Modal Noise and Implications for the CSRS Test

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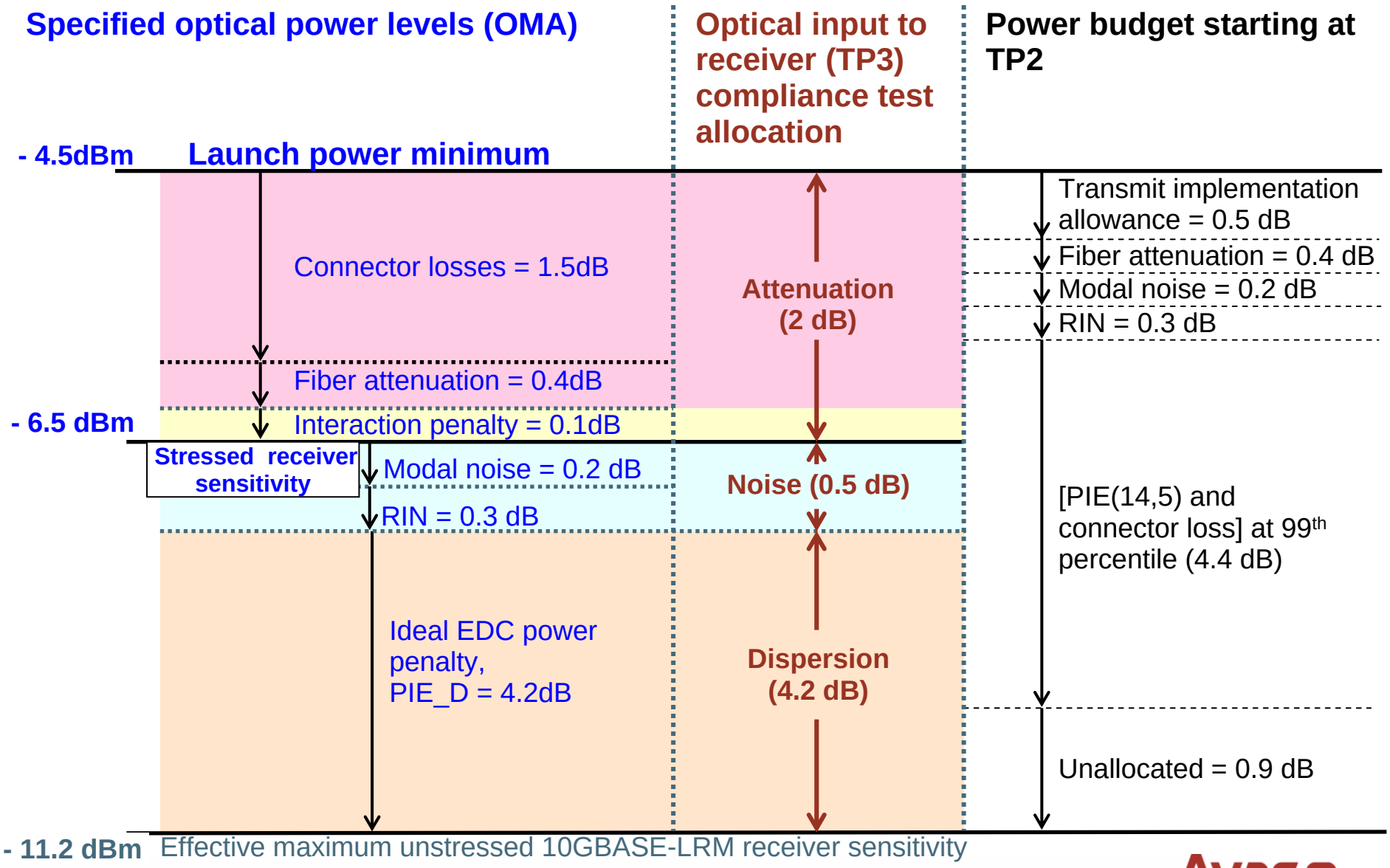
Outline

- Review of LRM power levels, power budget and testing
- History of modal noise allocation for LRM
- Standard deviation of connector loss due to modal noise
- Independent calculation of modal noise power penalty
- Observation that modal noise allocation is not required in CSRS test
- Observation that removal of additional noise loading beyond noise within the equipment would greatly simplify the CSRS test
- Recommendation that noise loading be removed from CSRS test

Optical Power, Compliance Testing and Budgeting



History of the 0.2 dB of Modal Noise allocation

The original worst case modal noise theory used to derive the modal noise power penalties for Gigabit and 10Gigabit Ethernet was modified to take into account:

- Actual launch mode power distributions
- Actual mode coupling at connectors
- Actual modal noise standard deviation at connectors

The results of this work were presented to the channel ad hoc by Pepeljugoski et al.[1]

The results indicated that the worst case modal noise penalty was 0.2 dB.

Total Link Modal Noise Standard Deviation

In this presentation: The modal noise standard deviation (SD) was calculated per [2] using worst case laser parameters per Gigabit Ethernet modal noise calculation method [1, 3].

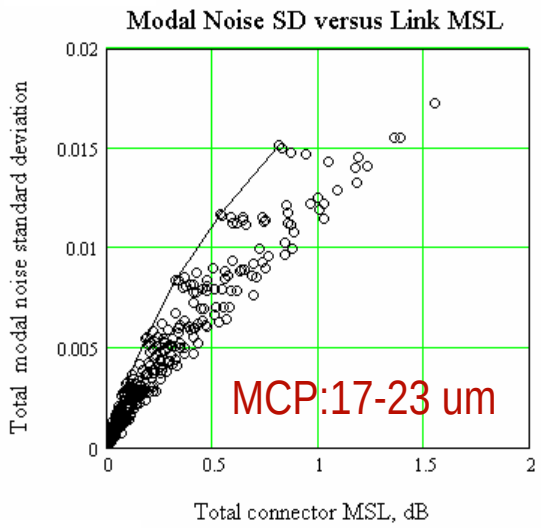
All combinations of connector offsets from 0 to 7 um and 0 to 8 um for a first and second connector in 1 um steps were calculated.

All offsets from 0 to 29 um in 1 um steps for the standard 10GBASE-LRM single-mode launch were included.

The worst-case connector combination was found to be a first connector of 7 um and a following connector of 8 um (This is equivalent to the three connectors with 7,7,4 um offsets that was found to be the worst-case combination that is within the loss budget for 10GBASE-LRM by Task 2 of the Channel Ad Hoc).

The worst case modal noise penalty was calculated with the 7,8 connector combination.

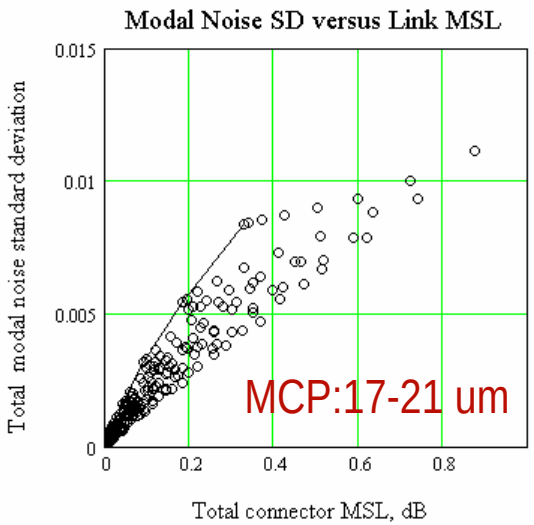
Modal Noise & Link Connector Mode Selective Loss

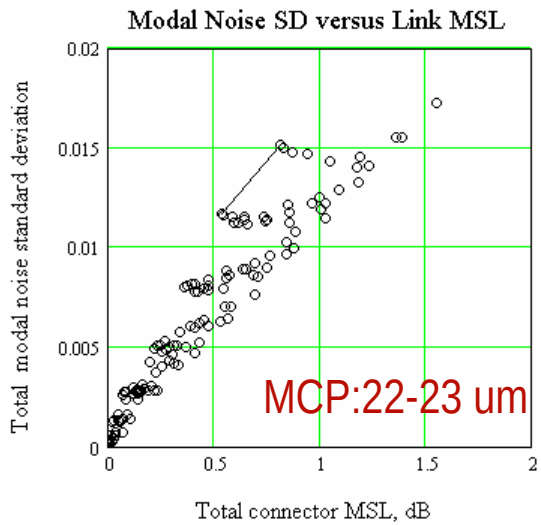


The standard deviation of the non-Gaussian modal noise is approximately proportion to the total connector mode selective loss in dB.

The extreme SD values are due to:

- MCP with 22 to 23 um offsets.
- All connectors at extreme offset range.

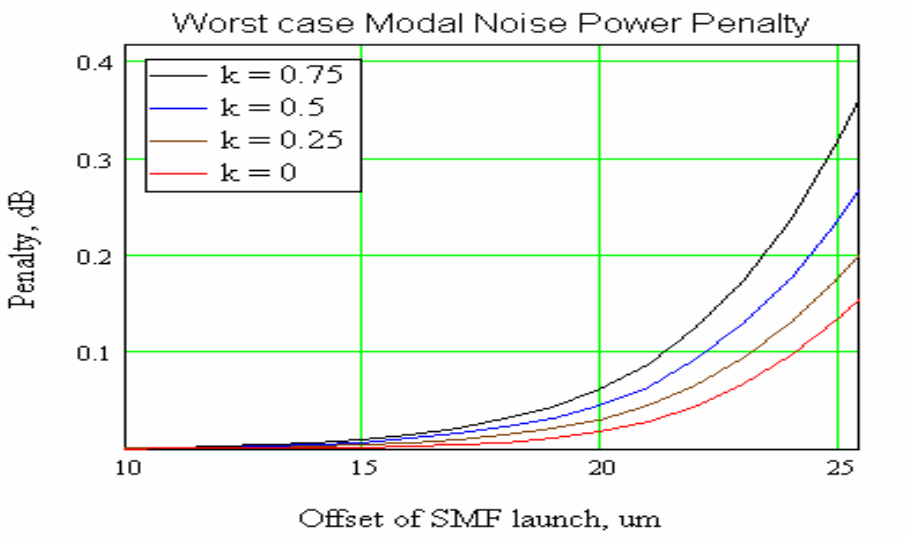


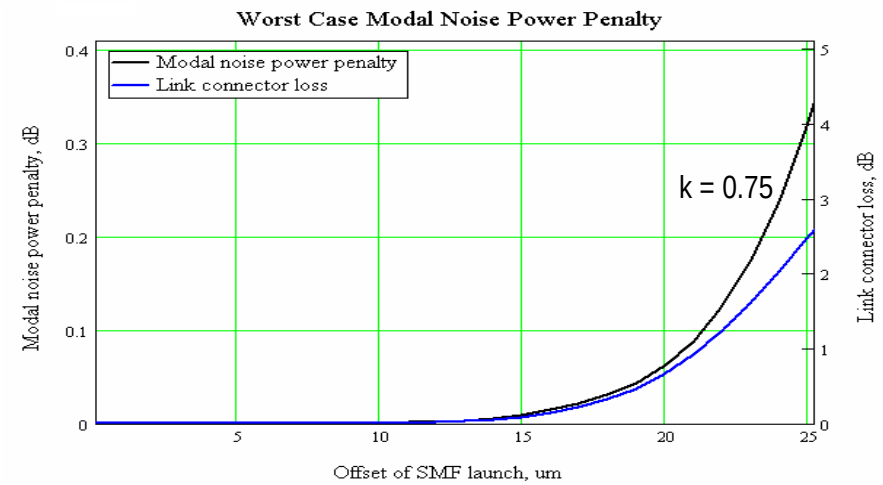


The graphs are plots of the SD for connector offsets (x, y) and SMF launch offset d: x ranges from 0 to 7 in 1 um steps, y ranges from 0 to 8 in 1 um steps and d is within the range stated on the graph, in 1 um steps.

The line shows the (0,8) trajectory versus d. This connector combination produces the maximum SD for a given MSL value.

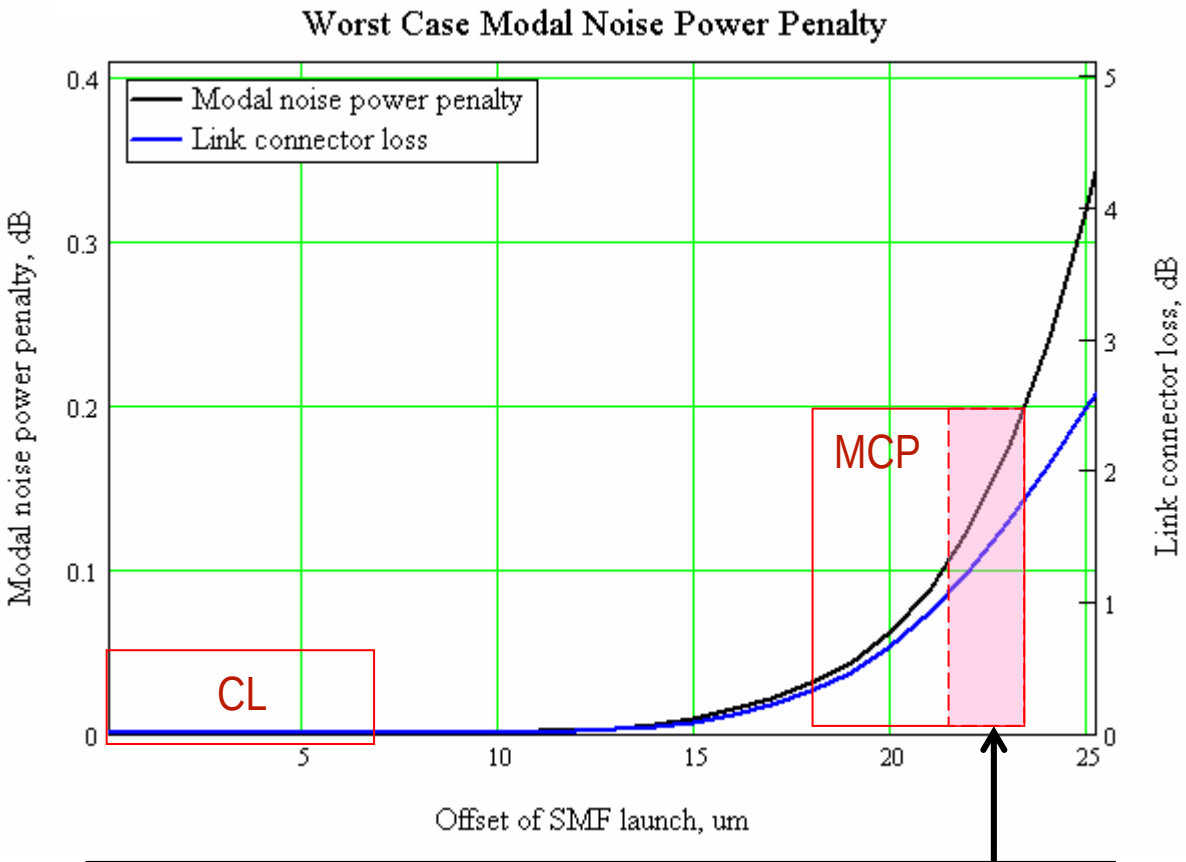
Independent Calculation of The Worst Case Modal Noise Power Penalty





- Same method as [1] but an independent programming of the worst case modal noise model: k is the so called laser mode partitioning factor.
- Two connectors 7, 8 um during first 10 m of the link: previously proven to be worse than or equivalent to 7,7,4 um connector configuration for MCP.
- Worst case penalty in agreement with the calculations presented to Channel Ad Hoc by Pepeljugoski et al., for 7,7,4 connector configuration.
- Worst case connector loss in agreement with calculations presented to Ad Hoc by Kropp et al., for 7,7,4 configuration [4].

Worst Case Modal Noise Power Penalty



- Observable modal noise can only be produced here
- Very narrow window of exposure.

Center launch

- CL is not burdened by modal noise.
- Therefore, no need for modal noise loading in CSRS for this case.

MCP launch

- Large offset MCP launches will rarely generate, true, split, bi-modal pulses.
- Only large offset MCP launches with rare connector combinations can produce observable modal noise.
- Therefore, D3.1 is based on having the most pessimistic level of modal noise.

Observations 1

Modal noise only an issue for the MCP.

Modal noise really only occurs under extreme and rare circumstances:

- MCP near 23 um offset for 62MMF
- MCP near 16 um offset for 50MMF
- Connectors all at extreme of possible offset range
- Laser with worst case k

We should not include a noise loading allocation for modal noise in conformance tests.

Therefore, we should reduce the noise loading in the conformance tests by at least 4 dB electrical.

Observations 2

The CSRS is extremely difficult to implement.

The additive noise is significant in making the test difficult to implement.

- The colour of the added noise is critical.
- The level of the added noise is critical.

Conclusions

The modal noise component of the CSRS can safely be removed from the test.

However, my preference is for all the added noise loading to be removed as this will greatly simplify the test.

If the committee is concerned about removing the noise loading then about 0.3 dB extra attenuation can be added to the CSRS test. The stress test would then be done at -6.8 dB dB OMA.

The effective receiver sensitivity would be -11 dBm OMA.

Margin in the budget would still remain to be allocated.

References

1. P. Pepeljugoski, D. M. Kuchta and A. Risteski, “ Improvements to Modal Noise Penalty Calculations,” presented to 10GBASE-LRM Channel Ad hoc.
2. K. Peterman, “Non-linear Distortions and Noise in Optical Communication Systems due to Fiber Connectors,” IEEE Journal of Quantum Electronics, Vol. QE-16; No.7, pp 761-770
3. R. J. S. Bates, D. M. Kuchta and K. Jackson, “Improved multimode fibre link BER calculations due to modal noise and non-self-pulsating lasers,” Optical and Quantum Electronics, vol. 27, pp 203-224, 1995.
4. J. R. Kropp, “Attenuation of worst case test configuration,” Contribution to Channel Ad hoc, 31st August 2004.

Back up

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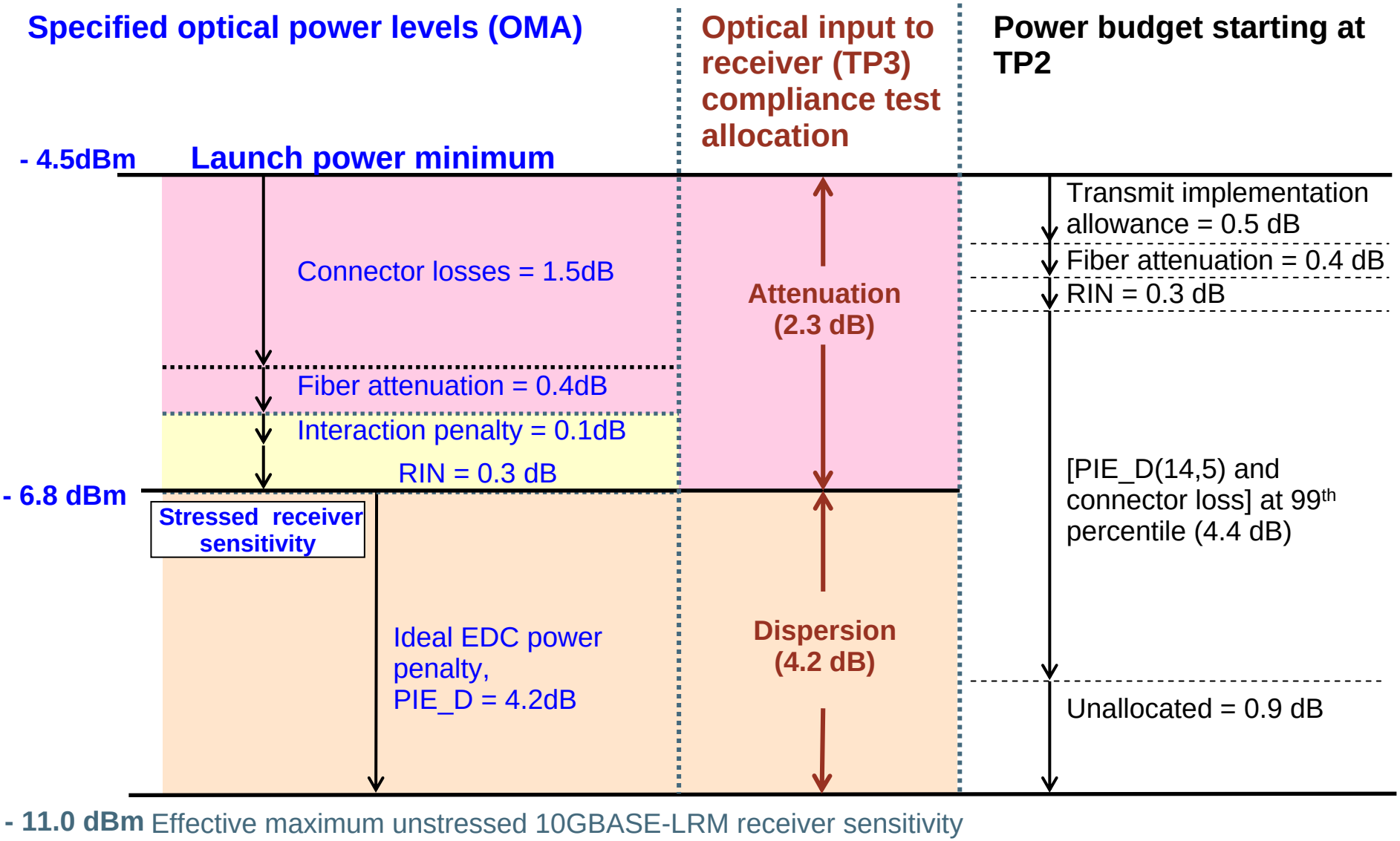

Observations 3

I have received feedback that at the current high values of added noise there is a risk that low power, low latency, CMOS and future highly integrated implementations will effectively be outlawed by the standard.

Observations 4

With noise the split symmetric stressor is known to be the most challenging stressor.

But in the real world of fibers a split symmetric type of stress in combination with modal noise is a corner case of a corner case which can only be observed if:

- k is worst case.
- MCP is within 2 um of the maximum allowed offset.
- Total link mode selective loss due to connectors at the transmitter end of link is close to the maximum of the link loss budget.
- The fiber is one of those rare ones that creates a bi-modal impulse response with offset launch producing a mode splitting greater ~ 150 ps in a 220 m length.
- The fiber is close to 220 m in length.