Triple Notch UWB Antenna Controlled by Novel Common Direction Pentagon Complementary Split Ring Resonators

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Abstract **—** A small-size CPW-feed multi-band planar monopole antenna is presented. A Swallow-Shaped-Patch (SSP) that covers the Ultra-Wideband (UWB) frequency range is used in the proposed design. To create a multi-band antenna, several narrow pentagon slots, acting as resonance paths, can be integrated with the SSP antenna. Triple-band antennas are simulated and good results are obtained, while showing a very sharp band-rejection performance at 3.92 GHz, 5.34 GHz and 5.88 GHz, respectively. The antennas have omnidirectional and stable radiation patterns across all the relevant bands. Moreover, a prototype of the triple-band antenna is fabricated and measurement results are compared with simulation results.

Index Terms - Monopole antenna, multi-band antenna and Ultra-Wideband (UWB) antenna.

I. INTRODUCTION

Ultra-Wideband (UWB) technology is now becoming widely used in a variety of applications, such as radar, short-range communications and positioning systems. This is because this technology offers advantages of large channel capacity, multipath propagation performance and potential for ultra-low-power implementation of transmitting-only devices. As is the case, in conventional wireless communication systems, antennas play a crucial role in UWB systems. However, there are more challenges in designing a UWB antenna than a narrow band one. In particular, a suitable UWB antenna should be capable of operating over an ultra-wide bandwidth, as allocated by the Federal Communications Commission (FCC); that is 3.1-10.6 GHz. At the same time, it needs to exhibit satisfactory radiation properties over the entire frequency range. In addition, the antenna needs to be compact in size and cheap to manufacture for consumer electronic applications. To satisfy these requirements, various wideband antennas have been studied [1]. However, other narrow band services coexist within the UWB spectra, such as C-band (3.7-4.2 GHz) satellite communication systems and Wireless Local-Area Network (WLAN) IEEE802.11a and HIPERLAN/2 systems, operating in the 5.15-5.35 GHz and 5.725-5.825 GHz band, respectively. To overcome this problem, agile software-defined radios provide a solution that demands the use of smart reconfigurable antennas capable of cancelling in-band interference. Hence, a UWB antenna with reconfigurable band-rejection characteristics at the WLAN or C-band satellite frequencies is highly desirable.

In this paper, we present a compact printed antenna with co-directional pentagon Complementary Split-Ring Resonators (CSRR), which has an UWB operating bandwidth with a tunable triple-notched frequency at 3.9 GHz, 5.2 GHz and 5.9 GHz. Band-notched operation is

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achieved by embedding co-directional modified CSRR slots on the radiated patch. The CSRR is under investigation by researchers to implement left-hand materials and the co-directional Complementary Split Ring Resonator (CSRR) is promising for UWB antennas to enable multiple notched bands [2]. Both triple-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.

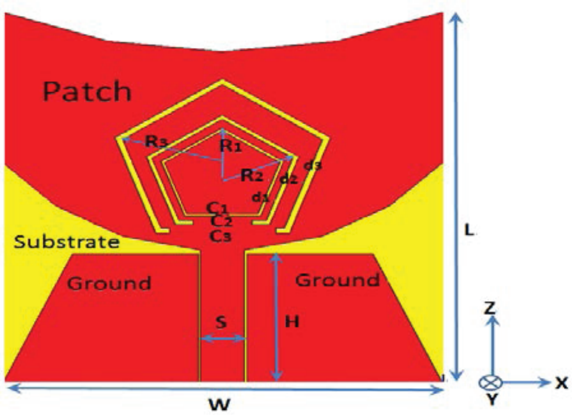
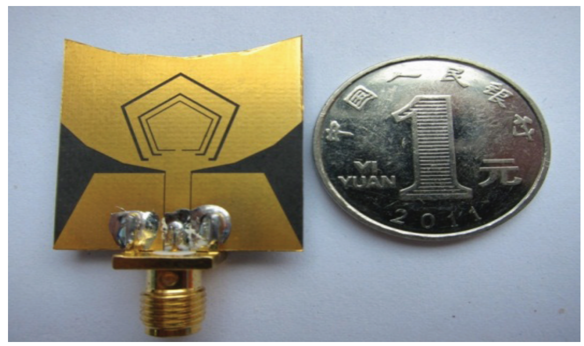


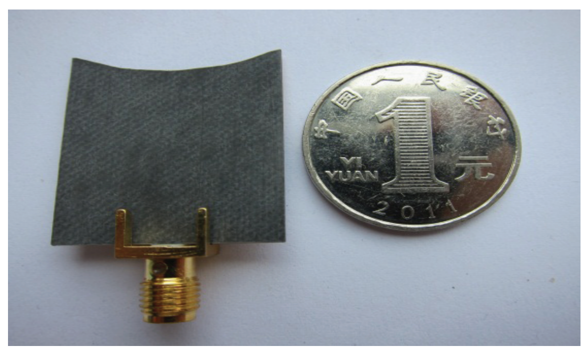
Fig. 1. Geometry of antenna, width dimensions are: R_1=4.01 mm, R_2=4.90 mm, R_3=6.95 mm, C_1=0.6 mm, C_2=3.35 mm, C_3=6 mm, d_1=0.2 mm, d_2=0.32 mm, d_3=0.45 mm, s=2.5 mm, H=9.8 mm, W=25 mm and L=27.9 mm.

II. ANTENNA DESIGN

The geometry of the proposed co-directional pentagon split-ring resonators slot UWB antenna with band-notch function, is depicted in Fig. 1. The antenna is located on the xz-plane and the normal direction is parallel to the xy-axis. The radiating ring is fed via the 50Ω Coplanar Waveguide (CPW) feed-line of width 2.5 mm, as illustrated in Fig. 2. The proposed antenna was fabricated on a dielectric substrate RT5880 with a relative permittivity (ε_r) of 2.2 mm and thickness of 0.508 mm. A common direction pentagon complementary split ring resonators slot are used and fabricated on the radiation patch. To achieve good impedance matching for the ultra-wide band operation, the swallow radiator is fed by a Coplanar Waveguide (CPW) transmission line with trapezoidal ground-plane, which is terminated with a Sub Miniature A (SMA) connector for the measurement purpose. Since the antenna and the feeding are fabricated on the same side of the plane, only one layer of substrate with single-sided metallization is used, which makes the manufacturing of the antenna very easy and extremely cost-effective. Good performance of multiple band-notched characteristic is simply accomplished by embedding common direction pentagon CSRRs to the swallow patch. The simulation is optimized using the commercial 3-D electromagnetic software HFSS [3].



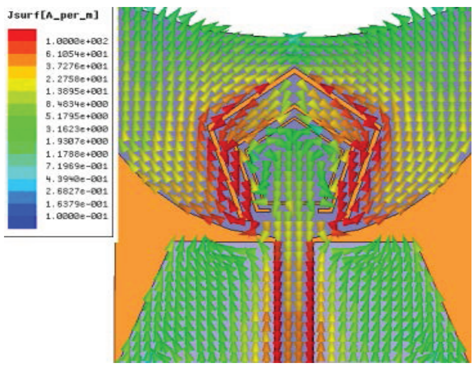
(a)



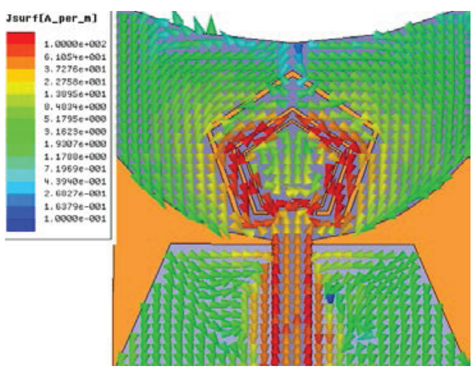
(b)

Fig. 2. Photograph of the proposed antenna: (a) front view and (b) bottom view.

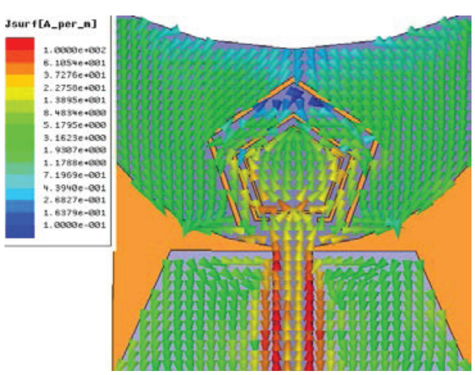
Figure 3 shows the current distributions at three center notched bands. The dimensions of three co-directional pentagons CSRRs are corresponding to three notched bands. When the antenna is working at the center of the lower notched band near 3.9 GHz, the outer CSRR behaves as a separator, shown in Fig. 3 (a), which almost has no relation to the other band-notches [4]. Similarly, the middle CSRR operates as a second separator for the center of the middle notched band near 5.2 GHz, in Fig. 3 (b). As seen in Fig. 3 (c), the upper notched band near 5.9 GHz is ensured by the inner CSRR [5]. Additionally, as a certain current crowded on the ground plane near the CPW feed line would affect the antenna performance, we find that the dimension of the ground plane particularly has a significant effect on the triple band-notches performance and the impedance bandwidth, according to the simulation results [6].



(a)



(b)



(c)

Fig. 3. The current distribution at: (a) 3.9 GHz, (b) 5.2 GHz and (c) 5.9 GHz.

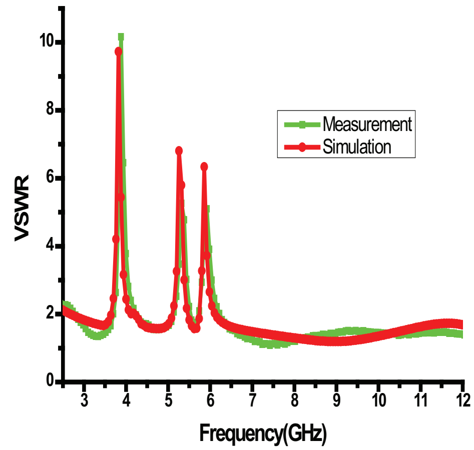
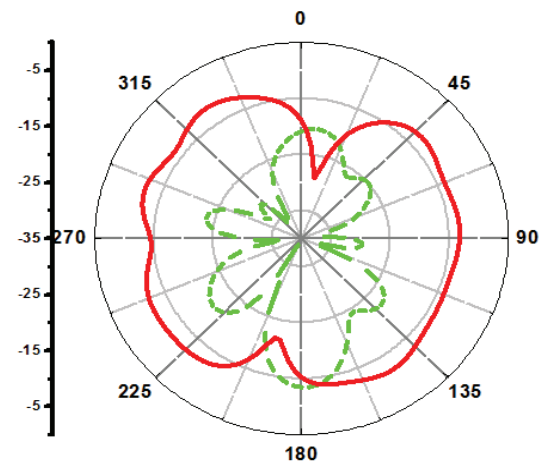
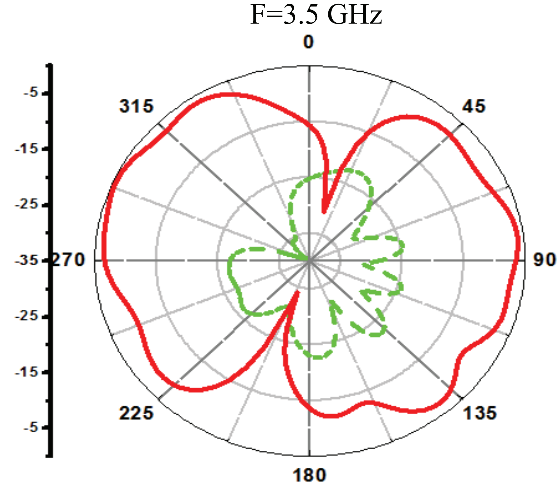


Fig. 4. Comparison of simulated and measured VSWR of proposed antenna.

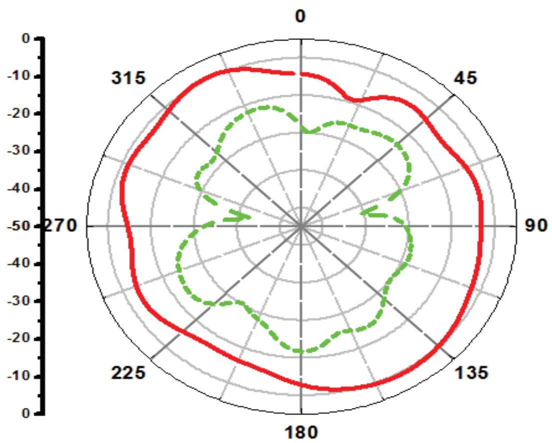


F=3.5 GHz

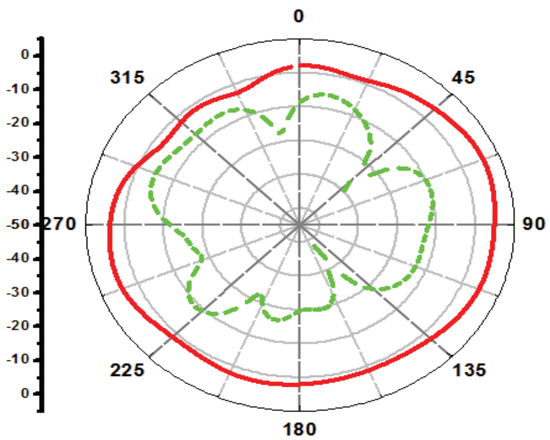


F=7.5 GHz

(a)



F=3.5 GHz



F=7.5 GHz

(b)

Co-polar:
Cross-polar:

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

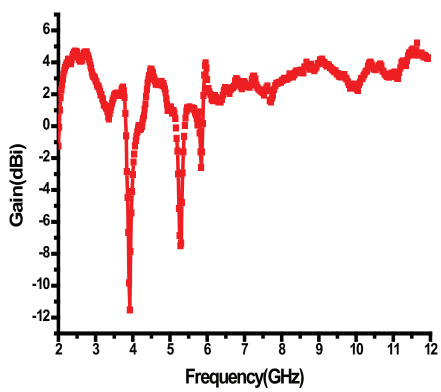


Fig. 6. Measured gain of proposed antenna.

III. RESULTS AND DISCUSSION

The VSWR performance of the fabricated prototype was measured using an Agilent 85052C vector network analyzer. Figure 4 shows the simulated and measured VSWRs for the proposed antenna, as well as the reference antenna. Band-notched function is obtained by introducing the co-directional pentagon CSRRs. The designed antenna has an impedance bandwidth of 2.6-12 GHz for VSWR less than 2, except the frequency-notched band of 3.68-4.20 GHz, 5.12-5.45 GHz and 5.72-6.08 GHz, respectively. Obviously, this measured frequency range covers commercial UWB band (3.1-10.6 GHz) and rejects the frequency band of C-band satellite communication systems and IEEE 802.11a, to overcome Electromagnetic Interference (EMI) problems among UWB and WLAN [7]. As shown in Fig. 4, it is also observed that the measured notched-band width is slightly wider than the simulated result. This may be caused by the use of an SMA connector and fabrication errors.

The measured far-field radiation patterns of the proposed antenna in H-plane (xy-plane) and E-plane (yz-plane) at frequencies 3.5 GHz and 7.5 GHz, are plotted in Fig. 5, respectively. Like the behavior of conventional wide slot antennas, the proposed antenna has relatively omnidirectional xy-plane (H-plane) radiation patterns with non-circularity of about 5-8 dB, over the operating frequency band [8]. The radiation patterns in yz-plane (E-plane) are monopole alike. All the obtained radiation patterns agree with those of the conventional printed UWB monopole antennas [9]. The proposed antenna has proved to be capable of providing favorable spatial-independent band-notched characteristics.

Figure 6 plots measured peak gain against frequency for the band-notched antenna [10]. It reveals that the antenna gain ranges from 1.9 dBi to 5 dBi within the 2-12 GHz frequency band. Note that this doesn't include the notched band in which it decreases significantly to about -12 dB, -8 dB and -3 dB [11]. It is confirmed that the proposed antenna provides a high level of rejection to signal frequencies within the notched band [12-15].

IV. CONCLUSION

A novel compact CPW-fed printed monopole antenna with three band-notched characteristics has been proposed for UWB applications. We showed that three more resonances are excited by embedding co-directional pentagon CSRRs with proper dimensions and position in the radiation pattern. As a result, wide impedance bandwidth from 2.6 GHz to 12 GHz is achieved. The designed antenna has a simple configuration and an easy fabrication process. The experimental results show that the proposed antenna with a very compact size, simple structure and wide bandwidth can be a good candidate for UWB application.

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