

CPW-Fed Circular Polarized Square Slot Antenna for GPS Applications

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Abstract - This study presents a design of a circular polarized square slot antenna (CPSSA) with a coplanar waveguide (CPW) for global positioning system (GPS) applications. The proposed antenna is composed of rectangular metal frame acting as a ground, two metal defected square rings at the back of the antenna and feed strip of CPW with an L-shaped. The GPS frequency of 1.57 GHz can be obtained by setting the corresponding parameters. The designed antenna has a small size of $56 \times 56 \times 0.8$ mm³. The simulated impedance bandwidth of the proposed antenna is 220 MHz from 1.54 to 1.76 GHz for VSWR less than 2, and the axial ratio (AR) bandwidth is 75 MHz less than 3 dB from 1.525 to 1.6 GHz, which appropriate the GPS L1 band requirement. Meanwhile, the radiation pattern is a bidirectional pattern with a maximum antenna gain of around -3.9 dB. The antenna can be used for GPS applications adopting circular polarization.

Index Terms — *Axial Ratio (AR); coplanar waveguide (CPW); Circularly Polarized (CP); GPS band; Square slot Antenna.*

I. INTRODUCTION

Using Global Positioning System (GPS) technology is becoming more popular. GPS system has been extensively utilized as a navigation system to identify positions, survey and detect various devices [1]. Circular polarization (CP) is common polarization in mobile satellite communication as well as communication systems which is designed for allowable flexibility in transmission and receiver. The purpose of this design is preventing the polarization mismatch between transmitter and receiver owing to multipath fading in the propagation environments [2]. It is true that one of the most important goals of antenna designer, from designing large size antennas operating in low frequency like horn antennas to small size antennas working in high frequency like on chip antennas, with considering the enhance antenna efficiency is to reduce the size of antenna. In order to achieve this goal different kinds of methods such as Defected Ground Structure (DGS), Electromagnetic Band Gap (EBG) or also different materials like ionize gas antenna are studied by researchers [3-5]. In this paper, a planar waveguide (CPW) antenna has enjoyed a significant consideration due to their low cost, light weight, easy fabrication, wide bandwidths and CP operation; however, by employing different methods, like modified

ground structure in terms of improving bandwidth and creating band notch to avoid interference among several applications these kinds of antennas can be enhanced in radiation features for various types of applications simultaneously [6-8]. The GPS antenna operates at the two GPS frequencies (L1: 1.575 GHz, L2: 1.227 GHz). Several kinds of microstrip antennas with various feeding network systems for dual-band circular polarization GPS antennas have been introduced in [9]. Wang et al. have suggested double layers of the truncated square patch with air gap between the substrates in [10]. An aperture-coupled stacked microstrip antenna with cross-slot feed by David and Sean have been investigated in [11]. The multilayer substrate using high dielectric constant material was suggested by Chen et al in [12].

In this study, a new design of a CPW-feed square slot antenna with CP polarization is introduced for the GPS systems at 1.57 GHz. The suggested antenna occupies a compact size of $56 \times 56 \times 0.8$ mm³. Such an antenna is simulated by means of Ansoft simulation software High-Frequency Structure Simulator (HFSS-v.15) based on the finite element method (FEM).

II. ANTENNA CONFIGURATION

The schematic of the proposed antenna is exhibited in Fig. 1. It is mounted on an economical plane of FR4 with dielectric constant = 4.4, thickness = 0.8 mm and loss tangent = 0.02. The overall dimensions of the antenna substrate are 56×56 mm² which were square with a lateral length L_s . The antenna is fed by a 50 Ω an L-shaped CPW with width 3 mm for generating circular polarization. On the back of the antenna, two metal defected square rings are loaded which leads to achieve an acceptable impedance bandwidth. The detail dimensions of antenna in Fig. 1, are listed in table I. The antenna design procedure will be discussed in the next section.

TABLE I

Proposed Antenna Dimensions in mm			
Parameter	amount	Parameter	amount
Ls	56	g ₂	1
G	39.4	r ₁	5
Lf ₁	35.5	r ₂	12.7
Lf ₂	29.5	S ₁	1.3
Ws	3	S ₂	1.6
g ₁	1.6		

III. ANTENNA PERFORMANCE AND DISCUSSION

The proposed square slot antenna is simulated by using ANSYS High-Frequency Structural Simulator Software (HFSS). In Fig.2, four improved structures of the suggested antenna are shown for demonstrating the design process.

Ant I. is composed of only a rectangular metal frame acting as a ground and a feed line which has allowable impedance bandwidth for 1.54 GHz; In Ant II, a metal defected square is loaded on the back of the antenna which aims to attain an acceptable impedance bandwidth but the axial ratio bandwidth is over than 3dB. In this stage at Ant III, for producing the dual-band CP radiation, the feed line is changed to an L-shaped feed strip of CPW to support two perpendicular modes with equal magnitude and a 90 degrees phase difference. Finally, in Ant IV, for frequency shifting to have less than -10dB return loss impedance and 3dB axial ratio bandwidths in width, the second metal defected square ring is loaded at the back of the antenna. Fig. 3, and Fig. 4, show simulated return loss and 3dB axial ratio alterations in four antenna design stages. With regard to the Fig. 4a, it can be seen that Ant I. and Ant II, have a linear polarization. The AR is considerably improved by transforming the feed line to an L-shaped feed strip CPW (Ant III). At last, by exploiting the second metal defected square ring, the suggested antenna not only is exhibited the desired axial ratio bandwidth (ARBW < 3 dB) from 1.525 to 1.6 GHz but also enjoys a -10 dB reflection coefficient bandwidth from 1.54 to 1.76GHz to cover the L1 GPS band.

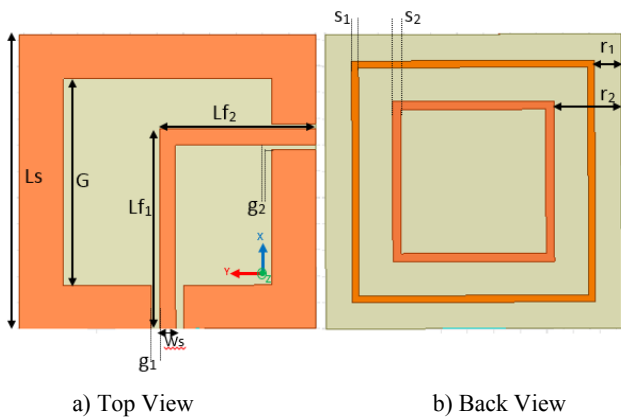


Fig 1. The shape of the proposed antenna

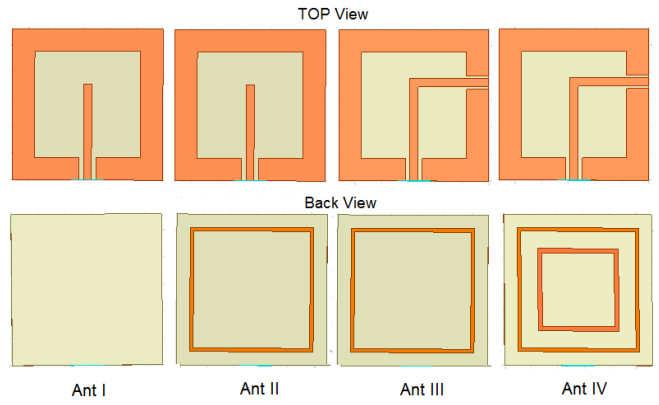


Fig 2. Four stages of proposed antenna design.

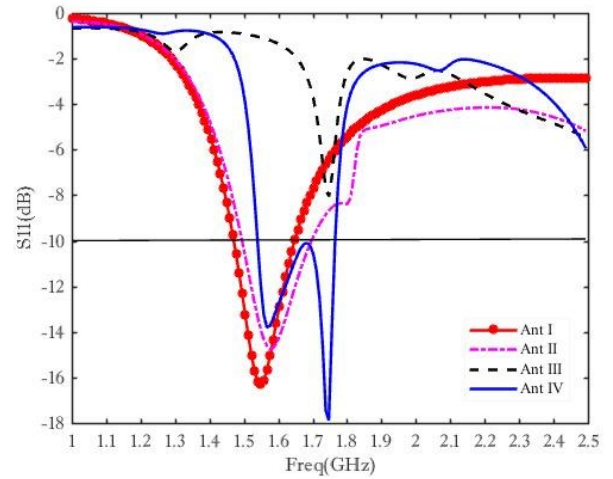
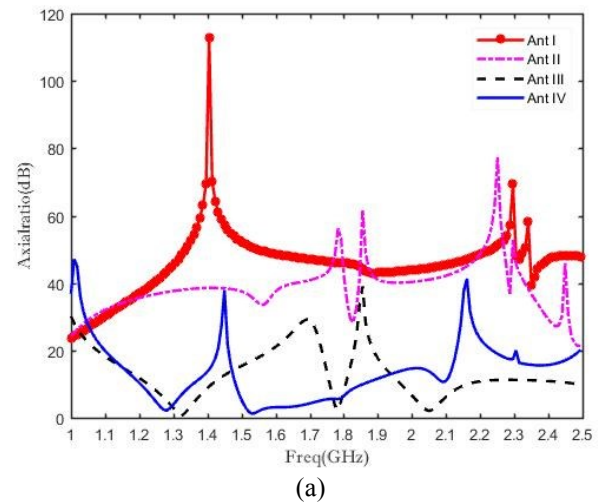
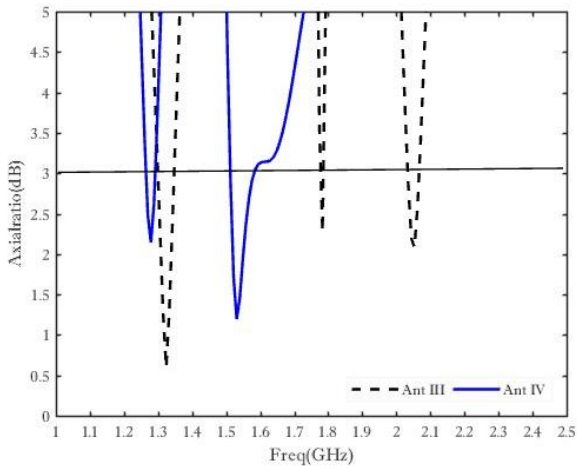


Fig 3. Simulated return loss of four proposed GPS antenna



(a)



(b)

Fig 4. Simulated (a) AR for four proposed CPS antenna and (b) AR for antenna IV

Fig.5, shows the simulated radiation pattern at GPS frequency in E-plane (XZ: $\phi=0$) and H-plane (YZ: $\phi=90$).

Fig.6, displayed desirable bidirectional characteristics at 1.57 GHz. Regarding Fig.6, it can be seen that the antenna structure produces right-hand circularly polarized (RHCP) radiation along the back side of the proposed antenna ($-Z$ orientation) and left-hand circularly polarized (LHCP) along the front side of the antenna ($+Z$ orientation). The obtained gain in the CP bandwidth range varies from -6.7 dB in the lower band to -3.3 dB in the higher band. In Fig.7, the simulated antenna possesses -3.9 dB gain for 1.57 GHz in the CP bandwidth range. The negative gain in dB means that the nominal gain is less than 1, but the signal strength received from GPS transmitter is high, therefore, the antenna can detect the message signal come from the GPS transmitter even if negative gain.

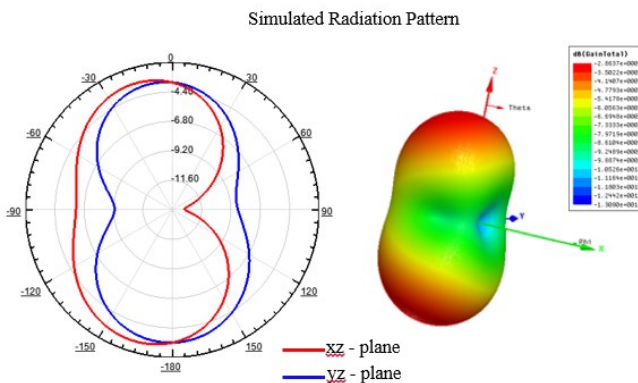


Fig 5. 3D and 2D simulated radiation patterns in E plane and H plane at 1.57 GHz

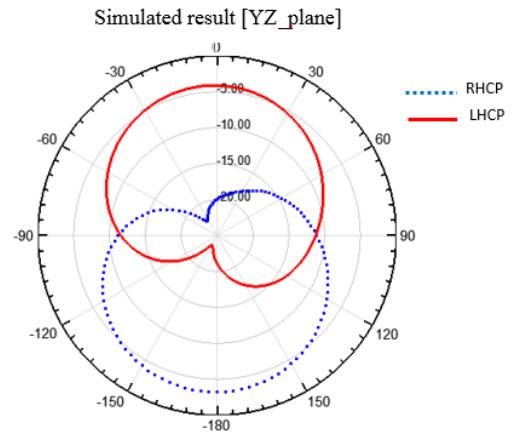
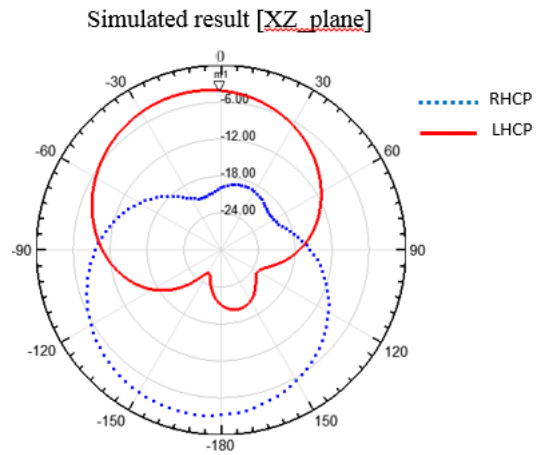


Fig 6. Simulated LHCP and RHCP radiation patterns of the proposed antenna at 1.57 GHz

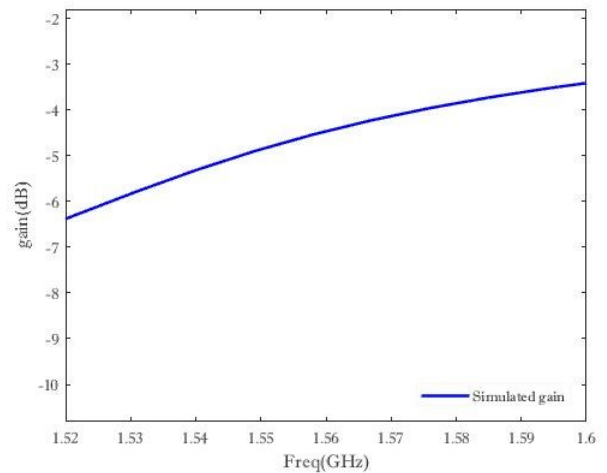


Fig 7. Simulated Gain of proposed antenna

IV. CONCLUSION

In this study, the design of a square slot antenna with circular polarization and coplanar waveguide (CPW) with the size of $56 \times 56 \text{ mm}^2$ was demonstrated. An L-shaped feed strip induced the circular polarization characteristics and 3 dB ARBW. The desirable impedance matching ($S_{11} < -10 \text{ dB}$ in reflection coefficient) and the 3 dB ARBW from 1.525 to 1.6 GHz can be achieved for center frequency of 1.57 GHz. The simulated radiation pattern exhibits a bidirectional pattern. Therefore, the proposed antenna is compatible with GPS applications.

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