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Circularly Polarized MACKEY with Improved Axial Ratio

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***Abstract*— A MACKEY (Metamaterial Antenna Chip developed by KIT EOE LaboratorY) that is sufficiently robust to metal object proposed. By combining two such MACKEYs, we develop an antenna that radiates circularly polarized waves with a good axial ratio.**

***Keywords*— MACKEY, circular polarization, metasurface-inspired antenna, artificial magnetic conductor substrate**

I. Introduction

A small electrical, termed MACKEY (Metamaterial Antenna Chip developed by KIT EOE LaboratorY) basic-type, which is robust to metal object, has been proposed [1]. In addition, an unbalanced MACKEY, which is thinner and improved as a one-port power feed, has been developed [2].

Fig. 1 shows the unbalanced MACKEY designed for the Wi-Fi 2.4GHz band. It is a three-layered structure consisting of a grid plate, an antenna plate, and a metal plate in descending order, with dielectric-filled materials between them. Impedance matching is performed based on the grid width g and antenna length ℓ. Fig. 2 shows the analysis results of the voltage standing wave ratio (VSWR) characteristics in free space and on metal these results show that. The unbalanced MACKEY works properly on metal.

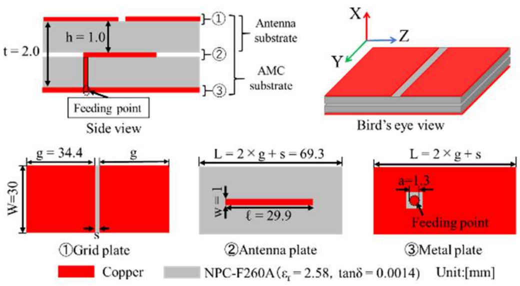

Fig. 1. Model diagram of the unbalanced MACKEY

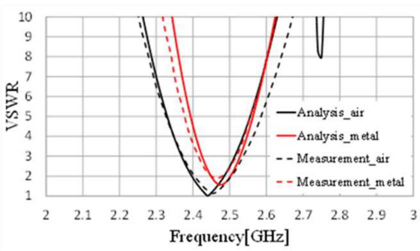

Fig. 2. Voltage standing wave ratio (VSWR) of the unbalanced MACKEY

II. PROPOSITION OF CIRCULAR POLARIZATION MACKEY

To radiate a circularly polarized wave, a 90° -phase difference needs to be added between two orthogonal linearly polarized waves. A typical MACKEY radiated linearly polarized waves. Hence, two unbalanced MACKEYs of the same size can be combined orthogonally to obtain circularly polarized waves. Fig. 3 shows the two unbalanced MACKEYs as part of the circular polarization system. By feeding them with a phase difference, it was believed that circularly polarized waves could be oscillated. Three power supply position patterns were compared, and the structure with the best performance was adopted. [3]

To feed the two antennas, current with a phase of 0° and 90° were applied to feed point 1 and 2, respectively as shown in the lower part of Fig. 3.

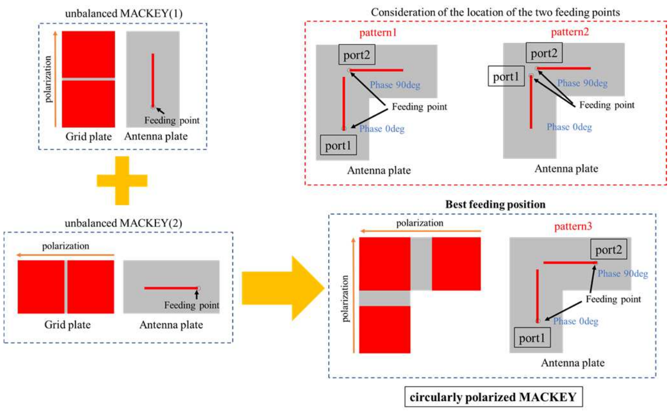

Fig. 3. Simplified diagram of the circularly polarized MACKEY

III. STRUCTURE OF MACKEY C3 TYPE

Based on the aforementioned proposal, the model with three grid plates and two antennas was termed MACKEY C3 type. The structure is shown in Fig. 4. The stacked structure is the same as that in the unbalanced MACKEY, with an artificial magnetic conductor substrate with of 2 mm thickness and an antenna position of 1 mm. In the actual design, a hot melt bond film of 0.06mm (blue in the figure) was used as the adhesive. A current with a phase of 0°and 90° was supplied to each of the two feeding points shown in the figure.

Impedance matching was performed by varying the length ℓ of the antenna, and the height and width g of the grid. A

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additionally, to reduce the interference of the current by the two feeding points, the slit width, s, was widened to 8 mm. [4]. The slit width, s, was varied to adjust the axis ratio.

The top and bottom widths of the antenna substrate denoted as *L* were 81.2 mm and the antenna length ℓ was 29 mm.

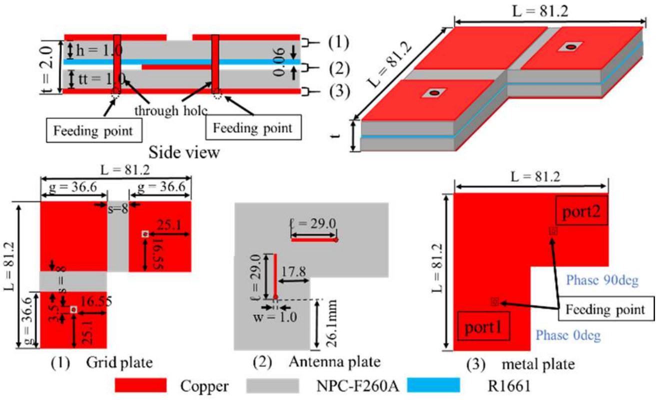
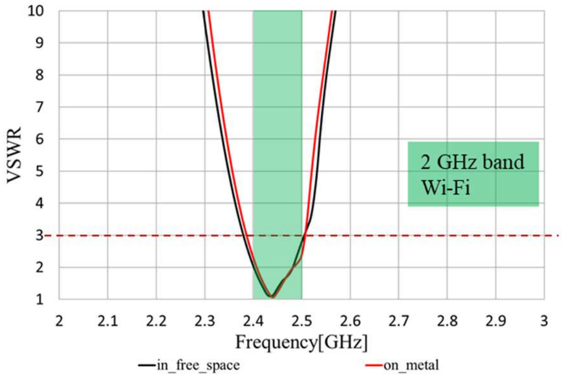


Fig. 4. Model diagram of the MACKEY C3

IV. Analysis Results

Fig. 5 shows the results of the analysis of the VSWR characteristics. The results in free space are indicated by black lines, and the results for metal are depicted by red lines. The VSWR was less than 3 dB both in free space and the metal, and the, difference in the specific bandwidth was insignificant. Therefore, the Wi-Fi 2GHz bandwidth was satisfied.

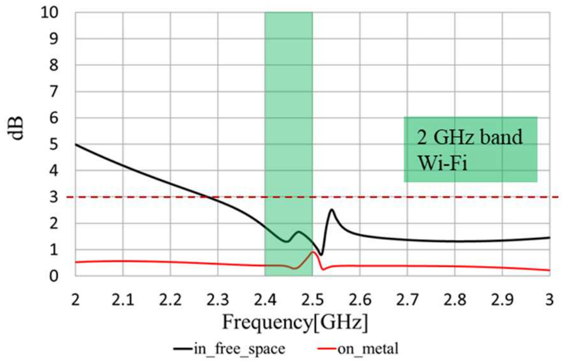


	free	on metal
VSWR=3[dB] or less bandwidth [GHz]	2.39〜2.50	2.40〜2.51

Fig.5 VSWR characteristics.

The axial ratio characteristics are shown in Fig. 6. Axial ratio characteristics of less than 3 dB were obtained over a wide range, both in free space and on metal. Therefore, the metal was not influenced by the axial ratio characteristics.

The diagram of the radial patterns obtained is shown in Fig. 7. The solid and dashed lines indicate left-handed and right-handed circular polarization, respectively. The large value of the solid line indicates that this antenna radiates left-handed circularly polarized waves. In addition, the values of radiation gain are good.



	free	on metal
Axial ratio of 3[dB] or less Bandwidth [GHz]	2.26〜3.00	2.00〜3.00

Fig.6 Axial ratio characteristics of MACKEY C3.

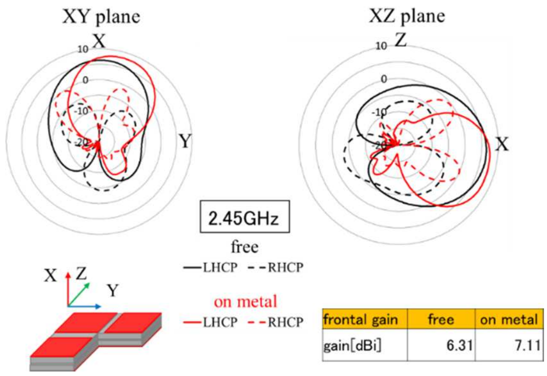


Fig.7 Radiation patterns of MACKEY C3.

V. Conclusion

In this study, a circularly polarized MACKEY was proposed. This model functioned as a circularly polarized antenna by combining two unbalanced MACKEYs oriented 90° to each other and feeding each antenna with a phase difference of 90°. The two unbalanced MACKEYs share a grid plate; however, the interference between them is reduced by separating the feeding points this antenna could operate on metals, which was the original characteristic of the basic-type MACKEY. In the future, miniaturization of this antenna should be considered.

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