DUAL-BAND CP ANTENNA BY LINE-COUPLING TO A PATCH AND A RING

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Abstract— A dual-band CP antenna is realized simply by line-coupling to a ring and a patch. The CP bandwidth is 46 MHz for GPS-L1 band and is 12 MHz for GPS-L2 band. The line is between the two radiation elements so that the polarizations are of the same sense. To get polarizations with opposite sense, both elements can be placed on the same side of the feed line. To increase the gain above 7.5 dBiC, an air layer of 12 mm is inserted between the FR4 substrate and the ground plane. The use of the air-layer, however, increases the size of the antenna to 105 mm in width and 90 mm in length.

Index Terms—Air-layer, Circular Polarization, Dual-Band, GPS Antenna.

I. INTRODUCTION

To receive the satellite signal, the circularly polarized antenna is more suitable than the linearly polarized antenna as the transmitted antenna is often circularly polarized (CP) to reduce the effect of Faraday rotation through the ionosphere. The GPS system includes the L1 (1.575 GHZ) and L2 (1.227 GHz) bands. Usually, two radiating elements are employed. The two elements can be excited by various feeding methods. For example, the antenna could contain two stacked-patches and could be excited by a coaxial cable. In such a feed, the coaxial line has a direct contact to the patch. In a stacked structure, the two elements are not on the same plane. Instead of using two stacked elements, one can use two coplanar elements, like a ring-patch combination. It is discussed in the literature that the ring is hard to match to 50 Ω [1]. Alternatively the ring is easier excited by the line-feed [2]. The ring-patch combination can be excited by the serial-aperture coupled method [3]. In [4], the line-feed method has been used to excite the ring-patch combination to generate two linearly polarized waves. In this paper, two circularly polarized waves are generated.

II. ANALYSIS

The structure of the purposed antenna is shown in Fig.1. It contains a rectangular patch and a rectangular ring which are separated by the coupled feed line. The horizontal spacing between the line and the patch is 1 mm and the horizontal spacing between the line and the ring is 13.95 mm. The distance from the feed point to the top of the feedline is 1mm, and is 11 mm from the feed point to the bottom of the line. Other main parameters are listed in Table 1.

Table 1 Parameters (in mm) of the proposed antenna

Lr	Wr	Sr	L1	W1	Sp	Sa	h1	h2	h3
90	105	3	61	77	4.6	1	1.6	1.635	12

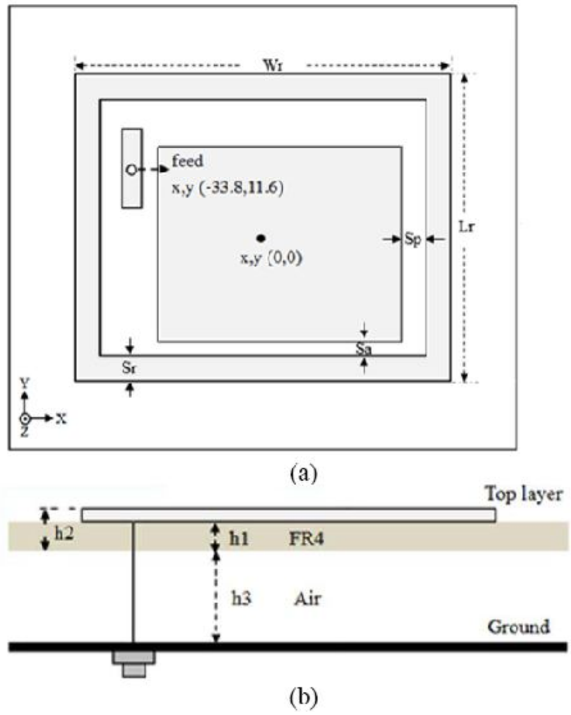

Fig.1 The proposed antenna (a) top view (b) side view

In Fig.1, the feed line is coupled to both the patch and the ring. The return loss, axial-ratio, and gain responses of the proposed antenna are shown in Fig.2. In Fig.2, the responses of two antennas which are associated to the proposed antenna are also shown. The antenna labelled “with ring” is referred to the antenna where the patch is removed from the proposed antenna. The antenna labelled “with patch” is referred to the antenna where the ring is removed from the proposed antenna. Since the three antennas are coupled by the same feed line, the length of the feedline may not be optimized for all the three antennas. It is shown that the antenna labelled “with patch” and the proposed antennas have similar response near 1.57 GHz. However, the antenna labelled “with ring” is poor-matched and the axial-ratio is about 8 dB near 1.22 GHz.

Fig.3 shows the configurations of the ring and the patch antenna when they are individually excited. The length of the feedline is adjusted to operate at their respective bands. The dimensions of the ring and patch are also slightly adjusted. In Fig.3 (a), the optimized size of the patch is L1=61 mm and

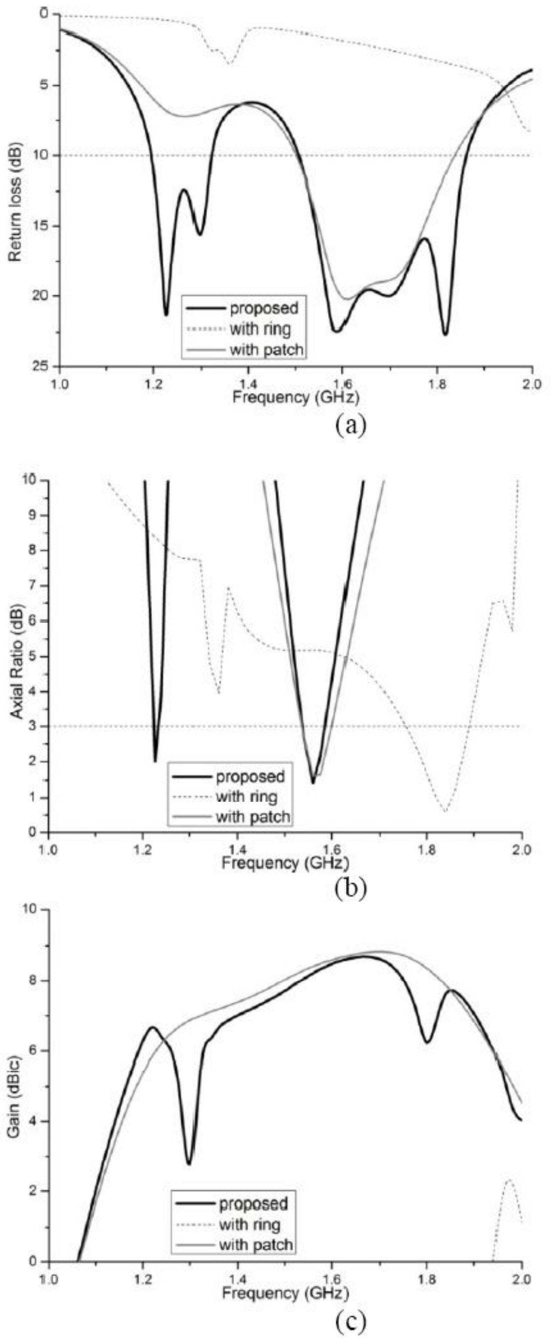

Fig.2 Comparison of the (a) return-loss (b) axial-ratio (c) gain responses of three antennas

W1=76 mm. In Fig.3 (b), the optimized size of the ring is Lr=62.5 mm and Wr=77 mm. The spacing of S in both cases is 1mm. The length of the feed line is 22 mm for the patch-only antenna and is 87.4 mm for the ring-only antenna. Fig.4 and Fig.5, respectively, show the axial-ratio of the patch-only and the ring-only antennas. In Fig.4 and Fig.5, the influence of the thickness of the air-layer on the axial-ratio is also displayed. The use of an air-layer is mainly used to increase the gain of the antenna. It can be applied to increase the gain of the patch-only, the ring-only, and the proposed antenna. It is shown that good CP performance and high gain in both bands can be achieved when the thickness of the air-layer is 12 mm.

In the line-coupling method, the real part of the input impedance of the antenna is controlled by the length of the feed line; and the imaginary part is controlled by the spacing between the line and the antenna. When either the ring or the patch is independently excited, there is only one feedline. When the ring and the patch are both excited, the ring and the

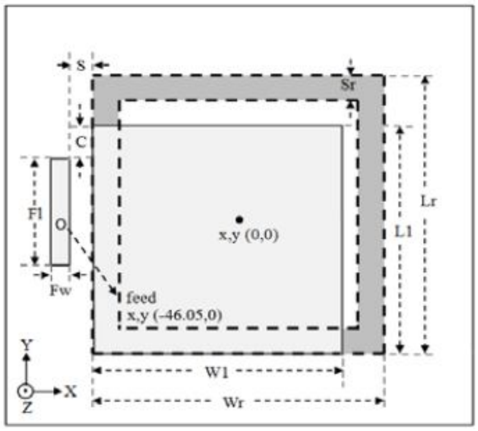

Fig.6 A dual-band CP antenna with the opposite polarization

patch can be placed on the same side of the feedline as shown in Fig.6. The patch is on the top of the FR4 layer, while the ring is on the bottom. Below the FR4 layer, there is an air-layer with a thickness of 12 mm. The size of the patch is with W1=77 mm and L1=67 mm and the size of the ring is with Wr=87 mm and Lr=81 mm. We have found that this antenna radiates a left-hand CP wave in the 1.22 GHz band and a right-hand CP wave at the 1.57 GHz band. For a GPS antenna, it is generally required that the antenna has the same sense of polarization on two bands. The proposed antenna shown in Fig.7 is designed to meet this requirement. To design the dual-band CP antenna, the length of the feed line is chosen equal to the length when the patch is independently excited, i.e. 22 mm. The spacing from the line to the patch is 1 mm when the patch is independently excited. Now, the spacing from the line to the patch, s1, is varied between 0.5 mm and 3 mm. Accordingly, the spacing from the line to the ring, s2, will also be varied as the positions of the patch and the ring are fixed. Table 2 displays the variations of the input impedance of the antenna at f1=1.227 GHz and f2=1.575 GHz. It is noted that the imaginary part of the input impedance for the patch is decreased as S1 is increased, while the imaginary part for the ring is increased as S2 is increased. The imaginary part of the input impedance of the ring may be positive or negative when the spacing is tuned.

III. EXPERIMENTS

A picture of the proposed antenna is shown in Fig.8. It is shown that the ring is coplanar with the patch. The feed line is situated between the ring and the patch. Fig.9, 10, and 11 respectively show the comparison of the simulated and measured return-loss, axial-ratio, and gain responses of the proposed antenna. The measured 10 dB return-loss bandwidth is from 1.51 GHz to 1.86 GHz and from 1.2 GHz to 1.25 GHz. The measured 3 dB axial-ratio bandwidth is from 1.542 GHz to 1.588 GHz and from 1.218 GHz to 1.23 GHz. The measured gains are greater than 7.5 dBiC on both bands. The simulated results for return-loss, axial-ratio, and gain are all agreeable with the measured results. We have also studied that the antenna performances change slightly when the patch and the ring are patterned on the opposite

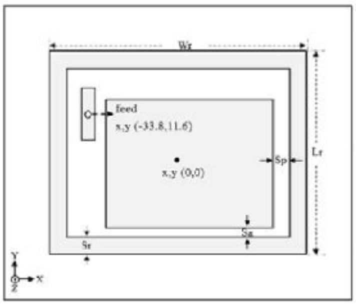

Fig.7 The proposed dual-band CP antenna

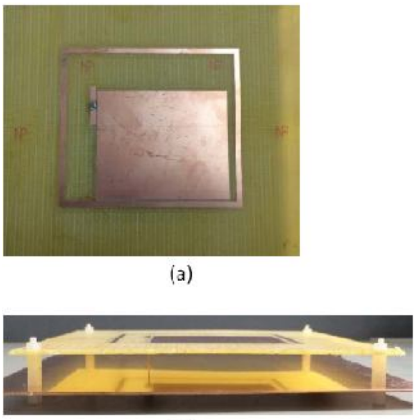

Fig.8 A picture of the proposed antenna (a) top view (b) side view

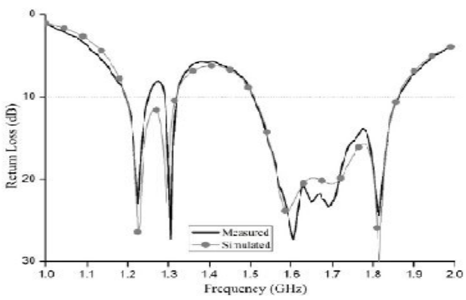

Fig.9 Simulated and measured return loss of the proposed antenna

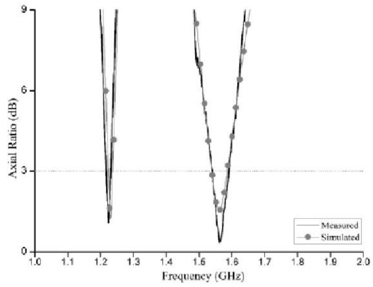

Fig.10 Simulated and measured axial-ratio of the proposed antenna

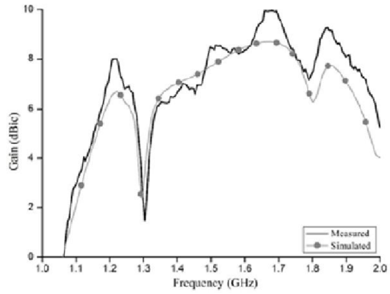

Fig.11 Simulated and measured gain of the proposed antenna

Table 2 Input impedance of the antenna as the spacing between the line and the patch is varied

S1 (in mm)	S2 (in mm)	Z_0(in Ω) (1.227GHz)	Z0 (in Ω) (1.575GHz
0.5	14.45	51.3+j25.8	55.8-j4.6
1	13.95	48.6+j6.4	50.2-j8.3
1.5	13.45	47.3-j7.3	46.0-j10.8
2.0	12.95	46.9-j18.1	42.7-j12.8
2.5	12.45	47.2-j27.0	40.0-j14.3
3.0	11.95	47.9-j34.4	37.7-j15.4

side of the FR4 substrate. The simulated and measured xz-plane patterns of the antenna are shown in Fig.12 and Fig.13, respectively for 1.227 GHz and 1.575 GHz. It is shown that the antenna is right-hand circularly polarized at the two frequencies.

CONCLUSION

Microstrip antenna can be coupled by various methods. The line coupling is one of them. Compared with the proximity-coupled, the edge-coupled, and the aperture-coupled methods, the line-coupled method is more suitable to excite the ring-patch antenna. It has the advantage to fully use the space inside the ring as the patch is inserted inside the ring. However, no attempt has been made before to excite the dual-band ring-patch antenna by the line-feed method. In this paper, we have successfully designed the dual-band GPS antenna by the line-feed method. The antenna's performance seems good in terms of the high gain and wide axial-ratio and return-loss bandwidths at the 1.575 GHz band. However, the axial-ratio bandwidth at the 1.227 GHz band is 12 MHz which may be enough for practical use, but may suffer from poor tolerance in tuning.

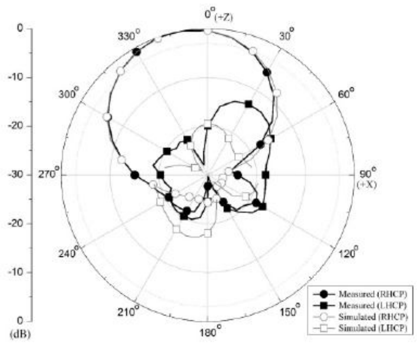

Fig.12 The simulated and the measured xz-plane pattern of the proposed antenna at 1.227 GHz

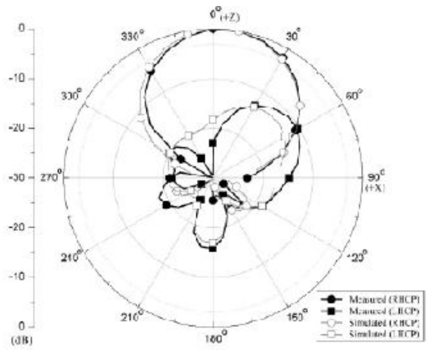

Fig.13 The simulated and the measured xz-plane pattern of the proposed antenna at 1.575 GHz

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