Ultra-Wideband Modified CSRR Antenna with Reconfigurable Notch Band

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Abstract **–** A novel technique of realizing notches for a compact ultra-wideband (UWB) antenna is proposed based on a modified complementary split ring resonator (CSRR). The UWB slot antenna is in the swallow shape of a modified CSRR. The notched band centered at 5.8 GHz for upper WLAN and 3.9 GHz for C-band satellite communication systems. The proposed antenna has a compact size of 25 × 27.9 mm^2. The measured results show that the proposed antenna can guarantee a wide bandwidth from 2 GHz to 12 GHz (VSWR < 2) with dual unwanted band-notches successfully. The antenna demonstrates omnidirectional and stable radiation patterns across all the relevant bands. Moreover, a prototype of the dual-band-notched UWB antenna is fabricated and measured results are compared with simulated results.

Index Terms **–** Monopole antenna, multi-band antenna, and ultra-wideband (UWB) antenna.

I. INTRODUCTION

Ultra-wideband (UWB) links have been shown increasing applications in short-range and high-bandwidth communication and surveillance links [1]. Due to interference from other services, it is often desirable to block out narrow frequency bands from the UWB spectrum. The antenna is often tasked with providing both the wide frequency range and narrowband notch, which should be tunable within a certain range. Quarter-wavelength transmission lines or slots have been primarily used within antenna structures, ground plane or feed lines to suppress unwanted narrow-band signals [2-5]. In this paper, we present a compact printed antenna with 90 degrees rotation angle quadrilateral complementary split ring resonator (CSRR), which has an UWB operating bandwidth with a tunable dual-band-notched frequency at 3.9 GHz and 5.8 GHz [6]. Band-notched operation is achieved by embedding 90 degree rotation angle quadrilateral CSRR slots on radiated patch [7]. The CSRR under investigation can be used to implement left-hand materials. The 90 degrees rotation angle quadrilateral CSRR is promising for UWB antennas for ensuring multiple notched bands. Both dual-band-notched characteristics and compact size are achieved. The antenna has promising features, including good impedance matching performance over the whole operating frequency band, stable radiation patterns and flexible frequency notched function [8-10].

II. ANTENNA DESIGN

The proposed band-notched monopole antenna is shown in Fig. 1. The antenna consists of a notched swallow radiation patch and a trapezoidal ground plane that plays an important role in the broadband characteristics of this antenna because the electromagnetic coupling effects between the patch and the ground plane and improve its impedance bandwidth can be adjusted without any cost of size or expense [11]. To fabricate swallow-shaped antenna, a half ellipse is cut from a rectangle radiating patch firstly and then moved into the bottom side of the radiating patch. This new shape with a gradient structure has the same area as the rectangle shape radiating patch [12]. In addition, the ground of the antenna has a trapezoidal-like shape so that the ground also has a gradient structure. Since both the radiating patch and the ground have a gradient structure, the antenna can ensure a smooth transition from one

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mode to another. In this case, the antenna has an excellent impedance matching within a broad bandwidth rang [13]. The proposed antenna fed by a microstrip line is printed on RT5880 substrate with thickness of 0.508 mm and permittivity of 2.2. The width and length of the microstrip feed are fixed at 1.5 mm and 10.25 mm, respectively. The size of the inner-square (R_1, R_2) should be adjusted to determine the dual-band-notched frequency of antenna. With other parameters being fixed, the dual-band-notched frequency increases with decreasing R_1 and R_2. For fixed R_1 and R_2, the resonance frequency could be enhanced by increasing slit width of squares (g). For the convenience of optimization, the width of squares (d_1, d_2) and distance between squares are set to be the same as (g). Then, the distance (C_1, C_2) between these two CSRRs can also be optimized. These optimization works were managed by using commercial 3-D electromagnetic software HFSS [14].

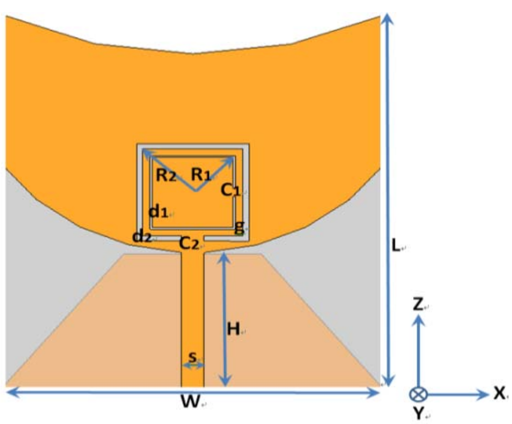
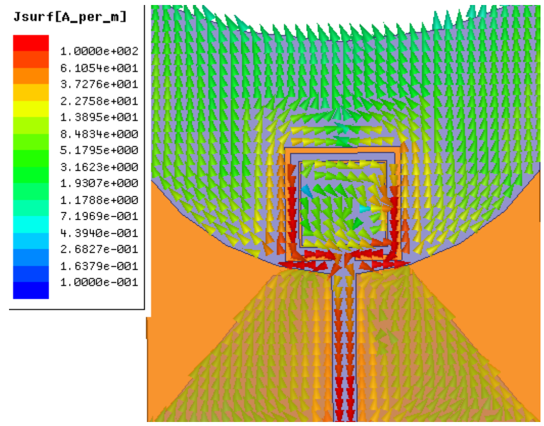
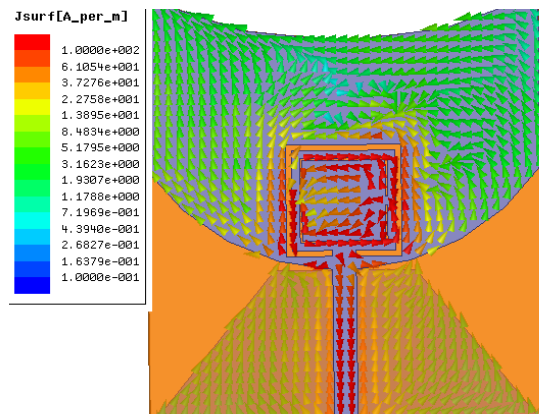


Fig. 1. Geometry of the antenna, with dimensions, R_1 = 3.75 mm, R_2 = 4.65 mm, C_1 = 0.6 mm, C_2 = 1.5 mm, S = 1.5 mm, H = 10.2 mm, W = 25 mm, L = 27.9 mm.

Figure 2 shows the current distributions at dual center notched bands. The dimensions of two 90 degrees rotation angle quadrilateral CSRR are corresponding to dual notched bands [15]. When the antenna is working at the center of lower notched band near 3.9 GHz, the outer CSRR functions as a separator in Fig. 2 (a), which is almost in dependent of the other band-notches. Similarly, from Fig. 2 (b), the upper notched band near 5.8 GHz is ensured by the inner CSRR [16].



(a)



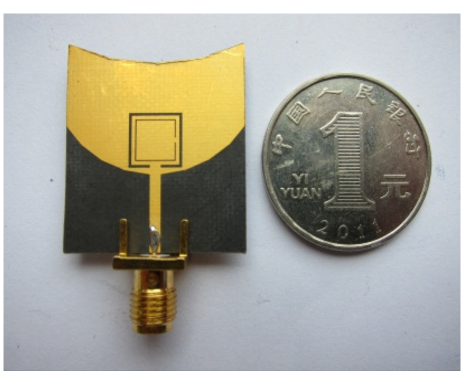
(b)

Fig. 2. The current distribution at (a) 3.9 GHz and (b) 5.8 GHz.

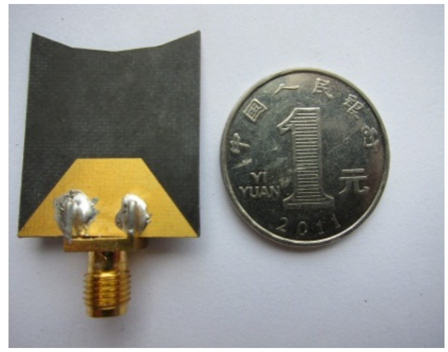
III. RESULTS AND DISCUSSION

The proposed novel 90 degrees rotation angle quadrilateral CSRR shows distinct double band gaps due to the weaker mutual coupling between inner and outer rings even though the two band gaps are adjacent [17]. Thus, 90 degrees rotation angle quadrilateral CSRR is selected to obtain adjacent dual notched bands for C-band (3.7 GHz–4.2 GHz) satellite communication systems and upper WLAN [18]. Figure 3 shows the photographs of the dual band-notch UWB antenna. It is noted that the inner opening ring and outer opening ring have just 90 degrees. Figure 4 shows the measured and simulated VSWRs versus frequency. The results show that the proposed antenna can offer sufficiently wide impedance bandwidth covering 2 GHz – 12 GHz or more with the dual notched bands. The measured dual notched bands include 3.65 GHz – 4.18 GHz and

5.7 GHz – 6.06 GHz, covering C-band satellite communication systems and upper WLAN, respectively. Therefore, by loading 90 degrees rotation angle quadrilateral CSRR with different centers, the CSRR can provide good dual band-notch performance. Owning to its dual band-notch structure, the CSRR can reduce the design space to achieve dual notched bands in comparison with the complementary edge-coupled SRR. The radiation characteristics of the frequencies across the band have also been studied [19]. Figures 5 and 6 show the simulated and measured 2-D radiation patterns, respectively at frequencies 3.5 GHz, 5 GHz, and 7.5 GHz for the proposed UWB antenna. Measurements of the radiation patterns of the prototype are carried out in an anechoic chamber. It can be seen that the radiation patterns in the xy-plane (H-plane) are almost omni-directional and the radiation patterns in the yz-plane (E-plane) are monopole alike. Clearly, the dual notch UWB antenna has an excellent radiation performance when it operates at 3.5 GHz, 5 GHz, and 7.5 GHz. By comparing with Figs. 5 and 6, the measured radiation patterns show slight deterioration in the co- and cross-polarization electric fields. To some extent, this is due to the measurement environment. Especially, the SMA feeding connector may have interference to radiation field in the test. Distortions in the E-plane patterns begin to occur at higher frequencies because the radiating elements are no longer small relative to those wavelengths. Figure 7 shows measured gains of the proposed antenna. It is observed that the antenna keeps a stable antenna gain about 3-4 dBi, which decreases significantly to about -10 dBi and -3 dBi at the dual notched bands. This demonstrates that the antenna has great dual band-notched characteristics.



(a)



(b)

Fig. 3. Photographs of the proposed antenna; (a) front view and (b) bottom view.

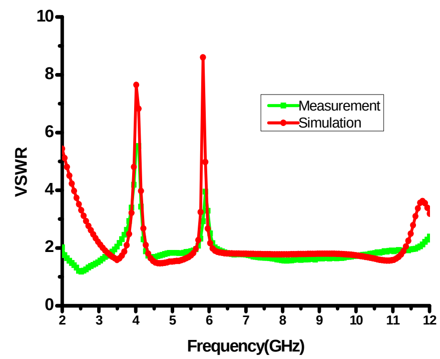
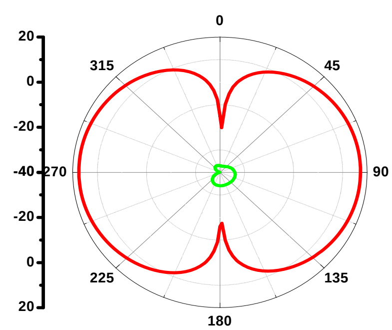
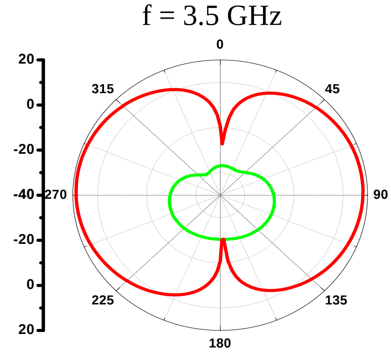


Fig. 4. Comparison between the simulated and measured VSWR of the proposed antenna.



f = 3.5 GHz



f = 5 GHz

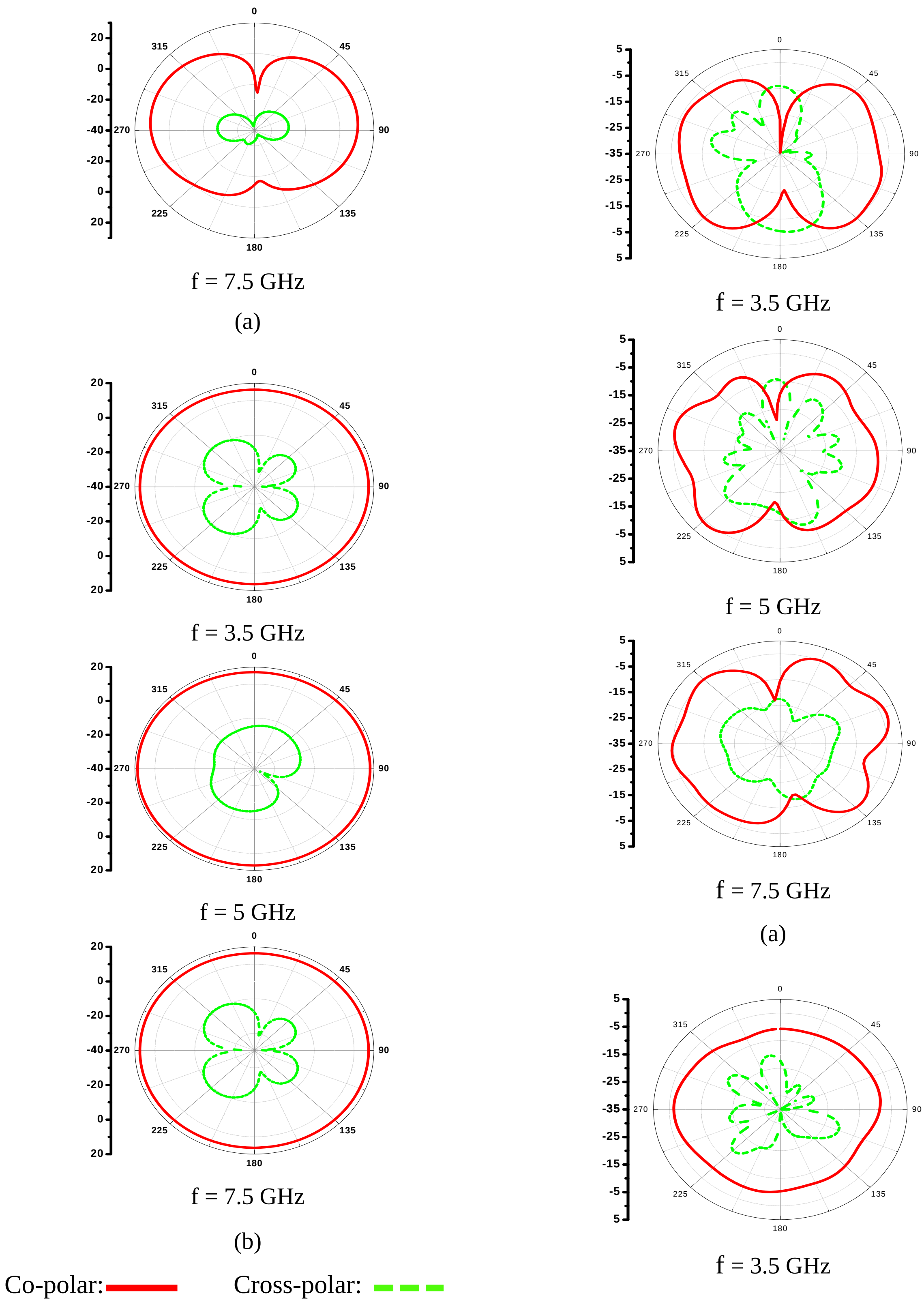
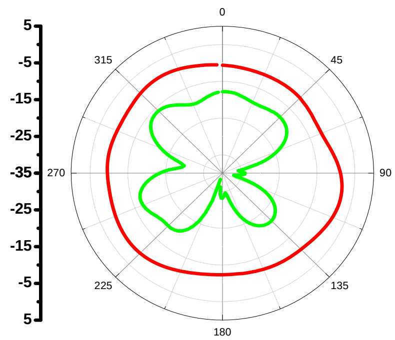
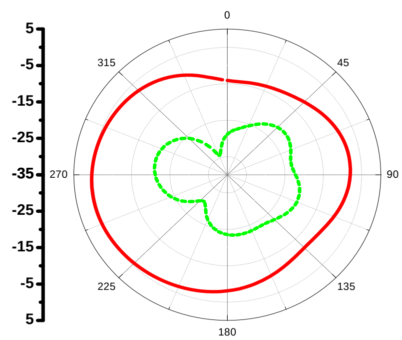


Fig. 5. Simulated radiation patterns at (a) yz -plane and (b) xy-plane.



f = 5 GHz



f = 7.5 GHz

(b)

Co-polar: Cross-polar:

Fig. 6. Measured radiation patterns at (a) yz -plane and (b) xy-plane.

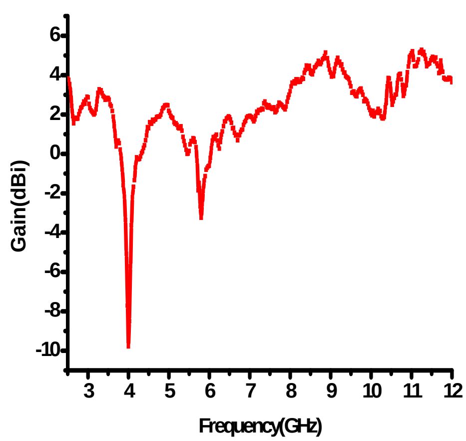


Fig. 7. Measured gain of the proposed antenna.

IV. CONCLUSION

A swallow shaped microstrip patch antenna with narrow loops leading to a small size multi-band planar monopole antenna has been presented. The swallow shaped patch antenna covers the UWB frequency range. By changing the length of the added resonant loops in the notched region, the center frequency of the multi resonances below the UWB frequency can be finely tuned. Furthermore, broad bandwidth and good monopole-like radiation patterns are obtained with a rather compact antenna size. Also, the prototype has been constructed and measured to show an excellent agreement with the simulated results. Therefore, the proposed antenna is extremely useful for short-range wireless communication systems.

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