Link Model Update

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Current position

- January 2001: “A revised link model and spreadsheet was adopted and shall be used as the basis for future PMD work”
- http://www.ieee802.org/3/ae/public/email_attach/10GEPBud2_4_1.xls
- March 2001: Resolved that “Interferometric noise shall be added to the spreadsheet link model”
- Summer 2001: Unofficial enhanced model test-driven by experts

Updated link model features

- Improvements to format and appearance, does more
  - Pictorial "noiseless eye" and mask
- "System level" model, focus on TP3, is OMA friendly
- Accounts for deterministic jitter
- Eye height calculation
- Reflection Noise (Interferometric Noise)
- Re-definition of Stressed Receive Sensitivity
- Separate test receiver, "product" receiver and RIN test receiver bandwidths
- Corrections
  - SMF attenuation formula corrected
  - Revision to RIN penalty, which was under-estimated
  - Modal noise treated as signal-borne
- Updated parameter values following draft

Format, appearance, does more

- Improvements for ease of use
  - Inputs and outputs at top of model sheet re-arranged in groups: Tx, fiber, Rx and so on
- Pictorial "noiseless eye and mask" has been added
- "Nominal Rx sensitivity" input cell added
  - Power budget P is now derived from this
  - Simplifies generation of triple trade off curves
- Stressed test "Vertical eye closure penalty" (V.E.C.P.) calculated

"System level" model, focus on TP3 not TP4

- Stressed Rx sensitivity and all penalties now calculated on a "system spec" basis, i.e. at eye centre
  - receiver eye opening penalty is now an implementer issue not a standards one
  - TP4 is mentioned, and some penalties are calculated at eye corners, for information only
  - DCD values are now for TP3 (6, 7.7 or 14 ps) rather than TP4 (8, 9.7 or 20.5 ps).
    - ***The 14 ps value is my guess: needs confirmation by WWDM team***
    - Parameter values are not part of the model per se but should be agreed

Accounts for deterministic jitter

- DCD penalty was always included in Pisi
- New DJ penalty calculation, like the former Rx eye opening penalty
  - Work out eye height at a timing offset from centre of eye
  - Uses the excess of DJ over DCD to avoid double counting
- Found P_DJ of 0.5 to 1.3 dB in fast, high DJ case
  - depending where Rx decision time is
  - Obviously the slow, low jitter case has more ISI but less jitter penalty

Eye height calculation

- Model predicts eye opening at Tx, allowing for risetime, DCD, DJ, RIN
  - Assumes all BLW is from Rx. Not always true but is the worst case split of BLW for link margin
  - “Eye height”is reported in % of full height
    - 50% = zero “eye margin”
- Method of use
  - Choose DCD, DJ, RIN
    - Adjust risetime Ts to give eye height >= 50% and VECP <= 3 dB (1550 nm only)
- Pessimistic: measurement noise forces a better eye in practice

Reflection Noise (Interferometric Noise)

- Formula is intended to follow Krister Fröjdh, Petar Pepeljugoski and their colleagues
- Because the noise is bounded and may be concentrated at extremes, it is calculated like a source of ISI not random noise
- Reflection noise factor of 0.6 introduced to avoid undue pessimism
  - ***The value (0.6) needs further consideration***

Test receiver bandwidth(s)

- Separate test receiver, "product" receiver and RIN test receiver bandwidths
- Boxes T5, W5, W6
  - Test receiver is used for eye mask
  - "Product" receiver bandwidth is not subject to specification
  - RIN test receiver for RIN alone

SMF attenuation formula

- We believe that attenuation is specified at
  - SMF 1310 nm
  - MMF 1300 nm
- C_att formula in SMF pages tweaked to make the Patt column show 5 dB attenuation at 10 km, 1310 nm, 0.5 dB/km nominal attenuation, as desired

Change for Stressed Receiver Sensitivity

- Change of definition to give same margin in stressed and unstressed sensitivity

  Now calculated as: Stressed Rx sensitivity =
  Informative Rx sensitivity
  + impairments included by the shape of the stressful test eye

  Same as: Stressed Rx sensitivity =
  Tx power
  - Losses
  - impairments not included by the shape of the stressful test eye
  - Margin

Classification of penalties for Stressed Receiver Sensitivity

Included by the shape of the stressful test eye	Not included by the shape of the test eye
DCD Deterministic jitter Inter Symbol Interference The part of Rx baseline wander which is exacerbated by the shape of the stressful test eye	RIN Modal noise Reflection noise Mode partition noise Relative intensity noise Anticipated Tx baseline wander
These are all pattern dependent penalties	These are noise-like, mainly non-pattern dependent penalties

Stressed Rx Sensitivity in 3.1.14

- Model 3.1.14 simplifies the division of BLW.
  - Half of Pcross on “each side” (Tx and Rx)
  - Not a significant error for a healthy system
- Model has a bug: double counts modal noise, making stressed Rx sensitivity e.g. 0.3 dB too –ve (severe?) for MMF

Revision to RIN penalty 1/2

- Model had shown RIN penalty improving over length. Now believe the opposite
  - Thanks to Dubravko Babic for pointing this out
  - More on next slide
- To avoid over-pessimism, model allows for reduction of “signal” by the RIN test measurement bandwidth specified, with mixed pattern
- RIN bandwidth no longer includes laser driver, which is upstream of source of RIN

Revision to RIN penalty 2/2

- Model had shown RIN penalty improving over length. Now believe the opposite
  - RIN penalty is exacerbated by ISI. We had noticed this for baseline wander (BLW); RIN is similar
  - Signal to Noise ratio caused by RIN is ISI-reduced eye opening / bandwidth-filtered noise
  - RIN variance goes down with length or reduced bandwidth (ISI)
  - But ISI increases faster than RIN variance decreases
  - So, like BLW, the penalty goes up with length

Modal noise

- Now treated like other signal-borne noises
- Modal noise is now an input to Pcross to allow for nonlinear addition with other random noise penalties
- Better prediction of error floors and similar, little difference for healthy systems
- See http://www.ieee802.org/3/ae/public/jul00/dawe_1_0700.pdf for the mathematics

Updated parameter values following draft

- The parameters populate the model, are not part of the model itself
  - These changes are ongoing
  - Example: recent proposal to change 850 nm MPN k factor from 0.5 to 0.3
- RIN values in each sheet for apparent worst case for each PMD/fiber combination
  - e.g. 1310 nm serial: low RIN, zero eye margin thought to be worse than high RIN, zero eye margin
  - e.g. 1550 nm serial: high RIN case because eye margin >0 anyway
- 850 nm additional insertion losses are added into connector losses cell

Model vs. reality

- Model appears to be pessimistic by ~1-2 dB
  - Reason is not known
    - Could be that receivers are better than we thought (always some transmitter penalty even with test equipment
  - A zero or slightly negative penalty output from the model may be acceptable
- Jitter measurements are inaccurate and not easily corrected by calibration. Big problem.
- Model does not include RJ
  - Assume most RJ is already accounted for as noise in amplitude domain
- The dispersion penalty calculation was meant for multimode lasers, is likely to be inaccurate for single mode lasers

Next steps

- We resolved to include reflection noise
- We should adopt the corrections to SMF attenuation, RIN and modal noise, for enhanced accuracy, flexibility and foundation for any future revisions
- We should account for DJ
  - Penalty in its own right
  - Supports eye-based specification
- We should adopt the new stressed Rx sensitivity calculation since stressed Rx sensitivity is now normative

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More references listed at
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