Feasibility Study of Wide-band MACKEY

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***Abstract* - Antennas installed on various domestic appliances should be small and not influenced by the background metal. Small antenna metamaterial antenna chip developed by KIT EOE laboratory (MACKEY) is a composite structure consisting of a metal plate loaded capacitance grid realized using an artificial magnetic conductor (AMC) substrate and a dipole antenna. It can be installed on a conducting plate without affecting the impedance and radiation characteristics, according to prior studies. In this communication, we report that, with the right choice of design parameters of the small antenna MACKEY, it is possible to realize a wide-band capable device.**

***Index Terms* — Small antennas, FEM, AMC, Grid.**

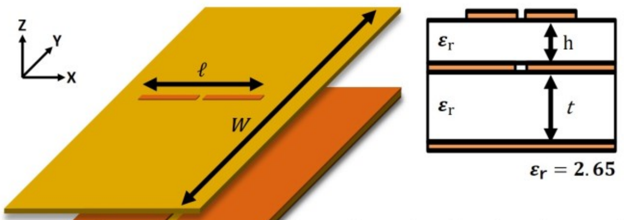
1. Introduction

According to previous research, an artificial magnetic conductor (AMC) can be realized using dielectric and metal plates with characteristics equivalent to the perfect magnetic conductor (PMC). An AMC substrate with capacitance grids can also achieve characteristics equal to PMC [1]. Examples of both finite and infinite periodic structures in the AMC, with a metal ground plate, are investigated in [2]. Multiple resonant bands are also possible in these structures [3]. The fabrication of a small antenna metamaterial antenna chip developed by KIT EOE laboratory (MACKEY) was reported in [4], demonstrating metal-like impedance characteristics; however, the bandwidth of the device was not investigated previously.

In this communication, we report on the results of the wide-band MACKEY capability test.

2. Design Parameters

Fig. 1 shows the antenna model and corresponding design parameters. The basic structure is the same as in reference [1]. A dipole antenna of length ℓ is deposited on a dielectric slab of thickness h. The capacitive grid consists of two metal plates with width g, separated by a slit of width s on a dielectric slab with thickness t. A metal plate is located on the backside of the dielectric slab. It is necessary to optimize the design parameters g, s, and t to ensure that the grid substrate exhibits PMC characteristics. The width of substrates W is a common parameter for both the dipole and grid substrates. The optimized values are calculated using the method of moments (MoM). The design frequency is set to 5.2 GHz in the calculations.



ℓ	g	s	h	t	W
14.3	12.1	0.5	0.8	3.2	25 - 35

Unit [mm]

Fig. 1. Design parameters.

3. Examples of the Numerical Calculation by FEM

The examples of the numerical calculation by the finite element method (FEM) are as follows. Parameters used in the calculations are ℓ = 14.3 mm, g = 12.1 mm, and s = 0.5 mm. The thickness of the dielectric slab with the dipole antenna is h = 0.8 mm and the grid substrate slab thickness is t = 3.2 mm. The relative permittivity of the dielectric ε_r = 2.65. The parameter W is variable.

Fig. 2 shows the voltage standing wave ratio (VSWR) as a function of frequency, calculated for the device in free space. Results shown in Fig. 2 illustrate that, for W = 25 mm, the resonant point is 5.2 GHz, which matches the design value; the VSWR becomes worse at higher

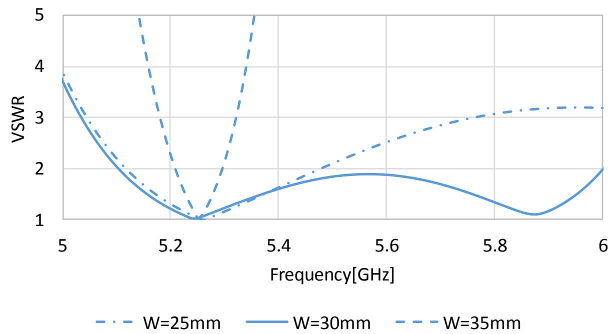


Fig. 2. VSWR characteristics as a function of W in free space.

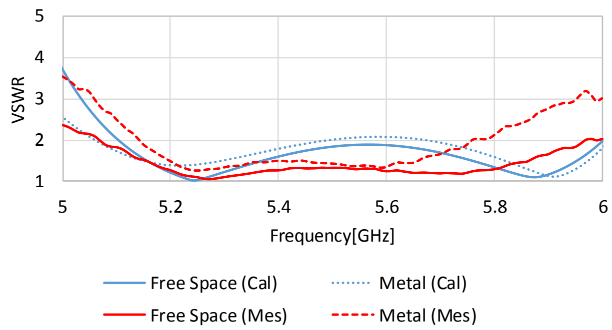


Fig. 3. Comparison of VSWR for the antenna structure located in a free space and on the metal plate

frequencies. For W = 30 mm, VSWR is improved from 5.2 GHz to 6.0 GHz, and the dependence is bimodal. In the case of W = 35 mm, the resonant frequency is 5.2 GHz, with the narrowest relative bandwidth. The results indicate that the wide-band characteristics of the device can be obtained by changing W.

A comparison of VSWR for the antenna structure located in a free space and on the metal plate is shown in Fig. 3. The solid line shows the case of calculated values (Cal) and measured values (Mes) in free space, and the dashed line shows the case on metal plate. The result is that the bandwidth is 11.2% (VSWR < 2), even for a metal background around MACKEY.

Fig. 4 shows the calculated current distribution. It is evident that the current, floating on the AMC substrate, is transmitted in part to the exit by the dipole. With the slit working as the feeder line, current is transmitted to the upper and lower edges of the grid. The current also flows on the left and right edges of the grid substrate. Because of this phenomenon, the line length is changed and an extra resonant point is added. It is conceivable that a wide-band capability is thus enabled. The observed current distribution is close to the one in reference [1], with a similar antenna model.

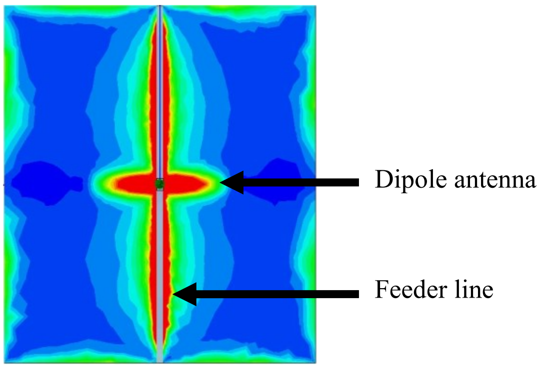


Fig. 4. Current distribution.

Fig. 5 shows the radiation patterns of the structure in a free space. Fig. 6 shows them for the device on a metal plate. The solid line shows the measured values, and the dashed line shows the calculated values. Each pattern shows only the main beam. These radiation patterns are almost identical in a free space and on a metal.

4. Conclusion

Numerical calculations demonstrate a wide-band capability of a small antenna MACKEY. As the width of the substrate W varies, two resonant points appear, and the VSWR shows bimodal frequency dependence. It is possible that the observed phenomenon is due to the line length change compared to that in the conventional model. In the future, we will verify the validity of the result by comparing the calculated values with experimentally measured values.

Acknowledgment

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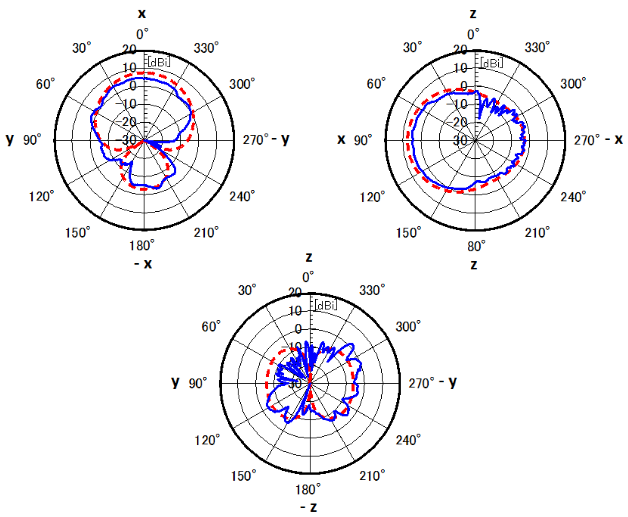

Fig. 5. Radiation patterns in free space.

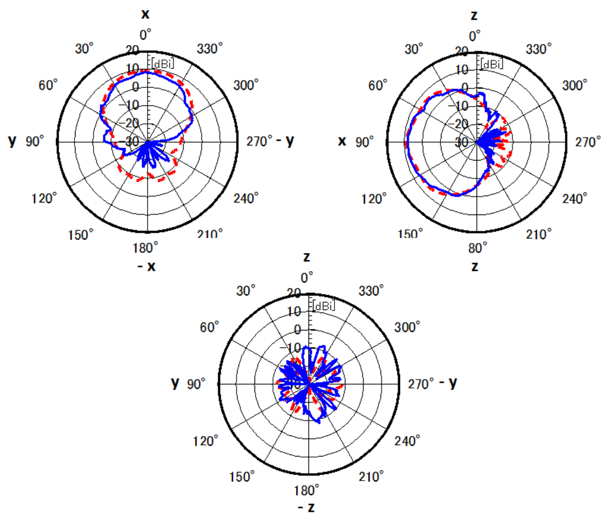

Fig. 6. Radiation patterns on metal plate.