DOWNLINK WEIGHT CONTROL IN TDD/SDMA BASED ON PREDICTION OF RADIO CHANNEL CHANGES

Yasutaka Ogawa(1) , **Takeo Ohgane**(2)

(1) *Graduate School of Engineering, Hokkaido University, Kita 13, Nishi 8, Kita-ku, Sapporo 060-8628 Japan*
E-mail: ogawa@ice.eng.hokudai.ac.jp
(2) *As (1) above, but E-mail: ohgane@ice.eng.hokudai.ac.jp*

ABSTRACT

A multibeam adaptive antenna at a basestation can separate spectrally and temporally overlapped signals in a TDMA mobile communication system. Thus, we can achieve space division multiple access (SDMA), which increases the channel capacity. For an uplink channel, weight vectors can be determined by applying a conventional method. In this paper, we consider the weight vectors for a downlink channel in a TDD system. Although the uplink and downlink channels have a common frequency band, we cannot neglect the changes in channel characteristics depending on the radio environment. We present two schemes to determine the downlink weight vectors.

INTRODUCTION

The development of mobile communications demand increasing channel capacity. A multibeam adaptive antenna at a basestation can separate spectrally and temporally overlapped signals in a TDMA system and enables space division multiple access (SDMA) as shown in Fig. 1 [1]-[3].

Fig. 2 shows a block diagram of the adaptive antenna for a single user. It has to handle a downlink signal as well as an uplink one. For an uplink channel, the weight vectors can be determined by using a conventional method such as the RLS algorithm. However, obtaining vectors for a downlink channel is not easy because downlink channel characteristics are not the same as those of the uplink one [4][5]. In this paper, we consider downlink weight control methods for a time division duplex (TDD) system in a micro cell. The personal handy phone system (PHS), one Japanese mobile communication system, uses the TDD micro cell system. Introducing the SDMA technique for PHS in Japan is now being considered. In the micro cell, the angle spread cannot be neglected, as shown in Fig. 3, and the fading can differ from antenna to antenna. Although the uplink and downlink channels have a common frequency band, we cannot neglect changes in channel characteristics depending on the maximum Doppler frequency. Fig. 4 shows a schematic of the optimum weight locus. If we use a fixed weight vector for the downlink slot, considerable error and performance degradation occur. In this paper, we propose and examine two methods to determine the downlink weight vectors based on predicting changes in radio channels.

DOWNLINK WEIGHT CONTROL

In the first method, we estimate the channel states during the uplink time slot. They are estimated from received signals by applying the minimum mean square errors (MMSE) algorithm. We predict the channel states in the downlink time slot using linear extrapolation, as shown in Fig. 5. In this figure, $h_n^{(k)}(i_1)$ denotes the channel state for the kth user at the nth antenna element at time i_1, and $\hat{h}_n^{(k)}(i)$ is the predicted value at time i. Using the predicted channel states, we calculate the weights $\hat{w}_n^{(k)}(i)$ that resolve signals in the downlink slot. We call this scheme the linear extrapolation (LE) method, which is simple and easy to implement.

The second method predicts the downlink channel states using superimposed complex exponential functions, as shown in Fig. 6. That is, the predicted channel is given by the summation of M complex exponential functions as

$$\hat{h}_n^{(k)}(i) = \mathbf{A}_n^{(k)T}\,\mathbf{Z}(i) \tag{1}$$

where $\mathbf{A}_n^{(k)}$ and $\mathbf{Z}(i)$ denote the complex amplitude vector for the kth user at the nth antenna element and the complex exponential function vector, respectively. They are defined as

$$\mathbf{A}_n^{(k)} = \left[A_{n1}^{(k)}\ A_{n2}^{(k)} \cdots A_{nM}^{(k)} \right]^T \tag{2}$$

$$\mathbf{Z}(i) = \left[e^{j2\pi f_1 i}\ e^{j2\pi f_2 i} \cdots e^{j2\pi f_M i} \right]^T . \tag{3}$$

This idea is natural because fading is caused by multiple scattering objects and can be expressed by several complex exponential functions. As with the LE method, the weight vectors are calculated by using the predicted channel states. This weight control scheme is referred to as the superimposed complex exponential extrapolation (SCEE) method.

COMPUTER SIMULATIONS

We evaluate the performance of the weight control methods for a two-user SDMA case using computer simulations. We assume the antenna array and user positions as in Fig. 7 and the TDMA frame format as in Fig. 8. Furthermore, we assume a Rayleigh fading environment and a QPSK modulation with a 400-kbps bit rate. It should be noted that the antenna array is large; that is, the antenna-element separation is 5 wavelengths apart to enable obtaining the space diversity. The time interval between the uplink time slot and the corresponding downlink one is only 1.92 msec. We cannot neglect this time interval for the large array. These scenarios are considered to be similar to PHS environments.

In the SCEE method, the frequencies in (2) and (3) are determined depending on the speed of the channel phase change as follows.

(i) $f_m = \pm 10$ Hz (M = 2), (ii) $f_m = 0, \pm 30$ Hz (M = 3), (iii) $f_m = \pm 20, \pm 60$ Hz (M = 4)

Fig. 9 shows the average bit error rate (BER) versus the average E_b/N_0 for different values of the maximum Doppler frequency (f_d). At $f_d = 5$ Hz, the fixed weight vectors determined at the end of the uplink slot show satisfactory performance, which is almost the same as that of the uplink channel in the wide region of the average E_b/N_0. At $f_d = 40$ Hz, the fixed weight vectors have a high error floor, whereas the LE and SCEE methods do not have a floor in this region. Both methods have almost the same BER performance. At $f_d = 80$ Hz, the BER performance of the SCEE method is better than that of the LE method in the average E_b/N_0 region above 18 dB. The SCEE scheme requires a more accurate channel estimation. Thus, the SCEE method shows better performance when the average E_b/N_0 is high.

Fig. 10 shows the average BER versus the maximum Doppler frequency at the average $E_b/N_0 = 30$ dB. We see that the proposed methods show a much better performance than that using fixed weight vectors. The LE method has a BER lower than 10^{-3} up to $f_d = 55$ Hz. Using the SCEE, this value can be extended to 75 Hz.

CONCLUSIONS

We have proposed two downlink weight control methods for the TDD/SDMA system. We demonstrated that they have much better performance than using fixed weight vectors. The LE method is simple and easy to implement. The SCEE method performs better when the average E_b/N_0 is high.

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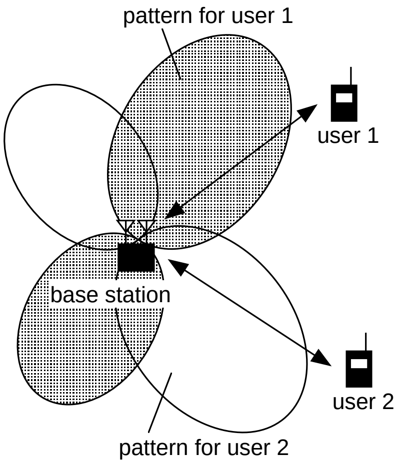

Fig.1 SDMA concept using an adaptive antenna.

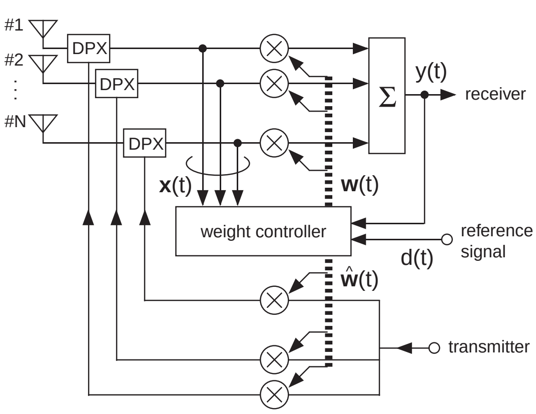

Fig.2 Block diagram of adaptive antenna for signal reception/transmission.

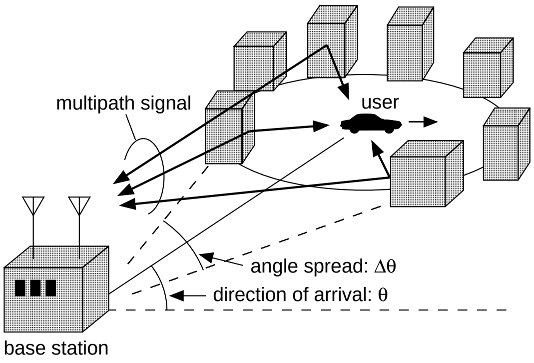

Fig.3 Model of Rayleigh fading channel.

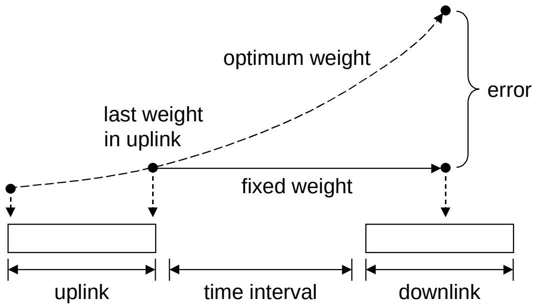

Fig.4 Fixed weight error in downlink.

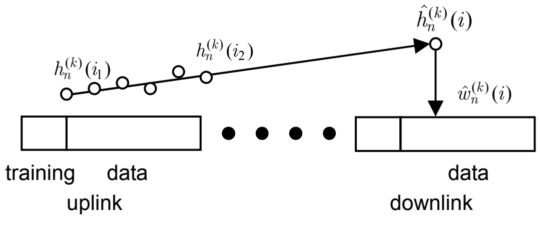

Fig.5 Channel prediction by linear extrapolation (LE).

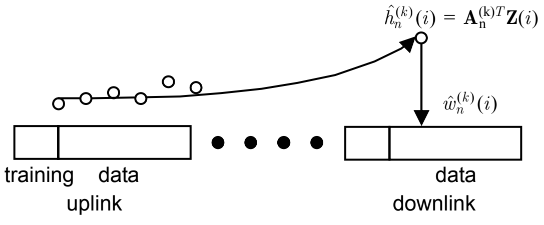

Fig.6 Channel prediction by superimposed complex exponentials extrapolation (SCEE).

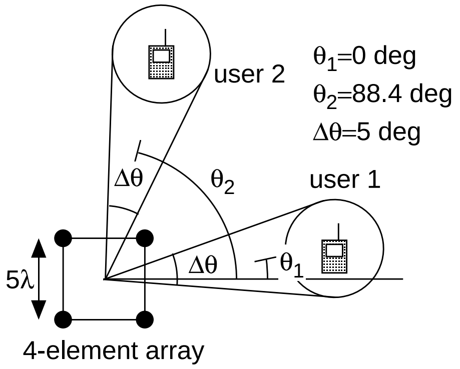

Fig.7 Antenna array and user positions.

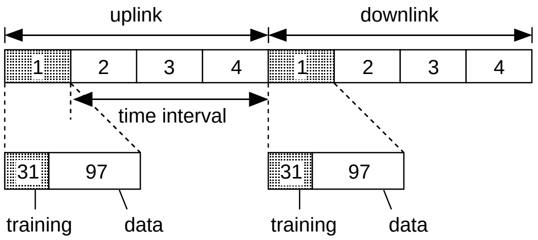

Fig.8 TDMA frame format.

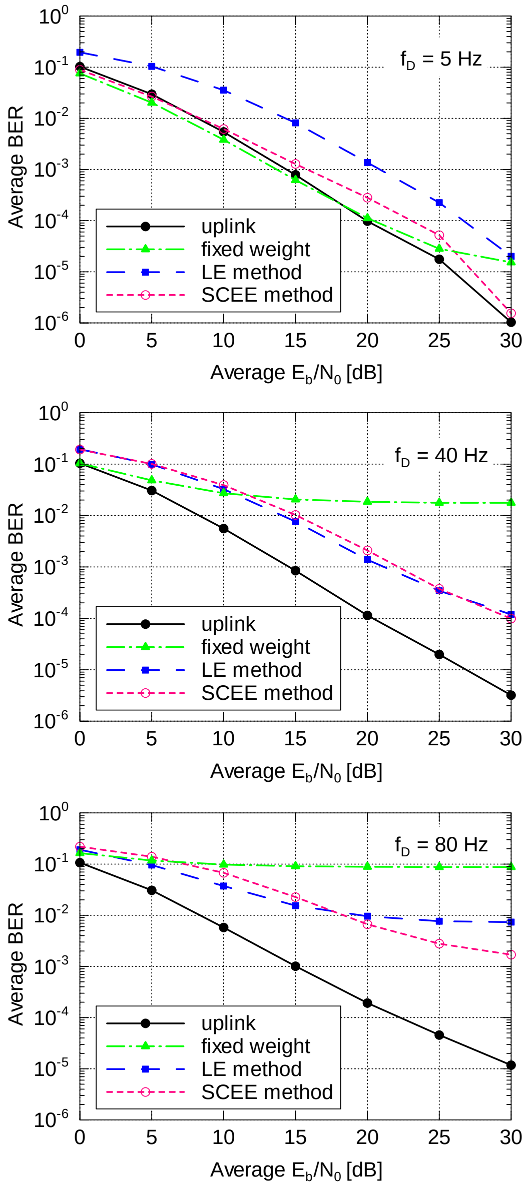

Fig.9 Average BER versus average E_b/N_0.

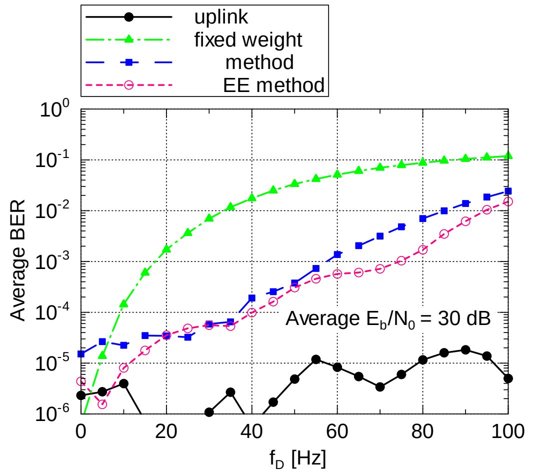

Fig.10 Average BER versus the maximum Doppler frequency f_d.