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Q-factor improvement in a jitter limited optical RZ system using nonlinearity of normal dispersion fiber placed at receiver

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Abstract: We adopted a new detection scheme using nonlinearity of normal dispersion fiber in a jitter limited 10 Gb/s soliton transmission. The obtained amplitude margin at BER of 10^{-9} was three times larger than the conventional sheme.

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1. Introduction

In ultra-high speed optical fiber communication systems, RZ pulse format is preferably used to improve the transmission performance. In optical RZ systems, an electrical Bessel-Thompson lowpass filter is normally employed after direct detection. The filter has two functions. One is that the filter limits the receiver bandwidth in order to reduce the noise power due to the accumulated amplified spontaneous emission (ASE) noise generated by EDFA repeaters. The other one is that the filter broadens the pulse provided that the duty ratio of the received pulse is small, and therefore reduces the influence of the fluctuation of pulse position[1]. The drawback of this method is that there exists a trade-off between the cut off frequency of the filter and the intersymbol interference. To solve this problem, we proposed a new technique by utilizing Kerr nonlinearity in normal dispersion fiber placed at the receiver[2, 3]. In this paper, we show that the Q-factor is greatly improved in a jitter limited optical RZ system by the proposed method.

2. Operation principle

It is well known that when an optical pulse propagates along normal dispersion fiber with Kerr effect, its temporal waveform changes to a rectangular-like profile[4, 5]. After propagation, the pulse is broadened and the center portion of the pulse becomes flat. By utilizing this property, the amplitude and phase margins at the receiver can be improved. Fig. 1 shows the schematic diagram of the setup. The system is constructed by an erbium-doped fiber amplifier (EDFA), an optical bandpass filter (OBPF) which removes the amplified spontaneous emission (ASE) noise, and normal dispersion fiber (NDF). The normal dispersion of this NDF may be effective in reducing the Gordon-Haus timing jitter accumulated in soliton transmission[6]. In the proposed scheme, however, the required bandwidth is wider than that of the conventional receivers, because the spectrum of the pulses spreads out due to

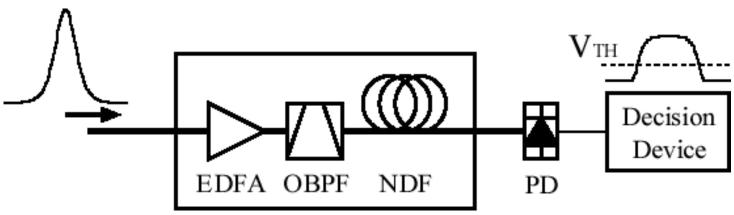

Fig. 1. Schematic diagram of the setup.

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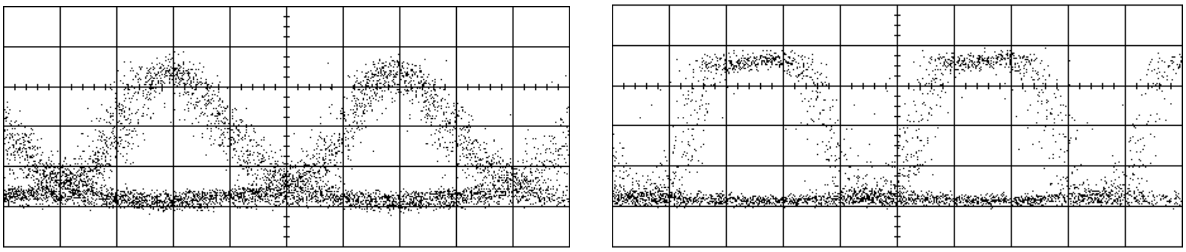
the nonlinear effect. This leads to the decreasing of signal to noise ratio in the detected electrical signals. Therefore, the proposed method may be effective in a jitter-limited transmission system.

3. Experiment

We carried out 10 Gb/s soliton transmission experiment in a sliding frequency recirculating loop, and compared the performance of the proposed method and the conventional RZ receiver. The setup of the loop transmission is the same as the one described in Reference[7] except the optical soliton source with a Mach-Zhender modulator[8, 9]. Because of the sliding frequency soliton control, ASE accumulation is effectively suppressed and the transmission distance is limited by timing jitter. The transmitted pulse width is estimated to be 18 ps. In the proposed method, we used 20 km NDF with the group velocity dispersion of - 3 ps/nm/km based on the results of numerical simulation. The averaged launched power to the NDF was 15 dBm. Fig. 2 shows the eye diagrams of the transmitted pulses over 12,000 km detected with (a) a lowpass filter with 7.5 GHz bandwidth and (b) the proposed method. We set the average optical power to the photodiode to be –4.6 dBm for both cases. We can see in Fig. 2 (a) that the pulse is broadened by the lowpass filter. However, the amplitude jitter on "0" signals was increased maybe due to intersymbol interference. By utilizing dispersion and nonlinearity in the NDF, the waveform of the pulses was changed to rectangular-like as seen in Fig. 2 (b). The eye opening is wider than that detected with the lowpass filter.



(a) with 7.5 GHz lowpass filter

(b) with the proposed method

Fig. 2. Eye diagrams of the detected 10 Gb/s solitons at 12,000 km (25 ps/div).

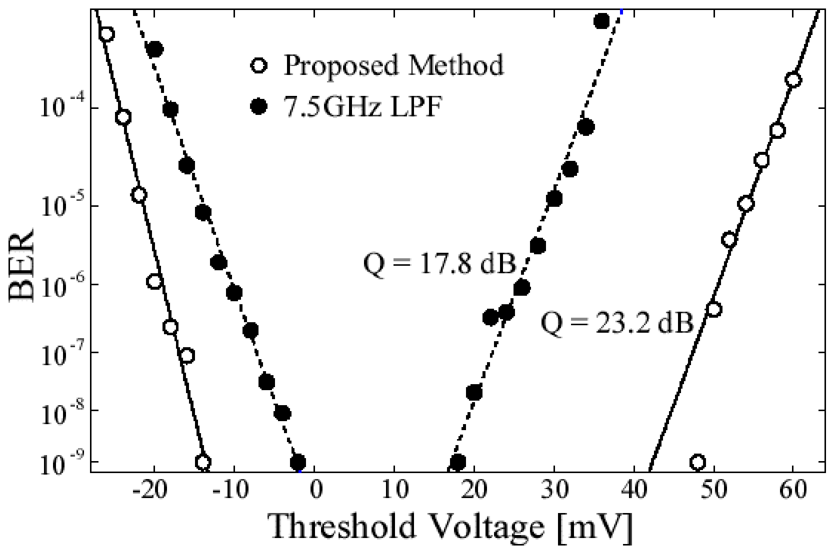


Fig. 3. Measured bit error rate while changing the threshold voltage with the detection time adjusted to maximize the amplitude margin in each case

In addition, the amplitude jitter on "1" and "0" signals is not increased. Next, we measured bit error rate (BER) while changing the threshold voltage of the BER detector. In the measurement, we adjusted the detection time to maximize the amplitude margin in each case. The electrical bandwidth of the BER detection scheme was 15 GHz. Fig. 3 shows the result. When the transmitted pulses were detected with the 7.5 GHz lowpass filter, the margin in the threshold voltage at the BER of 10^{-9} was 19.3 mV. On the contrary, when the transmitted pulses were detected with the proposed method, the margin was 56.0 mV. The estimated Q-factor were 17.8 dB for the low pass filter and 23.2 dB for the proposed method, respectively.

4. Conclusion

We adopted the new detection scheme in a jitter-limitted 10 Gb/s soliton transmission with a sliding frequency recirculating loop. We observed that the waveform of the transmitted soliton pulses over 12,000 km changed to rectangular-like. The obtained amplitude margin at BER of 10^{-9} was three times larger than the conventinal scheme. The estimated Q-factor was improved by 5.4dB.

5. References

[1] B. Bakshi, P. A. Andrekson, M. Karlson, and K. Bertilsson, “Soliton interaction penalty reduction by receiver filtering,” IEEE Photon. Tech. Lett. **10**, 1042-1044 (1998).

[2] M. Suzuki, H. Toda, A. Liang, and A. Hasegawa, “Improvement of a phase margin in optical RZ receiver using Kerr nonlinearity in normal dispersion fibers,” Techn. Dig. OECC2000, Yokohama, Japan, 12P-11.

[3] M. Suzuki, H. Toda, A. Liang, and A. Hasegawa, “Improvement of a phase margin in optical RZ receiver using Kerr nonlinearity in normal dispersion fibers: experimental verification,” Techn. Dig. ECOC2000, Munich, Germany, 10.3.3.

[4] H. Nakatsuka, D. Grischkowsky, and A. C. Balant, “Nonlinear picosecond-pulse propagating through optical fibers with positive group velocity dispersion,” Phys. Rev. Lett. **47**,. 910-913 (1981).

[5] R. J. Tomlinson, R. H. Stolen, and C. V. Shank, “Compression of optical pulses chirped by self-phase modulation in fibers,” J. Opt. Soc. Am. B. **1**, 139-149 (1997).

[6] V. Chandrakumar, M-S Alouini, J-B. Thomine, T. Georges, and F. Pirio, “Combination of in-line filtering and receiver dispersion compensation for an optimized soliton transmission,” IEEE/OSA J. Lightwave Technol. **12**, 1047-1051 (1994).

[7] H. Toda, K. Mino, Y. Kodama, A. Hasegawa, and P. A. Andrekson, "Influence of noise in optical pulse source on soliton transmission," IEEE/OSA J. Lightwave Technol. **17**, 1027-1031 (1999).

[8] J. J. Veselka and S. K. Korotky, "Pulse generation for soliton systems using lithium niobate modulators," IEEE J. Selected Topics in Quantum Electron., **2**, .300-310 (1996).

[9] H. Toda, N. Yamaguchi, Y. Kodama, T. Shiozaki, and A. Hasegawa, "Evaluation of dispersive waves in soliton pulses generated from Mach-Zehnder modulator and single mode fibre," Electron. Lett., **34**, 1246-1247 (1998).