A Band-Notched U-Shaped Ultrawideband Planar Monopole Antenna Using Open-Loop Ring Resonators

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Abstract

This paper presents a new band-notched ultrawideband (UWB) planar monopole antenna, consisting of a feed microstrip line, a U-shaped radiator, and a pair of open-loop ring resonators. By properly adjusting the circumferences of the open-loop ring resonators, the notched band of the proposed antenna can be controlled as anticipated.

Keywords : Band-notched, Ring Resonator, Monopole Antenna, Ultrawideband (UWB) Antenna.

1. Introduction

In the last decade, ultrawideband communication (3.1-10.6 GHz) has attracted plenty of attention for their high-speed transmission capability in indoor short-distance applications. Since the spectra for UWB, WLAN (5.15-5.825 GHz), and WiMAX (5.25-5.85 GHz) are overlapped with each other at the frequency band from 5-6 GHz, band-notched UWB antennas are desperately required to eliminate the potential signal interferences. A simple way, for achieving frequency filtering properties, is to etch slots on the antenna structure, such as the W-shaped slot [1], the split-ring slots [2], and etc. Alternatively, some studies introduce extra resonator loading to control the notched band [3]-[4], and even to achieve bandstop-filter-like response [5]-[6]. However, most of these advanced designs still involve a complicated architecture with elaborate synthesis method.

In the meantime, planar monopole antennas have become the prime choice for ultrawideband applications due to their compact size, planar structure, consistent radiation properties and inherent wideband operation. To develop a band-notched ultrawideband planar monopole with simple synthesis procedure, in this paper, we propose a new design with a pair of open-loop ring resonators. The resonators are etched beneath the radiator. By properly trimming the circumferences of the open-loop resonators, the notched band of the U-shaped planar monopole can be precisely controlled in a straightforward way. The proposed antenna shows a compact size, fairly wide impedance bandwidth, and promising band-rejected characteristics. The design concept, fabrication, and experimental results are carefully discussed in the following sections.

2. Antenna Design and Configuration

Fig. 1(a) and (b) shows the geometry of the proposed ultrawideband antenna, which is composed of a feed microstrip line, a U-shaped radiator, and a pair of open-loop ring resonators. For the purpose of improving the antenna impedance matching, the proposed antenna adopts a linear taper profile between the radiator and the ground plane, i.e. the aperture for radiating the electromagnetic waves. The taper profile plays a dominant role in determining the antenna impedance bandwidth; the shape (and size) of the ground plane affects the matching, as well. To realize the desired notched band, a pair of open-loop ring resonators, whose circumferences are approximate one guided wavelength at the desired rejection frequency, are etched under the strips of the radiator. By simply utilizing the resonance nature of the ring resonators, the frequency filtering properties can be achieved at the targeted rejection band. The experimental results are discussed explicitly in the next section.

3. Simulation and Experimental Results

To validate the aforementioned design concept, the proposed band-notched planar monopole was fabricated and experimentally demonstrated; a photograph is shown in Fig. 2. It was designed on a 20-mil RO4003C substrate with a dielectric constant of 3.38 and a loss tangent of 0.0027; the antenna dimensions in Fig. 1(a) and (b) are W = 34 mm, W_1 = 2.5 mm, W_2 = 14 mm, W_3 = 1.1 mm, W_4 = 8 mm, W_5 = 0.5 mm, W_{gap} = 0.2 mm, L = 34 mm, L_1 = 13 mm, L_2 = 15.4 mm, L_3 = 15 mm, L_4 = 8 mm, L_5 = 15 mm, and θ = 16.2°. The proposed antenna was simulated and measured, respectively, by Ansoft HFSS and Agilent PNA E8363B. Fig. 3 shows the simulated and measured antenna reflection coefficients ($|S_{11}|$); the $|S_{11}|$ of the antenna without the resonators is plotted for comparison purpose. The agreement between the results is fair; the discrepancy can be mainly ascribed to the effect of the SMA adaptor, as it introduces unpredictable nearby coupling and acts equivalent to an extended ground plane in the measurement. The $|S_{11}|$ of the antenna without the resonators is plotted for comparison purpose. As observed, except for a notched band at 5.24-5.9 GHz, the impedance bandwidth ($|S_{11}|$ > -9.5 dB) is from 3.07 to more than 12 GHz. The maximum attenuation at the center frequency of notched band reaches up to 2.23 dB. By properly adjusting the circumferences of the open-loop ring resonators, the controllability of the notched band is demonstrated in Fig. 4(a) and (b), as well.

The antenna radiation patterns were measured in an anechoic chamber using a NSI 700S-90 scanner. The measured E- and H-plane radiation patterns are illustrated in Fig. 5. Like a conventional planar monopole, the proposed antenna exhibits donut-like radiation patterns. Referring to the gain responses in Fig. 6, the agreement between the simulation and measurement is good; the mismatch at the high band can be attributed to the adaptor, as well. As depicted in this figure, the measured antenna peak gain is around 2-6.6 dBi; meanwhile, in the rejection band, a gain suppression up to 5.8 dB can be readily observed. The proposed antenna possesses well-behaved ultrawideband characteristics as expected.

4. Conclusion

A new band-notched U-shaped ultrawideband planar monopole antenna has been introduced and experimentally verified in this paper. By employing the resonance nature of the loaded open-loop ring resonators, a notched band with a gain suppression of 5.8 dB can be achieved at the 5 GHz-WLAN/WiMAX bands. The experimental results show that the proposed antenna could find applications in ultrawideband wireless communications using multilayer printed circuit board technology.

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Acknowledgments

This work was supported by the National Science Council, Taiwan (R.O.C.), under Grant 99-2628-E-011-001.

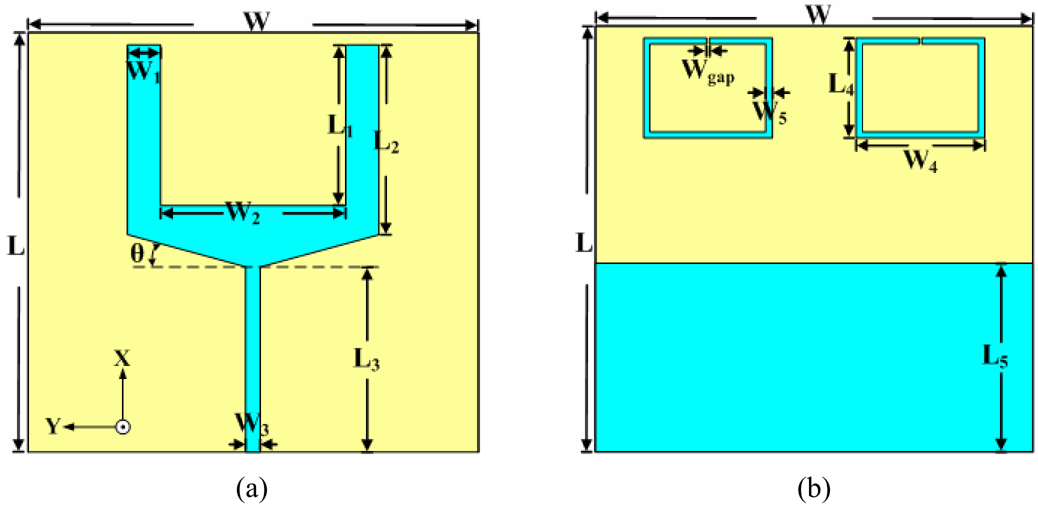


Figure 1: Layout of the Proposed Band-notched Ultrawideband Antenna. (a) Top Layer. (b) Bottom Layer.

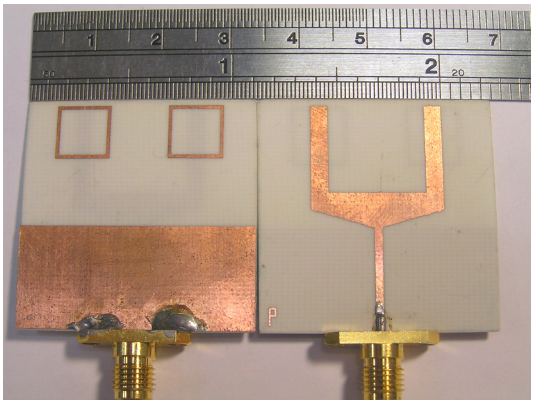


Figure 2: Photograph of the Fabricated Sample of the Band-notched Ultrawideband Antenna.

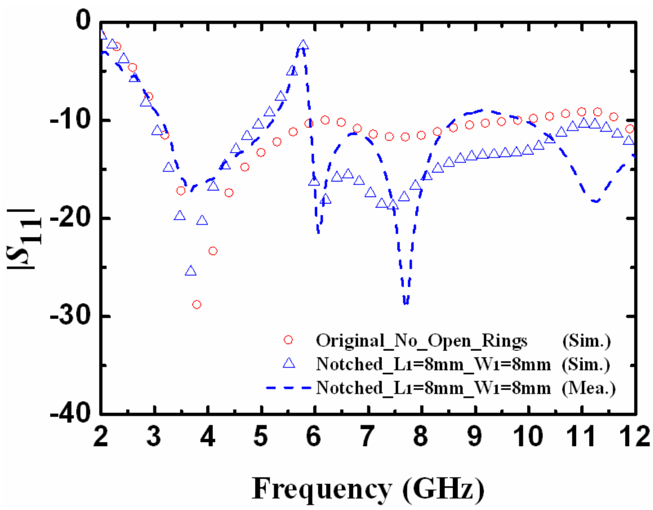
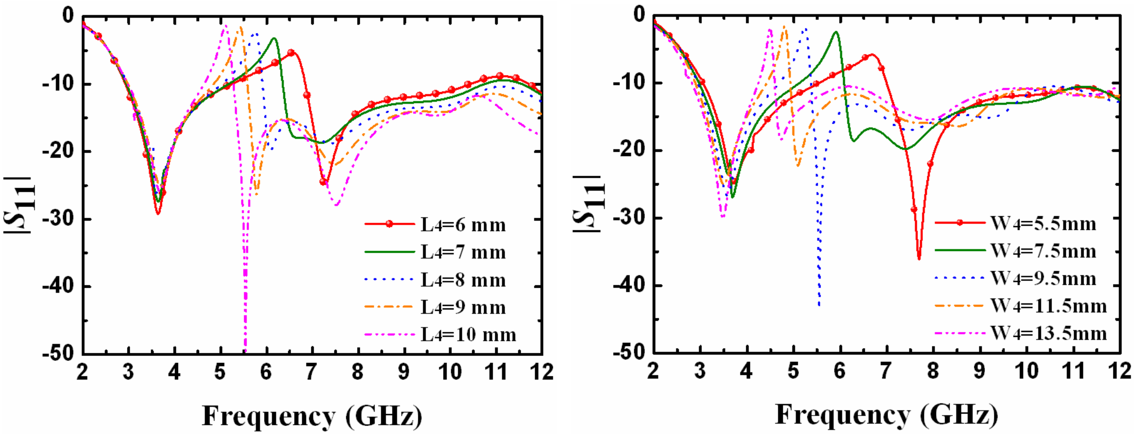


Figure 3: Simulated and Measured Reflection Coefficients of the Proposed Band-notched Ultrawideband Antenna.



(a) (b)

Figure 4: Controllability of the Rejection Band. (a) Various Ring Lengths (L_4) with a Fixed Width (W_4 = 8 mm) of the Ring Resonators. (b) Various Ring Widths (W_4) with a Fixed Length (L_4 = 8 mm) of the Ring Resonators.

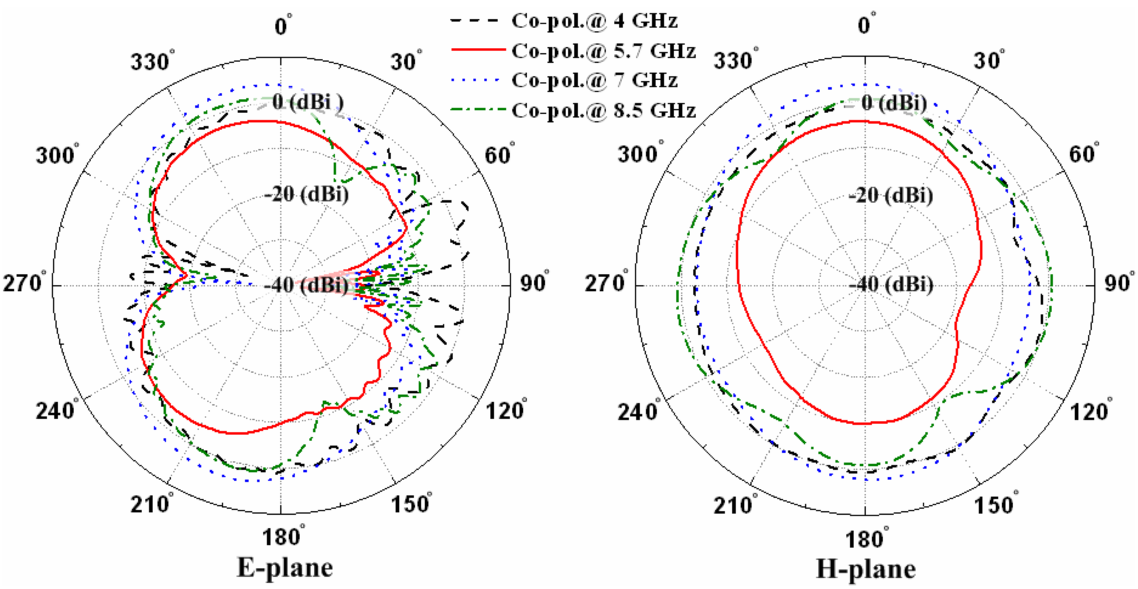


Figure 5: Measured E-plane (xz-plane) and H-plane (yz-plane) Patterns of the Proposed Band-notched Ultrawideband Antenna.

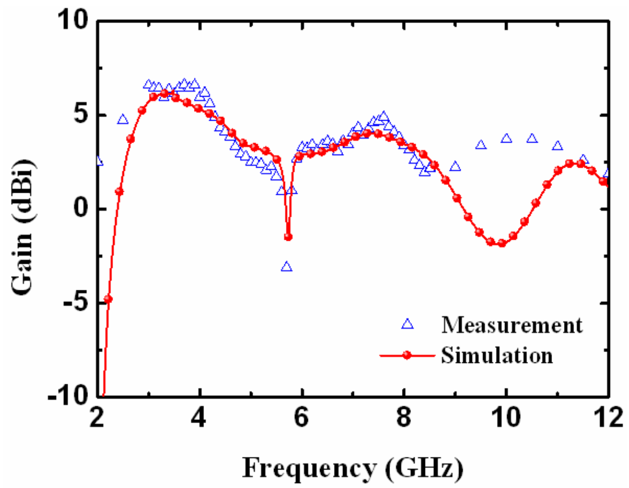


Figure 6: Simulated and Measured Peak Gain Responses of the Proposed Band-notched Ultrawideband Antenna.