Progress In Electromagnetics Research Letters, Vol. 41, 39–49, 2013

IMPROVED GRATING MONOPOLE ANTENNA WITH ZIGZAG FOR DVB-T APPLICATION

Chemsedinne Zebiri[1, *], Michel Ney[2], Raed A. Abd-Alhameed[3], Fatiha Benabdelaziz[4], Mohamed Lashab[5], and Chan Hwang See[3]

[1]Département d'Electronique, Université Ferhat Abbas, Sétif, Algeria

[2]Département Micro-Ondes, Telecom Bretagne, Technopôle Brest-Iroise, Brest, France

[3]Mobile Satellite Communication Research Centre, University of Bradford, Bradford BD7 1DP, UK

[4]Département d'Electronique, Université Mentouri, Constantine, Algeria

[5]Département de Génie Electrique, Université 20 Août 1955, Skikda, Algeria

Abstract—This work presents a novel broadband monopole antenna for digital video broadcasting-terrestrial (DVB-T) application. The proposed antenna consists of a grating zigzag patch and a concave rectangular ground plane. The zigzag patch is used to enable the antenna height reduction for fixed ranges of operating frequency. The proposed antenna can operate from 420 MHz to 1050 MHz frequency range corresponding to 85% of impedance bandwidth for $|S_{11}|$ better than -10 dB. This covers the working frequency band (470–862 MHz) of DVB-T system. The radiation pattern of the proposed antenna is omnidirectional across the desired operating frequency band. Details of the proposed antenna design and experimental results of the constructed prototypes are presented and discussed. Furthermore than the bandwidth enhancement, we have also arranged the structure for network antennas application.

Received 1 May 2013, Accepted 22 May 2013, Scheduled 10 June 2013

* Corresponding author: Chems Zebiri (zebiri@ymail.com).

1. INTRODUCTION

The antenna dimensions are inversely proportional to frequency, as the frequency increases the electrical length of the antenna becomes smaller [1]. Increasing the operating frequency is not always a favourable method to reduce the antenna size, as this shortens the communication distance. Thus, novel antenna miniaturization methods are in burgeoning demand. As for printed monopole antennas, in recent decades, these antennas have found application in a wide variety of fields. They have several advantages such as low-cost, wide bandwidth, omni-directional pattern and ease of integration into a PCB. Therefore they are attractive for portable systems, such as ultra wideband (UWB) communication systems [2–4], wireless local area network (WLAN) [5], Science and Medical (ISM) systems [6], and Digital Video Broadcasting-Terrestrial (DVB-T) applications [7–10]. The DVB-T system has been adopted by many countries. It offers high-data-rate transmission, provides interactive services, and operates at low power levels.

Several types of monopole antennas have been developed using several techniques to achieve the broad bandwidth that is needed for DVB-T applications [7–15]. These techniques include the use of

Table 1. Area and operating bandwidth of some planar antennas for DTV band.

Ref.	Ant. Area (mm × mm)	VSWR	S_{11} dB	Operation bandwidth (MHz)
[7]	35 × 242	2 : 1	−9.5	502 (458–960 MHz), 71%
[8]	5 × 10 × 79.5	2.5:1	−7.35	310 (470–780), 50%
[9]	26 × 238	2.5 : 1	−7.35	408 (463–871), 61%
[10]	20 × 227	2.5 : 1	−7.35	340 (470–810), 53%
[13]	15 × 170	2.5 : 1	−7.35	550 (465–1015), 74%
[21]	20 × 174	2.5 : 1	−7.35	392 (470–862), 58%
[25]	60 × 257	3 : 1	−6	240 (470–710), 41%
[26]	14 × 230	3 : 1	−6	490 (470–960), 69%
[27]	35 × 247	1.92 : 1	−10	461 (451–912), 68%
[28]	50 × 229	2.5 : 1	−7.35	560 (470–1030), 75%
[29]	70 × 195	1.92 : 1	−10	280 (465-745), 46%
[30]	75 × 135	3.5 : 1	−5.1	440 (470–870), 60%
Our work	64.5 × 170	1.92 : 1	−10	630 (420–1050), 85%

a concavity in the ground plane [7], sleeve monopole antenna [16–18], circular-ring monopole antennas [19], a multiple-ring monopole antenna with sleeve-shaped ground [9] and a bevelling radiating element [20]. They have lengths between 135 mm and 257 mm. A broadband printed dipole antenna with a pair of asymmetrical arms of length 227 mm was described in [10]. A meander-line monopole antenna with a coupling strip was developed to obtain a broad bandwidth for a longest length of 174 mm [21]. For DVB-H application, a printed spiral monopole antenna of 175-mm length with three switched impedance matching networks provide an operational frequency range from 470 MHz to 702 MHz with 5 dB return loss [22]. An antenna of dimension 142 × 50 mm combined with a matching network was reported in [23]. More recently, an electrically tunable DVB-H antenna was proposed working over the range from 470 MHz to 702 MHz with a 7 dB return loss [24].

In this paper we present a new printed monopole antenna which does not only preserve a large operation bandwidth but also reduces the antenna size. It is compared to other planar antennas in Table 1 as given in [13] and other added references. This monopole antenna with bended grating has an area of $64.5 \times 170\,\text{mm}^2$ and 630-MHz bandwidth (1.92 : 1 VSWR), thus suitable for DTV application. Simulated and measured results show that the proposed antenna can achieve sufficient impedance bandwidth and exhibit typical monopole antenna radiation characteristics. Finally, compared to published structures the proposed antenna has the shorter length (170 mm).

2. ANTENNA DESIGN

The original antenna geometry is a zigzag shaped monopole (Figure 1(a)), this is derived from a combination between an ordinary L-shaped monopole antenna [31, 35] and grating monopole antenna [7], that can clearly achieve a minimum antenna length. To achieve 420 to 1050-MHz wide-band operation proposed here, the zigzag-shape patch was derived from a square monopole antenna and can be viewed as superposition of two patches; a vertically oriented L-shaped antenna [31], and another horizontally aligned patch. In some works such as [32], a length reduction is achieved by increasing the substrate thickness. However, they have not removed the problem of surface wave excitation which generates power losses [33, 34]. Hence, it is not sufficient to miniaturize the structure without considering all side effects.

The objective of the designed antenna is to fabricate on a low-cost FR-4 substrate with dielectric constant $\varepsilon_r = 4.4$, loss tangent

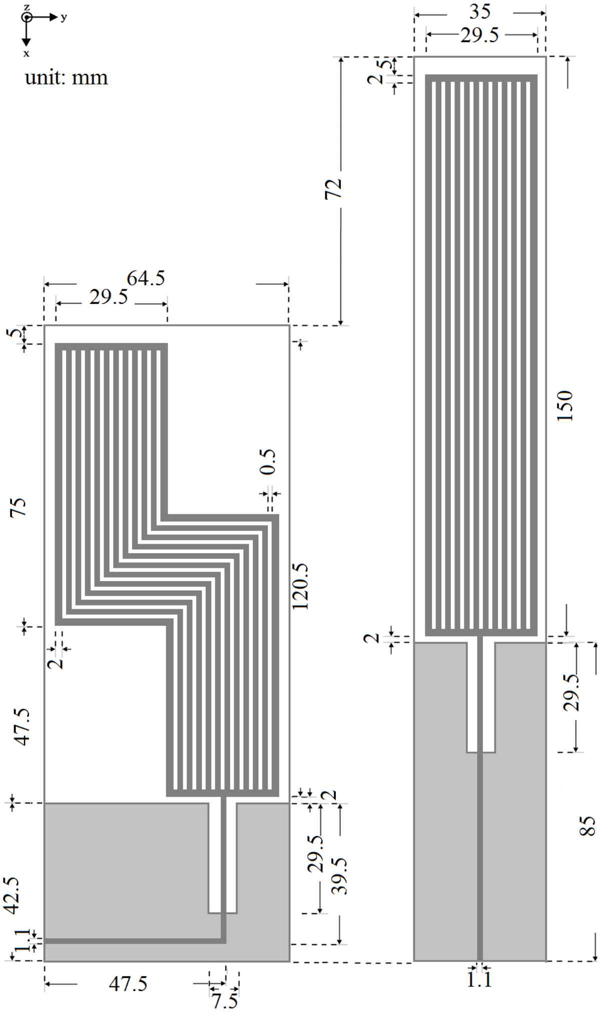

Figure 1. Geometry of the designed and the grating monopole antenna (the two antennas are presented simultaneously for size comparison).

$= 0.02$, and thickness $h = 0.8$ mm. The overall size of the antenna is $170 \times 64.5 \times 0.8\,\text{mm}^3$. A 50-$\Omega$ microstrip feed line is used to excite the monopole antenna.

The Figure 1(b) shows the geometry of the original grating monopole antenna [7]. The structure in Figure 1(a) shows two sections of the printed antenna connected with a 90°-bend towards its feed. As a result, the dimension of the ground plane and antenna are modified. The area of the ground on the backside becomes $64.5 \times 42\,\text{mm}^2$. It has a concave slot of $29.5 \times 7.5\,\text{mm}^2$ on the ground plane. The concave slot is used to adjust the characteristic impedance of the antenna to increase its bandwidth [7, 9, 19]. The designed antenna is presented in Figure 2.

3. ANTENNA DESIGN AND EXPERIMENTAL RESULTS

The prototype of the proposed grating bended monopole antenna for DVB-T receiving antenna is shown in Figure 2. It has 12 gratings; each has a 2 mm strip width of and 0.5-mm slot width. The simulated and measured of the return loss of the designed antenna is shown in Figure 3. One can observe that the measured matched impedance bandwidth reaches 630 MHz (420–1050 MHz with 10-dB minimum return loss). This means that the relative impedance bandwidth is expanded up to 85%. Good concordance is observed between the measured and simulated results. Simulated results were obtained using Ansoft simulation software HFSS® v.14 (High Frequency Structure Simulator).

Regarding the experimental and simulated results of the proposed antenna in Figure 3, one can observe some discrepancies. They may result from tolerance errors due to the process of antenna fabrication.

Measured radiation patterns of the proposed antenna in the xy-plane, xz-plane and yz-plane at the frequencies 470, 660, and 860 MHz are shown in Figure 4. It can be seen that radiation patterns in the

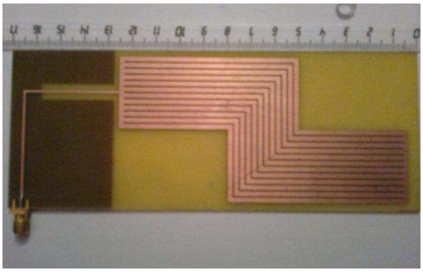

Figure 2. Prototype of proposed antenna.

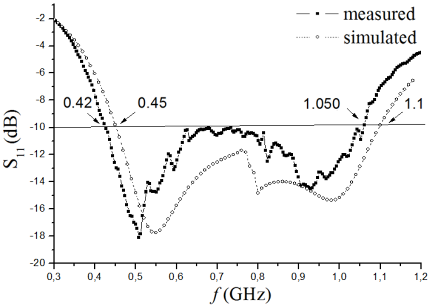

Figure 3. Simulated and measured return loss of the designed antenna.

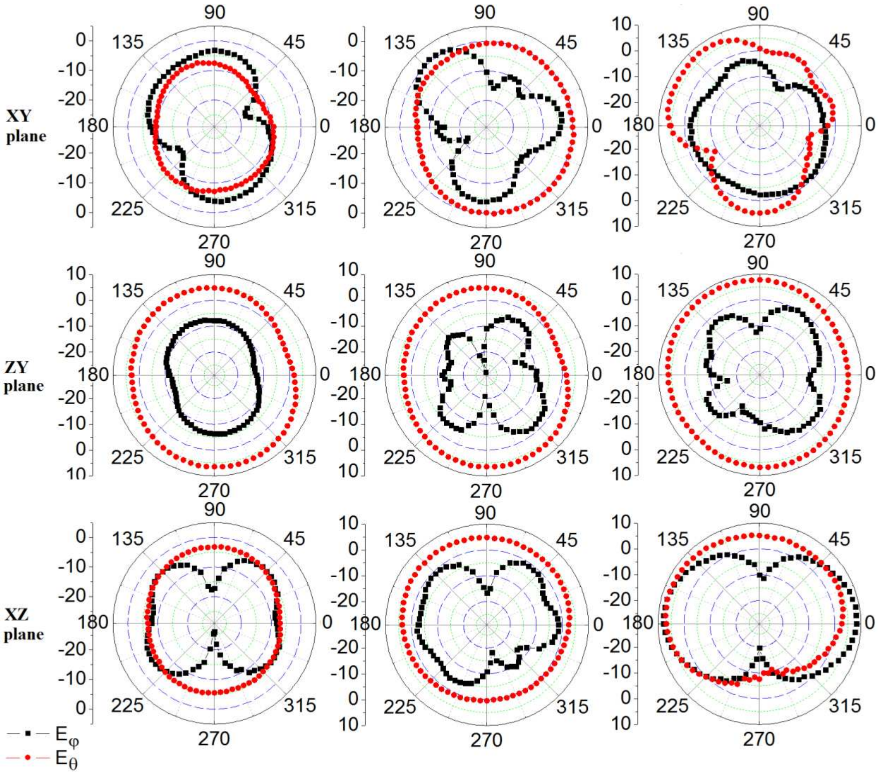

Figure 4. Measured radiation patterns for the proposed antenna given in Figure 2 at 470, 660, and 860 MHz.

xz-plane are omnidirectional and have low cross-polarization.

Also observed in Figure 4, the designed antenna displays good broadside radiation patterns in the xz-plane and yz-plane. The cross-polarization pattern is lower than about -10 dB in xz-plane, and very important in yz and xy-plane at all frequencies and especially at 860 MHz. This is due to the horizontal section. However, this relatively high cross-polarization level becomes an advantage for practical applications such as hand-held equipments, because their wave propagation environment is usually complex due to multiple reflections [36].

The measured and simulated gain of the proposed antenna is shown in Figure 5. It can be seen that antenna gain is found to vary from about 1.02 to 6.28 dBi over the DVB-T band.

In this section, we are also interested to shift the bending position of the zigzag patch of the antennas for future work on network antennas (Figure 6). This has led to several possible simulation by presenting the return loss of each case. According to simulation presented by Figure 7 also Table 2, we can conclude that the position of du zigzag path lead to a slight change in the return loss in the case of structures (a)–(f), and the return loss is very interesting for the DVB desired applications, whereas the case of structure (j), where the zigzag is close to the ground plane the return loss is very bad.

According to Figure 8, we can only assume one dimension of the authorized length, where we can have a structure dimension of $140 \times 64.5\,\text{mm}^2$, for a bandwidth of (470–1190) MHz.

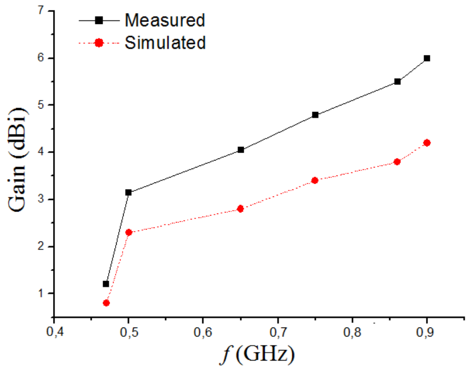

Figure 5. Measured and simulated antenna gain against frequency for the proposed antenna given in Figure 2.

Table 2. Simulated and operating bandwidth of planar antennas presented in Figure 6 for $|S_{11}|$ better than -10 dB.

Ref. of structure in Figure 6	Operation bandwidth (MHz)
(a)	540 (440–980), 76%
(b)	575 (445–1020), 79%
(c)	620 (445–1065), 82%
(d) proposed antenna	650 (450–1100), 85%
(e)	605 (470–1075), 78%
(f)	550 (475–1025), 73%
(j)	165 (710–875), 21%

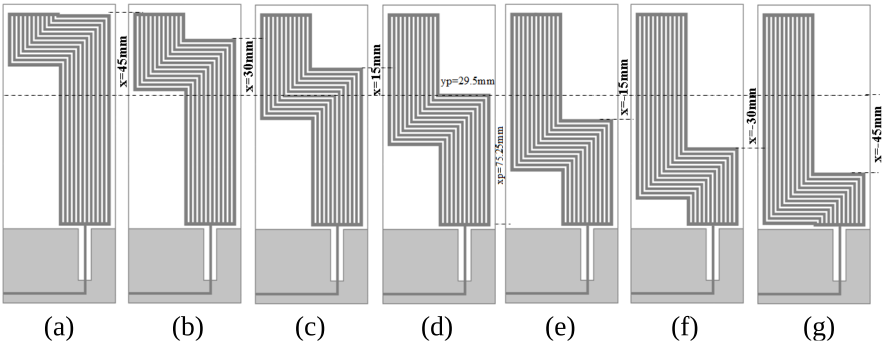

Figure 6. Different antennas compared with (d) the proposed antenna.

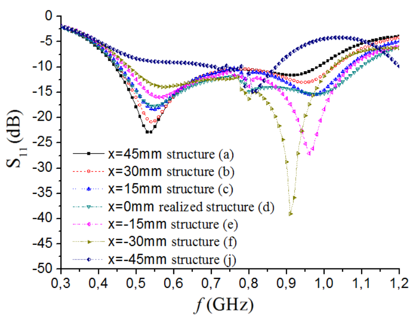

Figure 7. Simulated return loss of the different antennas compared with the proposed antenna presented in Figure 6.

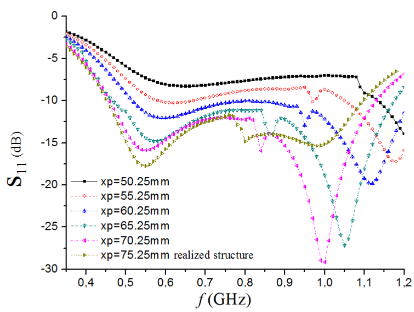

Figure 8. The effect of the antenna length on the simulated return loss.

4. CONCLUSION

A novel grating monopole (with zigzag) antenna for DVB-T application was proposed and studied. A technique for enhancing both the bandwidth and gain of microstrip patch antenna was designed and a prototype built and presented in this paper. It has a low-cost simple structure which can be easily fabricated; the designed antenna achieves a fractional bandwidth of 85% (420 to 1050 MHz) with minimum 10-dB return loss. The maximum achievable gain of the antenna is 6.28 dBi. The proposed patch has a compact dimension of $64.5 \times 170\,\text{mm}^2$, having a total length of 72 mm. Furthermore, due to its relatively high gain and broad bandwidth more applications can be anticipated. Finally, measured radiation patterns show some omnidirectionality for frequencies around the operating band.

REFERENCES

1. Surducan, E., D. Iancu, V. Surducan, and J. Glossner, "Microstrip composite antenna for multiple communication protocols," *International Journal of Microwave and Optical Technology*, Vol. 1, No. 2, 772–775, 2006.
2. Bao, X. L. and M. J. Ammann, "Investigation on UWB printed monopole antenna with rectangular slitted ground plane," *Microwave and Optical Technology Letters*, Vol. 49, No. 7, 1585–1587, 2007.
3. Suh, S. Y., W. L. Stutzman, and W. A. Davis, "A new ultra wideband printed monopole antenna: The planar inverted cone antenna (PICA)," *IEEE Transactions on Antennas and Propagation*, Vol. 52, No. 5, 1361–1364, 2004.
4. Chung, K., S. Hong, and J. Choi, "Ultrawide-band printed monopole antenna with band-notch filter," *IET Microwaves, Antennas and Propagations*, Vol. 1, No. 2, 518–522, 2007.
5. Pan, C. Y., T. S. Horng, W. S. Chen, and C. H. Huang, "Dual wideband printed monopole antenna for WLAN/WiMAX applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 6, 149–151, 2007.
6. Chen, I. F., C. M. Peng, and S. C. Liang, "Single layer printed monopole antenna for dual ISM-band operation," *IEEE Transactions on Antennas and Propagation*, Vol. 53, No. 4, 1270–1273, 2005.
7. Huang, C. Y., B. M. Jeng, and J. S. Kuo, "Grating monopole antenna for DVB-T application," *IEEE Transactions on Antennas and Propagation*, Vol. 56, 1775–1776, 2008.
8. Su, C. M., L. C. Chou, C. I. Lin, and K. L. Wong, "Embedded DTV antenna for laptop application," *2005 IEEE Antennas and Propagation Society International Symposium*, Vol. 4B, 68–71, Jul. 3–8, 2005.
9. 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.
10. 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 Transactions on Antennas and Propagation*, Vol. 55, No. 11, 3353–3356, 2007.
11. Li, W. Y., K. L. Wong, and S. W. Su, "Broadband integrated DTV antenna for USB dongle application," *Microwave and Optical Technology Letters*, Vol. 49, 1018–1021, 2007.

12. Su, S. W. and F. S. Chang, "Wideband rod-dipole antenna with a modified feed for DTV signal reception," *Progress In Electromagnetics Research Letters*, Vol. 12, 127–132, 2009.
13. 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.
14. Wong, K. L., C. I. Lin, T. Y. Wu, and J. W. Lai, "A planar DTV receiving antenna for laptop applications," *Microwave and Optical Technology Letters*, Vol. 42, No. 6, 483–486, Sep. 20, 2004.
15. Su, C. M., L. C. Chou, C. I. Lin, and K. L. Wong, "Internal DTV receiving antenna for laptop application," *Microwave and Optical Technology Letters*, Vol. 44, No. 1, 4–6, Jan. 5, 2005.
16. Shen, Z. and R. H. MacPhie, "Theoretical modeling of multi-sleeve monopole antennas," *Progress In Electromagnetics Research*, Vol. 31, 31–54, 2001.
17. Moon, J. I., S. O. Park, and K. Y. Park, "Broadband sleeve monopole type antenna for dual-band PCS/IMT-2000," *Electron. Lett.*, Vol. 39, 1829–1930, 2000.
18. Dong, T. and Y. Chen, "Novel design of ultra-wideband printed double-sleeve monopole antenna," *Progress In Electromagnetics Research Letters*, Vol. 9, 165–173, 2009.
19. Liang, J., C. C. Chiau, X. Chen, and C. G. Parini, "Printed circular ring monopole antennas," *Microwave and Optical Technology Letters*, Vol. 45, 372–375, 2005.
20. Ammann, M. J. and Z. N. Chen, "Wideband monopole antennas for multi-band wireless systems," *IEEE Antennas Propag. Mag.*, Vol. 45, No. 2, 146–150, Apr. 2003.
21. Chen, H. D., "Compact broadband microstrip-line-fed sleeve monopole antenna for DTV application and ground plane effect," *IEEE Antennas and Wireless Propagation Letters*, Vol. 7, 497–500, 2008.
22. Choi, D. H., Y. T. Im, Y. J. Cho, and S. O. Park, "A tunable antenna for DVB-H applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 6, 515–517, 2007.
23. Roo Ons, M. J., J. Hauck, M. Buchholz, and F. Aguado-Agelet, "Analysis, realization, and measurement of broadband miniature antennas for digital TV receivers in handheld terminals," *Microwave and Optical Technology Letters*, Vol. 50, No. 20, 293–297, 2008.
24. Huang, L. B. and P. Russer, "Electrically tunable antenna

design procedure for mobile applications," *IEEE Transactions on Microwave Theory and Techiques*, Vol. 56, No. 12, 2789–2797, 2008.

25. Iizuka, H., T. Watanabe, K. Sato, and K. Nishikawa, "Modified H-shaped antenna for automotive digital terrestrial reception," *IEEE Transactions on Antennas and Propagation*, Vol. 53, No. 6, 2542–2548, 2005.
26. Lee, C.-T. and K.-L. Wong, "Broadband planar dipole antenna for DTV/GSM operation," *Microwave and Optical Technology Letters*, Vol. 50, 1900–1904, 2008.
27. Huang, C.-Y., B.-M. Jeng, and C.-F. Yang, "Wideband monopole antenna for DVB-T applications," *Electron. Lett.*, Vol. 44, 1448–1450, 2008.
28. Zhou, S., J. Guo, Y. Huang, and Q. Liu, "Broadband dual frequency sleeve monopole antenna for DTV/GSM applications," *Electron. Lett.*, Vol. 45, 766–768, 2009.
29. Jeon, S.-G., D.-H. Seo, Y.-S. Yu, and J.-H. Choi, "Broadband internal antenna for mobile DTV handsets," *Progress In Electromagnetics Research*, Vol. 3, 1048–1052, 2007.
30. Yang, C., H. Kim, and C. Jung, "Compact broad dual-band antenna using inverted-L and loop for DVB-H applications," *Electron. Lett.*, Vol. 46, 1418–1419, 2010.
31. Su, S.-W., A. Chen, and Y.-T. Liu, "Wideband omnidirectional L-shaped monopole antenna for a wireless USB dongle," *Microwave and Optical Technology Letters*, Vol. 49, No. 3, 625–628, 2007.
32. De Morais, J. H. C. and A. L. P. S. Campos, "Printed grating monopole antenna for DTV applications," *2011 SBMO/IEEE MTT-S International Microwave & Optoelectronics Conference*, 213–216, 2011.
33. Collin, R. E., *Field Theory of Guided Waves,* Pression de Wiley, New York, 1990.
34. Zebiri, C., F. Benabdelaziz, and D. Sayad, "Surface waves investigation of a bianisotropic chiral substrate resonator," *Progress In Electromagnetics Research B*, Vol. 40, 399–414, 2012.
35. Guan, R., X. Zhang, L. Jin, Z. Zhang, and W. Zhou, "A compact multi-folded patch antenna for UWB application at the UHF band," *2010 International Symposium on Signals Systems and Electronics (ISSSE)*, Vol. 2, 1–4, Sep. 17–20, 2010.
36. Jeng, B.-M. and C.-H. Luo, "Integrated DTV antenna for portable media player application," *Progress In Electromagnetics Research Letters*, Vol. 23, 49–56, 2011.