A Novel NRZ/RZ Format Converter Based on Polarizer Modulator

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Abstract - A novel non-return-to-zero (NRZ) to return-to-zero (RZ) format converter is proposed and demonstrated through an optical simulation software. This converter first adopt a polarizer modulator (PolM), to polarizer modulate the input NRZ signal, then a RF clock signal is used to restrain the side-lobes, thus to achieve NRZ/RZ conversion. The proposed converter features a convenient way to adjust the duty cycle of the output RZ signal, a same wavelength before and after converter, a very small time-jitter, high conversion efficiency, low cost and some other advantages, which could be expected to have an extensive use in high-speed optical communication networks.

Index Terms - Format converter, polarizer modulator, NRZ, RZ.

I. Introduction

Along with the sustainable growth of data exchange service like voice and multimedia, the requirements of the capacity of communication system are getting higher and higher. For the growth of the present electronic technology can hardly follow this trend, the build of a high-speed, ultra-capacity and all-optical communication network is high on the list. Optical time division multiplexing (OTDM) and wavelength division multiplexing (WDM) are the mainly used signal multiplexing style in optical fiber communication systems. The main usage of OTDM is in long distance backbone network because of an ultra-high-speed can be obtained with single wave. RZ signal is in general use in OTDM, for the small cycle duty, relatively high polarization mode dispersion tolerance and some other advantages so it suits a long and fast transmit quite well. WDM has the advantages like compact wavelength channel spacing, relatively low bit rate and friendly to electronic device, is widely applied in metropolitan area network (MAN) and access network (AN). The main signal format used in WDM is NRZ signals, because it's high optical spectrum sufficiency and strong tolerance to time-jitter and dispersion. In order to establish an intellectualized high-speed ultra-capacity all-optical communication network, we have to combine OTDM and WDM, so that different parts of the network will get different signal format, thus make the study and research on how to unite these effectively are getting hot and have attracted broad attention [1].

The convert from NRZ to RZ are one of the key tech that mentioned above. There are two ways of format converter now available, the first adopt all optical format convert project, examples include the use of the gain compression effect of semiconductor optical amplifier (SOA) [2], a SOA and Mach-Zehnder interferometer [3], a periodically poled Lithium niobate optical waveguides [4], a nonlinear optical loop mirror with SOA [5], a cross phase modulation effect of the nonlinear of fiber [6]. The second way is some integrations of optoelectronic that mainly based on optoelectronic oscillator and phase modulator or some other high-frequency electronic devices [7]. In this paper, a novel NRZ-to-RZ format converter is proposed and build base on a PolM. In this project, a RF signal is in use to polarizer modulate the input optical NRZ signal, than an amplitude modulator (AM) is introduced in order to suppress the undesired side lobes, an output optical RZ signal is finally gained. There is also a simulation run in the numerical simulation software Optisystem designed to demonstrate and analyse the converter work at 10GBit/s.

II. Principle of System

The block diagram of the NRZ-to-RZ format converter based on a PolM is shown in Fig. 1. Assume the optical field of the input NRZ signal is expressed as

$$E_i(t) = E(t)\exp(-i\omega t) \tag{1}$$

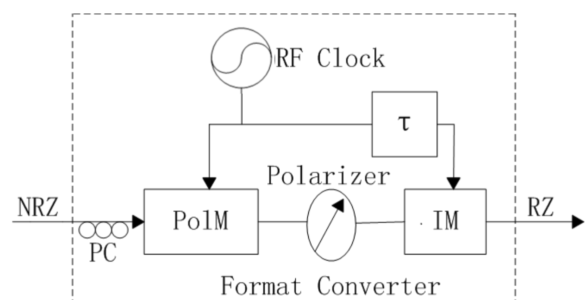

Fig. 1 Block diagram of the proposed format converter.

where *E(t)* is the amplitude of the NRZ signal, and ω as the angular frequency of the carrier. The input optical NRZ signal firstly gets through a polarizer controller (PC), and then it enters the PolM which is driven by a electronic RF clock signal. In the PolM, the polarization angle of the input signal is oriented at 45°to one principal axis so that the signal in x and y axis are complementary. The output optical field of the output signal of the PolM can be expressed in x and y direction as

$$E_x(t) = E(t)\exp\left(-i\frac{\alpha}{2}\sin(2\pi f_m t) - i\omega t\right) \tag{2}$$

$$E_y(t) = E(t)\exp\left(i\frac{\alpha}{2}\sin(2\pi f_m t) - i\omega t\right) \tag{3}$$

where α is the phase-modulation index of the PolM, f_m is the data rate of the input optical NRZ signal. The signal after phase modulate is transferred into polarization combiner to be combined and can be expressed as

$$E_p(t) = \sqrt{2}E(t)\cos\left(\frac{\alpha}{2}\sin(2\pi f_m t)\right)\exp(-i\omega t) \qquad (4)$$

it can be seen from the equation above that the phase information of the two complementary signals is completely converted to intensity variation. After go by a linear polarizer (LP), the modulated signal entries a AM which is driven by the RF clock signal which has been getting through a time delay. There is a stress that the time delay should be chosen carefully to make the effect of the suppression of the side lobes in the AM best. Thus the output optical RZ signal gained at last can be expressed as

$$E_o(t) = \sqrt{2}E(t)\cos\left(\frac{\alpha}{2}\sin(2\pi f_m t)\right)\exp(-i\omega t)\cos(2\pi f_e t - \tau) \qquad (5)$$

where f_e is the data rate of the RF clock signal, τ is the value of time delay.

The signals' waveforms in different parts of the system are shown in Fig. 2. NRZ signal is converted into RZ signal with redundant side lobes after passing the polarizer. In order to suppress the side lobes, an AM driven by the RF clock (dashed line) is in use, but a time delay is added. The coactions of the two signals make the main lobes of RZ signal being outputted while the needless side lobes under the maximum suppress.

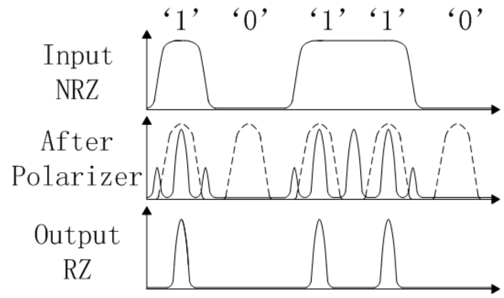

Fig. 2 The waveforms of signal in different parts of the system.

III. The Simulation Project and Result

The structure of the simulation project designed in Optisystem is shown in Fig. 3. NRZ pulse generator is driven by a user defined bit sequence generator at 10GBit/s, the bit sequence is 0101101110. NRZ pulse enters the AM driven by CW laser to convert into optical signals, just like NRZ signal from AN. RF clock signal has a duty cycle of 50%, 20GBit/s and a sequence as 0101010101. It's divided into two ways; one is used to modulate the optical signal passing PolM, another entry the second AM after an appropriate time delay. The azimuth of PC is 45°, the phase modulation index of PolM is 180°, and the device angle of LP is -45°, and the time delay is chosen as 0.03ns due to time window and other parameters in this project. As a result, the output is a RZ signal with a same 50% duty cycle and the side lobes being quite suppression.

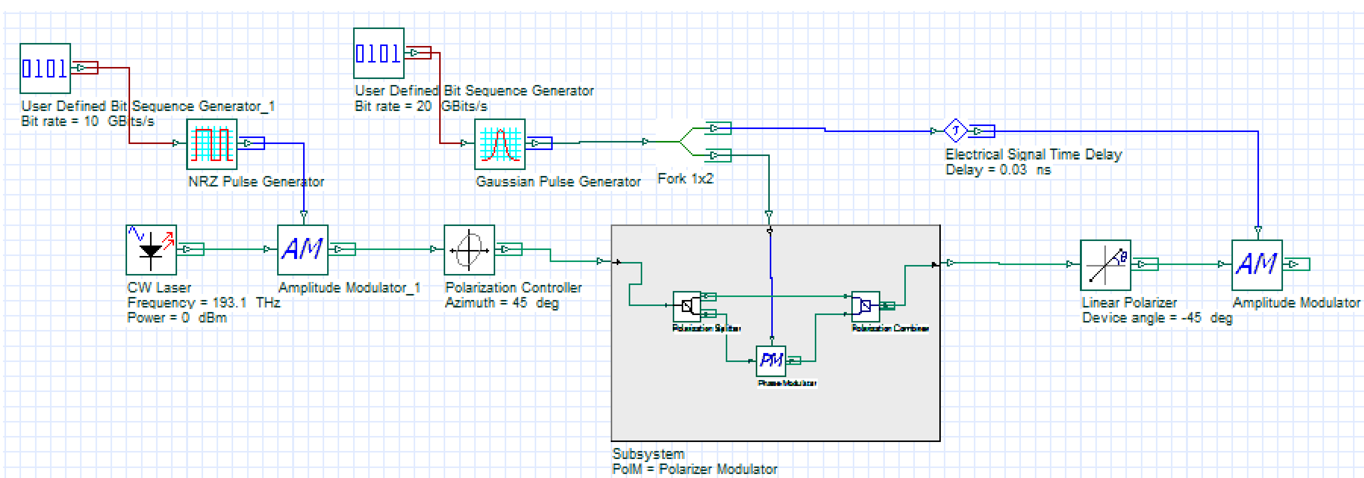

Fig. 3 Structure of the simulation in the software Optisystem.

The waveforms of different parts in the simulation are shown in Fig. 4. In Fig. 4, (a) is the original input NRZ signal, (b) is the output of LP with obvious side lobes, (c) is the last output RZ signal of the system. Owe to the modulation of the second AM, side lobes have a suppression of 15.2dB, but 3.88dB of the main lobes as well.

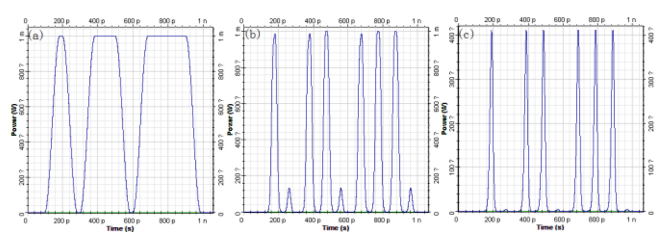

Fig. 4 Waveforms of the simulation: (a) the input NRZ; (b) signals with side lobes;(c) the output RZ.

The eye diagram of NRZ&RZ signal in the simulation is shown in Fig. 5. From the eye diagram, time-jitter can be calculated. The time-jitter of NRZ signal is 5.7ps, while RZ signal is 0.8ps, which means that this system possesses a good effect of time-jitter suppression.

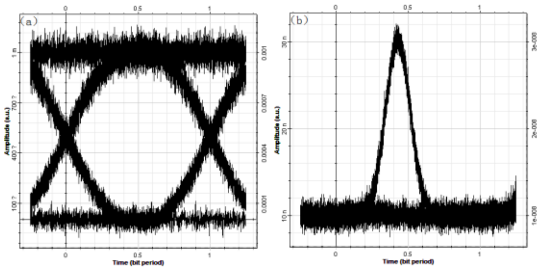

Fig. 5 The eye diagram of NRZ&RZ: (a) the input NRZ's; (b) the output RZ's.

The performance of the system while the output RZ signal has different duty cycles is shown in Fig. 6. As mentioned before, the duty cycle of output RZ signal is adjustable: just set the duty cycle of RF clock signal from 10% to 90%, then the duty cycle of output RZ signal will also change from 10% to 90% all the same, synchronously. This is due to that when change the duty cycle of RF clock signal, the signal's pulse width that modulated by PolM also changes, after modulated by AM, the output RZ signal's duty cycle will be modulated into the same pulse width, and the same duty cycle. What's more, the duty cycle of RF clock signal could be adjusted very convenient, makes the adjustment of output RZ signal very convenient too. The extinction ratio (ER) of the input NRZ signal stays the same, 23.3dB. When the duty cycle of RZ signal changes from low to high, its ER rises too. This is because that when duty cycle is low, the main lobes also undergo a great suppression, thus lowers the ER, and makes a greater opportunity of misjudgement cause a bigger bit error rate (BER). As shown in Fig. 6 (c), when the duty cycle is lower than 40%, BER is unacceptable, but when it's getting higher, the max Q factor come higher too, which means that the system loss is getting lower, the sensitivity is improved, associated with ER and BER.

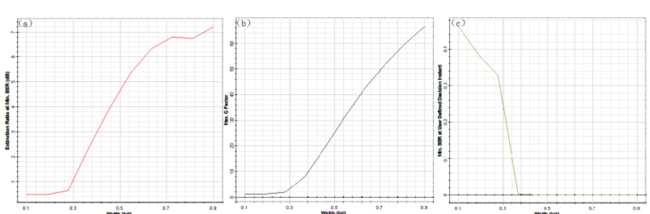

Fig. 6 The system performance under different duty cycle: (a) ER while lowest BER; (b) max Q factor; (c) lowest BER.

The ratio of main lobes to side lobes in different parts of the system under different duty cycle is shown in Fig. 7. When the duty cycle is higher than 20%, the ratio keeps declined, but it's quite obvious that the side lobes of LP output signal are much bigger than the output RZ signals, due to the function of the second AM. Although the ratio is much higher than 20dB when duty cycle is between 10% and 40%, but as mentioned before, the main lobes has too much suppressions that BER is too high. And when the duty cycle getting close to 100%, though the side lobes remains, but the judgment threshold of system is enhanced, makes the BER greatly reduced. It's notable that all the results are gathered only to change the duty cycle. Actually, just a proper time delay in different situation, a RZ output signal which its main lobes remains fine and side lobes being cut down could be received.

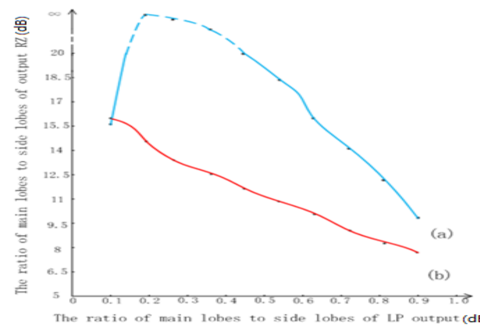

Fig. 7 The ratio of main lobes to side lobes under different duty cycle: (a) the output RZ signal; (b) the output of LP.

IV. Conclusions

This paper proposed a novel NRZ-to-RZ format converter base on PolM, and simulated it in Optisystem. The converter first use a PolM to modulate the input NRZ signal, then use a RF clock signal to suppress the side lobes, thus achieve the conversion. At last a converter that could control the duty cycle of RZ signal, have no wavelength alter, good time-jitter suppression, high convert efficiency, low cost and some other advantages. With a 10GBit/s input NRZ signal, the output RZ signal have a duty cycle that could adjust from 10% to 90%, and when it's 50%, the ER is 14.7dB, time-jitter is 0.8ps and BER is 10e-29.7. This system could be expected an extensive use in high speed optical networks.

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