - where sigma is the standard deviation of the modal noise relative to OMA/2
    - and Qmin depends on the pre-FEC BER
  - In dB, that's Pmn = -5*log10(1-(Qmin*sigma)^2)
  - The penalty goes as the square of the noise, but is reduced by using FEC
- This analysis starts with tab "850S2000" of 10GEPBud3_1_16a.xls
  - Modal noise penalty is 0.3 dB for:
  - Q = Qmin = 7.037
  - LP Pen central = 3.920 dB (including the modal noise penalty and the interactions between penalties)
  - giving
  - sigma = 0.0511, but in the spreadsheet, this is relative to 1/2 the ISI-closed eye
    - (Because when I prepared the spreadsheet I did not have solid evidence to know whether sigma would vary with ISI, and if so how)
  - Pisi central = 3.02 dB, P_DJ central = 0 dB
  - Giving sigma = 0.0255 relative to OMA/2
  - All other penalties together come to 3.52 or 3.53 dB
  - So, in the spreadsheet, in this scenario, there is 3.92-0.3-3.52=0.1 dB of Pcross associated with the modal noise penalty

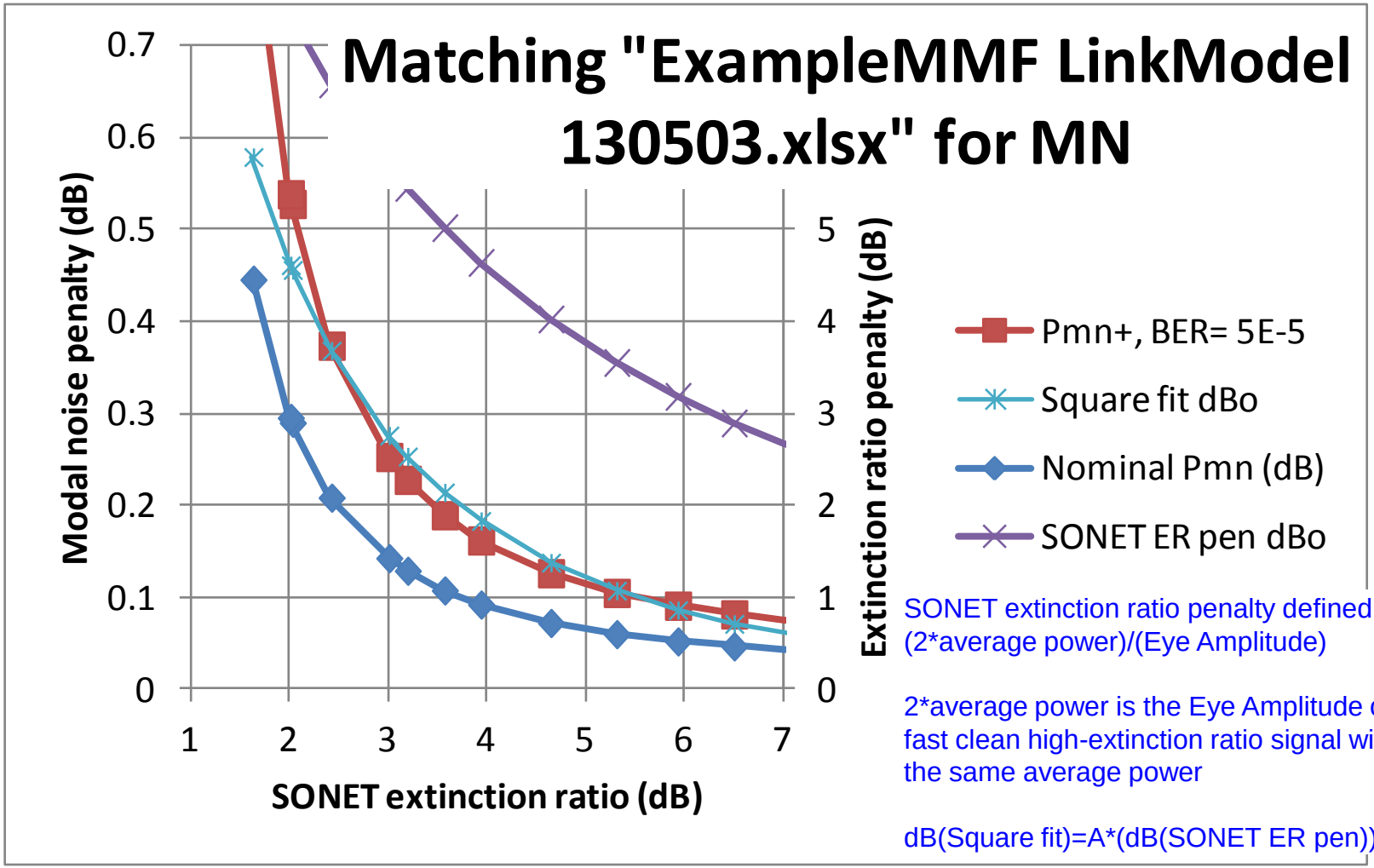
Modal noise depends on...

- The assumption that modal noise is proportional to the ISI-closed eye height seems questionable
- Assume it is proportional to the signal, as for RIN in one scenario in 100GBASE-SR4-penalties-v-ER.pdf
- The worst 1 in tab "850S2000" of 10GEPBud3_1_16a.xls is 1.75*OMA
- sigma/worst_1 = 0.0073
  - Assume this is also true for 100GBASE-SR4 (same connector specs in fibre plant)
- Now calculate modal noise and modal noise penalty for different extinction ratios
- Note that extinction ratio in spreadsheet and in spec have different definitions:
  - Spreadsheet: extinction ratio = settled_1 / settled_0
  - Spec: extinction ratio = average_1 / average_0
  - Estimate average 1 = (settled_1 + worst_1) / 2 and similarly for zeros
- In this scenario, the spreadsheet's extinction ratio ("OMA extinction ratio") is 3 dB and the "SONET extinction ratio" (as defined in the spec) is about 2.7 dB
  - For the Gaussian response in the model. For realistic responses with this ISI, the "SONET extinction ratio" would be higher e.g. up to 3.3 dB
- Changing the SONET extinction ratio from 3 dB to 2 dB, for this scenario, increases the modal noise penalty (including interaction of penalties) by 0.36 dB
  - Changing from OMA extinction ratio of 3 dB to SONET extinction ratio of 2 dB increases the modal noise penalty (including interaction of penalties) by 0.30 dB for a Gaussian response
  - In this region, the penalty increases faster than the square of the extinction ratio penalty

Now with 25G lanes

- Use tab "BaseOM4" of "ExampleMMF LinkModel 130503.xlsx"
  - Qmin = 3.891
  - Pisi central + P_DJ central = 3.16 + 1.76 = 4.92 dB
  - Nominal modal noise penalty Pmn = 0.1291 dB
  - LP Pen central (with Pmn = 0.129 dB) = 6.34 dB (including the modal noise penalty and the interactions between penalties)
  - All other penalties together come to 6.11 dB (!)
  - So, in the spreadsheet, in this scenario, there is 6.34-0.129-6.11=0.1 dB of Pcross associated with the modal noise penalty
- sigma/worst_1 = 0.0075 – almost exactly the same as the 10G scenario (0.0073)
  - Using 0.0073 would give a nominal Pmn of 0.120 dB (vs. 0.129 dB)
- Now calculate modal noise and modal noise penalty for different extinction ratios
- In this scenario, the spreadsheet's extinction ratio ("OMA extinction ratio") is 4 dB and the "SONET extinction ratio" (as defined in the spec) is about 3.2 dB
  - For the Gaussian response in the model. For realistic responses with this ISI, the "SONET extinction ratio" would be higher
- Changing the SONET extinction ratio from 3 dB to 2 dB, for this scenario, increases the modal noise penalty (including interaction of penalties) by 0.29 dB
  - In this region, the penalty increases faster than the square of the extinction ratio penalty
  - See next slide
- To move from this spreadsheet scenario to a spec with 2 dB SONET extinction ratio, we would need to change something by 0.31 dB

Modal noise penalty as a function of extinction ratio



SONET extinction ratio penalty defined as (2*average power)/(Eye Amplitude)

2*average power is the Eye Amplitude of a fast clean high-extinction ratio signal with the same average power

dB(Square fit)=A*(dB(SONET ER pen))^2

- Here the red modal noise penalty Pmn+ includes the associated interaction of penalties while the blue "Nominal Pmn (dB) does not

What to change?

1. Could revisit the extinction ratio limit, e.g. choose 2.5 dB SONET extinction ratio, aligning with spreadsheet scenario
   - "Half way" between current draft (2 dB) and 10GBASE-SR/40GBASE-SR4/D1.1 limit (3 dB)
   - Possibly losing a little net benefit to TDP of very low extinction ratio
     - Eye shape vs. RIN_OMA
2. Could reduce the TDP limit by 0.2 dB
   - The 5 dB draft limit seems too high for a stably secure link anyway (see dawe_01_0513_optx.pdf)
3. Could increase the noise in the stressed sensitivity test
   - Making all receivers pay for the benefit of an unknown proportion of transmitters
4. Could investigate modal noise more carefully
   - Hoping that the assumed amount of modal noise is pessimistic
5. Other?

- We reduced the extinction ratio limit in the expectation that it would allow improvements in TDP
  - If that improvement (between 2.5 dB and 2 dB extinction ratio) is at least 0.2 dB, choose option 2
  - If not, choose option 1
  - Could do some of each e.g. 2.2 dB, 0.1 dB

Thank You