Feasibility Study on Circularly Polarized MACKEY

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***Abstract*—A metasurface-inspired antenna chip (MACKEY), which was developed in the KIT EOE laboratory and operates in free space and on a metal plate, was investigated. In this study, we devised a MACKEY by varying the polarization from conventional linear to circular.**

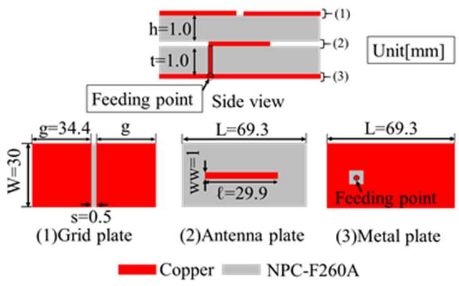
I. Introduction

The metasurface-inspired antenna chip (MACKEY), developed by the KIT EOE Laboratory)[1], is a robust antenna that is not affected by the surrounding metal. In this paper, we propose a new model, MACKEY C-type (hereinafter referred to as "C-type"), by varying the polarization from conventional linear to circular. The C-type is a square with a side length of λ/2. The C-type is based on MACKEY II [2], which is a thinner version of MACKEY, with an unbalanced feed using an inverted L-shaped element.

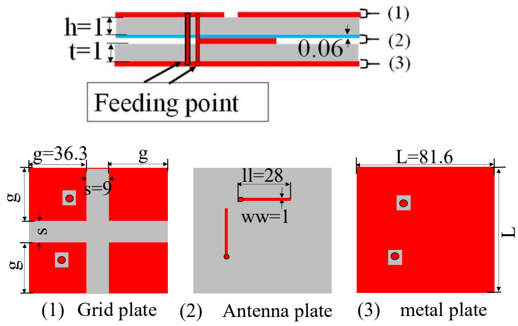
II. Proposal for C-type

Fig. 1 shows the model diagram of MACKEY II and the C-type. MACKEY II, which radiates linearly polarized waves, is placed orthogonally, and circularly polarized waves are radiated with a size of approximately λ/2 square by feeding powers of equal amplitudes and a phase difference of 90° to the two feeding points. After orthogonalization, a grid plate is added to provide symmetry to the antenna substrate. The design values are optimized by considering the slit width and antenna position.

In this study, we aim to achieve a voltage standing wave ratio (VSWR) of less than 3 and an axial ratio characteristic of less than 3 dB in both free space and on metal in the frequency band of 2.4–2.5 GHz, which is the operating band of 2 GHz Wi-Fi.



(a) Model diagram of MACKEY II (linear polarization)



(b) Model diagram of C-type (circular polarization)

Fig. 1. Model diagram of antenna.

III. Analysis of C-type

In this study, to investigate the possibility of circular polarization by using MACKEY, power feeding was conducted under ideal conditions of equal amplitudes and a 90° phase difference. The analysis was performed by using the finite element method on an electromagnetic field simulator (Ansys HFSS).Fig. 2 shows the VSWR and axial ratio characteristics in free space and on the metal, achieved by the C-type analysis. Fig. 2 indicates that the VSWR in free space and on metal and the axial ratio characteristics in free space achieve the target; however, the axial ratio characteristics on the metal are more than 3 dB in the band around 2.5 GHz, indicating that the target is not achieved.

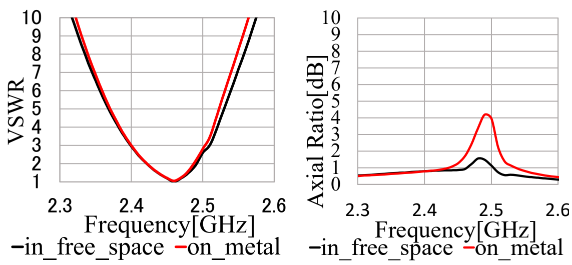


Fig. 2. Characteristics of VSWR and axial ratio in free space and on metal.

IV. CONSIDERATION OF PARASITIC ELEMENTS

Two parasitic elements were added to the antenna plate to improve the axial ratio by increasing the symmetry of the antenna structure. The addition of the parasitic elements was terminated at a resistance of 50 Ω. The model diagram is presented in Fig. 3. The VSWR and axial ratio characteristics in free space and on the metal are depicted in Fig. 4. As shown in Fig. 4, the axial ratio characteristic improves to a value close to 0 dB at all frequencies. In addition, the VSWR and axial ratio characteristics in both the free space and on the metal meet the target.

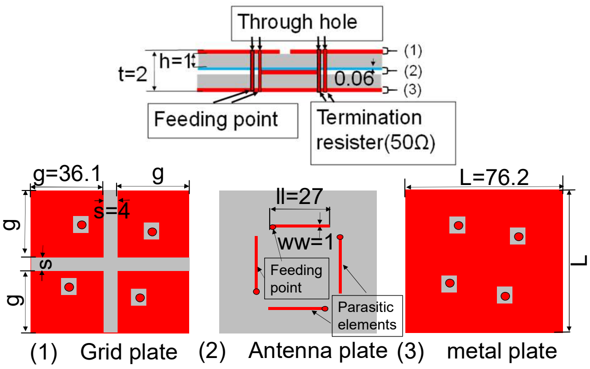


Fig. 3. Model diagram of C-type with the two additional parasitic elements.

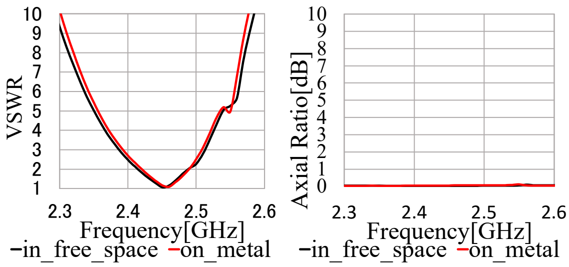
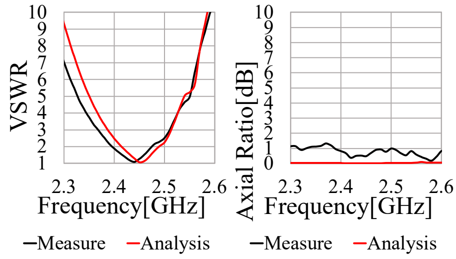


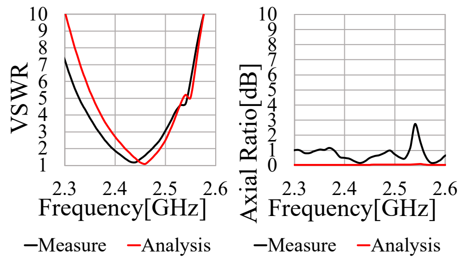
Fig. 4. Characteristics of VSWR and axial ratio in free space and on metal.

V. COMPARISON OF ANALYZED AND MEASURED VALUES FOR C-TYPE

Measurements were performed using the model displayed in Fig. 3. The VSWR and axial ratio characteristics in free space and on the metal are shown in Fig. 5, and the radiation pattern and frontal gain at 2.45 GHz are presented in Fig. 6. Fig. 5 shows that the measured VSWR is slightly higher than the analytical value for both the free space and metal. In case of the widening of the VSWR, Fig. 6 shows that the gain in the frontal direction is lower than the analytical value, indicating that the loss of the antenna is larger and that of the reflected wave is smaller. The reason for the higher axial ratio characteristics is that the antenna shifts slightly from the front at the time of measurement. As shown in Fig. 6, the gain of cross-polarization increases when the angle is shifted slightly from the front. Because the axial ratio depends on the level of difference between the gain of the main polarization and cross-polarization, the axial ratio characteristics may have become larger owing to the effect of this cross-polarization.

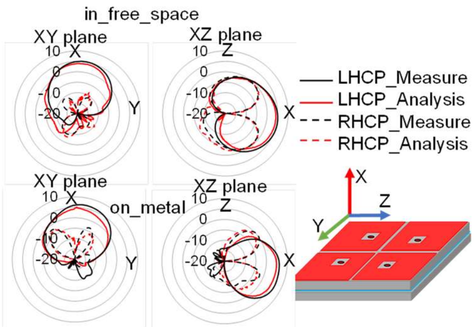


(a) Characteristics of VSWR and axial ratio



(b) Characteristics of VSWR and axial ratio on metal

Fig. 5. Characteristics of VSWR and axial ratio in free space and on metal.



Gain in front direction[dBi]	Measure	Analysis
in_free_space	4.04	4.90
on_metal	4.67	6.01

Fig. 6. Radiation pattern and frontal gain at 2.45 GHz.

VI. CONCLUSION

In this paper, we present a feasibility study of a new model for radiating circularly polarized waves based on the previously studied linearly polarized waves. We achieved a VSWR of less than 3 and an axial ratio characteristic of less than 3 dB at 2.4–2.5 GHz. In the future, we will further improve the characteristics of the system and study how to simplify the feed power, for example, by using only one feeding point.

Acknowledgment

This work was supported by JST CREST Grant Number JPMJCR20Q1, Japan.

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. et al., "Feasibility study of an unbalanced MACKEY type R with enhanced robustness on metal," in ISAP 2021, October 2021.