Development of MACKEY II type M miniaturized using multiple slits

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***Abstract*— A meta-surface-inspired antenna chip developed by KIT EOE Laboratory (MACKEY), which operates in free space and on a metal plate, was investigated in this study. We propose a method for reducing the size of MACKEY II of the 920 MHz band to the card size.**

Keywords—MACKEY; RFID-920MHz; Meta-surface inspired antenna; AMC substrate

I. INTRODUCTION

An electrically small antenna known as MACKEY basic-type, which is sufficiently robust to metal objects, has been developed [1]. In addition, the MACKEY II has been proposed as a reduced-thickness model [2].

Fig. 1 depicts the MACKEY II-back feed type model (MACKEY II) designed for the radio-frequency identification (RFID) 920 MHz band. The model is a three-layer structure consisting of an antenna plate, a grid plate, and a metal plate in descending order, with a dielectric material filled in between them. Impedance matching is performed based on the grid width g and antenna length. Fig. 2 depicts the measurement results of the voltage standing-wave ratio (VSWR) characteristics in free space and on the metal. The measurement results in Fig. 2 demonstrate that the MACKEY II-back feed type operates in both free space and the metal.

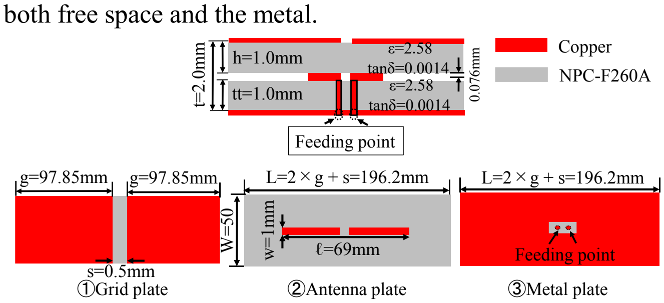

Fig. 1. Model diagram of the MACKEY II-back feed type

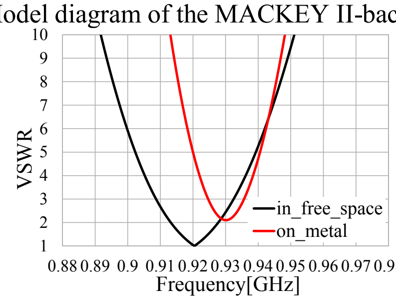

Fig. 2. VSWR characteristics of the MACKEY basic type

In this study, MACKEY II is proposed, which is fed inside the AMC substrate. It has been shown that MACKEY II is thinner than the MACKEY basic type.

II. PROPOSAL FOR MINIATURIZATION OF MACKEY II

In the conventional MACKEY II, the width L is λ/2, depending on the design frequency. Therefore, the base width L of the 920 MHz band MACKEY II is 190 mm, a problem associated with its large size. Therefore, we attempted to reduce the size of MACKEY II by cutting a slit in its grid plate to secure the current path of λ/2 or more, even if L is shortened.

Figure 3 shows the miniaturization principle. By cutting the slits along the long side of the grid plate, the current path (the blue line in Fig. 3) is extended in a meander-like pattern. This makes it possible to electrically secure a current path of λ/2 or more, even if the width L is reduced physically. MACKEY II designed using this structure will be analyzed as MACKEY II type M (multiple-slit type).

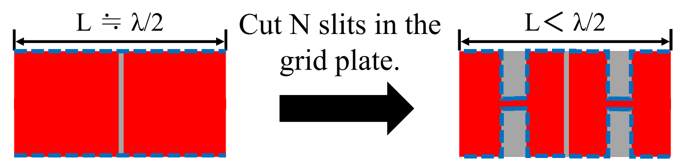

Fig. 3. Miniaturization principle

III. ANALYSIS OF MACKEY II TYPE M

When the number of type M slits is varied, the metal width gm that can be matched for each number of slits is determined. The number of slits was matched from 24 to 72 in increments of 8. The substrate width L was fixed at 80 mm, and the antenna length ℓ was fixed at 40 mm.

Figure 4 depicts the relationship between the metal width gm and the frequency at which the real part of the impedance of the analysis results intersects at 50 Ω for each number of slits.

There are several gm values for which the real part is 50 Ω at 920 MHz, indicating that several gm values can be matched for each number of slits. However, when the number of slits is fewer than 40, an optimal gm that minimizes the frequency exists.

Therefore, gm can be reduced by increasing the number of slits because it can be matched at a lower frequency when gm is thinner.

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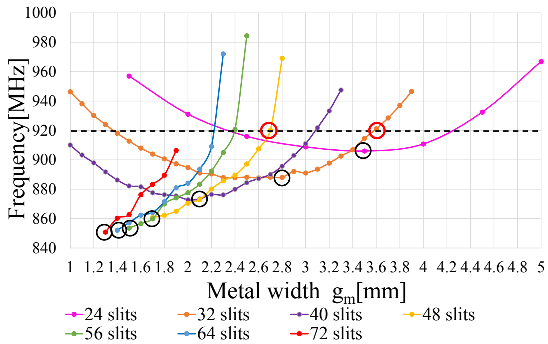

Fig.4 Relationship between metal width g_m and resonant frequency for each model

IV. ANALYSIS OF PROTOTYPE MODEL OF ANTENNA FOR RFID TAGS

Because the stacking structure of MACKEY II type M is the same as that of MACKEY II, the feed can be supplied at the back of the model by mounting through holes.

Figures 5 and 6 depict two design models with 32 and 48 slits, respectively, in the grid plate (red circle in Figure 4). For both models, the gm parameters were matched with L = 80 mm × W = 50 mm, resulting in a smaller model volume of approximately 40% of the MACKEY II volume.

Figures 7 and 8 show the analyzed values of the VSWR characteristics for MACKEY II, 32 slits, and 48 slits. Figures 9 shows the analyzed values of radiation patterns for MACKEY II, 32 slits, and 48 slits. The radiation pattern appears at the frequency where the VSWR has the lowest value.

The bandwidths of both models were narrower than that of MACKEY II but still satisfied the 920 MHz bandwidth in free space (Figs. 7 and 8).

The frontal gain of type M was lower than that of MACKEY II, and the gain in the frontal XY-direction of the free space was approximately −2 dB for both models (Fig. 9). The frontal XY gains on the metal were −0.97 dB for 32 slits and −2.32 dB for 48 slits. A possible reason was the decrease in radiation efficiency owing to the generation of the slits.

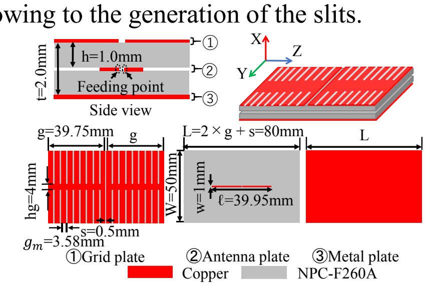

Fig.5 Model diagram of 32 slits-type M

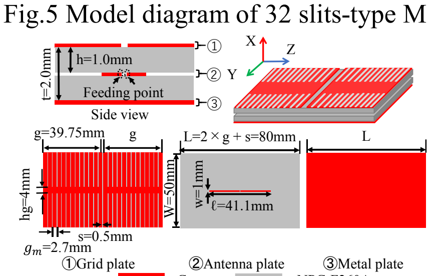

Fig.6 Model diagram of 48 slits-type M

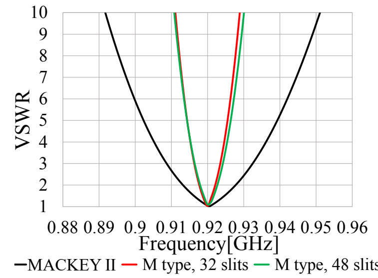

Fig.7 VSWR characteristics in free space

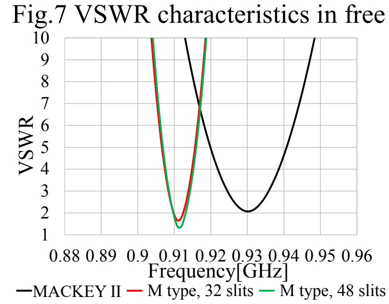

Fig.8 VSWR characteristics on metal

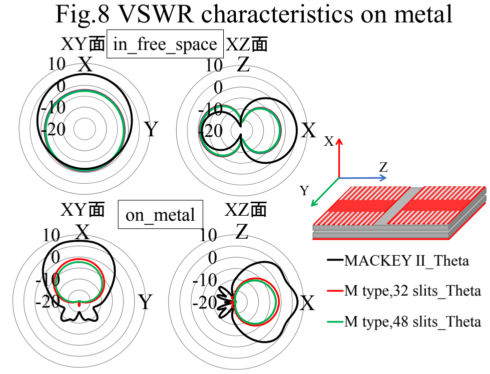

Fig.9 Radiation patterns

V. CONCLUSION

In this study, to reduce the size of the conventional MACKEY II, we applied the MACKEY II type M, which can secure the current path in a small area by cutting slits along the long sides of the grid plate. It was shown that the impedance could be controlled by changing the number of slits, and the size could be reduced. Furthermore, a prototype model of the antenna for RFID tags was investigated, and a card-sized antenna was produced. Two type M models, one with 32 slits and the other with 48 slits, were developed, and the analysis results of VSWR characteristics and radiation patterns were obtained. The size of the two proposed models was approximately 40% of that of MACKEY II, indicating that the MACKEY II type M can be smaller than MACKEY II.

VI. ACKNOWLEDGMENTS

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