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MULTIPATH FADING EQUALIZATION BY AN ADAPTIVE ARRAY

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I. INTRODUCTION

Because of the increasing needs of mobile communications, it has become a very important work to increase the reuse of the frequency resource. The improvement of frequency reuse principally depends on the reduction of the number of the cochannel-reuse zones.

The multipath fading and the cochannel interferences are the most important factors that affect the communication quality and limit the efficiency of the frequency resources in the cellular mobile communication systems. So far, the diversity technique has drawn great attention because it can overcome the multipath fading problem. However, the effect is limited since it cannot contribute to cancel the cochannel interference as well as the less-correlated scattered signals.

On the other hand, the excellent performance of adaptive arrays in suppressing interferences as well as in equalizing multipath fading makes it be a practically meaningful subject to study the application of them to mobile communications [1,2]. In this paper, we report some results achieved in the equalization performance of adaptive arrays and its application to mobile communications that contributes to increase the communication capacity.

II. THEORETICAL ANALYSIS

In a mobile communication environment, signals are propagated pricipally by reflection and scattering, and a multipath faded signal can be simulated by the sum of reflected and scattered signals [3,4]. In such a fading environment, the received signal usually forms a Rayleigh distribution in a small region, and its median forms a log-normal distribution. To suppress the effect of cochannel interferences, the received SIR should be ensured to exceed a given level called a radiation frequency protect margin (RFPM). Here, we assume that the base stations are the same and the propagation environment is uniform. It is also assumed that the size of the zones are identical. Thus, the cochannel-reuse distance depends only on the type of modulation and the required communication reliability. In a mobile communication system as shown in Fig.1, the cochannel reuse distance D is the sum of D_I and D_S, and D_I is determined by

$$\frac{D_I}{D_S} = 10^{SIR/(\alpha \times 10)}, \qquad (1)$$

where SIR is in dB, and α is a factor whose value is usually between 3 and 4 [5]. In this paper, we choose it 3.5.

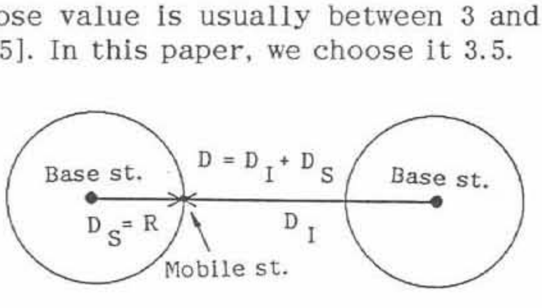

Fig.1 A mobile communication system

In this paper, only the equalization of the Rayleigh fading is discussed, so that the required RFPM due to the log-normal shadowing is assumed to be fixed. The experimental results have shown that, by considering the log-normal shadowing, there should be another 8dB margin above the median value of the SIR in considering the presence of Rayleigh fading [6]. Hereafter, this result will be applied.

We will use a simple model in considering the equalization by using an adaptive array. The received signal in a mobile station M is expressed as the sum of the direct signal d(t) and the reflected or scattered signals $r_i(t)$, where, as is often the case, d(t) may be absent. Each of $r_i(t)$ is considered to have the similar waveform with d(t) while its phase varies as the mobile station moves. Without using an adaptive array, the received signal, $s_1(t)$, is given by

$$s_1(t) = d(t) + \sum_i r_i(t). \qquad (2)$$

After using an adaptive array, the received signal, $s_2(t)$, is given by

$$s_2(t) = W^T(t)[D(t) + \sum_i R_i(t)], \qquad (3)$$

where W(t) is the weight vector determined by the LMS algorithm, and D(t) and $R_i(t)$ is the received direct and reflected signal vectors in the array corresponding to d(t) and $r_i(t)$, respectively. Also, ^{T} denotes transpose.

In the analyses, ideal isotropic antennas will be assumed as the antenna array elements, and no mutual coupling effect is considered.

III. COMPUTED RESULTS

First, we give a design example of the cochannel-reuse distance in the absence of an adaptive array. It is assumed that the output signal-to-noise ratio (SNR) and the output SIR are required to exceed 10 dB in the probability of 95%. Consider the condition where 3 waves of the desired signal and 3 waves of a cochannel interference signal are present, as is shown in Fig.2, and all the waves are assumed to arrive from the horizontal directions. Then, without using an adaptive array, we get the output SNR and the output SIR as Fig.3. In this case, we obtain that the required input SNR of the direct wave is 17.1 dB and the required median input SIR is 20.4 dB. Therefore, the resulted D/R ratio is 7.47 (including the consideration of the additional RFPM of 8dB required for the log-normal shadowing).

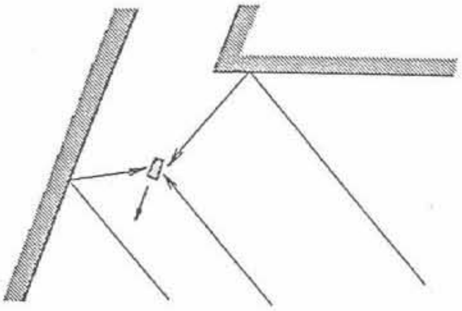

Fig.2 Propagation model I

Next, consider the case where a 3-element LMS adaptive array is used. A circular antenna array is used and the radius of the circle is 0.5 wavelength. In Fig.4, it is seen that, after the equalization by the adaptive array, the variation of the output SNR becomes very small, and no serious fading is observed. Therefore, the performance of the receiver is much improved by using the adaptive array through the equalization of multipath fading.

In Fig.4, we note that the output SNR and SIR after using the adaptive array are much greater than that are required. Therefore, to obtain the same output SNR and SIR as Fig.3, the required input SNR and the median input SIR is 7.0 dB and 11.7 dB, respectively. Simply, a 10.1 dB reduction in the input SNR means a 10.1 dB reduction of the transmitter power, and, from eqn.(1), a 8.7 dB reduction in the median input SIR means a 43.6% reduction in the D_I/D_S. In this case, the original D/R is 7.47 without the adaptive array, and with it the D/R ratio becomes 4.65. Therefore, the communication capacity become 2.58 times that of the original.

Next, we consider the case where the degree-of-freedom (DOF) of the array is less than the number of reflected signals. In practical situations of a mobile communication environment, there would be a number of reflected waves, although some of them may be of lower power as others. Therefore, it will be interested how the adaptive array performs in the cases where the DOF of the array is less than the number of the reflected waves.

We still use the same model as discussed above except adding two reflected waves of the desired signal, as is shown in Fig.5. Without using the adaptive array, as Fig.6 shows, the received signal shows more serious fading than that in Fig. 3, and the level that the output SNR exceeds with a 95% probability is 8.7 dB and it is 8.8 dB for the output SIR.

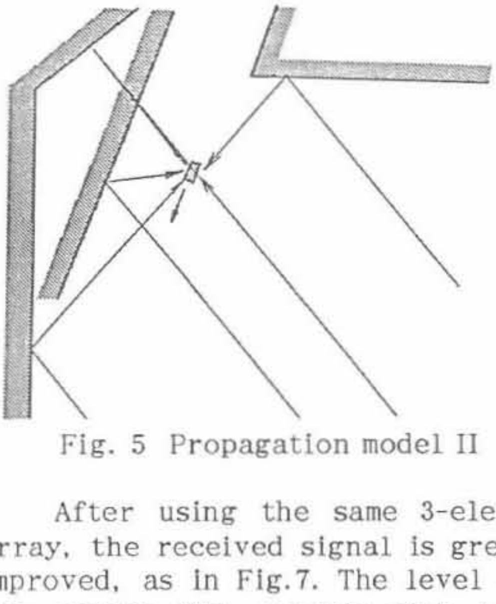

Fig. 5 Propagation model II

After using the same 3-element array, the received signal is greatly improved, as in Fig.7. The level that the output SNR exceeds with a 95% probability is 21.7 dB and it is 19.7 dB for the output SIR. They are 13.0 dB and 10.9 dB higher compared with the results without using the adaptive array. An interested fact seen here is that the adaptive array is still very effective when the number of the arrival waves is greater than that of the array elements. It means that it is sufficient if the adaptive array can change the amplitudes and / or the phases of only a few of the arrival waves, so that the total received signal is avoided from a null. However, to get better equalizing performance, it is necessary that the array elements be properly arranged to reduce the spatial correlation.

IV. CONCLUSIONS

The equalization of multiputh fading in mobile communications by using an LMS adaptive array is discussed and the main attention is paid to the increase of the communication capacity. The results show that an adaptive array is very effective in equalizing multipath fading, and the number of array elements is not necessary to be very large. This fact results the improvement of the communication quality and the increase of the communication capacity.

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REFERENCES

[1] M. J. Marcus & S. Das, Proc. 2nd Int'l Conf. on Radio Spectrum Conserv. Tech., Birmingham, pp.113-117, Sept.1983.

[2] Y. Ogawa, et. al., Proc. of ISAP, Tokyo, pp.857-860, Aug. 1989.

[3] T. Aulin, IEEE Trans., vol.VT-28, pp.182-203, Aug.1979.

[4] A. S. Akki & F. Habar, IEEE Trans., vol.VT-35, pp.2-7, Feb. 1986.

[5] Y. Okumura & M. Shinji, Principle of Mobile Communication, IECE Japan, 1986.

[6] Y. Zhang, Mobile Communications, Heilongjiang Sci. & Tech., 1985.

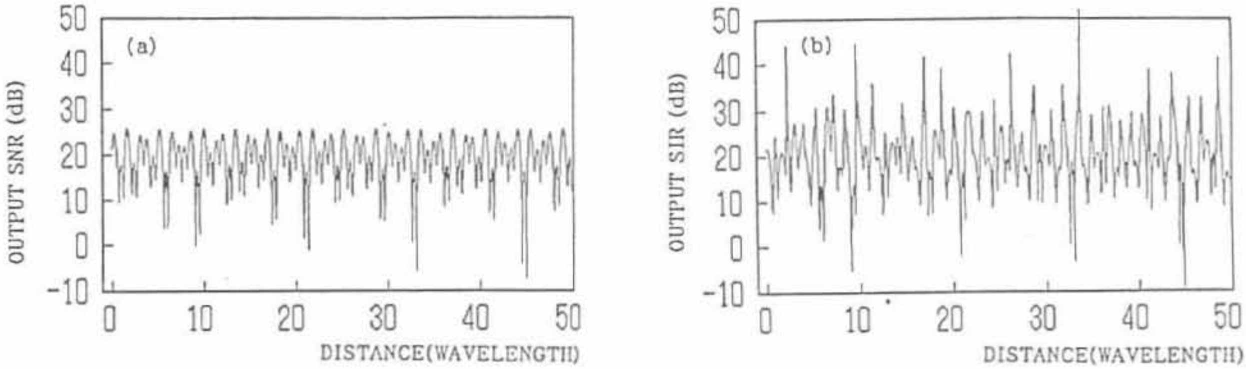

Fig. 3 Output SNR and output SIR without using adaptive array (input SNR=17.1dB, input SIR=20.4dB)

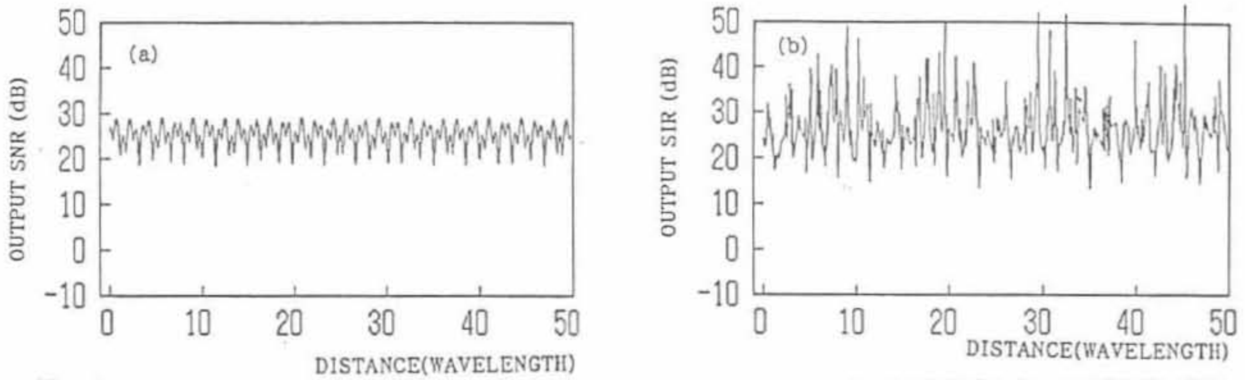

Fig. 4 Output SNR and output SIR with using adaptive array (input SNR=17.1dB, input SIR=20.4dB)

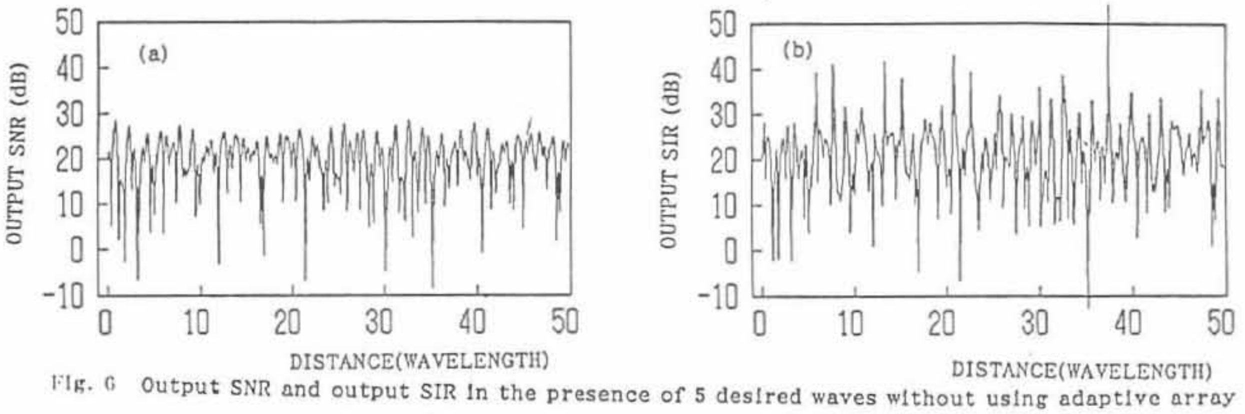

Fig. 6 Output SNR and output SIR in the presence of 5 desired waves without using adaptive array (input SNR=17.1dB, input SIR=20.4dB)

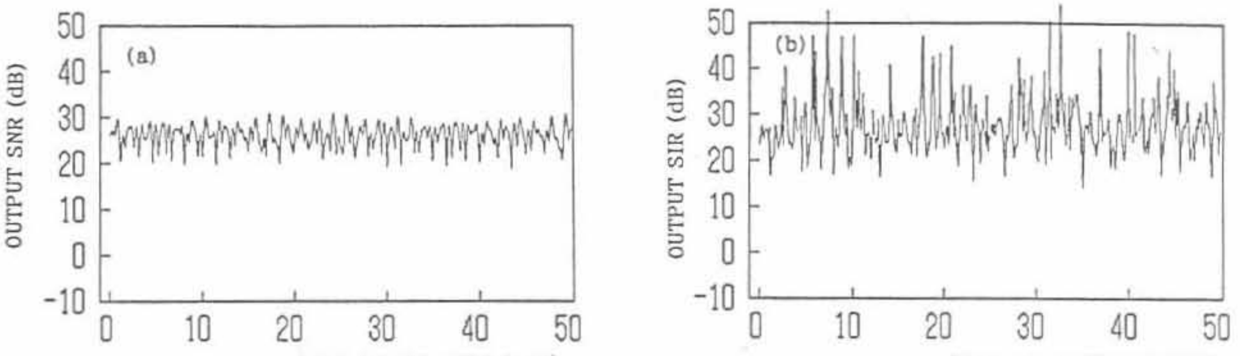

Fig. 7 Output SNR and output SIR in the presence of 5 desired waves with using adaptive array (input SNR=17.1dB, input SIR=20.4dB)