Comparative Study of Different Shape of Periodic Patch Electromagnetic Band Gap Structure for Planar Antenna Application

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1. Introduction

For the past few years, the research works within the area of electromagnetic band gap have been rapidly increased especially in the area of antenna design. Various shapes, structures and dimensions have been analyzed using different numerical methods [1] and a lot of novel applications have been achieved [2]. Some of the EBG properties that had been determined were band gap [3], stop band and band pass frequency [4]. One of the properties that make EBG structure unique is that the structure providing different phase reflection varies with frequency [5]. At certain frequency where the “band gaps” occur, the EBG structure provides in phase reflection which is good for artificial ground plane for low profile antenna design [5-6]. Other than in phase reflection, EBG structures provide stop band at certain frequency ranges where it is also called a forbidden frequency range [7]. In the forbidden frequency range, it will not support any propagation of waves within the substrate for all polarization state and all angles. Hence, this structure is suitable for planar antenna application for reducing the effect of surface waves and mutual coupling which is normally degrades the antenna performances [8].

2. Method of Analyzing the EBG Structures

In this paper, method of suspended transmission line (MoSTL) is used to determine the characteristic of different shape of EBG structures. Using this method, stop band frequency of EBG structures can be determined. Method of suspended transmission line is easy to be used for measuring the characteristic of stop band frequency of any single or periodic EBG structure. The arrangement of the structure using this method is illustrated in Figure 1. Using this technique, a 50 Ω transmission line is placed on the top of a supporting material using a 0.5 mm thick FR4 substrate with the total size of 50 mm x 50 mm. Beneath the supporting material, a 1.6 mm thick FR4 board with copper ground plane is placed as a bottom layer. Two 50 Ω SMA connectors are used to transmit and receive EM waves through the transmission line. Without the existence of EBG structure beneath the transmission line, the EM waves can pass through the transmission line with high efficiency within the range below 10 GHz. No band stop frequency can be found within the frequency range without the existent of EBG structure. Then, if any single or periodic EBG structures are placed below the transmission line, the stop band frequency will appears. The range of stop band frequency is depending to the geometrical shape of the EBG structures which provide different resonance property.

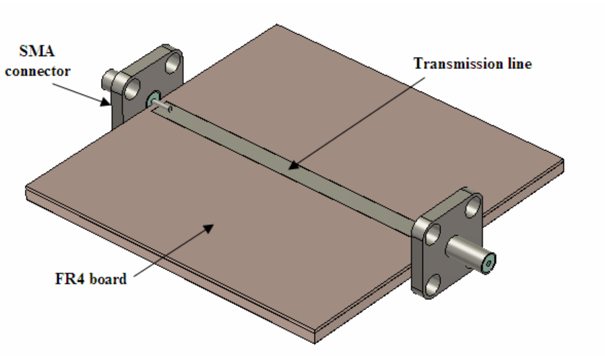


Figure 1: Simulation Set-up using Method of Suspended Transmission Line

3. Electromagnetic Band gap Structures

Based on the literature, various shape of EBG structures have been analyzed using different techniques such as reflection phase technique and dispersion technique. In this paper, 4 different shapes of periodic EBG structure are analyzed using MoSTL, which are mushroom-like EBG, circular EBG, fractal EBG and slotted patch EBG structure. The characteristic of the stop band frequency for all shapes are investigated by the S_{21} value through the simulation process using CST software. The width and period of the EBG lattice are set to be same for all cases which are 10 mm and 11 mm respectively to determine the different in term of the performances of the structures.

3.1 Mushroom-like EBG Structure

Mushroom-like EBG (mEBG) structure is well known as the simplest EBG structure that has been widely used for various analysis and applications. This structure consists of periodic arrangement of square metallic patch grounded with metallic vias as shown in Figure 2 (a). Lump element model consists of inductor, *L* and capacitor, *C* is the simplest model to represent the mEBG structure [9]. The inductance, *L* is due to the vias effects while the capacitance, *C* is provided by the mEBG patch and gap between the adjacent patches. 9 elements of mEBG patch are investigated to represent the periodic case for EBG structures. For mEBG structure, the gap width between adjacent patches is constant.

3.2 Circular EBG Structure

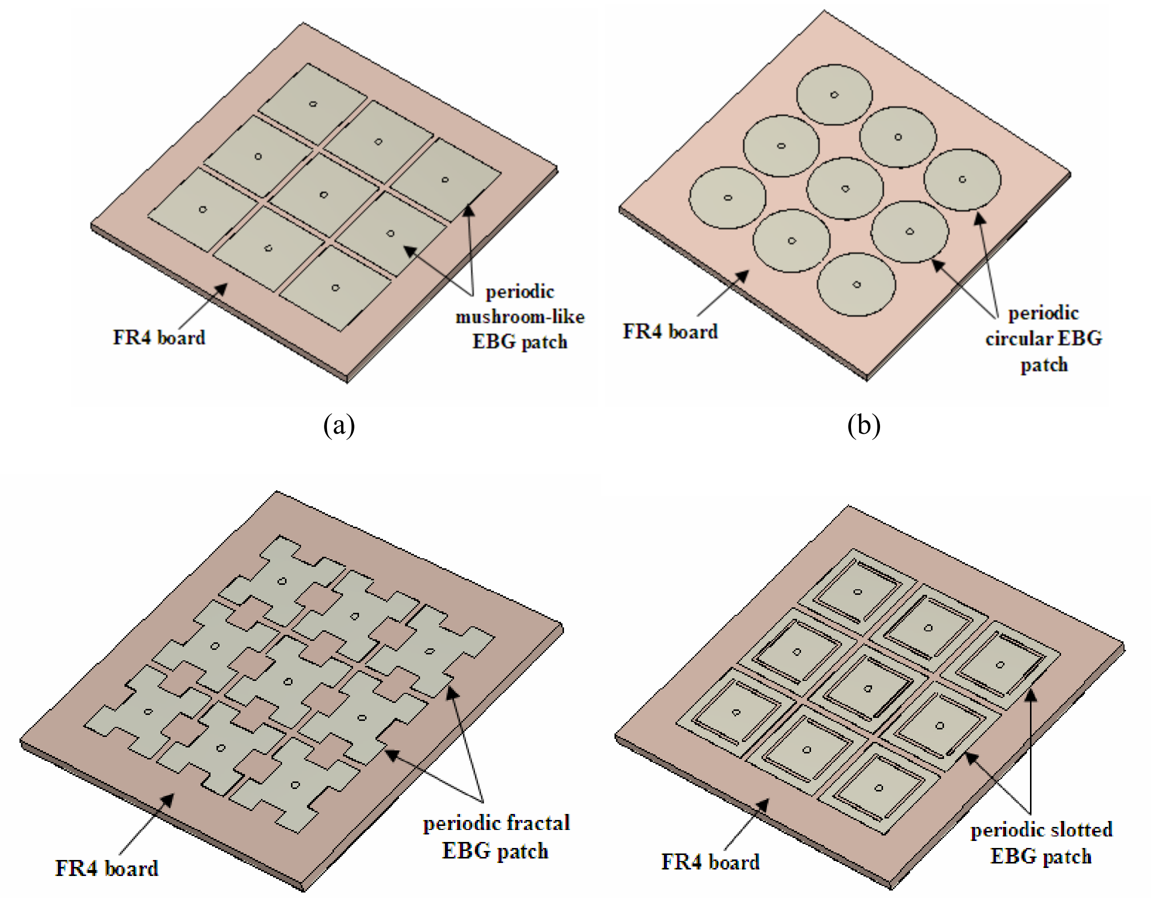
Circular EBG structure as shown in Figure 2 (b) is a structure that consists of circular metallic patch grounded with vias. Compared to the mushroom-like EBG, this structure has a circular shape, which is basically not using the area of the substrate effectively. The gap width between adjacent patches is not constant due to the nature of the circular shape.

3.3 Fractal EBG Structure

In the area of planar antenna design, fractal shape is very popular due to their ability to provide multi-band operating frequencies. Refer to Figure 2 (c), it shows the fractal shape of EBG which has been modified from the original mushroom-like structure. The scaling technique is used to scale down the structure into multiple size of mushroom-like structure which has been combined together in one fractal EBG patch. As same as the circular EBG case, the nature of the fractal shape do not provides the constant gap width between adjacent patches. The total area of the fractal patch also is less compared to the mushroom-like structure.

3.4 Slotted patch EBG Structure

Slotted patch EBG structure is developed by modifies the mushroom-like EBG structure as shown in Figure 2 (d). From the figure, it shows that dual L slots are created by removing certain part of mushroom-like structure. The idea to design this type of shape is to obtain dual stop band frequency.



(c) (d)

Figure 2: Different Shape of Periodic EBG Structure; (a) Mushroom-like EBG (b) Circular EBG (c) Fractal EBG (d) Slotted patch EBG

4. Result and Discussion

Table 1 shows the operating frequency and bandwidth for 4 different shapes of periodic EBG structure. The operating frequency is determined based on the value of S_{21} below -20 dB. Within this frequency ranges, the surface impedance is very high where it can stop the propagation of waves more than 99%.

From table 1, it shows that mushroom-like EBG structure and circular EBG structure provide single stop band frequency ranges. For mushroom-like EBG structure, the operating frequency is between 1.72 GHz and 2.41GHz with frequency bandwidth of 33.9%. For circular EBG structure, the operating frequency is between 1.9 GHz and 2.91 GHz with frequency bandwidth of 43%. It shows that the operating frequency for mushroom-like EBG is lower than the circular EBG and the bandwidth for mushroom-like EBG structure is narrower compared to the circular EBG structure.

For other two cases which are the fractal EBG structure and the slotted patch EBG structure, it shows that these structures provide dual stop band frequency ranges. For fractal EBG structure, the operating frequencies are from 1.92 GHz to 2.54 GHz and from 5.22 GHz to 5.56 GHz with frequency bandwidths of 24.1% and 6.3% for lower and upper frequency band respectively. For slotted patch EBG structure, the operating frequencies are from 1.56 GHz to 1.97 GHz and from 3.7 GHz to 4.72 GHz with frequency bandwidths of 23.4% and 24.4% for lower and upper frequency band respectively. It shows that the operating frequencies for slotted patch EBG structure are lower than fractal EBG structure for both upper and lower band of frequencies. It means that slotted patch EBG structure is winning in term of compactness where it need smaller size to operate at lower frequency band compared to other three cases.

Table 1: The operating frequency and bandwidth of the EBG structures

Type of EBG structure	*Operating frequency (GHz)*	Bandwidth *(%)*
Mushroom-like	1.72 – 2.41	33.9
Circular	1.9 – 2.91	43
Fractal	1.92 – 2.54 5.22 – 5.56	28.1 6.3
Slotted patch	1.56 – 1.97 3.7 – 4.72	23.4 24.4

5. Conclusion

This paper presents four different shape of EBG structures have been designed, simulated and compared in this paper. It shows that for all cases of different EBG shapes, it provide the stop band frequency. For mushroom-like and circular EBG structures, they are operating in single frequency range. For another 2 shapes which are fractal shape and the slotted patch EBG structures, they are operating at dual band stop frequency ranges due to the nature of their shape. Hence, these types of EBG structures are suitable for dual stop band operation in the area of planar antenna and filter design.

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