Chapter 5
1D Electromagnetic Band Gap Analysis and Applications

Abdelmoumen Kaabal
Abdelmalek Essaâdi University, Morocco

Mustapha El Halaoui
Abdelmalek Essaâdi University, Morocco

Saida Ahyoud
Abdelmalek Essaâdi University, Morocco

Adel Asselman
Abdelmalek Essaâdi University, Morocco

ABSTRACT

In this chapter, a detailed study of the one-dimension electromagnetic band gap (1D-EBG) structures and their application in a directional antenna design are presented. To improve the ability and analyze and understand the behavior of 1D-EBG, three techniques of analysis are developed. The results show that the periodicity of the dielectric permittivity makes it possible to stop the waves propagation in certain frequency bands. A comparison between the different methods shows an excellent agreement. An evolution of the transmission coefficient of a structure consisting of six layers with a cavity of thickness equal a wavelength in the middle of the structure, shows that there is a peak of transmission which is formed at the center frequency of the band gap and reflects a resonance phenomenon. This phenomenon of frequency filtering is exploited for the design of a directive EBG antenna by introducing an excitation to the cavity center.

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INTRODUCTION

Electromagnetic band gap (EBG) structures have attracted the attention of several researches in recent years, the EBG structures are regular arrays of materials with different refractive indices and are classified mainly into three categories, that is, one-dimensional (1D) (Joannopoulos, Johnson, Winn,, & Meade, 2011; Moghaddam, Entezar, & Adl, 2013), two-dimensional (2D) (Baccarelli, Paulotto, & Di Nallo, 2007), and three-dimensional (3D) (Mizeikis, Seet, Juodkazis, & Misawa, 2004; Johnson, & Joannopoulos, 2000) structures according to the dimensionality of the stack. The EBG structures that work in the microwave and far-infrared regions are relatively easy to fabricate. Those that work in the visible region, especially 3D ones are difficult to fabricate because of their small lattice constants. Into design a 3D EBG structures appropriately, there appears a frequency range where no electromagnetic eigenmode exists. Frequency ranges of this kind are called band gaps, since they correspond to band gaps of electronic eigenstates in ordinary crystals (Yablonovitch, 1993; John, 1987). In order to gain an intuitive understanding of the photonic bands and band gaps, the 1D EBG structures well be studied in more detail, then their applications in a directional antenna design. The simplest case in which two materials different are stacked alternately. Actually, many basic ideas are common and they will be utilized to build fundamental theories of the EBG structures (Sakoda, 2004; Kushwaha, & Kumar, 2014; Winn, Fink, Fan, & Joannopoulos, 1998; Subodha Mishra, & Satpathy, 2003), as will be shown.

The one-dimensional electromagnetic band gap structure consists in stacking two layers of materials with different permittivities whose periodicity in only one direction (Choubani, Choubani, Gharsallah, David, & Mastorakis, 2010; Joannopoulos, Johnson, Winn, & Meade, 2011). This arrangement is not a new idea. Lord Rayleigh (1887) published one of the first analyses of the optical properties of multilayer films (Rayleigh, 1888). As will be seen, this type of photonic crystal can act as a mirror (Bragg mirror) for light with a frequency within a specified range, and it can localize light modes if there are any defects in its structure. These concepts are commonly used in dielectric mirrors and optical filters (Baumeister, 1958; Fattal, Li, Peng, Fiorentino, & Beausoleil, 2010).

Taking the x-axis a direction perpendicular to the surface of the dielectric layers, and the y-axis a direction of the polarization. Only the electromagnetic waves propagated in the x direction and polarized linearly are deal here. The band gaps are found if the thicknesses of each layer are equal to a quarter of the guided wavelength.

In this chapter, the authors have developed the technique of the 1D EBE analysis and applications. these techniques has notably contributed to improving the ability to analyze and understand the behavior of this type of structure. The chapter is divided into four major parts.

In the first part, a study of the propagation of electromagnetic waves in periodic structures that consists of solving Maxwell's equations taking into account the Bloch-Floquet property, this method leads to the formulation of the dispersion equation to determine the bandgaps frequencies (Collin, 1960; Busch, Von Freymann, Linden, Mingaleev, Tkeshelashvili, & Wegener, 2007; Cheney, & Kincaid, 2012).

The eigenvalue problems for the radiation field in the EBG structures will be formulated in second part. An Hermitian operator related to the electric field will be introduced, and the properties of its eigenfunctions will be studied in detail. A straight forward solution to the exact eigenvalue equation for the one-dimensional periodic problem is obtained through the use of the Fourier series. The eigenvalue problem of the wave equation of the radiation field in the EBG structure will be formulated in the first step, and a general numerical method to solve it as will be given (Zeidler, 1995; Björck, 2016; Rylander, Ingelström, & Bondeson, 2012).

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