Removing the Angular Sensitivity of FSS Structures Using Novel Double-Layer Structures

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Abstract—**A double-layered periodic structure composed of shorted rings is employed to reduce the angular sensitivity of the reflection coefficient of a frequency selective surface (FSS). The angular sensitivity appears to vanish altogether for certain separation of the two layers. The configuration of the proposed cell element makes it suitable for dual orthogonal or circular polarized applications.**

I. Introduction

Frequency-selective surfaces are occasionally used in reflector antenna applications to separate different bands. Since various rays emanating from the feed impinge on the reflector with varying angles of incidence, the antenna performance becomes dependent on the FSS angular sensitivity. Reducing the angular sensitivity of the reflection coefficients is therefore essential for improving the antenna efficiency [1]. For single-layer structures this was investigated recently, and reasonable success was achieved for FSS elements of square patch surrounded by an open circuited ring [2]. However, since its geometry is asymmetric, it is not suitable for dual or circular polarization. For such cases a short circuited ring must be used, but this was found to have high angular sensitivity when implemented as a single-layer configuration. In an attempt to reduce the angular sensitivity, double-layer configurations were considered and investigated. For similar geometrical patterns on both layers, the only additional parameter is their separation distance, which was found to have an important influence on the angular performance of FSS.

A number of geometrical shapes for the FSS elements were selected and investigated. For short-circuited rings, satisfactory results were obtained by adjusting the separation of the layers in a double-layer configuration. Since the element geometry is symmetric, it can be used in dual or circular polarizations.

II. Theory

Method of moment was adopted for numerical simulation of the reflective characteristics of structure. This necessitates the derivation of dyadic Green's function, which has already been outlined in an earlier publication [3]. The expansion and testing functions of the unknown currents are selected on both rings and introduced in moment integrals, to account simultaneously for the presence of both rings. As a result, the following matrix equation results for unknown current coefficients on the conductors:

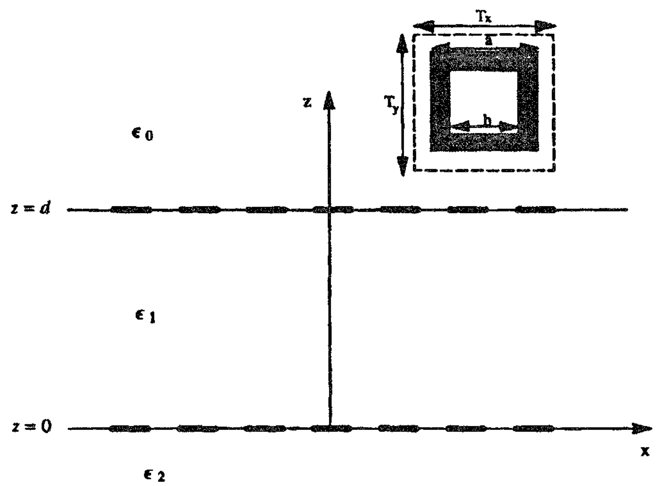

Fig. 1. Side view of the double-layered FSS and its cell element T_x and T_y are the cell dimensions.

$$\begin{bmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{bmatrix} \begin{bmatrix} I_x \\ I_y \end{bmatrix} = \begin{bmatrix} V_x \\ V_y \end{bmatrix}. \tag{1}$$

The square matrix on the left is the impedance matrix whose elements represent coupling between various segments on the conductors and the first and second subscripts denote the directions of test and source currents, respectively. The column vector on the left-hand side is composed of unknown current coefficients for the electric surface currents along x or y directions and the column vector on the right-hand side represents the excitation, which is assumed to be TE (to z) plane wave. Each of the comprising submatrices of the impedance matrix can be decomposed further into four submarines to account for coupling between elements on the upper and lower interfaces. Therefore, taking Z_{xy} as an example, it can be expressed as

$$[Z_{xy}] = \begin{bmatrix} Z_{xx}^{uu} & Z_{xy}^{ul} \\ Z_{yx}^{lu} & Z_{yy}^{ll} \end{bmatrix} \tag{2}$$

where the first and second superscripts show the interface on which the source and test elements are located, respectively ("u" for upper and "1" for lower interface). Triangular basis functions were used as the expansion and testing functions for the electric surface current densities on the conductors.

Manuscript received March 13, 1995.

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IEEE Log Number 9414125.

1051–8207/95$04.00

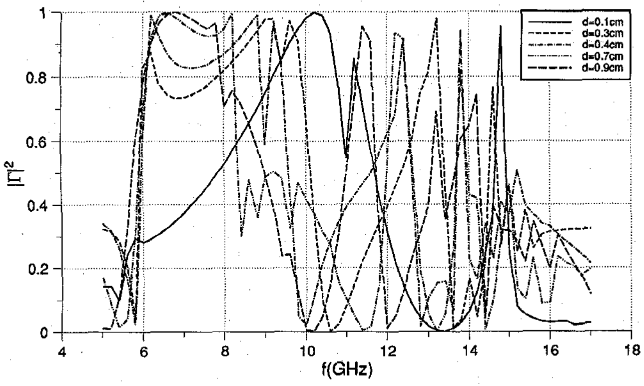
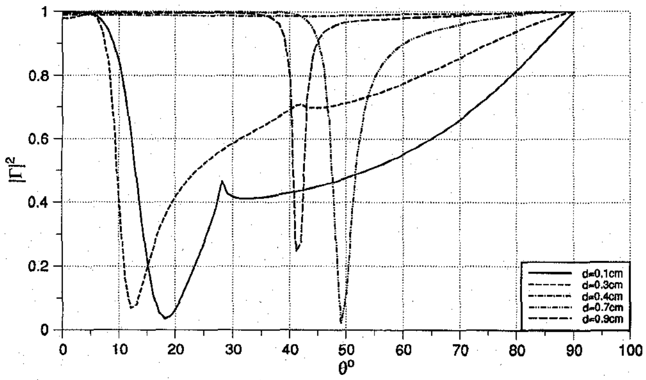
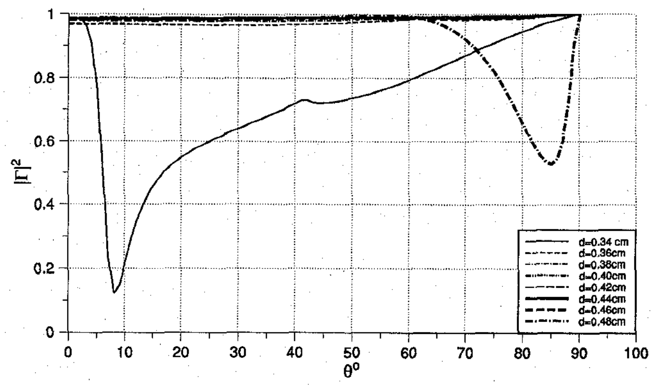


Fig. 2. Frequency dependence of reflection coefficients for different slab thicknesses of double-layer periodic structures composed of shorted rings. $\varepsilon_{11} = 3.5$, $\theta_{\text{inc}} = 89.9°$, $\varphi_{\text{inc}} = 0.1°$, $a = 1$ cm, $b = 0.64$ cm, $T_x = T_y = 2$ cm.



(a)



(b)

Fig. 3. (a) Angular sensitivity of reflection coefficients for different slab thicknesses of doublelayer periodic structures composed of shorted rings. $\varepsilon_1 = 3.5$, $\theta_{\text{inc}} = 89.9°$, $a = 1$ cm, $b = 0.64$ cm, $T_x = T_y = 2$ cm. (b) Angular sensitivity in the vicinity of $d = 0.4$ cm separation.

III. Results

Fig. 1 shows the geometry of the structure, where square cell elements are etched on both sides of a dielectric slab with a reflective permittivity of ε_1. A numerical simulation

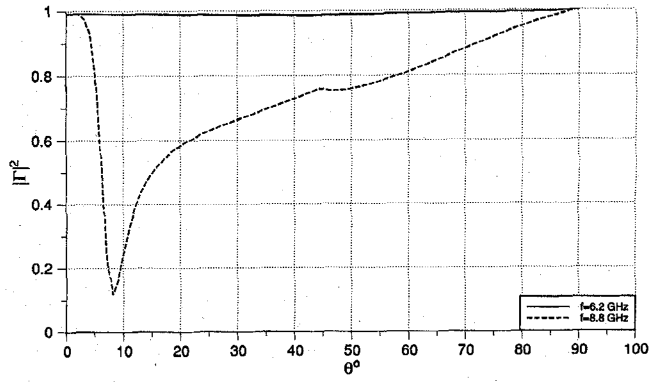


Fig. 4. Angular sensitivity at the two resonances of $d = 0.4$ cm case.

was carried out and the performance of the structure as a function of slab thickness d was investigated. The result for the reflectivity of the surface as a function of frequency are shown in Fig. 2. It indicates that for the small slab thickness, i.e. $d = 0.1$ cm, the reflection coefficient is well behaved and has only a single resonance. However, as the slab thickness increases additional resonances appear. In particular, a new resonance at a lower frequency emerges and persists. For this reason, the angular sensitivity of the structure is investigated around this resonance. Fig. 3(a) shows the results. The angular sensitivity deceases around $d = 0.4$ cm and then increases by increasing d. To provide more detailed performance data, Fig. 3(b) is also included. This figure shows the computed reflection coefficient in the vicinity of $d = 0.4$ cm, which are nearly constant and equal to unity. Therefore, for the selected parameters, the thickness range of $d = 0.36–0.46$ cm results in an optimum performance in terms of the angular response, i.e. a bandwidth in excess of 25% for the reflection coefficient as shown in Fig. 3(b) . Note that for each thickness, when two adjacent resonances are observed, the lower one was found to give more superior performance. This behavior is shown in Fig. 4 for $d = 0.4$ cm.

IV. Conclusion

In conclusion, a numerical simulation was conducted to investigate the performance of double-layer FSS structures. The separation of the layers was found to be the dominant parameter and was used to achieve a perfect angular performance. Representative results for short-circuited square rings, as FSS cell elements, were computed and presented.

References

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