A Dual-Band Printed Dipole Antenna for Unidirectional Radiation

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Abstract. This paper presents a dual-band printed dipole antenna for unidirectional radiation. The antenna is designed for the Wireless Local Area Network (WLAN) system that operating on both the frequency ranges of 2.400 – 2.483 GHz and 5.15 – 5.85 GHz. Radiated elements of the antenna are flat conductors on the surface of FR4 printed circuit board. All elements are on the same side of FR4. Coaxial line is chosen for feeding. It makes the antenna good matching and easy to assembly. The antenna is simulated by computer program before fabricating a prototype. It provides omni-directional radiation but has a direction with the gain about 5 dBi at the central of both operating frequencies. It is appropriate for the system that desired the signal to radiate surround but has some direction together. The size of the antenna is 44.0 x 60.0 mm\textsuperscript{2}. Advantages of the antenna are low profile structure, light weight, and can be fabricated with cheap material. So, it is a low-cost antenna.

1. Introduction

There are many wireless communication systems such as the Digital Video Broadcasting - Second Generation Terrestrial (DVB-T2) operate with the frequency range of 470 - 862 MHz, the Digital Cellular System (DCS) operate with the frequency range of 1.71 - 1.88 GHz, the Personal Communications System (PCS) operate with the frequency range of 1.85 - 1.99 GHz, the Universal Mobile Telecommunications System (UMTS) with the frequency range of 1.92 - 2.17 GHz, the Worldwide Interoperability for Microwave Access (WiMAX) operate with the frequency range of 2.496–2.690 GHz, and the Wireless Local Area Network (WLAN) operate with the frequency ranges of 2.400 - 2.483 GHz and 5.15 – 5.85 GHz. However, all systems must use the antenna for transmitting and receiving signals. Thus, many antennas are developed to support each system above. The antenna that operated cover more than one system is called broadband antenna [1] while the antenna that can be operated cover only 2 frequency bands together is called dual-band antenna [2].
Most of broadband antennas are wideband antennas. Wideband antennas had been proposed in many research works. For example, the planar monopole [3] that radiated in omni-direction, it provides a very wide bandwidth but had distort beam at the high frequency of its band. For the bi-directional radiation such as the wide slot antenna [4], although it has a wide bandwidth but squeeze beams occurs at the high frequency of the band as well. For uni-directional radiation antennas, there are many types of the antenna that provide the uni-directional radiation but their bandwidths are not wide enough. Form the problem of distort-beam at the high frequency of wideband antenna, the dual-band antenna is proposed.

Recently, various antenna designs such as those of micro-strip line, coplanar waveguide, and printed dipole antennas have been proposed in the literature. A printed dipole antenna with U-slotted arms was demonstrated in [5]. From the aid of an embedded U-shaped slot, it can generate a new resonant mode at 5.2 GHz. In [6], printed dipole antenna with parasitic elements was presented. The measured results show that parasitic strips can be coupled with dipole antennas for providing additional resonance modes. In [7], a broadband printed dipole antenna with a step shaped feed gap was presented. The wide operating band is controlled by the different lengths of the radiation arms. Therefore, it was shown that a dipole antenna with parasitic elements has the ability to give multiband operation.

This paper describes the dual-band antenna that can be used to operate with WLAN system in the frequency ranges of 2.400–2.483 GHz and 5.15–5.85 GHz. A prototype that operates in the both frequency bands is developed. By adding 3 parasitic strips with a dipole printed on the same side of the FR4, a WLAN antenna that active dual-band operation from 2.400 – 2.483 and 5.15 - 5.85 GHz is realised. The dipole and parasitic elements are able to produce three resonant modes. Additionally, the reflection coefficient, far-field radiation pattern and antenna gain of the proposed antenna are presented.

2. Antenna description
The analysis and design was conducted using the simulation software at first. After the optimization by software, we received the antenna dimensions through the parameters which depend on the reflection coefficient such as the length of the driven dipole. Few parameters are approximated such as the size of the substrate. To confirm the accuracy of the simulation, the prototype of the antenna is fabricated with the same dimensions and materials as receive from the simulation except the feeding.

A structure of the proposed antenna is shown in Figure 1. (a) while the prototype of the antenna is shown in Figure 1. (b). The antenna was contributed on an FR4 substrate with a thickness of 1.6 mm and a permittivity of 4.8. The overall dimensions of the structure were 44.0 x 60.0 (a x b) mm². The antenna was fed at the centre by a 50 Ω coaxial line (for the prototype while discrete port for the simulation) that connects to two symmetrical rectangular dipole arms (driven element). The length of the dipole, l₁, is used to determine the low frequency (2.400 – 2.483 GHz) band, and the width s₁ is adjusted to vary the impedance for the desire of impedance matching. To increase the resonant modes of the high frequency (5.15 – 5.85 GHz), 2 parasitic elements were added to the rectangular dipole. The long parasitic element (director), l₃, determines the high frequency band of the low-resonant mode (at 5.15 GHz). And the width s₃ is adjusted to vary the impedance for the desire of impedance matching. The short parasitic element, l₄, determines the high-resonant mode (at 5.85 GHz), while the width s₄ is adjusted for the desired impedance as well. The resonant band is obtained through coupling between the dipole and the 2 parasitic strips. In addition, the band of low-resonant mode (5.15 GHz) was able to combine with the band of high-resonant mode (5.85 GHz), resulting in operation from 5.15 to 5.85 GHz.

For the high frequency, we increased the gain of the antenna into the z-direction by extending the width of the director parasitic strip, s₃, in the z-direction. For the low frequency, we increased the gain of the antenna into the z-direction by adding the reflector parasitic strip width of s₂ and length of l₂ as in Figure 1. (a). The reflector is far from driven dipole d. In this way, a dual-band dipole antenna for a
unidirectional radiation for WLAN applications was designed. The optimal antenna parameters for WLAN are given as in Table 1.

![Antenna Diagram]

**Figure 1.** (a) Structure of the proposed dual-band printed dipole antenna (b) Prototype of the proposed dual-band printed dipole antenna

| Parameter | Dimension (mm) | Parameter | Dimension (mm) |
|-----------|----------------|-----------|----------------|
| s1        | 3.0            | g1        | 1.5            |
| l1        | 43.0           | g2        | 0.5            |
| s2        | 3.0            | g3        | 0.5            |
| l2        | 54.0           | a         | 44.0           |
| s3        | 8.0            | b         | 60.0           |
| l3        | 15.0           | d         | 18.0           |
| s4        | 3.0            | t         | 1.6            |
| l4        | 10.0           | t_s       | 0.05           |

3. **Simulated and measured results**

3.1. *Simulated and measured reflection coefficients*

The simulated and measured reflection coefficients are shown in Figure 2. The simulated result of the reflection coefficients is agrees with the experimental. The measured reflection coefficients of the antenna provides the bandwidths of 6.3% and 12.4% (VSWR<1.5:1) between the frequency range of 2.3 - 2.5 GHz and 5.0 - 5.9 GHz, respectively. However, the range of measured bandwidth is slightly wider than the simulated result. The discrepancy is mainly due to the simulation of the feeding that using the discrete port while the fabricated antenna is fed by 50 Ω coaxial line.
Almost parameters are varied to show the characteristics of the proposed antenna. The first parameter is $l_1$ or the length of dipole. The results of reflection coefficient with different $l_1$ are showed in Figure 3. It is found that $l_1$ is influence to the low frequency (2.400 – 2.483 GHz) band. When $l_1$ is increase from 40.0 mm to 43.0 mm and to 26 mm, the low frequency band is shelved to low.

The second parameter is $l_2$ or the length of reflector. The results of vary $l_2$ is showed in Figure 4. It is found that $l_2$ is little influence to the low frequency band. When $l_2$ is increase from 50.0 mm to 54.0 mm and to 58 mm, the impedance of the low frequency band is increase.

Figure 2. Simulated (a) and measured (b) reflection coefficient of the proposed antenna

Figure 3. Simulated reflection coefficients when changed parameter $l_1$.

Figure 4. Simulated reflection coefficients when changed parameter $l_2$. 

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\text{Figure 3. Simulated reflection coefficients when changed parameter } l_1. \\
\text{Figure 4. Simulated reflection coefficients when changed parameter } l_2.
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The third parameter is $l_3$ or the length of the director. The results of reflection coefficient with different $l_3$ are showed in Figure 5. It is found that $l_3$ is influence to the high frequency (5.15 – 5.85 GHz) band, especially for low-resonant mode. When $l_3$ is increase from 14.0 to 15.0 and to 16 mm, the low-resonant mode is shelf to high make the bandwidth decrease.

The next parameter is $s_3$ or the width of the director. The results of vary $s_3$ is showed in Figure 6. It is found that $s_3$ is little influence to both the low and high frequency bands but it is used to determine the gain of the antenna to direct to the $z$-direction at the high operating frequency. While $g_2$ is explicitly effect to the high frequency band as showed in Figure 7.

![Figure 5. Simulated reflection coefficients when changed parameter $l$.](image1)

![Figure 6. Simulated reflection coefficients when changed parameter $s$.](image2)

![Figure 7. Simulated reflection coefficients when changed parameter $g$.](image3)
The next parameter is $l_4$ or the length of the shortest parasitic. The results of reflection coefficient with different $l_4$ are showed in Figure 8. It is found that $l_4$ is used to determine the high frequency (5.15 – 5.85 GHz) band, especially for high-resonant mode. When $l_4$ is increase from 8.0 to 10.0 and to 12 mm, the high-resonant mode is shelf to low make the bandwidth decrease.

The next parameter is $s_4$ or the width of the shortest parasitic. The results of vary $s_4$ is showed in Figure 9. It is found that $s_4$ is little influence to both operating frequency bands but it is used to adjust the radiation pattern direct to the z-direction at the high operating frequency. While $g_3$ is explicitly effect to the high frequency band as showed in Figure 10.

**Figure 8.** Simulated reflection coefficients when changed parameter $l$

**Figure 9.** Simulated reflection coefficients when changed parameter $s$

**Figure 10.** Simulated reflection coefficients when changed parameter $g$
3.2. Simulated and measured radiation patterns

The experimental was operated in open area to decrease the effect of the reflection. The observed operating frequencies are 2.44, 5.15, and 5.85 GHz as shown in figure 11, 12, and 13, respectively.

Figure 11 shows the normalized of simulated H plane and E plane (or yz-plane and xz-plane, respectively, as indicated the coordinate and direction in Figure 1) co-polarization patterns compare with the measured results at 2.44 GHz. It was found that the front-to-back ratio is 8 dB. The half power beam-widths (HPBW) are 176° for yz-plane and 77° for xz-plane. The patterns in both plane are symmetry.

Figure 12 shows the simulated and measured co-polarized radiation patterns at 5.15 GHz. It was found that the front-to-back ratio is 12 dB. The HPBW are 177° for yz-plane and 68° for xz-plane. Figure 13 shows the simulated and measured co-polarized radiation patterns at 5.85 GHz. It was found that the front-to-back ratio is 14 dB. The HPBW are 160° for yz-plane and 68° for xz-plane.

However, gains of the antenna at the three points are 4.8 dBi, 5.5 dBi, and 8.0 dBi, respectively.

![Figure 11. Simulated (solid line) and measured (doted) co-polarized radiation patterns at 2.44 GHz (a) yz plane (b) xz plane](image1)

![Figure 12. Simulated (solid line) and measured (doted) co-polarized radiation patterns at 5.15 GHz (a) yz plane (b) xz plane](image2)
4. Conclusions

This paper presented the dual-band printed dipole antenna for unidirectional radiation. The antenna is fabricated from conductor on the surface of FR4 printed circuit board in one-side and fed by a coaxial line. The elements of the antenna composed of dipole, 2 parasitic, and reflector. From the analysis, we found that the antenna has the measured bandwidth cover both operating frequencies of 2.400 – 2.483 GHz and 5.15 – 5.85 GHz. Antenna gains are 4.8 dBi, 5.5 dBi, and 8.0 dBi at the operating frequencies of 2.44 GHz, 5.15 GHZ, and 5.85 GHz, respectively. The advantages of the antenna are low profile structure, easy to fabricate, light weight, and can be fabricated with the cheap material. It is the low-cost antenna that suitable for using both base station and receiving antenna with a linear polarized system.

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