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Abstract	This work presents a simple stacked rectangular dielectric resonator antenna (RDRA), which is dedicated for ISM band applications. To design this RDRA antenna, an EM simulator has been used. The proposed structure consists of a dielectric resonator, which is mounted on plastic substrate. This resonator is fed using a simple aperture-coupled feed line over a rectangular feeding slot made on a copper ground plane. The substrate has a relative permittivity of 2.65 and tan 0.025. The proposed antenna has a compact size of 49.5x49.5x1.6^3. The physical dimensions of the dielectric resonator are 30 mm, 30 mm, and 35 mm for the length, width, and height, respectively. The dielectric resonator of the proposed stacked RDRA has two layers. The first layer is constructed using plastic dielectric, which is used for the construction of our substrate. However, the second layer is fabricated using FR-4, which has a relative permittivity of 4.4 and tan 0.025. Due to the using of the second layer in our proposed stacked RDRA, an enhancement in the gain has been obtained, with a peak gain up to 5 dB and an efficiency up to 95% over the desired ISM band. In Addition, the obtained radiation pattern presents high stability over the operating frequency band.

Keywords (separated by '-')	Rectangular dielectric resonator antenna - ISM band applications - stacked antenna - aperture-coupled feed line

Tunable DRA with Parasitic Elements for ISM Band Applications

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AQ1

Abstract. This work presents a simple stacked rectangular dielectric resonator antenna (RDRA), which is dedicated for ISM band applications. To design this RDRA antenna, an EM simulator has been used. The proposed structure consists of a dielectric resonator, which is mounted on plastic substrate. This resonator is fed using a simple aperture-coupled feed line over a rectangular feeding slot made on a copper ground plane. The substrate has a relative permittivity of 2.65 and tan 0.025. The proposed antenna has a compact size of $49.5x49.5x1.6^3$. The physical dimensions of the dielectric resonator are 30 mm, 30 mm, and 35 mm for the length, width, and height, respectively. The dielectric resonator of the proposed stacked RDRA has two layers. The first layer is constructed using plastic dielectric, which is used for the construction of our substrate. However, the second layer is fabricated using FR-4, which has a relative permittivity of 4.4 and tan 0.025. Due to the using of the second layer in our proposed stacked RDRA, an enhancement in the gain has been obtained, with a peak gain up to 5 dB and an efficiency up to 95% over the desired ISM band. In Addition, the obtained radiation pattern presents high stability over the operating frequency band.

AQ2

Keywords: Rectangular dielectric resonator antenna · ISM band applications · stacked antenna · aperture-coupled feed line

1 Introduction

Wireless communications field has attended remarkable development in recent years. To ensure a high-quality communication, an important element presented in the antenna must be used. Generally, this antenna must be characterized by a suitable wide bandwidth and high gain. There are many types of antennas that can be used in wireless communications, such as microstrip antennas and dielectric resonant antennas [1]. Recently, dielectric resonant antennas (DRA) have become a promising solution in the modern antenna technology, due to the offered advantages in terms of low profile, high gain, and wide bandwidth [2]. The design of DRA antennas is based on the theory of resonant modes, which can investigate many specifications of our antenna in terms of frequency resonant, Q factor, and bandwidth. There are many works investigate on DRA with high permittivity to enlarge the bandwidth, reduce the size, and increase radiation efficiency.

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In other hand, DRAs with low permittivity are widely used due to its flexibility especially when these DRAs are fabricated using materials like polyvinyl chloride (PVC) and plastic which facilitate the manufacturing of these DRAs using 3D printers. DRA shape and feed techniques play an important role in bandwidth optimization [3]. The DRA antenna can be fed using many techniques such as coaxial probes, substrate integrated waveguide (SIW) coupling slot, and microstrip line. It has been reported that the rectangular resonator has been widely used, however there are many other shapes are existed such as cylindrical [4], hemispherical [5], and other forms [6, 7]. Many studies have focused on the design and optimization of DRAs by selecting resonator shapes and sizes to achieve desired performance characteristics such as high bandwidth, good efficiency, and radiation pattern.

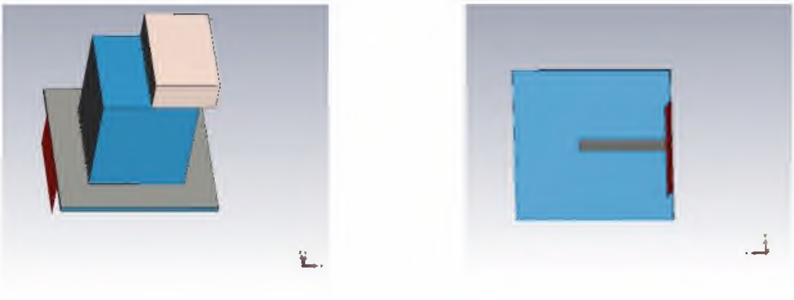
AQ3 Previously, several DRA designs have been proposed [8, 9, 10, 11, 12]. In [4], the authors were proposed novel two-segment RDRA antenna to enlarge the bandwidth. However, E. Vinodha and his colleagues presented in [9] a triple broadband RDRA antenna, which can work at different band frequencies. Researchers in [10] presented Dual Band DRA for Wireless Applications. In other work, H. Raggad proposed an RDRA that works at 0.8 GHz [11]. This last work presented the effect of parasitic element, which is mounted on the resonator at performance of the DRA through a parametric study. In [12], a hexagonal shaped DRA has been proposed for WLAN applications, which is operated at 2.4 GHz. The proposed DRA offers a gain up to 5.4 dBi over the operating frequency band.

In this paper, a stacked DRA for the ISM band is proposed. In our design, the stacked DR consists of two different layers. The first layer is fabricated using PLA while the second one is constructed using FR-4, which makes our DR is designed with two different permittivities. This paper is organized as follows: After an introduction in Sect. 1, we present the geometry of the proposed antenna in Sect. 2. The simulated results are given in Sect. 3. Finally, Sect. 4 summarizes the main conclusions.

2 Antenna Configuration

The geometry of the proposed stacked rectangular DRA is shown in Fig. 1. The DR has two layers, the first layer is fabricated from a plastic material with a relative permittivity of = 2.65 and tan = 0.025. However, the second layer is fabricated using FR-4 with a relative permittivity of = 4.4 and tan = 0.02. The dimensions of both layers are Wrec$\times$ Lrec $\times$ Hrec and Wrec2 $\times$ Lrec$\times$Hrec2, where Wrec = 30 mm, Lrec =30 mm, Hrec = 35 mm, W_{rec2} = 15 mm and H_{rec2} = 10 mm. The DR is mounted on the copper ground plane with the dimension of 49.5 mm $\times$ 49.5 mm.

The fed microstrip line has a length L_{feed} of 29 mm and a width W_{feed} of 4.2 mm. The ground plane is etched with two intersected rectangular slots, whereas the DRs are feed over these slots using the 50 Ω microstrip line. Some adopted dimensions during this study are tabulated in Table.1.



(a) (b)

Fig. 1. Configuration of the proposed stacked RDRA: side view in (a) bottom view in (b)

Table 1. Some geometric parameters of the proposed stacked RDRA.

Parameter	Value in mm	Parameter	Value in mm
W_S	49.5	Wrec	30
L_S	49.5	Lrec	30
H	1.5	Hrec	35
T	0.035	Wfeed	4.2
Lfeed	29	Hrec2	10

3 Results and Discussions

The proposed structure is designed and simulated using the EM CST studio simulator.

The obtained reflection coefficient of the proposed RDRA is represented in Fig. 2. This figure shows that the level of the reflection coefficient is lower than −30 dB at the resonant frequency 2.45 GHz and a bandwidth larger than 360 MHz over the band of interest.

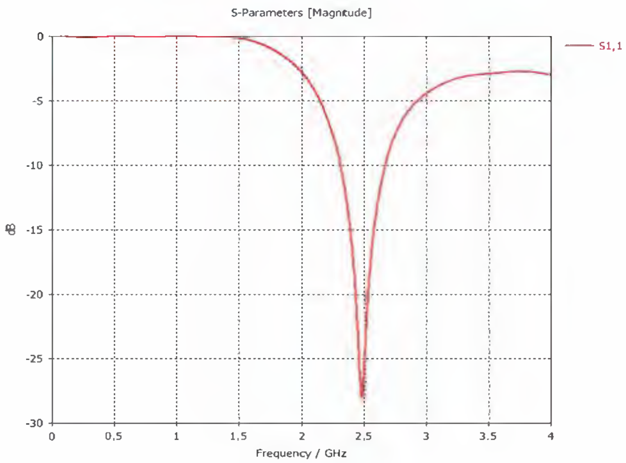
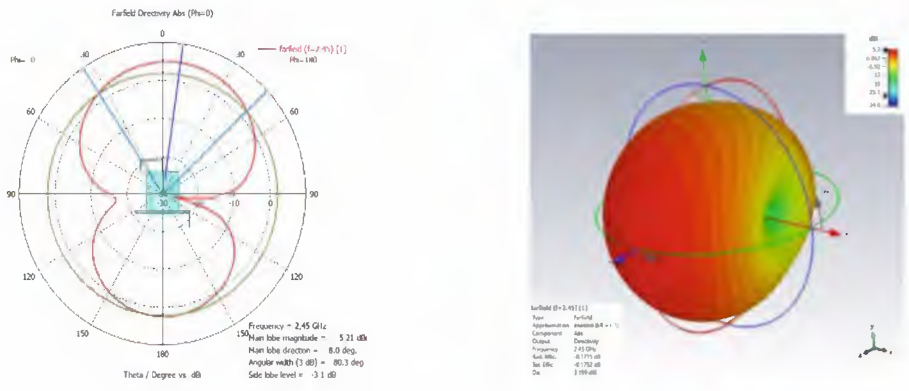


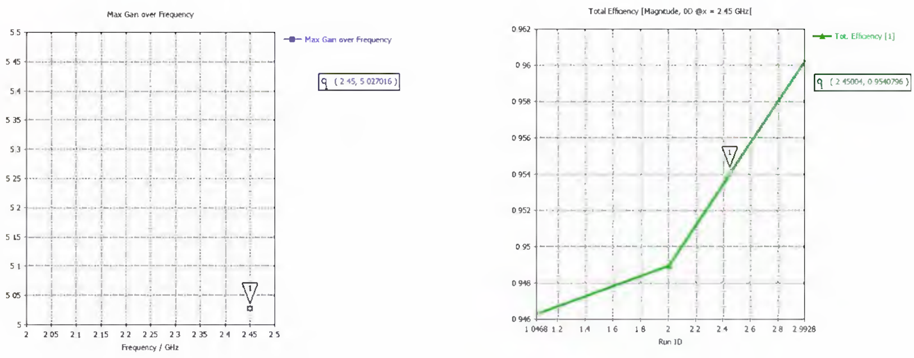
Fig. 2. Reflection coefficient of the proposed stacked RDRA.

As shown in Fig. 3, the far-field radiation patterns are simulated at the frequency 2.45 GHz. It can be seen that the obtained patterns have a peak gain up to 5.02 dBi. The efficiency of our stacked RDRA is illustrated in Fig. 4, which present an efficiency around 95% at the frequency of interest (2.45 GHz).



(a) (b)

Fig. 3. Simulated far-field radiation patterns of the stacked RDRA at the frequency 2.45 GHz: 2D far field patterns in (a), 3D far field pattern in (b)



(a) (b)

Fig. 4. Obtained results of the proposed stacked RDRA: gain in (a) and efficacity in (b)

Figure 5 describes the current distribution of the DRA antenna at 2.45 GHz. Figure 5 shows that the current is distributed uniformly along the ground plane and the feed line.

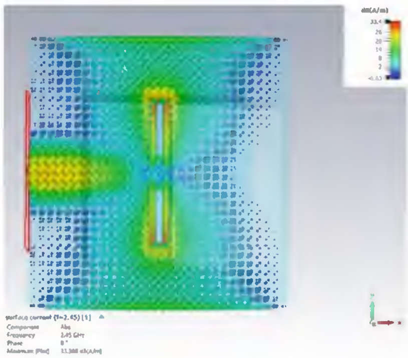


Fig. 5. Simulated current distribution of the proposed antenna at 2.45 GHz

4 Conclusion

A stacked rectangular dielectric resonator antenna has been demonstrated. In this paper, the obtained results show that the proposed RDRA offers a peak gain of more than 5 dBi with high efficiency up to 95%. The proposed antenna is suitable for applications in ISM systems. For future Works, the authors plan to use this antenna in a rectenna system, which can be implemented in ISM band applications.

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Chapter 40

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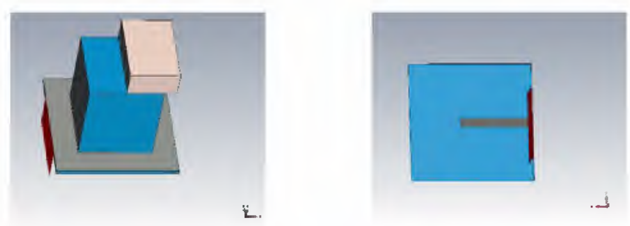
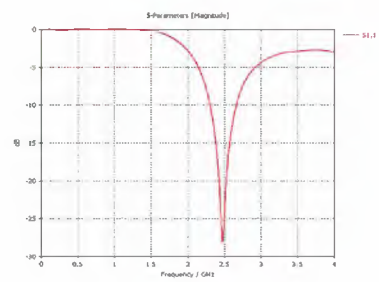
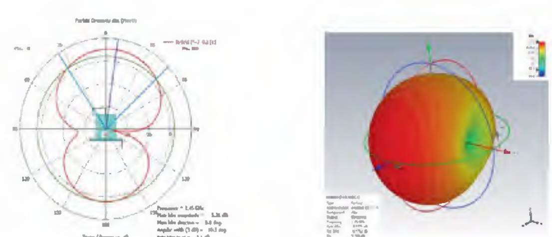
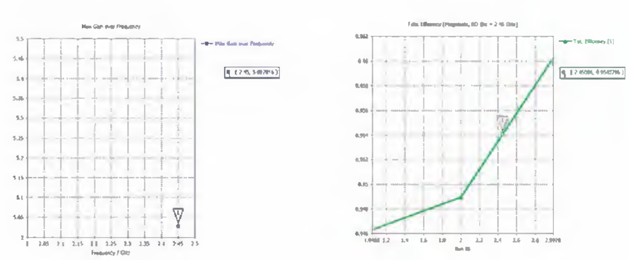
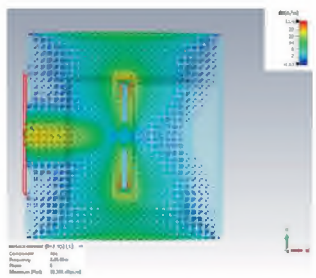
Page no	Fig/Photo	Thumbnail	Alt-text Description
3	Fig1	 (a) (b)	Two-panel figure showing 3D plots. Panel (a) displays a stacked arrangement of three rectangular prisms in different colors, positioned on a base. Panel (b) shows a side view of the same structure, highlighting the alignment and overlap of the prisms. Both panels include a coordinate axis in the lower corner for reference.
4	Fig2		Graph showing the magnitude of S-parameters over frequency. The x-axis represents frequency in GHz, ranging from 0 to 4, and the y-axis represents magnitude in dB, ranging from -30 to 0. The red line labeled "S1,1" shows a dip around 2.5 GHz, indicating a significant change in magnitude.
4	Fig3	 (a) (b)	Panel figure with two subfigures. (a) Polar plot showing farfield directivity with theta in degrees versus dBi. Key details include frequency at 2.45 GHz, main lobe magnitude of 5.21 dBi, and side lobe level of -3.1 dB. (b) 3D plot of a spherical radiation pattern with color gradient indicating dBi levels, ranging from -31.4 to 5.2 dBi. Axes are marked with arrows, and a legend provides additional data such as frequency and directivity.
5	Fig4	 (a) (b)	Two-panel figure showing X-Y charts. Panel (a): A chart titled "Max Gain over Frequency" with frequency in GHz on the x-axis and gain on the y-axis. A data point is marked at (2.45, 5.027016). Panel (b): A chart titled "Total Efficiency

Page no	Fig/Photo	Thumbnail	Alt-text Description
			(Magnitude, 00 @x = 2.45 GHz)" with Run ID on the x-axis and efficiency on the y-axis. A data point is marked at (2.4500, 0.9549706).
5	Fig5		A 3D plot illustrating surface current distribution in a rectangular area, with a color gradient from blue to red indicating varying intensity levels. The scale on the right shows values in dB(A/m) ranging from -6.63 to 33.4. The plot is labeled with parameters: component as "Abs," frequency at 2.45 GHz, and a maximum plot value of 33.368 dB(A/m). A small 3D axis indicator is present at the bottom right.