Study on Multi-user Detection Technology of MIMO-OFDM System

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Abstract: This article introduces the detection method of MIMO-OFDM, then introduces the V-Blast algorithm and compares the main interference cancellation algorithms. Finally, combining the advantages of the OBF algorithm and the V-BLAST signal detection algorithm, an improved OBF algorithm is proposed.

1. Introduction

Signal multipath fading and spectrum utilization are the most serious two challenges in wireless communication systems. Orthogonal frequency division multiplexing (OFDM) converts a frequency-selective fading channel into a flat channel in the frequency domain, which finally contributes to a lower effect of multipath fading. Multiple input multiple output (MIMO) technology uses the space freedom provided by multiple transmitting and receiving antennas to improve the spectrum efficiency of wireless communication system, which finally improves the transmission rate and communication quality. By using the advantages of both MIMO technology and OFDM technology, MIMO-OFDM system is able to realize a high transmission rate and high reliability, making it enjoy extensive application prospect in the field of wireless communication. However, in a MIMO-OFDM system, there may be multiple users communicating at the same frequency and time. In this case, multiple user signals will influence and interfere with each other, which highlights the detection and separation of user signals[1].

To solve this problem, this paper proposes the multi-user detection (MUD) technology, which can make full use of information of all user signals to detect each user’s information it is interested in on the basis of the traditional detection technology. Therefore, it solves the problem of anti-interference and near-far effect, and can effectively solve the problem of user detection and separation in MIMO-OFDM system. This paper also proposes an improved algorithm, which combines the orthogonal beamforming algorithm with equal power eigenvector and V-BLAST algorithm based on ZF-ordering SIC[2].

2. Multi-user Detection of MIMO-OFDM System

2.1. Traditional Multi-user Detection Method

Since 1979 when the idea of multi-user detection was first proposed, various multi-user detection methods have emerged, which can be roughly divided into optimal multi-user detection and sub-optimal multi-user detection. At present, sub-optimal multi-user detection is widely studied, which includes linear and nonlinear detection. To be specific, according to difference of the detection ways,
linear detection can be divided into two types: blind linear detection and non-blind linear detection. For non-blind linear detection, the linear transformation is first carried out to the output matrix of the matched filter, before making correlation decision. Interference cancellation is the main method in nonlinear detection, that is, the interference caused by multi-access and multi-path is estimated first, before the interference value is subtracted[3].

2.2 Orthogonal Beamforming

It is generally assumed according to the traditional multi-user joint beamforming method that each user uses one transmitting antenna and multiple receiving antennas are used for receiving. For uplinks, it is assumed that each transmitter knows its own channel information (CSI) and the receiver knows the channel information of all users.

The main indicators of the algorithm guidelines specifically introduced are mean square error (MSE) and signal to interference and noise ratio (SINR)[4].

3. Research on Improving Orthogonal Beamforming Algorithm

Orthogonal beamforming algorithm is to optimize the user signal detected, so as to achieve the signal quality required by the system. User signal detection can be considered to improve this algorithm. If the desired performance can be achieved while detecting user signals and then superposed to the orthogonal beamforming algorithm, the system performance can be improved. However, in the MIMO system, the receiving end receives multiple signals which are overlapping with each other both in time and frequency band. In the frequency-selective fading system, there is inter-code interference between signals at different times. Therefore, the performance of signal detection in MIMO system will directly affect the detection of the whole MIMO system[5].

3.1 V-BLAST signal detection algorithm

Essentially speaking, V-BLAST is a spatial feedback equalizer, which determines the detection order of each signal according to the SINR[4]. In BLAST structures, data is organized in layers, and detection of such structures is commonly referred to as layered detection. V-BLAST algorithm using layered detection has lower computational complexity than MIMO-ML detection or MIMO-quasi-ML detection but can get better performance, making it very practical detection algorithm. The specific V-BLAST signal detection algorithm will be studied in the following[6].

It is assumed that the received signal vector of the complex baseband of V-BLAST system model is [7]:

\[ \mathbf{r} = \mathbf{Hx} + \mathbf{n} \]  \hspace{1cm} (1)

where \( \mathbf{x} = [x_1 \cdots x_N]^T \) is the vector of the emitted signal, \( \mathbf{n} = [n_1 \cdots n_N]^T \) is the noise vector and \( \mathbf{H} = [h_1 \cdots h_N]^T \) is the channel matrix. The above can also be expressed as:

\[ \mathbf{r} = \sum_{j=1}^{N} h_j x_j + \mathbf{n} \]  \hspace{1cm} (2)

The \( i \)th received signal vector after eliminating interference can be expressed as:

\[ \mathbf{r}_i = \mathbf{r} - \sum_{j=1}^{N} \hat{h}_j \hat{x}_j \]  \hspace{1cm} (3)

where \( \hat{x}_j \) is the detected symbol. Assuming \( \hat{x}_j \) is correct, then Formula (3) can be expressed as:

\[ \mathbf{r}_i = \mathbf{r} - \sum_{j=1}^{N} h_j \hat{x}_j = \sum_{k=1}^{N} \hat{h}_k \hat{x}_k \]  \hspace{1cm} (4)

The main interference elimination algorithms are introduced in the following.
3.1.1. The comparison of the main interference elimination algorithms

![Performance comparison of signal detection method about MIMO](image1)

**Fig 1. Performance comparison of signal detection method about MIMO**

![Performance comparison of ZF-OSIC and ZF-IPIC](image2)

**Fig 2. Performance comparison of ZF-OSIC and ZF-IPIC**

3.2. Improvement of Orthogonal Beamforming Algorithm

Through the comparison in the previous section, it is found that OBF method and V-BLAST algorithm can be combined to improve the system performance. Among them, ZF-OSIC method has better performance. Here, ZF-OSIC method and OBF method are combined. Therefore, the signal received by the receiving end given in the orthogonal beamforming algorithm can be expressed as:

\[
r = Hs + n
\]

where \( H = [H_1, b_1, H_2, b_2, \cdots, H_K, b_K] \), \( s = [s_1, s_2, \cdots, s_K]^T \).

Both the ZF-OSIC algorithm and the OBF algorithm need to know the channel matrix. When the two methods are combined, the channel matrix is a new channel matrix formed by the beamforming vector and the channel matrix of all users.

![The bit error rate of method of eigenvector OBF and ZF-OSIC](image3)

**Fig 3. The bit error rate of method of eigenvector OBF and ZF-OSIC**
4. Conclusion
This paper studies the MIMO-OFDM system and the orthogonal beamforming algorithm in the multi-user detection method and proposes an improved algorithm for this method. In other words, the ZF-ordering SIC-based signal detection algorithm is combined with the eigenvector beamforming algorithm, so that the improved algorithm could bring a better performance compared with the traditional orthogonal beamforming algorithm.

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