Influence of Side Effect of EBG Structures on the Far-Field Pattern of Patch Antennas

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Abstract

The electromagnetic band gap structure always used as a part of antenna structure in order to improve the performance of the antenna especially for improves the gain and radiation pattern. In this paper, microstrip antenna is used due to the advantages such as easy and cheap fabrication, light weight, low cost, easy to feed, and better isolations among array elements, by suppressing surface wave modes. The two dominating side effects are the parasitic loading effect and cavity effect. The first causes the multi resonances antenna resulting in large bandwidth, the second effect is due to reflecting energy from EBG toward antenna and so decreasing the bandwidth. The EBG structure parameters and number of EBG rows is related to these effects.

In this paper, we propose a rectangular microstrip patch antenna with EBG substrate of different structure EBG parameters and number of EBG rows; we compare the performance of the proposed antenna with a conventional patch antenna, in a same parametric analysis with HFSS simulator.

Keywords: *Patch antenna, surface wave, EBG structure, gain and bandwidth.*

1. Introduction

With the drastic demand of wireless communication system and their miniaturization, antenna design becomes more challenging. Recently microstrip patch antennas have been widely used. In spite of its several advantages, they suffer from drawbacks such as narrow bandwidth; low gain and excitation of surface waves [1], to overcome these limitations of microstrip patch antennas two techniques have been used to suppress surface wave propagation, namely micromachining [2] and periodic structures called the electromagnetic bandgap (EBG) structures [3]. However, the effects of EBG structures surrounding the antenna can be considered as two effect, namely parasitic loading effect and cavity effect. The parasitic loading effect increases the bandwidth, whereas cavity effect is due to reflecting energy from EBG toward antenna results in a larger Q value and so decreasing the bandwidth. The EBG structure parameters and number of EBG rows is related to these effects.

In this paper, the influence of the EBG structures parameters and number of EBG rows on the far-field pattern of patch antennas is investigated. The changes in the far-field radiation patterns are discussed.

2. Theory of EBG

The parametric study on mushroom-like EBG structure is presented in [4]. It focused on four main parameters that affecting the overall performance of the antenna design. The parameters namely, patch width W, the spacing between mushroom-like EBGs, substrate thickness h and substrate permittivity εr. In this paper, the study is focusing not only on W, s and h as in [4], but also on the spacing between patch element, g and the number of rows of the EBG inserted between the patch elements.

Mushroom-like EBG consists of a ground plane, a dielectric substrate, metallic patches and vias that connecting the patches to the ground plane. The structure of this EBG and its equivalent lumped LC elements is shown in Figure 1. The inductance and capacitance of the circuit are due to the shorting vias and the spacing between the adjacent metal patches [5].

The central frequency of the band gap is

$$\mathrm{f} = \frac{1}{2\pi\sqrt{\mathrm{LC}}} \tag{1}$$

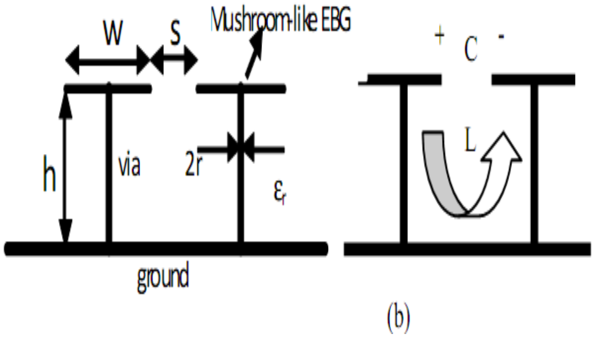


Fig.1 (a) Mushroom-like EBG structure (b) Lumped LC model.

3. Simulation of patch antenna integrated with EBG

The conventional microstrip antenna was designed on substrate (80*80mm) having dielectric constant $\varepsilon r = 2.5$ and height of the substrate h=1.588mm. The microstrip antenna is excited by a coaxial probe and the feed point is located at the distance (dx=1.7mm) away from the edge of the patch. The length L and the width W have been taken as 8.3and 11.34mm.

The antenna under investigation is a microstrip patch antenna integrated with one row of conventional mushroom like EBG patches located half wavelength (g=15mm) far from antenna radiating edges in E-plane with resonant frequency at 10GHz figure 2. The parameters of EBG unit cell are: w (EBG patch width) =3.5mm, s (gap between adjacent patches) =1mm, r (radius of via holes) =0.2mm.

Figure3 is shown return loss of antenna with and without EBG structure, and figure4 shown E-plane pattern of these two antennas.

As shown in figure 3, as expected, bandwidth of antenna whit one row EBG in E-plane is greater than antenna without EBG about 2%, due to domination of parasitic effects.

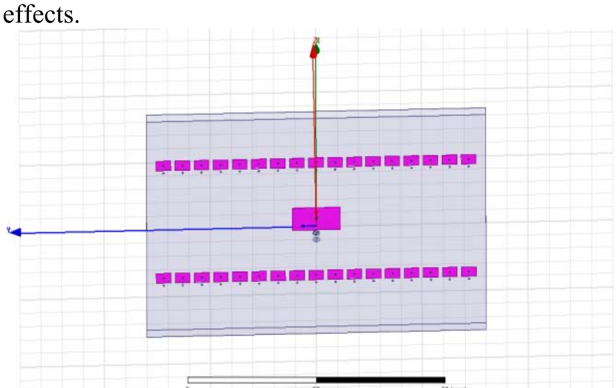


Fig. 2 Microstrip patch antenna with resonant frequency at 10 GHz

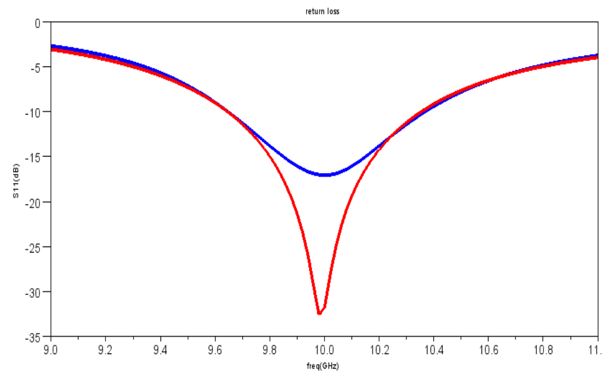


Fig. 3 Return loss of patch antenna with one row EBG (bleu) and without EBG structures (red)

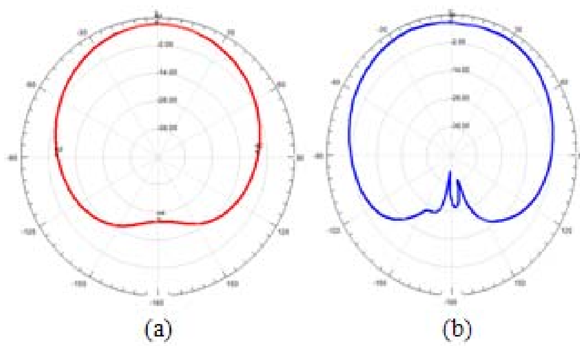


Fig 4 E-plane patterns of patch antenna (a) without EBG structures(b) with one row EBG

The reference antenna shows large radiation in the backward direction, and the antenna integrated with one row of conventional mushroom like EBG patches produces a lower backlobe, with less power wasted in the backward direction. Also, surface wave is reduced in EBG antenna.

In this part the antenna patch is simulated with increasing the number of EBG rows, figure 5 is shown the antenna patch with 4rows of EBG structures in E-plane. Figure 6 is shown return loss of antenna with different number EBG rows.

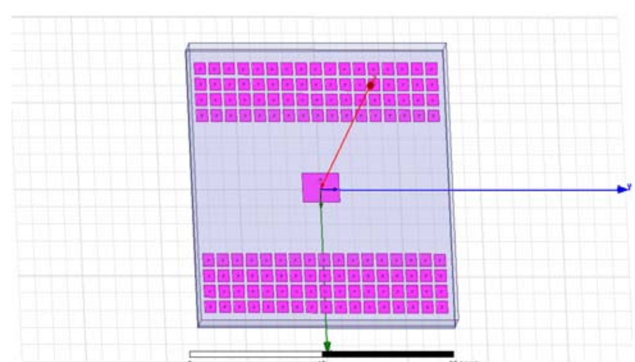


Fig. 5 Microstrip patch antenna, with 4 EBG rows.

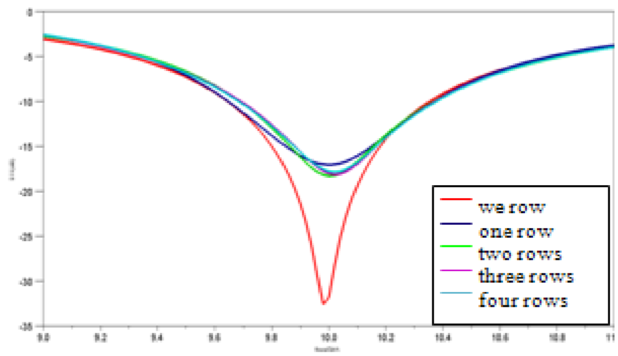


Fig.6 Return loss of the antenna with different number EBG rows.

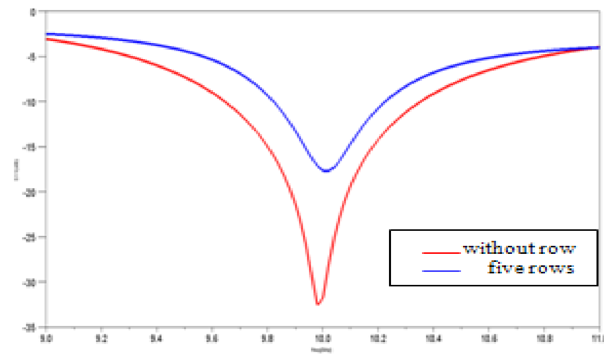


Fig.7 Return loss of the antenna with 5 EBG rows and without.

Table 1 shows the simulation results:

Table 1: Comparisons details between the results obtained with and without EBG rows

	Res.freq (GHz)	***S11 (dB)***	***BP (GHz)***	***Gain (dB)***
We EBG	9.98	-32.61	0.708	7.27
One row	10	-17.06	0.721	6.64
Two rows	10	-18.30	0.68	6.80
Three rows	10.02	-18.13	0.68	6.20
Four rows	10.02	-17.85	0.68	6.05

The performance of the antenna without EBG row is about the same as the antenna with EBG rows, except that the return loss is dropped from -32.6 dB to about -18dB.

With increasing EBG rows from 2 to 4 rows, the bandwidth variation is negligible which is the indication of parasitic effects dominations.

The figure 7 is shown the return loss of antenna with 5 rows of EBG structures in the E-plane, figure 8 represented E-plane pattern for antenna with 5 rows. With 5 EBG rows, bandwidth suddenly decreases (0.708GHz to 0.401GHz) which is the indication of cavity effect domination.

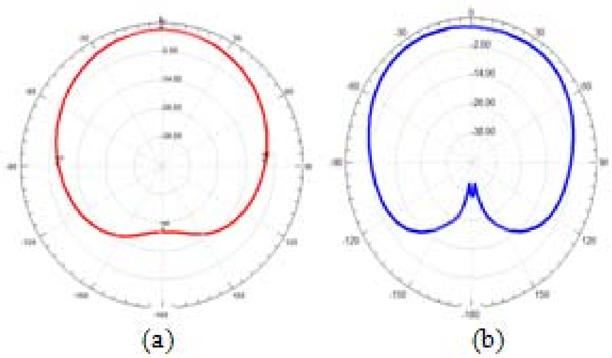


Fig.8 E-plane patterns of patch antenna (a) without (b) with 5 EBG row.

The reference antenna shows large radiation in the backward direction, and the antenna integrated with 5 rows of conventional mushroom like EBG patches produces a lower backlobe, with less power wasted in the backward direction. Also, surface wave is reduced in EBG antenna.

The same process is repeated in this part. The only different is that the spacing between patch is wider, that is 22.5mm (three quarter wavelength) from antenna radiating edges in E-plane to the row of conventional mushroom like EBG patches edge.

Figure 9 represented the return loss of antenna with one row.

It is seen from the Figure 9, the return loss for the conventional patch antenna is – 32dB at 10GHz and for the proposed patch antenna is – 21.25dB at 10.02GHz. A negative value for return loss shows that this antenna had not many losses while transmitting the signals.

With a wider spacing (three quarter wavelength), bandwidth suddenly decreases (0.708GHz to 0.64GHz) which is the indication of cavity effect domination.

The simulated results for gain that are obtained from conventional antenna and the proposed antenna on EBG substrates are shown in Figure 10.

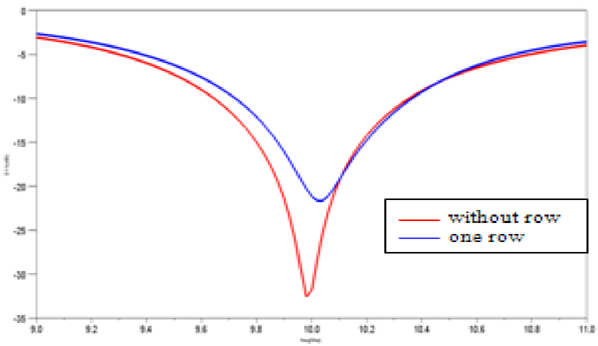
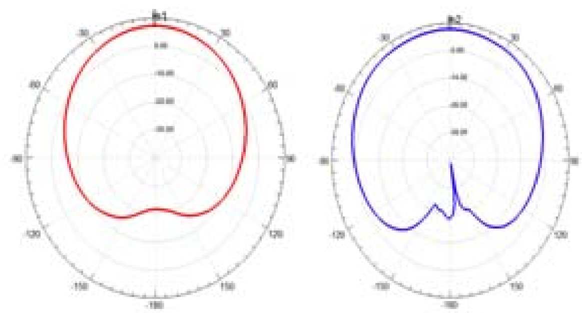


Fig .9 Return loss of the antenna patch with and without EBG row.



(a) (b)

Fig.10 E-plane patterns of patch antenna (a) without EBG row (b) with one EBG row.

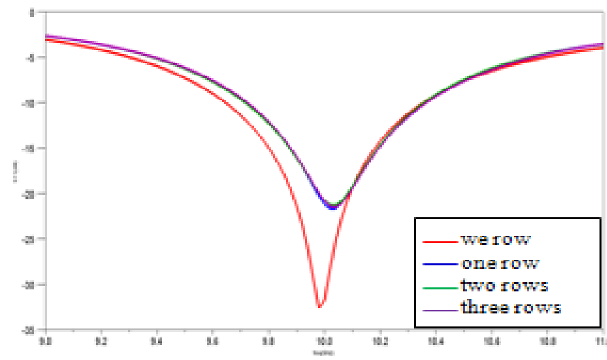


Fig.11 Return loss of the antenna with different number EBG rows.

Table 2: Comparisons details between the results obtained with and without EBG rows

	Res.freq (GHz)	***S11 (dB)***	***BP (GHz)***	***Gain (dB)***
We EBG	9.98	-32.61	0.708	7.27
One row	10.03	-21.64	0.642	7.48
Two rows	10.02	-21.27	0.637	7.42
Three rows	10.04	-21.47	0.640	7.4

From the simulated results, it is shown that the gain of the conventional antenna and the proposed antenna is 7.26dB and 7.49dB. So, the gain of the proposed patch antenna on EBG substrates is 3% more than the conventional patch antenna.
Now, we increase the number of EBG row from 1to 3, Figure 11 is shown return loss of patch antenna; table 2 shows the simulation results:
With increasing EBG rows from 1 to 3 rows, the bandwidth variation is negligible which is the indication of parasitic effects dominations, the gain of EBG patch antenna improved than the antenna without EBG. The conclusion from these two simulation results, the spacing from antenna radiating edges in E-plane to the row of conventional mushroom like EBG patches edge affect at the influence of side effects of EBG structure on the performance of the antenna.

4. CONCLUSION

The patch antenna mostly used in modern mobile communication. The goals of this paper are to design conventional patch antenna and the patch antenna on EBG substrates with same physical dimensions that can operate at 10GHz and study the influence of the side effects of EBG structure on the performance of the antenna.
Based on the results obtained in this work, the following can be concluded from the parametric analysis; it is obvious that for 2 rows of EBG structures, an acceptable bandwidth is achieved. When 3 or 4 rows of EBG rows are used, bandwidth variations is negligible, but side and back lobe levels decreases in the cost of larger size consumption.
The spacing from antenna radiating edges in E-plane to the row of conventional mushroom like EBG patches edge controls the degree of influence of the side effects of EBG structure on the performance of antenna.

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