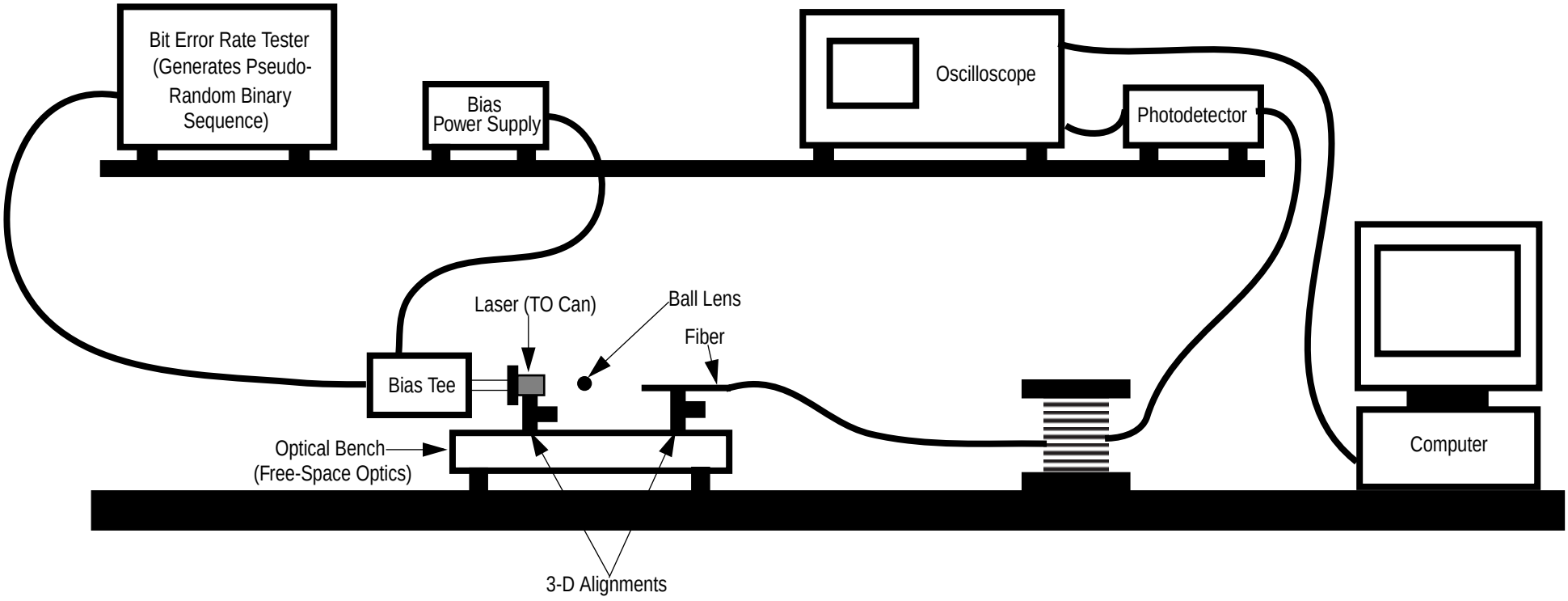
Progress Report on Equalization of Multimode Fibers

Ad Hoc Group on Equalization
January 12, 2001

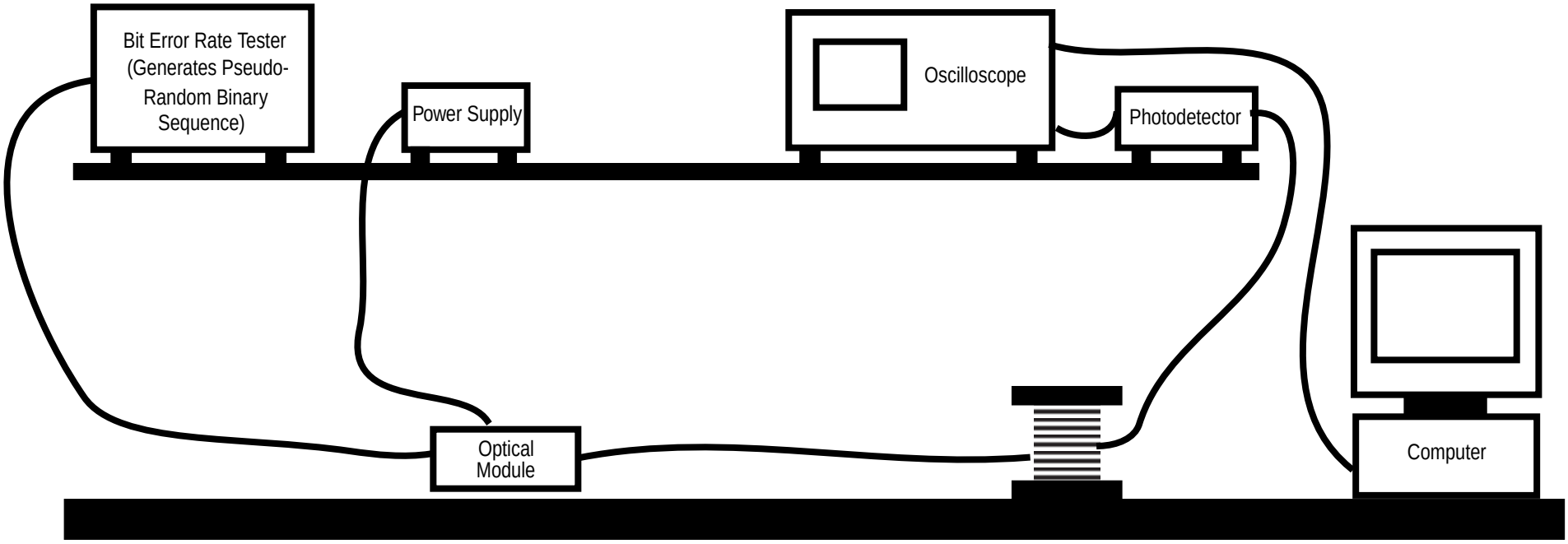
Overview

- **Procedure adopted for channel characterization and theoretical analysis of data**
- **TIA DMD-challenged fibers**
- **Preliminary measurement results**

Measurement Setup *(Free-Space Optics)*



Measurement Setup *(Connectorized Modules)*



Measurement Setup *(cntd)*

- **Bit Error Rate Tester (BERT) generates a 127-bit pseudo-random binary sequence (PRBS) at 1-10Gb/s data rate**
- **Laser is a 850nm VCSEL or 1310nm DFB**
- **Photodetector is a commercial 10GHz optical receiver**
- **High-bandwidth (1.5GHz), high sampling rate (8GHz) oscilloscope (Agilent Infinium), captures blocks of 65K samples**
- **For higher effective sampling rates interleaved sampling can be used (using instruments such as the HP 83480 Digital Communications Analyzer)**
- **TIA DMD-challenged fibers**
- **Fibers shaken during the measurements**
- **Measurements taken both with and without mode selective loss patchcord**
- **Connectorized modules or free-space optics**

Processing of Measured Data

- **The measured data is processed as per the document *"Measurement of Non-Stationarity of 10Gb/s Multimode Fiber Links"*, by O.Agazzi and T.Lenosky, available from:**

  http://www.ieee802.org/3/ae/public/adhoc/equal/NonStationarity112200.pdf

- **This procedure consists in adapting a software canceller using the LMS algorithm. After convergence, the canceller generates the best fit to the measured signal that can be produced by the *linear adaptive* model (NOTE: we use the name *linear adaptive* as a generalization of *linear time invariant*, since perfect time invariance is not required)**

- **The error is defined as the difference between the measured signal and the best fit generated by the model**

- **The Signal to Noise Ratio (SNR) is defined as the ratio of the measured signal power to the power of the error**

- **This measure of SNR would coincide with the slicer SNR for a receiver that achieves the *matched filter bound* (this is a well known bound in Communication Theory)**

- **For other receivers, the precise relationship between slicer SNR and input SNR depends on the design of the receiver**

Fibers Used in Measurements

- **DMD challenged fibers were shipped by David Hyer (Compaq) on December 21, 2000, to the following individuals:**
  - Tom Lenosky (Finisar)
  - Eva Peral (Lucent)
  - Oscar Agazzi (Broadcom)

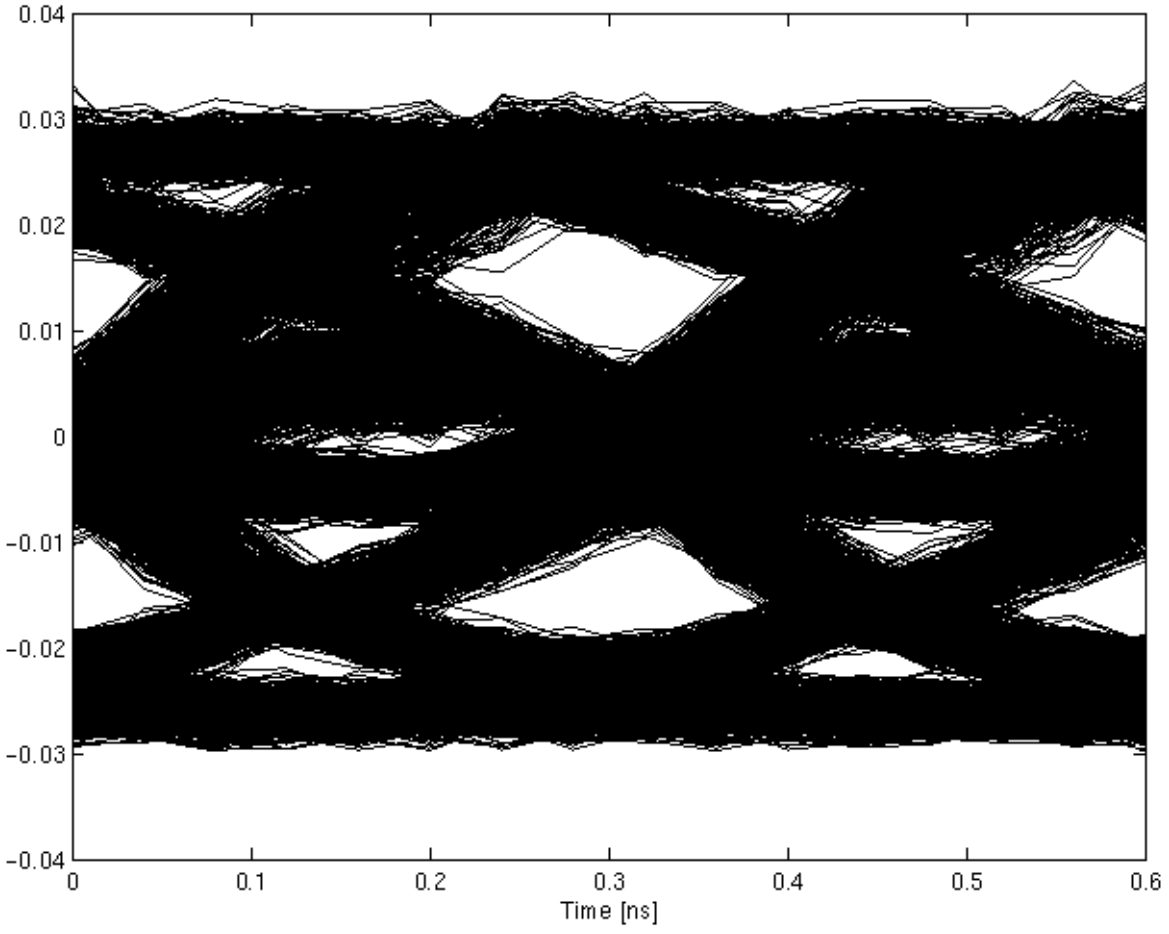
- **Measurement results have been presented at the meeting of the Ad Hoc Group on Wednesday (3 presentations of measurements were given)**

- **SNR values between 16 and 28dB have been observed depending on the fibers, lasers, and measurement conditions**

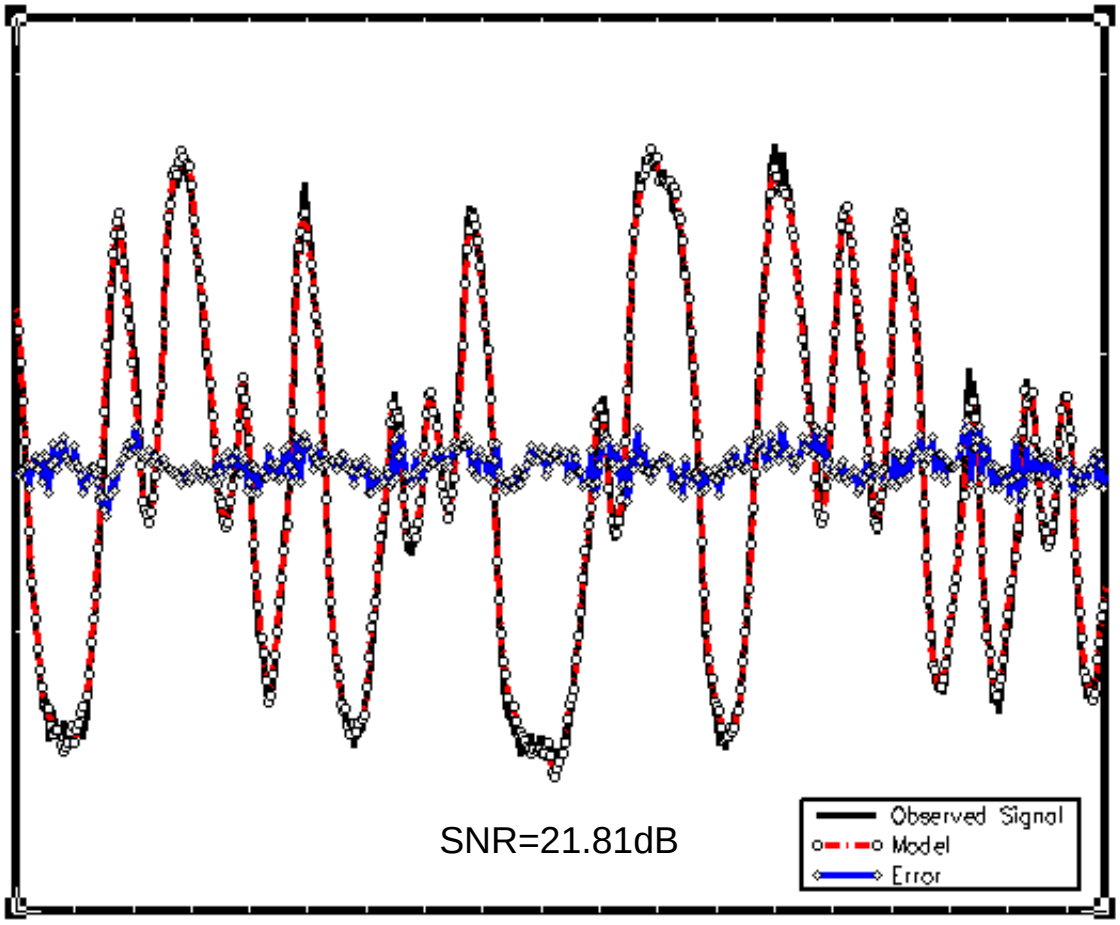
- **These measurements seem to support the validity of the linear adaptive model**

- **No “show stoppers” have been found (so far!)**

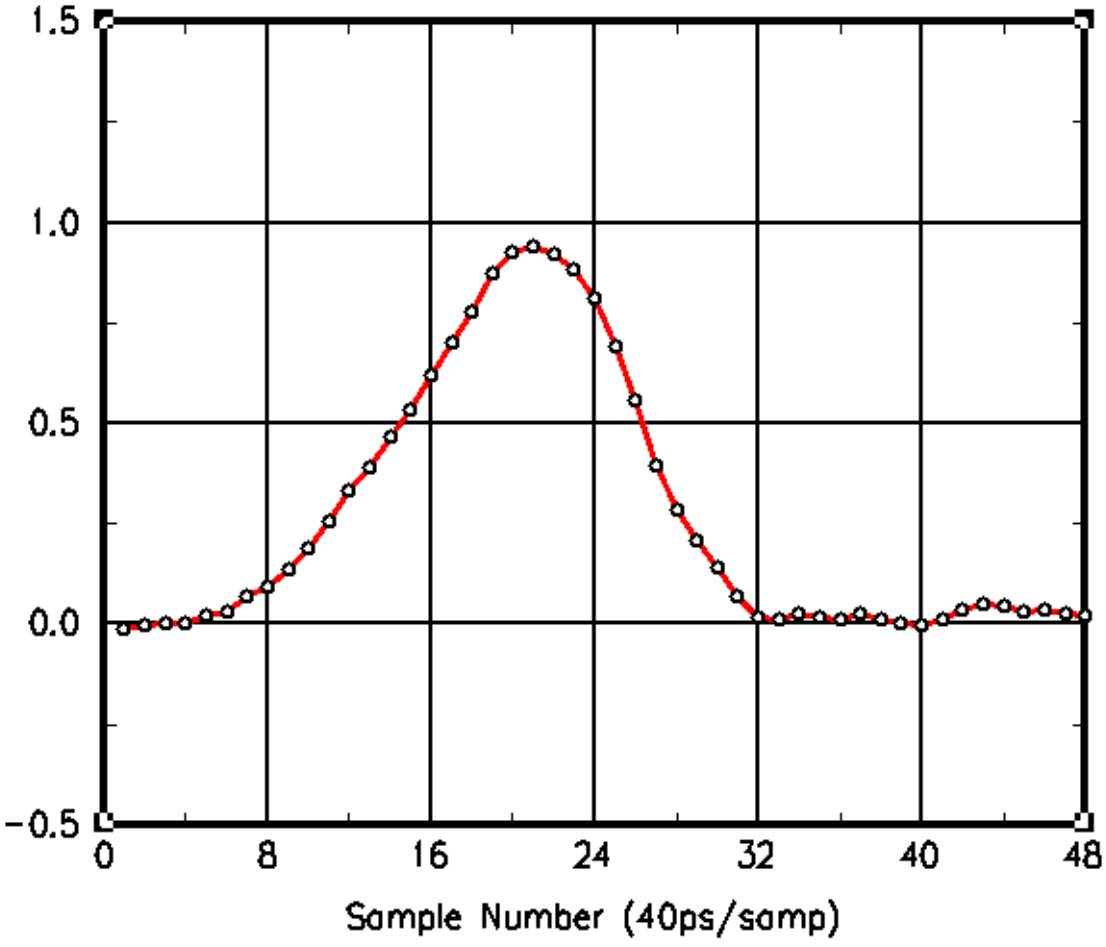
Eye Pattern for Non-Equalized System, DEC-01 Fiber, 1310nm Connectorized Module 3 at 3.125Gb/s Data Rate



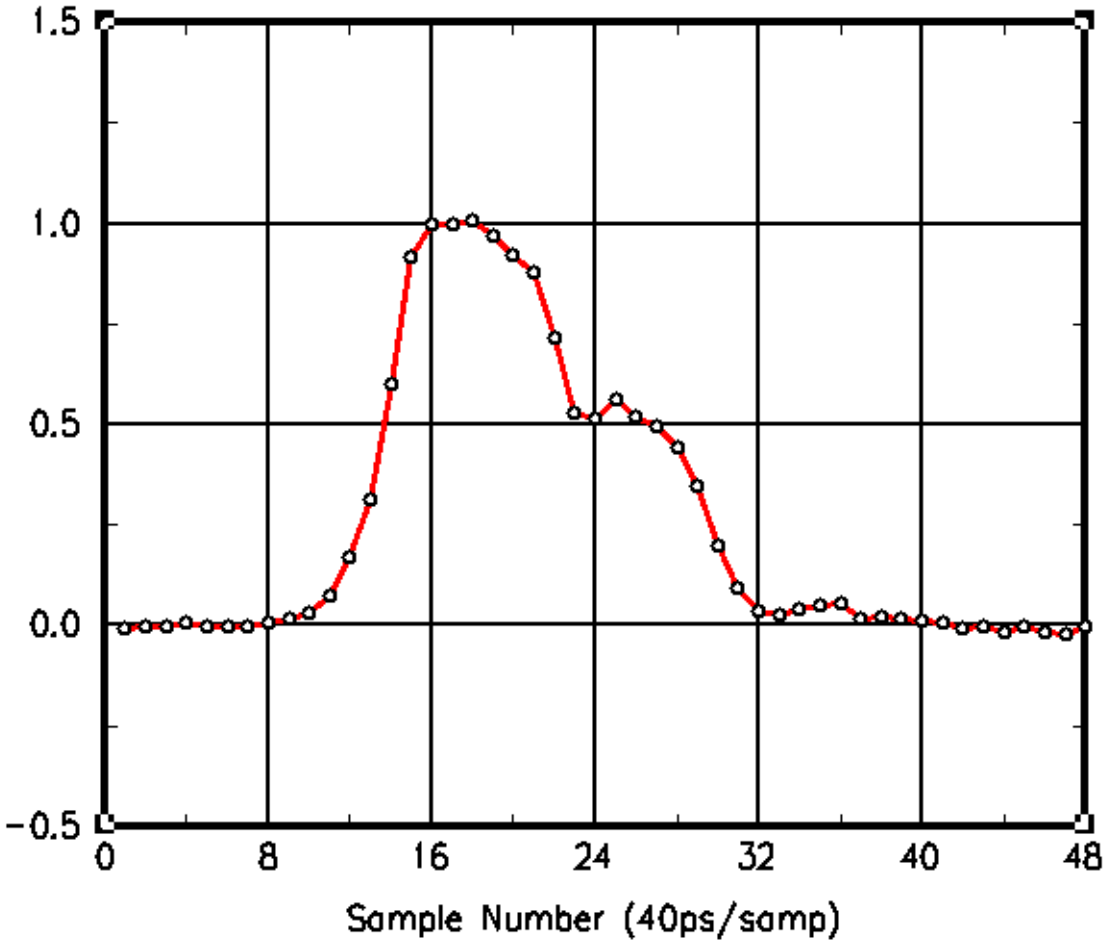
Measured Signal vs. Model and Error, DEC-01 Fiber, 1310nm Connectorized Module 3 at 3.125Gb/s Data Rate



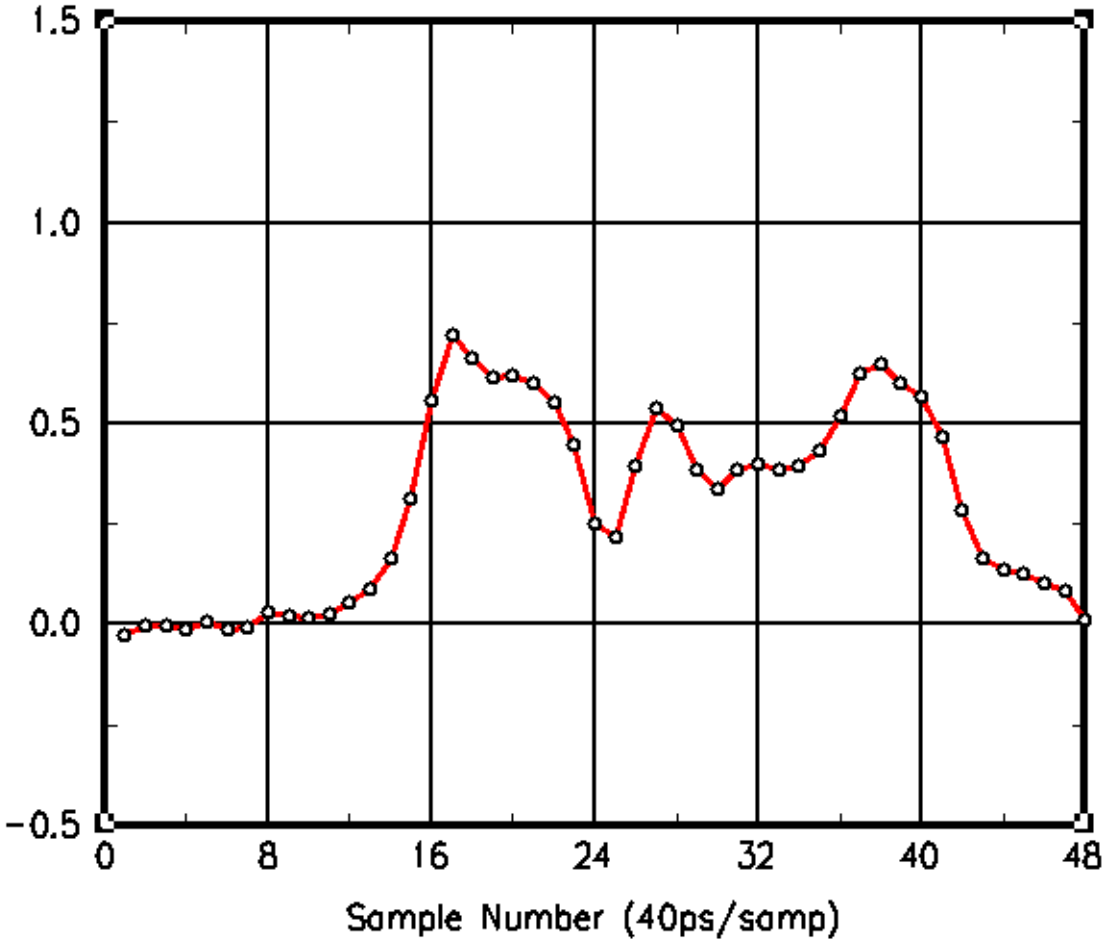
Impulse Response, DEC-01 Fiber, 1310nm Connectorized Module 3 at 3.125Gb/s Data Rate



Impulse Response, DEC-01A Fiber, 1310nm Connectorized Module 2 at 3.125Gb/s Data Rate



Impulse Response, DEC-01B Fiber, 1310nm Connectorized Module 3 at 3.125Gb/s Data Rate



Summary of Measurements as of 01/09/2001

- **11 DMD-Challenged Fibers:**
  - 4 provided by TIA/David Hyer, 1 provided by TIA/Joe Gwynn, and 6 others

- **15 measurements:**
  - 6 at 1310nm and 1Gb/s
  - 3 at 850nm and 2Gb/s
  - 3 at 1310nm and 3.125Gb/s
  - 3 at 850nm and 3.125Gb/s

Presentations

- *"Measurement Technique and Algorithm to Postprocess Measured Data"*, by Oscar Agazzi and Tom Lenosky
- *"Measurements of DMD-Challenged Fibers at 1310nm and 1Gb/s Data Rate"*, by Tom Lenosky, Giorgio Giaretta, and Oscar Agazzi
- *"Measurements of DMD-Challenged Fibers at 850nm and 2Gb/s Data Rate"*, by Tom Lenosky, Giorgio Giaretta, and Oscar Agazzi
- *"Measurements of DMD-Challenged Fibers at 3.125Gb/s Using Interleaved Sampling"*, by Oscar Agazzi, Matt Isaacs, Venu Gopinathan, and Ali Ghiasi

Summary of Discussions

- **Recommendations were made on how to enhance measurements, particularly how to evaluate the effect of**
  - DMD-Induced Pulse Splitting (~2ns/Km @1310nm)
  - Mode Partition Noise and Modal Noise
  - Back reflections

- **Recommendations on analysis of data:**
  - Histograms of noise
  - Show time variation of channel impulse response

Status

- **Preliminary results look very promising**
  - Linear adaptive model provides an excellent fit for data measured so far
  - No show stoppers found
- **More data needs to be collected and analyzed**
- **We are on track to provide a detailed report in March**