International Journal of Natural and Engineering Sciences 7 (1): 57-60, 2013
ISSN: 1307-1149, E-ISSN: 2146-0086, www.nobel.gen.tr

Compact Circularly Polarized Printed Slot Antenna with a Wrench Shaped Patch for UWB Application

Majid SHOKRI[1] Ch. GHOBADI[1] J. NOURINA[1] Hamed SHIRZAD[2*] Zh. AMIRI[2] S. ASIABAN[2]

[1] Department of Electrical and Electronic Engineering, Urmia University, Urmia, West-Azarbayjan, Iran
[2] Department of Electrical and Electronic Engineering, Urmia branch, Islamic Azad University, Iran

*Corresponding author:
E-mail: hamed.shirzaad@gmail.com

Received: August 04, 2012
Accepted: September 10, 2012

Abstract

A broadband circularly polarized square slot antenna (CPSSA) is presented using a coplanar waveguide (CPW) feed-line. The antenna occupies a volume of 25 ×25 × 0.8 mm^3 and is approximately six fold smaller than the state-of-art antennas of a similar type. The antenna comprises of a square loop shaped ground-plane with three L-shaped ground strips located at its internal corners, and a wrench shaped patch with a semi-circular tuning stub that is connected to the feed-line. The proposed antenna is shown to provide an impedance bandwidth covering 2.92–11.42 GHz (118.5%) with VSWR ≤ 2. Its axial-ratio bandwidth (ARBW) is wider than 50% over the frequency range 5.05-8.42 GHz. The simulated and measured results show the feasibility of the antenna for practical applications.

Keywords: slot antenna, CPW feeding and circular polarization

INTRODUCTION

Printed slot antennas possess attractive features of broad impedance bandwidth, low profile, adaptability to various feed-line structures, and ease of fabrication. Hence these types of antennas have attracted attention for use in circular polarization (CP) applications [1]. Various geometries have been reported lately to realise wideband CP slot antennas that overcome a narrow impedance and axial-ratio bandwidth (ARBW) while simultaneously achieving right-hand CP and left-hand CP. Techniques employed to realise this type of antenna includes: (1) embedding inverted-L grounded strips around two opposite corners of the slot with vertical tuning stub [1]; (2) inserting a lightning-shaped feed-line and inverted-L grounded strips [2]; (3) embedding a T-shaped grounded metallic strip that is perpendicular to the axial direction of the coplanar waveguide (CPW) feed-line [3]; and utilizing a spiral slot in the ground-plane [4].

In this paper, a circularly polarized square slot antenna (CPSSA) is presented for UWB (3.1-10.6 GHz) systems utilising a combination of techniques described in [1]. The antenna consists of a wrench shaped radiating patch which is enveloped with a square looped ground-plane. The antenna contains L-shaped ground strips connected at the corners of the ground-plane. The measured results show the antenna has an impedance bandwidth covering a frequency range 2.92–11.42 GHz (i.e. 3.91:1 or 118.5%), which is three times wider than previously published square slot antenna structures [2–3]. Its ARBW is extends from 5.05-8.42 GHz that is significantly broader than that in [1-5].

Antenna structure

The geometry of the proposed single-layer CPW-fed CPSSA is shown in Fig. 1. This shows the proposed antenna consists of a square loop shaped ground-plane enveloping the wrench shaped patch. The ground-plane loop also includes three L-shaped ground strips connected to the ground-plane loop at its corners. Also included is a tuning stub in the shape of a semi-circle that is connected to the feed-line structure. The proposed CPSSA was constructed on a commercially available substrate (FR4) with a loss tangent of 0.02, permittivity of 4.4. The proposed antenna in Fig.1 has dimensions of 25 × 25 × 0.8 mm^3 that is about six fold smaller than similar geometries [1]. To achieve 50Ω characteristic impedance, the width and length of the coplanar waveguide (CPW) feed-line is 3.1 mm and 11.7 mm, respectively. The width of the gap between the feed-line and the ground-plane (S) is 0.3 mm. Other dimensions of the antenna are given in Fig1.

The design of the antenna is accomplished using five steps. The first step includes only a single rectangular strip of patch that is surrounded with a square looped ground-plane structure. In the second step two L-shaped ground strips are inserted at two opposite diagonal corners of the ground-plane loop, and a semi-circle stub is attached to the feed-line. In the third step a square loop, which is oriented by 45^o, is attached to the rectangular shaped patch. In the fourth step section of the square loop is removed as shown in Fig. 1. In the final step a smaller L-shaped ground strip is connected at the top corner of the antenna's ground-plane to achieve the desired VSWR response.

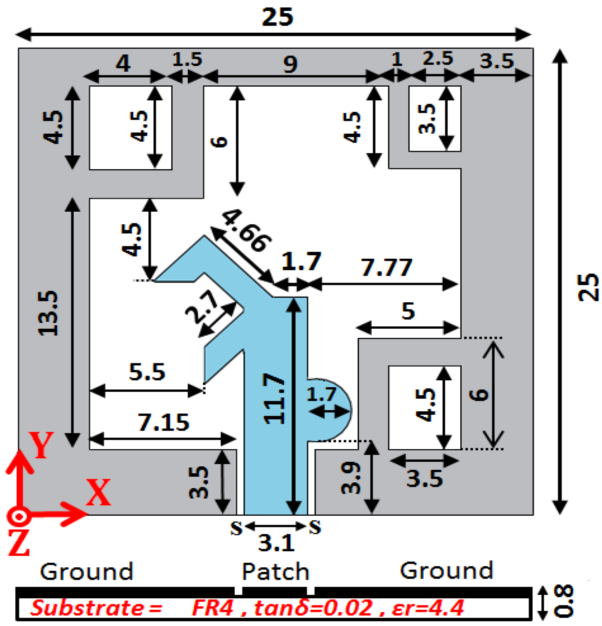

Fig. 1. Geometry of proposed CPW-fed CPSSA (dimensions given in mm)

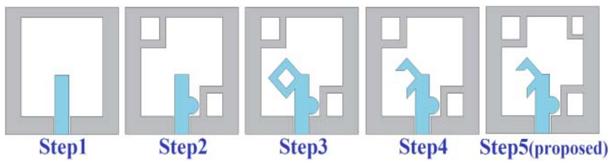

Fig. 2. Five prototype stages leading to the proposed CPSSA

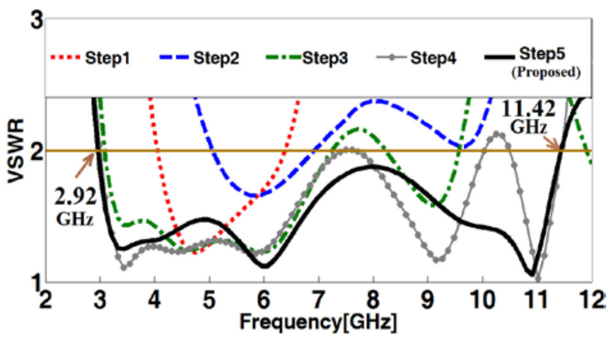

Fig. 3. VSWR curves of the antenna for the various implementation steps to realise the final structure

The VSWR curves of the antenna in the various steps to accomplish the final CPSSA structure are depicted in Fig. 3. The objective of the design was to: (1) enhancing the impedance bandwidth, which is dependent on the L-shaped ground strips, semi-circular tuning stub and the wrench shaped patch; and (2) generating and extending the antenna's ARBW, which is principally related to the L-shaped ground strips.

Parametric study was performed on the proposed antenna included studying the affect of the radius and location of the semi-circular stub. Presented in subsequent sections are the antenna's simulation and measured results of VSWR, ARBW, gain, surface current distribution on the antenna, and radiation patterns.

Table 1. Properties of the various CPSSA prototypes

	BW (VSWR ≤ 2) (GHz)	3 dB ARBW (GHz)
Step 1	4.03-6.35	_
Step 2	5.05-6.89	_
Step 3	3.06-7.19, 8.22-9.56	5.75-7.55, 8.42-8.74
Step 4	2.97-10.03, 10.94-11.45	5.54-7.79
Step 5 (Proposed)	2.92-11.42	5.05-8.42
Measured	3.09-11.61	4.64-8.72

SIMULATION RESULTS AND MEASUREMENTS

In this article the realisation of two objectives are paramount, namely: (1) broadening the impedance bandwidth, and (2) creating and extending the antenna's ARBW for AR 3 dB. Figures 2, 3 and Table 1 show how the first objective was achieved through the five implementation steps. Fig. 3 shows the antenna's impedance bandwidth becomes wider every step implemented. As will be shown later, the utilization of the above technique will enable the second objective to be realised. The antenna is shown to operate in the widely used frequency band of IEEE 802.11a between 5-6 GHz. Also the L-shaped ground strip used in step 5 is important in achieving the second requirement.

A semi-circular tuning stub that is connected perpendicular to the antenna's feed-line, which has a radius Rc and is located at a vertical position Yc measured from the base of the patch antenna. The parametric study was performed using Ansoft High Frequency Structure Simulator (HFSS). The results given below show the radius and vertical position of the semi-circular stub has an impact on the antenna's impedance bandwidth and ARBW.

The simulated VSWR and ARBW curves for different dimensions of parameters Rc and Yc are plotted in Fig. 4 to Fig. 7. Fig. 4 shows the impedance bandwidth expands as Rc is increased from 1 mm to 1.7 mm. The ARBW is marginally affected for Rc = 1.7 mm, as shown in Fig. 5. To maintain a broader impedance bandwidth Yc needs to be reduced to 5.6 mm, as shown in Fig. 6. The optimum values of Rc and Yc that leads to the widest impedance bandwidth and satisfying ARBW covering 5150–5350 MHz and 5725–5825 MHz (specified by IEEE 802.11a) bands for Wireless Local Area Network (WLAN), are 1.7 mm and 5.6 mm, respectively.

Fig. 8 indicates the approximate correspondence between the measured and simulated curves of gain and ARBW for the proposed antenna. The ARBW of the proposed antenna is between 5050 MHz to 8420 MHz (50%) that includes WLAN band, and its average gain is 1.5 dB across 5050 MHz to 8420 MHz. The photograph of the optimised antenna is shown in Fig. 9.

Time-varying surface current distribution over the antenna at 6.8 GHz, at the minimum point of AR, is shown in Fig. 10. It is observed that the surface current distribution in

180° and 270° are equal in magnitude and opposite in phase to 0° and 90°.

If the current rotates in the clockwise (CW) direction, the antenna radiates in the right hand circular polarization (RHCP). This is reversed when the current rotates in the counter clockwise direction where left hand circular polarization (LHCP) is achieved. The proposed CP slot antenna is able to generate an RHCP in the +z direction, whereas an LHCP is produced in the –z direction.

Fig. 11 shows the simulated normalized RHCP and LHCP radiation patterns of the CPSSA at 5.5 GHz, 6.8 GHz and 8 GHz across the antenna's operating bandwidth. The results show that this antenna radiates in right hand circular polarization as well as left hand circular polarization.

The measured and simulated VSWR of the antenna is shown in Fig. 12. The impedance bandwidth is between 2.92–11.42 GHz (118.5%) with VSWR≤2. The characteristics of the antenna make it an excellent candidate for UWB systems.

CONCLUSION

A circularly polarized square slot antenna was presented that is fed through a coplanar waveguide and uses a wrench shaped radiating patch. In comparison with the previous publications using similar techniques, this antenna exhibits the widest axial-ratio bandwidth. The antenna was optimised using parametric study. The antenna's measured performance shows that it possess the characteristics to be a good candidate for UWB applications. Also it is suitable for CP coverage in the IEEE 802.11a bands 5150–5350/5725–5825 MHz.

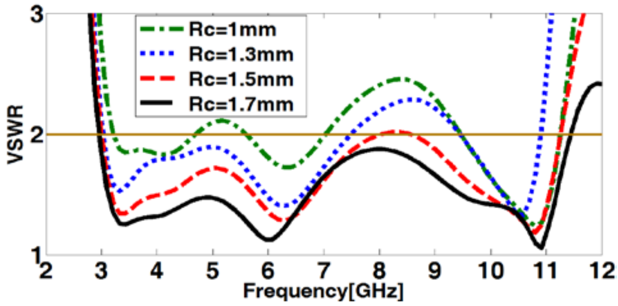

Fig. 4. VSWR curves at different values of parameter Rc (radius of semi-circular tuning stub)

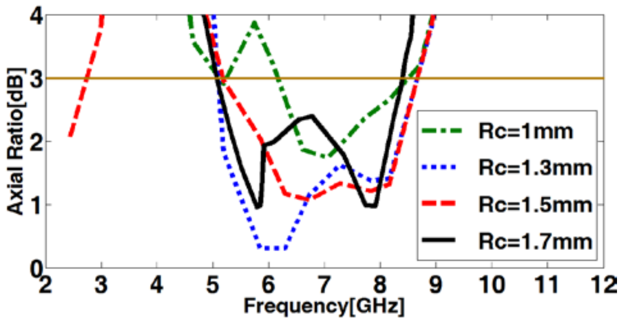

Fig. 5. ARBW of different values of parameter Rc (radius of semi-circular tuning stub)

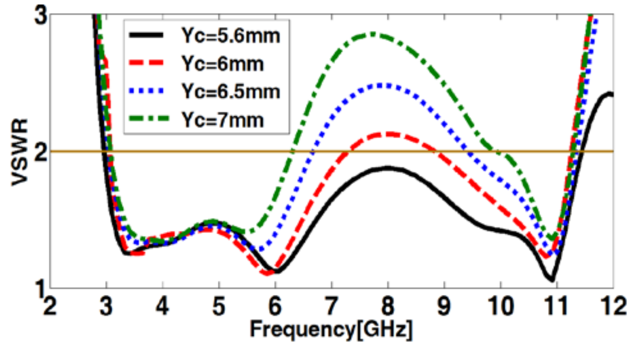

Fig. 6. VSWR curves at different values of parameter Yc (vertical location of semi-circular tuning stub)

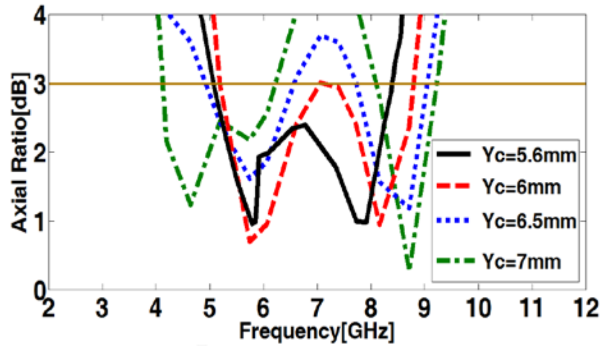

Fig. 7. ARBW at various dimensions of parameter Yc (vertical location of semi-circular tuning stub)

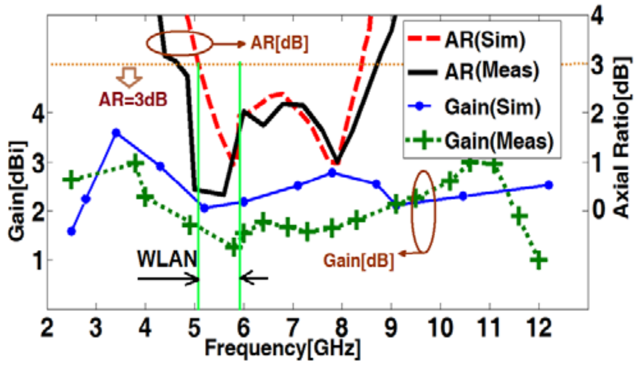

Fig. 8. Measured and simulated ARBW and gain of the proposed antenna

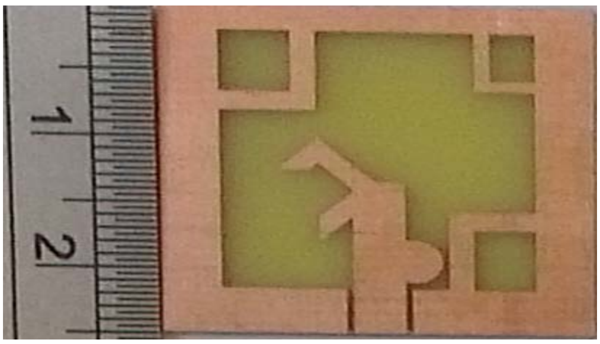

Fig. 9. Photograph of the realized antenna

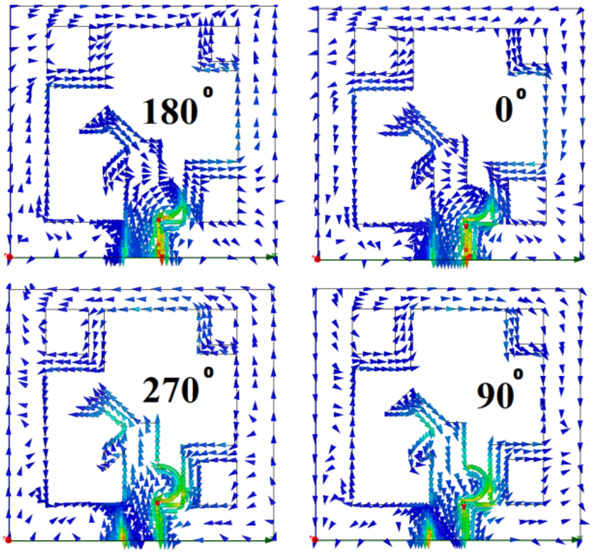

Fig.10. Surface current distribution on the feed and ground-plane of the CPSSA at 6.8 GHz in 0°, 90°, 180°, and 270°

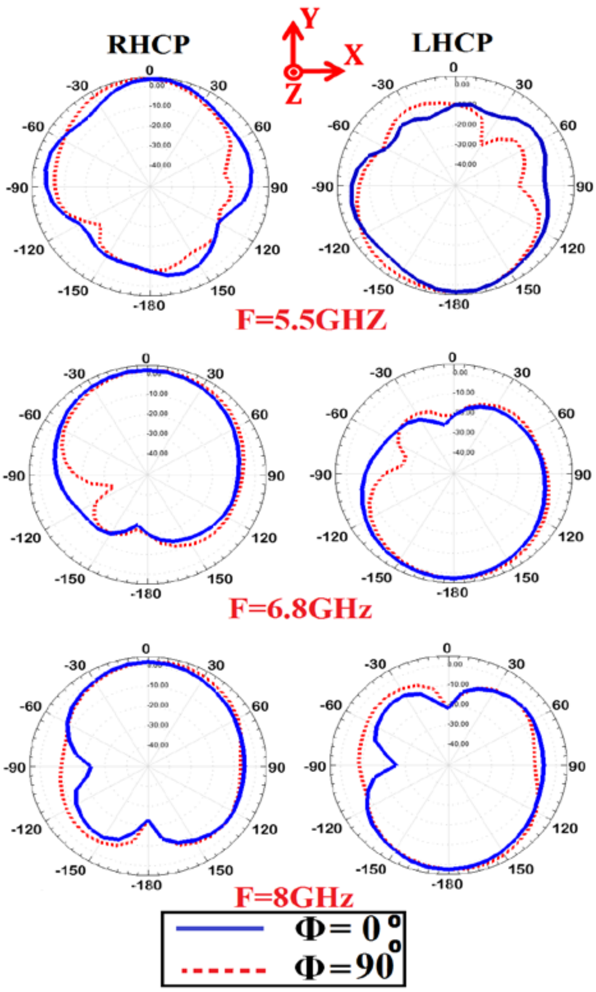

Fig.11. Measured radiation patterns of the proposed antenna at 5.5 GHz, 6.8 GHz and 8 GHz

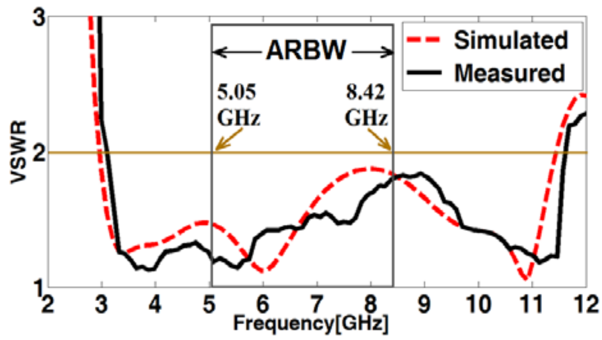

Fig.12. Simulated and measured VSWR of the proposed antenna

REFERENCES

[1] J. Pourahmadazar, Ch. Ghobadi, J. Nourinia, Nader Felegari, H. Shirzad,“Broadband CPW-fed circularly polarized square slot antenna with inverted-L strips for UWB applications,” IEEE Antenna Wireless Propag. Lett., vol. 10, pp. 369-372, 2011.

[2] Jia-Yi Sze, C-I. G. Hsu, Z-W. Chen, C-C Chang, “Broadband CPW-fed circularly polarized square slot antenna whit lightening shaped feed line and inverted-L grounded strips,” IEEE Trans. Antenna Propag. vol. 58, no .3, pp. 973-977, Mar. 2010.

[3] J-Y. Sze, K-L. Wong, C-C. Huang, “Coplanar waveguide-fed square slot antenna for broadband circularly polarized radiation,” IEEE Trans. Antenna Propag. vol. 51, no. 8, pp. 2141-2144, Aug. 2003.

[4] C. Chen, E.K.N. Yung, “Dual-band dual-sense circularly-polarized CPW-fed slot antenna with two spiral slots loaded,” IEEE Trans. Antenna Propag., vol. 57, no. 6, pp. 1829-1833, June 2009.

[5] M. Shokri, Ch. Ghobadi, J.Nourinia, H. Shirzad, S.Asiaban, Zh. Amiri, “Tiny circularly polarized printed slot antenna for UWB usage,” Life Science Journal. vol. 9, no. 3, pp. 2288-2291, June 2012.