Two-dimensional arraying of unbalanced MACKEY

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***Abstract*—In this study, we examine a compact and thin metasurface-inspired antenna chip developed by the KIT EOE Laboratory (MACKEY) that can operate in free space and on metals. In particular, MACKEY II is examined when it is converted to a two-dimensional array with element spacing λ/4 and λ/2.**

Keywords—MACKEY II, WiFi-2.4GHz, array

I. Introduction

With recent advancements in the Internet of Things, the metasurface-inspired antenna chip developed by the KIT EOE Laboratory (MACKEY) [1] has been established as a compact antenna that is less susceptible to the influence of the surrounding metal. In this study, we investigated MACKEY arraying to improve the gain and change directivity of wireless power transmission, that is, a technology that wirelessly transmits power. MACKEY can be easily arrayed with an element spacing of λ/4.

II. Consideration of One-Dimensional Array

Fig. 1 shows a model diagram of MACKEY II for the WiFi 2.4 GHz band modeled in this study. In particular, MACKEY II [2] was arrayed into two dimensions with element spacings λ/4 and λ/2, as shown in Figs. 2 and 3. The element spacings λ/4 and λ/2 have 16 and 4 elements, respectively. The element spacing λ/4 allows for two-polarization sharing. The dipole elements were arrayed in the Z direction. In this study, the difference in element spacing was examined.

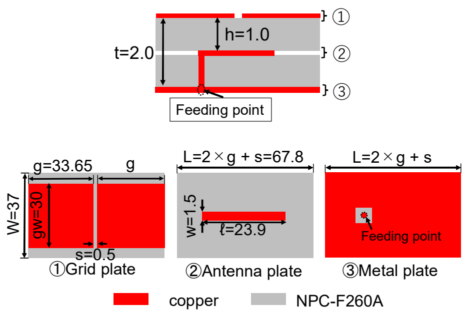

Fig. 1. Model diagram of MACKEYII

This work was supported by JST CREST (Grant Number JPMJCR20Q1), Japan.

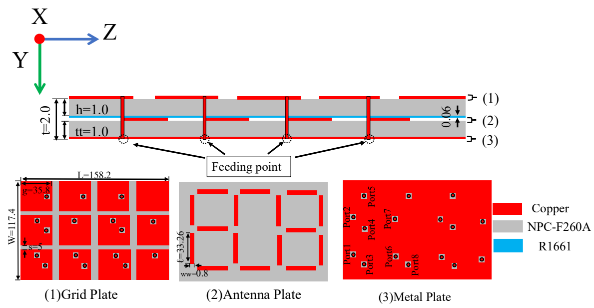

Fig. 2. Element spacing λ/4 model diagram

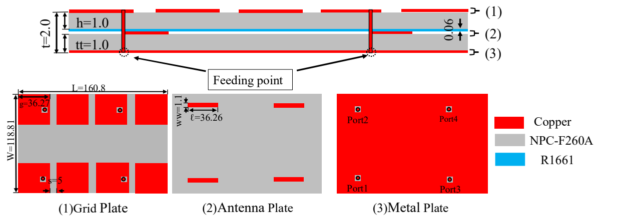

Fig. 3. Element spacing λ/2 model diagram

III. Analysis Results

For analytical conditions, we assumed an ideal power-feeding circuit with an equal amplitude and in-phase. The analysis software used was HFSS from Ansys. Fig. 4 compares the reflection loss for element spacings λ/4 and λ/2 when the antenna length ℓ was varied. When the antenna length ℓ was 33.26 mm, the element spacing λ/4 exhibited the lowest reflection loss. However, when the antenna length ℓ was 36.26 mm, the element spacing λ/2 exhibited the lowest reflection loss. Fig. 5 shows the reflection loss with varying antenna width, ww, for antenna lengths of 33.26 mm and 36.26 mm with element spacing of λ/4 and λ/2, respectively. The lowest reflection loss was observed for element spacing λ/4 when the antenna width was 0.8 mm, and for element spacing λ/2 when the antenna width was 1.1 mm. Figs. 6 and 7 show the power standing wave ratio (VSWR) characteristics. The element spacing λ/4 satisfied the wifi 2.45 GHz bandwidth, and the length of the grit plate was changed to 35.8 mm. Therefore, both λ/4 and λ/2 satisfied the wifi 2.45 GHz bandwidth. Figs. 8, 9, and 10 show the radiation patterns of the composite arrays. The gains when feeding the dipole elements in the Z direction with element spacing λ/4 were

11.09 dBi in free space and 11.46 dBi on metal. The gains when feeding the dipole elements in the Y direction were 8.31 dBi in free space and 11.41 dBi on metal. The gain in the Z-direction feeding was higher than that in the Y-direction. This can be attributed to the larger side lobes in the Y-direction. The gains for the element spacing λ/2 were 9.61 dBi in free space and 12.08 dBi on the metal. Both λ/4 and λ/2 element spacing improved the gain on the metal, as in conventional MACKEY. The aperture efficiency calculated from the formula 4πS/λ^2 using the antenna area S was 93.02 and 69.70 % when feeding the dipole elements in the Z- and Y-directions, respectively, and 79.92 % with element spacing λ/2.

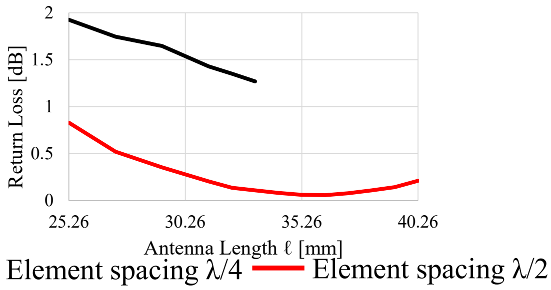

Fig . 4. Reflection loss when antenna length changes

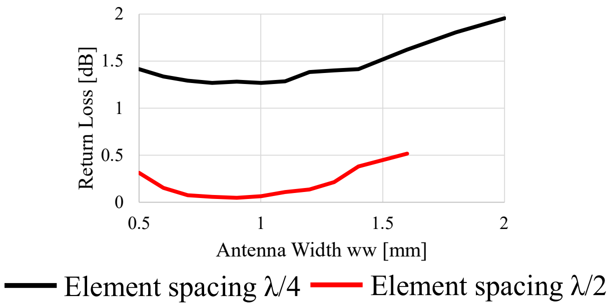

Fig. 5. Reflection loss when antenna width changes

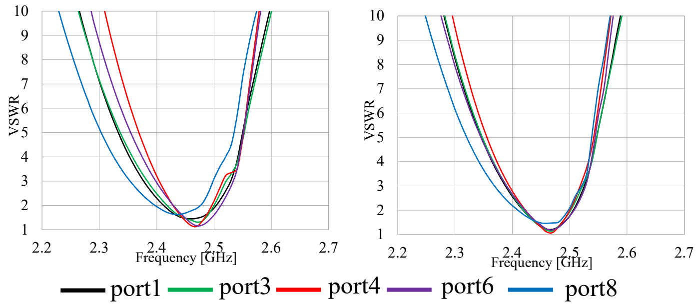

Fig. 6 VSWR characteristics of element spacing λ/4

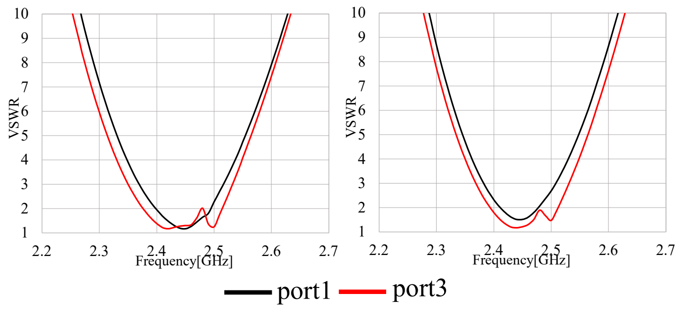

Fig. 7. VSWR characteristics of element spacing λ/2

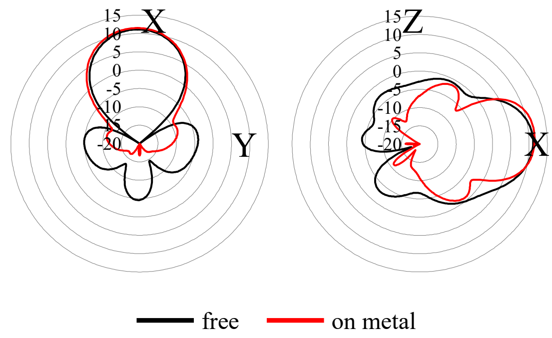

Fig. 8. Radiation pattern when fed in Z direction with element spacing λ/4

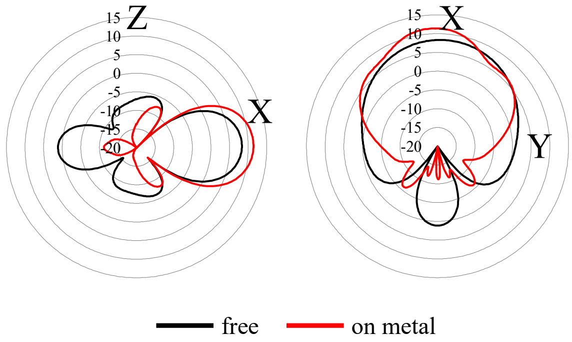

Fig. 9. Radiation pattern when fed in Y direction with element spacing λ/4

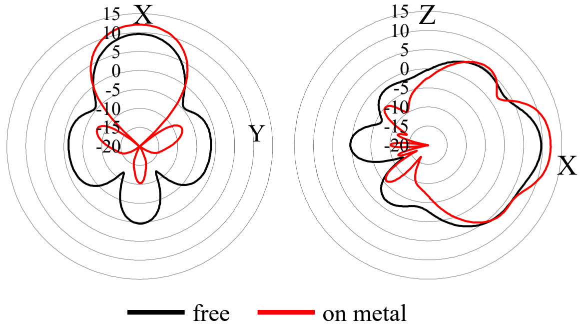

Fig. 10. Radiation pattern with element spacing λ/2

IV. CONCLUSIONS.

We examined the element spacings λ/4 and λ/2 of MACKEY II, which were particularly converted to a 2-dimensional array. Both λ/4 and λ/2 have sharper directivity and higher gain than the conventional MACKEY II, thereby suggesting that arraying was effective. The gain in the frontal direction was higher for the element spacing λ/4 than for λ/2, but the reflection loss was smaller for λ/2.

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