

BER Measurement on a Handset Adaptive Antenna Array in a Rayleigh-Fading Channel by a Variable-XPR Spatial Fading Emulator

Atsushi Yamamoto*⁽¹⁾, Tsutomu Sakata⁽¹⁾, Hiroshi Iwai⁽¹⁾, Koichi Ogawa⁽¹⁾,
Jun-ichi Takada⁽²⁾, Kei Sakaguchi⁽²⁾, and Kiyomichi Araki⁽²⁾

(1) Network Development Center, Matsushita Electric Industrial Co., Ltd.
1006, Kadoma, Osaka, 571-8501 Japan, Tel : +81-6-6900-9613

E-mail : yamamoto.on@jp.panasonic.com

(2) Graduate School of Science and Engineering, Tokyo Institute of Technology
2-12-1, Ohokayama, Meguro-ku, Tokyo, 152-8550 Japan

Introduction

There have been various investigations into adaptive antenna arrays for application to the handsets that are used in mobile communications [1], [2]. Previous studies have shown that adaptive antenna arrays function by null forming in line-of-sight (LOS) cases in order to remove co-channel interference, and by optimum combining [3] under a minimum mean square error (MMSE) criteria in a multipath environment in non line-of-sight (NLOS) cases. We have previously proposed a bit-error-rate (BER) measurement system for handset adaptive antenna arrays that uses a spatial fading emulator based on Clarke's model [4]. However, this system can only evaluate the BER characteristics of an adaptive antenna array in a multipath-fading channel that has vertically polarized components. This paper presents an empirical study of the BER performance of a handset adaptive antenna array in a Rayleigh-fading channel with a cross-polarized signal generated using a variable cross-polarization power ratio (XPR) spatial fading emulator. We have investigated the BER characteristics of a handset adaptive antenna consisting of a 1/4-wavelength monopole antenna and a planar inversed-F antenna (PIFA) as a function of XPR.

Experimental setup

Figure 1 shows the setup of the variable-XPR spatial fading emulator and vertically and horizontally polarized antennas simulating the scatterer (scattering unit). The emulator contains 15 scattering units that are composed of two half-wavelength dipoles crossing at right angles, as shown in Fig. 1(b). The distance between the radiating elements of the two dipoles is set at 10 mm. This arrangement enables the two components of the signal to propagate from the same direction. The 15 scattering units are located at evenly-spaced intervals around a 3 m diameter circle. The experimental configuration is shown in Fig. 2, which illustrates the relative position between the antenna array and the emulator. The desired signal was radiated from 7 of the 15 scattering units, shown by the black filled circles in Fig. 2. Other 7 scattering units shown as filled red circles were used to provide the interference signal. The adaptive antenna array, which is

comprised of a 1/4-wavelength monopole antenna (antenna #1) and a PIFA (antenna #2) on a radio chassis (see Fig. 3(a)), was set at the center of the scattering units. The control circuit is comprised of 7 sets of phase shifters and attenuators, which vary the phase and amplitude of the signals radiated from the scattering units. The amplitudes of the components that are radiated from the scattering units for each signal that have the same polarization can be matched by regulating them using the attenuators. The phase difference between the two components of each scattering unit was set at 0. A computer was used to calculate the values of the phase shift of the signals emitted from the units in order to obtain independent Rayleigh-fading channels based on Clarke's model for both the desired and the interference signals. The operating frequency was 2 GHz. Coherent detection of the quadrature phase shift keying (QPSK) signal at 64 kbps was used in order to evaluate the BER characteristics. The maximum Doppler shift (f_d) was set at 20 Hz, and the direction of motion of the array was at an angle of 10 degrees from the scatterer labeled #1. The Least Mean Squares (LMS) method was used as the algorithm for the adaptive antenna processing, with the step size and the number of iterations being 0.1 and 2000, respectively.

Average BER characteristics of the adaptive antenna array

Figure 4 shows the measured radiation patterns in the x-y plane of antennas #1 and #2. The radio chassis was tilted at an elevation angle of 30 degrees, as shown in Fig. 3(b). The results calculated using the Method of Moments are also plotted in Fig. 4. It was observed that both theta and phi components were radiated from antennas #1 and #2. Thus, the XPR might have a significant impact on the BER characteristics. We evaluate the average BER as a function of XPR for the average input SNR. In this paper, we define the input SNR (SNR_{in}) as the ratio of the power received by an isotropic antenna to the noise power. The input SNRs of both the vertically and horizontally polarized components (SNR_{in_v} , SNR_{in_h}) can be obtained from the following equations.

$$SNR_{in_v} = \frac{XPR}{1 + XPR} SNR_{in} \quad (1)$$

$$SNR_{in_h} = \frac{1}{1 + XPR} SNR_{in} \quad (2)$$

The sampling interval was 1/20 wavelength and the sample number was 500. In order to examine the BER of the array over quasi-static flat fading channels, the emulator was stopped at every sampling step during the BER measurements. Figure 5 shows the measured average BER of the handset adaptive antenna array versus the XPR for SNR_{in} values of 15 dB, 20 dB and 25 dB when the average signal-to-interference ratio (SIR) was 0 dB. The calculated results are also plotted in Fig. 5. The calculated results were obtained from the measured complex radiation patterns. From Fig. 5, the measured data of the adaptive antenna array are in good agreement with the calculated curves. This reveals that the array can suppress interference signals in a Rayleigh-fading channel with a cross-polarized signal. Furthermore, it can be seen from Fig. 5 that the measured BER for $XPR = 0$ dB is best for an identical value of the SNR_{in} . The reason for this phenomenon

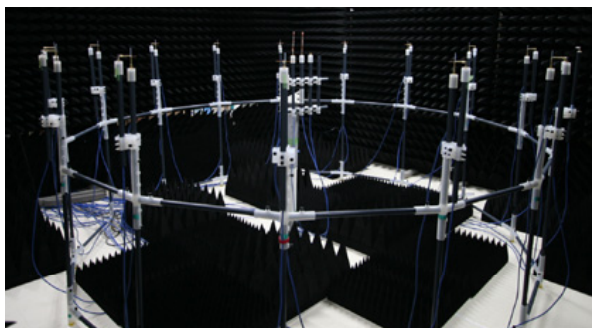
can be interpreted as the strong power received by the two antennas, since the theta component of the radiation pattern of antenna #1 and the phi component of antenna #2 are large. This indicates that a handset antenna array with both theta and phi components can exhibit a good BER performance in Rayleigh-fading channel with a cross-polarized signal.

Conclusion

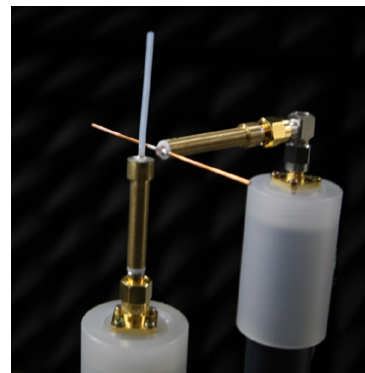
BER measurements of a handset adaptive antenna array in a Rayleigh-fading channel with a cross-polarized signal generated using a variable-XPR spatial fading emulator have been conducted. We investigated the average BER characteristics of a handset adaptive antenna consisting of a 1/4-wavelength monopole antenna and a PIFA as a function of a XPR. It can be concluded that the measured average BER of an adaptive antenna array with both theta and phi components has an excellent BER performance in a multipath propagation environment with a cross-polarized component.

References:

- [1] Y. Ogawa, H. Yagi, T. Ohgane, and K. Itoh, "An adaptive array in the presence of multipath signals beyond degrees of freedom in the pattern," *Proc. ISAP'96*, vol. 3, pp. 777-780, Sept. 1996.
- [2] Y. Ogawa and T. Ohgane, "Advances in adaptive antenna technologies in Japan," *IEICE Trans. Commun.*, vol. E84-B, no. 7, pp. 1704-1712, July 2001.
- [3] A. Yamamoto, T. Sakata, H. Iwai, K. Ogawa, J. Takada, K. Sakaguchi and K. Araki, "BER Measurements on a Handset Adaptive Antenna Array in the Presence of Co-Channel Interference Generated Using a Spatial Fading Emulator," *IEEE AP-S Conference*, Vol. 4A, pp. 26-29, July 2005.
- [4] R. Vaughan and J. B. Andersen, "Channels, Propagation and Antennas for mobile communications," *The IEE*, 2003.



(a) Setup in a radio anechoic chamber



(b) Scattering unit

Fig. 1 Photograph of the variable-XPR spatial fading emulator.

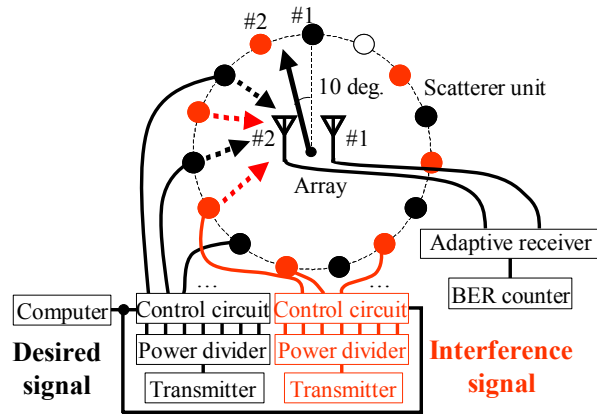


Fig. 2 Experimental setup of the adaptive antenna array.

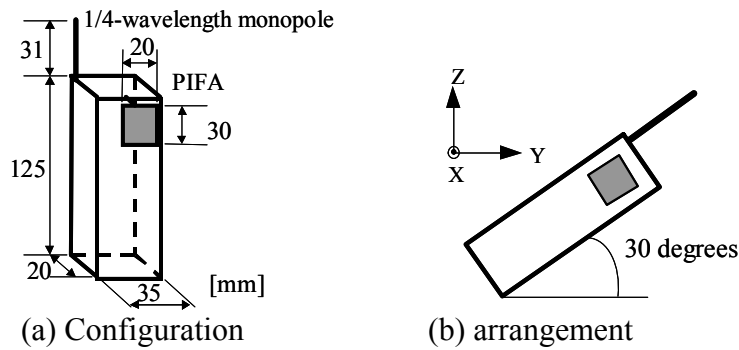
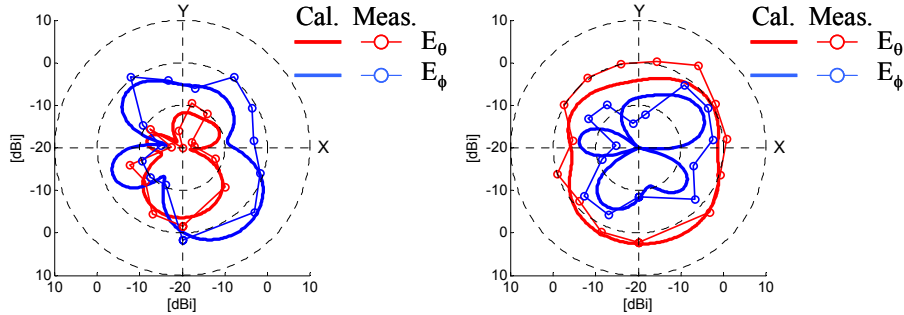


Fig. 3 Handset adaptive antenna array.



(a) 1/4 wavelength monopole (antenna #1) (b) PIFA (antenna #2)

Fig. 4 Radiation patterns of the 1/4-wavelength monopole and the PIFA.

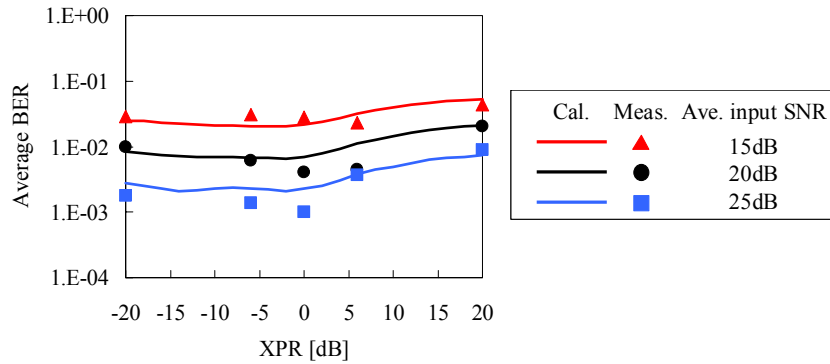


Fig. 5 Average BER versus XPR for average input SNRs of 15, 20 and 25 dB.