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Triple-Band CPW-Fed Monopole Antenna for WLAN/WiMAX Applications

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Abstract—In this letter, a new coplanar waveguide (CPW)-fed monopole antenna with equilateral-triangular shape is presented and experimentally investigated. The structure under study generates three different center frequencies corresponding to the lower, middle, and upper bands for Wireless Local Area Networks (WLAN) and worldwide interoperability for microwave access (WiMAX) applications. The proposed antenna is analyzed using the Computer Simulation Technology (CST) Software. To validate the simulation results, an experimental prototype of the proposed design is fabricated, tested and measured. The experimental results show a good agreement with the simulated ones.

1. INTRODUCTION

To support various services using modern wireless communication systems, antennas with multi-band operation are required [1]. For this purpose, multi-band antenna designs have been proposed with various configurations [2]. The printed monopole antennas with coplanar waveguide (CPW) feeding mechanism have become very important to researchers for their advantages, such as less dispersion, easy implementation of shunt circuits, absence of via holes [3], and ease of integration with active devices or monolithic microwave integrated circuits (MMIC) [1–4].

Recently, in wireless communication systems, many applications, such as WLAN (Wireless Local Area Network), require dual or multi-frequency operation that meets the standards of 2.4 GHz/5.2 GHz/5.8 GHz [5] and the World Interoperability for Microwave Access (WiMax) operating at 3.5 GHz WiMAX IEEE 802.16 (3.4–3.6 GHz) [6]. For this reason, different multi-band antennas have recently been proposed [7–9]. For instance in [7], two frequency bands have been achieved by adding L- and E shaped elements together with a dual-band compact radiator planar antenna. This design covers only the WLAN bands. To cover several services at different operating frequencies, triple-band antennas are required. For this purpose, several triple-band antenna designs have widely been reported in the literature [8, 9]. In this paper, a triple-band monopole antenna is developed for WLAN and WiMAX applications. In the same perspective, we propose in this letter a CPW-fed antenna with three-band operation and a smaller size compared to the antennas presented in [8, 9].

In the next section, the topology and design of the proposed antenna are presented. In Section 3, measurement results are presented and compared with simulated ones. Finally, conclusions are given in Section 4.

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2. ANTENNA DESIGN AND FABRICATION PROCESS

2.1. Structure and Dimensions

The geometry of the proposed antenna is shown in Fig. 1. The form of the antenna is an equilateral triangular monopole of length Wr, printed on the Rogers (RO4003) substrate with dielectric constant $\varepsilon_r = 3.55$, loss tangent $\tan\delta = 0.027$. Two equal finite ground planes, with length Lg and width Wg are placed symmetrically on either side of the CPW feed-line. The overall size of the substrate is $Ls \times Ws$ with a thickness of h, and the rectangular aperture, whose dimensions are $La \times Wa$, is inserted into the radiated element to obtain the second frequency. A pair of symmetrical L-shaped parasitic elements, with a length Lp, is added to realize the third frequency.

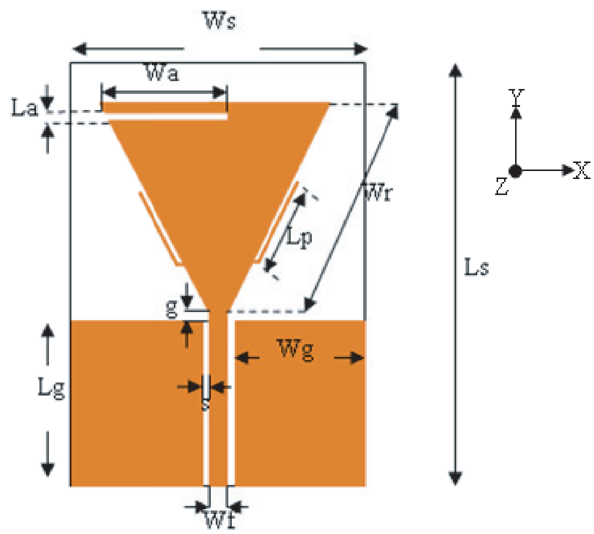


Figure 1. Configuration of proposed antenna.

A $50\,\Omega$ CPW transmission line is used for feeding the antenna to provide good performance over all the bands, which consists of a signal strip with width of Wf, centered and connected with SMA (Sub-Miniature version A) connector at the end of the CPW feed line. The parameters g represents the gap between the signal strip and coplanar ground plane. The basis of the antenna is an equilateral triangular monopole of width Wr. The design of the antenna was optimized using CST Microwave Studio commercial [10]. The optimized parameters of the proposed monopole antenna are listed in Table 1.

Table 1. Parameters of the proposed antenna.

Parameters	Value (mm)	Parameters	Value (mm)
Ls	40	La	0.8
Ws	36	Wa	12
h	1.52	Wf	2.5
Lg	14.4	Lp	6.75
Wg	16.53	g	0.1
Wr	25.5	S	0.22

2.2. Evolution of the Antenna Design

The evolution of the antenna design and its corresponding simulated reflection coefficients are presented in Fig. 2 and Fig. 3, respectively.

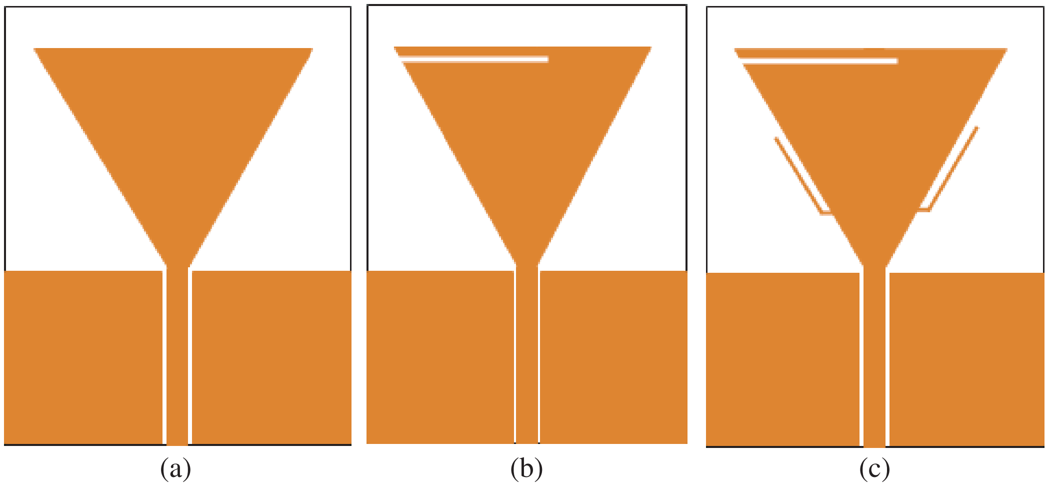


Figure 2. Design evolution of the proposed antenna; (a) antenna I, (b) antenna II, (c) proposed antenna.

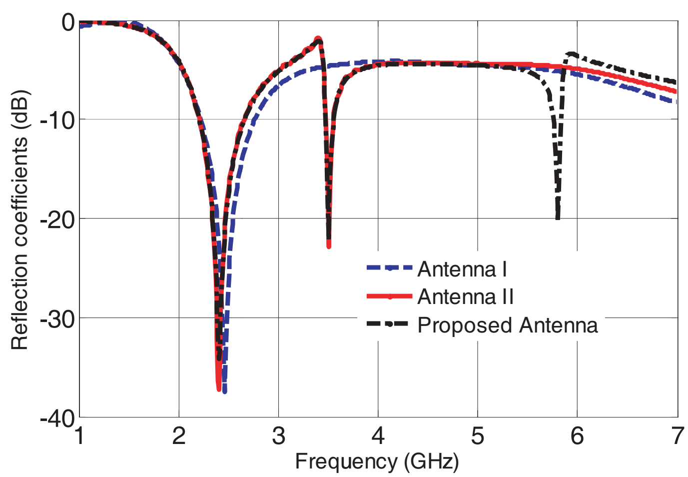


Figure 3. Simulated reflection coefficients of various antenna design.

Antenna I: A triangle monopole antenna excited by CPW as shown in Fig. 2(a) is firstly designed to generate one operating wide band around 2.21 GHz–2.76 GHz.

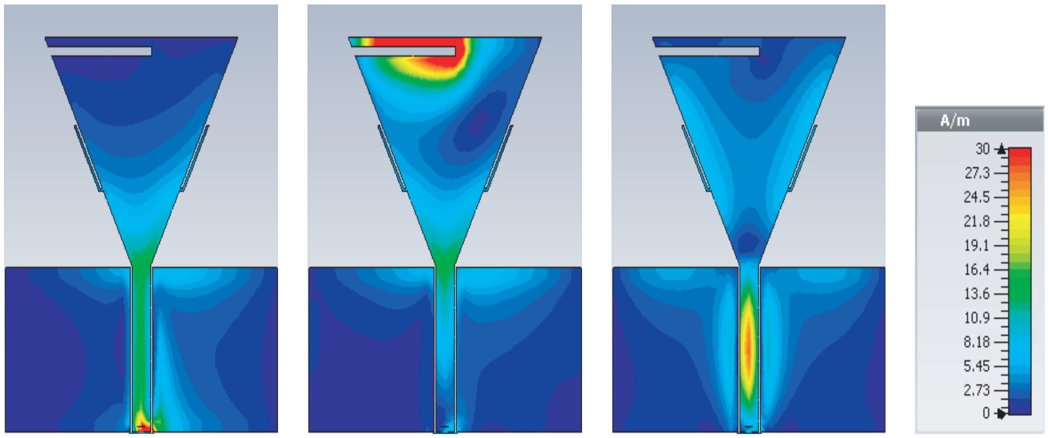
Antenna II: A rectangle-shaped aperture is etched on a triangular patch as illustrated in Fig. 2(b) to create two bands that cover from 2.20 GHz to 2.65 GHz and 3.47 GHz to 3.55 GHz.

Proposed Antenna: Afterwards, two inverted L-shaped parasites are added to antenna II to complete the final design of the proposed antenna as shown in Fig. 2(c).

From the results shown in Fig. 3, it can be seen that three separate working bands are obtained, covering from 2.20 GHz to 2.65 GHz, 3.47 GHz to 3.55 GHz, and 5.75 GHz to 5.83 GHz.

2.3. Current Distributions

The simulated surface currents on the final design antenna at 2.4 GHz, 3.5 GHz and 5.8 GHz are depicted in Fig. 4. From Fig. 4(b), it can be seen that the current surface distribution, at frequency 3.5 GHz, is concentrated on the rectangular slot while Fig. 4(c) indicates that the current is mainly distributed at the pair of symmetrical L-shaped parasites for the third resonant frequency 5.8 GHz.



(a) (b) (c)

Figure 4. Surface current distribution of proposed antenna at (a) 2.4 GHz, (b) 3.5 GHz, (c) 5.8 GHz.

3. MEASURED RESULTS AND DISCUSSION

The proposed triple-band monopole antenna was designed and simulated by CST Microwave Studio commercial software, which is based on the finite integration technique (FIT). After the optimizing of the antenna parameters, an experimental prototype of the final design was fabricated and tested. A photograph of the fabricated antenna is shown in Fig. 5. The measurements on the fabricated antenna were carried out using Agilent 8722ES Network Analyzer. In addition, the measurements of radiation characteristics, including the radiation patterns and peak gains, were carried out in an anechoic chamber.

Figure 6 illustrates the comparison between the simulated and measured reflection coefficients S_{11} of the proposed antenna. The measured results clearly indicate that the proposed antenna provides three bands. The first band is about 500 MHz (2.33–2.83 GHz). Moreover, the second and third bands have

Figure 5. Fabricated prototype of the proposed antenna.

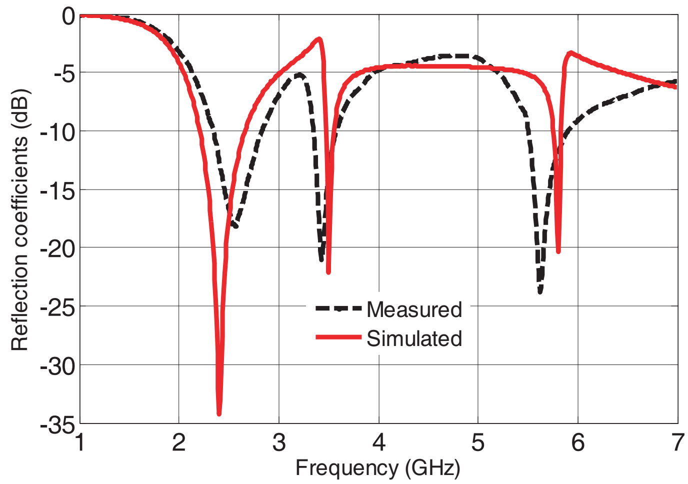
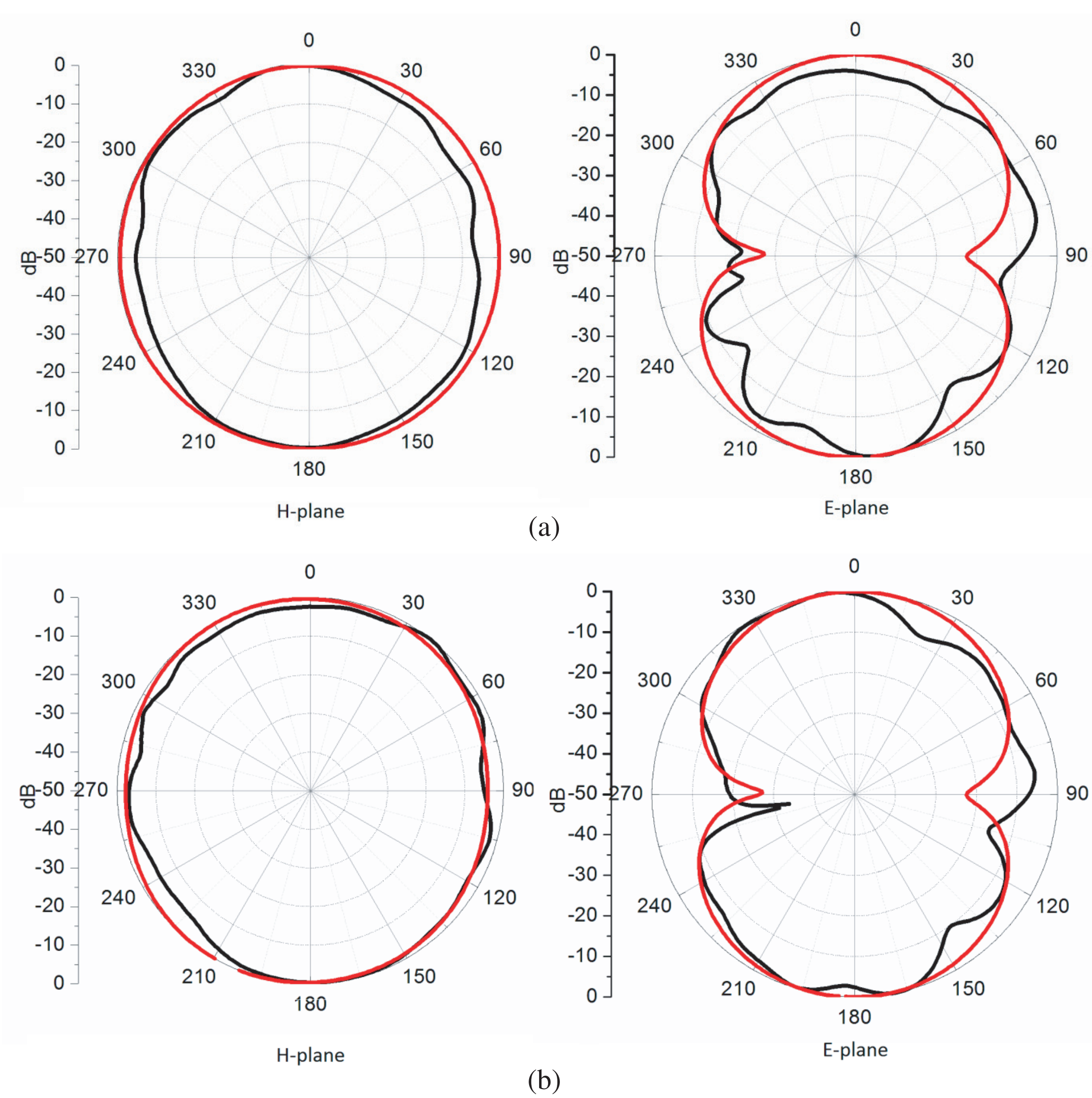
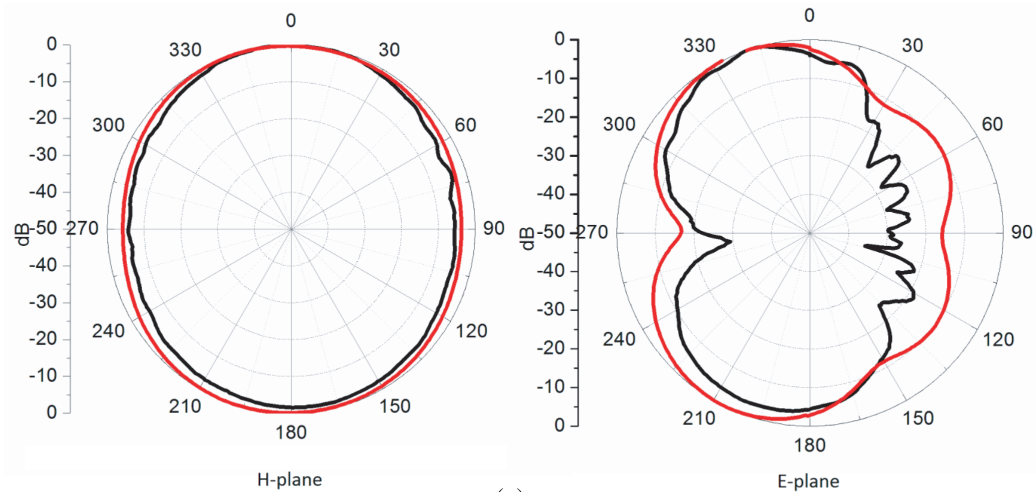


Figure 6. Simulated and measured reflection coefficient of proposed tri-band antenna.





(c)

Figure 7. Radiation patterns of the proposed antenna at (a) the first band, (b) the second band, (c) the third band. Dark lines for measurement and light lines for computation.

impedance bandwidths (for $S_{11} < -10\,\mathrm{dB}$) of 250 MHz (3.34–3.58 GHz) and 400 MHz (5.5–5.9 GHz), respectively. From this figure, it is clear that the simulated and measured results show a reasonable agreement. The small discrepancy is due to the fabrication tolerance. With these performances, the proposed antenna satisfies the requirements of WLAN and WiMAX applications concurrently.

Figure 7 shows the plot of the simulated and measured radiation patterns in the E-plane (xy) and H-plane (yz) at three operating frequencies. Measured results agree well with the simulated ones. From these curves, it can be concluded that the proposed antenna exhibits omnidirectional radiation patterns in the H-plane and a quite bi-directional form in the E-plane for all operating frequencies. A slight deformation of the expected pattern is noted for the third frequency band, which could be caused by the higher order modes.

The measured peak gains for the three bands (Band 1, Band 2 and Band 3) are summarized in Table 2. It is obvious that the measured gain ranges between 2 and 2.98 dB within the whole working bands. The gain of the proposed antenna meets the requirement of some wireless communication applications.

Table 2. Measured gain for the tri-band antenna.

Frequency Band	Gain (dB)
Band 1	2.1
Band 2	2
Band 3	2.98

4. CONCLUSION

A triple-band coplanar waveguide (CPW)-fed patch antenna with an etched rectangular slot and a pair of symmetrical L-shaped parasitic elements has been designed and fabricated for wireless applications. Measured and simulated results demonstrate that the proposed antenna can achieve three desired operating bands, higher isolation characteristic between adjacent bands, and stable gains. A good omnidirectional radiation in the H-plane has also been achieved. Finally, three operating bands of 2.33 GHz–2.83 GHz, 3.34 GHz–3.58 GHz, and 5.5 GHz–5.9 GHz have been obtained, which is very promising for practical WLAN/WiMAX applications.

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