Channel Estimation and Carrier Frequency Offset Estimation for Multiuser Uplink for OFDM System

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***Abstract* - In this paper we are estimating carrier frequency offset by using two different methods and we are showing that the performance of proposed method is better than the performance of Fusco's method because in the fusco's method we are using time domain method so that the signal is in the series so we cannot send more signals it takes more time so in the proposed method we are estimated the CFO by using frequency domain in this method the signal is travelled in parallel so more signals can be send through this method. In this paper we also estimated the iterative channel estimation by using LS &MMSE methods in fading conditions. And we show the MMSE is the best method for the channel estimation.**

Keyword: Orthogonal frequency division multiplexing (OFDM), Carrier frequency offset estimation (CFO), channel estimation, Least square (LS), Minimum mean square error (MMSE).

I.INTRODUCTION

In the last years, the interest for filter-bank multicarrier (FBMC) systems is incremented, since they provide high spectral containment. Therefore, they have been taken into account for high-data-rate transmissions over both wired and wireless frequency-selective channels. One of the most famous multicarrier modulation techniques is orthogonal frequency division multiplexing (OFDM), embedded in several standards such as digital audio and video broadcasting or Wi-Fi wireless LANs IEEE 802.11a/g. Other known type of FBMC systems are Filtered Multitone (FMT) systems, that have been proposed for very high-speed digital subscriber linestandards and are under investigation also for broadband wireless applications and moreover, OFDM based on offset QAM modulation (OQAM), considered by the 3GPP standardization forum. Unlike OFDM, OFDM/OQAMsystems do not require the presence of a cyclic prefix (CP) inorder to combat the effects of frequency selective channels.

The absence of the CP implies on the hand the maximum spectral efficiency and, on the other hand, an increased Computational complexity. However, since the subchannel filters are obtained by complex modulation of a single filter, efficient polyphase implementations are possible. Another fundamental difference between OFDM and OFDM/OQAM systems is the adoption in the latter case of pulse shaping filters very well localized in time and frequency.Orthogonal frequency division multiplexing (OFDM) systems have attracted great interest in wireless and wire-line transmissions because of their robustness to multipath channels. OFDM/OQAM systems giving rise to interference between successive symbols and adjacent subcarriers. Therefore, reliable and accurate timing and carrier-frequency offset (CFO) estimation schemes must be designed for these systems.

OFDM system is sensitive to carrier frequency offset estimation (CFO), which leads to degrade the system performance. The CFO is the mismatch of the transceiver oscillators or the Doppler Effect. The CFOs lead to both inter-carrier interference and multiple-access interference, which could severely degrade the system performance. Previously the CFO estimation scheme for OFDMA uplink transmissions has intensively been investigated like by using frequency domain pilot system,Using ML algorithm, but those methods are complex.

In this paper we are estimating carrier frequency offset estimation for multiuser uplink and also we are estimating channel estimation in fading conditions. CFOEstimation is same as in the paper [1] with just changes we are estimating by using same estimators. The CFO estimated by using Fusco's estimator as the first estimator and the proposed method is the second estimator. In paper [2]considered the problem of data-aided joint symbol timing and carrier frequency offset estimation for filter bank based multicarrier systems. In that they provided new joint symbol timing and CFO synchronization algorithm exploiting the transmission of a training sequence.

In the CFO estimation in the uplink of an OFDMA system, the base station (BS) needs to estimate multiple CFO's from multiple users. The choice of CFO estimation methods in the BS is closely related to the adopted subcarrier allocation scheme [3]. The main aim of this paper is to propose a low-complexity data-aided CFO estimation for OFDM with block allocation scheme.And also we are estimating the iterative channel estimation by using LS (Least square) channel estimation and MMSE (Minimum mean square) channel estimation which is present in paper [4].

The organization of the paper as follows. In the section 2 we describe the considered OFDMA system model. In Section 3 we derive the Carrier frequency offset estimation by using two methods: Fusco's estimation and Proposed estimation. In Section 4 we provide the iterative channel estimation followed by two methods: LS estimation and MMSE estimation. Numerical results are presented in Section 5 and conclusions are drawn in the final Section.

II. OFDM SYSTEM MODEL

We consider base station and it has p number of active users communicating with that station. It is considered as that there are total number of sub carriers as $N = P \times Q$ subcarriers, where $Q$is the number of subcarriers allocated to each user, including both active and guard subcarriers. We are assuming ${}_{P=0}^{P-1}S_P = \{0, 1, \ \ldots, \ \ N-1\}$and $S_P \cap S_q = \emptyset$, for $\forall\, P = q$. The received signal from base station is given by

$$r[n] = y[n] + v[n]$$

$$= {}_{P=0}^{P-1}y_p[n] + v[n] \qquad (1)$$

Where, $v[n]$ is an AWGN with variance σ_n^2 and $y_p[n]$ is the received signal from the pth user as

$$y_p[n] = \left(x_p[n] \ * c_p[n]\right)e^{j2\pi\varepsilon_p n/N}, \qquad (2)$$

Where, $x_p[n]$is the transmitted signal from pth user , and $c_p[n]$ is the channel response between the pth user and base station. It is assumed that $c_p[n]$ is non-zero only for $n = 0,1,\ldots,N_c - 1$, where $N_c$is the channel delay spread and ε_p is the normalized CFO of the pth user,$P = 0,1,\ldots \ ,P-1$.

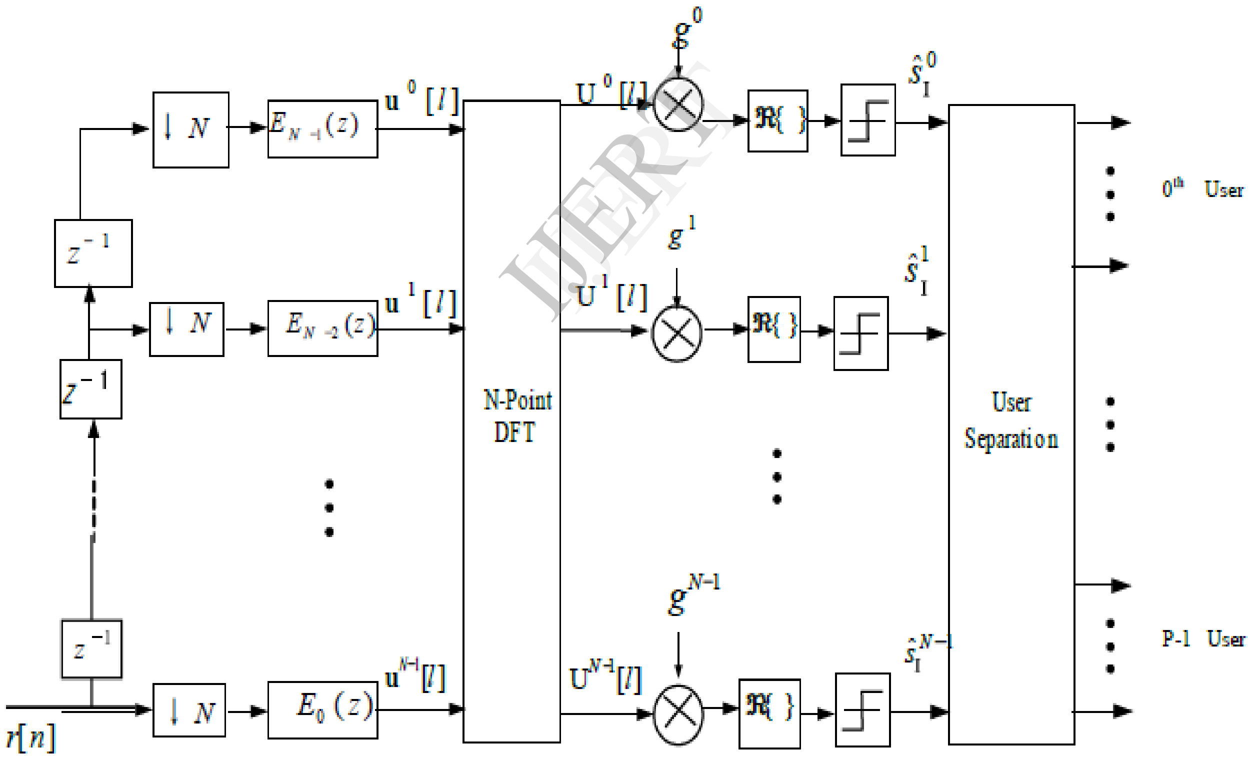

Fig.1.This is in-phase receiver part of OFDM

A. Polyphase structure

The components in the polyphase structure are $E_o(z)$ to $E_{N-1}(z)$ are the components of the filter $H(z)$. We assume each component has length of β. The DFT block performs the demodulation at the receiver side of the system but, in the polyphase components are often followed by an IDFT. This difference arises, because here we feed the input signal from the bottom of a tapped delay line, i.e., opposite to the general communication system which feed from top to bottom. This arrangement is because, it matches the presentation of an OFDM receiver.

From the fig.1,

The $N \times 1$ input vector to the DFT at the time instant l as shown in Fig. 1 can be written as

$$u[l] = \sum_{i=1}^{\beta} u^{(i)}[l], \quad (3)$$

Where

$$u^{(i)}[l] = r[l+i] \odot h[\beta - i] = (y[l+i] + v[l+i]) \odot h[\beta - i], \quad (4)$$

And $\odot$ denotes point-wise multiplication of vectors. Furthermorethe output vector of the DFT block is given by

$$U(l) = F\{u(l)\}, \quad (5)$$

Where F denotes the DFT operation. The output vector $U(l)$ is multiplied with a column vector$g = [g^0 g^1 \dots\ g^{N-1}]^T$. The equalizer output is then sent to a slicer and decisions on the transmitted data symbols $\hat{s}_l$ are obtained as shown in fig. 1. Data from different users are then separated through user separation.

III. CFO Estimation

A. *Fusco's multiuser CFO Estimator*

Previously Fusco *et al* proposed a joint CFO and timing Offset estimator in the uplink using non-periodical training sequences. The CFO estimator for the Pth user may be simplified to

$$\hat{\varepsilon}_P = \frac{1}{\pi} \angle \left\{ \sum_{i=0}^{N_c-1} A_i^* B_i \right\} \quad (6)$$

Where $\{\sum_{i=0}^{N_c-1} A_i^* B_i\}$ denotes the angle of a complex number and the parameters A_i and B_i are equal to

$$A_i = \sum_{n=0}^{\beta N-1} \left[r[n+i] \sum_{k \epsilon S_P} x_I^{k*}[n] \right] \quad (7)$$

$$B_i = \sum_{n=0}^{\beta N-1} \left[r\left[n+i+\frac{N}{2}\right] \sum_{k \epsilon S_P} x_Q^{k*}[n] \right] \quad (8)$$

And $x_I^k[n]$ and $x_Q^k[n]$ are transmitted signals produced by in-phase S_I^k and quadrature phase $S_Q^k$of the training symbol on the kth subcarrier.to achieve an accurate CFO estimation on the Pth user, $\sum_{k=0}^{N-1} S_I^k S_Q^k = 0$ should be satisfied.

The CFO estimation can be done before the DFT. Since, Cfo is estimated for different users independently, also complexity is improves as the number of user increases.

B. *The Proposed Estimator*

In a time-domain CFO estimation algorithm using periodical training sequences was proposed for single user OFDM systems. This may not be extended to multiuser case, where signals from P users have been received with different CFO's at BS which cannot be easily separated in the time domain. To overcomethis problem, we taken a frequency- domain CFO estimator for OFDM using periodical training sequences. To reduce this computational complexity of the estimator, used only real training sequences such that the estimator only uses the in-phase parts.in this the filter values taken as non-zero values i.e., $-N \leq n \leq N$.

The transmitted training signal $x_p[n]$ satisfies the following condition approximately,

$$x_p[n+N] \approx x_p[n] \quad , \quad n = N_1, \dots, N_1 + \beta N - 1 \quad (9)$$

Where N_1 is the transient in the time domain . By calling (2), we have two $\beta N \times 1$ successive overlapped signal vector from the Pth user called $Y_{p,1}$ and $Y_{p,2}$ such that

$$Y_{p,2} = e^{j2\pi\varepsilon_p} y_{p,1}, \quad p = 0,1, \dots, P-1 \quad (10)$$

According $N \times 1$ vectors $u_1$andu_2 are the received vectors at the input of DFT block due to r_1 and r_2 respectively as

$$\begin{Bmatrix} u_1 = \sum_{p=0}^{P-1} \sum_{i=1}^{\beta} y_{p,1}[l+i] \odot h[\beta - i] + w_1 \\ u_2 = \sum_{p=0}^{P-1} \sum_{i=1}^{\beta} e^{j2\pi\varepsilon_p} y_{p,1}[l+i] \odot h[\beta - i] + w_2 \end{Bmatrix} \quad (11)$$

If we put some subcarriers as a guard between each pair of adjacent user bands for multiuser case, the overlapping between adjacent users may be neglected. The CFO estimation may be performed after DFT.

The CFO estimated separately for OFDM in

$$\hat{\varepsilon}_p = \frac{1}{2\pi} \left(\sum_{k \in S_p} U_1^{k*} U_2^k \right) \quad (12)$$

Where U_1 and U_2 are the DFT outputs of vectors u_1 and u_2 respectively. Using similar approach as in (11), the mean squre error of CFO estimation of the Pth user can be given by

$$\text{MSE}(\widehat{\varepsilon}_p) = \text{E}\left\{ \left(\varepsilon_p - \hat{\varepsilon}_p\right)^2 \right\} = \frac{1}{4\pi^2.\text{SNR}.\sum_{k \in S_p} |\text{H}^k|^2} \quad (13)$$

Where H^k is the channel frequency response on the kth subcarrier and SNR $\triangleq \frac{\sigma_s^2}{\sigma_n^2}$, where σ_s^2 is the power of the transmitted signal.

IV. CHANNEL ESTIMATION

The channel estimation techniques are used for estimating the channel response at the reference symbols. Linear Interpolation is used to determine the channel at data symbols [6].

A.LS channel estimation:

LS (Least Square) channel estimation is the simplest channel estimation method. LS channel estimation is the channel estimator from least squares. Loop impulse response using the LS estimate allows $(Y - XH)^H(Y - XH)$ minimum, obtained by calculating

$$\hat{h}_{LS} = X^{-1}Y \quad (14)$$

Gaussian white noise and ICI have large impact on LS algorithm, so the accuracy of the algorithm, so the accuracy of the algorithm is limited [6]. Even though the performance of LS estimation is not perfect, but its implementation complexity is very low in certain error conditions, therefore LS is widely used.

B.MMSE Estimation:

Because the accuracy based on LS criterion is not high, in order to improve the accuracy of estimation algorithm, the estimation based on the MMSE (minimum mean square error) criterion is used to improve accuracy with the information of channel estimation.
The algorithm in the frequency domain is defined as the formula:

$$\hat{h}_{MMSE} = R_{HH}R_{YY}{}^{-1}Y \quad (15)$$

Where,

$$R_{HY} = R_{HH}X^H$$

$$R_{YY} = XR_{HH}X^H + \sigma_n^2 I_N$$

$\sigma_n^2$is the variance of additive Gaussian noise, $R_{HH} = E^{[HH]H}$ is the autocorrelation matrix about channel response [6]. Therefore, the estimation algorithm based on channel response MMSE in frequency domain can be expressed as the formula

$$\hat{h}_{MMSE} = R_{HH}(R_{HH} + \sigma_n^2(XX^H)^{-1})^{-1}\hat{h}_{LS} \quad (16)$$

The structure of MMSE estimator is more complicated than LS, but it is superior to LS algorithm on SNR.

V. RESULTS

In this paper we considered as N =256 and number of users is P=4. So total number of subcarriers is 64. The channel delay 0, 0.31,0.71,0.09,1.73 and 2.51 microseconds [1]. The value of ε is in between $[-0.5 - 0.5]$. The MSE of the proposed estimator and Fusco's multiuser CFO estimator are shown in Fig.2.

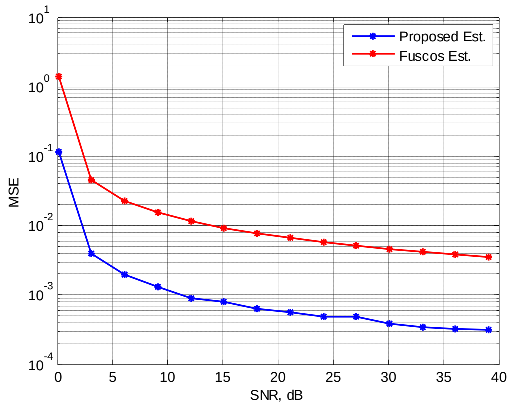

Fig.2. MSE of the proposed estimator and Fusco's multiuser CFO estimator.

The MSE for the proposed estimator is has better performance than the Fusco's estimator.

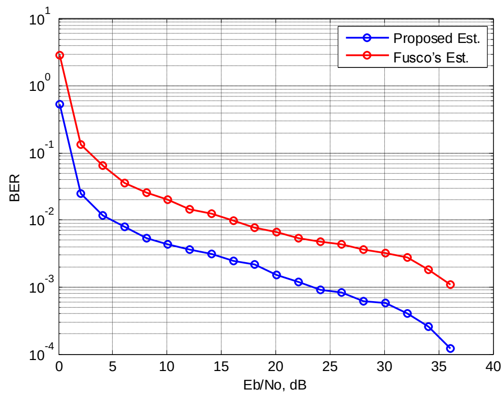

Fig.3.BER using proposed estimator and Fusco's multiuser CFO estimator.

In the above Fig.3. Shows that the Bit Error Rate for both estimators, for different values. We see that the BER of the proposed estimator has the better performance than the other estimator.

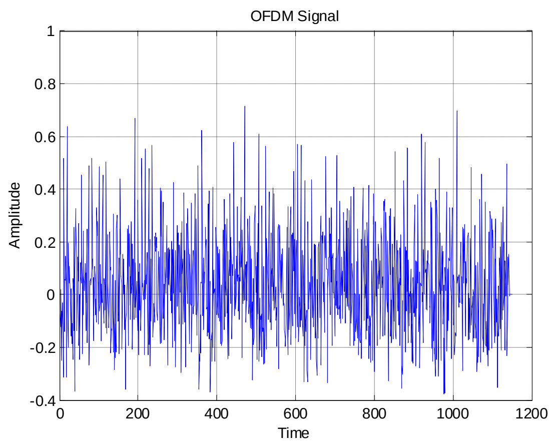

Fig.3. The OFDM signal

This is the signal we took for the channel estimation. By using this OFDM signal, we perform channel estimation by using LS and MMSE channel estimation techniques.

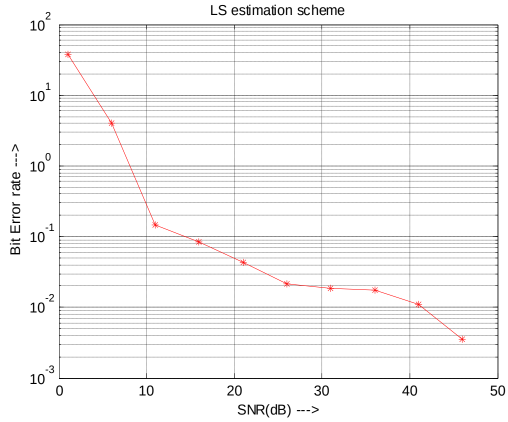

Fig.5.LS channel estimation scheme

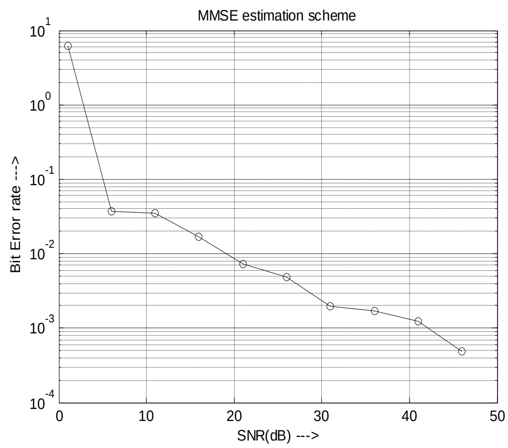

Fig.5.MMSE channel estimation scheme

The Fig.4 &Fig.5 shows the performance of the LS channel estimation and MMSE channel estimation scheme. The performance of the iterative LS estimation could near the MMSE estimation.The simulationresult shows that through the proposed iterative channel estimation method, dramatic performance improvements can beachieved with the LS estimation and that the advantage of low implementation complexity makes it possible widely used inthe practical OFDM system.

V. CONCLUSION

In this paper we presented the Carrier Frequency Offset estimation by using two estimators, in that proposed estimator has better performance. In channel estimation also two estimated two methods: LS channel estimation scheme and MMSE channel estimation scheme. MMSE channel estimation scheme is the good scheme compared to the LS scheme.

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