Q-Factor and Jitter performance in WDM systems using RZ, NRZ and Duo binary modulation formats at different distances

Anju Phogat
Department of Electronics and Communication Engineering
M.M.U
Ambala, Haryana, India

Tarun Gulati
Department of Electronics and Communication Engineering
Assoc. Prof., M.M.U.
Ambala, Haryana, India

Deepak Malik
Department of Electronics and Communication Engineering
Asst. Prof., M.M.U.
Ambala, Haryana, India

Abstract— In this paper, we will focus on the modulation formats used to create the optical pulses, which are return-to-zero (RZ), non-return-to-zero (NRZ) and Duo binary wavelength-division-multiplexing (WDM) signals in optical communication system. The performance of 10 Gbps optical communication system with the dispersion managed return-to-zero (RZ) pulse has been reported. The return-to-zero (RZ) pulse is efficient for long-distance, high-bit-rate, wavelength division multiplexed (WDM) transmission dispersion-managed systems. In this Quality Factor, Jitter performance and BER is evaluated at different distances (5Km, 10Km, 15Km, 20Km, 25Km, 30Km, 40Km, 50Km, 70Km, 100Km). We compare non return-to-zero (NRZ), return-to-zero (RZ) and Duo binary modulation formats for wavelength-division multiplexed systems operating at data rate 10 Gb/s.

Keywords—Wavelength Division Multiplexing (WDM), return-to-zero (RZ), non return-to-zero (NRZ), duo binary, quality factor, Jitter performance.

I. INTRODUCTION

Wavelength-division-multiplexing (WDM) technology is attractive for large capacity transmission systems [1]. Furthermore, WDM technology enables us to construct flexible optical networks. In multi gigabit WDM return to zero (RZ) signals has been studied [3]. Nonlinear crosstalk suppression methods using both dispersion management and timing controlled RZ signals [4], and using bit-phase arranged RZ signals have been proposed [5]. However, non return-to-zero (NRZ), RZ and Duo binary signal formats have not been studied in details when considering the 8 channel WDM system operates at 10Gb/s. In this paper, the WDM transmission performances of NRZ, RZ and Duo binary signal formats employing channel WDM system at different distances (5Km, 10Km, 15Km, 20Km, 25Km, 30Km, 40Km, 50Km,70Km and 100Km). Quality factor and Jitter of NRZ, RZ and Duo binary are compared graphically. The non-return-to-zero (NRZ) has been the most dominant modulation format in intensity modulated-direct detection fiber-optical communication systems for the last years. The reasons for using the NRZ in the early days of fiber-optical communication as it is not sensitive to laser phase noise, requires a relatively low electrical bandwidth for transmitter and receivers compare with the RZ and the simplest configuration of transmitter and receiver. The NRZ pulses have a narrow optical spectrum [7]. The reduced spectrum width improves the dispersion tolerance but it has the effect of inter symbol interference. The RZ pulse occupies just a part of the bit slot, so it has a duty cycle smaller than 1 and a broad spectrum. The RZ pulse shape enables an increased robustness to fiber non linear effects and to the effect of polarization mode dispersion (PMD) [10].

The rest of the paper is organized as follows. Wavelength division multiplexing is explained in section II. Experimental results are presented in section III. Conclusion is given in section IV.

II. WAVELENGTH DIVISION MULTIPLEXING (WDM)

Wavelength Division Multiplexing (WDM) Broad-band low-noise optical sources (LEDs) are of a vital importance for future large-capacity flexible optical network utilization of both optical time-division multiplexing (OTDM) and wavelength transmission systems, system performance is degraded by fiber nonlinear effects such as four wave mixing and cross-phase modulation (XPM). To suppress these fiber nonlinear effects, WDM transmission employing return-to--division multiplexing (WDM). The wavelength-division-multiplexed passive optical network (WDM-PON) offers large bandwidth to subscribers for efficient broadband access. For achieving wavelength division multiplexing (WDM) systems at different modulation formats it operates at bit rates of 10 Gb/s per channel. For increasing data rate per channel, the number of channels per fiber is also increased through wavelength division multiplexing (WDM) or dense WDM (DWDM) to further improve overall capacity. WDM technology enables us to construct flexible optical networks [7].

The main benefits of fiber are its exceptionally low loss, allowing long distances between amplifiers or repeaters and its inherently high data-carrying capacity, such that thousands of electrical links would be required to replace a single high bandwidth fiber. Another benefit of fiber is that even when are alongside each other for long distances, fiber cables experience effectively no crosstalk, in contrast to some types of electrical transmission lines With the explosive growth in demand for capacity in national, regional, and even metropolitan optical networks, high bit rate fiber transmission have recently become an essential part of communications. Modern optical networks are now primarily based on 2.5 Gb/s and 10 Gb/s data rate. In addition to increases in data rate per channel, the number of channels per fiber is also increased through wavelength division multiplexing (WDM) or dense WDM (DWDM) to further improve overall capacity. Due to high data rates, limitation due to dispersion and nonlinearities in the optical communication system has been of great concern as these parameters (Q- factor, Jitter and BER) limits the overall efficiency of the system. Most commercial systems use the NRZ modulation format. The non-return-to-zero (NRZ) has been the most dominant modulation format in intensity modulated-direct detection fiber-optical communication systems for the last decade. The reasons for using the NRZ in the early days of fiber-optical communication as it is not sensitive to laser phase noise, requires a relatively low electrical bandwidth for transmitter and receivers compare with the RZ and the simplest configuration of transmitter and receiver. The NRZ pulses has a narrow optical spectrum .The reduced spectrum width improves the dispersion tolerance. Number of channels can be changed which depends upon various constrains like bandwidth etc.

III. EXPERIMENTAL RESULTS

For the evaluation of experiment Q-Factor and Jitter performance in WDM systems using RZ, NRZ and Duo binary modulation formats at different distances at a data rate of 10 Gbps. OPTSIM 3.6 software is used for this evaluation.

(a) Performance of Optical System with Different Modulation Formats

The optical communication systems are used as high speed long haul communication system. Due to high data rates, limitation due to dispersion and nonlinearities in the optical communication system has been of great concern as these parameters limits the overall efficiency of the system. An optical modulation format is the method used to impress data on an optical carrier wave for transmission over optical fiber. The ideal modulation format for long haul, high speed and WDM transmission links is the one that has a narrow spectral width, low susceptibility to fiber nonlinearity, large dispersion tolerance and good transmission performance and has a simple and cost-effective configuration for generation. In RZ pulse, the power is transmitted only for fraction of bit period. It has been reported that the performance of the system is improved with increase in the value of dispersion parameter. Using the different types of modulation formats, it is predicted that the novel modulation formats enhance the overall performance of the optical communication systems at high bit rate. In intensity-modulated direct-detection (IM/DD) systems, there are two possible modulation formats, non return-to-zero (NRZ), in which a constant power is transmitted during the entire bit period, and return-to-zero (RZ), in which power is transmitted only for a fraction of the bit period. Most commercial systems use the NRZ modulation format. The non-return-to-zero (NRZ) has been the most dominant modulation format in intensity modulated-direct detection fiber-optical communication systems for the last decade. The reasons for using the NRZ in the early days of fiber-optical communication as it is not sensitive to laser phase noise, requires a relatively low electrical bandwidth for transmitter and receivers compare with the RZ and the simplest configuration of transmitter and receiver. The performance of NRZ, RZ and duo binary modulation format at 10 Gb/s for the eight channel WDM optical communication system is analyzed. The performance evaluation of the modulation format has been analyzed in terms of the Quality factor and Jitter performance graphically. It is reported that RZ modulation format has the edge over NRZ and duo binary

modulation format. The performance of the NRZ, RZ and duo binary has been observed which shows that RZ is better for long optical communication system at 10 Gb/s. NRZ is better for large number of channels in the system. The NRZ pulses has a narrow optical spectrum .The reduced spectrum width improves the dispersion tolerance. Optical duo binary format is a very interesting modulation format, which offers high spectral efficiency and chromatic dispersion tolerance. The optical spectrum of the duo binary signal is very compressed as compared to many other binary formats.

Table -1 Experiment Result

Distance (Km)	**RZ**			**NRZ**			**Duo Binary**		
	Q-Factor (dB)	**Jitter (ns)**	**BER**	**Q-Factor (dB)**	**Jitter (ns)**	**BER**	**Q-Factor (dB)**	**Jitter (ns)**	**BER**
5	34.79	0.0185	1e-040	33.59	0.02061	1e-040	24.63	0.021398	1e-040
10	32.13	0.01623	1e-040	30.946	0.01881	1e-040	21.81	0.02759	1.6872e-032
15	28.47	0.017643	1e-040	28.26	0.01823	1e-040	10.80	0.01613	0.0002576
20	18.60	0.021658	1e-040	26.77	0.018441	1e-040	10.64	0.01246	0.000300915
25	17.71	0.02043	1e-040	19.667	0.017871	1e-040	10.20	0.014446	0.0005034
30	14.25	0.01743	1e-040	16.62	0.016235	1e-040	7.56	0.01794	0.0071245
40	12.54	0.02169	1.27361e-034	11.027	0.015886	6.3279e-028	6.02	0.024877	0.0227501
50	10.90	0.01367	9.945e-027	08.78	0.01695	1.645e-018	6.02	0.02434	0.02434
70	9.83	0.01498	0.00131055	6.085	0.024615	1.8604e-009	-	-	-
100	9.63	0.018054	0.00126017	1.66	0.02630	0.0003718	-	-	-

The LPF duo binary has recently received significant attention. One reason for this is that duo binary can be easily created using simple low-cost techniques. So different types of modulation techniques are used now days to enhance the performance of optical communication system. Each modulation format has its own advantages and disadvantages. Depending upon the required applications modulation formats is used. Wavelength management, such as reconfigurable optical add/drop multiplexing, is essential to making optical networks transparent, scalable, and flexible, which ultimately reduces the operational expenditure of such networks. Thirdly, high spectral efficiency can be achieved in a WDM system that has a common channel grid through the use of high bit rate.

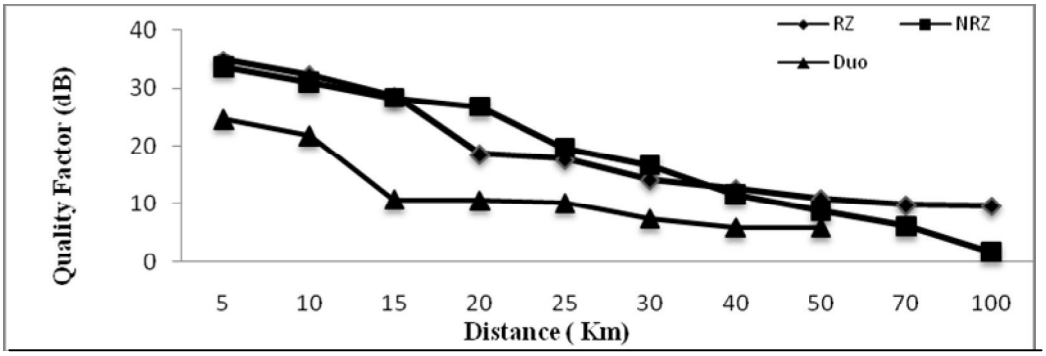

Figure1. Quality Factor of RZ, NRZ and Duo Binary modulation formats

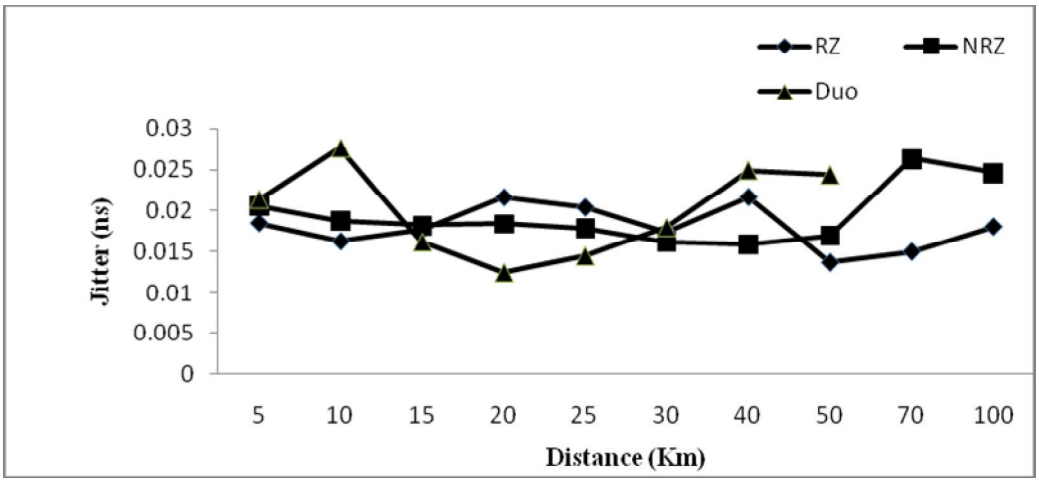

Figure2. Jitter Performance of RZ, NRZ and Duo Binary modulation formats

(b) Result and Discussion

We have compared the modulation formats used to create the optical pulses, which are return-to-zero (RZ), non-return-to-zero (NRZ) and Duo binary wavelength-division-multiplexing (WDM) signals on the basis of Quality factor, Jitter performance at a data rate of 10 Gb/s in 8 channel system. The overall Quality factor is better in case of NRZ modulation format and it will be decreases as the distance increases. Jitter or per delay will be less in case of NRZ modulation format. This analysis and investigation has shown that conventional NRZ turns out to be superior compared to RZ systems when single-mode fibers are used as transmission media. On the other hand, because of the narrower optical spectrum of the NRZ format, NRZ enables higher spectral efficiency in WDM systems compared to RZ. NRZ may be a better choice for a system with a large number of channels. It is numerically concluded that the RZ modulation format is best for the long distance optical communication system due to its low value of Jitter and BER at high bit rates. These two evaluation criteria provide different insights into transmission characteristics. The return-to-zero (RZ) pulse is efficient for long-distance, high-bit-rate, wavelength division multiplexed (WDM) transmission systems.

IV.CONCLUSION

In this paper, the performance of NRZ, RZ and duo binary modulation format at 10 Gb/s for the optical communication system is analyzed. It is reported that the Duo binary modulation format provides the higher dispersion tolerance among the three modulation formats. The duo binary modulation format can be recommended for long distance communication systems at high bit rates. It is observed that in NRZ modulation format the overall Quality factor is better and it will be decreases as the distance increases. Jitter or per delay will be less in case of NRZ modulation format. So NRZ is better and is used for small distance communication system at high bit rates. It is concluded that the RZ modulation format is best for the long distance optical communication system due to its low value of Jitter and BER to the dispersion at high bit rates.

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