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A Detection Decoding of Adaptive Iterative Algorithm Based on MIMO System

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Abstract: In this paper, the MIMO system and multi-user detection theory are firstly described. According to the signal model, the estimation algorithm based on the minimum mean square error criterion and the zero-forcing criterion is analyzed. Based on this theory, the algorithm is combined with the decision feedback and the optimal ranking idea. In this paper, an adaptive length spherical iterative decoding algorithm is proposed to improve the BER performance of the system, which can improve the channel capacity and improve the channel reliability and reduce the bit error rate. Finally, the performance of various algorithms is compared by simulation. The experimental results show that the spherical decoding algorithm has great advantages for wireless communication.

1. Introduction

Multi-Input Multiple-Output (MIIMO) technology was first proposed by Marconi in 1908 to protect against channel fading by using multiple antennas. It can be simply defined as: In an arbitrary wireless system, both the originating and receiving ends of the link use multiple antennas, including single-input multi-output systems and multiple-input single-out systems. The core idea of MIMO is to separate the signals at the transmitting end and combine the signals of the receiving antennas, so that the transmission quality of each MIMO user, the bit error rate (BER) or data rate, is improved, and the network service quality is improved. MIMO technology can take advantage of multipath effects as a favorable factor to multiply the capacity and spectrum utilization of communication systems without increasing bandwidth. Ideally, the channel capacity of a MIMO system increases linearly with the number of transmit antennas and the minimum number of receive antennas, providing the potential for capacity not currently available with other technologies. Multi-antenna transmission and reception technology is a combination of spatial diversity and time diversity technology, and has good anti-interference ability. If the multi-antenna transmission and reception technology can be further combined with channel coding technology, system performance can be improved to a greater extent.

Another research hotspot in the field of MIMO technology is space-time coding. Common space-time codes include layered space-time codes, space-time trellis codes, and space-time block codes. The main idea of space-time codes is to use space and time coding to achieve certain spatial diversity and time diversity, thereby reducing the channel error rate. MIMO wireless communication technology uses space-time processing technology for signal processing. In multi-path environment, wireless MIMO system can greatly improve spectrum utilization and increase system data transmission rate.

MIMO technology utilizes multiple antennas to achieve multiple transmissions and multiple receptions, fully exploiting spatial resources, and can multiply channel capacity, while also improving channel reliability and reducing bit error rate. The combination of multi-user detection technology and MIMO can further improve transmission efficiency. However, in the research of multi-user detection in MIMO system, although the full-space maximum likelihood (ML) detection can obtain the optimal detection performance, its algorithm complexity is too high to be practically applied, so the research complexity is low. The multi-user detection algorithm with performance close to ML is of great significance, MMSE algorithm, ZF algorithm, and improved MMSE-SIC

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algorithm and ZF-SIC algorithm.

1.1 Adaptive length spherical decoding algorithm

In the BLAST test, the ZF (zero forcing) algorithm, the MMSE (minimum mean square error) algorithm, the OSIC (sorted continuous interference cancellation) or the ML (maximum likelihood) criterion are currently used for decoding. The first three algorithms are simpler to implement, but the bit error rate performance is poor. However, using ML detection can get better performance, but its complexity is higher and it is not easy to implement. The SD (Spherical Decoding) algorithm based on ML detection is a performance optimization and moderate detection algorithm. It has been proved that the complexity of the ML detection algorithm using exhaustive search increases exponentially with the number of antennas, and the complexity of the SD algorithm has a polynomial relationship with the number of antennas in a large SNR range. Therefore, the SD algorithm can obtain maximum likelihood decoding performance with a small amount of computation.

1.2 System principle and model of sphere decoding

The basic idea of sphere decoding is to search for grid points in a multi-dimensional sphere with a radius d centered on a vector x, and reduce the number of points searched by limiting or reducing the search radius, thereby reducing the computation time. The advantage of the sphere decoding algorithm is that it does not need to search all the grid points in the whole grid as in the traditional maximum likelihood decoding algorithm, but only needs to search in a predetermined finite sphere area. If the number of points in the area is quite small relative to the total number of points in the entire grid, the search time will be greatly reduced.

The key issues affecting sphere decoding are: (1) How to choose the search radius d. If d is too large, the ball will contain too many points, and the complexity will be close to or reach the exponential complexity of maximum likelihood decoding. If d is too small, then a grid may not be included in the sphere, so the spherical decoding algorithm will not get a reasonable solution. (2) How can I tell if a point is inside the ball? If this judgment needs to be judged by the distance between each grid point and the vector, then this method is not ideal, because we need to examine all the points, and the amount of calculation generated is also exponential.

Sphere decoding solves the second problem. Here, the signal is considered to be a real number. Because the complex number can be opened by adding a multiple of the dimension, the real part and the imaginary part are opened. It is necessary to judge whether a point is in the m-dimensional sphere with radius d. It is difficult inside. If m is changed to 1, the ball is degraded to a pitch, which is equivalent to the real or imaginary part of the signal transmitted by a certain antenna. This operation is much simpler, and it can be known whether this point is within this distance. The real and imaginary parts of the signal on multiple transmit antennas are in many dimensions, and it is possible to take values in each dimension. The sphere decoding algorithm is equivalent to constructing a tree. The kth node of the tree corresponds to the grid point falling within the sphere with radius d and dimension k.

2. Algorithm derivation

Sphere decoding is to solve the following problems:

$$\min_{s \in D \subset Z^m} \|r - Hs\|_2 \tag{1}$$

Where Z^m is the set of integer lattice points and s is the transmitted signal. Now is looking for satisfaction:

$$d_s^2 \geq \|r - Hs\|_2^2 \tag{2}$$

Where d_s is the appropriate radius of choice and is not within the scope of the sphere decoding algorithm.

First, QR decomposition of the channel matrix is performed:

$$H = [Q_1, Q_2]\begin{bmatrix} R \\ 0_{(N-M)*M} \end{bmatrix} \tag{3}$$

Where, $Q_1 \in R^{N*M}, Q_2 \in R^{N*(N-M)}$, R is the upper triangular matrix of the M*M dimension.

$$d_2^2 = d_s^2 - \left\| Q_2^H y \right\|_2^2, y = Q_1^H r \tag{4}$$

Change equation (2) according to equation (4):

$$d_2^2 \geq \left\| y - Rs \right\|_2^2 \tag{5}$$

When R is an upper triangular matrix and equation (5) is expanded, the following equation can be obtained:

$$d_2^2 \geq \left\| \begin{bmatrix} y_1 - (R_{11}s_1 + R_{12}s_2 + \ldots + R_{1M}s_M) \\ y_2 - (R_{22}s_2 + R_{23}s_3 + \ldots + R_{2M}s_M) \\ \ldots \\ y_{M-1} - (R_{M-1,M-1}s_{M-1} + R_{M-1,M}s_M) \\ y_M - R_{MM}s_M \end{bmatrix} \right\|_2^2 \tag{6}$$

Analysis of equation (6) reveals that, based on the definition of vector 2-norm, the right end of the equation is the sum of squares.

Now start to solve from k=M and substitute to get:

$$d_2^2 \geq (y_M - R_{M,M}s_M)^2 \tag{7}$$

Because they are real operations, you can determine the range of possible values.

The above-mentioned spherical decoding is all about how to judge whether a point is inside the ball. The complete sphere decoding must include selecting the search radius d. If d is too large, the ball will contain too many points. The complexity will be close to or reach the exponential complexity of maximum likelihood decoding. If d is too small, then a grid may not be included in the sphere, so the spherical decoding algorithm will not get a reasonable solution.

If the performance is required to fully comply with the performance of the maximum likelihood detection, the initial radius must be a series of values, the initial value selected is d, if the appropriate point is not found in the range d, then the value of d needs to be increased. The expansion factor is 2 times; if the performance is required to be close to the performance of the maximum likelihood detection, the initial radius is larger than the above, and there must be some redundancy.

3. Simulation analysis

The following is a 4*4 transceiver antenna MIMO system. The transmitted symbols are 4QAM modulation, and the maximum likelihood ML detection (red), the two norm sphere decoding (blue), and the iterative number sphere decoding (green) are simulated and compared. The abscissa is SNR (dB) and the ordinate is BER and simulation time. The initial radius of the two-norm sphere decoding is given by the empirical formula. The initial radius of the iterative sphere decoding is 2/3 of the initial radius of the two-norm sphere decoding.According to the above conditions, the simulation curve is as shown in Fig.1 below:

It can be seen from the above simulation results that in the iterative sphere decoding, the two norm sphere decoding, and the maximum likelihood detection, the infinite norm sphere decoding performance is the worst, the two norm sphere decoding performance is in the middle, and the maximum is similar. However, the detection loss dB is small and the maximum likelihood detection performance is the best. From the simulation time, the maximum likelihood detection takes the longest time, the second norm sphere decoding is second, and the infinite norm sphere decoding takes the least time.

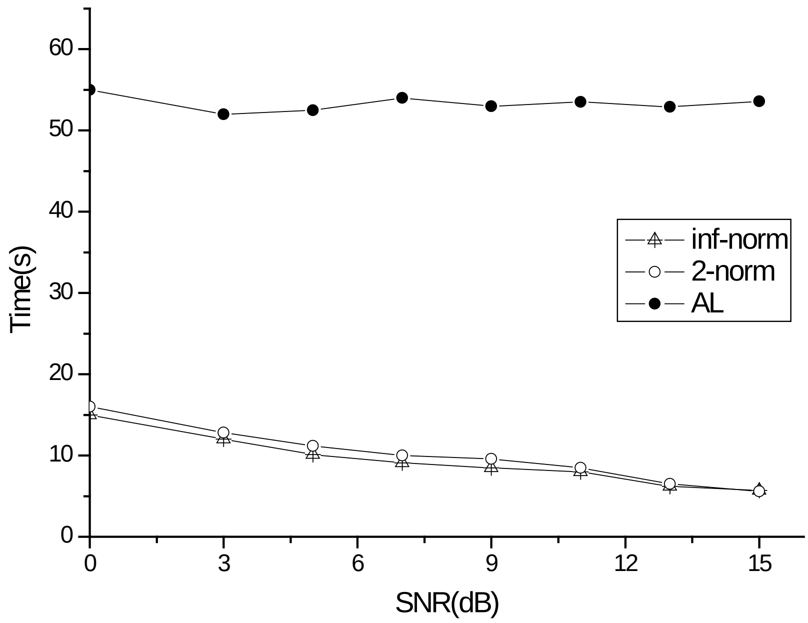

Fig. 1 Simulation time comparison of three decoding methods

4. Conclusion

This paper first introduces the basic principle of sphere decoding. The points to be noted are: (1) The signal is only considered in the real form, because the complex number is obtained by extending the dimension to the complex number; (2) the sphere decoding The algorithm does not explain how to choose the search radius d. In the complete sphere decoding, for the sphere decoding of the two norm which only requires performance close to the performance of the maximum likelihood detection, the initial radius is selected empirically. If the performance of the maximum likelihood detection is required, a series of values of the initial radius are required to prevent a valid set of signal points from being found in the previous radius. The complexity of the algorithm is polynomial with the number of antennas in a large signal-to-noise ratio range.

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