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BROADBAND MULTIPATH-REJECTION SHORTED ANNULAR PATCH ANTENNA FOR GPS APPLICATIONS

Luyang Ji*, Guang Fu, Zhiya Zhang, and Shuxi Gong

National Key Laboratory of Science & Technology on Antennas & Microwaves, Xidian University, No. 2 Taibai South Road, Xi'an, China

Abstract—A compact shorted annular patch antenna for global positioning system is presented in this paper. Multipath-rejection capability is realized with two stacked shorted annular patches (SAP). The broadband characteristic of the (-10 dB return loss) input impedance bandwidth and the 3 dB bandwidth of axial ratio is achieved by employing capacitively coupled feed structure while the shorted pins located between the upper and the lower patches will realize the impendence matching of the high frequency, which can cover $L5/L2/L1$ bands for GPS and the relative input impedance bandwidth can achieve 50.6%. The size is $0.3\lambda \times 0.3\lambda$ for 1.1 GHz.

1. INTRODUCTION

Global positioning system applications need a high-gain ground receiving antenna with the multipath-rejection capabilities. These specifications require an axial ratio lower than 3 dB on an extended angular range and a pattern amplitude roll-off of at least 10 dB from zenith to horizon [1]. At present, spiral antennas [2], linear arrays of dipoles, and patch antennas placed on choke rings [3], if properly designed, will match the requirements but they are not suited for aerospace applications as they are limited by space, weight and some other aspects.

As an alternative to these solutions, shorted annular patch antennas have been extensively studied as they possess many interesting characteristics. As is shown in [4, 5], when working on its dominant mode TM_{11}, the magnetic current distribution flowing on the external boundary of the patch is equivalent to the one of a

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* Corresponding author: Luyang Ji (luyangji078@gmail.com).

conventional circular patch that results in a similar radiation pattern. The inner shorted structure is not radiating and it can be used to tune the antenna resonant frequency. For this reason, the external radius can be chosen without the restrictions related to the resonant wavelength [6]. Otherwise, by restraining the generation of high mode, SAP antennas can inhibit the surface wave in order to realize the multipath-rejection [7].

In this paper, a compact broadband circularly polarized shorted annular patch antenna (SAP) that covers all the GPS frequencies ($L5$: 1.176 GHz, $L2$: 1.227 GHz, $L1$: 1.575 GHz) is presented. By restraining the generation of surface wave, the proposed structure can realize that the radiation pattern roll-off from zenith to horizon is above 10 dB. Fed by two L-probe feeds and a broadband feed network, the final antenna can provide very good circularly polarized radiation. In the following, a brief introduction in some characteristics of the proposed antenna will be given.

2. CONFIGURATION

2.1. Antenna Configuration

The geometrical configuration of the proposed antenna is shown in Fig. 1. It is composed of two stacked shorted annular patch antennas with two L-probe feeds which are placed symmetrically on the two main axes in orthogonal directions, two shorted pins connected the upper patch with the lower patch, ground plane and feed network. The patches are etched on the same substrate with $\varepsilon_r = 2.55$. The thicknesses of the upper and lower substrate are h and h_2 respectively. The ground plane is etched on the FR4 substrate with the thickness of h_t. Two stacked round patches are designed to resonate at $L5$, $L2$, and $L1$ frequency bands. The ground plane size is 90 mm × 90 mm (0.33λ of the lowest working frequency). For the upper patch, the selected outer and inner diameters are 76 mm (R_1) and 14 mm (R_3). By contrast, the outer and inner diameters of the lower patch are 69 mm (R_2) and 2 mm (R_4), respectively. The height of the vertical probes h_1, and the length of the coupled L-probe feeds l_s have strong effect on impedance matching. Other key parameter is the location of the shorted pins between the upper and the lower patch, which is represented by l_p.

All of the above-mentioned parameters have notable effects on antenna input impedance and radiation performance. Figs. 2–4 describe how the parameters of L-probe feeds affect the impedance. The impendence curve in Fig. 2 changed when h_1 varied from 5 to 7 mm (with other parameters fixed: $h = 3.2$ mm, $h_t = 0.52$ mm, $l_s = 23$ mm, $l_d = 38$ mm). As is shown in Fig. 2, the change of the imaginary and

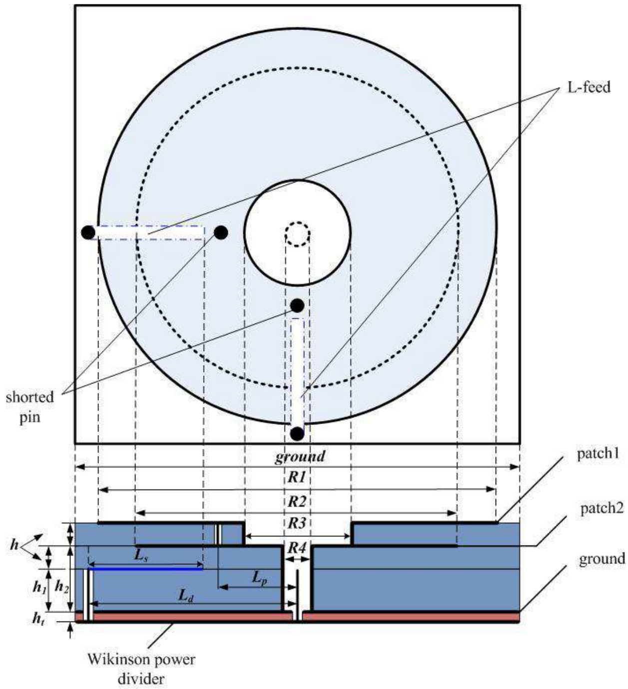

Figure 1. Geometry of the proposed antenna showing from top and side view.

real part of the impedance become more dramatic as h_1 increased, especially for the higher frequency. It can be explained as follows: the vertical part of the L-probe feeds will generate inductive reactance. With this vertical part rising, the inductive reactance becomes larger, resulting the mismatch of the input impedance. Therefore, the impedance bandwidth (return loss $<$ 10 dB) becomes narrower as shown in Fig. 3. In the following, the effect of the length of the L-probe feeds (l_s) has been given in Fig. 4: with the increase of l_s, the impedance bandwidth becomes narrower, especially for the lower frequency. Opposite to the condition of the vertical part, the horizontal part of the L-probe feeds will generate capacitive reactance, but the two curves share the same trend.

Figure 5 depicts the location of the shorted pins has significant influence on the low and high frequency end. If without the pins, the impedance bandwidth is 0.458 GHz and there is a resonance at 1.53 GHz. When the pins employed, the bandwidth increases to 0.487 GHz and the resonance moves to 1.57 GHz. However, with the

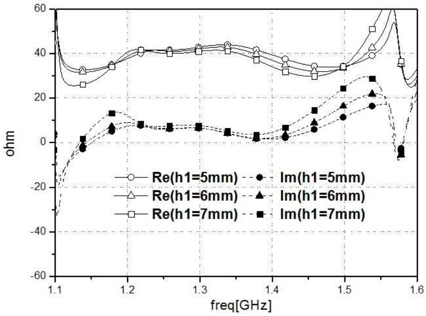

Figure 2. Simulated input impendence of the proposed antenna as the height of the L-probe feeds varies, $h_1 = 5\,\text{mm}$, $6\,\text{mm}$ and $7\,\text{mm}$.

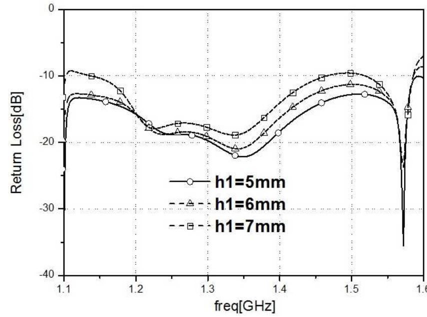

Figure 3. Simulated return loss of the proposed antenna as the height of the L-probe feeds varies, $h_1 = 5\,\text{mm}$, $6\,\text{mm}$ and $7\,\text{mm}$.

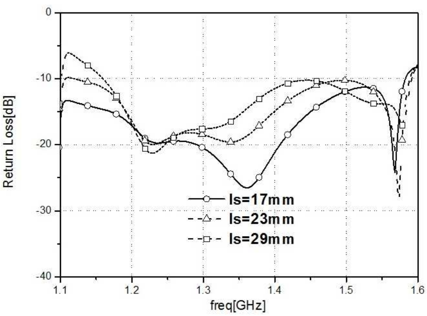

Figure 4. Simulated return loss of the proposed antenna as the length of L-probe feeds varies: $l_s = 17\,\text{mm}$, $23\,\text{mm}$ and $29\,\text{mm}$.

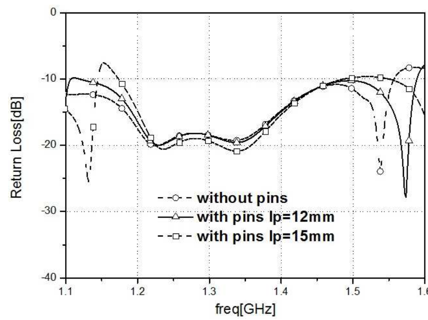

Figure 5. Simulated return loss of the proposed antenna with the effect of the shorted pins.

location of the pins father from the center, the impendence matching of the low frequency end has deteriorated. As a result, the bandwidth decreases to 0.425 GHz (1.175–1.6 GHz). By loading the shorted pins, the proposed antenna generate a new resonance so that the bandwidth becomes wider. Nevertheless, as l_p increases, the effective electrical size of the antenna becomes smaller and the resonant frequency shifts upward. That is the reason why bandwidth becomes narrower when l_p grows to 15 mm.

Optimum design can be achieved by adjusting these parameters with HFSS13 and the final dimensions for the proposed antenna are shown in Table 1.

Table 1. Dimensions of the antenna configuration.

Parameters	h	h_1	h_2	h_t	L_s	L_d
Dimensions (mm)	3.2	5	8.2	0.52	23	38
Parameters	L_p	R_1	R_2	R_3	R_4	*ground*
Dimensions (mm)	12	76	69	14	2	90

2.2. Feed Network Configuration

The amplitude and phase relationship between the two feeds to maintain circular polarization is obtained by two Wilkinson power dividers. Changing the position of two L-probe feeds can easily realize impedance matching. The feed network is shown in Fig. 6. Point A

Table 2. Dimensions of the Wilkinson power divider.

Parameters	W_1	W_2	W_3	W_4	W_5	W_6
Dimensions (mm)	10	3.88	5	28.14	10.86	3
Parameters	L_1	L_2	L_3	L_4	L_5	L_6
Dimensions (mm)	15	3.1	17	17	2.9	7.5

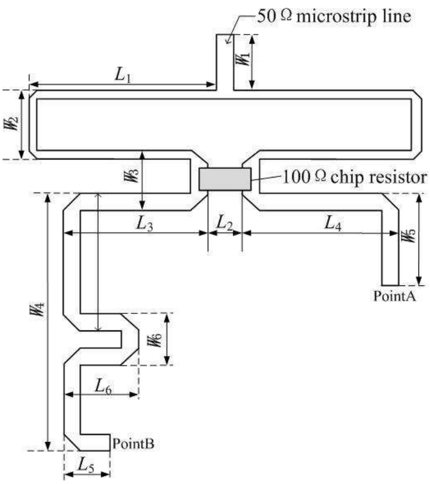

Figure 6. The Wilkinson power divider with two outputs having a 90° phase shift for feeding the proposed antenna.

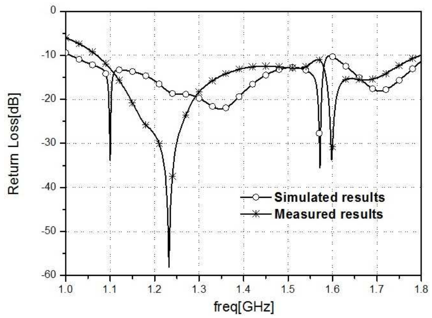

Figure 7. Comparison between the simulated and measured return loss of the proposed antenna.

leads Point B by 90°, and in this case, right-hand CP radiation is obtained. The optimal dimensions of the designed Wilkinson power divider are shown in Table 2.

3. EXPERIMENTAL RESULTS

The simulated and measured antenna reflection coefficients are reported in Fig. 7. A slight mismatch of the return loss over the frequency band of 1.0–1.8 GHz in the simulated and measured results is expected that the patches are cut out using cone cutters of the nearest possible diameters, leaving some mismatch in antenna dimensions.

Radiation patterns have been taken at the anechoic chamber.

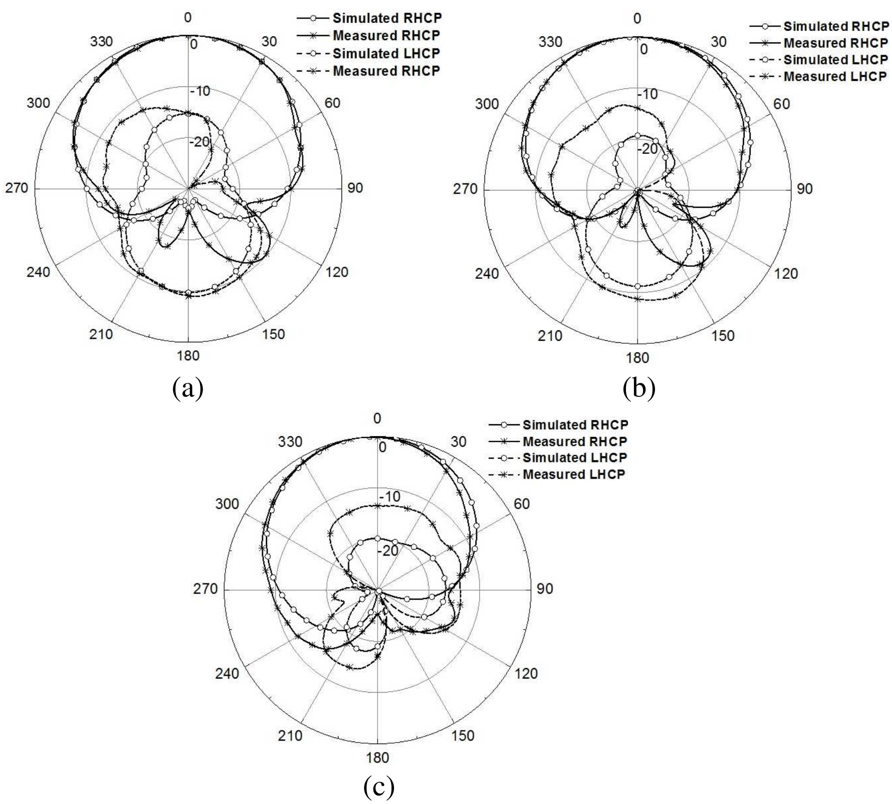

Figure 8. Comparison between the simulated and measured radiation patterns of the proposed antenna. (a) 1.176 GHz, (b) 1.227 GHz and (c) 1.575 GHz.

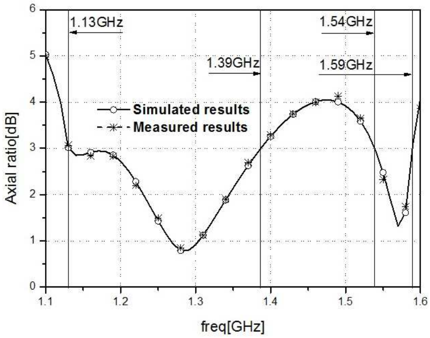

Figure 9. Comparison between the simulated and measured axial ratio of the proposed antenna.

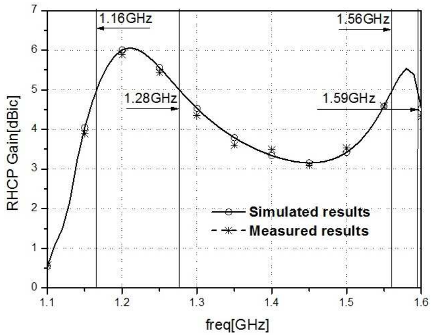

Figure 10. Comparison between the simulated and measured gain of the proposed antenna.

Figs. 8(a)–(c) give the antenna radiation patterns at 1.176, 1.227, and 1.575 GHz. The asymmetric radiation pattern at high frequency is due to the asymmetric structure of the feed points. The pattern roll-off from zenith to horizon is about 10 dB. This feature ensures an improved multipath rejection capability. Circularly polarized patterns have been then calculated by combining the linear response of each antenna under test in two orthogonal planes. Figs. 9 and 10 depict the characteristics of the axial ratio and gain. As the result of applying L-probe feeds, the axial ratio bandwidth has been extremely enhanced. The measured realized gain is greater than 5 dBic in the bands of 1.16–1.28 GHz and 1.56–1.59 GHz. Due to the inherent characteristics of the SAP antenna, the realized gain presents a narrow band feature. The axial ratio calculated based on the measured RHCP and LHCP gain is less than 3 dB in the antenna normal direction. Moreover, the cross-polarization is above 15 dB and the axial ratio less than 3 dB from -60° to 60° in the elevation plane, with the RHCP gain is greater than -2.7 dBic, showing the antenna has a broad pattern coverage.

4. CONCLUSION

A broadband circularly polarized SAP antenna is presented. A wideband feed network is applied to excite high-performance RHCP radiation. In fact, abandoning the constraint on the inhibition of surface waves [8], the proposed antenna can easily obtain with the characteristics of a 3 dB axial ratio at lower elevation and a radiation pattern roll-off from zenith to horizon higher than 10 dB. The realized gain is higher than 5 dBic with the axial ratio less than 3 dB at all the interesting GPS frequencies. Moreover, it is relatively compact, low profile, flexible and easy to build. As a result, the proposed antenna is an appropriate candidate for GPS applications.

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