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IMPROVING FITNESS FACTOR OF MULTI-USER MIMO-OFDM BASED VISIBLE LIGHT COMMUNICATION SYSTEM BY USING GENETIC ALGORITHMS

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Abstract - *The three parameters Transmission range, transmission rate and reliability are used for characterizing quality of service of any wireless communication system. In the case of traditional OFDM set-ups one of the above mentioned parameter can be increased on the cost of degradation of other two parameters. However by consolidating MIMO with OFDM systems, all of these parameters can be improved concurrently. The two imperative functions of MIMO-OFDM system are Symbol detection and channel estimation. These functions can be accomplished by various algorithms such as maximum likelihood (ML) detector, least square (LS) etc... The complexity of these algorithms is very high in the system with large number of transmitters and receivers and having large cluster size. We are proposing a Genetic algorithm for MIMO-OFDM based VLC, and investigated its signal- to-noise ratio (SNR) performance for numerous LED set-ups. The rectangular LED frame-up gives improved SNR as compared with linear frame-up for higher-order modulation schemes*

***Key Words*: MIMO-OFDM, GA, VLC, LEDs, SNR etc.**

1. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is an appropriate technique to manage higher data transfer rates in VLC due to its high spectral efficiency, high signal-to-noise ratio (SNR) and conveniently opposes ISI [1]. In case of the indoor Multiple-Input-Multiple-Output (MIMO) VLC technology improves data rate (Rb) without the requirement of additional bandwidth expansion as well as providing betterment in channel robustness can be obtained. Implementing an imaging MIMO-based VLC to contest the multipath induced distortion and increases the data transfer rate.

In this paper a MIMO-OFDM VLC system with genetic algorithm for satisfying the real and non-negative transmitted signal requirements under the optical domain is investigated. The ray-tracing algorithm [2] is used to evaluate 4×4 MIMO multipath channel characteristic and also to evaluate the channel impulse response parameters for achieving the channel gain matrix. We examined both rectangular and linear frame-ups of LED's within a room environment and analyzed the BER distribution on the receiver plane. We show with the proposed system data transfer rate R_b of 1.2 Gbps (BER < 3.8×10^{-3}) could be achieved [3].

The rest of the paper is organized as follow. VLC concept is described in Section II. Section III analyzes the System model with DFT and LS channel estimation. Section IV presents proposed system simulation results and conclusions are drawn in Section V and VI.

II. VLC CONCEPT

VLC is a technology of wireless communication using regulated light from the visible spectrum (between 400THz and 800 THz). The light sharpness from an assimilated light source may be recognized to encrypt information. This regulated light may be recognized by a photo sensor. If the transmission rate of information is fast enough, the human eye will not be able to realize the transmitter as a varying light source [4]. VLC may be used inward inter-connected lighting control setup to establish communication network between luminaries. In this case, as the regulated light travels, the optical channel gain increases as well. This indicates that if the transferred signal is compared with the received signal, the optical channel gain may be estimated from it. Since optical communication is established using Intensity Modulation and Direct Detection [5] [6], real rather than complex signal processing is mandatory in VLC setup. By adopting the design of MIMO mechanics, In VLC setup pattern of several LED‟s can be engaged which not only provides necessary light levels in indoor environment but also provides a chance to develop the realizable data rates. MIMO VLC setup eliminates the bandwidth limitation of a single LED and gives an improved system throughput as well as Spectral Efficiency (SE) [7] [8].

III. SYSTEM MODEL

The VLC system module block diagram can be given as shown in the Figure: 1. the concept of VLC depends upon the intensity modulation (IM) and direct detection (DD) so the information bits are profiled as symbol, which then modulates intenseness of the visible light produced by the LED array by LED driving circuit. On the receiver end Photo-Detectors (PD) are used for identifying the signals communicated through optical channels. An optical concentrator and optical filter is used before the Photo detector. When the Opto-electric Conversion (Optical to electrical) is done, data is received by the photo-detector, it will be demodulated and then original information bits are recovered after the amplification.

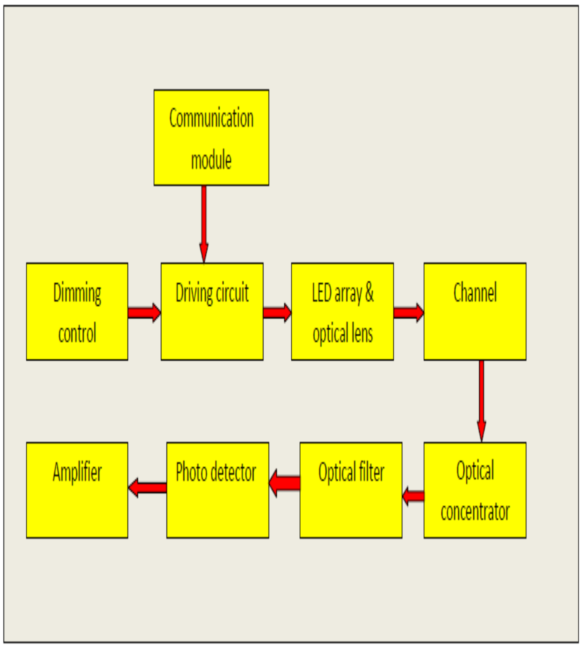

Figure 1: The VLC System module block diagram [4]

The source information bits are designated adaptively to profiled signal. The profiled signal of every subcarrier of the system is then multiplied with their interrelated channel matrix, after which inverse fast Fourier transform (IFFT), parallel to serial (P/S) conversion, and cyclic prefix (CP) insertion are done to recover the time domain signal [9][10]. For the channel estimation at receiver end, pilot symbols [11] are also inserted in the signal. The second-order Butterworth filters are used as LPFs (Figure 2.) DC bias is combined to drive LED after digital to analog conversion.

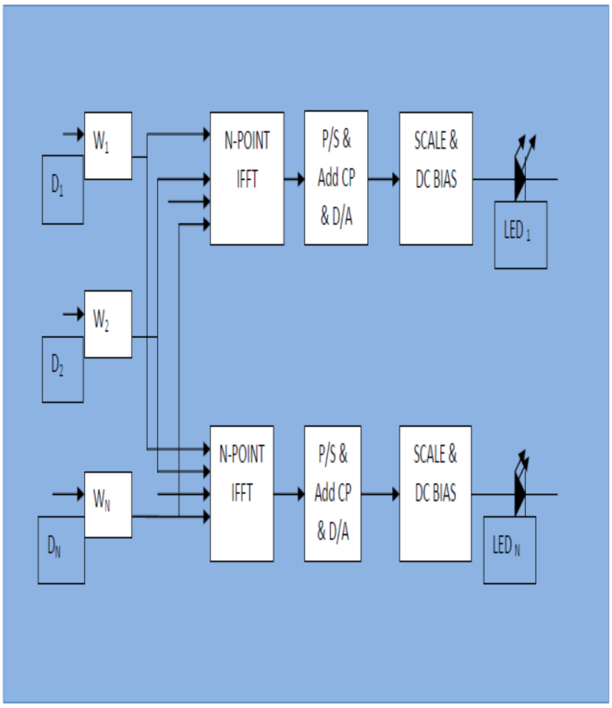

Figure 2: MU-MIMO-VLC SYSTEM

The nonlinear behavior of LED is mandatory for optical OFDM due to its susceptibility for the resulting distortion so that we are considering the non linear behavior of LED in this approach. The nonlinearity of LED's I-V property is also proposed by the scheme considered in .The I-V curve that is constructed by the data specifications in LED datasheet (OSRAM LUW W5AM) is presented in Figure 3[12].

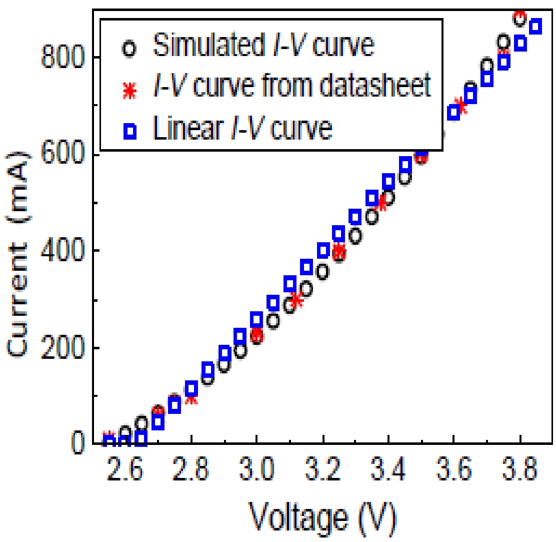

Figure 3: I-V property of LED

IV. PROBLEM FORMULATION AND RESEARCH METHODOLOGY

The channel estimation is the process for verifying the transmission channel capacity so that it may be analyzed that how much data can be transmitted through it. Because of the system bandwidth is fixed, it will also be checked that is it there any other option by which the channel capacity can be increased. The bandwidth has fundamental role for deciding the transmission rate in the network. It will be decided in such a way that collision will be avoided between two signals. There are various channel estimation schemes such as LS (Least Square), MMSE (Minimum Mean Square Error), DFT (Discrete Fourier Transform) etc. [13] [14].

The primary objective of this research work is to enhance the above-mentioned schemes by using Genetic Algorithm (GA). The algorithm results are compared on the basis of the signal to noise ratio parameters against subcarrier matrix for calculating the percentage of improvement. The research framework is explained in Figure 4 that shows the steps required for executing the proposed work.

Let us consider a multiuser MIMO-OFDM VLC setup in which there are A number of transmitters, B number of receivers, C are number of OFDM subcarriers. Let $P_i(C)$ represents the signal transmitted on C^{th} subcarrier by i^{th} transmitter and similarly, $Q_j(C)$ represents the signal received by j^{th} receiver on C^{th} subcarrier. The Qj(C) can be given as

$$Qj(C) = \sum_{i=1}^{A} Y_{ji}(C).P_i(C) + N_j(C) \quad (1)$$

Here $N_j(C)$ is the noise present in system with zero mean; $Y_{ji}(C)$ is the channel response from i^{th} transmitter to j^{th} receiver in frequency domain. Monte Carlo approach calculates the non-LOS response effectively and represents the channel characteristics of the setup of MU-MIMO OFDM VLC system [10].

Least Square (LS) estimation technique is adopted for analyzing the overall system response of VLC system with the help of pilot symbols [11]. The system response includes the non linearity behaviour of LEDs with low pass filtering approach and multi-reflection in VLC channels. The VLC systems estimated channel matrix for C^{th} subcarrier can be given as

$$Y(C) = \begin{bmatrix} Y_{11}(C) & ..... & Y_{1A}(C) \\ ... & ... & .... \\ Y_{B1}(C) & .... & Y_{BA}(C) \end{bmatrix} \quad (2)$$

To improve the LS or MMSE channel estimation performance, the DFT-based method has been proposed as it can advantageously target both noise reduction and interpolation purposes. Let Ŷ[C] represents the estimate of channel gain at the C^{th} subcarrier, obtained by either LS or MMSE channel estimation method. N is the number of pilot symbols in an OFDM symbol, ŷ is the impulse response of the pilots of one OFDM symbol, and Z is the AWGN channel noise. Taking the IDFT of

$$\{\hat{Y}[C]\}_{C=0}^{N-1} \quad (3)$$

The channel estimate

$$IDFT\{\hat{Y}[C]\} = y[n] + z[n]\square\hat{y}[n], \quad n=0,1,2,......, N-1 \quad (4)$$

Where z[n] represents the noise present in time domain. For better estimation accuracy, the noise component should be decreased. The maximum channel delay L can be given as

$$\hat{y}_{DFT}[n] = \begin{cases} y[n] + z[n], & n = 0,1,2, ..., L-1 \\ 0, & otherwise \end{cases} \quad (5)$$

For frequency domain transform of this delay, DFT will be taken as

$$\hat{Y}_{DFT}[C] = DFT\{\hat{y}_{DFT}(n)\} \quad (6)$$

The DFT scheme should be used for interpolation in frequency domain as well as for the orthogonality among the scattered pilot signal sequences [15].

Proposed Genetic algorithm

Genetic algorithm features the process of natural selection in a specific method for generating solutions to the confined or unconfined optimization and search problems. The basic principle of Genetic algorithm is the feasibility of the population of encoded solutions to various optimization problems that drive in time. It is related to a class of the transformative algorithms those are used to give optimum solutions using methods that fascinated from the natural evolution such as inheritance, mutation and crossover [16]. The genetic algorithm uses three main principles to generate the next generation from the present population as shown in Figure 4.

- Reproduction
- Crossover
- Mutation

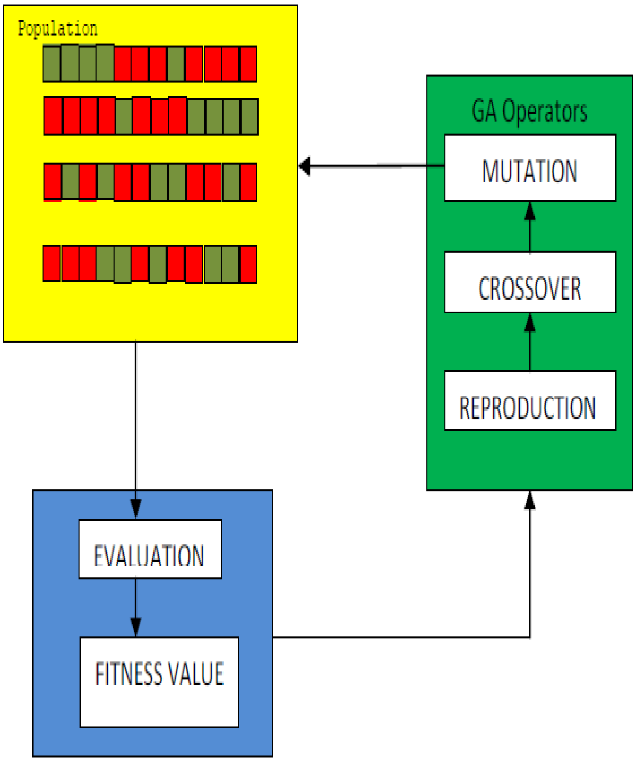

Figure 4: Evolution flow of genetic algorithm

The last step in applying genetic algorithm is the election of best genotypes which has a very important key performance in choosing the group of individuals, known as genesis, which contribute to the population at the next generation. They contribute their genes- the entries of their vectors- to their next generations. These individuals selected according to the fitness based method where fitter or best solution is, usually, selected [17].

The Pseudo-code for working of GA's is as following

- Initialize a population of strings at random
- Evaluate each string in the population
- Repeat
- Reproduction
- Crossover
- Mutation
- Evaluation of the population
- Until (termination criterion)

Steps to execute Genetic Algorithm

1. Initiates the algorithm process by originating a randomly chosen initial population which is a set of potential solutions in the search domain.
2. Calculates the fitness factor value for every individual of the present population to generate new generation.
3. The election of individuals called genesis depends on the basis of their fitness value factor,
4. There are some of the individuals who have lower fitness values. These are treated as Elite and are moved precisely to the next generation.
5. Genetic algorithms solution depends upon two factors that are Crossover and Mutation.
6. Crossover assures the algorithm to check out the best genes among random individuals and then link them again for improved average fitness value. It develops a potentially domineering progenies for the next generation.
7. Mutation employs random changes to an individual in the present generation by which it will arrange genetic diversity. Mutation also enables algorithm to search over a wider space for reducing the untimely concurrence which causes trapping of algorithm in global minima.
8. Changes the current population with the progenies for the production of the next generation.

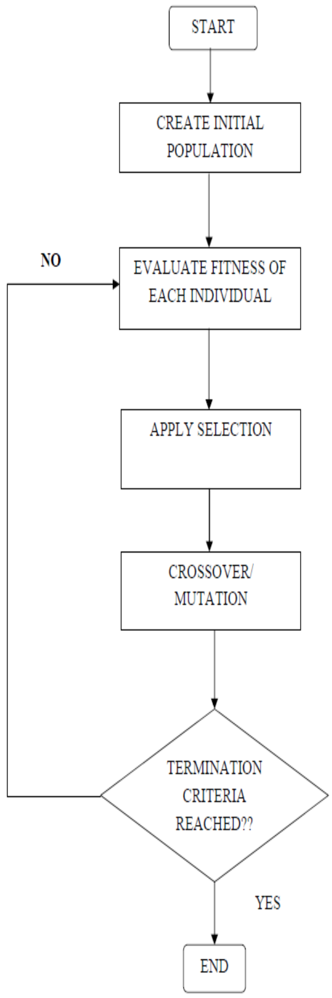

Figure 5: Flowchart of genetic algorithm

OFDM system parameters used in the simulation are indicated in the TABLE 1

TABLE 1: SIMULATION PARAMETERS

Parameters	**Values**
base station density	**0.7/2**
path-loss exponent	**3.8**
log normal parameters	**6910**
Speed of Light	300E6
Number of subcarriers	**64**
Cyclic prefix length	**16**
Number of Tx antennas	**2**
Number of Rx antennas	**2**
Delay spread of channel	**5**
MUE	**5**

V. RESULT

The spectral efficiency of each subcarrier in the setup with an average emitted optical power P=1 Watt (0 dBW) is managed with least DC bias for each transmitter in the case of MIMO OFDM as shown in figure 5. Because of Hermitian symmetry is applied in the system there are only 1st to 31st subcarriers contains effective information. It will be analyzed that as the subcarrier index escalated, the spectral efficiency gets better, completely in the case when ZF-MMSE min bias DC is operated. This is because of the reason that the subcarrier with higher index has more phase difference, which results the channel matrix more unrelated, and this improvement is more convenient for the interconnected scenario.

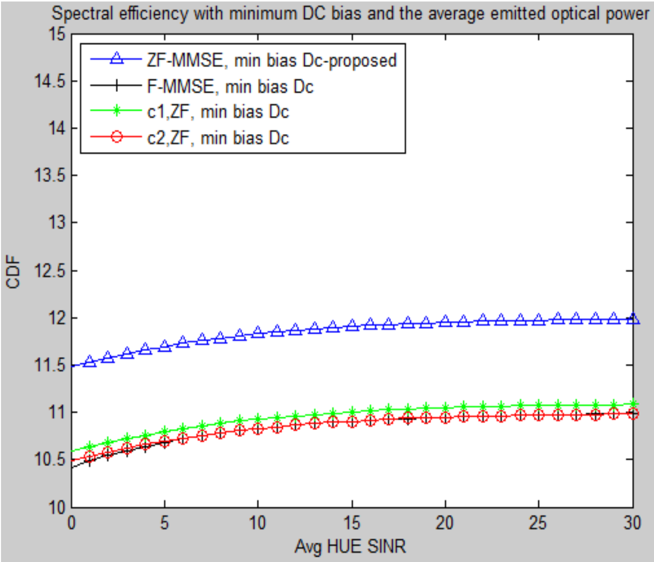

Figure 6: Spectral efficiency with minimum bias and the average emitted optical power

The result illustrates that there is an enhancement in the capacity of MIMO-OFDM system channel when the spectral efficiency fading solution is implemented for achieving capacity maximization which is utilized for allocating different power levels to the sub channels. For correlated DFT on MIMO channel along with the GA algorithm, the MIMO capacity with respect in increase in number of transmitting and receiving antenna for fixed values of snap length.

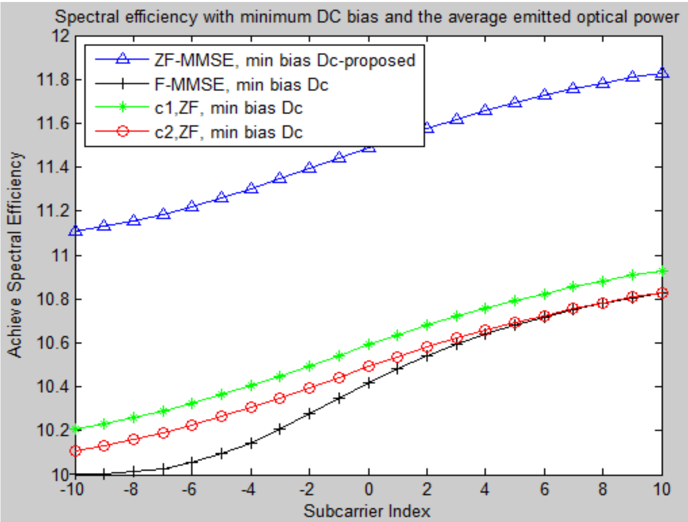

Figure 7: Spectral efficiency with minimum DC bias and the average emitted optical power

The figure 7 illustrates that the ZF-MMSE-min bias DC-Proposed get best spectral efficiency as compare to F-MMSE, c1 ZF, min bias DC and c2 ZF, min bias DC.

With the help of GA, we reduce the cost number of blocked MUE.

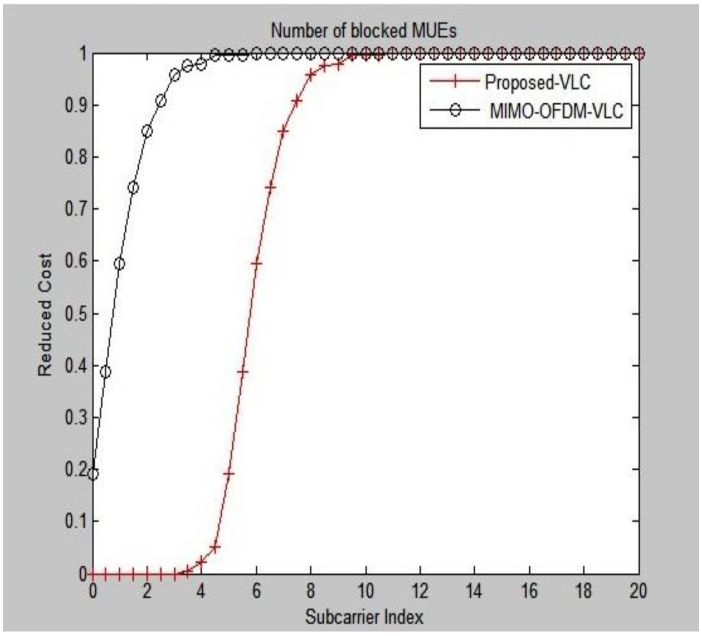

Figure 8: Reduction cost of MIMO-OFDM-VCO and Proposed VLC

VI. CONCLUSION

The purpose of this paper was to provide a cost effective and better performance system of the visible light communication technology. The idea was to design and implement a multiuser multiple input multiple output orthogonal frequency division multiplexed visible light communication system associated with generic algorithm for providing a cost efficient system with improved fitness factor. The combination of MIMOs and OFDM has emerged as a promising solution for future high-rate wireless communication systems. The setup was designed to use software defined radio devices which allowed an easy and fast implementation and enormous abilities to change the parameters of the communication links. The SDR devices allowed also the ability to use open-source software, allowing thus cost efficient implementation. The selected implementation platform was a good choice but required large amounts of working hours to get all the software to installed and learn to use them right. After the work with the software, the future use of it will be very simple. This paper will hopefully help and clarify future work.

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