A New CPW-Fed Circularly Polarized Square Slot Antenna Design

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Abstract: *In this work, a new wideband circularly polarized square slot antenna (CPSSA) with a coplanar waveguide (CPW) feed is proposed. The suggested antenna is wrought of one arc-shaped, two inverted-L grounded strips around, two opposite corners of the square slot and C shaped(smile) gap on the patch. In this outline the impedance bandwidth and the axial ratio bandwidth (ARBW) are increased compared to the previous CPSSA designs. In this way, the 3 dB axial ratio bandwidth of the designed antenna improved and reached to more than 57 % (3.2 GHz - 5.7 GHz) and the VSWR (Voltage Standing Wave Ratio) < 2 impedance bandwidth increased as large as 108 % (3 GHz - 10.1 GHz). Overall this work, the optimized method of the axial ratio (AR) and S11are provided and discussed in text. The fabricated antenna results agree well with the simulation analysis.*
Keywords: *CPSSA, CPW and C shaped gap.*

1. Introduction

A microstrip slot antenna is a good offer for communication systems, radar and remote sensing applications, as it is low specifications, low cost, lightweight, and can be easily integrated with monolithic microwave integrated circuits (MMICs) [5]. To prosper the operating bandwidth and not decrease the antenna size, applying the printed slot antenna is a feasible method. In this technology circularly polarized (CP) has been suggested more than liner polarized (LP) antenna [5]. CP antennas are more attention than other importance systems in wireless communications, sensors, radio frequency identifier (RFID), and vehicular radar. CP antennas is a good choice among the various designs and structures in wireless communications to raise of system implementation offering better mobility, and weather penetration, more than the linearly polarized (LP) antennas [1, 10,13,14,15 and 16]. Also by applying the CP antennas in wireless communication systems, arranging the direction of the antenna between the transmitter and receiver is not needed any more [6]. CP antennas overcome the multipath fading problem and enhance system performance. Through feeding methods, coplanar waveguide (CPW) feed has some advantages like wide bandwidth, easy integration and single metallic layer [7]. In order to producing CP radiation, created some of the methods such as : implementing two inverted-L grounded strips around two opposite corners of the slot [1,8], improvising T-shaped grounded metallic strip, which is orthogonal to the axis of the CPW feed-line [9], using an asymmetrical CPW fed from a corner of the slot with an embedding pair of grounded strips implanted in the slot [12], striped slot antenna with longer fraught [10], utilizing the additional arc-shaped grounded metallic strip for circular and linear polarization [11], and embedding a firelight shaped feed line and inverted-L grounded strips [3,8] are used in literature. In this work a new design of a CPW fed circularly polarized square slot antenna by combining previous methods and improve some part for getting better results is presented. Based on simulated results, the impedance bandwidth is about 108 %, totally inclusive the 3 dB AR bandwidth, which is about 57 %. This antenna is appropriate for IEEE 802.11a, (5.15–5.35GHz / 5.72–5.82 GHz) and for IEEE 802.16, (3.2–3.8 GHz / 5.2–5.8 GHz).

2. Antenna Design

The configuration of provided antenna has shown in figure 1. This antenna is printed on a commercially cheap FR4-epoxy substrate with εr =4.4, tan (δ) = 0.024. The feed line of the proposed antenna is CPW and is connected to a 50 Ω SMA connector. The gap between the feed line and the ground is 0.3 mm, which is widened at the end to improve the impedance bandwidth. The CP operation of the proposed antenna is greatly related to the one arc shaped and two inverted-L grounded strips in opposite sides placed around the corners of the square slot with C shaped gap on the patch. The antenna parameters are as follow respectively: G = 60, L = 40, h = 0.8, L1=10, L2 = 12, R1 = 11, R2 = 9, L3 = 1, W3 = 4.6, L4 = 1, W4 = 18.4, L5 = 11.6, L6 = 9.8, L7 = 9.6, L8 = 7.9, R3 = 7.5, W1 = 4, W2 = 3.15, L9 = 13, L10 = 6.7, L11 = 6, and W5 = 3.6 (All units are in millimeters).

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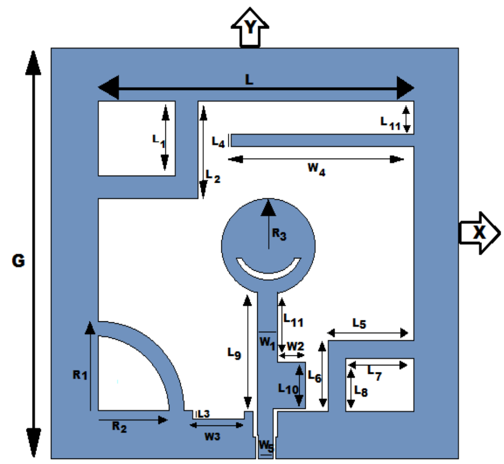


Figure 1. Configuration of the proposed antenna.

3. Simulation and Measured Results

In this section we provided antenna in six prototypes with simulations results for every prototype and measured for the final version. For designing antennas step by steps and tracing the results in each footstep Ansoft high frequency structure simulator software (HFSS, ver.16) has been used. For simplification in the antenna design G = 60 mm, L = 40 mm, h = 0.8 mm were already selected. Figure 2 clarifying the antenna designing process. Ant. 1 includes only a feed line connected to semicircular patch and ground plane; Ant. 2 includes two inverted-L grounded strips around top and bottom corners and one arc-shaped grounded strip at the bottom left side corner. In Ant. 3 a vertical tuning stub (L10 × W2) has been located in the feed structure and the gap between the signal strip and the ground plane is widened at the end. Ant. 4 has a tuning slit (L3 × W3) that has been removed from the ground plane at the left side of the feed line. In Ant. 5 a horizontal grounded strip (L4 × W4) embedded at top right corner and in Ant.6 C shaped gap created on the radiation patch.

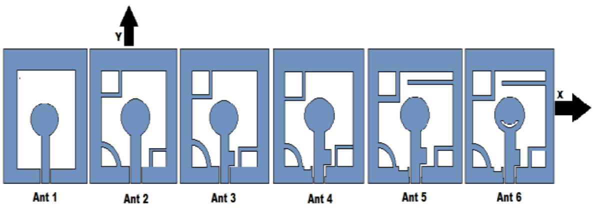


Figure 2: Antenna designing process.

Figure 3 and figure 4 indicate the simulated results for frequency responses of -10 dB S11 and 3 dB axial ratio variations for the six provided prototypes respectively. From Fig. 4, it could be seen that Ant. 1 has a linear polarization. By embedding two inverted-L and an arc-shaped grounded strip around the corners in ant 2, the AR is amended, in Ant 3, the AR is greatly better which reaches 5 % (4.8 GHz–5.4 GHz). However, in this case the AR is not guaranteed by -10 dB S11. A vertical tuning stub is added to the feed structure and the gap of CPW feed is organized to a step shape for improve the impedance matching.

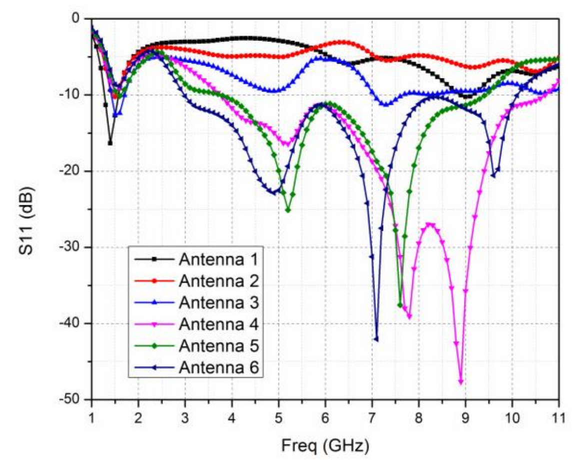


Figure 3: Simulated results of S11 for the six provided prototypes.

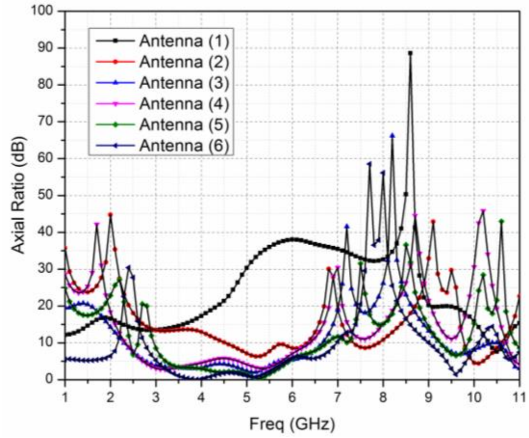
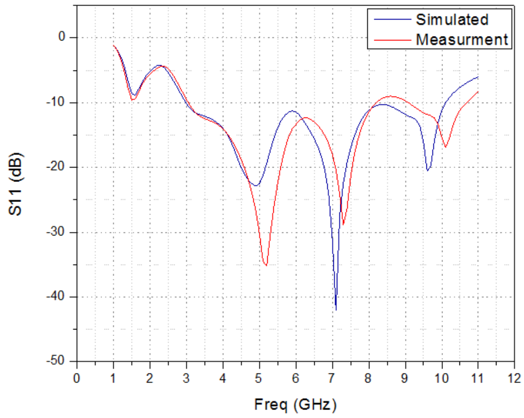


Figure 4: Simulated results of AR for the six provided prototypes.

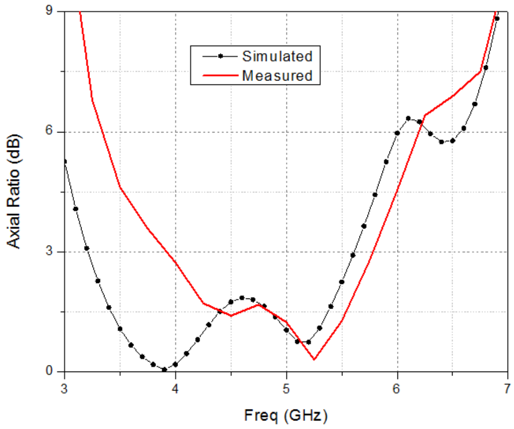
As shown in Fig 4, these structures have great effect on the impedance bandwidth of Ant. 2 (called Ant. 3). With embedded a rectangular slit the AR will be decreases 0.15% (3.017- 3.081) in Ant.4. In Ant. 5 by adding a horizontal strip at the top right corner after tested different length and choice a best length for antenna optimization of the ground plane the AR bandwidth will reach about 20 % (3.8 GHz – 5.7 GHz). At last, by embedding the semicircular gap at the patch of the feed, not only AR bandwidth is increased to 57 % (3.2 GHz – 5.7 GHz) but also the impedance bandwidth can be increased to cover the whole UWB bandwidth. The simulated results in Fig. 3 indicate that including the horizontal strip and C shaped gap, greatly influence the ARBW.

Figure 5 (a) and (b) illustrate the simulated S11 and AR characteristics for the designed antenna at least prototype. Close communication between the simulated and measured results is observed. As also indicated in Fig. 5 (a), the measured impedance bandwidth of the proposed antenna is from 3 GHz up to 10.1 GHz (108 %) for VSWR < 2 and the measured 3 dB ARBW is increased from 3.2 GHz to 5.7 GHz (57 %) that is about 2.5 GHz. Due to the AR and the impedance bandwidth.

In Table 1 the impedance bandwidth, AR bandwidth of the designed antenna has been compared with related work in literature [1, 2, 3]. It is observed that the proposed antenna has wider ARBW and impedance bandwidth than the other ones. All these antennas were fabricated on an FR4 substrate with a loss tangent of tan (δ) = 0.024, permittivity of $\varepsilon_r = 4.4$.



(a)



(b)

Figure 5: Measured and simulated diagrams of (a) S11 and (b) the AR of the proposed antenna (Ant 6).

Table 1. Compared of the measured characteristics of some CPSS antennas with proposed work

References	F_c (GHz)	Imp.Band (GHz)	ARBW (GHz),%
Ref.1	2.665	1.6-3.055	(2.3-3.03), 27.4%
Ref.2	5.969	2.674-13.124	(4.9-6.9), 32.2%
Ref.3	2.754	2.023-3.424	(2.07-3.4), 48.8%
Proposed Work	7.1	3-10.1	(3.2-5.7), 57.47%

The simulated and measured gain of proposed antenna is shown in figure 8.

Simulated radiation pattern for different frequencies and phases has been presented in figure 9 also.

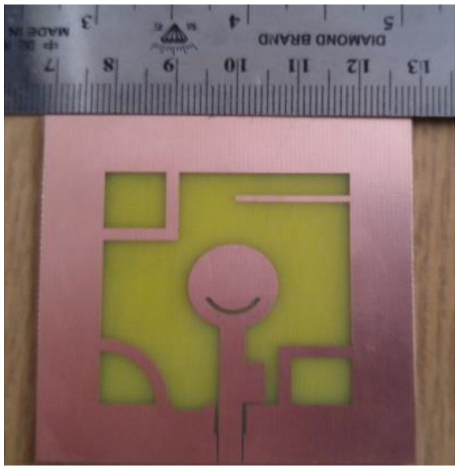


Figure 6: Photograph of the realized CPSS antenna.

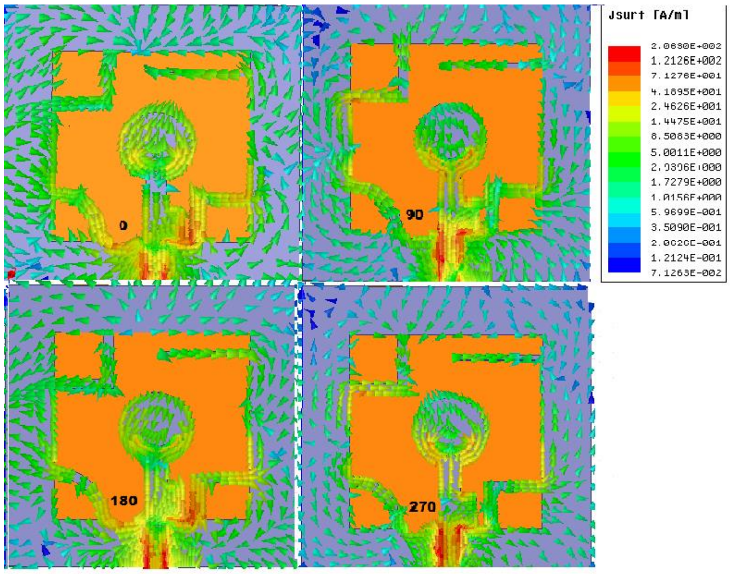


Figure7: Current distribution of the proposed antenna at 6.5 GHz in 0, 90, 180 and 270 phases.

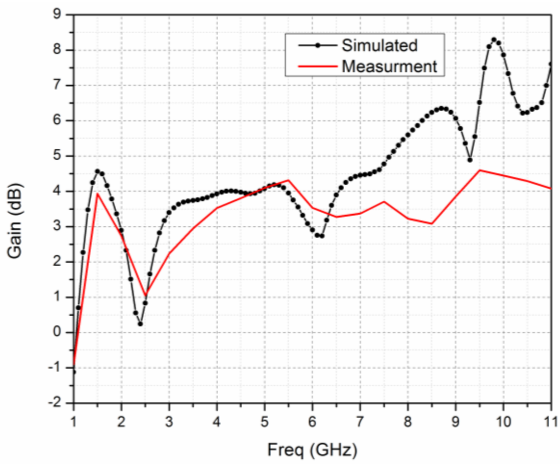


Figure 8: Measured and simulated antenna gain of proposed antenna.

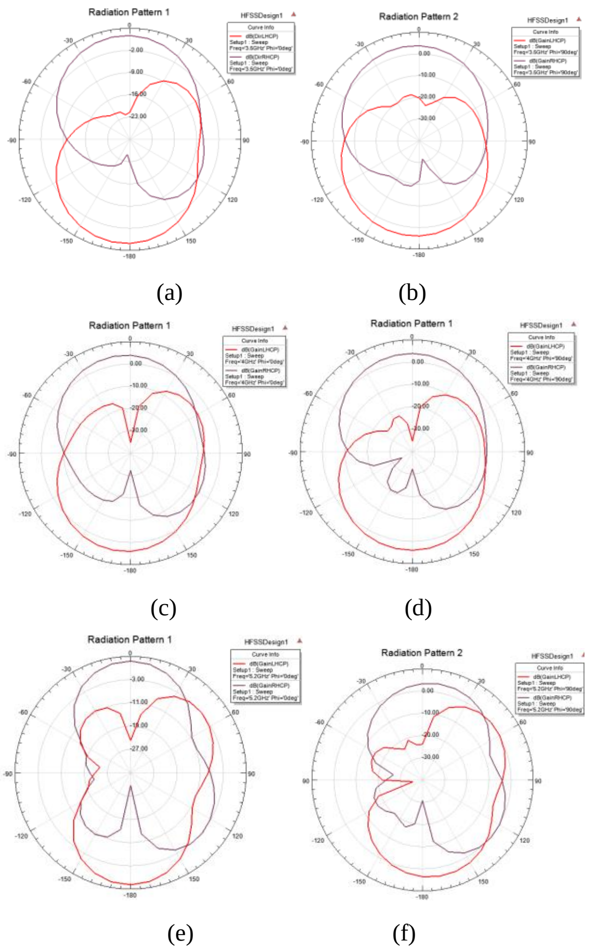


Figure 9: Simulated radiation patterns of the CPSS proposed antenna at:(a) 3.5 GHz, 0^0, (b) 3.5 GHz, 90^0, (c) 4 GHz, 0^0, (d) 4 GHz,90^0, (e) 5.2 GHz, 0^0, (f) 5.2 GHz,90.

4. Conclusions

This paper proposed a new wideband CPW-fed CPSSA for Ultra Wide Band (UWB) applications. In the antenna geometry, employing one arc-shaped, two inverted-L grounded strips and a C shaped gap on the patch, improved 3 dB ARBW and impedance bandwidth noticeably in compare with previous works. The obtained results show that the proposed antenna has an impedance bandwidth about 7 GHz (108 %) and a 3 dB AR bandwidth of about 2.5 GHz (57 %).

5. References

[1] J. Y. Sze and C. C. Chang, "Circularly polarized square slot antenna with a pair of inverted-L grounded strips," *IEEE Antennas Wireless Propag. Lett*., vol. 7, pp. 149-151, 2008.

[2] J. Pourahmadazar, C. Ghobadi, J. Nourinia, N. Felegari, and H. Shirzad., "Broadband CPW-Fedcircularly polarized square slot antenna with inverted-L strips for UWB applications," *IEEE Antennas Wireless Propag. Lett*., vol. 10, pp. 369- 372, 2011.

[3] J. Y. Sze, C. I. G. Hsu, Z. W. Chen, and C. C. Chang, "Broad band CPW-fed circularly polarized square slot antenna with lightening-shaped feedline and inverted-L grounded strips," *IEEE Trans.Antennas Propag*., vol. 58, no. 3, pp. 973–977, Mar. 2010.

[4] B. Boroomandisorkhabi, R. A. Sadeghzadeh, F. B. Zarrabi, and E. Ghahramani "A Novel UWB Circular CPW Antenna with TripleNotch Band Characteristics" *IEEE Trans Antennas Propag*, pp. 978, Nov. 2013.

[5] D. S. Javan and O. H. Ghouchani, "Cross slot antenna with u-shaped tuning stub for ultra wideband applications," *Appl. Comp. Electro.Society (ACES) Journal*, vol. 24, no. 4, pp. 427- 432, Aug. 2009.

[6] K. L. Wong, F. S. Chang, and T. W. Chiou, "Low-cost broadband circularly polarized probe-fed patch antenna for WLAN base station," I*EEE Antennas Propag. Soc. Int. Symp.*, 2002, vol. 2, pp.526–529.

[7] C. C. Chou, K. H. Lin, and H. L. Su, "Broadband circularly polarized cross-patch-loaded square slot antenna," *Electron. Lett.*, vol. 43, no. 9,pp. 485–486, Apr. 26, 2007.

[8] Jia-Yi Sze, Chi-Chaan Chang "Circularly Polarized Square Slot Antenna With a Pair of Inverted-L Grounded Strips" *IEEE Antennas And Wireless Propagation Letters*, VOL. 7, 2008.

[9] Saeid Karamzadeh, Vahid Rafii, Mesut Kartal, and Morteza Dibayi "Circularly Polarized Square Slot Antenna Using Crooked T-Shape Technique" *Applied Computational Electromagnetics Society Journal (ACES)*, Vol. 30, No. 3, March, 2015.

[10] N. M. Jizat, S.K.A. Rahim, Y.C.Lo, M. M. Mansor "Compact Size of CPW Dual-Band Meander-Line Transparent Antenna for WLAN Applications" *IEEE*, Dec 2014

[11] M. J. Chiang, T. F. Hung, and S. S. Bor., "Dual band circular slot antenna design for circularly and linearly polarized operations," *Microw. Opt.Technol. Lett*., vol. 52, no. 12, pp. 2717-2721, Dec, 2010.

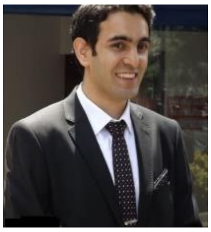
[12] J. Y. Sze, J. C. Wang, and C. C. Chang, "Axialratiobandwidth enhancement of asymmetric CPW fed circularly-polarized square slot antenna," *Electronics Lett.*, vol. 44, pp. 1048-1049, 2008.

[13] S. Karamzadeh, Bal Virdee, V. Rafii, M. Kartal, "Circularly polarized slot antenna array with sequentially rotated feed network for broadband application ", *International Journal of RF and Microwave Computer*-*Aided Engineering*, vol. 25, no.4 pp. 358-363, May, 2015.

[14] S. Karamzadeh, M Kartal "Circularly polarised MIMO tapered slot antenna array for C-band application", *Electronics Letters*, Vol.51, no.18, pp. 1394 -1396, August, 2015.

[15] S. Karamzadeh, M. Kartal, "Circularly polarized 1× 4 square slot array antenna by utilizing compacted modified butler matrix and branchline coupler " *International Journal of RF and Microwave Computer*-*Aided Engineering*, Vol.26, no:2, pages 146–153**,**October**,** 2015.

[16] S Karamzadeh, V Rafii, M Kartal, H Saygin, "Compact UWB CP square slot antenna with two corners connected by a stripline ", *Electronics Letters*,Vol.52, no.1, pp.10-12, December, 2015.



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