MMSE Adaptive Antenna for OMC-CDMA Mobile Communication

Yosuke FUJINO Yoshihiko KUWAHARA
Faculty of Engineering, Shizuoka University
3-5-1 Johoku Hamamatsu, Shizuoka 432-8561, Japan
e-mail: tykuwab@ipc.shizuoka.ac.jp

1. Introduction

In recent years, the OFDM is attracted attention as the high-speed radio data communication. The OFDM can take advantage of the bandwidth efficiently because of use of orthogonal multi-carriers. And, Inter Symbol Interference (ISI) occurs hardly because of the guard interval and lower symbol rate. Orthogonal Multi Carrier (OMC) CDMA is known as a method of multiplying the OFDM signals. Whereas time-sequence spreading code is multiplied to each data bit in case of Direct Sequence (DS) CDMA, spreading code is multiplied to each carrier in the frequency domain in case of the OMC-CDMA. The OMC-CDMA has higher efficiency of bandwidth as compared with the DS-CDMA. However, communication quality degrades due to Multiple Access Interference (MAI) and multi-path waves with large delay beyond the guard time. The adaptive antenna is an effective technology to solve these problems.

In this paper, Bit Error Rate (BER) and user capacity of OMC-CDMA reverse link have been examined by computer simulation. In order to increase user capacity, we propose a new receiver with adaptive beamforming. Propagation model with Rayleigh fading and Frequency Selective Fading (FSF) has been assumed. Also, Transmitting Power Control (TPC) for near/far problem and the convolution code for error correction have been taken into account.

2. OMC-CDMA

A block diagram of OMC-CDMA communication system is shown in Fig.1. N_2 is defined as number of the sub-carriers, and is equal to division number per symbol N_1. An n_1-th modulation signal for k-th user $x_{k,n1}$ is expressed as follows:

$$x_{k,n1} = d_k \sum_{n2=0}^{N2-1} c_{k,n2}\, exp\left(\frac{j2\pi n_1 n_2}{N_1}\right) \tag{1}$$

Here, $c_{k,n2}$ is spreading code, and d_k is transmitting data bit of k-th user. Transforming time sequence signal to the frequency domain, sub-carrier components are extracted. The spreading code is multiplied to the component for de-spreading. An n_2-th de-modulation signal for k-th user $x_{k,n2}$ is expressed as follows:

$$y_{k,n2} = c_k{}^*{}_{,n2} \frac{1}{N_1} \sum_{n1=0}^{N1-1} x_{k,n1}\, exp\left(-\frac{j2\pi n_1 n_2}{N_1}\right) \tag{2}$$

Sub-carriers are combined using such algorithm as MMSE. When adaptive weight is defined by $w_{k,n2}$, the combined signal is expressed as follows:

$$d_k = \sum_{n2=1}^{N2} w_{k,n2}{}^* y_{k,n2} \tag{3}$$

3. Adaptive Array Antenna

It is necessary for improvement of communication quality by the error correction code to maintain SINR to a goal. Signals except for a desired user are considered as a kind of noise for the DS-CDMA. In order to maintain communication quality under the environment of multiple accesses, it is necessary to cancel signals of the other users. Interferences of which Direction OF

Arrival (DOA) are different from the desired signal can be canceled by the adaptive antenna. Though it cannot perform sufficiently under the conditions that difference of DOA between the desired signals and the interferences are small, such interferences are able to reduce by means of optimal combination of sub-carriers. When higher rate transmission signal is existed in the DS-CDMA system, SINR of the other users degrades and user capacity becomes small. And, the SINR for each user observed at the base station changes vigorously due to Rayleigh fading. Therefore, observing SINR for each user at the base station, the transmission power of each user is controlled as to maintain SINR to a goal.

A receiver for reverse link as shown in Fig.2 has been proposed. This receiver is equipped with capabilities of adaptive beamforming and optimal combination for sub-carriers. Phase rotation due to propagation and fading is compensated by use of the pilot symbols. Furthermore, average and dispersion of SINR for each user are measured to control power of the mobile stations and to apply soft-decision Viterbi decoding

Signal $r_{s,n1}$ received by s-th antenna element is transformed to the frequency domain by Discrete Fourier Transform (DFT).

$$x_{s,n2}(t)=\frac{1}{N_1}\sum_{n1=1}^{N2} r_{s,n1}(t)exp\left(-\frac{j2\pi n(n_1-1)}{N_2}\right) \tag{4}$$

The frequency domain signal is de-spread as follows :

$$Y_k(t)=[y_{k,1,1}(t)\ \ y_{k,1,2}(t)......y_{k,1,N2}(t)\ \ y_{k,2,1}(t)...y_{k,2,N2}(t)..............y_{k,S,1}(t).....y_{k,S,N2}(t)]^T \tag{5}$$

$$y_{k,s,n_2}(t)=x_{s,n2}(t)c^*_{k,n2}(t)$$

De-spread signals are combined by the MMSE.

$$z_k(t)=W_k^H(t)Y_k(t) \tag{6}$$

$$W_k(t)=[w_{k,1,1}(t)\ \ w_{k,1,2}(t).....w_{k,1,N2}(t)\ \ w_{k,2,1}(t)...w_{k,2,N2}(t)..............w_{k,S,1}(t).....w_{k,S,N2}(t)]^T$$

Each weight is renewed by the MMSE using Pilot symbols as the reference. As for ordinary LMS algorithm, the range of feedback co-efficient is decided by eigenvalues of the co-variant matrix. On such Rayleigh fading environments that the eiganvalues change vigorously, it is difficult to decide the range. Therefore, Normalized LMS of which coefficient can be decided as $0<\alpha<1$ without any constraints is applied.

$$W_k(t+1)=W_k(t)+\frac{\alpha}{Y_k^H(t)Y_k(t)}Y_k(t)e_k(t)^* \tag{7}$$

$$e_k(t)=1-z_k(t)$$

The output is normalized as follows:

$$zz_k(t)=\frac{z_k(t)}{\mu_k(t)} \tag{8}$$

$$\mu_k(t)=(1-\beta)\mu_k(t-1)+\beta z_k(t)$$

Here, β is a forgotten co-efficient. SINR for use of the TPC and soft-decision Viterbi encoding is defined as:

$$SINR_k(t)=\frac{1}{\sigma_k^2(t)} \tag{9}$$

$$\{\sigma_k(t)\}^2=(1-\beta)\{\sigma_k(t-1)\}^2+\beta zz_k(t)$$

4. Propagation Model

N scatters are located around a mobile station at a distance of r. It is assumed that delay of scattered waves can be neglected and there are L_K large reflectors that generate the FSF. If N scattered waves formed a path, complex channel gain $\xi^{(s)}_{k,l}$ of s-th antenna element is defined by

$$\xi^{(s)}_{k,l}(t)=\sum_{n=1}^{N} G\left(\alpha^{(s)}_{n,k,l}\right)\beta_{n,k,l} exp\left\{j2\pi f_D t cos\theta_{n,k,l}+j\frac{2\pi}{\lambda}\left(x^{(s)} sin\alpha^{(s)}_{n,k,l}+y^{(s)} cos\alpha^{(s)}_{n,k,l}\right)\right\} \tag{10}$$

$$\alpha^{(s)}_{n,k,l}=\alpha_{k,l}+tan^{-1}\left\{\frac{r}{d_{k,l}} sin\left(\varphi_{k,l}+\theta_{n,k,l}\right)\right\}$$

Here, $G(\alpha)$ is the array element pattern, $\beta_{n,k,l}$ and $\theta_{n,k,l}$ are amplitude and angle distribution of each scattered waves, f_D is Doppler frequency, λ is wavelength, $\varphi_{k,l}$ and $\alpha_{k,l}$ are DOA at the base station and at the mobile station for l-th path of k-th mobile station, $(x^{(s)},y^{(s)})$ is a position of antenna element of the base station, and $d_{k,l}$ is propagation length.

5. Simulation

In order to evaluate user capacity of the reverse link, it is assumed that only Pilot symbols are transmitted under the statistic environment. Table 1 shows the parameters for computer simulation. Fig.3 shows the relation between BER and user numbers, changing element number of the adaptive antenna. Number of which user can achieve BER of 10^{-3} increase to 4 times for 4 elements and 7.6 times for 8 elements adaptive antenna in comparison with 1 element antenna. Fig.4 shows an example of converged pattern in case of 6 users and 3 paths per a user. ▽ and + are DOA of the desired user and those of interferences, respectively. It can be seen that the gain at 3 paths of a desired user becomes large. However, gain in the frequency domain changes since interferences closed to the desired path cause the FSF and SINR for each sub-carriers is not the same. Fig.5 shows total receiving power, relative power of the interferences, and transmitting power of the desired user in case of applying the TPC under Rayleigh fading environment. The power of interferences keeps a constant value when the total receiving power changes slowly. However, the power of interferences rises temporarily when the total receiving power changes rigorously. In these situations, the TPC cannot follow the change.

6. Conclusion

In this paper, BER and user capacity of OMC-CDMA reverse link have been examined by computer simulation. We propose a new receiver with adaptive beamforming to increase user capacity. Propagation model with Rayleigh fading and FSF has been assumed. Also, the TPC for near/far problem and the convolution code for error correction have been taken into account. Number of which user can achieve BER of 10^{-3} increase to 4 times for 4 elements and 7.6 times for 8 elements adaptive antenna in comparison with 1 element antenna.

References

[1]S. Hara, "Overview of Multicarrier CDMA," IEEE Commun., pp.123-133, Dec.1997

[2]S. Tanaka, "Pilot Symbol-Assisted Decision-Directed Coherent Adaptive Array Diversity for DS-CDMA Mobile Radio Reverse Link," IEEE Trans. Fundamentals, Vol.E80-A, No.12, pp.2445-54, Dec.1997.

[3]C. K.. Kim, "An Adaptive Beamforming Algorithm for MC-CDMA System with Antenna Array," IEICE Trans. Commun., Vol.E83-B, pp.2712-16, Dec.2000.

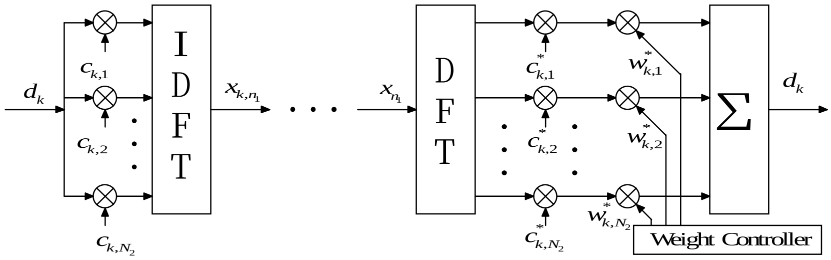

Fig.1 Block diagram of an OMC-CDMA system

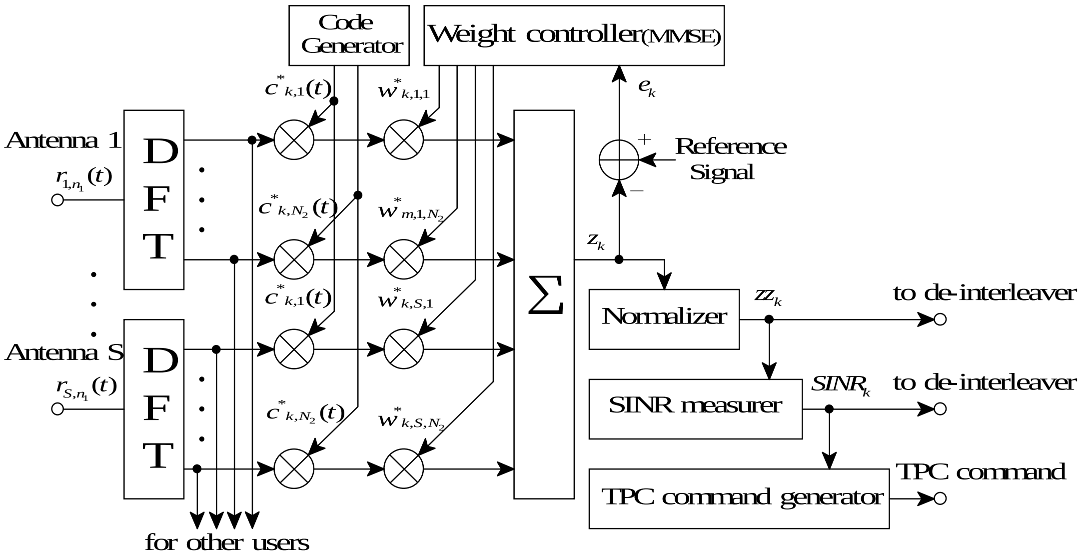

Fig.2 Block diagram of MMSE Adaptive Antenna for OMC-CDMA Mobile Communication.

Table 1 Simulation parameters

Configuration of array	Uniformaly spaced linear array
Interelemental spacing	λ /2
Carrier freqency	2.0GHz
Number of subcarriers	16
Chip rate	4.096Mcps
Symbol duration	16chips (3.8 μ s)
Guard interval duration	4chips(0.95 μ s)
Channel model	3paths / delay 0–4chips(0–0.95 μ s)
Maximum doppler frequency	10Hz
Maximum SNR	20dB
Data modulation / Spreading	QPSK/QPSK
Spreading code	Long random sequence
Channel coding / decoding	convolutional coding(R=1/2,K=7) / soft-dicidion Viterbi decoding
TPC interval	Every 50 pilot symbols
TPC step	1.5dB

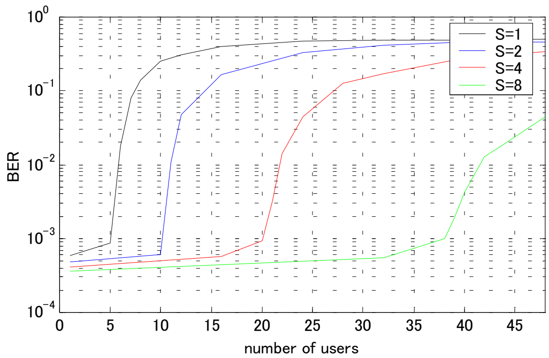

Fig.3 BER vs. user numbers

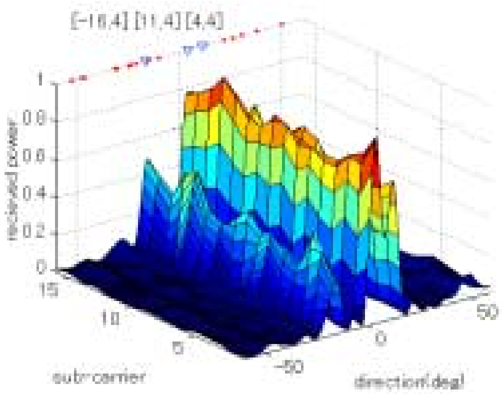

Fig.4 Beam pattern (K=6)

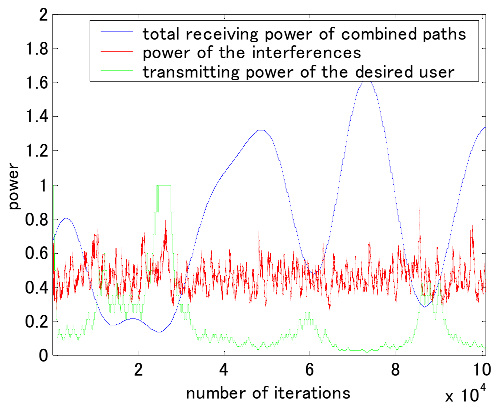

Fig.5 The effects of applying TPC