Gain Enhanced UWB Dielectric Resonator Antenna

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

[1]Wireless communication centre (WCC), Universiti Teknologi Malaysia, Malaysia
[2]Periyar Maniammai University, India

Abstract— An ultra-wideband dielectric resonator antenna (DRA) with enhanced gain is presented and investigated for wireless applications. The antenna has a compact shape with UWB characteristics. The radiator's structure is a split Z-shaped DRA with dielectric constant (ε_r) of 10. The antenna is mounted on a copper ground plane of size $75 \times 90\,\mathrm{mm}^2$ and is fed by a split bevel-shaped strip to improve the impedance matching. Also, an air gap has been introduced between DR and ground plane to reduce the Q factor and dielectric constant, which in turn improves the impedance bandwidth. Extensive parametric studies have been carried out on different parameters in order to achieve an optimum structure. Ansoft HFSS v14 has been used for the simulation of the proposed antenna. The simulated results show that the antenna can efficiently operate over the frequency range from 2.5 GHz to 10.6 GHz covering the entire UWB range.

1. INTRODUCTION

In the last two decades, antennas using high-permittivity dielectric materials as radiation elements have received extensive attention due to several attractive features such as high radiation efficiency, low profile, considerable bandwidth and low temperature coefficient [1]. Also, Dielectric Resonator Antennas (DRAs) can be designed with various shapes [2] and excited by different feeding methods such as microstrip feed-line [3], coaxial probe [4], and etc.. In addition, DRAs have been used for dual-band [5], and multi-band [6] applications. DRAs are able to produce circularly polarized wave by exciting orthogonal modes [7, 8]. Over the last decades, researchers have focused on the bandwidth enhancement and various techniques have been developed for DRAs. Besides, ultra-wideband antennas have received lots of consideration due to the facility and mobility wireless communications. These antennas generally strive to be compatible with the Federal Communications Commission (FCC), which supports an impedance bandwidth of 7.5 GHz, i.e., from 3.1 to 10.6 GHz [9, 10]. This paper presents an UWB DRA with enhanced gain with impedance bandwidth of 8.1 GHz.

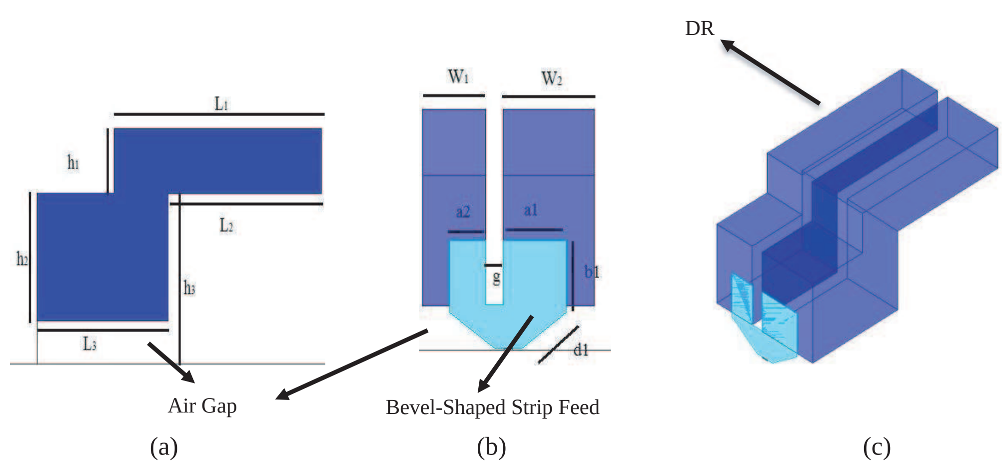


Figure 1: Geometry of the proposed UWB DRA: (a) Side view, (b) front view, and (c) 3-D view.

2. ANTENNA DESIGN AND CONFIGURATION

Figure 1 shows the geometry of the proposed UWB DRA. As it can be seen that from Figure 1(a) two split Z-shaped DR have been used as radiator elements. DRs are mounted on top of the ground plane and excited by split bevel-Shaped strips from one side of DRs as it shown in Figure 2(b). Figure 1(c) illustrates the 3-D view of the proposed UWB DRA. The DRA is lifted above the ground plane by an air gap. The reason for using the split Z-shaped DRA is to improve the electric field distribution inside the DRA over the whole UWB frequency range. It is noted that, the split bevel shaped feeding structure has been employed to provide a smooth transition from one mode to another to widen the bandwidth. Also, using air gap between DRA and ground plane will reduce the effective permittivity, hence impedance bandwidth will be enhanced. Dielectric constant of 10 has been chosen for DR radiator elements by thickness of 5.12 mm. The final dimensions of the DR are $L_1 = 27$ mm, $L_3 = 17$ mm, $h_1 = 6.3$ mm, $h_2 = 12.6$ mm, $h_3 = 16.6$ mm, $W_1 = 7$ mm, $W_2 = 10.1$ mm, $g = 2$ mm mounted on a $75 \times 90\,\text{mm}^2$ ground plane. The best matching is achieved when the parameters of the feed line are as follows: $a_1 = 4$ mm, $a_2 = 7$ mm, $b_1 = 6.9$ mm, and $d_1 = 6$ mm.

3. PARAMETRIC STUDIES AND DISCUSSIONS

For a better understanding of the behaviour of the designed UWB DRA, parametric study is performed to see the effect of variation of some parameters on the impedance bandwidth. For this purpose, the Ansoft HFSS v14, which is based on the finite element method, is used for the parametric analysis. Figures 2 and 3 illustrate the effect of d and dielectric constant on the reflection coefficient.

4. SIMULATIOMN RESULTS

By using optimal DR, air gap, and feed line dimensions, UWB DRA can cove frequency range from 2.5 GHz to 10.6 GHz. Figure 2 presents simulated return loss of the presented antenna. UWB frequency range of coverage is obtained because of exciting different modes by using bevel-shaped feeding structure, an air gap and using split Z-shaped DRAs.

Figure 5 shows the simulated 3D radiation patterns for proposed antenna at 5.2 GHz and 8 GHz. It must be noted that H-plane patterns are symmetrical and patch-like across the operating frequency range for presented antenna. However, the E-plane patterns are not as symmetrical as in the H-plane. In addition, gain values of the presented UWB antenna varied between 7 dB at 3 GHz and 10 dB at 10.6 GHz which is greater than gain value in [8, 9].

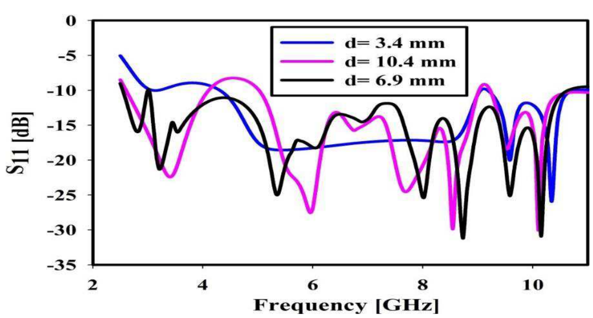


Figure 2: Simulated S_{11} with different value of d (length of bevel-shaped feed line).

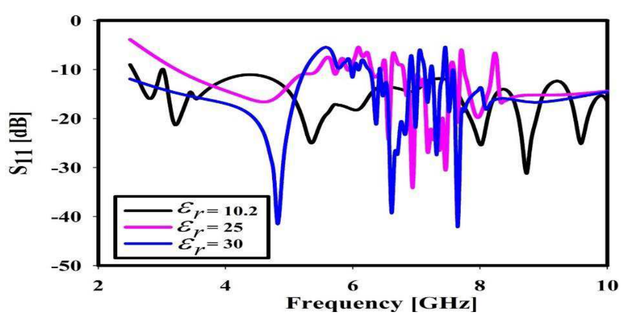


Figure 3: Simulated S_{11} with different value of ε_r.

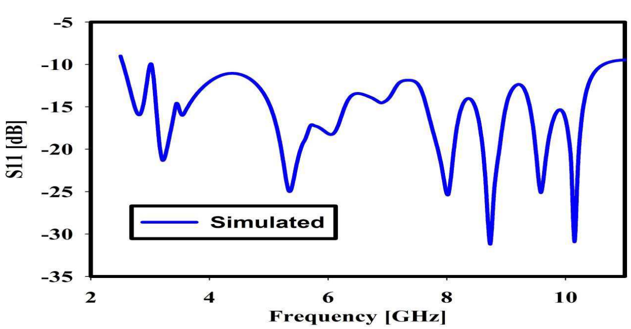
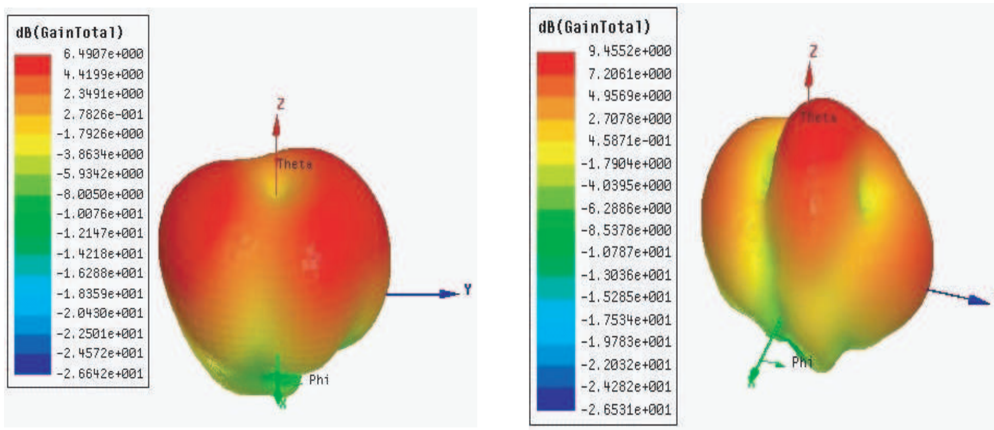


Figure 4: Return Loss of the proposed UWB DRA.



(a) (b)

Figure 5: Simulated 3-D radiation patterns at (a) 5.2 GHz and (b) 8 GHz.

5. CONCLUSION

An UWB DRA with a good radiation characteristics has been proposed in this paper. The antenna consist of two Z-shaped dielectric resonators mounted on a copper plane fed by a bevel shaped feed. There is also an air gap between radiator elements and ground plane to reduce Q-factor, hence improving the impedance bandwidth. It is found that the proposed antenna is able to operate in the UWB frequency range covering from 2.5 GHz to 10.6 GHz. The gain of the antenna is 7 dB to 10 dB and the efficiency is more than 85% throughout the UWB frequency range. Simulated results prove that the proposed enhanced gain UWB DRA is a good candidate for UWB 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 rectangular dielectric resonator antennas," *IEEE Trans. Antennas Propag.*, Vol. 45, No. 9, Sep. 1997.
2. Khalily, M., M. K. A. Rahim, A. A. Kishk, and S. Danesh, "Wideband P-shaped dielectric resonator antenna," *Radioengineering*, Vol. 22, No. 1, Apr. 2013.
3. 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 Antennas and Wireless Propagation Letters*, Vol. 11, 905–907, 2012.
4. 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 Antennas and Wireless Propagation Letters*, Vol. 12, 1256–1259, 2013.
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 Oprical Technology Letters*, Vol. 55, No. 5, May 2013.
6. 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.
7. 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.
8. Khalily, M., M. R. Kamarudin, M. Mokayef, and M. H. Jamaluddin, "Omnidirectional circularly polarized dielectric resonator antenna for 5.2-GHz WLAN applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 13, 443–446, 2014.
9. Denidni, T. A., Z. Weng, and M. Niroo-jazi, "Z-shaped dielectric resonator antenna for ultra-wideband applications," *IEEE Trans. Antennas Propag.*, Vol. 58, No. 12, 4059–4062, Oct. 2010.

10. Abedian, M., S. K. A. Rahim, and M. Khalily, "Two-segments compact dielectric resonator antenna for UWB application," *IEEE Antennas and Wireless Propagation Letters*, Vol. 11, 2012.