International Journal of Natural and Engineering Sciences 7 (2): 33-37, 2013
ISSN: 1307-1149, E-ISSN: 2146-0086, www.nobel.gen.tr

Design of Compact Planar Antenna with WLAN/WiMAX Applications Using Slotted Conductor-Backed Plane

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Received: October 03, 2012
Accepted: November 14, 2012

Abstract

A compact microstrip-fed monopole antenna is proposed for wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) applications. The main features of the proposed antenna are the compact dimensions and band-operating characteristics that are obtained without modifying the radiator or the ground plane. The size of the antenna is 18mm × 18mm × 0.8mm. By Using of a pair of mirror ɼ-shaped slots in the conductor-backed plane, the proposed antenna can operate in multiband. The -10 dB s_{11} bandwidths of them are (2.3 - 2.5 GHz), (3.1 - 4.2 GHz), and (4.6 – 7.5 GHz), respectively, which can cover both the WLAN bands (2.4-2.484 GHz, 5.15-5.35 GHz, and 5.725-5.825 GHz) and the WiMAX bands (3.4-3.69 GHz and 5.25-5.85 GHz). Good omnidirectional radiation pattern characteristics and enough gains are obtained over the operating bands.

Keywords: Wireless local area network; worldwide interoperability for microwave access; triple-band antenna; multiband antenna

INTRODUCTION

There is a tremendous increase in the applications that use the wireless local area network (WLAN) of 2.4-2.484 GHz (IEEE 802.11/b/g)/ 5.15-5.825 GHz (IEEE 802.11a) and the worldwide interoperability for microwave access (WiMAX) of 3.4-3.69 GHz/ 5.25-5.85 GHz technologies [1-15]. One of the major challenges in the design of multiband antennas is how to achieve small size antennas with low cost, low weight, and desired radiation pattern characteristics. For the design of a monopole antenna, the shape of the antenna patch and the geometry of the ground plane slots are of great importance for access to band-operating with planar structure. Proposed slot shapes have included rectangular, triangle, and circular ones [2-6]. Several designs in the literature concerning the monopole antenna with multiband characteristics and large size or even compact size for increasing the frequency range accepted by WLAN/WiMAX have been reported in recent years. However, printed antennas with broadband and multiband functionality can be operated at multiple frequency bands. Those designs use different types of slots, slits, and parasitic elements in the radiator, the ground plane or even in the feeder to achieve the required band- operating characteristics [7-15].

In this paper, a novel microstrip-fed monopole antenna is presented for WLAN and WiMAX applications. In this designed antenna, the target is to present a compact structure with a step-by-step design procedure. By inserting a pair of mirror ɼ-shaped slots on the conductor-backed plane and suitable adjusting the lengths of the element and slot, we can tune frequency bands. Prototypes of the proposed antenna for WLAN operations at the 2.4-, 5.2-, and 5.8-GHz frequencies and also for WiMAX operations at the 3.5- and 5.5-GHz frequencies have been constructed and tested. Compared with those reported, the constructed antenna has simple structure and compact size 18 × 18 mm^2, moreover, can provides good omnidirectional radiation patterns for multiband characteristics. Measured and simulated results of the realized antenna with the difference structures of conductor-backed plane are presented.

MATERIALS AND METHODS

Figure 1 shows the geometry of the proposed antenna with $W_{sub} \times L_{sub}$ dimensions. The top layer includes the main radiator in the form of rectangular patch with the dimensions of 8 ×9.5 mm^2. The bottom layer includes a partial ground plane and slotted conductor-backed plane. The proposed antenna, with compact dimensions of 18 ×18 mm^2, is constructed with a substrate made of FR4, with the thickness 0.8 mm and the relative dielectric constant 4.4. The width of the feed-line microstrip is fixed at 1.56mm for 50-Ω impedance. For the impedance matching, the distance between the patch and the ground plane is indicated with a gap (gap=L_f – L_{gnd}), which provides suitable control between the lower edge patch and the ground plane. The optimum gap between the radiator and the ground plane is 2.2mm. In the first step of the design, the dimensions of the substrate, radiator and ground plane are optimized using the software HFSS for multiple frequency coverage. The optimized dimensions are 18 mm × 18 mm for the substrate, 8 mm × 9.5 mm for the radiator, and 4.9 mm for the width of the ground plane. To modify the performance of the antenna by creating two bands at the WLAN and also WiMAX bands, the conductor-backed is slotted in the manner shown in Figure 1. With inserting a pair of mirror inverted L-shaped slots at the conductor-backed plane, 3.4-3.6/ 5.25-5.85 GHz for WiMAX operation can be obtained, whereas by using a pair of mirror r-shaped slots inside the conductor-backed, band of (2.4-2.484GHz) can be achieved and also additional resonance frequency is generated. The simulated current distributions for the proposed antenna are shown in Figure 2 at 2.35 and 3.7 GHz. From this figure, it can be found that by inserting this r–shaped form at the conductor-backed plane and improving it, currents are regularly concentrated on the edges of these slots at resonant frequencies. As a result, the antenna impedance changes at these frequencies. The modified conductor-backed is designed to achieve better impedance matching. The optimization of the structure is obtained using the Ansoft simulator (HFSS). The optimal parameters of the constructed antenna are as follows: W_{sub} = 18mm, L_{sub} = 18mm, gap = 2.2 mm, W = 8 mm, L = 9.5mm, L_{gnd} = 4.9 mm, W_f = 1.56 mm, L_f = 7.1 mm. The other optimized dimensions of the antenna are indicated in Figure 1.

RESULTS AND DISCUSSION

The design antenna was fabricated (Figure 1b) and tested. The impedance bandwidth with different structures of the conductor-backed plane was tested by using an Agilent 8722ES Vector Network Analyzer (VNA). Figure 3 shows the structure of the various conductor-backed plane antennas. With introducing a pair of mirror inverted L-shaped slots at the conductor-backed plane in the manner shown in Figure 3b, 3.4-3.6/ 5.25-5.85 GHz for WiMAX operation can be obtained. Using a pair of mirror r-shaped slots on the conductor-backed plane in the manner shown in Figure 3c, 2.4-2.484/5.15-5.35/5.725-5.825 GHz for WLAN operation can be achieved and also a proper control on the triple-band operation can be obtained as shown in Figure 4. Also, by suitable adjusting the lengths of the r–shaped design, much wider impedance bandwidth can be produced, especially at the lower band of WLAN/WiMAX. A very good agreement between the simulated and measured results can be seen in Figure 4. Figure 5 clearly highlights the measured maximum peak antenna gain from 2.3 to 2.5 GHz, 3.2 to 4 GHz, and 5 to 7 GHz. The ranges of antenna gain are about 0.65-0.9 dBi for 2.4 GHz , 1-1.15 dBi for 3.5 GHz, and 1.2-3 dBi for 5.5 GHz. Figure 6 shows the measured radiation pattern for four different frequencies of operating bands at 2.4GHz, 3.7GHz, 5.4GHz, and 6 GHz in H-plane (xoz-plane) and E-plane (yoz-plane). From an overall view of these radiation patterns, the proposed antenna behaves quite similar to the typical printed monopoles in the operating bands. The figure is approximately exhibits an omnidirectional radiation pattern in H-plane and a monopole-like radiation pattern in the E-plane.

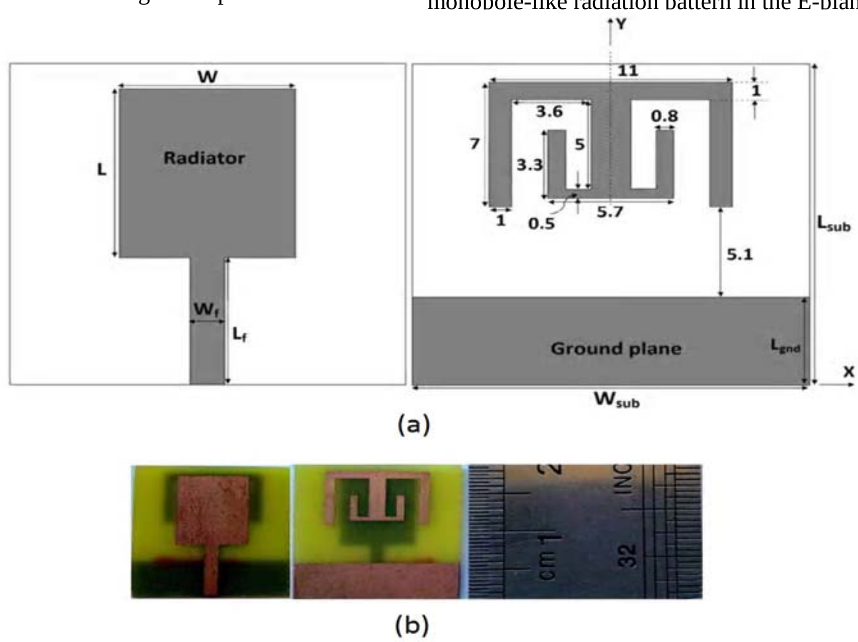

Figure 1. Configuration of the proposed antenna with a pair of mirror r–shaped on the conductor-backed plane. (a) Dimensions and parameters of the proposed antenna (units: mm). (b) Photograph of the printed monopole antenna

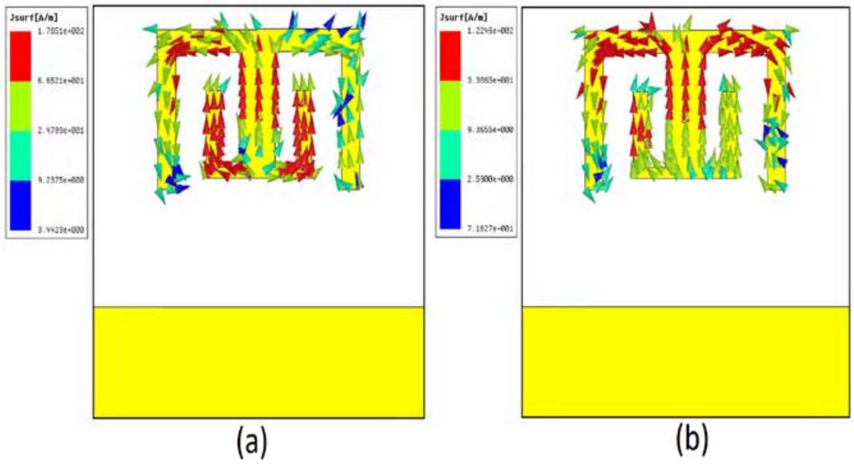

Figure 2. Simulated surface current distributions on the conductor-backed plane for the proposed antenna at (a) first resonance frequency (2.35 GHz) and (b) second resonance frequency (3.7GHz)

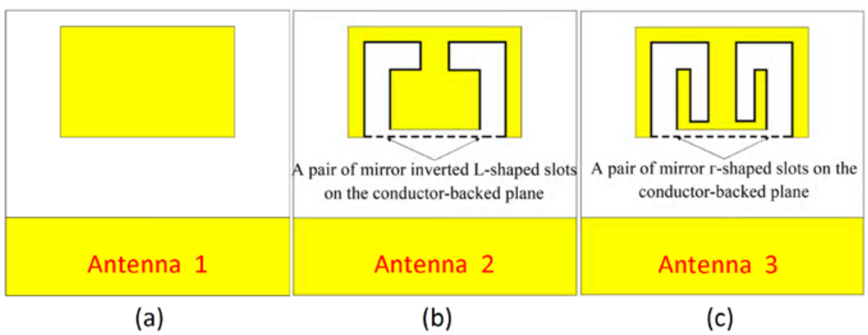

Figure 3. (a) Antenna without slot. (b) Antenna with a pair of inverted mirror L-shaped slots inside the conductor-backed plane. (c) Antenna with a pair of mirror r–shaped slots inside the conductor-backed plane

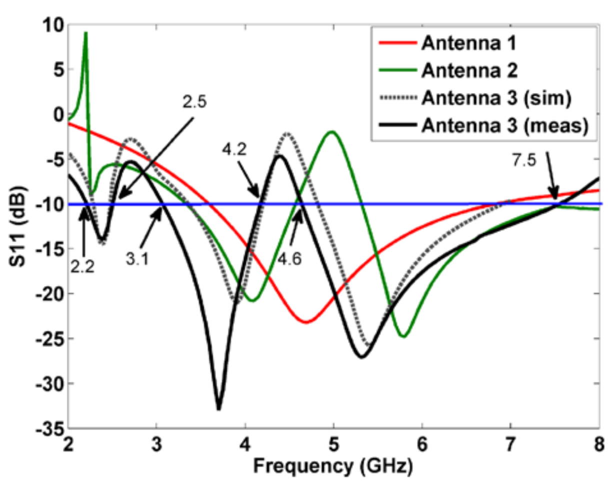

Figure 4. Measured and simulated S_{11} for antenna shown in Figure 3

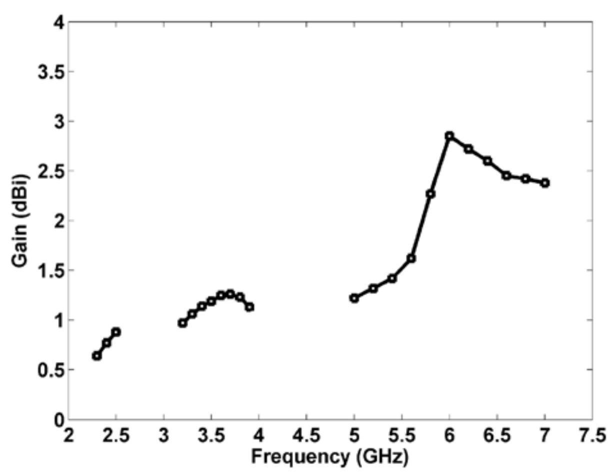

Figure 5. Measured antenna gain for the proposed antenna

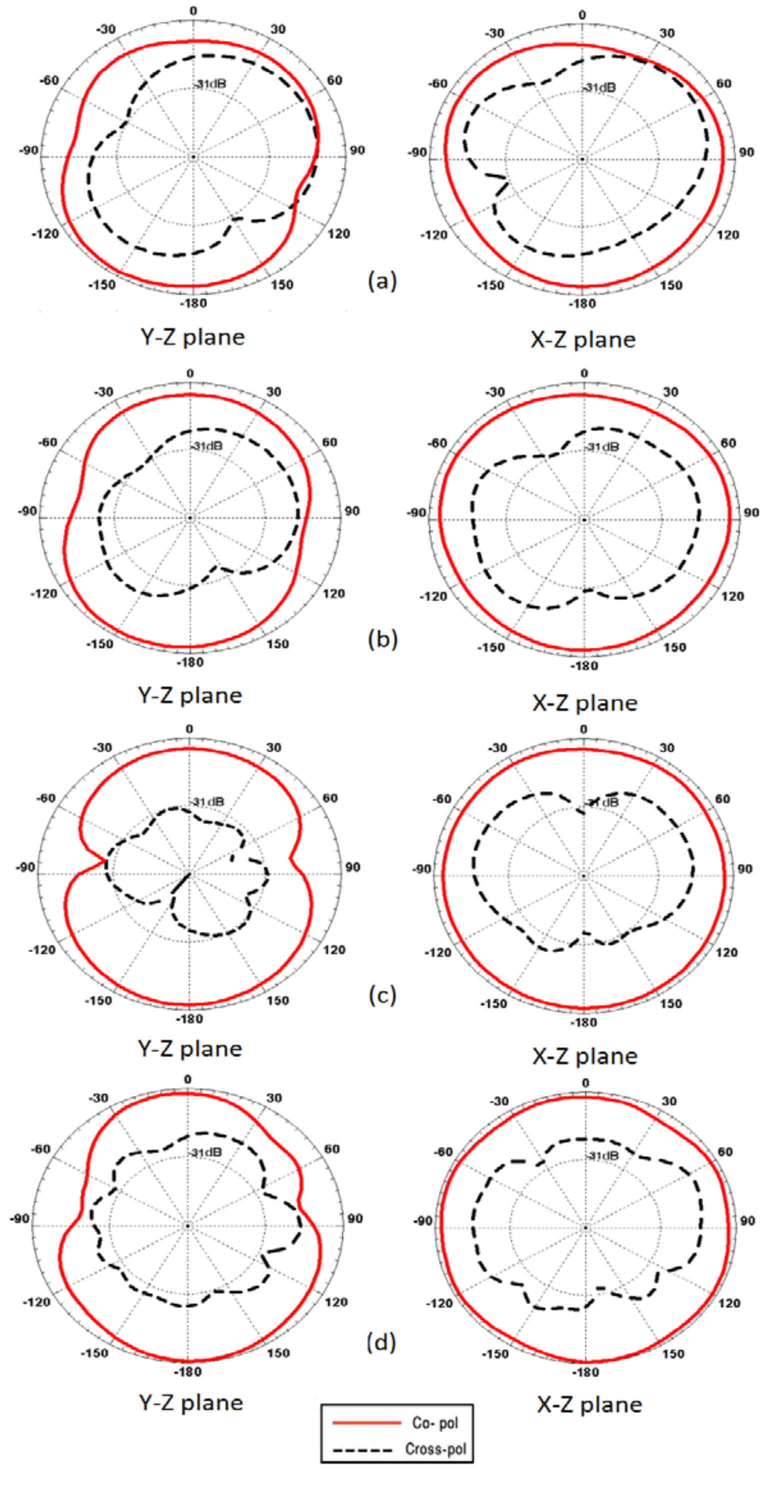

Figure 6. The radiation pattern of the proposed antenna at: (a) 2.4 GHz; (b) 3.7 GHz; (c) 5.4 GHz; and (d) 6 GHz. Solid line: co-polarization; dashed line: cross-polarization

CONCLUSION

In this article, a novel printed monopole antenna with a very compact size for satisfying WLAN operations at the 2.4/5.2/5.8 GHz and also for WiMAX operations at the 3.5/5.5 GHz has been presented. By using of a pair of mirror r-shaped slots on the conductor-backed plane with proper values, a good impedance matching and improvement in bandwidth can be achieved, especially at the lower bands. The proposed antenna with proper dimensions and aforementioned characteristics with good omnidirectional radiation characteristics, enough impedance bandwidth, and reasonable gains can be suitable for various applications of the future developed WiMAX/WLAN technologies for handheld devices.

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