ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 9, September 2015

Design of a Low Cost High Gain Microstrip Antenna for Wireless Applications

Kaushik Mandal[1]

Associate Professor, ECE, Academy of Technology, Hooghly, India[1]

Abstract: A method to enhance gain of a microstrip patch antenna is investigated. Here the main radiating square patch is surrounded by four side patches. The effect of side patches on the absolute gain of antenna is studied. In absence of side patches the highest absolute gain of the antenna is 5.3 dBi. Maximum absolute gain of 7.85 dBi is obtained in presence of all the side patches. Prototypes of the antenna are fabricated for experimental validation. The measured return loss, gain and radiation patterns are in good agreement with their simulated counterpart for all four antennas. The proposed antenna is simple, less costly and highly suitable for wireless communications.

Keywords: Microstrip patches antenna; low cost; high gain.

I. INTRODUCTION

Microstrip antennas are the most common form of printed antennas and are used in a broad range of applications owing to their simplicity, conformal structure and low manufacturing cost. However it has also some major shortcomings, such as narrow impedance bandwidth and low gain, which seriously limit their applications. Many broadband techniques for microstrip antennas have been reported [1], [2]. Several techniques have been previously demonstrated to enhance the gain of patch antenna, including the use of parasitic patch [3], [4], using superstrate layers [5], [6], cavity backed slot antenna [7] and double layer array antenna [8]. All of them compel to increase the antenna height at the same time presence of superstrates above an antenna may adversely affect the antenna’s basic characteristics such as radiation pattern, resistance and efficiency. Use of costly substrate like photonic band gap [9], [10] and electromagnetic crystal substrate [11] are also reported. Different kinds of design techniques like removal of substrate [12] and slotted ground plane [13] are also reported but most of them provide gain around 5-7 dBi. Unfortunately, a single layer microstrip-fed slot antenna naturally radiates bi-directionally and has a low gain level. In this article we proposed a new design variety of single layer patch, which is simple and different from that reported in [1]–[13], but able to achieve higher gain. The geometry of the proposed microstrip antenna consists of a main square shaped radiating patch surrounded by four narrow side patches. The radiating elements are printed on an electrically thin and low cost glass PTFE substrate and fed by a co-axial probe. The effects of different side patches on absolute antenna gain are studied. We have analysed the proposed high gain microstrip antenna structure theoretically by soft Designer® software which works on the Method of Moments. The simulated results obtained have been compared with the experimental measured data. It is interesting to note that the simulated theoretical and experimental results are in close agreement. This paper is organized as follows. Section II briefly describes the design scheme of the proposed antenna structure and associated parameters for parametric study purpose. Simulated as well as measured results are presented in Section III to understand the effects of different structures and to prove the design concepts. Finally, the concluding remarks are given in Section IV.

II. ANTENNA GEOMETRY

The geometry and dimensions of the proposed high gain antenna are shown in Fig. 1 where all the dimensions are in mm. Since the novelty of this reported article is the simplicity and low cost so it is fabricated on an inexpensive planer glass PTFE substrate having dielectric constant (ε_r) = 2.4, thickness (h) = 1.6 mm and loss tangent = 0.00022. A very small square shaped 20 mm x 20 mm radiating patch is printed on the upper side of the microwave glass PTFE substrate of dimensions 100 mm x 100 mm. The square-shaped radiating patch is surrounded by four narrow side patches “a”, “a$^{/}$”, “b” and “b$^{/}$”. The side patches “a” and “a$^{/}$” are with same dimensions 20 mm x 5 mm, similarly “b” and “b$^{/}$” are with same dimensions 5 mm x 34 mm. All the side patches are separated from the main square radiating patch by 2 mm. The antenna is fed by co-axial probe at the upper corner of main radiating patch as shown in Fig. 1.

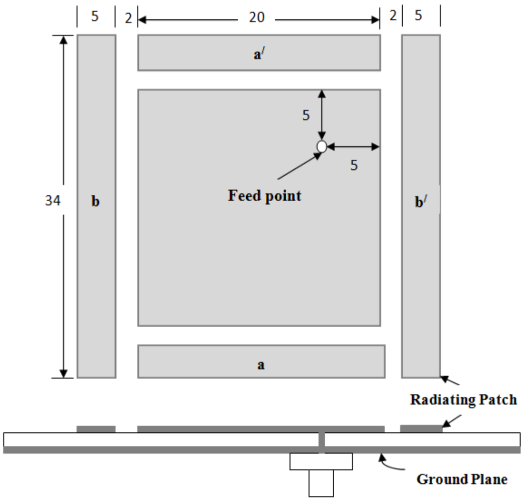
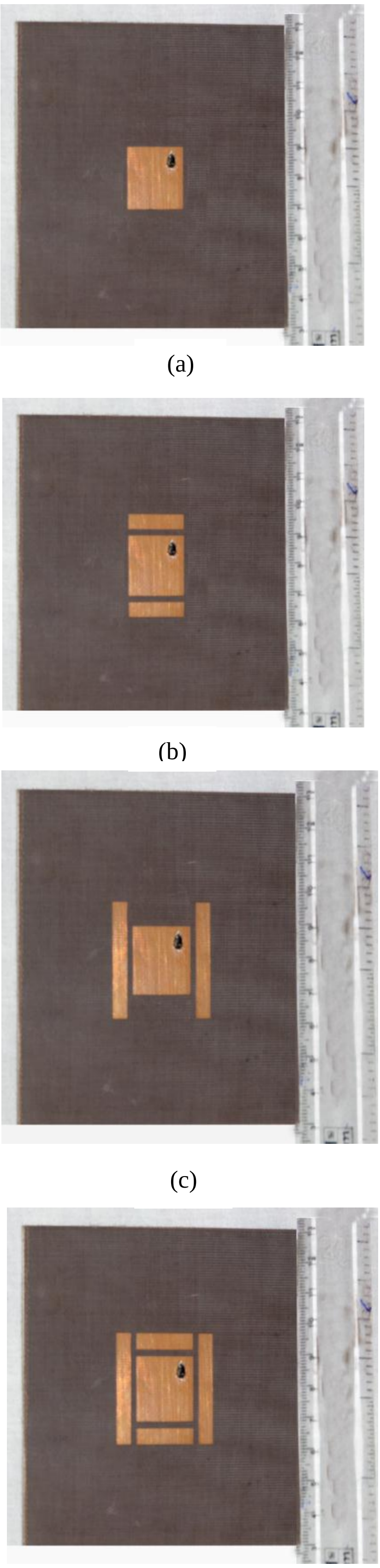


Fig. 1 Illustration of the proposed gain enhanced antenna.

DOI 10.17148/IJARCCE.2015.4906



(a)

(b)

(c)

(d)

Fig. 2 Photographs of the fabricated prototype antennas. (a) Type “A”. (b) Type “B”. (c) Type “C”. (d) Proposed antenna.

To study the effects of side patches four kinds of antenna structures have been studied using simulated results. All these four kinds of antenna structures have been fabricated and measured to verify the simulated results of different parameters. The antenna with all side patches provides the maximum gain and it is presented as the proposed antenna. Photographs of the four fabricated antennas are depicted in Fig. 2. A prototype of the proposed antenna i.e. in presence of all the side patches is fabricated and shown in Fig. 2(d). The return loss, gain and radiation pattern of the antennas are measured. In order to understand the effect of side patches we consider three kinds of antenna structures: “A”, “B” and “C” for the parametric study purpose. Type “A” stands for the main square radiating patch in absence of all the side patches [Fig. 2(a)]. Type “B” means main radiating patch along with the side patches “a” and “a$^{/}$” only [Fig. 2(b)]. Antenna “C” is the main radiating patch along with the side patches “b” and “b$^{/}$” only [Fig. 2(c)].

III.RESULTS AND DISCUSSIONS

Fig. 3 shows the plot of simulated and measured return loss for the different kinds of antenna structures. It shows that depending on the side patches resonant frequency and return loss is varying. Measured return loss validates its simulated counterparts for all four antennas.

Fig. 4 shows the plot of simulated and measured gain for the different kinds of antenna structures. Antenna gain is varying from 5.49 dBi to 7.39 dBi (simulated) and 5.29 dBi to 7.85 dBi (measured). Measured gain confirms its simulated counterparts. Antenna “A”, “B” and “C” are studied with the help of their simulated as well as measured results to understand the effects of side patches on absolute gain and performances of the antenna. The results of parametric study carried out are represented in Table I.

TABLE I SIMULATED AND MEASURED RESULTS

Antenna	Resonant frequency (GHz)		Gain (dBi)	
	Simulated	Measured	Simulated	Measured
Type-“A”	4.6	4.8	5.49	5.29
Type-“B”	4.8	4.8	6.01	6.61
Type-“C”	4.5	4.5	6.27	6.7
Proposed Antenna	4.8	4.6	7.39	7.85

Fig. 5 represents the measured return loss plot of all four antennas for comparative study purposes. The proposed antenna provides maximum bandwidth of around 350 MHz (4.41-4.76 GHz). Measured impedance bandwidth of antenna “A”, “B” and “C” are 250 MHz (4.65-4.90 GHz), 150 MHz (4.71-4.86 GHz) and 200 MHz (4.42-4.62 GHz) respectively. In all cases the impedance bandwidth is defined for return loss ≤ -10dB.

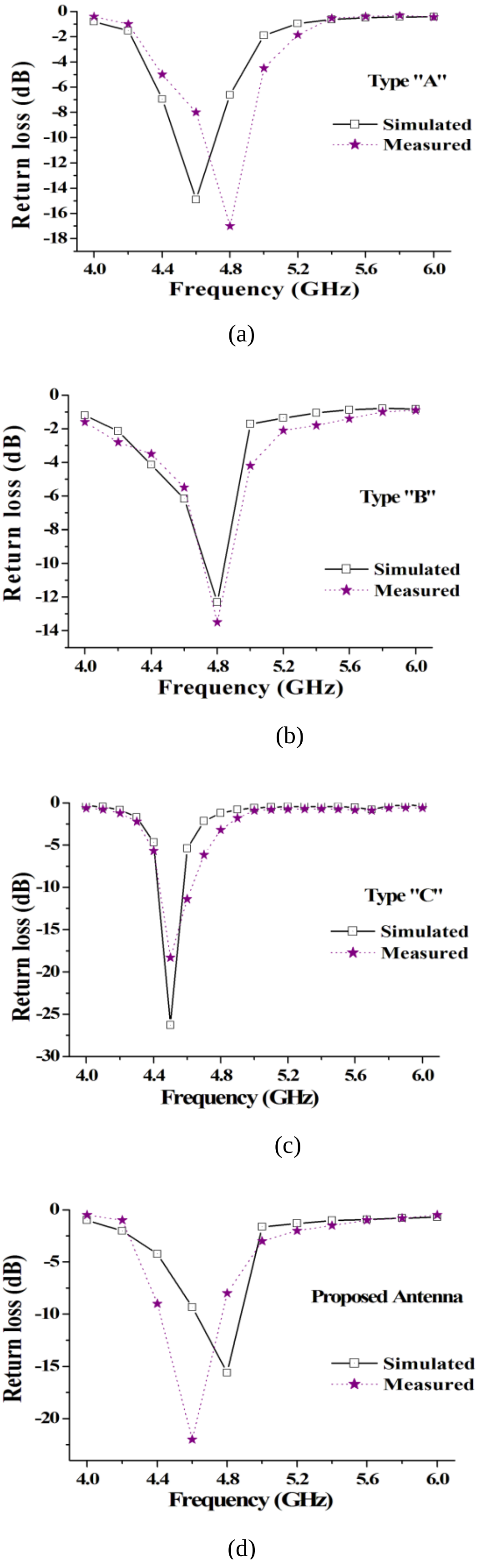


Fig. 3 Plots of simulated and measured return loss for different antenna structures. (a) Type “A”. (b) Type “B”. (c) Type “C”. (d) Proposed antenna.

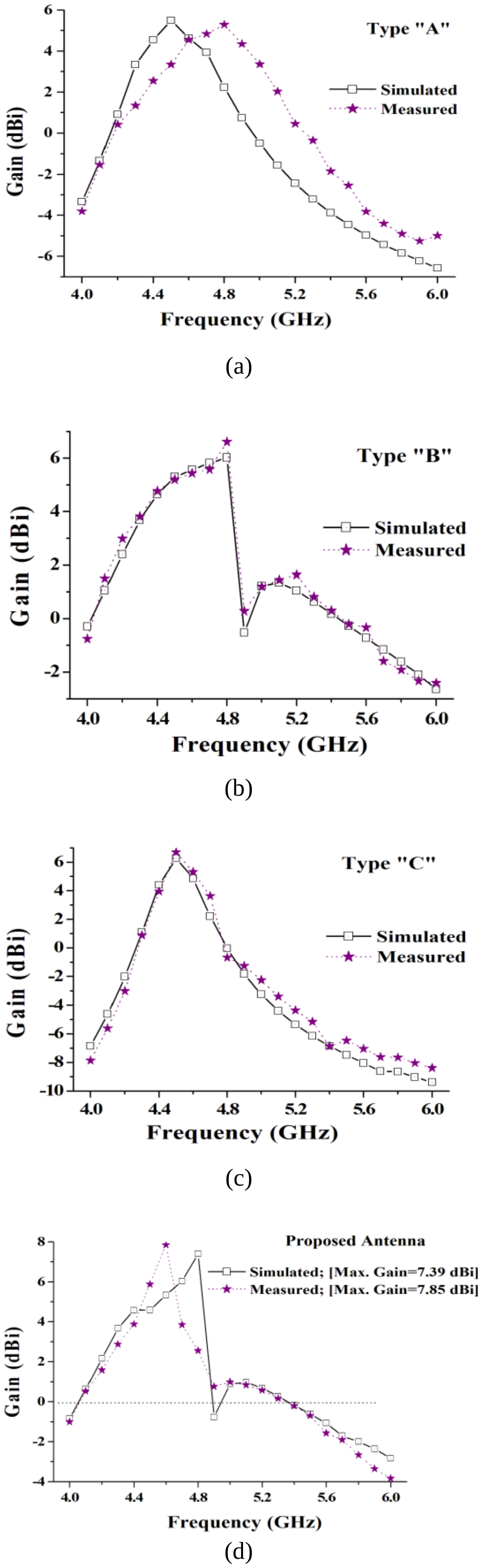


Fig. 4 Plots of simulated and measured gain for different antenna structures. (a) Type “A”. (b) Type “B”. (c) Type “C”. (d) Proposed antenna.

DOI 10.17148/IJARCCE.2015.4906

Measured gains of all four antennas are presented in Fig. 6 for comparative study purposes. Antenna gains are varying from 5.29 dBi to 7.85 dBi. One more thing is that over a wide frequency band gain of the antenna are positive as well as high. Presence of all side patches provides the maximum gain of 7.85 dBi. The proposed antenna exhibits enhancement of gain by 48.39% in compare to the conventional square patch antenna "A". Maximum measured gain for antenna "A", "B" and "C" are 5.29 dBi, 6.61 dBi and 6.7 dBi respectively.

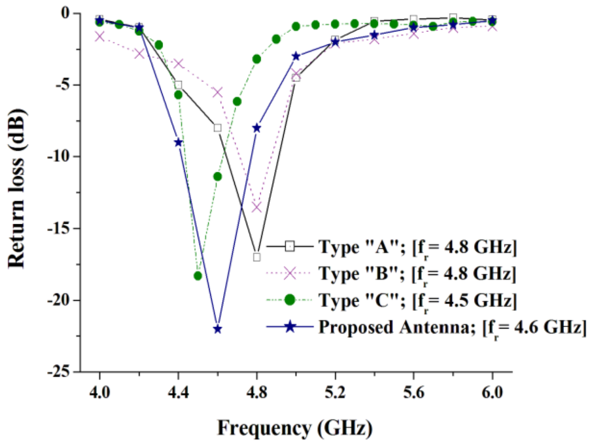


Fig. 5 Measured return loss plot of antenna "A", "B", "C" and the proposed antenna for comparative study purpose.

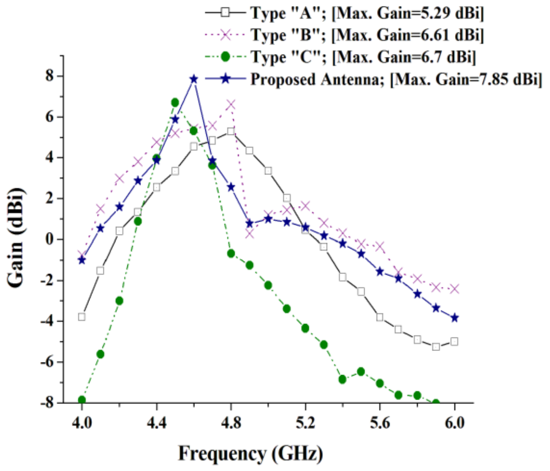
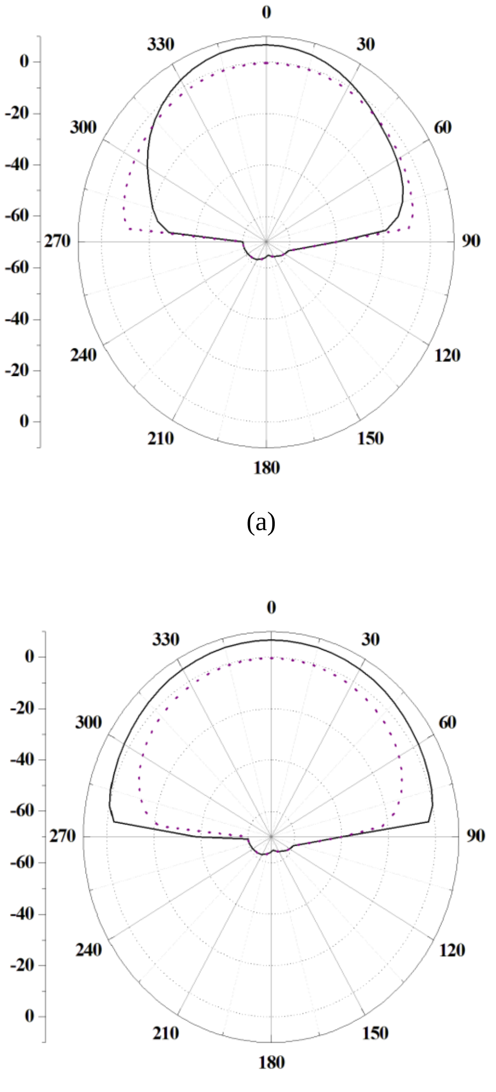


Fig. 6 Measured gain plot of antenna "A", "B", "C" and the proposed antenna for comparative study purpose.

Fig. 7 shows the measured radiation patterns including the co-polarization and cross polarization in two principal planes namely, the E-plane (y-z plane) and H-plane (x-z). It can be seen that the radiation patterns in both plane are nearly directional for the resonant frequency 4.6 GHz. More significantly the radiation patterns in both planes are with low cross-polarization values and there are no such back lobe portions. The proposed antenna provides a favourable radiation pattern along with the high gain. It can be noted that the little disagreement between measured and simulated results may be due to the fabrication tolerances, loss of the connectors or the measurement process.



(a)

(b)

Fig.7. Measured radiation patterns of the proposed antenna at 4.6 GHz. (a) E- plane and (b) H- plane.

IV. CONCLUSION

A low cost coaxial probe fed patch antenna with enhanced gain is presented. The presence of side patches appears as critical parameters. Without any additional layers and costly substrate the proposed antenna successfully achieves higher gain. By using the side patches surrounding the main square patch, we can enhance the gain of conventional square patch antenna by more than 48.39%. Also, these results suggest that planar antenna structure may offer new design opportunities for low-cost devices.

REFERENCES

[1] G. F. Khodaei, J. Nourinia, and C. Ghobadi, "A practical miniaturized U-slot patch antenna with enhanced bandwidth", Progress In Electromagnetic Research B, Vol. 3, pp. 47–62, 2008.

[2] K. Mandal, S.Sarkar and P. P. Sarkar, "Bandwidth enhancement of microstrip antennas by staggering effect", Microwave and Optical Technology Letters, Vol. 53, pp. 2446-2447, 2011.
[3] K. M. Luk, K. F. Tong, and T. M. Au, "Offset dual-patch microstrip antenna", Electron Lett , Vol. 29, pp. 1635–1636, 1993.
[4] Lee, R. Q. and K. F. Lee, "Gain enhancement of microstrip antenna with overlaying parasitic directors", Electron Lett, Vol. 24, pp. 656–658, 1988.
[5] Chang, T. N., M. C. Wu, and J.-M. Lin, "Gain Enhancement for circularly polarized microstrip patch antenna", Progress In Electromagnetic Research B, Vol. 17, pp. 275-292, 2009.
[6] C. Y. Huang, J. Y. Wu, C. F. Yang, and K. L. Wong, "Gain enhancement compact broadband microstrip antenna", Electron Lett, Vol. 34, pp. 138–139, 1998.
[7] Quan Li and Zhongxiang Shen, "Inverted microstrip-fed cavity-backed slot antennas", IEEE Antennas and Wireless Propagation Letters, Vol. 1, pp. 98-101, 2002.
[8] Tung-Hung Hsieh and Choon Sae Lee, "Double-layer high-gain microstrip array antenna", IEEE Trans. Antennas and Propagation, Vol. 48, pp. 1033-1035, 2000.
[9] G. P. Gauthier, A. Courtay, and G. M. Rebeiz, "Microstrip antennas on synthesized low dielectric-constant substrates", IEEE Trans. Antennas and Propagation, Vol. 45, pp. 1310–1314, 1997.
[10] R. Coccioli,W. R. Deal, and T. Itoh, "Radiation characteristics of a patch antenna on a thin PBG substrate", IEEE Antennas and Propagation Society International Symposium, pp. 656–659, June 1998.
[11] Halim Boutayeb and Tayeb A. Denidni, "Gain enhancement of a microstrip patch antenna using a cylindrical electromagnetic crystal substrate", IEEE Trans. Antennas and Propagation, Vol. 55, pp. 3140-3145, 2007.
[12] Siew Bee Yeap and Zhi Ning Chen, "Microstrip patch antennas with enhanced gain by partial substrate removal", IEEE Trans. Antennas and Propagation, Vol. 58, pp. 2811-2816, 2010.
[13] Jieh-Sen Kuo and Gui-Bin Hsieh, "Gain enhancement of a circularly polarized equilateral-triangular microstrip antenna with a slotted ground plane", IEEE Trans. Antennas and Propagation, Vol. 51, pp. 1652-1656, 2003.

BIOGRAPHY

Dr. Kaushik Mandal was born in West Bengal, India, in 1980. He received his B.Tech and M.Tech degree in Radio Physics and Electronics from the University of Calcutta, in 2004 and 2006 respectively. He did his Ph.D. on Microstrip patch antenna in the Department of Engineering and Technological Studies, University of Kalyani, in July 2014. Presently he is working as an associate professor in the department of electronics and communication engineering at Academy of Technology, West Bengal, India, from June 2007 to at present. He has contributed eight research papers in various international journals and conference of repute. His current research interests are in enhancement of bandwidth and gain of microstrip patch antenna, compact UWB antenna for Wi-MAX, WLAN and mobile applications and Dielectric resonator antenna. Dr. Mandal is a senior member of IEEE Antennas and Propagation Society.

DOI 10.17148/IJARCCE.2015.4906