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TRANSMIT DIGITAL BEAM FORMING USING TWO-STAGE WEIGHT CONTROL FOR MC-CDMA/DS-CDMA TDD SYSTEM

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1. Introduction

In fourth generation mobile communication systems, multi-carrier code division multiple access (MC-CDMA) has attracted attention [1]. MC-CDMA achieves high quality and high capacity communication under a multi-path fading environment in the down-link with synchronous transmission. On the other hand, if MC-CDMA used in the up-link, the performance degrades because the orthogonality of the spreading codes is deteriorated by asynchronous transmission. In order to solve this problem, an asymmetric MC-CDMA/DS-CDMA system with time division duplex (TDD) has been proposed [2]. In this system, direct sequence code division multiple access (DS-CDMA) is used in the up-link communication and MC-CDMA is used in the down-link communication. Since the channel status of the up-link channel and the down-link channel is the similar in TDD system, the weight of each element for transmit digital beam forming (DBF) using array antenna is easily obtained. DBF can improve the performance by directing the main beam to the target users and by directing the null beam to the interference signals.

In general, the optimal received weights of antenna for the up-link communication can be used for the transmit weights for the down-link communication in TDD system. However, in asymmetric CDMA systems, the optimal weights are different between up-link and down-link because the spreading method is different. MC-CDMA uses a frequency domain spreading codes with multicarrier modulation and DS-CDMA uses a time domain spreading codes with single carrier modulation. In such MC-CDMA/DS-CDMA system, if the transmitter generates the beam with interference reduction for down-link MC-CDMA by using the weights of up-link DS-CDMA with minimum mean square error (MMSE) algorithm, the performance degrades because the additional null steering to other users degrades signal to noise ratio (SNR). Here, we consider two kinds of quality of communication for user data. One is high quality communication (HQ) users' data and the other one is normal quality communication (NQ) users' data. DBF transmitter generates null beam against HQ users when NQ users transmit the signals. This process improves the performance of the HQ users. However, the performance of NQ users degrades because the additional null steering to other NQ users and SNR of own signals degrades. Therefore, in this paper, in order to improve the SNR of the NQ users with keeping the performance of HQ users, a two-stage weight control method for MC-CDMA/DS-CDMA TDD system is proposed. By using the proposed technique, the performance of the NQ user is improved without large degradation of HQ users' performance.

2. System Model

In this paper, we assume that the down-link communication method is MC-CDMA and the up-link communication method is DS-CDMA with TDD. MC-CDMA is one of the multicarrier CDMA system, and the signals are spreaded by the frequency domain spreading code. In the down-link communication, two kinds of quality of communications are considered and the priority control is performed by DBF using array antenna. Figure 1 shows the base station for transmitting MC-CDMA and receiving DS-CDMA with plural elements. In this system, in the up-link, the DS-CDMA signals received at each element are input to the matched filter (MF) and separated to the signals of each path. After that, the k-th user and the e-th element signal of each path is multiplied by the weight $w_{k,e}$, which is common among all paths. The weighted signals are combined among elements in each path and are coherently combined among paths. In the down-link, MC-CDMA signals are generated and the weights decided in the up-link signals are multiplied to the signals in each user. The weighted signals are combined among users in each element and transmitted to the

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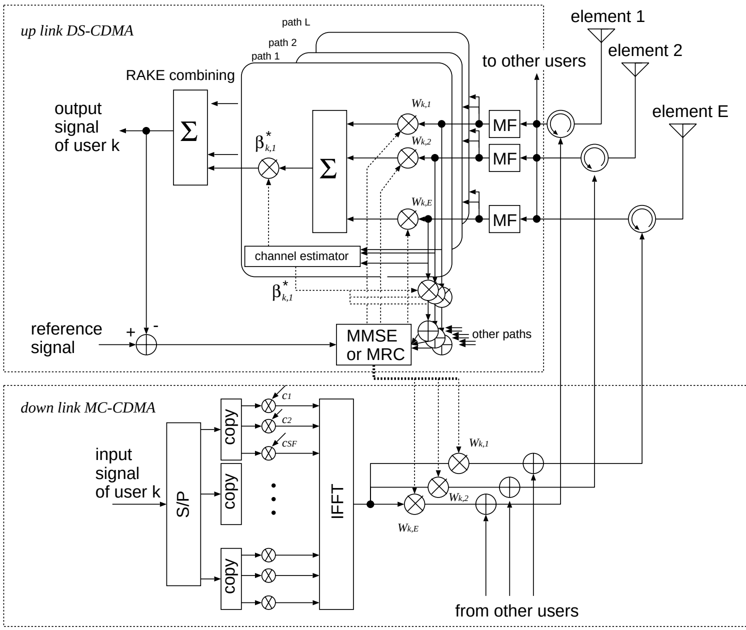

Fig. 1. Transmit DBF for MC-CDMA/DS-CDMA TDD system.

channel.

As for the weight decision algorithm, MMSE algorithm [3] and maximum ratio combining (MRC) are used. MMSE maximizes the signal to interference plus noise ratio (SINR) and MRC maximize the SNR. In this paper, in order to give priority to HQ users' data, MRC is used for HQ users and MMSE is used for NQ users. On the up-link channel, HQ users transmit the pilot signal with P_{up} [dB] power increasing. Therefore the weights of the NQ users using MMSE direct the null beam to HQ users. On the other hand, the weights of the HQ users are decided to maximize their own SNR by MRC, so the main beam of HQ users is directed to their own.

3. Proposed Two-Stage Weight Control Method

In the previous section, we show the transmit weight control method for MC-CDMA using the up-link DS-CDMA signal. This method can generate weights to give null steering toward HQ users, which transmit P_{up} large power than NQ users in the up-link pilot signals. However, the SNR of NQ users degrades because the other NQ users' signals are regarded as interferences when the MMSE adaptive algorithm is performed. In MC-CDMA system, since the multiple access interference can also be removed by processing gain, the null steering to NQ users is not effective. As a result, even if the number of elements is more than the number of the HQ users, the performance of the NQ users degrades. In this paper, in order to improve the performance of the NQ users without degradation of the performance of the HQ users, we propose a two-stage weight decision technique combined MMSE and equal gain combing (EGC) method. The proposed two-stage adaptive algorithm is only used when the NQ users derive the weights.

The proposed two-stage weight decision system is shown in Fig. 2. In this figure, the despreading operation using the MF and the path separating operation are not described but each MMSE processor performs the same operations as shown in Fig. 1. In the first stage, adjacent elements are grouped and MMSE adaptive algorithm is performed to determine the weight of each element. The number of elements in the group is set to the number of HQ users plus one to generate the null steering to the direction of HQ users. The groups of elements are overlapped among elements and the number of groups is the same as the number of elements, so the received signal of each element is copied after analog to digital converter (A/D). In each group, MMSE adaptive algorithm is performed using DS-CDMA adaptive array antenna algorithm shown in Fig. 1 and the combined signals are input to the second stage. In the second stage, the phase of the each input signal from the first stage is estimated and combined coherently in the group by using EGC in order to increase SNR. For example, when the number of HQ users is one and the number of total elements is three, the two-stage weight decision system at the receiver is shown in Fig. 2. In the first stage, three MMSE pro-

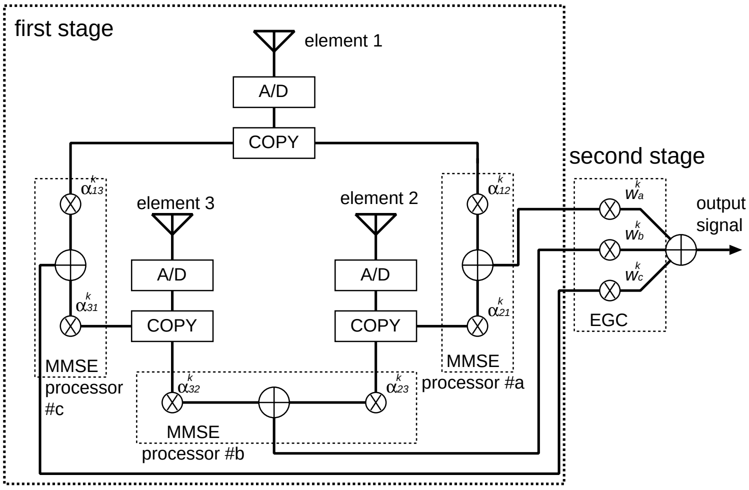

Fig. 2. Two-stage DBF weight decision system for 1 HQ user, 3 elements.

Table 1. Simulation conditions.

Common conditions	
Number of elements	3 elements
Element space	$\lambda/2$ circular array
E_b/N_0 per 1 element	20 dB
Channel model	5-path Exponential Rayleigh
Delay Spread	10 MC-CDMA samples / path
Number of waves in each path	32
Angle spread	Gaussian distribution (σ = 3 degrees)
MMSE algorithm	RLS (forgetting factor = 0.99)
Down-link MC-CDMA	
Modulation method	QPSK
The number of carriers	512
Length of guard interval	20% of a symbol length
Spreading factor	SF=32
Combing method	EGC
Up-link DS-CDMA	
Modulation method	QPSK
Process gain	64
Number of RAKE finger	5

cessors are prepared and each processor decides the weights of the adjacent elements. The weights of user k in the first stage are defined as α_{xy}^k and α_{yx}^k, where x and y shows the element number in the same group. For example, in the processor #a of user k, α_{12}^k and α_{21}^k are decided using MMSE based weight decision algorithm shown in Section 2. In the second stage, the output signals of the first stage are multiplied by the weights (w_a^k to w_c^k), which is generated based EGC algorithm. The decision weights of the first stage and the second stage are multiplied and the transmitting weights of three elements are generated, which is given by

$$\left\{ \begin{array}{lcl} w_{k,1} & = & \alpha_{12}^k w_a^k + \alpha_{13}^k w_b^k \\ w_{k,2} & = & \alpha_{21}^k w_b^k + \alpha_{23}^k w_c^k \\ w_{k,3} & = & \alpha_{31}^k w_c^k + \alpha_{32}^k w_b^k \end{array} \right. . \tag{1}$$

The total power of the output signal is normalized to be the same as that of one element transmitting systems. These weights are used for transmitting the NQ users. On the other hand, the weights of HQ users are decided by using MRC. At the transmitter, these weights are multiplied to the MC-CDMA signals after IFFT in each user and in each element. These signals are combined among users and are transmitted to the channel.

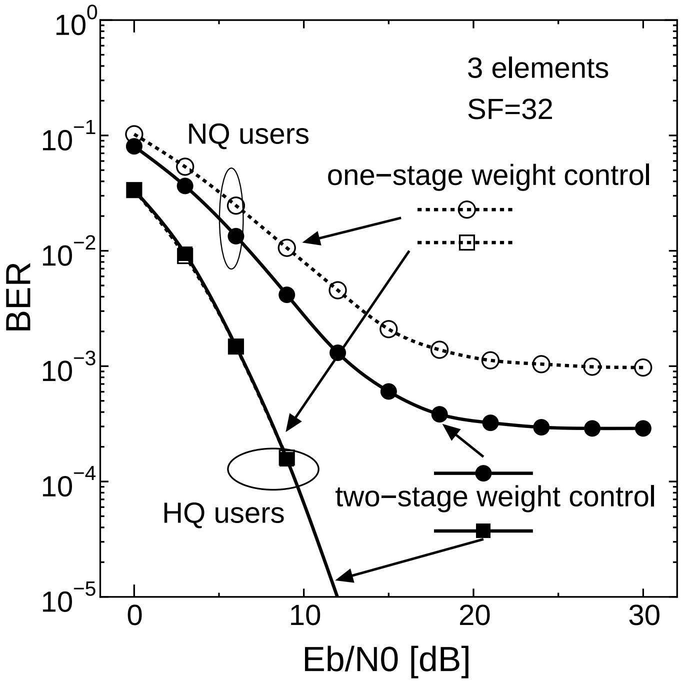

Fig. 3. BER performance of the proposed two-stage weight control.

4. Computer Simulation

In order to confirm the effectiveness of the proposed system, computer simulation is performed. Simulation conditions are shown in Table 1. In the simulation, we assume the number of NQ users is eight and the number of HQ users is one, so the number of elements in each group at the first stage is two (the number of HQ users + 1). The angle of arrival of each user is random from – 180 degrees to 180 degrees with 3-degree angle spread. In the up-link channel, the power of the HQ users' pilot signal is $P_{up} = 20$ [dB] up compared with the average power of NQ users. In the down-link, all users transmit the same power with the different weights. The bit error rate (BER) performance of the down-link MC-CDMA is shown in Fig. 3. The BER performance of the HQ users is almost the same performance as one-stage and two-stage weight control, and the proposed system can effectively give the priority to the HQ users. In NQ users, the proposed two-stage weight control system can improve the BER performance compared with the original one-stage weight control system.

5. Conclusion

In this paper, we propose a two-stage transmit digital beam forming weight control for MC-CDMA/DS-CDMA TDD system. The proposed method can improve the performance of the normal quality users, which generate the null beam toward the direction of the high quality users, without degrading the performance of the high quality users.

References

[1] H. Atarashi, N. Maeda, S. Abeta, and M. Sawahashi, "Broadband packet wireless access based on VSF-OFCDM and MC/DS-CDMA," Proc. PIMRC2002, Sept. 2002.

[2] I. Jeong and M. Nakagawa, "A time division duplex CDMA system using asymmetric modulation scheme in duplex channel," IEICE Trans. on Commun., vol.E82-B, no.12, pp.1956–1962, Dec. 1999.

[3] S. Tanaka, M. Sawahashi, and F. Adachi, "Pilot symbol-assisted decision-directed coherent adaptive array diversity for DS-CDMA mobile radio reverse link," IEICE Trans. on Commun. vol.E80-A, no.12, pp.2445–2454, Dec. 1997.