Using EDC to Relax Component Specifications

Paul Voois (ClariPhy Communications, Inc.)
Norm Swenson (ClariPhy Communications, Inc.)
Edward Cornejo (Opnext, Inc.)

IEEE 802.3, Vancouver, BC
January 11-15, 2004
Motivation

- 10-Gbit/s EDC standard should solve two key problems:
  - Achieve 300m over FDDI MMF
  - Reduce cost of the 10-Gbit/s optical modules used for 300m applications
- Support both Technical and Economic Feasibility efforts of Study Group
- Details to follow in Task Force
Module Cost

• Take the opportunity of creating a new PMD to address the highest cost areas:

• Once a module matures, the optical front end typically accounts for most of the cost

• Aggressive approach needed to reach 3 x $\{1000\text{Base-SX}\}$ for 300m applications

• $\{10\text{GBase-LR} + \text{EDC}\} \geq \{10\text{GBase-LR}\}$: Solution is NOT to simply add EDC to LR
Key Factors Impacting Transmitter Cost

Modulation Scheme

Laser Trise / Tfall

Launch Condition

Optical PMD Transmitter

Patch Cord

Fiber Optic Cabling (Channel)

System Bulkheads

Optical PMD Receiver

MDI

TP2

TP3

PMA

Signal_Detect

PMA
Launch Conditions to Consider

• Specify launch into multimode fiber only
  – No single mode fiber launch required
  – This will support lower cost TOSA’s, but we sacrifice a common platform between 10GBASE-LR solution and the EDC PMD

• If offset launch is necessary, specify single condition for all MMF (62.5µm and 50µm)
  – Studies show optimal offset for 50µm and 62.5µm differ.
    • Optimal offsets: 50µm (7 to 17µm), 62.5µm (18 to 28µm)
  – Different conditions requiring different TOSAs will add cost

• Lowest cost solution: launch down the middle of the fiber and make full use of the core
  – Maximum possible alignment tolerance
  – Can EDC compensate for possible DMD?
  – What is the worst case OFL BW in this case?
Laser Response Requirements

- Relaxing the Laser rise and fall times will improve yields, however, the eye will begin to close at TP2
  - What can EDC live with?
Effect of Transmit Specifications on Channel

• Relaxed transmit eye
  – Enables higher rise/fall time
  – Enables lower reference receiver bandwidth and lower relaxation oscillation frequency
  – Causes more channel (i.e. laser+fiber+optical receiver) ISI

• Relaxed launch conditions
  – Allow more DMD in fiber
  – Cause more channel ISI

• EDC compensates for increased channel ISI
  – Some increase in ISI penalty that must be accounted for
Modulation Scheme Choices

• Stay with NRZ
  – Can still relax transmitter specs, but must deal with increase in ISI penalty

• Consider multi-level modulation
  – Highest potential for reducing cost of optical packages and devices
    • Could enable using standard TO packaging technology versus the high speed packages we use today

• Need to study impact of multilevel modulation on linearity requirements of optical devices, RIN penalties, modal noise penalties, etc.
Simple Approach: PAM-4

• Motivation:
  – Works well with lower speed, lower cost optics
  – Well suited to severe ISI from 300m FDDI MMF
  – Enables significant increase in available power budget

• How it works
  – 4-level symbols, 2 bits per symbol
  – Symbol rate = 10.3125/2 Gbaud
  – No additional coding beyond 64/66 ==> no change to PCS; simple interface to PMD
  – Multilevel power penalty vs. NRZ? Actually, it’s a gain:
    • 3x reduction in signal spacing => 4.8 dB power penalty
    • 2x reduction in baud rate => 1.5 dB reduction in RMS noise power
    • 2x reduction in baud rate => Varying reduction in ISI
    • For severe ISI channels, PAM4 has a net gain versus NRZ
PAM4 Channel Model

• Use same impulse responses as 802.3ae link model
  – Fiber: Gaussian model, modal BW = 500 MHz*km
• Transmit 4 levels instead of 2

Eye diagram shows 4G laser
• Two cases:
  – 1. NRZ, 10G optics
  – 2. PAM4, 4G optics
  – Both use ideal DFE
• 10G optics specs from 10GBase-LR
• 4G optics specs from published data sheets
• Power penalty indicates receive OMA required for $10^{-12}$ BER, relative to 10GBase-LR receive sens.
PAM4 Performance (Cont.)

• Additional (> 4.5 dB) power budget provided by PAM4 at 300m can be used to
  – Operate over worse fiber
  – Relax launch requirements
  – Lower Tx power

• Issues for Further Study
  – Laser linearity
  – RIN
  – Modal noise
  – Compliance methods and specs
Summary

- Relaxing the mask at TP2 will improve yields and lower costs for optical module manufacturers
- EDC can and should enable such relaxation
- Relaxing specs possible with NRZ
- Even better cost and performance available with PAM4
- Media supported needs to be clearly defined in the EDC PAR
- Task Force should look at
  - Relaxed transmitter specs
  - PAM4