

# AN EFFECT OF A HEAD ON AN ANTENNA PATTERN DIVERSITY FOR A PORTABLE HANDSET

Jun-ichi TAKADA and Yuji TAKEUCHI  
 International Cooperation Center for Science and Technology  
 Kiyomichi ARAKI  
 Faculty of Engineering  
 Tokyo Institute of Technology  
 Meguro-ku, Tokyo 152, JAPAN  
 E-mail: takada@icc.titech.ac.jp

## 1 Introduction

Diversity is an important technique to reduce the fading in the multipath environment. Among several diversity techniques, the angle diversity or antenna pattern diversity utilize the directive antennas, and it is advantageous in reducing the level-crossing rate[1].

A candidate of the pattern diversity antenna for portable handset is two parallel half-wave dipole antennas with matched loads[2]. When the distance between two dipoles is  $0.1\lambda$ , strong mutual coupling causes the directivity, and two-branch pattern diversity antenna is realized.

On the other hand, the radiation characteristics of portable handset antenna are seriously suffered from the existence of the head. The effects of the head on the antenna characteristics have been actively discussed recently, from the viewpoints of the SAR distribution[3], the input impedance[4] and the radiation pattern[5, 6].

This paper discusses the effect of the head on the pattern diversity antenna for a portable handset. For simplicity, the two parallel dipoles without the body of the handset[2] is considered as the pattern diversity antenna. The effects of the diversity is estimated by the correlation of the horizontal radiation pattern assuming the Rayleigh fading environment[7]. Surface patch modeling of a metal sphere simulates the head[6], and the radiation patterns are calculated by the method of moments using NEC2[8]. The diversity effects are compared among different settings of the diversity antenna relative to the head.

## 2 Pattern Diversity Antenna

In this paper, two parallel dipoles with matched loads shown in Fig. 1 are considered as the pattern diversity antenna[2]. The distance between two dipoles is  $0.1\lambda$ , and the strong mutual coupling causes the directivity. Each matched load  $Z_m$  corresponds to a diversity branch.

Figure 2 shows the horizontal radiation patterns for two branches of the diversity antenna. The patterns are calculated by the method of moments using NEC2[8]. In this case, radiation patterns are deformed much from isotropic patterns due to strong mutual coupling, and the front-to-back (FB) ratio is 6.2dB.

As a measure of the diversity effect, the following correlation factor  $k$  between two radiation patterns is used[7].

$$k = \frac{\left| \int_0^{2\pi} E_1(\theta) E_2(\theta) d\theta \right|^2}{\int_0^{2\pi} |E_1(\theta)|^2 d\theta \int_0^{2\pi} |E_2(\theta)|^2 d\theta} \quad (1)$$

$k$  equals to the correlation of diversity branches in Rayleigh fading environment[7]. The correlation is  $k_{free} = 0.005$  for the model antenna, which is almost an ideal value as a diversity antenna.

## 3 Effect of Head on Antenna Pattern Diversity

In this paper, the head is simulated by the metal sphere with the diameter of  $1\lambda$ , which corresponds to 20cm at 1.5GHz[6]. The sphere is modeled by the surface patch elements in NEC2, and the accuracy of the modeling is confirmed by comparing with the rigorous solution obtained analytically[9]. As far as concerning with the radiation patterns, the metal sphere gives almost the same results as the lossy sphere[9].

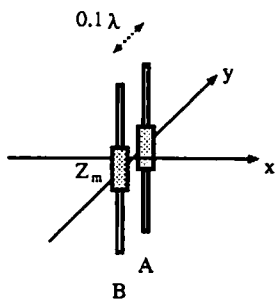


Figure 1: Two parallel dipoles with matched loads as a pattern diversity antenna

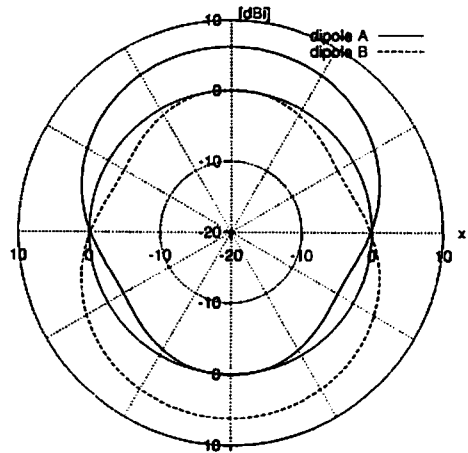


Figure 2: Radiation patterns of two parallel dipoles with matched loads in free space

Two settings of the diversity antenna relative to the head are considered. The pattern diversity antenna itself is the same as shown in Fig. 1.

Figure 3 shows the setting (I) with two dipoles arranged in radial direction, i.e., one beam is toward and the other is opposite to the head. Figure 4 shows the horizontal radiation patterns for two branches. Both patterns are deformed and the main beams are oriented opposite to the head, which can be easily predicted from reference [6], and these two patterns look alike. The correlation is  $k_{rad} = 0.77$  in this case, which means the antenna is almost useless for diversity.

Figure 5 shows the setting (II) with two dipoles arranged in circumferential direction, i.e., both beams are perpendicular to the head direction. Figure 6 shows the horizontal radiation patterns for two branches. Both patterns are again deformed, but the effect of the head is smaller and the directive patterns are still opposite to each other. The correlation is  $k_{cir} = 0.26$  in this case, which is a sufficient value for diversity.

## 4 Conclusion

This paper discussed the effect of the head on the pattern diversity antenna for a portable handset. From the comparison of two antenna settings, the orientation of the antenna is very important in view of antenna pattern diversity, and generally it seems to be better to put the antenna with the beams toward the orthogonal direction of the head direction.

This is the preliminary study, and more realistic simulations together with the experiments are left for future study.

## Acknowledgment

The authors express their gratitude to Prof. Makoto Ando (Tokyo Inst. Tech.) for his important suggestion, and Mr. Kay Noguchi for offering the reference data.

## References

- [1] F. Ikegami, T. Takeuchi and S. Yoshida, "Effects of Antenna Radiation Pattern on Multipath Fading in Urban Mobile Radio." Trans. IEICE (B), J68-B, 3, pp. 403-410 (in Japanese, Mar. 1985).
- [2] K. Tsunekawa and K. Kagoshima, "A Diversity Performance Analysis of Paralleled Two Dipole Antennas Mounted on a Small Metal Body." Trans. IEICE (B-II), J75-B-II, 9, pp. 629-637 (in Japanese, Sep. 1992).

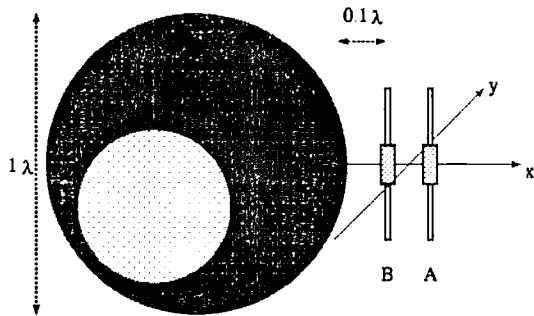


Figure 3: Two parallel dipoles near the head (I); radial arrangement (center of sphere on  $x$ -axis)

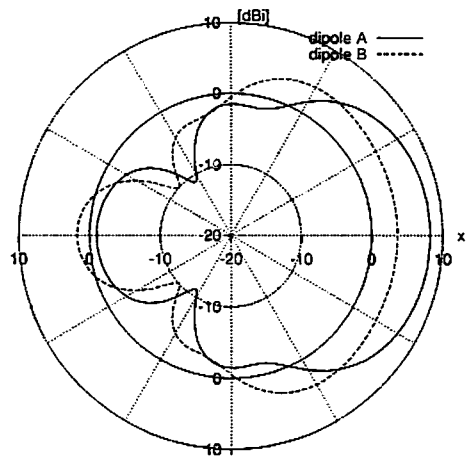


Figure 4: Radiation patterns of two parallel dipoles near the head (I); radial arrangement

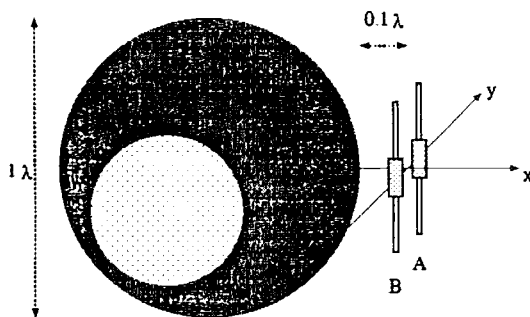


Figure 5: Two parallel dipoles near the head (II); circumferential arrangement (center of sphere on  $x$ -axis)

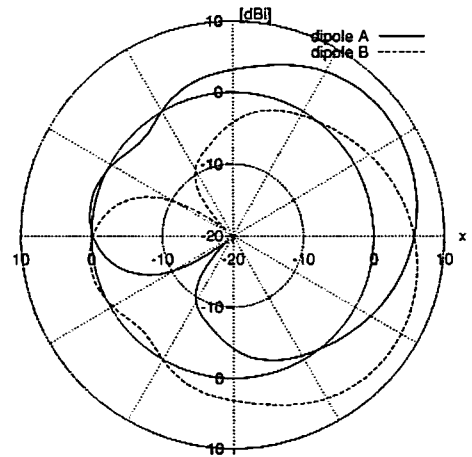


Figure 6: Radiation patterns of two parallel dipoles near the head (II); circumferential arrangement

- [3] M. A. Jensen and Y. Rahmat-Samii, "EM Interaction of Handset Antennas and a Human in Personal Communications," *Proc. IEEE*, 83, 1, pp. 7-17 (Jan. 1995).
- [4] X. Thiry and R. Mittra, "Modeling of Hand-Held Receiving Antennas in the Presence of a Human Head," 1995 IEEE AP-S Intl. Symp., pp. 1116-1119 (June 1995).
- [5] J. Toftgård, S. N. Hornsleth and J. B. Andersen, "Effects on Portable Antennas of the Presence of a Person," *IEEE Trans. Antennas and Propagat.*, AP-41, 6, pp. 739-746 (June 1993).
- [6] K. Noguchi, M. Ando, N. Goto, M. Hirose, T. Uno and Y. Kamimura, "Directional Antenna for Portable Telephones," 1995 IEEE Intl. Conf. Universal Personal Comm. (ICUPC), pp. 369-372 (Nov. 1995).
- [7] T. Takeuchi, F. Ikegami, S. Yoshida and Y. Tokui, "Analysis on Antenna Pattern Diversity Effect for Complex Radiation Pattern," *Trans. IEICE (B)*, J67-B, 5, pp. 570-571 (in Japanese, May 1984).
- [8] G. J. Burke and A. J. Poggio, "Numerical Electromagnetic Code (NEC) — Method of Moments," NOSC Tech. Doc. 116 (July 1977).
- [9] K. Noguchi, personal communication.