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Small-Size Monopole Antenna with Dual Band-Stop Function for Ultra-Wideband Wireless Communications

Naser Ojaroudi Parchin[*], **Mehdi Salimitorkamani**

Microwave Technology Company, Tehran, Iran

Email address:
n.ojaroudi@yahoo.com (N. O. Parchin)
[*]Corresponding author

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Abstract: In this letter, a different method to design an ultra-wideband (UWB) monopole antenna with dual frequency band-stop performance is presented. The proposed antenna consists of a rectangular-ring radiating patch with a meander-line strip as a resonator protruded inside the ring, and a ground plane. The measured results reveal that the presented dual band-notched monopole antenna design exhibits an operating bandwidth (VSWR<2) form 2.8 GHz to 13.8 GHz with two notched bands, covering the 5.2/5.8 GHz, 3.5/5.5 GHz, and 4 GHz to suppress any interference from the wireless local area network (WLAN), worldwide interoperability microwave access (WiMAX) and C-band systems, respectively. Good return loss, antenna gain and radiation pattern characteristics are obtained in the frequency band of interest. The proposed monopole antenna configuration is simple, easy to fabricate and can be integrated into any UWB system. The antenna has a small dimension of 10×17 mm^2.

Keywords: Band-Notched Property, Meander-Line Resonator, Monopole Antenna, UWB Communications

1. Introduction

Recently, the ultra-wideband (UWB) wireless communication systems have received much attention due to its many attractive features. One of the main issues and also fundamental parameters of the UWB systems is designing an antenna to cover the required frequency bandwidth while maintaining compact size with sufficient radiation properties in terms of impedance bandwidth, omni-directional radiation pattern, antenna gain and efficiency, fabrication process and etc. [1-2]. Various types of the UWB microstrip antennas with different geometries have been reported [3-5]. Slot and conductor-backed plane structures in [3], fan-shaped radiator with a sprocket-shaped ground-plane in [4], and defected ground structure [DGS] elements in [5] are used to generate new resonators and improve the UWB antenna bandwidth. Furthermore, some techniques to enhance the UWB antenna operation bandwidth have been investigated [6-10].

Since there are many narrow-band wireless systems such as WLAN, WiMAX, and C-band which interfere with the UWB communication system, the antennas with band-stop property to avoid the interference while keeping the UWB characteristics are desirable [11-13].

Different kinds of UWB microstrip antennas with various band-stop charcteristics have been designed and their performances are investigated [14-18]. Many techniques are, also, used to introduce the notch band for rejecting the interference in the UWB antennas. It is done either by inserting parasitic structures in the ground plane, or using a reconfigurable structure in the ground plane, or by inserting step-impedance resonators (SIR) at feed-line [19-22].

All of the above methods are used for rejecting a single band of frequencies. However, to effectively utilize the UWB spectrum and to improve the performance of the UWB system, it is desirable to design the UWB antenna with dual band rejection. It will help to minimize the interference between the narrow band systems with the UWB system. Some methods are used to obtain the dual band rejection in the literature [23-30].

In this paper, a new design of the microstrip monopole antenna is proposed to obtain the dual band rejection of frequency bands for WiMAX/C-band and WLAN systems. For the first time, a novel technique to generate single or multiple band-stop for the UWB antenna. Using a meander-line element inside the antenna radiation patch of the antenna has been presented in this study. Unlike other band-notched antennas reported in the literature to date, this antenna has a very compact size of 10×17 mm^2 [18-30]. The proposed antenna with the dual band-notched function is successfully implemented and the simulation results show reasonable agreement with the measurement results. Furthermore, Good properties in terms of VSWR and radiation pattern characteristics are obtained in the frequency band of interest.

2. Antenna Design

Configuration of the designed UWB antenna with double band-filtering characteristic is illustrated in Fig. 1. A low cost FR4 substrate with properties of thickness (h) = 0.8 mm, permittivity (ε) =4.4, and loss tangent (δ) =0.018 has been employed as the antenna dielectric. The deaigned antenna configuration is composed of a square radiation patch with width of W connected to the feed-line with length and width of W_f and (L_f +L_{gnd}).

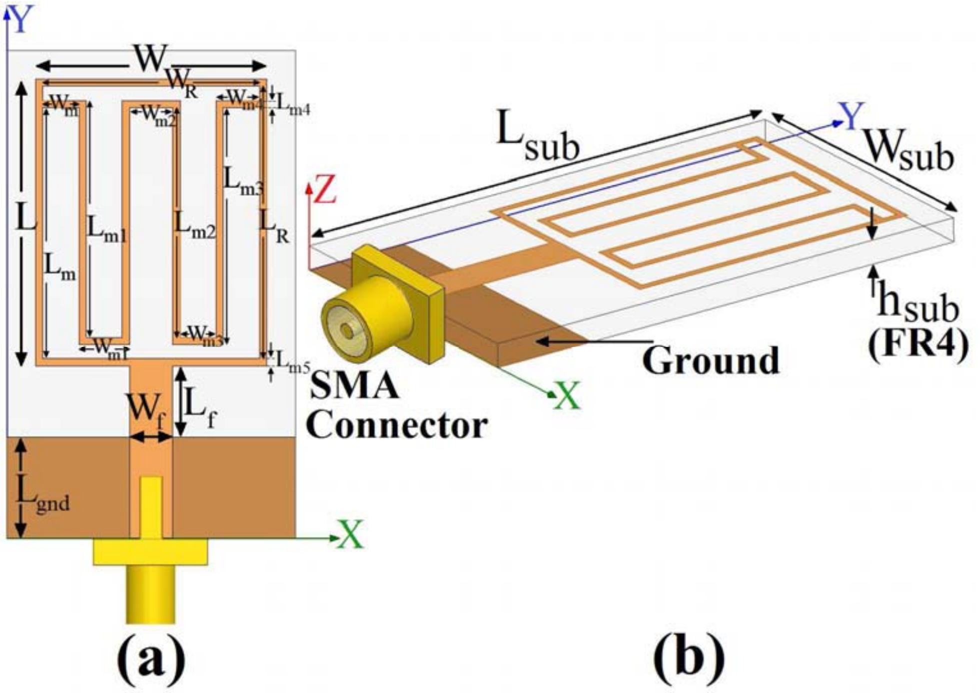

Fig. 1. *Geometry of proposed monopole antenna, (a) top view, (b) side view.*

In this study, the protruded meander-line strip in the rectangular-ring radiating patch is used to give a dual frequency band-notched operation. The Ansoft simulation software high-frequency structure simulator (HFSS) [31] is used to optimize the design. The final dimensions of the designed antenna are specified in Table 1.

Table. 1 *The final dimensions of the designed Antenna.*

Param.	mm	Param.	mm	Param.	mm
W_{sub}	10	L_{sub}	17	h_{sub}	0.8
W	8	L	9	W_f	1.5
L_f	3.5	W_R	7.5	L_R	8.5
W_m	0.75	L_m	7.75	W_{m1}	1.75
L_{m1}	7.25	W_{m2}	1.5	L_{m2}	7
W_{m3}	1.5	L_{m3}	7.25	W_{m4}	1
L_{m4}	0.25	L_{m5}	0.5	L_{gnd}	3.5

3. Results and Discussions

In this section, the microstrip monopole antenna with various design parameters was constructed, and the numerical and experimental results of the input impedance and radiation characteristics are presented and discussed. The proposed antenna is designed and its fundamental properties have been investigated using Ansoft simulation software high-frequency structure simulator (HFSS) software.

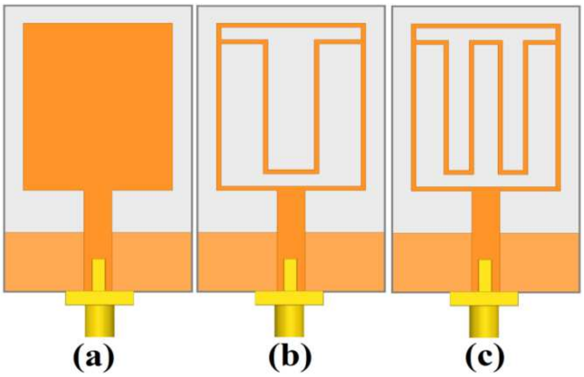

Fig. 2. *(a) Ordinary monopole antenna, (b) antenna with an inverted protruded Ω-shaped strip, and (c) the proposed antenna structure.*

The structure of the various antennas used for simulation studies were shown in Fig. 2. VSWR characteristics for the ordinary monopole antenna (Fig. 2(a)), antenna with an inverted Ω-shaped strip protruded in the rectangular-ring antenna (Fig. 2(b)), and the proposed antenna (Fig. 2(c)) are compared in Fig 3.

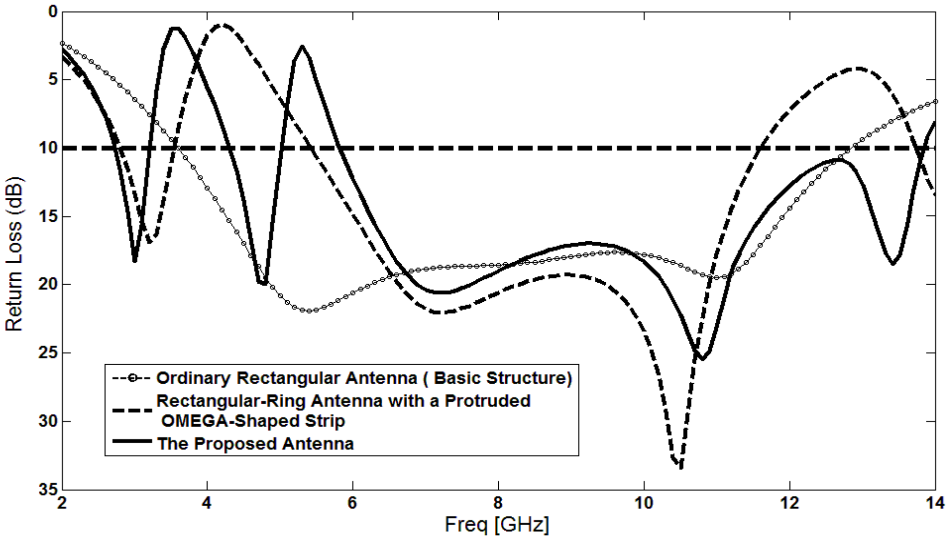

Fig. 3. *Simulated return loss characteristics for the various structures shown in Fig. 2.*

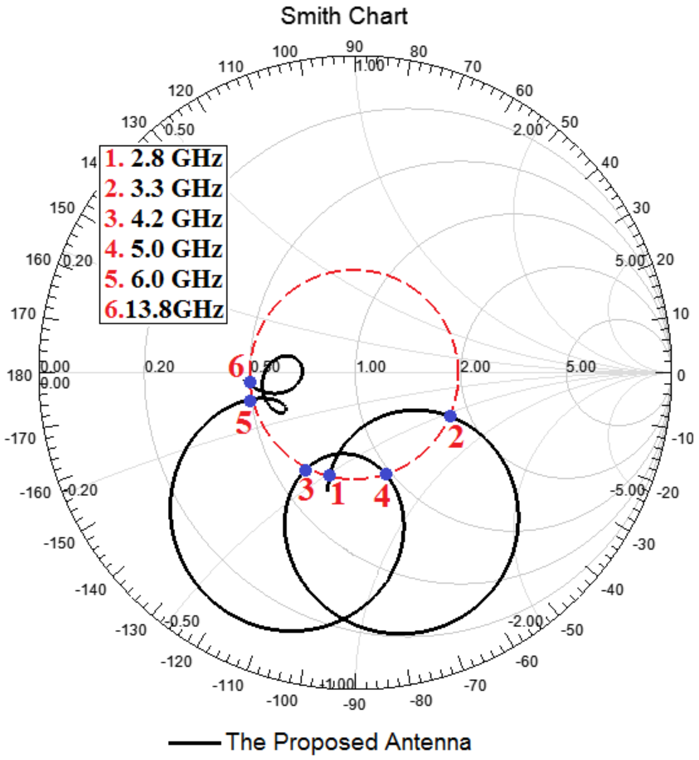

Fig. 4. *Simulated input impedance on a Smith Chart of the proposed antenna.*

As shown in Fig. 3, in the proposed antenna configuration, the ordinary square monopole can provide the fundamental and next higher resonant radiation band at 4 and 8 GHz, respectively. To generate a single band-stop characteristic, an inverted Ω-shaped strips protruded inside rectangular-ring radiating patch was applied in the antenna configuration. By converting this structure to the protruded meander-line strip inside rectangular-ring antenna, a dual band-notched function is achieved, which is covering all the 5.2/5.8GHz WLAN, 3.5/5.5 GHz WiMAX and 4- GHz C bands. Moreover, the input impedance of the proposed antenna on a Smith Chart is shown in Fig. 4. In order to understand the phenomenon behind this dual band-stop performance, the simulated current distributions for the proposed antenna at the notched frequencies presented in Fig. 5.

As shown in Fig. 5(a), it is found at the first notched frequency (3.9 GHz), the current flows are that the current concentrated on the edges of the interior and exterior of the meander-line strip. At the second notched frequency (5.5 GHz), the current flows are more dominant around of center-side of the protruded meander-line strip which is shown in Fig. 5(b) [32].

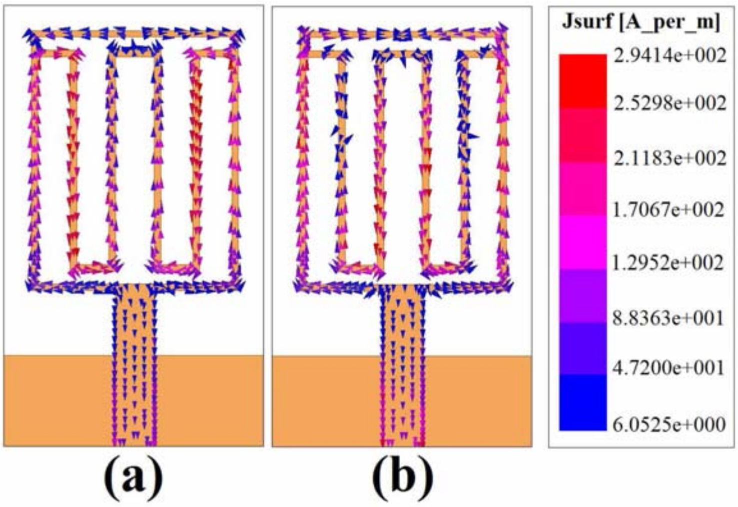

Fig. 5. *Simulated surface current distributions for the proposed antenna at the notched frequencies (a) 3.9 GHz, and (b) 5.5 GHz.*

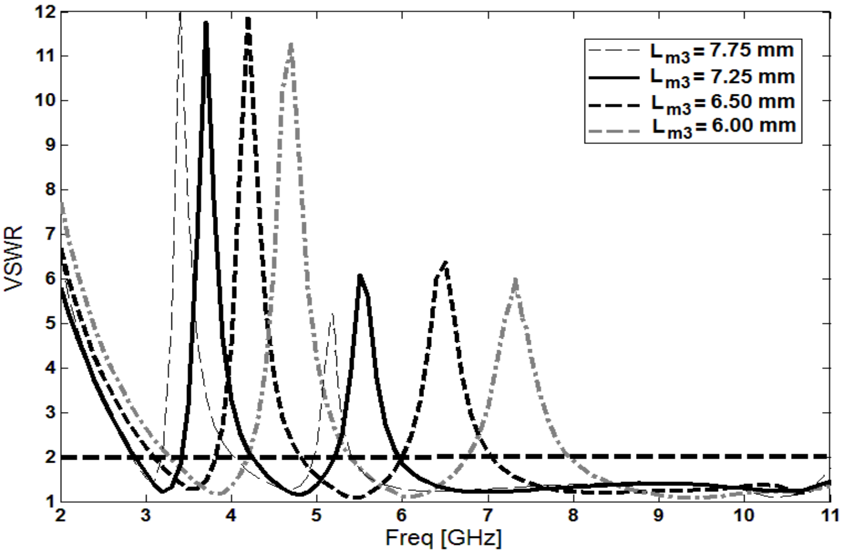

Fig. 6. *Simulated VSWR characteristics of the proposed antenna for different values of* L_{m3}.

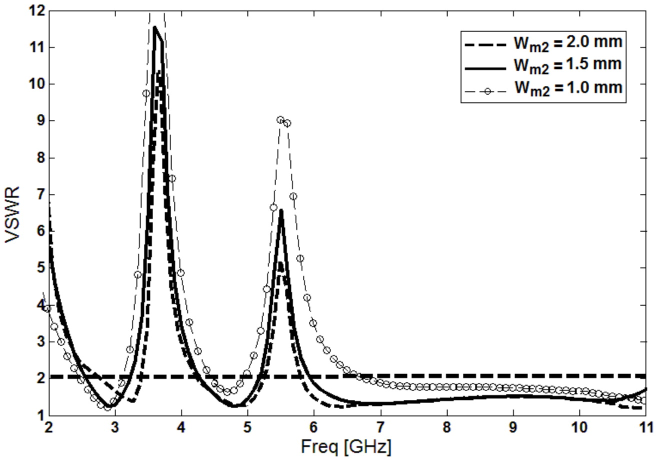

Fig. 7. *Simulated VSWR characteristics of the proposed antenna for different values of* W_{m2}.

The simulated VSWR curves with different values of L_{m3} are plotted in Fig. 6. As shown in Fig. 6, when the height of the protruded meander-line strip increases from 6 to 7.75 mm, the center of lower notched frequency is decreased from 4.8 to 3.4 GHz and also the center of higher notched frequency is decreased from 7.5 to 5.2 GHz. From these results, we can conclude that the notched frequency is controllable by changing the interior height of the protruded meander-line strip. Fig. 7 illustrates the simulated VSWR characteristics with various values of W_{m2} .

As the width of W_{m2} increases from 1.0 to 2.0 mm, the filter bandwidth is varied from 0.8 to 1.5 GHz for lower notched frequency and also varied from 0.7 to 1.9 GHz for higher notched frequency. The proposed microstrip monopole antenna with final design as shown in Fig. 8 was built and tested. Fig. 9 shows the measured and simulated VSWR characteristics of the proposed antenna. The fabricated antenna has the frequency band of 2.98 to 13.43

GHz with two rejection bands around 3.31-4.23 and 5.07–6.05 GHz.

However, as shown in Fig. 9, there exists a discrepancy between measured data and the simulated results. This discrepancy 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. In order to confirm the accurate return loss characteristics for the designed antenna, it is recommended that the manufacturing and measurement processes need to be performed carefully. Moreover, SMA soldering accuracy and FR4 substrate quality need to be taken into consideration.

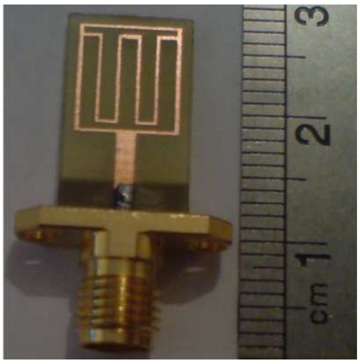

Fig. 8. *Photograph of the realized antenna.*

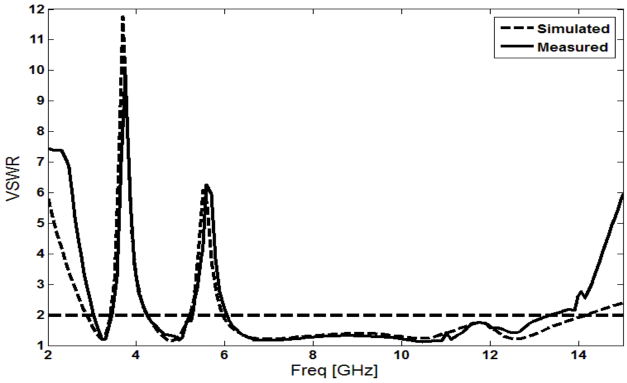

Fig. 9. *Measured and simulated VSWR characteristic for the proposed antenna.*

Fig. 10 depicts the radiation patterns of the antenna including the co-polarization and cross-polarization in the H-plane (x-z plane) and E-plane (y-z plane). It can be seen that nearly omnidirectional radiation pattern can be observed on x-z plane over the whole UWB frequency range, especially at the low frequencies. The radiation patterns on the y-z plane are like a small electric dipole leading to bidirectional patterns in a very wide frequency band. With the increase of frequency, the radiation patterns become worse because of the increasing effects of the cross polarization [32-35].

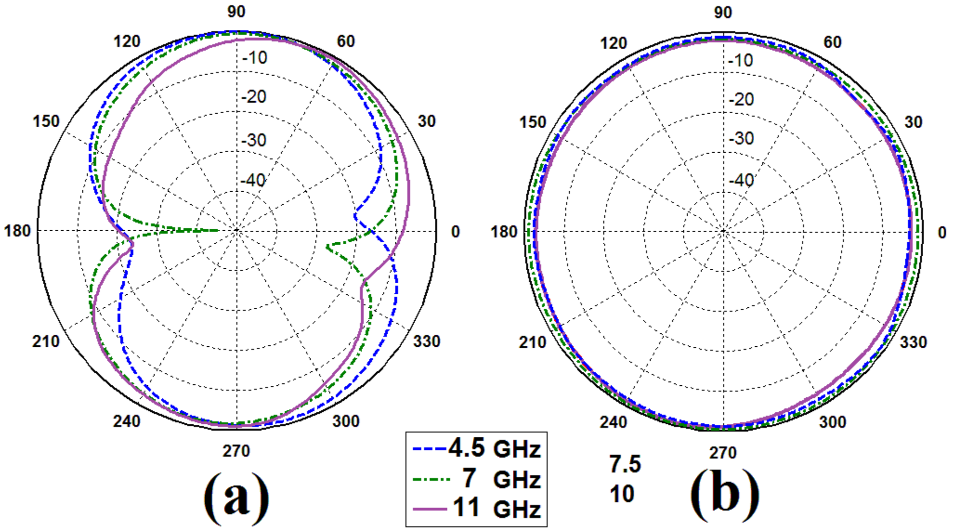

Fig. 10. *Radiation patterns of the proposed antenna, (a) E-plane, and (b) H-plane.*

4. Conclusion

In this letter, a novel and compact printed monopole antenna (PMA) with dual band-notched performance for UWB applications has been proposed. The basic monopole antenna structure consists of a rectangular radiating patch, feed-line, and a ground plane. Single and dual band-notched functions are obtained by converting the rectangular radiating patch to the rectangular-ring structure with a protruded meander-line strip as a resonator. Simulated and measured results are presented to validate the usefulness of the proposed antenna structure for UWB applications. The fabricated antenna satisfies the VSWR<2 requirement for 2.8-13.8 GHz with dual band rejection performance in the frequency band of 3.3- 4.2 GHz and also 5-6 GHz, covering all the 5.2/5.8GHz WLAN, 3.5/5.5 GHz WiMAX and 4-GHz C bands. The proposed antenna has a small size of 12×18 mm^2 and simple configuration. Good VSWR and radiation pattern characteristics are obtained in the frequency band of interest. Experimental results show that the proposed antenna could be a good candidate for UWB applications.

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