CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The abbreviation *RFID* comes from Radio Frequency Identification, sometimes this technology is called an Automatic Identification and Data Capture *(AIDC)* and come into being as a natural upgrade of *Barcode Labels*, commonly used in 80's and of course nowadays (Łukasz Geldner & Paweł Nowiński, 2003).

Radio Frequency is a term that refers to alternating current (AC) having characteristics such that, if the current is input to an antenna, an electromagnetic field is generated suitable for wireless broadcasting and communications. These frequencies cover a significant portion of the electromagnetic radiation spectrum, extending from 9 kilohertz to thousands of gigahertz (Siti Ruzzana Binti Roslant, 2009).

Any radio frequency field has a wavelength that is inversely proportional to the frequency. In the atmosphere or in outer space, if *f* is the frequency in megahertz and *s* is the wavelength in meters, then

$$s = \frac{300}{f}$$

RFID is a contactless technology that uses radio frequency signals to transmit and receive data wirelessly, from a distance, from RFID tags or transponders to RFID readers (Ann Cavoukian, 2008). RFID is relatively new invention. First works, tests and ideas appeared in 1991, but first real solutions appeared in 1995 (Łukasz Geldner & Paweł Nowiński, 2003). RFID technology is generally used for automatic identification and to trigger processes that result in data collection or automation of manual processes (Ann Cavoukian, 2008). RF tags are available in a variety of shapes and sizes.

Figure 2 below shows an example of the RF tag.

Figure 2: RFID Tag

RFID is being employed to help manage and track document assets. In fact, about 35% of the document- tracking market in Malaysia is expected to use RFID by 2010. In the United States, several legal firms and tax courts, not to mention dental offices, have recently started tracking assets with RFID. Other potential uses would be in police departments, where paper-based case files are regularly maintained (RFID Applications: Document Tracking, 2006)

2.2 Frequency Ranges

The RFID system is distinguished by its frequency ranges. With the exception of the lowest-frequency segment, each band represents an increase of frequency corresponding to an order of magnitude (power of 10). Low frequency (30 KHz to 500 KHz) systems have short reading ranges and lower system costs. They are most commonly used in security access, asset tracking, and animal identification applications. High frequency (850 MHz to 950 MHz and 2.4 GHz to 2.5 GHz) systems, offering long read ranges (greater than 90 feet) and high reading speeds, are used for such applications as railroad car tracking an automated toll collection. However, the higher performance of high-frequency RFID systems incurs higher system costs (Siti Ruzzana Binti Roslant, 2009).

Table 1 depicts the eight bands in radio frequency spectrum, showing frequency and bandwidth ranges.

Table 1: Radio Frequency spectrum

Designation	Abbreviation	Frequencies	Free-space Wavelength
Very Low Frequency	VLF	9 kHz – 30 kHz	10 km – 100 km
Low Frequency	LF	30 kHz – 300 kHz	1 km – 10 km
Medium Frequency	MF	300 kHz – 3 MHz	100 m – 1 km
High Frequency	HF	3 MHz – 30 MHz	10 m – 100 m
Very High Frequency	VHF	30 MHz – 300 MHz	1 m – 10 m
Ultra High Frequency	UHF	300 MHz – 3 GHz	10 cm – 100 cm
Super High Frequency	SHF	3 GHz – 30 GHz	1 cm – 10 cm
Extremely Hugh Frequency	EHF	30 GHz – 300 GHz	1 mm – 10 mm

2.3 Basic component

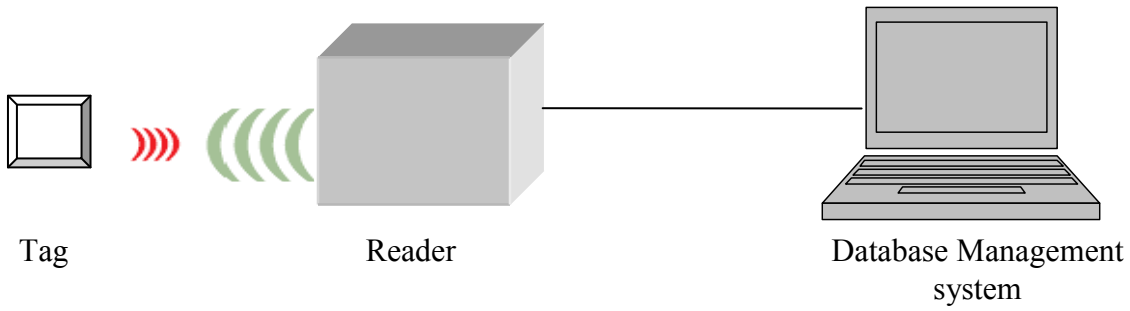

Figure 3: Basic components of RFID system.

A Radio-Frequency Identification system (RFID) has three component parts:

i. A transponder - the RFID tag - that has been programmed with unique information
ii. A reader or interrogator which is connected to an antenna that sends and receives the information
iii. A Database management system

2.3.1 RFID Tag/Transponder

Most RFID tags contain at least two parts. One is an integrated circuit for storing and processing information, modulating and demodulating a radio-frequency (RF) signal, and other specialized functions. The second is an antenna for receiving and transmitting the signal ("Radio-Frequency Identification", n.d.).

RFID tags have a wide variety of shapes and sizes. Animal tracking tags, inserted beneath the skin, can be as small as a pencil lead in diameter and one-half inch in length. Tags can be screw-shaped to identify trees or wooden items, or credit-card shaped for use in access applications ("RFID / What is RFID / Component", n.d). Examples of RFID tags are:

Figure 4: Polymer Flexible RFID tag

Figure 5: RFID tag use in electronic toll collection

Besides that, RFID tags may be of one of two types: active or passive. Active RFID tags have their own power source whereas passive RFID tags do not have batteries, can be much smaller, and have a virtually unlimited life span.

2.3.2 RFID Reader/interrogator

RFID reader is an electronic device used for communication between RFID tags and a host computer system. A reader generally consists of an RF transmitter and receiver and an antenna for communicating with tags. A digital interface enables the reader to communicate with the host computer system.

Often the antenna is packaged with the transceiver and decoder to become a reader, which can be configured either as a handheld or a fixed-mount device. The reader emits radio waves in ranges of anywhere, depending upon its power output and the radio frequency used. When an RFID tag passes through the electromagnetic zone, it detects the reader's activation signal. The reader decodes the data encoded in the tag's integrated circuit and the data is passed to the host computer for processing (Siti Ruzzana Binti Roslant, 2009). Examples of RFID antenna are:

Figure 6: High Frequency Reader RFID Writer with Antenna

Figure 7: Portable Handheld RFID Reader

2.3.3 Operating Frequency

The radio frequencies at which a tag transmits and receives signals have implications for the ability of the tag's signal to penetrate materials. As a general rule, higher frequencies are less able to penetrate substances such as metals or liquids than lower frequencies. Depending on the application, the penetration capabilities of a particular frequency can be either a benefit or a shortcoming (Guidelines for Securing RFID Systems, 2007).

Table 2: RFID operating frequencies and associated characteristics.

Band	LF Low Frequency	HF High Frequency	UHF Ultra High Frequency	Microwave
Frequency	30 - 300 kHz	3 - 30 MHz	300 - 1 GHz	2 -30 GHz
Typical RFID Frequency	125 -134 kHz	13.56 MHz	433 MHz or 865 956MHz	2.45 GHz
Approximate Read Range	Less than 0.5m	Up to 1.5m	433 MHz = up to 100m 865 - 956 MHz = 0.5 to 5m	Up to 10m
Typical Data Transfer Rate	Less than 1 kilobit per second (kbit/s)	Approximate 25 kbits/s	30 kbit/s	Up to 100 kbit/s
Characteristics	Short-range, low data transfer rate, penetrates water but not metal.	Higher ranges, reasonable data transfer rate (similar to GSM phone), penetrates water but not metal.	Long ranges, high data transfer rate, concurrent read of less than 100 items, cannot penetrate water or metals	Long ranges, high data transfer rate, cannot penetrate water or metal
Typical Use	Animal ID, Car, Immobiliser	Smart labels, Contact-less, Travel Cards Access and Security	Specialist Animal Tracking	Moving vehicle toll

As a general rule, radio signals at lower frequencies will propagate farther than signals at higher frequencies, assuming similar transmitter power levels. The attenuation (or decrease) of a radio signal as it travels through a medium such as air is directly related to its wavelength. All signals experience the same decrease in signal strength *per wavelength* when traveling through the same medium. Due to signals at lower frequencies have longer *wavelengths*; the signal attenuation occurs at a slower rate.

The figure below shows some of the common and less-common frequency bands in which RFID systems operate. Also shown is the corresponding wavelength - the distance between points at which the field has a fixed value when the signal moves at the velocity of light (Daniel M. Dobkin, 2005).

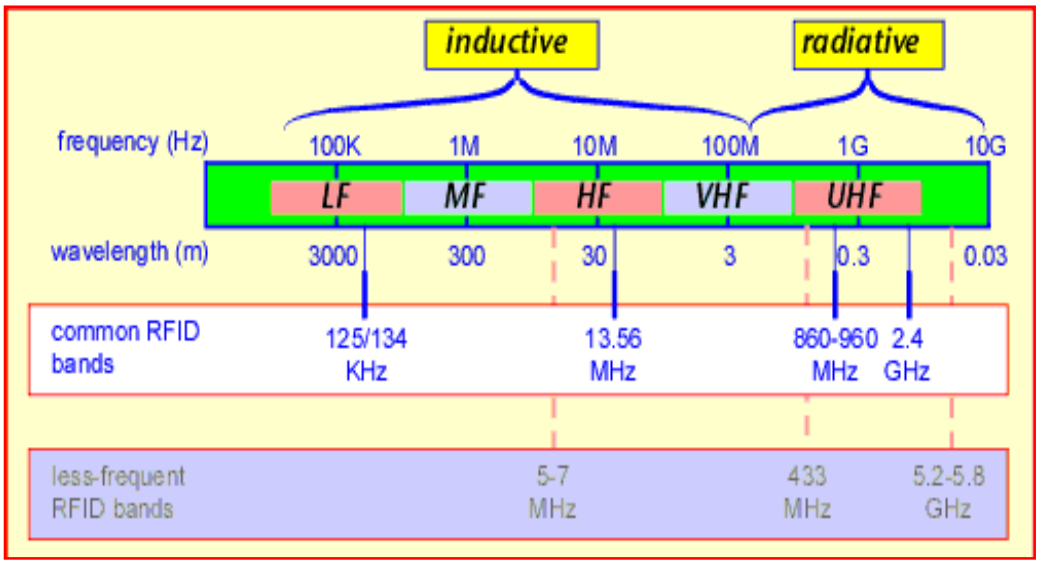

Figure 8: Common and less-common frequency bands in which RFID systems operate

Several issues are involved in choosing a frequency of operation. The most fundamental, as indicated in the Figure 8, is whether inductive or radiative coupling will be employed.

The distinction is closely related to the size of the antennas to be used relative to the wavelength. When the antennas are very small compared to the wavelength, the effects of the currents flowing in the antenna cancel when viewed from a great distance, so there is no radiation. Only objects so close to the antenna that one part of the antenna appears significantly closer than another part can feel the presence of the current. Thus, these systems, which are known as inductively-coupled systems, are limited to short ranges comparable to the size of the antenna (Daniel M. Dobkin, 2005). The systems at lower frequencies, such as 13.56 MHz, depend on inductive coupling as the primary mode of interaction. The range of an inductively coupled system drops sharply with distance, making communication beyond 10 to 20 feet impractical. Using longer-range electrical coupling at these frequencies is not recommended due to their high susceptibility to noise and interference from other devices.

Besides that, the radiative systems use antennas comparable in size to the wavelength. The very common 900 MHz range has wavelengths around 33 cm. Reader antennas vary in size from around 10 to 30 cm and tags are typically 10 to 18 cm long. These systems use radiative coupling, and are not limited by reader antenna size but by signal propagation issues (Daniel M. Dobkin, 2005).

The ability for signals to propagate within crowded environments is also dependent on the signal wavelength, and hence frequency. Within warehouses, truck yards, and other facilities, the ability for an RFID system to operate in and around obstructions is critical. These obstructions are often metal, such as vehicles, requiring signals to propagate “around” rather than “through” the obstructions. Active RFID signals propagate “around” obstructions by means of diffraction, and the level of diffraction is dependent on the size of the object versus the signal wavelength. Diffraction occurs when the wavelength approaches the size of the object.

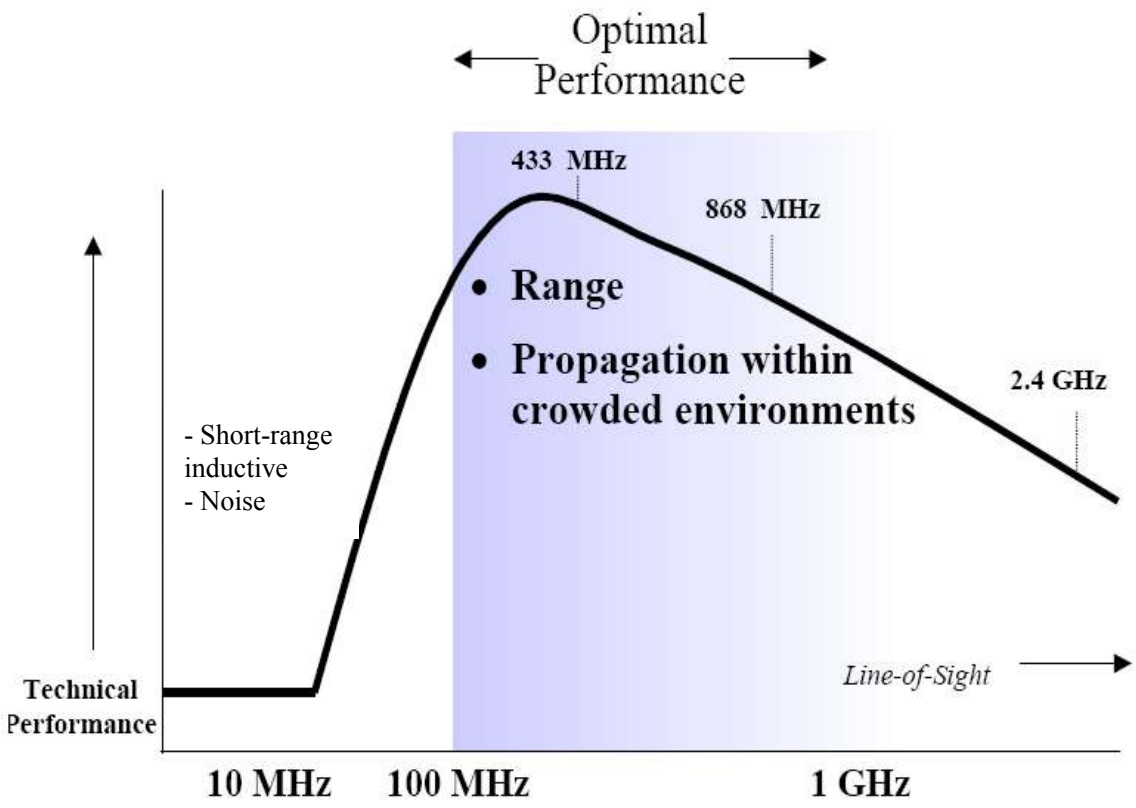

Figure 9: Frequencies between 100 MHz and 1 GHz offer the best technical performance for Active RFID.

For example, at 433 MHz the wavelength is approximately a meter, enabling signals to diffract around large obstructions. At 2.4 GHz, the wavelength is approximately a tenth of a meter and diffraction is very limited and creates blind spots and areas of limited coverage. Frequencies above 2 GHz present significant challenges for operation in crowded environments and are therefore not recommended for most RFID applications (Active and Passive RFID, 2009).

2.3.4 Working Principle

The three primary components that make RFID "Work" are Tags, Readers, and Software that collects data from the readers and helps turn it into actionable information (How RFID "Works", n.d).

Generally, for RFID to work, the antenna emits radio signals to activate the tag and to read and write data to it. Antennas are the conduits between the tag and the transceiver, which controls the system's data acquisition and communication. The electromagnetic field produced by an antenna can be constantly present when multiple tags are expected continually. If constant interrogation is not required, a sensor device can activate the field. Often the antenna is packaged with the transceiver and decoder to become a reader, which can be configured either as a handheld or a fixed-mount device. The reader emits radio waves in ranges of anywhere, depending upon its power output and the radio frequency used ("RFID / What is RFID / Component", n.d).

Basically, for a passive tag, when it passes through an electromagnetic field within reader, the tag is then powered on and transmits its information to the interrogator. The reader decodes the data encoded in the tag's integrated circuit. The information then is automatically sent into the Data System. Information exchange is done via air interface, precisely through electromagnetic waves, so without physical contact with reader (Łukasz Geldner & Paweł Nowiński, 2003).

If compared to the passive tag which is only powered on when passing through the reader's field, the active tag is always power on or continuously energized. This is due to the battery which it posses. Active tag has a read range of up to 300', but when the battery runs out, it will stop working.

2.4 RFID Types

2.4.1 Active RFID

Active RFID is a long range communication approach that has a reading distance between 50 m (150 feet) to 100 m (300 feet). Tags are powered by an internal battery and are typically read/write, where tag data can be rewritten and/or modified. An active tag's memory size varies according to application requirements; some systems operate with up to 1MB of memory.

In a typical read/write RFID work-in-process system, a tag might give a machine a set of instructions, and the machine would then report its performance to the tag. This encoded data would then become part of the tagged part's history. The battery-supplied power of an active tag generally gives it a longer read range. The trade off is greater size, greater cost, and a limited operational life (which may yield a maximum of 10 years, depending upon operating temperatures and battery type) (“RFID / What is RFID / Component”, n.d).

2.4.2 Passive RFID

Tags operate without a separate external power source and obtain operating power generated from the reader. Passive tags are consequently much lighter than active tags, less expensive, and offer a virtually unlimited operational lifetime. The trade off is that they have shorter read ranges than active tags and require a higher-powered reader. Read-only tags are typically passive and are programmed with a unique set of data (usually 32 to 128 bits) that cannot be modified. Read-only tags most often operate as a license plate into a database, in the same way as linear barcodes reference a database containing modifiable product-specific information.

2.4.3 Differences between active and passive RFID

Active RFID and Passive RFID technologies, while often considered and evaluated together, are fundamentally distinct technologies with substantially different capabilities. In most cases, neither technology provides a complete solution (Active and Passive RFID, 2009). The majority of the RFID tags in use today are of the passive variety. Active RFID tag technology is still evolving and its widespread availability is expected to increase over the next several years ("Solving the New Technology Requirements for RFID Business Applications", 2009).

Table 3: Technical differences between Active and Passive RFID technologies.

	Passive RFID	**Active RFID**
Tag Power Source	External (Energy transferred from reader through RF)	Internal (Battery)
Tag Readability	Only within the area covered by the reader, typically up to 3 meters.	Can provide signals over an extended range, typically up to 100 meters.
Energization	A passive tag is energized only within field of reader.	An active tag is always energized.
Magnetic Field Strength	High, since the tag draws power from the electromagnetic field provided by the reader.	Low, since the tag emits signals using internal battery source.
Available Signal Strength from Tag to Reader	Low	High
Shelf Life	Very high, ideally does not expire over a life time.	Limited to about 5 years, the life of a battery.
Data storage	Limited data storage, typically 128 bytes.	Can store larger amounts of data.
Cost	Cheap	Expensive
Size	Smaller	Slightly bulky (due to battery)

Table 4: Summary of functional capabilities of Active and Passive RFID technologies.

	Active RFID	Passive RFID
Communication Range	Long range (100m or more)	Short or very short range (30m or less)
Multi-Tag Collection	Collects 1000s of tags over a 7 acre region from a single reader	Collects hundreds of tags within 3 meters from a single reader
	Collects 20 tags moving at more than 100mph	Collects 20 tags moving at 2mph[2] or slower
Sensor Capability	Ability to continuosly monitor and record sensor input; data/time stamp for sensor events	Ability to read and transfer sensor values only when tag is powered by reader; no date/time stamp.
Data Storage	Large read/write data storage (128kb) with sophisticated data search and access capabilities available	Small read/write data storage (e.g. 128 bytes)

2.5 Current Document Tracking Application

2.5.1 GAO RFID Asset Tracking's LocateWare

GAORFID Inc. announces, LocateWare(TM), an RFID middleware that is cost effective, easy to setup and configure and reports real-time location of people, animals and things. LocateWare(TM) enables comprehensive tracking, locating and identification for a wide range of businesses. LocateWare(TM) working in conjunction with RFID readers and RFID tags can significantly improve the utilization of critical resources and reduces search time and increases overall efficiency and security.

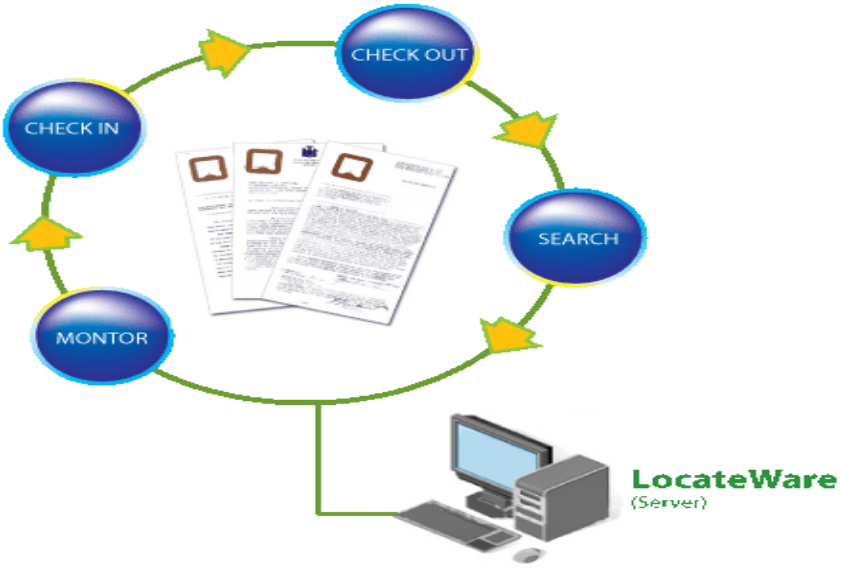

Figure 10: LocateWare system overview for document tracking

LocateWare, as shown in Figure 10, together with GAO RFID Asset Tracking's RFID readers successfully capture and distribute RFID tag information to the user in a customized report format for their unique job requirements. Document trays with RFID readers can hold as many as one hundred documents that can be read at one time. The number of documents read simultaneously can grow to the thousands just by adding more antennae in the read vicinity (Ken Cheung, 2007).

2.5.2 DocuTrack3000

DocuTrack3000 is a total RFID solution for document tracking as shown in Figure 11. It includes RFID labels, RFID reader and a document tracking software. DocuTrack3000 is designed to keep track of electronic documents and hard copy documents such as project file, document file and many others. Books and file can be tracked in the application in details ("Solving the New Technology Requirements for RFID Business Applications", 2009).

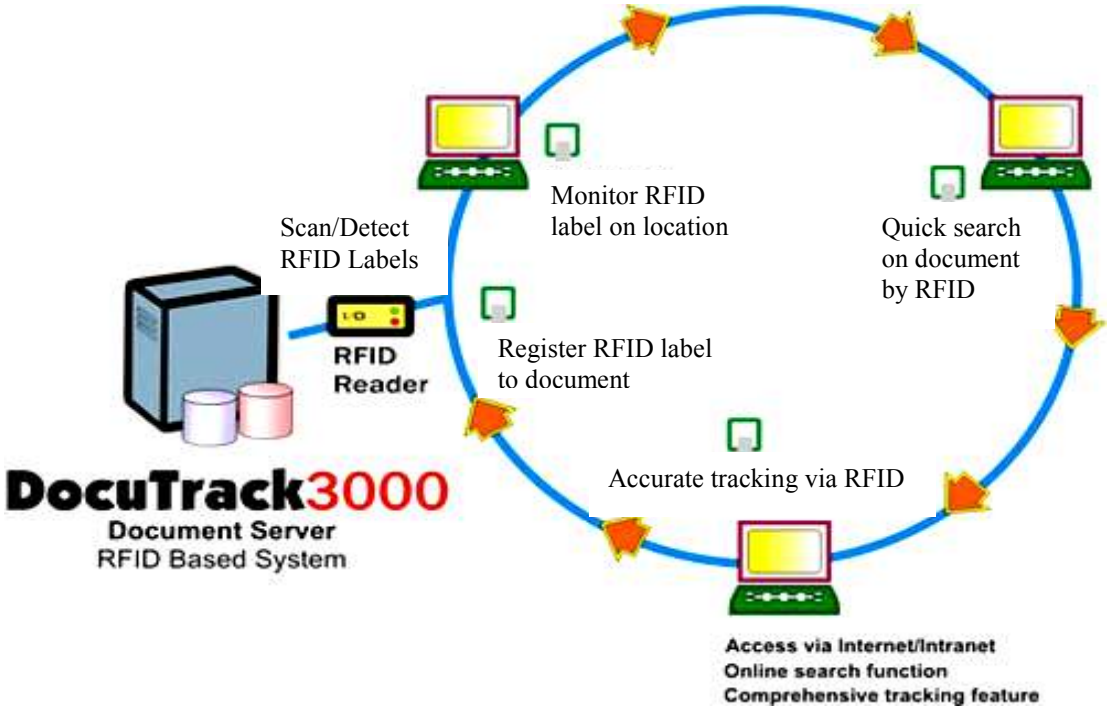

Figure 11: DocuTrack3000 system diagram

For the electronic documents, they will be encrypted and stored on a central media server. Printed documents and files are tracked using electronic tracking systems. Collaborative document development and workflow management tools enable users to develop, share, approve, and archive electronic documents in one streamlined system. The result is higher productivity and increased profit (DocuTrack3000 Intelligent Document Tracking, n.d).

CHAPTER 3
METHODOLOGY

3.1 Project Identification Procedure

There are several methodologies need to be done in order to complete the project. The Gantt chart of the project timeline can be found in Appendix A. Whereas the methodologies are summarized below:-

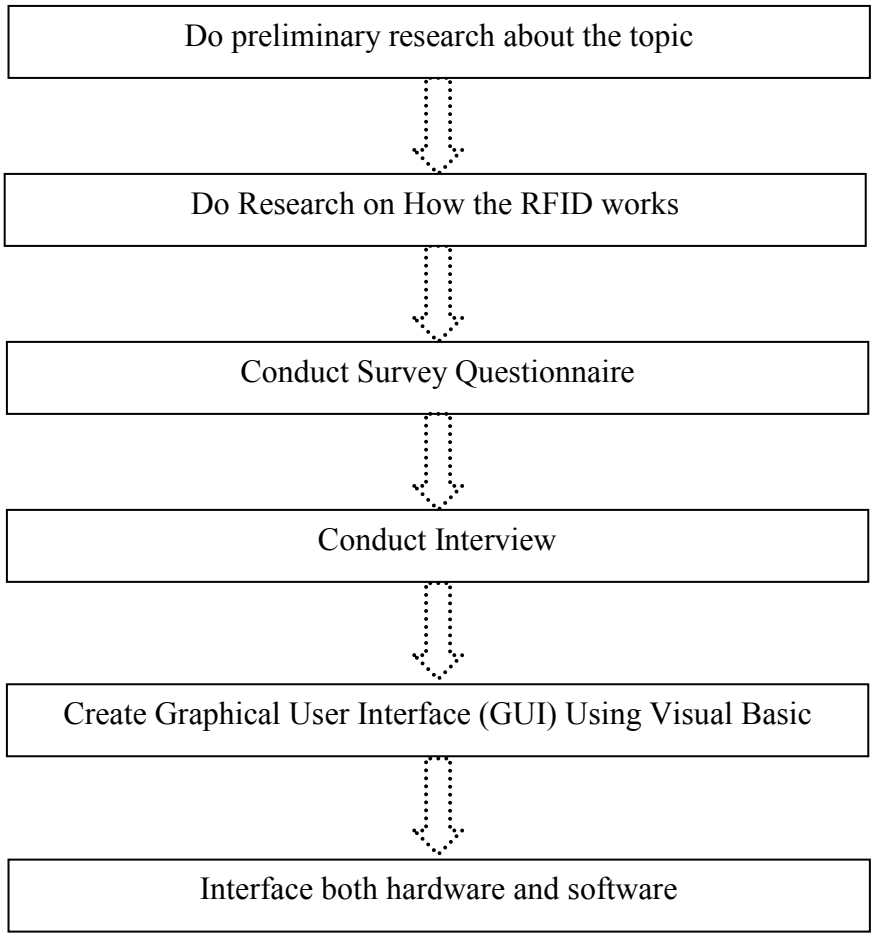

Figure 12: Project Flow Chart

3.1.1 Preliminary Research about the Topic.

In order to undergo the project, the basic understanding of the RFID technology is very important. The Dissertation, Paper works, journal, engineering books or anything relevant to the project are reviewed.

3.1.2 Do Research on How the RFID works

Instead of reading about the RFID technology, the basic understanding of how the RFID system works is very important. The author has gone to the communication lab to play around with the RFID kit. This is done in order to observe and understand the nature of RFID system itself.

3.1.3 Survey Questionnaire

A survey questionnaire has been conducted in order determine the feasibility of the project. A set of survey questionnaires has been created and randomly distributed to ninety four respondents. The survey was conducted through internet. The result of the survey is shown in the result and discussion within this report.

3.1.4 Interview

The author has conducted two interviews with the exam unit personnel regarding the UTP Strong room especially for the exam papers storage. These interviews were conducted in both verbally and non-verbal (through email) in order to understand more about what is actually stored in the room, the current technology used for the security of the room, how the document been stored and etc. The result of the interviews is shown in Appendix C.

3.1.5 Create *Graphical User Interface (GUI) Using Visual Basic.*

The author has decided to use Visual Basic 2008 to create an interface between tag and reader. In the project, this software is used to create a graphical user interface and linking information within the computer. The information on Visual Basic 2008 were obtained from various written sources, which includes lecture notes from UTP Business Information Technology students, as well as books that provide guidelines on how to use Visual Basic. Some development is shown result and discussion.

3.2 Applied Tools and Technology

3.2.1 Software

- MICROSOFT WORDS

  This software is used to complete job on documentation.

- VISUAL BASIC 2008 version

  This software is used to develop programme for the operation of the system.

- My SQL

  "My Structured Query Language" is a program that runs as a server providing multi-user access to a number of databases (“My SQL”).

3.2.2 Hardware / Tools

Figure 13: *ActiveWave RFID Kit.*

3.2.2.1 RFID Kit Components:

- 1 Activewave Reader and Power Supply
- 1 Activewave Reader RS-232 Connector Cable
- 1 ActiveWave Reader RJ-45 Cable
- 6 Activewave Wristband Tags
- 2 ActiveWave Jumbo Tags
- 2 Activewave Card Tags
- 1 Programming Station Software Application
- 1 Tracker Program Software Application (Demo Version)
- 1 API with Documentation and Example Software Application

3.2.2.2 Specification

- **Tags** – Based on the comparison of active and passive tags; and also the operation frequency in the Literature Review, the author has decided to choose active tags with ultra high frequency (UHF) band which suits the best to be used throughout this project. Several ActiveWave tag model are available, each one transmitting at 916 MHz, 868 MHz or 927 MHz. Tags may be electronically enabled or disabled, so they can be "seen" or "unseen" by ActiveWave Readers. All ActiveWave tags have anti-collision circuitry that assures each tag's information is received when more than one tag is transmitting. An on-board temperature sensor can also be included to fit the customer's requirements.

- **Readers** – Readers interface the Host applications to the rest of the ActiveWave system. Readers transmit data at 433 MHz and receive data at 916 MHz, 868MHz or 927 MHz. Readers communicate to the Host computer via an RS-232 cable or via an Ethernet network connection. Readers are used to read the tags and transmit the received data to the Host computer. Readers are also used to enable, disable, wake up and program tags.

3.3 Project Overview

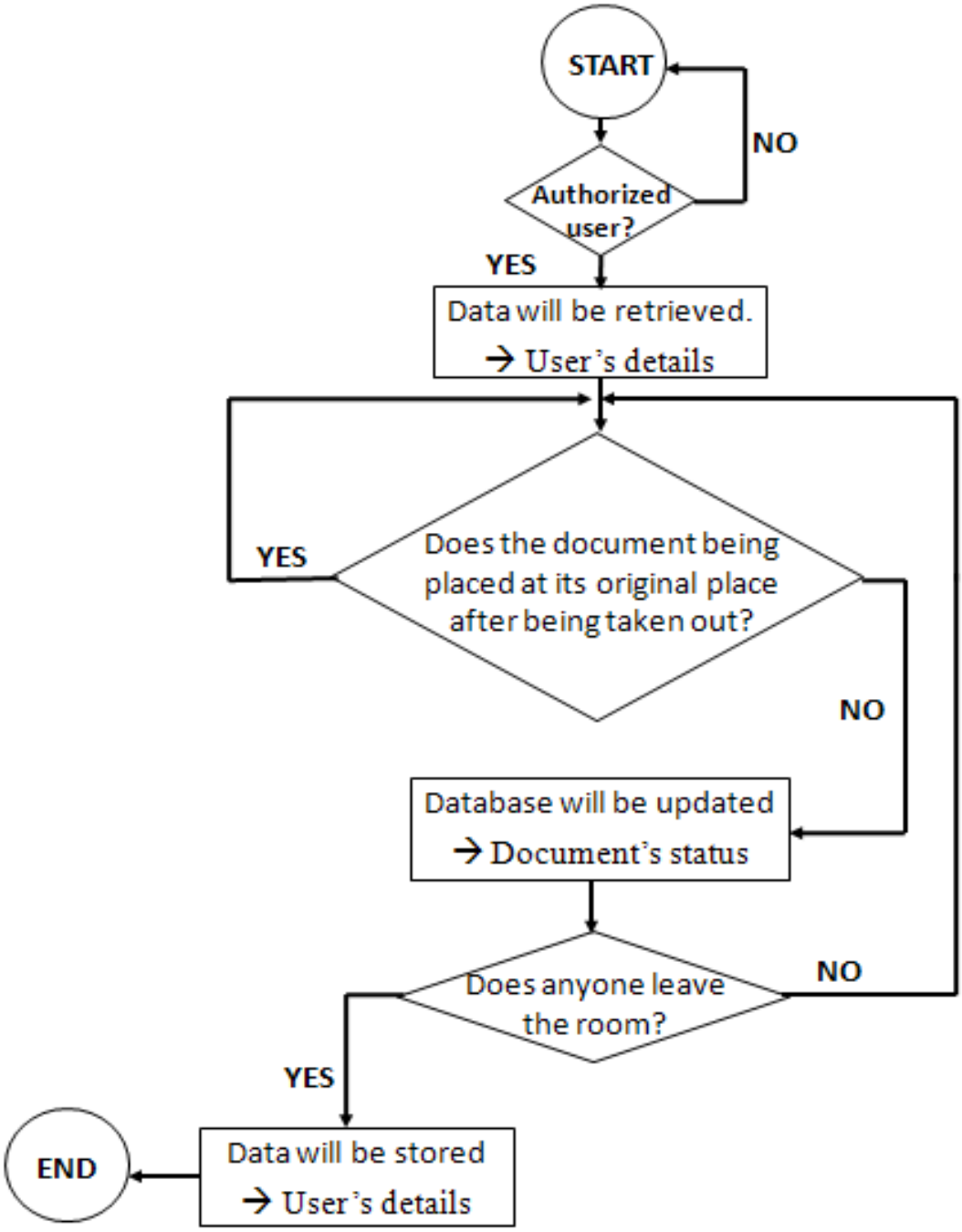

Figure 14: Tracking System Flow Chart

3.3.1 System Overview

Basically, the main components of the system are Active RFID tags, readers and controller PC. Two readers will be used for this project. One reader will be located near the cabinet to monitor the document folder in and out the cabinet. Another reader will be located at the entrance. The controller PC will be located in the room. Because of the document stored is high value, only the authorized staffs have access to the strong room and the controller PC. This controller PC contains the system software and control the operation of the entire system.

The system works by the sequence of process as follows;-

1. Each course has its own folder where the copies of the draft are kept until the final version; both soft and hard copies together with the answer scheme, course syllabus since all are subjected to audit at any time.
2. The RFID (radio frequency identification) tag is then attached to the folder.
3. The administrator will key-in the details in the database.
4. If an authorized user enters the room and takes out the folder, the time will be recorded and the person who takes it out will also be recorded.
5. The other users can view the history of the document in order to check the availability of the document and also to keep track where the document is and with whom.

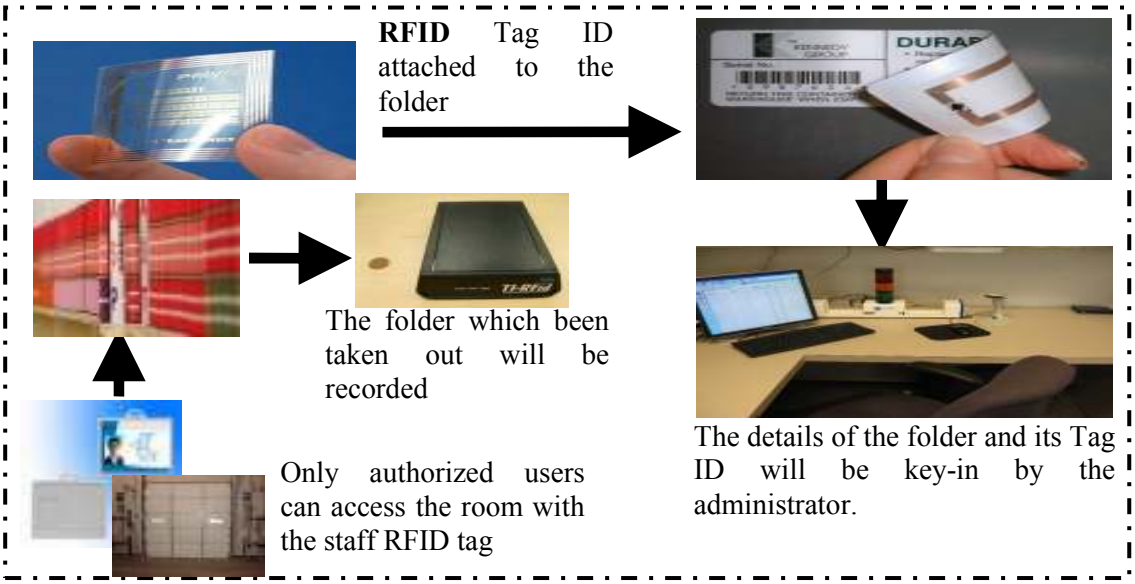

Figure 15: How the System Works

3.3.2 Authentication and Access Control Database Server

The database (My SQL) is created in order to store details about the users and document folders. Users' details such as user's identification number, password and full name are created, followed by the documents' details such as the course code, course name and location of the document. In order to increase the security of the system, the database will only be viewed by the administrator, who is responsible in editing the users or documents' details.

Then, the user interface is created in order to help the users to view the availability of the documents. The history of the system can be checked through the interface main page. Besides that, the data is retrieved from the database, as well as from the hardware. The details of the documents will be displayed based on the availability of the document.