Design of compact RFID antenna using meandering technique at 870 MHz using felt substrate.

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Abstract: We present the design of a compact RFID antenna utilizing a meandering technique, specifically tailored for operation at 870 MHz using felt substrate. The proposed antenna features a meander line structure that effectively reduces the overall dimensions while maintaining optimal performance characteristics suitable for UHF RFID applications. By employing a felt substrate, the antenna not only achieves significant size reduction but also enhances flexibility and ease of integration into various surfaces. The design incorporates advanced impedance matching techniques to ensure efficient power transfer between the antenna and the RFID chip, facilitating improved read range and signal integrity. Simulation results demonstrate that the antenna exhibits an omnidirectional radiation pattern and meets the required specifications for effective RFID tag functionality. This work contributes to the ongoing advancements in RFID technology by providing a practical solution for compact and efficient antenna designs in real-world applications.

I. Introduction

Radio Frequency Identification (RFID) technology has emerged as a transformative solution across various sectors, enhancing operational efficiency and accuracy in tracking and managing assets. Its ability to automate data collection without the need for direct line-of-sight scanning has made it invaluable in applications ranging from retail inventory management to healthcare patient tracking. The UHF band, particularly around 870 MHz, is widely utilized for RFID systems due to its favourable propagation characteristics and ability to support multiple tag reads simultaneously, making it ideal for environments with high item density. In this context, the design of RFID antennas is critical to optimizing the performance of RFID systems. Traditional antenna designs often face challenges related to size and integration, especially in compact applications. This report focuses on the design of a compact RFID antenna using a meandering technique, which allows for significant size reduction while maintaining effective performance at 870 MHz The use of felt substrate not only contributes to the lightweight and flexible nature of the antenna but also enhances its applicability in various real-world scenarios where traditional rigid substrates may be impractical. By exploring innovative design methodologies, this report aims to contribute to the ongoing advancements in RFID technology, ultimately facilitating improved efficiency and functionality in diverse applications such as supply chain management, access control, and healthcare logistics. The findings will provide insights into how compact antenna designs can meet the growing demands of modern RFID systems while ensuring robust performance. [1]

II. Literature Review

The literature on RFID antennas, particularly those operating in the UHF band, highlights significant advancements in design techniques aimed at enhancing performance while minimizing size. This review focuses on the meandering technique, a popular approach for compact RFID antenna design, and its implications for applications at 870 MHz

Overview of UHF RFID Antennas
UHF RFID antennas have gained prominence due to their ability to facilitate non-line-of-sight communication, enabling simultaneous detection of multiple tags and longer read ranges compared to low-frequency and high-frequency counterparts. The compact size of these antennas is crucial for integrating them into various products, from retail items to healthcare devices. A comprehensive review of UHF RFID tag antennas emphasizes the importance of antenna design and substrate selection in optimizing performance metrics such as gain, bandwidth, and efficiency.

Meandering Technique for Antenna Miniaturization
The meandering technique is particularly effective in reducing antenna dimensions while maintaining functionality. Meander line structures can achieve significant size reductions up to 62% compared to conventional designs without compromising performance. [2] The inclusion of parasitic elements and T-match structures further enhances impedance matching with RFID chips, which is critical for optimal power transfer. [3]

Performance Analysis and Applications
Research indicates that antennas designed with meander lines exhibit omnidirectional radiation patterns, making them suitable for various applications, including supply chain management and asset tracking. The performance of these antennas can be evaluated through simulation tools like HFSS, which provide insights into how design parameters affect resonance frequency and radiation characteristics. [3]

Additionally, experimental validations under controlled conditions confirm the feasibility

and reliability of these compact designs. In conclusion, the literature underscores the significance of innovative design techniques such as the meandering method in developing compact RFID antennas that meet the demands of modern applications. As RFID technology continues to evolve, ongoing research will likely focus on further enhancing antenna designs to support new use cases and improve integration across diverse platforms.

III. Antenna Design

Working Principle: The working principle of RFID antennas is used for automatic identification and tracking. Here’s a concise explanation:

1. **Signal Transmission**: The RFID reader emits electromagnetic radio frequency signals through its antenna at 870 MHz
2. **Powering the Tag**: When an RFID tag enters the reader's range, it captures these signals. For passive tags, the energy from the radio waves induces a voltage in the tag's antenna, powering its microchip.
3. **Data Transmission**: Once activated, the tag uses its antenna to send back stored information to the reader.
4. **Signal Reception**: The reader's antenna captures this modulated signal, converting it back into electrical energy for processing.
5. **Data Interpretation**: The reader decodes the received signals to extract unique identification information from the tag, enabling various applications like inventory management and access control.

Specifications: The tag will operate at 870MHz and it will be designed to conjugate match the input impedance of the Alien Higgs-3 (AH3) integrated circuit (I.C.) whose impedance is 30 – $j185\Omega$ at 870MHz. [4] All the simulations have been carried out using the HFSS simulation software. [5]

Design Procedure: In our design, the antenna is mainly composed of Felt substrate (Relative permittivity=1.63 loss tangent= 0.044 Thickness=3mm) and Copper (Conductivity = 5.8×10^{7} S/m) which comprises the Radiating element of our antenna as shown in Figure 1ans Figure 2.

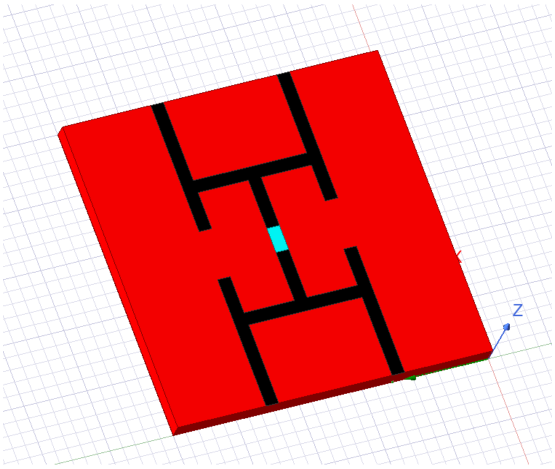

Figure 1.Geometrical Arrangement (Recommended)

The dimensions of the Felt Substrate are 50 x 50 x 3 mm^3. The I.C. is then placed on the substrate (4 x 2 mm^2) and the meandered path on both sides of an IC is designed effectively for compactness and performance.

For 870 MHz, the wavelength is given by,

$$\lambda_0 = \frac{c}{f} = \frac{3\times10^8}{870\times10^6} \approx 344.83\text{ mm}$$

and the antenna's effective wavelength (λ_{eff}) in the felt substrate is reduced due to it’s relative permittivity:

$$\lambda_{\text{eff}} = \frac{\lambda_0}{\sqrt{\epsilon_r}} = \frac{344.83\text{ mm}}{\sqrt{1.63}} \approx 270.78\text{ mm}$$

Generally, for a compact antenna, the length of the antenna should be around ($\lambda_{\text{eff}}/4$), which gives us:

$$L_{\text{antenna}} \approx \frac{270.78\text{ mm}}{4} \approx 67.7\text{ mm}$$

But the meandering technique will help reduce this size to fit within the antenna.

IV. Results

The s-parameter plot of the antenna is shown in Figure 3.

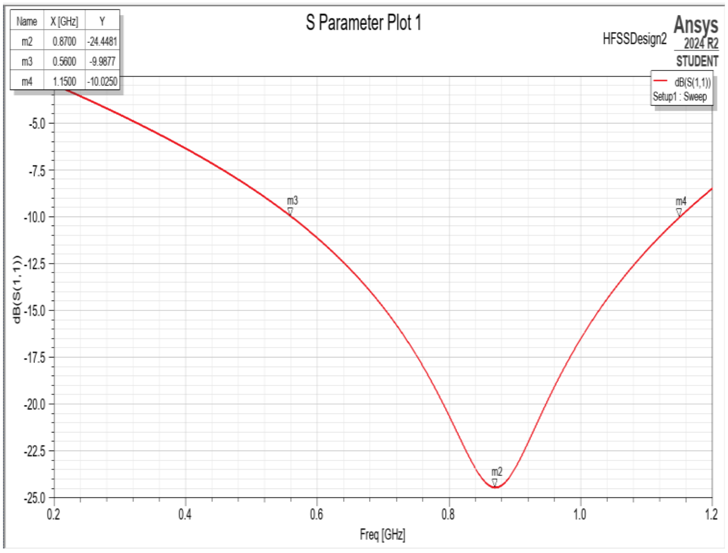

Figure 2. S-Parameter Plot

The System Gain Plot of the antenna is shown in Figure 4.

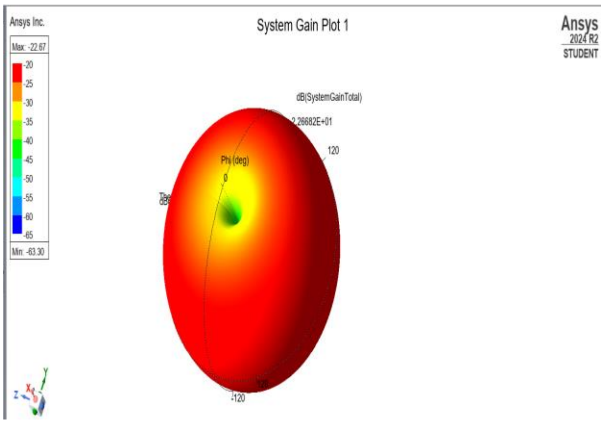

Figure 3. System Gain Plot

V. Conclusion

The innovative use of a meandered path on both sides of the integrated circuit (IC) has demonstrated significant advantages in terms of size reduction and performance optimization.

The design process involved careful consideration of key parameters such as impedance matching, The proposed antenna configuration not only meets the operational requirements for UHF RFID applications but also enhances flexibility and integration capabilities in real-world scenarios.

The results indicate that the meandered antenna exhibits an omnidirectional radiation pattern and efficient power transfer, leading to an improved read range essential for various applications, including inventory management and access control systems. This work contributes valuable insights into the ongoing advancements in RFID technology by providing practical solutions for compact antenna designs.

Future research may focus on further optimizing the meandered path design to support emerging technologies in the Internet of Things (IoT) and smart systems, where space constraints and performance are increasingly critical. Overall, this study reinforces the importance of innovative antenna design techniques in enhancing the functionality and applicability of RFID systems in diverse fields.

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