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Joint Detection Method for Non-orthogonal Multiple Access System Based on Linear Precoding and Serial Interference Cancellation

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Abstract

In the non-orthogonal multiple access (NOMA) system, multiple user signals on the single carrier are superimposed in a non-orthogonal manner, which results in the interference between non-orthogonal users and noise interference in the channel. To solve this problem, an improved algorithm combining regularized zero-forcing (RZF) precoding with minimum mean square error-serial interference cancellation (MMSE-SIC) detection is proposed. The algorithm uses RZF precoding combined with successive over-relaxation (SOR) method at the base station to preprocess the source signal, which can balance the effects of non-orthogonal inter-user interference and noise interference, and generate a precoded signal suitable for transmission in the channel. At the receiver, the MMSE-SIC detection algorithm is used to further eliminate the interference in the signal for the received superimposed signal, and reduce the calculation complexity through the QR decomposition of the matrix. The simulation results show that the proposed joint detection algorithm has good applicability to eliminate the interference of non-orthogonal users, and it has low complexity and fast convergence speed. Compared with other traditional method, the improved method has lower error rate under different signal-to-interference and noise ratio (SINR).

Keywords

Joint Detection Algorithm, NOMA, RZF Precoding, Serial Interference Cancellation

1. Introduction

The user data services are growing rapidly with the development of information and communication technology. The development of wireless communication technology puts forward higher requirements on the data transmission rate. How to effectively improve the transmission performance of mobile communication systems has become one of the research focuses. Multiple-input multiple-output (MIMO) system combined with non-orthogonal multiple access (NOMA) technology [1,2] can greatly improve the spectrum efficiency and link utilization of the communication systems. So MIMO technology has become one of the key technologies in 5G wireless communication system [3,4].

In the NOMA technology, the power domain is introduced in the same subcarrier during the communication process between the base station and the users. So the multiple user signals are transmitted in the same subcarrier and differentiated by the superimposed power. Each user signal may suffer the co-

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channel interference (CCI) from other users. At the same time, it will form multiple signal components because of the signal reflection and refraction through the building. Since the multiple signal components have different delay, the superimposed signals will include mutual interference and noise interference in the channel [5]. To remove the interference, the precoding technology can be used to balance the interference and noise at the base station, or use interference cancellation technology to detect and eliminate the interference at the receiver.

In precoding technology, how to reduce the precoding complexity and ensure the algorithm performance is a difficult problem. The precoding technology includes linear precoding and nonlinear precoding [6]. In MIMO system, the nonlinear precoding technology can approximate the theoretical capacity upper limit for multi-antenna channel well. However, in the large-scale MIMO system, linear precoding technology is more suitable than nonlinear precoding technology [7,8]. The interference and noise can be reduced by designing an accurate precoding matrix. Its main idea is to combine the modulated signal with channel state information (CSI) through matrix operations and convert them into a signal adapted to the current channel [9]. Yang and Marzetta [10] proposes a simple and effective zero-forcing (ZF) precoding algorithm based on single-cell massive MIMO system. The channel orthogonalization for the target user and the non-target user can be achieved by finding the pseudo-inverse of the channel matrix. This method can reduce the interference between users and increase the system capacity. But the algorithm ignores the noise impact on the system performance. Kammoun et al. [11] proposes a regularization zero-forcing (RZF) precoding algorithm. The algorithm optimizes the precoding matrix by adding the load coefficients before the channel matrix calculation. The authors of [12] obtains the optimal regularization parameters, which improves the system performance than ZF algorithm. However, its performance reduced significantly when the antenna number is almost same for the base station and the receiver.

The receiving performance of the serial interference cancellation (SIC) receiver is closely related to the detection algorithm used by the receiver. The maximum likelihood (ML) detection is the optimal detection algorithm for bit error rate (BER) performance criteria. Although the ML detection algorithm can achieve the optimal performance in terms of BER performance and system capacity, it has high complexity. It is very difficult to apply to the practical applications when the system has too many modulation orders and antennas [13]. As discussed in [14], the SIC detection method based on soft demodulation algorithm is studied. Although it has better detection performance, it does not make full use of the signal characteristic information of other user signals. The minimum mean square error (MMSE) detection algorithm is studied in [15], which taking into account the effects of interference and noise on improving system performance. The authors in [16] further study the nonlinear multi-user detection algorithms in MIMO system, especially the performance of SIC algorithms in MIMO system.

In view of the above analysis, this paper combines RZF precoding with MMSE-SIC algorithm to jointly detect the signals at the transmitter and the receiver. It is assumed that the base station in a single cell is equipped with multiple antennas and the each user has a single antenna. At the base station, the RZF precoding technology is used to balance the noise and the interference between users. At the same time, this method reduces the computational complexity of the precoding matrix by the successive over-relaxation (SOR) iteration method. At the receiver, the MMSE detection algorithm is combined with the SIC receiver to detect the signal. At the same time, this method reduces the computation complexity by QR decomposition.

2. Key Principles of NOMA Downlink System

2.1 NOMA Single Cell System Model

In a multi-user single-cell, the base station installs M antennas. The K single-antenna users are installed on a single sub-carrier. The system model is shown in Fig. 1.

In the NOMA system, after linear precoding processing, the base station's transmit signal $x \in C^{M\times 1}$ can be expressed as

$$x = Ws \tag{1}$$

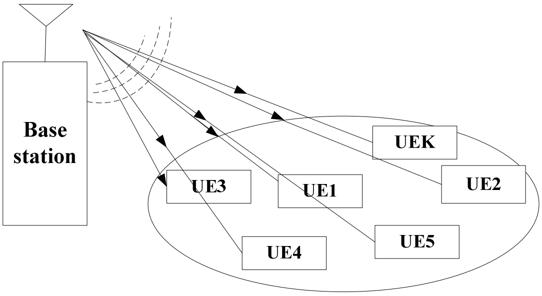


Fig. 1. Single-cell multi-user NOMA downlink system model diagram.

where signal $W \in C^{M\times K}$ is a linear precoding matrix and $s \in C^{K\times 1}$ is the source signal or the modulated information.

In the NOMA system, multiple access interference (MAI) on each sub-channel seriously affects system performance due to non-orthogonal transmission of user signals. In existing research, wireless communication can suppress multiple access interference through multi-user signal detection methods. The system uses a SIC receiver to detect the received signal. At the system receiver, the received signal can be expressed as

$$y_k = H_k \sum_{i=1}^{K} \sqrt{\beta_i P} x_i + n_k \tag{2}$$

At the receiver, the principle of the SIC algorithm based on the Mini-Mental State Examination (MMSE) criterion is to eliminate the current maximum user interference layer by layer. The algorithm detects the user signal with the highest signal-to-interference and noise ratio (SINR) according to the MMSE criterion, then eliminates the influence of the detected signal on all undetected signals, and gradually detects until all signals are detected.

2.2 Basic Principle of RZF Precoding

In the downlink of NOMA system, the main principle of linear precoding technology is to obtain CSI by using channel reciprocity to perform channel estimation on the base station side. Then it designs a precoding matrix for the acquired CSI information, and decomposes the user signal into parallel data streams to achieve anti-interference capability. Different linear precoding algorithms have different precoding matrices, and the transmitted signal gain is also different. The difference in the precoding matrix leads to the difference in the signal received at the user end. RZF precoding is an algorithm with excellent performance in linear precoding [17].

RZF precoding is an algorithm with excellent performance in linear precoding [17]. Before inverting the channel matrix, the RZF precoding algorithm balances the effects of noise interference and inter-user interference by adding regularization terms. The precoding matrix is defined as

$$W_{RZF} = \beta H^{H}\left(HH^{H} + \xi I_{K}\right)^{-1} \tag{3}$$

where β is the power normalization factor, scalar ξ is the regularization coefficient, which is related to the total transmit power and noise variance, H^H is the conjugate transpose of the channel matrix, I_K is the identity matrix.

2.3 Basic Principles of SIC Detection Technology

The SIC detection receiver detects the signal in a serial manner. Each stage only detects and decodes one user signal, and then reconstructs the first signal to obtain this the signal level. After that, the total received signal subtracts the first decoded reconstructed signal and then decodes to reconstruct the second signal. The remaining total signal subtracts the second signal, and then the third signal is decoded. This process is repeated in turn until all user signals are translated. At the same time, the interference between users is also eliminated step by step [18]. The SIC receiver principle is shown in Fig. 2.

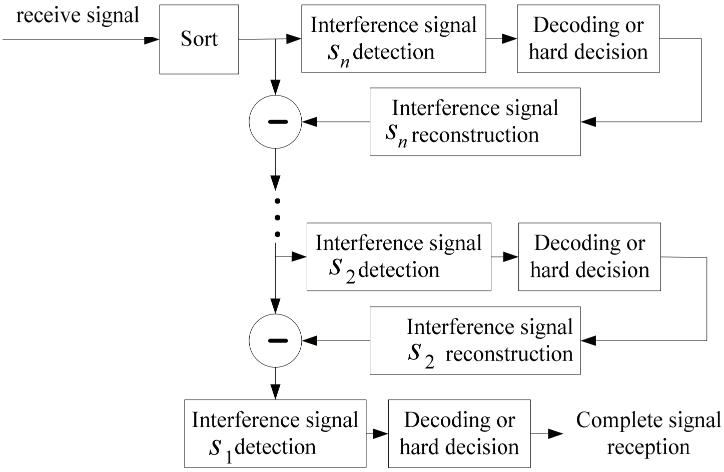


Fig. 2. Schematic diagram of the SIC receiver in the NOMA system.

It can be seen from Fig. 2 that the NOMA system needs to sort the user signals before using the SIC technology to detect and decode the signals. The sorting order of user signals directly affects the detection and elimination performance of SIC technology. The SIC detection ordering in the NOMA system is generally sorted according to the SNR or signal power of the user signals. After sorting, the currently detected signal is the user signal with the highest power among the remaining signals. The greater the power is, the smaller the SNR of the signal is. The priority detection of this signal is beneficial to protect the edge user signals and improve the reliability of signal detection. In the downlink of NOMA system, the base station uses power allocation techniques to allocate power to the signals. Different signals carry different powers. The user signal power does not change at the receiver. The receiver sorts the signals by the power from large to small. And then the signals are detected one by one, and finally the receiver correctly receives all user signals.

3. Research on Joint Detection Method based on RZF Precoding and MMSE-SIC NOMA Technology

In the system uplink, the receiver obtains CSI by performing channel estimation on the pilot signal, and then feeds back the information to the base station. In the time division duplex system, the downlink channel estimation result can be obtained by the uplink and downlink channel reciprocity. The transmitting end processes the signals through the RZF precoding algorithm and reduces the algorithm computational complexity by the SOR iterative method with parameters. This method can effectively balance the effects of inter-user interference and noise interference, and produce the signal suitable for transmission in the channel downlink. At the receiver, the SIC receiver uses the MMSE detection algorithm to perform interference signal detection and user self-signal detection, which can suppress the channel noise while eliminating interference and improve the overall system performance. In order to reduce the complexity of the MMSE-SIC detection algorithm, QR decomposition is used to further reduce the interference between users. The overall block diagram is shown in Fig. 3.

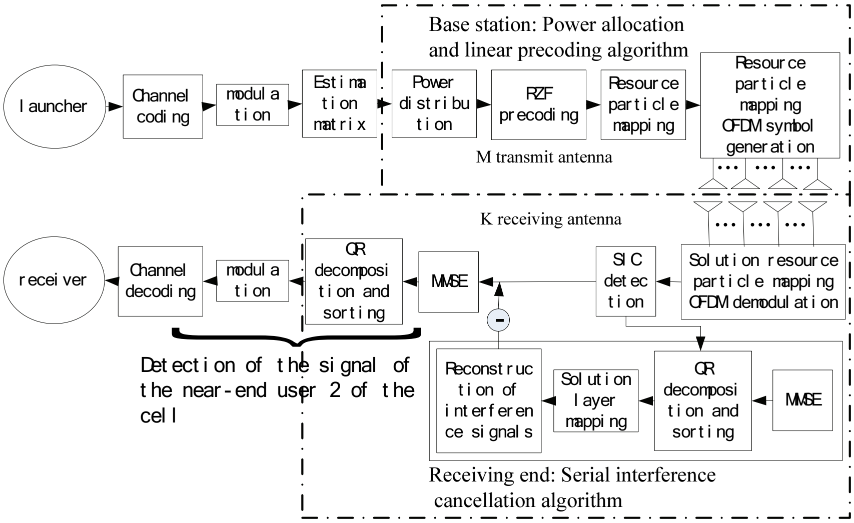


Fig. 3. Block diagram of the joint detection algorithm of this scheme.

3.1 RZF Precoding Technology based on Iterative Method

In (3), in order to simplify the calculation and reduce the computational complexity, here let $G = HH^H + \xi I_K$, W_{RZF} can be expressed as

$$W_{RZF}=\beta H^{H}G^{-1} \tag{4}$$

RZF precoding involves a high complexity operation for calculating the matrix inversion. Therefore, the precoding technology can simplify the G matrix and reduce the complexity. G is substituted into (1) to obtain the following equation.

$$x=\beta H^{H}G^{-1}s \tag{5}$$

In the flat Rayleigh channel, the channel matrix H is a full rank matrix. For a $k \times 1$ non-zero vector q, $q^{H}HH^{H}q = q^{H}H(q^{H}H)^{H}$, then $q^{H}H \neq 0$, $q^{H}H(q^{H}H)^{H} > 0$, so HH^{H} is a Hermitian positive definite matrix. From the above analysis, G matrix is still a Hermitian positive definite matrix. The algorithm decomposes the G matrix into $= D + L + L^{H}$, where D, L, and L^{H} represent the diagonal component of G, the strict lower triangular component, and the strict upper triangular component. The solution to the linear equation $\hat{s} = G^{-1}s$ by the super-relaxation iteration method is

$$\widehat{s}^{i+1}=\left(D-\gamma L\right)^{-1}\left\{\left[\left(1-\gamma\right)D+\gamma L^{H}\right]\widehat{s}^{i}+\gamma s\right\} \tag{6}$$

where the superscript i is the number of iterations, γ is the relaxation factor and $\gamma > 0$. On this basis, the algorithm introduces the trade-off parameter η to improve the SOR as shown in the following formula.

$$\widehat{s}^{i+1}=\left(\eta D-\gamma L\right)^{-1}\left\{\left[\left(\eta-\gamma\right)D+\gamma L^{H}\right]\widehat{s}^{i}+\gamma s\right\} \tag{7}$$

where η is the added parameter. When $\eta = 1$, it is the original SOR method. When η changes within a certain range, the algorithm can find the optimal iteration value faster. $\hat{s}^{(0)}$ represents the initial value, usually taking a zero vector of $K \times 1$ as the solution of $\hat{s}^{(0)}$.

This algorithm compares the spectral radius with the convergence of the original SOR iterative method. The algorithm analyzes the spectral radius of the iterative method according to the weak regular splitting principle of the matrix. In (6), let $G = M_1 - N_1$, then the SOR iteration matrix is $T_{SOR} = M_1^{-1}N_1$, where

$$M_1=\frac{1}{\gamma}\left(D-\gamma L\right) \tag{8}$$

$$N_1=\frac{1}{\gamma}\left[\left(1-\gamma\right)D+\gamma L^{H}\right] \tag{9}$$

$$M_1^{-1}=\left[\frac{1}{\gamma}\left(D-\gamma L\right)\right]^{-1}=\gamma\left\{D+\left(\gamma L\right)+\left(\gamma L\right)^{2}+\cdots\right\}\geq 0 \tag{10}$$

So, $T_{SOR} = M_1^{-1}N_1 \geq 0$. On the other hand, in (7), let $G = M_2 - N_2$, then the SOR iteration matrix is $\tilde{T}_{SOR_\eta} = M_2^{-1}N_2$, where

$$M_2=\frac{1}{\gamma}\left(\eta D-\gamma L\right) \tag{11}$$

$$N_2=\frac{1}{\gamma}\left[\left(\eta-\gamma\right)D+\gamma L^{H}\right] \tag{12}$$

$$M_2^{-1}=\left[\frac{\eta}{\gamma}\left(D-\frac{\gamma}{\eta}L\right)\right]^{-1}=\frac{\gamma}{\eta}\left\{D+\left(\frac{\gamma}{\eta}L\right)+\left(\frac{\gamma}{\eta}L\right)^{2}+\cdots\right\}\geq 0 \tag{13}$$

So $\tilde{T}_{SOR_\eta} = M_2^{-1} N_2 \geq 0$. From $0 < \gamma \leq \eta < 1$, comparing the elements of $M >_2^{-1}$ and M_1^{-1}, $M_2^{-1} \geq M_1^{-1}$, thus the spectral radius $\rho(\tilde{T}_{SOR_\eta}) \leq \rho(T_{SOR})$. The algorithm convergence rate is $R(T_{SOR}) = -\ln(p(T_{SOR}))$, $R\left(\tilde{T}_{SOR_\eta}\right) = -\ln\left(p\left(\tilde{T}_{SOR_\eta}\right)\right)$. It can be obtained $R\left(\tilde{T}_{SOR_\eta}\right) \leq R(T_{SOR})$ according to the relationship of spectral radius. So the SOR iteration with parameters is faster than the SOR iteration method. The signal vector after precoding is

$$x = \beta H^H \widehat{s}^{(i+1)} \tag{14}$$

The properties of D matrix and L matrix can get that $\eta D - \gamma L$ is a lower triangular matrix, so the algorithm can get $\hat{s}^{(i+1)}$ through a less complex calculation process. G is a positive definite matrix. When $0 < \gamma \leq \eta < 1$, this algorithm converges for any initial solution.

3.2 Receiver MMSE-SIC Detection Technology Processing

For MMSE detection technology, the weight matrix based on the MMSE criterion w_{MMSE} is defined as

$$w_{MMSE} = \left(H^H H + \delta^2 I\right)^{-1} H^H \tag{15}$$

where the channel noise obeys $(1, \delta^2)$. The output of the signal through the MMSE linear filter is

$$\hat{x} = \left(H^H H + \delta^2 I\right)^{-1} H^H y \tag{16}$$

Here introduces the extension matrix $\underline{H}$ of the channel matrix H and the extension matrix $\underline{y}$ of the received signal as follows.

$$\underline{H} = \begin{bmatrix} H \\ \delta I \end{bmatrix}, \underline{y} = \begin{bmatrix} y \\ 0 \end{bmatrix} \tag{17}$$

Based on the above definition, (16) can be rewritten as

$$\hat{x} = \left(\underline{H}^H \underline{H}\right)^{-1} \underline{H}^H \underline{y} \tag{18}$$

This algorithm applies the MMSE criterion to the QR decomposition, and performs QR decomposition on the extended channel $\underline{H}$ in (17) to obtain the following result.

$$\underline{H} = \begin{bmatrix} H \\ \delta I \end{bmatrix} = QR = \begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} R = \begin{bmatrix} Q_1 R \\ Q_2 R \end{bmatrix} \tag{19}$$

where Q is a unitary matrix, and each column is orthogonal to each other. This part decomposes Q into a Q_1 matrix and a Q_2 upper triangular matrix. R is also an upper triangular matrix. After the QR decomposition of the extended channel matrix, the extended receiver vector $\underline{y}$ is

$$\underline{y} = QRx + \underline{n} \tag{20}$$

where $\underline{n} = [n^T - \delta^2 x^T]^T$. The estimated value of x is as follows.

$$\hat{x} = R^{-1}Q^{H}\underline{y} \tag{21}$$

Defining the sufficient statistic $R\hat{x}$ of the transmitted signal x as $\hat{x}$, it can be expressed as

$$\tilde{x} = Q^{H}\underline{y} = Rx + Q^{H}\underline{n} = Rx - \delta^{2}Q_{2}^{H}x + Q_{1}^{H}n \tag{22}$$

The SIC technology detects and eliminates interference signals in a certain order. Since the transmitting end allocates different transmission power to each user when performing power multiplexing. The receiver distinguishes users according to different power allocation factors, and detects signals in descending order of allocated power.

3.3 Two-User Signal Joint Detection Implementation Steps

This algorithm takes two users as examples to illustrate the detection steps in detail. Suppose the cell edge user is UE1 and the cell center user is UE2. The base station allocates power for the signals of users, then linearly superimposes and finally transmits them with the same time-frequency resource. According to the NOMA system power allocation criterion, the power allocated to the UE1 is larger, so that when the receiver detects the signal of the UE1, the signal x_2 of the UE2 is regarded as noise processing.

1) Signal detection at the UE1 end

Extend the signal received by the UE1 end, and the received signal can be expressed as

$$\underline{y}_{U1} = Q_{U1}\mathrm{R}_{U1}\left(\sqrt{\beta P}x_{U2} + \sqrt{(1-\beta)P}x_{U1}\right) + \underline{n}_{U1} \tag{23}$$

The specific detection steps are as follows.

Step 1: Decompose the QR matrix according to the weight matrix w_{MMSE} to obtain the Q matrix and the R matrix.

Step 2: Use an improved detection algorithm.

$$\tilde{x} = Q_{U1}^{H}\underline{y}_{U1} = Q_{U1}^{H}\left(Q_{U1}\mathrm{R}_{U1}\left(\sqrt{\beta P}x_{U2} + \sqrt{(1-\beta)P}x_{U1}\right) + \underline{n}_{U1}\right) \tag{24}$$

Step 3: Estimate the signal normalization.

$$\breve{x}_{U1} = \frac{\tilde{x}}{\sqrt{(1-\beta)P}} \tag{25}$$

where $\breve{x}_{U1}$ is the UE1 detection signal.

2) Signal detection at the UE2 end

Extend the signal received by the UE2 end, and the received signal can be expressed as

$$\underline{y}_{U2} = Q_{U2}\mathrm{R}_{U2}\left(\sqrt{\beta P}x_{U2} + \sqrt{(1-\beta)P}x_{U1}\right) + \underline{n}_{U2} \tag{26}$$

According to the main idea of the SIC detection algorithm, the receiver needs to eliminate the interference caused by the UE1 signal. The specific steps are as follows.

Step 1: Decompose the QR matrix according to the weight matrix w_{MMSE} to obtain the Q matrix and the R matrix. Here estimates the interference signal to get

$$\lceil \breve{x}_{U1} \rceil = \left\lceil \frac{\tilde{x}}{\sqrt{(1-\beta)P}} \right\rceil \tag{27}$$

where ⌈ ⌉ represents a signal that does not require channel decoding but has not undergone demodulation and decision.

Step 2: Reconstruct the interference signal, demodulates the estimated value $\lceil \breve{x}_{U1} \rceil$ of the edge user signal and remodulates it into $\breve{x}_{U1}$ without channel decoding.

Step 3: Eliminate the interference signal and normalizes the residual signal energy.

$$\bar{x}_{U2} = \frac{y_2 - \sqrt{(1-\beta)}PQ_{U2}\mathrm{R}_{U2}\breve{x}_{U1}}{\sqrt{(\beta)}P} \tag{28}$$

Step 4: Use the improved detection method to get the UE2 estimated value.

$$\breve{x}_2 = Q_{U1}^{H}\bar{x}_{U2} \tag{29}$$

Step 5: Demodulate and decode the center user signal estimate $\breve{x}_2$ to recover the desired signal.

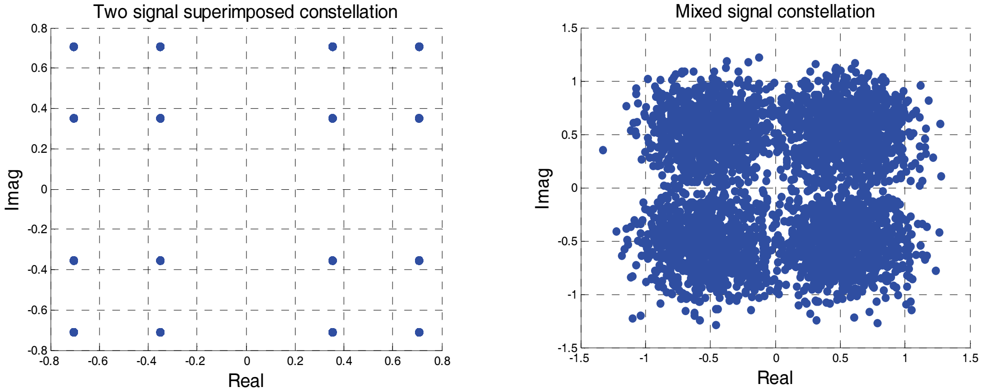
4. Simulation Results and Analysis

The algorithm is simulated in the MATLAB environment. It combines the precoding algorithm with the MMSE-SIC algorithm to detect two user signals and analyze the BER. The algorithm simulation parameters are listed in Table 1.

Table 1. Simulation parameter configuration

Parameter type	Parameter size
Wireless access solution	OFDM
Base station antenna	4
User number	2
Near end user modulation	QPSK
Remote user modulation mode	QPSK
Channel decoding method	Turbo decoding
Channel model	EVA
Channel estimation	Ideal

The SIC uses a joint precoding algorithm and an improved MMSE detection algorithm to detect the signal. It is assumed that a single carrier transmits two user signals, one remote user 1 and one near end user 2 are located in the cell. A power allocation algorithm is used to distribute power for two-user signals at a signal-to-noise ratio (SNR) of 20 dB. The algorithm separately modulates the two-symbol signal by quadrature phase shift keying (QPSK), and multiplies the allocated power by the modulated signal to obtain the modulated signal after carrying the power. After the signal is allocated power, it is needed to superimpose the signal and then transmit it. As shown in Fig. 4, Fig. 4(a) is a constellation diagram of the two-user superimposed signal. The signal is transmitted in the analog channel, and the noise is introduced to interfere with the signal. Fig. 4(b) is a signal constellation diagram transmitted in the channel after adding noise, which contains two useful signals and noise.



(a) (b)

Fig. 4. Transmitter user transmission signal diagram: (a) constellation diagram of the two-user superimposed signal and (b) signal constellation diagram transmitted in the channel after adding noise.

The algorithm uses a precoding algorithm to process the superimposed mixed signal, reduce interference and noise between users, and then transmit the signal to the receiver. According to the SIC interference cancellation principle, at the user 1 receiver, the algorithm directly detects the decoded user 1 signal. At the user 2 receiver, the algorithm needs to first detect the decoding user 1 signal, and then cancel the user 1 signal and then decode the user 2 signal. Here takes user 2 receiving signal as an example to analyze the algorithm performance, as shown in Figs. 5–7.

At the user 2 receiver, the algorithm sorts the total received signals according to the power from large to small. The algorithm first performs the first-level detection and decodes on the signal with the highest power. The detection method uses the MMSE-QR algorithm to decode the detected signal to obtain the signal constellation diagram as shown in Fig. 5. The method subtracts the signal of the first stage detection and decodes from the total signal to obtain the total input signal of the second stage, as shown in Fig. 6, where the signal contains the user 2 signal and the noise. The method uses the same MMSE-QR detection algorithm to detect and decode the signal to obtain a constellation diagram of the user 2 detection signal and the modulated signal, as shown in Fig. 7.

Fig. 8 is a comparison of the performance of ZF, MMSE, ZF-SIC, MMSE-SIC and the proposed algorithm. The simulation results show that when the two signals power distribution ratio (P1, P2) is (0.2, 0.8), the performance of the ZF-SIC algorithm and the MMSE-SIC algorithm combined with the detection algorithm and the SIC algorithm are better than the traditional ZF algorithm. This result reflects the superiority of joint detection method. The MMSE-SIC detection effect is better than the ZF-SIC detection effect. The proposed algorithm uses the combination of precoding and MMSE-SIC detection based on MMSE-SIC detection. The simulation results show that this algorithm performance is significantly better than MMSE-SIC algorithm and ZF-SIC algorithm. When the BER is 1%, its SINR is lower than the MMSE-SIC and ZF-SIC algorithms by 6 dB and 8 dB, respectively, the BER decreases with the increase of the SNR. When the SNR = 30 dB, the BER of the joint detection algorithm is BER = 0.01%.

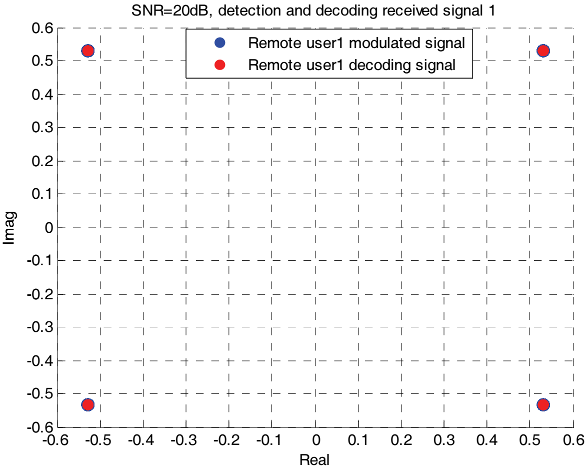


Fig. 5. Comparison of SIC receiver decodes user 1 signal and modulation signals.

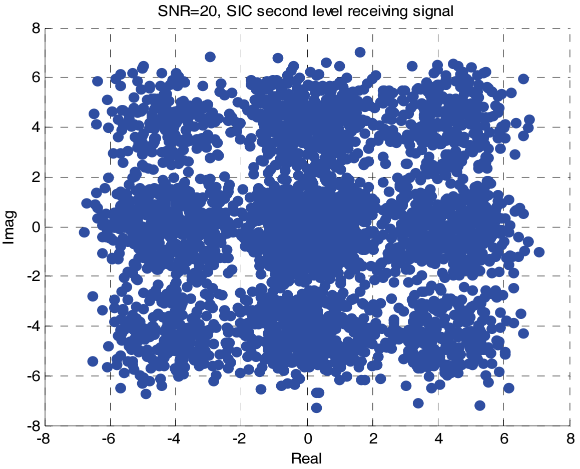


Fig. 6. SIC second stage cancel signal 1 received signal.

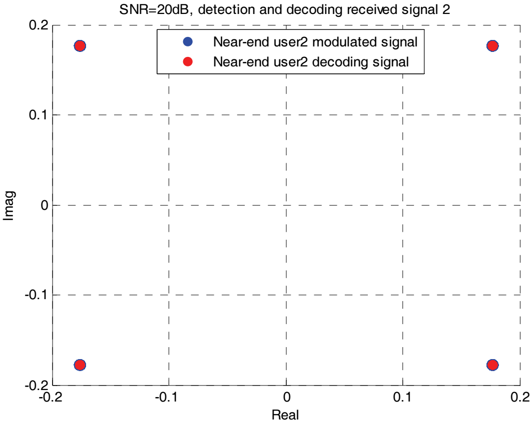


Fig. 7. Comparison of SIC second level decoded signal and modulation signals.

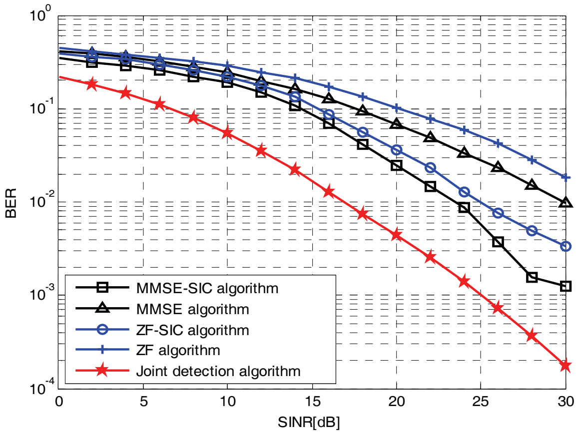


Fig. 8. NOMA system SIC receiver this joint detection algorithm and other traditional algorithm simulation comparison chart.

Fig. 9 is a performance comparison diagram of the joint detection algorithm and the conventional SIC detection algorithm under different power allocations. The simulation results show that when the power distribution ratio (P1, P2) is (0.2, 0.8) and the SINR is 18 dB, the BER of the traditional SIC receiver is 7.34%, and the error rate of the joint detection algorithm is 0.75%. When the power distribution ratio (P1, P2) is (0.3, 0.7) and the SINR is 18 dB, the BER of the traditional SIC receiver is 9.17%, and the error rate of the joint detection algorithm is 1.32%. Moreover, with the increase of the SNR, the joint detection algorithm performance is better.

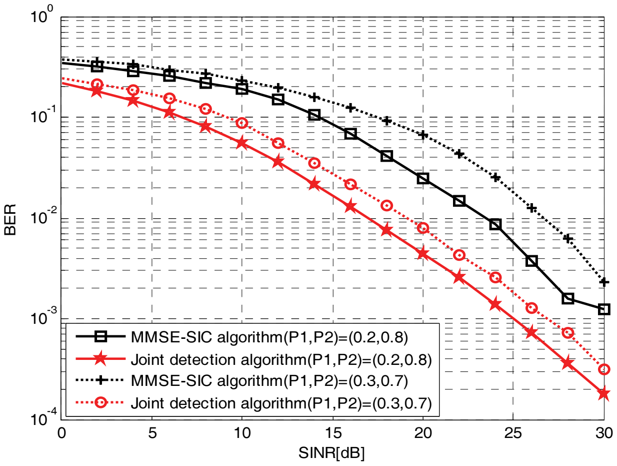


Fig. 9. Simulation comparison of the joint detection algorithm and MMSE-SIC algorithm under different power allocations.

5. Conclusion

This paper studies the signal detection method in the NOMA systems. The algorithm processes the signal at the transmitting end and the receiver to achieve the ability to eliminate interference and correctly detect the signal. At the base station, the algorithm uses RZF precoding technology to process the signals so that the signal has better anti-interference ability before transmitting in the channel. At the receiver, the algorithm uses SIC technology to detect the signals sequentially and the detection technology is realized by MMSE combined with QR decomposition, which has stronger signal detection capability. Simulation results show that the improved algorithm has better performance and lower BER than traditional algorithms. However, this algorithm uses a SIC algorithm, so the signal needs to be detected one by one, which adds the algorithm complexity.

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