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Simulative Analysis of 40 Gbps DWDM System Using Combination of Hybrid Modulators and Optical Filters for Suppression of Four-Wave Mixing

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Abstract

Optical networks offer higher data rates, and are fast and error free. However, non-linearity hinders them from being a perfect medium. Especially, FWM degrades the transmission characteristics of the optical systems and networks. FWM may result in crosstalk among optical channels. The paper presents a new approach to suppress the effect of four wave mixing using combination of hybrid modulator and optical rectangular filters. The performance of DWDM system and behaviour of four wave mixing is analysed. Hybrid modulator used here consists of Mach-Zehnder modulator followed by dual drive Mach-Zehnder and AM modulator. The system comprises of 8 channels each of data rate 5 Gbps. Also, comparative analysis is carried out using different fibres (Single mode fibre and ITU-T G.655). The maximum achieved Q-factor for SMF is 13.05 and 17.87 in case of ITU-T G.655.Dispersion compensating fibre is used to control dispersion. System is analysed for the length of 580 km in case of SMF and 530 km in case of ITU-T G.655.

Keywords: *Four wave mixing, Hybrid modulators, Optical filters, Single mode fibre*

1. Introduction

Optical fibre has enormous bandwidth which led to development of high capacity long-haul optical communication system. Various impairments such as chromatic dispersion and fibre non-linearity impose certain limitation on such optical networks. FWM can cause fluctuation in BER that leads to degradation of optical signal to noise ratio and quality of service in WDM systems having complex non-linear effects [1]. Among all the non-linear effects FWM is a process that generates new frequency components from existing components. Hybrid modulation techniques play significant role in suppression of four wave mixing [2]. Increasing the number of channels by reducing the channel spacing can increase FWM effect and have a negative effect on FWM suppression [3]. Various factors such as channel power, channel spacing, dispersion effective area and transmission interact distance are major reasons for undesirable frequency harmonics in WDM systems. Optical rectangular filters remove all the undesired frequency components, and hence are helpful in suppression of four wave mixing [4]. As the signal propagate inside the fibre, both dispersive and non-linear effects influence the shape and spectrum of the optical signal. In case of long distance transmission non-linear effects play more important role because of more interaction [5]. Crosstalk is power transfer from one channel to another which is due to non-linear effects, especially four wave mixing

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[6]. There have been several techniques to mitigate the effect of four wave mixing such as polarisation interleaving techniques, parametric amplifiers, optical code division multiple access and many more. In this paper a new technique is presented to suppress four-wave mixing. The system uses combination of hybrid modulation technique and optical rectangular filters in same system. There are 4 sections in the paper. Section 1 presents introduction to four-wave mixing. System description is given in section 2. Section 3 presents the result and discussion. Finally, section 4 concludes the paper.

2.System Design

Simulation is performed and analysed in optisystem 7. The system setup is shown in figure 1. In this paper system is analysed to reduce the effect of four wave mixing. The system consists of 8 channels each of data rate 5 Gbps. Transmitter consists of pseudo-random sequence generator, pulse generator (RZ), CW laser source and hybrid modulators. Pulse generator converts the bits into pulses using return-to-zero modulation format. The input power of the laser source use is 0 dBm. Hybrid modulator comprises of Mach-Zehnder modulator followed by dual drive Mach-Zehnder and AM modulator. The channel comprises of single mode fibre, erbium doped fibre amplifier and dispersion compensation fibre. EDFAs are used to amplify the optical signal as signal strength decreases with increase in distance. Channel spacing between the channels is 100 GHz. The transmission link is made up of several repeating loop where, each loop has 40 km SMF, an EDFA having a gain of 10 dB and noise figure of 4 dB. Dispersion compensating fibre having a negative dispersion equals to -85 ps/nm.km is used to control chromatic dispersion. The loop is repeated 12 times to make the total distance to 580 km. The system is analysed using SMF and ITU-T G.655 fibre. At the receiving end, photodiode is used to convert the optical signal to electrical signal. Photodiode is followed by low pass Bessel filter, 3-R regenerator and eye diagram analyser. The input signals are passed through multiplexer having bandwidth of 40 GHz and at receiving end a de-multiplexer is used. The frequency of first channel is 193.1 THz.

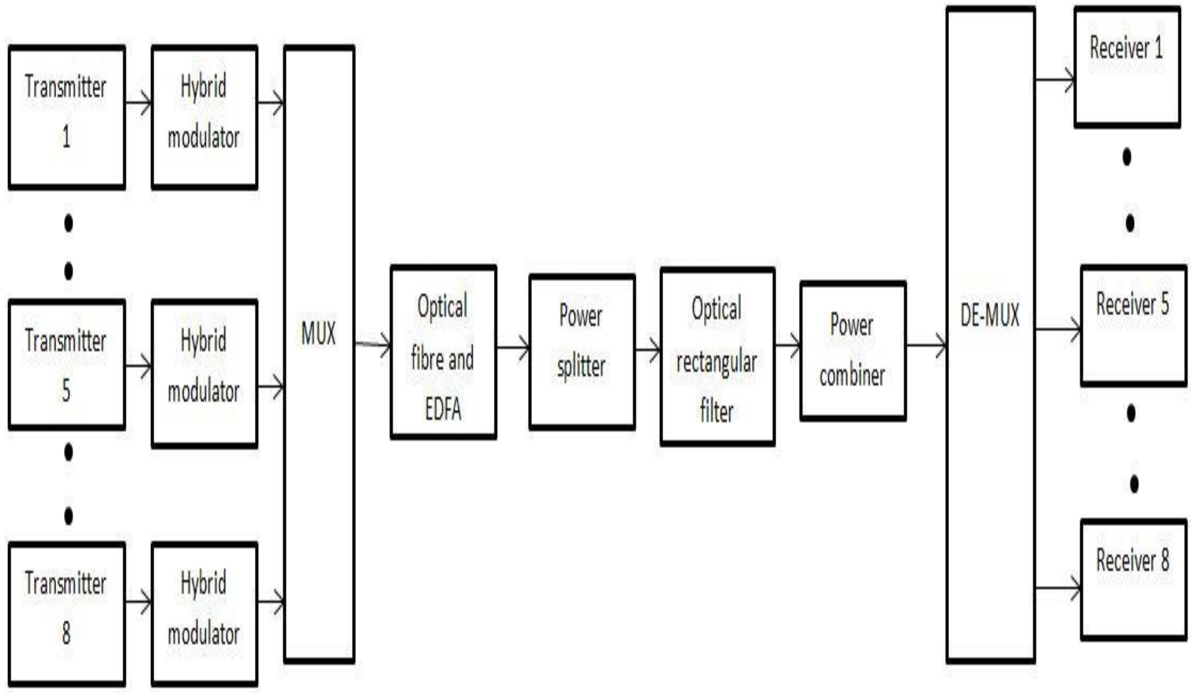


Figure 1. Block Diagram of 40 Gbps DWDM System

The optical rectangular filter is basically a sinc function that eliminates all frequency above the cut-off frequency. Optical filters have bandwidth of 10 GHz. The power splitter split the power equally among all the filters which individual signal is passed through rectangular filter having specific cut-off frequency. Power combiner is used to combine the individual signals.

Table 1. System Parameters

Parameters	Values	Units
Data rate	40	Gbps
Attenuation	0.2	dB/km
Amplifier gain	10	dB
Amplifier noise figure	4	dB
No. of channels	8	-
Filter bandwidth	10	GHz
Dispersion	16.75 for SMF 8.85 for ITU-T G.655	Ps/nm.km

3.Results and Discussion

To evaluate the system performance, BER and Q-factor are the two important parameters that need to be analysed. In the eye diagram analyser, wider is the eye better is the performance of the signal, better is the BER. BER is the rate at which transmitted bits are received in errors and is calculated in comparison of transmitted bits to received number of bits.

a) Single mode fibre

Figure 2 shows the spectrum at the transmitter side. Figure 3 shows the spectrum as the signal propagates through the fibre showing four wave mixing. Figure 4 shows the spectrum of reduced FWM components. Q-factor and BER of all the 8 channels are given in table 2. Figure 5, 6 and 7 shows the eye diagram of channel 1, 5 and 8 respectively.

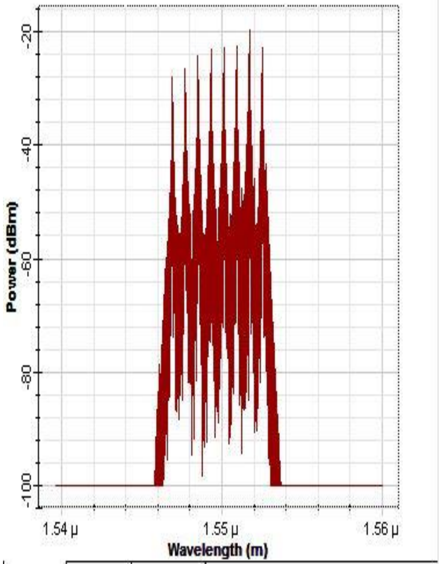


Figure 2. Spectrum at Transmitting End

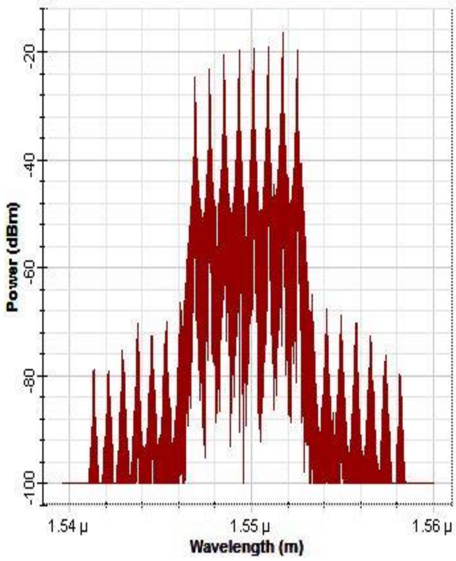


Figure 3. Spectrum Showing FWM Effect

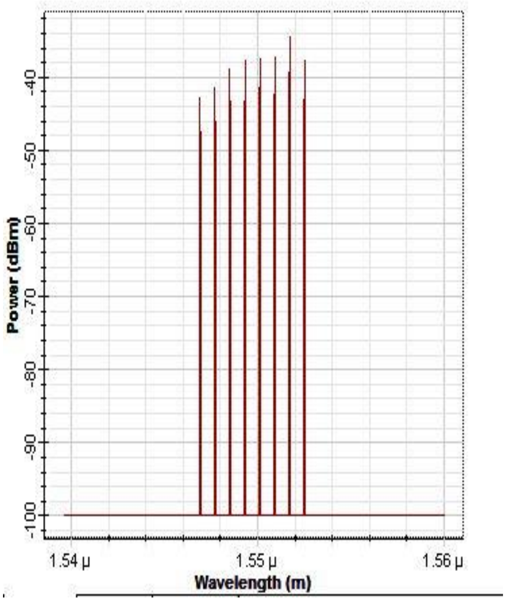


Figure 4. Spectrum Showing Reduction of FWM

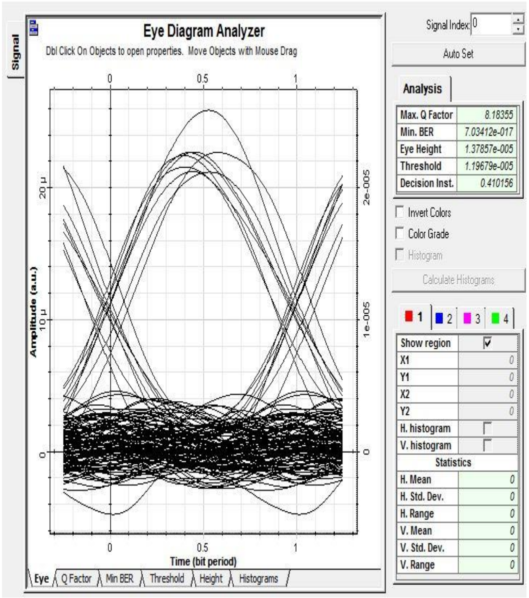


Figure 5. Eye Diagram for Channel 1

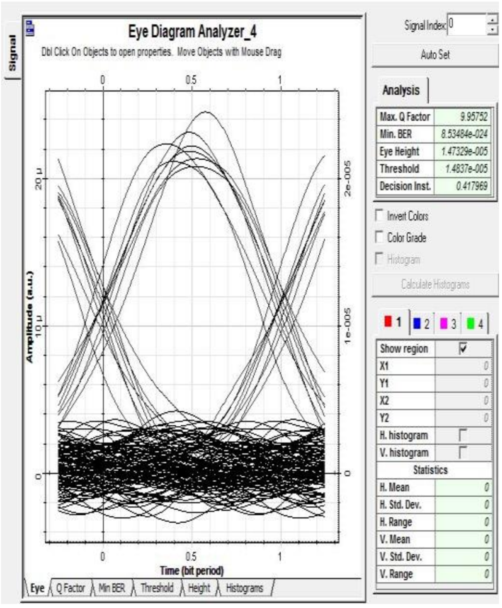


Figure 6. Eye Diagram for Channel 5

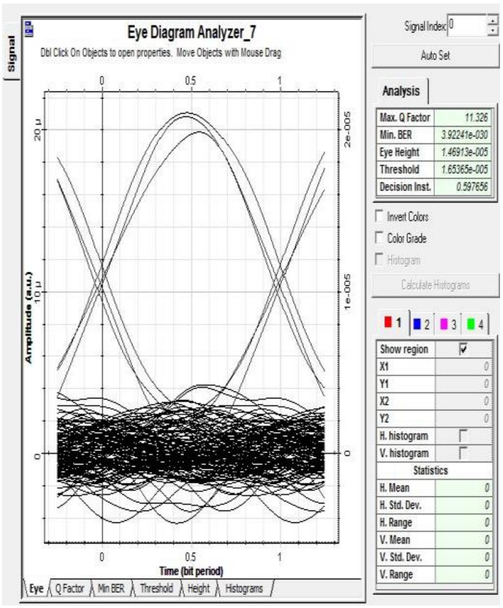


Figure 7. Eye Diagram for Channel 8

a) ITU-T G.655

System is also analysed for G.655 fibre, having positive dispersion 8.85 ps/nm.km . The maximum transmission achieved here is 530 km. Figure 8 shows the effect of four-wave mixing and figure 9 shows suppression of FWM. Figure 10 and 11 shows eye diagram for channel 1 and 8 respectively. Q-factor and BER of all channels are given in table 2.

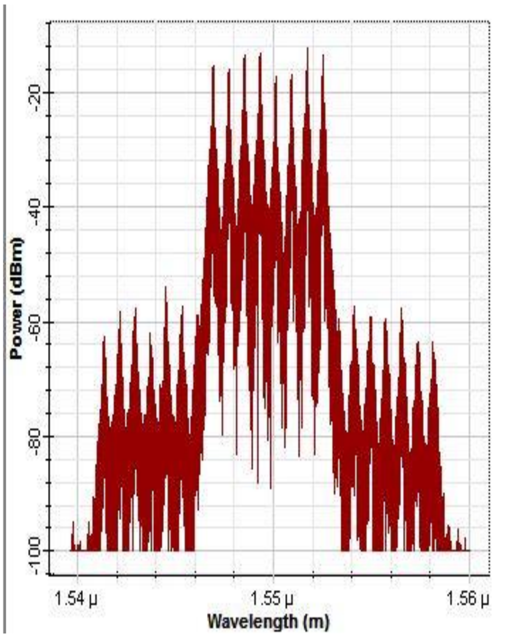


Figure 8. Spectrum Showing FWM

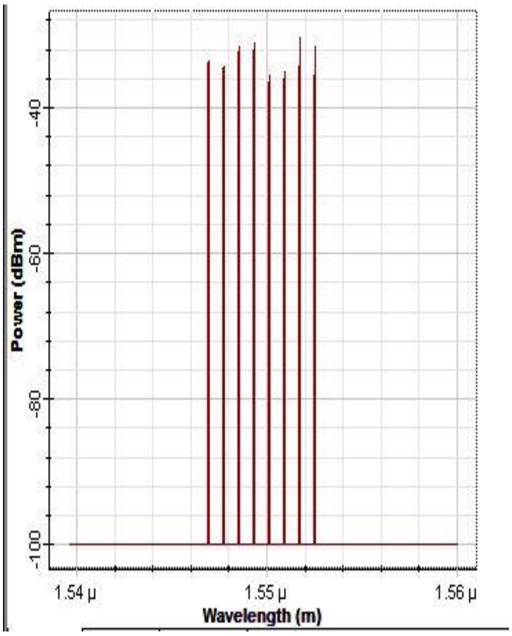


Figure 9. Spectrum Showing Reduced FWM Sidebands

As the signal propagates through the fibre, new components are generated. These new components interact with existing one and cause four-wave mixing as shown in figure 8.

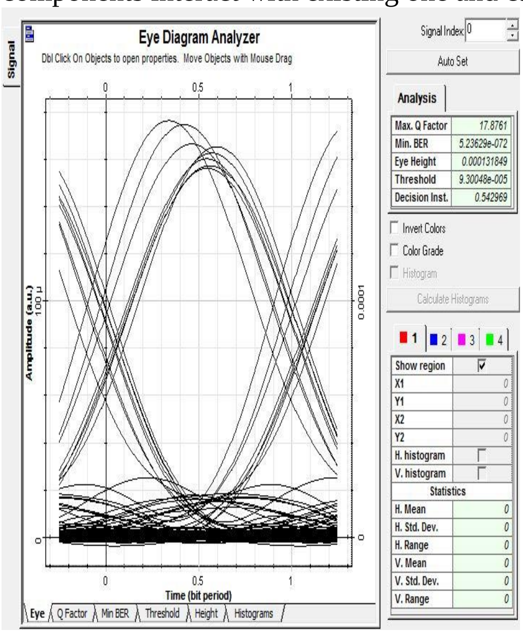


Figure 10. Eye Diagram for Channel 1

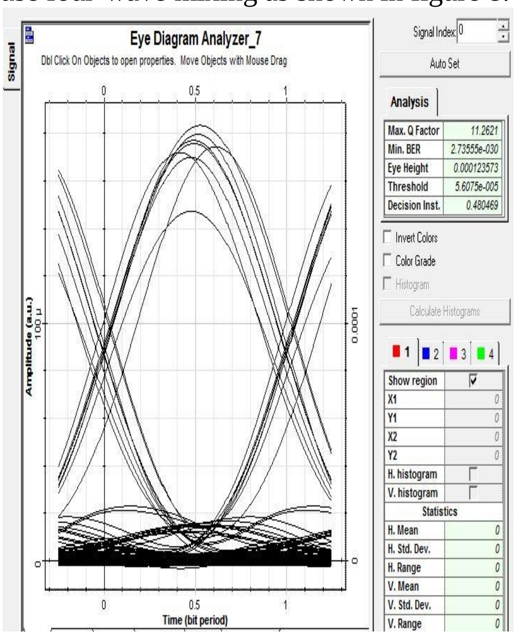
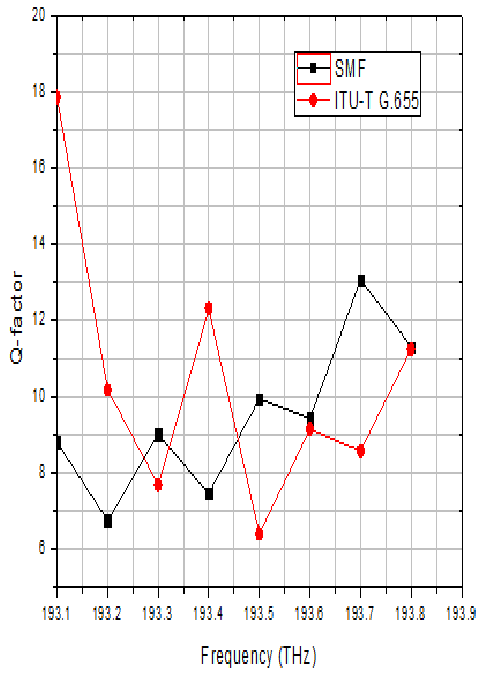


Figure 11. Eye Diagram for Channel 8

Figure 12 and 13 shows the graph of comparison of Q-factor v/s channel frequency of SMF and G.655 and BER v/s channel frequency respectively.



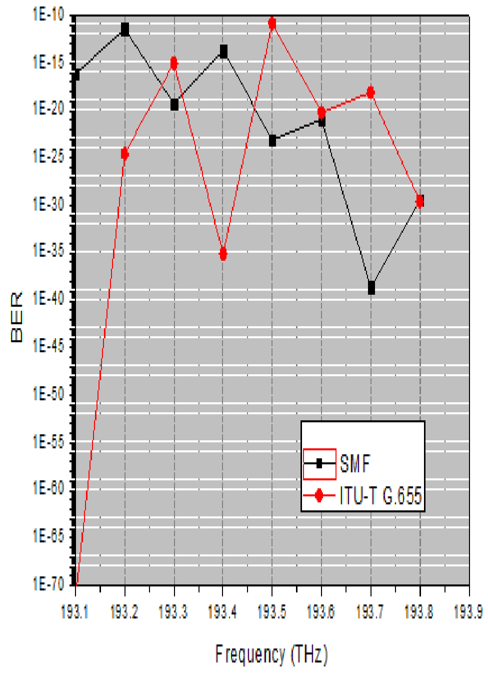


Figure 12. Q-Factor v/s Frequency **Figure 13. BER v/s Frequency**

Table 2. Comparative Analysis of DWDM System

Channels	parameters			
	SMF		ITU-T G.655	
	Q-factor	BER	Q-factor	BER
Channel 1	8.813	10^{-17}	17.87	10^{-72}
Channel 2	6.75	10^{-12}	10.20	10^{-25}
Channel 3	9.02	10^{-20}	7.69	10^{-16}
Channel 4	7.46	10^{-14}	12.30	10^{-36}
Channel 5	9.95	10^{-24}	6.40	10^{-11}
Channel 6	9.44	10^{-21}	9.15	10^{-21}
Channel 7	13.05	10^{-39}	8.58	10^{-19}
Channel 8	11.32	10^{-30}	11.26	10^{-30}

4. Conclusion

The paper demonstrates the Q-factor and BER performance of FWM effects for 40 Gbps DWDM systems. It is concluded that FWM effects the signal propagation in the optical medium and hence, should be reduced. In this paper, new technique is discussed to suppress FWM effect using combination of hybrid modulators and optical rectangular filters. The maximum achievable Q-factor is 13.05 and 17.87 in case of SMF and ITU-T G.655. The minimum BERs achieved are $10^{-39}$and 10^{-72} in case of SMF and G.655. Hence, the above technique results in suppression of four wave mixing. Transmission distance is limited to 580 km and 530 km in case of SMF and G.655. Output of spectrum analyser shows the reduction of four-wave mixing. It is conclude that G.655 is better optical channel for system employing combination of hybrid modulation technique and optical rectangular filters.

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