Varied Operating Frequency RFID Scanner for Motorized Robot

Introduction

The process of semi-autonomously navigating through an environment and scanning elements in a storage container of various sizes and dimensions to maintain an updated database is highly desirable in various industries and labs that must track and locate assets. Currently, one of the most efficient ways of quickly detecting and correctly identifying an item is using an RFID scanner and tag. Some of the major challenges with implementing RFID technology is interference from other sources of electromagnetic waves (EMI), frequency range tradeoffs, and reliably detecting tags from different positional configurations. This technical review summarizes contemporary RFID scanner and tag technologies, briefly explains how the underlying technology works, and considers how such methods could be effectively implemented.

Commercial Options of High and Low Frequency RFID Systems

Considering the frequency range of RFID systems and passive or active tags, an optimal solution for the motorized RFID robot would utilize a high frequency (3 MHz – 30 MHz) or low frequency (30 kHz – 300 kHz) scanner [1,2]. This will allow the robot to transfer data at a reasonable rate (higher frequency transfers data faster) and have a range of up to 10 cm (LF) or 1 m (HF), which can vary between devices and technologies implemented. For the application of the motorized RFID robot, a large scanning distance is not as much a concern as interference from other materials and radiating devices in its environment, which is a more common issue with ultra-high frequency RFID systems.

Considering a passively powered, low frequency RFID device made by GAO RFID, Inc., it is possible to obtain a relatively high reading distance if under ideal conditions (up to 100 cm) [4]. This RFID device also has an in-built antenna operating at 125 kHz, requires a DC 12 V power supply, and is compliant with ISO 18000 transponders. Since the reader itself has a shorter read distance, it will be less expensive compared to higher frequency readers, but the tags must account for this small signal and are generally more expensive than their higher frequency counterparts. The specific price of this product would need to be obtained by inquiring directly with the company, but depending on the frequency of the reader, the prices could generally range from about $3,000 to nearly $20,000 for passive RFID scanners [3]. The performance of this RFID scanner would also be largely unaffected by surrounding materials, such as metal, which would make this product ideal for varying manufacturing conditions that the motorized robot could be placed in.

One high frequency RFID microcontroller is made by DLP Design, the DLP-RFID2, which operates at 13.56 MHz and requires a DC 3-5 V power supply, which is less than half that of the low frequency scanner [6]. This device has an in-built antenna that can natively couple with RFID tags, but one of its biggest advantages is its modularity, in which several different sized antennas can be attached externally. This (and type of tags used) directly affects the reading range of the scanner and can be adjusted depending on the application. The dimensions and weight make this device much smaller than other prebuilt scanners on the market and is highly desirable for mounting purposes, being 1.65 inches in length, 0.735 inches in width, 0.17 inches in height [6]. This device can be found on several online electronic stores (such as Digi-Key electronics), and the price can be found to be around $34.95 [5]. Also, this RFID scanner must be compliant with ISO 15693 transponder types. RFID, Inc. has compatible and relatively inexpensive passive tags ($1.99 each), which would work optimally with this scanner [7] and provide an advantage over lower frequency RFID tags.

Underlying Technology of High and Low Frequency RFID Systems

An RFID system is made up of two components, being a scanner (interrogator) and tag (transponder). This general design has been unchanged for decades, but each component has been vastly improved over time. Modern scanners, such as the ones discussed previously, consist of a processing chip and a coupling element (antenna). Each element has been improved over the years, with modern scanners utilizing smaller and more efficient antennas and microchips with more sophisticated signal processing algorithms. This has allowed current scanners of all frequencies to extend their detection (interrogation) range, have better electromagnetic compatibility, and increase data read/write speeds. Absorption rate of surrounding materials and susceptibility to electromagnetic interference from other radiating devices are critical consequences of the operating frequency of the scanner. Stand-alone scanners on the market today will contain custom software and scanning algorithms, with the primary goal of successfully identifying multiple tags simultaneously with minimal signal collisions between tags. One such modern anti-collision algorithm utilizes modular arithmetic, which estimates the number of tags scanned, divides them into groups, and identifies the tags based on group placement and a binary search [8].

Currently, all scanners use a coupling method in order to interact with their tags. Coupling is simply a transfer of energy between electronic circuits with electric or magnetic waves, and the distance at which coupling is effective depends on the type of coupling used. Scanners today utilize capacitive (1 cm), inductive (1 cm – 1 m), and backscatter coupling (1 m+) [9]. Considering an ultra-high frequency, passive RFID system, which would be optimal for large-scale asset tracking, one of the most common methods of interrogation between a scanner and tag is backscatter coupling. This is done by sending energy via electromagnetic waves (for longer range), propagated through the scanner's antenna. Once this signal reaches the tag, there must be enough energy to activate the tag's microchip and propagate a modulated signal from the tag's antenna back to the scanner for identification [10]. Lower frequency scanners have shorter interrogation ranges, and therefore, must use near-field (electric or magnetic field) coupling in order to interact with their corresponding tags. Inductive and capacitive coupling methods are used in this case [9], in which a signal is transmitted via an induced voltage or current from the scanner to the tag.

Implementation of RFID Scanner in Motorized Robot

Reviewing the known tradeoffs, there exist options for RFID scanners that operate at low, high, or ultra-high frequencies and are coupled with their respective tags either passively or actively. With higher frequencies, there are faster reading speeds at larger distances, but these scanners will be more sensitive to electromagnetic interference. For the purposes and scope of the motorized robot and its environment, an ultra-high frequency scanner would be optimal. With this close proximity to the storage container, the materials that the robot may scan through must be considered, which could include high water content substances, metals, and others. To keep the design of the RFID tags as simple as possible and keep the costs down, a passively powered configuration would need to be implemented.

The specific way in which this could be implemented would be a mechanical arm that extends above the motor and has a mounting configuration to house the RFID scanner. This mounting configuration would need to be adapted based on the shape and weight of the scanner, itself, but could be modular enough to house many different types of scanners. To help the robot position the RFID scanner and avoid random orientations, there would need to be an imaging device next to the scanner, which could be configured to trace colored labels on or near the objects within the container. A similar configuration could be seen by a patented technique for altering interrogating rates based on movement [11]. In the case of the robot, differently sized objects within the container could be detected with the imaging device, which could then either cause the mechanical arm to move closer to the object or adjust the interrogation rate of the scanner, if possible.

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