Broadband circularly polarized antenna for mobile application on low cost FR-4 material

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A broadband CP antenna for wireless communication is presented and experimentally investigated in this communication. The proposed antenna consists of a triangle shape radiator connected with 50Ω microstrip feed line. The antenna has achieved measured impedance bandwidth of 1.03 GHz (1.68-2.71 GHz) and 1.43 GHz (3.27-4.7 GHz) with 3dB axial bandwidth of 230 MHz (2.51-2.74 GHz). The electric dimension of the proposed antenna is 0.26λ × 0.21λ × 0.01λ, at lower frequency. Moreover, the antenna has shown a stable radiation pattern with good antenna performances. The performance has been studied with different substrate materials. In addition, the Specific Absorption Rate (SAR) analysis has been investigated for the proposed antenna.

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1. Introduction

Nowadays, circular polarized antennas are playing promising role in the wireless communication for their various attractive capabilities. Several studies have been reported on circular polarization along with linear polarization [1-4]. Wong et al has been investigated ring slot CP antenna which achieved 3 dB axial ratio of 4.3% (1.695-1.755 GHz) with size of 80×80 mm^2[5]. Moreover, a shorted ring slot CP antenna has been proposed where achieved 3 dB axial ratio is less than 10% and the antenna dimension was 95 mm × 95 mm [6]. In addition, the 3-dB AR bandwidth effect on orthogonal slot in circular patch is analyzed in [2]. In [3], a novel coupling mechanism has been applied for achieving circular polarization and 3-dB AR bandwidth of 0.6% at 2.7GHz centre frequency has been achieved. Moreover, Akbar et al proposed Y-shaped CP antenna, which can cover 2.25GHz to 2.35GHz [4]. In this letter, a microstrip fed CP antenna is proposed for mobile wireless communication. The proposed antenna has achieved 230 MHz (2.51-2.74 GHz) 3 dB axial ratio bandwidth. The 3dB axial ratio bandwidth is also found completely enclosed by the reflection coefficient of less than-10dB. The proposed antenna has shown simple and compact physical size with wide bandwidth in comparison to [1-6]. In addition, the proposed antenna is capable to operate in PCS, WiMAX, Bluetooth and WLAN frequency bands.

2. Antenna design and material study

The geometric configuration of the proposed CP antenna is illustrated in Fig. 1, which is printed on low cost FR4 substrate material of 47×37×1.6 mm^3. The proposed antenna consists of a triangle shape radiator and defected ground plane. A 50 Ω microstrip feed line is connected with the main radiator. The antenna design parameters are: L= 47 mm, W= 37 mm, Wf = 2.46 mm, Lf= 20 mm, L1=22 mm, L2=15.55 mm, L3= 15.55 mm, L4=25.75 mm, L5=24.5 mm and L6= 12 mm, L7 =16 mm.

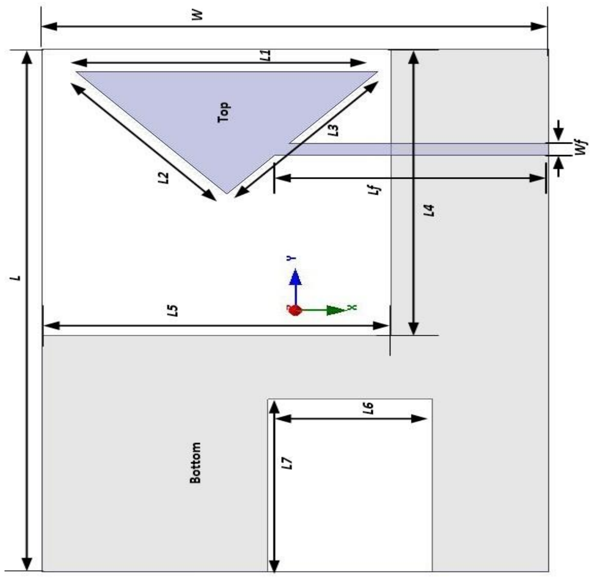


Fig. 1. Geometry layout of the proposed antenna.

Several antennas analyzed the material effects on the antenna performance like impedance bandwidth, radiation efficiency and gain [7, 8]. The effect of substrate material on antenna performance has been studied for five different substrate materials. The dielectric properties of the materials are listed in Table 1. Initially, we observe the reflection coefficient of the proposed antenna with listed materials, shown in Fig. 2. It is observed that the FR-4 substrate material shows maximum operating impedance bandwidth than others substrate materials. Radiation efficiency and realized gain of the proposed antenna has also been investigated with listed materials, depicted in Fig. 3 and 4, respectively. It is shown from Fig. 3 that FR-4 shows lowest radiation efficiency at entire operating frequency bands than other listed substrate materials. The reason behind this, the dielectric loss tangent is maximum, which is 0.02. Moreover, a parametric study has been performed using $L6\times L7$, shown in Fig. 5. From the Fig. 5, it is shown that the $L6\times L7$ slot has an important effect on lower and upper frequencies to achieve wide impedance bandwidth. In addition, the optimum value of the $L6 \times L7$ is obtained using several parametric studies.

Table 1. Dielectric properties of substrate materials.

Substrate Material	**Dielectric Constant**	**Dielectric Loss tangent**
Teflon PTFE	2.10	0.0002
FR-4	4.60	0.02
Taconic RF	3.5	0.0025
Rogers 4035	3.66	0.004
Rogers 3006	6.15	0.002

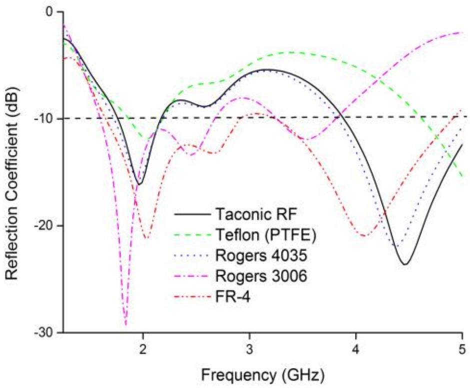


Fig. 2. Simulated Reflection coefficient of the proposed antenna for various substrate materials.

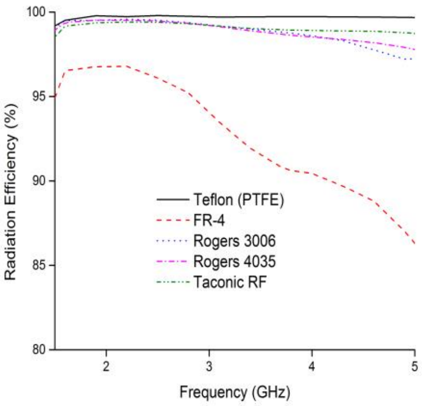


Fig. 3. Simulated radiation efficiency of the proposed antenna for various substrate materials.

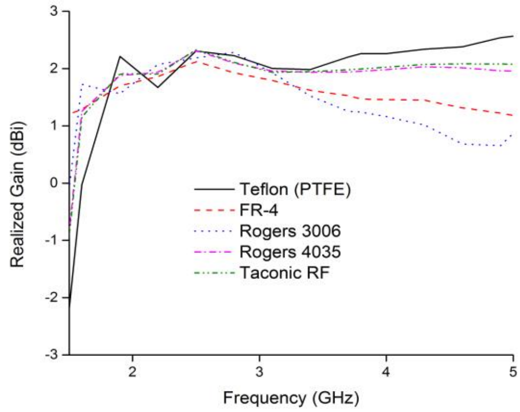


Fig. 4. Realized gain of the proposed antenna for various substrate materials.

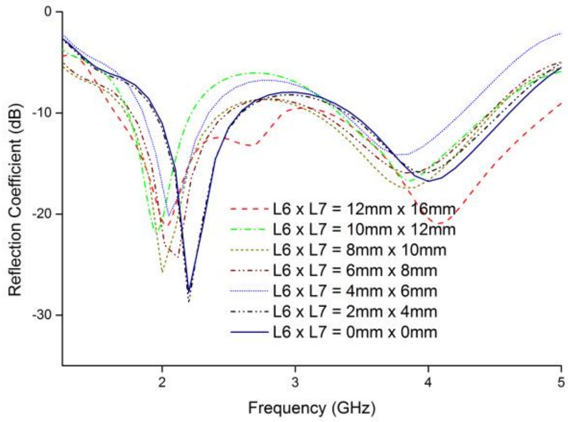


Fig. 5. Reflection coefficient of the proposed antenna for various values of L6× L7.

3. Antenna performance analysis

The proposed antenna prototype has been fabricated and experimentally studied. The design and simulation of the proposed antenna have been performed by using the commercially available Ansoft high-frequency structure simulator (HFSS) software.

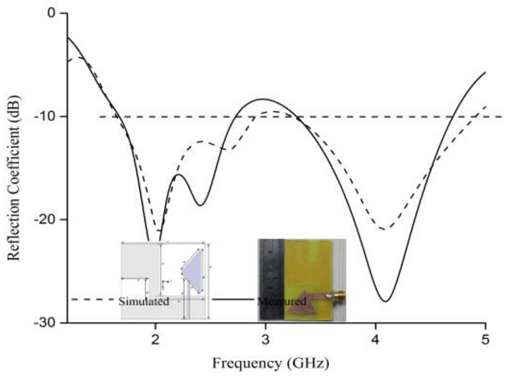


Fig. 6. Simulated and measured reflection coefficient of the proposed antenna.

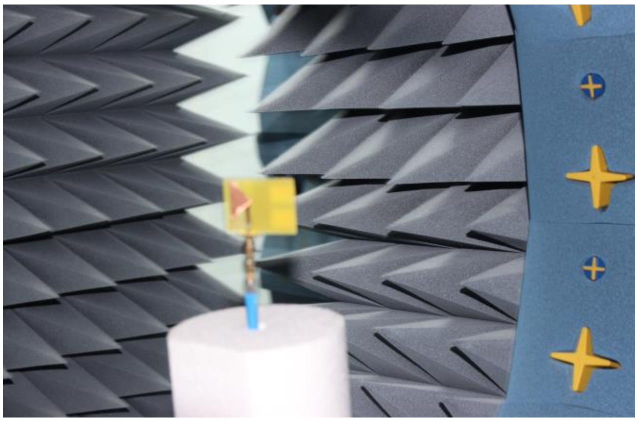


Fig. 7. Proposed antenna measurement in the Satimo star lab.

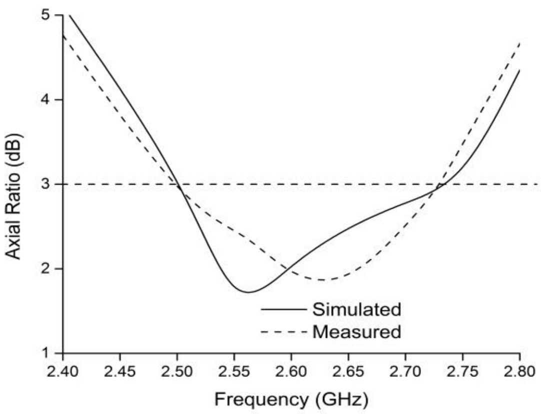


Fig. 8. Axial ratio of the proposed antenna.

The reflection coefficient measurement has been performed using an Agilent TE8362C network analyzer. The simulated and measured reflection coefficient is presented in Fig. 6. It is seen that the antenna has achieved impedance bandwidth of 1.03 GHz (1.68-2.71 GHz) and 1.43 GHz (3.27-4.7 GHz). The proposed antenna farfield characteristics have been measured in the Satimo star lab, shown in Fig. 7. The axial ratio of the proposed antenna is depicted in Fig. 8. The achieved simulated and measured 3dB axial ratio bandwidth of the proposed antenna is about 230 MHz (2.5-2.74 GHz).

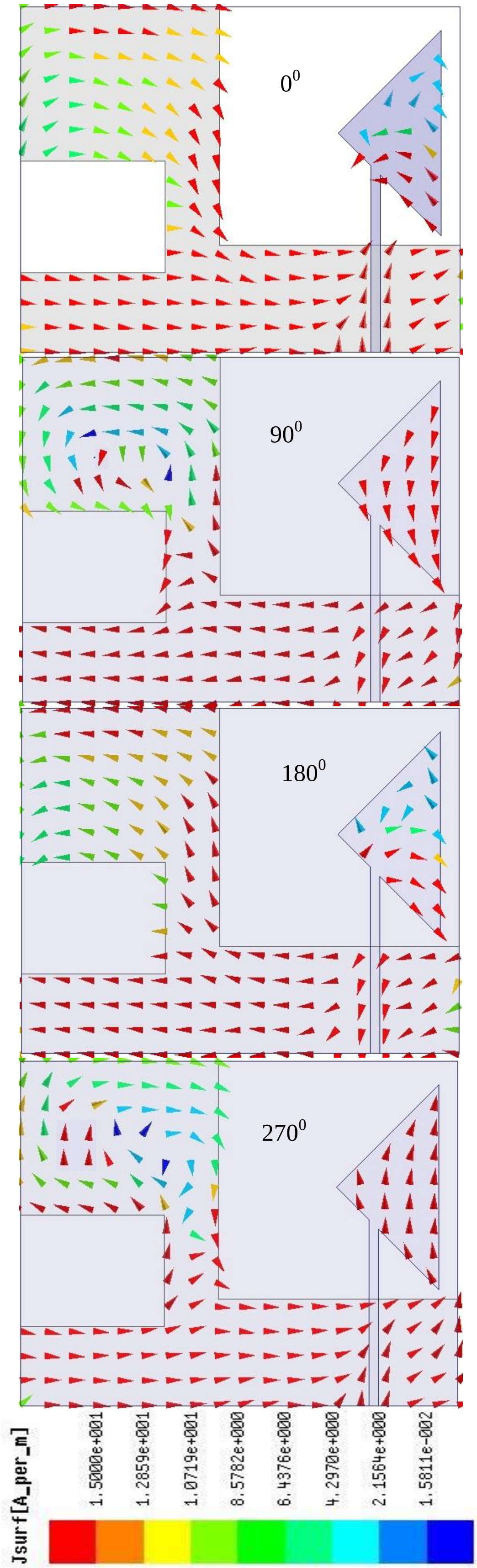
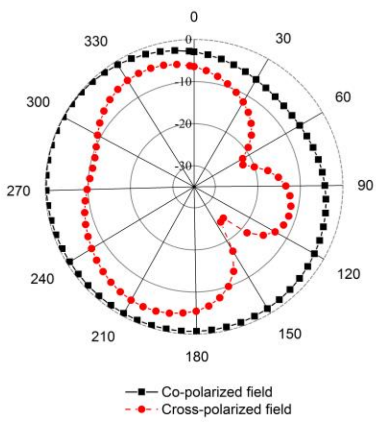
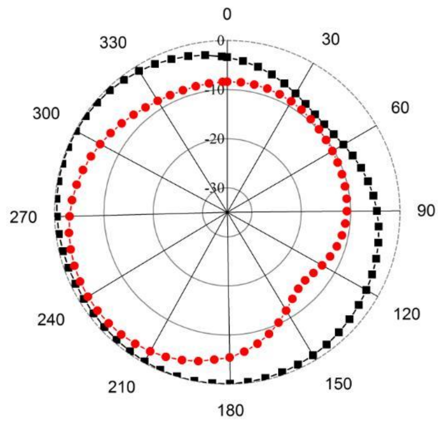


Fig. 9. Surface current distribution of the proposed antenna at 2.55 GHz.



(a)



(b)

Fig. 10. Radiation Pattern of the proposed antenna - 1.8 GHz and 2.4 GHz for yz-plane.

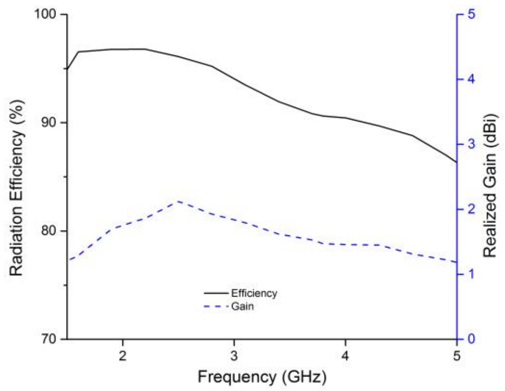
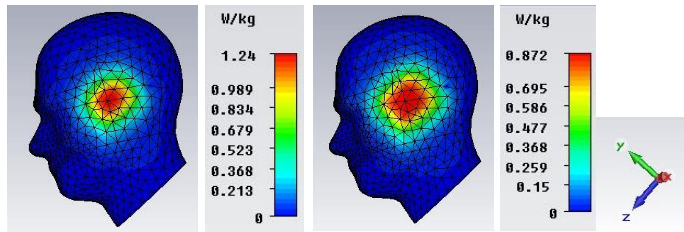


Fig. 11. Radiation efficiency and realized gain of the proposed antenna.

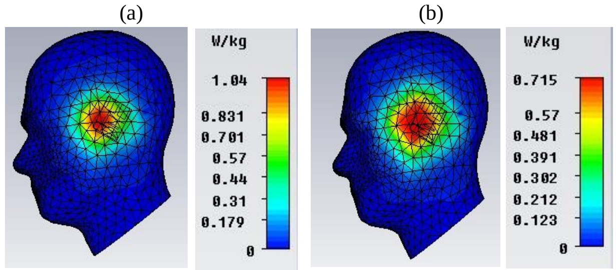
The surface current distribution of the proposed antenna at 2.55 GHz for four phases of 0^0, 90^0, 180^0 and 270^0 are presented in Fig. 9. It is seen from Fig. 9 that the direction of the current in the loop rotates clockwise as the time increases. The movement of the surface current distribution in clockwise fashion depicts the behavior of left hand circular polarization (LHCP). The radiation pattern of the proposed antenna has been demonstrated in Fig. 10. It is seen from Fig. 10 that the antenna shows a nearly omnidirectional radiation pattern at 1.8 and 2.4 GHz. The radiation efficiency and realized gain of the proposed antenna has also been analyzed, shown in Fig. 11. The antenna exhibits maximum 96% of radiation efficiency at 1.7 GHz and minimum 88% at 5 GHz. The average realized gain of the proposed antenna is 1.42 dBi.

4. Specification absorption rate (SAR)

In designing antennas for wireless communication, it is very important to analysis SAR values of the proposed antenna. In this paper, SAR analysis has been performed, where the reference power of the wireless device is set to 500mW and antenna was placed 10 mm away from the head phantom. Moreover, the commercially available CST Microwave Studio software package, which is based on finite integrated time-domain (FITD) technique, has been adopted in this study. In addition, the SAR values at 1.8 and 2.4 GHz are presented in Fig. 12 and listed in Table 2.



(a) (b)



(c) (d)

Fig. 12. (a) 1g SAR at 1.8 GHz, (b) 10g SAR at 1.8 GHz, (c) 1g SAR at 2.4 GHz and (d) 10g at 2.4 GHz.

Table 2. SAR value of the proposed antenna.

Frequency (GHz)	**SAR 1g**	**SAR 10g**	**Absorbed power (rms) W**	**S_{11} with human head model (dB)**
1.8	1.24	0.872	0.1179	-12
2.4	1.14	0.732	0.0957	-15

5. Conclusion

A compact multifunctional wireless application with the feature of circular polarization is proposed. The proposed antenna illustrates 1.03 GHz (1.68-2.71 GHz) and 1.43 GHz (3.27-4.7 GHz) of impedance bandwidth with measured 3dB axial ratio (AR) bandwidth of 230 MHz (2.5-2.74 GHz) with compact size of $0.26\lambda \times 0.21\lambda \times 0.01\lambda$**.** So the proposed antenna might be suitable for respective wireless application.

Acknowledgments

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