# Dual-Frequency Sharing in MACKEY Q Type

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***Abstract*—The meta surface-inspired antenna chip developed by KIT EOE Laboratory (MACKEY) is a small antenna that is unaffected by metal. The MACKEY Q type was developed based on MACKEY. It was miniaturized to a square with λ/4 on a side. This article proposes an antenna that can radiate radio waves of two polarizations with different desired frequencies by varying the design parameters of the antenna.**

***Keywords*—MACKEY, metasurface-inspired antenna, two polarizations, λ/4 squared**

## I. Introduction

The metasurface-inspired antenna chip developed by the KIT EOE Laboratory (MACKEY) is a small antenna that remains unaffected by the surrounding metal [1]. The MACKEY II unbalanced type, which is a thinner version of MACKEY that uses an inverted L-shaped antenna as a feeding element for an unbalanced power supply, was also developed [2]. The MACKEY Q type was developed based on the MACKEY II unbalanced type [3]. It was miniaturized to a square with a side length of λ/4 by using two shorting plates.

Fig. 1 shows the model diagram of the MACKEY Q-type designed for the Wi-Fi 2-GHz band. The model consists of three layers, namely, metal, antenna, and grid plates, with a dielectric filling the gap between the plates. The grid plate (a) and metal plate (c) act as artificial magnetic conductor substrates for working on the metal, and the grid plate (a) and antenna plate (b) act as antenna substrates for radiation (Fig. 1). Fig. 2 shows the voltage standing wave ratio (VSWR) characteristics of this model. This model works in both free space and on metal (Fig. 2).

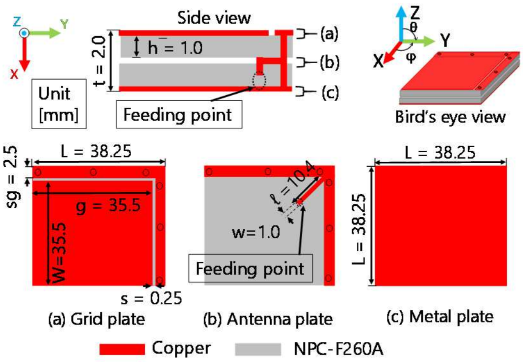


Fig. 1. Model diagram of the MACKEY Q

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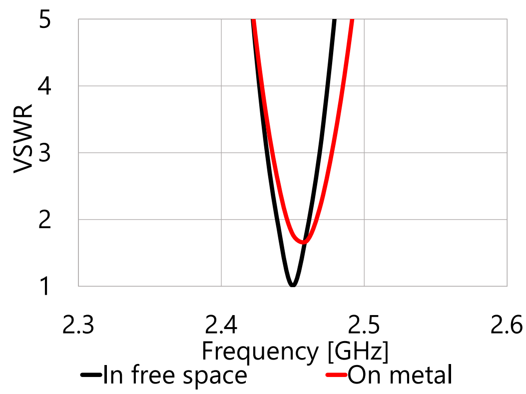



Fig. 2. VSWR characteristics of the MACKEY Q

## II. Proposed Dual-Frequency Shared MACKEY Q

### *A. Principle of MACKEY Q*

The principle of the MACKEY Q system is discussed below. Power is supplied from the second layer of the antenna plate, and the supplied power is transmitted between the shorting and grid plates. Ratio waves are radiated at the left and bottom edges of the grid plate. Because the radio waves radiating from each side are orthogonal with equal amplitudes and phases, the combined wave radiates a linearly polarized wave of φ = 135°, and the gain is 3 dB greater than that at φ = 90°, where φ is the angle of rotation along the x-axis.

### *B. Design Method for Dual Frequency*

Based on the operating principle described above, the MACKEY Q-type radiates a linearly polarized wave at an oblique angle of 45° by combining vertical and horizontal polarizations. Therefore, different frequencies can be resonated at the two polarizations by varying the length $W$ and width $g$ of the grid plate. Furthermore, varying the length and width of the grid plate create a difference in the distance of the transmission line from the feeding point to the left and bottom edges of the grid plate. Consequently, the feeding element in the MACKEY Q-type for oblique 45° linear polarization, which was installed in the upper-right corner, must be shifted slightly to equalize the distance of the transmission lines.

## III. Analysis Results

The results of the analysis of the dual-frequency shared MACKEY Q-type are discussed below. The analysis was performed using an electromagnetic field simulator (ANSYS HFSS) based on the finite element method. The model diagram used for the analysis is shown in Fig. 3. *W*, *g*, ℓ, and ℓℓo are frequency-dependent design parameters. Specifically, W and G are adjusted so that the resistance is 50 Ω at the desired frequency by varying W and G, and the reactance is adjusted to 0 Ω by varying l. ℓℓo is a parameter to facilitate matching by distributing the power equally between the two frequencies. *W* and *g* are the length and width of the grid plate, respectively, ℓ is the length of the feeding element, and ℓℓo is the position of the feeding element. In this study, one frequency was fixed at 2.45 GHz, and the other was varied at four points in the range of 2–3 GHz. The design parameters of the four models are presented in Table I. The VSWR characteristics in free space and on metal for the four models listed in Table I are illustrated in Figs. 4(a) and 4(b), respectively. Fig. 5 demonstrates the radiation patterns of model 1 at 2.10 and 2.45 GHz with cut planes φ = 0° and φ = 90°.

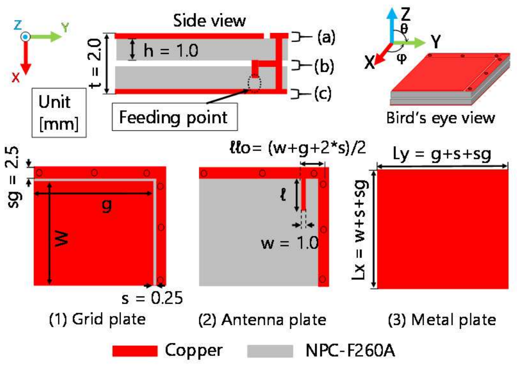
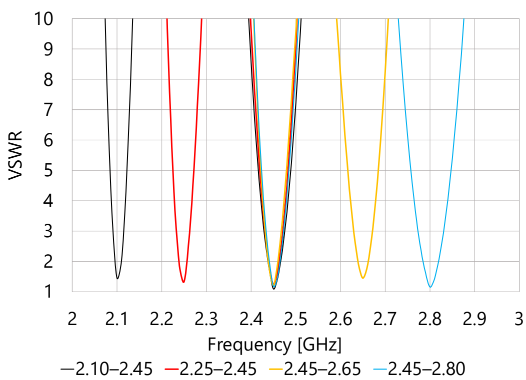


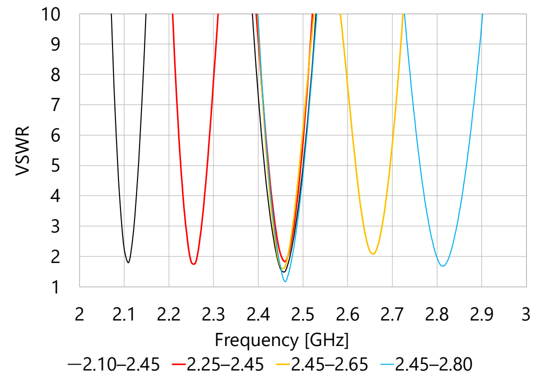

Fig. 3. Model diagram of the dual-frequency shared MACKEY Q

TABLE I. DESIGN PARAMETERS PER FREQUENCY

| | Frequency [GHz] | W [mm] | g [mm] | ℓℓo [mm] | ℓ [mm] |
|---|---|---|---|---|---|
| Model 1 | 2.10 & 2.45 | 35.5 | 41.9 | 2.95 | 15 |
| Model 2 | 2.25 & 2.45 | 35.7 | 38.9 | 1.35 | 16.5 |
| Model 3 | 2.45 & 2.65 | 32.9 | 35.6 | 1.1 | 16.1 |
| Model 4 | 2.45 & 2.80 | 30.9 | 35.5 | 2.05 | 15.5 |




(a) Free space




(b) On metal

Fig. 4. VSWR characteristics of each model

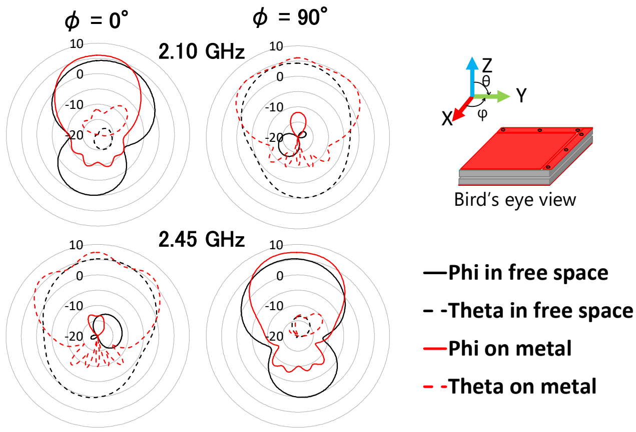



Fig. 5. Radiation pattern of model 1

Fig. 4(b) shows that the proposed antenna works on metal, although it is slightly shifted to the high-frequency side compared with that in Fig. 4(a). Fig. 5 illustrates that the realized gain in the frontal direction is 4.3 dBi in free space, 6.03 dBi on metal at 2.10 GHz, and 5.25 dBi in free space and 7.43 dBi on metal at 2.45GHz. It is clear that both frequencies radiate sufficiently.

## IV. Conclusion

In this study, we developed an antenna that radiates radio waves of different frequencies in two polarizations by varying the length and width of the grid plate in the first layer of the MACKEY Q-type. ℓℓo is an important design parameter for changing the position of the feeder elements because modifying the size of the grid plate causes differences in the length of the transmission line. The analysis results demonstrate that the model operates at the desired frequency, both in free space and on metal, radiating sufficiently in the frontal direction. Future plans include examining the feasibility of implementing this model at other frequency bands.

## References

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