Analysis, fabrication, and measurement of Y aperture element frequency selective surface

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The analysis of Y aperture element frequency selective surface (FSS) using the spectral domain method and the moment method is presented. With the vacuum depositing and photolithography, the corresponding Y aperture element FSS was produced, and it was tested in the microwave darkroom. The calculated and measured results are in good agreement.

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Frequency selective surface (FSS) is a two-dimensional (2D) period structure array, which can well control the transmission and scattering of the electromagnetic wave[1−4]. Thus, depending on physical construction, material, and geometry, it can be divided into low-pass, high-pass, band-pass, and band-stop filters[1,2,5]. FSS is widely used in the all-electromagnetic spectrum[6−9], especially in stealth band-pass radome.

For the radome application, however, it was desired to employ a triangular grid structure, because this grid structure is more suitable for maintaining the required surface periodicity on radome shape, what's more, triangular grid arrays have been found that it could provide superior center frequency stability in applications where the signal polarization varies with the grid orientation[10]. Y aperture element has many favorable performances, such as simple shape, easy to be fabricated, and suitable for a triangular array grid structure[11]. In this paper, the analysis, fabrication, and measurement of Y aperture element FSS is presented.

For Y aperture element FSS, applying the concepts of duality, and enforcing the continuity of the total magnetic field on either side of the aperture, the magnetic-field integral equation for a single unit cell was obtained. Because FSS is a 2D period array, the magnetic-field integral equation can be modified by the application of Floquet's theorem. The modified equation, governing the characteristics of the Y aperture element FSS, can be solved by the moment method[5,12]. The parameters associated with the Y aperture and the array lattice are marked in Fig. 1, where the element arm length $L_1 = 4.7$ mm, the arm width $W = 0.5$ mm, the lattice parameters $D_1 = D_2 = 10$ mm, and the lattice angle is 60°. The substrate is an 8.7-mm-thick dielectric, whose dielectric constant is 3.8 and loss tangent is 0.005. The calculated transmission coefficient curves are shown in Fig. 2 for various incident angles (H-plane incidence is defined so that the plane determined by the H-field vector and the incident plane wave Poynting vector is perpendicular to the plane containing FSS). It was found that the center frequency does not drift for incident angles from 0° up to 22.5°, the center frequency drifts 200 MHz when the incident angle reaches 60°, and the bandwidth decreases when the incident angle increases. Figure 3 shows the calculated transmission coefficient curves for various incident angles (E-plane incidence is defined so that the plane determined by the E vector and the incident plane wave Poynting vector is perpendicular to the plane containing FSS). These curves show a quite stable center frequency, and the bandwidth increases with the increase of the incident angle.

Using vacuum deposition technology, the thin copper film has been deposited on the polyester sheet (dielectric constant $\varepsilon = 3.8$ and loss tangent $\tan\delta = 0.005$), which is 300×300 (mm) in size and 8.7 mm thick. Then

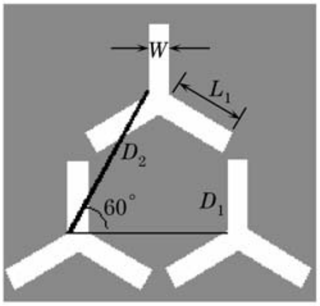

Fig. 1. Y aperture element array parameters.

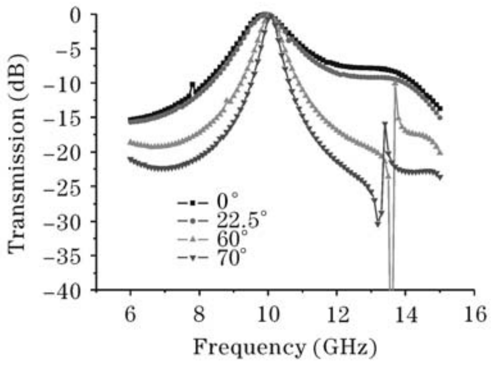

Fig. 2. Calculated transmission coefficient curves for various incident angles (H-plane).

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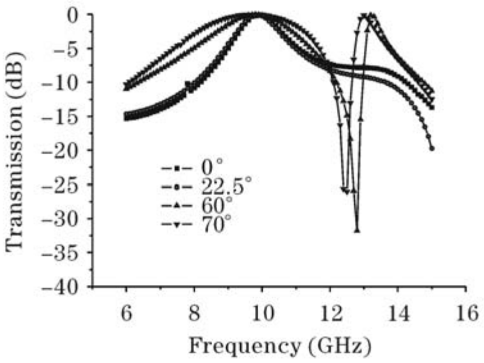

Fig. 3. Calculated transmission coefficient curves for various incident angles (E-plane).

Fig. 4. Experimental sample of Y aperture element FSS.

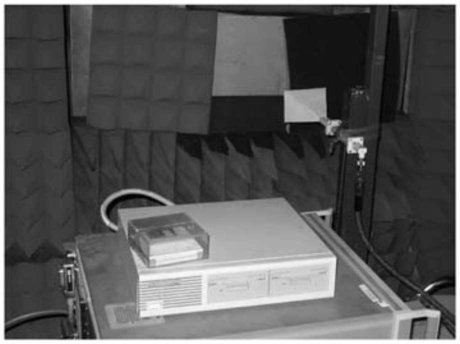

Fig. 5. Measuring system.

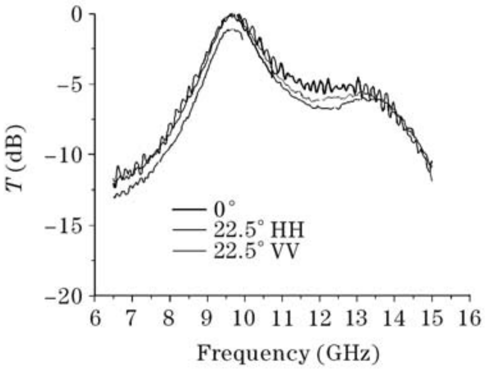

Fig. 6. Measured transmission coefficient curves.

electroplating in copper sulfate solution, the thickness of the copper film can reach 15 μm. The Y aperture element FSS figure can be obtained by photolithography[13]. The experimental sample of Y aperture element FSS is shown in Fig. 4. Its transmission coefficients were measured by the PNA8363B vector network analyzer and two ridge horns in a microwave darkroom. Figure 5 shows the measuring system. The measured transmission coefficient curves corresponding to Figs. 2 and 3 are shown in Fig. 6. It is found that the calculated and measured results are in good agreement.

Using the spectral domain method and the moment method, a solution for the plane wave transmission coefficients for Y aperture element FSS is obtained, and the tests of Y aperture element FSS in the microwave darkroom were given. It is found that, the bandwidth decreases with the increase of the incident angle for E-plane incidence, on the contrary, the bandwidth increases with the increase of the incident angle for H-plane. And the center frequency almost does not drift at all for E-plane incidence, except a comparatively poor performance in H-plane incidence. Therefore, Y aperture element FSS is suitable for use in radome.

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