Dual-Band Dipole Antenna with Unequal Arm Lengths

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1. Introduction

With the development of wireless local area network (WLAN), the antennas with small size, dual-band operation, and low cost characteristics are becoming popular [1, 2]. In order to further reduce the antenna thickness and decrease the fabrication cost, a dual-band printed dipole antenna, which can be embedded into the notebook, has been published [1]. However, the antenna needs two pairs of radiators, which make the antenna more complicated, and the total length is too long for some applications.

In this article, a novel dual-band dipole antenna with unequal arm lengths is proposed. As we know the conventional straight dipole antenna is fed at the center of the antenna, however, the frequency ratio of the first two resonant modes is about 3, which is not suitable for practical application. Thus, we change the feeding position of the dipole antenna, which makes the dipole antenna with unequal arms and leads the frequency ratio decreasing to the value we need. Details of the design considerations for achieving dual-band operation, and experimental results of a constructed prototype for operating in the 2.4 and 5.2 GHz bands are presented.

2. Antenna Design

Figure 1 shows the geometry of the proposed dual-band dipole antenna with unequal arm lengths (the longer and shorter arms with different lengths ℓ_1 and ℓ_2, respectively) printed on a microwave substrate of dimensions 51 × 6 mm^2, a practical size for being embedded into the notebook. The microwave substrate used here is inexpensive FR4, which has a thickness 0.8 mm and a relative permittivity 4.4. The proposed dipole antenna, easily fed by a 50-Ω cable line, is assembled by the longer and shorter arms and both arms are of constant width 2 mm. To make the study simple, the gap between the longer and shorter arms is fixed to 2 mm.

With the help of the commercially available software Ansoft HFSS (High Frequency Structure Simulator), the total length of the proposed dipole antenna is chosen to be 47 mm, which is corresponding to about 38% of the wavelength at 2450 MHz and generates a resonant mode for the lower operating frequency of the proposed dual-frequency operation. The length of the proposed dipole antenna is smaller than one-half wavelength of a conventional straight dipole antenna in free space. This behavior is largely due to the effect of the microwave substrate supporting the proposed dipole antenna, which leads to decreasing resonant length for the proposed dipole antenna. This effect is also helpful for achieving a smaller antenna size for a fixed operating frequency.

To control the upper operating frequency, we change the feeding position of the proposed dipole antenna. It is then found that, by increasing the length of longer arm ℓ_1 and decreasing the length of shorter arm ℓ_2, the upper operating frequency decreases rapidly and can be controlled and only very slight variations are observed at the lower operating frequency. With this characteristic, a constructed prototype is easily demonstrated for WLAN applications in the 2.4 and 5.2 GHz bands.

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3. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 2 shows the measured and simulated return loss of the dual-band dipole antenna with various arm lengths. The simulated results are obtained from the simulation software Ansoft HFSS. The measured data with other cases are also given in Table 1 for comparison. It is seen that the lower operating frequency (f_1) is all close to 2450 MHz, as designed, and very slight variations are observed for five cases studied. Conversely, the upper operating frequency (f_2) decreases obviously with the increasing the length of the longer arm ℓ_1 and decreasing the length of the shorter arm ℓ_2. This is because increasing the length of the longer arm ℓ_1 changes the 2nd mode current distribution of the dipole antenna, and thus the 2nd resonant frequency decreases. In this study, as ℓ_1 is varied from 22.5 to 40 mm, the obtained frequency ratios (f_2/f_1) of the two operating frequencies are in a range from about 3.05 to 2.17. Also notice that the impedance matching becomes worse with increasing the longer arm length ℓ_1 that leads the lower operating frequency cannot be used.

Antenna 2 (ℓ_1 = 32 mm and ℓ_2 = 13 mm) has a frequency ratio about 2.27, and is suitable for 2.4/5.2 GHz WLAN applications. The obtained impedance bandwidths, determined from 10-dB return loss, are 350 and 830 MHz, respectively, for the lower and upper bands and are both enough for 2.4 and 5.2 GHz bands applications.

Radiation characteristics were also studied. Figure 3 plots the measured radiation patterns for antenna 2 at 2.45 GHz, and the results at 5.25 GHz are shown in Figure 4. From patterns in x-z and x-y planes of Figure 3, it is clearly known that the lower operating frequency (f_1) is the 1st mode of dipole antenna and from those in Figure 4, the upper operating frequency (f_2) is the 2nd mode of dipole antenna. Figure 5 presents the measured antenna gain for operating frequencies across the WLAN bands at 2.4 and 5.2 GHz. For 2.4 GHz band, the antenna gain is about 1.2 dBi, with quite stable gain variations. For 5.2 GHz band, the antenna gain is about 3.5 to 3.8 dBi.

Table 1: Performance of the proposed dual-band dipole antenna with unequal arm lengths. Impedance bandwidth (BW) is determined from 10-dB return loss.

	ℓ_1, ℓ_2 (mm)	f_1, BW (MHz)	f_2, BW (MHz)	f_1/f_2
Reference	22.5, 22.5	2583, 425	7884, 407	3.05
Antenna 1	28, 17	2434, 365	5545, 345	2.28
Antenna 2	32, 13	2335, 350	5296, 830	2.27
Antenna 3	36, 9	2235, 87	5022, 695	2.25
Antenna 4	40, 5	2235, - - -	4848, 267	2.17

4. Conclusion

Novel dual-band operation of the dipole antenna with unequal arms has been proposed. The proposed antenna has a simple geometry and is easy to implement. By adjusting the feeding position, dual-frequency operation with a wide range in frequency ratio can be obtained for the proposed dipole antenna. In the study, a constructed prototype has also been successfully implemented, and two separate operating bands suitable for WLAN operations in the 2.4 and 5.2 GHz bands are obtained.

References

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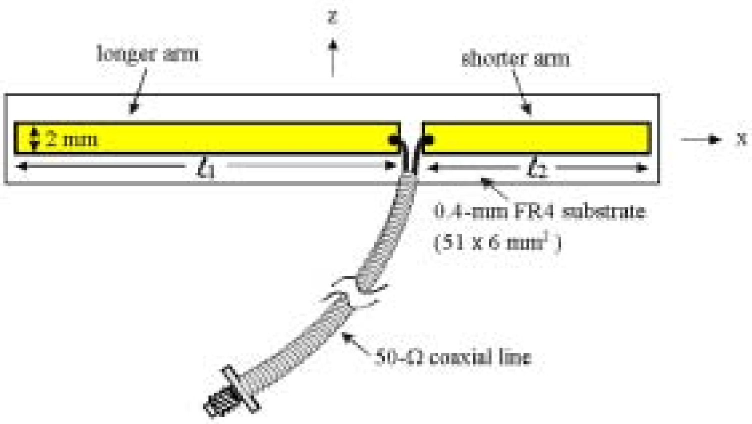

Fig. 1 Geometry and dimensions of the proposed dual-band dipole antenna with unequal arm lengths printed on a microwave substrate for 2.4 and 5.2 GHz operations.

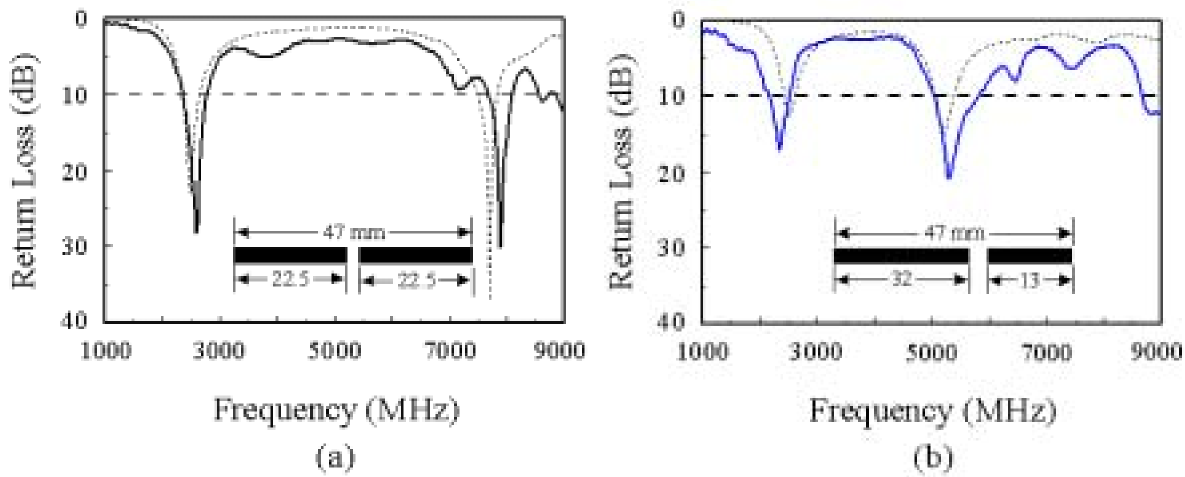

Fig. 2 Measured and simulated return loss of the proposed antenna with different ℓ_1 and ℓ_2. Solid lines are measured data, and dash lines are simulated by Ansoft HFSS.

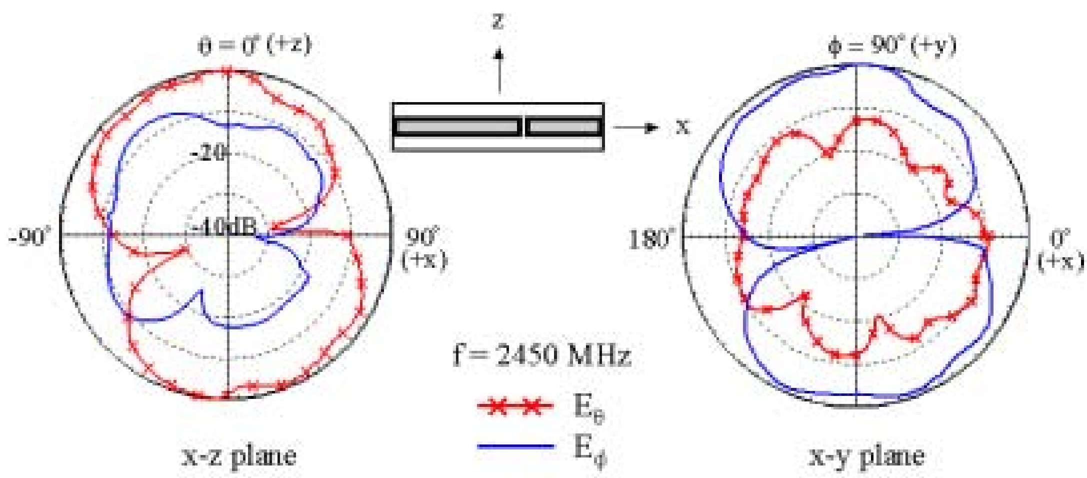

Fig. 3 Measured radiation patterns for antenna 2 at 2450 MHz.

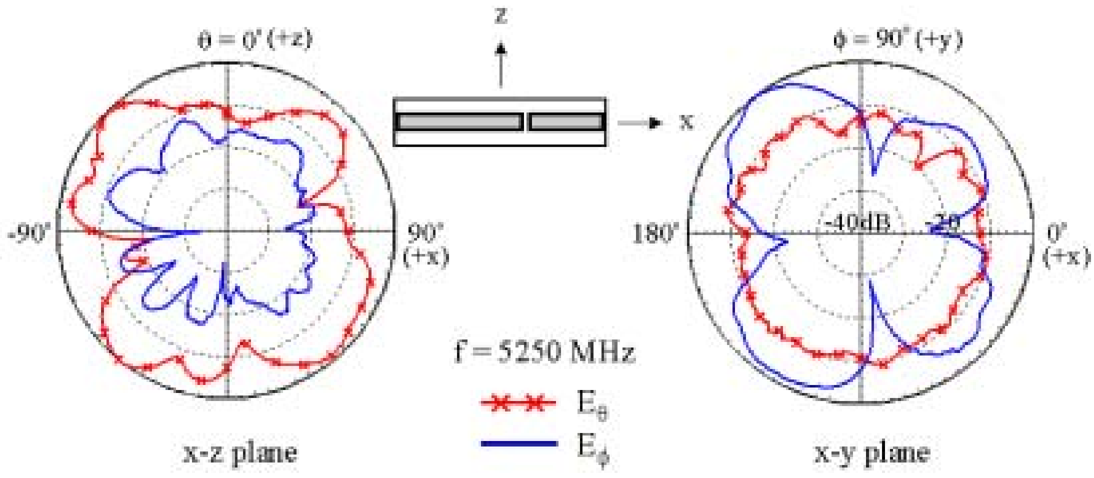

Fig. 4 Measured radiation patterns for antenna 2 at 5250 MHz.

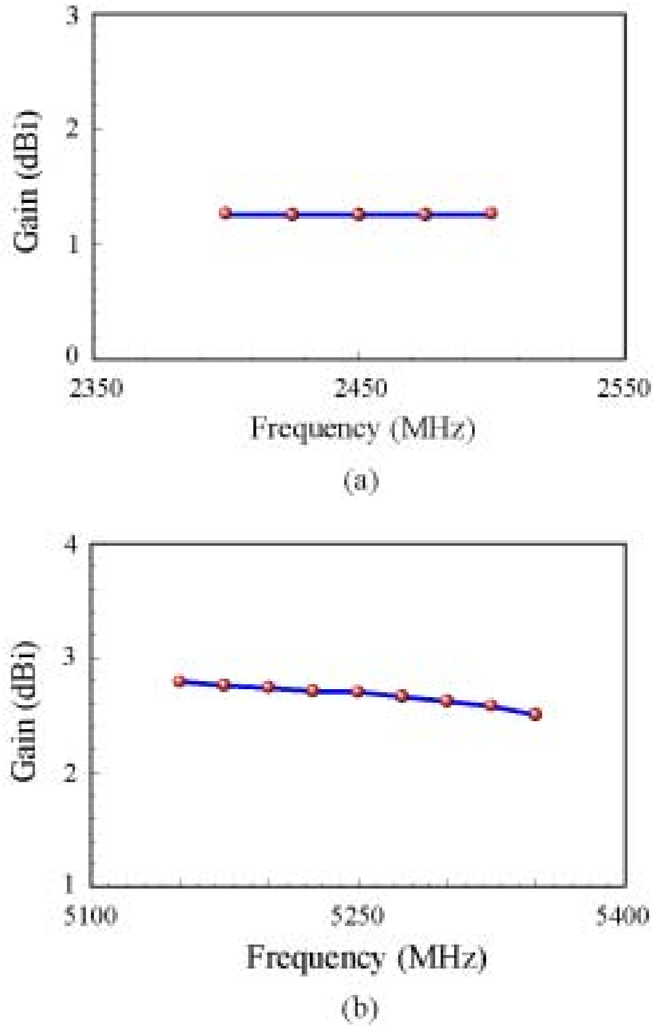

Fig. 5 Measured antenna gain of antenna 2 for operating frequencies across (a) the 2.4 GHz band (2.4–2.484 GHz) and (b) the 5.2 GHz band (5.15–5.35 GHz) for WLAN operation.