Proceedings of ISAP'04, Sendai, JAPAN

A CONSIDERATION ON MMSE ADAPTIVE ARRAYS FOR PORTABLE RADIO TERMINALS IN A MULTIPATH ENVIRONMENT

Hiroko ISHIKAWA   Nobuyoshi KIKUMA   Kunio SAKAKIBARA
Hiroshi HIRAYAMA
Department of Computer Science and Engineering
Nagoya Institute of Technology
Gokiso-cho, Showa-ku, Nagoya 466-8555, Japan
E-mail: hiroko@luna.elcom.nitech.ac.jp

1 Introduction

Development of mobile communications is remarkable as seen from increased users of cellular phones in recent years. To increase channel capacity in mobile communication systems, the use of adaptive array antennas has been proposed. Particularly, much attention is focused on MMSE(Minimum Mean Square Error) adaptive array because it has space diversity effects in multipath environments as well as interference cancellation ability[1][2].

However, it is known that the diversity performance will be somewhat degraded when the diversity branches are not perfectly decorrelated[2]. The branch correlation may be caused by a number of factors such as angular despreading of incoming waves or mutual coupling between antenna elements[2].

If the adaptive array is equipped with the portable terminals, the elements of array are forced to be put closely because of small size of the portable terminals. As a result, mutual coupling will influence the cross-correlation between the received signals and will be particularly important in the diversity reception.

In this paper, we consider the effects of mutual coupling on the space diversity performance and interference cancellation of the MMSE adaptive array whose antenna elements are closely spaced in a multipath environment including interference.

2 Two-Element Dipole Array and MMSE Adaptive Array

Figure 1 shows the two-element parallel vertical dipole array with the element spacing of d. Each element is connected with a load impedance Z_L. The adaptive array system is depicted in Fig. 2. The input signals (element outputs) $x_1(t)$ and $x_2(t)$ are calculated by evaluating the mutual coupling with ICT[3] in this paper.

With the vector notation $\boldsymbol{X}(t) = [x_1(t)\ x_2(t)]^T$ and $\boldsymbol{W} = [w_1\ w_2]^T$, the array output signal $y(t)$ is expressed as $y(t) = \boldsymbol{X}^T(t)\boldsymbol{W} = \boldsymbol{W}^H\boldsymbol{X}(t)$. Then, the optimal weight vector of MMSE adaptive array using a reference signal $r(t)$ is given by

$$\boldsymbol{W}_{opt} = R_{xx}^{-1}\boldsymbol{r}_{xr} \tag{1}$$

where $R_{xx} = E[\boldsymbol{X}(t)\boldsymbol{X}^H(t)]$ and $\boldsymbol{r}_{xr} = E[\boldsymbol{X}(t)r^*(t)]$.

ISBN: 4-88552-206-4 C3055©IEICE

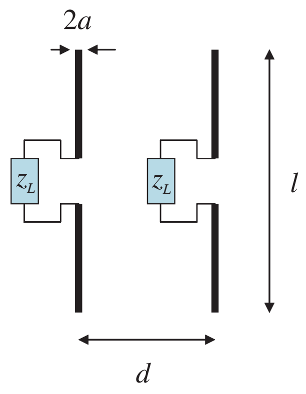

Figure 1: Two-dipole array.

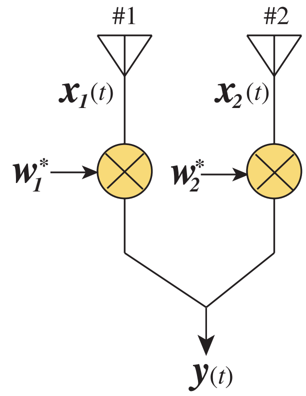

Figure 2: Adaptive array system.

3 Computer Simulation

In this section, computer simulation is carried out to examine the performance of MMSE adaptive array in a multipath environment. SMI(Sample Matrix Inversion) algorithm is employed for optimization of MMSE. The reference signal of MMSE is identical to the desired signal. The desired signal and interference are assumed to be vertically polarized and incident in the horizontal plane. To realize the quasi-static fading environment, eight multipath waves of each signal are coming at intervals of 22.5° from −90° to 90° as shown in Fig. 3 where the incident angles are measured from the broadside direction of the array. Also, the center angle of the desired signals is 0.5° and that of interfering signals is 11.75°. There is no delay time difference among the eight multipath waves. Other simulation conditions are shown in Table 1. The transmitted data of each signal are random codes, and each burst is composed of 256 symbols. In the reception, the random phase shifts are given to the received signals burst-by-burst. In SMI algorithm, one sample per symbol is used and weight update is carried out every 16 samples which is regarded as one iteration. In addition, the average BERs are calculated by using 1000 bursts, and the output SNRs (or SINRs) are given by using the first 20 bursts only.

Figure 5 shows the average BER characteristics when the desired signals only are incident (no interference). For a reference, BER in the case of one-element reception is drawn in the figure. From Fig. 5, it is found that the BER characteristics including mutual coupling are better than those without mutual coupling. In particular, when the element spacing is less than 0.3λ, there is considerable difference. This is because the cross-correlation between two element signals is reduced by the mutual coupling effect and so diversity gain of MMSE adaptive array is increased. Figure 6 shows the cross-correlation between received signals of two elements as a function of element spacing d. It is seen from the figure that the cross-correlation with mutual coupling differs substantially from that assuming no mutual coupling and also that mutual coupling actually decreases the cross-correlation when the element spacing is less than 0.3λ.

Next, the output SNR characteristics for the element spacing of $d = 0.15\lambda$ are shown in Fig. 7. It turns out from the figure that the SNR in the case of including mutual coupling is higher than that in the case of no mutual coupling at any iteration.

Then, the average BER characteristics when interfering signals are incident simultaneously are shown in Fig. 8 The performance with mutual coupling is also better than that without mutual coupling, although the BERs cannot be said to be low enough. However, it is clear that the adaptive array can keep low BER in comparison with one-element reception. Besides, it is found from Fig. 9 that the output SINR with mutual coupling is always higher than that in other cases for the element spacing of $d = 0.15\lambda$.

Table 1: Simulation conditions.

array configuration	linear arrays
number of elements	2 elements
antenna element	vertical dipole antenna ($l = 0.47\lambda$, $a = 0.0032\lambda$, $Z_L = 50\Omega$)
modulation code	random sequence
modulation scheme	$\pi/4$-shift QPSK
input SNR	20 dB

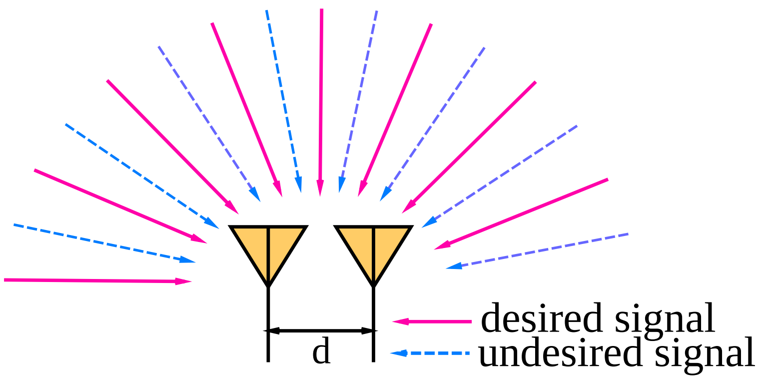

Figure 3: Array and incoming waves.

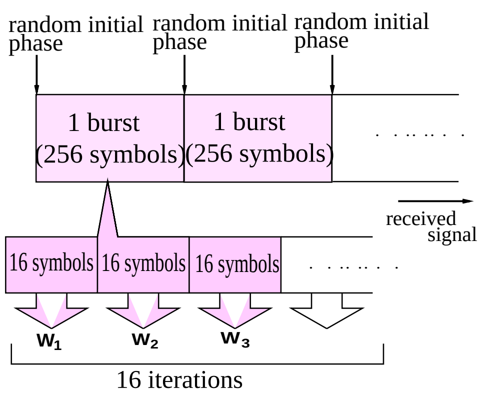

Figure 4: Data format of transmitted signal.

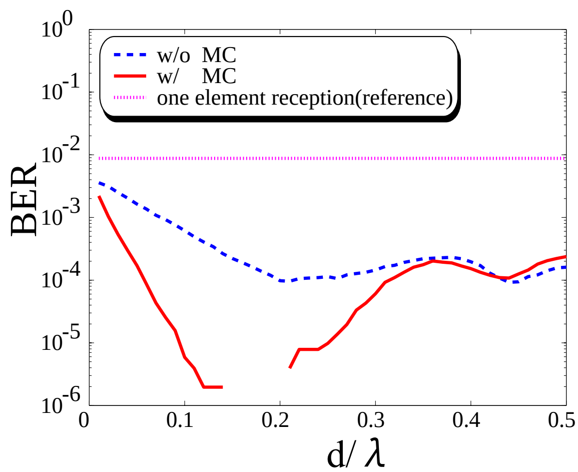

Figure 5: Average BER versus element spacing in the case of no interference.

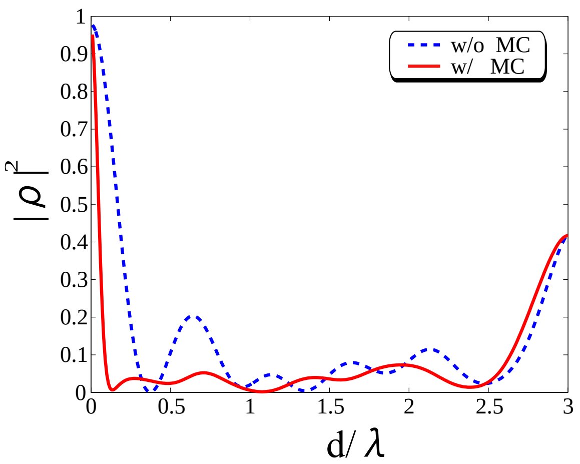

Figure 6: Cross-correlation between two elements versus element spacing.

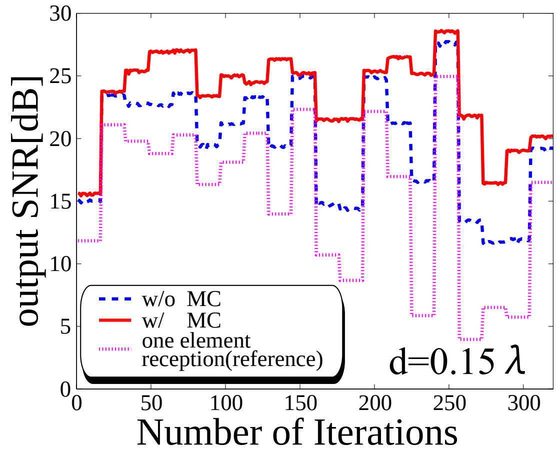

Figure 7: Output SNR characteristics with no interference.

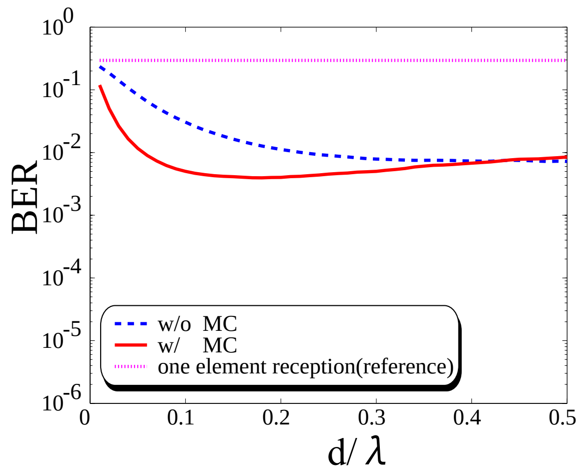

Figure 8: Average BER versus element spacing in the case of interference incident.

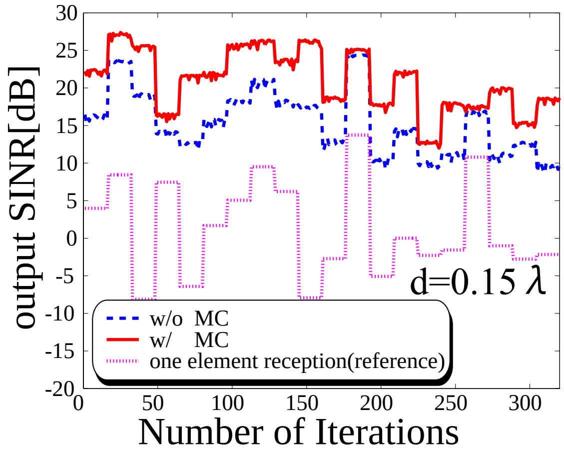

Figure 9: Output SINR characteristics with interference.

4 Conclusion

In this paper, supposing the adaptive array for portable radio terminals, we have investigated the effects of mutual coupling on the performance of MMSE adaptive array consisting of two dipoles. Consequently, it has turned out that average BER and output SINR (or SNR) characteristics are improved by mutual coupling effects not only when the interference is not incident, but also when interfering multipath signals are incident simultaneously. It is expected that these results will help us to integrate the adaptive array into the portable radio terminals including cellular phones.

References

[1] N.Kikuma: *Adaptive Antenna Technologies (in Japanese)* , Ohmsha, Inc., 2003.

[2] R.Janaswamy: *Radiowave Propagation and Smart Antennas for Wireless Communications*, Kluwer Academic Publishers, 2001.

[3] N.Inagaki: "An Improved Circuit Theory of a Multielement Antenna," IEEE Trans. Antennas Propagat., Vol.AP-17, No.2, pp.120–124, March 1969.