USE OF SOA IN MANAGING DISPERSION AFFECTED AUTO AND CROSS-CORRELATION IN 3-D OCDMA SYSTEMS

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Abstract- In this paper, an effort has been made to improve the performance of a 3-D optical code division multiple access system by simultaneously managing the auto and cross-correlation peaks affected by chromatic dispersion (CD) with the help of semi-conductor optical amplifier (SOA). A simulation setup of the proposed OCDMA system based on 3D W/T/S MPR codes is simulated for eight users at 7Gbps and performance analysis is carried out in terms of BER, number of users and transmission distance. Further a SOA have been employed on the decoder side to mitigate the effect of CD on auto and cross-correlation peaks of proposed OCDMA system. Simulation results shows that SOA has effectively managed both auto and cross-correlation peaks allowing all the eight users to transmit simultaneously and also BER decreases to $1.00E^{-50}$ thus improving the system performance.

Keywords- OCDMA, 3D W/T/S MPR codes, BER , Auto correlation , Cross correlation, Chromatic dispersion.

I INTRODUCTION

Future communication network demands superior bit rates and ultrafast quality of service (QOS) such as video on demand, HDTV and IPTV [1]. A huge amount of data can be transmitted by using short pulses of light and one such technique is OCDMA which uses codes based on multi-wavelength picosecond optical pulses as the data carriers. Encoding in OCDMA system involves multiplying the data bit by a code sequence either in the time domain, wavelength domain or in space domain or it can also be done as combination of time and wavelength domain or time and space domain (2-D coding). On the other hand, the combination of all three domains results in 3-D coding. In this work the codes used are 3D W/T/S MPR codes. W/T/S MPR codes can be characterized as by N(R x L_T x S, W, λ_a=1, λ_c=1) where, N is the number of codes, R is the number of wavelengths, L_T is the number of timeslots, S is no of code channels, W is the weight of the code, W_P = W/R is the weight per row, λa is the peak out-of-phase autocorrelation and λc is the peak cross-correlation. Code words of 3D codes are represented by 3D matrices that have binary (1or 0) values for their elements. The 3D code is expanded over wavelength, time and space domains and it consists of (WxTxS) matrices where W, T and S denote the number of wavelengths, time slots and spatial channel respectively [2]. During data transmission is very important to preserve its undistorted shape in order to maintain the highest performance of OCDMA systems. As these code carrier pulses are short, transmitted codes will be strongly affected by chromatic dispersion (CD), even if the transmission distance changes by a few meters [3]. At the receiver side the incoming data is recovered for each user by a decoding process which produces a so called OCDMA auto-correlation function. If CD is not properly implemented, the recovered OCDMA auto-correlation by an OCDMA decoder will show temporal skewing among individual wavelength code carriers, thereby severely impacting OCDMA system performance. The CD related pulse distortion and related time skewing will cause undesirable broadening of recovered OCDMA auto-correlation. The auto-correlation surrounding cross-correlation will also be impacted by CD, leading to a reduced auto-to-cross-correlation ratio. This in turn will increase the multi-access interference noise and cross-talk leading to performance degradation and a drastic reduction in the number of simultaneous users [4]. Therefore to fully mitigate the effect of CD on OCDMA systems there is a need to compensate both auto and cross correlation.

The effects of CD on the performance of OCDMA systems and various mitigation techniques have already been studied by various researchers [5-9]. It has been observed that the conventional methods of CD compensation are often tedious and time consuming and becomes difficult to implement if the fiber lengths are not known beforehand or dispersion is changing due to changing conditions in environment.

A semiconductor optical amplifier (SOA) was also investigated for the chromatic dispersion compensation (CDC) of a data transmission that uses a single wavelength as the data carrier [10]. The advantage of using an SOA is that it offers a convenient tunable approach to CD compensation [10-13]. Concept behind using an SOA for distorted OCDMA auto-correlation width adjustment is based on exploiting refractive index and gain changes in a biased SOA [10, 14, 15, 16]. Such changes can be introduced in a variety of ways:

- by varying the SOA bias current,

- through an SOA gain depletion,
- by injecting an optical continuous wave (cw) called a continuous-wave holding beam (CW/HB) together with a data signal at the SOA input, or
- by using an optical pulse stream called an optical pulse holding beam (for short OP/HB).

In this paper SOA is to be used to mitigate the effect of CD on 3D W/T/S MPR OCDMA codes based on picosecond wavelength carriers by varying the SOA bias current and thus managing the auto and cross correlation peaks so that all the eight users can transmit simultaneously.

II SIMULATION SET UP OF 3-D OCDMA SYSTEM

In the simulation setup, the 3D OCDMA system has been configured based on the W/T/S code, where very user is assigned a code word matrix as its own address signature. A user transmit data bit "1" with a sequence of pulses spread in the wavelength, time and space domain according to the code matrix of its intended receiver. At the receivers, the pulses of different spatial channels are separated and in each spatial channel, the pulses of each wavelength are correlated separately in time domain. After correlation, all pulses are collected together. Only at intended receiver, all the spread pulses are assembled in the same time chip and one large optical pulse is obtained, which is dubbed as the auto-correlation function. Whereas, at other receivers, a series of small pulses are obtained, this is dubbed as cross-correlation function. Figure 1 shows the simulation setup of 3D W/T/S OCDMA system having four wavelengths, 97 time slots and 4 spatial channels.

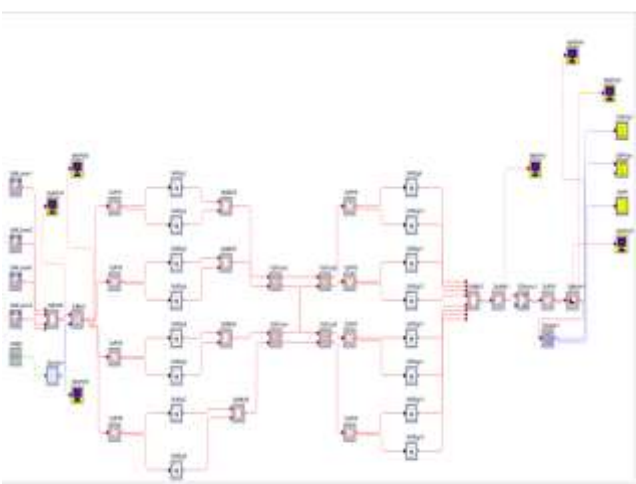


Figure 1 Schematic of 3D W/T/S OCDMA system

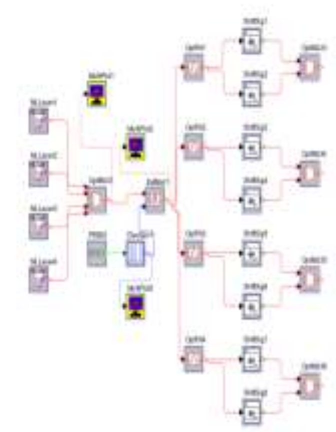


Figure 2 Encoder Structure of 3D OCDMA System

Figure 2 shows the encoder structure, encoder is used to encode the modulated signal using fiber optic CDMA technique. Different wavelengths are multiplexed and data signal is modulated with this multiplexed signal using optical modulator. The output of this signal is passed through optical filter 1.e. the first stage of encoder. Then these signals are passed through shift signal to provide appropriate delay .i.e. the second stage of encoding. Time delay can be calculated using equation (1).

$$Time\ Delay = Code * Chip\ Period \ldots\ldots (1)$$

Where $Chip\ Period\ (T_c) = Bit\ Period\ (T_b)/(Total\ Number\ of\ Time\ Slots)$

In this system multiple pulses per row are used, so there will be multiple delays provided to each wavelength. Then signals from delay line are multiplexed together to transmit through single non-linear fiber.

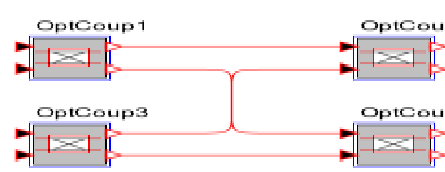


Figure 3 Star Coupler Used in 3D OCDMA System

As the signal with different wavelengths will follow different paths and enter the decoder circuit. Before entering decoder circuit these signal will pass through star coupler shown in figure 3. A star coupler is designed by cascading 2*2 optical couplers as per the requirement of the system. For N no. of codes N*N star coupler is required. Here 4 star couplers are used as 4 spatial channels are used.

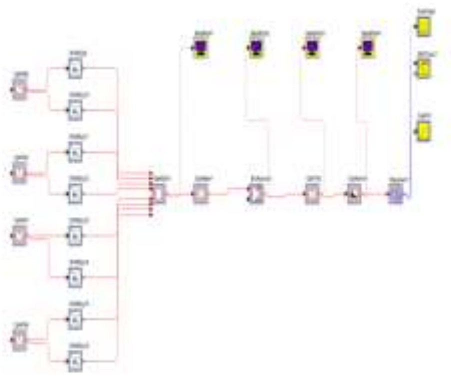


Figure 4 Decoder Structure of 3-D OCDMA System

Figure 4 shows the decoder structure. The function of decoder is exactly opposite to encoder, except that the time delays replaced with the desired time reversed sequence. Time delay provided at this stage can be calculated using equation (2).

$$Time\ Delay = (Total\ Number\ of\ Time\ Slots - Code) * Chip\ Period \ldots\ldots\ (2)$$

When the transmitter and receiver configured with the identical code sequence, it will result in a high-peak auto correlation value result. A threshold detector detects this peak. Otherwise, a low amplitude cross-correlation function is detected, that will be considered to be the interference. This condition indicates a difference in the encoder and the decoder configuration. Table 1 show the parameter used in simulations All the simulation s have been performed on Optsim5.4 by Rsoft.

Table 1 3D OCDMA System Parameter

PARAMETER	VALUE
ML Laser 1	1550.00nm
ML Laser 2	1550.40nm
ML Laser 3	1550.80nm
ML Laser 4	1551.20nm
Bit Rate	7Gbps
Bit Period	$14e^{-10}$s
Time Slots	97
Width of Wavelength Carrier	8ps
Fiber length	10-100Km
No. of Users	8
Power	$3e^{-3}$W

III RESULTS AND DISCUSSION

The performance of the proposed system is evaluated regarding Bit Error Rate (BER), Quality factor (Q-factor) and received powers at different transmission distances. BER is measured at receiver end by using eye diagram analyzer and received power is measured by using an optical meter. The highest constraint of BER indicates the largest number of sustainable users that can access the same channel simultaneously with reliable system performance. Figure 5 shows the variation in BER with respect to number of users for the different length of optical fiber at 7 Gbps bit rate. The BER value of two users reduces from 1.0E-40 to 1.0E-13 as the optical fiber length increases from 20 to 100 km. The result also shows that as the number of user's increases from 2 to 8 the BER degrades from $1.0E^{-40}$ to $1.0E^{-30}$ at a distance of 20 km. it is observed that BER is less at smaller transmission distance compared to that of larger distance irrespective of the different number of users. Figure 5 also shows that the number of users supported is reduces to 6 as the length of fiber increases. The results depict that with the increase in a number of users the BER is also degraded. At the same time, as the length of the optical fiber is increased for a given number of users the BER is further deteriorated. The system performance is poor for 8 users at larger distance this is due to the effects of chromatic dispersion (affecting auto and cross correlation peaks) which is managed by using SOA on the decoder side as shown in figure 4 and further results shows that the system simultaneously supports 8 users.

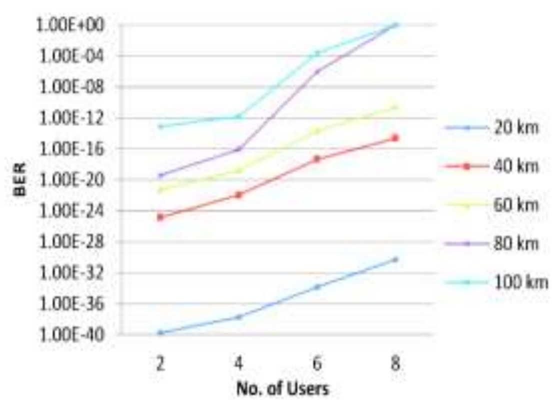


Figure 5 BER versus number of users at different distance without SOA

Cross- correlation occurs when two or more users transmit simultaneously over a network. If the effect of dispersion is neglected, even if more than one user are transmitting at a time, the system will still give good performance as there will not be any distortions in the auto correlation peak (it will be a needle-like peak) and the cross correlation peaks will be minimum. The ideal case when only one user is transmitting, there will not be any cross-correlation at the output as shown in figure 6. These result were taken for 1 user and transmission distance =20Km in this proposed system without using SOA.

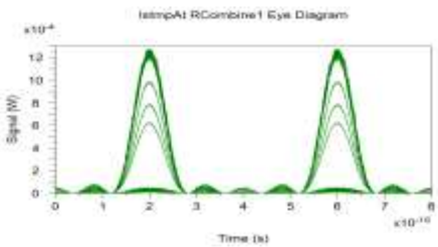


Figure 6 Ideal Auto Correlation Peaks with Zero Cross Correlation

It can be seen from the figure 6 that the auto-correlation peaks are in ideal shape and thus this result is used as reference for analyzing the performance of system. As the number of users will increase, all the data pulses travelling through the fiber will be affected by chromatic dispersion 1.e. they will undergo skewing and spreading effects, due to which the output at the decoder will get distorted. Figure7 shows the results obtained for number of users n=4 and distance d=20Km.

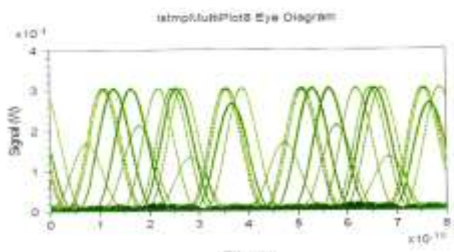


Figure 7 Distorted auto-correlation and enhanced cross-correlation peaks due to CD when n=4 and d=20Km

To limit the distortion of auto and cross correlation peaks, a SOA has been connected on the decoder side as shown in figure 4. By changing the SOA bias current, the refractive index changes and these changes can be exploited for compression or expansion of data pulses travelling through the SOA. This concept is used here and the whole system is scanned for different values of SOA's bias current. Results obtained are shown in figure 8 and it can be seen that the SOA bias current of 12 mA gives the best performance because BER is minimum at this value. Thus in this work SOA bias current of 12 mA has been used to reduce the distortion produced in auto and cross-correlation peaks.

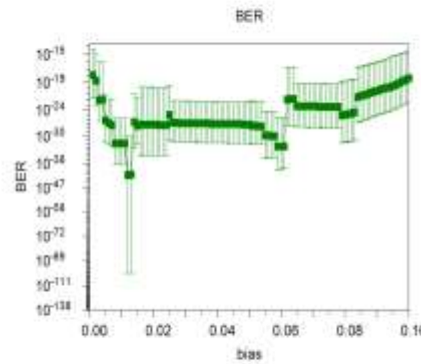


Figure 8 System's Performance by Using Different Values of SOA Bias Current

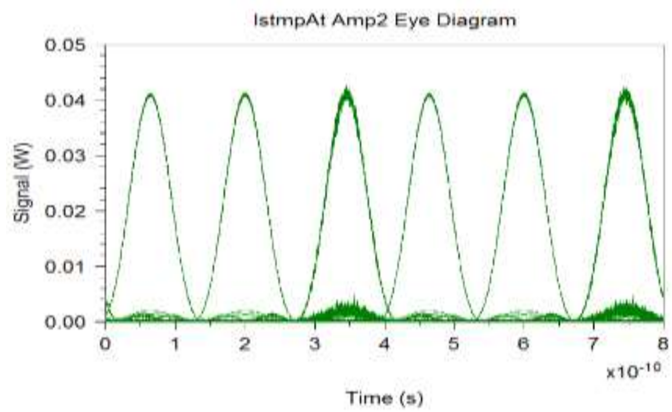


Figure 9 Auto and Cross-Correlation Peaks Obtained with SOA for n=4 and d=20 Km

It can be seen from the figure 9 that it is very much close to ideal case (figure 6) and almost all the cross-correlation peaks have been diminished and also BER obtained in this case is also reduced by a large amount, it is in the powers of 10^-50 as shown in figure 10.

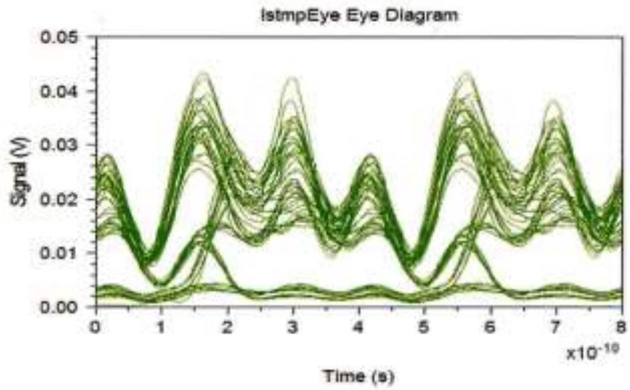


Figure 10 Eye diagram corresponding to n=4 and d=20Km with SOA

On increasing the number of users the cross-correlation will increase and thus the system will start deteriorating as seen from the figure 5 that the system performance is poor for 8 users transmitting simultaneously on the other hand when SOA is connected on the decoder side, all the 8 users transmit simultaneously.

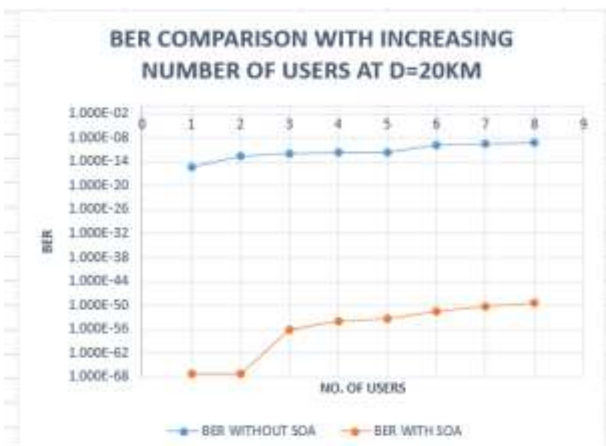
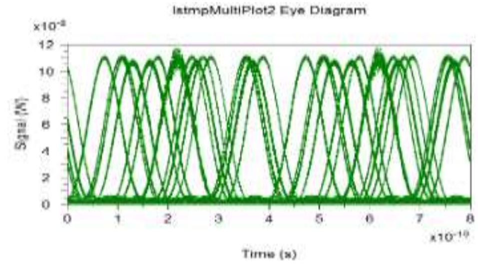
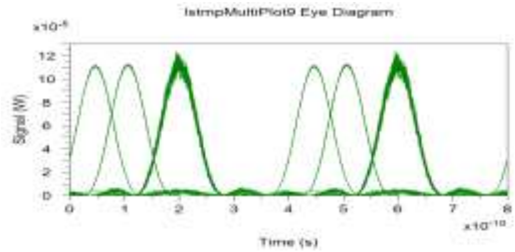


Figure 11 BER comparisons with increasing number of users with and without SOA.

It is very much clear from the figure 11that without using SOA only a few numbers of users were able to give acceptable BER values but after using SOA, the BER of the system greatly reduces and all 8 users can simultaneously operate in the system. Also the auto and cross –correlation peaks are shown for number of users =6 and 8 at transmission distance of 20km in figure 12 and 13.

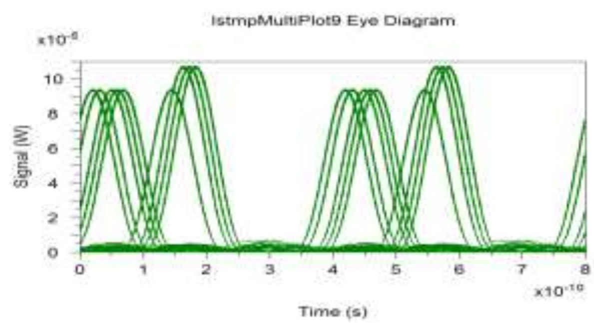


(a)

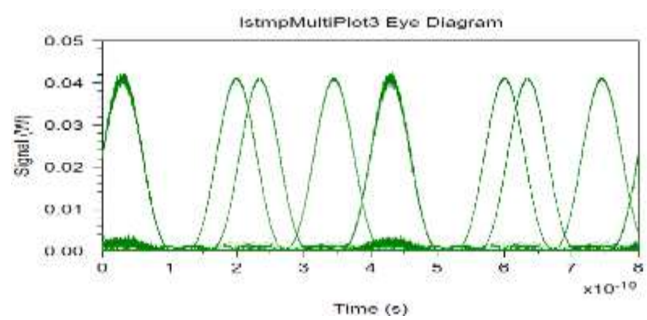


(b)

Figure 12 Auto and Cross Correlation peaks with n=6, d=20KM (a) without SOA (b) with SOA



(a)



(b)

Figure 13 Auto and Cross Correlation peaks with n=8, d=20KM (a) without SOA (b) with SOA

With the use of SOA the system cardinality increases and figure 14, 15 and 16 shows that system performance also improves in terms of transmission distance with the use of

SOA as system is simulated by varying the transmission distance up to 100km and keeping the number of active users constant.

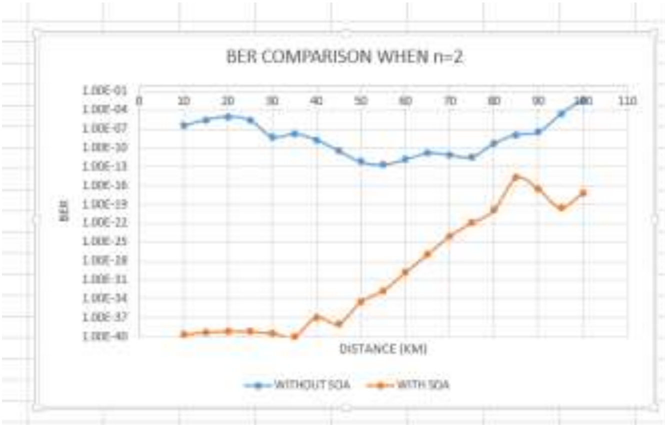


Figure 14 BER Comparisons with and without SOA for n=2 and d=10 Km to 100 Km

From figure 14 it is clearly seen that with SOA the users can effectively transmit up to 100 Km as BER values are in acceptable limits.

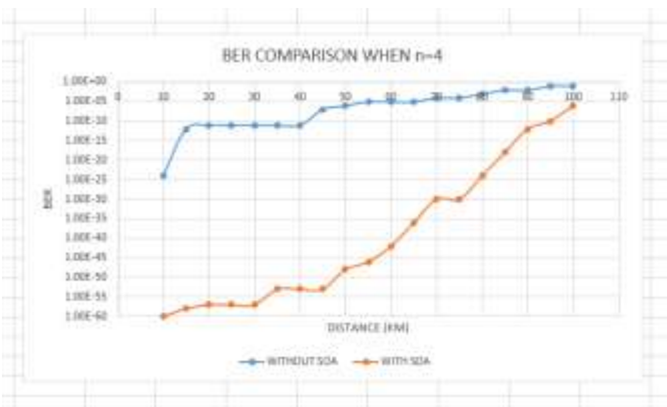


Figure 14 BER Comparisons with and without SOA for n=4 and d=10 Km to 100 Km

Figure 14 shows that as number of users increased to 4 the system give good performance for distance up to 90Km.

Figure 15 BER Comparisons with and without SOA for n=8 and d=10 Km to 100 Km

As the numbers of users increases to 8 and transmission distance increases from 10 to 100 Km , without having SOA in the system , the system performance was limited to 20 Km. Whereas on employing SOA in the system , the system performance increases and the proposed system could effectively operate up to 80Km. Thus there is trade-off between number of users and transmission distance.

CONCLUSION

In the present work, an OCDMA system is designed successfully using 3D W/T/S MPR codes. The performance of this system is analyzed. This system can support 8 active users at 7Gpbs data rate up to transmission distance of 80 Km by employing SOA on the decoder side which effectively manages the dispersion affected auto and cross correlation peaks and thus increasing the cardinality of the system by keeping BER values in acceptable limit. In this work the number of spatial channels is limited by number of wavelengths 1.e. 4. By increasing the number of wavelengths more number of spatial channels can be increased thus more numbers of users can be supported by the system.

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