

# Design and Performance Analysis of Wide Band Circularly Polarized EBG Microstrip Antenna for Base Station Applications

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## Abstract

Over the past decades, there is a rapid growth in development of various EBG antennas. The performance of all such EBG antennas depends on the design and proper selection of the antenna dimensions. This paper presents design of two antennae and their performance analysis. The best performed antenna is fabricated and results are validated. The proposed antenna is designed at 2.4GHz which is suitable for GPS and base station applications. The fabricated antenna provides circular polarization with wider bandwidth.

## Keywords

Low Profile Microstrip Patch Antennas (LFMPAs), Electromagnetic Band Gap (EBG), Microstrip Patch, High Frequency Structure Simulator (HFSS), Circular Polarization (CP), Bandwidth.

## I. Introduction

Low Profile Microstrip Patch Antennas (LFMPAs) are widely used in WLAN base station and GPS applications. Single feed microstrip antennas are usually more compact when compared to dual-feed circularly polarized microstrip antennas [1].

Various methods for single-feed circularly polarized microstrip antennas have been published in the literature. A method has been proposed to make circularly polarized radiation for a square patch using the truncated- corners method and a rectangular slot embedded at the square patch's center [2]. However, the truncated-corners method did not provide any size reduction and parametric study has not been considered regarding bandwidth. Later, established a single-feed circularly polarized technique using a cross slot embedded at the center of the circular patch [3]. The antenna structure was based on a proximity feed. A coaxially fed cross-slot circular patch antenna was also proposed [4]. The circularly polarized radiation could be achieved with a circular microstrip-patch antenna by using a tuning stub [5]. However, the tuning-stub method is expensive to manufacture and also was not useful for a compact circularly polarized microstrip-antenna design. The circular-ring microstrip antenna with two symmetrical inner stubs can also be used for circular polarization [6].

Recently, single feed circular patch antenna with circular polarization was proposed by embedding circular holes in microstrip resonator [13]. Simply embedding two circular slots can stimulate two orthogonal near-degenerate modes. With proper size and position of two slots on circular patch, single band and dual band CP operation can be generated separately. Good impedance matching and axial ratio for both single band and impedance matching for dual band operation are achieved, but bandwidth and radiation pattern obtained was poor [7].

Also it is reported that a new type of EBG Microstrip antenna is designed in which again bandwidth and radiation pattern found meager. In our project, circular microstrip patch is employed, since many literatures say the circular patch shows better directivity and provides more gain. The first antenna is designed and analysed on circular microstrip patch over which two dissimilar circular, hexagonal, square and ring slots are etched, then in the second antenna design, the hexagonal slots are omitted. The optimized design is then analysed with respect to their performances like return loss, bandwidth, radiation pattern and axial ratio.

## II. First Antenna Design

Both antennas are designed with circular microstrip patch. The patch radius  $a$ , can be determined by using following equation [14],

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \epsilon_r F} \left[ \ln \left( \frac{\pi F}{2h} \right) + 1.7726 \right] \right\}^{1/2}} \quad (1)$$

Where,

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\epsilon_r}} \quad (2)$$

$h$  = Height of substrate

$\epsilon_r$  = Dielectric constant of substrate

$f_r$  = Resonant frequency

Equation (1) does not take into consideration the fringing effect. Since fringing makes the patch electrically larger, the effective radius of patch,  $a_e$ , is used and is given by [14],

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

Hence, the resonant frequency for the dominant TM<sub>z</sub>110 is given by [14],

$$(f_r)_{110} = (1.8412V_0) / (2\pi a_e \sqrt{\epsilon_r}) \quad (4)$$

Where,  $v_0$  is the free space light speed.

Initially, a circular microstrip patch antenna is designed with radius 15.8mm. The patch is placed above the FR4 Epoxy substrate having dimension 60mmx60mmx1.6mm with ground plane dimension 60mmx60mm. On diagonal line two dissimilar circular slots are made over the main circular patch. The bigger circular slot has radius 5.5 mm and the smaller one has radius of 3mm. Then EBG slots are prepared over the main patch. Diagonally and near to outer circumference of bigger circular slot five hexagonal slots having radius of 0.5mm is made and on right side of the bigger circular slot, six numbers of 2mmx2mm square slots are etched.

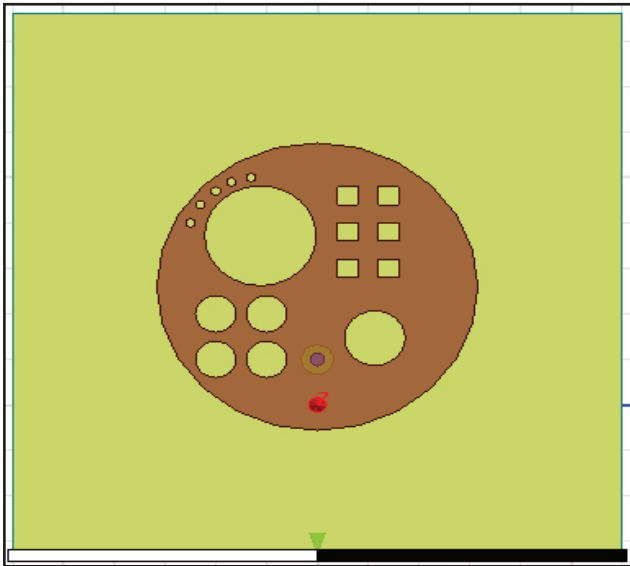


Fig. 1: First Antenna Design: Microstrip Antenna with EBG Structures of Hexagonal, Square and Small Circular Slots

And below the big circular slot again four circular slots of radius 2mm are designed. The feeding point is set at 8mm from centre of the main patch. The designed antenna with EBG structure is as shown in the fig. 1.

### III. Second Antenna Design

For the second antenna design, the previous antenna design is used with small alteration. Both first and second antennas are designed and simulated using High Frequency Structure Simulator (HFSS). After repeated optimization to meet resonant frequency of 2.4 GHz, the various antenna dimensions are found as mentioned below.

The total antenna size is length x width x height=60mm x 60mm x 1.6mm with ground plane of 60mm x 60mm. Substrate used is FR4 epoxy material having dielectric constant of 4.4. The main circular microstrip patch radius is 15.8mm.

Big slotted ring has radius of 5.5mm and that of small ring has radius of 2.75mm. Regarding EBG, the four circular holes have 1.7mm radius with 1mm gap between them. The six numbers of identical square holes have 3mm x 3mm dimension with 2mm gap between them. The antenna is excited by co-axial feed near small slotted ring at resonant frequency of 2.4GHz as shown in the fig. 2.

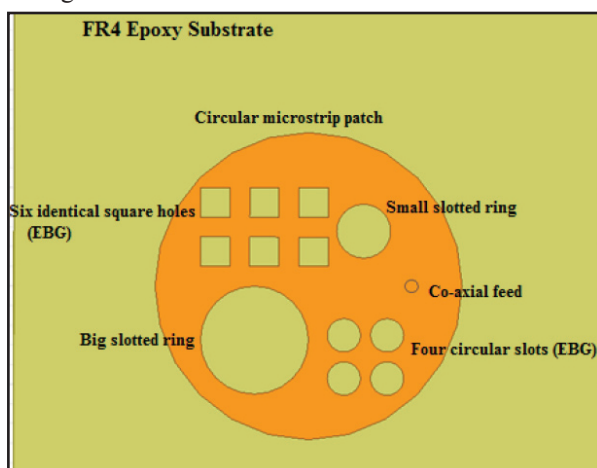


Fig. 2: Proposed Second Antenna with Square and Small Circular Slots

## IV. Simulated Result

### A. First Antenna

The size of the perturbation and feed point are two important parameters to obtain CP, which were optimized using HFSS to obtain desired axial ratio Band Width (BW). The resonating frequency is set at 2.4GHz. The s11 graph, axial ratio, gain and radiation pattern are obtained and is shown respectively in the fig. 3, fig. 4, fig. 5 and fig. 6. The return loss at 2.4GHz is 18.7342, axial ratio is 2.4895dB, and gain is 1.387dBi at theta 00. The bandwidth at 10dBi is 100MHz.

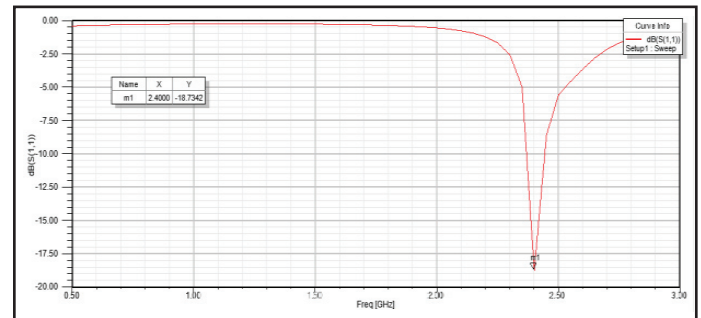


Fig. 3: Return Loss versus Frequency Graph of First Antenna Design

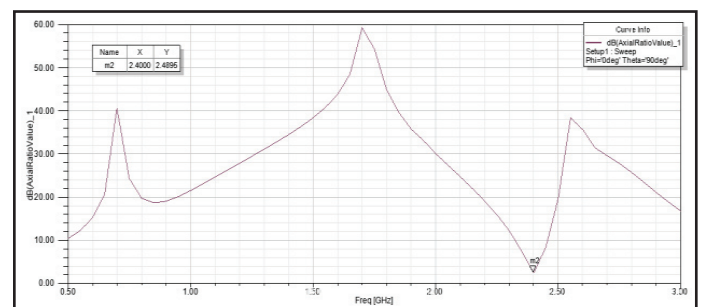


Fig. 4: Axial Ratio for First Antenna Design

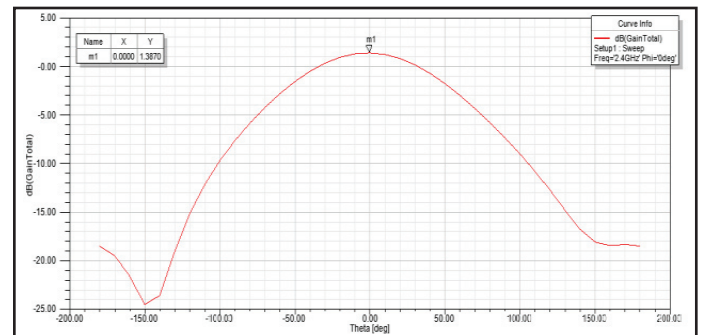


Fig. 5: Gain Plot for First Antenna Design

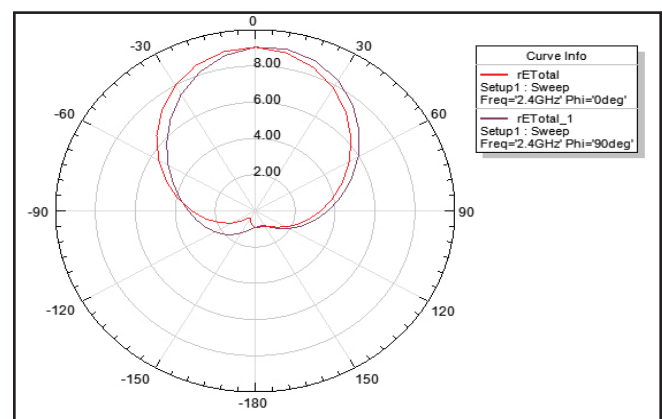


Fig. 6: Radiation Pattern of First Antenna Design.

## B. Second Antenna

Initially, the circular microstrip patch with slots symmetrically located at slanting procession is started. In that case, the radii and the position from the patch center of the both slots were the same. However, in order to attain wide bandwidth, circular polarization and impedance matching for specific band, slots dimension and position need to be adjusted accordingly.

Computed input return loss trace of single band for the proposed antenna is shown in fig. 7 which shows the return loss of 35.3953dB. The antenna has bandwidth extends from 2.3654GHz-2.5455GHz (180.1MHz) within 10dB return loss. Figure 8 shows the antenna radiation pattern. It is observed that the resulted pattern is best and gain obtained is 1.6566dB as shown in the fig. 9.

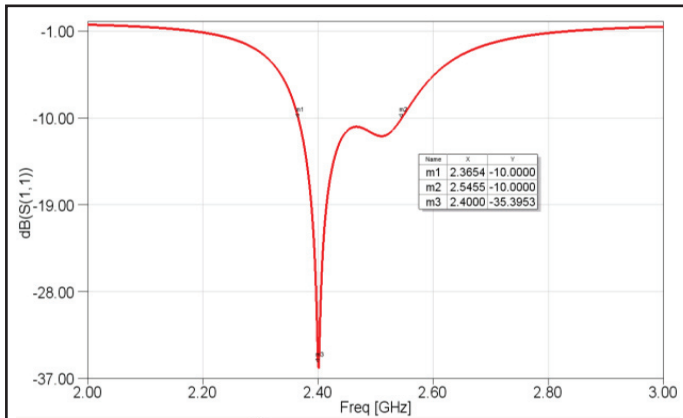


Fig. 7: Simulated S-parameter (s11) Graph of the Second Antenna

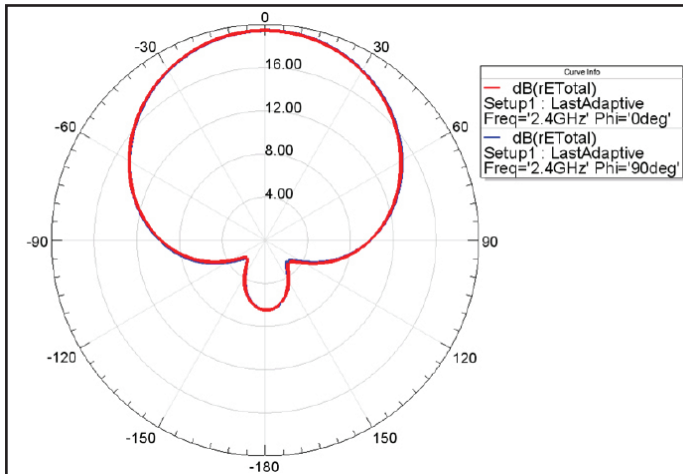


Fig. 8: Radiation Pattern Plot of Second Antenna

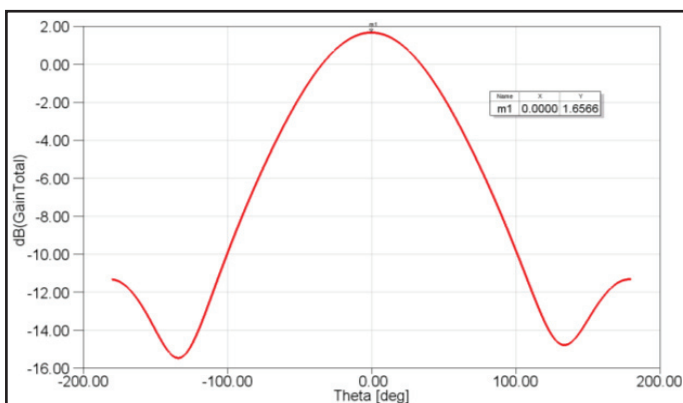


Fig. 9: Simulated Gain Plot of Second Antenna

## C. Inference

From the simulation results obtained for both antenna design it is observed that, the second antenna design shows better performances. The following table gives the comparative statement.

Table 1: Comparative Statement

Antenna Design	Return Loss (at 2.4GHz)	Gain	Bandwidth (at 10dB)
1	18.7342dB	1.387dB	100MHz
2	35.3953dB	1.6566dB	180.1MHz

## V. Fabrication and Measurement

It is clearly observed from the above table that, the second antenna design provides better results in terms of bandwidth and radiation pattern. Also, the second antenna offers circular polarization required for base station applications.

The optimized second antenna is then fabricated using standard procedure. Prototype of this antenna is shown in fig. 10. The antenna is fabricated on FR4 substrate of 1.6mm thickness. An SMA adapter is connected at co-axial feed of the circular microstrip patch to measure various antenna parameters using network analyzer. Fig. 11 demonstrates the measured SWR graph in which bandwidth and representation of circular polarization can be observed for this prototype antenna. It is seen that the bandwidth is extended from 2.401GHz to 2.56962GHz. At 2.44GHz the SWR graph shows the measurement of 1.0874. Also shown is the measured radiation pattern in the fig. 12.

It is observed that broad side array radiation pattern is obtained. From the curves, the conformance of the simulated and measured results is noticed for the designed EBG antenna. The correctness of the simulation results can be verified. From the simulated S11 graph found the bandwidth obtained is 180.1GHz, but measured bandwidth is 168.62GHz. The discrepancies between simulations and measurements are presented. It is observed that measured bandwidth is lesser than the corresponding simulated one with frequency deviations. This could be caused probably by the fact that EBG in antenna is more resistant to outside interference.

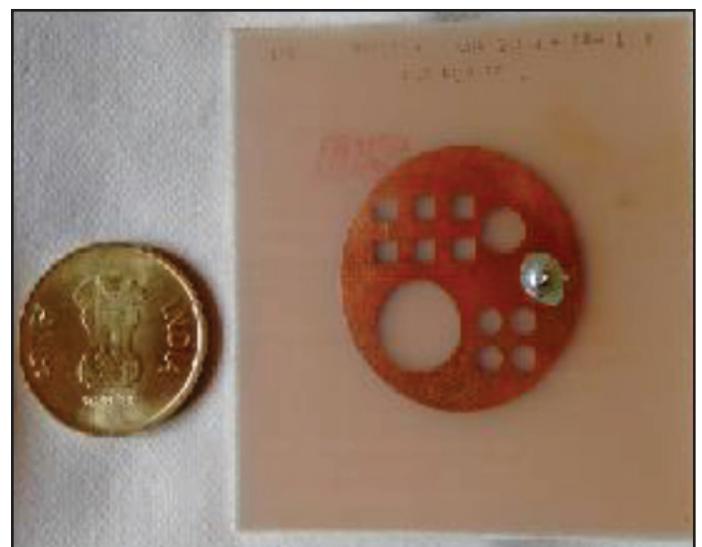


Fig. 10: Prototype of the Designed Circular Patch Antenna with Slotted EBG.





Fig. 11: Measured SWR Graph for the Prototype Antenna

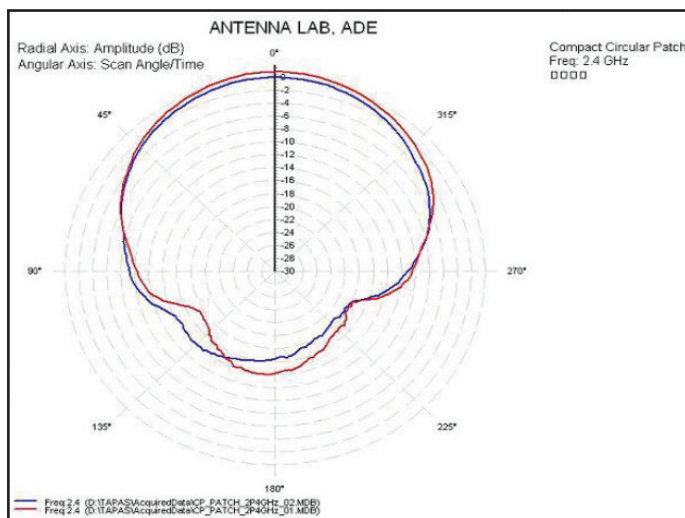


Fig. 12: Broad Side Array Radiation Pattern of Prototype Antenna.

## VI. Conclusion

Two different types of microstrip EBG antennae are designed and simulated. Their performances are compared at 2.4GHz resonating frequency which is suitable for GPS and Base station applications. The best performing antenna out of those two types is then fabricated and results are validated. Since two dissimilar circular slots placed diagonally over main circular microstrip antenna it is possible to have circular polarization. With the inclusion of circular and square slots as EBG, surface wave is suppressed and it is found that, the antenna resonates perfectly at 2.4GHz, radiation pattern is improved and band width is enhanced.

## References

- [1] S. D. Targonski and D. M. Pozar, "Design of Wideband Circularly Polarized Aperture-Coupled Microstrip Antennas", IEEE Transactions on Antennas and Propagation, AP-41, 2, February 1993, pp. 214-219.
- [2] P. C. Sharma and K. C. Gupta, "Analysis and Optimized Design of Single Feed Circularly Polarized Microstrip Antennas", IEEE Transactions on Antennas and Propagation, AP-31, 6, June 1983, pp. 949-955.
- [3] H. Iwasaki, "A Circularly Polarized Small Size Microstrip Antenna with Cross Slot," IEEE Transactions on Antennas and Propagation, AP-44, 10, October 1996, pp. 1399-1401.

- [4] J. S. Row, C. Y. Ai, "Compact Design of Single-Feed Circularly Polarized Microstrip Antenna," Electronics Letters 40, 18, September 2004, pp. 1093-1094.
- [5] K. L. Wong, Y. F. Lin, "Circularly Polarized Microstrip Antenna with a Tuning Stub", Electronics Letters, 34, 9, April 1998, pp. 831-832.
- [6] H. M. Chen, K. L. Wong, "On the Circular Polarization Operation of Annular-Ring Microstrip Antennas", IEEE Transactions on Antennas and Propagation, AP-47, 8, 1999, pp. 1289-1292.
- [7] Tzong-Chee Yo, Chien-Ming Lee, Ching-Hsing Luo, "Small Single Band Circular Polarization and Dual Band Circular Patch Antenna", IEEE March 2007, pp. 435 – 438.
- [8] Rukmini T S Rao, "Performance Analysis of Wide Band Circularly Polarized EBG Microstrip Antenna for Base Station Applications", International Journal of Applied Engineering Research, Vol. 10 No. 1 (2015) pp. 37-40 © Research India Publications.
- [9] M.A. Kossel, R. Kung, H. Benedickter, W. Bachtold, "An active tagging system using circular polarization modulation", IEEE Trans. Micro. Theo. Tech., Vol. 47 pp. 2242-2248, Dec. 1999.
- [10] Garg R, Bhartia P, Bahl I, Ittipiboon, A, "Microstrip Antenna Design Handbook", Artech House, Norwood, MA, 1995.
- [11] Suh Y H, Wang C, Chang K, "Circularly Polarized Truncated Corner Square Patch Microstrip Rectenna for Wireless Power Transmission", Electronics Letter, Vol. 36, pp. 600-602, March 2000.
- [12] Iwasaki H, "A Circularly Polarized Small-size Microstrip Antenna with a Cross Slot," IEEE Transaction Antennas Propagation, Vol. 40, pp. 1399-1401, Oct. 1996.
- [13] Y J Sung, Y S Kim, "Circular Polarised Microstrip Patch Antennas for Broadband and Dual-band Operation", Electronics Letter, Vol. 40, No. 9, pp. 520-522, April, 2004.
- [14] C A Balanis, "Antenna Theory, Analysis and Design", John Wiley & Sons, New York, 1982.
- [15] Rukmini T S Rao, "Design and Performance Analysis of EBG Antenna for Wireless Applications", IEEE Applied Electromagnetic Conference and IEEE Antenna Week, Volume 978-1-4577-1099-5/11/2011 IEEE Xplore.
- [16] C Y Huang, J Y Wu, C F Yang and K L Wong, "Gain Enhanced Compact Broadband Microstrip Antenna", Electronics Letter 34, 1998, pp. 138-139.
- [17] Yuehe Ge, Karu P Esselle, Yang Hao, "Design of Low-Profile High Gain EBG Resonator Antennas Using Genetic Algorithm", IEEE Antennas and Wireless Propagation Letter, Vol. 6, 2007.
- [18] Rukmini T S Rao, "Design and Performance Analysis of Electromagnetic Band Gap Square Microstrip Patch Antenna", IJECT Vol. 5, Issue 3, July - Sept 2014.



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