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Improved Multiuser MIMO Block Diagonalization

Yutao Li [1], Feng Li [1], Qingrui Guo [1], Xuerang Guo [1], Lin Ma [1], Bin Wang [1] ,Shuqi Qiu [1]
1. State Grid Xinjiang Electric Power Research Institute, Urumqi, China
1045332110@qq.com, kasuo5215@126.com, gqr1008@163.com , gxrgxr820@163.com,linma0406@163.com
wangbin2918@163.com,379378512@qq.com

***Abstract*—This paper analyzes the status quo of the precoding algorithm, and puts forward a power allocation mode called SINR, which has low computation complexity in the precoding relative to the water-filling power allocation. This algorithm obtains the precoding matrix by SVD singular value decomposition and uses SINR to realize the power allocation. Due to the avoidance of the iterative computation of the water flooding principle, the computational complexity of the power allocation is reduced. At the same time, the system and capacity and bit error rate have significantly improved over traditional average power allocation.**

***Keywords*—Power Allocation; Computational Complexity; Multiple Input; Multiple Output; Block Diagonalization**

I. INTRODUCTION

With the rapid development of mobile wireless networks, the demand for network upload and download capabilities has increased.Multiple Input Multiple Output（MIMO）Antenna system becomes one of the research hotspots. Because MIMO technology can increase the capacity of the communication system [1] and improve the communication quality, it has become one of the key technologies of the fourth generation of communication LTE Zhongguan, and it has begun to receive widespread attention.In simple terms, MIMO technology uses multiple antennas at the base station and the user end to form a multiple-input multiple-output communication link. From the perspective of the number of users, MIMO communication can be subdivided into a multi-user MIMO communication system and a single-user MIMO communication system. In a multi-user MIMO system, multiple users share the same frequency band for communication with the base station, resulting in inevitable mutual channel interference between users.（Co-Channel Interference CCI）In simple terms, MIMO technology uses multiple antennas at the base station and the user end to form a multiple-input multiple-output communication link. From the perspective of the number of users, MIMO communication can be subdivided into a multi-user MIMO communication system and a single-user MIMO communication system. In a multi-user MIMO system, multiple users share the same frequency band for communication with the base station, resulting in inevitable mutual channel interference between users. How to make CCI be eliminated and reduced to improve the communication quality has become one of the research hotspots.

Dirty paper coding（DPC）[2] can improve communication quality and increase system capacity. However, due to its relatively high computational complexity, it is difficult to apply to an actual communication system. Therefore, a compromise between complexity and communication quality, some relatively simple linear precoding algorithms such as Block Diagonalization（BD）[3-4]、Zero-Forcing（ZF）[5]、Signal to Leakage and Noise Radio（SLNR）[6] And criteria Minimum Mean Square Error (MMSE) began to replace nonlinear precoding algorithms.

For any pre-coding algorithm, the corresponding power distribution is essential to obtain better bit error rate and capacity. Take the BD algorithm as an example, it combines fair power distribution or power distribution of the water injection principle. In the two distribution methods, the former is relatively poor, while the latter has higher computational complexity. To solve this problem, this paper proposes a power allocation method that combines the maximum signal to interference noise ratio (SINR) under the BD algorithm. It can reduce the bit error rate and increase the system's capacity while optimizing the transmission power. It is also relative to water injection. The complexity of the principle has declined.

II. THE MUTI-USER MIMO SYSTEM MODEL

We assume that the number of transmit antennas configured by the base station is M, the number of receive antennas per user configured is NK, and the number of users is set to K, so the total number of antennas at the user end is $N=\sum_{k=1}^{K} N_k$（$M \geq N$）. We only consider the case where the channel is a flat fading channel, And under the condition that the base station knows all the channel state information, it is assumed that the signal sent by the base station to each user is X=[X1,X2,..........XK], For any user k, the received signal named y_k can be expressed as:

$$y_k=H_k\sum_{i=1}^{K}\sqrt{P_i}W_iX_i+n_k=H_k\sqrt{P_k}W_k+H_k\sum_{i=1,i\neq k}^{K}\sqrt{P_i}W_i+n_k \quad (1)$$

In formula (1), y_k is the receive signal，X_i is the transmit signal，W is the precoding matrix，H_k is the channel matrix，$\sqrt{P}$ is the diagonal matrix representing the power，and n_k is the Gaussian white noise that follows the N（0，$\partial^2 I_k$） distribution. In this paper, we assume that this state information for any channel matrix is known. In order to simplify the complexity of the system, we use the encoded BD algorithm at the sender to eliminate interference and control noise to reduce their impact on the useful signal.

III. PRECODING ALGORITHM AND POWER ALLOCATION ALGORITHM

In this section, we mainly divide the precoding algorithm and the power distribution method into two parts for comprehensive description and analysis. First, for the detailed description of the precoding algorithm, the block diagonalization algorithm is used in this paper to precode the channel; second, the SINR power allocation proposed in the text is introduced, and the classical average power method and the water injection principle are compared. The power allocation algorithm compares the power allocation algorithm.

A. Precoding based on block diagonalization algorithm

The block diagonalization (BD) algorithm requires minimal interference between users. Therefore, the precoding matrix W_k for any user k Need to meet the zero space requirements of other user channels as much as possible, that is, to achieve $W_k H_i = 0,\ i \neq k$. In this formula, We assume that the H_k lines are linearly independent. We can get the precoding matrix by using singular value decomposition (SVD):

$$\tilde{H}_k = \tilde{U}_k\ [\tilde{D}_k\ 0]\ [\tilde{V}_k^{(1)} \dot{V}_k^{(0)}] \qquad (2)$$

In the formula, $\dot{V}_k^{(0)}$ can be regarded as an orthogonal base on $\tilde{H}_k$, and The H_k and $\dot{V}_k^{(0)}$ can obtain the independent parallel channels of each user in the MIMO system. $H_k \dot{V}_k^{(0)}$ can be viewed as an equivalent independent channel for any user k. In order to maximize the system and capacity, the system efficiency is improved and the singular value decomposition is performed on the $H_k \dot{V}_k^{(0)}$ by the block diagonalization algorithm:

$$H_k \dot{V}_k^{(0)} = U_k D_k V_k \qquad (3)$$

Defining $V_k^{(1)}$ is the first N_K term of V_k ,we can get the precoding matrix: $W_k = \dot{V}_k^{(0)} V_k^{(1)}$.

B. Power Allocation Algorithm

For the block-diagonal precoding (BD) algorithm, there are mainly two kinds of average power allocation and water injection algorithm. The average power allocation method is suitable under ideal conditions in which the state information of each channel is known and all have better channel conditions. However, in most cases, the transmission capability of each channel is not the same, and only the average power distribution method may cause limited results. The waste of resources, in serious cases, may result in transmission errors and failure to communicate properly.And for the water injection principle, which is based on the BD algorithm, after dividing each user's channel into N independent sub-channels, each user's channel of the multi-channel system can be equivalent to each bandwidth considered as B Sub-channels. The Shannon formula shows that the sub-channel capacity of user k is:

$$C(k) = \mathrm{Blb}\left(1 + |f_k|^2 \frac{p_k}{n_0}\right) \qquad (4)$$

In the formula, p_k , $|f_k|$, n_0 are the transmission power, frequency response, and noise component of thenumber k sub-channel, respectively. Because when N is large enough, the SNR of each channel can be considered as a constant. In the case of channel SNR, we can assign different power signals to each different channel to achieve the overall system and maximum capacity, so the maximum and capacity can be expressed as：

$$\max C = \sum_{k=1}^{N} Blb\left(1 + |f_k|^2 \frac{p_k}{n_0}\right) \qquad (5)$$

$$s.t. \begin{cases} \sum_{k=1}^{N} p_k = P \\ p_k \geq 0 (n=1,2,\ ...,N) \end{cases} \qquad (6)$$

P is the total power In this formula. According to the Lagrangian multiplier algorithm, the power p of any user can be obtained as:

$$p_k = \frac{B}{\lambda} - \frac{n_0}{f_k} \qquad (7)$$

λ is the Lagrangian multiplier factor, and $\frac{B}{\lambda}$ is called the water injection principle.

The principle of water injection can achieve the maximum system and capacity theory and get better communication quality, so it is widely used. However, because the selection of water injection lines is difficult, and because the Lagrange multiplier method uses the iterative algorithm to obtain the final power, the complexity is high. Under this condition, this paper proposes a relatively fair and reasonable use of sub-channels. The signal to interference to noise ratio (SINR) is used for power allocation, and the computational complexity is reduced when the system performance is not greatly affected. In order to obtain fair signal transmission opportunities for each user channel, the signal to interference plus noise ratio (SINR) of each signal is required before power allocation. For any user m, the user's channel is not considered when the user's allocated power is not considered first. The formula for the SINR is as follows：

$$SINR_m = \frac{\|H_m W_m\|^2}{N_k \partial^2 I_k + \sum_{j=1, j\neq m}^{K} \|H_m W_j\|^2}, m = 1,2,3,... \qquad (8)$$

After the channel signal to interference and noise ratio of user m is obtained, the power of the independent channel can be obtained by comparing the signal to interference and noise ratio with the total signal to noise ratio, expressed as:

$$p_m = P\frac{SINR_m}{\sum_{j=1}^{K} SINR_j}, m, j = 1,2..... \quad (9)$$

IV. ANALYSIS AND SIMULATION

The above power allocation algorithm is analyzed in terms of complexity, and the BD precoding algorithm and different power allocation methods are used to simulate the system's capacity and bit error rate. For convenience, the algorithm in this paper is called BD-SINR algorithm. Compared with the water injection principle algorithm, the BD-SINR power allocation algorithm reduces the computational complexity of the system by a factor of 1/K (it reduces the highest complexity from K2 to K) because it does not require iterative calculations. The BD algorithm and the BD-SINR algorithm for average power allocation are compared and simulated. The channel parameters can be set as follows: total power of transmission power P=1; total number of transmission antennas M=4; number of users K=4; reception The number of antennas Nk = 2, in order to facilitate the implementation of the simulation user data stream is set to the data flow system; the system is modulated by QPSK; coherence time is 300ms.

The simulation system is set according to the above parameters. The precoding algorithm is a block diagonalization (BD) algorithm. The power distribution method is compared with the average power allocation method. The SINR power allocation algorithm and the average power are allocated based on the system's capacity and error. The rate performance is compared to give the resulting image of the simulation. Select the number of iterations of 200 iterations of the loop to ensure that the output is more accurate.

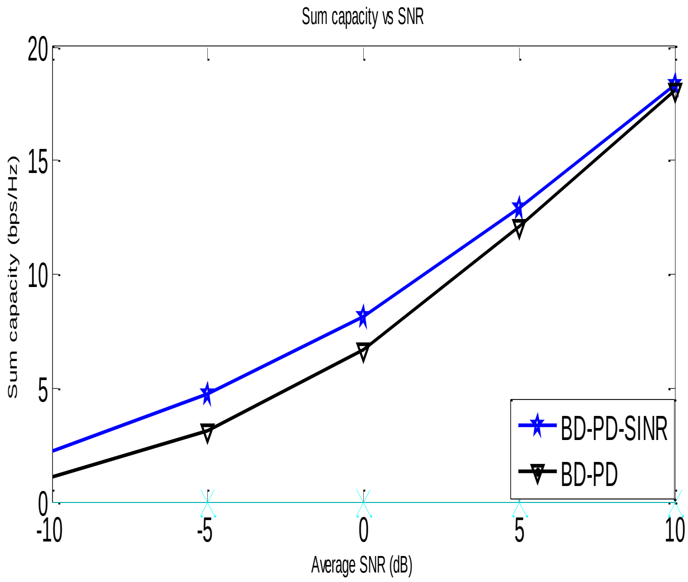

fig. 1. Comparison of two algorithms and capacities in a multi-user system

As can be seen from the figure, different power allocation algorithms under different user systems are different in capacity and under the same precoding algorithm. Compared with the average power allocation method, the BD-SINR has a relative increase in the signal-to-noise ratio and capacity, and as the signal-to-noise ratio continues to increase, the sum of the two algorithms is infinitely close to the capacity, with almost no difference. With the increase of SNR, the signal-to-interference-plus-noise ratio of each channel will be infinitely close. Therefore, due to the close signal to interference and noise ratio of each channel under high SNR conditions, the channel capacity will be almost the same, and at a lower level. The average power allocation in the SNR case cannot achieve better sum capacity, because the poor channel quality causes each channel to let the information channel with good signal noise to transmit more information. Therefore, the BD-SINR algorithm will have a better system at this time. And capacity performance.

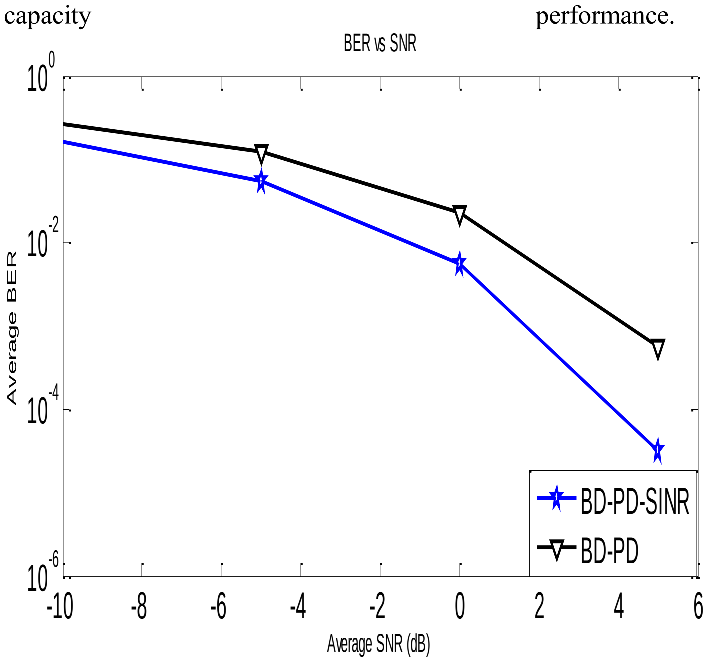

fig. 2. Comparison of Bit Error Rates of Two Algorithms in Multi-user System

As we can clearly see from the figure, the BER-SINR system has a significantly lower error rate than the BD algorithm combined with the average power allocation algorithm at a lower signal-to-noise ratio, and with an increase in the SNR, the SNR improves. The downward trend is even more pronounced because BD-SINR is faster. It is shown that the algorithm combining BD and SINR proposed in this paper has better BER performance than the traditional power distribution method, and can make the system channel transmission accuracy improve.

V. CONCLUSION

In this paper, a BD-SINR algorithm is proposed. The algorithm is based on the BD algorithm combined with the average power allocation algorithm. The power allocation method is improved. The signal to interference and noise ratio of the channel accounts for the total signal to interference and noise ratio. A way to distribute power in proportion. The theoretical analysis and simulation results show that the proposed algorithm has better capacity and bit error rate performance than the tie power allocation. Compared with the power allocation method, the algorithm reduces the system complexity. However, due to more reasons, the system is not perfect, and there is room for improvement. It is hoped that future researchers can use this as a reference for further improvement of the composition, and the bit error rate and capacity can be further improved.

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