A Broadband Center-Fed Circular Microstrip Monopolar Patch Antenna with U-Slots

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***Abstract*-A novel center-fed circular microstrip patch antenna is presented. The proposed antenna consists of a circular ground plane and a circular patch antenna. A set of concentric U-shape slots are etched on the patch to improve the operating bandwidth. With the proposed structure, a broad corresponding impedance bandwidth of 15.4% is obtained from 2.3 GHz to 2.72 GHz. A monopole like radiation pattern is obtained and the average gain is about 6dBi. Details of the proposed antenna including reflection coefficient, radiation patterns are presented and discussed.**

***Index Terms*—circular patch antenna (CPA), microstrip antenna, U-Slot**

I. Introduction

Monopole antennas are widely used in the wireless communication systems since they radiate an omnidirectional pattern in the horizontal plane. Typically, monopole antennas are in the form of a straight rod and placed vertically with a height of λ/4 [1, 2]. Due to low cost and easy to manufacture, planar monopole antennas have been achieved. These planar monopole antennas are printed on a substrate for mobile phone, laptop and other applications [3-5]. However, in these designs, a relatively large height is still needed. To obtain a monopole like radiation pattern, researches have been made investigations on the circular microstrip patch antenna [6-10]. In Reference [6], a circular microstrip antenna equivalent to simple monopole was designed. The antenna has a very narrow band width of about 1.5 % for a profile of 0.0152λ. To reduce the size of the circular patch, slots [7] and shorting via [8] are added to the antenna. Apart from miniaturization, multiband performance has also been achieved [9]. However, the narrow bandwidth is still limited for wireless communication application.

Recently, center-fed circular microstrip patch antennas excited in the TM01 or TM02 mode have been proposed [10, 11]. These designs have the advantages of low profile and wide operating band. Reference [10] achieved a 12.8% corresponding bandwidth, but with a large radius of about 0.72λ. Reference [11] improved the corresponding bandwidth to 18%, but too many shorting pins are difficult to manufacture. Adding U-slot is an efficient and convenient way to improve bandwidth for microstrip patch antenna. U-slot on the patch introduces an additional resonant mode near the fundamental mode resonance frequency. Reference [12] made a conclusion that disk patch loaded with U-slot exhibited broad bandwidth. But the antenna in reference [12], fed by an off-center coaxial probe, excited a broadside radiation.

In this paper, we introduce a novel center-fed circular microstrip patch antenna with U-slots for bandwidth improvement. To maintain the omnidirectional radiation pattern of the circular patch antenna, a set of concentric U-shape slots were etched on the patch appropriately. With the proposed structure, an extra resonant mode is excited near the fundamental resonant frequency. The achieved corresponding bandwidth is improved to 15.4%. The parameters of the U-slot are studied with the simulated results. Details of the proposed antenna including reflection coefficient, radiation patterns are presented and discussed.

II. Antenna Geometry

Fig. 1 shows the geometry of the center-fed circular microstrip patch antenna with U-slots, which is printed on a substrate with a thickness of 10 mm (0.084 λ) and a dielectric constant of 2.33. The radius of the ground plane (R_g) is 90 mm (0.756 λ) and the radius of the patch (R_p) is 48 mm (0.403λ). A 50Ω coaxial connector is attached through the center of the ground.

On the top of the patch, a set of N U-slots opening to outwards had been concentrically etched around the patch. The inner edge of each u-slot is at a distance (a) to from the

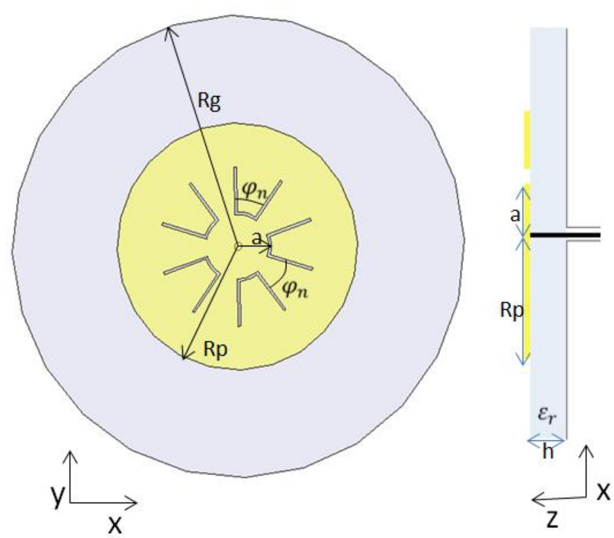

Figure 1. Geometry of the center-fed circular microstrip patch antenna with U-slot.

TABLE I
PARAMETERS OF THE PROPOSED ANTENNA

N	5
R_p	48 mm
a	12.5 mm
R_g	90 mm
L	19 mm
w	1 mm
h	10 mm
ε_r	2.33

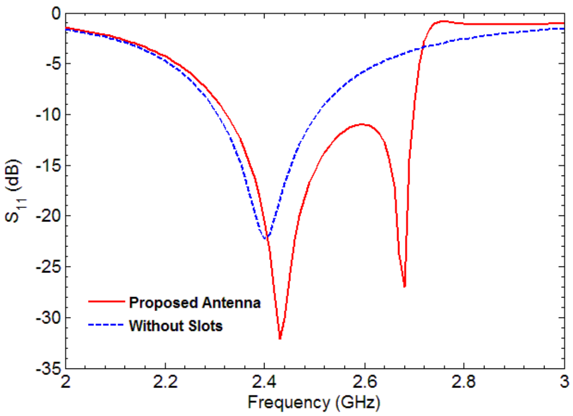

Figure 2. Reflection coefficients of the proposed antenna and without slots

center of the circular patch. Other parameters of U-slots are: length of the slot (L), the number of U-slot N, base corner angle ($\varphi_n = \pi/N$) and width of the slot (w). Through optimization and adjustment based on simulated result, the final antenna parameters are shown in Table I.

III. Results and Discussion

As shown in Fig. 2, the proposed antenna generates an extra resonant frequency at 2.66 GHz compared to the conventional circular microstrip patch antenna. The achieved bandwidth covers from 2.3 GHz to 2.72 GHz. In Fig. 3, the surface current distributes almost invariant in the Ø-direction at 2.44 GHz, which is similar to the conventional circular microstrip patch antenna. The TM02 mode is excited by the circular patch with the first resonant frequency (2.44 GHz). In Fig. 4, the surface current distributes mainly near the U-slots at 2.68GHz. The U-slots limits the surface current in a smaller circle, which generates a higher resonant frequency at 2.68 GHz.

The parameters of the U-slots are studied with the simulated results. It can be seen in Fig. 5 that the number of U-slots makes an influence to the higher resonant frequency. As the number of U-slots increases, the surface current is limit in a smaller circle, which increases the higher resonant frequency. However, as the higher resonant frequency becomes far away from the fundamental resonant frequency, the impedance match gets worse, that because the higher resonant frequency

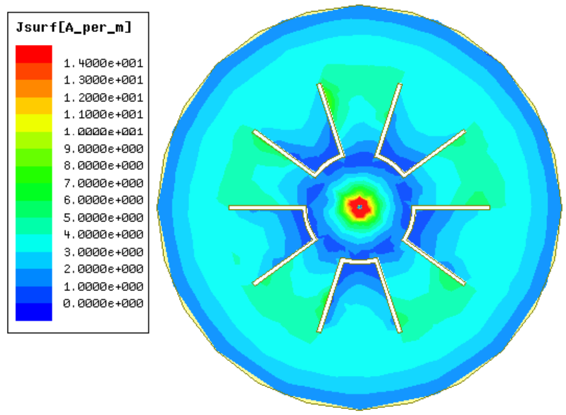

Figure 3. Simulated current distributions at 2.44GHz.

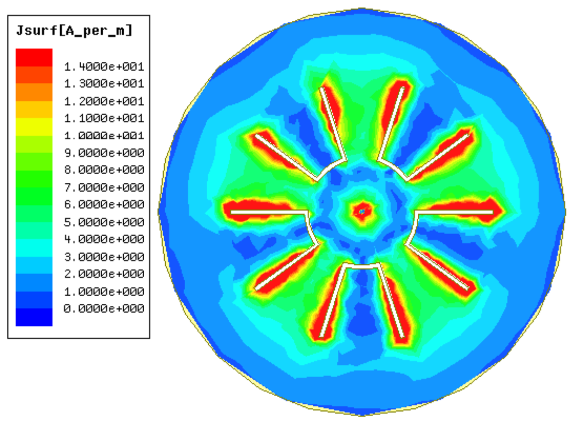

Figure 4. Simulated current distributions at 2.68GHz.

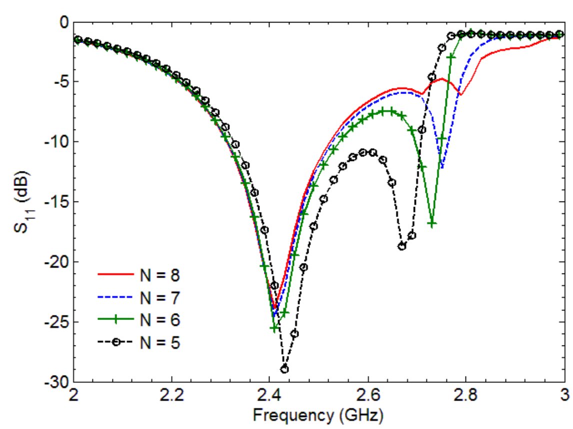

Figure 5. Simulated reflection coefficients for different number of the U-slots, other parameters are the same in Table I.

is excited by the fundamental mode. In Fig. 6, the higher resonant frequency falls, when the distance (a) between the U-slots and the center of the patch in opposite side increases. As the distance (a) increase, the limitation of the U-slots becomes weaker and the surface current can distribute in a larger area. The same effect can be seen in Fig. 7. As the length (L) of the U-slot increase, the higher resonant frequency falls. In general, the parameters of the U-slots control the limitation of the surface current in the second resonant mode.

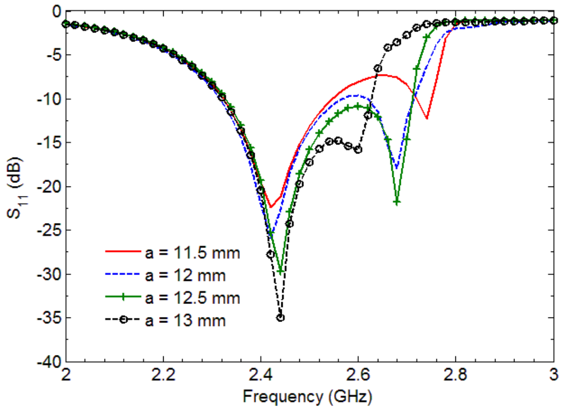

Figure 6. Simulated reflection coefficients for different distance of the U-slots, other parameters are the same in Table I.

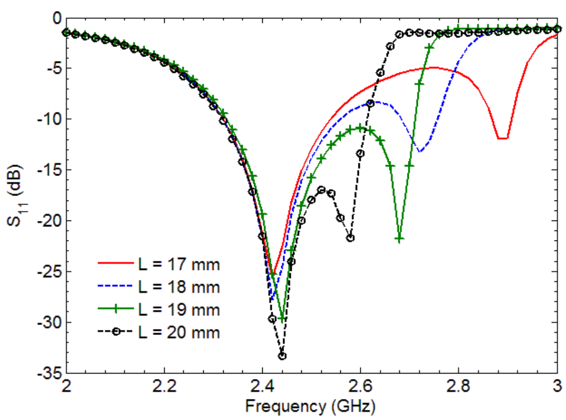

Figure 7. Simulated reflection coefficients for different length of the U-slots, other parameters are the same in Table I.

Fig. 8 shows the simulated radiation patterns at 2.44 GHz and 2.68 GHz for the proposed antenna. The simulated radiation patterns of the proposed at two different frequencies are identical to the conventional monopole antenna. A omnidirectional radiation pattern is achieved in the H-plane. The patterns at these two frequencies are similar. The Simulated results show that the cross polarization is 20 dB below the co-polarization level. When the frequency increases, the cross polarization becomes stronger. As shown in Fig. 9, the gain has a relatively stable value about 6 dBi within the bandwidth from 2.3 GHz to 2.72GHz. The maximum gain is achieved at 2.64 GHz with 7dBi.

IV. CONCLUSION

A new microsrtip circular antenna fed at center is presented. This antenna has a monopole like radiation pattern over the whole operating band. A set of U-slots are cut inside at appropriate position the patch concentrically, which enhance the bandwidth. The parameters of U-slots have been studied with the simulated results. It obtains a wide impedance corresponding bandwidth of 16.3%, from 2.3 to 2.72 GHz.

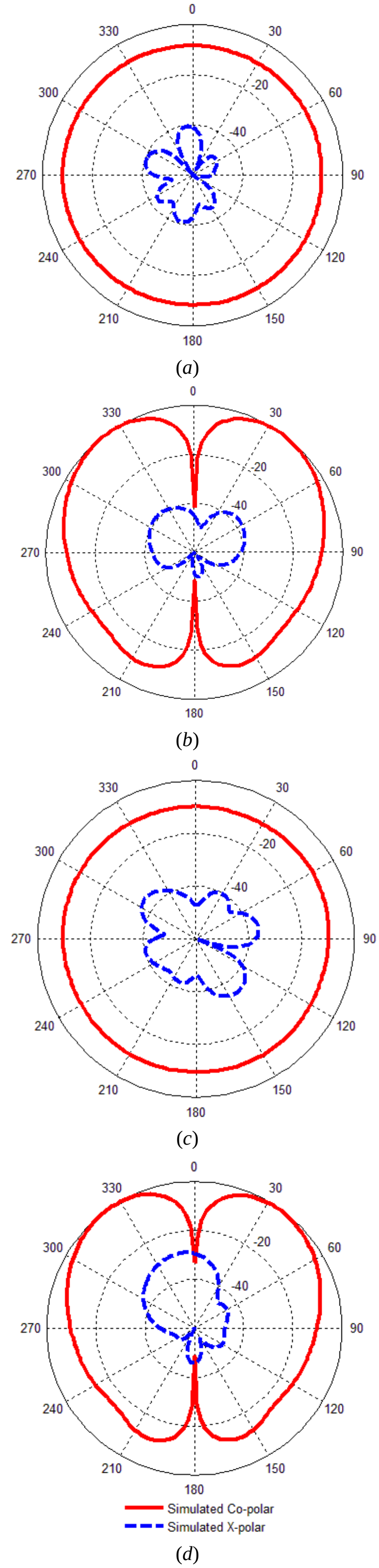

Figure 8. Simulated H-plane radiation patterns of the proposed antenna at: (*a*) 2.44 GHz; (*c*) 2.68 GHz. Simulated E-plane patterns of the proposed antenna at: (*b*) 2.44GHz; (*d*) 2.68 GHz.

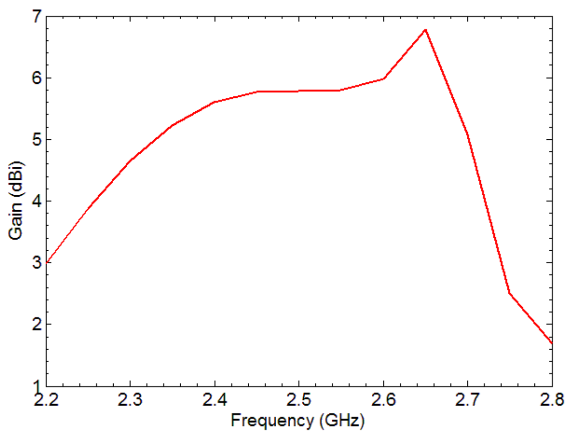

Figure 9. Simulated Gain for the proposed antenna.

The average gain within the bandwidth is about 6 dBi and the maximum gain is achieved at 2.64 GHz with 7dBi.

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REFERENCES

[1] W. L. Stutzman and G. A. Thiele, *Antenna Theory and Design*, 2nd ed. New York: Wiley, 1998.
[2] R. Chair, K. F. Lee, C. L. Mak, K. M. Luk and A. A. Kishk, “Miniature Wideband Half U-Slot And Half E Patch Antennas,” *IEEE Transactions on Antennas And Propagations*, vol. 52, no. 8, August 2005, pp. 2645-2652..
[3] Z. W. Zhong, Y. X. Li, Z. X. Liang, and Y. L. Long, “Biplanar monopole with DSPSL feed and coupling line for broadband mobile phone,” *IEEE Antennas and Wireless Propa. Lett.*, vol. 11, pp. 1326-1329, 2012.
[4] S. A. Rezaeieh, “Dual band dual sense circularly polarized monopole antenna for GPS and WLAN applications,” *Electron. Lett.*, vol. 47, no. 12, pp. 1212-1214, Oct. 2012.
[5] D. B. Lin, H. P. Lin, I. T. Tang, and P. S. Chen, “Printed inverted-F monopole antenna for internal multi-band mobile phone antenna,” in Proc. *VTC*, May. 15-18, 2011, pp. 1-5.
[6] L. Economou. and R. J. Langley, “Patch antenna equivalent to simple monopole,” *Electron. Lett.*, vol. 33, no. 9, pp. 727–728, Apr. 1997.
[7] C. B. Ravipati, “Compact circular microstrip antenna for conical pattern,” in Proc. *IEEE AP-S Int. S*ymp. Dig., Jun. 2004, vol. 4, pp. 3820–3823.
[8] C. B. Ravipati, D. R. Jackson, and H. Xu, “Center-fed microstrip antennaswith shorting vias for miniaturization,” in Proc. *IEEE AP-S Int.Symp. Dig*., Jul. 2005, vol. 3B, pp. 281－284.
[9] A. Al-Zoubi, F. Yang, and A. Kishk, “A low-profile dual band surface wave antenna with a monopole-like pattern,” *IEEE Trans. Antennas Propag.*, vol. 55, pp. 3404－3412, Dec. 2007.
[10] A. Al-Zoubi, F. Yang, and A. Kishk, “A broadband center-fed circular patch-ring antenna with a monopole like radiation pattern,” *IEEE Trans. Antennas Propagation*, vol. 57, no. 3, pp. 789–792, Mar. 2009.
[11] J. Liu, Q. Xue, H. Wong, H. W. Lai, and Y. L. Long, “Design and analysis of a low-profile and broadband microstrip monopolar patch antenna,” IEEE Transactions on Antennas and Propagation, vol. 61, no. 1, pp. 11-18, January 2013.
[12] N. P. Yadav, Anurag Mishra, P. Singh, J. A. Ansari, “A Broadband U-slot loaded circular disk patch Antenna,” in Proc. ELECTRO International Conference, Dec. 22-24, 2009 , pp. 317- 319.