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Dual Band Characteristics of a Linear Antenna over a Capacitance–Grid-Type AMC Substrate

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***Abstract* - In this study, the dual band characteristics of the capacitance-grid (CG)-type Artificial Magnetic Conductor (AMC) substrate are presented, it is shown that the substrate works as an AMC substrate at the dual bands separated three times.**

***Index Terms* — CG substrate (metal-plate loaded capacitance grid), AMC substrate, PMC property, thin antenna, FSR.**

I. INTRODUCTION

The Perfect Magnetic Conductor (PMC) characteristics of a capacitance grid with a metal plate were demonstrated [1]. A design method for a capacitance-grid-type AMC substrate was devised by using an equivalent circuit. It was also shown that the PMC bandwidth shared a linear relationship with the thickness of the AMC substrate.

In this study, the dual band characteristics of the capacitance-grid-type AMC substrate will be demonstrated.

II. PRINCIPLE OF DUAL BAND OPERATION

Fig. 1 shows the design parameters of the capacitance grid, where P is the period and W is the width of the space between the metal strips. When the AMC substrate is infinitely large, and the dielectric sheet has a fixed relative permittivity ε_r and a fixed thickness t, the substrate can have similar reflection phase characteristics for several combinations of P and W. This is because the PMC bandwidth depends only on the thickness t of the dielectric sheet [1].

The PMC condition is expressed as follows [1].

$$B = \sqrt{\varepsilon_r}\cot\beta t\,, \tag{1}$$

where B is the normalized susceptance of the capacitance grid and $\beta = 2\pi\sqrt{\varepsilon_r}/\lambda$. Fig. 2 shows the frequency characteristics of B and $\sqrt{\varepsilon_r}\cot\beta t$. At the frequencies of the cross points of the both curve, the substrate shows the PMC characteristics.

Here, the following approximations are applied,

$$B \approx 2\pi Cf\,, \tag{2}$$

$$\sqrt{\varepsilon_r}\cot\beta t \approx a(f - f_0) \qquad (0 < \beta t < \pi)\,, \tag{3}$$

where C is the capacity of the capacitance grid and f_0 is the frequency at $\beta t = \pi/2$. Moreover, a is the inclination of $\beta t = \pi/2$ at $\sqrt{\varepsilon_r}\cot\beta t$ and is expressed as follows:

$$a = \left|\frac{d(\sqrt{\varepsilon_r}\cot\beta t)}{df}\right|_{f=f_0} = -\frac{2\pi\sqrt{\varepsilon_r}t}{c_0}\,, \tag{4}$$

where c_0 is the velocity of light. Using (2) and (3), the first PMC frequency f_1 can be expressed as follows.

$$f_1 = \frac{af_0}{a - 2\pi C}\,. \tag{5}$$

Similarly, $\sqrt{\varepsilon_r}\cot\beta t$ at around $\beta t = 3\pi/2$ is approximated as follows.

$$\sqrt{\varepsilon_r}\cot\beta t \approx a(f - 3f_0) \qquad (\pi < \beta t < 2\pi)\,. \tag{6}$$

Using (2) and (6), the second PMC frequency f_2 can be expressed as follows.

$$f_2 = \frac{3af_0}{a - 2\pi C}\,. \tag{7}$$

Comparing (5) and (7), it is found that the substrate works as an AMC substrate at the dual bands separated three times.

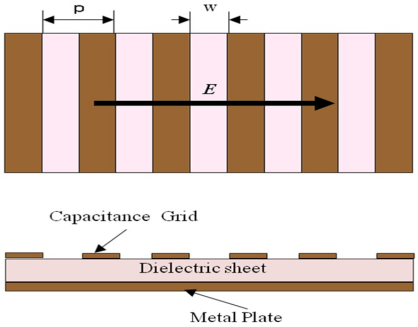

Fig. 1. Capacitance grid with a metal plate.

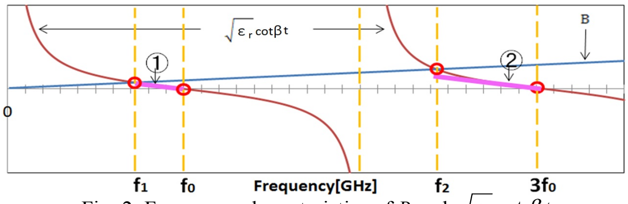

Fig. 2. Frequency characteristics of B and $\sqrt{\varepsilon_r}\cot\beta t$

III. CHARACTERISTICS OF A LINEAR ANTENNA OVER AN AMC SUBSTRATE

Fig. 3 shows the reflection phase characteristics of the AMC substrate simulated by the method of moment. The design parameters of the AMC substrate are as follows.

$P = 8.31$ mm
$W = 0.5$ mm
$t = 0.764$ mm
$\varepsilon_r = 2.65$

Fig. 3 shows the PMC characteristics observed at the frequencies of 10 GHz and 30 GHz.

Fig. 4 shows the analysis model. An AMC substrate was placed on the YZ-plane and a half wavelength dipole antenna was placed along the Z-axis over the AMC substrate with a 1.5 mm separation.

The size of the AMC substrate changes from one wavelength (30 mm) square to three wavelengths (90 mm) square. The finite element method solver high frequency structural simulator (HFSS) was used in this research.

Fig. 5 shows the frequency characteristics of the VSWR. The PMC characteristics were observed around frequencies of 10 GHz and 28 GHz, independent of the AMC substrate size.

Fig. 6 and Fig. 7 show the radiation patterns at 10 GHz and 28 GHz, respectively. The radiation patterns depend on the size of the AMC substrate. In the case of a wavelength (30 mm) square size of the AMC substrate, it radiates toward X-direction and the radiation experiences about 10 dB gain. The radiation patterns at 28 GHz are very complicated as the antenna size is as long as about 1.5 wavelengths and the grating lobes are radiated from the capacitance grids.

IV. CONCLUSION

This research shows that the capacitance-grid-type AMC substrate works as an AMC substrate at the dual bands separated about three times.

ACKNOWLEDGMENTS

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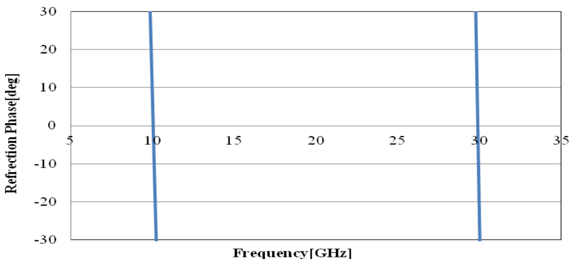

Fig. 3. Reflection phase.

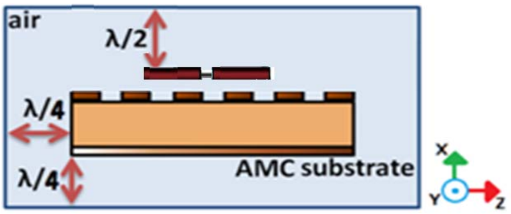

Fig. 4. Analysis model.

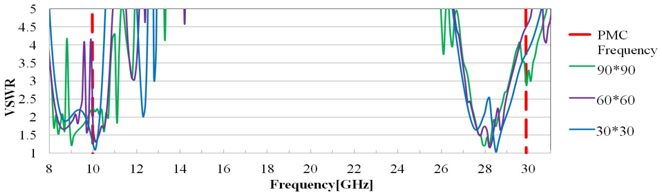

Fig. 5. VSWR.

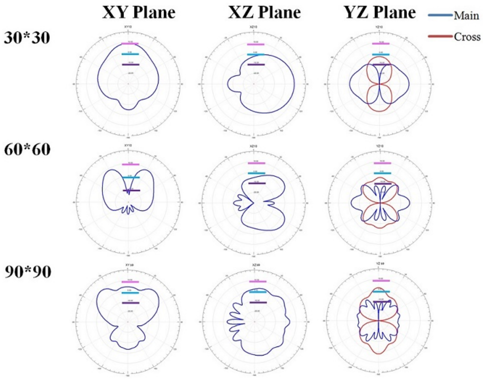

Fig. 6. Radiation patterns at 10 GHz.

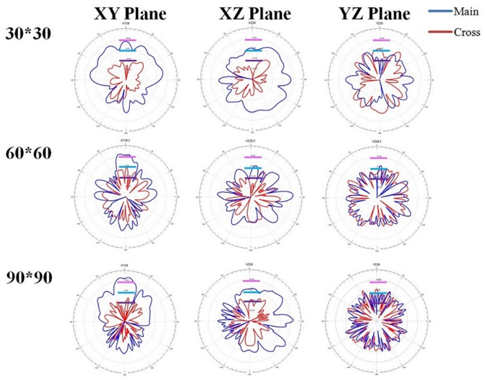

Fig. 7. Radiation patterns at 28 GHz.