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DUAL-WIDEBAND MONOPOLE LOADED WITH SPLIT RING FOR WLAN APPLICATION

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Abstract—This paper presents a novel monopole antenna which uses split ring loading in order to achieve a dual-wideband operation for WLAN (2.4/5.2/5.8 GHz) application. By adjusting the split ring position and its natural resonant frequency, the proposed antenna can produce more than 1 GHz wideband match in the 5 GHz band. According to the measured results, the bandwidth with reflection coefficient less than -10 dB is about 715 and 1017 MHz in the two bands. Good radiation patterns are also achieved. The dimensions of the monopole loaded with split ring are 27.2 mm $\times$ 16.2 mm $\times$ 1 mm, which is suitable for a hallway antenna or ceiling mount antenna of WLAN application.

1. INTRODUCTION

The wireless local area network (WLAN) has become almost ubiquitous with even increasing market penetration. The lower band ranges from 2.4 to 2.484 GHz for IEEE 802.11b/g and upper band covers frequency band from 5.15–5.35/5.725–5.825 GHz for IEEE 802.11a. Nowadays, dual-band WLAN systems combining IEEE 802.11a/b/g standards are becoming more attractive [1, 2]. A dual-band antenna is a key component for such communication systems [3–9], especially for "universal" applications, where it should be covering the whole 2.4–2.484 GHz and 5.15–5.825 GHz bands for dual-band WLAN. Designs range from those based on branched monopole [3, 4], dipole [5, 6], or multibranch [7, 8] to those based on dielectric resonators. Recently, it has been demonstrated that loading with magnetic resonator can facilitate dual-band operation [9]. It takes advantage of the additional physical resonator structure to create a monopole standing-wave

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resonance in the second frequency band. So, it works monopole mode in dual-band. But the structure is complex. There are many parameters to affect the loaded magnetic resonator. Loading with split ring resonators can also obtain dual-frequency operation with arbitrary frequency ratios [10]. But the impedance bandwidth is too narrow.

In this paper, a simple split ring loading is used in the design to achieve a dual-wideband operation for WLAN (2.4/5.2/5.8 GHz) application. Only adjusting the split ring position, the split ring radius and the split angle, the proposed antenna can easily produce more than 1 GHz wideband match in the 5 GHz band. Among the parameters, the split angle α is a key parameter to affect the 5 GHz band. The uniform width monopole is incorporated with a split ring resonator skillfully to obtain dual-wideband operation. The proposed antenna has a simple and compact structure, and a good impedance characteristic. A prototype is constructed and tested. Details of the antenna design and analysis are presented, with the measured results.

2. ANTENNA DESIGN

The basic geometry of the antenna is shown in Fig. 1. The antenna consists of a loaded split ring attached to a uniform width monopole. The antenna was designed on an FR4 substrate with parameters $h = 1\,\text{mm}$, $\varepsilon_r = 4.4$ and $\tan\delta = 0.016$.

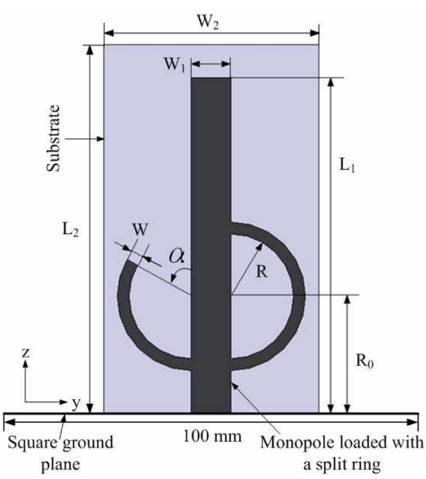


Figure 1. Geometry of proposed monopole antenna loaded with a split ring. All dimensions are: $L_1 = 24.7\,\text{mm}$, $W_1 = 3\,\text{mm}$, $L_2 = 27.2\,\text{mm}$, $W_2 = 16.2\,\text{mm}$, $R = 4.7\,\text{mm}$, $W = 0.9\,\text{mm}$, $R_0 = 8.8\,\text{mm}$, $\alpha = 50\,\text{deg}$.

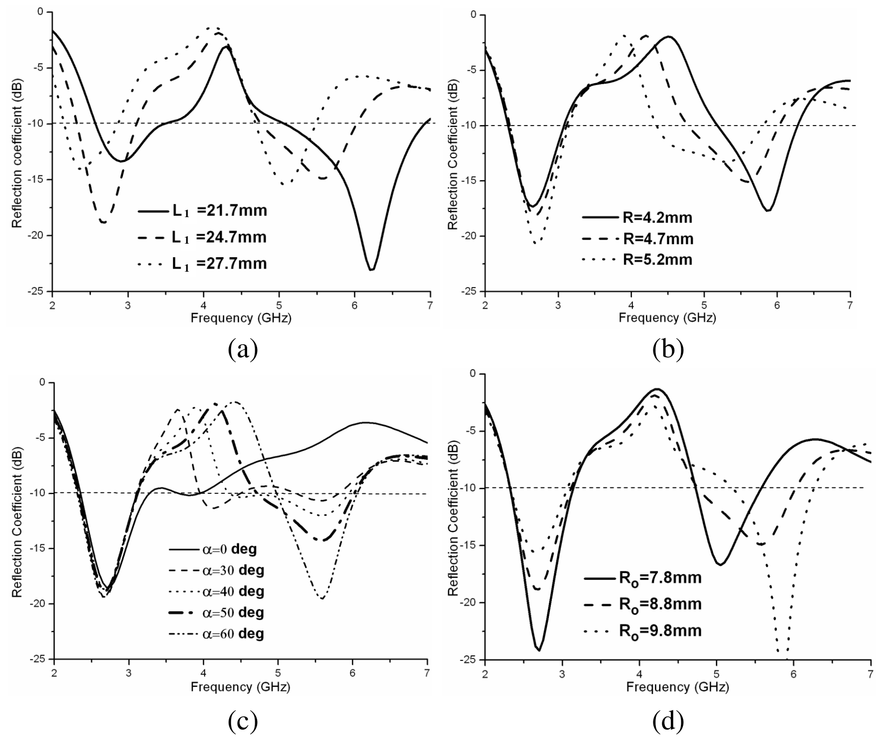


Figure 2. Parametric study of the variation of reflection coefficient with respect to (a) the monopole length L_1, (b) the split ring radius R, (c) the split angle α, and (d) the split ring offset R_0.

Figure 2(a) shows the effect of monopole length L_1 on dual-operating bands of the antenna. It is observed that the operating bands are shifted down as the monopole length L_1 increases, so the design begins with L_1 approximately equal to a quarter-wavelength at 2.45 GHz and subsequently tuning this parameter to achieve match in the first band. The split ring resonator is essentially a half-wavelength resonator because the fundamental mode number is $n = 1$ ($l_c = n\lambda_g/2$, l_c is the circumference of a ring and $n \in N$), while the split ring resonator used in the proposed antenna operates properly when $n = 2$ ($l_c = \lambda_g$) in order to obtain impedance match. So the split ring resonator radius R can be expressed as

$$R = \frac{c}{2\pi f \sqrt{\varepsilon_{eff}}} \tag{1}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{10h}{w}\right)^{-\frac{1}{2}} \tag{2}$$

where c represents the speed of light in free space, f represents the resonant frequency of the split ring resonator, ε_r and h represent the permittivity and thickness of the FR4 substrate and w represents the split ring resonator width. The resonant frequency of the split ring resonator is chose to 5.5 GHz, so the R is equal to 5.09 mm. The proper value of R is needed to tune after incorporating with the uniform width monopole.

The split ring radius R shifts the second band without significantly affecting the first band in Fig. 2(b). Fig. 2(c) shows that there is no resonance in the 5 GHz band when the split ring angle α is equal to 0 deg. But as the angle α is increased, a resonant frequency is obviously moved towards another resonant frequency of the 5 GHz band. When α is equal to 40 deg there are two resonant frequencies in the second band to get wide impedance bandwidth. But in order to get reflection coefficient much less than -10 dB the split angle α is chose to 50 deg. Meanwhile the second band is more than 1 GHz. Fig. 2(d) exhibits the effect of the split ring position offset R_0 on the performance of the monopole. It is observed that the second band is shifted down as the R_0 decreases.

After the initial design, a fine-tuning process of the above mentioned parameters is necessary to allocate the operating bands according to the standard requirements. Fig. 1 shows the dimensions of the fabricated prototype. The prototype of the proposed antenna is shown in Fig. 3.

3. SIMULATION AND EXPERIMENTAL RESULTS

The prototype antenna shown in Fig. 3 was mounted on a large ground plane (100 mm × 100 mm) via a SMA panel connector. The reflection coefficient shown in Fig. 4 was measured with an Agilent 8722D vector network analyzer with 50 Ω as the reference impedance and agrees well with the High Frequency Structure Simulator (HFSS) simulation model. The available bandwidth is enough to cover the WLAN requirements, obtaining 715 MHz (2302–3017 MHz) in the 2.4 GHz band and 1017 MHz (5080–6097 MHz) in the 5 GHz band.

In order to explain in more detail of the antenna, Fig. 5 shows the simulated surface current distributions at different frequencies. Fig. 5(a) shows a $\lambda/4$ standing wave on the uniform width monopole at 2.45 GHz where current on the split ring is very week. This indicates that the uniform width monopole is the major radiating element for the

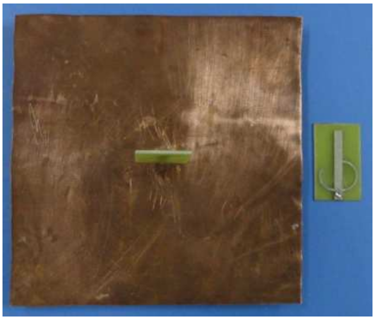


Figure 3. Photograph of the proposed antenna.

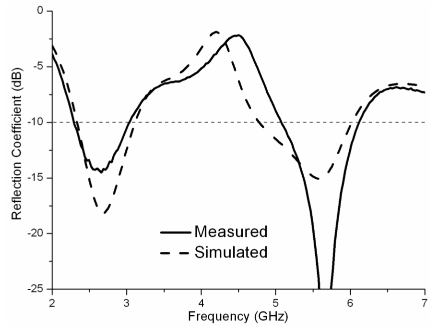


Figure 4. Measured and simulated reflection coefficient for the prototype antenna whose dimensions are shown in Fig. 1.

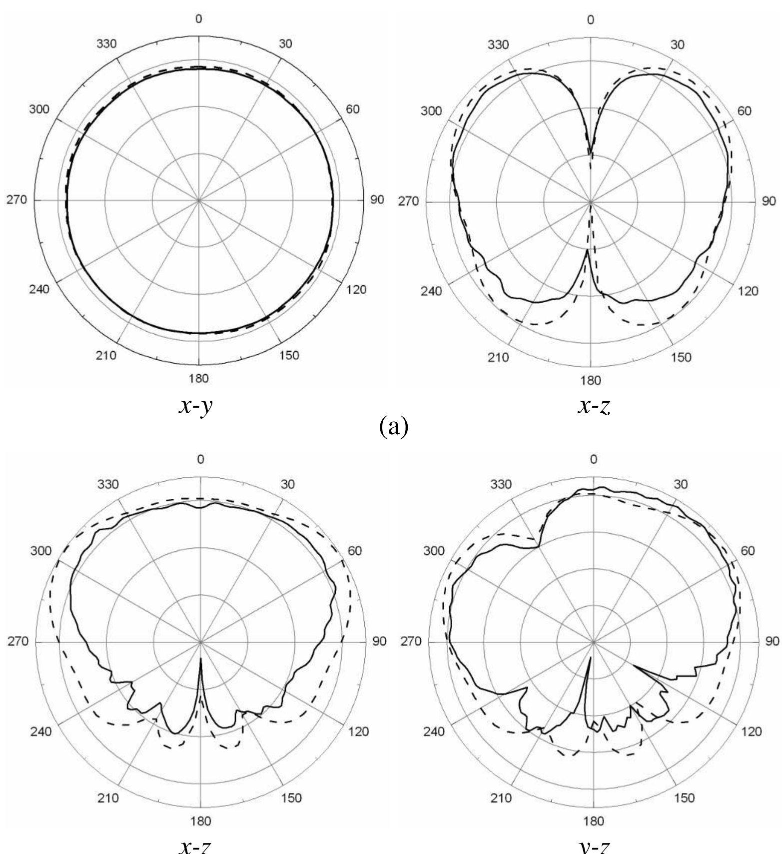
(a) (b) (c)

Figure 5. Simulated surface current distributions at different frequencies. (a) 2.45 GHz, (b) 5.2 GHz, (c) 5.8 GHz.

antenna at the 2.45 GHz. Figs. 5(b) and (c) show there are two currents oriented in opposite directions on the uniform width monopole. The current in the lower part of the uniform width monopole is dominant at 5.2 GHz, and upper part at 5.8 GHz. Meanwhile the current on the split ring begins to increase and has corresponding resonant frequency which is shown in Fig. 2. These results indicate that the uniform width monopole and the split ring are the major radiating elements for the proposed antenna at the 5 GHz band.

The measured and simulated radiation patterns for the monopole loaded with split ring in the x-y and x-z planes at 2.45 GHz are shown in Fig. 6(a). The monopole-like radiation patterns verify that at

2.45 GHz the proposed antenna enables it to operate as a monopole. Fig. 6(b) and (c) show the measured and simulated radiation patterns for the proposed antenna in the x-z and y-z planes at 5.2 and 5.8 GHz, respectively. The radiation patterns exhibit a broad beam for the main lobe in the $+z$ direction which is because they are superposed of the monopole and ring antenna radiation patterns. From the figures of y-z planes, it can be seen that hollow points are both formed in $+330°$ due to the split of the ring. The radiation patterns in the x-z and y-z planes at 5.2 and 5.8 GHz also indicate that the uniform monopole and the split ring are the major radiating elements for the proposed antenna at the 5 GHz band. Fig. 7 shows the measured peak gains and radiation efficiencies across the operating bands and the peak gains do not change very seriously at their operation bands.



(a)
(b)

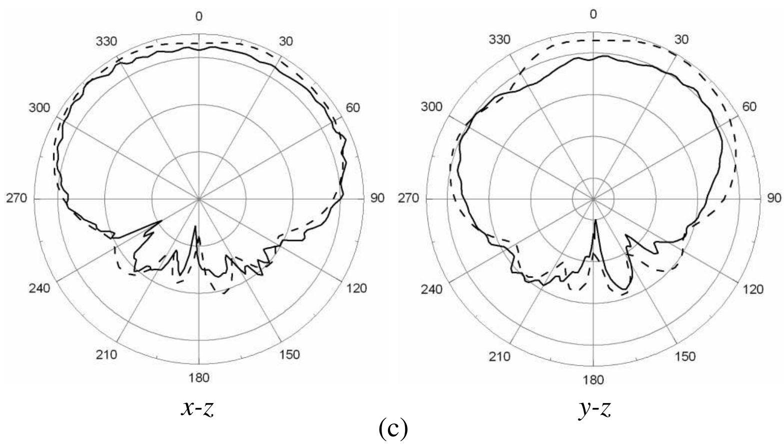


Figure 6. Radiation patterns for the proposed antenna (measured (——) and simulated (- - -)). (a) 2.45 GHz, (b) 5.2 GHz, (c) 5.8 GHz.

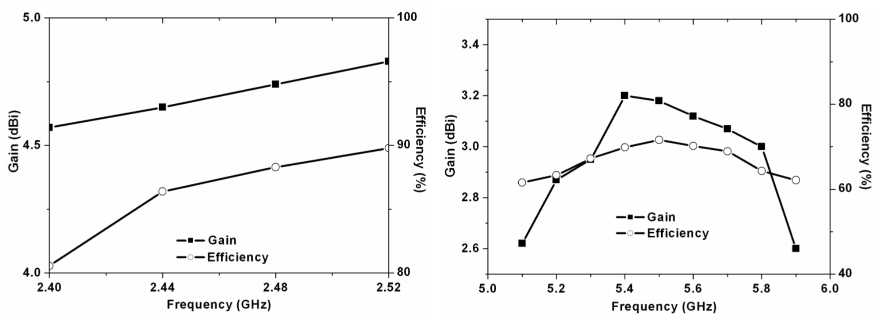


Figure 7. Measured peak gains and radiation efficiencies across the operating frequencies.

4. CONCLUSION

A simple design procedure for an universal WLAN (802.11a/b/g) monopole antenna has been presented, which employs split ring loading on a conventional printed monopole design in order to create a dual-wideband antenna. The split angle α is a key parameter to create the second band. Results indicate that the antenna impedance bandwidth is easy to cover the 2.4/5.2-GHz and 5.8 GHz bands for WLAN operation and good radiation patterns have been obtained. The antenna is suitable to be used as a hallway antenna or ceiling mount antenna for WLAN application.

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