Grenze International Journal of Engineering and Technology, June Issue

Design of a Miniaturized Microstrip Antenna using Slots on the Radiating Patch for Wireless Applications

Susmita Bala[1], Biplab Bag[2], Sushanta Sarkar[3] and ParthaPratim Sarkar[4]
[1]Dept. of Electronics,Vidyasagar University, Midnapore, India
Email: susmitabala@mail.vidyasagar.ac.in
[2]Dept. of Electrial Engineering Murshidabad Instutute of Technology, India
[3-4]DETS, University of Kalyani, Kalyani, India
Email: bbgateie@gmail.com, sushantasarkar@aol.com, parthabe@yahoo.co.in

***Abstract*—This paper proposed a miniaturized microstrip antenna (MMA). The design consists of a microstrip antenna having a radiating patch with modified U slots. Dielectric substrate of PTFE is used to design the antenna. Co-axial probe feeding technique is used to energise the MMA. HFSS software is used to model the design of the MMA. Initial patch antenna without slots, resonant at 6.65 GHz. After etching slots on the radiating patch, the MMA resonant at 3.85 GHz. So the 66.46% of miniaturization has been done. The MMA provides a maximum gain of about 5.54 dBi at 3.85 GHz. This design may be used to operate for wireless applications.**

***Index Terms*— Miniaturization, Reflection co-efficient, Gain, Radiation Pattern, Modified U-slots, PTFE.**

I. INTRODUCTION

The design of a miniaturized antenna has emerged as one of the most important issues for modern broadcasting systems due to the rapidly expanding wireless networks. Due to its favorable characteristics, including as compactness, inexpensive manufacture, simplicity of structure, and effective compatibility with small electronic apparatus, microstrip antennas are the most suitable candidate for wireless applications [1-2]. For the purpose of shrinking the antenna's size, slots of various sizes and shapes have been inserted into the radiating patch, ground planes, or both [3,4]. S. Islam & et al. reports on a small antenna for RFID applications [5]. The antenna has slots of various sizes to accomplish its 32% compactness. It has been observed that employing slots for a multiband patch antenna reduced size by 30% presented in [6]. M.S.H. Ali & et al. [7] demonstrates a small Patch antenna. This offers two bands. The antenna has two L-shaped slots that are mirror images of one another, along with two slits and a square slot. This antenna offers a compactness of 41.2%. A comparison study has been done on a compact equilateral triangular patch antenna with various slot shapes, and the best compactness of 43.47% is reported in [8]. It is estimated that a small microstrip antenna for mobile communication can achieve 46.13% more compactness by employing two irregular rectangular slots at the patch's edge [9]. By utilizing open end meandering slots in the ground plane, a rectangular microstrip antenna reports an 83% compactness [10]. Using an H-shaped slot on the radiating patch and a U and L slot combination on the ground plane, it is reported that the compactness is 86% [11]. A circular patch antenna adds an open ended slot to the radiating patch to increase compactness by 86.5% [12]. A miniaturization of 50% has been reached by only using defected ground structure

Grenze ID: 01.GIJET.9.2.59

in [13]. Koch fractal geometry was applied on the square patch to reach 45 % of size reduction in [14]. Miniaturization was done by altering not just the iteration but also the number of segments on the boundary while maintaining the same iteration of a patch in [15]. Complementary split ring resonators were used for size reduction of a patch in [16]. Fractal geometry of Mandelbrot reduces 58.5% of area in [17]. The insertion of slots in the various directions was proposed in [18] for miniaturization. A 33 % of size reduction has been achieved by using slits in a slot antenna in [19]. A slotted microstrip antenna provides 67 % of size reduction was informed in [20]. A CPW fed slot antenna achieves miniaturization using spiral ring resonator in [21].

In this paper, a miniaturized microstrip antenna (MMA) has been designed using slots. The miniaturization of 66.46% has been achieved by using only U slots on the radiating patch. This antenna may be useful in wireless applications.

II. Antenna Geometry

The layout of the proposed miniaturized antenna (MMA) is depicted in figure.1. The MMA is modeled using glass PTFE substrate material. Its specification is, dielectric constant (ε_r) = 2.5, height= 1.6 mm and loss tangent=0.002. The antenna is modeled by HFSS software. The MMA is excited by co-axial probe feed. The evolution process of the MMA is shown in figure.2. The evolution process consists of three steps. Three steps are Ant_A, Ant_B and Ant_C. Dimensions of the Ant_A are 13 mm and 17.75 mm. The Ant_A is given in figure.2(x). An extended U-similar slot is placed on the Ant_A. This modification on the patch is named Ant_B. After this, other U-similar slot is placed on Ant_B. This modification is named as the Ant_C (figure.2.2 (z)). This Ant_C is considered as MMA. The design parameters of the MMA are given in the Table I. The small black box presents the feed location of the MMA. The width of each section of the slots are fixed and it is 0.4 mm. The reflection co-efficient of different steps of the MMA is given in figure.3. The resonant frequency and its magnitude is given in the Table II.

TABLE I: Design Parameters of the Proposed Reported Antenna [Mm]

a	**b**	**c**	**d**	**e**	**f**
50	50	13	17.75	10.6	7.6
g	**h**	**i**	**j**	**k**	**l**
10.6	7.6	8	6.6	1	1.4

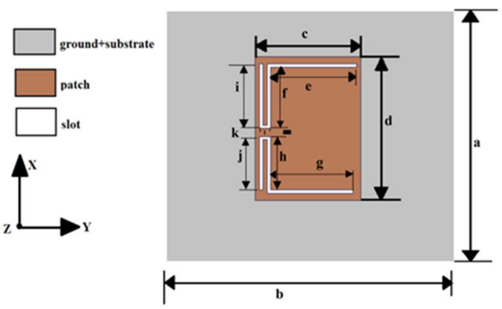

Figure.1: The layouts of the MMA

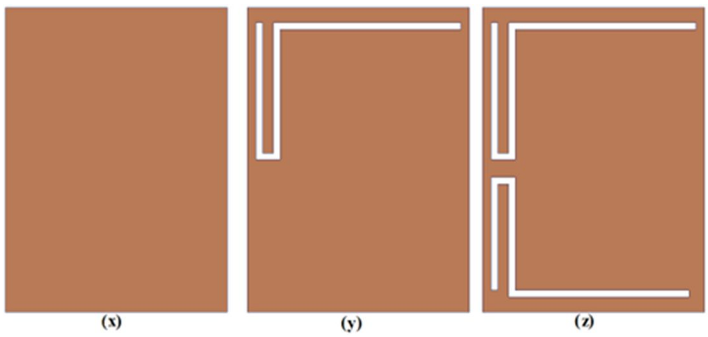

Figure.2(x-z): The evolution of the MMA (Ant_A to Ant_C)

TABLE II: Comparison Information Table Regarding Different Steps of the Proposed Antenna

Steps	Resonant Frequency	Reflection co-efficient	Gain	Compactness (%)
Ant_A	6.65 GHz	-26.23 dB	6.64 dBi	Not applicable
Ant_B	3.93 GHz	-7.9 dB	5.45 dBi	Not applicable
Ant_C	3.85 GHz	-17.99 dB	5.54 dBi	66.46%

III. Result and Discussion

This section presents simulated results of the MMA. Figure.6 shows the reflection co-efficient (S11) of the MMA. 3.85 GHz resonant frequency is obtained from the MMA. The gain of the MMA is 5.54 dBi at the

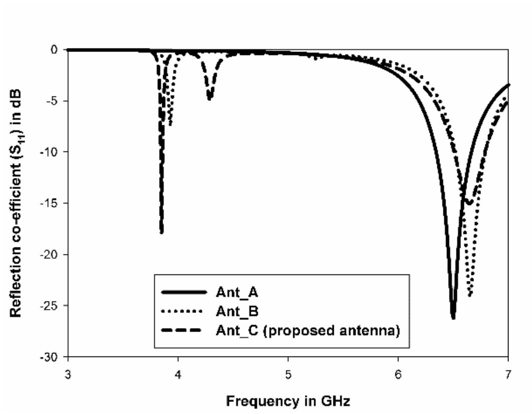

Figure.3: Comparison reflection co-efficient versus frequency plot for ANT_A to ANT_C

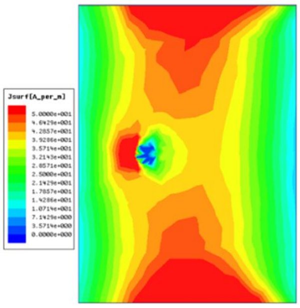

Figure.4(a): Surface current distribution(J_surface) at 6.65 GHz of the basic patch antenna (Ant_A)

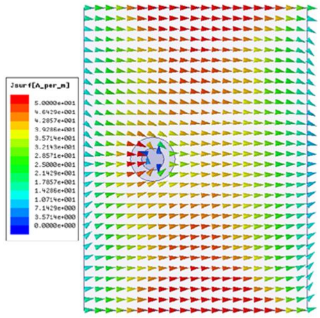

Figure.4(b): Surface current distribution (J_vector) at 6.65 GHz of the MMA

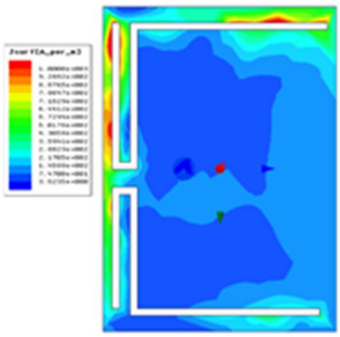

Figure.5(a): Surface current distribution (J_vector) at 3.85GHz of the MMA

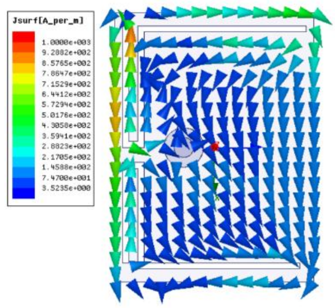

Figure.5(b): Surface current distribution (J_vector) at 6.65 GHz of the MMA

resonant frequency of 3.85 GHz. The plot of the gain is given in figure.7. The radiation patterns (E and H plane) of the MMA are given in figure.8 and figure.9. In this article, initial rectangular patch antenna (Ant_A) without slot gives resonant frequency of 6.65 GHz. After placing slots on the patch (Ant_C), the frequency shifts from 6.65 GHz to 3.85 GHz.

Figure 4(a) shows the surface current distribution of the Ant_A and its vector current distribution is shown in figure 4(b). Figure 5(a) shows the surface current distribution of the proposed antenna and its vector current distribution is shown in figure 5(b). Red color indicates maximum current density. In case of figure 4(b), it is shown that current flows from left to right on entire radiating patch but in case figure 5(b), the current path becomes leathered due to the presence of the slots. As the current path increases that means length increases and frequency decreases. So the frequency shifts from higher to lower range. This phenomenon is called miniaturization or compactness. The compactness of the proposed antenna has been calculated by using following equations (1-8).

Perimeter of the Ant_A to resonate at the frequency of 6.65 GHz is =2× (17.75+13) mm=61.5 mm…… (1)
So, the perimeter of the proposed antenna to resonate at 3.85 GHz is (61.5×6.65)/3.85=106.22 mm……… (2)
Therefore, total length and breadth of proposed antenna= 106.22/2=53.11 mm……… (3)
The length of the proposed antenna with respect to initial antenna is (17.75/30.75) ×53.11=30.65 mm….. (4)
The breadth of the proposed antenna with respect to initial antenna is (13/30.75) ×53.11=22.45 mm….. (5)
The area of Ant_A=17.75×13 mm2=230.75 mm2……… (6)
The area of the proposed antenna is =30.65×22.45 mm2= 688.1 mm2………… (7)
So, the compactness= {(688.1 -230.75)/ 688.1 }×100%=66.46 %.......(8)

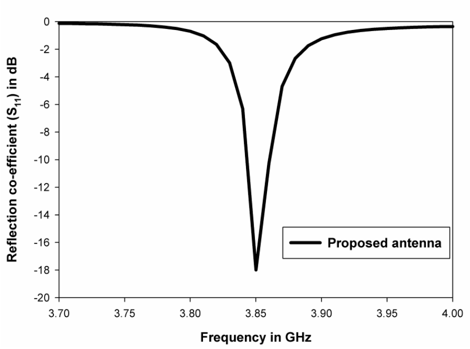

Figure.6: Reflection co-efficient plot of the MMA

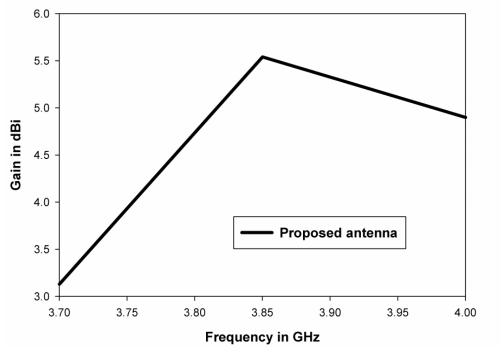

Figure.7: Gain plot of the MMA

IV. COMPARISON TABLE

In this section comparison of the proposed antenna with the previously reported antennas have been done (Table III). After comparison with respect to substrate area, techniques of miniaturization and % of miniaturization, it is concluded that proposed MMA provides very good results.

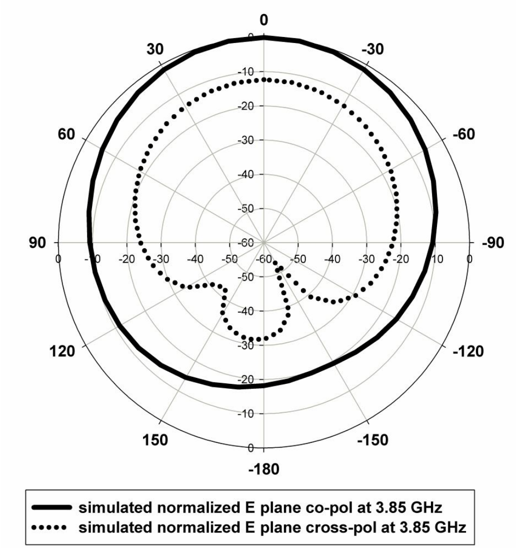

Figure.6: The radiation patterns (E plane) of the proposed MMA

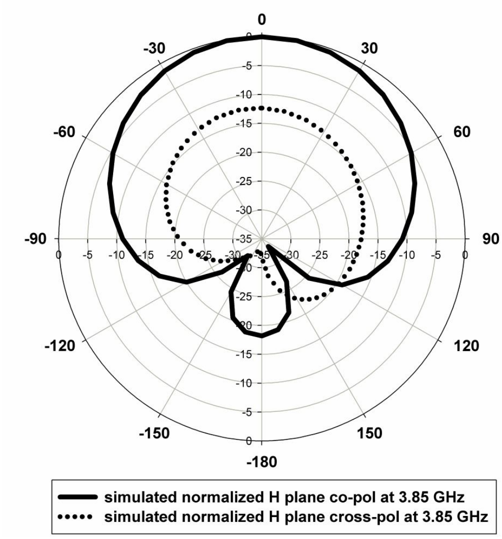

Figure.7: The radiation patterns (E plane) of the proposed MMA

V. CONCLUSION

This article presents a miniaturized microstrip antenna. Only insertions of slots on the radiating patch have been done. HFSS software simulation tool is used to model and simulate the proposed miniaturized microstrip antenna. The design is very simple and easy. It provides 66.46% of miniaturization. This antenna may be useful in wireless applications.

TABLE III: COMPARISON TABLE

Ref	Substrate area	Techniques to achieve miniaturization	% of Miniaturization
[5]	37.7×28.4	Slots on the patch	32%
[6]	24×24	Slots on the patch	30%
[8]	120×120	Slots on the patch	43.47%
[9]	24×30	Slots on the patch	46.13%
[13]	22×20	DGS on the ground plane	50%
[14]	60×60	Koch fractal geometry	45%
[19]	45×25	Slots and slits	33%
Proposed MMA	50×50	Slots on the patch	66.46%

REFERENCES

[1] J. S. Kuo and K. L. Wong, “A compact microstrip antenna with meandering slots in the ground plane,” Microwave Opt. Technol. Lett. vol 29, pp. 95-97, April 20, 2001.

[2] C. L. Tang, H. T. Chen, and K. L. Wong, “Small circular microstrip antenna with dual frequency operation,” Electron. Lett. Vol 33, pp. 1112–1113, June 19, 1997.

[3] H. Malekpoor and S. Jam, “Design of a multi-band asymmetric patch antenna for wireless applications”, Microwave Opt. Tech. Lett. vol. 55, pp. 730–734, April, 2013.

[4] U. Kiran, V. R. M, R. M. Yadahalli, P. V. Hunagund and S. F. Farida, “Microstrip-line-fed rectangular microstrip antenna with open end meandering slots in the ground plane for compact broadband operation” Microwave Opt Technol Lett. Vol 49, pp. 824 – 827, April, 2007.

[5] K. L. Wong and K. P. Yang, “Compact dual-frequency microstrip antenna with a pair of bent slots,” Electron. Lett. Vol 34, pp. 225–226, Feb. 5, 1998.

[6] S. Islam and M. Latrach, “Design construction and testing of a compact size patch antenna for RFID applications” Microwave Opt. Tech. Lett. vol. 55, pp. 2920–2925, 2013.

[7] M. S. M. ALI, S. K. A. RAHIM, M. I. SABRAN, M. ABEDIAN, A. ETENG AND M. T. ISLAM, “Dual band miniaturized microstrip slot antenna for WLAN applications”, MICROWAVE OPT. TECH. LETT. VOL. 58, PP. 1358–1362, JUNE, 2016.

[8] S. Dasgupta, B. Gupta and H. Saha, “Compact equilateral triangular patch antenna with slot loading” vol. 56, pp. 268–274, February, 2014.

[9] S. Chatterjee, U. Chakraborty, I. Sarkar, P. P. Sarkar, and S. K. Chowdhury, “A compact microstrip antenna for mobile communication” India Conference (INDICON), Annual IEEE, 17-19 December, 2010, Kolkata, India.

[10] U. Kiran, V. R. M, R. M. Yadahalli, P. V. Hunagund and S. F. Farida, “Microstrip-line-fed rectangular microstrip antenna with open end meandering slots in the ground plane for compact broadband operation” Microwave Opt Technol Lett. Vol 49, pp. 824 – 827, April, 2007

[11] S .I .H. Shah, S. Bashir, A. Altaf, and S. D. H. Shah “Compact multiband microstrip patch antenna using defected ground structure (DGS)” XIXth International Seminar/Workshop on Direct and Inverse Problems of Electromagnetic and Acoustic Wave Theory (DIPED), 22-25 September, 2014, Tbilisi, Georgia.

[12] K. Mondal, L. Murmu, and P. P. Sarkar, “Investigation on compactness, bandwidth and gain of circular microstrip patch antenna” Devices for Integrated Circuit , 23-24 March, 2017, Kalyani, India.

[13] Hanae Elftouh, Naima A. Touhami, Mohamed Aghoutane, Safae El Amrani, Antonio Tazon and Mohamed Boussouis, “Miniaturized Microstrip Patch Antenna with Defected Ground Structure” Progress In Electromagnetics Research C, vol. 55, pp. 25–33, 2014.

[14] Il-Kwon Kim, Jong-Gwan Yook and Han-Kyu Park, “Fractal-shape small size microstrip patch antenna” Microwave and Optical Technology Letters, vol. 34, no. 1, July 5 2002.

[15] Jeevani Jayasinghe, Omar Saraereh, Rajas Khokle and Karu Esselle, “Design and analysis of m-segment fractal boundary antennas” vol.61, issue 9, pp. 2119-2125, 2019.

[16] Yang Cai, Zuping Qian, Wenquan Cao and Yingsong Zhang, “Research on the half complementary split-ring resonator and its application for design” Microwave and Optical Technology Letters, vol. 57, no. 11, November 2015.

[17] D. R. Minervino, 1 A. G. D’Assuncaoand C. Peixeiro2, “Mandelbrot fractal microstrip antennas” Microwave and Optical Technology Letters vol. 58, no. 1, January 2016

[18] Jai Mangal and L Abhinav Varma, “A Miniatueized rectangular slotted patch antenna for WiFi frequency range applications” IEEE 2nd international conference on applied electromagnetic, signal processing and communication (AESPC), Bhubaneswar, India, 26-28 November, 2021.

[19] Ziyang Li, Leilei Liu, Pinyan Li and Jian Wang, “Miniaturized design of CPW-Fed slot antennas using slits” 2017 Sixth Asia-Pacific Conference on antenna and Propagation (APCAP), Xi'an, China, 16-19 October 2017.

[20] Sudipta Das, Parimal Chowdhury, Arindam Biswas, Partha Pratim Sarkar, and Santosh Kumar Chowdhury, "Analysis of a Miniaturized Multiresonant Wideband Slotted Microstrip Antenna With Modified Ground Plane", IEEE antennas and wireless propagation letters, vol. 14, pp. 60-63, 2015
[21] Biswarup Rana, Soumen Banerjee, Priyasha Chatterjee, Ritam Banerjee, Rituparna Basak, "Design of a CPW-Fed Spiral Ring-Loaded Miniaturized Slot Antenna" International Conference and Workshop on Computing and Communication (IEMCON), Vancouver, BC, Canada, 15-17 October 2015.
[22] Balanis, C.A., "Antenna Theory: Analysis and Design", John Wiley & Sons, Inc, 1997.