A Novel Wideband Electromagnetic Band Gap Structure for Circular Polarization Conversion

M. H. Ghazizadeh*, G. Dadashzadeh†, M. Korshidi‡

Department of Electrical Engineering, Shahed University, Tehran, Iran
*mohammad.h.ghazizadeh@ee.kntu.ac.ir
†gdadashzadeh@shahed.ac.ir
‡m.khorshidi@shahed.ac.ir

Abstract — **In this paper a new polarization dependent electromagnetic band gap (PDEBG) structure is introduced. The structure is made up of numerous periodic cells, where each constituent cell consists of a square patch surrounded by a square metal loop. The patch and the loop are connected in one of their corner, and a via is placed on the diameter of the square patch near the connection. The designed structure is simulated and the results show that the structure has axial ratio less than 3 dB in the frequency bandwidth from 9.94 GHz to 11.98GHz, and from 13.53 GHz to 16.57 GHz. the proposed PDEBG structure has a wider frequency band width for linear to circular polarization conversion than previously introduced PDEBG structures.**

Keywords-polarization dependent electromagnetic band gap; polarization convert surface; circular polarization.

I. INTRODUCTION

The electromagnetic band gap (EBG) structures are formed by repeating a specific pattern called "unit cell". These structures prevent propagation of electromagnetic waves in particular frequency bands which are, therefore called "band gaps". To obtain high performance antenna, EBG structures are used to prevent propagation of surface waves in planar antennas [1-3] and, and to decrease the mutual coupling between array antenna elements [4, 5]. Moreover, they can be used to suppress undesired harmonics in various microwave devices [7, 6], and to achieve high-Q filters and cavity structures [8-11]. Another important property of EBG structures is that the difference between the phases of the wave incident to and the wave reflected from the surface of these structures, is proportional to the wave frequency. At specific frequencies impinging waves on EBG structures are reflected in-phase, thus, causing EBG structures performance to be the same as that of perfect magnetic conductors. Upon this feature, EBG structures have been extensively used in the designing of low profile antennas [13-16].

Polarization dependent EBG structures (PDEBG) are types of EBG structures that are able to change the incident electromagnetic wave polarization at a specific frequency band on their surface. Most of PDEBG structures are made by the change of a mushroom-like square patch EBG structure which is polarization independent by itself. mushroom-like structures with rectangular patch, square patch loaded with slots, square patch with offset via, square patch with two vias [18], square patch with sheet via [19], meander patch [20], square patch with offset via on the diameter of the patch [21], and structures with spiral patch [22] are among PDEBG structure that have been introduced before.

PDEBG structures with rectangular patch, square patch loaded with slots, square patch with offset via, square patch with two vias [18], and mushroom-like structure with meander patch [20], are designed such that their reflection phases for the x- and y- components of the incident wave are different and subsequently the polarization of the reflected wave may be determined. The above mentioned structures are able to convert waves from linearly polarized to circularly polarized and vice versa. In contrast to perfect electric conductor (PEC) and perfect magnetic conductor (PMC), the mushroom-like structure with rectangular patch and square patch with offset via maintains the polarization of incident circular wave at particular frequencies.

The mushroom-like structure with square patch and offset via along diameters of patch introduced in [21] converts x-linear to and from y-linear polarized waves at particular frequencies.

To date, there has been great efforts among researchers in designing PDEBG structures that convert linear to circular polarized waves. In this paper, a novel mushroom-like structure is proposed which has a relatively wide frequency band of circular polarization conversion in comparison with those proposed before.

II. NOVEL PDEBG STRUCTURE

Four iterations of the constituent cells of the proposed PDEBG structure are shown in Fig.1. It is a mushroom-like structure with metal square patch surrounded by a square loop on top of the dielectric, at the corner of each unit cell the metal square loop is connected to the square patch through a small strip of metal called “bridge”. Moreover, the metal patch is connected to the ground plane through a via

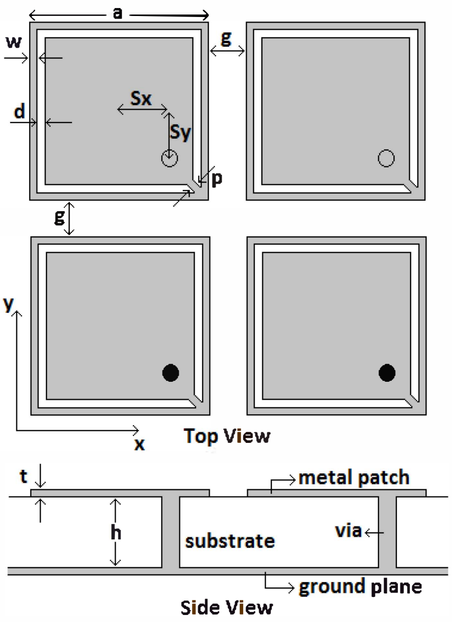

Figure 1. Four iterations of the constituent cells of the proposed PDEBG structure.

which is placed on the diameter of the square patch near the bridge. The dielectric constant used in this design is 2.6 and the parameters shown in Fig.1 are evaluated as below: a=6.8mm, w=0.4mm, d=0.25mm, S_x=S_y=1.7mm, g=0.4mm, h=1.75mm, p=0.2mm, via-radius=0.4mm, t=0.1mm.

The proposed structure has been simulated with HFSS and Microwave CST Studio software by applying periodic boundary conditions to each cell of the structure. The surface of each cell is vertically illuminated by TE (y- linear) and TM (x- linear) planar waves. Fig. 2 shows the model of each cell and the imposed periodic boundary conditions for the simulation of the novel PDEBG structure in the HFSS software.

The polarization conversion of the incident wave on the structure may be determined from reflection coefficients. Pertinent to the proposed PDEBG structure, both the magnitude and phase of the reflection coefficients obtained from simulation are shown in Fig.3. Fig 3 (a) and 3(b) correspond to simulation of HFSS and Fig 3 (c) and 3(d) correspond to simulation of CST software. The HFSS and CST simulation results have good agreement which indicates that the simulation is highly accurate. It is seen that the resonant frequencies occur nearly at 9.54 GHz, 12 GHz, and 17.21 GHz, where the values of s11 and S22 drop down well below -30 dB and the values of S12 and S21 are close to 0 dB (the parameters S11, S22, S12, and S21 are defined in table 1). This means that if at these frequencies a TE wave (y- polarization) impinges the PDEBG structure's surface, the reflected wave will be mainly a TM wave (x- polarization). In other words, at these resonant frequencies the structure is

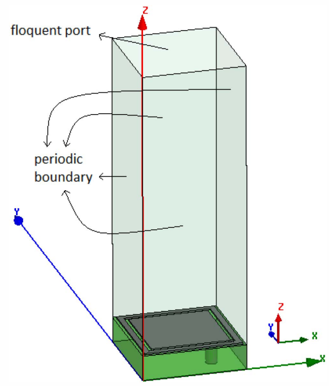

Figure 2. Model of each cell and periodic boundary conditions for simulating the novel PDEBG structure.

TABLE I. REFLECTION COEFFICIENT DEFINITIONS

parameter	impinging wave	reflection coefficient
S_{11}	TE mode	TE mode (y-polarization)
S_{12}	TE mode	TM mode (x-polarization)
S_{21}	TM mode	TE mode (y-polarization)
S_{22}	TM mode	TM mode (x-polarization)

able to convert linear x- polarized to and from y- linear polarized waves.

It is observed in fig.3 that in the frequency bandwidth from 9.94 GHz to 11.89 GHz, and from 13.53 GHz to 16.57 GHz, the magnitudes of S11=S22 and S12=S21 are approximately equal. Moreover, it is seen that in the former frequency band the phase difference between S11 and S12 is 90 degree, whereas in the latter frequency band it is -90 degree. Therefore, in the former frequency band an incident x-linear polarized / y-linear polarized wave reflects with both x- and y- components of polarization which are equal in magnitude, but have 90 /-90 degree phase difference, and so the reflected wave is a right- hand circular polarization (RHCP)/ left- hand circular polarization (LHCP) one. Conversely, in the latter frequency band, x-linear / y-linear waves reflect as LHCP/RHCP waves.

Fig.4 verifies that the proposed PDEBG structure has axial ratio less than 3 dB in the frequency bands of 9.94 GHz to 11.89 GHz, and of 13.53 GHz to 16.57 GHz, which conveys that the performance of the structure in these frequency bands is favorable.

Furthermore, for the sake of comparison the bandwidth of linear to circular polarization conversion for the proposed PDEBG structure and several previously introduced structures have been obtained from HFSS simulations, and are given in table2. It can be readily concluded that the designed PDEBG structure has a relatively wide bandwidth for linear to circular polarization conversion compared with other well-known structures.

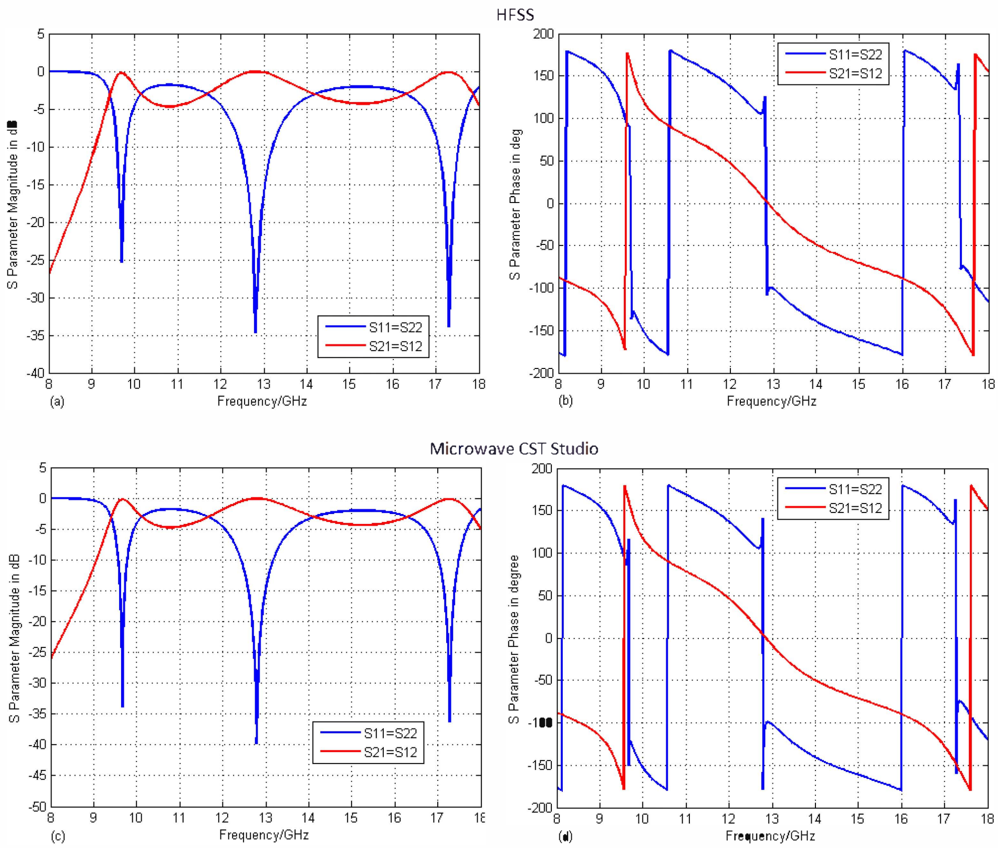

Figure 3. The reflection coefficients of the novel proposed PDEBG structure (a) and (b) HFSS simulation results (c) and (d) CST simulation results.

TABLE II. LINEAR TO CIRCULAR CONVERSION BANDWIDTH FOR SEVERAL PDEBG STRUCTURES

PDEBG structure	Frequency band (GHz)	Bandwidth (%)
Novel PDEBG structure	9.94-11.89 13.53-16-57	17.86 20.19
Mushroom-like rectangular patch PDEBG [7]	5.53-5-85 8.64-9.44	5.62 8.84
Mushroom-like square patch Loaded with strips PDEBG [6]	3.34-3.60	7.49
Mushroom-like square patch offset via PDEBG [6]	2.26-2.30 2.40-2.30 3.23-4.04	1.75 3.27 22.28
Mushroom-like square patch two vias PDEBG [6]	3.33-4.17	22.40
Mushroom-like meander square patch PDEBG [7]	5.27-5.46 7.18-7.97	3.54 10.42
Mushroom-like square patch sheet via PDEBG [8]	2.80-3.01	7.22
Mushroom-like square patch diagonal offset via PDEBG [5]	5.29-6.36 7.92-9.70	18.36 20.20
Spiral patch PDEBG [9]	2.51-2.60 2.59-2.76	3.52 6.35

III. CONCLUSION

Up to the moment, Various PDEBG structures have been introduced in literature. Each of them performs a specific polarization conversion in particular frequency bands. In this paper the novel PDEBG structure introduced, is a mushroom-like structure with metal square patches surrounded by a square loop on the top of the dielectric. The metal square loop is connected to the square patch at one of its corners. A via is placed on the diameter of the square patch and near the corner where the bridge connection exists. Linear to circular polarization conversion of the new PDEBG structure was described by considering the reflection coefficients of the structure. This new PDEBG structure has axial ratio less than 3dB in the frequency bands of 9.94GHz to 11.98GHz, and of 13.53GHz to 16.57 GHz, which are wider bands compared with some of those of previously introduced PDEBG structures.

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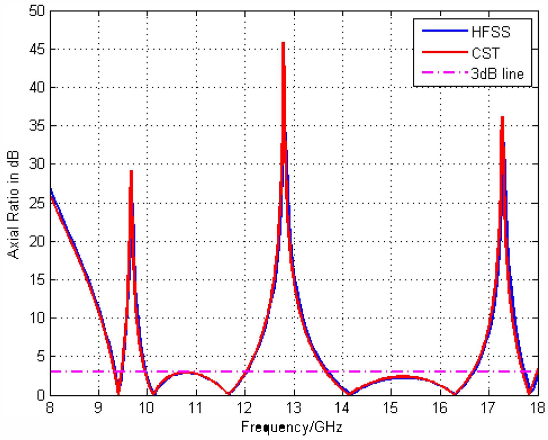

Figure 4. Axial Ratio of the reflected wave from the PDEBG structure illuminated by a x-linear polarized wave.

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