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Optimizing the geometry of a cylindrical dielectric resonator antenna (CDRA) in combination with the design of a microstrip patch antenna to improve antenna efficiency

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ABSTRACT

The primary objective of this study is to improve the efficiency of dielectric resonator antennas (DRAs) by the manipulation of their geometric and material characteristics. Two distinct cylindrical dielectric resonator antenna (DRA) with microstrip patch antenna designs chosen, and deliberate modifications implemented in a systematic manner to enhance crucial characteristics including gain, bandwidth, S-parameters, voltage standing wave ratio (VSWR), and directivity. Furthermore, an investigation was conducted to assess the efficacy of incorporating additional layers into the design of the DRA to achieve increased gain and enhanced efficiency at a frequency of 28 GHz. The research encompassed the process of collecting and designing and simulating CDRA and microstrip patch antenna antennas utilizing the CST framework. The study investigates different configurations of apertures and alterations or holes in the patch geometry to improve both the gain and efficiency. A comparative analysis between both antennas was carried out utilizing performance criteria such as S-parameters, gain, directivity, bandwidth, and VSWR and efficiency. The discourse explores the progress made in the field of technology pertaining to the improvement of gain and bandwidth. This includes the utilization of high-dielectric-constant materials, modifications in resonant frequencies, and the implementation of metamaterial (MTM) cells. The CST program is utilized for conducting realistic trials and assessments. The research highlights the advantages of CDRA antennas and microstrip patch antennas, including improved radiation efficiency, smaller size, lower profile, and lightweight design. The integration of photonic crystal layers into the design of the cylindrical dielectric resonator antenna (CDRA) was emphasized as a noteworthy enhancement, resulting in amplified gain. The significance of considering both intrinsic characteristics and external factors, such as surface Plasmon waves, in the computational modeling of DRA antennas to achieve maximum efficiency is emphasized by the research.

Keywords: Microstrip patch antenna, Slots, cylindrical CDRA antenna, Polarization, Gain, Radiation pattern, efficiency, CST program.

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1. Introduction

Dielectric resonator antennas (DRA) are a kind of antenna that employs a dielectric resonator as a fundamental constituent. Dielectric resonators refer to materials that lack electrical conductivity and exhibit the ability to resonate at specific frequencies upon stimulation by an electromagnetic field. The DRA antenna under consideration is a unique type that has a rectangular dielectric structure positioned above a ground plane. The DRA antenna under consideration has a notable combination of wide bandwidth and substantial gain. Furthermore, it possesses the capability to handle power. Rectangular dielectric resonator antenna (DRA) has additional merits in terms of its width and height, rendering it adaptable to many orientations. Rectangular Dielectric Resonator Antennas (DRAs) are commonly employed in wireless communication applications owing to their numerous advantages in comparison to other antenna types. Nevertheless, there are certain advantages associated with rectangular Dielectric Resonator Antennas (DRAs). One notable characteristic of rectangular dielectric resonator antennas (DRAs) is their high-quality factor (Q-factor), enabling them to efficiently resonate at a specific frequency. Because of this, they possess the capability employed in sophisticated communication systems. Rectangular directive radiation antennas (DRAs) are highly suitable for use in point-to-point communication systems due to their exceptional gain and distinctive emission pattern characterized by directionality. Rectangular dielectric resonator antennas (DRAs) exhibit favorable characteristics for deployment in systems with stringent selectivity requirements, including radar systems, owing to their low bandwidth and enhanced selectivity. Furthermore, the device exhibits exceptional directivity. Rectangular directive radiation antennas (DRAs) are highly suitable for directional communication systems because of their inherent capability to focus their radiation pattern in a singular direction. In addition, it noted that Rectangular Dielectric Resonator Antennas (DRAs) exhibit a favorable characteristic of low cross-polarization. This attribute enables them to effectively transmit and receive signals while experiencing minimum disruption from undesired polarization elements. Hence, it inferred that Rectangular Distributed Reconfigurable Antennas (DRAs) possess a compact physical size, thereby enabling their seamless integration with diverse communication networks and devices. Furthermore, convenience plays a significant role in the creation of rectangular Dielectric Resonator Antennas (DRAs), as many prevalent manufacturing procedures such as milling, cutting, and polishing were employed for their fabrication. Additionally, rectangular dielectric resonator antennas (DRAs) offer a range of advantages including high Q-factor, high gain, limited bandwidth, high directivity, low cross-polarization, low profile, and simple construction. Due to the numerous advantages, they offer, these devices are commonly employed in wireless communication systems, particularly in radar and point-to-point networks. Determining the optimal fit for a given application and design, whether it be a circular or square DRA, is ultimately contingent upon subjective preference.

There exist several distinctions between microstrip and dielectric resonator antenna (DRA), notably in terms of their radiation modes. Hence, the dielectric resonator antenna (DRA) exhibits sufficient surface area, with the exception of some regions. Furthermore, the radiation will emanate from the entire expanse of this surface region. However, in the case of a microstrip patch antenna, the area reduced. Consequently, radiation will emanate from this limited aperture. Additionally, the microstrip configuration exhibits several drawbacks due to its small slot and radiation characteristics. Certain issues exhibit characteristics of being both limited in gain and bandwidth. Nevertheless, to address this issue, the DRA antenna employed is due to its compatibility in terms of gain and bandwidth, as well as its ability to exhibit a high mode of radiation. By varying the values or dimensions of height, breadth, and length, the performance and efficiency of the DRA antenna can be improved [1,2]. Furthermore, an approach employed for the study of DRA antennas that combines the approximation techniques of Marcatili and EDC. This methodology is beneficial for examining some attributes of antennas. Nevertheless, several characteristics of the DRA antenna exhibit mode degeneracy in comparison to alternative structural designs. One potential solution to address this issue involves selecting an appropriate ratio between the height and width of the DRA antenna. This phenomenon results in a decrease in the stimulation of polarization levels and a reduction in the presence of unwanted modes. Furthermore, when analyzing the rectangular dielectric resonator antenna (DRA), it is crucial to consider two primary factors. Firstly, the model of the dielectric waveguide must be considered. Secondly, the model of the magnetic wall, as designed by Okaya and Barash [3], should also be considered. Therefore, certain antennas, such as the RDRA antenna with multi-dimensional modes, can support a variety of applications. Hence, the many types of radiation serve as manifestations of the phenomenon of radiation. An illustration of the H field and E field design can be seen in reference [3]. The modes of resonance seen in solitary rectangular DRA antennas were identified by the researchers as TE and TM modes. However, the experimental or practical verification of the TM mode has not been demonstrated [2]. Nevertheless, these modes fulfill the requirements of the resonator surface in the context of a Dielectric Resonator Antenna (DRA).

2. Related work

The CDRA antenna is a type of antenna that is composed of a cylindrical dielectric. It was positioned on the ground plane. This type of DRA antenna offers significant amplification and wide frequency range due to its efficient energy management. Nevertheless, this antenna is utilized throughout a broad spectrum of microwave frequencies. One of the advantages of this antenna is its absence of metal components. These metal parts will see a decrease in performance at high frequencies. Consequently, the complete decrease in energy will become evident. Nevertheless, the efficacy of this antenna surpasses that of a metal antenna. This efficiency is evident both at millimeter wave frequencies and microwave frequencies. A cylindrical Dielectric Resonator Antenna (DRA) utilizes a cylindrical dielectric material to facilitate the transmission and reception of signals by supporting resonant electromagnetic modes. Hence, the cylindrical dielectric resonator antenna (DRA) is typically constructed using materials with high dielectric constants such as ceramic or plastic. Furthermore, the dimensions and configuration of the CDRA can be tailored to accommodate a diverse range of applications and operating frequencies. Due to its cylindrical design, the DRA can support numerous resonant modes with minimal radiation losses, resulting in exceptional radiation efficiency and gain. Furthermore, cylindrical dielectric resonator antennas (DRAs) offer advantages to many communication systems such as satellite communication, wireless communication, and radar systems. Therefore, they are highly effective as feed antennas for reflector antennas in satellite communication systems, as well as for other applications that demand significant amplification and focused signal transmission. They can be utilized as array components in phased array antennas for radar systems or as independent antennas for wireless communication systems. However, cylindrical Dielectric Resonator Antennas (DRAs) are highly efficient and versatile antennas that can be used in various situations requiring strong signal amplification and focused radiation.

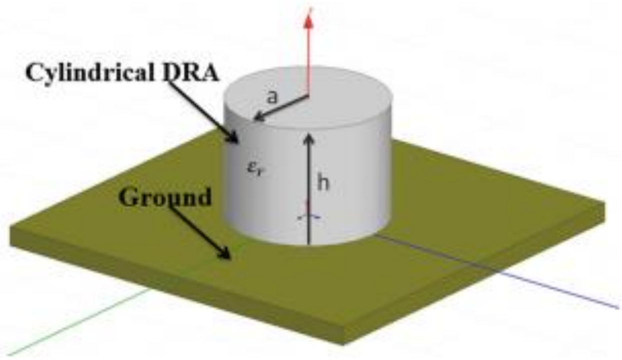

Figure1. Diagram of designing of CDRA antenna

The figure above depicts the design of a cylindrical DRA antenna with specified dimensions. Figure 1 illustrates the characteristics of cylindrical DRAs, including their radius (a), diameter (D), and height (h). The extensive utilization of cylindrical Dielectric Resonator Antennas (DRAs) in wireless communication systems has attracted significant interest. The infinite perfectly conducting plane assumption is also employed in the cylinder DRA to streamline the computations. Nevertheless, Cylindrical DRAs possess an additional degree of freedom compared to their hemispherical counterparts. Therefore, the shape's free parameters include the permittivity ε_r, the height of the cylinder, and the radius of the cylinder.

3. Methodology

By using Computer simulation technology to design and simulate both CDRA antenna and microstrip patch antenna together. The aim of this article is to enhance the gain and efficiency of the new design. Therefore, we design cylindrical dielectric resonator antenna with microstrip patch antenna in one shape. However, there are many technologies to enhance the results as explained below. Therefore, the arrangement of new design explained later in part of experimental results. A microstrip patch antenna is a radio frequency (RF) antenna known for its compact size, simple manufacturing process, and flexibility in design. It is extensively utilized in diverse communication systems, encompassing microwave and wireless communication applications.

3.1. Substrate technology

The utilization of a resonator antenna can lead to a significant enhancement in antenna efficiency, which is achieved through the implementation of a suitable substrate. Hence, it recommended that the shape of the coupling slot be modified to enhance the coupling efficiency. Nevertheless, this approach is deemed appropriate for some frequencies, such as the millimeter range. As an illustration, millimeter wave frequencies exhibit robust antenna performance and great efficiency.

The issue with this approach is its lack of suitability for all frequencies. This technique exclusively operates within the millimeter frequency range to achieve optimal antenna efficiency.

3.2. Polarization technology

A different study discusses a compact coplanar waveguide-fed monopole. This is a type of dielectric resonator antenna (DRA) that exhibits an omnidirectional radiation pattern. Ryu et al. [4] have presented a technique for ultra-wideband (UWB) that exhibits a significantly low level of cross polarization. The frequency range of this operation spans from 3.1 to 10.6 GHz. The rectangular DR-antennas, as proposed by Khalily et al. [5], include tapered strip excitation on one side and a thin strip design. The technique employed to enhance the radiation pattern and expand the bandwidth to 96%, specifically ranging from 2.13 GHz to 6.08 GHz, as compared to the conventional antenna, which only achieved a bandwidth of 66%. To control the frequency range in which the transmission of ultra-wideband (UWB) signals attenuated, Niroo-Jazi et al. (introduced a circular patch with radiation characteristics like that of a monopole into the distributed resonator (DR) structure. This modification aimed at achieving a stopband response between 5.15 and 5.825 GHz, while maintaining the UWB range of 2 to 10.7 GHz. The UWB rectangular stacking dielectric resonator antenna (DRA) developed by Shao et al. [6] operates within the frequency range of 3.1 to 10.6 GHz. This antenna incorporates a band notch, which is produced by a thin printed dipole positioned in proximity to the feeding probe. This study demonstrates that the utilization of single-band distributed reflector antennas (DRAs) entails a higher level of complexity compared to studies including dual- or multiband DRAs. The significance of the DR shape surpasses that of the coupling mechanism, permittivity, and mode of operation when it comes to determining the range within which the system may effectively operate. Hence, it is possible to get improved bandwidth by utilizing a wider patch with slotted dielectric resonator, assuming the presence of a perfectly matched network. Additionally, combining several modes, particularly lower modes, might be advantageous in terms of achieving a broader impedance bandwidth. Furthermore, considering the coupling aspect is also important in this context. On the contrary, this study enhanced by incorporating a hybrid form consisting of DRA combined with Sierpinski and Minkowski fractals, hence enabling its application in both wideband and multiband scenarios.

3.3. Feed of DRA antenna in different modes technology

This strategy is effective in mitigating polarization rotation. However, the rotation in polarization is influenced by atmospheric forces. One example pertains to the impact of fading on the geometry of multipath or reflections. The impacts were a direct consequence of the encountered barriers. Hence, this antenna is designed to operate autonomously in both the transmission and reception of circularly polarized signals. The subject matter pertains to the individual's autonomous stance. However, this division arises from disparate perspectives. For instance, the choice between a single point or dual point can be considered. Additionally, the study explores various techniques for sequential rotation. Moreover, the utilization of antennas with circular polarization observed in wireless communications [7,8]. The DRA antenna is widely utilized for various applications involving satellite and WiMAX technologies. The antenna was fed by H-shaped metal strips [7]. Nevertheless, the bandwidth of the complex impedance of the CP exhibits a variation of around 20%. This phenomenon arises because of the presence of metal strips. Consequently, the production of a dual set of modes characterized by significant excitation results in an impedance with a bandwidth of approximately 20% and a gain value of 6.8 dBi. However, many approaches are responsible for the feeding of the RDRA antenna. For instance, modifying the structural configuration of the DRA (Dielectric Resonator Antenna) by incorporating a monopole antenna for enhancing its loading capabilities. The utilization of a singular focal point in the context of circular polarization observed across various feed configurations. However, the generation of a polarizing effect in a circular shape is achieved through the utilization of notches.

3.4. Change the Shape of DRA antenna or microstrip antenna to enhance bandwidth

Enhancing the bandwidth of a Dielectric Resonator Antenna (DRA) might pose challenges due to the high susceptibility of the DRA's resonant frequency to variations in the dielectric constant of the resonator material. The bandwidth of a DRA antenna enhanced by carefully considering specific design elements. The enhancement of the bandwidth of a Dielectric Resonator Antenna (DRA) achieved by the manipulation of the resonator's geometric configuration. The size of broadband tends to be less for resonators with spherical and cylindrical geometries, whereas it tends to be bigger for resonators with geometries that are more complex. Hence, the bandwidth of the antenna expanded by utilizing resonators of diverse shapes, each of which presents a distinct frequency response. Additionally, the choice of material used in the resonator might affect the bandwidth of the antenna. The enhancement of the antenna's resonance frequency and bandwidth is achieved through the utilization of materials possessing a reduced dielectric constant. The present work addresses the issue of improving the bandwidth of a Dielectric Resonator Antenna (DRA) by the utilization of materials with reduced dimensions. Furthermore, the properties of the materials have an impact on both the resonance frequency and the bandwidth.

3.5. The proposed technology of microstrip patch antenna and DRA antenna

This proposed technology was very useful to enhance the gain of microstrip patch antenna to 11.62 dBi. We used four kinds of square holes inserted inside the patch of microstrip antenna. Two of the holes or gaps were small, but the other two slots were big in size. However, the positions of the four slots were different. For example, the first holes created upper direction inside patch of microstrip antenna (width=0.75, length=0.95), then we created another small hole with same scale below the first hole inside the patch with distance Y = - 3 on Y-axis. However, the other two big slots created in middle direction inside patch in both directions right and left along X-axis. For example, the right big slot created with scale (width=3.7, length=2.5) in the right direction inside patch of microstrip antenna. Then we created another big slot with the same size. However, in the left direction inside patch of microstrip antenna with distance x= -4 on x-axis. In addition, these different slots were necessary to enhance radiation pattern and efficiency of microstrip antenna .therefore, the gain arrived 11.62dbi.then the efficiency of microstrip antenna improved to 90%.However, this technology called Optimizing the geometry of a cylindrical dielectric resonator antenna (CDRA) in combination with the design of a microstrip patch antenna to improve antenna efficiency .Therefore, the both antennas designed together in one design. For example, cylindrical DRA antenna with microstrip patch antenna as explained in figure 6.The efficiency increased to 91% Moreover, we designed cylindrical DRA antenna (CDRA) with measurements listed in table3,table6.then,the materials that are used in design of antenna are showed in table7.Finallyall the results of comparison of new design explained in table8with the final figure of collecting CDRA antenna with microstrip patch antenna together are mentioned in figure 6 The purpose was to enhance efficiency of antenna when the two designs used together in one design .therefore the efficiency of two designs together was 91%.

4. Implementation

We designed CDRA and Microstrip antenna by CST program as explained in figures below. The values of design of Antenna explained in table1 and table3.However, figure6 explains the new design of both CDRA and Microstrip patch antennas in one shape. The purpose was to enhance the gain and efficiency as explained in table 7.

5. Results and discussion

This article presents a novel technological advancement aimed at improving the operational effectiveness of CDRA (cylindrical dielectric resonator antenna) systems. The method referred to as the slots of Special Patch of microstrip Antenna with Square Slots utilized to improve the gain of microstrip antennas as well as the efficiency. Hence, the utilization of slots technology in conjunction with the integration of a patch of microstrip antenna as well as four square slots or apertures .This technology collectively aims to enhance the overall performance of the microstrip and CDRA antennas, as depicted in the newly proposed design illustrated in Figure 6.Furthermore, it should be noted that the dimensions of the antenna patch remain unchanged, as indicated in Table3.Therefore, the strategic placement of several gaps or slots proved advantageous in optimizing the radiation pattern and increasing the antenna's gain. Consequently, we have developed and conducted simulations on a cylindrical dielectric resonator antenna (CDRA) and microstrip patch antenna with varying geometries, distinct from the previously described design illustrated in figure 6. The objective of the study was to improve the gain of the CDRA and microstrip antennas as well as efficiency of both antennas. As a result, the gain boosted to 11.62dBi, and the antenna's efficiency increased to 90%. for microstrip antenna as explained in equation1.Furthermore, there was a clear improvement in the bandwidth and other characteristics, such as S-parameters.in addition the gain of CDRA antenna arrived 7.511dBi with efficiency about 91.2%as showed in figure5 and table8.The alterations in the geometric configuration of the cylindrical dielectric resonator antenna (CDRA) and microstrip antenna elucidated by the utilization of Computer Simulation Technology (CST) software, specifically at a frequency of 28 GHz. The subsequent sections will elucidate the rationale for the alterations made to the shape of the CDRA antenna. Finally, the results of collecting two designs together gave us efficiency of about 91%.as shown in Figure 6 and Table 8.

5.1. Basic Geometry

The height measurements in the Z direction are unnoticeable due to their small scale. In this section, a conventional rectangular dielectric resonator antenna (DRA) simulated and developed using a unique patch design by computer simulation technology CST program. Figure 2 illustrates the geometric characteristics of the rectangular DRA antenna, while Table 1 and Table 3 provide a comprehensive listing of its corresponding values with proposed symbols.

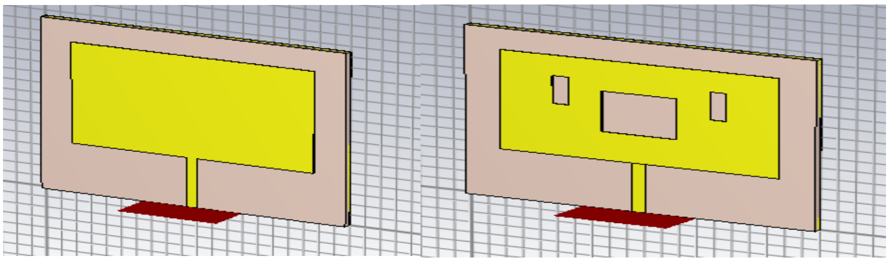

Figure 2. The basic configuration of the initial rectangular antenna exported from CST. The grid displays the millimeter scale

Table 1. Symbols employed to represent the parameters, together with their respective 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
Slot1	small hole inside patch of DRA antenna in upper direction
Slot2	small hole inside patch of DRA antenna in lower direction
Slot3	big gap inside patch of DRA antenna in middle right direction
Slot4	big gap inside patch of DRA antenna in middle left direction
ε_r	relative permeability

Table 2. The initial values of the DRA parameters in the first stage prior to any modifications in the design A.

Parameter	G (dBi)	D (dBi)	BW (GHz)	$VSWR$	S_{11} (dB)
Value	11.34	12.20	0.5661	1.7929179	−10.97304

5.1.1. 2nd geometry

In the second geometry, the dimensions of the antenna patch modified. The shape of the patch utilized in our study closely resembled the design outlined in the wider context, particularly as elucidated in the values presented in Table 3 and Figure 3. The CST (Computer Simulation Technology) software program provides an explanation of this phenomenon, utilizing values at a frequency of 28 GHz, as seen in Table 3. Hence, the modification proved to be advantageous in improving the performance of the CDRA and microstrip antennas, as well as various other parameters including bandwidth, S-parameter, VSWR, and Directivity. Subsequently, the enhancement in the efficiency of the microstrip patch antenna became evident as indicated by the subsequent equation.

$$\eta = \frac{G}{D} \cdot 100\ \% = \frac{11.62}{12.95} \cdot 100\ \% = 90\% \quad (1)$$

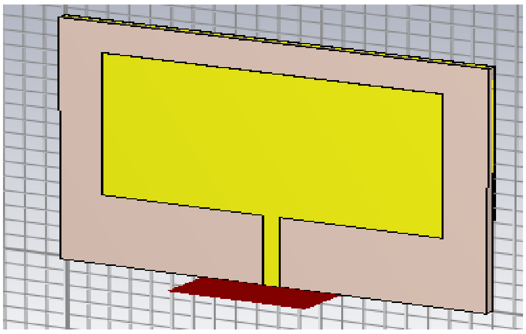

Figure 3. The second geometry of the antenna's geometry enhanced using the same patch design for a frequency of 28 GHz, as illustrated in CST. The dimensions provided are in millimeters.

Table 3. The dimensions of the various components of a rectangular dielectric resonator antenna (DRA)and microstrip antenna made of copper material include the ground plane, substrate, patch, feed, gap, and slots

Parameter	X_{min}	X_{max}	Y_{min}	Y_{max}	Z_{min}	Z_{max}
Ground						
Formula	0	W_{gr}	0	L_{gr}	0	H_{gr}
Dimension (mm)	0	20	0	16.5	0	0.035
Substrate						
Formula	0	W_{st}	0	L_s	H_{gr}	$H_{gr} + H_s$
Dimension (mm)	0	20	0	16.5	0	$0.035 + 0.508$
Patch						
Formula	$\frac{W_{gr}}{2} - \frac{wp}{2} - 3$	$\frac{W_{gr}}{2} + \frac{wp}{2} + 3$	L_f	$L_f + Lp$	$H_{gr} + H_s$	$H_{gr} + H_s + H_p$
Dimension (mm)	$\frac{20}{2} - \frac{9.9}{2} - 3$	$\frac{20}{2} + \frac{9.9}{2} + 3$	4.75	$4.75 + 9.7$	$0.035 + 0.508$	$0.035 + 0.508 + 0.035$
Feed						
Formula	$\frac{W_{gr}}{2} + \frac{W_f}{2}$	$\frac{W_{gr}}{2} - \frac{W_f}{2}$	0	L_f	$H_{gr} + H_s$	$H_{gr} + H_s + H_p$
Dimension (mm)	$\frac{20}{2} - \frac{0.7}{2}$	$\frac{20}{2} + \frac{0.7}{2}$	0	4.75	$0.035 + 0.508$	$0.035 + 0.508 + 0.035$
Gap						
Formula	$\frac{W_{gr}}{2} - \frac{W_f}{2} - W_g$	$\frac{W_{gr}}{2} - \frac{W_f}{2}$	L_f	$L_f + L_g$	$H_{gr} + H_s$	$H_{gr} + H_s + H_p$
Dimension (mm)	$\frac{20}{2} - \frac{0.7}{2} - 0.5$	$\frac{20}{2} + \frac{0.7}{2}$	4.75	$4.75 + 2.4$	$0.035 + 0.508$	$0.035 + 0.508 + 0.035$
Slots						

Parameter	X_{min}	X_{max}	Y_{min}	Y_{max}	Z_{min}	Z_{max}
Slot1	$\frac{W_s}{2}-\frac{w0}{2}+4$	$\frac{ws}{2}+\frac{w0}{2}-1$	$7.5+3$	$7.5+l0$	hs	$hs+ht$
Dimension (mm)	$\frac{20}{2}-\frac{4.25}{2}$ +4	$\frac{20}{2}-\frac{4.25}{2}$ -1	10.5	7.5+3.95	0.508	$0.508+1$
Slot2 $+shift$ $y=-3$	$\frac{W_s}{2}-\frac{w0}{2}+4$	$\frac{W_s}{2}-\frac{w0}{2}-1$	$7.5+3$	7.5+l0	Hs	H_s+Ht
Dimension (mm) +shifty= -3	$\frac{20}{2}-\frac{4.25}{2}$+4	$\frac{20}{2}+\frac{4.25}{2}$ -1	10.5	7.5+3.95	0.508	0.508+1
Slot3	$\frac{W_{gr}}{2}+\frac{W_f}{2}$+3	$\frac{W_{gr}}{2}-\frac{W_f}{2}$	$10+2$	9.5	hgr+hs	$H_{gr}+H_s+H_p$
Dimension (mm)	$\frac{20}{2}+\frac{0.7}{2}$ +3	$\frac{20}{2}-\frac{0.7}{2}$	12	9.5	0.035+0.508	$0.035+0.508+0.035$
Slot4 +shift x=-4	$\frac{W_{gr}}{2}+\frac{W_f}{2}+3$	$\frac{W_{gr}}{2}-\frac{W_f}{2}$	$10+2$	9.5	hgr+hs	$H_{gr}+H_s+H_p$
Dimension (mm) +shift x= -4	$\frac{20}{2}+\frac{0.7}{2}$ +3	$\frac{W_{gr}}{2}-\frac{W_f}{2}$	$10+2$	9.5	hgr+hs	$H_{gr}+H_s+H_p$

5.1.2. 3 rd. geometry

In this part of geometry of DRA antenna with microstrip patch antenna, we created two small apertures that were incorporated into the patch of the microstrip patch antenna; they collected with two square slots of varying shapes and placements. To improve the gain and efficiency of the microstrip patch antenna, as illustrated in Table 1. Furthermore, the dimensions and configuration of the patch remain unaltered in this revised design, except for modifications made to the quantity and geometry of the slots within the DRA antenna patch. Consequently, the geometric configuration of the microstrip patch antenna underwent a distinct alteration in its shape. All the values of the slots with patches, as described earlier, are presented in Table 3. The patch contains a small hole or slot positioned in the upper direction, as described in Table 3 of the mathematical measurement values. Another hole was formed below the initial hole at a vertical distance of Y=-3 on the y-axis. Furthermore, a large slot is created and inserted in the middle of the patch, oriented in the correct direction. However, we have generated an additional duplicate of a large slot positioned to the left of the antenna patch at a distance of x = -4 along the x-axis. Hence, there were four slots, each characterized by distinct shapes, sizes, and placements. The objective of this operation is to optimize the gain and thus improve the efficiency of the DRA antenna. The alterations made to the geometry of the microstrip patch antenna have resulted in enhancements to its properties, including improvements in parameters such as S-parameter, bandwidth, and VSWR .Consequently, the effectiveness of the microstrip patch antenna significantly improved. Therefore, the gain of the antenna improved to 11.62dBi with efficiency about 90%

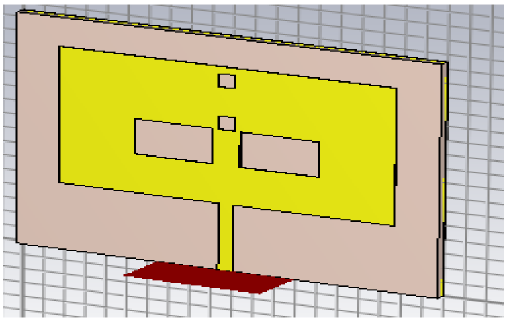

Figure 4. The second geometry, which consists of four distinct slots, depicted in CST

Table 4. The values of the microstrip parameters for the second and third geometries of design B,C

Parameter	G (dBi)	D (dBi)	BW (GHz)	$VSWR$	S_{11} (dB)
Value	11.62	12.95	0.34602	1.0174393	−41.811206

Table5. Comparison the Final results between the design A and new design B,c microstrip antenna

Parameter	G (dBi)	D (dBi)	BW (GHz)	$VSWR$	S_{11} (dB)
Design A	11.34	12.20	0.5661	1.7929179	−10.97304
Design B,C	11.62	12.95	0.34602	1.0174393	-41.811206

5.1.3. 4th Geometry of designing of Cylindrical DRA antenna

The following new design referred to CDRA antenna design. We used cylindrical shape of DRA antenna. This was useful to enhance gain to 7. 511dBi. Therefore, the dimensions of the ground plane, patch and substrate are listed in Table 3. Moreover, the values and measurements of cylindrical DRA antenna are mentioned in table6 with the types of materials that are listed in Table 6. In addition, the efficiency of CDRA antenna arrived 91.2%

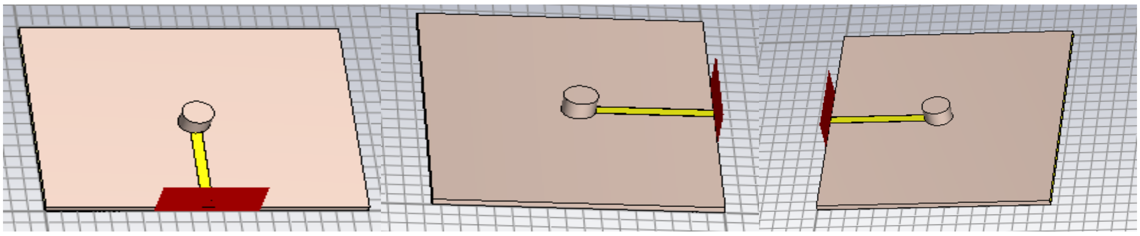

Figure 5. Design of our cylindrical CDRA antenna

Table 6. The geometric parameters required for designing the cylindrical; dielectric resonator antenna (CDRA) with a frequency of 28 GHz, and materials used in the design of the CDRA antenna

Dimension	Size (mm)	Parameters	Materials
CDRA outer radius	1	CDRA	Rogers RT5880(Lossy)
CDRA U center	4.75		
CDRA Wmin	2.043	Feed/strip	Copper (annealed)
CDRA Wmax	0.578		
Relative permittivity	ε_r= 9.8	substrate	Rogers RT 5880 Lossy
Strip length	4.75		
Strip width	0.7		
Strip thickness	0.035	ground	copper

5.1.4. 5th Geometry of Collecting the CDRA antenna and the microstrip patch antenna together in one design

We created the final design by collecting cylindrical DRA antenna with microstrip patch antenna in one design as explained in figure6.This design was useful to enhance the performance of this antenna. Moreover, other parameters such as s-parameter, bandwidth, gain, and directivity improved clearly. Then the efficiency of the new geometry increased to 91% as explained in the final Table 7. However, we called this technology of new design of DRA antenna is Optimizing the geometry of a cylindrical dielectric resonator antenna (CDRA) in combination with the design of a microstrip patch antenna to improve antenna efficiency.

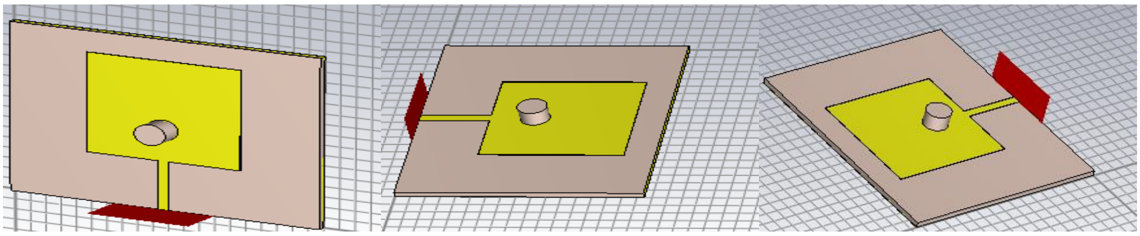

Figure 6. Geometry the collect of CDRA antenna and microstrip patch antenna in one design

Table 7. Results of comparison of design A and new designs C, D, and E of microstrip antenna and of cylindrical $CDRA$ antenna

Parameter	G (dBi)	D (dBi)	BW (GHz)	$VSWR$	S_{11} (dB)	Efficiency η
Design (A)previous design	11.34	12.20	0.5661	1.7929179	-10.97304	92.9%
Design(C)new design of microstrip antenna	11.62	12.95	0.34602	1.0174393	-41.811206	90%
Design (D) new design of CDRA antenna	7.511	8.236	0.52602	1.0176841	-41.177556	91.2%
Design(E) collecting of CDRA+ microstrip in one design (final design)	5.311	5.830	1.0931	1.3551962	-16.431175	91%

5.2. Simulation results

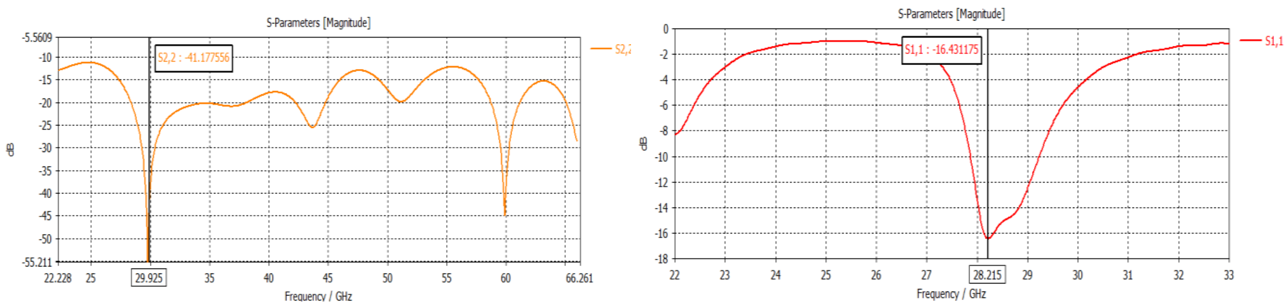

Figure 7. The numerical value of S_11. Designed by CST. The first subplot relates to design, the second subplot to design D

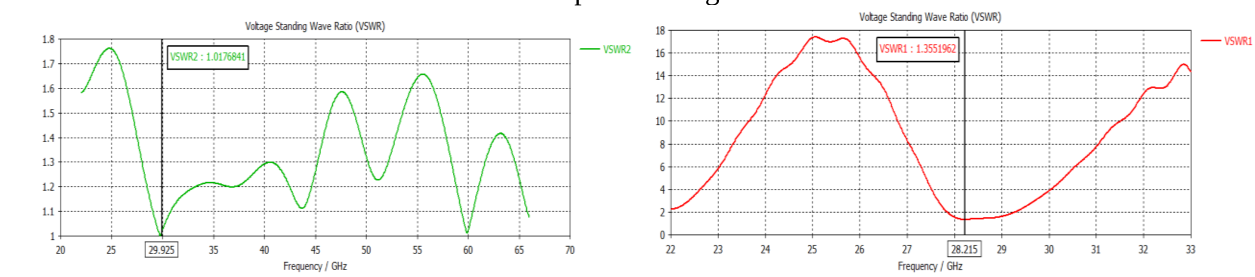

Figure 8. The Voltage Standing Wave Ratio (VSWR) is modeled using CST software. The first subplot corresponds to design C, the second subplot corresponds to design D

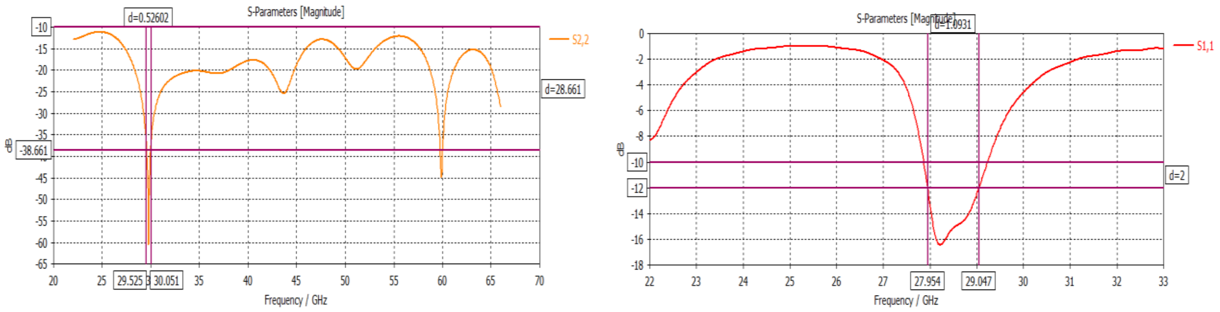

Figure 9. The determination of the bandwidth value from the parameter S_11. Simulation conducted using CST software. The first subplot relates to design C, the second subplot to design D,

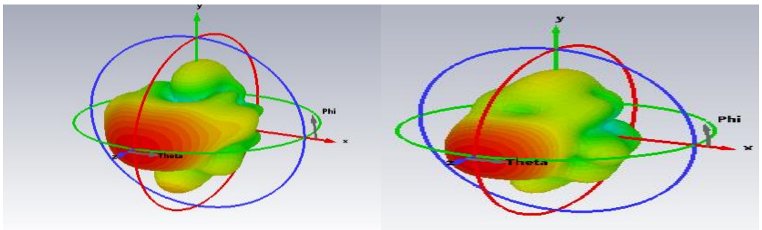

Figure 10. The gain G of 11.62 dBi and directivity D of 12.95 dBi are explained by the radiation pattern. Designed by CST. The first subplot relates to design C, the second subplot to design D,

In order to make the far field gain *G* and directivity *D* also visible, Figure 11below contains these values for designs, C, D .

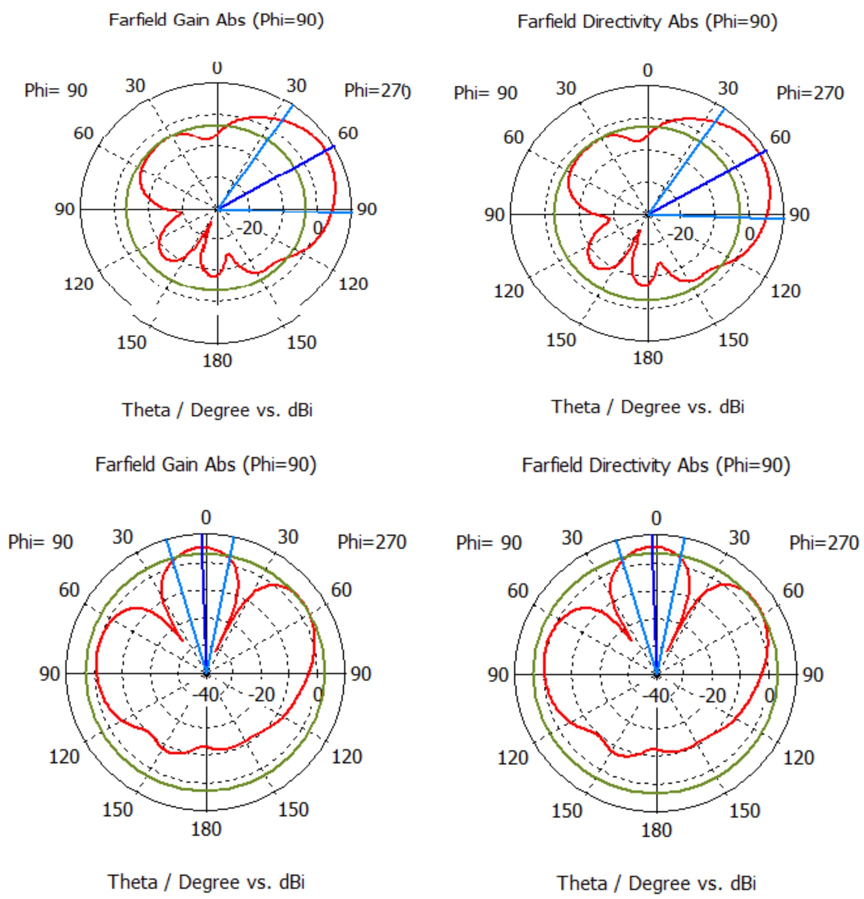

Figure 11. The far-field gain (on the left) and directivity (on the right) at a frequency of 28 GHz, as calculated by CST. The top row displays design C, while the bottom row show case of design D

It observed that modifying the geometry of the CDRA antenna was essential to enhance the gain and other characteristics, as elucidated in Table 6. Hence, the utilization of four slots proved to be beneficial in improving the radiation pattern. Of microstrip patch antenna Subsequently enhancing the effectiveness of the cylindrical Dielectric Resonator Antenna (CDRA), with microstrip patch antenna as mentioned in figure6, particularly when the patch dimensions were increased compared to previous iterations with smaller patch sizes. However, a potential improvement for enhancing the attributes of CDRA in subsequent iterations could be lowering the number of slots. As a result, the efficiency of the microstrip patch antenna enhanced to 90% with increasing in gain about 11.62dBi.in addition the gain of CDRA antenna was 7.511 and directivity was 8.236The the efficiency of CDRA antenna arrived to 91.2%.However, the collecting of microstrip antenna and CDRA antenna in one design gave us efficiency of 91%.Therefore, this antenna considered advantageous in several communication sectors including radio telecommunications. In our future research, we propose considering the implementation of circular slots or combination mutable slots to improve the efficiency of the microstrip and DRA antennas. This would include the sequential development of the antenna. To enable its operation across several communication sectors. In this study, we propose modifying the geometry of the CDRA antenna to improve its characteristics and performance, hence increasing both the gain and efficiency. However, it was important to incorporate a range of apertures or discontinuities to improve the radiation pattern. Additionally, the materials employed, such as copper or Rogers RT 5880 (which is a Lossy material), had a crucial role in the overall performance. Therefore, the comparison of results of both designs illustrated in Table 7. That means the new design had high gain and performance as compared to the previous design. In addition, this proposed technology was useful to get high gain and useful to enhance the characteristics of this antenna because of high efficiency. However, Table 8 explained some important differences between CDRA antenna and microstrip path antenna.

Table 8. shows the important differences between CDRA antenna and Microstrip patch antenna

Microstrip patch antenna	CDRA (cylindrical dielectric resonator antenna
Wide bandwidth	Narrow bandwidth
Directional or omnidirectional patterns.	Often Omni- directional. patterns
more complex design	Simple geometry
Applications where directional or broadband performance is needed.	Suitable for applications requiring Omni-directional radiation in a narrow frequency band.

6. Conclusion and future work

As previously elucidated, the enhancement of the microstrip antenna's gain was seen, resulting in a rise in antenna efficiency to a value of 90%, as indicated by equation 1. This improvement was achieved by modifying the geometry of the CDRA antenna as well as the shape of microstrip patch antenna. This involved the utilization of four distinct square slots, which positioned within the antenna patch in various orientations, including to the right, left, and above the patch. However, two of the holes or gaps were small, while the other two gaps or holes were large. The technique referred to collecting two kinds of antenna such as cylindrical DRA and microstrip patch antenna in one design. Therefore, the results were useful, and efficiency increased to 91%. Furthermore, a specialized patch of same dimensions to the one employed in the prior design was utilized to augment the attributes of the CDRA antenna. In the future, we possess numerous plans and ideas aimed at enhancing the performance of the DRA antenna, specifically focusing on augmenting its gain and efficiency. One potential approach involves modifying the geometric configuration of the DRA antenna. For instance, use a combination of many slots, circular slots, or collecting patches or minimizing of the size of the DRA antenna or collect antennas together in one design. Furthermore, the modification of some characteristics of the DRA antenna was undertaken to provide a novel design that distinguishes itself from existing designs, hence improving the overall gain. The efficiency of the CDRA antenna enhanced when the properties of the antenna improved. Nevertheless, the study demonstrates an enhancement in gain to 11.62 dBi at a frequency of 28 GHz for microstrip patch antenna, accompanied by improvements in other parameters such as VSWR, directivity, and bandwidth. Hence, the incorporation of this novel CDRA antenna with microstrip patch antenna design holds potential for application in various communication domains, including radio communication, owing to its notable efficiency of 91%.

However, in future as previously elucidated, the enhancement of the microstrip patch antenna's gain was observed, resulting in an increase in antenna efficiency to a value of 90%, as indicated by equation 1. This improvement was achieved through modifications made to the geometry of the microstrip antenna. This involved the utilization of four distinct square slots positioned within the antenna patch in various orientations, including both right and left directions as well as the upper region of the patch. Furthermore, we employed an identical patch of the same dimensions as the patch utilized in the prior design to augment the attributes of the CDRA antenna. In the future, we possess numerous plans and ideas aimed at enhancing the performance of the DRA antenna, specifically focusing on augmenting its gain and efficiency. One potential approach involves modifying the geometric configuration of the DRA antenna. For instance, employing various configurations such as multiple slots, circular slots, or compact patch or feed in different spatial orientations. Furthermore, modifying certain aspects of the DRA antenna to develop a novel design that distinguishes itself from existing designs and improves the overall gain. The efficiency of the DRA antenna is expected to improve when its properties are enhanced. However, the study demonstrates an enhancement in gain of microstrip patch antenna to 11.62 dBi, accompanied by improvements in other parameters such as VSWR, directivity, and bandwidth at a frequency of 28 GHz .Hence, this novel iteration of the microstrip antenna exhibits potential utility in various communication domains, including radio communication, owing to its notable efficiency of 90%.However,the efficiency of collecting of both antennas microstrip patch and CDRA antennas in one design arrived 91% .that means this new design was useful for communication and radio telecommunications systems because of high performance.

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.

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References

[1] Abdulmajid. A. A., Khalil, Y., & Khamas. S. “Higher-Order-Mode Circularly Polarized Two-Layer Rectangular Dielectric Resonator Antenna”. IEEE Antennas and Wireless Propagation Letters, Vol.17, no.6, pp1114–1117, 2018 doi:10.1109/lawp.2018.2834981.

[2] 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, vol. 12, no. 1, 115–119. 2018, doi:10.1049/iet-map.2018, 0593.

[3] Abedian. M., Rahim, S. K. A., & Khalily. M.. “Two-Segments Compact Dielectric Resonator Antenna for UWB Application”. IEEE Antennas and Wireless Propagation Letters, vol. 6, no 4, pp 1533–1536. 2012, doi:10.1109/ lawp.2012.2232639.

[4] S. Pillai, K. Catchpole, T. Trupke, and M. Green., “Surface plasmon enhanced silicon solar cells,” J. Appl. Phys. Vol. 101, no. 9, 2007. doi:https://doi.org/10.1063/aip-crossmark-policy-page

[5] Lai, Q., Almpanis, G., Fumeaux, C., Benedickter, H., & Vahldieck, R. Comparison of the radiation efficiency for the dielectric resonator antenna and the microstrip antenna at Ka band. IEEE Transactions on Antennas and Propagation, Vol. 56, no. 11, pp3589–3592,2008, doi :10.1109/TAP.2008.2005551

[6] 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.

[7] Drossos, G., Wu, Z., & Davis, L. E. “The air gap effect on a microstrip-coupled cylindrical dielectric resonator antenna”.Microwave & Optical Technology Letters, Vol. 20, no. 1, pp. 36–40, 1998,doi:10.1002/(sici)1098-2760.1999

[8] 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.