FADING EQUALIZATION USING AN ADAPTIVE ANTENNA FOR HIGH-SPEED DIGITAL MOBILE COMMUNICATIONS

Yasutaka OGAWA, Manabu OHMIYA, Kiyohiko ITOH

Faculty of Engineering, Hokkaido University
Sapporo 060 JAPAN

1. INTRODUCTION

High-speed digital transmission is essential for flexible land mobile radio communications using time division multiple access (TDMA). A multipath signal with a long delay time is one of the most serious hindrance in the high-speed digital land mobile transmission. Although several techniques have been studied to cope with the multipath propagation problem, the performance of them degrades when the delay time is very long [1].

An adaptive antenna cancels an interference signal by steering nulls of an antenna pattern. Thus, the adaptive antenna has a potential to reduce the multipath fading. In this paper, we present multipath fading equalization using the adaptive antenna, and clarify the fundamental characteristics. Since the adaptive antenna surpresses the multipath signal with a long delay time sufficiently, it is expected to be useful for the high-speed digital transmission.

2. LMS ADAPTIVE ARRAY AND ITS FUNDAMENTAL CHARACTERISTICS

Fig.1 shows an N-element adaptive array antenna based on a least-mean-square algorithm (abbreviated as LMS adaptive array) [2]. Complex-valued weights are determined in such a way that the mean square error is minimized.

We assume that two signals of $\tilde{s}(t)$ and $\tilde{m}(t)$ are incident on a three-element circular array as shown in Fig.2. The antenna elements are assumed to be isotropic and a half-wavelength apart. $\tilde{m}(t)$ is delayed from $\tilde{s}(t)$ by τ. The modulation method is binary phase-shift keying (BPSK) with a time-slot T. We assume that the signals are band-limited by a third-order Butterworth filter with a 3-dB bandwidth 2/T. We represent the power of $\tilde{s}(t)$, $\tilde{m}(t)$ and thermal noise at each antenna element by S_I, M_I and N_I, respectively. Furthermore, we assume that the reference signal $\tilde{r}(t)$ in the LMS adaptive array coincides with $\tilde{s}(t)$. Then, $\tilde{s}(t)$ is a desired signal and $\tilde{m}(t)$ is an undesired one.

Fig.3 shows the output DUR (desired-to-undesired-signal-ratio) versus τ/T in a case where the weights in the LMS adaptive array have the steady-state mean value [3]. Ψ denotes the phase delay of $\tilde{m}(t)$ from $\tilde{s}(t)$ at the antenna element #1. Here, we assume that a mobile unit is stationary. From Fig.3, the longer the delay time is, the tendency of the better performance is seen. This means that the LMS adaptive array suppresses sufficiently the multipath signal which has a long delay time.

Fig.4 shows the array pattern. It is seen that the longer τ is (correlation between $\mathbf{s}(t)$ and $\mathbf{m}(t)$ is lower), the more exactly the null is pointed toward the undesired signal $\mathbf{m}(t)$. This is the reason why the LMS adaptive array suppresses the multipath signal with a long delay time sufficiently.

3. SIMULATION OF MOBILE COMMUNICATIONS

In this section, we show the computer simulation results of the LMS adaptive array in the digital mobile communication.

Array configuration and multipath propagation environment are illustrated in Fig.5. Namely, a six-element circular LMS adaptive array is equipped on a mobile unit. The diameter of the array is $1/\sqrt{2}$ wavelength. The mobile unit moves at a velocity of $v = 50$ km/h. We assume that five signals are incident on the array. We represent the most preceding signal by $\mathbf{s}(t)$. The other multipath signals are represented by $\mathbf{m}_K(t)$ $(k=1\sim4)$ whose power at each antenna element is M_{IK}. We assume that $\mathbf{m}_K(t)$ is delayed from $\mathbf{s}(t)$ by τ_K. Moreover, we assume that the modulation method is binary phase-shift keying with a data rate of 1 Mbps and that the carrier frequency is 1.5 GHz.

When the input signal power is large, the convergent time of the LMS adaptive array is short but the stability at the steady state is poor. Inversely, when the input signal power is small, the stability is excellent but the convergent time is long. Then, we employ the power-dependent time constant τ_c of the low-pass filter in the LMS adaptive array. τ_c is given by

$$\tau_c = 10PT/N_I$$

where P denotes the mean value of the power at the antenna elements. In the simulation, we employed the power value (P) at t=0.

As in the preceding section, we assume that the reference signal coincides with $\mathbf{s}(t)$. Then, $\mathbf{s}(t)$ is the desired signal and the other multipath signals are the undesired ones.

Fig.6 shows the output DUR versus time. It is seen that the convergent time is about 20 time-slots and that the multipath equalization performance is not affected by the mobile unit movement at a speed of 50 km/h. Similar results were obtained in the other multipath environments.

4. CONCLUSIONS

We have presented the LMS adaptive array for multipath fading qualization. From the numerical results, it may be said that the LMS adaptive array is useful for the high-speed digital mobile communications.

In this paper, we considered that the most preceding signal is the desired one. However, occasionally a delayed multipath signal may have the largest power. In this case, we should consider the strongest multipath signal to be the desired one. If we synchronize the reference signal with the strongest multipath signal, we may obtain the better performance.

Generation and synchronization of the reference signal are important subjects which should be studied further. Moreover, digital signal processers with high-speed operations will be needed to implement the adaptive antenna.

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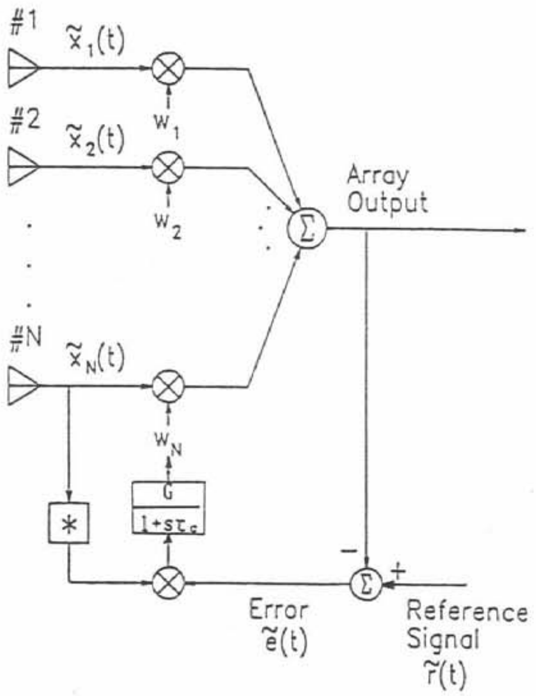

Fig.1 LMS adaptive array.

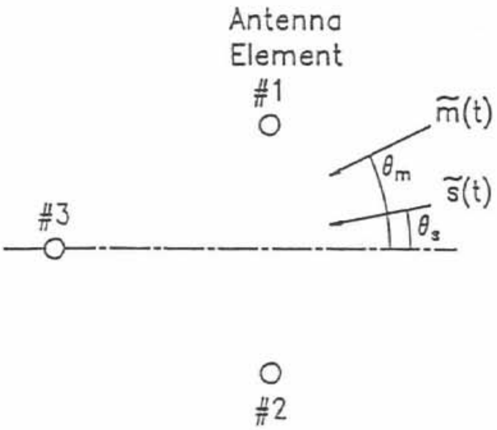

Fig.2 Three-element circular array.

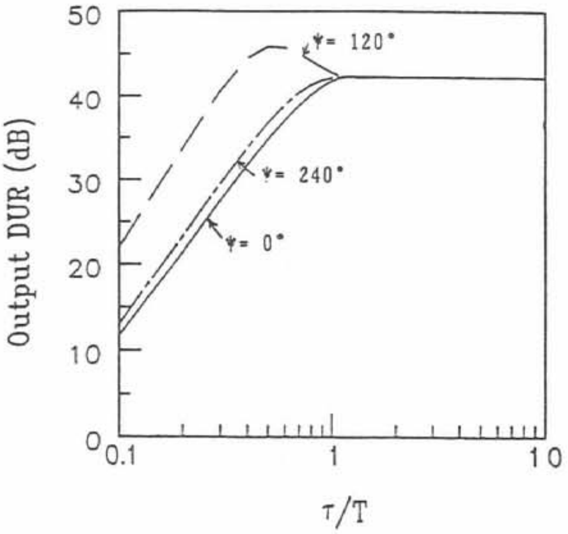

Fig.3 Output DUR vs. τ /T.
$\theta_s=0^\circ$, $\theta_m=30^\circ$, $S_I/N_I=M_I/N_I=20$dB, $GN_I=10$.

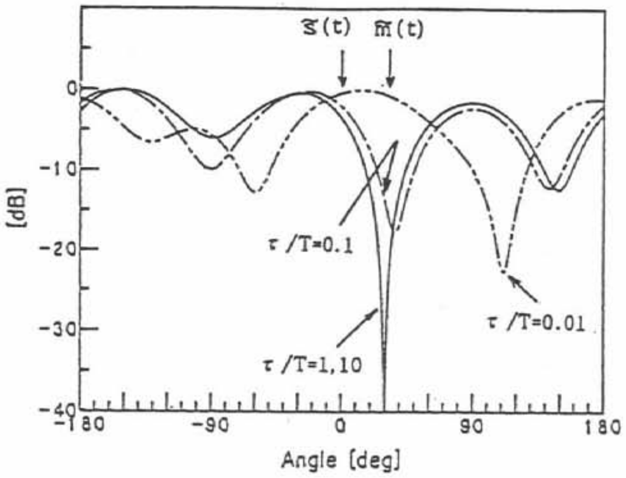

Fig.4 Array pattern.
θ_s=0° , θ_m= 30° , S_t/N_t=M_t/N_t=20dB, GN_t=10, Ψ=0° .

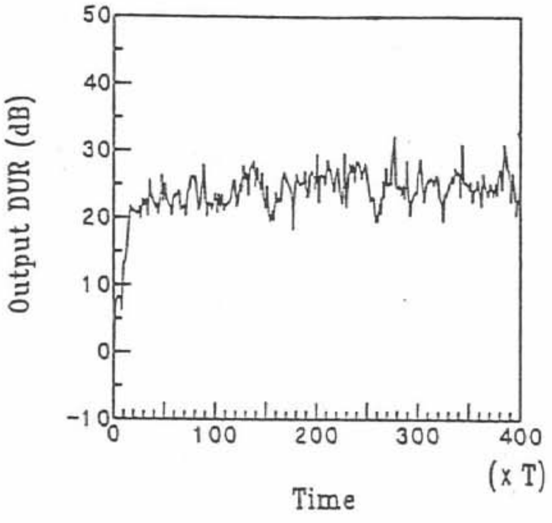

Fig.6 Simulation result.
S_t/N_t=20dB, M_{t1}/N_t=10dB, M_{t2}/N_t=15dB, M_{t3}/N_t=20dB, M_{t4}/N_t=15dB, τ_1/T=0.4, τ_2/T=1, τ_3/T=10, τ_4/T=2, GN_t=20.

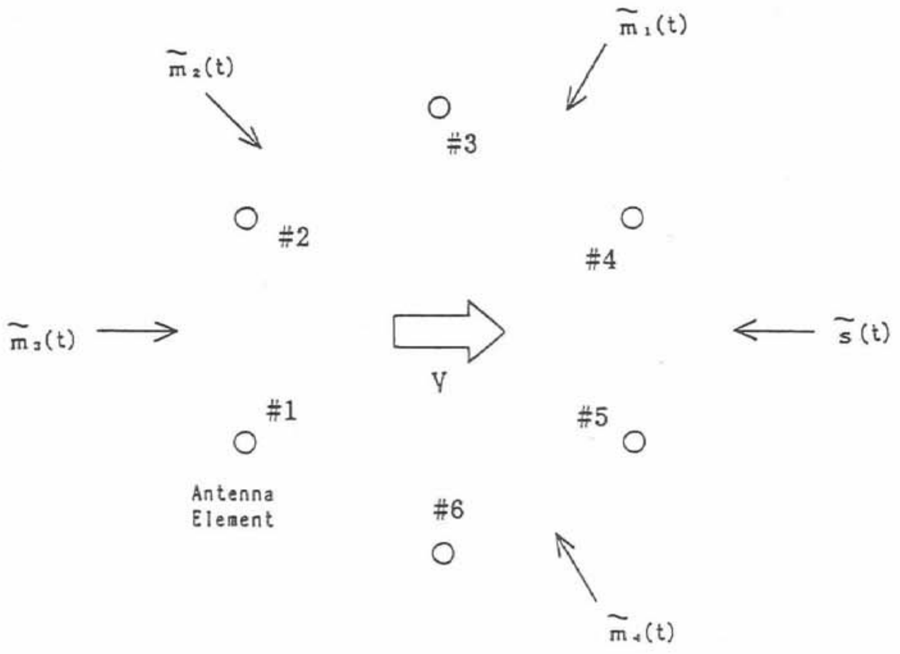

Fig.5 Array configuration and multipath environment.