

100GBASE-SR4
link penalties vs ER:
MNP, MPN, RIN

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Summary

- 100GBASE-SR4 (clause 95, draft 1.2) has a lower minimum ER spec, reduced from 3 dB to 2 dB, to allow for the significant eye-closure expected of worst case 25.6 Gb/s VCSELs.
- An estimated upper bound penalty increase due to the lower ER limit was calculated, using an augmented 10GE Ethernet spreadsheet model, for MNP, MPN, and RIN_OMA.
- For MNP and MPN, the expected change in penalty is less than 0.05 dB in each case.
- For RIN, the expected change in penalty is between 0.1 dB and 0.5 dB.

MNP

- Assumption: for modal noise penalty (MNP) or mode partition noise (MPN), the fluctuation of received power is proportional to the '1' rail power of the laser.

- For constant '1' power of 1.36 mW

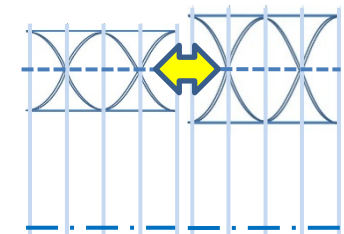
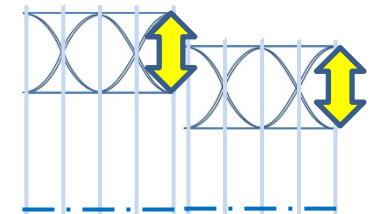
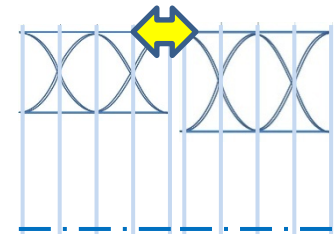
- for ER = 3 dB, OMA = 0.68 mW
- For ER = 2 dB, OMA = 0.5 mW
- Relative power fluctuation could increase by factor of ~ 1.36

- For constant OMA of -3 dBm

- for ER = 3 dB, '1' power = 1 mW
- For ER = 2 dB, '1' = 1.36 mW
- Relative power fluctuation could increase by factor of ~ 1.36

- For constant average power of 0.5 dBm

- for ER = 3 dB, '1' power = 1.495 mW, OMA = 0.746 mW
- For ER = 2 dB, '1' power = 1.375 mW, OMA = 0.508 mW
- Relative power fluctuation could increase by factor of ~ 1.36

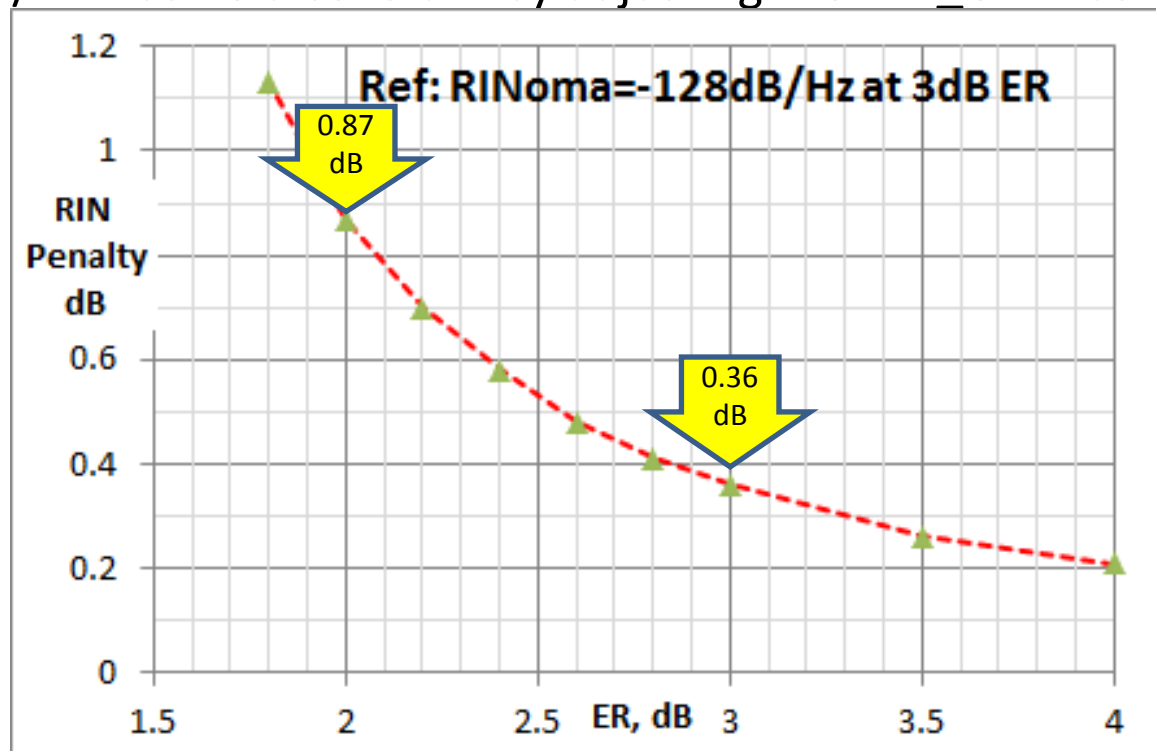


- Current allocation for MNP is 0.13 dB, could increase to ~ 0.18 dB.
- Current allocation for MPN is 0.11 dB; could increase to ~ 0.15 dB.
 - less than 0.05 dB change in both cases

RIN 1 (RIN_OMA = -128 dB/Hz at 3dB ER)

- Assumption: Laser RIN (Relative Intensity Noise) in dB/Hz is assumed to be independent of ER and power.
 - Since the 10GE spreadsheet uses RIN_OMA to calculate RIN penalty, an equivalent RIN_OMA was used in the spreadsheet to take into account the effect of changing ER.
 - The 10GE spreadsheet calculates the equivalent RIN in dB/Hz from the input values for RIN_OMA and ER. The 100GBASE-SR4 link model used RIN_OMA = -128 dB/Hz, equivalent to a RIN dB/Hz of -137.6 dB/Hz.
- The calculated RIN dB/Hz was held constant by adjusting the RIN_OMA as ER was changed.
 - Here's the plot:

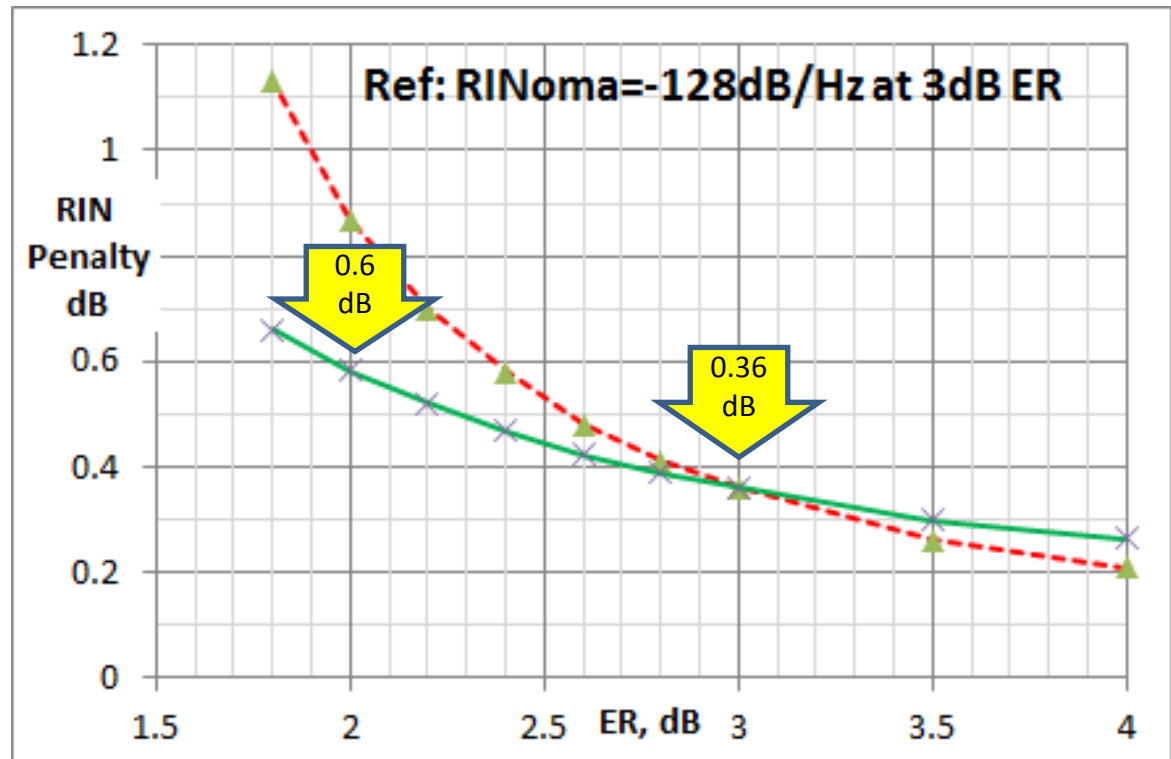
Up to 0.51 dB increase of RIN penalty as ER changes from 3 to 2 dB.



RIN 2 ($RIN_{OMA} = -128$ dB/Hz at 3dB ER)

- Assumption: Laser RIN (Relative Intensity Noise) in dB/Hz is assumed to be dependent on square root of power. RIN penalty calculated for constant OMA = -3 dBm and RIN = -137.6 dB/Hz
 - Since the 10GE spreadsheet uses RIN_{OMA} to calculate RIN penalty, an equivalent RIN_{OMA} was used in the spreadsheet to take into account of the effect of changing ER and the decrease in RIN in dB/Hz with rising '1' power.
 - Here's the plot superimposed on the last one...

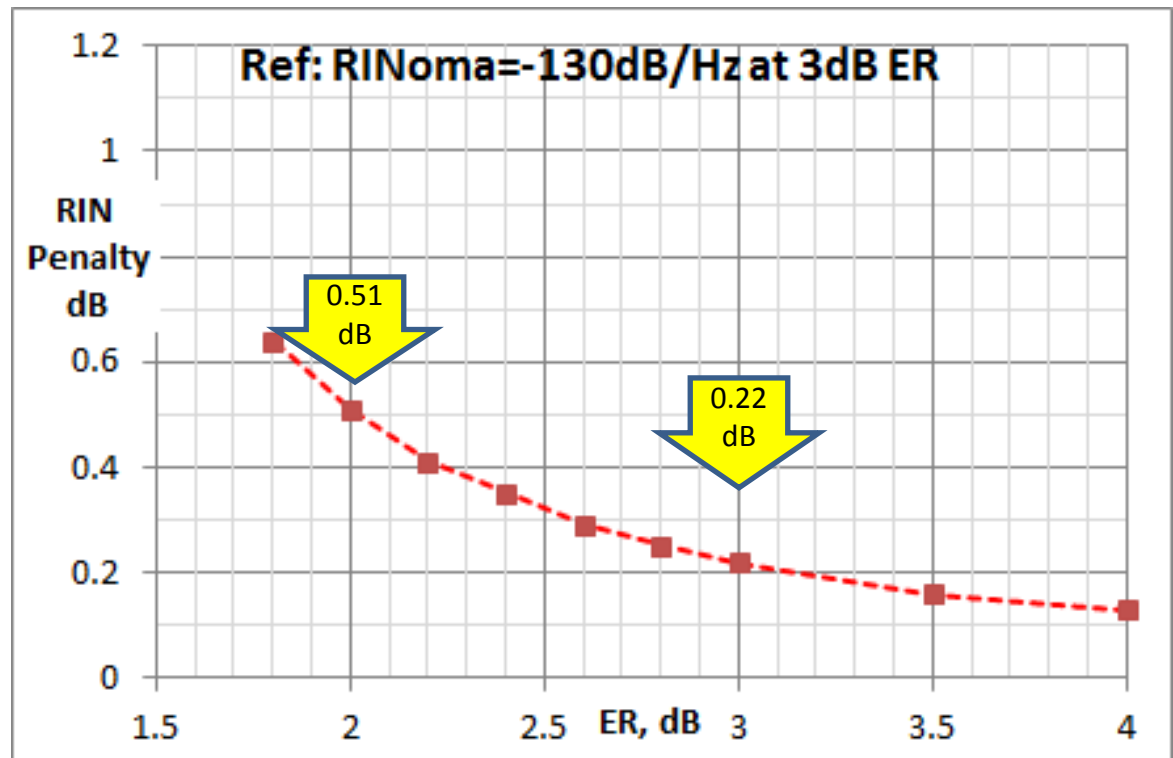
Shows 0.25 dB increase of RIN penalty as ER changes from 3 dB to 2 dB.



RIN 3 (RIN_OMA = -130 dB/Hz at 3dB ER)

- Assumption: Laser RIN (Relative Intensity Noise) in dB/Hz is assumed to be independent of ER and power.
 - Since the 10GE spreadsheet uses RIN_OMA to calculate RIN penalty, an equivalent RIN_OMA was used in the spreadsheet to take into account the effect of changing ER.
 - The 10GE spreadsheet calculates the equivalent RIN in dB/Hz from the input values for RIN_OMA and ER. The 100GBASE-SR4 link model used RIN_OMA = -130 dB/Hz, equivalent to a RIN dB/Hz of -139.6 dB/Hz.
 - Here's the plot:

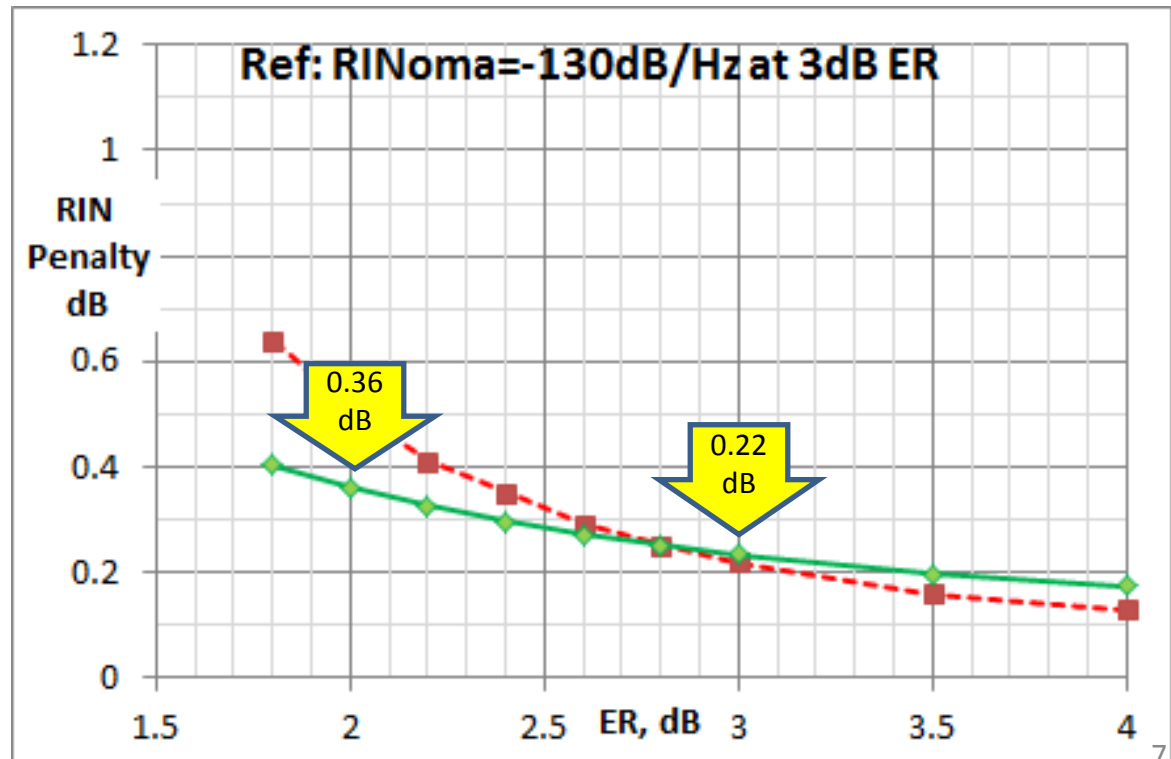
Shows 0.29 dB increase of RIN penalty as ER changes from 3 dB to 2 dB.



RIN 2 (RIN_OMA = -130 dB/Hz at 3dB ER)

- Assumption: Laser RIN (Relative Intensity Noise) in dB/Hz is assumed to be dependent on square root of power. RIN penalty calculated for constant OMA = -3 dBm and RIN = -139.6 dB/Hz
 - Since the 10GE spreadsheet uses RIN_OMA to calculate RIN penalty, an equivalent RIN_OMA was used in the spreadsheet to take into account of the effect of changing ER and the decrease in RIN in dB/Hz with rising '1' power.
 - Here's the plot superimposed on the last one...

Shows 0.14 dB increase of RIN penalty as ER changes from 3 dB to 2 dB.



MNP notes

- Modal noise penalty is the result of mode selective loss interacting with the variation of power distribution within a multi-mode fibre core.
- Assuming the laser chirp and spatial mode distribution are independent of ER, then the power fluctuation will be proportional to the power in the '1' and '0' levels.
- For an AC coupled receiver chain (i.e. the slicing threshold is at the 50% point of the eye) the noise on the '1' level will tend to dominate BER

MPN notes

- Modal Partition Noise (MPN) is the result of power fluctuation of individual wavelengths of a multi-wavelength source interacting with the chromatic dispersion of a multi-mode fibre.
- Assuming the laser's k factor is independent of ER, then the power fluctuation will be proportional to the power in the '1' and '0' levels.
 - The k factor is related to the degree fluctuation of the individual wavelengths.
 - In practice, the k factor would be expected to decrease with lower ER, which would tend to reduce MPN*.
- For an AC coupled receiver chain (i.e. the slicing threshold is at the 50% point of the eye) the noise on the '1' level will tend to dominate BER.

* References:

“Direct high-frequency modulation of VCSELs and applications in fibre optic RF and microwave links”, A Larsson, C Carlsson, J Gustavsson, A Haglund, P Modh and J Bengtsson, Photonics Laboratory, Department of Microtechnology and Nanoscience, Chalmers University of Technology, SE-41296 Göteborg, Sweden, Nov 2004.

“An Investigation of Mode Partitioning in VCSELs”, Paul Coe, HP Laboratories Bristol, Oct 1996.

RIN notes

- In an ideal laser, RIN (relative intensity noise) is the result of the coherent mixing product of the spontaneous emission and the recirculating power within the laser cavity. The spontaneous emission is stochastic in nature and uncorrelated phase with respect to the recirculating optical power.
 - Output power = $P_r + P_{sp} + 2.(P_r.P_{sp})^{1/2}$
- As laser output power is increased, the recirculating power increases, but the spontaneous emission remains constant (because the round trip gain is clamped at ~ 1 once the laser is above threshold). The result of the mixing product of spontaneous emission and recirculating power, and thus RIN, increases as the square root of the laser output power.
- For an AC coupled receiver chain (i.e. the slicing threshold is at the 50% point of the eye) the noise on the '1' level will tend to dominate BER.