Avenues to Improve Channel Estimation Using Optimized CP in STBC Coded MIMO-OFDM Systems—A Global Optimization Approach

Shovon Nandi, Narendra Nath Pathak, and Arnab Nandi

Abstract A new semi-blind channel estimation with optimized Cyclic Prefix (CP) assisted Space Time Block Coded Multi-Input Multi-Output Orthogonal Frequency Division Multiplexing (STBC-MIMO OFDM) system is proposed. The main hurdle of high complexity and low convergence in earlier systems are avoided by our proposed scheme in flat fading environment. In our work, the hyper parameters are optimized with proposed Lévy Krill-herd (LKH) algorithm and it is clear that the channel estimation performance is varied with this parameter values and by this global optimization technique the incorrect selection of hyper parameters (local optima) are eliminated. The selection process of this algorithm can be simplified with the number of bounds used. The improvement performance is shown by using BER vs SNR plot of Forward-backward (FB) Kalman helical approach and different pilot carrier insertions. Also a comparative plot is shown among FB Kalman, Krill-herd (KH) and finally LKH approach by using Matlab software.

Keywords MIMO-OFDM · Kalman helical process · Lévy Krill-herd algorithm · Cyclic prefix · Alamouti-STBC · BER

1 Introduction

In current focused world, we make an endeavor to deliver a most extreme growth or advantage from the confined measure of usable asset. The high speed data communication process is grateful to the advancement of optimization process. Several

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optimization techniques are established from the inspiration of naturally happened phenomena of different bodies. The burden of low convergence and high complexity in data transmission has been mitigated by the proposed modified global approach [1]. The population diversity of the solutions, improvement of the whole search region covering up and to increase the convergence rate of the multi objective heuristic algorithm is possible and shown here. The MIMO combining technology with the OFDM (i.e. MIMO-OFDM) is generally employed in wireless communications systems [2] and it is a well-known method for high-data-rate wireless transmission, specially in 4G, 5G or beyond standards [3]. The utilization of MIMO-OFDM upgrades the channel limit and improves the communication unwavering quality [4, 5]. The bandwidth efficiency of OFDM along with diversity technique has led to the use of this technology in many advanced wireless communication systems [6, 7]. The OFDM eliminates the Inter-Symbol Interference and Inter Carrier Interference. Additionally, on account of the utilization of a cyclic prefix and an orthogonal transform [8, 9].

In OFDM framework, channel estimation stays a present worry, since the general execution relies emphatically upon it. Especially for enormous MIMO systems the Channel State Information (CSI) turns out to be more testing [10, 11]. Insufficient CP in OFDM transmission prompts ISI and ICI, which influences both channel estimation and data detection. Whenever overlooked, it can prompt a mammoth detection error in MIMO-OFDM. To ease this issue, various channel estimation and data detection techniques for inadequate CP frameworks have been proposed in writing [12, 13]. Employing CP in multi-carrier systems not only protects the signal from ISI but also allows circular interpretations of the channel which improves the estimation and equalization process.

To the extent data identification occurred, a time domain (TD) finite impulse response filter can regulate insufficient CP MIMO-OFDM circulation [14]. The FD (Frequency-domain) per tone equalization (PTEQ) was proposed and the precoding procedures are utilized to evacuate the distortion because of deficient CP [15]. ISI and ICI induced by insufficient CP length can complicate channel estimation and cause large estimation error. To lighten this issue, a lot of channel estimation strategies can be suggested in writings [16].

Different techniques have been proposed in writing for estimating channel impulse response in OFDM frameworks. These join pilot based techniques, blind and semi-blind algorithms [17–19]. Semi-blind strategies offer a trade-off dealing with pilot formed and blind estimation plan. A preliminary channel estimation utilizing pilots has to be acquired by the strategies, stated earlier and make use of a grouping of from the prior prerequisites to improve it further [20]. Regularly, channel estimation inside MIMO-OFDM systems relies upon the PACE—Pilot-aided channel estimation process. The channel estimation in a canister without pilot images is acquired by right initiation [22].

The surrounding of this paper is sorted out as follows. The background study or literature survey portion is given in Sect. 2. Section 3 depicts the system model, where we introduce the MIMO Alamouti-STBC architecture and we present the proposed EM based helical FB Kalman Filter approach. Performance metrics are given in next section. The obtained simulated results of various graphs have been produced in Sect. 5 to prove the supremacy of the proposed approach over the existing mechanisms. Finally, conclusions and few glimpses on future scope is drawn in Sect. 6.

2 Related Work

Pham et al. [13] have proposed the joint channel estimation and identification for orthogonal frequency-division multiplexing systems utilizing lacking cyclic prefix and pilot sub-carriers. The bandwidth usage is being minimum for the shorter CP in OFDM architecture. Alternatively, their methods can enable range extension for OFDM transmission with a certain CP length. The cost was increased by ISI and ICI that corrupts the pilot subcarriers and leads to a large channel estimation error. They then formulated a PSB-MMSE—Pilot sub-carrier based minimum mean square error scheme to estimate the TD channel response for SIMO—Single input multiple output systems within the sight of ISI and ICI. From that, an iterative reception process of channel estimation and data detection is constructed.

Tae-Jun Lee and Young-Chai Ko [23] have proposed the moderating plan to lessen the impacts of phase noise in MIMO-OFDM framework using autonomous oscillator in every RF chain. Their suggesting plans comprising two phases—channel estimation dais and information decoding dais. In the main stage, they proposed the channel estimation algorithm dependent on MAP—Maximum a posteriori estimator and a strategy for selecting those sequence of training used for channel estimation with numerical investigation of recommended plot. In the subsequent moment, MAP estimators were utilized to mutually appraise phase noise at transmitter as well as receiver and distinguish data symbols. For examination of MSE—Mean Square Error exhibitions, they infer Bayesian Cramer-Rao lower bound (BCRLB) at every phase for estimation issue of different parameter.

Chih-Yu Chen, and Wen-Rong Wu [24] proposed another joint Angle-of-departure (AoD), Angle-of-arrival (AoA), and channel estimation process for pilot-based MIMO-OFDM frameworks. Initial, a compressive detecting system was utilized to evaluate the channel impulse response, abusing the sparsity property of remote channels. At that point, AoA and AoD were mutually evaluated for each recognized way by the Maximum Likelihood (ML) strategy. The Cramer-Rao Lower Bound (CRLB) was moreover construed and a transmit beam forming plan was proposed in like way. In the situation of accessible prior data, a most extreme posteriori estimation was proposed. The BCRLB issue was additionally inferred and a transmit beam framing plan was additionally proposed. Incidentally, just two training OFDM images were required for the estimation.

A novel algorithm is likewise use the various estimation vectors at the getting radio wires. In any case, they alter the known Multiple Sparse Bayesian Learning (MSBL) calculations for pilot-based a-bundle meager divert estimation in MIMO-OFDM structures. Thusly, they summarize the MSBL calculation to get a novel J-MSBL figuring for joint a-bunch sparse channel estimation and data disclosure (Prasad and Murthy [25]).

Amir Aminjavaheri et al. [26] has investigated the channel distortions without CP blur away and effects on the performances of the standard Maximum Ratio Combining (MRC) receiver. Their examination uncovers that in this recipient, there reliably remains some leftover obstruction inciting immersion of signal-to-interference-pulse noise ratio. To determine that issue, they proposed utilizing the Time Reversal (TR) strategy. In addition, so as to additionally lessen the multiuser interference, they proposed a zero-forcing equalization out to be sent after the TR joining.

Some major crisis may arise during channel estimation and we found that these exert influence on efficiency of MIMO. Due to huge lacking CP in OFDM, the huge sum of detection error and channel estimation hitch come about along with the performance delay [27]. The heart of the work i.e. proposed system model is discussed below.

3 System Model

In association with CP, the channel estimation and data detection problem occurs and in this paper, the center is essentially around the optimization of these techniques. Figure 1 shows the framework model of STBC MIMO OFDM, where we can configure the transmitting and receiving antenna as per needed. The codes of ST blocks are utilized for MIMO frameworks for empowering the sending of different stream of duplicate information over various reception antennas for abusing different collected variants to enhance the authenticity of communication [16]. Also Fig. 2 shows Expectation maximization (EM) based helical Forward-Backward (FB) Kalman Filter approach.

The CP is modified using enhanced Kalman filter technique. The Kalman filter is enhanced further by using the proposed Krill-herd and Lévy flight krill-herd (LKH) algorithm techniques [1] which improves the quality of the cyclic prefix assisted data. This is a *bio-inspired metaheuristic approach* (BIMA) which mimics the herding behavior of ocean krill individual. The best fitness parameters are used to further

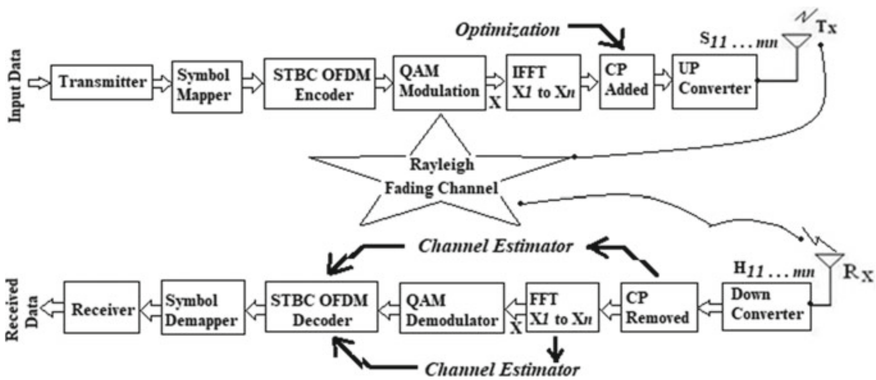

Fig. 1 Framework model of STBC MIMO OFDM system

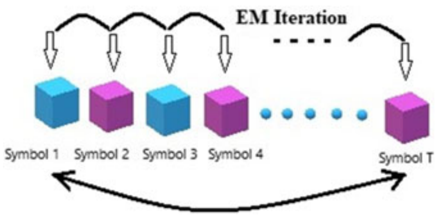

Fig. 2 EM based helical FB Kalman Filter approach

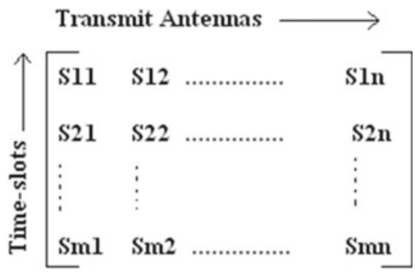

Fig. 3 Representation of Matrix form of STBC

modify the KH approach. The spatial and temporal form of data are used jointly to construct space time block code [17]. Space-time coding consolidates each of the duplicates of the received signal in an ideal manner to remove however much data from every one of them as could reasonably be expected. Alongside this MRC receiver, it gives better diversity and boosts the SNR.

The propelled mobile communication framework consequently utilizes this plan to demonstrate the best execution. Other assorted variety plot can also be hired through this scheme [13]. STBC is ordinarily addressed by a grid as appeared in Fig. 3, where columns are proportional to the amount of transmit radio antenna and its rows are identical to the amount of the schedule vacancies required to transmit facts [21]. The code structure is symmetrical. The recipient is experienced about the straightforward and ideal deciphering plan.

The space time codes are supplanted by the Alamouti STBC code that compensates for the channel hazards, for example, fading and warm clamor. The STBC Alamouti contrive was made subject to space time coding framework. The scientist S M Alamouti presented a two reception apparatus STBC in 1998. It doesn't require any extended form of bandwidth at the sending end. In perspective on expanding the volume of block information it summed up to receiving wires and plan to join several antenna in the framework [28].

Using the channel least square (LS) method the channel covariance in matrix form and different way outs are obtained for the sub-carriers during the pilot insertion. Then the maximum likelihood task is used to optimize the time-scale. The proposed algorithm utilizes both the time and frequency information on behalf of correlation. By using this technique, we experienced a better outcome in data detection and iterative joint estimation in the MIMO OFDM systems containing space time block code.

4 Performance Metrics

Least Square (LS) Algorithm: We first check the free noise MIMO channel by this calculation. Lower bound is availed by immaculate approximation. Expected Rayleigh flat-fading MIMO channel [29] is described with S and H, the training succession, and corresponding output signal as Y [30]. Then, $Y = SH + N$, where additive white Gaussian noise is N.

The algorithm simplified $\hat{H}$ so that

$$S\hat{H} \approx Y \tag{1}$$

The Euclidian distance $(S\hat{H} - Y)$ is minimized by using the ensuing stages,

$$\left\| S\hat{H} - Y \right\|^2 = (S\hat{H} - Y)^H (S\hat{H} - Y) \tag{2}$$

Derive this with respect to H and calibrate the equation as zero, it reduces to,

$$\hat{H} = (S^H.S)^{-1}.S^H.Y \tag{3}$$

This solution is used to LS channel estimation algorithm.

Channel Estimation Algorithm MMSE—Minimum Mean Square Error: Mean square error crop up the average mistake linking the evaluated wave and the genuine info wave. Clearly, the smaller the MSE is, the better efficiency of the proposed work [31].

$$\hat{h}_{n,MMSE} = [S^H R_{nn}^{-1} S + R_{hh}^{-1}]^{-1} S^H R_{nn}^{-1} Y_n \tag{4}$$

Where $R_{hh} = E\{h_n h_n^H\}$ and considering the presence of additive white noise, the MMSE Channel estimates as

$$\hat{h}_{n,MMSE} = [S^H S + \frac{\sigma_n^2}{\sigma_h^2}]^{-1} S^H Y_n \tag{5}$$

So the Least Square channel is estimated by putting the term $\frac{\sigma_n^2}{\sigma_h^2}$ to zero.

The channel is considered as frequency particular and time variant. The channel response is represented by $h_{r_x}^{t_x}$ where p distinct paths are created between transmit antenna t_x and receiving antenna r_x. Sequence vector $t_x = 1.....Tx$ and $r_x = 1......Rx$. The consisting ST (Space Time) blocks, channel decay factor and the Doppler frequency are also assumed, then the acknowledgement form of the transmit and receive antenna is presented by,

$$h_{t+1} = (I_{TxRx} \otimes F)h_t + (I_{TxRx} \otimes G)u_t \; (\hat{h} \text{ is an estimation of } h) \tag{6}$$

Where power detain is G and Doppler detain is F. The detection of transmitted data will be more visualized by the joint estimation detection scheme under the CP based EM environment.

Two possible extreme cases are analyzed (a) in first case the information is totally known at the recipient (b) secondly when the load is totally undisclosed at the receiver. These two cases are set up inferable from its semi blind nature.

(a) The information is totally known at the recipient: Consider an input time series is T + 1, also the ST (space time) symbols $\bar{I}_0^T (= \bar{I}_0, \bar{I}_1, \bar{I}_2, \ldots.., \bar{I}_T)$ and $\tilde{j}_0^T$ The limit of posteriori estimate of h_0^T is controlled by boosting the log probability function,

$$£ = \ln p(\bar{j}_0^T \,|\, \bar{I}_0^T, h_0^T) + \ln p(h_0^T) \tag{7}$$

Which minimizes to,

$$£ = -\sum_{t=1}^{T} \|\bar{j}_t - (I_{Rx} \otimes \bar{I}_t)\, h_t\|^2_{\frac{1}{\sigma_n^2}} - \|h_0\|^2_{\pi_0^{-1}} - \sum_{t=1}^{T} \|h_t - (I_{TxRx} \otimes F)\, h_{t-1}\|^2_{(GR_u G^H)^{-1}} \tag{8}$$

Value of h_t is determined by incorporating the prototype with FB Kalman viewpoint as mentioned by [16] and [18]. Beginning from starting condition $h_{0|-1} = 0$ and $p_{0|-1} = \Pi_0$.

Two approaches are considered in Kalman filter as mentioned below,

Forward run approach:

For i = 1,……, T, Determine,

$$R_{e,t} = \sigma_n^2 I_{TxRxN} + (I_{Rx} \otimes \bar{X}_t) P_{t|t-1} (I_{Rx} \otimes \bar{X}_t^H) \tag{9}$$

$$K_t = P_{t|t-1} (I_{Rx} \otimes \bar{X}_t^H) R_{e,t}^{-1} \tag{10}$$

$$\hat{h}_{t|t} = (I_{TxRx(P+1)} - K_t (I_{Rx} \otimes \bar{X}_t)) \hat{h}_{t|t-1} + K_t \tilde{j}_t \tag{11}$$

$$\hat{h}_{t+1|t} = (I_{TxRx} \otimes F) \hat{h}_{t|t} \tag{12}$$

$$P_{t+1|t} = (I_{TxRx} \otimes F)(P_{t|t-1} - K_t R_{e,t} K_t^H)(I_{TxRx} \otimes F^H) .GR_u G^H \tag{13}$$

Say, $N = 2(N_{CP} + N_{Data})$ where N_{CP} and N_{Data} are the CP length and information part of the OFDM symbol [32].

Backward run approach:

Beginning from $\lambda_{T+1|T} = 0$ and for t = T, T – 1,…..,0; Determine,

$$\lambda_{t|T} = (I_{P+N} - (I_{R_x} \otimes \bar{I}_t^H)K_t^H)(I \otimes F^H)\lambda_{t+1|T} + (I \otimes \bar{I}_t) \\ .R_{e,t}^{-1}(\tilde{j}_t - (I \otimes \bar{I}_t)\hat{h}_{t|t-1}) \quad (14)$$

$$\hat{h}_{t|T} = \hat{h}_{t|t-1} + P_{t|t-1}\lambda_{t|T} \quad (15)$$

So, $\hat{h}_{t|T}$ is the final estimation.

5 Simulated Result

The performance investigation of the optimized CP cooperated MIMO-OFDM framework with the transmit diversity of Alamouti STBC is uncovered in this work. We reproduce a several plots using Matlab to make a comparative study to finding out the best fitness value. The Rayleigh fading channel, experiences receive diversity of MRC procedure which furthermore shown in this paper. The modulation scheme is taken as the 16-QAM. Figure 4 shows the bit error rate performance when two different pilot sub-carriers (8 and 16) are used for the same algorithm. It is proved that the higher valued pilot sub-carriers perform well. Figure 5 compares the BER vs SNR simulation of EM based FB Kalman helical coded and uncoded data format when 16 pilot subcarriers are inserted [33].

Obviously the coded helical structure outperforms the uncoded one. Figure 6 compares the BER performance of proposed optimization scheme (Lévy-flight Krill-herd) along with the other three cases of without optimization, EM based FB Kalman and Krill-herd global optimization schemes. It is easily established that the nature inspired Lévy-flight Krill-herd optimization has the ability to improve the performance of BER and accuracy over FB Kalman algorithm and also Krill-herd algorithm [34].

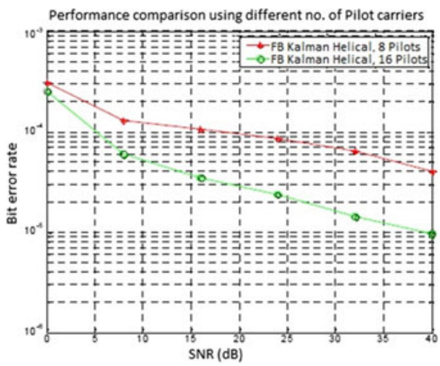

Fig. 4 Performance comparison between 8 and 16 Pilots FB Kalman helical approach

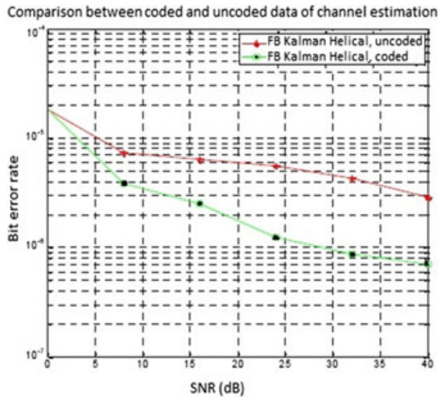

Fig. 5 Comparison between EM based FB Kalman Helical coded and uncoded simulation

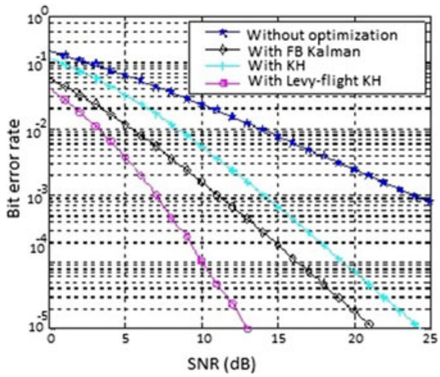

Fig. 6 BER vs SNR plot for (i) Without Optimization (ii) With FB Kalman (16 Pilots) (iii) With Krill-herd (iv) With Lévy-flight Krill-herd algorithm

6 Conclusion and Future Work

Continuous research since few decades is still a huge problem and in practical impact on the high complexity and low convergence speed in MIMO-OFDM network.

In this paper, the novelty of proposed Lévy-flight Krill-herd algorithm proved an optimized way-out over expectation maximization based forward-backward Kalman technique and Krill-herd approach. The higher order pilot inserted coded EM based FB Kalman helical model provide better SNR performance. Also the proposed optimization process (Lévy-flight Krill-herd algorithm) applied in the receiving end with the existing system deliver better performance using Alamouti space time block coded semi-blind nature of fading environment. Theoretical concept, system model and simulation results are given to support the statement.

In future we will investigate several bioinspired algorithms to find-out the more improved fitness parameters which in turn produce a better system to mitigate a strong demand of efficient spectral bandwidth in wireless communication.

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