

Radiation pattern of composite finite arrays of conducting elements with an exciting elementary dipole

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Abstract: radiation patterns of composite finite arrays with one or two layers of thin strips and Split Ring Resonators (SRR) excited by an elementary dipole are presented. An integral formulation of Method of Moments (MoM) for triangular meshing [1] of perfectly conducting (PeC) bodies has been used. These finite composite structures derive from an infinite periodic array that behaves as a left-handed metamaterial [2][3].

INTRODUCTION

A left-handed material presents dielectric constants (permeability and permittivity) simultaneously negative. This leads to some very interesting consequences, such as the reversal of the Snell's law at the interface with a normal medium. Metamaterials are engineered composites exhibiting properties not observed in the constituent materials but inherent to the left-handed media.

An array of thin straight strips exhibits a negative permittivity below a cut-off frequency. A periodic array of SRR's behaves as a material with negative permeability at a certain narrow frequency band. The combination of both conducting elements can behave as an effective medium with negative dielectric constants.

RESULTS

The two composite finite structures analysed in this paper are the *2-layer combined array* (see Fig. 2) and the *1-layer combined array* (readily derived up from the previous one by removing the second combined array in the $-x$ direction). All the geometries have been meshed very finely for the sake of accuracy. The frequency band of interest must come from the study of both structures without the thin-strips; indeed, the corresponding arrays with only SRR's [3] are the *2-layer SRR array* and the *1-layer SRR array*.

The discretization of the *2-layer SRR array*, the *1-layer SRR array*, the *2-layer combined array* and the *1-layer combined array* has been carried out, respectively, with 28224, 16672, 48576 and 19072 triangles. A block-ILU preconditioner [4] has been used to speed-up the iterative algorithm. The Multilevel Fast Multipole Method [5] has been applied to accelerate the matrix-vector product at each iterative step.

Such geometries with only SRR's are excited with a plane-wave impinging normally onto the YZ plane such that the E-polarization be parallel to the strips and the H-polarization become parallel to the SRR's axes (see Fig. 1). The magnetic far-field in the forward and backward normal directions is computed for a range of moderately high frequencies (5.2-5.6GHz). Note that, since the electrical dimensions of the structures at these frequencies are pretty high, most of the scattered power must flow along the normal direction. The appropriate frequency range must be such that there is very little power transmission in the forward direction, for which the phase of the far-

field must be close to zero (according to the phase convention adopted in Fig. 2). In view of Fig. 3, this requirement is best accomplished in the vicinity of 5.4GHz. Indeed, at $F=5.45$ GHz, one can perceive (see Fig. 4) an evident cancellation of the forward lobe of the radiation pattern of the *1-layer SRR array* under the excitation due to an elementary ideal dipole z -oriented and placed at 55.045 mm (1λ) in the $+x$ -direction.

For the combined structures, the far-field graphs at the forward and backward directions under the same plane-wave normal incidence for the frequency range 5.1-5.6GHz are shown in Fig. 5. It can be seen how at $F=5.4$ GHz now there is little power scattered to the backward direction. Again, with the same elementary dipole now exciting the combined structures at such frequency ($F=5.4$ GHz), an enhanced forward lobe exists (see Fig. 6 and Fig. 7) for, respectively, the *1-layer combined array* and the *2-layer combined array*.

CONCLUSIONS

The finite structures with only SRR's *1-layer SRR array* and *2-layer SRR array* behave as a magnetic conductor in the vicinity of $F=5.4$ GHz. The structures derived from combining them with a grid of thin strips of half a wave-length at the same frequency (*1-layer combined array* and *2-layer combined array*) show a transmission-lobe. These finite combined structures of electrically small conducting elements can behave as a medium with effective dielectric constants, which can reproduce the physical behaviour of a specific dielectric slab.

ACKNOWLEDGEMENTS

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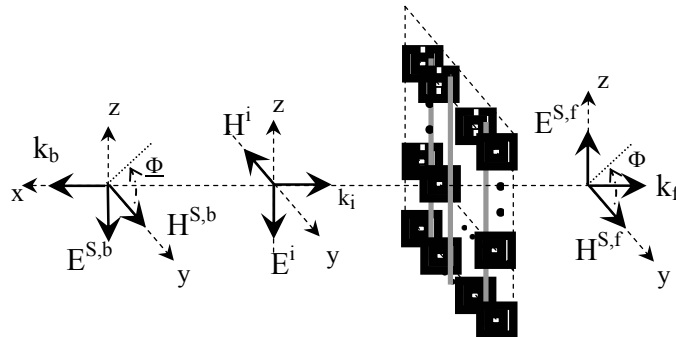


Figure 1.- Normally impinging planewave E-polarized along z and scattered fields on the forward and backward normal directions

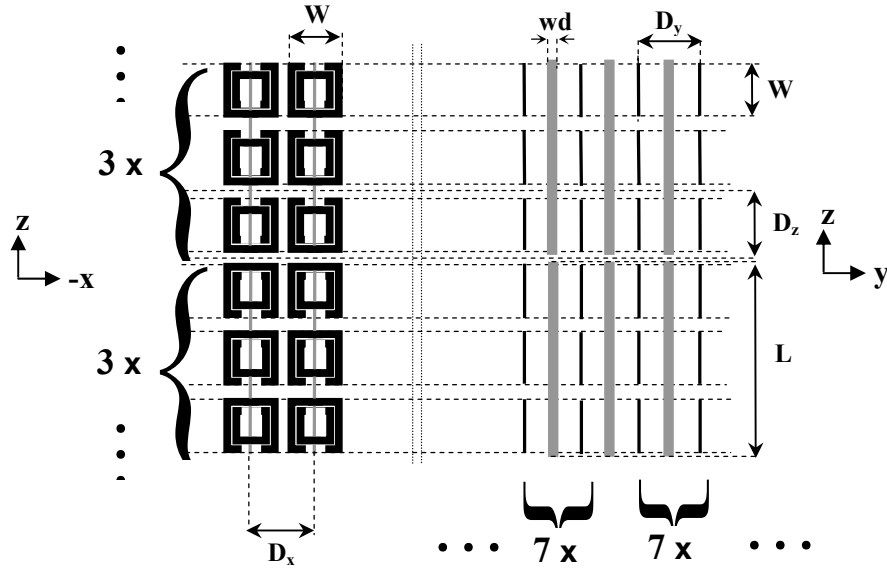


Figure 2.- XZ and YZ sections of the array of SRR and thin strips.
 $D_x=8\text{mm}$, $D_y=8\text{mm}$, $D_z=10\text{mm}$, $W=6.6\text{mm}$, $L=27.52\text{mm}$, $wd=1.5\text{mm}$

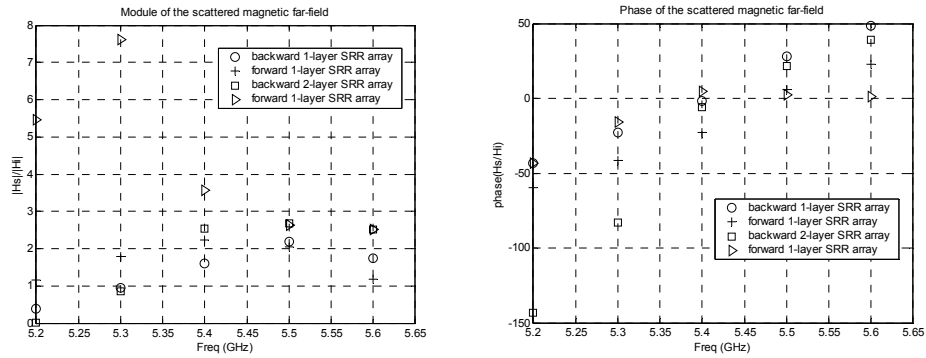


Figure 3.- Scattered magnetic far-field at the normal forward and backward directions for the structures 2-layer SRR array and 1-layer SRR array over the frequency range 5.2–5.6 GHz

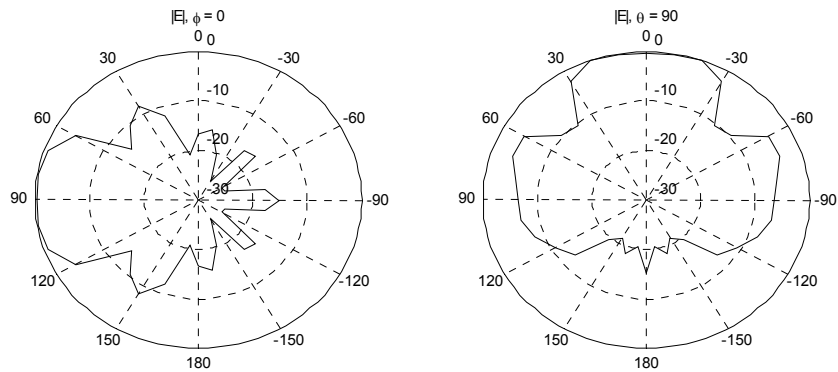


Figure 4.- Radiation pattern of the 1-layer SRR array excited at $F=5.45\text{GHz}$ with an elementary ideal dipole z-oriented at 1λ of distance in the +x-direction

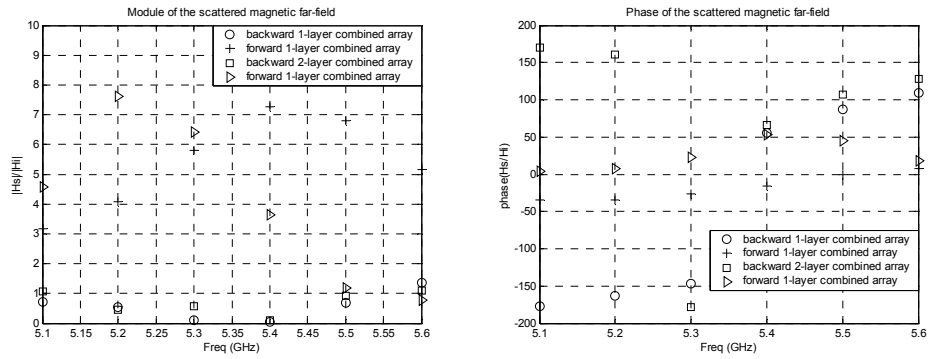


Figure 5.- Scattered magnetic far-field at the normal forward and backward directions for the structures *2-layer combined array* and *1-layer combined array* over the frequency range 5.1–5.6 GHz

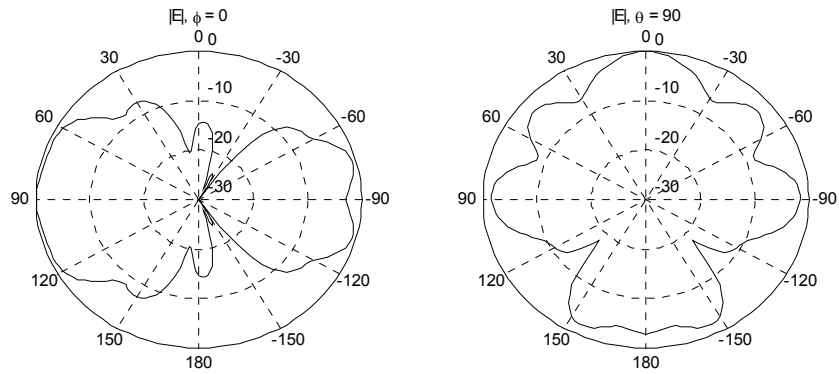


Figure 6.- Radiation pattern of the *1-layer combined array* excited at $F=5.4$ GHz with an elementary ideal dipole z -oriented at 1λ of distance in the $+x$ -direction

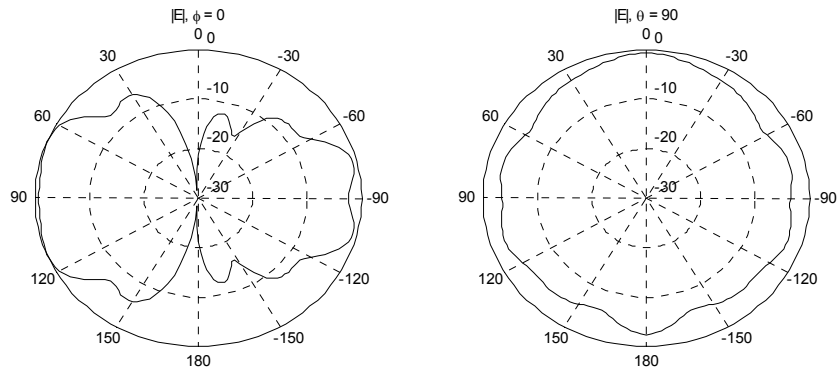


Figure 7.- Radiation pattern of the *2-layer combined array* excited at $F=5.4$ GHz with an elementary ideal dipole z -oriented at 1λ of distance in the $+x$ -direction