# Joint Time Frequency Channel Estimation in MIMO-OFDM Using Firefly Heuristic

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***Abstract***
*For Channel Estimation (CE) in Orthogonal Frequency-Division Multiplexing (OFDM) Systems various techniques have been used in the literature. Using 8x8, 12x12 or 16x16 antennas with large scale Multiple Input Multiple Output (MIMO) configurations becoming a real challenge in implementing large systems which include proper placement of antenna and an emerging research area in multimedia data transmission in wireless telemedicine applications. For CE in the frequency domain, pilots have been extensively used and have the major disadvantage of high overheads that has reduced the spectral efficiency. Using preamble in the subcarriers, the time domain techniques alternatively used for CE and using the high MIMO system in the mobility of the device, it has the disadvantage of increased system overheads and poor estimation. Using systems with combining time and frequency techniques, many of these shortcomings were overcome to acquire delay estimation and gains using Time and Frequency based existing techniques.*

*A decent estimate of the channel is required for the efficient performance measure of the receivers. CE reduces the Euclidean distance for optimisation problem between the estimated and the exact channel coefficients. Matrix inversion has been incorporated to the resolution, and the popular Least-Squares (LS) or Minimum Mean Square Error (MMSE) estimator is not proficient. The maximum a Posteriori Probability (MAP) has been showed that the CE algorithms generate optimal results when compared to the LS / MMSE techniques.*

*The computational complexity could be extremely high when MAP has been applied to MIMO-OFDM systems which make a poor choice for mobile devices. Swarm Intelligence algorithm has been effectively used for CE but has the disadvantage of local optima problem. In this work, a FireFly heuristic is proposed for CE to overcome the issues. The OFDM is viable for improving the performance of transmitting multimedia data seamlessly in wireless telemedicine application. Experimental results show improved performance over TFT based technique and Particle Swarm Optimization (PSO) based technique.*

**Keywords:** Channel Estimation (CE), Heuristic-Based Firefly Algorithm, Maximum Likelihood (ML), Multiple Input Multiple Output (MIMO), Semi-Blind channel estimation, Orthogonal Frequency-Division Multiplexing (OFDM).

## Introduction

Telemedicine an evolving telecare system with the aid of telecommunication and computer technology enhances the delivery of medical care. Mobile communication and multimedia technologies are integrated in healthcare delivery systems. These systems are required to seamlessly transmit multimedia data, combination of video, audio and medical images, which is a challenge due to Inter Symbol Interference (ISI) and frequency selective fading. OFDM offer a solution to these problems and can be effective in telemedicine applications.

To achieve huge benefits by the side of transmitters as well as receivers of multiple antennas, a MIMO communications system has been used, and also antenna arrays are used for achieving antenna gain to increase the SNR output of the system. More recently, for achieving diversity and multiplexing gain, different ways are discovered for the use of multiple antennas by exploiting the unconstructive consequence of multipath. Because of this effects scatterers are caused in rich environment and among several antennae at the transmitters as well as receivers, channel path are regarded as an independent [1]

The process in MIMO wireless communication systems with Channel State Information (CSI) provides some key information, needs to be estimated correctly. Many CE algorithms are developed in recent years. MIMO CE methods are classified into training based, blind as well as semi- blind.

To identify MIMO channel state information, one of the most usual approaches is the Training-Based CE (TBCE). TBCE method is optimal with high SNRs and is suboptimal at low SNRs. It has been alleged that the optimal design for MIMO CE training sequences has been associated with the channel statistical character. A long training is necessary for pure training based scheme for obtaining a dependable channel estimate to substantially reduce the system bandwidth economically [2].

Blind estimation method has eliminated the training overhead completely. Among the training-based and in blind approach, a more practical way has been lying which is semi-blind estimation method. More than either of them, it can perform better through the exploitation of the information, increasing the training length residing in the unidentified branch of the signal. Furthermore, to exhibit robust performance, the semi-blind method has been shown in the presence of asynchronous intrusion and non-ideal conditions [3].

If the CSI is available in a MIMO receiver, the Optimized Hierarchy Reduced Search Algorithm (OHRSA) aided detector can be performed with the optimal ML data detection for the higher conservatory of the complex sphere decoder. A challenging task is accurately estimating a MIMO channel with an elevated amount of symbols trained for obtaining a dependable Least Square Channel Estimate (LSCE). This has reduced the system throughput considerably, and it cannot be achieved by means of blind joint Maximum Likelihood Channel Estimation (ML CE). It suffered from the demerits of extremely large computation complexity with an inherent opinion and decision ambiguity [4]

For partially-blind joint ML CE as well as data detection with an interesting strategy of optimisation has two levels. A population-based optimisation protocol termed as Repeated Weighted Boosting Search (RWBS) protocol for an optimum estimation of the channel is the upper level. While lower level is the OHRSA detector, which recovers the forwarded data. By iteratively exchanging the information from the Joint ML CE, data recognition is being achieved with the RWBS-aided channel estimator while OHRSA is the detector. Since it has employed some symbols for training, the scheme is partially-blind, aiding the RWBS channel estimator for providing an initial LSCE and also to improve its convergence.

For suboptimal solutions in practice, one repeatedly has to resolve systems mainly with a huge quantity of antennae employed in higher-command Quadrature Amplitude Modulation (QAM) signalling because of the unnecessary computation difficulty in the optimum ML solution. Fortunately, Evolutionary Algorithms (EAs) provide possible optimum or near-optimum solutions, with joint CE as well as turbo MUD/decoding at a reasonable complexity [5]. Genetic Algorithms (GAs), RWBS, PSO, and Differential Evolution Algorithms (DEAs) are the most popular Evolutionary Algorithms. In applying these EAs, significant advances have been made in particular user joint channel and estimation of data, in CE as well as MUD for the multi-user code-division multiple access Up Link (UL). It aided OFDMUL in the Space-Division Multiple-Access (SDMA) for MIMO systems in joint CE as well as data detections with a various series of other applications. Though, offerings on EA-aided joint CE as well as turbo MUD/decoding methods there is a scarcity for OFDM/SDMA systems.

The advantages of PSO are: (1) PSO can be used to apply systematic investigation and engineering exploration. (2) PSO has no overlapping and transformation calculation. By the speed of the particle, the investigation can be done. The most optimal element can transmit information in the growth of some generations in other elements, and the research speed is very rapid. (3) The computation in PSO is extremely easy to calculate. It occupied the larger optimisation capacity when compared to the other early calculations (4) PSO adopts and decides the original code number directly. The constant solution is equivalent to the number of dimensions.

Disadvantages of the PSO algorithm: (1) It easily falls into local optima in higher dimensional space (2) It has lower convergence rate in the iterative procedure.

Advantages of FA: The popular and successful reasons behind FA are listed below [6]:

- FA automatically splits its population, due to the information that confined draw is stronger than the extended distance draw.
- The historical person best and the open world-wide best are not used in FA. The possible drawback of the early meeting has been reduced by this. The issues related to velocities in Particle Swarm Optimization (PSO) have been eliminated automatically since it does not use the velocities.
- To control the parameter such as $\gamma$, FA has ability to its mobility and possibility.

Hence it can be clearly seen in respects of controlling parameters that the FA is more efficient with local search ability, robustness, and elimination of premature convergence.

This work proposes a semi-blind CE, MIMO and firefly heuristic. Section 2 details the relevant work in literature. Section 3 details methods used while Section 4 discusses experiment results. Section 5 gives the conclusion of the paper.

## Related Works

Banani et al[7] provided a novel approach for high date rate MIMO systems to joint blind CE and data recovery operating over flat Rayleigh channels. This technique has its basis in the Independent Component Analysis (ICA) for tracking the time-varying channel with particle filtering. From the channel matrix coefficients' second-order statistics, non-stationary self-governing part investigation of one value was given to a generalised exponential function of density that was used for separating signal source. Through simulations as well as comparison with optimum coherent detection as a bench mark, the performance was evaluated. With Kalman-based estimation, improved performance was demonstrated by the "conventional" blind approach and also over two identified pilot-aided system. Finally, by simulation, the effect of time selectivity of the channel on error performance was also assessed.

Lenin and Malarkkan[3] analysed a widespread review used on multiple CE methods in MIMO-OFDM such as pilot based LS & amp; MMSE method, Least Mean Square (LMS) & amp; Recursive Least Squares (RLS) techniques also with other CE techniques had been utilized to achieve their results in MIMO-OFDM.

Wang et al[8] focused the Joint Timing and Channel Estimation (JTCE) in a band limited long-code-aided Multi-Carrier Direct-Sequence Code Division Multiple Access (MC-DS-CDMA) systems. The author had established the optimum multi-user timing as well as channel estimation to minimise for the up-link receiver of MC- DS-CDMA concerning active users of K with a cost function weighted LS independent parameters. Repeated Weighted Boosting Search (RWBS) as a guide for random investigate procedure was invoked to solve the multivariate optimisation challenging issue numerically to produce close-to-optimum timing as well as the channel estimates. To benchmark the performance, the Cramer-Rao Lower Bound (CRLB) for interest in JTCE issue had been derived with this proposed RWBS based estimator.

Zhang et al[9] analysed and compared stochastic optimisation that had assisted the joint CE as well as MUD in the framework of MIMO-aided Orthogonal Frequency-Division Multiplexing/Space Division Multiple Access (OFDM/SDMA) systems. The progress in stochastic optimisation protocols like GA, RWBS, PSO as well as DE had provided broad comfort in the signal processing area as well as the communications one in the research domain. But, the comparison among the quantitative presentation and difficulty of GA, RWBS, PSO as well as DE methods had been practical to joint CE as well as MUD was a difficult problem at the writing time, that had to concern both issues in nonstop-valued CE optimisation as well as the discrete-valued MUD optimisation.

Eshwaraiah and Chockalingam[10] introduced a Cooperative Particle Swarm Optimization (CPSO) based on CE equalisation method in MIMO Zero-Padded Single-Carrier (MIMO-ZPSC) scheme in the selection of frequency channels with high dimensions. The author had estimated time domain receiver with channel state information by means of PSOA based protocol in the training stage. Utilizing the channel estimation, the author had performed data symbol recognition in Frequency Domain by means of FFT based processing. The author had used a low complexity for the detection with Overlap Add (OLA) likelihood ascent investigates equaliser to use MMSE equaliser as the initial solution. Various iterations were carried out to improve the mean square error as well as bit rate error of the receiver performance among CE and data detection.

Senthilkumar and Priya[11] investigated an optimal assignment of the channel by using the channel parameters. The channel estimation methods such as pilot-assisted channel estimation, blind and semi-blind estimation technique, as well as decision directed channel estimation technique were investigated.

It was observed from the surveyed results, that the existing spectrum sensing and the prediction-based techniques had consumed more energy and minimal data transmission rate for the detection of the idle channel. Further, the end-to-end delay, energy consumption, and bandwidth were not minimised by the existing techniques.

Chen et al[12] presented a difficulty less semi-blind joint CE as well as data detection method for Space-Time Shift Keying (STSK) which has its basis in MIMO systems. The minimum STSK training block had been associated with the number of antennas to the transmitter antennas which was utilised to provide an initial LSCE. Next, it also carried out complex less single stream ML detection and those data were utilized for refining the decision directed LSCE. It had been established that only some iterations were enough to move towards the ML optimal detection performance which had acquired the channel state information perfectly.

Knievel et al[13] proposed iterative receiver structures to perform CE and decoding guaranteed a considerable gain in performance; though, these gains were materialised with adequately precise early channel estimation. Here, initialization can be done by using Multi-Objective PSO (MOPSO) and that had been analysed. MOPSO supported initial CE of less complexity with training symbols. Also, it had shown that the MOPSO had worked fine in rank-lacking condition by means of random training sequence. Arithmetical outcomes had validated the improvement performance of MOPSO initialization that was incorporated with a chart based on the iterative receiver.

Knievel and Hoeher[14] provided a general idea of the inventive PSO and with the improvement that was appropriate. An expansion of PSO termed as CPSO had been practical for MIMO CE provided earlier junction with less complexity. In place of formative the standard iterations that were essential empirically, a technique was developed for a wide range of parameters for calculating maximum iterations to evaluate complexity. A thorough assessment was given for the difficulty faced in the PSO algorithm to a conservative MMSE estimator. Also, Monte Carlo simulation was presented for illustrating the performance of MSE performance over an MMSE estimator.

Zhang et al[15] introduced a scheme of optimum pilot design for multiuser MIMO-OFDM/SDMA systems. The author had derived the optimal pilot design criterion in regards to the computational complexity and the MSE of the LS estimator. Furthermore, in order to find the optimal position, the author had proposed a binary-tree based search scheme for placement of the Space-Time Coded pilot symbols. It was shown through the analysis and simulations that the pilot design had been complied with the proposed placement criteria would obtain the lowest computational complexity and the optimum estimate performance. Mohammadi[16] proposed a semi-blind watermarking method on chaotic maps for colour images. The simulation results had shown that this projected system had performed superior in the Peak Signal to Noise Ratio (PSNR) and the rate of bit error quality measures.

Ngo and Larsson[17] overviewed multi-cell multiuser MIMO systems at the base station with, especially huge antenna arrays. The author had proposed an approach based on Eigen value decomposition for estimating channel from the data acquired. This move had exploited the asymptotic orthogonality of vector channels in large MIMO systems. The author had shown by covariance matrix of the signal received that the channel in each user can be estimated for the remaining scalar multiplicative uncertainty. To determine this uncertainty, it required a small training series. Furthermore, the author had combined it with the Iterative Least-Square Projection (ILSP) protocol for improving the approach performance. Arithmetical grades had verified the efficiency of the channel estimation.

Kim et al., [18] analysed the joint Carrier Frequency Offset (CFO) as well as channel estimation over time-altering channels for up-link MIMO-OFDMA systems. The particular response on user channel was reorganised through Kalman filters bank that trained on the CFO model trajectories. Simulations' outcomes had indicated that this suggested method could achieve high precise CFO/channel and it outperformed the particle filtering in the SK-APF (Schmidt-Kalman Approximate Particle Filter) when compared with the conservative Schmidt Extended Kalman Filter.

## Methodology

In this section, MIMO system model with OFDM and Heuristic-Based Firefly Algorithm (HBFA) using semi-blind scheme are described.

**MIMO System Model:** A MIMO system which comprises $M_T$ transmitter antenna as well as $M_R$ receiver antennae has communications across the flat fading channels. By the known MIMO model the system [19] is described as:

$$y(k) = H_s(k) + n(k) \quad (1)$$

Wherein k refers to the index of the k –th symbol, H indicates the channel matrix of $M_T$ x $M_R$ MIMO system.

$$s(k) = \left[s_1(k) s_2(k) \cdots s_{M_T}(k)\right]^T \quad (2)$$

denotes the vector symbols transmitted by the transmitter with the symbol energy as follows:

$$E[|s_m(k)|^2] = \sigma_s^2 \quad , \text{for } 1 \le m \le M_T \quad (3)$$

$$y(k) = \left[y_1(k) y_2(k) \cdots y_{M_R}(k)\right]^T \quad (4)$$

gives the received vector signal while:

$$n(k) = \left[n_1(k) n_2(k) \cdots n_{M_R}(k)\right]^T \quad (5)$$

mentions the complex-valued Gaussian white noise vector related to MIMO channels with energy:

$$E[n(k) n^H(k)] = 2\sigma_n^2 I_{M_R} \quad (6)$$

Quadrature Phase Shift Keying (QPSK) is the modulation system. The narrow band MIMO channel matrix has been given as:

$$H = \left[h_{p,m}\right] \text{ for } 1 \le p \le M_R, \; 1 \le m \le M_T$$

wherein $h_{p,m}$ indicates the channel coefficient linked the m –th transmitters with the p –th receivers. For the period of time, the fading is supposed to be slow for a small block of L symbols, each entry is deemed unaffected in the MIMO channel matrix H. From frame to frame, the impulse response of the channel taps $h_{p,m}$ are separately and uniquely spread in the complex-valued Gaussian procedure with mean 0 and $E\left[\left|h_{p,m}\right|^2\right] = 1$. The SNR is defined by $E_b/N_o = \sigma_s^2/2\sigma_n^2$ .

The main motivation of MIMO - OFDM refers to the fact that OFDM modulation turns a frequency-selective MIMO channel into a set of parallel frequency streams. This makes simple multi-channel equalisation certainly as for every OFDM symbol solely a constant matrix has to be inverted. In a MIMO-OFDM system with N subcarriers (or tones), the individual data streams are first passed through an Inverse Fast Fourier Transform (IFFT) which perform OFDM modulation on blocks of length N after which comes a parallel-to-serial conversion.

The transmitted information symbols into frequency vectors which are denoted as:

$$d_k = \left[d_k^{(0)} d_k^{(1)} \cdots d_k^{(M_T-1)}\right]^T, (k = 0,1,\cdots,N-1) \quad (7)$$

With $d_k^{(i)}$representing, the k-th data symbol forwarded from i-th antennae, then the rebuilt data vector for the k-th symbol is as follows:

$$r_k = H\left(e^{j\frac{2\pi}{N}k}\right) d_k + n_k \quad , \text{where } (k = 0,1,\cdots,N-1) \quad (8)$$

wherein $n_k$ is complex-valued circularly symmetric additive white Gaussian noise (AWGN) fulfilling $\varepsilon\{n_k n_l^H\} = \sigma_n^2 I_{M_R} \delta[k-l]$.

**Signal Structure of MIMO-OFDM:** An OFDM multi-carrier system may be effectively executed in discrete time through an IFFT function as a modulator as well as an FFT for acting as a demodulator. The "frequency" domain communicated data are converted into "time" domain output at IFFT stage. Figure 1 (a) denotes a general MIMO-OFDM and (b) shows the structure of CP OFDM for a symbol [20].

Let $D = \{D_0, D_1, \cdots, D_{N-1}\}$ represent the length N data symbol block. The IDFT of the date block D produces the time domain sequence $d = \{d_0, d_1, \cdots, d_{N-1}\}$ , i.e., $d_n = IIFT_N\{D_k\}(n)$

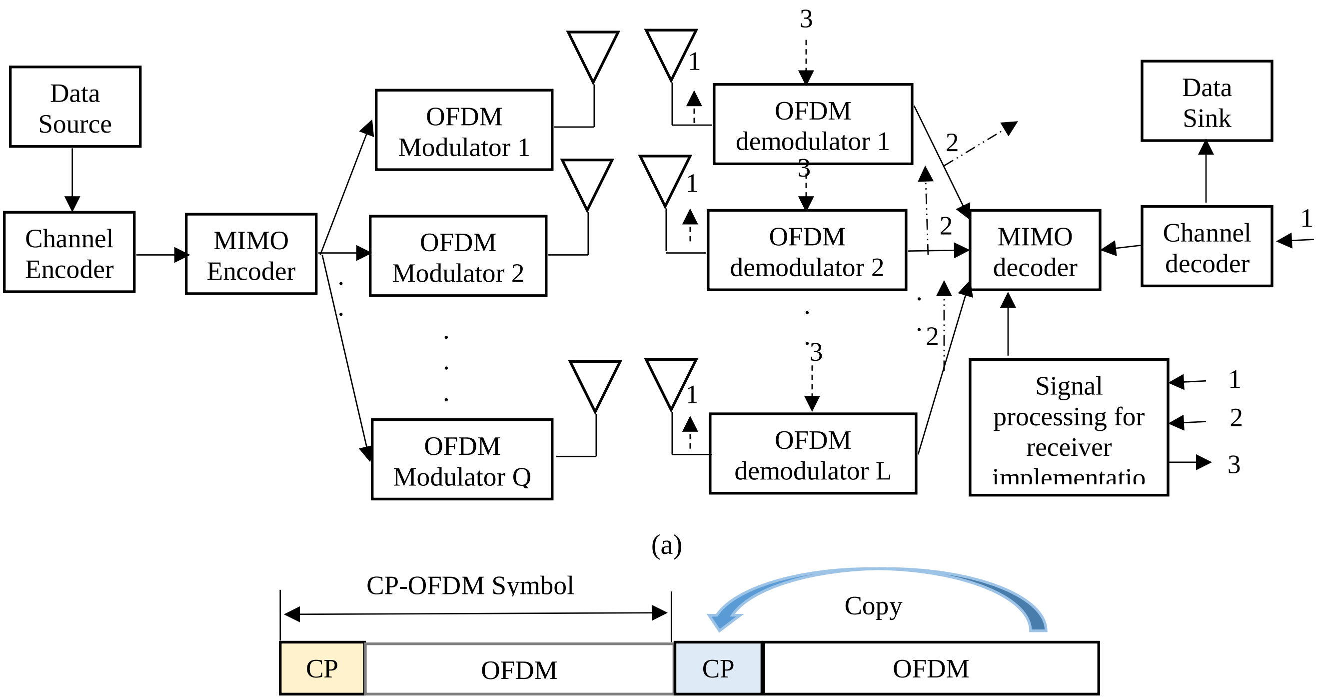


**Figure 1: (a) MIMO-OFDM system; (b) Conventional CP OFDM**

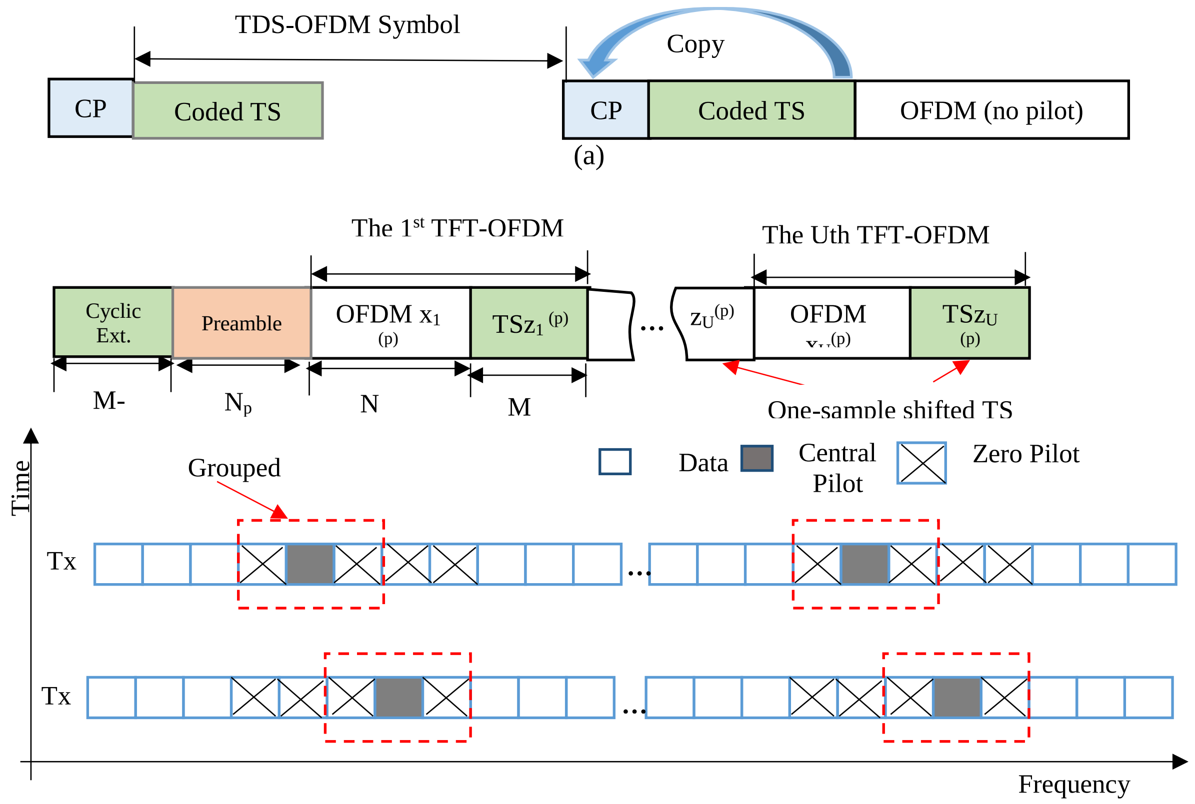


**Figure 2: Time-frequency frame structure comparison of the MIMO systems on the basis of: a) Conventional TDS-OFDM; b) The proposed TFT-OFDM.**

Guard interval of either CP or suffix is added to the sequence D for mitigating the impacts of channel delay distribution. In the event of a CP OFDM, the forwarded sequence with guard interval is given as $d_n^g = d_{(n)_N}, n = -G,\cdots,-1,0,1,\cdots,N-1,$ wherein $(n)_N$ refers to the residue of n modulo N while G refers to the guard interval length in examples.

The CP length G should be the same as the length of the discrete-time channel impulse response M, to avoid ISI. The OFDM signal is communicated over the passband RF channel, obtained, as well as down converted to base band. Since CP OFDM, the discrete linear convolution of the forwarded sequence with the channel impulse response turns into a circular convolution. At the receiver the original N examples from every received block are discarded, followed by an N-point Fast Fourier transform (FFT) on the resultant sequence. Since constant tracking is essential for channel coefficients, inserting known pilot symbols at each sub-carrier is required.

**TFT-OFDM MIMO System Model:** Before describing the TFT-OFDM, the another type of OFDM signal structure described in fig. 2(a) is TDS-OFDM. Normally the length of CP is chosen to be ¼ of the block size, which results in reduction in bandwidth efficiency of 80%. To overcome this limitation, the known training sequence (TS) is used instead of the CP for the guard interval in the TDS-OFDM strategy. This avoids the usage of a huge quantity of frequency domain pilots and outperforms CP-OFDM in spectral efficiency by about 10%. But it causes mutual interference between TS and OFDM data block which is to be completely discarded before channel estimation as well as equalisation. This needs iterative interference cancellation methods. All the above-mentioned limitations can be overcome by the method called TFT-OFDM system model. The highlight of this system model is that it uses only few PN sequence and few pilots for channel estimation. This paper concentrates on TFT-OFDM.

The TFT-OFDM signals are forwarded by each frame, as shown in the time-frequency frame structure of Fig. 2 (b), and every frame consists of a single preamble with the cyclic extension and the consequent *U* TFT-OFDM symbols (sub-frames). It is presumed $M_T$ transmit antennae while $M_R$ receive antennae in MIMO systems.

In the time domain, the *i*-th TFT-OFDM symbol ($1 \le i \le U$) for the *p*-th transmit antennae ($1 \le p \le M_T$) comprises the length-*N* OFDM symbol:

$$DX_i^{(p)} = \left[d_{i,0}^{(p)}, d_{i,1}^{(p)}, \cdots, dx_{i,N-1}^{(p)}\right]^T \quad (9)$$

followed by Training Sequence of length-M is:

$$z_i^{(p)} = \left[z_{i,0}^{(p)}, z_{i,1}^{(p)}, \cdots, z_{i,M-1}^{(p)}\right]^T \quad (10)$$

Constant TS is not optimum for channel tracking, the TS $z_i^{(p)}$ is produced through cyclical shifting of the basic :

$$z_i^{(p)} = \left[z_{i,0}^{(p)}, z_{i,1}^{(p)}, \cdots, z_{i,M-1}^{(p)}\right]^T \quad (11)$$

by *i* instances to the left as:

$$z_i^{(p)} = \begin{bmatrix} 0_{(M-1)\times i} & I_{M-i} \\ I_i & 0_{i\times(M-1)} \end{bmatrix} Z^{(p)} \quad (12)$$

wherein $z^{(p)}$ refers to the Zadoff-Chu sequence as given below:

$$z_m^{(p)} = exp\left(j\frac{M-1}{M}\pi m^2 R_p\right), 0 \le m \le M-1 \quad (13)$$

where $R_p$ is relatively prime to *M*.

In the frequency domain, TFT– OFDM MIMO systems adopt randomly selected G orthogonal pilot groups in the signal bandwidth. The group pilot consists of solely 1 non-0 central pilot in the middle surrounded by $Z_p$ 0 pilots on the left as well as right side. Figure 3(b) shows the signal structure of TFT-OFDM MIMO system, grouped pilot with $Z_p$=1, the ICI enforced on the fast fading channel is sufficiently alleviated. For ensuring the orthogonality of the grouped pilots related to every transmitting antenna, needs ($M_T$-1) (2$Z_p$+1) additional 0 pilots are needed for every grouped pilot possessing (2$Z_p$+1) pilots. But, the grouped pilots are for adjacent 2 transmit antennae, the overlapping of d 0 pilots are allowed. Hence, solely ($M_T$-1) ($Z_p$+1) is required rather than ($M_T$-1) (2$Z_p$+1). The pilot power is presumed to be equivalent to the useful data.

The channel impulse response (CIR) of the p-th transmit antennae can be denoted as:

$$\mathrm{h}_i^{(p)} = \left[\mathrm{h}_{i,0}^{(p)}, \mathrm{h}_{i,1}^{(p)}, \cdots, \mathrm{h}_{i,L-1}^{(p)}\right]^T \quad (14)$$

where $h_{i,l}^{(p)}$ denotes the route gain of the i-th path with the delay $\tau_l^{(p)}$. L represents the maximal channel distribution. For avoiding interference between 2 neighbouring OFDM data blocks, assume L=M.

At the receivers, the signal received from distinct transmitter antennae, the received OFDM data block is:

$$\mathrm{y}_i = \left[\mathrm{y}_{i,0}, \mathrm{y}_{i,1}, \cdots, \mathrm{y}_{i,N-1}\right]^T. \quad (15)$$

The subcarrier may be given after applying DFT to the received OFDM data block:

$$Y_{i,k} = \sum_{p=1}^{N_t} X_{i,k}^{(p)} H_{i,k}^{(p)} + W_{i,k}, \quad 0 \le k \le N-1 \quad (16)$$

where, ,$H_i^{(p)} = \sqrt{N}\boldsymbol{F}_{N,L}\boldsymbol{h}_i^{(p)}$ is the Channel Frequency Response (CFR) of the of $h_i^{(p)}$ (CIR).

**TFT-OFDM MIMO Receiver Design:** The design of channel estimation of TFT-OFDM MIMO system, adopted in this study is shown as a figure for better understanding in fig. 3.

The route delay as well as and route gains are estimated concurrently by the time domain TS and frequency domain pilots respectively.

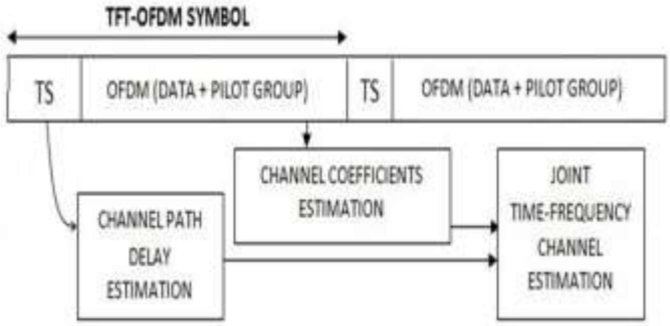


**Figure 3: Concept of Joint channel estimation on proposed TFT-OFDM.**

The received TS, the i-th TFT – OFDM MIMO symbol is denoted as:

$$d_i = \left[d_{i,0}, d_{i,1}, \cdots, d_{i,M-1}\right]^T \quad (17)$$

$$d_i = \sum_{p=1}^{N_t} \left(\underline{h}_{i,ISI}^{(p)} z_i^{(p)} + \underline{h}_{i,IBI}^{(p)} x_{i,N-M:N-1}^{(p)}\right) + v_i \quad (18)$$

wherein $\underline{h}_{i,ISI}^{(p)}$ and $\underline{h}_{i,IBI}^{(p)}$ denotes the M x M Toeplitz lower as well as upper triangular matrices. The term $\left(\underline{h}_{i,ISI}^{(p)} z_i^{(p)}\right)$ denotes that $d_i$ is affected by ISI components and the term $\underline{h}_{i,IBI}^{(p)} x_{i,N-M:N-1}^{(p)}$ mentions that di is contaminated by the IBI caused by the proceeding OFDM data blocks. $v_i$ denotes channel noise.

Based on the property, path delay in wireless communication varies more slow than route gains. Hence the averaged route delay is taken. Path gains of TS are directly ignored as inaccurate because of the lack of interference cancellation. Estimation of path delays the reduction in unknowns from L to Q. Thus, only the grouped pilots in small amount is enough for estimating the channel route gains Q. The received central pilots among different antennas can be expressed as

$$Y_{i,k} = \sum_{p=1}^{N_t} X_{i,k}^{(p)} H_{i,k}^{(p)} + W_{i,k} = H_{i,k}^{(p)} + W_{i,k},\ k \in \boldsymbol{G}^{(p)} \quad (19)$$

Thus, combining the path delays on the basis of time – domain obtained TS as well as the route gain acquired on the basis of the frequency domain obtained pilots, the complete Channel Impulse Response (CIR) can be estimated for all transmit antennas, by the defined time-frequency joint channel estimations.

In the proposed channel estimation, RWBS protocol is suggested for an optimum estimation of the channel, the Optimized Hierarchy Reduced Search Algorithm - Maximum Likelihood (OHRSA - ML) the has recovered the forwarded data. The rest of the paper discusses the Heuristic-Based Firefly Algorithm.

**Heuristic-Based Firefly Algorithm (HBFA):** HBFA for estimating the optimum as well as binary solution of bound constrained non-linear optimisation problems [21].

In place of searching for any limited resolution, it needs the most excellent binary point. Since it does not assume differentiability, direct search methods might be suitable. When a universal resolution arrives but there is no security; they are only local optimisation procedures. Stochastic systems are usually essential for global optimisation and have planned to discover the search area and congregate to a universal resolution. Meta-heuristics are high-point events or heuristics which are intended to explore for high-quality solutions, termed as close-to-optimum solutions, without much computation effort as well as time over traditional protocols. They are non-deterministic frequently, and their characters problem's properties are independent. To solve various issues in optimisation from continuous to combination, population-based meta-heuristics have been used.

For solving discrete binary optimisation problems, meta-heuristics are common. To solve nonlinear programming problems, many approaches have been developed aiming with varied-discrete variables into a continuous one by means of transforming the discrete issue. The significant approach has solved the continuous and discrete problem to obtain the solution by means of the rounding system. For simple with small dimension, this type works well for the benchmark problems. However, it restricted on a few valid-world applications.

By biochemical and communal aspects FA is inspired of authentic fireflies. Authentic fireflies produced a small and musical flash to help them in communications with their mating partners, and it functions as a defensive word of warning method. This blinking behaviour is optimised and formulated by means of FA with the intention function. The following rules are idealised for basic FA formulation[8]:

- Fireflies will attract each other apart from their sex since each of the fireflies is unisex.
- Attractiveness is being comparative to their intensity between two flies' decreases as distance increases. Hence the less intensity advance to the high intensity and it will difficult to detect when it moves at random.
- By the landscape of the object function, the intensity is determined for a firefly.

The basic FA assumes there exists n fireflies $x_i$, i=1,2,........,n initially positioned arbitrarily in the space as well as intensity i of all fireflies are related to the objective function in (20).

f(x), i.e I = α f(x) (20)

The firefly with greater flash intensity attracts the other firefly

Ii>Ij, j=1,2…n, j≠i. (21)

Attractiveness or the brightness of firefly differs with the distance between firefly i as well as j. Attractiveness that is light intensity is inversely proportional to the distance r from the light. Hence, light intensity as well as attractiveness are decreased as the distance increases and is defined as,

$$I(r) = I_0 e^{-\gamma r^2} \quad (22)$$

where, I=light intensity, $I_0$ = light intensity at initial or original light intensity, $\gamma$ =the light absorption coefficient, r=distance between firefly i and j.

Attractiveness is proportional to the brightness observed by the other fireflies. Hence, attractiveness β is given as:

$$\beta = \beta_0 e^{-\gamma r^2}, \quad (23)$$

$\beta_0$ =Attractiveness at r is 0

The distance between 2 fireflies may be defined through Cartesian distance is:

$$r_{ij} = |x_i - x_j| = \sqrt{\sum_{k=1}^{d} (x_{i,k} - x_{j,k})^2} \quad (24)$$

Firefly i is attracted toward the more attractive one j, the measure is given by:

$$\Delta x_i = \beta_0 e^{-\gamma r_{ij}^2} (x_j^t - x_i^t) + \alpha \varepsilon_i,\ x_i^{t+1} + \Delta x_i \quad (25)$$

In $\Delta x_i$ equation, $\beta_0 e^{-\gamma r_{ij}^2} (x_j^t - x_i^t)$ is for attraction, has limitation when the value tends to 0 or too huge. If $\gamma$ approaches zero, the attractiveness as well as light intensity become constant i.e. $\beta = \beta_0$. Otherwise put, fireflies may be seen in any position, easy for completing global searches. If $\gamma$ the is approaching infinity or very huge the attractiveness as well as light intensity become reduced. The firefly movement becomes arbitrary.

In this work the Maximum likelihood for data estimation is achieved using Optimized Hierarchy Reduced Search Algorithm (OHRSA)-Maximum Likelihood (ML) method. OHRSA –ML is designed for detecting constant envelope modulation schemes, like QPSK, wherein the forwarded symbols fulfil the criterion of $|s|^2 = 1, \forall_s \in M$ while M represents the set of M complex-valued constellation points.

As discussed in the MIMO-TFT- OFDM system, the signal is transmitted and received by receiving antenna with noise and interference. Initially, fitness value is calculated. Here delay estimation and initial phase estimation is considered as fitness values of the signal. The phase estimation of the signal is obtained with the use of pilots.

Steps followed for the algorithm:

1. Initialized population as signals with channel noise.
2. Evaluate fitness values.
3. If the fitness value of the signal is better, then channel decoding is initiated.
4. If the fitness of the signal is not satisfied, the worst signals are re-estimated using a cross over operation. Two encoding bit points are randomly selected for every pair of crossover parents & exchange the intermediary component of the 2 points. Select an individual as well as its 2 encoding bits arbitrarily.
5. Obtain signals are combined to form the transmitted original data signal with noise and interference.

## Results and Discussion

In the proposed method, MIMO-OFDM system with TFT-OFDM signal structure is used with group pilot. The $M_T$ transmitting antenna transmitted U frames of length N and $M_R$ receiving antennas receives the signal with interference and channel noise. The system is executed with the conventional CP-OFDM to describe its performance. 4X4 MIMO system, practical resolvable path taken is 10, 50 iterations, 48 subcarriers, Rayleigh channel are used for analysis.

The performance of CP-OFDM and TFT-OFDM is given by fig. 4. The mean square error reaches $10^{-5}$ at the SNR 30db, but in the case of CP-OFDM it reaches to $10^{-3}$ only. This improvement in MSE is reflected in the performance of BER Vs SNR.

In the proposed Firefly algorithm evaluated Bit Error Rate (BER) and compared with OHRSA and PSO techniques. The parameters used in this work are

**Table 1**
**Simulation Parameters**

| Parameter | Specification |
|---|---|
| Number of transmitting antenna $M_T$ | 4 |
| Number of receiving antennas $M_R$ | 4 |
| Modulation used | QAM |
| Number of subcarriers used | 256 |
| Number of symbols used | 50, 100 |
| Channel | Rayleigh |
| Number of resolvable paths (visual) | 10 |
| Step | 1 |
| gamma | 0.5 |

Figure 5 shows the BER achieved for the various methods.

Here, the performance of the FA is contrasted with conventional PSO algorithm with symbols 50 and 100. The same firefly is compared with OHRSA. From simulation, it shows that firefly performance better than other methods. It shows that at SNR 14db the BER reaches $10^{-6.}$

It is clear from the graphs that the suggested firefly method achieves lesser BER compared with OHRSA and PSO technique.

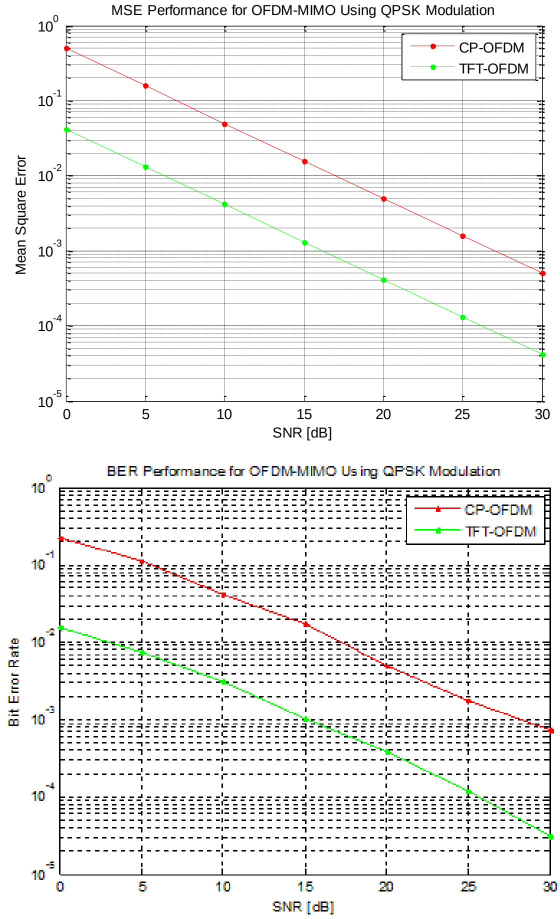


**Figure 4: Performance Measure of TFT-OFDM with CP-OFDM. (a) MSE performance (b) BER performance.**

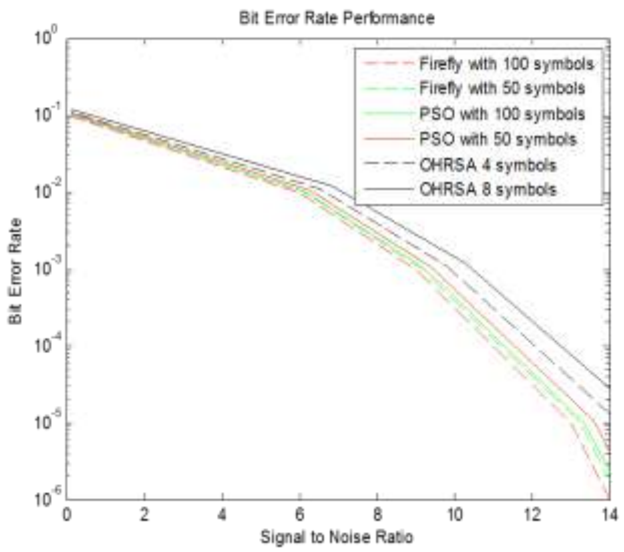


**Figure 5: Bit Error Rate achieved**

## Conclusion

A new method of Joint time frequency channel estimation as well as data detection is proposed for MIMO systems and shows that TFT method outperforms other methods. This work used firefly algorithm for better optimisation and the proposed method overcome the issue faced in PSO. The simulations' result prove that the suggested protocol functions better than existing methods. The bit error rate is taken as performance metrics for evaluating the performance of the suggested technique. Outcomes demonstrate that the suggested method attains lower BER than OHRSA and PSO method.

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