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Compact Circularly Polarized Slot Antenna with a Wide Impedance Bandwidth for VSWR≤ 1.5

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Abstract

A new design of circularly polarized (CP) slot antenna is presented in this paper that operates across 3.09–11.31 GHz with an impedance bandwidth (IBW) of 114.1% for VSWR≤2. Moreover with applying a tuning stub to the feed line the impedance matching of the antenna is enhanced that leads to a bandwidth of 107.5% (3.32-11.04 GHz) for VSWR≤1.5. The CP antenna consists of a rectangular radiation patch which is fed through a coplanar waveguide (CPW), three asymmetric rectangular slots on the ground plane and a tuning stub added to the feed-line. Furthermore two slots at center of the patch have been used to excite two orthogonal resonant modes for circular-polarization radiation, also to widen the CP bandwidth a rectangular branch strip is attached to top end of the radiation patch. The proposed antenna exhibits CP bandwidth of 41.93% across 4.88–7.52 GHz, which incorporates the WLAN band. In addition, the antenna has a significantly compact volume of 25×25×0.8 mm^3. The measured and simulated results confirm the usefulness of the antenna for practical applications.

Keyword: circular polarization, CPW-fed, UWB antenna.

INTRODUCTION

Demand for CP antennas has increased in modern systems such as wireless communications, radar and satellites, because of its ability to solve the multipath fading problem, provide better mobility and deliver an enhanced service. Other advantages of CP antennas are their good operation in the adverse weather conditions and without the need to of the accurate polarization alignment between antennas [1]. To achieve circularly polarized radiation, several antennas with various techniques have been reported recently such as: CP antenna with arc-shaped metallic strip [2], square slot antenna fed by an asymmetric coplanar waveguide from a corner of the slot [3], CPW circularly polarized antenna using corrugated structure and meander line loaded [4], slot antenna loaded with a cross patch [5], protruding into the slot a halberd-shaped metal strip from the signal line of the CPW [6], printed slot antenna excited by an L-shaped strip with a taper end [7], CPW-fed broadband circularly polarized square slot antenna with a widened L-type strip along the diagonal line of the square slot [8] and applying an open slot [9].

The authors present a significantly smaller and structurally simpler CP antenna in this paper that exhibits a wider IBW than previous CP antennas reported in [2–9]. The outstanding advantages of this design are its innovative technique used to achieve and widen CP band width and its 7.72 GHz impedance bandwidth for VSWR≤1.5. The measurement results confirm the antenna's properties.

ANTENNA STRUCTURE

The geometry of the discussed single-layer CPW-fed CP antenna is shown in Figure 1. The antenna consists of a square ground-plane, three asymmetric rectangular notches (TARN), a tuning stub conjoined to the feed structure, rectangular patch with a rectangular branch strip, and two slots have been severed from the patch. The proposed antenna was constructed on a commercially available FR4 dielectric substrate with a loss tangent of 0.02, permittivity of 4.4, and dimensions of 25 × 25 × 0.8 mm^3. To achieve 50Ω characteristic impedance, the width and length of the coplanar waveguide feed-line is 3.1 and 8.2 mm, respectively. The gaps between the feed-line and the ground plane are 0.3 mm. The length of the feed-line structure affects the field distributions in the antenna aperture. In this design the feed-line is extended from the CPW section to control the antenna's impedance matching. As illustrated in Figure 2, the antenna design is implemented in five steps, which are listed and briefly discussed in Table 1.

The two main factors that are enhanced in the proposed antenna design are its impedance and CP bandwidths. The IBW was for VSWR ≤2 and the CP bandwidth for AR ≤3. The results show that by using the rectangular slots on the patch the CP is achieved, and by attaching the strip branch to the patch it has been widened enough to cover the whole WLAN band For the final design of the antenna, simulated return loss and AR results are accomplished and deeply studied by using the Ansoft High Frequency Structure Simulator (HFSS Ver.11).

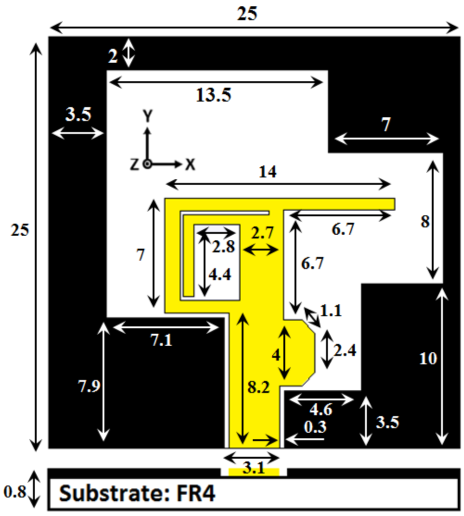

Figure 1. Geometry of the proposed CP antenna (optimized dimensions in mm).

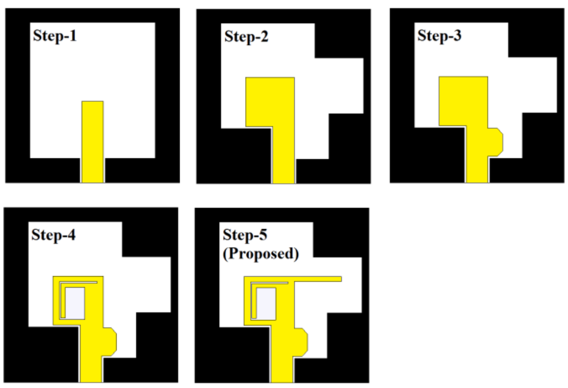

Figure 2. Antenna five steps evolution

RESULTS AND DISCUSSION

The main objectives of developing the antenna design are to enhance its IBW, generate CP, and widening the CP bandwidth.

Table 1. Summary of the CPSSA components and properties

STEP	IBW(GHz)	ARBW(GHz)
1st	4.01-6.41	zero
2nd	3.63-8.04	5.77-5.88
3th	3.64-9.46 & 10.22-12.63	zero
4th	3.57-11.79	6.45-7.35
5th	3.06-11.46	5.01-7.71

Figure 3 shows how the impedance bandwidth of the antenna is enhanced by the five successive steps taken to implement the final antenna design given in Figure 1.The correlation between the simulated and measured VSWR of the final antenna prototype is excellent as shown in Figure 4. The experimental results are accomplished by using the Agilent 8722ES Vector Network Analyzer.

Figure 5 shows the AR curves for the five steps evolutionary antenna for the optimized values given in Figure 1. As seen the combination of the TARN and slots inside patch are shown to greatly affect the antenna's ARBW. A close correspondence between the measured and simulated AR curves is depicted in figure 6.

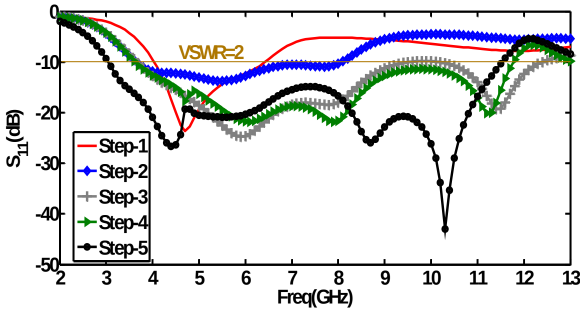

Figure 3. Return loss response of the antenna design for each of the steps.

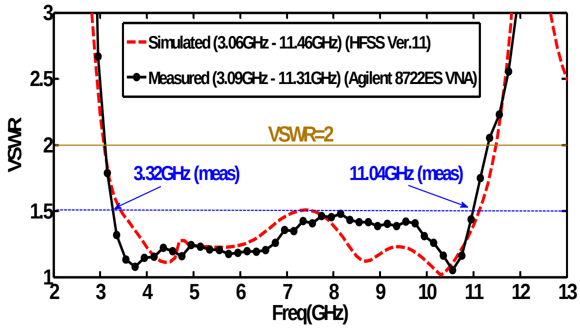

Figure 4. The correlation between the simulated and measured VSWR.

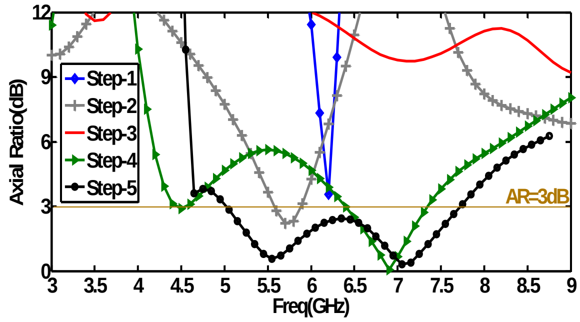

Figure 5. CP axial ratio of the antenna design for each of the steps.

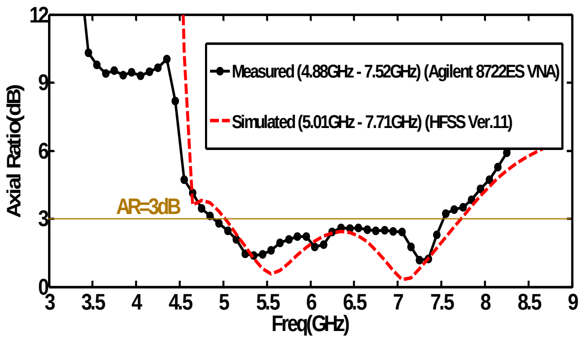

Figure 6. The correlation between the simulated and measured AR.

The ARBW of the proposed antenna extends from 4.88 to 7.52 GHz (41.93%). The simulated and measured right-hand circular polarization (RHCP) and left-hand circular polarization (LHCP) radiation patterns of the CP antenna at frequencies of 5.8, and 7.3 GHz are given in Figure 7. It shows the antenna exhibits omnidirectional radiation characteristics but whose gain variation is evident over certain angular directions.

The surface current distribution over the antenna at 5.5 GHz, at the minimum point of AR, is shown in Figure 8. It is observed that the surface current distribution at 180° and 270° are equal in magnitude and opposite in phase at 0° and

90°. When the current rotates in the clockwise/counter clockwise direction, the antenna correspondingly radiates in the RHCP/LHCP.

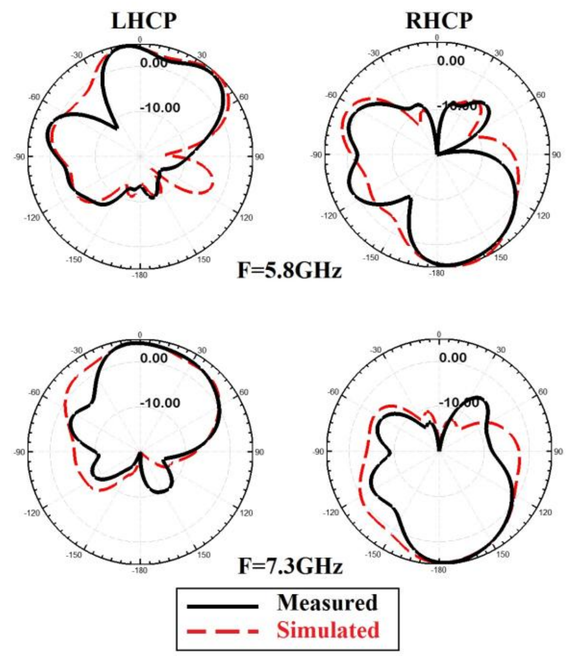

Figure 7. Simulated and measured radiation patterns of the proposed antenna at 5.8, and 7.3 GHz.

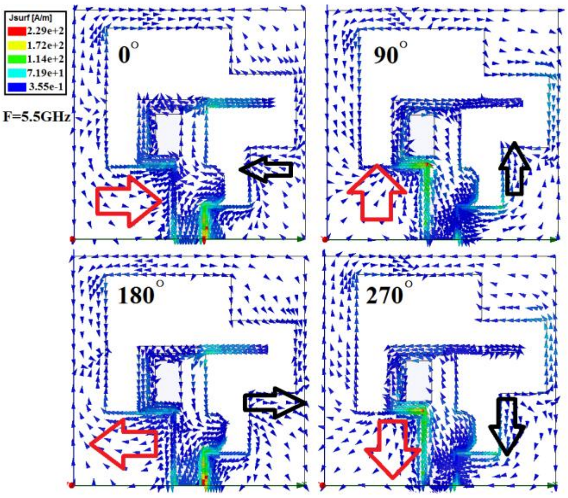

Figure 8. Distribution of the surface current on the antenna at 5.5 GHz in 0°, 90°, 180°, and 270°.

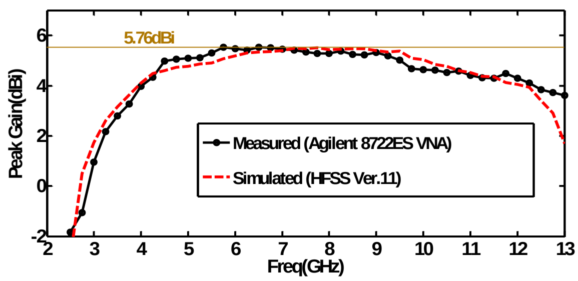

Figure 9. Measured and simulated gain of the proposed antenna.

The proposed CP antenna is able to generate an RHCP in the - z direction, whereas an LHCP is produced in the +z direction. Moreover Figure 9 indicates the close correspondence between the measured and simulated curves of gain for the proposed antenna with optimized values. Furthermore the maximum gain of the proposed antenna is 5.76dBi at 5.82 GHz.

Fabrication of the Antenna and Comparison

Recently numerous CP slot antennas have been reported with various techniques to generate CP operation. Actually, the compactness of size and extension of IBW&ARBW characteristics of a CP antenna, will allow antenna engineers to compare the characteristics of a CP antenna with the other works. The proposed CP antenna exhibits wide IBW and ARBW that covers the WLAN band and compact size. All these properties are listed in Table 2 and compared to recent similar works. Table 2 is presented in order to compare the characteristics of the proposed antenna in this paper with the recent works reported in [2–9] that are manufactured on the same substrate and use various techniques to generate CP operation. Although the ARBW of the antenna is reported in [7] is wider than proposed antenna with 44%, whilst, its size is 32 times larger than this work. It is clear that the axial ratio bandwidth of the proposed antenna is one of the best in the Table 2, while the impedance BW and total size of the antenna with 8220 MHz and 25×25×0.8 mm^3 (500 mm^3) respectively are the most outstanding ones and so admirable. Finally the prototype of the optimized CP antenna is fabricated. Photograph of the antenna is shown in Figure 10.

Table 2. Comparison of proposed antenna with other recent works

Ref.	3-dB AR (%)	BW(VSWR<2) (MHz)	Dimensions (mm^3)
[2]	14.5	866 & 984	40×40×0.8
[3]	30	819	60×60×0.76
[4]	12.4	250	70×70×1.6
[5]	12.4	846	70×70×1.6
[6]	3.81	81	60×60×1.6
[7]	**44**	1420	100×100×1.6
[8]	17	1100	100×100×1.6
[9]	27	5330	50×50×0.8
Proposed	**41.9**	**8220**	**25×25×0.8**

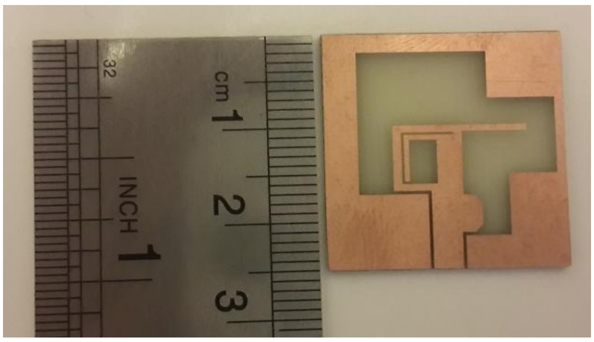

Figure 10. Photograph of the realized antenna.

CONCLUSION

A compact CP antenna is presented that operates across 3.32-11.04 GHz with an impedance bandwidth of 107.5% for VSWR ≤ 1.5. The antenna is a combination of a square ground-plane, three asymmetric rectangular notches, a tuning stub conjoined to the feed structure, rectangular patch with a rectangular branch strip, and two slots have been severed from the patch. In this design the proposed antenna exhibits CP bandwidth of 41.93% across 4.88–7.52 GHz which is applicable for wireless standard technologies such as IEEE 802.11 (5150–5350/5725–5825 MHz).

REFERENCES

[1] M. Shokri, V. Rafii, S. Karamzadeh, Z. Amiri and B. Virdee, "Miniaturised ultra-wideband circularly polarised antenna with modified ground plane," Electronics Letters, Vol. 50 No. 24, pp. 1786–1788, 2014.

[2] Meng-Ju Chiang, Tian-Fu Hung and Sheau-Shong Bor, "Dual-band circular slot antenna design for circularly and linearly polarized operations," Microwave And Optical Technology Letters, Vol. 52, No. 12, pp. 2717–2721, 2010.

[3] J. Sze, J. Wang and C. Chang, "Axial-ratio bandwidth enhancement of asymmetric-CPW-fed circularly-polarized square slot antenna," Electronics Letters, Vol. 44 No. 18, pp. 1048 - 1049, 2008.

[4] C.H. Chen, E.K.N. Yung and B.J. Hu, "Miniaturized CPW- fed circularly polarized corrugated slot antenna with meander line loaded," Electronics Letters, Vol. 43 No. 25, pp. 1404 - 1405, 2007.

[5] C.C. Chou, K.H. Lin and H.L. Su, "Broadband circularly polarized crosspatch-loaded square slot antenna," Electronics Letters, Vol. 43 No. 9, pp. 485 - 486, 2007.

[6] Jia-Yi Sze and Shien-Piao Pan, "Design of CPW-Fed Circularly Polarized Slot Antenna with a Miniature Configuration," IEEE Antennas Wireless Propag. Lett., vol. 10, pp.1465-1468, 2011.

[7] Lin-Yu Tseng and Tuan-Yung Han, "Microstrip-Fed Circular Slot Antenna for Circular Polarization," Microwave and Optical Technology Letters, Vol. 50, No. 4, pp. 1056–1058, 2008.

[8] Y.B. Chen, X.F. Liu, Y.C. Jiao and F.S. Zhang, "CPW-Fed Broadband Circularly Polarized Square Slot Antenna," Electronics Letters, Vol. 42 No. 19, pp. 1074 - 1075, 2006.

[9] Jen-Yea Jan, Chien-Yuan Pan, Kuo-Yung Chiu and Hua-Ming Chen, "Broadband CPW-Fed Circularly-Polarized Slot Antenna with an Open Slot" IEEE Transactions on Antennas and Propagation, Vol. 61, No. 3, pp. 1418 - 1422, 2013.