Feasible study of MACKEY II type R with Enhanced Robustness on metal

Keisuke Miyashita, Shigeru Makino, Kenji Itoh
Kanazawa Institute of Technology
7-1 Ogigaoka, Nonoichishi
Ishikawa, 921-8501 Japan
b1613494@planet.kanazawa-it.ac.jp

***Abstract*— In this study, a meta-surface-inspired antenna chip, developed by KIT EOE Laboratory (MACKEY), that is sufficiently robust to a metal object and MACKEY II type R with enhanced robustness against metal is proposed. Moreover, the antenna width was optimized to obtain a wider operating bandwidth.**

Keywords—MACKEY; WiFi-2GHz; Meta-surface inspired antenna; AMC substrate; robustness

I. Introduction

A meta-surface-inspired antenna chip developed by KIT EOE Laboratory (MACKEY) basic-type electrically small antenna that is sufficiently robust to a metal object has been proposed [1]. In addition, MACKEY II is proposed as a reduced-thickness model of the MACKEY basic-type [2].

Fig. 1(a) shows the MACKEY II which is designed for the Wi-Fi 2.4 GHz band. The model has a three-layer structure comprising a grid plate, an antenna plate, and a metal plate in descending order, with a dielectric filled between them. In addition, Fig. 1(b) shows the model of the patch antenna with a similar structure as a planar antenna. It's designed to have the same size as MACKEY II shown in Fig.1. Moreover, Fig.2 depicts the analysis results of VSWR characteristics in free space and on metal of two models. The analysis results in Fig. 2 show that both MACKEY II and the patch antenna operates in free space and on metal.

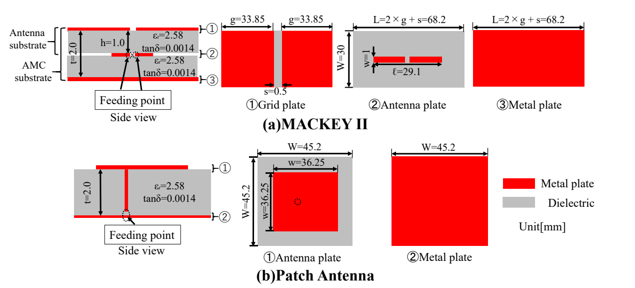


Fig. 1. Model diagram of the MACKEY II and the patch antenna

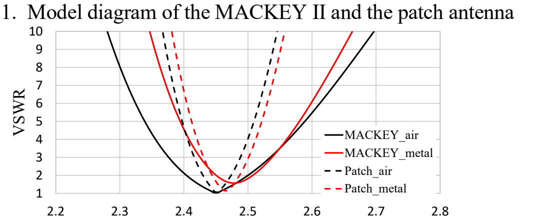


Fig. 2. VSWR characteristics of the MACKEY II and the patch antenna

In this study, MACKEY II type R was proposed, which has enhanced robustness. It has been shown that MACKEY II type R reduced the frequency shift in free space and on metal compared to the conventional MACKEY.

II. Novel MACKEY II R Type with Enhanced Robustness

Section 1 showed that MACKEY II and the patch antenna operates not only in free space but also on metal. However, there is a frequency shift in the metal compared to that in free space. Therefore, they do not fully satisfy the Wi-Fi 2.4 GHz bandwidth (2.4–2.5 GHz) in free space or on metal. In a conventional study, it was revealed that the effect on the metal could be reduced by varying the vertical length of the antenna, while the grid vertical width is fixed in the basic type [3]. Therefore, a similar study was performed on MACKEY II to reduce the frequency shift in free space and on metal. Fig. 3 illustrates a structural diagram of the MACKEY II type R (robustness type). In this study, as shown in Fig. 3, the optimization of the vertical length of the antenna is performed for front and back feed types, which enable feeding through holes in MACKEY II, in consideration of actual modeling. In the two models, the grid vertical width gw was fixed at 30 mm, and the antenna vertical length W was changed from 30 mm to 40 mm in increments of 1 mm. Thus, it is possible to determine the vertical width of the antenna that represents the optimal operating bandwidth. Here, the operating bandwidth indicates the relative bandwidth of the metal minus the frequency shift between the free space and metal. Therefore, when the frequency shift is small and the relative bandwidth is wide, the operating bandwidth is also large. In addition, in this study, impedance matching was performed on the metal, and the model was analyzed in free space to examine the operating bandwidth.

Fig. 4 depicts the frequent shifts of the two models. As shown in Fig. 4, the frequency shift decreases in both the models as the substrate height W is increased; however, when the shift decreases to a certain level, it generally levels off. In addition, Fig. 5 shows the operating bandwidth of the two models. As shown in Fig. 5, the operating bandwidth increases as W increases, but decreases slightly after increasing to a certain level, similar to the frequency shift shown in Fig. 4. When comparing the frequency shift and operating bandwidth of the front and back feed types, the front-feed type has better overall performance; however, after W=37 mm, both models are generally consistent.

Based on the results in Fig. 5, in this study, a model with an antenna width of W=37 mm is designed for both models to create a model with the smallest size possible and a wide operating bandwidth.

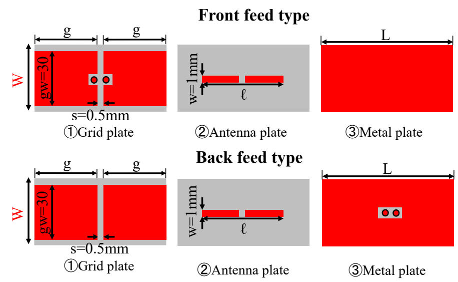


Fig. 3. Structural diagram of MACKEY II type R

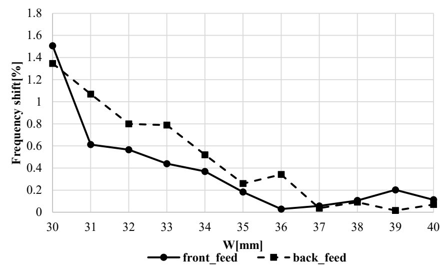


Fig. 4. Frequency shift of two models

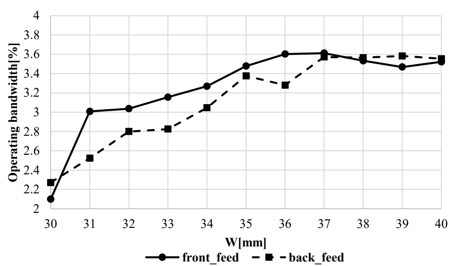


Fig. 5. Operating bandwidth of two models

III. DESIGHNED MACKEY II TYPE R

Based on the previous discussion, Fig.6 shows the model diagram of the front-feed and back-feed types designed with W=37mm. For both models, the AMC substrate thickness was fixed at 2mm, and the antenna position was fixed to 1mm.

As a result of impedance matching of the two models, the width of the front feed type was 69.6 mm, and that of the back feed type was 68 mm. Fig. 7 shows the analysis results of the VSWR characteristics of the two models. As shown in Fig. 7, there is almost no frequency shift in free space and on the metal for both models. However, while both models satisfy the Wi-Fi 2.4 GHz bandwidth in free space, they do not completely satisfy the bandwidth of the metal. Fig. 8 shows the analysis results of the radiation patterns of the two models. As shown in Fig. 8, the radiation is sufficient, both in free space and on metal.

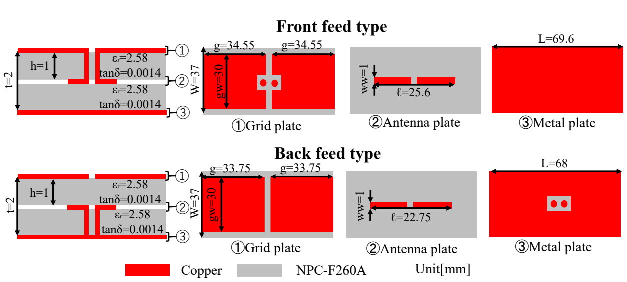
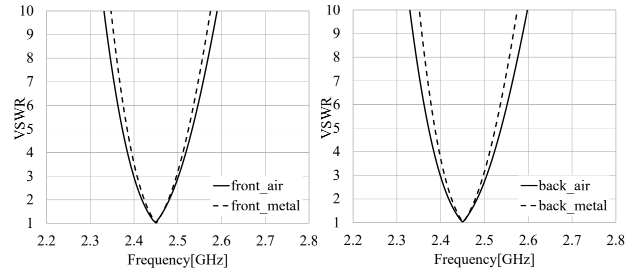


Fig. 6. Model diagram of the MACKEY II type R



(a)Front feed type (b)Back feed type

Fig. 7. VSWR characteristics of the MACKEY II type R

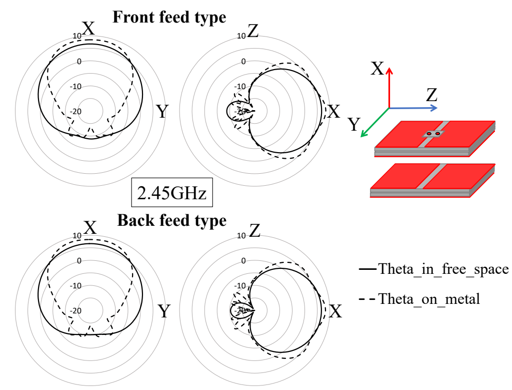


Fig. 8. Radiation pattern of the MACKEY II type R

IV. CONCLUSION

In this study, a MACKEY II type R with enhanced robustness on metal was proposed. When compared to the basic model, this model takes advantage of the feature of reducing the frequency shift by varying the grid vertical width in the reduced thickness of MACKEY II. In this study, the antenna height was optimized by shifting the frequency and optimizing the operating bandwidth, while the grid height was fixed at 30 mm for the front and back feed types of MACKEY II. As a result, the antenna height of W=37 mm was determined to be the most optimal for both models.

The analysis results for the front and back feed types almost satisfied the Wi-Fi 2.4 GHz bandwidth in free space. Therefore, the two designed models are found to have less frequency shift than the conventional MACKEY II and wider bandwidth than the patch antenna. In addition, both models radiated well in free space and on metal.

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, p. 786794, Sep. 2016

[2] K. Miyashita et al., “Mackey II model with reduced thickness,”, 2021 15th Eur. Conference on Antennas and Propagation (EuCAP), pp. 1–4, Mar. 2021

[3] T. Tamura et al., “Feasibility Study of MACKEY with improved operation on metal,” IEEE APS, pp. 189–190, Jul. 2020