Asymmetry Effects on Optical Duobinary Transmitters

Dong-Soo Lee* · Hyun-Gue Huh

Abstract

We have theoretically investigated the asymmetry effects on 10[Gb/s] optical duobinary transmitters from the viewpoint of the driving voltage ratios by computer simulations. For driving voltage ratios(=driving voltage/switching voltage) with smaller than 100[%], the transmission performance has been greatly affected by the asymmetry of the bandwidth of LPFs than that of the Mach-Zehnder Modulator driving voltage. On the other hand, for driving voltage ratios with 100[%], the transmission performance has been degraded by the asymmetry of the driving voltage and is not sensitive to that of the bandwidth of LPFs. For the transmission performance within 1[dB] power penalty under the asymmetry condition, the driving voltage ratio with 100[%] has performed better than the low driving voltage ratios.

Key Words : Optical Duobinary Transmitter, Driving Voltage Ratios, Mach-Zehnder(MZ) Modulator, Low Pass Filter(LPF), Eye Diagram, Bit Error Rate(BER)

1. Introduction

Optical duobinary coding is an effective coding method which is known to increase the spectral efficiency by narrow optical filtering and the tolerance to chromatic dispersion[1-3]. It has received considerable attention recently in wavelength division multiplexing(WDM) transmission systems to increase the transmission capacity[4]. Successful experimental demonstrations of this technique has been shown for 10[Gb/s] and 40[Gb/s][5-6]. The transmitter using a dual-arm Mach-Zehnder(MZ) modulator driven with complementary three-level data is still popular because of higher tolerance to chromatic dispersion and optical spectral efficiency than other type. These merits notwithstanding, it needs stringent symmetry requirements in dual arm MZ modulator and low pass filters(LPFs)[7-9]. The other drawback is high driving voltage to modulators which is larger than that of the NRZ(non return zero) modulation format. Recently, it is reported that reducing the driving voltage ratio of the MZ modulator improves the system performance due to the modulator nonlinear transfer function[10-11]. In this paper, we theoretically investigate the effect of the asymmetry occurring in the driving voltage of MZ modulators and the bandwidth of LPFs in duobinary transmitters from the view point of the driving voltage ratios.

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2. Setup for simulation

Figure 1 shows the optical duobinary transmitter. The transmitter consists of a precoder, two electrical LPFs, a continuous wave(CW) laser source, and an $LiNbO_3$ MZ external modulator with two electrodes. For driving the MZ modulator in a push-pull manner, complementary 10[Gb/s] NRZ data are filtered using electrical filters and then properly amplified, so that we can convert a three-level duobinary signal to two-level duobinary signal as shown in Fig. 1.

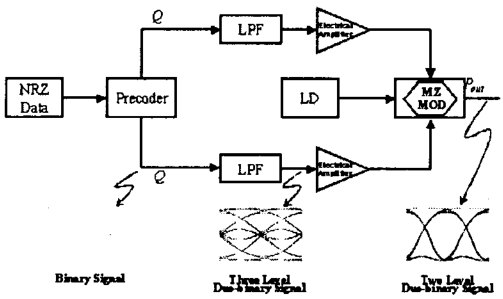

Fig. 1. A schematic of optical duobinary transmitter

The schematic diagram of a transmission link used in our simulation is shown in Fig. 2. Optical signals at 1550[nm] wavelength were transmitted to 200[km] standard single mode fiber(SSMF) with an average optical power at the fiber input of 6[dBm]. The signal was modulated at 10[Gb/s] with 2^7 PRBS(pseudo-random binary sequence) using an MZ modulator. The type of LPFs is a 5th order Bessel-Thomson filter with the cut off frequency range of 2.0 to 3.2[GHz]. Different driving voltages were applied to the dual electrode MZ modulator so as to provide the driving voltage of 25[%] to 100[%] normalized to the switching voltage(V_π). The switching voltage was set to 8[V]. The signal was launched into the fiber with dispersion parameter of D=17[ps]/([nm]·[km]). The propagation along the fiber was modeled by

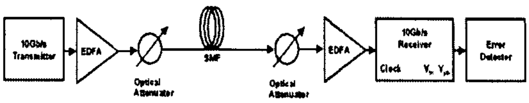

Fig. 2. A link configuration of duobinary transmission systems

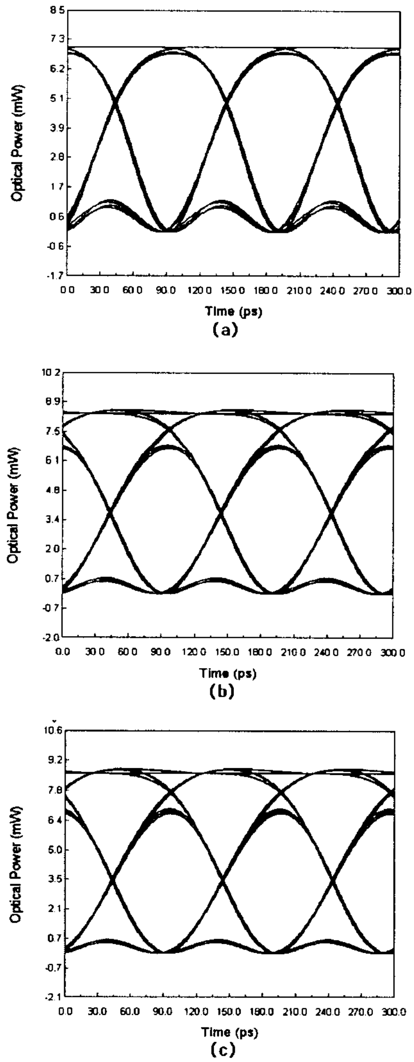

Fig. 3. Calculated eye diagrams as a function of driving voltage ratios with the symmetric condition at 0[km] (a) 100[%] (b) 50[%] (c) 25[%]

the nonlinear Schrödinger equation and simulated using the split-step Fourier method. An erbium doped fiber amplifier(EDFA) with 32[dB] of gain and noise figure of 5[dB] was used to compensate the fiber loss in the link. The receiver is composed of PIN and an electrical filter modeled by 4th order Bessel-Thomson filter. In our experiment, the magnitude of asymmetry was based on allowable tolerance for 200[km] transmission within 1[dB] power penalty[12].

The calculated eye diagrams with different driving voltage ratios are shown in Fig. 3.

If the driving voltage ratio is reduced, the ripple level in the middle of each space decreases. This effect is clearly observed in eye diagrams in Fig. 3. The ripple level is related to dispersion tolerance. The smaller ripple level is, the higher dispersion tolerance expects. The output electrical field of MZ modulators E_{out} can be modeled using the parameter γ as following[8]:

$$E_{out} = \frac{E_0}{2}\exp\left(\frac{j\pi V_1(t)}{V_\pi}\right) + \frac{\gamma E_0}{2}\exp\left(\frac{j\pi V_2(t)}{V_\pi}\right) \quad (1)$$

where γ is the scaling factor between 0 and 1 that accounts for an asymmetric power ratio. E_0 is the electric field of CW laser source. $V_1(t)$ and $V_2(t)$ are the voltages applied to two electrodes, and V_π is the switching voltage of the modulator. A BER of 10^{-9} is considered in this paper.

3. Results and Discussion

3.1 Effects of asymmetric LPF bandwidth

The optimum 3[dB] bandwidth frequency of the LPF was used to be 2.7[GHz]. Figure 4 shows the graph of receiver sensitivities at 10^{-9}[bit] error rate(BER) with the transmission distance of 0[km] to 200[km]. The transmission performance of the driving voltage ratios with 50[%] and 25[%] are more affected by the asymmetric LPF bandwidth than that of the driving voltage ratio with 100[%]. Especially, in case of decreasing the bandwidth, the power penalty is increasing rapidly. This results from the effect of increasing mutual signal interference by extended rising and falling time. As a result, The transmission performance of the

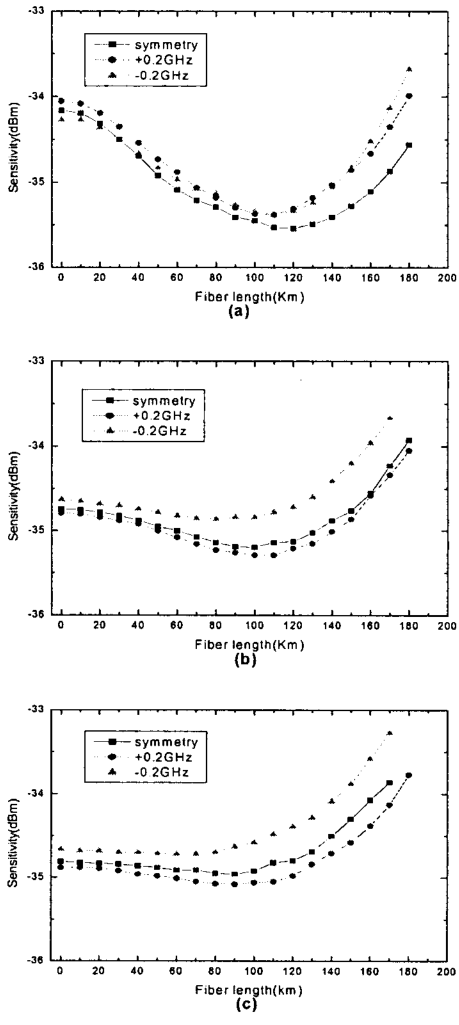

Fig. 4. Calculated receiver sensitivities at 10^{-9} BER for driving voltage ratios with asymmetric LPF bandwidth as a function of transmission distance (a) 100[%] (b) 50[%] (c) 25[%]

driving voltage ratio with 25[%] within 1[dB] power penalty is more degraded than that of driving voltage ratio with 100[%].

Figure 5 and 6 show the calculated eye diagrams for larger or smaller bandwidth asymmetry, respectively, compared to the normal bandwidth. Especially, for driving voltage with 25[%], it has the smallest magnitude of mark level that caused the lowest extinction ratio. It is originated from the power reduction at the output of the MZ modulator due to its operation closer to a transmission null.

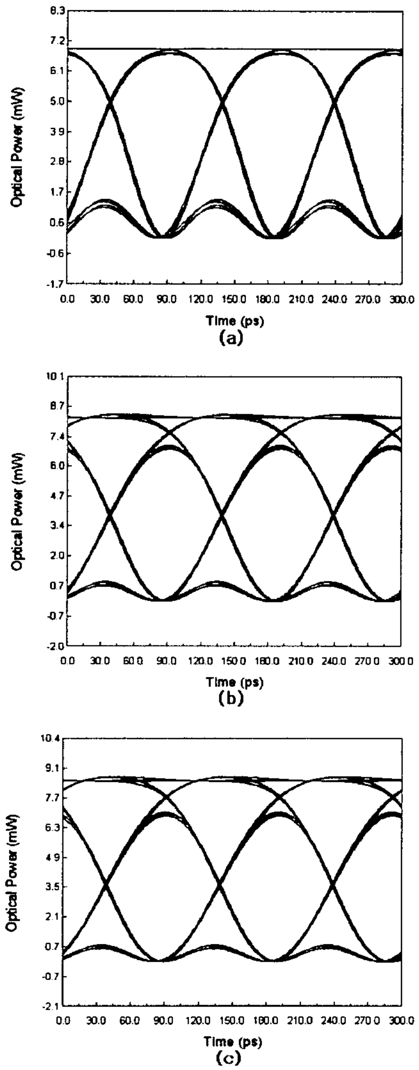

Fig. 5. Calculated eye diagrams as a function of driving voltage ratios with asymmetric LPF bandwidth at 0[km] (+200[MHz]) (a) 100[%] (b) 50[%] (c) 25[%]

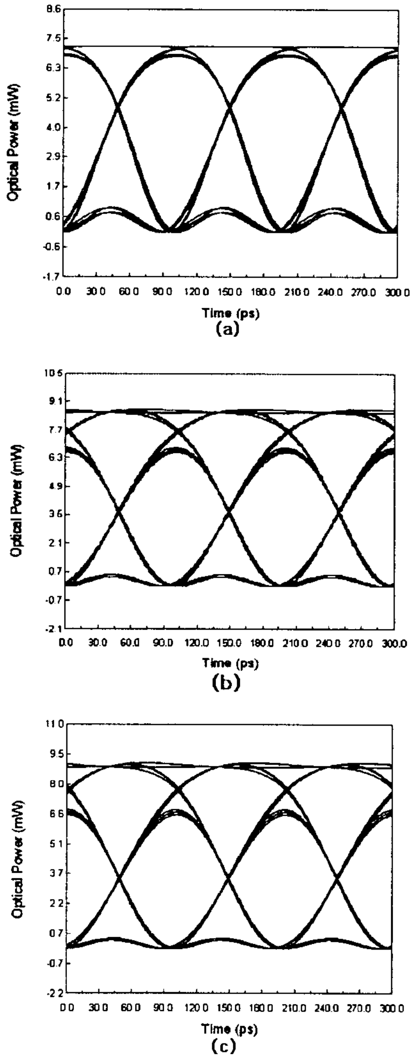

Fig. 6. Calculated eye diagrams as a function of driving voltage ratios with asymmetric LPF bandwidth at 0[km] (-200[MHz]) (a) 100[%] (b) 50[%] (c) 25[%]

3.2 Effects of asymmetric MZ modulator driving voltage

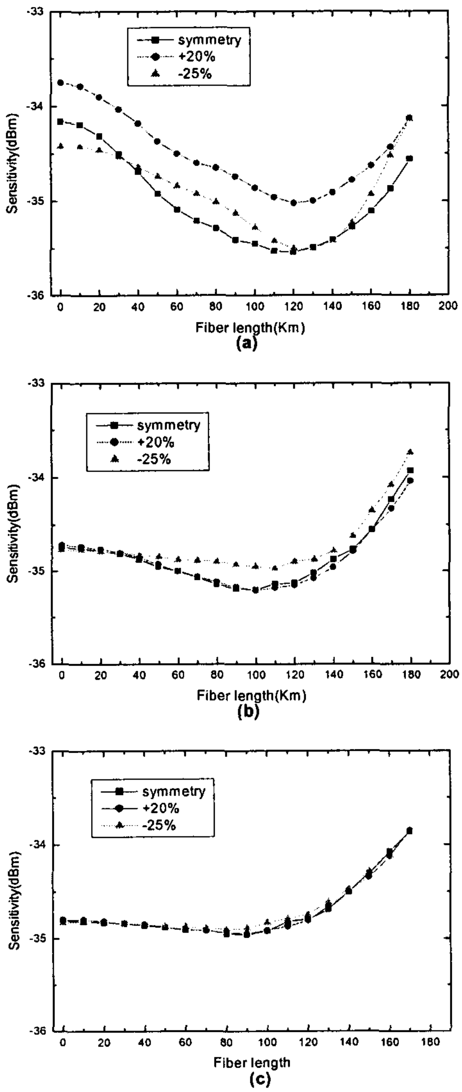

Fig. 7. Calculated receiver sensitivities at 10^{-9} BER for driving voltage ratios with asymmetric driving voltage as a function of transmission distance (a) 100[%] (b) 50[%] (c) 25[%]

The driving voltage ratio with 100[%] is greatly affected by the asymmetric amplitude of MZ modulator driving voltages shown in Fig. 7. The transmission performance was maintained with 0.4 ~0.7[dB] power penalty. On the contrary, the driving voltage ratio with 25[%] has little affected by the asymmetry condition.

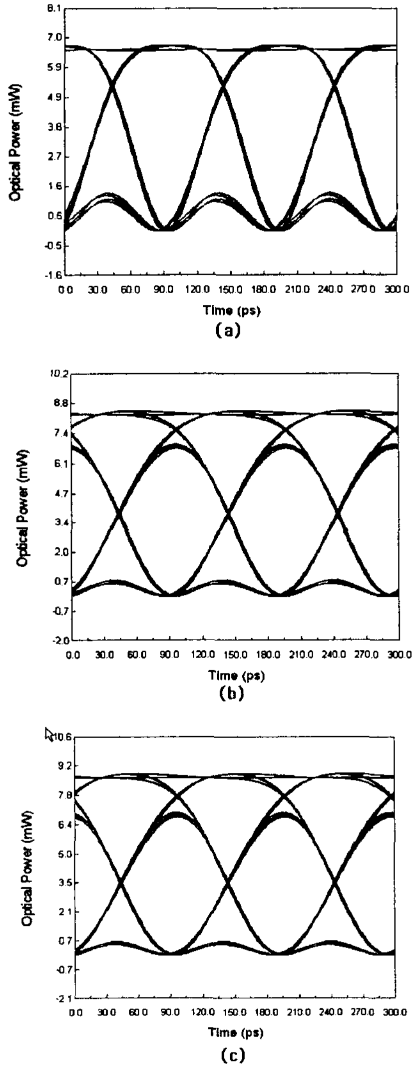

Fig. 8. Calculated eye diagrams as a function of driving voltage ratios with asymmetric voltage amplitude(+20[%]) at 0[km] (a) 100[%] (b) 50[%] (c) 25[%]

Figure 8 (a) shows the driving voltage ratio with 100[%] which has larger amplitude asymmetry causing thicker mark level and narrower space level due to the over-driving

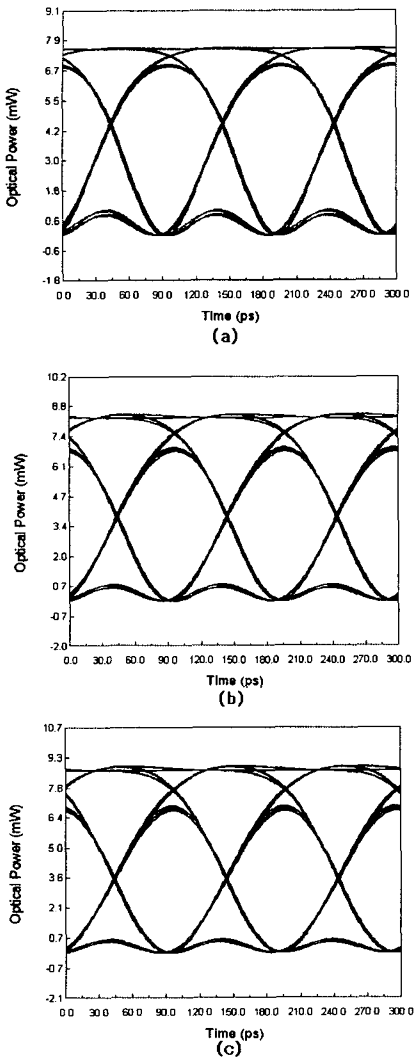

Fig. 9. Calculated eye diagrams as a function of driving voltage ratios with asymmetric voltage amplitude(-25[%]) at 0[km] (a) 100[%] (b) 50[%] (c) 25[%]

voltage. The thicker mark level results from the overlap of eye diagrams due to the over-driving voltage that makes the distortion in transfer curve of the MZ modulator. On the contrast, the driving voltage ratios with 50[%] and 25[%] has little affect to the amplitude asymmetry. Figure 9 shows the eye diagrams which has smaller amplitude asymmetry.

4. Conclusion

We investigated the effect of the asymmetry condition in the 10[Gb/s] optical duobinary transmitters from the MZ modulator driving voltage ratios viewpoint. For the driving voltage ratio small than 100[%], the asymmetry of LPF bandwidth which has smaller bandwidth than the optimum bandwidth limited the transmission performance by the extended rising and falling time. For the driving voltage ratio with 100[%], the asymmetry of the MZ modulator driving voltage which has larger voltage amplitude than the normal amplitude considerably affected to the transmission performance because of over-driving voltage. For the transmission performance within 1[dB] power penalty, the driving voltage ratio with 25[%] has more degraded than the driving voltage 100[%] because of the operation close to the transmission null.

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Biography

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