Extended Reach Proposal

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Outline

- Extended Reach *ad hoc* Charter
- Summary/Conclusions
- Extended Reach Annex Proposal
- Market Estimates
- Statistical Module Analysis
- Baseline/Example Link Module Attributes

Background
Extended Reach (XR) ad hoc Charter

Munich Straw Poll

- **"Straw Poll #15**: Should we continue to work on a proposal for an annex to extend the reach of a 40GBASE-SR4 and 100GBASE-SR10 in addition to the proposal ("pepeljugoski_01_0508.pdf") as in "jewell_01_0508.pdf".
  Yes: 55
  No: 3
  Approximate Room Count: 108"

- "Petar Pepeljugoski suggested that an Ad-Hoc be formed to study an extended reach option over parallel multimode fiber. The Chair noted the interest from the straw poll the previous night, and asked the group if there were any objections to forming an Extended Reach Parallel MMF Ad-Hoc. There were no objections. The Chair appointed the Alessandro Barbieri and John Petrilla as Co-Chairs of the Extended Reach Parallel MMF Ad-Hoc. The Ad-Hoc's mission is to formulate a technical proposal for extended reach over parallel multimode fiber."

See Munich Minutes,
http://www.ieee802.org/3/ba/public/may08/minutes_01_0508_approved.pdf

Extended Reach Options
Summary/Conclusions

- **Any additional module or module development cost required for an extended reach option for 40G will discourage suppliers and reduce competition.**
  - The incremental market size is too small (1.2% to 2.8% of links > 10 m) and will be further reduced due to availability of alternative solutions including user-selected baseline modules to justify investment.
  - The total market will shrink due to the higher cost structure.
- **Any additional module or module development cost required for an extended reach option for 100G will discourage suppliers and reduce competition.**
  - The incremental market size is small (1.2% to 2.8% of links > 10 m) and will be further reduced due to availability of alternative solutions, including XLAUI/CAUI interface modules, user-selected baseline modules, ganged SFP+ modules, FEC and point-to-point links to justify investment.
  - The total market will shrink due to the higher cost structure.
- **Since the small market size for > 100m links doesn't justify additional investment but the performance of XLAUI/CAUI interface modules and a high percentage of baseline modules will support the target extended reach lengths, we should take advantage of this and enable it as a solution in a more formal manner.**
  - An informative annex is proposed that will identify alternative approaches and available tradeoffs, develop methods to determine if a particular system can support the target extended reaches and provide estimates of the likelihood of successful operation for links over 150 m of OM3 and 250 m of OM4.

Extended Reach Annex Proposal

- Goal: Prepare an annex that offers methods that may be used to extend operation of 40GBASE-SR4 and 100GBASE-SR10 beyond that considered, e.g. maximum link length, in clause 156.
- Approach:
  - Examine likely PMD implementations, e.g. XLAUI/CAUI (NAUI) interface modules and PMD service (PPI) interface modules, for expected worst case operation, identify alternative approaches and available performance tradeoffs and define methods for making and taking advantage of these tradeoffs.
  - Develop methods that can be used with installed systems that determine if support of extended operation will be successful or that determine probability of success.
  - Examine performance distributions of likely PMD implementations and using methods that estimate probability of successful extended operation determine the likelihood of successful operation for links using 150 m of OM3 and 250 m of OM4 to provide guidance to the user.

Data Center Link Distribution

Interpreting flatman_01_0108

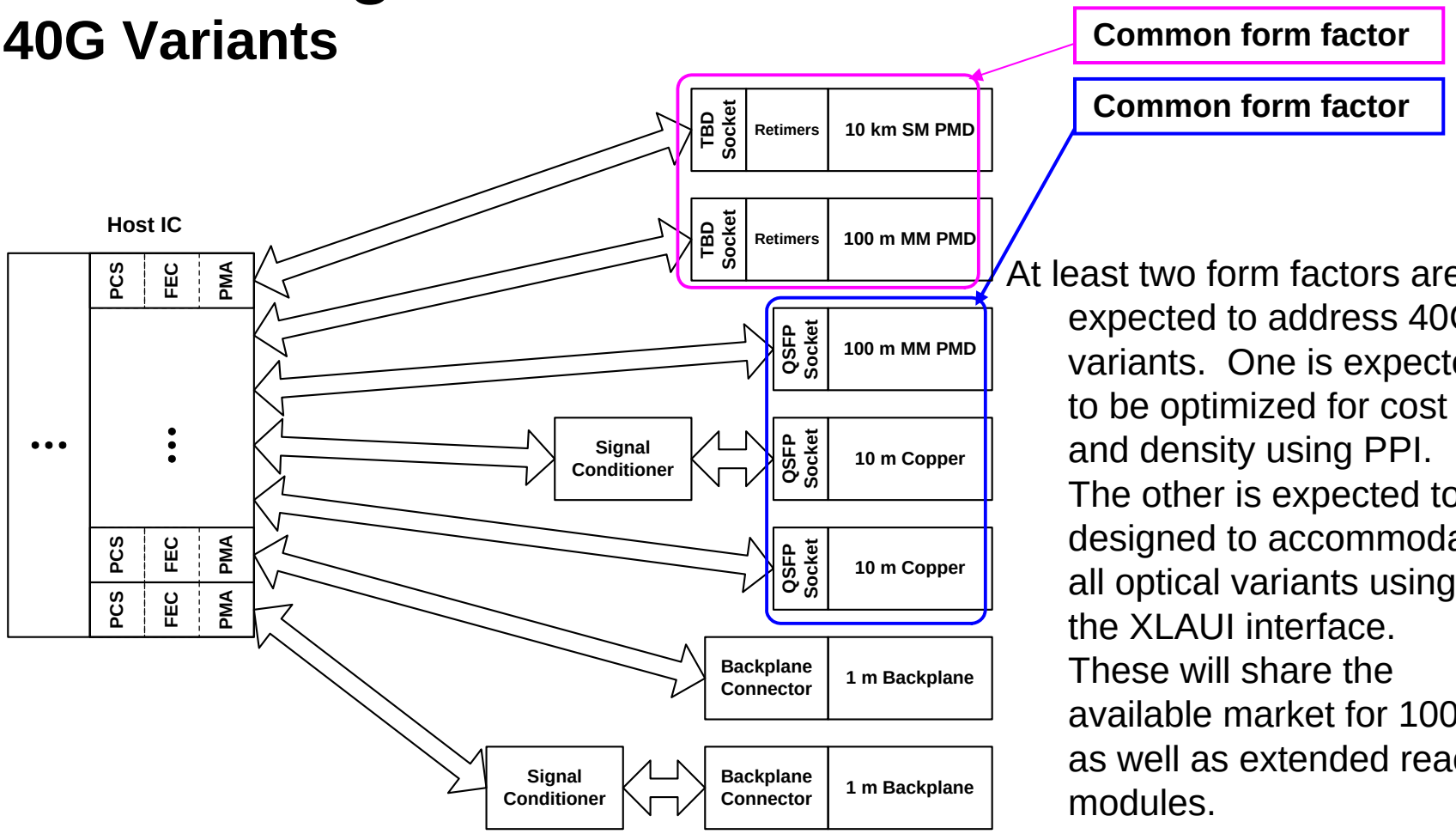
Application	Sample Size (all lengths)	Sample Size (> 10 m)	Ratios (> 10 m)	> 100 m % Flatman	> 100 m % Swanson*
Client to Access, C-A	250000	166750	55.6	0% of C-A 0 links 0% >10m	
Access to Distribution, A-D	16000	16000	5.3	11% of A-D 1760 links 0.95% >10m	32% of A-D 5120 links 2.76% >10m
Distribution to Core, D-C	3000	3000	1.0	15.2% of D-C 456 links 0.25% >10m	

- The above table is derived from analysis of the results in flatman_01_0108 adjusted per the Alan Flatman message of August 29, 2008. The reported sample sizes are used to estimate the relative sizes of the different data center applications. These are combined with the percentages given for links longer than 100 m to estimate the number of links greater than 100 m. Finally the percentages (>100m links / total >10m links) are calculated for each application.
- The above data is appropriate to data centers and may not reflect high performance computer installations.

* As reported in flatman_01_0108.

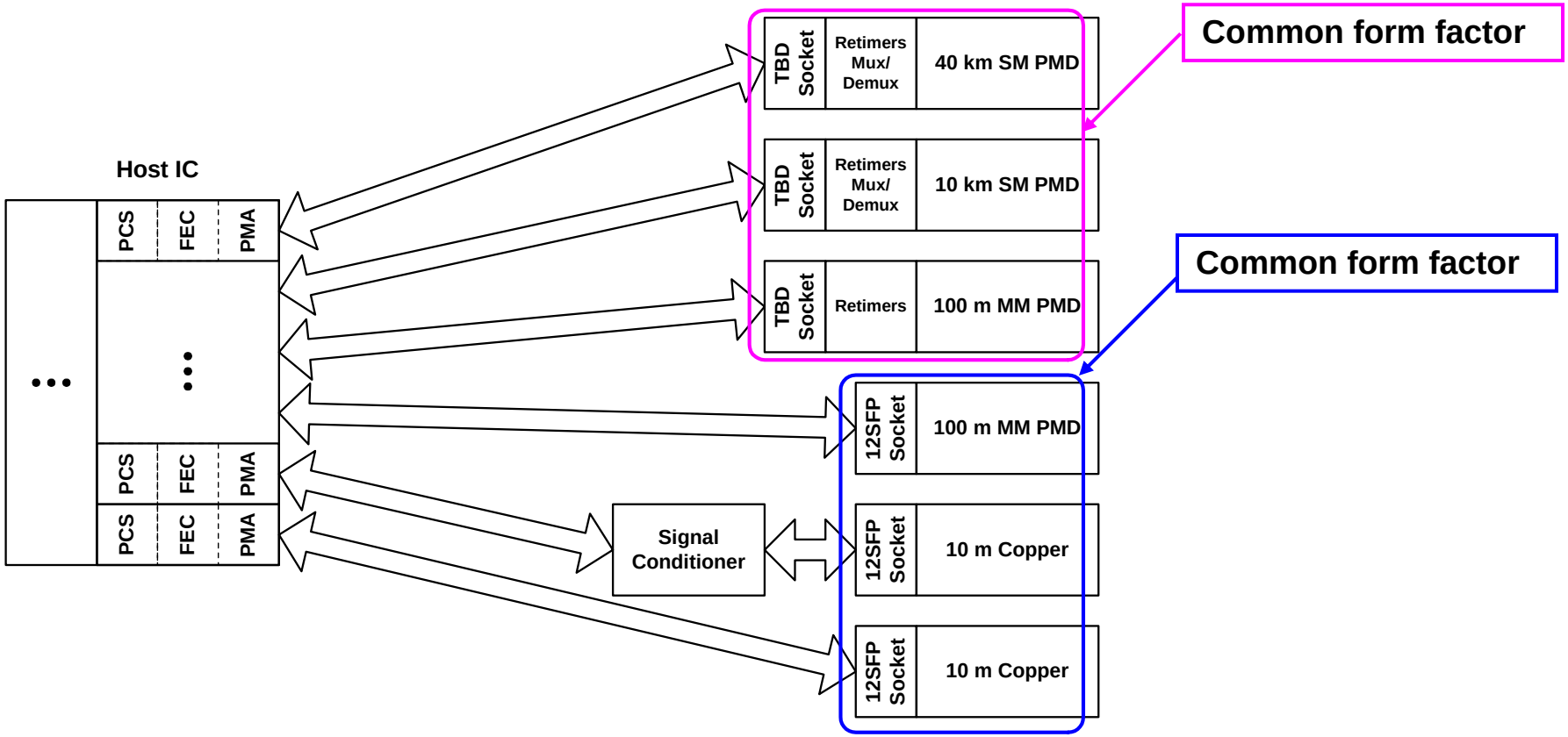
Market Segmentation

40G Variants



At least two form factors are expected to address 40G variants. One is expected to be optimized for cost and density using PPI. The other is expected to be designed to accommodate all optical variants using the XLAUI interface. These will share the available market for 100 m as well as extended reach modules.

Market Segmentation:
100G Variants



At least two form factors are expected to address 100G variants. One is expected to be optimized for cost and density using PPI. The other is expected to be designed to accommodate all optical variants using the CAUI interface. These will share the available market for 100 m as well as extended reach modules.

Extended Reach Statistical Example Summary

	NAUI Modules	PPI Modules (WC baseline)	Example 98% Probability	Example 92% Probability
OM3 reach two-sided	208 m	100 m	150 m	TBD
OM4 reach two-sided	251 m	126 m	TBD	250
PCB host IC to Tx	~ 10” for SDD21 at -1dB/inch	3” to 4” for SDD21 at -1dB/inch	3” to 4” for SDD21 at -1dB/inch	3” to 4” for SDD21 at -1dB/inch
PCB host IC to Rx	~ 10” for SDD21 at -1dB/inch	3” to 4” for SDD21 at -1dB/inch	3” to 4” for SDD21 at -1dB/inch	3” to 4” for SDD21 at -1dB/inch

The performance of the Internal CDR option was based on a combination of expected CDR characteristics and optical transmitters and receivers equivalent to those in the baseline proposal. It should be expected that as these modules are optimized for cost and power their fiber reach performance may approach that of the baseline modules.

Statistical Module Analysis
Example Distributions

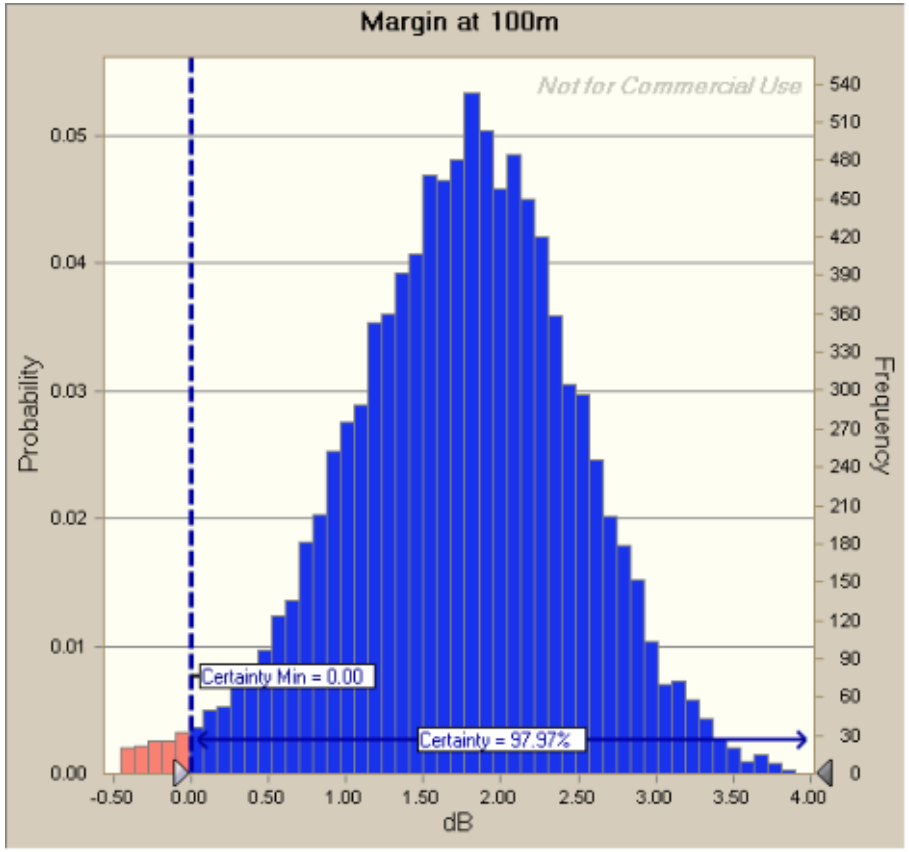
Attribute	Min/Max	Mean	Std. dev.	Notes
Tx OMA, dBm	-3.00	-2.50	0.50	(1) Informative Min
Tx RIN(OMA), dB/Hz	-128 to -132	-132.0	2.00	(1) Informative Max
Tx Rise & fall times (20%-80%), ps	35.0	33.0	2.00	(1) Informative Max
Tx Contributed DJ, ps	11.00	11.00	2.00	(1) Informative Max
Tx RMS Spectral width, nm	0.65	0.45	0.05	Normative Max
Rx Sensitivity, dBm	-11.30	-12.00	0.75	(2) Informative Max
Rx Bandwidth, MHz	7500	10000	850	(2) Informative Min
Rx Contributed DJ, ps	8.00	7.00	1.00	(2) Informative Max

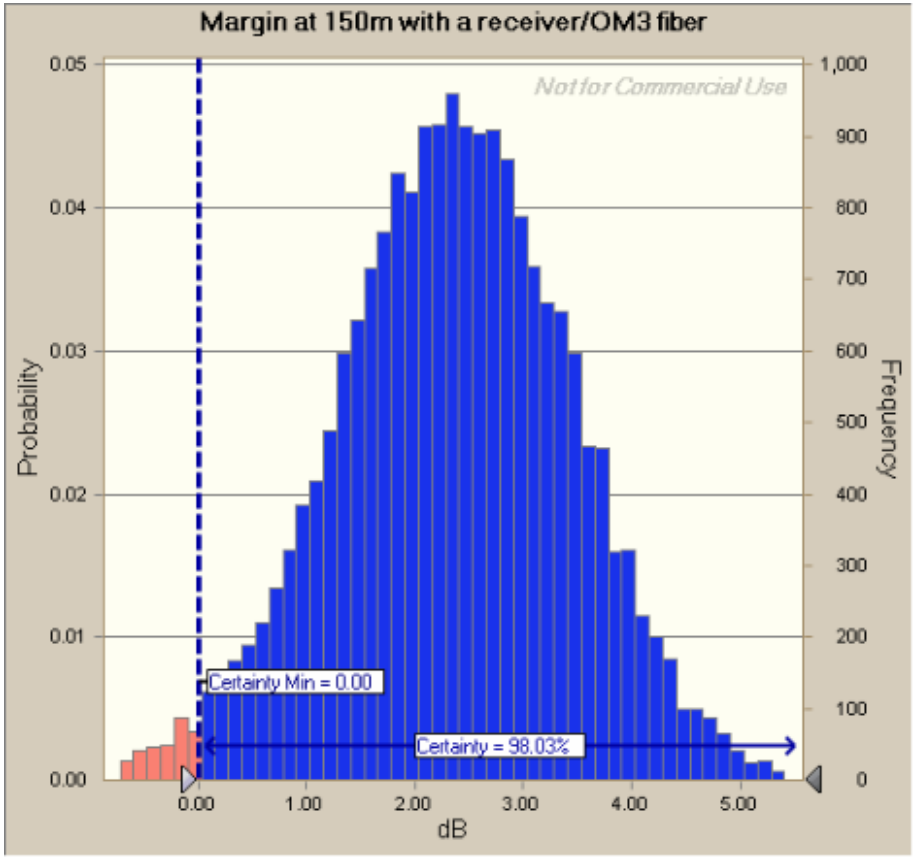
(1) Included in aggregate Tx test.

(2) Included in aggregate Rx test.

- The above table shows the module attributes which were converted to distributions, the associated normative limit or informative limit and the distributions which were used in the example analysis.

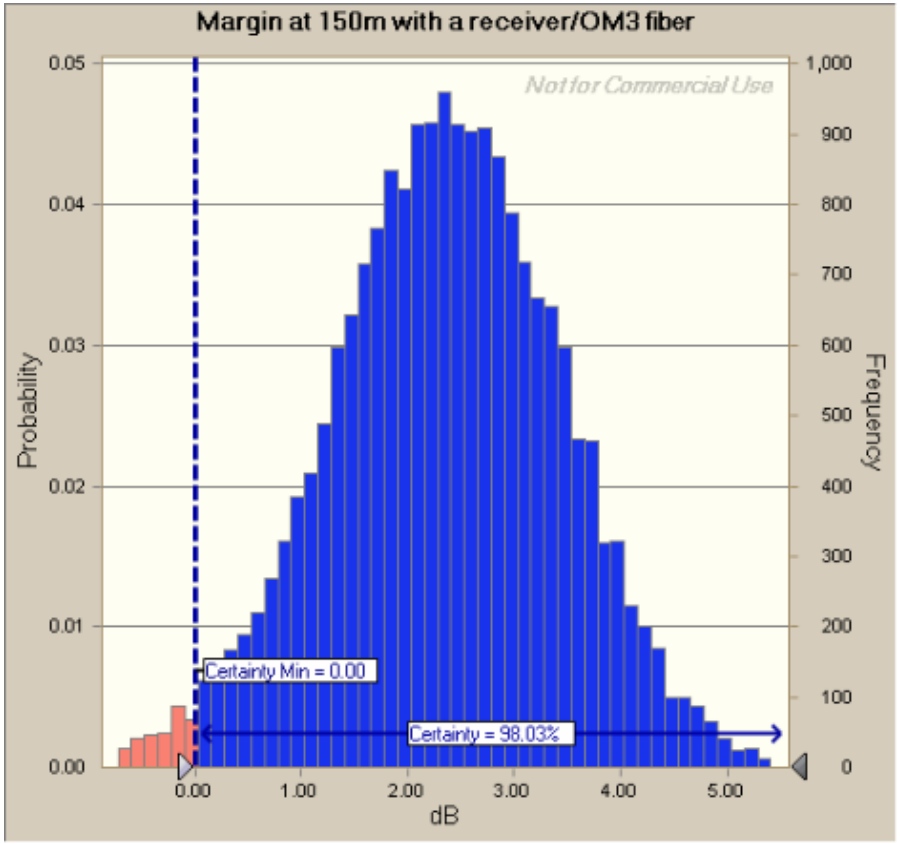
Baseline/Example Margin Distributions

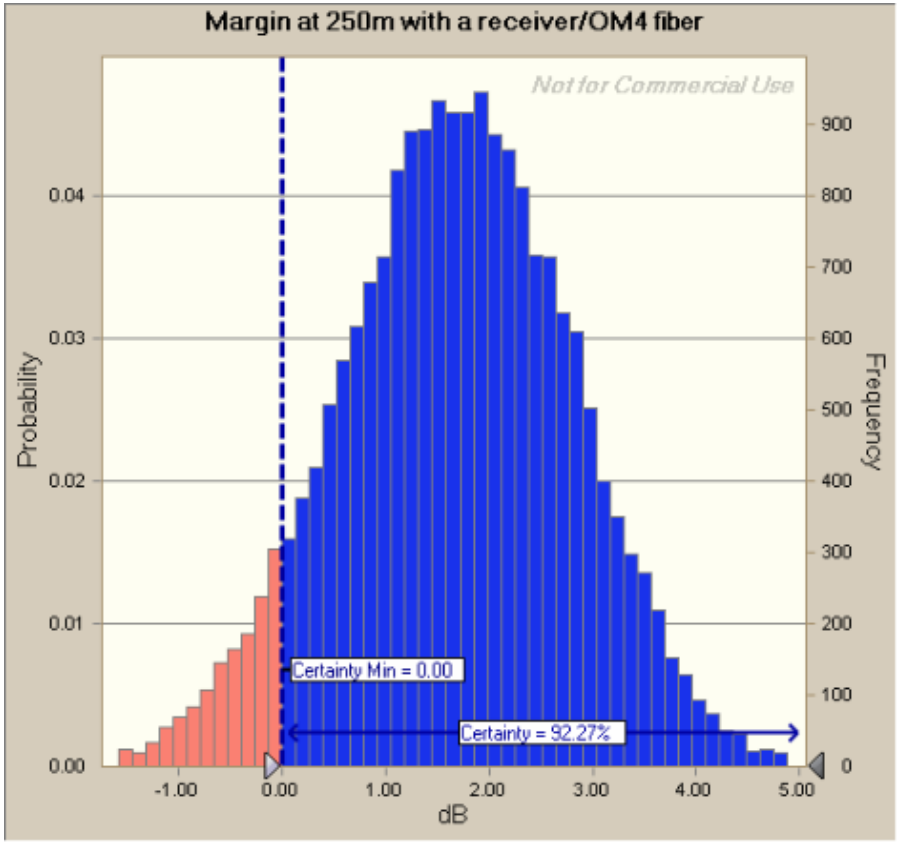




The above figures show link margin distributions using the example attribute distributions for operation over 100 m and 150 m of OM3 fiber. The 100 m OM3 case is representative of an aggregate Tx test expected at the module supplier and here units with less than zero margin would fail such a test and not be found in the field. However, in this analysis they remain in the distribution. While the quantity of units with less than zero margin are similar for these two cases, it should not be assumed that they represent the same units.

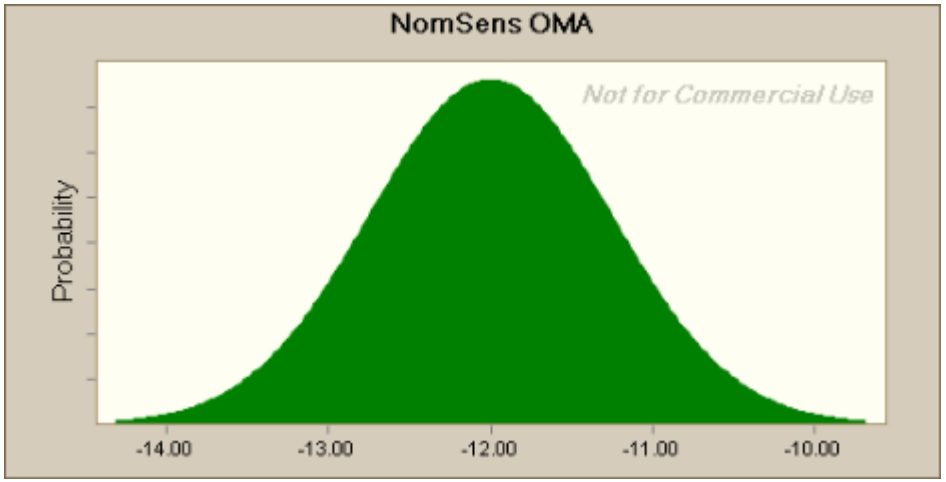
Baseline/Example Margin Distributions

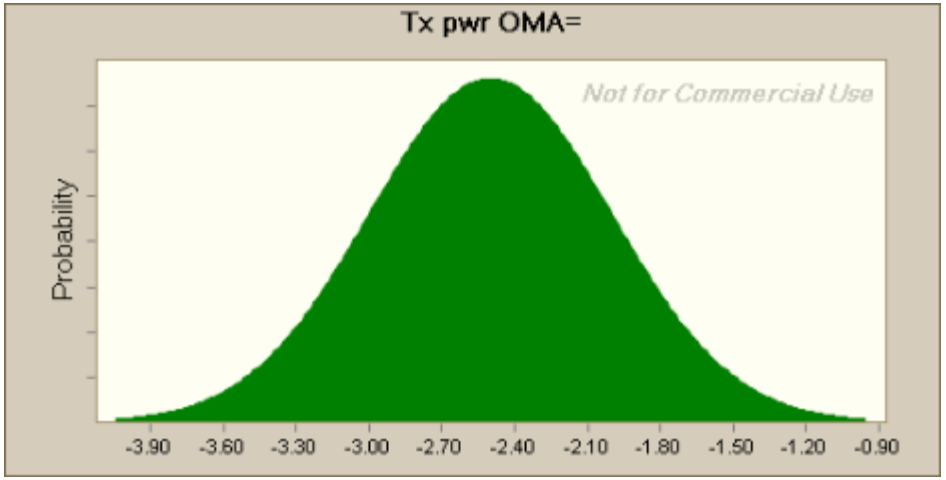




The above figures show link margin distributions using the example attribute distributions for operation over 150 m of OM3 and 250 m of OM4. Note this example analysis represent a single lane. For multiple lane devices, the probability of a module where one of N lanes having margin less than zero will be one to N higher depending on the correlation of attributes among the N lanes. However, the module vendor is expected to improve the attribute distributions until acceptable yields are realized resulting in something not too unlike that shown here.

Baseline/Example Attribute Distributions





The adjoining figures show samples of the attribute distributions used in the example analysis. All attribute distributions used in the example analysis are Gaussian.

40GBASE-SR4 & 100GBASE-SR10 Proposal

Baseline/Example Transmitter Attributes (Each Lane)

- Min OMA: -3.0 dBm
- Min ER: 3.0 dB
- Min Center Wavelength: 840 nm
- Max RMS Spectral Width: 0.65 nm
- Max Transition Time (20%, 80%): 35 ps (1)
- Max RIN12OMA: -130 dB/Hz (2)
- RIN Coefficient: 0.70 (1)
- Mode Partition Noise Coefficient: 0.30 (1)
- Min Optical Reflection Tolerance: -12 dB
- TP1 Jitter Allocation: TJ = 0.300 UI, DJ = 0.150 UI (3)
- TP2 Jitter Allocation: TJ = 0.488 UI, DJ = 0.284 UI (3)

Above attributes are included in the baseline proposal unless otherwise noted.

(1) Attribute is required for link model but is not part of proposal.

(2) Proposal is examining values in the range of -128 dB/Hz to -132 dB/Hz.

(3) TP1 DJ, TP1 TJ & TP2 DJ are informative.

40GBASE-SR4 & 100GBASE-SR10 Proposal

Baseline/Example Receiver Attributes (Each Lane)

- Max Sensitivity: -11.3 dBm (1)
- Min Bandwidth: 7500 MHz (1)
- RMS Base Line Wander: 0.025 (1)
- Max Rx Reflection: -12 dB
- TP3 Jitter Allocation: DJ = 0.284 UI, DCD = 0.103 UI (1)
- TP3 Jitter Allocation: TJ = 0.511 UI (2)
- TP4 Jitter Allocation: TJ = 0.700 UI
- TP4 Jitter Allocation: DJ = 0.367 UI (2)

Above attributes are included in the proposal unless otherwise noted.

(1) Attribute is required for link model but is not part of proposal.

(2) TP3 TJ, & TP4 DJ are informative.

40GBASE-SR4 & 100GBASE-SR10 Proposal

Baseline/Example Link Attributes (Each Lane)

- Signal Rate: 10.3125 GBd
- BER: < 10^{-12} (Q = 7.034)
- 100 m of OM3
- 1.5 dB connector loss allocation
- Signal Power Budget: 8.3 dB (1)
- Attenuation = 0.36 dB (1)
- Center Eye Penalties (1)
  - Pisi = 1.40 dB
  - Pdj = 0.22 dB
  - Pmn = 0.30 dB
  - Pmpn = 0.02 dB
  - Prin = 0.15 dB
  - Pcross = 0.14 dB
- 0.30 UI Eye Width Penalty = 4.11 dB (1) (see figure on page 9)

Above attributes are included in the proposal unless otherwise noted.

(1) Output of link model.