Microstrip-Fed Small Slot Antenna with Dual Band-Notched Function for UWB Wireless Communications

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Abstract **─** A simple and compact microstrip-fed ultra wideband (UWB) slot antenna with dual band-notch characteristic for UWB applications has been presented. In order to increase the impedance bandwidth of the square slot antenna, we insert a T-shaped slot in the ground plane that with this structure UWB frequency range can be achieved. Additionally, by using a pair of L-shaped slits at the square radiating stub, a dual band-notch performance has been obtained. The measured results reveal that the presented dual band-notch slot antenna offers a wide bandwidth with two notched bands, covering all the 5.2 GHz / 5.8 GHz WLAN, 3.5 GHz / 5.5 GHz WiMAX and 4 GHz C bands. The designed antenna has a small size of 20×20 mm^2. Good return loss and radiation pattern characteristics are obtained in the frequency bands of interest.

Index Terms **─** L-shaped slit, microstrip-fed slot antenna, T-shaped slot, and ultra-wideband communication systems.

I. INTRODUCTION

In UWB communication systems, one of key issues is the design of a compact antenna while providing wideband characteristic over the whole operating band. Consequently, a number of planar slots with different geometries have been experimentally characterized [1, 2]. Moreover, other strategies to improve the impedance bandwidth have been investigated [3-6]. The frequency range for UWB systems between 3.1 GHz to 10.6 GHz will cause interference to the existing wireless communication systems, such as, the wireless local area network (WLAN) for IEEE 802.11a operating in 5.15 GHz – 5.35 GHz and 5.725 GHz – 5.825 GHz bands, WiMAX (3.3 GHz – 3.6 GHz), and C-band (3.7 GHz – 4.2 GHz), so the UWB antenna with a single and dual band-stop performance is required [7-10].

A simple method for designing a novel and compact microstrip-fed slot antenna dual band-notch characteristics for UWB applications has been presented. In the proposed structure, by inserting a T-shaped slot in the ground plane, we can gave an UWB frequency range and by using a pair of L-shaped slits on the square radiating stub, dual band-notch characteristic is obtained. Simulated and measured results are presented to validate the usefulness of the proposed antenna structure for UWB applications.

II. ANTENNA DESIGN

The presented small square slot antenna fed by a 50-Ω microstrip line is shown in Fig. 1, which is printed on an FR4 substrate of thickness 0.8 mm, permittivity 4.4, and loss tangent 0.018. The basic slot antenna structure consists of a square radiating stub, a feed line, and a ground plane. The proposed antenna is connected to a 50-Ω SMA connector for signal transmission.

Regarding defected ground structures (DGS), the creating slots in the ground plane provide an additional current path. Moreover, this structure changes the inductance and capacitance of the input impedance, which in turn leads to change the bandwidth. The DGS applied to a microstrip line

Submitted On: Oct. 2, 2012
Accepted On: Jan. 27, 2014

causes a resonant character of the structure transmission with a resonant frequency controllable by changing the shape and size of the slot [8]. Therefore, by cutting a T-shaped slot at the ground plane and carefully adjusting its parameters, much enhanced impedance bandwidth may be achieved. In this structure, The L-shaped slits perturb the resonant response and also acts as a half wave resonant structure [6]. At the notch frequency, the current concentrated on the edges of the interior and exterior of the L-shaped slit. As a result, the desired high attenuation near the notch frequency can be produced.

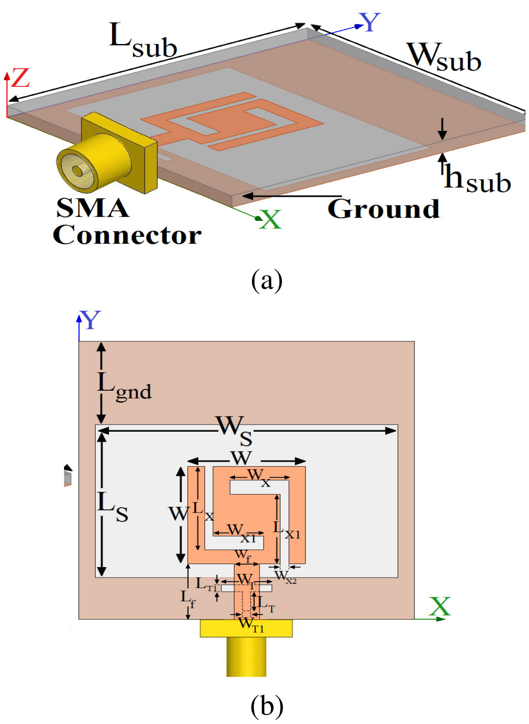


Fig. 1. Geometry of the proposed microstrip slot antenna, (a) side view and (b) top view.

The optimal dimensions of the designed antenna are as follows: W_{sub} = 20 mm, L_{sub} = 20 mm, W_S = 18 mm, L_S = 11 mm, h_{sub} = 0.8 mm, W_f = 1.5 mm, L_f = 4 mm, W = 7 mm, W_T = 3.5 mm, L_T = 1.5 mm, W_{T1} = 0.5 mm, L_{T1} = 1.5 mm, W_X = 4 mm, L_X = 6 mm, W_{X1} = 3.5 mm, L_{X1} = 5.5 mm, W_{X2} = 0.5 mm, and L_{gnd} = 6 mm.

III. RESULTS AND DISCOSSIONS

The proposed microstrip-fed slot antenna with various design parameters were constructed, and the numerical and experimental results of the input impedance and radiation characteristics are presented and discussed. The Ansoft simulation software high-frequency structure simulator (HFSS) [11] is used to optimize the design and agreement between the simulation and measurement is obtained. Figure 2 shows the structure of the various antennas used for dual notch performance simulation studies.

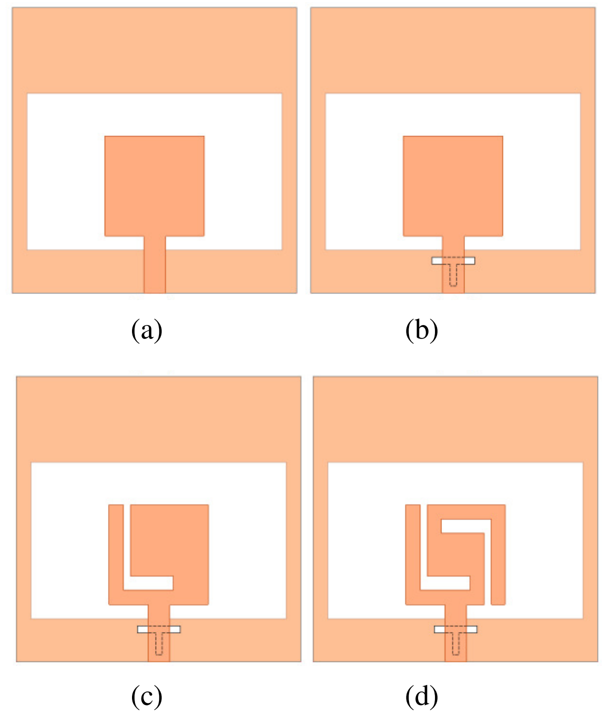


Fig. 2. (a) The ordinary square slot antenna, (b) antenna with a T-shaped slot in the ground plane, (c) antenna with a T-shaped slot in the ground plane and an L-shaped slit in the radiating stub, and (d) the proposed slot antenna.

VSWR characteristics for the ordinary square slot antenna (Fig. 2 (a)), with a T-shaped slot in the ground plane (Fig. 2 (b)), with a T-shaped slot in the ground plane and an L-shaped slit at the radiating stub (Fig. 2 (c)), and the proposed slot antenna (Fig. 2 (d)) are compared in Fig 3. As shown in Fig. 3, it is observed that the upper frequency bandwidth is affected by using the T-shaped slot. As shown in Fig. 3, the first notch frequency bandwidth is sensitive to the single L-shaped slit on the radiating stub, and also by inserting a pair of L-shaped slits at the radiating stub a dual band–notch function is achieved that covering all the 5.2 GHz / 5.8 GHz WLAN, 3.5 GHz / 5.5 GHz WiMAX and 4 GHz C bands [12-15].

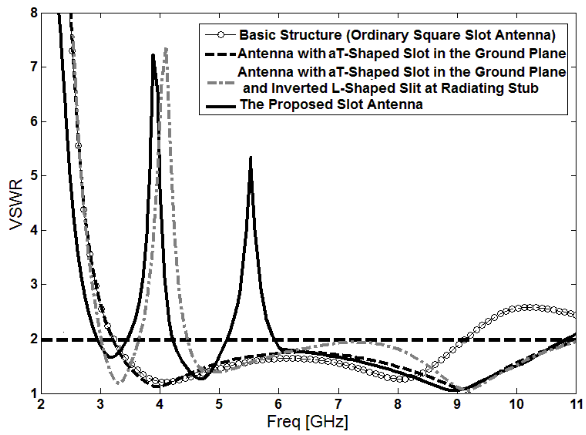
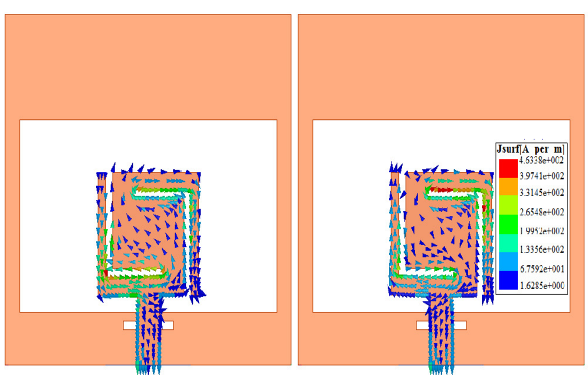


Fig. 3. Simulated VSWR characteristics for the various square slot antenna structures shown in Fig. 2.

To understand the phenomenon behind this dual band-notch UWB performance, on the radiating stub at the notch frequencies of 3.9 GHz and 5.5 GHz is presented in Fig. 4 (a), and 4 (b) respectively. It can be observed in Fig. 4 (a) and 4 (b) that the current concentrated on the edges of the interior and exterior of the L-shaped slits at 3.9 GHz and 5.5 GHz. Therefore, the antenna impedance changes at these frequencies due to the band notch properties.



(a) (b)

Fig. 4. Simulated surface current distributions for the proposed antenna on the radiating stub (a) at the first notch frequency (3.9 GHz) and (b) at the second notch frequency (5.5 GHz).

The simulated input signal and impulse response for the proposed antenna is shown in Fig. 5. A first-order Rayleigh pulse is used as the source signal to drive the transmitter [16]. One of the characteristics of UWB signals is pulse distortion, which is inherently determined by their huge bandwidth. Good impedance matching over the operating frequency band is desired to minimize reflection loss and to avoid pulse distortion [17]. Therefore, the signal distortions shown in Fig. 5 are mainly due to the bandwidth mismatch between the source pulse and the antenna. As a result, some frequency components of the pulse cannot be transmitted effectively by the monopole, leading to the distortions of the received signal.

The proposed antenna with optimal design was built and tested in the antenna measurement laboratory at Microwave Technology Company (MWT). The measured and simulated VSWR characteristics of the proposed antenna are shown in Fig. 6. The fabricated antenna has the frequency band of 3.08 GHz to over 10.83 GHz with two rejection bands around 3.37 GHz – 4.3 and 5.1 GHz – 6.05 GHz. As shown in Fig. 6, there exists a discrepancy between measured data and the simulated results. This discrepancy between measured and simulated results is mostly due to a number of parameters such as the fabricated antenna dimensions as well as the thickness and dielectric constant of the substrate on which the antenna is fabricated, the wide range of simulation frequencies and also the effect of SMA soldering.

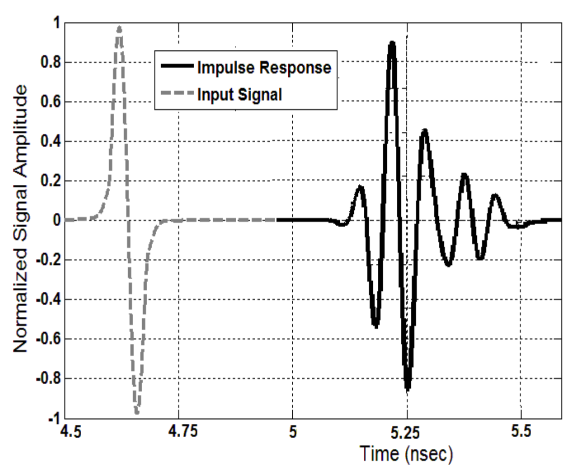


Fig. 5. Simulated time-domain analysis (input signal and impulse response).

In a physical network analyzer measurement, the feeding mechanism of the proposed antenna is composed of a SMA connector and a microstrip line (the microstrip feed line is excited by an SMA connector) whereas the simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS), that in HFSS by default, the antenna exited by wave port that it is renormalized to a 50-Ohm full port impedance, therefore this discrepancy between measured data and the simulated results could be due to the effect of the SMA port [6]. In order to confirm the accurate VSWR characteristics for the designed antenna, it is recommended that the manufacturing and measurement process need to be performed carefully, besides, SMA soldering accuracy and FR4 substrate quality needs to be taken into consideration. In conclusion, as the slot is a short radiator, the SMA connector can modify its impedance matching.

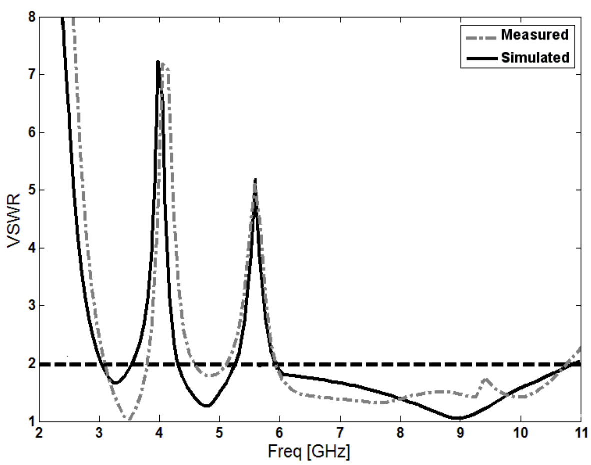


Fig. 6. Measured and simulated VSWR for the proposed slot antenna.

Figure 7 shows the measured radiation patterns including the co-polarization and cross-polarization in the H-plane (x-z plane) and E-plane (y-z plane). The main purpose of the radiation patterns is to demonstrate that the antenna actually radiates over a wide frequency band. It can be seen that the radiation patterns in x-z plane are nearly omnidirectional for the two frequencies [18-21]. Figure 8 shows the effects of the L-shaped slits at the square radiating stub, on the maximum gain in comparison to the same antenna without them.

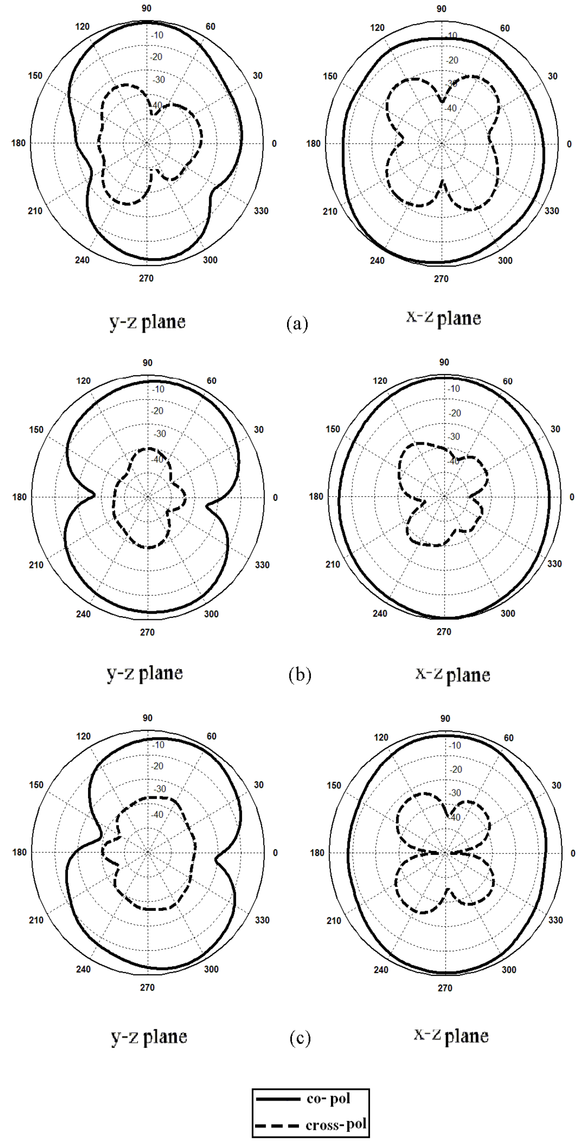


Fig. 7. Measured radiation patterns of the proposed antenna (a) 4.7 GHz, (b) 7.5 GHz, and (c) 10 GHz.

As shown in Fig. 8, the basic structure (ordinary slot antenna with) has a gain that is low at 2 GHz and increases with frequency [8]. It is found that the gain of the basic structure is decreased with the use of the L-shaped slits at the square radiating stub. It can be observed in Fig. 8 that by using the L-shaped slits at the square radiating stub, two sharp decrease of maximum gain in the notched frequencies band at 3.9 GHz and 5.5 GHz are shown. For other frequencies outside the notched frequencies band, the antenna gain with the filter is similar to those without it.

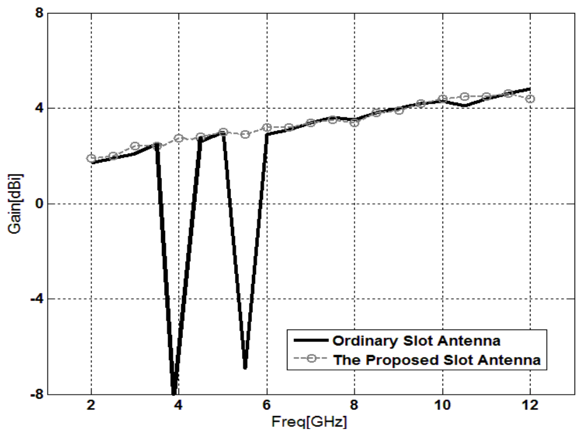


Fig. 8. Maximum gain comparisons for the ordinary slot antenna (simulated) and the proposed antenna (measured) in the z-axis direction (x-z plane).

IV. CONCLUSION

In this paper, we propose a novel design of ultra wide band slot antenna with dual band-notch function. The presented slot antenna can operate from 3.08 GHz to 10.83 GHz with two rejection bands around 3.37 GHz – 4.3 GHz and 5.1 GHz – 6.05 GHz. By cutting a T-shaped in the ground plane we can give UWB frequency range, and also by inserting a pair of L-shaped slits at radiating stub, dual frequency band-notch function can be achieved. The designed antenna has a small size. Good antenna radiation behavior within the UWB frequency range have also been obtained.

ACKNOWLEDGMENT

The authors are thankful to Microwave Technology (MWT) Company staff for their beneficial and professional help (www.microwave-technology.com).

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