Progress In Electromagnetics Research C, Vol. 42, 165–175, 2013

SIMPLE PRINTED ANTENNA WITH PARASITIC ELEMENT FOR DVB-H, LTE/700 AND GSM HANDHELD TERMINALS

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Abstract—A simple wideband antenna with parasitic element is proposed in this paper. The printed antenna is comprised of an L-shape monopole and a parasitic element. By optimizing geometrical parameters of the parasitic element structure, a good impedance bandwidth which covers DVB (470 MHz∼702 MHz) for return loss being higher than 5 dB and LTE/700 (704 MHz∼787 MHz), GSM850/900 (824 MHz∼894 MHz/880 MHz∼960 MHz) for return loss being higher than 10 dB is achieved. The protype of the antenna is in size of 150 mm × 56 mm. The measured and simulated efficiency, gain and radiation pattern which is quasi omni-directional in the *yoz* plane make it to be a good candidate of mobile communicational terminals.

1. INTRODUCTION

As the development of wireless communication proceeding, more and more applications (DVB system, LTE, and GSM.) have been added to a single handheld terminal. Digital Video Broadcasting-Handheld (DVB-H) system has been developing a lot in recent years because of its TV, movies, news and other public services for consumers [1]. As an evolution of the existing third-generation services, Long Term Evolution (LTE) provides enhanced performance in wireless communication system by offering data rates at least 100 Mb/s in the downlink and 50 Mb/s in the uplink on the movement [2]. The GSM850/900 is the common used wireless communication system. Because a quarter wavelength at 470 MHz is 160 mm, it is a difficult task to

Received 24 June 2013, Accepted 30 July 2013, Scheduled 2 August 2013
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design an antenna in small size operating simultaneously in DVB-H band (470 MHz∼702 MHz) and LTE/700 (704 MHz∼787 MHz), GSM850/900 (824 MHz∼894 MHz/880 MHz∼960 MHz). To achieve this function, a bandwidth of 69% must be realized. There exists many ways to effectively enhance the bandwidth. One method to effectively enhance the wide bandwidth is to add impedance matching circuit [3, 4]. The additional circuit would bring extra inserted loss and add the complexity of structure. Folded metal plate monopole with L-shape slit [5] is a method to obtain wide band. Also the sleeve monopole has been used to broaden the bandwidth [6–8]. The sleeve strip occupies main part of these antennas.

The structure of the fat dipole antenna with step-shaped feed gap [9] and multiple-ring monopole antenna with a sleeve-shaped ground plane [10] are also good to enhance bandwidth for DVB application. In [9], the antenna can create two adjacent resonant modes to generate a wide operating band of (470 MHz∼806 MHz) larger than 50% in 2.5 : 1 VSWR bandwidth. The size of the antenna is as large as 227 mm × 20 mm. In [10], a wide operating 2.5 : 1 VSWR bandwidth of 408 MHz between 463 MHz and 871 MHz is achieved. But the dimension of the antenna is as large as 261 mm × 26 mm. The DVB-H antenna with CRLH structure in size of 150 mm × 60 mm has been also reported in [11]. There exist three layers and one via in the antenna. The backside layer and the middle layer are two rectangle patches. The ground plane and two meander lines are etched on the front side. They composite a CRLH structure to broaden its operating band. The return loss is higher than 5 dB in the DVB-H band (474∼858 MHz) and is higher than 7.5 dB in the GSM-900 band (870∼960 MHz).

Parasitic element is a good candidate to improve operating bandwidth [12, 13]. In [12, 13], multiband operation can be achieved by a suitable the design of parasitic part. In this paper, the author presents a simple antenna structure, consisting of an L-shape monopole, a ground plane and a parasitic part being composed of a simple meander shorted strip and C-shape patch. With this parasitic part, the antenna has a wide bandwidth of 77% from 455 MHz to 1020 MHz. The return loss from 452 MHz to 600 MHZ is higher than 5 dB, and the return loss from 600 MHz to 1020 MHZ is higher than 10 dB. The overall antenna performances of the proposed antenna compare with the previous antennas [9–11] in Table 1. The design consideration of proposed antenna is shown. The simulated and measured result are also presented and discussed.

Table 1. Comparison results of proposed and reference antennas.

	This work	[9]	[10]	[11]
Operating band	455 MHz~1020 MHz	470 MHz~806 MHz	463 MHz~871 MHz	470 MHz~960 MHz
bandwidth	77%	52%	61%	68.5%
Gain (f_0)	3.1 dB	2.1 dB	2.7 dB	2.9 dB
size	150 mm× 56 mm	227 mm× 20 mm	261 mm× 26 mm	150 mm× 60 mm
Via process	Not required	Not required	Not required	required
layer	single	single	double	multi

2. ANTENNA DESIGN AND PARAMETERS STUDY

The configuration of the planar antenna structure is shown in Figure 1(a). The antenna is designed on FR4 substrate of size 150 mm × 56 mm, which has a constant dielectric of $\varepsilon_r = 4.4$ and

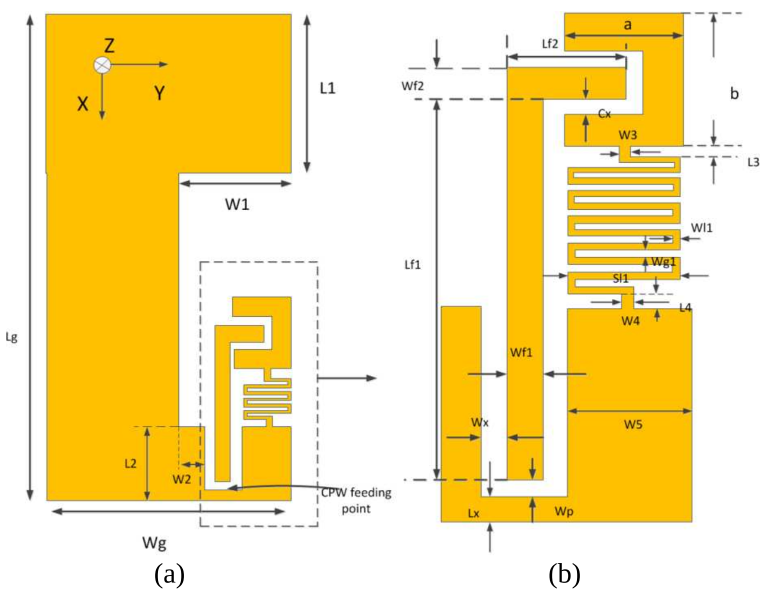


Figure 1. The configuration of the proposed antenna. (a) The overview. (b) The detail of parasitic element and L-shape monopole.

thickness of $h = 2.4$ mm. The ground plane, L-shape monopole, C-shape patch and meander shorted strip are printed on the front of proposed antenna. There is nothing on the backside of proposed antenna. The antenna is fed by CPW with its feeding point locating at the edge of the antenna. For careful view, the detail of the parasitic part and L-shape monopole is depicted in Figure 1(b). The parasitic element consists of C-shape patch and mender shorted strip. In consideration of practical application, the length of substrate is chosen as about 150 mm (a quarter wavelengths at 470 MHz). The L-shape monopole plays a role as a main radiator while the parasitic element is used to increase the current length. With the length of L-shape monopole (Lf_1) being 47 mm and turns (N) being 10, the total current length ($Lg + L_2 + 10 \times Sl_1 = 276.5$ mm) in Figure 2(a) creates half wavelength resonant mode at 470 MHz. The second current length ($Lg + wg = 206$ mm) in Figure 2(b) creates the half wavelength resonant mode at 625 MHz while the third current length ($0.3 \times lg + 10 \times Sl_1 + Lf_1 = 171.5$ mm) in Figure 2(c) creates the half wavelength resonant mode at 923 MHz. The width (Wl_1) of meandering strip is 0.5 mm. The turns (N) of meandering strip is 10. All the other parameters are listed in Table 2.

The parasitic part is utilized to create a lowest resonant frequency. The antenna without parasitic part is shown in Figure 3(a), while its performance does not cover the DVB-H band. The return loss of the antenna with and without parasitic element obtained by using Ansoft

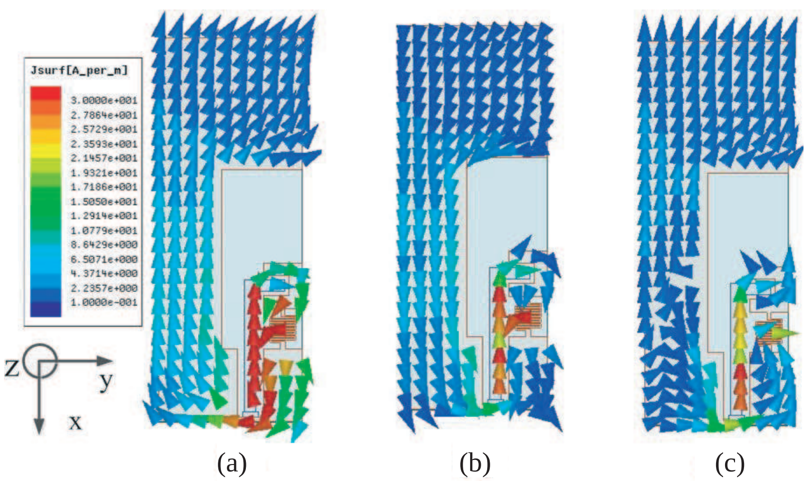


Figure 2. Surface current distribution at (a) 472 MHz, (b) 658 MHz, (c) 932 MHz.

Table 2. Geometrical parameters of the loaded antenna (unit: mm).

Lg	wg	W_1	L_1	W_2	L_2	W_3	L_3	W_4	L_4	W_5	L_x
150	56	31.4	51.5	6	26.5	1.5	2.5	2	2.5	15	2

Lf_1	Wf_1	Lf_2	Wf_2	a	b	Wl_1	Wg_1	Sl_1	C_x	Wp
47	4.4	15.2	4.5	16	18	0.5	0.5	10	1.6	2

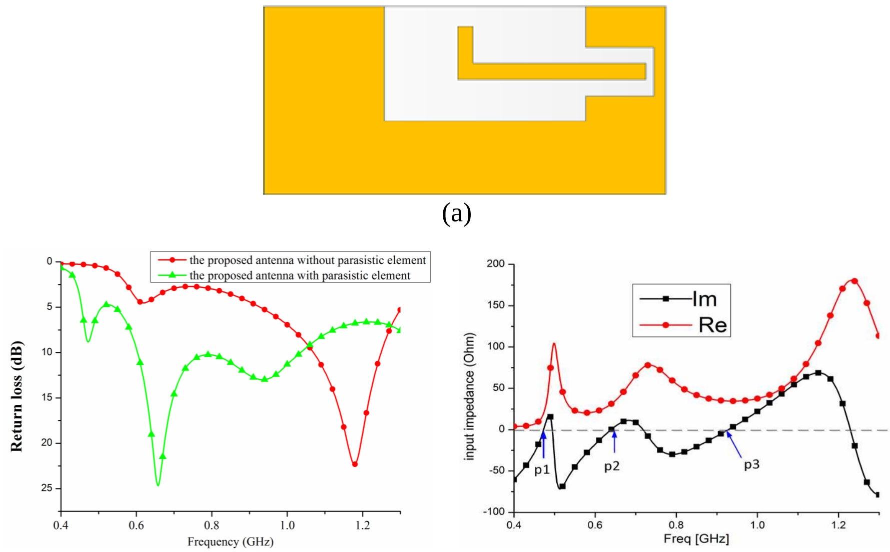


Figure 3. (a) Overview of the antenna without parasitic element. (b) The return loss of the proposed antenna with or without parasitic element. (c) Simulated input impedance for the antenna with parasitic element.

HFSS V13 shows in Figure 3(b).

As the Figures 3(b) and (c) shows, the proposed antenna with parasitic element has three resonant modes. The lowest resonant frequency about 472 MHz is obtained with the parasitic element, the second and third resonant mode are created by the initial structure whether the parasitic element exists or not. The parasitic element shifts the third resonant frequency of the antenna without parasitic element because the parasitic element increases the current length as shown in Figure 2(c).

The first resonant mode existing in the proposed antenna with parasitic element works with the second resonant mode to cover the DVB-H band (470 MHz$\sim$702 MHz). Truly, with optimizing the parameters, the first resonant mode and the second resonant mode can create the lowest operating frequency 455 MHz while the return loss is higher than 5 dB for DVB-H band.

To determine the geometrical parameters of parasitic element is an essential part in the proposed antenna. The width C_X of gap between the L-shape monopole and C-shape patch plays an important role to determine the return loss. Figure 4 shows the different values of return loss of antenna for different C_X value.

In Figure 4, the first and second resonant frequency shifts with C_X increasing. Through the optimization, $C_X = 1.6$ mm is the suitable value to broaden the first operating band to cover DVB-H band.

The meandering line M_S has a great effect on the performance of the proposed antenna by greatly shifting resonant frequency. As the Figure 1(b) shows, the turns of meander line M_S is 10. The return loss of the proposed antenna with different turns N is shown in Figure 5.

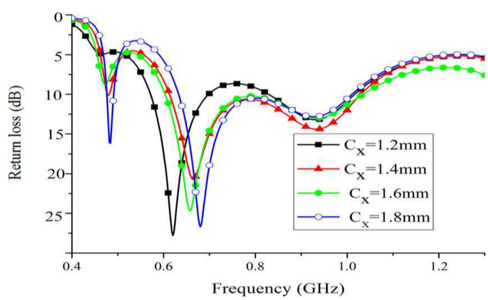


Figure 4. The return loss of the proposed antenna for different C_X values.

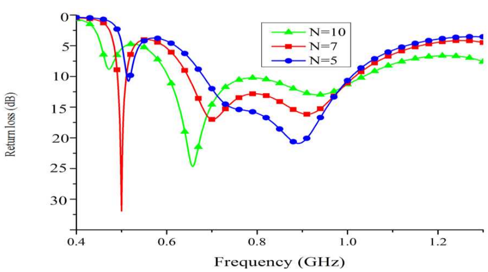


Figure 5. The return loss of the proposed antenna for different N value.

Figure 5 shows that the first and second resonant frequency increase significantly with the turns N increasing while the third resonant frequency decreases. According to simulated results, $N = 10$ is chosen as the optimizing value.

3. SIMULATION AND EXPERIMENTAL RESULT

The proposed antenna with the optimal geometrical parameters is fabricated as the photos shown in Figure 6.

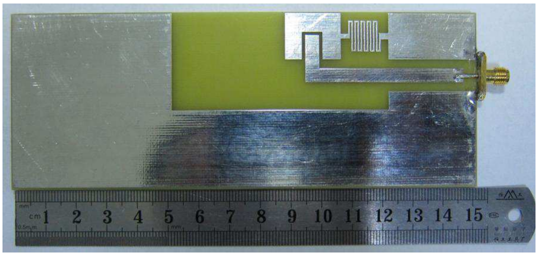


Figure 6. The photograph of fabricated antenna.

The measured and simulated return losses are shown in Figure 7.

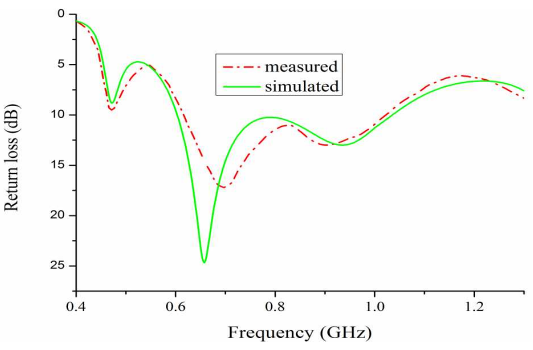
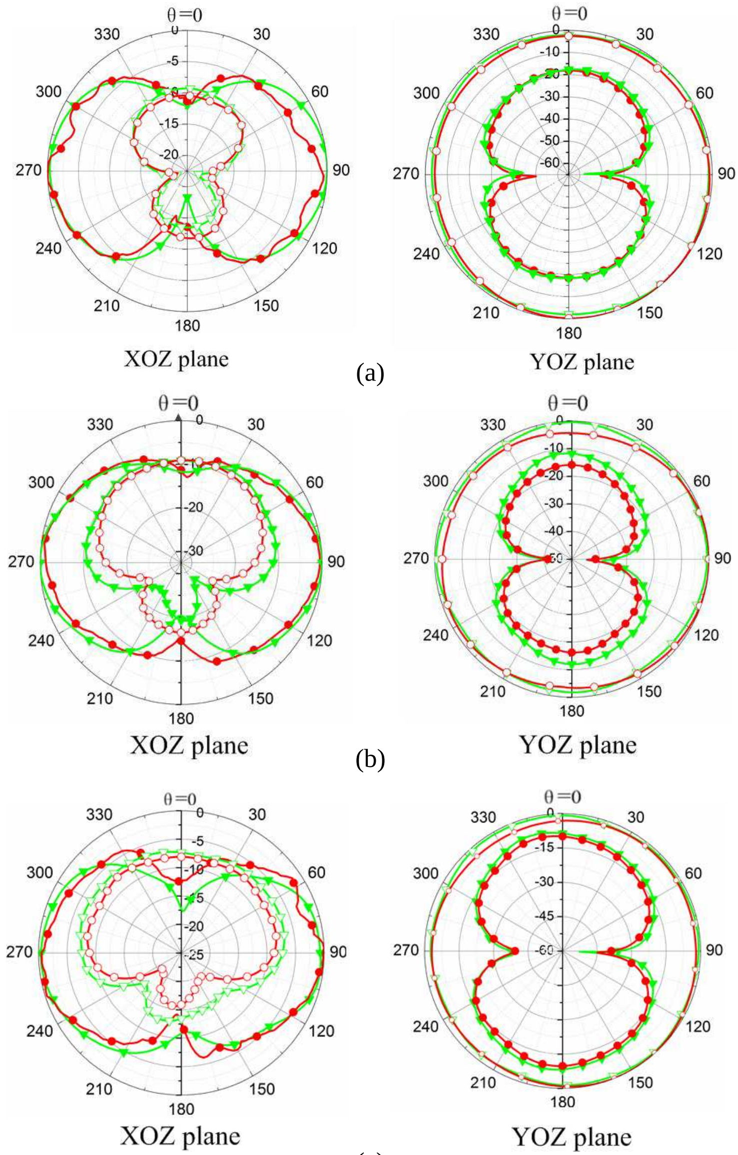


Figure 7. The simulated and measured return loss of proposed antenna.

The measured results agree with the simulated results well. As Figure 7 shows, there exist three resonant points in the fabricated antenna. The first and third resonant points nearly do not shift while the second resonant point shifts a little to higher frequency. The lowest frequency for return loss > 5 dB is 448 MHz while the lowest frequency is 450 MHz for return loss > 5 dB in simulation. The measured minimum value of return loss is 5.2 dB at 543 MHz in DVB-H band. The disagreements between the measurement and simulation are caused by the fabrication of the antenna. The second resonant point can be shifted by different value of C_X without the other influence. Also the environment to test the antenna may contribute to



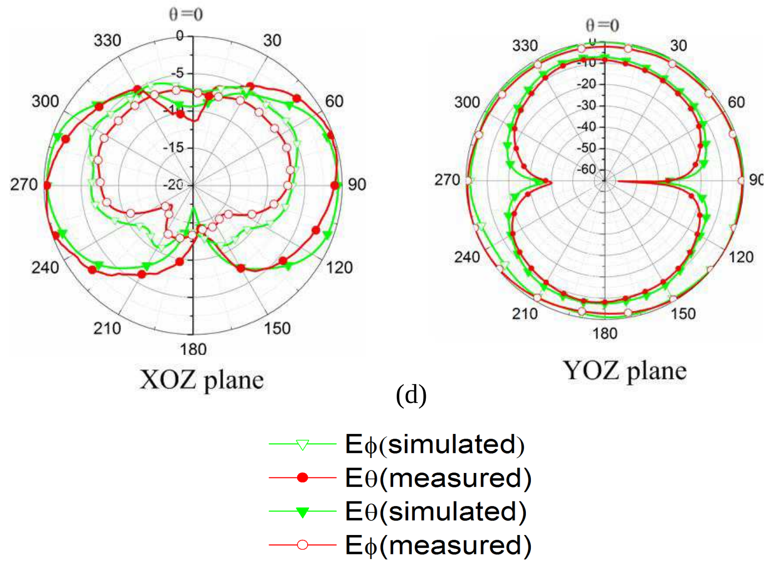


Figure 8. The simulated and measured radiation pattern in *xoz* and *yoz* plane. (a) 625 MHz, (b) 750 MHz, (c) 850 MHz, (d) 920 MHz.

the disagreement. The bandwidth of (448 MHz$\sim$702 MHz) for return loss $>$ 5 dB is obtained in measurement to totally cover the DVB-H band (470 MHz$\sim$702 MHz). The return loss is higher than 10 dB in the LTE/700 (704 MHz$\sim$787 MHz) and GSM850/900 (824 MHz$\sim$894 MHz, 880 MHz$\sim$960 MHz).

The simulated and measured radiation pattern in *xoz* and *yoz* plane at 625 MHz, 750 MHz, 850 MHz and 920 MHz are shown in Figure 8.

Also the center frequency of DVB-H, LTE/700 and GSM band are 625 MHz, 750 MHz, 850 MHz and 920 MHz. These four frequencies are selected to represent different wireless system. By the measured and simulated results, the radiation pattern in *xoz* and *yoz* plane in operating band is stable. Note that, in *yoz* plane, these radiation patterns at the four frequencies reveal relatively quasi Omni-directional characteristic, which makes this antenna to be a good candidate for communication applications.

The measured maximum realized gain and total efficiency are shown in Figure 9. The gain of the proposed antenna is at least 0.04 dB in the DVB-H band. Compared with the specification of the DVB-H standard, the gain of antenna in the DVB-H band is 7 dB higher than it. The maximum measured gain and total efficiency of the proposed

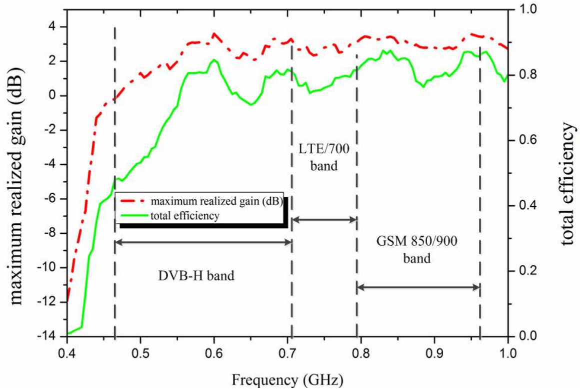


Figure 9. The measured total efficiency and maximum realized gain of the fabricated antenna.

antenna are also suitable to be applied in the LTE/700 and GSM/850, 900 band.

4. CONCLUSION

A simple planar antenna with wide operating band is presented. The L-shape monopole, C-shape patch, meander shorted strip, and ground are designed on the same plane. C-shape patch and meander shorted strip compose a parasitic element. The parasitic element is applied to create a new resonant mode and broaden its operating band. By optimizing the geometrical parameters of the antenna, the wide bandwidth of 450 MHz$\sim$1020 MHz is obtained. Considering its radiation patterns, the proposed antenna works as a monopole antenna with its high enough gain and efficiency to make the antenna to a candidate in DVB-H, LTE/700 and GSM/850, 900 application.

REFERENCES

1. Digital Television Major Initiatives of Federal Communications Commission, Online Available: http://www.fcc.gov/dtv/.
2. Sesia, S., I. Toufik, and M. Baker, *LTE — The UMTS Long Term Evolution: From Theory to Practice,* Wiley, Chicester, UK, 2009.
3. Li, W. Y., K. L. Wong, and J. S. Row, "Broadband planar shorted monopole antenna for DTV signal reception in a portable media player," *Microw. Opt. Technol. Lett.*, Vol. 49, No. 3, 558–561, 2007.

4. Ban, Y.-L., J.-H. Chen, S.-C. Sun, J. L.-W. Li, and J.-H. Guo, "Printed wideband antenna with chip-capacitor-loaded inductive strip for LTE/GSM/UMTS WWAN wireless USB dongle application," *Progress In Electromagnetics Research*, Vol. 128, 313–329, 2012.
5. Jeon, S.-G., D.-H. Seo, Y.-S. Yu, and J.-H. Choi, "Broadband internal antenna for mobile DTV handsets," *PIERS Online*, Vol. 3, No. 7, 1048–1052, 2007.
6. Hsu, C.-K. and S.-J. Chung, "A wideband DVB forked shape monopole antenna with coupling effect for USB dongle application," *IEEE Trans. Antennas Propag.*, Vol. 58, No. 9, 3029–3036, 2010.
7. Chen, H.-D., "Compact broadband microstrip-line-fed sleeve monopole antenna for DTV application and ground plane effect," *IEEE Antennas Wireless Propag. Lett.*, Vol. 7, 497–500, 2008.
8. Pan, C.-Y., J.-H. Duan, and J.-Y. Jan, "Coplanar printed monopole antenna using coaxial feed line for DTV application," *Progress In Electromagnetics Research Letters*, Vol. 34, 21–29, 2012.
9. Chi, Y. W., K. L. Wong, and S. W. Su, "Broadband printed dipole antenna with a step-shaped feed gap for DTV signal Reception," *IEEE Trans. Antennas Propag.*, Vol. 55, No. 11, 3353–3356, Nov. 2007.
10. Jeng, B.-M., C.-M. Lee, and C.-H. Luo, "Multiple-ring monopole antenna with sleeve-shaped ground for DVB-T applications," *Progress In Electromagnetics Research C*, Vol. 14, 155–161, 2010.
11. Zheng, L., X. L. Quan, H. J. Liu, and R. L. Li, "Broadband planar antenna based on CRLH structure for DVB-H and GSM-900 applications," *Electron. Lett.*, Vol. 48, No. 23, 1443–1444, 2012.
12. Lin, K.-C., C.-H. Lin, and Y.-C. Lin, "Simple printed multiband antenna with novel parasitic-element design for multistandard mobile phone applications," *IEEE Trans. Antennas Propag.*, Vol. 61, No. 1, 488–491, 2013.
13. Chu, F.-H. and K.-L. Wong, "Planar printed strip monopole with a closely-coupled parasitic shorted strip for eight-band LTE/GSM/UMTS mobile phone," *IEEE Trans. Antennas Propag.*, Vol. 58, No. 10, 3426–3431, 2010.