Research on the Linear Precoding Algorithm Based on 5G Mobile Communication Technology

Ting Bi
Support Technology Institute
China Industrial Control Systems Cyber Emergency Response Team
Beijing, China
biting2016@163.com

Xuehong Chen
Support Technology Institute
China Industrial Control Systems Cyber Emergency Response Team
Beijing, China
chenxuehong@cics-cert.org.cn

***Abstract*—This paper mainly studies the large-scale MIMO downlink precoding algorithm in 5G key technology. Firstly, the key technology of 5G and precoding technology are summarized. Then, the maximum ratio emission (MRT), zero forcing (ZF), minimum mean square error (MMSE) and other precoding methods are analyzed in detail. Finally, the capacity and bit error rate of the main algorithms are compared by simulation.**

***Keywords*—linear precoding, algorithm, 5G mobile communication technology**

I. Introduction

A. 5G mobile communication technology

At present, with the development of technology, people begin to put forward higher requirements for the mobile system: compared with the 4G system's 10-100 times of user speed requirements, 10-100 times of the number of wireless device connections, etc., 5G has made great technical evolution and performance upgrade in speed, delay, power consumption, connection, terminal, etc. At the same time, 5G will also have the following key technologies:(1)large scale dense network (large scale distributed MIMO): this technology provides flexible 5G intensive cells. It is a transmission point composed of many inexpensive antennas, which can serve multiple users at the same time. With a large-scale MIMO system, multiple messages of several terminals can be transmitted on the same time and frequency resources, and get the maximum beamforming gain and the minimum interference, so it can improve the system capacity and network coverage, and then maximize the utilization of frequency resources.(2)Cognitive Radio: in the case of no interference to other devices, mobile phones can adaptively find unused frequency bands by continuously detecting the frequency, and allow different radio technologies to effectively share the same spectrum by changing the transmission scheme. This kind of perception is all-round, and should have a comprehensive understanding of the comprehensive information based on the geographical environment and climate conditions of the location. The above dynamic management of wireless resources is realized by distributed and software defined radio.(3)ultra wideband spectrum: because the capacity of channel increases with the increase of bandwidth, in order to achieve the Gbps order of magnitude communication rate required by 5G mobile communication, it should also have the continuous bandwidth of high frequency band. However, due to the strong low-frequency penetration, in addition to the high-frequency band, 5G also needs to use the low-frequency band.

B. Precoding technology

Precoding is a process of signal preprocessing based on known channel state information at the transmitter of downlink. The precoder can be regarded as a multi-mode beamformer, which forms the spatial orthogonal characteristic beam after the transmission signal is decoupled, so that the interference between each user and antenna will be minimized, and according to the current channel condition, more energy will be allocated in the channel with better channel condition and relatively stable channel, and less or no energy will be allocated to the poor channel, so as to improve the spectrum efficiency and channel capacity of the large-scale antenna system, simplify the algorithm complexity of the receiver, reduce the bit error rate, obtain a better signal-to-noise ratio, and ultimately optimize the performance of the system. And after the mobile station receives the signal, it only needs to process the signal more simply.

According to the design scheme, the precoding technology can be divided into linear and nonlinear precoding technology. Linear Precoding schemes include: maximum ratio emission precoding scheme, zero forcing precoding scheme, block diagonalization precoding scheme, minimum mean square error precoding scheme and other precoding schemes. The processing methods of nonlinear precoding mainly include Tomlinson-Harashima precoding and vector precoding. In the conventional scenario, because of the high complexity of nonlinear precoding and the ideal performance of Linear Precoding, Linear Precoding is more suitable for practical scenarios.

II. Analysis of Linear Precoding Algorithm

We studied the performance of several main Linear Precoding algorithms in large-scale MIMO systems. For the convenience of expression, in a single cell system, we use $\mathrm{H} = [\mathrm{h}_1^{\mathrm{T}} \dots \mathrm{h}_k^{\mathrm{T}}]^{\mathrm{T}}$ indicates the downlink channel matrix from base station to user. Based on the theoretical analysis, we studied the performance of the main Linear Precoding algorithms, and made performance simulation under the actual scene conditions, and compared with the theoretical results.

In the single cell large-scale MIMO transmitter block diagram shown in Fig. 1, the base station precodes the signal and sends the signal vector to the user. S represents the original signal, and X represents the information vector sent by the sender to the user after precoding.

There are:

$$x = \sqrt{\rho}\, Ws \quad (1)$$

ρ is the average transmission power of the base station. Therefore, the signal received by the kth user in the cell can be expressed as:

$$y_k = Hx + n = \sqrt{\rho} H_k W_k S_k + n_k \quad (2)$$

Here, n_k is the superposition of user interference signal and channel noise of the same pilot in other cells.

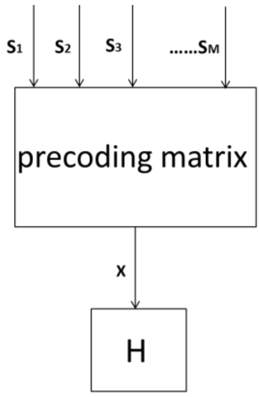

Figure 1 Single cell large-scale MIMO transmitter block diagram

A. Maximum Ratio Emission Precoding Algorithm

In downlink, the MRT precoding technology is actually the matched filter precoding algorithm. The performance of MRT precoding in large-scale MIMO system depends on the channel transmission environment to a great extent, and the ideal environment is that the channels from the base station to different user terminals are as independent as possible. The expression of MRT precoding for the kth user in the cell is formula 3。 MRT precoding is a very simple precoding technology, which can maximize the SNR of each user, but does not consider the interference between users.

$$W_K = H_k^H \quad (3)$$

B. Zero Forcing Precoding Algorithm

Zero forcing linear precoding scheme was originally proposed by Freescale Semiconductor Company. Different from the MRT precoding technology, ZERO FORCING precoding can completely remove the interference among users. It requires that all the signals received by users in the system do not contain the interference generated by other users, that is, make the precoding vector w_k of user K in the channel matrix of other users$[h_1^T, \ldots. h_{k-1}^T, h_{k+1}^T, \ldots. h_k^T]^T$ in the zero space of, that is, the interference items of other users in the signals received by user K:

$$\sum_{i=1,\ i\neq k}^{k} h_k w_i s = 0 \quad (4)$$

The specific implementation process of Zero forcing linear precoding is as follows:

1)the channel is estimated in the client. That is to say, the pilot signal is used to estimate the channel among users and the estimated value of channel matrix is obtained $\hat{H}_k$ （k=1,2,⋯⋯.K）.

2)feedback channel estimation of the client. The channel matrix estimated above $\hat{H}_k$ （k=1,2,…….K） is used to calculate the precoding matrix. In the TDD system, the base station directly estimates the channel information state of the downlink channel transmitter at the uplink pilot, and improves the accuracy of the channel information state; in the frequency division duplex system, the base station needs to obtain the channel information state of the transmitter through the uplink feedback channel.

3)the precoding matrix is calculated at the transmitter. Zero forcing precoding can be expressed as pseudo inverse matrix of user channel matrix:

$$W_k = H_k^H (H_k H_k^H)^{-1} \quad (5)$$

It can be seen from the above formula that precoding in multiuser MIMO can be regarded as a process of maximizing the ratio of target user gain to inter user interference plus noise to some extent. MRT maximizes the target user's signal. When the interference between users is negligible compared with the noise, MRT is a near optimal algorithm in the signal limited system. Zero forcing precoding is intended to cancel the interference between users and lose some signal gain at the same time. When the number of users is large or the noise is relative to the interference, it can get the performance close to the system capacity limit. The main problem of Zero forcing precoding is that according to its scheme, antenna data must be processed together at the same time, and each antenna cannot be processed separately.

C. Minimum Mean Square Error Precoding Algorithm

Zero forcing precoding scheme reduces the interference of other users to zero, and does not consider the impact of noise on the system. When the noise causes the channel matrix to become ill conditioned or near ill conditioned, and the coefficient will be close to zero, the received signal component will be weakened, and the received signal to interference plus noise ratio (SINR) will be reduced. Meanwhile, the system will be affected. The difference is that in 2005, Christian B. peel, Bertrand M. hochwald and A. Lee swindlehurst proposed the minimum mean square error precoding scheme. It aims to maximize the SINR of the receiver, comprehensively considers the performance of the whole system, and makes MMSE precoding scheme perform better in the environment of low SNR by introducing parameters. The precoding matrix can be expressed as follows:

$$W_K = H_K^H\, (H_K H_K^H + \beta I)^{-1} \quad (6)$$

Where, when SINR is the best, $\beta = \frac{K}{P_S}$, P_S indicates the ratio of total power to noise power in the downlink. From the formula six shows that MMSE precoding algorithm is similar to ZF precoding matrix. When the signal-to-noise ratio is large, the interference of other users is the main factor that restricts the system performance. At this time, β tends to 0, and MMSE precoding degenerates into ZF precoding; when the signal-to-noise ratio is small, it becomes larger, and MMSE precoding matrix, at the cost of allowing partial interference to be retained, tries to Maximize the received SNR. Therefore, the performance of MMSE precoding technology is better than ZF precoding technology.

III. Simulation Test

Next, the performance of several representative Linear Precoding algorithms described above is simulated. Assuming that the channel is Rayleigh fading, the channel matrix is made up of elements randomly generated by CN (0,1) with independent and same distribution, and normalized. The total transmit power of each base station is fixed, and the power is evenly distributed. In the scenario, it is assumed that the number of transmit antennas is m = 20, the number of receive users is k = 20, and the number of receive antennas for each user is 1. Here, we use Matlab software to write simulation program for simulation.

Figure 2 shows the capacity simulation results of several Linear Precoding algorithms. It can be seen. From Figure 2 that the system capacity after ZF, MMSE and MF precoding increases with the increase of SNR, meanwhile, MMSE precoding grows the fastest, ZF and MF Secondly. At the same time, under the same SNR, it can be seen that MMSE precoding capacity is significantly better than the other two precoding. This shows that MMSE precoding can suppress the interference between users.

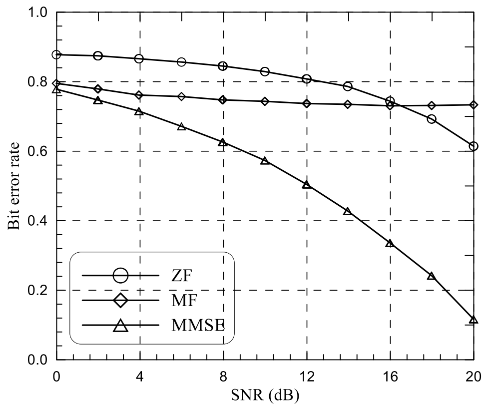

Figure 2 Results of several linear precoding algorithms

Figure 3 is a simulation of bit error rate (BER) of ZF, MMSE and MF precoding with SNR True curve, using 4QAM modulation. It can be seen from the figure that in the case of low SNR, the bit error rate of MMSE precoding is significantly lower than the other two; with the increase of SNR, the bit error rate of each precoding method decreases gradually, MF In the environment of high SNR, ZF precoding performs well.

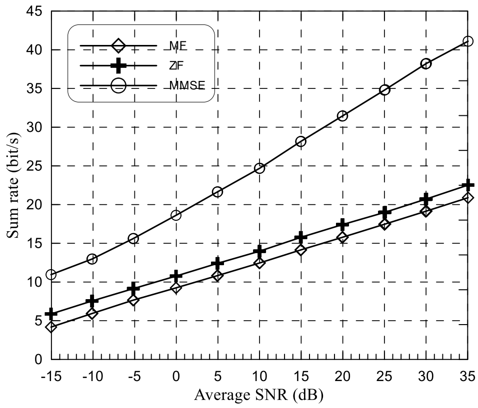

Figure 3 Bit error rate of several linear precoding algorithms

The number of antennas equipped in the base station is increased to 100, while the number of users remains at 20. The simulation results show that ZF and MMSE are available. The bit error rate of precoding is shown in Fig. 4. It can be seen from Figure 4 that when the number of base station antennas increases, the advantages of MMSE precoding compared with ZF precoding are significantly reduced, which verifies that in the case of large-scale antennas, simple linear precoding can also have good performance.

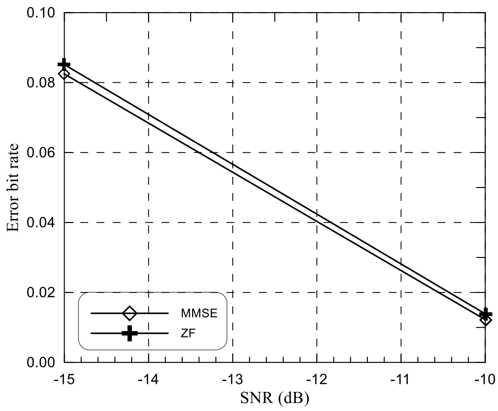

Figure 4 Bit error rate of ZF and MMSE precoding

IV. Conclusion

In this paper, the main performance indexes of MRT, ZF and MMSE Linear Precoding schemes are analyzed under the model of single cell MIMO. At the same time, the rate and bit error rate of MRT, ZF and MMSE precoding are compared by simulation, and MMSE is obtained The precoding technology is obviously better than the other two precoding technologies, especially in the environment of low SNR, which verifies the conclusion of theoretical derivation.

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