Tunable and Reconfigurable Frequency Rejection Circular Slot Antenna for UWB Communication Applications

Yingsong Li[1] **and Raj Mittra**[2]

[1]College of Information and Communications Engineering, Harbin Engineering University, Harbin, China
[2]Electromagnetic Communication Lab, Penn State and Central Florida Universities, USA

Abstract— In this paper, a tunable and reconfigurable circular slot antenna with frequency rejection characteristics is proposed for UWB communication applications. The proposed antenna can provide triple-band-notch characteristics by using various stubs designed to filter out unwanted narrowband signals whose frequencies overlap with those of the UWB band. Center frequencies of these notch bands are tunable, and tunability is realized by adjusting the dimensions of the proposed stubs. Also, the proposed antenna has a reconfigurable frequency rejection characteristic to render the designed antenna suitable for UWB, band-notched UWB, dual band-notched UWB, tri-band-notched UWB, or multi-band communication applications. Experimental results show that the proposed antenna can provide tunability over a wide range, excellent reconfigurable frequency rejection characteristics and good omnidirectional radiation patterns, which make it attractive for indoor UWB communication applications.

1. INTRODUCTION

Even since the Federal Communications Commission (FCC) released the frequency band of 3.1–10.6 GHz for use in commercial ultra-wideband (UWB) communication systems, a large number of research studies have been directed toward UWB applications. UWB antennas are one of the crucial components for UWB communication systems and have been widely studied for many years. Recently, a wide variety of printed microstrip-fed monopole and CPW-fed UWB antennas with different configurations have been proposed to produce a broad impedance bandwidth covering the UWB band and their performance characteristics have been investigated both numerically and experimentally [1–4].

However, there exist several narrowband wireless communication systems that work in the frequency range of UWB systems such as the 3.5 GHz worldwide interoperability for microwave access (WiMAX); wireless local area network (WLAN) operating at 5.15–5.35 GHz and 5.725–5.825 GHz; and the satellite communication system operating at 8 GHz [5, 6], which may interfere with the UWB systems. Consequently, it is necessary to develop UWB antenna designs with multiple band-notch characteristics to suppress the interferences from these narrowband signals. In view of this, a large number of prototype designs for compact UWB antennas with band-notch characteristics have been presented by a number of authors [5–12]. The band-notch forming techniques reported in the literatures can be classified into three categories, namely, etching slot, stubs and parasitic strip techniques. Among these, the parasitic strip techniques including strip near patch [5], strip near ground [6] and stepped impedance resonators (SIRs) [7] are difficult to tune in practice. Many antenna designs have been carried out by embedding diverse slots in the UWB antenna designs, including those with U-shaped [8], C-shaped [9], H-shaped [8], V-shaped [10] and complementary SRR- shaped slots [11]. However, the etched slots on the radiating patch or ground plane leak electromagnetic wave, which may interfere with the adjacent radio frequency front-ends. Additionally, most of these papers are designed to generate either a single- or dual-notch band. In [12], a triple band-notched UWB antenna has been proposed by etching various slots in the radiating patch, which may excite leaky waves and, hence, limit its practical application.

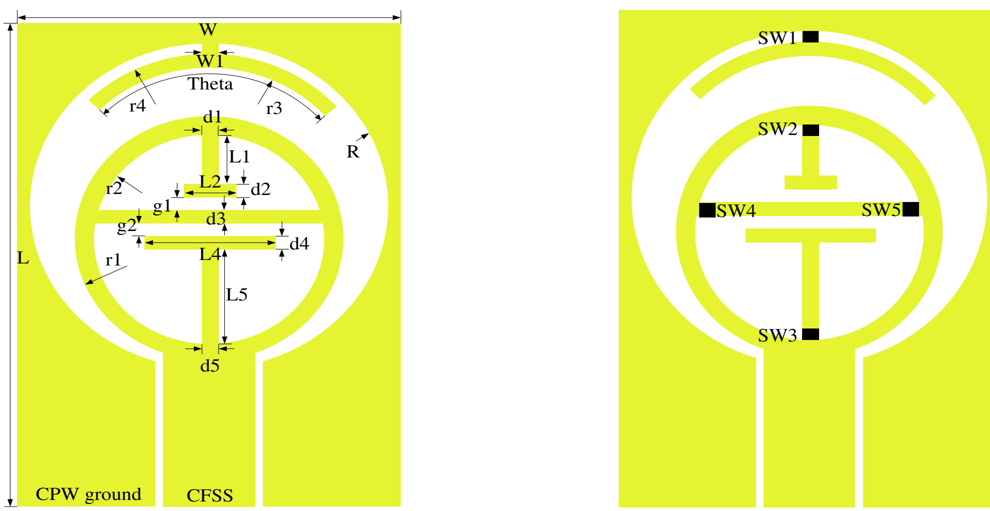
Although these band-notched UWB antennas can provide designated band-notch characteristics to suppress the unwanted narrowband signal interference, they cannot cover the entire UWB band. Thus, designing a UWB antenna with desired reconfigurable characteristics is highly desired. Several reconfigurable UWB antennas have been presented by using switch techniques [13–16]; however, they are not compatible UWB antennas with triple band-notch characteristics.

In this paper, a triple band-notched UWB antenna with tunable and reconfigurable frequency rejection characteristics is proposed and its performance is investigated in detail. The triple notch-bands are generated by using an arc-shaped stub and two T-shaped stubs with an isolating element which is inserted in-between the two T-shaped stubs. The reconfigurable band-notched function is obtained by integrating five switches into the stubs. The simulated results show that the proposed antenna can provide a wide bandwidth covering the entire UWB band, as well as a wide tunable and reconfigurable band-notched characteristic and omnidirectional radiation patterns, which render it suitable for UWB and multi-mode wireless communication applications.

2. ANTENNA DESIGN

Figure 1 depicts the configuration of the proposed tunable and reconfigurable UWB antenna with frequency rejection. The proposed antenna is fed by a coplanar waveguide and is printed on a substrate with a relative permittivity of 2.65, a loss tangent of 0.002, and a thickness of 1.6 mm. The proposed antenna consists of a wide slot with a circular shape, a circular ring radiating patch, an arc-shaped stub (AS), two T-shaped stubs (TSs), an isolation element (IE), five ideal switches integrated into the AS and TSs, and a CPW-fed structure together with a CPW ground plane. The CPW-fed structure is comprised of a CPW-fed signal strip (CFSS) with width of 3.6 mm and a gap of 0.2 mm between the CFSS and the CPW ground plane. In this study, the ideal switches are used for evaluating the proposed reconfigurable antenna and the presence of a metal bridge represents the ON state, while the absence of a metal bridge represents OFF state [13–16]. The triple band-notched function is obtained by using the arc-shaped slot and T-shaped subs, while the reconfigurable function is realized by controlling the ON/OFF states of the ideal switches.

We begin by designing a triple band-notched UWB antenna (antenna-1) and then integrate five ideal switches into this antenna to develop the reconfigurable characteristic antenna denoted as antenna-2. The proposed antenna is optimized by using the HFSS simulation code and the optimized parameters are: $L = 32$, $W = 24$, $W1 = 1.6$, Theta $= 90°$, $L1 = 2$, $L2 = 2.8$, $L4 = 8.2$, $L5 = 4.8$, $d1 = d2 = d3 = d4 = d5 = 1$, $g1 = g2 = 0.5$, $R = 11.8$, $r1 = 6.7$, $r2 = 5.4$, $r3 = 10.47$, $r4 = 11.47$ (unit:mm).



(a) Antenna-1 (b) Antenna-2

Figure 1: Configuration of the proposed antenna.

3. PERFORMANCE OF THE PROPOSED ANTENNA

In this section, tunability, reconfigurable band-notched characteristics, as well as the radiation pattern characteristics are investigated and the results are discussed in detail. Figure 2(a) shows the effects of $L5$ on the band-notch characteristics. It is observed that the center frequency of the lowest band-notch shifts from 3.9 GHz to 3.2 GHz with an increment of $L5$, which can be used to suppress the unwanted interference signal from 3.5 GHz WiMAX band. However, the center frequencies of the other two notch bands remain unchanged. In this case, increasing $L5$ increases the lower T-shaped stub, which prolongs its resonance length, which in turn modifies the location of its lowest notch band. Figure 2(b) shows the performance of the proposed antenna as the angle Theta (see Figure 1(a)) is varied. We can see that the center frequency of the middle band-notch moves to a lower frequency as we prolong the length of the AS, which can be controlled by varying the angle Theta. As Theta increases from 80° to 100°, the center frequency of the middle notch drops rapidly from 6.1 GHz to 4.8 GHz. Thus, the middle notch band can be utilized to prevent

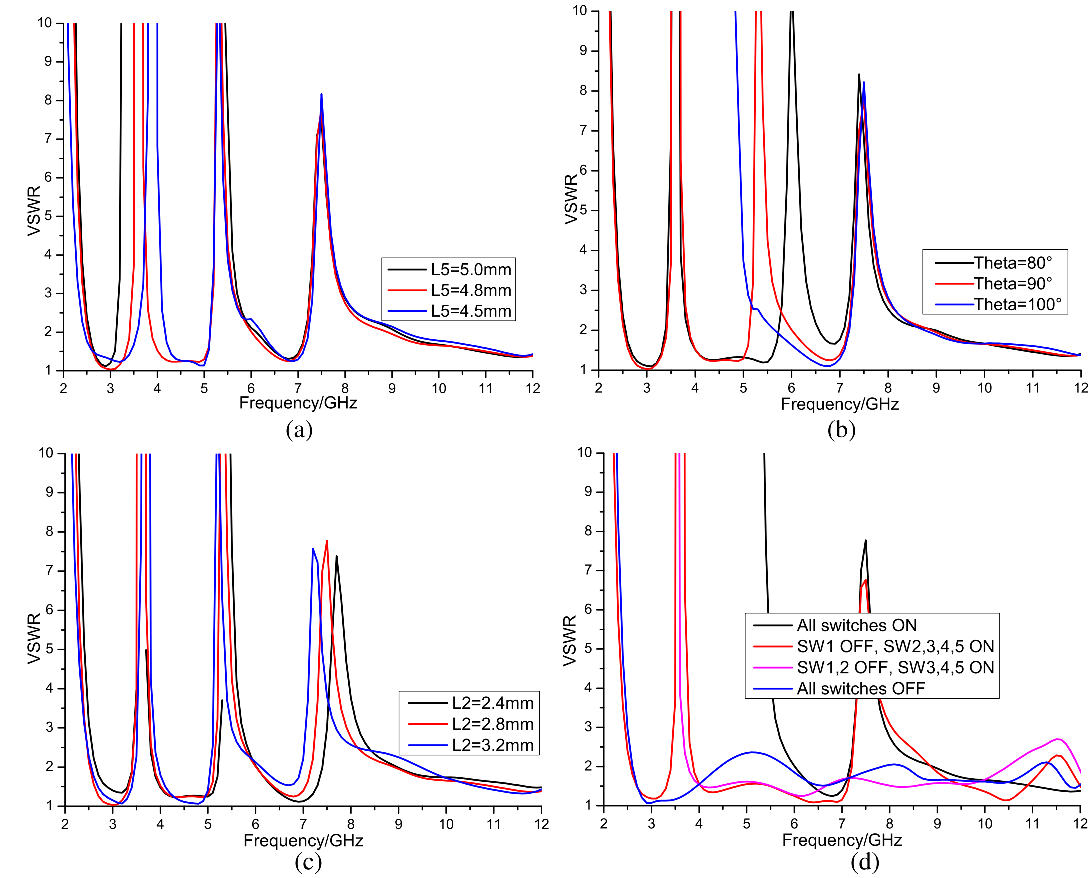
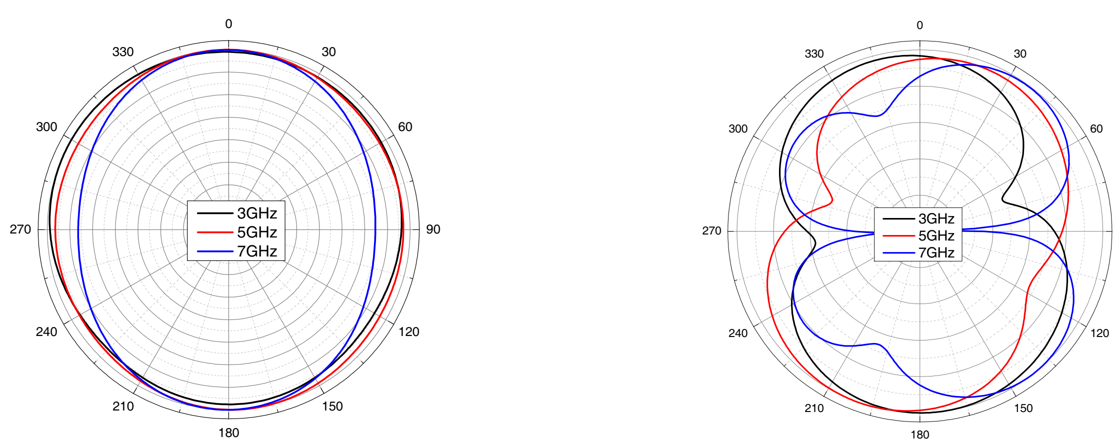


Figure 2: Parameter effects and the reconfigurable characteristics of the proposed antenna. (a) L5. (b) Theta. (c) L2. (d) Reconfigurable function.



(a) *H*-plane (b) *E*-plane

Figure 3: Radiation patterns of the proposed antenna.

the potential interference that may arise from the 5.5 GHz WLAN band. Figure 2(c) exhibits the trend of impedance bandwidth with an increment of $L2$ ranging from 2.4 mm to 3.2 mm. It is found that the center frequency of highest band-notch shifts within a range of 0.8 GHz, including the frequency band of 7.5 GHz satellite and 8.0 GHz ITU communication bands. Thus, we can conclude that the center frequencies of these three band-notches are tunable by adjusting the dimensions of the arc-shaped slot and T-shaped stubs. Figure 2(d) depicts the reconfigurable characteristics of the proposed antenna controlled by the states of the switches. When all the switches are ON, the proposed antenna is a UWB antenna with three band-notches which help to suppress the interference from the WiMAX, WLAN and ITU bands. When SW1 is OFF and SW2, 3, 4, 5 are ON, the antenna has two band-notches at the WiMAX and ITU bands, but not at the WLAN band. As for the antenna with only SW3, 4 and 5 ON, the proposed antenna functions as a UWB antenna with a band-notch at WiMAX band. When all the switches are OFF, the antenna is a UWB antenna with a mismatch, which is caused by the coupling between the isolation element and the T-shaped stubs. The radiation patterns of the proposed antenna have been investigated for the case when all the switches are ON and are presented in Figure 3. We can see that the proposed antenna has an omnidirectional radiation pattern in the H-plane, and a figure of 8-type of radiation pattern in the E-plane.

4. CONCLUSION

A circular, wide-slot UWB antenna with tunable and reconfigurable triple band-notched characteristics has been proposed and its performance has been investigated in detail. The results show that triple notch-bands can be realized by using the arc-shaped slot and T-shaped subs, and the tunable band-notched function is achieved by adjusting the dimensions of the slot and the T-shaped stubs. The reconfigurable band-notch characteristic has been realized by controlling the ON/OFF states of the ideal switches. Consequently, the proposed antenna can be used as a triple-band-notched UWB antenna, a dual band-notched UWB antenna, a single band-notched UWB antenna, a UWB antenna, or even a multi-band antenna, which render it suitable for UWB and multi-mode communication applications.

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