FREQUENCY-SELECTIVE DIELECTRIC LAYER AND ITS MODELING BY METHOD OF AUXILIARY SOURCES

D. Kakulia, G. Kajaia, G. Ghvedashvili, D. Karkashadze, R. Zaridze

Tbilisi State University, Natural Science Department, 3, Chavchavadze ave., 0128, Tbilisi, Georgia
e-mail: dkakulia@laetsu.org

Abstract – **Paper presents applications of the Method of Auxiliary Sources (MAS) for solving problems of electromagnetic wave's diffraction on the one and two periodic structures. The Method of Auxiliary Sources is expanded (MAS) for two-periodic problems. The numerical investigation of reflection\transmission properties of dielectrics with periodical shape is performed.**

I. INTRODUCTION

A Frequency Selective Surface (FSS) is any surface construction designed as a "filter" for plane waves. It finds applications in radomes, "Dichroic" subreflectors, reflect array lenses, low-probability of intercept systems ("stealth") etc. and more recent application in Photonic crystals (PC) [1] - the structures with a periodically modulated refractive index. They attract a lot of interest in connection with their numerous potential technological applications ranging from antenna substrates to photonic integrated circuits. PC performance is determined by frequency gaps forbidden for the propagation of the electromagnetic waves, so-called photonic band gaps (PBG). Usually, only nonmetallic materials are used for the fabrication of PC operating in the spectral range of a material transparency. It will be more optimal if modeling and property investigations of periodic structures will take the lead over the fabrication and not vice versa. The goal of the present work is to develop the Method of Auxiliary Sources (MAS) [2] for modeling 2D and 3D periodic structures, especially dielectrical frequency selective surfaces, and to study their reflection\transmission properties. Generally, a bent to fast convergence and possibility of achieving high solution accuracy are premises to apply the MAS. MAS allows estimating the accuracy of solution by checking satisfaction of boundary conditions. Basing on Poisson summation, MAS is expanded for two periodical structures. In 3D [3, 4] it is well known that this sum is characterized by worst convergence on the plane where discrete sources are placed. In spite of this there is possibility to model two periodical surfaces separating media. E and H field expressions for lattice of discrete sources are developed. The possibility of avoiding areas with worth convergence follows from choosing of surface shape and MAS nature. In other words, planes with discrete sources don't cross field's definition areas, and therefore convergence is achievable.

II. METHOD OF AUXILIARY SOURCES FOR PERIODIC STRUCTURES

Generally, MAS was developed for solving boundary problems. Mainly, it finds application in Computational Electrodynamics for Diffraction Problems. The main idea consists in representation of scattered field by sum of fundamental solutions of Helmholtz equation (Auxiliary Sources (AS)). In contrast to the Integral Equations Method (IEM), in MAS the radiation centers of fundamental solutions are shifted from real surface to the so called Auxiliary Surface. When a scatterer is Perfectly Electric Conductor (PEC) and incident field doesn't penetrate inside. Auxiliary Surface should be built in inner area of the scatterer and AS should be distributed there to describe outgoing scattered field. In case, the scatterer is dielectric or dielectric with finite conductivity, two set of auxiliary surfaces should be considered - inner and outer. AS placed on inner Auxiliary Surface will describe scattered field, and AS placed on outer Auxiliary Surface will describe field inside of dielectric scatterer. For both cases unknown confections of AS should be obtained be satisfaction corresponding boundary conditions.

For solving periodic problems by MAS, essential Green function of AS should be replaced by Green Function of periodically placed AS and satisfaction of boundary conditions on interval of one period is sufficient.

Poisson summation formulas for two- and three-dimensional, periodic, Green functions of the Helmholtz and Laplace equations are well known and cataloged in [5]. Finding the expressions of E and H fields from corresponding periodic Green functions, are necessary to apply the MAS for solving two- and three-periodic

1-4244-0490-8/06/$20.00 © 2006 IEEE.

diffraction problems. Here, the numerical problem which was mentioned above in introduction regarding to the field's convergence of two-periodic lattice should be taken in account.

III. GEOMETRIES AND CALCULATION RESULTS

First of all, proposed three-dimensional two-periodic MAS approach was tested on simple problem to calculate transmission property of dielectric plate with ε=10 in case of normal incident of plane wave. Corresponding result is shown on Fig.1.

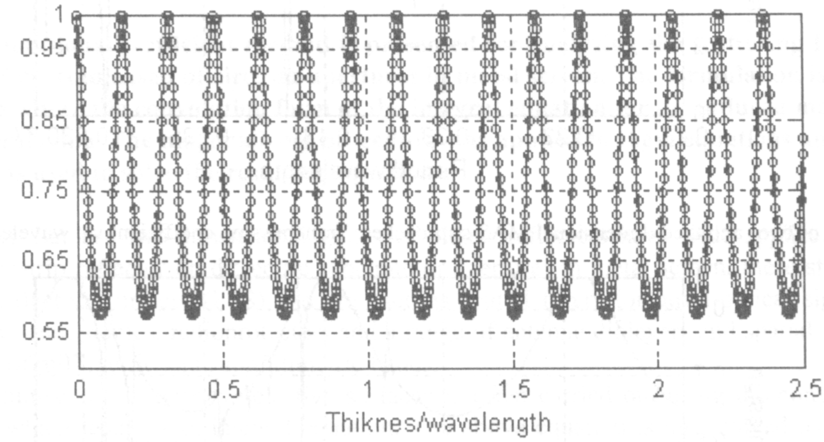
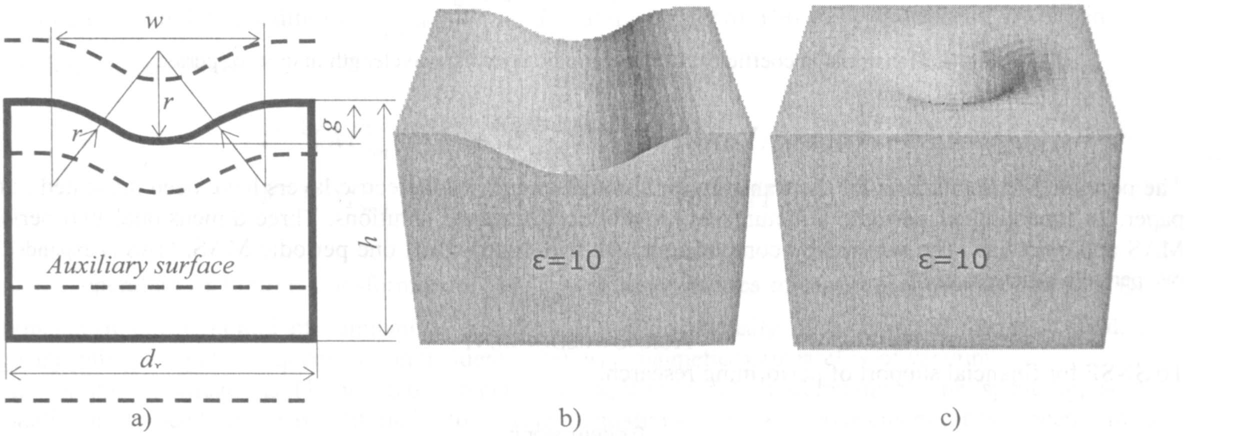


Fig.1. Transmission coefficient versus layer thickness in units of wavelength

The next step of testing is comparison of three-dimensional two-periodic MAS approach with two-dimensional one periodic MAS. For this aim, dielectric layer with periodical ditches is proposed. Corresponding geometry is illustrated on Fig.2 a),b). The permittivity of layer is ε=10. d is period of structure. $h=0.75d$ is thickness of the layer. $w=0.75d$ is width of the ditch. $g=0.125d$ is depth of the ditch. $r=(4*g^2+w^2)(16*g)$ is radius of rounds-up. All geometry data are given in period units.



a)

b)

c)

Fig. 2. Geometry of the layers in one period.

It should be noted that proposed structure can be considered as one-periodic also as two-periodic. Transmission coefficient in case of normal incident of plane wave is calculated, as two dimensional periodic MAS as three-dimensional two-periodic MAS. Incident E field polarization is parallel to ditch direction. Comparison of results is shown on the Fig.3. Continues curve corresponds to calculation result obtained by two-dimensional periodic MAS. The rings on the curve depict results of MAS simulation of proposed layer as two-periodic, three-dimensional structure. Results are in good agreement.

Three-dimensional two-periodic structure is shown on Fig.2 c). In case of normal incident plane waves corresponding transmission characteristic are presented on Fig. 4.

1-4244-0490-8/06/$20.00 © 2006 IEEE.

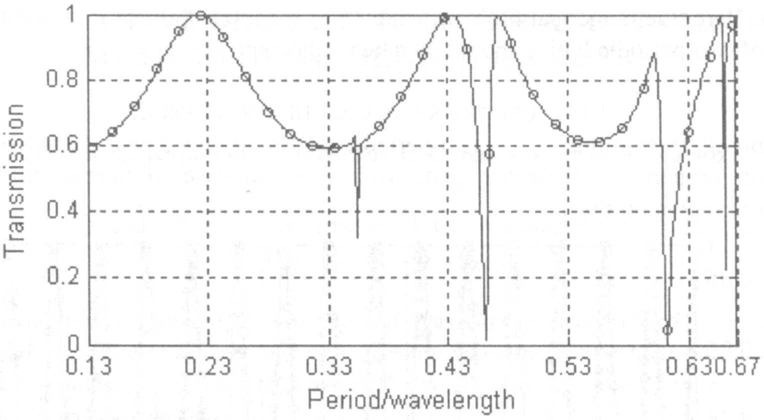


Fig.3. Comparison of two- and thee-dimensional MAS approaches. Transmission coefficient vs. wavelength in units of period.

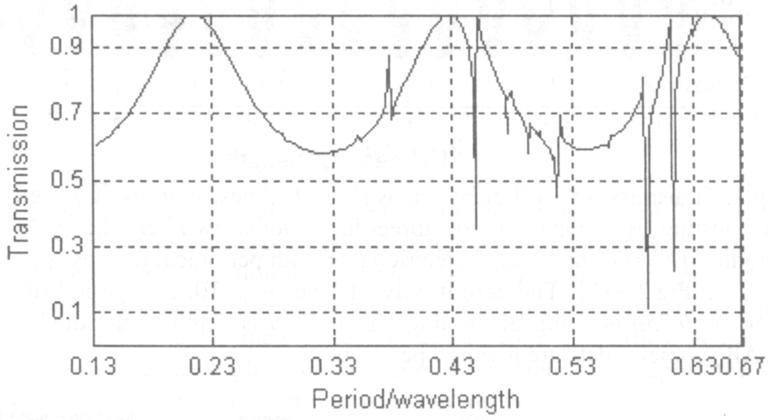


Fig. 4. Transmission coefficient of two periodic layer vs. wavelength in units of period.

IV. CONCLUSION

The periodic MAS solutions for the transmission through an infinite dielectric layers have been presented in this paper. In modeling of periodic structures MAS produces accurate solutions. Three-dimensional two-periodic MAS approach has been verified by comparing it with two-dimensional one periodic MAS. MAS is expanded for two periodic structures in 3D.

ACKNOWLEDGEMENT

To SNSF for financial support of performing research.

REFERENCES

[1.] V. Poborchii, T. Tada, and T. Kanayama. " Silver-coated silicon pillar photonic crystals: Enhancement of a photonic band gap". Applied Physics Letters, vol. 82, Number 4, 27 JANUARY 2003, p. 508-511.

[2.] R. Zaridze, G. Bit-Babik, K. Tavzarashvili, N. Uzunoglu, D. Economou. "Wave Field Singularity Aspects Large-Size Scatterers and Inverse Problems." IEEE Transactions on Antennas and Propagation, vol. 50, No. 1, January 2002, p. 50-58. R.

[3.] John Blackburn and Luk R. Arnaut "Numerical Convergence in Periodic Method of Moments Analysis of Frequency-Selective Surfaces Based on Wire Elements". IEEE Transactions on Antennas and Propagation, vol. 53, No. 10, October 2005, p. 3308-3315.

[4.] C. H. Chan, R. Mitra. "On the Analysis of Frequency-Selective Surfaces Using subdomain Basis Functions". IEEE Transactions on Antennas and Propagation, vol. 38, No. 1, January 1990, p. 40-50.

[5.] R. Lampe, P. Klock, P.Mayes. "Integral Transforms Useful for the Accelerated Summation of Periodic, Free-Space Green's Functions". IEEE Transactions on Microwave and Techniques, Vil. MTT-33,No. 8August 1985, p 734-736.