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Investigation on the Influence of Duobinary and CSRZ Modulation Formats on Self Phase Modulation Effect in Optical Communication Network

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Abstract—Optical communication is a prominent technology for future communication sector because of its low power consumption, high capacity and lower attenuation. It is also affected by the detrimental effects of optical fiber such as dispersion and nonlinear effects. In this paper, the impact of Carrier Suppressed Return to Zero (CSRZ) and Duobinary modulation formats on unfavorable nonlinear Self phase modulation effect of fibers has been analyzed. Modulation formats can have also significant influence on nonlinear effect due to its spectral characteristics. The performance characteristics of this system such as BER and Q-factor are measured with the help of *optisystem* software. Duobinary gives Q-factor of about 5.57276 and BER of 9.68E-09 even in the case of 40 Gbps bit rate and power 20dBm, whereas CSRZ has the Q-factor of 4.12739 and BER of 1.46E-05 respectively.

Keywords— Fiber Nonlinearity, Self-Phase Modulation, Modulation format, Quality (Q) Factor, Bit error rate.

I. INTRODUCTION

With the increasing growth and demand for capacity in national, regional, and even metropolitan optical networks, high bit rate fiber transmission has recently become an essential part of the optical communication. Optical modulation format is used to impress data on an optical carrier wave for transmission over optical fiber. The simplest optical modulation format is on-off-keying (OOK) intensity modulation, which can take either of two forms: non-return-to-zero (NRZ) or return-to-zero (RZ) [1, 2]. The return-to-zero (RZ) pulse is efficient for long-distance, high-bit-rate, Wavelength Division Multiplexed (WDM) transmission dispersion-managed systems [3]. The nonlinear effects such as self-phase modulation (SPM), cross-phase modulation (CPM) and four-wave mixing (FWM) occur either due to intensity dependence of refractive index of the medium or due to inelastic-scattering phenomenon [4]. Fiber Non-linear effects are just a consequence of increasing the need for high data rates, number of wavelengths, transmission lengths and optical power levels. The fiber non-linearity came into picture in 1970's but initially these effects were ignored, later studied with the development of LASERs. Increased input power affects the system as it makes SPM grow which eventually degrades the signal. SPM occurs in single channel configurations, where it basically converts optical power fluctuations into phase fluctuations in the same wave [5]. The spectral broadening of the pump pulse through self-phase modulation in a time-domain distributed Brillouin sensor has a considerable detrimental effect in the measurement, especially in the case of long distances and high-resolution pulses. Using 30 ns pump pulses with peak power of 276 mW, self-phase modulation leads to a doubling of the effective gain line width after some 20 km, which is equivalent to a contrast loss of 2 dB in the measurement [6]. Akira Suda analytically investigated the spectral broadening by self-phase modulation with strongly chirped optical pulses. The dispersion due to the nonlinear optical process is expressed as functions of a linear and a nonlinear initial chirp. As a result, it is found that the third-order dispersion strongly depends on the initial linear chirp and the nonlinearity for self-phase modulation [7]. T.Wuth reported that, influence of self-phase modulation on duo binary and single sideband modulation, and additionally compared the receiver sensitivity for a bit error ratio of 10E-9 by varying fiber length and input power [8]. In this paper, we demonstrate the influence of CSRZ and duobinary modulation formats on SPM effects in optical communication. We analyzed the effects of SPM in terms of Q-factor and Bit Error Rate (BER). This paper is organized as follows, 2nd section is the experimental setup, 3rd section is the results and discussion and the final section is the conclusion.

II. EXPERIMENTAL SETUP

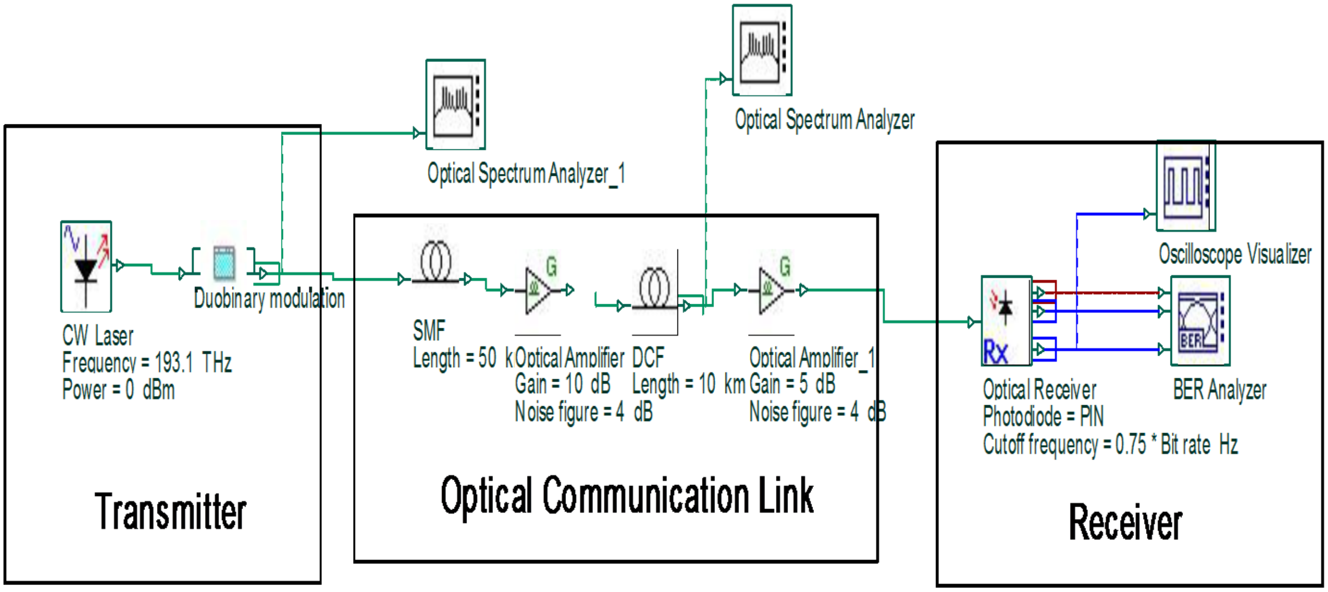

Fig.1 Optical communication setup with Duo-binary modulation

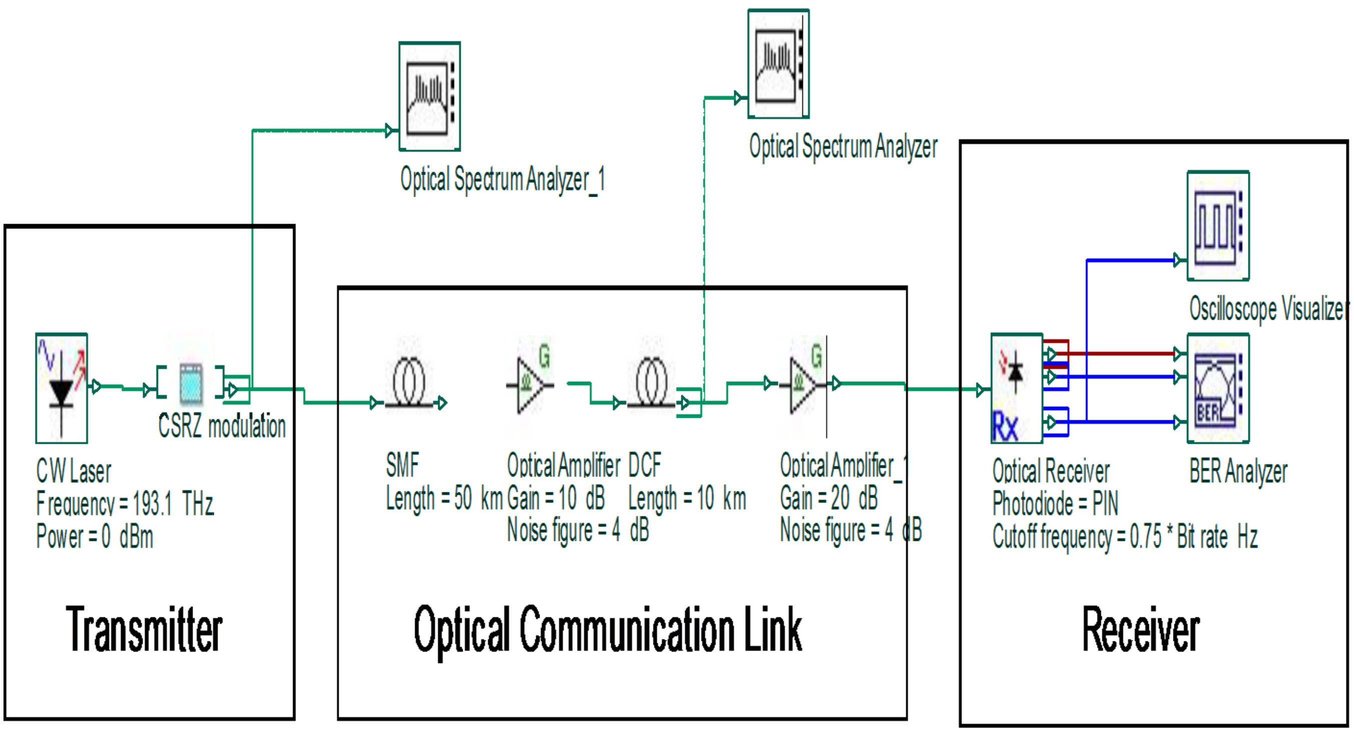

Fig.2 Optical communication setup with Duo-binary modulation.

Fig.1 and 2 show the optical communication system setup along with 2 different modulation formats. As in fig (3), the Duobinary signal was generated by first creating an NRZ duobinary signal of pseudo random bit sequence using a precoder and a duobinary pulse generator. The generator drives the first Mach-Zhender Modulator (MZM), and then concatenates this modulator with a second modulator that is driven by a sinusoidal electrical signal with the frequency equal to the bit rate. The duobinary precoder is composed of an exclusive-or gate with a delayed feedback path. In order to obtain the recursive decoding in the receiver, the precoder is used.

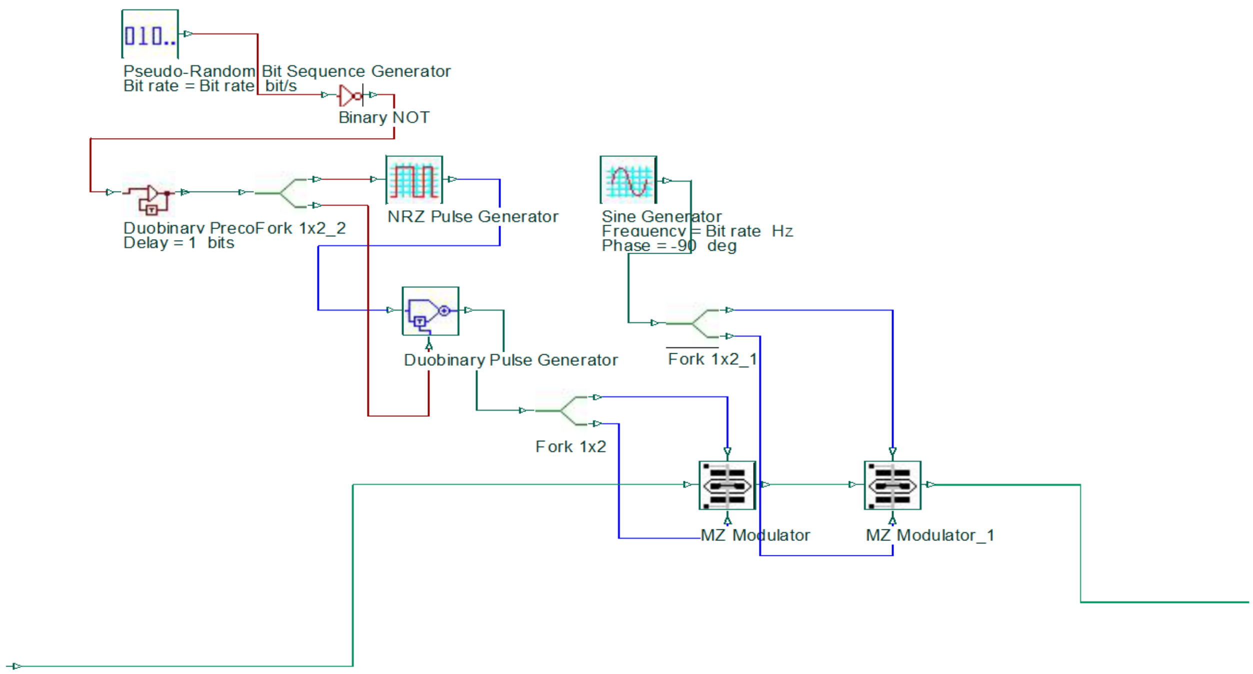

Fig.3 Duobinary subsystem

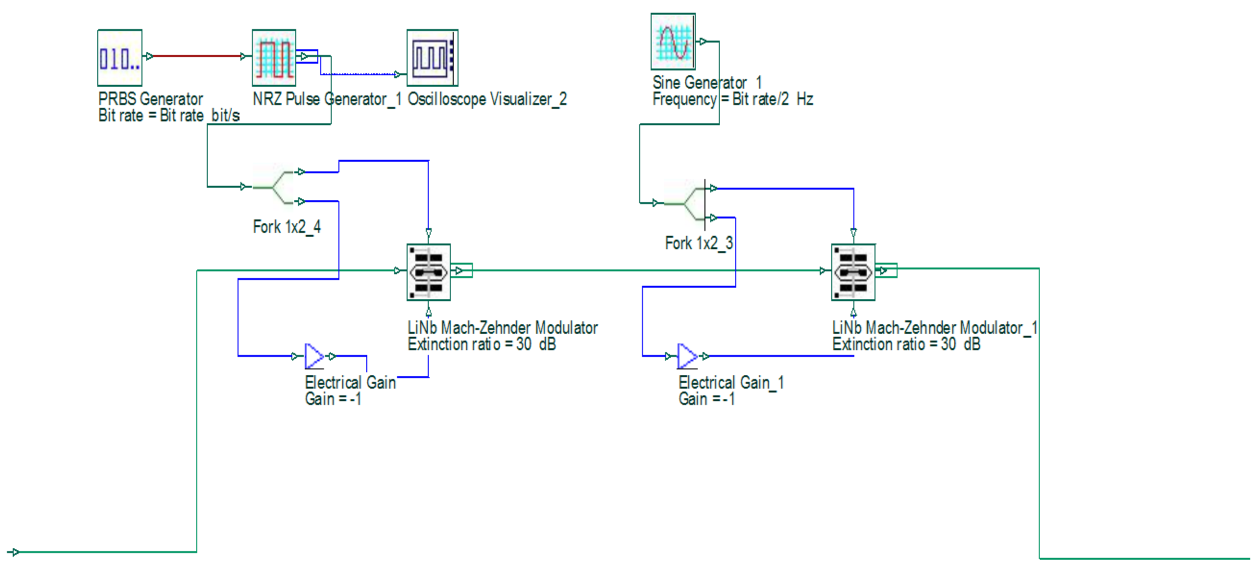

Fig. 4 CSRZ subsystem

As in fig (4), the CSRZ signal is generated in a similar way to the RZ format. However, the frequency of the sinusoidal electrical signal applied in the second MZM has half of the bit rate. The second MZM is biased in a way to provide alternating optical phases between 0 and π for the neighboring time slots. The phase of bits '1's is alternating with a difference of 180 degrees. This phase difference causes the elimination of the carrier at 193.1 THz. The modulated duobinary and CSRZ signal are transmitted through a transmission link. This transmission link is established by two fibers such as single mode fiber (SMF) of 50 km and dispersion compensation fiber (DCF) of 10 km. EDFA is used in this system to eliminate transmission losses. Various fiber parameters are tabulated in Table 1. The optical receiver consists of PIN photodiode and Bessel filter. Photodiode in the transmission link is used to convert the optical to electrical signal and Bessel filter is used to eliminate the unwanted noise in the received signal. The received signal BER and Q-factor are measured using optical receiver and BER analyzer. The *optisystem* simulation parameters are given in Table 2.

Table. 1 optical Fibers parameters

Fiber properties		
Parameters	Values	
	SMF	DCF
Reference wavelength	1550 nm	1550 nm
Fiber Length	50 km	10 km
Dispersion	17 ps/nm/km	-85 ps/nm/km
Dispersion slope	0.075 ps/nm^2/km	-0.1 ps/nm^2/km
Effective Area	80 um^2	55 um^2
N2	26E-021 m^2/w	26E-021 m^2/w

Table 2. Optisystem simulation parameters

Simulation parameters	Values
Bit rate	10 to 40 Gbps
Sequence Length	128
Samples per bit	32
Number of samples	4096

III. RESULTS AND DISCUSSIONS

Nonlinear effects are often categorized into two sets of effects. First one is those resulting from the propagation of a single channel and the second is those resulting from the interactions between WDM channels. Single channel nonlinear effects are caused mainly through self-phase modulation, where each channel alters its own phase. It leads to spectral broadening of optical pulses. It is difficult to detect separately each signal's nonlinear effects in complex WDM system. Therefore, for creating SPM effects, we use only one signal for performance estimation. We have analyzed the effects of SPM in terms of Q-factor and Bit Error Rate (BER), for which modulated continuous wave laser at wavelength of 193.1 THz is used as a source at different power levels in the range of 0 to 25 dBm. We have also analyzed the system for two cases. The first case is the effects of SPM in Duobinary modulation. The measured parameters for the first case are tabulated in Table 3 and 4.

Table 3 Measured Q factor for the different input power and bit rate in Duobinary modulation

	Q-factor for different Bit rates			
Power(dBm)	10 Gbps	20 Gbps	30 Gbps	40 Gbps
0	93.2277	69.6225	56.4158	49.0455
5	150.37	110.009	82.9196	76.5846
10	217.576	90.4859	60.9226	48.9658
15	125.569	29.6706	22.782	18.3916
20	16.6307	5.53607	5.71804	5.57276
25	8.83921	2.84929	3.20546	0

Table.4 Measured BER for the different input power and bit rate in Duobinary modulation

	BER for different Bit rates			
Power(dBm)	10 Gbps	20 Gbps	30 Gbps	40 Gbps
0	0	0	0	0
5	0	0	0	0
10	0	0	0	0
15	0	6.03E-194	2.16E-115	4.79E-76
20	2.06E-62	1.12E-08	3.80E-09	9.68E-09
25	2.81E-19	0.001501	0.00067	1

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The proposed system has exhibited a good performance for the bit rate of 10 Gbps. As in Table 3 and 4, Q-factor increases initially with increased power and reaches a maximum limit of 217.576 at the input power of 10 dBm and bit rate of 10 Gbps. Then the Q-factor reduces with increasing input power level from 15 dBm. Initially at 40 Gbps bit rate and 0 dBm power the measured Q-factor is 49.0455. But, the signal is vanished at the power of 25 dBm in the same bit rate. So, the overall system is affected more by SPM effects at higher bit rates. The proposed system produces a good Q-factor of 5.57276 and BER of 9.68E-9 even in the case of high bit rate of 40 Gbps and input power of 20 dBm. Fig 5. shows, Q-factor for the duobinary modulation. It decreases with increasing input power. The Q-factor drastically reduces at high input power.

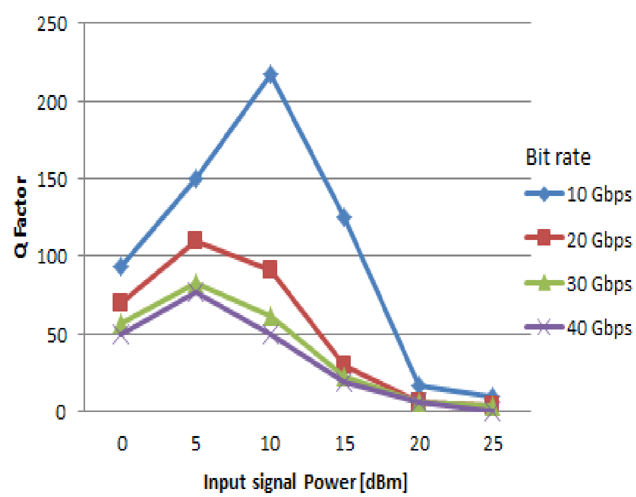

Fig.5 Q factor obtained for SPM effect in duobinary modulation

The second case is that the effects of SPM in CSRZ modulation. The measured values in second case are tabulated in Table 5 and 6.

Table.5 Measured Q factor for the different input power and bit rate in CSRZ modulation

Power(dBm)	Q-factor for different Bit rates			
	10 Gbps	20 Gbps	30 Gbps	40 Gbps
0	99.1019	73.1474	60.6608	50.8688
5	161.801	106.43	83.0796	71.0975
10	123.821	81.5784	42.3614	42.941
15	26.4195	26.9348	14.5306	15.0503
20	10.9605	4.8559	3.67006	4.12739
25	5.28852	2.97461	0	0

Table.6 Measured BER for the different input power and bit rate in CSRZ modulation

Power(dBm)	BER for different Bit rates			
	10 Gbps	20 Gbps	30 Gbps	40 Gbps
0	0	0	0	0
5	0	0	0	0
10	0	0	0	0
15	2.55E-154	2.84E-160	2.45E-48	1.03E-51
20	2.89E-28	5.10E-77	1.02E-04	1.46E-05
25	3.86E-08	0.001438	1	1

As in Table 5 and 6, Q-factor increases initially with increased power, reaches the peak value of 161.801, at the input power of 5 dBm and bit rate of 10 Gbps. Then the Q-factor reduces with increasing input power level from 10 dBm. At 40 Gbps bit rate and power 0 dBm, the measured Q-factor is 50.8688. But, the signal is not present at the power of 25 dBm in the same bit rate. So, the overall system is affected more by SPM effects at higher bit rates. The designed CSRZ system produces good Q-factor of 4.12739 and BER of 1.46E-5 even in case of high bit rate of 40 Gbps and input power of 20 dBm. Fig 6. shows, the Q-factor with increasing input power for the CSRZ modulation format.

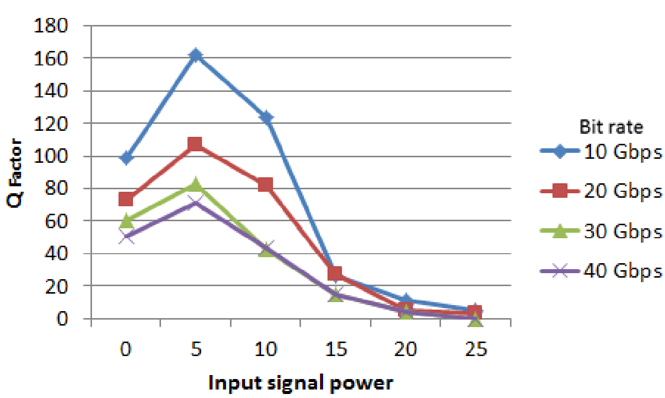

Fig. 6 Measured Q factor with SPM effect in CSRZ modulation

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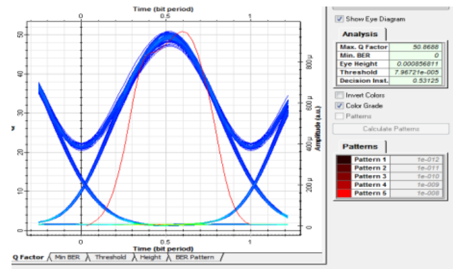

Fig.7 Eye diagram of Duobinary system for 40 Gbps data rate and input power of 0 dBm

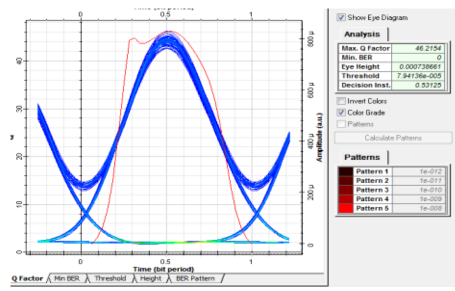

Fig.8 Eye diagram of CSRZ system for 40 Gbps data rate and input power of 0 dBm

Fig. 7 and 8 show the eye diagrams at input power level of 0 dBm and bit rate of 40 Gbps for duobinary and CSRZ systems respectively

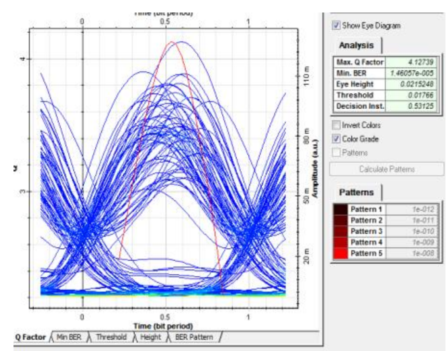

Fig.9 Eye diagram of Duobinary system for 40 Gbps data rate and input power of 20 dBm

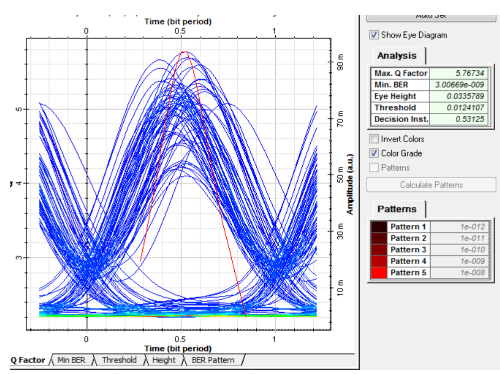

Fig.10 Eye diagram of CSRZ system for 40 Gbps data rate and input power of 20 dBm

Fig. 9 and 10 show the eye diagrams at input power level of 20 dBm and bit rate of 40 Gbps for duobinary and CSRZ systems respectively.

From the results of Duobinary and CSRZ system, Duobinary gives better Q-factor of 5.57276 and BER of 9.68E-09 performance for the case of 40 Gbps bit rate and 20 dBm input power whereas CSRZ has the Q-factor of 4.12739 and BER of 1.46E-05 respectively for the same input conditions.

IV. CONCLUSION

In this paper, self-phase modulation effects on the duobinary and CSRZ modulation formats have been analyzed using the *optisystem* software. The proposed Duobinary system produces good Q-factor of 5.57276 and BER of 9.68E-9 for the case of high bit rate of 40 Gbps and input power of 20 dBm. But, CSRZ system produces Q-factor of 4.12739 and BER of 1.46E-5 only under similar input conditions. Hence it is concluded that the duobinary system has better performance for SPM effects than the CSRZ system.

V. REFERENCE

[1]. V. Bobrovs, J. Porins, G. Ivanovs. Influence of Nonlinear Optical Effects on the NRZ and RZ Modulation Signals in WDM Systems // Electronics and Electrical Engineering. – Kaunas: Technologija, 2007. – No. 4(76). – P. 55–58..

[2]. Virendra kumar, A.K.Jaiswal, Mukesh kumar, Nilesh agrawal, Rohini Saxena, "Design and Performance Analysis of Optical Transmission system**"** *IOSR Journal of Engineering (IOSRJEN), ISSN (e): 2250-3021, ISSN (p): 2278-8719Vol. 04, Issue 05 (May. 2014), ||V3|| PP 22-26*

[3]. Varun Marwaha, Ankur Singhal, Satinder Pal Ahuja, "Performance Evaluation of Modulation Format for Optical System**"** International organization of Scientific Research **(**IJECT), Vol. 3, Issue 1, Jan. - March 2012.

[4]. S. P. Singh and N. Singh "Nonlinear Effects In Optical Fibers: Origin, Management And Applications" Progress In Electromagnetics Research, PIER 73, 249–275, 2007.

[5]. Narender Kumar Sihval and Amit Kumar Garg **"**Simulation and Analysis of Self Phase Modulation Fiber Non Linearity" Journal of Multidisciplinary Engineering Science and Technology (JMEST), ISSN: 3159-0040, Vol. 2 Issue 6, June - 2015.

[6]. Stella M. Foaleng. et al., "Detrimental effect of self-phase modulation on the performance of Brillouin Distributed fiber sensors" Optical letters, vol. 36, Issue 2, PP. 97-9.

[7]. 7. Akira Suda and Takanori Takeda "Effects of Nonlinear Chirp on the Self-Phase Modulation of Ultra short Optical Pulse" Appl. Sci., Vol. 2, Issue 2, PP.549-557; doi:10.3390/app2020549.

[8]. T.Wuth, W.Kaiser and W.rosenkranz "Impact of Self-Phase Modulation on Bandwidth Efficient Modulation Formats" Optical Fiber Communication Conference and Exhibit, 2001. OFC 2001, DOI: 10.1109/OFC.2001.927923.

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