ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 1, July 2012

Performance Analysis of a Bi-Directional DWDM Optical Transmission System

M.M. Atiqur Rahman, Bobby Barua

Abstract—The light wave communication is useful because the ability of the silica optical fibers to carry large amounts of information over long repeater less spans. To utilize the available bandwidth, we can multiplex numerous channels on the same fiber. Dense Wavelength Division Multiplexing (DWDM) enables the utilization of a significant portion of the available fiber bandwidth by allowing many independent signals to be transmitted simultaneously on one fiber, with each signal located at a different wavelength. Again DWDM systems are popular with telecommunications companies because they allow them to expand the capacity of the network without laying more fibre. In this paper we analyze the performance of an optical transmission system with bi-directional DWDM. Performance results are evaluated in terms of SNR and bit error rate (BER) with different system parameter.

Index Terms— **Bit Error Rate (BER), Dense Wavelength Division Multiplexing (DWDM), Multipath User, Single Mode Fiber (SMF), and Signal to Noise Ratio (SNR).**

I. INTRODUCTION

Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber. In fibre-optic communications, wavelength-division multiplexing (WDM) is a technology which multiplexes multiple optical carrier signals on a single optical fiber by using different wavelengths (colours) of laser light to carry different signals [1-2]. This allows for a multiplication in capacity, in addition to enabling bidirectional communications over one strand of fibre [3]. In today's high-end WDM systems designed for long-distance communications, each optical signal (often referred to as a channel or a wavelength) can operate at up to 2.5 Gbps or 10 Gbps. Currently, available systems support from 32 to 64 channels and vendors are promising up to 160 channel systems in the near future. This enables a single fiber to carry more then 1 terabit/s of information [4]. WDM has increased the carrying capacity of fiber optic cables and also made it possible for data to flow both ways in a single strand of fiber [5]. By adjusting the data streams into a different part of the light spectrum several types of data are able to travel on its own unique color band. The origin of optical networks is linked to WDM which arose to provide additional capacity on existing fibers [6]. The advent of Dense Wavelength Division Multiplexing (DWDM) has fundamentally changed the economics of core optical networks [7]. Consequently, virtually all operators of long distance fiber optic networks have implemented or are expected to implement DWDM. It offers an attractive, cost-effective way for the telecommunications industry to expand network bandwidth. This technology allows telecom operators to meet ever-growing requirements for new services and have greater flexibility in the provisioning of these services [8]. Therefore, in this paper we include the Bit Error Rate (BER) performance of a DWDM transmission link in the presence of multipath users with varying different system parameters related to the transmission link.

II. SYSTEM MODEL

The model of DWDM system is shown in figure 1. The transmitted signal is given by

$$S_m(t) = ACos(W_m t + \phi_m), \text{ Where, m = 1, 2… M} \quad \textbf{(1)}$$

In the transmitter, the data of 10 Gbps is used to directly modulate a laser to generate the signal which is transmitted through a single-mode fiber. In Bidirectional DWDM two or more waves are transmitted simultaneously over the same fiber. Figure 1 is shown in Appendix. It involves sending information in one direction at a wavelength $\lambda_1$and simultaneously transmitting data in the opposite direction at a wavelength λ_2.

III. THEORETICAL ANALYSIS

The output photo current of optical transmitter is given below:

$$I_p = \frac{\eta P_{oe}}{hf} \quad \textbf{(2)}$$

Where,
e= charge of an electron
h=plank's constant
f=frequency of the incident photon
η=quantum efficiency
P_o =incident optical power in watt

The equation of dark current noise

$$\overline{i_d^2} = 2eBI_d \quad \textbf{(3)}$$

Where,
I_d = dark current
B = post detection (electrical) bandwidth
The short noise current i_s on the photo current I_p is

$$\overline{i_s^2} = 2eBI_p \quad \textbf{(4)}$$

Combining equation (2) & (3) we get the total shot noise

$$\overline{i_{T_s}^2} = 2eB\left(I_p + I_d\right) \quad \textbf{(5)}$$

So, the root mean square (r.m.s) shot noise current is

$$\overline{i_{T_s}^2} = \left[2eB\left(I_p + I_d\right)\right]^{1/2} \quad \textbf{(6)}$$

The thermal noise in the load resistor is given by

$$\overline{i_t^2} = \frac{4KTB}{R_L} \quad \textbf{(7)}$$

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 1, July 2012

Therefore, the r.m.s thermal noise in the load resistor is given by

$$\overline{i_t^2} = \left[\frac{4KTB}{R_L}\right]^{1/2} \quad (8)$$

The expression for the SNR can be written as follows, where F_n is the noise figure

$$\frac{S}{N} = \frac{I_p^2}{\left[2eB(I_p + I_d) + \frac{4KTBF_n}{R_L}\right]} \quad (9$$

Therefore $SNR\ in\ dB = 10\log_{10} SNR$ It is possible to conduct the calculation in dB if we neglect the shot noise $\left(\overline{i_{T_s}^2} = 0\right)$

The Bit Error Rate (BER) is given below

$$BER = P_e = 0.5\left(erfc\sqrt{\frac{E_b}{N_0}}\right) \quad (10)$$

Where

E_b = CT_b =Average energy of a received bit.

C = Average power of received carrier

N_0 = Noise density =Noise power in 1 Hz of RF or IF bandwidth

T_b = Unit of bit Duration = $1/f_b$; f_b = Bit rate.

IV. Results and Discussion

Following the analytical approach presented in previous section, we evaluated the BER performance of bi-directional DWDM system considering the effect of different system parameters. For the convenience of the readers the parameters used for computation in this paper are shown in table 1.

TABLE I. NOMINAL PARAMETERS OF OPTICAL COMMUNICATION LINK

Parameter Name	Value
Bit Rate, B_r	100 Mbps
Temperature	300
Fiber attenuation, α	0.24 dB/Km
Responsivity, R	0.5 A/W
Load Resistance, R_l	50 ohm
Channel Spacing D_{ch}	20 GHz

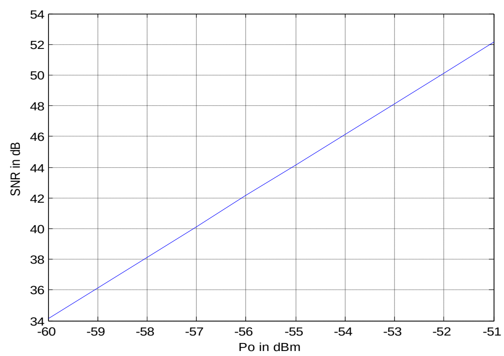

Fig 2: Relation between P_0 in dbm and SNR in db

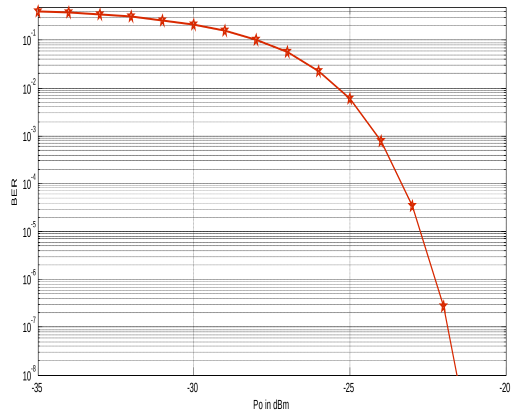

Fig 3: Relation between P_0 in dbm and bit error rate (BER).

The plot of Optical Power vs. SNR is shown in Fig. 2. In the figure a linearly increasing straight line curve represents that the SNR is increased with increasing the incident of optical power P_0. Fig. 4 shows the plots of BER vs.P_0 with different channel. From the figure it is found that the bit error rate increase as the band- width increases.

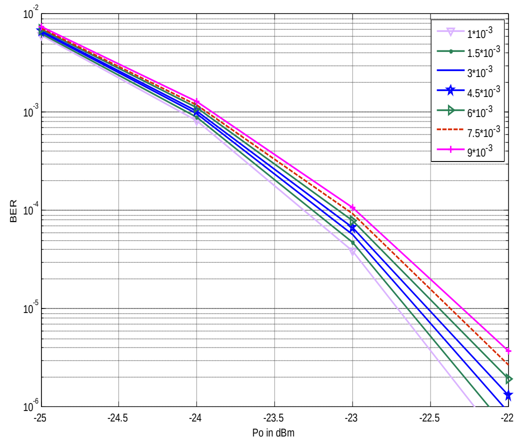

Fig. 4: Plots of BER vs. P_0 for Different Channel

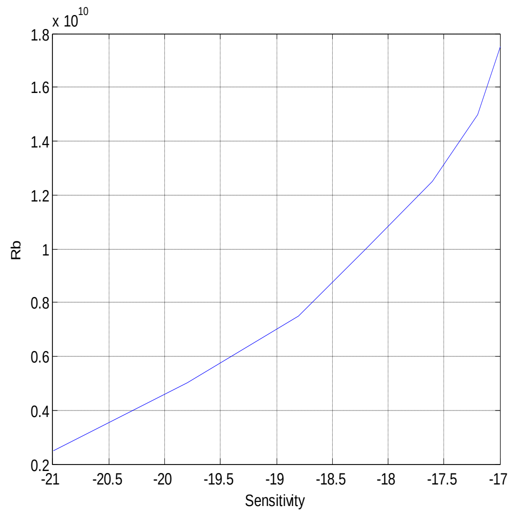

Fig 5: Relation between channel sensitivity (R_x) and bit rate (R_b)

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 1, July 2012

Now by drawing a straight line parallel to the horizontal axis from the $\mathbf{10^{-5}}$ BER point we get some crossing point of the curve. Drawing perpendicular line from each point on to the horizontal axis we can find the channel sensitivity. If we plot sensitivity (R_x) vs. bit rate (R_b) then we get a exponentially increasing curve which is shown in Fig.5. Fig. 6 shows the plot of P_0 vs. BER at the presence of crosstalk. The analysis shows that the BER is increased with the addition of crosstalk.

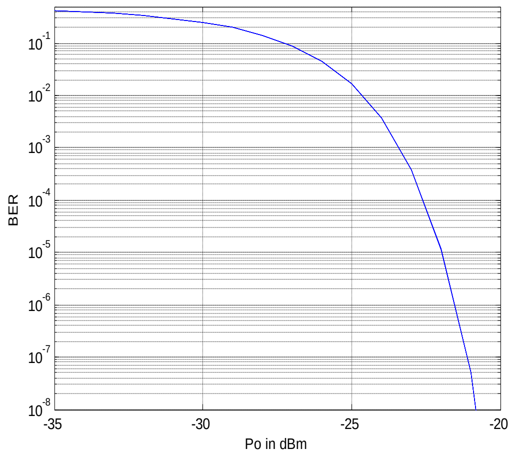

Fig. 6: Plot of P_0 vs. BER at the Presence of Crosstalk (Noise).

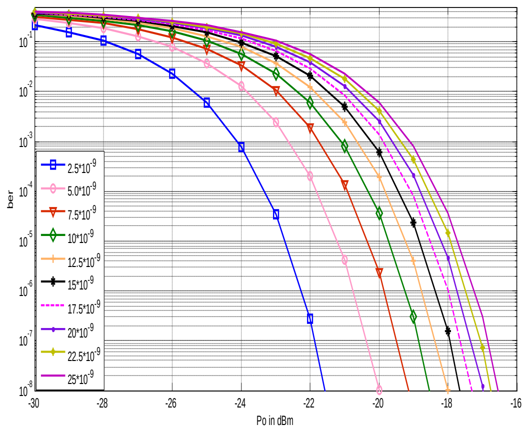

Fig 7: Plots of BER vs P_0 for no. of channel

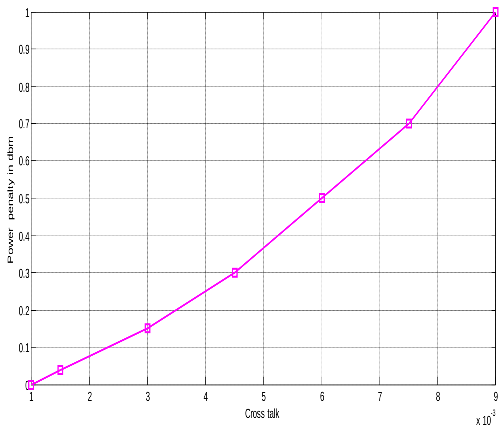

Fig 8. Relation between Cross-Talk and Power Penalty

The BER performance for different no. of channel is shown in Fig.7 which represents the BER decreases with the increase of optical power P_0. Fig. 8 shows the plot of power-penalty vs crosstalk. From the figure it is found that as the cross-talk increases the power penalty also increases.

V. CONCLUSION

A detailed analytical approach is presented to evaluate the bit error rate performance of optical transmission system with bi-directional DWDM. Analysis shows that Bit Error Rate increases as the number of user increases and for a certain number of users Bit Error Rate increases as the message bit rate increases. If we plot power-penalty vs crosstalk then we get an exponentially increasing curve, which represent that as the cross-talk increases the power penalty also increases. Interference power increases as the number of user increases and for a certain number of user's interference power decreases as chip length increases.

ACKNOWLEDGEMENT

The authors would like to acknowledge with gratitude to the Dept. of EEE, AUST for providing unfailing support to the work.

REFERENCES

[1] Chraplyvy, A.R. "Limitations on Light wave Communications Imposed by Optical-Fiber Nonlinearities," J. Light wave Technology, vol. 10, no. 8, pp. 1548-1557. 2002.

[2] Senior, J.M., Optical fiber communication, 2nd edition, Prentice-Hall, India, 2002.

[3] Singh, S.P., Kar, S., Jain, V.K. "Performance of All-optical WDM Network in Presence of Four-wave Mixing, Optical Amplifier Noise, and Wavelength Converter Noise" Volume 26, Issue 2, pp 79-97. 2007.

[4] Brackett, C. A. "Is there an Emerging Consensus on WDM Networking," J. Light wave Techno. vol. 14, pp. 936–941, June 2000.

[5] Numai T. and Kubota O., "Analysis of Repeated unequally Spaced Channels for FDM Light wave Systems," IEEE J. Light wave Techno. vol. 18, no. 5, May 2000.

[6] Forghieri, F., Tkach, R. W., Chraplyvy, A. R. "WDM Systems with unequally Spaced Channels,"J.Lightwave Techno., vol 13, no. 5, pp. 889-897. 1995.

[7] Mizrahi, V. et al., "The Future of WDM systems," in Proc. ECOC 2000, pp. 137–141.

[8] Eiselt, M. "Limits on WDM Systems Due to Four-Wave Mixing: A Statistical Approach," J. Light wave Technology, vol. 17, no.11, pp. 2261-2267, 1999.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 1, July 2012

APPENDIX

Fig. 1: Bidirectional WDM System