Bandwidth Enhancement of Microstrip Patch Antenna Using Air Holes for WLAN Applications

Khaled A. Alblaihed, Jalil ur Rehman kazim, Qammer H. Abbasi, Muhammad Ali Imran, and Lina Mohjazi

[1] James Watt School of Engineering University of Glasgow, Glasgow, G12 8QQ, UK.

Email: 2613464A@student.gla.ac.uk; J.kazim.1@research.gla.ac.uk; {Qammer.Abbasi, Muhammad.Imran, Lina.Mohjazi}@glasgow.ac.uk

***Abstract* - In this paper the design of a rectangular patch antenna with a capacitive coupled probe fed strip is presented. The antenna is placed on a Rogers RO3003 substrate with a dielectric constant of 3.00. The antenna resonance is kept around 5.5 GHz. The proposed work enhances the impedance bandwidth by placing air holes in the substrate, which reduces the effective permittivity and, consequently, increases the bandwidth. As a result, the proposed method enhances the bandwidth by approximately 8%. The simulated gain is around 8 dB. The antenna design is suitable for 5.5 GHz WLAN and V2X applications.**

Keywords - Rectangular patch antenna; Capacitive Coupled Probe; WLAN

I. INTRODUCTION

Microstrip patch antenna has been utilized for various wireless applications due to its lightweight, low cost, low profile, and is easy to fabricate. However, major disadvantages of these antennas with low profile include narrow impedance bandwidth [1]. Over the years, a few effective methods have been proposed to enhance the impedance bandwidth. First, a simplest method to enhance the bandwidth is the increase of substrate thickness [2]. The typical narrow bandwidth of a patch antenna can be increased by a thick dielectric substrate [3]. Moreover, the bandwidth enhancement attained by increasing the substrate thickness comes at the cost of surface wave generation and spurious feed radiation. Other techniques to improve the bandwidth are by using the stacked patch configurations [4-6], proximity coupling feed [7-8], or aperture coupling feed [9-10]. However, these solutions led to use multilayer substrate, resulting in complexity and high fabrication cost. In this work, we will apply a technique to enhance the impedance bandwidth, i.e., by inserting air holes into the substrate. To the best of our knowledge, this method is novel and has not been investigated in the open literature before. The impedance bandwidth of the design was 44% which is increased to about 52%, and thus, an improvement of 8% is achieved. This paper is organized as follows. In section II, the antenna design is presented, followed by section III, which contains results and discussion. Then, the paper concludes in section IV.

II. ANTENNA DESIGN

The antenna is designed and simulated in CST MWS studio 2019. The capacitive coupled probe feeding technique is adopted from [11]. The patch antenna acts as the radiator and the smaller feed patch placed beside the radiator couples the energy to the radiator. The radiator patch is located on the substrate which is located above the ground plane with an air gap of 6 mm between them.

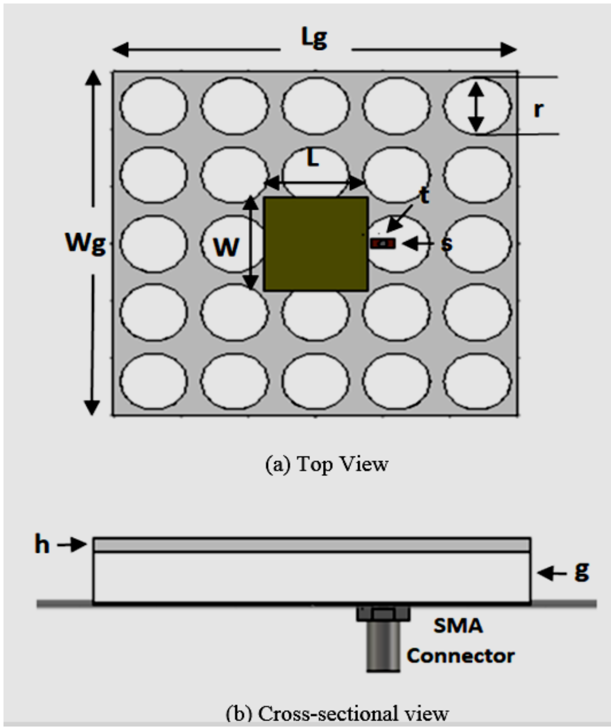


Fig. 1. Rectangular patch antenna with capacitive feed.

The antenna is placed on a Rogers RO3003 substrate with a dielectric constant of 3 and a thickness of 1.56 mm. Air holes of diameter 5 mm are inserted into the substrate in order to reduce the permittivity and increase bandwidth. The dimension of the radiator patch L and W are kept 15.5 mm and 16.4 mm, respectively. The feed strip length and width (t and s) are optimized as 3.5 and 1.7. Fig. 1. shows the proposed antenna layout in CST and the design parameters are summarized in Table I.

TABLE I. ANTENNA DESIGN PARAMETERS

Parameter	Value (mm)
Length of the ground plane (Lg)	60
Width of the ground plane (Wg)	60
Length of the patch (L)	15.5
Width of the patch (W)	16.4
Length of the feed strip (s)	1.7
Width of the feed strip (t)	3.5
Thickness of air gap (g)	6
Thickness of substrate (h)	1.56
The radius of air hole (r)	5

III. RESULTS AND DISCUSSION

The simulated results of the impedance bandwidth are shown in Fig. 2. The results show that without the air holes, -10 dB impedance bandwidth is (4.1- 6.5) GHz. By introducing holes in the structure, the bandwidth becomes (4.5- 7.7) GHz. The holes in the substrate boost the bandwidth improvement by almost 800 MHz with just a little impact on the gain and efficiency, which are 8.07 dBi and 98%, respectively. Also, it is noticed that there is a shift in the resonance frequency due to a reduction in permittivity.

Fig. 3. shows the effect of changing the radius of the air holes on the impedance bandwidth. The radius was varied with different values.

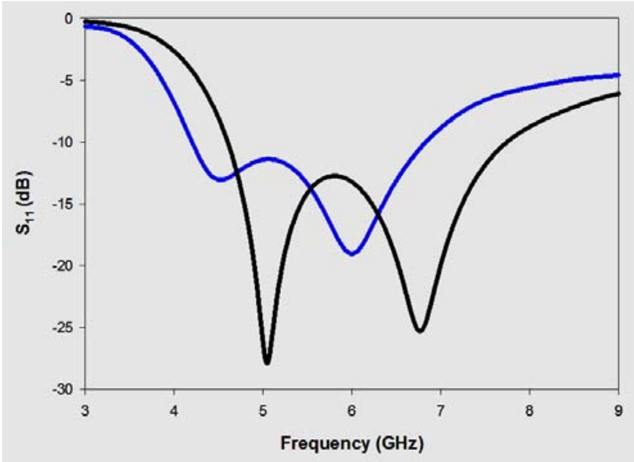


Fig. 2. Input impedance of the proposed antenna with and without air holes.

It can be seen that when the radius of the air holes increases, the impedance bandwidth also increases. For the proposed design, 5 mm is chosen as the radius of the air holes which gives a wider bandwidth. Additionally, increasing the dimension of the air holes beyond 5 mm will affects the mechanical stability of the structure, because of the holes will be closer to each other, resulting in fault in fabrication.

Fig. 4 shows, next page, that the radiation pattern at 5.5 GHz and the proposed design illustrate approximately identical beamwidth in H and E planes.

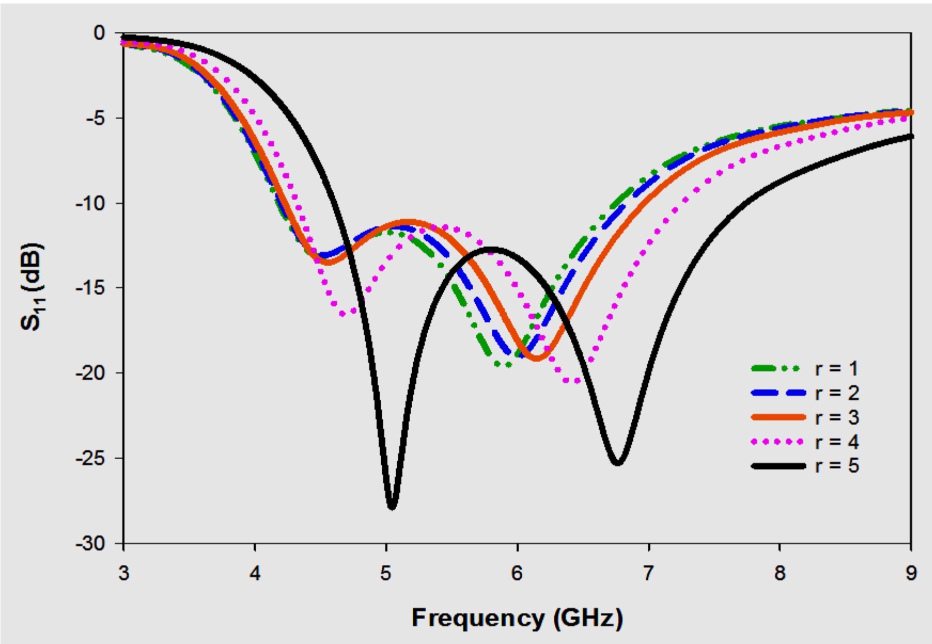
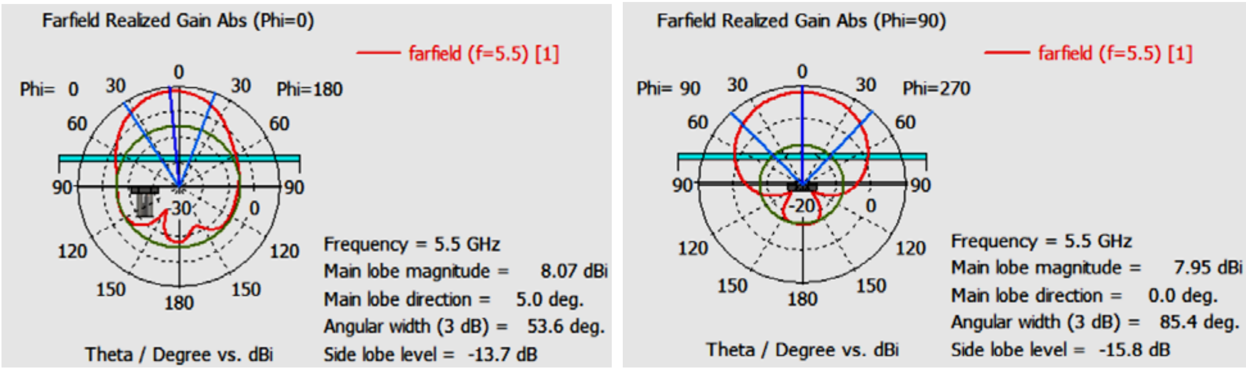


Fig. 3. Effect of changing the radius of the air holes.

DOI 10.5013/IJSSST.a.23.02.07 ISSN: 1473-804x online, 1473-8031 print



E-plane H-plane

Fig. 4. E-plan and H-plan radiation patterns of the proposed antenna.

IV. CONCLUSION

In this paper, a rectangular patch antenna with a capacitive coupled probe feed was presented. The introduction of the air holes in the substrate is used for the bandwidth enhancement. The results demonstrated that the bandwidth at the center frequency is improved from 44% to 52%, which translates to about 8% enhancement. The simulated gain is around 8 dB. The proposed antenna is suitable for automotive applications operating at V2X band.

REFERENCES

[1] Y. P. Zhang, "Design and experiment on differentially-driven microstrip antennas," *IEEE Trans. Antennas Propag*., vol. 55, no. 10, pp. 2701–2708, Oct. 2007.

[2] D. M. Pozar, "Microstrip antennas," *Proc. IEEE*, vol. 80, no. 1, pp. 79–91, Jan. 1992.

[3] J. Kovitz, and R-S. Yahya, "Using thick substrates and capacitive probe compensation to enhance the bandwidth of traditional CP patch antennas," *IEEE Transactions on Antennas and Propagation*, vol. 62, no. 10, pp. 4970-4979, Oct. 2014.

[4] G. GUO, L.S. Wu, Y.P. Zhang, and J.F. Mao, "Stacked patch array in LTCC for 28 GHz antenna-in-package applications," *IEEE Electrical Design of Advanced Packaging and Systems Symposium (EDAPS)*. IEEE. p. 1-3, 2017.

[5] V. P. PATIL, "Enhancement of bandwidth of rectangular patch antenna using two square slots techniques," *International journal of engineering sciences & emerging technologies*, vol.3, no. 2, pp. 1-12, Oct. 2012.

[6] Y. Chen, S. Yang, and Z. Nie, "Bandwidth enhancement method for low profile E-shaped microstrip patch antennas," *IEEE transactions on antennas and propagation*, vol. 58, no. 7, pp. 2442-2447, July, 2010.

[7] D. M. Pozar, and B. Kaufman, "Increasing the bandwidth of a microstrip antenna by proximity coupling," *Electron. Lett.,* vol. 23, no. 8, pp. 368–369, Apr. 1987.

[8] D. Sun, W. Dou, L. You, X. Yan, and R. Shen, "A broadband proximity-coupled stacked microstrip antenna with cavity-backed configuration," *IEEE Antennas and wireless propagation letters*, vol. 10, pp 1055-1058, 2011.

[9] M. Honari, A. Abdipour, and G. Moradi, ABDIPOUR, "Bandwidth and gain enhancement of an aperture antenna with modified ring patch," *IEEE Antennas and Wireless propagation letters*, vol. 10, pp. 1413-1416, 2011.

[10] N.-W. Liu, L. Zhu, W.-W. Choi, and X. Zhang, "A low-profile aperture-coupled microstrip antenna with enhanced bandwidth under dual resonance," *IEEE Trans. Antennas Propag.,* vol. 65, no. 3, pp. 1055–1062, Mar. 2017.

[11] M. C. Tan, M. Li, Q. H. Abbasi, and M. Imran, "A wideband beamforming antenna array for 802.11 ac and 4.9 GHz in modern transportation market," *IEEE Transactions on Vehicular Technology*, vol. 69, no. 3, pp. 2659-2670, March, 2019.