Progress In Electromagnetics Research Letters, Vol. 16, 191–197, 2010

A BENT, SHORT-CIRCUITED, METAL-PLATE DIPOLE ANTENNA FOR 2.4-GHZ WLAN OPERATION

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Abstract—A novel, short-circuited, flat-plate dipole antenna for WLAN operation in the 2.4 GHz band is presented. The dipole antenna is narrow (5 mm in width) and structured to be of an L shape to fit in corners of possible wireless communications devices. The open ends of the two dipole arms are folded and face each other, so as to achieve a compact structure, and short-circuited via a short-circuiting strip, making it possible for the antenna to be cost-effectively fabricated by stamping one single metal plate only. The antenna when unbent into a flat, rectangular structure has dimensions 5 mm $\times$ 47 mm and can be easily fed by using a 50-Ω mini-coaxial cable. Details of a design prototype are described and discussed.

1. INTRODUCTION

There has been a great success in developing WLAN technology over the past few years. Many Wi-Fi-enabled, consumer-electronic devices are very common and easily accessible in the market. For these wireless devices, the antenna plays an important role among some key components in deciding RF performance. Because of diverse industrial designs and appearances of wireless products, there is no one antenna that fits all applications, especially since the antenna characteristics are prone to vary from free space to the device housing. One particular type of these antennas is the coaxial-line-fed, metal-plate (or wire), mobile-unit antenna that has a small form factor. For years, many of these kinds of antennas have been studied [1–5] and they have been found very attractive due to their flexibility in the deployment of the antenna to fit into many kinds of WLAN device. In this paper, we

Received 23 June 2010, Accepted 23 July 2010, Scheduled 17 August 2010
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introduce a new, metal-plate, mobile-unit dipole antenna, which is fed by using a mini-coaxial cable, for WLAN operation in the 2.4 GHz (2400–2484 MHz) band. The dipole antenna was stamped from a single flat plate with dimensions 5 mm × 47 mm and further bent into an L shape with equal lengths of 23.5 mm to fit in corners of possible wireless communications devices. In addition, the dipole was short-circuited at around the folded points of the dipole arms (see Fig. 1). The short-circuiting strip is relatively long in the design and can provide an additional path for in-phase surface currents. In this case, good antenna gain, along with omnidirectional radiation, in the band is expected. Detailed antenna design and the results thereof are described and discussed in the article.

2. ANTENNA DESIGN

Figure 1(a) shows the configuration of the proposed, bent, flat-plate dipole antenna. The dipole antenna mainly consists of two folded radiating arms perpendicular to each other and a narrow short-circuiting strip that connects the two radiating arms at around the folded points (denoted by C and D). The folding mechanism for the dipole arms allow the overall size to be much reduced. With the dipole

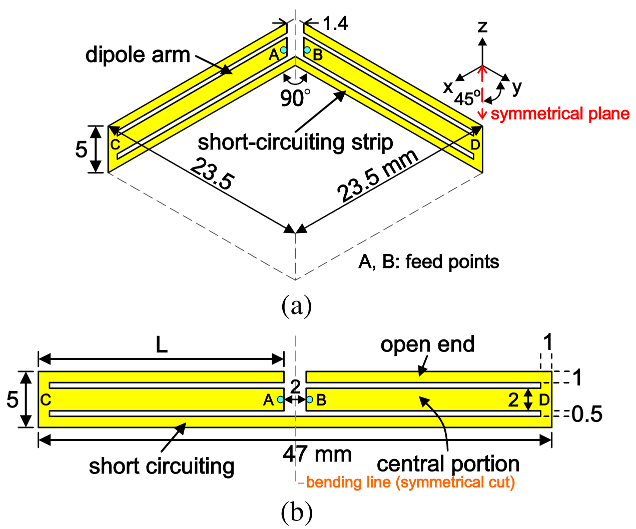

Figure 1. (a) Configuration of the proposed, bent, short-circuited, metal-plate dipole antenna. (b) Detailed dimensions of the antenna unbent into a flat plate structure.

further short-circuited, the antenna can easily be manufactured from stamping only a single, flat metal plate. The antenna was also bent, and the included angle between the two dipole arms is about 90°, which makes the antenna resemble the shape of L. Detailed dimensions for the antenna unbent into a flat plate are given in Fig. 1(b). The proposed dipole can be seen in the form of a rectangle with dimensions $5\,\text{mm} \times 47\,\text{mm}$ and symmetrical with respect to the bending line. The gap between the feed points A and B is 2 mm, and the central portion of the dipole arms on the two sides of the feed points is 2 mm in width and 22.5 mm in length. The open ends of the dipole and the short-circuiting strip are set at opposite sides of the central portion and have length L and 47 mm respectively. When the antenna is bent, the width 5 mm and the half length 23.5 mm of the dipole allows the antenna to be installed at corners inside wireless devices for practical applications. A photo of a constructed prototype made of a 0.3-mm-thick, copper-nickel-zinc alloy is demonstrated in Fig. 2.

To test the design prototype in experiments, a short, 50-Ω mini-coaxial cable with an I-PEX connector was utilized. The inner conductor of the cable is connected to the feed point A, and the outer, braided shielding is connected to the feed point B. Notice that the points A and B can be designated vice versa due to the proposed dipole antenna being symmetrical in shape. Although the two feed points are separated by a gap of 2 mm, this distance becomes shorter (about 1.4 mm) and is the hypotenuse of an isosceles, right-angled triangle when the antenna is bent as can be seen in Fig. 1(a). Further decrease in the feed gap causes more difficulties for cable soldering, and thus, poor reliability is expected in mass production. The antenna operating

Figure 2. Photo of a constructed prototype made of a 0.3-mm thick alloy and fed by a 50-Ω mini-coaxial cable.

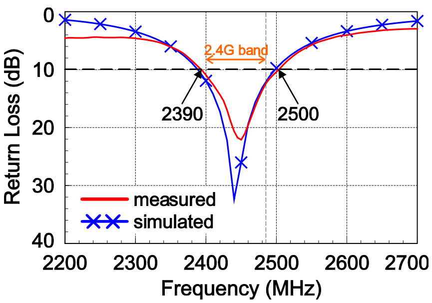

Figure 3. Measured and simulated return loss of a constructed prototype; $L = 22.5\,\text{mm}$.

frequency can be fine-tuned by adjusting the length L of the open end as an easy option. Another alternative is to vary the length (47 mm) of the antenna while the other parameters are kept the same. Moreover, in the case of the width of the central portion set to 1 mm (that's, the dipole antenna has a constant strip width), the antenna prototype had a length of 46 mm and showed that the achievable impedance bandwidth can still cover the 2.4 GHz band but with a return loss of 7.3 dB only. This prototype is, however, also applicable for use in some wireless devices. Notice that in this study, the wider the central portion is, the larger the impedance bandwidth of the dipole is.

3. RESULTS AND DISCUSSION

The proposed antenna was constructed and tested based on the design and dimensions thereof described in Fig. 1. Fig. 3 shows the measured and simulated return loss of a design prototype. In general, the experimental data compare favorably with the Ansoft HFSS simulation results [6], which were calculated using the finite element method (FEM). The measured impedance bandwidth, defined by 10 dB return loss (or about VSWR of 2), reaches about 110 MHz (2390–2500 MHz) and meets the bandwidth specification for the 2.4 GHz WLAN operation. Further, when there is no short-circuiting strip (the reference antenna, see Fig. 4), the input matching of the corresponding reference antenna with two separate dipole arms deteriorates rapidly and can not cover the 2.4 GHz band with 10-dB return-loss requirement. Notice that in this study, the central operating frequency was seen to decrease from about 2.44 GHz to 2.37 GHz, which is different from the behavior reported in [3]. This is probably because in the proposed antenna structure, the short-circuiting strip is comparatively long and can change the relative distance between the antenna feed and the short circuiting. With the overall dipole-arm size remaining the same, a decrease in the shorting strip yields a lowered operating frequency similar to the behavior of a conventional planar PIFA [7]. Fig. 5 shows the simulated return loss as a function of the open-end length L of the dipole for comparison. The length L was modified in steps of 2 mm, from 22.5 mm to 18.5 mm, and accordingly, the antenna frequencies shifted to a higher value. The return loss also decreases with the length in the frequency band of interest. From the Smith chart (not shown for brevity), the impedance curve was seen to move towards the termination of open circuit (i.e., the resistance became larger) and its diameter became smaller, which in turn led to the operating frequencies move off the 2 : 1-VSWR circle. Nevertheless, this parameter, the open end length of the antenna, is still very useful for post-tuning of the central frequency of the operating band when the antenna is to be installed inside a wireless communications device because the antenna frequency-band is affected by dielectric loading (device housing) effects [8], normally shifting the frequency to a lower value.

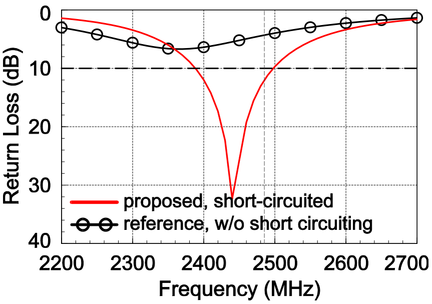

Figure 4. Simulated return loss for the proposed antenna (short-circuited) and the reference antenna (without short-circuiting strip).

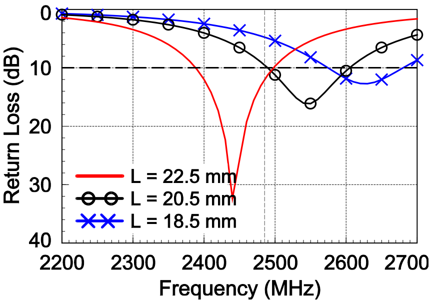

Figure 5. Simulated return loss for the proposed antenna as a function of the open-end length L of the dipole.

Figure 6 shows the measured 3-D, far-field, radiation patterns at 2400, 2442, and 2484 MHz for the constructed prototype. Other frequencies in the bands of interest were also measured; no inconsistency on the patterns was found. The measurement was made by the ETS-Lindgren OTA test system using the great-circle method in a CTIA authorized test laboratory [9]. Similar to the conventional dipole radiation characteristics, good omnidirectional-radiation patterns are obtained. Notice that in this design, the omnidirectional radiation exists in the cut (see dashed line in Fig. 1) which is a symmetrical plane in the geometry of the proposed design. Fig. 7 presents the measured peak antenna gain, the average gain of the 3-D patterns in free space, and the measured radiation efficiency of the prototype. The peak gain level reaches about 2.5 dBi and is larger than the average gain by about 3 dBi in the 2.4 GHz band. The radiation efficiency exceeds about 85%, which corresponds to the total radiated power (TRP) of -0.7 dB when the antenna input power is 0 dBm. The gain measurement here takes account of the antenna mismatch loss, and thus, the "realized gain" [10] is measured. The radiation efficiency was obtained by calculating the TRP of the antenna under test (AUT) over the 3-D spherical radiation first and then dividing that total amount by the input power of 0 dBm given to the AUT. In this case, the TRP (in dB) is equal to the 3-D average gain here.

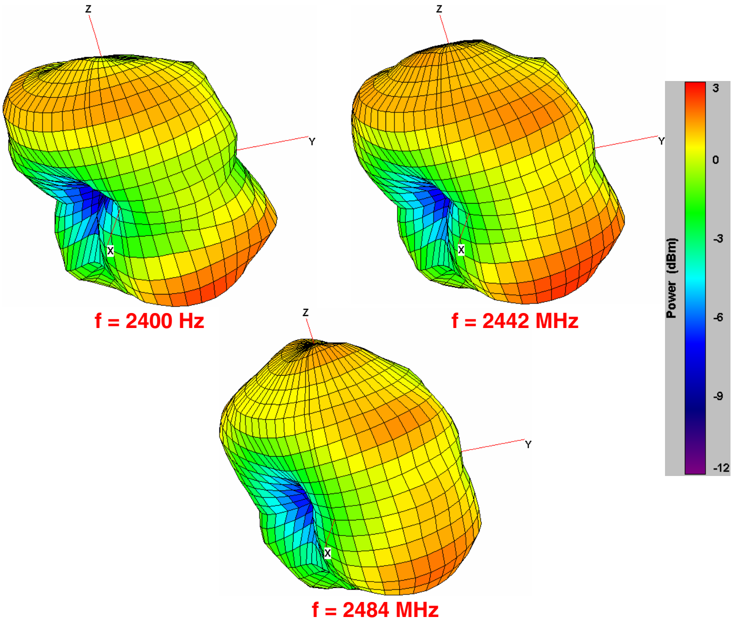

Figure 6. Measured 3-D radiation patterns at 2400, 2442, and 2484 MHz for the design prototype studied in Fig. 3.

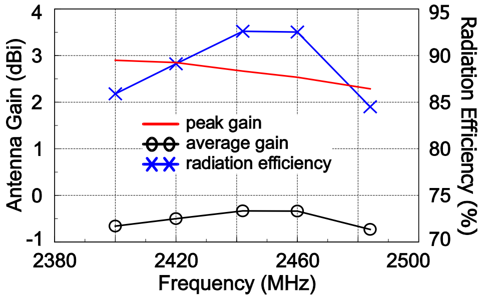

Figure 7. Measured peak antenna gain, average gain, and radiation efficiency of the prototype.

4. CONCLUSION

A bent, short-circuited dipole antenna ideally suited to installation at corners inside wireless communications devices in the 2.4-GHz WLAN band has been proposed and studied. A prototype constructed from a one-piece metal plate of size 5 mm × 47 mm has been tested. The antenna structure is easy to implement and can be a promising solution for keeping the cost down. With the narrow width of 5 mm, the antenna can find many practical uses, where the low-profile antenna designs are required. Good omnidirectional radiation patterns across the operating band have been observed with good radiation efficiency and TRP exceeding about −0.7 dB.

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