PROCEEDINGS OF ISAP '92, SAPPORO, JAPAN

A Consideration on the Thin Planar Antenna Analysis with Wire–Grid Model

Nozomu ISHII Kiyohiko ITOH
Faculty of Engineering, Hokkaido University
Sapporo 060, JAPAN

1 Introduction

In recent years, the growth of the mobile communication is remarkable. In particular, it is considered that the personal demand will grow more rapidly. The card-sized receiver has indeed just the right geometry for the personal communication, because we can carry this type of the receiver anywhere.

Therefore, the development and researches of antenna for the card-sized receiver are urgently required. However, electrical characteristics of the antenna using such a receiver are undesirable, because of the electrical small antenna. Experimental approach as well as theoretical approach is required to solve and overcome these characteristics and develop antennas which are satisfied with their given specifications.

In this paper, we analyze the characteristics of the card-sized receiver antenna for mobile communication system, using the moment method with the wire-grid model [1]. The large merit of this method is the use of the rapid and accurate moment method for the thin-wire problem since the antenna can be modeled with wire-grid. Therefore, if the antenna is constructed only by wire elements, the accurate numerical analysis is possible. On the other hand, in the case that the antenna is constructed by not only wire elements but also plate elements, the accuracy of the wire-grid approximation of the plate elements is a problem. This problem occurs when we estimate the characteristics of the only antenna, that is, in the case of not taking account of the body of the receiver. In analyzing the wire-grid model, we have to face this problem.

In this view point, the physical backbone for the wire-grid approximation are required. The quasi-electric theory [2] for this backbone was reported, however, the explicit theory related the wire-grid model to the corresponding continuous conducting plate has not been reported. Therefore, the modeling with the wire-grid is indeed ambiguous.

In this paper, based on the above facts, we analyze the characteristics of a thin planar antenna using the moment method with the wire-grid model. And, we focus the validity of the wire-grid model rather than the characteristics of the antenna by the numerical analysis.

2 Overview of Analysis Method for Wire Antennas

We divide the wire scatterer into the suitable dipoles, and express it as the superposition of V-shaped dipoles. Namely, we expand electric current distribution $\overline{J}^s$ in known expansion functions $\overline{J}_n$:

$$\overline{J}^s = \sum_{n=1}^{N} I_n \overline{J}_n, \tag{1}$$

where the complex coefficient I_n is a sample value of function $\overline{J}_n$. And we use the expansion function $\overline{J}_n$ with unit current density at the terminals. From Eq.(1) and the zero reaction theorem, we obtain the simultaneous linear equations :

$$\sum_{n=1}^{N} Z_{mn} I_n = V_m \qquad \text{for} \quad m = 1, 2, 3, \ldots, N, \tag{2}$$

where

$$Z_{mn} = -\iint_n \overline{J}_n \cdot \left[\overline{E}_m - (\hat{n} \times \overline{H}_m) Z_s\right] dS, \qquad V_m = \iint_m \overline{J}_m \cdot \overline{E}^i dS, \tag{3}$$

where Z_s denotes the surface impedance and the unit vector $\hat{n}$ is directed outward on S.

The expansion functions are set up as overlapping tubular piecewise sinusoidal surface currents, and the filamentary currents which are parallel to the tubular surface currents, are used as the test functions. Since the cross-sectional distribution of the expansion currents is different from that of the test currents, the mutual impedance is not always satisfied with the symmetry or the reciprocity. This asymmetry occurs between two monopoles which have the different arm lengths and no coincident axis.

In this paper, throughout the calculation of the mutual impedances, the locations of the expansion dipoles and the test dipoles are fixed. Here, the expansion dipoles are placed above (or beneath) the grid plane shifted with their radius. Therefore, the reciprocity theorem is often not satisfied. However, the numerical antenna impedance coincides with the experimental one as shown below.

3 Numerical Examples

In this section, we consider the wire-grid model for the card-sized antenna as shown in Fig. 1. This antenna is composed of the rectangular sheet copper having l =80mm length and w =48mm width and two wire with h =2.0mm height. These sheet and wires are connected at two corners of sheet, one point (Point C) is shorted on the ground and the other point (Point B) is fed at the ground. A sample of the wire-grid model for this antenna is shown in Fig. 2. This model is an approximation model divided into 3 parts for the x direction and 5 parts for the y direction.

The height of the antenna shown in Fig. 1 is much smaller than the size of the plate, and the fed point on the ground plane exists in close proximity to the wire-grid.

Therefore, the effect of the grid size are larger, as the grid mesh is coarser. Table 1 shows the grid division number versus anti-resonant frequency for the wire-grid model divided into m parts for the y direction and n parts for the x direction. The radius of the wire of the grids part and of the wire parts are 0.6mm.

In the case of n=1, the current in the y direction cannot express with the wire-grid so that the anti-resonant frequency is not converged to 532 MHz which is that of the original composite model shown in Fig. 1, as m is large number. For n=2, the characteristics are similar to the above case. In the case that m is fixed number, the anti-resonant frequency is smaller for $m \leq 2$, and larger for $m \geq 3$, as n is larger. When the grid geometry is close to the square, this anti-resonant frequency approaches to 532 MHz.

Next, we investigate the relation of input impedance versus the radius of the wire of the grid using the above numerical analysis. Fig. 4 show the impedance of the wire-grid model shown in Fig. 2. From Fig. 4, the anti-resonant frequency is 525 MHz for the grid radius $a_g = 0.6$ mm, while 542 MHz for $a_g = 1.0$ mm. Similarly, in the case of the finer wire grid model shown in Fig. 3, the anti-resonant frequency is 518 MHz for $a_g = 0.6$ mm, while 535 MHz for $a_g = 1.0$ mm (Fig. 5). This is because the reaction between wire of the fed part and one of the grid parts is very sensitive for their radii. Therefore, the antenna near-field characteristics depend on not only the grid size but also the the radii of the wires of the grid.

4 Conclusion

In this paper, we show that the wire-grid model is very sensitive for the radii of the wires of the grid and the grid geometry. However, on the condition of $a_g = 0.6$ mm, the error of the anti-resonant frequency between the model shown in Fig. 2 and the finer model shown in Fig. 3 is less than 5%. Therefore this analysis method is valid for good choice of both the grid size and wire radius of grid.

Acknowledgements

This work was supported by Grant-in-Aid for Science Research 62420033 from the ministry of Education, Science and Culture of Japan.

References

[1] N. Ishii, K. Itoh, "Analysis on small planar antenna in a paging system," *IEICE Trans.*, **E74**, 10, pp.3233–3240, Oct. 1991.

[2] K. S. H. Lee, L. Martin, J. P. Castillo, "Limitations of wire-grid modeling of a closed surface," *IEEE Trans. Electromag. Compat.*, **EMC-18**, pp.123–129, Aug. 1976.

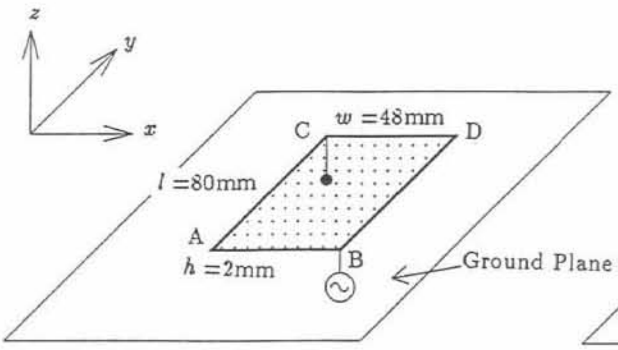

Fig. 1 : The thin card-sized planar antenna

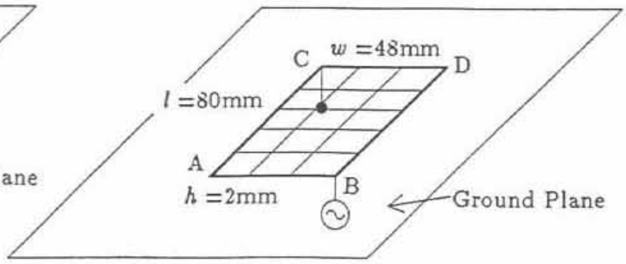

Fig. 2 : The wrie-grid model for thin planar antenna shown in Fig.1 (m=5, n=3)

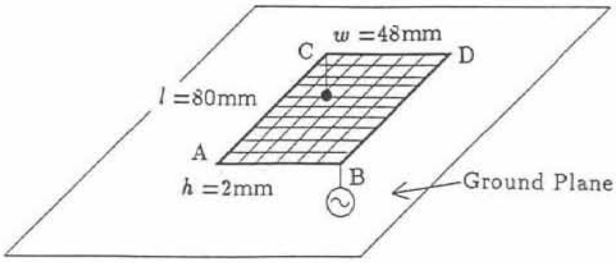

Fig. 3 : The wrie-grid model for thin planar antenna shown in Fig.1 (m=10, n=6)

	n=1	n=2	n=3
m=1	572 MHz	550 MHz	525 MHz
m=2	550 MHz	547 MHz	535 MHz
m=3	530 MHz	542 MHz	540 MHz
m=4	505 MHz	525 MHz	533 MHz
m=5	485 MHz	512 MHz	525 MHz

Experimental anti-resonant frequency : 532MHz

Table 1 : Anti-resonant frequency vs. division number of grid

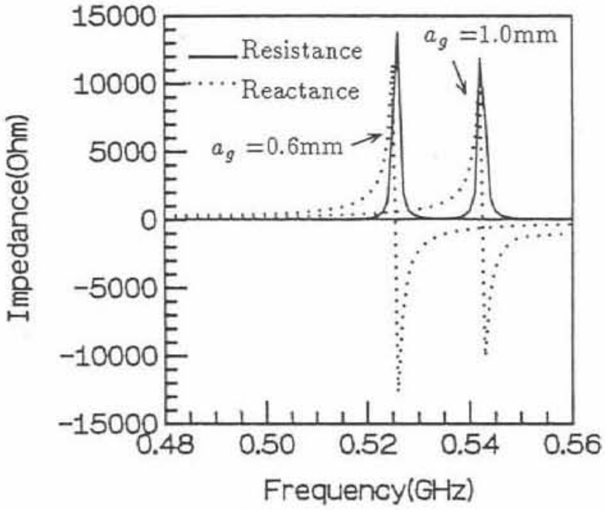

Fig. 4 : Input impedance vs. frequency for wire-grid model shown in Fig.2 (m=5, n=3)

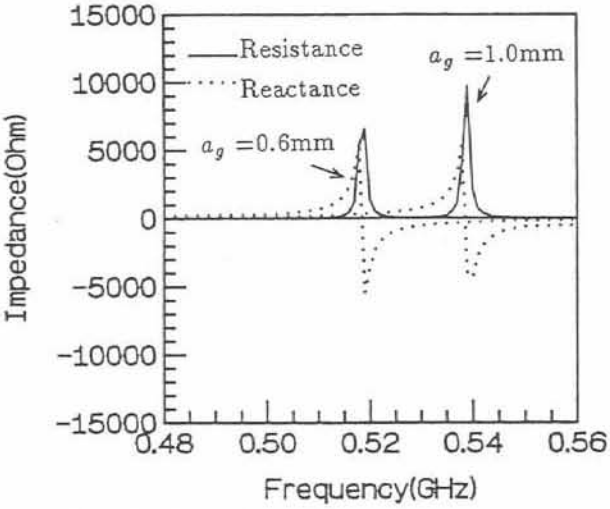

Fig. 5 : Input impedance vs. frequency for wire-grid model shown in Fig.3 (m=10, n=6)