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APPLICATION OF KMA ADAPTIVE ARRAY ANTENNA TO DS-CDMA SIGNALS

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1. Introduction

The application of spread spectrum modulation techniques with Code Division Multiple Access (CDMA), especially Direct Sequence(DS)-CDMA, is one of the currently favored approaches in terms of modulation schemes and access techniques toward the next generation mobile radio systems. DS-CDMA systems feature being extremely tolerant of interference and fading. However, they have a serious problem that the quality of communication might be degraded by co-channel interferences (CCI) due to the correlation between the spreading codes of co-channels. Therefore, in order to increase the channel capacity, the DS-CDMA systems using interference cancellers have been studied[1]-[3].

On the other hand, the CMA (Constant Modulus Algorithm) adaptive array antenna is receiving considerable attention as a means of capturing successfully the desired signal having constant envelope properties[4]-[5]. It is expected that the CMA adaptive array contributes greatly to canceling interference and increasing the spectrum efficiency of wireless networks. In this paper, therefore, we examine the performance of the CMA and the KMA (Known Modulus Algorithm)[5] adaptive arrays in receiving the DS-CDMA signals. The KMA is the modified CMA which changes the reference envelopes in accordance with the varying modulus of the array output signal. Through computer simulation, we discuss the availability of the CMA and KMA adaptive arrays in DS-CDMA mobile communications.

2. CMA and KMA Adaptive Arrays

We consider a K-element antenna array. Let $x_k(t)$ and w_k represent the input and weight at the kth element ($k = 1, \cdots, K$) respectively, and also $\boldsymbol{X}(t)$ and $\boldsymbol{W}$ denote the input vector and weight vector, respectively, which are defined as $\boldsymbol{X}(t) = [x_1(t), \cdots, x_K(t)]^T$ and $\boldsymbol{W} = [w_1, \cdots, w_K]^T$. Then, the array output $y(t)$ is expressed as $y(t) = \boldsymbol{X}^T(t)\boldsymbol{W}^*$.

The CMA adaptive array works to eliminate the amplitude fluctuations of the array output signal due to the incidence of interferences. Therefore, the cost function to be minimized is normally represented as

$$Q_{C_1}(\boldsymbol{W}) = E\left[\left||y(t)|^2 - \sigma^2\right|^2\right] \tag{1}$$

where $E[\,\cdot\,]$ denotes the ensemble mean and σ is the amplitude of the array output signal expected in the absence of signal degradation[4].

Next, we introduce the cost functions modified for the DS-CDMA with matched filters. Figure 1 shows the example of 7-tap matched filter. In the figure, T is symbol duration of the transmitted data and Δ is chip duration of the spreading codes. As understood from this figure, the matched filter outputs have two possible envelope states, say 1 and 7 in Fig. 1. This information can be exploited for making the cost functions for the DS-CDMA signals, and one of them is written as follows:

$$Q_{C_2}(\boldsymbol{W}) = E\left[\left||y(t)| - \sigma_1\right|\left||y(t)| - \sigma_2\right|\right] \tag{2}$$

where σ_1 and σ_2 are the amplitudes associated with the two possible states.

Another cost function was proposed by Treichler[5], which is given by

$$Q_K(\boldsymbol{W}) = E\left[\left||y(t)|^2 - h^2(t)\right|^2\right] \tag{3}$$

where $h(t)$ is a modulus function practically known or predictable at the receiving site. This is referred to as the KMA for capturing known modulus signals and it is interpreted as a generalization of the CMA. In the DS-CDMA, the desired matched filter outputs are completely known, therefore the $h(t)$ can easily be provided at the receiver.

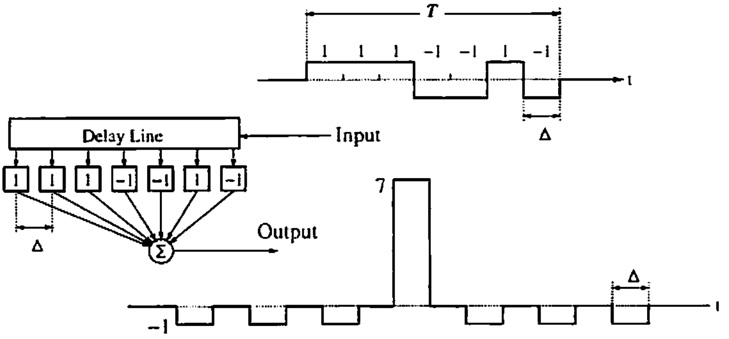

Figure 1: Example of 7-tap matched filter and its performance

3. Computer Simulation

We show the results of computer simulation using a linear array of isotropic antenna elements. The element spacing of the array is a half wavelength of the carrier frequency(1.5GHz). The details of simulation conditions or parameters are given in Table 1. The number of users is 2 and so we generate the desired signal and one CCI which are summarized in Table 2. The angles of arrival are measured from the broadside direction of array, and each channel is assumed to be static.

In the CMA optimization, we let $\sigma = 7$ for the cost function Q_{C_1}, and $\sigma_1 = 1, \sigma_2 = 7$ for the Q_{C_2}. For the the Q_K, the $h(t)$ is given by

$$h(t) = \begin{cases} 1, & 7n\Delta \leq t < (7n+6)\Delta \\ 7, & (7n+6)\Delta \leq t < 7(n+1)\Delta \end{cases} \quad (n = 0, 1, 2, \ldots) \tag{4}$$

The steepest descent method is employed to iteratively update the weights and 15 snapshots are used for one update of the weights. Each snapshot is taken at the center of a chip of the desired signal. The initial weight vector is set to $\boldsymbol{W}_0 = [1, 0, \cdots, 0]^T$, which means the initial array pattern is isotropic.

Figure 2 shows the average BER versus the input SNR. The original CMA with Q_{C_1} degraded the BER performance adversely, which is not shown in Fig.2. In contrast, the modified cost function Q_{C_2} provides the better performance at the SNR higher than 10dB. However, at the low SNR, the modified one has an adverse effect on the BER performance. On the other hand, it is noted that the KMA with Q_K reveals the significantly improved BER performance over the initial states (before adaptation).

For the KMA in case that the SNR is equal to 0dB, Figures 3 and 4 show the relation of output powers and the average BER to the number of iteration of weight update. You can see the KMA suppresses the CCI almost completely, and as a result the error-free states are attained after 330 iterations even at such a low SNR.

Table 1: Computer simulation model

Number of Elements (K)	4
Carrier Frequency	1.5GHz
Spreading Method	Direct Sequence
Spreading Code	M-Sequence Code
Length of Sequence	7
Modulation (data)	QPSK
Modulation (spreading)	BPSK
Demodulation	Coherent Detection
Symbol Rate	1.5Msymbols/s
Chip Rate	10.5Mchips/s
Sampling Rate	21Msamples/s
Filter for Data	Nyquist ($BT = 1, \alpha = 0.5$)
Number of Users	2

Table 2: Radio environment

	Power	Angle of Arrival
Desired Signal	0 dB	0°
CCI	0 dB	60°

4. Conclusion

In this paper, we have investigated the performance of the CMA and KMA adaptive array antennas for capturing the desired signal and canceling the co-channel interference in the DS-CDMA wireless systems. Via computer simulation, it is shown that the KMA adaptive array antenna has high capability of canceling the interference, and hence it is much useful in the next generation mobile radio systems.

References

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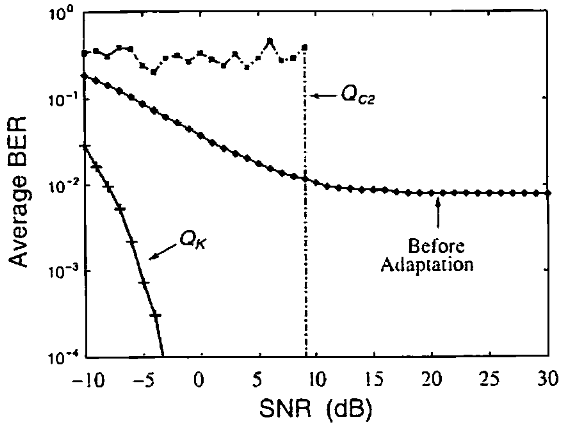

Figure 2: Average BER vs. input SNR

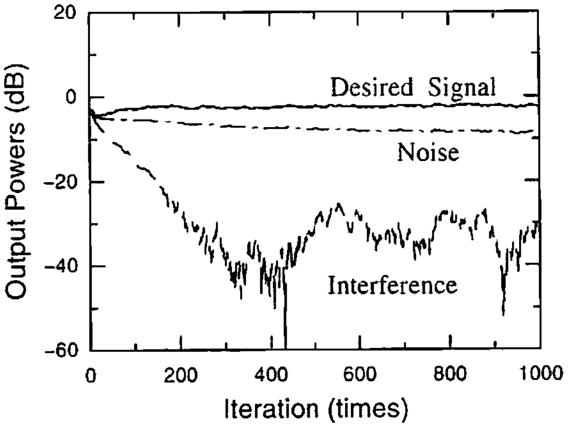

Figure 3: Output powers vs. number of iteration (KMA:Q_K, SNR=0dB)

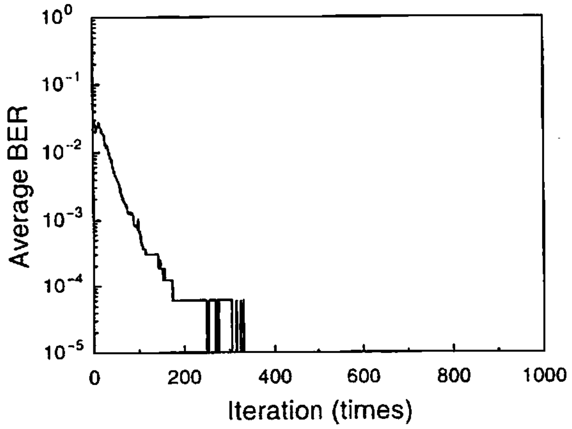

Figure 4: Average BER vs. number of iteration (KMA:Q_K, SNR=0dB)