A Planar UWB Monopole Antenna with On-Ground Slot Band-Notch Performance

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Abstract **─** A planar monopole antenna with variable frequency band-notch characteristic for ultra wideband applications is presented. The proposed antenna consists of a truncated ground plane and a radiating rectangular patch. By employing two L-shaped strips on the top edge of the ground plane, the ultra wideband property is achieved. Electromagnetic interference (EMI) from IEEE 802.11a can be avoided for a wideband antenna with a stop-band. For a notched frequency band, two L-shaped slits are embedded on the ground plane. The designed antenna has a stop-band of 5 GHz to 5.9 GHz while maintaining wideband performance from 3.1 GHz to 10.6 GHz for VSWR < 2.

Index Terms **─** Band-notched, slot, slit, and ultra wideband.

I. INTRODUCTION

In the last few years, UWB technology has attracted a great interest for use in the industry and academia especially since Federal Communication Commission (FCC) allowed using the (3.1 GHz ─ 10.6 GHz) band for commercial applications. The antenna is one of the important components in UWB systems and it affects their overall performance. It is of a particular interest to design an antenna with simple structure, low profile, easy manufacturing, and low cost. Moreover, the UWB antenna should have good impedance matching characteristics over the whole UWB frequency range. Also, it should have a flat gain, linear phase, and constant group delay to minimize distortion of transmitted pulses waveforms. Different types of planar wideband monopoles using various bandwidth enhancement techniques have been proposed for UWB applications [1-8]. However, there exist narrow band for other communication systems over the designated frequency band, such as: the wireless local area network (WLAN) for IEEE802.11a operating at 5.15 GHz ─ 5.35 GHz, which may cause severe electromagnetic interference to the UWB system. Therefore, it is desirable to design UWB antennas with band-notched performance in this frequency band to avoid potential interference. In this way a number of different techniques have been reported recently [9-12]. The commonly used approach is to insert different shapes of slot in the main radiator [9-10]. In reference [11] it is shown that parasitic elements can be utilized to implement the desired band-rejection at a particular frequency and by embedding a slit in the feeding strip band-notched performance was achieved [12]. For most of the work mentioned above, the band-notched structures are designed on the main radiator. It is demonstrated in [13] by inserting simple slits in antenna ground plane, a band-notched performance can also be achieved.

Submitted On: May 12, 2012
Accepted On: Aug. 10, 2013

The main idea in this article is the deviation of the current on the ground plane. Instead of changing the patch or the feed line shapes, by using two L-shaped strips on the ground plane, a pair of additional current paths are introduced and much wider bandwidth is produced. Also the notched band, covering the 5 GHz ─ 5.9 GHz WLAN band, is provided by a pair of folded slits inserted on the ground plane. As a different method we apply both slits and slots on the ground plane that provides a simple structure. In comparison with previous works the proposed antenna has a small size and simple structure. In this study, antenna design is experimentally investigated; its characteristics and radiation patterns are analyzed and discussed. By adopting different source signals, the influence of the frequency notch as well as the antenna's propagation characteristics is clearly presented giving the reader a thorough understanding about the antenna performance.

II. ANTENNA CONFIGURATION

Figure 1 shows the geometry of the proposed antenna, which is symmetrical with respect to the longitudinal direction. It consists of a main patch and a conductor truncated ground plane in the back, a pair of folded strips, and a pair of L-shaped slits on the ground plane. The L-shaped strip with width of 0.4 mm is printed on the top edge of the ground plane at a distance of 0.93 mm (= 0.5 W_F) from the feed line. It consists of a vertical arm of length L_Y and a horizontal arm of length L_X. In this study the length L_Y of the strip is fixed at 1.2 mm. The L-shaped slits are embedded on the ground plane at a distance of 3.2 mm from the feed line. The proposed slits comprise of a vertical arm (along y-axis) of length L_V and a horizontal arm (along x-axis) of length L_H connected at their ends, where the two arms are of the same width (g). In this study L_V is fixed at 0.4 mm.

The antenna is fed with a 50 Ω microstrip line and is printed on a 22 × 22 mm^2 FR4 substrate with dielectric constant of 4.4 and substrate thickness of 1 mm. The rectangular patch with size of 10 × 13 mm^2 is attached to a feed line of width (W_F = 1.86 mm) and length 7.5 mm on the front surface of the substrate. A conducting ground plane with size of 22 × 4.5 mm^2 is also printed on the other side of the substrate. The gap distance between the radiating patch and ground plane is fixed at 3 mm.

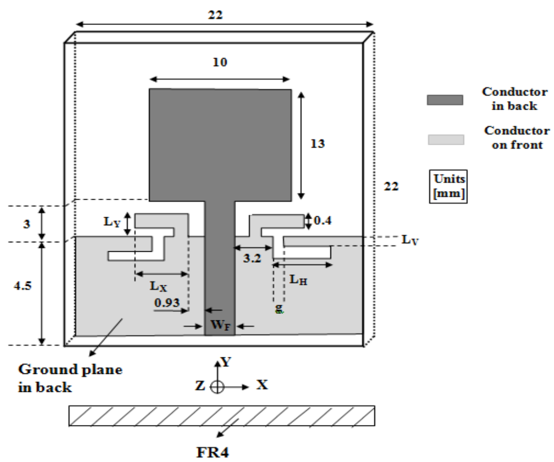


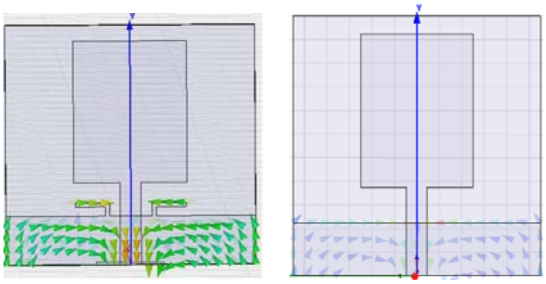
Fig. 1. Geometry of the proposed antenna.

III. RESULTS AND DISCUSSIONS

The proposed antenna is designed using Ansoft's HFSS and its simulated results in terms of bandwidth are presented and compared with that of the measured ones. As mentioned, the main idea in the design of this antenna is the deviation of the current path on the ground plane. By inserting two L-shaped strips a pair of current paths are presented that influence current distribution on the ground plane. The proposed folded strips served as an impedance-matching circuit at higher frequencies and an additional coupling is introduced between the lower edge of the rectangular patch and the folded strips [14].

In order to have a good insight, Fig. 2 shows the difference of current distributions on the ground plane with and without the strips. By adjusting the length L_X the strip, the third resonance occurs at f_t and much more enhanced impedance bandwidth can be achieved. As shown in Fig. 3 by fine-adjusting from experiments for the desired center frequency at 10 GHz, the dimensions of the folded strip are selected. The figure shows as L_X increases, the upper frequency limit is shifted downward. It can be observed that, by fine-adjusting L_X, the antenna bandwidth increases leading to the third resonance. On the other hand, the lower edge frequency of the band is insensitive to the changes of L_X.

To achieve the band-notched characteristic, the lengths of both slits are close to λ/4 at the desired center frequency of the rejection. Regarding the defected ground structure (DGS), the creating slits on the ground plane provide an additional current path, which greatly increases the small VSWR observed at the λ/4 mode for the antenna without slits. The successful excitation of the λ/4 mode is mainly due to the length L of the slit, $L = L_V + L_H$. The center frequency of the stop-band f_r is varied by adjusting the length of L_H. In Fig. 4 the simulated VSWR curves for different values of L_H are considered. As illustrated, with an increase in the length L_H of the slit from 5.2 mm to 7.2 mm, the center frequency of the rejection shifts downward from 7.2 GHz to 5.5 GHz.



(a) (b)

Fig. 2. Current distribution on the ground at 10 GHz; (a) with and (b) without strips.

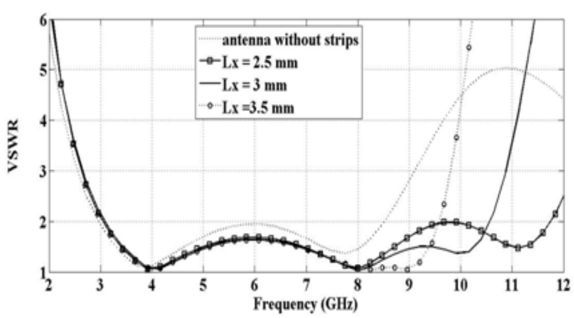


Fig. 3. Simulated VSWR characteristics for different values of L_X (L_Y = 1.2 mm).

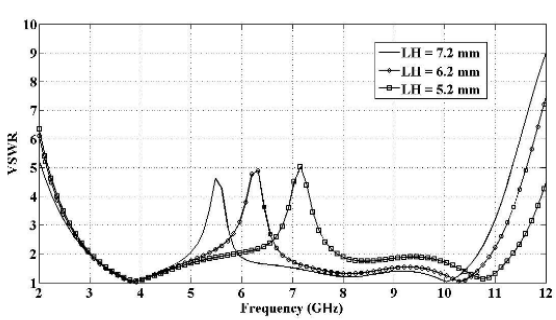


Fig. 4. Simulated VSWR characteristics for different values of L_H (g = 0.2 mm).

The notched center frequency f_r can be empirically approximated. To provide desired bandwidth of the rejection at f_r, the width of the slit, "g", is an important parameter. By carefully adjusting this parameter suitable band-notch width can be obtained. The band-rejection characteristics of the proposed antenna influenced by the "g" size are investigated in Fig. 5 (L_H = 7.2 mm). It is observed that the bandwidth of the rejection increases monotonically with an increase in "g". The antenna has been fabricated and its photo is shown in Fig. 6. The measured results for the fabricated prototype of the proposed antenna based on the optimized simulated design parameters are presented. Figure 7 shows the measured and simulated VSWR curve for the fabricated antenna.

The measured far-field radiation patterns of the proposed antenna in the x-z and y-z planes at sampling frequencies 3.5 GHz and 9.5 GHz are investigated in Figs. 8 (a) and (b). The proposed antenna has relatively omni-directional radiation pattern in the x-z plane (H-plane) at these frequencies. For comparison, the measured antennas gain in the y-z plane at θ = 180˚, for the two antennas (with and without slits) is presented in Fig. 9. As expected, the gain decreases sharply at the notched frequency band for the antenna with slits respect to the same antenna without them.

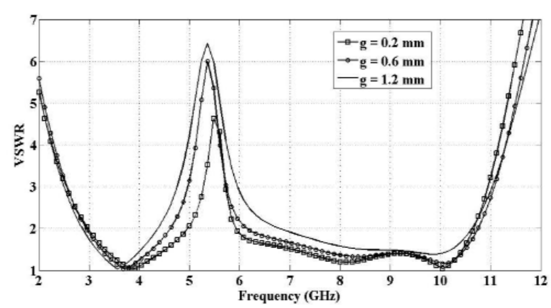


Fig. 5. Simulated VSWR characteristics for different values of g (L_H = 7.2 mm).

Fig. 6. Photographs of the manufactured antenna.

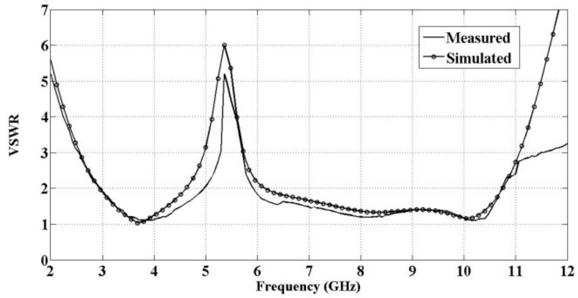


Fig. 7. Simuated and measured VSWR characteristics for the fabricated antenna.

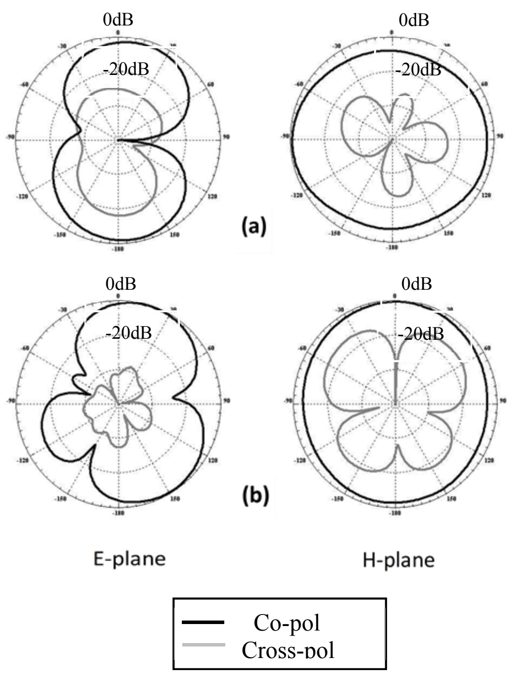


Fig. 8. Measured E-plane and H-plane radiation patterns for the proposed antenna at (a) 3.5 GHz and (b) 9.5 GHz.

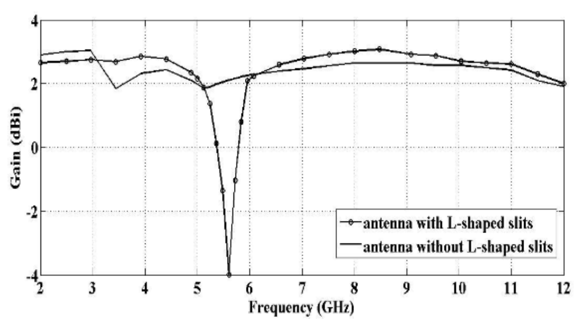
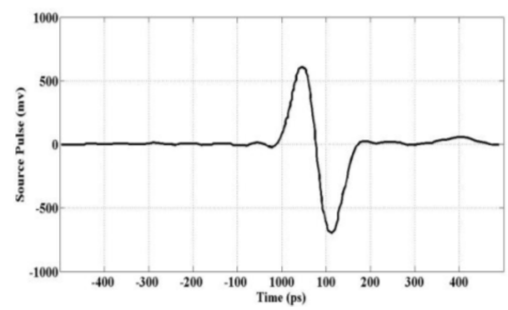


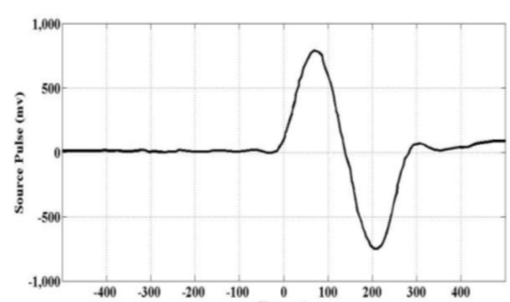
Fig. 9. Measured antennas gain (with and without L-shaped slits).

IV. TIME DOMAIN PERFORMANCE

In ultra wideband systems, the information is transmitted using short pulses. Hence, the temporal behavior of the transmitted pulse is important. The communication system for UWB pulse transmission must provide as minimum as possible distortion, spreading, and disturbance. Here different input signals are introduced to fully examine the influence of the frequency notch as well as the antenna abilities in transceiving signals. In our communication setup, two identical antennas have been used that were aligned side-by-side at a distance of 50 cm (antennas are in the far field of the each other). Two bipolar signals with different waveform widths were employed (Figs. 10 (a) and (b)). Since the antennas have a notch from 5 GHz ─ 6 GHz, considerable spectral information loss is expected to take place when transmitting the 170 ps bipolar signal. Figures 11 (a) and (b) present the received transient responses for the 170 ps and 280 ps bipolar signals, respectively. It is seen that the detected signal for the 170 ps bipolar pulse is quite weak and suffers distinct distortion. Compared with the 170 ps pulse, the received signal for the 280 ps pulse has larger magnitude and undergoes less distortion. The observed late time ringing is caused by the frequency notch.

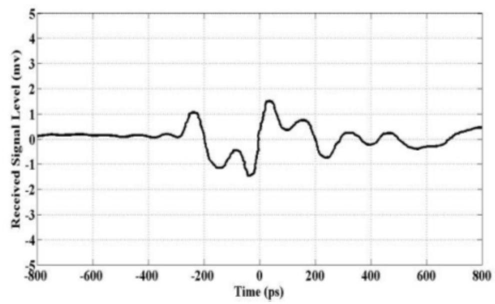


(a)

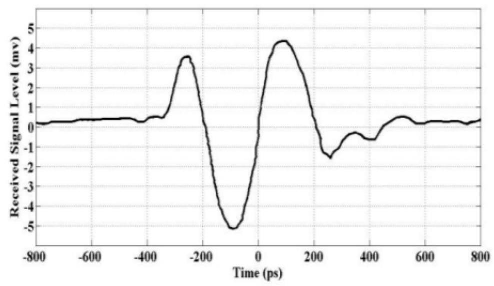


(b)

Fig. 10. Input bipolar signals for (a) 170 ps and (b) 280 ps.



(a)



(b)

Fig. 11. Output signal waveforms for (a) 170 ps and (b) 280 ps input pulses.

To examine the time-domain performance of the antenna, Gaussian pulses are selected to be the source waveforms and applied to the proposed antenna. The time domain characteristics of the proposed antenna are studied using CST Microwave Studio and presented in Fig. 12. the correlation between the transmitting antenna's input signal and the receiving antenna's output signal shows approximately 83 % antipodal resemblance that is clearly acceptable among the other UWB antennas. So it can preserve signal shape by a little distortion that makes it suitable for UWB applications.

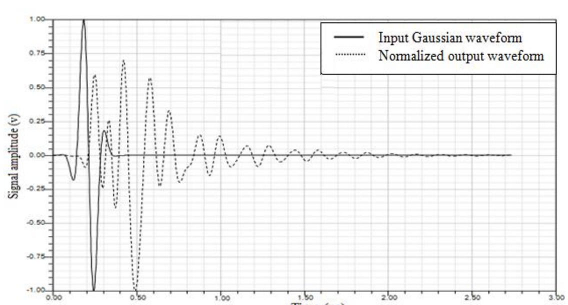


Fig. 12. Simulated time domain analysis: input and output pulse waveforms.

V. CONCLUSION

A printed monopole antenna with controllable band-notched configuration for ultra wideband applications is presented. A pair of L-shaped strips is used to satisfy the desired characteristics of the antenna. By embedding a pair of L-shaped slits on the ground plane, the frequency band-stop performance is achieved. The designed antenna has a stop-band of 5 GHz to 5.9 GHz while maintaining wideband performance from 3.1 GHz to 10.6 GHz for VSWR < 2. The antenna is fabricated and tested. A good agreement is achieved between the simulated and measured results.

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