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Optimization of Axial Ratio Characteristics of Circularly Polarized MACKEY

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***Abstract*—This research aimed to convert linear convectional polarization to circular polarization using an unbalanced the metasurface-inspired antenna chip developed by the KIT EOE Laboratory (MACKEY). Moreover, we aimed to achieve a Voltage Standing Wave Ratio (VSWR) of less than three and axial ratio of less than 3 dB in free space and on metal at 2.4–2.5 GHz. For this purpose, we proposed a circularly polarized MACKEY C4 antenna with four grid plates. We achieved our goal by examining the slit width and antenna position.**

Keywords—MACKEY, Circular Polarization, 2.45 GHz

I. Introduction

The metasurface-inspired antenna chip developed by the KIT EOE Laboratory (MACKEY) [1] was devised as a robust antenna that is not affected by surrounding metals. In this report, we propose a new model, MACKEY type-C4 (hereinafter referred to as "MACKEY C4"), based on MACKEY II [2], which is a thinner version of MACKEY and uses an inverted L element for unbalanced power supply, along with four grid plates to change the polarization from conventional linear to circular.

II. Proposal for MACKEY C4

Fig. 1 shows a model diagram of MACKEY II, which radiates linearly polarized waves, and MACKEY C4, which radiates circularly polarized waves. MACKEY C4 combines MACKEY II orthogonally and feeds power with equal amplitude and a phase difference of 90° to the two feed points to radiate circularly polarized waves with an antenna size of approximately λ/2 square. After orthogonalization, a grid plate is added to provide symmetry to the antenna plate. The model in Fig. 1 shows the optimal design values considering the slit width and feeding element position.

In this study, we aim to achieve a Voltage Standing Wave Ratio (VSWR) of less than three and an axial ratio of less than 3 dB in the 2.4–2.5 GHz range, which is the bandwidth of Wi-Fi 2 GHz, both in free space and on metal.

In the initial model of MACKEY C4, the axis-ratio characteristic was more than 3 dB. Therefore, two studies were conducted to improve the axial ratio, using the slit width and feeding element position.

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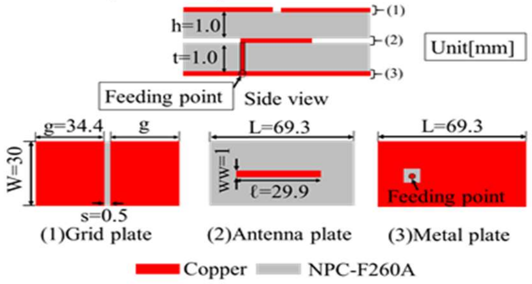
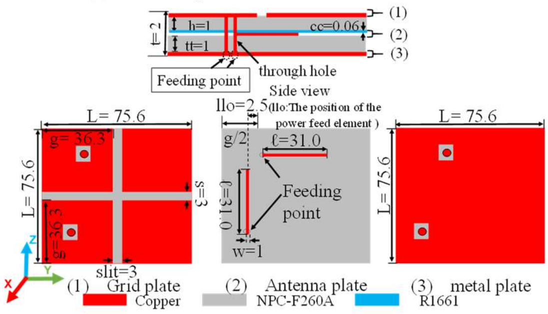


(a) Linear polarization MACKEY II



(b) Circular polarization MACKEY C4

Fig. 1. Model diagram of antenna

III. Examining of MACKEY C4

In this study, to investigate the possibility of circular polarization by MACKEY, power feeding was performed under ideal conditions of equal amplitude and a phase difference of 90°. The analysis was performed using an electromagnetic simulator (ANSYS, HFSS) based on the finite-element method.

The effects of the slit width were examined by varying the slit width. Fig. 2 shows the change in the maximum value of the axial ratio and relative bandwidth of the VSWR when the slit width is varied. The axial ratio improved slightly as the slit width increased on the metal. The VSWR became narrower as the slit width increased.

The position of the power feed element was examined by moving it from the center of the grid plate to the inside or outside of the substrate. The width of the slit used in this study was 9 mm. Fig. 3 shows the change in the maximum value of the axial ratio and relative bandwidth of the VSWR when the feeding element was moved. The axial ratios were improved by moving the feeding element at a certain distance. The bandwidth of the VSWR did not change as the element moved.

Fig. 4 shows the maximum value of the axial ratio and the change in the specific bandwidth of the VSWR when the feeding element position was optimized for each slit width. Fig. 4 indicates that the axial ratios in free space and on metal are less than 3 dB for each slit width, and the smaller the slit width, the wider is the specific bandwidth.

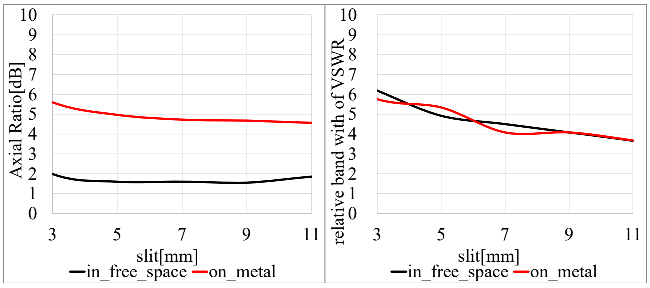


Fig. 2. Change in the maximum value of the axial ratio and relative bandwidth of the VSWR when the slit width was varied

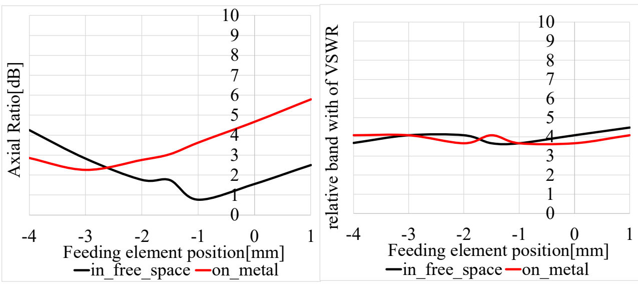


Fig. 3. Change in the maximum value of the axial ratio and relative bandwidth of the VSWR when the feeding element was moved.

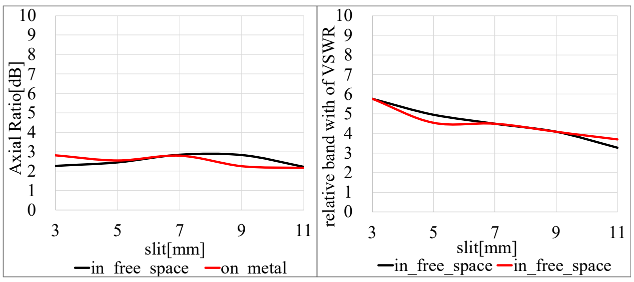


Fig. 4. Change in the maximum values of the axial ratio and relative bandwidth of the VSWR.

IV. Analysis Results for MACKEY C4

The VSWR and axial ratio in free space and on metal, obtained by the analysis of the optimized MACKEY C4 model in Fig. 1, are shown in Fig. 5; the radiation patterns are shown in Fig. 6. As parameters during optimization, the slit width was 3 mm and the feed element was moved 2.5 mm inside the substrate.

Fig. 5 shows that the VSWR is less than three in the range of 2.36–2.5 GHz, both in free space and on metal, which is wider than the target range of 2.4–2.5 GHz. The axial ratio is less than 3 dB at all frequencies, indicating that the target has been achieved. Fig. 6 indicates that the cross polarization along the x-axis, which is the frontal direction, is considerably smaller, and the realized gain of the main polarization is 5.61 in free space and 6.82 on the metal.

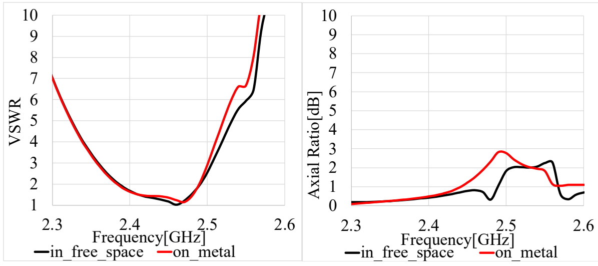


Fig. 5. VSWR and axial ratio

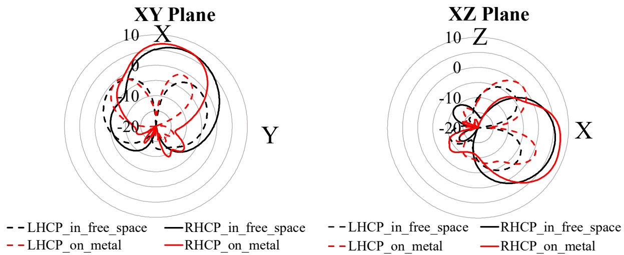


Fig. 6. Radiation pattern

V. Conclusion

This study presents a basic study of a new model for radiating circularly polarized waves from linearly polarized waves, an aspect that has been studied in the past. The target of achieving a VSWR of less than three and an axial ratio of less than 3 dB was accomplished by adjusting the slit width and feeding element position in a model with a four-grid plate structure. In the future, we could investigate simpler ways to feed power, such as using a single feeding point.

References

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[2] K. Miyashita, S. Makino, and K. Itoh, “Feasibility study of an unbalanced MACKEY type R with enhanced robustness on metal,” in ISAP 2021, October 2021.