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A Review of Antenna Design for UHF RFID Tags

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ABSTRACT: ***RFID stands for Radio Frequency Identification and refers to a wireless technology that consists of two parts: tags and readers. The reader is a device that emits radio waves and receives signals from the RFID tag through one or more antennas. Tags may be passive or active, communicating their identification and other information to nearby readers through radio waves. Passive RFID tags do not have a battery and are powered by the reader. The purpose of this article is to provide an overview of antenna design for passive radio frequency identification (RFID) tags. We go through the different criteria for such designs, describe a general design approach that includes range measuring tools, and focus on one real-world application: RFID tags for warehouse box monitoring. For this application, a loaded meander antenna design is presented, with different practical issues such as sensitivity to manufacturing process and box content examined. The findings of modeling and simulation are also given, and they are in excellent agreement with the measurement data.***

KEYWORDS: Antennas, Passive Modulated Backscatter, Radio Frequency Identification (RFID), Tags.

1. INTRODUCTION

RFID Tags are tiny items containing a chip and an antenna that may be used to wirelessly identify the things they are connected to (or implanted in) using an RFID reader. RFID tags, unlike barcodes, do not need line of sight between the tag and the reader and may read and write data [1]. Most RFID tags are passive, which means they don't need any maintenance and may last for years without needing to be recharged. RFID tags are divided into two categories: passive and active. Passive RFID tags [2] are powered by an electromagnetic field emitted by a fixed or mobile RFID reader. The antenna on the tag collects energy from this field and sends it to the reader. The reader's frequency must correspond to the tag's frequency. Low, high, and ultra-high frequencies have been defined for passive tags (LF, HF, UHF) [3].

A battery powers active RFID tags, which transmit over BLE (Bluetooth Low Energy) or WiFi. Radio frequency identification (RFID) is a fast-evolving technology that utilizes radio frequency signals to identify things automatically. Despite the fact that the first article on modulated backscatter (the fundamental concept of passive RFID) was published in 1948 it took a long time for the technology to develop to its present state. RFID is now used in a wide range of applications, including electronic toll collection, asset identification, retail item management, access control, animal monitoring, and vehicle security. RFID systems are presently used according to many standards (ISO, Class 0, Class 1, and Gen 2). To transmit data, RFID systems utilize radio waves of various frequencies [4]. RFID technologies are use in the following applications in health care and hospitals:

- Inventory management
- Tracking of equipment
- Detection of getting out of bed and detecting a fall
- Personnel management
- Assuring that patients get the appropriate medicines and medical equipment
- Keeping counterfeit medicines and medical gadgets out of circulation
- Patients are being watched.

- Providing information for electronic medical records

The FDA is not aware of any RFID-related adverse occurrences. However, there is worry regarding the potential for radio frequency transmitters like RFID to cause electromagnetic interference (EMI) to electronic medical equipment. An electromagnetic disturbance causes EMI, which degrades the functioning of equipment or systems (such as medical devices). Because this technology is evolving and becoming more frequently utilized, it's essential to remember that it may interact with pacemakers, implanted cardioverter defibrillators (ICDs), and other medical devices. Physicians should be aware of how RFID systems are used. Whether a patient has a problem with a device, ask questions to see if RFID was a role, such as when and where the incident happened, what the patient was doing at the time, and whether or not the issue went away after the patient left that setting. If you think RFID was involved, device interrogation may help you link the incident to the exposure. MedWatch, the FDA's voluntary adverse event reporting system, may be used to report any suspected medical device failures [5].

Each nation has its unique RFID frequency allotment on a global scale. RFID UHF bands include 866–869 MHz in Europe, 902–928 MHz in North and South America, and 950–956 MHz in Japan and a few Asian nations, for example. An antenna and an application specific integrated circuit (ASIC) chip make up a standard passive RFID transponder, often known as a "tag." RFID tags may be active (battery-powered) or passive (non-battery-powered) (batteryless). The following is how a passive back-scattered RFID system works. The tag antenna receives a modulated signal with periods of unmodulated carrier from a base station (reader). During the unmodulated period, the RF voltage generated on antenna terminals is converted to dc. This voltage turns on the device, which uses its front end complicated RF input impedance to transmit information back. The impedance usually toggles between two states, conjugate match and some other impedance, modifying the back-scattered signal efficiently. In RFID, proper impedance matching between the antenna and the chip is critical. RFID tag antennas are built for a particular ASIC available on the market since fresh IC design and production is a large and expensive endeavor. Due to cost and fabrication difficulties, adding an external matching network with lumped components to RFID tags is typically expensive. To get around this, the antenna may be directly matched to the ASIC, which has a complicated impedance that varies with frequency and input power [6].

Covered slot antenna design, circular patch antenna analysis, meander antenna optimization, planar inverted F-antenna, folded dipole antenna, and others have all been published on RFID antennas for passive and active tags. However, only a few publications offered an overview of RFID tag antenna design requirements as well as an analysis of actual application issues. Simultaneously, numerous publications exist on the practical analysis and design of certain classes of antennas for various purposes [7].

2. DISCUSSION

We looked at the design criteria for passive UHF RFID tag antennas, detailed the design process, discussed range measurement methods, and presented a tag analysis performance chart. A particular application case was also presented: a passive UHF tag design for an RFID tag put on a cardboard box that is monitored in a typical supply chain. The antenna is a tile-loaded meander antenna that may be readily adjusted for boxes containing a variety of contents, such as dry goods or plastics. This example is backed up by modeling and simulation findings that closely match the observed data.

2.1 Performance Criteria for Antenna Design

The read range of an RFID tag is the greatest distance at which the backscattered signal from the tag can be detected by an RFID reader. The read range is determined by the tag response threshold, which is usually large in contrast to reader sensitivity. The read range of a tag is also affected by its orientation, the substance on which it is put, and the propagation environment.

The antenna gain, impedance, and bandwidth compromises in the RFID tag antenna design process are unavoidable. For every instance of EIRP and threshold power of the semiconductor for a particular frequency, the normalization factor for this performance chart may be readily determined [8].

2.2. Requirements for Design

The next paragraph discusses a number of basic RFID tag design criteria whose relative significance varies depending on tag use. The parameters for choosing an RFID tag antenna are mainly determined by these factors.

1) Frequency band is a term that refers to the range of frequencies that may desired frequency range for operation is determined by the laws of the nation in which the tag will be deployed.

2) Dimensions and shape. Tags must be able to be inserted or connected to the necessary items (cardboard boxes, airline luggage strips, identity cards, and so on) or fit within a printed label.

3) Read the whole range. For different: EIRP, the minimum necessary read range is typically given. Local nation regulations decide the EIRP [9].

Objects. When a tag is put on different items (for example, cardboard boxes with varied contents) or when other objects are present in the area of the tagged object, the tag's performance varies. Tag antennas may be created or adjusted to perform optimally on a certain item or to be less sensitive to the content on which they are put.

Orientation. The read range is determined by the antenna orientation. Some applications demand that a tag have a particular coverage pattern, such as omnidirectional or hemispheric coverage.

4) Applications that are mobile. RFID tags may be utilized in circumstances where tagged items, such as pallets or boxes, move at rates of up to 600 feet per minute or 10 miles per hour on a conveyor belt. At 915 MHz, the Doppler shift is less than 30 Hz, which has no effect on RFID operation. The tag, on the other hand, spends less time in the RFID reader's read field, necessitating a high read rate capability. In these situations, the RFID system must be meticulously designed to guarantee accurate tag recognition.

5) Cost. A low-cost RFID tag is required. This constrains the antenna structure as well as the materials utilized in its fabrication, including the ASIC employed. Copper, aluminum, and silver ink are common conductors in tags. Flexible polyester and stiff PCB substrates such as FR4 are among the dielectrics.

6) Reliability. The RFID tag must be a dependable device that can withstand temperature, humidity, and stress, as well as operations like label insertion, printing, and laminating.

2.3. Design Methodology

The frequency-dependent complex impedance provided by the chip has a significant impact on RFID tag antenna performance. In order to meet design criteria, the tag read range must be carefully monitored throughout the design phase. Because the highest achievable gain and bandwidth are limited by antenna size and frequency of operation sacrifices must be made to

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achieve optimal tag performance to meet design constraints. Tolerating tag manufacturing differences and optimizing antenna performance on various materials in different frequency bands, a tunable antenna design is often used. System requirements may be converted into tag requirements after the RFID application [10] has been chosen. The materials for tag antenna fabrication and ASIC packaging are determined by these requirements. A network analyzer may be used to determine the impedance of a specified ASIC in a chosen RF package (such as flip-chip, etc.) to which the antenna will be matched.

The antenna is studied and optimized parametrically until the design criteria are satisfied in simulation. RFID tag antennas, like other antennas, are too complex for an analytical solution since they may be utilized in a complex environment. Electromagnetic modeling and simulation tools are typically used to analyze tag antennas, with the method of moments (MoM) for planar designs (such as thin flexible tags) and the finite-element method (FEM) or finite-difference time-domain method (FDTD) for more complicated three-dimensional designs (e.g. thick metal mounted tags) [4]. For effective tag design, quick EM analysis tools are essential. Modeling and simulation tools may be compared to measurements in a normal design process. In EM software, the read range computation may be done directly. By monitoring the tag range, antenna gain, and impedance, the tag antenna is initially modeled, simulated, and optimized on a computer, giving the designer a thorough knowledge of the antenna behavior.

Prototypes are produced at the end of the design phase, and their performance is meticulously assessed. The antenna design is complete if all design criteria are met. Otherwise, the design is tweaked and refined until it meets the criteria.

2.4. Range Determination

In a controlled setting, such as an anechoic chamber or a transverse electromagnetic (TEM) cell, accurate tag range measurement may be performed. Tag location may be set in both ways, and transmitter output strength can be adjusted via controlled attenuation. This enables for precise tag range characterization while avoiding the need of huge, costly chambers or cells. A tiny TEM cell is useful for evaluating small tags, whereas a larger anechoic chamber may be utilized to assess tag performance on a variety of items.

2.5. Application

Consider the following scenario: a smart label for cardboard box labeling in a warehouse setting anywhere in the globe. On cardboard boxes with different contents, such a label with a bar code written on it and an RFID tag implanted underneath it may be put. Boxes may be transported on a conveyor belt, or by forklifts equipped with RFID readers via huge gateways. The following are the requirements for the tag design:

• In the final construction, when the tag is put into a label and placed on a cardboard box, the tag should be readily tunable to any frequency in the 860–960 MHz range for different contents.

• To satisfy worst-case application requirements, tags should have at least 2.5 m range with 4 W EIRP in the 915 MHz band (902–928 MHz frequencies, US) and at least 2.2 m range with 2 W ERP (3.3 W EIRP) in the 868 MHz band (866–869 MHz frequencies, Europe).

• The tag should fit on a 6 4-inch label. For other potential uses, it's preferable to have a tiny footprint to fit inside 4 2 inch and 4 1-inch labels.

• It is preferable for a tag to have omni-like read range performance.

3. CONCLUSION

Radio frequency identification (RFID) is a fast-evolving technology that allows items to be automatically identified. An overview of antenna design for passive UHF RFID tags was given in this article. We went through the different criteria for such designs, outlined a general design approach that included range measuring techniques, and focused on one practical application, RFID tags for warehouse box monitoring. For this application, we proposed a loaded me- ander antenna design and examined several practical factors such as sensitivity to manufacturing process and box content. We also showed modeling and simulation findings that matched the experimental data well. The results of this study may also be applied to active tags and tags that operate at different frequencies.

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