Mutual Coupling Reduction in Waveguide-Fed Slot Array Antenna Using Uniplanar Compact EBG (UC-EBG) Structure

E. Ghahramani, R. A. Sadeghzadeh, B. Boroomandisorkhabi, M. Hasanalizadeh Kolagari
Faculty of Electrical and Computer Engineering
K. N. Toosi University of Technology
Tehran, Iran
Email: ehsan.ghahremani7@gmail.com

Abstract—Reducing mutual coupling is an important topic in array antenna design. This paper proposes a uniplanar compact electromagnetic band-gap (UC-EBG) structure in order to reduce mutual coupling between waveguide-fed slot array antennas by suppressing the unwanted surface waves. The paper proposes a UC-EBG arrays configuration and a waveguide broadside resonant slot arrays of $2 \times 5$ elements at X-band.

Keywords—slot array antenna; mutual coupling reduction; uniplanar compact electromagnetic band-gap (UC-EBG).

I. Introduction

Electromagnetic band-gap structures have become more interesting in recent years because of having desirable properties [1]. Suppressing unwanted surface waves on the antenna, producing steady field distribution in the rectangular waveguide, increasing the antenna gain and reducing mutual coupling between antenna radiation elements are some of these properties [2]. This paper focuses on reduction of mutual coupling properties of EBG structure between two waveguide slot array antennas. This purpose is achieved by employing the UC-EBG structure. Compact structure is one of the advantages of using UC-EBG. Also this structure reduces mutual coupling between slot array antennas by suppressing unwanted surface waves on the rectangular waveguide. Mushroom-like EBG can cancel unwanted surface waves at both TE and TM modes, simultaneously [3]. In the other hand, because UC-EBG structures can only effectively cancel surface waves in TE modes, they are using in the rectangular waveguide slot array antennas. If antenna center frequencies are within the UC-EBG band-gap areas, mutual coupling will be reduced effectively. Slot waveguide antenna has wide applications in communication systems [4]. Because of using this antenna in radar and communication systems in planar form, the application of the antenna increases. In this paper, in order to reduce mutual coupling, two rows of UC-EBG are used in an array of $2 \times 5$ elements antenna. The waveguide slot array antennas have narrow bandwidths so they have good compatibility by the narrow band-gap UC-EBG structures. The proposed antenna is simulated using CST Microwave Studio.

Fig. 1. (a) Dispersion diagram and (b) unit cell of UC-EBG structure: $a = 8.571$ mm, $b = 7.428$ mm, $s = g = 1.1428$ mm, $l = 1.7142$ mm.
Antenna Design and Results

The unit cell consists of a patch element and ground plane, separated by a dielectric slab. One of the most important features in the UC-EBG design is the elimination of vertical vias. Thus, compared to mushroom-like EBG structure, the fabrication process is simplified. UC-EBG operational mechanism can be explained by the lumped LC model [5]. Fig. 1 shows a unit cell of the UC-EBG structure which is used in the proposed antenna. The frequency band-gap of UC-EBG structure can be adapted by altering the dimensions of each unit cell [2]. In this paper, the applied slot array antenna center frequency is 10.27 GHz. According to the geometry design of UC-EBG structure, this frequency is situated in band-gap frequency of the structure. Fig. 1(a) shows the unit cell UC-EBG dispersion diagram with a band-gap frequency range between 8.7 GHz and 10.5 GHz. Dispersion diagram shows the dispersion relation of surface waves between wave numbers and frequency [6]. UC-EBG unit cell design parameters are shown in Fig. 1(b). This configuration is on RT/ Duroid substrate with $\varepsilon_r = 2.2$ and $h = 1.1$ mm.

Fig. 2 shows the geometry of the proposed waveguide-fed slot array antenna. The slots have been cut in the broadside of the standard rectangular waveguide (WR-90). The dimensions of antenna are shown in table I.

In Fig. 3, two rows of UC-EBG are designed between waveguide-fed slot array antennas. The results of these structures are compared with the case without UC-EBG structure. Fig. 4 shows the simulated mutual coupling ($S_{12}$) and return loss ($S_{11}$) of these antennas. As shown in Fig. 4, the presented configuration has improved mutual coupling (-5dB) between two adjacent parallel slot array antennas around their center frequencies that its value is about 100% fewer than previous result improvement (-2dB) for applied single layer UC-EBG [7].

| TABLE I Dimensions of the Rectangular Waveguide (WR-90) |
|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| WR-90                  | $W_a$ (mm)             | $W_b$ (mm)             | $W_t$ (mm)             | $X$ (mm)               | $sW$ (mil)            | $sL$                   | $\lambda_0$ (mm)       | $\lambda_g$ (mm)       |
| 22.86                  | 10.16                  | 1.27                   | 5                      | 5                      | $\lambda_0/2$         | $\lambda_g/2$          | 28.94                  | 37.37                  |
III. Conclusion

In this paper, a waveguide-fed slot array antenna is designed by using UC-EBG structure. The simulation results show that the mutual coupling ($S_{12}$) between conventional slot array antennas can be reduced 5 dB when the UC-EBG structure is applied among them so its value is about 100% better than previous result improvement. Also, it is expected that the EBG structure can be applied in various type of antennas for improve their performance by suppressing unwanted surface waves. This purpose is achieved by using characteristics of high-impedance surface (HIS) UC-EBG structure.

Acknowledgment

The authors have special thanks to Faculty of Micro-Electronic for financial support.

References