

# Optimization of OADM DWDM Ring Optical Network using Various Modulation Formats

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**Abstract**—In this paper, the performance of the ring optical network is analyzed at bit rate 2.5 Gbps and 5 Gbps for various modulation formats such as NRZ rectangular, NRZ raised cosine, RZ soliton, RZ super Gaussian, RZ raised cosine and RZ rectangular. The effect of insertion losses is analyzed. It is observed that RZ Soliton performs better than all other formats and using this scheme system can exist up to 95 dB insertion loss. It has been observed that there is a rise in the system performance for NRZ rectangular and RZ soliton formats after 10 GHz bandwidth.

**Keywords**—NRZ; RZ; OADM; WDM; ADM; ROADM; PRBS

## I. INTRODUCTION

With the increasing requirement of bandwidth expansion & higher data rates, the network providers are moving towards the Optical Communication. Therefore, DWDM technology is developed to support tremendous bandwidth. An OADM drops one or more pre-selected wavelengths from the multi-wavelength signal entering the input fiber followed by adding of one or more pre-selected wavelengths into the multi-wavelength signal that exits from an output fiber. An optical add-drop multiplexer can be referred as certain kind of optical cross-connect [1,2].

In WDM ring network, the devices are connected in a circularly manner. Each node in this network works as a repeater and works under same protocol. The rings formed can be unidirectional or bidirectional depending upon the flow of data. In case of a unidirectional ring, a failure may occur due to breaking of cable or other damages in cable and thus may disrupt the signal flow. In case of bidirectional ring, no such failure occurs and the signal continues to travel even if cable breakdown occurs [3,4]. The most widely used fiber optical ring network is SONET (Synchronous optical network) which consists of bidirectional ring. Wavelength Division Multiplexing (WDM) is used in SONET ring. Even with the increase in online users, the data transfer rate does not get affected in WDM [5,6].

Add Drop Multiplexers (ADMs) are network elements that are used to bypass traffic through different nodes. Electronic ADMs indeed are very costly; thus, Optical Add-Drop Multiplexers (OADM) was introduced to cut down the cost. OADM can also be referred as wavelength add-drop multiplexers (WADM). With the use of OADMs, cost of network can be decreased as number of ADMs needed in the network decreases [7,8]. The WDM ring is presented in Fig. 1.

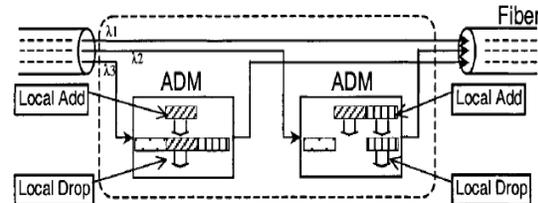


Fig. 1. WDM ring network

An OADM is a device which is employed to be used in WDM systems. OADMs are used for selecting the paths for different light channels entering or exiting a single mode fiber. “Add” here means to add new wavelength channels to the WDM signal and “Drop” means to remove the channels [9,10,11]. The internal structure of OADM system is presented in Fig. 2.

There are three stages in OADM. These are de-multiplexer, multiplexer and path between them used for adding or dropping signals. The de-multiplexer is used to separate the input signal in different wavelengths. The multiplexer is used to multiplex the wavelength from de-multiplexer and add port [12,13].

In Reconfigurable Optical Add-Drop Multiplexer (ROADM), Wavelength selective switching module is used to switch traffic from a WDM system at the wavelength layer. ROADM allows adding and dropping of channels in fiber without the need of converting it to electronic signal and then to optical signal [14,15].

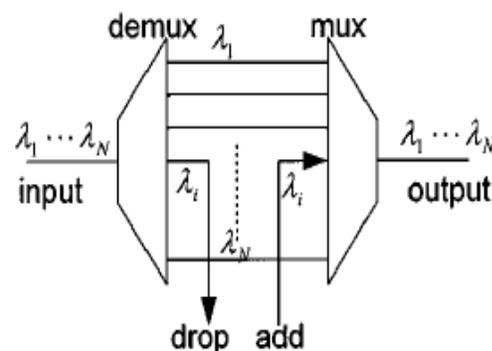


Fig. 2. Internal structure of OADM [1]

## II. RELATED WORK

R.Randhawa et al. [16] investigated and compared the various network topologies. Analysis is done with the signal, as it passes through each node in each of the network topology. It was found that in case of ring topology, there was no detectable signal degradation in the ring network. An increase in quality factor was found in a ring network. In the case of bus topology, it was observed that with the increased number of nodes, the quality of signal decreases and the power penalty increases. For the star topology, it was observed that the received power values of each node at a same distance from the hub are same and performance was also same. The performance of tree topology was almost indistinguishable to the performance of the ring topology.

A.Sheetal et al. [17] presented the simulation analysis of 40 Gbps long haul DWDM System with enormous capacity up to 1.28Tb/s. The simulations were done for Carrier-Suppressed Return-to-Zero (CSRZ), Duobinary Return to-Zero (DRZ) and Modified Duobinary Return-to-Zero (MDRZ) modulation formats. A modified modulation format MDRZ was presented in the paper. A maximum transmission distance of 1450 km for 32 channels DWDM system was obtained with MDRZ modulation format using symmetric compensation.

Dhiman et al. [18] investigated different modulation formats for four-channel WDM CATV system with OADM. The impact of wavelength and frequency on eye opening and Q-value was observed for added & dropped channels at various length spans.

Sharma et al. [19] studied 16 wavelengths with channel spacing of 0.4 nm on unidirectional non-linear single mode fiber for 10 Gbps. The evaluation of the system was observed using different modulation formats such as RZ, NRZ, DPSK and CRZ using design parameters, namely, BER, eye diagram and Q<sup>2</sup>dB. It was observed that CRZ modulation capable of achieving BER of  $e^{-27}$  and Q factor in the range of 20.3.

S. Bang et al. [20] demonstrated the Q factor performance resulting from CPM and FWM effects for the signaling formats like NRZ, RZ, DPSK and the RZ-Soliton. It was found that RZ-Soliton was most efficient among all data formats used for 16 channel DWDM systems. It was also determined from the simulation results that DPSK signal is least affected by the generated FWM. It was concluded that DPSK signaling format was reliable for transmission of fiber.

## III. MODULATION FORMATS

Various modulation formats are discussed as follows:

1) *NRZ Rectangular*: Depending upon the transmitted bit, an electrical output signal is obtained. When the input bit is '1', the output signal remains at the low level during the entire bit time and when input bit is '0', the output signal remains at high level during entire bit time.

2) *NRZ Raised Cosine*: It is same as NRZ rectangular, the only difference is that in this case the signal is forced to return to zero level at the end of each bit even if the two consecutive bits are '1'.

3) *RZ Rectangular*: In this case, the output signal has two electrical levels. When '1' is applied as input signal, a high is obtained at output for time period with the value of bit time multiplied with duty cycle and for the remaining time the output goes low. When '0' is applied as input signal the output remains low for the entire bit time.

4) *RZ Raised Cosine*: This is same as RZ rectangular modulation, the only difference is that the switching between the two levels i.e. high and low is not instantaneous. It has a raised cosine shape.

5) *RZ Super gaussian*: When '1' is applied as input, a super gaussian shaped pulse is obtained at the output and when '0' is applied as input, a low level signal is obtained at the output.

6) *RZ Soliton*: When '1' is applied as input a soliton shaped pulse is obtained at the output and when '0' is applied as input, a low level signal is obtained at the output.

## IV. SIMULATION ENVIRONMENT

The block diagram of simulation setup is presented in Fig. 3. It is a 36-node ring network with one channel being added or dropped at each node. In order to analyze the network; performance parameters namely Q-factor, BER, and optical spectrum analyzer is provided at each node. The input source is low noise signal which is further connected to OADM. OADM is used to add and drop frequency at each node. The two nodes are connected by a fiber channel. A Single mode fiber of 100 km span having dispersion of 16 ps/nm/km and dispersion compensation fiber of 20 km span having dispersion of 80 ps/nm/km is utilized in the simulation. A semiconductor optical amplifier is used to boost the signal. Here the saturation power of SOA is set to 9.14 mw and the insertion loss at input and output is 3 dB. Since it is a ring network, all the frequencies are connected circularly such that frequency  $f_1$  of node 1 is added and frequency  $f_{36}$  of node 36 is dropped and at next node  $f_3$  is added and  $f_1$  is dropped. The reference frequency is 193 and simulation is done at this frequency at bit rate 10 Gbps. The laser power for OADM is 0 dBm. PRBS sequence degree is 7, crosstalk is fixed at -90 dB and bandwidth of filter is 8 GHz.

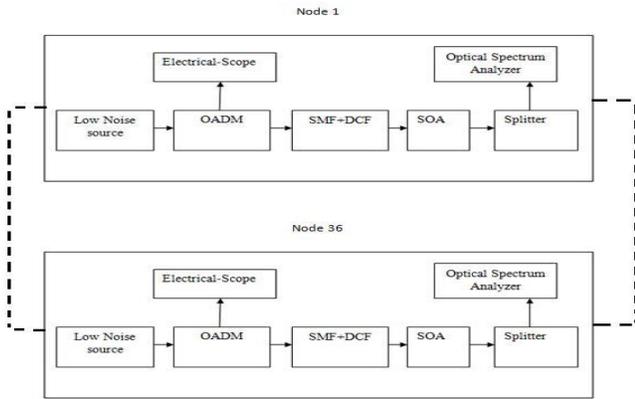


Fig. 3. Block diagram of simulation setup

### V. SIMULATION RESULTS

The simulation setup is analyzed at four different bandwidths of OADM such as 5, 10, 15 & 20 GHz. The results are analyzed for different modulation formats such as NRZ raised cosine, NRZ rectangular, RZ soliton, RZ super Gaussian, RZ raised cosine and RZ rectangular. The simulation results are presented in Fig. 4 to Fig. 11.

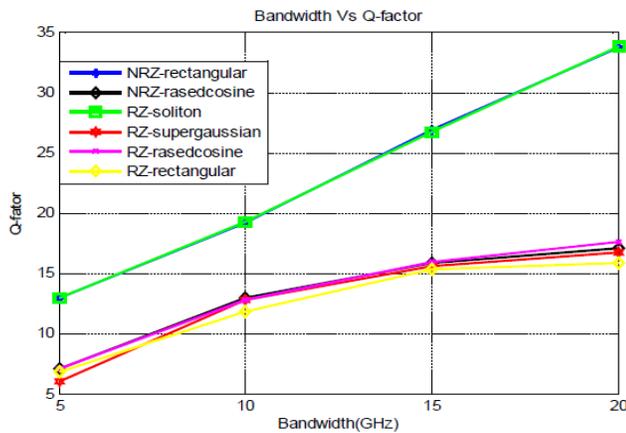


Fig. 4. Bandwidth versus Q-factor for 2.5 Gbps

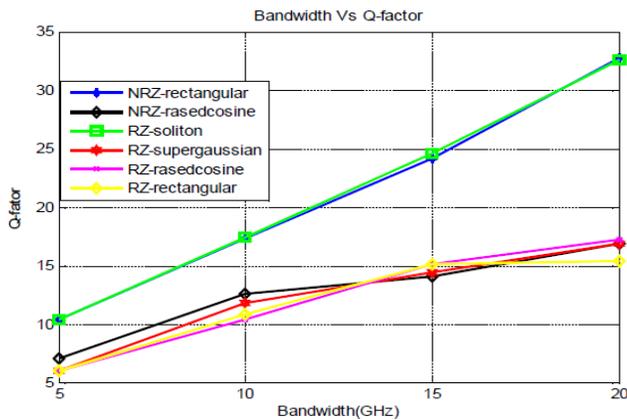


Fig. 5. Bandwidth versus Q-factor for 5 Gbps

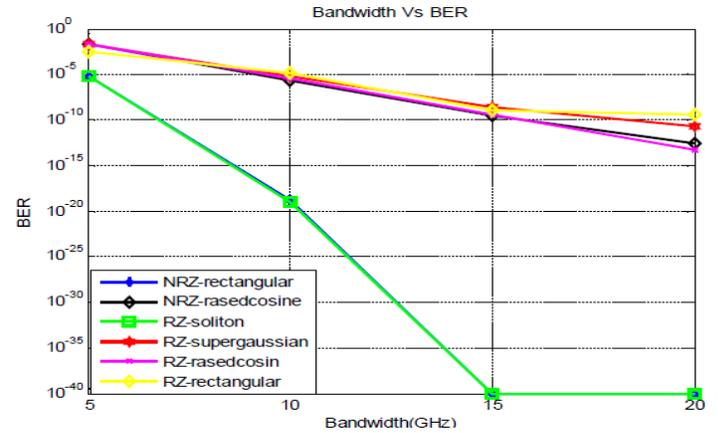


Fig. 6. Bandwidth versus BER for 2.5 Gbps

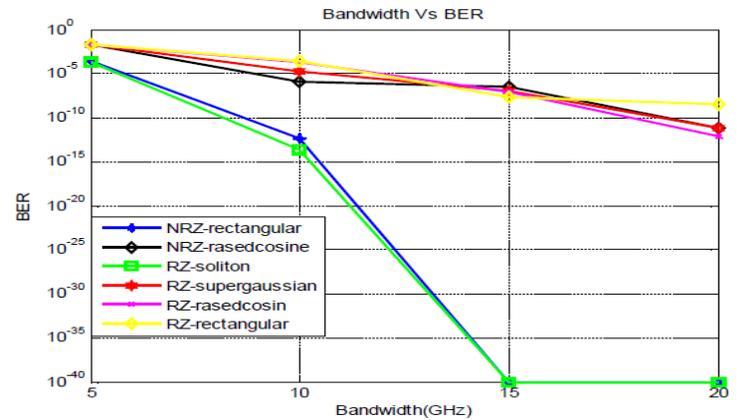


Fig. 7. Bandwidth versus BER for 5 Gbps

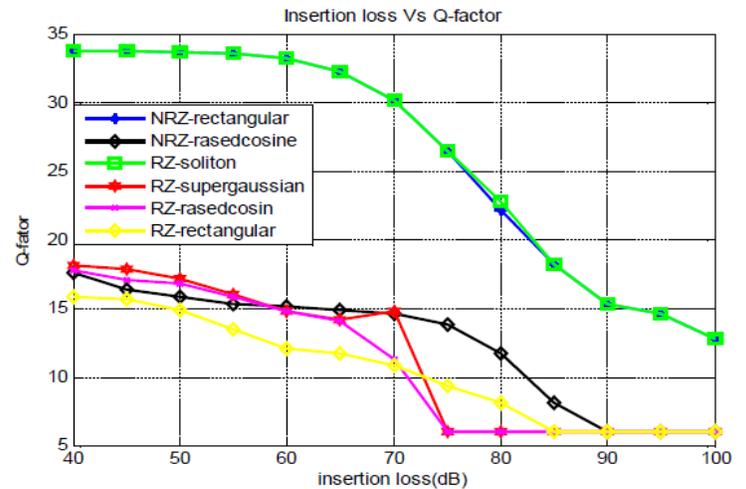


Fig. 8. Insertion loss versus Q-factor for 2.5 Gbps

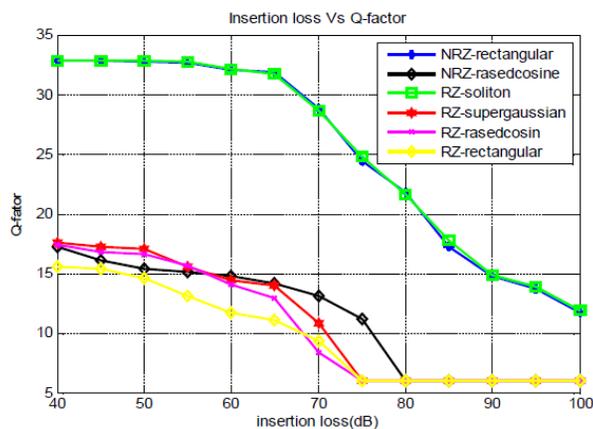


Fig. 9. Insertion loss versus Q-factor for 5 Gbps

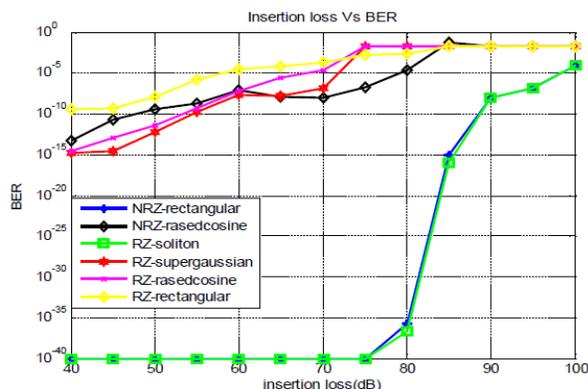


Fig. 10. Insertion loss versus BER for 2.5 Gbps

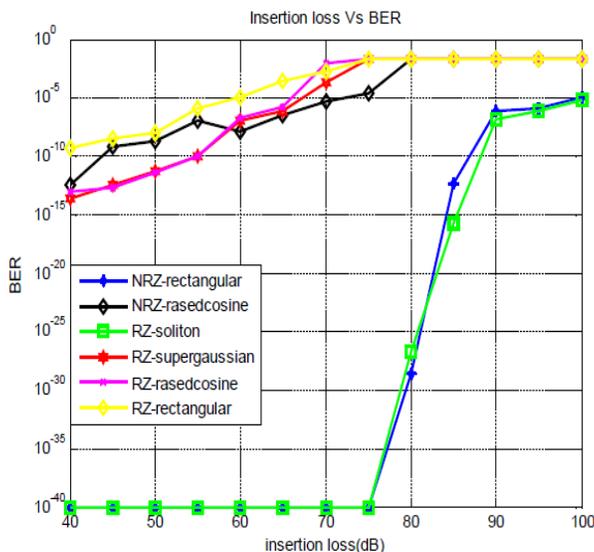


Fig. 11. Insertion loss versus BER for 5 Gbps

## VI. DISCUSSION

The simulation results at 2.5 Gbps & 5 Gbps for Q-factor versus Bandwidth at different modulation formats are presented in Fig. 4 to Fig. 5 and Bandwidth versus BER are presented in Fig.6 and Fig. 7. NRZ rectangular and RZ soliton were observed to be better as compared to other modulation

formats. Q-factor of 33.6 dB was observed for NRZ rectangular modulation format and was observed to be 33.56 Db for RZ soliton modulation format for 20 GHz. The value of BER (bit rate error) for NRZ rectangular and RZ soliton is  $1.6e^{-19}$  and  $2.1e^{-14}$  respectively. It is observed from Fig. 5 that the Q factor reduces with increase in bit rate from 2.5 Gbps to 5 Gbps. Reduced Q factor value was observed to be 31.79 dB for NRZ rectangular modulation format and was observed to be 32.55 dB for RZ soliton modulation format for 20 GHz bandwidth. The value of BER for NRZ rectangular and RZ soliton is  $4.2 e^{-13}$  and  $2.1e^{-12}$  respectively. The simulation results at 2.5 Gbps & 5 Gbps comparison of Insertion Loss versus Q-factor for different modulation formats are presented in Fig.8 to Fig. 9 and Insertion Loss v/s BER are presented in Fig.10 and Fig. 11. It is observed from Fig. 8 and Fig. 9 that the value of Q factor for NRZ rectangular format and RZ soliton is 33.69 dB for insertion loss of 40 dB and these modulation formats have survivable BER up to insertion loss of 90 dB. It is observed from Fig. 10 and Fig. 11 that the Q factor is 32.79 and 32.82 for NRZ rectangular and RZ soliton modulation format respectively for insertion loss of 40 dB and these modulation formats have survival BER up to 85 dB.

## VII. CONCLUSION

The performance of the ring optical network was analyzed at bit rate of 2.5 Gbps and 5 Gbps for various modulation formats. It was observed that the system could exist for 2.5 Gbps and 5 Gbps for RZ soliton and NRZ rectangular format at bandwidth less than 10 GHz. It was observed from the results that the quality of the signal was degraded as the frequency increased from 10 GHz, also, the value of Q factor and BER increases for RZ soliton and NRZ rectangular formats. Also, it was observed that 90 dB of insertion loss can be achieved for a system.

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