2009

Compact UWB Antenna With I-Shaped Band-Notch Parasitic Element for Laptop Applications

Nakchung Choi
Kwangwoon University

Changwon Jung
Seoul National University of Technology

Joonho Byun
Samsung Electronics

Frances J. Harackiewicz
Southern Illinois University Carbondale, fran@engr.siu.edu

Myun-Joo Park
Kwangwoon University

See next page for additional authors

Published in Choi, N.; Jung, C.; Byun, J.; Harackiewicz, F. J.; Park, M.-J.; Chung, Y.-S.; Kim, T.; Lee, B. (2009). Compact UWB antenna with I-shaped band-notch parasitic element for laptop applications. IEEE Antennas and Wireless Propagation Letters, 8, 580 - 582 doi: 10.1109/LAWP.2009.2021286

Authors
Nakchung Choi, Changwon Jung, Joonho Byun, Frances J. Harackiewicz, Myun-Joo Park, Yong-Seek Chung, Taekyun Kim, and Byungje Lee

Compact UWB Antenna With I-Shaped Band-Notch Parasitic Element for Laptop Applications

Nakchung Choi, Changwon Jung, Joonho Byun, Frances J. Harackiewicz, *Senior Member, IEEE*, Myun-Joo Park, Yong-Seek Chung, Taekyun Kim, and Byungje Lee, *Member, IEEE*

***Abstract*—A compact ultrawideband (UWB) antenna with a band-notch function is proposed for laptop applications. The band-notch function is realized by a half-wavelength parasitic element printed on the rear side of the substrate. The impedance bandwidth ($\mathrm{VSWR} < 2$) of the antenna is $3.1 \sim 11.4$ GHz (114%) with a notched frequency from 5.05 to 5.90 GHz. The antenna has a fairly good omnidirectional pattern, and the average gain is $-3.0 \sim -1.2$ dBi over the UWB frequency band except for the notched frequency band. The performance of the proposed antenna is confirmed by simulation and measurement results.**

***Index Terms*—Band-notch function, laptop application, parasitic element, ultrawideband (UWB) antenna.**

I. Introduction

With the development of wideband wireless communication systems, ultrawideband (UWB) systems have been expanding rapidly. The Federal Communications Commission allocated the frequency band $3.1 \sim 10.6$ GHz for the UWB services in 2002 [1]. These UWB systems have been used for radar applications, localizations, data communications, etc. The UWB system for data communications is especially applied to home networking systems as a technology of wireless personal area networks (WPANs). The home networking system is widely used in multimedia devices such as HDTVs, DVDs, cameras, and personal computers through the UWB service channels. The antennas of UWB systems are embedded into these multimedia devices. Here, the antenna design is challenged with the difficulties of satisfying the antenna characteristics of wide impedance bandwidth, high gain, omnidirectional radiation pattern, and small and compact size [2]. Planar antennas have been proposed for UWB antenna solutions [3]–[5]. For UWB systems, the antenna with a band-notch function is also necessary to provide rejection of the interference from the wireless local area network service (IEEE 802.11a) band, $5.15 \sim 5.825$ GHz. The methods to realize a band-notch function have been studied by using the various shaped slots [6]–[8], tuning stubs [9], [10], spurlines [11], embedded resonant cells [12], and parasitic elements [13]. Even though these methods are able to achieve a frequency band-notch function, their bandwidth of the notched frequency cannot be easily tuned due to the difficulty in the input impedance match. The dimensions of these antennas are also somewhat large (length: $20 \sim 40$ mm$\times$ width: $20 \sim 40$ mm) so that they may not be implemented into laptop computers since laptop computers are getting thinner and smaller. Therefore, it is not easy to find many articles about UWB antennas embedded into laptop computers. In [14], although the UWB antenna is implemented into a laptop computer, it has no band-notch function.

In this letter, we propose a planar embedded monopole antenna with a band-notch parasitic element for laptop applications. To achieve a band-notch function, an I-shaped parasitic el-

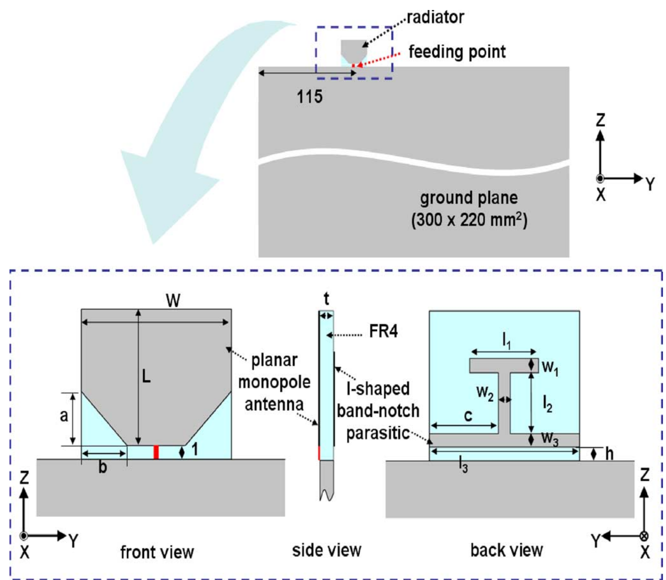
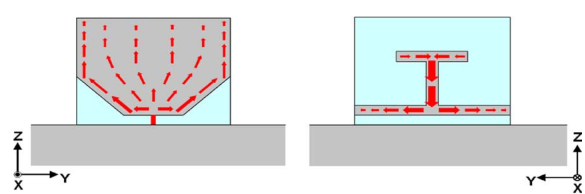


Fig. 1. Geometry of the proposed antenna.



(a) (b)

Fig. 2. Simulated current distributions at 5.49 GHz: (a) on the radiating element, (b) on I-shaped band-notch parasitic element.

Manuscript received March 22, 2009; revised April 08, 2009. First published April 21, 2009; current version published July 01, 2009.

N. Choi, M.-J. Park, Y.-S. Chung, and B. Lee are with the Department of Wireless Communications Engineering, Kwangwoon University, Seoul 139-701, Korea (e-mail: bj_lee@kw.ac.kr).

C. Jung is with the Graduate School of NID Fusion Technology, Seoul National University of Technology, Seoul 139-743, Korea.

J. Byun is with Samsung Electronics Co., Ltd., Suwon-Si 433-742, Korea.

F. J. Harackiewicz is with the Department of Electrical and Computer Engineering, Southern Illinois University Carbondale, Carbondale, IL 62901 USA.

T. Kim is with the Division of General Education-Mathematics, Kwangwoon University, Seoul 139-701, Korea.

Color versions of one or more of the figures in this letter are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/LAWP.2009.2021286

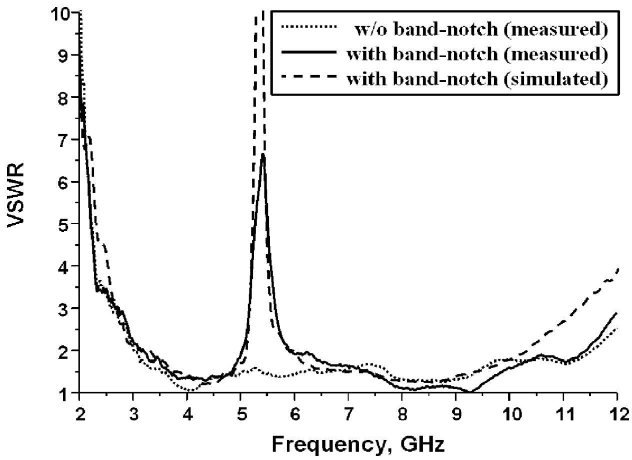


Fig. 3. Simulated and measured VSWR of the proposed antenna.

ement is printed on the rear side of the substrate and yields great stopband rejection. In addition, the I-shaped parasitic element is easily able to adjust both the center frequency and the bandwidth of the notched band. The parameters of an I-shaped parasitic element are analyzed in terms of the notch frequency and bandwidth. A compact optimized UWB antenna is then fabricated and examined both experimentally and numerically. The results show that a new design method with a band-notch function provides sufficient antenna performances such as, wide impedance bandwidth, great band rejection, high gain, and omnidirectional radiation pattern.

II. Antenna Structure and Design

Fig. 1 shows the geometry of the proposed antenna for laptop computers. The overall size of the antenna that is fabricated on the FR-4 substrate (dielectric constants $= 4.6$, thickness $= 1.2$ mm) is $\mathrm{W} \times \mathrm{L} = 13 \times 11$ mm^2. The size of the ground plane on the 14-in display screen of a laptop computer is 300×220 mm^2. The antenna is located 115 mm away from the edge of the ground plane. The antenna is fed at the center of the radiating element. Then, the input impedance is matched by cutting off both lower sides ($\mathrm{a} = \mathrm{b} = 4$ mm) of the radiator and adjusting the distance (1 mm) between the radiator and the ground plane. The I-shaped parasitic element is printed on the rear side of the antenna and is electrically separated from the main radiator and ground plane. The electrical length of an I-shaped parasitic element is approximately a half-wavelength at the center frequency (5.49 GHz) of IEEE 802.11a (5.15 $\sim$ 5.825 GHz) band. Fig. 2 shows the current distributions both on the radiating element and on the I-shaped parasitic element. It is noticed that the current distribution on the I-shaped parasitic element is out of phase with that on the radiating element so that the I-shaped parasitic element rejects the IEEE 802.11a band. This parasitic element is placed near to the feed point and electromagnetically coupled to the feed line so that it does act as a microstrip transmission line at the notched frequency band.

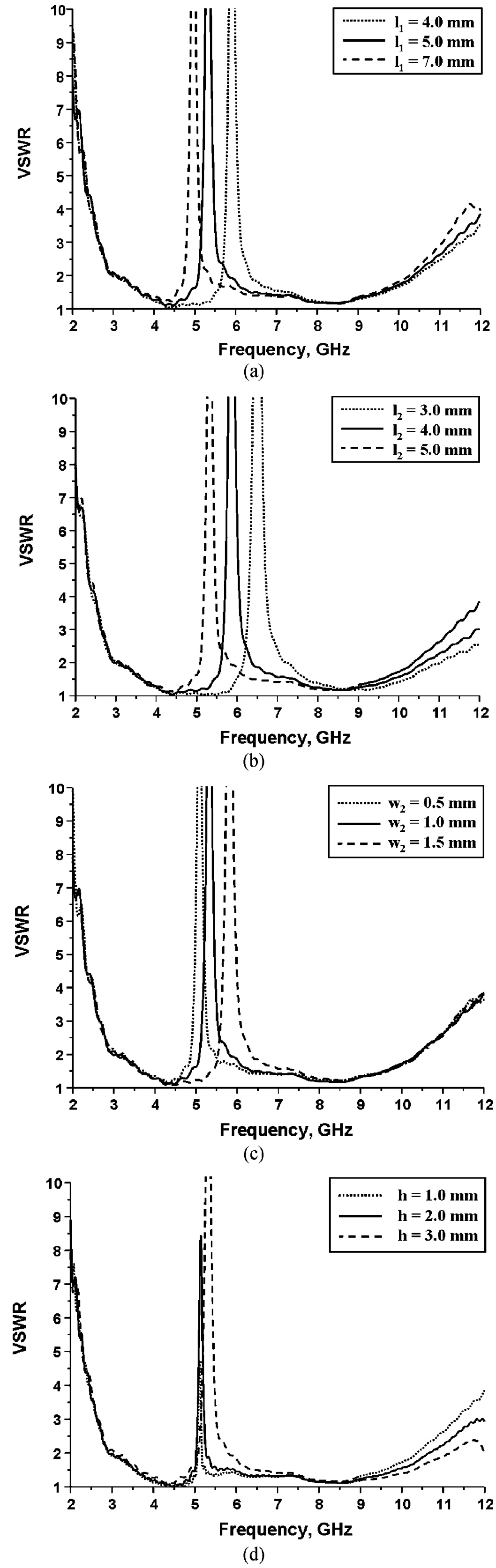


Fig. 4. Simulated VSWR with varying parameters: (a) l_1, (b) l_2, (c) w_2, (d) h.

III. Simulation and Measurement

Fig. 3 shows the simulated and measured VSWR of the proposed antenna. The notched frequency band is $5.05 \sim 5.9$ GHz,

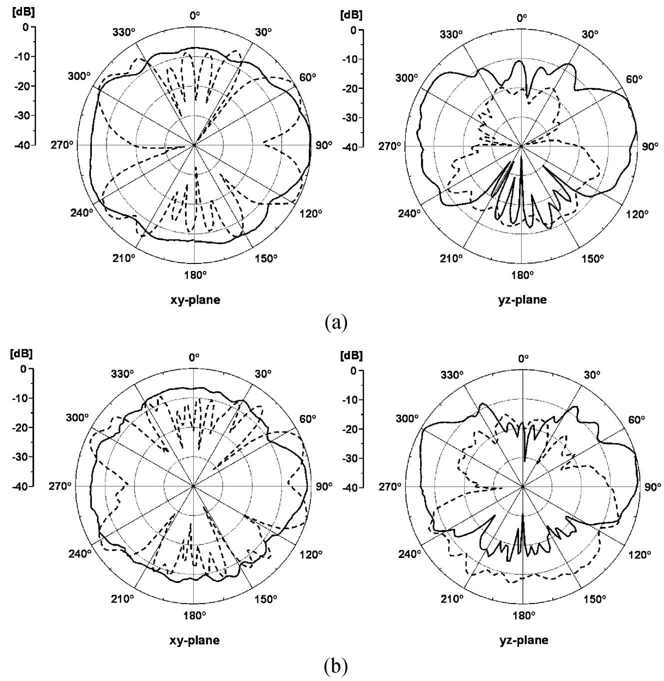


Fig. 5. Measured radiation patterns (a) at 4 GHz and (b) at 7 GHz. (solid line: copolarization, dashed line: cross-polarization).

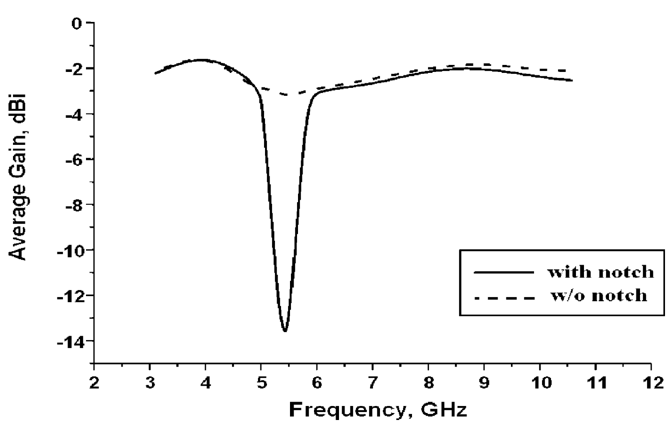


Fig. 6. Measured average gain.

and the center frequency is about 5.4 GHz. The dimensions of the parameters used in Fig. 3 are $\mathrm{l}_1 = \mathrm{l}_2 = 5$ mm, $\mathrm{l}_3 = 13$ mm, $\mathrm{w}_1 = \mathrm{w}_2 = \mathrm{w}_3 = 1$ mm, $\mathrm{c} = 6$ mm, and $\mathrm{h} = 1$ mm, which is optimized by the following parametric-analysis.

Fig. 4 shows the simulated VSWR varying by l_1, l_2, w_2, and h, which are more susceptible parameters for the band-notch function. Other dimensions used in Fig. 4 and not stated are the same as those used in Fig. 3. As shown in Fig. 4(a)–(c), varying the lengths, l_1 and l_2, and width, w_2, the center frequency of the notched band can be easily turned while the VSWR at the UWB frequency is barely changed. Fig. 4(d) shows the VSWR varying with the gap (h) between the ground plane and the I-shaped band-notch parasitic element. As the length of the gap increases, the notched bandwidth becomes narrow because the I-shaped parasitic element is less coupled with the feed line. It is noticed that the bandwidth of the notch-frequency function can be easily tuned by adjusting the length of this gap. Fig. 5 shows the measured antenna radiation patterns normalized by the peak gain at 4 and 7 GHz. In the *xy*-plane, the proposed antenna has fairly good omnidirectional radiation pattern. The radiation patterns in the *yz*-plane are similar to each other. Without taking in account the losses in the display panel, Fig. 6 shows the measured average gains of the antenna without and with the band-notch function. The proposed antenna has the average gain of $-3.0 \sim -1.2$ dBi, except that it has much smaller gain at the notched frequency band (5.05–5.90 GHz). The measured efficiency of this antenna ranges from 55% to 72%, except for the notched band.

IV. Conclusion

A notch-frequency band for a UWB antenna, which can be embedded into laptop computers, is obtained by employing an I-shaped parasitic element. This novel band-notched UWB antenna has the capability to provide easy tuning of the notch-frequency function and bandwidth with good stopband rejection.

References

[1] FCC, “First report and order,” 2002.
[2] Z. N. Chen, *Antennas for Portable Devices*. Hoboken, NJ: Wiley, 2007.
[3] W.-C. Liu and P.-C. Kao, “CPW-fed triangular monopole antenna for ultra-wideband operation,” *Microw. Opt. Technol. Lett.*, vol. 47, pp. 580–582, Dec. 2005.
[4] M. J. Ammann and Z. N. Chen, “Wideband monopole antenna for multi-band wireless systems,” *IEEE Antennas Propag. Mag.*, vol. 45, no. 2, pp. 146–150, Apr. 2003.
[5] A. Mehdipour, K. Mohammadpour-Aghdam, R. Faraji-Dana, and A.-R. Sebak, “Modified slot bow-tie antenna for UWB applications,” *Microw. Opt. Technol. Lett.*, vol. 50, pp. 429–432, Feb. 2008.
[6] Y. Kim and D.-H. Kwon, “CPW-fed planar ultra wideband antenna having a frequency band notch function,” *Electron. Lett.*, vol. 40, pp. 403–405, Apr. 2004.
[7] X. L. Bao and M. J. Ammann, “Printed UWB antenna with coupled slotted element for notch-frequency function,” *Int. J. Antennas Propagat.*, vol. 2008, pp. 1–7, 2008.
[8] W.-C. Liu and P.-C. Kao, “CPW-fed triangular antenna with a frequency-band notch function for ultra-wideband application,” *Microw. Opt. Technol. Lett.*, vol. 48, pp. 1032–1035, Jun. 2006.
[9] Y. Gao, B.-L. Ooi, and A. P. Popov, “Band-notched ultra-wideband ring-monopole antenna,” *Microw. Opt. Technol. Lett.*, vol. 48, pp. 125–126, Jan. 2006.
[10] W. J. Lui, C. H. Cheng, Y. Cheng, and H. Zhu, “Frequency notched ultra-wideband microstrip slot antenna with fractal tuning stub,” *Electron. Lett.*, vol. 41, pp. 294–296, Mar. 2005.
[11] A. M. Abbosh, “Ultra wideband planar antenna with spurline for subband rejection,” *Microw. Opt. Technol. Lett.*, vol. 50, pp. 725–728, Mar. 2008.
[12] Y. Ding, G.-M. Wang, and J.-G. Liang, “Compact band-notched ultra-wideband printed antenna,” *Microw. Opt. Technol. Lett.*, vol. 49, pp. 2686–2689, Nov. 2007.
[13] K.-H. Kim, Y.-J. Cho, S.-H. Hwang, and S.-O. Park, “Band-notched UWB planar monopole antenna with two parasitic patches,” *Electron. Lett.*, vol. 41, pp. 783–785, Jul. 2005.
[14] Z. N. Chen, D. Liu, and B. Gaucher, “A planar dualband antenna for 2.4 GHz and UWB laptop applications,” in *Proc. IEEE Veh. Technol. Conf.*, May 2006, vol. 6, pp. 2652–2655.