DATA FORMAT CONVERSIONS USING MZI

Jatinder Singh*

Abstract: *Employing a Mach-Zehnder Interferometer (MZI), this paper describes simulation demonstration of an all optical scheme for data format conversion between nonreturn-to-zero (NRZ) and return-to-zero (RZ). Data format conversion between NRZ and RZ at 60 Gb/s has been simulated for the first time using a MZI.*

Keywords: *Data Formats, Mach-Zehnder Interferometer (MZI), NRZ, RZ.*

***Department of Electronics and Communication Engineering, Sant Longowal Institute of Engineering and Technology, Longowal, Sangrur, Punjab.

1. INTRODUCTION

Future all optical networks are likely to employ both wavelength-division multiplexing (WDM) and optical-time-division multiplexing (OTDM) techniques. OTDM, a scheme that can increase the bit rate of a single optical carrier to values above 1 Tb/s. A key feature of WDM is that the discrete wavelengths from an orthogonal set of carriers that can be separated, routed, and switched without interfering with each other. Transmultiplexing or interconversion between wavelength-division multiplexing (WDM) and optical-time-division multiplexing (OTDM) may become an important operation for future optical networks [1-2].

All wavelength-division multiplexed (WDM) and optical-time-division multiplexed (OTDM) networks are required to support a variety of data formats. The extensively used two data formats in these networks are non return-to-zero (NRZ) and return-to-zero (RZ). NRZ is preferred in WDM networks for its ease of implementation, relatively high spectral efficiency and timing-jitter tolerance. Although RZ format requires twice the NRZ transmission bandwidth, it is quite useful in applications including passive time-division multiplexing and demultiplexing due to its tolerance to fiber nonlinearities in spite of dispersion-induced effects. There will be a need for all-optical data format conversion between WDM and OTDM signals [3]. It has been stated that fully functional WDM networks should have the capability of all-optical format conversion between RZ and NRZ format [4]. Therefore data format conversions are likely to be used for future all optical networks in order to improve the flexibility of the optical networks. Especially, all the optical data format converters between NRZ and RZ are an essential function in interfacing metro/access and optical core networks [5]. All-optical data format conversions have been demonstrated using SOA gain compression [4], a monolithically integrated Michelson interferometer (MI) employing SOAs [6], an SOA/fiber grating wavelength converter [7], a nonlinear optical loop mirror (NOLM) with an SOA [8-9], cross-phase modulation (XPM) in an integrated Mach–Zehnder interferometer (MZI) employing SOAs [10-12], and Fabry–Pérot (FP) laser diode with dual-wavelength injection locking [13] and Mach-Zehnder delay interferometer (MZ-DI) [5, 15]. Jianjun et al. [5] reported the NRZ-RZ data format conversion for data rate of 40 Gb/s. Moreover, conversion between NRZ and RZ has been reported for maximum data rate of 40 Gb/s. In this paper, I have simulated 60 Gb/s data format conversion between NRZ and RZ using a Mach-Zehnder Interferometer (MZI).

2. FORMAT CONVERSION USING MZ-INTERFEROMETER

The principle of data format conversion from NRZ- RZ based on Mach-Zehnder Interferometer (MZI) is shown in figure 1. Consecutive ones in the symbol sequence alternate between two phase levels to provide the converted RZ signal [14]. The input signal directly goes to the output coupler without any delay whereas the signal in the upper arm is delayed and combined with the un-delayed signal to provide the RZ signal. In principle, any duty cycle of RZ signal can be generated by choosing the proper delay between two arms using Mach-Zehnder Interferometer (MZI), however the pulse width or duty cycle is limited by the rise and fall time of the data [14].

Figure 2 shows the simulation set up for the data format conversion from NRZ-RZ. A continuous wave (CW) laser wavelength is 1558.2 nm. A binary 60 Gb/s NRZ electrical source is placed at the input. The generated 60 Gb/s NRZ is modulated using MZ modulator before it is applied to the Mach-Zehnder Interferometer (MZI), The input power of CW laser is -3 dBm. Then, we use a Mach-Zehnder Interferometer (MZI) to realize the data format conversion. The time delay between the two arms in the MZ Interferometer are set at 3, 5, 10, 15 and 20 psec. Figure 3 demonstrated the eye diagrams of input signal and output signals after simulation for NRZ-RZ data format conversion. We observed that smaller the time delay between the two arms of the MZ Interferometer (MZI), the smaller the duty cycle and the wider the spectrum [14]. Because for the 60 Gb/s the rise time and the fall time of the signal are 8.3 psec, the shortest pulse width of the optical signal is approximately 8.3 psec. Also, from the figure 3, if the time delay between the two arms of the MZ Interferometer (MZI) is increased, the quality of the converted signals decreases. For the data format conversion from RZ-NRZ, the same setup is used as shown in figure 2. In this converter, the input electrical source placed at the input is 60 Gb/s RZ. The duty cycle of the input RZ signal is 0.5.For the same time delays between the two arms in the MZ Interferometer (MZI) as in case of NRZ-RZ converter, the figure 4 shows the observed eye diagrams of input signal and output signals after simulation for RZ-NRZ data format conversion. We can see that smaller the time delay between the two arms of the MZ Interferometer, the better is the quality of the NRZ signal. conversion. We observed that smaller the time delay between the two arms of the MZ Interferometer (MZI), the smaller the duty cycle and the wider the spectrum [14]. Because for the 60 Gb/s the rise time and the fall time of the signal are 8.3 psec, the shortest pulse width of the optical signal is approximately 8.3 psec. Also, from the figure 3, if the time delay between the two arms of the MZ Interferometer (MZI) is increased, the quality of the converted signals decreases. For the data format conversion from RZ-NRZ, the same setup is used as shown in figure 2.

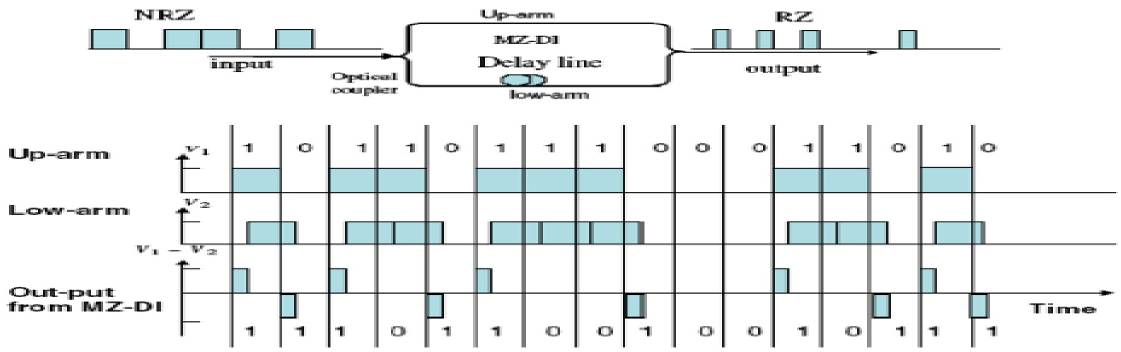


Figure 1: The Principle of Data Format Conversion Using MZ-Interferometer

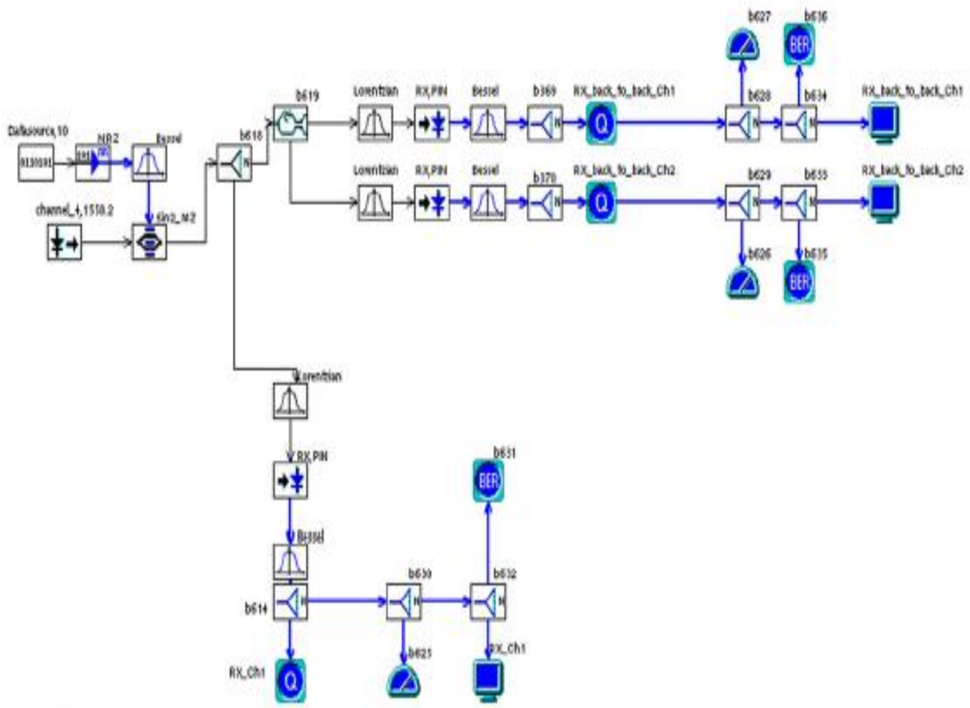
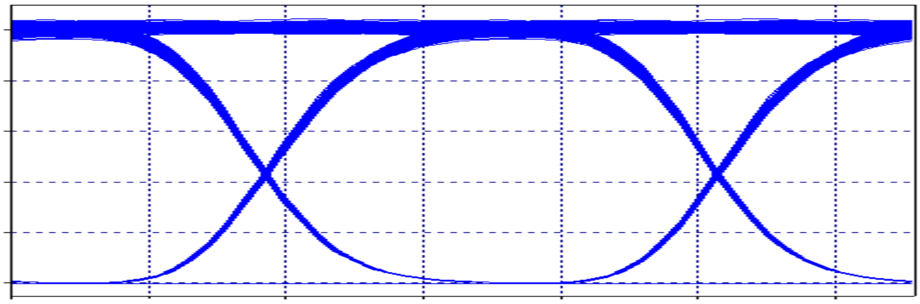


Figure 2: Simulation Setup of Data Format Converter with Ideal MZ

In this converter, the input electrical source placed at the input is 60 Gb/s RZ. The duty cycle of the input RZ signal is 0.5.For the same time delays between the two arms in the MZ Interferometer (MZI) as in case of NRZ-RZ converter, the figure 4 shows the observed eye diagrams of input signal and output signals after simulation for RZ-NRZ data format conversion. We can see that smaller the time delay between the two arms of the MZ

Interferometer, the better is the quality of the NRZ signal. This is also in good agreement with the results reported in [14].



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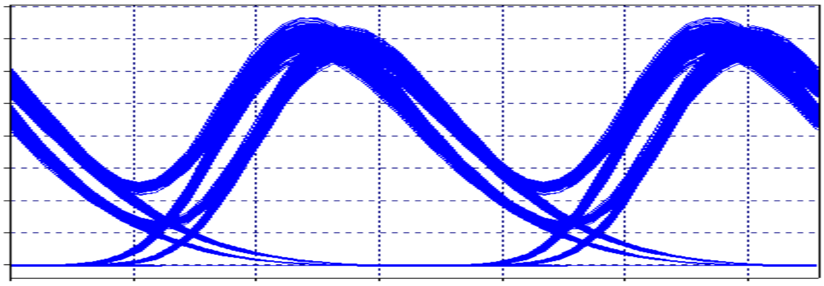

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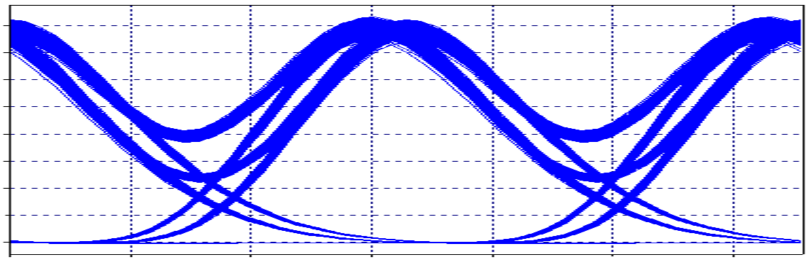

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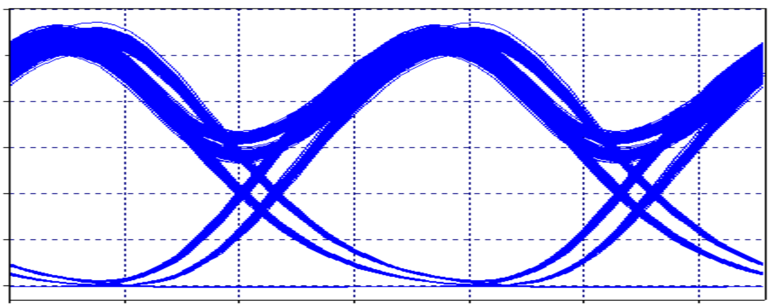

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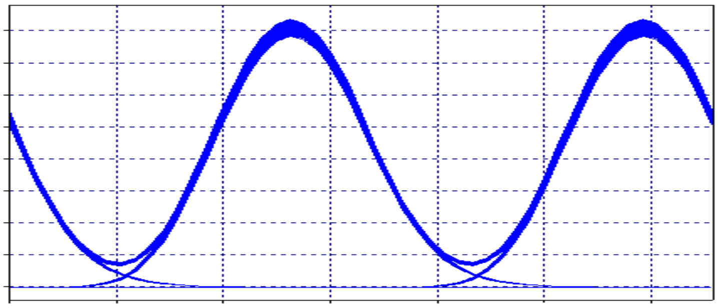
Figure 3: Eye Diagrams at Input and Output Signals at 60Gb/s (a) Input Signal (b) 5psec (c) 10psec (d) 15psec



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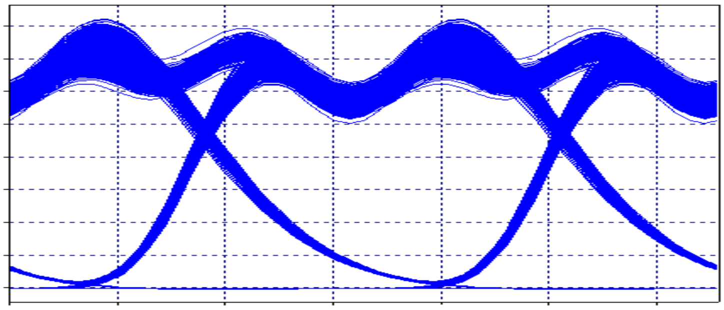

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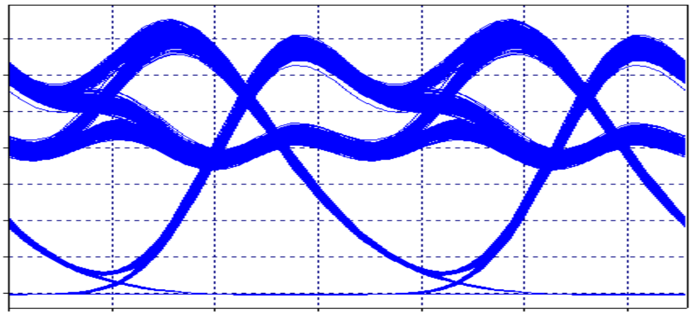

(c)

Figure 4: Eye Diagrams at Input and Output Signals at 60 Gb/s (a)Input Signal (b) 5psec (c) 10psec

Time Delay (psec)	Output BER (dB)		Received Power (dBm)		Q Factor (dB)	
	NRZ-RZ	RZ-NRZ	NRZ-RZ	RZ-NRZ	NRZ-RZ	RZ-NRZ
5	1e-040	1e-040	-100	-98.55	28.63	25.45
10	1e-040	1e-040	-94	-93.95	31.29	15.74
15	1e-040	1e-040	-90	-94.63	29.14	27.45
20	2.9e-018	1.7e-013	-89.54	-94.35	18.8	17.40
25	6.61e-006	0.01176	-89.37	-93.26	12.78	7.08

Table 1: Comparison of NRZ-RZ and RZ-NRZ data format converters at 120 Gb/s

Table 1 shows the comparison of NRZ-RZ and RZ-NRZ data format converters in terms of converted BER, quality factor and received power, when the input power is -3 dBm. As shown in the table, the NRZ-RZ data format converter has slightly better performance than the RZ-NRZ data format converter at 60 Gb/s. Therefore, the performance of NRZ-RZ data format converter at 60 Gb/s has been compared with different time delay between two arms of MZI. The comparisons of BER with different time delay between two arms of MZI at 60 Gb/s is shown in figure 5. As shown in the figure5, the BER for the all input signals except RZ-NRZ input format are almost constant throughout the time delay span of 5 to 25 psec.

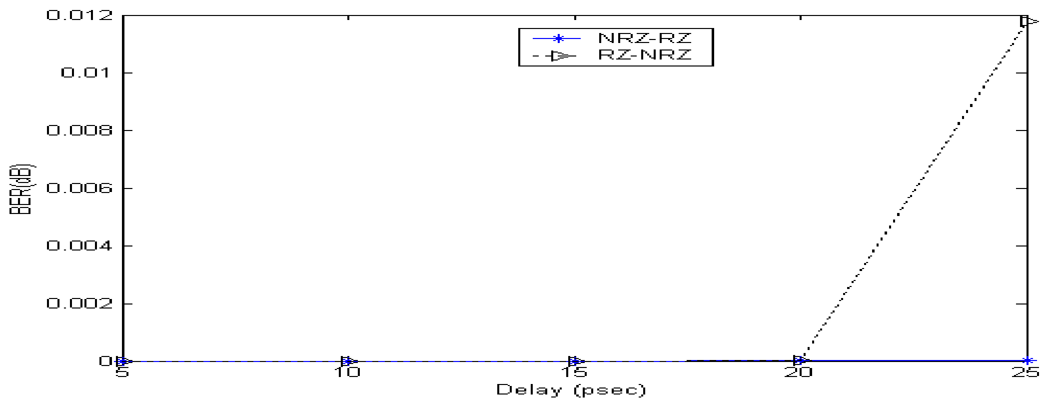

Figure 5: Comparison of BER at 60 Gb/s for different input data formats

The received electrical power measurements are shown in figure 6 for different types of input data formats at different time delays between two arms of MZ-Interferometer at 60 Gb/s. As shown in the figure 6, as the delay between two arms is increased the received electrical powers are increased up to 15 psec, beyond this range the received electrical powers has attained the almost saturated values. The NRZ-RZ converter has highest received electrical power as compared to other data format converters. At 15 psec the power sensitivity at a BER of 10^{-40} is -90 dBm for NRZ-RZ data format; however the power sensitivity at a BER of 10^{-40} is -94.3 dBm for RZ-NRZ data format. Therefore, for NRZ-RZ data format the power sensitivity of the data format converter is dropped by 4.3 dBm.

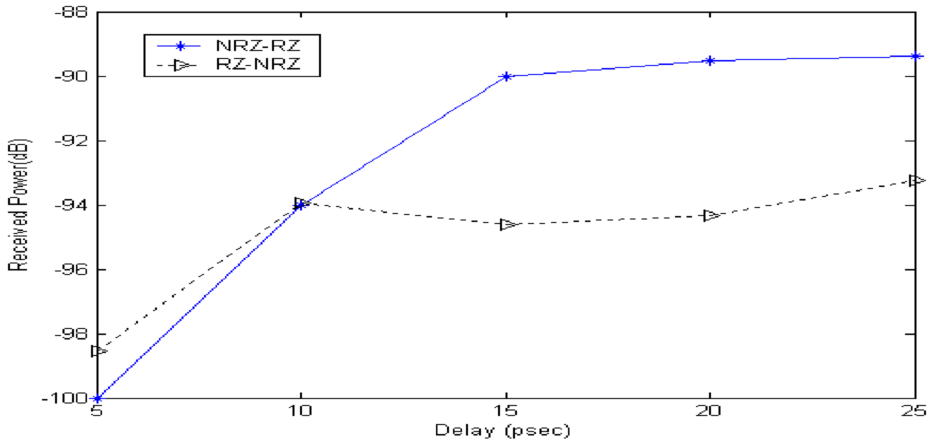

Figure 6: Comparison of Received Power at 60 Gb/s for different input data formats

The quality factor measurements are shown in figure 7 for different types of input data formats at different time delays between two arms of MZ-Interferometer at 60 Gb/s. As shown in the figure 7, as the delay between two arms is increased the received electrical powers are increased beyond 15 psec the quality of the converted signal decreases because the rise and fall times of data format at 60 Gb/s is 8.3 psec, the shortest pulse width of the input data is 8.3 psec. So, to obtain the good quality converted signal with the delay between the two arms should be less than 8.3 psec

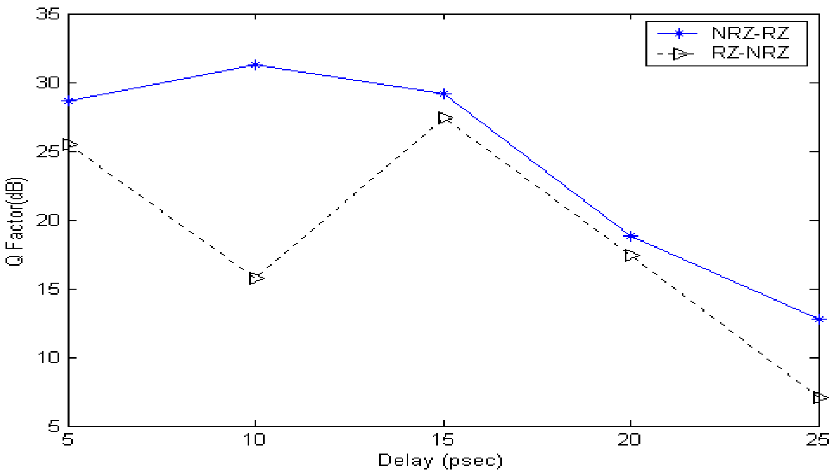

Figure 7: Comparison of Quality factor at 60 Gb/s for different input data formats

3. CONCLUSION

I have proposed a 60 Gb/s data format conversion between NRZ and RZ signals and successfully demonstrated for the first time using ideal MZ-Interferometer. At 15 psec the power sensitivity at a BER of 10^{-40} is -90 dBm for NRZ-RZ data format; however the power sensitivity at a BER of 10^{-40} is -94.3 dBm for RZ-NRZ data format. Therefore data format converter for NRZ-RZ has 4.3 dBm power sensitivity better than the data format converter for RZ-NRZ when the delay between two arms is 15 psec.

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