NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

THE FEASIBILITY OF RADIO FREQUENCY IDENTIFICATION IN LOGISTICS APPLICATIONS

by

Leonard Richard Kojm Jr.

December 1991

Principal Advisor: Dan C. Boger
Associate Advisor: Alan W. McMasters

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ECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION /AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
. DECLASSIFICATION/DOWNGRADING SCHEDULE	
PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
. NAME OF PERFORMING ORGANIZATION Naval Postgraduate School 6b. OFFICE SYMBOL (*If applicable*) AS	7a. NAME OF MONITORING ORGANIZATION Naval Postgraduate School
. ADDRESS (*City, State, and ZIP Code*) Monterey, CA 93943	7b. ADDRESS (*City, State, and ZIP Code*) Monterey, CA 93943-5006
. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (*If applicable*)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
. ADDRESS (*City, State, and ZIP Code*)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. | PROJECT NO. | TASK NO. | WORK UNIT ACCESSION NO.

. TITLE (*Include Security Classification*)

The Feasibility of Radio Frequency Identification in Logistics Applications

. PERSONAL AUTHOR(S)

Kojm, Leonard R. Jr.

a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (*Year, month day*)	15. PAGE COUNT
Master's Thesis	FROM______ TO______	December, 1991	59

. SUPPLEMENTARY NOTATION

he views expressed in this thesis are those of the author and do not reflect the official policy or osition of the Department of Defense or the U.S. government.

COSATI CODES			18. SUBJECT TERMS (*Continue on reverse if necessary and identify by block number*)
FIELD	GROUP	SUB-GROUP	Radio frequency (RF); Radio frequency Identification (RF/ID); Automatic identification

. ABSTRACT (*Continue on reverse if necessary and identify by block number*)

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. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSICIATION UNCLASSIFIED
2a. NAME OF RESPONSIBLE INDIVIDUAL . Boger	22b. TELEPHONE (*Include Area Code*) (408) 646-2607 2c. OFFICE SYMBOL AS/Bo

D Form 1473, JUN 86 *Previous editions are obsolete.* SECURITY CLASSIFICATION OF THIS PAGE

S/N 0102-LF-014-6603 UNCLASSIFIED

Approved for public release; distribution is unlimited

THE FEASIBILITY OF RADIO FREQUENCY IDENTIFICATION IN LOGISTICS APPLICATIONS

by

Leonard Richard Kojm Jr.
Lieutenant , United States Navy
B.S., United States Naval Academy, 1982

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

From the

NAVAL POSTGRADUATE SCHOOL
December 1991

ABSTRACT

The objective of this paper is to examine Radio Frequency Identification (RF/ID) as a possible automatic identification system to assist in managing material assets in the DOD Supply system. The feasibility of implementing RF/ID is the principal question examined. This paper discusses the characteristics, capabilities, and limitations of RF/ID as well as advantages and disadvantages. The paper will analyze the necessary elements to consider in implementing RF/ID. This study will serve as a feasibility and implementation guide in determining requirements for deploying a RF/ID system. A radio frequency identification system can provide many benefits to the military logistics system. Abnormal environments (i.e., harsh, high relative speeds, etc.) offer ideal circumstances for RF/ID. The feasible implementation of a RF/ID system is primarily a question of cost, in which the cost savings contributions to the objectives of the DMR initiative must be appraised.

TABLE OF CONTENTS

I. INTRODUCTION

A. BACKGROUND

The resources required to move and track material are large in terms of numbers and effort. To manually input data into the database or manually scan the material to download to the database is time consuming, manpower intensive, and prone to errors. With the initiatives to reduce costs for just about every element of the Department of Defense (DOD) organization and with specific tasking in more detail within the Naval Supply Systems Command, current technology is available to help eliminate material identification and tracking costs. Bar coding has been implemented extensively throughout the Navy as an initial means to curtail some of the costs. However, technology today presents us some possible alternative solutions to this problem. Radio Frequency (RF) Identification is just one of those technologies that has already been implemented in the commercial sector to assist in reducing costs.

B. OBJECTIVE

The objective of this paper is to examine Radio Frequency Identification (RF/ID) as a possible automatic identification system to assist in managing material assets in the DOD supply system. Given today's technology and the technology of the near future, what is the feasibility of implementing RF/ID for logistic purposes in the military? In support of the primary question, there are several subsidiary research questions. What are the capabilities and limitations of RF/ID as well as the advantages and disadvantages? What is the reliability and accuracy? What are the costs associated with procurement, operations, and maintenance? How does this system meet current and future needs?

C. SCOPE/METHODOLOGY

The scope of the paper focuses on the application of RF/ID in the logistic system. Although the potential that RF/ID possesses for identification application is limitless, the paper is limited to the tracking and identification of material. The paper will analyze the necessary elements to consider before implementing such a system. The elements include: costs, capacity, reliability, range, programmability, speed, and life cycle. This study will serve as a feasibility study and implementation guide in determining requirements and concerns involved for employing a RF/ID system.

Since DOD has not conducted much research in this area, the majority of the research focuses on the commercial sector, both in the manufacturing of RF/ID systems or components and the actual implementation of a RF/ID system. However, studies of actual RF/ID projects implemented by DOD will be used to evaluate the elements contained in each project.

D. ORGANIZATION OF THE STUDY

Chapter II presents a background of radio frequency identification and the status of its use by DOD. Chapter III examines the technology involved in RF and RF/ID systems. It explains the system elements and the system characteristics. Chapter IV is the qualitative analysis of the factors to consider in determining implementation/application. This chapter also considers external factors (licensing, standards, and radiation hazards) to be regarded in a feasibility analysis. Chapter V provides information on some of the various DOD RF/ID projects, while examining some of the difficulties experienced in implementing those projects. Chapter VI suggests some of the costs and benefits associated with incorporating a RF/ID system. This non-quantitative discussion can assist in the decision to employ a RF/ID system. Chapter VII provides the conclusions and recommendations of this study.

II. BACKGROUND

A. THE NEED FOR DATA

Industry and the military have evolved into complex organizations that require diverse numbers of operations to perform their daily tasks. The resources required to perform these tasks are large in terms of numbers and effort. Efficiency, quality and flexibility are paramount in performing these operations in today's organizations. Today's operations require that more information be available to the manager so he can make sound judgements about how to improve or streamline the organization. As a result of this need for greater efficiency, we have become a society of information. Computers are used to help collect, compile, and sort the information associated with these required tasks, but to manually input data into the computer database is both manpower intensive and prone to errors.

B. NEED FOR AUTOMATION

Automating some of these tasks will help the organization become more efficient and successful. Automation of nearly every aspect of industry is being accomplished today. The need to become more efficient has lead to technological breakthroughs in the area of automation. The area in which this paper concentrates is in automatic identification of material and material handling.

Automatic identification systems are powerful tools in the manufacturing and material movement environments. Controlling material and the associated inventories is fundamental to effective operations management.

Tighter control from warehouse receipt to customer shipment leads to faster order completion, improved resource utilization and lower inventory investment.

Automatic identification reduces the problems associated with information gathering and input. It will increase accuracy of input, guarantee the validity of data, and guarantee the transportation of data from point to point. It will also provide control of decision making with a quicker response from operations management. When properly implemented, automatic identification systems can have a direct impact on labor productivity, space utilization, inventory control, production control, customer service, and operation cost (Soltis, 1985, p.55).

However, the primary benefit of automatic identification systems is timely, accurate data collection. Traditional collection methods produce error rates ranging from one in 30 for handwritten documents to one in 300 for keyboard input. Automatic identification systems operate in the accuracy range of one error in three million entries, and most offer audible entry feedback for immediate error correction (Soltis, 1985, p.55).

There are several types of automatic identification technologies employed in military logistics and in industry. Three of the most common automatic identification systems are based on optical technologies. These are bar codes, optical character recognition (OCR), and machine vision systems. Other technologies include magnetic stripe systems, which record information on cards in much the same way that data is recorded on computer disks, and voice systems, which convert spoken words to computer format and back again. Another technology available for automatic identification employs Radio Frequency (RF).

C. RADIO FREQUENCY IDENTIFICATION

Radio Frequency Identification (RF/ID), a major branch in automatic identification, provides a new alternative to information handling problems. This technology uses bi-directional radio transmissions to interchange information. The system typically consists of an identification tag or transponder, an antenna and a transmitter/reader. Upon activation the tag transmits information which is picked up by the antenna and sends it to the reader. This information can then be downloaded into a computer. These systems are utilized as a data storage medium to gather and input information about places, items, people, animals, or just about anything imaginable.

The microcircuit technology used in RF/ID offers distinct advantages over other forms of automatic identification. Some of these advantages are: non line-of-sight operation; forgiving target orientation; re-programmability without physical contact; ability to carry large amounts of data; and protection of data from environmental extremes. The biggest disadvantage with RF/ID is the inherent investment costs and the RF/ID industry's lack of uniformity of product standards. This paper will analyze these factors in further detail.

D. MILITARY LOGISTIC INVOLVEMENT

The Department of Defense (DOD) has been involved in automatic identification technologies for many years. Military information systems for the supply and distribution of material in peace time and during combat are evolving toward the more frequent use of automatic identification technologies. In light of world events, national policy, force reductions and budget realities, there is an increased emphasis toward a new and more efficient organization for managing the DOD supply system. Management, within DOD, has long recognized the usefulness of automatic identification in reducing system costs and has stepped up efforts in examining and implementing the various technologies.

The Logistics Applications of Automated Marking and Reading Symbols (LOGMARS) Program Office was established within DOD on 15 March 1982 to manage the implementation of LOGMARS systems. LOGMARS systems have been applied to a wide range of distribution management tasks including shipping, receiving, inventory management, and asset tracking. LOGMARS markings are currently machine-scanned bar codes.

As mentioned, marking technology has advanced to include microchip-based innovations. With the advent of this new technology a separate Microcircuit Technology in Logistics Applications (MITLA) organization has been established within DOD as a focal point for implementation of these microchip products. The MITLA organization provides direction to DOD through the MITLA Coordinating Group, which has representation from each of the Services/Agencies. Headquarters, Air Force Logistics Command (HQ AFLC/DSXS) at Wright-Patterson AFB is the DOD Executive Agent for MITLA. Their primary responsibility is to implement MITLA within the Services/Agencies and to be responsible for the establishment of standards. The MITLA organization and the Naval Supply Systems Command

(NAVSUP) are active with the RF/ID industry in applying a wide range of microcircuit technologies to a variety of logistics activities.

III. RADIO FREQUENCY IDENTIFICATION TECHNOLOGY

A. OVERVIEW

Radio frequency identification technology employs a small integrated circuit with an electronic memory, an antenna system, a reader/transmitter and a host computer system (Figure 1). The integrated circuit, referred to as a tag, contains the information that is desired. This information is encoded on the tag and usually describes the material or vehicle on which it is placed. As the tagged object approaches a reader/transmitter, the reader/transmitter broadcasts a radio frequency signal toward it. This action initiates the communication between the tag and the rest of the system. The information from the tag is then transmitted to the reader/transmitter via radio frequency communications. This information is transmitted when the reader/transmitter and the tag are in close proximity to each other. The data is transmitted by radio frequencies by the use of antennas on both the tag and reader/transmitter. The host computer then translates the information to its desired format and use.

B. SYSTEM ELEMENTS

1. Tag

The data tag is primarily used to record, store, and transmit data on that item to which it is attached. The tag includes a coil (antenna), transceiver electronics, control logic, and some form of nonvolatile storage or memory.

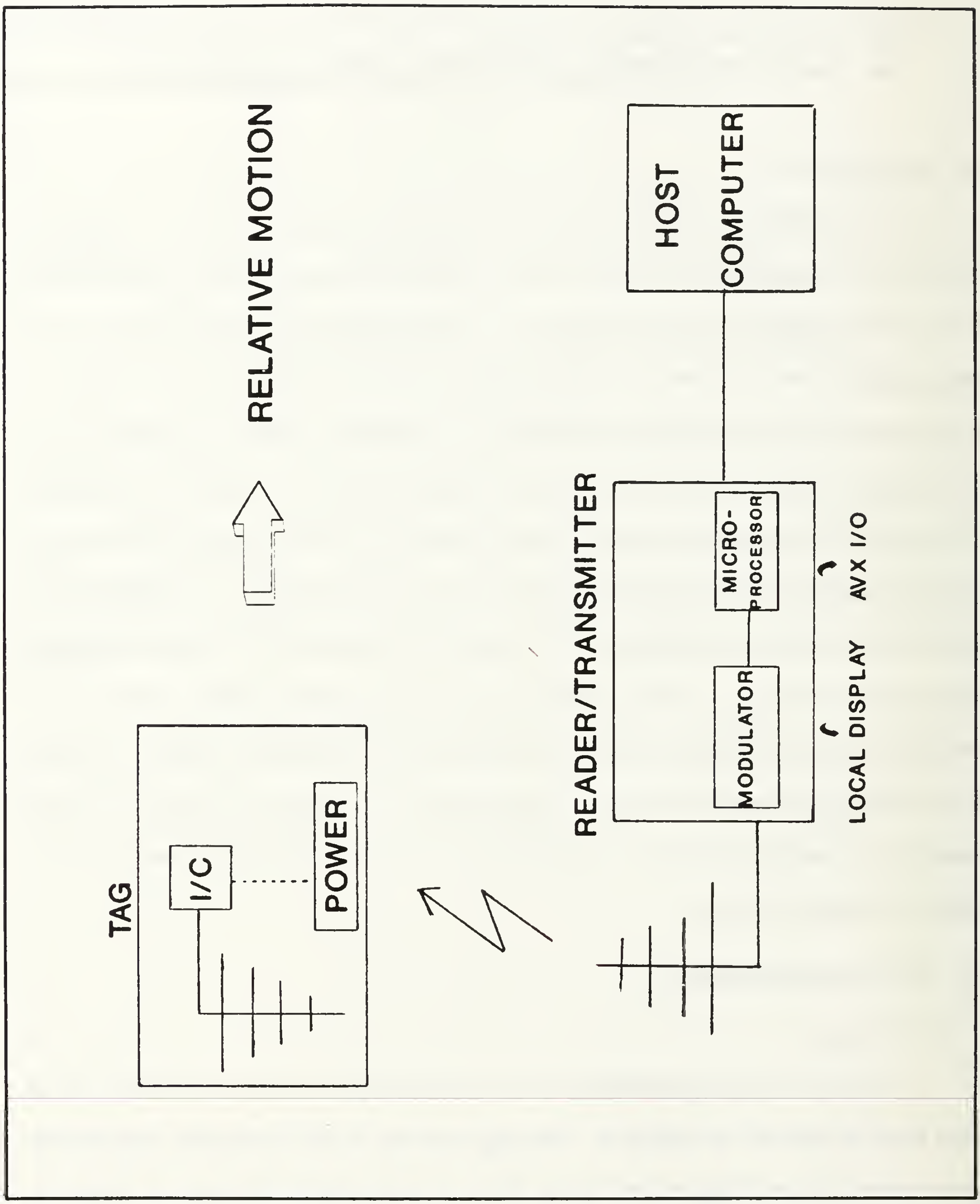

Figure 1. Block Diagram of the Host Computer, Reader/Transmitter, Antenna and Tag

Each tag is encoded with a unique identification message. This encoded message can range in size from a few bits of information to a few thousand bits, depending on the need and application.

When the tag is queried by the carrier signal broadcast from a system antenna, it generates a RF frequency response, with the encoded information, back to the system antenna for decoding. The reader/transmitter receives this signal, extracts the data from it, and presents it in visual form to a human, or electronically to a host computer.

The tags are attached to the objects being tracked or identified. Tag sizes, complexity, how they are powered, and how they are read may vary from system to system. The more powerful the tag and reader technology, the faster the information can be transmitted or received (Schwind, 1987, p.101). These different tag characteristics will be discussed later.

2. Reader/Transmitter

The reader/transmitter is the device containing the digital electronics which transmit to, and collect information from, the tags. When the tag is in the acceptable range for communication, the reader/transmitter broadcasts a frequency to the tag, which serves, at a minimum, to notify the tag that a reader is present and wants to receive its identity or perform some transaction. The reader/transmitter receives the modulated signal from the tag, decodes the identification information, validates the information, and transmits the code along with any appended information to the host computer system or to a human-readable display.

The reader/transmitter performs its communication functions through the use of RF modules. The RF modules control the communications to the tags and to the host computer. They control the generation and receiving of RF signals. Through the antenna(s), the RF module delivers the transmitting signal and receives the incoming tag signal for demodulation.

The reader/transmitter may also be able to perform the function of encoding the information on the tag. During this process, the user reads the information on the tag and alters all or some of the data, as desired. Data elements such as the date received, new routing instructions, or other identification or control data can be updated. Also, during this function, the entire database of the tag can be erased for tag recycling. The information can be altered at any point of the tag's travel in its environment. This operation is accomplished using appropriate user interface systems (i.e., keyboard, monitor).

The reader/transmitter may also be able to incorporate a mini-processor. This can function as a limited local system controller. This type of unit makes it possible to process data and make decisions based on information carried in the memory module. The advantage is that fast and simple decisions can be made without burdening the controlling computer (Draxler, 1988, p.7). Reader/transmitters can be either stationary or portable.

3. Antenna

Antennas can broadcast and receive RF signals in a range of radio frequency bands. The antennas are mainly used to transmit and receive RF to and from the tag but can be used to communicate information back to the host computer. The antenna sizes and shapes vary with intended application and frequencies employed.

C. SYSTEM CHARACTERISTICS

There are numerous ways in which to employ a RF identification system. The different types of equipment used depend on the intended application. RF/ID is usually employed in systems where operating conditions rule out other kinds of coding or identification systems such as bar codes or Optical Character Recognition (OCR). These conditions are usually harsh environments such as high temperature, caustic, toxic, or an environment with high relative motion speeds.

The intended use of the RF/ID system more accurately determines which type of system, and specific characteristics, to use. The following sections will discuss the different system characteristics. The majority of the characteristics are focused on the RF tag, which is the most environmentally sensitive part of the RF/ID system.

1. Programming

The main classification of RF tags is the type of memory programming that is performed. There are two types of programming classifications: read-only and read-write. This characteristic describes whether data that is encoded on the tag can be changed during its life cycle.

a. Read-only

Read-only tags, as the name implies, only respond to the queries of an interrogator. This type of memory is usually nonvolatile, and is typically written or "burned in" by the manufacturer during production. There is no way for the user to change the recorded data. The tag essentially performs as a license plate or identification tag. Due to the limited capability of these tags, the amount of data storage capability is relatively small. The memory used is written to only once, but could be read any number of times, as required. These tags are usually smaller in size and cheaper in cost.

Another type of read-only tag manufactured is the Erasable Programmable Read Only Memory (EPROM) tag. Many MITLA tag manufacturers employ this type of non-volatile memory which can be initially programmed by the user. Although EPROM can be erased by exposure to ultraviolet light, most MITLA manufacturers permanently shield the microchip to ultraviolet exposure, thus making the data stored permanent (Reboulet, 1990, p.3). When this type of memory is employed, data is appended and eventually fills the memory, expiring the tag.

b. Read-write

Read-write tags allow the user to modify the contained information. This latest advancement in MITLA devices employs Electrically Erasable Programmable Read Only Memory (EEPROM). These tags are normally much larger and contain more circuitry but can carry much more information. Data can be added or removed from the built-in memory circuits as the tag travels throughout a system. These devices act as distributed data bases, containing instructions to be implemented by reading stations. Instead of just transmitting an identification code that a host computer uses to look up a series of instructions for a work center, EEPROM tags may contain the instructions themselves (Sharp, 1990, p.26). Because of the increased capabilities, these tags have enormous diversity in application.

2. Active/Passive

Tags are also categorized by their source of power. There are two types of classifications: passive and active.

a. Passive tag

Passive tags require no internal power supply to transmit their information. The power needed for the tag to identify itself or provide encoded information comes from the radio frequency energy that was broadcasted from the reader or interrogator.

b. Active tag

Active tags are those which contain a battery. The use of the battery varies on active tags. The battery can be used to power all of the elements, including the transceiver, the logic, and the memory, or it can be used to power certain portions of the tag (Ames, 1988, p.14).

3. Capacity

There are basically four levels of tag capacity. The tag's capacity is measured in the number of bits stored in the memory of the tag.

The simplest tags, Level I, are primarily used for electronic article surveillance. They usually contain only one bit of information, indicating the presence of the tag.

Level II is used for identification and typically provides a bit capacity from 8 bits to 128 bits. The bits are employed to serially number the tags and are usually either factory or field programmable.

Level III tags typically store up to 512 bits of information and are used to store or record events such as routing, operations, or a history of progress of the item attached to the tag (Schwind, 1987, p.101).

Level IV tags are called portable data bases. They have the largest capacity, usually carrying from 256 bits to 256 thousand bytes of alphanumeric information. These tags are, in effect, portable data bases offering interaction without mainframe computer assistance (Ames, 1988, p.15).

4. Frequencies Used

Operation of RF/ID equipment is divided into low and high frequencies with a variety of carrier modulations. This refers to the wave length of the signal used to activate the code carrier or tag.

Low frequency systems operate in the radio or TV broadcasting range or from about 100 to 600 KHz.

Systems using frequencies of 900 MHz and greater are classified as high frequency systems.

Each of these systems operates differently, uses different components and has some capabilities that are the same and some different (Schwind, 1987, p.107). Frequencies from 1.7 MHz to 10 MHz were recently also made available in the United States by the Federal Communications Commission (FCC) for low powered communication devices, so more products are starting to use these frequencies. These are sometimes referred to as medium frequencies (Ames, 1990, p.12).

IV. QUALITATIVE ANALYSIS

A. FACTORS TO CONSIDER

Integration of RF/ID systems generates several unique factors to consider. These factors are, but not limited to, the following: frequency and range; power source; durability and life cycle; orientation; capacity; programmability; and reliability. This chapter will analyze each of these factors for its impact on the system design. In the analysis of each of the factors, cost is an underlying question in determining implementation/application.

1. Frequency and Distance

As mentioned in the previous chapter, there are various frequencies used in RF/ID operations. Basically, the range over which the reader can read the tag is directly proportional to the frequency used. As the frequency increases the range will also increase (Schwind, 1986, p.84). Frequency can also affect the data transmission rate and cost of the system.

a. High Frequency

High frequency systems, equipment operating above 900 MHz, are more expensive to purchase and operate, because of the added power and circuitry requirements. However, because high frequencies have characteristics similar to visible light and propagate wave patterns in a narrow beam, these systems have a longer range of operation (Draxler, 1988, p.9). This advantage will allow for a greater operating distance between the reader/transmitter and the tag. This transmitted narrow beam also increases the need for a more precise alignment between the reader/transmitter and the tag.

High frequency signal energy is also susceptible to absorption by materials (i.e., liquids and grease) thus introducing signal attenuation and distortion in an industrial type environment. Multi-path ("cross-talk") transmissions, due to reflection of the emitted signal off surrounding metal, is another point to evaluate and is usually a limitation found in very high frequency transmissions (Draxler, 1988, p.9).

A major advantage of high frequency transmissions is a capability for a high data transmission rate. This characteristic is especially useful for items requiring a large amount of data to be transferred over a short period of time. This is one of the principal reasons why many telephone transmissions are done by high frequencies (microwaves). Because of the need for high data transmission rate, high frequency systems are better adapted to environments of faster relative motion between the reader/transmitter and the tag such as reading railcar identifications during transit. The high transmission rate is needed to overcome the short period of time the two elements are in proximity to each other.

b Low Frequency

Low frequency systems have characteristics quite the opposite of high frequency systems. Because of the associated low power, the range of low frequency transmission is shorter than that of high frequency. The low frequency transmission beam is not very narrow and spreads out rapidly from the source. In essence, this "beam" becomes omni-directional and is less sensitive to the reader/transmitter and tag alignment. Because the RF transmissions are less focused, they loose their energy faster, thus reducing the range.

Because of the reduced power requirements and complexity of equipment, low frequency systems generally cost one forth less than high frequency systems. However, low frequency transmissions have associated slower data transmission rates. Since the carrier frequency governs the upper limit to the rate at which data can be transferred, low frequency systems have an inherently lower data rate. Their reduced cost is countered by the reduced efficiency of speed of transmission.

2. Power Source

As mentioned earlier, tags can be categorized by the source of power: active and passive.

Active tags, containing an internal power source, are normally associated with the read-write concept of encoding tag data. This is due to the power supply needed to transmit the data to the reader/transmitter. Battery-powered systems make possible greater transmission range, higher memory capabilities, and microprocessor intelligence. They are also more expensive and may suffer from battery failure and lost data (Kitsz, 1987, p.4).Passive tags are non-battery systems and are powered (excited) by the radio frequency energy from the read/transmitting station, so they are small, simple, and failure free. On the other hand, the range is short (can be as little as two centimeters), memory capability is usually small, and they are rendered instantly inactive when they leave the energizing field (Kitsz, 1987, p.4).

3. Durability and Life Cycle

The durability and life cycle of a RF/ID system are focused on the tag, especially the power source. The tag is the element in the system that has the largest degree of design variability and also is subject to the harshest environments. Passive tags are more durable than active tags because they have less circuitry and do not contain a battery.

When required, the battery is the determining factor of the length of the tag's life cycle. The life of the battery is dependent on the battery electrical capacity and the consumption of energy by the circuitry of the tag's components. Obviously, the more the tag is in use the more energy will be consumed. However, to save energy, new tag designs have incorporated an electrical system that throttles down to a "sleep" state, while not transmitting or being queried. Also, new technology in battery design has dramatically increased the life of batteries giving this question less seriousness. For example, a solar- powered version for outdoor use is feasible.

The tags themselves have a nearly infinite life span (Hill, 1985, p.77). The tags are encapsulated to seal out dirt and paint, and they can even be designed to withstand fairly high temperatures that would destroy common labels used in vision-based automatic identification systems.

4. Orientation

Orientation refers to the relative positioning of the antennas of the tag and reader/transmitter. Orientation can affect the reliability of the transferred data. As the tag passes through the RF field emitted from the reader/transmitter, it should pass through the strongest (largest) part of the RF field rather than the furthest portion (Draxler, 1990, p.5). This optimum path normally occurs when both coils (antennas) have the same axis, if the coils are similar in size. If the coils are dissimilar in size, the optimum path will be tangential. Plane and spatial angles (pitch, skew, and roll) will also affect the performance of data transmission (Figure 2).

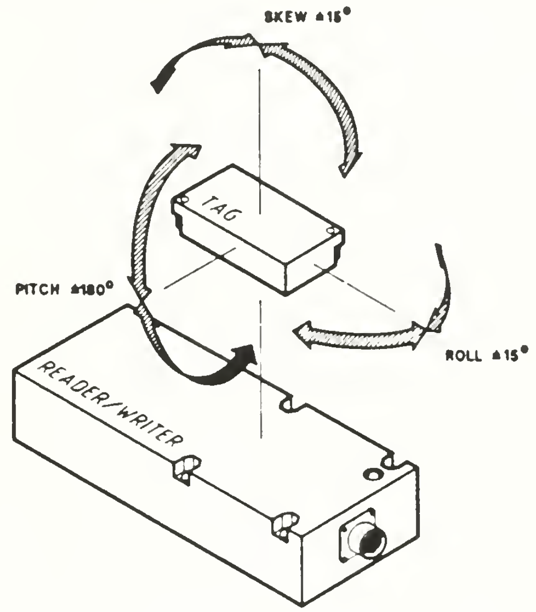

Figure 2. Relative Plane and Spatial Angles
(Source: Ames, 1990, p.3-24)

If the tag is not properly aligned with the reader/transmitter, then the data exchange becomes unreliable. The more misalignment between the tag and reader/transmitter the greater the unreliability of the data transmission.

Another factor used in determining the precision of the orientation is the required distance between the tag and reader/transmitter. As mentioned, high frequency systems have a longer range of operation. This longer range requires that the alignment be more precise due to the possible attenuation of the RF field. For proper information exchange, a nominal distance for transmission is recommended.

The relative speed between the tag and the reader/transmitter, along the same axis, also determines the required alignment. The faster the relative speed the more need for precision in the alignment in the two different coils (antennas). As the relative speed increases, the time allowed for the transmission of data is shorter. In most RF/ID systems, data transmission is accomplished at least twice during each encounter to verify the data from the first transmission. As the speed increases the probability of verifying the data through the second transmission decreases proportionately. This impacts the reliability of the transmitted data.

5. Capacity

The capacity of the tag is classified by the number of bits of data it can store. The desired capacity of a tag will depend on its potential application. Because less circuitry and memory is involved, read-only tags will have less capacity than read-write tags. However, read-only tags are ideal for small amounts of data exchange and for applications requiring reduced tag size. In fact, read-only RF/ID tags measuring 0.082 inches in diameter and 0.04 inches long have been produced and used in laboratory experiments. However, their data capacity was limited to only eight bits of information (Schwind, 1986, p.84).

Having larger data capacity, read-write tags are initially the preferred choice for most applications and have the added advantage for meeting future data requirements. Generally, as the level of the capacity increases so does the cost of the tag. This is primarily due to the added circuitry and power requirements.

This advantage is countered by the added size of the tag (typically three inches by four inches by one inch), memory requirements, and the added cost of the system. Read-write tags can double in function as portable data storage in case of host computer failure.

6. Programmability

The programmability of the RF/ID system refers to the tag's ability to accept data. This factor focuses on the type of tag, whether it classified as read-only or read-write. As mentioned, read-only tags are normally factory programmed and are used strictly in a "license plate" role. Because of their reduced circuitry and power, these tags cannot accept large amounts of data. This characteristic of read-only tags limits their application.

Read-write tags have a much wider application range. As noted earlier, because of their more complex design, these tags have the ability to store large amounts of data and are capable of allowing the data to be changed when required or desired. This characteristic renders them reusable for as long as the life of the battery.

7. Reliability

Reliability pertains to the correctness and accuracy of the information stored on the tag and of the communication of that data between the tag and the reader/transmitter. Data integrity is affected by the previously mentioned factors of orientation, range, relative motion of modules and environment, plus error management.

As mentioned, if the orientation of the tag and the reader/transmitter is not within the acceptable limits then the data that is transmitted will be subject to error. The same is true with the relative distances and speeds between the tag and reader/transmitter. If the system is operating outside the manufacturer's "envelopes" or limits, data reliability values can become increasingly low. These limits vary among the manufacturers and are also affected by the type of tag used. Hence, the cost of the system will also be affected by these limits. As the performance capabilities of the system increase so will the cost of the system.

However, if the system is set up within the manufacturer's limits the system is very reliable for data exchange. An Automatic Vehicle Identification (AVI) system installed on the Texas Turnpike has been well over 99 percent accurate for over a six-month period (Susca, 1989, p.24).

Reliability is also affected by the input of the data. As with any computer system, the initial input of data is accomplished by humans using some type of keyboard. This type of input is normally associated with potentially high error rates. However, some manufacturers allow the input of some data elements be accomplished by scanning bar codes attached to the various input sources. The bar code scanner would integrate with the RF/ID system at the reader/transmitter interface.

RF/ID systems also control data reliability by incorporating error checking techniques. Because of the micro-circuitry involved in RF/ID, error checking virtually requires no human intervention and is self-contained within the system. Error checking is accomplished in different ways by the various manufacturers.

First, check sums may be used. Check sums are digits in the data, placed throughout the data, and when read by the computer they equal the sum of the preceding digits. If the check sums are equal, the data is assumed to be correct and the computer continues reading. If the check sums are not equal, the reader/transmitter re-reads the data until the information is correctly read. The check sum control is accomplished during the encoding of the data on the tag.

Another method incorporates a cyclical redundancy check (CRC) of several words. This method, CRC, is obtained by adding the contents of the information fields and subtracting the lower eight bits of the sum from 256 (Draxler, 1988, p.14). The system compares the result and re-reads the information, same as above, until the information is read correctly.

B. LICENSING DILEMMA

The Federal Communications Commission (FCC) is a branch of the Federal Government with the responsibility to regulate the level of RF emissions from commercial and public devices in which the generation of radio frequency energy is transmitted through wires or from antennas. Every frequency within reach of state-of-the-art radio equipment is reserved for specific purposes; licenses are required to use most of them (Glass, 1990, p.53).

Most of the RF/ID frequencies will be controlled by the FCC. The extent of the FCC's involvement will depend on the type of frequency used in the RF/ID system. One of two criteria must be met to legally use or emit radio frequency energy under FCC regulations. Either the energy emitted must be very low or a license must be obtained from the FCC. If the higher frequencies are used in the system, further FCC approval is required, not only for the product but for the site itself. This is to eliminate the duplication of frequencies in that area in hopes to avoid any interference.

Licenses for the use of certain frequencies are not easy to obtain, especially if the long-term objective is to have one standard national or worldwide frequency or band for use in a RF/ID system. The allocation of the radio frequencies by the FCC is increasingly difficult due to the limited nature of the radio spectrum and the increasing spectrum congestion. Also, in some heavily populated areas the airwaves may already be so full that the FCC may deny licensing altogether. This national communications dilemma could have serious implications on the RF/ID industry.

Implementing a DOD worldwide RF/ID system will also pose considerable licensing problems. Obtaining a frequency license in another country is as least as hard as obtaining one in the United States. Plus, if the DOD was to implement a standard RF/ID system with a universal frequency range (band), the licensing problem would become exponentially complex. This is because the different countries have different allocating procedures and different frequencies that are reserved for specific purposes. Trying to find a frequency that would be available to use on an international basis would be virtually impossible.

The power, or radiation, that emanates from these frequencies are also regulated by the FCC. The FCC has several categories to restrict intentional or unintentional radiation devices. Falling under the classification of intentional radiation devices, MITLA devices have restriction requirements that are covered in Sections 15.209, 231 and 249 under FCC Radiation

Emission Limits, General Requirements (FCC, 1990). These sections require that intentional radiators don't exceed the worst-case field strength levels.

This radiation further complicates the licensing problem. The frequencies used may be licensable but the emanating radiation may not be legally acceptable. Most of the radiation hazards are concerned with worker safety, which will be discussed later.

C. STANDARDS

Standards are the key to the successful growth of any automatic identification technology. The rapid growth of bar codes has been the result of several carefully considered symbology standards (Ames, 1988, p.46). However, "this standard symbology was hammered out, over quite a long period, by various technical societies" (Burke, 1990, p.48). Unfortunately, RF/ID is a relatively new product and has not experienced bar code's overwhelming acceptance. The technology is new and the investment costs are considerably more than bar coding.

The underlying problem with the RF/ID industry is the abundance of manufacturers. The biggest problem with establishing standards is that most of the systems are proprietary, and companies are unwilling to give up a share of the present, relatively small market, in exchange for cross licensing of competing RF/ID systems (Adams, 1990, p.23). Each one of them offers a slightly different approach to RF/ID that adds more confusion to an already complex issue and offers equipment that is not compatible with other equipment of a different manufacturer. The abundance of manufacturers is driving the price of the technology down while proliferating the types of equipment and technologies.

There are two ways in which to combat this problem of non-standardization. The first is to have the industry itself coordinate and implement a standard for its products much like what was done in the computer industry and audio product industry. The second method is to have the procuring industries initiate application standards in procuring and using RF/ID equipment.

Automatic Identification Manufacturers, Inc, (AIM) has initiated the development of a RF/ID standard for the manufacturers (Ames, 1988, p.46). They have surveyed the industry to collect data from the different manufacturers in hopes of developing a standard. To date, AIM has not developed a RF/ID standard but recognizes the need for one and continues the effort. Some organizations have initiated the development of standards in their respective industries.

The Automotive Industry Action Group (AIAG) is working on a standard for RF/ID for manufacturing applications of automotive production lines. A nonprofit action-oriented association, AIAG has its basis in the automotive industry but their activities have implications beyond. It was through AIAG that standard bar code shipping labels are used in various applications throughout the world (Major, 1990, p.29). Currently, they have not reached consensus on an acceptable standard.

The Association of American Railroads (AAR) has developed an automatic equipment identification standard. This AAR Standard specifies requirements for the automatic electronic identification of equipment used in rail transportation (AAR, 1990, p.2). The American Trucking Association (ATA) has also developed a similar standard for use on identifying trucking equipment. This standard is compatible with the AAR Standard. The two industry standards also state the mandatory usage of RF/ID systems by the respective industries in the near future.

A problem in the way the two associations developed their standards is that they decided on a specific manufacturer which met their requirements and evolved a standard around his specifications. This might do well in the commercial sector, but DOD would be hard fought if they tried to develop a standard that way. The DOD standard will be more complicated for that reason, as well as many others. A standard that has national or worldwide distribution, as the DOD system will need to be, will be significantly more complicated to architect. The MITLA Working Group is working on the standard problem, but is currently far from agreement on most of the issues.

D. RADIATION HAZARDS

The hazards associated with RF/ID are focused on the radiation energy that is produced when the system is transmitting information or energizing circuits. As mentioned earlier, there are various frequencies at which the different RF/ID systems operate. Associated with the different frequencies are different radiation hazards. Some of these hazards are well studied and their effects well documented, while some hazards are not yet understood. Radiation hazards can either affect personnel or they can affect the equipment or material located in close proximity to the radiating source.

1. Personnel

It is well known that microwaves and other radio frequency radiation at sufficiently high intensities can cause adverse biological effects due to the generation of heat in the organism. However, the extent and importance of more subtle changes which may occur at lower intensities (frequencies), particularly with continued or long term exposures and various modulation modes, are not known adequately.

To control the radiation hazards, the FCC and the American National Standards Institute have developed energy level limits of certain frequencies. The concentration of effort on the standards and recommendations are in the high frequency RF/ID systems, which more adversely affect humans. The absorption rates of RF emissions on personnel were found to be direct functions of the size of a specific individual and the frequency of the signal (Markley, 1986, p.82). This means that, as the mass of an individual and the RF frequency increases, the absorption rate of that individual also increases.

While the primary damaging effect is thermal, other effects have been speculated, including nervous system involvement and behavioral changes. These radiation hazard concerns must be resolved by either the government or the RF/ID industry if the RF/ID concept is to succeed. In this era of increasing environmental concerns, the effect of RF radiation on the surrounding natural environment must also not be forgotten. Very few studies have been conducted in this area.

2. Equipment/Material

The careful placement of equipment around any installed RF/ID system can preclude any radiation hazard to that equipment. Adjustments in the work place or in the RF/ID system configuration will commonly occur. However, the radiation hazard that still exists is with the material that is being identified. Electronic and other radiation sensitive equipment could be exposed to radiation doses that could damage the product. Special packaging or handling of sensitive items could alleviate this concern, but could add more costs to the system. To exclude certain material from being identified by RF defeats the purpose of an identification system.

Another prime concern for RF/ID military logistics application is the safety issues of using MITLA technology for munitions tracking and inventory management. Due to the explosive nature of this material, all the safety concerns are paramount. The military is unique in this type of material movement and therefore must initiate the required studies and standards. Fortunately, some evaluations have already been conducted on this issue. The U.S. Army Armament Research Development & Engineering Center has evaluated the MITLA technologies on electromagnetic sensitive munitions. In their study, they have determined that with sufficient electromagnetic energy (high frequencies), the electronic fuses could detonate under certain conditions. Due to the different types of armament in the military inventory, the study used a worst case scenario and concluded the following:

- If MITLA devices limit their RF power transmissions to 30 uWatts or less, they will be safe to use regardless of operating frequency.
- Frequency of operation should be 2.45 GHz
- To maintain low RF power transmissions, to increase transmission range, and to increase the tag's capacity to store large amounts of information, active tags are recommended for use. (AED AEC, 1991, p.20)

These are the results of just one study. More studies will have to be conducted on the entire military armament inventory of all services to eliminate the possibility of a catastrophe.

V. APPLICATIONS

A. INTRODUCTION

There are many areas within DOD where RF technology could improve readiness, save resources, provide more accurate inventories, and track critical assets. One of these projects under study is the marking of hazardous material with a MITLA device which would carry shipping, handling, storage, and emergency care information. This information would reside with the item at all times and be easily accessible throughout the logistics pipeline. Other areas which will benefit from MITLA technology are the DOD medical functions and depot maintenance (serialized control).

The marking technology of tomorrow, RF/ID, is available today. The devices can be made to fit nearly any application. The limitation for the possible applications is the human imagination.

The following sections provide information on some of the various DOD RF/ID projects. A description of the project, analysis of the surrounding conditions, as well as the current status is given for each project.

B. SMART PALLETS

The Smart Pallets project is a Navy project set up in Charleston, South Carolina at the Navy Supply Center (NSC). The project was initially set up to help track material in a specific warehouse. The initiation of the proposed project came through the Navy Supply Systems Command, coordinated through the LOGMARS Project Office. Apparently, the receiving warehouse was misplacing and losing material. This seriously degraded customer service. A tracking system was needed for the warehouse to track the material from when it was received until the material was ready for further distribution. The proposal was to use MITLA technology and attach RF tags to material and pallets and set up a RF reader/transmitter grid network within the given warehouse. This system could monitor palletized material loads from their original receiving area to their final storage area (Reboulet and Wagner, 1991, p.33).

The implementation was to have a RF tag attached to an empty pallet and, as material was received, a bar code wand would scan the material through the RF reader/transmitter and encode the RF tag attached to the pallet with the information. As the pallet would fill up with material, the RF tag would store the data for each item. The data contained on the tag for each item would be the item stock number, quantity, document number, and other local information. As the pallet moved through the warehouse, passing through the reader/transmitter grid, the exact location of the pallet could be obtained. The location was determined by the readers in the grid, identifying the pallets that had just passed through and forwarding this information to the host computer. Once the inquiry (which was accomplished through a internal electronic manifest) was made about a pallet or the material on the pallet, the host computer could assimilate the location through constant updates by the readers.

The objective was a real-time monitoring system that would allow the NSC to better utilize their personnel and time resources and increase customer service levels. To a degree, the project worked. However, it did have its problems. After all, this was the Navy's first attempt at an actual application. The major problem with the program was with the RF transmission interference. This interference was from both transmitting and receiving RF. The RF frequencies used interfered with foreign aircraft transiting through Charleston Air Force Base. As mentioned, foreign countries have different frequency allocation procedures and, in this case, the frequency ranges were close enough to interfere. This problem remained unsolved because of the pre-set frequencies of the RF/ID equipment.

The other area of concern was the degradation of receiving and transmitting RF in the warehouse. When the site inspection was conducted and the system ultimately designed, the conditions on which both were based was a very static and uncluttered environment. Inadvertently, the actual cluttered and dynamic work place was unaccounted for in the design. This produced "dead spots" in which it was impossible to transmit or receive RF in certain areas due to high attenuation by the surrounding material (i.e, pallets and boxes). The RF reader/transmitter grid was rendered partially ineffective. Efforts were made to move material through the warehouse to avoid producing "dead spots". However, this was difficult to do because of the nature of the receiving warehouse, being a very dynamic environment with a large volume of material throughput.

Because the efforts to correct and avoid these two problems failed, the project was canceled. Although the project had some technical flaws, it did provide, when operating properly, a very effective method to track the material in the warehouse. In fact, plans were generated on expanding the scope of the original project to include more warehouses and other logistic operations. This project provided the impetus to proceed further with exploring the potential of RF/ID systems in logistic applications. The RF equipment used in this project is no longer used and is currently stored in a warehouse.

C. RED RIVER ARMY DEPOT

The Army had engineered and installed a RF/ID system at the Red River Army Depot for performing paperless quality assurance. The RF tag was used to replace the quality paperwork (i.e., defect reports, repair reports, etc.) for vehicles undergoing repair. The RF/ID system also provided required management functions which include defect tracking, historical record keeping, trend analysis, and statistical process control (Reboulet and Wagner, 1991, p.23).

As vehicles were received at the depot for major repairs and overhauls, a RF tag was placed on the vehicle. Initially the identification, operating instructions, and other vehicle-related data was encoded on the tag. As the vehicle advanced through the assembly line, each work station would initially read the tag for any special operating instructions. Once the work was performed, the tag was encoded with the information on the services that were performed on the vehicle. The information was forwarded to the host computer as it passed through each work station.

This vehicle tracking program permitted employees to quickly determine status of a specific vehicle on the maintenance line. This eliminated the need to manually check written documentation or to physically walk the line to find a specific vehicle.

Despite minor technical set-up problems and software problems, the project was successful in providing the information on the tracked vehicles. Many of the information errors that occurred were found to be operator induced. This project provided for less labor requirements and higher quality through higher visibility. The project was initially designed as a feasibility study for RF/ID in the maintenance environment.

Due to the project's funding limits, much of the system was secured after the successful review. Unrelated to the performance of the project, the manufacturer of the utilized RF/ID equipment went out of business.

As discussed in a previous chapter, the manufacturers have unique systems that are not compatible with other manufacturers' systems. This lack of standardization has left this Red River equipment useless. Most of it remains in place for future development.

D. COMPONENT TRACKING SYSTEM

Another RF/ID tracking system that the Army utilized was at Ft. Hood, TX. A serial number tracking concept evaluation was conducted by the TEXCOM Combined Arms Test Center at the Apache helicopter maintenance facility. The purpose was to evaluate the concept of tracking selected sensitive and high-dollar value serially numbered items using MITLA technology.

RF tags were attached to individually serially numbered items to record, store, and transmit data on the item. The RF tags were attached to supply parts and airframes at a central receiving point. As these moved through the supply network, antennas automatically transmitted signals to the host computer. The tags stored maintenance and operational data on the airframe and the parts. The information programmed into the tags included stock number, serial number, document number, and condition code. When maintenance personnel installed a part on an aircraft, the RF tag was removed from the part. The information on the tag was transferred to the onboard tag on the aircraft, which was used as a master tag for the entire aircraft and its parts. When a part was removed from an aircraft, a RF tag was reinstalled on the part and the onboard aircraft data tag was updated. As the parts moved through the maintenance network, antennas transmitted signals to the host computer via the reader/transmitters. When personnel performed maintenance, they updated the tag immediately. The tag remained attached to the part until the part was reinstalled or turned in (TEXCOM Combined Arms Test Center, 1989, p.4).

Tests were conducted on the system to determine reliability and faults in the system. During the testing the system failed several times. Most of the problems were failure to communicate the information correctly from the tag to the reader/transmitter. Although the manufacturer did not claim frequency attenuation, the problem persisted throughout the testing procedures. Some of the communication problems occurred because of too few reader/transmitters. This left some tags in "dead spot" areas unable to be queried and transmit their information. Other failures were attributable to software and hardware problems such as power failures in some of the equipment. Some of these problems were corrected on-site.

Despite these setbacks, the Army assessed the RF/ID component tracking system as follows:

> The concept of tracking selected sensitive and high-dollar value serially numbered items in their operational environments using off-the-shelf microchip technology demonstrates a high degree of user acceptance and system reliability. (TCATC, 1989, p.10)

The Army research team made recommendations to improve the performance of the system. These recommendations are to use more powerful antennas or increase the number of antennas to obtain full area coverage, and to provide uninterrupted power for continued operations. Since the project was a concept study, the project results have been utilized on a very limited basis. Also, as with the previous Army project and unrelated to the performance of the project, the manufacturer of the RF/ID equipment has since gone out of business.

E. WHAT NEXT?

The projects described in this chapter are just a few that DOD has initiated to study the potential uses for RF/ID. Other DOD projects have been looked at container tracking, ammunition tracking, and inventory control. Most of these projects are still in active status and are obtaining positive results for further implementation of RF technology.

The LOGMARS Office plans to pursue development of a Dynamic Real-time Tag and Reader System. This system is intended to communicate over a dynamically configured RF network to establish communication between the tag and reader, regardless of the distance which may separate the tag from the reader (Reboulet and Wagner, 1991, p.23). Current RF/ID system costs would be reduced by these efforts due to lower transmission distance requirements and lower number of readers to adequately cover a given geographical area.

The application of RF/ID is virtually limitless. However, other automatic identification systems may be more beneficial in performing certain functions. The user must be judicious when selecting the technology for the function desired to be performed. While RF/ID offers some distinct advantages (i.e., read-write capability, not limited to line of sight), it is not always associated with the most economical solution. Although RF tags could be placed on every pallet in the military and tracked through an elaborate network system, the costs to construct and run such a system would clearly outweigh the benefits.

Functions in the military logistics process that are potential areas for RF/ID development are limited. Not all functions would be suitable for RF applications, but there are a few that would. As previously mentioned in this chapter, material identification and tracking functions are ideal tasks. Expanding the function of property accounting to more information variables could provide preference to RF/ID over bar coding which is the existing method. In supporting the "paperless office", RF/ID could be the choice of management for manifesting material in transportation. Work in process and vehicle identification and control have already been studied and implemented.

Security is an ideal function for implementing RF technology. Personnel identification tags utilizing the RF/ID concept can control access and provide security measures for both humans and material. These "smart cards" have been implemented throughout the civilian sector and limited applications are found in the military.

The decision to employ RF technology in any portion of the military logistic environment is difficult. The advantages that RF technology possesses over other technologies is apparent. However, the economic justification is the topic that bears the majority of the weight in the decision making process.

VI. A FRAMEWORK FOR COST/BENEFIT ANALYSIS

A. INTRODUCTION

Automatic identification systems have proven their success in today's industry. They have been justified economically to warrant implementation in just about every facet of our daily life. Being the most common of automatic identification systems, bar codes have demonstrated the potential economic return on investment that can be achieved by automatic identification systems. One survey of bar code users found that almost 80 percent of the survey respondents' bar code systems paid for themselves in less than two years and 52 percent of the systems produced more than $25,000 per year in direct savings (Sharp, 1990, p.5).

Although RF/ID systems are relatively new, there have been many decisions made to employ them. They have been employed by manufacturers such as General Motors, and they have been used to collect tolls in New Jersey and Texas. The San Francisco International Airport uses a RF/ID system to assist in eliminating commuter vehicle traffic congestion. Law enforcement has also used RF/ID technology to help recover stolen cars which had RF tags attached. However, there is very little data available to analyze the economic decisions made to choose RF/ID as the choice for automatic identification.

This chapter will examine some of the costs and benefits associated with incorporating a RF/ID system in the logistics field. The measurements will be non-quantitative because of the lack of available corporate data. Obviously, to perform an actual analysis for a particular application, a more direct economic analysis will need to be conducted. In that analysis, many calculations of current quantitative elements (i.e., labor costs, inventory costs, etc.) must be made.

Most automatic identification investments are justified on the basis of direct economic gain. Direct economic gain calculations use traditional project justification techniques - return on investment, net present value, and similar calculations - to prove that the capital investment in automatic identification equipment directly pays for itself and returns a minimum threshold savings (Sharp, 1990, p.5). Direct economic gain in automatic identification systems comes from increasing the productivity of direct and indirect labor, increasing billing accuracy and speed, improving machine utilization, allowing quicker responses to problems, and permitting drastically reduced inventory levels.

B. BENEFITS

As mentioned in the previous chapters, there are many benefits to any automatic identification system. A primary benefit is timely, accurate data collection. Another benefit is speed. This section will attempt to associate some of the savings with some of the benefits of installing a RF/ID system. Some of the primary benefits associated with a RF/ID system are: increased data accuracy, increased traceability, reduced inventories, reduced labor force, and work simplification.

1. Increased Data Accuracy

As with any automatic identification system, data accuracy is increased due to the elimination of the manual input of information. The economic benefit is the difference between the initial data entry cost and the total cost of manual data entry, qualification, and transcription. Unfortunately, RF/ID systems are relatively new and not much data has been accumulated on their data error rates. Although the actual average error rate is not known, it is estimated to be at least equal to or better than that of bar coding. Automatic identification systems operate in the accuracy range of one error in three million entries (Soltis, 1985, p.55).

2. Increased Traceability

Traceability is a major factor in limiting the theft and loss of items that represent "leakage" in almost every line of business. The costs attributable to these losses are fairly easy to calculate. RF technology expands the concept of tracking material and makes the attained information more dynamic. RF tracking now can be performed instantaneously, without the need of the host computer's data files, in the work place because of the data on board the RF tags.

3. Reduced Inventories

Because of the increased traceability, the costs saved by RF/ID can be related to the cost of maintaining those parts of inventory that are no longer needed. This benefit clearly supports the Just-in-Time (JIT) concept of parts delivery. As the acceptance of JIT increases, so will the contributions that RF/ID can make to that concept. With the advent of higher technology items in our inventory, hence an increase in inventory costs, the savings achieved are often enough to justify RF/ID without considering any other factor (Burke, 1990, p.206).

4. Reduced Labor Force

With increased productivity, fewer individuals are required to do the same amount of work. There will be less personnel required to do many of the functions associated with a manual operation. The largest impact on reducing personnel requirements will be in the information input area. Other areas such as tracking, inventory, and quality assurance will also result in a decrease in personnel strength.

5. Work Simplification

Instead of the workers needing to receive instructions on "how to" for a specific item, they simply need to monitor the material or process. The RF tags, containing the instructions or cues for the instructions, will help minimize the communication process by simplifying the human process involved (Burke, 1990, p.208). This work simplification will also reduce the work skill required to interface with the RF/ID system and thus reduce direct labor hour costs.

C. COSTS

Because of the diversity of the different available RF/ID systems, the costs associated with each system will be different. However, as technology advances, the price of that technology will decrease. The prices for RF/ID systems have already decreased despite the systems' relative market infancy. The acceptance of RF/ID will also impact the price because as the demand for an item increases the price tends to decrease due to economies of scale.

The implementation of a RF/ID system will involve various expenses. The associated implementation costs include the following: equipment purchase, installation, maintenance, and training.

1. Equipment Purchase

As previously mentioned, the equipment costs will vary with the different configurations of installed RF/ID systems. The more functions that the system can perform (i.e., control versus simple identification) the more the initial investment costs will increase. The purchasing of the equipment has a strong impact on the return on investment.

The size of the operation also affects the total purchase price. Obviously, as the size of the operation increases so will the amount of equipment utilized. Most sites will utilize an assembly line setup with reader/transmitters positioned at strategic locations depending on their function. Most systems will have at least one reader/transmitter, one host computer, and numerous identification tags. As the requirements for the control of the material increases within that environment, more reader/transmitters will be needed, but the host computer requirement remains the same. So, some of the variation in costs will depend on the number of reader/transmitters required and the number of tags utilized.

System costs can decrease if the RF/ID system is used to replace an existing automatic identification system or if it is to be integrated with an existing management information system. The reason for the cost decrease is mainly due to the existing hardware in supporting these systems. The host computers for the existing systems can be employed, if compatible, significantly reducing procurement costs.

2. Installation

Once again, the costs associated with the installation of a RF/ID system are directly related to the size of the operation and the complexity of the system's functions. These installation costs correspond to those costs associated with installing other types of automatic identification system. However, because RF/ID systems are more susceptible to outside interference (i.e., other RF, absorption, or attenuation), the site survey, which is required with any automatic identification system, will be more complex and costly. This is due to the increased efforts needed to determine "dead spots" in the area and the possible requirement to shield the surrounding equipment and environment.

Once the installation is complete, the testing and adjusting will be performed. Because RF/ID systems are more versatile in application they must be tested and adjusted to the different variables involved (i.e., relative speed, orientation, surrounding conditions). To adjust the system for the different values of these variables requires numerous system runs at those values. This makes the installation process more difficult and more costly.

3. Maintenance

The maintenance associated with the RF/ID system will again be directly related to the complexity of the system. The costs should be comparable to the costs of other automatic identification systems. If the initial installation was correctly performed, the maintenance should be relatively low. This is primarily due to the increased reliability of modern circuitry.

4. Training

The costs of conducting the training for the personnel to operate the RF/ID system will initially be costly. However, these up front costs will dramatically decrease once the system is operational. This is very typical with the installation of any new operating system. Training costs could decrease if the work place was operating under an existing automatic identification system such as bar codes. This is primarily due to the residual learning curve of operating a similar designed system.

If one considers training as more of an investment than a cost than this expense could be ignored in the economic analysis.

D. ANALYSIS

To implement a RF/ID system, the organization must be willing to commit resources. The decision tool to help decide in committing resources is normally a cost/benefit analysis. Once the estimate for how much the investment will cost and how much costs will be incurred by maintenance, training, etc., then the benefits will need to be estimated to begin formalizing an analysis. All this information should be massaged into economic benchmarks and the decision to implement RF/ID should become apparent.

Integrated in the justification process must also be the assessment of its contribution to the objectives of the entire process against any alternative means. The contributions that RF/ID can make to reduce the logistic system's costs can be very measurable. As DOD moves towards a new and more efficient organization for managing the supply system, RF/ID can be integrated into the Defense Management Review (DMR) program to improve the efficiency and accuracy of basic inventory management and warehousing operations, from receipt and storage of material to physical inventory to improved asset visibility.

Because the underlying theme of the DMR is "to do more with less", it is imperative that the overall contributions, in terms of savings that RF/ID can make in the DOD supply system must heavily outweigh the initial equipment procurement costs. Currently, DOD has estimated that the savings from the insertion of new technologies, such as LOGMARS and MITLA, into logistic operations can be substantial. Table 1 demonstrates some of the DOD-predicted costs and savings.

TABLE 1. DOD MITLA SAVINGS
(Dollars in Millions)

	FY 92	FY 93	FY 94	FY 95	FY 96	FY 97
COSTS	9.0	10.0	-	-	-	-
SAVINGS	1.5	3.5	6.5	10.5	15.0	15.5
NET	(7.5)	(6.5)	6.5	10.5	15.0	15.5

(Source: DOD, 1991, p.14)

Table 1 suggests that those technologies have less than a four-year return on investment. Although the data used to substantiate these savings is not readily available, the economic benefit of employing these technologies is large enough to have the DMR program commit resources and emphasize future development and implementation (DOD, 1991, p.18).

VII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

A radio frequency identification system can provide many benefits to a military logistics system. The following general benefits are quite different from other automatic identification methods:

- They are not limited to line-of-sight communication.
- The tags can provide a read-write capability.
- The tags can carry large amounts of data.
- The operating range can be far greater than that of optical systems.

Hence, if the operating requirements for an automatic identification system include one or more of the above RF/ID capabilities, then RF/ID is the appropriate solution.

Not all identification functions in the logistic system are suitable for RF applications. However, abnormal environments (i.e., harsh, high relative speeds, etc.) offer ideal circumstances for RF/ID.

As DOD moves towards a new and more efficient organization, RF/ID can improve material control and asset visibility. It can also create efficiencies in overall management operations. The technology is expensive, compared to other identification methods, but RF/ID provides some options not available from vision-based systems.

The feasibility of implementing a RF/ID system is primarily a cost consideration. The overall savings must outweigh the capital investment and operating costs, and the assessment of its contributions to the objectives of the DMR initiatives must be appraised.

B. RECOMMENDATIONS

Because of their unlimited potential in future applications, military RF/ID systems should employ the active, read-write tags. Employing other types of tags could limit the systems' capabilities as new requirements develop.

The development of a DOD-wide standard for RF/ID systems is necessary and has begun. The increase in RF vendors currently creates a huge variation of system components in the market. Without a standard, different systems could be operationally useless together, further misusing DOD's declining financial resources.

The DOD and the commercial shipping industry should work to use compatible tracking and identification systems. Having a "universal tag" with standard formats would provide both DOD and the commercial shipping industry with the ability to read data on any RF container identification tag. This would provide for a more comprehensive tracking system.

The MITLA Office should continue to coordinate the implementation of MITLA technology throughout the services. Doing this will save resources in eliminating duplicate efforts, plus the MITLA Office can evaluate the results of implementation studies to achieve desired productivity gains.

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