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Improvements and Modeling of RFID Technology

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Chapter 1

Introduction

1.1 Motivation and Background

This dissertation investigates the backscattering within two implementations, radio frequency identification (RFID) and radar cross section (RCS). The RFID is associated with biological research, specifically the antenna design for bio-logging.

Bio-logging is the data collecting of animal behavior and movement. The bio-logging of specimens can be a long, tedious, inaccurate, intrusive tasked that the researcher has to part take. Recent advancements in RFID is enabling these researchers to utilize this technology. The benefits that RFID have upon this area of research are minimal disturbance to subjects, automatized and full-time monitoring, and low cost tag. However, current commercial available RFID technology tend to be expensive, not setup for animal tracking, difficult to apply modifications such as hardware and software, and proprietary equipment. There has been research and development of an open-source inexpensive modifiable RFID tag system. This system is called Electronic Transponder Analysis Gateway (ETAG) Reader developed via Dr. Bridge from University of Oklahoma. The ETAG Reader is near-range via a passive transponder (tag), the system is a modified Arduino M0. Arduino have a lot of built functionality and documentation.

Previous work has shown a direct relationship between RFID tag's realized gain when placed upon a metallic object. This relationship indicates as the metallic object electrically dimensions is increases so does too the tag's realized gain. There is a quantitative relationship between antenna gain and antenna RCS due to its re-radiation properties. **sinclair1947measurement king1949measurement appel1979accurate** Thus this will present the finding The other backscattering investigation involves the impact on RCS of metallic object with a placement of RFID tag.

1.2 Background of RFID

As large-scale manufacturing keeps increasing to meet population demand, rapid identification techniques have been developed. Among these identification techniques, automatic identification procedures (Auto-ID) has become popular in many fields of industries, biological research, manufacturing, etc. Some of the most commonly used auto-ID procedures include the following but not limited to barcode system, optical character recognition (OCR), bio-metric MM, and Radio frequency identification (RFID). This dissertation will focus on RFID technology.

RFID technology uses electromagnetic fields to enable its users' to automatically identify uniquely tagged specimens at a distance wirelessly without a line of sight. Current use of this technology includes tracking applications of crates and pallets, access control systems, automatic toll collection systems, vehicle tracking and immobilizers, ID and security, etc. The bulk of the research conducted in this dissertation is associated with biological research, this will be further discussed in Section 1.4 Research Objectives.

An RFID system is composed of three components:

- A transponder (tag), generally a construction of antenna, chip, and sometimes a battery. It is the data-carrying device.
- An interrogator (the reader/write device), generally a construction of an antenna, an RF electronics, and control module
- A controller (host electronic or computer), generally hosts the database

Some RFID systems can have the interrogator and the controller be one component. The simple interaction between these components is that the tag and interrogator communicate information between each other via radio-frequency (RF) waves. This interaction occurs when the tagged specimen enters the read zone of the interrogator, retrieves information from the tag. The information that tags can store can be serial numbers, time stamps, or other useful data. Once the interrogator retrieves the tag's information the controller can implement another procedure such as recording inventory, granting access, active another electronic such as a motor, etc.

The RFID tags fall into two categories, passive and active transponders. Passive RFID tags do not have on-board power supply instead they obtain their power from the interrogator's transmitted signal (magnetic or electromagnetic field). The tag transmits its data via modulation (e.g. by load modulation or modulated backscatter). In most cases, passive tags are smaller and less expensive than active tags. Active tags contain an on-board power supply, such as a battery or solar cell, to provide voltage to the chip. The active tags can generate their own fields and modulation thus increasing the read-range between the transponder and the interrogator. Important to note that active tags are typically not able to generate high-frequency signals alone, can only modulate the fields from the interrogator.

Tags can also be categorized as read-only (RO) and read/write (RW). The RO tags can only be read. Once these RO tags are fabricated their data can be altered. Typically used for static information such as part numbers, ID, serial numbers, etc. The RW provides more flexibility such as allowing the data to be changed, storing much more information than RO tags, and easy accessibility.

As previously mentioned the tag transmits its data via modulation. The two modulations are load modulation or modulated backscatter. The load modulation uses the near-field coupling between reader and tag, can be describe via Faraday's principle. An alternating current is passed through the reader's (coiled) antenna, generating a magnetic field. Once the RFID tag is placed within the reader's fields this will result in an induced alternating voltage across the tag. This voltage will be used within the tag to turn its chip. Once the chip has been successfully activated, the tag yields its own magnetic fields that interact with the reader. The tag's load is applied to the reader's coiled antenna over time, causing a modulation. Typically load modulations operating under 100MHz (LF and HF).

This modulation can be encoded to retrieve the tag's data. The modulated backscatter (or far-field coupling) retrieves the electromagnetic waves from the tag's antenna when not within the near-fields. These tags are typically designed for a frequency band such that there is a mismatch causing energy to be reflected back to the reader. The tag's impedance can be changed over-time to cause modulation, this modulation can be encoded by the reader to obtain the tag's data. Typically modulated backscatter operates within the UHF frequency band.

A brief mentioned two basic modulation techniques used within RFID is amplitude shift keying (ASK) and binary phase-shift keying (BPSK). ASK represents digital data as variations in the amplitude of a carrier wave. The binary symbol 1 is represented as a duration of T seconds at a fixed-amplitude and binary symbol is for all other cases that are not that fixed-amplitude. BPSK (or PRK or 2PSK), a form of phase-shift keying, is a two-phase modulation scheme. The signal has two different phase states in the carrier signal, $\theta = 0°$ (binary 1) and $\theta = 180°$ (binary 0). In Figure [] shows an example of these two modulation schemes.

1.3 Background of RCS

Similarly, as RFID's backscatter (or far-field coupling), radar cross section (RCS) is backscatter procedure. RCS is a measurement of the reflective strength of a target defined as 4π times the ratio of the power unit solid angle scattered in a specified direction to the power unit per unit area in-plane wave incident on the scatterer from a specified direction as defined in **jay1977standard**. A simplified explanation is an electromagnetic wave that is transmitted from a source, the wave interacts with the target thus the wave is absorbed and scattered, the return scattered waves to the receiver are measured..

However, an important distinguished between RFID and RCS implementation of backscatter is that RFID backscatter contains a modulated signal (i.e. information associated with binary data) and RCS is associated with the field strength measured upon the backscatter. RCS obtains information relating to the target's electrically geometrical and electrical material properties.

The system that is used to take RCS measurements are constructed of 4 subsystems: An RFID system is composed of three components:

- A transmitter, subsystem that creates the waveform to be transmitted via the transmit antenna
- Antenna(s), front end devices that transmit and/or receives the scattered energy

- A receiver, subsystem that detects and signal processes the received scatter energy

- An indicator, subsystem to display the measured data. Typically the data is converted into In-phase(I) and Quadrature-phase(Q) signals.

The I signals are created via mixing the received signal and a local oscillator (LO) signal that is phase coherent with the transmitted signal. The Q signals mixed with a 90° phased shifted version of the received signal with the LO. Many current systems have an Analog-to-digital (A/D) converters to convert the measurements into digital for signal processing.

The signals transmitted in RCS can be a continuous wave (CW) or signal pulsed. CW radar setup is more simple than the pulsed setup. However, unmodulated CW provides no range information. The general setup for a CW radar is a CW signal that is transmitted when the target object's scatter signal is measured. This setup allows the user to calculate the object's doppler shift in post-processing. CW radar provides the highest average power for a given peak source power. Frequency-modulated continuous wave (FM-CW) radar systems vary its operating frequency during measurements. This allows for improved tracking target's range and relative velocity.

Pulsed radar is the more commonly used setup for RCS. This RCS system transmits a continuous train of pulses at a certain pulse repetition frequency (PRF) where the signal's amplitude is modulated. Once the pulse reaches upon the target the signal is scattered, backscattered measured by the RCS system is detected and displayed. This setup allows the user to obtain range information. This is possible due to pulsewidth (τ) which is defined as the amount of time allotted for the transmitted pulse.

1.4 Research Objectives

The research objectives are separated into two projects. The first project as previously discussed involves bio-logging using an inexpensive open-source RFID tag system. The objectives is to create a GUI software tool to enable non-antenna engineers to rapidly prototype multi-coiled wire antennas for LF and HF frequencies bands, provide design improvements, provide a software user guide, and instructions on the construction of multi-coiled wire antennas. The second project involves the investigation of impact on RCS of metallic object with placement of RFID tag. This investigation will report the findings that include bounds in which the RCS is impacted upon RFID tag's placement, those effects upon RCS, and recommend placement of the tag on the metallic object.

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