AMC Substrate Inspired Small Antenna MACKEY

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***Abstract*—Various domestic appliances that can use WiFi are becoming more common. Therefore, it is necessary to establish a design method for installing a small antenna within these appliances. In this paper, a model that has a dipole antenna unified with an artificial magnetic conductor (AMC) substrate inspired small antenna is proposed, and its radiation and impedance characteristics are shown.**

I. Introduction

Recently, the number of domestic appliances that can use WiFi have increased. Antennas mounted into appliances need to the ability to be installed anywhere; therefore, a design method to establish a small antenna is necessary. Metamaterial contributes a technology that an antenna can be thin for installing on the metal [1], [2]. As an example, an artificial magnetic conductor (AMC) is feasible with a dielectric and a metal plate for characteristics equivalent to Perfect Magnetic Conductor (PMC) and studies are performed [3]-[5].

In this paper, we propose a model that has a dipole antenna unified with an artificial magnetic conductor (AMC) substrate. This model is called MACKEY (metamaterial antenna chip developed by the KIT EOE Laboratory), and its principle of operation and analysis results are presented.

II. Difference Between MACKEY and the Conventional Model

The antenna model of a conventional metal-plate-loaded AMC substrate has capacitance grids that contain some metal slits in the dielectric and metal-plate layers [3]. However, the model dimensions are $3\lambda \times 3\lambda$ and too large for use.

Considering the statement above, we developed MACKEY, which reduces the number of grids as much as possible. The simple shape for the grids of the AMC substrate is a wide-plate dipole antenna. The structure of MACKEY is shown in Fig. 1, and the design parameters are shown in Fig. 2.

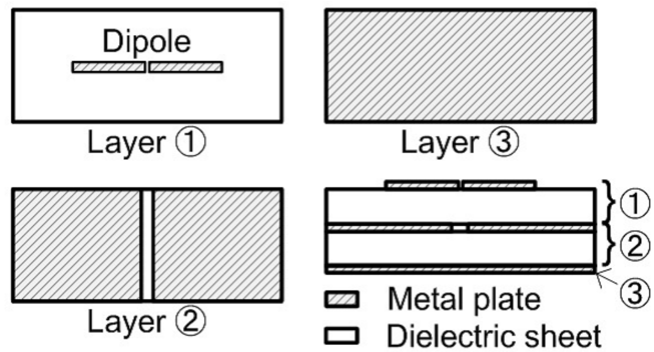

Fig. 1. The structure of MACKEY.

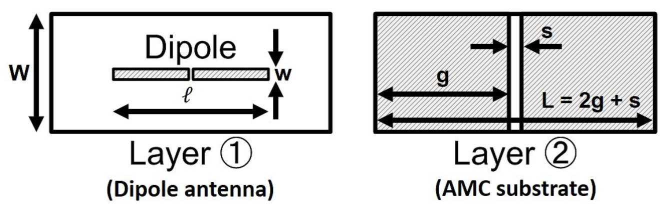

Fig. 2. Design parameters.

MACKEY has three layers: the first is a substrate that has a dipole for excitation on a dielectric substrate, the second is the AMC substrate that consists of two plates that function as a dipole and dielectric substrate, the third is a reflection plate. The design parameters are the length ℓ of the dipole for excitation, the width w of its dipole, the length L of the substrate, the width W of the substrate, the length g of the plate on the AMC substrate, and the width s of the slit. L is equal to $2g+s$ and contains two plates and one slit.

III. A Design Example

The design frequency is assumed to be 2.4 GHz, and the design parameters are $g = 27.8$ mm, $W = 30.0$ mm, $s = 0.5$ mm, $\ell = 27.0$ mm, $\varepsilon_r = 2.65$, $t = 3.2$ mm, and $h = 0.8$ mm. The dimensions of MACKEY are 56.1 mm

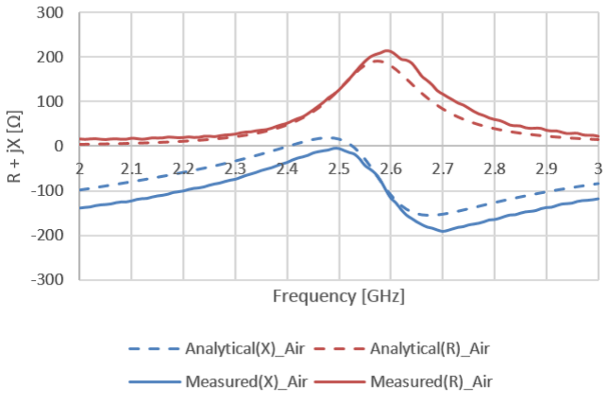

Fig. 3. Impedance characteristics of MACKEY in free space.

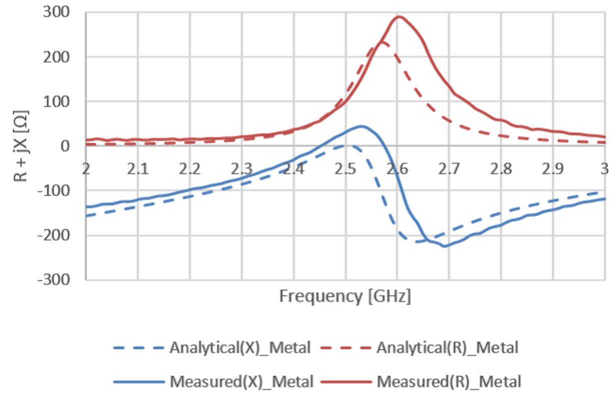

Fig. 5. Impedance characteristics of MACKEY on a metal plate.

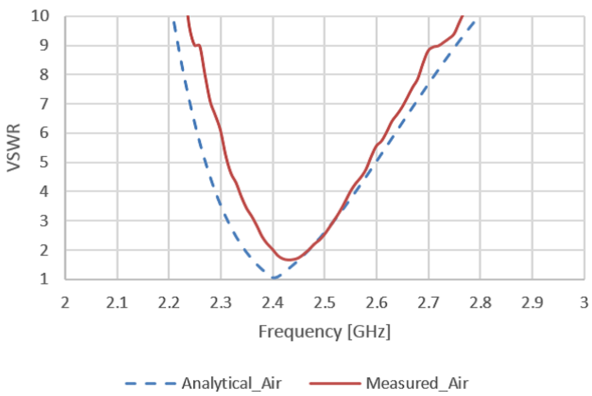

Fig. 4. VSWR of MACKEY in free space.

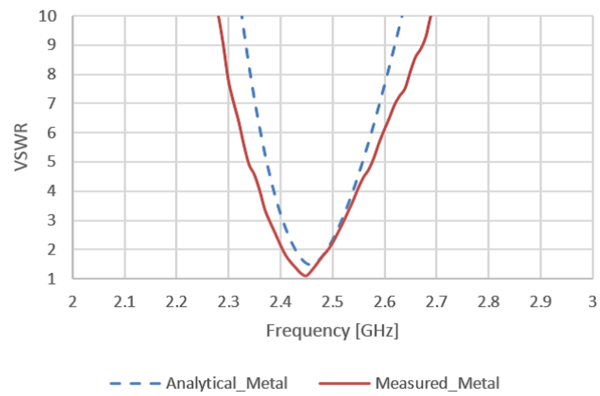

Fig. 6. VSWR of MACKEY on a metal plate.

$\times$ 30.0 mm $\times$ 4.0 mm ($0.46\lambda \times 0.25\lambda \times 0.033\lambda$). At the first layer, the thickness of the dielectric substrate h is 0.8 mm. The thickness of the second layer t is 3.2 mm.

The results from measurements and calculations (FEM) for the impedance with MACKEY in free space are shown in Fig. 3. The solid line shows the measured values, and the dashed line shows the calculated values. The VSWR characteristics of MACKEY in free space are shown in Fig. 4. In the case of using a metal plate ($3\lambda \times 3\lambda$), the impedance results and VSWR are shown in Fig. 5 and Fig. 6, respectively. The impedance characteristics and VSWR exhibit good agreement between the measurements and calculations. The resonant frequency is approximately 2.4 GHz in free space and on the metal plate. The results confirmed that MACKEY will be able to operate, even if there is metal around installation space.

IV. Principle of Operation of MACKEY

To understand the principle of operation of MACKEY, the current distribution of the AMC top surface is shown in Fig. 7. A current of approximately 30 A/m was found to flow in the center part. The radiated fields from the excited dipole antenna were coupled to the center part of the AMC. As part of the slit acted as the feeder line, the current was then transmitted to the edge of the top and bottom of each plate as well. Further, hardly any current was found to flow into the center of each plate.

From the results above, the AMC substrate excited by a dipole antenna is considered to be wide-plate dipole to act as a radiation element.

V. Parametric Study

The results of a parametric study are presented in this section.

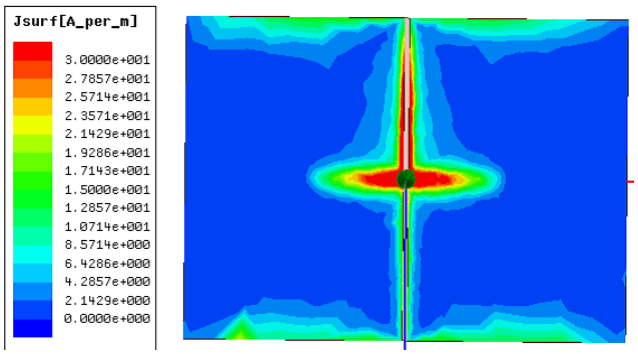

Fig. 7. Current distribution on the AMC.

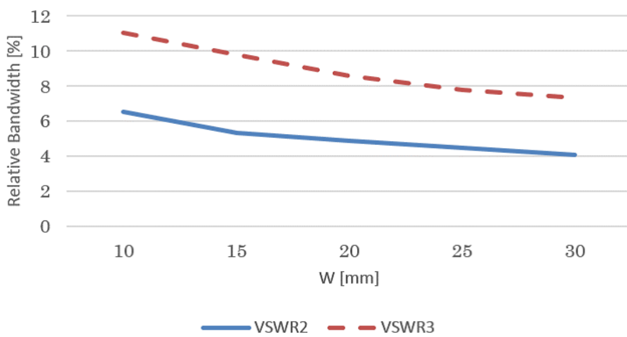

Fig. 8. Width W of the AMC substrate versus the relative bandwidth in free space.

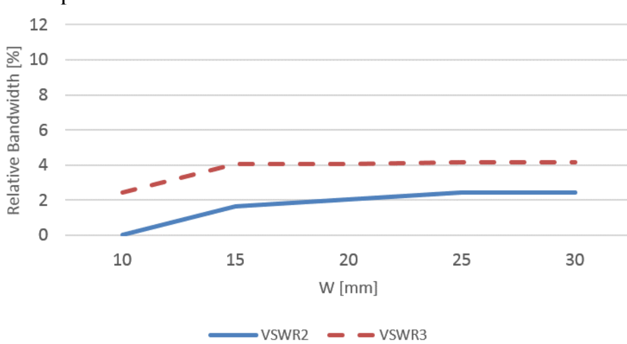

Fig. 9. Width W of the AMC substrate versus the relative bandwidth on a metal plate.

A. Impedance and VSWR Characteristics when Changing the width W of MACKEY

Fig. 8 shows the relative bandwidth when W was changed from 10 to 30 mm, and VSWR shows a case of 2 and 3. In this figure, the relative bandwidth become narrow if W of the AMC substrate increased. In these studies, g and l are adjusted so that the resonant frequency becomes 2.4 GHz in free space.

Fig. 9 shows the relative bandwidth on a metal plate when W was changed from 10 to 30 mm, and VSWR shows a case of 2 and 3. In this figure, the relative bandwidth was adversely found to become wide in comparison to the free-space case if W of the AMC substrate increased.

B. Radiation Patterns of MACKEY

Figs. 10 and 11 show the radiation patterns when MACKEY was installed in free space and on a metal plate, respectively. The measured and analytical patterns are indicated by the solid and dashed lines, respectively. Each pattern is similar, regardless the presence of a metal plate. In addition, these figures show that the electric field is radiated in the x direction. The AMC was confirmed to act as a plated dipole antenna.

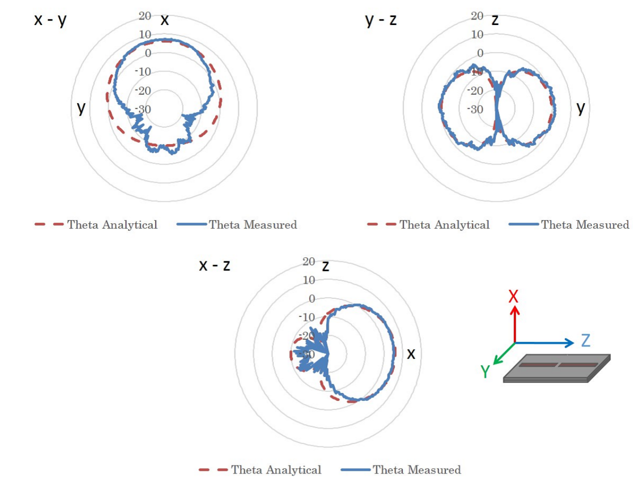

Fig. 10. Radiation pattern in free space.

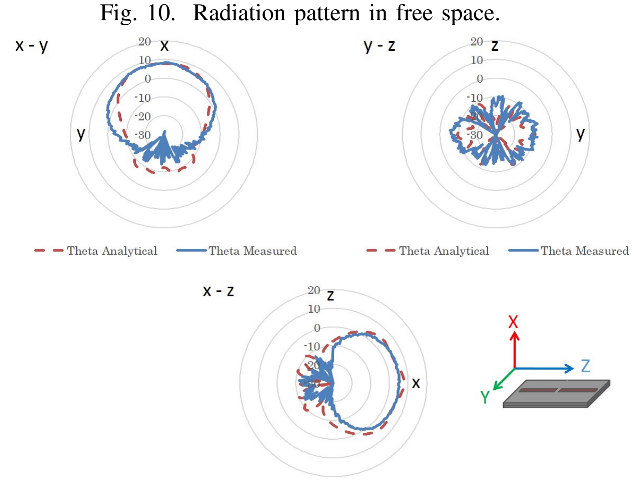

Fig. 11. Radiation pattern on a metal plate.

VI. Conclusion

In this study, we proposed MACKEY and explained the principle of operation from the results of a numerical analysis. The impedance and VSWR were calculated from parametric studies, and impedance matching was possible both in free space and on the metal plate. For the future establishment of the design theory, we will study the construction of an equivalent-circuit model and the principle of operation. In addition, we will study the multiband and broadband characteristics to improve the performance of MACKEY.

ACKNOWLEDGEMENT

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