Progress In Electromagnetics Research Letters, Vol. 26, 125–134, 2011

A COMPACT, PLANAR PLATE-TYPE ANTENNA FOR 2.4/5.2/5.8-GHz TRI-BAND WLAN OPERATION

C.-T. Lee[1], S.-W. Su[1,*], and F.-S. Chang[2]

[1]Network Access Strategic Business Unit, Lite-On Technology Corporation, New Taipei 23585, Taiwan

[2]Department of Electronics, Cheng Shiu University, Kaohsiung County, 83347, Taiwan

Abstract—A novel, tri-band, planar plate-type antenna made of a compact metal plate for wireless local area network (WLAN) applications in the 2.4 GHz (2400–2484 MHz), 5.2 GHz (5150–5350 MHz), and 5.8 GHz (5725–5825 MHz) bands is presented. The antenna was designed in a way that the operating principle includes dipole and loop resonant modes to cover the 2.4/5.2 and 5.8 GHz bands, respectively. The antenna comprises a larger radiating arm and a smaller loop radiating arm, which are connected to each other at the signal ground point. The antenna can easily be fed by using a 50 Ω mini-coaxial cable and shows good radiation performance. Details of the design are described and discussed in the article.

1. INTRODUCTION

Compact planar antennas capable of providing multi-band operation in the 2.4 GHz (2400–2484 MHz), 5.2 GHz (5150–5350 MHz), and 5.8 GHz (5725–5825 MHz) bands for WLAN applications in diverse wireless electronic devices are in growing demand nowadays. One of the reasons is that the RF module pricing was driven down by major chipset vendors. In this case, more 802.11a/b/g/n transceivers are available on the market, and the antennas thereof are required. Many compact planar antennas were reported in the literature [1–11], including printed antenna structures [1–6] in either monopole [1–4] or dipole [5, 6] designs and metal-plate antenna structures in planar inverted-F antennas (PIFA) [7, 8] and shorted dipoles [9–11] designs. The latter can be more widely used in industry than the former.

Received 30 July 2011, Accepted 26 August 2011, Scheduled 6 September 2011

* Corresponding author: Saou-Wen Su (stephen.su@liteon.com).

Regardless of a great variety of the WLAN devices and antenna types, the aforementioned antennas are usually fed by mini-coaxial cables because of flexibility in deployment inside the devices and avoidance of clashing with the predetermined mechanical configuration. Moreover, except for dipole-like antennas [4, 5, 9, 10, 11], these designs above have less omnidirectional radiation patterns over the 2.4, 5.2, and 5.8 GHz bands. In this letter, we propose another promising, compact and planar plate-type antenna for tri-band WLAN operation and able to yield good omnidirectional patterns with high radiation efficiency. The design was obtained from stamping a small metal plate of size 10 mm × 38 mm with one T-shaped and one L-shaped slits inserted. The antenna comprises a larger radiating arm and a smaller loop radiating arm, which are linked at the signal ground point of the antenna. Three resonant modes to cover the 2.4, 5.2, and 5.8 GHz bands contribute to a 0.5-λ dipole mode, a 1.0-λ dipole mode, and a 0.5-λ loop mode formed at the same time in the antenna. The operating principle of the proposed antenna will be described and discussed more in detail with the aid of surface-current analyses and parametric studies. The experimental and simulated results are presented.

2. PROPOSED PLATE-TYPE ANTENNA

Figure 1 shows the geometry of the proposed planar plate-type antenna. The antenna is easily made of a rectangular metal plate, a 0.3-mm-thick copper-nickel-zinc alloy. The area of the design occupies a size of 10 mm × 38 mm. By cutting a T-shaped slit (of width 1 mm) and an L-shaped slit (of width 2 mm) in the plate, the proposed antenna is achieved. The antenna is further separated into two portions: a larger radiating arm and a smaller loop radiating arm, which are linked at the signal ground point, point B. Notice that the opposite point B is the antenna feed point, point A, with a feed gap of 1 mm. The first resonant mode for the 2.4 GHz band is mainly generated by the portions surrounding the T-shaped slit. The second resonant mode for 5.2 GHz operation is the higher-order mode of the first resonance and shows current nulls in the loop radiating arm (see Fig. 4). In this study, the distance d of the T slit is found to affect both the 2.4 GHz band and the upper band for 5.2 GHz operation (the second mode) for the antenna. Finally, the third resonance for the 5.8 GHz band is formed by a loop structure that begins from point A and arrives at point B through the conductive path. The length L in the loop radiating arm is introduced to control the desired operating frequencies to combine with the second mode for a wide operating band to include the 5.8 GHz band. The said two parameters will be analyzed, and the results thereof

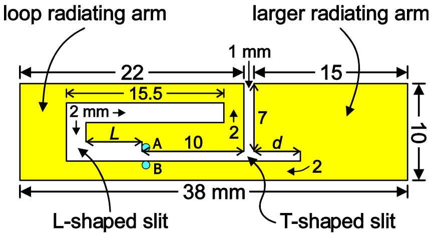


Figure 1. Geometry of the proposed, planar plate-type antenna operating in the 2.4/5.2/5.8 GHz bands for WLAN applications.

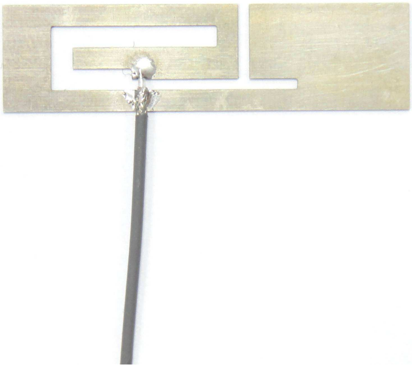


Figure 2. Photo of a constructed prototype made of a 0.3-mm thick plate and fed by a short mini-coaxial cable.

will be elaborated in the next section.

A photo of the design prototype is demonstrated in Fig. 2. Clearly, the antenna can be constructed from a single piece of a flat plate at a low cost. A short, 50-Ω mini-coaxial cable of overall diameter (O.D.) 1.13-mm type with an miniature coaxial RF connector, for example I-PEX [12] and U.FL [13] connectors, is utilized to electrically couple the signals from the antenna to the WLAN module in practice. The inner conductor of the cable is connected to point A; the outer, braided shielding is soldered at point B. The location of the antenna port (over points A and B) is essential for good input matching and needed concerning in conjunction with the parameters d and L. The preferred dimensions for this design were attained by rigorous parametric studies with the aid of an electromagnetic-field simulation tool, Ansoft HFSS [14], and the task was laborious before reaching near optimal values.

3. RESULTS AND DISCUSSION

A prototype of the proposed antenna as shown in Fig. 2 was constructed and tested. Fig. 3 shows the measured and simulated return loss of the constructed prototype. The experimental data in general agree with the simulation results. Three resonant modes for the 2.4, 5.2, and 5.8 GHz bands are excited. The measured impedance matching over the lower and the two upper resonant modes is all below a return loss of 10 dB [about voltage standing wave ratio (VSWR)

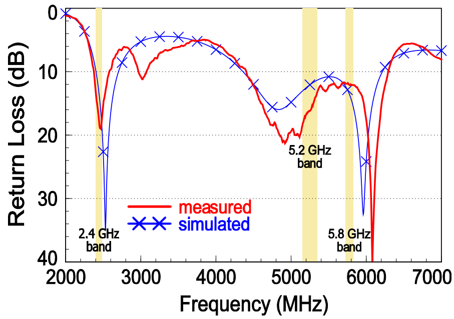


Figure 3. Measured and simulated return loss for a design prototype.

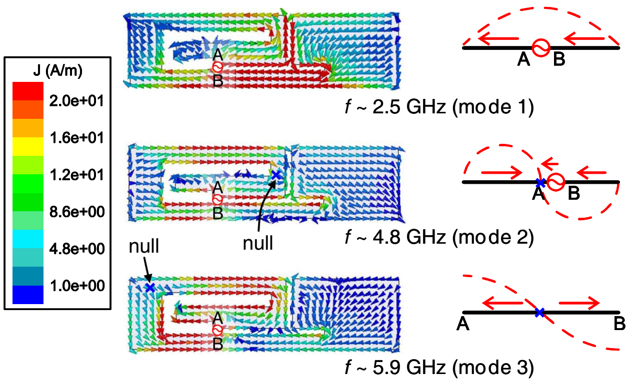


Figure 4. Simulated excited surface currents in the form of vectors at 2.5, 4.8, and 5.9 GHz for the antenna studied in Fig. 3.

of 2]. That's, the achievable impedance bandwidth of the proposed antenna satisfies the bandwidth specification for WLAN operation. The simulated surface-current distributions for the antenna excited at 2.5, 4.8, and 5.9 GHz (modes 1, 2, and 3) are presented in Fig. 4. The currents are plotted in the form of vectors (an arrow shape), and the current nulls are denoted as crosses in the figure. The dotted line represents the current magnitude. For the first and the second resonant modes, the antenna can be considered a bent dipole. Notice that mode 1 is of a 0.5-λ dipole mode, and mode 2 is of a 1.0-λ dipole mode. For the third resonance, the design acts like a 0.5-λ loop antenna with one current null located in the middle of the loop conductive path. The studies of the surface currents help illustrate the basic operating principle of the proposed design.

The simulation studies of the effects of the parameters d and L on the antenna impedance bandwidth were also conducted for analyses of the operating principle; the results are shown in Figs. 5 and 6 respectively. The operating frequencies of the first resonant mode are seen quickly shifted to the lower frequencies with an increase in the distance d from 2.5 to 6.5 mm while those for the second resonance (mode 2) are slightly lowered. This phenomenon is due largely to the stronger surface currents surrounding the slit d portion for mode 1. Notice that the third resonant mode is also affected because the two upper modes occur in close proximity and thus have some "pull" or "push" effects. For the small variation in the length L, it is seen

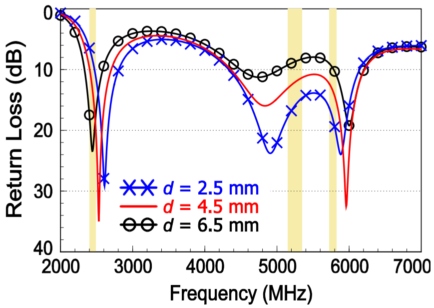


Figure 5. Simulated return loss for the proposed antenna as a function of d with the other dimensions kept the same as studied in Fig. 3.

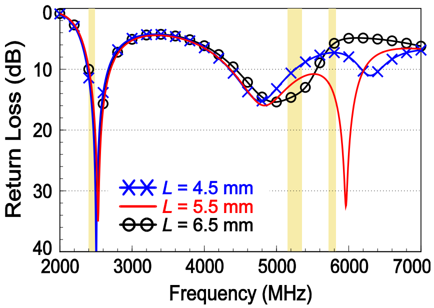
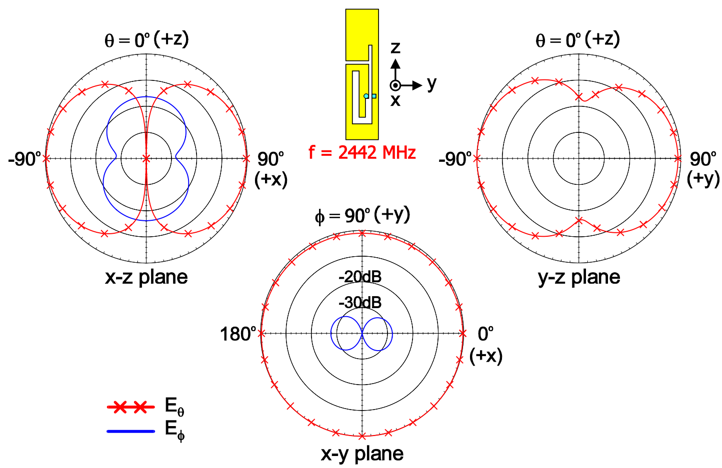
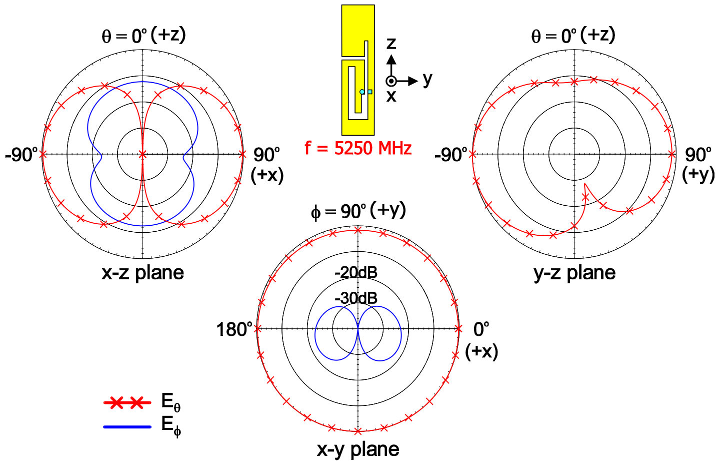


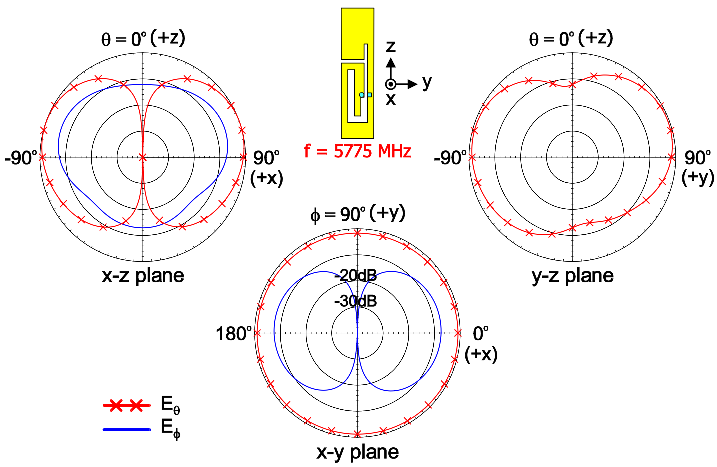
Figure 6. Simulated return loss for the proposed antenna as a function of L with the other dimensions kept the same as studied in Fig. 3.



(a)



(b)



(c)

Figure 7. Simulated 2-D radiation patterns at (a) 2442 MHz, (b) 5250 MHz, and (c) 5775 MHz for the antenna studied in Fig. 3.

that in Fig. 6, the frequencies of mode 3 is substantially impacted and decreased with a step of 1 mm from 6.5 to 4.5 mm. This suggests that the third resonant mode for 5.8 GHz operation can be controlled by the parameter L in the smaller loop radiating arm.

The over-the-air (OTA) performance of the prototype in free space was studied. Figs. 7(a), (b), and (c) show the far-field, 2-D radiation patterns at 2442, 5250, and 5775 MHz, the central operating frequency of the 2.4, 5.2, and 5.8 GHz bands, in E_θ and E_φ fields. The radiation patterns were normalized with respect to the maximum field strength among three major planes: the x-z, y-z, and x-y cuts. Good dipole-like, omnidirectional radiation patterns with large antenna gain lying in the x-y plane are observed. Figs. 8, 9, and 10 plot the

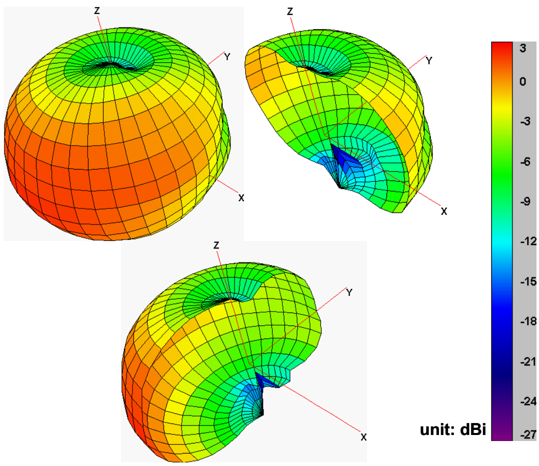


Figure 8. Measured 3-D radiation patterns (including the x-z and y-z cuts) at 2442 MHz for the antenna studied in Fig. 3.

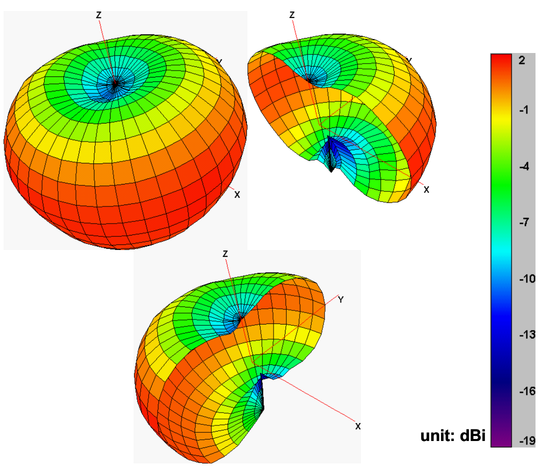


Figure 9. Measured 3-D radiation patterns (including the x-z and y-z cuts) at 5250 MHz for the antenna studied in Fig. 3.

measured far-field, 3-D radiation patterns at 2442, 5250, and 5775 MHz respectively. The ETS-Lindgren OTA test system using the great-circle method in one local CTIA authorized laboratory [15] was utilized for the measurement. Good consistency in the patterns across the three operating bands (also compared with other in-band frequencies measured) was obtained. Again, dipole-like, omnidirectional patterns in the x-y plane can be found. Good agreement between the 3-D (measured) and the 2-D (simulated) radiation patterns are also reached. Fig. 11 plots the measured, peak antenna gain and the radiation efficiency against frequency for the proposed antenna. The peak gain in the 2.4 GHz band is at a constant level of about 2.4 dBi with radiation efficiency exceeding 80%, which corresponds to the total

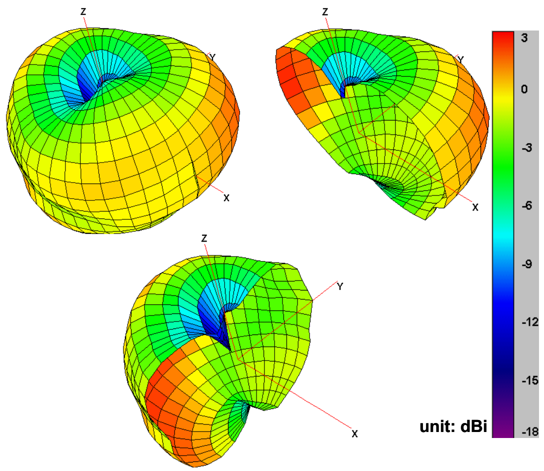


Figure 10. Measured 3-D radiation patterns (including the x-z and y-z cuts) at 5775 MHz for the antenna studied in Fig. 3.

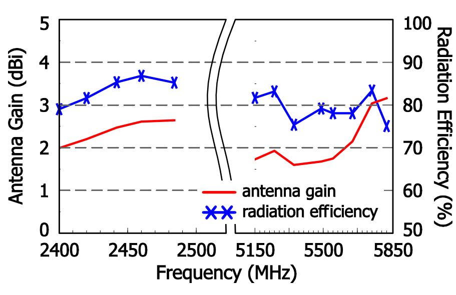


Figure 11. Measured antenna gain and radiation efficiency for the antenna studied in Fig. 3.

radiated power (TRP) of −0.96 dBm when the antenna input power is 0 dBm. For the 5.2/5.8 GHz bands, the peak varies from 1.6 to 3.2 dBi with the radiation efficiency in the range of 75% to 83%, corresponding to the TRP of −1.24 to −0.80 dBm. The gain measurement here takes account of the mismatch of the antenna, and the "realized gain" [16] was measured.

4. CONCLUSION

A new, compact, planar metal-plate antenna has been proposed and tested. Prototypes for WLAN operation in the 2.4/5.2/5.8 GHz bands have been constructed and studied. The antenna is simply made of a rectangular flat plate of size 10 mm × 38 mm and can be mass-produced at a low cost. The results show that the antenna is well matched with a return loss of 10 dB within the bands of interest. In addition, omnidirectional radiation patterns with TRP about −0.96 and −1.24 dBm over the 2.4 and 5.2/5.8 GHz bands are obtained. The proposed design is very suitable to fit in possible space inside the housing of wireless communications devices, leading to an internal antenna solution for WLAN operation.

REFERENCES

1. Fang, C. Y., H. T. Chen, and K. L. Wong, "Printed uni-planar dual-band monopole antenna," *Microwave Opt. Technol. Lett.*, Vol. 37, 452–454, 2003.
2. Yang, H. Y., "Miniaturized dual-band printed antennas for wireless communications," *IEEE Antennas Propagat. Soc. Int. Symp. Dig.*, Vol. 1A, 450–453, Washington, DC, 2005.
3. Deepu, V., K. R. Rohith, J. Manoj, et al., "Compact uniplanar antenna for WLAN applications," *Electron. Lett.*, Vol. 43, 70–72, 2007.
4. Su, S. W. and F. S. Chang, "Compact, printed mobile-unit antenna for 2.4 and 5 GHz WLAN applications," *Microwave Opt. Technol. Lett.*, Vol. 52, 2648–2653, 2010.
5. Su, C. M., H. T. Chen, and K. L. Wong, "Printed dual-band dipole antenna with U-slotted arms for 2.4/5.2 GHz WLAN operation," *Electron. Lett.*, Vol. 38, 1308–1309, 2002.
6. Hwang, S. H., J. I. Moon, W. I. Kwak, and S. O. Park, "Printed compact dual band antenna for 2.4 and 5 GHz ISM band applications," *Electron Lett.*, Vol. 40, 1568–1569, 2004.

7. Fang, C. Y., S. W. Su, and K. L. Wong, "Narrow flat metal-plate antenna for dual-band WLAN operation," *Microwave Opt. Technol. Lett.*, Vol. 38, 398–400, 2003.
8. Su, S. W. and Y. T. Liu, "Compact paper-clip-shaped wire antenna for 2.4 and 5.2 GHz WLAN operation," *Microwave Opt. Technol. Lett.*, Vol. 50, 2572–2574, 2008.
9. Su, S. W. and Y. T. Liu, "A one-piece flat-plate dipole antenna for dual-band WLAN operation," *Microwave Opt. Technol. Lett.*, Vol. 50, 678–680, 2008.
10. Su, S. W., "Low-cost flat metal-plate dipole antenna for 2.4/5-GHz WLAN operation," *Microwave Opt. Technol. Lett.*, Vol. 50, 1686–1687, 2008.
11. Su, S. W. and T. C. Hong, "A bent, short-circuited, metal-plate dipole antenna for 2.4-GHz WLAN operation," *Progress In Electromagnetics Research Letters*, Vol. 16, 191–197, 2010.
12. I-PEX Co., Ltd, http://www.i-pex.com/.
13. Hirose Electric Co., Ltd, http://www.hirose-connectors.com/.
14. Ansoft Corporation HFSS, Pittsburgh, PA, http://www.ansoft.com/products/hf/hfss.
15. CTIA authorized test laboratory, CTIA, the wireless association, http://www.ctia.org/business_resources/certification/test_labs/.
16. Volakis, J. L., *Antenna Engineering Handbook*, 4th edition, Chap. 6, 16–19, McGraw-Hill, New York, 2007.