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DUAL BAND-NOTCHED SEMI-ELLIPTICAL MONOPOLE ANTENNA WITH TWO BRANCH FEED LINE

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Abstract—In this paper, we present a modified semi-elliptical monopole antenna with a two-branch feed line and dual band-notched filter structure for UWB applications. By adjusting the parameters of the proposed antenna an UWB impedance bandwidth with a very good impedance matching can be achieved. The designed antenna has a small size of 20 mm × 20 mm and operates over the frequency band between 2.7 to 11 GHz, rejecting the undesired frequency bands from 3.3 to 3.8 GHz and 5.1 to 5.85 GHz.

1. INTRODUCTION

The development of ultra-wideband (UWB) applications as a part of wireless technology has increased the demand for ultra wideband antennas. The commercial usage of UWB frequency band in wireless systems, from 3.1 to 10.6 GHz, was approved by Federal communication commission (FCC) in 2002 [1]. Printed monopole antennas have received much attention due to their wideband matching characteristic, omnidirectional radiation patterns, high radiation efficiency, and simple hardware configuration. Hence, they are recently used in communication applications such as RFID devices, sensor networks, radar and location tracing [2–4]. To increase the impedance bandwidth in these antennas, techniques such as adding steps to the lower edge of the patch [1], increasing the ellipticity ratio of ellipse-shaped patch [2], the insertion of additional stub to the one side of circular patch [3] and adding of the slit on one side of the radiating element [4], have been reported. On the other hand, the frequency rang for UWB systems will cause interference to the existing WLAN and WiMAX networks operating in 5.15–5.85 GHz and 3.3–3.85 GHz,

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respectively. So the UWB antenna with a double band-notched characteristic is required. It was demonstrated in [5, 6] that by etching a specific feature in a planar monopole, a narrow and deep notch band can be achieved within a wide operating band. In this paper, we present a novel Printed Modified Elliptical Monopole antenna for UWB applications.

2. ANTENNA DESIGN AND PERFORMANCES

The geometry of the proposed monopole antenna is illustrated in Fig. 1. The proposed antenna has a very small size of 20 mm × 20 mm, is printed on a conventional 1 mm-FR4 substrate with relative permittivity of 4.4. The antenna structure is composed of two semi-elliptical monopoles with two pair of slits and 50 Ω microstrip feed line which is partially backed by a notched rounded ground plane. The two monopoles are symmetrically placed with respect to the feed line and are connected to it. To achieve a good impedance a parametric study of proposed antenna on the main parameters of the patch radiator, the notched modified ground plane and filter structure is done. Simulations are performed using High frequency structure simulator [7].

2.1. Monopole Antenna with a Two-branch Feed Line

The radiating structure is composed of two semi-elliptical monopole antenna which are connected by two-branch feeding line to the main

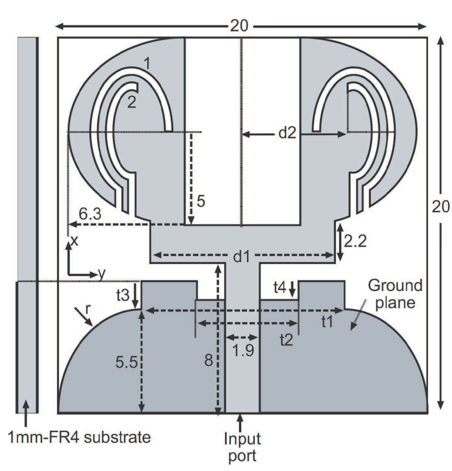

Figure 1. Geometry of the proposed monopole antenna (unit: mm).

feed line. The physical structure of the half-ellipse-shaped radiation patches are adapted to increase the effective electrical length at the lower frequency band. The two branches are distanced by d_1, as shown in Fig. 1. The simulated return losses as function of frequency for different values of d_1 are depicted in Fig. 2. By adjusting the value of d_1 mm, which affect the coupling between the planar monopole and the ground plane, a much enhanced impedance bandwidth for the proposed antenna can be achieved.

2.2. Modified Ground Plane

The modified ground plane is shown in Fig. 1. Both side edges of the ground plane are in a semi-elliptical shape in order to reduce the beam tilting and to obtain the wide bandwidth [8, 9]. The main parameters of the modified ground plane are shown in Fig. 1 and considered to optimize in Fig. 3 and Fig. 4. As depicted in Fig. 3, in the proposed antenna, values of the parameters of the extended ground plane, t_1, t_3, changes the impedance matching in the upper and middle frequency band, respectively. Also the effect of elliptical sides of the ground plane is shown in Fig. 3 with $r = 0$ and $r = 0.8$. It is seen that as r increases, the impedance matching of the proposed antenna improves. It is obvious from Fig. 3 that the changes of the values of t_1, t_3 and r, have significant effect on the impedance matching and so the impedance bandwidth of the proposed antenna. In order to obtain

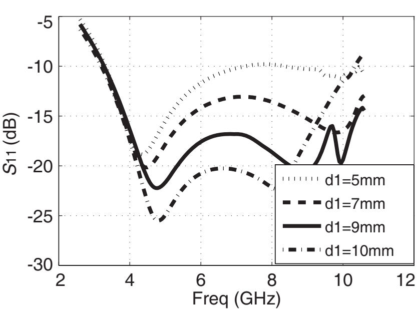

Figure 2. Simulated S_{11} parameter for various horizontal feed line distance d_1, $t_1 = 1.5\,\mathrm{mm}$, $t_2 = 1\,\mathrm{mm}$, $t_3 = 5.5\,\mathrm{mm}$, $t_4 = 5\,\mathrm{mm}$, $L_1 = 13\,\mathrm{mm}$, $L_2 = 8.5\,\mathrm{mm}$, $r = 0.8$, $d_2 = 6.8\,\mathrm{mm}$.

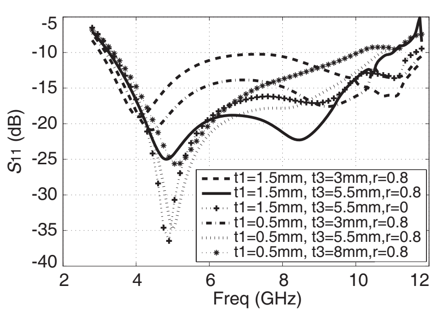

Figure 3. Simulated S_{11} parameter for different values of the parameters of the modified ground plane, t_1, t_3, $d_1 = 9\,\mathrm{mm}$, $t_2 = 1\,\mathrm{mm}$, $t_4 = 5\,\mathrm{mm}$, $L_1 = 13\,\mathrm{mm}$, $L_2 = 8.5\,\mathrm{mm}$, $r = 0.8$, $d_2 = 6.8\,\mathrm{mm}$.

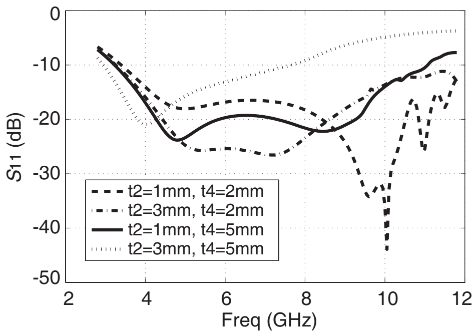

Figure 4. Simulated S_{11} parameter for different notch dimension introduced in the modified ground plane, t_2, t_4, $d_1 = 9$ mm, $t_1 = 1.5$ mm, $t_3 = 5.5$ mm, $L_1 = 13$ mm, $L_2 = 8.5$ mm, $r = 0.8$, $d_2 = 6.8$ mm.

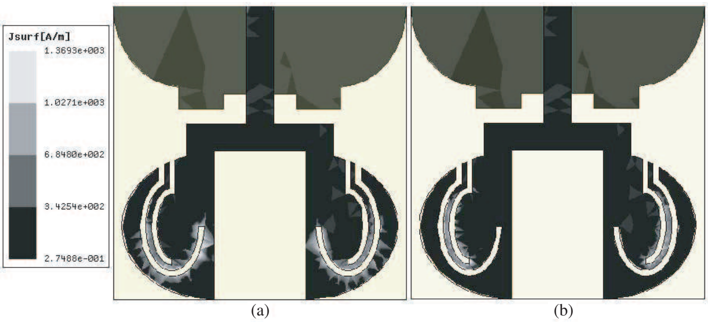

Figure 5. Simulated current distribution on the patch at: (a) first notch frequency, 3.6 GHz, and (b) second notch frequency, 5.56 GHz, $d_1 = 9$ mm, $t_1 = 1.5$ mm, $t_2 = 1$ mm, $t_3 = 5.5$ mm, $t_4 = 5$ mm, $L_2 = 8.5$ mm, $r = 0.8$, $d_2 = 6.8$ mm.

a good performance, the trimmed ground was used in the proposed antenna [10]. Fig. 4 indicates that by adjusting the size of the notch, t_2, t_4, good impedance matching over a wide frequency band can be achieved.

2.3. Dual Band-notched Filter Structure

As shown in Fig. 1, in order to achieve dual band notch characteristic, two pair of slits are inserted in the radiating patch, symmetrically. The total length of slits are L_1 and L_2. At shown in Fig. 5, the surface current is concentrated around the edges of the slits and flows

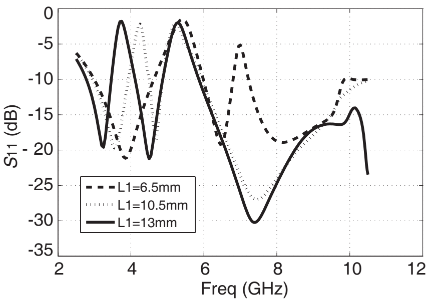

Figure 6. Simulated S_{11} parameter for different values of L_1, $d_1 = 9\,\mathrm{mm}$, $t_1 = 1.5\,\mathrm{mm}$, $t_2 = 1\,\mathrm{mm}$, $t_3 = 5.5\,\mathrm{mm}$, $t_4 = 5\,\mathrm{mm}$, $L_2 = 8.5\,\mathrm{mm}$, $r = 0.8$, $d_2 = 6.8\,\mathrm{mm}$.

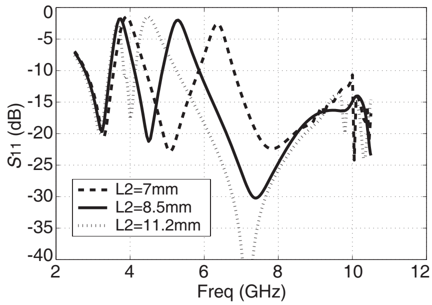

Figure 7. Simulated S_{11} parameter for different values of L_2, $d_1 = 9\,\mathrm{mm}$, $t_1 = 1.5\,\mathrm{mm}$, $t_2 = 1\,\mathrm{mm}$, $t_3 = 5.5\,\mathrm{mm}$, $t_4 = 5\,\mathrm{mm}$, $L_1 = 13\,\mathrm{mm}$, $r = 0.8$, $d_2 = 6.8\,\mathrm{mm}$.

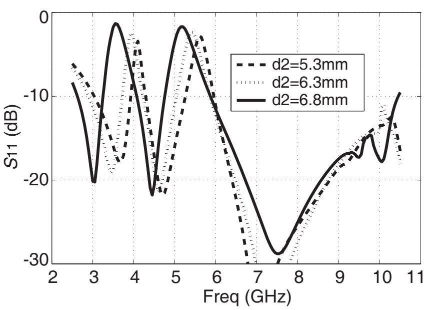

Figure 8. Simulated S_{11} parameter for different values of d_2, $d_1 = 9\,\mathrm{mm}$, $t_1 = 1.5\,\mathrm{mm}$, $t_2 = 1\,\mathrm{mm}$, $t_3 = 5.5\,\mathrm{mm}$, $t_4 = 5\,\mathrm{mm}$, $L_1 = 13\,\mathrm{mm}$, $L_2 = 8.5\,\mathrm{mm}$, $r = 0.8$.

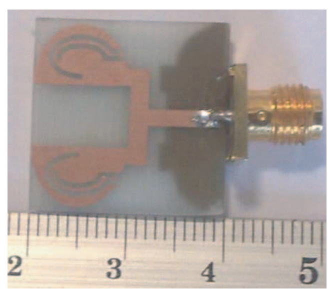

Figure 9. Photograph of the prototyped band-rejected UWB antenna: (a) top view, (b) bottom view.

back to the feeding part at the notch frequencies. This in turn leads slits to act as a dual-band resonant structure. As shown in Fig. 6 and Fig. 7, the first and second resonant frequencies change with different values of L_1 and L_2, respectively. By adjusting the lengths of the slots to be about a half-wavelength at the center frequency of the desired notched-frequency band (about 3.5 GHz for WiMAX and 5.5 for WLAN frequency band), the proposed UWB planar monopole antennas will become non-responsive at that frequency bands [12]. Moreover, The horizontal distance between the center of the curved slits and the center of the antenna is denoted by d_2. By increasing d_2

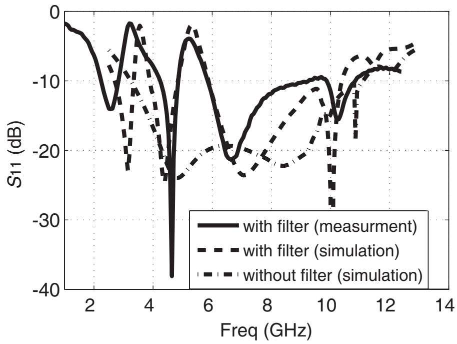

Figure 10. Comparison between measured and reflection coefficient for the optimized UWB antenna [see Fig. 1].

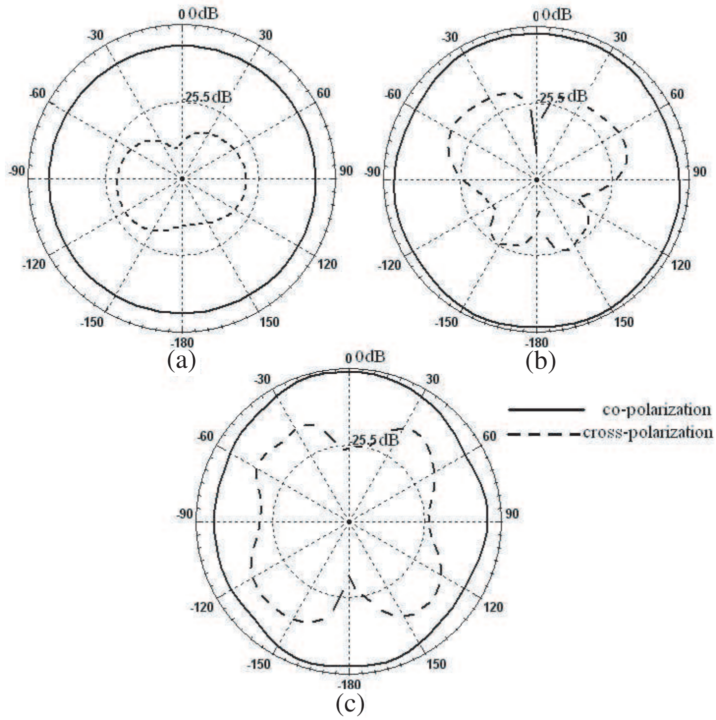

Figure 11. Measured H-plane plane radiation patterns for the proposed band-notched UWB antenna at: (a) 3.5 GHz; (b) 6.5 GHz; (c) 10 GHz.

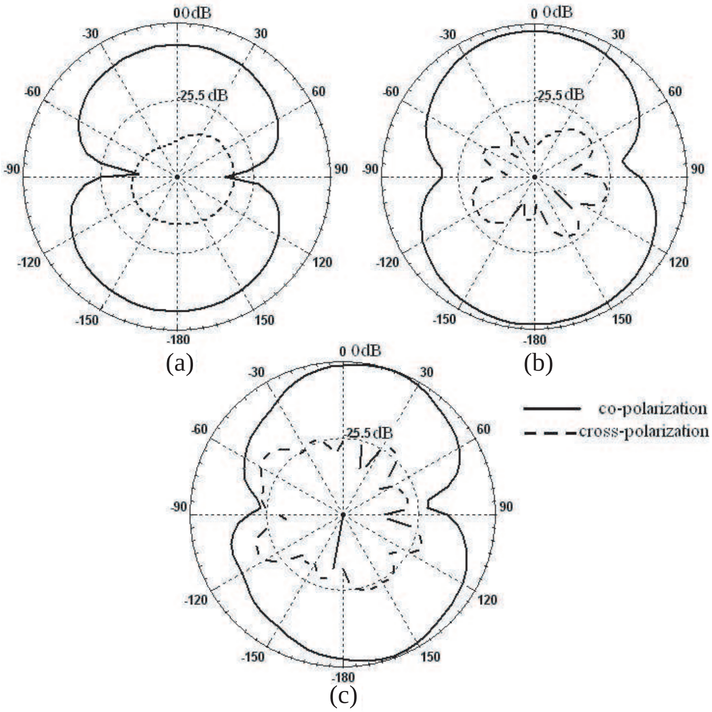

Figure 12. Measured E-plane plane radiation patterns for the proposed band-notched UWB antenna at: (a) 3.5 GHz; (b) 6.5 GHz; (c) 10 GHz.

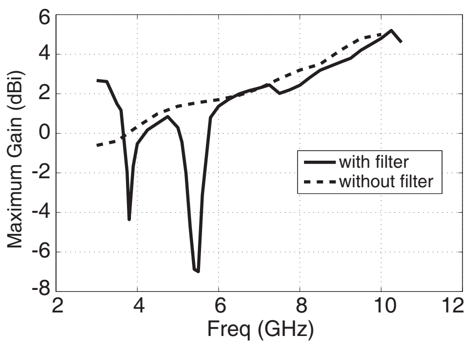

Figure 13. Maximum gain of the optimized UWB antenna with and without filter.

the filter structure is distanced from the feed point so it is expected that the bandwidth of the band rejection performance would decrease due to the reduction of the current density of the edges of the slots and vice versa. As shown in Fig. 8, the impedance bandwidth of the notched bands are decreased as d_2 increases. It must be noted that using the curved slits, the antenna achieves compactness of 82%, without any distortion in the antenna performance.

3. EXPERIMENTAL RESULTS

The optimized antenna design is manufactured using the substrate FR4-epoxy. The photographs of the prototyped antenna including its soldered SMA connector is shown in Fig. 8. The simulated and measured reflection coefficient of the proposed antenna with and without the filter structure are presented in Fig. 9. As shown in Fig. 9, there is a good agreement between simulated and measured result in the middle and upper frequency bands but the measured bandwidth of the first rejected band is wider and the lower band-edge frequency is decreased in comparison with simulation. As seen from measured results, the proposed antenna is operating over the frequency band between 2.2 to 11 GHz, rejecting the the existing WLAN and WiMAX bands from 3.1 to 3.8 GHz and 5.1 to 5.8 GHz. The measured radiation patterns in the H-plane (y-z plane) and E-plane (x-z plane) at 3.5, 6.5, and 10 GHz are plotted in Fig. 10 and Fig. 11, respectively. From an overall view of these patterns, the antenna behaves quite similarly to the typical printed monopole antennas in the operating frequency band. The stability of the radiation patterns in the overall frequency band is due to the symmetrical structure and two branch feed line of the proposed antenna [13]. Fig. 12 presents the measured peak antenna gain with and without filter structure. As shown in Fig. 12, gain decreases drastically at the frequency band of 3.5 and 5.5 GHz. Stable antenna gain with gain variation of less than 2 dB is however achieved in the desired UWB band.

4. CONCLUSION

A modified semi-elliptical monopole antenna with a two-branch feed line and dual-notched filter structure is proposed for UWB applications. By adjusting the parameters of the proposed antenna an UWB impedance bandwidth from 2.2 to 11 GHz with a good impedance matching is achieved. Two slits are etched on the radiating patch, rejecting the undesired frequency bands from 3.3 to 3.8 GHz and 5.1 to 5.85 GHz. Omni-directional radiation pattern in the overall frequency band is obtained. Proposed antenna gain is almost flat in the operation frequency band with sharp notched bands.

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