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COMPACT TRIPLE-BAND MONOPOLE ANTENNA WITH C-SHAPED AND S-SHAPED MEANDER STRIPS FOR WLAN/WIMAX APPLICATIONS

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Abstract—A novel CPW-fed triple-band monopole antenna designed by embedding an S-shaped meander strip into a C-shaped strip is proposed for WLAN and WiMAX applications. The antenna with a very simple and compact structure is easy to be fabricated, and the prototype of the proposed antenna has been constructed and measured. The triple operating bands with 10- dB return-loss bandwidths of about 110 MHz centered at 2.45 GHz, 310 MHz centered at 3.55 GHz, and 39% ranging from 4.1 to 6.2 GHz, covering the required bandwidths of 2.4/5.2/5.8 GHz WLAN and 3.5/5.5 GHz WiMAX standards, are obtained. In addition, good radiation performance and antenna gain across the three frequency ranges have been obtained.

1. INTRODUCTION

The rapid development of the modern wireless communication system leads to a great demand for novel, multiband and compact antennas. Since the latest decade, Wireless Local-Area Network (WLAN) and Worldwide Interoperation for Microwave Access (WiMAX) technologies have been widely applied in mobile devices such as handheld computers and intelligent phones. To adapt to the complicated and diverse WLAN and WiMAX environments, therefore, the antennas in these devices should provide stable operations at multiple frequency bands, which cover 2.4/5.2/5.8 GHz WLAN and 3.5/5.5 GHz WiMAX bands. In addition, because of the limited equipment space of WLAN/WiMAX devices, the requirements for antenna with low-profile, light weight, easy integration with system

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circuit as well as high performances make the research and design of multiband antennas a new trend. Several promising dual and multiband planar antenna designs have already been proposed for WLAN/WiMAX applications such as a split-ring monopole antenna [1], a symmetrical G-shaped monopole antenna [2], a CPW-fed dual rectangular ring monopole [3], a CPW-fed monopole antenna with a L-strip for higher band and a meander strip for lower band [4], a four-element printed dipole array with bidirectional high gain performance [5], a U-slot antenna with radial stub feeding [6], a disc-slit monopole planar antenna with a meander feed line [7], a compact dual-band antenna with a square slot and a circular slot [8], a rhombic patch monopole antenna applied with a technique of fractal geometry [9], and a S-shaped monopole antenna with two different strips in length [10]. Although the antennas mentioned above are able to satisfy the WLAN or WiMAX standards, some of them either have large sizes and complex structures, which are not practical for mobile devices, or have narrow bandwidths and fail to cover certain required frequency bands.

In this article, we demonstrate a novel S-shaped meander strip monopole antenna embedded into a C-shaped strip for 2.4/5.2/5.8 GHz WLAN and 3.5/5.5 GHz WiMAX operations. The antenna is fed by a CPW structure so that a simple single-metallic layer is needed, which is able to decrease the complexity of the antenna structure. In addition, the antenna can be easily integrated into active devices or MMICs. Details of the antenna design are described in the article, and both simulated and measured results are presented. The measured results show good agreement with the simulated ones.

2. ANTENNA DESIGN

The basic geometry and dimensions of the proposed antenna are shown in Fig. 1. The antenna is designed and fabricated on a 1.6 mm-thick FR4 substrate, with relative permittivity 4.6 and the dimension of $29 \times 20\,\mathrm{mm}^2$. A 50-$\Omega$ CPW transmission line that consists of a signal strip width 3.6 mm and a pair of gaps with distance of 0.4 mm between the signal strip and the coplanar ground plane is applied to feed the antenna. In this design, the proposed antenna consists of an S-shaped meander strip and a C-shaped strip. The shorter strips (L_5 and L_4) control the upper operating band of the designed antenna, with central frequency of 5 GHz. On the other hand, a portion (L_3) of the S-shaped strip forms the middle resonant frequency of the proposed antenna, which achieves the 3.5 GHz WiMAX application. Furthermore, the coupling effects of the longer strips (L_1 and L_2) have

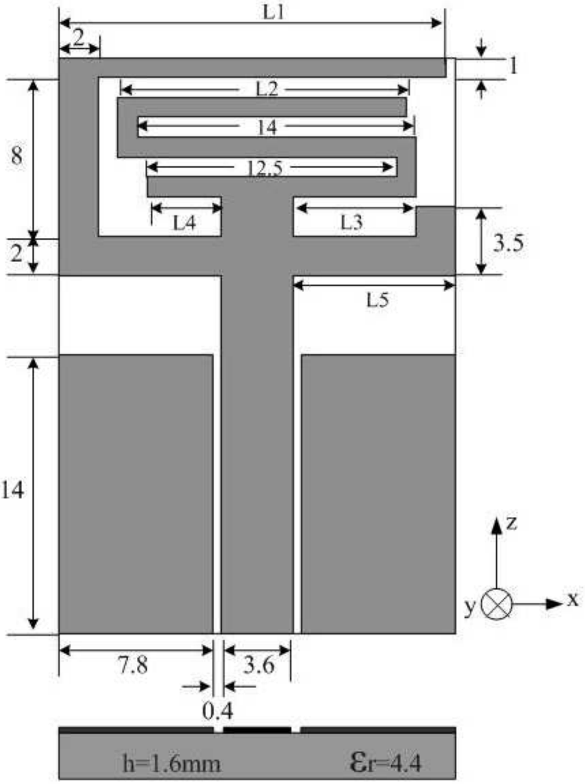


Figure 1. Geometry and dimensions of the proposed antenna (in mm).

a significant influence on the lower operating band. Therefore, the lower band (2.4–2.484 GHz) operation can be achieved by adjusting the dimensions of the two longer strips (L_1 and L_2). To investigate the performance of the proposed antenna configuration, the commercially available simulation software of Ansoft HFSS was used for the required numerical analysis and to obtain the proper geometrical parameters. The prototype of the printed monopole antenna has been fabricated and its photo is shown in Fig. 2. The geometric parameters were adjusted carefully and, finally, the optimal parameters for the proposed configuration are obtained as follows: $L_1 = 19.5\,\mathrm{mm}$, $L_2 = 14.5\,\mathrm{mm}$, $L_3 = 6.2\,\mathrm{mm}$, $L_4 = 3.7\,\mathrm{mm}$, and $L_5 = 8.2\,\mathrm{mm}$. The width of the S-shaped strip is 1 mm and other parameters are described in Fig. 1.

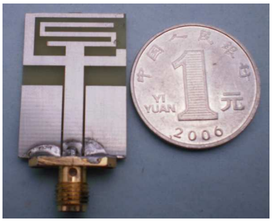


Figure 2. Photograph of the proposed antenna.

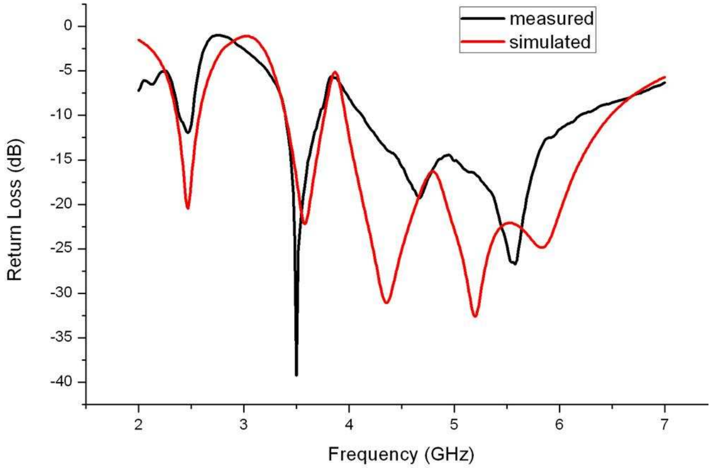
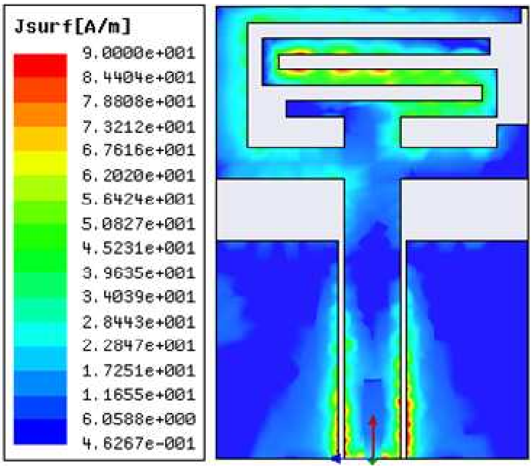


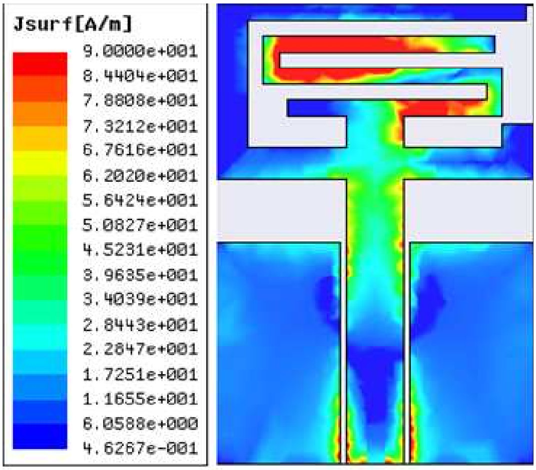
Figure 3. Measured and simulated return loss curves of the proposed antenna.

3. RESULTS AND DISCUSSIONS

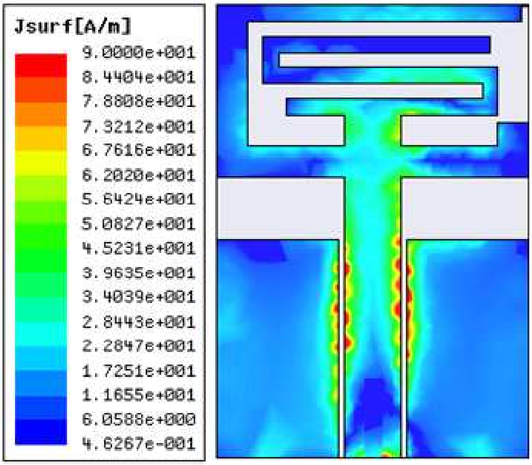
The prototype of the proposed antenna has been constructed and experimentally studied. The measurement was made with a WILTRON 37269A vector network analyzer. The simulated and measured return loss curves are presented in Fig. 3, respectively. From the results, it can be seen that several resonate modes are excited at 2.4, 3.5, 4.5, and 5.5 GHz, which cover the required WLAN and WiMAX bands. The 10 dB bandwidths in the lower and middle bands reach 0.11 GHz (2.39–2.5 GHz) and 0.31 GHz (3.4–3.71 GHz), respectively, which meet the demands for 2.4 GHz WLAN and 3.5 GHz WiMAX applications. For the upper band, an impedance bandwidth of 2.1 GHz (4.1–6.2 GHz), or about 39% referred to the center frequency at 5 GHz, which is sufficient to cover the 5.2/5.8 GHz WLAN and 5.5 GHz WIMAX bands, is obtained. To explain more details on the excited resonant modes of the proposed antenna, the simulated surface current distributions at different resonant frequencies (2.4, 3.5, and 5.5 GHz) are shown in Fig. 4. For the 2.4 GHz excitation, larger surface current distribution is observed on the longer path along the S-shaped and C-shaped strips, which suggests that these longer parts of the strips are the major radiating elements at the 2.4 GHz bands. For the 3.5 GHz operation, strong surface current distribution on the S-shaped meander strip indicates that the S-shaped meander strip is the major radiating element at the 3.5 GHz band. In addition, from



(a) 2.4 GHz



(b) 3.5 GHz



(c) 5.5 GHz

Figure 4. Simulated surface current distributions on the proposed antenna at (a) 2.4 GHz, (b) 3.5 GHz, and (c) 5.5 GHz.

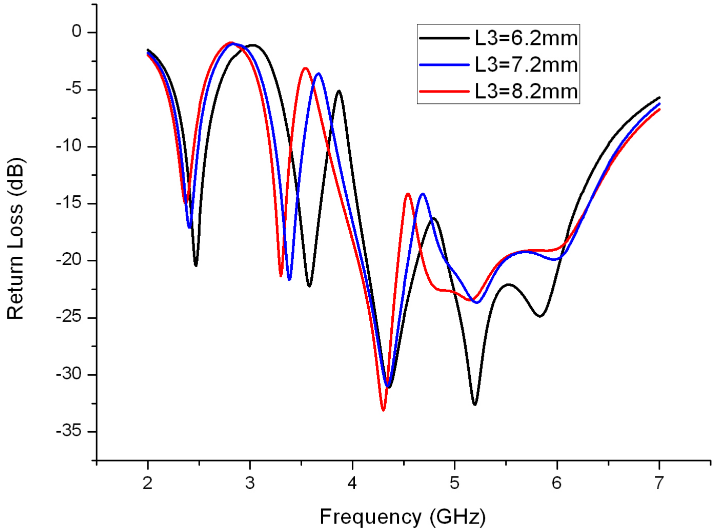
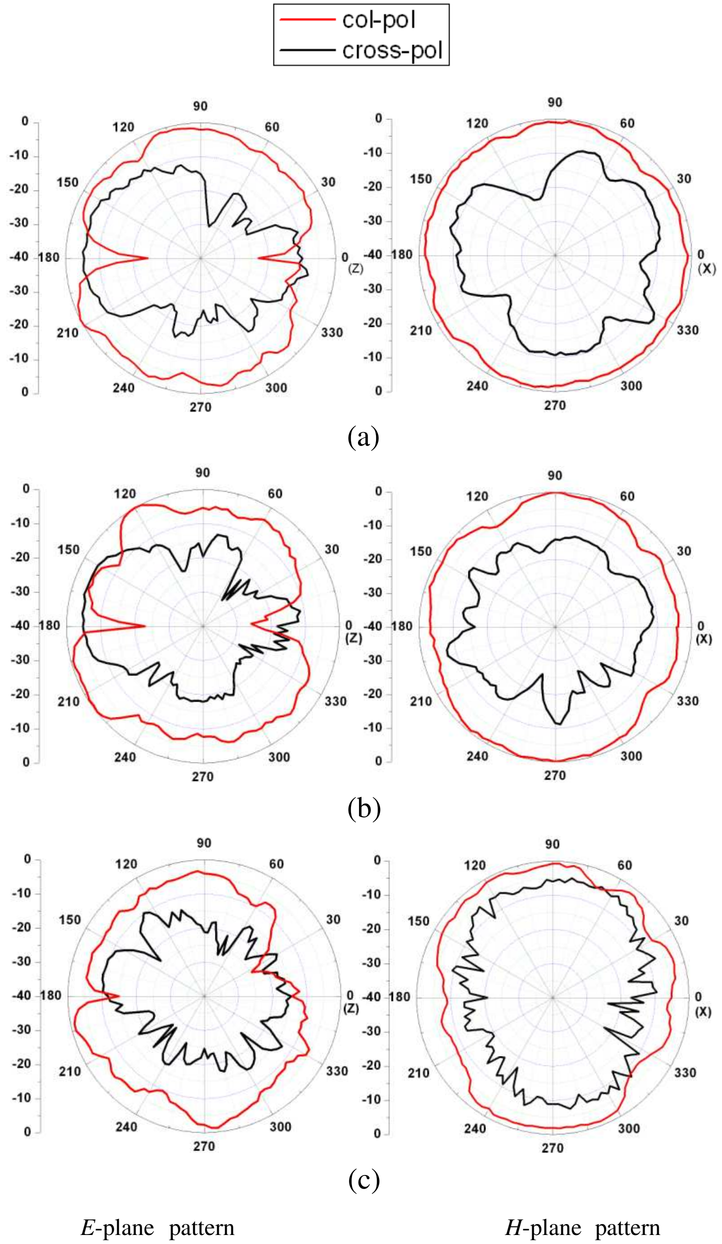


Figure 5. Simulated return loss curves of the proposed antenna for different strip length L_3 (other parameters are the same as in Fig. 1).

the concentrated surface current distribution on the connected part of the two strips, we know that the connected part, acting as the major radiating element, makes the antenna working at 5.5 GHz bands successfully.



(a)

(b)

(c)

Figure 6. Measured radiation patterns of the proposed antenna: (a) 2.45 GHz, (b) 3.5 GHz, and (c) 5.5 GHz.

The effects of the strip length L_3 of the S-shaped strip on the impedance matching of the proposed antenna have been studied. The simulated return loss curves with different strip length of L_3 are shown in Fig. 5. It shows that with the increase of the length L_3, the middle resonate frequency shifts down, while the bandwidth of the upper band changes slightly. Since the strip length L_3 is a part of the S-shaped strip, it also influences the lower band and makes the 2.4 GHz resonate band move to lower resonate band a bit. For the middle and lower bands, increasing the length of L_3 will effectively lengthen the current path, which turns the resonant frequencies at 2.4 and 3.5 GHz.

The far-field radiation patterns of both co-polarization and cross-polarization at the frequencies of 2.45, 3.5, and 5.5 GHz have also been measured and shown in Fig. 6. It can be obviously noticed that the nearly omnidirectional radiation in the H plane (x-y plane) and bidirectional radiation in the E plane (x-z plane) are obtained, which show a monopole-like radiation pattern. The peak gains for frequencies throughout the matching bands are also measured and the results are shown in Fig. 7. The obtained average gains are 2.8 dBi (2.75–2.85 dBi), 3.23 dBi (3.183.27 dBi) and 3.6 dBi (3.4–3.8 dBi) for the 2.4, 3.5 and 5.5 GHz operating bands, respectively. Finally, Fig. 8 shows the measured radiation efficiency of the fabricated prototype. Obviously, in the 2.4, 3.5, and 5.5 GHz bands, the radiation efficiencies are better than 89%, 83%, and 74%, respectively.

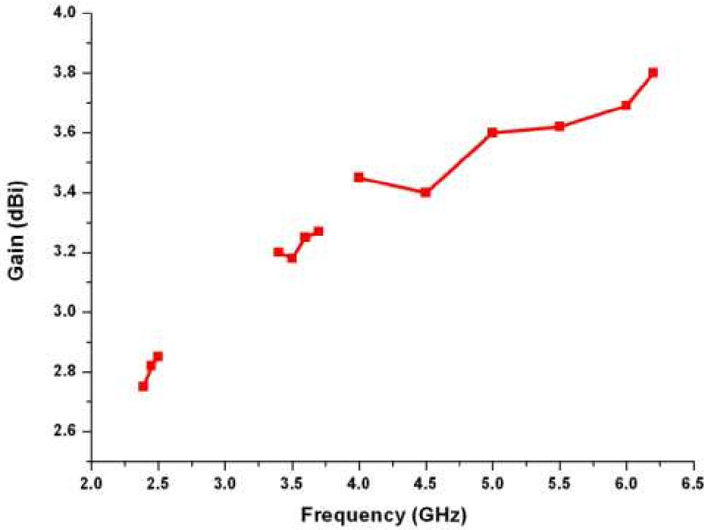


Figure 7. Measured antenna gains of the proposed antenna.

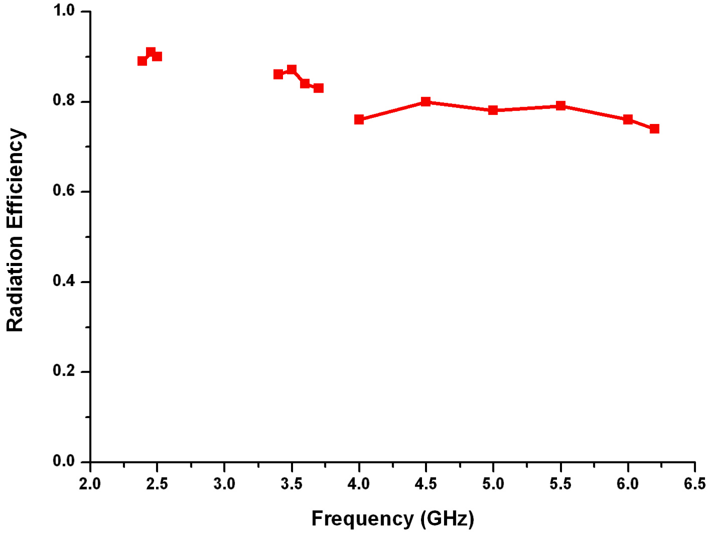


Figure 8. Measured radiation efficiency of the proposed antenna.

4. CONCLUSION

A compact single-layer CPW-fed monopole antenna designed by simply embedding an S-shaped strip into a C-shaped strip bas been presented. The prototype has been constructed and measured. The measured results show a good agreement with the simulated ones. With an antenna size of only $29 \times 20\,\text{mm}^2$, including the ground plane, multiresonance performance having triple operating bands to satisfy the WLAN 2.4/5.2/5.8 GHz and WiMAX 3.5/5.5 GHz applications is achieved. Due to the good radiation pattern performance and stable gain in required bands, the proposed antenna has wide and promising applications for wireless communication systems.

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