Planar arrays of wavy microstrip lines as thin resonant magnetic walls

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1 Introduction

High-impedance surfaces and artificial magnetic walls are very useful in the microwave and antenna techniques, extending the design space. The main challenge in realizations of artificial magnetic walls is to make the structure thin and the operation broadband. It is known that an array of patches positioned near a metal surface behaves as a high-impedance surface near the parallel resonance of the capacitive grid impedance of the array and the inductive input impedance of a thin substrate backed by the metal plane. The electric field reflection coefficient (normal incidence) equals $+1$ at the resonance. Far from the resonance the reflection coefficient is close to -1, and the structure behaves as an ideal metal screen coated by a thin dielectric layer. The bandwidth is rather limited, mainly due to a small value of the input inductance if the substrate is thin.

One possibility to reduce the structure thickness is to use microstrip periodic structures formed of complex shaped particles. Due to a complex shape a narrow strip particle can have stretched length much longer than the size of the periodic structure cell. This way one can obtain microstrip arrays of complex shaped particles having resonant wavelength much longer than the lengths of the array periods [1, 2]. In particular, there are so called "space-filling curves". The periodic array of wire particles having the form of the Hilbert curve and placed over a ground plane was proposed recently as a high-impedance surface [3]. Another way to realize thin artificial magnetic coatings is to use an array of small dipoles loaded by bulk inductances [4].

To control artificial magnetic coatings it is convenient to use electron devices included in each cell of the array. The properties of the array may be controlled by bias currents in uninterrupted array elements loaded by control electron devices. Thus, a periodic coating with uninterrupted elements may be useful for some applications. The planar grating of infinitely long wavy strips is an example of such double periodic structure. In addition, this geometry gives a possibility to increase the inductance of the structure, potentially increasing the operational bandwidth. The reflection properties of periodic gratings of wavy metal strips in free space were studied in [5]. The aim of this paper is to present the resonant properties of planar arrays of wavy microstrip lines in view of possible applications as artificial high-impedance surfaces.

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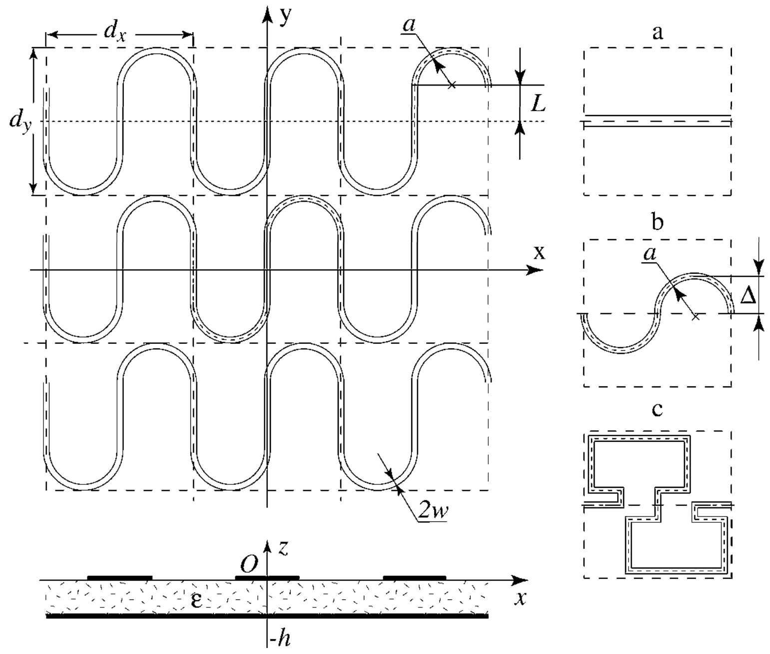

Figure 1: Geometry of microstrip arrays with wavy strips.

2 Problem definition and the method of analysis

A planar array of wavy microstrip lines is presented in Figure 1. The method of moments was used to solve the problem of electromagnetic reflection from microstrip arrays of thin narrow curvilinear strips. By enforcing the boundary conditions we get a vector integral equation for the induced current. This integral equation reduces to an algebraic one by using the standard spectral Galerkin technique.

3 Numerical results and discussion

The absolute values of reflection coefficients $|r_{xx}|$ and $|r_{yy}|$ of array are equal to unity, because we consider lossless structures. The frequency dependencies of the arguments of reflection coefficients (normal incidence) from microstrip arrays are shown in Figures 2 and 3.

The surface admittances of the array are

$$Y_x = H_y/E_x = (1/Z_0)(1 - r_{xx})/(1 + r_{xx}), \tag{1}$$

$$Y_y = H_x/E_y = (1/Z_0)(1 - r_{yy})/(1 + r_{yy}) \tag{2}$$

for the incident wave polarized along x- and y-axes, respectively. Here $Z_0 = \sqrt{\mu_0/\varepsilon_0}$.

The surface admittance tends to zero at the resonant frequency. Thus, the surface of the array is a high impedance surface near the resonance. A linearly polarized along x- or y-direction normally incident wave is reflected by a microstrip array at the resonant frequency in the same way as from a surface of an ideal magnetic.

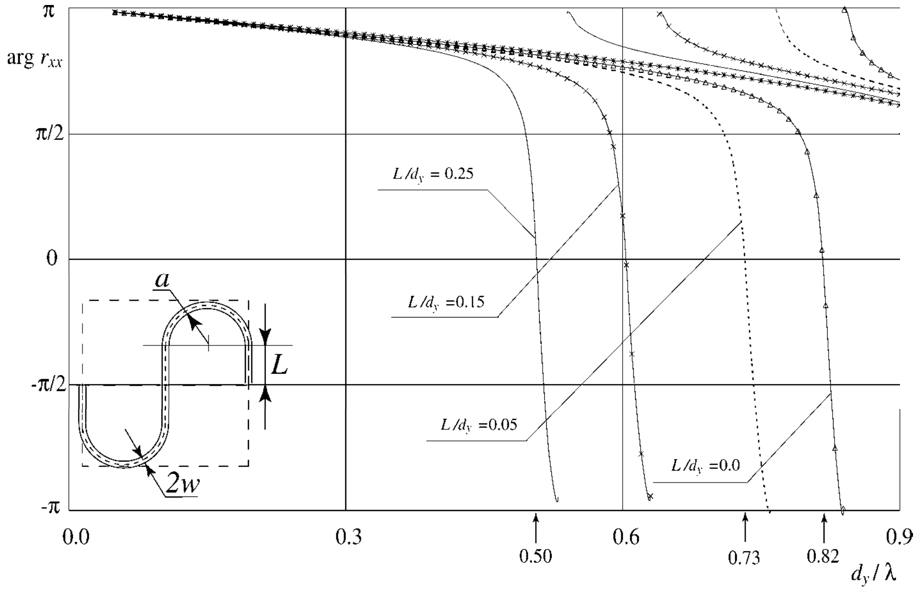

Figure 2: Argument of the reflection coefficient r_{xx} versus the normalized frequency: the incident electric field is polarized along x, $d_x = d_y$, $a/d_y = 0.25$, $2w/d_y = 0.05$, $h/d_y = 0.1$, $\varepsilon = 3.0$.

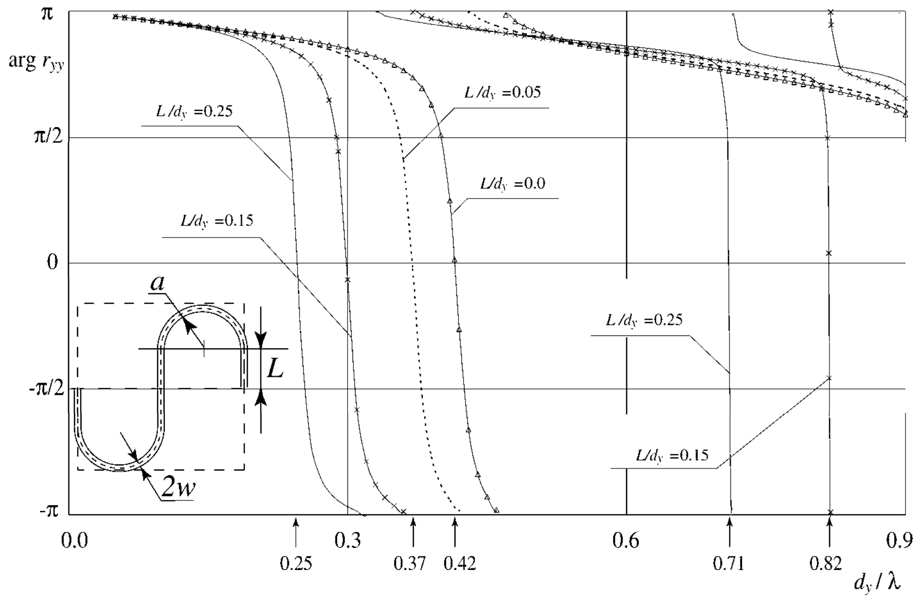

Figure 3: The same as in Figure 2 for the incident electric field polarized along y.

To explain the resonant properties of planar array of wavy microstrip lines let us use a simple approximate formula for a wavelength of microstrip line [6]:

$$\lambda_g = \lambda/\sqrt{\varepsilon_e}, \tag{3}$$

where

$$\varepsilon_e = \frac{\varepsilon + 1}{2} + \frac{\varepsilon - 1}{2\sqrt{1 + 5h/w}},$$

$2w$ is the width of the strips, h is the substrate thickness, and ε is the substrate permittivity.

The lowest resonant frequency of the array corresponds approximately to the wavelength of the microstrip line (3) which equals to the length $S = \lambda_g$ of the line in the periodic cell boundaries for the case of y-polarized incident wave and $S = 2\lambda_g$ for the case of the x-polarization.

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