Progress In Electromagnetics Research Letters, Vol. 27, 63–73, 2011

DUAL-BROADBAND TWIN-PAIR INVERTED-L SHAPED STRIP ANTENNA FOR WLAN/WIMAX APPLICATIONS

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Abstract—A simple and novel printed monopole antenna with dual broad operating bands is presented. The antenna fed by a 50-Ω microstrip line is composed by dual twin-pair inverted-L shaped strips as well as a small back truncated ground. By properly selecting widths of these inverted-L shaped stripes, dual broad bandwidths formed from triple resonances to meet the band requirement of the 2.4/5.2/5.8 WLAN or the 2.5(3.5)/5.5 GHz WiMAX standard can be achieved. Experimental results for case of the obtained antenna prototype suitable for use in a 2.4/5.2/5.8 GHz WLAN system have been done and shown good agreement with simulation. Good radiation performances including dual wide bandwidths of 270 MHz and 3.16 GHz, high average antenna gains of $\geq$ 2.6 and 4.6 dBi, and monopole-like radiation patterns over the two operating bands, respectively, make this antenna a good candidate for use in the modern dual-broadband wireless communication system.

1. INTRODUCTION

Design of a simple and compact antenna with a broadband or multiband function for simultaneously integrating more than one communication standard into a single system has become an increasing demand for enhancing the mobile performance of a modern portable wireless communication device. For this, one interesting candidate seems belong to the planar antenna, especially the printed

Received 13 September 2011, Accepted 7 October 2011, Scheduled 26 October 2011
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prototypes. It has been reported that this kind of antenna can be designed as various types such as the inverted-F antennas [1, 2], the coplanar waveguide (CPW)-fed antennas [3–7], and the microstrip-line-fed antennas [8–14] for broad- or multi-band operation, which is suitable for two multiband wireless communication systems such as 2.4/5.2/5.8 GHz (2.4–2.484/5.15–5.35/5.725–5.825 GHz) wireless local area network (WLAN) and the 2.5, 3.5/5.5 GHz (2.5–2.69, 3.4–3.69/5.25–5.85 GHz) worldwide interoperability for microwave access (WiMAX). However, most of these designs are either complex in antenna structure or large in antenna size for practical applications. The difficulty in designing a simple and compact antenna with a broadband or multiband function still challenges engineers when the complexity and size of the antenna's structure reduce and the bandwidths of operating frequency bands increase.

In this paper referring the prototypes reported in works [12, 13], we propose a printed antenna design with a simpler structure and a more compact size for dual-broadband operation. The design is basically a prototype of groundbacked strip monopole fed by a microstrip line. From properly selecting the dimensions of the strip radiators, the microstrip feedline, and the ground plane, triple resonances accompanying with dual broad impedance bandwidths and good radiation characteristics suitable for the 2.4/5.2/5.8 GHz WLAN or the 2.5, 3.5/5.5 GHz WiMAX communication system can be effectively achieved.

2. ANTENNA DESIGN

Figure 1 presents the geometrical configuration of the proposed dual-broadband antenna design. The antenna was printed on a low-cost and easy-acquirement FR4 epoxy substrate with relative permittivity 4.4 and substrate thickness 1.6 mm. Its structure is practically simple and symmetrical with respect to the longitudinal direction (i.e., z-direction). For the radiator, it comprises dual twin-pair folded strips and each of the dual has two symmetrical inverted-L-shaped strips. For dominantly exciting the first (lowest) resonance, we arranged each of the upper-pair strips with a longer length than that of the lower-pair strips. Therefore, the lower two symmetrical strips have shorter lengths aimed for use to produce the higher-frequency resonance. Meanwhile, on this design if the upper- and lower-pair strips are both close enough, additional resonances may be caused from the coupling effect between them. Thereafter, we fed the strip radiator with a microstrip-line and printed a rectangular ground plane on another side against these radiators. To obtain the geometrical dimensions

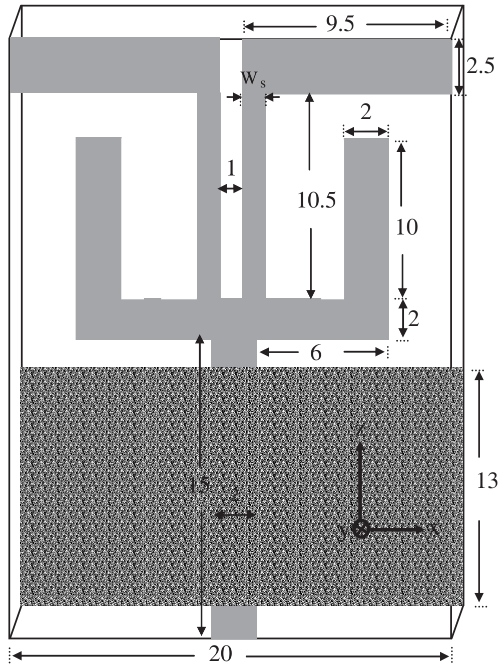


Figure 1. Geometrical configuration of the proposed dualbroadband microstrip-fed strip antenna for WLAN/WiMAX application (dimensions in mm).

of the proposed antenna with optimal dual-broadband operation, the electromagnetic solver, IE3D, was applied for required analysis in the antenna's impedance characteristic. Via iterative trials, finally, the optimal geometrical values for the strips, the feedline, and the ground plane were all obtained and as those denoted in Figure 1. The overall size of the proposed antenna, including the ground plane, is only $20 \times 30\,\mathrm{mm}^2$, which has a size reduction of about 31%, comparing to the reported antenna with the similar function [10].

3. THEORETICAL RESULTS AND DISCUSSION

The simulated frequency response of return-loss for the proposed antenna was shown in Figure 2, denoted as curve (ii). Clearly, triple-mode resonances with dual broad operating bands have been excited at 2.45, 4.75 and 6 GHz. The obtained impedance bandwidth (10-dB return loss) of the lower operating band reaches 180 MHz (2.34–2.52 GHz), whereas that of the upper operating band is about 3.12 GHz

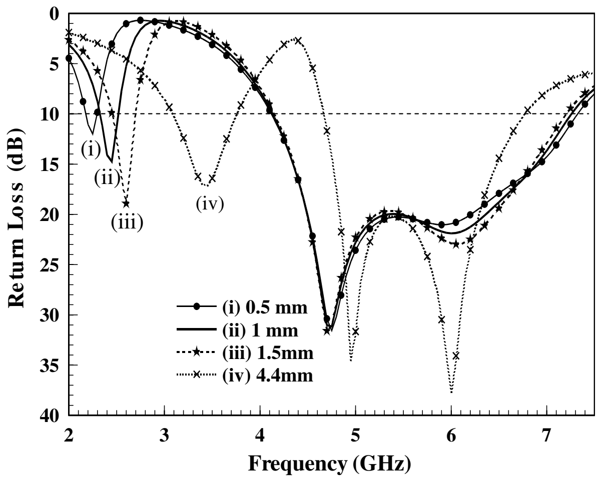


Figure 2. Simulated return losses for proposed antenna with varying strip width w_s, other parameters are the same as shown in Figure 1.

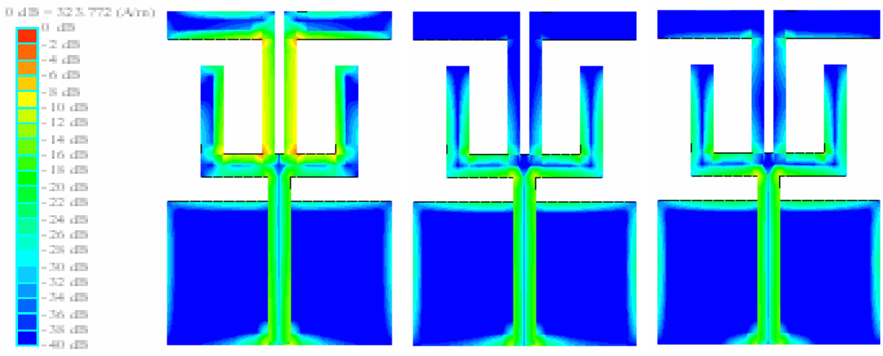


Figure 3. Simulated surface current distributions for proposed antenna ($w_s = 1$ mm) at (a) 2.45, (b) 4.75, and (c) 6 GHz.

(4.14–7.26 GHz) due to that the two higher resonant modes are as close as to fuse together and thus form a continuous wide bandwidth of about 3.12 GHz. Obviously, the dual bandwidths obtained theoretically are sufficient to cover the required operating bandwidths of the 2.4/5.2/5.8 GHz WLAN or the 5.5 GHz WiMAX standards. To further examine the mechanism of mode excitation of the proposed design, the surface current distributions on the proposed antenna ($w_s = 1$ mm) when operating at the three main resonant frequencies were therefore investigated and presented in Figure 3. When operating at the first resonant frequency, 2.45 GHz, it is seen that most current density is concentrated on the upper-pair longer strips, whereas at the second resonant frequency (i.e., 4.75 GHz), a significant current flow along the lower-pair shorter strips is found. In addition, when operating at 6 GHz, large current distribution is not only observed along the lower-pair inverted-L shaped strips, but also along the upper-pair strips' edges near the lower-pair strips. These results clearly indicate that the first (lowest) and the second resonances are dominated by the upper- and the lower-pair strips, respectively, whereas the third (highest) resonance is excited from the coupling effect between the lower- and the upper-pair strips. Based on this, we therefore tuned the strip widths (denoted as w_s) of the vertical sections for the upper-pair strips to see how the first (lowest) resonance is affected. The analyzed results for case of $w_s = 0.5$, 1.5, and 4.4 mm were also added into Figure 1 for convenient comparison with the previous case of $w_s = 1$ mm, which, as discussed before, is the proposed design suitable for use in a 2.4/5.2/5.8 GHz WLAN system. Clearly, with an increase in the width w_s the first resonant frequency is moved toward the higher band, while for most of these cases, no significant frequency shift happens to the two higher resonances except for some change in matching condition. Also note that when selecting w_s to be 1.5 and 4.4 mm, the produced bandwidths, denoted as curves (iii) and (iv), respectively, will fully cover the bandwidth requirement of the 2.5/5.5 and the 3.5/5.5 GHz WiMAX system. Meanwhile, according to the surface current distribution on the proposed antenna as shown in Figure 3, it has been seen that large current density is concentrated on the vertical section of each of the dual twin-pair inverted-L shaped strips. For this, we thus examined the tuning effect on the proposed antenna's input impedance by respectively tapering the widths of the vertical sections of the antenna's shaped strips. Figure 4 presents the simulated results of return-loss against frequency by linearly tapering each vertical width of the upper twin-pair inverted-L strips from 1 mm (i.e., w_s) to $w_u = 1$, 2, 3, 4, and 5 mm. The other geometrical dimensions are kept the same as those shown in Figure 1. Note that the case of $w_u = 1$ mm is the proposed optimal design for 2.4/5.2/5.8 WLAN application, as shown in Figure 1. Apparently, the lowest resonant mode is moved toward the higher frequency when w_u getting larger, whereas both the two higher dominant modes are only slightly affected on matching condition. The effect is resulted due to that when increasing w_u the effective electric current path, which is along the edge of each upper strip, will be shortened to thus move the resonance to a higher frequency. As for the tuning effect of linearly tapering each vertical width for the lower twin-pair inverted-L strips from 2 mm to w_d was also analyzed and shown in Figure 5. Varying w_d from 2 to 5 mm with an increment of 1 mm, not only the second resonant mode is shifted to the higher frequency as w_d increases, but also the highest resonance is defected due to the increased coupling effect between the upper-pair and the lower-pair inverted-L shaped strips.

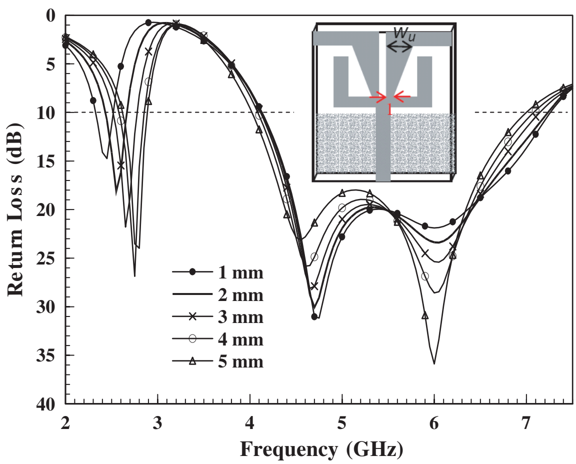


Figure 4. Simulated return losses for proposed antenna with varying tapered-strip width w_u, other parameters are the same as shown in Figure 1.

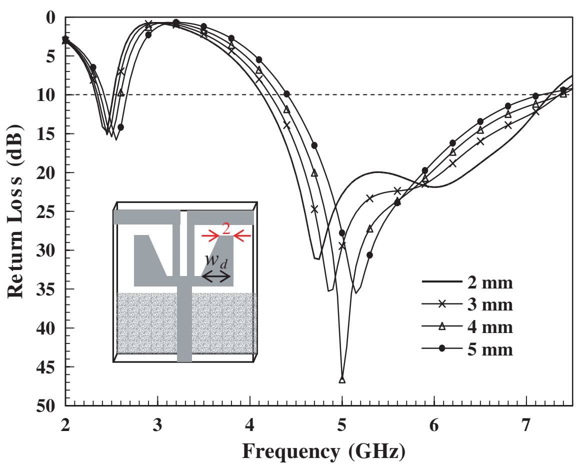
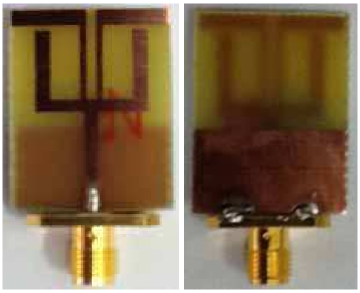


Figure 5. Simulated return losses for proposed antenna with varying tapered-strip width w_d, other parameters are the same as shown in Figure 1.



(a) (b)

Figure 6. Photograph of the fabricated dual-broadband strip antenna with $w_u = w_s = 1\,\text{mm}$ and $w_d = 2\,\text{mm}$, (a) top view, (b) bottom view.

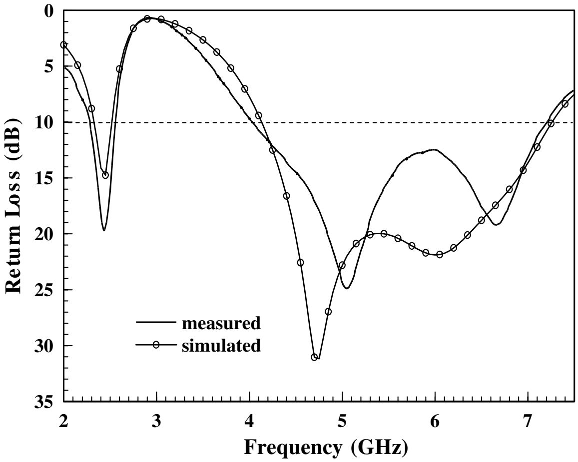


Figure 7. Measured and simulated return losses of proposed dual-broadband strip antenna.

4. EXPERIMENTAL RESULTS

The prototype of the proposed antenna for 2.4/5.2/5.8 GHz WLAN application, case of curve (ii) in Figure 2 (i.e., $w_u = w_s = 1\,\text{mm}$ and $w_d = 2\,\text{mm}$), was constructed and experimentally investigated. Figure 6 presents the photograph of the fabricated dual-band antenna. The results of the measured and simulated return losses against frequency for this design are shown in Figure 7. The measurement shows dual 10-dB wide impedance bandwidths of 270 MHz (2.29–2.56 GHz) and 3.16 GHz (4.04–7.2 GHz) at the lower and the upper bands, respectively. Their percent bandwidths are about 11% and

63% with respect to the two dominant frequencies, 2.43 and 5.05 GHz, of the two available operating bands. Agreement between the simulation and measurement seems good beyond a frequency deviation at the two higher resonant frequencies. This difference may mainly be caused by fabrication tolerances due to the uncertainty of the thickness and/or the dielectric constant of the substrate. The far-

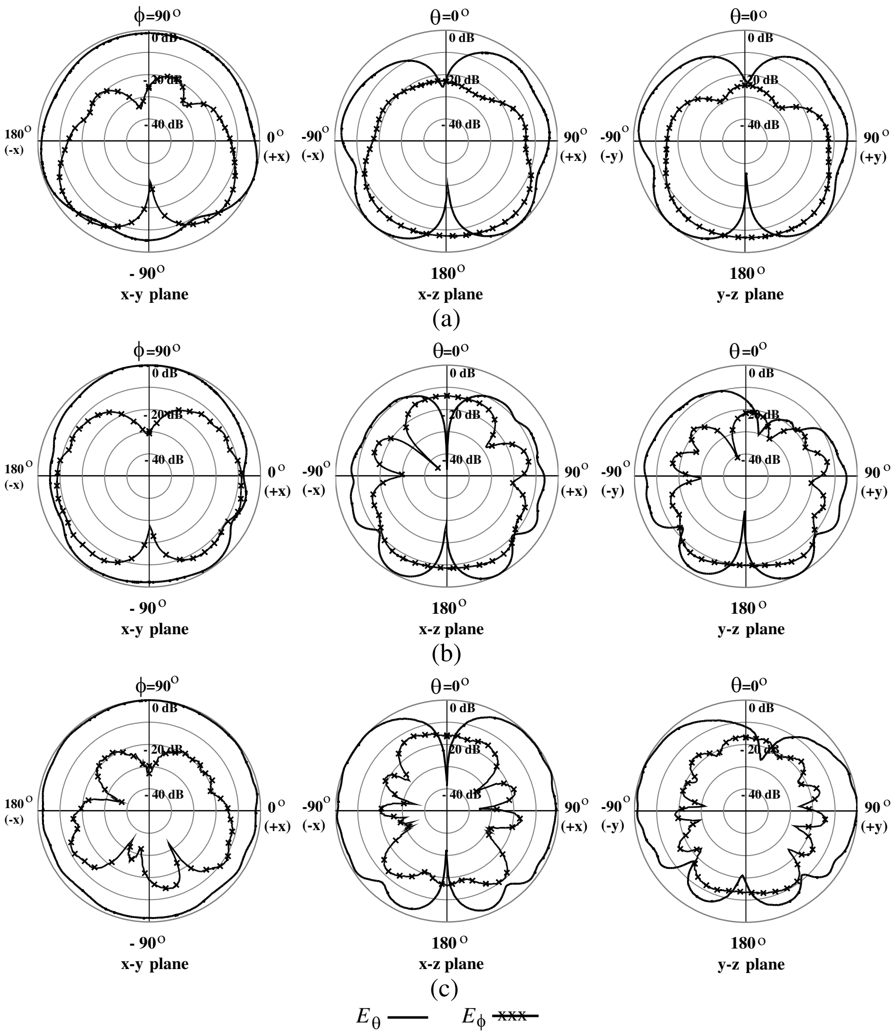


Figure 8. Measured radiation patterns for proposed antenna (a) $f = 2.43\,\text{GHz}$, (b) $f = 5.05\,\text{GHz}$, (c) $f = 6.66\,\text{GHz}$.

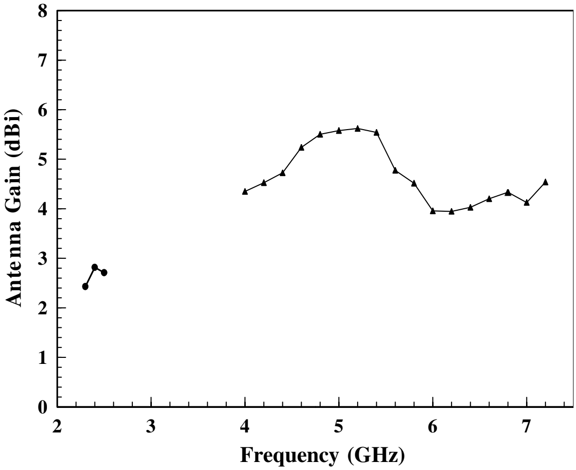


Figure 9. Measured antenna peak gains across the lower and upper bands for proposed antenna.

field radiation characteristics when operating at the three measured dominate resonant frequencies, 2.43, 5.05, and 6.66 GHz, for the proposed 2.4/5.2/5.8 GHz WLAN antenna have also been measured. Figure 8 presents the co- and cross-polarization patterns in the azimuth cut (x-y plane) and the elevation cuts (x-z and y-z planes). In general, a typical monopole-like pattern, which shows a near omin-directional pattern in the x-y plane and similar conical radiations in the x-z and y-z planes, for each operating frequency has been obtained. It should be noted that measurements at other operating frequencies across the bandwidth of each band show radiation patterns similar to those plotted here. Finally, Figure 9 shows the measured peak antenna gain for frequencies across the two operating bands. The antenna provides an average gain of about 2.6 dBi (2.4–2.8 dBi) and 4.6 dBi (3.9–5.6 dBi) for the lower and upper band, respectively

5. CONCLUSIONS

A simple dual-broadband antenna based on the microstrip-fed monopole prototype for WLAN- or WiMAX-band operation has been designed, and a prototype is successfully constructed and experimentally investigated. By properly arranging both the length and width of the dual twin-pair inverted-L shaped strips, sufficient bandwidths and suitable radiation characteristic can be easily obtained for simultaneous use in a 2.4/5.2/5.8 GHz WLAN or a 2.5(3.5)/5.5 GHz WiMAX system.

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