Iterative ICI Cancellation Algorithm For Uplink OFDMA System With Carrier-Frequency Offset

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Abstract—In orthogonal frequency-division multiplex access (OFDMA) uplink, it is admitted that the carrier-frequency offsets (CFOs) between multi-transmitter and receiver introduce inter-carrier interference (ICI) and cause severe performance loss. In this paper, with reference to a detailed analysis of the ICI caused by CFOs, we propose a novel low-complexity iterative ICI cancellation algorithm, which is based on the perfect estimation of each user’s CFO. Moreover, the convergence behaviors of the iterations are studied with three theorems, and the user-interleaving patterns suitable for this algorithm are presented. In accordance with the simulation results, we come to the conclusion that the low-complexity iterative algorithm can effectively suppress and cancel the ICI due to CFOs.

Index Terms—Orthogonal frequency-division multiplex access (OFDMA), inter-carrier interference (ICI), carrier-frequency offset (CFO), iterative algorithm, uplink.

I. INTRODUCTION

Orthogonal frequency-division multiplex access (OFDMA) is a multiplex technique, in which subcarriers are grouped into sub-channels and these sub-channels are allotted to multiple users for simultaneous transmissions. In this way, the intrinsic orthogonality among subcarriers can eliminate each user’s self-interference and multiuser interference (MUI). Due to its strong multiple access capability, OFDMA technology has been recognized as the candidate for physical layer multi-access technology in wireless metropolitan area network (WMAN) standard IEEE 802.16a [1].

In OFDMA system, carrier-frequency offsets (CFOs) between multiple transceivers can introduce serious inter-carrier interference (ICI). Unlike the single-user or multiuser downlink OFDM cases, in multiuser uplink, different transmitters have their own carrier-frequencies, so the received signals may suffer from multiple CFOs, which cannot be reduced completely by mere adjusting the receiver’s carrier-frequency. As in ordinary OFDM system, the subcarriers’ orthogonality at OFDMA uplink receivers is quite sensitive to CFOs. The destruct of subcarriers’ orthogonality would introduce ICI and cause severe performance loss.

In OFDMA uplink systems, the CFOs and channel state information (CSI) can be estimated [2][3][4], which leads to that the cancellation of ICI is available. One type of method is to inform all the transmitters of their corresponding CFO estimates through downlinks. But this feedback process will increase the system overhead. To improve the system efficiency, an alternative type of methods is to cancel the ICI at the receiver. Recently, these high-efficiency methods to mitigate CFOs are focused on. In [5], the authors try to reconstruct the orthogonal spectral signals based on MMSE and LS criteria. They construct an interference matrix and take out part of non-diagonal entries for simplicity. However, though the MMSE and LS methods are linearly optimal, they should operate high-complexity matrix inversion. In [6], an iterative method is put forward to mitigate MUI. That method suppresses co-interference in a per-user fashion, and operates multiple circular convolution operations in each iterative step. So it also consumes high complexity. Besides, a theoretical analysis of convergence is lacking.

In this paper, we propose a novel iterative ICI cancellation algorithm in a per-subcarrier fashion. In order to reduce the algorithm complexity, we cope with both MUI and self-interference simultaneously at each iteration step. Based on this architecture, flexible stopping-criterions can be applied, and then, the amount of operations can further decrease. Through three theorems, the convergence of iterations is analyzed and proved, which implies the elimination of ICI. Further, we present suitable user-interleaving patterns, under which we can mitigate large CFOs by separating interference. Simulation results show the algorithm’s ability to cancel ICI caused by large CFOs with low complexity.

This paper is organized as follows. In Section II, the OFDMA uplink system model is established, in which multiple CFOs are introduced. In Section III, our proposed iterative ICI cancellation algorithm is presented, with the proof of convergence and the analysis of different user-interleaving patterns. The simulation results are given in Section IV to evaluate the performance in different CFO environment. Finally, conclusions are drawn in Section V.

Throughout the paper, the symbol $\left( \cdot \right)^T$ represents matrix transposition, the norm of a matrix and the spectral radius of a matrix respectively. Besides, I represents...
we consider an OFDMA uplink that employs $N$ subcarriers and accommodates $K$ users, which is shown in Fig. 1. [3] ${\Omega}_k$ represents the set of subcarriers assigned to user $k$, $k = 1, 2, \cdots, K$, and

$$\Omega_k \cap \Omega_{k'} = \varnothing, \quad \text{if} \quad k \neq k',$$  

(1)  

$$\bigcup_{k=1}^{K} \Omega_k = \{1, 2, \cdots, N\}. \quad (2)$$

Hence, the signals of different users are absolutely orthogonal in frequency domain. Different subcarrier assignment methods are classified as three typical user-interleaving patterns shown in Fig. 2. Each user utilizes his exclusive subcarrier set and carries out OFDM modulation through an IFFT transform. Cyclic prefixes (CP) are added in all transmitters. Here we assume the length of CP is long enough that there exists no inter-symbol interference (ISI) at all.

The signal stream arriving at Base Station (BS) is the sum of all users’ signals in time domain. Each user’s signal experiences independent multi-path fading channel and suffers from different CFO. For simplicity, a user is called a large- or small-CFO user when he suffers from large or small CFO respectively. Then, a subcarrier is called a large- or small-CFO subcarrier when it is assigned to a large- or small-CFO user.

After CP being removed, the signal at the receiver is expressed as

$$\gamma(n) = \frac{1}{N} \sum_{k=1}^{K} e^{j2\pi \xi^{(k)} n/N} \sum_{m=0}^{N-1} X^{(k)}_m H^{(k)}_m e^{j2\pi m n/N} + w(n),$$

$$n = 0, 1, \cdots, N. \quad (3)$$

Therein $\xi^{(k)} = \Delta f^{(k)}/f_{sub}$ denotes user $k$’s relative CFO value, $f_{sub}$ is the frequency distance between two adjacent subcarriers and $\Delta f^{(k)}$ is user $k$’s absolute CFO. $H^{(k)}_m$ and $X^{(k)}_m$ are user $k$’s CSI and transmitting data at subcarrier $m$ when $m \in \Omega_k$. [5]

Through a FFT transform for $\gamma(n)$, the symbol at subcarrier $m$ is represented as

$$Y_m = R_m I_{m,m} + \sum_{m'=0,m' \neq m}^{N-1} R_{m,m'} I_{m',m'} + \eta_m, \ m = 0, 1, \cdots, N-1. \quad (4)$$

Therein $R_m = H_m X_m = H^{(k)}_m X^{(k)}_m$, $\eta_m$ is an AWGN noise with variance $\sigma^2_n$. The influence factor from subcarrier $m'$ to $m$ is represented as [5]

$$I_{m,m'} = \frac{1}{N} \sum_{n=0}^{N-1} e^{j2\pi [(m'-m)+\xi^{(k)}] n/N}, \quad (5)$$

where $k = \text{arg}_k m' \in \Omega_k$. It reaches the maximum when $m' = m$, and rapidly decreases as the distance between $m'$ and $m$ increases.

III. PROPOSED ALGORITHM

A. Algorithm Flow

We disregard the concept of multiuser, and define the compound fading factor of subcarrier $m$ as $\alpha_m = H_m \cdot I_{m,m}$ and the co-influence factor from subcarrier $m'$ to $m$ as $\beta_{m,m'} = H_{m'} \cdot I_{m,m'}$, whether subcarrier $m'$ and $m$ are assigned to different users or not. In (4), $Y_m$ consists of three terms- the data term $R_m I_{m,m}$, the interference term $\sum_{m'=0,m' \neq m}^{N-1} R_{m,m'} I_{m',m'}$ and the AWGN noise term $\eta_m$. Our target is to retrieve the data term from the interference and noise. Apparently, the data term for some subcarrier is a part of interference terms for other subcarriers. Just because of the existence of this interactional relation among all the subcarriers, the interference terms can be cancelled gradually through iterations.

Thus, we put forward an iterative ICI cancellation algorithm. In each step the operation is for $m = 0, 1, \cdots, N-1$ until the stopping criterion is satisfied.

Initialization:

$$\hat{X}^{(0)}_m = Y_m/\alpha_m. \quad (6)$$

Loop step:

$$\hat{X}^{(l)}_m = \left(Y_m - \sum_{m'=0,m' \neq m}^{N-1} \frac{\hat{X}^{(l-1)}_{m,m'} \beta_{m,m'}}{\alpha_m}\right)/\alpha_m, \ l = 1, 2, \cdots. \quad (7)$$

A simple stopping criterion is a fixed iterative number according to CFO values. Another more efficient one is based on constant module characteristic: when the module of $\hat{X}^{(l)}_m$ reaches a constant for M-QAM or M-PSK modulation, it will not update its value in the next iteration. In this way, the number of updated subcarriers, which is denoted as $n_i$, where $i$ is the index of iteration, will gradually decrease until zero. If the decreasing of $n_i$ is linear with $i$, the total amount of operation will be reduced half.
This algorithm can also be described in matrix form. Suppose that
\[ \mathbf{Y} = [Y_0 \ Y_1 \ \cdots \ Y_{N-1}]^T, \]
\[ \hat{\mathbf{X}}^{(l)} = [\hat{X}_0^{(l)} \ \hat{X}_1^{(l)} \ \cdots \ \hat{X}_{N-1}^{(l)}]^T, \]
and construct the diagonal matrix \( \alpha \) and zero-diagonal matrix \( \beta \) as
\[ \alpha = \begin{bmatrix} 1/\alpha_0 & 0 & \cdots & 0 \\ 0 & 1/\alpha_1 & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ 0 & \cdots & \cdots & 1/\alpha_{N-1} \end{bmatrix}, \]
\[ \beta = \begin{bmatrix} 0 & \beta_{0,1} & \beta_{0,2} & \cdots & \beta_{0,N-1} \\ \beta_{1,0} & 0 & \cdots & \cdots & \beta_{1,N-1} \\ \beta_{2,0} & 0 & \cdots & \cdots & \beta_{2,N-1} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \beta_{N-1,0} & \beta_{N-1,1} & \beta_{N-1,2} & \cdots & 0 \end{bmatrix}. \]
Then, the algorithm flow can be described as
\[ \hat{\mathbf{X}}^{(0)} = \alpha \mathbf{Y}. \] (8)
Loop step:
\[ \hat{\mathbf{X}}^{(l)} = \alpha (\mathbf{Y} - \beta \hat{\mathbf{X}}^{(l-1)}), \quad l = 1, 2, \cdots. \] (9)
In each iteration step, a total of \( N^2 + N \) multiplications are operated. Hence, the complexity of the iterative algorithm is \( O(\text{LN}^2) \), where \( L \) is the number of iterations.

B. Convergence Analysis

For subcarrier \( m \), \( \alpha_m \) represents the signal’s gain and \( \beta_{m,m'} \) represents the interference’s gain. So the signal-interference-ratio (SIR) reciprocal factor at subcarrier \( m \) is defined as
\[ \omega_m = \sum_{m'=0, m' \neq m}^{N-1} |\beta_{m,m'}|/|\alpha_m|, \quad m = 0, 1, \cdots, N-1. \] (10)
The larger \( \omega_m \) is, the more severely subcarrier \( m \) suffers from CFOs and channel fading.
Plugging (4) into (6) yields
\[ \hat{\mathbf{X}}^{(0)}_m = X_m + \sum_{m'=0, m' \neq m}^{N-1} X_{m'} \beta_{m,m'}/\alpha_m + N^{(0)}_m, \] (11)
therein \( N^{(0)}_m \) is an equivalent AWGN noise.
Continuously substituting the new value of \( \hat{\mathbf{X}}^{(l-1)} \) obtained from iterations into (7) yields
\[ \hat{\mathbf{X}}^{(1)}_m = X_m - \sum_{m' \neq m} \sum_{m'' \neq m'} X_{m''} \beta_{m'',m''} \beta_{m',m} / \alpha_{m''} \alpha_m + N^{(1)}_m, \] (12)
\[ \hat{\mathbf{X}}^{(2)}_m = X_m + \sum_{m' \neq m} \sum_{m'' \neq m'} \sum_{m''' \neq m''} X_{m'''} \beta_{m''',m'''} \beta_{m'',m'} \beta_{m',m} / \alpha_{m'''} \alpha_{m''} \alpha_m + N^{(2)}_m, \cdots. \] (13)
For (11)–(13), we consider the ICI terms for subcarrier \( m \), i.e.,
\[ \psi^{(0)}_m = \sum_{m' \neq m} X_{m'} \beta_{m,m'}/\alpha_m, \]
\[ \psi^{(1)}_m = -\sum_{m' \neq m} \sum_{m'' \neq m'} X_{m''} \beta_{m'',m''} \beta_{m',m'} / \alpha_{m''} \alpha_m, \]
\[ \psi^{(2)}_m = \sum_{m' \neq m} \sum_{m'' \neq m'} \sum_{m''' \neq m''} X_{m'''} \beta_{m''',m'''} \beta_{m'',m''} \beta_{m',m'} / \alpha_{m'''} \alpha_{m''} \alpha_m, \cdots. \]
Here, \( \{\psi^{(l)}_m\} \) can be translated into the residual interference through iterations \( l = 0, 1, \cdots. \).

The convergence of iterations (6), (7) can be proved by two theorems below. First, Theorem 1 provides a sufficient condition for the absolute convergence; then, Theorem 2 points out in which case the condition is satisfied.

**Theorem 1:** \( \lim_{l \to \infty} |\psi^{(l)}_m| = 0, \forall m, \text{ when } \omega_m < 1, \forall m. \)
**Proof:** For any limited constellation modulation, \( |X_m| \leq c, \forall m \), where \( c \) is a constant. Then,
\[ |\psi^{(0)}_m| \leq \sum_{m' \neq m} |X_{m'}| |\beta_{m,m'}| / |\alpha_m| \leq c \cdot \sum_{m' \neq m} |\beta_{m,m'}| / |\alpha_m| = c \cdot \omega_m, \] (14)
\[ |\psi^{(1)}_m| \leq \sum_{m' \neq m} \sum_{m'' \neq m'} |X_{m''}||\beta_{m'',m''}| |\beta_{m',m'}| / |\alpha_{m''}||\alpha_m| \leq c \cdot \sum_{m' \neq m} \sum_{m'' \neq m'} \omega_{m''} |\beta_{m'',m''}| |\beta_{m',m'}| / |\alpha_{m''}| |\alpha_m|, \] (15)
\[ |\psi^{(2)}_m| \leq \sum_{m' \neq m} \sum_{m'' \neq m'} \sum_{m''' \neq m''} |X_{m'''}| |\beta_{m''',m'''}| |\beta_{m'',m''}||\beta_{m',m'}| / |\alpha_{m'''}| |\alpha_{m''}| |\alpha_m| \leq c \cdot \sum_{m' \neq m} \sum_{m'' \neq m'} \sum_{m''' \neq m''} \omega_{m'''} |\beta_{m''',m'''}| |\beta_{m'',m''}||\beta_{m',m'}| / |\alpha_{m'''}| |\alpha_{m''}| |\alpha_{m}|. \] (16)
Since \( \{\omega_m\} \) is a limited set, we can define \( \omega_{\text{max}} = \max_m \omega_m \). So \( |\psi^{(l)}_m| \leq c \cdot \omega_{\text{max}} \cdot \omega_m \).
Similarly, \( |\psi^{(2)}_m| \leq c \cdot \omega_{\text{max}} \cdot \omega_m \cdots, |\psi^{(l)}_m| \leq c \cdot \omega_{\text{max}} \cdot \omega_m \).
If \( \omega_m < 1, \forall m \) satisfied, then \( \lim_{l \to \infty} |\psi^{(l)}_m| = 0 \), hence \( \lim_{l \to \infty} |\psi^{(l)}_m| = 0 \). \( \square \)

**Theorem 2:** For a large-CFO subcarrier \( m_0 \), \( \omega_{m_0} < 1 \), only if \( \forall m \in B(m_0, \varepsilon) \), subcarrier \( m \) is assigned to a small-CFO user.
**Proof:** For subcarrier \( m_0 \), \( \beta_{m_0,m} \) rapidly decreases with the increase of the value of \( |m - m_0| \). With this property, \( P_{m_0} = \sum_{m=0, m \neq m_0} |\beta_{m_0,m}| \), which is the sum of the co-influence factors, is mostly depended on those entries \( |\beta_{m_0,m}|, m \in B(m_0, \varepsilon) \). From (10), the value of \( \omega_{m_0} \) equals the ratio of the compound fading factor, \( |\alpha_{m_0}| \), to the sum of the co-influence factors, \( P_{m_0} \). At small \( |\alpha_{m_0}| \), which is due to the
large CFO value, $P_{m_0}$ should decrease as well. So it is required
that $\forall m \in B(m_0, \varepsilon)$, $|\beta_{m_0, m}|$ should be small enough. This
only happens when $\forall m \in B(m_0, \varepsilon)$, subcarrier $m$ is assigned
to a small-CFO user.

Theorem 1 and 2 present a sufficient condition for an absolute convergence, which implies that the initial SIRs are larger than 1 for all the subcarriers. In practice, when the subcarriers with $\omega < 1$ take up a relatively large proportion and are distributed uniformly, the effective SIR value at each subcarrier gradually increases with iteration index $l$, and at last all of subcarriers will reach ICI-free.

Actually, this sufficient condition for the absolute convergence can be given by another theorem in correspondence with the matrix form of the algorithm.

**Theorem 3:** In iterations (8), (9), the sequence $\{\hat{X}^{(l)}\}$ is convergent, if

$$\max_m \sum_{m' = 0, m' \neq m} N - 1 |\beta_{m, m'}| / |\alpha_m| < 1.$$  

**Proof:** Plugging (8) into (9) yields

$$\hat{X}^{(1)} = \alpha(Y - \beta\hat{X}^{(0)}) = \alpha(Y - \beta\alpha Y) = (I - \alpha\beta)\alpha Y.$$  

Continuously substituting the new value of $\hat{X}^{(l-1)}$ into (9) yields

$$\hat{X}^{(2)} = \alpha(Y - \beta\hat{X}^{(1)}) = \alpha(Y - \beta(I - \alpha\beta)\alpha Y) = (I - \alpha\beta + (\alpha\beta)^2)\alpha Y,$$

$$\ldots$$

$$\hat{X}^{(l)} = (I - \alpha\beta + (\alpha\beta)^2) \cdots + (\alpha\beta)^l \alpha Y = \sum_{k=0}^{l} (-1)^k (\alpha\beta)^k \alpha Y.$$  

Three conclusions about matrix power series are given here, which are proved in [7].

C1) Given a power series $f(z) = \sum_{k=0}^{\infty} c_k z^k$ with its convergence radius $r < \infty$, if there is a square matrix $A$ such that $\rho(A) < r$, then the matrix power series $\sum_{k=0}^{\infty} c_k A^k$ is absolutely convergent.

C2) If $\| \cdot \|$ is any matrix norm and if $A \in \mathbb{C}^{n \times n}$, then $\rho(A) < \|A\|_\infty$.

C3) The convergence radius $r$ of the power series $f(z) = \sum_{k=0}^{\infty}(-1)^k z^k$ equals 1. For any $z \in \mathbb{C}$ such that $|z| \leq 1$, $f(z) = \sum_{k=0}^{\infty}(-1)^k z^k = 1/(1 + z)$.

The power series $f(z) = \sum_{k=0}^{\infty}(-1)^k z^k$ has its convergence radius $r = 1$. From C1 to C3, we can directly infer that for any matrix norm $\| \cdot \|$, if $\|\alpha\beta\| < 1$, then $\rho(\alpha\beta) < \|\alpha\beta\| < 1$, and further, the matrix power series $\sum_{k=0}^{l}(-1)^k (\alpha\beta)^k$ is absolutely convergent.

Expanding the expression of $\alpha\beta$, we obtain

$$\alpha\beta = \begin{bmatrix} 0 & \beta_{1,0} / \alpha_0 & \beta_{2,0} / \alpha_0 & \cdots & \beta_{N-1,0} / \alpha_0 \\ \beta_{0,1} / \alpha_0 & 0 & \beta_{1,2} / \alpha_2 & \cdots & \beta_{N-1,1} / \alpha_2 \\ \vdots & \vdots & \ddots & \ddots & \vdots \\ \beta_{N-1,1} / \alpha_2 & \beta_{N-1,2} / \alpha_2 & \cdots & 0 \end{bmatrix}$$  

(20)

Here we adopt the maximum row sum matrix norm

$$\|A\|_\infty = \max_{i} \sum_{j=1}^{n} |a_{ij}|,$$

where $A = [a_{ij}] \in \mathbb{C}^{m \times n}$ [7]. Obviously,

$$\|\alpha\beta\|_\infty = \max_{m} \sum_{m' = 0, m' \neq m} N - 1 |\beta_{m, m'}| / |\alpha_m|.$$  

(21)

If the condition

$$\|\alpha\beta\|_\infty = \max_{m} \sum_{m' = 0, m' \neq m} N - 1 |\beta_{m, m'}| / |\alpha_m| < 1.$$  

(22)

is satisfied, $\sum_{k=0}^{l} (-1)^k (\alpha\beta)^k$ will be absolutely convergent. Since $\hat{X}^{(l)} = \sum_{k=0}^{l} (-1)^k (\alpha\beta)^k \alpha Y$, in iterations (8), (9), $\hat{X}^{(l)}$ tends to a convergent value.  

**C. User-Interleaving Pattern**

Besides the different frequency diversity gain, the three typical user-interleaving patterns in Fig. 2 also show different robustness to ICI caused by CFOs when using our proposed algorithm. Under the block pattern, all the subcarriers that are assigned to a large-CFO user would suffer from severe ICI, for all these subcarriers’ neighbors are assigned to the large-CFO user. Hence block pattern may lead to the result that through iterations only the subcarriers assigned to small-CFO users will reach ICI-free, and those large-CFO users will have all their subcarriers lose orthogonality.

Conversely, the comb and random patterns have the ability to separate the severe interference due to large CFO. In this case, the neighborhood of each subcarrier does not consist of all large-CFO subcarriers. Hence, unless all the users have large CFO, these two patterns could make all the subcarriers ICI-free, whether this subcarrier is assigned to a large-CFO user or not. Generally, compared with the probability that only one user has large CFO, the probability that two or more users all have large CFO is much lower. Besides, If most subcarriers are assigned to large-CFO users, the comb pattern with regular assignment cannot guarantee subcarriers to have enough small-CFO neighbors, and hence cannot suppress ICI through iterations. The random pattern, with more chances available for small-CFO subcarriers assigned nearby, will perform better than the comb pattern. Obviously, this performance gain comes from the arrangement of multiple users’ subcarriers, and it is improved by the increase of the number of spectral-sharing users.
under the block pattern, user 1 and 2 with large CFO values

Fig. 4. Illustration of the convergence of iterations under random pat-

tern. Y-scale denotes four users’ average BER. Left figure shows

\[ U \sim \mathcal{U}([-0.5, 0.5]) \]

their index \( k, k = 1, 2, 3, 4 \).

\[ \xi_{m,m}(k) \sim U[-0.1, 0.1] \]

two users with relatively small CFO values can cancel the

ICl among their assigned subcarriers. Conversely, under the

comb and random patterns, since the subcarriers assigned to
different users are interleaved, those assigned to small-CFO
users can first get rid of ICI, and then help their nearby large-
CFO user’s subcarriers. Finally all the subcarriers of the four
users can reach ICI-free after convergence.

The convergence performance of the proposed iterative
algorithm is shown in Fig. 4, where the performance bound is
defined as the case without any CFO. Through the iterations,
the BER curves with our algorithm rapidly approach the
performance bound. This is the same as the linear optimal
LS and MMSE methods [5], but with much lower complexity.
The LS and MMSE methods consume the complexity \( O(N^3) \),
and our iterative one consumes \( O(LN^2) \), where \( N \) is the total
number of subcarriers, and \( L \) is the number of iterations.
Obviously, \( L \ll N \). CFO not only induces ICI, but also
decreases compound channel gain. Thereby, when \( \xi_{m,m}(k) \sim
U[-0.5, 0.5] \) (i.e., uniformly distributed at \([-0.5, 0.5]\)), the
fading can make effective SNR at all the subcarriers decrease.
That is why the convergence’s limit 3dB worse than the no-
CFO bound. With small CFO, \( \xi_{m,m}(k) \sim U[-0.1, 0.1] \),
and convergence’ limit is close to 1. In this case, the algorithm
converges through only one time of iteration, and, moreover, the convergence’s limit
perfectly accords with the no-CFO bound.

V. CONCLUSION

An iterative ICI cancellation algorithm for uplink OFDMA
system with carrier-frequency offset is presented. Based on the
interaction among all the subcarriers, the ICI due to CFOs can
be suppressed gradually and eliminated finally. Three theorems
are put forward to prove the convergence of iterations. In
addition, three typical user-interleaving patterns are analyzed
whether they can separate and cancel interference. Both the
theoretical analysis and simulation results indicate that the
proposed iterative algorithm can mitigate large CFOs under
the comb and random patterns, and consumes much lower
complexity relative to LS and MMSE methods.

REFERENCES

[1] Carl Eklund, Roger B. Marks, Kenneth L. Stanwood and Stanley Wang,
“IEEE Standard 802.16: A Technical Overview of the WirelessMAN
Air Interface for Broadband Wireless Access,” IEEE Communications
frequency offset estimation for interleaved OFDMA uplink,” IEEE
estimation of carrier frequency offset and channel in uplink OFDMA
3193–3196.
for Generalized OFDMA Uplink,” in GLOBECOM 2004, IEEE, vol. 2,
pp. 1071–1075.
broadband OFDM in a multiuser environment,” in PIMRC 2003, IEEE,
vol. 2, pp. 1149–1153.