A Novel Chirp-free Optical Manchester Signal Transmitter with Enhanced Dispersion Tolerance

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Abstract: We propose and demonstrate a simple chirp-free optical Manchester signal transmitter that consists of a single-drive Mach-Zehnder modulator and a passive electronic power combiner. A 5-Gb/s optical Manchester signal is generated and its dispersion tolerance enhancement is investigated. The bandwidth of the modulator and driving circuit is reduced by half.

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1. Introduction

Manchester coding, in which the original symbols are encoded by the transition directions (“rise” or “fall”) at the center of each bit, enables easy clock extraction at the expense of bandwidth doubling. It has been widely used in copper-based Ethernet 10BASE-T. The unique self-clocking property together with differential detection also makes Manchester coding a promising candidate for high-speed optical burst mode transmission links [1,2]. In addition, as the Manchester code has negligible low-frequency spectral components, it can also be used in optical access network to reduce the re-modulation crosstalk [3].

Manchester coding can be realized in electoral domain via an exclusive OR (XOR) gate or a multiplying mixer. Then the obtained electrical Manchester signal can be used to drive an electro-optical modulator, operating in the linear transfer region, to generate the optical Manchester signal. However, the modulator requires a driver amplifier with a bandwidth twice as large as that for the non-return-to-zero (NRZ) signal generation at the same bit rate. A dual parallel Mach-Zehnder modulator (MZM) has been used to realize Manchester coding directly in optical domain, eliminating high-speed electronic processing at the expense of more complicated modulator structure [4]. A more elegant approach has been proposed by using a single dual-drive MZM to implement high-speed Manchester coding directly in optical domain [5]. However, as the two driving signals (data signal and clock, respectively) are not complementary, the generated optical Manchester signal cannot be chirp-free and is thus vulnerable to chromatic dispersion during transmission, especially in the differential detection case.

In this paper, we propose a novel chirp-free optical Manchester signal transmitter that consists of a conventional chirp-free single-drive MZM together with a passive electronic power combiner. The driving signal is obtained simply by adding the original NRZ data and the synchronized clock signal via the power combiner. The chirp-free optical Manchester signal can be generated by leveraging on the inherent sinusoidal transfer curve of a MZM.

2. Principle and Experimental Demonstration

Fig. 1(a) illustrates the proposed optical Manchester signal transmitter. The combination of the original raised-cosine shaped NRZ data and the synchronized clock signal is used as the driving signal as shown in Fig. 2. The marks in the original NRZ data plus the clock signal results in the mark-level oscillation between ~V_π and ~$2V_\pi$ in the combined signal, while the spaces in the NRZ data plus the clock signal results in the space-level oscillation

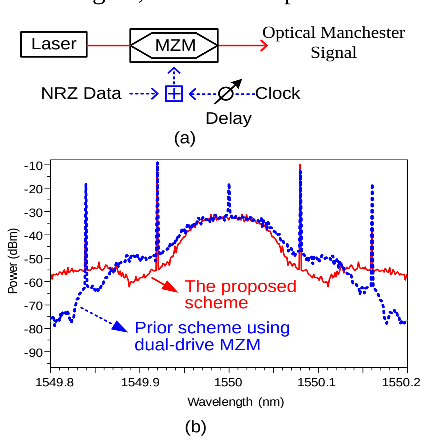

Fig. 1. (a) Proposed optical Manchester signal transmitter. (b) simulated spectrum of the optical Manchester signal.

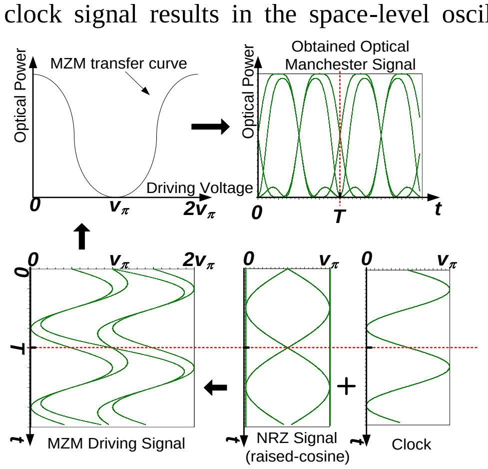

Fig. 2. Operation principle of the proposed optical Manchester signal transmitter.

between ~ 0 and $\sim V_\pi$ in the combined signal. Within a bit period T, the mark-level oscillation will experience the swing from the peak voltage $\sim 2V_\pi$ to the valley voltage $\sim V_\pi$, corresponding to a "fall" transition at the center of a bit in the MZM output; similarly, the space-level oscillation will experience the swing from the peak voltage $\sim V_\pi$ to the valley voltage ~ 0, corresponding to a "rise" transition at the center of a bit in the MZM output. Thus, the original NRZ data are now encoded by the transition directions ("rise" or "fall") at the center of each bit in the MZM output, realizing the Manchester coding directly in optical domain. The simulated spectrum of the optical Manchester signal is shown by the red line in Fig. 1(b). For comparison, we also show the simulated spectrum of the optical Manchester signal, generated by a dual-drive MZM [5], as the blue line in Fig. 1(b). The blue-line spectrum is wider due to the inherent chirp in the scheme using a dual-drive MZM.

We have experimentally demonstrated the proposed optical Manchester signal transmitter based on the setup shown in Fig. 1(a). Continuous-wave (CW) light at 1550 nm was fed into a MZM driven by the combination of a 5-Gb/s 2^{31}-1 pseudorandom binary sequence (PRBS) and a 5-Gb/s sinusoidal clock signal. It is worth mentioning that the bandwidth of the driving signal generated by a passive power combiner is reduced by half [6, 7], compared with that of the driving signal generated by an XOR gate or a multiplying mixer. Thus, the bandwidth of the MZM and driving circuit is also reduced in the proposed scheme. To compare the dispersion tolerance between the proposed scheme and the prior scheme using dual-drive MZM [5], the obtained optical Manchester signal from the MZM output was transmitted through a span of 20-km standard single-mode fiber (SMF) with a dispersion coefficient of -17 ps/nm*km, before being detected by a 10-Gb/s p-i-n receiver. The bit-error-rate (BER) measurement results are shown in Fig. 3. Compared with the BER curve of the B2B Manchester signal, around 0.4-dB power penalty at BER of 10^{-9} is observed after 20-km transmission in SMF. It should be noted that for the 5-Gb/s Manchester signal generated by a dual-drive MZM, the reported power penalty is 1.5 dB after 20-km transmission in SMF [3]. The dispersion tolerance of both schemes was also investigated through simulation, as show in Fig. 4. The proposed scheme is more robust to dispersion than the scheme using a dual-drive MZM, for both direct detection and differential detection cases. As the dispersion accumulates, the optimal decision threshold always rests on the "0" level for the proposed scheme using differential detection as show in Fig. 4(b). In contrast, for the scheme using a dual-drive MZM, the optimal decision threshold in differential detection drifts away quickly as the dispersion accumulates.

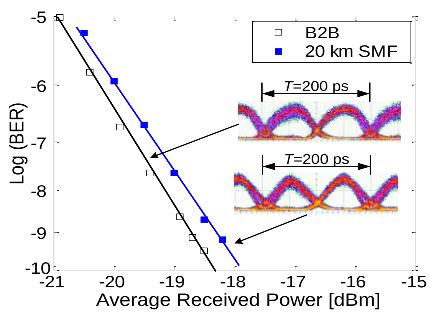

Fig. 3: BER measurements. Inset: eye diagram of the detected optical Manchester signal by a 10-Gb/s p-i-n receiver.

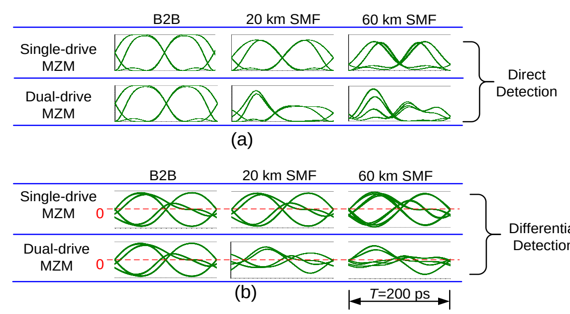

Fig. 4. Dispersion tolerance comparison between the proposed scheme and the prior scheme using dual-drive MZM [5].

In conclusion, we have proposed and experimentally demonstrated a novel chirp-free optical Manchester signal transmitter with enhanced tolerance to dispersion. The proposed scheme eliminates the conventional bandwidth doubling issue in optical Manchester signal generation and will potentially find application in high-speed optical burst mode transmission links. This project is supported in part by RGC CUHK 411007.

3. References

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