



IMPLEMENTATION AND ANALYSIS OF CYLINDRICAL DIELECTRIC RESONATOR ANTENNA AT 6GHz, 4GHz USING HFSS

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Abstract: The project presents the Implementation and Analysis of CDRA antenna operating at 6GHz frequency on Rogers RT substrate using ANSYS HFSS simulation software. The cylindrical geometry is selected due to its fabrication simplicity, and its capacity to deliver a uniform radiation pattern, which is essential for reliable communication. Dielectric resonator antennas are widely recognized for their exceptional radiation efficiency and broad operational bandwidth, making them highly suitable for advanced applications such as Internet of Things (IoT), 5G communication networks, and Satellite Communication systems. By employing HFSS, critical antenna performance metrics, including Return loss (S11), VSWR, Radiation patterns can be accurately derived and optimized.

Index Terms – CDRA antenna, HFSS, Return loss, VSWR, Radiation pattern

I. INTRODUCTION

A Cylindrical Dielectric Resonator Antenna (CDRA) is a type of antenna that utilizes a cylindrical dielectric material to achieve efficient radiation. These antennas are particularly suitable for high-frequency applications due to their low loss and compact design. When operated at frequencies like 6GHz and 4GHz, they can cater to various wireless communication needs, including 5G and beyond. The Rogers RT 5880 substrate is often chosen for such designs because of its excellent dielectric properties, including a low dielectric constant ($\epsilon_r = 2.2$) and minimal loss tangent ($\tan \delta = 0.0009$). These are the characteristics that ensure high efficiency and stable performance. The CDRA is typically excited using techniques like microstrip lines, aperture coupling, or probes, which help achieve the desired resonant modes and frequencies.

This antenna design is ideal for applications requiring high data rates and bandwidth, as it minimizes conductor and surface wave losses. The cylindrical shape allows for versatile mode excitation, making it adaptable for various configurations.

II. LITERATURE SURVEY

Dielectric Resonator Antenna (DRA) using alumina ceramic and Rogers RT substrates are widely preferred for C-band applications (4 GHz–6 GHz) due to their high radiation efficiency, low loss, compact size, and wide bandwidth. The alumina ceramic dielectric resonator ($\epsilon_r \approx 9.9$) enables miniaturization while ensuring stable resonance, whereas Rogers RT substrates (RT5880) minimize dielectric and conductor losses, enhancing signal transmission. The microstrip feed network simplifies integration with RF circuits, making DRAs more efficient than microstrip patch antennas by eliminating surface wave losses. These antennas find applications in wireless communication (5G, Wi-Fi, fixed wireless access), satellite communication (C-band uplink/downlink), radar systems (weather, air traffic control, military), biomedical imaging, and aerospace/defense (UAVs, electronic warfare). Their advantages over conventional antennas include higher efficiency, broad bandwidth, superior temperature stability, and seamless integration with modern RF circuits. Additionally, future advancements in metamaterial-based DRAs, hybrid feeding techniques, and reconfigurable designs will further enhance their gain, bandwidth, and adaptability for next-generation wireless and satellite communication systems.

III. IMPLEMENTATION METHODOLOGY

The design and simulation of the Cylindrical Dielectric Resonator Antenna (CDRA) were carried out using Ansys HFSS 11 software. The antenna structure was developed to operate at dual resonant frequencies of 4 GHz and 6 GHz, making it suitable for wireless and communication applications in this frequency range. Rogers RT/Duroid 5880 was selected as the substrate material due to its low dielectric constant ($\epsilon_r = 2.2$) and low loss tangent ($\tan \delta = 0.0009$), which make it highly suitable for high-frequency antenna designs, ensuring minimal signal loss and enhanced efficiency.

The antenna model comprises a cylindrical dielectric resonator mounted on the Rogers RT/Duroid 5880 substrate. The resonator is made from a high-permittivity dielectric material, such as Alumina ($\epsilon_r = 9.8$), to achieve compact size and high radiation efficiency. The substrate dimensions were chosen as 50 mm $\times$ 50 mm with a thickness of 1.6 mm. The dimensions of the cylindrical dielectric resonator specifically, its height and radius were calculated using the dielectric waveguide model (DWM) to support the mode at 4 GHz and a higher-order mode at 6 GHz. A microstrip feed line was designed to excite the resonator effectively, and a full ground plane was included to ensure proper radiation characteristics.

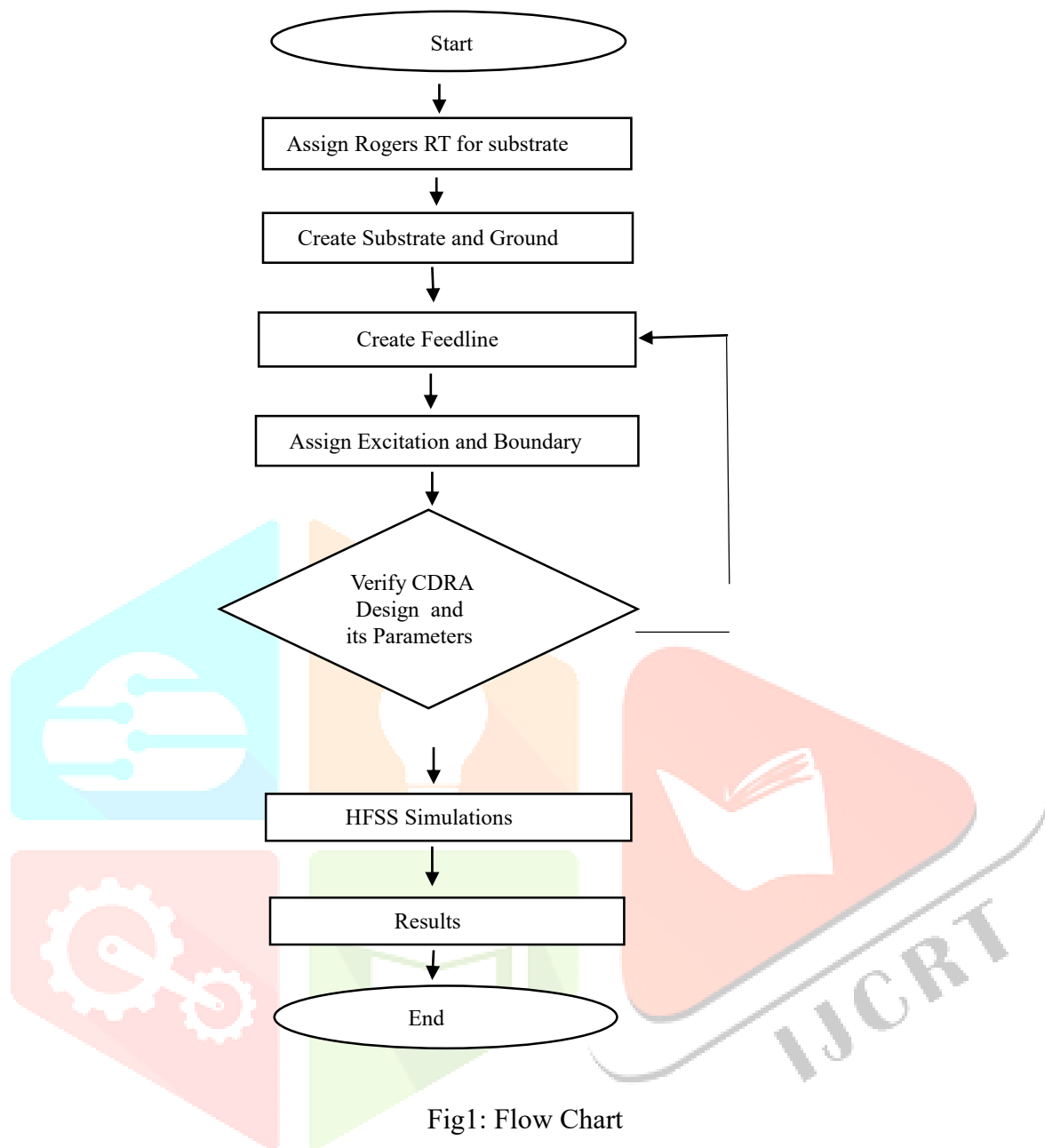


Fig1: Flow Chart

The design was modeled and simulated in HFSS by defining the geometry of the substrate, resonator, and feed structure in the 3D simulation environment. The material properties were assigned to each component, and wave ports were used to excite the antenna. Radiation boundaries were applied around the model to allow electromagnetic waves to propagate freely. Mesh refinement was performed using adaptive meshing to ensure accurate computation of electromagnetic fields, and convergence was achieved over multiple simulation passes.

After the initial simulation, the antenna parameters were optimized to achieve better performance. Parameters such as resonator height, radius, feed line dimensions, and feed position were adjusted to fine-tune the resonance behaviour. The antenna was optimized to provide good return loss ($S_{11} < -10$ dB) at both 4 GHz and 6 GHz. The simulation results were then analyzed to evaluate the return loss, VSWR, radiation pattern, gain, and surface current distribution. These parameters helped in understanding the radiation mechanism, impedance matching, and overall performance of the designed CDRA antenna.

Design Equations:

- Resonator dimension: $r = \frac{c}{2\pi f_r \sqrt{\epsilon_r}}$
- Substrate Dimensions: **Length (Ls):** $L_s = \lambda/2$ (Where: $\lambda = c/f_r$)

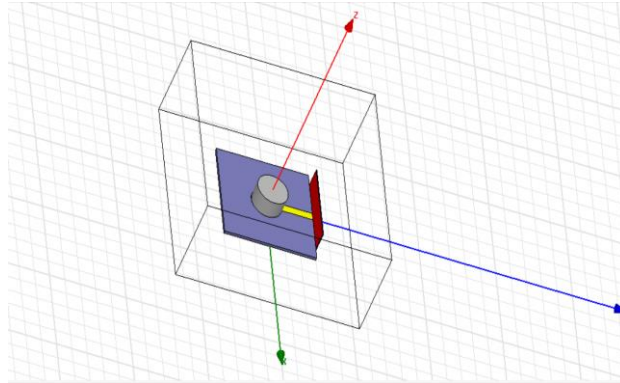


Fig2: CDRA Design model

RESULTS AND DISCUSSION

The following results are obtained with output results being mainly concentrated on the basic antenna parameters such as Return Loss, VSWR, Radiation pattern and Gain

1. RETURN LOSS :

The variation of the Frequency versus Return Loss (S11) of the CDRA antenna at 4GHz and 6GHz are shown in figure. It can be observed that the antenna resonates at a frequency of 4GHz with a return loss of -27dB, 6GHz with a return loss of -19dB

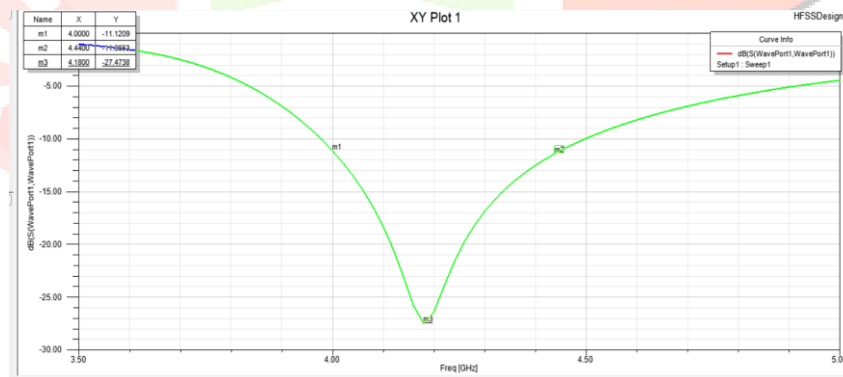


Fig3: S11 parameter of CDRA at 4GHz

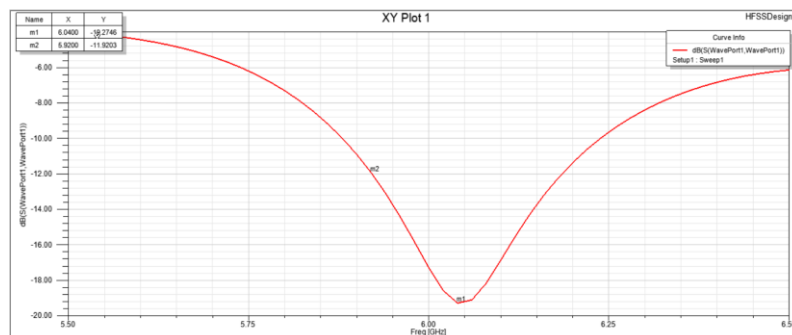


Fig4: S11 parameter of CDRA at 6GHz

2. RADIATION PATTERN:

Describes how an antenna radiates power in different directions.

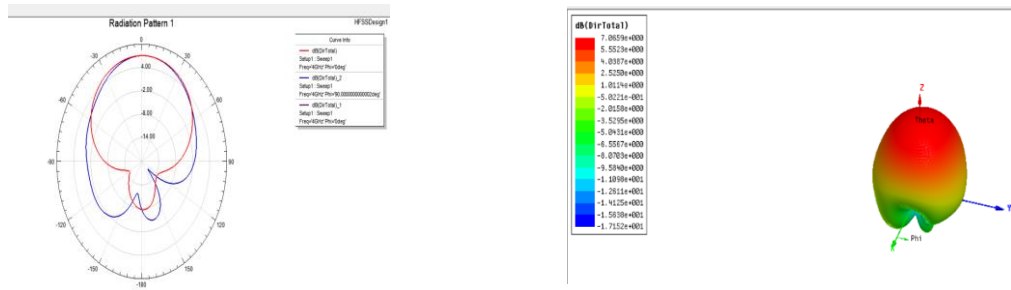


Fig5. Radiation pattern and 3D Polar Plot of Total radiated Electric field of a CDRA at 4GHz

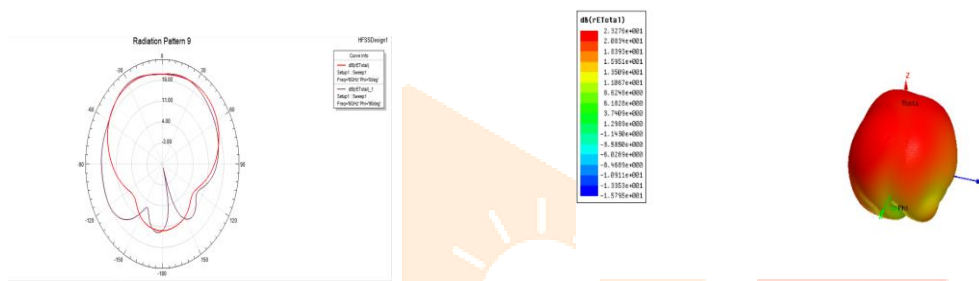


Fig6: Radiation pattern and 3D Polar Plot of Total radiated Electric field of a CDRA at 6GHz

3. GAIN:

The term antenna gain describes how much power is transmitted in the direction of peak radiation. From the following figure, it is seen that the maximum gain observed is 6.89dB.

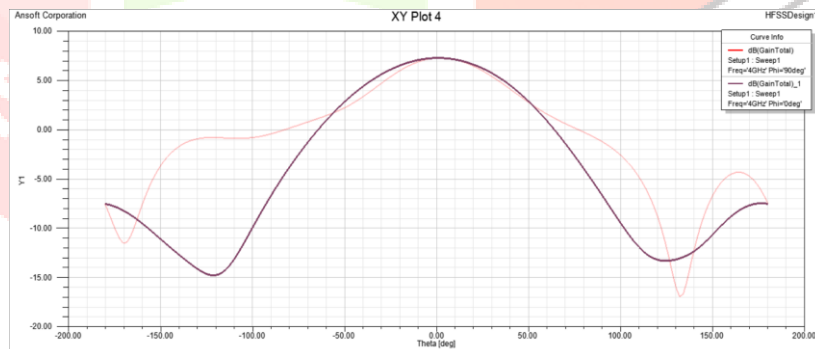


Fig7: Gain of CDRA at 4GHz

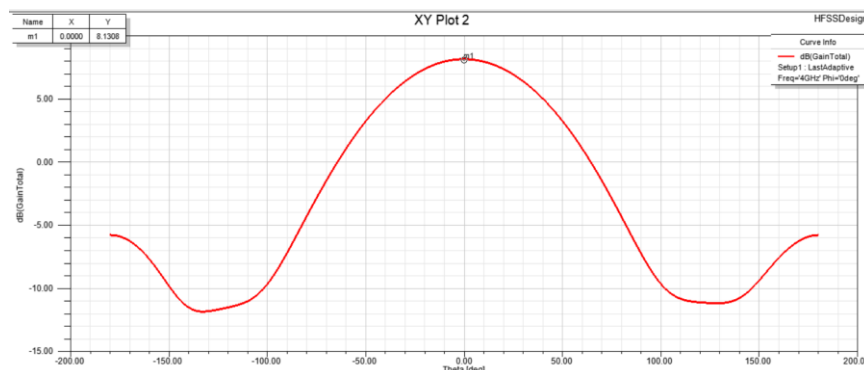


Fig8: Gain of CDRA at 6GHz

4. VSWR:

It illustrates the variation of Frequency with the VSWR. From the figure, it can be noted that the VSWR is 0.7 at 4.1GHz, 1.93 at 6GHz

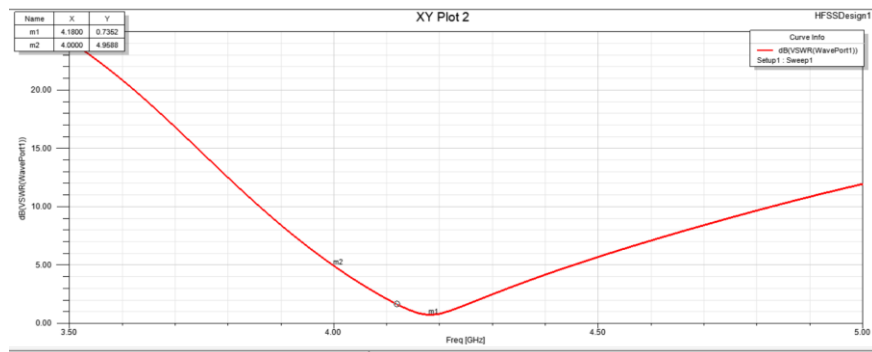


Fig9: VSWR of CDRA at 4Ghz

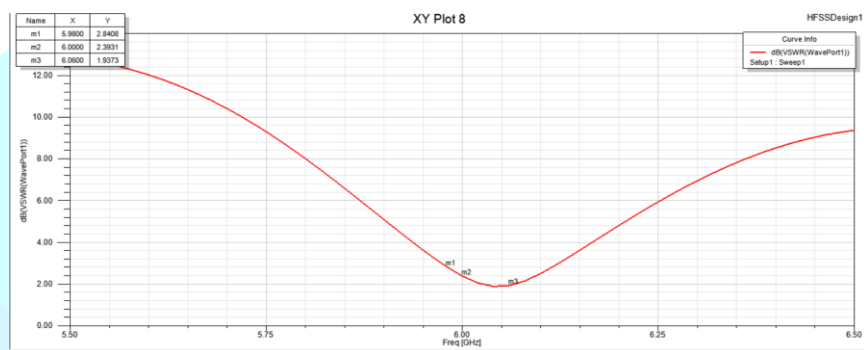


Fig10: VSWR of CDRA at 6Ghz

V. CONCLUSION

In this project, Cylindrical Dielectric Resonator Antenna (CDRA) was designed and analysed for operations at 4 GHz and 6 GHz

frequency using Alumina Ceramic as the resonator and Rogers RT 5880 as the substrate. The goal was to evaluate the antenna's performance in terms of return loss, gain, VSWR, and radiation efficiency at these frequencies. The simulation results obtained from HFSS indicate that at 4 GHz, the antenna exhibited good gain and stable radiation characteristics, while at 6 GHz, it demonstrated enhanced bandwidth and improved impedance matching. Overall, the combination of Alumina as the resonator and Rogers RT 5880 as the substrate provides a balance between compact size, efficiency, and bandwidth, making it suitable for high-frequency applications.

VI. REFERENCES

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