Feasibility study of an unbalanced MACKEY type R with enhanced robustness on metal

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***Abstract*— A meta-surface-inspired antenna chip developed by KIT EOE Laboratory (MACKEY), which operates not only in free space but also on a metal plate, is proposed. In this study, an unbalanced MACKEY using an inverted L-shaped antenna as the feed element is proposed. In addition, to improve the characteristics of unbalanced MACKEY on metals, an unbalanced MACKEY type R is proposed with an optimized antenna width.**

Keywords— MACKEY WiFi-2GHz, meta-surface-inspired antenna, AMC substrate, unbalanced, robustness.

I. Introduction

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

Fig. 1 shows a MACKEY II back-feed type, which is designed for the Wi-Fi 2.4 GHz band. The model has a three-layered structure comprising a grid plate, antenna plate, and metal plate in descending order, with a dielectric filled in between, as shown in Fig. 1. Impedance matching is performed based on the grid width g and antenna length ℓ. Fig. 2 depicts the measurement results of the VSWR characteristics in free space and on metal. The measurement results in Fig. 2 show that the MACKEY II back-feed type operates in both free space and metal.

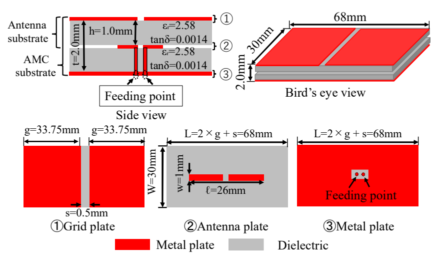

Fig. 1. Model diagram of the MACKEY II back-feed type

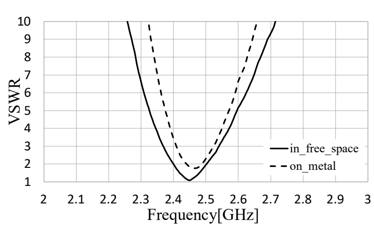

Fig. 2. VSWR characteristics of the MACKEY II back-feed type

In this study, an unbalanced MACKEY that can be connected to devices in unbalanced systems, and an unbalanced MACKEY type R with improved characteristics on metal.

II. Novel Unbalanced MACKEY with Inverted L Antenna as Feed Element

The basic type and MACKEY II are balanced types with dipole antennas as the feed elements, causing difficulties in connecting them with unbalanced lines and chips. An unbalanced MACKEY that can be easily connected to an unbalanced system using an inverted L-shaped antenna as a feed element, is proposed. In addition, the S-parameter measurement method [3] is used in a balanced MACKEY because of its two-port feed, which increases the measurement time. On the other hand, an unbalanced MACKEY has only one port and can be measured using a coaxial connector, shortening the measurement time compared with the conventional S-parameter method.

Fig. 3 shows the designed unbalanced MACKEY model. The structure comprises a grid plate, antenna plate, and metal plate, in descending order, similar to MACKEY II. Moreover, a through-hole is provided to enable back feeding in the model to realize the inverted L-shaped antenna as a feed element. In this model, the AMC substrate thickness and antenna position were fixed at 2 mm and 1 mm, respectively. As the impedance matched with the grid width g and antenna length ℓ, the thickness, length, and width of the model were 4 mm, 30 mm, and 69.3 mm, respectively. In terms of the model size, the results were generally consistent with those of the balanced MACKEY type.

Fig. 4 shows the measurement results of the VSWR characteristics of the proposed model. The measurement results of MACKEY II back-feed type are also shown for comparison. Fig. 4 indicates that the proposed unbalanced MACKEY operates both in free space and on metal, similar to the conventional model. In addition, there is no significant difference in the bandwidth compared to that of the balanced type, which indicates that the robustness of the unbalanced MACKEY to a metal object.

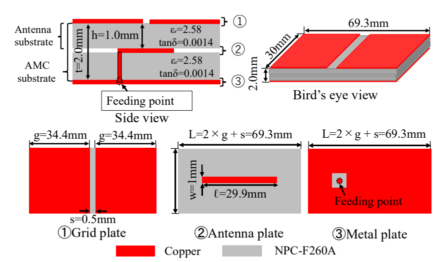

Fig. 3. Model diagram of the unbalanced MACKEY II

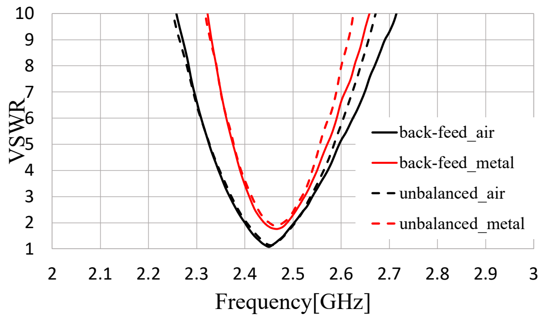

Fig. 4. VSWR characteristics of the two models.

III. Improving the Robustness of Unbalanced MACKEY

In Section 2, the unbalanced MACKEY as an antenna with robustness on metal, which works both in free space and on metal, is demonstrated. However, because of a frequency shift in metals compared with that in free space, it does not fully satisfy the Wi-Fi 2.4 GHz bandwidth on metal in the measurement results. A previous study reported that the effect on metal could be reduced by varying the vertical length of the antenna, with the grid vertical width remaining fixed in the basic type [4]. Therefore, a similar experiment was conducted to further enhance the robustness of MACKEY on metal.

In this study, the grid vertical width gw was fixed at 30 mm, and the antenna vertical length W was increased from 30 mm to 50 mm in increments of 2 mm. The operating bandwidth was calculated for each antenna width, and the antenna width with the widest operating bandwidth was investigated. The operating bandwidth is defined as the relative bandwidth on metal minus the frequency shift between free air and metal, and wider the operating bandwidth, wider the bandwidth that can be used both in free space and on metal.

Fig. 5 shows the operating bandwidth of the unbalanced type; although it increased with an increase in W, it decreases slightly after increasing to a certain level. In addition, it can be seen from the figure that the antenna width W, which has the widest operating bandwidth, is 40 mm.

Fig. 6 shows the analysis results of the VSWR characteristics at W = 40 mm, which show only a negligible frequency shift in free space or on metal. However, it does not fully satisfy the Wi-Fi 2.4 GHz band owing to the overall narrower bandwidth.

Fig. 7 shows the analysis results of radiation patterns for W = 50 mm, which show that the radiation is sufficient, both in free space and on metal.

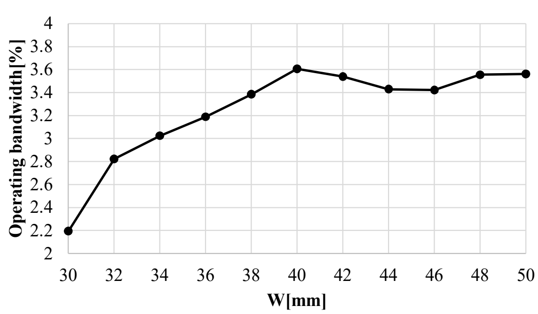

Fig. 5. Operating bandwidth of unbalanced MACKEY

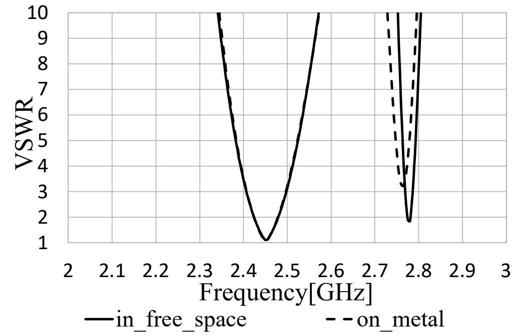

Fig. 6. VSWR characteristics of the unbalanced MACKEY type R

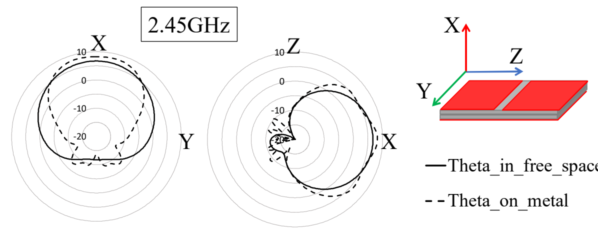

Fig. 6. Radiation pattern of the unbalanced MACKEY type R

IV. Conclusion

In this paper, an unbalanced MACKEY, which can be easily connected to unbalanced devices by using an inverted L antenna as the feed element, and an unbalanced MACKEY type R, which has enhanced robustness on metal, are proposed.

The proposed unbalanced MACKEY with an inverted L antenna as the feed element performs comparably with the balanced-type conventional model , and works both in free space and on metal.

In addition, the proposed unbalanced MACKEY type R is an improved version of the unbalanced MACKEY, with better robustness against metal owing to the varying antenna vertical lengths. In the model, the antenna vertical lengths varied from 30 mm to 50 mm, and the operating bandwidth was the highest for W = 40 mm. The unbalanced MACKEY type R designed with W = 40 mm showed only a negligible frequency shift in free space and on metal, and was comparable to the conventional model in terms of radiation pattern and gain.

Acknowledgment

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