ANALYSIS OF CYLINDRICAL FREQUENCY-SELECTIVE SURFACES FOR ANTENNA RADOMES

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Abstract

An analysis technique is described for cylindrical frequency selective structures, useful for antenna radome applications. The structures are made by free-standing conducting rectangular patches, or slots. Approximate relations are employed to study in particular structures with many elements. A comparison is reported with previous results given in the literature. The opacity, or transparency, of the surface for a suitable frequency range is shown.

Index Terms – Antenna Radomes, Cylindrical Floquet modes, Electromagnetic Scattering, Frequency Selective Surfaces (FSS).

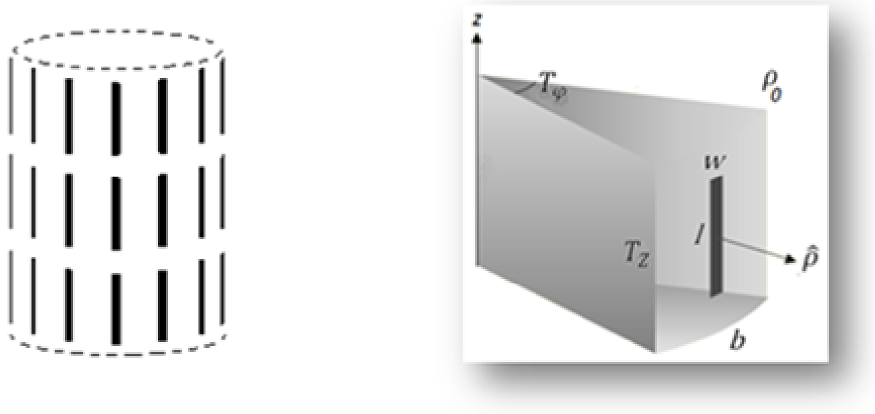
I. INTRODUCTION

Frequency Selective Surfaces (FSS) have been an extensive research topic since a long time [1],[2]. The case of Cylindrical Frequency Selective Surfaces (CFSS), which may be of interest for antenna radome applications, has been less studied in the literature [3],[4]. In the present paper an analysis technique is described, particularly useful for structures with many constitutive elements.

II. METHOD EMPLOYED AND RESULTS OBTAINED

Figure 1 shows the infinitely long cylindrical structure we have considered. It may consist of free-standing conducting rectangular patches, or of a perfectly conducting circular cylinder perforated with axial slots. Patches or slots are located periodically along the circumferential direction φ (T_φ periodicity) and along the axial direction z (T_Z periodicity).

Because of periodicity, the scattered fields are computed by analyzing the unit cell shown in Fig. 1b). Scattered fields are calculated according to the procedure described in [4]: however, we have extended this formulation for structures with a larger number of circumferential patches/slots (e.g., more than 64). This improvement has been obtained using approximated expressions of Bessel functions products [5],[6] and symbolic calculations performed with Matlab, to avoid overflow and underflow problems due to large-order and large-argument functions.



a) b)

FIG. 1 – a) Cylindrical Frequency Selective Surface, made by conducting patches or slots; b) relevant unit cell parameters.

For the case of free-standing conducting patches, a cylindrical wave with TM polarization (E_φ=0; H_Z=0), generated by an electric line current located on the cylinder axis, is considered. It is assumed $w<l/10$ and $w<\lambda/20$ where λ is the wavelength of the incident field. With these hypotheses the φ component of the electric surface current is considered constant: consequently, only the z component of the electric field and the φ component of the magnetic field are taken into account.

Being the structure under consideration periodical along φ and the z axis, the scattered fields are written as infinite sums of cylindrical Floquet modes. The amplitude coefficients of the cylindrical waves that compose the scattered field depend on the surface current on the conducting patch. This relation is found applying the boundary conditions on the tangential component of the electric field, that should be continuous at $\rho=\rho_0$, and on the tangential component of the magnetic field, that should be discontinuous at $\rho=\rho_0$ by an amount equal to the induced current density J_Z.

Finally, equating the total tangential electric field to zero on a strip surface, an integral equation is obtained, where the unknown quantity is the current distribution. This integral equation may be solved numerically by using a method of moments technique. To obtain a numerical solution, the current is expanded into seven entire domain sinusoidal basis functions for narrow strips.

For the case of free-standing slots, a cylindrical wave with TE polarization (E_Z=0; H_φ=0) generated by a magnetic line current located on the cylinder axis is considered. The slot size is the same as for the patch case and the conclusions for the field components are dual. For the numerical solution, the electric slot field is expanded into seven entire domain sinusoidal basis functions.

Figure 2 shows a comparison between a plot in [4] and our result obtained with a Matlab code using the above-mentioned approximated forms. Figure 3 is the same as Fig. 2, but with a larger cylinder radius.

In both we can see that near l=0.5λ the CFSS does not allow the power to flow out.

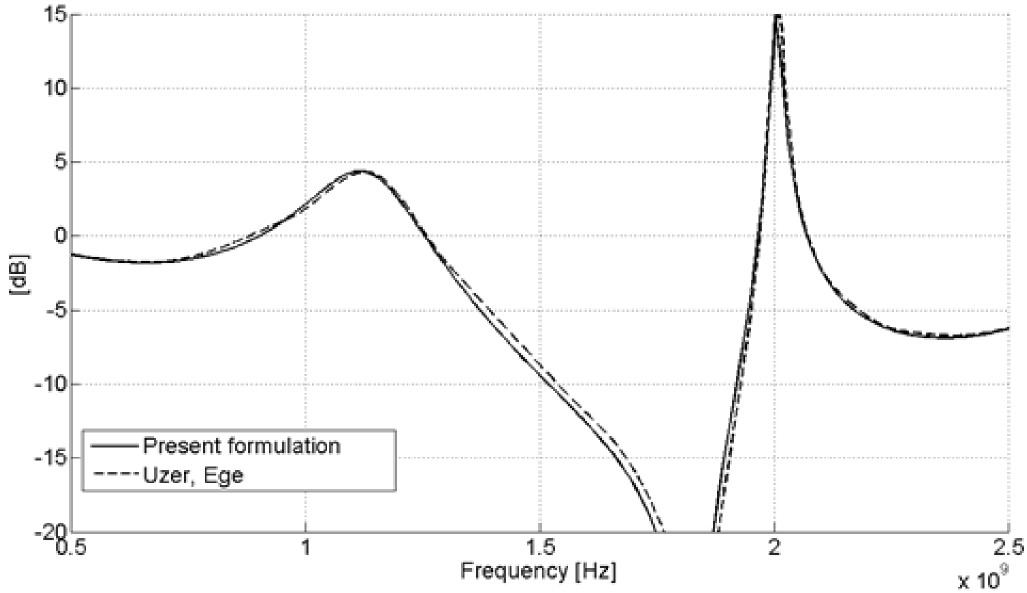


FIG. 2 – Ratio (dB) between radiated power measured away from the electric line current, with and without the CFSS, with N =16 circumferential patches and unit cell parameters: b =50 mm, T_Z =100 mm, l =90 mm, w =4 mm.

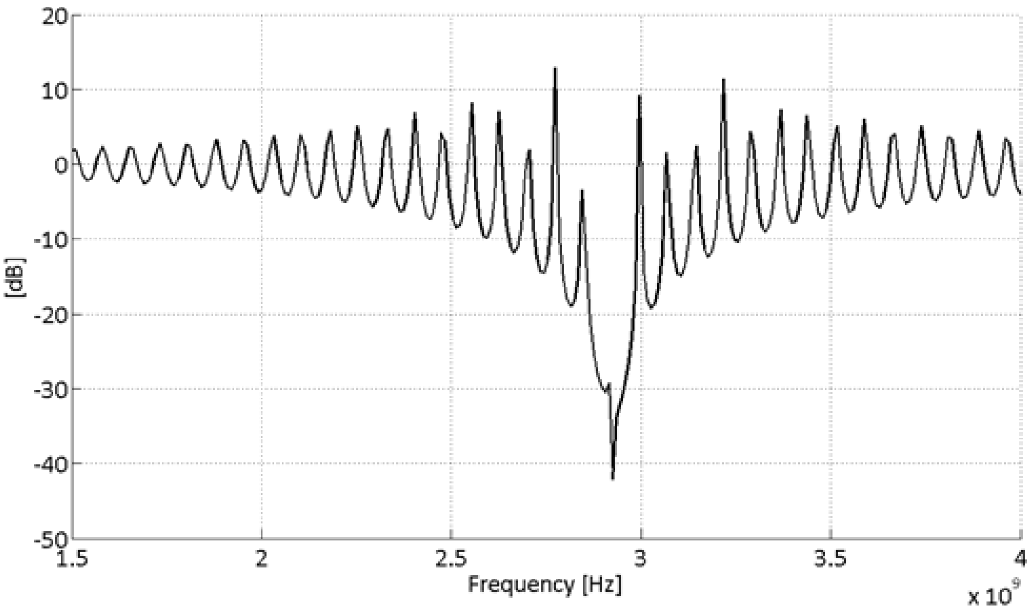


FIG. 3 – Same as in Fig. 2, for N =250 circumferential patches, and unit cell parameters: b =50 mm, T_Z =55 mm, l =50 mm, w =4 mm.

The plot in Fig. 4 is related to a conducting cylinder periodically drilled with axial slots. Near l=0.6λ the CFSS allows the whole longitudinal magnetic field to flow out.

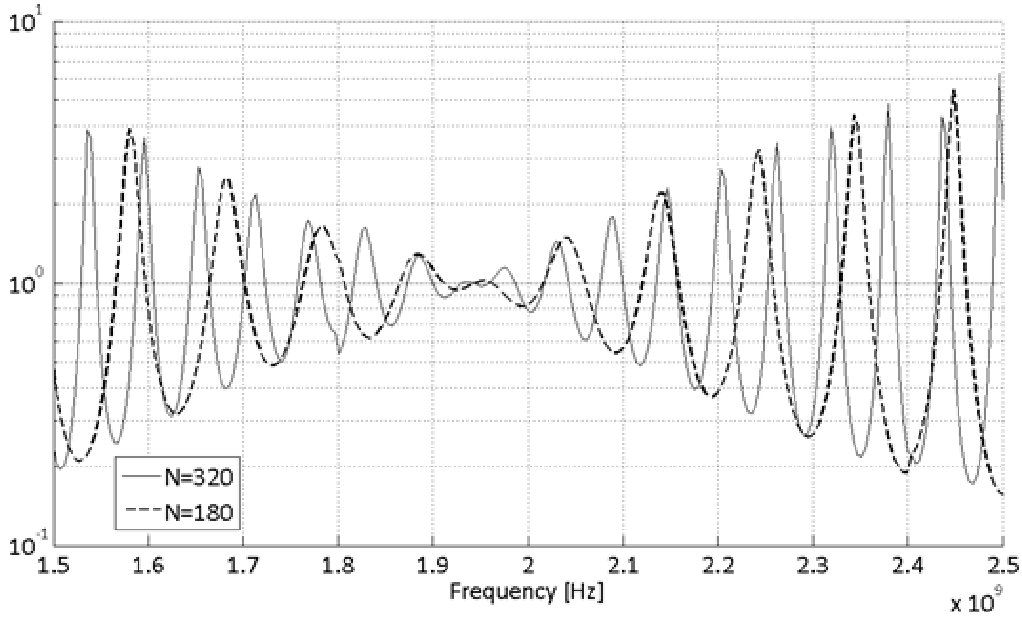


FIG. 4 – Ratio between longitudinal magnetic field (magnitude) measured away from the magnetic line current, with and without the CFSS, presenting 180 or 320 circumferential slots and: b =50 mm, T_Z =100 mm, l =90 mm, w =4 mm.

III. CONCLUSION

The described technique is able to analyze cylindrical frequency selective structures with a large number of elements, useful for antenna radome applications. Further developments may concern the application of the technique to different patch/slot geometries.

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