Band Splitting in 2D EBG Structure by Geometry Modulation

Ladislau Matekovits
Department of Electronics and Telecommunications
Politecnico di Torino
Torino, Italy
ladislau.matekovits@polito.it

Aldo De Sabata
Department of Measurement and Optical Electronics
Politehnica University Timisoara
Timisoara, Romania
aldo.de-sabata@upt.ro

Ovidiu Lipan
Department of Physics
University of Richmond
Richmond, VA, USA
olipan@richmond.edu

***Abstract*—The dispersion diagram of a 2D periodic structure built in stripline technology is determined by full-wave simulation. One of the geometrical parameter of the structure is then binary modulated in two orthogonal directions, yielding a new periodic structure with a unit cell that is four times larger with respect to the original one. The calculated dispersion diagram of the latter structure exhibits the phenomenon of band splitting determined by modulation. The newly introduced modes and enriched band contents have potential applications to antenna technology, filtering and dispersion engineering.**

I. Introduction

Periodic structures have been applied to microwaves and antenna technology for a long time [1]. However, classic applications have been mainly restricted to 1D periodic devices. Stripline and microstrip technologies allowed for a convenient practical realization of structures that are periodic in two dimensions [2]. A vast literature flourished after the initial application of 2D periodic surfaces to microwaves and antenna technology. These realizations proved useful in various fields such as antenna feeding and beamforming, filtering, signal integrity, cloaking, dispersion engineering etc.

Propagation of the electromagnetic field in 2D periodic structures parallels propagation of electron waves in crystals. Therefore, similar concepts are employed. The dispersion characteristics of the structures are assessed through dispersion diagrams (DDs) that display frequencies of modes of propagation versus wavenumbers. For Cartesian geometry, DDs are determined on the the ΓXMΓ spectral triangle bounding the first irreducible Brillouin zone [3]. Frequency bands in which propagation is not possible play an important role in applications and are called electromagnetic band-gaps (EBGs).

In this communication, we consider a geometry-modulated 2D stripline periodic structure. The modulation is binary in both *x* and *y* directions and is applied to one geometrical parameter in the unit cell, which is square shaped. In this way, a new periodic structure is obtained, having a square macro unit cell that is obtained by reunion of four adjacent unit cells from the original one. 1D counterparts of such structures have been studied in Physics and have been shown to exhibit the band-splitting phenomenon i.e. each EBG splits into several ones, separated by modes in the DD [4]. As we show below, the same phenomenon occurs in the 2D case.

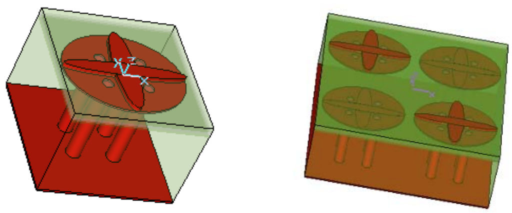
The structure used for illustration has been introduced previously [5]. The DDs reported in the next section have been calculated by means of a commercial solver [6].

II. Modulated 2D Structure and Results

The unit cell of the considered 2D periodic structure consists of two parallel confining metal planes, two dielectric layers and a patch connected to the ground plane by four vias, Fig. 1 (a). Supplementary, corrugations have been introduced (the elliptic cylinders), the heights of which are subject to modulation in order to obtain a double periodic structure on both *x* and *y* directions. The upper metal plane is removed in the represented CAD model. The initial dimension of the unit cell is d=10 mm (it becomes 20 mm after modulation). The lower dielectric layer has a height t_1=6.4 mm and ε_{r1}=3.5. The axes of the elliptic patch are 2a=9 mm and 2b=7.2 mm and the vias, of radii r_v=0.4 mm, are placed at $(x,y)=(\pm a/3, \pm b/3)$. The upper dielectric layer has a height $t_2=0.1t_1$ and ε_{r2}=12. The corrugations are elliptic cylinders of axes 2a and $b/6$ if the large axis is parallel to the *x* axis and $a/5$ and 2b if the large axis is parallel to the *y* axis. The height of the corrugation is $h_c=mt_2$, with an initial value of 1/2 for m.

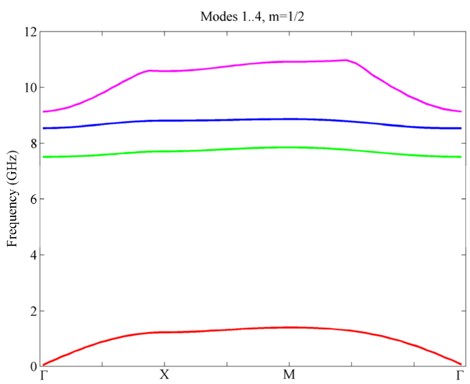
The binary modulated CAD model of the unit cell is represented in Fig. 1 (b). The parameter *m* has alternatively values of 1/4 and 3/4 in both *x* and *y* directions.

The DDs containing the first four modes of the initial and the first eight modes of the modulated structures are reported in Figs. 2 (a) and (b) respectively.

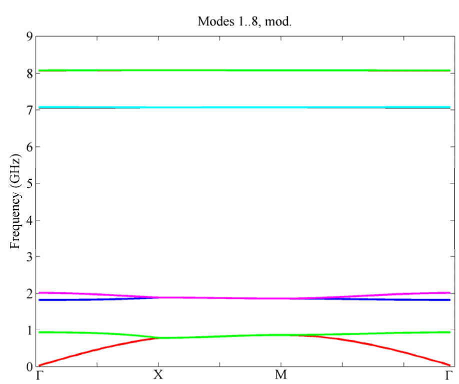


(a) (b)

Figure 1. CAD models of unit cells for (a) unmodulated and (b) modulated structures. (In both cases the upper metal plane is removed for revealing the interior).



(a)



(b)

Figure 2. DDs for (a) unmodulated (4 modes) and (b) modulated structures (8 modes).

An analysis of the details of the DDs in Fig. 2 and of the DDs corresponding to the two unmodulated structures with *m*=1/4 and 3/4 (not reported here) reveal that each mode in the initial DD splits into four modes in the DD obtained after modulation. An explanation for this will be provided at the time of the presentation. Therefore, the eight modes in Fig. 2 (b) are "child" modes of the first two modes in Fig. 2 (a). The first EBG occurring in the DD of the initial structure splits in two EBGs as revealed by the DD corresponding to the modulated one.

The restriction of the first mode in Fig 2 (a) to the ΓX path of the spectral Brillouin triangle, corresponding to waves propagating in the *x* direction with respect to the reference frame in Fig 1 (a), exhibits positive group velocity. This mode splits into four "child" modes having alternatively positive and negative group velocities as frequency increases. The same is true for the other restrictions of the modes to the sides of the ΓXMΓ triangle.

The unusual properties revealed by the DD corresponding to the modulated structure open many possibilities for applications in filtering and dispersion engineering.

III. CONCLUSIONS

We have shown that by binary modulating the geometry of a 2D period structure, built in stripline technology, in two orthogonal directions, each initial propagation mode splits into four modes as displayed by the DD corresponding to the modulated structure. Initial EBGs also split into new EBGs and monotonous modes give rise to equally monotonous "child" modes, alternatively increasing and decreasing.

The presented paradigm has potential applications to antenna conception, filter design and dispersion engineering.

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