RFID Tags for the Autonomous Processing of Warehouse Inventory

Introduction

Engineering a system to autonomously navigate and process the inventory of a warehouse requires a method of identifying the item to be entered. RFID systems provide a means of obtaining that information utilizing a short-range backscatter communication scheme. An integral part of the RFID system is the choice of the RFID tag that contains the information, as well as the electrical mechanics that facilitate communication. This technical review will summarize current commercially available RFID tags, explain the technology that drives the tags, and provide insight on how to integrate the RFID system into an autonomous platform.

Commercial Applications of RFID Tags

The RFID tag is obviously an integral part of the RFID system, and as such a great deal of effort should be directed towards selecting a tag that will operate efficiently in each unique warehouse topology. The diversity of communication and configuration needs have created a high demand for companies that specialize in the engineering and analysis of RFID Systems. One such company which specializes in passive/active RFID tags is known as Omni-ID. Omni-ID offers an extensive selection of RFID tags that operate within the UHF Gen2 standard ultra-high frequency band 860 – 960 MHz [1]. The Omni-ID Flex 1200 offers a competitive scanning range of 6m, along with a highly directive radiation pattern when the tag is attached to a metal surface [2]. This high directionality allows the tag to focus backscattered radiation towards the reader, provided the reader is pointed near the front face of the tag. Achieving this will improve both the reading range and the probability of a successful interrogation. The Flex 1200 comes at a relatively high cost of around $0.61-$0.82 per tag for a batch order of ~1000 tags [3, 4].

Another company competing in the RFID market is Smartrac. Smartrac offers a product by the name of Dogbone, which uses IMPINJ’s Monza R6 a one-time programmable IC to act as the data modulation center [5]. The Dogbone RFID tag offers an increased read range of 11m with a bi-directional radiation pattern when placed on a dielectric surface [3, 5]. This implies that the Dogbone can also behave as a more directional antenna if placed on a solid metallic surface (similar to Omni-ID’s Flex 1200). The Dogbone RFID tag can be purchased for $0.259 per tag for a batch order of 1000 tags [6]. Although the Dogbone is less physically rugged than the Flex 1200, it has a clear competitive edge with respect to price per tag and read range performance.

Technology of RFID Tags

Summary

The RFID tag consists of an antenna front end, which is usually a half-wave dipole for its omnidirectional radiation pattern characteristics. This antenna is then matched to an IC that will take some RF input, which can be either continuous wave or modulated in some way, operate on that signal, and re-transmit the signal using a different modulation scheme. This is not to say that the IC performs some computational operation on the input signal, as passive tags can simply switch between open circuits and matched loads to amplitude modulate the information encoded on the tag back to the reader (this is known as amplitude shift key (ASK) modulation). Active RFID tags operate on a slightly different paradigm; they usually contain an active power source which can be a battery, energy-harvester, or solar cell to supply enough power for the tag to transmit its own signal independent of a reader. The active RFID tag then begins to operate as a type of beacon awaiting a sync bit or encoded message from the reader to inform the onboard IC to transmit its information [7]. Because the active RFID tag can transmit its own signal independent of the reader, the radio link budget of the communication scheme only experiences one path loss factor and little dependency of the radar cross section (RCS) of the tag. This increases the effective read distance between the reader and tag [7]. In contrast, the passive tag must receive all its operational power from the reader, so the link budget then contains two factors of path loss as well as a heavy dependency on the passive tags RCS.

Technological Advances

Recently, efforts have been made by electromagnetic research groups at the Georgia Institute of Technology to increase the range and efficiency of RFID tags. Various applications of tunnel diodes are of interest to the advancement of RFID technology. Applications include using the diode as an active load to increase the tag's RCS (reflection amplifier), and in microwave rectifiers to serve as RF energy harvesting devices to power logic in the tag [8, 9]. The use of tunnel diodes in reflection amplifier circuitry has produced gains of up to 41.4 dB using a bias power of 0.029 mW with an RF stimulus of -92 dBm [8]. Chapter 6 of Francesco Amato's Dissertation "*Achieving Hundreds-Meter Ranges in Low Powered RFID Systems with Quantum Tunneling Tags"* provides experimental verification that the use of quantum tunnel reflections (QTR) can achieve a range of ~1.2 km with a transmit power of 28 dBm [8].

Implementation of RFID Tags into an Automated Warehouse Inventory System

Implementation of an RFID system requires careful consideration of the propagation environment in which the system must operate. For a warehouse configuration, this likely means that the environment will contain vast amounts of stationary clutter. This clutter can complicate the implementation of a stable backscatter communication link, so experiments must be performed to characterize a variety of configurations before deciding on an RFID solution. One method of mitigating multipath propagation fading is antenna diversity. A type of antenna diversity commonly implemented is spatial diversity. Spatial diversity usually consists of a single transmitting antenna (or single reader) and many receiving antennas. The result is that if one channel experiences a “deep fade” via random deconstructive signal interference the other channels are less likely to experience the same fade at the same instance in time [10]. Once the RFID system is tested, more thought will need to be placed into the location tracking of the automated platform. One preliminary concept is to implement the PIXY camera which has an integrated computer vision software capable of tracking color [11]. Color tracking would allow the RFID system to divide the warehouse into a grid, thus simplifying the task of tracking product locations.

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