



A Furukawa Company

Recovering a Common MMF Link Model

Robert Lingle Jr.

Kasyapa Balemarthy

IEEE P802.3bm 40 Gb/s and 100 Gb/s Fiber Optic Task Force

September 2012, Geneva

Laser-based MMF link model (I)

- **Link model created for Gigabit Ethernet 802.3z**
 - See for example, “Proposed Worst Case Link Model for Optical Physical Media Dependent Specification Development;” by Cunningham, Nowell, Hanson; San Diego, Jan 1997, http://grouper.ieee.org/groups/802/3/z/public/presentations/jan1997/dc_model.pdf
 - Built on previous Del Hanson model for LED-based links
 - Uses Gaussian models for link “filters” and noise sources
 - Mode partition noise and RIN treated as AWGN with closed form expressions; simple allotment for modal noise penalty.
- **Model updated for 10GBASE-SR in 802.3ae**
 - See for example, “Review of the 10Gigabit Link Model” by Cunningham and Dawe; ONIDS 2002, White Paper.
 - Supported by Monte Carlo simulations of the ISI penalty accounting for variation in and limits of the VCSEL mode power distribution, fiber DMD, and launch and connector offsets.
 - “Modeling and Simulation of Next-Generation Multimode Fiber Links,” by Pepeljugoski, Golowich, Ritger, Kolesar, Risteki, J. Lightwave Technol., vol. 21, p. 1242 (2003).
 - “Development of System Specification for Laser-Optimized 50- μ m Multimode Fiber for Multigigabit Short-Wavelength LANs,” by Pepeljugoski, Hackert, Abbott, Swanson, Golowich, Ritger, Kolesar, Chen, Pleunis, J. Lightwave Technol. Vol. 21, p. 1256 (2003)

Laser-based MMF link model (II)

Skill and experience are required to use spreadsheet correctly

- Example: There are multiple ways to make a compliant 10GBASE-SR source passing TDP. The realistic parameter space should be spanned:

RIN (dB/Hz)	R/F time (ps)	DCD (ps)
-128	47	1
-130	47	2
-128	34	10
-130	37	10
-130	35	10
-136	35	13
-136	51	1
-130	39	7.7

Examples of hypothetical 10GBASE-SR sources passing TDP; from email on 8GFC reflector by M. Dudek

- What constitutes a working link? How far away must one stay from “the cliff”?

Do we have an “accepted” link tool today?



A Furukawa Company

- Spreadsheet model has evolved through the parallel 10G lanes of 802.3ba to face parallel 25G lanes in 802.3bm
- Different experts have different beliefs and practices for accounting for impact of jitter
- MPN plays a larger role at 25G; multiple questions have been raised about the Ogawa-Agrawal model and its implementation in the spreadsheet in 802.3 forums
 - Is Ogawa-Agrawal (OA) MPN model sufficiently accurate?
 - Is the OA model correctly implemented in spreadsheet formulae?
 - Is the Gaussian spectrum assumption too pessimistic?
 - Is worst-case bit pattern for ISI used in the spreadsheet also the worst case for MPN?
 - Is 0.3 the most appropriate value of k_{MPN} ?
- As speed increases, is the VCSEL-DMD coupling described in sufficient detail by a single bandwidth parameter for Gaussian filter?
- Is Monte Carlo simulation needed to re-validate spreadsheet at 25G?
- It is important to discuss and align on these (and other) issues so that Task Force members can work confidently from a common MMF link model.

Addressing the issues in study group and task force



General Issue	Status
Spreadsheet & Jitter analysis; eye-opening at TP4	Hope to start aligning at this meeting
MPN: Is OA model implemented correctly in the spreadsheet?	lingle_01_0712_optx Issue resolved; additional ISI-scaling required
MPN: Is OA formalism sufficiently accurate?	balemarthy_01_0912_optx
MPN: Is use of isolated “1” as worst-case bit pattern too optimistic? too pessimistic?; values away from optimum sampling	balemarthy_01_0912_optx
MPN: Is Gaussian spectrum assumption too pessimistic?	lingle_01_0512_optx requires further study
Appropriate value of k_{MPN} for 10G, 25G comparing theory with experiment	balemarthy_01_0912_optx experiments are underway by several

Recommendations



- **Work toward a public model accessible to all willing to invest reasonable effort**
- **Use the MMF *ad hoc* to debate and resolve questions based on**
 - Monte Carlo simulation
 - Experimental link data
 - Representative component and prototype performance data
- **Work steadily to resolve questions about methodology to handle jitter allocations**
- **MPN**
 - Implement ISI-scaling described in lingle_01_712_optx, then compare spreadsheet and link simulation with link data on 10G and 25G devices to adjust k_{MPN} and/or adopt truncated Gaussian spectrum approach in lingle_01_0512_optx, if warranted by data.
 - Temperature-dependent data on noise floors and/or mode-partitioning at 10G and 25G are required to complete a standard
 - Share representative device performance data (anonymously) to aid link modeling
- **Check spreadsheet calculations with Monte Carlo simulations**