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Evaluation of Security Aspects of Some Optical Code Division Multiple Access (OCDMA) Systems

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Abstract:

Optical Code Division Multiple Access (OCDMA) is an attractive multiple accessing technique that is used in fiber optics network. As the data being transmitted can be analysed be the eavesdroppers. Therefore, security is a major concern in OCDMA. We have analysed and examined different modulation schemes for three dimensional Single Pulse per plane for direct detection in case of On-Off Keying or differential detection in case of Code Shift Keying and Differential Phase Shift Keying to deduce which of these techniques are best suited against eavesdroppers.

Keywords — **Optical Fiber Communication, Optical Code Division Multiplexing (OCDMA), On-Off Keying (OOK), Code Shift Keying (CSK), Differential Phase Shift Keying (DPSK), Four Wave Mixing (FWM)**.

I. INTRODUCTION

Optical transmission has been topic of tremendous interest for past few decades. A fiber is used as a waveguide to transmit the information from one place to another and optical wave is used as information carrier. As optical signal operates in the frequency range of THz, large bandwidth is available for use. In optical transmission, higher data-rate and data security demands can be met which has been a global challenge. Optical code-division multiple access (OCDMA) takes advantage of both: extreme wide bandwidth offered by optical fiber and flexibility of CDMA to achieve reliable high speed connectivity [1-2].

In optical CDMA system, different users whose signals may be overlapped both in time and frequency share a interference from other users.In an Optical CDMA system, each bit is divided up into n time's periods called chips. An optical signature sequence or a codeword is created, by transmitting short optical pulses during some chip interval but not for others. Pulse can be transmitted in time, frequency or space or in the combination of these domains. Each user has a unique code assigned to them. The encoder of each transmitter represents each '1' by transmitting the unique codeword and represents each '0' by transmitting an all zero sequence [3].

The Literature survey of many different 1D, 2D and 3D OCDMA codes has been done. It is observed that as we introduce a new dimension in the system, we can achieve a larger codeset and have better BER performance. All the codes emphasise on the reduction of out of phase auto correlation and cross correlation. Main objective of these codes is to increase the total number of simultaneous users that can be allowed in a system while keeping the multiple access interference minimum. The security of the data is also improved as we increase the dimensions of the code. Yet, the security of OCDMA codes is still a major concern. So, we need different schemes which can improve the security of the information signal.

In this paper we analysed and examined different modulation schemes for three dimensional (3D SPDD) Single Pulse per plane for direct detection in case of On-Off Keying or differential detection [4, 5] in case of Code Shift Keying and Differential Phase Shift Keying. We simulated OCDMA system by comparing different modulation schemes based on the received power, number of planes used in code, number of active users and bit rate of the operating network to reckon the BER and security performance [6-9] using Optisystem™ software.

The remainder of this paper is organised as follows: Section II consists of the simulation setups of OCDMA system using modulation schemes like On-Off Keying (OOK), Code shift Keying (CSK) and Differential Phase Shift Keying (DPSK). This helps us understand how the OCDMA system will work under the effects of different modulation schemes. Section III involves the results and discussion part of this paper. Section IV discussed the future scope for the research. And at the last conclusion is given in Section V.

II. SIMULATION SETUPS

In the section, we are going to explain the simulation setup of different modulation schemes like ON-Off Keying (OOK), Code Shift Keying (CSK) and Differential Phase Shift Keying (DSPK). All the setups are performed on the OptiSystem v14 software. The simulation setups of these schemes are as given below:

A. *On Off Keying*

As shown in Figure 1, there are five main blocks for OOK in any OCDMA codes: User, Encoder, Fiber, Decoder and Receiver. The value of wavelength, time slots and Space channel is $W = 4$, $T = 4$ and $S = 2$. The setup works at the bit rate of 4.5 Gbps. We have a total number of four wavelengths, four time slots or delays and two space channels. Each space channel has for wavelengths that depends upon the time slots or delay. This is the simplest scheme among all others.

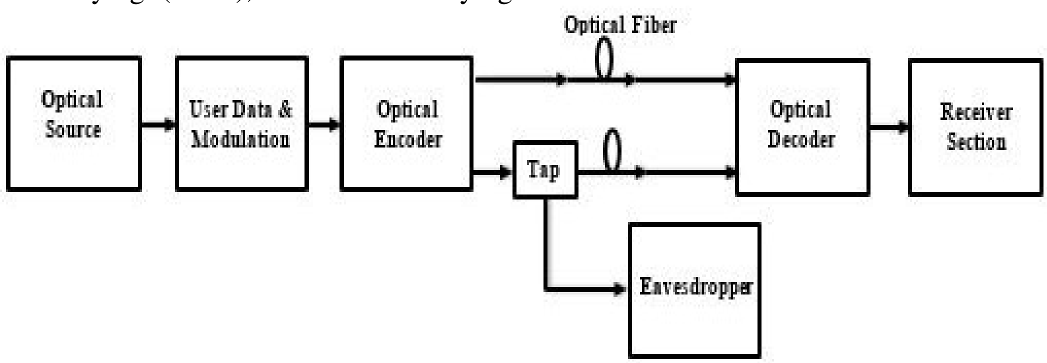

Figure 1 Simulation setup for implementation of 3D SPDD codes with eavesdropper using On-Off Keying.

The performance of the setup is analysed using BER analyser and eye diagram. As for the security analyses we use the eavesdropper. As the light travelling in the fiber may leak out of the core and clad, the person eavesdropping may place a tap that receives a portion of the light that is leaked out. By analysing this light and then analysing, there is a chance that the eavesdropper will be able to decode the user data successfully. We have studied two types of eavesdropper devices: Simple energy detector eavesdropper and DPSK eavesdropper. It has been observed in pass studies that an isolated user is more vulnerable to the eaves dropping, therefore we have analysed a single user more carefully. In case of OOK, the simple eavesdropper works well so we didn't analyse DPSK eavesdropper but it will be analysed for other methods.

B. *Code Shift Keying*

As shown in Figure 2, the light is transmitted for both '0' and '1' in this case. So, the energy in present at all-time intervals which makes eavesdropping using the Simple Eavesdropper difficult. Therefore DPSK eavesdropper is used. Basic setup is same as On-Off Keying.The encoder is used to encode both the signals separately. Due to this the actual number of users is half of the code set size and OOK users. Signal for space channel 1 and 2 for both data and data bit is first multiplexed and then transmitted over optical fiber.For the security analysis both simple and DPSK eavesdropper are analysed. This scheme is the one which shows best results among all the other studied schemes.

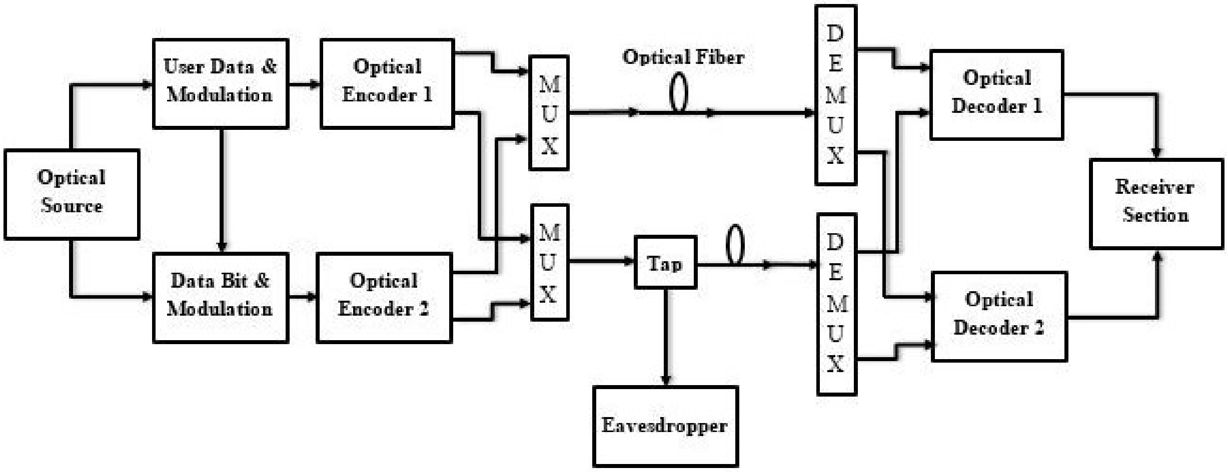

Figure 2 Simulation setup for implementation of 3D SPDD codes with eavesdropper using Code Shift Keying.

C. Differential Phase Shift Keying

Basic outlook of the DPSK and OOK is approximately same with few internal changes. The bit rate at which the setup works is 4.8 Gbps. The number of wavelengths, time slots and space channels is also same. The layout for 3D SPDD codes for DSPK is given in Figure 3. Both Simple and DPSK eavesdropper are analysed for security. This scheme is most difficult to implement both on the transmitter and receiver side.

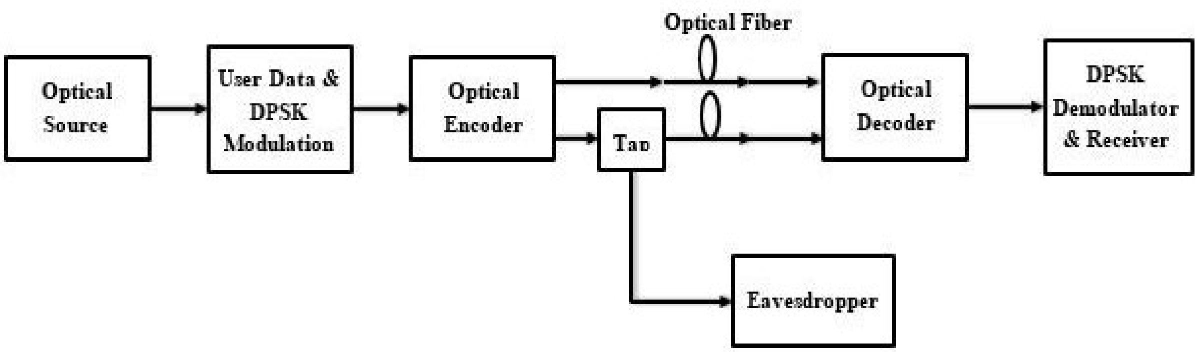

Figure 3 Simulation setup for implementation of 3D SPDD codes with eavesdropper using Differential Phase Shift Keying.

III. RESULTS AND DISCUSSION

We have implemented the three dimensional SPDD codes in Optisystem for different number of space channels, different number of users, different received power levels and different bit rates while keeping the value of number of wavelengths W and time slots T constant. We will analyse all these parameters and observe for which parameter value the OCDMA system gives best performance. We have also compared the performance of all the methods such as On-Off Keying, Code shift Keying and Differential Phase Shift Keying to find out which of them works better on the account of performance and security. The comparison of all the modulation techniques (On-Off Keying, Code shift Keying and Differential Phase Shift Keying) is done by varying the received power against the BER, by varying the number of space channels against the BER, by varying the number of users against the BER and by varying the Bit rate on which the system works against the BER. The power at the receiver is measured using the Optical Power Meter and the BER is measured using the BER analyser.

Figure 7 shows that as we change the value of received power, the BER value is also changed. As the Received power of the signal decreases the BER value of the signal increases. By varying the received power using the attenuator at the receiving terminal for all the modulation schemes i.e. OOK, CSK and DPSK and then measuring the BER using BER analyser, we can compare the BER for all the methods and thus from their combined plot between received power the BER, find out which of the three schemes shows best results based on performance and security analysis. By observing this graph, CSK shows the best BER performance compared to OOK and DPSK until the received power approx. drops below -45 dBm. Also, security wise the CSK again shows better performance than the rest. OOK has the least security against the eavesdroppers, while DPSK shows medium performance compared to the CSK.

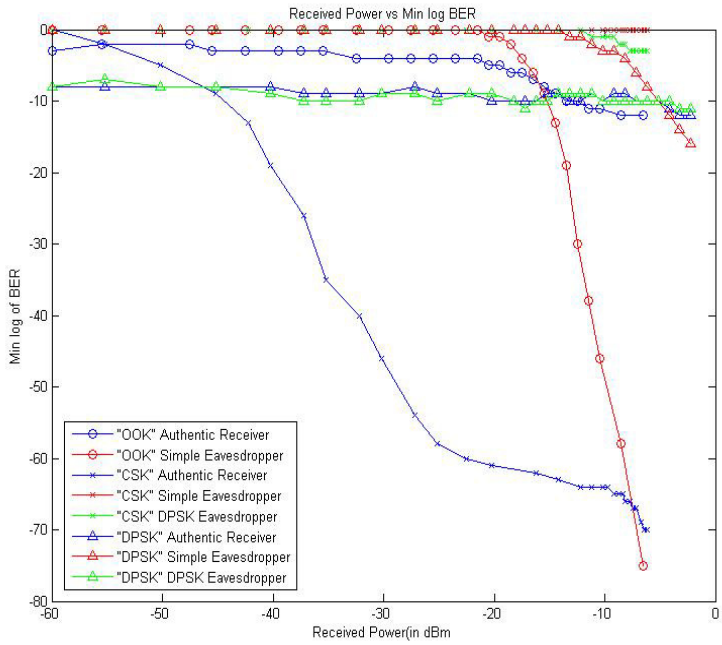

Figure 7 Effect of Received power on BER performance of Different OCDMA modulation schemes.

Figure 8 shows how the BER of the signal is affected with the change in number of space channels used. As the number of lanesincreases,the BER value of the signal decreases.By varying the value of number of planes $S = 2$, $S = 3$ and $S = 4$ for OOK, CSK and DPSK, their corresponding BER value is measured and compares the varied Number of Planes versus BER for all the modulation schemes and find out among all of the analysed scheme which one shows the better performance and security than the rest. By observing the graph, it can be interpreted that DPSK receiver shows best performance among all the three schemes, them after the DPSK is CSK which also shows better performance than OOK. As far as the security is concerned, for simple eavesdropper, OOK is the least secure and DPSK is the most secure but for the DPSK eavesdropper the security of the DPSK is least among all the other techniques.

Figure 9 shows that with the variation in the Bit Rate of the system, the BER also changes.As the Bit rate of the system increases the BER value of the signal decreases. By varying the bit rate (in Gbps) on which the systemperforms for all three modulation schemes OOK, CSK and DPSK, their corresponding BER value is measured using the BER analyser.After that the results are compared for all the schemes using varied Bit Rate versus BER and we find out that among all these schemes which one performs better.On observing the graph, it can be deduced that the BER performance of OOK with respect to changing Bit Rate is best among all the schemes. After the OOK, the CSK modulation performs better and DPSK performs least good of all. Also it can be noted that around 4.5 Gbps all the scheme converges to almost same BER and as we increase the Bit Rate from that point all the scheme shows similar performance. Also, Security of the DPSK against the DPSK eavesdropper for low bit rate is more vulnerable. Then the OOK is less secure against simple eavesdropper but security improves with increasing Bit rate. Out of all the schemes the CSK is most secure for almost all value of bit rate.

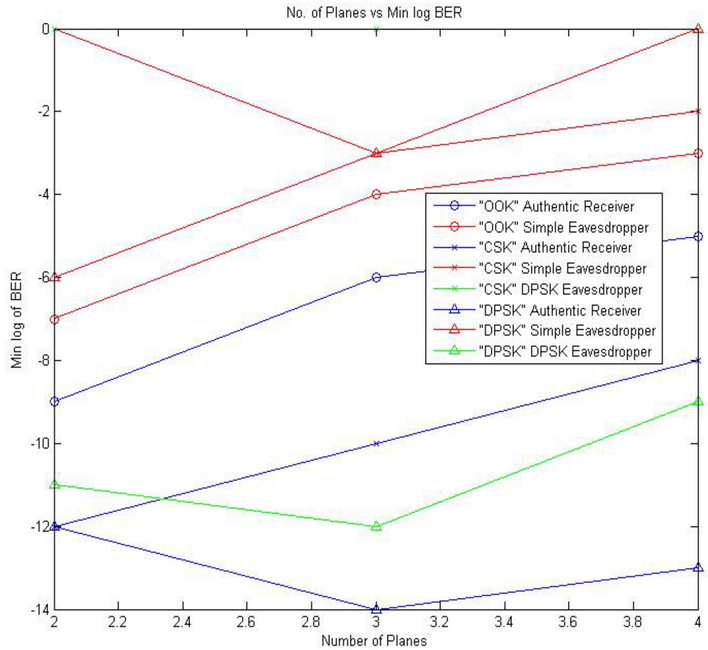

Figure 8 Effect of Number of Space Channels on BER performance of Different OCDMA modulation schemes.

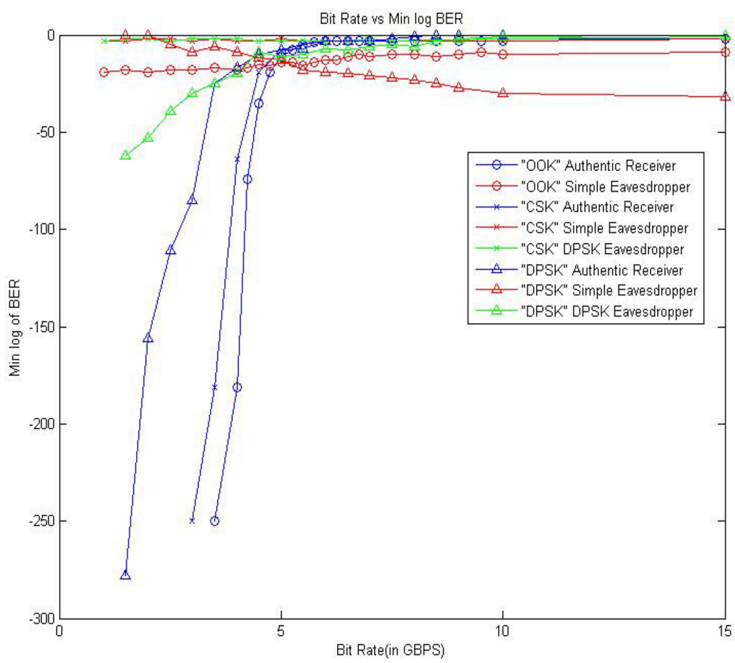

Figure 9 Effect of Bit rate on BER performance of Different OCDMA modulation schemes

Figure 10 shows how the change in number of users affects the BER of the User 1 while previously no other users were active. Figure 11 shows how the change in number of users affects the BER of the User 2 while previously only one user was active. Figure 12 shows how the change in number of users affects the BER of the User 3 while previously two users were active. The varied number of users are applied to all the modulation schemes and the BER values of all the users are measured. The maximum number of users analysed are four. Based on the measured value we are able to find which scheme shows best performance as we increase the number of active users in the system. On observing all these graphs, it can be deduces as with increase in number of users the performance of the users slightly decreases and the security of the users improves by a huge margin. The performance of newly active user is also better than previous users.

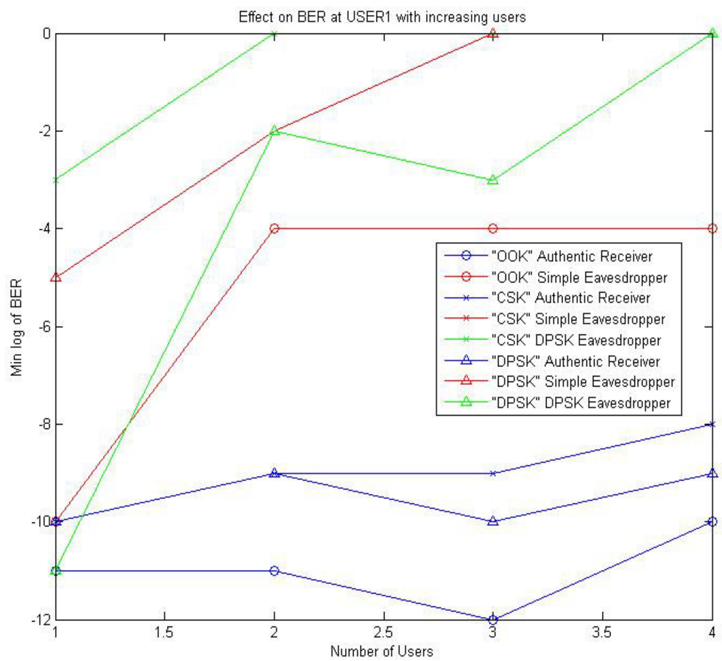

Figure 10 Effect of increasing users on BER performance of Different OCDMA modulation schemes at User 1.

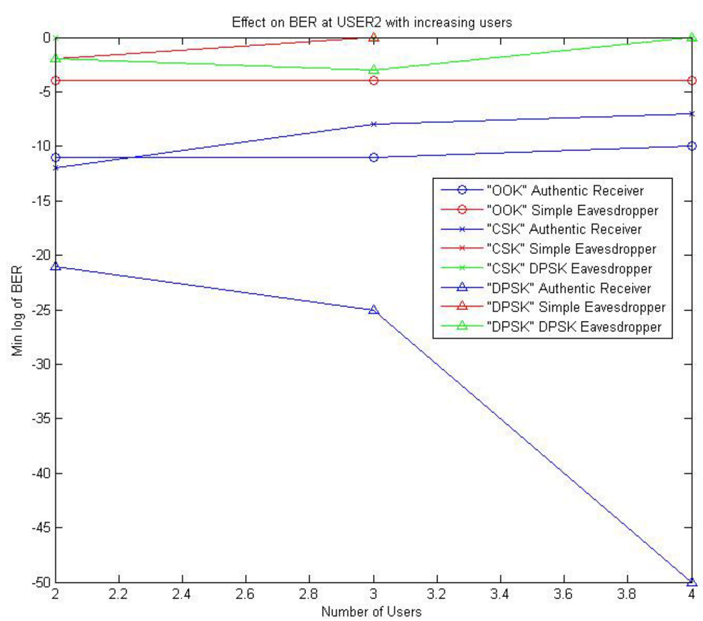

Figure 11 Effect of increasing users on BER performance of Different OCDMA modulation schemes at User 2.

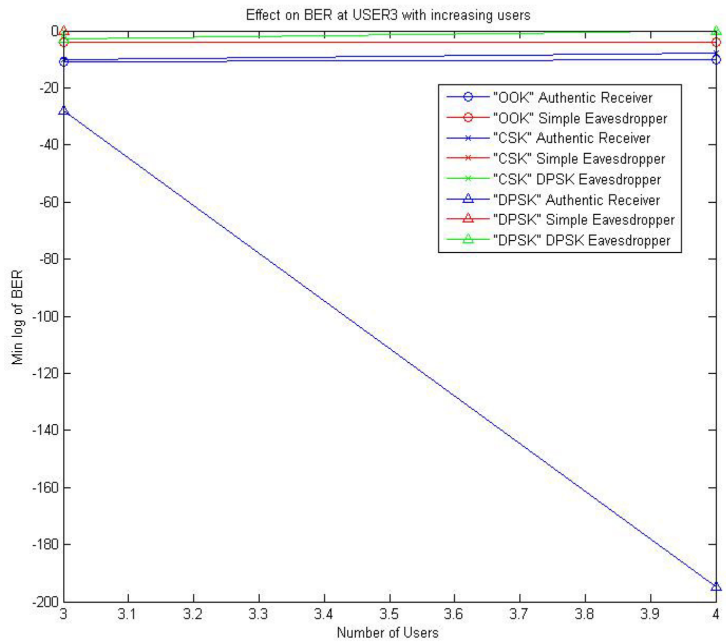

Figure 12 Effect of increasing users on BER performance of Different OCDMA modulation schemes at User 3.

IV. FUTURE SCOPE

During the course of this research, several avenues for the continuationof this study became evident. So, here brief remarks on the future scope of the present researchwork have been listed and a number of open problems/issues related to the work are summarized as under: This work can also be extended to study of OCDMA system by further investigating the modulation schemes using BSK, FSK, QPSK and m-ary techniques.

V. CONCLUSIONS

Based on the performance analysis, by varying different patterns such as bit rate, number of planes, number of users and received power for three different modulation schemes: OOK, CSK and DPSK for three dimensional SPDD codes we can conclude that based on all the parameters Code Shift Keying shows the overall better BER performance and security than any other modulation scheme for constant wavelength W = 4and time slots T = 4. On-Off Keying is the simplest and easy to implement among all coding schemes. DPSK is the most complex scheme to be implemented and its performance is better than OOK. The number of total users is also high for both OOK and DPSK than CSK as in case of CSK each user is assigned set of two codes. The overall performance of CSK is better than other two schemes and can be easily implemented as same as On-Off keying.

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