Consideration of a One-Dimensional MACKEY Array

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***Abstract*— This study examined a compact and thin metasurface-inspired antenna chip developed by the KIT EOE Laboratory (MACKEY). It can operate in free space and on metals. This study investigates the operation of MACKEY II when it is continuously arrayed in the electric and magnetic field directions.**

Keywords—MACKEY Ⅱ; WiFi 2.4 GHz; array

I. Introduction

Recently, with 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. This study investigated MACKEY arraying to improve the gain and change directivity for wireless power transmission, a technology that transmits power wirelessly. 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 used as the model for this study. In this study, MACKEY II [2] was continuously arrayed in the electric and magnetic field planes, as demonstrated in Figs. 2 and 3. "E-plane array" and "H-plane array" are models with continuous arrays in the electric and magnetic field planes, respectively. Four-element arrays were used for the E-plane and H-plane arrays, and the dipole elements were arranged in the *Z*-direction. This study examined the differences in the direction of the element array. In addition, the element spacing was verified as λ/4.

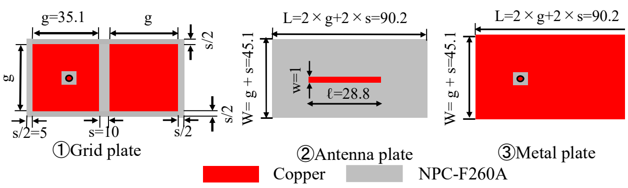

Fig. 1. Model diagram of MACKEY II

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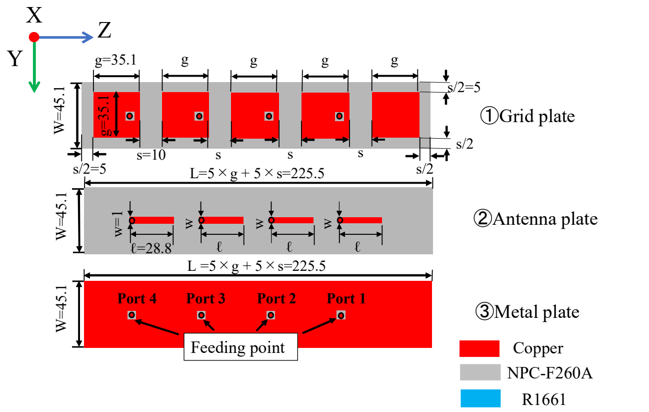

Fig. 2. Model diagram of E-plane array

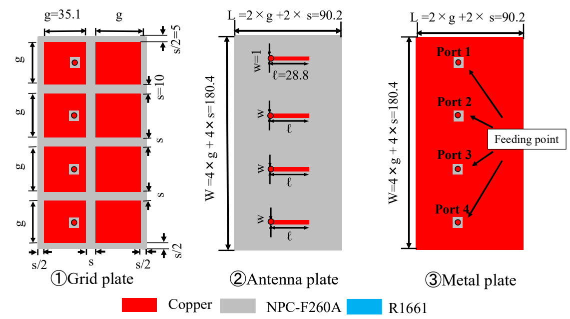

Fig. 3. Model diagram of H-plane array

III. Analysis Results

The analysis conditions assume an ideal power supply circuit with equal amplitude and phase. The analysis software used was HFSS from Ansys. Fig. 4 shows the loss for the E-plane and H-plane arrays for different slit widths (s). The E-plane array exhibited the highest actual gain and lowest reflection loss when s was 10 mm. The H-plane array had the highest actual gain and lowest reflection loss when s was 15 mm, but the reduction in reflection loss was smaller than when s was 10 mm. Therefore, considering the area of the antenna, a slit width of 10 mm was used. Figs. 5 and 6 demonstrate the actual gain of the E-plane and H-plane arrays when synthesized. The gains of the E-plane and H-plane arrays in the frontal direction were 9.55 and 10.95 dBi, respectively. The frontal gain of the H-plane array was higher than that of the E-plane array because the antenna area of the former was greater than that of the latter. Considering the conventional MACKEY II, the gain on the metal was greater than that in free space.

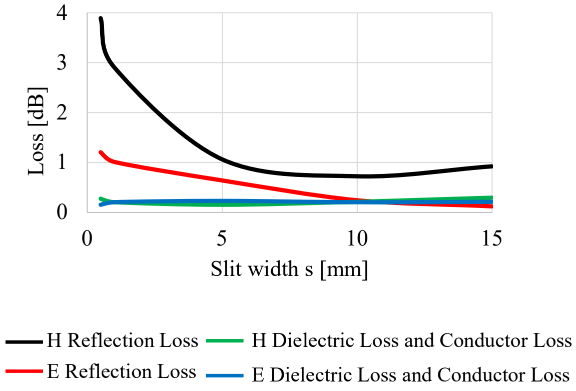

Fig. 4. Comparison chart for each loss

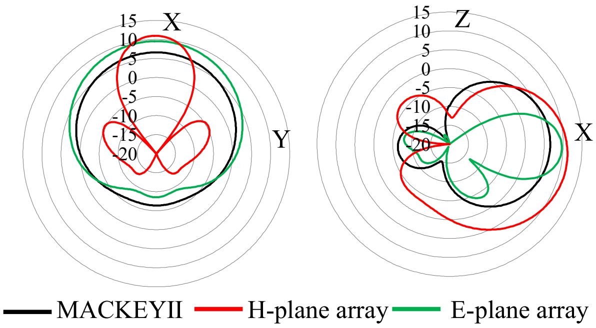

Fig. 5. Analysis of radiation pattern in free space

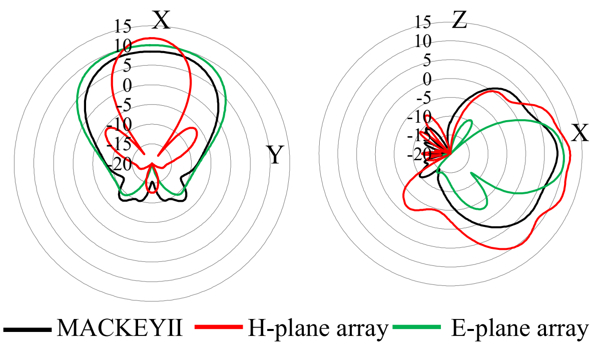

Fig. 6. Analysis of radiation pattern on metal

IV. MEASUREMENT RESULT

Fig. 7 demonstrates the voltage standing wave ratio (VSWR) characteristics, which are well within the WiFi 2.45-GHz frequency band. No significant change was observed between the free space and metal, indicating that the device works on metal as well. Figs. 8 and 9 illustrate the radiation pattern of the composite array. Closer to the analytical values, the gains in the frontal direction for the E-plane and H-plane arrays were 9.51 and 10.61 dBi, respectively. On metal, the E-plane and H-plane arrays exhibited gains of 10.61 and 10.90 dBi, respectively, which were similar to the analytical values and higher than the free space values. The cause of the error in the analytical value is considered to be the phase difference and distributor loss used in the measurement. When the measured gain in the frontal direction was compared with the gain obtained from 4πS/λ^2 using the area S, the aperture efficiencies of the E-plane and H-plane arrays were 102.61% and 83.50%, respectively, indicating that sufficient gain was obtained. The formula 4πS/λ^2 was originally used when the antenna diameter was sufficiently larger than λ. Consequently, the aperture efficiency can exceed 100%.

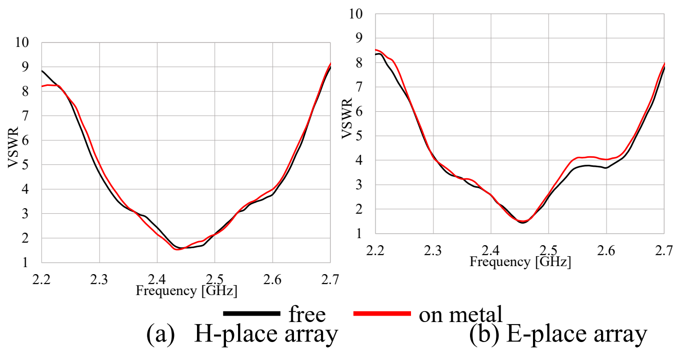

Fig. 7. Measured VSWR characteristics

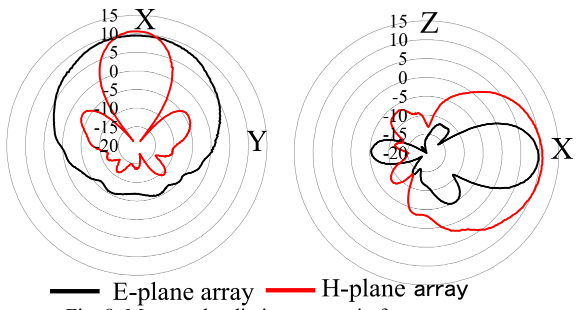

Fig. 8. Measured radiation pattern in free space

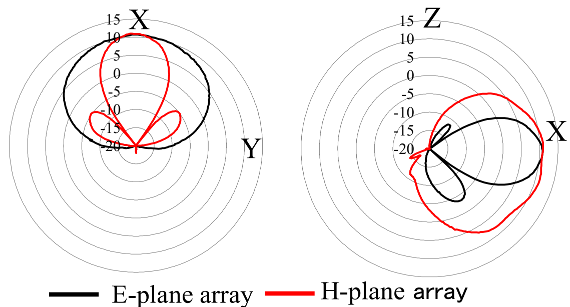

Fig. 9. Measurement radiation pattern on metal

V. CONCLUSIONS.

This study investigated continuous MACKEY II arrays in the electric and magnetic field directions. The E-plane and H-plane arrays had a higher gain and sharper directivity than the conventional MACKEY. The gain in the frontal direction was higher for the H-plane array. The gains of the E- and H-plane arrays were compared with the gain calculated from 4πS/λ^2, and the gain was observed to be sufficient.

REFERENCES

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