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COMPACT DUAL-BAND DIELECTRIC RESONATOR ANTENNA FOR 2.4/5.8 GHZ WLAN APPLICATIONS

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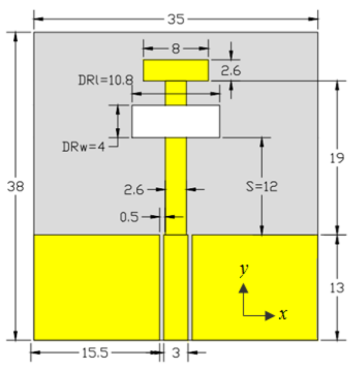
A. Mataria, M. R. Kamarudin*, M. Khalily

Wireless Communication Centre (WCC), Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor. Malaysia

*Corresponding author
ramlee@fke.utm.my

Graphical abstract



Abstract

Design of a Dual-Band Dielectric Resonator Antenna (DRA) for the radio-frequency identification (RFID) and wireless local area network (WLAN) is presented. The necessity of a compact sized dual-band antenna is to allow the manufacturers to produce small size high-performance WLAN access points. The proposed antenna consists of printed T-Shaped monopole antenna and rectangular dielectric resonator to operate simultaneously at 2.4 and 5.8 GHz. The monopole antenna was printed on a standard 1.6 mm FR4 substrate material. Impedance bandwidth for -10 dB return loss in the 2.35 GHz and 5.86 GHz center frequency reaches 0.25 GHz (2.22 GHz to 2.47 GHz) and 0.28 GHz (5.72 GHz to 6 GHz), respectively. A good agreement is achieved between measured and simulated results. This compact antenna fed by a 50 Ω microstrip line is a low-profile and easy to manufacture antenna.

Keywords: Dielectric resonator antenna, radio frequency identification, wireless local area network, monopole antenna, impedance bandwidth

Abstrak

Over recent years, there has been an explosive growth of interest in the development of novel gel-phase materials based on small molecules. It has been recognised that an effective gelator should possess functional groups that interact with each other via temporal associative forces. This process leads to the formation of supramolecular polymer-like structures, which then aggregate further, hence gelating the solvent. Supramolecular interactions between building blocks that enable gel formation include hydrogen bonds, interactions, solvatophobic effects and van der Waals forces.

Kata kunci: Dendritic gels, tunable materials

1.0 INTRODUCTION

In the past three decades, dielectric resonator antennas (DRAs) became an attraction in antenna design due to its various features. DRA serves its own degree of versatility and flexibility, which rarely can be found in any common antennas [1]. The common advantages of DRAs are ease of excitation, low loss, low cost, light weight and small size [2, 3]. In addition, DRAs have low dissipation loss at higher frequencies compared to conventional antennas. Furthermore, DRAs have higher radiation efficiency at higher frequencies due to its ohmics and surface wave losses. A wide bandwidth with high radiation efficiency was achieved by carefully choosing the suitable DR dimensions and position. In order to improve the DRA bandwidth, several techniques can be used such as: notched DR shapes [4], multi-segmented DR [5], stacking [6, 7] and parasitic-element methods.

It is preferable to have a dual-band antenna rather than using two separate antennas for dual-band wireless communications. As such, it is challenging to design a single antenna which can cover several allocated bands [8]. However, until now, there has been no simple and single DRA that has the ability to cover the upper and the lower bands of the IEEE 802.11 (WLAN standard). As a solution, the DR can be combined with other types of radiators such as microstrip, patches and slots to achieve the dual-band radiation feature.

In this article, a dual-band DRA for RFID and WLAN applications is presented. A combination of DR and monopole antenna was achieved on the proposed structure in order to achieve the dual-band feature. The proposed antenna resonates at 2.4 GHz and 5.8 GHz IEEE 802.11 WLAN standard. In this article, the simulated and measured results of return loss, peak antenna gain and radiation patterns are presented. Furthermore, the analysis section contains a parametric study of the DR dimensions (DR*l*, DR*w* and DR*h*) and its offset distance (*S*). By carefully tuning the dimensions and the position of the DR on the structure, the upper band impedance bandwidth can be easily obtained.

2.0 ANTENNA GEOMETRY

Figure 1 shows the structure of the proposed dual-band dielectric resonator antenna. It consists of a single rectangular DR, and a monopole antenna [9 - 11] fed by microstrip line printed on FR4 substrate. The FR4 substrate has a thickness of 1.6 mm and relative permittivity (ε_r) of 4.3. The dimension of the FR4 substrate is L × W (38 × 35 mm^2). The DR has a length of DR*l* = 10.8 mm, a width of DR*w* = 4 mm, a height of DR*h* = 2.4 mm, and a relative permittivity ε_r = 30. The T-Shaped monopole antenna has a length of 27 mm. A 50 Ω microstrip line is used for the excitation for both monopole and DR with a width of 3 mm. The remaining detailed design parameters are shown in Figure 1. The DR is placed above the microstrip line with an offset distance of S = 25 mm. The overall adjustments of DR dimensions and position, and the length of the monopole were done to achieve the required impedance bandwidth for upper and lower bands, respectively.

3.0 ANTENNA DESIGN AND ANALYSIS

The performances of the proposed antenna at the upper band are basically affected by the DR specifications. There are several parameters that affect the antenna characteristics such as, DR's dimensions, position and permittivity. A parametric study was investigated and delivered to achieve the required antenna performance. For the proposed design in this article, the initial parameters were chosen carefully as shown in Figure 1. The studies on the effects of changing dimensions, offset distance and permittivity of DR are presented.

Figure 2, Figure 3 and Figure 4, show the effects of changing the DR length (DR*l*), width (DR*w*) and height (DR*h*), respectively on the resonant frequency of the proposed antenna. As shown from the above-mentioned figures, increasing the dimensions of DR with respect to its offset distance will lead to decrease the resonant frequency of the upper band, and vice versa. It can be clearly seen from that results that the lower band is approximately immune to the changes occurred on the DR dimensions.

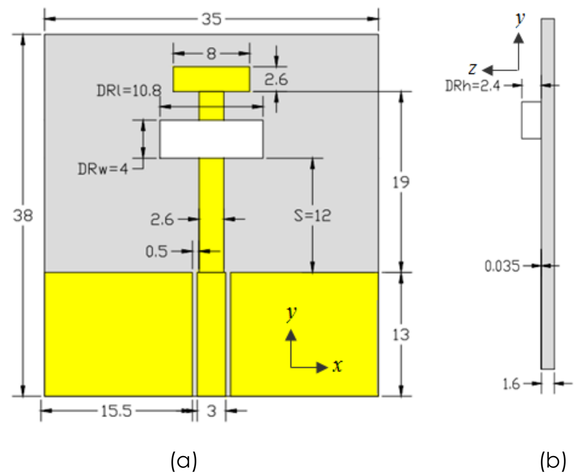


Figure 1 Geometry of the proposed dual-band DRA (a) Front view (b) Side view

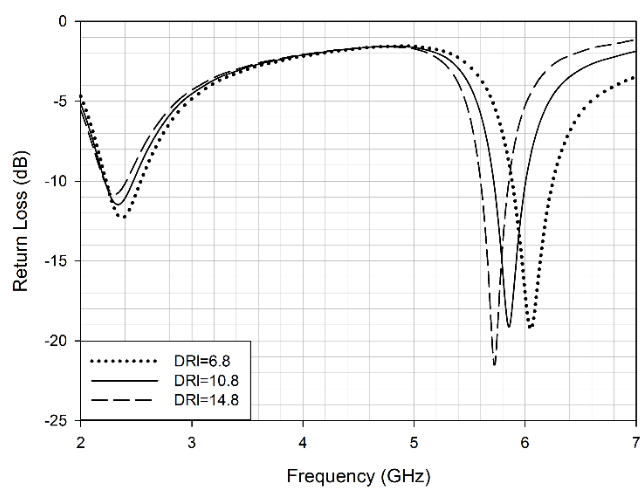


Figure 2 Simulated return loss for different DR length (DR*l*)

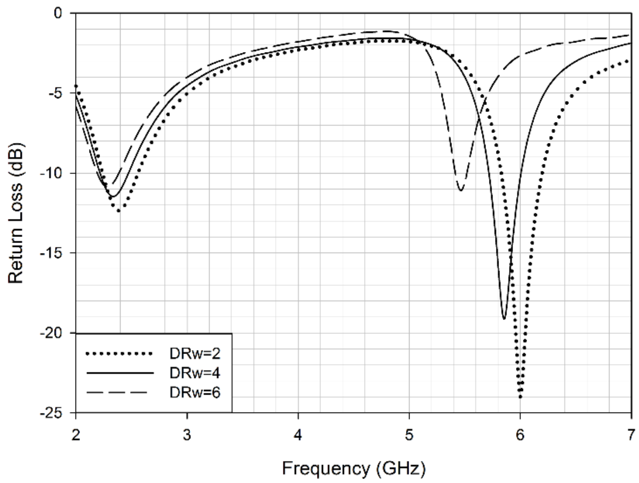


Figure 3 Simulated return loss for different DR width (DRw)

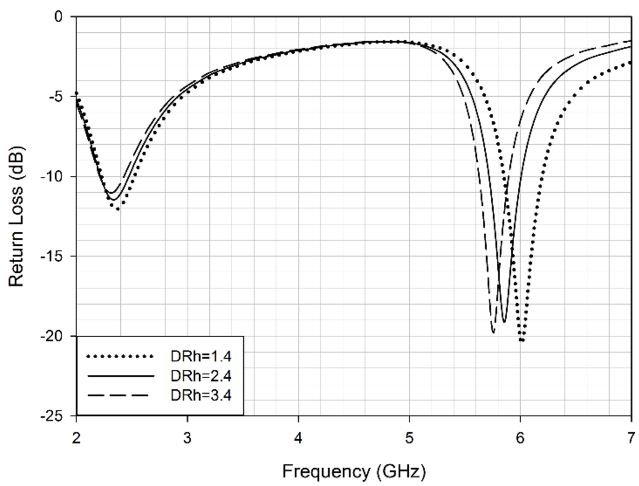


Figure 4 Simulated return loss for different DR height (DR*h*)

The effects of several DR offset distances on the resonant frequency, and the impedance bandwidth of the proposed antenna are shown in Figure 5. The figure shows that increasing the offset distance (S) of the DR will increase the upper band resonant frequency, and vice versa.

The dimensions of the DR element in the proposed antenna were carefully chosen and calculated using the equations developed for the dielectric waveguide model (DWM) for a DR in free space environment. By considering that m = n = 1 as shown in [12], the following equations are obtained for the wave numbers and the dominant mode of resonant frequency :

$$k_x = \frac{m\,\pi}{l} \quad (1)$$

$$k_y = \frac{n\,\pi}{w} \quad (2)$$

$$k_x{}^2 + k_y{}^2 + k_z{}^2 = \varepsilon_r\, k_0{}^2 \quad (3)$$

where k_x, k_y and k_z denote the wave-numbers along the x, y and z directions, respectively, inside the DR also should satisfy :

$$k_z \tan\left(\frac{k_z\, h}{2}\right) = \sqrt{(\varepsilon_r - 1)\, k_0^2 - k_z^2} \quad (4)$$

where k_0 denotes the wave-number in the free space.

In Figure 6, the resonant frequencies of different DR permittivity with respect to the normal DR dimensions and position are presented. It is well known that increasing the dielectric permittivity of the DR will lower the resonant frequency of the antenna, and vice versa. The following equation shows the relationship between the resonant frequency (f_r) and DR permittivity value :

$$f_r = \frac{c}{2\,\pi\,\sqrt{\varepsilon_r}} \sqrt{k_x^2 + k_y^2 + k_z^2} \quad (5)$$

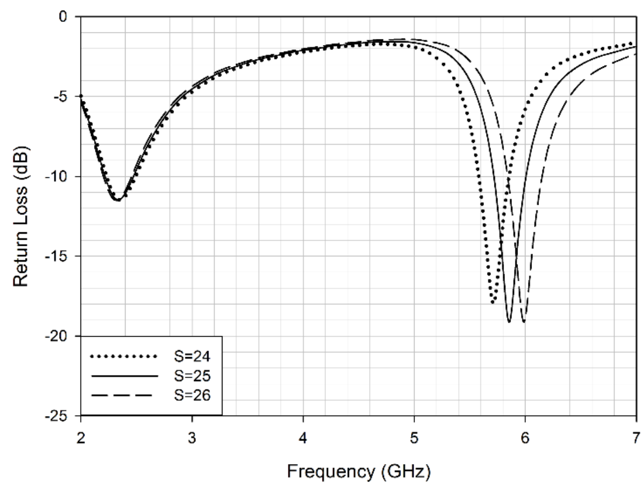


Figure 5 Simulated return loss for different DR offset distance (S)

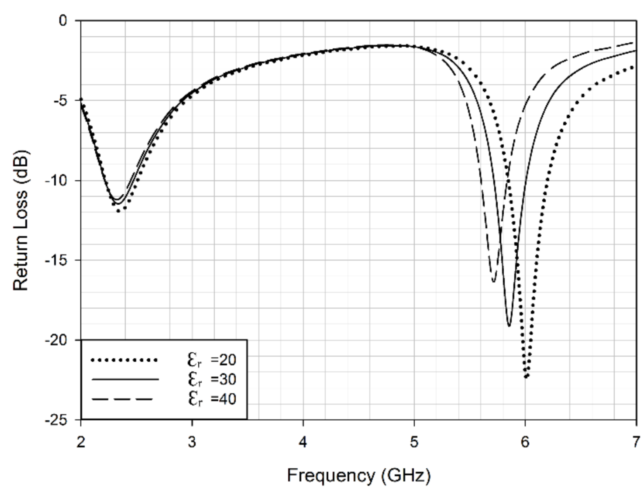


Figure 6 Simulated return loss for different DR permittivity (ε_r)

4.0 RESULTS OF PROPOSED ANTENNA

Based on optimized parameters, the prototype of the proposed antenna was fabricated as shown in Figure 7. Figure 8 shows the return loss comparison between measured and simulated results of the proposed DRA. It can be clearly seen that the antenna has a good agreement between measured and simulated results. The radiation patterns of the proposed dual-band DRA at 2.4 GHz and 5.8 GHz are shown in Figure 9 and Figure 10, respectively. The figures show that the antenna directivity is omnidirectional at 2.4 GHz. While, it is directional at 5.8 GHz.

However, the simulated peak gain is about 1.91 dBi for 2.22-2.47 GHz band, and about 4.5 dBi for 5.72-6 GHz band as shown in Figure 11. Furthermore, the simulated and measured results in Figure 8 show that the antenna has a -10 dB impedance bandwidth of 0.25 GHz (2.22 GHz to 2.47 GHz) at 2.4 GHz band, and an impedance bandwidth of 0.28 GHz (5.72 GHz to 6 GHz) at 5.8 GHz band.

Figure 7 Prototype of the proposed dual-band DRA

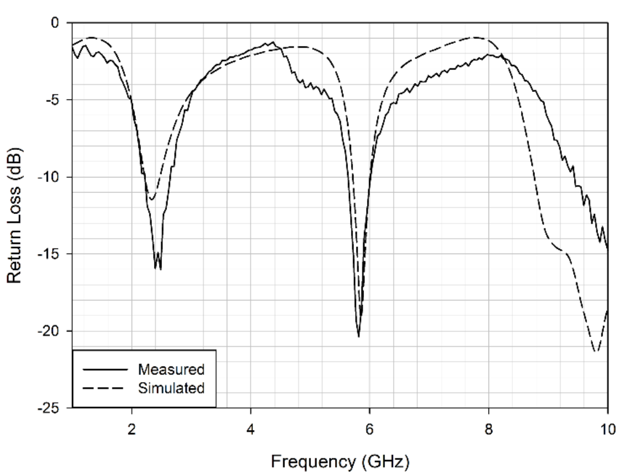
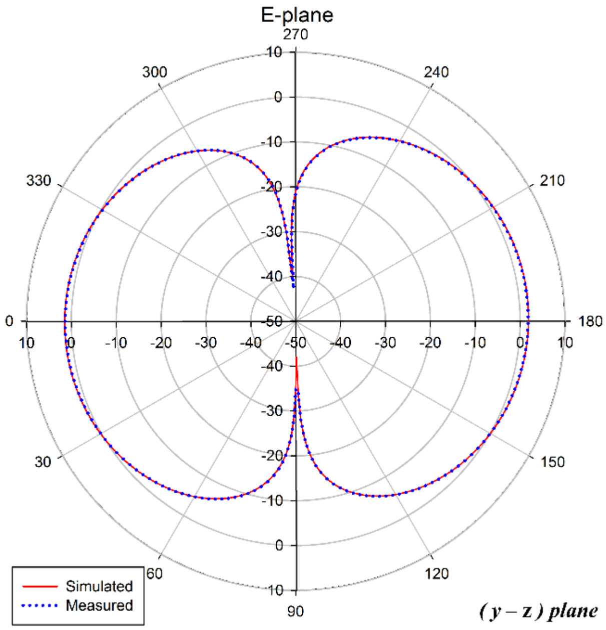
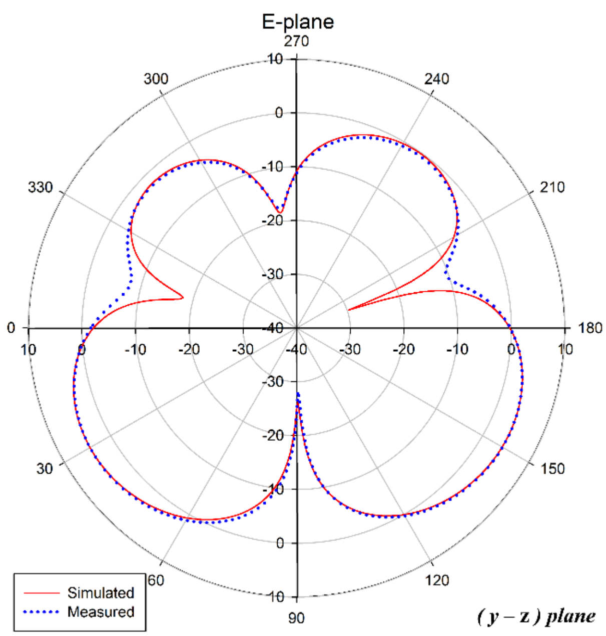


Figure 8 Comparison of measured and simulated return loss for the proposed dual-band DRA



(a)



(b)

Figure 9 The radiation pattern of the proposed dual-band DRA at 2.4 GHz (a) E-plane (b) H-plane

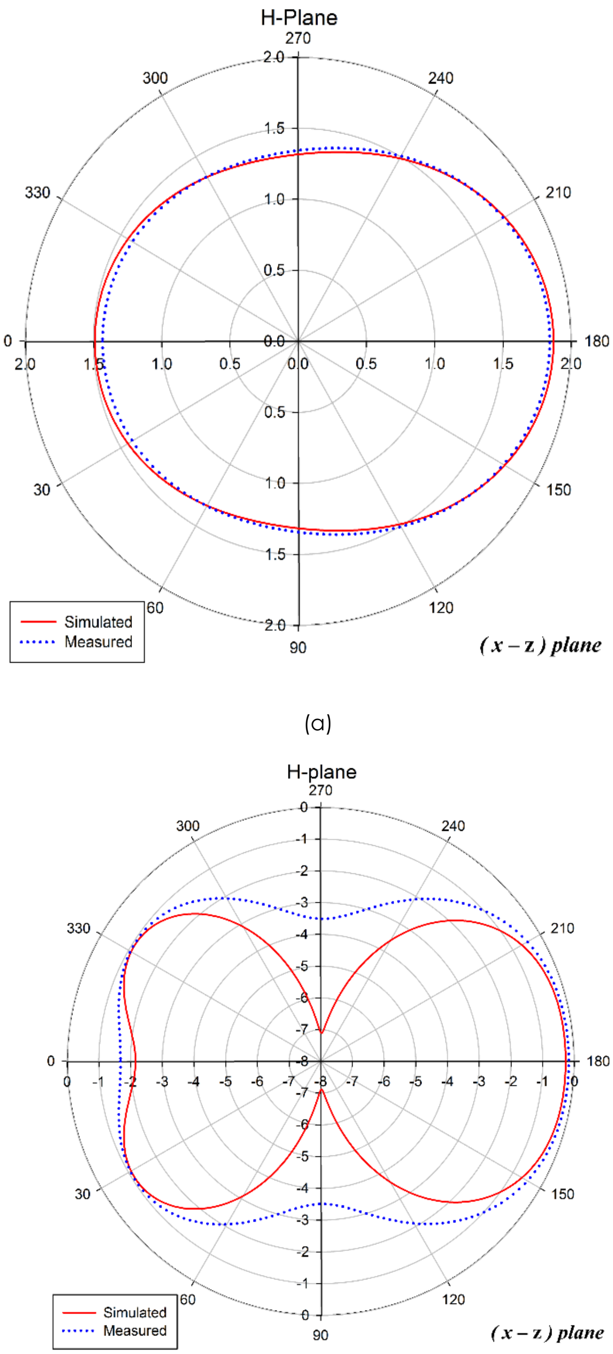


Figure 10 The radiation pattern of the proposed dual-band DRA at 5.8 GHz (a) E-plane (b) H-plane

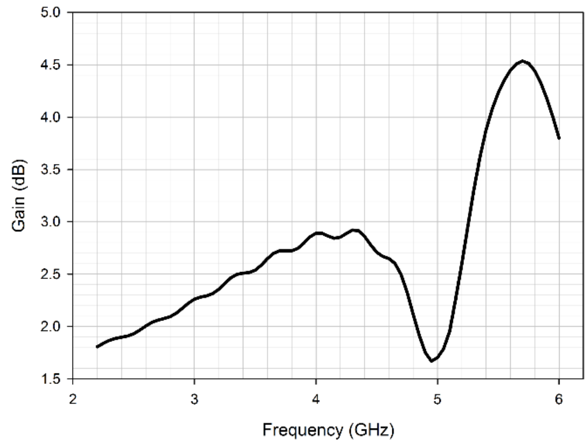


Figure 11 Simulated peak antenna gains (dBi) versus the resonant bands (GHz)

5.0 CONCLUSION

Compact dual-band dielectric resonator antenna fed by a 50 Ω microstrip line has been demonstrated and successfully implemented. By carefully adjusting the position and dimensions of the DR, the proposed antenna can operate at 2.4 and 5.8 GHz IEEE 802.11 (WLAN standard). Moreover, a parametric study is clearly discussed in terms of its effects on the upper band resonant frequency and impedance bandwidth of the antenna. The corresponding bandwidth of the proposed antenna is about 10.66% and 4.78% at 2.4 and 5.8 GHz bands, respectively. The simulated peak gain is about 1.91 dB and 4.5 dB for the lower and upper bands, respectively. The proposed antenna is simple, compact in size and its gains meet the requirements of indoor wireless applications.

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