New Design of Low Cost and Easy Tuning Compact GPS Microstrip Antenna

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Abstract— A new low cost and easy tuning compact GPS microstrip antenna structure has been proposed. RHCP (right-hand circular polarized) radiation is realized with corner truncated on a square patch as the radiating element. The size of the antenna is reduced by cutting the central slot and marginal slits, which force the current to follow extra paths. Coaxial single-probe center feed loaded with microstrip stub is used to achieve impedance matching. The best operating frequency tuning can be achieved by varying the marginal slits. The design and tuning method is given. The final optimized antenna dimension has been obtained after a large of electromagnetic simulations. The simulated results show that the antenna has a good matching and CP radiation performance.

1. INTRODUCTION

In recent years, there has been an increase in demand for circularly polarized microwave antenna designs for civilian Global Positioning System (GPS) from small applications like in smart phones to complex applications found in marine operations. Microstrip antennas have several advantages compared to conventional microwave antennas such as low profile, small volume, light weight, low cost, compatibility with integrated circuit, ease of fabrication. Therefore, they are very useful for satellite and mobile communication applications [1].

The circular polarisation (CP) microstrip antennas are classified into single-feed type and dual-feed type. Single feed truncated corner square patch is the radiator largely used as a GPS receiver antenna because single-probe feeding makes the antenna a cost effective choice for mass production. The technique of truncating the patch corners of a square microstrip patch to obtain single-feed CP operation is well-known [2] and has been widely used in practical designs [3–8]. Characteristics of a novel design of single-feed, reduced-size CP square microstrip antenna with square-ring shaped patch [3] and slits cut in the patch [4] have been studied. Experimental results show that the proposed design has reduced antenna size as compared to the conventional CP square microstrip antenna with truncated corners at a given operating frequency. A feed method of placing the microstrip line at the inner patch boundary was demonstrated in [5]. It is possible to manufacture microstrip antennas with substrates having high loss tangent (like FR4) without severe degradation of their electrical performance was reported in [6]. Recently, a single-feed CP microstrip patch antenna with multi-frequency operation has been developed for GPS applications [7, 8].

In this paper, a new single probe feed CP microstrip antenna with low-cost FR4 as substrate for GPS applications has been designed. Variations in FR4 electrical permittivity can shift the operating frequency. So one microstrip stub is used to achieve impedance matching and two marginal slits are introduced for the best operating frequency tuning. The purpose is to get the best axial-ratio and the return loss at the fixed frequency. Design concepts and procedures are introduced, followed by simulations and discussions.

2. ANTENNA CONFIGURATION AND DESIGN

The configuration of the proposed antenna element is shown in Fig. 1. The square microstrip patch with a central slot, having an outer side length of L, and an inner side length of S, is printed on a substrate of thickness h and relative permittivity ε_r. The truncated corners are of equal side length ΔL. The feed position is located at the patch centre with a microstrip matching stub of width W_3 and length L_3. Two narrow marginal slits are cut at two adjacent edges in the patch with the size of width W_1, W_2 and length L_1, L_2. This antenna has a ground plane size of $G \times G$.

The main consideration is the cost of the substrate, when a low-cost radiator is required in antenna design for civilian GPS applications. FR4-epoxy substrate is a good choice. FR4-epoxy with $h = 2$ mm thick was selected because it is easily available in the market. The use of low-cost FR4 as substrate introduces some additional complexity on the antenna design. This additional complexity is due to the inaccuracy of the FR4 relative permittivity and its high loss tangent. Variations in FR4 electrical permittivity can shift the operating frequency.

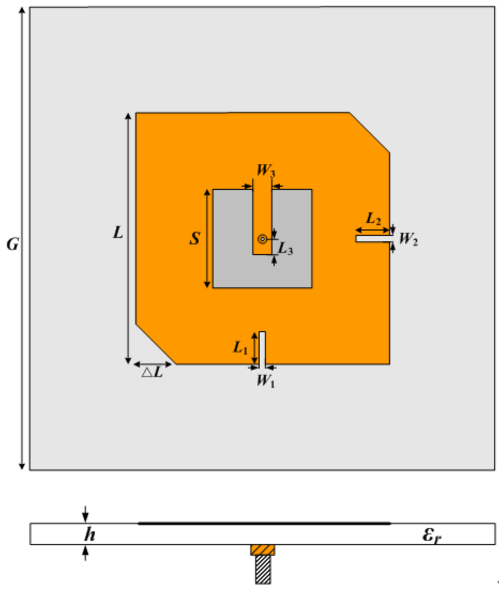
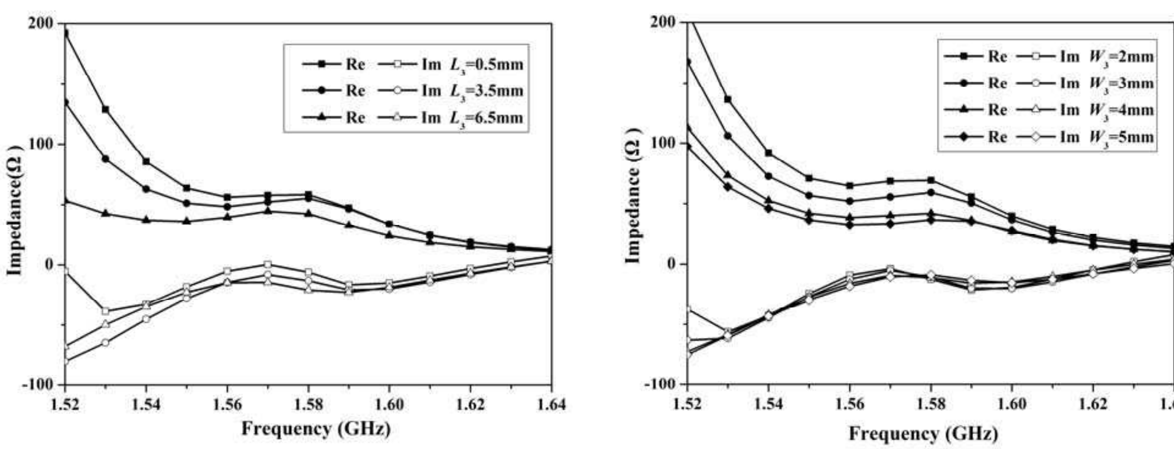


Figure 1: Configuration of the proposed antenna.

In order to minimize this effect, modifications are introduced in the antenna design. One microstrip open stub is used to achieve impedance matching and two marginal slits are introduced for the best operating frequency tuning. It should be mentioned that the side length ΔL of truncated corners dominates the axial ratio of CP and the microstrip matching stub determines the impedance matching of the antenna.

Throughout the studies, it is found that the real part of the antenna input impedance can be controlled by changing W_3 and L_3, while the imaginary part of the antenna input impedance can be adjusted mainly by changing L_3, which can be seen in Fig. 2. So we can first change L_3 to get a real input impedance (zero imaginary part), and then change W_3 to get the input resistance that we need. The impedance matching can be achieved without major modification of the radiator and the CP characteristic is also not so sensitive to the changing of the matching stub.

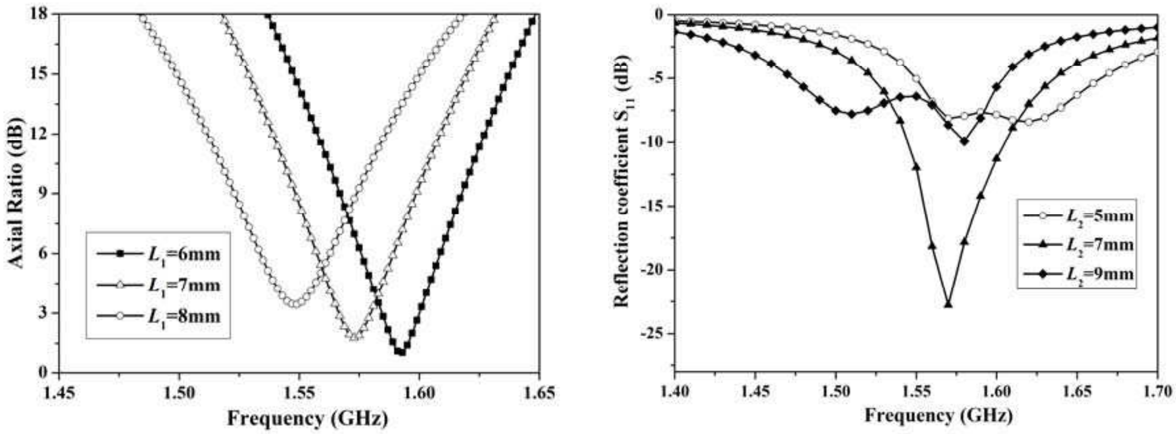


(a) Impedance curve as a function of L_3

(b) Impedance curve as a function of W_3

Figure 2: Input impedance as a function of matching stub length and width.

As mentioned before, the use of low-cost FR4 as substrate causes the frequency deviations due to the inaccuracy of its relative permittivity. The proposed antenna configuration to compensate this effect has two narrow slits, as shown in Fig. 1. Cutting properly the slits length, frequency deviations can be compensated. It is shown in Fig. 3 that by adjusting the inserted slit length L_1 (the slit width fixed to be $W_1 = 1\,\text{mm}$), the CP axial ratio can be tuned. Meanwhile, the input reflection coefficient can be tuned by adjusting the inserted slit length L_2 (the slit width fixed to



(a) Axial ratio curve as a function of L_1 (b) Reflection coefficient curve as a function of L_2

Figure 3: The operating frequency deviations by varying the slit length.

be $W_2 = 1\,\text{mm}$). It gives a convenient tuning option for the best operating frequency by varying the slit length.

3. SIMULATION RESULTS AND DISCUSSIONS

The proposed antenna has been optimized for operation in the L_1 band with the centre frequency of 1575.42 MHz. The commercial simulation tool HFSS has been used in this study. After extensive simulations, the following values are selected: $L = 37\,\text{mm}$, $\Delta L = 4.4\,\text{mm}$, $S = 15\,\text{mm}$, $L_1 = 7\,\text{mm}$, $W_1 = 1\,\text{mm}$, $L_2 = 7\,\text{mm}$, $W_2 = 1\,\text{mm}$, $L_3 = 2.5\,\text{mm}$, $W_3 = 3\,\text{mm}$, $h = 2\,\text{mm}$, $\varepsilon_r = 4.4$, $G = 70\,\text{mm}$. The simulation results show that the final antenna displays good input impedance matching and excellent circular polarization radiation pattern.

Figure 4 shows the simulated input impedance match characteristics of the antenna. It is seen that the simulated $|S_{11}| < -15\,\text{dB}$ in the range from 1550 MHz to 1590 MHz, which is about 40 MHz bandwidth. Fig. 5 shows the simulated axial ratio and the power gain in the bore-sight direction. As can be seen from the figure, the simulated 3-dB axial ratio bandwidth is found to be from 1565 MHz to 1580 MHz and the lowest axial ratio is found to be 0.8 dB at 1576 MHz. In the 3-dB axial ratio bandwidth, the power gain is about 1 dB due to FR4 high loss tangent. The radiation patterns in two orthogonal planes of both right-hand circular-polarization (RHCP) and left-hand circular-polarization (LHCP) at the center frequency are shown in Fig. 6. It is clearly seen that this antenna can provide RHCP and very pure circular polarization radiation can be produced within a broad angular range.

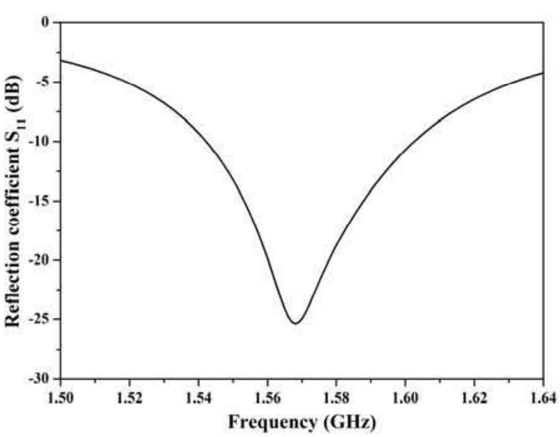


Figure 4: Simulated reflection characteristics versus frequency.

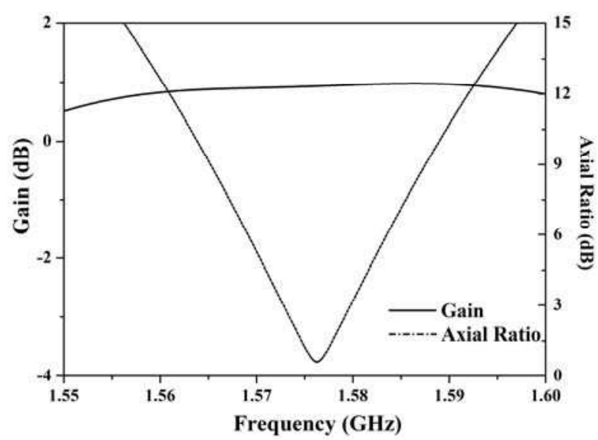


Figure 5: Gain and axial ratio characteristics of the antenna.

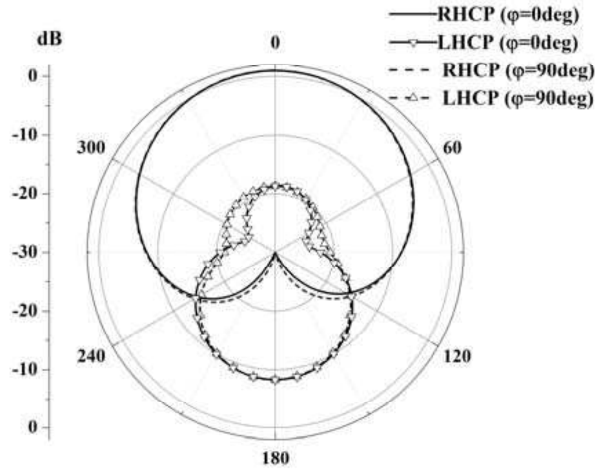


Figure 6: Simulated radiation pattern of antenna in two orthogonal planes at the center frequency.

4. CONCLUSION

A new compact GPS microstrip antenna with low-cost FR4 as substrate has been proposed. The size of the antenna is reduced by cutting the central slot and marginal slits. Coaxial single-probe center feed loaded with microstrip stub is used to achieve impedance matching. The best operating frequency tuning can be achieved by varying the marginal slits. Good antenna characteristics are achieved with a 3-dB axial ratio bandwidth of 15 MHz, and a $|S_{11}| < -15$ dB impedance bandwidth of 40 MHz. The results obtained for the proposed antenna meet the performance specifications for civilian GPS applications.

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