International Journal of Research in Engineering, Science and Management
Volume-1, Issue-7, July 2018
www.ijresm.com
ISSN (Online): 2581-5782

Design of Dual-Band Circular EBG Antenna for Different Applications

Roopali Gurjar[1], Divya Jain[2]

[1]Research Scholar, Department of Electronics and Communications Engg., Technocrats Institute of Technology, Bhopal, India

[2]Assoc. Professor, Department of Electronics and Communications Engg., Technocrats Institute of Technology, Bhopal, India

***Abstract*: In this paper, electromagnetic band gap (EBG) based dual band circular patch antenna (CPA) have been proposed for the operating frequency range of 2 GHz to 6 GHz. The proposed CPA is developed on FR-4 substrate (εr=4.4) and design three different structures. The first structure of design CPA is resonating at two center frequency of 3.4 GHz, and 5.1 GHz with fractional bandwidth of 210 MHz and 360 MHz respectively. In second design the obtained bandwidth is 160 MHz, return loss is -21.26 dB. In third design the bandwidth is enhanced by 2.57 times as compare of second design and minimum axial ratio is 5.5 at 3.4 GHz center frequency. The obtained resonance frequencies and radiation characteristics are very much suitable for E band and C band applications. The proposed antenna is model and simulated through ansys HFSS software which is based on method of moments (MOM).**

Key words: Dual band, circular patch, EBG, radiation characteristics, HFSS

1. Introduction

In last four decades, wireless communication systems progresses remarkably that demands more superior electromagnetic materials for high-performance applications, and it unlocked up new era in the electromagnetic field. The electromagnetic bandgap (EBG) materials are periodic arrangement of metallic or dielectric elements [1]. These periodic arrangement of elements creates the frequency band gape that prevent the propagation of EM (electromagnetic) wave passing through it and mainly depends on material structure i.e., dimensions, periodicity, and permittivity. EBG structures shows exceptional characteristics in antenna applications to suppressing surface waves and reducing antenna profile [2-3]. EBG based antennas are also known as Fabry–Perot cavity antennas, owing to their ability to enhance the broadside directivity of conventional antennas. These concept is first published by Jackson et al.[4-5] to enhance the gain of antenna. The recent research in EBGs and periodic structures are motivate the researchers to work in this field and advances the wireless system. Some common structures of EBG based antenna are frequency selective surface [6], dielectric slabs [7], and modified substrate and ground plan [8].

Recently, Gao et al [9] presents a circular ring antenna for wearable application with dielectric substrate of thickness of 2 mm work in the range of 2.3 to 2.5 GHz with single bandwidth of about 200 MHz. Zhang at el [10] presents a dual band microstrip patch antenna which is incorporated with pinwheel-shaped electromagnetic band-gap (EBG) structures. The simulation results give dual bands of bandwidth 130 MHz and 140 MHz for frequency of 4 GHz to 8 GHz. Similarly, in articles [11-12], reported a large bandwidth and new prototype for high frequency range. In article [13], a special type of composite patch antenna is presented, in which the mushroom-like electromagnetic band-gap (EBG) structure is grownup on the traditional metallic patch. In article [14] explain a dual-band circularly polarized (CP) electromagnetic band-gap (EBG) resonator antenna (ERA) and obtained maximum gains are 16.1 dBic for left-hand circular polarization (LHCP) and 16.2 dBic for right-hand circular polarization (RHCP), the outcome of the axial ratios are 1.9 dB and 1.5 dB at 9.65 and 11.75 GHz, respectively. Lee [15] presents a 1-D EBG antenna with split ring resonator structures which is embedded between two monopole antennas in order to reduce mutual coupling between them. The reported mutual coupling by more than 42 dB between the two antennas and reduced the back lobes by 6 dB. Liu at el [16] presents a single-fed circularly polarized microstrip patch antenna for ISM band of 2.4-2.48 GHz with capacitive loading techniques. Quan Wei Lin [17], presents a compact and wideband circularly polarized (CP) patch antenna. This patch antenna is designed in such a way that it excites in orthogonal modes of resonance to generate a circularly polarized. Author also used the concept of stacking of substrate to further improve the axial-ratio (AR) as well as bandwidth of the antenna to for different application. The proposed antenna achieves impedance bandwidth of about 42.3%.

Despite of the various advantages like light weight, low profile, easy fabrication and conformability to mounting, the conventional microstrip patch antennas, two major disadvantages that limit its applications are narrow bandwidth and lower gain. In order to overcome the disadvantages of patch antenna, we proposed, a multiband antenna design with improved gain for a basic circular patch. Thus we have designed the three different structures, and the final 3rd design shows better result in order to overcome the above problems. The paper is organized as follows, In section 2, the design of EBG based circular patch antenna will be proposed, In section 3, result and discussion and in section 4, conclusion of the papers will be discussed.

2. EBG based Circular Patch Antenna Design

Microstrip circular patch antenna have been entirely studied in last century. The basic construction of circular patch antenna is identical to that of rectangular patch antenna, both of them having three section, metallic patch on top of the structure and in bottom ground plane is present which is also metallic and a dielectric material substrate is placed between patch and ground plane. Typically the size of the circular patch antenna is determined by the following equations:

$$(f_r)_{mn0} \cong \frac{1}{2L\sqrt{\varepsilon\mu}}\left(\frac{x'_{mn}}{a}\right) \quad (1)$$

Where x'_{mn} is zeros of the bessel function $J_m(x)$ derivative, which is useful for the calculation of the order of the resonant frequency, a is the radius of patch (circular) and other symbol are having standard representation. The initial four value of zeros (x'_{mn}) is specified as: $x'_{11} = 1.8412$, $x'_{11} = 1.8412$, $x'_{21} = 3.0542$, $x'_{01} = 3.8318$ and $x'_{31} = 4.2012$. Based on these values, the resonant frequency of TEM_{110} is given by:

$$(f_r)_{110} \cong \frac{1.8412}{2\pi a\sqrt{\varepsilon\mu}} = \frac{1.8412\ c_0}{2\pi a\sqrt{\varepsilon_r}} \quad (2)$$

Where c_0 has its usual meaning, after considering fringing effect, the effective radius of CP (circular patch) is given by:

$$a_e = a\left\{1 + \frac{2h}{\pi a\varepsilon_r}\ln\left(\frac{\pi a}{2h}\right) + 1.7726\right\}^{\frac{1}{2}} \quad (3)$$

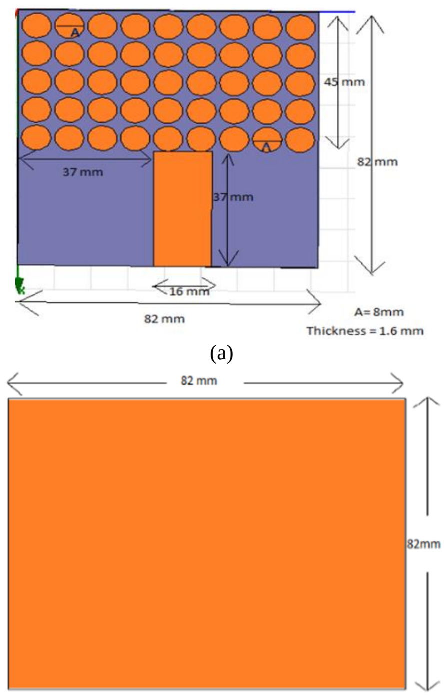
Hence the effective resonant frequency is represented as:

$$(f_r)_{110} \cong \frac{1.8412}{2\pi a\sqrt{\varepsilon\mu}} = \frac{1.8412\ c_0}{2\pi a_e\sqrt{\varepsilon_r}} \quad (4)$$

The fundamental blueprint of CMPA initiate with dielectric material of dielectric constant ε_r, operating frequency f_r(in Hz) and height of CMPA i.e h (in cm) and then we find the measurement of CP using subsequent formula:

$$a = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}*\left\{1+\frac{2h}{\pi a\varepsilon_r}\ln\left(\frac{\pi a}{2h}\right)+1.7726\right\}^{\frac{1}{2}}} \quad (5)$$

A. 1st Design of EBG CPA Model



(a)

(b)

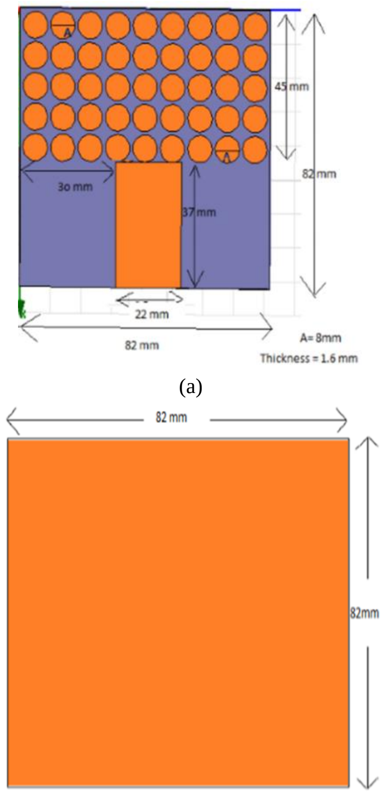
Fig. 1. Proposed geometry-1 (a) Top view (b) Bottom view

The 1st design is an EBG CPA with 45 mushroomed circular patch of radius of 4 mm is implanted. The radiating part of patch is a matrix of mini circular patches with 5 rows and 9 columns. For the excitation of presented design we use a feed line with step indexing of dimension shown in fig. 2. The ground plane and substrate has equal area of dimension 82 x 82 mm^2 x and height of 1.6 mm. we use metallic copper for radiation in both patch and ground plane.

The feeding line is made up of rectangular section which is connected to the main circular ring has dimension of 37 mm × 16 mm which feed 5th and 6th circle in Y axis, detail of the proposed design is shown in Fig. 1.

B. 2nd Design of EBG CPA Model

In the 2nd design we use almost same as that of first design the only change is in the thickness of feed line, the radius of circular patches are is 4 mm as shown in Fig. 2. The CPA is energized by a feed line of measurement 37 mm x 22 mm. The ground plane and substrate has equal area of dimension 82 x 82 mm^2 and height of 1.6 mm. Ground plane and patches are metallic copper.



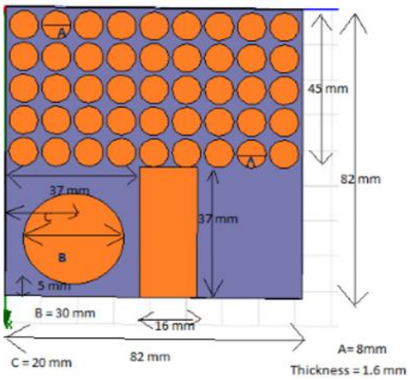
(a)

(b)

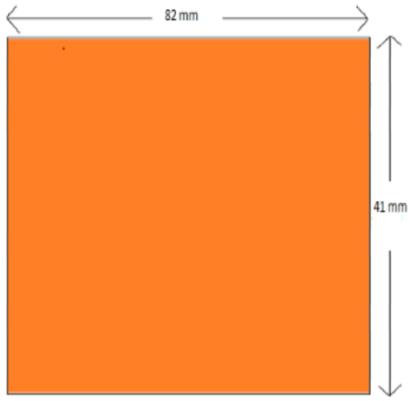
Fig. 2. Proposed geometry-2 (a) Top view (b) Bottom view

C. 2nd Design of EBG CPA Model

The third design is a Modified ground EBG Based CPA which is developed by the finding of above proposed two antennas, here we introduced an extra circular patch which is implanted on the major circular patch with radius of 15 mm and other circular patch with radius of 4 mm, for the excitation of presented design we use a feed line of dimension 37 mm × 16 mm which feed 5th and 6th circle in Y axis, the feed line is same as that of first proposed design, the radiating patch is increased by adding extra circular patch of radius of 15 mm described above shown in Fig. 3. This strip line generates enhanced result in provisions of larger bandwidth and dual operating bands. The substrate has equal area of dimension 82 82 mm^2 x and height of 1.6 mm. Ground plane is metallic copper with modification in this design the dimension of ground plane is reduced by half in X axis and its dimension is 41 x 82 mm^2.



(a)



(b)

Fig. 3. Proposed geometry-3 (a) Top view (b) Bottom view

3. Results and Discussion

The simulation result carried out on HFSS software for the different proposed antennas are presented in this section. We have analysis the performance of proposed antenna in terms of Peak Gain, VSWR, Return loss (S11), Bandwidth, number of radiating bands and axial ratio.

A. First Proposed Antenna Design

Simulation results for 1st Design of printed EBG based CPA Model is discussed in this section.

The Fig. 4, shows the return loss graph generated from the simulation of 1st proposed design. In this design we achieved, only one operating band of very large bandwidth. At this point, the bandwidth for VSWR ≤ 2 and fractional bandwidth of about 520 MHz at center frequency of 5 GHz. The obtained minimum return loss is -21.098 dB.

The Fig. 5, shows the VSWR graph generated from the simulation. The minimum VSWR is achieved at frequency of 5 GHz and its value is 1.93.

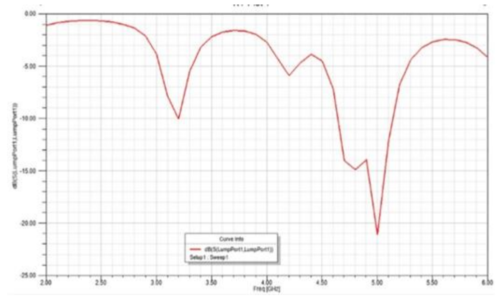


Fig. 4. Return loss for 1st design of EBG CPA model

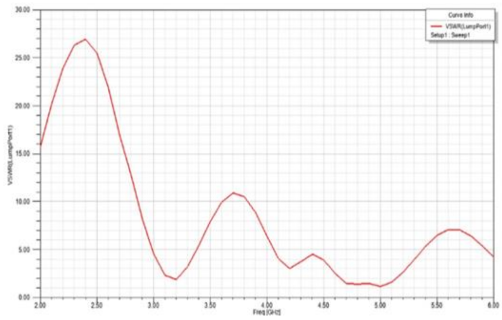


Fig. 5. VSWR in dB of simulation result for 1st design of EBG CPA model

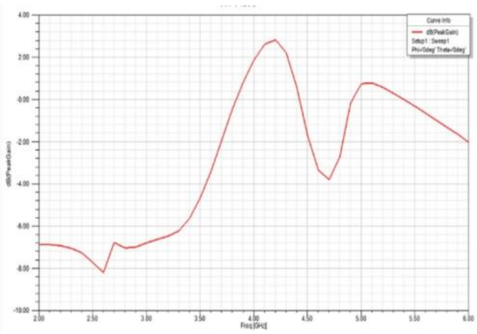


Fig. 6. Gain for 1st design of EBG CPA model

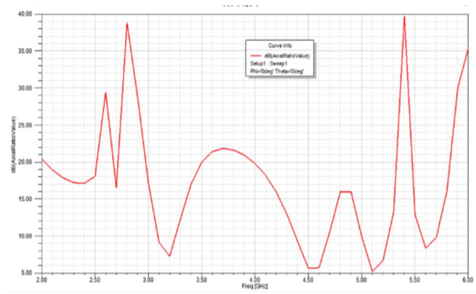


Fig. 7. Axial ratio of 1st design of EBG CPA model

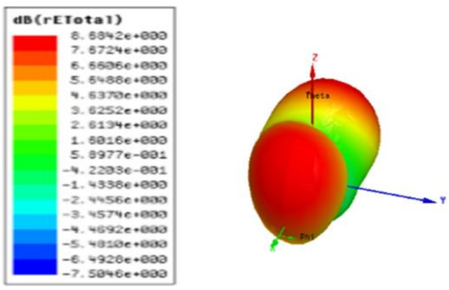


Fig. 8. Far field radiation pattern of 1st design of EBG CPA model

International Journal of Research in Engineering, Science and Management
Volume-1, Issue-7, July 2018
www.ijresm.com ISSN (Online): 2581-5782

The Peak gain of proposed design is shown in Fig. 6, and axial ratio is displayed in Fig. 7, the minimum axial ration for the 1st design at radiating frequency is found to be 9.95 dB at 5 GHz frequency.

B. Second Proposed Antenna Design

The Fig. 9, shows the return loss graph generated from the simulation of 2nd proposed design. In this design we achieve two operating bands with center frequency 3.1 and 4.7 GHz. At this point, the bandwidth for VSWR ≤ 2 or or return loss less than -10 dB is calculated in which we found that the design 2 has BW of about 160 MHz at 3.1 GHz and 140 MHz at 4.7 GHz frequency that means the design has dual band of operation for -10 dB return loss point. The minimum return loss is achieved at frequency of 3.1 GHz and its value is -21.26 dB.

The Peak gain of proposed design is shown in Fig. 11, and axial ratio is shown in Fig. 12, and we find the peak gain of -6.44 dB and -2.07 dB at 3.1 GHz and 4.7 GHz respectively. On the other hand the minimum axial ration for the 2nd design at radiating frequency is found to be 28.76 dB at 3.1 GHz frequency and axial ratio at 4.7 GHz is 42.49 dB.

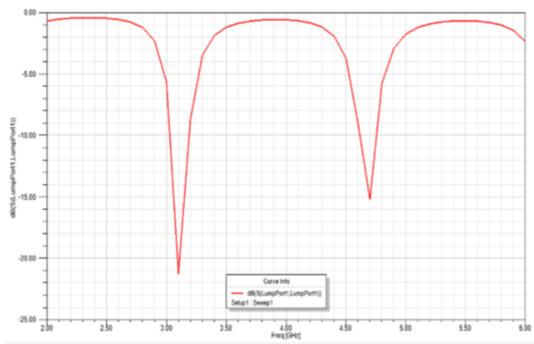


Fig. 9. Return loss of 2nd design of EBG CPA model

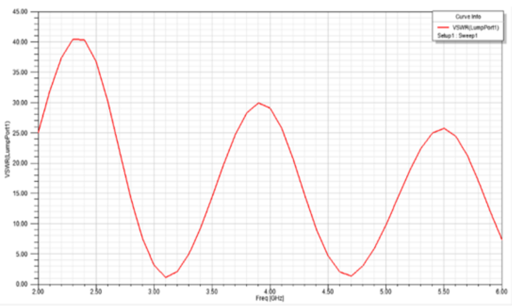


Fig. 10. VSWR of simulation result of 2nd design of twin CPA model

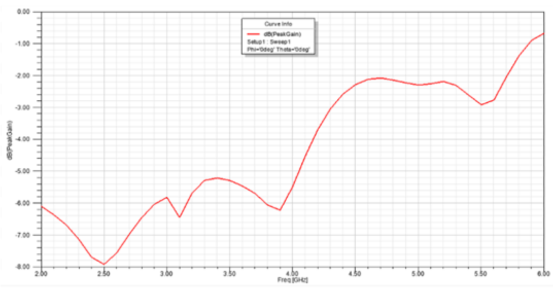


Fig. 11. Peak gain of 2nd design of EBG CPA model

The Fig. 10, shows the VSWR graph generated from the simulation. The minimum VSWR is achieved at frequency of 3.1 GHz and its value is 1.19.

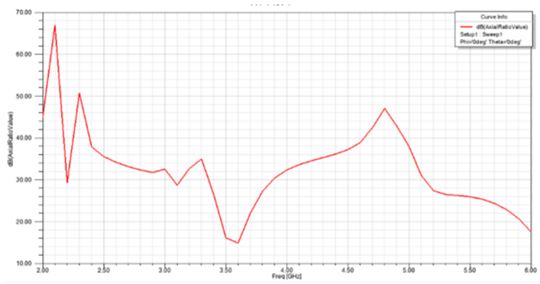


Fig. 12. Axial ratio of 2nd design of EBG CPA model

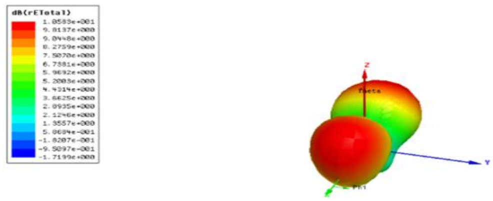


Fig. 13. Far field pattern of 2nd design of EBG CPA model

The three dimensional radiation pattern for 2nd design is shown in Fig. 13, and it is found to be peak radiation of about 10.58 dB.

C. Third Proposed Antenna Design

The result for 3rd design of modified ground EBG Based CPA model will be discussed, which has again dual bands of operations with larger bandwidth at 3.4 GHz and 5.1 GHz.

The Fig. 14, shows the return loss graph generated from the simulation of 3rd proposed design. In this design we achieve dual strong operating band, hence we calculate the various performance parameter for all dual wide-range of operation with center frequency 3.4 GHz and 5.1 GHz. At this point, the bandwidth for VSWR ≤ 2 or or return loss less than -10 dB is calculated in which we found that the design 3 has BW of about 210 MHz, and 360 MHz at 3.4 GHz and 5.1 GHz respectively, that means the design has two band of operation for -10 dB return loss point. The minimum return loss is achieved at frequency of 3.4 GHz and its value is -20.15 dB.

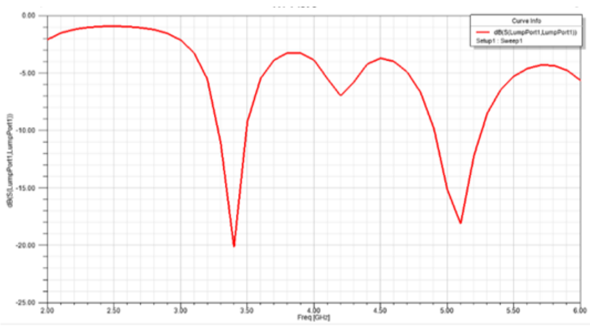


Fig. 14. Return loss of 3rd design of modified ground EBG based CPA model

The Fig. 15, shows the VSWR graph generated from the simulation. The minimum VSWR is achieved at frequency of 3.4 GHz and its value is 1.21.

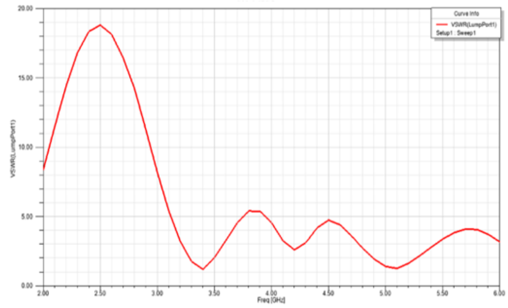


Fig. 15. VSWR of simulation result of 3rd design of modified ground EBG based CPA model

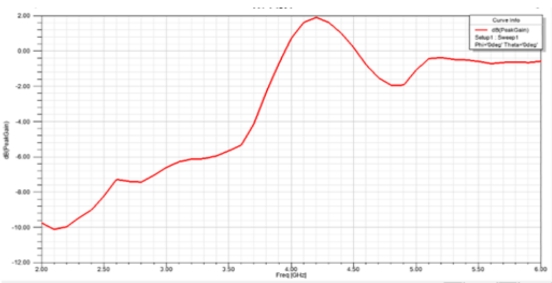


Fig. 16. Peak gain of 3rd design of modified ground EBG based CPA model

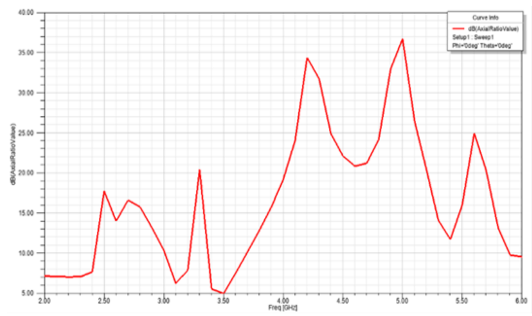


Fig. 17. Axial ratio of 3rd design of modified ground EBG based CPA model

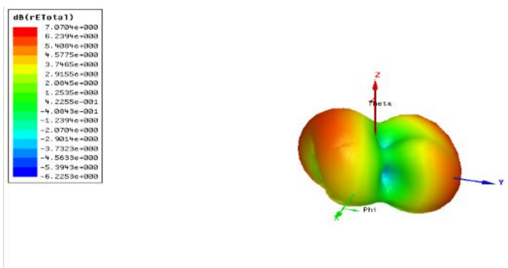


Fig. 18. Far field pattern of 3rd design of modified ground EBG based CPA model

The Peak gain of proposed design is shown in Fig. 16, and axial ratio is shown in Fig. 17, and we find the peak gain of – 0.43 dB at 5.1 GHz. On the other hand the minimum axial ration for the 3rd design at radiating frequency is found to be 5.5 dB at 3.4 GHz frequency and axial ratio at 5.1 GHz is 26.48 dB. The three dimensional radiation pattern for 3rd design is shown in Fig. 18, and it is found to be peak radiation of about 7.07 dB.

4. Conclusion

We have studied and analysis of customized circular EBG Patch antenna with third different structures, in the third design, we observed the dual operating bands at center frequency of 3.4 GHz, and 5.1 GHz with bandwidth of 210 MHz and 360 MHz respectively. Also we observed peek Gain of -0.43 dB at corresponding resonance frequency of 5.1 GHz and minimum axial ration of 5.5 dB at 3.4 GHz frequency which makes our proposed antenna as circularly polarized antenna. In second design we monitor that its bandwidth is 160 MHz and obtained return loss is -21.26 dB which is better than of other designs, except its peak gain which is -6.44 dB. In third design the bandwidth is enhanced by 2.57 times as compare of second design. The operating bands of third design is more than that of first design. After studying the simulation results of Table-1, we can wrap up with the fact that embedding of various parasitic EBG patches and additional CP (circular patch) improve the multi-band capability of MPA. On the other hand large impedance parasitic patch can enhance the Gain of antenna along with satisfactory bandwidth and return loss.

Table-1
Radiation characteristics of all the proposed designed antenna

Design	Radiating Frequency (GHz)	BW(-10dB) \(MHz)	Gain (dB)	Return Loss (dB)	VSWR	Axial Ratio (dB) minimum
1st	5	520	0.75	-21.098	1.93	9.95
	3.1	160	-6.44	-21.26	1.19	28.76
2nd	4.7	140	-2.07	-15.19	1.42	42.49
	3.4	210	-5.94	-20.15	1.21	5.5
3rd	5.1	360	-0.43	-18.10	1.28	26.48

References

[1] Berger, V., O. Gauthier-Lafaye, and E. Costard. "Fabrication of a 2D photonic bandgap by a holographic method." *Electronics letters,* 33.5 (1997): 425-426.

[2] Yang, Fan, and Yahya Rahmat-Samii. Electromagnetic band gap structures in antenna engineering. Cambridge, UK: Cambridge university press, 2009.

[3] Weily, Andrew R., et al. "A planar resonator antenna based on a woodpile EBG material." *IEEE Transactions on Antennas and Propagation*, 53.1 (2005): 216-223.

[4] Jackson, David, and N. Alexopoulos. "Gain enhancement methods for printed circuit antennas." *IEEE transactions on antennas and propagation* 33.9 (1985): 976-987.

[5] Jackson, David R., et al. "The fundamental physics of directive beaming at microwave and optical frequencies and the role of leaky waves." *Proceedings of the IEEE,* 99.10 (2011): 1780-1805.

[6] Moustafa, Lina, and Bernard Jecko. "Broad band high gain compact resonator antennas using combined FSS." *Antennas and Propagation Society International Symposium*, 2008. AP-S 2008. IEEE. IEEE, 2008.

[7] Zeb, Basit Ali, et al. "A simple dual-band electromagnetic band gap resonator antenna based on inverted reflection phase gradient." *IEEE Transactions on Antennas and Propagation*, 60.10 (2012): 4522-4529.

[8] Weily, Andrew R., et al. "A planar resonator antenna based on a woodpile EBG material." *IEEE Transactions on Antennas and Propagation* 53.1 (2005): 216-223.

[9] Gao, Guo-Ping, et al. "Wearable Circular Ring Slot Antenna With EBG Structure for Wireless Body Area Network." *IEEE Antennas and Wireless Propagation Letters*, 17.3 (2018): 434-437.

[10] Zhang, Xiaoyan, et al. "A dual band patch antenna with a pinwheel-shaped slots EBG substrate." *International Journal of Antennas and Propagation,* 2015 (2015).

[11] Hashmi, Raheel M., Basit A. Zeb, and Karu P. Esselle. "Wideband high-gain EBG resonator antennas with small footprints and all-dielectric superstructures." *IEEE Transactions on Antennas and Propagation*, 62.6 (2014): 2970-2977.

[12] Haraz, Osama M., et al. "Dense dielectric patch array antenna with improved radiation characteristics using EBG ground structure and dielectric superstrate for future 5G cellular networks." *IEEE Access 2* (2014): 909-913.

[13] Xu, Wei-Wei, et al. "A novel microstrip antenna with composite patch structure for reduction of in-band RCS." *IEEE Antennas Wireless Propag. Lett*.,14 (2015): 139-142.

[14] Zeb, Basit Ali, Nasiha Nikolic, and Karu P. Esselle. "A high-gain dual-band EBG resonator antenna with circular polarization." *IEEE Antennas and Wireless Propagation Letters*, 14 (2015): 108-111.

[15] Lee, Jae-Yeong, Seung-Han Kim, and Jae-Hyung Jang. "Reduction of mutual coupling in planar multiple antenna by using 1-D EBG and SRR structures." *IEEE Transactions on Antennas and Propagation,* 63.9 (2015): 4194-4198.

[16] Liu, Changrong, Yong-Xin Guo, and Shaoqiu Xiao. "Capacitively loaded circularly polarized implantable patch antenna for ISM band biomedical applications." *IEEE Transactions on Antennas and Propagation,* 62.5 (2014): 2407-2417.

[17] Lin, Quan Wei, et al. "Printed meandering probe-fed circularly polarized patch antenna with wide bandwidth." *IEEE Antennas and Wireless Propagation Letters,* 13 (2014): 654-657.

[18] Sun, Chao, et al. "Analysis and design of a novel coupled shorting strip for compact patch antenna with bandwidth enhancement." *IEEE Antennas and Wireless Propagation Letters*, 13 (2014): 1477-1481.