The 10G Ethernet Link Model

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What is it?

- A spreadsheet with equations
  - Runs in Excel
- Can be populated with parameter values to represent different fibre-optic links
  - One sheet per scenario
  - Equations on each sheet are identical
- Available to all on www

Purpose

- For developing optical spec numbers
  - Portable, runs quickly
  - Not intended as a transceiver design tool
- An agreed framework for comparing options
  - Uses standard engineering theory, mostly available in textbooks
  - Open source, open to peer review, some documentation
  - Earlier, Gigabit Ethernet model was validated by experiments in multiple labs
- Generally used for worst case analysis

History

- Model was developed in late 90's for Gigabit Ethernet
- Recent extensions to meet needs of 802.3ae, 10 Gigabit Ethernet
- Latest version on the web today is 3.1.14
- Latest version accepted by 802.3ae is 3.1.16
  - Accepted Tuesday 16 October 2001
  - To be uploaded
  - Each file has detailed change notes

Physical effects in model 1/3

- For short block codes or unbounded codes
  - e.g. 8B10B, SONET, 64B66B
- Multimode fibre (MMF), Single mode fibre (SMF)
  - Fibre modal bandwidth (MMF), polarisation mode dispersion (PMD) (SMF)
- “1st, 2nd, 3rd windows”
  - 850,1310, 1550 nm bands
- Fibre attenuation, connector attenuation

Physical effects in model 2/3

- Optical Modulation Amplitude OMA
- Mean power
- Extinction ratio ExR

- Duty cycle distortion DCD
- Deterministic Jitter DJ
  - Controversial
- Receiver eye opening requirement (timing)
  - Not used in 802.3ae

Physical effects in model 3/3
Noise effects

- Receiver sensitivity
  - "thermal noise"
- Laser relative intensity noise RIN
- Laser mode partition noise MPN
- Interferometric or Reflection noise RN
- Baseline wander BLW

Methodology: How does it work? What you see

- Each loss or penalty is calculated separately
  - Results displayed
  - Losses, and penalties plotted against link length
- Overall losses and penalties calculated together
  - Margin plotted against link length
- Example eye diagram drawn

What it does 1/2 Deterministic

- Fibre attenuation and dispersion calculated according to standard formulae
- All risetime, bandwidth, chromatic distortion calculated as Gaussian impulse responses
- DCD, DJ and receiver eye opening requirement determine timing pulse edges and/or “decision point”
- Eye closure is calculated
- Result: effective signal strength

What it does 2/2
Noise, margin

- Almost all noises combined as variances
- Effective signal/noise ratio related to target
  - Determines margin
  - Interactions of impairments (cause of error floors) are predicted
- Exceptions
  - Mode partition noise calculated by textbook formula
  - Reflection noise is more like a bounded noise or “deterministic” effect - like crosstalk

Advantages of 10 Gigabit model

- Trusted and familiar
  - Mostly
- Seen as Official
- Source code can be inspected
- Clean, not over complicated
  - but growing
- “Fit for purpose” (10 Gigabit Ethernet)
- Each physical effect can be turned on or off independently

Disadvantages of 10 Gigabit model

- Not accurate for laser mode partition noise
- Not at all accurate for chromatic dispersion penalty of single mode lasers (“chirp”)
  - There is no simple generally accepted model for this
- Does not cover crosstalk - coherent or incoherent
- Spurious accuracy
- Some areas need experimental verification
- Some definitions differ between Ethernet and SONET

What is stressed sensitivity?

- Two sensitivities in Gigabit and 10 Gigabit Ethernet
- “Nominal” sensitivity
  - Measured with a very good transmitter
- Stressed sensitivity
  - Measured with a transmitter as slow and with as much deterministic jitter as allowed
  - Intent is to prove interoperability by measurement
- Don’t have to use stressed sensitivity to use model

Compatibility with EFM goals

- Forward Error Correction
  - Model knows nothing of coding but target signal/noise ratio is a variable
- Splitters and WDMs
  - Think can use “connector loss” input for any loss
- Single fibre operation
  - May be able to use reflection noise term for coherent crosstalk
    - Use Tx, Rx reflection coefficients?
- ***Other issues?***

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- More references listed at http://www.ieee802.org/3/10G_study/email/msg01127.html