Chapter 2
Performance of Microstrip Patch Antennas Embedded in Electromagnetic Band-Gap Structure

Fangming Cao and Suling Wang

Abstract Electromagnetic band-gap structures are widely used in antenna and microwave element designs due to their unique electromagnetic features which are shown in two aspects: forbidden band gap and in-phase reflection. In this paper, three different antennas are designed and simulated by Ansoft HFSS to know the use of the EBG structure in microstrip antenna engineering. Radiation characteristics such as gain, radiation patterns and s-parameters of these microstrip antennas are performed. The simulated results verify that the gain has been increased noticeably, the radiation pattern has been improved and the sidelobe and backlobe levels have been reduced by using the mushroom-like EBG structures. Especially, the microstrip antenna over the EBG structures not only shows the best electromagnetic characteristics but also maintains its small dimensions.

Keywords EBG structures · Radiation characteristics · Patch antenna · HFSS

2.1 Introduction

Recently, perhaps there is nothing more that has attracted people extremely than Electromagnetic band gap (EBG) structure which is originated from a kind of new artificial electromagnetic material called photonic crystal in the electromagnetic and antenna community. As one special electromagnetic material, electromagnetic band gap structure is composed of cyclical array of dielectric or metal elements [1, 2]. EBG structures have two distinctive electromagnetic properties including the

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frequency band gap and the phase reflection [3]. The application of EBG structure is focused on these two aspects in microwave antenna designs. First the property of surface-wave suppression enables one to design the microstrip patch antenna with high gain, suppress high order harmonic and depress the mutual coupling of plannar antennas; second some typical applications of the in-phase reflection property are to raise the the antenna gain as a reflection plate, inhibit the rear lobe and design low profile antennas [4, 5]. This paper concentrates on the mushroom-like EBG structure whose compactness property is more attractive compared to other EBG structures.

The strong points of microstrip patch antennas including small size, ease of integration, light weight and low price have led to their numerous favorable applications in wireless communication field [6]. Miniaturization has become one of the essential antenna design requirements with the revolutionary development of the related field. All kinds of methods have been put into effect to make the antenna small in size. Raising the permitivity of the substrate is recognised as the most common measure [7, 8], yet applying the substrate with high permittivity to the microstrip antenna will deteriorate the antenna performance [9]. In this paper, we apply the mushroom-like electromagnetic band gap structures to the microstrip antennas in order to inhibit the surface waves generated by the dielectric substrates with higher permittivity.

2.2 Design Microstrip Patch Antennas

First a traditional patch antenna is designed for comparison. We make the reference antenna work at 1.8 GHz so that the center frequency of the antenna can be covered with the band gap region of the mushroom-like EBG structure. The patch is fabricated on a ground plane with a relative permittivity of 10.2 to remain its compact size. Figure 2.1 presents this conventional antenna. Its resonant frequency is at 1.8 GHz when the area of the patch is $L \times W = 24.8 \times 38.3\,\text{mm}^2$, and the feed location L_1 is 3.34 mm, L_1 is the distance between the feed and the center of the patch [6].

Then we make the radiation patch surrounded by a layer of mushroom-like EBG structure. The mushroom-like EBG structure revealed in Fig. 2.2 is fabricated on the ordinary microwave substrate and the metal patches printed on the surface of substrate are connected to the ground floor through the metal hole [10]. Figure 2.3 depicts the antenna surrounded by the EBG structures which consist of patches and vias array [11]. The EBG structure is devised so that the antenna resonant frequency falls into its surface wave band gap and hence the surface wave excited by this patch antenna is inhibited from propagation. The dimensions of the EBG structures are displayed in Fig. 2.4. The antenna can achieve a good match of 50Ω around 1.8 GHz after continuous optimizations. The L is 24.8 mm, W is 38.3 mm and the L_1 is 3.65 mm. It is worthwhile to point out that the period gap of electromagnetic

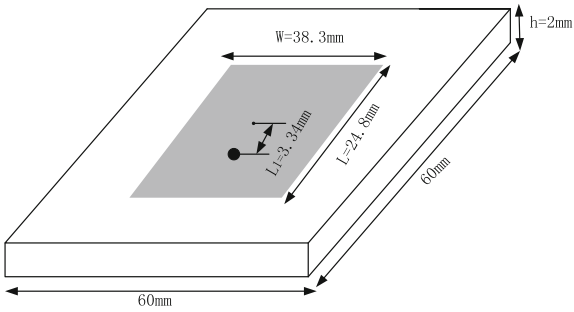


Fig. 2.1 Conventional antenna dimensions

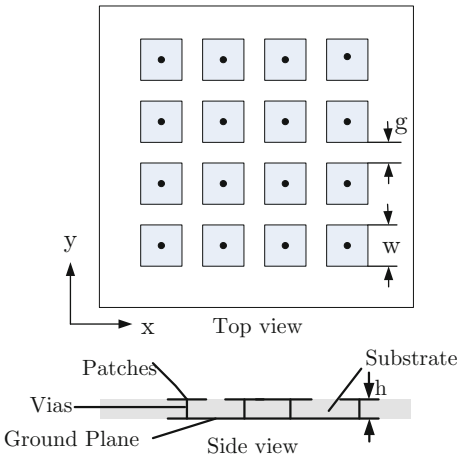


Fig. 2.2 Geometry of mushroom-like EBG structure

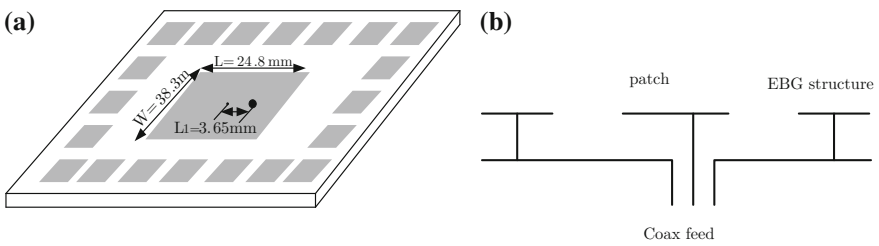


Fig. 2.3 Patch antenna surrounded by mushroom-like EBG structure: **a** geometry and **b** cross section

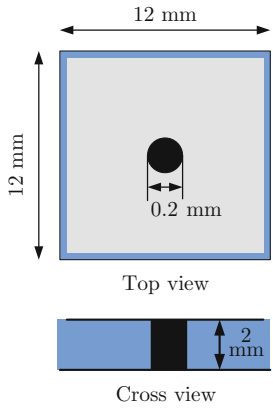


Fig. 2.4 Cell dimensions

band gap cells should be smaller than the interval between the EBG cells and the patch in order to obtain a good radiation characteristic [6].

Generally the EBG structure is applied to placing around the patch antenna in the patch antenna design. But the problem is that the size of the patch will become so large that it can't reach the purpose of miniaturization. The EBG structure attached to the back of the patch as the ground not only inhibits the surface wave but also miniaturizes the antenna. In view of this, we have designed the antenna as shown in Fig. 2.5. When the patch length is 32.1 mm and width is 28 mm, the antenna can work at 1.8 GHz.

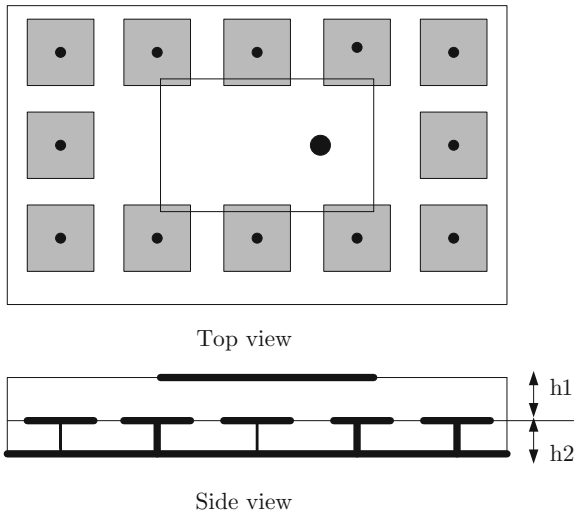


Fig. 2.5 Microstrip antenna over EBG structure

2.3 Simulated Results and Discussion

The simulated s-parameters for these three structures are compared in Fig. 2.6. Curve1 stands for the S_{11} of the traditional antenna, curve2 is on behalf of the S_{11} of the antenna surrounded by the EBG structure, curve3 means the S_{11} of the antenna over the EBG structure. From the S_{11} plot, it can be observed that all the three patches are tuned to resonate at the same frequency 1.8 GHz with better return loss less than-10 dB, especially the microstrip antenna on top of the EBG structure.

Figure 2.7 presents the directional pattern in E-plane. Curve1 stands for the the directional pattern of the conventional antenna, curve2 is on behalf of the the directional pattern of the antenna surrounded by the mushroom-like EBG structure, curve3 means the directional pattern of the antenna over the EBG structure. We can

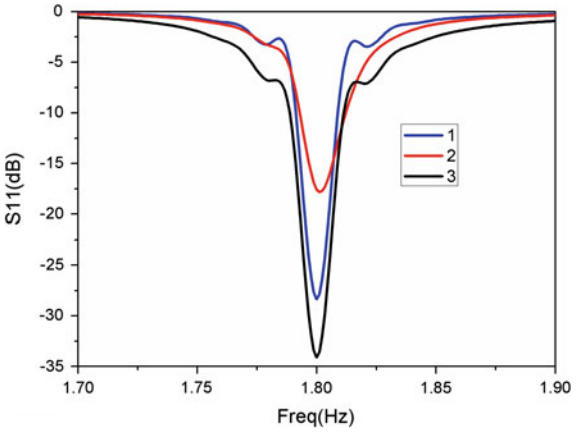


Fig. 2.6 Return loss

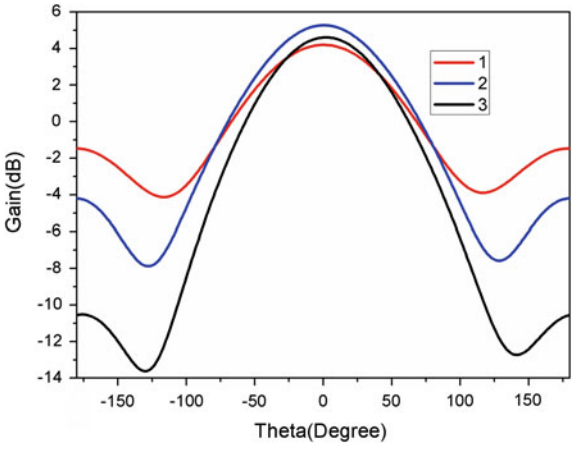


Fig. 2.7 E-plane radiation patterns of patch antennas

conclude that the antenna pattern is influenced by the EBG structure, curve 3 has the lowest back radiation which is more than 9 dB lower than curve 1, though its front radiation only increases 0.41 dB than curve 1. Curve 2 has the highest front radiation which is 5.27 dB. It is apparent that surface-wave suppression improves the back radiation by reducing edge scattering waves.

Some key values are listed in Table 2.1. Figure 2.8 depicts the simulation models of microstrip patch antennas with EBG structure. The area of this microstrip antenna over the EBG structure surface is about half of the area of the microstrip antenna surrounded with the EBG structure by calculating. From above comparisons it can be concluded that the microstrip antenna on top of the EBG has the best radiation performances on basis of miniaturization.

Table 2.1 Antenna characteristics

Structure	s_{11} (%)	Front radiation (dB)	Back radiation (dB)
1	−28.32	4.19	−1.47
2	−17.60	5.27	−4.21
3	−34.08	4.60	−10.55

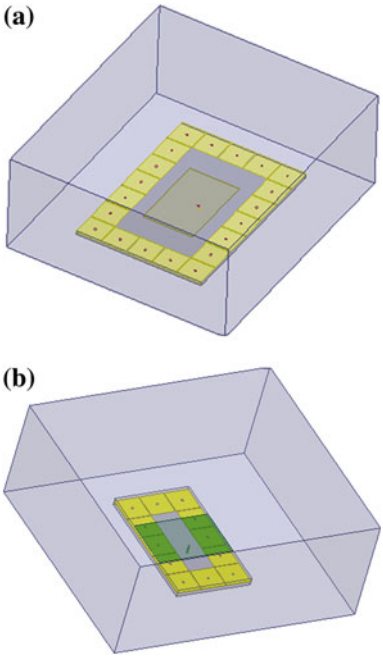


Fig. 2.8 Simulation models of antennas with EBG structures. **a** Simulation model of patch antenna surrounded by mushroom-like EBG structure. **b** Simulation model of patch antenna on top of EBG structure

2.4 Conclusion

In this paper, three kinds of antennas have been designed and simulated by Ansoft HFSS.We conclude that the EBG structures may hinder the propagation of surface wave and thus improve the radiation performance of an antenna. In particular, the patch antenna over the EBG structure has the best performance while keeping its small dimensions. This also specifies that EBG structures can compensate for the shortcomings of the microstrip antenna on the substrate with higher permittivity.

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