BER Measurements on a Handset Adaptive Antenna Array in the Presence of Co-Channel Interference Generated Using a Spatial Fading Emulator

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1. Introduction

Adaptive antennas for the handsets used in mobile communications have attracted growing interest [1], [2] due to the potentially massive increase in co-channel interference and delay signals, which cause severe deterioration in communication quality. So far, analytical studies on the bit error rate (BER) performance of adaptive antenna arrays in a multipath environment in a non line-of-sight (NLOS) case have been carried out [1], [2]. However, few works have been done on measurement of the BER characteristics of an adaptive antenna in a multipath-fading channel.

This paper presents an empirical study of the BER performance of a handset adaptive antenna array in a Rayleigh-fading channel generated using a spatial fading emulator. The spatial fading emulator [3], which is based on Clarke's model [4], produces Rayleigh-fading channels for both the desired and interference signals. The effectiveness of an adaptive antenna array composed of 2 half-wavelength dipoles subjected to signals generated by the spatial fading emulator was confirmed by measurements of the BER performance.

2. Experimental setup

The spatial fading emulator setup is shown in the photographs in Fig. 1. This consists of 15 half-wavelength dipoles, two power dividers, two control circuits and a computer. The 15 half-wavelength dipoles, which function as scatterers, are located at evenly spaced intervals on a 2 m diameter circle. The control circuit comprises 7 sets of phase shifters and attenuators, which vary the phase and amplitude of signals radiated from the scatterers. The amplitudes of the signals radiated from the scatterers can be matched by regulating them using the attenuators. The computer calculates values of the phase shift of the signals in order to obtain independent Rayleigh-fading channels based on Clarke's model for both the desired and interference signals.

The experimental configuration is shown in Fig. 2, which illustrates the relative position between the antenna array and the spatial fading emulator used to generate the Rayleigh-fading environment. The desired and interference signals, which were modulated by the transmitter, were divided into 7 by the power dividers. The desired signals were radiated from 7 of the 15 scatterers, shown as black filled circles in Fig. 2. The interference signals were radiated from the 7 scatterers shown as red filled circles. The adaptive antenna array, comprising 2 half-wavelength dipoles with a half-wavelength spacing, was set at the center of the scatterers. A vertically polarized wave of 2.07 GHz was radiated for both the desired and interference signals. Coherent detection of the quadrature phase shift keying (QPSK) signal at 64 kbps was used for evaluating the BER characteristics. The maximum Doppler shift (fd) was set to be 20 Hz and the direction of motion of the array was at an

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angle of 10 degrees from the scatterer labeled #1. The method of Least Mean Squares (LMS) was used as the algorithm for the adaptive antenna processing, with the step size and the number of iterations being 0.1 and 1000, respectively.

3. Performance of the fading emulator

Figure 3 shows the measured received powers of antennas #1 and #2, from which the adaptive antenna array was constructed, when the desired signals were radiated from the 7 scatterers (see Fig. 2). Figure 3(a) shows the measured instantaneous received power as a function of the product of the maximum Doppler shift and time (fd*t). The sampling frequency was 400 Hz and the sample number was 500. It is observed from Fig. 3(a) that the mean signal power of both antennas has the same value, –57 dBm, although the variation of the received power of antenna #1 is different from that of antenna #2. This indicates that the brunch correlation of the 2 antennas was small, this being just 0.36. Figure 3(b) shows the cumulative distributions of the received powers of each antenna for the desired signal, which are normalized to their corresponding medians. The theoretical curve of a Rayleigh-fading channel, normalized to the median, is also plotted in Fig. 3(b). As can be seen from Fig. 3(b), the measured received powers are good approximations to the cumulative distribution of a Rayleigh-fading channel.

4. Average BER characteristics of the adaptive antenna array

Figure 4 shows the cumulative distribution for the BER of a QPSK signal for an average input signal-to-noise power ratio (SNR) of 15 dB and an average signal-to-interference power ratio (SIR) of 0 dB. During the measurement, at every sampling step the fading emulator was stopped and the BER characteristics evaluated. The theoretical value is also plotted in Fig. 4, in which the interference signals are assumed to be equivalent to the additive white Gaussian noise (AWGN). In the calculation, the mutual coupling between the antennas was not taken into account. As can be seen in Fig. 4, the measured and calculated BERs are approximately in agreement.

Figure 5 shows the measured average BER of the adaptive antenna array as a function of the average input SNR and an average SIR = 0 dB. The measured results for a single half-wavelength dipole and the adaptive antenna array without an interference signal are shown in Fig. 5. The theoretical curves of a single half-wavelength dipole and the space diversity with two half-wavelength dipoles using the Maximum Ratio Combination (MRC) in a Rayleigh-fading channel are also plotted as solid black and broken red lines, respectively, in Fig. 5. From Fig. 5, the measured data of the adaptive antenna array without an interference signal are in good agreement with the theoretical curve of the MRC. This indicates that the adaptive antenna array is capable of providing space diversity when there is no interference signal present. Furthermore, it is found that the BER performance of the array with an interference signal is similar to that of a single antenna without an interference signal. The reason for this phenomenon can be interpreted as there being no diversity effect obtained in this case since the array consumes all of the "degrees of freedom", which is defined as the number of the interference waves that can be suppressed by the array. This reveals that the array can suppress interference signals even in a Rayleigh-fading channel, and the series of measurements conducted in this paper provides experimental confirmation of this.

5. Conclusion

An experimental study on the BER performance of an adaptive antenna array in a Rayleigh-fading channel generated using a spatial fading emulator has been conducted. The fading emulator is capable of creating Rayleigh-fading channels for both the desired and interference signals.

The BER characteristics were evaluated using a QPSK signal with coherent detection at a transmission rate of 64 kbps. The measured average BER of the adaptive antenna array with one interference signal was found to be similar to that of a single antenna without an interference signal. This shows that the array is able to suppress the interference signal even in a Rayleigh-fading channel.

References

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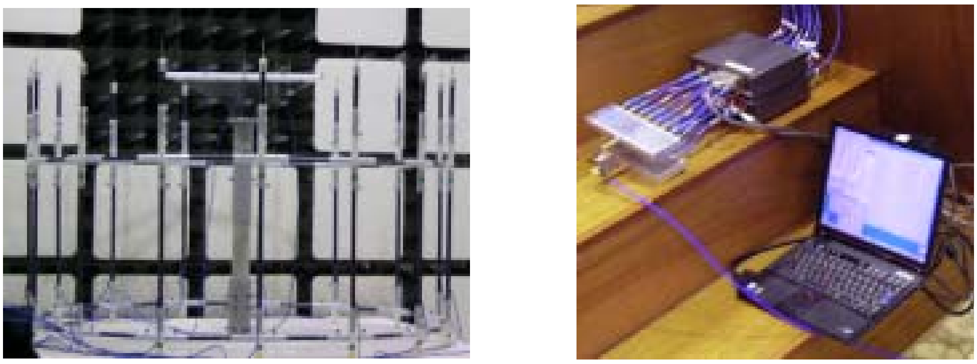


(a) Scatterers (b) Power dividers, control circuits and computer

Fig. 1 Photograph of the spatial fading emulator.

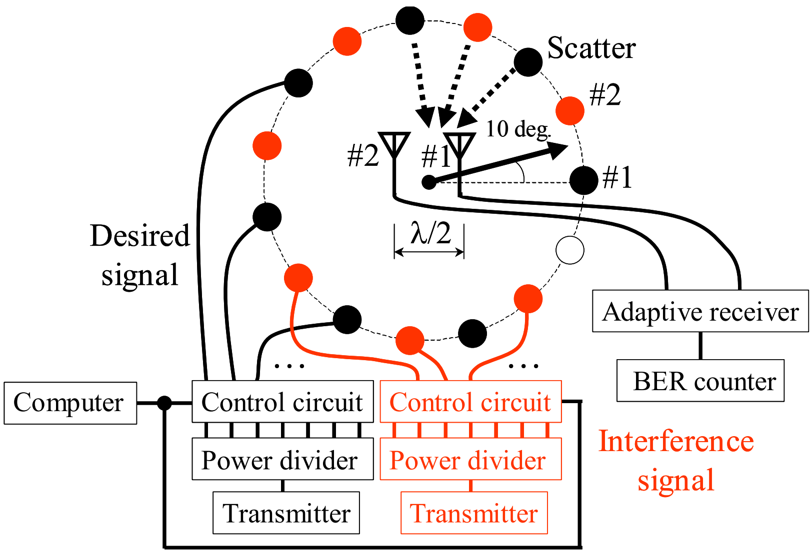
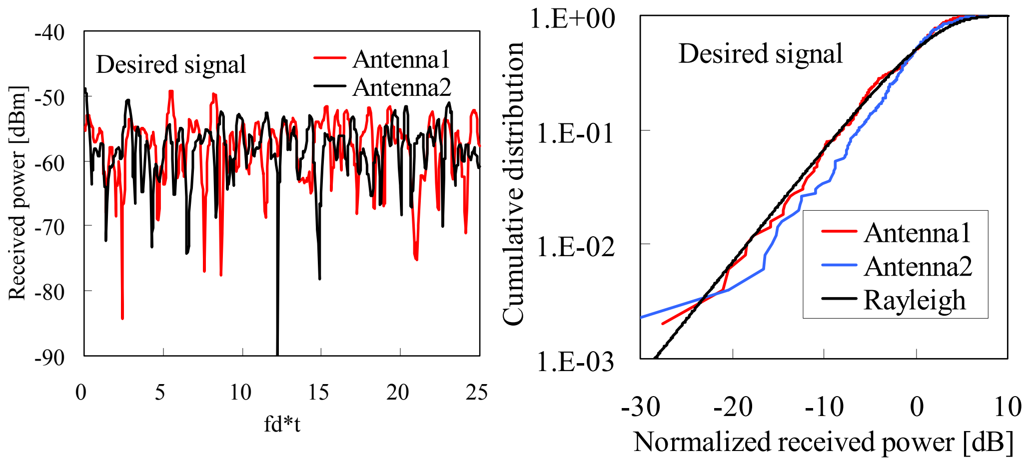


Fig. 2 Experimental setup of the adaptive antenna array.



(a) Instantaneous variations in received power (b) Cumulative distributions

Fig. 3 Measured received power of each antenna when the desired signal is radiated.

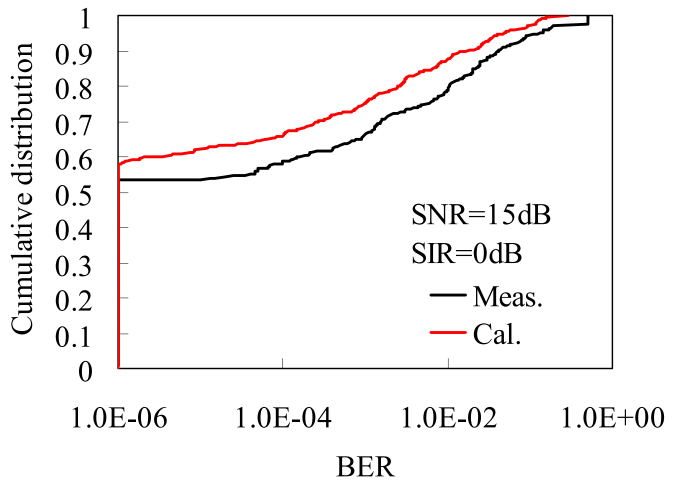


Fig. 4 Cumulative distribution of the BER for an input SNR = 20 dB and SIR = 0 dB.

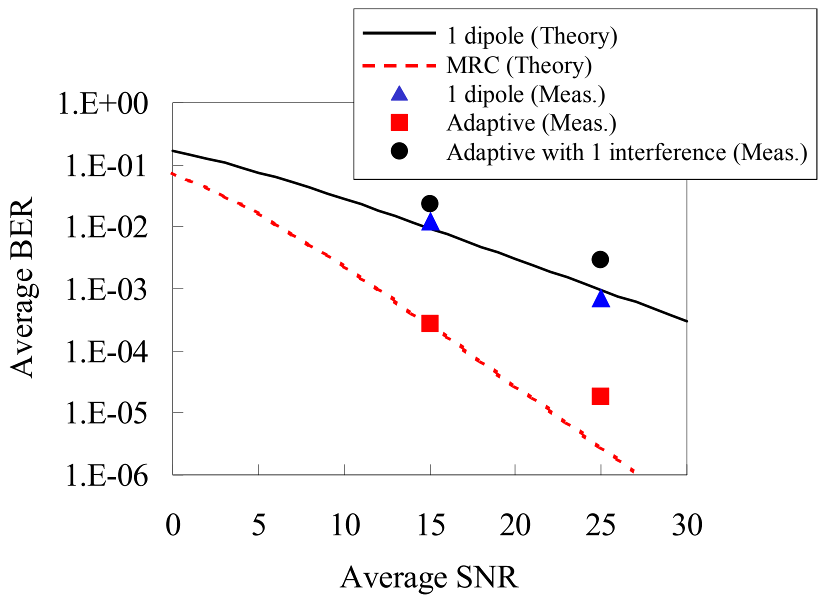


Fig. 5 Average BER as a function of average input SNR.