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Design and Simulation of a Cylindrical Dielectric Resonator Antenna at 4GHz

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Abstract: *This paper presents the detailed design, analysis, and simulation of a Cylindrical Dielectric Resonator Antenna (CDRA) operating at 4 GHz in the C-band frequency range. Dielectric Resonator Antennas offer high radiation efficiency, compact size, and minimal conductor losses at microwave frequencies. The proposed antenna uses a cylindrical dielectric resonator with relative permittivity of 10 and is excited using a coaxial probe feed to stimulate the dominant TE01δ mode. The antenna is modeled and optimized using ANSYS HFSS. Simulated results demonstrate a minimum return loss of –32.29 dB at 4.18 GHz, VSWR of 1.05, peak gain of 7.39 dBi, and bandwidth of approximately 260 MHz (S11 < –10 dB). The radiation pattern is broadside and stable across the operating band. The proposed antenna is suitable for radar, satellite, and wireless communication systems operating in the C-band.*

Keywords: Dielectric Resonator Antenna (DRA), HFSS Software, C-Band, Return Loss, Radiation Pattern, Microwave Antenna

I. INTRODUCTION

With the rapid advancement of wireless communication, radar systems, and satellite technology, there is an increasing demand for compact and efficient microwave antennas. Conventional metallic antennas suffer from conductor losses at higher frequencies, reducing their overall radiation efficiency. Dielectric Resonator Antennas (DRAs) have emerged as an effective alternative due to their low loss characteristics, high radiation efficiency, and flexible design configurations.

The C-band frequency range (4–8 GHz) is widely used in satellite communication, weather radar, military radar, and high-speed wireless backhaul systems. Antennas designed for this band must exhibit stable impedance matching, sufficient bandwidth, and directional radiation characteristics. Cylindrical DRAs are particularly attractive due to their simple geometry and ability to support well-defined resonant modes.

II. DESIGN METHODOLOGY

The resonant frequency of a cylindrical dielectric resonator depends on its radius (a), height (h), and dielectric constant (εr). The dominant TE01δ mode is commonly used for radiation because of its stable broadside pattern and efficient performance.

According to the Dielectric Waveguide Model (DWM), increasing the dielectric constant reduces the resonant frequency and antenna size, while decreasing the dielectric constant improves bandwidth. The radiation quality factor (Q-factor) is inversely proportional to bandwidth. Therefore, an optimal dielectric constant of approximately 10 is selected to balance size reduction and bandwidth performance.

Proper probe placement and feed height adjustment are essential for achieving good impedance matching near 50 Ω. The excitation of the TE01δ mode ensures efficient radiation and minimal reflection.

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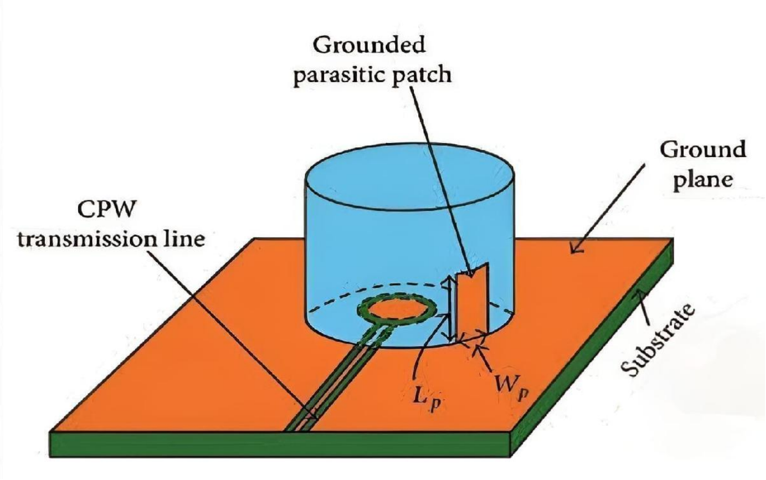

Fig 2.1.Working Model

The resonant behavior of the cylindrical dielectric resonator is strongly influenced by its physical dimensions and dielectric constant. Proper optimization of these parameters helps achieve efficient mode excitation and stable antenna performance at the desired operating frequency.

III. ANTENNA CONFIGURATION AND IMPLEMENTATION

The proposed CDRA consists of a cylindrical dielectric resonator mounted on a copper ground plane. The dielectric material used has a relative permittivity of 10 and low loss tangent. The antenna is excited using a 50-ohm coaxial probe feed inserted into the resonator at an optimized position.

The cylindrical dielectric resonator is designed to operate at a target frequency of 4 GHz in the C-band. The dimensions of the resonator, including radius and height, are determined based on the dielectric waveguide model to ensure proper excitation of the dominant $TE_{01}\delta$ mode. A dielectric material with relative permittivity ($\varepsilon r \approx 10$) is selected to achieve a compact size while maintaining good radiation efficiency.

The resonator is placed on a metallic ground plane, which acts as a reference surface and helps in shaping the radiation characteristics of the antenna. The coaxial probe feed is inserted through the ground plane into the dielectric resonator at an optimized position to achieve proper impedance matching and efficient energy coupling.

The surrounding region is modeled as an air box, and appropriate radiation boundary conditions are applied to simulate free-space radiation. The feed dimensions, probe height, and position are carefully optimized through simulation to minimize return loss and improve bandwidth. This configuration ensures stable antenna performance and efficient radiation in the desired frequency range.

In addition, parametric analysis is carried out to study the effect of various design parameters such as dielectric constant, resonator dimensions, and probe position on antenna performance. By adjusting these parameters, the antenna characteristics such as return loss, bandwidth, and gain are optimized. This iterative design approach ensures that the antenna meets the desired specifications for C-band applications with improved efficiency and stable radiation characteristics.

The simulation is carried out using ANSYS HFSS. A radiation boundary is applied around the antenna structure to simulate free-space conditions. Adaptive meshing is used to ensure accurate electromagnetic field computation.

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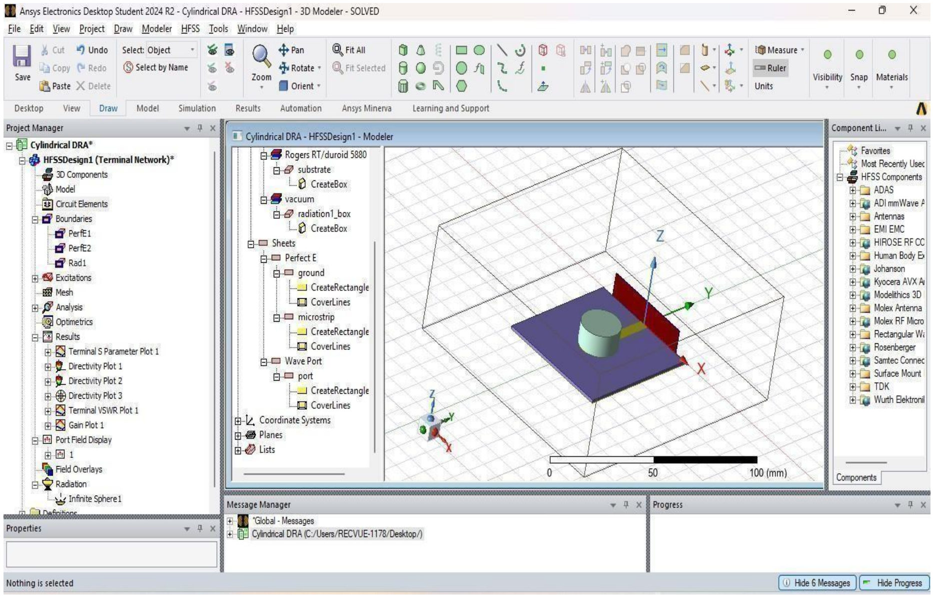

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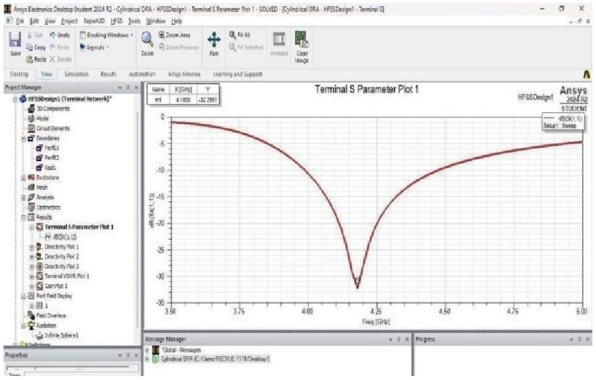
Cylindrical DRA (C:/Users/RECVUE-1178/Desktop/)

Fig 3.1 Implementation in HFSS

Key simulation parameters include resonant frequency at 4 GHz, copper ground plane, coaxial feed excitation, and air box enclosure. The resonator dimensions are optimized to achieve minimal return loss and maximum gain.

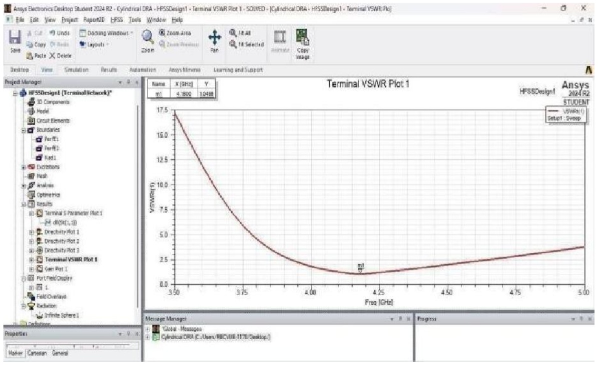
IV. RESULTS

The simulated return loss (S11) reaches a minimum of –32.29 dB at 4.18 GHz, indicating excellent impedance matching. The –10 dB bandwidth spans from 4.05 GHz to 4.31 GHz, giving a bandwidth of approximately 260MHz



Name	X [GHz]	Y
m1	4.1800	-32.2897

Fig.4.1 Return Loss Plot



Name	X [GHz]	Y
m1	4.1800	1.0498

Fig.4.2 VSWR Plot

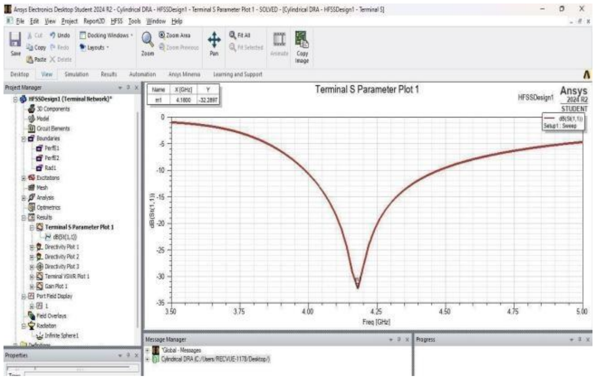


Fig.4.3 Gain Plot

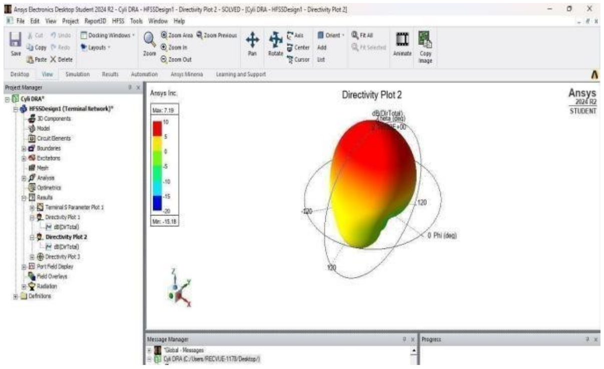


Fig.4.4 Directivity Plot

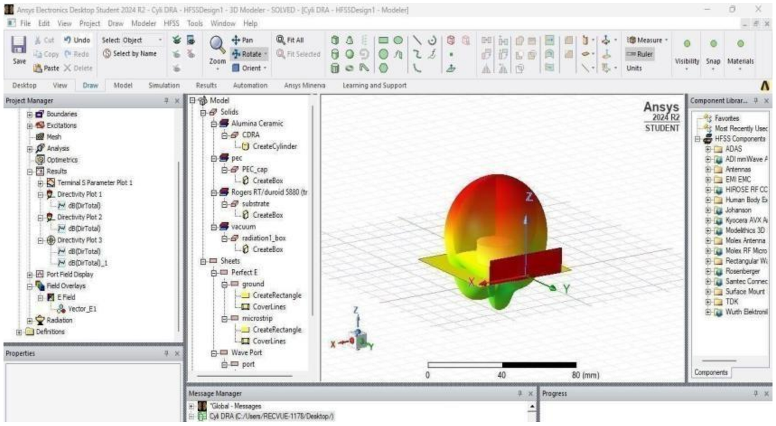


Fig.4.5 Radiation Pattern

The VSWR at resonance is 1.05, confirming efficient power transfer from the feed to the antenna. The input impedance at resonance is close to 50 Ω.

The simulated peak gain of the antenna is approximately 7.39 dBi. The radiation pattern shows a broadside main lobe perpendicular to the ground plane. The pattern is symmetric and stable, making the antenna suitable for point-to-point communication applications.

The combination of compact size, high efficiency, and adequate bandwidth makes the proposed CDRA suitable for integration into C-band communication systems.

The obtained results indicate that the antenna achieves good impedance matching at the desired operating frequency. The low VSWR value confirms efficient power transfer from the feed to the antenna. The radiation pattern shows stable directional characteristics suitable for C-band communication systems. These results demonstrate that the proposed CDRA design provides reliable performance for microwave and wireless communication applications.

V. APPLICATIONS

The proposed antenna can be used in satellite ground terminals, radar systems, C-band wireless communication systems, UAV communication modules, and high-speed microwave links. The compact size allows easy integration into modern embedded RF systems.

Furthermore, the compact size and low-loss characteristics of the cylindrical dielectric resonator antenna make it ideal for integration into modern wireless devices and embedded systems. It can be used in Internet of Things (IoT) devices, smart communication modules, and portable RF systems where size and efficiency are critical. The

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antenna's ability to provide consistent performance with minimal interference makes it a strong candidate for next-generation wireless technologies.

VI. FUTURE SCOPE

Future enhancements may include designing multiband or wideband DRAs, developing DRA arrays for higher gain, and implementing reconfigurable feeding techniques. Fabrication and experimental validation can also be performed to compare practical and simulated results.

Future improvements of the proposed CDRA can focus on enhancing bandwidth and gain by modifying the resonator geometry or by using multilayer dielectric structures. Techniques such as stacking multiple dielectric layers or introducing air gaps can be explored to achieve wideband performance. Additionally, optimization of feeding techniques, such as slot coupling or microstrip feeding, can further improve impedance matching and radiation efficiency.

VII. CONCLUSION

A Cylindrical Dielectric Resonator Antenna operating at 4 GHz has been successfully designed and simulated. The antenna demonstrates excellent return loss, low VSWR, good gain, and stable radiation pattern. The proposed CDRA is suitable for C-band radar, satellite, and wireless applications.

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