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RFID based Anti-theft System for Metropolia UAS Electronics laboratories

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The aim of this thesis is to study different types of RFID based anti-Theft system implementation suitable for Metropolia Electronics laboratory environment to deter theft taking into account several installation requirements. The operating frequencies of the RFID anti-theft system are from low frequency to High frequencies range and governed by different standards based on the region it is going to be implemented.

The introduction of this thesis will go through Radio Frequency Identification (RFID) and different RFID based anti-theft system advantages in various areas for instance in access management and control application. Study current Metropolia UAS electronics laboratory overall control mechanism comparing to the anti-theft RFID system used by Metropolia library to prevent and deter various theft actions to their valuable items and books.

The scope of this thesis is limited to study different RFID based anti-theft technologies based on their power source, cost, reading range and deployment requirement. However, encryption and related security aspects are beyond the scope of this project. In addition, the project is only to study different cases of RFID based anti-theft implementation. Otherwise, there is no hardware or software design or related implementation including testing of the technology is conducted due to expensive cost constraint to buy the proposed RFID gate but propose measurement set-up that can be done in the future on entrance door of the fifth floor electronics laboratory corridor of Metropolia UAS campus.

Thesis provides better understanding different types of RFID based anti-theft system suitable for Electronic laboratory. As feature plan this thesis proposes the security gate to be interfaced using Lab view to Metropolia UAS Electronic Laboratory Database to store information and monitor laboratory devices, components and tool

Keywords	RFID Based Anti-theft System for Metropolia UAS Electronic Laboratories

Contents

1 Introduction

Radio Frequency Identification (RFID) is a wireless technology used in numerous areas for instance in access management and control application. One of the advantages of using RFID systems is its implementation in anti-theft and monitoring application. To mention few anti-theft systems are in supermarket [1], airport luggage handling [2], animal tracking [3], museum [4], auto-shops [5].

The Metropolia University of applied sciences (UAS) laboratory has various expensive equipments and devices that require consistent monitoring infrastructure. However, manual implementation that is currently used gave poor management that leads not only to misplacement and disorder of equipments but also losses and risk of theft due to lack of automation to the overall control mechanism. Thus the need for better management and reliable monitoring system has become significant to the laboratory as user escalade.

This thesis refers to the anti-theft RFID system used by Metropolia library to prevent and deter various theft actions to their valuable items and books. Therefore, the goal of this project is to study RFID based anti-Theft system implementation suitable for laboratory environment considering several installation requirement including physical topologies. In addition, the thesis will propose suitable and efficient infrastructure to meet the needs and technical requirement for the laboratory in applying the technology.

The scope of this thesis is limited to study different RFID based anti-theft technologies based on their power source, cost, reading range and deployment requirement. However, encryption and related security aspects are beyond the scope of this project. In addition, the project is only to study different cases of RFID based anti-theft implementation. Otherwise, there is no hardware or software design or related implementation including testing of the technology is conducted.

2 Anti-Theft System

An anti-theft in the sense of technology is a system that is used to protect and deter action of theft [6]. Several protection mechanisms have been exercised through time starting from the traditional way of setting up security guard in target places. Eventually, it gradually evolves through different steps of implementations for instance barcode, biometric, smartcard and etc.

CCTV (closed circuit TV) camera and vigilant security guards were used mainly at department stores, small groceries, jewelry shop and shopping malls for anti-theft protection. However, the CCTV camera system installation and maintenance cost were more expensive than the cost of the goods shoplifted but suitable for jewelry shop where each item is much more expensive than a grocery item.

The use of RFID based antitheft system becomes popular as its implementation becomes affordable by companies who cannot do it with CCTV. In addition to the cost, surveillance camera is used after theft is detected and the security personnel have to go through all the recorded footages to pick out the action. The process requires time, system memory and other resources which will add extra cost to the operation. Thus, the use of RFID not only minimize the cost but also invite manufacturers to add more reliability and cost effective design that lead the technology to be used widely in many sectors including automotive and healthcare facilities.

In many department stores nowadays management relies on RFID system more than CCTV camera and security guards to protect their goods. Note that, there are several types of anti-theft systems available in the market, it is important to determine the appropriate system that best suits for a particular application in our case would be metropolia laboratory.

2.1 Automatic identification systems

This is a tracking system that is used to identify an object and exchange the information about the object automatically without having physical contact [7, 1]. The actual accessibility of item identity provides information about the item current condition and future related measures that needed. The overview of Auto-ID technology is shown in figure 1 below.

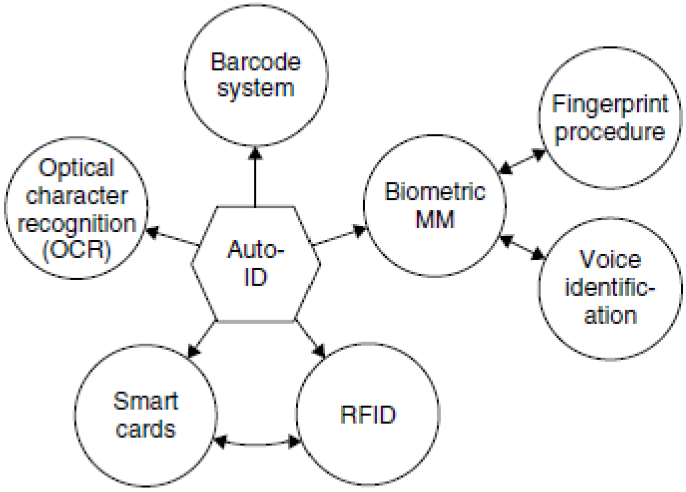

Figure1. (Basic Auto-Id procedure Copied from Klaus Finkenzeller [7,2])

The wide introduction of Auto-ID systems can improve information flow and tracking system. As shown in figure 1, an Auto-ID technology is applied with many systems including RFID.

2.2 Barcode

Barcodes consists of vertical black bars separated by white gaps that are aligned in parallel pattern [7, 2] as shown in figure 2. There are wide and narrow sizes which are arranged according to a predetermined code to indicate a corresponding number and symbol. An optical scanner that consists of a laser is used to read and decode the information from the barcode. However, despite being identical in their physical design, every barcode represents a unique code in the item list.

Figure2. (Bar code that contains unique international standard book number copied from Klaus Finkenzeller [6, 3]).

The European Article Number (EAN) code was well known barcode pattern designed particularly for retail items worldwide [7, 3]. It consists of 13 digits grouped in four parts as shown in figure 3 below.

Country identifier		Company identifier					Manufacturer's item number					CD
4	0	1	2	3	4	5	0	8	1	5	0	9
FRG		Company Name 1 Road Name 80001 Munich					Chocolate Rabbit 100 g					

Figure 3. (Barcode in EAN code Klaus Finkenzeller [7, 3]).

As shown in figure 3, the first two digits represent the country of the manufacturer. The next group identifies the company's code. The item number represents a unique code for a specific item and lastly the check digit is used for checksum purposes.

2.3 Optical character recognition

This application is used to scan characters, image and etc to automatically by using optical mechanism such as human eye and scanner or digital camera. The most important advantage of OCR systems is it allows you to convert and store scanned document, pdf or image file from camera into text or editable document [7].

Today, OCR is widely used in sectors including education, government organization, and banking sector for processing checks avoiding human error and help digitalize paper work. However, OCR systems have limitations due relative high quality scanning device cost and the poor quality of scanned document that often give out noise and distorted characters.

2.4 Biometric

This is an automatic recognition system that uses physical or biological characteristic of a person for authentication purpose. In practice, these are fingerprinting and hand printing, voice recognition and, often retina (or iris) identification [8].

The two stages involve in biometric operation are enrollment module and identification module. Enrollment module refers to initializing the system and the process of recognition. The identification module on the other hand will verify the recognized identity. The system performance is mostly affected by sensor noise, cost, system integration and privacy concern.

2.5 Smart card

A smart card is an electronic data storage system that consists of microprocessor that gives additional computing capacity which is implanted into a plastic enclosure [7]. Smart card contains programmable memory used to record user defined data. These data can also be updated when new application is released even after it is delivered to the customer. Smart cards that used for access control are read by the reader when there is physical connection to the reader by slide in the smart card. It is mostly applied for toll booth or car parking card.

Smart card can be categorized Based on their memory and integrated microprocessor. It uses encryption mechanism to protect data theft and widely used in financial industry sector to make inexpensive and secured financial transaction. However, smart cards are expensive to maintain and defenseless to contacts to wear, corrosion and dirt.

Both RFID systems and smart card have programmable memory card that is embedded into the chip. The smart card use galvanic or physical contacts for supplying power and data exchange however RFID system uses electromagnetic field to power the chip and data exchange between the card and reader. Thus RFID system became popular Due to cost, operational environment and etc. for example of is the use of contactless RFID cards as tickets for public transport.

2.6 RFID System

Radio Frequency Identification (RFID) is a systems use Radio waves to transfer information between tags and reader contactless to identify an object or a person. During World War II, the application of radar plays a major role informing the existence of an air craft within the range. However, it was still difficult to identify which side the air craft belongs to. Therefore, scientists from the USA and British developed an Auto-ID system called identify friend or foe (IFF) [9]. The IFF helped radar ground station and pilots to communicate and identify friendly aircraft from enemies by using RF signal.

A few years later, an electronic Article Surveillance system (EAS) was introduced to protect theft and shoplifting. It consisted of a one bit transponder and a reader antenna used to identify the transponder that passes through. These anti-theft systems were mainly used in department stores, libraries and retail shops. The operation is in such a way that first items are tagged with activated transponder when it is registered at the store. When the item is purchased or need to leave the store, the transponder should be deactivated so that the antenna would not be able to identify the transponder and trigger an alarm. Thus, when the transponder is deactivated, it means that the item is paid and when an activated transponder crosses the reader antenna, an alarm will be triggered to inform theft action [9]. EAS systems just detect the presence of the tag; unlike RFID that automatically identify a particular tag.

The RFID patents were given for passive transponders as well as active RFID tag with rewritable memory used to unlock a door without a key. When a valid RFID tag is read by the reader, the door will be unlocked after authentication was confirmed using the embedded code found inside the card [9]. Scientists in Los Alamos laboratory in USA developed a Low –Frequency (LF) transponder covered in glass can be injected to an animal for tracking. They also introduced access control application using card system that incorporates a micro-chip inside the transponder. Moreover, companies from Europe also started using high frequency transponders to track containers, valuable assets and anti-theft devices in automobiles. Later on engineers developed and patented an ultra-high frequency (UHF) RFID system which offered longer reading range and faster data [8] and can be intergraded with cards to control access to buildings.

The Massachusetts Institute of Technology (MIT) which is found in USA established an auto-ID center that is dedicated in automatic identification of an item and became the global EPC (electronic product code) standard [9]. In addition, RFID systems are widely used in inventory management, health care sector to ID patients, logistic supply management, automotive sector, luggage control in transportation. Therefore, the levels of advancements in automatic identification technology provides noticeable improvements in increasing the reading rate, distance, operating environment, reliability, security and etc that leads the technology to be widely acceptable in the market today.

2.7 Comparison of different ID systems

A comparison between the identification systems described the strengths and weakness of RFID in relation to other Auto-id systems as shown on table 1 below.

System parameters	Barcode	OCR	Voice recog.	Biometry	Smart card	RFID systems
Typical data quantity (bytes)	1–100	1–100	—	—	16–64 k	16–64 k
Data density	Low	Low	High	High	Very high	Very high
Machine readability	Good	Good	Expensive	Expensive	Good	Good
Readability by people	Limited	Simple	Simple	Difficult	Impossible	Impossible
Influence of dirt/damp	Very high	Very high	—	—	Possible (contacts)	No influence
Influence of (opt.) covering	Total failure	Total failure	—	Possible	—	No influence
Influence of direction and position	Low	Low	—	—	Unidirectional	No influence
Degradation/wear	Limited	Limited	—	—	Contacts	No influence
Purchase cost/reading electronics	Very low	Medium	Very high	Very high	Low	Medium
Operating costs (e.g. printer)	Low	Low	None	None	Medium (contacts)	None
Unauthorised copying/modification	Slight	Slight	Possible* (audio tape)	Impossible	Impossible	Impossible
Reading speed (including handling of data carrier)	Low ~4 s	Low ~3 s	Very low >5 s	Very low >5–10 s	Low ~4 s	Very fast ~0.5 s
Maximum distance between data carrier and reader	0–50 cm	<1 cm Scanner	0–50 cm	Direct contact**	Direct contact	0–5-m, microwave

Table 1(the advantage and disadvantage of different Automatic-id systems Klaus Finkenzeller [7, 8])

As shown in table 1 different Automatic-id system have advantage and disadvantage based on their use, reading range and speed, memory capacity, cost and operational environment.

RFID systems have much more advantage than the rest automatic identifications systems. Therefore, they have more memory capacity, don not need line of sight between the tag and reader and long read range compared to other Auto-id system.

Smart card might have the same memory capacity as RFID system but with less reading speed, cost and direct physical contact between the card and the reader. When it comes to biometry system they are difficult to be copied, have low reading speed and expensive to manufacture as voice recognition.

Barcode and OCR have almost the same selections criteria except they have different reading range and readability by human eye.

3 Frequency range and radio licensing regulation

As we mentioned on section 3.2, RFID systems use radio wave mostly in LF, HF, UHF and etc. Therefore, manufacturing companies' are required to follow radio licensing regulations to properly apply the technology and protect electromagnetic interference to other systems including medical devices. Hence RFID operating frequencies are regulated by government and standard bodies such as: [10]

- International Organisation of Standardisation(ISO)
- Global Electronic Product Code (EPC)
- European Telecommunications Standards Institute(ETSI)
- Federal Communications Commission(FCC)

EPCglobal provides information about changes in regulation for RFID systems that operate in the UHF band. On the other hand, ETSI deal about regulation on electromagnetic compatibility and radio spectrum matters (ERM) until regulations created by European Conference of Postal and communications Administrations (CEPT) implemented across all European countries. Regulation and Standards developed by the International Telecommunications Union (ITU) concedes with other standards and regulatory bodies with FCC, CEPT and ETSI [10].

The European Electronic Communication Committee (ECC) Short Range Devices Maintenance Group (SRD/MG) has very important document and ECC recommendations 70-03 dealing with specific regulations for all short range devices including RFID [10]. Therefore, RFID tags and system can be considered as short range devices (SRDs) .Hence, different RFID frequencies that can be implemented in European standard (EN) are listed below.

- EN300 220 (Parts 1-3) radio devices in frequency range 25 MHz to 1000 MHz with power levels up to 500 mW (1997-2005)
- EN 300 330 (Parts 1-2) radio devices from 9 KHz to 25 Mega Hz frequency range
- EN 300 440 (Parts 1-2) radio devices 1 GHz to 40 GHz frequency range
- EN 302 208 (Parts 1-2) radio devices from 9 KHz to 25 MHz ,865 MHz to 868 MHz frequency range with power levels up to 2W

Electromagnetic compatibility (EMC) ensures different electronic devices including RFID devices to operate without interference. Therefore, medical, radio and electronic devices must comply with emission, immunity and different EMC standards of the country which it is going to be implemented based on ISO, ETSI and EPC standards.

4 Literature review on anti-theft systems

P.v Supa Oy is a company that resides in Helsinki Finland. They operate in development of automation system and provide related products, accessories and software services for library automatization or customer's existing platform technology.

The PG50 RFID security gates was one of the product that was introduced during the interview conducted with p.v Supa Company. The reason was it could work in different materials like metal, liquid and etc. They organized a demonstration to illustrate how it could be possible to monitor items that goes in and out of the company's warehouse by using PG50 RFID gate. In addition, it also shows that the gate control software could be integrated to a video surveillance to monitor the operation and trigger an alarm during theft or other inappropriate activities. [11]

Vilant systems Oy is a company found in Finland. It mainly operates in industrial process efficiency using RFID. They provide RFID systems for Asset tracking, Railway application, and in supply chain sectors. Their customers include large companies such as Nokia, ABB, Volvo and etc [12].

Vilant provides Gen2 UHF RFID tags which can be used in metallic materials, glasses, plastic bag and track tagged picking boxes. They also supply passive Gen2 RFID system for locationing trains and metro in harsh environment conditions.

Kun Yang, Domenic Forte, and Mark Tehranipoor [13] proposed an RFID system used for anti counterfeit detection and add traceability (CST) for electronic components. The system integrates different types of sensors into the RFID chips to help monitor the activity of the component and track PCB board using board identification from tampering criminal activities.

Anti-theft system used in security and access control applications could also integrate biometric devices in addition to RFID. These systems usually authenticate the image on the card read by RFID reader to the image saved on the database to grant access or deny and trigger an alarm for unauthorized access [7].

Anti-theft in automobile tracking system using global positioning system GPS, global system for mobile communication GSM and GPRS [14] is also another widely used application. Moreover, Anti-theft system using UHF and active RFID tag integrated with motion sensor to protect high value asset such as books, artwork, artifacts and etc [15]. Other applications of anti-theft systems are bicycle management system [16], container tracking [17] and etc.

As stated above, RFID based anti-theft system can integrate various sensors and other technologies like GPS, GSM, alarm and etc to increase efficiency and reliability of use. These implicates the system not only can operate in different environments but also could work in different types of material.

5 Components of anti-theft system using RFID

RFID based anti-theft systems are composed of tag, reader, an antenna and host computer as shown in figure 4. The tag carries object identifying data. The reader is another component of an RFID it reads and writes data into a corresponding tag. The host computer, which is also another component of RFID uses the tag information and processes it for different management and security user side application.

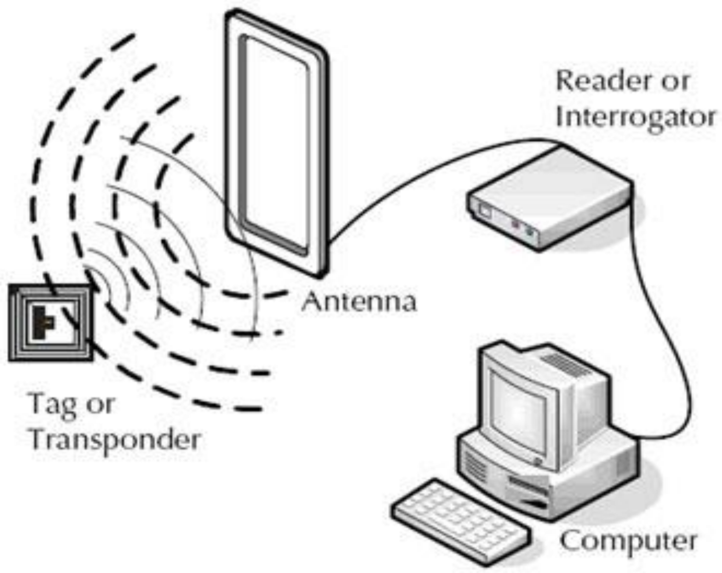

Figure 4. RFID components [18]

5.1 RFID Tags

A tag consists of antenna and microchip that is used to store unique code for item identification. The tags can be classified according to operational environment, reading range, integration with different technology, power source and operating frequency, which helps to choose types and the cost of tags. These important differences will be discussed later on in section 5.

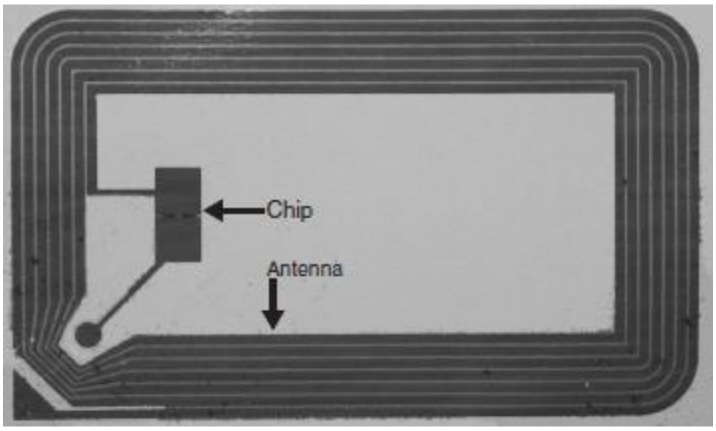

Figure 5. RFID tag [19]

RID tags as shown above in figure 5 have integrated circuits (IC) and an antenna. The tag IC provides computation, memory to store data and different features. The antenna or coils of wire on the tag can be used to transmit data stored in IC to the reader. RFID tags can be classified based on read and write data capabilities [20].

- Class1: a Read-only, no power and ID tag with un-editable memory and factory programmable.
- Class 2: a write-read, no power one time programmable memory tag.
- Class 3: a write-one read-many (WORM), programmable memory with semi-passive tag.
- Class 4: a read-write with semi-passive or active tag that uses built-in battery to power the chip and the tag to transmit the signal to a reader.
- Class 5: a read-write with an active tag that can communicate with other class 5 tag and other devices without the presence of the reader.

5.2 RFID Reader

Readers are scanning devices that use radio frequency to read the tag information and send it to the host computer. The processing time can enhanced using anti-collision algorithm to read multiple items at once.

Nowadays, readers can be categorized by internal storage memory, processing time, portability and operating frequency. Therefore, RFID reader can be fixed or hand-held [21]. Retailer sector uses fixed RFID reader placed on the entrance to control theft and mobile readers allow users to read and write the tag, in addition to making the inventory easy and efficient.

5.3 RFID Antenna

The antenna is the most important component of any RFID based system since it makes possible the communication between the reader and tag. Therefore, it can be used to transmit and receive data from the reader to tag and vice versa. Antennas are made of conductive substance like copper which has a high electrical conductivity and operate on RFID operating frequencies as shown on table 2. The antenna can be adjusted to operate in specific frequency range or resonant frequency. There are different RFID coupling methods that are used between RFID reader and tags are inductive coupling, backscatter coupling, etc.

An inductive coupled RFID system consists of an antenna and passive tag with the chip that needs to be powered by the reader. Therefore, the reader generates a strong electromagnetic field around reader and tag coils. When the tag antenna coil cross the electromagnetic field generate by reader antenna a voltage is produced on the tag antenna by inductance and rectified to be used as power supply for the chip. Inductive coupling is near field effects because of the distance between the coils is short and operate in high frequency (HF). [7, 41-44].

An electromagnetic backscatter coupling uses energy radiates to free space in the form radio wave emitted from the reader transmitter and reflected backs some of the wave by the tag to the reader receiver to transmit a signal. Backscatter coupling is a far field coupling due to longer range and operates in ultra high frequency [7, 47-49].

5.4 Host computer/middleware

This consists of application software that read-write data to and from the tag via the reader. The data will be processed or updated and is given to the control station. The reader uses wireless network or wired connectivity to deliver the data to the host computer. The host computer can be used to monitor multiple systems such as the RFID system integrated with video surveillance.

6 Selection criteria for RFID based Anti-theft system

6.1 Power source

The voltage necessary to power the tag generated either by induction process from the reader antenna or with own power source for instance a battery. There are three main types of tags based on power sources used: active, semi-passive and passive.

Active tags are powered by built-in battery and transmit their signal to the reader. Since they have their own battery or power source to supply the tag, active tags have longer reading range and are expensive.

Active RFID systems which have a long reading range generally operates in Ultra High Frequency between 300 MHz-3GHz. Therefore, active RFID tags are used to track and monitor on objects remotely and implemented in different sectors such as railway, car manufacturing industries, in logistic and transportation industry of cargo tracking, etc. Active tag with an accelerometer sensor could detect and record falling shipping container lost in the sea [20].

Passive tags do not have a power source and need energy to power the chip from the reader. Therefore, a passive tag acquires the power from the reader by inductive coupling when the reader antenna coil generates electromagnetic field that induces voltage at the tag antenna when they are at close proximity.

Passive tags are small in size, does not require external battery, have less maintain cost and cheap to manufacture relatively to active and semi-passive tags. However, it has a short reading range that is limited by the need of external power source from the reader and by the size of the antenna. A passive tag can also have longer reading range using reflected electromagnetic energy from reader during electromagnetic coupling. It can survive extreme temperature, dust and operating frequency. Passive tag can be used in automobile identification application by mounting the tag on the windshield of cars and provide successful ID reading even at high speed [21].

Semi-passive tags communicate with the reader using electromagnetic coupling even though they have a built-in battery to power the chip. Hence the tag uses reflected electromagnetic energy from the reader to generate tag response. They do offer a longer reading range than passive tags. However, the semi-passive tag can remain idle if it's out of range of the reader to save power.

6.2 Operating frequency

RFID systems operate at various frequencies within the specified band as shown in table 2 and that can be used for different type's applications. The operating frequency is affected by the transmission mode, material properties, frequency allocation and power source.

Low Frequency(LF)30-300 kHz	125-134 KHz in Europe and the USA
High Frequency(HF) 3-30 MHz	13.56 MHz in Europe and the USA
Ultra- High Frequency(UHF) 300 MHz-3GHz	865 – 868 MHz in Europe 902 – 928 MHz in the USA
Microwave	2.45 & 5.8 GHz in Europe and USA
Ultra-wideband(UWB)	3.1-10.6 GHz

Table 2 RFID operating frequencies and region [22]
RFID systems mainly operate on the frequency band listed in table 2.

6.2.1 Low Frequency (LF)

Low frequency systems operate in the frequency range 125-134 KHz frequency ranges used for short reading application [23] and governed by ISO18000-2 standard. Usually LF system have slow data transfer rate due to operating frequency and read only a single tag at a time. LF has 1-10 centimeter reading range depending on the size of the tag and Reader antenna.

One of the features of LF tags is that it can operate near to different material type such as metal, liquids and plastic. Therefore, it is ideal to be used for different application such as identifying vehicles and equipment, automobile immobilizer system [26], animal tracking [24] and etc.

LF RFID system might be affected by interference generated by electrical motor in industrial environment. The cost and size of the LF tag depend on the size of the antenna for example LF tags have larger antenna size than High frequency tags that restrict the reusability of LF tags.

6.2.2 High Frequency (HF)

High frequency RFID tags operate at 13.56 Megahertz frequency and can be used for access control and contactless payment applications. HF system have higher data transfer rate and faster communication speed between the reader and tag. Hence the reader can read multiple tags at the same time and have lower tag prices comparing to LF tags. The larger HF tag antenna size increases the read range between the reader and tag.

HF tags can operate near most material types such as liquid, body tissues and electrical motor in industrial environment. However, metals affect HF tags in contrast to LF. The tag antenna can also be manufactured with less than 0.1mm thickness and with several antenna size types that can be printed onto a substrate, using conductive ink and then attached to the tag.

There are different standards for HF technology such as ISO 15693 for tracking objects, ISO 15962 for contactless card, ISO 14443 for fare collection and electronic payment, air interface standardsISO18000-3 standard and etc. RFID regulatory bodies issues, HF operating reading is less than a meter as shown in table 3.

6.2.3 Ultra- High Frequency (UHF)

Ultra- High Frequency operates in the frequency range 865 – 868 MHz in Europe governed by ISO18000-6 air interface standard and 902 – 928 MHz in the USA. UHF offer better reading range and faster data transfer than LF and HF. The larger UHF tag antenna size the wider the read range between the reader and tag. Therefore, the tag antenna size should take in account the item size to be tagged.

UHF RFID system can read multiple tags at once and have faster data transfer speed than LF and HF systems. UHF was affected by interference near to metal, water and electronics equipment or surrounding environment [25]. However, nowadays some UHF tag antennas are designed to be used near metallic object [26]. For example

UHFGen2 tags can be used on containers or on bottles filled with liquids and are widely used in vehicle access control, industrial automation, asset tracking, and inventory management and etc.

UHF system can be implemented in applications with different frequency range in different countries [24]. Therefore, data stored on any UHF Gen2 tag can be read by any Gen2 reader.

6.3 Operating distance between reader and tag (Range)

The reading range of the RFID based system depends on the tag size, orientation, angle and antenna gain, polarization, power setting and cable used [20].

As mentioned section in 6.1 the lager the tag size the larger the reading range. Linear polarized antennas can be used for the reader to achieve longer reading distance depend on the arrangement of tag orientation and angle respect to the antenna position. In addition reader can achieve longer reading range using circularly polarized antenna even though the tags are placed vertically or horizontally.

RFID readers reading range can be affected by its antennas gain based on the power received from the reader and tagged object distance. In addition, the length of the cable between the antennas and reader affect the reading range due to the loss of energy and if the antenna is somehow very far away from the reader, higher insulation rating cable should be used to increase the reading range.

Depending on the RFID system operating frequency range, the reading range of the RFID can be from a few centimeters to a few meters as shown in table3

Frequency	reading range
LF 124 kHz – 135 KHz	less than half meter
HF 13.56 MHz	less than a meter
UHF 860 MHz – 960 MHz	more than 6meters
Microwave 2.45 GHz	more than 10meters

Table3 Operating RFID frequency and their Reading Range

Usually the higher the operating frequency, the larger the reading range and vice versa. Hence, the RFID operating frequencies affects desired reading distance as shown in table3.

6.4 Security requirement

To protect the RFID system from forgery or cloning, eavesdropping appropriate common authentication must takes places between the tag and reader. However, when it comes to some applications like industrial automation and tool identification security is often unnecessarily and expensive. Applications with high security risk such as ticketing and payment system must have secret key or code for authentication purpose to access the service [7, 8].

Encryption is used to encrypt data stored on the tag or data transfer between the tag and reader to stop eavesdropping or manipulation.

6.5 Memory capacity and cost

As explained in section 5.1 depending on the chip memory storage space and tag types it is possible read or write data to the tag. For instance LF tags have read-only memory but when it comes to HF tags they can be either read or write only and rewritable tags with memory from 64 bytes-8 kilobyte. Unlike HF tags, UHF tags can read/write data with smaller memory from 24-110 byte [27].

For instance Gen 2 RFID tags have 96 bits EPC memory to store the identity of an item and additional data about the tagged item [28].

The cost of RFID system implementation depends on the tag and reader type, installation and complexity of the host computer to process data. Therefore, the cost of RFID system varies from hundreds to thousands euro depending on volume, memory capacity, power source, packaging of the tag and the reader tag reading speed , memory and types of communication port. Moreover simplicity of UHF antenna design and hardware availability for production to manufacture UHF tags cheaper as shown in the figure 6 below.

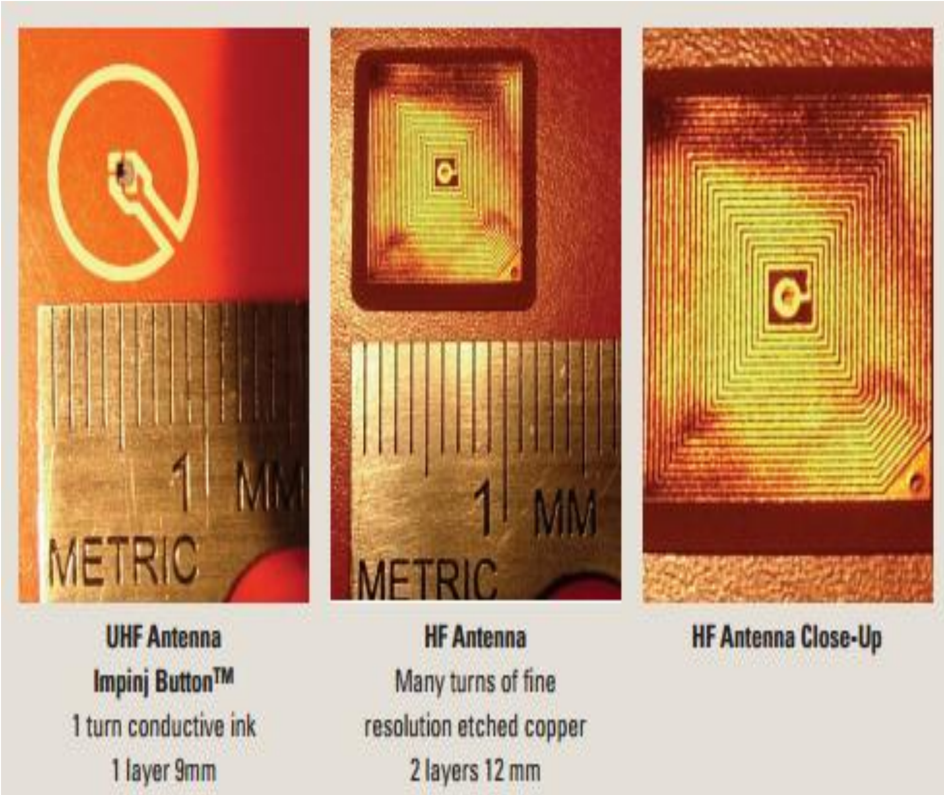

Figure 6. UHF tag costs VS HF [28]

As shown in the figure 6 UHF tag antenna uses a single turn compared to HF tag antenna that is made of many coils and expensive to manufacture due to high raw material requirement. Therefore, less complexity in design and material requirement reduces manufacturing costs.

Vilant Company manufactures different types of RFID tags such as:

- Passive tags with reading range up to 10 meter and costs about 0.1-0.2 Euro.
- Semi passive tags with reading range more than 20 meter and costs about 1-5 Euro.
- Active tags with reading range more than 30 meter and costs about 20 Euro.

Here is some of the summary of cost of RFID Tags and Reader such as passive tags on all types of material except metallic object costs 10 cent US dollars per piece. Passive Tags that work on metallic objects is about 1.5 dollar per piece and Batter powered tags (active) is about 15-20 US dollars. In addition to this, the price of portable reader (handheld) is about 3000 US dollars and passive stationary RFID gate costs about ten to twenty thousand US dollars [29].

Battery power RFID reader that can be used to monitor large area with active tag costs about one thousand to one thousand five hundred US dollar [29].P.V.SUPA PG45 and PG50 RFID security gate cost about 4500Euro and 5700Euro respectively.

6.6 Operational environment

RFID tags have relatively high tolerance to environmental conditions such as temperature, vibration, pressure with the exception of water, plastic and metal depending of the tag type. Therefore the communication between the reader and tag depends on the material type where tags are attached and harsh operating environment.

Radio signal can be affected by water and metal with which the RFID tag signal interacts. Therefore, radio signal cannot go through metal and water as they intend to absorb some of the signal energy.

7 Anti-theft System layout for Metropolia UAS laboratory

The Metropolia UAS has several campuses around Helsinki. The main laboratories for Electronics department are located in Albertinkatu Helsinki and have several valuable equipment and tools. To mention some of the equipments are oscilloscope, function generators, spectrum and network analyzer, different multi-meters, other devices and tools. The two laboratories are located at the fifth floor of the department building. The layout shown in the figure 7 illustrates, that there is one entry or exit to the corridor that connects the two laboratories staff offices, rest room and laboratory store.

The campus uses video surveillance security to monitor the activity around the campus building. In addition, there is also access control system applied to every door which gives access grant to school members. The authorization varies as staff members might have higher level than students. For instance students can access entrances door to the campus and class rooms but laboratory with special authorization granted by school security personnel. Therefore, when student or staff member lose their electronic key they are required to inform the security personnel so that particular key must be deactivated and issued with new one.

It is necessary for the students and teachers to be aware of the existences of laboratory security risk. When students or teachers lost access key and laboratory doors left unattended can be used for unauthorized entry that might lead to illegal activities. Therefore, the current security system implemented by the Metropolia UAS monitors doors entry and it is not satisfactory on the other hand protecting laboratory devices and tools that might be carried inside a bag or pocket. Therefore, this thesis is going to propose suitable RFID based anti-theft system to protect metropolia UAS laboratory equipments based on the selection criteria in section 6 and layout of the Laboratory rooms as shown in the figure 7 below.

Figure7 Anti-theft system of Metroplia UAS Laboratory

Based on the measurement taken, the entry door to the laboratories corridor is 2.10 metres long and 1.40 metres wide and made of wood. Depending on the reader type and size it is possible to deploy RFID based anti-theft system monitor 1.40 meter wide entrance door. Therefore, the reader coverage area and tags operating range selection criteria mentioned in section 6.3 could cover the entrance area and meet operating frequency tag that could work near to different material types as explained in section 6.2. For instance, low tags are cheap and good to work on metal and fluid objects but they have limitation in their reading range if the distance between the readers and LF tags are more than 0.5 meter .However, high frequency tags could work reasonably well around metal and fluid object when the distances between the readers and HF tag are less than a meter with multi tag reading and faster data transfer rate compared to LF based RFID system.

Apart from LF and HF, UHF RFID system offer much longer reading range with fast data transfer rate but it doesn’t work well near to metal. Despite the fact that UHF RFID affected by interference from laboratory devices and tools, there UHF tags antenna that are designed to work on near metallic objects. For instance UHF Gen 2 tags could be used almost on most objects as well near metallic object.

LF tags uses less power to penetrate non metallic objects and HF tags uses more power than LF tags to penetrate well metallic objects. On the other hand UHF RFID system uses more power to transfer data faster and cover large reading range. Hence the power transmitted in UHF band by the reader should be 2w effective radiated power (ERP) and 500 effective Isotropic radiated power (EIRP) due to EU regulatory bodies (ETSI).

As explained in section 5.1 and 6.5 Tags memory size affect data transfer and communication with the reader. These require higher radio frequency RFID system such as HF and UHF to read or write and transfer data faster. However, the position where the tag is attached affects the type of antenna the reader uses to read or write on to the tag. Thus, as explained in section 6.3linear polarized or circularly polarized antenna could be used either to achieve longer read range taking into account the position of the attached tag on the laboratory devices or tools with respect to the reader position.

In addition to the alignment of the reader on the floor or wall depends on the historic code building and need permission for installation. Reader can use Power sources found on side wall of the lobby and could be connected to the host computer in the room opposite side of lift. Implementation of the RFID system depends on the price tag of the RFID reader and tags that accommodate all characteristics of metroplia electronic laboratory device and tool based on the selection criteria.

The proposed measurement set-up can be in the entrance door on the fifth floor electronics laboratory corridor of Metropolia UAS campus. The frequency ranges from 10 MHz - 15 MHz and 800 MHz - 960 MHz with output power 60 dBu and 27 dBm respectively for HF or UHF RFID anti-theft system. Therefore, the power step could be adjusted in 10 dBu and 1 dBm as the tagged object moving in 5 degree steps with respect to antenna orientation and 0.5 - 1.7 meter distance between the two antennas or single antenna could be used. The actual setup the RFID gate experiment mounted to plastic stand secured to the floor is shown in the figure 8 below.

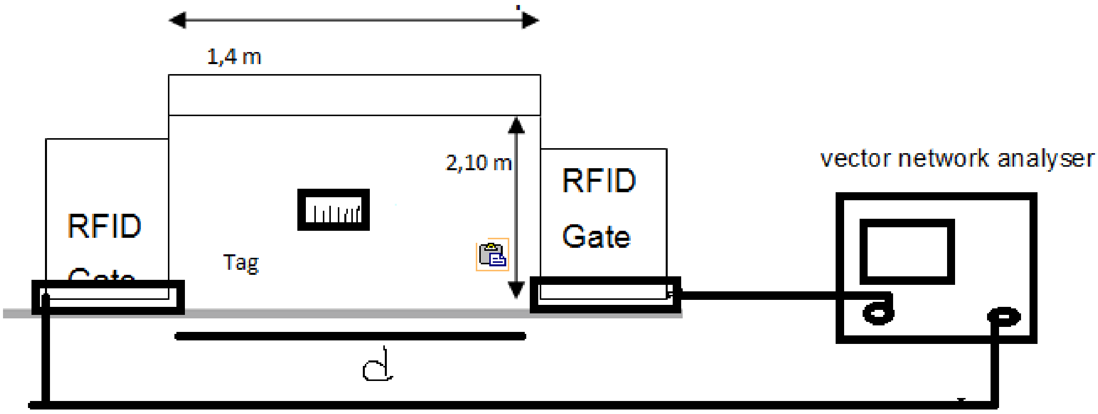

Figure 8 RFID gate measurement set-ups.

After connecting the FRID gate to power source to vector or spectrum analyzer using coaxial cable start measuring received power from the reader responses to different transmitted power, tag distance and orientation changes with minimum 0.7 m from the reader antenna.

The maximum read range of far field RFID system theoretically can be calculated using Friis transmission Equation.

$$P_r = P_t \frac{G_r G_t \lambda^2}{(4\pi R)^2} q$$

Where the gain (G_r / G_t), impedance mismatch factor (q) and power at receiving antenna(P_r) and output power of transmitting antenna (P_t), wave length (λ) of the operating frequency, R is the distance between the antennas in our case d. After substituting and rewriting Friis equation the maximum reading range can be derived.

$$R = \frac{\lambda}{4\pi^2}^{2} \sqrt{\frac{qGrGtPt}{Pr}}$$

8 Conclusion

The practicability using RFID based anti-theft system for Metropolia UAS to deter theft and monitor laboratory devices and tool is significant. Therefore, tagging laboratory devices with RFID tag will deter theft and improve laboratory management system to monitor devices and tools. As explained in section 7 RFID tag in LF RFID system could not penetrate non-metallic and metallic object respectively with limitation of short read range that is not suitable for metropolia laboratory RFID based anti-theft system. However passive HF and Gen2 UHF RFID tag on the other hand could be used to tag metallic objects. Therefore, I propose PG50 or PG45 RFID security gate from P.V.SUPA Company to protect the entrance door to the laboratory and integrate with existing video surveillance system. My thesis could provide better understanding different types of RFID based anti-theft system and propose suitable for Electronic laboratory.

The effectiveness of the system could not be tested the proposed RFID based anti-theft system in actual laboratory entrance due to high implementation cost to install and buy the RFID gates.

As feature plan this security gate could be interfaced using Lab view to Metropolia UAS Electronic Laboratory Database to store information and monitor laboratory devices, components and tool. Therefore, it is possible to check maintenance status of the laboratory devices and efficient.

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