

# STUDY ON THE CHARACTERISTICS OF ARRAY ANTENNAS CLOSE TO LOSSY OBJECTS

Teruo ONISHI<sup>1\*</sup> and Koichi ITO<sup>2</sup>

<sup>1</sup>Graduate School of Science and Technology, Chiba University  
(Working for Nippon Ericsson K.K., Japan)

<sup>2</sup>Faculty of Engineering, Chiba University  
1-33 Yayoi-cho, Inage-ku, Chiba 263-8522, Japan  
Phone: +81-43-290-3931 Fax: +81-43-290-3933  
E-mail: onishi@ap.tu.chiba-u.ac.jp

## 1. Introduction

Some studies have been performed to improve the antenna performances or reduce the SAR (Specific Absorption Rate) when the human head is close to the antenna. For example, a few studies used another element, such as a reflector or GND plane, with successful improvement in the radiation efficiency or reduction of the SAR [1-3]. Recently, mobile phone terminals have been used not only for voice but also data. This tendency suggests that the phone has various closed positions to a human body rather than the ear. For example, the phone can be located in front of the head when users read or write a message on the display. Such an investigation of antenna characteristics was performed [4]. The relationship between the characteristics of antennas and the relative positions between the antenna and the object was studied as well [5]. Nevertheless, it seems that array antennas such as a phased array antenna or an adaptive array antenna, which could be used for mobile equipment with higher speed transmission in the near future, have not been taken into account so far. These types of antennas can produce different radiation patterns in the far-field and, at the same time, their electromagnetic distributions in the near-field might be also different each other. From this point of view, it is interesting to study the performances of an array antenna near an object.

In this study, an array antenna composed of two parallel half-wave dipole antennas placed side by side and a rectangular parallelepiped-shaped lossy object are used. The FD-TD method is employed for numerical simulations as well. In this paper, numerically simulated results of the radiation efficiency and the maximum local SAR are shown and the relationship between the results and the near-field is discussed.

## 2. Configuration

Fig. 1 shows the array antenna composed of two parallel half-wave dipole antennas placed side by side and the rectangular parallelepiped-shaped lossy object used for this study. The size of the object is  $0.3\lambda_0 \times 0.6\lambda_0 \times 0.6\lambda_0$  (with  $\lambda_0$  defined at 900 MHz) and its relative permittivity and conductivity are 41.0 and 0.88 (S/m), respectively. “ $d$ ” is defined as the distance between the antenna elements and the closest surface of the object. Concerning the distance between two elements, it is  $0.25\lambda_0$  and  $0.5\lambda_0$ . Both elements are fed with the same amplitude. In one case, the array is fed in phase, in another case, it is fed  $180^\circ$  out of phase. These conditions generate radiation patterns with the null and with the maximum beams in the direction of the lossy object (+x direction), respectively.

## 3. Numerical simulations and results

All numerical simulations are performed using the software SEMCAD [6] based on the FD-TD method. The operating frequency is 900 MHz. Both elements are fed with the same amplitude but in one case they are fed in phase and in the other case, they are fed  $180^\circ$  out of phase in order to generate the null and the maximum beams in the direction of the lossy object (+x direction), respectively. Figs. 2 and 3

show the simulated results of the radiation efficiency and the maximum local SAR (normalized to 1W input power). In addition, note that the simulated results of one element, which is located along the vertical center line of the object at a distance “ $d$ ”, are plotted for comparison. It can be seen that variations of the efficiencies are almost the same when  $d$  is small except for the case  $0.25\lambda_0$  fed out of phase, especially in the vicinity of the array antenna. When  $d$  reaches around  $0.25\lambda_0$  and above, the efficiencies of the antennas fed  $180^\circ$  out of phase get higher than the ones that are fed in phase. From this figure, it seems that the latter antennas do not tend to reach 100% near  $0.5\lambda_0$ . Concerning the maximum local SAR, the values of the array antennas are approximately half of the value of one element around  $0.05\lambda_0$ . However like the result of the efficiency when  $d$  is increased, different behaviors appear. Precisely, in the case the antennas are fed in phase, values of SAR decrease and become almost constant from  $d = 0.4\lambda_0$ . However, in the case of antennas fed out of phase, the SARs diminish. As a result, when focusing on a small distance between the array antenna and the lossy object, it cannot be seen that there is a definite relationship between the radiation pattern and the characteristics, i.e. the radiation efficiency and the maximum local SAR.

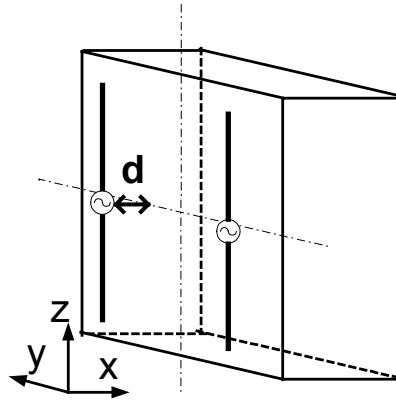


Fig. 1 Configuration of the two dipoles and the lossy object

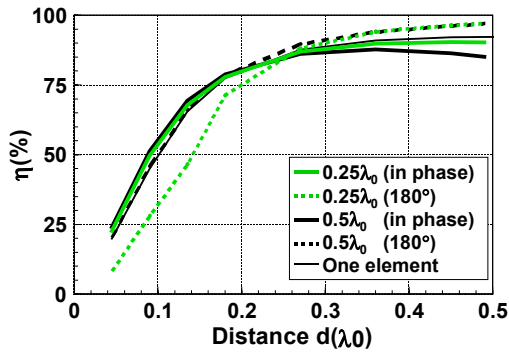


Fig. 2 Radiation efficiency

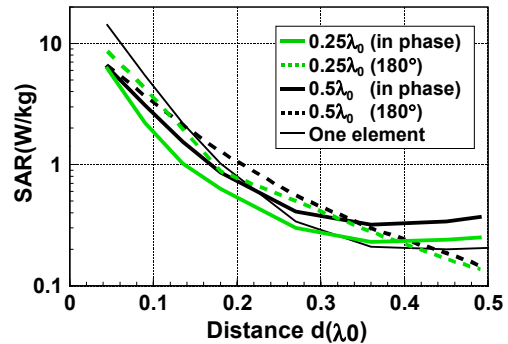


Fig. 3 Maximum local SAR

#### 4. Discussion

It has been previously shown that the behavior of the variation of the characteristics is different depending on the investigated antennas. To verify these results for both distances  $0.25\lambda_0$  and  $0.5\lambda_0$  when the array is fed in phase or out of phase, some SAR distributions on the surface of the lossy object located at a distance  $d = 0.045\lambda_0$  and  $0.27\lambda_0$ , respectively, are shown in Figs. 4 and 5. Note that these figures show the distribution of not only the local SAR but also the power dissipated on the surface. In addition, these

distributions are normalized to the highest value for each distance. It can be seen that there are two peaks for all the cases and a hollow between two peaks in case the antenna is fed  $180^\circ$  out of phase. The two peaks could reduce the value of the maximum local SAR of the array antennas even though their radiation efficiencies are equal to or worse than the ones of one element. Additionally, in case of  $0.25\lambda_0$  fed  $180^\circ$  out of phase at  $d = 0.045\lambda_0$ , the strength of the two peaks is higher than when in phase. In this case, the strength of current distributions flowing on the two elements is higher than when in phase. This may be due to the mutual coupling effect. This fact might induce the phenomenon described above with respect to the efficiency. Though SAR distributions at other distances are omitted, when  $d$  is increased, the peaks are horizontally moved to the edges of the lossy object (similarly to  $d = 0.27\lambda_0$ ). In addition, in case of the antennas fed in phase another peak appears. However, the hollows of SAR distributions for the antenna fed  $180^\circ$  out of phase at  $0.045\lambda_0$  still remain. Consequently when  $d$  is increased, i.e. exceeding around  $d = 0.27\lambda_0$ , the SAR distributions may depend on their radiation patterns rather than the current distribution of the element. As a result, there are different variations for both the radiation efficiency and the maximum local SAR between the cases of the antennas fed in phase and  $180^\circ$  out of phase. Therefore, when a lossy object exists near an array antenna, considerations of both relative position between them and of its radiation patterns is important.

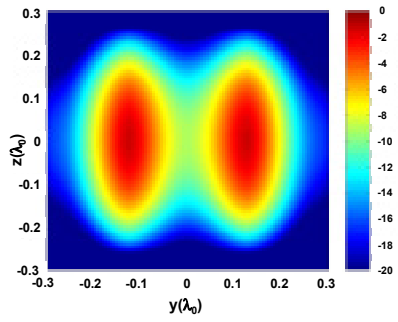
## 5. Conclusion

In this paper, the study on characteristics (radiation efficiency and SAR) of an array antenna composed of two parallel half-wave dipole antennas placed side by side and a rectangular parallelepiped-shaped lossy object was performed when a lossy object is located in the vicinity of the antenna. Two different distances between two elements, i.e.  $0.25\lambda_0$  and  $0.5\lambda_0$  and two different beams, i.e. the null and the maximum in the far-field were investigated. When the lossy object is located in the vicinity of the array antenna, the efficiencies are almost the same except for  $0.25\lambda_0$  out of phase. The reason why the case  $0.25\lambda_0$  fed  $180^\circ$  out of phase is worse than the others may be due to the mutual coupling effect. Additionally, at a small distance " $d$ ", values of the maximum local SAR are the same and approximately half of the value of one element. On the other hand, when the distance between the lossy object and the array antenna is increased and exceeds around  $0.25\lambda_0$ , variations of both the radiation efficiency and maximum local SAR may depend on the radiation patterns rather than on the current distribution of the element.

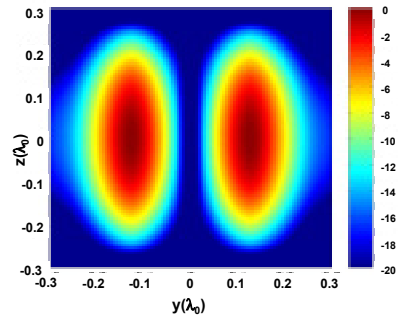
Therefore when a lossy object exists near an array antenna, it might be necessary to consider both near- and far- field distribution of the antenna and a relative position between them as well.

## References

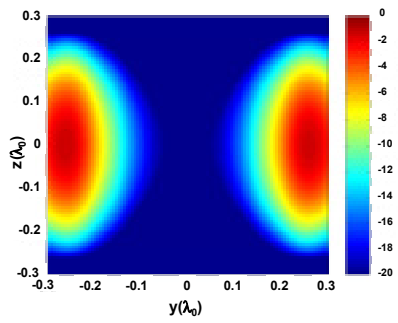
- [1] R. Y.-S. Tay, Q. Balzano and N. Kuster, "Dipole configurations with strongly improved radiation efficiency for hand-held transceivers," *IEEE Trans. Antennas Propagat.*, vol. AP-46, no. 6, pp. 798 – 806, June 1998.
- [2] Z. Wang and X. Chen, "A novel antenna for low-SAR mobile handsets," *Proc. of ISAP2000*, pp. 1071-1074, Fukuoka, Japan, Aug. 2000.
- [3] Y. Okano, H. Kawai, Y. Koyanagi, H. Yoshimura and K. Ito, "A study on the reduction of the local SAR by use of the folded dipole antenna with a planar reflector," *Tech. Rep. of IEICE*, AP2001-159, pp. 23-30, Dec. 2001. (in Japanese)
- [4] A. Mutoh and H. Arai, "The characteristics of measurement of portable computer terminals with ceramic phantom," *Tech. Rep. of IEICE*, AP99-147, pp. 17-22, Oct. 1999. (in Japanese)
- [5] T. Onishi and K. Ito, "A basic study on characteristics of antenna system including lossy objects," *2002 IEICE General Conference*, B-1-149, pp. 165, June 2002. (in Japanese)
- [6] <http://www.speag.com/>



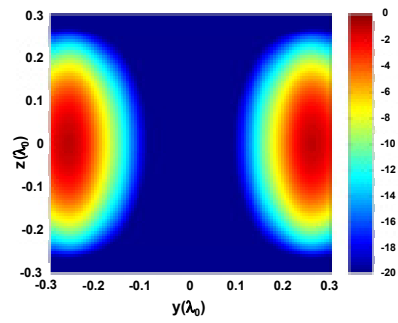
(a)  $0.25\lambda_0$  in phase



(b)  $0.25\lambda_0$   $180^\circ$  out of phase

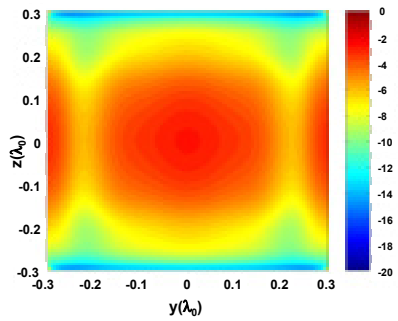


(c)  $0.5\lambda_0$  in phase

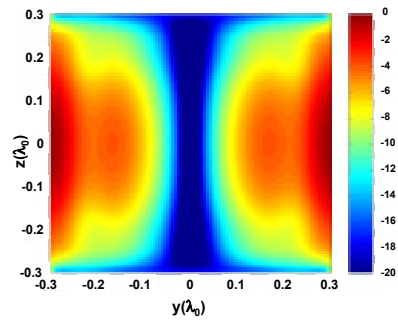


(d)  $0.5\lambda_0$   $180^\circ$  out of phase

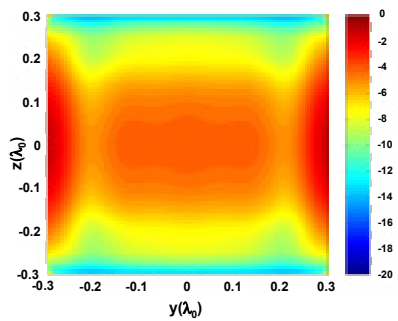
Fig. 4 SAR distributions at  $d = 0.045\lambda_0$



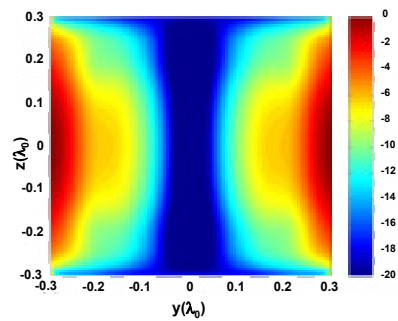
(a)  $0.25\lambda_0$  in phase



(b)  $0.25\lambda_0$   $180^\circ$  out of phase



(c)  $0.5\lambda_0$  in phase



(d)  $0.5\lambda_0$   $180^\circ$  out of phase

Fig. 5 SAR distributions at  $d = 0.27\lambda_0$