Frequency selective surface with a flat topped passband

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Two frequency selective surface (FSS) configurations with flat topped passband are presented in this paper. One configuration is single layer FSS with $\lambda/4$ thickness dielectric loaded on both sides, and the other is double layers FSS. Based on the modal matching method, the frequency response properties including angle effect and polarization effect of both FSS configurations are analyzed, and the plots of the frequency versus transmission coefficient are obtained for different incident angles and polarizations. It is shown that the structure with the single layer FSS embedded centrally in the $\lambda/2$ thickness dielectric has a wider flat top bandwidth of 6.8 GHz than that of the double layers FSS of 3 GHz. In addition, the fabrication of single layer is relatively easier than the double layers FSS.

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The frequency selective surface (FSS) exhibits frequency filtering properties similar to those of frequency filters in traditional radio frequency (RF) circuits, which has received immense attention due to its ability to control the propagation of electromagnetic wave[1−3]. FSS properties depend upon the element's shape and dimensions of the element, the thickness and permittivity of the loading dielectric layers, as well as the layer number of FSS screen[4−7].

The FSS with transmission performance of flat tops and sharp skirts has wide application in the antenna reflector for satellite communication and various radomes. Although the double layers FSS is often selected to obtain ideal transmission property, it is not the unique approach. The transmission properties of flat tops and sharp skirts can also be obtained by using the single layer FSS with $\lambda/4$ thickness dielectric symmetrically loading on both sides.

Based on the modal matching method[8], the transmission properties of both FSS structures are analyzed in this paper. The angle effect and polarization effect on the frequency characteristic of both configurations are evaluated in the range of $8-12$ GHz. A comparison on frequency response between two structures is given.

Two configurations, double layers FSS with dielectric in the middle and FSS embedded centrally in the $\lambda/2$ thickness dielectric, are shown in Fig. 1. Ring loop elements are chosen for the FSS element, as they have better polarization independence.

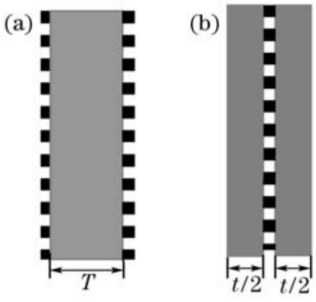

Fig. 1. Two different kinds of FSS configurations for flat top property.

The elements are arranged on a square lattice. Parameters of the element array and the loading dielectric are illustrated in Figs. 1 and 2. For double layers FSS, they are element spacing $D_x = D_y = 10.668$ mm, ring inner radius $R_1 = 4.32$ mm, ring outer radius $R_2 = 5.08$ mm, dielectric thickness $T = 5.38$ mm, and dielectric constant $\varepsilon = 1.2$. For single layer structure, $D_x = D_y = 6.8$ mm; $R_1 = 2.5$ mm, $R_2 = 3$ mm; $t = 8$ mm, and $\varepsilon = 4$.

The frequency responses of two structures are analyzed based on the modal matching method[8]. The solution is obtained by matching the tangential field components at each interface. The resulting integral equation is solved by the method of moments which reduces the integral equation to a linear algebraic equation system. We can expand the electric field of ring loop slot aperture as

$$\overrightarrow{E}_{bj} = \begin{cases} \sin(\frac{2n\pi l}{S})\mathrm{e}^{-j\Gamma_n z}\overrightarrow{G}(l) & j = 1,3,5; n = \frac{j+1}{2} \\ \cos(\frac{2n\pi l}{S})\mathrm{e}^{-j\Gamma_n z}\overrightarrow{G}(l) & j = 2,4,6,8; n = \frac{j}{2} \end{cases}, \tag{1}$$

where

$$\Gamma_n = \begin{cases} \sqrt{(k_b)^2 - (\frac{2n\pi}{s})^2} \\ \pm j\sqrt{(\frac{2n\pi}{s})^2 - (k_b)^2} \end{cases},$$

(choose positive radical)

and l is measured arc as shown in Fig. 3, from $\theta = 0$

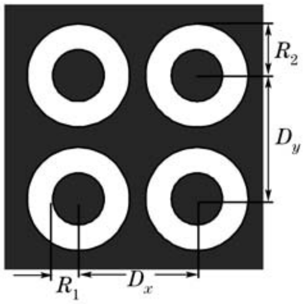

Fig. 2. Ring loop elements.

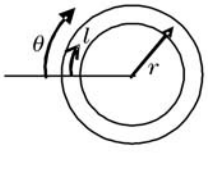

Fig. 3. Coordinate system for expressing the approximate mode set for ring loop slot.

along the center of the coaxial opening. The vector function $\overrightarrow{G}(l)$ is merely equal to $\vec{r}$ for the coaxial waveguide. The subscript j uniquely determines the mode, i.e., $j = 1$ is the $n = 1$ sine mode, $j = 2$ is the $n = 1$ cosine mode, etc.. The subscript b denotes that the mode is valid in the slot region rather than in the free and dielectric space (Floquet mode) region. And $k_b = \omega\sqrt{\mu_b \varepsilon_b}$, where ε_b and μ_b are the dielectric constant and magnetic constant of the slot medium.

Once the set of linear algebraic equations are calculated, the aperture field distribution is obtained. Then we can determine the transmission coefficients.

By using the modal matching method, the plots of the frequency versus transmission coefficient are obtained for different incident angles and polarizations to illustrate the difference between the two configurations.

Figure 4 presents the plots of transmission coefficient versus frequency of the double layers FSS. Obviously, the unique feature of the curve is the flat top[9−12]. For the normal incidence, the flat top range is 3 GHz, from 9.1 to 12.1 GHz. As the incident angle increases to 45° for transverse electric (TE) incidence, it can be noted by comparing normal incidence that the bandwidth of flat topped passband becomes narrower and a dip appears at 10.9 GHz in the resonance region, the transmission loss is -0.72 dB. For the transverse magnetic (TM) incidence, when the incidence angle is 45°, frequency property curve is similar to the normal incidence situation, which only slightly moves to the higher frequency region. The same general feature of a broad flat topped passband remains at 45° TE and 45° TM. However, a higher order resonance noted appears at lower frequency.

The transmission coefficient curve of single layer FSS embedded centrally in the $\lambda/2$ thickness dielectric is depicted in Fig. 5, which also exhibits very broad passband. The bandwidth of the flat top is 6.8 GHz, from 6.6 to 13.4 GHz, in the case of normal incidence. There is less change about the shape of transmission coefficient curve at 45° TE and 45° TM. The noticeable differences are the dips of -0.439 and -0.29 dB at 8.2 and 11.9 GHz respectively for 45° TE incidence, as well as an early higher order resonance like the double layers FSS.

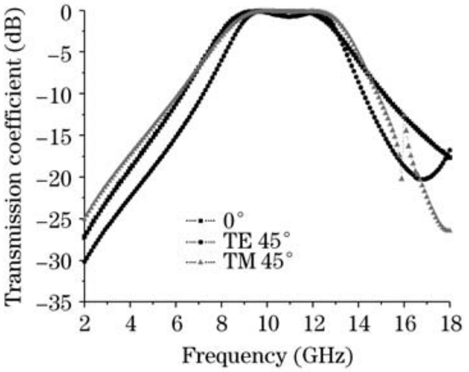

Fig. 4. Transmission properties of double layers FSS.

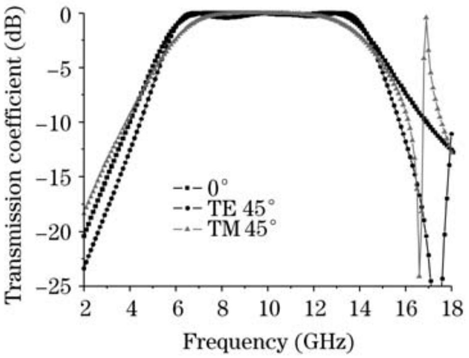

Fig. 5. Transmission properties of single layer FSS embedded in the $\lambda/2$ thickness dielectric.

We can choose the proper structure taking into account of a certain practical application by comparing the frequency response between the two configurations. Both structures have better performance with flat top and rapid roll-off. However, there are some differences between the two structures. The single layer structure has a wider flat topped passband and its dependence on angle and polarization is better than the double layers one, while the fabrication of the single layer FSS is relatively easier.

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