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Original Article

Design of Space-Time Coded Multi-Carrier CDMA System based on Metaheuristic Optimization Algorithms

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Abstract - *Multiple Carrier Code Division Multiple Access (MC-CDMA) system performances are evaluated with the MMSE (Minimum Mean Square Error) equalization algorithm in this framework. The system's performance is augmented with the assistance of meta-heuristic optimization algorithms. Nature-inspired Krill Herd algorithm with an oppositional-based learning method (OKH) is used to improve performance. And the system was also implemented using Kinetic Gas Molecule Optimization (KGMO) algorithm. KGMO is also a metaheuristic-based process that operates with the concept of thermodynamics. Procuring wireless channel details is a difficult task in mobile wireless systems. Both algorithms help in obtaining channel information. Multiple inputs and multiple outputs (MIMO) are primary in existing and ensuing wireless communications. Space-time coding (STC) is integral to multi-antenna operations, mainly concerned with integrity. The proposed optimisation algorithms based on the multi-carrier CDMA system using space-time coding are implemented, and the BER parameter is evaluated. 2 transmitting and 1 receiving antennae are considered in the proposed system. Simulations are done in Rayleigh fading channel.*

Keywords - *CDMA, MC-CDMA, MIMO, OFDM, Optimization Algorithm.*

1. Introduction

In everyday life, Wireless Communications have become a necessary part. And cellular communications have experienced massive growth in the past two decades. CDMA is the most suitable method for multiple subscriber communications. And it works based on the spreading process. Due to spreading, only the authorized subscriber receives and thus reduces the interference. MC-CDMA is a joint procedure of CDMA and Orthogonal Frequency Division Multiplexing (OFDM). CDMA system with multi carriers offers the profits of both technologies [1],[2]. OFDM is one of the most favourable technologies for the latest communication systems. MIMO is one of the enabling techniques that enhance the performance of the system in recent developments. MIMO performs Space-time coding, spatial multiplexing, and precoding functions [3]. In the proposed system, Alamouti coded space-time processing method is used for transmitting and receiving information [4]. Several receivers are designed using STBC codes for the MC CDMA system [5] since Space-time coding is the most suitable technology for wireless systems, as it addresses the reliability issue.

The receiver needs accurate channel information to obtain reliability in the wireless system. There are many methods to obtain channel information. Training-based methods, semi-blind methods and blind methods. Even though the training-based methods provide a better solution, training data is needed for designing the system, which is not the optimum utilization of resources. Similarly, blind methods suffer from huge complexity and calculations. And semi-blind methods are in between the two other methods. Obtaining accurate channel information is the most difficult task in the wireless system. Metaheuristic optimization algorithms utilization is one of the brilliant solutions for any complex problem. The optimization algorithms are useful when the solution cannot obtain using deterministic methodologies. There are several algorithms used for obtaining the channel state information. They are suffering from the problems of many iterations, poor solutions and complexity. In [6], Channel information is estimated using the MC-CDMA system's LS-PSO algorithm. This paper implements the system for single-input and single-output antennas. And in the proposed technique, the system is implemented with 2X1 antennas. OKHA, KGMO algorithms-based estimations are done to obtain the channel information.

Krill Herd algorithm is a bio-based nature-inspired algorithm introduced by Gandomi and Alavi in 2012 [25]. The algorithm was developed on cognizance of ocean krill. And to improve the convergence speed, the proposed system uses an oppositional-based learning procedure [9]. Another metaheuristic optimization algorithm is the KGMO algorithm. In this gas, molecules are search agents. Agents intensively probe the search space and produce the optimum solution. KGMO works based on thermo dynamics principles [10].

The paper is structured with an analysis of the Literature In section 2. The system model is given in 3; the design methodology of the proposed system is discussed in 4 sections. Computational results are discussed in 5 sections. Section 6 consists of conclusions.

2. Literature Survey

Kumaratharan et al. [12] have introduced channel estimation using a turbo procedure multi-antenna-based multiple carrier systems. A proposed method utilized an outdoor model for channel implementation. The turbo method performance is superior to the iterative channel estimation method.

Marousis et al. [13] have proposed advanced semi-blind channel estimators for MIMO MC CDMA systems. The proposed approach uses embedded pilots for obtaining channel details. The number of pilots was also found dynamically. Channel is evaluated initially with the help of Exaggerated code-multiplex pilots. The process is further improved with despread pilots. The proposed approach ensures high throughput and maintains low redundancy and complexity.

Ashrafinia et al. [14] have implemented a biography-based optimization algorithm to design the STBC MIMO system receiver. The proposed technique provides a cost-effective solution since the complexity of the proposed method is low compared to the maximum likelihood-based detector. At the same time, the BBO method provides near-optimum performance. In the paper, the BBO is compared with other algorithm-based receivers, and BBO based receiver provides enhanced performance with low cost and low complexity.

Alireza Askarzadeh et al. [15] proposed Simulated Annealing (SA) optimization algorithm, which works based on population. This algorithm is most suitable for large and sensitive issues. In addition, the algorithm's performance goes down because of the lengthy computational time to obtain an adequate solution.

Tang et al. [16] have initiated a channel estimation procedure by utilizing the Kalman filter approach for the MIMO-OFDM system. The proposed method estimates the channel response for dynamic environmental conditions. Noise is also reduced by using the threshold concept.

Arifianto *et al.* [17] have created GA of Binary based procedure-aided MUD for the multi-carrier system. The system is implemented based on STBC. The proposed method is developed with an EGC detector. Compared with the existing system, the current system provides enhanced performance. Nevertheless, the proposed approach suffers from local optimum even though it has simple steps.

The above-specified methodologies provide solutions for channel information. But they are suffering either with a large number of iterations to obtain the solution or poor exploration capability. So to overcome these problems, the proposed system is implemented with OKH and KGMO methods, which are working intelligence-based methodologies and provide better solutions.

3. System Model

Fig. 1 represents the proposed algorithms-based transmitter and receiver blocks. In this multiple users, data is carried by a multi-carrier system. The information bits are modulated and encoded using the Alamouti space-time block code procedure. Then the coded data is spread. Walsh-Hadamard codes are utilized for spreading. And then, the data is OFDM converted to introduce the multi-carrier notion. For that IFFT block is employed.

Then the data is transmitted through multiple antennas during two continuous time periods. A receiver at receive side applies FFT demultiplexing, despread and demodulation operations. And the channel effects are balanced using the MMSE detection procedure [18],[21].

The channel information is originally not known to the receiver. The proposed system estimates channel information using a training-based channel estimation procedure [24]. Optimization algorithms are used combined with channel estimation procedure. So that accurate information can be obtained. That leads to improvement in performance. Execution procedures are demonstrated in the next section.

4. Design Procedure

Alamouti-coded proposed system steps are discussed below.

4.1. OKHA based System

In the proposed method, the channel coefficients are optimally selected with the help of the OKH algorithm. First, the data generated at the transmitter is modulated, and CDMA is encoded with the Walsh Hadamard chipping code. Then the spread data is transmitted through multiple carriers. Modulated user symbols are encoded as shown in the given equation 1.

$$\Phi_m(r) = \frac{1}{\sqrt{2}} \begin{bmatrix} m_b(r-1) & -m_b^*(r) \\ m_b(r) & m_b^*(r-1) \end{bmatrix} \quad (1)$$

Where $\Phi_m(r)$ represents the encoded output of the user, and $r = 1,3,5...$ then encoded symbols are sent through two antennas over two continuous time intervals $\tau_1 \tau_2$. Over τ_1 instant, both modulated symbols $m_b(r-1)$ and $m_b(r)$ are sent by first and second antennas. And in τ_2 the symbol $-m_b^*$ is transported by the first antenna $-m_b^*(r-1)$ is transported by the second antenna. Complex conjugated denoted by (*) symbol. The symbols are transmitted through multiple carriers. Before transmission, they are spread using chipping codes. The chipping code length is the same as the number of multiple carriers in the transmission.

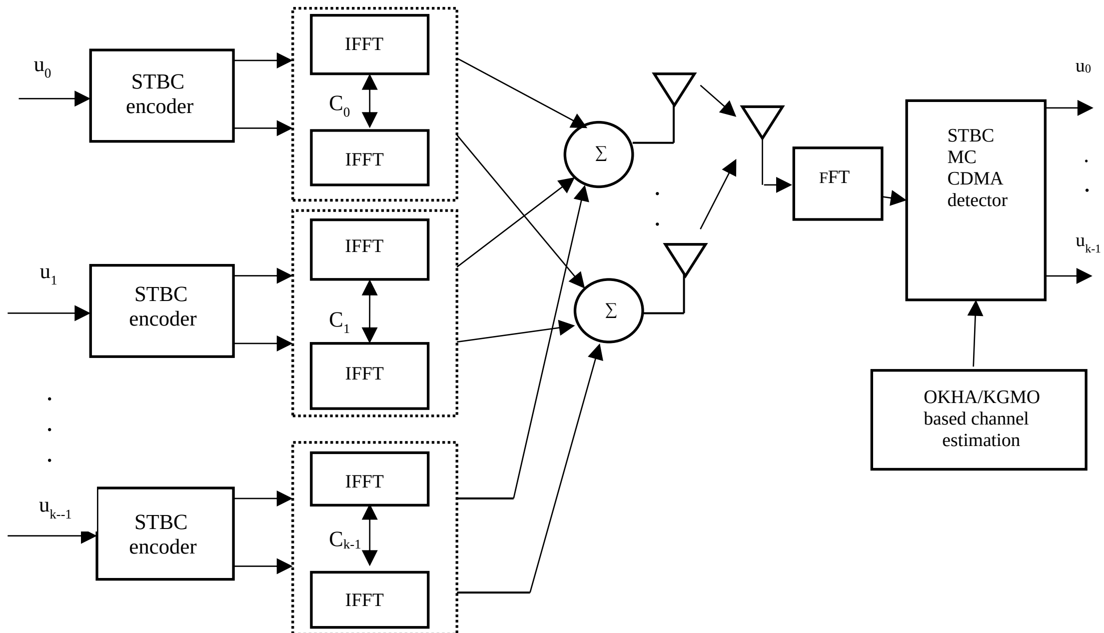

Fig. 1 Transmitter and receiver set-up of the proposed system

The symbols are transmitted through a wireless channel and reach the receiver. Given below expressions represents the received data at the receiver.

$$S(r-1) = H_1 DM(r-1) + H_2 DM(r) + \varphi(r-1) \quad (2)$$

$$S(r) = -H_1 DM^*(r) + H_2 DM^*(r-1) + \varphi(r) \quad (3)$$

Where, $S(r-1)$ and $S(r)$ are received data. And φ represents the additive white Gaussian noise data H_1,H_2 are channel coefficients, D is the spreading code matrix, $M(r-1)$ and $M(r)$ are the user data symbols of STBC matrix from multiple users.

Now the channel information is optimally chosen with the aid of the OKH algorithm. In a practical receiver, the channel coefficients H_1 and H_2 are not familiar, but these values have to be restored with their estimated values. Procedural steps are described below.

Step 1: Opposition solution generation: In this step set of opposition solutions is generated [9].

Step 2: Fitness value is computed. The fitness computation function is shown in the below equation

$$O(\hat{H}_1, \hat{H}_2) = \left\| S(r-1) - \hat{H}_1 DM(r-1) - \hat{H}_2 DM(r) \right\|^2 + \left\| S(r) + \hat{H}_1 DM^*(r) - \hat{H}_2 DM^*(r-1) \right\|^2 \quad (4)$$

Step 3: The individual Krill position is updated by the following activities [7],[8].

(i) Mobility persuaded by other krills
(ii) Searching action for food and,
(iii) Arbitrary physical spread

The position of the krills is updated, and to enhance the functioning of the algorithm, cross-over and mutation activities of the Genetic Algorithm (GA) are performed [20]. And the algorithm terminates with the optimum number of iterations, and then the best fitness value gives the best channel matrix. The proposed channel estimation method includes twin levels. One is training and the second is Decision directed. The flowchart is shown in Figure 2.

Every user training sequence is transmitted with Q bits in the training step. In addition, by minimizing equation 4, channel information can be obtained once training is completed, and then the decision step is executed. And this step further improves the estimated channel information in a training phase. Finally, the estimated channel matrices are assigned for decoding the STBC MC-CDMA system.

4.2. KGMO based System

KGMO algorithm executes similarly to the OKHA working method. First, KGMO parameters are prepared according to requirements. The population is initialized first. And the gas molecules' position, velocity, kinetic energy and mass parameters are initialized. After setting the parameters, the cost value is computed using the expression 4 for each gas agent [10],[11]. The position of gas agents is updated with the following activities.

(a) Updating the velocity of the molecules,
(b) Updating the position of the molecules

Once the parameters are updated, fitness is computed, and the algorithm runs for an adequate number of repetitions and gets the best fitness value. Once the best fitness is obtained, the algorithm stops the execution and allocates the best fitness value, which holds the best channel matrix. The channel estimation procedure is shown in Figure 2.

5. Numerical Results

The proposed system is implemented with the Walsh sequence. BER is measured for different E_b/N_o values. MATLAB is used for simulation. The data rate is 1024 kbps, the Doppler spread is 100 Hz, and the multiple carriers are 8. The spreading code length is 8. BPSK and QPSK modulations are used for modulation. Rayleigh fading channel used for simulation [22]. The number of users is 2 and 4. And for optimization algorithms, the population size is 30 for training and 10 for decision directed step. w (inertia factor ranges from 0.85 to 0.2.

The graph in Fig. 3 presents the error attainment of the presented methods. The number of transmitters is 2, and the receiver is 1. 2 users are considered in the implementation. From the graph, at 8 dB, error rate is 0.0008, 0.0012, 0.0019, 0.0024 for OKHA, KHA, KGMO and GA. And without optimization, its value is 0.0034. And from the plot, it is clear that the OKHA obtains improved performance compared to other methods. As GA and KGMO algorithms are easy to execute, they cannot attain accurate values.

Fig. 4 shows the BER performance for 4 users' cases; this graph also shows that OKHA is better than other algorithm-based systems.

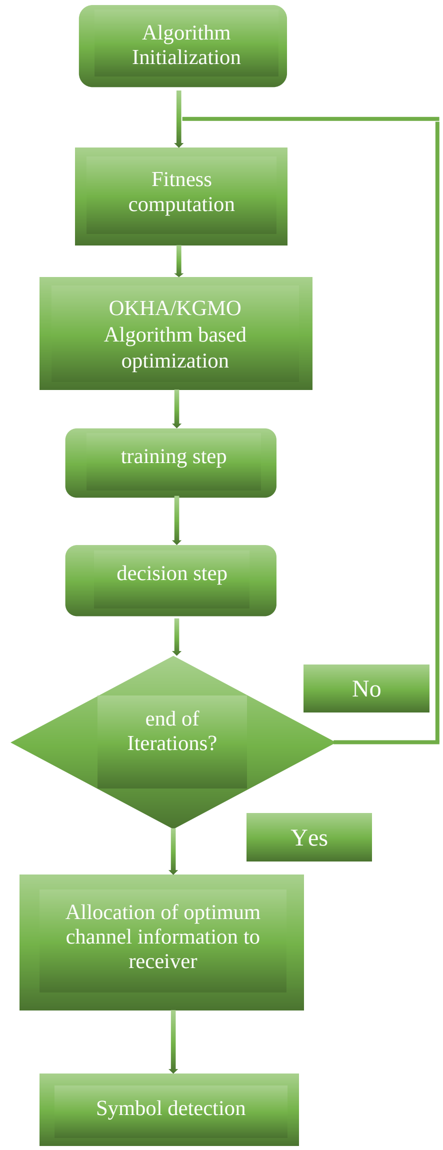

Fig. 2 Channel estimation procedure

Fig. 5 shows the performance plot of OKHA, KHA, and KGMO algorithms, for 4 user cases. And the modulation used here is QPSK modulation. At 0 dB, the OKHA error rate is 0.0218 and is minimum compared with other methods.

Table 1 shows the performance comparison of four users' presence in both BPSK and QPSK modulated systems at a 4 dB value. And it is clear that the proposed OKH provides better error performance than other techniques. And for higher-modulated systems, the error is higher than for lower-order modulation.

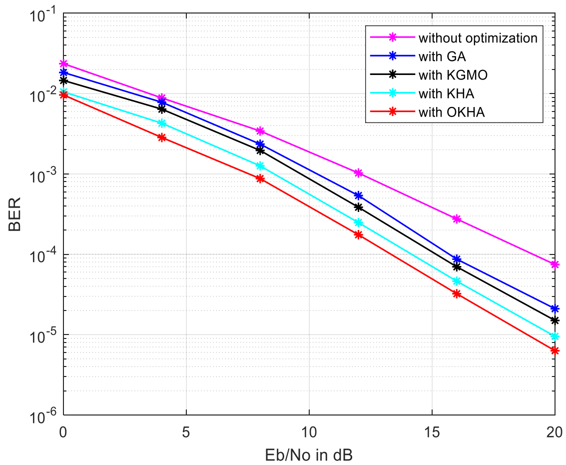

Fig. 3 BERVs. Eb/No graph of 2X1 system for 2 users using BPSK modulation

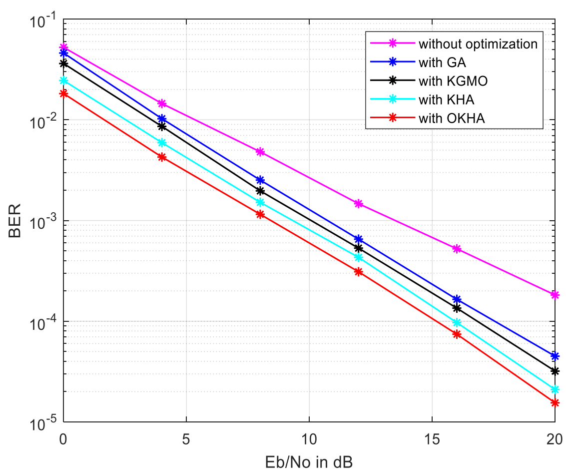

Fig. 4 BER graph of BPSK modulated 2X1 system for 4 users

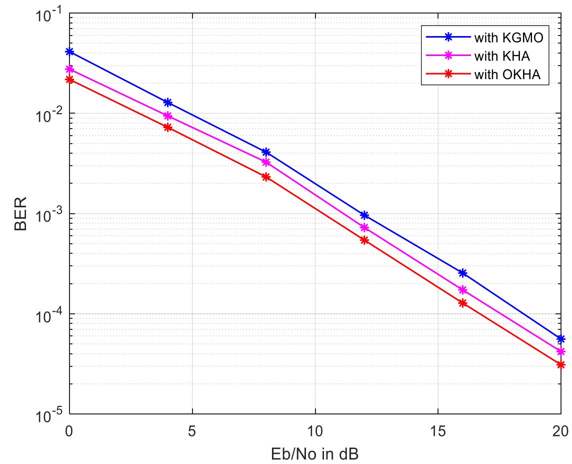

Fig. 5 BER plot of QPSK modulated system for 4 users

Table 1. performance comparison of the proposed system at 4 dB

E_b/N_o (dB)	KGMO	KH	OKH
BPSK modulation	0.0086	0.0057	0.0046
QPSK modulation	0.013	0.0095	0.0072

6. Conclusion

MC-CDMA fixes the channel fading issue since it utilizes the merits of multi-carrier communication. In this paper, metaheuristic optimization algorithm-based channel estimations are computed, and system performance is improved with obtained optimal channel information. The OKHA-based system provides better performance than the KGMO algorithm-based system since KGMO is simple to implement and, because of poor exploration capability, cannot get global optimum. Further, the proposed techniques can be applied to spatially multiplexed MIMO systems, and channel estimation steps can be reduced, which causes a reduction in the complexity of the evaluation.

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