RZ/CSRZ-DPSK signal generation using only one Mach-Zehnder modulator

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Abstract: We demonstrate a novel scheme to generate return-to-zero /carrier-suppressed return-to-zero differential phase-shift keyed (RZ/CSRZ-DPSK) signal, which needs only one Mach-Zehnder modulator (MZM). It is more cost-effective compared to conventional schemes due to its simple configuration.

OCIS codes: (060.2330) Fiber optics communications, (060.4080) Modulation, (060.5060) Phase modulation

1. Introduction

Differential phase-shift keyed (DPSK) format, which carries the information by optical phase changing between bits, has been widely used in long-haul optical communication systems for its ~3dB lower optical signal-to-noise ratio (OSNR) requirement than on-off keying (OOK) signals when using balanced receiver. It also shows more resilience to cross-phase modulation compared to OOK [1]. On the other hand, return-to-zero (RZ) optical signals possess advantage in operating with high input powers, small inter-symbol interference and high receiver sensitivity than non return-to-zero (NRZ). Carrier-suppress (CS) RZ signal, which is a variation of the RZ format, provides higher efficiency in spectrum utilization. The combination of RZ/CSRZ and DPSK format can greatly enhance the transmission quality and therefore has attracted much interest [2,3].

In general, RZ/CSRZ-DPSK signal is generated by two Mach-Zehnder modulators (MZMs): one is used for phase modulation, the other is for pulse carving to generate RZ or CSRZ format. The method is straightforward but results in high cost and complex configuration. Recently, some novel configurations are presented to reduce the number of modulators [4,5]. In [4], chirped RZ-DPSK signal is obtained by using a dual-drive MZM and two high-speed differential amplifiers, however, the high-speed analog components incurs the complexity in fabrication. In [5], a proposal was made to generate RZ/CSRZ-DPSK signal by one dual-drive MZM by providing only analytic and simulation results. In this paper we proposed and experimentally demonstrated a new scheme to generate RZ/CSRZ-DPSK signal, which only uses a MZM and simple, commercially available digital Integrated Circuits (ICs).

2. Principles

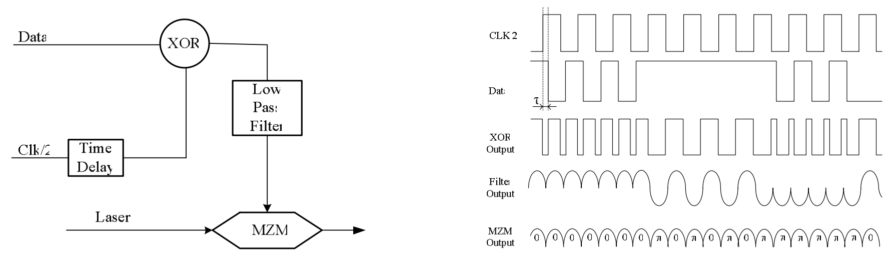
To generate the RZ/CSRZ-DPSK signal with one MZM, one approach is to use an electrically encoding process to replace the pulse-carving performed by a second MZM in conventional schemes. The key of this approach is to generate an electrically pulse-carved bipolar drive signal, where “+1” state corresponds to “0” phase and “-1” state corresponds to the “π” phase, or vise versa. In this paper, a new method using a XOR gate and low-pass filter is used to implement this encoding process.

2.1 CSRZ-DPSK encoder

The schematic of the proposed CSRZ-DPSK generator is shown in Fig. 1a. A differential pre-coded data sequence and a B/2 (half of bit rate B) clock stream with a certain delay are firstly fed into a high-speed XOR gate, the XOR output is sent to a low pass filter to generate a sinusoidal carved bipolar signal. This signal is then directly amplified to drive a Mach-Zehnder $LiNbO_3$ modulators, which is biased at its transmission null. Fig. 1b shows the principle of this encoding.

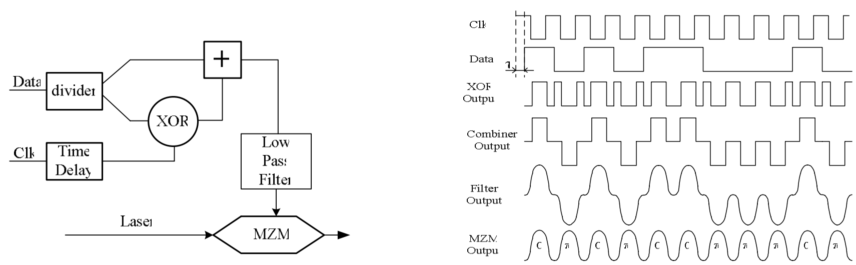
2.1 RZ-DPSK encoder

As shown in Fig. 2a, the differential pre-coded data is divided into two parts, one is sent to the input of the XOR gate together with the full-rate clock with certain delay, and the other is combined with the output of the XOR gate. Then, the resulting signal is passed to a low-pass filter to generate a pulse carved bipolar signal, and amplified to drive a Mach-Zehnder $LiNbO_3$ modulator biased at its transmission null. The coding process is shown in Fig. 2b.



(a) (b)

Fig. 1 Principle of CSRZ-DPSK encoder



(a) (b)

Fig. 2 Principle of RZ-DPSK encoder

3. Experimental Setup and Results

The experimental set-up is shown in Fig. 3. The transmitter consists of a DFB laser, a $LiNbO_3$ MZ modulator and a CSRZ-DPSK (or RZ-DPSK) encoder. A 10-Gb/s pseudo-random binary sequence (PRBS) with a length of 2^{23}-1 and a 5-GHz (or 10GHz) clock are sent into the encoder to generate the pulse carved bipolar drive signal. The required delay in the encoder is optimized by monitoring the eye diagram of the drive signals. The signal is fed to an MZM to generate CSRZ-DPSK (or RZ-DPSK) signal. After being amplified by an EDFA, the CSRZ-DPSK (or RZ-DPSK) signal is sent into a 1-bit delay Mach-Zehnder interferometer (MZI) for de-modulating, which is then detected by a single-ended optical receiver.

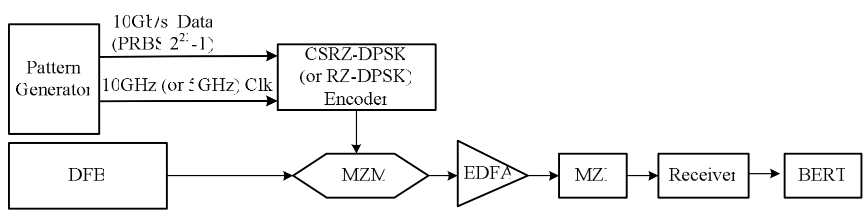
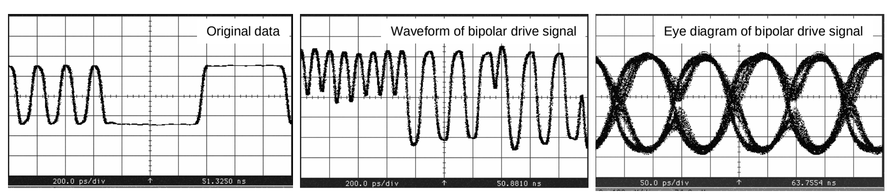
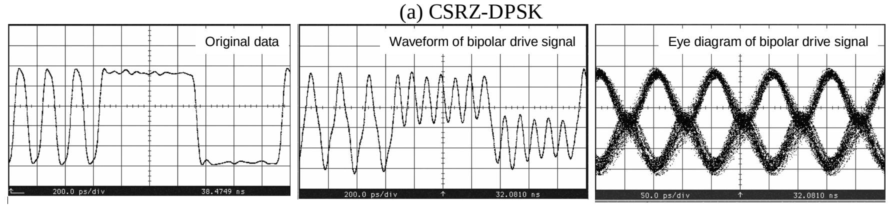


Fig. 3. Experimental Setup for CSRZ-DPSK (or RZ-DPSK) Signal Generation

Fig. 4 shows the measured waveforms and eye diagrams of the electrically pulse carved bipolar drive signals for CSRZ-DPSK and RZ-DPSK. Clearly, a three-level signal is obtained through the encoder. The amplitude noise and timing jitter are induced by the non-ideal impedance match of the printed circuit board of the encoder.



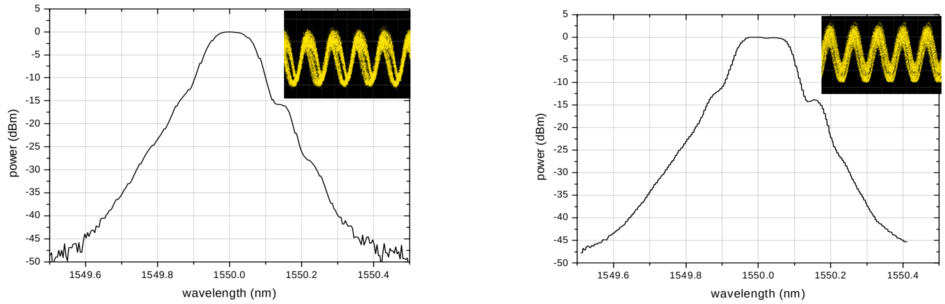
(a) CSRZ-DPSK



(b) RZ-DPSK

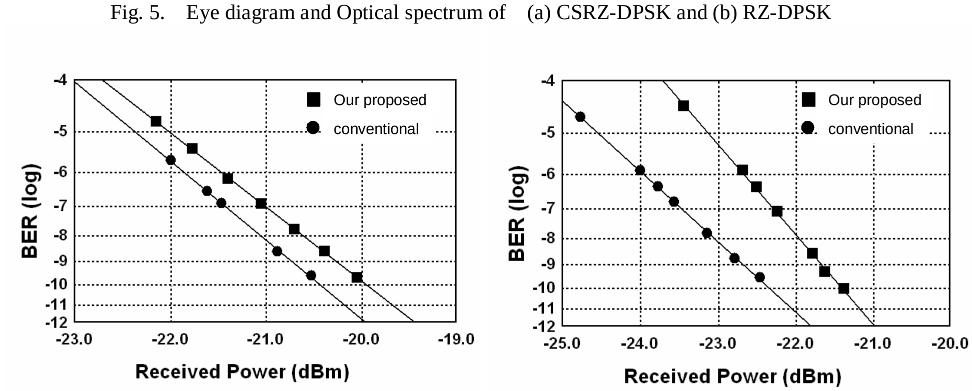
Fig. 4. Measured waveforms and eye diagram of the electrically pulse carved bipolar drive signals for (a) CSRZ-DPSK and (b) RZ-DPSK

Fig. 5 shows the measured eye diagrams and optical spectra of the RZ-DPSK and CSRZ-DPSK signals. The BER curves of the signals based on our proposed scheme and a conventional method using two MZMs are provided in Fig. 6. It shows ~0.5dBm power penalty for the CSRZ-DPSK and ~1dBm power penalty for the RZ-DPSK, which are mainly attributed to signal reflection in our PCB board of the encoder.



(a) CSRZ-DPSK (b) RZ-DPSK

Fig. 5. Eye diagram and Optical spectrum of (a) CSRZ-DPSK and (b) RZ-DPSK



(a) CSRZ-DPSK (b) RZ-DPSK

Fig. 6. Compared BER curves of (a) CSRZ-DPSK and (b) RZ-DPSK

4. Conclusions

We proposed and experimentally demonstrated a method to generate RZ/CSRZ-DPSK signal by using one MZ modulator and simple commercially available digital ICs. Experimental results of the transmitter are presented, showing its simplicity in the implementation.

Acknowledgement

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