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FSO Optical System Utilizing DPSK Advance Modulation Technique

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Abstract— This paper propose Free Space Optics Systems (FSO) which is considers one of the most effective solutions to the optical communication environment.0.00, especially for atmospheric turbulence due to the weather and environment structure. Free space optics system suffers from various limitations. The main objective of this article is to modulate the transmitted signal by using Digital Phase Shift Keying (DPSK) modulation technique at 33% of modulation signal. CW laser input source with wavelength at 1550 nm, power 10mw.Free Space Optic (FSO) used as a media transmission line produces less effect in atmospheric attenuation. Short link range between the transmitter and receiver can optimize the FSO system transmission parameters or components. Based on the analysis, it is recommended to develop an FSO system of 40 Gbps with 1550 nm wavelength and link range up to 700 km .the implementation of this system requiring anew design of OCDMA technique to avoid the suffering system from the problem of multiple access interference (MAI).

And then we can achieve an Optical Code Division Multiplexer (OCDMA) system asynchronous transmission, secure communication, of capacity on demand, and high degree of scalability.

Keywords: laser, DPSK modulation, Binary NOT, Duo binary DeLay, Optical Null, LiNb MZ modulator.

1- INTRODUCTION

Free space Optics (FSO) has emerged as a promising solution. It is due to the advantages of FSO. FSO is the best solution for last –mile bottleneck problem. It offers broader and unlimited bandwidth and license free compare to deployment of microwave link. it can be installed in a shorter time and lower cost compare to laying down fiber optics cable [1].Then can deliver the same bandwidth as optical fiber but without the extra cost of right of way and trenching, without the electromagnetic interference due to the nature of information carrier photons unlike the RF based system, it has light weight and is very compact and consumes low power [2].

Figure(1). Below shows free space optical (FSO) transmission system. This diagram shows that free space optical transmission systems loose some of their energy from signal scattering, absorption and scintillation. Optical signal scattering occurs when light signals are redirected as they pass through water particles. Optical signal absorption occurs as some optical energy is converted to heat as it strikes particles (such as smog). Scintillation occurs when heated (such as from smokestacks) air cause a bending of the optical beam. This example shows that it is possible to transmit multiple light wave signals on different wavelengths (WDM) to increase the overall data transmission rate.

Fig.1: Free Space Optics-FSO Diagram

The SCM technique is attractive because it encompasses the multiplexing of both multichannel of analog and/or digital signals. These signals can carry either voice, data, video, digital audio, high-definition video or any other analog or digital information. In SCM system, the input signals are modulated with different electrical carriers at microwave frequencies and then they are combined by using a combiner. The combined signal is then modulated by intensity modulation or external modulation techniques. The modulated light wave signal is transmitted through an optical fiber. At the receiver end, the optical signal is converted back to an electrical current by a photodetector. The particular signals can then be De multiplexed and demodulated, using conventional detection methods. The attractive feature of SCM is the independence of the different channels. This allows for great flexibility in the choice of modulation schemes. In addition to being flexible, the current SCM technology is also cost-effective as it provides a way to take advantage of the multi-gigahertz bandwidth of the fiber optics, using well-established microwave techniques for which components are commercially available. Furthermore, it is less expensive than the corresponding WDM technology [3].In this paper, a new and simple detection scheme named as AND subtraction is proposed. The studies were made using EDW code of SAC-OCDMA system. The EDW code has a fixed weight of three. The SCM is employed to improve the channel data rate of the OCDMA [4, 5]. A large number of channels can be achieved with many code sequences and few subcarriers per code sequences, or with the converse. It is shown in this paper that the hybrid of SCM SAC-OCDMA system using the proposed AND subtraction detection technique provides a significantly better performance than the hybrid system using complementary subtraction technique. The transmission distance of the hybrid SCM SAC-OCDMA system can be extended using this new technique compared to the complementary subtraction technique. The signal-to-noise ratio (SNR) is improved by 7dB when the transmitted power is fixed at 0dBm.

2. System Analysis

The block diagram of a typical FSO system is shown in Fig. 2.This figure shows the basic concept and devices that have been used in designing the unidirectional WDM system. There are Pseudo-Random Bit Generator, NRZ Pulse Generator, CW Laser, Mach-Zehnder Modulator at transmission part; while, APD photo detector and Low Pass Gaussian Filter at the receiver part. However, some of measurement tools such as Oscilloscope, Optical Time Domain Visualize are used as well. The impact on system design parameters are illustrated in the representative characteristic and data observation given in Table 1; with proper parameters, FSO based on WDM system can be optimized to achieve a maximum link range of operation. The quality of the received signal is greatly depends on the conditions of the free space channel and the WDM system design. In order to suppress the beam diffraction that occurs naturally with propagation, an optical signal is then sent through an optical fiber to a collimating optical system [7].

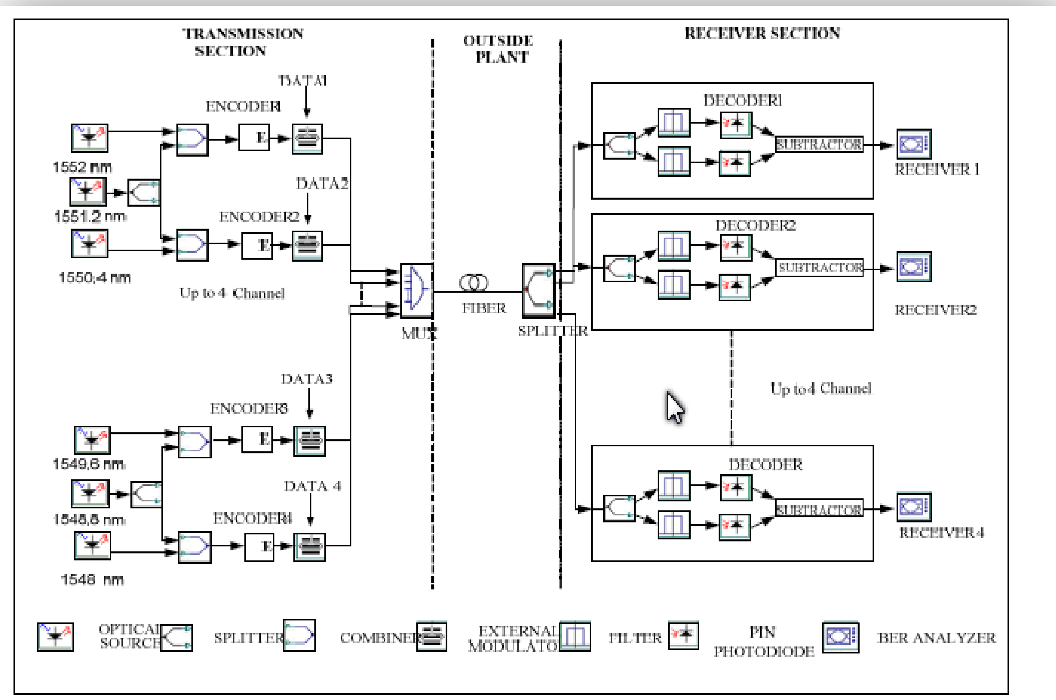


Fig.2: the system architecture of the OCDMA network.

Table 1
Representative characteristic and data observation

Characteristic		Data Observation
Data rate	40 Gbps	Data rate versus bit error ratio
Power	4mw	Power versus bit error ratio
Link range	700 km	Link range versus bit error ratio
No. of user	Depend	No. of user versus bit error ratio
Channel spacing	0.8 nm	Channel spacing versus bit error ratio

2.1 OCDMA system

OCDMA system provide asynchronous transmission, secure communication, soft capacity on demand, and high degree of scalability. This is the most advantages, but also OCDMA have more problems representing that OCDMA system provide high degree of scalability and security .the optical CDMA systems suffer from the problem of multiple access interference (MAI) as the number of users increase the BER error rate degrade because the effect of MAI increase, so there is a limitation in number of users, as the number of users increase SNR degrease and probability of error increase. There is a limitation of speed also in optical CDMA system, since very short pulse are to be required within each bitrate, there is also a problem of high optical splitting at encoder\decoder. Fig.(2) shows the conceptual OCDMA network diagram for many of the OCDMA. On the transmitter side of an

OCDMA system, an OCDMA encoder is used to encode the input data bit stream into an optical signal depending on the mark sequence that is discrete for each user on the system. This encoded signal is multiplexed with the signal generated from all other users. On the receiver an OCDMA decoder uses a matched filter that corresponds to the signature sequence of the desired user. Depending on the technology of choice, this decoder optical signal is then passed into a direct detection known as a photo-detector (e.g., InGaAs PIN, Ge APD) or a differential detection balanced receiver, which generates an electrical signal by Decoding on the channel code correctly situation the threshold for tough choice, or by performing soft choice The purpose of an optical receiver is to convert modulated optical power to a binary data torrent. The composed of a PIN` photo detector diode, a trans impedance amplifier, an AGC post amplifier, a clock and data recovery, and a DE multiplexer circuit the function and operating characteristics of these circuits within the optical receiver

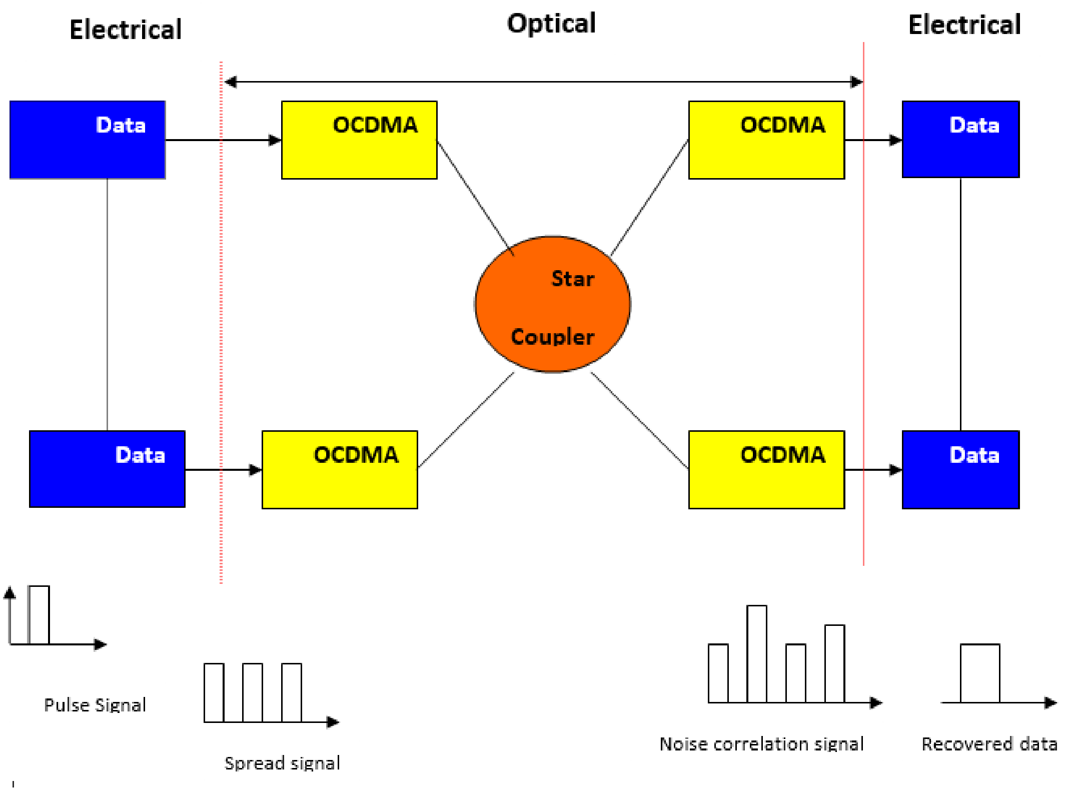


Fig.3 Conceptual diagram of an OCDMA network

2-2 Asynchronous DPSK Receivers:

Now let us treat the BPSK modulator and differential encoder jointly. Let us assume that the elementary signal *s0(t)*. From the respective waveform in Figure(4). we see that the 180◦ phase shift with respect to the current phase is triggered by the data symbol *ai* = 1, whereas there is no phase shift if the data symbol *ai* = 0 appears on the modulator input. Such a modulation is called *Differential Phase Shift Keying* (DPSK) and it can be achieved also through differential encoding and regular BPSK modulation.

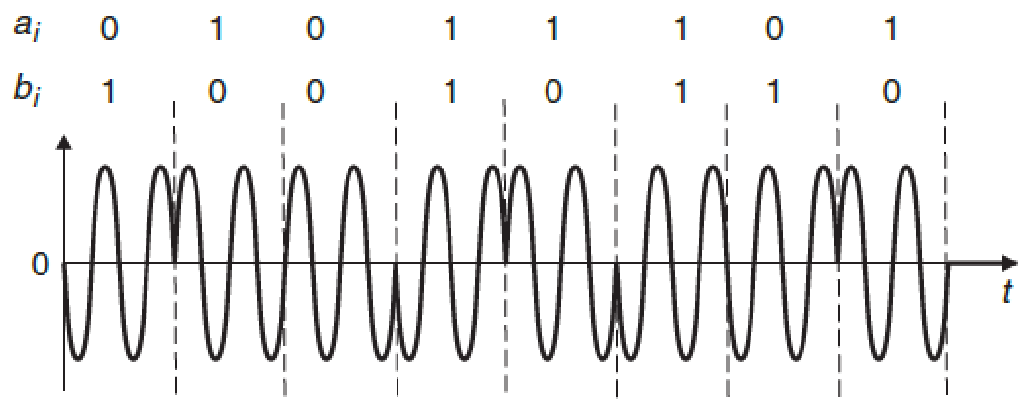


Figure 4: Example of DPSK-modulated signal waveform

Instead of regular PSK modulation a DPSK modulation with asynchronous reception can be applied. The signal is described by formula shown below, and the in-phase and quadrature baseband components of signal (4) are determined by the expressions

$$x^I(t) = \sum_{n=-\infty}^{\infty} d_n^I p(t - nT) \quad x^Q(t) = \sum_{n=-\infty}^{\infty} d_n^Q p(t - nT)$$

Signals on the output of both receive filters are sampled once per modulation period and are proportional to the cosine and sine of the angle $\varphi n + \theta$, respectively, where θ represents the carrier phase difference between the received signal and the demodulating signal. For DPSK modulation for which information is carried by the phase difference between the current and previous modulation periods, besides a correlative receiver another type of asynchronous receiver is also possible. This receiver is called an *auto correlative receiver*, because correlation is performed between the currently received signal and the signal received during the previous modulation period and stored in the delay line. Two versions of a DPSK auto correlative receiver are shown in Figure 5.

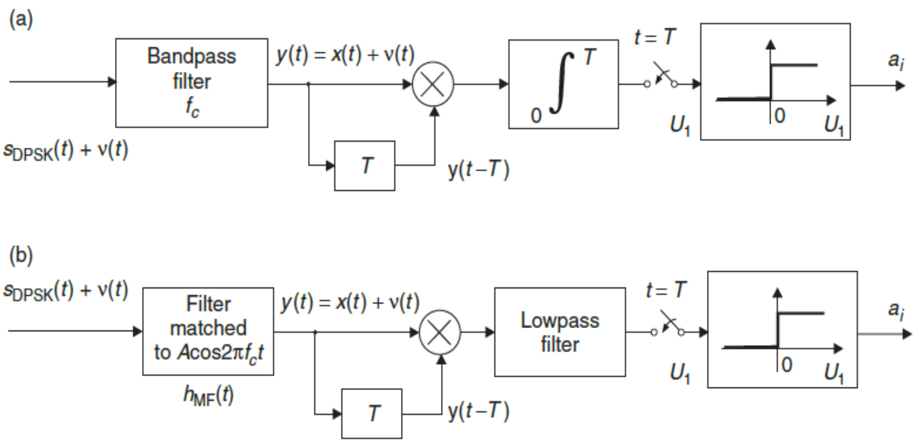


Figure 5- Auto correlative receiver for binary DPSK signals:
(a) suboptimal receiver; (b) optimal receiver with a matched filter

Neglecting noise for a while, which is approximately equivalent to the assumption of a high signal-to-noise ratio, we can describe the sample on the output of the correlator as a random variable U1：

$$U_1 = \int_0^T A\cos(2\pi f_c t + \varphi_n + \theta) A\cos[2\pi f_c (t - T) + \varphi_{n-1} + \theta]\mathrm{d}t$$

$$= \frac{A^2}{2}\int_0^T \left[\cos(\varphi_n - \varphi_{n-1}) + \cos(4\pi f_c t - 2\pi f_c T + 2\theta + \varphi_n + \varphi_{n-1})\right]\mathrm{d}t$$

$$= \frac{A^2 T}{2}\cos(\Delta\varphi_n)$$

The scheme is rather simple but its performance is inferior to the other receiver types, because in reality the noise from the current and previous modulation periods disturbs the correlation process. for high signal-to-noise ratio the error probability on the receiver output can be approximated by the following formula shown below:

$$P_{\mathrm{DPSK}}(\mathcal{E}) = \frac{1}{2}\operatorname{erfc}\left(\sqrt{\frac{1}{1 + \frac{BT}{2}\frac{N_0}{E_s}}\frac{E_s}{2N_0}}\right)$$

3. SYSTEM DESIGN

Figure 6 shows the proposed SCM-SACOCDMA network which is designed based on MDW code. In the transmitter side, external optical modulator (EOM) is utilized to merge data with independent unipolar digital signal which is optically modulated onto the code sequence [2]. The EOM such as Mach–Zehnder modulator is utilized to combine the RF signal with the code sequences and with the transmitter on FSO link

[4]. While at the receiver side, an optical Splitter is used to separate the different modulated code sequences. The MDW code sequences are filtered by using Fiber Bragg Grating (FBG) filters and then, transferred to photo-detector (PD) at the receiver [5]. Consequently, the SCM signals that are combined with each MDW code sequence are split by an electrical splitter and band pass filter (BPF) to filter and reject unwanted signals.

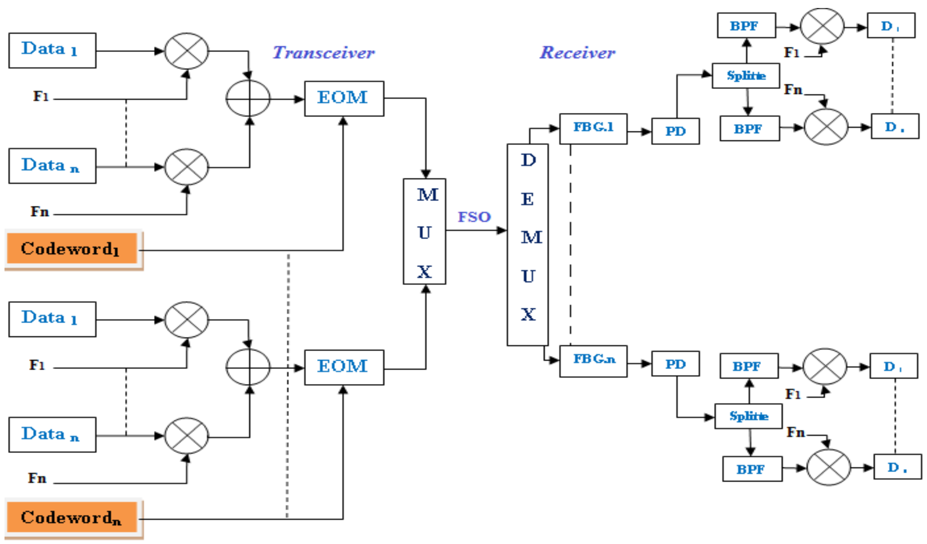


Figure 6: Performance of SCM-SAC-OCDMA based FSO.

3.1 Review of EDW CODE

EDW code is another version of DW code family [7]. The EDW code weights can a variable weight that is greater than one. In this paper, the EDW with the weight of three is used as an example. As a family of DW code, EDW can also be represented by using the KxN matrix. The essential EDW code denoted by (6, 3, and 1) is shown below

$$H1= \left| \begin{matrix} 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 \end{matrix} \right| \begin{matrix} 0 & 1 \\ 1 & 1 \\ 0 & 0 \end{matrix}$$

Perceive that a similar structure of the basic DW code is still maintained with a minor modification, whereby, the double weight pairs are maintained in a way to consent to
only two overlapping chips in every column. Thus, the 1, 2, 1 chips combination is maintained for every three columns as in the basic DW code [8, 9]. This is important to maintain $\lambda=1$. The same mapping technique as for DW code is used to augment the number of user. The example shows that we can increase the number of users from three to six while the weight is still fixed at three. An MDW code with weight of four denoted by (N, 3, 1) for any given code length N, which can be related to the number of user *K* through.

4. Performance Analysis

The performance of EDW, code with DPSK code modulation was simulated by using commercial simulation software, OptiSystem Version 7.0. A simple schematic block diagram consisting of 4 users is illustrated in Fig. 7. Each chip has a spectral width of 0.8 nm. The test was carried out at the rate of 10 Gbps for 700 km distance with the ITU-T G.652. Standard single mode optical fiber. All the attenuation (i.e. 0.25 dB/km), dispersion (i.e. 18 ps/nm-km) and non-linear effect was activated and specified according to the typical industry values to simulate the real environment as close as possible. The performance of the system was evaluated by referring to the bit error rate, BER and the eye pattern. At the receiver side of the system, the incoming signal splits into two parts, one to the decoder who has an identical filter structure with the encoder and the other to the decoder who has the AND filter structure. A subtracted is then used to subtract the overlapping data from other users. The results (eye pattern) taken after the

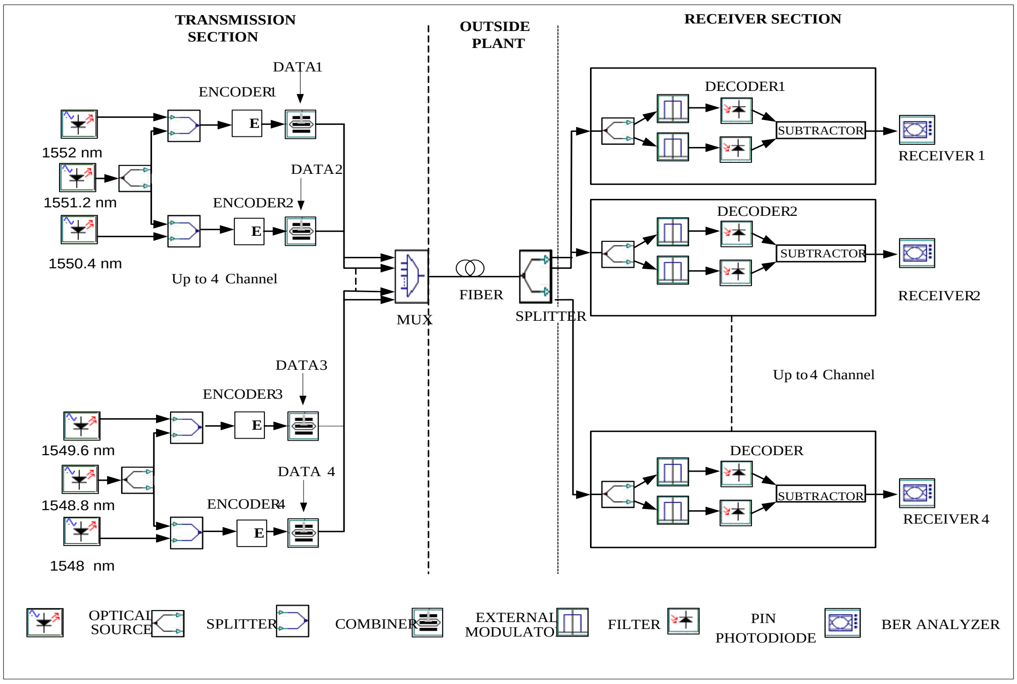


Fig. 7. *The system architecture of the OCDMA network*

Referring to figure 7. , we can see that in free space transmitter the data can transmit for more than 700 Km, at very stable system. The transmitter uses CW laser at the source specifications as follow

- with maximum signal power of 6 dBm

- wavelength at 1550 nm

- noise power equal to (-100 dBm)

- lower frequency limited = 1620.5nm

-upper frequency limited = 1498.96nm

To ensure the linearity of the system, the CW laser is properly biased and the peak –to-peak voltage of the input signal cannot exceed the specified values. The data can transfer clearly as BER function that equal to the value of 7.2 e^{-7} for maximum value while at the minimum length 100Km the value of BER will be at 2.8 e^{-215} . Hence, we can say this is a good result for this system. For these results, the following parameters were used: line width thermal noise= $3.75x10^{12}$ Hz; electrical bandwidth will be equal to 80 MHz at the operating wavelength of 1550 nm. We can take the Erbium Doped Fiber Amplifier (EDFA) with 20 dB gain, immediately after the transmitter to lunch power signals into fiber to transmit the signal for long distance as possible which is depend to the type of amplifier and the system design it mean the transmitter and receiver design . in this system we used the AND –subtraction detection techniques in the receiver to demodulate the signal, also the complementary –subtraction detection technique can be used in this system .for EDW code the more suitable technique is AND-subtraction

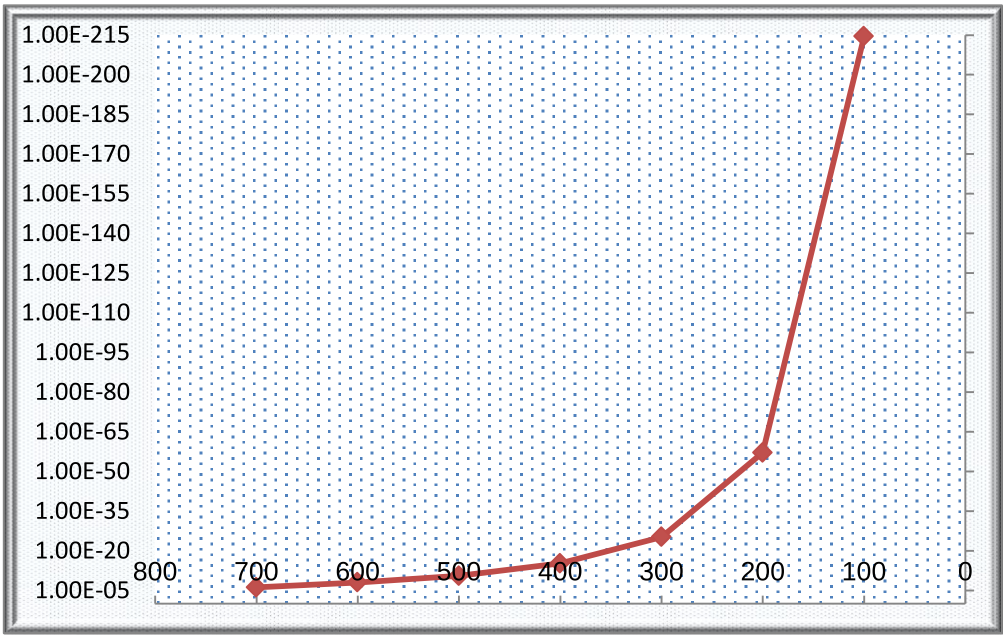
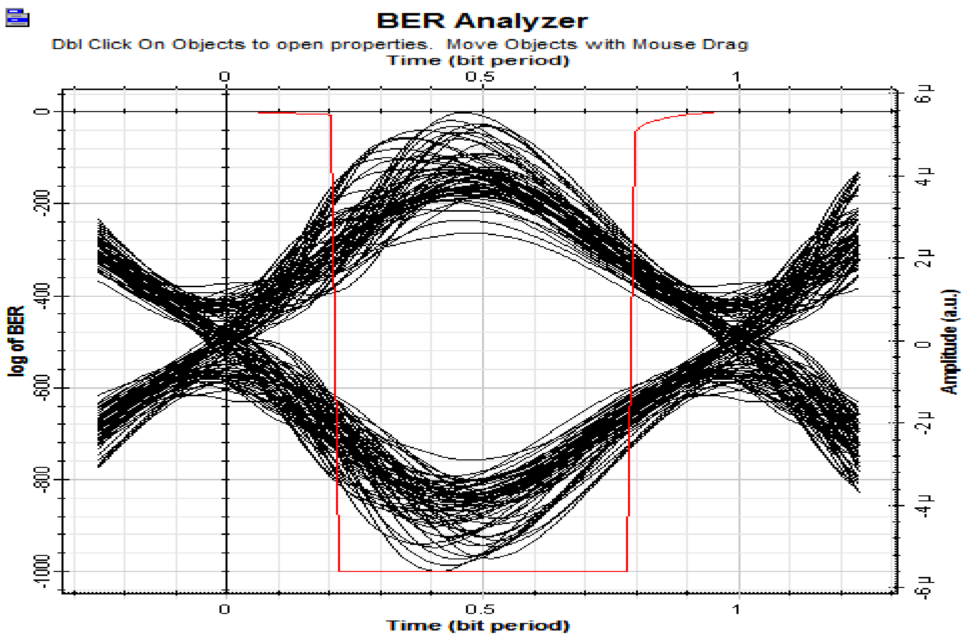
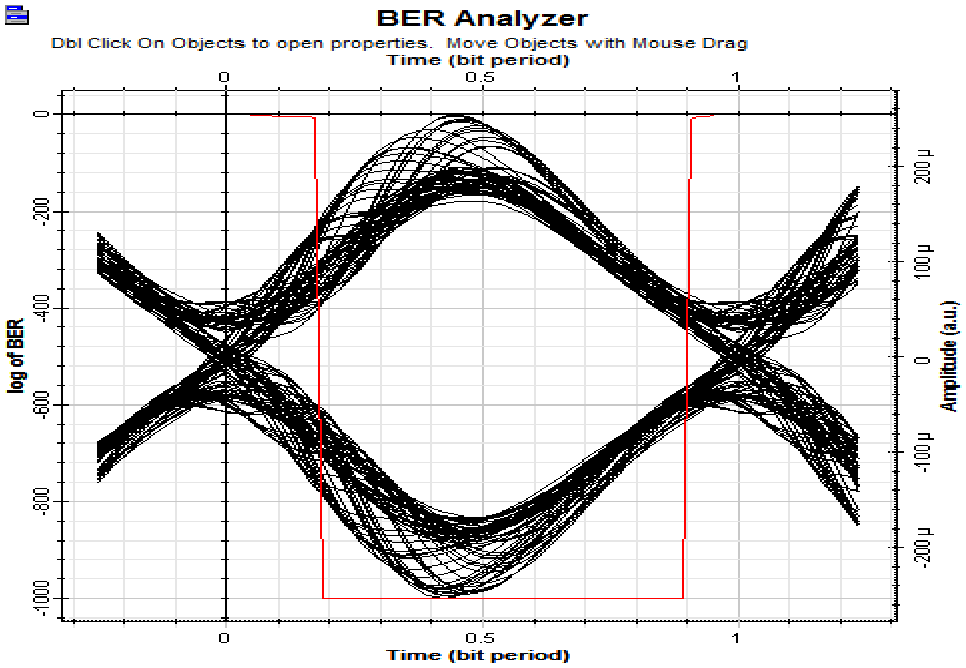


Fig.8: Relation between fiber length and BER

Figure (8) referring to the relation between fiber length which is starting from 100 km to 700 km fiber length ,in the other side corresponding to the Bit Error Rate (BER) relation which is equally to the vales of 8.13, also it can be represented by use of eye diagram as shown in figure (9) below a, and b.



a) BER diagram at 100km

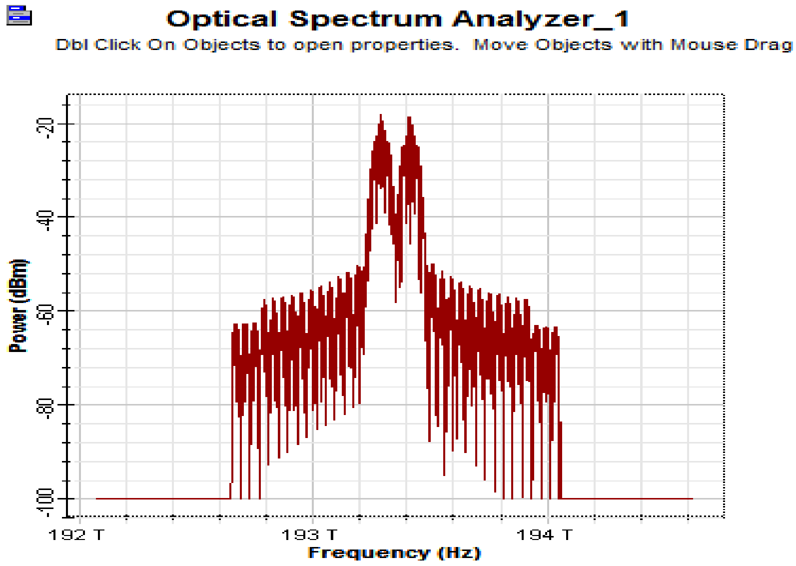


b) BER diagram at distance of 700km

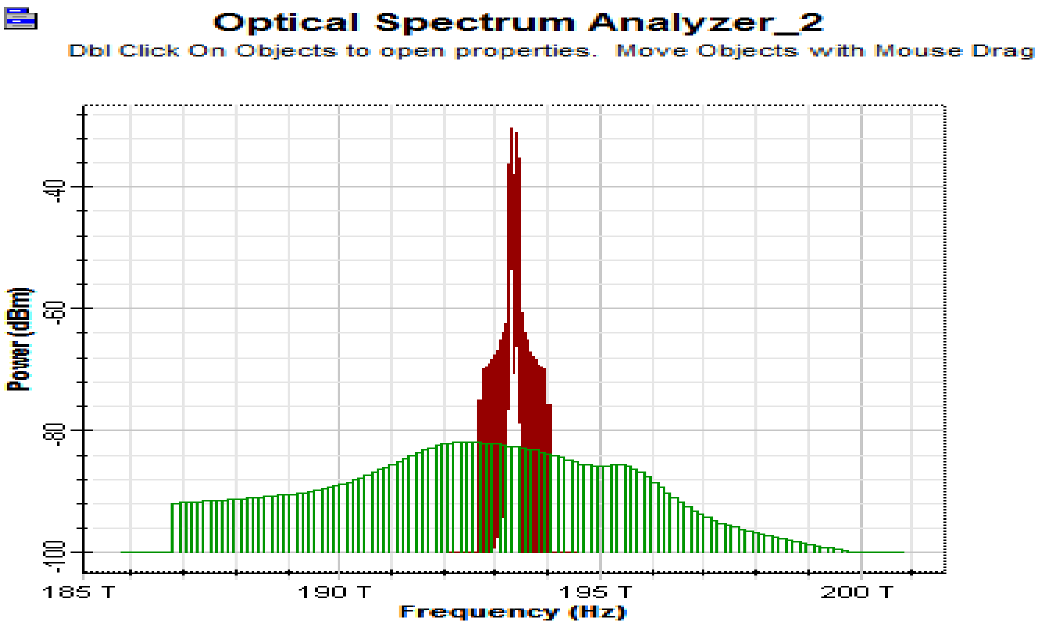
Fig (9) Eye diagram relation between fiber length in km long and the BER ,a &b

From fig.(9) illustrate the output results represented by eye diagram ,at the 100Km distance the Bit Error Rate was equal to 8.13 x e^{-44} while at 700 Km the BER will be at value 1.8 x e^{-9} .it is an good results that meaning we can transmit the all data for more than 700 Km with sufficient depending on the stable designing of the system using FSO media .

The scheme of DPSK design is rather simple but its performance is inferior to the other receiver types, because in reality the noise from the current and previous modulation periods disturbs the correlation process.



a)Signal spectrum at the receiver section



b)signal spectrum at the receiver section

Fig.10 The spectrum analysis waveform in transmitter and receiver a &b

Fig.10 gives a quick examination of the quality of the optical signal, the spectrum signal analysis referring to the shape of the signal at the transmitter which is totally equal to (- 20dBm) as a power transmit with the center frequency equal to (1.9×10^{14} Hz) and at the receiver channel the power is almost equal to (-50 dBm) at the same frequency (1.9×10^{14} Hz).otherwise its clearly depict that the EDW code system gives a better performance working in this system depending on its simple performance in code construction than other codes.

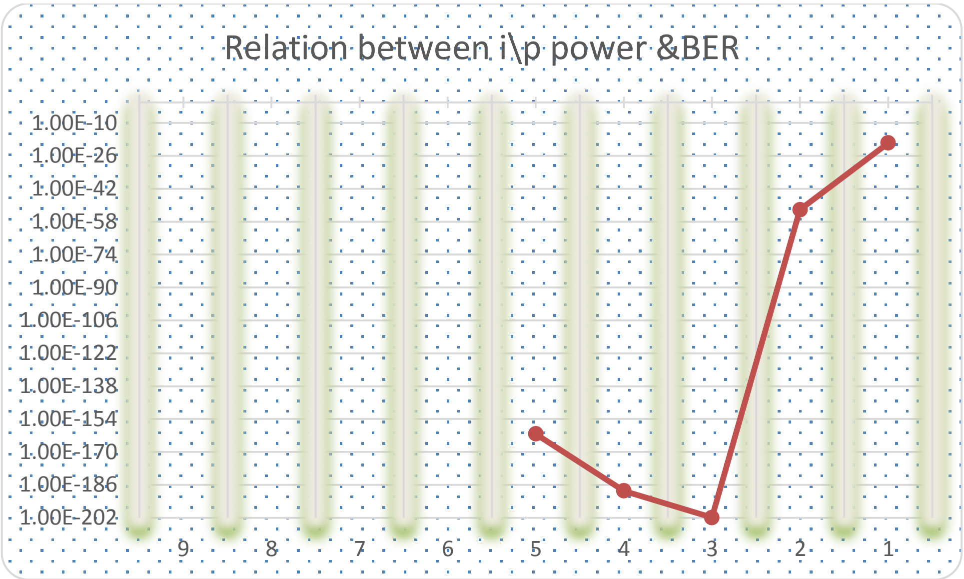


Fig .11: Relation between input power and BER

From the fig (11) we can see the relation between input power which is equal to 10 mw maximum the graph starting from 1 mw equal to 1x e^{-25} BER while at 5 mw it is equal to 1x e^{158} BER. This is because of the use of CW leaser working as a source laser.

5- Conclusion

The unlicensed, higher speed, broader and unlimited bandwidth, low-cost solution, and shortest deployment time frame are some of the drive to deploy FSO. In this paper we have discussed that sucsusffly used the advantages of transfer voice, TV and data using free space optic by help of DPSK modulation technique. As from the above mentioned we can use another way of modulation in the same system depending on the type of detection which is more suitable for the design system**.**

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