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LETTER

Circularly polarized MACKEY with one feeding point

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Abstract With the spread of Internet of Things (IoT) technology, the requirements for antennas mounted on electrical devices have increased. These antennas are required to have a small size and thin profile, and to be unaffected by metals. A metasurface-inspired antenna chip developed by the KIT EOE Laboratory (MACKEY) is proposed as an antenna that satisfies these conditions. Among IoT devices, smartphones and smartwatches use circularly polarized waves to accommodate polarization at various angles. Therefore, MACKEY, which radiates circularly polarized waves, has also been proposed. In this paper, we propose a one feeding-point model with broadband axial ratio characteristics.

Keywords: MACKEY, Wi-Fi, circular polarization, axial ratio
Classification: Antennas and propagation

1. Introduction

In recent years, wearable devices such as smartphones, glasses, and watches equipped with communication functions and the Internet of Things (IoT) have been rapidly developed. The antennas used in these products must be compact, thin, and unaffected by metals. Circular polarization is used in mobile communications because there is no need to adjust the polarization. Therefore, a metasurface-inspired antenna chip developed by the KIT EOE Laboratory (MACKEY) [1, 2, 3, 4] for a circularly polarized model [5, 6, 7] has been proposed. This model requires two feeding points. With these two feeding points, the feeding conditions become more complex. In this study, we propose a model with one feeding point. Microstrip antennas (MSA) using degeneracy effect are used as circularly polarized wave antennas with small and low profile characteristics [8, 9]. This antenna is known to have a narrow-bandwidth axial ratio characteristic, which indicates the quality of communication. Therefore, various studies have been conducted to broaden its bandwidth, including the use of air layers and parasitic elements [10, 11, 12, 13]. However, the thickness and size of the antennas have increased. In this study, we develop a MACKEY with broadband axial ratio characteristics. Chapter 2 proposes a single-point power supply model. Chapter 3 compares the MACKEY and MSA, and shows that the MACKEY has a wider bandwidth. Chapter 4 compares the analysis results with the measurement results and demonstrates their validity.

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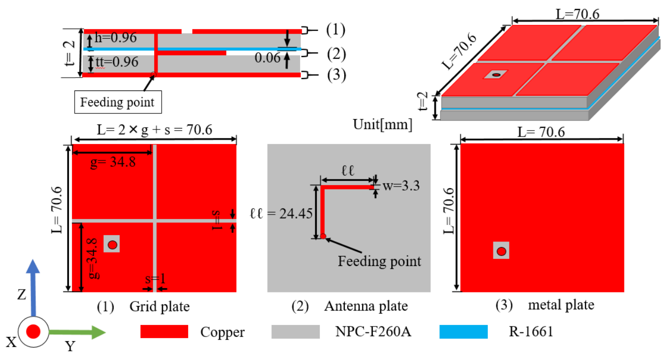
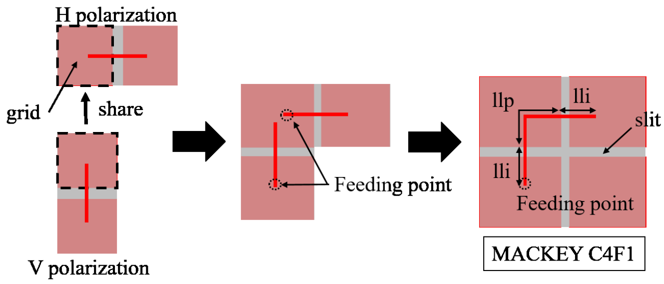
2. Proposal for MACKEY C4 one feed point type

Figure 1(a) shows a model diagram of the MACKEY C4 feeding-point type (MACKEY C4F1). The MACKEY C4F1 radiates circularly polarized waves using a one-point feed system. This model is designed for use in the 2.4 GHz band, which is the 2 GHz Wi-Fi band. The MACKEY C4F2 consists of three layers: a grid plate, antenna plate, and metal plate. In between each layer is a dielectric material. The substrate used is an NPC-F260A (Nippon Pillar Industry Co., Ltd.). R1661 is mounted as prepreg for adhesion. Power is supplied from the metal plate to the antenna plate by mounting it through the holes. The antenna dimensions are as follows: substrate thickness: t = 2 mm, length and width: L = 70.6 mm, grid width: g = 34.8 mm, and antenna length: $\ell\ell$ = 24.45 mm. Figure 1(b) shows the design concept of the MACKEY C4F1. The left figure in Fig. 1(b) shows two linearly polarized MACKEYs, one for V polarization and the other for H polarization, each consisting of two



(a)Model of MACKEY C4F1



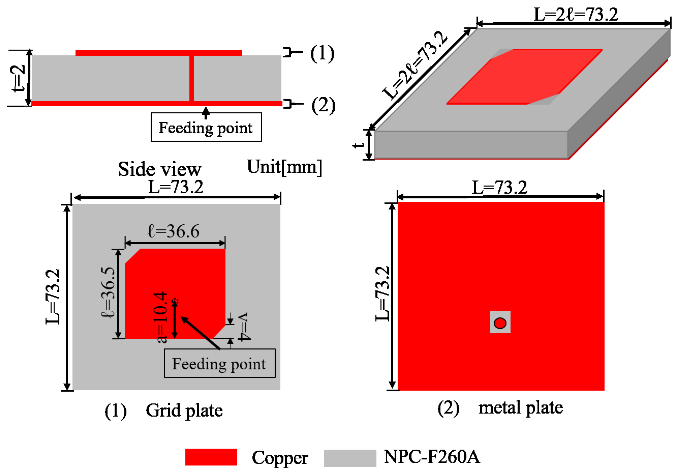
(b)Design concept of the MACKEY C4F1

Fig. 1 Proposal for the MACKEY C4F1

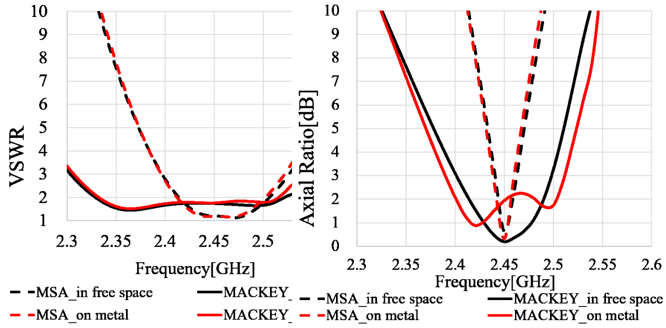
grids. The central figure of Fig. 1(b) shows two linearly polarized MACKEYs combined into one. In this case, there are originally four grids. However, by sharing the grids of each MACKEY, the number of grids is reduced to three, making the MACKEY smaller. This model has two power-feed elements and two power-feed points. The image on the right side of Fig. 1(b) shows a model that combines a single power-feeding element. One grid is added to provide a grid plate with vertical and horizontal symmetries. This model also has a single feed point. In MACKEY, the grid plate acts as the radiating element. The left end of the grid plate radiates V polarization by excitation from the left end of the feeding element, and the top end of the grid plate radiates H polarization by excitation from the top end of the feeding element. The grid plate is excited using a slit. The length between the slits, llp, is adjusted so that the phase difference is 90°. Impedance matching is also achieved by adjusting the remaining length of the antenna element lli.

3. Comparison of MACKEY C4F1 and MSA

The MSA has a narrow-bandwidth axial ratio when fed from a single point. Although it is possible to improve its antenna by improving the structure and increasing the number of feeds, the size of the antenna increases, and the feeds become more complex. This chapter compares the VSWR and axial ratio characteristics of the MACKEY and MSA to show the broadening of the bandwidth. MACKEY C4F1 implements an AMC board, so it operates similarly to free space on metal. The VSWR and axial ratio characteristics are less than 3 on metal. The size of the metal plate is $3\lambda \times 3\lambda$ and is placed behind the antenna. The antenna is placed in the center of the metal plate. The same conditions are applied to MSA for analysis on metal. Figure 2(a) shows a model diagram of MSA. The antenna size of the MSA is the same as that of the MACKEY. Figure 2(b) shows the VSWR characteristics of the MACKEY and the MSA. At 2.45 GHz, the center frequency of the MSA is lower than that of the MACKEY C4F1; however, that of the MACKEY C4F1 is less than 2 and has a wider frequency bandwidth. Figure 2(c) shows the axial ratio characteristics of the MACKEY and MSA. The axial ratio of the MSA is lower than that of the MACKEY C4F1 at 2.45 GHz. However, the axial ratio of the MACKEY C4F1 is less than 3 dB at 2.45 GHz , and its frequency bandwidth is much wider than that of the MSA, and even wider than the 2.4 GHz Wi-Fi bandwidth. These results also show that the VSWR and axial ratio characteristics are less than 3 on metal.



(a)Model of MSA



(b)VSWR (c)Axial Ratio

Fig. 2 Comparison of the MACKEY C4F1 and MSA

4. Comparison of analysis and measurement results

This chapter compares analysis and measurement results of MACKEY C4F1. The size of the metal plate used for the measurement is 36 mm square. This is approximately 3λ of the center frequency of 2.45 GHz. Figure 3(a) shows the VSWR characteristics of the analysis and measurement results for the MACKEY C4F1. An electromagnetic simulator based on the finite-element method (ANSYS HFSS) was used for the analysis. The specific bandwidths with a VSWR less than three in the analysis and measurement results were 13.33 and 12.10 in free space, respectively, and 12.58 and 10.95 on metal, respectively. In both free space and on the metal, the analysis and measurement results were almost identical. Figure 3(b) shows axial ratio characteristics for the MACKEY C4F1. These results confirm that the MACKEY C4F1 operates both in free space and on metals. In both free space and on the metal, the analysis and measurement results are almost identical. Figure 3(c) compares the measured and analyzed radiation patterns in free space and on the metal. The coordinate axes are shown in Fig. 1(a). The gain in the frontal direction, in free space, the measurement is 6.41 dBi, analysis is 7.20 dBi. On metal, the measurement is 7.70 dBi and analysis is 8.50 dBi. Figure 3(c) shows that the measured and analyzed radiation patterns were almost identical.

5. Conclusion

In this paper, we propose a single-point feeding model for a circularly polarized MACKEY. Compared with the MSA, the VSWR and axial ratio characteristics of this model have a wider bandwidth. In addition, the measurement and analysis results were compared and found to be in agreement.

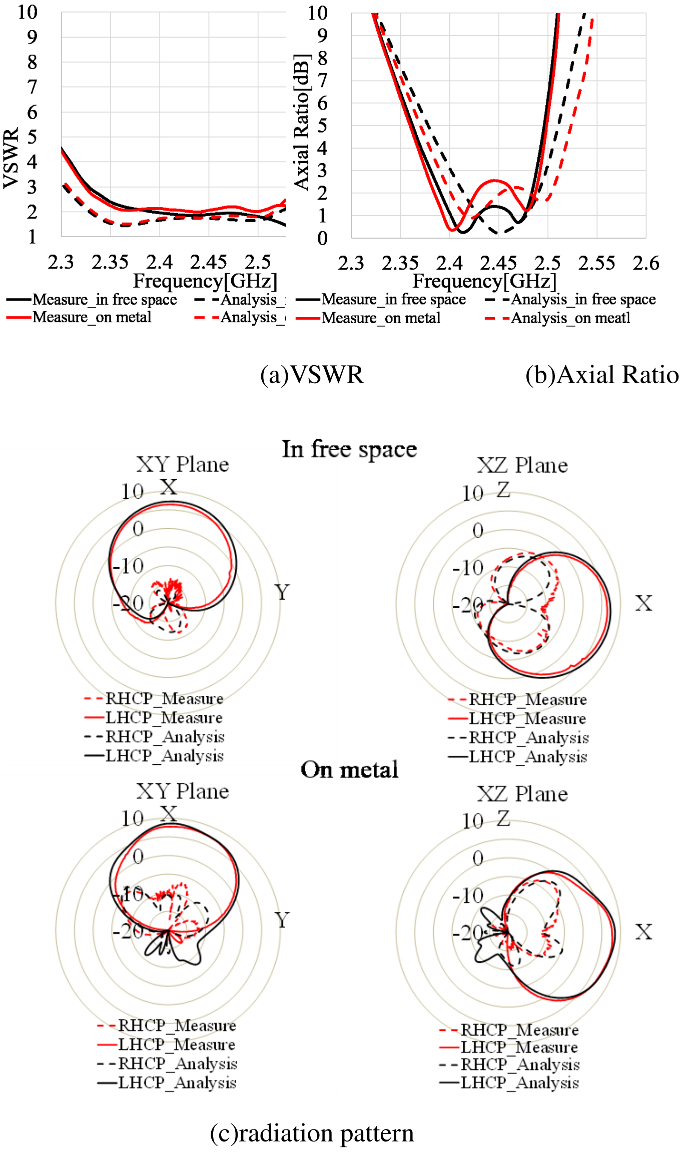


Fig. 3 Comparison of the measurement and analysis results

Acknowledgments

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