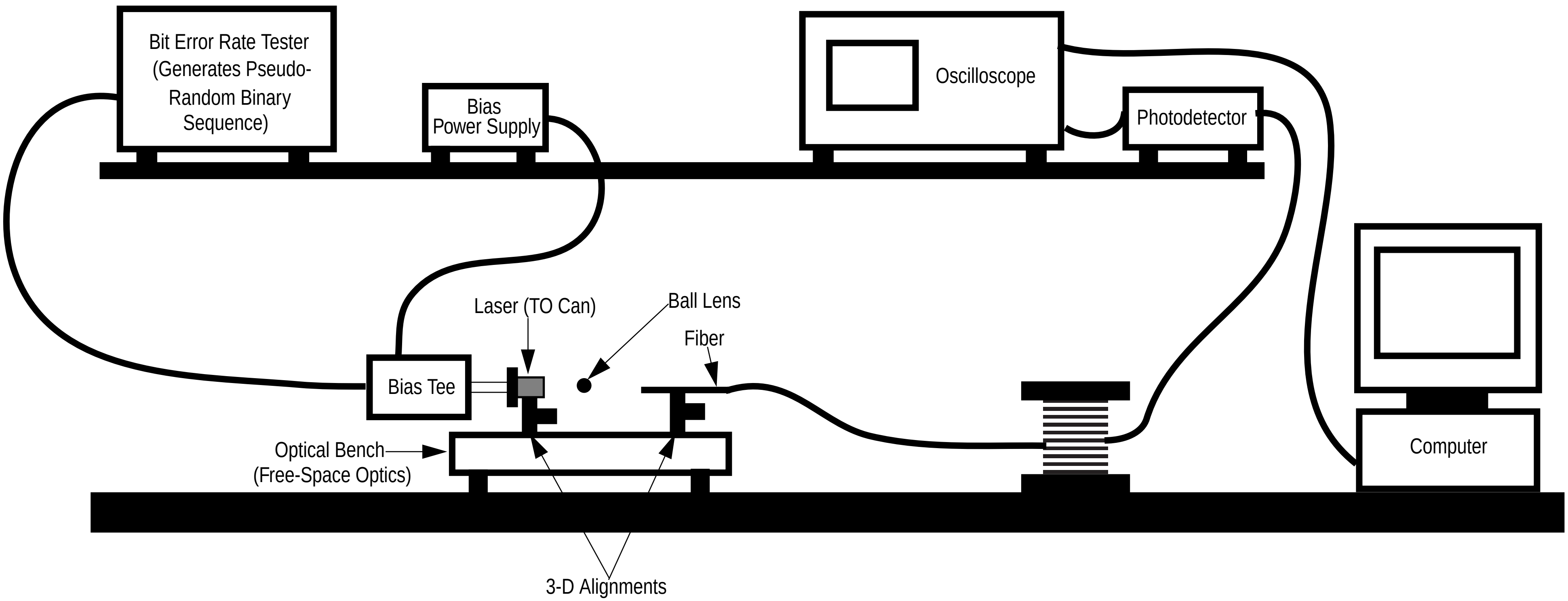
Algorithm to Postprocess Measured Data

Oscar Agazzi(*) *and Tom Lenosky*(**)
January 10, 2001

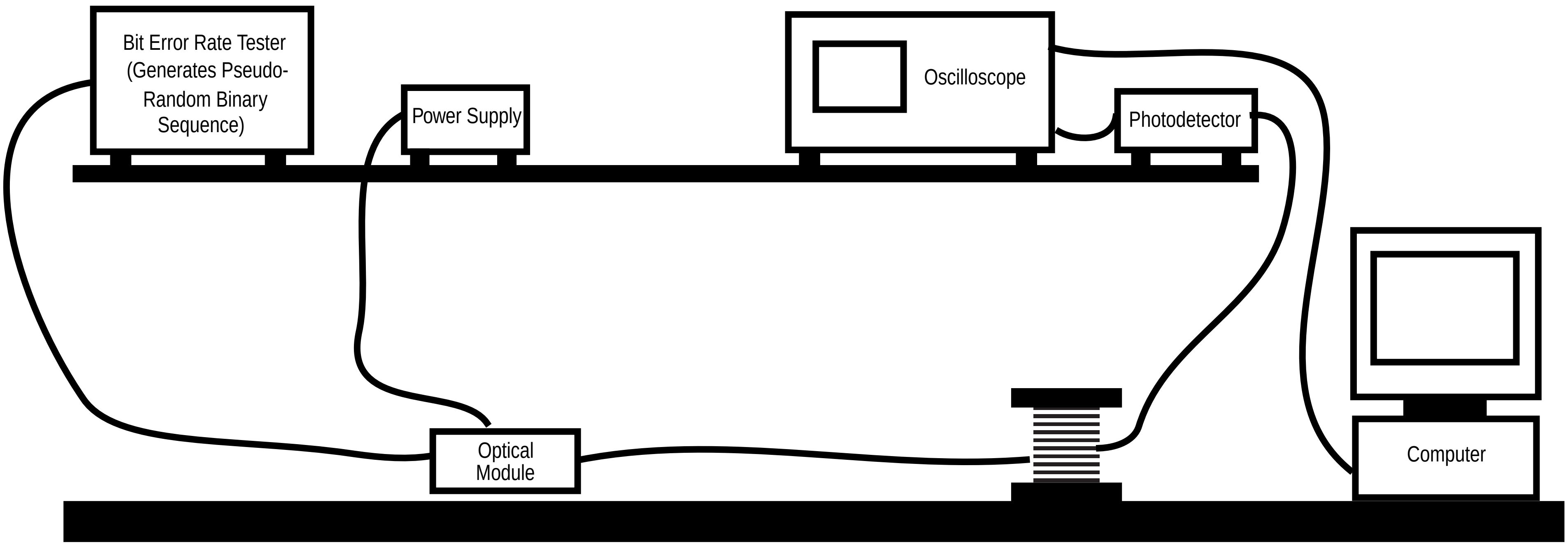
(*) ***Broadcom***

(**) ***Finisar***

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)**

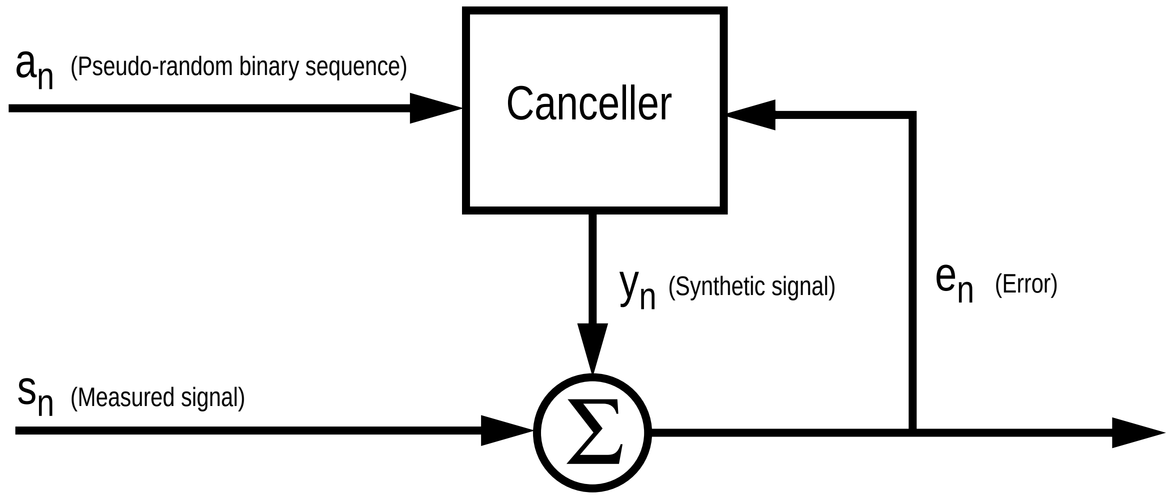
- **The error is defined as the difference between the measured signal and the best fit generated by the model**

- **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**

Block Diagram of Algorithm



Channel Identification Algorithm

- **The synthetic signal y_n is generated as a convolution of the transmitted bit sequence a_n with the sequence of coefficients c_k:**

$$y_n = \sum_{k=0}^{N-1} c^{(n)}{}_k \cdot a_{n-k}$$

- **The coefficients c_k are initially zero, and they are adapted using the Least Mean Squares (LMS) algorithm, which iteratively updates each coefficient c_k by adding to it the product of the error e_n with delayed versions of the transmitted bits a_{n-k}, where β is a small gain factor**

$$c_k^{(n+1)} = c_k^{(n)} + \beta \cdot e_n \cdot a_{n-k}$$

- **After the canceller is fully converged, we can compute the Signal to Noise Ratio (SNR) as:**

$$SNR = 10 \cdot \log 10(\sigma_s^{\ 2} / \sigma_N^{\ 2})$$

Channel Identification Algorithm (cntd)

Where

$$\sigma_s^{\ 2} = \frac{1}{N} \cdot \sum_{k=0}^{N-1} S_k^{\ 2} - \left(\frac{1}{N} \cdot \sum_{k=0}^{N-1} S_k \right)^2$$

is the power of the signal, and

$$\sigma_N^{\ 2} = \frac{1}{N} \cdot \sum_{k=0}^{N-1} e_k^{\ 2} - \left(\frac{1}{N} \cdot \sum_{k=0}^{N-1} e_k \right)^2$$

is the power of the noise

Channel Identification Algorithm (cntd)

- **Although for simplicity of notation the algorithm was described in the context of a baud-rate-sampled system, it can be generalized to an oversampled system in a straightforward way**

- **If the signal is sampled R times per baud, the block diagram of Viewgraph 6 would consist of R identical cancellers operating in a time interleaved fashion**

- **The algorithm described in Viewgraphs 7 and 8 would be replaced by R identical replicas of the equations, each one with an independent set of coefficients c_k**

- **The samples of the input signal would be split among R interleaved streams, each one being supplied to one of the interleaved cancellers, but the input data bits would be shared by all cancellers. Each canceller would be adapted based on its own version of the error**

Results of the Algorithm

- **The final products of this algorithm are:**
  - A synthetic signal which represents the best fit to the measured signal that can be produced by the linear adaptive model
  - The error, which is the difference between the measured and synthetic signals
  - The SNR, which is a measure of the goodness of the model, and
  - The canceller coefficients c_k, which represent the impulse response of the optical channel

Examples of Application

- **This algorithm was coded in C, and used to process all the measurements reported in the following presentations**
- **In these measurements the signal was oversampled by a factor R=8, except for the 2Gb/s 850nm measurements where the oversampling factor was R=4**