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Improving Gain and Efficiency of RDRA Antennas through the Integration of a Cylindrical Coaxial Dielectric for Multi-Frequency Applications

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Abstract: Many lifestyle applications require various types of antennas, especially in the communication field. One such antenna used in this domain is the dielectric resonator antenna (DRA). In this article , we designed RDRA antenna with coax : dielectric ,cylindrical inner conductor as well as outer conductor ,then we will use different types of frequencies in designing RDRA antennas, such as(12;13;14;....) GHz, based on their S-parameters, gain, directivity, bandwidth, and voltage standing wave ratio (VSWR). We will enhance the gain and the characteristics of this antenna and explain the new design that used for enhanced gain and bandwidth enhancements in detail, including the use of high-dielectric-constant, PEC material for ground plane, adjusting resonant frequency. The Practical experiments utilize CST (Computer Simulation Technology) software to evaluate the mentioned parameters of DRA antennas. DRA antennas are known for their high radiation efficiency, small size, low profile, and lightweight, which can be improved by modifying certain elements or structures, thus reducing attenuation. To enhance S-parameters and gain, the suitable design of a DRA depends on the geometrical and material characteristics chosen. This approach enables us to achieve high gain, efficiency and acceptable results. Therefore, simulations of the antenna must consider these properties and characteristics, along with the effects of surface Plasmon waves on the DRA's properties. Adding different frequencies in new design with coaxial dielectrics of RDRA antenna were necessary enhance the results, leading to higher gain.

***Key word**: Gain; Geometry of RDRA antenna; Coax: dielectric; inner conductor; outer conductor: S- Parameter; PEC ground plane; Multiple frequencies; radiation pattern.*

1. Introduction

In the field of antenna design, leveraging coaxial cable dielectric in the construction of rectangular dielectric resonator antennas (DRAs) presents both advantages and disadvantages, warranting thorough consideration. Primarily, incorporating coaxial cable dielectric allows for precise control over the resonant frequency and bandwidth of the DRA, crucial factors in achieving optimal performance. This level of control stems from the dielectric's permittivity, which directly influences the antenna's resonant behavior. Moreover, coaxial cable dielectric offers inherent structural support, aiding in the stability and durability of the antenna assembly. Additionally, the coaxial cable's inner conductor facilitates efficient energy transfer to the resonator, ensuring robust radiation characteristics. However, despite these advantages, there exist certain drawbacks to using coaxial cable dielectric in DRA design. One notable limitation is the potential for increased complexity and cost associated with integrating coaxial cable into the antenna structure. Furthermore, the presence of the coaxial cable may introduce additional losses and impedance mismatches, which could degrade overall antenna performance. Moreover, the geometry constraints imposed by coaxial cable integration may limit the design flexibility of the DRA, potentially hindering its adaptability to various applications. Thus, while coaxial cable dielectric offers notable benefits in rectangular DRA design, careful consideration of its associated drawbacks is imperative to ensure the realization of an effective and efficient antenna system. In addition, modifying certain parameters of antenna [1] can be affact on increasing the radiation pattern. Additionally, certain structures have been widely adopted due to their advantages, such as bandwidth expansion. These structures are known as electromagnetic band gaps. Gap issue is one of problems of DRA antenna. Therefore, many methods used to solve this problem [2], because the design of DRA antenna is not easy with these problems .Hence, it requires a combination of two different structures. For example, to make DRA easy to evaluate, we need to mix spectral domain method with another structure such as ME. This makes analyze of aperture of DRA difficult. However addition , there is a relationship between bandwidth and the Q-factor [3,4,5].For example, a low BW and a low Q-factor can complicate the design of certain types of DRA antennas [6,7].

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2. Coaxial dielectric

Using coaxial dielectrics in the design of Dielectric Resonator Antennas (DRAs) offers several advantages. Firstly, they simplify implementation due to their straightforward structure, making integration easy and connections stable. Coaxial dielectrics also ensure efficient power transfer by facilitating impedance matching and minimizing transmission losses. Additionally, they support broadband performance, making them flexible for various frequency bands. These materials allow for precise radiation pattern control and selective mode excitation, enhancing the antenna's functionality. They are compatible with standard interfaces, simplifying testing and measurements. Moreover, their compact design contributes to space efficiency and aesthetic integration. Coaxial dielectrics are cost-effective, reducing manufacturing complexity with affordable and widely available components. Finally, they provide excellent noise immunity due to their superior shielding against interference, ensuring clean signal transmission. These benefits make coaxial dielectrics a valuable choice in DRA design for modern communication systems. However, to enhance the ratio of deictic in the antenna, some experts utilized water as the dielectric material [8].

Incorporating the dielectric material, inner conductor, and outer conductor of a coaxial cable in the design of a dielectric resonator antenna (DRA) yields numerous advantages. The dielectric material, with its high permittivity, facilitates the miniaturization of the antenna while preserving high efficiency and broad bandwidth. The inner conductor of the coaxial cable ensures efficient energy transfer and precise excitation of the resonator, thereby optimizing radiation characteristics. Moreover, the outer conductor functions as a shield, mitigating interference and signal loss, which significantly enhances the overall performance and reliability of the antenna. Collectively, these components synergistically improve impedance matching, reduce unwanted radiation, and enable the development of a compact and robust design that is well-suited for contemporary wireless communication systems. However, the following table 1 explains some benefits and problems of coaxial dielectric. The dielectric constant (Ɛr) is necessary in designing DRA antenna. Therefore, the frequency changes and then reduces when this dielectric constant increases [9].

Table 1. Advantages and disadvantages using of coaxial dielectric in design of DRA antenna

Advantages	Disadvantages
Enables precise control over resonant frequency and bandwidth	May incur increased complexity and cost due to integration requirements
Provides structural support, enhancing antenna stability and durability losses	Potential introduction of additional and impedance mismatches
Facilitates efficient energy transfer to the resonator, ensuring robust	Imposes geometry constraints that may limit design flexibility

3. Surface current

Surface current refers to the electrical currents that flow along the surface of the dielectric material of the antenna.

Advantages of Surface current in DRAs antennas

3.1. Surface Current Basics:

Surface currents are the currents that appear on the surface of a conductor or dielectric material when it is exposed to electromagnetic fields. In DRAs, these currents are induced by the interaction of the electromagnetic waves with the dielectric material.

3.2. Dielectric Resonant Antenna (DRA):

A DRA is an antenna that uses a dielectric material (a non-conductive material) to produce resonant modes for radiation. Unlike traditional metallic antennas that rely on the conductive properties of metals to support surface currents, DRAs use the dielectric properties to store and radiate electromagnetic energy. In a DRA, the surface currents are generated by the electromagnetic fields within the dielectric resonator. These currents play a crucial role in the radiation mechanism of the antenna. They influence the distribution of the electromagnetic fields around the antenna. Then affecting its radiation pattern, impedance, and other performance characteristics.

3.3. Mechanism:

When the dielectric material is excited by a feed mechanism (such as a coaxial probe, microstrip line, or aperture coupling), surface currents are induced on its surface. These surface currents, along with the dielectric properties of the material, that determine the resonant modes of the DRA. The interaction between the surface currents and the electromagnetic fields leads to the radiation of energy into free space. Hence, using a probe for coupling is another method to consider. The probe's location varies between different parts .Therefore, the position of the DRA and the height of the probe are adjusted to optimize coupling. When the probe is close to the DRA, it excites a magnetic field, whereas positioning the probe in the middle of the DRA results in a vertically oriented mode radius. An additional advantage of using a probe is the ability to couple directly without matching with networks. However, increasing the slot size may make coupling impractical.

3.4. Analysis and Design:

The analysis of surface currents is essential for the design and optimization of DRAs. Engineers can predict the antenna's performance, including its resonant frequency, bandwidth, and radiation pattern. Computational tools like the Method of Moments (MoM) or Finite Element Method (FEM) are often used to model and analyze these surface currents in DRAs .In summary, surface currents in dielectric resonant antennas DRA refer to the electrical currents induced on the surface of the dielectric material by the electromagnetic fields. These currents are critical in defining the antenna's resonant characteristics and overall performance. The following figure 1 shows the movement of currents across the surface of DRA antenna.

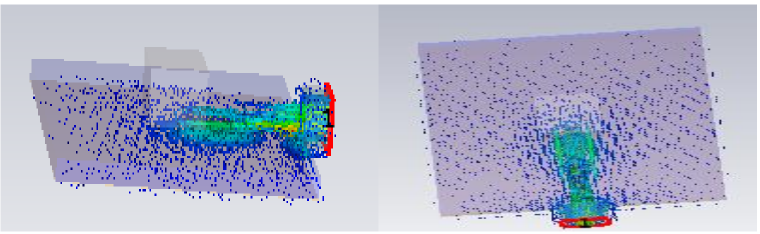


Fig 1.Sprading the current on surface of DRA antenna

In the field of dielectric resonator antenna (DRA) excitation, coaxial probe placement offers versatile options, whether situated within the DRA structure or positioned adjacent to it. When placed within the DRA, optimal coupling occurs by aligning the probe with the electric field of the DRA mode, as depicted in Figure 2. Conversely, in the adjacent configuration, the probe couples with the magnetic field of the DRA mode, illustrated in Figure 2. In both scenarios, the probe effectively excites the fundamental mode of the rectangular DRA, showcasing the adaptability and efficacy of coaxial probe excitation techniques.

However, in the context of excitation probe placement within the resonator, meticulous consideration must be given to the air gap between the probe and the dielectric material. The presence of an air gap attenuates the influence of the dielectric constant, consequently diminishing the Q factor. Furthermore, the selection of probe location affords the flexibility to excite various modes within the resonator, thereby influencing the antenna's operational characteristics and performance.

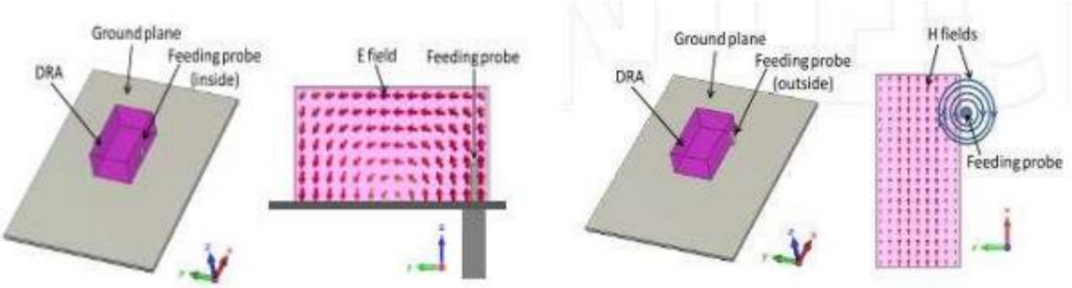


Fig.2 coupling E-field and H-field by coaxial probe [10]

4. Experimental results

4.1. The basic design A

The height measurements in the Z direction are negligible due to their small scale. In this section, a standard rectangular dielectric resonator antenna (DRA) is designed and simulated using a coaxial dielectric, inner conductor, and outer conductor via the Computer Simulation Technology (CST) program. Additionally, Figure 3 illustrates the geometric properties of the rectangular DRA, while Tables 2 and 5 provide a comprehensive list of its corresponding values with proposed symbols.

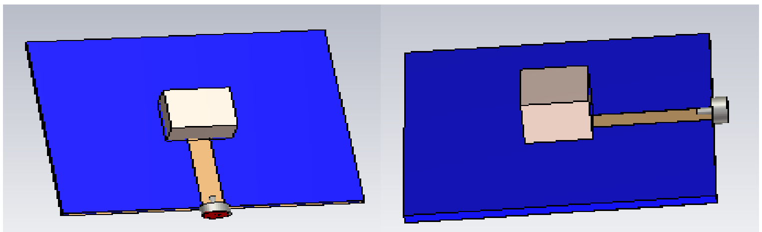


Fig 3. Shows the fundamental design of the initial rectangular antenna with coaxial dielectric with measurements of the grid indicating in millimeters by CST software.

Table 2. Symbols and notations used to denote the parameters along with their corresponding definitions and meanings.

Notation	**Meaning**
W_{gr}, L_{gr}, H_{gr}	width, length and height of ground
W_f, H_f	width and height of feed
W_p, L_p, H_p	width, length and height of patch
W_s, L_s, H_s	width, length and height of substrate
W_g, L_g	width and length of gap
X	width dimensions
Y	length dimensions
Z	depth/thickness dimension
X_{min}, X_{max}	minimum and maximum value in x direction
Y_{min}, Y_{max}	minimum and maximum value in y direction
Z_{min}, Z_{max}	minimum and maximum value in z direction
Y_0	inset length
DRA	Dielectric Resonator antenna
Coax - Dielectric	
Coax - inner conductor (IC)	The input conductor of Coax dielectric
Coax – outer Conductor (OC)	The output conductor of Coax dielectric
Outer diameter (OD)	The output diameter of Coax dielectric
Inner diameter (ID)	The input diameter of Coax dielectric
IR	Inner radius
OR	Outer radius

Table 3. The initial values of the DRA parameters with coaxial dielectric, inner conductor and outer conductor in the first stage prior in the design A.

Parameter	G(dBi)	D(dBi)	BW(GHz)	VSWR	S_{11}(dB)	Efficiency
Design A	6.066	6.846	0.72825	1.4648754	-14.489168	88.7%

4.2. Geometry of RDRA to improve the gain by decreasing characteristics of antenna at f=13GHz

Starting from equation

$$f_{resonance} = \frac{c}{2\pi\sqrt{\varepsilon_r}}\sqrt{\left(\frac{\pi}{w}\right)^2 + \left(\frac{\pi}{h}\right)^2 + \left(\frac{\pi}{t}\right)^2}, \quad (1)$$

we modified the geometry of design A to become small as shown in Figure 4. These changes in parameters of the RDRA antenna were necessary to enhance the gain and the efficiency. Therefore, the values of height h, width w, and thickness t of the DRA antenna are reduced to be half of their original values as shown in Figure 4. The dielectric constant was selected to be 12.34 at frequency 13 GHz, as calculated from

$$\varepsilon_r = \left(\frac{c}{2\pi f_{resonance}}\right)^2 \left[\left(\frac{\pi}{w}\right)^2 + \left(\frac{\pi}{h}\right)^2 + \left(\frac{\pi}{t}\right)^2\right], \quad (2)$$

which in the case of this frequency enhanced the results clearly, as listed in Table 7. The dielectric constant was important in the design of the DRA antenna, because there is inverse relationship between the size of DRA antenna and the dielectric constant. For example, if the dielectric constant is increased, it resulted in reduction in the size of the DRA antenna, therefore we reduced the size of the dielectric resonator as well as reducing the size of the ground plane and substrate to improve the characteristics of the antenna and then to enhance the performance. Table 4 shows the original values of design A and the reduced values of the new design B.

Table 4. The geometry of the designs

F(GHz)	**Design A**							**Design B**					
5.9	DRA	H	W	T				H	W	T			
		11	11	8.5				5.5	5.5	4.1			
12	Ground/substrate	X_{min}-X_{max}	Y_{min}-Y_{max}	Z_{min}-Z_{max}				X_{min}-X_{max}	Y_{min}-Y_{max}	Z_{min}-Z_{max}			
		0-50	0-50	0.035				0-25	0-25	0.035			
13	Feed	X_{min}-X_{max}	Y_{min}-Y_{max}	Z_{min}-Z_{max}				X_{min}-X_{max}	Y_{min}-Y_{max}	Z_{min}-Z_{max}			
		0-3.7	0-20.5	0.035				0-1.85	11.75	0.035			
14	Coax : Dielectric	Outer radius	Inner radius	U centre	V center	W_{min}	W_{max}	Outer radius	Inner radius	U centre	V center	W_{min}	W_{max}
		$\frac{OD}{2}$	$\frac{ID}{2}$	0	0	-2	$\frac{9.9999\ e-0.1}{2}$	$\frac{ID}{2}$	$\frac{ID}{2}$	0	0	-2	$\frac{9.9999\ e-0.1}{2}$
	Inner conductor	Outer radius	Inner radius	U centre	V center	W_{min}	W_{max}	Outer radius	Inner radius	U centre	V center	W_{min}	W_{max}
15		$\frac{ID}{2}$	0	0	0	-2	3	$\frac{ID}{4}$	0	0	0	-2	7
	Outer conductor	Outer radius	Inner radius	U centre	V center	W_{min}	W_{max}	Outer radius	Inner radius	U centre	V center	W_{min}	W_{max}
20		$\frac{\frac{OD}{2}}{} + \frac{Oc}{2}$	$\frac{OD}{2}$	0	0	-2	$\frac{9.9999\ e-0.1}{2}$	$\frac{\frac{OD}{2}}{} + \frac{Oc}{2}$	$\frac{OD}{2}$	0	0	-2	$\frac{9.9999\ e-0.1}{2}$

In the table above we explained both values of design A and design B after modifying the geometry of the antenna according to the following equations with respect to height, width and thickness of antenna as well as the changes in dielectric constant at f=13GHz. However, the results of modifying of geometry of antenna at the frequencies such as (f=12, 14, 15, 20) GHz were not enhanced more as compared to the results when the frequency arrived 13 GHz. Therefore ,according to these frequencies, the values of the dielectric constant were $\varepsilon_r = (10.64, 9.27, 5.21)$ at frequencies $f = (14, 15, 20)$ GHz which were small but the size of the DRA antenna was too large. This considers problem in design DRA antenna, because we need to decrease the size of DRA antenna to improve the result. In addition, when the frequency reduces to become 5,9 GHz the result of the dielectric constant increases to become 59.86. Therefore, the size of the DRA antenna will be very small and very difficult to design DRA antenna as calculated below in Equation (2), Hence, the following equation explains the inverse relationship between the dielectric constant and the size of the DRA antenna. Variety of materials were further useful to enhance the gain and efficiency of DRA antenna. Therefore, we used materials such as, PEC, Alumina 99.9% (Lossy) as shown in Table 5. All of these changes in geometry of DRA antenna helps us to improve the gain to 7.064 GHz and efficiency to 91% at $f = 13$ GHz as shown in Equation 10.

4.3. Mathematical geometry of RDRA antenna to enhance Gain and efficiency

The resonance frequency is approximately 12.98 GHz, which is very close to 13 GHz as shown in equation 1. This indicates that using the given dimensions and dielectric constant of 12.34, the DRA will resonate very close to the desired frequency of 13 GHz. The small deviation might be attributed to minor inaccuracies in calculations or approximations. Therefore, these dimensions (height = 5.5 mm, width = 5.5 mm, thickness = 4.1 mm) and the dielectric constant of 12.34 are suitable for achieving a resonant frequency very close to 13 GHz according to Equation (1). Starting from the Equation (1) of resonance frequency. The parameters of DRA antenna can be calculated mathematically as below.

Starting from Equation (1) we can create equations for height, width, and thickness of the RDRA antenna as follows,

$$k = \frac{2\sqrt{\varepsilon_r} f_{resonance}}{c} = 956.15 \text{ rad/m}, \quad (3)$$

$$h = \frac{1}{c\sqrt{k^2 - \frac{1}{w^2} - \frac{1}{t^2}}} = 5.5 \text{ mm} \quad (4)$$

$$w = \frac{1}{\sqrt{k^2 - \frac{1}{h^2} - \frac{1}{t^2}}} = 5.5 \text{ mm} \quad (5)$$

$$t = \frac{1}{\sqrt{k^2 - \frac{1}{h^2} - \frac{1}{w^2}}} = 4.1 \text{ mm} \quad (6)$$

At $f = 13$ GHz, the value of the dielectric constant can be calculated by Equation (2) arising from Equation (1), resulting in $\varepsilon_r = 12.34$ at $f = 13$ GHz for the dimensions given in Equations (4), (5) and (6).

According to these results, the gain and efficiency are enhanced at $f = 13$ GHz. Moreover, the design of RDRA antenna is not difficult with these values if the dielectric constant is not changed very much. However, at different frequencies, the design and characteristics of DRA antenna change and become difficult, because, the dielectric constant will change and then the size of the DRA antenna changes, too.

4.4. 2 nd geometry of design B

In this design, I changed the geometry of DRA antenna as well as the types of materials. All of these changes by using CST program help us to enhance the gain from 6.066 dBi at frequency F=5.9 GHz to 7.062 dBi at F= 13 GHz. Then the efficiency of new design B increased to 91% instead of 88.6% in case of previous design A. Therefore, the characteristics of RDRA antenna enhanced too. However, we decreased the size of ground plane and substrate to 25 mm instead of 50 mm .Then we changed the size of feed to be half of the original shape that becomes 10.25 mm plus length l=1.5 mm to become 11.75 mm instead of 20.5 mm as shown in figure 4 ,table5 and table6 in details. However, the values of DRA changed to half value of the previous design which becomes 5.5 mm instead of 11 mm as shown in details in table 6.

However, we added coax dielectric including dielectric, inner conductor and outer conductor to improve the performance of DRA antenna. Then the gain improved clearly as well as efficiency improved as compared to the previous design A .Therefore, the values of inner conductor and outer conductor can be calculated by the following equations as listed in table 6.

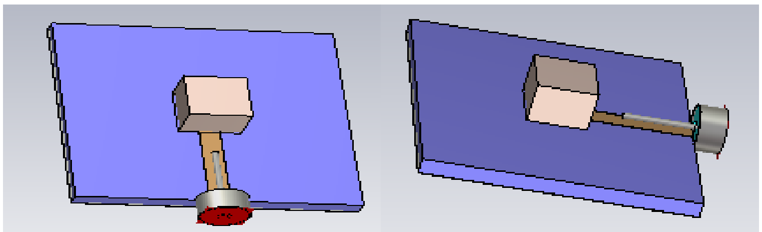


Fig 4. Design of our RDRA antenna with coaxial dielectric, inner conductor and outer conductor.

For the Coax: dielectric

The outer radius is equal to Outer Diameter/2

OR =OD
/2
(7)

For inner conductor

The outer radius is equal to

OR= inner diameter /4 = IR / 4 which is half of the value of the previous design (8)

For outer conductor

The outer radius is equal to

OR = Outer Diameter/2+OuterConductorThickness/2 = OD / 2 + OC /2 (9)

However, the careful consideration of materials is integral to the design process of a dielectric resonator antenna (DRA). The choice of dielectric material significantly influences the antenna's resonance frequency, bandwidth, and radiation efficiency. By selecting materials with specific permittivity values, engineers can tailor the antenna's performance to meet desired specifications. Additionally, the materials used for the inner and outer conductors of the coaxial cable play vital roles in ensuring efficient energy transfer and shielding against interference, respectively. Thus, the judicious selection of materials is indispensable in optimizing the performance, reliability, and functionality of DRAs, aligning them with the requirements of modern wireless communication systems. In additions, these changes calculated and simulated by CST program for different types of frequencies as listed in table 7.

Table 5. Geometric the parameters for the design B of the DRA with coaxial dielectric, inner conductor and outer conductor, with different materials.

Dimension	Size (mm)	Parameters	Materials
DRA height	5.5	DRA	Alumina (99.5%)Lossy
DRA width	5.5		
DRA thickness	4.1	Feed/strip	PEC
Ground plane	25		
Substrate	25	substrate	FR- 4 (Lossy)
Feed length	11.75		
Feed width	1.85		
Feed thickness	0.035	Ground plane	PEC

However, when designing dielectric resonant antennas (DRAs), employing a Perfect Electric Conductor (PEC) for the ground plane is crucial as it significantly impacts the antenna's performance. A PEC is an ideal material with infinite electrical conductivity and no resistance, meaning the electric field is fully reflected and does not penetrate the surface. This idealization is essential in theoretical and computational analyses of DRAs, providing a consistent and simplified boundary condition that helps predict the antenna's electromagnetic behavior accurately. By using a PEC ground plane in the design, one can better control the radiation pattern, impedance matching, and overall efficiency of the antenna. The PEC ground plane acts as a reflective surface that boosts the antenna's directivity and gain by constructively reflecting the radiated waves. This is especially important in DRAs, where the interaction between the dielectric material and the ground plane affects the resonance characteristics and radiation efficiency. Simulating with a PEC allows for an idealized assessment of these parameters, offering insights vital for optimizing the antenna's performance. In real-world applications, materials like copper or aluminum are used, but the PEC concept serves as a standard to evaluate their potential and limitations. Thus, using PEC material for the ground plane in DRA design is key to advancing both the theoretical understanding and practical development of high-performance antenna systems. However, the material might not be a perfect conductor. Pillai et al. suggested improvements in absorption at λ = 1050 nm by depositing silver particles greater than 100 nm in size onto a thin insulator [11].

Table 6. The dimensions of the various components of a rectangular dielectric resonator antenna (DRA) with coaxial dielectric, inner conductor and outer conductor that made of different materials including the ground plane (PEC) material, substrate, feed.

Parameter	X_{min}	X_{max}	Y_{min}	Y_{max}	Z_{min}	Z_{max}
Ground						
Formula	0	W_{gr}	0	L_{gr}	0	H_{gr}
Dimension (mm)	0	12.5	0	12.5	0	0.035
Substrate						
Formula	0	W_{st}	0	L_s	H_{gr}	$H_{gr} + H_s$

Dimension (mm)	0	12.5	0	12.5	0	$0.035 + 1.6$
Feed						
Formula	$\frac{Lf}{4}-$	$\frac{Lf}{4}-$	L_f	$L_f + L$	H_f	$H_{gr} = Hf$
Dimension (mm)	$\frac{-3.7}{4}-$	$\frac{3.7}{4}-$	0	$10.25 + 1.5$	0	0.035
Coax : Dielectric						
Formula	$\frac{OD}{2}$	$\frac{ID}{2}$	$Ucenter$	$Vcenter$	$Wmin$	$Wmax$
Dimension (mm)	$\frac{4.1}{2}$	$\frac{1.2}{2}$	0	0	-2	$\frac{9.9999\ e{-0.1}}{2}$
Coax : inner conductor						
Formula	$\frac{ID}{4}$	0	$Ucenter$	$Vcenter$	$Wmin$	$Wmax$
Dimension (mm)	$\frac{1.2}{4}$	0	0	0	-2	7
Coax : outer conductor						
	$\frac{OD}{2} + \frac{Oc}{2}$	$\frac{OD}{2}$	$Ucenter$	$Vcenter$	$Wmin$	$Wmax$
Dimension (mm)	$\frac{4.1}{2} + \frac{0.41}{2}$	$\frac{4.1}{2}$	0	0	-2	$\frac{9.9999\ e{-0.1}}{2}$

5. Simulation results

The figures include S-parameters, voltage standing wave ratios (VSWR), bandwidths (BW), gains (G), and directivities (D) for the designs at points A and B of both the new rectangular dielectric resonator antenna with coaxial dielectric (design A) and the RDRA antenna without coaxial dielectric (design B). Figure 5 represents the S11 parameters, Figure 6 represents the VSWR, Figure 7 illustrates the calculation of bandwidth, and Figure 8 displays the radiation patterns in 2-dimensional graphs. To ensure comparability, we categorized the simulation outputs based on the parameters as well as the designs. The top subplots on the right consistently represent the new RDRA antenna with coaxial dielectric (design B), while the bottom subplots on the left pertain to the RDRA (design A) in all Figures 5 to 9.

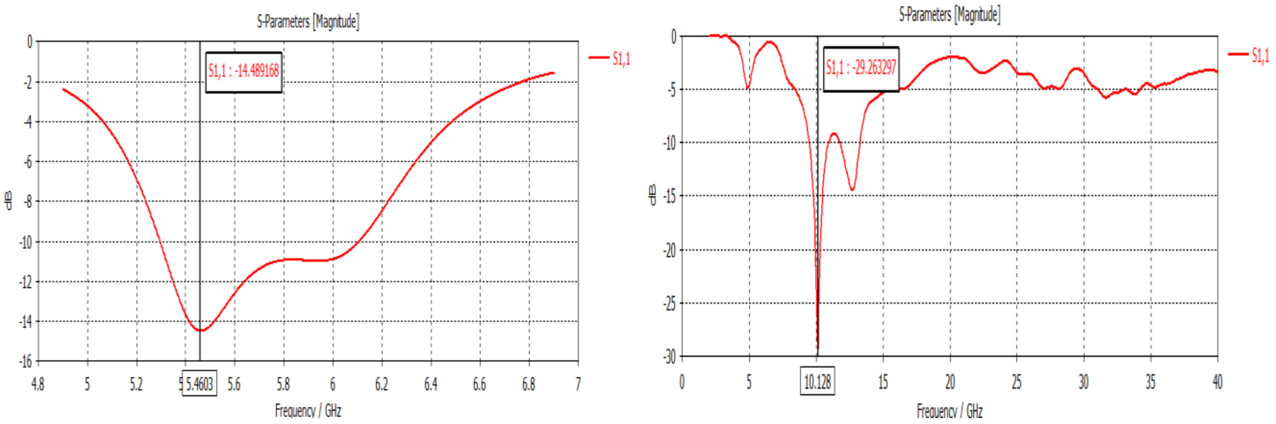


Fig 5. The value of the reflection coefficient S_11. Designed by CST. The first subplot belongs to design A, whereas the second subplot relates to design B

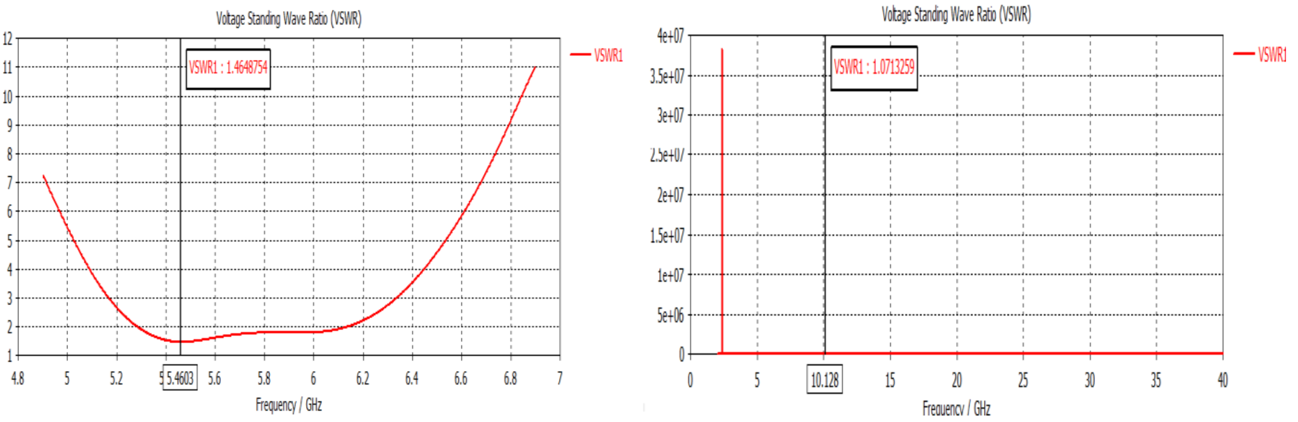


Fig 6 . The voltage standing wave ratio (VSWR). Designed by CST. The first subplot relates to design A, whereas the second subplot belongs to design B

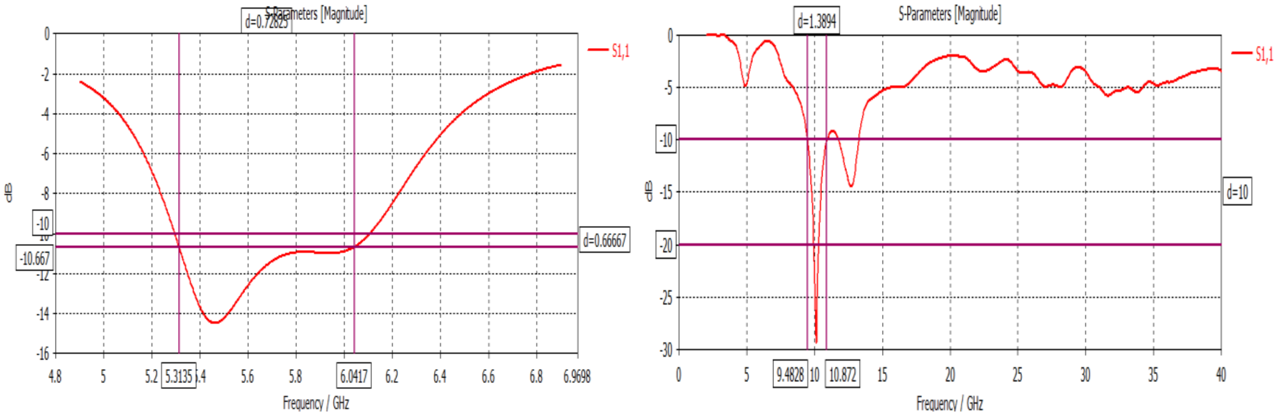


Fig 7.Calculating the value of bandwidth (BW) based on the value of S_11 parameter

Simulation conducted using CST software. The first subplot refers to design A, whereas the second subplot belongs to design B.

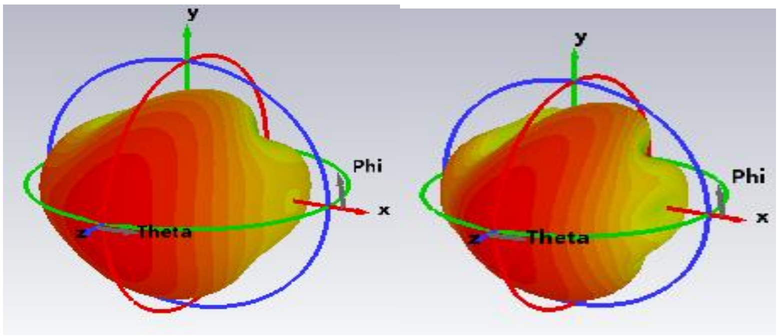
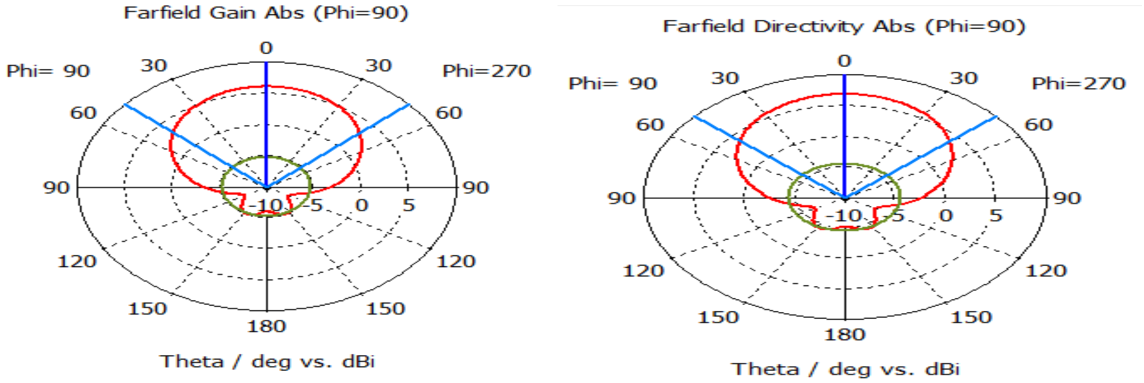


Fig 8. Radiation pattern explains the gain G=7.062 dBi with directivity D=7.794 dBi. Model by CST. The top subplot corresponds to design A and the 2nd subplot to design B.



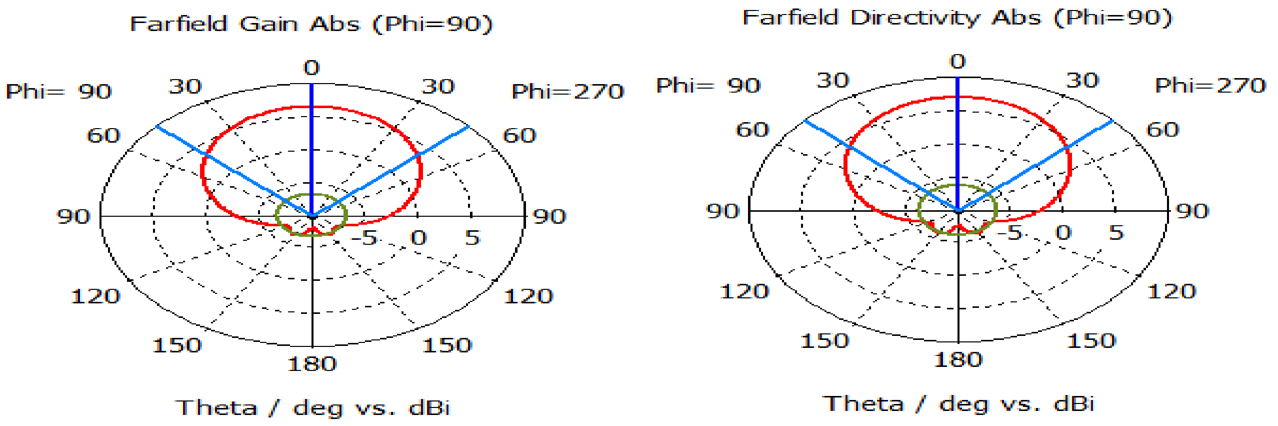


Fig 9. Far field gain (on the left) and directivity (on the right) at a different frequencies , as determined by CST. The top row displays design A, while the bottom row showcases design B.

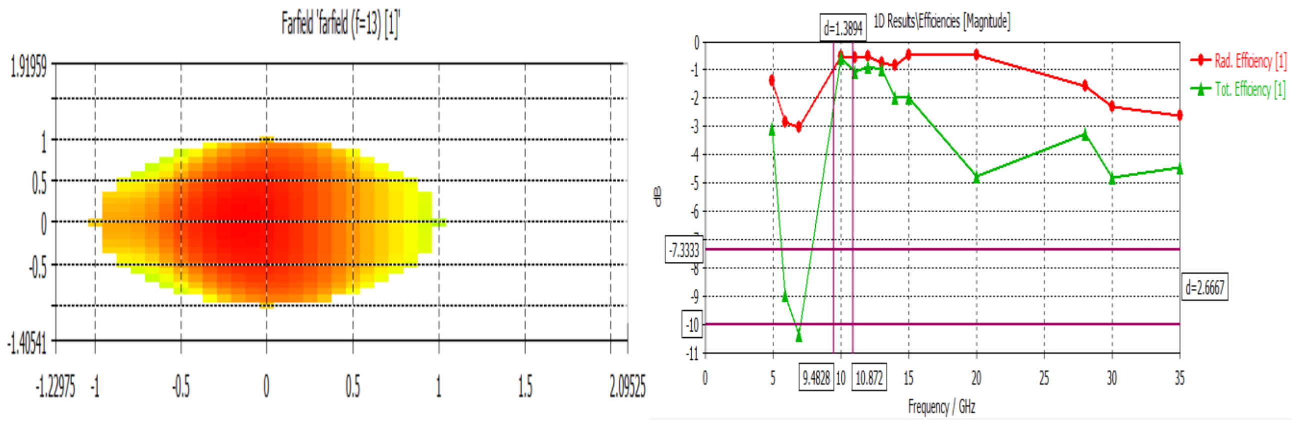


Fig 10. Farfield and efficiency spreading modes at frequency F=13GHz.

However,by using different kinds of frequencies to enhance rhe gain and effiency.we simulated the new design of RDRA antena with coaxial dielectric,inner conductor and outer conductor by CST software.We got the following results as shown in the following table.Therfore,the rsult was clear at frequency f=13 GHz which means increasing the gain from 6.066 dBi at 5.9 GHz to 7.062 dBi at 13 GHz.moeover,the effiency of design B incresed to 91% instead of effiency of design A which was 88.6% as shown in the following table with using different range of frequencies as listed in the following table 7.

Table 7. Different frequenciies used to compare and to enhance gain and effiencicy

Frequency (GHz)	Gain (dBi)	Directivity (dBi)	Efficiency %
F=5.9(design A)	6.066	6.846	88.7%
F=12	6.471	7.012	92%
F=13 (design B)	**7.062**	**7.794**	**91%**
F=14	6.622	7.459	88.7%
F=15	6.252	6.739	92.7%
F=20	6.338	6.803	93%

However,the final results of comparision between design A and new design B explains that the gain enhanced clearly to arrive 7.062 dBi in design B,while the gain was 6.066 dBi in design A.That means the design of coaxial dielectric with geometryof DRA antenna was necessary to enhance the gain as well as the effiency to reach 91% in new design B instead of 88.6% in case of design A in different range of frequencies as shown in table 7,table 8 and explained in equation10.

Table 8 . The final results of design A and design B

Parameter	G(dBi)	D(dBi)	BW(GHz)	VSWR	S_{11}(dB)	Efficiency
Design A	6.066	6.846	0.72825	1.4648754	-14.489168	88.6%
New Design B	7.062	7.794	1.3894	1.0713259	-29.263297	91%

Therefore the efficiency of design B enhanced in successful values to become 91% as explained in the following equation

$\eta = G / D \cdot 100\ \% = 7.062 / 7.794 \cdot 100\ \% = 91\%$
(10)

6. Conclusion and future work

According to the explanation in tables before the dielectric resonator antennas (DRAs) come in many shapes and sizes, although the most popular are rectangular and cylindrical. In addition, dielectric resonant antenna DRA can be either rectangular or cylindrical in shape. Therefore, the antennas' resonance frequency, bandwidth, and radiation pattern that all modified by the form difference. The changes in design of RDRA was necessary to enhance gain. Also, using different types of frequencies with designing coaxial dielectric, cylindrical inner conductor and outer conductor helped us to improve the gain clearly as compared to the previous design to become 7.062 dBi in design B instead of 6.066 dBi in case of design A as shown in figure 7 at F=13GHz. In addition, the efficiency of new design B increased to 91% instead of 88.6% in case of design A as shown in table 8 after changing the geometry of RDRA antenna with adding coaxial dielectric, inner conductor and outer conductor to the new design. However, we can increase the efficiency of RDRA antenna by changing the geometry of this antenna without coaxial dielectric regarding reducing the height, width and thickness of antenna. Therefore, when the height decreases to 1.25 mm, width reduces to 2.25 and the thickness of RDRA antenna equals to 4.458 mm with dielectric constant $\epsilon r = 9.8$ the efficiency arrive 93.7% but the gain will reduce to 6.094 dBi [12].In general, integrating coaxial dielectrics into the DRA design optimizes its performance parameters, minimizing signal losses and interference, thereby ensuring clearer and more dependable communications. Furthermore, the using of coaxial dielectrics enables the antenna to operate across a broader range of frequencies, which is essential for modern communication systems that operate across diverse bands. Incorporating coaxial dielectrics to enhance the gain of a dielectric resonant antenna (DRA) brings forth several benefits. Firstly, it enhances the antenna's compatibility with other components, facilitating more efficient power transfer between the antenna and the transmission line. This increased efficiency directly contributes to improving the antenna's overall performance. Secondly, the coaxial setup enables a more streamlined and integrated antenna design without compromising its effectiveness, which in turn can lead to higher gain. . Moreover, leveraging coaxial dielectrics offers improved control over how the antenna emits its signals, resulting in enhanced precision in signal transmission and reception. However, Rectangular DRAs often have a smaller bandwidth since they optimized for a single resonant mode. Due to their more directed emission pattern, rectangular DRAs are the best used for point-to-point transmission. That makes them an excellent choice for use in compact wireless communication devices. Generally, rectangular DRAs have a higher manufacturing complexity than cylindrical DRAs as shown in some studies of researchers. This is because achieving peak performance with a rectangular DRA calls for finer construction and calibration. Hence, the tiny size and omnidirectional emission pattern of cylindrical DRAs make them ideal for usage in portable communication devices like smartphones and tablets [13]. Due to their directional emission pattern, rectangular DRAs find widespread application in point-to-point communication systems like satellite communication and radar. Therefore, rectangular DRAs, on the other hand, are more suited for point-to-point transmission because of their more directional emission pattern. Depending on the needs of the application and the limitations of the design, one of the two DRA kinds should be selected. DRA antenna is very important in radio communication systems. In future, we want to enhance the gain and bandwidth and other parameters such as, x,y,z. This occurs by changing the shape of this antenna with different styles inside the DRA antenna like removing some legs or adding different shapes inside the antenna as well as, removing or adding some substrates to enhance the gain of DRA antenna. Also, feeding the antenna by suitable ports. For example, optimization of characteristics of rectangular DRA antenna. This can occur by adding or removing some parts of this antenna using many elements or layers for stacking of this antenna [14]. However, we can enhance gain also by adding some layers such as, using many layers of photonic crystal by removing some parts of this antenna as shown in designs above, as I simulated them by CST software program to reduce the size of DRA antenna. However. These processes can be performed by using CST (Computer Simulation Technology) as explained above by listing the designs that I simulated by CST. Therefore, we will enhance the following designs in future by adding some changes in the structure of the DRA antenna to improve the performance this antenna and then enhancing the characteristics of DRA antenna. For example, reducing the size of DRA antenna by changing the values of x,y,z parameters with radius as shown in figures above . Overall, these changes in future will help us to enhance gain more and bandwidth as well as enhance the efficiency of antenna as simulated by CST. However, we will keep working to enhance and develop the gain and bandwidth and efficiency with radiation pattern in future by changing the structure and parameters of DRA antenna or using DRA as diode or filter to radiate more radiation pattern by Computer Simulation Technology.

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