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2.50 Gbps Optical CDMA Transmission System

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ABSTRACT

Optical CDMA technique is required to meet the increased demand for high speed, large capacity communications in optical networks. Data access security and ability to support asynchronous burst data transmission are the major driving forces to generate interest in the OCDMA techniques. In this paper, we have presented an OCDMA model to the range of 100 km. The simulation results reveal that the transmission distance is limited mainly by the multi-access interference (MAI) which arises when there are a large number of users in the system because of the fact that one user data becomes noise for all other users in the channel.

General Terms

Optical Code Division Multiple Access, Multi User Interference

Keywords

1. Optical Code Division Multiple Access (OCDMA), Bit Error Rate (BER), Pseudo Orthogonal (PSO) code, Multi-Access Interference (MAI), Non-Return-to-Zero (NRZ), Single Mode Fiber (SMF).

2. INTRODUCTION

Extensive study of Code Division Multiple Access (CDMA) has been carried out in the context of microwave communications. It allows users to access any shared channel randomly at any arbitrary time. Its use in optical fiber networks has attracted considerable attention since 1985 [1]. In long distance optical networks, the information consists of a multiplexed aggregate data stream originating from many individual subscribers and normally is sent in a well time-synchronous format. Optical CDMA transmission systems do not require any time or frequency management [2]. It operates asynchronously without centralized control and does not suffer from packet collisions. As a result, OCDMA systems have lower latencies than TDMA. In an OCDMA system each bit is divided into N time periods, called chips [3]. An optical signature sequence can be created by sending short optical pulse during some chip intervals, but no others. A user on the OCDMA system has unique signature sequence. The encoder of transmitter represents each bit by sending signature sequence [4-5]. The crosstalk between different users sharing the common fibre channel, known as Multiple Access Interface (MAI) is usually the dominant source of bit errors in an OCDMA system[6].

Future optical CDMA networks need to support multimedia services. Research is still going on to develop a better OCDMA code which will support the multimedia services. The design of a set of eight matrix codes for operation at 2.5 Gbps has been described [7]. The results indicate that the codes propagate satisfactorily if dispersion management is used. Multi-access interference (MAI) in a bursty traffic environment is also discussed. The design consideration of matrices and performance analysis from communication point of view has been studied [8]. OCDMA implementation complexity could be avoided by using a guard time in the codes and an optical hard limiter in the receiver which shows that 2-D wavelength/time codes are better than one-dimensional (1-D) CDMA/WDM combinations [9]. The design of OCDMA system with improved coding techniques which helps in reducing hardware requirement and still offers better performance for higher number of users [10]. In this paper we propose the simulative OCDMA transmitter and receiver with optical fibre reported in section 2. The simulation results have been discussed in section 3. The conclusion of our simulation results is presented in section 4.

3. SYSTEM DESCRIPTION

In the proposed optical CDMA transmission link (Fig. 1.), 2.50 Gbps data signal is generated with NRZ modulation. The 2.50 Gbps NRZ data signal is then modulated by means of MZM modulator and then transmitted over SM fiber. Four mode-lock lasers are used to create a dense WDM multi-frequency light source of 3 mW operating at 1550.0-1551.2 nm. Encoded optical CDMA signal is transmitted over SM fibre having an attenuation of 0.2 dB/Km. Here we are using sixteen OC-48 users requiring sixteen distinct signature codes. For this purpose Pseudo orthogonal (PSO) matrix codes [7] are used as they are popular for OCDMA applications primarily because they retain the correlation advantages of PSO linear sequences while reducing the need for bandwidth expansion. PSO matrix codes also generate a larger code set. An interesting variation is described in [8] where some of the wavelength/time (W/T) matrix codes can permit extensive wavelength reuse and some can allow extensive time-slot reuse. In this model, an extensive time-slot reuse sequence is used for User 1 ($\lambda1\lambda3$; 0; $\lambda2\lambda4$; 0). There are four time slots used without any guard band giving the chip period of 100 ps. At the receiver information is retrieved by a decoder using the same PSO code and then the optical signal is converted back into electrical form through a PIN photo diode and hence 2.50Gbps optical CDMA data is recovered successfully.

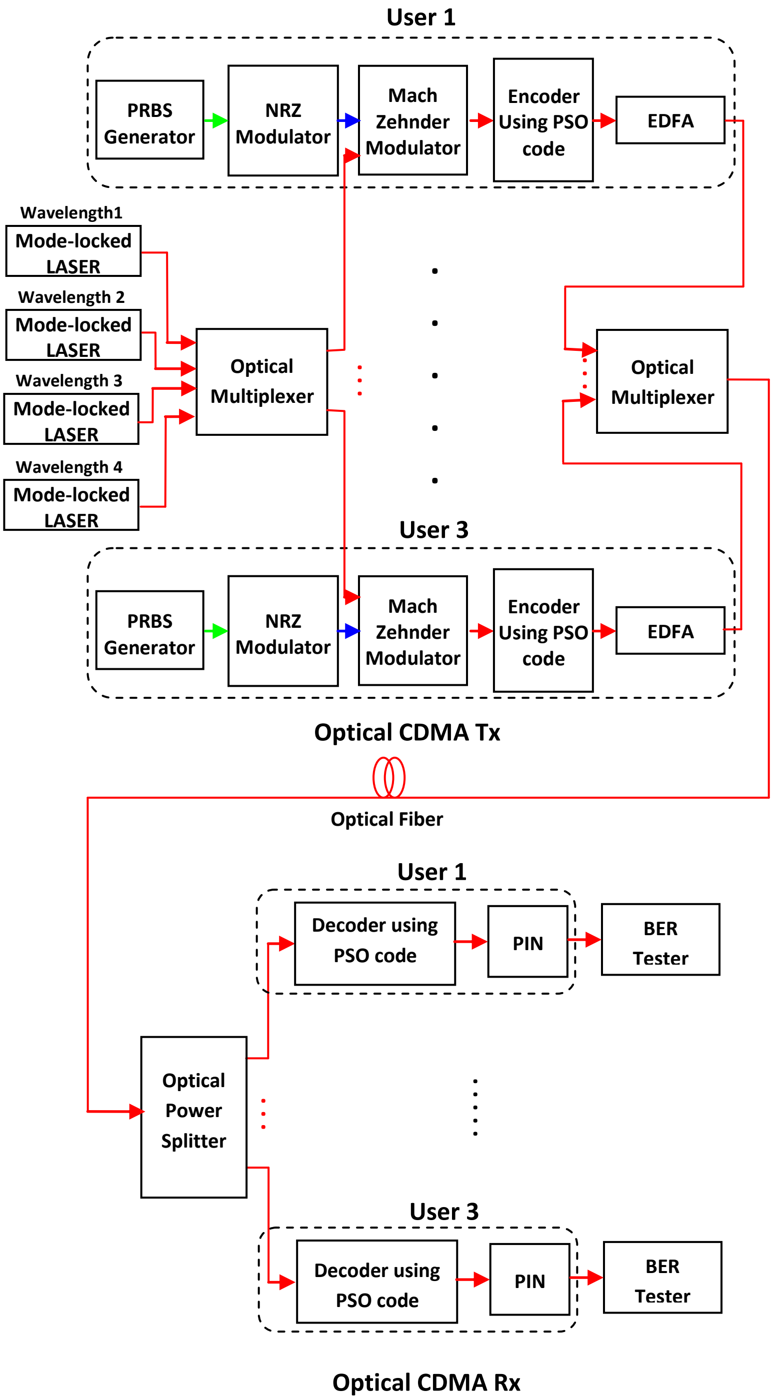


Fig 1: Simulation setup of optical CDMA transmission link

4. RESULTS AND DISCUSSION

Three cases of performance analysis are: Case I describes the analysis of Optical CDMA transmission links with NRZ and RZ modulation, Case II investigates different parameters on optical CDMA transmission link and Case III gives impact of MAI in optical CDMA transmission link.

Case I: Performance Investigation in optical CDMA transmission link with NRZ and RZ modulation

The parameters used in this case are data rate 2.50 Gbps, aperture area 180 cm^2, transmitted power 3 mW, fiber length 100 km and dispersion 16.75 ps/nm/km.

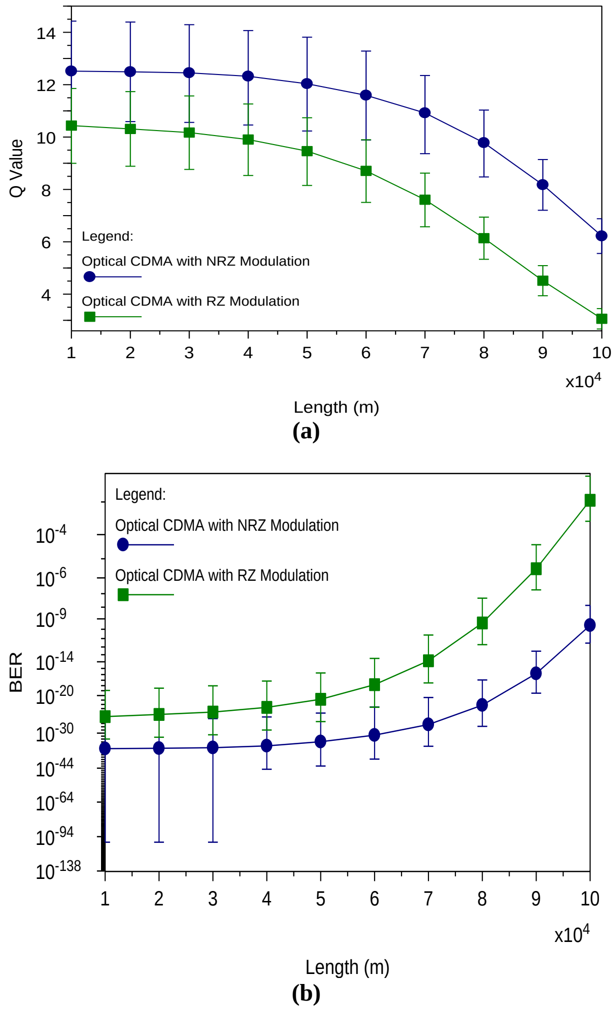
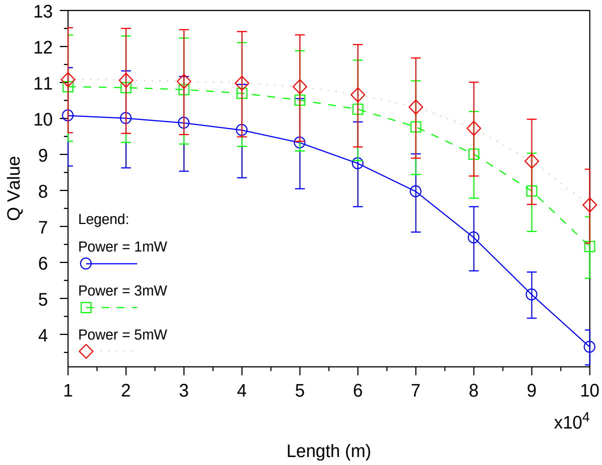


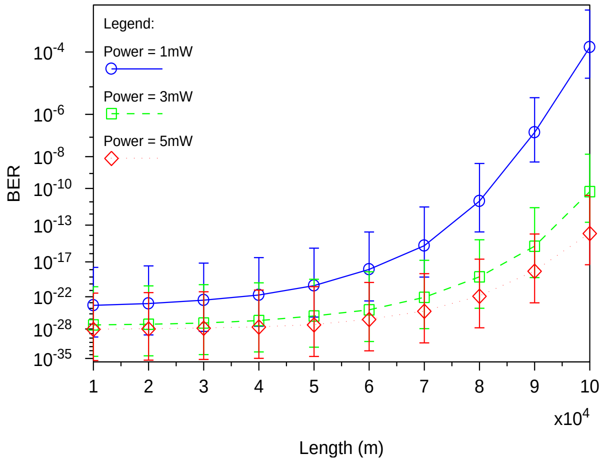
Fig 2: (a) Evaluation of Q-value versus transmission length with NRZ and RZ modulation
(b) Evaluation of BER versus transmission length with NRZ and RZ modulation

The graphs of Q-value and BER versus transmission length for NRZ and RZ modulation are presented in figure 2 (a) & (b). From results it has been observed that there is a significant increase in the value of Q factor when we apply NRZ modulation technique. The Q-value lies within [12.5, 12 and 6.2] and [10.4, 9.5, and 3] for transmission distance of 10 km, 50 km and 100 km in case of NRZ and RZ modulation respectively. In case of BER, it has been observed that there is a significant decrease in the value of BER, which lies within [10^{-37}, 10^{-33}, and 10^{-10}] and [10^{-26}, 10^{-21}, and 10^{-3}] for transmission distance from 10 km, 50 km and 100 km in case of NRZ and RZ modulation respectively

Case II: Performance Investigations of Different parameter in optical CDMA transmission link



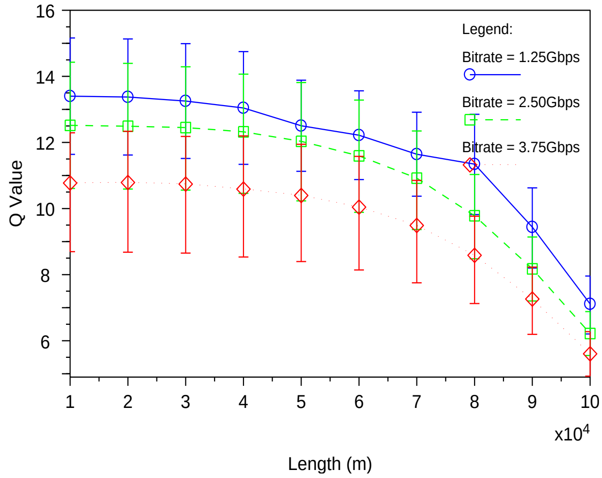
(a)



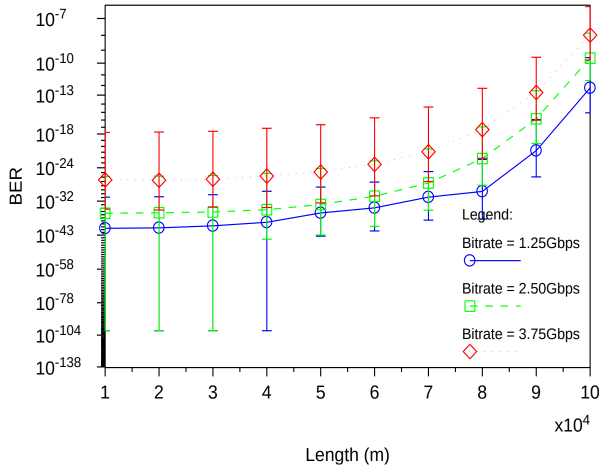
(b)

Fig. 3: (a) Evaluation of Q Value versus transmission length with different input power levels for single user (b) Evaluation of BER versus transmission length with different input power levels for single user

The graphs of Q-value and BER versus transmission length at different transmitter power level are presented in figure 3 (a) & (b). From results it has been observed that there is significant increase in the value of Q factor when we increase the transmission power. The Q-value lies within [11.8, 10.6 and 3], [12.5, 12 and 6.3] and [12.8, 12.4 and 7.6] for transmission distance of 10 km, 50 km and 100 km in case of 1 mW, 3 mW and 5 mW respectively. In case of BER, from results it has been observed that there is a significant decrease in the value of BER when we increase the transmission power. BER lies within[10^{-32},10^{-26} and 10^{-5}], [10^{-33}, 10^{-31} and 10^{-8}] and [10^{-34}, 10^{-32} &10^{-14}] for a transmission distance of 10 km, 50 km and 100 km in case of 1 mW, 3 mW and 5 mW of transmitter powers respectively.



(a)

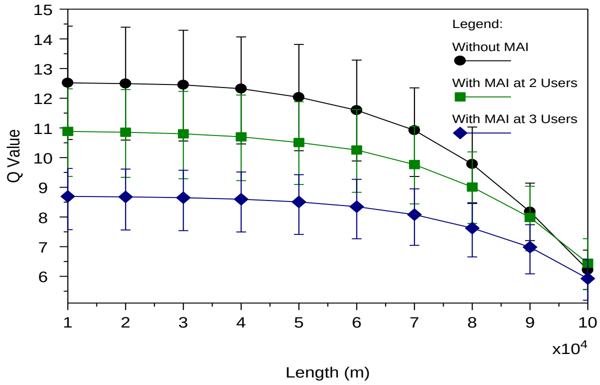


(b)

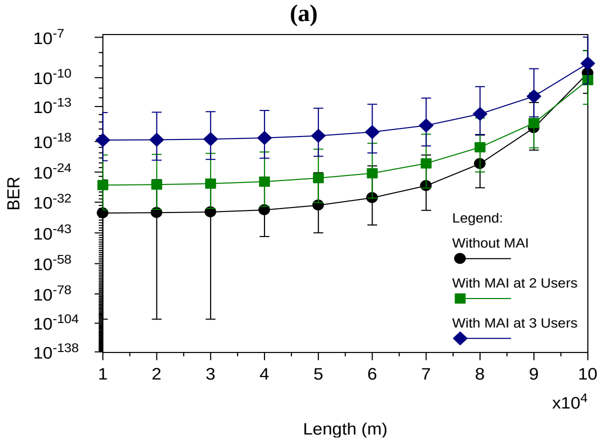
Fig. 4: (a) Evaluation of Q Value versus transmission length with different input bit rates for single user (b) Evaluation of BER versus transmission length with different input bit rates for single user

The graphs of Q-value and BER versus transmission distance at different bitrates are presented in figure 4 (a) & (b). From results it has been observed that there is significant decrease in the value of Q factor when the bitrate is increased. The Q-value lies within [13.5, 12.5 and 7.1], [12.5, 12 and 6.2] and [10.8, 10.4 and 5.1] for transmission distance of 10 km, 50 km and 100 km in case of bitrates 1.25 Gbps, 2.50 Gbps and 3.75 Gbps respectively. In case of BER, from results, it has been observed that there is significant increase in the value of BER when the bitrate is increased. BER lies within[10^{-41} ,10^{-35} and 10^{-12}], [10^{-35}, 10^{-33} and $10^{-9.5}$] and [10^{-27}, 10^{-25} & 10^{-8}] for transmission distance from 10 km, 50 km and 100 km in case of bitrates 1.25 Gbps, 2.50 Gbps and 3.75 Gbps respectively.

Case III: Impact of MAI in optical CDMA transmission link



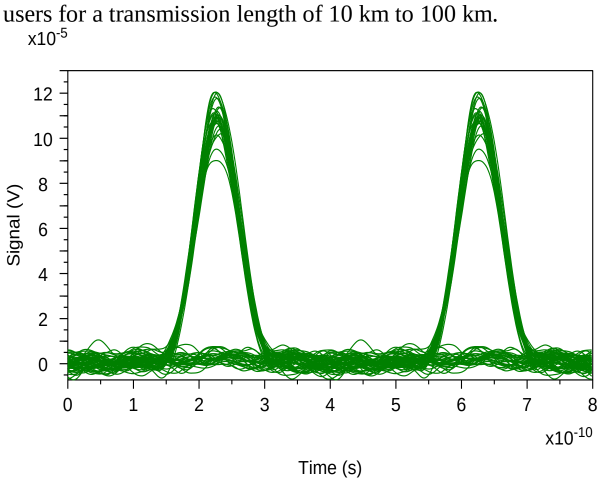
(a)



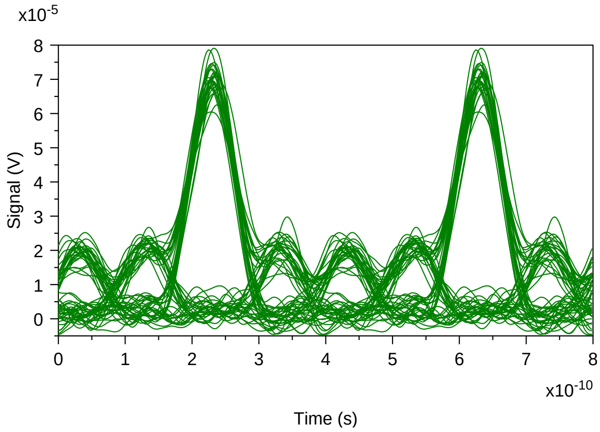
(b)

Fig. 5: (a) Evaluation of Q Value versus transmission length with and without MAI
(b) Evaluation of BER versus transmission length with and without MAI

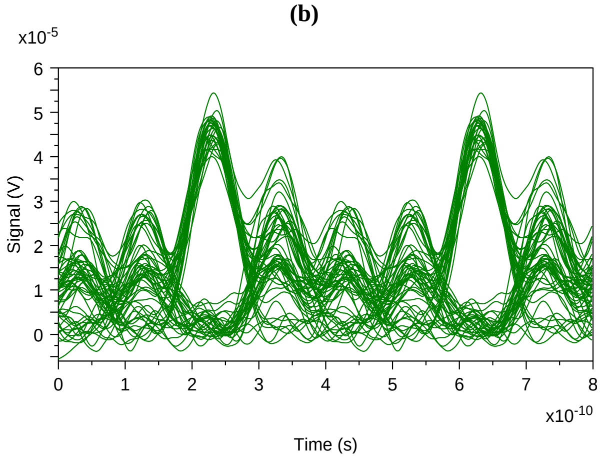
The graphs of Q value and BER versus transmission length with and without MAI are given in figure 5(a) & 5(b). It has been observed that the Q-value starts decreasing and BER starts increasing when number of users increase due to Multi Access Interference (MAI) [11]. The Q factor lies within 12.5 to 6.2 for without MAI case, 10.8 to 6.5 for with MAI case at 2 users and 8.7 to 5.9 for with MAI case at 3 users for a transmission length of 10 km to 100 km. The BER lies within 10^{-37} to 10^{-10} for without MAI case, 10^{-28} to 10^{-5} for with MAI case at 2 users and 10^{-18} to $10^{-8.8}$ for with MAI case at 3 users for a transmission length of 10 km to 100 km.



(a)



(b)



(c)

Figure 6: Eye diagram of received signal for single user taking NRZ signal (a) without MAI at single user
(b) With MAI at 2 users, (c) with MAI at 3 users

The eye diagrams for single, two and three users are shown in figure 6 (a), (b) & (c). It has been observed that the efficiency of the system is degraded with the increase in number of users. Thus it is established that MAI plays key detrimental role in optical CDMA communication system.

4. CONCLUSION

The design of an optical CDMA transmission system at data rate of 2.5 Gbps for 100 km length is presented. Performance investigation on this designed optical CDMA was carried out using NRZ and RZ modulation for comparative study, with different parameters and with and without MAI. It is concluded that NRZ gives us better performance as compare to RZ in optical CDMA. Further, transmission range also increases with the increase in transmitter power. However the efficiency of OCDMA is degraded with the increase of bit rates. It is also concluded that the efficiency of OCDMA is degraded by increasing number of users.

5. REFERENCES

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