Identification of Car Passengers with RFID for Automatic Crash Notification

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ABSTRACT

Automatic Crash Notification is a system designed to be used in a crash situation. When a crash occurs, the intelligent system is activated and automatically sends select crash details to the appropriate Emergency Medical Service Center. These details can be the position of the vehicle and the likely severity of the damage. Using the information, the medical treatment resources demanded for the accident is assessed at Emergency Center. Accordingly, first-aid facilities are promptly and properly delivered to help the victims. Moreover, it would be a great advantage to include information about the passengers, such as the number of passengers, their age, sex and identity, in order to prepare the emergency services for their mission.

The project focuses on implementation of Radio Frequency Identification technology (RFID) to improve the Crash Notification System of Autoliv Electronics together with First-Aid Profile (FAP). First-aid active RFID tag is pre-coded with a unique serial number (FAP-ID) that can be used to gain access to the First-Aid profile of that tagged person. Compatible reader detects the presence of First-aid tags and reports their FAP-IDs to Autoliv control unit, so that in crash situation, all passengers' FAP-IDs will be messaged to Emergency Medical Service Center.

During the project, the possibilities and constraints of using RFID technology for identifying passengers in vehicle is investigated, based on given hardware technological solution. Several tests are designed and carried out to investigate communication between the active RFID tag and the reader. Software program is also developed to build up the passenger identification system. According to experimental results, two possible implementations of the passenger identification system are proposed. Furthermore, the reliabilities of these two systems are tested against the situation when tag is buried in user's pocket or bag.

SAMMANFATTNING

Automatic Crash Anmälan är ett system som skall användas i en krasch situation. När en olycka inträffar, det intelligenta systemet aktiveras och skickar automatiskt väljer krasch information till lämplig Emergency Medical Service Center. Dessa uppgifter kan farkostens position och sannolikt allvarliga skador. Med hjälp av information, medicinsk behandling resurser krävs för olyckan bedöms till Emergency Center. Därför första hjälpen snabbt och korrekt som levereras för att hjälpa offren. Dessutom skulle det vara en stor fördel att inkludera information om passagerare, till exempel om antalet passagerare, deras ålder, kön och identitet, i syfte att förbereda räddningstjänsten för sitt uppdrag.

Projektet är inriktat på genomförandet av Radio Frequency Identification teknik (RFID) för att förbättra Crash Anmälningssystemet för Autoliv Electronics tillsammans med First-Aid Profile (FAP). Första hjälpen aktiva RFID-taggen är pre-kod med ett unikt serienummer (FAP-ID) som kan användas för att få tillgång till första hjälpen-profil att tagged person. Kompatibla läsaren upptäcker närvaro av Första hjälpen-taggar och rapporter sina FAP-IDs till Autoliv styrenhet, så att kraschа, samtliga passagerares FAP-ID kommer att messaged ambulansflygningar Center.

Under projektets möjligheter och begränsningar med att använda RFID-teknik för identifiering av passagerare i fordonet är undersökta, som bygger på viss hårdvara teknisk lösning. Flera tester utformas och genomföras för att undersöka kommunikationen mellan de aktiva RFID-taggar och läsare. Programvara Programmet är även utvecklat för att bygga upp passageraren identifieringssystemet. Enligt experimentella resultat, två möjliga implementeringar av passageraren identifieringssystemet föreslås. Dessutom har reliabilities av dessa två system testas mot situationen när taggen är begravd i användarens ficka eller väska.

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1 Introduction

The project is done at Autoliv Electronics AB, as a part of its telematics system in the vehicle. The Autotiv's Automatic Crash Notification system (ACNs) is a crash robust system that builds a connection between the occupants and the operator at Emergency Medical Service Center after a sever crash occurs. When activated, the vehicle's electronics system sends a text message to Volvo-on-call Alarm Center via the integrated car phone. At the mean time, a telephone-line is opened so that the operator at the Volvo-on-call Alarm Center can speak to car occupants and obtain detailed information about the accident. However, if no one inside the car is able to answer the calling, the operator can also send the ambulance and rescue team to the vehicle. The location provided by the car's Global Positioning Satellite navigation system, is included in the Volvo-on-call Alarm message.

It is proved that ACNs has been helpful to save more lives by giving the rescue teams the exactly location of the vehicle so that they can arrive in time. It would be better if the information about the passengers can be included when message the Emergency Medical Service Center to help them better prepared in the case of special medical service demanded. Moreover, medical resources are economized by saving unnecessary first-aid facilities.

This project is done for an improvement of ACNs to implement the First Aid Profile (FAP) database system into the post-crash SOS-system. FAP is a secure database that contains information such as a current photo, name, address, age, contact information for relatives and medical records. The first aid profile of an individual is linked with a unique FAP-ID number. Only through this FAP-ID one can get access to the database of its linked person. The FAP-ID is usually printed on FAP carrier, such as a key washer or a FAP card.

When the text message is sent to the Emergency Medical Service Center, including the location of the vehicle; the information about the passengers, such as the number of passengers, their FAP-ID numbers and their likely positions, are also provided to the operator at the Emergency Medical Service Center.

The structure of this report is as follows. Section 2 reviews the problem statement and main contribution of the project. Section 3 presents an overview of the auto-identification technologies and explains the essential knowledge of the RFID technology. Section 4 analyzes the fundamental requirements to which the Passenger Identification System is obliged and describes how the Passenger Identification System is designed. Section 5 describes how the system is implemented. Section 6 presents the results of the tests which examine the performance of the system. Section 7 states the conclusion of the project studies and section 8 proposes some improvements that can be employed in the Passenger Identification System in the future.

2 Problem Statement and Main Contribution

The purpose of this project is to further develop the Automatic SOS-system by including information about the individual passengers when the automatic crash notification message is sent from a vehicle to Emergency Medical Service Center in order to prepare the emergency services for their mission. The additive information that is automatically generated can consist of a number of the passengers, their FAP-IDs and position in the vehicle.

During the project, RFID technology is applied to the Autoliv SOS-system for identifying individual car passengers. The passenger identification functionality is accomplished by an active RFID system. With unique tags attached to individual passengers, a RFID reader detects presences of tags on demand and reports them to Autoliv SOS-system’s control unit for further process.

The possibility and limitation of car passengers recognition in the case when they carry unique radio transmitters is tested with serial experiments. The received signal strength is analyzed to estimate the relative position of tag from the reader. Successful identification rate is used for measurement of system performance.

Based on a given technological solution of RFID transponder and transceiver, implementations of the passenger identification system is proposed with three different reader placement positions. A C program is developed for the control unit to communicate with the RFID reader. With the given hardware equipments and program, the passenger identification system is built. Moreover, the system performances are tested as well as their reliability when the tag is buried in user’s pocket or bag. System with the RFID reader lying in the centre area is verified to be the best placement of the proposed solutions. Method to speculate the likely position of the passenger based on statistical data of identification process is also given.

3 Background and Related Works

3.1 Wireless identification and tracking

When speaking of wireless identification, the first name that comes to our mind is GPS, Global Positioning System. Thanks to the rapidly developing technologies, GPS is one of the most popular tracking technologies nowadays. However, GPS has its limitations in indoor environment with blockages and obstacles. Because GPS signals have low power level indoors, the GPS receiver is facing a challenge to improve signal-to-noise ratio to track the signals [1]. Moreover, indoor, a multipath is experienced more seriously as the direct line-of-sight signal can be undetected, and algorithms applied for outdoor GPS application are no any longer useful [1]. Due to these problems, indoor wireless identification technologies are the most interesting in for this project.

One of the indoor tracking technologies is infrared one. The basic idea is to attach a beacon to the object that transmits infrared signals out in all directions. Several sensitive infrared sensors are placed in advance in the environment. By calculating the arriving instant of the signal at these sensors, the position of the tracked object can be determined. Nathan and Tomonari proposed an Infrared Local Positioning System that is designed for localization Unmanned Aerial Vehicle (UAV) in a non-calibrated indoor environment [2]. Directional scanners are used in the local environment to track tags that emit a unique infrared signal. Estimating the angle which defines how the target UAV is related to the two defined points, with a known, distance between them, the locations of the target UAV can be calculated.

In [3], the authors proposed a pyroelectric infrared detector-based human-tracking system. They viewed human body as infrared resource which can be detected by pyroelectric sensors. Fresnel Lens Arrays are designed to aid in the sensing of motion by dividing the region into many zones. The velocity and direction of the motion can be extracted from the data obtained by the detectors.

Another popular indoor tracking technique is ultrasound indoor positioning system. This kind of system uses motion activated tag sending out unique identification ultrasound signals. Special detectors are located in each room to receive the tags’ signals. As the object moves throughout the monitored field, when and where the object is located will be reported to the central control computer. Sonitor Technologies Company has successfully installed ultrasound real time location system at Brigham and Women’s hospital in Boston, Massachusetts [4]. Due to the fact that the ultrasound waves do not interfered with the hospital equipments, the system performs safely. The selected patient in the hospital can be tracked and monitored by the staff.

Chun-Chieh Hsiao and Polly Huang proposed a water-drop shaped radio model and took the furniture settings in the environment into account to determine how many ultrasound beacons are needed to overcome the problem of ultrasound signals being blocked [5]. They discovered that the coverage of ultrasound transmitter signals is smaller than a perfect sphere and the placement of the obstacles in the room have impact on the deployment of ultrasound beacons.

In some applications, ultrasound is used together with radio waves. Because radio waves transmit about 10^6 times faster than ultrasound, the beacon unit broadcasts periodically ultrasonic pulses and radio waves with their unique identification messages. The listener calculates its distance from the beacon using the arrival time of the different signals. [6] Based on several known reference beacons' position, the location of listener can then be computed based on the distances and the beacons' coordinates using multilateration technique [6].

However, the disadvantage of ultrasound technology is that ultrasound signals are sensitive to temperature change and multipath signals. With infrared, although the hardware components are inexpensive, the circuitry to make them work is not and the identification range of the system is limited in 1-2 meter. Moreover, compared with ultrasound or infrared, radio waves can better penetrate through obstacles. Because in this project, the passenger identification system will be implemented in a complex car environment, Radio Frequency Identification (RFID) is considered as the identification technology that will be employed. More detailed information about RFID will be present in section 3.2.

3.2 RFID Technology and Its Applications

3.2.1 Components of RFID System

RFID systems have three main elements: tag (or transponder), reader (or transceiver) and middleware, as shown in Figure 2.1.

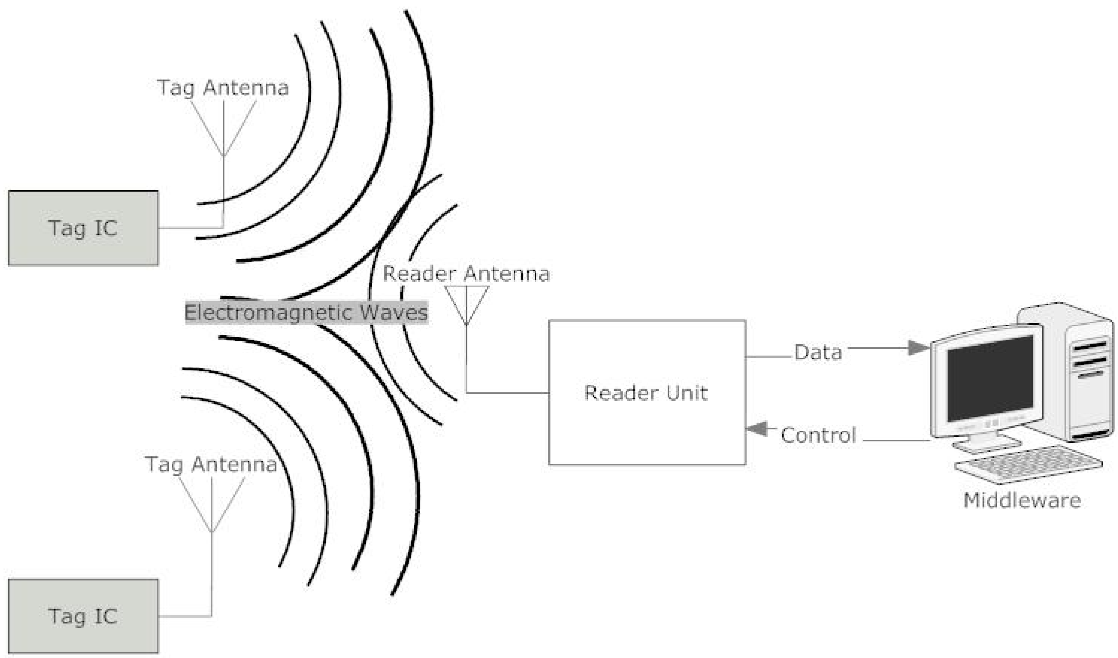


Fig. 2.1 Components of an RFID System

Tag

A typical RFID tag contains a chip and tag antenna. Chip's memory stores data, such as a unique serial number or other information that is used to identify the individual item which affixed with the tag. The antenna is attached to the tag chip, which transmits radio wave signals from the tag. Through the tag antenna, the information stored in tag chip can be captured by the reader. Tag chip can be propose-oriented that one type is designed for one special application purpose and also rule-based RFID tag that uses a ubiquitous chip which can be easily customized from different applications [15]. There are briefly three sorts of tags, differentiated by how they communicate and how that communication is initiated: passive, active and semi-active tag. Comparisons of these three types of tag are briefly shown in Table I.

Most popular tags today are *passive tag*, due to the fact that passive tag can be produced at a very low cost. They are called passive tags because they require no battery power in the tag circuits. Passive tags rely on RF electromagnetic energy emitted from the reader to run their circuits and transmit signals back to the reader. Improvement of efficiency to power a passive tag and gain more available output power has been studied [16]. However, due to the fact that passive tags get their power by harnessing the electromagnetic energy from the reader, passive tags are very restricted in the reading range. Typical read range is about 3 meters for passive tags, but can be up to 9 meters determined by the tag design.

Usually, passive tags cost from 20 cents to several dollars, based on the memory size of the tag chip, the antenna design, the radio frequency it used, and packaging materials and other tag requirements for the application [17]. Typical application areas for passive RFID system nowadays involve asset management, industrial automation, electronic article surveillance, access control and animal tracking [18].

Different from passive tags, *active tags* are consist of not only tag chip and antenna, but also it own power source that is used to run the microchip's circuitry and broadcast radio waves out. Therefore, under the same restrictions, active tags are able to be achieved by the reader from a longer distance compared with passive tags. Moreover, active tags can respond to lower-level signals transmitted from the reader, but passive tags requires high-levels for both powering and communicating. Lager memory and simple processing functions can be supported by active tags also. Active tags can transmit its unique serial number and other information to the reader and has better performance against background noise and interferences [19]. However, active tag requires battery replacement after its being used for a certain amount of time. In some circumstance, the change of battery is not feasible, which demand that the active tag has to be designed as low energy consumption by reducing total identification time and active time [20].

Active tags are currently used in various areas, such as transportation, automation and asset tracking. It is adequate to real time location system to focus and monitor the exact location of real time objects in neighborhood [21], [22].

The third class of tag is called *semi-passive* or *semi-active tags*. Semi-active tags contain their battery sources, but only simply draw power to energize and operate the tag chips. Semi-active tags still utilize electromagnetic field provided by the reader to be activated and gain their power for transmitting the signal with the data back to the reader. Therefore, semi-active tags have longer read range than passive tags for the reason that the energy that they harnessing from the reader is only used for sending signals back. A key topic of semi-active RFID system development is to operate the tag with the lowest possible power [23]. Since the batteries in semi-active tags are only used for operating the tag chip, they usually have longer life-time compared with active tags.

Passive, active and semi-active tags have their own areas for application depending on their characteristics. For instance, due to the relatively high cost of active tags, they are much more used for tracking and tracing high value goods and items. Table I provides a summary of the characteristics of these three types of tags.

TABLE I
TYPICAL CHARACTERISTICS OF RFID TAGS

	Passive Tags	*Semi-active Tags*	*Active Tags*
Power Supply	From reader	Internal battery and also partly from reader	Internal battery
Memory	Mostly read-only	Read-write	Read-write
Price	About $.20	$2 to $10	$20 or more
Communication Rage	Around 3 m	Around 10 m	30 m or more depending on the design
Life of tags	Up to 20 years	2 to 7 years	5 years or less
Application Examples	Animal tracking. Parking lot pass. Asset management. Industrial automation. Electronic article surveillance.	Airline bag tracking. Supermarket products tracking. Factory automation. Package tracking.	Military shipping. Electronic price label. Personal tracking. Patient monitoring.

Reader

Reader, as a scanning device, detects the tags that attached to or embedded in the selected items. It varies in size, weight and may be stationary or mobile. Reader communicates with the tag through the reader antenna, which broadcasting radio waves and receiving the tags response signals within its reading area. After the signals from tags are detected, reader decodes them and passes the information to middleware.

Middleware

Middleware stores information about tagged items after reader recognize the presence of the tag and get the information. Typical information about the tagged objects includes their identifications, descriptions, locations, motion directions and so on. Middleware can be linked to other systems or networks that require the information for further analysis or calculation.

Tag, reader and middleware are essential components of a RFID system. When applied in certain applications, other factors also affect the performance of the system as well as the cost. Many issues have to be considered during the design and implementation of RFID system, such as which type of tag is more suitable, how much information is needed to be stored on a tag, what size of tag antenna is necessary, where to put the reader, how many readers antennas are required and their location and so on.

3.2.2 Applications of RFID Technology

RFID has been implemented and viewed as an automated data acquisition technology that will capture, analyze and store information. Thanks to the rapidly development of science and technology, RFID system has already been adopted into various application areas [7]-[11]. The main application fields for RFID system are involved track and trace, process efficiency, security and safety. Table II shows some of the most popular uses of RFID technology.

TABLE II
APPLICATIONS OF RFID TECHNOLOGY

Application	Benefits
Electronic article surveillance (EAS)	Put tag with products such as clothes in a retail store or books in the library can help preventing pilferage. Alarms can help for people to notice when the tagged objects is being moved out of the monitoring area [12].
Document authentication	To reduce the possibility of counterfeiting, tags can be affixed with documents. With the tags uniquely identify and confirm the authentication of the documents, the overall security will be increased [14].
Access control	Because the tags can hardly be duplicated or destroyed, having RFID systems for access control is cost effective and convenient. The reader can be programmed of certain control rules so that only the authenticated tag users are allowed to entre. If the access rules are changed, only the program for the reader is need to be updated with no need to involve any trouble for the users to change the tags [12].
Animal tracking	During the registration process, sub-dermal tag is injected under the skin of the animal, so that the animal is linked with its owner. Because this kind of tag can not easily be removed, when the identification of the animal can be checked when the suspected for not being the illegal owner of that animal is caught [13].
Patient Care	Real-time tracking and monitoring of the patients in the hospital can be achieved by implementing RFID systems. Another typical usage is that having the RFID tag attached with new-born babies to ensure that they are matched with their mothers, and they are not being transferred without authentication [12].
Track and trace	Affixing tags with products for inventory control in factories and warehouses can help to track the products. Applied RFID systems for track and trace can help save time and money for manual work and operations. Automated tracking systems can also be used for luggage or package transportation to ensure that they are sent to the desired destinations [13].

3.2.3 RFID Frequencies Characteristics and Applications

A key factor that affects communication speed and reading distance of a RFID system is the frequency it uses. There are mainly four frequencies that are in used for RFID system nowadays, presented in Table III.

TABLE III
SUMMARY OF CHARACTERISTICS AND APPLICATIONS OF RFID FREQUENCIES

	Frequency	*Key Characteristics*	*Typical Applications*
Low Frequency (LF)	< 135 KHz	Performance well around metal and liquid. Low data transfer rate. Very short read range.	Animal identification Industrial automation Access control
High Frequency (HF)	13.56 MHz	Common worldwide standards. Poor performance around metal. Longer read range than Low Frequency (>0.9m) Lower tag costs than LF tags	Payment cards Access control Luggage tracking Patient monitoring
Ultra High Frequency (UHF)	860--930 MHz	Susceptible to environment involved liquid and metal. Longer read range than High Frequency (>3m) Incompatibility issues related to regional regulations	Factory automation Inventory control Warehouse management Asset tracking
Microwave Frequency (MF)	2.45/5.8 GHz	Poor performance around liquid and metal. Fast data transfer rate. Read range is similar to Ultra High Frequency.	Access control Electronic toll collection Industrial automation

LF and HF use near-filed coupling for communication process. Illustrated in figure 2.2, when a tag is placed in an alternating magnetic filed that is generated by the reader, an alternating voltage across the tag is introduced. Tag draws its power from it to operate the chip. This power consumption can be measured from the voltage change across R_i of reader. Varying the load applied in the tag antenna will result in a change of the voltage across reader antenna. Monitoring this change can a reader recognize and decode the signal send back by the tag.

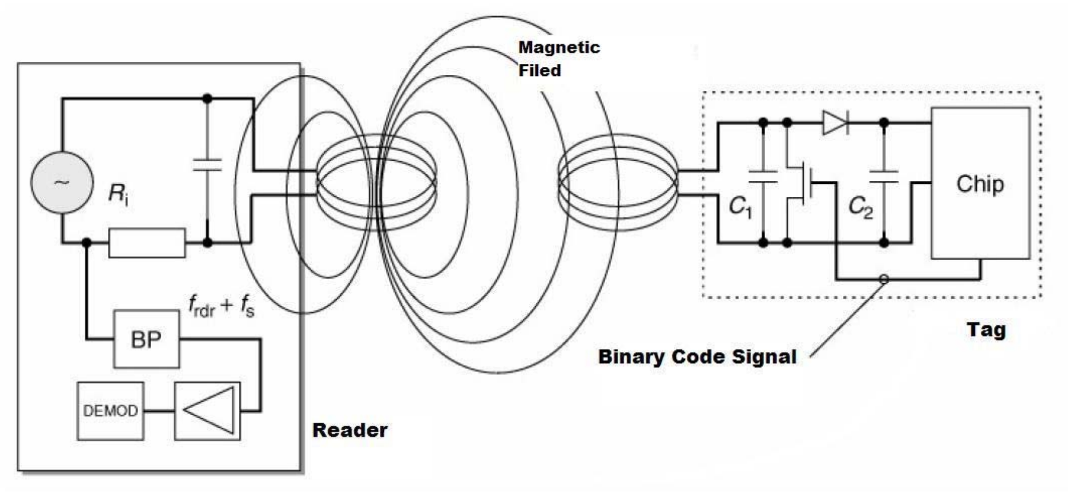


Fig 2.2 Near-filed Coupling

UHF and MF use backscattering technique to communicate with reader, which is similar to radar technique. Electromagnetic waves are transmitted out via reader antenna to the space, with part of the energy being absorbed by the tag that it reached. When the tag antenna is tuned to the frequency band with precise dimension, it will absorb most of the incoming energy. In other case, if there is impedance mismatch, part of the energy is reflected back. Therefore, by changing the impedance of the tag antenna, the signal that will be reflected back can be controlled according to the serial number 0/1 stored in the tag chip. Reader can detect more or less the signal is reflected back and decode it as the tag's identification information.

4 Requirements and Architecture of Passenger Identification System

This chapter discusses the design and implementation of the Passenger Identification System. Section 4.1 analyzes the fundamental requirements of the Passenger Identification System. Section 4.2 presents an overview design of the Automatic Crash Notification System and how the Passenger Identification System functions as part of it.

4.1 Requirement Analysis

Since this project is to investigate the possibility and constrains for identifying individual car passengers, a requirement analysis of hardware and software is performed to achieve an effective and reliable solution.

4.1.1 Hardware Requirement

The system is intended for identify passenger inside vehicle, so the main requirement for the system is to not being harmful to people and environment. Since the system should be working all the time, it should not distract driver or other road users for the safety reason. Moreover, the reader should comply with vehicle design requirements. For the after-crash system to be functional, the system is required to be crash-robust. The system needs to be resistant to environmental conditions, such as various temperature and humidity. Furthermore, since the aim of this product is to implement this system to every possible vehicle, the design should be suitable for mass production.

The functionality of the identification system is that all the passenger identification (ID) inside the vehicle will be gathered, neither the people outside from nearby cars nor the pedestrians from outside who pass by. In practice, it is extremely difficult to exclude all the signals come from outside of the vehicle. However, if the signal strength received are distinguishable between the outside tags and the inside tags, it is easy to analyze and pick the desired tags out after the identification process. Therefore, the fundamental function of the Passenger Identification System can be considered as follows. The signals from all the tags inside the vehicle that received by the reader are remarkably stronger than the signals from the tags outside, so that the middleware can evaluate which tags are detected inside.

Further more, it is better that the information about position of the passenger is sent together with the IDs, so that the rescue corps can have some knowledge about the possible degree of injury of that passenger. Received signal strength information is used for estimated the distances between tags and reader in this project. Due to multipath interference, there is no clearly theoretical model that maps received signal strength to distance, but this information can be used for roughly distinguish whether the tagged person is in front seats or back. Consequently, it is desired that the received signal strength information from the tags in front areas differ from tags in back areas. So that by analyzing the signal strength which area the tagged passenger is in can be estimated.

4.1.2 Software Requirement

The RFID reader streams the data of detected RFID tags to the virtual serial port emulated in the host laptop, which has a Linux environment. Therefore, C code will be programmed under Linux environment of the serial port so as to connect the RFID reader. For testing reasons, it is better to not only store IDs of RFID tags and other desired information in the laptop but also display them on the laptop screen.

4.2 System Architecture

Passenger Identification System works as a part of the Autoliv Crash Notification System. As illustrated in figure 4.1, the functionality of passenger identification is accomplished by an active RFID system. As discussed in the background section, unlike passive tag, an active tag has its own battery source to power the circuit and can continuously transmit radio frequency signal carried pre-programmed information data. The advantage of using active RFID system is that the active tag does not have to be placed in the interrogation area of the reader to gain power from the incoming signal to power up. This means that the communication between the active tags to the reader will be more reliable than a passive RFID system.

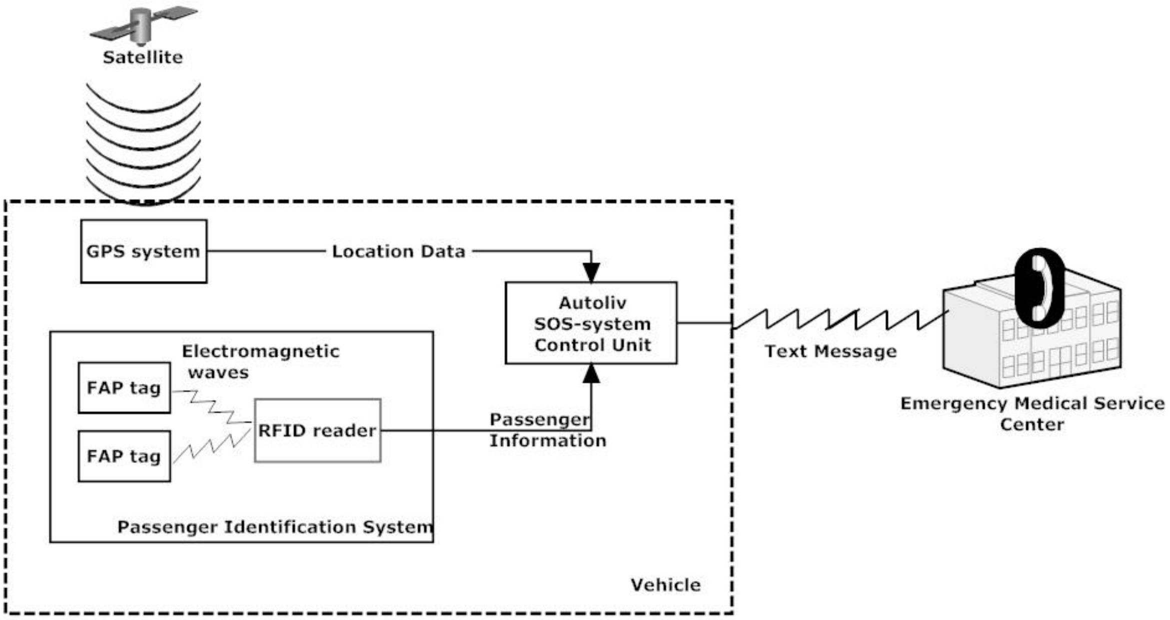


Fig. 4.1 Automatic Crash Notification System Architecture

Each FAP tag is pre-programmed with unique FAP-ID in its chip as the serial number. This FAP-ID is linked with the First Aid Profile of that tagged passenger, including personal information and medical records. These active FAP-tags generate signals and continuously emit the signals by radio frequency waves. The wave in the diagram represents the transmission of the information-carried signal from the tag antenna to the reader antenna.

When the reader is turned on, it receives all the tags' signals in its reading range through reader antennas. The received signal is converted to data stream and passed on to the middleware, as Autoliv SOS-system control unit in this project, by the reader. The information data stream from the reader to the Autoliv SOS-system control unit is shown by the arrow. Autoliv SOS-system analyzes and stores the requested information about the tagged passengers.

The specific location of the vehicle is provided by the GPS navigation system and also passed to the Autoliv SOS-system control unit. When a crash occurs, control unit automatically sends out a message to the Emergency Medical Service Center, providing the necessary information about the vehicle and its passengers, such as location, situation, the number of passengers and their likely position, etc. Given the FAP-ID number, the secured database can index the corresponding entry of the passengers. It is aimed to help the ambulances from Emergency Medical Service Centers arrive at the scene faster and better prepared for the first-aid and medical help.

Only the functionality of Passenger Identification will be focused on in this report, with a general consideration of Crash Notification functionality.

5 Implementation of Passenger Identification System

This section presents the overview of the proposed implementation of the active RFID system for passenger identification. Section 5.1 presents the C code programmed to connect and obtain information from Bluei RFID Reader to the laptop. Section 5.2 build up the passenger identification system with chosen hardware devices and describes methods used to investigate the placement of the Bluei RFID Reader inside the vehicle.

5.1 Programming for RFID Reading

The section discusses the program used to open, read and close the serial port of the laptop, which has Linux environment. Linux provides access to serial ports via device's files. Therefore to access a serial port can be implemented by a simply opening of the corresponding device file. With the help of the protocol specification of Bluei RFID reader, a C program is designed to achieve its main function as recognizing the bytes packets which obtains the tag ID and RSSI value.

Before the correct data can be received from the corresponding serial port, the serial port has to be properly configured. According to the information sheet of the Bluei RFID reader, the Bluei RFID reader provides data in the 8 bit format, no parity, 1 stop bit, at 57600 baud. (See Appendix A for the information sheet of the Bluei RFID reader.) According to the protocol specification of the Bluei RFID reader, there are totally 38 bytes in one message, with the first byte as the packet header having the decimal value "85". The second packet byte, which shows the number of bytes in data part, has a fixed value of '32'. The bytes from number 6 to number 8 are also headers with fixed decimal value as "33", "42" and "42". The first two bytes and the bytes from number 6 to 8 are used to distinguish the expected messages from others. The tag ID and the received signal strength indication (RSSI) value of the signal are the most interesting information in the message, which are contained in bytes from 22 to 25 and 28. RSSI value represents the signal strength information of the signals from the tag, which is measured by the reader.

The figure 5.1 illustrates the flowchart of the designed program (RFID_tag_read.c), with arrows meaning the next process. (The C program is shown in Appendix C.)

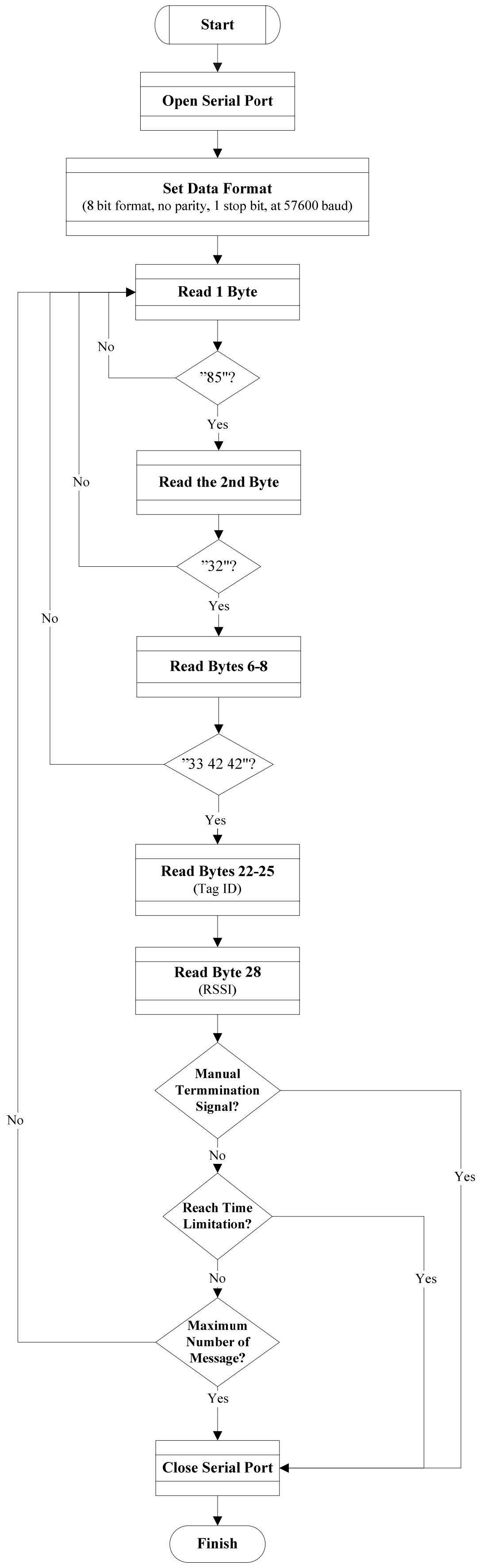


Fig.5.1 Flowchart of the C program (RFID_tag_read.c)

As can be seen from figure 5.1, after successfully open the serial port, the serial port need to be configured in the 8 bit format, no parity, 1 stop bit, at 57600 baud so that the data stream can be correctly decoded. The reading process starts from read one byte in order to find the header of the whole message packet, which will be “85” as an unsigned integer.

The program keeps reading from the serial port until the header “85” is found. When succeed, it reads the next byte and checks if it is “32”. If no, the program will restart searching for the header. When the header followed by the byte equals 32 has been read, the following next thirty-six bytes will be input. From these thirty-six bytes, the bytes from 6 to 8 are verified. If they are not the decimal value as “33”, “42” and “42”, the program goes back to searching for the header “85”.

After confirmed that it is the expected message by checking the 1^{st}, 2^{nd} and 6 to 8 bytes, the corresponding bytes of the tag ID and RSSI will be recorded for this message packet. The reading process will stop when the termination condition is satisfied. The termination condition can be manual or pre-set time limitation e.g. ten minutes, or pre-set maximum number of messages received such as 200 messages. (The detailed RFID_tag_read.c program is shown in Appendix C.) The serial port is closed after the termination of the reading process.

5.2 Wavetrend Active Tag and Bluei RFID Reader

The whole research is based on two assumptions:

- The given active tag functions properly and is compatible to the reader.
- Reader can detect the presence of tag within its reading range.

The active system for Passenger Identification consists of RFID active tag, RFID reader and laptop functioning as the Autoliv SOS-system control unit. The active tag used is Wavetrend L-TG501, as shown in figure 5.2, which is generally used for personnel tagging with estimated tag life at five years at a transmission time interval of approximately 1.5 seconds in the frequency of 868 MHz. Consequently, the tag sends out coded message 40 times per minute. Detailed specifications are shown in Appendix B.

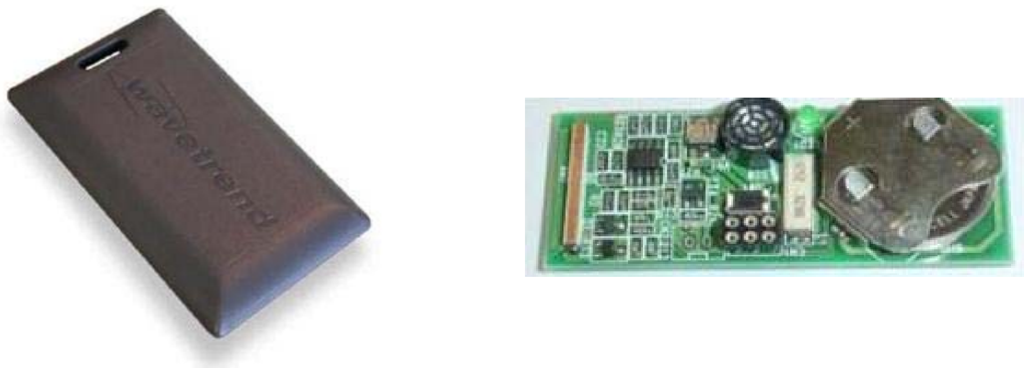


Fig. 5.2 Wavetrend L-TG501 active tag

The RFID reader used is Bluei RFID reader, shown in figure 5.3, which detects the presence of all compatible active tags within its read range and continuously streams the data over the Bluetooth link to the laptop. The Bluei RFID reader is portable at the size of $73(L)\times 42(W)\times 22(H)$ mm and has a built-in rechargeable battery and embedded antenna. The Bluetooth used in Bluei RFID reader is class 2 and have a coverage range of ten meters. More technique information is listed in Appendix A.

Fig. 5.3 Wavetrend L-TG501 active Tag and Bluei RFID Reader

A laptop is used as the middleware in this system. Therefore, the data stream will be sent by the reader via Bluetooth link to the serial port of the laptop. The serial port is controlled and monitored by a C program (RFID_tag_read.c). The program is also used to extract useful information from the data stream according to the specified protocol and stored the information for further analysis in the laptop.

The Passenger Identification system architecture is illustrated in figure 5.4. Each Wavetrend active tag stores a FAP-ID in its chip as the ID number, which is linked with the First Aid Profile of that tagged passenger. Wavetrend active FAP-tags continuously emit the signals by radio frequency waves at the frequency of 868 MHz. The dashed in the diagram shows the transmission of the information-carried signal from the Wavetrend tag antenna to the Bluei RFID reader antenna. Bluei RFID reader receives all the Wavetrend tags' signals in its reading range through its build-in reader antennas and converts them to data stream. The information data stream will be passed from the Bluei RFID reader to the laptop via Bluetooth link. The laptop, working as the Autoliv SOS-system control unit, is programmed to store and analyze the requested information about the tagged passengers.

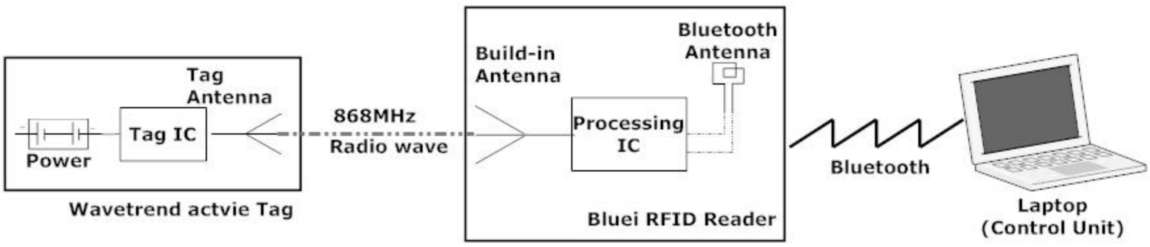


Fig 5.4 Passenger Identification System

5.3 Communication Tests

Since how the tag will be carried by the passenger is unpredictable, the placement of the reader in the vehicle for the best performance of the system has to be investigated. A number of factors can affect the distance at which a tag can be read successfully (the read range). The frequency used for identification, the antenna gain as well as the orientation and polarization of the reader antenna and the tag antenna will all have an impact on the RFID system's read range.

The frequency used in this Passenger Identification System is 868 MHz. In UHF systems, reader antennas may be either circularly polarized or linearly polarized. The performance of a tag antenna is related to the position of a reader antenna, which means the reader's antenna and the tag's antenna should have the same polarization. If the same polarization is not realized, a severe loss in signal, along with a drastic decrease in a read range, which results in unsuccessful communication with a tag, can be experienced. Therefore, it is important to evaluate the way that the tag and reader antennas are orientated.

Unfortunately, neither the specification about the antenna of the Wavetrend active tag is given, nor the detailed information about the build-in antenna of the Bluei RFID reader. Consequently, tests 1.1 to 1.3 are designed to get some knowledge about the antenna orientation of Wavetrend active tag and the Bluei RFID reader. All the tests are conducted in one garage, which is pre-tested and assumed as an ideal environment. Two important metrics for tag performance are focused on: orientation sensitivity and read range.

For a tag and reader in space, there are three angles of rotation, denoted as in figure 5.5. The rotations along x-axis, in $Y-Z$ plane is defined by the symbol α; rotations along y-axis, in $Z-X$ plane is defined by the symbol β; and the rotations along z-axis, in $X-Y$ plane is defined by the symbol θ. These three angles and three planes represent the different ways that tag and reader will be rotated.

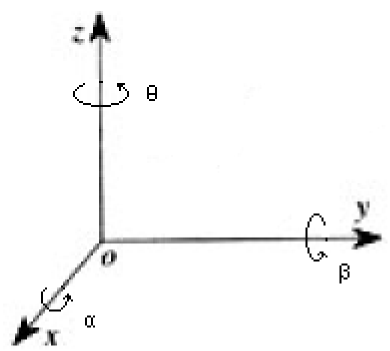


Fig. 5.5 Planes of Rotation in space for tag and reader

Test 1.1 Test of Bluei RFID reader performance

Test 1.1 is done to test the Bluei RFID reader performance by placing the Bluei RFID reader in different positions relative to the Wavetrend active tag. The aim is to test, which position of the Bluei reader is a better to receive the signal, when there are signals transmitting by the Wavetrend active tag. Test 1.1 is carried out in the way as shown in figure 5.6.

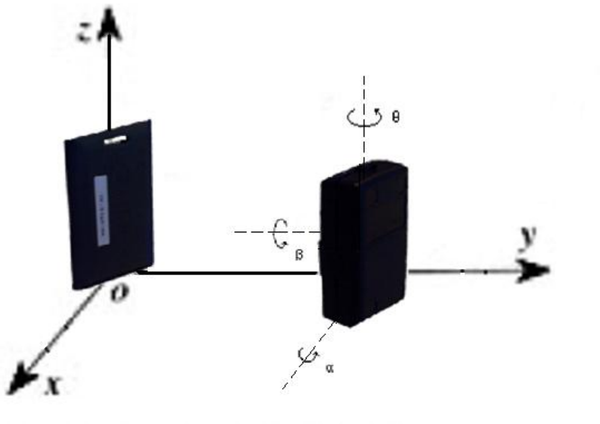
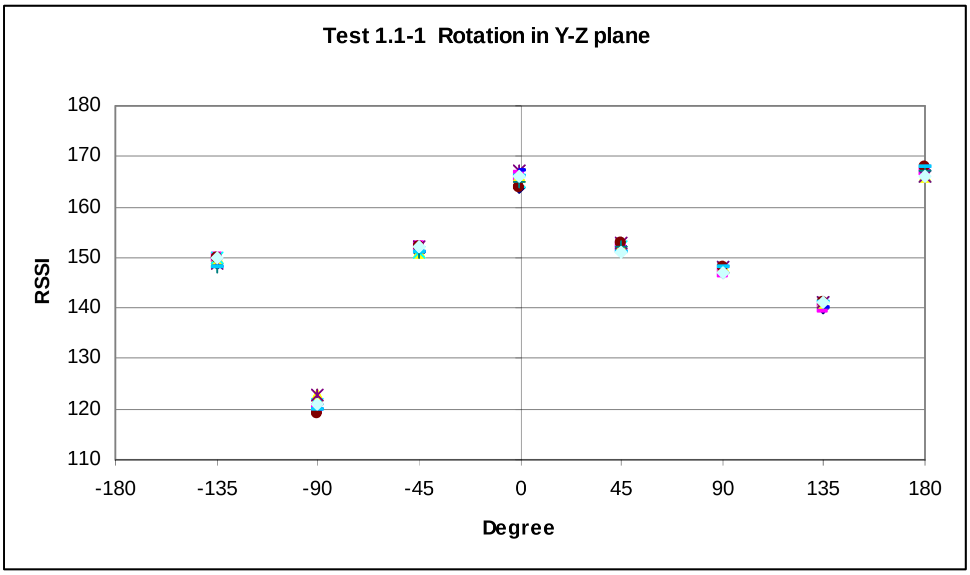
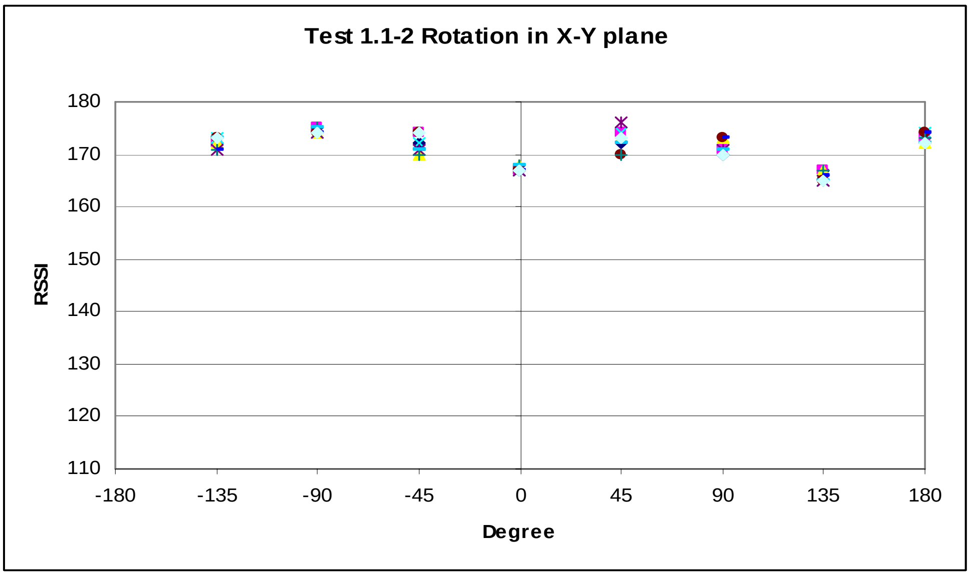


Fig. 5.6 Sketch map of Implementation of Test 1.1

Remain the Wavetrend active tag standing steadily perpendicular to the $X-Y$ plane. Place the Bluei RFID reader parallel to the tag, also perpendicular to the $X-Y$ plane, at a distance of 1 meter. Start with the Bluei RFID reader and Wavetrend active tag facing front to front and rotate the reader in three planes separately. Record the RSSI values received ten times at eight different angle values (-135°, -90°, -45°, 0°, 45°, 90°, 135°, 180°) in rotations α, β and θ (see Fig. 5.6) of the reader. Outcomes are shown in the figure 5.7.





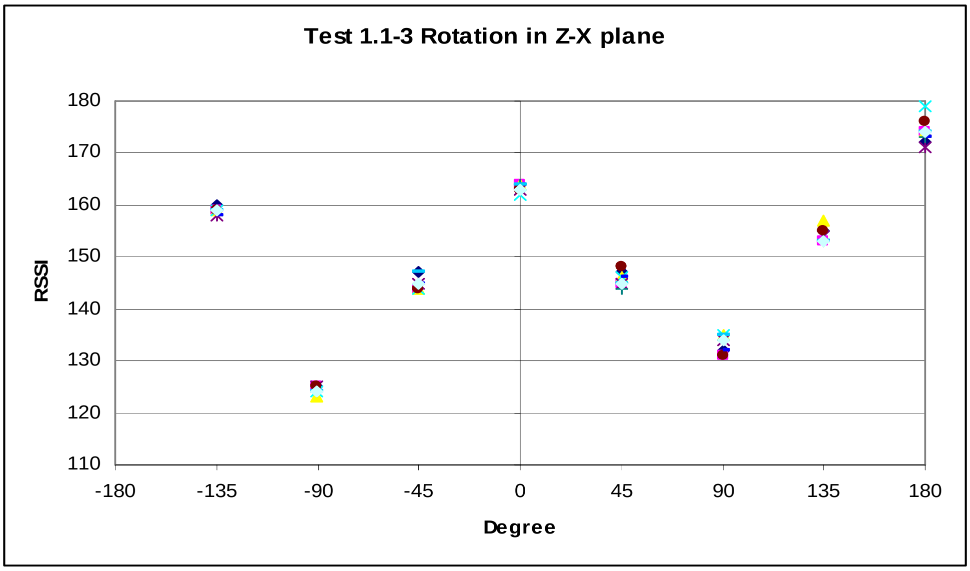


Fig. 5.7 Results of Test 1.1

It can be noticed that when the Bluei RFID reader is rotated along z -axis, in $X-Y$ plane, the RSSI values do not differ as much as in the other two rotation cases. Accordingly, the position of the Wavetrend active tag will not make much impact on the system performance when the Bluei RFID reader stands perpendicular to $X-Y$ plane.

Test 1.2 Test of tag orientation

Test1.2 is done to investigate how various orientations of the Wavetrend active tag will affect the reading performance when having the Bluei RFID reader standing perpendicular to $X-Y$ plane. Test 1.2 is accomplished by the method illustrated in figure 5.8.

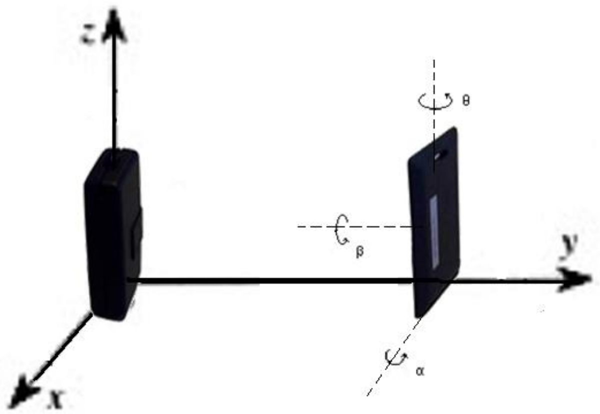


Fig. 5.8 Sketch map of Implementation of Test 1.2

In the Test 1.2, the Bluei RFID reader is remained at stationary position perpendicular to the $X-Y$ plane, with the Wavetrend active tag initiating paralleled to the reader, also at a distance of 1 meter. Rotate the active tag in three planes separately, from the original position when the tag and the reader are facing front to front. Record the RSSI values received ten times at eight different angle values (-135°, -90°, -45°, 0°, 45°, 90°, 135°, 180°) in three rotations planes (see Fig. 5.8) of the Wavetrend active tag. Test 1.2 has the results shown in the figure 5.9.

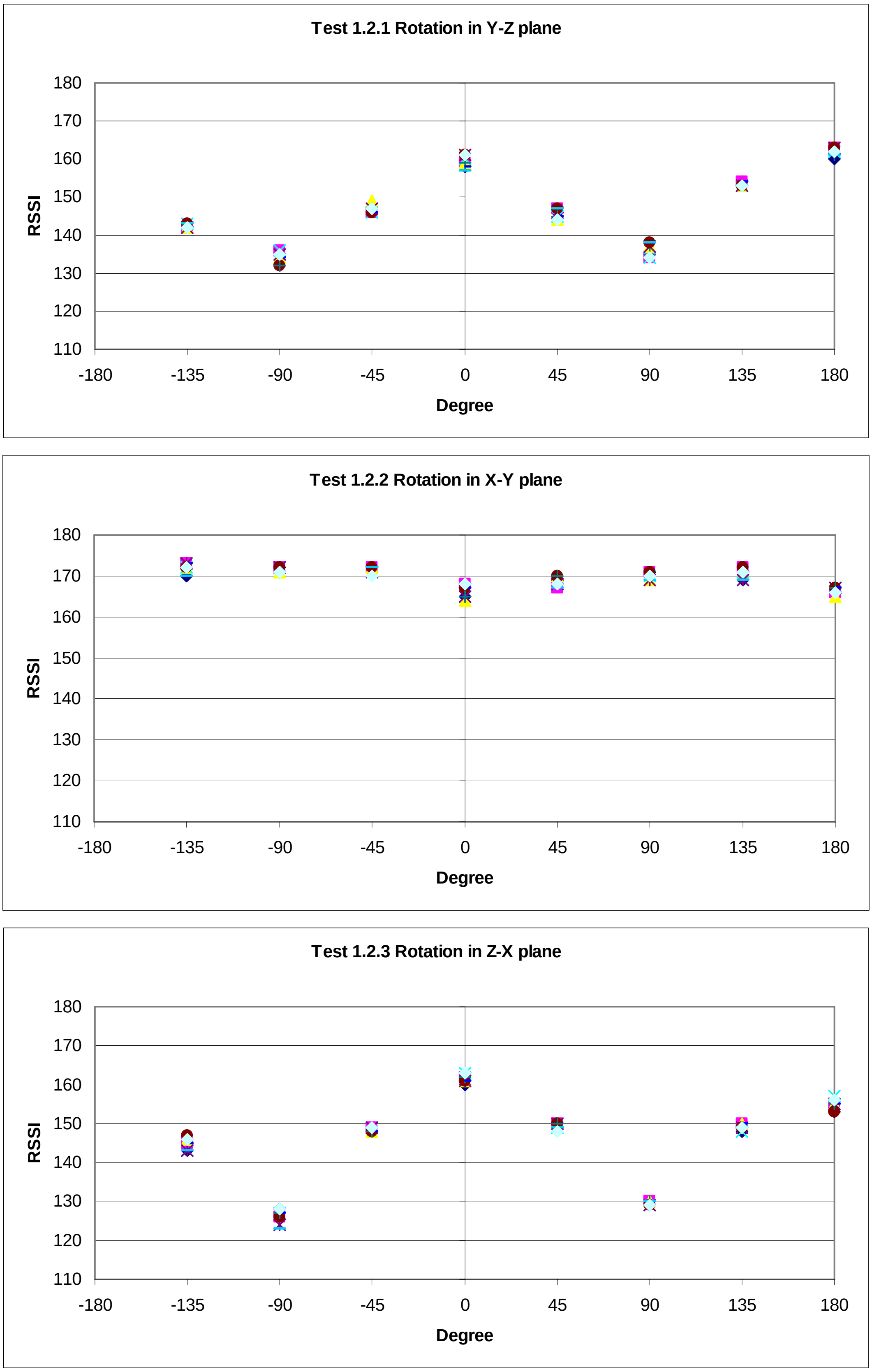


Fig. 5.9 Results of Test 1.2

When the Wavetrend active tag is rotated along z -axis, the RSSI values keep between 165 and 175. When it is rotated along x -axis, the difference between the highest and lowest RSSI is nearly 30, from 165 to 135. In the case of rotating along y -axis, the RSSI values differ even more, with the lowest about 125 and the highest 165. It can be seen that the various rotations and positions of the Wavetrend active tag affect the communication between the Bluei RFID reader and Wavetrend active tag. From the tests, we see that RSSI values various slightly when the Wavetrend active tag or Bluei RFID reader rotated along z -axis. In the cases of rotation along x -axis and along y -axis, the largest RSSI value appears in 0°and 180° and the smallest RSSI value occurs in -90°and 90°degrees. Wavetrend tag and Bluei RFID reader have dual-dipole antennas that are elliptical polarization.

Test 1.3 Test of reading range

However, there is no restriction of the way the passenger carrying his or her tag. Therefore, it is interested to test how far the Wavetrend tag active can be captured with different orientations, which will be helpful to determine the possible placement of the Bluei RFID reader inside the vehicle.

Test 1.3 is designed to investigate the reading range with various orientations of the Wavetrend active tag. Test 1.3 is implemented as fellows. Having the Bluei RFID reader stands perpendicular to $X - Y$ plane at fixed point, rotate the Wavetrend active tag along x -axis, y -axis and along z -axis. Record the read distances for eight different angle values（-135°, -90°, -45°, 0°, 45°, 90°, 135°, 180°) in three rotation planes.

Since the transmission interval of the Wavetrend active tag is 1.5 seconds, which means the signal is sent 40 times per minutes, the threshold of successful reading in Test 1.3 is chosen as over 10 times in one minute. When the Wavetrend active tag is read less than 10 times in one minute, the reading process is deemed to be failed. The testing is started with the Wavetrend active tag 4 meters from the fixed point at each orientation and the tag will be moved 0.01 meter closer to the fixed point until the reading process is considered as success. Figure 5.10 displays the testing outcome.

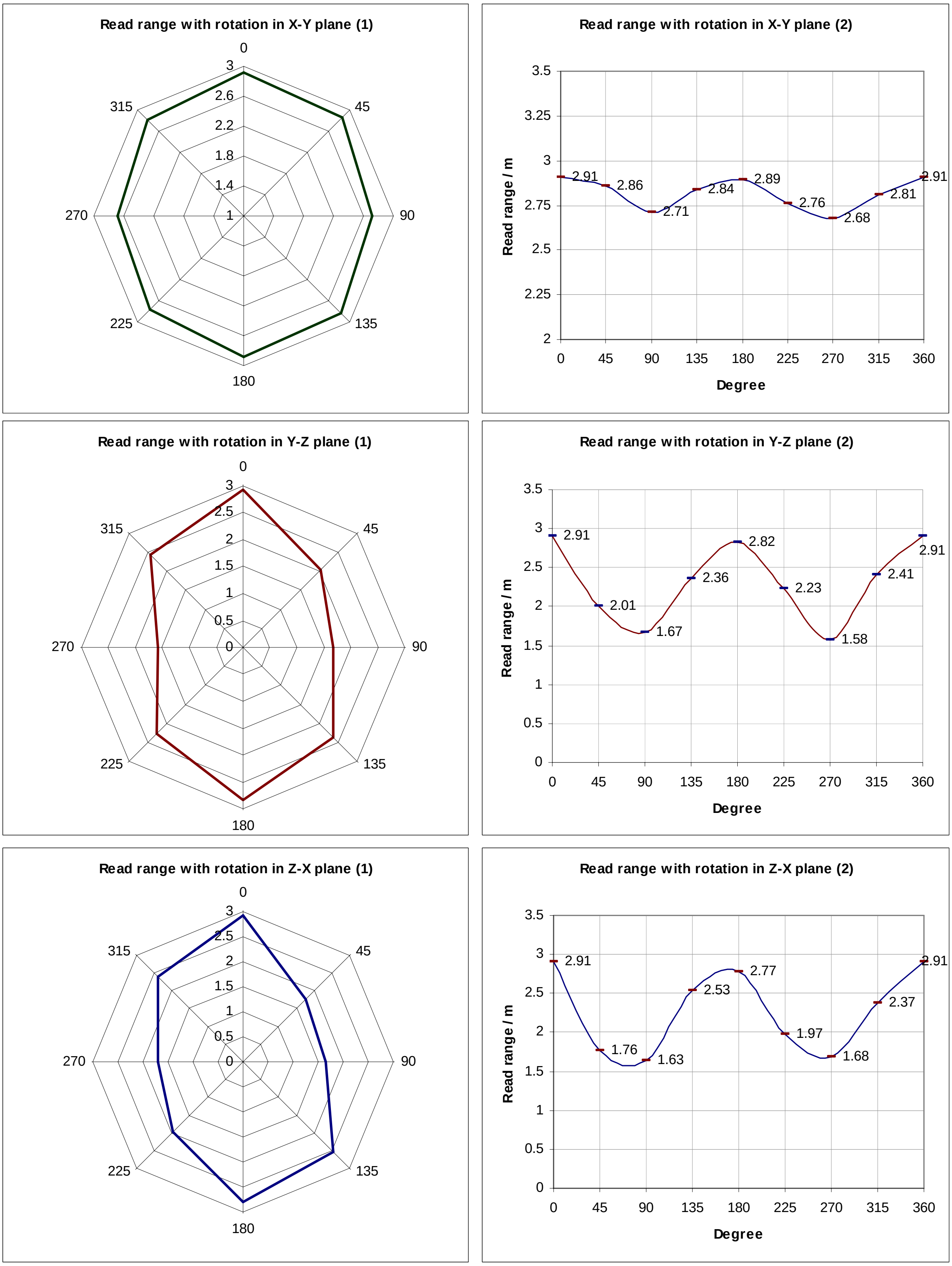


Fig. 5.10 Results of Test 1.3

We can notice that read range is sensitive to the tag orientation. In all cases, the shortest reading range occurs at the rotation of 90° and 270°. The longest reading range is approximately 3 meters when the Bluei RFID reader and the Wavetrend active tag are exactly parallel to each other, where the reader and the tag has the largest overlap area. Results of the tests are summarized in Table IV.

TABLE IV
SUMMARY OF TEST 1.2, 1.3

Tag Rotation	Span of RSSI	Shortest Read Range	Longest Read Range
along z -axis	165-175	2.71 m at 90°	2.91 m at 0°
		2.68 m at 270°	2.89 m at 180°
along x -axis	135-165	1.67 m at 90°	2.91 m at 0°
		1.58 m at 270°	2.82 m at 180°
along y -axis	125-165	1.63 m at 90°	2.91 m at 0°
		1.68 m at 270°	2.77 m at 180°

From test 1.1, it can be concluded that the best placement of the Bluei RFID reader is having it perpendicular to $X-Y$ plane, because this is the case when the position of Wavetrend active tag to the reader affects the communication the least. As can be seen from the Table IV, when rotating tag along z -axis, the RSSI value varies much less than the other two cases, the longest read range is about 3 meters. The smaller overlap area that reader and tag have, the worse communication between them, for example rotates tag at 270° along x -axis or 90° along y -axis. The shortest read range is approximately 1.6 meters.

5.4 Reader Placement Investigation

Stated in section 4.1, the functionality requirement of the identification system is that the signals received from the tags inside the vehicle are remarkably stronger than the signals from the tags outside. Further more, the RSSI value of the signal received from the tag can be used for analyzing the possible seats that the passenger has taken.

Based on the presented studies, three possible placements, A, B and C, of the Bluei RFID reader inside the vehicle are proposed, illustrated in figure 5.11. Green circles represent the outside areas of the vehicle and the five pink areas represent the location of five seat-areas inside. Dashed lines show the doors of the car and the half-circle is the position of the wheel, which is close to the driver seat.

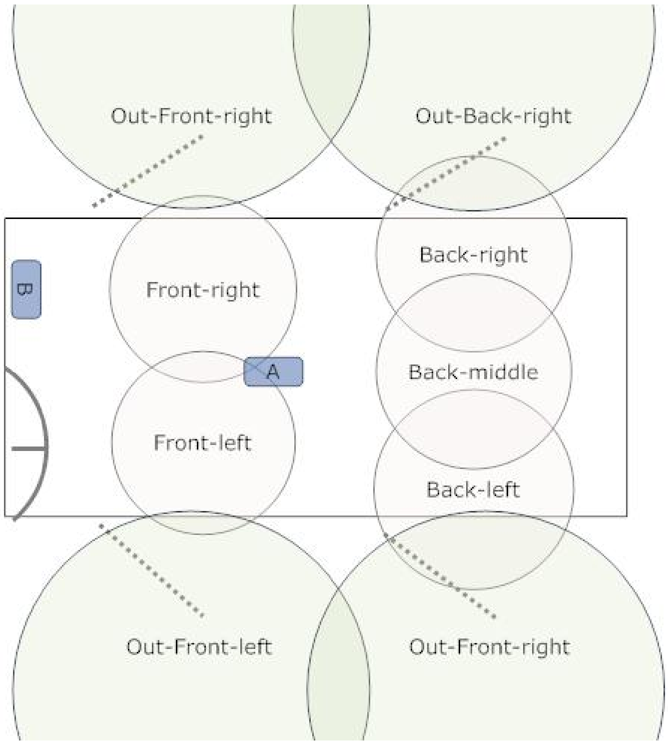


Fig. 5.11 Illustration of vehicle areas and proposed Bluei RFID reader placement

The fist location is Bluei RFID reader standing in the centre of the vehicle, noted as A. Sizes of several different common cars is summarized in Table V. The advantage of reader location A is that the farthest distance from the central point to any other corner inside the vehicle will be around 1.7 meters; while the disadvantage is that because the distances from the centre to the different seats are almost identical, it may be difficult to estimate the position of the passenger on base of the RSSI value received from the tag attached.

TABLE V
COMMON CAR SIZE

Car	Volvo S80	SAAB 9-3	Audi A4	Benz C200	Lexus GS450H
Picture					
Long (inside)	2835 mm	2675 mm	2751 mm	2760 mm	2850 mm
Wide (inside)	1540 mm	1510 mm	1470 mm	1460 mm	1500 mm
High (inside)	1334 mm	1367 mm	1372 mm	1348 mm	1420 mm

The second proposal is that placing the Bluei RFID reader in the glove box of the vehicle, in the left-front part. The pro of having the reader at this corner is that the likely position of the tag detected may be easily recognized from the RSSI value received. Nevertheless, the longest distance from the glove box to the left-back corner may exceed 3 meters, seen from Table V, which can results in the failure of identification process.

The third place C is that Bluei RFID reader is placed in the centre of the vehicle but lying down. According to the Test 1.1 in section 5.3, this position of the reader reduces the sensitivity of identification process.

How does the Passenger Identification System perform in these two cases is investigated and presented in section 6.

6 System Performance Tests

Two Bluei RFID reader placements are suggested after investigation in section 5.3. In this section, some system performance experiments are excogitated to scrutinize if the passenger identification system functions as demanded.

6.1 Test Description

Before initiating the tests, some definitions have to be put forward. The vehicle is divided into five areas during the system performance tests: front-left, front-right, back-left, back-middle and back-right. The area out of the vehicle is also divided into four areas: out-front-left, out-front-right, out-back-left and out-back-right as illustrated in figure 5.11.

Moreover, the passengers are supposed to take the active tag everyday with them, which means that holding the tag in their hands will seldom happen in real life, but keep it in the bag or pocket. Therefore, the system performance tests also involve investigating the impacts of the bag or pocket to the identification process.

The system performance tests for the two proposed locations of the Bluei RFID reader are accomplished as follows:

- Step 1: Placing the Bluei RFID reader in the fixed position and switch it on.
- Step 2: Locating the Wavetrend active tag in front-left area inside vehicle as defined above.
- Step 3: Randomly varying the orientation and location of tag in the area.
- Step 4: Logging the successful reading times and their RSSI values for five minutes. Since the tag transmission interval is 1.5 seconds. The total attempts to detect the Wavetrend active tag are 200 times within five minutes.
- Step 5: Analyzing the successful read rate and distribution of the RSSI values.

The same steps from 1 to 5 are repeated three times with the tag kept:

- in hand (uncover)
- in bag
- in pocket

6.2 Tests of System Performance with Reader Location A

Test A.1 The reader in position A and uncovered tag moving within inside areas

Having the Bluei RFID reader located in position A and turned on, Test A.1 is done with tag in the five different inside areas and uncover. The result of the Test A.1 is shown in Table VI.

TABLE VI
RESULTS OF TEST A.1

Tag Position	Successful Read Rate (read times/200)	Mean RSSI Value	Standard Deviation
Front-Left	89%	156.7	5.6
Front-Right	93%	156.6	4.9
Back-Left	79%	146.3	8.3
Back-Middle	87.5%	154.7	5.7
Back-Right	83%	148.4	7.6

In front-left and front-right areas, mean RSSI values are above 150. Front-right area has the highest successful read rate as 93% with the lowest standard deviation of RSSI value. When tag is randomly moved in back areas separately, the mean RSSI values are lower than the front areas. The lowest successful rate occurs when tag is in back-left area, with a highest standard deviation.

Test A.2 The reader in position A and tag moving within out-front-left area, uncovered tag

Test A.2 is done with the uncovered Wavetrend active tag located in out-front-left area. Changing the position and orientation of the tag and logging the identification result for five minutes. Result of Test A.2 is plot in figure 6.1.

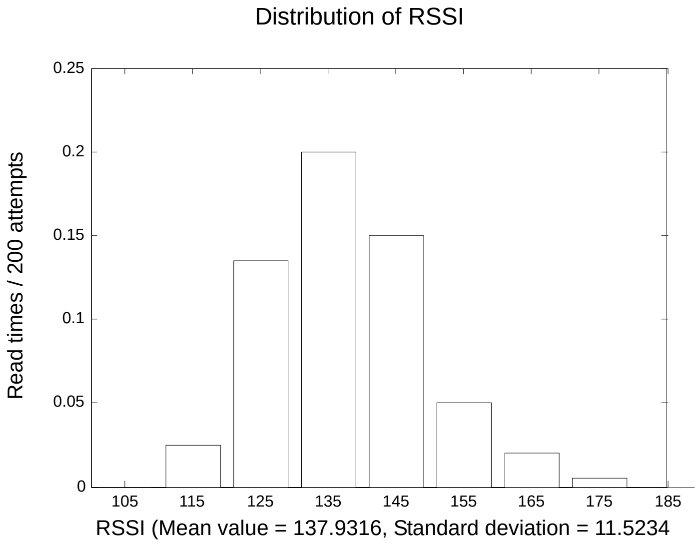


Fig. 6.1 Result of Test A.2 with Wavetrend active tag in out-front-left area

Successful read rate is 58.5%. Mean RSSI value is 137.9 with standard deviation as 11.5. Compared with the results when tag is inside the vehicle, the Mean RSSI value is ratherish smaller. Successful read rate is appreciably lower, together with a higher standard deviation.

Test A.3 The reader in position A and uncovered tag 1.7 meters away from the vehicle

An extra test A.3 is done to checkout how far can the Wavetrend active tag be considered as not recognizable. Hold the Wavetrend active tag in hand and keep the Bluei RFID reader continue indentifying the Wavetrend active tag. Start with the active tag placed 0.5 meter away from the window out of front-left area, lentamente move the active tag away from the vehicle until the RSSI value appear more in the value range from 120 to 130, which is about 1.7 meters away. Repeat the testing process as the tests above with the Wavetrend active tag in out-front-left area, 1.7 meters away from the vehicle. Results are shown in figure 6.2.

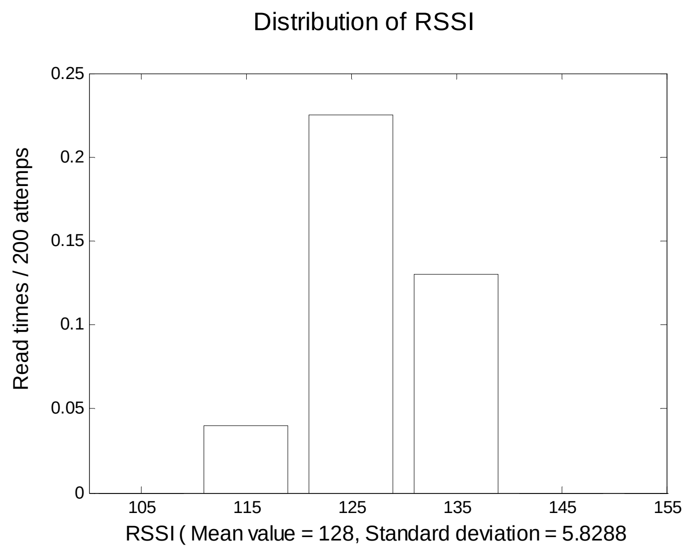


Fig. 6.2 Result of Test A.3

In this circumstance, successful read rate is lower than 40%, which means that the tag that is 1.7 meters away from the car can be considered as unrecognizable.

If implementing the Passenger Identification System with the Bluei RFID reader set in the centre, the Bluei RFID reader probably will take the active tag carried by people outside into account, such as pedestrian passing by, and report it to the control unit, this placement of the Bluei RFID reader can not be considered as proper or practical.

6.3 Tests of System Performance with Reader Location B

Test B.1 Wavetrend active tag inside vehicle

Having the Bluei RFID reader located in position B and switched on, Test B.1 is accomplished following testing steps, with the tag uncover, in bag and in pocket. The results are shown in Table VII.

TABLE VII
RESULTS OF TEST B.1

Tag Position (Uncover)	Successful Read Rate (read times/200)	Mean RSSI Value	Standard Deviation
Front-Left	96.5%	177.2	1.6
Front-Right	96.5%	162.2	2.5
Back-Left	81%	141.4	11.0
Back-Middle	90%	148.1	6.0
Back-Right	88.5%	141.7	9.8
Tag Position (in bag)	**Successful Read Rate (read times/200)**	**Mean RSSI Value**	**Standard Deviation**
Front-Left	92.5%	159.6	6.3
Front-Right	92.5%	170.1892	6.3
Back-Left	29%	129.8	15.8
Back-Middle	65%	135.2	8.7
Back-Right	48%	130.9	9.6
Tag Position (in pocket)	**Successful Read Rate (read times/200)**	**Mean RSSI Value**	**Standard Deviation**
Front-Left	82.5%	141.6	3.1
Front-Right	86.5%	155.0	2.0
Back-Left	24%	113.3	9.0
Back-Middle	57.5%	124.9	5.7
Back-Right	45%	119.8	6.5

Location B is proposed as the Bluei RFID reader standing in the glove box of the front right corner inside the vehicle. As conjectured, due to the fact that the distances from the glove box and the different seats are remarkably various, the RSSI values of the signals received from the Wavetrend active tags at different seats differ significantly. The front-right area is closest to where the reader is located, thus when tag is kept in that area, we obtain the most successful reading times. Generally, the longer distance away from the reader, the worst the recognitions are accomplished. However, compare to back-right and back-left areas, the system performs better when the tagged person moving in the back-middle area, with more read times and higher Mean RSSI values.

Moreover, from Test B.1, the same phenomenon can be noticed that remaining the Wavetrend active tag in pocket will affect the performance of the identification system much more than in bag or uncovered.

Test B.2 Wavetrend active tag in outside areas

Test B.2 is done to examine the possibilities of recognition of the passenger outside when Bluei RFID reader is placed in location B. Reading processes are recorded and analyzed with the results shown in Table VIII.

TABLE VIII
RESULTS OF TEST B.2

Tag Position (Uncover)	Successful Read Rate (read times/200)	Mean RSSI Value	Standard Deviation
Out-Front-Left	11.5%	130.1	6.9
Out-Front-Right	65%	136.9	5.3
Out-Back-Left	4%	129.2	3.8
Out-Back-Right	45%	132.2	9.2
Tag Position (in bag)	**Successful Read Rate (read times/200)**	**Mean RSSI Value**	**Standard Deviation**
Out-Front-Left	5%	117.3	4.1
Out-Front-Right	39%	124.8	2.2
Out-Back-Left	-	-	-
Out-Back-Right	-	-	-

Tag Position (in pocket)	Successful Read Rate (read times/200)	Mean RSSI Value	Standard Deviation
Out-Front-Left	-	-	-
Out-Front-Right	31%	119.5	4.3
Out-Back-Left	-	-	-
Out-Back-Right	-	-	-

From the Test B.1's result, when the Wavetrend active tag is tested in the back-left area, it can be detected no more than 30% when the tag is kept in pocket and average RSSI as 113. Compared Test B.1 with B.2, Wavetrend active tags can be identified likely the same or even more times in the out-front-right area than in the back-left area inside the vehicle. Consequently these two situations will be considered the same for the identification system, which is absolutely unwanted.

Due to the reason that the control unit can hardly distinguish these two different situation, they will be treated the equally, which means that either the passengers outside the car are recognized, or the passengers in have high possibility to be excluded during the identification process.

6.4 Tests of System Performance with Reader Location C

To check if it would be a better placement than location B, Location C is proposed as the Bluei RFID reader being rotated 90° as lying down in the center of the vehicle. System performance tests are repeated with this location C.

Test C.1 Reader in position B and Wavetrend active tag in hand (Uncover)

Holding the Wavetrend active tag in hand and following the testing steps from 1 to 5, described in chapter 6.1, we have the result of Test C.1, which is tabled in Table IX.

TABLE IX
RESULTS OF TEST C.1

Tag Position (Uncover)	Successful Read Rate (read times/200)	Mean RSSI Value	Standard Deviation
Front-Left	83.5%	169.1	9.5
Front-Right	87.5%	165.5	7.4
Back-Left	89.5%	153.8	5.4

Tag Position (Uncover)	Successful Read Rate (read times/200)	Mean RSSI Value	Standard Deviation
Back-Middle	93%	154.2	4.2
Back-Right	83%	151.3	9.9

Tag is moving and rotating randomly in different areas. In all areas, there are more than 83% successful readings. In front areas, mean RSSI values are above 165 which are larger compared to back areas. The higher successful read rates, the smaller standard deviation RSSI values have, which indicates that RSSI values are more centralized. In back-middle area, successful read rate is the highest with the lowest standard deviation.

Test C.2 Wavetrend active tag in bag

Test C.2 is done with the situation when Wavetrend active tag is buried in bag. Identification results are listed in Table X.

TABLE X
RESULTS OF TEST C.2

Tag Position (in bag)	Successful Read Rate (read times/200)	Mean RSSI Value	Standard Deviation
Front-Left	83.5%	164.3	12.2
Front-Right	84.5%	163.4	11.2
Back-Left	86%	153.5	7.6
Back-Middle	86%	156.4	6.7
Back-Right	92%	152.6	3.8

In the case the Wavetrend active tag is put in bag, the success reading rate in all five areas are over 83.5%. Back-right area got the highest successful read rate and the smallest standard deviation. In the front two areas, mean RSSI values distributed above 163, but successful read rates are lower than the back areas, and standard deviation are higher. In the back areas, the mean RSSI values are below 160 but read rates are higher along with smaller standard deviation.

Test C.3 Wavetrend active tag in pocket

During the Test C.3, the Wavetrend active tag is kept in passenger's pocket. The Successful read rate, mean RSSI value and standard deviation are computed and summarized in Table XI.

TABLE XI
RESULTS OF TEST C.3

Tag Position (in pocket)	Successful Read Rate (read times/200)	Mean RSSI Value	Standard Deviation
Front-Left	74%	151.1	15.6
Front-Right	78%	153.2	13.5
Back-Left	82%	140.3	6.1
Back-Middle	82.5%	145.4	5.8
Back-Right	81.5%	138.1	6.8

It is noticed that the systems functioning is worse when preserving the Wavetrend active tag in pocket than the other two cases, with lower successful read rates and lower mean RSSI values compared with the other two cases when the Wavetrend active tag is kept in hand or bag. However, it is still possible to distinguish whether the tag is in back areas or front by the differences of mean RSSI values. It is also noticed that in front areas mean RSSI values are higher but with lower successful read rate together with higher standard deviation.

Conclusion from Tests C1 – C3

It can be concluded from Tests C.1 to C.3 that maintaining the Wavetrend active tag in pocket has more effect on the system performance than it in hand or bag, since the RSSI values are highly distributed in the range from 135 to 155 rather than 150 to 160 of other two cases. Therefore, if the passengers carry the Wavetrend active tags in their pockets, the identification system implemented with the Bluei RFID reader lying in the centre of the vehicle will be less sensitive to the active tag.

Test C.4 Wavetrend active tag in out areas

Test C.4 is carried out to check if the system recognizes the tagged passenger outside the car. Identification results are logged in Table XII.

TABLE XII
RESULTS OF TEST C.4

Tag Position (Uncover)	Successful Read Rate (read times/200)	Mean RSSI Value	Standard Deviation
Out-Front-Left	42%	136.2	9.5
Out-Front-Right	32.5%	130.8	11.1
Out-Back-Left	30.5%	127.5	11.8
Out-Back-Right	45%	137.7	7.7
Tag Position (in bag)	Successful read times	Mean RSSI value	Standard deviation
Out-Front-Left	5%	126.9	6.5
Out-Front-Right	11.5%	126.8	3.3
Out-Back-Left	3.5%	118.9	8.1
Out-Back-Right	6%	125.5	6.1
Tag Position (in pocket)	Successful read times	Mean RSSI value	Standard deviation
Out-Front-Left	2%	117.3	2.4
Out-Front-Right	2%	118.5	3.8
Out-Back-Left	3.5%	124.4	2.7
Out-Back-Right	1.5%	124.7	2.6

Conclusion from Tests C4

When the person is out of the car, the requirement of the passenger identification system is that the carried tag will not be detected or easily recognized as outsider. From the tests, we can see that uncovered tag has more possibilities of being identified compared with its being buried in bag or pocket. The successful reading rates when the tag is uncovered in out areas are below 45%, with the mean RSSI value far below the cases when the tag is inside.

As cited in the beginning of this section, in real life, it is more common that people put the active RFID tag in their bag or pocket rather than holding the tag in their hands all the time.

Therefore, it can be considered that with the Bluei RFID lying in the location one, the system will exclude all the Wavetrend active tag outside during the identification process.

For all the passengers inside, the worst situation for them being recognized by the system is their having the Wavetrend active tags in pockets. Even in this worst circumstance, the passenger can be identified within 2 seconds.

6.5 Analysis of All Test Results

Three placements of the Bluei RFID reader for the passenger identification system are tested in this chapter:

- standing in the centre, location A;
- standing in the glove box, which is the front right corner of the vehicle, location B;
- lying down in the centre, location C.

For location A, the Bluei RFID reader successfully detects the Wavetrend tag when the tag is moved in different areas inside the vehicle. According to the logged mean RSSI value and standard deviation, it can be told whether the tag is in front areas or back. However, the Wavetrend active tag outside can be identified only until 1.7 meters away from the car. This passenger identification system results in more than actual numbers of passengers being reported to the Emergency Medical Service Center.

After the location B is tested, it can be concluded that this placement where the Bluei RFID reader stands in the glove box is neither a suitable nor practical solution of the Passenger Identification System. The Bluei RFID reader can not discriminate signals transferred by Wavetrend active tag in the back-left seat from the signals sent by the Wavetrend active tag outside the front right area. Accordingly, this identification system will either detect more people as the passengers in the vehicle or ignore the actual passenger as the passerby. None of these two situations satisfies the fundamental demands of the Passenger Identification System.

In the third case when the Bluei RFID reader is implemented as lying in the centre of the vehicle, location C, and the systems performs fulfilled the primary requisite. Notwithstanding there is a few times that the Wavetrend active tag outside is picked up by the Bluei RFID reader during the five minutes testing time, the frequency is much lower than the Wavetrend active tag inside.

Obviously, the average RSSI value of the recorded successful identifications is significantly larger in the case of active tag inside the car than it is outside. Thus, it can be determined that the identification system will exclude all the Wavetrend active tag outside during the recognition process. For all the tags inside, the worst situation is that passengers burry the Wavetrend active tags in pockets. However, even in this worst circumstance, the passenger can be identified within 2 seconds.

7 Conclusion

In the project, RF technique is studied and implemented in Passenger Identification System as part of Autoliv Crash Notification System in vehicle. The functionality Passenger Identification System is accomplished by an active RFID system.

As discussed in section 4.1, the basic functionality requirement of the Passenger Identification System using the RFID technology is that the signals sent from all the active tags inside the vehicle can be distinguished distinctly from the signals coming from the outside. Furthermore, it is preferable that the likely position of the tagged passenger can be derived based on the RSSI value of the signal transmitted from the unique active tag.

After the experiments investigating how various orientations of the Wavetrend active tag impact on the read range of the Bluei RFID reader, three different placements of the Bluei RFID reader are proposed. According to the experiment results presented in section 6.5, location C as the reader lying in the centre of the vehicle is the most suitable solution for this project. The passenger identification system, with reader location C, can detect all the passengers inside the vehicle and ignore the tagged persons situated outside, by measure mean RSSI value and successful read rate.

In reality, the tag is carried by passengers at will. Three circumstances are supposed and tested during the project: tag carried in hand, buried in bag and kept in passenger’s pocket. It is seen from the performance tests results that when the tag is carried in hand the Passenger Identification System achieves the highest successful read rate. In the case that RF signals from the tag have to penetrate through bag, identification process is affected which brings the increasing of failure read rate. The tag being buried in pocket results in a worst system performance. The results suggest that materials around the tag will influence on system performance and human body is a major factor that affects the identification process.

Moreover, the functioning of the RFID system is also influenced by surroundings, especially large obstacles such as car seats etc. In other words, the less blocks in the line-of-sight between the reader and the tag the better the identification system performs. Therefore, optimal position of the reader is the location that is more open, which means more directly path to the tags.

In our case, the radio waves emitted from the tag take different paths to reach the reader, which results in the varying RSSI value as can be seen from the span of standard deviation of RSSI. The RSSI value is a measure how strong the received signals from the tag are. Due to multipath interference, it is uneasy to find a theoretical model that links the RSSI value with the distance from the tag to the reader. Therefore, with a single time of identification it is possible but arduously for the Passenger Identification System to calculate the exactly distance between the tag and reader and then define which seat the tagged passenger is taken from the RSSI values of the signals from the tag.

However, likely position of the passenger can be proposed by analyzing the statistical data of a serial of readings, as shown in the project. Three parameters are utilized for the analysis, which are successful read rates, mean RSSI values and standard deviation. As seen from the outcomes of Tests C.1-C.3, tag in the back areas results in smaller mean RSSI values, lower successful read rates with larger standard deviation of RSSI values. Moreover, the highest successful read rate with smallest standard deviation of RSSI values comes from the case that the tagged person sitting in the back-middle seat, which has the least blocks between the reader and the tag.

In general, higher successful read rates together with the smaller standard deviation of RSSI values indicates that RSSI values are more centralized, means there are less obstacles in the line-of-sight between the tag and the reader. In addition, higher mean RSSI values suggest the closer distance from the reader to the tag. Thus, by analyze the statistical data about reading results over certain minutes can the control unit derive the likely position of the identified tag.

8 Future Work

Even though a reliable solution is found in this project, there are some questions to be discussed and a few improvements are required. Since in this project, only one Wavetrend active tag is provided, no studies has been done to investigate the interferences between two or more active tags. To make it possible air interface protocol has to be modified in to overcome the problem of collision between different tags.

Moreover, a failure of the system caused by powerless of the active tag has to be investigated. In the information sheet of the Bluei RFID reader, bytes 15 to 18 are used as Life Cycle Counts of the tag, which indicates the battery level of the Wavetrend active tag. The influence of the battery level on the transmitted signal needs to be proved. Furthermore the Passenger Identification System can be improved by using this parameter to warning the passenger about a need to change the battery. Otherwise, it is difficult for the owner to notice when the Wavetrend active tag runs out of power.

Additionally, Bluetooth technology can be used as an assist the Passenger Identification System. Nowadays it becomes more common for the mobile phone to have Bluetooth applications. Since each Bluetooth mobile has its own MAC address, appearance of that MAC address suggests the owner sitting in the car. The MAC addresses detected can be included in the message that sent by the Passenger Identification System to the Emergency Medical Service Center. With both FAP-ID and MAC address information, the system can provide a more accuracy identification of the passenger inside the vehicle.

I. Appendix A—Bluei RFID Integration Guide

Bluei Spec.

Antenna Type:	Embeded Antenna
Acquisition Time:	Open Sky, Stationary
Reacquisition	2 sec., average
Cold start	< 90 sec., average
Warm start	< 38 sec., average
Hot start	< 14 sec., average
Dynamic Conditions:	
Altitude:	< 18,000 meters
Velocity	< 515 meters / second
Acceleration:	< 4g (39.2 meters / sec2)
Motional Jerk:	< 20 meters / sec3
Interface:	
Connection:	Bluetooth (class2) Serial Port Profile
Protocol:	NMEA 0183 v3.0
Power:	Built-in rechargeable battery
Operation time:	Default: 12 hours after fully charged, in continuous operation mode
Device Size:	73(L) x 42(W) x 22(H) mm
Weight:	65 grams
Environmental:	
Operating Temperature:	-20 C to +60 C
Charging Temperature:	0 C to +45 C
Relative Humidity:	5% to 90%, non-condensing

INTRODUCTION

The Bluei RFID Reader detects the presence of all compatible Active Tags within its read range and continuously streams the data over the Bluetooth link to the virtual serial port emulated in the host device (Phone, PDA, Laptop).

BLUETOOTH

The Bluetooth in Bluei RFID is class 2 and will have a coverage range of 10 meters. It is named Bluei and has the PIN code '0000'.

Bluei RFID will provide data on the format 8 bit, no parity 1 stop bit at 57 600 baud.

PROTOCOL SPECIFICATION

Protocol Type C:

Byte	Name	Data	Example	Description
1.	Header	0x55	85	Header of 485 Packet
2.	No. Data Bytes	0x20	32	Number of bytes in Data part(Byte 6 to 37). Fixed value of 32 bytes.
3.	Reader Id	0x50	80	Number of current Reader. Fixed value.
4.	Reserved	0x01	1	Reserved Byte for other protocol structures
5.	Reserved	0x02	2	Reserved Byte for other protocol structures
6.	Header	'!'	33	Header. Fixed value
7.	Header	'*'	42	Header. Fixed value
8.	Header	'*'	42	Header. Fixed value
9.	Interval	48 0x30 49 0x31 50 0x32 51 0x33 32 0x20	49	Time Interval between transmissions 1 Transmission every 30 seconds 1 Transmission every 1.5 seconds 1 Transmission every 0.8 seconds 1 Transmission every 0.4 seconds 1 Transmission every 15 seconds
10.	Counter	0 → 127	129	2nd Counter (7 Bit Counter with bit (Bits 0 → 6)) Bit 7 → Reed Open/Close
11.	FW Version	0x28	40	Firmware Version Number (40/ 10) = v4.0
12.	Reserved	'B'	66	Reserved
13.	Reserved	'C'	67	Reserved
14.	Alarm Counter	0 → 255	0	Movement Counter
15.	Age	0 → 255	0	Life Cycle Counter Byte of Tag (MSB)
16.	Age	0 → 255	152	Life Cycle Counter Byte of Tag
17.	Age	0 → 255	136	Life Cycle Counter Byte of Tag
18.	Age	0 → 255	60	Life Cycle Counter Byte of Tag (LSB)
19.	Site Code	0 → 255	0	Vendor Code (MSB)
20.	Site Code	0 → 255	0	Vendor Code
21.	Site Code	0 → 255	4	Vendor Code (LSB)
22.	Tag ID	0 → 255	0	Tag ID (MSB)

23.	Tag ID	0 → 255	0	Tag ID
24.	Tag ID	0 → 255	0	Tag ID
25.	Tag ID	0 → 255	108	Tag ID (LSB)
26.	Type of Tag	0 → 255 48 0x30 50 0x33	51	Wavetrend type of Tag (consult tag user manual for more info) NB : 51 → L-TG501 Tag is Fused. Cannot be re-programmed Tag is not Fused. Can be re-programmed.
27.	Reader Address	0 → 255	80	Address of the Multifunction Reader
28.	RSSI Value	0 → 255	127	RSSI Value (Signal Strength)
29.	Checksum	0 → 255	177	Error Check (see below on how to calculate)
30.	Reserved	0x20	32	Reserved
31.	Alarm Byte	0 → 255	80	Alarm Byte
32.	Reserved	Reserved	80	Reserved Byte for other protocol structures
33.	Reserved	Reserved	0	Reserved Byte for other protocol structures
34.	Reserved	Reserved	0	Reserved Byte for other protocol structures
35.	Reserved	Reserved	40	Reserved Byte for other protocol structures
36.	LF	0 → 255	10	Post-amble
37.	CR	0 → 255	13	Post-amble
38.	Checksum 2	0 → 255	45	Checksum for total packet (see below on how to calculate)

NB : To calculate the checksums referenced at **[Byte 29]** and **[Byte 38]** of the data packet you need to evaluate the following calculations. Please note that all example values from the table above is represented in byte format and not in hexadecimal.

II. Appendix B—Wavetrend Active Tag

wavetrend
innovating wireless identification

L-Series
Product Information Sheet

Tag

Product Code: L-TG501 / L-TG501 MS

Description: Secure Card

An internal battery powers The Link-it™ series of Active Tags. The Tag will, for the duration of its life, transmit a Radio Frequency (RF) signal at a pre-set time-interval. The Tag life is estimated at 5 years at a transmission time interval of approximately 1.5 seconds. The lifespan of the Tag ends when the battery life is exhausted. Battery status can be inferred by interrogating the internal Tag Age Counter Value.

The transmitted Tag data includes Customer Site Code (CSC), Tag ID, Tag Age Counter Value, Movement Alarm and Tamper Alarm status.

For protection against adverse environmental conditions, Link-it™ Tags are encapsulated in a moulded plastic case, which is ultrasonically sealed during the manufacturing process.

The Slimline Tag is generally used for personnel tagging, although it may be used in other applications such as asset monitoring. The mounting and affixing of a Tag depends on the type of application. The standard method is by VHB type double-sided adhesive tape.

The Tag can be configured to accommodate Wiegand interfacing.

Link-it™ Tags can be mounted on a variety of items. Where permanent fixing is required VHB double-sided tape is used, otherwise, the tags may be worn on a necklace or clipped to clothing.

Features

- Configurable settings, including Site / Vendor ID, Tag ID, Transmission Repetition Interval and Alarm functions (these are programmed at order placement stage).
- Low power consumption. Tag life is estimated at 5 years when transmitting at a 1.5-second interval.
- Housing incorporates a clip-slot for convenient wearing.
- Sealed to IP65 standards.
- A Collision avoidance algorithm is used to disperse the transmissions around the mean repetition interval.

Specification

Environmental

Operational temperature	-10º C to +60º C
Storage temperature	-20º C to +70º C
Humidity	5% to 90% (non condensing)

Physical

Size	86mm x 54mm x 5mm (Slimline Enclosure)
Weight	15 grams
Colour	Grey (Clariant 04 -600 2%)
Type of material	PVC (ultrasonically sealed) IP 65

Certification

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

1. This device may not cause harmful interference and
2. This device must accept any interference received, including interference that may cause undesired operation.

The following standards applied in accordance with Article 5 of the directive, 1999/5/EC:

EN 300 220-1 V1.2.1 (1997-11)

ETS 300 683 (1997-03).

Summary of tests

Effective radiated power	25MHz - 4GHz
Range of modulation bandwidth for wideband equipment	
Frequency stability under low voltage conditions	
EN55022	Radiated emissions 30MHz – 1GHz
EN61000-4-3	Radiated immunity 80MHz – 1GHz, excl 434 MHz ± 20MHz
EN61000-4-2	Electrostatic discharge
RTCA / DO-160C sec 21 cat Z	Aircraft safety specification

III.Appendix C—RFID_tag_read.c

```
/*******************************************************************************
 * Copyright (C) 2005 Autoliv Electronics Europe. All rights reserved.
 *
 * @par      Project:
 *           VISAS TEM3 EXP
 *
 * @par      Module:
 *           RPC Handler for HMI+
 *
 * @par      Purpose:
 *           Implements HMI+ talking XML to Flash application
 *
 *
 *******************************************************************************/

//#include <pthread.h>
//#include <arpa/inet.h>
//#include <unistd.h>
//#include <sys/socket.h>
//#include <sys/ioctl.h>
//#include <limits.h>
//#include <netinet/in.h>

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <signal.h>
#include <fcntl.h>
#include <errno.h>
#include <termios.h>
#include <time.h>

//*********************************************************************************
// RFID_TAG_READ/
//*********************************************************************************

#define RFID_DEVICE "/dev/rfcomm0"
#define RFID_BAUDRATE B57600
#define RHMI_RFID_MAX_NO_OF_ID 1000
#define RHMI_RFID_MAX_ID_LENGTH 38      /* sends 38 bytes per message */
#define TAG_DIGIT_NO 4    /* number of tag ID digits */

//* Brief Serial port handle *//
static int RFIDPort;

/* Set hint for programme to clean up and quit */
int QUIT = 0;

void signal_handler_INT (int status) {
 QUIT = 1;
}
```

```
/* Close Serial port*/
void closeRfidPort(int porth)
{
      close(porth);
}

/* Passenger ID*/
struct Passenger {
 unsigned char ID_number[TAG_DIGIT_NO]; /* Tag ID is four bytes*/
 unsigned int tag_digit; /* Tag ID in digital number*/
 int number_of_ID;
 int next; /* to check if there are more IDs to read, 0-->no more to read */
};


int main (int argc, char *argv[]) {

 struct Passenger ID[RHMI_RFID_MAX_NO_OF_ID], *ID_ptr;

 /* set up handler for SIGINT (Ctrl+c) to close port and cleanup */
 struct sigaction saio;
 saio.sa_handler = signal_handler_INT;
 sigemptyset(&saio.sa_mask);
 saio.sa_flags = 0;
 saio.sa_restorer = NULL;
 sigaction(SIGINT, &saio, NULL);

 // Non-blocking stdin
 fcntl(0, F_SETFL, O_NONBLOCK);
 printf("Connect to RFID device...\n");
struct termios RFID_options; /* The options */

 /* open the serial port */
RFIDPort = open(RFID_DEVICE, O_RDWR| O_NOCTTY | O_NDELAY);
if(RFIDPort == -1) {
    printf("failed to open port.\n");
    exit(0);
  }
else {
    printf("Rfid serial port opened and initialising...\n");
    fcntl(RFIDPort, F_SETFL, 0);

      //* Get the current options *//
    tcgetattr( RFIDPort, &RFID_options );
    /*
                BAUDRATE: Set bps rate. could also use cfsetispeed and cfsetospeed.
                CRTSCTS : output hardware flow control (only used if the cable has
                          all necessary lines. See sect. 7 of Serial-HOWTO)
                CS8     : 8n1 (8bit,no parity,1 stopbit)
                CLOCAL  : local connection, no modem contol
                CREAD   : enable receiving characters
       */
 //RFID_options.c_cflag |= (CRTSCTS | CS8 | CLOCAL | CREAD);
 //RFID_options.c_cflag |= (CRTSCTS);
 RFID_options.c_cflag &= ~PARENB;
 RFID_options.c_cflag &= ~CSTOPB;
 RFID_options.c_cflag &= ~CSIZE;
```

```
 RFID_options.c_cflag |= (CS8 | CLOCAL | CREAD);
 RFID_options.c_cflag |= CRTSCTS;
 cfsetispeed(&RFID_options, RFID_BAUDRATE);
 cfsetospeed(&RFID_options, RFID_BAUDRATE);
        /*
                    IGNPAR    : ignore bytes with parity errors
                    ICRNL     : map CR to NL (otherwise a CR input on the other computer
                                will not terminate input)
                    otherwise make device raw (no other input processing)
 */
 RFID_options.c_iflag &= ~(ICRNL);
 RFID_options.c_iflag &= ~(INLCR);
 RFID_options.c_iflag |= (IGNPAR);
 RFID_options.c_iflag &= ~(IXON|IXOFF|IXANY);

 /* Raw Input. */
 RFID_options.c_lflag &= ~(ICANON | ECHO | ECHOE |ISIG);

 /* Raw output. */
RFID_options.c_oflag &= ~OPOST;

/* Set the options */
      tcsetattr(RFIDPort, TCSANOW, &RFID_options );
      printf("done!\n");
 }

 int num_ID_Read = 0; /* number of ID read*/
 printf("Entering Ctrl+C to stop loop...\n");
 time_t start_time = time(0);

 while(!QUIT)
 {
 // Read data from the port until a head is get

  unsigned char buffer[RHMI_RFID_MAX_ID_LENGTH];      /* Input buffer, binary */
  unsigned char *buffptr;
  int nbytes = 0; /*number of bytes read*/
  int i,j,count;
  memset(buffer,0,sizeof(buffer));
  i=0;
  j=0;
  buffptr = buffer;

  while ((nbytes = read(RFIDPort, buffptr, 1)) > 0)
  {
   if (buffer[0] == 85)
   {
//   printf("no.1==> yes!");
    buffptr = buffer + 1;
    nbytes = read(RFIDPort, buffptr, 1);
    if ((nbytes > 0) && (buffer[1] == 32))
    {
//    printf("no.2==>yes!");
     buffptr = buffer + 2;
     break;
    }
    else
```

```
   {
    buffptr=buffer;
    continue;
   }
  }
  else
  {  buffptr=buffer;
    continue;
  }
 }

 if (nbytes == 0)
 {
  if (num_ID_Read != 0)
  {
   ID[num_ID_Read-1].next = 0;
  }
  else
  {
   ID[num_ID_Read].next = 0;
  }
               printf (" No more data to read.\n");
               break;
            }
           if (nbytes < 0)
 {
              perror("Unable to read from RFID connection");
  break;
        }

 int bytes;
 bytes = 2;

 while ((nbytes = read(RFIDPort, buffptr, (buffer + RHMI_RFID_MAX_ID_LENGTH-buffptr)))>0)
 {
  buffptr += nbytes;
  bytes +=    nbytes;
  if (bytes == RHMI_RFID_MAX_ID_LENGTH)
   break;
 }

// printf("bytes total read :%d\n", bytes);
 bytes=0;
 /* read 38 bytes from serial port */


 if(!((buffer[5]==33)&&(buffer[6]==42)&&(buffer[7]==42)))
 {
  printf("no!\n");
  continue;
 }


 ID[num_ID_Read].number_of_ID = num_ID_Read + 1;/* get the Tag Id*/
 printf("--DATA (No. %02d)(M->L) :" , ID[num_ID_Read].number_of_ID);
 ID[num_ID_Read].tag_digit = 0;
 for (i=0;i<TAG_DIGIT_NO;i++)
```

```
  {
   ID[num_ID_Read].ID_number[i]=buffer[21+i];
   ID[num_ID_Read].tag_digit = ((ID[num_ID_Read].tag_digit)*256)+ ID[num_ID_Read].ID_number[i];
//    printf("%03u" , ID[num_ID_Read].ID_number[i]);
  }
```

………
………

```
   if (num_ID_Read == RHMI_RFID_MAX_NO_OF_ID)
   {
    ID[num_ID_Read-1].next = 0;
    break;
   }
   ID[num_ID_Read-1].next = 1;
   printf("\n");

  }

 ID[num_ID_Read-1].next = 0;        /* in case of manually stop*/
 time_t end_time = time(0);
 printf("start time : %s\n",ctime(&start_time));
 printf("end time : %s\n",ctime(&end_time));
 printf ("Total number of ID read: %02d \n", num_ID_Read);

// for (ID_ptr=ID;;ID_ptr++)
// {
//  if(num_ID_Read==0){
//   break;
//  }
//
//  if(ID_ptr->next == 0)
//  { printf("Tag ID (No.%02d): %u\n",ID_ptr->number_of_ID,ID_ptr->tag_digit);
//   break;
//  }
//  printf("Tag ID (No.%02d): %u\n",ID_ptr->number_of_ID,ID_ptr->tag_digit);
// }
 num_ID_Read = 0;
 ID_ptr=ID;
 printf("Closing connection...");
 close(RFIDPort); /* not cloesd for testing */
 printf("done!\n");
 return 0;
}
```

IV. Appendix D—Sample of Reading Result

Connect to RFID device...
Rfid serial port opened and initialising...
done!
Entering Ctrl+C to stop loop...
--DATA (No. 01)(M->L) :(5046)
--RSSI Value (signal strength) : 153 (0->255)
--DATA read (No. 01) : 0x55 0x20 0x50 0x01 0x02 '!' '*' '*' 0x31 020 040 'B' 'C' 000 002 237 062 207 000 000 020 000 000 019 182 051 080 153 081 032 080 080 000 000 040 010 013 085

--DATA (No. 02)(M->L) :(5046)
--RSSI Value (signal strength) : 152 (0->255)
--DATA read (No. 02) : 0x55 0x20 0x50 0x01 0x02 '!' '*' '*' 0x31 020 040 'B' 'C' 000 002 237 062 208 000 000 020 000 000 019 182 051 080 152 082 032 080 080 000 000 040 010 013 072

--DATA (No. 03)(M->L) :(5046)
--RSSI Value (signal strength) : 154 (0->255)
--DATA read (No. 03) : 0x55 0x20 0x50 0x01 0x02 '!' '*' '*' 0x31 020 040 'B' 'C' 000 002 237 062 209 000 000 020 000 000 019 182 051 080 154 083 032 080 080 000 000 040 010 013 074

--DATA (No. 04)(M->L) :(5046)
--RSSI Value (signal strength) : 153 (0->255)
--DATA read (No. 04) : 0x55 0x20 0x50 0x01 0x02 '!' '*' '*' 0x31 020 040 'B' 'C' 000 002 237 062 210 000 000 020 000 000 019 182 051 080 153 084 032 080 080 000 000 040 010 013 077

--DATA (No. 05)(M->L) :(5046)
--RSSI Value (signal strength) : 154 (0->255)
--DATA read (No. 05) : 0x55 0x20 0x50 0x01 0x02 '!' '*' '*' 0x31 020 040 'B' 'C' 000 002 237 062 211 000 000 020 000 000 019 182 051 080 154 085 032 080 080 000 000 040 010 013 078

--DATA (No. 06)(M->L) :(5046)
--RSSI Value (signal strength) : 151 (0->255)
--DATA read (No. 06) : 0x55 0x20 0x50 0x01 0x02 '!' '*' '*' 0x31 020 040 'B' 'C' 000 002 237 062 212 000 000 020 000 000 019 182 051 080 151 086 032 080 080 000 000 040 010 013 071

--DATA (No. 07)(M->L) :(5046)
--RSSI Value (signal strength) : 153 (0->255)
--DATA read (No. 07) : 0x55 0x20 0x50 0x01 0x02 '!' '*' '*' 0x31 020 040 'B' 'C' 000 002 237 062 213 000 000 020 000 000 019 182 051 080 153 087 032 080 080 000 000 040 010 013 073

--DATA (No. 08)(M->L) :(5046)
--RSSI Value (signal strength) : 152 (0->255)
--DATA read (No. 08) : 0x55 0x20 0x50 0x01 0x02 '!' '*' '*' 0x31 020 040 'B' 'C' 000 002 237 062 214 000 000 020 000 000 019 182 051 080 152 088 032 080 080 000 000 040 010 013 068

--DATA (No. 09)(M->L) :(5046)
--RSSI Value (signal strength) : 153 (0->255)
--DATA read (No. 09) : 0x55 0x20 0x50 0x01 0x02 '!' '*' '*' 0x31 020 040 'B' 'C' 000 002 237 062 215 000 000 020 000 000 019 182 051 080 153 089 032 080 080 000 000 040 010 013 069

--DATA (No. 10)(M->L) :(5046)
--RSSI Value (signal strength) : 154 (0->255)
--DATA read (No. 10) : 0x55 0x20 0x50 0x01 0x02 '!' '*' '*' 0x31 020 040 'B' 'C' 000 002 237 062 216 000 000 020 000 000 019 182 051 080 154 090 032 080 080 000 000 040 010 013 074

--DATA (No. 11)(M->L) :(5046)
--RSSI Value (signal strength) : 159 (0->255)
--DATA read (No. 11) : 0x55 0x20 0x50 0x01 0x02 '!' '*' '*' 0x31 020 040 'B' 'C' 000 002 237 062 217 000 000 020 000 000 019 182 051 080 159 091 032 080 080 000 000 040 010 013 079

--DATA (No. 12)(M->L) :(5046)
--RSSI Value (signal strength) : 162 (0->255)
--DATA read (No. 12) : 0x55 0x20 0x50 0x01 0x02 '!' '*' '*' 0x31 020 040 'B' 'C' 000 002 237 062 218 000 000 020 000 000 019 182 051 080 162 092 032 080 080 000 000 040 010 013 118

………
………

--DATA (No. 158)(M->L) :(5046)
--RSSI Value (signal strength) : 156 (0->255)
--DATA read (No. 158) : 0x55 0x20 0x50 0x01 0x02 '!' '*' '*' 0x31 020 040 'B' 'C' 000 002 237 063 233 000 000 020 000 000 019 182 051 080 156 108 032 080 080 000 000 040 010 013 074

--DATA (No. 159)(M->L) :(5046)
--RSSI Value (signal strength) : 156 (0->255)
--DATA read (No. 159) : 0x55 0x20 0x50 0x01 0x02 '!' '*' '*' 0x31 020 040 'B' 'C' 000 002 237 063 234 000 000 020 000 000 019 182 051 080 156 109 032 080 080 000 000 040 010 013 072

--DATA (No. 160)(M->L) :(5046)
--RSSI Value (signal strength) : 156 (0->255)
--DATA read (No. 160) : 0x55 0x20 0x50 0x01 0x02 '!' '*' '*' 0x31 020 040 'B' 'C' 000 002 237 063 235 000 000 020 000 000 019 182 051 080 156 110 032 080 080 000 000 040 010 013 074

start time : Thu Sep 11 13:10:25 2008

end time : Thu Sep 11 13:13:27 2008

Total number of ID read: 160
Closing connection...done!

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