A Double Band-Notched UWB Antenna for Flexible RF Electronics

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Abstract ─ A double band-notched UWB compact antenna based on ultrathin liquid crystal polymer (LCP) substrate is designed and experimented for flexible electronics in this paper. The antenna is constituted by swallow tail radiation patch and trapezoid ground. Two elliptic single complementary split-ring resonators (ESCSRRs) are used to realize double band-notched characteristic in UWB band. The measurement results show that the VSWRs of antennas are lower than 2 in the whole UWB band (3.1 GHz-10.6 GHz) except the two band-notched frequency-bands in 3.7 GHz-4.2 GHz and 5.15 GHz-5.825 GHz. The bending performance of band-notched UWB antenna are measured. The measured radiation patterns indicate that the antenna is an omni-directional antenna both at flat and bent circumstances. The overall dimension of the antenna is 27 mm × 21 mm × 0.05 mm. These results suggest that this compact mechanical flexible antenna would be useful for flexible UWB wireless system.

Index Terms ─ Band-notched, ESCSRR, flexible electronics, Liquid Crystal Polymer (LCP), UWB antenna.

I. INTRODUCTION

Since the ultra-wideband (UWB) spectrum (3.1 to 10.6 GHz) is allocated by the US Federal Communications Commission (FCC) to use for commercial communication purposes in 2002, high performance UWB antenna are widely concerned [1-2]. There are some narrow band interferences in UWB, such as C-band satellite communications system (3.7 GHz-4.2 GHz) and Wireless Local Area Network (5.15 GHz-5.825 GHz). Based on this situation, the best solution to reduce these interferences is introducing an antenna with band-notched performance instead of using narrow band filters [3-4]. In addition, many UWB applications need more than one band-notches in complex electromagnetic environment, so it is essential to design multiple band-notched UWB antennas [5-8].

Recently, as the increasing demands of wireless communication in wireless wearable and implanted electronics, compact microwave antenna with mechanical flexibility is become popular [9-10]. Considering the superiority of UWB wireless communication systems (i.e., high transmission data rate, low transmission power, etc.), design of compact band-notched UWB antenna with mechanical flexibility would be meaningful to wireless communication in wearable and implanted electronics [2].

In this paper, in the aim of developing mechanical flexible UWB antenna, a double band-notched UWB antenna is designed. To realize compact size, ultra-thin LCP with copper-clad laminated, which has been proved excellent mechanical flexibility [11], is used as the substrate. The antenna is constituted by swallow tail radiation patch and trapezoid ground. And the band-notched characteristics are realized by etching two elliptic single complementary split-ring resonators (ESCSRRs) on radiation patch. The performances are measured both at flat and bent circumstances.

II. ANTENNA DESIGN

The geometric structure and size of the antenna are shown in Fig. 1. The antenna is designed with 50μm-thick LCP substrate with 18μm-thick copper laminated on both sides [11]. The dielectric constant and loss tangent of the LCP used in the design are 2.9 and 0.0025, respectively. The feeding line of the antenna is microstrip line with 50 ohm characteristic impedance. The overall dimension of UWB antenna is 27 mm × 21 mm × 0.05 mm, which is more than 50% smaller area compare with Ref. [8].

The simulation of antenna is realized by using Ansys HFSS. Both of bending and flat condition can be well predicted. Without ESCSRR, the VSWRs can be achieved lower than 2 in the whole UWB band (3.1 GHz-10.6 GHz) by optimizing the swallow tail radiation patch radian and the gradient of trapezoid ground. When adding an ESCSRR, a notched band in its corresponding frequency can be produced, because of the ESCSRR

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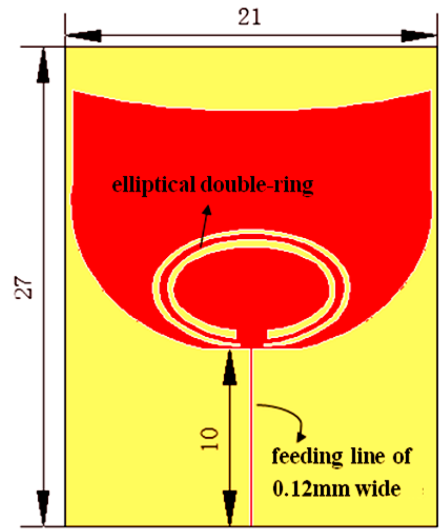
cutting and changing the radiation currents at its notched band frequency. The relationship between the dimensions of ESCSRR and the notched band frequency (f_{notch}) is shown in the following equations:

$$S_e = K_e \pi (R_2 - w_2) = \frac{\lambda_g}{2} = \frac{c}{2 f_{notch} \sqrt{\varepsilon_{eff}}}, \quad (1)$$

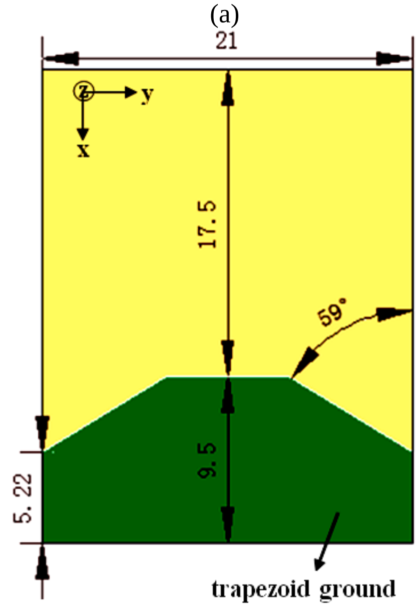
$$K_e = 3(1 + k) - \sqrt{(3 + k)(1 + 3k)}, \quad (2)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} (1 + \frac{12h}{\omega_f})^{-0.5}, \quad (3)$$

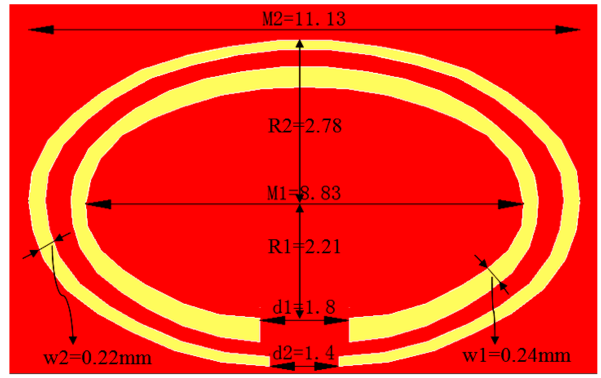
where S_e means the circumference of the ESCSRR, which is approximately equal to half of the guided wavelength λ_g at the desired notch frequency. K_e is a factor related to k ($k = M_2/2R_2$). The values of w_2, M_2, and R_2 are shown in Fig. 1 (c). The effective dielectric constant is calculated through Equation (3), where h, ω_f, and ε_r are the substrate height, width of the microstrip feed and relative permittivity of substrate, respectively.



(a)



(b)

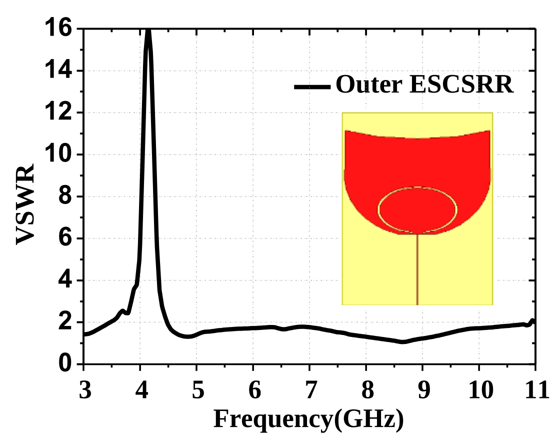


(c)

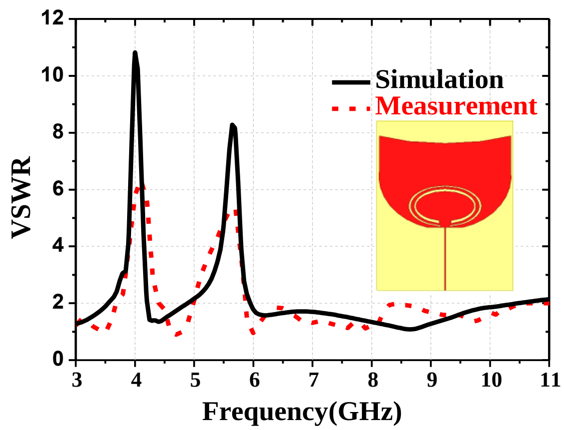
Fig. 1. Geometric structure and size of the antenna (unit: mm): (a) top view, (b) bottom view, and (c) two elliptical single complementary split-ring resonators.

By calculating the w_2, M_2, and R_2 of ESCSRR and optimizing the geometric parameters d_2, which is the key factor in effect the peak of VSWR as shown in Fig. 1 (c), the notched band between 3.7 GHz-4.2 GHz can be produced as shown in Fig. 2 (a). The second notched band between 5.15 GHz-5.825 GHz can be produced in the same way. When the antenna is operating at the center of upper notched band, the inside ESCSRR behaves as a separator, which has no effects on the other band-notches [6], as shown in Fig. 2 (b). At the same time, Fig. 2 (b) indicates the good agreement between simulated and measured results. The existing discrepancy may be attributed to fabrication tolerance.

The photography of fabricated antenna is shown in Fig. 3. The SMA connector is soldered onto the feeding microstrip. The temperature of the soldering iron tip should be kept below 200℃ in the soldering period to prevent melting the flexible substrate, meanwhile, the soldering time should be as short as possible. Figure 3 (b) is the photo of antenna bending over a polystyrene foam with a diameter of 25 mm in order to facilitate the measurement of the antenna under the bending condition.

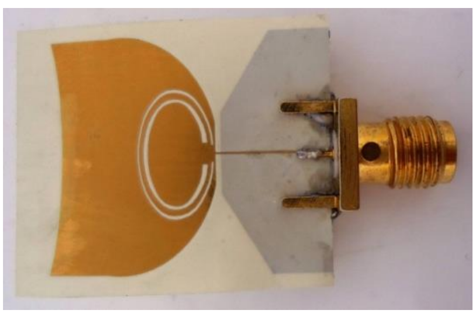


(a)

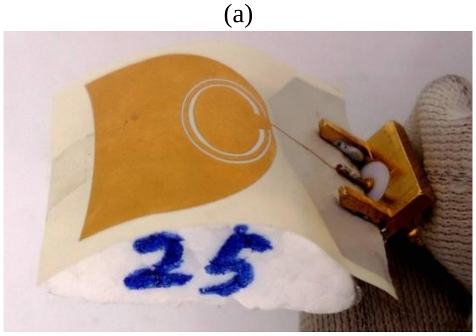


(b)

Fig. 2. Comparison of simulation and measurement results of VSWRs: (a) antenna with only outer ESCSRR, and (b) antenna with two ESCSRRs.



(a)

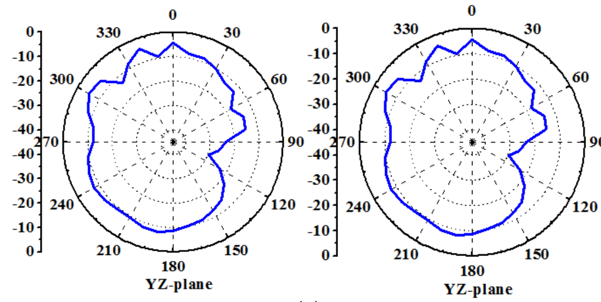


(b)

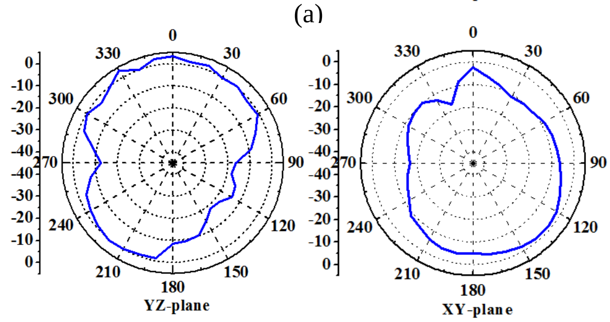
Fig. 3. Photograph of the fabricated antenna with SMA connector: (a) flat and (b) bent (diameter = 25 mm).

III. RESULTS AND DISCUSSION

The VSWRs and radiation patterns of the antenna in flat and bent circumstances are measured in the Satimo spherical near field measurement system. Good agreement between simulated and measured VSWR results has been shown in Fig. 2 (b). The measured radiation patterns of 4.5 GHz and 6 GHz are shown in Fig. 4. The measured maximum radiation gains of the flexible antenna at 4.5 GHz and 6 GHz are -4.4 dBi and 3.54 dBi, respectively. The antenna is omni-directional in XY-plane, while has directionality in YZ-plane. These results are consistent with the monopole antenna radiation pattern.



(a)



(b)

Fig. 4. Measured radiation patterns of the antenna at: (a) f = 4.5 GHz and (b) f = 6 GHz.

The measured VSWRs of the antenna under the bending and flatting conditions are shown in Fig. 5. Because of the dielectric constant of the polystyrene foam is only 1.06, which has little effects to antenna [12], it is reliable to measure the characteristics in this way. It is shown that there is little difference between the antenna VSWRs under the flat and bent conditions.

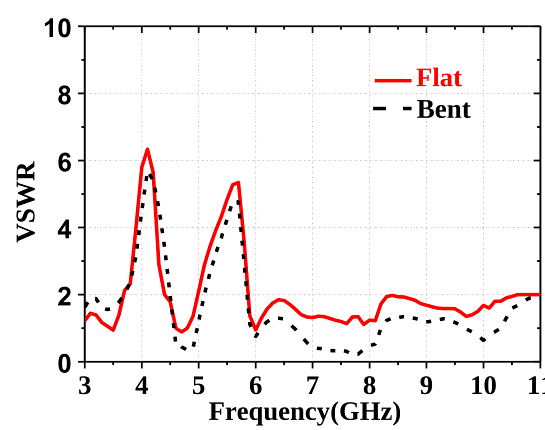


Fig. 5. Comparison of the measured VSWR results at flat and bent (diameter = 25 mm) circumstances.

Figure 6 shows the comparison of measured antenna radiation patterns at the flat and bent circumstances at 6 GHz. The monopole antenna shows good performance in bending condition with diameter of 25 mm and 33 mm, which proves that it is a good candidate for flexible systems [13].

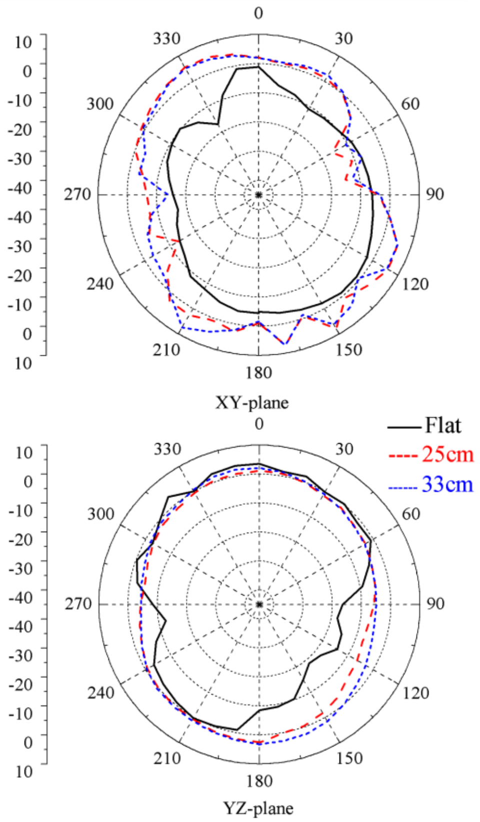


Fig. 6. Comparison of the radiation pattern at flat and bent (diameter = 25 mm and 33 mm) circumstances at 6 GHz.

IV. CONCLUSION

A two band-notched swallow tail antenna with mechanical flexibility is designed. The band-notched characteristics are realized by etching two elliptic single complementary split-ring resonators (ESCRRs) on radiation patch. The antenna is designed with more than 50% smaller size by using ultra-thin LCP substrate compared with FR-4 substrate. And good performance is shown both at flat and bent circumstances. This antenna can be used in flexible UWB system.

ACKNOWLEDGMENT

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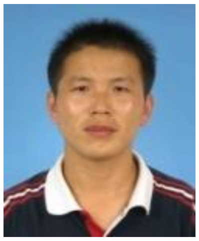

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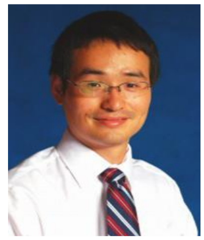

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