

Experimental Analysis of Dense Optical System using Optical Amplifier for High Transmission Capacity

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This paper has evaluated the performance of 120 channels dense wavelength division multiplexing (DWDM) system with power amplification from erbium-doped optical fiber amplifier (EDFA). Further, analysis has carried out with considering the varied channel spacing (0.9 nm to 0.1nm), varied communication distance (20 km to 120 km), and varied transmission data rate (6 Gbps to 16 Gbps) to maintain the required bit error rate (BER). Final analysis has recommended that transmission data rate of 6 Gbps is the suitable choice for varied channel spacing with EDFA to deliver the required signals characteristics, while rest of the transmission data rates has shown the worst response with decreasing the channel spacing.

Keywords: Bit Error Rate, Channel Spacing, Gain, Noise Figure, Dense Wavelength Division Multiplexing, Erbium-Doped Optical Fiber Amplifier

1 Introduction

Novel ideas and technologies are given the right platform to increase the optical communication applications for long distance without go thought signals regenerations. This has really given strong backbone to optical networks and systems for maintained high transmission data rate with reasonable cost.¹⁻⁴ Further, it has been very difficult to incorporate a greater number of channels in wavelength division multiplexing (WDM) system due to signals transmission go through electronics regenerator. Because each transmitting signal has been required separate electronics regenerator which was very costly and time-consuming approach. So, this has also been rectified with the support of dense wavelength division multiplexing (DWDM) system using optical amplifiers.⁵⁻⁷ Furthermore, various design and techniques have been recommended for high transmission capacity with mitigate the effect of fiber linear and nonlinear.

Bobrovs *et al.* examined the 12 channels DWDM system with the channel spacing of 0.3 nm for the data rate of 2.5 Gbps to get the least noise effect for 80 km distance. Further, this analysis has also been repeated for the data rate of 10 Gbps for the channel spacing of 0.2 nm for getting the same parameters.⁸

Jansen *et al.* have been investigated the features of 16 channels DWDM systems with the channels spacing of

100 GHz for suitable transmission distance with the support of single mode fiber (SMF).⁹ Further, desired results in terms of bit error rate (BER) has also achieved with the use of dispersion compensation fiber (DCF).

Suzuki *et al* demonstrated 100 channels dense communication system with channel spacing of 0.1 nm for the data rate of 2.5 Gbps.¹⁰ Further, this research has also been extended in the research works for raising the data rate for long distance communication.¹¹⁻¹⁴

Up to now, it is observed that all the above explored research work are only valid for less number of channel and no suitable techniques have been explored to raise the number of channels with good rating data rate for dense optical communication, which is most desirable for current end users.

So, this research work has shown acceptable approach to raise the high transmission data rate with cost acceptable manner for 120 channels. Further, recommended research work is organized in four sections. Section one is shown the limitations of published work. Section two is shown the descriptions of recommended model which further fed to final results and analysis in section three. Final evaluation is made in section four respectively.

2 Materials and Methods

2.1 Descriptions of Recommended Model

Recommended experimental with details information for analysis the high transmission capacity with the

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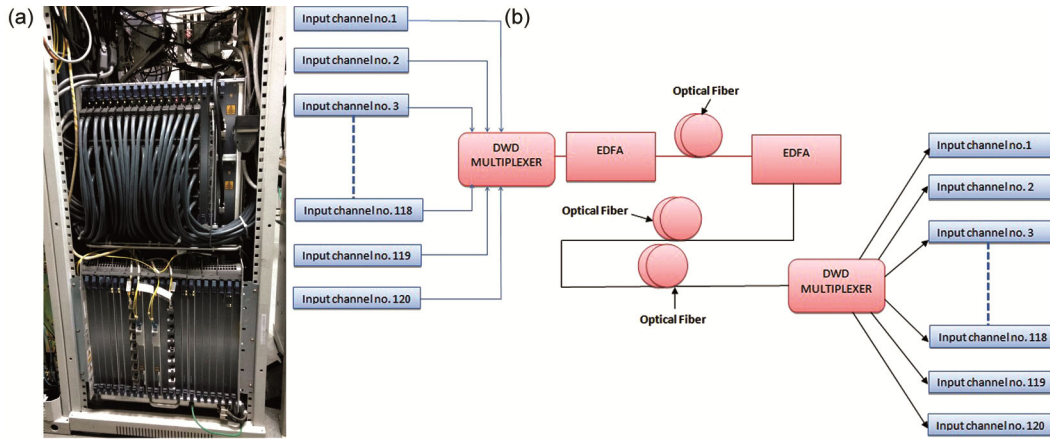


Fig. 1 — (a) Experimental setup for dense communication system, & (b) Model with details for high transmission capacity for dense communication system.

Table 1 — Features of EDFA for 120 channels dense multiplexing system

Feature	Value
Gain	39.11 dB
Noise Figure (F)	2.41 dB
Noise	Yes
Force Time Domain	No
Loss	1.22 ps/nm.km
Output Power	18.14 dBm

support of optical amplifier is shown in Fig. 1(a) and Fig. 1(b) for 120 transmitter channels. Initially suitable arrangement of channel spacing is arranged which later on varied as per research requirement. In the similar manner, data rate is also arranged at varied data rate for measuring the various characteristics of recommended model. Digital data generator, signal convertor, optical source, and signal modulator are the main components of the transmitter. Optical sources are operated for the wavelength range from 1544.1 nm to 1548.4 nm with the data format of RZ. Range of generated signals is maintained from -2.4 V to +2.4 V. High rating optical signal is come out from one transmitter set and same process is also repeated for rest of the transmitters. All the signals are combined with the support of dense multiplexer on the transmitter section. Erbium-doped optical fiber amplifier (EDFA) is placed in the middle of optical fiber to deliver the power. Further, basic features of EDFA are also arranged as per given Table 1.

On the other hand, optical signals on the receiver section are converted in original electrical domain with the help of optical converter and filter to analysis the outcomes from the recommended DWDM system. BER analyzer and eye diagram analyzer are also the main measuring components, which are used as per requirement.

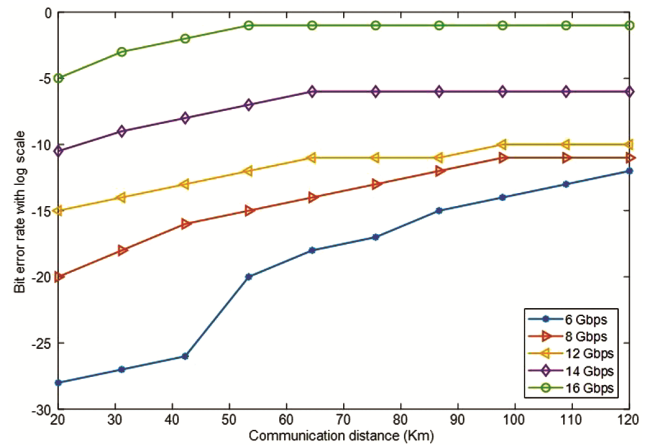


Fig. 2 — Bit error rate Vs communication distance.

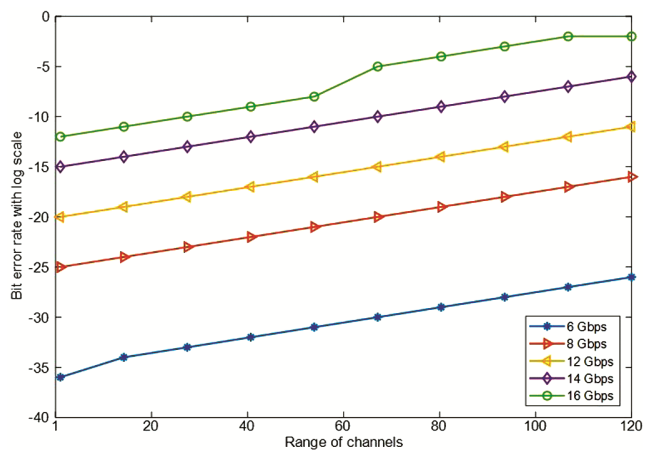


Fig. 3 — Bit error rate Vs range of channels.

3 Results and Discussions

Experimental results from the recommended model are analyzed and presented from Fig. 2 to Fig. 10 with different aspects of optical communication. Highly dominating losses in the optical communication

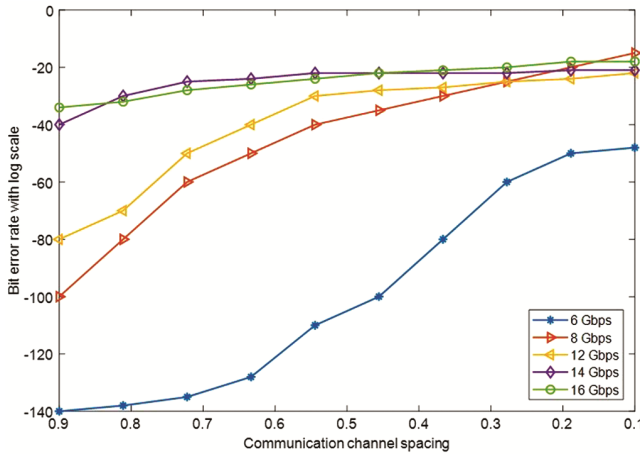


Fig. 4 — Bit error rate Vs communication channel spacing for varied transmission data rate.

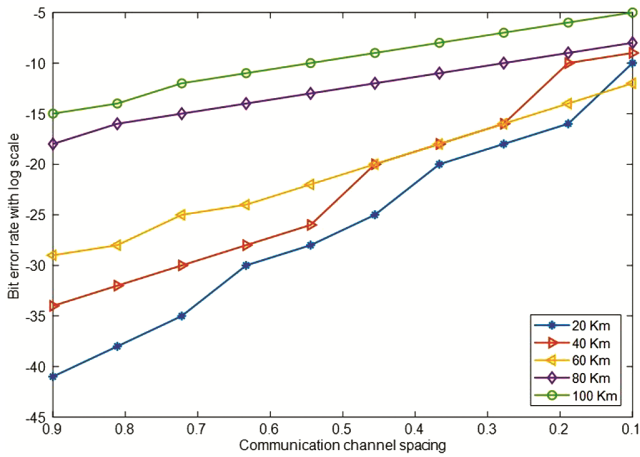


Fig. 5 — Bit error rate Vs communication channel spacing for varied communication distance.

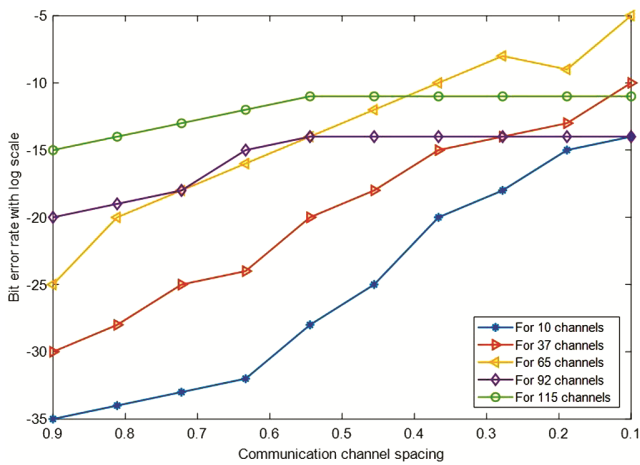


Fig. 6 — Bit error rate Vs communication channel spacing for varied number of channels.

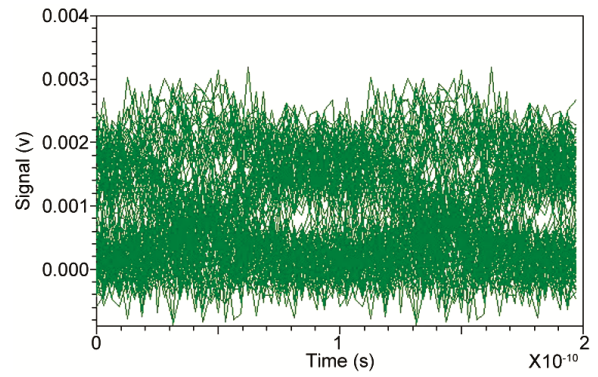


Fig. 7 — Eye diagram at 0.1 nm channel spacing.

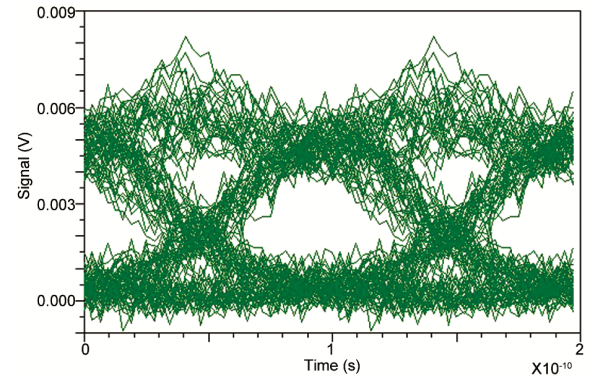


Fig. 8 — Eye diagram at 0.2 nm channel spacing.

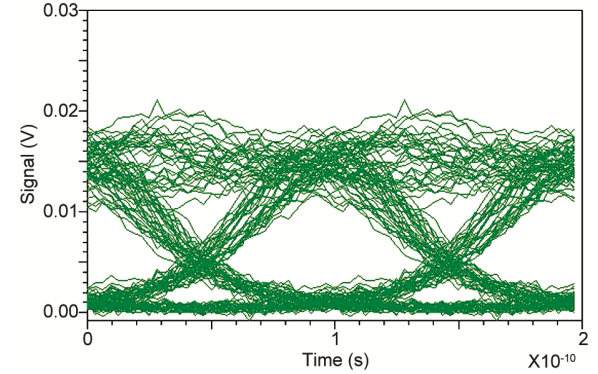


Fig. 9 — Eye diagram at 0.3 nm channel spacing.

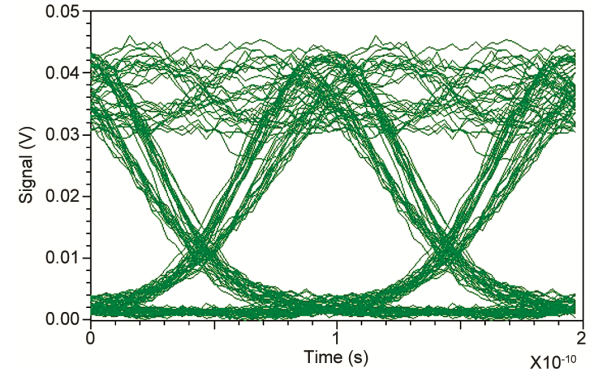


Fig. 10 — Eye diagram at 0.8 nm channel spacing.

medium are encountered the power strength of the signals resultantly, original signals are not traced out at the receiver section. In this way, good rating power injection is the main approach to retain the power level in terms of attain good rating of BER.

Fig. 2 is shown the outcomes in terms of BER for the communication distance from 20 km to 120 km for varying data rate from 6 Gbps to 16 Gbps respectively. Recorded values are given as -4.99 to -1 for 16 Gbps, -10.5 to -6 for 14 Gbps, -15 to -10 for 12 Gbps, -20 to -11 for 8 Gbps, and -28 to -12 for 6 Gbps. In the same way, same measuring feature for the channels range from 1 to 120 is analyzed and recorded values from fig.3 are given as -35.99 to -26 for 6 Gbps, -25 to -16 for 8 Gbps, -20 to -11 for 12 Gbps, -15 to -6 for 14 Gbps, and -12 to -2 for 16 Gbps. After go through the received values, it is shown that 6 Gbps is the acceptable rating data rate to maintain the least values of BER while as the transmitting data rate is increase above the 6 Gbps, values of the BER are also increase, which is not good indication for the dense communication.

Further, this research work is also extended with including the effect of channel spacing from 0.9 nm to 0.1 nm in Fig.4 to Fig.6. Suitable channel spacing is the major concern in dense optical communication to tolerate the effect of fiber nonlinearity and ISI. As the channel spacing is decrease, the evaluated values in terms of BER are also increase, which is also shown in Fig.4 for different rating data rate. This approach is also measured for different communication distances (20 km, 40 km, 60 km, 80 km, and 100 km), and random number of channels (for 10 channels, for 37 channels, for 65 channels, for 92 channels, and for 115 channels) in Fig.5 and Fig.6 respectively. Final analysis is recommended that 6 Gbps is the best most suitable data rate for recommended system with good rating power amplification from EDFA, while rest of the data rate is shown the high dominating losses with increasing the data rate. This is also fully justified with the recorded eye diagrams at different channel

spacing in Fig. 7 to Fig. 10 and recommended that decreasing in channel spacing shown the worst response for dense communication without the good rating of power amplifier.

4 Conclusion

This paper has evaluated the required outcomes in terms of bit error rate (BER) for 120 channels dense communication system for the first time best of our known. Further, varied channel spacing, varied data rate, and varied communication distance have also the major concerned. Further, final analysis is recommended that 6 Gbps data rate is the good choice of communication with the channel spacing of 0.9 nm to neglect the neglecting the effect of dispersion, ASE, ISI, fiber linearity, and nonlinearity, which are the main dominating features of dense optical communication.

References

- 1 Gerstel O, Jinno M, Lord A, Yoo S, *IEEE Commun Mag*, 50(2) (2012) s12.
- 2 Zhu B, Chandrasekhar S, Liu X, Peckham D W, *IEEE Photon Technol Lett*, 23 (2011) 1400.
- 3 Nelson L E, Zhou X, Zhu B, Yan M F, Wisk P W, Magill P D, *IEEE Photon Technol Lett*, 26 (2014) 242.
- 4 Zhu B, Doerr C R, Gaarde P, Nelson L E, Stulz S, Stulz L, *Electron Lett*, 39 (2003) 1528.
- 5 Sakamaki Y, Kawai T, Fukutoku M, Kataoka T, Suzuki K, *Opt Express*, 20 (2012) B131.
- 6 Zimmerman D R, Spiekman L H, *J Lightwave Technol*, 22 (2004) 63.
- 7 Xie C, Zhu B, Burrows E, *J Lightwave Technol*, 32 (2014) 2324.
- 8 Bobrovs V, Ivanovs G, *Electron Elec Eng*, 4(92) (2009) 53.
- 9 Jansen S L, *IEEE Photon Technol Lett*, 16(7) (2004) 1763.
- 10 Suzuki H, Fujiwara M, Takachio N, Iwatsuki K, Kitoh T, Shibata T, *IEEE Photon Technol Lett*, 14(3) (2002) 405.
- 11 Nooruzzaman M, Halima E, *IEEE Commun Mag*, 54(8) (2016) 153.
- 12 Turukhin A, *Proc. SPIE*, 10130 (2017) 1.
- 13 Mizuno T, Shibahara K, Ye F, Sasaki Y, *J Lightwave Technol*, 35(3) (2017) 488.
- 14 Nooruzzaman M, Alloune N, Tremblay C, *IEEE Commun Lett*, 21(3) (2017) 512.