Review on Channel Estimation Using Convex Optimization

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Abstract-Substitution to the problem employed OFDMA system for its uplink transmission. OFDMA based communication systems provide low Peak-to-Average-Power Ratio, which in turn utilises power amplifiers more efficiently and saves battery power of User equipment (UE)In OFDMA systems, channel estimation and channel equalization play a key role in overcoming distortions caused by phenomena like fading, delay spread and multipath effect. In this thesis, channel estimation and equalization techniques are analyzed to improve the performance of OFDMA system.OFDM is a powerful and efficient modulation technique employed in wireless communication systems. OFDM uses orthogonal subcarriers to convey information to the receiver. OFDMA or Orthogonal Frequency Division Multiple Access is an OFDM based scheme which enables multiple users to access the channel simultaneously. OFDMA is preferred as it provides high data rate and can eliminate the problem of Inter Symbol Interference (ISI).

Keywords- International Mobile Telecommunication, Orthogonal Frequency Division Multiple Access, Long term evolution, Peak-to-Average-Power Ratio.

I. INTRODUCTION

The wireless applications have now grown much rapidly. There is a demand of high quality as well as high speed of data in wireless communication applications [1]. To cater it, International Mobile Telecommunication (IMT) and 3rd Generation partnership project (3GPP) proposed LTE system. The features of LTE system are as under:

- To provide End-to-End quality service.
- To provide high download rates of about 300Mbps and upload rates of 75Mbps.
- To expand the capacity of cell so as to accommodate 200 active users.
- To support user mobility of around 350Km/hr.
- Orthogonal Frequency Division Multiple Access (OFDMA) used for downlink and Single Carrier-Frequency Division Multiple Access (SC-FDMA) for Uplink.
- Support for FDD and TDD Communication Systems.
- Increased Spectrum Flexibility (1.4 MHz, 3MHz, 5MHz, 10 MHz, 15MHz, 20MHz)

So as to provide these features, 3GPP Long Term Evolution system has adopted OFDMA for its down link transmission and SC-FDMA for its Uplink transmission as multiple access techniques. OFDM is a powerful and efficient modulation technique employed in wireless communication systems. OFDM uses orthogonal subcarriers to convey information to the receiver. OFDMA or Orthogonal Frequency Division Multiple Access is an OFDM based scheme which enables multiple users to access the channel simultaneously. OFDMA is preferred as it provides high data rate and can eliminate the problem of Inter Symbol Interference (ISI). It utilises spectrum efficientlyand also provides robustness towards various multipath fading phenomenon. An important issue of an OFDMA based system is its transmitted signal Peak-to-Average- Power Ratio (PAPR). In OFDMA superposition of many time-domain data subcarriers results in high values of PAPR. As large numbers of subcarriers are employed during transmission, this results in a time-domain signal exhibiting a Rayleigh characteristics and large amplitude variations in time domain. These large peaks of signal require power amplifiers of high power. The increase in the level of the signal causes various nonlinear distortions which leads to inefficient operation of power amplifiers. So, OFDMA has a disadvantage of high PAPR which causes increase in the size of user terminal and thus causes increase in overall cost of the system. In Long term evolution (LTE) system OFDMA is adopted only for downlink transmission because base stations called eNodeB can transmit on high power. As a substitution to the problem of PAPR, 3GPP LTE had employed OFDMA system for its uplink transmission. OFDMA based communication systems provide low Peak-to-Average-Power Ratio, which in turn utilises power amplifiers more efficiently and saves battery power of User equipment (UE).

A. OFDMA systems: Orthogonal Frequency Division Multiple Access is a multiple access scheme employed in various communication system for transmission of data. OFDMA has been selected by various standards like IEEE as its physical layer interface for next generation wireless communication systems. OFDMA is a multichannel system in which many orthogonal sub-carrier signals which are closely spaced and having overlapped spectrum are employed for transmission of information [2, 3]. These orthogonal sub–carriers do not interfere with each other and provide robustness to channel fading and Inter Symbol Interference (ISI).Orthogonal Frequency Division multiplexing is a special case of FDM where each subcarrier is made orthogonal to all other subcarriers as shown in Fig 1.1. This technique allows overlapping of the different subcarriers as compared to conventional guard band between carriers and hence leads to good spectrum utilizations. Subcarrier signals are used to carry the input data. These subcarrier signals are generated using the Nyquist criterion for the multi-carriers.The data to be transmitted is first of all divided into different parallel data streams respectively for each of the sub-carrier. Each of the sub-carrier is modulated by using modulation schemes like QPSK, QAM, BPSK etc. at low symbol rate. Each of these modulation techniques have their own set of advantages which are offered to the communication system [3]. An OFDM system also employ other operations like IFFT, FFT, addition and removal of cyclic prefix , serial-to-parallel as well as parallel-to-serial conversion, digital to analog and analog to digital conversion process. Fig.1 gives block diagram representation of an OFDM system:

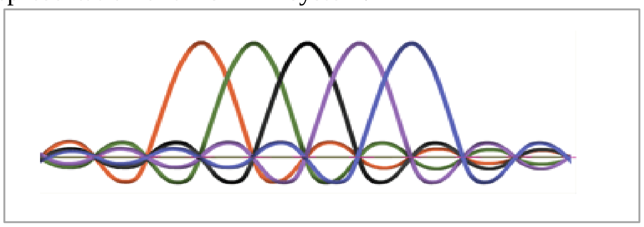

Fig.1: OFDM Spectrum

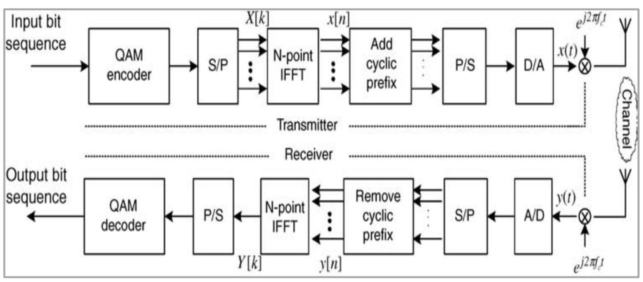

Fig.2: Block diagram representation of transmitter & receiver in OFDM system

At OFDM transmitter, message bits are mapped into sequence of modulated symbols using QAM or PSK modulation technique. This serial data is then converted into parallel data stream using serial-to-parallel converter. This parallel data stream is then divided among N differentparallel paths after employing N-point Inverse Fast Fourier Transform (IFFT). Each of the orthogonal sub-carrier signals is modulated by any one of the *N* data sets. These Nprocessed points form one OFDM symbol. Due to this conversion process, the transmission time interval (TTI) for N different symbols becomes NT_s, where T_s is the interval of single symbol. After this a copy of last L of the samples of one symbol are copied onto the front as a cyclic prefix. This data is then converted into serial data stream using parallel to serial conversion process [4]. At the end after this process a digital-to- analog conversion is employed. At receiver to recover back the original information a reverse process is carried out. Firstly, the received analog signal is converted into digital signals. This digital signal is then converted into parallel form using serial to parallel conversion process. The CP added to the signal at transmission end is then removed. A N-Point FFT will be conducted on the left over samples to recover back the frequency domain data. This data in frequency domain is converted into serial format and converted back into original data by employing a decoder.

B. Advantages of OFDM system: Some of the advantages of the system are listed below:

- High data rates
- High spectral efficiency
- Provides robustness to different multipath fading effects
- Low complexity
- Robustness to inter-symbol interference
- No use of very expensive equalisers
- Spatial diversity
- Multiplexing gains
- High rates of data transmission over multipath fading channels
- Increased link capacity

C. Drawbacks of OFDM system: OFDM Gaussian distributed signals have large Peak-to-Average Power Ratio causing:

- Poor power efficiency
- Spectral re-growth
- Sensitive to nonlinear effects of power amplifiers
- OFDM signal being clipped by high power amplifiers
- Degradation in system performance due to In-band distortion
- Adjacent channel interference due to out-band radiation

D. PAPR

In OFDM large variations in the envelope of transmitted signal is due to the transmission of data over several parallel subcarriers which could add in phase and generate a signal with high instantaneous peak power compared to the average power of signal [5].The Peak to Average Power ratio of a signal is defined as the ratio of maximum power of pass band signal to the average power of signal.

$$PAPR=P_{peak} / P_{average} \quad \ldots (1.1)$$

PAPR of a signal vector $\mathbf{x}_n=x_0, x_1,....x_{N-1}$ is given as follows:

$$PAPR(x) = \frac{\max\left\{\left|x_n\right|^2\right\}}{E\left\{\left|x_n\right|^2\right\}}, 0 \le n < N-1 \quad \ldots\ldots (1.2)$$

Where, E{.} is expectation operator.The high value of PAPR in OFDM based communication system requires highly linear power amplifiers to avoid excessive inter modulation distortion. The power amplifier is required to operate with large back off from its peak value. So the power amplifier has low power efficiency. These high peak signals can also get clipped by high power amplifiers. This degrades system performance due to In-band distortion and causes adjacent channel interference due to out-band radiation. Large value of PAPR requires that user terminal (UE) should be able to handle large power which increases size of UE.Because of various disadvantages associated with high PAPR of OFDM signals, it is to be reduced [6]. The performance of any PAPR-reduction technique in effectively reducing PAPR is evaluated in terms of its complementary cumulative distribution function (CCDF). CCDF is defined as the probability that PAPR exceeds a certain threshold value $PAPR_0>0$, i.e.

$CCDFx_n\ PAPR_0=Prob\ PAPRx_n>PAPR_0$………………(1.3)

CCDF of OFDM signal is calculated as:

CCDF(Y) = Pr(PAPR >Y) = 1− Pr(PAPR <Y)……. (1.4)

E. PAPR Reduction Techniques: Different PAPR reduction techniques can be classified into following approaches:

1) Clipping techniques: The clipping technique is one which employs clipping of the peaks of the signal so as to reduce its PAPR. This technique is really simple to implement but it has disadvantage of in-band and out-of-band interferences which can destroy the orthogonality among sub-carriers. This PAPR reduction technique also requires additional methods for signal processing so as to reconstruct the received signals [6].

2) Coding techniques: Coding techniques select few code words that can minimize the PAPR of a signal. Coding techniques suffers from the disadvantage of poor bandwidth efficiency as we reduce code rate. This technique comprises of the complexity of finding the best code words and it also has to store a large number of lookup tables required for encoding and decoding of data.

3) Probabilistic or scrambling techniques: The probabilistic technique scrambles a block of input OFDM symbols and then transmits only one of them having minimum value of PAPR. This reduces the probability of achieving high PAPR. This method does not have problem of out-of-band power [7]. But it has reduced spectrum efficiency also the complexity of system increases with an increase in the number of subcarriers employed.But this technique does not offer PAPR below a certain specified level.

4) Adaptive pre-distortion technique: This technique compensate for various nonlinear effects of high power amplifiers (HPA) employed in an OFDM system. It can really work with the time variations of nonlinear amplifiers by modifying the constellation of input by using Memory lookup encoder and requires least hardware.

5) DFT-spreading technique: The DFT-spreading technique employs Discrete Fourier Transform technique to spread the input signal spectrum. This technique can cause reduction in the PAPR level of OFDM system to a level of communication system employing single-carrier only. This technique is employed for transmission. It is also called Single Carrier-FDMA (SC-FDMA).

F. SC-FDMA

Single carrier frequency division multiple accesses is a multiple access technique employed for transmitting signal in uplink and is employed in 3rd generation partnership project (3GPP) Long Term Evolution system. SC-FDMA is basically linearly pre-coded OFDMA.SC-FDMA signal is basically an OFDM signal in which data symbols in time-domain are transformed into frequency-domain by using discrete Fourier transform process [8].

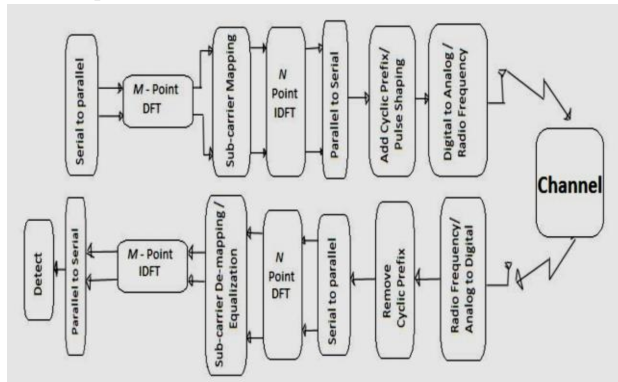

Fig.3: Block Diagram representation of SC-FDMA transmitter and receiver

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At the OFDMA transmitter, a baseband modulator maps the input bits stream into a sequence of complex numbers by using various modulation techniques like BPSK, QPSK, 16QAM, 64QAM etc. After this, the transmitter will group the modulation symbols into blocks which contain Ndifferent symbols. The transmitter then performs *N*-point DFT operation to convert signal into its frequency domain representation. The transmitter than maps each of its outputN-DFT to any one of the *M* (>*N*) different orthogonal sub-carrier signal. An M-point IDFT operation then transforms these subcarrier amplitudes into a time domain signal.

Three different sub carrier mapping techniques are employed:

1) Distributed subcarrier mapping: In this mode, N different DFT output signal are distributed over the entire bandwidth of the system. This is known as distributed FDMA or DFDMA.

2) Localized subcarrier mapping: In this mode, outputs of DFT block are assigned to N consecutive subcarriers with total M numbers of subcarriers (M>N) available. This is called Localized FDMA or LFDMA.

3) Interleaved subcarrier mapping: In this mode, the DFT outputs are distributed employing an equal distance between the occupiedsubcarriers. This is called Interleaved FDMA or IFDMA. In IFDMA output is allocated over the entire system bandwidth. OFDMA transmitter also performs the operation of adding cyclic prefix. It inserts a set of symbols so as to provide a guard time. C P is a copy of the last part of the symbol block and is added to the start of each block. This addition of CP prevents inter-block interference (IBI) which is caused by multipath propagation. The SC-FDMA transmitter also performs operation of linear filtering called pulse shaping so as to reduce out-of-band signal energy.The OFDMA receiver transforms its received signal back into its representation in frequency domain by using DFT technique. It then de-maps the subcarriers signals and perform its frequency domain equalization.

H. Advantages of SC-FDMA system

- It provides robustness against multipath signal propagation.
- Low PAPR as compared to OFDMA due to use of single carrier structure.
- High rate of data transmission.
- Uses power amplifier more efficiently, so LTE terminals are able to increase coverage and reduce their power consumption, which is extremely important in battery powered devices.
- As each user is assigned different set of orthogonal subcarriers so there is no Multiple Access Interference.
- Power efficient system.
- Increased coverage area of the System.
- Allows use of small size terminal.

Because of these advantages of OFDMA system over OFDMA system, OFDMA system is employed for uplink communication in 3GPP Long term evolution (LTE) system.

I. Channel Estimation

In order to achieve good performance a communication receiver needs to know the impact of channel on received signal. This is called channel estimation. An important factor for any wireless communication system is estimation of its channel and channel parameters. The motive of a channel estimation process is to minimize Mean Squared Error (MSE) between desired signal and received signal. Different channel estimation algorithm had been designed so as to achieve high performance. Using channel estimation algorithm impulse response of a channel and its behavior can be approximated. By employing channel estimation techniques, coherent demodulation technique can be implemented at the receiver. In communication system for channel estimation a known signal sequence called pilot signals are inserted at specific location within the information signal. These symbol sequences allow receiver to extract channel attenuations and phase rotation estimates for each received symbol. By identifying channel parameters error in the received signal can be reduced. The aim of most channel estimation algorithms is to minimize the mean squared error (MSE), while utilizing little computational resources in the estimation process. Fig.4 gives block diagram of system using channel estimation.

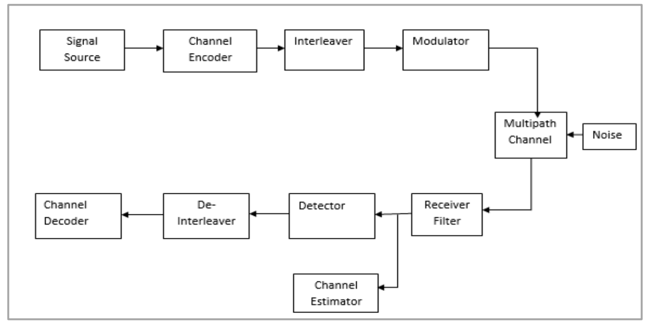

Fig.4: Block Diagram of a system using Channel Estimation

Different Channel estimation techniques are:

1) Pilot based channel estimation technique: Pilot or Training based estimation method exploit presence of known training symbol. These channel estimation techniques either uses deterministic or random parameters. Using deterministic parameters there are following channel estimation techniques:

- Maximum Likelihood (ML) estimator
- Least Square (LS) estimator
- Normal Least Square (NLS) estimator
- DFT based LS estimator

2) Estimation techniques based on random variables are:

- Minimum Mean Square Error (MMSE)
- Linear Minimum Mean Square Error (LMMSE)
- Max a Posterori (MAP)

J. Adaptive channel Estimation: Adaptive channel estimation is a process of self-modifying coefficients of digital filtration process to minimize the error function of filter. The error function is defined as a distance between its desiredsignal and the output of an adaptive filter [9]. The adaptive filters are employed for noise and echo cancelling, channel equalization, signal prediction, etc. The basic block representation of an adaptive filtration process is given in Fig.5 below:

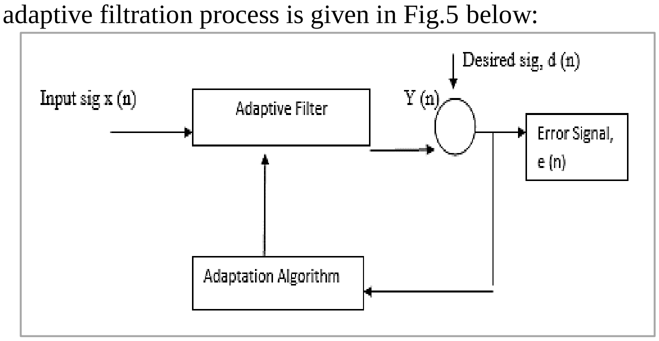

Fig.5: Basic representation of Adaptive Filters

Where the error function is represented as:

$$e(n)=d(n)-y(n) \quad \ldots\ldots\ldots.. \quad (1.5)$$

Where, x(n) is the input signal,

d(n) is desired output signal, and *y*(n) is an output of adaptive filter.

This error signal e(n) is used by an adaptation algorithm so as to update its coefficient vector **w**(n) according to some defined performance criterion. The adaptive channel estimation is different from traditional methods as the coefficients of an adaptive filter can change over time. So they have self-learning ability. Adaptive

filters can accomplish certain processing tasks that traditional digital filters cannot perform. Adaptive filters can complete certain real-time or online modeling tasks which traditional digital filters cannot. The channel estimation can be done by using wiener filter. Wiener filters are basically linear filters which can perform estimation of a desired signal sequence linearly from other related sequences. A Wiener filter is a Mean Square Error optimal linear filter employed for signals which are degraded by additive noise [10]. An advantage of using wiener filter for filtering operations is that it has prior knowledge of channel parameters. The wiener filter design is given below:

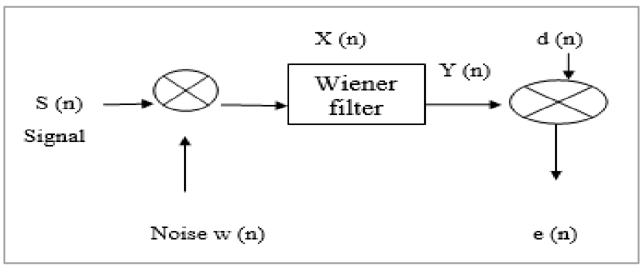

Fig.6: Channel Estimation using Wiener Filter

In this diagram, an error signal generated by filter is used by an adaptation algorithm to update its coefficient vector h(n) according to some defined performance criterion. This complete adaptation process minimizes error signal and also it forces the adaptive filter output signal to approximate the reference signal. In communications systems, the transmitted signal is heavily distorted by the characteristics of transmission channel [11]. The original signal can then be recovered l by employing an adaptive filter. A training sequence *s*(n) which is known to the receiver is sent via a given transmission channel which generates a distorted signal. Sequence *s*(n), after time shift in accordance with transmission delays is used as a reference signal in the receiver for the adaptive filtering process. When the error function e(n) becomes zero, the output signal *y*(n) will then represent the transmitted signal *s*(*n*). This indicates that the adaptive filter is compensating for any channel distortions. After this training process, all desired information can be sent through the channel. This adaptation of the filter coefficients generally follows a minimization procedure for an objective.

Output y(n) of the filter is given as:

$$y(n)=\sum_{k=0}^{p-1} \square(k) * x(n-k) \ldots\ldots\ldots\ldots\ldots\ldots \quad (1.6)$$

The Mean Square Error is represented as:

$$MSE=E[|d(n)-y(n)|^2]\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (1.7)$$

The value of vector, w which minimizes the MSE is defined by finding derivative of above equation w.r.t each w_i and is given by wiener-hopf equations which form basis of wiener filter:

$$R_xH^0=P_{dx}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \quad (1.8)$$

Using this channel estimation is made as

$$H^0=R_x^{-1}P_{dx} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots... \quad (1.9)$$

Where,

R_x is the autocorrelation matrix of an input sequence x(n) and is

$$R_x=E[x(k)x^T(k)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1.10)$$

P_{dx} is a Cross-Correlation matrix between input sequence x(n) and desired response y(n) and is given by

$$P_{dx}=E[y(k)x^T(k)]\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (1.11)$$

H^0 is called Wiener solution for minimizing MSE.

II. RELATED WORK

D. J. Krusienski et al. in [1] gave an application of ADAPTIVE techniques for generalizing nonlinear adaptive and recursive filter structure designs. ADAPTIVE is an optimization algorithm that can perform a randomized and structural search for some unknown parameter space. It manipulates apopulation of estimate of a parameter to converge onto a particular desired solution. These types of search techniques are not dependent on the type of an adaptive filter structure being employed. These techniques are capable of fast converging on to a global solution for any optimization problem. The authors had analysed that ADAPTIVE's had more controlled randomness than the use of Genetic Algorithms (GA). In ADAPTIVE, particles can take the directed steps within a well-defined region while in case of GA's particle updates are much less directed and are also more redundant. This affects the rate of Convergence of Genetic Algorithm. The authors had concluded that ADAPTIVE algorithm can also eliminate search redundancy by retaining the previous best and velocity values. Also in ADAPTIVE search is more readily controlled by using acceleration coefficients. So, the rate of convergence of ADAPTIVE can be tuned much faster than that of GA even with space of increased dimensionality. This makes ADAPTIVE better suited for many on-line adaptive filtering applications.Hyung G. Myung in [2] gave an overview of SC-FDMA based system. The authors explained the complete SC-FDMA process. It gave a detail insight of the different techniques used by OFDMA transmitter and receiver. The author gave PAPR characteristics of OFDMA based system and also channel dependent resource scheduling scheme of SC-FDMA system.Meili Zhou et al. in [3] proposed a channel estimation technique based on spline interpolation. Further to improve performance of estimation process extendible inverse Discrete Cosine Transform (EIDCT) and DCT/EIDCT approach was suggested. In this process, Discrete Cosine Transform of the signal is performed and then least square (LS) and linear minimal mean square error (MMSE) is derived in DCT domain. Authors observed that performance of spline interpolation based estimation process decreases with increase in number of users. DCT/EIDCT based estimation process performs better than spline interpolator in terms of MMSE providing a gain of 7 to 10dB for two users and a gain of 5 to 8 dB for 8 users.Md. Masud Rana et al. in [4] described different sub-carrier mapping schemes like IFDMA (Interleaved FDMA) and LFDMA (Localised FDMA) for LTE-OFDMA systems. Through simulations the author had proved that IFDMA sub-carrier mapping scheme provides lower PAPR as compared to LFDMA by a level of 1dB. Further the authors had shown that IFDMA sub-carrier mapping scheme improves system performance significantly as compared to LFDMA mapping scheme. Shih-Chan Huang et al. in [5] proposed a channel estimation technique for OFDMA system operating over time-varying multipath channels. The proposed method utilized block-type pilot arrangement and needed no prior knowledge about channel statistics. Authors used sliding windowing technique so as to mitigate the effect of interferences effectively. The proposed method works effectively at low SNRs to achieve perfect channel estimation but performance degrades at high SNR with long window length.Md. Masud Rana et al. in [6] proposed an adaptive algorithm for estimation of channel impulse response from block of received data in OFDMA system. Authors had developed variable step size – Least mean square algorithm for channel estimation which can adapt the weighting coefficients to optimum \value in accordance with channel conditions. The algorithm is updated on each iteration so as to minimize the error. The algorithm converges towards the true channel coefficient. Further author compared the proposed algorithm with exiting algorithm and had proved that the proposed algorithm outperform the existing algorithm by about 3dB. Md. Masud Rana et al. in [7] had presented a new channel estimator for an OFDMA system to avoid the least square (LS) problem. This proposed channel estimation method used knowledge of channel properties so as to estimate the transfer function of an unknown channel at non-pilot sub-carriers. This proposed method also reduces the computational complexity of the system.Sosth`ene Yameogo et al. in [8] presented a new channel estimation technique based on adding signal method. The channel subcarriers are estimated without using any interpolation techniques. The hidden signal is added in the useful signal band. The statistical properties of hidden signal permitted retrieval of channel information under the assumption that channel characteristics remain static over a long interval of communication duration so as to ensure fast convergence of the algorithm. This resulted into a better value for Symbol Error Rate and gain.Hen-Geul Yeh et al. in [9] had proposed a modified scheme called as Hadamard OFDMA which takes the advantage of Hadamard based spreading orthogonal CDMA code to lower PAPR in uplink transmission. The authors had compared the performance of pulse shaped Hadamard OFDMA systems and pulse shaped OFDMA systems. The authors had shown that Hadamard based OFDMA systems have lower PAPR as compared to the pulse shaped OFDMA systems and OFDMA systems. Also the authors had concluded that in Hadamard OFDMA with IFDMA subcarrier mapping the PAPR improvement reduces as the roll-off factor α increases, which is same as in the case of OFDMA. SER performance for the proposed scheme is tested in multipath channels. The results had showed that the Hadamard OFDMA scheme not only achieved reduction in PAPR but has SER advantages atlower system complexity**.**Mohan Kumar et al. in [10] had presented a design of a digital FIR filter with linear phase which employs ADAPTIVE with constriction factor and inertia weight. The author had designed ADAPTIVE algorithm so as to find optimal solution for the Mean Square Error between actual filter and ideal filter. The authors had proved that ADAPTIVE algorithm by employing constriction factor and inertia weight find optimal solution for the Mean Square Error between actual filter and ideal filter and thus require less number of iterations to optimize its fitness function.Adnan Kiayani et al in [11] discussed the problem of radio impairment in uplink multiuser SC-FDMA systems. Authors designed signal models of received signal when uplink transmissions are impaired by TX and RX I/Q imbalances, CFOs and channel distortions. These impairments cause Inter channel interferences. Authors then proposed a compensation structure for joint mitigation of radio impairment effects. The compensation structure operated on pairs of mirror subcarriers and employed ZF (Zero forcing) and MMSE (Minimum Mean Square Error) equalizer. The joint mirror-carrier MMSE equalizer outperformed ZF. Further the authors modeled joint channel and RF impairment responses using basis function and designed three models namely, polynomial Basis, PW Polynomial Basis and Spine Basis model. The authors concluded that Spline-based estimation technique using joint mirror-carrier MMSE equalization provided good accuracy and better receiver performance while having reduced complexity.

Table.1 Inferences Drawn

Author's Name	Year	Algorithm Used/ Technology Used	Outcomes

D. J. Krusienski et al.	2003	Genetic Algorithms (GA)	Gave an application of ADAPTIVE techniques for generalizing nonlinear adaptive and recursive filter structure designs. The authors had analysed that ADAPTIVE's had more controlled randomness than the use of Genetic Algorithms (GA).
Hyung G. Myung	2007	PAPR characteristics of OFDMA based system and also channel dependent resource scheduling scheme of SC-FDMA system.	Gave an overview of SC-FDMA based system. The authors explained the complete SC-FDMA process. It gave a detail insight of the different techniques used by OFDMA transmitter and receiver. The author gave PAPR characteristics of OFDMA based system and also channel dependent resource scheduling scheme of SC-FDMA system.
Masud Rana et al.	2010	IFDMA (Interleaved FDMA) and LFDMA (Localised FDMA)	Described different sub-carrier mapping schemes like IFDMA (Interleaved FDMA) and LFDMA (Localised FDMA) for LTE-OFDMA systems. Through simulations the author had proved that IFDMA sub-carrier mapping scheme provides lower PAPR as compared to LFDMA by a level of 1dB. Further the authors had shown that IFDMA sub-carrier mapping scheme improves system performance significantly as compared to LFDMA mapping scheme.
Mohan Kumar et al.	2015	ADAPTIVE algorithm	Has presented a design of a digital FIR filter with linear phase which employs ADAPTIVE with constriction factor and inertia weight. The authors had proved that ADAPTIVE algorithm by employing constriction factor and inertia weight find optimal solution for the Mean Square Error between actual filter and ideal filter and thus require less number of iterations to optimize its fitness function.
Adnan Kiayani et al.	2016	Multiuser SC-FDMA systems.	Discussed the problem of radio impairment in uplink multiuser SC-FDMA systems. Authors designed signal models of received signal when uplink transmissions are impaired by TX and RX I/Q imbalances, CFOs and channel distortions. The authors concluded that Spline-based estimation technique using joint mirror-carrier MMSE equalization provided good accuracy and better receiver performance while having reduced complexity.

III. ALGORITHM

1. Firefly optimization algorithm (FOA): *It*is a recently invented optimization algorithm. It is inherited from the natural inspiration of firefly process. It mimics the process of flowering planets reproduction via firefly. As pollinators are mainly responsible for transferring pollens among flowers, firefly may occur in either local or global flow [4]. Firefly process can fall into two form categorizes; biotic and abiotic based on the pollens transferring mechanism. For biotic fireflys, flowers always depend on insects and/or animals as pollinators to transfer the flowering pollens. However for abiotic, flowers do not need any pollinators for the pollens transferring process [11, 12]. Naturally most of flowers considered to follow the biotic firefly form. This indicates that firefly or crossfirefly process can take place by pollinators' movements or travelling long distances causing a global firefly. Travelling pollinators are usually follows the L'evy's flight behavior. Their flying steps are also follows the L'evy's flight distribution [13]. For each kind of pollinators, there is a specific type of flowers that it is responsible for, this called flower consistency. Flower consistency helps to minimize the cost of investigation of each pollinator. Evolutionary wise, it increase the transferring time of pollens and hence optimize and maximize the reproduction process. With the limited available memory of pollinators, flower consistency eliminates the learning, investigation and switching. Furthermore, it can be considered as an incremental step based on the similarity/difference of any two flowers. The biological objective of flower firefly is to optimally reproduce a new enormous generations of the flower kind with the fittest features that ensure the kind`s survival. In order to ideally formalize the flower firefly algorithm, characteristics of firefly process, flower constancy and pollinator behavior should be approximated based on the following essential rules:

- Global firefly achieved by L'evy's flights` travelling pollinators for both biotic and cross-firefly.
- Local firefly achieved abiotic and self-firefly.
- The new generation reproduction probability depends on the flower consistency and proportional to flowers` similarities/differences.
- The switch probability p ∈ [0, 1] controls the shift between local and global firefly.

The simple flower firefly model assume that each plant has only one flower, and each flower only produce one pollen gamete. Thus, there is no need to distinguish a pollen gamete, a flower, a plant or solution to a problem.

2. Grey Wolf Optimization: It is a meta-heuristic algorithm which simulates the leadership hierarchy and hunting behavior of wolves. The fitness of the wolves measured in the form of alpha,

beta and delta. The Fig.6 given below shows the hierarchy level of the wolves. Grey wolves have the ability of memorizing the prey position and encircling them. The alpha as a leader performs in the hunt. For simulating the grey wolves hunting behavior in the mathematical model, assuming the alpha (α) is the best solution. The second optimal solution is beta (β) and the third optimal solution is delta (δ). Omega (ω) is assumed to be the candidate solutions. Alpha, beta and delta guides the hunting while position should be updated by the omega wolves by these three best solutions considerations.

Encircling prey*:* Prey encircled by the grey wolves during their hunt. Encircling behavior in the mathematical model, below equations is utilized.

$$\vec{A}(T+1) = \overrightarrow{A_P}(T) - \vec{X}.\vec{Z}$$
$$\vec{Z} = \left|\vec{Y}.\overrightarrow{A_P}(T) - \vec{A}(T)\right|$$

Where

T←iterative number

$\vec{A}$←grey wolf position

$\overrightarrow{A_P}$←prey position

$$\vec{X} = 2x.\overrightarrow{r_1} - x$$
$$\vec{Y} = 2\overrightarrow{r_2}$$

Where

$\overrightarrow{r_1}$and $\overrightarrow{r_2}$←random vector range [0,1]

The x value decrease from 2 to 0 over the iteration course.

$\vec{Y}$← random value with range [0, 1] and is used for providing random weights for defining prey attractiveness.

Hunting: For grey wolves hunting behavior simulation, assuming $\alpha, \beta,$ and δ have better knowledge about possible prey location. The three best solutions firstly and ω (other search agents) are forced for their position update in accordance to their best search agents position. Updating the wolves' positions as follows:

$$\vec{A}(T+1) = \frac{\overrightarrow{A_1}+\overrightarrow{A_2}+\overrightarrow{A_3}}{3}$$

(1)

Where $\overrightarrow{A_1}, \overrightarrow{A_2}, and\ \overrightarrow{A_3}$ are determined,

$$\overrightarrow{A_1} = \left|\overrightarrow{A_\alpha} - \overrightarrow{X_1}.Z_\alpha\right|$$
$$\overrightarrow{A_2} = \left|\overrightarrow{A_\beta} - \overrightarrow{X_2}.Z_\beta\right|$$
$$\overrightarrow{A_3} = \left|\overrightarrow{A_\delta} - \overrightarrow{X_3}.Z_\delta\right|$$

Where $\overrightarrow{A_\alpha}, \overrightarrow{A_\beta}, and\ \overrightarrow{A_\delta}$← first three best solution at a given iterative T

Z_α, Z_β, and Z_ω are determined,

$$\overrightarrow{Z_\alpha} \leftarrow \left|\overrightarrow{Y_1}.\overrightarrow{A_\alpha} - \vec{A}\right|$$
$$\overrightarrow{Z_\beta} \leftarrow \left|\overrightarrow{Y_2}.\overrightarrow{A_\beta} - \vec{A}\right|$$
$$\overrightarrow{Z_\delta} \leftarrow \left|\overrightarrow{Y_3}.\overrightarrow{A_\delta} - \vec{A}\right|$$

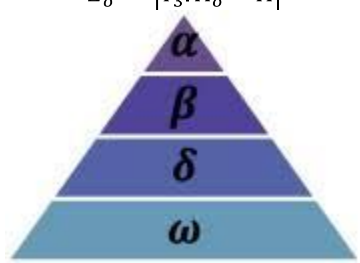

Fig.6: Hierarchy levels of the wolves.

1) The first level wolver are called are alpha wolves. They are dominant in nature and all the wolves followed their orders. They are the best decision makers and having the best fitness value in the whole pack. They are also the leaders of the pack.

2) The Second level wolves are the beta wolves and also called as

subordinate wolves which help in decision making in alpha and also the other members of the pack.

3) The third level wolves are the delta wolves they work after the beta wolves. They are considered when the beta wolves are not working properly. These wolves are also called as scouts.

The fourth and the last level of the hierarchy are related to the omega wolves. Omega wolves have low fitness value.

IV. CONCLUSION

An efficient design of channel estimation technique for OFDMA system is presented and this design has been optimised using Particle Swarm optimisation technique. The design is simulated using MATLAB. This particle swarm optimized LMS channel estimation technique can estimate channel dynamics and support multiple access. In this scheme weighting coefficients are updated by the algorithm dynamically without any information regarding channel statistics. The signals while travelling through noise channel keep on fluctuating, these fluctuations are nullified using this algorithm. The given algorithm converges towards the accurate channel coefficients. This advantage of convergence of channel coefficients towards the true channel coefficient as well as BER performance could be of relevant use in future mobile communication.

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