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A New Compact Printed Triple Band-Notched UWB Antenna

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Abstract—A novel planar ultra-wideband (UWB) antenna with triple-notched bands using triple-mode stub loaded resonator (SLR) is presented in this paper. The basic UWB antenna consists of a circular-shaped radiating element, a 50 Ω microstrip feed line, and a partially truncated ground plane. Then, the resonance properties of the SLR are studied. Results reveal that the multiple-mode property of the SLR can be utilized in the UWB antenna design to achieve triple band-notched performance. To validate the design concept, a novel planar UWB monopole antenna with three notched bands respectively around the WiMAX band, WLAN band, and X-band satellite communication band is designed and fabricated. The results indicate that the proposed planar antenna not only retains an ultrawide bandwidth, but also owns triple band-rejections capability. The UWB antenna demonstrates omnidirectional radiation patterns across nearly whole operating bandwidth that is suitable for UWB communications.

1. INTRODUCTION

Ultra-wideband (UWB) radio technology has attracted much attention since the U.S. Federal Communications Commission (FCC) allocated a frequency range with a bandwidth of 7.5 GHz (3.1 $\sim$ 10.6 GHz) for unlicensed radio applications. Many applications have been developed based on UWB technology such as short-range broadband communication, radar sensing, and body-area networking [1]. It is a well-known fact that planar monopole antennas present attractive features, such as simple structure, small size, low cost, stable radiation patterns, and constant gain over the entire operating band. Owing to these characteristics, planar monopoles are attractive for use in emerging UWB applications, and research activity is increasingly being focused on them [2–5].

However, in practical applications, antenna design for UWB applications is still facing many challenges. One such challenge is to avoid interference with some other existing narrowband services that already occupy frequencies in the UWB band, such as WiMAX in some European and Asian countries (2.75 GHz $\sim$ 3.15 GHz) and IEEE 802.11a WLAN in the USA (5.15 $\sim$ 5.35 GHz). Furthermore, X-band satellite communication services (XSCS) from 7.25 to 8.395 GHz also operate in the UWB band. Therefore, it is necessary to design antennas with multiband filtering functionality to reject these unwanted interfering signals [6–11]. To achieve desired band-notched performance, a half-wavelength U-shaped slot structure is usually inserted on initial the UWB monopole antenna in [6], however, only one notched band is created. In [7], a new UWB antenna with dual-notched bands using defected ground structure (DGS), however, it is based on a multilayer structure and hardly compatible with the existing microwave-integrated circuit. In [8], two notched bands can also be obtained, and these antenna structures are very simple and easy to fabricate; however, they use two or three single-mode resonators. Then, the spurious notched bands obtained by spurious resonances of the conventional resonance structures [9–11].

In this communication, a novel, compact, printed UWB monopole antenna with triple band-notched characteristics based on triple-mode stub loaded resonator (SLR) is proposed. Firstly, the

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resonance properties of the triple-mode SLR are studied. The analyzed results reveal that triple band-stop performance can be obtained based on the triple-mode resonant property of the triple-mode SLR. Then, the triple notched-bands characteristic is achieved by putting the triple-mode SLR near by the feed line of the UWB antenna. The proposed coupled triple-mode stub loaded resonator is found to have the advantage of introducing triple-notched bands simultaneously. Notice that the spurious notched-band of the triple-mode SLR is also far away from the UWB antenna work band. To validate the design concept, a novel planar UWB antenna with triple sharply rejected notched bands respectively centered at frequencies of 3.0 GHz, 5.2 GHz, and 8.0 GHz is designed and fabricated. The simulated and measured results show that the antenna achieves an ultrawide bandwidth ranging from 2.0 GHz to 11.0 GHz and avoid the WiMAX, WLAN, and XSCS interference. An omni-directional pattern across the entire bandwidth in the H-Plane of the antenna is achieved.

2. TRIPLE-NOTCHED UWB ANTENNA DESIGN

Figure 1 depicts the geometry of the proposed UWB antenna with triple-notched bands. It consists of the following major parts: the main patch with a feed, a triple-mode SLR resonator on the front surface of the substrate, and a conductor ground plane in the back. It is printed on a Rogers 4350B microwave substrate of thickness 0.508 mm and relatively permittivity 3.48. The triple notched-bands are realized by coupling the triple-mode SLR to 50 Ω microstrip feed-lines. The design of triple-notched bands will be discussed in Section 3. The proposed planar UWB antenna has a circular patch with radius $R_1 = 8.5$ mm, which is fed by 50 Ω microstrip line of width $w_0 = 3.5$ mm. In order to improve impedance matching performance, a rectangular slit is embedded in the ground plane, located under the microstrip feed line. The final optimized parameters of the planar UWB antenna are as follows:

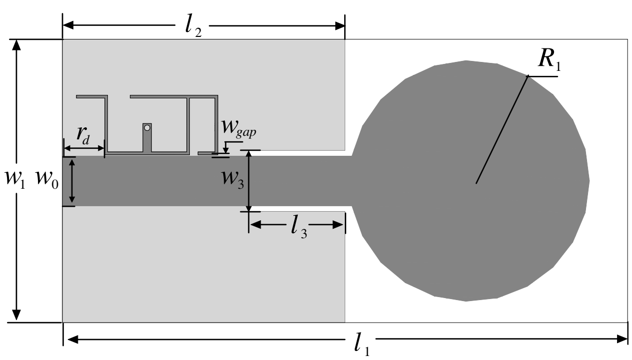


Figure 1. Layout of the proposed UWB antenna with triple notched-bands.

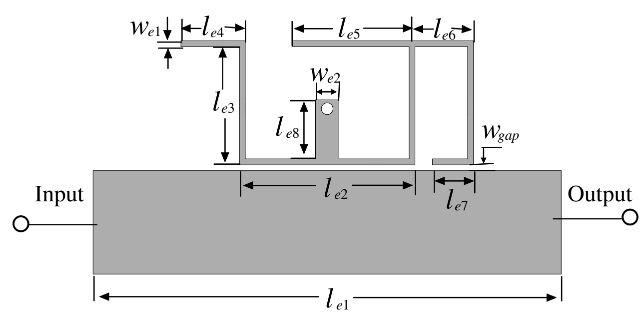
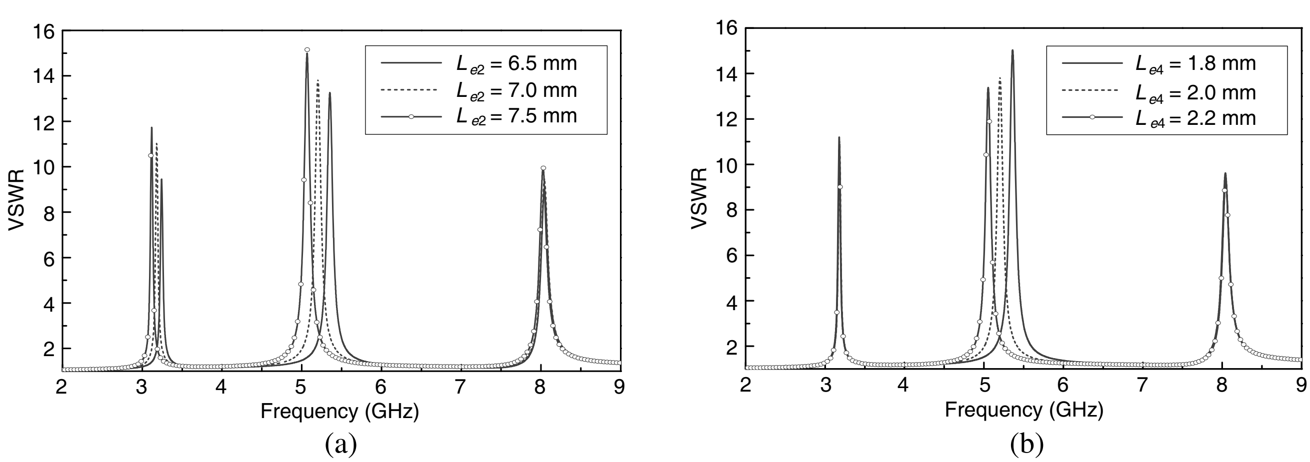
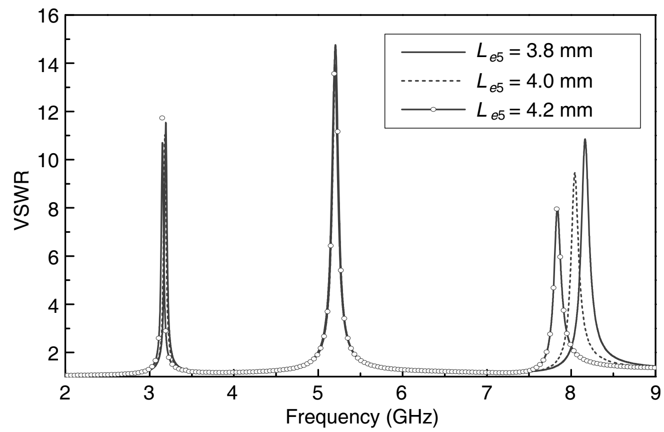


Figure 2. Geometry of proposed triple-mode SLR.



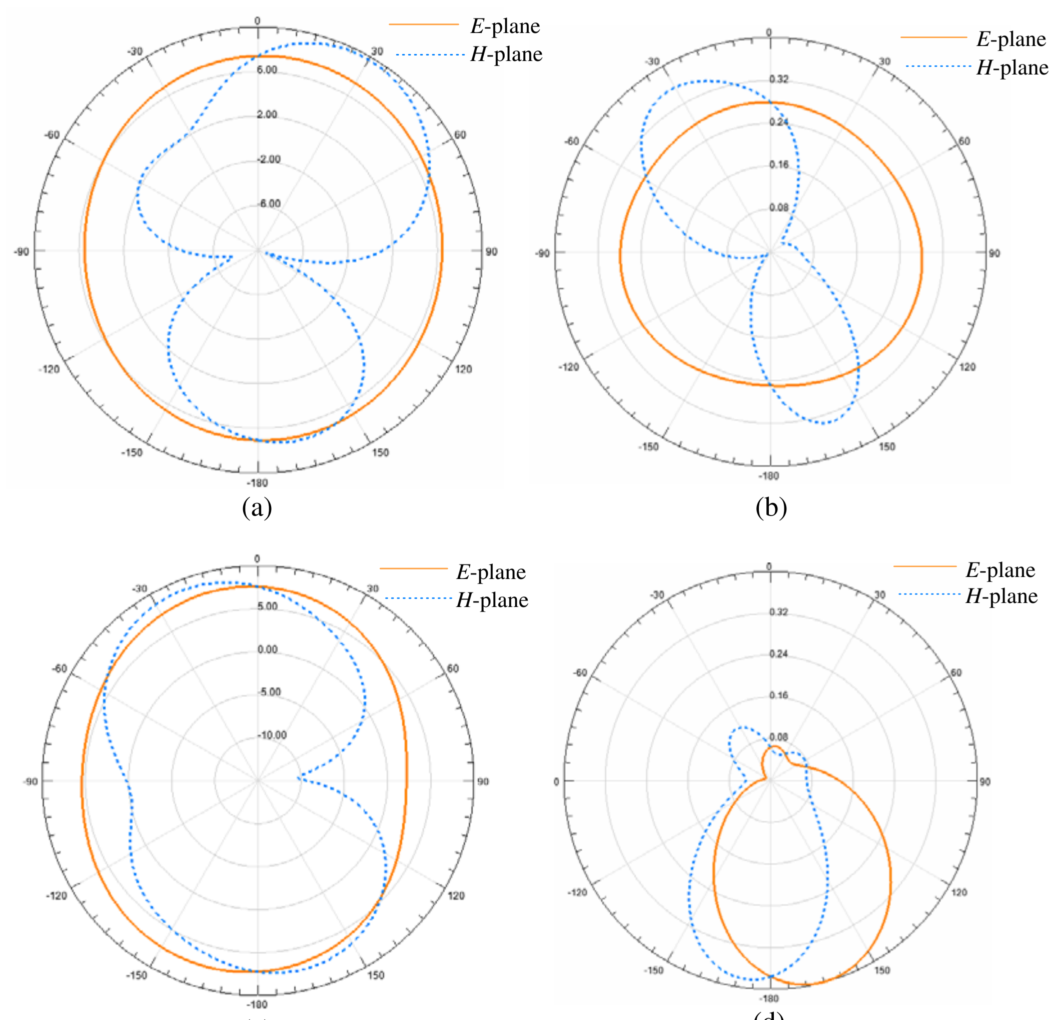


(c)

Figure 3. Simulated VSWR of the coupled triple-mode SLR for various dimensions: (a) L_{e2}, (b) L_{e4}, (c) L_{e5}.

$w_1 = 20\,\text{mm}$, $w_3 = 3.9\,\text{mm}$, $l_1 = 40\,\text{mm}$, $l_2 = 20\,\text{mm}$, $l_3 = 6.8\,\text{mm}$, $r_\text{d} = 3.0\,\text{mm}$, $w_\text{gap} = 0.1\,\text{mm}$.

Figure 2 shows the geometry of the proposed novel triple-mode SLR, which introduces another open stub load based on the traditional dual-mode resonator. The triple-mode SLR can result in triple band-notch performance when placed next to the microstrip line. The transfer characteristics of the



(a) (b) (c) (d)

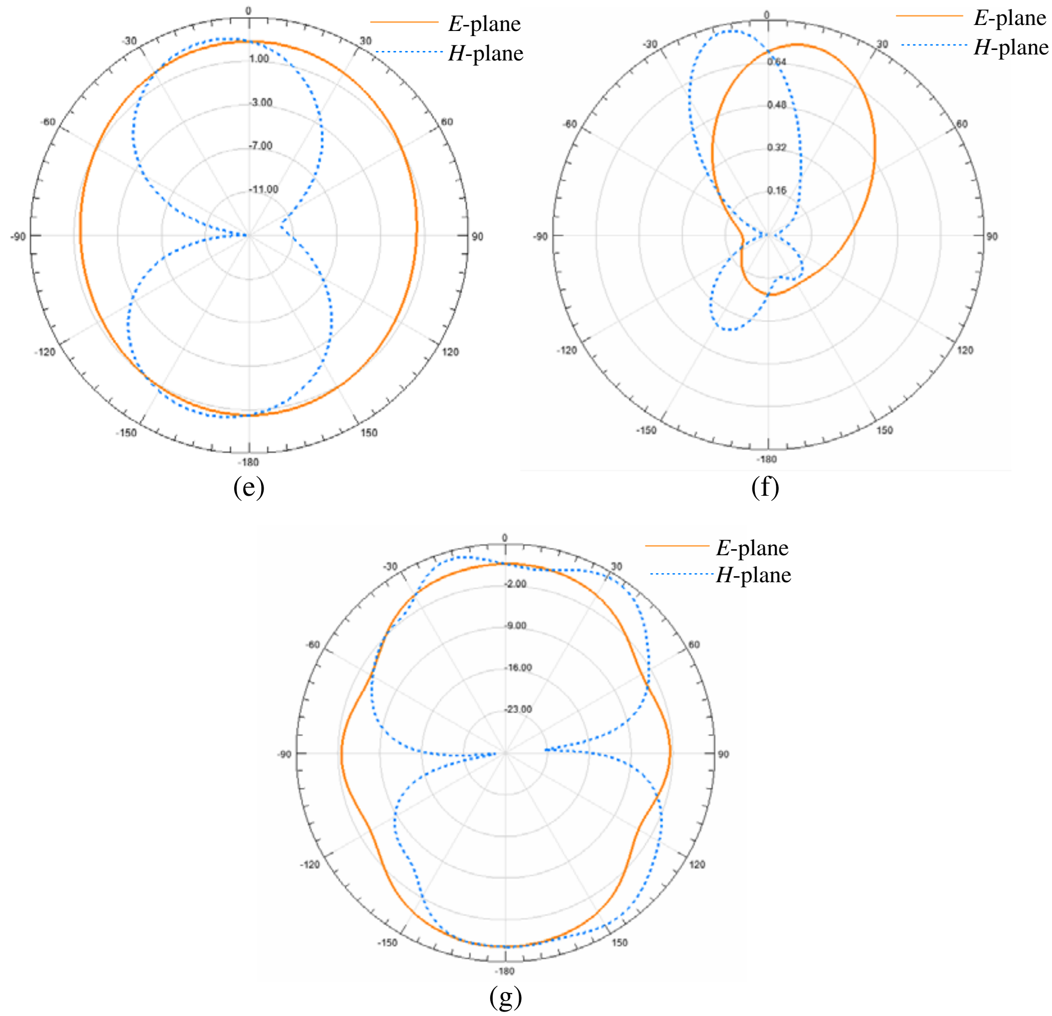


Figure 4. Measured radiation pattern of the UWB planar monopole antenna: (a) 2.5 GHz, (b) 3.0 GHz, (c) 5.0 GHz, (d) 5.2 GHz, (e) 7.5 GHz, (f) 8.0 GHz, (g) 10.0 GHz.

proposed SLR with various dimensions are studied by HFSS 11.0, as shown in Fig. 3. It can be seen that the first and the second notched bands move down simultaneously as increasing the dimensions of L_{e2}, whereas decreasing L_{e4}, only the second notched band moves up. But only the third notched band increases as decreases L_{e5}. Therefore, by appropriately adjusting the triple-mode SLR dimensions, triple notched bands can be achieved at desired frequencies.

3. UWB ANTENNA WITH TRIPLE-NOTCHED BANDS

Based on the triple band-stop filter previously described, a novel UWB planar monopole antenna with triple sharply rejected notched bands is proposed and designed. All simulations have been carried out using Ansoft HFSS 11.0 simulation software based on the finite element method (FEM). The normalized radiation patterns in the E- and H-planes are measured at 2.5 GHz, 4.0 GHz, 5.0 GHz, 5.2 GHz, 6.8 GHz, 7.5 GHz, and 10.0 GHz as in Fig. 4. It can be found that the antenna has good omnidirectional radiation patterns in the H-plane (dotted). The radiation patterns in the E-plane (continuous) are in symmetry. Simulated and measured VSWR of the UWB antenna as shown in Fig. 5 for comparison. We can notice that the UWB antenna possesses the impedance bandwidth from 2.0 GHz to 11.0 GHz for VSWR < 3 except in notched bands from $2.89 \sim 3.17$ GHz, $5.11 \sim 5.56$ GHz, and $7.64 \sim 8.92$ GHz, respectively. The central frequencies of the notched-bands are about 3.0 GHz, 5.2 GHz, and 8.0 GHz, as well as the notch

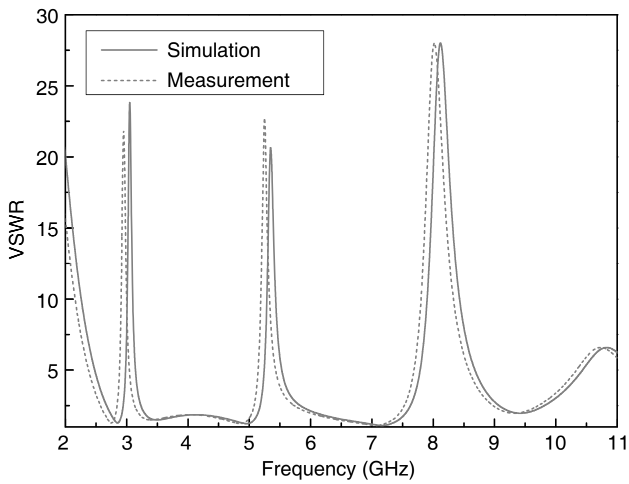


Figure 5. Measurement and simulation of VSWR.

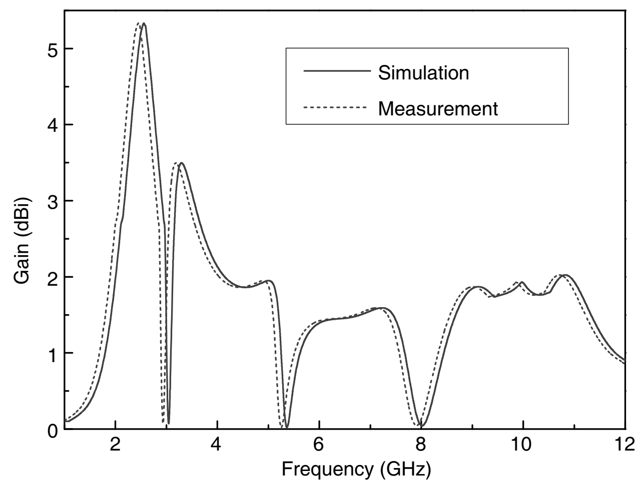


Figure 6. Measured and simulated peak gain of the proposed UWB antenna with triple-notched bands.

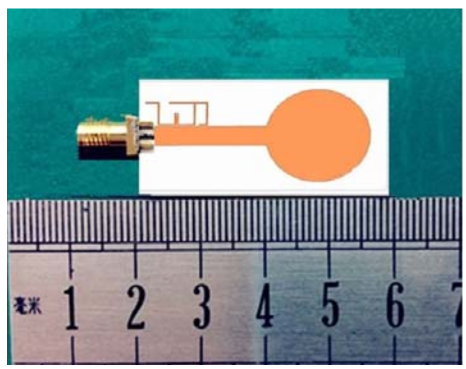


Figure 7. Photograph of the fabricated UWB antenna with triple-notched bands.

frequencies of the filter designed in Section 3. The notched-bands are very suitable to implement the rejection of 3.0 GHz WiMAX signal, 5.2 GHz WLAN signal, and 8.0 XSCS signal. The deviations of the measurements from the simulations are expected mainly due to the reflections from the connectors and the finite substrate. The measured peak gain in the E-plane is given in Fig. 6. The proposed antenna exhibits three significant antenna gain decreases at 3.0 GHz, 5.2 GHz, and 8.0 GHz; this is indicative of the effect of the notched bands. Fig. 7 shows the photograph of the fabricated planar UWB antenna with triple-notched bands. The overall size is about $40 \times 20\,\mathrm{mm}^2$.

4. CONCLUSION

In this work, a high-performance UWB planar monopole antenna, with triple highly rejected notched-bands, has been successfully implemented and investigated. The triple notched-bands can be easily tuned to the desirable frequency location by controlling the parameters of the proposed triple-mode SIR. The proposed antenna covers the frequency range for the UWB systems, between 2.0 GHz and 11.0 GHz, with a rejection band around WiMAX, WLAN, and XSCS services. The introduced triple-mode SIR is simple and flexible for blocking undesired narrow band radio signals appeared in UWB band. Using the advantage of small real estate, outstanding performance can be realised for broadband antennas, which are now widely demanded in UWB applications. The measured results show good performance in terms of the reflection coefficient, antenna gain and radiation patterns. To summarise, the proposed planar monopole antenna is very useful for modern UWB wireless communication systems owing to its marked properties of simple topology, compact size, and excellent performance.

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