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Eliminating the Effect of MAI in FSO SACOCDMA under Different Haze Conditions

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ABSTRACT: Free space optical (FSO) communication system plays an important role in the optical communication which employing the Spectral Amplitude Coding Optical Code Division Multiple Access (SAC OCDMA) technique in various field of application. Multiple-Access Interference (MAl) and Phase-Induced Intensity Noise (PIIN) which are the major noises in incoherent SAC-OCDMA systems, which are eliminated by using codes and detection techniques. The FSO SACOCDMA implemented using diagonal double weight (DDW) code and different detection techniquessuch as Direct detection, Complementary subtraction and AND Subtraction under different haze conditions.Fibre Bragg Grating(FBG) acts as both encoder and decoder. FBG is designed according to DDW codes. The performance of FSO SACOCDMA under various haze conditions can be analysed by varying power of transmitter.The simulation was carried out in optisystem(version 12) software.

KEYWORDS: DDW Codes, Detection Techniques, FBG, FSO,Multiple Access Interference, Phase Induced Intensity Noise, SACOCDMA.

I.INTRODUCTION

Free space optical communication uses light to transmit data through atmosphere instead of fiber. It is the best solution for communicationin areas where laying down fibre is a tough job. It is the best alternative for wireless communication systems to transfer high data rate. FSO can be used in many optical links, such as building to building, ship to ship, aircraft to ground and satellite-to ground.It is also used in optical LAN network [1].Moreover it provides license free operation. But communication through FSO has a disadvantage of being affected by weather conditions. Rain, haze and fog can reduce the visibility and affect the line of sight communication. So it becomes necessary to study the effect of climate for FSO SACOCDMA because free space is the channel between Transmitter and Receiver of SACOCDMA [2].

Optical code division multiple accesses has become popular choice for supporting multiple users.OCDMA systems operate asynchronously and result in increased capacity. However OCDMA system suffers from different noises such as PIIN and MAI [3]. Among these noises MAI is dominating noise source. So it is important to design SACOCDMA with elimination of MAI by using codes and detection techniques. Spectral amplitude coding is a good solution to reduce the effect of MAI.Each user is assigned a unique code. These codes are orthogonal codes. Orthogonal codes possess minimum cross correlation among them and hence help in suppressing the effect of MAI. Also different detection techniques employing in receiver of SACOCDMA eliminating these effects [4].

The FSO SACOCDMA designed based on DDW codes and detection techniques such as Direct detection, Complementary subtraction and ANDsubtraction [3]. DDW code has an advantage of using less bandwidth and code length is small.Direct detection OCDMA systems have been investigated widely to apply for high speed LAN, because they allow multiple users to access network simultaneously.Several code families have been developed for SAC-OCDMA to improve security of transmission. Therefore it is desirable to develop a detection technique that provides the multiple access interference (MAI) elimination capability.Different components act as encoder and decoder. Here FBG act as bothencoder and decoder. FBG is designed based on DDW codes.Then Compare different detection techniques under different haze conditions.

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II.LITERATURE SURVEY

A. General background

Multiple access techniques are generally used to accommodate large number of users through a same channel. Different types of multiple access techniques are developed such as TDMA, FDMA and CDMA. Among these techniques CDMA techniques improves security of data transmission between transmitter and receiver. Security can be increased by encoding data from each user is coded with unique codes. Spectral amplitude coding is providing better solution for increasing security. Noises in SACOCDMA can be eliminated by different types of detection techniques. Effect of atmospheric turbulence can be eliminated by increasing power of the transmitter.

B. Diagonal double weight(DDW) code design

DDW code has an advantage of using less bandwidth and length of code is small and hence it produce broad spectrum for transmission. DDW codes are developed using K x N code matrix, where K represents number of users and N is code length. DDW code is designed such that:

- Weight of each code is 2.
- Cross correlation between only two codes is equal to 1.
- Length of code is always equal to K+1.
- Combination of 121 is always maintained between only two codes having cross correlation of value 1.

The basic DDW matrix for two users can be expressed as:

$$\begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \end{bmatrix}$$

C.Haze attenuation

Haze is an atmospheric phenomenon due to accumulation of dust, smoke and other pollutant particles in the air which leads to unclarity of atmosphere, lower visibility level. It results in more particles to stay longer time in atmosphere and hence presents more serious degradation on FSO performance. Haze causes issues in the FSO channel. Attenuation values under different haze conditions can be determined from Kim and Kruse model[3]

$$\beta = (3.91/V)\,(\lambda/550nm)^{-q} \quad (1)$$

Where

β = haze attenuation, V= visibility in Km, λ=wavelength in nm

q= size distribution of scattering particles 1.3 for average visibility (6km<V<60km)
.585V 1/3 for low visibility (V< 6km)

Weather condition	Attenuation db/Km
Clear	.233
Light haze	.55
Heavy haze	2.37

TABLE I. HAZE CONDITIONS WITH ATTENUATION

TABLE I shows that attenuation values under different haze conditions obtained from equation(1) and attenuation under clear conditions is small[4].

D.Direct detection technique

This is the simplest technique for DDW code implementation. The implementation of direct detection technique is completely different from other detection techniques. For this detection scheme, only desired spectral chip

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in the optical domain is filtered. This detection scheme doesn't need subtraction detection technique. Therefore, MAI and Phase Induced Intensity Noise (PIIN) will not exist in this detection scheme. Nevertheless, this technique is only applicable to codes, which the spectral chips are not overlapped with other spectral chips of the other channel, i.e. a minimum of one clean chip in every code sequence [5].

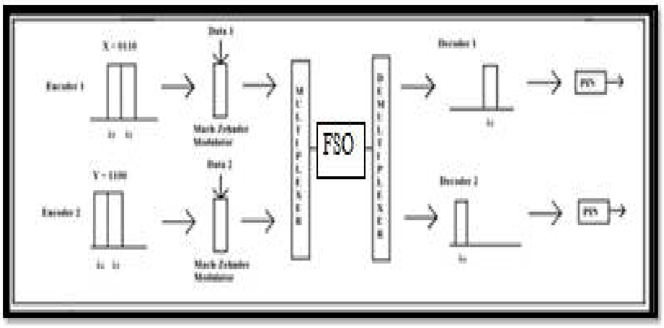

Figure 1: Direct detection technique

E Complementary Subtraction Technique

Transmitter model of Complementary model is similar to that of direct detection. In the receiver, the received signal is divided into two complementary branches of spectral chips using splitter as shown in figure 2.These two branches of spectral signals are sent to a subtractor that computes the correlation difference[6].

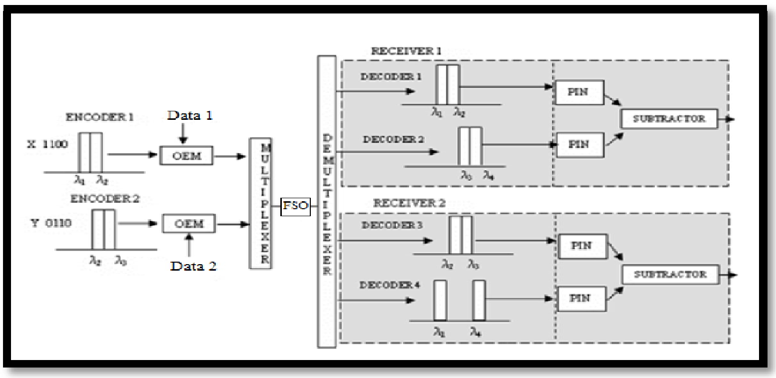

Figure 2: Complementary detection technique

In complementary subtraction technique, the cross-correlation is defined as:

θ_{XY}(k)= $\sum_{i=0}^{N-1} X_i Y_{i+k}$(2)

Where X and Y are two OCDMA code sequences. The complement of sequence (X) is given by ($\bar{X}$) whose Elements are obtained from ($\bar{X}$) by = 1- X_i. Let X = 0011 and Y = 0110 and therefore $\bar{X}$= 1100. The periodic cross correlation sequence between two sequences 1100 and 0110 is expressed as:

$\theta_{\bar{X}Y}$(k)=$\sum_{i=0}^{N-1} \bar{X}_i Y_{i+k}$ (3)

So the sequence is

$$\theta_{XY}(k) = \theta_{\bar{X}Y}(k) \qquad (4)$$

At the receiver, the photo detectors will detect the two complementary inputs which will be fed to the subtractor whose cross-correlation output, Z can be expressed as:

$Z_{Complementary}$=θ_{XY}(k)=$\theta_{\bar{X}Y}$(k) (5)

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F.AND Subtraction Technique

In this technique, the received signal is divided into two AND branches of spectral chips as shown in figure 3. In AND subtraction technique, where represents the AND operation between sequences X and Y. For example, let X = 0011 and Y = 0110 and therefore (X AND Y) = 0010. At the receiver[7].

$$Z_{AND} = \theta_{XY}(\text{k}) - \theta_{(X\&Y)Y}(\text{k}) \quad (6)$$

Equation (6) shows that, with AND subtraction technique, the multiple access interference or the interference from other channels can also be cancelled out. This subtraction technique can be implemented with any OCDMA codes, but for comparison purposes, the Diagonal Double Weight (DDW) code is used as an example.

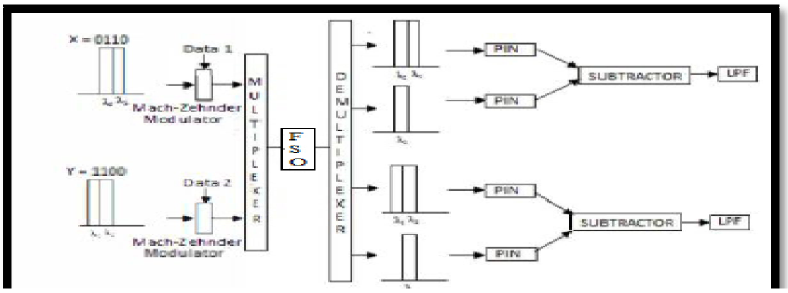

Figure 3: AND Subtraction detection techniques

III. PROPOSED METHODOLOGY

In FSO SACOCDMA, encoder and decoder are the main component and it is implemented using FBG. The FBG is designed using diagonal double weight code. In this system, it uses incoherent unique code and detection techniques are used. Here mainly direct detection, complementary subtraction and AND subtraction detection techniques are discussed under different haze conditions.

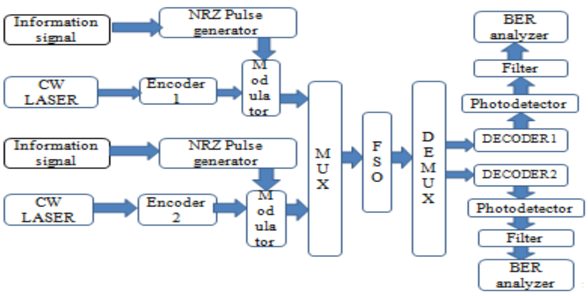

Figure 4:General block diagram of FSO SAC OCDMA

Figure 4 shows that general block diagram of two usersFSO SACOCDMA system. It consists of transmitter, channel and receiver. Data from different users are encoded with different codes and transmitted through FSO channel. At receiver decoding and detection techniques are performed and retained original signal.

The role of the optical transmitter is to convert the electrical signal into optical form and to launch the resulting optical signal into the FSO channel. The transmitting section of FSO SAC-OCDMA consists of Light source, encoder, Mach Zehnder modulator and data. PRBS generator is producing the bit stream and is directly fed to the NRZ electrical driver, the output of the electrical driver is multiplied is goes to the Mach Zehnder modulator. Modulator modulates the input signal. The function of the encoder is to amplitude spectrally encoding the source. LASER with a central wavelength of 1550nm is used to produce carrier and spectral components optical source the encoded by FBG based on DDW code.

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The receiving section of consist of different detection techniques such as direct detection, complementary subtraction and AND subtraction. Transmitting section for each detection techniques is same. An optical receiver converts the optical signal received and converted back into the original electrical signal.It consists of a photo detector (PD), filter and decoder. FBG act as decoder and decoders are designed based on diagonal double weight code. FBS implemented based on different detection techniques. The received signal is in the form of optical pulses representing 1 and 0 bits and it is converted directly into an electrical current. Such a scheme is referred to as intensity modulation with direct detection (IM/DD). The noises generated at the receivers were set to be random and totally uncorrelated.The dark current value was 5nA and the thermal noise co efficient was 1.8 x W/Hz for each of the photo detectors. After passing it through low pass Bessel filter the original data is recovered.

Wavelength	1550nm
Power	30dBm
No. of users	2
FSO length	.5 – 10 km
Transmitter aperture diameter	10cm
Receiver aperture diameter	25cm
Beam divergence	2 mrad

TABLE II: PARAMETERS USED IN DESIGN

TABLE II shows that parameter used for designing FSO SAC OCDMA. The important parameter in this design is power used in transmitter section.

IVSIMULATION AND RESULTS

In this chapter, the methodology and the approach taken to achieve the goal are described. The work was carried out using simulation software, Optisystem (Version 12). The major aspect during methodology stage is simulation process. The main objective of simulation is to eliminate effect of MAI in FSO SACOCDMA system using codes namely diagonal double weight and different detection techniques in receiver section. This software will not only save time but also can provide a clear picture based on eye diagram, then can create performance graph. The performance of each model is characterized by Bit Error Rate (BER), Q factor. Encoders and decoders can be implemented using any type of optical filtering technology, including thin-film filters, Fiber Bragg Gratings (FBGs), or free-space diffraction gratings, etc; of which FBGs is used here.

A. Transmitting Section

Figure 5 shows that simulation diagram of transmitting section of FSO SACOCDMA. Here FBG act as encoder and designed based on DDW codes. The spectral components of carrier encoded according to DDW code. Then modulated with data signal , then modulating data transmitted through the channel. Transmitter section is same for all receiver section. But at receiver, different detection techniques are used.

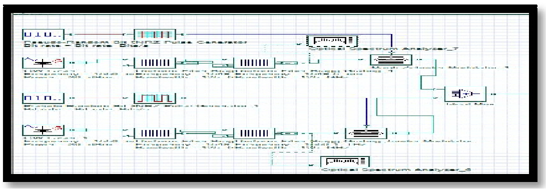

Figure 5: Block diagram of transmitting section of FSO SAC OCDMA

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B. Receiving Section

i) **Direct detection**

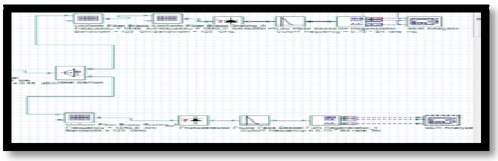
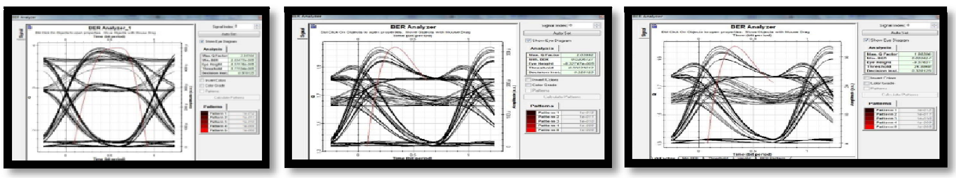


Figure 6:Simulation diagram of direct detection of FSO SAC OCDMA

Figure 6 shows that direct detection techniques. Here one decoder is user for each receiver. Overlapping components are not detected. Non overlapping components are retained. MAI does not exist. Here only separate chips are determined



(a)(b) (c)

Q-Factor = 3.941Q-Factor = 2.039Q-Factor =1.982

Figure 7: Eye diagram of SAC OCDMA at different haze conditions using direct detection

(a) Clear (b) Light haze (c) Heavy haze

Figure 7 shows that Eye diagram of SAC OCDMA at different haze conditions. From the figure7a, 7b, 7c shows the eye diagram under clear, light haze and heavy haze conditions. It is clear that Q-Factor high at clear conditions. That means attenuations of signal through the atmosphere are less at clear and maximum data transmitted.

ii) **Complementary subtraction**

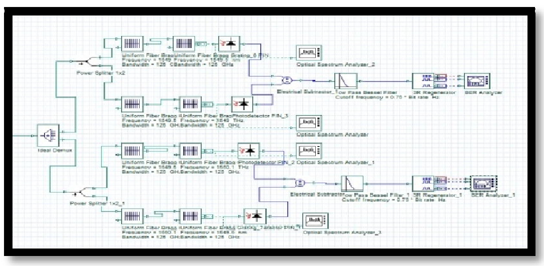


Figure 8: Simulation diagram of complementary detection of FSO SAC OCDMA

Figure 8 shows that the simulation diagrams of FSO SAC OCDMA using complementary subtraction. In complementary subtraction detection technique, at the receiver the photo detectors will detect the two complementary inputs which will be fed to the electric subtractor whose output is calculated which is always zero. So there will be no more cross-correlation terms indicating that there is no more signal from other users in the intended channel and hence there will be no more MAI.

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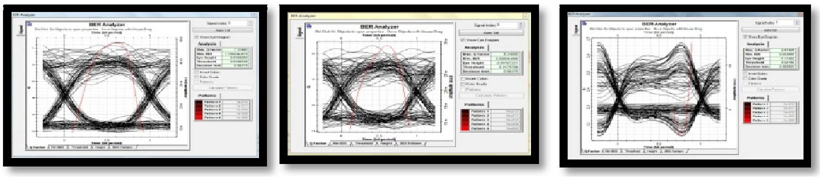


(a) (b) (c)

Q-Factor = 7.319Q-Factor = 5.310Q-Factor = 2.674

Figure 9: Eye diagram of SAC OCDMA at different haze conditions

(a) Clear (b) Light haze (c) Heavy haze

Figure 9 shows that Eye diagram of SAC OCDMA at different haze conditions using complementary subtraction detection techniques. From the figure9a, 9b, 9c it is clear that Q-Factor high at clear conditions due to this opening of eye diagram is maximum and Q-Factor is higher than direct detection techniques under all haze conditions.

iii) **AND Subtraction**

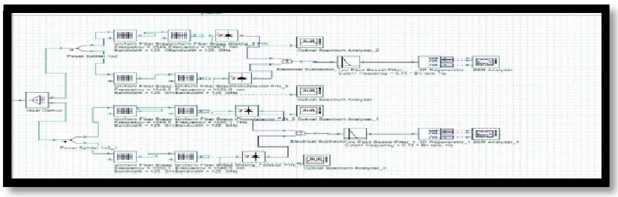
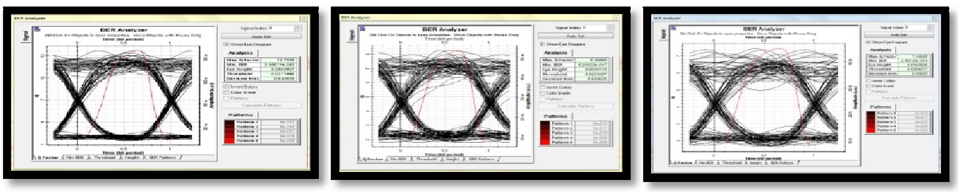


Figure 10: Simulation diagram of AND subtraction detection of FSO SAC OCDMA

The simulation of the AND subtraction detection technique is shown in figure 10. In AND subtraction detection technique, MAI gets eliminated by subtracting the cross-correlation output between the upper and lower branches of the detector. Second decoder for each receiver is designed based on AND operation between sequences.



(a) (b) (c)

Q-Factor = 13.723 Q-Factor = 8.269Q-Factor = 7.446

Figure 11: Eye diagram of SAC OCDMA at different haze conditions using AND subtraction

(a) Clear (b) Light haze (c) Heavy haze

(b)

Figure 11 shows that Eye diagram of SAC OCDMA at different haze conditions using AND subtraction detection techniques. From the figure 11a,11b,11c, it is clear that AND subtraction detection technique provide better Q-Factor under different haze conditions than other two detection techniques. So that among these detection techniques, receiver section of SACOCDMA Implemented using AND subtraction detection techniques under different haze conditions

Figure 12 shows that comparison of different detection techniques under different haze conditions. From the figure 12 it is clear that FSO SACOCDMA using AND subtraction detection techniques provide high Q-Factor than other two techniques.So that the elimination of MAI can be minimised by detection techniques. Among these detection techniques AND subtraction provides maximum Q-Factor under different haze conditions.

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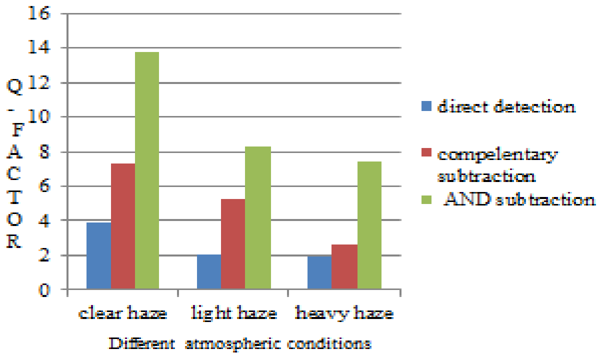

Figure 12: Graphical analysis of different detection techniques under different haze conditions

Performance of FSO is improved by increasing power of the transmitter. As the power increases, effect of haze conditions is lessaffected to channel and provide maximum Q-factor at the receiver section. By increasing power of transmitter, maximum Q-Factor is obtained at 30dBm.

V. CONCLUSION

The FSO SACOCDMA system implemented using DDW codes and different detection techniques such as direct detection, complementary subtraction and AND subtraction under different haze conditions. When comparing different detection techniques under different haze conditions, AND subtraction perform better than other two detection techniques and provide maximum suppression of effect of MAI than other two techniques. The analysis was based on bit error rate and Q -factor. Under clear conditions haze attenuation is small so Q-factor is high than light and heavy haze conditions. Thus out of this analysis AND subtraction detection technique exhibits better results for all haze conditions. The performance of FSO channel improved by increasing power

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