# Comparing standard and revised MPN treatment in 10G Ethernet spreadsheet models, benchmarking to 10GBASE-SR

Jonathan king

May 2012

# MPN treatment background

- During the MMF ad hoc calls there was some discussion on whether Mode Partition Noise (MPN) penalty is enhanced by ISI, and how it should be treated in the 10GE spreadsheet model.
  - Mode partition noise handling in spreadsheet model *
    pepeljugoski_01_0112_NG100GOPTX_MMFAdHoc.pdf
- A revised 10GE spreadsheet model, with an explicit ISI term added to modify MPN penalty, was posted to the MMF ad hoc archive.
  - 10GEPBud3_1_16a_25G with MPN changes pepeljugoski for web *
- This presentation compares the standard 10GE spreadsheet and revised spreadsheet for legacy 10GBASE-SR link modeling, and reports recent work by David Cunningham on MPN treatment, submitted to Fibre Channel

*Both available at: http://www.ieee802.org/3/100GNGOPTX/public/mmfadhoc/meetings

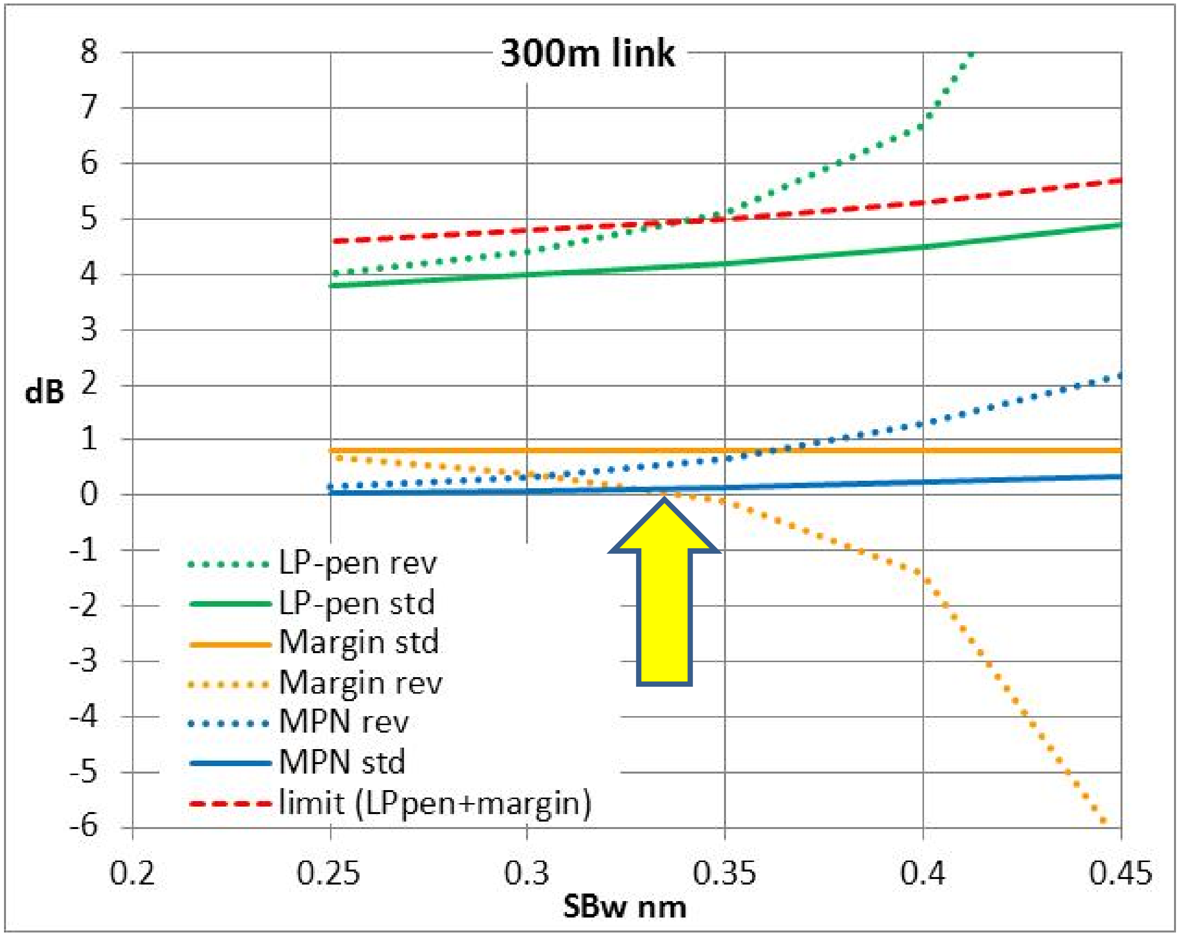
# Set up

- Spreadsheet input parameters were set to identical values for each spreadsheet version (as illustrated in the eye test below)
- LP-pen, margin and MPN penalty were compared for 300m and 280m OM3 link lengths, for various source spectral widths.
  - For each spectral width, Tx OMA was set to the minimum allowed by the triple trade off table in cl.52, 802.3, assuming worst case TDP

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spreadsheet by Del Hanson, David Cunningham, Piers Dawe, David Dolfi  Agilent Technologies | | | | | | | | | | Rev. 3.2/3 | | | This file | 10GEPBud3_1_16a.xls | | | of | 17-Oct-01 | |
| *Basics* Input= | **Bold** | | Ts(20-80) | **35** | ps | Case: 850nm serial | | **newMMF** | | | Attenuation= | **3.5** | dB/km | Model/format rev | 3.1.16a | | of | 31-Oct-01 | |
| Q= | **7.04** | | Ts(10-90) | 53 | ps | *Target* | Target reach | **0.28** | km | *Fiber* | at | 850 | nm | NomSens OMA | **-11.10** | dBm | Margin | -0.89 | dB at |
| Base Rate= | **10313** | MBd | RIN(OMA) | **-130** | dB/Hz | *and* | L_start= | **0.2** | km | | C_att= | 1.00 | | *Receive* Refl Rx | **-12** | dB | *Answer!* | 0.28 | km |
| *Transmitter* | | | RIN at MinER | -139.6 | dB/Hz | *graph* | L_inc= | **0.008** | km | | Attenuation= | 3.62 | dB/km | Rec_BW= | **8,250** | MHz | est Rx BW | **7500** | MHz |
| Wavelength Uc | **840** | nm | RIN_Coef= | **0.70** | | | Power Budget P= | 8.30 | dB | | at | 840 | nm | c_rx | **329** | ns.MHz | | | |
| Uw (see notes) | **0.45** | nm | Det.Jitter | **6.0** | ps inc. DCD | | Connections C | **1.5** | dB | | Disp. min. Uo= | **1320** | nm | T_rx(10-90) | 39.9 | ps | Test Source ER= | | |
| Tx pwr OMA= | **-2.80** | dBm | DCD_DJ= | **6** | ps TP3 | | Pwr.Bud.-Conn.Loss | 6.8 | dB | | Disp. So= | **0.11** | ps/nm^2*km | TP4 Eye | 19 | ps | *Test Tx* | **6.5** | dB |
| Min. Ext Ratio= | 3.00 | dB | Effect. DJ= | 0.00 | (UI) ex DCD | | C1= | **480** | ns.MHz | | Disp. D1= | -117.76 | ps/(nm.km) | Opening | | (=Tx ey | TestERper | 1.98 | dBo |
| Worst"ave.TxPwr | **-1.03** | dBm | MPN k(OMA) | **0.3** | | | Reflection Noise factor | **0** | no units | | | | | RMS Baseline wander SD | **0.025** | fraction | of 1/2 eye | | |
| Ext. ratio penalty | 4.78 | dBo | Tx eye height | 70.7% | | | Effective Rate | 10993 | MBd | | (not in use) | **10** | | | | | V.E.C.P. | 3.19 | dBo |
| Tx mask X1= | **0.3** | UI | Refl Tx | **-12** | dB | | Tb_eff= | 91 | ps | | BWm= | **2000** | MHz*km | P_BLW (no ISI) | 0.07 | dB | | | Stressed |
| X2= | **0.4** | UI | ModalNoisePen | **0.3** | dB | | Effective Rec Eye | 0.21 | UI | | Eff. BWm= | 2.0E+03 | MHz*km | P_BLW | 0.07 | dB | | | Rx sens |
| Y1= | **0.25** | | Tx mask top | 0.2 | UI | Pisi | P Eye | P_DJ | P_DJ | Preflection | | | | Pcross | Ptotal | <Ptotal | LP Pen | | OMA |

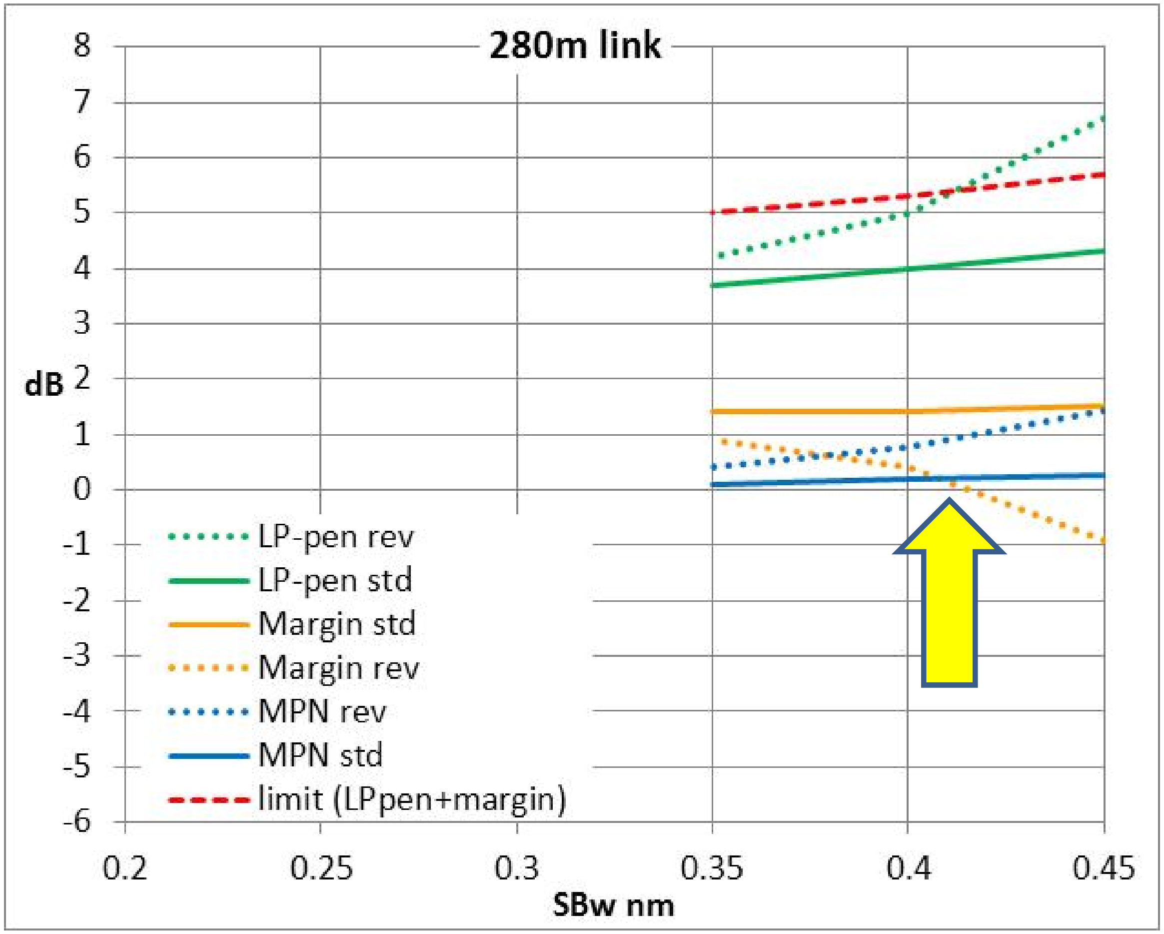
| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spreadsheet by Del Hanson, David Cunningham, Piers Dawe, David Dolfi  Agilent Technologies | | | | | | | | | | Rev. 3.2/3 | | | This file | 10GEPBud3_1_16a.xls | | | of | 17-Oct-01 | |
| *Basics* Input= | **Bold** | | Ts(20-80) | **35** | ps | Case: 850nm serial | | **newMMF** | | | Attenuation= | **3.5** | dB/km | Model/format rev | 3.1.16a | | of | 31-Oct-01 | |
| Q= | **7.04** | | Ts(10-90) | 53 | ps | *Target* | Target reach | **0.28** | km | *Fiber* | at | 850 | nm | NomSens OMA | **-11.10** | dBm | Margin | 1.50 | dB at |
| Base Rate= | **10313** | MBd | RIN(OMA) | **-130** | dB/Hz | *and* | L_start= | **0.2** | km | | C_att= | 1.00 | | *Receive* Refl Rx | **-12** | dB | *Answer!* | 0.28 | km |
| *Transmitter* | | | RIN at MinER | -139.6 | dB/Hz | *graph* | L_inc= | **0.008** | km | | Attenuation= | 3.62 | dB/km | Rec_BW= | **8,250** | MHz | est Rx BW | **7500** | MHz |
| Wavelength Uc | **840** | nm | RIN_Coef= | **0.70** | | | Power Budget P= | 8.30 | dB | | at | 840 | nm | c_rx | **329** | ns.MHz | | | |
| Uw (see notes) | **0.45** | nm | Det.Jitter | **6.0** | ps inc. DCD | | Connections C | **1.5** | dB | | Disp. min. Uo= | **1320** | nm | T_rx(10-90) | 39.9 | ps | Test Source ER= | | |
| Tx pwr OMA= | **-2.80** | dBm | DCD_DJ= | **6** | ps TP3 | | Pwr.Bud.-Conn.Loss | 6.8 | dB | | Disp. So= | **0.11** | ps/nm^2*km | TP4 Eye | 19 | ps | *Test Tx* | **6.5** | dB |
| Min. Ext Ratio= | 3.00 | dB | Effect. DJ= | 0.00 | (UI) ex DCD | | C1= | **480** | ns.MHz | | Disp. D1= | -117.76 | ps/(nm.km) | Opening | | (=Tx ey | TestERper | 1.98 | dBo |
| Worst"ave.TxPwr | **-1.03** | dBm | MPN k(OMA) | **0.3** | | | Reflection Noise factor | **0** | no units | | | | | RMS Baseline wander SD | **0.025** | fraction | of 1/2 eye | | |
| Ext. ratio penalty | 4.78 | dBo | Tx eye height | 70.7% | | | Effective Rate | 10993 | MBd | | (not in use) | **10** | | | | | V.E.C.P. | 3.19 | dBo |
| Tx mask X1= | **0.3** | UI | Refl Tx | **-12** | dB | | Tb_eff= | 91 | ps | | BWm= | **2000** | MHz*km | P_BLW (no ISI) | 0.07 | dB | | | Stressed |
| X2= | **0.4** | UI | ModalNoisePen | **0.3** | dB | | Effective Rec Eye | 0.21 | UI | | Eff. BWm= | ###### | MHz*km | P_BLW | 0.07 | dB | | | Rx sens |
| Y1= | **0.25** | | Tx mask top | 0.2 | UI | Pisi | P Eye | P_DJ | P_DJ | Preflection | | | | Pcross | Ptotal | <Ptotal | LP Pen | | OMA |

# 10GBASE-SR, standard vs revised model, 300m OM3




- Revised model shows negative margin for sources with RMS spectral width >0.33nm
  - Quite likely to see this spectral width in practice at room temperature
- Sources with RMS spectral width = 0.45nm do not have a closed link budget over 300m of worst case fibre.
  - The shortfall is >6dB, unlikely to be covered by Tx or Rx margins.

# 10GBASE-SR, standard vs revised model, 280m OM3



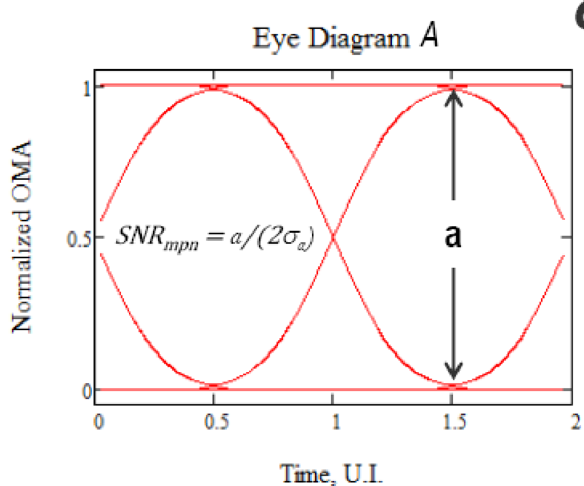

- Revised model shows negative margin for sources with RMS spectral width >0.41nm
  - Likely to see this spectral width for some VCSELs at cold temperatures
- Sources with RMS spectral width = 0.45nm do not have a closed link budget over 280m of worst case fibre.
  - The shortfall is >1dB, but could be covered by Tx or Rx margins to spec

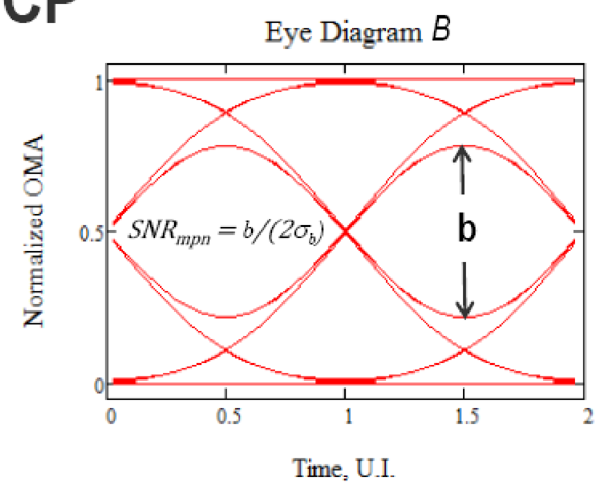
# Input to Fiber Channel from David Cunningham - 1

- From Feb 2012 T.11 meeting, contribution number 12-042v0.pdf

Your Imagination, Our Innovation

## $\sigma_{mpn}$ & VECP




$$f_i = \cos(\pi \cdot B \cdot (t_0 - \Delta\tau_i))$$

$$\sigma_a = k \cdot \sqrt{\left[\sum_{i=1}^{N} a^2 \cdot f_i^2 \cdot \overline{A_i} - \left(\sum_{i=1}^{N} a \cdot f_i \cdot \overline{A_i}\right)^2\right]}$$

$$\sigma_a = a \cdot k \cdot \sqrt{\left[\sum_{i=1}^{N} f_i^2 \cdot \overline{A_i} - \left(\sum_{i=1}^{N} f_i \cdot \overline{A_i}\right)^2\right]}$$

$$f_i = \cos(\pi \cdot B \cdot (t_0 - \Delta\tau_i))$$

$$\sigma_b = k \cdot \sqrt{\left[\sum_{i=1}^{N} b^2 \cdot f_i^2 \cdot \overline{A_i} - \left(\sum_{i=1}^{N} b \cdot f_i \cdot \overline{A_i}\right)^2\right]}$$

$$\sigma_b = b \cdot k \cdot \sqrt{\left[\sum_{i=1}^{N} f_i^2 \cdot \overline{A_i} - \left(\sum_{i=1}^{N} f_i \cdot \overline{A_i}\right)^2\right]}$$

$$\therefore \sigma_b = \frac{b}{a} \cdot \sigma_a$$

AVAGO TECHNOLOGIES

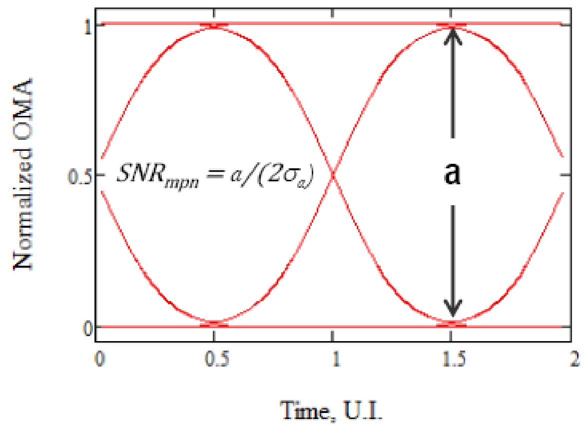
# Input to Fiber Channel from David Cunningham - 2

- From Feb 2012 T.11 meeting, contribution number 12-042v0.pdf

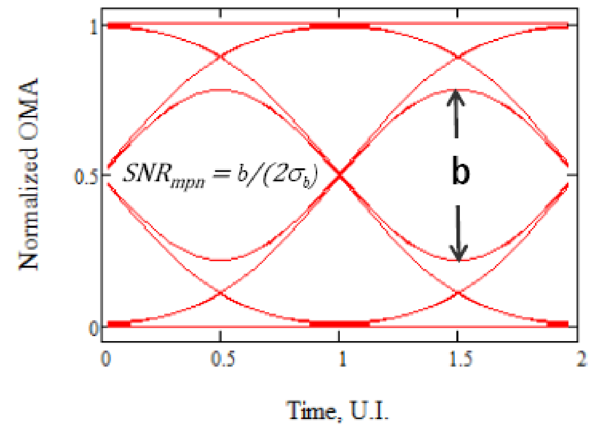
Your Imagination, Our Innovation

## $P_{mpn}$ and VECP for Non-Equalised Links

Eye Diagram *A*




Eye Diagram *B*




Since, $\sigma_b = (b/a)\sigma_a$, both of the inner eyes, *A* and *B*, have the same SNR due to mpn

But signal *B* has suffered an additional penalty due to ISI of: $VECP = P_{isi} = 10log(b/a)$

The link model calculates the loss of signal due to ISI, $P_{isi}$, as a separate penalty

The total penalty for signal *B*, due to the combination of ISI and mpn, is then: $P_{isi} + P_{mpn}$

This means that the power penalty equation for $P_{mpn}$ is already normalised with respect to VECP

AVAGO TECHNOLOGIES

# Comments and conclusion on MPN treatment

- ISI *should* be accounted for in calculating MPN penalties
  - The standard version of the 10GE spreadsheet model does so; this was demonstrated by David Cunningham (Fibre Channel, Feb 2012 T.11 meeting, contribution 12-042v0.pdf)
- The revised spreadsheet model adds an explicit ISI modifying term (in column Q of the model, MPN penalty calculation)
  - this double counts the effect of ISI on MPN penalty
  - in it's present form, the revised spreadsheet predicts link failures for worst case 300m links, and increased probability of fails for 280m links
- Conclusion:
  - The treatment of MPN penalty in the standard 10GE spreadsheet model already includes the effect of ISI, no modifications are required.

# Back up

# Example: 26Gb/s 100m OM4 penalties