Excitation of Enhanced Hybrid Cylindrical Dielectric Resonator Antenna to be used for Wireless Applications

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Abstract. An improved version of dielectric resonator antenna design is presented and investigated. Numerous approaches were exploited in order to meet the targeted features in particular the multi-band goal. The main method that was applied within this work is the two hybrid modes excitation, namely $HE_{12\delta}$ and $HE_{11\delta}$, in which several bands were accomplished. The outcomes and antenna size both make the antenna as an appropriate candidate for heterogonous network.

Keywords: Multiple bands, HFSS, DR structure.

1 Introduction

The concept of the (DRA) was firstly exploited in 1938 and been used as a device for energy storage [1]. A few years later and in 1953, Schlike has come up with the fact that there are such materials with high permittivity ε_r greater than 1000 exists [2]. A decade ahead Okaya and Barash carried out research to study the TE_{xyz} and TM_{xyz} modes propagation and distribution within the dielectric slab [3].

Gradually in 1983 and for the first time, the DRA was utilized as a radiator. The DRA has come up with several and different shapes that depend on the preferred and required radiation patterns, size and permittivity that features the patterns. The most common forms that have been used include rectangular [4], circular [5]-[6] triangular [7]-[9] and ring DR forms [10]. Gangwar was proposed as the most imperative approach that exploited in producing DRA higher-order hybrid modes (See Fig.1) [11].

The work of DRA antenna presented in this article is based on one presented in Gangwar [11] (**Fig. 1**). The computed out are all implemented and accomplished in which proves that this antenna covers several bands such as 1.92-2.3 GHz, 3.13-4.6 GHz and 5.4-6.5 GHz. Such simulated studies were achieved by using the HFSS v15.

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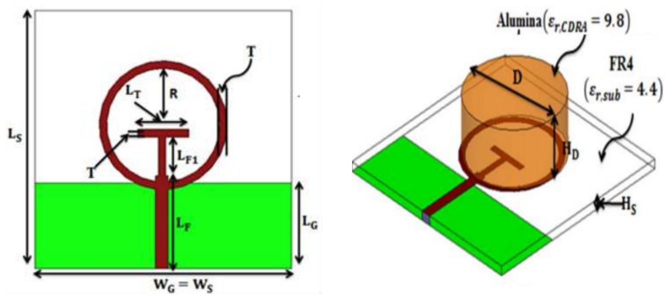


(a) (b)

Fig. 1. Top veiw (a), 3D veiw of the antenna geometry from [11].

2 Antenna Design and Geometry proposed in [11]

The presented structure was obtained from the idea that was proposed by Gangwar [11], the antenna layout is illustrated in Figure 1. The final antenna elements are stated in Table 1. The idea behind the proposed design lies on composting **the** cylindrical DR alumina (ε_{rCDRA}=9.8, tanδ=0.002), this latter is placed on an annular ring with a T-cut copper line. Both the radiator the ground are printed on a substrate FR4 (tan δ = 0.02, $\varepsilon_{r,sub}$ = 4.4). The designed antenna is considered as a multi-segmented antenna, which in this case meaning that the two dielectric layers (FR4 and Alumina) will the reasonable for the resonant frequency.

Table 1. Antenna parameter in mm.

Parameter	Dim. (mm)	Parameter	Dim. (mm)
l_s	50.0	h_d	10.0
w_s	50.0	h_s	1.60
l_g	16.5	t	1.50
w_g	50.0	l_{f1}	8.0
R	22.0	l_f	18.0
D	25.0	lt	10.0

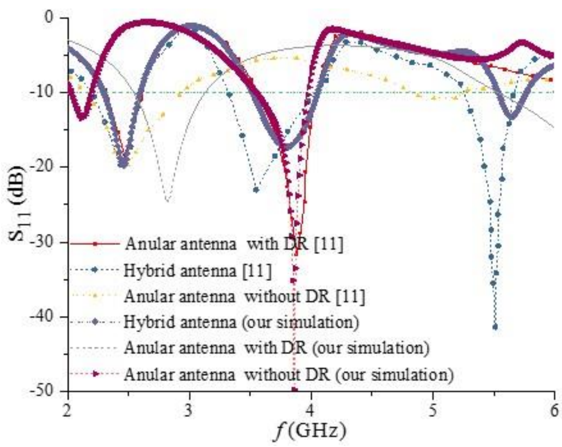


Fig. 2. The antenna results validation compared to those of reference [11].

3 Results and Discussions

The outcomes that were achieved from the HFSS software were compared with the ones that already exist in the state of the art reported by Gangwar in [11].

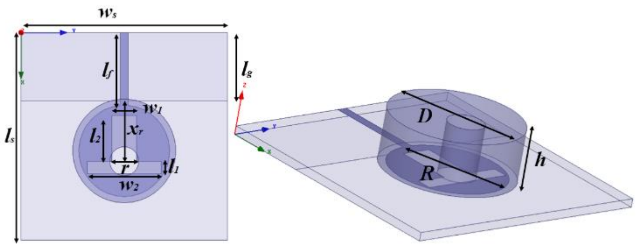


Fig. 3. Top view (a), 3D view (b) of the suggested antenna.

Figure 3 displays the antenna structure that was proposed within this work and Table 2 shows the dimensions of the antenna parameters.

Table 2. Antenna elements in mm

Element	size	Element	size
r	3.5	l_1	3
w_1	6	l_2	11
w_2	18	x_r	31

The reasonable concordance between the computed results of the current antenna and the outcomes of the by reference [11] are indicated in Figure 4. Such results of three different bands along with the dual-mode features can support or meet several wireless systems. These varied bands are met and accomplished by exploiting the two approaches, the first one is to generate higher-order modes in cylindrical Dielectric Resonator, the other technique is to utilize the hybrid antenna concept. The annular ring works as a feed line for CDRA and it is also working as a radiator in the 2. GHz frequency. HE12δ mode is generated as a result of the T-cut as an electric dipole [11].

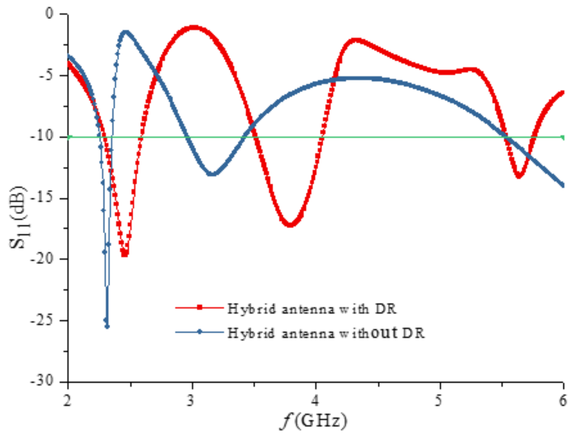


Fig. 4. The S_{11} of the CDRA with and without DR.

Adding the CDRA element to the proposed antenna affects the coefficient S_{11} as well as the input impedances shown in Figure 4 and Figure 5 respectively. One can clear note that, the reflection coefficient S_{11} was improved by the and a good matching was achieved.

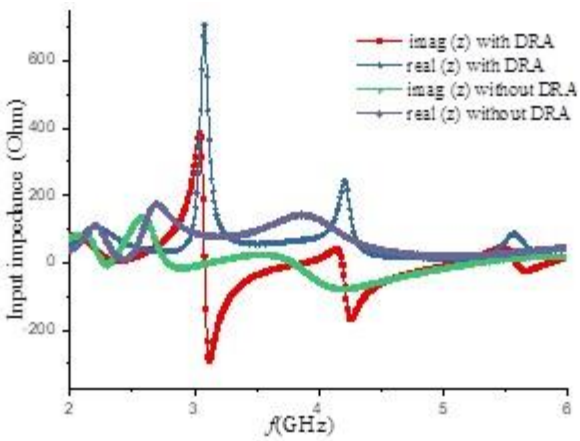


Fig. 5. Response of Zin for CDRA and the antenna without DR.

4 CDRA with T-form slot fed

4.1 The proposed antenna geometry

Within this part, the antenna design was gradually optimized and modified with several procedures are depicted in Figure 6 (a, b, c, and d). This optimization process was check from the results of the S11 as shown in Figure 7. It is obvious that and from Figure 7, the bandwidth of 1.5GHz was improved with comparison to that achieved in the reference design.

The antenna design in (Fig. 6.d) is a type of CDR structure, which has some similarities with the reference antenna reported in [11], the only difference is that rather than making the T-cut line, a sort of slit is generated on the circular antenna, in order to have properties that are close to the one that the reference antenna has [11], the present design operates in several frequency channels such as 2.4-2.6Ghz, 3.5-4.2GHz and 5.5-5.8GHz The use of DRs is noted on the results of the S11.

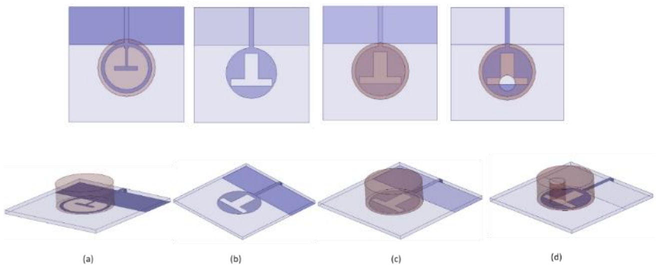


Fig. 6. The procedures of the tragted antenna structures.

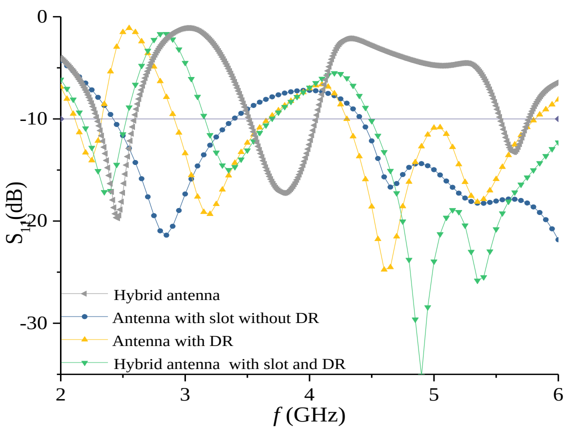


Fig. 7. S_{11} over various geometrical structures.

This can be considerably seen in Figure 7 for both cases with and without DR. The proposed structure is said to a sort of wide band antenna covers the bands from (4.4 -5.5 GHz), thus, the exclusion of such resonator made the proposed design operates at 2.3 GHz and at 3.2 GHz as indicated in Figures6 and 7.

4.1.1 The influence of T-slot dimensions

The influences of the T-Slot along with it sizes are demonstrated in Figure. It should be distinguished that the influence of the T-form is substantial and crucial on the performance of the S_{11}. Both the resonant frequencies and the size are directly related and considered by the following;

The slot length is equivalent to:

$$L_s = 0.5\lambda_g \tag{1}$$

Equation 2 is given for the guided wavelength:

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{re}}} = \frac{c}{f\sqrt{\varepsilon_{re}}} \tag{2}$$

Where f_r presents the resonant frequency, and the active relative constant within the slot ε_{re} can be expressed by:

$$\varepsilon_{re} = \frac{\varepsilon_{rs}+1}{2} \tag{3}$$

ε_{rs} presents the relative permittivity of the substrate. Uisng both (1), (2) and (3), this can predict:

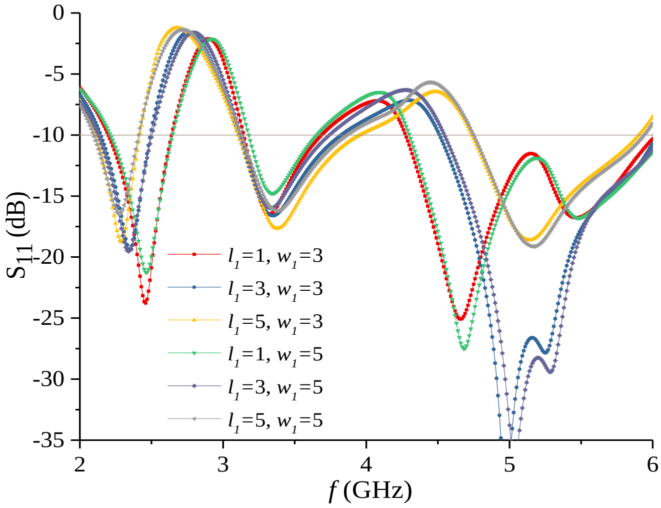


Fig. 8. Response of S_{11} against the *slot size.*

$$f_r = \frac{c}{L_s\sqrt{2(\varepsilon_{rs}+1)}} \quad (4)$$

Stating the provided slot length, the accomplished frequency is very similar to the one reported in the literature (inaccuracy of around 7%). The effective slot length is selected to be 20 mm that provides or offers a frequency of 5.8GHz.

4.1.2 The air cavity effect

The influences of the air cavity radius that is drilled in the DRA are shown in Fig. 9 . As can be noted that the air cavity of the DRA effect rises up to D_1=7mm (ideal value), frequency range as well augments over several frequencies, namely 2.15-2.55 GHz, 3.15-3.7GHz and 4.45-6GHz. The effective permittivity reduces because of the gap between the DR and the substrate [10], however, in this scenario the bandwidth is increased and improved.

A good finding relation between both the bandwidth and the quality factor is realized due to the and The ring resonator (with air cavity). It is clearly illustrated that when it empty high quality factor is feasible, the quality factor may be lower in the case of having greater frequency isolation compared to other forms of resonators within such cavities with same sizes [12] [13]. Moreover, the DRs can support similar sort of modes like RDCs. The dielectric ring resonant frequencies are larger than that in the case of the cylindrical resonator. Also, the ring quality factor is said to be smaller that one of the cylindrical. Therefore, the ring will come up with bigger BW than the CDR. Such features can be imperative mode results in [12] [13].

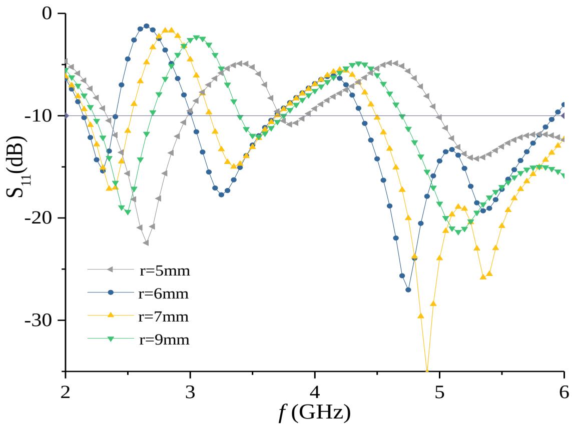


Fig. 9. Response of the S11 for various values of r.

4.1.3 The hybrid antenna power gain and farfield

Figure 10 illustrates the computed power gains. It is said that the present design has some influences on many antenna parameters and in particular on the gains and bandwidth. With comparison to the particle results, there will be also minor differences between the computed ones and the one of the fabricated structure, and basically this can be attributed to the misalignment between both simulated and manufactured version and also due to the losses related with the RF cables.

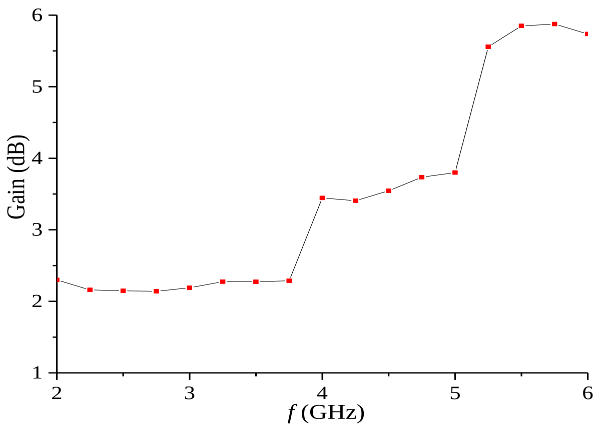
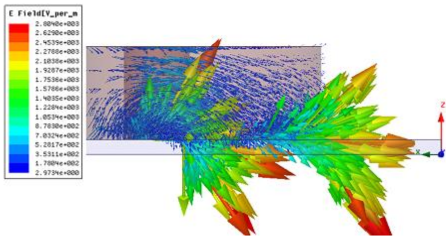
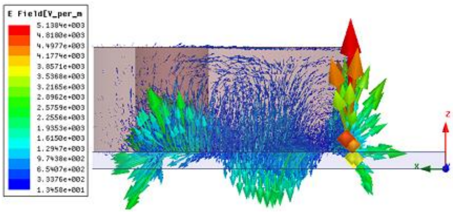


Fig. 10. Response of the power antenna gain.

One can obviously note that the provided gains at the frequency of 2.4GHz is lower than the one of the spectrum of 3.5GHz. This may be because of the fact that the annular patch is always having some losses. Also, it is likewise in the case of 5.5GHz band, the gain is higher here with comparison to the 3.5GHz, that is because of that the gain is in direct relation with squared frequency, at the higher-order mode HE_{12d} observed at 5.5 GHz [11]. The power gain is not having such higher value at the targeted frequency bands, due to the fact that the partial ground plane is exist [14].



(a) 3.5 GHz



(b) 5.5 GHz

Fig. 11. Field distribution of the DRA at two frequencies.

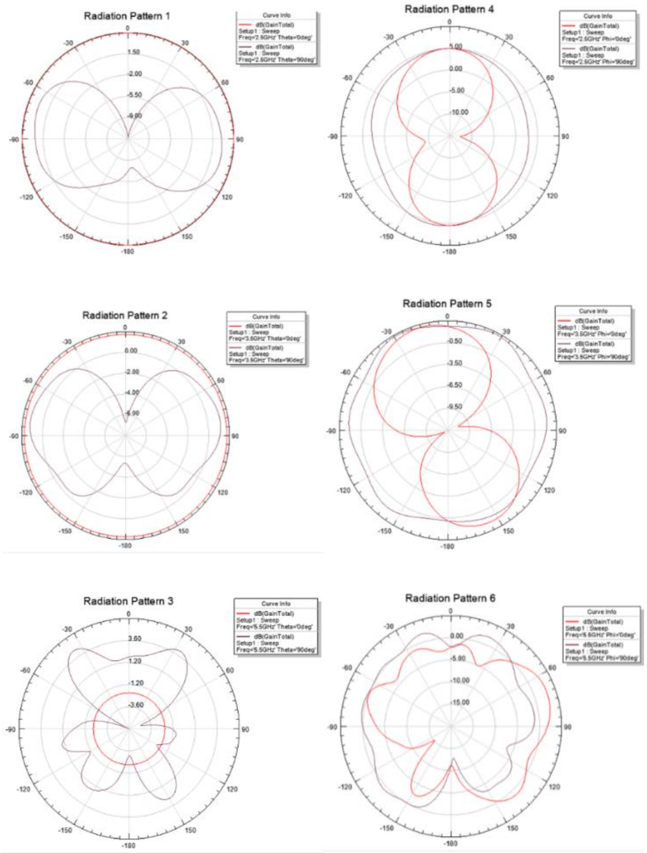


Fig. 12. farfield patterns of proposed antenna over three frequencies.

5 Conclusion

A simple and effective CDRA has been presented and investigated within this paper. The main goal of this study was to focus on a novel DR hybrid antennas along with simple approach of having a magnetic dipole and a slot bored in the DRA, in which was hugely contributed in optimizing the antenna characteristics. In the second version scenario, with two CDRs loaded with an air gap has been introduced. The EM outcomes were compared to the one already reported in previous similar studies for validation purposes. Such approaches and design ideas may be categorized as one of the beneficial, favorable and useful methods exploited to produced hybrid modes and therefore the hybrid antenna concept. The present design fits numerus heterogeneous networks and systems covering wireless Lan and satellite applications.

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