A Compact Stacked-Patch Endfire Antenna for WiFi Application

Yuanhua Sun[1], Guangjun Wen[1], Ping Wang[1, 2], Yongjun Huang[1], and Zhibo Du[3]

[1] Centre for RFIC and System Technology, School of Communication and Information Engineering
University of Electronic Science and Technology of China, Chengdu, 611731, China
sunyuanhua17@gmail.com

[2] College of Electronic and Information Engineering, Chongqing Three Gorges University, Chongqing, 404000,China
wangpingcqz@163.com

[3] Chengdu University of Information Technology, Chengdu, 610225, China
du139123456789@163.com

Abstract **─** The new stacked-patch endfire antenna is proposed for wireless fidelity (WiFi) access point and base station. The proposed using three copper patches is presented. The new antenna uses easily fabrication. The advantage of the endfire antenna with three patches compared to the conventional Yagi antenna is a reduction in the length of the antenna and the dimension of the antenna is 0.504 λ × 0.664 λ × 0.075 λ mm^3. The antenna has a gain of 9 dB, return loss better than -10 dB around the WiFi band from 2.4 GHz to 2.483 GHz and the front-to-back can achieve 15 dB. We described the antenna structure and presented the comparison of simulation results with experimental data. The proposed antenna is fabricated, and measured reflection coefficient, radiation patterns, and gain are presented.

Index Terms **─** Endfire antenna, stacked-patch antenna, and wireless fidelity.

I. INTRODUCTION

Wireless fidelity (WiFi) has become the standard for wireless local area network (WLAN) communication in 2.4 GHz industrial, scientific, and medical bands, with frequency ranges from 2.4 GHz to 2.483 GHz. WiFi provides wireless network communications between computers and other portable devices by fixed access points over a short distance, typically in the order of tens of meters through WLANs. The antenna is an important part in the WiFi system.

WiFi antenna can be categorized into three groups, namely, designs for mobile applications, outdoor, and indoor. For each group, the antenna design features specific requirements: antennas for mobile devices provides omnidirectional coverage with an average gain from -5 to 5 dB. The physically and electrically small antennas are required also [1-3]. Outdoor antennas include directional patch antenna arrays and highly directional Yagi antennas [4]. Indoor antennas can provide directional/omnidirectional coverage with gain from 2 dB to 6 dB. These patch or monopole antennas are usually mounted on walls and ceilings. A small-form or low-profile design is important because of the limited space and aesthetical concerns [5-7]. However, some of them do not have the directional radiation, and have low gain. The conventional directional antennas such as Yagi antennas have high gain, but they have large dimensions.

In this paper, we propose a compact endfire antenna for WiFi applications. The advantages of the proposed antenna is more compact than the conventional Yagi antenna. The proposed antenna is designed to cover the IEEE 802.n band from 2.4 GHz to 2.483 GHz with endfire performance and impedance matching. Meanwhile, the antenna configuration is simple and easy for fabrication. Also, the return loss, gain, and radiation pattern of

Submitted On: Sep. 2, 2012
Accepted On: May 16, 2013

1054-4887 © 2013 ACES

the manufactured prototype has been measured. From the measured results, there is agreement between simulation and measurement.

II. ANTENNA CONFIGURATION

Similar to the conventional Yagi antenna, Fig. 1 shows the geometry of the proposed antenna. The final antenna parameters are optimized using the commercial electromagnetic (EM) solver HFSS 13.0, and are given in the table 1. The antenna is designed for WiFi access point and basic station in the frequency range of 2.4 GHz - 2.483 GHz

The theory of the proposed antenna is on basic of the conventional Yagi antenna. The antenna comprises of two suspended patches and a ground patch. The main radiating patch is directly fed by an SMA connector, which is connected to the RF input and simplifies the antenna structure. A parasitic patch is positioned right above the main radiating patch for enhancing the bandwidth and gain. Air substrate among three copper patches is used to achieve high gain and low cost. The main radiating patch is suspended above the ground plane. The input impendence of the patch and its resonance frequency can be tuned by adjusting the parameters of the dimension of the patches giving freedom for optimization. The antenna has directional radiation pattern, high gain, and higher terminal impedance.

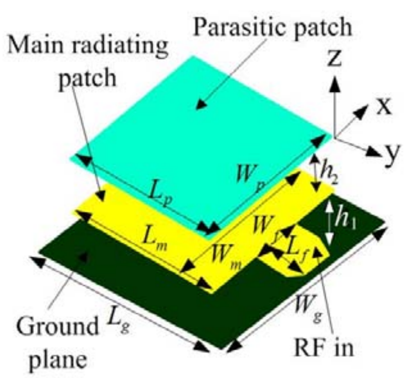


Fig. 1. The designed stacked-patch antenna geometry.

The finally chosen dimension of the proposed antenna are illustrated in table 1. The proposed antenna is designed based on the basic Yagi-Uda antenna principle, consists of two radiating patches. Both patches were shaped to fit into the available dimension while maintaining their resonant frequencies in the desired band. Key parameters in the design are their mutual spacing. The antenna was tuned to achieve 50 ohm impedance without using any external matching circuit that will occupy additional space.

For demonstration purpose in the laboratory, the proposed antenna was designed using three 0.44 mm thickness copper patches. The overall dimension of the antenna is 63 × 83 × 9.32 mm^3, or equivalently roughly 0.504 λ × 0.664 λ × 0.075 λ mm^3.

Table 1: The dimensions of the antenna (in mm).

L_g	W_g	L_m	W_m	L_p
63	83	53	56	53
W_p	L_f	W_f	h_1	h_2
43	16	18.5	5	3

III. SIMULATION AND MEASUREMENT

To verify the proposed antenna design, a prototype is fabricated as shown in Fig. 2, and the results are presented here. All the measured results are carried out in anechoic chamber using a vector network analyzer (VNA) and other microwave test instruments.

(a) (b)

Fig. 2. Stacked-patch antenna prototype; (a) top view and (b) side view.

All simulations were performed by Ansoft high-frequency structure simulation (HFSS) based on the finite-element method (FEM) [8, 9]. The simulated and measured antenna magnitude of S_{11} are shown in Fig. 3. The simulation was performed by HFSS 13.0 and the measurement was taken by an Agilent performance network analyzer.

As shown in Fig. 3, there is a good agreement between the simulation and measurement results and a bandwidth of 250 MHz is obtained. The measured resonance frequency is slightly shifted down in frequency compared to the simulation, owing to fabrication tolerances using the copper patches and soldering the connector. The measured XZ- and YZ- planes radiation pattern and 3D radiation at 2.4 GHz and 2.483 GHz are illustrated in Figs. 4 (a) and (b), respectively. The radiation patterns are measured in a 7 × 3 × 3 m^3 anechoic chamber and the measurement is performed by an Agilent network analyzer along with far-field measurement software. In the measurement the connecting cables along the Bakelite support ware carefully shielded by absorbers to reduce the multi-reflection interference. Meanwhile, the simulated -10 dB reflection coefficient bandwidths are from 2.32 GHz to 2.5 GHz and the corresponding measurement data are given by 2.35 GHz -2.5 GHz. The current distribution at 2.45 GHz is shown in Fig. 5. The experimental results demonstrate that the proposed design completely complies with the stringent requirement of impedance matching imposed on WiFi antenna, and the operating bandwidth with return loss is better than -10 dB and covers the whole allocated spectrum for WiFi applications.

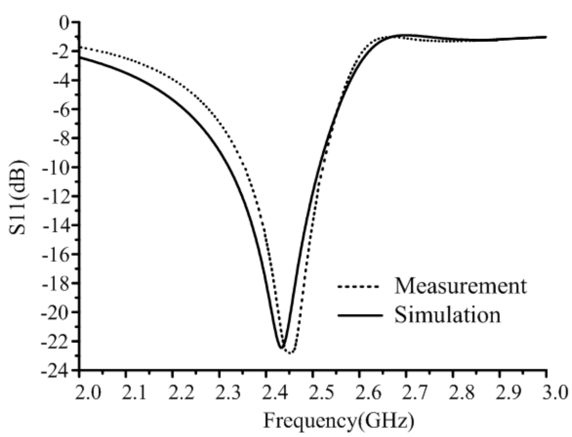
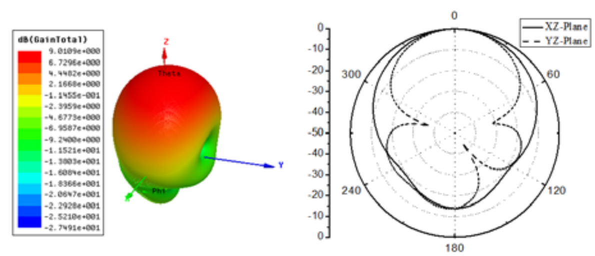
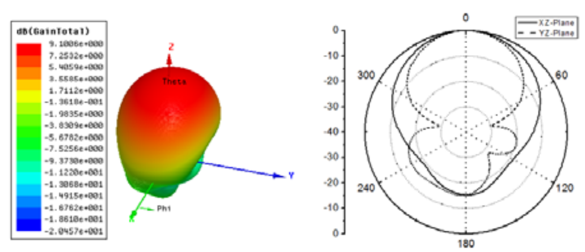


Fig. 3. S11 simulation and measurement results.

For ease of practical applications, the studies of an important parameters of the distances between patches and is also performed by simulations. One parameter is changed, while the other parameters are kept as in table 1. Figure 6 shows the return loss (S11) and gain of the proposed antenna corresponding to different distances between the radiation patch and ground patch (h_1). As shown in Fig. 6 (a), it is observed that there is one resonant frequency, and the resonant frequency is decreased from 2.49 GHz to 2.35 GHz when h_1 is increased from 3 mm to 9 mm. Figure 6 (b) shows the gain of the proposed antenna do not change when h_1 increases from 1 mm to 7 mm. As the value of the distance between the parasitic patch and the main radiating patch (h_2) increases, as shown in Fig. 7, there is one resonant frequency, the resonant frequency decreases from 2.65 GHz to 2.25 GHz when h_2 increased from 1 mm to 7 mm, and the gain decreased in range from 2.4 GHz to 2.5 GHz.

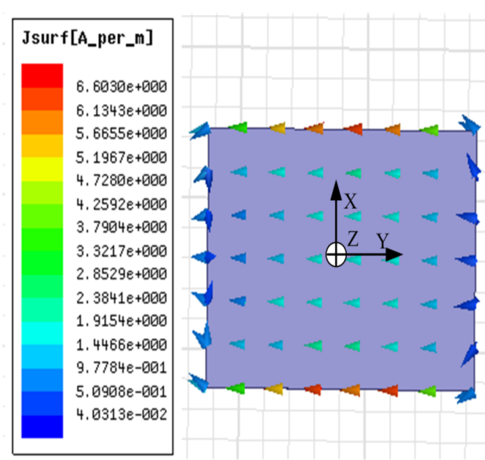


(a)

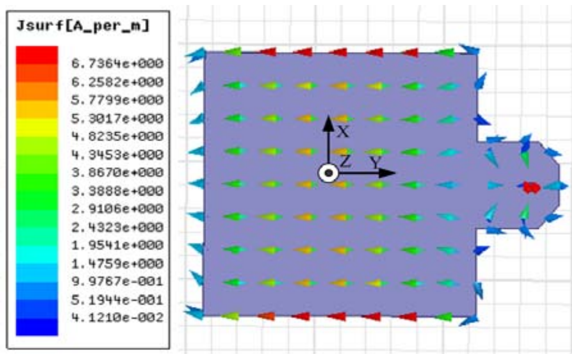


(b)

Fig. 4. The radiation pattern of the stacked-patch antenna at (a) 2.4 GHz and (b) 2.483 GHz.

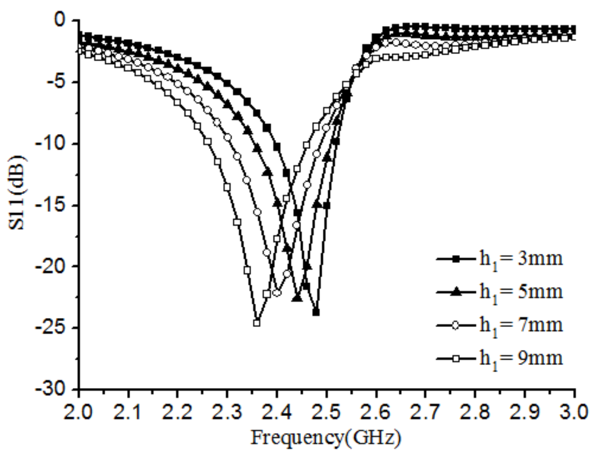


(a)

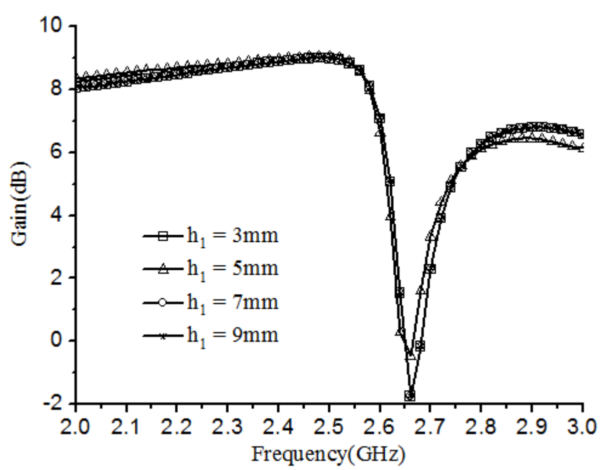


(b)

Fig. 5. The current distribution at 2.45 GHz for (a) the parasitic patch and (b) the main radiating patch.



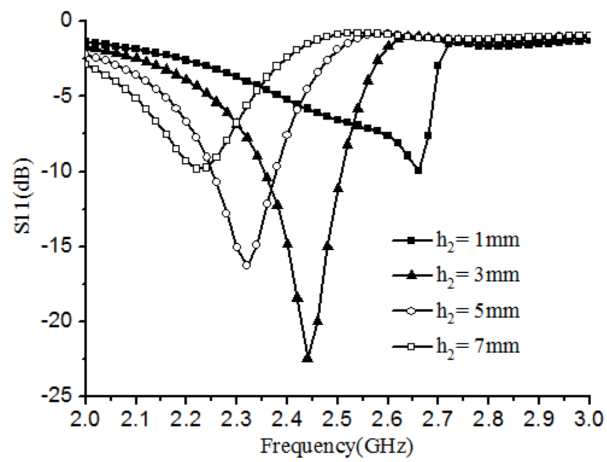
(a)



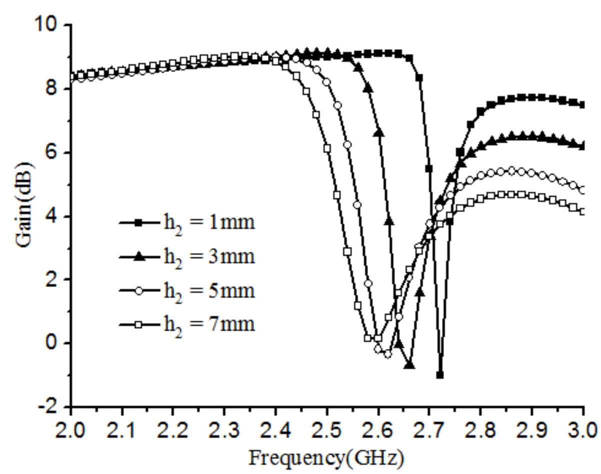
(b)

Fig. 6. Effect of the height of the main radiating patch h_1 on the antenna performance on the (a) return loss and (b) gain.

The gain of the antenna was measured using the gain comparison method [10], where the received power of the antenna under test is compared with known gain of a standard horn antenna. The simulated and measured gain and efficiency are shown in Fig. 8, variation between the simulated and measured gain is within 0.5 dB, and this may be due to losses of patches. The referring to Fig. 3, measured results can be observed over the frequency band of interest. Clearly, Fig. 4 shows the radiation patterns similar to the conventional Yagi radiation characteristics.



(a)



(b)

Fig. 7. Effect of the height of the parasitic patch h_2 on the antenna performance on the (a) return loss and (b) gain.

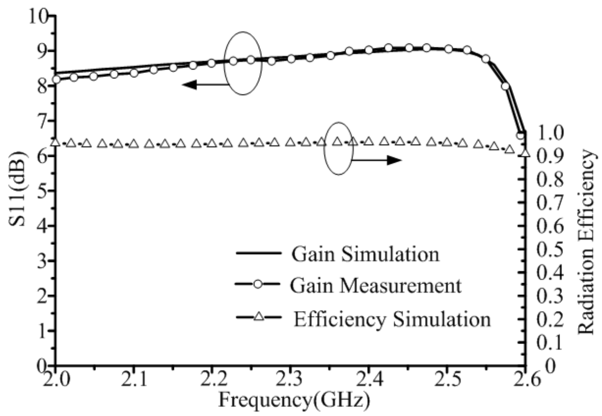


Fig. 8. Simulated, measured gain in the Z-direction and the simulated efficiency of the antenna.

The measured front-to-back ratio is at least 15 dB at 2.4 GHz and reaches 9 dB and remains better than 9 dB over the whole WiFi band from 2.4 GHz to 2.483 GHz. Adding director elements can increase the front-to-back ratio, but on the other hand they will increase the dimensions of the antenna. The measured bore sight gain is illustrated in Fig. 8. Referring to Fig. 8, the antenna gain steadily achieve 9 dB from 2.4 GHz to 2.483 GHz. The efficiency of the proposed antenna steadily achieve above 90 %.

IV. CONCLUSIONS

In this paper, we proposed a stacked-patch endfire antenna for WiFi applications. The proposed antenna is suitable for fabrication. The antenna is based on the conventional Yagi antenna, the input impendence of the antenna can be tuned by properly adjusting the distances of three patches giving freedom for optimization. The antenna configuration, design, simulated, and measured results have been well discussed. The experimental results reveal that the proposed antenna features a compact size of 0.504 $\lambda \times$ 0.664 $\lambda \times$ 0.075 λ, wide -10 dB return loss bandwidth can cover 150 MHz, high gain among 8.5 dB to 9 dB and have good directional radiation patterns. Good return loss and radiation pattern characteristics are obtained and measured results are presented to validate the usefulness of the proposed antenna structure for wireless fidelity (WiFi) applications.

ACKNOWLEDGMENT

This work is supported by Research Fund for the Doctoral Program of Higher Education of China (Grant No 20110185110014).

REFERENCES

[1] Z. N. Chen, *Antennas for Portable Devices*, London, U.K.: Wiley, March 2007.

[2] C. C. Lin, L. C. Kuo, and H. R. Chuang, "A horizontally polarized omnidirectional printed antenna for WLAN applications," *IEEE Trans. Antennas Propag.*, vol. 54, no. 11, pp. 3551-3556, Nov. 2006.

[3] R. A. Rahim, S. I. S. Hassan, F. Malek, M. N. Junita, M. F. Jamlos, and M. N. Azizan, "2.45 GHz harmonic suppression rectangular patch antenna," *IEEE Symposium on Computer Applications and Industrial Electronics (ISCAIE),* pp. 242-246, 2012.

[4] Z. N. Chen and K. M. Luk, *Antennas for Fixed Base-Stations in Wireless communications*, New York: McGraw Hill, May 2009.

[5] H. Nakano, H. Iwaoka, K. Morishita, and J. Yamauchi, "A wide band low-profiled antenna composed of a conducting body of revolution and a shorted parasitic ring," *IEEE Trans. Antennas Propagat.*, vol. 56, no. 4, pp. 1187-1192, Apr. 2008.

[6] P. Callaghan and J. C. Batchelor, "Dual-band pin-patch antenna for WiFi applications," *IEEE Antennas and Wireless Propagation Letters,* vol. 7, pp. 1757-1760, 2008.

[7] D. Wu, M. Zhao, Y. Fan, and Y. Zhang, "A wide band 8-elements omnidirectional array for wireless system," *Microwave and Optical Technology Letters*, vol. 49, no. 12, pp. 2944-2946, Dec. 2007.

[8] K. Elmahgoub, T. Elsherbeni, F. Yang, A. Z. Elsherbeni, L. Sydänheimo, and L. Ukkonen, "Logo-antenna based RFID tags for advertising application," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 25, no. 3, pp. 174-181, Mar. 2010.

[9] HFSS: High Frequency Structure Simulator Based on the Finite Element Method.

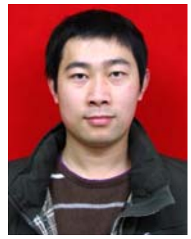
[10] C. A. Balanis, *Antenna Theory: Analysis and Design*, John Wiley & Sons, Inc., New York, 2nd ed., 1997.

Yuanhua Sun received the B.Sc. degree in Communication Engineering from the Liaocheng University in 2007, and M.Sc. degree in Signal and Information Processing from Chengdu University of Information Technology in 2010. He is working toward the Ph.D degree in UESTC. His research interests include analytical and numerical modeling of metamaterials and antenna theory and design and signal processing.

Guangjun Wen was born in Sichuan, China, in 1964. He received his M.Sc. and Ph.D. degrees in Chongqing University of China in 1995 and UESTC in 1998, respectively. He is currently a Professor and doctor supervisor in UESTC.

His research and industrial experience covers a broad spectrum of electromagnetics, including RF, microwave, millimeter wave integrated circuits and systems design for wireless communication, navigation, identification, mobile TV applications, RFIC/MMIC/MMMIC device modeling, system on chip (SoC) and system in package (SiC) design, RF/microwave/millimeter wave power source design, “The Internet of things” devices and system, RFID system and networks, antennas, as well as model of electromagnetic metamaterial and its application in microwave engineering area.

Ping Wang received the B.Sc. degree in Physics from Western Chongqing University of China in 2005 and the M.Sc. degree in Theoretical Physics from Chongqing University, Chongqing, in 2008. Currently, he is working toward the Ph.D. degree in UESTC. His current research interests include patch antennas, wideband antennas, and arrays.



Yongjun Huang received the B.Sc. degree in Mathematics from Neijiang Normal University of China in 2007, M.Sc. degree in Communication Engineering from University of Electronic Science and Technology of China (UESTC) in 2010, and is currently working toward a Ph.D. degree in UESTC. His research activities are electromagnetic metamaterial and its application in microwave engineering area, FDTD and CAD analysis for the metamaterial model and characteristics.

Zhibo Du received the B.Sc. degree in Computer Science and Technology from the Hebei University of Science and Technology in 2007, and M.Sc. degree in Computer Application from Chengdu University of Information Technology in 2010. He is working as assistant in Chengdu University of Information Technology. His research interests include application of antenna, and side channel attack on the security chip, for example electromagnetic attack, power attack and so on.