Application Specific DWDM System Optimization for High Speed Transmission

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***Abstract*-The tremendous growth of the field of telecommunication has created increasing demand on high capacity optical communication networks. Wavelength-division multiplexing (WDM) techniques provide many advantages for building high capacity optical networks. Dense Wavelength Division Multiplexing (DWDM) has the same concept as WDM but the spacing between the channels in DWDM is closer than does in WDM. To satisfy the ever increasing traffic demand, and to utilize the available fiber bandwidth, a valid approach for improving the transmission capacity is to scale WDM channel spacing to high dense dimensions so as to meet the application requirements. Therefore an iterative analysis is done in this paper to obtain an optimized DWDM system in terms of data rate, channel spacing and number of channels. The simulation results have shown that the minimum channel spacing for 20 Gbps, 32 channel system need to be not less than 0.35 nm and that for a 20 Gbps, 64 channel system it should be not less than 0.4 nm. The simulation is done using OptSim 5.3 version.**

Keywords: - Bit Error Rate, Dense Wavelength Division Multiplexing

I. INTRODUCTION

Innovations in optical fiber technology are enabling transmission of high-speed signals over transcontinental distances without the need for electronic regeneration. It has thus given thrust to networks or systems with higher capacities and at lower costs. To fulfill the enormously increasing capacity requirements especially in long haul optical link communications, it has become imperative to increase the number of channels as well as the data rate per channel. Dense wavelength division multiplexing (DWDM) is an extension of optical networking[2]. The use of ultra-high bit rate channels for DWDM transmission is an attractive approach in increasing the capacity of future optical networks. In order to maximize the system capacity and to minimize the performance degradation caused by reduced channel spacing, the system needs to be investigated by increasing the number of channels at high bit rates. DWDM devices combine the output from several optical transmitters for transmission across a single optical fiber. At the receiving end, another DWDM device separates the combined optical signals and passes each channel to an optical receiver. A key advantage to DWDM is that it's protocol and bit-rate independent. Degradation of the digital signal, caused by the transmission channel, may be recognized and measured using eye diagrams[3].The technology of Erbium Doped Fiber Amplifier also plays a key technology which is capable of overcoming the limitations due to power losses within the channel[4].

The need for DWDM system is application dependent with varying parameters like signal data rate and number of users. Applications like terrestrial, undersea networks and wireless optical communication system for personal area networking demands high speed transmission.

All the previous research work reported on WDM systems is targeted for data rate of less than 10Gbps, as Bobrovs [5] reported that the minimal channel interval for 2.5Gbit/s High Density WDM system should be more than 0.2 nm, and for 10Gbit/s system not less than 0.3 nm. H. Suzuki et al. in [3] reported that 512 channels of 2.5Gbps signal spaced at 12.5 GHz (0.1 nm) could be transmitted over 320 km of single-mode fiber (SMF).

In this paper a DWDM system was designed and analyzed for three channel numbers of 16, 32 and 64. For each of the these three system, the output was analyzed by varying the bit rate by 5Gb/s, 10Gb/s and 20Gb/s and channel spacing by 30GHz, 40GHz and 50GHz.The work is done to obtain a system with optimum characteristics for high speed applications using a simulation software tool of Optsim version 5.3 developed by RSoft

II. SYSTEM ARCHITECTURE

The block diagram of DWDM is shown in Fig. 1 in which, each of data signals are modulated with lasers of different wavelength and then multiplexed onto an optical fiber for different channel spacing. For the detection of all the data signals, the multiplexed signal is passed through an optical demultiplexer after which each of these signals are given to a number of photo detectors which are highly sensitive. Before detecting the optical wavelengths they are filtered through an optical filter. The electrical signal is perfectly filtered to avoid the accumulated noise and then the signals are given to spectrum analyzers. The experimental transmission system employs several optical channels with external intensity modulation (IM), and

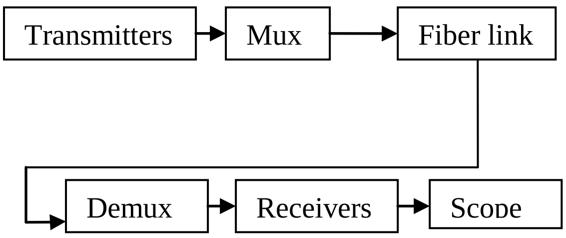


Fig.1: DWDM block diagram

non-return-to-zero (NRZ) pulse shapes. The laser is always switched on and its lightwaves are modulated via the electro-optic Mach-Zender (MZ) modulator by data pulse sequence output of a pseudo random bit sequence generator (PRBS), using the principles of interferometric constructive and destructive interference to present ON and OFF of the lightwaves. In the receiver section the optical signal is first passed through an optical filter. The optical filter employed is raised cosine optical filter which filters out the specified wavelength from the optical signal that is added up with the noise in the channel. The filtered optical signal is then converted to corresponding electrical signal by a photodetector. For high selectivity, the high sensitivity PIN diode is used as the detector. In PIN diode the output current generated by the photodetector depends on the input optical power and on the dark current. For accurate detection the electrical output signal is further filtered out by a Guassian filter. The link in use is normal Single Mode fiber of varying distances maximum up to 80 km.

A scope is used to view the eye diagram and BER of the signal demodulated by the PIN diode. While eye diagrams provide an accessible and intuitive view of parametric performance, systems ultimately are judged on their ability to pass bits faithfully, and without error. The BER, Bit Error Ratio, or Bit Error Rate as it is sometimes called, is a ratio of the number of bits received incorrectly (errors) divided by the total number of bits received. This provides an overall score for how well a system is performing.

III. SIMULATION MODELING

The simulation is done for 16, 32, and 64 channel system and the simulation layout of the 32 channel system is shown in the fig. 2. In each of the transmitter channel, NRZ modulation format is used with continuous wave laser operating at 193.4 THz frequency and modulated using a Mach-Zehnder modulator.The system is analyzed for a transmission distance of 80 km with fiber loss of 0.2 dB/km and the dispersion over the link is compensated using a dispersion compensating fiber. An Erbium doped fiber amplifier is used to overcome the limits due to attenuation with a gain of 20dB.

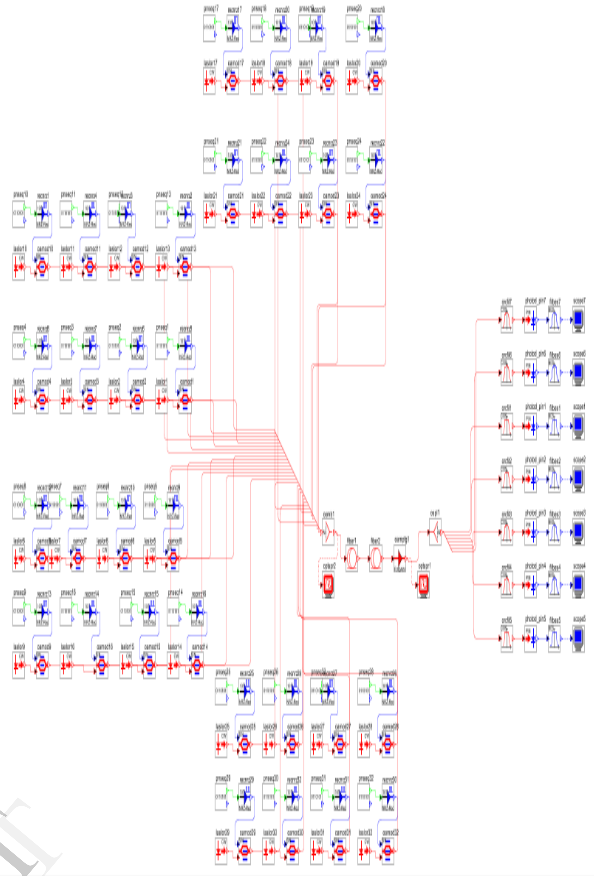


Fig. 2: Simulation layout of DWDM system

IV. RESULTS AND DISCUSSIONS

Bit error rate (BER) is the ratio between the number of bits received in error to the total number of bits received. In essence, BER is the probability of receiving a single bit in error. From the various results obtained the BER trend is studied for optimization.

Fig.3 shows the eye diagram obtained for a DWDM system with channel spacing of 50GHz and data rate of 5Gb/s with BER of 1e-040. The variation in BER is analyzed for a 50GHz DWDM system by varying the data rate by 5, 10 and 20Gb/s.

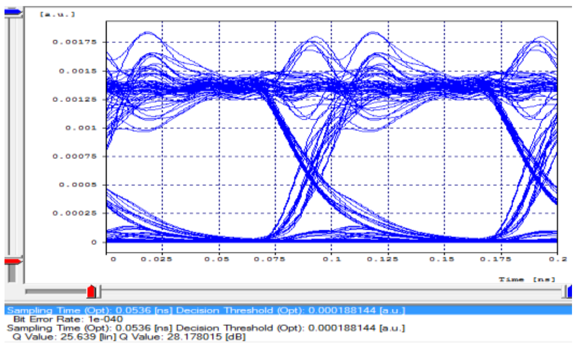


Fig. 3: Eye diagram for 50GHz ,5Gb/s DWDM system

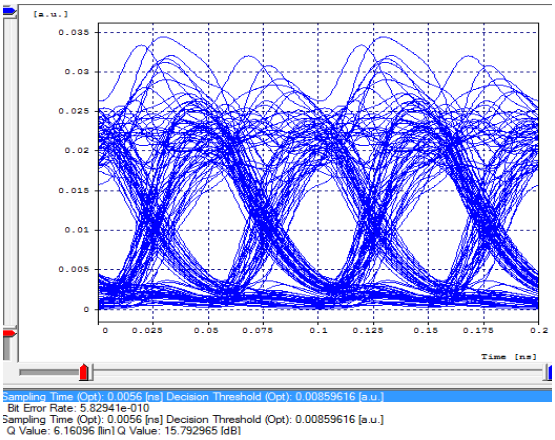


Fig. 4: Eye diagram for 30GHz ,32 channel DWDM system

Fig. 4 shows the eye diagram obtained for a 32 channel DWDM system with channel spacing of 30 GHz having BER of 5.82941e-010 The output of the system was analyzed in terms of BER by changing the number of channels from 16 to 32 and 64 channels.The analysis indicated that BER increases with number of channels.

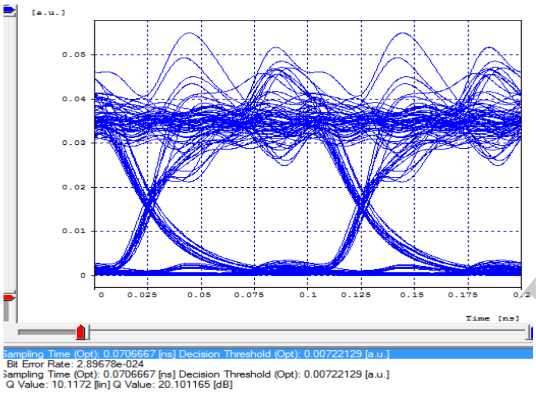


Fig. 5: Eye diagram for 40GHz, 5Gb/s DWDM system

Fig.5 shows the eye diagram obtained for a 40GHz system with a data rate of 5Gb/s having BER value of 2.89678e-024. By analysing the output obtained from DWDM systems with different channel spacing of 30GHz, 40GHz and 50GHz it was observed that the BER is low for system with large channel spacing.

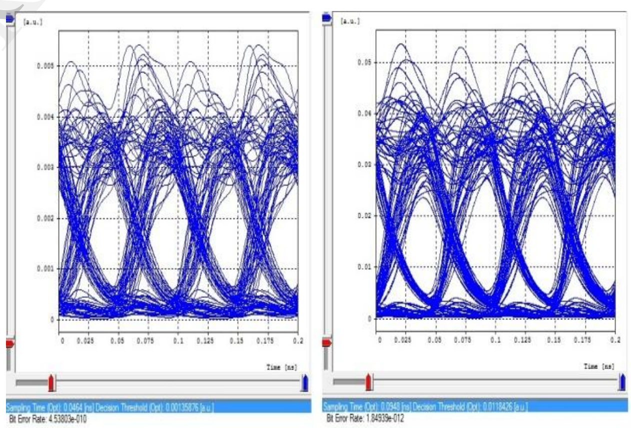
Table shown below represents the BER values obtained from the iterative analysis. The values are shown for all the three systems i.e, 16, 32 and 64 channels, which are analyzed for different data rates and channel spacing. The data rates that are employed for each of these systems are 5Gb/s, 10Gb/s and 20Gb/s. The spacing between the adjacent channels are arranged as 30GHz (0.25nm), 40GHz(0.35nm) and 50GHz(0.4nm). From the table the two optimized systems that can be taken are for 20Gb/s data rate.

TABLE I

BER TREND FOR VARIOUS BIT RATES AND CHANNEL SPACING

Data rate	30GHz spacing			40GHz spacing			50GHz spacing		
	16	32	64	16	32	64	16	32	64
5 Gb/s	2.42e-003	1.59e-002	2.27e-002	4.10e-018	2.71e-022	2.89e-024	1e-040	1e-040	8.779e-027
10 Gb/s	3.24e-003	4.43e-003	5.53e-003	1.49e-017	5.82e-010	7.31e-004	1.08e-029	3.32e-027	9.35e-011
20 Gb/s	1.12e-002	7.88e-003	1.87e-002	3.45e-015	4.53e-010	7.63e-004	1.58e-025	2.76e-018	1.849e-012

From the iterative analysis carried out to obtain the system with optimized capacity, it was observed that for applications requiring high speed communication and more number of users like 64, a DWDM system with 50 GHz channel spacing proved to give better performance.



(a) (b)

Figure 6: Eye diagrams obtained for the optimized system a) 32channel with 20Gb/s and 40GHz spacing b) 64 channel with 20 Gb/s and 50GHz spacing

For applications that require 20Gb/s datarate and 32 number of users it was observed that a 40GHz DWDM system was the optimized one which is shown in Fig. 6.

V. CONCLUSION

The DWDM system has been designed, simulated and the result was obtained by using OPTSIM software. In this paper an investigation was done to obtain a DWDM system that could support the traffic demands of high speed and more number of users.The results confirmed that for a 64 channel system with data rate of 20Gb/s the channel spacing should not be less than 50GHz and for a 32 channel system with 20Gb/s data rate the spacing should not be less than 40GHz. The analysis also confirmed that BER increses with increased data rate, number of channels and decreased channel spacing.

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