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Compact Triple-Band Monopole Antenna with Inverted-L Slots and SRR for WLAN/WiMAX Applications

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Abstract—A compact coplanar waveguide-fed tri-band monopole antenna for WLAN/WiMAX applications is proposed. By employing a pair of inverted-L slots etched on the ground plane and a split-ring resonator (SRR) and further carefully adjusting the lengths and positions of these structures, two notched bands can be obtained. Measured results show that a tri-band of 280 MHz (2.28–2.56 GHz), 920 MHz (3.29–4.21 GHz), and 860 MHz (5.05–5.91 GHz) with reflection coefficient less than −10 dB is obtained covering all the 2.4/5.2/5.8 GHz WLAN bands and 3.5/5.5 GHz WiMAX bands. In addition, good dipole-like radiation characteristics over the required bands is achieved in both E- and H-planes.

1. INTRODUCTION

With the wide application of wireless local area network (WLAN: 2.4–2.484 GHz, 5.15–5.35 GHz, and 5.725–5.825 GHz) and worldwide interoperability for microwave access (WiMAX: 3.4–3.69 GHz and 5.25–5.85 GHz) technologies in wireless communication systems, the antenna with multiband operations has drawn the antenna engineers' attention. Planar multiband monopole antenna is a good candidate to supply fast wireless access for multiband communication systems because of light weight, low profile, low cost, and compact size. Recently, amounts of planar multiband antennas have been already proposed. To generate multiband resonant modes, various branch strips or slots are employed to meet the desired bands [1–6], such as circular-arc-shaped strips [1], inverted U-shaped slot [2], L-shaped slots [3], inverted T-shaped stub [4], L-shaped strips [5], and a triangular patch as well as two folded shorter arms [6]. In [7], three inverted L-shaped strips used to obtain resonances at 2.4, 3.5 and 5.5 GHz, the structure of the proposed antenna is simple but the bandwidth is necessary to be improved. In the design of [8], the proposed antenna with a dual-layer metallic structure has good triple-band characteristics for WLAN/WiMAX applications. In [9], two asymmetric radiated loops are used to implement multiband modes. However, complicated structures of the proposed antennas make them hard for practical application. Two pairs of complementary capacitively loaded loop slots etched on the radiating element are introduced to achieve three distinct resonant modes in [10]. Obviously, the large size ($70 \times 78.5\,\mathrm{mm}^2$) of the antenna is the main drawback for integrating with portable devices.

In this letter, a compact CPW-fed tri-band monopole antenna for WLAN/WiMAX applications is proposed. By employing inverted-L slots and SRR, two notched bands of 2.54 to 3.13 GHz and 4.22 to 4.93 GHz are achieved. The simulation and analysis for the proposed antenna are performed using the electromagnetic simulator ANSYS HFSS 13, which is based on the finite-element method. Details of the antenna design and measured results are presented and discussed.

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2. ANTENNA DESIGN

The geometry of the proposed antenna is shown in Fig. 1. The proposed antenna is fabricated on an FR4 dielectric substrate with a compact size of $23 \times 38 \times 1.6\,\mathrm{mm}^3$, a relative permittivity of 4.4, and a loss tangent of 0.02. A coplanar waveguide transmission line is introduced to feed the antenna, and the width of the signal strip and the gap between the signal strip and the ground plane are respectively fixed at 1.9 mm, 0.3 mm for 50-Ω characteristics impedance. The design of the proposed antenna can follow three steps. Firstly, the antenna with only circular ring radiator defined as Ant 1 is designed to obtain a wide bandwidth from 2.46 to 6.27 GHz, and the corresponding reflection coefficient curve is shown in Fig. 2. Secondly, a pair of inverted-L slots etched on the ground plane is introduced to implement a notched band at 2.8 GHz for dual-band operation. Tuning the dimensions of the inverted-L slots, a dual-band from 2.26 to 2.55 GHz and 3.19 to 5.88 GHz is obtained. Thirdly, loading a split-ring resonator can generate the upper notched band at 4.7 GHz, and the proposed antenna creates triple-band operation at the 2.4/5.2/5.8 GHz WLAN bands and 3.5/5.5 GHz WiMAX bands. The optimised dimensions of design parameters shown in Fig. 1 are as follows (unit: mm): $W = 23$, $L = 38$, $Wf = 1.9$, $s = 0.3$, $Lg = 16$, $W1 = 6.8$, $L1 = 10$, $s1 = 0.3$, $d = 2.3$, $g = 1.5$, $r1 = 9.9$, $r2 = 7.1$, $r3 = 5.7$, $rd = 1.4$, $rs = 0.5$, $t = 0.5$, $h = 1.6$.

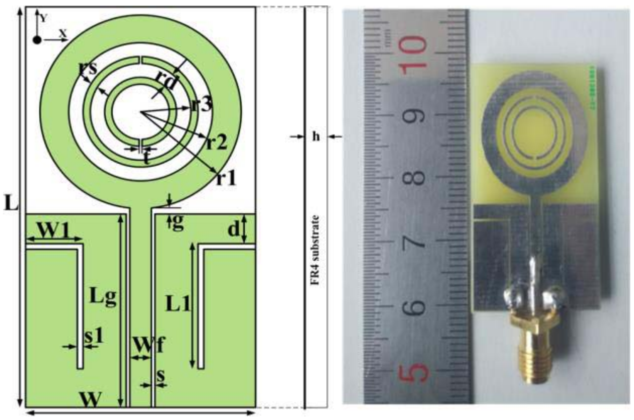


Figure 1. Configuration and photograph of the proposed antenna.

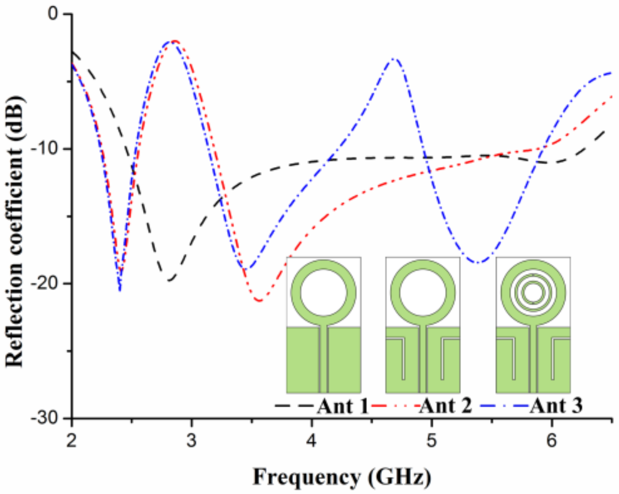
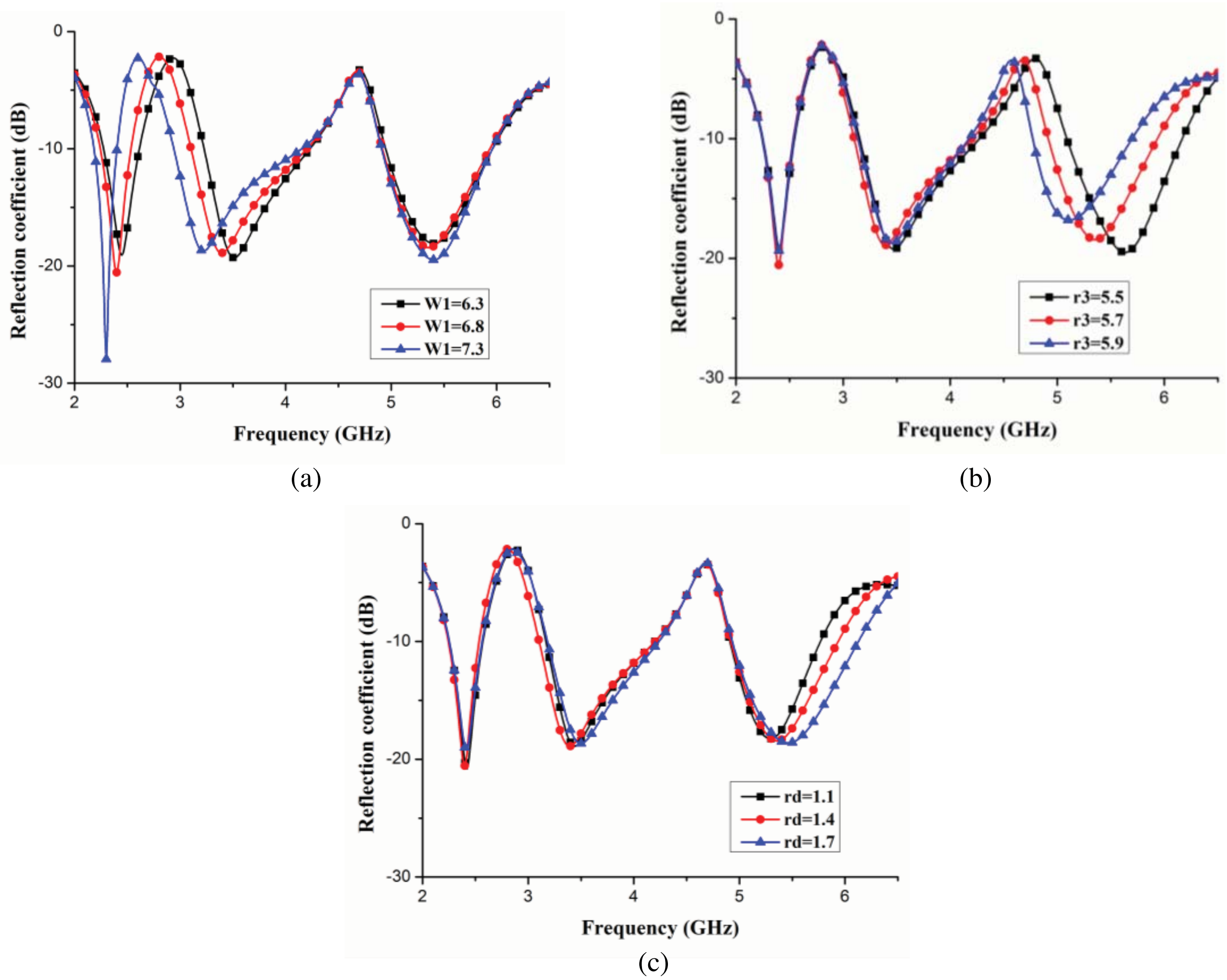


Figure 2. Simulated reflection coefficients of various antennas involved.

3. PARAMETRIC ANALYSIS

The proposed antenna with two notched bands is designed by etching inverted-L slots on the ground plane and loading a split-ring resonator. Figs. 3(a), (b) and (c) show the simulated reflection coefficients of the proposed antenna with various parameters of $W1$, $r3$ and rd, respectively. As indicated in Fig. 3(a), we can see that the lower notched band shifts towards the lower frequency with the increase of $W1$. Adjusting the length of the inverted-L slot can easily control the centre of notched band, and the total length $(W1 + L1 = 16.8\,\mathrm{mm})$ of the inverted-L slot is about a quarter guided wavelength at 2.8 GHz. Fig. 3(b) shows the simulated reflection coefficients of the proposed antenna with various $r3$. It can be seen that as $r3$ increases from 5.5 to 5.9 mm in increments of 0.2 mm, the centre of upper notched band shifts down. Meanwhile, the upper operating band shifts down, too. In Fig. 3(c), as the distance rd between the two split rings increases, the bandwidth in the upper operating band increases significantly which indicates that the distance rd is an important factor in broadening the bandwidth of the upper operating band.

Figure 4 shows the surface current distributions on the proposed antenna at different frequencies. As can be seen, the current distributions focus mainly on the circular ring radiator at 2.4, 3.5 and 5.4 GHz

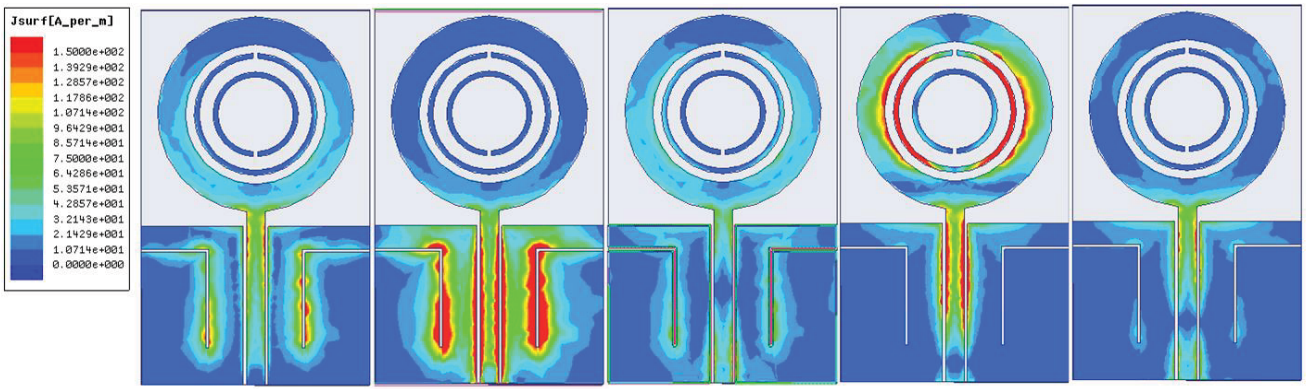


(a)

(b)

(c)

Figure 3. Simulated reflection coefficients of the proposed antenna with various parameters of (a) $W1$, (b) $r3$ and (c) rd.



(a)

(b)

(c)

(d)

(e)

Figure 4. Current distributions of the proposed antenna at (a) 2.4, (b) 2.8, (c) 3.5, (d) 4.7 and (e) 5.4 GHz.

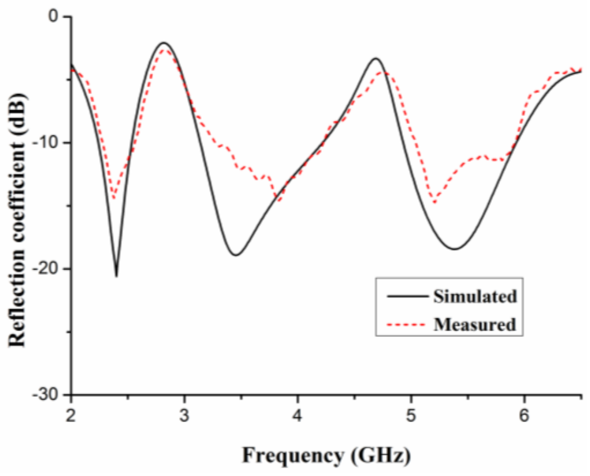
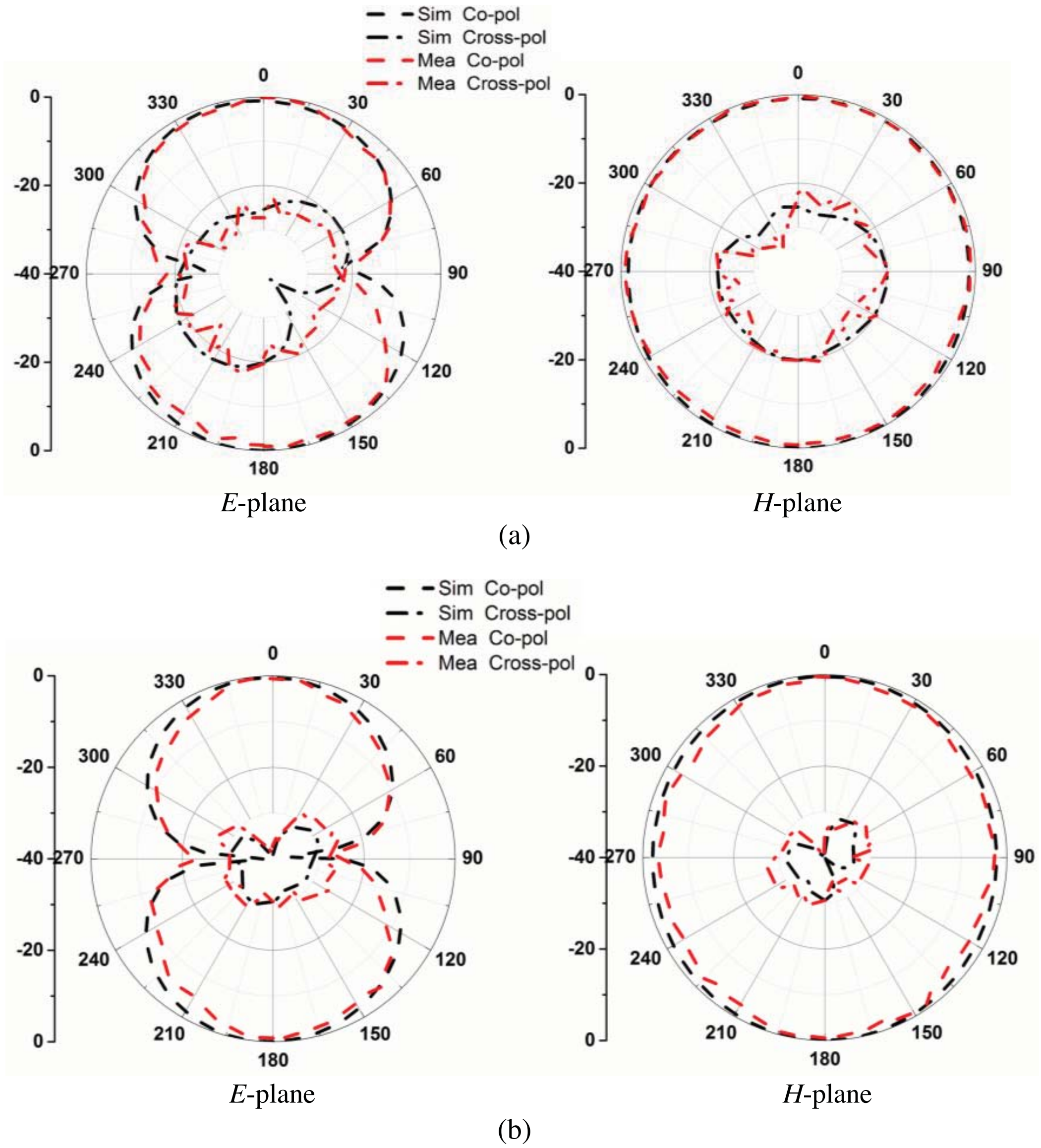


Figure 5. Simulated and measured reflection coefficients of the proposed antenna.

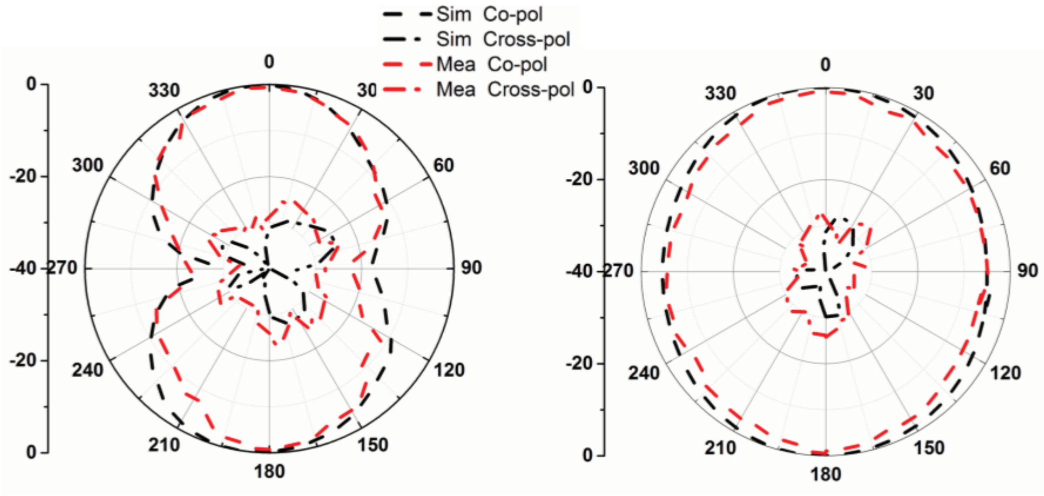


E-plane *H*-plane

(a)

E-plane *H*-plane

(b)



E-plane

H-plane

(c)

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

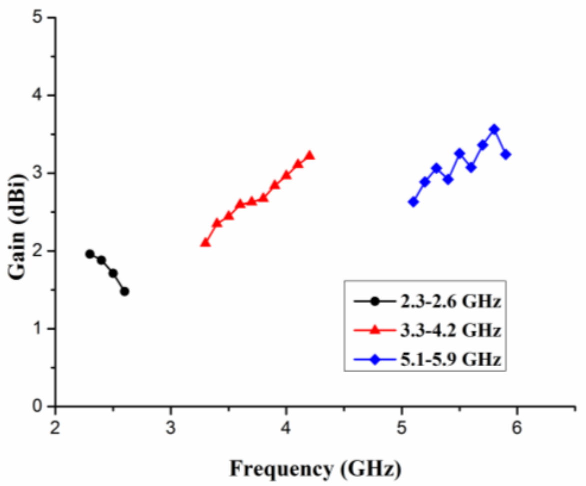


Figure 7. Measured gains of the proposed antenna.

while on the inverted-L slots and the SRR at 2.8 and 4.7 GHz, respectively, which further illustrates that the inverted-L slots and the SRR works well at the rejected frequencies. As is well known, the inverted-L slot and the split-ring resonator work as resonators at rejected frequencies, causing serious impedance mismatching of the proposed antenna, the antenna cannot radiate electromagnetic energy outside in the notched bands.

4. RESULTS AND DISCUSSION

A prototype of the proposed antenna based on the optimised dimensions is fabricated and tested, and the photograph of the prototype is shown in Fig. 1. The measurement is carried out by WILTRON 37269A vector network analyzer. Fig. 5 shows the simulated and measured reflection coefficients of the proposed antenna. It can be seen that there is a good agreement between the simulated and measured results. The measured 10-dB bandwidths of 280 MHz (2.28–2.56 GHz), 920 MHz (3.29–4.21 GHz), and

860 MHz (5.05–5.91 GHz) can cover all the 2.4/5.2/5.8 GHz WLAN bands and 3.5/5.5 GHz WiMAX bands.

The measured and simulated far-field normalised radiation patterns at 2.45, 3.5 and 5.5 GHz are exhibited in Fig. 6. It is clear that the proposed antenna expresses good dipole-like radiation patterns in the E-plane and omnidirectional radiation patterns in the H-plane in all operating bands. Also, the cross-polarization levels in the E-plane and H-plane are less than -15 dB and -20 dB, respectively. Fig. 7 shows the measured peak gains of the proposed antenna. We can see that the peak gains vary from 1.48 to 1.96, 2.1 to 3.22 and 2.63 to 3.56 dBi in the operating bands, respectively.

5. CONCLUSION

A compact tri-band monopole antenna for WLAN and WiMAX applications is proposed in this letter. The proposed antenna consists of a circular ring radiator, a pair of inverted-L slots and a split-ring resonator. The antenna has a compact size of $23 \times 38\,\mathrm{mm}^2$. Measured results show that the proposed antenna can generate three distinct bands covering all the 2.4/5.2/5.8 GHz WLAN bands and 3.5/5.5 GHz WiMAX bands. Also, it shows good dipole-like radiation patterns in three bands. Consequently, the proposed antenna is a good candidate for practical WLAN and WiMAX applications.

REFERENCES

1. Zhai, H.-Q., Z.-H. Ma, and C.-H. Liang, "A compact printed antenna for triple-band WLAN/WiMAX applications," *IEEE Antennas Wirel. Propag. Lett.*, Vol. 12, 65–68, 2013.
2. Dong, X., Z. Liao, J. Xu, Q. Cai, and G. Liu, "Multiband and wideband planar antenna for WLAN and WiMAX applications," *Progress In Electromagnetics Research Letters*, Vol. 46, 101–106, 2014.
3. Chen, H., X. Yang, Y.-Z. Yin, S.-T. Fan, and J.-J. Wu, "Triband planar monopole antenna with compact radiator for WLAN/WiMAX applications," *IEEE Antennas Wirel. Propag. Lett.*, Vol. 12, 1440–1443, 2013.
4. Huang, S. S., J. Li, and J. Z. Zhao, "A novel compact planar triple-band monopole antenna for WLAN/WiMAX applications," *Progress In Electromagnetics Research Letters*, Vol. 50, 117–123, 2014.
5. Yoon, J.-H., "Triple-band cpw-fed monopole antenna with three branch strips for WLAN/WiMAX triple-band application," *Microw. Opt. Technol. Lett.*, Vol. 57, 161–166, 2015.
6. Huang, H.-F. and Y.-H. Hu, "A compact dual-band printed monopole antenna for WiMAX/ WLAN applications," *Progress In Electromagnetics Research Letters*, Vol. 49, 91–97, 2014.
7. Ellis, M. S., Z. Zhao, J. Wu, Z.-P. Nie, and Q. H. Liu, "A new compact microstrip-fed monopole antenna for triple band WLAN/WiMAX applications," *Progress In Electromagnetics Research Letters*, Vol. 48, 129–135, 2014.
8. Xu, Y., Y.-C. Jiao, and Y.-C. Luan, "Compact CPW-fed printed monopole antenna with triple-band characteristics for WLAN/WiMAX applications," *Electron. Lett.*, Vol. 48, No. 24, 1519–1520, 2012.
9. Peng, C.-M., I.-F. Chen, and J.-W. Yeh, "Printed broadband asymmetric dual-loop antenna for WLAN/WiMAX applications," *IEEE Antennas Wirel. Propag. Lett.*, Vol. 12, 898–901, 2013.
10. Si, L.-M., Q.-L. Zhang, W.-D. Hu, W.-H. Yu, Y.-M. Wu, X. Lv, and W.-R. Zhu, "A uniplanar triple-band dipole antenna using complementary capacitively loaded loop," *IEEE Antennas Wirel. Propag. Lett.*, Vol. 14, 743–746, 2015.