Four Identical Element Triangular Dielectric Resonator Dual Band Antenna with L-shaped Coax Probe Feed for Wireless Applications

Chemseddine Zebiri[1,2], Widad Mshwat[2], Jamal Kosha[2], Djamel Sayad[5], Issa Elfergani[4], Jonathan Rodrigues[4], Yasir Al-Yasir[2], Mohamed Lashab[3] and R. A. Abd-Alhameed[2]
{czebiri@univ-setif.dz, jsmkosha@bradford.ac.uk, wfaamshw@bradford.ac.uk}

[1]Department of Electronics, University of Ferhat Abbas, Sétif -1-, 19000 Sétif, Algeria.
[2]School of Electrical Engineering and Computer Science, University of Bradford, BD71DP, UK.
[5]Department of Electronics, University of Larbi Ben M'hidi, Oum El-Bouaghi, Algeria
[4]Instituto de Telecomunicações, Campus Universitário de Santiago, Aveiro, Portugal.
[5]Department of Electrical Engineering, University of 20 Aout 1955-Skikda, 21000 Skikda, Algeria.

Abstract. A simulation study is carried out for the improvement of a four elements triangular dielectric resonator antenna (TDRA) using the commercial software HFSS. The antenna structure is fed through a 50 Ω L-shaped coaxial transmission line.. The simulated antenna parameters are compared with both single and four element triangular dielectric resonator antenna (TDRA) using an ordinary coaxial feeding. About 55% impedance bandwidth enhancement is achieved, in the 4.25-7.45GHz frequency band for a -10 dB return loss. A gain enhancement of 180% is realized to achieve 8.5dB. The simulation results are found to be in good accord when compared to the published theoretical results.

Keywords: TDRA, Coaxial feed, L-shaped feed, Four element DRA.

1 Introduction

The introduction of the DRA structures as an alternative to the conventional antennas was considered a long time ago. The dielectric resonators were firstly (in 1939) exploited for the realization of energy storage devices [1]. By the production of high permittivity materials in 1953 [2], these structures earned their place for the antenna applications. Since the early sixties, the field distribution of the TMxyz and TExyz modes and the propagations have been studied [3]. Later on, in 1982, it was the first time that DR had been employed as a radiating element. In this context, different DR shapes and dimensions have been used depending on the desired radiation patterns, however, rectangular [4] [5] [6], circular [7] [8] [9] and triangular shapes are the most commonly used ones [10]-[14]. Recently, a compact PIN diode reconfigurable antenna with dielectric resonator (DRA) has been studied and presented for GSM, LTE and 5G services. This antenna comprises three rectangular dielectric resonators each with different permittivity and dimensions [5]. Also in [6], a research was conducted to enhance the performance of a

IMDC-SDSP 2020, June 28-30, Cyberspace

DOI 10.4108/eai.28-6-2020.2298243

rectangular dielectric resonator antenna (DRA). The slot coupling technique between the circular section and the other sections is used to improve the bandwidth from 1.08 GHz to 1.75 GHz. An antenna with two cylindrical DRA fed by a microstrip line for a wideband application has been proposed. The optimization of the parameters could have two antenna configurations: the first one has an impedance bandwidth around 55%, and a power gain of 12dBi, and the second one covers an impedance bandwidth of around 58% with a power gain of 10dBi [8].
The triangular dielectric resonator antenna (TDRA) is becoming more and more attractive to be used in contemporary communication systems due to their multiple advantages compared to the other forms. They are less cumbersome, easy to be built and they show a large impedance bandwidth characteristic. Using TDR for antenna designs requires a thorough knowledge of their operating principles, benefits and eventual drawbacks. On the other hand, it would be very significant to examine the distinctive modes, also diverse probable radiation patterns and the related fabrication techniques to assure a proper feeding for an optimal radiation characteristic. It would be also of importance to consider the operating frequency band, and the way it how depends on the DR-based-structure dimensions.

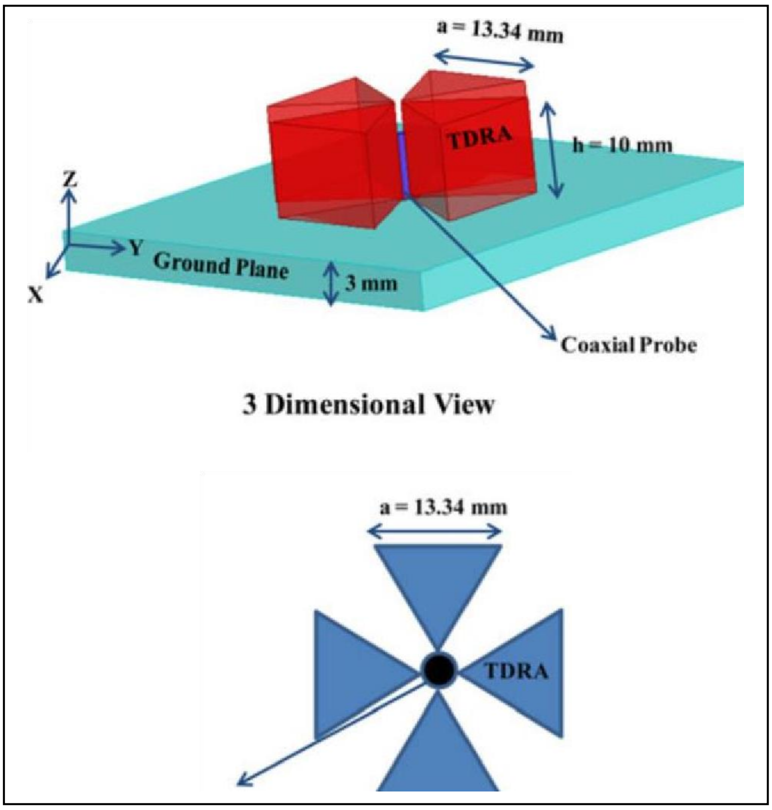

Fig. 1. Geometry of a four-element triangular dielectric resonator antenna

In [13], a coaxial fed isosceles (equilateral) TDR antenna is presented. The triangular form is characterised by a height of h=24mm, a side of a=66mm, angles of 30°, 30° and 120°, with a permittivity of εr=12. The proposed isosceles TDR antenna exhibits two operating bands centred at both 2.48GHz and 1.68GHz. In [11], another isosceles/equilateral shaped TDRA has been presented. In this study, the same dielectric material (εr = 12), the same height (h = 24mm) and the same side (a = 66mm) dimensions are maintained as in [13]; the difference lies in the isosceles triangular angles: 45°, 45° and 90° and the feeding probe position. The DR is placed on top of a metallic ground plane and is fed by a 50Ω coaxial transmission line placed in the middle of the TDRA side. This TDRA is operating on the broadband as shown by the simulation results [11].

2 Antenna Design

From conventional TDRAs, we designated a radiating structure presented in [10] as a reference antenna. The antenna consists of four radiating triangular resonators. This study aims at the improvement of the antenna operating bandwidth. The geometry of the antenna and its structure are shown in Figure 3, while Table 2 summarizes its associated geometrical parameters.

Table 1. Different parameter dimensions

Parameter	Dimension (mm)	Parameter	Dimension (mm)
Xg	50.0	H2	10.7
Yg	50.0	A	-7.71
Zg	3	B	12.34
R1	2.25	L4	50
R2	0.6	HD	10

3 Discussion of the findings

The proposed TDR antenna has been designed and the reflection coefficient S_{11} parameter has been simulated by using High Frequency Structure Simulator (HFSS) to verify and validate the antenna predicted characteristics it has compared with the characteristics of the antenna simulated and measured in [10].

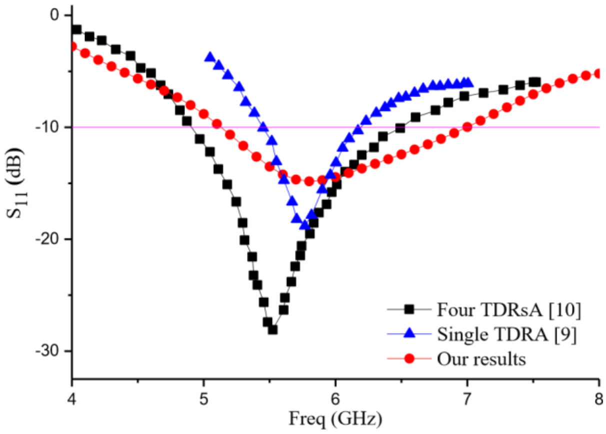

Fig. 2. Return loss S_{11} compared with Ref. [10]

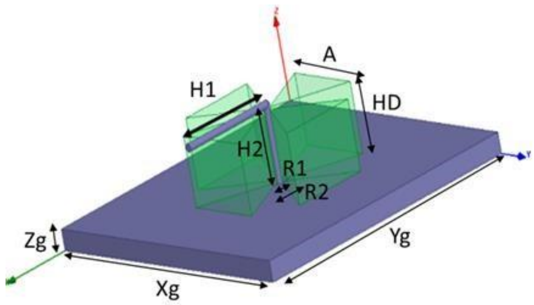

Fig. 3. L-shaped coaxial line-fed four-element TDR antenna

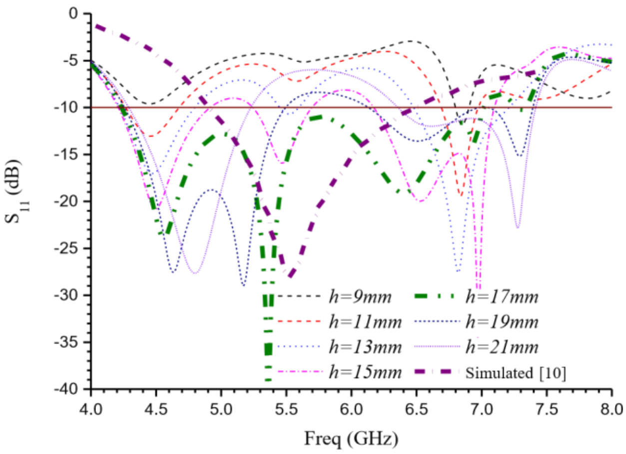

Fig. 4. Simulation results of the return loss S_{11} of the TDRA compared with Ref. [10].

Figure 2 shows a comparison of our simulations and results obtained by reference [10]. This TDR antenna is suitable for wireless applications in the 4.2-7.1GHz band. These results show a

100% bandwidth improvement operating frequency band. The proposed L-shaped coaxial probe fed four-element TDRA geometry is presented in Figure 3. Figures 4 and 5 show the simulated results of the return loss S_{11} and the input impedance, respectively.

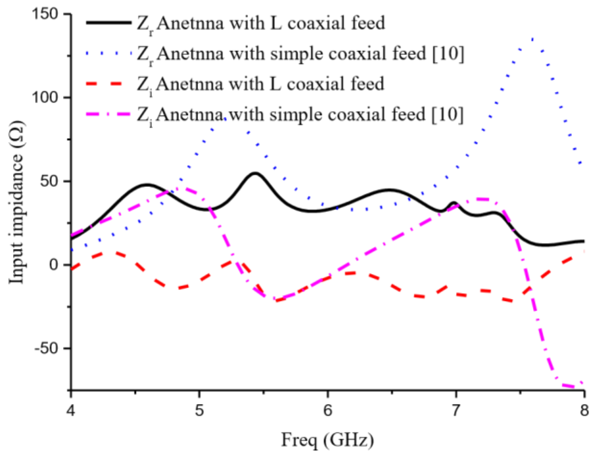

Fig. 5. Simulated input impedance of the proposed L-shaped coaxial fed TDRA

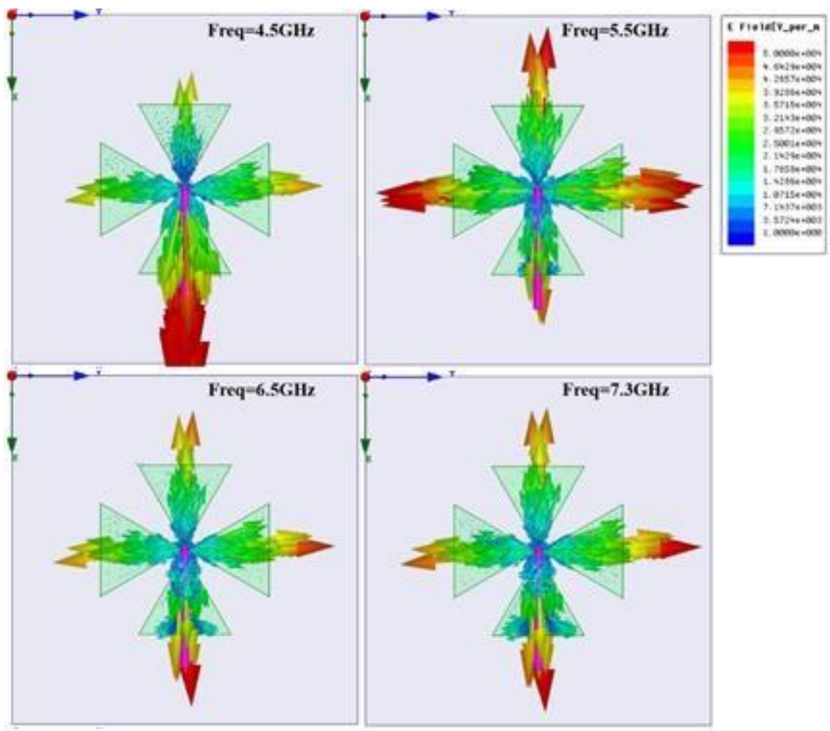

Fig. 6. Resonant modes of the proposed antenna in the xy plane at 4.5, 5.5, 6.5 and 7.3 GHz

It is clear that the number of TDRs did widen the bandwidth and the L-shaped coaxial feeding did increase the bandwidth and made the antenna ultra-wideband (Fig. 4). The proposed TDR antenna is characterized by an impedance bandwidth of 55% ranging from 4.25 to 7.45 GHz while the same antenna with a simple coaxial probe feed [10] possesses a 37% impedance bandwidth.

As shown in Figures 4 and 5, the significant increase in the operating frequency band is due to the appearance of 3 new modes resonating at: 4.5, 5.5, 6.5 and 7.3 GHz, respectively. In addition, the values of the impedance real part approach 50 Ohms compared to the case of the antenna presented in [10]

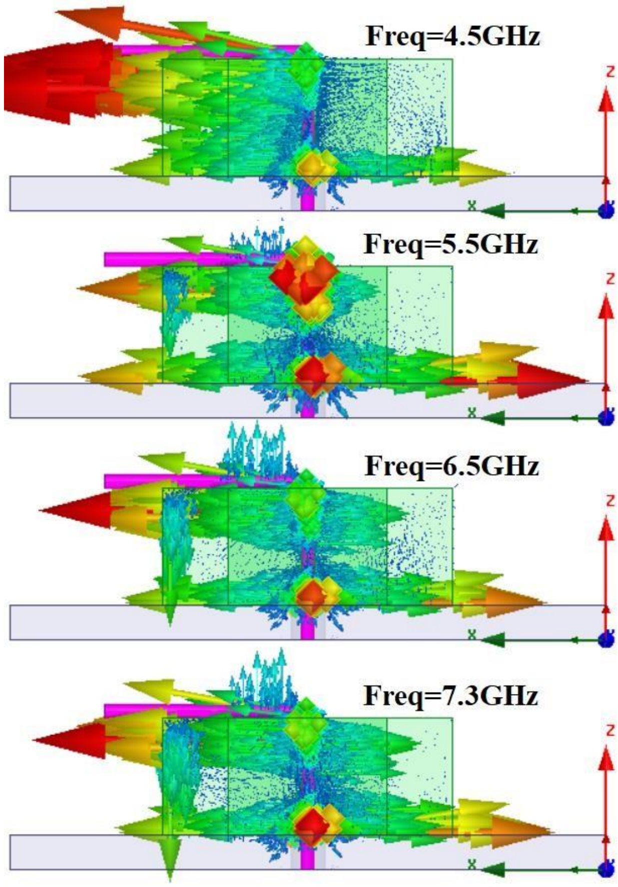

Fig. 7. Resonant modes of the proposed antenna in the xz plane at 4.5, 5.5, 6.5 and 7.3 GHz.

The electric field distributions of the three modes excited in the TDRA at 4.5, 5.5, 6.5 and 7.3 GHz, respectively, in xy and xz planes are presented in Figures 6 and 7, respectively. These modes are excited by a single DR and combinations of two, three and four DRs. This is clearly illustrated in Figure 7.

Figure 8 illustrates three-dimensional (3D) radiation patterns of the proposed TDR antenna at 4.25 and 7.45 GHz. Figure 9 presents the simulated maximum gain of the proposed TDR antenna for these frequencies. A peak of 6.65 dB at 4.25 GHz and 6.81 dB at 7.45 GHz are achieved.

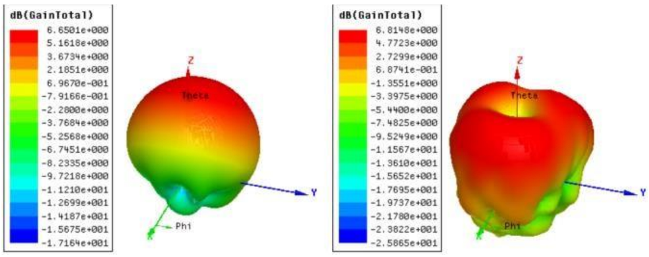

Fig. 8. Radiation pattern of the proposed 4-element TDR antenna at 4.25 and 7.45 GHz.

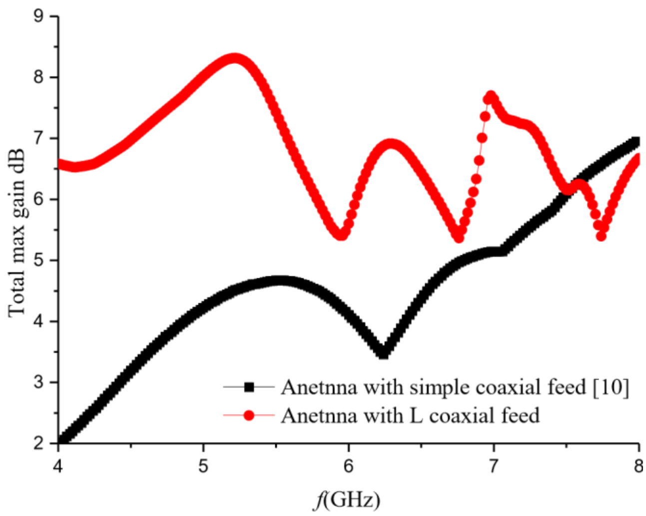

Fig. 9. Simulated gain of the proposed TDR antenna compared with [10].

4 Conclusion

An isosceles four-element TDR Antenna with an L-shaped coaxial line feed is investigated. A simulation study of the proposed antenna is carried out using Ansoft HFSS software for the improvement of the antenna parameters over single DR and conventionally coax fed TDR structures. The introduction of a new L-shaped coaxial probe feeding has significantly increased the impedance bandwidth and the gain. We can conclude that it is possible to increase the impedance bandwidth and gain using multi DR structures, and by adjusting the feeding line further improvements may be achieved. The resulting antenna structure is suitable for WiMAX and 5.0 GHz (IEEE 802.16) WLAN networks applications.

References

[1] RD. Richmeyer, "Dielectric resonators", International Journal of Applied Physics, vol.210, pp. 391-398, 1939.

[2] H. Schlike, "Quasi-Degenerated Modes in High-ε Dielectric Cavities, " J. Appl. Phys., v.24, 1953-publié en 2004.

[3] A. Okaya, " The rutile microwave resonators", Proc. IRE, v.48, (1960), 1921

[4] Rahim, S. B. A., Lee, C. K., Qing, A., & Jamaluddin, M. H. (2018). A Triple-Band Hybrid [5] Rectangular Dielectric Resonator Antenna (RDRA) for 4G LTE Applications. Wireless Personal Communications, 98(3), 3021-3033.

[5] C. Zebiri, D. Sayad, J. Kosha, W. F. A. Mshwat, I. T. E. Elfergani, J. Rodriguez and R. Abd-Alhameed (2020) "A compact frequency reconfigurable DRA for GSM, LTE, and 5G applications services," 14th European Conference on Antennas and Propagation (EuCAP), Copenhagen, Denmark, 2020, pp. 1-5, doi: 10.23919/EuCAP48036.2020.9135747.

[6] C. Zebiri, M. Lashab, D. Sayad, I. E. Elfergani, A. Ali, M. Al Khambashi,, F. Benabdelaziz and R. A. Abd-Alhameed. (2018). Bandwidth Enhancement of rectangular dielectric resonator antenna using circular and sector slot coupled technique. In 12th European Conference on Antennas and Propagation (EuCAP 2018) (pp. 1-4). IET.

[7] Zebiri, C. E., Lashab, M., Sayad, D., Elfergani, I. T. E., Sayidmarie, K. H., Benabdelaziz, F., and Noras, J. M. (2017). Offset Aperture-Coupled Double-Cylinder Dielectric Resonator Antenna with Extended Wideband. IEEE Transactions on Antennas and Propagation, 65(10), 5617-5622.

[8] C. Zebiri, D. Sayad, N. T. Ali, M. Lashab, F. Benabelaziz, R. A. Abd-Alhameed, I. T. E. Elfergani and J. Rodriguez. (2017, March). Reduced ground plane aperture-coupled DRA fed by slotted microstrip for ultra-wideband application. In 2017 11th European Conference on Antennas and Propagation (EUCAP) (pp. 965-969). IEEE.

[9] C. Zebiri, D. Sayad, I. T. E. Elfergani, J. S. Kosha, W. F. A. Mshwat, C. H. See, M. Lashab, J. Rodriguez, K. H. Sayidmarie, H. A. Obeidat and R. A. Abd-Alhameed (2019). Antenna for Ultra-Wideband Applications With Non-Uniform Defected Ground Plane and Offset Aperture-Coupled Cylindrical Dielectric Resonators," in IEEE Access, vol. 7, pp. 166776-166787,, doi: 10.1109/ACCESS.2019.2949527

[10] Gangwar, R. K., Ranjan, P., & Aigal, A. (2015). Four element triangular dielectric resonator antenna for wireless application. *International Journal of Microwave and Wireless Technologies*, *9*(1), 113-119.

[11] Maity, S., Saha, R., Basu, R., De, R., Pal, A., Singh, H. V., & Gangopadhyay, M. (2017, August). The 45°–45°–90° triangular dielectric resonator antenna. In Industrial Automation and Electromechanical Engineering Conference (IEMECON), 2017 8th Annual (pp. 300-302). IEEE.

[12] Sarkar, S., Bhattacharjee, A., Kundu, A., Das, D., Gangopadhyay, M., Maity, S., & Gill, B. (2016, October). 30°-60°-90° Triangular Dielectric Resonator Antenna: A new shaped Dielectric Resonator Antenna. In Information Technology, Electronics and Mobile Communication Conference (IEMCON), 2016 IEEE 7th Annual (pp. 1-4). IEEE.

[13] MAITY, Sudipta, DAS, Debarshi, PANDEY, Ashutosh Kumar, et al. Dual Band 30°–30°–120° triangular dielectric resonator antenna. In : Information Technology, Electronics and Mobile Communication Conference (IEMCON), 2017 8th IEEE Annual. IEEE, 2017. p. 493-496.

[14] Ranjan, P., Sharma, A., & Gangwar, R. K. (2017, May). Experimental investigation on probe feed equilateral triangular dielectric resonator antenna for 5.8 GHz ISM band (IEEE 802.11). In *Progress In Electromagnetics Research Symposium-Spring (PIERS), 2017* (pp. 2195-2199). IEEE.