

Robustness of Modulation Formats Technique to Four Wave Mixing Crosstalk Under 80 Gbps Data Rate.

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Abstract

Four wave mixing (FWM) in optical fibers is an undesirable effect to an optical transmission system that can cause a severe limitation in the wavelength division multiplexing (WDM) and reduces the system performance. Within this paper, the normal intensity of RZ robustness modulation and the Modified-Duobinary-Return-Zero modulation (MDRZ) on FWM was investigated. In addition, the performance of the system under the fiber length variation effect was evaluated under the impact of (80) Gbps data rate for both types of modulation format. The results showed that the RZ modulation introduces a minimum (FWM) power of (-54) dBm at (70) kms fiber length, while MDRZ offers FWM power of (-44) dBm at the exactly same fiber length, In-term of the performance of the system at channel 4, a minimum BER was noticed in normal RZ modulation which equals to 2.27×10^{-43} at (-35.31) dBm received power. However, the BER was 4.98×10^{-15} at the same received power and channel, in the existence of MDRZ modulation format. The finding reveals the progress of RZ modulation in reducing the FWM crosstalk and enhances the WDM system performance even with the impact of high data rates.

Keywords:– Optical Fiber, Four Wave Mixing.

I. Introduction

Modern systems of optical communication can be established through the use of wavelength division multiplexing (WDM). WDM is the modern issue that permits very high capacity in optical networks. It permits data to be transferred in huge amounts in different channels at different wavelengths [1]. In equally spaced WDM optical fibers, the product terms that generated by FWM in the bandwidth of the system fall at the channel frequencies, giving an increase to (FWM) cross talk [2]. The most significant defect of (FWM) is reducing the performance of (WDM) optical networks which creates a probable distortion of the channel energy wastage and the output signal [3, 4]. (FWM) comes when the refractive index inside the fiber varies with the power [5]. Recently, to reduce the deleterious effects of FWM in WDM communication systems, many techniques have been proposed [6, 7, 8, 9, 10, 11]. Gao & Jin studied the (FWM) in dispersion-managed transmission lines putting in mind the power-dependent-phase matching. The conclusion was that when the channel power is low, the FWM effect shows power-independent phase matching. Fabrizio et al proposed a channel spacing allocation design to reduce the impact of FWM cross talk. It revealed that for a 10-channel system, selecting of suitable channel spacing can reduces the FWM cross talk and increases the power at the receiver to (9) dBm. However, this design couldn't decrease the FWM cross talk outside the bandwidth of the receiver. Shao et al suggested an optical modulation transmitter which can transmit the RZ-FSK signal. Through adjusting the frequency-tone-spacing (FTS) for a data rate 40-Gb/s FSK (with two different values of FTS, 100-GHz & 60-GHz), it can improve the sensitivity of the receiver. The results explained that the power penalties after transmission above (80) km SMF are (0.58) dB and (0.46) dB respectively. The limitation of this work that no investigation of the effect of modulation format on FWM power cross talk in-term of BER.

Within this paper, we investigate the durability of RZ & MDRZ modulation format to the FWM nonlinear under high data rate of 80 Gbps. The system performance is figured for fiber length variation effect. This paper was organized as follows. In section (II) we investigated the design of the system simulation and the parameters. In Section III we introduced the results of our simulation system with discussion. At last, the conclusion of this work was reported in Section IV.

If three optical waves with frequencies f_i, f_j and f_k are propagating in the fiber, they can interact via the third order susceptibility of the material and new waves with the frequencies

$$f_{i,j,k} = f_i; + f_j - f_k$$

II. System simulation design and parameters

Figure.1 illustrates the proposed configuration of the system of the receiver and the transmitter. At the transmitter section, the continuous wave laser (L1–L14) array is used to generate the signal of the carrier. The frequency of first user is set to (191.5) THz, and the spacing between each user is (100) GHz. Each user is modulated with (10) Gb/s data rate. The external modulator comprised of MDRZ transmitter circuit or RZ transmitter circuit and system design details is clear in [10]. Then, it is connected to the Mach-Zehnder modulator (MZM), which acts like an intensity modulator. Post dispersion compensations map is used by the optical link to compensate the dispersion in the link, which consists of two optical fiber with two amplifiers (EDFAs) between them. The dispersion map is made of a single mode fiber (SMF) and a dispersion-compensation-fiber (DCF). An EDFA amplifier with a gain of (10) dB and noise figure of (4) dB was used in the transmitter to amplify the optical signal. Two types of nonlinear optical fiber were used namely, single mode fiber (SMF) and dispersion compensation fiber (DCF). The signal was detected by using a PIN photodiode for direct detection. PIN has a responsivity (β) of (0.8) A/W. Then, it's passed through the low-pass Bessel filter. The BER analyzer was connected directly to the electrical filter, which is used to create the graph. Table (1) describes the system-simulation parameters.

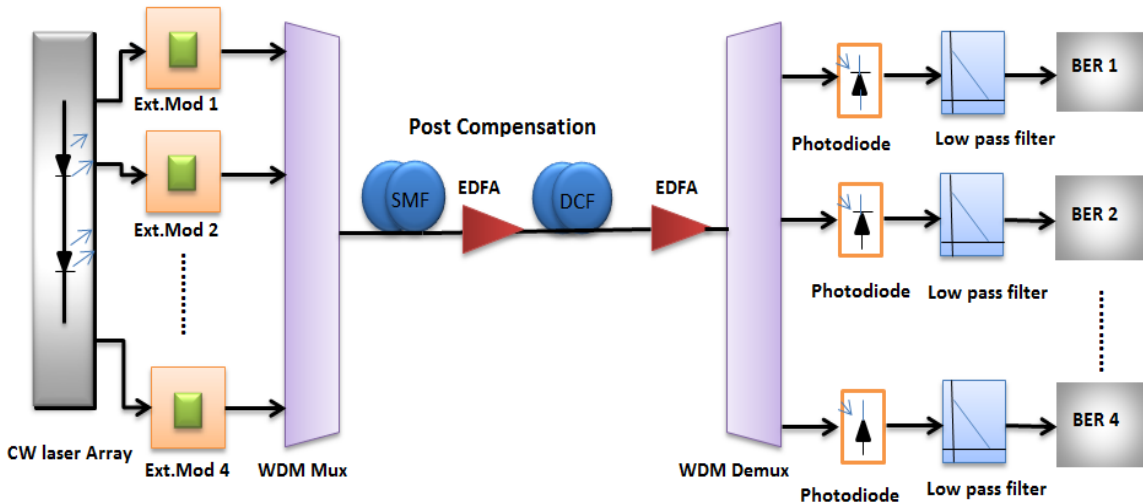


Figure.1 A. System design parameter of receiver and transmitter of, RZ and MDRZ

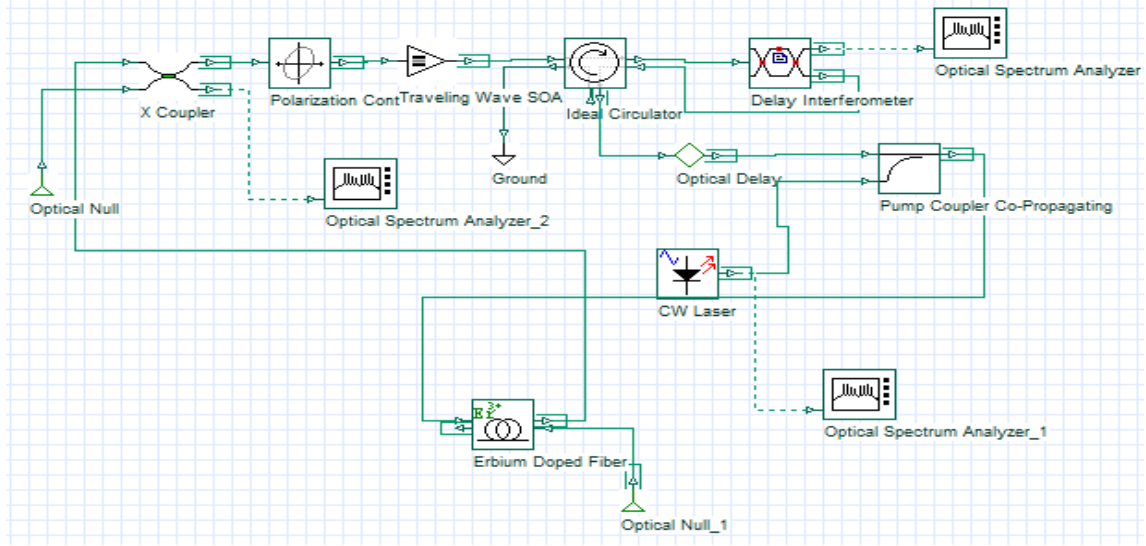


Figure.1 B. OptiSystem circuit of design parameter of receiver and transmitter of, RZ and MDRZ

Table.1 Optical system simulation parameters

Parameter	Unit	Values
Fiber length, L	Km	70 to 95
Input power, P_i	dBm	-2
Dispersion, D_c	ps/nm.km	(16.87) in SMF and (-85) in DCF
Cross effective area, A_{eff}	μm^2	(70) in SMF and (22) in DCF
Degeneracy factor, D	--	6
Third order Susceptibility, X_{111}	$m^3/w. s$	6×10^{-15}
Speed of light, c	(m/s)	3×10^8
Input frequencies, F_{in}	(THz)	191.5 -191.8
Channel Spacing, Δf	(GHz)	100
Attenuation factor, α	(dB/ km)	0.2
Number of channels, N_c	--	4
Data Rate, B	Gb/s	80

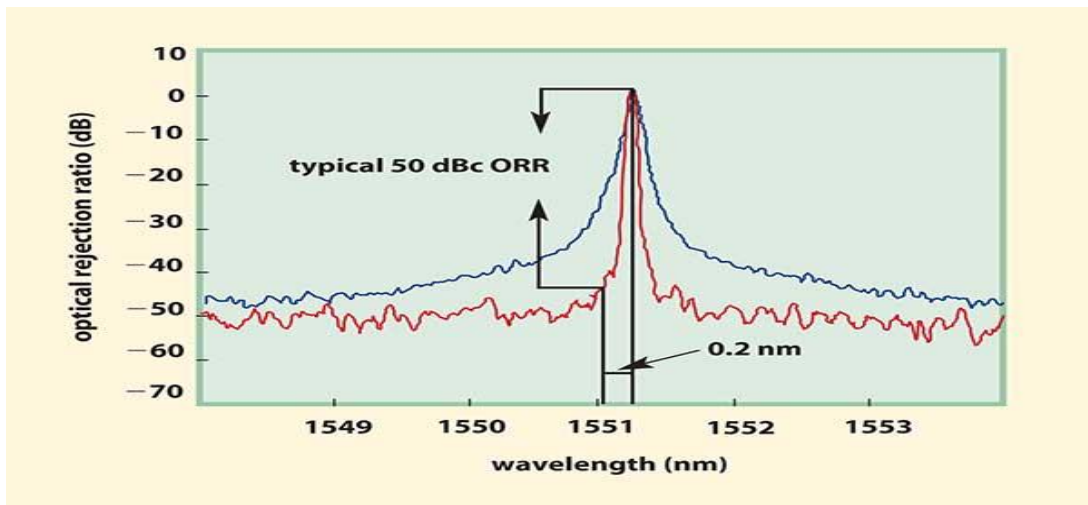


Figure.1 C. OptiSystem analysis of design parameter of receiver and transmitter of, RZ and MDRZ

III. Results and discussions

In this section, the effect of decreasing the fiber length on FWM power in an available RZ and MDRZ modulation format. The performance of the system is simulated in-terms of BER between the two-modulation format mentioned. The results are summarized as follows:

1. Investigate the FWM power using optical spectrum analyzer

System simulation was done under decreasing the fiber length values from 95 to 70km with RZ and MDRZ modulation techniques. Figure (2-A) and (2-B) shows the optical spectrum of (70) km optical fiber. It is clear from this Figures that the power of FWM was (-44) dBm in MDRZ modulation format, while in the existence of RZ modulation technique, the power FWM was dropped to (-54) dBm.

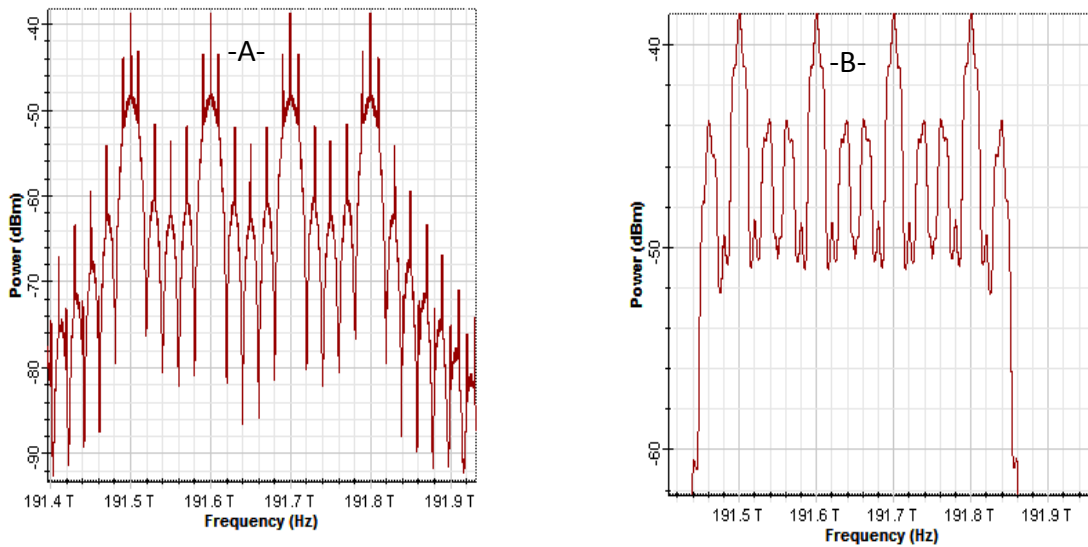


Fig 2. Optical spectrum analysis after 70 km fiber length of 40 Gb/s in the existence of modulation format (A) RZ, and (B) MDRZ.

2. Investigate the System Performance (BER) using BER tester.

Figure.3 explains the relation between BER and the received power under fiber length tuning. The system performance has been performed using single mode fiber (SMF) and in the case of normal RZ and MDRZ modulation. It can be seen that as an increment in the received power decreases the bit error rate in the system. It is observed from figure (3-A), at the first channel, the RZ modulation offered a minimum BER of 2.09×10^{-38} at (-35.31) dBm received power. However, with MDRZ modulation, the BER was $\sim 4.06 \times 10^{-27}$ at the same channel and received power. At the fourth channel, the trend of the system performance was similar with the first channel. In case of RZ modulation, BER was 2.27×10^{-43} at (-35.31) dBm received power, while in case of MDRZ modulation, BER was $\sim 4.98 \times 10^{-15}$ at the same received power and the same channel.

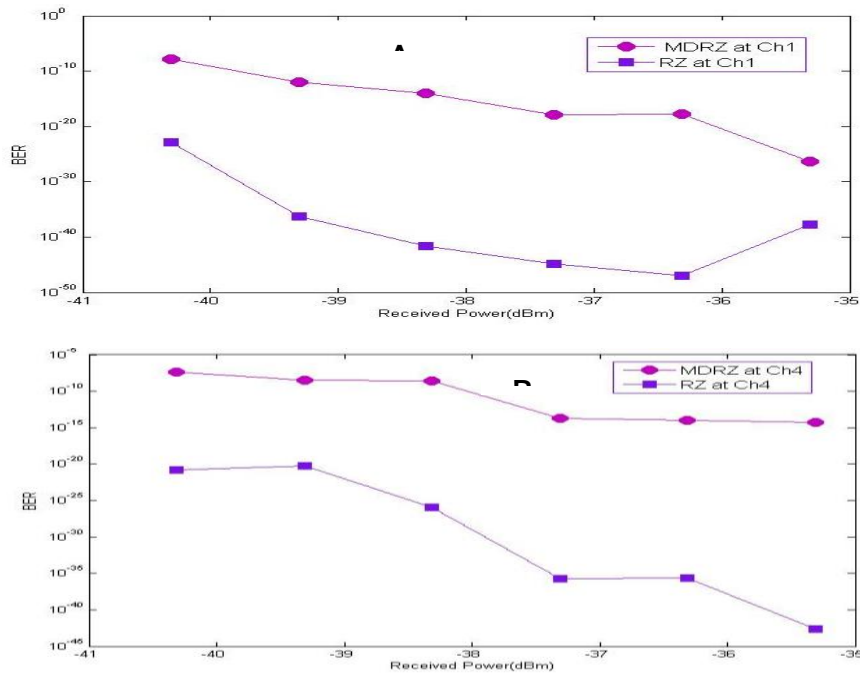


Figure.3 The relationship between the received power and BER for (A) (RZ-modulation format effect) and (B) (MDRZ modulation format effect).

More importantly, it can be concluded from the modulation behavior, that RZ intensity modulation is more tolerant to nonlinear effect than MDRZ. Table.2; explain the summary of the comparison of the fiber length reducing effect on the FWM power and system performance both modulation formats used. Fig.4 explains that the optimum eye diagram for both RZ and MDRZ modulation. It is obvious that the eye diagram of RZ modulation is clearer and higher than the eye diagram of MDRZ modulation for the two channels. At 70 km fiber length, the optimum eye diagram was height with RZ modulation of BER (2.27×10^{-43}) at channel 4. Inversely with MDRZ modulation, where the eye diagram was less clarity and high of BER (4.98×10^{-15}) at same channel. The More opening eye diagrams means that the RZ modulation has a higher tolerance to nonlinear effect in high data rate and receiving bits (1 & 0) are correctly detected at the receiver without any noise or interference.

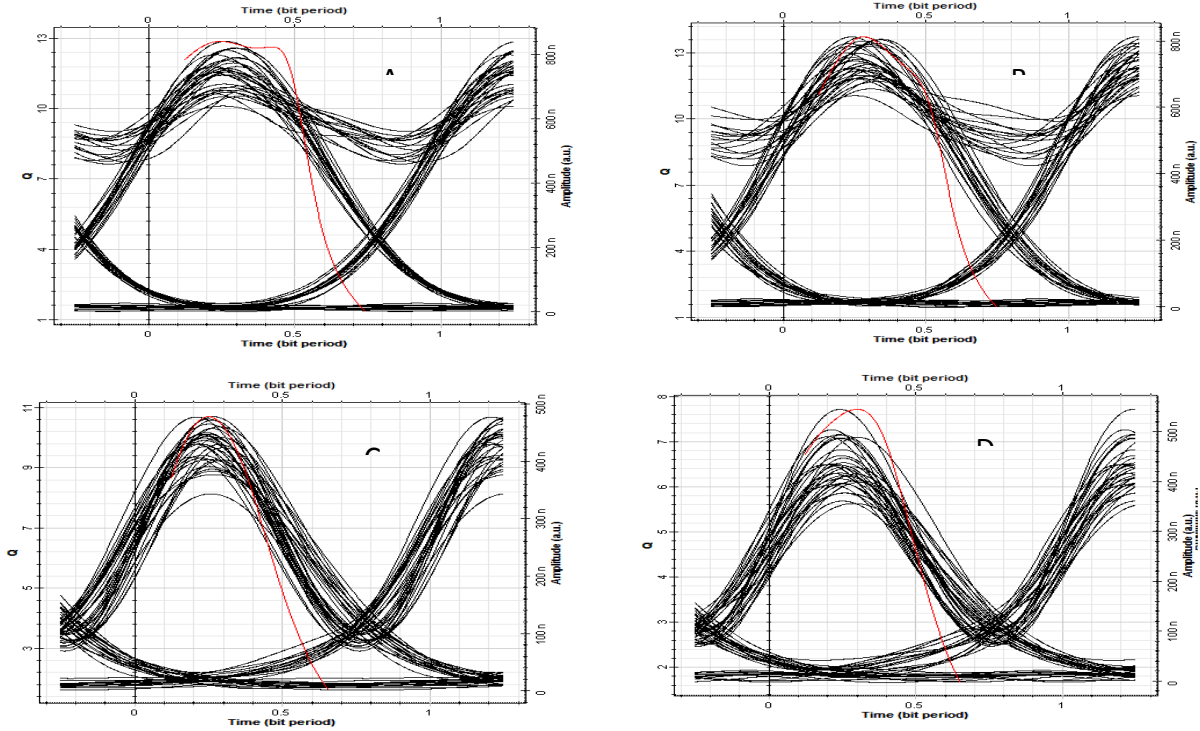


Fig.4: Performance of the optimum Eye diagram at L = (70) Km of (A) RZ modulation of BER 2.09×10^{-38} at ch1, (B) RZ modulation of BER $=2.27 \times 10^{-43}$ at ch4, (C) MDRZ modulation at of BER $=4.06 \times 10^{-27}$ at ch1, and (D) MDRZ modulation of BER $=4.98 \times 10^{-15}$ at ch4 .

Table 2. Summary of fiber length effect on FWM and BER

Fiber Length (Km)	Modulation format name	Minimum FWM power (dBm)	Minimum BER	
			Ch1	Ch4
70	RZ	-54	2.09×10^{-38}	2.27×10^{-43}
	MDRZ	-44	4.06×10^{-27}	4.98×10^{-15}
95	RZ	-42	1.20×10^{-23}	1.43×10^{-21}
	MDRZ	-36	1.33×10^{-08}	3.80×10^{-08}

IV. Conclusion

In this paper, the performance of (WDM) optical system has been investigated under the effects of fiber length variation and in an available of (RZ) intensity modulation and (MDRZ) modulation. Furthermore, the study was conducted for the effect of reducing fiber length on (FWM) behavior. The results proved that the (RZ) incurs the least (FWM) power, i.e. (-54) dBm, while (MDRZ) modulation incurs the most (FWM) power of (-44) dBm. In-terms of the performance of system at channel 4, reducing the fiber length introduces the lowest (BER) of 2.27×10^{-43} at a received power of (-35.31) dBm in (RZ) modulation. Nonetheless for MDRZ-modulation format, it offers a (BER) with less than 4.98×10^{-15} at the same received power. At last, it can be concluded that the (RZ) modulation offered more robustness to FWM crosstalk and improve the performance of the system in-term of (BER) in contract with (MDRZ) modulation even with a high data rate value.

Conflicts of Interest

The author declares that they have no conflicts of interest.

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الخلاصة:

يعد الاختلاط بأربع موجات في الألياف الضوئية تأثيراً غير مرغوب فيه لنظام إرسال بصري يمكن أن يتسبب في وجود قيود شديدة في مضاعفة تقسيم الطول الموجي ويقلل من أداء النظام. في هذا البحث، تم التحقيق في الكثافة الطبيعية لتعديل مائة RZ ومساواة التعديل الثنائي-العودة-صفر. بالإضافة إلى ذلك، تم تقييم أداء النظام تحت تأثير تباين طول الألياف تحت تأثير معدل بيانات 80 جيجابايت في الثانية لكلا النوعين من تنسيق التشكيل. أظهرت النتائج أن التشكيل RZ يقدم الحد الأدنى من القدرة (-54) ديسيبل عند طول الألياف (70) كم، في حين يوفر قدرة (-44) ديسيبل في نفس طول الألياف بالضبط، على المدى الزمني لأداء النظام عند القناة 4، لوحظ أدنى معدل BER في التشكيل RZ العادي الذي يساوي 27، 10-3 عند (35، 31) dBm (القدرة المستقبلية). ومع ذلك، كان معدل الخطأ في البتات من 4، 98 إلى 10-15 في نفس القدرة والقناة المستقبلية، بوجود نسق التشكيل ويكشف هذا البحث عن زيادة التقليل RZ

الكلمات الدالة: الألياف البصرية، الضوضاء رباعية الخلط.