

# Design of Single-Layer Single-Fed Patch Antenna for GPS and WLAN Applications

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**Abstract**-A design of single-layer single-feed dual-frequency patch antenna with different polarizations is presented for the first time. The structure of the proposed antenna is a single layer patch, which mutually nested inside and outside patches and connected together with four conducting strips. Two operating frequencies of the proposed antenna can be observed in the simulated and measured results. The inside patch operates at the high frequency and outside square patch operates at the low frequency. The center frequency of the antenna prototype for Global Positioning System (GPS) is 1.575 GHz with circular polarization and 2.4 GHz for Wireless Local Area Networks (WLAN) with linear polarization respectively. The impedance bandwidth and axial ratio of the proposed antenna is studied through electromagnetic simulations and measurements.

**Index Terms**-circular polarization, single-layer, single-feed, dual-frequency, patch antenna, GPS, WLAN.

## I. INTRODUCTION

With the rapid development of wireless communication, Miniaturization dual-frequency antenna is one of the hot spots in these researches in recent years. Microstrip antenna has been applied widely owing to their attractive features of low profile, easy to manufacture, light weight and low cost. They are often used in multifunctional wireless products to reduce the number of the required antennas [1]. Several designs related to the dual-frequency, single-layer or single-feed antennas have been reported [2-5], and these designs can provide the antenna to be with specific radiation characteristic at each operating frequency to comply with system requirements.

The antenna in ref.[2] consists of two radiating elements which are arranged in a stacked structure, in which the top is a square patch and the bottom is a corner truncated square-ring patch [3], and the two patches are connected together with four conducting strips. Two operating frequencies can be observed in the simulated and measured results. One element is designed for GPS operation and it has circular polarization (CP) broadside radiation. The other element operates at the WLAN band and its radiation is linear polarization (LP) conical pattern. Moreover, the two elements can be simultaneously excited by a single feed [4].

The design in ref.[5] realizes dual-frequency by using a half-ring structure and a half-circular patch structure, it consists of a half-width circular microstrip antenna and a narrow half-ring patch, which are connected by a microstrip feeding line [6], and has a revised formula to calculate the

resonant frequency of the proposed narrow half-ring structure [7]. The similar antenna performances can also be carried out by a single-layer circular patch antenna surrounded by two concentric annular rings [8].

In this paper, a new type of single-layer single-feed and dual-frequency microstrip antennas for GPS and WLAN application is proposed. A special slot is used to make the patch become the nested patches, in which the inside and outside patches correspond to high and low resonance frequency respectively. The circular polarization characteristics in outside patch are realized by truncating equal corners in the patch, while inside patch operates at the WLAN band. Finally, some structure parameters of the proposed antenna are discussed and analyzed for the effect on the reflected coefficient and the axial ratio.

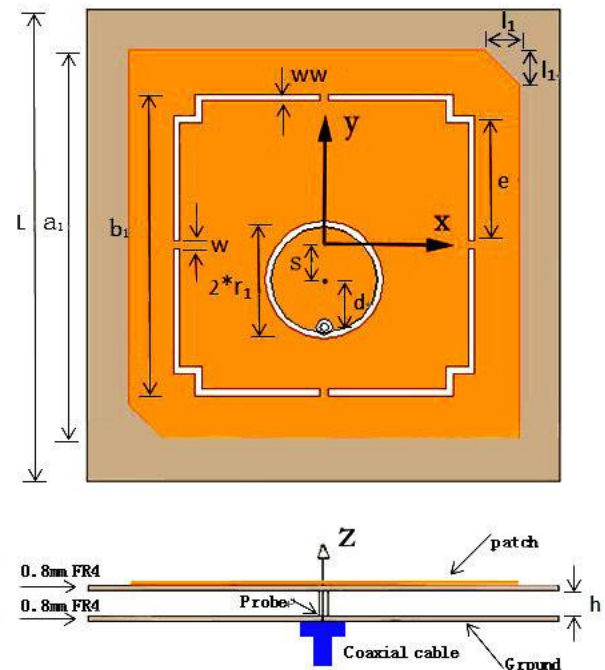


Fig.1. Geometry of the single-layer single-feed dual-frequency patch antenna

## II. ANTENNA STRUCTURE

The proposed single-layer single-feed dual-frequency patch antenna is shown in Fig.1. The antenna is designed by nested inside and outside square patches, having an outside length of  $a_1$  and an inside length of  $b_1$ . The antenna patch is printed on a FR4 substrate\_2 with the thickness  $h_2=0.8\text{mm}$  and the relative permittivity  $\epsilon_r=4.4$ . The height of air layer is  $h$  which is placed above the substrate\_1 with the thickness  $h_1=0.8\text{mm}$  and the relative permittivity  $\epsilon_r=4.4$ . The inside patch and the outside patch are connected by four conducting strips, which have the same width  $w$  and are attached to four edges of the square patch respectively. The truncated corners of outside patches have equal side length  $l_1$  for right hand circular polarization operation. The center of circular patch with radius  $r_1$  in inside patch is along y-axis, and it is at a distance of  $s$  away from the center of the inside patch. Four slots with equal size are cut between inside and outside patch and the side length and the width are marked as  $e$  and  $ww$ , as shown in Fig.1. A coaxial probe with radius  $r=0.7\text{mm}$  is used to excite the antenna, and the distance between the feed point and the center of the square-ring slot is  $d$ . The proposed antenna is fabricated and its photograph is shown in Fig.2.

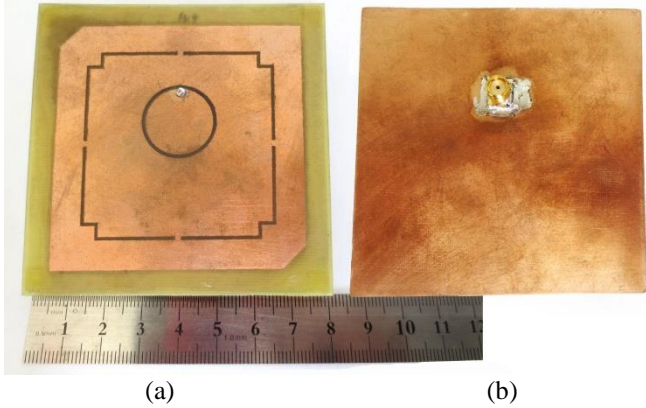


Fig. 2. Photograph of the proposed antenna: (a) front view (b) ground plane

## III. MEASURED AND SIMULATED RESULTS

The reflected coefficient ( $S_{11}$ ) and the axial ratio are obtained by the electromagnetic simulation software HFSS. The optimized structure sizes of the proposed antenna are shown in Table I. The simulated results and measured results of the  $S_{11}$  are exhibited in Fig.3. It is clearly observed that good agreements between the simulated results and the measured results are obtained, and some slight differences occur at the frequency could be due to the dimension error during the manufacture. It has two center operating frequencies of 1.575GHz and due to the square patch antenna

TABLE I

Parameters	$a_1$	$b_1$	$e$	$h_1$	$h_2$	$h$	$l_1$
Values/mm	66	51	20	0.8	0.8	4	6
Parameters	$w$	$ww$	$s$	$d$	$r$	$r_1$	$L$
Values/mm	1.5	1	6	8	0.7	9	80

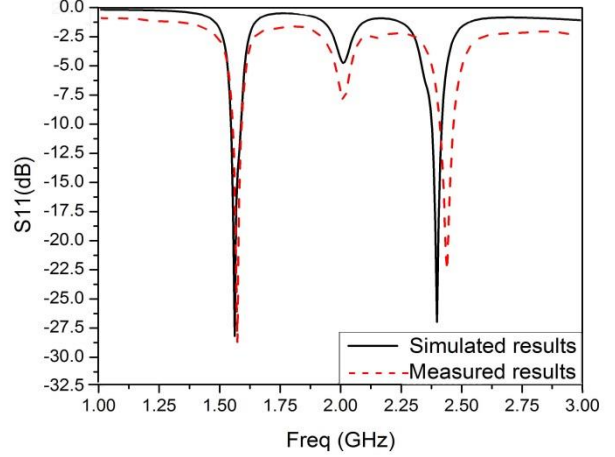


Fig. 3. Measured and simulated reflected coefficient of the proposed antenna

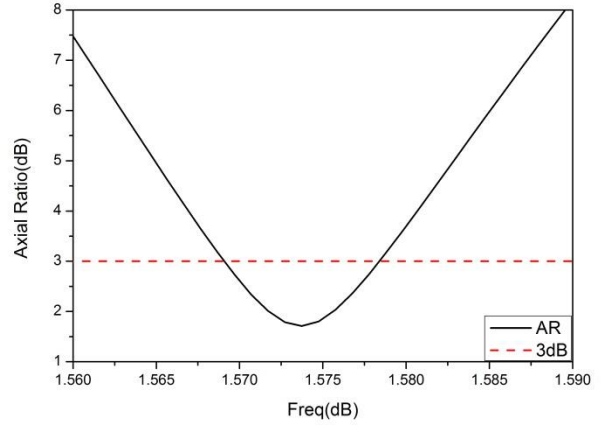


Fig.4. Simulated axial ratios of the proposed antenna

operating at the  $\text{TM}_{11}$  mode, and the perturbations of the truncated corners allow the fundamental mode to split into two orthogonal degenerated modes. The  $S_{11}$  of the GPS band referred to -10 dB is from 1.546 to 1.886 GHz. The  $S_{11}$  of the WLAN band referred to -10 dB is from 2.37 to 2.42 GHz.

Fig.4 shows axial ratio characteristics at the GPS band with the center frequency of 1.575GHz. The obtained results in Fig.4 clearly indicate that the antenna has good CP performance and its CP bandwidth referred to 3 dB.

## IV. PARAMETER ANALYSES AND DISCUSSION

The key structure parameters of the proposed antenna, such as  $b_1$ ,  $l$  and  $w$ , have significant effects on the  $S_{11}$  and the axial ratio. When other dimensions are fixed, as for the effects of  $b_1$ , the simulated results are given in Fig.5. When  $b_1$  is increased, the resonant frequency of the inside patch, defined as the frequency with minimum return loss, is moved to a lower frequency but the resonant frequency of outside patch is almost constant. The variations of  $b_1$  directly affect the performance of the proposed antenna at the operating frequency. The optimization about the position of coaxial probe is shown in Fig.6. As  $d$  is increased, the reflected

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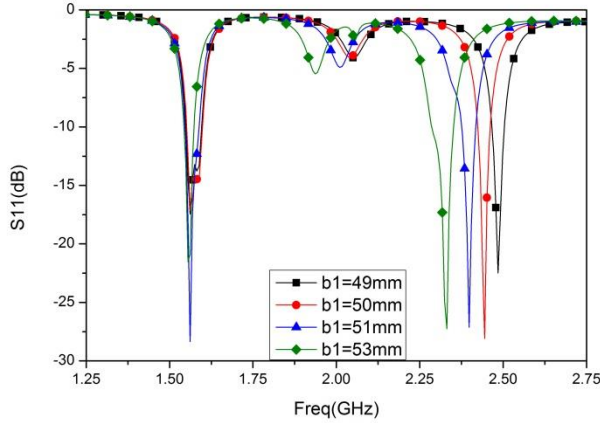


Fig. 5. Simulated return loss of various  $b_1$  for the antenna

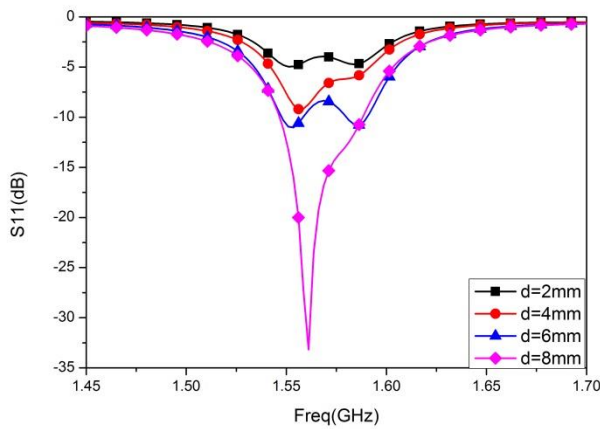


Fig. 6. Simulated return loss of various  $d$  for the antenna

Coefficient ( $S_{11}$ ) of GPS is obviously moved to a lower point. However, the position  $d$  cannot be set too small or large, or it will causes resonance frequency point to mismatch. A proper parameter  $d$  is required to take into account when achieve good impedance bandwidth characteristics of the proposed antenna.

## V. CONCLUSIONS

In this paper, a new antenna with single-layer single-feed for GPS and WLAN has been presented. The antenna is nested by two patches within each other, where a circle patch is located in the inner nested patch. The proposed antenna has some advantages, such as low profile, easy to manufacture and light weight. Simulation and test results show that the proposed antenna exhibits a good performance.

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