Specifying
Optical Modulation Amplitude
instead of
Extinction Ratio

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Some OMA History

- Adopted by Hippi-6400-Opt (12-wide laser arrays at 1 Gbps).
  - Suggested by Mike Dudek, Cielo.
  - Proposed by Steve Joiner, HP.
  - Motivated by difficulty of maintaining high extinction ratio of laser array over temperature.

- Adopted by Fibre Channel optical working group June 1999.
  - Proposed by Tom Lindsay, Vixel.
**Extinction Ratio Power Penalty**

- Recognizes power in ‘0’ bit is wasted.
- Usually attributed to receiver sensitivity.

\[
\text{Power Penalty} = 10 \log \left( \frac{P_1}{P_0} \right) - 1 + 1
\]

where \( ER = 10 \log \frac{P_1}{P_0} \)

- 1.1 dB @ 9 dB ER
- 2.2 dB @ 6 dB ER
- 4.8 dB @ 3 dB ER
Optical Modulation Amplitude

Optical modulation amplitude is defined as the difference in power between the logic 1 and logic 0 levels.

$$OMA = (P_1 - P_0)$$

To convert from average power $A$ and extinction ratio to optical modulation amplitude:

$$OMA = 2A \left( \frac{P_1}{P_0} - 1 \right) + 1$$

where $2A = P_0 + P_1$
Optical Modulation Amplitude - Justification

- Photoreceivers respond to signal swing not average power.
  - Differential input. Circuitry responds the same to: 
    \[ '0' = 0 \ \mu W, \ '1' = 40 \ \mu W \]
    \[ '0' = 40 \ \mu W, \ '1' = 80 \ \mu W \]

- Receivers are dominated by thermal noise.
  - Additional shot noise at higher currents negligible.
Optical Modulation Amplitude - Why?

- More freedom to set bias and modulation currents in transmitter $\Rightarrow$ lower cost.
  - Trade-off between ER and jitter.
  - Trade-off between ER and min. avg. power (when absorbing ER power penalty in transmitter budget).

- May need lower extinction ratios at 10 Gbps.
  - Laser turn on delay induced jitter (set ‘0’ bit bias current just above laser threshold current)
  - May help reduce chirp.

- Receiver performance not compromised.
  - ER power penalty absorbed by transmitter.
Effect of laser bias -- the benefits of specifying OMA

Low bias filtered Tx

Rx output from low bias Tx

Med bias filtered Tx

Rx output from med bias Tx

Ext. ratio (dB) | 15.59dB
Crossing % (C): | 30.2%
OutCycDist (ppm): | 17%
Jitter p-p (ps): | 155 ps

Ext. ratio (dB) | 8.53dB
Crossing % (C): | 47.2%
OutCycDist (ppm): | 22%
Jitter p-p (ps): | 58 ps
Biasing above threshold helps even for fast, low turn on delay lasers

10 Gbps 850nm VCSELs

Biased below threshold

Biased above threshold

IEEE 802.3
Higher Speed Study Group
September 1999
Example GbE 1000SX budget

For -9.5 dBm to -17 dBm at 9 dB ER: 174 μW to 31 μW
Proposal for 10GbE

• Consider specifying Tx and Rx minimum optical modulation amplitudes instead of extinction ratio.
  • Address technical and marketing concerns over reflector.
  • Make a motion at November, 1999 meeting.

• Monitor OMA progress in Fibre Channel and Hippi-6400-Optical standards.
  • Currently working through issues.