Dual Band Rectangular Dielectric Resonator Antenna Design

Raghuraman Selvaraju[1,2], **Mohsen Khalily**[1], **Muhammad R. Kamarudin**[1], **Mohd H. Jamaluddin**[1], **and Jamal Nasir**[1]

[1]Wireless communication center (WCC), Universiti Teknologi Malaysia, Malaysia
[2]Department of Electronics and Communication Engineering, Periyar Maniammai University, India

Abstract— A Dual band rectangular dielectric resonator antenna (RDRA) capable of frequency tunings at two different resonant modes is presented and investigated. In this design two rectangular dielectric resonators with different permittivity situated on top of the substrate are employed. The antenna is fed by $50\,\Omega$ microstrip feedline etched on the top of the Fr-4 epoxy printed circuit board (PCB) with a total size of $80 \times 50 \times 1.6\,\mathrm{mm}^3$ and $\varepsilon_{rs} = 4.6$ (loss tangent $= 0.02$). In order to excite two resenant frequencies, two RDRA with relative permittivity of $\varepsilon_{r1} = 10$ and $\varepsilon_{r2} = 30$ are chosen to operate at 2.4 GHz and 3.8 GHz. From the parametric study the lower permitivity DRA resonates at 3.8 GHz whereas the higher permitivity DRA resonates at 2.4 GHz. Ansoft HFSS v14 has been used for the simulation of the proposed dual-band antenna. The simulation results show that the 3.8 design can efficiently perform in both frequency bands.

1. INTRODUCTION

Dielectric resonators antenna (DRA) was first proposed by professor Long in 1983, the DRAs have been an active research area for the last two decades due to the several characteristics such as high radiation efficiency, small in size, light weight and low profile. Antennas that use dielectric resonators experience very low loss, so they ensure higher efficiency without conductor loss [1]. DRAs are able to perform with different performance such as wide-band [2], ultra-wideband [3], dual-band [4], and multi-band [5]. In adittion DRAs can produce circular polarized field by exiting orthogonal modes [6–9]. There are three major dielectric resonator shapes; Hemispherical, Cylindrical, Rectangular which rectangular one has more advantages rather than two others because of having two aspect ratios and simplicity of fabrication. Furthermore various types of feeds can be employed to excite DRAs such as Microstrip feedline, coaxial probe, aperture coupling, and coplanar waveguides (CPWs). Today, dual-band systems are commonly found in the modern wireless communications, because we have different wireless systems, WiFi, Wimax, LTE, etc., each systems operates at different frequencys so all the wireless device should be able to operate at different frequencys, this motivating the study of the dual-band DRA. In this paper, dual band DRA for 2.4 GHz and 4 GHz is investigated and presented. The configuration and design guidelines of the proposed antenna structures are presented in the Section 2. Parametric study is present in the Section 3. Simulation and experimental results are presented in Section 4. Finally, a conclusion is given in Section 5.

2. ANTENNA DESIGN AND CONFIGURATION

The proposed dual band rectangular DRA is shown in the Fig. 1, it consists of two layers, the first layer is a feed-line structure which is seen in the Fig. 1(a). This layer is printed on top of FR-4 epoxy substrate with the relative permittivity of 4.6 and dimension of $50 \times 80 \times 1.6\,\mathrm{mm}^3$. It must be noted that this feeding structure has no resonance and only it is used to excite DR radiation elements. In order to excite two resonance frequency, two rectangular dielectric resonators with the different relative permittivity of $\varepsilon_{r1} = 10$ and $\varepsilon_{r2} = 30$ are employed on the top of the feedline which can be shown in Fig. 1(b). The dimensions of both rectangular dielectric resonator are $15 \times 15 \times 8\,\mathrm{mm}^3$, the distance between these dielectrics and the top edge of the substrate is optimized and fixed at 17.5 mm. Finally, a rectangular with 20 mm $\times$ 2 mm slot is introduced in the center of the ground plane to improve the impedance matching. All optimal dimensions can be shown in Figs. 1(a) and (b).

3. PARAMETRIC STUDIES AND DISCUSSIONS

In this study the performance of the proposed with and without dielectric resonator is considered. The proposed antenna is simulated by High frequency structural simulator software (HFSS). First, the feed-line structure is studied. The important parameter of the feed-line structure is three

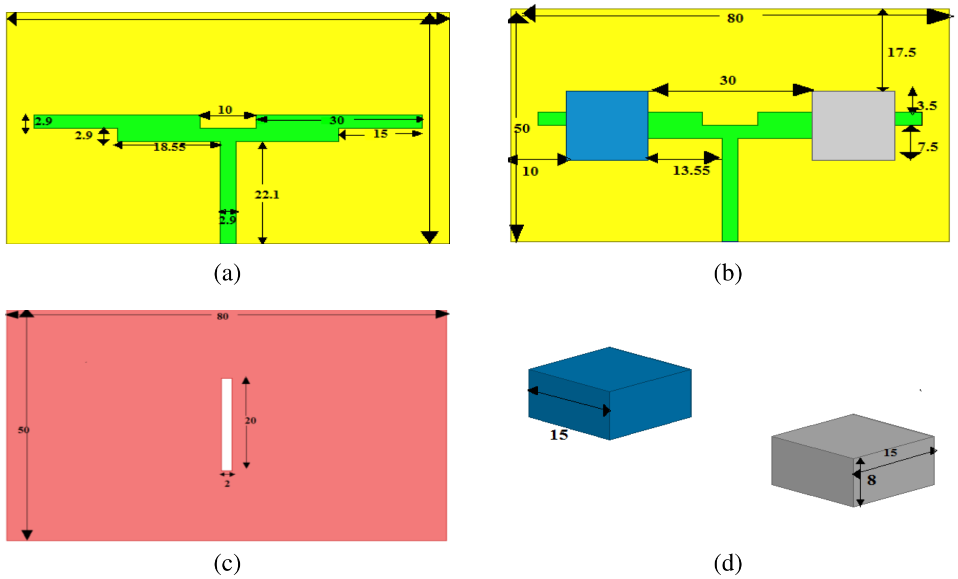


Figure 1: (a) Top view without DR. (b) Top view with DR. (c) Bottom view of the presented antenna. (d) DR side view.

rectangular notches at two top corners of the patch and one at top center of the patch which their dimension are seen in the Fig. 1(a). Fig. 2 clearly shows the return loss of the modified microstrip feed-line. In this case there is not any resonance and it will be shown that dual-band operation is only related to both DRA. In order to achieve dual-band operation, two RDRAs with different permitivities are introduced in the structure.

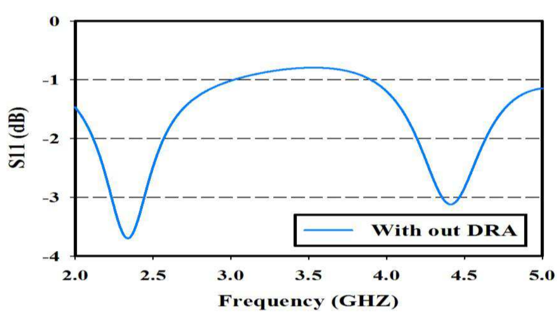


Figure 2: Simulated Return loss of the proposed antenna without DRs.

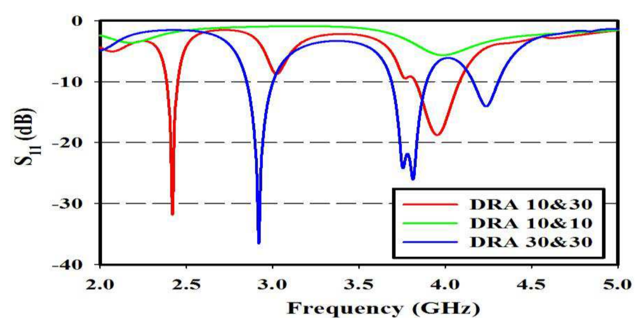


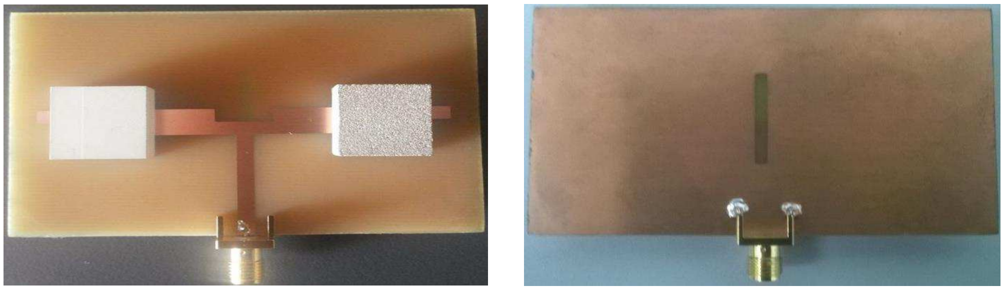
Figure 3: Simulated return loss of the proposed antenna with different permitivities.

After introducing the dielectric radiators, the performance of the antenna is verified by varying the relative permittivity of the DRA. When same permittivity either 10 or 30 are chosen simultaneously, dual-band cant be achieved. Fig. 3 shows the return loss of the proposed antenna with different radiator permittivities.

4. SIMULATION AND EXPERIMENTAL RESULTS

The rectangular dielectric resonators are the main components in this design. By employing two DRs with different dielectric constants dual band operation has been achieved. In fact, both the DRs have the same dimensions, the one with high permittivity resonates at lower frequency band and the other with low permittivity resonates at the high frequency band. Therefore the antenna can support two wireless systems which are 2.4 GHz-WLAN and 3.82-4.08-C-band. Fig. 4 illustrates the prototype of the proposed dual-band DRA. Fig. 5 provides a comparison of simulated and measured return loss results of the proposed antenna. The discrepancy between the simulated and measured results may be due to the effect of fabrication errors and the use of glue for pasting the DRs. As it can be seen that from this figure dual band antenna is archived.

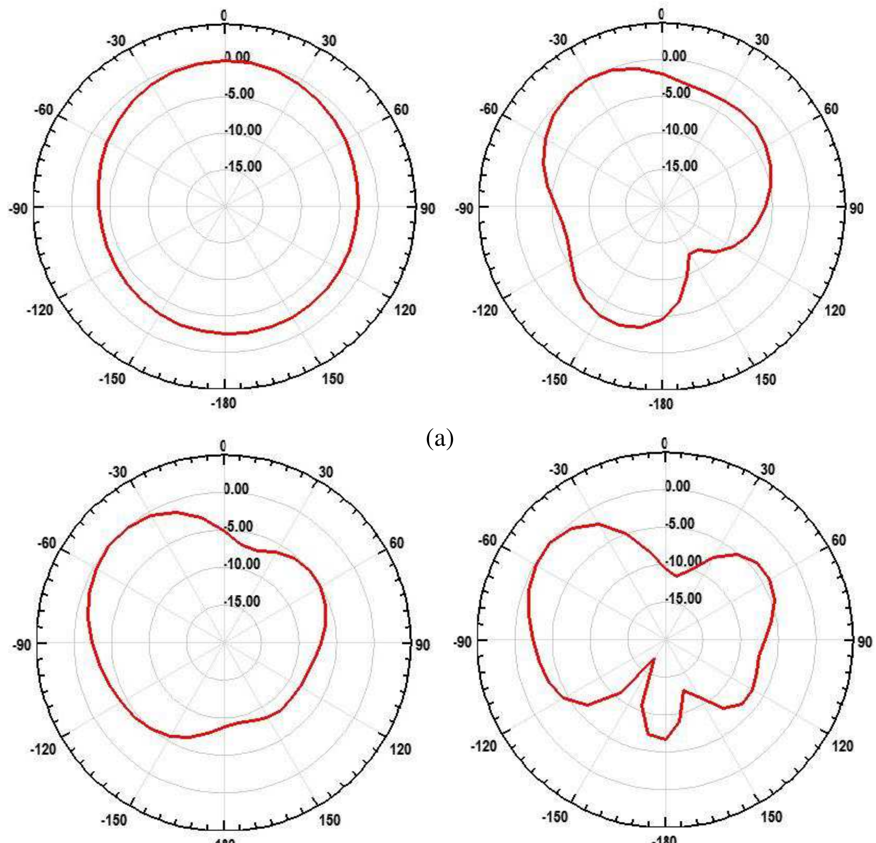
Figure 5 shows the simulated H- and E-plane radiation patterns for proposed antenna at 2.4 GHz and 3.8 GHz. It must be noted that gain of the designed antenna is 1.22 dB at 2.4 GHz and 1.86 at



(a) (b)

Figure 4: Prototype of the proposed DR antenna. (a) Top view. (b) Bottom view.

3.8 GHz.



(a)

(b)

Figure 5: Simulated radiation patterns H-plane and E-plane at (a) 2.4 GHz and (b) 3.8 GHz.

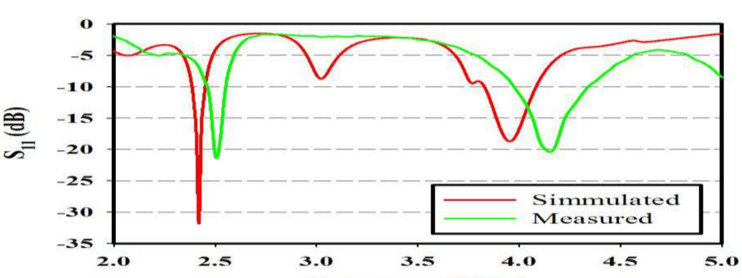


Figure 6: Simulated and measured reflection coefficient magnitudes of the proposed antenna.

5. CONCLUSION

In this paper, a dual band rectangular dielectric resonator antenna has been presented. In this design, a modified monopole antenna and two different relative permittivity rectangular dielectric resonators antenna has been employed. By using these design the antenna can support two wireless systems 2.4 GHz-WLAN and 3.8–4.4 GHz-C-band. Simultaneously. The proposed antenna was fabricated and tested, the good agreement between the measured and simulated (HFSS) results was presented. As a results the proposed antennas has excellent characteristics that makes them good candidates for two various wireless applications.

ACKNOWLEDGMENT

The authors wish to thank Ministry of Higher Education (MOE) and Universiti Teknologi Malaysia (UTM) for providing some funding through GUP (Vote 05H34) and FRGS (Vote 4F283) to enable this work to be completed.

REFERENCES

1. Mongia, R. K. and A. Ittipiboon, "Theoretical and experimental investigations on rectangualr dielectric resonator antennas" *IEEE Transactions on Antennas And Propagation*, Vol. 45, 1348–1356, 1997.
2. Khalily, M., M. K. A. Rahim, A. A. Kishk, and S. Danesh, "Wideband P-shaped dielectric resonator antenna," *Radioengineering*, Vol. 22, 281–285, 2013.
3. Abedian, M., S. K. A. Rahim, and M. Khalily, "Two-segments compact dielectric resonator antenna for UWB application," *IEEE Antennas and Wireless Propagation Letter*, Vol. 11, 1533–1536, 2012.
4. Khalily, M. and M. K. A. Rahim, "A novel hybreid design of printed hemi-cylindrical dielectric resonator monopole antenna with multi-bands operation," *Progress In Electromagnetics Research C*, Vol. 15, 175–186, 2010.
5. Khalily, M., M. K. A. Rahim, N. A. Murad, N. A. Samsuri, and A. A. Kishk, "Rectangular ring-shaped dielectric resonator antenna for dual and wideband frequency," *Microwave and Optical Technology Letters*, Vol. 55, 1077–1081, 2013.
6. Khalily, M., M. K. A. Rahim, and A. A. Kishk, "Planar wideband circularly polarized antenna design with rectangular ring dielectric resonator and parasitic printed loops," *IEEE Antenna and Wireless Propagation Letters*, Vol. 11, 905–908, 2012.
7. Khalily, M., M. R. Kamarudin, and M. H. Jamaluddin, "A novel square dielectric resonator antenna with two unequal inclined slits for wideband circular polarization," *IEEE Antenna and Wireless Propagation Letters*, Vol. 12, 1256–1259, 2013.
8. Danesh, S., S. K. A. Rahim, and M. Khalily, "A wideband trapezoidal dielectric resonator antenna with circular polarization," *Progress In Electromagnetics Research Letters*, Vol. 34, 91–100, 2012.
9. Khalily, M., M. R. Kamarudin, M. Mokayef, and M. H. Jamaluddin, "Omnidirectional circularly polarized dielectricresonator antenna for 5.2-GHz WLAN applications," *IEEE Antenna and Wireless Propagation Letters*, Vol. 13, 443–446, 2014.