Periodicals of Engineering and Natural Sciences
Vol. 11, No. 6, December 2023, pp.105-134
ISSN 2303-4521
Original Research

Design and comparison of rectangular and cylindrical DRA antennas for enhanced efficiency and gain

Hussein Turki Alateewe[1] and Szilvia Nagy[2]
[1] Ministry of Education, Vocational Secondary School, Iraq ORCID: 0009-0003-4211-2190, PhD student at Széchenyi István University, Egyetem, Hungary
[2]Szilvia Nagy is with the Széchenyi István University, ORCID: 0000-0001-9556-5095Egyetem tér 1, 9026 Győr, Hungary

ABSTRACT

Many applications in lifestyle need to use some kinds of antenna especially in communication field. One of these antennas that is used in this field of communication is called dielectric resonator antenna (DRA). In this review, we will compare different kinds of DRA antennas, for example, cylindrical and rectangular DRA antennas, based on their S-parameters, gain, directivity, bandwidth, and voltage standing wave ratio (VSWR). After discovering the studies about characteristics of these antennas according, the technology of gain, bandwidth enhancements used in the literature will be explained in detail, such as using a high-dielectric-constant material, adjusting its resonant frequency, property of lensing of MTM cells. In practical experiments, the software CST (Computer Simulation Technology) is used for this purpose, to evaluate the above-mentioned parameters of DRA antennas. The advantages of DRA antennas are high radiation efficiency, small size, low profile, and lightweight after changing some elements or structure of DRA antenna, which makes the antenna have more attenuation. To enhance the S-parameters and gain magnitude, the suitable design of DRA depends on the geometrical and material characteristics used for this purpose. This also enables us to achieve acceptable results with high efficiency. Therefore, the simulation of the antenna must consider beside these properties and characteristics, the effects of surface plasmon waves on the properties of DRA antenna. Adding layers of photonic crystal to the DRA antenna enhances the results and leads to higher gain.

Keywords: Gain; coupling of apertures; *S*-parameter; radiation pattern; surface plasmon; physical ground plane; microstrip antenna; resonation frequency.

Corresponding Author:

Hussein Turki Alateewe
Ministry of Education, Vocational Secondary School,
, Iraq. PhD student at Széchenyi István University, Egyetem, Hungary.
E-mail: name. husseinalateewe1983@gmail.com

1. Introduction

Dielectric resonator antenna (DRA) is a kind of antenna used in radio communication with different shapes, for example, rectangular or cylindrical. A ceramic material used in this antenna as well as a dielectric resonator on the surface of the antenna. The frequencies are microwaves that are used in this antenna to enhance the results and give the antenna enough energy to spread and arrive long distance. In high frequencies, the metallic parts of DRA antenna loss. Therefore, this case considers advantage for this antenna because; the energy will reduce in these high frequencies. Therefore, this advantage makes the DRA antenna better than Dielectric waveguide antennas because of the loss that will be small and high efficiency, in high microwaves frequencies. However, in 1939 Robert Richtmyer is the first person who suggested the first Dielectric waveguide antenna in some wireless devices or radar devices. Hence, the first designed DRA antenna was in 1982. Then the first antenna was tested by Long et al. In this year. So, the designer focus on the dielectric surface with taking in account the leak of waveguide. Therefore, the model HEM11d developed in the new HEM12d model. In addition, this was in 2012. Moreover, the new model puts in cylindrical shaped ceramic block to radiate broadside pattern. This discovers by Guha in year of 2012. Hence, there are similarity between two kinds of antenna. For example, Marconi antenna. This similarity between Marconi antenna and dielectric antenna in working. However, the only difference in material of dielectric [1] that replaced instead of the inductive element. One of most important issue in DRA antenna is relative permittivity. This is useful in designing of this antenna. In addition, this constant is considered acceptable in value 9.8 as dielectric constant of antenna. Therefore, the simulation of this antenna by CST program depends on this constant. However, some problems appear in the properties of this antenna. For example, choosing the suitable size during the design of this antenna. In addition, bandwidth (BW) plays the important role in this design in different shapes. However, with different characteristics lead to different variety in results. For example, cylindrical DRA antenna differs from Rectangular DRA antenna in shape and characteristics as well as results. The differences in design or radiation pattern with different parameters as feed in this antenna. Hence, reducing of radiation pattern is one of many problems in the simulation of DRA antenna. This can see in losses of ohmic properties. This is for many kinds of DRA antenna. This makes design of antenna difficult. However, the designer should choose the suitable value of dielectric constant. That is because of inversely relationship between Er and the size of DRA antenna. Therefore, radiation pattern goes up ground and depends on dielectric constant. In addition, each design contains dielectric constant according to the suitable design. All these constants are different in values or numbers. Therefore, the designer will choose the suitable value of dielectric constant during the design of suitable DRA antenna. However, in millimetre frequency design of DRA antenna appears without problems in design. That means the losses of the design of DRA antenna does not appear clearly. In addition, depending on the material of ground plane (GP). If the GP used with physical material differs from the using of boundary GP. Therefore, the values will reduce because of losses in ohms when physical GP has used.

However, using of a circular slot as technology to improve the BW of a rectangular DRA antenna is considered important tool to enhance efficiency of DRA antenna. This is good technology to get high results and achieve good properties of DRA antenna. However, the software program for simulation is called CST program. Therefore, the bandwidth will arrive as rate 36.44% by using circular slot technology in frequencies range of (0.92 -1.33 GHz). While rectangular slot gives bandwidth value, arrive 6.39% in the different range. This was in the range of frequencies (1.6-1.13 GHz). That means the circular slot is better than rectangular slot in increasing of bandwidth five times. However, some studies focused on DRA antenna for many reasons.one of this reason is efficiency of radiation. In addition, other advantages are different modes of radiation in different positions. This means this antenna is useful in different places (positions). Moreover, the band width will be high as compared to other antenna of patch Microstrip as well as no metal losses [2]. However, high permittivity (Er) used to avoid some problems in collection with system. Then, in frequencies (around 1 GHz), the size of DRA antenna is big. Therefore, in applications of UHF band the DRA antenna used popularly in different positions. Hence, a single antenna has the possibility to replace other narrow band antenna to reduce the cost of applications with small frequencies. In general, there are three kinds of DRA antenna. For example, rectangular, cylindrical and hemispherical antenna.in many applications the rectangular DRA antenna is widely used. That is because of more freedom in design or simulation. It denotes by RDRA antenna [3].

2. Theoretical framework

Many studies wanted to get high bandwidth of this antenna. The simple way is using metal with small value to get high bandwidth [4]. However, another ways or methods to get high B.W is to change the shape of DRA antenna and change some characteristics or parameters. Moreover, multiple DRA for stacking to enhance bandwidth [5]. Also, using another kind of DRA antenna. For example, hybrid antenna for increasing the radiation pattern with high bandwidth. Another way by feeding the DRA antenna by slot to make the bandwidth large in the wide range of frequencies [6]. Each technology contains some advantages and disadvantages. For example, the problem in these technologies is the variety size of DRA antenna. Therefore, the large bandwidth results from using of slot DRA technology with feeding this Antenna without increasing the size of Antenna. This technology used in low frequency. In addition, the slot of feeding the antenna is rectangular shape. However, other slots in shape might use in this technology. For example, ring slot, circular slot, etc. In addition. Last years ago, the designers used different kinds of slot such as circular slot. This slot used in many advantages such as, coupler to enhance and increase the bandwidth of this antenna [7]. However, other types of slots might use for this purpose to increase bandwidth such as radiator. This slot makes the radiation pattern with large bandwidth and enhance characteristics of DRA antenna [8]. This is in the large of B.W and UWB applications for frequencies from 3.1 to 10.6 GHz. Hence, to enhance bandwidth and create RDRA antenna the circular slot should be replaced into rectangular shape. This might be in different dimensions such as, 0.257ko 3 0.257ko 3 0. 051ko. Therefore, the following figure 1 shows the comparison of results of s-parameter (S11). this values in both cases of simulated and measured results by CST soft program. The acceptable value of S11 was 210dB. This value is about 90% of transmitted value, the rate is 10% of reflected energy. Therefore, the figure1 shows both results of measured and simulated values.

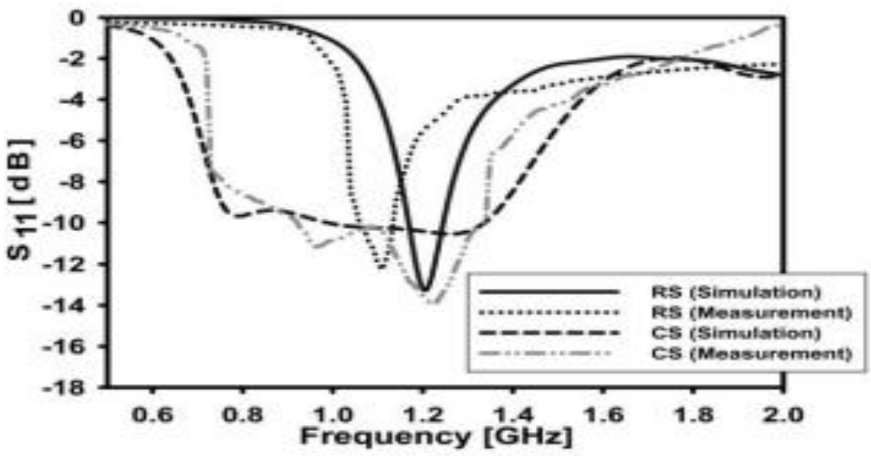


Figure 1. Using circular and rectangular slots to compare the simulated and measured values of coefficient of reflection [9]

Some studies related to feeding RDRA antenna by two kinds of slots such as rectangular, and circular slots. They found that bandwidth extended when circular slot used. Then the BW improved much during the use of this slot. Therefore, the BW rate was 36.44% by using circular slot. In addition, other parameters not affected again and radiation pattern. However, the rate of bandwidth was 6.39% by using rectangular slot. Therefore, circular slot is better than rectangular slot five times. However, some properties of resonant studied by R. D. Richtmyer. These properties related to different kinds of dielectric materials such as ring and spherical properties in 1939[18]. This used to generate radiation of electromagnetic. Therefore, this study was not used and not good for scientists because the materials of dielectric were unavailable as low loss. However, DRs (dielectric resonators) were developed by those scientists. This was popularly used with high permittivity and low loss for different shapes. For example, hemispherical, rectangular, and circular shapes of dielectric resonators (DRs). In addition, microwave resonators of metallic replaced by dielectric resonators in 1960s early. That is because of development in the industry of ceramics and low losses in dielectric materials. The early study focused on resonators of dielectric especially, in applications of electronic. For example, filters and oscillators. This was preliminary research in the first time [10] in these electronic shapes. However, another study collects the comparison between crystals of rutile and resonators of cavity [11]. So, the crystals of rutile give factor (Q) of quality more important than resonators of cavity which reported by Okaya and Barash in 1962. However, in 1967 Q-factor of radiation was discovered by other researchers in resonators of spherical dielectric. They were Gastine et al. Hence, for constant of high dielectric, many studies reported. For example, in resonators of dielectric. The study was in different modes of these resonators and distribution of f ield of electromagnetic.

However, these developments make the use of the resonators of dielectric suitable for many applications. These explorations help us to use the resonators of dielectric as elements of circuit with their properties in many applications of DRA antenna. Moreover, the important issue is to reduce the leak of radiation. That is by covering the resonators of dielectric by metallic cavity. This helps to reduce the leaks of radiation and enhance Q-factor. Another advantage of resonators of dielectric is working as radiators. For example, in electromagnetic waves. These advantages of resonators of dielectric be after reducing the dielectric of constant and removing the metallic cavity. Therefore, DRAs developed by these concepts by scientists. The development made the resonators of dielectric move from circuit components to radiating elements. Because there are more leaks electromagnetic after removing metallic cavity. When the permittivity of DRA reduces these DRA, antennas radiate. In addition, Antennas radiate when removing metallic above them. However, some studies in 1980 year by Long, McAllister, and Shen used the DRA as element of antenna [12]. Hence, they studied some characteristics of this antenna in the field of electricity. However, many kinds of DRA antenna that studied as, hemispherical, rectangular, and cylindrical. Moreover, theoretically, they calculated radiation pattern with low efficiency of radiation and low cost as well as some studies compared between DRA antenna and metallic antennas. This study discovered that DRA antenna was better than metallic antennas. However, the researchers used many ways to evaluate results and to limit or to know Q-factor, frequency of resonance in 1990 year. Previously, studies focused on exciting resonators of dielectric by feeding mechanisms. For example, feed of probe, coupling of apertures in the mid-to-late 1990s. Therefore, the studies focused on some characteristics such as bandwidth, dual-band, polarization in shape of cylindrical to design DRA antenna. Some suggestions refer to kinds of DRA in complex engineering shapes. Some of them like trapezoidal. Also, other types of design of DRA Antenna such as stair shaped. These types of design DRA antenna give this Antenna more efficiency and performance with high improving.

Hence, the constant of dielectric should be high to achieve electromagnetic coupling. This coupling is between the source and resonator. Therefore, the material of DRA antenna must be high dielectric with constant to achieve high electromagnetic coupling. However, Antennas of DRA work in wide bandwidth, but they need to be that material of DRA is low dielectric material with constant. However, technologies have changed more in the years ago. For example, many experiments explained that equation.

$$P = P_{rad} + P_{dis} \qquad (1)$$

is related to evaluate of effects of radiation of power P_{rad}, and dissipation power P_{dis}.

Therefore, some studies focused on changing parameters of DRA antenna such as x, y, z. For example, Ong and McAllister changed some dimensions of antenna. They tried to enhance results and get high efficiency [13]. For example, changes were in radius $R = 2.54$ cm, $E = 8.9$ and $L = 1.52$ mm. These changed dimensions were necessary to get high results with high efficiency. Also, frequency changed to value $f = 1.89$ GHz theoretically instead of resonance values which is $f_r = 1.88$ GHz as well as, changing in BW with following equation.

$$(\Delta TE)^2 = J\,(K \cdot a)H_1\,(K_{oa}) - \sqrt{E}\;J_1\,(K_a)H_1^2(K_{oa}). \qquad (2)$$

However, some methods invented by some researchers in application of $FDTD$ to solve some problems in DRA antenna such as, slow stimulation and low results. Some of these problems related to electromagnetic fields. However, there are some differences in exciting of feeding to TE_{11}.Therfore, results of TE_{11} will be different with increasing linearly case. This invention was introduced by Luck and Shum with gave high value of ε_r. But the disadvantages were losses of time. In addition, some methods include entering part of material inside center of DRA. Therefore, the DRA antenna will be small with these changes in dimensions of this antenna. This method is practically not difficult. So, this method was invented by Mongia et. In addition, they used high value of ε_r. These changes have developed since 1994 year. However, the disadvantages were that the size of antenna became small. Nevertheless, in the case of cylindrical antenna, this method was suitable. However, in many kinds of Antennas this method can be use in the wide area. For example, annular antenna. Another study is interested in extending this way or method by making the size of antenna suitable for designing. Also, reducing of value of size of antenna in acceptable value. These changes lead to getting acceptable results as well as, high efficiency. Therefore, the antenna will work with good results as well as suitable size. Moreover, some other studies related to change of frequency or bandwidth of DRA antenna.

In addition, the value of ε_r used in high value. These studies were introduced by Leung et al. However, profile using or low profile reduced during this study. The results were not bad. In other size, they tried to develop this study to get high bandwidth. This was by putting 2 parasitic DR inside DRA Antenna. This development was suitable for some results of designing of DRA antenna. This invention was discovered by some researchers such as Simon and Lee. In the other side, they tried to extend more information in design by adding dielectric constant to DRA for variety of bandwidth. Another development by Chen et al as well as Luck. The last one developed this method to get high results by covering DRA antenna with dielectric. This is sometimes useful for getting high power and impedance. Therefore, impedance increased during the covering of DRA with dielectric. The results were enhanced in acceptable ways.

However, the problem was there are many effects on results that come from the frequency. Moreover, air gaps that are related to frequency affect the results directly. This method or study introduced by dunker et al. therefore, the results changed with problems in design of DRA antenna [14]. However, to solve this problem they used double layer of DRA to avoid the effects of air gap. In addition, the gain of DRA antenna enhanced with some improvements in Q-factor. Other scientists tried to deal with the resonance such as Marcatili. However, some techniques were important to study or evaluate some properties or characteristics of DRA antenna. For example, some evaluations of efficiency. Hence, the following equation that is responsible for evaluation explained below such as Wheeler cap.

$$\frac{1}{Q_0} = P_{rad} + \frac{P_{dis}}{W_W} = \frac{1}{Q_{rad}} + \frac{1}{Q_{dis}} \qquad (3)$$

Therefore, some older studies studied nano-plasmonics. Therefore, gold was the source of light. However, silver used to excite SP phenomena instead of using the gold material. Because silver is a good material to reduce chemical reactors [15]. Therefore, the results could be like each other by using silver material. However, the purpose of these experiments is to get high ε_r, as well as less complexity in design of DRA antenna. Some studies recorded some increasing in Q-factor. These increasing results from increasing in value of ε_r. However, the size of DRA reduced according to these developments. Hence, increasing of surface to volume ratio during chosen suitable parameter. However, water dielectric is used in DRA antenna by some experts. This was useful to increase the ratio of deictic in antenna. Therefore, efficiency of radiation is considered one of important issues in designing of DRA antenna. The method of wheeler cap is suitable for this purpose to enhance efficiency. This method invented by O'Keefe and Kingsley. Therefore, evaluation and analyzing of efficiency are acceptable by this method. However, some scientists noticed some differences in parts of characteristics. For example, Lai et al discovered the differences of some characteristics between DRA and micro strip. These differences are not big but in some properties.

Therefore, the mode of radiation of micro strip is less than the mode radiation in DRA antenna. However, the differences in radiation are result from putting arrays of DRA over micro strip. That leads to an increase in radiation mode and causes these differences.

Hence, the differences in radiation because many layers. However, individually each DRA radiates to avoid these problems in differences of radiation. That means the energy reduced between two antennas. Therefore, to avoid these problems by putting multi-segment of DRA. The energy will increase by these changes. This invention was proved by Kishk and Kajfez. The results increased and efficiency enhanced. This method will be difficult to enhance bandwidth. Because many elements of DRA stacked [16]. This considers problems in designing of DRA antenna. However, for DRA such as, hybrid resonator has some advantages like size, low profile. However, many resonators consider problems in designing DRA antenna. Some advantages of hybrid resonator antenna such as size, low profile. However, there are some disadvantages, for example many resonators are used together. Therefore, the interaction between resonators is difficult by using this antenna. In addition, variety in frequency leads to different results. Therefore, bandwidth is playing an important role in designing thus antenna. Therefore, performance of antenna enhances by increasing the bandwidth. Hence, Luk suggested this method to increase bandwidth. This method uses air gap to modify the DRA antenna and enhance results [17]. For high results and enhance bandwidth by using stacked elements of annular DRA. That means both energy and efficiency will improve together.

They suggested the use of SPS to enhance energy. Then getting high results. However, Edward Hutchinson, Synge, Einstein tried to reduce scattering in fields by using source of light, introduced another suggestion. This method is suitable in some applications such as fields. The materials will be changed according to use the suitable design of Antennas. Therefore, electromagnetic fields improved by using these developments. However, in some frequencies such as, optical frequency the material maybe not perfect conductor. Different study suggested by Pillai. et to improve in absorption at $\lambda = 1050$ μm Also, depositing of >100 nm silver particles on thin isolator. This will make some results suitable and acceptable by changing these materials.

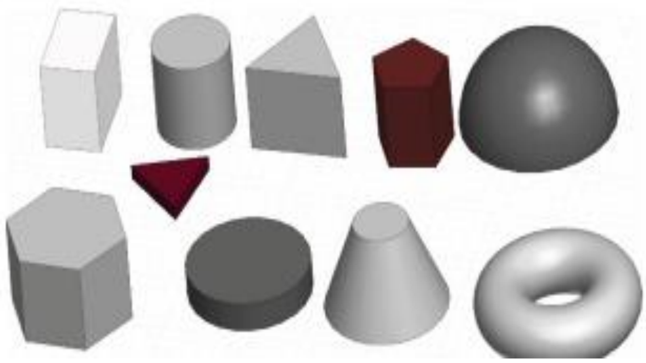


Figure 2. Different kinds of DRA antenna [18]

Therefore, each shape or kind of DRA has some advantages to radiate. In addition, gain and directivity are different for each one of DRA antenna in frequency around 1–100 GHz. In addition, Polarization (electric field) and capacity of DRA antenna is required and useful in the case of designing. Moreover, energy plays an important role in getting results and enhancing characteristics of DRA antenna. For example, storing of energy took place by using of material of permittivity (ε_r). Hence, directivity is responsible for measuring the direction of radiation of antenna. However, asymmetrical T-shaped are used as modified structures by some techniques to enhance bandwidth of DRA antenna. The shapes of modified structures of DR were in different types such as L, U, E, etc. [19]. This enhances the bandwidth of DRA antenna. This leads to an increase in the size of the antenna. Therefore, increasing the size of antenna is considered one of the most important problems in the communication field. Therefore, the researchers in some studies tried to design wide bandwidth and reduce the size of DRA antenna by compact DRA. This method leads to provide small size as well as low profile of DRA antenna. This method provides two DRs Antenna excited by a single microstrip feed. The ends will be inserted inside between the rectangular dielectric resonators (DRs). Therefore, this leads to a reduction in the size of antenna and enhanced bandwidth. However, techniques of fabrication of the compact design includes the following steps

First: placing the lower DR in the substrate within a cut while fixing the upper side on the substrate in the upper side of surface.

Second: before adding the upper side of DR antenna, the conductive strip placed on the lower side of DR antenna. Therefore, within substrate both DRs inserted with high permittivity. Therefore, thickness of the antenna (in the x-direction) reduced with mode of radiation in stable side with height denoted by h.That is smaller than two dimensions when using model of dielectric waveguide (DWM). Therefore, that is useful to excite the resonance [20]. Hence, for two rectangular DR the mechanism with dimensions $a \times b \times h$m m3, loss tangent tan δ = 0.002, and dielectric constant of 20. All of these improvements are used to enhance bandwidth and to reduce the size of DRA antenna. The following Figure 2 shows two kinds of DRA antenna with reflection coefficient. One of DRA antenna (DR placed on the top of dielectric substrate) and inserted DRA. Therefore, band wide will extend with reducing the size.

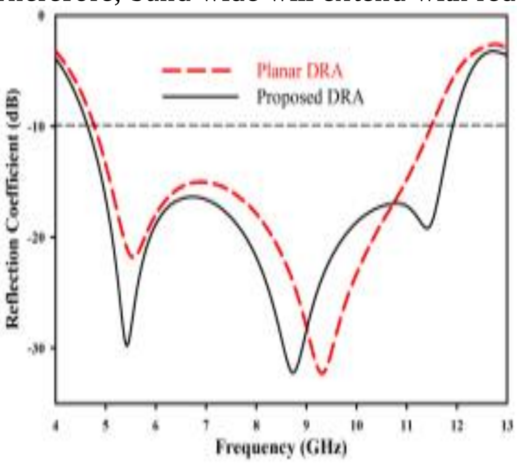


Figure 3. Reflection coefficient of two DRA antenna [9]

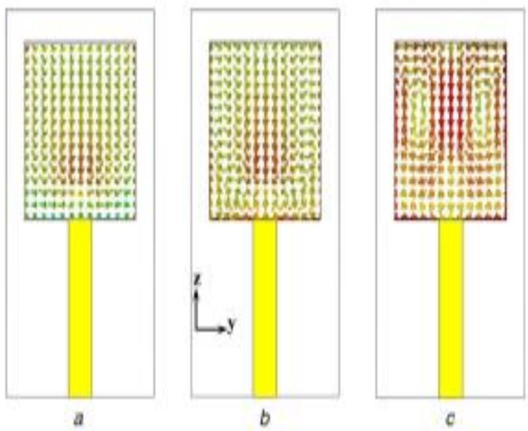


Figure 4. E-field vectors inside DRs (5.4, 8.7, 11.4) GHz for a,b,c [20]

The effects of E-field explained in Figure 3, Figure 4. That showed inside the DRs Antenna for three values of frequencies that are (5.4, 8.7, 11.4) GHz. However, the bandwidth of DRA increased when constantly used. Hence, this leads to reduce Q-factor of modes of resonant.

2.1. Rectangular DRA antenna

It is one of kinds of DRA antenna that consists of dielectric as, shape of rectangular placed on (ground plane). This kind of DRA antenna has high bandwidth with high gain. In addition, it has the capacity of power handling. Other advantages for rectangular DRA antenna are width and height that are suitable in different positions. Rectangular Dielectric Resonator Antennas (DRAs) frequently used in wireless communication applications due to their many benefits over alternative antenna configurations. However, some benefits of rectangular DRA antennas are as follows: One-distinguishing feature of rectangular DRAs is their high quality (Q) factor, which allows them in case of the efficiently resonate at a chosen frequency. Because of this, they can be used in advanced communication systems. Rectangular DRAs are well suited for usage in point-to-point communication systems because of their high gain and directional emission pattern. Rectangular DRAs are well suited for use in systems that demand high selectivity, such as radar systems, because of their narrow bandwidth and increased selectivity. In addition, great directivity. Therefore, Rectangular DRAs are well suited for directional communication systems because of their ability to concentrate their radiation pattern in a single direction. Moreover, Rectangular DRAs have low cross-polarization, which allows them to send and receive signals with minimal interference from unintended polarization components. Therefore, Rectangular DRAs have a small footprint, making them compatible with a wide range of communication networks and devices. In addition, Convenience in production most common manufacturing processes can used to produce rectangular DRAs, including milling, cutting, and polishing. Moreover, high Q-factor, high gain, limited bandwidth, high directivity, low cross-polarization, low profile, and simple fabrication are only some of the benefits of rectangular DRAs. Because of these benefits, they frequently used in wireless communication systems, especially in radar and point-to-point networks. Whether a circular or square DRA is the better fit for a given application and design is ultimately a matter of personal preference.

There are many differences between microstrip and resonators DRA antennas such as, radiation mode. Therefore, DRA (dielectric resonator antenna) has enough area along the surface except. In addition, the radiation will result from all this whole area of surface. However, in the case of microstrip patch antenna the area will be reduced. Therefore, radiation will occur from this narrow slot. Moreover, the microstrip has some disadvantages because of the narrow slot and radiation. Some of these problems are small in gain, small in bandwidth properties. However, to overcome this problem we use the DRA antenna that is suitable in case gain and bandwidth with high mode of radiation. By choosing different values or dimensions of height, width and length values, this will enhance the results and efficiency of DRA antenna [21] . In addition, there is method used to analyze DRA antenna that collects between approximation of Marcatili's way and approximation of EDC. This is useful to analysis some characteristics of antenna [22]. However, some features of DRA antenna related to mode degeneracy compared to other structure shapes. To overcome this problem by choosing the suitable ratio between height and width of DRA antenna.

This leads to reduce the excitation of levels of polarization as well as, reduce the undesirable modes. In addition, to analyze the rectangular DRA antenna two main issues should take in an account, first, the Model of Dielectric waveguide second, Okaya and Barash that designed model of Magnetic wall [22]. Hence, some antennas such as, RDRA antenna with muti-dimensional modes supports a different of applications Therefore, modes of radiation represent the phenomena of radiation. For example, pattern of H field and E field [22]. However, the researchers named the modes of resonance in isolated rectangular of DRA antenna are modes of TE and TM. However, experimentally, or practically TM mode not proved. However, these modes achieve the conditions of the surface of resonator DRA antenna. The confined mode showed in the first equation while the no confined mode explained in the second equation [23], where.

$$\vec{E} \cdot \hat{n} = 0 \tag{4}$$

$$\hat{n} \times \vec{H} = 0 \tag{5}$$

However, some researchers such as Van Bladel explained that DRA is suitable for the modes of non-confined only. However, other shapes like spherical and cylindrical support the mode of confined. However, many number of modes that DRA antenna has clearly. Otherwise, small numbers of modes could be found in cylindrical and hemispherical shapes. Therefore, the impedance of Bandwidth will improve because of these features in modes when same radiation of adjacent modes. The use of method of DWM to generate $TE\delta$ from E and H-field. Therefore, the following approximation of RDRA explained as follows [24]

$$k_x \tan\frac{k_x d}{2} = \sqrt{(\varepsilon_r - 1)k_0^2 - k_x^2} \quad (6)$$

Where,

$$k_x^2 + k_y^2 + k_z^2 = \varepsilon_r k_0^2,\ \ k_0 = \frac{1\pi f_0}{c},\ \ k_y = \frac{\pi}{w},\ \ k_z = \frac{\pi}{2h}. \quad (7)$$

The parameters of RDRA are k_x, k_y, k_z and k_0 that represent wavenumbers in x, y, z-axes, whereas w, d and h are length, width and height represent free space of RDRA. Some mechanisms and techniques are considered important to determine the radiation excitement for each mode and to evaluate the amount of power between the antenna and the port. This is useful for determining the frequency of resonance, Q-factor as well as, input impedance. In addition, determining the characteristics of RDRA. However, there are some techniques to excite RDRAs antenna as shown below.

2.2. Cylindrical DRA antenna

It is a kind of DRA antenna, which consists of dielectric in the shape of cylindrical. It was placed on (ground plane). This kind of DRA antenna provides high gain and high bandwidth because it treats the energy successfully. However, in frequencies of microwave this antenna used in a wide range. The lack of parts of metal considers one of advantages of this antenna. These metal parts will lose at high frequencies. Therefore, the reduction of energy will appear fully. However, the efficiency of this antenna is better than the efficiency of metal antenna. This efficiency appears clearly at frequencies of millimeter wave as well as at frequencies of microwave. To broadcast and receive signals, a cylindrical Dielectric Resonator Antenna (DRA) uses a dielectric material fashioned like a cylinder to support resonant electromagnetic modes. Therefore, the cylindrical DRA is commonly fabricated from high dielectric constant materials like ceramic or plastic, and its size and shape can be customized to suit a wide variety of applications and operating frequencies. Since the DRA is cylindrical in shape, it can accommodate a great deal of resonant modes while suffering little radiation losses, leading to excellent radiation efficiency and gain. In addition, communication systems, including satellite communication, wireless communication, and radar systems, all benefit from the use of cylindrical DRAs. Hence, they excel as feed antennas for reflector antennas in satellite communication systems, as well as other applications requiring high gain and strong directivity. They are also useful as array elements in phased array antennas for radar systems or as stand-alone antennas for wireless communication systems. On the other hand, cylindrical DRAs are an extremely effective and flexible form of antenna that may deployed in a variety of contexts calling for high gain and directivity.

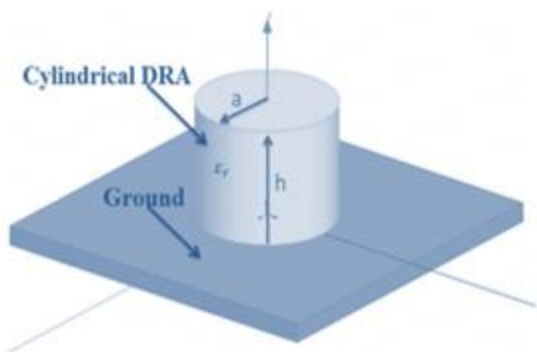


Figure 5. Diagrammatic representation of a cylinder DRA, showing its dimensions (a), (D), and (h) [25]

However, figure 5 above refers to design of cylindrical DRA antenna with the dimensions. Cylindrical DRAs explained in Figure 12 to show their radius a, diameter D, and height. h. The widespread use of cylindrical DRAs in wireless communication systems has garnered a lot of attention. To simplify the calculations, the infinite perfectly conducting plane assumption is utilized in the cylinder DRA as well. However, Cylindrical DRAs have an extra degree of freedom over their hemispherical counterparts. Hence, Permittivity ε_r, cylinder height, and cylinder radius are the shape's free parameters. The various characteristics of cylindrical DRA summarized in Table 3. Due to its various benefits, cylindrical dielectric resonator antennas (DRAs) are frequently used in wireless communication systems. In addition, some benefits of cylindrical DRA antennas include the following, Because of its capacity to sustain numerous resonant modes, cylindrical DRAs have a larger bandwidth than other types of DRAs. This qualifies them for deployment in high-speed networks. Therefore, the cylindrical symmetry of a DRA gives it a more omnidirectional radiation pattern than that of other DRA shapes. As a result, they can be implemented in portable communication devices that need to provide coverage in all directions. In addition, Compact design makes it is possible to manufacture cylindrical DRAs in extremely small sizes, making them an excellent candidate for use in compact wireless communication devices. In addition, cylindrical DRAs have a small footprint, which facilitates their use in a wide range of communication systems and devices. High efficiency cylindrical DRAs are used in many wireless communication systems because of their high radiation efficiency due to their low loss dielectric material. In addition, durability, cylindrical DRAs are more resistant to the effects of hostile environments and manufacturing variances. Moreover, convenience in production milling, turning, and polishing are all common methods for producing cylindrical DRAs. However, cylindrical DRAs have many advantages including a large operating frequency range, omnidirectional radiation pattern, compact size, low profile, great efficiency, resilience, and simplicity of construction. These benefits have made them a favor in a wide variety of wireless communication applications, including mobile phones, satellite networks, and radar. Kishk et al. [26] provided a precise moment-based characterization of the radiation properties of the cylinder-shaped DRA. However, Radiation patterns are affected by the dielectric constant, ground plane size, and resonator dimensions. In addition, coaxial probes coated in low-permittivity materials have the potential to boost the efficiency of DR antennas [27]. For a dielectric resonator in a MIC environment, the resonant frequency of the TE01 mode has been calculated using an appropriate equation for an effective dielectric constant [28]. Hence, exciting the half-split of DR antenna structure with a microstrip line-slot feed technique detailed in a new antenna arrangement. With this feed technique, the resonator's "magnetic dipole" mode can be easily excited. To get a better front-to-back ratio, Chow et al. [29] conducted experimental research on a two-element linear CDRA array. Two cylindrical DRAs excited by coaxial [30], four-element linear broadside arrays using microstrip-coupled CDRAs [31], two linear four-element probe-fed CDRA arrays probes [32], four-element planar arrays, and four-element linear aperture-coupled cylindrical dielectric [33] were all investigated by Drossos et al. to improve the directional sensitivity of broadside DRA arrays theoretically and experimentally.

Another study presents the design and fabrication of a cylindrical dielectric resonator antenna utilizing a Barium Zirconated Trioxide ($BAZrO_3$) ceramic with a permittivity of 27. Hence, for antenna applications, the best dielectric resonators (DRs) have a dielectric constant of 10 r 100, allowing for some wiggle room in terms of physical size, operating frequency, and other radiation properties. These antennas are extremely simple to incorporate into mobile phones and other wireless gadgets. However, it demonstrated that dielectric blocks of cylindrical [34], rectangular parallelepiped [35], hemispherical, half-split cylindrical, and equilateral triangular [61] shapes might be designed to radiate efficiently by correct choices of feed location and feed dimensions.

So, The HE_{11} mode is excited in the spherical DRA by feeding. Therefore, cylindrical DRA's resonant frequency calculated theoretically with following equation [36]

$$f_0 = \frac{3 \cdot 10^8}{2\pi\sqrt{\varepsilon_r}} \sqrt{2\left(\frac{\pi}{a}\right)^2 + \frac{\pi^2}{2h}} \tag{8}$$

In this study, Dielectric resonator antennas fed by both coaxial and microstrip lines have their properties analyzed here. Barium zirconated trioxide (BZT, $BaZrO_3$) is the raw material for CDRA production. Both setups' return loss characteristics are calculated. The results from the simulation and the experiments accord well with one another. However, the radiation pattern of co-axially fed CDRA was examined at a range of resonant frequencies. BZT stands out as a material that could successfully implement a DRA [36].

However, the problem is this study used BZT as a good element to enhance the pattern of radiation in case cylindrical DRA antenna, but this element does not give us a good role in exciting the radiation when they use it in RDRA antenna. Because of the loss and leakages of radiation in the RDRA antenna.

In addition, some studies explain a new method of building cylindrical dielectric resonator antennas by stacking ceramic disks [37]. To get broad beam widths in both principal planes, the antenna excites hybrid modes within the dielectric resonator and supplied by a large aperture slot. To establish the parameters of the broad slot, the design also introduces a new frequency, the limited frequency. The suggested antenna works between 5.49 GHz and 7.2 GHz, has a wide beam from 6.1 to 6.7 GHz, and has an E-plane and H-plane 3 dB beam width of 124°

to 149° and 112° to 126°, respectively. The proposed design of the antenna verified by its production and measurement.

However, the problem is the aperture slot will be large as well as thick of CDRA antenna becomes big as compared to the normal CDRA antenna. Therefore, the measurements of the new antenna need more cost. However, the frequency is good with the new design. Other researchers such as Dadgarpour et al. [38] proposed a combination antenna with two separate beams. Therefore, arrays of metamaterial inclusions are used to artificially alter the dielectric constant of the antenna substrate, resulting in a beam width of 60 3 dB. It was shown that the 3 dB beam width in the H-plane and the E-plane both increased by 75% when a rectangular patch was placed on a composite substrate [39].

However, one problem of this study is the narrow beam width. Therefore, Hybrid modes in a dielectric resonator, denoted by HEM_{mnp}, are required for this investigation. There is also a method [40] which provides a detailed numerical investigation and evaluation of modes inside the cylindrical DRA (CDRA). However, Haidan presented in [41], one of the earliest attempts to use dielectrics in microstrip patch antenna construction to improve the 3 dB beam width. There is study by using a no resonant microstrip patch, Guha et al. propose HEM_{12} as a novel mode and offer a method to excite this mode (mnp). Despite being a broadside mode, HEM_{12} produces small beam widths in both the planes, with estimates of less than 80 in both primary planes. There is a documented inverse relationship between gain and radiation pattern of beam widths. A CDR is also used as a feed in [12]. The resulting radiation pattern is also broadside, however the beam width in either plane expected to be less than 70°.However, the problem is this study refers to the HEM_{12} produces small beam widths in both the planes, with estimates of less than 80 in both primary planes.

2.3. Micro strip antenna

They function similarly to antennas and can serve a variety of purposes. The mobile phone industry relies on it because of the features which render it well suited for mobile phone communications. Low price, small size, and simple construction are just a few examples. The narrow bandwidth (BW.) is a disadvantage of this type of antenna. Due to its compact size, this antenna can handle some high frequency (HF) at its resonance frequency. The gain may also vary depending on the most optimal array configuration. The gain from a single array is less than that from a patch array. There are times when you require a lot of gain, like for airplanes, for instance. These uses call for modest profile with improving gain. The variety of polarization offered by this type of antenna is just one of its many benefits. Therefore, the microstrip antenna may share the same rectangular route. Today, it has become a market standard. However, it was obvious that the dielectric constant grew. As a result, antenna length would be shortened. Some features of an antenna can be altered by adjusting a few crucial factors. The following equation describes the connection between resonant frequency and length as only one illustration specifically,

F_c = C/2Lr = 1/(2⟦L r⟧_oo) (9)

Therefore, frequency is a function of length L. However, width may also play a role in determining impedance. As a result, they are counter-proportional to one another. Therefore, low impedance results from a wide bandwidth. Permittivity is also essential to fields. As a result, if r was to get smaller, the radiation pattern would get better. As a result, BW. Is thinking about a crucial factor. As a result, it would be possible to improve the situation by raising the antenna. With the help of the following equation,

B r2W h/L (10)

The efficiency and gain of this type of antenna, however, previously demonstrated to be low. Gain of −6 dB is possible. It also has a narrow BW, and Q-factor. In addition, it has a wide variety of antennas, including dipole patch, printed slot, and more. Some unique features shared by these categories. One side of a micro strip patch, for instance, covered in a narrow square of pitch. It often used to denote a "special type" [42]. As a result, it serves as a rectangle typeface. On the other side, it is compatible. This type of antenna is often linear; however, there are exceptions, such as circular designs. There are further emissions from this antenna owing to the surrounding farms. Consequently, the effectiveness of an antenna may be impacted by factors like its thickness. However, this antenna's output may vary at random in some cases. That is, little to no improvement in outcomes. The antenna size, for example, can have a significant impact on these outcomes. Altering some dielectric constants may also influence efficiency. There are benefits and drawbacks to using each antenna. Such as, the case of low gain and low power. The drawbacks of using a microstrip antenna are considered here. Narrow bandwidth may also have an impact on efficiency. As a result, this antenna has some limitations. There is room for improvement in both weight and construction. Some benefits of this antenna design are discussed. Moreover, we are becoming less visible. However, by adjusting a few variables, the quality of the emitted radiation might be greatly enhanced. Some structures, as bandwidth expanding, are frequently adopted because they offer benefits. The term "band gap” is used to describe these electromagnetic. One of studies focused on Frequency selective surfaces (FSS), metallic reflectors, parasitic patches, superstrate, shorting pins, and partial substrate removal are all examples of approaches used in this investigation.

This study provides used to increase the gain and simplify the installation of microstrip antennas for usage in a variety of wireless applications. These studies are useful for determining the optimal method of improving the gain of microstrip antennas. However, the patch antenna's ability to create in-phase reflected radiations with the main lobe can be improved by placing artificial magnetic conductors (AMCs), metallic reflectors, and frequency-selective surfaces (FSSs) [43] at the optimal height below the antenna. Removing some of the substrate is the technique for increasing gain by decreasing dielectric losses and surface waves. One method to reduce mutual coupling and boost the efficiency of microstrip antennas is to use frequency selective surfaces (FSS). Limiting their filtering effectiveness to a small frequency range, FSS structures are notorious for having a narrow bandwidth. Fabricating FSS structures can be difficult due to the strict requirements placed on the substrate's thickness. Conductivity and dielectric constant. The problem of FSS technology is Fabricating of FSS structures. This can be difficult due to the strict requirements placed on the substrate's thickness, conductivity, and dielectric constant. In addition, it has a narrow bandwidth.

3. Methodology

Using CST program to design both cylindrical and rectangular DRA antenna then compare between them according to the results. Then we enhanced the gain and efficiency by using some technologies that explained below. Therefore, many ways or methods that used to improve the performance of DRA antenna explained in detail in the next pages

3.1. Coupling of Aperture technology

This kind of feeding is necessary to increase the polarization of RDRA antenna. This method provides isolation between the feed network and aperture. In addition, this method provides low radiation from the feed line as explained before. The magnetic field is affected by the position of slot in state of amount of power and strength. However, there is an inverse relationship between slot length and frequency of resonance. So, if the length of slot increases that leads to decrease in frequency of resonance. Whereas the relationship is not inversely between length of slot and coupled power. That means if length of slot increases that leads to increase in coupled power. This technique of feeding is suitable for providing bandwidth with small value. However, for low frequencies, the coupling of aperture is not suitable because of the size of slot. That means the slot is large in size. However, the problem in this method is not suitable for low frequencies.

3.2. Coupling of probes

This method relates to probe. Therefore, the probe was placed adjacent to RDRA antenna. In addition, we can place the probe inside the RDRA antenna as all. However, the efficiency of radiation mode will be high if the probe is placed inside RDRA antenna. In addition, the coupling will be high according to this case. However, the problem of this structure is inside the RDRA, the holes drilled more. Then the dimensions of hole need to be similar with width and length of probe. Otherwise, the frequency of resonance will shift. Because of the changing of dielectric constant of RDRA. The problem in this method is that it is that more holes a well, as the dimensions of holes should be similar to the height and length of probe.

3.3. Coupling of line of microstrip

Here, we can excite RDRA by using this method. Therefore, TEδ11 will be exciting. However, mode of excitation and coupling strength is determined by Strip line. Therefore, to achieve strong coupling we use length of strip suitable for this operation with short value. However, at frequency of resonance the wavelength should be one quarter bigger than length of strength at the same frequency. While there is problem along the microstrip such as, air gap. On the other hand, this gap produced by drilling on the same substrate along the line of antenna between substrate and Rectangular DR. This work is to provide structure in the planar shape. However, the problem with this method is the air gap. Therefore, this gap results from drilling on the same substrate along the line of antenna.

To reduce air gaps between elements of DRA antenna, the following research elucidates, at 28 GHz, glue is used to minimize air gaps between connected DRAs and the ground plane, as proposed in [44]. The construction consists of four interconnected rectangular ring DRA elements. In addition, the alignment constraints were addressed by incorporating dielectric arms into the design. While the DRA is shown to be effective in terms of mutual coupling, radiation efficiency, and gain, it has shown that the performance is highly sensitive to the placements of the dielectric arms. Gain of 8 dB achieved together with an efficiency of 86% and a bandwidth of 31.6%. The results of a comparison of linear polarization mm-wave DRA arrays reported in Table 1.

Table 1. Linear polarization mm-wave DRA array performance comparison [45]

Ref	DRA shape	Frequency GHz	Bandwidth %	Gain(dB)	Efficiency (%)	Mode	No.of Elements
[20]	Rectangular	34	4.7	11.7	90	TE_{10}	4
[21]	Rectangular	35	6.4	21.5	85	TE_{111}	64
[22]	Rectangular	38	2.5	13	91	TE_{118}	12
[23]	Grid	32	18.4	12	76	TE_{10}	8
[25]	Cylindrical	28	9.8	15.6	88	HEM_{118}	16
[26]	Cylindrical	24	1	16.3	87	HEM_{133}	4
[27]	Rectangular	26	2.18	20.5	92	TE_{111}	64
[28]	Rectangular	28	31.6	8	86	TE_{381}	4

3.4. Coupling of Coplanar of Waveguide

From substrate, we can get high efficiency of antenna by resonator antenna. Therefore, coupling slots should change in shape to improve coupling. However, this technique is suitable for some frequencies like millimeters. For example, frequencies at millimeter wave where the antenna works strongly as well as with high efficiency. The problem with this method is not suitable for all frequencies. This method is only at millimeter wave frequencies to get high efficiency of antenna.

Another study refers to a compact coplanar wave guide fed monopole type DRA with an omnidirectional radiation pattern. This was very low cross polarization that has been proposed by Ryuet al., for ultra-wideband (UWB). This is operation from 3.1 to 10.6 GHz. Rectangular DR-antennas with tapered strip excitation on one side and narrow strip designed by Khalily et al. [46]. This is used to improve the radiation pattern and increase the bandwidth to 96% (i.e. 2.13–6.08 GHz) from 66% in a convectional antenna. To regulate the stop band between a UWB of 2 to 10.7 GHz and a stopband response of 5.15 to 5.825 GHz, Niroo-Jazi et al., incorporated a circular patch with monopole-like radiation into the DR structure. The probe fed UWB rectangular stacking DRA created by Shao et al., [47] operates between 3.1 and 10.6 GHz, and features a band notch that generated by a thin printed dipole close to the feeding probe.

This study shows advantages that single-band DRA is significantly more involved than dual- or multiband studies. The DR shape is more important than the coupling mechanism, permittivity, and mode of operation in determining the usable operating range. Therefore, Wider patch with slotted DR could achieve better bandwidth provided perfect matching network, (b) from mode point of view combination of multiple modes, preferably lower modes can be combined for wider impedance bandwidth, and (c) from coupling point of view. In the other hand, this study could improve by using shape hybrid of DRA with Sierpinski and Minkowski for wideband as well as multiband.

3.5. Polarization of RDRAs circularly

This method is useful to avoid the rotation in polarization. However, effects of atmospheric caused to this rotation in polarization. For example, effects of fading in shape of multipath or reflections. These effects resulted from the obstacles. Therefore, this kind of antenna considers independent in both transmission and reception in circular polarization shape. It deals with the position independently. However, this polarization generates from different points feed. For example, single point or dual point. Also, methods of sequential rotation. In addition, communications in wireless properties used this kind of antenna with circular polarization. For applications of satellite and WiMAX the DRA antenna is used in a wide range. The feed of this antenna by metal strips of H-shape. However, the value of bandwidth of CP impedance is around 20%. This results from metal strips. Therefore, the generation of a pair of modes weigh high excitation gives impedance with value of bandwidth around 20% and 6.8 dBi for gain value. However, some different techniques are responsible for feeding of RDRA antenna. For example, changing the shape of DRA antenna, antenna of monopole for loading. This used single point in case of polarization in circular shape in a different feed shape. However, to generate polarizing in circular shape by using notches. The problem is the effects of atmospheric caused to this rotation in polarization. Then polarization will not be ideal. Another problem in designing DRA antenna by stacking more antennas. This leads to cost with working in difficult structure and more parameters.

Multiple studies have compared the effectiveness of Dielectric Resonator Antennas (DRAs) with Microstrip Antennas (MSAs), with DRAs emerging as the clear winners at higher frequencies due to lower ohmic losses. It demonstrated that electrically large antennas benefit from the employment of higher-order DRA resonance modes by increasing bandwidth and providing greater tolerance to manufacturing faults. An expensive and difficult-to-assemble three-layer mm-wave hemispherical DRA with an impedance bandwidth of 35.8% presented. By adding air holes to a compact hybrid multi-permittivity DRA, we were able to improve its working bandwidth by 27.4% without sacrificing any of the gain it had previously obtained (5.65 dBi) as shown in Figure 6.

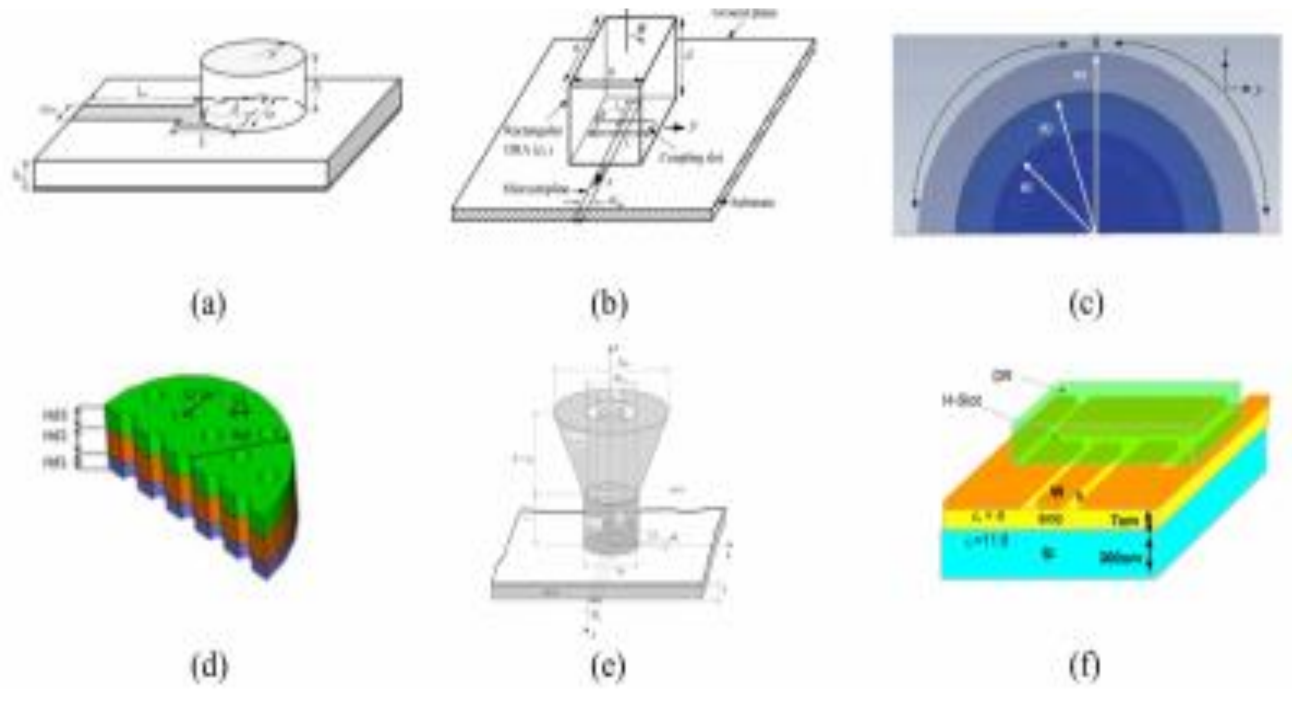


Figure 6. DRA setups with a linear polarization: (a), (b), (c), (d) and (f) [48]

Figure 6a shows the results of several experiments comparing the performance of DRAs and microstrip antennas (MSAs), with the DRA emerging as the clear winner at higher frequencies (and thus greater ohmic losses). Next, Figure 6b, operating at 24 GHz to reduce manufacturing defects. As shown in Figure 6c, a wideband high-gain three-layer mm-wave hemispherical DRA is proposed in [48], boasting a maximum gain of 9.5 dBi, an impedance bandwidth of 35.8%, and a 90% radiation efficiency. Similarly, the gain of a multilayer DRA increased by introducing air holes, as illustrated in Figure 6d, in the antenna. Another approach, which aimed to enhance the gain, used a DRA with a plastic-based conical horn, as illustrated in Figure 6e, for mm-wave applications. A different experiment that aims to increase the DRA gain reported by some studies, whereby the high-permittivity DRA placed over an H-slot on chip antenna, as illustrated in Figure 6f, with an impedance bandwidth of 4.15% at 35 GHz.

In the feedline for excitation of antenna [49], the following figure6 shows rectangular RDRA in the circular polarization in case of representation structure. According to their studies, the values of impedance bandwidth around 58.36% at 2.5 GHz with 3 dB axial ratio. Also, bandwidth of 47.27% at same frequency. However, the researcher method to operate the operation with dual band by stacking rectangular resonator DRA antenna [50]. Thus, to achieve high bandwidth with circular polarization, the antenna will feed across slot. This slot of unequal arm lengths. However, the resonance will divide in two modes when cross-slot with arm length chosen half wavelength.

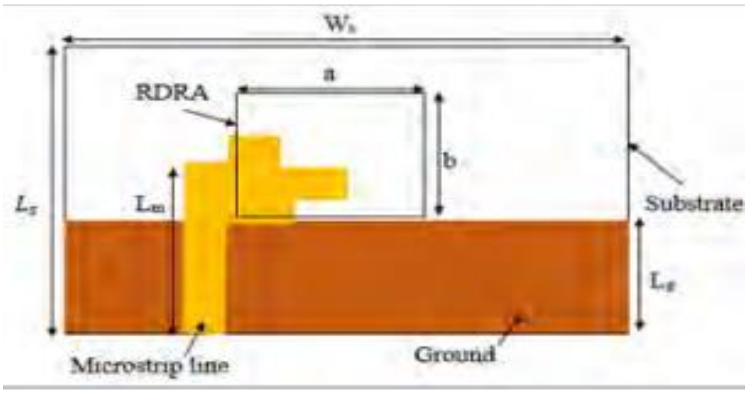


Figure 7. Representation structure of RDRA antenna in circular polarization [49]

Another problem in this method is that resonance will be not one mode but more. In addition, the slot of feeding of DRA antenna has different lengths of arms. The researchers tried to enhance the bandwidth by changing in some parameters like x, y, z. For example, lengths with unequal arm of cross-slot to feed DRA antenna [66]. Therefore, the polarization in circular shape will be extended. This suggestion was proposed by researchers in case of stacking of RDRA antenna used to enhance the results. This is explained in Figure 6. However, the results were 58.36% of impedance of bandwidth long ratio of axis level of 3 dB. Another value of bandwidth was 47.27% at frequency 2.5 GHz, therefore, according to their studies the polarization was divided in two modes if the wavelength was half value. Another suggestion by researchers used two kinds of RDRA antenna to enhance circular polarization (CP) bandwidth. This includes getting wide of bandwidth ratio about axis level by feeding two RDRA antenna by stair shaped slot [51]. The value of lower band AR BW was 9.7%, while the upper band was 20% percentage that they got during the operation. However, to enhance bandwidth more they used layer with conductive metal to cover the op notched corner. Therefore, this layer was necessary and represented as an adjacent 3 dB band and element as parasitic. Therefore, at frequency of 4.75 GHz, they got the rate of 66.45% for AR bandwidth and 55.22% for impedance bandwidth. In addition, the value of 2 dBi was the gain value as explained in Figure 8. The problem in this method is the difficult in design of DRA antenna with more different arms. Also, with different shapes and the cost and the time of the design.

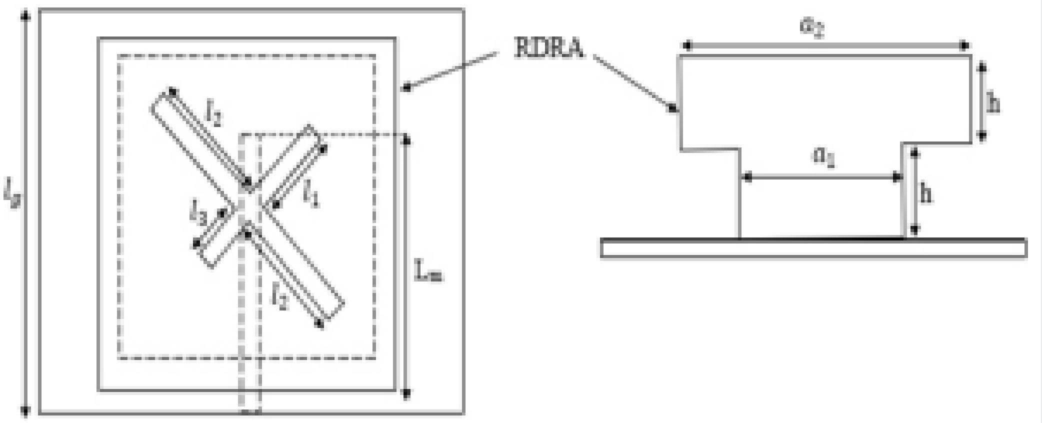


Figure 8. Circular polarization with aperture of cross-slot of rectangular DRA antenna [66]

3.6. Techniques of enhancing of bandwidth

It can be difficult to increase the bandwidth of a Dielectric Resonator Antenna (DRA) since the DRA's resonant frequency is so sensitive to the dielectric constant of the resonator material. It is possible to increase a DRA antenna's bandwidth, though, by paying attention to certain design details. The bandwidth of a DRA antenna can be improved by adjusting the resonator's shape. Broadband tends to be smaller for spherical and cylindrical resonators and larger for more complicated resonators. Therefore, the antenna's bandwidth can be increased by employing resonators of various forms, each of which offers a different frequency response. Secondly, the material employed in the resonator can influence the antenna's bandwidth. The antenna's resonant frequency and bandwidth can be improved by employing materials with a smaller dielectric constant. The problem in this study is that materials of small size to enhance bandwidth of DRA antenna. In addition, the materials affect the frequency of resonance as well as bandwidth.

However, this can also cause the antenna gain to drop. Thirdly, the feeding method employed by the DRA antenna can influence the bandwidth. The bandwidth of the antenna can be increased with a feeding method that gives a broader bandwidth, such as aperture coupling or coaxial feeding. However, multiple resonant modes allow DRAs to function, each with a slightly distinct frequency response. The antenna's bandwidth can be increased, if the DRA made to function in a variety of different modes. In addition, the trade-off is that this strategy often results in a more intricate design that needs fine-tuning. Therefore, Coatings used the dielectric resonator that are another factor in determining of the DRA antenna's bandwidth. It is possible to increase the bandwidth by coating the resonator with a high-loss substance, such as, a conductive material. However, a DRA antenna's bandwidth can be improved by paying attention to the form of antenna’s resonators, construction, feeding method, multimode operation, and dielectric coatings. Moreover, wider bandwidths for the DRA antenna can be achieved by adjusting these design parameters. This is used to achieve some requirements. For example, in case of rates of data or large impedance of bandwidth. Therefore, these techniques produced and developed more. Therefore, the increasing of impedance of bandwidth of DRA antenna occurs by choosing high value of (ε_r). This constant is called dielectric constant, which is necessary to enhance value of bandwidth. However, there is relationship between this constant and bandwidth of DRA antenna. Therefore, the suggestion refers to reducing the area or volume of surface and enhance impedance of bandwidth. This is by changing some parameters of Antenna such as, some values in parameters x, y, z. Therefore, placing a gap of air between resonator and (ground plane) leads to enhance bandwidth [56]. Then the value of bandwidth will increase from 50.3% to 81% by this changing in parameters of DRA antenna. However, lowering Q-factor is also necessary to enhance the value of bandwidth. The problem is the difficulty in designing DRA antenna with different values of parameters. They need high accuracy in the design of DRA antenna. In addition, the coating of DRA antenna affects bandwidth. For example, conductive material is necessary to enhance bandwidth. Moreover, other issues effect on increasing bandwidth of DRA antenna such as, form, construction, feeding method, multimode operation, and dielectric coatings.

Therefore, this change in air gap was studied more by some researchers in a wide range case. Therefore, some approaches to improve bandwidth by stacking one or more layers of DRA antenna. Dielectric constants were used for this operation in case of stacking of layers [52]. For example, the value bandwidth around 131% when they used two constants of dielectric [53]. There are other ideas to improve the bandwidth of DRA antenna. For example, the technique of perforation. Therefore, the researchers used this method to change the permittivity of material of dielectric. These changes depend on changing the radius and the space between holes. However, by using four holes in the rectangular drilled along DRA antenna to achieve the polarization in circular shape [53]. Therefore, the bandwidth of impedance around 56% at frequency 2.4 GHz according to the method of perforation. In addition, the weight reduced more. However, this method is suitable for matrix application and helps us to design DRA antenna easily. In addition, some researchers used Hybrid RDRAs to improve bandwidth. According to this study, the Hybrid refers to either a network of feeding for radiation or a different structure as radiator. However, the rectangular resonance used as radiator [54]. Also, it is used to feed the network. The design was an inductor with center fed CPW. Therefore, the value of BW around 28.9% at frequency 5 GHz in case of using the height of DRA with the length of slot in suitable and acceptable dimension. The problem in this method is that needs many dielectrics of constants during stacking of antenna layers to improve the bandwidth of antenna, but the design of antenna will be difficult. However, if they use two dielectric constants the results will be different if they use four dielectric constants. However, the method of technique of perforation has benefits such as reducing in weight of antenna as well as, easily in designing of DRA antenna.

3.7. Techniques of enhancement of Gain

A dielectric resonator antenna (DRA) is an antenna in which the radiating element is a dielectric resonator. Several design considerations can be used to increase the gain of a DRA antenna performance that can impacted by several factors, the first of which is the dielectric constant of the material employed in the resonator. Therefore, Antenna gain increases with increasing dielectric constant. In addition, the gain of the DRA antenna can be improved by using a high-dielectric-constant material. Then the antenna's efficiency can also be impacted by the resonator's size. Gain increased with increasing resonator size of Antenna. Therefore, the gain of the DRA antenna can be improved by increasing the size of the resonator. In addition, the gain of an antenna can be improved by adjusting its resonant frequency. The DRA antenna at the desired operating frequency can achieve higher gain by setting the resonant frequency to that frequency. Therefore, the performance of a DRA antenna can also be influenced by the feeding method that is employed. So, the connection between the resonator and the feed line should be optimized by the feeding strategy. Moreover, Aperture coupling, and probe feeding are two methods that can used to accomplish this. Radiation pattern: The DRA antenna's radiation pattern can be modified to increase gain. However, Antennas with more directional emission patterns have greater gain in the direction of their intended use. But, the gain of a DRA antenna can be improved by paying attention to the resonator's dielectric constant, size, resonant frequency, feeding method, and radiation pattern. Therefore, gain in the intended frequency range and orientation can improved by adjusting these design factors. Therefore, gain properties play an important role in communication field, especially in Antenna. Therefore, most studies tried to enhance the gain of Antenna. Moreover, the researchers proved some techniques to improve gain of DRA antenna. Some of techniques related to use the property of lensing of MTM cells. Therefore, at 7.8 GHz the gain arrives around 14 dBi as well, as bandwidth of impedance about 16% at the same frequency. This was achieved in the region of far field. However, the RDRA antenna is designed with loading cell of MTM that consists of 50-unit cells. Therefore, 8-strips in shape of copper used in way of 5×10 to enhance the gain of RDRA antenna [55]. However, the levels of polarization will reduce in case of cross polarization by this method. In the case of communication fields like radar, this antenna is good candidate for this purpose. In addition, the antenna is good and suitable for satellite communication. For high gain applications, some researchers used another method. They designed RDRA antenna as array prototype. Therefore, in case of different ratios for different modes of resonance to excite each element of array individually. In addition, the value of gain will arrive up to 10.2 dBi by this excitation of elements of array. However, the researchers proved that the DRA antenna radiates in high order modes with controlling radiation. Another suggestion related to use elements of parasitic. This suggestion is [56] to get arrays of RDRA antenna in high gain in state of the following structures, first: in the shape of H-plane array, the seven arrays of elements in linear array arranged successfully. Second: in cross-shaped structure, five elements arranged in the useful way as shown in Figure 8.

Therefore, the coupling of elements will be electromagnetic. However, two kinds of radiation appear in this coupling. One of radiation of broadside pattern and vane beam. Therefore, the value of gain was 10.1 dB. This value of gain in case of beam width of 610/410 E/H-plane. Also, the value of arrived 11.14 dB in case of beam width. Therefore, this value of beam width with 1000/280 E/H-plane. The problem In MTM method that consists of 50-unit cells with 8-strips in shape of copper to enhance gain of antenna. That leads to a reduction in level of polarization. However, other researchers used matrix to get gain up to 10.2 dBi by exciting of elements of array. However, the problem is exciting of elements of matrix individually.

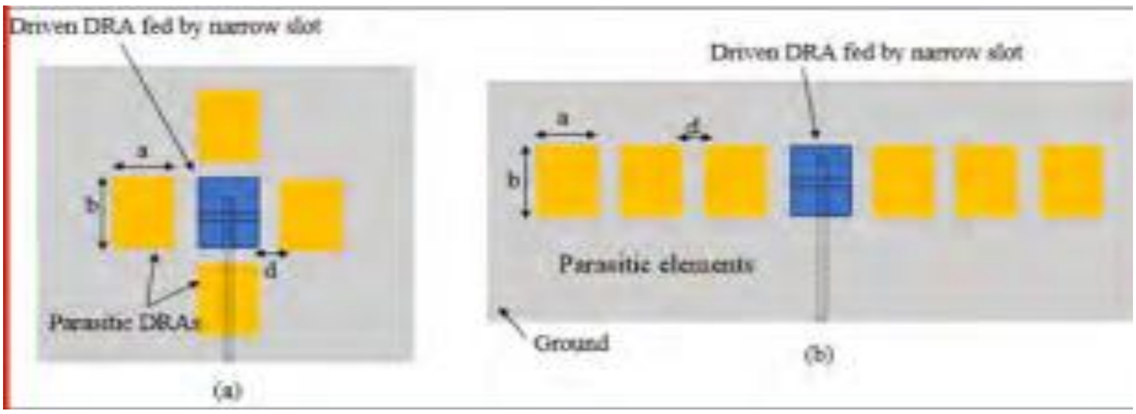


Figure 9. Coupling of RDRA antenna by parasitic element array, (a) shaped array in case of five elements, (b) array in linear element in case of seven elements [56]

To reduce the beam width of RDRA antenna. This method includes inserting elements on the sidewalls. That leads to an increase in the pattern of radiation and reduces the beam width of RDRA antenna. Therefore, the value of gain will arrive 9.6 dB by adjusting the depth of notch. In addition, value of 9.6dB refers to maximum peak gain. Because of the magnitude of electric field in the notch, the increasing in value of gain appeared clearly. For applications in high frequency, the need of exciting RDRA antenna appeared to get high gain. Therefore, the requirements of these applications are acceptable with exciting of RDRA antenna. However, some problems appear in waves such as attenuation. That is because of the conditions of the atmosphere. So, the DRAs in shape of circular polarization are considered suitable for these environmental conditions. In higher mode, RDRA antenna of two layers in shape of circular case designed and operated in these modes with high types of cases. However, the bandwidth of antenna improved more by the outer layer of dielectric. Also, the collection between high permittivity of RDRA and lower permittivity of RDRA to enhance bandwidth of antenna. So, at frequency of 11.3 GHz the gain arrives 11 dBi, then the excitation of RDRA antenna appeared in high mode. Hence, the bandwidth will increase if the constant of dielectric reduces by techniques of miniaturization [59]. Therefore, the strips in shape of metal placed on sidewalls of RDRA antenna as proposed by some researchers. This is suitable for a band of frequency about 6/4 GHz in the field of satellite communication.

However, another way to enhance bandwidth of RDRA antenna. To enhance the efficiency of antenna such as, bandwidth or gain by using high value of permittivity as well as, RDRA antenna with low profile. Therefore, the value of $\varepsilon r=20$ [57]. Then technology was inserted between two resonators to feed the microstrip antenna. Therefore, the compactness will be improved by using this method. The results were impedance of bandwidth around 88.2% and the radiation was Omni directional at frequency 4.8 GHz. Therefore, the characteristics of antenna improved. Another technique to enhance the gain of antenna is called technique of fractal. This technique is used to structure in compact case. This method is useful to reduce the size of RDRA antenna in case of resonator. In addition, this way is used to enhance bandwidth with these fractals. However, the factor of quality reduces with increasing the iterations of fractal. Therefore, two kinds of rectangular DRA antenna placed concentrically with different dielectric of materials. However, one DR with $\varepsilon\_r=10.2$ and the other DR with $\varepsilon\_r=4.3$, thus the first has high value of permittivity which inserted inside the material with low permittivity. Whereas the other DR used to extend the bandwidth. In addition, the bandwidth extends to 66% at frequency between 3.5–7.02 GHz. However, the factor of quality of DRA is necessary to measure the loss in power especially in systems of microwave. However, the permittivity of DRA antenna is responsible for storing the capacity of energy. In addition, it is related to polarization or capacitance. The weak point in this method is attenuation of waves because of atmospheric conditions. However, circular polarization is considered suitable for these environmental conditions. Moreover, the technique of fractal improves the gain of antenna, but because of iterations, the factor of quality reduced. Rectangular dielectric resonator antennas (RDRAs) studied extensively because of the advantages they offer over other types of antennas in terms of design freedom. Therefore, the radiation characteristics of RDRAs can optimized using two different aspect ratios. For instance, by modifying the field distribution, one can create structures with a large impedance bandwidth when the dimensions of an RDRA are off; undesirable modes are excited closer to the targeted modes, leading to excessive cross polarization. The geometry functions as a hybrid topology for low profile and broad bandwidth applications, and the feed network serves as a radiator with the right feeding mechanism. In addition, excited modes of the antenna are also affected by the feeding source and position. Modifying the fundamental antenna designs or excitation of higher order modes, etc., can result in high gain antennas. Therefore, the antenna size decreased by using a high permittivity material, but the bandwidth is increased. More and more people are starting to take an interest in circularly polarized antennas because they are less susceptible to multipath fading caused by atmospheric conditions and work regardless of the orientation of the transmitter or receiver. Table 1 details some of the reference topologies that can be used to modify the resonator's radiation properties.

Table 2. Reference rectangular antenna radiation characteristics [58]

Reference / Year	Dielectric constant	Coupling Mechanism	Resonance Frequency (GHz)	Impedance Bandwidth (%)	Peak Gain (dBi)
[Jamaluddin.M.H et.al….] /2019	10	H-shaped conformal strips	3.85	27.7	6.8

Reference / Year	Dielectric constant	Coupling Mechanism	Resonance Frequency (GHz)	Impedance Bandwidth (%)	Peak Gain (dBi)
[Pandey.V. S et.al..]/2018	12.8 66.45	Stair shaped slot 2.67	5.8		
[Krishsagar.P et.al..] /2017	4.3-9.2	Conformal microstrip feed	10	131.24	10
[Gebril.K.K et.al…]/2011	15-30	Microstrip line	5.8	12	5.1
[Patel.P et.al..]/2015	10.2	Coaxial proble	2.82	56	6.2
[Abdulmajid A.A et.al ..]/2018	3.5-10	Cross slots	11.1	21	11
[Mongia.R.K et.al..]/1994	100	Aperture coupling	7.72	3.24	NA
{Kiran.D.V et.al..]/2020 NA not available	9.8	Microstrip line	6.35	23.3	5.6

Table 2 above explained some studies to enhance gin and impedance of bandwidth. These studies distributed in the different years from 1994 until 2020. They used permittivity of dielectric constant in different values to enhance the results. For example, 10, 9.8, 15–30, etc. However, the mechanism of coupling was different too. For example, the value of gain was 6.8 dBi when the mechanism of coupling was H-shaped conformal strips. Then, the impedance of bandwidth was 12.2% at resonance frequency of 3.85 GHz. However, the results of gain increased to 11 dBi when the mechanism of coupling was cross-slots. Then, the impedance of bandwidth was 21% at resonance frequency of 11.1 GHz. Overall, they got different values of gain and bandwidth at different methods. In addition, they used different values of permittivity to enhance the results.

Another study refers to Miniaturizing of RDRAs is important since low profile antennas are a crucial component of wireless networks. Selecting a high-permittivity material, modifying the regular designs, and choosing a high surface-to-volume ratio are only a few ways to reduce the size of antennas. In most cases, the dielectric constant of a DRA is proportional to its size, however this is not always the case (−1/2). Therefore, the size of the DRA can be decreased by opting for high dielectric constant material. High dielectric constant, along with size decrease, reduces the impedance bandwidth. As a result, there is a compromise between storage capacity and transfer rate. For low-profile applications requiring a suitable bandwidth of about 3%, proposes an aperture coupled RDRA with a high dielectric constant (r =100). The problem of miniaturizing DRA antenna depends on choosing the suitable high value of permittivity. Also, the need of high dielectric material for this purpose of Miniaturizing of DRA.

3.8. Single-feeding aperture

Various techniques exist for exciting antennas. One of these alternatives is to use a slot in place of a distinct port. This opening serves as feed for the antenna when the strip is removed. When attaching or collecting with, this spot or feeding is helpful for reducing interference. As a result, accurate measurements are required for constructing the structure and improving the radiation output. Combining several characteristics results in an optimal transmission mode [59]. However, to achieve a satisfactory outcome, certain features of the design require a distinct wavelength. Some antennas may benefit, for instance, when the wavelength is (/2). Additionally, the mode of radiation is determined by these characteristics. Therefore, these advances in dimensions may help with propagation [60]. In addition, modern market demands center on antenna and signal propagation efficiency. When it comes to electron scattering, these measurements are inversely proportional.

The following equation describes the connection between velocity and power. Therefore, the formula for K2X can written as follows,

$$K\_2X = 12/1+2\ W\_2\ C\_2, \quad \text{"or"} \quad K\_2X=12/1+2\ W\_2C2. \qquad (11)$$

For air, the dielectric constant, k, is 1. However, we can provide light on two critical aspects. Both are connected to the mode of energy. The first piece will be to blame for a few slightly different values. There is a tremendous energy cost connected with this. Thus, the first kind of results lack accuracy, while the second kind is linked to a low energy value. Nonetheless, there is unmistakable attenuation of the light wave. Consequently, this causes less energy to use. Consequently, it might be beneficial to employ some alternative method of boosting this vitality. As a result, stimulating SP can help alleviate this issue. However, the size of the metal is a prerequisite for this method. Metals having small dimensions are easier to absorb light from, so thick metals are more challenging to excite.

One of studies refers to get high coupling called aperture coupling. Acting through an opening in the ground plane is a frequent technique for activating a DRA. Excitation of the mode of a rectangular DRA with a rectangular hole illustrated as an example in Figure9. The opening must be in a DRA with a large magnetic region in order to produce significant coupling. Aperture feeding the main aperture dimension needs to be about, which is very challenging to achieve at low frequencies. Another level of adaptability and versatility added by the availability of alternative feeding methods, such as the selection of different DRAs shapes.

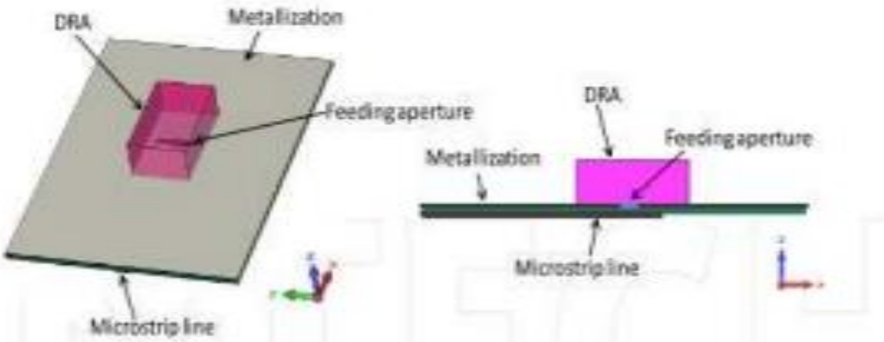


Figure 10. Coupling of apertures [61]

Therefore, the dimension of aperture given by the equation: $D=\lambda\_g/2$. The problem with this method that, it is not useful at low frequencies. In addition, variety of DRA shape and flexibility play an important role in improvement this method. However, the size of the metal is a prerequisite for this method. Metals having small dimensions are easier to absorb light from, so thick metals are more challenging to excite. Of radiation pattern when their permittivity lowered and their metallic surroundings removed, dielectric resonators begin to emit radiation. Dielectric resonators as antenna elements have been the subject of systematic research since the early 1980s. The theoretical radiation pattern of cylindrical, hemispherical, and rectangular dielectric resonator antennas researched and estimated by Long, McAllister, and Shen [62]. Studies have shown that DRAs outperform more conventional metallic antennas. However, despite having poorer radiation efficiency and gain. Since then, various studies have investigated different geometries and possible resonance modes for simple dielectric resonators. Input impedance, resonance frequency, and radiated Q-factor of DRAs of varying forms measured using numerical and analytical approaches in the 1990s.

Figure 10 shows the study that shows how the mid- to late-1990s saw a rise in the usage of aperture coupling, probe feeding, and microstrip coupling to excite dielectric resonators [57]. Since year 2000, when 3D commercial electromagnetic simulators became widely available, studies on DRAs have concentrated on developing DRAs with enhanced characteristics like those shown in Figure 11, wideband operation, dual bands, circular polarization, high gain, configurability, and array structures. There have also been proposals for DRAs with intricate geometries and enhanced performance, such as, stair shaped and trapezoidal DRAs, among others [63]. In addition, the DRA needs to be constructed from a high dielectric constant material to achieve high electromagnetic coupling between the source and resonator. However, for the DRAs to function over a broad frequency range, they must be constructed from a material with a low dielectric constant.

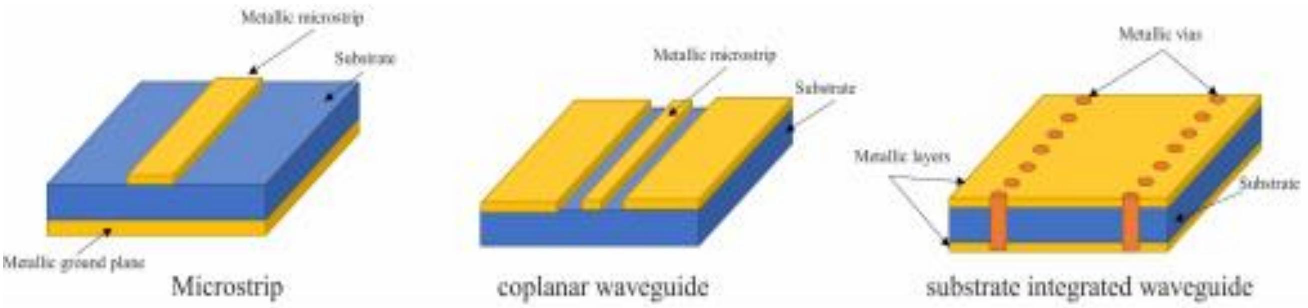


Figure 11. Dielectric resonator antenna feeding techniques [64]

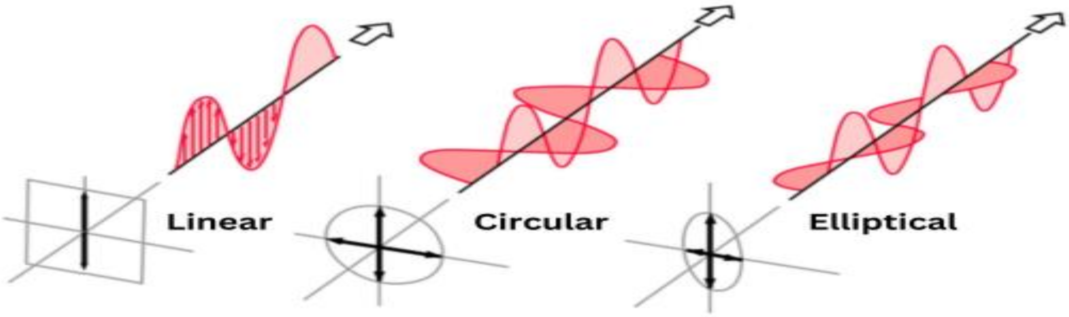


Figure 12. Types of polarization [65]

4. Results and discussion

Here, we designed two kinds of DRA antenna such as, RDRA and CDRA antennas. Then we simulated them by CST program to enhance the results. Moreover, the values of gain, directivity, bandwidth, and efficiency enhanced too. The purpose of this design was to enhance the radiation pattern and efficiency of both antennas and compare them according to the results that we got from them. Therefore, Table 1 and Table 2 present a thorough compilation of design respective values, together with the suggested symbols.

Table 3. Symbols used to denote the parameters of the antenna, together with their corresponding definitions

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
RDRA	Rectangular dielectric resonator antenna
CDRA	Cylindrical dielectric resonator antenna
ε_r	Relative permittivity
CST	Computer simulation technology

Table 4. Fundamental design of a rectangular dielectric resonator antenna (DRA) composed of alumina material consists of the ground plane, substrate, and feed or strip. These components determine the size of the base of the antenna.

Parameters	Width (w)	Length (l)	height(h)
Ground	10	8.25	0.035
Substrate	10	8.25	0.508
Feed /strip	0.7	4.75	0.035

A.1st RDRA antenna Geometry

We designed a rectangular DRA antenna as shown in Figure 13. We used rectangular DRA antenna with the dimensions and the type of materials that are used in the design of the antenna as shown in table 6.

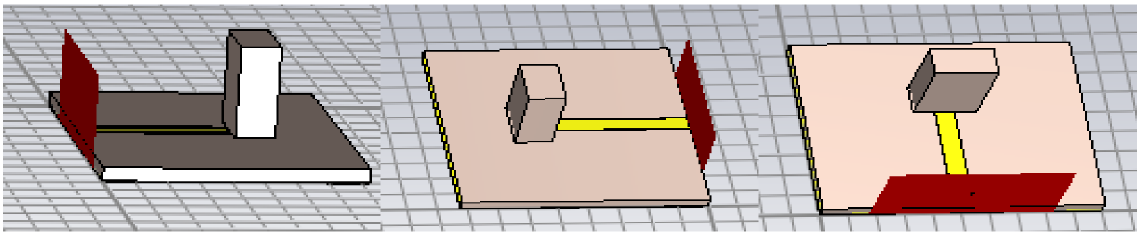


Figure 13. Design of our rectangular DRA antenna

Table 5. Geometric parameters for the design of the DRA at $f = 28$ GHz, with electric boundary conditions and kinds of materials

Dimension	Size (mm)	Parameters	Materials
DRA height	1.25		
DRA width	2.25	DRA	Alumina99.5% lossy
DRA thickness	4.458		
Relative permittivity	ε_r= 9.8	Feed/strip	Copper (annealed)
Strip length	4.75		
Strip width	0.7	Substrate	Rogers RT 5880 Lossy
Strip thickness	0.035	Ground	Copper

B.2st CDRA antenna Geometry

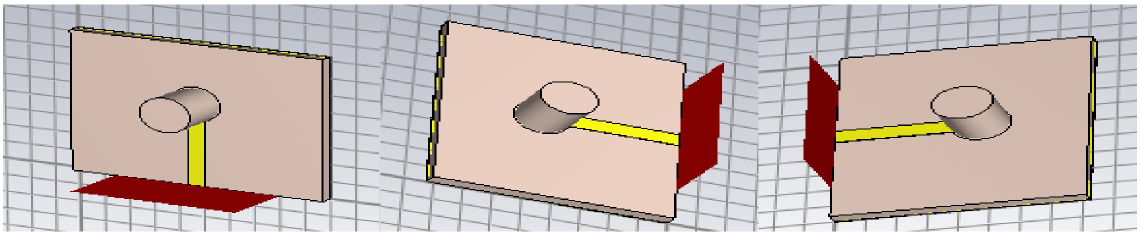


Figure 14. Design of our cylindrical CDRA antenna

The subsequent design pertains to the CDRA antenna design. We employed a cylindrical configuration for the DRA antenna. This was beneficial in increasing the gain to 7. 511dBi.Hence, the measurements of the ground plane, patch, and substrate are provided in table 8. Furthermore, table 6 provides the values and measurements of the cylindrical DRA antenna, while table 7 lists the sorts of materials used. The CDRA antenna achieved an efficiency of 91.2%.

Table 6. Geometric parameters required for designing the cylindrical; dielectric resonator antenna (CDRA) with a frequency of 28 GHz, considering the electric boundary conditions, are as follows

Dimension	**Size (mm)**
CDRA outer radius	1
CDRA U center	4.75
CDRA Wmin	0.508
CDRA Wmax	2.543
Relative permittivity	ε_r= 9.8
Strip length	4.75
Strip width	0.7
Strip thickness	0.035

Table 7. The type of materials used in the design of the CDRA antenna

Parameters	**Materials**
CDRA / RDRA	Alumina99.5% lossy
Feed/strip	Copper (annealed)
Substrate	Rogers RT 5880 Lossy
Ground	Copper

4.1. Simulation results

The figures include the S-parameters, voltage standing wave ratios (VSWR), bandwidths (BW), gains (G), and directivities (D) for the designs at points A and B of both Rectangular dielectric resonator antenna and cylindrical DRA antenna. Figure 15 represents the S_11-parameters, Figure 16 represents the VSWR, Figure 17 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 rather than the designs. The highest subplots consistently represent the RDRA antenna (design A), and the lowest subplots pertain to the CDRA (design B) in all Figures 15 to 18.

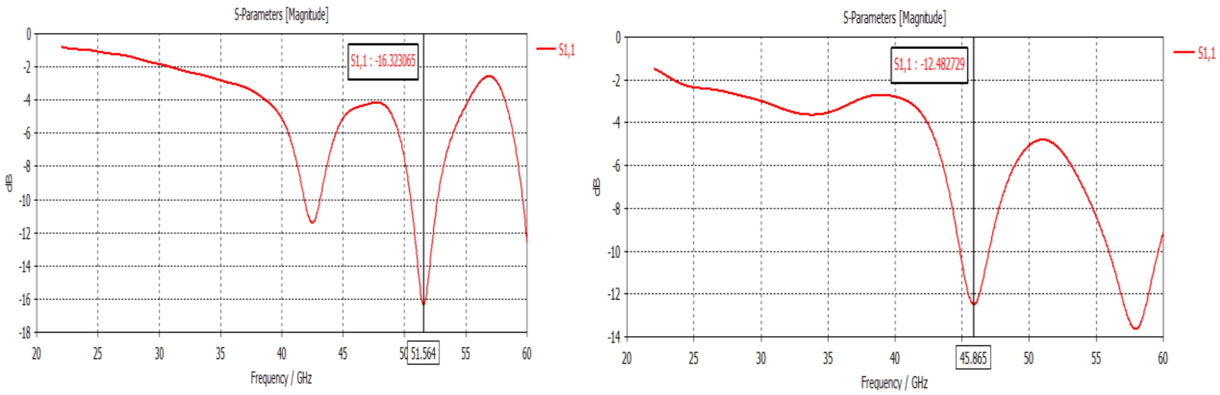


Figure 15. Magnitude of the reflection coefficient S_11. Designed by CST. The first subplot relates to design A, whereas the second subplot belongs to design B

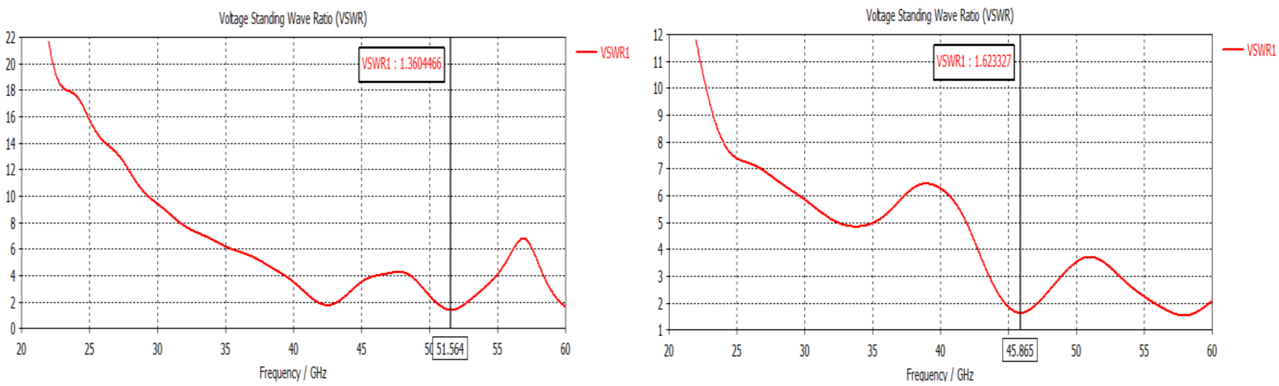
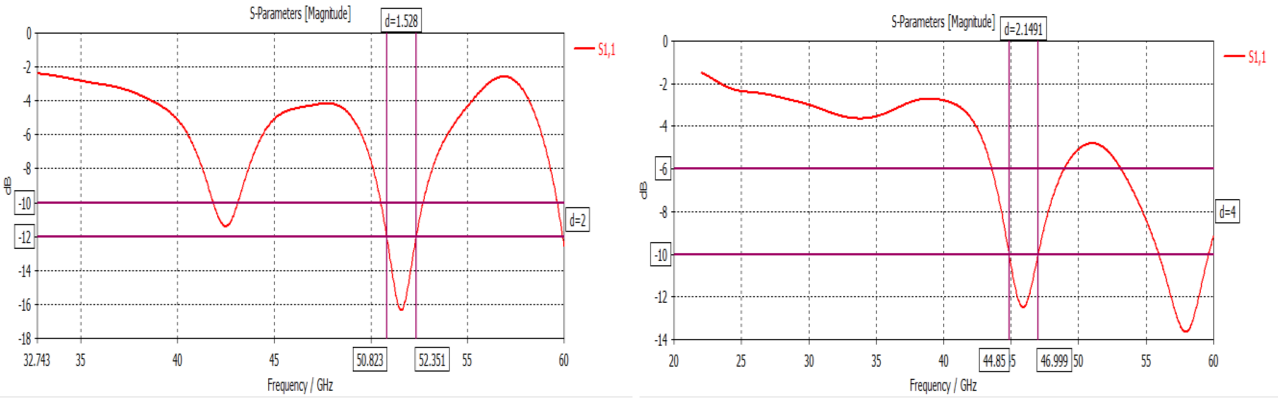


Figure 16. Voltage standing wave ratio (VSWR). Designed by CST. The first subplot relates to design A, whereas the second subplot belongs to design B



.

Figure 17. Process of determining the bandwidth value based on the S_11 parameter

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

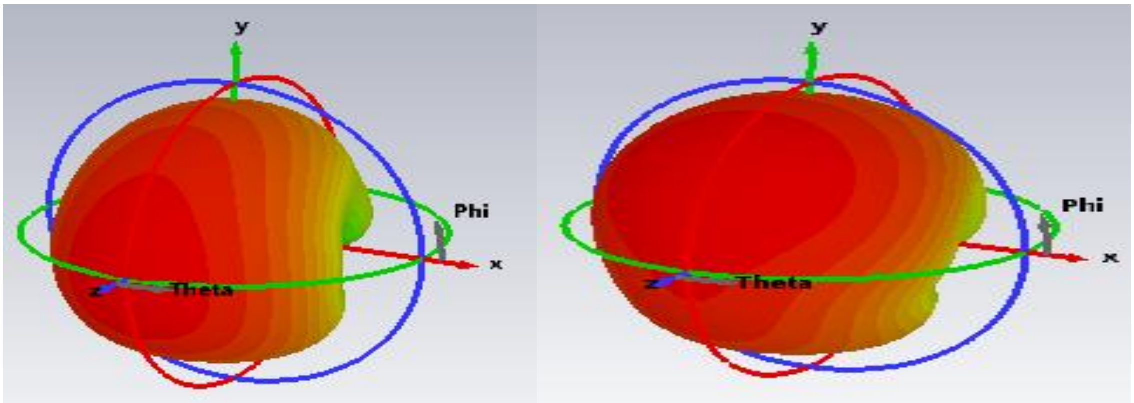


Figure 18. Radiation pattern explains the gain G=6.094 dBi with directivity D=6.497 dBi. Model by CST. The top subplot corresponds to design A and the 2nd subplot to design B

However, Figure 19 displays the values of far field gain (G) and directivity (D) for designs A and B, rendering them visible.

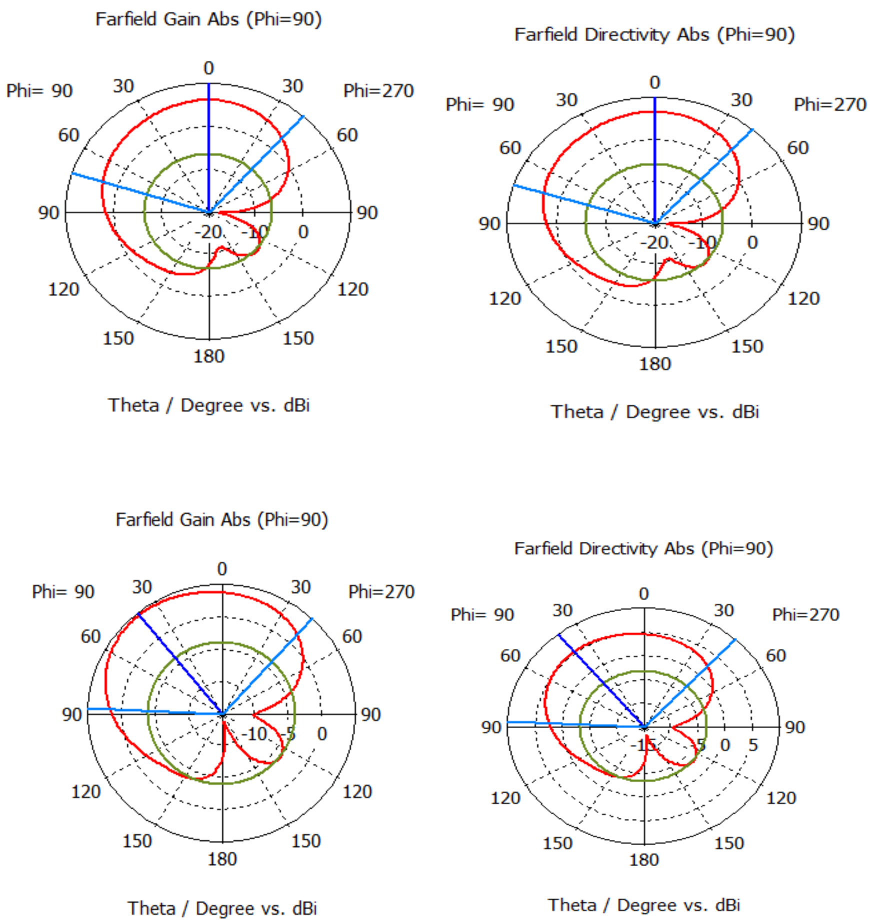


Figure 19. Far field gain (on the left) and directivity (on the right) at a frequency of 28 GHz, as determined by CST. The top row displays design A, while the bottom row showcases design B.

Table 8.Rsults of comparison rectangular DRA design (A) and cylindrical DRA design (B)

Parameter	G (dBi)	D (dBi)	BW (GHz)	$VSWR$	S_{11} (dB)	Efficiency η
design (A) RDRA	6.094	6.497	1.528	1.3604466	-16.323065	93.7%
design (B)CDRA	4.596	5.288	2.1491	1.623327	-12.482729	86.9%

4.2 Results of comparison

We concluded the following points, listed in Table 9, from the comparison between the rectangular and cylindrical DRA antennas.

Table 9. Comparison between rectangular and cylindrical of DRA antennas

Rectangular DRA antenna	**Cylindrical DRA antenna**
1. Shape and Size	**1. Shape and Size**
Small size	Bigger size than Rectangular antenna
2. Radiation Pattern	**2. Radiation Pattern**
In most cases, a rectangular DRA will have a broadside radiation pattern, with the strongest radiation going in a direction perpendicular to the antenna plane	The cylindrical DRA emits in all directions equally, a property known as Omni directionality.

Rectangular DRA antenna	Cylindrical DRA antenna
3. Bandwidth	**3. Bandwidth**
has a greater bandwidth than the spherical DRA Has modes of resonance order bigger than cylindrical. Range of frequency is large.	Has bandwidth smaller than Rectangular Has resonance modes and frequency range smaller than rectangular
4. Gain	**4. Gain**
Has gain smaller than cylindrical.	Has gain bigger than rectangular. Has large in size and high modes of resonance that leads to high efficiency of radiation.
5. Polarization	**5. Polarization**
Both linear and circular polarizations supported by the rectangular DRA	There is no other polarization mode that the cylindrical DRA can accommodate.
6. Application	**6. Application**
Applications where a large amount of bandwidth needed, including satellite communications and wireless networks, favor the rectangular DRA.	Base station antennas and mobile communication systems are two commonplace examples of the cylindrical DRA's typical use case because to its high gain and omnidirectional radiating pattern.
Conclusion	**Conclusion**
In conclusion, there are benefits and drawbacks to both rectangular and cylindrical DRAs and the best option will depend on the requirements of the given application.	

This article paper explained in detail some studies to enhance the efficiency of DRA antenna in both kinds rectangular and cylindrical antenna. For example, techniques to enhance gain and bandwidth. Also, other studies changed some parameters of DRA antenna to get high characteristics. Then comparison of results between rectangular and cylindrical DRA antenna as shown in table 9. However, we discussed the weak points of each study and tried to enhance the results individually. In addition, we noticed some advantages and disadvantages for each kind of DRA antenna according to these studies. Then, we got high efficiency about 93.7% with respect to design A, while the values of efficiency reduced to 86.9% according to design B. In addition, the value of Gain and other parameters increased in design A clearly. Therefore, design A, which is RDRA antenna was suitable for communication environment. That means design A was better than design B in characteristics as shown in Table 8.

5. Conclusion and future work

According to the explanation in table before the dielectric resonator antennas (DRAs) come in many shapes and sizes, although the most popular are rectangular and cylindrical. Therefore, the areey distinctions between cylindrical and rectangular DRA antennas explained above, one readily apparent distinction between the two DRA varieties is their respective geometric forms. In addition, discrete random arrays (DRAs) can be either rectangular or cylindrical in shape. Therefore, the antennas' resonance frequency, bandwidth, and radiation pattern that all modified by the form difference. Due to the cylindrical shape's capacity to sustain numerous resonant modes, cylindrical DRAs often have a broader bandwidth than rectangular DRAs as explained before in some studies. However, Rectangular DRAs often have a smaller bandwidth since they optimized for a single resonant mode. In addition, a cylindrical DRA's radiation pattern is often more omnidirectional than that of a rectangular DRA because of the symmetry of the cylindrical shape. Due to their more directed emission pattern, rectangular DRAs are the best used for point-to-point transmission. Moreover, cylindrical DRAs are more compact than their rectangular counterparts are. 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 [26]. Due to their directional emission pattern, rectangular DRAs find widespread application in point-to-point communication systems like satellite communication and radar. However, cylindrical DRAs, on the other hand, have advantages over their rectangular counterparts in terms of bandwidth, omnidirectional radiation pattern, size, and manufacturing complexity. 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 some substrate 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 [52]. 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 figure below, as I simulated them by CST software program to reduce the size of DRA antenna. However, in the case of cylindrical DRA antenna we can enhance the efficiency of antenna by increasing or decreasing some elements or parameters x,y,z as well as, height h. These processes can be performed by using CST (Computer Simulation Technology) as explained in the following 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 Antenna. For example, increasing the height of cylindrical DRA antenna by changing the values of x,y,z parameters with radius as shown in figure below. Overall, these changes in future will help us to enhance gain 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 in future by changing the structure and parameters of DRA antenna by Computer Simulation Technology.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

Funding information

No funding was received from any financial organization to conduct this research.

References

[1] "New Theory Leads to Gigahertz Antenna on Chip". Retrieved 19 April 2015.

[2] B. Li and K. W. Leung, "On the Differentially Fed Rectangular Dielectric Resonator Antenna," in *IEEE Transactions on Antennas and Propagation*, vol. 56, no. 2, pp. 353-359, Feb. 2008, doi: 10.1109/TAP.2007.915463.

[3] M. Khalily, M. R. Kamarudin, M. Mokayef and M. H. Jamaluddin, "Omnidirectional Circularly Polarized Dielectric Resonator Antenna for 5.2-GHz WLAN Applications," in *IEEE Antennas and Wireless Propagation Letters*, vol. 13, pp. 443-446, 2014, doi: 10.1109/LAWP.2014.2309657

[4] A. Petosa and A. Ittipiboon, "Dielectric Resonator Antennas: A Historical Review and the Current State of the Art," in *IEEE Antennas and Propagation Magazine*, vol. 52, no. 5, pp. 91-116, Oct. 2010, doi: 10.1109/MAP.2010.5687510.

[5] A. A. Kishk, "Experimental study of broadband embedded dielectric resonator antennas excited by a narrow slot," in *IEEE Antennas and Wireless Propagation Letters*, vol. 4, pp. 79-81, 2005, doi: 10.1109/LAWP.2005.844648

[6] A. Buerkle, K. Sarabandi and H. Mosallaei, "Compact slot and dielectric resonator antenna with dual-resonance, broadband characteristics," in *IEEE Transactions on Antennas and Propagation*, vol. 53, no. 3,

pp. 1020-1027, March 2005, doi: 10.1109/TAP.2004.842681.

[7] M. Leib, A. Vollmer and W. Menzel, "An Ultra-Wideband Dielectric Rod Antenna Fed by a Planar Circular Slot," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 59, no. 4, pp. 1082-1089, April 2011, doi: 10.1109/TMTT.2011.2114050

[8] A.A. Kalteh, G.R.D. Salleh, M.N. Moghadisi, and B.S. Virdee, Ultra wideband circular slot antenna with reconfigurable notch band function, IET Microwave Antennas, Vol. 6, no. 1, pp. 108–112, 2012, DOI: 10.1049/iet-map.2011.0125

[9] Bulu, I. and Caglayan, H. 'Designing Materials with Desired', Microwave and optical, vol. 48, no. 12, pp. 2611–2615. 2006, doi :https://doi.org/10.1002/mop.

[10] Fiedziuszko, S. Microwave dielectric resonators. Microwave Journal, vol. 29, pp. 189-196, 1986

[11] A. Okaya and L. F. Barash, "The Dielectric Microwave Resonator," in *Proceedings of the IRE*, vol. 50, no. 10, pp. 2081-2092, Oct. 1962, doi: 10.1109/JRPROC.1962.288245.

[12] McAllister, M.; Long, S.A.; Conway, G. Rectangular dielectric resonator antenna. Electronics Letters, vol. 19, no. 17, pp. 218, 219. 1983 doi: 10.1049/el:19830150

[13] M.W. McAllister and S.A. Long, 'Resonant hemispherical dielectric antenna,'Electron. Lett., VOl.20, PP.657-659, Aug.1984.

[14] P. Gupta, D. Guha and C. Kumar, "Dielectric Resonator Working as Feed as Well as Antenna: New Concept for Dual-Mode Dual-Band Improved Design," in *IEEE Transactions on Antennas and Propagation*, vol. 64, no. 4, pp. 1497-1502, April 2016, doi: 10.1109/TAP.2016.2521887.

[15] U. C. Fischer and D. W. Pohl, "Observation on single-particle plasmons by near-field optical microscopy," Phys. Rev. Lett. 62, 458–461 (1989).

[16] Huang, W. and A. A. Kishk, \Apertures-coupled multi-layer cylindrical dielectric resonatorantennas and modal nalysis," Applied Computational Electromagnetics Society (ACES) 2007Conf., Verona, Italy, vol. 19, no. 23, 2007.

[17] Shum, S. M. and K. M. Luk, \Characteristics of dielectric ring resonator antenna with air gap," Electronics Letters, Vol. 30, No. 4, pp. 111-121, Feb. 1994.

[18] McAllister, M. W., & Long, S. A. Resonant hemispherical dielectric antenna. IEE Electronics Letters, Vol. 20, no

16, pp. 657–659,1984. DOI: 10.1049/el:19840450

[19] Xian-Ling Liang and T. A. Denidni, "Wideband dielectric resonator antenna using a trapezoid-patch feeding technique," *2008 IEEE Antennas and Propagation Society International Symposium*, San Diego, CA, USA, 2008, pp. 1-4, doi: 10.1109/APS.2008.4618992. [20]. A. Rashidian, L. Shafai and D. M. Klymyshyn, "Compact Wideband Multimode Dielectric Resonator Antennas Fed with Parallel Standing Strips," in *IEEE Transactions on Antennas and Propagation*, vol. 60, no. 11, pp. 5021-5031, Nov. 2012, doi: 10.1109/TAP.2012.2210018

[21]. Abedian. M., Oraizi. H., Abdul Rahim, S. K., Danesh. S., Ramli, M. R., & Jamaluddin, M. H. "Wideband rectangular dielectric resonator antenna for low-profile applications". IET Microwaves, Antennas & Propagation, 12(1), 115–119. 2018, doi:10.1049/iet-map.2018, 0593.

[22] Abedian. M., Rahim, S. K. A., & Khalily. M. (2012). "Two-Segments Compact Dielectric Resonator Antenna for UWB Application". IEEE Antennas and Wireless Propagation Letters, vol6, no 4, pp 1533–1536. 2012, doi:10.1109/ lawp.2012.2232639.

[23] Ankit Kumar Roy., & Sukla Basu. "Broadband, High Gain, Narrow Width Rectangular Dielectric Resonator Antenna with Air Gap". journal of electronic science and technology.doi:10.11989/JEST.1674-62X.70728079. (2019).

[24] Biswajeet Mukherjee, Pragati Patel & Jayanta Mukherjee, "A review of the recent advances in dielectric resonator antennas", Journal of Electromagnetic Waves and Applications, vol. 24, no.9, pp. 350-352, 2020, doi: 10.1080/09205071.2020.1744484

[25] Guha, B. Gupta and Y. M. M. Antar, "Hybrid Monopole-DRAs Using Hemispherical/ Conical-Shaped Dielectric Ring Resonators: Improved Ultrawideband Designs," in *IEEE Transactions on Antennas and Propagation*, vol. 60, no. 1, pp. 393-398, Jan. 2012, doi: 10.1109/TAP.2011.2167948.

[26] A. A. Kishk, H. A. Auda and B. C. Ahn, "Radiation characteristics of cylindrical dielectric resonator antennas with new applications," in IEEE Antennas and Propagation Society Newsletter, vol. 31, no. 1, pp. 6-16, February 1989, doi: 10.1109/MAP.1989.6095674.

[27] Junker, G. P., Kishk, A. A., Glisson, A. W., & Kajfez, D. Effect of an air gap around the coaxial probe exciting a cylindrical dielectric resonator antenna. IEE Electronics Letters, Vol. 30, No. 3, pp. 177–178, 1994, DOI: 10.1049/el:19940191

[28] R. K. Mongia, "Resonant frequency of cylindrical dielectric resonator placed in an MIC environment," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 38, no. 6, pp. 802-804, June 1990, doi: 10.1109/22.130982.

[29] Chow, K. Y., Leung, K. W., Luk, K. M., & Yung, E. K. N. Cylindrical dielectric resonator antenna array. IEE Electronics Letters, vol. 31, No. 18, pp. 1536–1537. 1995, DOI: 10.1049/el:19951080

[30] Drossos, G., Wu, Z., & Davis, L. E. Two-element broadside arrays using cylindrical dielectric resonator antennas. Microwave and Optical Technology Letters, Vol. 11, no. 6, pp. 342–345. 1996. https://doi.org/10.1002/(SICI)1098-2760(19960420)11:6

[31] Drowses, G.,Wu, Z., & Davis, L. E. Implementation of four element linear arrays using microstripcoupled cylindrical dielectric resonator antennas. Microwave and Optical Technology Letters, Vol. 19, no. 5, pp. 375–379.1998. https://doi.org/10.1002/(SICI)1098-2760(19981205)19:5

[32] Drossos, G., Wu, Z., & Davis, L. E. Linear arrays consisting of four probe-fed cylindrical dielectric resonator antennas. Microwave and Optical Technology Letters, Vol. 18, no. 6, pp. 367–370. 1998. https://doi.org/10.1002/(SICI)1098-2760(19980820)18:6

[33] Drossos, G., Wu, Z., & Davis, L. E. Aperture-coupled cylindrical dielectric resonator antennas forming four-element linear array. Microwave and Optical Technology Letters, vol

20, no. 2, pp. 151–153. 1999. https://doi.org/10.1002/(SICI)1098-2760(19990120)20:2<151::AID-MOP21>3.0.CO;2-J

[34] S. Long, M. McAllister and Liang Shen, "The resonant cylindrical dielectric cavity antenna," in *IEEE Transactions on Antennas and Propagation*, vol. 31, no. 3, pp. 406-412, May 1983, doi: 10.1109/TAP.1983.1143080.

[35] M. W. McAllister, S. A. Long, "Rectangular DielectricResonator Antenna," IEE Electronics Letters, 19, March 1983, pp. 218-219.

[36] Petosa Aldo, "Dielectric Resonator Antenna Handbook", Artech House publications.

[37] Z. S. Duan, S. B. Qu, Y. Wu, and J. Q. Zhang, 'Wide bandwidth and broad beamwidth microstrip patch antenna,'' Electron. Lett., vol. 45, no. 5, pp. 249–250, Feb. 2009. DOI: 10.1049/el:20092326

[38] A. Dadgarpour, B. Zarghooni, B. S. Virdee and T. A. Denidni, "Single End-Fire Antenna for Dual-Beam and Broad Beamwidth Operation at 60 GHz by Artificially Modifying the Permittivity of the Antenna Substrate," in *IEEE Transactions on Antennas and Propagation*, vol. 64, no. 9, pp. 4068-4073, Sept. 2016, doi: 10.1109/TAP.2016.2574881

[39] A. A. Kishk, M. R. Zunoubi and D. Kajfez, "A numerical study of a dielectric disk antenna above grounded dielectric substrate," in *IEEE Transactions on Antennas and Propagation*, vol. 41, no. 6, pp. 813-821, June 1993, doi: 10.1109/8.250458

[40] A. W. Glisson, D. Kajfez and J. James, "Evaluation of Modes in Dielectric Resonators Using a Surface Integral Equation Formulation," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 31, no. 12, pp. 1023-1029, Dec. 1983, doi: 10.1109/TMTT.1983.1131656

[41] He Haidan, "A novel wide beam circular polarization antenna - microstrip-dielectric antenna," *2002 3rd International Conference on Microwave and Millimeter Wave Technology, 2002. Proceedings. ICMMT*

2002., Beijing, China, 2002, pp. 381-384, doi: 10.1109/ICMMT.2002.1187716.

[42] Constantine A Balanis, ’Antenna Theory, Analysis and Design 3rd Edition, ‘published by Wiley.

[43] R. V. S. Ram Krishna and R. Kumar, “Slotted ground microstrip antenna with FSS reflector for high-gain horizontal polarisation,” Electron. Lett., vol. 51, no. 8, pp. 599–600, 2015.

[44] Liu, Y.T.; Ma, B.; Huang, S.; Wang, S.; Hou, Z.J.; Wu, W. Wideband Low-Profile Connected Rectangular Ring Dielectric Resonator Antenna Array for Millimeter-Wave Applications. IEEE Trans. Antennas Propag. 2022, 71, 999–1004.

[45] Alanazi, M.D. ‘A Review of Dielectric Resonator Antenna at Mm-Wave Band’, Eng, 4(1), pp. 843–856. 2023, https://doi.org/10.3390/eng4010051.

[46] Q. Lai, G. Almpanis, C. Fumeaux, H. Benedickter and R. Vahldieck, "Comparison of the Radiation Efficiency for the Dielectric Resonator Antenna and the Microstrip Antenna at Ka Band," in *IEEE Transactions on Antennas and Propagation*, vol. 56, no. 11, pp. 3589-3592, Nov. 2008, doi: 10.1109/TAP.2008.2005551.

[47] Petosa, A.; Ittipiboon, A. Dielectric resonator antennas: A historical review and the current state of the art. IEEE Antennas Propag. Mag. 2010, 52, 91–116.

[49] S. Fakhte, H. Oraizi and L. Matekovits, "Gain Improvement of Rectangular Dielectric Resonator Antenna by Engraving Grooves on Its Side Walls," in *IEEE Antennas and Wireless Propagation Letters*, vol. 16, pp. 2167-2170, 2017, doi: 10.1109/LAWP.2017.2702584

[50] Gebril, K. K., Rahim, S. K. B. A., & Abdulrahman, A. Y. “Bandwidth Enhancement and Miniaturization of Dielectric Resonator Antenna For 5.8 GHz WLAN”. Progress in Electromagnetics Research C, 19, pp. 179–189. doi:10.2528/pierc10121203.

[51] A. Gupta and R. K. Gangwar, "Dual-Band Circularly Polarized Aperture Coupled Rectangular Dielectric Resonator Antenna for Wireless Applications," in *IEEE Access*, vol. 6, pp. 11388-11396, 2018, doi: 10.1109/ACCESS.2018.2791417.

[52] Kshirsagar, Poonam, Shubha Gupta, and Biswajeet Mukherjee. “A Two-Segment Rectangular Dielectric Resonator Antenna for Ultra-Wideband Application.” *Electromagnetics* Vol. 38, no. 1, pp. 20-33, 2018, doi:10.1080/02726343.2017.1406682.

[53] Kumar Mongia, R., & Ittipiboon, A. “Theoretical and experimental investigations on rectangular dielectric resonator antennas”. IEEE Transactions on Antennas and Propagation, Vol. 45, no. 9, pp. 1348–1356. 1997, doi:10.1109/8.623123.

[54] Mongia, R. K., & Bhartia, P. “Dielectric resonator antennas—a review and general design relations for resonant frequency and bandwidth”. International Journal of Microwave and Millimeter-Wave ComputerAided Engineering, Vol. 4, No. 3, pp. 230–247. 1994, doi:10.1002/ mmce.4570040304.

[55] Mongia, R. K., Ittibipoon, A., & Cuhaci, M. “Low profile dielectric resonator antennas using a very high permittivity material”. Electronics Letters, Vol. 30, No. 17, pp. 1362–1363. 1994, doi:10.1049/el:19940924.

[56] M. Pan, K. W. Leung and K. Lu, "Study of Resonant Modes in Rectangular Dielectric Resonator Antenna Based on Radar Cross Section," in *IEEE Transactions on Antennas and Propagation*, vol. 67, no. 6, pp. 4200-4205, June 2019, doi: 10.1109/TAP.2019.2911198

[57] Petosa, A., & Ittipiboon, A. “Dielectric Resonator Antennas: A Historical Review and the Current State of the Art”. IEEE Antennas and Propagation Magazine, vol. 52, no. 5, pp. 91–116, 2010 doi:10.1109/map.2010.5687510.

[58] V, L.P., B. Raut, R. and Mukherjee, B. ‘Overview on Optimization Methods of Rectangular Dielectric Resonator Antenna’, HELIX, vol. 10, no. 4, pp. 133–140. 2020, https://doi.org/10.29042/2020-10-4-133-140.

[59] Lezec.H.J.et alBeaming light from a sub wavelengthaperture. Science 107.1895(2002)

[60] Porto, J. A., Garcia-Vidal, F. J. &Pendry, J. B. Transmission resonances on metallic gratings with very narrow slits. Phys. Rev. Lett. Vol. 83, no. 12, pp. 2845–2848, 1999,

https://doi.org/10.1103/PhysRevLett.83.2845

[61] Nalanagula, R. et al. ‘Circularly polarized hybrid dielectric resonator antennas: A brief review and perspective analysis’, Sensors. MDPI AG. Vol. 21. no.12, pp. 4100, 2021 https://doi.org/10.3390/s21124100.

[62] McAllister, M.; Long, S.A.; Conway, G. Rectangular dielectric resonator antenna. Electron. Lett. Vol. 19, no.6, pp. 219-218. 1983. DOI: 10.1049/el:19830150

[63] X. -L. Liang, T. A. Denidni and L. -N. Zhang, "Wideband L-Shaped Dielectric Resonator Antenna with a Conformal Inverted-Trapezoidal Patch Feed," in *IEEE Transactions on Antennas and Propagation*, vol. 57, no. 1, pp. 271-274, Jan. 2009, doi: 10.1109/TAP.2008.2009783

[64] Alanazi, M.D. ‘A Review of Dielectric Resonator Antenna at Mm-Wave Band’, Eng, vol. 4, No. 1, pp. 843–856. 2023 https://doi.org/10.3390/eng4010051

[65] Bhatnagar, M. Theoretical analysis and optimization of circular patch microstrip antenna. Int. Res. J. Eng. Technol, vol. 2, pp 1675–1681. 2015

[66] U. Illahi, J. Iqbal, M. I. Sulaiman, M. M. Alam, M. M. Su’ud and M. H. Jamaluddin, "Singly-Fed Rectangular Dielectric Resonator Antenna with a Wide Circular Polarization Bandwidth and Beamwidth for WiMAX/Satellite Applications," in IEEE Access, vol. 7, pp. 66206-66214, 2019, doi: 10.1109/ACCESS.2019.2917702.