A Review on RFID Based Biosensor for Medical Applications

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Abstract

This paper presents a comprehensive review of the recent advances in RFID-based biosensors and their applications in the medical field. The primary focus is on the latest and most advanced technologies utilized in RFID sensors, along with their operational processes in[1] the medical arena. The paper also evaluates various design methodologies for RFID biosensors and identifies the most efficient approach. Furthermore, it examines the current systems that use RFID technology in healthcare, including the components of the antenna and biosensor. The present state-of-the-art technologies in this domain are also analyzed and discussed. The objective of this paper is to assist researchers in creating affordable and easily accessible RFID-based biosensors that can enhance medical and healthcare outcomes.

Keywords: *RFID based biosensor, medical applications, design methodologies, state of the art*

1. Introduction

Radio-Frequency Identification (RFID) technology has the potential to revolutionize the way we monitor and track physiological parameters in the medical field. RFID-based biosensors offer non-invasive and highly mobile solutions for real-time and continuous monitoring of various biological parameters, making them a promising technology for medical applications. In recent years, there has been a growing interest in the use of RFID-based biosensors for early detection of diseases, such as cancer.

This paper provides a technical review of RFID-based biosensors for medical applications, with a focus on the latest and most advanced technologies used in this field. The paper will examine the operational processes of RFID-based biosensors in medical applications, including their design and fabrication. Additionally, the paper will explore the different design approaches for RFID biosensors and evaluate their performance metrics, such as sensitivity, specificity, and stability.

The paper will also review the current state-of-the-art technologies that employ RFID technology in the medical field, including the design of the antenna and biosensor components. The goal is to provide technical insights into the development of RFID-based biosensors for medical applications and to assist researchers in developing cost-effective and accessible solutions for the medical and healthcare field.

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2. Technology Focused

Radio Frequency Identification (RFID) technology utilizes radio waves to facilitate communication between a reader or interrogator and a tag or transponder. A small

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electronic device such as a product or package, is attached to or embedded in an object to serve as the tag, while the reader or interrogator emits radio waves and captures signals from the tag. By absorbing energy from the radio waves transmitted by the reader, the tag reflects back a signal containing the object's identification data. The technology operates on electromagnetic coupling principles.

RFID technology is widely used across several industries, including healthcare, retail, logistics, transportation, and manufacturing. The technology's ability to allow real-time, contactless, and automatic identification of objects streamlines business processes and enhances operational efficiency. For example, RFID technology is used to track inventory levels, monitor product movement, prevent theft in the retail industry, and facilitate patient tracking, asset management, and medical equipment monitoring in the healthcare sector.

Typically, RFID systems consist of three components: the RFID reader, antenna, and tag. The reader emits radio waves, the antenna receives and transmits the radio waves, and the tag contains an integrated circuit and an antenna that captures energy from the radio waves to power its electronics. The tag also stores the identification data of the object and transmits it back to the reader when it receives a signal.

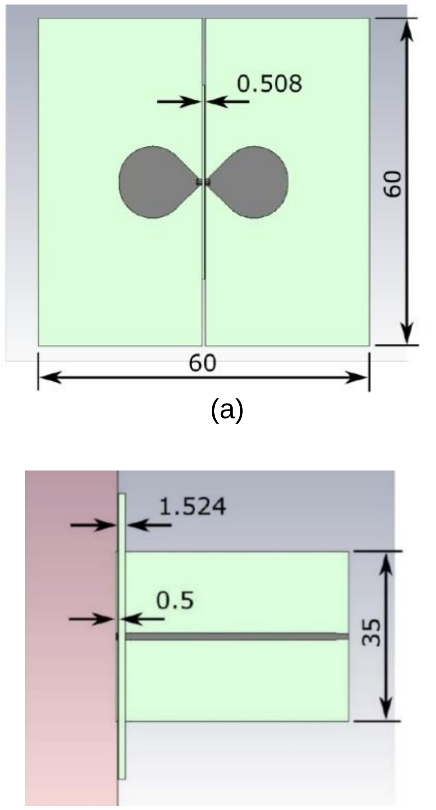
RFID tags can be classified as either passive or active. Passive tags do not have their own power source and rely on energy transmitted by the reader to function. They are smaller, cheaper, and have a shorter read range than active RFID tags. On the other hand, active RFID tags have their own power source, such as a battery, and can transmit signals over a longer distance than passive tags.

RFID technology surpasses other identification technologies such as barcodes and QR codes because it does not require line-of-sight communication and can operate in harsh environments. Additionally, RFID tags can store more data and can be updated or rewritten, making them more flexible and adaptable to changing business requirements.

3. Insights on State of the Art

3.1 Antenna Design

A compact "ultrawideband (UWB) bowtie antenna and balanced-to-unbalanced (balun) circuit for medical microwave imaging (MWI) applications were designed and experimentally validated in" paper [2]. "The planar bowtie arms of the UWB balun are perpendicularly attached and the bowtie edges were rounded for miniaturization purposes. The reflection coefficient of the antenna was below −12 dB for tissues with higher water content, and the radiation efficiency was over 80%, with very low backward radiation" [2]. The antenna demonstrated a symmetrical radiation pattern, as evidenced by the predicted and measured specific absorption rate (SAR) and electric field |E| distributions. The success of image reconstruction using MWI methods demonstrated the potential of the presented antenna element. "The MWI system had eight antennas, and a radar approach was used to determine the region of interest (ROI) for microwave tomography reconstruction. The Born approximation method at 1 GHz was used to construct the dielectric properties within the ROI, which confirmed that the antenna can be used as the basis for more accurate multifrequency MWI systems and can be implemented in UWB MWI hybrid systems" [2]. The design of the antenna is illustrated in Figure 1.



(b)

Figure 1. Geometry of the designed antenna proposed in [2]: (a) front view and (b) side view. All dimensions are in millimeters

The paper [3] outlines the design of a bowtie antenna that is capable of operating over a broad frequency range in the Industrial, Scientific and Medical (ISM) band. In order to effectively power the antenna, " a tapered balun is developed to ensure that the bowtie antenna and the coaxial input source have impedance matching" [3]. The proposed antenna is constructed on a "Glass Epoxy FR4 substrate that is 1.6mm in thickness and has a dielectric constant of 4.4" [3]. The dimensions the bowtie antenna is 70mm x 40mm. The simulated results of the proposed design are compared to the actual results and are found to be in close alignment. The antenna design offers a bandwidth of 38% for S_{11}<-10 dB, a gain of over 2 dB, and a VSWR of under 2 for the entire frequency range. The design of bowtie antenna is shown in Figure 2.

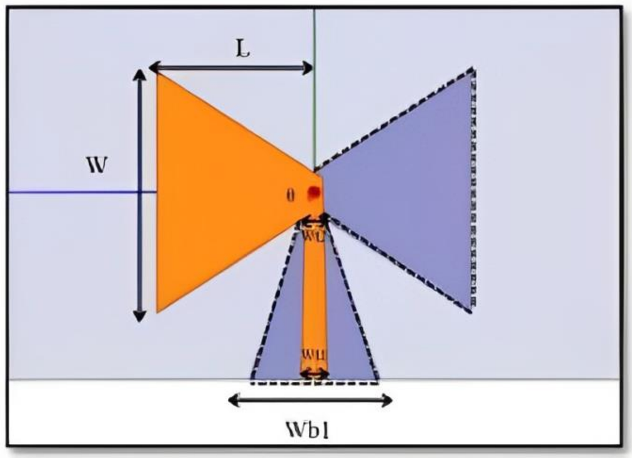


Figure 2. "Design of Bowtie Antenna" [3]

Paper [4] details a miniature implantable antenna designed for RFID biomedical monitoring at an ultrahigh frequency band of 902-928 MHz. The proposed antenna is very small and compact, measuring only "π × (6)2 × 1.27 mm3, which was achieved by using an extended ring with symmetrical meandered lines" [4]. This design introduces two orthogonal modes, which significantly improves circular polarization performance. To ensure good impedance matching between the chip and tag antenna, "a modified T-match stub is employed. Simulation results reveal that the antenna has a -10dB impedance bandwidth of 42 MHz (902-944 MHz) and a 3dB axial-ratio bandwidth of 53 MHz (892-945 MHz)" [4].

In addition, "the specific absorption rate is calculated to ensure human safety, and the antenna's measured reading range is a maximum distance of approximately 87 cm" [4]. Figure 3 depicts the configuration of the proposed antenna design.

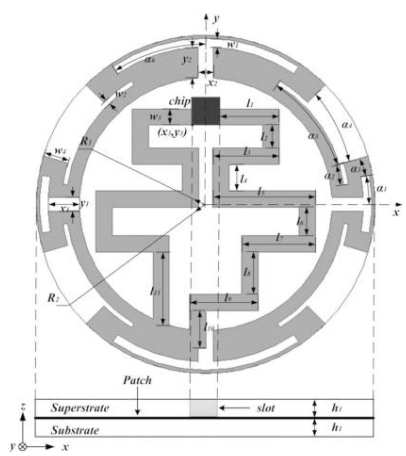


Figure 3. "Configuration of the proposed antenna" [4]

Paper [5] proposes a reader antenna designed for radio frequency identification systems used in medical environments, which is capable of identifying multiple tags. The antenna is comprised of four planar inverted-F antennas (PIFAs), four power dividers, and two hybrid couplers. Through a symmetric design and the use of four power dividers, the antenna achieves high isolation. The power dividers are fed by the two hybrid couplers. Experimental data reveals that the antenna achieves over "40 dB isolation across the North American (902-928 MHz), Korean (917-923.5 MHz), and Japanese (916.7-923.5 MHz)

RFID frequency bands" [5]. Figure 4 shows the geometry design of Planar Inverted F Antenna.

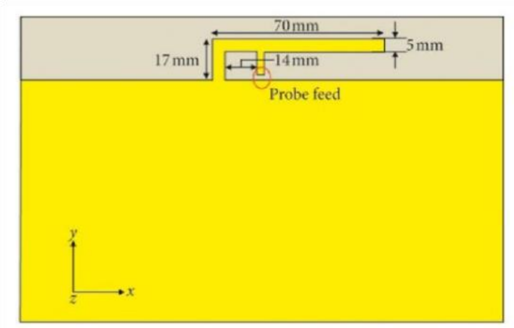


Figure 4. "Geometrical design of Planar Inverted F Antenna" [5]

Paper [6] discusses the use of X-ray irradiated blood in medical transfusions and the need for improved monitoring techniques. To address this need, the paper proposes wireless dosimeter tags with flexible and efficient antennas that can be mounted on blood bags. The proposed design features a "low-cost, inkjet-printed dipole antenna on a flexible Kapton substrate for a 2.45 GHz RFID dosimeter tag. The antenna is designed to operate in a lossy blood environment, which can negatively impact radiation performance" [6]. To optimize impedance and gain performance, the antenna incorporates artificial magnetic conductor (AMC) unit cells. The resulting AMC-backed antenna provides "broadside radiation with gains ranging from 4.1 dBi to 4.8 dBi under various conditions, including planar, bending, and lossy blood bag environments. In a rectenna configuration, the antenna can power sensors up to a range of 1m and generate output dc voltages up to 1.7 V across a 25 kΩ resistor" [6]. The design is flexible, compact, efficient on lossy structures, and can be integrated with biomedical sensing chips. The dipole antenna's dimensions are shown in Figure 5.

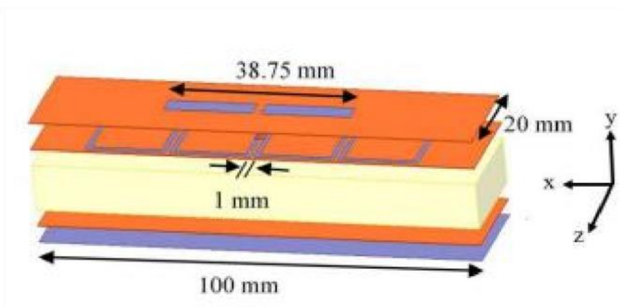


Figure 5. "Layout view of dipole antenna over a 1×4 AMC surface and its dimensions" [6]

3.2 Biosensors

For individuals with diabetes, accurate monitoring of glucose levels is critical, leading researchers to investigate the development of glucose biosensors. This paper [7] introduces a "glucose microwave biosensor that incorporates RFID technology for non-contact measurements of glucose concentrations. The biosensor's Reader component consists of a complementary split-ring resonator (CSRR), while the tag comprises a squared spiral capacitor (SSC)" [7]. "A polydimethylsiloxane microfluidic quantitative cavity is integrated into the tag to ensure that the glucose solution is accurately placed on the sensitive area and fully exposed to the electromagnetic flux.

The capacitance of the SSC changes when it contacts glucose solutions of different concentrations, altering the resonant frequency of the CSRR" [7]. The changes in resonant frequency in relation to glucose concentration provide the biosensing response. "Both bare CSRR and RFID-based biosensors respond in under 1 second, with the biosensors achieving sensitivities of 0.31 MHz/mg·dL^{-1} and 10.27 kHz/mg·dL^{-1}, and detection limits of 13.79 mg/dL and 1.19 mg/dL respectively" [7]. "Linear regression analysis confirms the biosensors' excellent linear relationships. This proposed design offers a practical solution for developing microwave biosensors that enable non-contact measurement of glucose concentration" [7]. S_{11} for the reader and RFID biosensor is depicted in Figure 6.

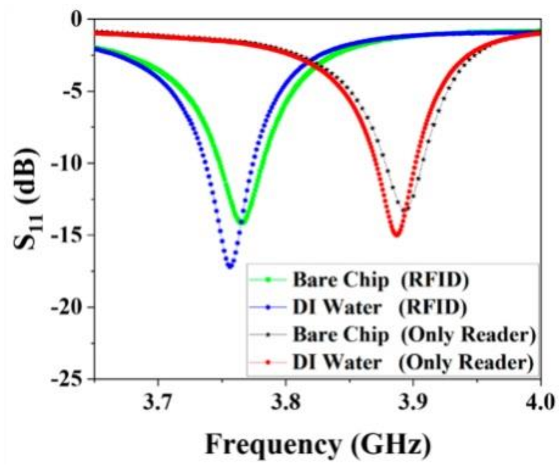


Figure 6. "Measured reflection spectra (S_{11}) for reader and RFID based biosensor" [7]

Paper [8] presents the creation of an RFID tag that incorporates a "Battery Assisted Passive (BAP) system in the Ultra High-Frequency band and an inertial measurement unit (IMU) sensor to monitor human body movements" [8]. "A meandered Planar Inverted-F Antenna (PIFA) is used in the device design, along with a dual-access RFID chip that provides both wired and wireless memory access. To enhance sensitivity and power supply, the device uses a decoupled cell battery to power the ultra-low power microcontroller and sensors" [8].

The device is built using low-cost components that are easily available, and an FR4 substrate is used for the device's construction. Two sensor-tags are mounted on the pelvis and torso of an individual to capture actual human movements. "Algorithms are employed to process and filter the sensor data, and a musculoskeletal virtual model is controlled using OpenSense software" [8]. The system's ability to accurately replicate human movements is demonstrated in the results, indicating the effectiveness of the proposed RFID-sensor in wireless movement capture applications. The design of the sensor is presented in Fig.7.

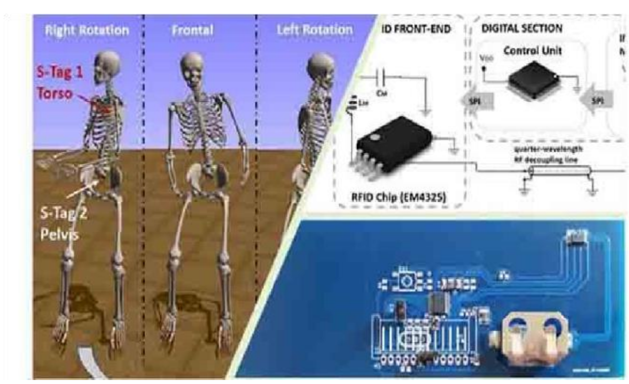


Fig.7. "Design of Battery assisted Passive UHF RFID" [8].

4. Conclusion

This paper has presented an overview of the progress made in the application of RFID biosensors especially in medical applications. In conclusion, RFID biosensors have proven to be a crucial technology in the field of medical applications. The advancements made in the technology have allowed for the development of various systems that make it easier to collect and transmit data accurately. The antenna design is also an essential aspect of the technology, and a proper design is crucial for the optimal performance of the biosensors. In modern medical applications, RFID biosensors have shown great potential for improving patient care and facilitating the early diagnosis of various diseases. With the continued development of RFID biosensors, it is expected that the technology will continue to play a significant role in the advancement of the medical field.

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