REFERENCE SIGNAL GENERATION IN AN LMS ADAPTIVE ARRAY FOR MULTIPATH FADING REDUCTION

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1. INTRODUCTION

An LMS adaptive array may reduce the multipath fading effectively for any correlation coefficient between multipath signals when a reference signal is generated properly [1]. In this paper, we obtain required synchronization accuracy in reference signal generation and we propose processor configuration which generates the reference signal.

2. ASSUMPTIONS AND BASIC DEFINITIONS

We assume that two multipath components $\tilde{s}(t)$ and $\tilde{m}(t)$ of a narrow-band signal are incident on an N-element LMS adaptive array shown in Fig. 1. The elements are assumed to be isotropic and a half wavelength apart. We express both signals on the first element as $\tilde{s}_1(t)$ and $\tilde{m}_1(t)$. It is assumed that $\tilde{m}_1(t)$ is delayed from $\tilde{s}_1(t)$ by τ and that the carrier phase of $\tilde{m}_1(t)$ is delayed from that of $\tilde{s}_1(t)$ by Ψ. Then, we have

$$\tilde{m}_1(t) = \sqrt{Mi/Si}\ \tilde{s}_1(t-\tau)\ e^{-j\Psi'} \tag{1}$$

$$\Psi = \omega_c \tau + \Psi' \tag{2}$$

where Si and Mi denote the power of $\tilde{s}(t)$ and $\tilde{m}(t)$ on each element respectively, and ω_c denotes a carrier angular frequency. Also, it is assumed that thermal noise is present on each element signal. We represent the thermal noise power on each element by Ni.

We express the reference signal as

$$\tilde{r}(t) = \tilde{s}_1(t-Tr)\,. \tag{3}$$

When Tr=0, the reference signal coincides with $\tilde{s}(t)$. Similarly, when $Tr=\tau$, it coincides with $\tilde{m}(t)$.

In order to generate the reference signal, a pilot signal is always transmitted together with an information signal [2]. The pilot signal is assumed to be biphase modulated by a pseudonoise sequence which is fully known at the receiver. For simplicity, we consider only the pilot signal portion. Moreover, we assume that the period of the PN code is very long. Then, we may express the autocorrelation function of the complex envelope of the signal normalized by Si as

$$\tilde{\rho}(t) \simeq \begin{cases} 1 - |t|/T & \text{for } |t| \le T \\ 0 & \text{for } |t| > T \end{cases} \tag{4}$$

where T denotes a clok pulse duration.

We represent the power of $\tilde{s}(t)$, $\tilde{m}(t)$ and the thermal noise at the array output by So, Mo and No respectively. When So≥Mo, we consider that $\tilde{s}(t)$ is the desired signal and that $\tilde{m}(t)$ is the undesired signal. On the other hand, when Mo>So, we consider that $\tilde{m}(t)$ is the desired signal and $\tilde{s}(t)$ is the undesired signal.

3. SYNCHRONIZATION ACCURACY

From the above assumptions, we may calculate the steady-state performance of the LMS adaptive array. Fig. 2 shows the output DUR (desired-to-undesired signal ratio) versus Tr/T. When $\tau/T=0.5$, $\tilde{s}(t)$ and $\tilde{m}(t)$ are correlated with each other according to (4). When $\tau/T=5$, they are independent each other. When Tr/T=0, the reference signal coincides with $\tilde{s}(t)$. Similarly, when $\tau/T=0.5$ and Tr/T=0.5, it coincides with $\tilde{m}(t)$. It is seen that the satisfactory output DUR is obtained around Tr/T=0 or Tr/T=0.5 for $\tau/T=0.5$. On the other hand, when $\tau/T=5$, the output DUR has a steady and satisfactory value for $-1<Tr/T<1$.

Fig. 3 shows each output power normalized by Ni versus Tr/T. The period for which the output undesired signal power is suppressed less than No is about 0.2T around Tr/T=0 or Tr/T=0.5.

From these results, it may be said that the synchronization in the reference signal generation must be extremely accurate in the case where the input multipath components are correlated with one another.

4. REFERENCE SIGNAL PROCESSOR

Now, we propose the configuration of the reference signal processor. The reference signal generation consists of two parts just as the synchronization process in a spread spectrum receiver [3]. One is acquisition and the other is tracking. The acquisition is implemented by a sliding correlator which performs the search process and calculates the correlation between the transmitted pilot signal and reference signal. The sliding correlator makes the reference signal coincide with the pilot signal within T. During the initial acquisition, we do not make the LMS adaptive processor operate. Namely, the weights are frozen on fixed values, for example $w_1=1$, $w_2=w_3=\cdots=w_N=0$. This is because we prevent all of the weights from converging to zero.

Now, we discuss the tracking process which is the second part of the synchronization. The tracking circuit operates in such a way that the reference signal coincides with the transmitted pilot signal as precisely as possible. Fig. 4 shows the normalized MSE (mean-square error) in the LMS adaptive array versus Tr/T. Here, the MSE is defined as $MSE = \langle \tilde{e}^*(t)\ \tilde{e}(t) \rangle$. It is seen that when the reference signal coincides with $\tilde{s}(t)$ or $\tilde{m}(t)$ (Tr/T=0 or Tr/T=0.5), the MSE has an extremely low minimal value. Then, the MSE may be used for the recognition of the synchronization.

After the initial acquisition is achieved by the sliding correlator, we make the LMS adaptive processor and tracking circuit begin to operate. The configuration of the tracking circuit is shown in Fig. 5. The VCO (voltage-controlled oscillator) is controlled in such a way that the MSE has a minimal value. This circuit is similar to a tau-dither clock-tracking loop used in a spread spectrum receiver [3]. Fig. 6 shows an example of waveforms in the tracking circuit.

We set the duration time (T′) of the rectangular wave *1* longer than the convergence time of the weight. At a leading edge of the rectangular wave, the clock phase of the reference signal is shifted back by a fraction of a clock pulse duration. It is shifted forth by the same amount at a trailing edge of the rectangular wave. Then, the MSE varies with time as *2*. The LPF (low-pass filter) placed in front of the VCO extracts the DC component *4* from the product *3* of the MSE and rectangular wave. Since the VCO is controlled by the DC component in such a way that the MSE has a minimal value, the reference signal coincides with $\tilde{s}(t)$ or $\tilde{m}(t)$ in time. Thus, by using the tracking circuit, we may generate the highly accurate reference signal.

5. CONCLUSIONS

We have shown that the reference signal must coincide with the pilot signal in time very accurately. Moreover, we proposed the configuration of the reference signal processor.

REFERENCES

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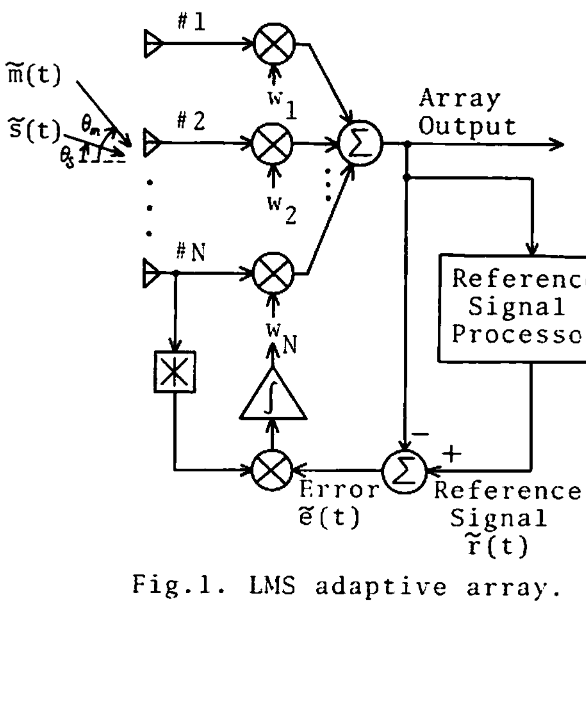

Fig.1. LMS adaptive array.

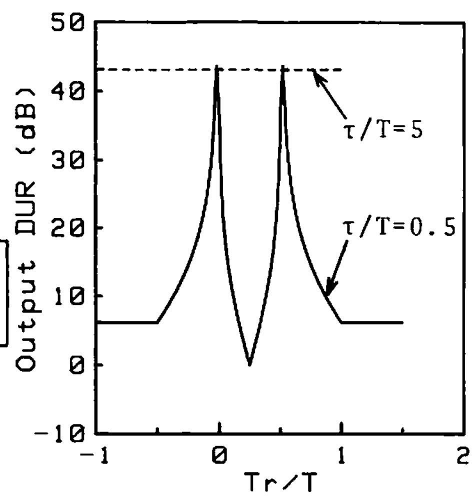

Fig.2. Output DUR vs. Tr/T. Si/Ni=Mi/Ni=20dB, N=2, $\Psi=0°$, $\theta_s=0°$, $\theta_m=30°$.

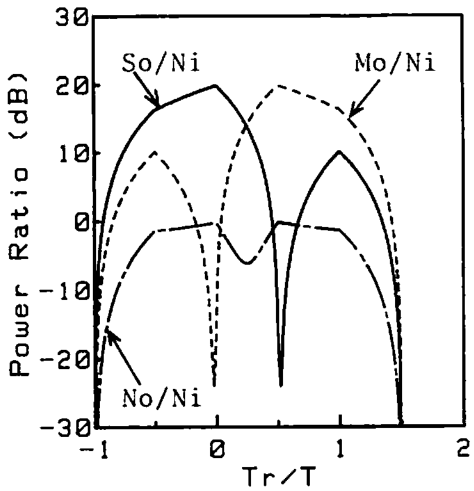

Fig.3. Power ratio vs. Tr/T. Si/Ni=Mi/Ni=20dB, N=2, $\Psi=0°$, $\tau/T=0.5$, $\theta_s=0°$, $\theta_m=30°$.

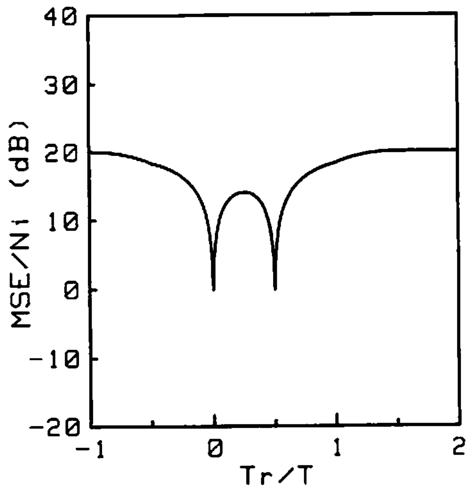

Fig.4. MSE/Ni vs. Tr/T. Si/Ni=Mi/Ni=20dB, N=2, $\Psi=0°$, $\tau/T=0.5$, $\theta_s=0°$, $\theta_m=30°$.

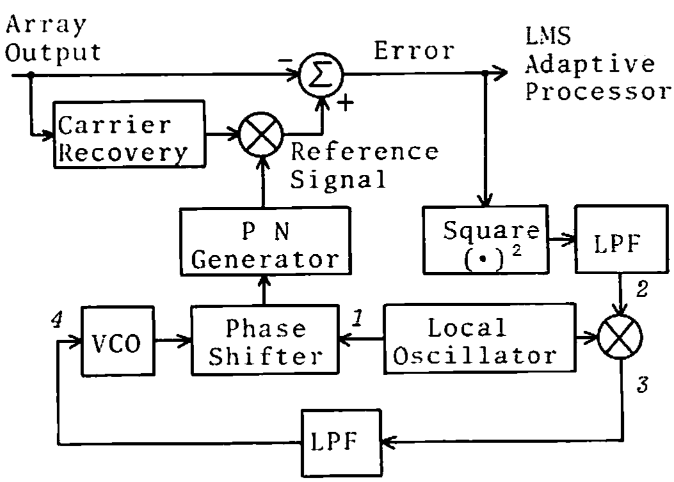

Fig.5. Tracking circuit.

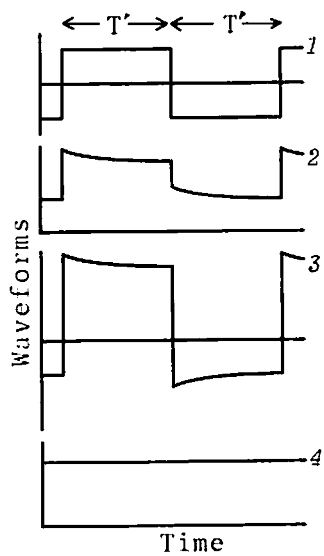

Fig.6. Waveforms in tracking circuit.