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A Feasibility Study of Circularly Polarized MACKEY Using Sequential Array Technique

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***Abstract*— This study aimed to convert linear convectional polarization to circular polarization using an unbalanced metasurface-inspired antenna chip developed by the KIT EOE Laboratory (MACKEY). 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 sequential type using sequential array technology. We achieved our goal by optimizing the slit width.**

***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 unaffected by surrounding metals. In this study, we proposed a new model, MACKEY C4 sequential type (hereinafter referred to as "MACKEY CS"), based on MACKEY II [2], which is a thinner version of MACKEY and uses an inverted L element for an unbalanced power supply along with four grid plates to change the polarization from conventional linear to circular.

II. Proposal for MACKEY CS

Fig. 1 shows a diagram of MACKEY II radiating linearly polarized waves and MACKEY CS radiating circularly polarized waves. MACKEY CS is a sequential array of four MACKEY II chips fed to four feeding points with equal amplitude and phase differences of 0°, 90°, 180°, and 270°, respectively [3]. The size of a normal antenna is 1 λ square when converted into a sequential array. However, as shown in Fig. 2, MACKEY CS shares a grid plate; therefore, it radiates circularly polarized waves with an antenna size of λ/2 square. As a result, it is possible to radiate circularly polarized waves with an antenna size that is 1/4 of the usual size.

In this study, we evaluated the radiated gain and the relative bandwidth satisfying a voltage standing wave ratio (VSWR) of 3 or less and an axial ratio of 3 dB or less in free space and on metal when the center frequency was 2.45 GHz, which is used in Wi-Fi 2GHz. The model in Fig. 1 shows the optimal design values considering slit width.

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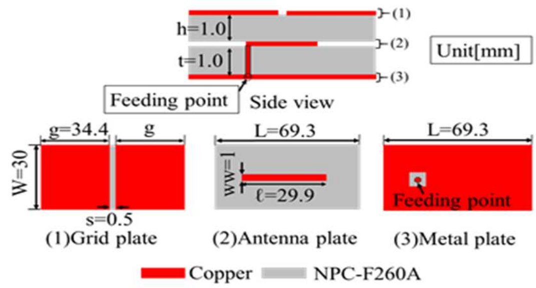
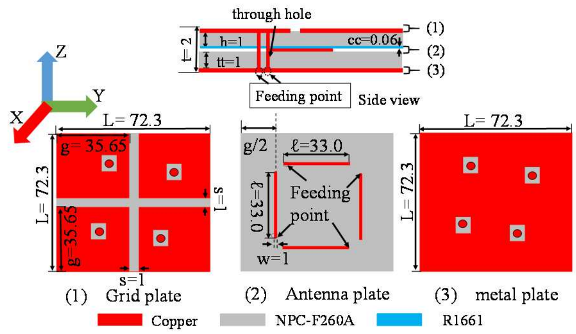


(a) Linear polarization MACKEY Ⅱ



(b) Circular polarization MACKEY CS.

Fig. 1. Model diagram of antenna

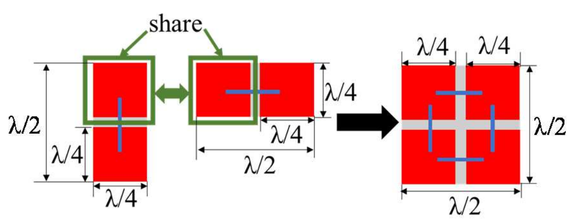


Fig. 2. Shared grid plate

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III. EXAMINING OF MACKEY CS

In this study, to investigate the possibility of circular polarization using MACKEY CS, power feeding was performed under ideal conditions of equal amplitude and phase differences of 0°, 90°, 180°, and 270°, respectively. The analysis was performed using an electromagnetic simulator (ANSYS, HFSS) based on the finite element method.

The effects of the slit width were also examined by varying the slit width. Fig. 3 shows the change in the maximum value of the axial ratio between 2 and 3 GHz, and the relative bandwidth of the VSWR when the slit width was varied. The axial ratio does not change at any slit width and is almost zero between 2 and 3 GHz, which is the ideal value. The relative bandwidth of the VSWR widened as the slit width decreased. Fig. 4 shows the change in the realized gain of the main and cross polarization in the frontal direction (x-axis direction shown in Fig. 1) at 2.45 GHz when the slit width was varied. The realized gain of the main polarization increases when the slit width increases. Fig. 5 shows the change in radiation efficiency at 2.45 GHz and the antenna size when the slit width is varied. Fig. 5 shows that the radiation efficiency remains the same and the antenna size increases when the slit width is increased, suggesting that the reason for the increase in the realized gain of the main polarization is the antenna size.

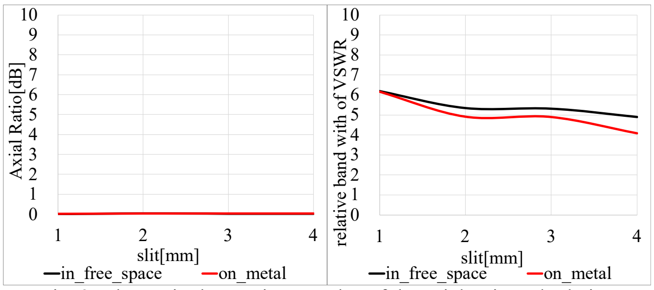

Fig. 3. Change in the maximum value of the axial ratio and relative bandwidth of the VSWR when the slit width is varied

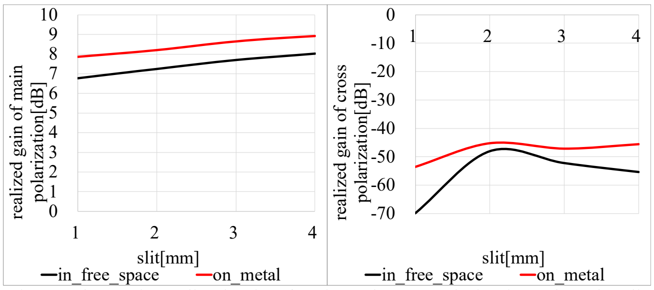

Fig. 4. Change in realized gain of main and cross polarization when the slit width is varied

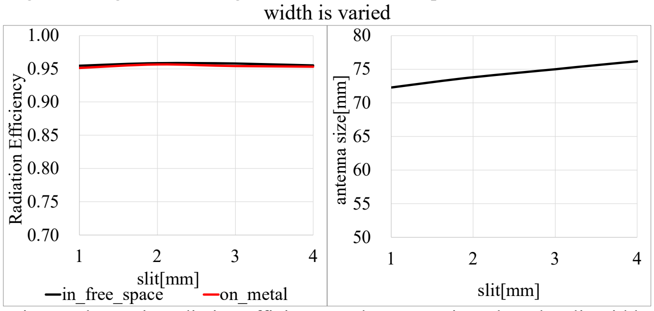

Fig. 5. Change in radiation efficiency and antenna size when the slit width is varied

IV. ANALYSIS RESULTS FOR MACKEY CS

From the slit-width study, the analysis was performed on a model with a slit width of 1 mm, as shown in Fig. 1. Fig. 6 shows the axial ratio characteristics and VSWR in free space and on metal. The axial ratio characteristic is close to the ideal value of 0 at all frequencies, both in free space and on metal. The relative bandwidth of the VSWR, where the VSWR is less than 3, is 6.19 in free space and 6.16 on metal, indicating a wide bandwidth. Fig. 7 shows the radiation patterns in free space and on metal. The realized gain in the frontal direction in free space is 6.76 dB and the realized gain in the frontal direction on metal is 7.87 dB. The realized gain of the main polarization is maximum in the frontal direction, while the realized gain of the cross polarization is small.

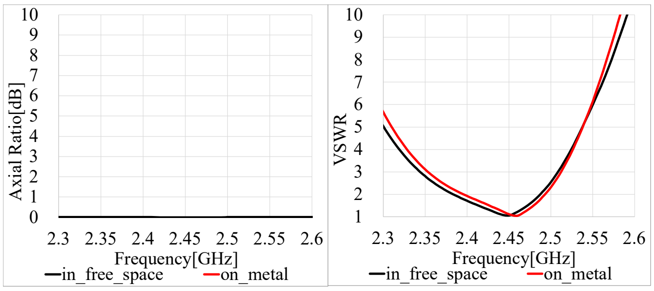

Fig. 6. Axial ratio and VSWR

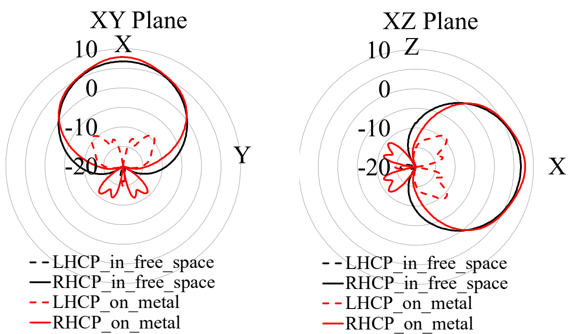

Fig. 7. Radiation pattern

V. CONCLUSION

This paper presents a feasibility study of a new model for radiating circularly polarized waves from linearly polarized waves, an aspect that has been studied previously. The study confirmed that circularly polarized waves are radiated with an antenna size of λ/2 square.

. In the future, simpler ways to feed power could be investigated, such as using two feeding points.

REFERENCES

[1] T. Moroya, et al., “AMC-inspired small antenna MACKEY,” IEICE. Trans. Commun., vol. J99-B, no. 9, pp. 786–794, September 2016.

[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.J

[3] T Teshirogi, M Tanaka, W Chuoo, “Wideband circularly polarized array antenna with sequential rotations and phase shift of elements” in ISAP 1985, August 1985.