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ADVANCED AND SELF IMPROVED META HEURISTIC ALGORITHMS FOR FREQUENCY TRACKING IN OFDM SYSTEMS

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ABSTRACT

The primary objective of this Paper is to enhance the OFDM system, the proposal has been channelized to introduce advancements in the Meta heuristic procedures for blind Carrier Frequency Offset (CFO) estimate, the purpose of this paper is defined as follows. To improve the quality of service by enhancing the OFDM systems, address the challenges reside on frequency tracking and so the impact of interference on OFDM systems. Also review various principles CFO estimation and algorithms and categorize them based on various criteria. In order to experimentally investigate the performance of various state of the art Meta heuristic search algorithms on estimating the CFO and Adopting Grey-Wolf Optimization for estimating the CFO. To investigate the self adaptive mechanisms persist in the literature that is suitable for CFO estimate process. Introduced a novel based self-adaptive mechanism for Grey Wolf Optimization and hence to propose a blind and global CFO estimate procedure. Finally to conduct an extensive comparative study under various OFDM system and channel models to demonstrate the global compatibility feature and blind estimation characteristics of the proposed CFO estimation.

Keywords: *Carrier Frequency Offset (CFO) estimate, Orthogonal Frequency Division Multiplexing (OFDM), Inter Carrier Interference (ICI), Minimum Mean Square Error (MMSE), Cramer Rao Lower Bound (CRLB), Non Blind CFO estimation, Blind CFO estimation, Alternating Projection Frequency Estimation (APFE).*

1. INTRODUCTION

At present, orthogonal frequency division multiplexing (OFDM) has been embraced in many standards such as asymmetric digital subscriber line (ADSL), wireless local area networks (WLANs) and digital video broadcasting (DVB) [1] [2] [3] [4] [5] [9] [10] [11] [12] [13] [14] [15] [16].The objective of the Orthogonal frequency-division multiplexing (OFDM) is to transform a frequency-selective fading channel in to multiple-selective fading channels. This transformation is used for designing a receiver using the simple signal processing techniques [6]. Without introducing the inter-channel interference, the orthogonality of the subcarriers allows the overlapping between the sub-bands, and therefore, the spectral efficiency is increased. However, OFDM systems are highly sensitive to frequency synchronization errors, which are referred to as carrier frequency offset (CFO) [25] [26] [27]. It is occurred when the Doppler spread or the local oscillator's instability deliberates the orthogonality of the system, which leads the received signal suffers from the attenuation, phase rotation and inter- carrier interference (ICI) and thus the serious performance degradation of the system is occurred [7] [8] [9].

Generally, the range of the each CFO can be reduced by downlink synchronization procedure. The residual CFO'S can be evaluated and remunerated in order to reduce inter - carrier interference [2] [17] [28] [29] [30]. There are several methods which have dealt by many researchers to estimate the CFOs [3] [4]. Further, minimum mean-squared error (MMSE) and least square method are used to reduce the difference between the reconstructed signal and the received signal without utilizing the grid search process. Though, these methods require less computational time, it can reach the Cramer–Rao lower bound (CRLB) only at high signal- to- noise ratio (SNR) [11] 12]. Although several methods were

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accomplished to estimate the frequency, CFO is a much more challenging problem in OFDM [16]. Literature survey indicates the estimation of CFO through several optimum techniques. However, it remains impractical for the large number of active users because it requires comprehensive multi-dimensional search and high computational load [18] [19] [20] [21] [22] [23] [24]. Therefore, it is essential to allocate the methodologies for CFO estimation with high accuracy and reducing such limitations.

Orthogonal Frequency Division Multiplexing (OFDM) is a multiuser communication system based on the concept of introducing orthogonality on Frequency Division Multiplexing (FDM). In this method bandwidth is subdivided into several subcarriers and each sub carrier has a different frequency. In this technique, all the carrier signals should be orthogonal to each other. So that cross talk between the sub channels is fully eliminated. In this method (ie) OFDM, the user data stream to be transmitted is divided it in to multiple data stream (i.e) parallel and each data stream is modulated on to a separate sub carrier frequency. Different modulation schemes are suggested such as BPSK, QPSK and QAM can be used for modulation.

In OFDM all the carriers are modulated by a digital scheme. Orthogonal Frequency Division Multiplexing (OFDM) is used to transform a frequency selective fading channel in to multiple selective fading channels. Using this transformation we can design a receiver using the simple signal processing techniques [6]. Without introducing the Inter Channel Interference (ISI), the orthogonality of the subcarriers allows the overlapping between the sub bands. Therefore the spectral efficiency is increased by this technique. OFDM systems are highly sensitive to frequency synchronization errors. Such errors are referred to as Carrier Frequency Offset (CFO). It is occurred when the Doppler Spread or the local oscillator's instability deliberates the orthogonality of the system, which leads the received signal are affected by the attenuation, phase shifts and Inter Carrier Interference (ICI). Thus leads the serious performance degradation of the system. Hence we cannot obtain quality signal in the receiver side. So frequency tracking algorithm is required to calculate at the receiver side to extract the sub carrier and estimate the frequency range.

The range of each CFO can be reduced by downlink synchronization procedure. The CFO'S can be evaluated and remunerated in order to reduce Inter Carrier Interference. There are several methods which have dealt by many researchers to estimate the CFOs. Minimum Mean Square Error (MMSE) and Least Square (LS) methods are used to reduce the difference between the reconstructed signal and the obtained signal without utilizing the grid search process. Though, these methods require less computational time, it can reach the Cramer-Rao Lower Bound (CRLB) only at higher range of Signal to Noise Ratio (SNR).Although several methods were accomplished to estimate the frequency, CFO is a much more challenging problem in OFDM. Literature survey indicates the estimation of CFO through several optimum techniques. CFO estimation further classified into two: (i) Non Blind CFO estimation (ii) Blind CFO estimation.

2. RELATED WORKS

In 2013, Hardip *et al* [5] have proposed novel canonical particle swarm optimisation (CPSO)-based method to estimate the carrier frequency offset in OFDM. Without revealing the performance and the premature convergence, the computational complexity of this method was reduced. The simulation results were compared with other conventional algorithm like alternating projection frequency estimation (APFE) and linear PSO, and came to the conclusion that it completely avoids the premature convergence.

In 2013, Abdel Aziz *et al* [9] have exploited the novel-data aided CFO estimator in OFDM which is based on the determination of eigen value. In this estimator, the eigen vectors corresponding to a two-dimensional diagonal matrix was transmitted in order to estimate the value of CFO. Further from the analysis, it has proved that the CFO estimation was equivalent to determine the eigen values of the two-dimensional ICI coefficient. Since the algorithm is simple, it has proved that it is maximum likelihood estimator. Moreover, it obtains the high accuracy even in the presence of noise and fading.

In 2014, Hsien-Kwei Ho, Jean-Fu Kiang [7] has bought about the efficient Alternating Projection (AP) methodology in order to estimate the CFOs in OFDM. This method has used the inherited properties of the matrix when compared with the conventional AP. Here, the multiplication of the large sparse projection was transformed to a series of products which contains the small opaque matrices. Afterwards, the inverse operation of the large matrices was substituted by the direct computation. Therefore, the cost of the computation is greatly reduced without affecting the accuracy.

In 2015, Weile Zhang et al [8] have adopted the new blind CFO estimator for ORPD which consists of multiple receive antennas. By analysing the several observations of the receive antennas, the cost function of the CFO was designed which was revealed as the cosine function even with the effect of noise. Then the analysis was carried out and obtains the result that it performs well in fully loaded condition and therefore, the spectral efficiency of the system is saved. In addition, the computational complexity is reduced when compared with the existing algorithms.

In 2015, WeiyangXu *et al.* [10] have dealt with the blind estimator of CFO and in-phase/ Quadrature (I/Q) imbalance in OFDM system. This estimator does not require the knowledge about the training symbols or the information of the channel side. It contains the null sub-carriers as in other conventional algorithms. Initially, the frequency offset was estimated and later based on the estimated value, the (I/Q) imbalance was performed. It has proved from the analysis that, the minimization of the cost function of the CFO estimator provides the exact estimate of the frequency offset and the CFO estimator allocates the accurate result if the (I/Q) imbalance is unbiased. Thus the spectral efficiency of the method leads to high range.

In 2016, Hong-Yu Liu and Yung-Chang Yin [6] have suggested the Maximum likelihood (ML) called simplified linearly-combined carrier frequency offset (SLC-CFO) where the set of arctangent functions of the LC-CFO was replaced by the low-complexity limiters. Hence, the receiver design has simplified and the computational load is minimized. Further, it obtains the quite wide tracking range, improved mean-square error (MSE) at low signal-to-noise ratio (SNR) which was almost close to Cramer-Rao lower bounds (CRLBs) and increased convergence speed. The demonstration of the properties were analysed by using static channel and Rayleigh fading.

3. PROBLEM STATEMENT

The contents of the literature with corresponding features and challenges are shown in table1. It declared the effects of CTO in OFDM and the process of CFO estimation. This is evaluated by several approaches such as Canonical PSO [5], ML estimation [6], Alternating projection [7], Eigen value based estimator [9], Sequential estimator [10], Closed form estimator [8] respectively. However, all the aforementioned solutions do not consider the identifiability problem in CFO estimation and extension to multiple antenna (rack receivers) scenarios, and need to be subjected to handle the challenges yet. Those challenges include complex search space [5], increased computational load [8], slow convergence [9], complex iterations etc. Hence the literature survey stated that OFDM needs the improvement in the estimation of CFO.

Table1. Features And Challenges In CFO Estimate Algorithms / Literature Survey

Adopted methodology	Features	Challenges
Canonical PSO	• Completely avoids premature convergence • Reduced computational complexity	• Settings of the parameters make the search-space complex.
ML Estimation	• High accuracy • Achieve channel estimation	• Not suitable for Convex optimization problem
Alternating Projection	• Computational load is reduced	• Feasibility of the convex problem is not guaranteed.
Closed form Estimator	• Good performance for noisy conditions • Increased spatial efficiency	• Increased computational complexity
Eigen value based estimator	• Simple procedure • It will provide High accuracy even with	• Very slow convergence • Cannot find large

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	presence of noise and fading	Eigen values
Sequential Estimator	• Spectral efficiency is high	• Can't implement complex iterations • Iterations must proceed according to the pre defined sequence.

4. METHODOLOGY

The CFO method of frequency estimation increases the accuracy and reducing such Carrier symbol Interferences. Since the conventional estimators excluding canonical PSO of exhibits step size based update, the estimation consumes more computing time. However, the canonical PSO has been found to be promising, yet it suffers from sticking with local optima and parameter dependent. Hence, this proposal intends to adopt advanced Meta-heuristic searching procedures in OFDM systems for efficient CFO estimate. In the course of advanced meta-heuristic searching algorithms, Grey Wolf Optimization has been recently proposed in the literature. The Grey Wolf Optimization technique give the hierarchy of leadership and the hunting behavior of grey wolves. Its searching efficiency under multi objective search spaces, this proposal adopts Grey Wolf Optimization for CFO estimate as the first phase of research. In the second phase, a novel and efficient self-adaptive mechanism will be introduced for Grey Wolf Optimization and so the precise CFO estimate can be achieved

3.1 Carrier Frequency Offset

Carrier Frequency Offset (CFO) is the widely using baseband receiver design technique. By designing a baseband receiver, we should consider not only the degradation by non ideal channel and noise, also we should consider Radio Frequency (RF) and analog parts also the main consideration. The common non - ideal problems include sampling Clock offset, IQ power amplifier, phase noise and carrier frequency offset.

Carrier frequency offset frequently occurs while the local oscillator signal for down conversion at the receiver side. Which does not synchronize with the carrier signal contained in the received signal. This phenomenon attributed to two important factors they are (i) Frequency mismatch at the source (ii) The destination oscillators.

While this occurs, the received signal will shifted in frequency. For any OFDM system, the orthogonal among sub carriers is maintained. The receiver uses a local oscillator signal that is synchronous with the carrier signal contained in the received signal. Otherwise, mismatch in the carrier frequency which leads an Inter Carrier Interference (ICI).The oscillators in the transmitter and the receiver can never be oscillating at identical frequency.

The range of estimated carrier frequency offset is given by $- U_{fs} /2 \leq \Delta_f \leq U_{fs} /2$ .Carrier Frequency estimator can also be applied to preambles consisting of several repeated segments with specific sign changes. With correct acquired symbol timing, the received 'U' segments of the preamble are multiplied by their corresponding signs.

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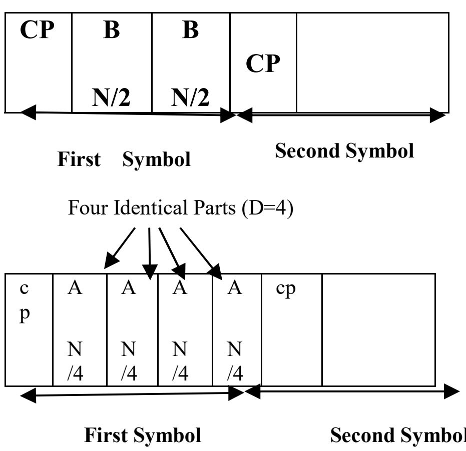

Figure1 : Sequence of OFDM
CFO Estimator

Consider a null sub carrier is also called as a virtual sub-carrier in convention, virtual sub carrier is the key element in the proposed algorithm and its property is certainty not contain any data. In order to estimated frequency offset is suppose to denoted by ϕ . the impact of the carrier frequency offset is cannot be mitigated directly because of the co existence of real and conjugate original signals in $Z_{m,k}$..

Here we propose to compensate for the received signal with both positive and negative ϕ, usually multiplication of both $Z_{m,k}$ and $e^{-2j\Pi\phi k/N}$ And $e^{2j\Pi\phi k/N}$. Therefore the resultant two signals in the time domain and it should be denoted as $e^{-ti\theta}$

CP Based: With perfect symbol synchronization, a CFO of ξ results in a phase rotation of $2\pi n\xi/N$ in the received signal. Under the assumption of negligible channel effect, the phase difference between CP and the relevant rear part of an Orthogonal Frequency Division Multiplication symbol (spaced N samples apart) are $2*3.14N\xi/N = 2*3.14\xi$. Therefore, the CFO can be found from the phase angle of the product of CP and the relevant rear part of an OFDM symbol, CFO estimation using CP based are given in the following :

$\xi = (1/2*3.14\pi)\arg\{y*l[n]yl[n+N]\}$ (9) --- (1)

$n = -1, -2, \ldots \ldots -N_g$. so that used to indicate reduce the noise effect, its average should be taken as over the samples in a CP interval.

$$\hat{\varepsilon} - ((1/2\pi)\arg\{\sum_{n=-N_g}^{-1}(y_l[n]y_l[n+N]\})\quad \text{--- (2)}$$

arg() performed $\tan^{-1}$ (), in order to consider the range of the CFO estimation are [-0.5+0.5] and mean square error performed by $\xi e - \xi$.

Two identical training symbols are transmitted not comparable and the relevant signals with CFO of ξ are corresponding with each other. For an Orthogonal Frequency Division Multiplexing transmission symbol at one receiver with an assumption of the absence of noise the 2N Point sequence is

$$rn = 1/N\sum_{k=0}^{N-1} H_k X_k e^{2*3.14j(k+\xi)/N} \quad \text{--- (3)}$$

$n = 0, 1, \ldots \ldots 2N-1$,

The k th element of the N Point DFT of the first N points is

$$R_{1k} = \sum_{n=0}^{-1} r_n + Ne^{-2*3.14jkn/N} \quad \text{---(4)}$$

$k = 0, 1, 2, \ldots \ldots N-1$,

The second half of the sequence is

$$R_{2k} = \sum_{n=0}^{-1} r\,n + Ne^{-2*3.14jkn/N} \quad \text{---- (5)}$$

and

$$rn + N = r_n e^{2\pi j\xi},\ R_{2k} = R_{1k} e^{2\pi j\xi},$$

consider AWGN noise

$$Y1k = R1k + W1k \quad \text{--- (6)}$$

$$Y2k = R1ke\ 2\pi j\xi + W2k\ ;\ k = 0, 1, 2, .\ N-1. \quad \text{-- (7)}$$

DFT symbols are obtained from the first and second symbols , both Inter Channel Interference and signal are changed occordingly in exactly the same way, by a phase shift proportional to frequency offset. Therefore, the corresponding frequency offset ξ is estimated using above observations,

3. 2 Meta-Heuristic Algorithm

In Computer science & math optimization, meta-heuristic is a higher level procedure or heuristic designed to find,

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generate, or select a heuristic that may provide a sufficiently good solution to an optimization problem, especially with incomplete or imperfect information or limited computation capacity. Meta-heuristics sample a set of solutions which is too large to be completely sampled. Meta-heuristics may make few assumptions about the optimization problem being solved, and so they may be usable for a variety of problems.

4. IMPLEMENTATION

We have proposed a novel based Canonical Particle Warm Optimization (CPSO) technique to estimate the Carrier Frequency Offset in an OFDM system. Without revealing the performance and the premature convergence, the computational complexity of this method was reduced. The simulation results were compared with other conventional algorithm like Alternating Projection Frequency Estimation (APFE) and linear PSO, and came to the conclusion that it completely avoids the premature convergence.

Carrier Frequency Offset (CFO) Estimation

```
Clc;
Close all;
Clear all;
Cp = 64;
Load file_cfotxpkt;
Load file_cfopreamble;
Tx_Packet = awgn(Tx_Packet,40,’measured’);
offset
CFO = 40e3; %Hz Herrre 40 KHz frequency
offset; CFO = (CFO)/20e6;
Rx_data)_fo = impairments(Tx_Packet,CFO);
symbol preamble in time domain
Sh_dat = rx_data_fo((CP+1):256+CP);
For m = 0:128
Theta(m+1)= angle(sh_dat(65+m:128+m)*
sh_dat(1+m:64+m)’)/2*pi); End
Theta = mean(theta);
F_off1 = (theta*4)*20e6/256
symbol preamble in time domain
Lo_dat = rx_data_fo((2*CP+256+1):
256+2*CP+256);Theta = angle(lo_dat
(129:256)* lo_dat(1:128)’)/(2*pi);
F_off2 = (theta*2)*20e6/256
F_off = (f_off+f_off2)/2
Correction
rx_data_corrected = rx_data_fo.*exp(-i*2*pi*
(f_off/20e6)*(o:length(rx_data_ fo)-1));
```

In non - blind scheme we should know the estimation of CFO in the receiver side parameter such as system model, channel model subcarrier channel known in the receiver side (Alternating projection, Closed form estimator, Sequential estimator and Eigen value based estimator). In blind scheme we should not know the estimation of CFO in the receiver side parameter such as system model, channel model subcarrier channel known in the receiver side (Canonical PSO, ML Estimation).

5. RESULT AND DISCUSSION

In this section we show the comparison between the previous CFO estimation techniques. Estimated simulation parameters are shown in Table 2. The symbol based estimator output by approximately 27dB.

Table2: Simulation Results

No.	Parameter	Simulation Value
1	Modulation Scheme	QPSK
2	Channel	AWGN
3	Carrier Frequency offset (CFO)	0.2
4	Number of Iterations	1000
5	Symbol Duration Length	3
6	Number of Bits per Symbol	2
7	SNR Level	0-30 dB

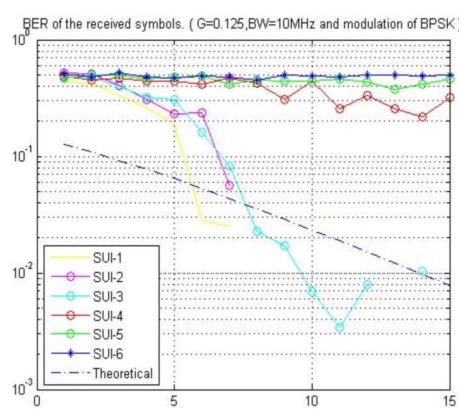
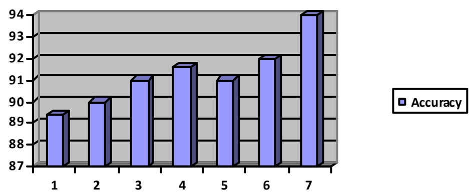


Figure :2 Performance Of System With Bandwidth = 10 MHZ And Cyclic Prefix = 0.125



1. Sequential Estimator 2. Eigen value based Estimator 3. Closed form Estimator 4. Alternating Projection 5. ML Estimation 6. Canonical PSO 7. Carrier Frequency Offset Estimation

Figure:3 Accuracy Comparison Chart For The Various Schemes Of Estimation

6. CONCLUSION and FUTURE SCOPE

The proposed CFO estimate procedure will be implemented in OFDM is simulated in MATLAB and the performance investigation will be carried out in terms of mean squared error between the estimate and the known CFO's. The comparative analysis will be made with the state of the art Meta-heuristic based CFO estimate procedures and the superiority of our estimate process will be demonstrated.

The proposed CFO estimate algorithm will be implemented in OFDM is simulated in MATLAB is gives 94% of accuracy will be carried out in terms of mean squared error between the estimate and the known CFO's. But in future it can be develop to obtain accuracy up to 98%.

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