A study on frequency-selective characteristic for periodic structure

Minnyun Kim, Gyoo-Soo Chae
Division of Information and Communication, Cheonan University
115 Anseo-dong, Cheonan, Chungnam 330-704, Korea
E-mail: myki@cheonan.ac.kr

1. Introduction

In present, dielectric periodic structures(DPS) having frequency-selective behavior have been progressed in its research[1]. In this paper, three results using different techniques are compared those of coupled wave theory[2], CAD tool(CST-MWS) modelling and thin phase film approximation method. The purpose of such comparison makes a matter of merits and demerits of coupled-wave theory till now through CST-MWS simulation supporting a close situation with actual environment, and is to demonstrate the logicality of the thin phase screen approximation(TPS) method[3]. We analyze the periodic structure spectrum of rectangular shape when a uniform plane wave is incident at an oblique angle θ_i upon the structure interface. During CAD tool simulation of TE-mode, the incident field generates a transmitted and reflected field. The simulation results are good agreement with those of coupled-wave theory applied. In addition, we propose a thin phase film approximation method offered phase change without amplitude attenuation of incident field and also the results provide useful insight into fundamental studies on basic theories.

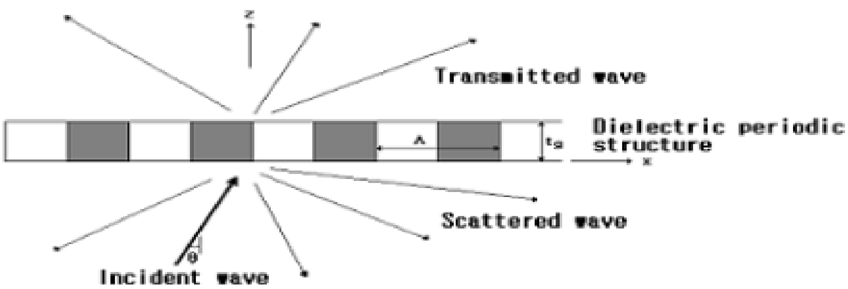

Fig. 1 Transmission and scattering of incident electromagnetic wave in a dielectric periodic structure

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2. Theoretical analysis

A dielectric periodic structure is shown in Fig. 1 to investigate the scattered, transmitted field due to the incident field.

According to the theory of periodic structure, when a TE-polarized(or TM-polarized) wave is incident, the incident wave is an infinite set of the TE eigenmodes(or TM). The fields of each TE(or TM) eigenmode will consist of an infinite set of space harmonics. Therefore, the propagation constant along the x-direction of the n^{th} space harmonic in each region (consist of upper half space, periodic layer and lower half space) can be expressed as following

$$k_{xn} = k_{x0} + 2n\pi / \Lambda \qquad (1)$$

where Λ is the period, and k_{x0} is related with the incident θ_i angle as following.

$$k_{x0} = k_0 \sin\theta \qquad (2)$$

In general, the propagation constant becomes a real value such that the wave propagates along the positive or negative direction of propagation, while a imaginary value makes the field decay evanescently. The amplitude of electro-magnetic field can be calculated by imposing the boundary condition in each region.

3. Results and discussion

Fig. 2 shows the field amplitude in far-field region (not effective evane-scent field) with parameter of $\theta_i = 45^0$ and the frequency is swept from 1 to 5GHz. The structure parameters are $\varepsilon_1 = 1.44$, $\varepsilon_1 = 2.56$, $\Lambda = 12cm$ and $t_g = 20cm$, respectively.

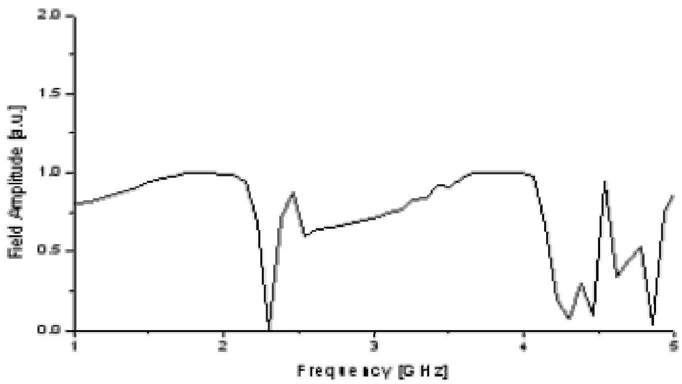

Fig. 2 Transmission spectrum from dielectric periodic structure

The total reflection is occurred when the layer thickness is close to a multiple of one-half effective wavelength along the z-axis. Then the result is compared to the results of CST-MWS simulation in the Fig. 3, which is showing the field amplitude spectrum according to various distances from the dielectric surface.

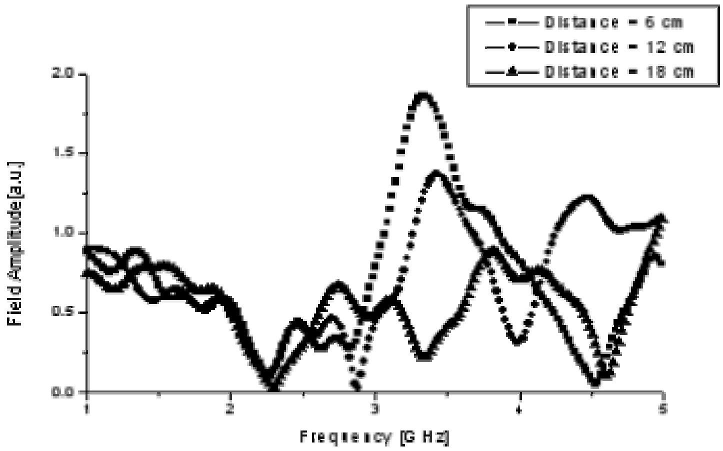

Fig. 3 Field amplitude spectrum by change of distance from dielectric periodic structure

At nearly 2.1GHz, the transmitted field vanishes as shown in fig. 3. In the Fig. 4, incident TE-field from left-bottom of 45 degree is divided to two major components toward the direction of left and right 45 degree by DPS.

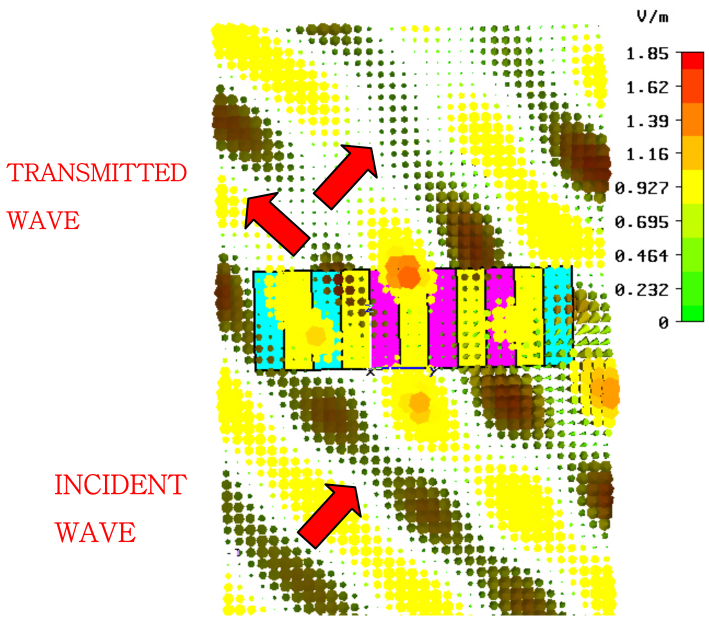

Fig. 4 Field distribution of incident and transmitted

At about 2.1GHz, two different modes propagate along the z-axis. These modes satisfy the traveling wave theory in the periodic structure and propagation condition along z-axis as well as the decaying harmonic fields beyond the structure.

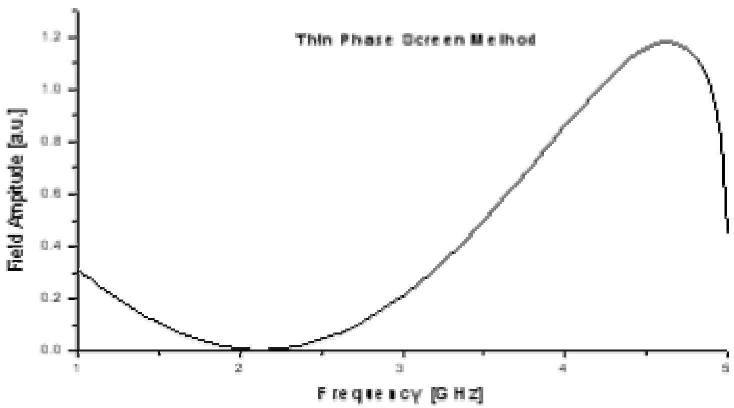

Fig. 5 Field amplitude spectrum applied thin-phase screen approximation

Fig. 5 is the result of thin phase screen approximation method considering the dielectric periodic structure as a thin film, which has an effect on only phase without decay of incident field.

By this time, three simulation results were compared. Through the results of two simulations are relatively well agreement but the thin phase screen approximation is differed from the rest. However, TPS have a good point of calculation easiness and fastness. TPS will help a lot on study to develop a simple simulation tool.

References

[1]. Bertoni, H. L., et dal, "Frequency-selective reflection and transmission by periodic dielectric layer", IEEE Trans., vol. 37, no. 1, Jan. 1989.

[2]. M. G. Moharam and T. K. Gaylord, "Rigorous coupled-wave analysis of planar-grating diffraction," J. Opt. Soc. Am. 71, 811-818 1981.

[3]. M. Born and E. Wolf, *Principles of Optics, 7th ed.,* Ch. 13, Cambridge University Press, 1999.