PRINTED DUAL BAND MONOPOLE ANTENNA STRUCTURES FOR WLAN APPLICATIONS

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Received 23 January 2008

ABSTRACT: This article proposes printed dual-band monopole antenna structures for Wireless Local Area Network (WLAN) applications in IEEE 802.11a/b/g. The proposed antennas are fabricated on a low cost easily available FR4 substrate, which effectively covers both 2.4 and 5 GHz bands. The antenna structures are derived from an E-shape dual-band monopole antenna, which generates two separate resonant frequencies for the desired dual-band operations. The one arm resonates at the 5 GHz band, whereas the other resonates at the 2.4 GHz band. The proposed antennas can easily be fed by using a 50-Ω probe feed. The measured VSWR is <2 over the 2.4–2.5 GHz and 5.15–5.875 GHz. The radiation patterns indicate the suitability of these antennas for WLAN applications.


Key words: dual band; ISM band; WLAN; monopole antenna; planar antenna

1. INTRODUCTION

Dual and multifrequency band operation of antennas has increasingly become common, mainly because of the tremendous growth in modern wireless communication systems. Wireless Local Area Network (WLAN) is one of the most important applications of the wireless communication technology that takes advantage of license-free industrial, scientific, and medical (ISM) bands and uses 2.4–2.5 GHz (IEEE 802.11b and IEEE 802.11g) and 5.15–5.35 and 5.725–5.875 GHz (IEEE 802.11a) frequency bands. To integrate these bands for use in one device, it is essential to develop efficient dual-band anten-
Dual-band monopole antennas have been reported in [1-5], but these, however, offer narrow impedance bandwidth characteristics. Rectangular planar monopole antennas (RMA), on the other hand, have been shown to exhibit a relatively wide impedance bandwidth and good radiation pattern characteristics [6, 7]. The planar monopole antenna is a good candidate for wireless communication because of its simple structure, omnidirectional radiation characteristic, low profile, and lightweight [8]. It is significant that the designed dual-band RMA maintained good radiation efficiency values at both bands [9].

2. ANTENNA DESIGN THEORY

In planar monopoles, most of the current is concentrated on the outside edge of the radiating element, and therefore the center section of a rectangular monopole can be removed with negligible effect on antenna impedance or radiation characteristics. This leads to the formation of a U-shaped monopole antenna resonating at 5 GHz band. A planar rectangular monopole is placed in the central portion of U-shaped monopole antenna to resonate at 2.4 GHz band, leading to E-shaped dual band antenna [10, 11]. If the slots are removed or the arms resonating at 5 GHz are allowed to coincide with central arm, it give rise to an E-shape antenna without slots (ESAWS). This antenna can also be treated as one with the width discontinuity. L-shaped antenna is obtained from E-shaped antenna without slots by slicing the one side of upper band with negligible effect on antenna impedance or radiation characteristics. F-shaped antenna is obtained from L-shaped antenna by bending the long arm, which also reduces the size of antenna. The antenna offers a reduction in size without any degradation in radiation pattern. An inverted U-shaped with offset arm (IUSWOA) antenna is designed by bending the longer arm on the other side in U shape. In all structures, longer arm resonates at 2.4 GHz band, whereas the shorter at 5 GHz.

Theoretical current path length of shorter arm of monopole antenna structures to resonate at 5.5 GHz, which is about 13.6 mm corresponding to λ/4 in free space at 5.5 GHz, whereas the current path length of longer arm is about 30.6 mm corresponding to λ/4 in free space at 2.45 GHz. The width of the two arms determines impedance bandwidth at two bands. The antenna design and results are described in the following sections.

3. ANTENNA GEOMETRY AND SIMULATION RESULTS

The geometry of the proposed antenna structures are shown in Figure 1. The antenna structures are designed and simulated using FR4 substrate. The relative permittivity and thickness of substrate are 4.4 and 1.59 mm, respectively.

To achieve the desired dual-band characteristics for WLAN operations in the 2.4 and 5 GHz bands, the dimensions of the longer arm of rectangular monopole is optimized to resonate at 2.4 GHz, whereas dimensions of the shorter arm of monopole is optimized to resonate at the upper 5 GHz band. Hence, the proposed antennas provide effective control of the lower and upper operating bands. In addition, Ground plane dimensions are also optimized to achieve the desired dual-band operation as it affects
Figure 4  (a) Radiation pattern of E shaped without slot antenna, (b) radiation pattern of L-shape antenna, (c) radiation pattern of F-shape antenna, and (d) radiation pattern of IUWOA antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]
the resonant frequencies and operating bandwidths in dual bands. Overall dimensions in E-shaped antenna without slots and L-shape antenna is 20 × 40 mm, whereas substrate dimensions reduces to 20 × 35 mm in case of F shape and inverted U with offset arm antenna. A dipole or monopole-like radiation pattern can be obtained by varying the ground-plane dimensions. The antenna structure is simulated using IE3D software [12].

The simulated impedance variations of the antenna structures are shown in Figure 2. Dual band with wide bandwidths are observed. The simulated lower and upper band for VSWR ≤ 2 is tabulated in Tables 1. The lower band covers 2.4–2.5 GHz (IEEE 802.11b and IEEE 802.11g) ISM band, and the upper band covers 5.15–5.875 GHz (IEEE 802.11a) band. The current distribution at 2.45, 5.25, and 5.8 GHz is shown in Figure 3. The normalized radiation patterns at 2.45, 5.25, and 5.8 GHz are shown in Figure 4. The radiation pattern is observed to be nearly omnidirectional in θ = 0° plane in all the structures. Cross polar component is observed to be more in L and F shape when compared with ESAWS and IUSWOA antennas. Cross polarization component also increases in upper band. The pattern variation over the frequency band is small. The gain variation versus frequency is shown in Figure 5, which is less than 1 dB over the two frequency bands 2.4–2.5 GHz and 5–6 GHz.

5. FABRICATION AND MEASURED RESULTS

The antenna structures are fabricated and tested. The measured results are in close agreement with the simulated results. The measured and simulated VSWR plots of E-shape antenna without slots (ESAWS) and L-shape antenna and F-shape and inverted U-shape antenna with offset arm (IUSWOA) are shown in Figures 6 and 7, respectively.

6. CONCLUSION

Printed dual-band monopole antenna structures for WLAN applications are analyzed. A dual band with wide bandwidth characteristics is observed in each structure, which covers 2.4–2.5, 5.15–5.35, and 5.725–5.875 GHz ISM bands. The proposed antennas are designed on low cost easily available FR4 substrate. The results obtained clearly indicate that the antennas are capable of generating nearly omnidirectional radiation pattern in 802.11 a/b/g frequency bands. These antenna structures provide flexibility of shape and also space availability on substrate beside satisfactory and comparative performance for WLAN applications.

REFERENCES

1. INTRODUCTION

Conventional planar inverted-F antennas (PIFAs) have been widely applied in the mobile phone as internal antennas for dual-band or multiband operation at about 900 and 1900 MHz [1]. These PIFAs generally use two separate resonant paths of different lengths operated at their quarter-wavelength modes to cover the operating bands at about 900 and 1900 MHz. It is also promising to use the first two resonant modes of a single resonant path operated at its quarter- and half-wavelength modes. These conventional PIFAs usually occupy a volume of larger than 2 cm³ inside the mobile phone [1].

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The proposed PIFA comprises a single resonant path close to about one-eighth wavelength at 900 MHz only, and a coupling feed [2] is used, which is different from the use of a direct feed of the conventional PIFAs. With the coupling feed, the large input impedance at 900 and 1900 MHz can be greatly decreased to allow the proposed PIFA to generate two operating bands at about 900 and 1900 MHz to cover the desired multiband operation. The coupling feed in the proposed PIFA can also be considered as an internal matching circuitry, which does not increase the occupied volume of the antenna inside the mobile phone. This is different from the external matching circuitry that has been reported [3–6], which will occupy some valuable board space on the system circuit board of the mobile phone and increase some insertion loss also.

Detailed design considerations of the proposed PIFA are described in the article. Experimental and simulation results for fabricated prototypes of the proposed PIFA are presented and discussed.

2 DESIGN CONSIDERATIONS OF PROPOSED PIFA

Figure 1(a) shows the configuration of the proposed PIFA with a coupling feed for mobile phone application. In this study, the PIFA is printed on a 0.4-mm thick FR4 substrate, which is then folded into a compact configuration to be mounted on the top no-ground portion (size 6 × 60 mm²) of the system circuit board of the mobile phone. In this study, a 0.8-mm thick FR4 substrate of size 106 × 60 mm² is used as the system circuit board; on its back side, there is a printed system ground plane of length 100 mm and width 60 mm. The dimensions of the system circuit board and ground plane considered here are practical for general smart phones or PDA (personal digital assistant) phones [7, 8].

The total occupied volume of the PIFA is 0.78 cm³ (5 × 6 × 26 mm³) only. Owing to its small volume, the PIFA is flushed to the left side edge of the system circuit board in this study, leaving a large unoccupied portion in the top no-ground portion of the system circuit board, which can be used to accommodate other components of the mobile phone.