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A Linear Recoding and Power Allocation Scheme with Complex Parameters Based on Block Diagonalization Algorithm

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Abstract

MIMO system performance mainly by correlation of spatial interference presence and space, In order to overcome these effects, it is necessary by pre-coding technology to achieve, Here we mainly use block diagonalization algorithm both linear pre-coding for analysis and further integration of the average power allocation algorithm and power allocation algorithm MATLAB simulation. Through research and data analysis, system performance block diagonalization algorithm is better than under zero forcing algorithms. When the same number of transmit antennas, the number of receive antennas are the same, the average power and power calculation algorithm with SNR increases, can effectively channel capacity to achieve the desired optimum value.

Keywords*: MIMO systems; recoding technology; power allocation; block diagonalization algorithm*

1. Introduction

MIMO is called Multiple Input Multiple Output, which were at the receiving end and the transmitting end to set a plurality of receiving antenna and the transmitting antenna, so that the spatial propagation of multipath components can be effectively utilized, high rate data streams at the transmitter side by dividing [1-2], becoming lower rate plurality of sub-data streams using the same frequency band by using a plurality of antennas simultaneously transmit different data streams in parallel. When used in a multi-cell MIMO technology, each user has a different location but not simultaneously receiving synergies between the adjacent cells having the same frequency interference caused to the user an interference-limited system. Back in 2000 Catrcux study presents the same when the adjacent channel interference between cells occurs, will sharply reduce MIMO system spectrum efficiency, interference is severe, it is possible to make spectral efficiency can only reach the level of a single antenna. At this point, we need to use MIMO technology reasonable pre-coding technology to effectively eliminate interference. When a known transmission of the channel state, the pre-coding technique by pretreatment of the transmitter, to transmit the policy to make reasonable adjustments, designed to pre-coding matrix [3-4], equalizer at the receiving end, the information separately from different users, effectively making the same reduce interference between data streams, when the MIMO system performance improvement while greatly simplifying the receiver. This paper focuses on an in-depth study of the linear pre-coding. On the transmit side, we often channel matrix through a series of pre-processing approach. In different coding guidelines, we need to set specific constraints, for better system performance. At the same

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time, the proper use of power distribution optimized channel capacity, under different circumstances; affect the power distribution different criteria for each user service quality and capacity of the big difference.

2. Basic Theory of MIMO Technology

2.1. MIMO System Model

MIMO system, all of the wireless technology is not static optimization channel, to a certain extent, is also facing weak signals, multipath debilitating problem. In reality, it is a multi-user MIMO system interference-limited system, show Figure1:

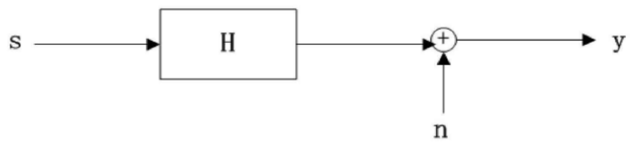

Figure 1. MIMO Channel System Block Diagram

As it can be seen from Figure 1, the receiving vector:

$$y=Hs+n \quad (1)$$

At the transmitter, the input serial bit stream various pretreatment methods modulation, coding, weighting, maps, etc., to make it into a number of parallel independent sub stream transmitted simultaneously over the same frequency band on different transmit antennas [5-8]. At the receiving end, the transmitting end antenna must not be more than the receiver antenna, according to the coding relationship between the sending sub-stream and the estimated channel transmission characteristics, in time and space domains handle multiple reception signals, so that a number of separate road send sub-stream and eventually into serial data, and then output, show Figure2:

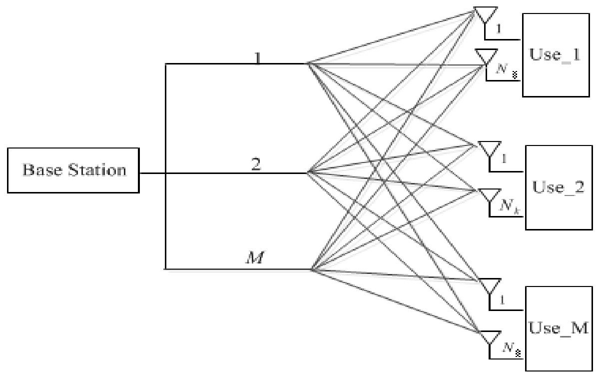

Figure 2. MU-MIMO System Model of FIG

Set at the base station side transmit antennas, the receiver end having K users, N_k used to indicate the number of the k user of the receiving antenna, Channel matrix between the base station and the user k is a $N_k \times M$ matrix. Each user at the receiving end are set to the number of receiving antennas, So that the receiving end of the useful signal strength increases. When sent to the first user's signal is S_c the total signal received k user can be expressed as:

$$y_k = \sum_{i=1}^{K} H_k S_i + n_k \quad (2)$$

User expectations of the received signal *i.e*,. the useful signal H_kS_k in the above formula represents, Interference signal from the user to the first user k caused by other, that is, we want to eliminate the signal,is $\sum_{i=1}^{K} H_k S_i$ Channel also has a Gaussian distribution of $C_n(0,\sigma^2)$ obey the complex additive white Gaussian noise n_k.

2.2. MIMO System Channel Capacity

Rate limits if the system channel capacity bandwidth and MIMO, reliable transmission channel, simply put, is error-free communication system maximum transmission rate. The size of the system channel capacity is to evaluate the quality of an important channel performance basis. When there is a white Gaussian noise channel, information on the maximum transmission rate is expressed as:

$$C=W\log_2(1+S/N) \tag{3}$$

Where: W on behalf of Hertz channel bandwidth, S behalf of watts of signal power, N represents noise power in watts. Shannon appropriate channel for the additive Gaussian noise channel.

By singular value decomposition theory, we can for any $n_R \times n_T$, H matrix singular value decomposition to obtain:

$$H=UDV^H \tag{4}$$

We nonnegative $n_R \times n_T$ diagonal matrix of the above equation represents D, $n_R \times n_R$, $n_T \times n_T$, m, n are represented by a unitary matrix U,V,so,$UU=I_{nR}$、$VV^H=I_{nT}$, among，$n_R \times n_R$ unit matrix formula is in front of I_{nR}, $n_T \times n_T$ unit matrix is in front of formula I_{nT} , D is the H diagonal elements of the singular values matrix HH^H is the characteristic value of the non-negative square root.

The formula (4) into equation (1) to give:

$$y=UDV^H s+n \tag{5}$$

The following conversion:

$$y'=U^H y \tag{6}$$

$$s'=V^H s \tag{7}$$

They can get：

$$y'=Ds'+n' \tag{8}$$

We know that the value of H matrix H is the number of singular values matrix, represented by γ .We use the singular value H $(\lambda_i)^{1/2}$represented. By the above formula (8), know the received signal element：

$$y_i^{'} = \sqrt{\lambda_i} \times s_i^{'} + n_i^{'} \quad (i = 1,2,3\cdots,r) \tag{9}$$

$$y_i^{'} = n_i^{'} \quad (i = \gamma+1, \gamma+2\cdots n_R) \tag{10}$$

At this time, constituting equivalent MIMO channel into a plurality of decoupling parallel sub-channels. Equivalent channel gain and is ready to singular value assigned to each sub-channel matrix. When the channel is independent and identically distributed Rayleigh fading channels, N_T represents the number of transmission antennas; P represents the number of receiving antennas; P/N represents the total transmit power; The same total power receiving antenna and the transmitting antenna on the channel with additive white Gaussian noise channel, the noise power receiving antenna is represented by σ^2, Noise ratio (SNR) of each of the receiving antenna are expressed as:

$$\rho=P/\sigma^2 \tag{11}$$

Suppose the transmitted signal is sufficiently narrow narrowband emission signal, so we see it as a channel having a flat frequency response, Channel matrix with a complex matrix $N_R \times N_T$, H to represent the i transmit antenna to the j channel with weak coefficient expressed by H_{ij}. The use of Shannon theorem, we can calculate what the total channel capacity:

$$C = W\,log_2\left(1+\frac{P_{ri}}{\sigma^2}\right)/\,s \tag{12}$$

Through the formula, we can clearly see, MIMO system can make full use of multipath components, each transmit signals in a plurality of different channels at the same time in parallel with the transmitting frequency, so that the bandwidth cannot increase, nor to increase the transmission power, and also so that the transmission rate information is effectively improved. At the receiving end of the channel state information is known, the transmitter is unknown, according to a set formula derivation, we can draw under the average power allocation algorithm channel capacity is:

$$C = W\sum_{i=1}^{K} log_2\left(1+\frac{\lambda_i P}{N_T\sigma^2}\right) = W\, log_2 \prod_{i=1}^{K}\left(1+\frac{\lambda_i P}{N_T\sigma^2}\right) \tag{13}$$

After a series of derivation, we can find the power allocation algorithm in the channel capacity is:

$$C = W\sum_{i=1}^{r} log_2\left(1+\frac{1}{\sigma^2}\left(\lambda_i\mu-\sigma^2\right)\right) \tag{14}$$

3. MIMO Preceding Technique

3.1. Recoding Technology Introduction

Each user is in different locations, the received base station to the plurality of data streams through the different receiving antennas [9-11], the receiving antenna can not work, plus equalizer cumbersome, difficult to handle a variety of reasons, would have a co-channel interference (CCI) system can cause the system to fall, forming interference limited systems [12-14], At this point we need to use a pre-coding technique: the sender is known, when the channel state information, by way of coded modulation can optimize the system, which is the pre-coding technology [15-16]. That is, at the sending end to use of channel state information, spatial diversity and spatial multiplexing gain, so the receiver equalizer simplified error rate lower, but also more user information may be separated, removing the interference signal, the system performance can be improve. Pre-coding structure shown in Figure 3 shows:

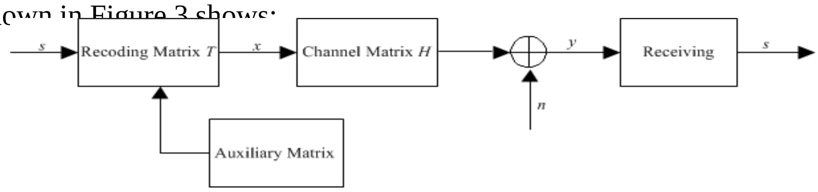

Figure 3. MIMO Recoding System Configuration Diagram

s for transmitting data, *T* is the preceding matrix, *H* represents weakness flat Rayleigh channel, *n* represents white Gaussian noise variance, σ^2 through chart, *y* to obtain a received signal can be expressed as:

$$y=HTs+n \tag{15}$$

y received signal demodulated after recovery and then through a series of signals.

Channel state information extreme impact on the effect of pre-coding MIMO system. Pre-coding according to the transmitter channel state information is known were divided into: no channel state information, partial channel state information, complete channel state information pre-coding of these three. On the contrary, when the pre-encoded using unreasonable, not only can not improve system performance, but also enables the system performance greatly deteriorated. Pre-coding technology can solve the problems there are many, here we focus on at full channel state information between multiple users pre-coding eliminate co-channel interference and power allocation users.

3.2. Multi-user MIMO Linear Recoding Technique

According to Figure 3, it can be seen *s* represents transmitted data, *H* represents flat Rayleigh channel matrix breakdown, *T* is the pre-coding matrix, Here is a channel matrix pseudo-inverse matrix, *n* represents a variance of σ^2 Gaussian white noise through structural diagram, can be seen: *s* and *T* are equal, through a series of space on the receiving end of the transmission and the quantization process finally get *s*. For zero-forcing pre-coding technique, that is to say when the transmitting antenna is less than the number of receiving antennas can be through the pre-coding matrix *T*, *H* matrix processing enable channel interference caused by the complete elimination.

Thus, we obtain a preceding matrix zero forcing algorithms are:

$$F_{ZF}=H^{+}=H^{H}(HH^{H})^{-1} \tag{16}$$

When we require linear pretreatment method, T_k must be a linear function of *H* and *S*, then according to the above formula can be drawn:

$$y_k = H_k T_k S_k + \sum_{i=1, i\neq k}^{k} H_k T_i S_i + n_k \tag{17}$$

When T_k and *s* has nothing to do, but also to meet the $H_i T_k=0$, $i \neq k$, then the inter-user interference all user *K*, Forced by the T_k zero forcing way to get pre-encoded form, the eventual elimination of interference.

Zero-forcing equalization of the linear pre-exists in the processing may be based on the noise increase is due to the use of a pseudo inverse matrix of a channel matrix is the recoding matrix to eliminate interference, the reception signal and multiplying the inverse matrix, so that interference cancellation, noise and also the inverse of the channel matrix multiplied, Typically, the channel matrix coefficient is less than 1, then the inverse matrix is greater than 1, and a noise factor of greater than 1 is multiplied after lead to greater signal to noise ratio is smaller, less systematic.

3.3. Block Diagonalization (BD) Recoding Technique

Our user *K* and between the base station channel state information to calculate the characteristics of a single-user MIMO system linear pre-coding matrix A_k, when a signal is sent from the base station to the user when a known channel state information of the condition, we will set up in other users user *K* and base station channel V_k in zero space, this zero space matrix V_k can use the contact information among all the other users to find the channel state. At this time, multi-user MIMO systems to process the transmitter pre-coding matrix T_k can be written as:

$$T_k=V_k A_k \tag{18}$$

Equivalent single-user MIMO system block diagram of a plurality of independent parallel, shown in

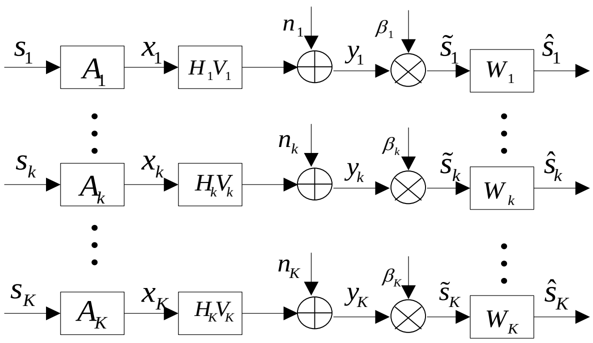

Figure 4. Equivalent Multiple Single-User MIMO System Block Diagram of an Independent Parallel

We can know the received signal of user K is:

$$y_k = H_k T_k S_k + \sum_{i=1, i\neq k}^{k} H_k T_i S_i + n_k \tag{19}$$

In the formula, we denote by H_k channel matrix between the user and the base station K, T_k represents the pre-coding matrix K-th receiving user signal obtained by the user's desired, it can be said that the useful signal, H_k in the above formula represents interference signals from other users caused by the k-th user, that is to say we want to get rid of the signal, the channel also has a complex Gaussian distribution $C_n(0,\sigma^2)$ obey the additive white Gaussian noise n_k.

In this way, we can get through the user block block diagonalization zero space pre-coding matrixes. We set the channel between the base station and other users with $\tilde{H}_k$ joint matrix, ie:

$$\tilde{H} = \left[H_1, H_2, L, H_k\right]^T \tag{20}$$

In order to obtain a zero space matrix, we conduct joint matrix $\tilde{H}_k$ SVD decomposition:

$$H_k = U_k \Lambda_k V_k^H = U_k \Lambda_k \begin{bmatrix} V_k^H \\ V_k^H \end{bmatrix} \tag{21}$$

$$H_i V_k^H = 0,\ \ i \neq 1,2,3 \cdots L \tag{22}$$

For users K, V_k is zero space user k-1other users of the matrix, therefore:

$$\sum_{i=1, i\neq k}^{K} H_k T_i S_i = \sum_{i=1, i\neq k}^{K} H_k V_i A_i S_i = 0 \tag{23}$$

Then eliminate interference to other users. Formula (24), (25) is constrained by:

$$M \geq \sum_{i=1, i\neq k}^{K} \left(N_i\right) \tag{24}$$

$$N_k \geq m_k \tag{25}$$

M represents the number of the base station side transmitting antennas, N_i represents the number of receive antennas of the i-th user, user k and m_k represents the number of transmission data streams. Total other users receiving end receiving antenna in addition K is not greater than the total number of users transmitting antenna base side.it is greater than the number of transmission data streams receiving antenna number.

When satisfying the above two constraints household k in block block diagonalization recoding channel matrix arithmetic condition can be expressed as:

$$H_k = H_k V_k \tag{26}$$

4. Linear Pre-coding Simulation and Analysis

For performance, error rate and channel capacity evaluation system is an important evaluation criteria, on the face by a zero-forcing pre-coding and algorithm research and analysis block diagonal pre-encoding, need to compare the performance of two algorithms, the following will be under the complete channel information, setting parameters, simulation of two algorithms, and compare. Specific parameter is set to Table 1:

Table 1. Channel Setting Simulation Parameters Table

parameter	Value
Transmit antennas	8
user number	4
Each user receiving antennas	2
Channel types	Flat Rayleigh fading channel
Modulation	QPSK

Take tolerance set SNR 5dB, from the number of column values of 0dB to 30dB. Compare the same signal to noise ratio, two algorithms channel capacity.

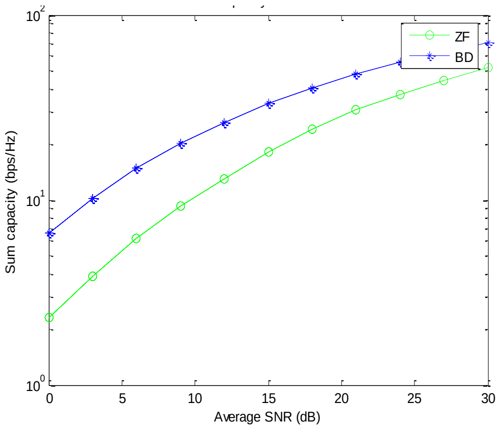

Figure 5. SNR Capacity Comparison Chart

Figure 5 is a zero-forcing pre-coding algorithm and block diagonalization algorithm between pre-coding capacity and SNR graph in the same situation. Shows: With noise ratio becomes larger, the channel capacity increases linearly along. In the same signal-to-noise ratio and zero - forcing the pre - coding algorithm and channel large diagonal pre-encoding algorithm, performance is superior. Take tolerance set SNR 5dB, from the number of column values of 0dB to 30dB. Compare the same signal to noise ratio, bit error rate of two algorithms.

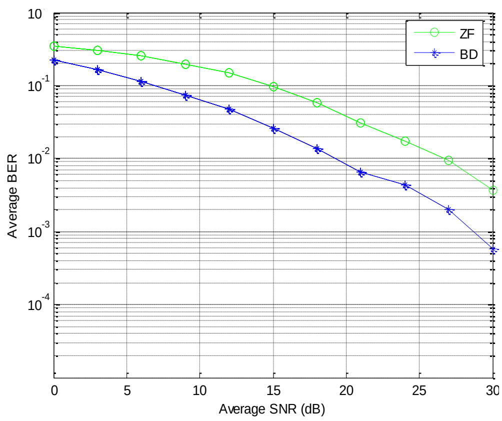

Figure 6. Compares the Two Algorithms at the Same SNR BER

Figure 6 is a graph in the same situation SNR zero forcing pre-coding algorithm and block block diagonalization recoding algorithm between BER and SNR. Shows: Fewer than two algorithms can effectively reduce the bit error rate, improve system performance.

And, at a certain signal to noise ratio, block diagonal pre-encoding algorithm compared to the pre-coding algorithm zero forcing lower bit error rate, superior performance.

Set the number of transmit antennas and receive antennas in turn take 4×4,8×4,8×5,8×6,8×7,8×8. Channel type is not related independently distributed Rayleigh fading channels, the modulation scheme is QPSK, signal to noise ratio in turn take between -10dB to 20dB 5dB tolerance value of the number of columns. MIMO system channel capacity at an average power allocation algorithm relationship between SNR and shown:

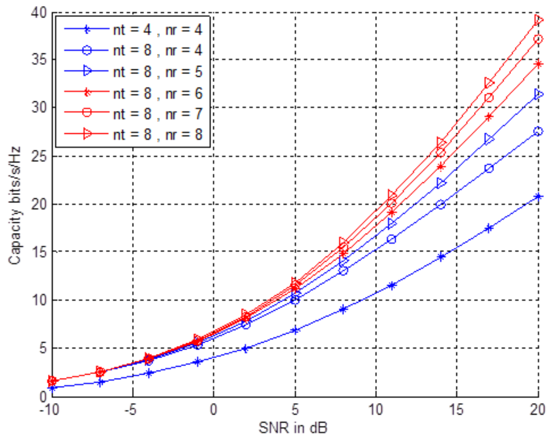

Figure 7. Under The Average Power Distribution

Figure 7 shows: -10dB SNR successively take between 5dB to 20dB tolerance value of the number of columns, when the signal to noise ratio becomes large, along with MIMO channel capacity becomes larger, and the more the number of antennas, channel capacity increases with the SNR faster. When a transmitting antenna is fixed, a receiving antenna, the greater channel capacity of MIMO system; when the receiving antenna is fixed, the more transmit antennas, the greater the MIMO system channel capacity.

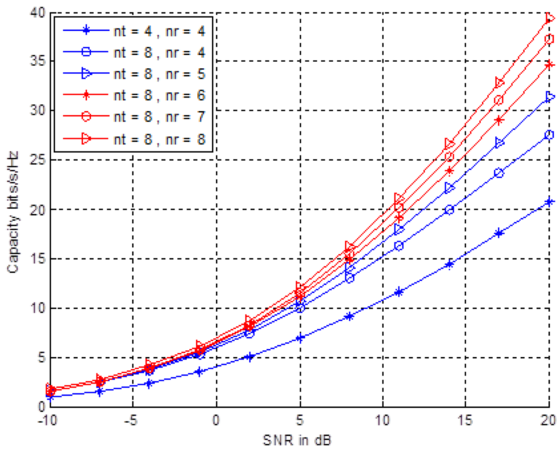

Figure 8. Power Allocation Algorithm Channel Capacity Diagram

Figure 8 shows: -10dB SNR successively take between 5dB to 20dB tolerance value of the number of columns, with the SNR becomes large, along with MIMO channel capacity also becomes larger, and the more the number of antennas, channel capacity increases with the SNR faster. When the sender to set the same antenna, the receiver antenna more, MIMO system capacity greater; when the receiving end of the same antenna set, the more natural barrier transmitting end, MIMO system capacity is greater.

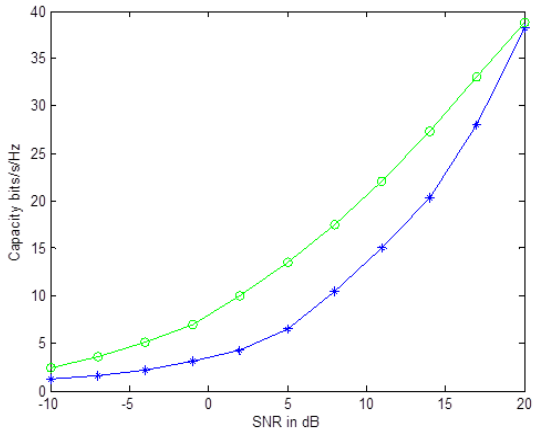

Figure 9. Send and Receive Antennas Compared to the Same Time the Two Power Distribution Capacity

Figure 9 shows: SNR take tolerance is 5dB, between the value of the number of columns from -10dB to 20dB, channel capacity under two power allocation algorithm increases the signal to noise ratio has increased, when the signal to noise relatively small, at the same signal to noise ratio, average power allocation algorithm capacity gain lower than power allocation algorithm; When the signal to noise ratio is increased to reach a certain range, average power allocation algorithm and power allocation algorithm capacity gain gradually close。

Through the above simulation results, we can know: When bandwidth and transmit power are not increased when the number of antennas set up more, it will make the channel capacity also will be larger. The number of transmit and receive antennas are fixed the same, using the average power and power calculation algorithm can effectively channel capacity to achieve the desired optimum value and tolerance take SNR 5dB, the value of the number of columns from -10dB to 20dB between when filling algorithm can make optimal channel capacity. Therefore, MIMO technology has unlimited potential research, far-reaching impact on the wireless communication.

5. Conclusion

When the receiver antenna set is not greater than the total number of the sender to set the total number of antenna, then we must first choose a simple structure, based on pre-coding for easy zero-forcing (ZF) criterion of interference to other users will be set to zero, but make noise amplification Therefore to improve, use the pre-coding MIMO block block diagonalization calculated using singular value decomposition of the channel matrix null space orthogonal basis, to give a pre-coding matrix, so that interference cancellation. When the receiver is fully aware of the channel and the sender does not know when, we used the average power allocation method for the rational allocation of power. When the sender is known under the channel, we use efficient power allocation algorithm. MIMO systems use under constraints block block diagonalization (BD) recoding and power allocation algorithm and the average power allocation algorithm focuses on, through

MATLAB simulation results: MIMO system without causing bandwidth and transmit power becomes larger At the same time, set up more antennas, channel capacity increases linearly along. Using Block diagonalization (BD) recoding performance is better than zero forcing (ZF) recoding, when the same number of transmit antennas, number of receive antennas are the same, the average power and power calculation algorithm with increased SNR, can be effectively to make the channel capacity to achieve the desired optimum value.

MIMO system is conducive to the realization, low cost, powerful value, a wide range, play a huge role in unparalleled communications aspects of people's daily life. Although a MIMO system has had a profound research in various aspects have a wealth of research, more and more showing the superiority of its high rate, but in the future, MIMO technology also has unlimited potential and broad Research prospects.

Acknowledgments

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