# Reconfigurable Radar Antenna Design for UAV Application


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*Abstract*— **Unmanned Aerial Vehicle (UAV) plays an important role in surveillance due to its long endurance and adaptability in locating targets. Sensors are necessary for accessing information in the surveillance area, which could be mounted on the UAV. Radar, particularly those used for surveillance and defence purposes can perform a variety of tasks, alter their configuration parameters, and modify their performance levels in response to the environment's unique characteristics (such as the quantity and variety of threats and tracks) in order to offer the best possible response and handling. As a result, those systems are required to have high efficiency and flexibility. This allows for the resource savings from non-essential functions to be used to improve the performance of other appropriate functions in accordance with operational requirements, such as resolution, search volume, high accuracy, renewal time, track refresh rates, and initialization, among others. By considering all the above-mentioned aspects here, the work is taken up on designing the reconfigurable radar antenna array of 8 × 8. CST software is used to design and analyse the performance of reconfigurable antenna array at various configurations, such as Uniform Linear Array (ULA), Uniform Rectangular Array (URA), and Uniform Circular Array (UCA) based on the directivity, gain, and radiation efficiency.**



***Keywords—UAV, Directivity, Gain, Radiation Efficiency, Reconfigurable Radar Antenna Array.***


## I. INTRODUCTION

Every day, the use of unmanned aerial vehicles (UAVs) is growing. There is no debate that using them can have a significant positive impact in several areas. The primary purpose of UAV is intelligence, surveillance, and reconnaissance because of their extended loiter duration, versatility in locating targets, and difficulty in being detected by adversaries [1]. The UAV's long endurance capability is crucial for surveillance. While surveillance, a proper communication system is necessary to transmit the information.

The continual enhancement and upgrading of wireless communication systems in recent years have substantially increased both the number and complexity of antennas in the same platform [2]. The number of antennas cannot be increased indefinitely due to space limitations. Furthermore, possessing an excessive number of antennas would have several negative impacts, such as increasing electromagnetic interference between them, rendering it challenging to ensure the electrical performance of antennas [3]. The idea of "reconfigurable antenna" emerges at the optimal place and has developed quickly. An antenna that can perform the tasks of numerous antennas while employing a single physical aperture is referred to as being reconfigurable. Examples of such functions include operating in various frequency bands and antenna pointing [4].

The goal of reconfigurable antenna design is to modify the antenna structure to alter the current distribution on the antenna surface and hence modify the antenna's radiation properties. The design of reconfigurable antennas currently relies primarily on engineering expertise, which changes its properties by altering the distribution of current on the antenna element or array using mechanically movable parts, p-i-n diodes, optical switches, and MEMS switches, among other devices [5].

Fractal Reconfigurable Antennas (FRAs) are quickly becoming the current research emphasis due to the significant advancement in antenna engineering research. They are extremely attractive for multifunctional antenna designs because of the alluring characteristics of fractals like self-similarity, self-affinity, and space-filling, as well as electrical reconfigurability to dynamically modify different antenna parameters. The majority of FRAs use traditional microstrip patch antennas on which fractal geometries and reconfigurability are integrated as a crucial part of the antenna design process [6]. Based on the operational antenna parameter that is dynamically altered, reconfigurable antennas can be divided into four categories: frequency reconfigurable antennas, pattern reconfigurable antennas, polarisation reconfigurable antennas, and compound reconfigurable antennas.

This work uses pattern reconfiguration of the fractal antenna array to increase the directivity and radiation efficiency with the limited number of antennas. The performance of various antenna configurations such as ULA, URA, and UCA are investigated for 8×8 antennas. This concept can be used for the UAV application. As the UAV moves randomly, the signal received by the antennas mounted on it from the base-station may degrade at the end-fire direction if ULA is preferred [7]. So, according to the requirement, antenna reconfiguration could be done.

The rest of the paper is arranged as follows. Section II contains the description of the Reconfigurable radar antenna

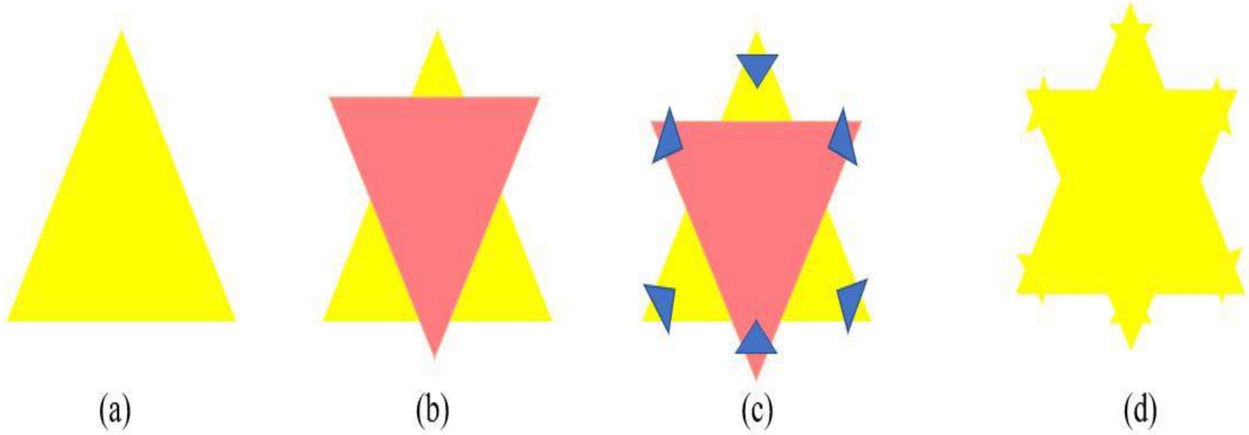

Fig. 1: Patch stages

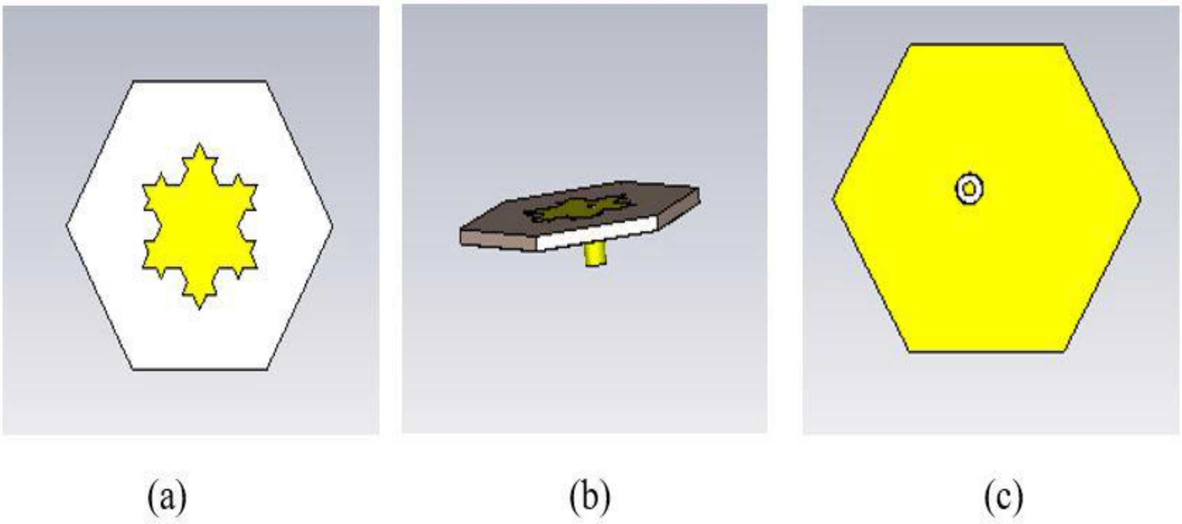

Fig. 2: Single antenna design (a)Front View (b) Side View (c) Bottom View

pattern design. Section III contains the simulation results, and finally, section IV concludes the work.

## II. RECONFIGURABLE RADAR ANTENNA PATTERN DESIGN

### A. Design of Antenna Pattern

The antenna pattern design of the single antenna is depicted in Fig. 2. The top, side and the bottom view of the antenna array are shown in Fig. 2(a), (b), and (c). In the array of antennas, the antenna consists of ground, substrate, patch, and port. The top view contains a patch along with the substrate, and the bottom view includes the ground and port of the antenna.

The material used for the ground was lossy copper with a thickness is 0.35mm. The substrate has been designed in hexagon shape with dimensions A(18, 0), B(9, 15.58), C(- 9, 15.58), D(-18, 0), E(-9,-15.58), F(9, -15.58). The material that was used for the substrate is Rogers RT/duroid 5880 with a thickness of 1.57mm. The patch was made out of lossy copper with a thickness of 0.35mm on top of the substrate.

For the snowflake patch, three iterations are considered. The dimension of an equilateral triangle in the 0th iteration is 15.588mm, with the distance from the vertex to the centroid of this equilateral triangle being 9mm. At every iteration, the size of the triangle is decreased by a factor of 0.3, and it was placed on each side with a distance of 1/3 rd from each vertex on which it was placed. The stages of patch are depicted in Fig. 1.

A coaxial probe was also added. The inner pin is with 0.7mm radius. The outer pin which is in the form of a cylinder is with a outer radius of 1.6mm and inner radius of 1.5mm. A Teflon layer with PTFE material was added between the external pin and the ground to prevent it from shorting. Dimensions of the Teflon are 1.5mm and 0.7mm. The outer pin has been merged along with the ground, and then the internal pin extends until the patch has been merged.

### B. Proposed Mechanism

There are different mechanisms used by the researchers to reconfigure the antennas for different applications. In this work, reconfiguration is done by activating the particular ports of the antennas in the array to radiate while leaving other ports inactive. Reconfiguration of 8 × 8 antenna arrays is done with various patterns such as ULA, URA, and UCA.

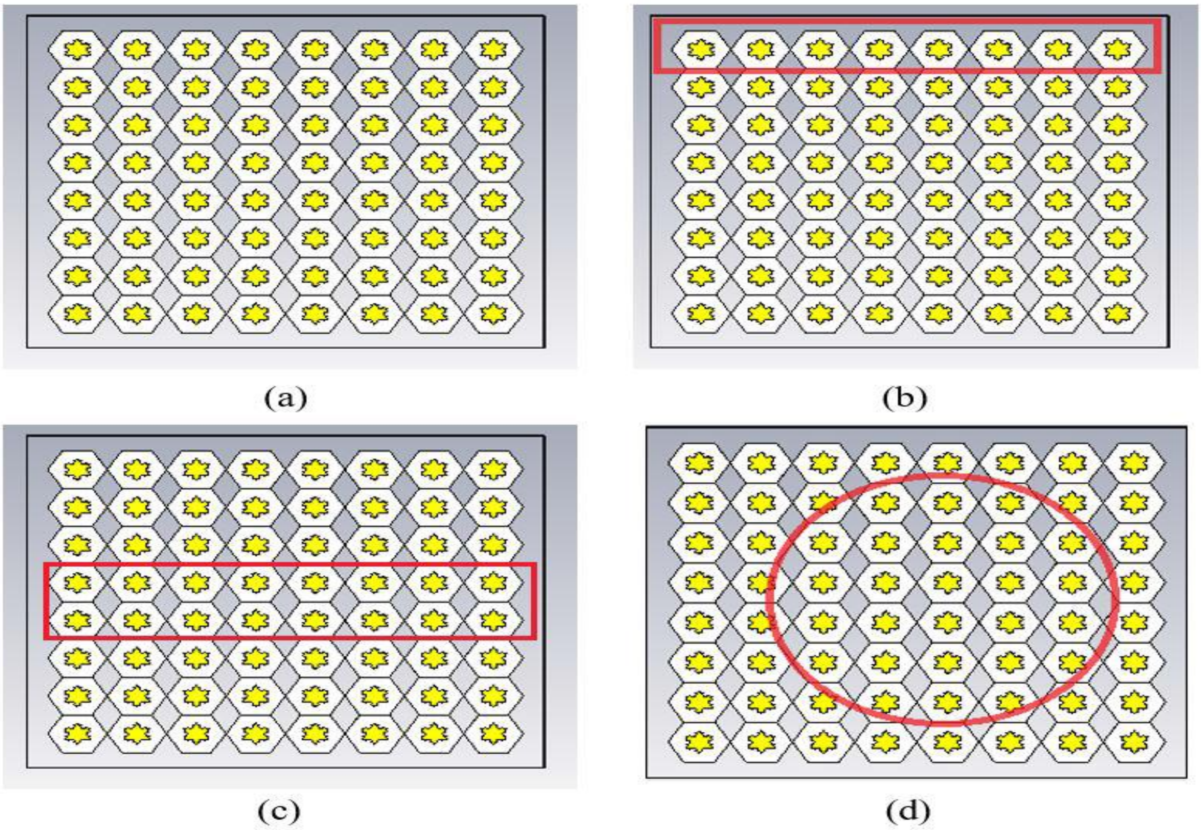


Fig. 3: Antenna Array (a)8 × 8 (b) ULA Configuration (c) URA Configuration (d) UCA Configuration

These particular patterns are selected because they are the most basic configurations used by the researchers.

Fig 2. depicts the single antenna design with its Front, side, and bottom view. Fig 3. represents the Antenna Array with 8 × 8. Fig 3 (b) depicts when 1 × 8 antennas are active, i.e., ULA configuration. Similarly, Fig 3 (c) depicts the activation of 2 × 8 antenna pattern, i.e., URA, and Fig 3 (d) shows the UCA configuration.

### *C. Application*

The proposed mechanism can be used in the UAV application. Considering a scenario where a swarm of UAVs is used for patrolling over an area. For communicating among themselves, the antenna is required. For transmitting the signal, an array of antennas can be used to obtain high directivity and gain for proper communication. The continuous and random movement of UAVs and stable links among themselves is tough. In order to do so, a reconfigurable antenna pattern can be used during data transmission with less power consumption. If the received data by the antennas is in the end-fire direction, then the quality of the signal may degrade for ULA configuration [7]. So, according to the signal reception, the configuration of the antenna array can be modified for a quality result.

## III. Simulation Results

The antenna model is designed and simulated on CST 2020 version. The bandwidth of the proposed antenna was observed to be 268.7 MHz, while the operating frequency is at 10.52 GHz. In this section, results are discussed based on the Gain, Directivity, Radiation efficiency and Radiation pattern.

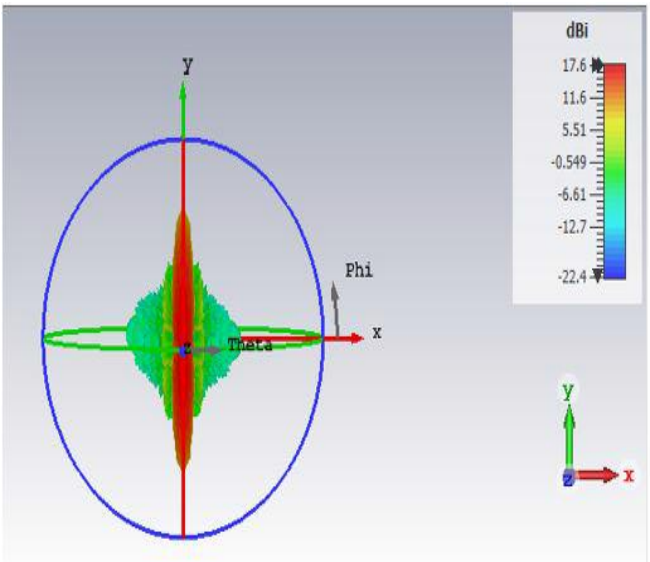


Fig. 4: ULA Directivity

### *A. Gain, Directivity and Radiation Efficiency*

The directivity and gain values of various antenna configurations are depicted in Fig. 4-6 and Fig. 7-9, respectively. The radiation efficiency of all types of array simulations is greater than 95%. The values of the gain and directivity are tabulated in Table 1.

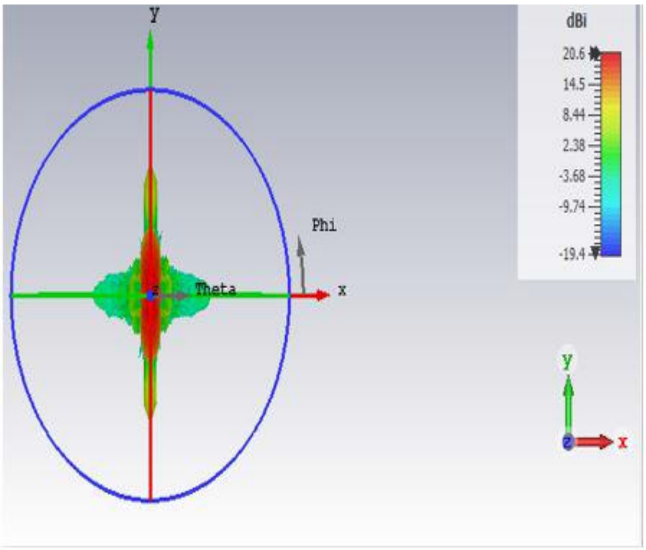


Fig. 5. URA Directivity

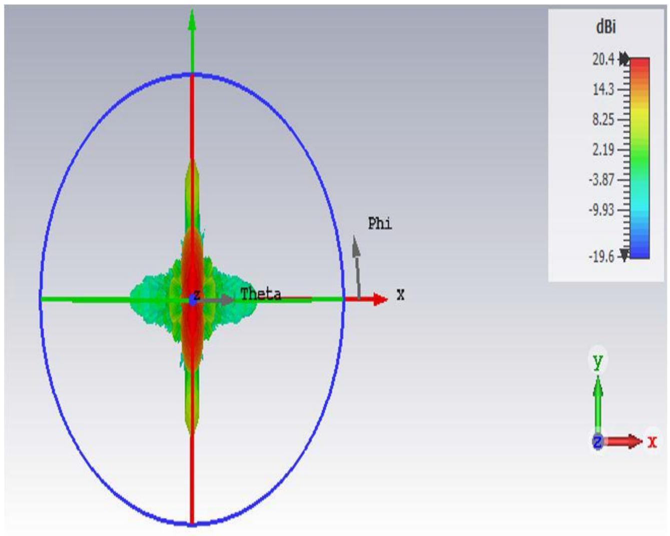


Fig. 8. URA Gain

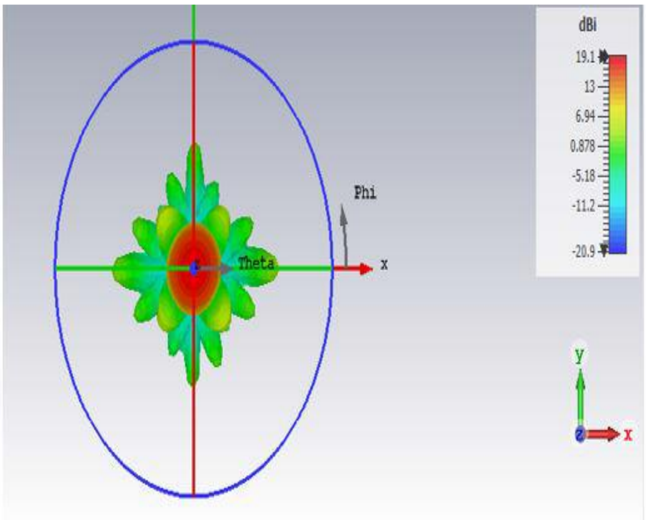


Fig. 6. UCA Directivity

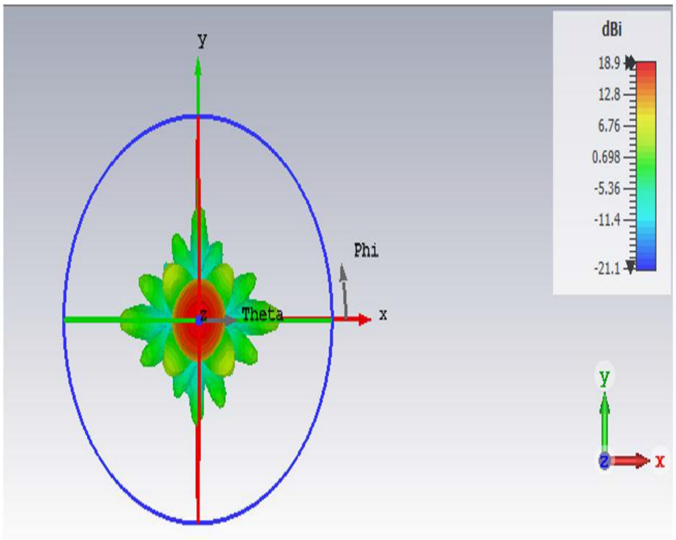


Fig. 9. UCA Gain

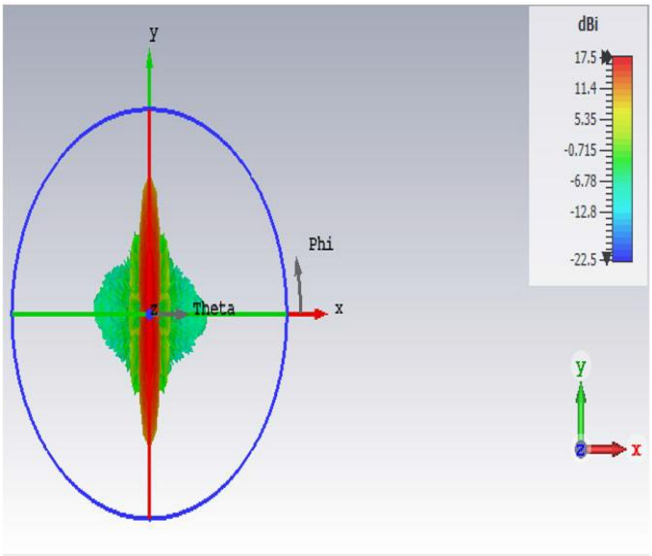


Fig. 7. ULA Gain

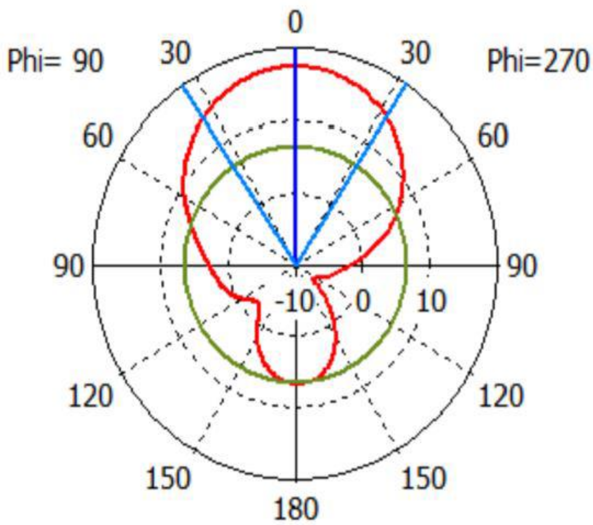


Fig. 10. ULA E-field

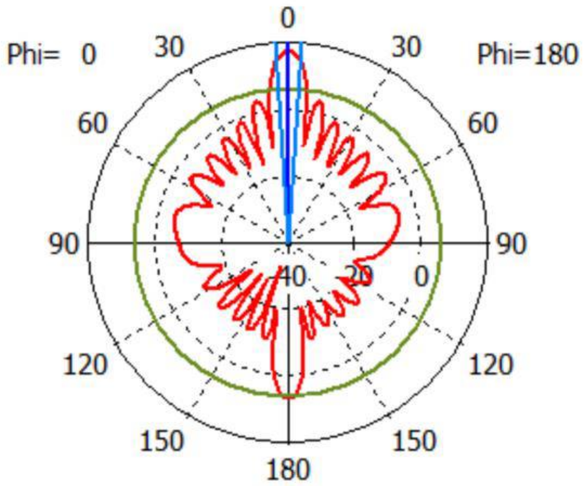


Fig. 11. ULA H-field

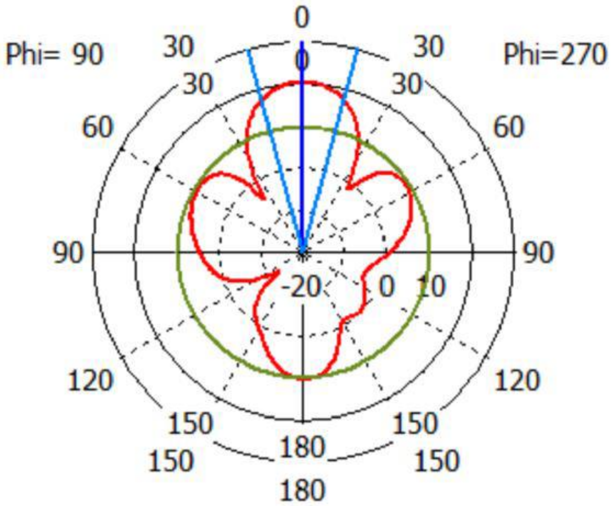


Fig. 12. URA E-field

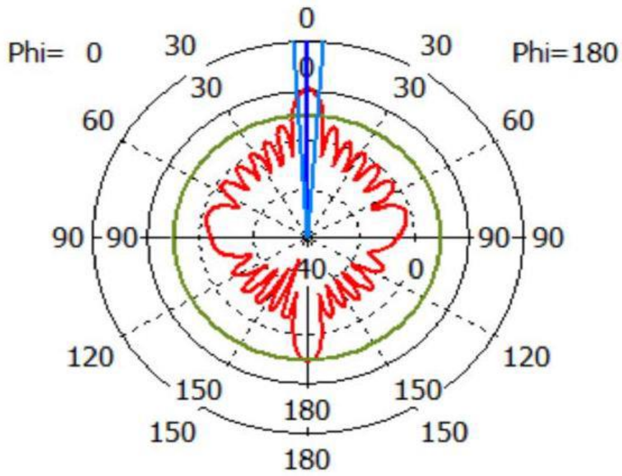


Fig. 13. URA H-field

Table. 1. Gain, Directivity and Radiation Efficiency of various configurations

| Configuration | Directivity | Gain | Efficiency |
|---|---|---|---|
| ULA | 17.63dBi | 17.47 dBi | 96.23 % |
| URA | 20.56 dBi | 20.38 dBi | 95.82 % |
| UCA | 19.06 dBi | 18.88 dBi | 95.93 % |

Table. 2. Comparison with Existing work

| Year | Antenna Array | Directivity | Gain | Efficiency | Band |
|---|---|---|---|---|---|
| 2013 [8] | 4 × 1 | 13.24 dBi | 12.87 dBi | 91.90 % | X Band |
| 2016 [9] | 64 | 8.3 dB | 7.4 dB | 80.71 % | X Band |
| 2019 [10] | 1 × 8 | - | 6.39 dBi 3.82 dBi | - | C& X Band |
| 2020 [11] | 1 × 2 | 15.5 dBi | 14.20 dBi | 89.65 % | X Band |
| Proposed | 8 × 8 (1 × 8 (ULA), 2 × 8 (URA), UCA) | 17.63 dBi, 20.56 dBi, 19.06 dBi | 17.47 dBi, 20.38 dBi, 18.88 dBi | 96.23 %, 95.82 %, 95.93 % | X Band |

### *B. Radiation Pattern*

The E-field and H-field radiation patterns of all three configurations are observed at the resonant frequencies at f=10.52 GHz depicted in Fig. 10-15. In all the cases, the radiation pattern is stable and highest towards the main lobe.

### *C. Proposed reconfigurable radar antenna vs Existing work*

The proposed reconfigurable radar antenna is compared with the existing work in Table. 2. It could be observed that

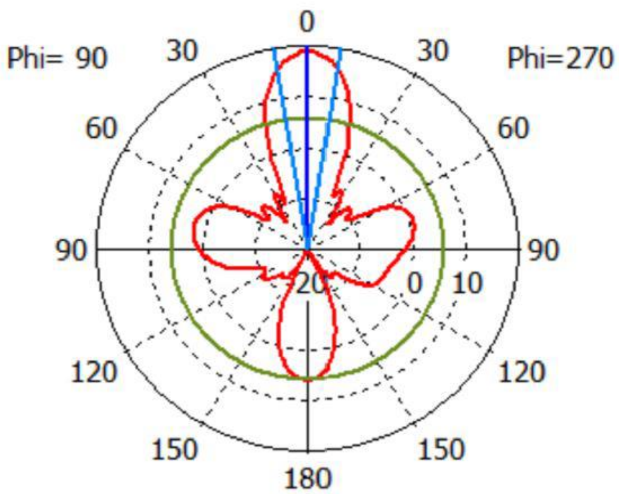


Fig. 14. UCA E-field

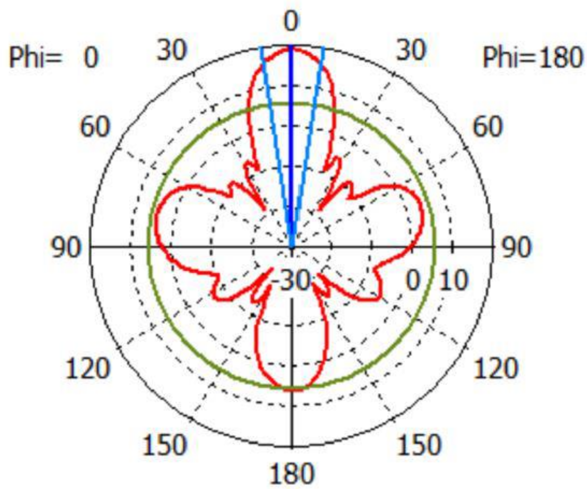


Fig. 15. UCA H-field

proposed reconfigurable radar antenna perform better than other existing works.

## IV. Conclusion

In this paper, 8 × 8 antenna array is designed using a snowflake fractal antenna to monitor the behaviour at various configurations such as ULA, URA, and UCA. Reconfiguration of the antenna is examined using the directivity and gain. The radiation efficiency of the ULA is more as compared to the other two configurations, whereas the directivity of URA is better. As the UAV moves continuously, the Direction of Arrival of the signal will vary, which may degrade the system's performance. So, according to the requirement of the application 8 × 8 antenna array could be reconfigured. The operating frequency is 10.52 GHz which is feasible for the military radar application for intruder detection. URA can be preferred for obtaining higher directivity, whereas ULA for getting better radiation efficiency in order to get quality signal processing.

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