Design of Multi-Band Indexed Circular EBG Antenna for Different Applications

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Abstract- As we know that the application range of RPA i.e Rectangular microstrip patch antenna is exceptionally large for example Mobile cell phone, WiFi dongle etc. the requirement of distinct antenna applicable for extensive range of applications like 4G, 5G and GSM technology support us as to plan a multiband antenna with enhanced bandwidth. Thus in this manuscript we presented Indexed Circular EBG based patch with three designs and on the basis of understanding the various results of different proposed design we anticipated a modified indexed EBG based circular patch antenna (CPA) finally which has working range of 2 GHz to 6 GHz. The proposed CPA is developed on FR-4 substrate (εr=4.4) of thickness 1.6 mm. After studying the simulation results we can wrap up with the fact that embedding of various indexed Circular EBG patches and additional CP (circular patch) improve the multi-band capability of MPA. On the other hand large impedance circular parasitic patch can enhance the Gain of antenna along with satisfactory bandwidth and return loss.

Keywords-Electromagnetic band gap (EBG), EBG resonator antenna (ERA), Step Indexed EBG, Peak Gain, Axial Ratio.

I. INTRODUCTION

As the innovation changes quickly, there is an incredible interest of compact size, large bandwidth, low cost, and multi-band of operation in any modern wireless communication system. Antenna is an indispensable component in recent communication system. In rejoinder to this demand, in present days many planar Antennas with large bandwidth and multi-band performances have received extensive attention. Various techniques and methodologies had been investigated in past days for designing of such Antennas. As the application range of patch antenna (PA) is very wide such as WiFi, cell phone, etc. the requirement of a single antenna which is applicable for wide range applications like satellite communication, 4G and 5G technology encourage us as to design a multiband antenna with better bandwidth. Hence in this paper we proposed two novel design based on indexed circular patch, is presented and improving from first design we proposed a final modified indexed circular EBG antenna which is used for multi-band operation for 1 GHz to 6 GHz of frequency range. The rest of the paper is structured in following sections. Section II, describe the basic concepts and equations for Circular Patch Antenna (CPA). Section III presents two indexed circular EBG patch antenna designs proposed. Section IV describes the simulation results and different figure of merits using HFSS software for the presented designs, and finally, in section V conclusion and future work is presented.

II. CHARACTERISTIC OF CPA

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 substrate in between and ground plane in bottom as shown in figure 1. The fundamental blueprint of CPA initiate with dielectric material of dielectric constant ε_r, operating frequency f_r(in Hz) and height of CPA i.e h (in cm) and then we find the measurement of CP using subsequent formula:

$$a = \frac{F}{\left\{1+\frac{2h}{\pi a\,\varepsilon_r} ln\left(\frac{\pi a}{2h}\right)+1.7726\right\}^{\frac{1}{2}}} \text{ …………………….. (1)}$$

Where,

$$F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}} \text{ ……………….……………. (2)}$$

Where f_r is the effective resonant frequency represented by:

$$(f_r)_{110} \cong \frac{1.8412}{2\pi a\sqrt{\varepsilon\mu}} = \frac{1.8412\; c_0}{2\pi a_e\sqrt{\varepsilon_r}} \text{ …………………. (3)}$$

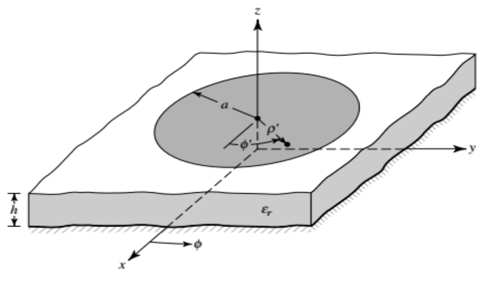

Figure 1: Geometry of Circular Microstrip Patch Antenna

III. PROPOSED INDEXED EBG ANTENNA

In this section we have presented two unique design of Indexed EBG Patch antenna structure the proposed design is made up on a glass epoxy FR-4 (εr =4.4) dielectric material with thickness of 1.6 mm. We use two design in both we are using Indexed circular patch in EBG configuration but different shape and introduction of parasitic circular patch in second proposed design. In both design we use 35 circular patch in step indexed manner in such a way that each row is decreased by one circular patch from the previous one shown in subsequent sub sections.

A. Indexed EBG CPA without Parasitic Patch

First proposed design is a is a EBG CPA with 35 mushroomed circular patch of radius of 4 mm each is implanted, [4,5,6] with indexing effect, the radiating part of patch is a matrix of mini circular patches with 5 rows and 9 columns with reducing one circular patch in each row. this design is used to analysis the effect of step indexing on the performance of antenna. The presented antenna is excited by a feed line of 37 mm x 16 mm. which is shown in the Figure 2.

The ground plane and substrate has equal area of dimension 82 x 82 mm2 x and height of 1.6 mm. we use PEC for radiation in both patch and ground plane.

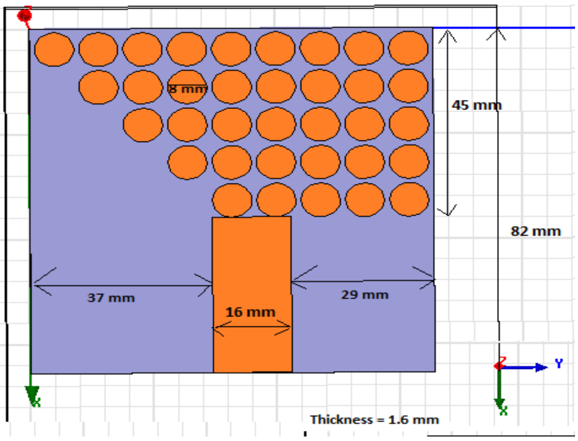

Figure.2 Top View of 1st Design Model.

The feeding line is made up of rectangular section which is connected to the main circular ring has dimension of 37 mm × 16 mm stated above, The bottom view of substrate, is shown in Fig.3.

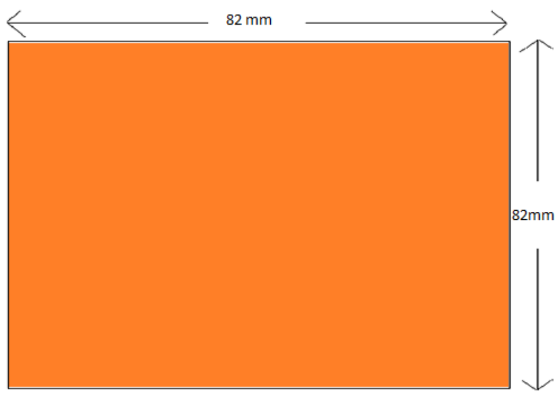

Figure.3 Bottom view of 1st Design ground plane.

B. Step Indexed EBG CPA without Parasitic Patch

In the second design we again use same indexed circular EBG with three extra circular patch which is implanted on the basic indexed patch structure with radius of 17 mm, 9 mm and 10 mm, for the excitation of presented design we use a feed line of dimension 37 mm × 24 mm which feed 5th and 6th circle in Y axis, the radiating [10,11,12] part of patch is increased by adding one extra circular patch of radius of 4 mm in each rows in step indexed manner as shown in figure 4.

The ground plane and substrate has equal area of dimension 82 x 82 mm2 x and height of 1.6 mm. we use PEC for radiation in both patch and ground plane as shown in fig. 3.

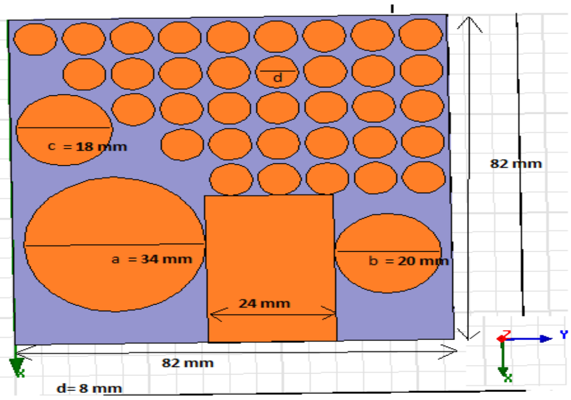

Figure.4 Bottom View of 2nd Design Ground Plane.

IV. RESULTS

The most important figure of merits [10,13] we have taken in account for Antenna design are Peak Gain, VSWR, Return loss (S11), Bandwidth, number of radiating bands and Axial ratio. The results obtained in the presented design we get triple-band. We observed that the final second design gives three operating bands at center frequency of 3.2 GHz, 4.7 GHz and 5.9 GHz with bandwidth of 120 MHz, 162 MHz, and 253 MHz respectively. We also obtained peek Gain of 2.14 dB at 5.9 GHz. In first design we monitor that its bandwidth is 500 MHz at 5 GHz frequency and obtained return loss is -17.53 dB which is not as per our multiband requirement, its peak gain which is 0.78 dB only, the summary of overall results is tabled in table 1 and table 2.

Table 1: Result analysis of First Design.

Radiating Frequency (GHz)	BW (-10dB) (MHz)	Gain (dB)	Return Loss	VSWR	Axial Ratio (dB) minimum
5	500	0.78	-17.53	1.30	12.05

In the figure 5, 6, 7, 8 and 9 represents return loss S11, VSWR, Peak Gain, and Axial Ratio for 1st design. The minimum return loss is achieved at frequency of 5 GHz and its value is -17.53 db on the other hand the minimum VSWR is achieved at frequency of 5 GHz and its value is 1.30. The minimum return loss is achieved at frequency of 5 GHz and its value is -17.53 db

The minimum VSWR is achieved at frequency of 5 GHz and its value is 1.30. The Peak gain of proposed design and axial ratio are 0.78 dB 12.05 dB respectively at 5 GHz frequency.

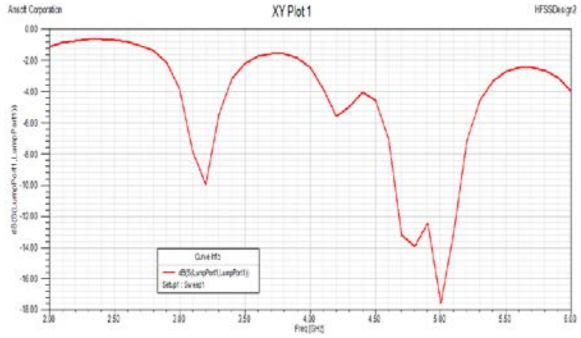

Figure 5: Return loss of simulation result for Design 1 with FR-4 substrate.

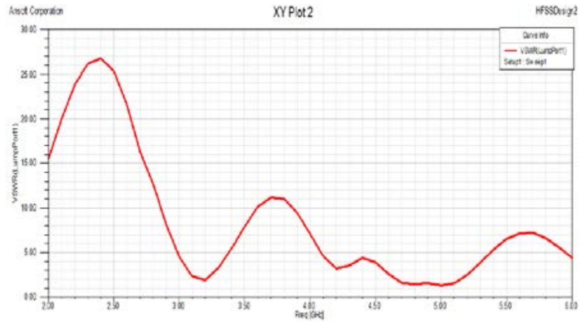

Figure 6: VSWR of simulation result for Design 1 with FR-4 substrate.

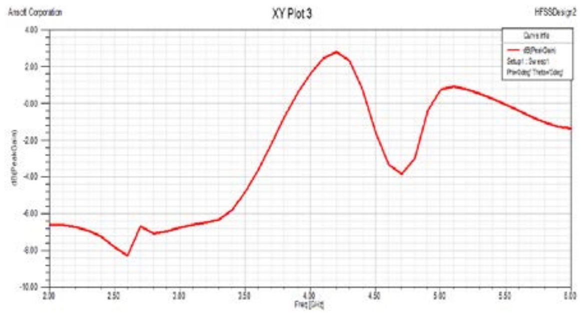

Figure.7: Peak Gain of simulation result for Design 1 with FR-4 substrate.

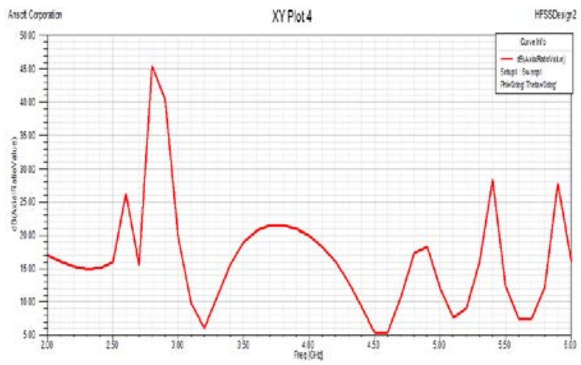

Figure.8: Axial Ratio of simulation result for Design 1 with FR-4 substrate.

Table 2: Result analysis of Second Design With FR-4 substrate.

Radiating Frequency (GHz)	BW (-10dB) (MHz)	Gain (dB)	Return Loss	VSWR	Axial Ratio (dB) minimum
3.3	120	-2,14	-17.0	1.33	14.69
4.7	162	-0.28	-22.34	1.16	12.73
5.9	253	2.14	-21.25	1.19	20.59

In the figure 9, 10, 11 and 12 represents return loss S11, VSWR, Peak Gain and Axial Ratio for second design.

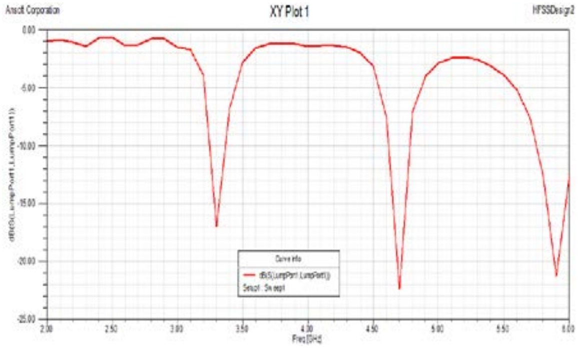

Figure.9: Return loss of simulation result for Design 2 with FR-4 substrate.

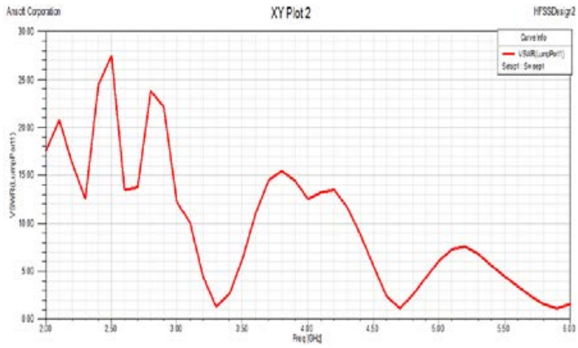

Figure.10: VSWR of simulation result for Design 2 with FR-4 substrate.

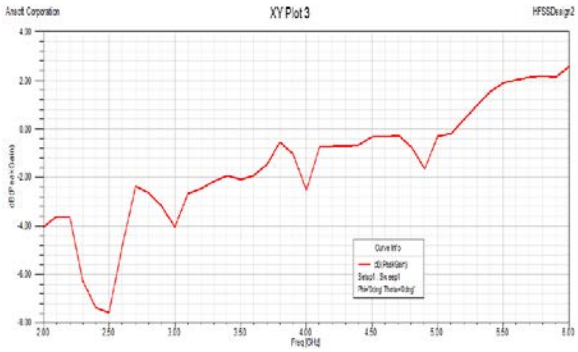

Figure.11: Peak Gain of Simulation result for Design 2 with FR-4 substrate.

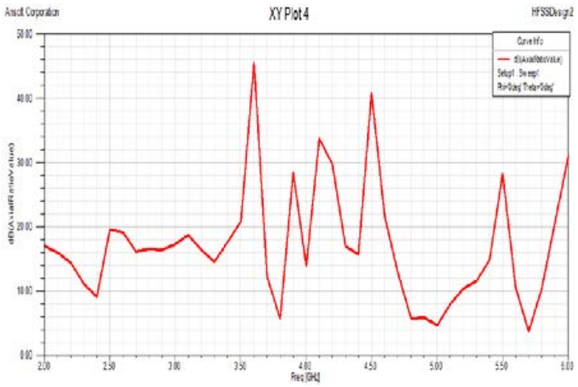

Figure.12: Axial Ratio of simulation result for Design 2 with FR-4 substrate.

V. CONCLUSION

In this paper a customized circular EBG Patch Antenna design and analysis has been presented. We observed that the final third design gives three operating bands at center frequency of 3.3 GHz, 4.7 GHz and 5.9 GHz with bandwidth of 120 MHz, 162 MHz and 253 MHz respectively. We also obtained peek Gain of 2.14 dB at 5.9 GHz. We can wrap up with the fact that embedding of various parasitic circular EBG patches along with step indexed structure, 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.

Thus for all proposed design we can see that the introduction of Indexed EBG increase the number of operating band along with improved Gain and Bandwidth.

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