300 meters on installed MMF

Part III: Link Simulations

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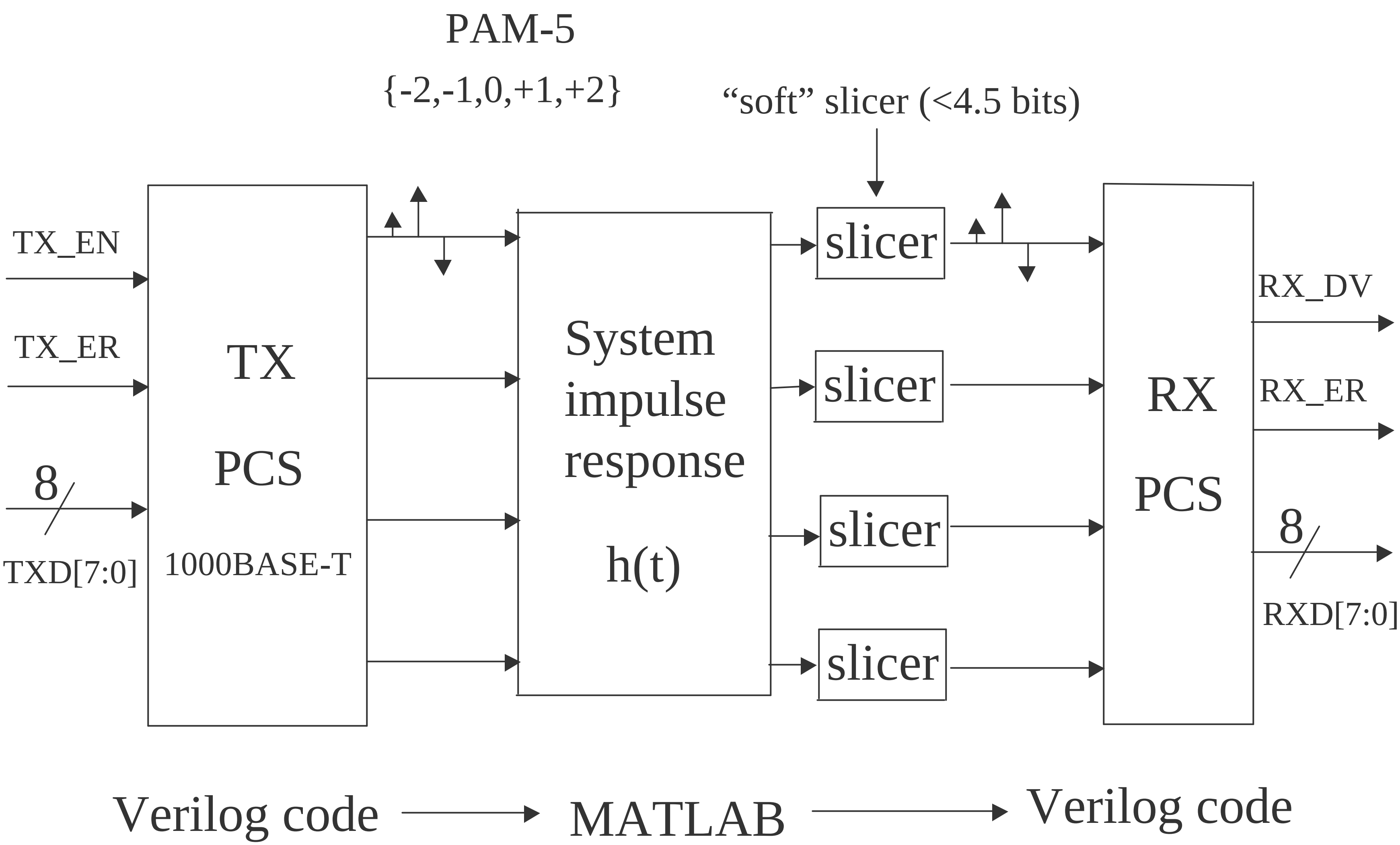
System simulations @ 1.25 Gbaud/s

- A complete system is simulated adding the PCS of the 1000BASE-T standard.
- The TX uses convolutional encoding to generate 6 dB of coding gain (see Ref 3).
- The RX recovers the transmitted frames using Viterbi decoding

SIMULATED SYSTEM



1.25 Gbaud/s

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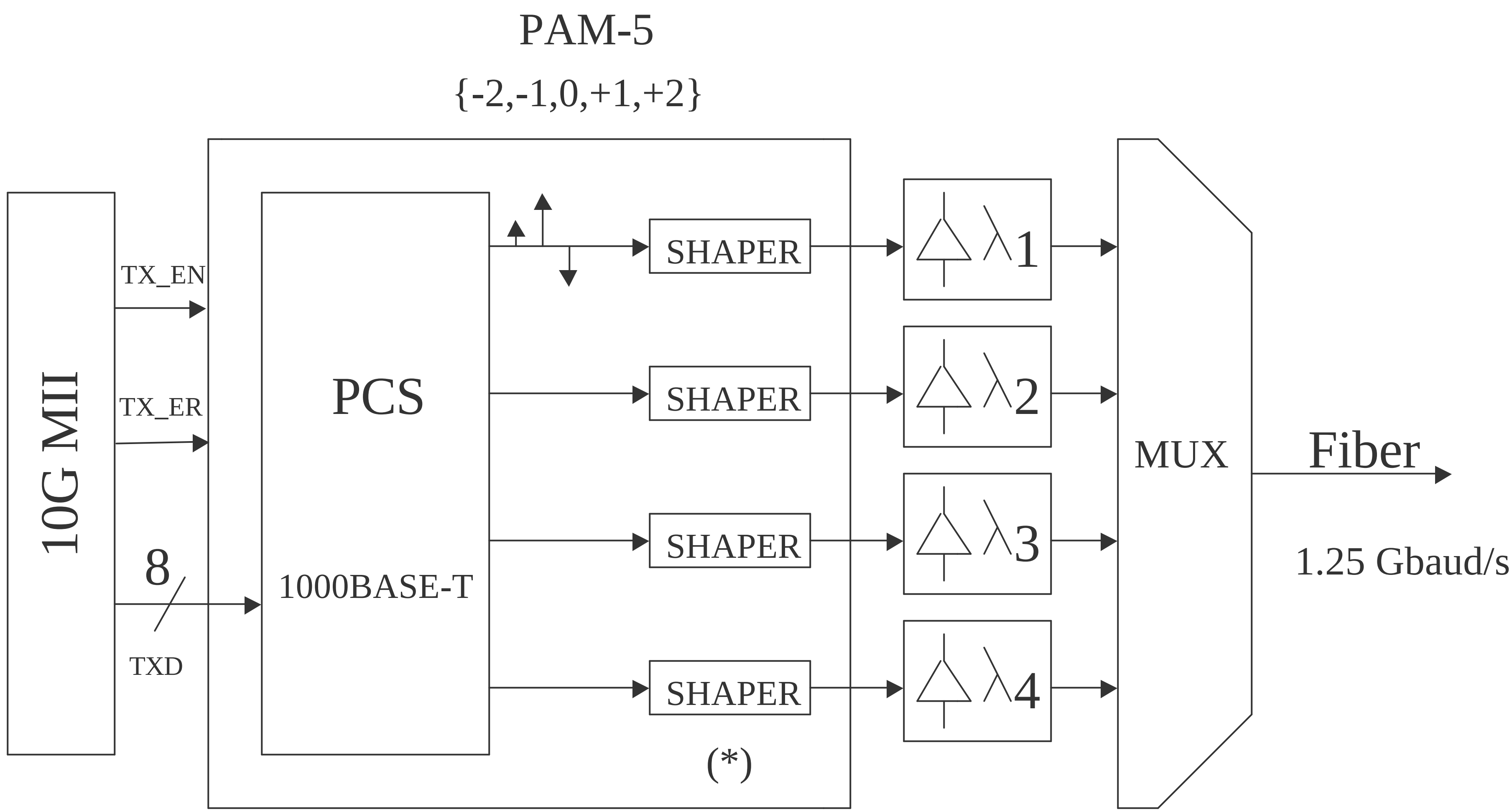
PAM-5 + scrambling + 4-WDM: TX zoom-in



(*) optional shaper, may be used to improve the laser linearity

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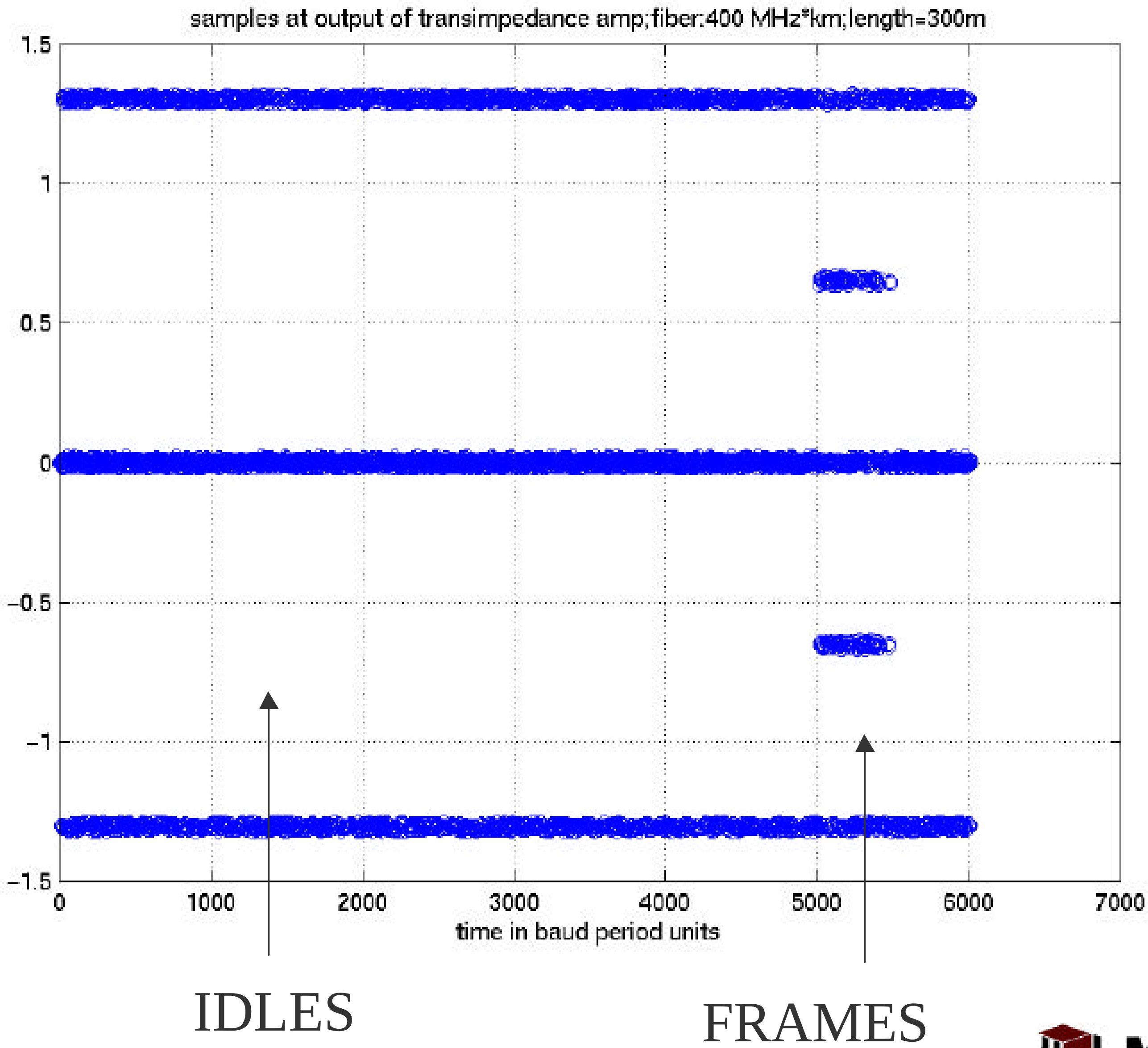
Samples at output of transimpedance amp (one channel)



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Receiver PCS results - 300 m

- The receiver PCS synchronized its descrambler during the IDLE mode and then recovered the transmitted frames with no errors (*)

(*) no errors were detected even when the Viterbi decoder was disabled (0 coding gain)

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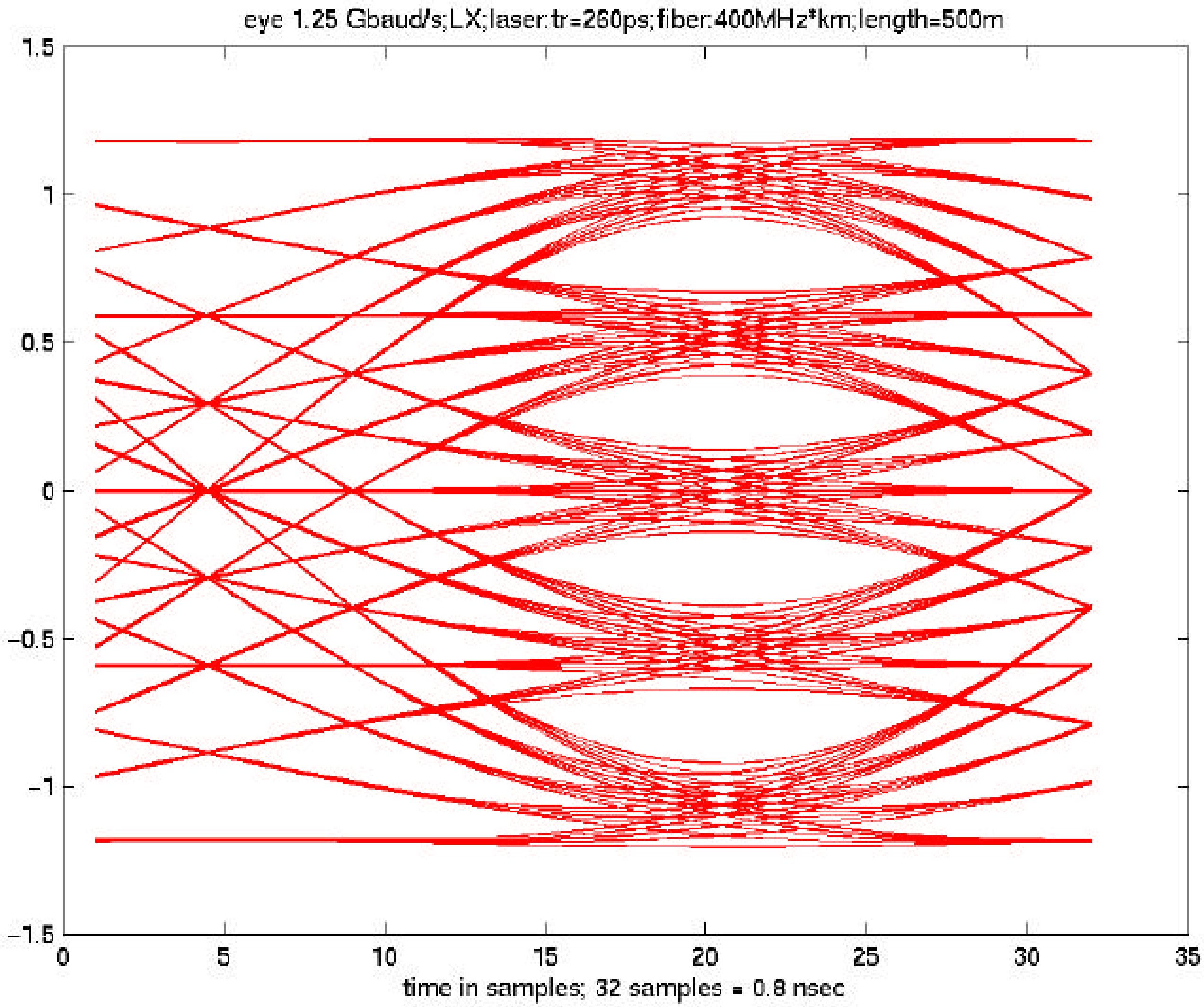
500 meters (*)

- @ 500 meters fiber length
  - eye open using PAM-5 @ 1.25 Gbaud/s. Frames successfully recovered
  - eye closed using 8b/10b @ 3.125 Gbaud/s

(*) 500 m is not recommended as a spec: simulated only to check for rate of performance degradation with increased link length

1.25 Gbaud/s; link length = 500 meter



(frames recovered with no errors)

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Laser non-linearity @ 1.25 Gbaud/s

- @ 300 meters fiber length:
  - laser non-linearity was added. Frames successfully recovered using compression ratios up to 1.5 dB (not recommended as a spec; simulated to test the robustness of the receiver)

Note: "Early analysis of a limited sample of standard digital DFB lasers used in OC-48 [2.5 GHz] indicate sufficient linearity performance [of commercially available lasers]" (see Ref 4 for extensive analysis)

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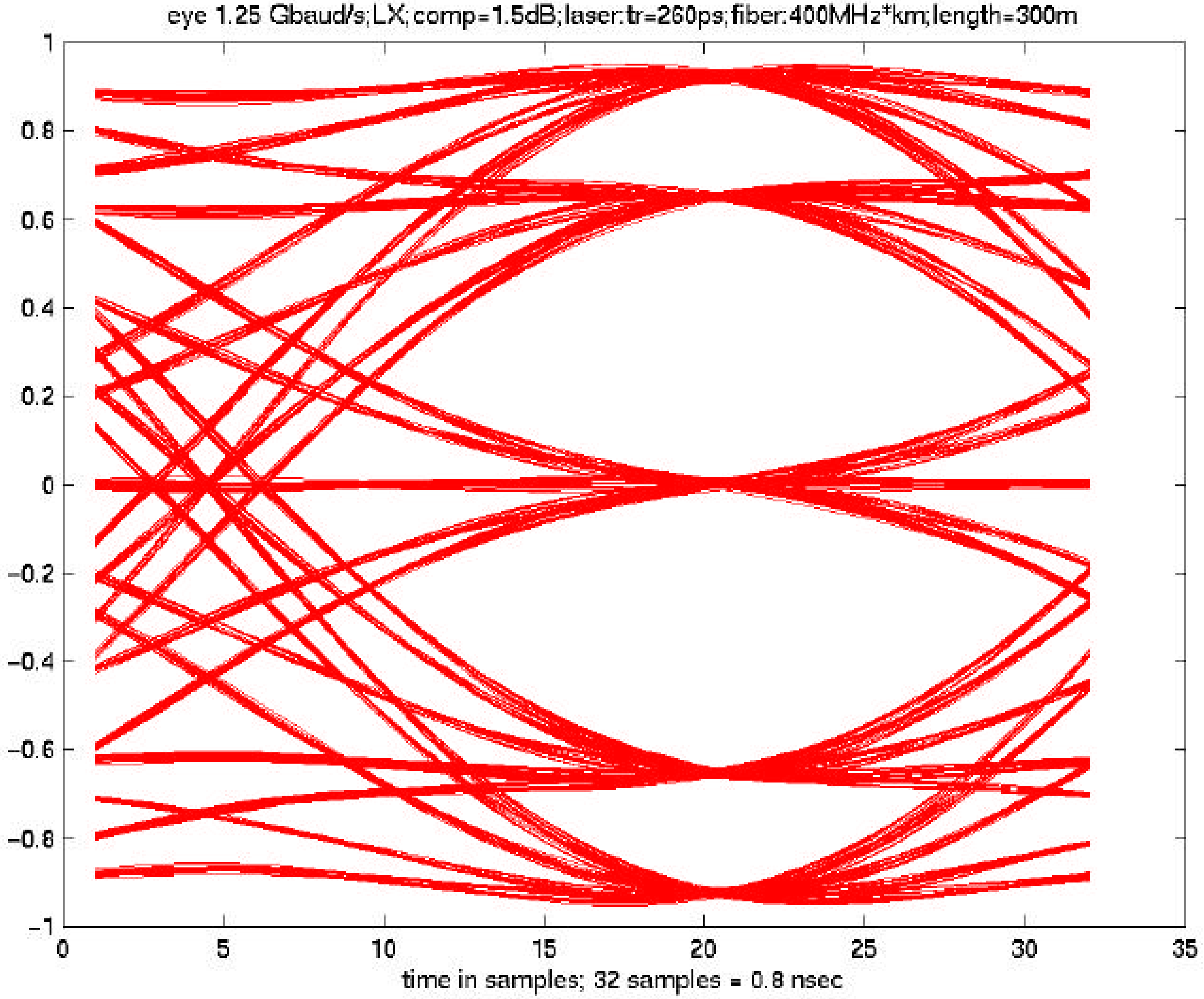
1.25 Gbaud/s;300m;compression_ratio=1.5 dB



(frames recovered with no errors)

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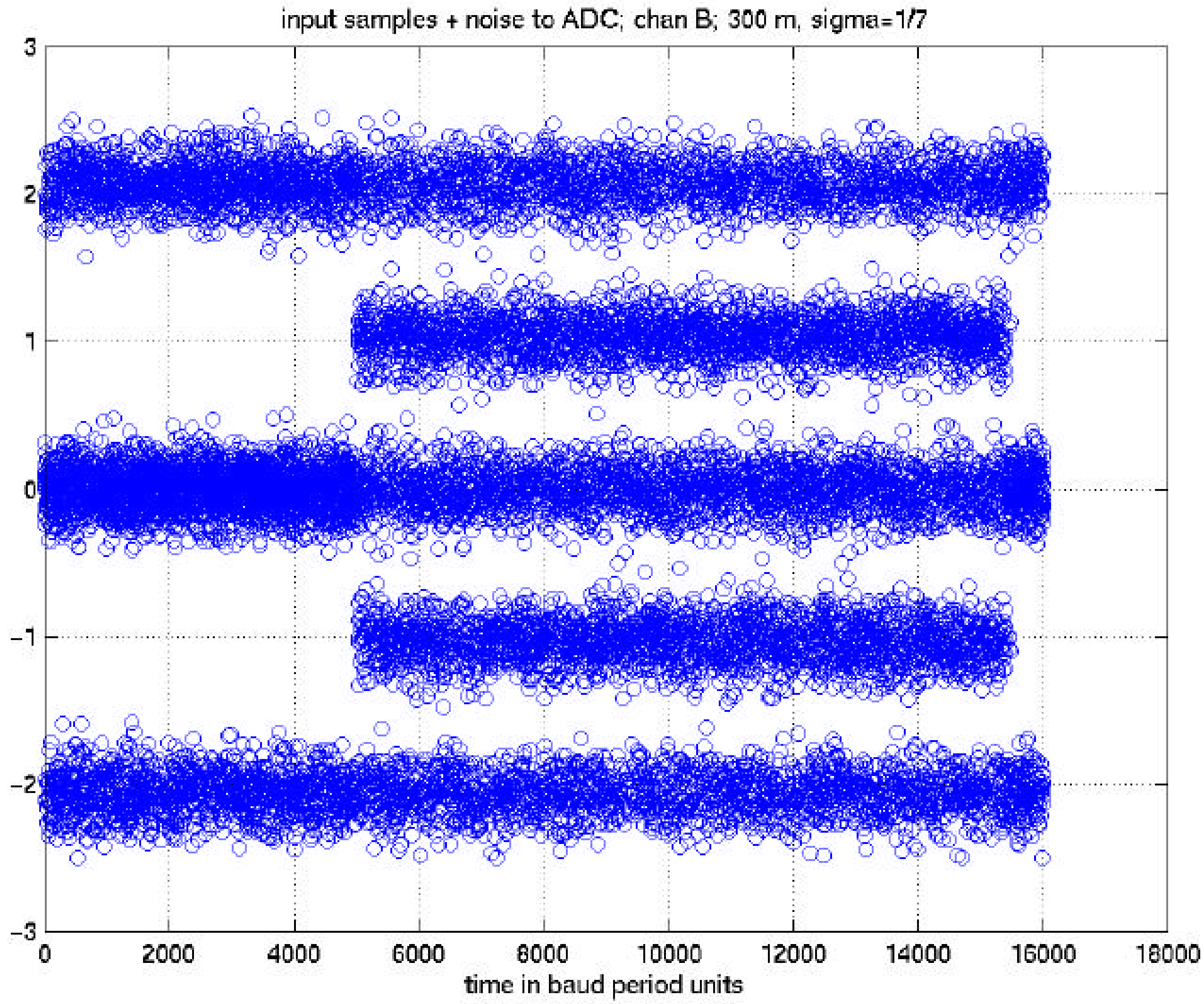
Add thermal noise

- Simulation conditions:
  - laser risetime = 0.26 psec
  - fiber bandwidth = 400 MHz * km
  - added Gaussian noise: Is/In = 7
  - two successive frames: 10,400 and 14 octets, respectively (~83,300 bits of data, total)

The following two Figures show the samples after the AGC, at the input of the soft slicer (ADC) with 300m and 500 meter link length, respectively (one channel)

Samples at soft-slicer input (one channel) 300m - Is/In=7



Measured: SER=0 BER=0

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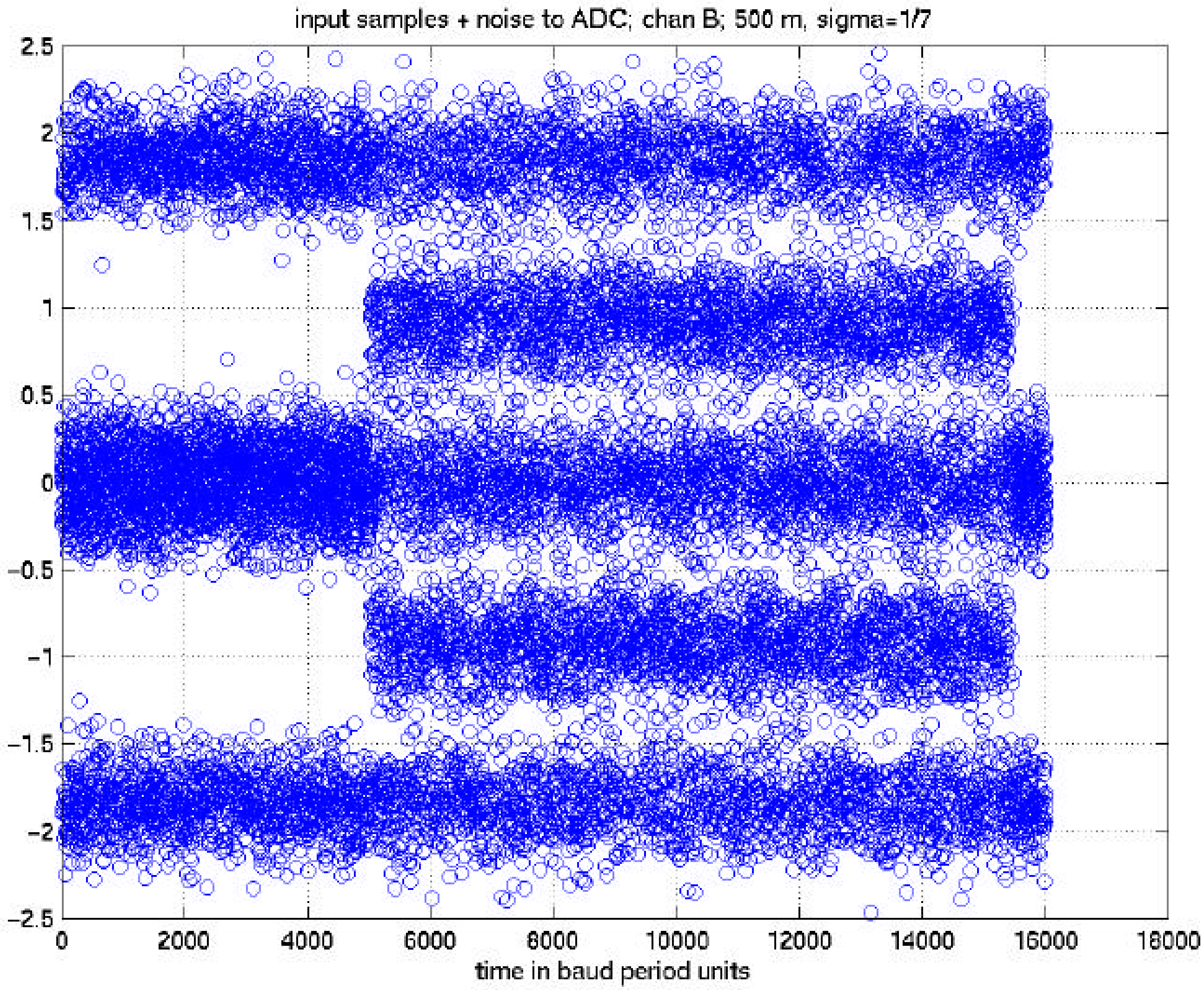
Samples at soft-slicer input (one channel) 500m - Is/In=7



10 incorrect symbols; SER~9.6e-4, BER~3.3e-4

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Longer frames

- Two successive frames were sent: 100,400 and 14 octets, respectively (803,312 bits, total). The transmitted frames went through 300 meters of fiber and the Is/In at the receiver input was set to Is/In =7.
- The measured SER and BER were:

$$SER = 0; \quad BER = 0$$

Viterbi decoding at 1.25 GHz ?

- The Viterbi decoder can run at a much lower speed using parallel processing (see, for example, Ref 5, and references therein).

(work in progress, viability for 10 GbE case not tested yet)

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Summary

- An architecture using the lowest baud rate in the optical fiber (1.25 Gbaud/s) is an attractive alternative to reuse the installed base of multimode fiber up to 300 meters length.
- This architecture reuses the PCS of an 802 standard, 802.3ab (1000BASE-T), saving valuable 10 GbE Standard development time.

References

- (1) D.G. Cunningham and W. G. Lane, “Gigabit Ethernet Networking”, MacMillan, 1999
- (2) B.E. Lemoff and L.A. Buckman, “WWDM transceiver update and 1310 nm eye-safety”, Montreal, July 1999
- (3) J.E. Kardontchik, “Tutorial for 4D encoding in 1000BASE-T”, Idaho, June 1999
- (4) R. Taborek and B. Dahlgren, “Multi-Level Analog Signaling Techniques for 10 Gigabit Ethernet”, Montreal, July 1999
- (5) H. David, G. Fettweis and H. Meyr, “A CMOS IC for Gb/s Viterbi decoding: System Design and VLSI Implementation”, IEEE Trans. on VLSI Systems, vol 4, pages 17-31, March 1996