Elliptical Slot Antenna with Dual Band-Notched Characteristics for UWB Applications

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Abstract **—** A novel elliptical slot antenna with band-notched characteristics is presented for ultra-wideband (UWB) applications. The proposed antenna is fed via a microstrip-line that is connected to an elliptically shaped patch. Dual band-notched characteristic is achieved by utilizing an L-shaped strip and an inverted U-shaped slot incorporated within the antenna's structure. This antenna configuration enables the notch band to be finely tuned by simply adjusting the parameters of notch function components, the L-shaped slot and the inverted U-shaped slot. The antenna with optimal parameters was fabricated on RT/Duroid 6006 that has a thickness of 1.27 mm and a relative permittivity of 6.15. The size of the actual antenna is 50×50 mm^2. The measured VSWR, gain, impedance and radiation characteristics of the proposed antenna confirm it satisfies UWB system requirements.

Index Terms **—** Dual band notched, elliptical slot antenna, UWB.

I. INTRODUCTION

Ever since the Federal Communications Commission (FCC) first approved the regulations for the commercial use of ultra-wideband (UWB) in 2002 [1], the design and implementation of feasible UWB systems has become a highly competitive topic in both academic and industry communities of telecommunications. Antennas are the particularly challenging aspect of UWB technology. To satisfy such a requirement, various wideband antennas have been studied [2]-[4]. The design of UWB systems is further complicated as other radio systems co-exist within the 3.1–10.6 GHz UWB frequency band. These systems include the IEEE802.16 WiMAX system with an operating band of 3.3–3.7 GHz, the C-band (3.7–4.2 GHz) satellite communication systems, and IEEE802.11a WLAN systems operating between 5.15–5.825 GHz. Inevitably UWB communication systems are likely to experience unwanted electromagnetic interference with such communication systems. To overcome this interference, various UWB antennas with single or multiple notch functions have been investigated for UWB communication systems [5]-[9].

In this paper, a novel elliptical slot antenna with dual band-notched characteristics is described for UWB applications. The proposed antenna comprises of an elliptical shaped patch etched on the front side of the substrate which is excited via a microstrip-line, and an elliptical shaped slot etched in the ground-plane on the back side of the substrate. To achieve dual band-notched characteristics at the frequency band of WLAN and C-band satellite communication systems, an inverted U-shaped slot and an L-shaped stub are included within the antenna structure. The bandwidth and center frequency of the notched bands can be finely controllable by adjusting the parameters of the inverted-U slot and an L-shaped stub. The proposed antenna is shown to operate over the commercial UWB frequency range (3.1–10.6 GHz) and also effectively suppresses interference with wireless local area network (WLAN) and C-band satellite communication systems. Effects of the notch function parameters on the performance of antenna have been investigated using Ansoft HFSS software [10]. A conceptual circuit model, which is based on the measured impedance of the proposed antenna, is presented to explain the dual band-notched characteristics. The prototype of the proposed antenna with optimal dimensions was fabricated and its characteristics are measured to confirm the validity of

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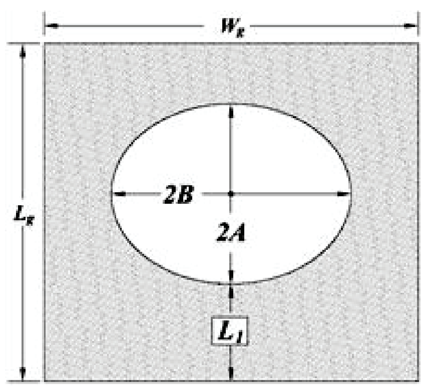
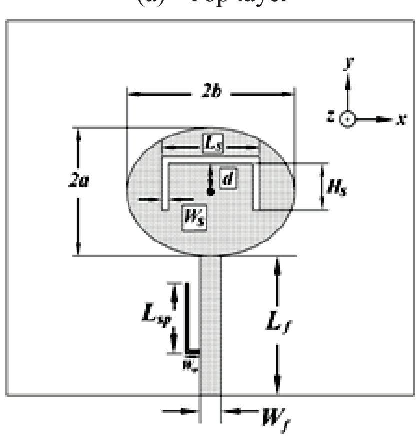
the design. Comparison between experimental and simulation results demonstrate good agreement over virtually the entire UWB operating range. The remaining part of the article is organized as follows: Section 2 presents the configuration of proposed antenna, and parametric study of antenna is investigated in Section 3. The simulated and measured results are discussed in Section 4, and finally the conclusion is provided in Section 5.

II. ANTENNA GEOMETRY

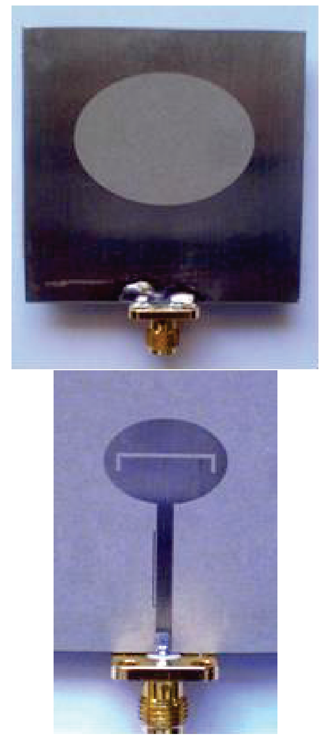
The configuration of the proposed UWB elliptical slot antenna possessing two band-notched functions is depicted in Fig. 1, where the parameters of the geometry are defined. The antenna is located on the *x–y* plane and the normal direction is parallel to *z*-axis. The antenna consists of an elliptical slot with axial dimensions of *A* and *B*. The elliptical slot is located directly below an elliptical radiating patch with axial dimensions of *a* and *b*, and is feed via a 50 Ω microstrip-line of width $W_f = 2$ mm. The band-notching characteristics of antenna are achieved by creating an inverted-U slot within the elliptical patch and by connecting a thin L-shaped strip to the feed line. The proposed antenna is constructed on a dielectric substrate RT/duroid 6006 with relative permittivity (ε_r) of 6.15 and thickness of 1.27 mm. The antenna has a ground-plane size of $L_g \times W_g = 50 \times 50$ mm^2.



(a) Top layer



(b) Bottom layer



(c) Top and bottom layers of fabricated antenna

Fig. 1. Geometry of proposed UWB antenna.

III. PARAMETRIC STUDY OF ANTENNA

To achieve the desired band-notched characteristic, the effect of the L-shaped stub and inverted U-shaped slot parameters on the antenna's overall performance was studied. The simulated VSWR of the antenna for different values of L_{SP} is plotted in Fig. 2. This figure shows that by increasing the length of L_{SP} the first notch's frequency shifts towards lower frequencies. In this case, the values of L_s and H_s are fixed at 12 mm and 2.25 mm respectively.

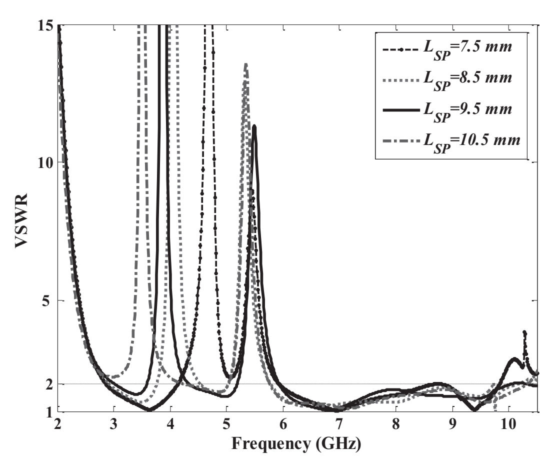


Fig. 2. Effect of L_{SP} on the antenna's band-notching characteristics.

Figure 3 shows the VSWR curve of the proposed antenna for L_{sp}=9.5 mm, H_s=2.25 mm and for different values of L_S. It can be observed that, in this case the second notch's center frequency decreases with the increase of the length L_S. Also, we can see that when the length of L_S increases to 13 mm, the first notch's center frequency shifts towards higher frequencies.

Figure 4 shows the simulated VSWR response of antenna for different values of H_S and fixed values of L_s and L_{sp}. It can be observed in that, in this case the second notch's center frequency decreases with the increase of H_S length.

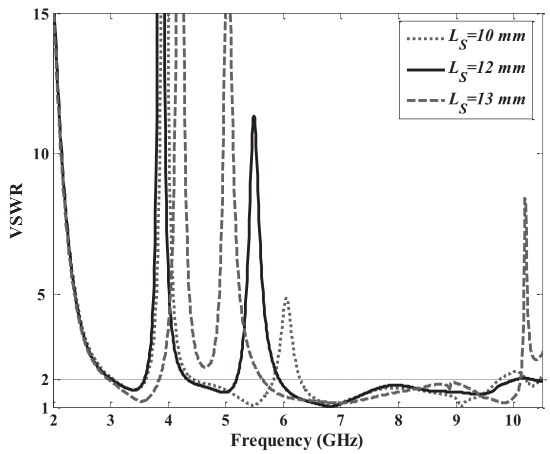


Fig. 3. Effect of L_S on the antenna's band-notching characteristics.

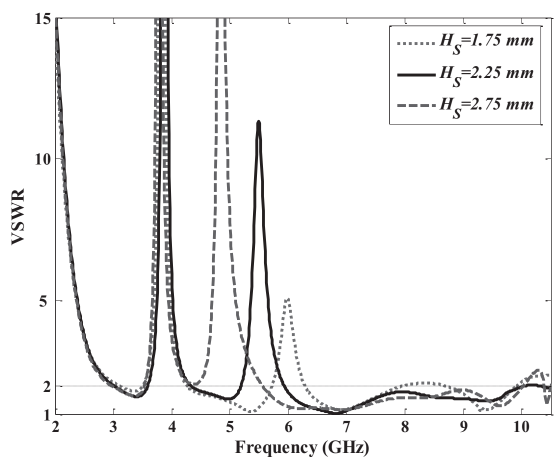


Fig. 4. Effect of parameter H_S of inverted-U slot on the antenna's band-notching characteristics.

As observed in Figs. 2 to 4, the filtering property of the antenna can be tuned by varying the principal parameters of L-shaped stub and inverted U-shaped slot.

IV. RESULTS AND DISCUSSIONS

The simulated and measured results of VSWR, radiation patterns, gain, and input impedance of the proposed antenna are presented in this section. The simulations were performed using Ansoft HFSS and CST Microwave Studio, which utilize numerical methods for electromagnetic computations. The VSWR and input impedance of antenna was measured by the Agilent 8722ES network analyzer and radiation characteristics measurements were performed in anechoic chamber at the antenna laboratory of Iran Research Institute for ICT (ITRC).

A. VSWR

The simulated and measured VSWR curves of the proposed dual band-notched UWB antenna, whose dimensions are given in Table 1, are shown in Fig. 5. This figure shows the simulated bandwidth of the proposed antenna for which VSWR≤2 is from 3 GHz to greater than 11 GHz, and it includes two notched frequency bands between 3.6–4.35 GHz (consistent with the C-band satellite communication system) and between 5.2–6 GHz (frequency band of WLAN systems) for VSWR≥2. The measured 3-dB bandwidth of fabricated antenna is from 2.5 GHz to greater than 11 GHz with VSWR≤2, and the notched bandwidths are over 3.65–4.35 and over 4.85–5.9 GHz for VSWR≥2. The measured frequency range encompasses the commercial UWB band (3.1–10.6 GHz), and the notch functions reject the frequency bands of C-band satellite communication and IEEE 802.11a to overcome EMI problems of UWB systems with WLAN and C-band satellite communication systems. The correlation between the numerical and experimental results is considered to be excellent.

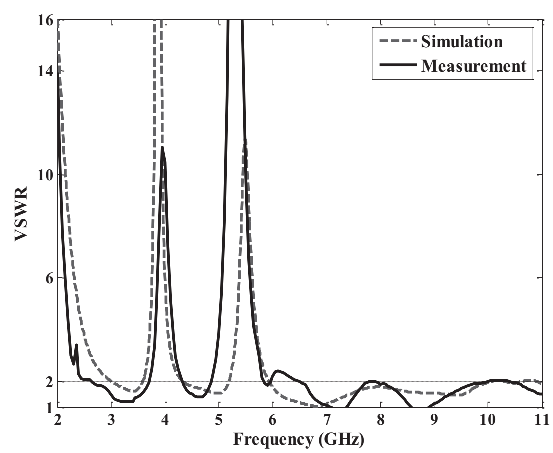


Fig. 5. The VSWR response of the proposed UWB antenna with dimensions given in Table 1.

B. Input impedance

The input impedance curve of the proposed dual band-notched UWB antenna is shown in Fig. 6. In the notched-bands, the imaginary component curve shows parallel resonance characteristics and the real component presents high resistance characteristics. As a result of impedance curve of proposed antenna, the input impedance of the notched antenna is equivalent to the input impedance R_a of the un-notched reference antenna connected with two parallel LC-resonant circuits in series. The conceptual circuit model is shown in Fig. 7.

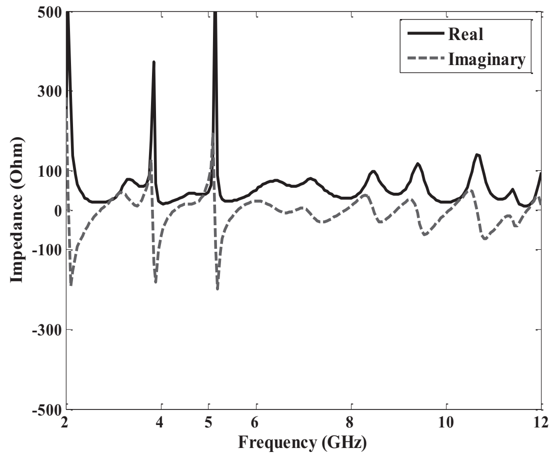


Fig. 6. The measured input impedance of proposed dual band-notched antenna.

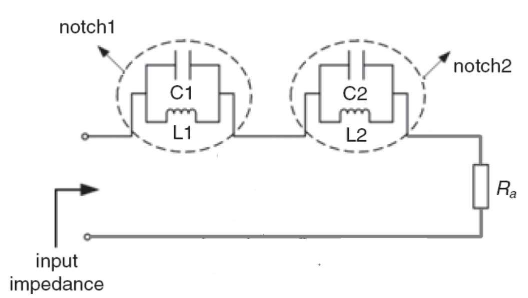


Fig. 7. Conceptual circuit model for proposed dual band-notched antenna.

When the proposed antenna is operating at the two desired notched frequencies, the two corresponding LC-resonant circuits lead to the input impedance to be opened-circuited. Therefore, proposed band-notched UWB antenna presents high impedance characteristics at notched frequencies.

C. Radiation patterns and gain

The simulated and measured antenna gain over the entire UWB band is shown in Fig. 8. This graph shows a sharp drop in gain occurring over the bands 3.6–4.2 and 5–6 GHz. However, for other frequencies outside the reject bands, the antenna gain variation is steady and is less than 2 dBi across the UWB band.

The measured and simulated radiation patterns of proposed dual band-notched UWB antenna in the E-plane (*yz*-plane) and H-plane (*xz*-plane) for three different spot frequencies of 4.5, 7.5, and 10 GHz are shown in Fig. 9. As shown in the H-plane, the antenna design exhibits an omni-directional profile at low and high frequencies and quasi bidirectional in the mid-range frequencies. However in the E-plane, the radiation pattern is bidirectional at low frequencies and quasi bidirectional at mid and high frequencies. The agreement between the measured and simulated radiation patterns is very good. However at 10 GHz a discrepancy is occurred.

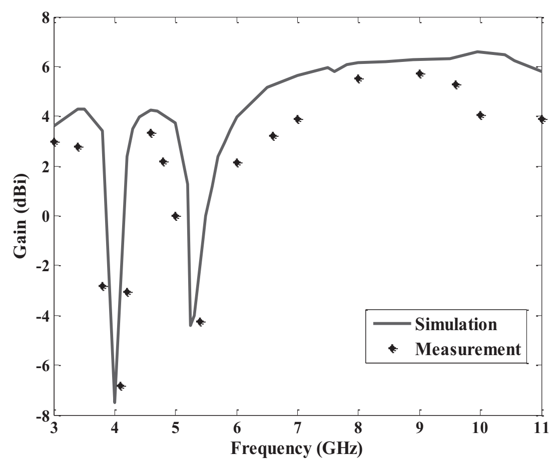
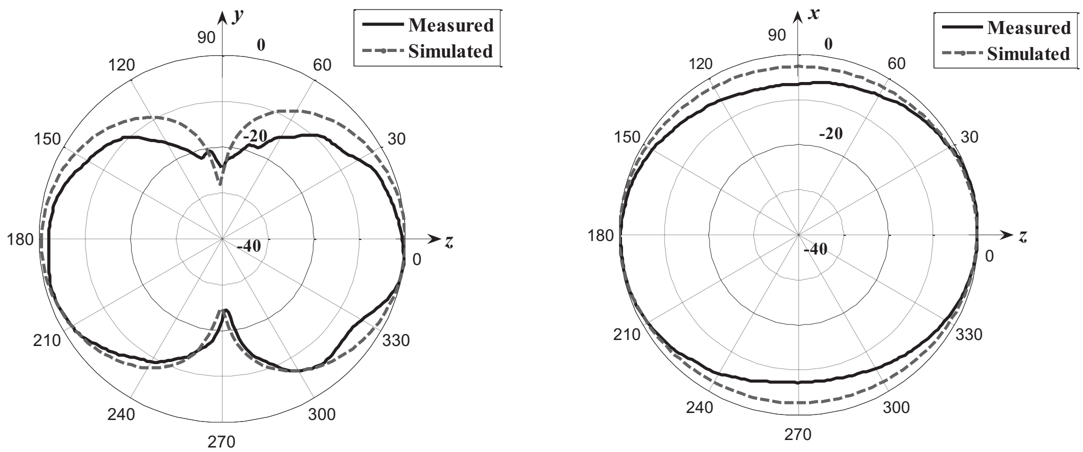


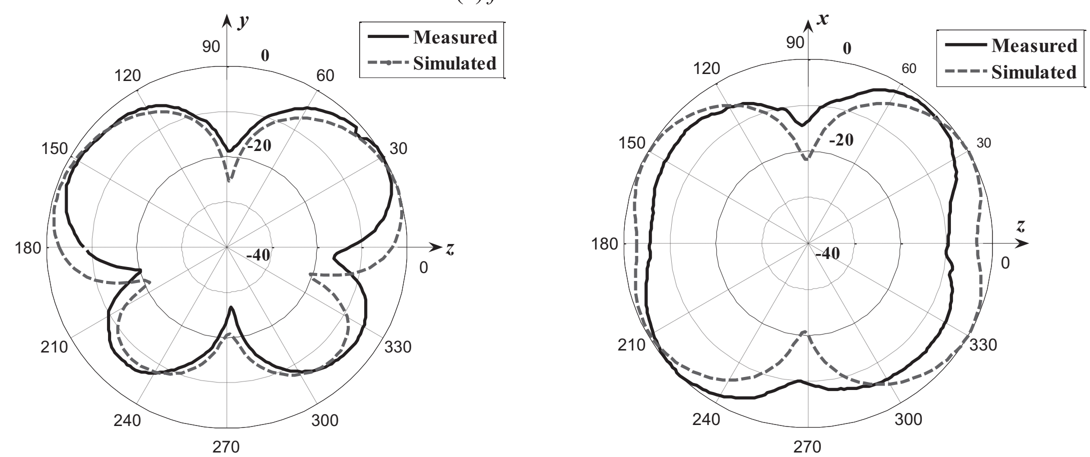
Fig. 8. The calculated and measured gain of the proposed UWB antenna.

Table 1: Dimensions of the proposed UWB antenna

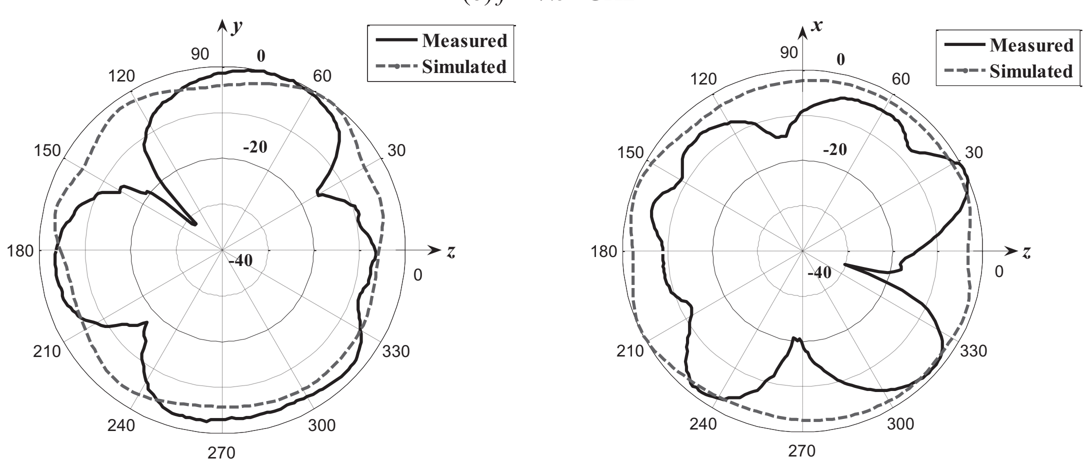
Parameter	W_g	L_g	A	B	L_1	a	b	W_f	L_f	W_s	L_s	H_s	d	L_{sp}	W_{sp}
Value (mm)	50	50	12	16	13	5.25	7.5	2	13.3	0.5	12	2.25	0.5	9.5	0.4



(a) $f = 4.5$ GHz



(b) $f = 7.5$ GHz



(c) $f = 10$ GHz

E-plane H-plane

Fig. 9. Measured and simulated E-plane and H-plane radiation patterns for proposed antenna at: (a) 4.5 GHz, (b) 7.5 GHz, and (c) 10 GHz.

V. CONCLUSION

An UWB elliptical slot antenna with dual band-notched characteristics at C-band (3.7–4.2 GHz) satellite communication systems and WLAN frequencies has been proposed and fabricated. The measurements show that VSWR is below 2 within the desired UWB frequency bandwidth from 2.5 to greater than 11 GHz, and two notched frequency bands obtained where VSWR≥2 are 3.65–4.35 and 4.85–5.9 GHz. Stable radiation patterns and approximately constant gain in the UWB band, with the exception of notched bands, are obtained. The mechanism of the antenna's filtering properties was represented by a conceptual circuit model based on the dual band-notched phenomenon. The proposed antenna is compact and is considered to be a very candidate for use in various UWB systems.

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