ELECTROMAGNETIC WAVE DIFFRACTION BY THE MICROSTRIP TWO-PERIODIC GRATING OF CURVILEAR METAL STRIPS HAVING CHIRAL SHAPE

Pavel Mladyonov

Institute of Radio Astronomy of National Academy of Sciences of Ukraine, Kharkov, Ukraine
Phone: (057) 744-85-96; e-mail: mladyon@rian.ira.kharkov.ua.

Abstract –Reflection characteristics of microstrip two-periodic gratings of perfectly conducting infinitely long strips having the complex shape are considered. The effect when reflected field possess orthogonal polarization relative to incidence wave polarization is considered. The possibility of insertion the control device in strips for the transformation considered grating to the array from the strip disconnected elements is proposed. The possibility for the structure application as high-impedance surface is considered. The comparison of the reflection properties of the two-periodic gratings of non-chiral strips and straight-line strip gratings is presented.

Introduction

Recently, new applications of periodic structures are very popular to design the frequency-selective surface and so-called electromagnetic structures known also as photonic band gap (PBG) structures for microwave devices. As a result, interest to two- and even one-dimensional periodic structures is renewed. Two-periodic plane strips structures are more attractive for application because of their possess resonance properties in the frequency band of single-wave regime due to a complex shape of the array elements and their very small thickness. The periodic structures could find many applications for passive microwave devices such as filters, reflectors or antenna covers.

The reflection microstripe gratings can was used for phase correction and polarization change for the reflected field. In recent years, many papers studying the two-periodic arrays of metal strips of C-, S-, Ω-shape and curvilinear strips placed in free space, on dielectric substrate [1] and on background substrate [2,3] were published. The main goal of this report is to study the reflected properties of two-periodic structures of infinitely long strips having the chiral shape. The period of the grating is mach greater than strip width.

Method of problem solution

Let us consider a microstrip two-periodic grating of planar perfectly conducting infinitely long strips having the arbitrary shape within a periodically repeated cell as Fig.1. The shape strips within the periodic cell can be as symmetrical (Fig1c and Fig.1d) as well as no symmetrical or chiral (Fig.1a). I assumed that the longitudinal component of current flowing of strips exceeds essentially the cross component and, consequently, that it is possible to neglect the cross component.

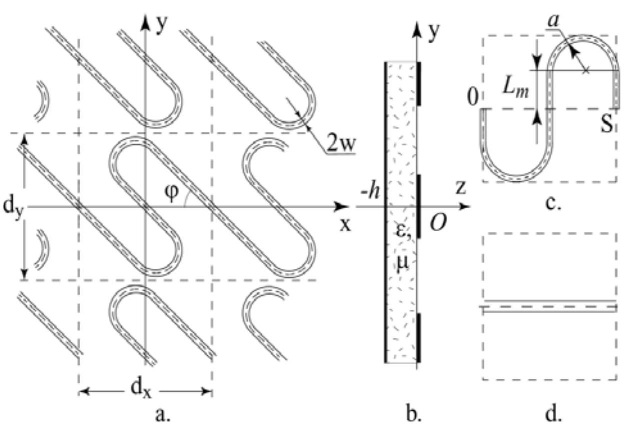

Fig.1. The microstrip grating of infinitely long strips

Let the electric field of the incident wave have form $\vec{E}^i = \vec{P}\exp(-i\vec{k}^i\vec{r})$. For simplicity, I assumed that $k_x^i = 0$, i.e. $\vec{k}^i = \vec{e}_y k_y^i + \vec{e}_z k_z^i$. The method of moments with expansion of the field in plane waves is used. The formula derivation for it, the analysis of errors and the comparison from other methods have been considered in [1-3] more explicitly. Therefore, I will present only final formulas.

The reflected field over gratings can be represented as sum a field reflected by background dielectric substrate without gratings on its surface - $\vec{E}_d$ and superposition partial waves

$$\vec{E} = \vec{E}^d + \sum_{\varsigma,\nu=-\infty}^{\infty} \vec{a}_{\varsigma\nu} \exp\{-i[\vec{\kappa}_{\varsigma\nu}\vec{\rho} + |z|\gamma_1(\vec{\kappa}_{\varsigma\nu})]\},$$

where $\vec{\kappa}_{\varsigma\nu} = \vec{e}_x 2\pi\varsigma / d_x + \vec{e}_y (k_y^{\,i} + 2\pi\nu / d_y)$, $\gamma_1(\vec{\kappa}) = \sqrt{k^2 - |\vec{\kappa}|^2}$, $\vec{a}_{\varsigma\nu} = \{\tilde{\vec{E}}^s \tilde{\vec{J}}\}(\vec{\kappa}_{\varsigma\nu})/(d_x d_y)$, $\{\tilde{\vec{E}}^s \tilde{\vec{J}}\}(\vec{\kappa})$-operator determined connection the strip current density and the field exited it. $\vec{E}^d = \vec{E}^i + \vec{R}\exp(-i\vec{k}^s\vec{r})$, where vector $\vec{R}$ is determined from boundary conditions and the expression for it had been presented in [2,3].

Numerical results and discussion

The scattering characteristics of the microstrip two-periodic gratings for the cases of different strip shapes are presented and discussed below. For simplicity, the normal incident wave and the case of one-mode regime was considered.

Now we consider the structure having the regular shape within a periodically repeated cell (Fig.1c). For such grating the absolute value of complex reflection coefficients R_{xx}, R_{yy} (presented from them the components of the reflection matrix) is equal to unit if losses in the dielectric substrate are absented. Only argument reflection coefficients are varied resonantly closely range wave length which proportions the length strip on period cell (Fig.2a). The reflection coefficients R_{xy} and R_{yx} are equal to zero because the structure is regular. In case the illumination by E-polarized wave (the polarization vector was directed along the x-axis) the resonant wave length is $\lambda_e \cong 2S$ ($\arg R_{xx}$, $d_y/\lambda \cong 0.5$) where λ_e is the wave length microstrip structure which have been considered in [4] more explicitly. For case the illumination by H-polarized wave (the polarization vector was directed along the y-axis) the resonant wave length is $\lambda_e \cong S$ ($\arg R_{yy}$, $d_y/\lambda \cong 0.25$). The such resonances was not observed (Fig.2a) for the grating from straight strips (Fig.1d). To take attention, the property of the magnetic wall is realized and the impedance surface is approached by infinity when the argument reflection coefficient is passing from zero. That mean's the polarization vectors incident and reflect waves are paralleled.

If the strip grating was had chiral shape (Fig.1a) the reflection coefficients R_{xy} and R_{yx} are became not equal to zero what result's in the variation direction of the polarization vector reflected wave. The results for two angle values φ and respecting different lengths strip on period cell are presented (Fig.2.b-e). In contrast to case regular structure the both class resonates corresponding wave length $\lambda_e \cong 2S$ and $\lambda_e \cong S$ for each E- and H-polarization wave are saw. As results the effect when almost orthogonally polarization vectors incident and reflect waves is observed. Like as for regular structure, the argument reflection coefficient is passing from zero for the resonant wave length. I regard what scattering from the consider grating for the cross-component reflect wave may by interpreted as scattering from surface was had the property of the magnetic wall.

If an electronic device such as a photo diodes or any other control devices have placing in the each strip of period cell there is a possibility of the grating transformation from the infinitely long strips to the array of the disconnected strip elements [4]. The disconnected strip elements gratings (for example S-shaped elements, [2]) have different scattering characteristics in comparison with considered array. Using of such control devices allows to switch the reflection properties of the consider grating.

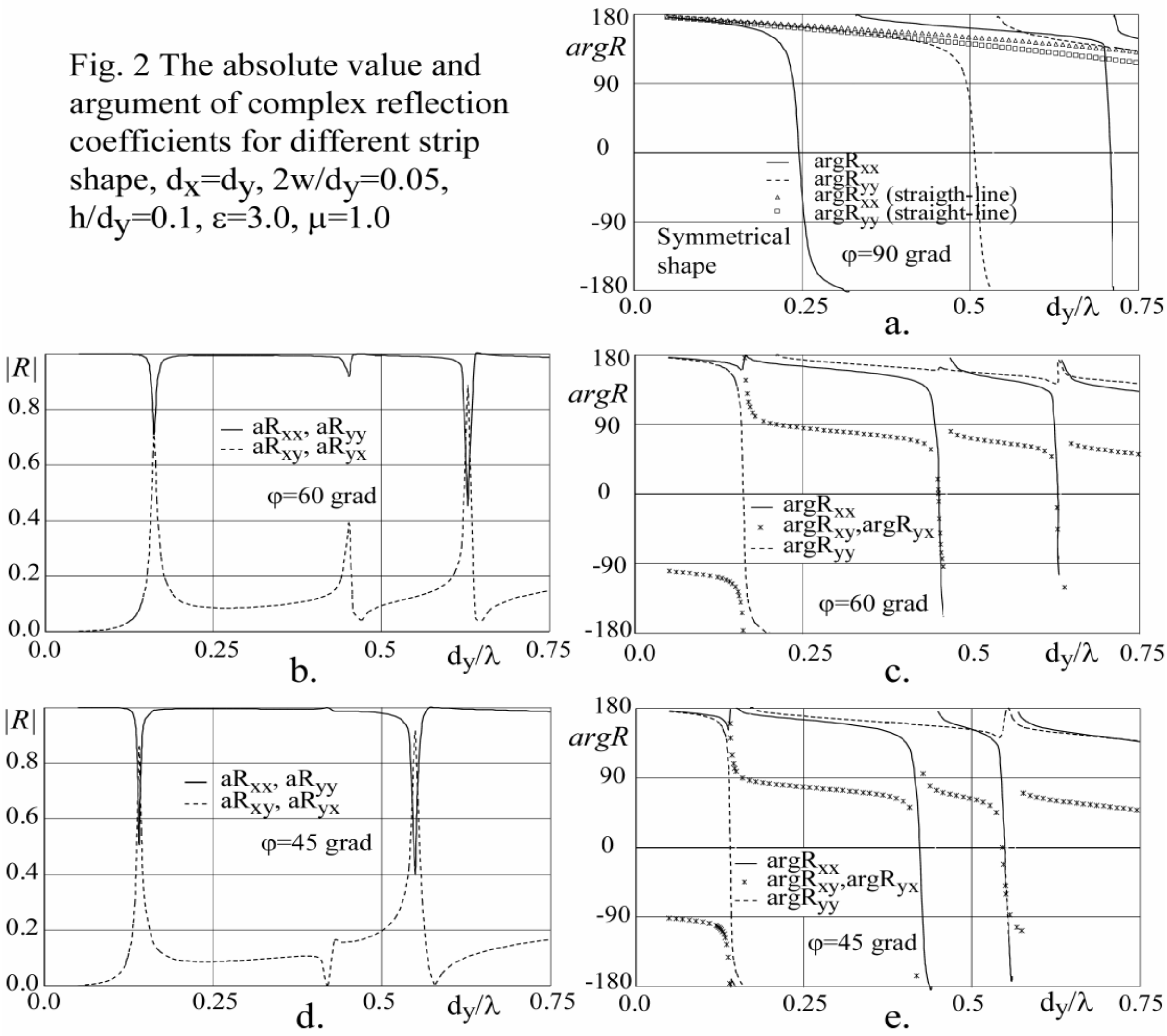

Fig. 2 The absolute value and argument of complex reflection coefficients for different strip shape, $d_x=d_y$, $2w/d_y=0.05$, $h/d_y=0.1$, $\varepsilon=3.0$, $\mu=1.0$

Conclusion

The reflection characteristics of microstrip two-periodic gratings of perfectly conducting infinitely long strips having the complex shape were considered. The comparison of the reflection properties of the two-periodic gratings of non-chiral strips and gratings straight-line strips was presented. The possibility for the structure application as high-impedance surface was considered.

The author is grateful to S.L. Prosvirnin for the problem formulation and encouragement during the performance of this work.

References

[1] S.L. Prosvirnin, S.A. Tretyakov, P.L. Mladyonov, “Electromagnetic wave diffraction by planar periodic gratings of wavy metal strips.”, *J. Electromagnetic Waves and Applications*, vol. 16, no. 3, pp. 421-435, 2002.

[2] S.L. Prosvirnin, “Polarization transformation at the reflection of waves from microstrip gratings consist of elements of complex shape”, *Radiotekhnika I Elektronika*, vol. 44, no.6, pp. 681-686, 1999 (in Russian).

[3] P.L. Mladyonov, S.L. Prosvirnin, “Microstrip Doubly-Periodic Grating of Continuous Curvilinear Metal Strips as a High-Impedance Surface”, *Radio Physics and Radio Astronomy*, vol.8, no.4, pp. 375-382, 2003 (in Russian).

[4] Sergey L. Prosvirnin, Said Zouhdi, “Multi-Layered of Conducting Strips: Switchable Photonic Band Gap Structures”, *International Journal of Electronics and Communications, Special Issue: Bianisotropics 2000*, v. 55, no. 4, pp. 260-265, 2001.