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 can operate in free space and on a metal plate, was investigated in this study. We propose a method to reduce the size of MACKEY II for the 920 MHz band to that of a card.**

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

I. Introduction

An electrically small antenna, known as MACKEY basic-type, sufficiently robust to interact with metal objects, was developed in [1]. Subsequently, MACKEY II was proposed as a model with small thickness in [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 comprising an antenna plate, a grid plate, and a metal plate in descending order, with a dielectric material in between these plates. Impedance matching was realized based on the grid width g and antenna length. Fig. 2 shows the measured voltage standing wave ratio (VSWR) characteristics in free space and on the metal. The results in Fig. 2 demonstrate that the MACKEY II operates in both free space and the metal.

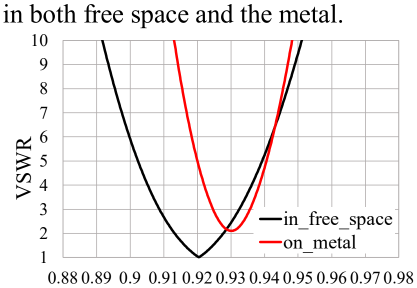


Fig. 1. Model diagram of the MACKEY II-back feed type

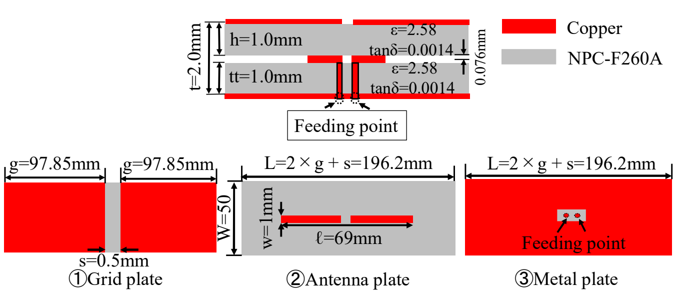


Fig. 2. VSWR characteristics of the MACKEY basic type

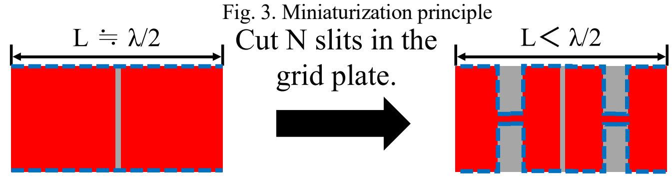
In this study, MACKEY II is proposed, which is fed inside the AMC substrate. It has been shown that MACKEY II is thinner than the MACKEY basic type.

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. Thus, we attempted to reduce the size of MACKEY II by cutting a slit in its grid plate to secure a minimum current path of λ/2, even if L decreases.

Fig. 3 illustrates the principle of miniaturization. By cutting slits along the long side of the grid plate, the current path (blue line in Fig. 3) is extended to a meander-like pattern, thus electrically securing a minimum current path of λ/2, even if L is physically reduced. 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 g_m that can be matched for different numbers 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 at 40 mm.

Fig. 4 depicts the relationship between the metal width g_m and the frequency at which the real part of the impedance of the analysis results reaches 50 Ω for each number of slits. Several g_m values exist for which the real part is 50 Ω at 920 MHz, indicating that several g_m values can be matched for different numbers of slits. However, if the number of slits is fewer than 40, an optimal g_m that minimizes the frequency exists. Therefore, g_m can be reduced by increasing the number of slits, because the thinner the g_m, the lower are frequencies at which it can be matched.

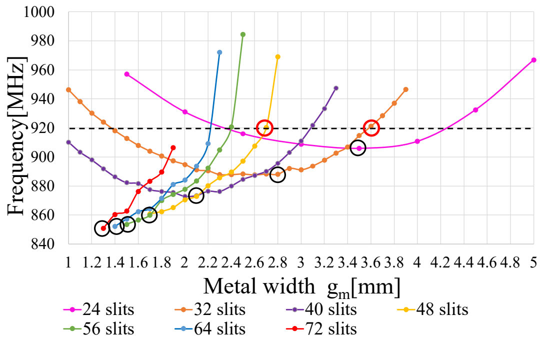


Fig.4 Relationship between metal width g_m and resonant frequency for each model

IV. ANALYSIS OF PROTOTYPE MODEL OF ANTENNA FOR RFID TAGS

Figs. 5 and 6 depict two analytical models with 32 and 48 slits, respectively, in the grid plate (red circles in Fig 4). In the analysis, the antennas were fed directly to each other. However, in the measurements, the antennas were back-fed using through holes. For both models, the g_m parameters were matched with L = 80 mm × W = 50 mm, resulting in a smaller model volume, i.e., approximately 40% the volume of MACKEY II.

Figs. 7 and 8 shows the analyzed and measured values of the VSWR characteristics and the radiation patterns, respectively, for 32 slits (a) and 48 slits (b). The radiation pattern appeared at the frequency where the VSWR exhibited the lowest value.

Both in free space and on metal, the measured results are lower than the analyzed results, and the specific bandwidth was slightly wider, as shown in Fig. 7. The reason for the discrepancy between the measurement and analysis results may be that the prepreg and through-hole were not considered in the analysis.

The radiation patterns of the measurement and analysis results were generally consistent. However, Fig. 8 shows that the gain in the frontal direction of the measurement results was lower than that of the analysis results.

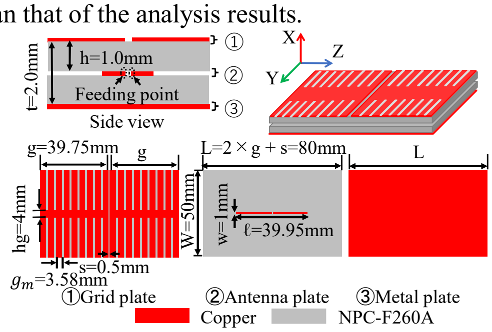


Fig.6 Model diagram of 32 slits-type M

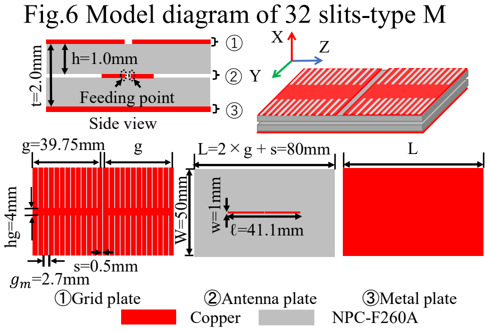


Fig.7 Model diagram of 48 slits-type M

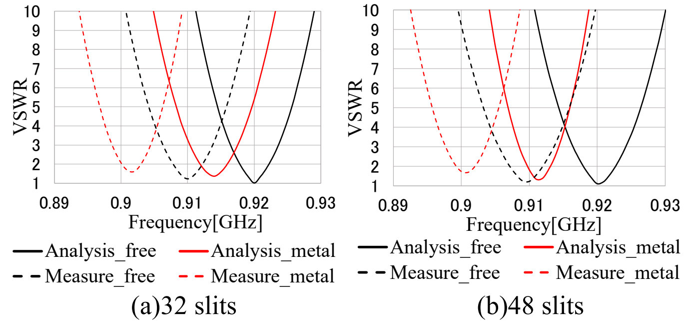


Fig.7 VSWR characteristics

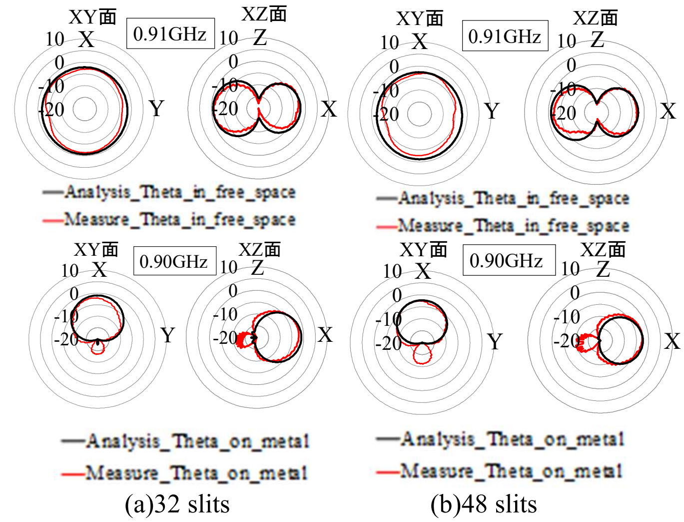


Fig.8 Radiation patterns

V. CONCLUSION

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

VI. ACKNOWLEDGMENTS

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