Design of a Two Bands Circularly Polarized Square Slot Antenna for UWB Application

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Abstract **─** A novel ultra-wideband slot antenna fed by a coplanar waveguide (CPW) is presented and experimentally investigated. The proposed antenna has capability of both the circular polarization and ultra wideband (UWB) performance. The designed antenna has a size of 40 × 40 × 0.8 mm^3. The experimental results show that the antenna has an impedance bandwidth of 142 % and axial-ratio (AR) bandwidths of 35 % for the lower band and 22.6 % for the upper band.

Index Terms **─** Antenna, CPW-fed, CPSSA, circularly-polarized square slot antenna, and UWB.

I. INTRODUCTION

The interest in UWB technology has increased after the U.S. Federal Communications Commission (FCC) allocation of the frequency band on 3.1 GHz – 10.6 GHz for commercial use. Recently, UWB technology has been widely used in various radars and has attracted much attention for communication systems. Although there are many antennas to cover the UWB systems [1-3], but there are few articles that designed UWB antennas with circular polarization (CP) [4-6]. By using the circular polarization in wireless communication systems, arranging the orientation of the antenna between transmitter and receiver is not needed any more. Circularly polarized (CP) antennas overcome the multipath fading problem and enhance system performance [6]. In this paper, we suggest a circularly polarized square slot antenna (CPSSA) for UWB systems with the combination of the techniques introduced in [7-8]. Two main characteristics have been used in the presented antenna: a fork-like feed line for improving impedance bandwidth, three T-shaped and one L-shaped grounded strips mainly for creating circular polarization operation. The measurements indicate that it has an impedance bandwidth of 1.95 GHz – 11.55 GHz (142 %) and also the CP bandwidth is from 2.38 GHz to 3.4 GHz (35 %) for lower band and from 5.1 GHz to 6.4 GHz (22.6 %) for upper bands, respectively.

II. ANTENNA DESIGN

The geometry of the proposed circularly-polarized square slot antenna (CPSSA) and a photograph of the fabricated antenna are depicted in Figs. 1 (a) and (b). The presented antenna consists of a square ground plane with length of 40 mm, three T-shape and one L-shape strips. The T-shape strips consist of a centre arm with fixed length of 4 mm and upper arm with length of L_t and the L-shape strip has a horizontal arm with fixed length of 10.5 mm and a vertical arm with length of L_1. The CPSSA has been printed on a commercially cheap FR4-epoxy substrate with relative permittivity 4.4, thickness 0.8 mm, and loss tangent 0.024 g^2. The width of the coplanar waveguide (CPW) feed line is 3.1 mm, and the width of the gap between the feed line and the ground plane is 0.3 mm (Fig. 1 (a)). To enhance the bandwidth the fork-like microstrip line has been used. Also, to generate circular polarization

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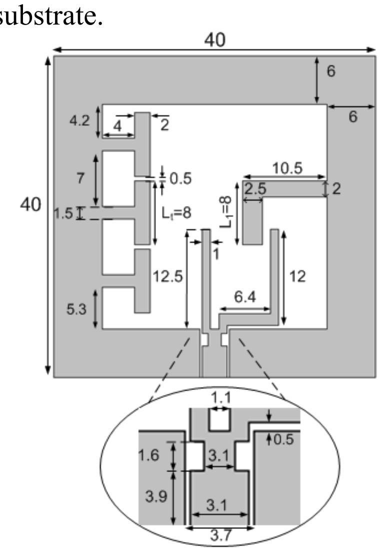
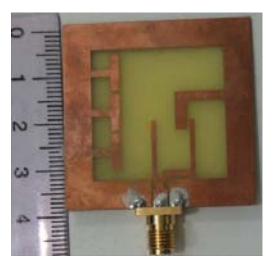
three T stubs and L strip were embedded in the ground plane. The T-Shaped grounded strip was first proposed in [9]. Also, Fig. 1 illustrate the structure of the CPSSA that will generate left and right-handed circularly-polarized (LHCP and RHCP) radiations in lower and upper bands, respectively with AR below 3 dB.

III. EXPERIMENTAL RESULTS AND DISCUSSION

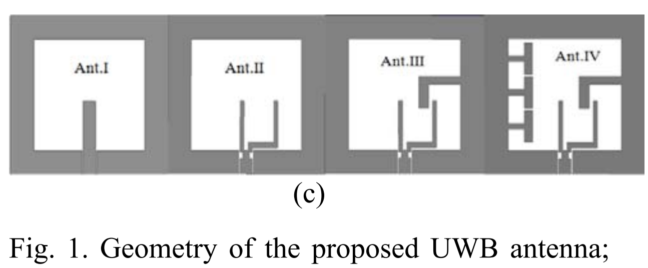
The performance of the CPSSA at parametric studies has been investigated to find the optimized parameters using Ansoft high frequency structure simulator (HFSS ver. 13) based on the finite element method (FEM). To clarify the performance of the antenna, four prototypes of the proposed antenna are defined as follows (Fig. 1 (c)). Ant. I includes only a single strip and a ground plane, Ant. II contains fork-like feed line, Ant. III has a fork-like feed line, and L strip. The proposed antenna or Ant. IV contains T-shaped stubs and L strip embedded in the ground plane. The fabricated antenna has been measured using an Agilent 8722ES vector network analyzer in its full operational span (10 MHz – 20 GHz). Simulated and measured return loss and CP axial ratio are shown in Figs. 2 (a) and (b). The simulated results show that the variation in the feed line shape from straight to fork-like shape assists in creating additional resonances and thus enhances the bandwidth. It should be mentioned that the impedance bandwidth is greatly increased by tuning the fork like feed line while the polarization of antenna become linear. The CP operation of the proposed antenna is mostly related to the T- and L-shaped stubs embedded in the ground plane. Note that Ant. IV has already attained a dual band -3 dB ARBW (2.38 GHz – 3.4 GHz, 5.1 GHz – 6.4 GHz). As exhibited in Figs. 2 (a) and (b), the measured impedance bandwidth for Ant. IV has an operating frequency range from 1.95 (GHz) to 11.55 GHz (142 %) and 3 dB ARBW of 35 % on lower band and 22.6 % on upper band. As mentioned earlier, the T-shape and L-shape strips are used to obtain dual band CP performance of the proposed antenna. To more clarify, the role of these metallic strips in CP operation, the -3 dB axial ratio curves for different values of L_l and L_t are shown in Figs. 3 and 4, respectively. From the simulation results, it is seen that the small changes in the metallic strips lengths (T-shape and L-shape strips) has a significant effect on the CP operation. By increasing L_l, the -3 dB AR bandwidth is fine improved specially on the upper band, whilst the variations of the parameter L_t impress the CP performance, particularly on the lower band as shown in Fig. 4. From the results it is found that the optimum values for L_p and L_t are 8 mm. Usually in design of circularly polarized antennas, obtaining large CP bandwidth is very important (Table I). The size and simulated and measured characteristics of some CPSSA have been summarized in Table I. Meanwhile, all these antennas were fabricated on an FR4 substrate.



(a)



(b)



(c)

Fig. 1. Geometry of the proposed UWB antenna; (a) antenna configuration, (b) photo of the optimized antenna, and (c) four prototypes of the CPSSA under investigation.

Table I: Summary of the measured characteristics of some CPSSA.

Type	Size (mm^3)	Impedance bandwidth (GHz)	3dB ARBW (GHz, %)
Ant. I	40×40×0.8	2.85-4.25	0, (0%)
Ant. II	40×40×0.8	2.65-3.25 3.75-9.4 10.6-more than 12	0, (0%)
Ant. III	40×40×0.8	1.85-2.15 3.1-9.65 10.3-more than 12	5.65-6.05, (6.8%)
Ant. IV (Simulation)	40×40×0.8	1.85-more than 12	2.37-3.31, (33.1%) 5.2-6.66, (24.6%)
Ant. IV (Measurement)	40×40×0.8	1.95-11.55	2.38-3.4, (35%) 5.1-6.4, (22.6%)
Ref.[1]	60×60×0.8	2.67-13	4.9-6.9, (32.2%)
Ref.[2]	25×25×0.8	2.98-11.23	5.012-7.382, (38.2%)
Ref.[3]	60×60×0.8	2-7.07	2.03-5.12, (85%)

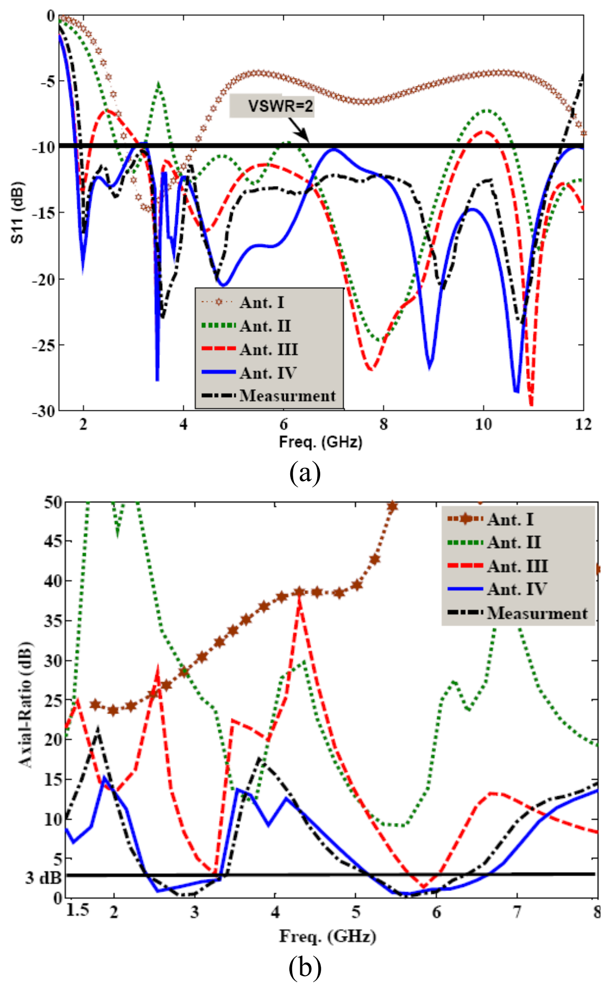


Fig. 2. Measured and simulated S_{11} and CP axial ratios for Ants. I to IV.

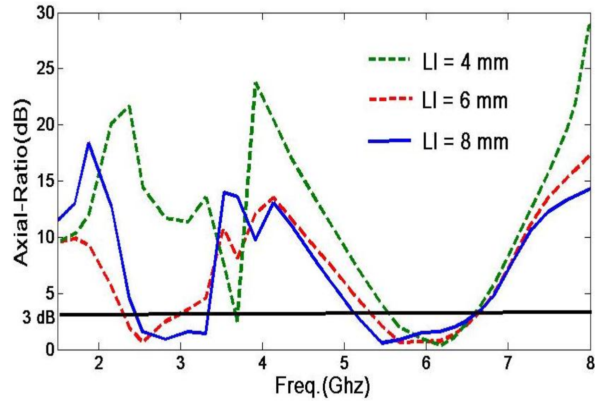


Fig. 3. Simulated AR curves of the proposed antenna with different values of L_l (L_t was fixed at 8 mm).

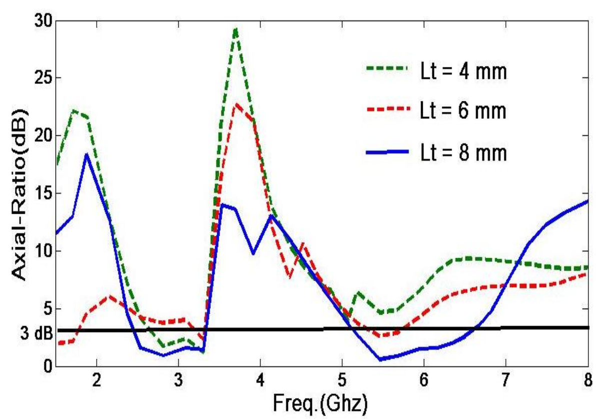


Fig. 4. Simulated AR curves of the proposed antenna with different values of L_t (L_l was fixed at 8 mm).

Figure 5 shows the measured normalized RHCP and LHCP radiation patterns of the proposed antenna at frequencies of 3 GHz, 5.5 GHz, and 8 GHz.

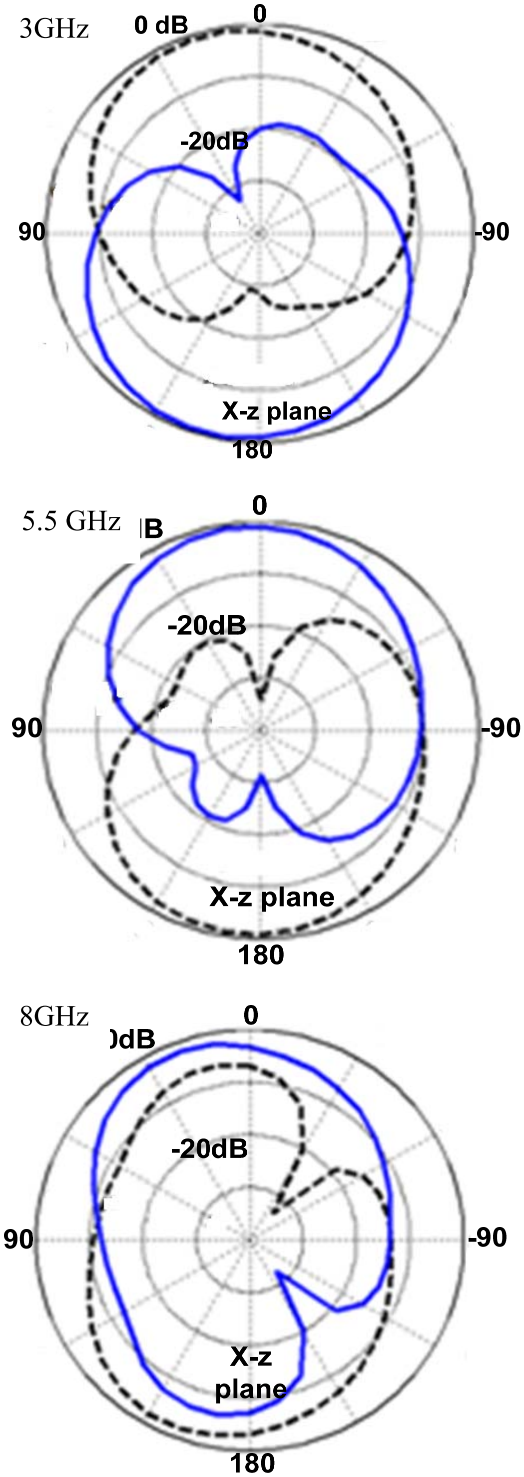


Fig. 5. Measured radiation patterns of the proposed antenna.

IV. CONCLUSION

A novel ultra-wideband antenna fed by a coplanar waveguide has been proposed. The novel structure helps to enlarge the 3 dB ARBW on both of the lower and upper bands to be greater than 35 % and 22.6 %, respectively. The designed antenna has a size of 40 × 40 × 0.8 mm^3. The measured results show that the antenna has a broad bandwidth of 142 %. According to the impedance bandwidth and -3 dB axial ratio bandwidth, the proposed antenna is a good candidate for various wireless systems and applications.

REFERENCES

[1] M. Mighani, M. Akbari, and N. Felegari, "A CPW dual band notched UWB antenna," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 27, no. 4, pp. 352-359, April 2012.

[2] M. Mighani, M. Akbari, and N. Felegari, "A novel SWB small rhombic microstrip antenna with parasitic rectangle into slot of the feed line," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 27, no. 1, pp. 74-79, January 2012.

[3] R. Azim, M. T. Islam, and N. Misran, "Design of a planar UWB antenna with new band enhancement technique," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 26, no. 10, pp. 856-862, October 2011.

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

[5] J. Pourahmadazar and S. Mohammadi, "Compact circularly-polarized slot antenna for UWB applications," *Electron. Lett.*, vol. 47, no. 15, pp. 837-838, 2011.

[6] N. Felegari, J. Nourinia, C. Ghobadi, and J. Pourahmadazar, "Broadband CPW-fed circularly polarized square slot antenna with three inverted-L-shape grounded strips," *IEEE Antennas Wirel. Propag. Lett.*, vol. 10, pp. 274-277, 2011.

[7] J. -Y. Sze and K. -L. Wong, "Bandwidth enhancement of a microstrip-line-fed printed wide-slot antenna," *IEEE Tran. Antennas Propag.*, vol. 49, no. 7, pp. 1020-1024, 2001.

[8] J. -Y. Sze, K. -L. Wong, and C. C. Huang, "Coplanar waveguide-fed square slot antenna for broadband circularly polarized radiation," *IEEE*

Trans. Antennas Propag., vol. 51, pp. 2141-2144, 2003.

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