Low-complexity Parameter Update for Spatio-Temporal Filter to Suppress the Cochannel Interference in MIMO-OFDM Mobile Communication System

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Abstract—This paper proposes a low-complexity parameter update algorithm to spatio-temporal filter for suppressing the cochannel interference in multiple-input multiple-output (MIMO) orthogonal frequency-division multiplexing (OFDM) modulation systems. The conventional spatio-temporal filter employs the recursive eigenvalue decomposition algorithm to perform the parameter estimation and update. In the mobile environment, all the points during a data OFDM symbol are used for parameter update. This paper proposes an incomplete parameter update for the conventional spatio-temporal filter, where only a fraction of points during a data OFDM symbol are used for parameter update, while the others are ignored. In this way, the computational complexity of the parameter update can be reduced to some extent with negligible performance degradation. Computer simulations under IEEE 802.11a demonstrate the validity of the proposed incomplete parameter update algorithm.

Index Terms—MIMO-OFDM, cochannel interference, spatio-temporal filter, reduced-complexity, parameter update

I. INTRODUCTION

Multiple-input multiple-output (MIMO) antenna technologies and orthogonal frequency-division multiplexing (OFDM) are the two key techniques for improving the link reliability as well as the spectral efficiency of wireless communications systems [1-3]. In MIMO-OFDM, fast Fourier transform (FFT) will be used to extract the subcarrier components from the received signals for detection. However, conventional receivers such as the maximum likelihood detector (MLD) deteriorate in the presence of cochannel interference. To deal with the cochannel interference, various approaches using spatial filtering (SF) with MLD have been proposed to deal with cochannel interference [4-7]. This joint processing can be broadly classified into two categories: 1) postFFT-SF [4, 5], where SF is performed after FFT operation and the filter coefficients are computed in the frequency domain, and 2) preFFT-STF [6, 7], in which spatio-temporal filtering (STF) is used prior to FFT operation and the filter coefficients are estimated in the time domain. Under the condition of limited preamble symbols, preFFT-STF outperforms postFFT-SF, therefore this paper will focus on the preFFT-STF.

The parameter estimator of preFFT-STF is based on the recursive eigenvalue decomposition algorithm. In a mobile environment, all the points during a data OFDM symbol are used for parameter update in order to track the channel variation. However, the computational complexity of the parameter update is linearly proportional to the number of points during a data OFDM symbol. Hence, for reducing the computational complexity, this paper proposes an incomplete parameter update algorithm, where only a fraction of points during an OFDM symbol are used for parameter update. In this way, the computational complexity can be reduced to some extent with negligible performance degradation. Computer simulation results under IEEE 802.11a demonstrate the validity of the proposed low-complexity parameter update scheme.

II. SYSTEM MODEL

A. MIMO-OFDM multiuser uplink system

In this paper, we consider the uplink of the MIMO-OFDM system as shown in Fig. 1. There are $N_U$ users sharing the same frequency band, and each user has $L_T$ transmit antennas, whereas the receiver has an $L_R$-element array antenna. Without loss of generality, the first user is assumed to be the desired one and the other users are interfering users.

![Figure 1. System model](image)
B. Transmitter

Fig. 2 shows a block diagram of the MIMO-OFDM transmitter. An information bit sequence is divided into \( L_T \) parallel streams. Then each stream is fed into an OFDM modulator to generate the OFDM signals that has \( N \) subcarriers with the guard interval (GI). After the pulse shaping, the OFDM signals are up-converted into RF signals and transmitted.

C. Receiver

Fig. 3 shows a block diagram of preFFT-STF with the eigenvalue decomposition based parameter estimator. The signals received by \( L_R \) antennas are fed into \( L_B \) branch metric generators, where generally \( L_B \) is larger than \( L_T \). The generator is mainly composed of a spatio-temporal filter and replica generators. The spatio-temporal filter consists of \( L_R \) fractional tap-spacing transversal filters (FTFs) and an adder to combine the FTFs’ outputs. It can suppress cochannel interference and noise by STF. Signal components corresponding to GI are removed from the STF outputs. FFT transforms the resultant signals into \( N \) subcarrier signals. Subtracting replica signals from the subcarrier signals and squaring the result generate \( N \) subcarrier branch metrics. Multiplying symbol candidates that MLD provides by estimated channel frequency responses yields the replica signal.

A parameter estimator estimates coefficients of the STF and the channel impulse response. The estimation is based on the eigenvalue decomposition of an autocorrelation matrix of a signal vector. This signal vector is composed of two parts: one is the received signal, while the other is the known preamble or the detected symbol provided by MLD. It should be noted that the computational complexity of EVD is very large, even if we use the recursive method to solve the eigenvalue decomposition. Hence, it is necessary to investigate the low-complexity parameter update algorithm.

III. Parameter Estimation and Update

Let \( \mathbf{w}_{l, \text{ext}} \) denote the combination vector of the filtering coefficient and the channel impulse response vector of the \( l \) th branch metric generator. \( \mathbf{x}_{\text{ext}}(m) \) represents the extended signal vector at the \( m \Delta_t \), where \( \Delta_t \) is the sampling period. Specifically, \( \mathbf{x}_{\text{ext}}(m) \) consists of the received and the estimated signal vectors. \( \mathbf{w}_{l, \text{ext}} \) is estimated by applying the eigenvalue decomposition into the correlation matrix of \( \mathbf{x}_{\text{ext}}(m) \), denoted by \( \mathbf{R}_s(m) \), given as

\[
\mathbf{R}_s(m) = \sum_{m'} \lambda^{m-m'} \mathbf{x}_{\text{ext}}(m') \mathbf{x}_{\text{ext}}^H(m') = \lambda \mathbf{R}_s(m-1) + \mathbf{x}_{\text{ext}}(m) \mathbf{x}_{\text{ext}}^H(m)
\]

where \( \lambda \) is a positive forgetting factor in the interval of \((0,1]\). Based on the right hand side of (1), we can use the recursive method to estimate or update \( \mathbf{w}_{l, \text{ext}} \), in order to reduce the complexity. However, the complexity is still very large. In order to reduce the complexity furthermore, we only use a fraction of \( \mathbf{x}_{\text{ext}}(m) \) during a data symbol to update \( \mathbf{w}_{l, \text{ext}} \), while the other parts of \( \mathbf{x}_{\text{ext}}(m) \) are directly ignored. In this way, the modified \( \mathbf{R}_s(m) \) is given as

\[
\mathbf{R}_s(m) = \lambda \mathbf{R}_s(m-P) + \mathbf{x}_{\text{ext}}(m) \mathbf{x}_{\text{ext}}^H(m)
\]
where $P$ is a positive integer ($1 \leq P \leq N$). $P = 1$ and $P = N$ represent the case of complete parameter update and the case of no update, respectively. It can be seen that the other points, such as $\mathbf{x}_{ext}(m-P+1) \ldots \mathbf{x}_{ext}(m-1)$, are not considered. In order to maintain the weight of the current point in estimating $\mathbf{R}_x(m)$, we modify $\mathbf{R}_x(m)$ in further as

$$\mathbf{R}_x(m) = \lambda^P \mathbf{R}_x(m-P) + P \mathbf{x}_{ext}(m) \mathbf{x}^H_{ext}(m)$$

$$\frac{1}{P} \mathbf{R}_x(m) = \frac{\lambda^P}{P} \mathbf{R}_x(m-P) + \mathbf{x}_{ext}(m) \mathbf{x}^H_{ext}(m)$$

(3)

From this equation, we can apply the method in [7] to solve the eigenvalue decomposition of $\frac{1}{P} \mathbf{R}_x(m)$ recursively. It can be easily found that the computational complexity is reduced to $\frac{1}{P}$ compared with the conventional preFFT-STF. When $P$ becomes larger, the complexity is reduced with increased performance degradation.

IV. SIMULATION RESULTS

In order to demonstrate the performances of the proposed scheme, simulations were conducted in a fading channel under the IEEE 802.11a standard. The simulation parameters were summarized in Table I. Fig. 4 shows some numerical results. In Fig. 4 (a), the effect of $P$ on the BER performance of the proposed scheme is shown. It can be seen that when $P$ is not large, such as in the region of $P \leq 6$, the proposed scheme nearly keeps the optimal performance. However, the performance degradation becomes obvious when $P$ is larger than 6. Hence, to achieve a suitable tradeoff between the performance and complexity, $P$ is set to 6. In this case, the computational complexity of the proposed scheme is reduced to $\frac{1}{6}$ of the complexity of the conventional preFFT-STF. Fig. 4 (b) shows the BER performance of the proposed and conventional schemes versus the average $E_b/No$. It can be easily found that the proposed scheme can achieve nearly the same performance as the conventional one. Meanwhile, compared with the conventional scheme, the proposed scheme can reduce the computational complexity to about $\frac{1}{6}$, which demonstrate the validity of the proposed scheme.

ACKNOWLEDGMENT

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TABLE I

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<tr>
<th>Items</th>
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<tr>
<td>Modulation scheme</td>
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<td>Packet format</td>
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<tr>
<td>$L_T, L_R$</td>
<td>2, 3</td>
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<tr>
<td>$N_U$</td>
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<tr>
<td>Number of subcarriers</td>
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<td>Symbol duration: $T_s$</td>
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<tr>
<td>FFT points: $N$</td>
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<tr>
<td>Doppler spread</td>
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<td>Forgetting factor</td>
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(a) BER versus $P$

(b) BER versus average $E_b/No$

Figure 4. BER performance
REFERENCES


