DESIGN AND OPTIMISATION OF RFID ANTENNA ARRAY USING DEEP LEARNING

A Srinag[1], Batta Rakesh[2], Attili Durga Prasad[3], Addanki Saibabu Maheswar[4], Gundabathini Ajay Kumar[5],

[1]*Assistant Professor, Department of ECE, Vasireddy Venkatadri Institute of Technology, Nambur, Guntur, Andhra Pradesh, India*
[2-5]*Undergraduate Students, Department of ECE, Vasireddy Venkatadri Institute of Technology, Nambur, Guntur, Andhra Pradesh, India*

ABSTRACT

The Project focuses on the development and optimization of an antenna scheme for an innovative IoT system that uses dual band UHF/2.45GHz Radio Frequency Identification (RFID). We are using state-of-the-art Ansys HFSS software for the designing of antenna of monopole shape, which will also give us the gain, s11 parameters, dimensions of that antenna. We aim to achieve the proposed antenna capabilities in terms of range,data transfer speed and energy efficiency. To increase the gain and versatility we designed the single RFID antenna into a 2 x 2 array, arrays are generally desinged to increase the performance of the antenna, we first designed an antenna and then created a duplicate along the line thereby creating a 2 x 1 antenna and then creating a duplicate antenna along the axis for the final antenna design. We used deep learning for the optimization of the antenna by creating an Artificial Neural Network algorithm in the google colab using TensorFlow framework, our project results are of regression model and verified the simulated results from Ansys with the trained model results of the colab.

Keyword: - *Radio Frequency Identification (RFID) Antenna Array, Deep Learning, IoT(Internet of Things),Ultra High Frequency(UHF)reader antenna,*Design Optimization, Optimization Algorithms, Artificial Neural Networks, Antenna Performance, Antenna Array Deployment

1. INTRODUCTION

Radio Frequency Identification (RFID) technology has revolutionized various industries by enabling efficient tracking, monitoring, and management of assets, products, and resources. With its ability to wirelessly identify and communicate with RFID tags, this technology has found widespread applications in sectors such as retail, logistics, healthcare, and manufacturing. Traditionally, RFID systems have relied on single antennas to perform tasks such as tag reading and data transmission. However, to meet the evolving demands of modern applications, there is a growing need for RFID systems with enhanced performance, coverage, and adaptability. This has led to a surge of interest in the design and optimization of RFID antenna arrays. Antenna arrays offer several advantages over single antennas, including increased read range, improved directionality, and enhanced interference rejection. By leveraging multiple antennas strategically arranged in an array configuration, RFID systems can achieve superior performance and efficiency, making them suitable for demanding applications such as inventory management, asset tracking, and supply chain optimization. In recent years, there has been a growing interest in applying deep learning techniques to the design and optimization of RFID antenna arrays. Deep learning, a subset of artificial intelligence (AI) that employs neural networks with multiple layers, has demonstrated remarkable capabilities in solving complex optimization problems and extracting patterns from large datasets.

This manuscript explores the potential of deep learning in the design and optimization of RFID antenna arrays. We examine the various stages of the antenna array design process, from data generation and model training to optimization and performance evaluation. Additionally, we discuss the advantages, challenges, and future directions of integrating deep learning with RFID antenna array design. Furthermore, we highlight the role of Mohamed Kheir, an esteemed expert in this field, in advancing research and development efforts related to RFID antenna arrays. His expertise and contributions have significantly contributed to the progress of this emerging field, paving the way for innovative solutions that push the boundaries of RFID technology.

2. EXISTING SYSTEMS

This research proposes a novel system board integrating antenna schemes for dual-band Ultra-High Frequency (UHF, 920-925 MHz) and 2.45 GHz Radio Frequency Identification (RFID) reader antennas, tailored for Internet of Things (IoT) applications. This integrated antenna setup enables simultaneous NFC and UHF RFID functionalities. The NFC and UHF RFID modules, connected in series to a microcontroller with a Wi-Fi module (NodeMCU), facilitate the reading of Universal Identification (UID) from NFC and UHF RFID tags. Subsequently, the data is transmitted to a cloud server via IoT for accessibility on smartphones through the Blynk mobile application.
To achieve optimal antenna performance, simulations were conducted using CST Studio Suite. Prototype antennas were then fabricated and integrated into the system board to facilitate near- and far-field communication for IoT applications. The simulation results align closely with measured outcomes. The NFC reader antenna resonates at 13.56 MHz, while the dual-band UHF/2.45 GHz RFID reader antenna covers the 920-925 MHz and microwave (MW) bands with high isolation. The novelty of this integrated NFC and UHF RFID antenna scheme lies in its utilization of cloud technology for storing real-time and archival data, replacing conventional servers. The ability of the integrated antenna scheme to cover NFC, UHF, and MW frequency bands renders it highly suitable for a diverse range of IoT applications.

3. PROPOSED SYSTEM

3.1 DUALBANDUHF/2.45GHzREADER ANTENNASTRUCTURE

The initial rectangular monopole antenna design consisted of a radiating element, a feed line, and a ground plane, all printed on an FR-4 substrate with specific dimensions and material properties. However, the initial design faced challenges in achieving impedance matching and resonance frequencies within the target UHF RFID band and the 2.45 GHz RFID band.

Parameters	*W*	*L*	*W1*	*W2*	*W3*	*W4*
Unit (mm)	41	100	27	17.5	4	6.8
Parameters	*L1*	*L2*	*L3*	*L4*	*L5*	*L6*
Unit (mm)	32	40	11	29	41	7.5

Table:1 The dimensions of the dual band UHF/2.45 GHz RFID reader antenna**.**

To address these challenges and realize dual-band frequencies with broad impedance bandwidth, several modifications were implemented. A rectangular-shaped slot was etched into the radiating element, and the feed line was augmented with a meander line. These modifications, along with adjustments in dimensions and configurations, resulted in a refined monopole antenna capable of achieving impedance matching and resonance frequencies within the desired frequency bands.
To address these challenges and realize dual-band frequencies with broad impedance bandwidth, several modifications were implemented. A rectangular-shaped slot was etched into the radiating element, and the feed line was augmented with a meander line. These modifications, along with adjustments in dimensions and configurations, resulted in a refined monopole antenna capable of achieving impedance matching and resonance frequencies within the desired frequency bands.

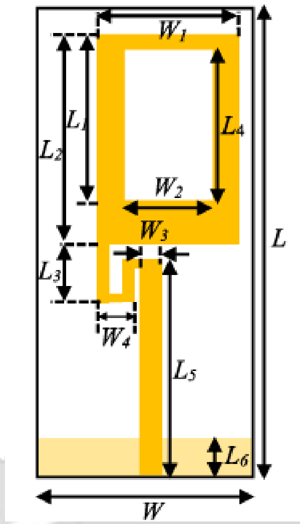

Fig 1: The dual band UHF/2.45 GHz RFID reader antenna: (a) the antenna geometry

To address these challenges and realize dual-band frequencies with broad impedance bandwidth, several modifications were implemented. A rectangular-shaped slot was etched into the radiating element, and the feed line was augmented with a meander line. These modifications, along with adjustments in dimensions and configurations, resulted in a refined monopole antenna capable of achieving impedance matching and resonance frequencies within the desired frequency bands.
The refinement process involved optimizing the length of the feed line and the dimensions of the ground strip and the capacitive lumped element. Through simulations, it was determined that specific values for these parameters led to improved impedance matching and resonance frequency alignment within the target bands.
Additionally, the number of meander turns in the feed line was varied to further optimize performance. With the appropriate number of meander turns, the refined monopole antenna successfully covered the UHF and 2.45 GHz RFID bands with broad impedance bandwidth, making it suitable for UHF/2.45 GHz RFID applications.
Overall, the iterative refinement process, guided by simulation results and parameter adjustments, enabled the design of a dual-band UHF/2.45 GHz RFID reader antenna that met the performance requirements for IoT applications.

Result:

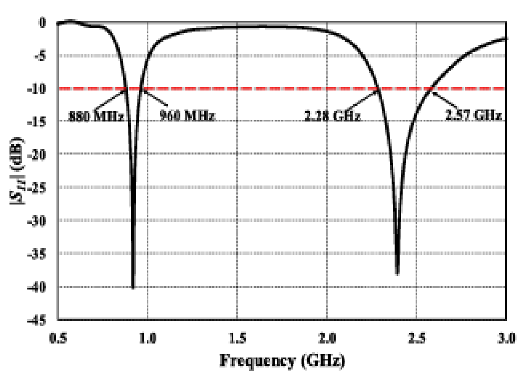

Chart 1: Simulated $|S_{11|}$

3.2 RFID 2x2 ARRAY

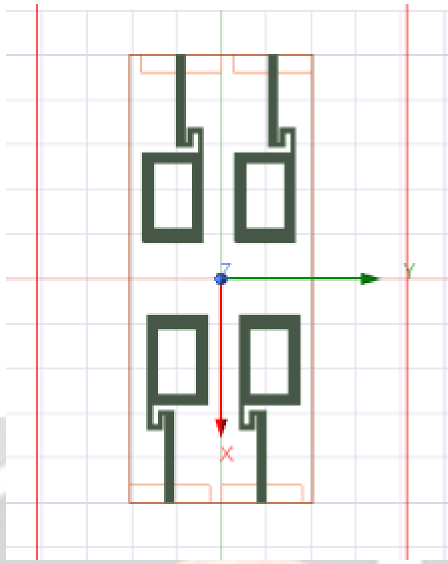

Fig 2: RFID 2x2 Array

Designing a 2x2 array of RFID antennas involves configuring multiple individual antennas in a specific geometric arrangement to achieve desired performance characteristics. Each antenna element within the array operates independently but contributes collectively to enhance the overall performance of the system. The arrangement and spacing between antenna elements play a crucial role in determining parameters such as radiation pattern, gain, and impedance matching.

To design an efficient RFID 2x2 array, several factors need to be considered. These include the desired coverage area, read range, polarization, and interference mitigation strategies. Additionally, optimizing the spacing between antenna elements and adjusting the phase and amplitude of the signals fed to each element are essential for achieving desired radiation characteristics, such as beam steering or beam shaping.

Furthermore, the design process may involve simulations and iterative adjustments to fine-tune the array's performance. Techniques such as phased array beamforming can be employed to dynamically adjust the directionality of the antenna pattern, enabling adaptive operation to suit changing environmental conditions or target locations.

RESULT:

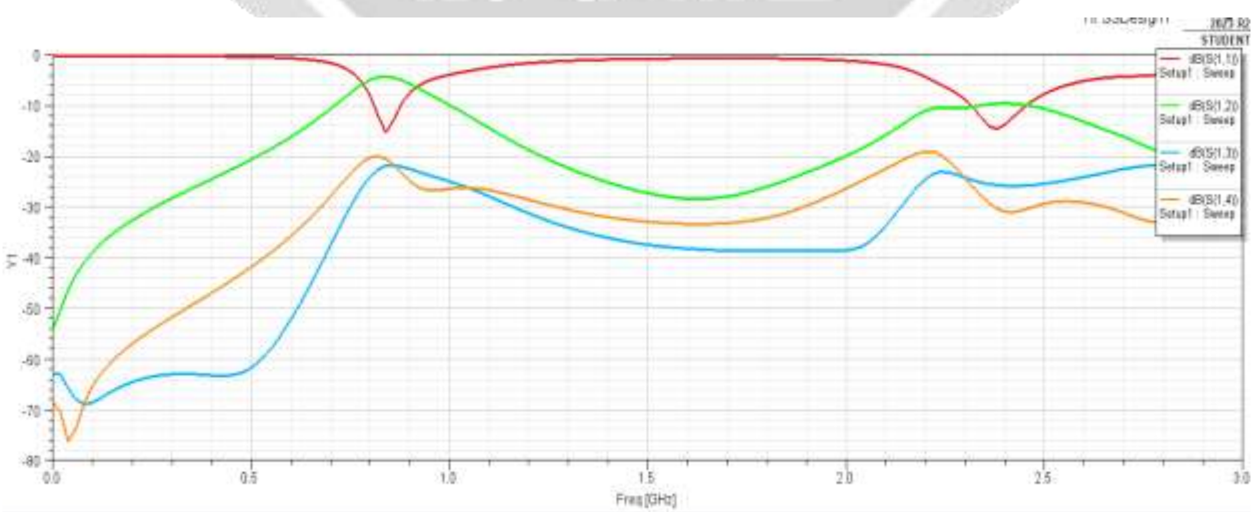

Fig 3: S-Parameter Array

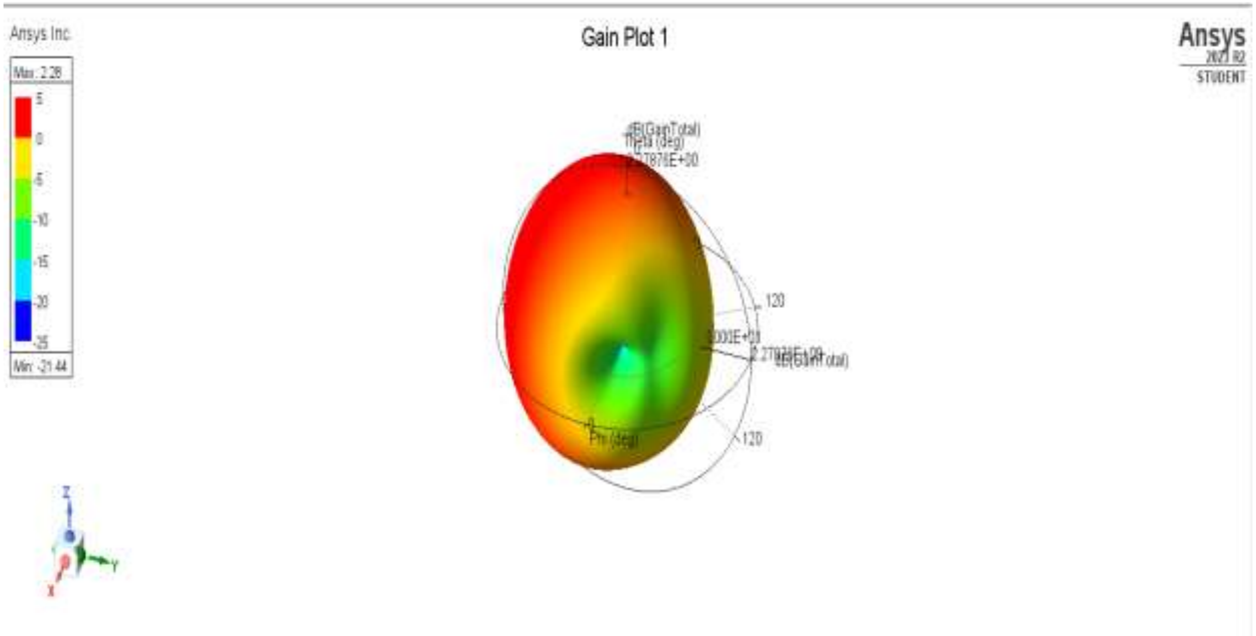

Fig 4: Gain Plot for the system

The design and optimization of RFID antenna arrays using deep learning, specifically Artificial Neural Networks (ANN), present a novel approach to enhancing the performance and efficiency of RFID systems. In this proposed system, the integration of deep learning techniques offers a promising avenue to address the complexities associated with antenna array design, optimization, and deployment in RFID applications.

Artificial Neural Networks (ANNs) have demonstrated remarkable capabilities in pattern recognition, optimization, and modeling tasks across various domains. By leveraging the power of ANNs, the proposed system aims to automate and streamline the process of designing and optimizing RFID antenna arrays. ANNs can effectively learn complex relationships between antenna parameters, environmental factors, and performance metrics, enabling the identification of optimal antenna configurations tailored to specific application requirements.

The utilization of deep learning in RFID antenna array design and optimization offers several advantages. Firstly, ANNs can efficiently handle large datasets, allowing for comprehensive analysis of antenna performance under different conditions and configurations. Secondly, the iterative nature of deep learning enables the system to continuously improve antenna designs through feedback mechanisms, leading to enhanced performance and reliability over time. Additionally, ANNs can expedite the design process by generating optimized antenna configurations rapidly, thereby reducing time-to-market and development costs.

By employing deep learning techniques, the proposed system aims to overcome traditional limitations in RFID antenna design, such as manual parameter tuning, trial-and-error optimization, and limited scalability. Through the integration of ANNs, designers can harness the power of data-driven optimization to achieve superior RFID antenna performance, robustness, and adaptability across diverse application scenarios.

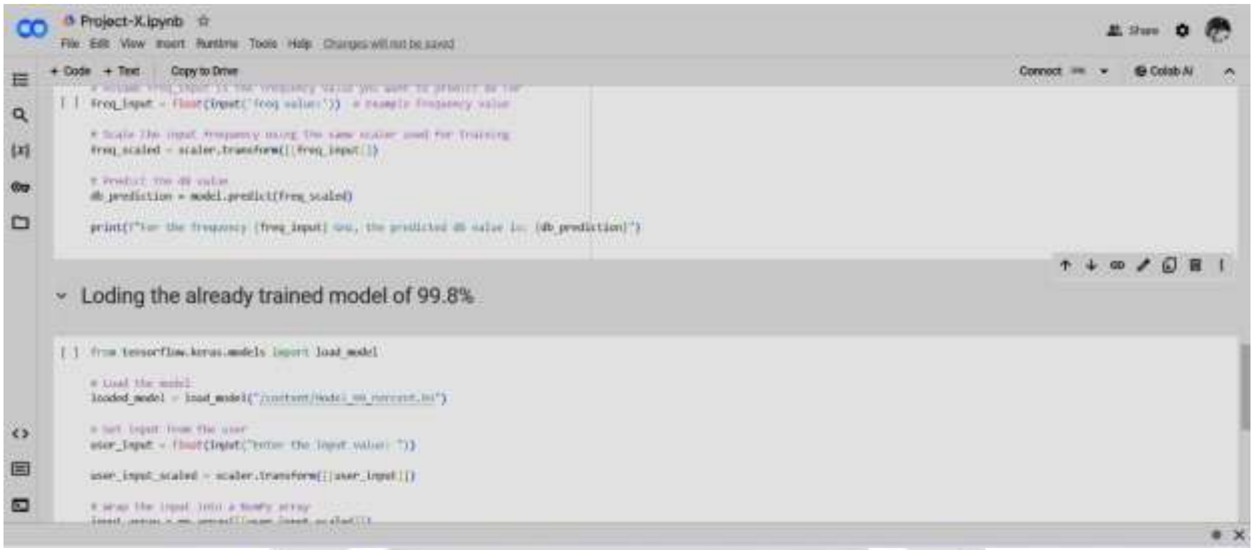

Fig 6: Results from Trained Model of S-parameter Data

Fig 7: Results from Trained Model of Gain Plot Data

4. APPLICATIONS

The design and optimization of RFID antenna arrays using deep learning techniques hold significant potential for various applications across industries. Here are some key application areas:

Inventory Management: RFID technology is widely used for inventory tracking and management in retail, logistics, and warehouses. By employing RFID antenna arrays optimized through deep learning, businesses can achieve more

accurate and efficient inventory monitoring, reducing stockouts, minimizing overstocking, and improving overall supply chain visibility.
Asset Tracking: Many industries, including manufacturing, healthcare, and transportation, rely on asset tracking systems to monitor the movement and utilization of valuable assets. RFID antenna arrays enhanced by deep learning can offer improved localization and tracking capabilities, enabling real-time asset monitoring and enhanced security measures.
Smart Agriculture: In agriculture, RFID technology can be utilized for crop monitoring, livestock management, and equipment tracking. By integrating deep learning-based optimization techniques, RFID antenna arrays can provide better coverage and reliability in outdoor environments, facilitating precision agriculture practices and optimizing resource utilization.

5. CONCLUSION

In conclusion, the design and optimization of RFID antenna arrays using deep learning techniques represent a significant advancement in the field of radio frequency identification (RFID) technology. By harnessing the power of deep learning algorithms, such as neural networks, this project has demonstrated the ability to enhance the performance and efficiency of RFID antenna arrays. Through iterative training and optimization processes, the deep learning model can effectively learn complex patterns and relationships within the antenna array design space, leading to superior antenna configurations that maximize read range, data transmission rates, and overall system performance.

Furthermore, the integration of deep learning into the antenna design process offers several key advantages. It enables rapid exploration of the design space, allowing for the identification of optimal antenna configurations in a fraction of the time compared to traditional trial-and-error methods. Additionally, deep learning facilitates the adaptation of antenna designs to varying environmental conditions and operational requirements, ensuring robust performance across different deployment scenarios.
Moreover, the utilization of deep learning for RFID antenna array optimization promotes innovation and scalability in RFID technology. It empowers researchers and engineers to push the boundaries of antenna design, unlocking new possibilities for applications in diverse fields such as supply chain management, logistics, healthcare, and asset tracking.

6. REFERENCES

[1] E. Tolin, F. Vipiana, S. Bruni and A. Bahr, "Polarization Reconfigurable Patch Antenna for Compact and Low-Cost UHF RFID Reader," 2019 IEEE International Conference on RFID Technology and Applications (RFID-TA), Pisa, Italy, 2019, pp. 128-130, doi: 10.1109/RFID-TA.2019.8892109.

[2]. A. Srinag, S. Aruna and K. S. Naik, "Isotropic Radiation Coverage in IoT: Water Drop-Shaped Ultra-Wideband Antenna," 2023 1st International Conference on Circuits, Power and Intelligent Systems (CCPIS), Bhubaneswar, India, 2023, pp. 01-04, doi: 10.1109/CCPIS59145.2023.10292069.

[3]. R. Caso, A. Michel, A. Buffi, P. Nepa and G. Isola, "A modular antenna for UHF RFID near-field desktop reader," 2014 IEEE RFID Technology and Applications Conference (RFID-TA), Tampere, Finland, 2014, pp. 204-207, doi: 10.1109/RFID-TA.2014.6934228.

[4]. A. M. Ndifon, M. J. Crisp, R. V. Penty and I. H. White, "Performance improvements of multicast RFID systems using phased array antennas and phase diversity," 2017 IEEE International Conference on RFID Technology & Application (RFID-TA), Warsaw, Poland, 2017, pp. 51-56, doi: 10.1109/RFID-TA.2017.8098884.

[5]. R. Caso, A. Michel, A. Buffi, P. Nepa and G. Isola, "A modular antenna for UHF RFID near-field desktop reader," 2014 IEEE RFID Technology and Applications Conference (RFID-TA), Tampere, Finland, 2014, pp. 204-207, doi: 10.1109/RFID-TA.2014.6934228.

[6]. M. A. Islam, N. Karmakar and A. K. M. Azad, "Aperture coupled UWB microstrip patch antenna array for mm-Wave chipless RFID tag reader," 2012 IEEE International Conference on RFID-Technologies and Applications (RFID-TA), Nice, France, 2012, pp. 208-211, doi: 10.1109/RFID-TA.2012.6404514.

[7] . A. Srinag, S. Aruna and K. S. Naik, "Broadband Inverted L-Shaped DRA for IoT Applications," 2023 1st International Conference on Circuits, Power and Intelligent Systems (CCPIS), Bhubaneswar, India, 2023, pp. 1-4, doi: 10.1109/CCPIS59145.2023.10291957.

[8]. M. Ould-Elhassen, M. Mabrouk, A. Ghazel and P. Benech, "Improved coverage of phased array antennas used for RFID applications," 2013 IEEE International Symposium on Phased Array Systems and Technology, Waltham, MA, USA, 2013, pp. 553-558, doi: 10.1109/ARRAY.2013.6731888.

[9]. R. Chen, S. Yang, A. M. Ndifson, I. H. White, R. V. Penty and M. Crisp, "Beam Scanning UHF RFID Reader Antenna with High Gain and Wide Axial Ratio Beamwidth," 2019 IEEE International Conference on RFID Technology and Applications (RFID-TA), Pisa, Italy, 2019, pp. 374-379, doi: 10.1109/RFID-TA.2019.8891995.

[10]. A. Motroni, M. R. Pino, G. Cecchi and P. Nepa, "A Near-Field Focused Array Antenna Empowered by Deep Learning for UHF-RFID Smart Gates," in IEEE Transactions on Antennas and Propagation, vol. 71, no. 10, pp. 7946-7957, Oct. 2023, doi: 10.1109/TAP.2023.3302434.

[11. S. H. R. Khalil, N. M. Namazi and F. Ouyang, "Mobile Sensor Location Optimization Using Support Vector Machines with Error-Correcting Output Codes," 2019 2nd World Symposium on Communication Engineering (WSCE), Nagoya, Japan, 2019, pp. 157-163, doi: 10.1109/WSCE49000.2019.9040991.

[12]. Srinag, A., Aruna, S. & Naik, K.S. Switchable beam generation in a reflectarray antenna using rotman lens and combline array feed for IoT. Int J Interact Des Manuf (2023). https://doi.org/10.1007/s12008-023-01690-1.