MACKEY type S miniaturized using short circuit plate

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***Abstract*—Meta-surface inspired antenna chip developed by KIT EOE Laboratory (MACKEY) that operates not only in a free space but also on a metal plate has proposed. In this paper, two new types of MACKEY with shorting plates and how to make them are proposed.**

***Index Terms*—MACKEY , Through hole , thermoplastic polyurethane film , short circuit plate**

I. Introduction

A meta-surface inspired antenna chip developed by KIT EOE Laboratory (MACKEY), which integrates a dipole antenna and an artificial magnetic conductor (AMC), has been developed[1]. The MACKEY chip has proved its capabilities of matching the impedance even when installed in a free space or on a metal plate.

In this paper, two new types of MACKEY chips with shorting plates, as well as a process for their manufacture, are proposed.

II. Structure of original MACKEY

Fig.1 depicts a model diagram of MACKEY basic type. From top to bottom, it comprises an antenna plate, a grid plate, and a metal plate. A dielectric layer is placed between each of them. Impedance matching can be achieved using the design parameters g and ℓ. Fig.2 depicts the analysis results of the VSWR characteristics, indicating that the MACKEY chip can operate not only in a free space but also on a metal plate.

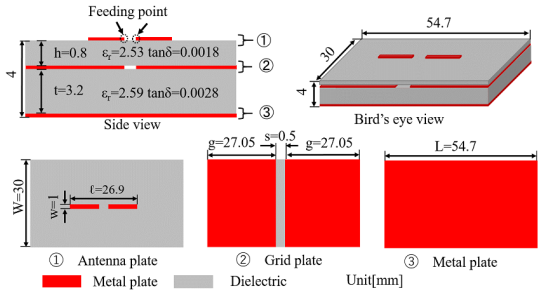

Fig. 1. Model diagram of the basic MACKEY basic type.

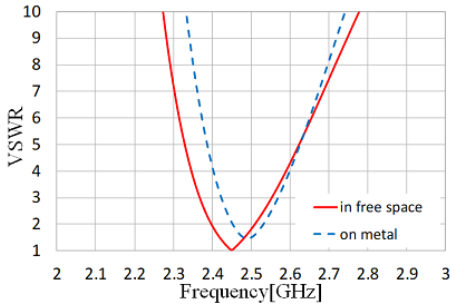

Fig. 2. VSWR characteristics of the basic MACKEY basic type.

III. Model diagrams and measured values of the S1- and S2-type MACKEYs

The MACKEY basic type presented in Fig.3(B) only uses two elements (separated by dotted lines in the figure) of an AMC based capacitance grid of the infinite periodic structure of Fig.3(A). The mirror image principle is used to miniaturize the basic type. Fig.3(C) and Fig.3(D) depicts how the miniaturization is conducted.

Fig.3(C) is a model in which the basic type of Fig.3 (B) is cut in half along the dotted line and a short-circuit plate is provided. The structure of Fig.3(B) is a target structure by a dotted line. Fig.3(C) in which a short-circuit plate is provided by cutting in half with a dotted line is equivalent to Fig.3(B) from the principle of mirror image. The MACKEY type S1, which is miniaturized by shorting one side, has been proposed.

Fig.3(D) depicts a model in which a short circuit plate is installed at the dotted line portion of the capacitance grid in Fig.3(A), as well as a dipole antenna placed thereon. The model in which only the two elements in Fig.3(A) are left cut by a dotted line, and the short-circuit plate is installed, is equivalent to the model depicted in Fig.3(A) owing to the mirror image principle. The model with a dipole antenna placed on top is presented in Fig.3(D). MACKEY type S2, which is miniaturized by shorting on both sides, has been proposed. Compare the width L and the specific bandwidth of the basic model and the two S models.

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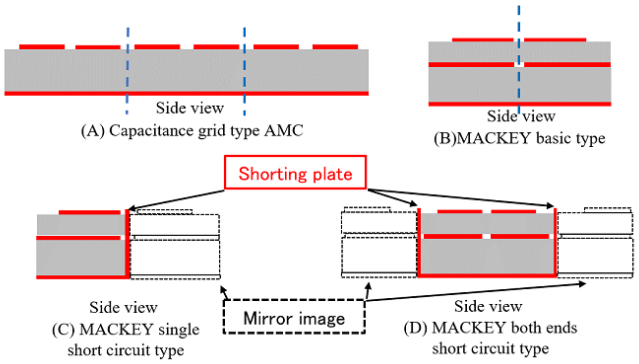

Fig. 3. Model diagram of small MACKEY.

IV. Study of the MACKEY type S short circuit plate

There are two possible methods for creating the short-circuit plate. The first is to open a through hole and short it. This method is generally used as a means for short-circuiting. However, to open the hole, it is necessary to ensure that additional space is available to accommodate it; this requires a larger model, which is a drawback. With the second method, a short-circuit plate is created by sticking the thermoplastic polyurethane (TPU) film to cover the side and bottom. TPU film is composed of an 18 μ m electrolytic copper foil transferred 30 μ m TPU hot melt bond film. The TPU film is thin. By creating a short-circuit board via sticking TPU film, the resultant model size will be smaller than that if using a through-hole. A comparison analysis of the results and the model dimensions of the two mentioned creation methods is presented in the following figure.

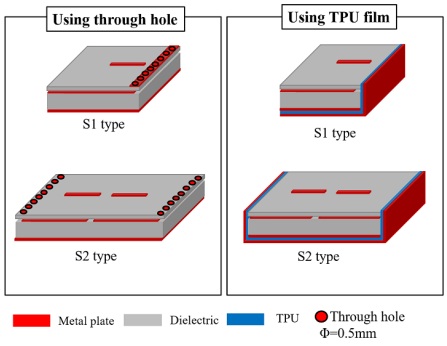

Fig. 4. Model diagram of MACKEY type S using through hole.

V. Study of MACKEY type S using through hole

Fig.9 and Fig.10 depict the model diagrams of S1- and S2-type MACKEYs using through-holes, respectively. A through hole with a diameter of 0.5 mm is opened on one side of the type S1 and on both sides of the S2 type. The MACKEY chip is miniaturized by short-circuiting the through hole. The substrate width of the type S1 MACKEY is 32.55 mm, which is 60% smaller than that of the basic type, with a width of 54.7 mm. The substrate width of the type S2 MACKEY is 47.2 mm, which is 86% smaller than that of the basic type, with a width of 54.7 mm. Fig.11 and Fig.12 show the VSWR characteristics analysis results of the S1- and S2-type MACKEYs using through-holes, respectively. The type S1 is narrower than the basic type. The type S2 has a wider bandwidth than the basic type. However, it is affected by metal.

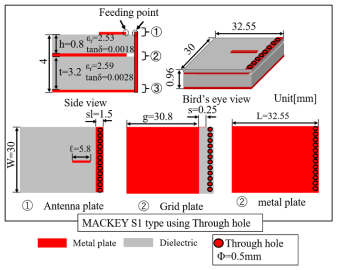

Fig. 5. Model diagram of the MACKEY type S1 using through hole.

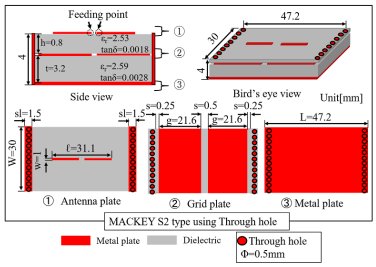

Fig. 6. Model diagram of the MACKEY type S2 using through hole.

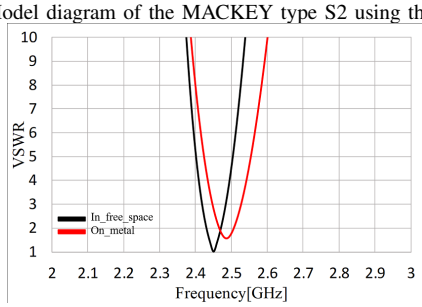

Fig. 7. VSWR characteristics of the MACKEY type S1 using through hole.

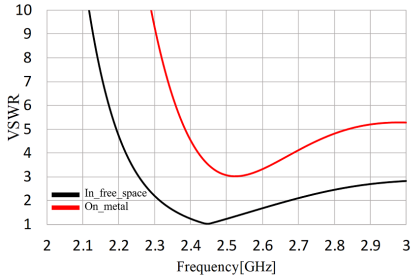

Fig. 8. VSWR characteristics of the MACKEY type S2 using through hole.

VI. Study of MACKEY type S using TPU film

Fig.9 and Fig.10 present the model diagrams of the S1- and S2-type MACKEYs using TPU film, respectively. The

MACKEY chip is miniaturized via short-circuiting using TPU film. The substrate width of the MACKEY type S1 is 29.05 mm, which is 53% smaller than the basic type with a width of 54.7 mm. The substrate width of the MACKEY type S2 is 37.4 mm, which is 68% smaller than the basic type with a width of 54.7 mm. Fig.11 and Fig.12 present the VSWR characteristics analysis results of the S1- and S2-type MACKEYs using TPU film. The type S1 is narrower than the basic type. The type S2 has a wider bandwidth than the basic type. However, it is affected by metal.

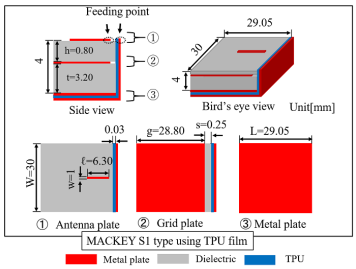

Fig. 9. Model diagram of the MACKEY type S1 using through hole.

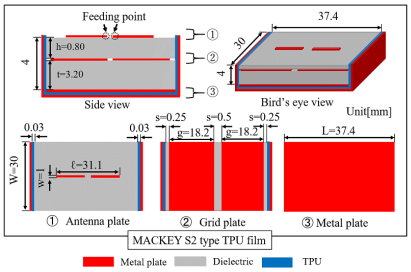

Fig. 10. Model diagram of the MACKEY type S2 using through hole.

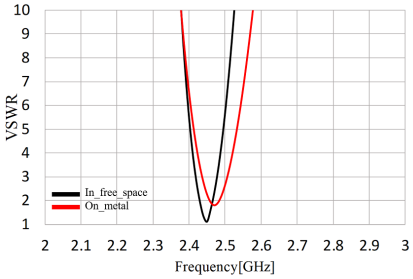

Fig. 11. VSWR characteristics of the MACKEY type S1 using through hole.

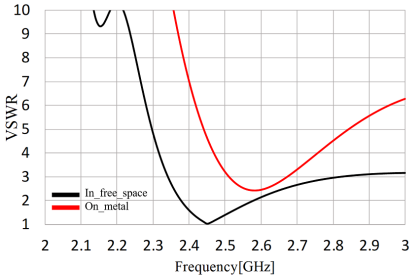

Fig. 12. VSWR characteristics of the MACKEY type S2 using through hole.

VII. Comparison of MACKEY type S creation methods

Table.I presents a comparison of the width L between the model using TPU film and the model using through holes (SH). When comparing the width L of a board having a TPU film and through holes, the type S1 has little change of size. However, the type S2 was approximately 10 mm wider when made with through holes. When comparing the specific bandwidth of a board created with a TPU and a SH, the type has little change. The type S2 was made with SH. However, the specific bandwidth was wider and the effect on the metal was larger. With both methods, the miniaturization is successful because the obtained width L is smaller than the width of the basic type.

TABLE I
Comparison of width L

	type S1		type S2	
	TPU	SH	TPU	SH
width L : [mm]	29.05	32.55	37.4	47.2

VIII. Conclusion

A basic MACKEY type was miniaturized using the mirror image principle, and an MACKEY type S1 and double-sided short-circuit type MACKEY were proposed. The width L and the specific bandwidth of the basic model and the two S models were compared. Both methods succeeded in miniaturization because the width L is smaller than the width of the basic type. The type S1 became narrower and the type S2 became wider. However, the type S2 has a large influence on metal.

The analysis results of two creation methods, namely using a through hole and using TPU film, were compared. For the type S1, the width L and the analysis results hardly changed compared with the board having a TPU film. For the type S2, the width L is approximately 10 mm larger when a TPU film is used. Moreover, the specific bandwidth is widened.

IX. Acknowledgments

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References

[1] T. MOROYA et al, "AMC Inspired Small Antenna MACKEY," IEICE. Trans. Commun, vol. J99-B, no. 9, pp. 786794, Sep. 2016.
[2] T. MOROYA et al, "AMC Inspired Small Antenna MACKEY," IEICE. Tech. Rep, AP2015-6, pp. 25-30, 2015.