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Performance Optimization of Roadm Based Wdm Network

Jai Sukh PaulSingh
Division of Research and Development
Lovely Professional University,
Punjab, India.
khalsa128@gmail.com

Satnam Singh
Department of Electronics and Communication,
Panjab University,
Chandigarh, India.
er.satnamsingh1992@gmail.com

Abstract—ROADM are used intensively for routing channels and add/drop of wavelengths in WDM systems. ROADMs have successfully replaced the conventional add/drop multiplexers following their losses and time consuming optical to electrical to optical conversions. This paper implements.WDM systems with and without using ROADM over 100kms.The performance of a WDM system after introducing a ROADM is discussed and the required improvement is also carried out. The performance comparison of the various WDM systems is done by BER rate-Factor provided by corresponding eye diagrams.

Keywords— Bit Error Rate(BER), Reconfigurable optical add drop multiplexer (ROADM),Quality Factor(Q-factor),

I. Introduction

WDM system is an essential constituent of global telecommunication system. A large amount of data is multiplexed into a large no. of channels over an optical fiber and is communicated all over the globe. The use of WDM systems has increased manifolds in recent years in case of long-haul optical communication systems. Tremendous bandwidth of optical fiber provides a large capacity and is a very cost-effective transmission medium [1].

Optical communication systems are a significant and fast-growing constituent of communication networks [2]. WDM systems consists of large no. of channels and are required to route accordingly. In an optical communication system, it is required to add or drop information at various nodes throughout the line. Conventionally add/drop multiplexers were used but due to many optical to electrical to optical conversions recently their application has become limited [3].

ROADMs are being intensively used for routing channels and add/drop of wavelengths in an optical communication system. The wavelength selective switch has gone through a significant development to improve performance of ROADM [4]. ROADM is a salable application that allows the transparent optical switching of wavelength channels into and out of optical fiber being controlled by software. ROADMs are very efficient in add/drop of wavelength channels as it completely nullifies the optical to electrical and back to optical conversions. There are two general types of ROADMs, two degree and multi-degree where degree refers to number of optical fibers entering and exiting the ROADM[5].

Colorless, Directionless and Contention-less ROADMs are advancement to the conventional ROADMs. Colorless refers to adding and dropping of any wavelength at anyport. Hence it is not wavelength selective. Directionless means that it is not nodal degree selective but any channels added on any add/drop port can be directed to any outbound nodal degree. Contention-less means that two same colored wavelengths can converge on same add/drop structure simultaneously[6].

The Non-Return to Zero (NRZ) and Return to zero (RZ) modulation formats are considered for data communication at 10 – 40Gigabytes per second. In a system with bit rate 10 – 40Giga bytes per second and single mode fiber alternating with dispersion compensated fiber, NRZ is more adversely affected by non-linearities, whereas RZ is more affected by dispersion.RZ format gives best performance as compared to NRZ format for 10 GBPs as explained in[7].

A fair amount of analytical research has been completed on Goldsmith the advancements in ROADMs technology, It is an utmost requirement to implement ROADM in a simulating environment and analyze its behavior. In this paper an effort is being made to compare BER rate, Q-factor through eye diagrams of the corresponding output of the optical transparent network using and without using ROADMs.

The remainder of the paperis divided into four sections. Introduction about ROADM is discussed in Section1. Section 2 focuses on the System model and its description. Section 3 discusses the results and discussions. Conclusion and future scope are discussed in Section 4.

II. SystemDescription

There are three systems involved for comparison in this paper. First system is a basic WDM system in which no wavelength channel is being added or dropped. The basic

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block diagram of the system is represented in Figure 1.The transmitted system consists of a laser array and an external modulated system. The line width of CW laser is kept at 0.1 Megahertz. Externally modulated subsystem consists of pseudo-random bit sequence (PRBS) generator, NRZ pulse generator and Mach–Zehnder modulator. Multiplexer is used to multiplex a user defined number of WDM channels. The transmission channel consists of Single Mode Fiber (SMF), dispersion compensated fiber (DCF) and Erbium Doped Fiber Amplifiers (EDFAs).A postdispersion compensation is used to compensate the dispersion and attenuation losses occurring in SMF whereas DCF is compensated byEDFA.

A Reconfigurable Optical Add Drop Multiplexer (ROADM) is used to drop a user defined wavelength from the line in the second system. The signal after dropping wavelength is again passed through the same transmission channel. The remaining wavelength is propagated over the main transmission of length 50Km.

The utility of ROADM is shown as the wavelength that is dropped at the intermediate node is also made available at the output. It proves that ROADM can be made to route the signal at various nodes without significant loss in the signal strength. The system for dropping wavelength is described using block diagram in figure 2. Similarly, in third system ROADM is used to add a user defined wavelength into the line. The line now contains five wavelength channels. The block diagram is depicted in Figure 3.

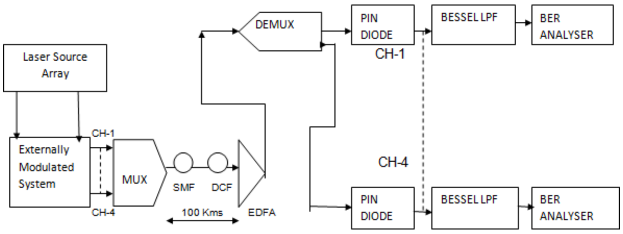

Figure 1: Block diagram representation of WDM system without add/drop of wavelength channel

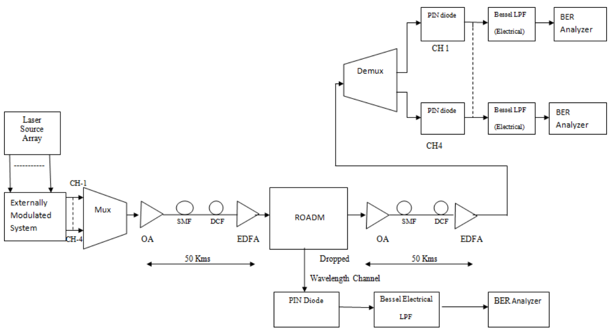

Figure 2: Block diagram representation of WDM system for dropping of wavelength channel

A demultiplexer is deployed to demultiplex the user defined number of WDM channels. The receiver consists of photo-diodes and electrical filters.PIN diode is used as photo diode. A low-pass Bessel filter is used as the electrical filter with cutoff frequency equals to 0.75 times the bit rate. Then bit error rate (BER) analyzers were used as the visualizer to generate graphs and results such as eye diagram, BER and Q-factor.

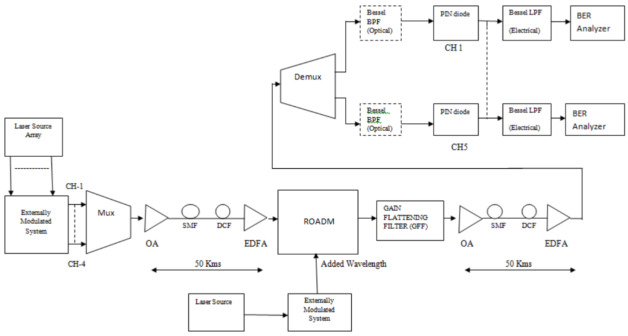

Figure 3: Block diagram representation of WDM system for addition of wavelength channel

III. RESULTS ANDSIMULATION

In order to simulate the block diagrams mentioned in the system description section a simulator Opti-system is used. In this section three case are discussed, in first case the WDM system without add/drop of wavelength channels is discussed, in second & third case the WDM systems with dropping/addition of wavelength channel are discussed by keeping the parameters same as were in the first case and both the output are compared with first case output and methods are proposed to improve theoutput.

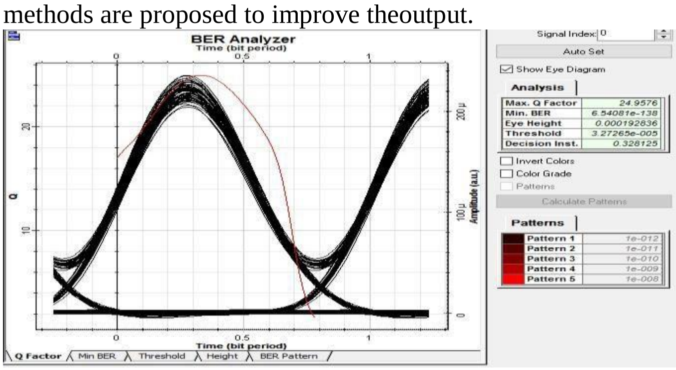

Figure 4:Performanve of worst effected channel in terms ofQ-factor

WDM System without add/drop of wavelength channels: The implementation of the block diagram discussed earlier is done using Optisystem simulator. Four frequencies taken at 193.1, 193.2, 193.3, 193.4 THz after being modulated with RZ modulation format using Mach-Zhender modulator are multiplexed into an optical fiber of 100 km and is demultiplexed using WDM demultiplexer. The BER analyzer shows the output of each wavelengthchannel.

The parameters used in the above simulation are shown in Table 1.The worst effected channel is shown in Figure 4 and

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the Q factor of all the wavelength channels is shown in tabulated manner in Table 2.

Table 1: Baseline Parameters

S. no.	Parameters	Symbol	Baseline value
1	Power	P	1mW
2	Line width (CW laser)		0.1 MHz
3	Modulation format		RZ
4	Bit rate	B	10 and 25 Gbit/s
5	Effective area (SMF)	Aeff	80 μm^2
6	Dispersion (SMF)	D	17 ps/nm/km
7	Attenuation (SMF	α	0.2 dB/km
8	Length (SMF)	L	100km
9	Effective area (D	Aeff	22 μm^2
10	Dispersion (DC	D	-85ps/nm/km
11	Attenuation (D	α	0.5 dB/km
12	Length (DC)	L	20 km
13	Gain (EDFA)	G	According to the attenuation losses
14	Noise figure (EDFA)		According to the attenuation losses
15	PIN diode responsivity	R	1 A/W
16	Threshold quality factor	Q	6
17	Min. acceptable bit error rate	BER	10^{-9}
18	WDM grid C-band		191.1 to 191.4THz

Table 2: Q factor information at output

S. no.	Frequency	Power	Q-Factor
1	193.1 THz	1 mw	24.95
2	193.2 THz	1 mw	29.98
3	193.3 THz	1 mw	26.84
4	193.4 THz	1 mw	25.21

WDM system with Dropping of wavelength: This case discusses the simulation of WDM system with dropped wavelength and the functioning of ROADM using a Optisystem simulator. Four frequencies taken at 193.1, 193.2, 193.3, 193.4 THz after being modulated with RZ modulation format using Mach-Zhender modulator are multiplexed into an optical fiber of 50 km and is a wavelength (193.1 THz) is dropped at an intermediate node using ROADM. After dropping wavelength channel another optical fiber of 50 km is used and the signal is de multiplexed and output is taken on a BER Analyzer. So a 100km distance is covered in two spans of 50 km each separated by an ROADM.The dropping of wavelength is done by using ROADM. The structure of ROADM is explained in[8] and dropped wavelength is shown in the Figure 5

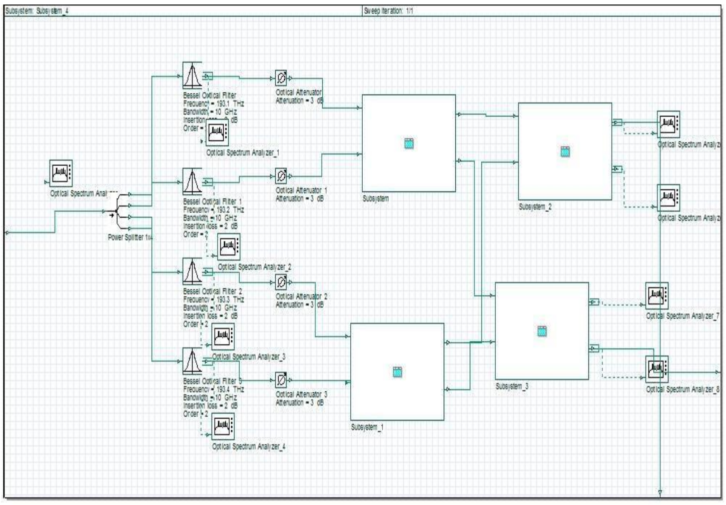

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Figure 5: Structure of ROADM dropping a wavelength channel

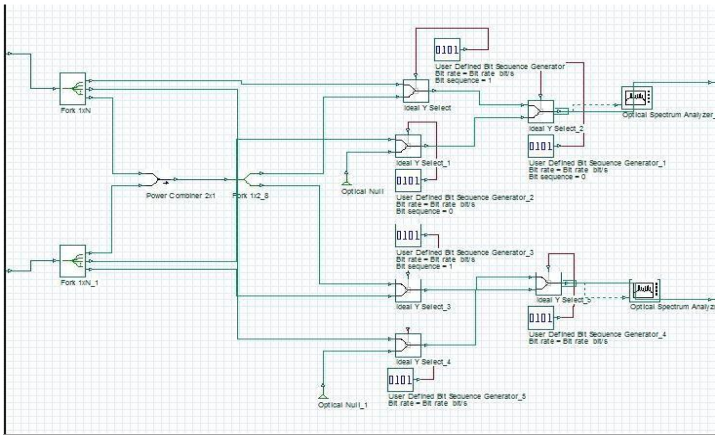

Figure 6: Structure of subsystem used in ROADM

The worst effected channel is shown in figure 7 and the Q factor and BER of all the wavelength channels is shown in Table 3.

The parameters are kept same as used in the first case without add/drop of wavelength channels. The output is heavily distorted.

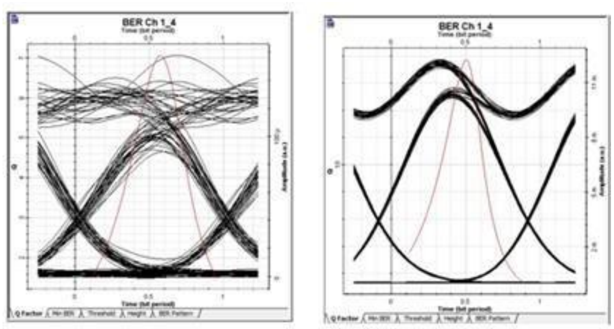

Figure 7: Comparison of worst effect channels of dropping of wavelength channels with original parameters(a) and new parameters(b).

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Hence an improvement is made in the above simulation structure by introducing optical amplifier of gain 10 dB and noise figure of 4 dB along the transmission line optical fiber.The transmitted power is also increased from 1mw to 3mw in every case. The worst-case outputs in both cases are shown in figure 7. A comparison is made on the basis of Q factor and BER in both case and is shown in tabular manner

Table 3: Comparison between the Q-Factor and BER of both cases

S. no.	Frequency	Q-Factor (Without changing parameters)	BER (Without changing parameters)	Q-Factor (With parameter change)	BER (With parameter change)
1	193.1 THz	7.548	$\sim 10^{-14}$	18.054	$\sim 10^{-73}$
2	193.2 THz	7.231	$\sim 10^{-13}$	18.040	$\sim 10^{-73}$
3	193.3 THz	7.606	$\sim 10^{-15}$	19.730	$\sim 10^{-87}$
4	193.4 THz	7.059	$\sim 10^{-13}$	17.737	$\sim 10^{-71}$

As, it is clearly seen by comparing both the worst effected channels, the output in the latter case is improved as compared as compared with the former.
Also, the table clearly shows the improvement in Q-factor and BER with changed parameters. The results got by changing the parameters are improved than the results got by keeping the parametersunchanged.

WDM system with addition of wavelength: This case discusses the simulation of WDM system with added wavelength and the functioning of ROADM using a Optisystem simulator. Four frequencies taken at 193.1, 193.2, 193.3, 193.4 THz after being modulated with RZ modulation format using Mach-Zehnder modulator are multiplexed into an optical fibre of 50 kmand isa wavelength (193.5 THz) is added at an intermediate node using ROADM. After adding wavelength channel another optical fiber of 50 km is used and the signal is de multiplexed and output is taken on a BER Analyzer. The line now contains 5 channels and the outputs are taken on the BER analyzer.The parameters used are kept same as in the first case to compare the worst effected channels in bothcases.

The addition of wavelength is done by using ROADM. One of the four outputs of ROADM is made to contain all the four inputs and with the help of mux demux combination wavelength channel is added and the total channels on the line become five. The structure of ROADM[5] adding wavelength is shown in the figure 8.

The above parameters are same as used in the first case without add/drop of wavelength channels. The output is heavily distorted as shown in figure 10 (a).
The reason for the decrease in the performance are regarded a crosstalk, power excursions at high frequencies and insertion losses[9-13]. Hence an improvement is made in the above simulation structure by introducing optical amplifier along with optical fiber. The transmitted power is also increased from 1mw to 4mw in every case. The signal added has higher power levels than the corresponding wavelengths travelling along the line. A gain flattening filter is used to reduce the power levels of the added wavelength. A comparison is made between the wavelengths with and without GFFs is shown in the figure 9. The overall output is still distorted and further Bessel optical filter and a preamplifier is attached at the output. The worst case outputs in both cases is shown in figure 10 . A comparison is made on the basis of Q factor in both case and is shown in table 4

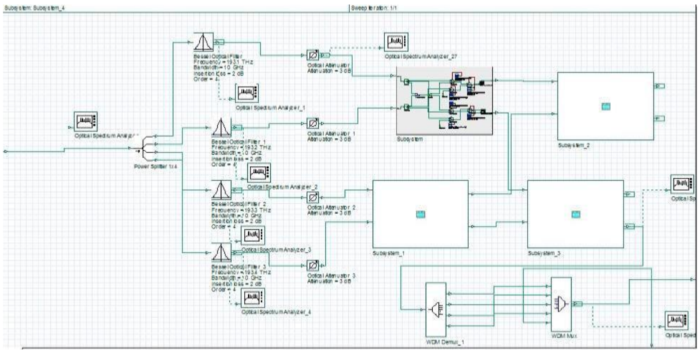

Figure 8: Optisystem representation of WDM system with no add/drop of wavelength channels

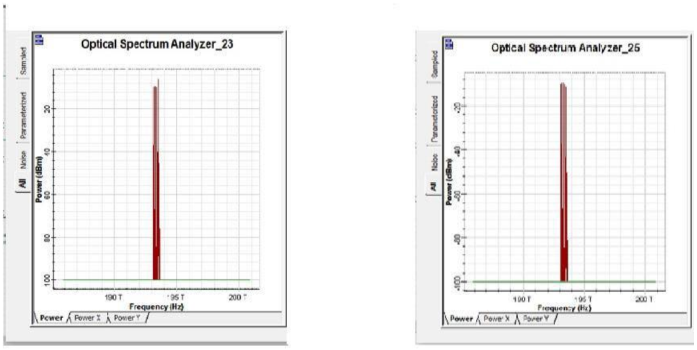

Figure 9: Comparison of output of ROADM before (a) and after (b) using gain flattening filter.

Table 4: Comparison between the Q-Factor and BER of both cases

S. no.	Frequency	Q-Factor (Without changing parameters)	BER (Without changing parameters)	Q-Factor (With parameter change)	BER (With parameter change)
1	193.1 THz	3.214	0.00063	13.615	$\sim 10^{-42}$
2	193.2 THz	3.149	0.00078	14.472	$\sim 10^{-48}$
3	193.3 THz	3.212	0.00062	14.59	$\sim 10^{-48}$
4	193.4 THz	2.867	0.00192	13.983	$\sim 10^{-45}$

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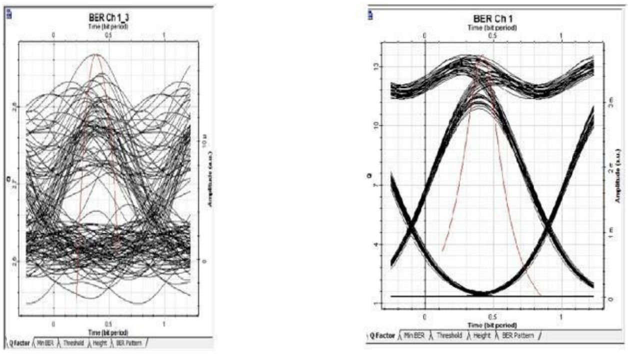

Figure 10: Comparison of worst effect channels of adding of wavelength channels with original parameters (a) and new parameters(b)

IV.CONCLUSION

From the proposed theory, it has been clearly shown that the output response of the WDM system without add/drop of wavelength channel is better than the WDM system with add and drop of wavelength channels keeping all the parameters constant in all the three cases. When wavelength channels were added or dropped in the WDM system, the system experienced crosstalk, insertion losses and power excursions due to which the overall performance of the WDM system degraded giving rise to distorted output. To improve the output of the WDM system in drop case the transmitted power was increased and optical amplifiers were introduced and similarly to improve the output of the WDM system in add case the transmitted power was increased optical amplifiers, GFFs, Optical Bessel filter and pre-amplifier (EDFA) were introduced. The strength of the signal decreases as it progresses in the optical fiber, to increase the strength of the signal the transmitted power in the both the cases of add/drop wavelength channel is increased and optical amplifier is introduced to tackle the decreased signal strength. The wavelength channel added has very high-power levels and such a high power adversely affects the other travelling wavelengths along the line. Hence a Gain Flattening Filter is used to reduce the power levels of newly added wavelength and to make them equal to the power levels of the other wavelengths. In case of the adding wavelength the overall signal levels at the receiving end multiplexer goes very low. Hence an optical Bessel filter along with an EDFA is introduced to further increase the power levels. So, with the performance analysis done in this paper future work can be inferred for using the ROADMs for a distortion free long haul transparent optical network. The length of the SMF is taken 100 km which can be increased further for future research. This paper provides a basis for predicting the behavior of the long haul optical transparent network using ROADMs and simulates the ROADMs with a single wavelength channel added or dropped which can be enhanced further with more than one wavelength channelsimultaneously.

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