

etsiit

App for mapping and inventorying emergency backpacks



Bachelor of Engineering in
Telecommunication Technologies

Final Year Project

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Resumen

La Comunidad Foral de Navarra está formada por 58 zonas básicas de salud. Dentro de la red de urgencias extrahospitalarias, los equipos de interés de este trabajo son los 46 puntos de atención continuada de los equipos de atención primaria de dichas zonas básicas de salud, en los que un enfermero y un médico acuden para atender las emergencias sanitarias que surjan en su zona de acción.

Dichos equipos poseen dos mochilas botiquines con el instrumental y la medicación necesaria para llevar a cabo las curas necesarias. El problema surge a raíz de la cantidad de elementos diferentes que componen dichos botiquines, cercano a 500 referencias, lo que dificulta la localización dentro de los propios botiquines, aumentando los tiempos de respuesta.

En este trabajo se ha desarrollado una aplicación para seleccionar el material que el sanitario necesite utilizar en un momento dado, y se le indique su localización dentro de la mochila. Además, se incluye en este trabajo un proceso de inventariado de los materiales para reducir los tiempos de inoperabilidad, por medio de tecnología RFID.

Finalmente se ha observado que Flutter es una tecnología reciente pero madura para el desarrollo de aplicaciones, que ha cumplido las expectativas para el desarrollo de esta aplicación. Además, se han evidenciado las diferentes casuísticas que empeoran la calidad de señal RFID.

Palabras clave

RFID, inventario, botiquín, emergencias, aplicación, flutter

Abstract

The Comunidad Foral de Navarra is made up of 58 basic health zones. Within the network of out-of-hospital emergencies, the teams of interest in this work are the 46 points of continuous care of the primary care teams of these basic health areas, in which a nurse and a doctor attend to attend to the health emergencies that arise in their area of action.

Said teams have two first-aid backpacks with the necessary instruments and medication to carry out the necessary cures. The problem arises from the number of different elements that make up these kits, close to 500 references, which makes it difficult to locate them within the kits themselves, increasing response times.

In this work, an application has been developed to select the material that the health specialist needs to use at any given time, and its location within the backpack is indicated. In addition, a materials inventory process is included in this work to reduce downtime, by means of RFID technology.

Finally, it has been observed that Flutter is a recent but mature technology for the development of applications which has fulfilled the expectations for the development of this application. In addition, the different cases that worsen the quality of the RFID signal have been evidenced.

Keywords

RFID, inventory, first aid kit, emergencies, application, flutter

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Part I.

Memory

1. Introduction

1.1. Motivation

The Emergency Medical Service (EMS) have mobilized 102,586 health resources during 2020 in Navarra [23]. Many of these attentions are time-dependent, that is, they must be treated quickly and appropriately to avoid aggravating the patient's situation, but also to achieve greater autonomy for the person once they have overcome the disease and have the minor possible sequelae.

During the year 2020 the European project *InDemand* arises, by which the professionals of the Health Systems adhered to it, could propose projects that would later be evaluated and selected by a court to be executed by an external company. In addition, the financing of a certain number of projects by public and private entities was proposed.



Figure 1.1: Agents involved in the Navarrese version of inDemand. [1]

In Navarra, within the framework of the aforementioned project, the Navarrabiomed Biomedical Research Center was in charge of administrative management. In this context, the SNS Pharmacy Sub-Directorate proposed the realization of the project known as 'MapsMochila', through which it would try to reduce the action times derived from the search for the necessary material among the different emergency kits as well as supporting temporary or newly incorporated staff in their day-to-day activities. As the project was not selected, different ways were sought for its execution, which is why this Final Year Project (FYP) is carried out as a collaboration between the SNS and the Universidad Pública de Navarra (UPNA).

1.2. Objectives

The objective of this FYP is to create a multi-device mobile application that allows locating within the emergency kits the medicines or materials needed by the health personnel, as well as the design of the hardware necessary to carry out the inventory of the medical equipment. Likewise, it is intended to develop other additional objectives, among which are:

- To carry out an exhaustive bibliographic research on the topics of interest, to deepen the knowledge acquired about the Navarra Health System, especially the operation and protocols of the Emergency Medical Service (EMS), to adapt the design of the FYP to the needs of professionals. This will lead to an increase in knowledge about various topics such as emergency coordination, patient care or medications.
- To carry out practical experiments to compare the results obtained with those expected according to the theoretical procedures in force in the field of application, entering into the use of the scientific method as a way to acquire and transfer knowledge.
- To develop a technical project based on specifications agreed with healthcare professionals. Thanks to this, I will become familiar with the SCRUM methodology, interface design and development of multi-platform mobile applications.
- To select the equipment, both hardware and software, most suitable for the development of the project based on the needs and characteristics of the work environment in which they will be used.
- To compare the obtained results with those expected as well as a verification of the methods used.

1.3. Document structure

The structure of this document has been developed based on the FYP Presentation Guide of the Higher Technical School of Industrial and Telecommunications Engineers of the Public University of Navarra [24]. This script has been structured in four parts: Report, Plans, Specifications and Budget.

Furthermore, the most extensive part, the memory, has been separated into the different chapters:

- **Chapter 1 - Introduction:** In this first section the project is described in a general way, explaining what has motivated me to carry out a development in this field, the need for it, and the objectives that I intend to achieve with the present FYP.
 - **Chapter 2 - Theoretical framework:** The necessary knowledge in pre-hospital care and health procedures of interest for understanding the rest of the work is explained. It presents a historical journey through pre-hospital care as well as a description of the current health system in the Autonomous Community of Navarra.
 - **Chapter 3 - State of the art:** It contains the information gathered in the bibliographic research on the topics of interest, and exposes the techniques and materials related to the present FYP.
 - **Chapter 4 - Methodology:** It informs about the equipment and procedures used for the development of this work. A justification of the equipment used, both software and hardware, is made, to later justify the use of work methods and procedures.
-

- **Chapter 5 - Simulations:** The methodologies used during the simulations carried out within the framework of this work are exposed, in order to compare them with the practical results obtained.
 - **Chapter 6 - Results:** It shows the results obtained during the development of this work, both in the theoretical and practical fields.
 - **Chapter 7 - Discussion:** It compares the evidence generated and discuss its adequacy.
 - **Chapter 8 - Conclusions and future lines of research:** It summarizes the development of the FYP.
-

2. Theoretical framework

2.1. Navarre's extra-hospital emergency service

Prehospital care is a system made up of agents of different kinds and belonging to different agencies, which makes it an extremely complex network and must be very well coordinated to function properly. In this section, there will be a brief explanation about the process of constitution of the same as well as its operation.

2.1.1. Historical walkthrough

Prehospital health care has been linked since its inception to the care of wounded in military battles or wars. The first documented assistances were carried out by religious institutions such as the Order of Knights of the Hospital of Saint John of Jerusalem, attending to soldiers and civilian personnel in the Crusades, during the 11th century. Years later, and in the context of the Napoleonic wars, Doctor Dominique-Jean Larrey created ambulance transport in 1792.

It is at the end of the fifties and beginning of the sixties when much more advanced prehospital care systems are put into operation. This improvement is partly due to the invention by Dr. Jame Francis Pantridge of the Cardiopulmonary Resuscitation (CPR), and of the first portable defibrillator in 1965. It represented a revolution in care, since it advanced from a methodology based on move as quickly as possible to hospital, to one focused on providing first aid on site.

Focusing on Spain, it is in Barcelona when in 1951 the Fire Brigade created the first unit made up of practitioners to offer health assistance to firefighters during the actions, since there was not so much emphasis on Prevention of Occupational Hazards (POH) and more accidents occurred. The lack of an institutionalized organization for the care of the injured continues to be evidenced, so voluntary associations are created such as the Detente Y Ayuda (DYA) Association, founded in Bizkaia by Dr. Juan Antonio Usparitza in 1966 and commissioned together with Red Cross and other organizations that care for traffic accidents or emergencies.



Figure 2.1: DYA association ambulance in the sixties. [2]

Subsequently, in 1988, the Ombudsman based on the recommendations of the Spanish Society of Intensive Medicine and the European Health Committee, issued a report for the creation of prehospital emergency services, which would be launched once the health competencies were transferred to the Autonomous Communities. In 1991, the European Commission established *112* as the unique emergency number. [25]

In Navarra, Agencia Navarra de Emergencias (ANE) was created in 2005, being the one in charge of managing and coordinating civil protection services, emergency care.

2.1.2. Equipment

Medical transport by road is regulated in DF 8/2011 [26], which establishes the technical characteristics, medical equipment and personnel of the ambulances. This Decree includes two main types of assistance ambulances: those of Basic Life Support (BLS) and those of Advanced Life Support (ALS).

BLS They are one of the first resources for prehospital health care. It is made up of at least two Emergency Medical Technicians and has the equipment to meet most requests for care. In Navarra, these ambulances are equipped exactly like those of ALS to be able to convert them into mobile ICUs only with the presence of qualified health personnel.

ALS They are made up of at least one Emergency Medical Technician, a doctor and a nurse. Also known as mobile ICUs, these types of ambulances are capable of performing complex techniques and procedures necessary for the maintenance of life in critical patients. In Navarra there are currently 9 medical ambulances located in Pamplona (3), Estella (1) and Tudela (2).

In addition, through the Health Centers there are units without the capacity to transport patients, included in the services of Servicio de Urgencias Rurales (SUR), Servicio de Urgencias Extrahospitalarias (SUE) and Servicio Normal de Urgencias (SNU). These units, called Rapid Response Unit (RRU) are initially sent by the 112 Coordinating Center for the first care and later it is an ambulance of BLS or ALS who transfers the patient to a hospital if necessary by its pathology.

2.1.3. Operation

The management of calls in the 112 Coordination Center must be concise and fast, since there are emergencies that are time-dependent. To achieve this, the first thing the caller is asked, is to indicate the location of the incident, in case the call is cut off, to know where to send the resources. Subsequently, both the 112 operator and the coordinating doctor, if it is a health emergency, ask different questions in order to know the real magnitude of the incident, number of injuries, their severity ... with a view to send the resource or more appropriate available resources.

For their part, health workers, regardless of the service to which they belong, carry out a complete review of the material at the beginning of their working day, in order to verify that they have all the necessary equipment and that the electromedical material does not present any problem. In the figure 2.2 it is observed that the complete revision of the material without a support method such as the MapsMochila application can be close to 40 minutes, depending on the skill of the worker. On the other hand, if we add the application, we will be able to reduce this time to only 10-15 minutes since it directly shows a list of the missing materials and only the electromedical material would have to be reviewed.

In the example diagram, we see that the first aid kit check task cannot be completed as a call has come in during the kit review. Although priority is given to reviewing the most important materials for time-dependent codes (those intended for resuscitation of a cardiopulmonary arrest, drowning ...)

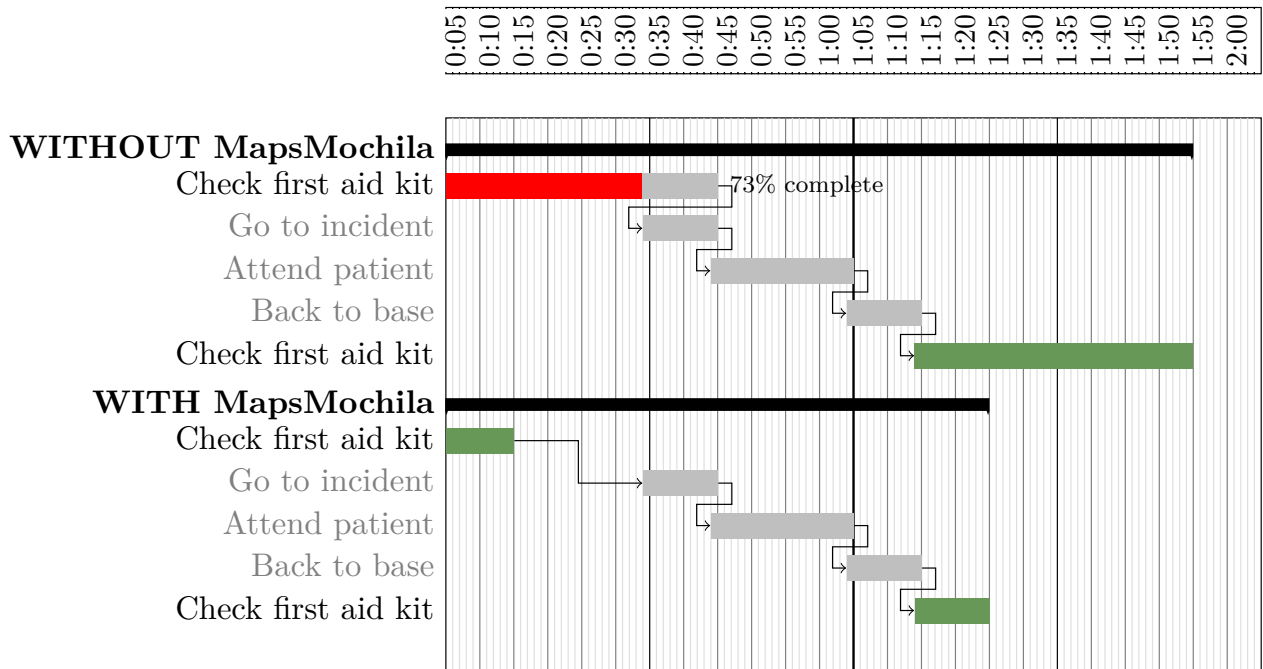


Figure 2.2: Time difference between the use or not of MapsMochila.

it may be that the material necessary to answer the call has not had time to be reviewed still and is not in perfect condition.

In addition, after each intervention, the material is rechecked to replace the consumable material that has been used up, and the non-consumable material that is outside the hospital (for example, an immobilization splint remains in the hospital until the patient is x-rayed and subsequently collected).

3. State of the art

3.1. Wireless communication

Wireless communication of signals is carried out by means of electromagnetic waves, which are those that do not require a material medium for their propagation, such as visible light or X-rays, among others. In contrast, mechanical waves need a material medium, such as air (gas), water (liquid) or strings (solid).

3.1.1. Electromagnetic waves

These waves, such as the one in the figure 3.1, propagate thanks to the excitation of electric and magnetic fields, as their name suggests. These fields are perpendicular to each other, and in turn, to the direction of propagation of the wave. These types of waves transport energy without transporting matter, and circulate in a vacuum at the speed of light, since this is an example of an electromagnetic wave.

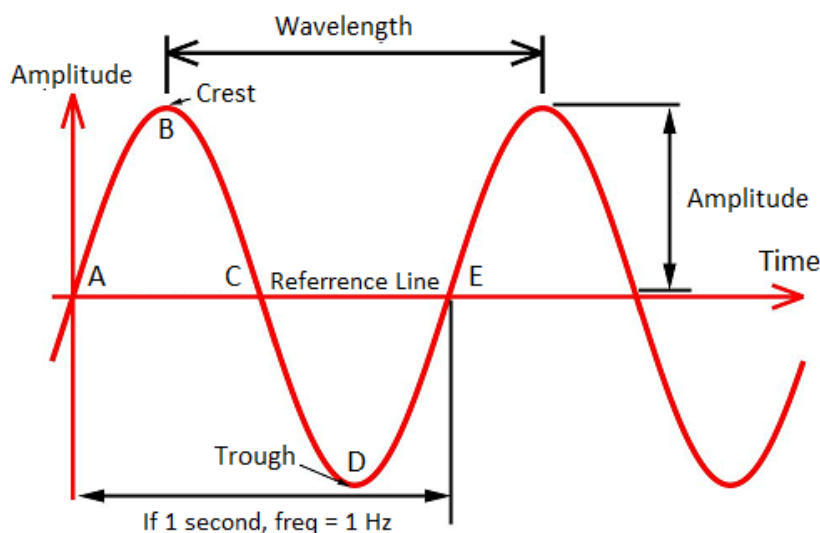


Figure 3.1: Example of electromagnetic wave. [3]

3.1.1.1. Characteristics

Amplitude: Indicates the maximum voltage of the wave, and it is half the height between the crest (highest point) and the valley (lowest point) of the wave. It is generally measured in Volts.

Period: It is the duration of the wave until it repeats again, that is, the time distance between two maximums or two minimums. It is measured in seconds.

Frequency: It is the inverse of the period, it measures the number of times the wave repeats per unit of time. The most used unit is Hertz, which indicates the number of repetitions per second. The amount of energy transmitted by the waves varies according to the frequency, within the radioelectric spectrum as distinguished in the figure 3.2:

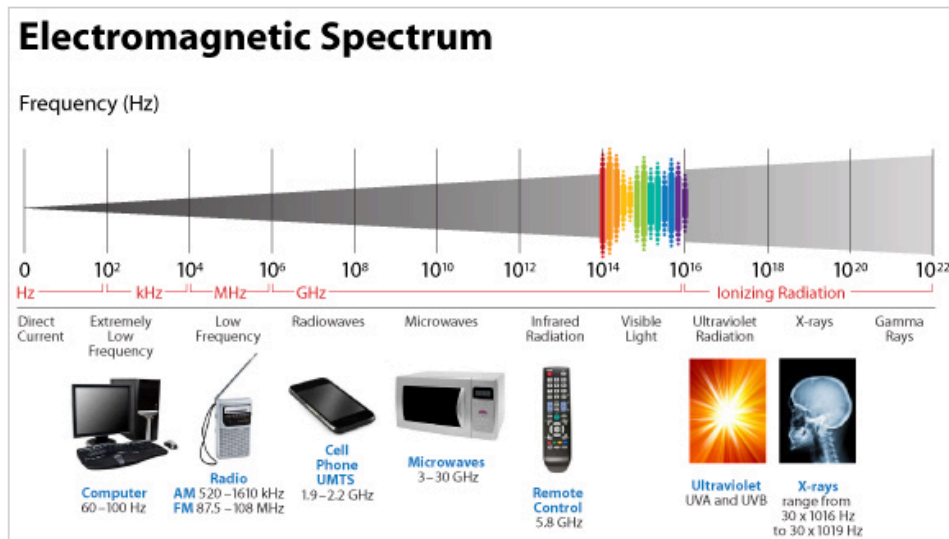


Figure 3.2: Radioelectric spectrum. [4]

Velocity: There are two velocities, the **phase velocity**, which is the velocity at which the wave propagates in some medium. In addition, the **group velocity** is defined as the envelope of the signal moves through space and they can coincide with each other or not.

Wavelength: It is defined as the distance advanced by the movement in one period.

Polarization: Indicates the path that the vector component of the electric field describes as well as its variation within time. The following cases are distinguished:

Linear: The components of the electric field (both in the X and Y axes) are in phase ($\delta = 0$) or in push-pull ($\delta = \pi$). Figure 3.3a

Horizontal: The electric field propagates in a direction parallel to the earth's surface.

Vertical: The electric field propagates in a direction perpendicular to the earth's surface.

Circular: The components of the electric field in both axes have the same amplitude (equal module) and the difference between the phases is $\pm\pi$. Figure 3.3b

Elliptical: It is the remaining case, the amplitudes are different and the phase differences are not $\pm\pi$. Figure 3.3c

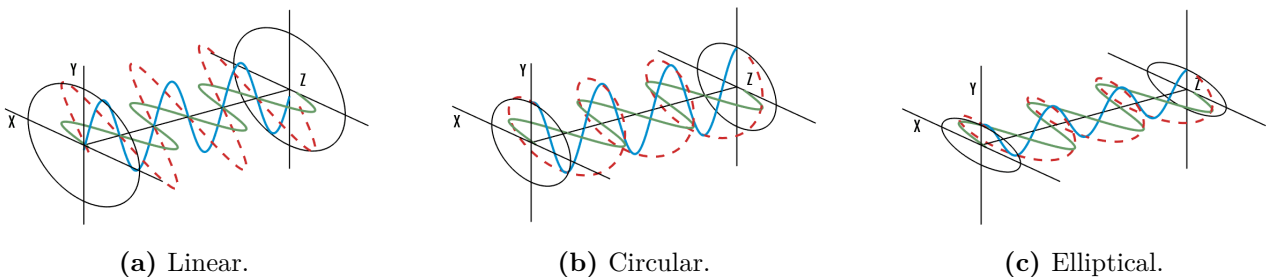


Figure 3.3: Polarization of an electromagnetic wave.[5]

3.1.1.2. Propagation

The propagation of electromagnetic waves is a very complex phenomenon, since there can be many variants of propagation and a great majority of propagation modes can occur simultaneously in the same communication.

The study of propagation can be carried out theoretically according to Maxwell's equations (1873), described in the figure 3.1. James Clerk Maxwell compiled a set of equations that combine the basic knowledge discovered by scientists such as Ampere, Faraday or Gauss in the field of electromagnetic phenomena.

$$\begin{aligned}
 \frac{\partial \mathcal{D}}{\partial t} &= \nabla \times \mathcal{H}, && \text{(Faraday-Lenz's law)} \\
 \frac{\partial \mathcal{B}}{\partial t} &= -\nabla \times \mathcal{E}, && \text{(Ampère's law)} \\
 \nabla \cdot \mathcal{B} &= 0, && \text{(Gauss' law)} \\
 \nabla \cdot \mathcal{D} &= 0. && \text{(Colomb's law)}
 \end{aligned} \tag{3.1}$$

In order to explain the variants of propagation that a wave can undergo, we may suppose two different transmission media (for example, air and water). Each one will have its intrinsic characteristics to the medium and, therefore, different speeds of propagation. If we have a wave that travels from medium 1 to medium 2, on the border between both one of these two phenomena (or both simultaneously) can occur:

Reflection: The indexing wave is reflected back, with the same angle on the normal of the boundary plane between both media.

Refraction: On the contrary, in this case the incident wave passes through the second medium, with an angle complementary to that formed on the normal of the boundary plane.

Furthermore, it can happen that the electromagnetic wave passes through an obstacle with a hole. If this hole were of a magnitude of the order of the wavelength, the phenomenon of **diffraction** would occur, through which the incident wave would propagate turning the hole into a secondary source of waves. If the hole were not large enough with regard to the wavelength, no diffraction would occur and there would be areas at the border without good coverage. These three phenomena can be observed in the figure 3.4.

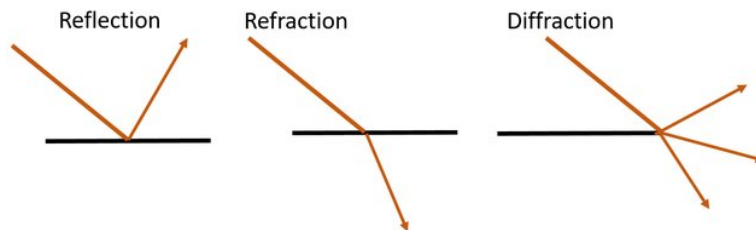


Figure 3.4: Reflection, refraction and diffraction phenomena. [6]

3.1.2. RFID

3.1.2.1. Introduction

An RFID system is a remote identification system capable of storing and reading data wirelessly. Lately this technology has grown exponentially thanks to the low cost on a large scale, and the ease of development. The sectors that have benefited the most are commerce, logistics, animal control or highway payments.

RFID technology is currently replacing barcodes and, to a lesser extent, QR codes, since neither of these two technologies allows reading without direct vision, as well as data rewriting. It is included in the *Auto-ID Labs* network in which there are designs focused on identification in a quick and univocal way, among which are the already mentioned barcodes, biometric identification or smart cards, all of them operating with Electronic Product Code (EPC).

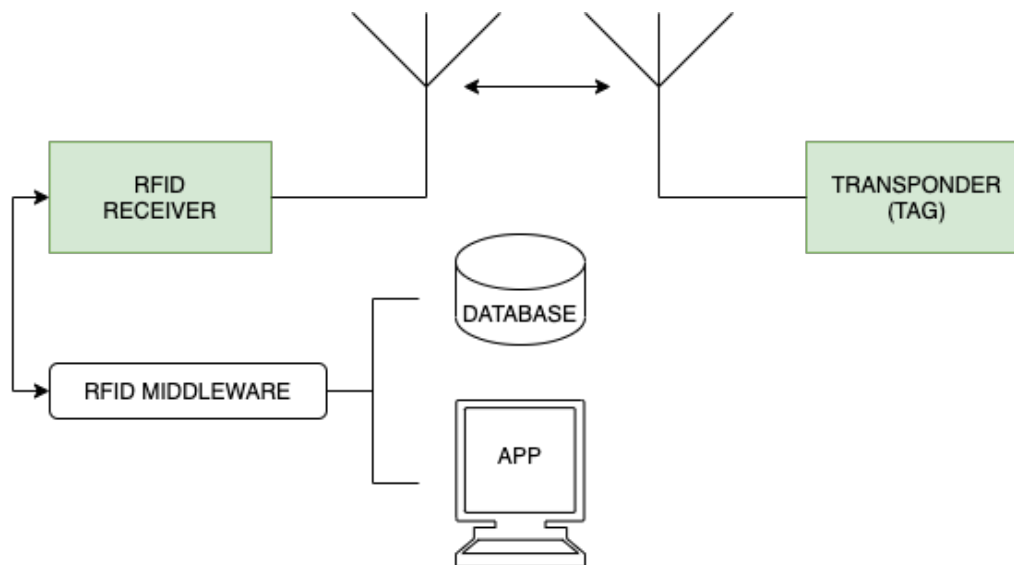


Figure 3.5: Component diagram of an RFID system. [Own]

To function the following elements, which will be described later, are needed at least:

Tag: It can be active (if it has an external power supply) or passive (if it doesn't). Stores the information and answers the reader.

Reader: It reads and generally also writes the information in the tags.

Antenna: It emits the signal generated by the reader, and receives the signal sent from the tags.

Middleware: It acts as a gateway between the reader and the database or system.

3.1.2.2. History

We have to go back to World War II to find the first examples of RFID technology. In those years, the use of radar as a method of locating aircraft began to expand. However, it was impossible to discern by means of the aforementioned technology whether an aircraft was an enemy or its own. In order to do that, German troops discovered that if the pilots carried out specific maneuvers in the vicinity of the base, the waves received by the radar would be modified and it would serve them to identify the side of the aircraft. The problem was the high difficulty that this added to the landing process in time of war, but it can be assimilated to the first RFID tag in history, as it was an element that modified

the received signal.

A few years later, in 1939, the British Army developed and launched a new system known as “*Identification, friend or foe (IFF)*”. This system was based on a regenerative receiver¹, so it could be assimilated to the first active tag.

In 1948, Stockman [27] concluded the following reflection on the future of RFID, and it is that many developments were yet to come that would make possible the large-scale use of this technology, such as BJT transistors and integrated circuits, among others :

Evidently, considerable research and development work has to be done before the remaining basic problems in reflected-power communication are solved, and before the field of useful applications is explored.

During the 1960s, the Electronic Article Surveillance (EAS), a device focused on the prevention of theft, was invented. It is composed of 1-bit tags capable of storing information on whether the item had been paid for or not. If not, this device trigger alarms. The fact that it only needed one bit of storage, let it expand very quickly through department stores worldwide, thus being ahead of the first major use of Radio Frequency IDentification (RFID).

The 70s were marked by the scientific-technical development of RFID systems, with companies, universities, private and public laboratories actively working on RFID research. 1973 is the year in which Charles Walton patented the active tag, and Mario W. Cardulla [7] did the same with the passive tag of the figure 3.6 with read and write memory, thus initiating the legal bases of RFID communication. Cardulla would go to the Port Authority of New York to present his project for an automated toll system for automobiles, being rejected by the bulkiness of the transceiver that had to be located in the vehicle. Later, it would be the Port Authority itself *that* would carry out tests with similar systems from different companies, including General Electric, Philips or Glenayre Landt [28].

In the following years, between the 80s and 90s, all RFID technology as we know it today is implemented and developed. The first applications, both in the US and European markets, were focused on the control of animals, the payment of tolls as well as control of warehouses and merchandise. In 1991, the first automatic toll highway in Oklahoma was opened to road traffic. In 1999, Massachusetts Institute of Technology (MIT) created an international alliance known

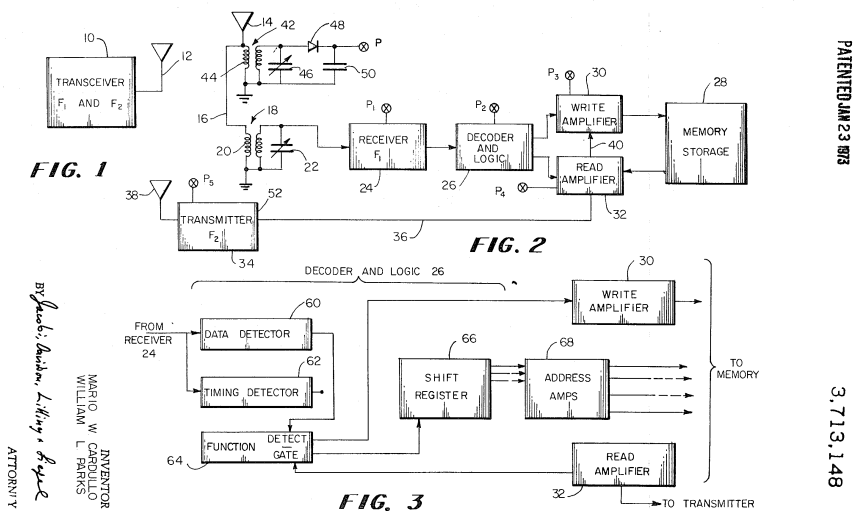


Figure 3.6: Patented design by Mario W. Cardulla. [7]

¹A regenerative circuit is an amplifier circuit of the received signal. This is achieved thanks to separating a part of the output signal and adding it back to the input signal.

as AutoID Labs focused on research and which includes academic institutions such as the University of Cambridge, and companies for instance Hewlett-Packard.

Nowadays and during the coming years, the research will focus on new working frequencies, such as the 5.9GHz microwaves, in addition to the securing of the information contained in the tags and the use of the RFID in the Internet of the Things (IoT).

3.1.2.3. Frequencies

The RFID system has various operating frequencies, depending on the type of application to be developed. In addition, these frequencies vary between regions (Europe, North America, Japan...) to adapt to local regulations of the radioelectric spectrum. In this section, a study is carried out of the three largest frequency ranges in use today, as well as the predominant applications in each one. There are currently four ranges: Low frequency (LF), High frequency (HF) and Ultrahigh frequency (UHF) and microwave. In the figure 3.7 we can observe the differences of the frequencies in different characteristics.

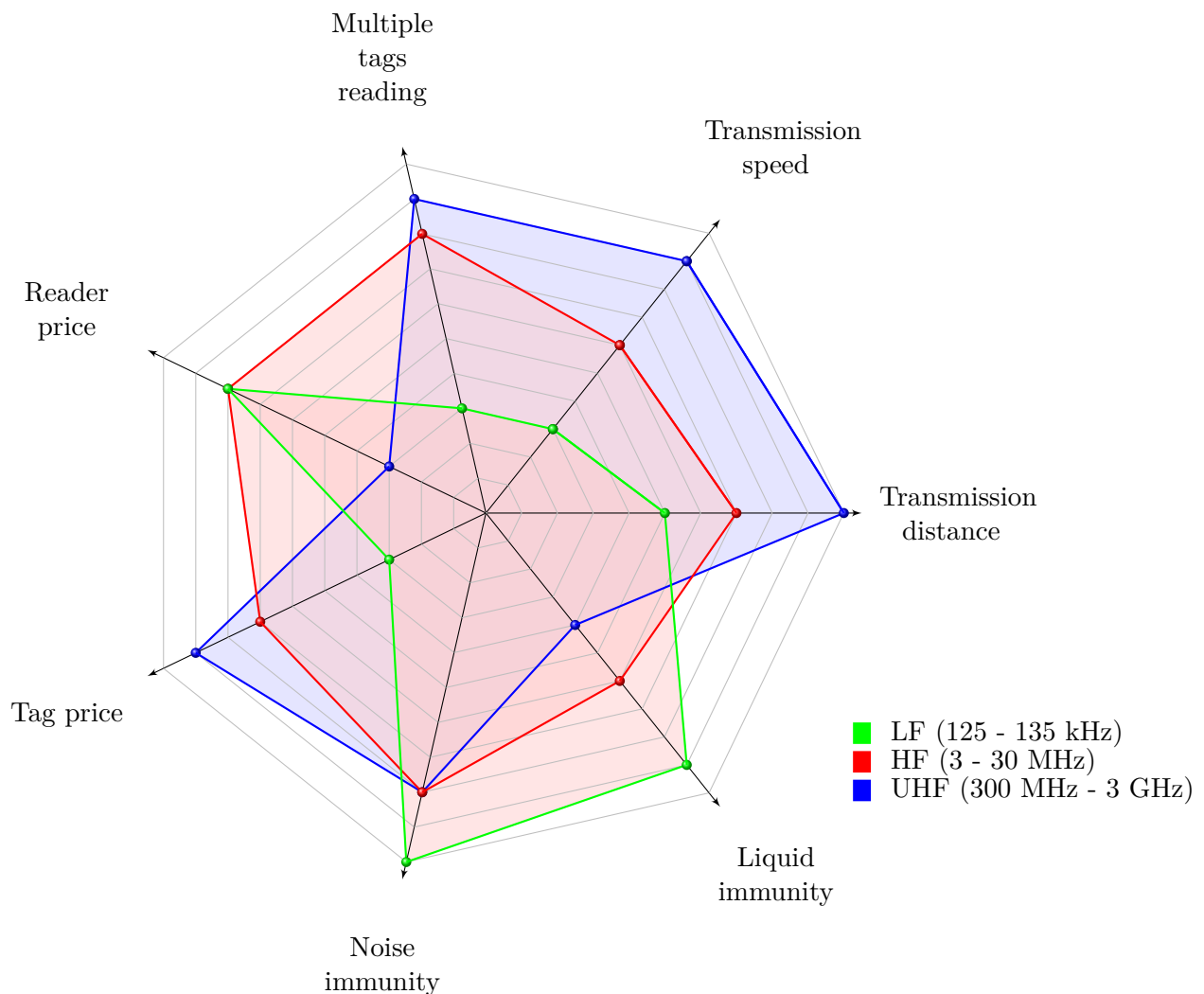


Figure 3.7: Comparison of the different frequencies. [Own]

Low frequency (LF) Frequencies between 125-135 kHz are used through inductive near field coupling. Using low frequencies makes data transmission rates low, in this case between 200 bps and 1 Kbps.

By making use of inductive coupling and therefore magnetic fields, the reading distance is the smallest of those offered by RFID standing at a maximum of 50 cm for passive tags. Capabilities such as anti-collision control or simultaneous reading of elements are not available.

Typically, they have been used in animal control, in control of liquid materials, wood or metals, as they have a greater protection against interference than the rest of the frequencies of the technology.

High frequency (HF) High frequency range covers between 3 and 30 MHz, worldwide the most common frequency is 13.56MHz. Like LF, it also makes use of inductive coupling to capture energy from the emitter and establish communication.

Reading ranges are typically between 10 cm and 1 meter. They suffer more interference but on the contrary, they have larger storage capacity in the tags, between 512 bits and 8 Kbits, as well as a higher transmission rate, between 25 and 100 Kbps. Tags at this frequency are the cheapest, having only one integrated chip and between 3 and 7 turns of copper for the antenna, compared to hundreds of LF antennas.

The uses of HF are focused on wireless payments (cards and mobiles), pallet tracking, book tracking, access control, among others.

Ultrahigh frequency (UHF) UHF band ranges from 300 MHz to 3 GHz. The UHF Gen2 standard, one of the most important ones, makes use of frequencies between 860 and 960 MHz, according to the regulations applicable to each geographic location in which it is used.

UHF Gen2 standard implements anti-collision technologies and simultaneous tag reading, allowing several hundred tags per second to be read. The labels have a storage capacity between 32 bits and 4 Kbits, with a transfer rate close to 28 Kbps.

It is the most sensitive to interference, but on the other hand it allows readings from several meters away.

The typical applications for this frequency range are stock control in large warehouses, or applications that require a large reading range or transmission rate.

Microwave Microwave frequencies used by RFID are 2.45 and 5.8 Ghz. The disadvantage of this standard is the fact that it is in frequency bands shared by other technologies that populate the spectrum, even so transmission rates between 100 Kbps and 1 Mbps are obtained.

Reading range is close to 100 meters, depending on the type of label and the characteristics of the system. It is very sensitive to interference, and to the reflection produced by metallic elements.

It is mainly used for long-range access control for vehicles and highway tolls applications.

3.1.2.4. Components

In a RFID communication, various components take part to make it possible. In this section we will review and describe them, but on figure 3.8 there is a comprehensive representation.

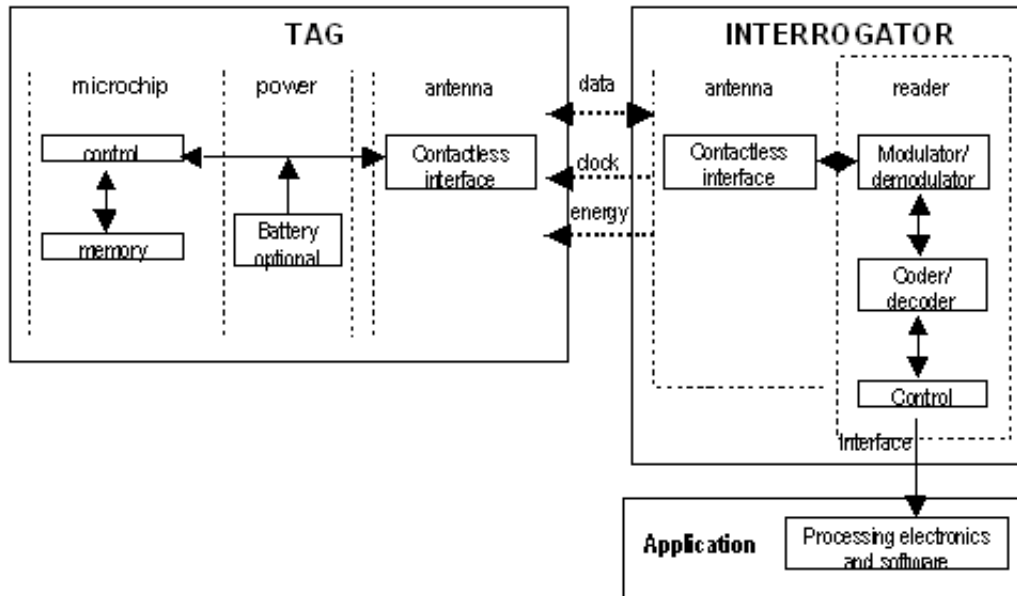


Figure 3.8: Communication and description of RFID components. [8]

RFID reader It is the central element for reading and processing data. A signal, which will be captured by the tag, is sent and returned to the reader to analyse data. The reader acts as a gateway to the information system or database in which the aforementioned information is stored.

The RFID reader, by acting as a gateway between two types of communication, has at least two communication ports: one for the RFID antenna and another for the connection to the system, which can vary between different technologies or incorporate more than one. The best known are USB, Ethernet, WiFi, Bluetooth, RS232, RS485 or Modbus.

There are three main modes of operation: the reader interrogates without stopping its entire coverage area, the reader periodically interrogates the coverage area or the reader interrogates when an external event tells it to do so.

In addition, depending on the mobility or type of installation, two types of readers are distinguished:

Fixed: They are the most used in applications for stock controls or vehicle or animal fleet controls. They can be constituted by a single reader and antenna, by a set of antennas connected to a single reader, or by several antennas connected to several readers, depending on the type of application and its needs.

Mobile: They are not fixed in any location, but being smaller and connected to external power sources, they are portable. They can be used to make inventories in specific areas of a store.

Tag It is a basic element of the RFID system that is included in each element to be tracked. The tag is composed of an antenna, generally made of copper, and an integrated circuit that is responsible for storing the tag information (Identifier and information programmed by the user) as well as managing the requests received by the RFID reader. It may have different forms depending on the application that is going to be given to the tag, as can be seen in the figure 3.9.



Figure 3.9: Examples of the great variety of existing tags. [9]

According to the operating mode of the tag, two large operating groups are distinguished:

Active: They have an external power supply connected to the tag's integrated circuit, which allows them to obtain a greater reading range than passive tags. In contrast, these tags are more expensive and the useful period depends on the battery life.

Passive: On the contrary, these tags do not have any type of power supply, so the only energy they have is that captured by the electromagnetic field created by the reader. The energy comes from the reader, which is captured by the tag's antenna, processed by its integrated circuit, and is again sent to the antenna to be received by the reader. This phenomenon is known as *backscatter*. These types of tags are the cheapest.

Antenna The antennas convert the electrical energy of the signal sent by the RFID reader into radio frequency waves in order to establish the connection. They do not have any intelligence, they only act as a converter between the air and the integrated circuit formed by the RFID reader.

Different characteristics can be distinguished in the antenna, which we must adjust for the type of application to be developed in order to obtain the most optimal results:

Directivity: Theoretically, it is the ratio of the power density radiated in one direction, at a given distance, and the power density that an isotropic antenna radiating the same power would radiate at that same distance. It indicates the divergence of the radiated power in a particular direction. The figure 3.10 shows the difference between an isotropic and a directive radiation pattern.

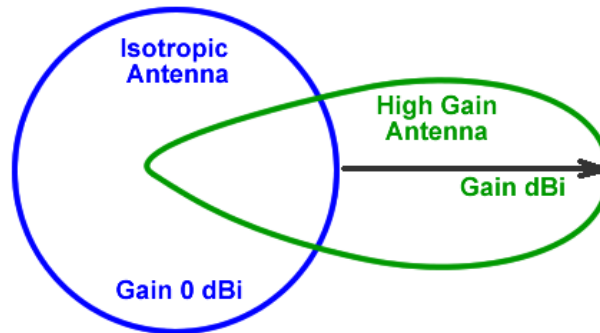


Figure 3.10: Directional and isotropic antenna radiation pattern. [10]

Gain: Quantifies the directivity and electrical efficiency of the antenna, indicating if a higher or lower power is emitted with respect to an isotropic antenna without losses in a certain direction. It is generally noted in dB or dBi. [29]

Polarity: The polarization of an antenna corresponds to the polarization of the signal emitted by it. Thus, the polarization of a signal is the figure described by the extreme of the electric field vector at a fixed point in space located in the plane perpendicular to the direction of propagation. Polarization can generally be of three types: linear, circular, or elliptical. The use of each one depends on the application to be developed, but we must try to ensure that the orientation between the tag and the antenna is adequate. If it is not, it produces large loss due to depolarization, as shown in the figure 3.11.

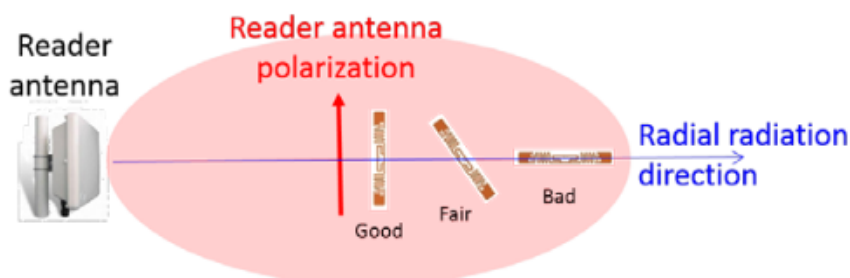


Figure 3.11: Changes in tag reading based on tag polarization and orientation. [11]

RFID programmer It is the element in charge of dumping the information we want to the RFID tag so that it remains stored, although pre-recorded tags with the information provided to the manufacturer in a data sheet can also be acquired.

Depending on the type of programmer, it may or may not have a printer to include other complementary technologies such as bar codes, or information that must be readable without the use of RFID technology such as an expiration date.

Even so, the programmer can be included in the reader itself and have both functions, especially for cases in which the information in the tag has to be rewritten (for example, because a characteristic of the item in which the tag is located is modified during a process and having to withdraw it to take it to a programmer would make technology less effective).

Middleware It consists of the software located in the RFID reader or in a system connected to it, and it is responsible for managing the data obtained from the tags by the reader as well as controlling the devices.

Middleware is a highly specialized software that must fulfill different tasks, among which are:

Device management: It should be able to control the devices that are associated with the system regardless of the type. Printers, RFID readers and tags should be configurable from the middleware.

Data capture: The most obvious function is capturing the data sent by the reader as well as checking the quality of it with cyclic redundancy codes (CRC) if the tags incorporate them.

Filtering data: If the user wishes, the middleware should be able to filter the data to show only those of interest. Even if the user does not set a filter, filtering must also be performed to eliminate duplicates or incorrect readings.

Data storage: The middleware communicates with the database services available to the company, to store the information, in order to have historical series of readings or system status.

Data integration: Depending on the type of application being developed, it may be necessary to transfer information with other applications (Enterprise Resource Planning -ERP-, Supply Chain Management -SCM-, Customer Relationship Manager -CRM-. ..) or with other hardware, which will be done by the middleware.

3.2. Hybrid applications

The use of mobile devices has grown exponentially in recent years making it one of the most used technologies today, unlike previous years where computers were in first place.

There are several operating systems for mobile phones or smartphones, although there have been two which have acquired great relevance, being the majority and occupying more than 90 % of the market share between Android, by Google and iOS, by Apple as evidenced in figure 3.12.

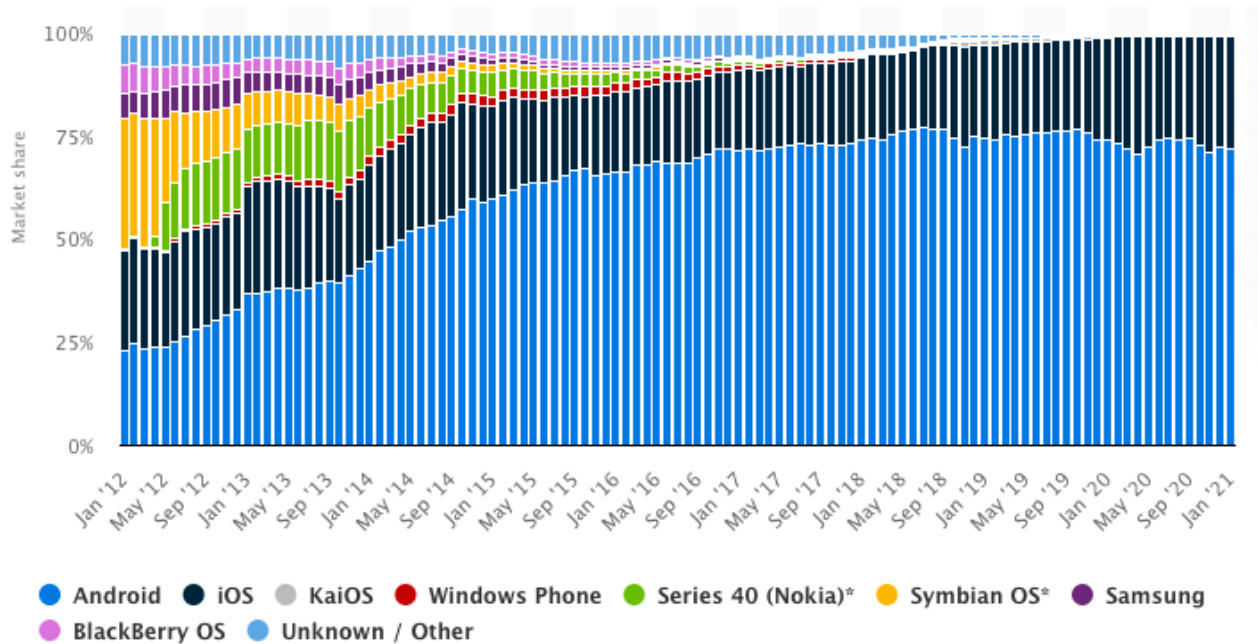


Figure 3.12: Market share according to operating systems. [12]

The fact that there is more than one operating system improves competitiveness, enhances developments and research and offers several alternatives for users, although it is a problem for developers since they should at least duplicate developments (one for Android and another for iOS) if they want to cover practically the entire market and the code is not reusable from one platform to another.

In order to reduce the problems caused by multi-development, different solutions have been created based on different paradigms that allow the majority of the code to be reused for both Android and iOS.

These solutions have been implemented by both external teams (Ionic, Cordova) and the companies that own the previously mentioned operating systems (Google with Flutter or Angular).

Therefore, the paradigms that we find today when developing an application are the following:

Native development: It is offered by the operating system itself, using the programming language chosen by each company (Java for Android and Swift for iOS, mainly). Being the official operating system, it is the one that offers the highest efficiency and performance, as well as full access and control of the elements of the smartphone. In addition, the consistency with the operating system design guides is complete, as they include the same designs. The operation diagram of this paradigm is found in figure 3.13.

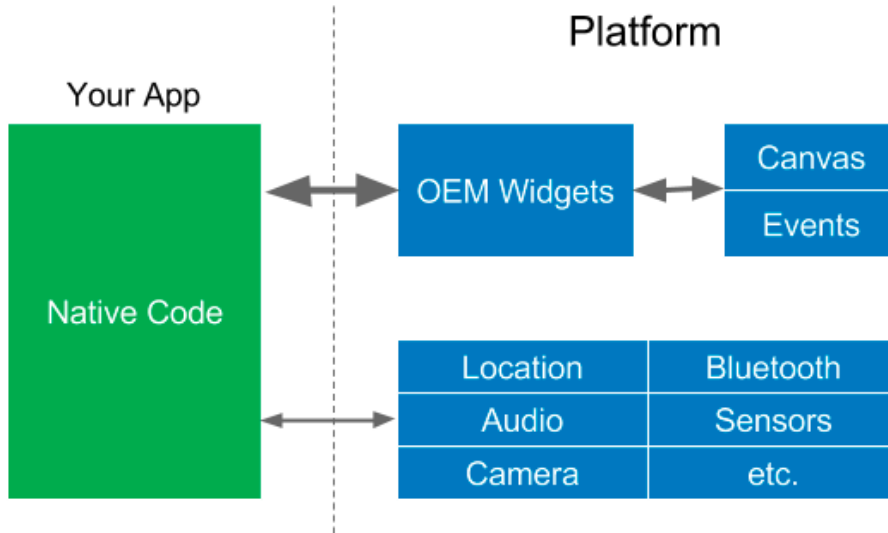


Figure 3.13: Native applications diagram.[13]

Webapp development: Makes use of the "Web View" element to embed a web page within a mobile application. The application being based on web code (generally HTML and JavaScript) becomes much lighter but has great difficulties in terms of access to smartphone equipment such as the camera, sensors ... They must use a bridge that translates calls in JavaScript into calls in native code, which greatly reduces its performance, as seen in 3.14. They were the first paradigms apart from native development that were created, with examples like Ionic, Cordova or PhoneGap.

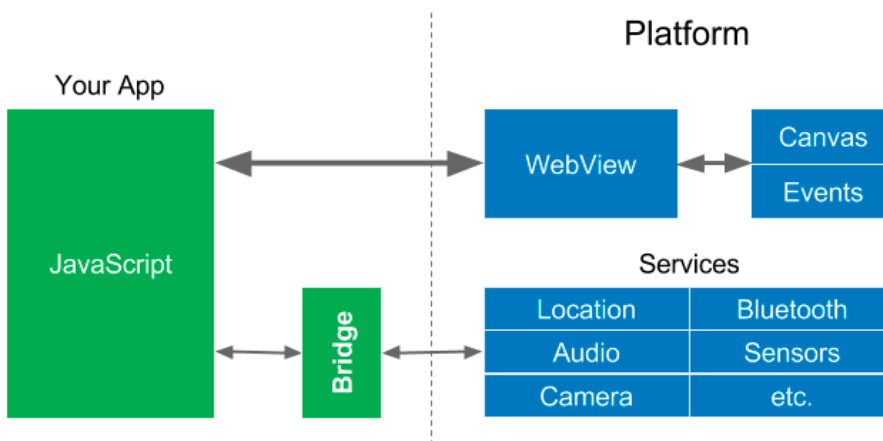


Figure 3.14: Webapps diagram.[13]

Hybrid development: As its name suggests, it is a combination between the two previous ones since they are developed and generally viewed through native widgets, but they have the possibility of accessing the smartphone equipment by making a previously commented bridge, such as shown in figure 3.15. It is usually necessary to rewrite certain parts of the code because the code does not have a total reuse, and it must be compiled for each platform. Angular or React Native should be highlighted as the majority options for this type of development.

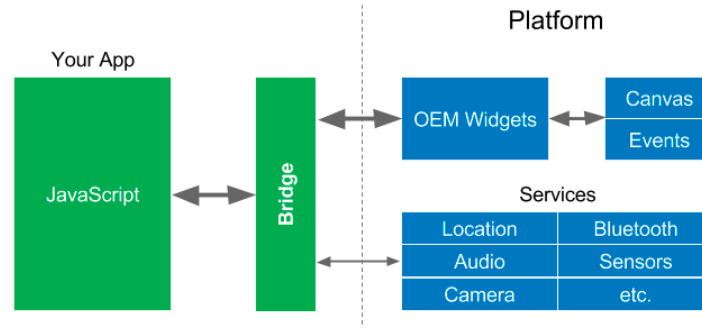


Figure 3.15: Hybrid Applications Diagram.[13]

3.2.0.1. Flutter

It is the main technology of the development of this project. It cannot be faithfully included in any of the paradigms described above, although its characteristics make it resemble a hybrid development framework. The fact that it is not a traditionally hybrid development because Flutter performs an Ahead Of Time (AOT) compilation translating the application to the native code of the platform, which allows it not to need a bridge to access the views or equipment of the smartphone, as evidenced in figure 3.16.

Compiling the application to native code achieves much higher performance than in a traditional hybrid application as well as shorter loading times when starting the application.

Flutter makes use of Widgets, a set of graphical and logical standards that create a class capable of being used in the graphical interface. There are two types of Widgets, *Stateless* (it is not automatically reconstructed, that is, they generally present static content) and *Statefull* (which are automatically reconstructed if the information or the state of the Widget is modified, for example, the drawing of an analog clock).

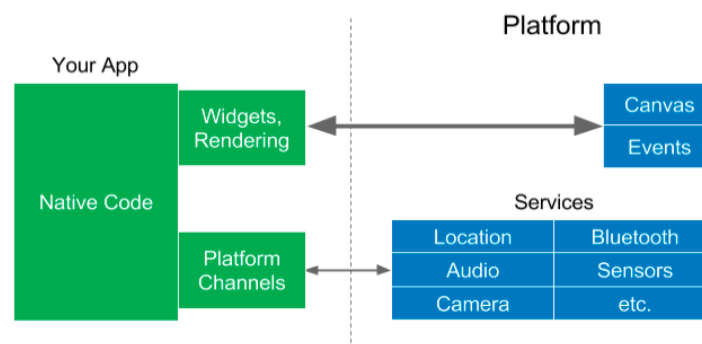


Figure 3.16: Flutter diagram.[13]

4. Methodology

4.1. Materials

This section provides a description of the materials both hardware and software that have been used at some point during the development of the application, its backend or the RFID reader. The basic characteristics of the same are explained and, if necessary, its benefits with respect to another element that offers the same characteristics are commented.

4.1.1. Hardware

4.1.1.1. ESP32

The project requires a hardware controller for all the devices, as mentioned before, it will perform the functions of *middleware* in the RFID project.

The basic characteristics that this hardware must meet are: communication via Bluetooth for connection with the application, communication via serial for managing the RFID reader and control capabilities. We found the ESP32 to be the best tool by fulfilling all the functionalities, having a low cost as well as being backed up by a good community and documentation.

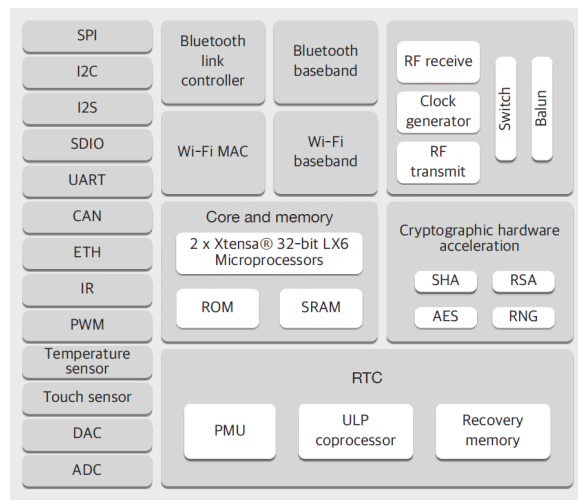


Figure 4.1: ESP32's block diagram. [14]

The ESP32 is a family of dual-core microcontrollers developed by the company *Espressif Systems*. They are marketed as microchips, modules (microchips that include key components, such as an antenna or oscillator crystal), or development kits. Within the modules there are three different types: WROVER (they include PSRAM ¹), WROOM and SOLO (they are composed of single-core microcontrollers).

¹Pseudo Static RAM is an external RAM memory connected to the circuit and that allows expanding the initial memory.

In this case, and taking into account the technical characteristics we will use the ESP32-WROOM-32 [30].

The programming of the ESP32 chips can be done in two ways, by means of the ESP-IDF framework designed in C and C++ languages, or by means of Arduino, using the C++ language,. However, the fact that libraries available for Arduino can be used improves the time spent writing the code.

The following are the technical characteristics of ESP32-WROOM-32:

General

Chip	ESP-32-D0WDQ6
Flash	32 Mbit 3.3V SPI Flash
Crystal	40 MHz Crystal
Operating voltage	3.0 ~ 3.6 V
CPU Frequency	80 MHz ~ 240 MHz

Connectivity

Wi-Fi	802.11 b/g/n (802.11n up to 150 Mbps)
Bluetooth	Bluetooth v4.2 BR/EDR and BLE specification
Interfaces	SD card, UART, SPI, SDIO, I ² C, I ² S, LED PWM, Motor PWM, IR, pulse counter, GPIO, capacitive touch sensor, ADC,DAC
Pinout	36 pines GPIO

Finally, a NodeMCU-type development board has been chosen because it is widely used in the construction and debugging of prototypes. This ESP32-based board facilitates prototyping by including a USB connection, connections through pins and reset buttons. In addition, the low power mode and the small size of the board make it ideal for this project.

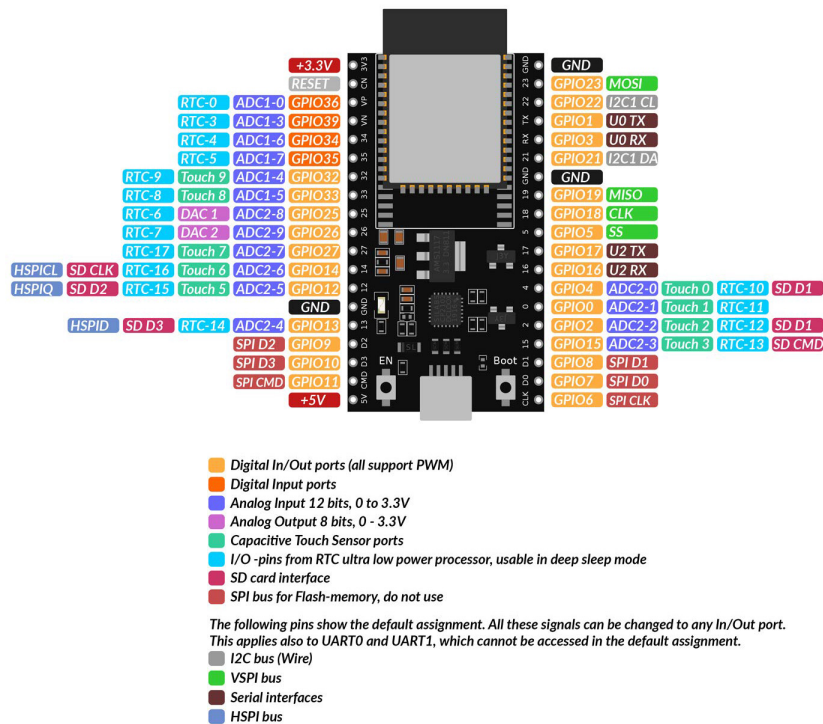


Figure 4.2: ESP32 - NodeMCU's connections. [15]

4.1.1.2. RFID Reader

The choice of the RFID reader was conditioned by the little variety offered by the distributors to which we had access and fulfilled the needs of the project. The needs were to have a serial connection for control from the microcontroller, and operation in the RFID UHF range.

The ThingMagic Mercury6E reader was chosen as it was the only one to meet the previously mentioned requirements. The M6E reader family includes 4 variants depending on the size and reading power although in this project we will focus on the M6E-nano due to its small size.

The most relevant characteristics of the M6E-nano [31] are the following:

General

RFID Protocol	EPCglobal Gen 2V2
Operating voltage	3.3 ~ 5.5 V
Maximum power	0 ~ 27 dBm
Maximum read	200 tags/second
Consumption	0.84 W without transmission
	1.50 W @ 0 dBm
	3.20 W @ 27 dBm

In order to carry out a rapid prototyping the Sparkfun development board was used which implements the M6E-nano chip as well as direct connection to the reader ports. It is interesting to highlight the advantages that this development kit offers compared to the chip itself, for a first approximation:

1. Plate connection by means of pins, without the need for SMT welding.
2. Switch that allows the change between serial connection by hardware or software.
3. Built-in buzzer that can be configured to activate when a tag is detected allowing the developer to focus on other activities instead of viewing the serial connection to check if the tag has been detected or not.
4. Power dissipation through the motherboard since the M6E at high power produces a lot of heat.
5. Integrated antenna for rapid prototyping and IPEX connector to modify the antenna if deemed appropriate.

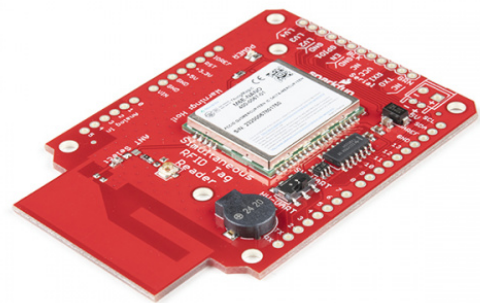


Figure 4.3: M6E reader on Sparkfun development board. [16]

In addition, the fact of being developed by a company focused on *Do It Yourself (DIY)* such as Sparkfun means that there is a library to control the reader quickly from Arduino, as well as a dozen sample codes that allow you to start the tests only by setting a couple of parameters.

4.1.1.3. Antennas

Initially, it was decided to carry out the development with the antenna that the Sparkfun's RFID reader integrates. However, due to the low reading range (less than 10 centimeters), solutions allowing greater range to cover the entire backpack from a single point had to be found.

In order to achieve it, three different antennas were acquired as shown in the table 4.1 in order to test the response of the RFID reader and its operation according to the antenna that was attached to it. Different measurements were made in order to choose the most suitable for the application, as distinguished in the data in figure 6.4.

	ANT-868-CW-HWR	PENTABAND DIPOLE GSM	SWIVEL HINGED RUBBER DIPOLE
Frequency (Hz)	853-883	824-894	862-870
Gain (dBi)	2	0	2
Impedance (Ω)	50	50	50

Table 4.1: Main characteristics of the antennas.

4.1.1.4. Spectrum analyzer

The need of a spectrum analyzer has become evident when taking radiated power measurements. A spectrum analyzer is a piece of equipment, in this case portable, that measures the power level and the frequency within a specific space of the radioelectric spectrum. This device allows the spectral components of the signal to be displayed on its screen indicating on the ordinate axis the spectral content of the signal on a logarithmic scale of decibels and the frequencies on the abscissa axis, allowing the latter to be modified according to the selected parameters.

In order to analyze data in this project the Agilent FieldFox N9912A analyzer has been used. The most relevant characteristics of which are shown below:

General

Frequency range	2 MHz ~ 4 GHz
Connectivity	USB, Ethernet, MiniSD, Audio
Precision	0.1 dB
Range	+30 dBm ~ -170 dBm
Weight	2.8 Kg



Figure 4.4: Keysight N9914A Spectrum Analyzer. [17]

4.1.1.5. Tags

Another very important aspect in RFID communication are tags. Elements that are placed on the item to be inventoried and that are in charge of answering to the RFID reader after it makes a query to see what elements are on its reading radio.

In this case, two types of tags of different sizes have been used since there are medicines of reduced size that need adhesive labels to be as small as possible. In addition, it has served to make a comparison in terms of signal quality for both types of tags. In the table 4.2 and figure 4.5 it is observed that the only difference between both tags is the size of the antenna.

	RF600598	RF600600
Format	Wet-Inlay	Wet-Inlay
Antenna dimensions	70.0 x 14.5 mm	41.4 x 16 mm
Face Sheet	White PET	White PET
Frequency	860 – 960 MHz	860 – 960 MHz
RFID Protocol	ISO-18000-6C, EPC Class 1, Gen 2	ISO-18000-6C, EPC Class 1, Gen 2
EPC Memory	96 bit	96 bit

Table 4.2: Comparison of the characteristics of both tags.

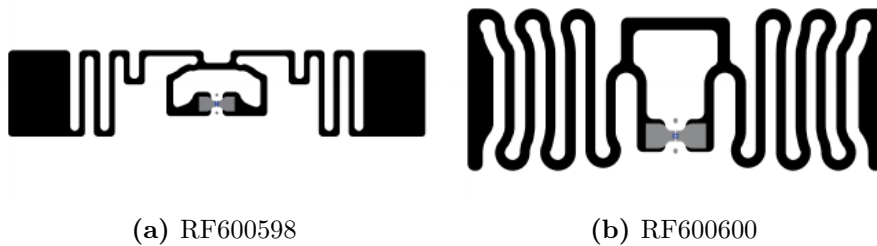


Figure 4.5: Design differences between tags.[18]

4.1.2. Software

4.1.2.1. Flutter

Flutter is a development framework created by Google for cross-platform application programming. By allowing the application to be compiled for both iOS and Android starting from the same base code it reduces development time significantly or increases the potential users of the application by not depending only on one operating system.

Rumors about it began in 2015, when the Dart developer conference was held and the framework was unveiled as a prototype under the name *Sky*. Years later, in 2018, Google publishes the first stable version with the definitive name of *Flutter*. The framework employs the Dart programming language and can be compiled into native applications for Android, iOS, Google Fuchsia, Windows, macOS, Linux or web.

The Flutter kernel is developed in C, C++, and Dart. This framework was conceived with high performance, good versatility, and an attractive design in mind.

The structure of an application developed in Flutter is divided into Widgets, small code modules interconnected and replicable according to the needs of the app. A large number of Widgets are available in the repository created by the community allowing to reduce work time or include more advanced functionalities than if it had to be developed from scratch each time. In addition, the framework itself includes visual Widgets based on the most popular graphical interfaces, Material Widgets makes use of Android's material design, and Cupertino Widgets incorporates Apple's design to resemble a native application as closely as possible.

Another advantage offered by this framework is the possibility of *hot reload*, a paradigm through which the application's graphical interface is immediately reloaded after each change, allowing to develop and layout in a much more agile way, as well as perform experiments or fix bugs in no time.

The figure 4.6 shows the different calls from Flutter to the native elements of operating systems, although a large part of Flutter's own components remain unchanged for both paradigms.

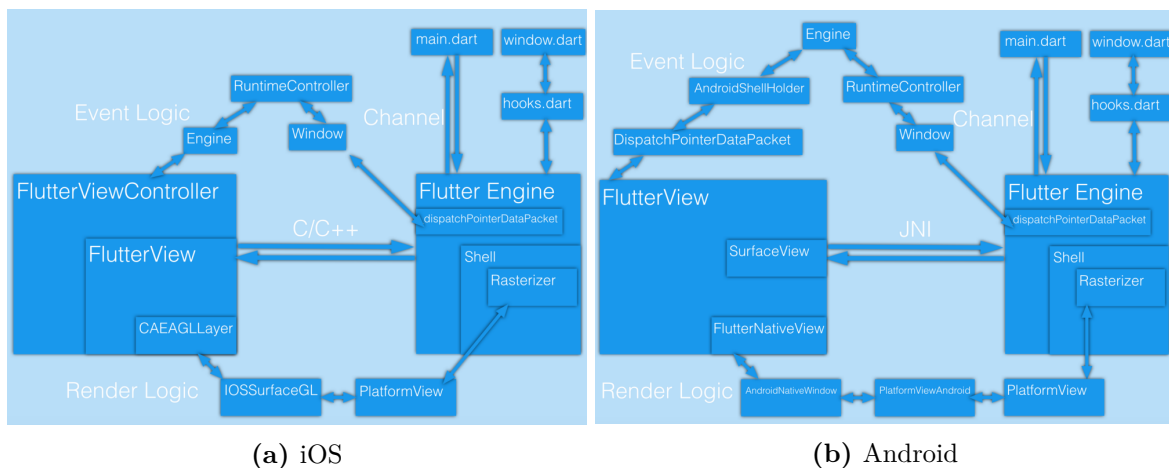


Figure 4.6: Execution logic according to operating system. [19]

4.1.2.2. Adobe XD

The application must meet two main characteristics: being fast and being suitable for professionals. The first requirement will be achieved through Flutter, by choosing a framework that offers great robustness.

However, to solve the second particularity it was necessary to develop it jointly with the professionals who are going to use it. To do this, a first pooling was done identifying the key processes that the application should comply with and later a preliminary design was made thanks to the knowledge and experience of having been working in an ambulance. This first design was translated into an Adobe XD prototype which allowed it to be reviewed used and refined by the healthcare team who would end up using the application.

Adobe Experience Design is free software distributed by Adobe that allows you to create very realistic application prototypes thanks to the ability to structure and interact as if it were a finished app. Among the most notable features of this program we find:

- The use of reusable **components**, as Flutter would do with Widgets, it allows us to create designs of a specific area (for example, a button) and later replicate or modify it according to the needs of the design.
- Incorporates **states** into the prototype, which allows linking different views by clicking on the buttons or graphic elements, to give the feeling of a functional application and not a static application.
- The **repeat grid** allows us to automatically copy components following equidistant gaps, ideal for creating lists.
- It allows us to develop prototypes following the **official style guides** of the Android and iOS operating systems by having templates for their use.
- It simplifies the process of reviewing a design by being able to share a link with the design to those interested and for them to make **comments** about it as evidenced in figure 4.7.

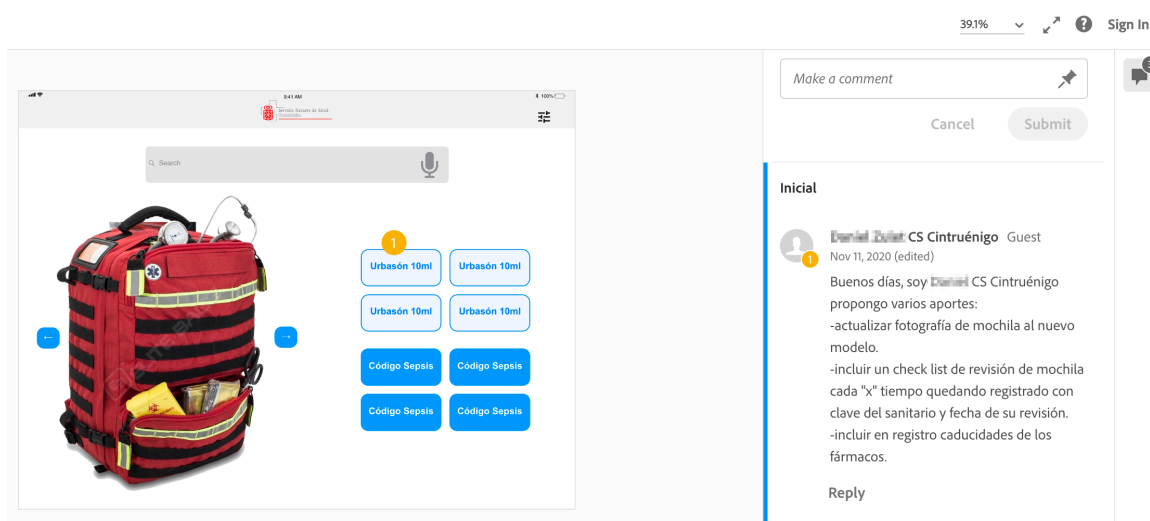


Figure 4.7: Example of a comment in AdobeXD next to the component it refers to. [Own]

4.1.2.3. API (Flask)

An Application Programming Interface (API) is the set of functions, methods and routines that allow modules and applications to access a set of services offered by an entity, facilitating access to the backend and, above all, allowing the reuse of these functions in different types of applications or platforms.

The implementation of this service has been done through Flask, a Python microframework capable of designing and developing web applications. It was developed by Armin Ronacher in 2010, currently positioning itself as one of the most powerful frameworks in his language.

In addition, it makes use of external dependencies such as Jinja2 for structuring its HTML documents, although as we will use it as an API and will only need returns of files in JSON format it will not be necessary to use it. Flask is built following the REST architecture which allows queries to be made simply and quickly through the HTTP protocol.

This microframework has been chosen for the speed of prototyping and development, being able to have a functional API with less effort than in other frameworks. In addition, another reason was the possibility of using Docker to encapsulate the entire system formed by the API and the database in order to replicate it on other servers (for example, the Government of Navarra) if any day was necessary.

To use the API in an environment other than the local one, a public IP address of the endpoint to which the requests will be made is required. In this case, Amazon Web Services has been chosen as the provider of said endpoint and API infrastructure, as it is a scalable provider with free options that cover current development needs.

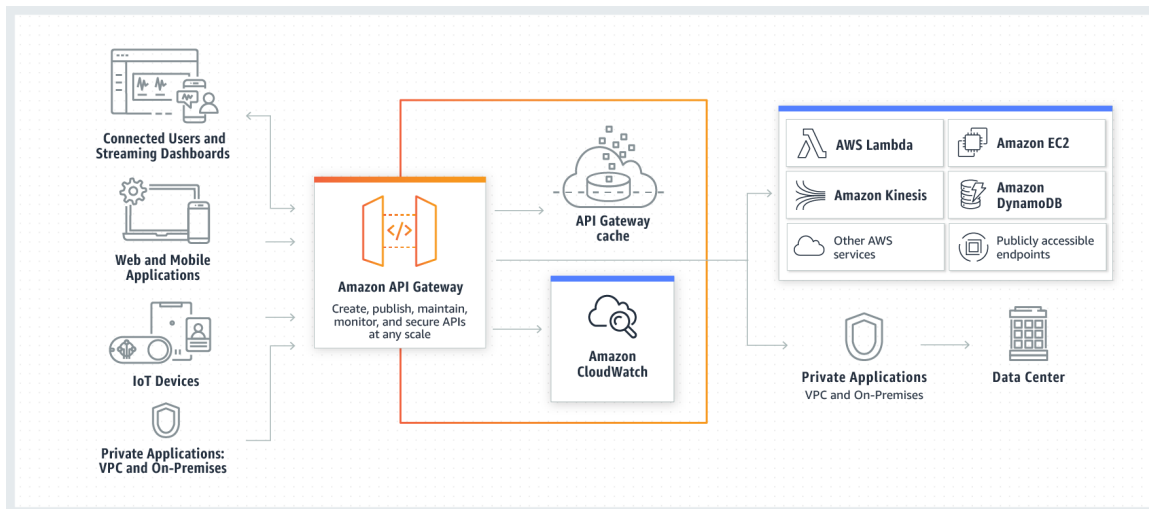


Figure 4.8: Diagram of the API and Amazon services. [20]

4.2. Methods

In the previous section, the elements of both software and hardware that will be used in this project have been defined. In this section, a description will be made of how said equipment has been used to achieve the objectives proposed within the framework of this project. In addition, the operation of the application that will serve as a basis for the healthcare team to locate the drugs within the emergency kits will be explained in depth.

4.2.1. Software

4.2.1.1. Flutter

In order to work with Flutter, the first thing we had to do was install the appropriate development environment. We installed Flutter, Visual Studio Code as a text editor, as well as XCode and Android Studio to be able to create simulators and sign the final codes of the application.

Flutter itself offers a command to verify the quality of the installation and the elements that are still required to be installed, as seen in the 4.1 code.

Listing 4.1: Flutter doctor command

```

1 inigogarcia@MacBook-Pro-de-Inigo mapsmochila % flutter doctor
2 Doctor summary (to see all details, run flutter doctor -v):
3 [OK] Flutter (Channel beta, 2.1.0-12.2.pre, on macOS 11.3 20E5210c darwin-x64, locale es-ES)
4 [OK] Android toolchain - develop for Android devices (Android SDK version 30.0.3)
5 [OK] Xcode - develop for iOS and macOS
6 [OK] Chrome - develop for the web
7 [OK] Android Studio
8 [OK] VS Code (version 1.54.3)
9 [OK] Connected device (1 available)

```

Subsequently, the application was created with the command `flutter create mapsmochila` and a folder hierarchy was established that would help organize the code and improve productivity. The most interesting used folders and their description are these:

assets: It contains information related to static elements of the application, such as images.

ios: It is the folder that contains the iOS project, to open it from the XCode.

android: Like the previous one, but in this case it contains the code for the Android application.

web: It includes the compiled application as a web page, useful for debugging without the need for an emulator.

lib: It stores all the code in Dart language, it is the core of the Flutter application.

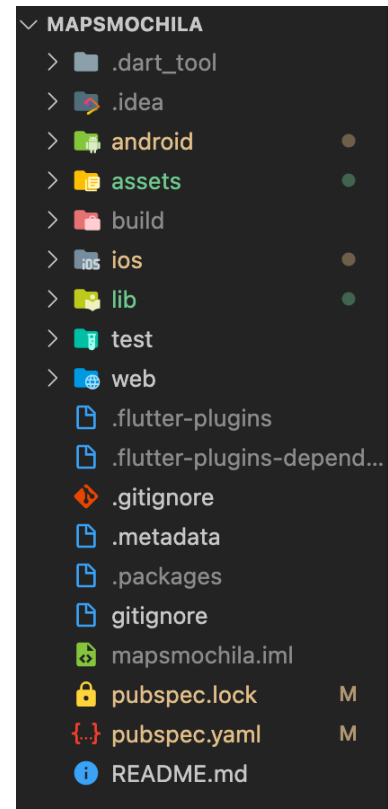


Figure 4.9: Folders structure used

4.2.1.1.1. App screens

Initial This screen shows an overview of the backpack that can be rotated to access the side pockets. From there, clicking on the pocket of interest leads to another screen that specifies the content of said pocket. In addition, some 'quick' links are included to click on the medicines that you may need faster access.

Search list In this page appears a list of all the elements present in the backpacks. It allows searching both in writing and by voice, since using nitrile gloves makes writing on a smartphone difficult.

Element page It is one of the main screens as it shows information about the location of the element, as well as its loading dose if it is a drug and the technical data sheet.

Item page It allows to carry out an inventory manually, indicating the section of the backpack that is currently being checked.

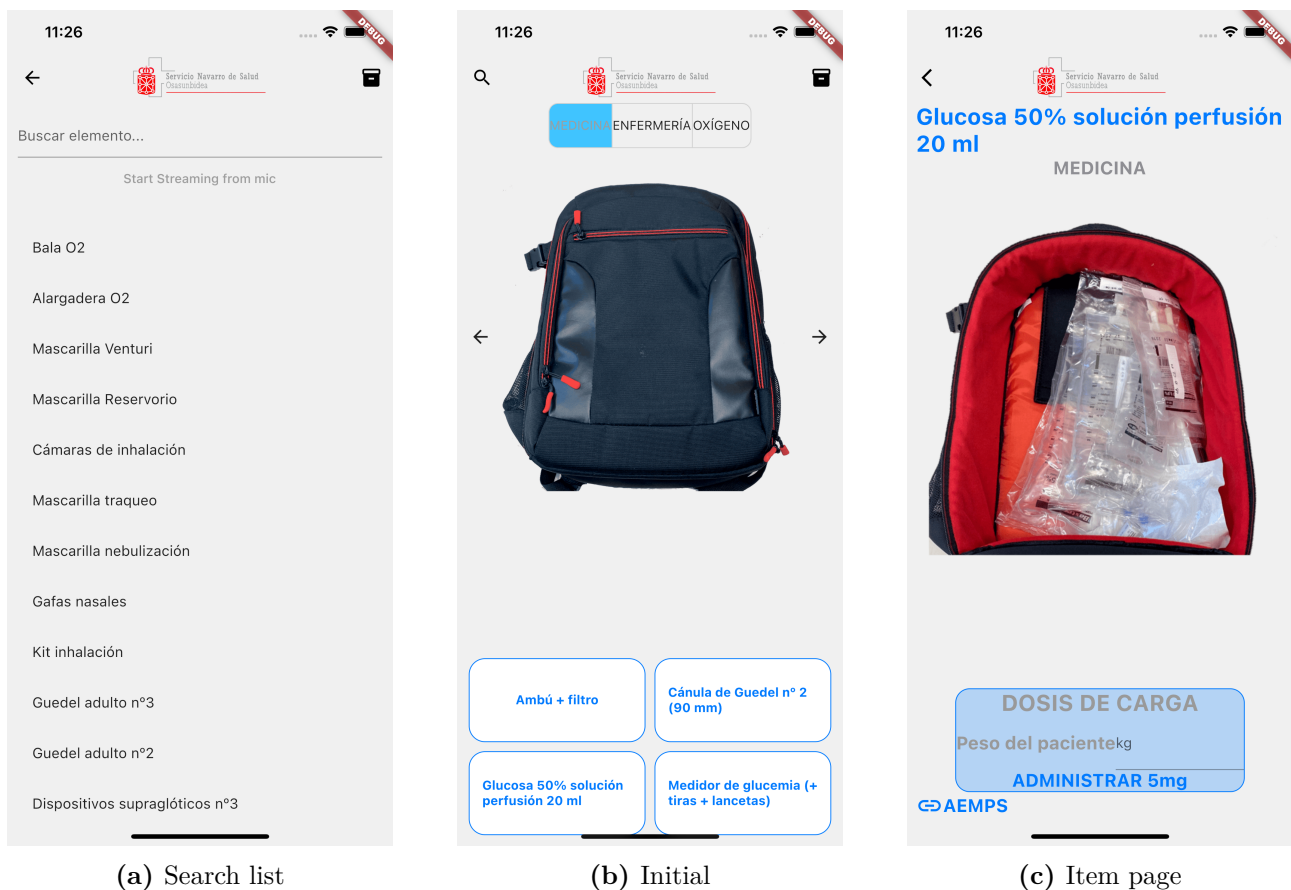


Figure 4.10: Most important pages within the application

4.2.1.2. API (Flask)

Once the different views that the app would have and the design had been established, a study and subsequent design of the data models that would be necessary was carried out, in order to adapt them as much as possible to both the needs of the developer and the healthcare professionals. To do this, a first sketch was made which was subsequently agreed between both parties and improved in the aspects that were necessary. Initially, the need to have two data models was established which are described below.

The first, *ItemModel*, will correspond to the items that will populate the backpacks and will be defined by the following fields:

id: An auto-incremented id to have a unique identification of the item.

name: Name to be displayed in the application. It will correspond to the commercial name, active ingredient or description of the item.

qty: The quantity of said item that must be carried in the medicine backpack to meet the requirements established by the Navarrese Health Service.

expiration: Will store the expiration date of the item if it exists. It is currently not operative since the Navarrese Health Service cannot offer such information.

starred: It indicates the items that should be highlighted on the initial screen of the application.

location _id: It refers to the **id** of the *LocationModel* to know the location of the item inside the backpack.

bag _id: It refers to the type of backpack (medicine, nursing or oxygen therapy). It has not been necessary to create a specific model for said information because only 3 fixed values would be used.

aemps: It indicates the information related to the medicine in the Spanish Agency for Medicines and Health Products (AEMPS).

dose: For those items that are drugs, it expresses the dose in milligrams per kilogram of the patient to calculate the necessary loading dose to administer.

Listing 4.2: Item model

```

1 class ItemModel(db.Model):
2     __tablename__ = 'items'
3
4     id = db.Column(db.Integer, primary_key=True)
5     name = db.Column(db.String(80))
6     qty = db.Column(db.Integer)
7     expiration = db.Column(db.String(30))
8     starred = db.Column(db.Boolean)
9     location_id = db.Column(db.Integer, db.ForeignKey('location.id'))
10    location = db.relationship('LocationModel')
11    bag_id = db.Column(db.Integer)
12    aemps = db.Column(db.String(30))
13    dose = db.Column(db.Integer)

```

The second model, *LocationModel*, collects the locations where these items will be found with the following properties:

id: An auto-incremented id to have a unique identification of the location.

name: Name to be displayed in the application. It will correspond to a brief description of the location.

bag_id: It refers to the type of backpack (medicine, nursing or oxygen therapy). It has not been necessary to create a specific model for said information because only 3 fixed values would be used.

inner: It indicates if the referenced location is inside the backpack or is an outer compartment.

url: It includes the URL to an image of the location to display in the application.

Listing 4.3: Location model

```

1 class LocationModel(db.Model):
2     __tablename__ = 'location'
3
4     id = db.Column(db.Integer, primary_key=True)
5     name = db.Column(db.String(80))
6     bag_id = db.Column(db.Integer)
7     inner = db.Column(db.Boolean)
8     url = db.Column(db.String(80))

```

Afterwards, the necessary procedures were established to acquire and send data from the application as well as the endpoints to access them. Again, a revision of the application was made establishing which areas of it would need to collect information from the database and the access points were established accordingly.

The following list indicates the endpoints of each procedure as well as the HTTP methods that they support in the requests.

Listing 4.4: API's endpoints

```

1 #----- ITEM -----
2 api.add_resource(Item, '/item') # [POST] Create new item
3 api.add_resource(ItemSingle, '/item/<int:id>') # [GET, DELETE, PUT] Show, delete or modify an item
4 api.add_resource(ItemList, '/items') # [GET] List all items
5 api.add_resource(ItemStarred, '/items/starred') # [GET] List all starred items
6 api.add_resource(ItemLocation, '/items/<int:location_id>') # [GET] List all items within a location
7
8 #----- LOCATION -----
9 api.add_resource(Location, '/location') # [POST] Create new location
10 api.add_resource(LocationSingle, '/location/<int:id>') # [GET, DELETE, PUT] Show, delete or modify a location
11 api.add_resource(LocationList, '/location/all') # [GET] List all locations
12 api.add_resource(LocationInner, '/location/inner/<int:bag_id>') # [GET] List all locations inside a backpack

```

All possible routes within the API were tested with the Postman tool to simulate HTTP requests and check their operation and suitability for needs. So for example, a request to `/item/2` currently returns the following information:

Listing 4.5: API's response

```

1 [{
2     "id": 2,
3     "name": "Desinfectante manos",
4     "qty": 1,
5     "expiration": null,
6     "starred": false,
7     "location_id": 1,
8     "bag_id": 1,
9     "aemps": "n/a",
10    "dose": null
11}]

```

5. Simulations

In order to disseminate the knowledge acquired during the development of this work, a paper is being sent to a scientific journal. This section explains the measurements that have been carried out to compare them with the simulated data.

5.1. Methods

5.1.1. Physical measurements

A measurement of the power emitted by the RFID reader was carried out, in order to compare it with the results obtained in the simulation. To do this, the reader was put in capture mode (that is, sending response requests to the tags) and the data obtained with the Agilent FieldFox N9912A spectrum analyzer was taken, connecting to both the OmniLOG 30800 antennas. The transmit power was set to 27 dBm, and the spectrum analyzer focused on the 867 MHz band.

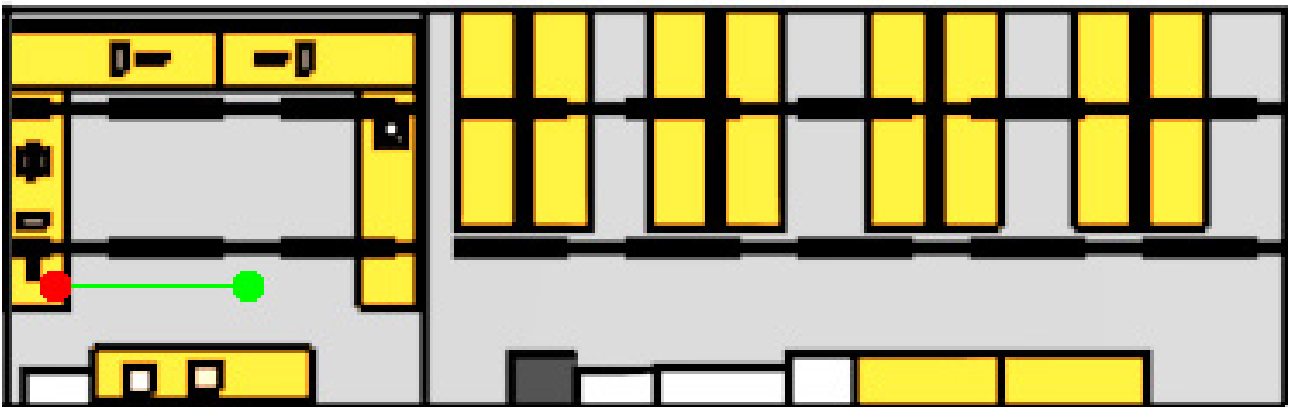


Figure 5.1: Emitter (red) and receiver (green) in the Luis Mercader laboratory (UPNA).[21]

The reader was set at a table in the Luis Mercader laboratory of the UPNA with the antenna perpendicular to the ground as marked by the red dot of the 5.1. For its part, the spectrum analyzer was placed in various positions between 0 and 3 meters, every 10 centimeters, in a straight line and taking measurements at each point, as shown in figure 5.2.



Figure 5.2: Spectrum analyzer and reader setup. [Own]

Prior to taking measurements, a short-distance test was carried out to locate the central frequency of the transmission. Since the RFID standard contemplates different channels in the range of frequencies available for a certain region (the European in this case, which covers from 865 to 868 MHz) this step was necessary. In addition, a direct measurement was made with an RG coaxial cable with 3.5mm SMA connectors to measure the power transmitted by the reader without losses due to the antennas, expressed in figure 5.3.

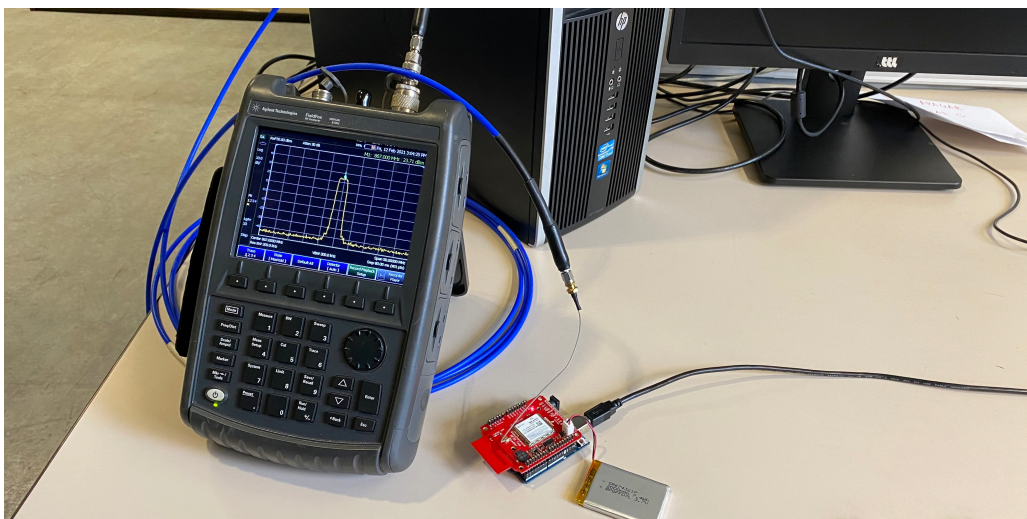


Figure 5.3: Configuration with coaxial cable. [Own]

5.2. Results

5.2.1. Measured results

Then the measurements were taken every 10 centimeters as previously explained, obtaining the following results:

The laboratory, being full of objects, makes measurements very difficult to be carried out without

interference or even without the effects of multipath propagation. This last reason is the main one why in the following graph of the figure 5.4 a linear decrease of the received signal is not observed.

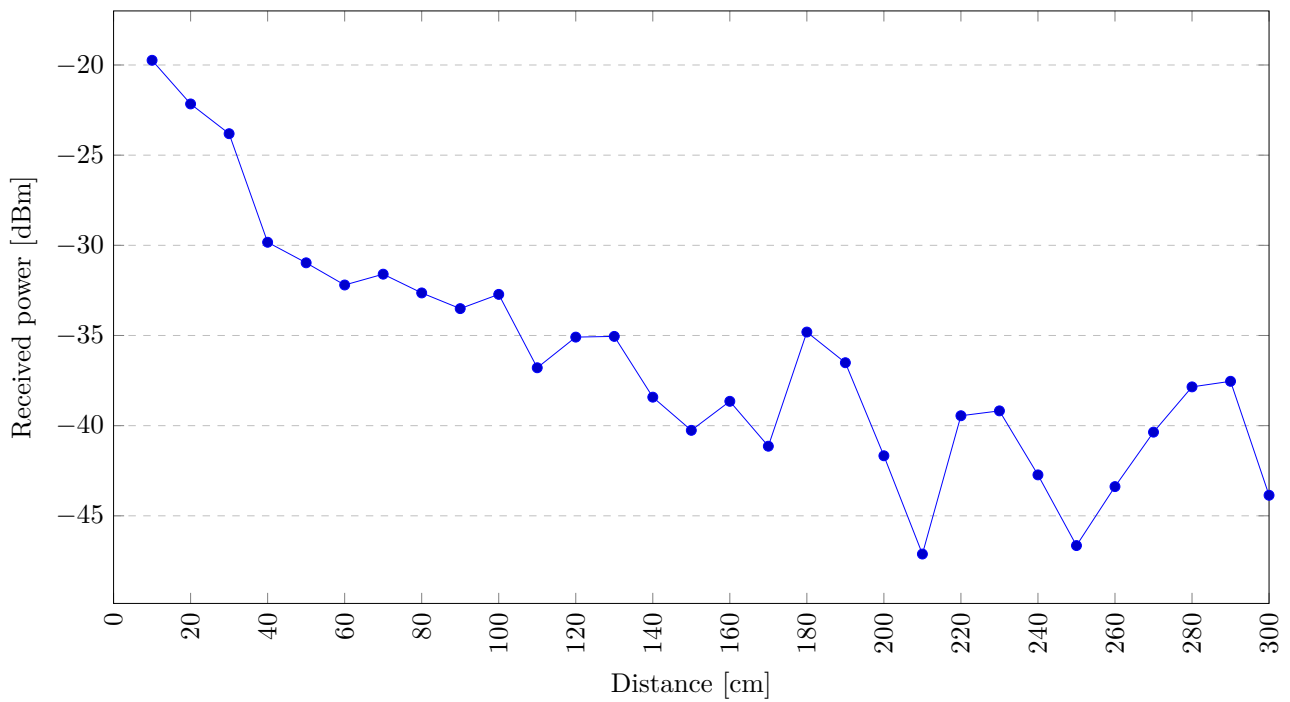


Figure 5.4: Received power measurements every 10 cm.

5.2.2. Simulated results

This comparative study between the simulations and the measured data is being prepared for the possible presentation of a paper, so the work has not been completed.

6. Results

Before carrying out the studies, the possible problems that the system would face were raised. First, an attempt was made to establish the maximum scope offered by the system, to see if it was enough according to the needs of the project. Subsequently, several studies were carried out placing the tags in different orientations, powers and locations to check how they behaved in different cases that the project would have to face if it were used in the day-to-day life of an emergency unit.

6.1. Line-of-sight propagation

The first analysis was done through NFC technology since it offers several advantages over UHF RFID. Especially, these advantages are the ease of finding equipment and the much lower price of an NFC reader than a UHF one.

For this study, the Adafruit PN532 reader was used connected to an Arduino UNO connected to it as seen on image 6.1. The readings that were achieved showed a range of less than 10 centimeters, something completely useless for this application due to the dimensions of the backpack.

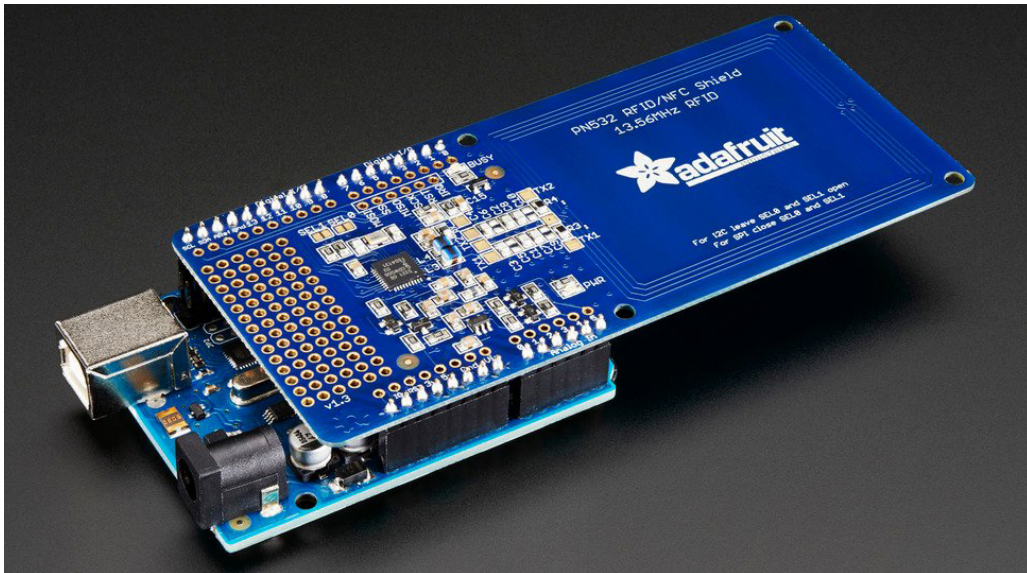


Figure 6.1: Adafruit PN532 reader. [22]

As the use of Adafruit PN532 was not possible due to range limitations, we had to seek for another reader: the Sparkfun M6E RFID Simultaneous Reader, as seen in figure 6.2. In this section, we want to measure the scope offered by the RFID reader selected for the project in order to check its suitability according to the observed needs. To do this, the code of a sample project offered by the reader's library is taken and compiled on an Arduino UNO connected to the reader board. In addition, a measurement environment is established indicating the distance from the emitter every 10 centimeters.



Figure 6.2: Configuration for taking measurements. [Own]

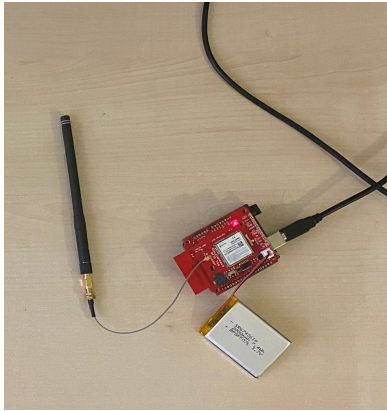
Once the configuration is finished and with the code uploaded to the microcontroller a serial connection is opened with it to collect the information it is reading. On this first occasion, we realized that the reader's reach is not more than 10 centimeters in the best of cases, a measure completely insufficient for the needs of the project, so solutions had to be found.

After reviewing the RFID reader documentation, the possibility of increasing the range in two ways was observed:

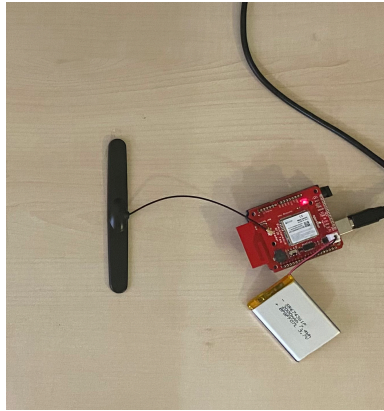
Increasing the current: It must be taken into account that until now the reader was being powered by means of a USB cable which generally cannot offer more than 500 mA. This amount of current was insufficient for the power needs presented by both the reader and the Arduino board. It was decided to solder a JST connector for external power by a 2000 mAh battery.

Connecting an external antenna: The antenna integrated by the circuit does not have the minimum characteristics in terms of gain and directivity desirable for the application. The reader development kit allowed modifying the circuit to add an external antenna through an IPEX connector, which later left the door opened for making measurements with different antennas and choosing the most appropriate one.

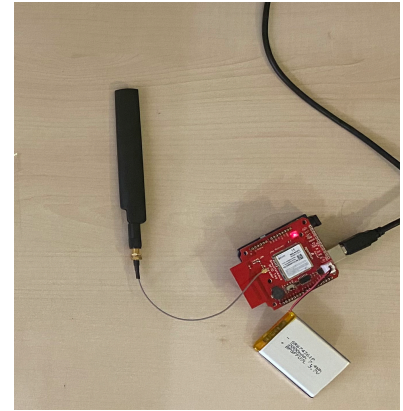
Once the improvements were made to increase the range of the reader, it was set to the maximum transmission power (27 dBm) to measure the maximum reading distance. Likewise, and as mentioned, three different antennas have been tested: *ANT-868-CW-HWR* 6.3a, *PENTABAND DIPOLE GSM* 6.3b and *SWIVEL HINGED RUBBER DIPOLE* 6.3c represented in the image 6.3.



(a) ANT-868-CW-HWR type antenna.



(b) PENTABAND DIPOLE GSM antenna.



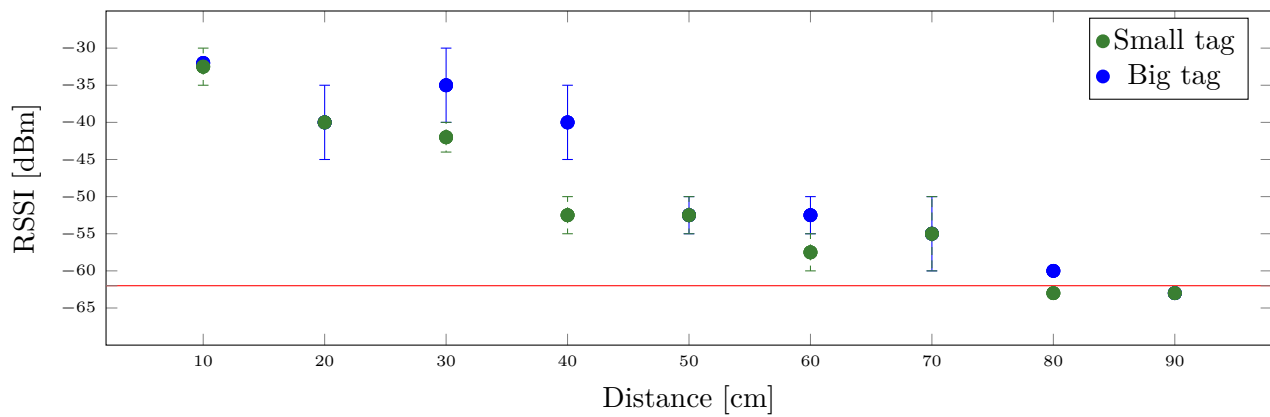
(c) SWIVEL HINGED RUBBER DIPOLE antenna.

Figure 6.3: System configuration with different antennas. [Own]

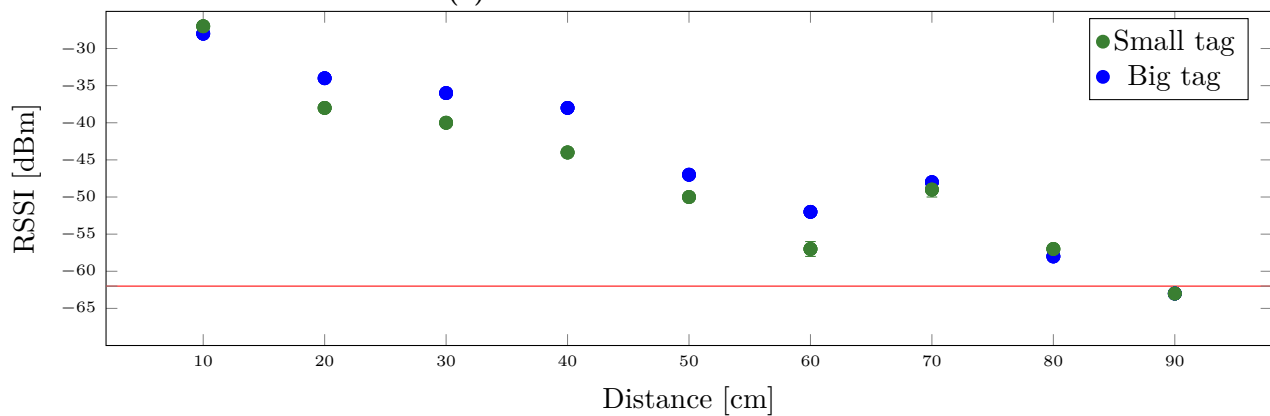
For the measurement, the Received Signal Strength Indicator (RSSI) level has been taken into account since it quickly and easily indicates the quality of the signal. In addition, the library itself incorporated the calculation of said information, thus simplifying the process.

The RSSI is an approximately linear indicator in the conditions in which the data were collected (we must take into account the existence of interferences, reflected rays, scattered rays ...) and is very similar to the power level received by the reader RFID. Furthermore, the measurements were made taking into account the two types of tags to be used, in order to evaluate the differences between one and the other in terms of signal quality.

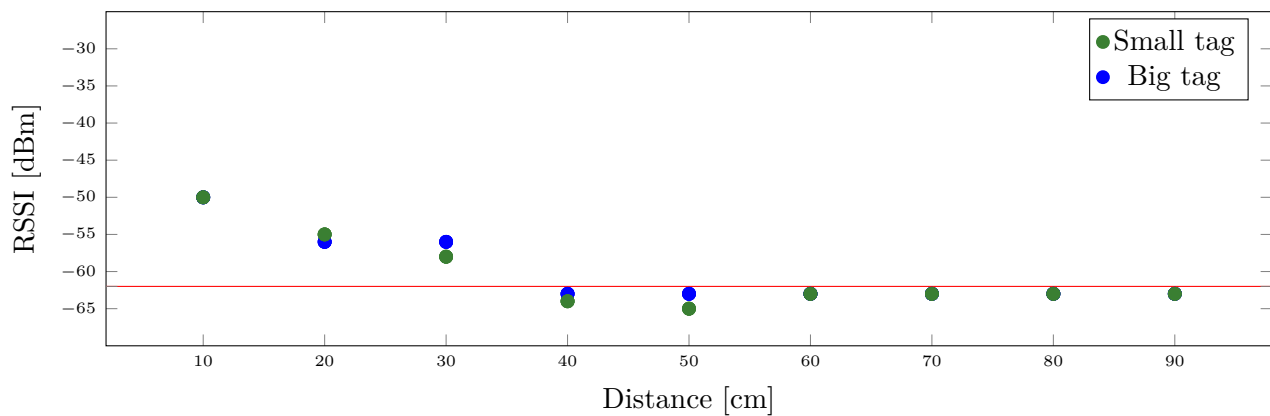
In the figure 6.4 there are three graphs with the results obtained, indicating the reading distance, the RSSI value for both the large and small tag, and a red line at the reading limit . We observe that both the antenna 6.4a and the 6.4c offer worse results, since the first has a great variability in terms of the data obtained and the second has a very low range. Therefore, the most suitable antenna for the project is the PENTABAND DIPOLE 6.3b due to the results in figure 6.4b.



(a) SWIVEL HINGED RUBBER



(b) PENTABAND DIPOLE



(c) ANT-868-CW-HWR

Figure 6.4: RSSI of the tag according to the type of antenna.

6.2. Range with backpack

Subsequently, a similar measurement to the previous one was carried out but with the RFID reader inside the backpack, in which it will be a final location.

This test was carried out in order to obtain the range of the signal that passes through the backpack to the outside, as shown in figure 6.5. Such a measure can be useful to take into account the possibility of false readings of materials from other backpacks if they are placed too close and the reading range is too wide.



Figure 6.5: Configuration for measuring the range with the reader inside. [Own]

The data obtained were those of the figure 6.6, again establishing a power of 27 dBm and taking measurements every 10 centimeters. There is a significant reduction in the range of the signal from the initial 90 cm to the current 40 cm.

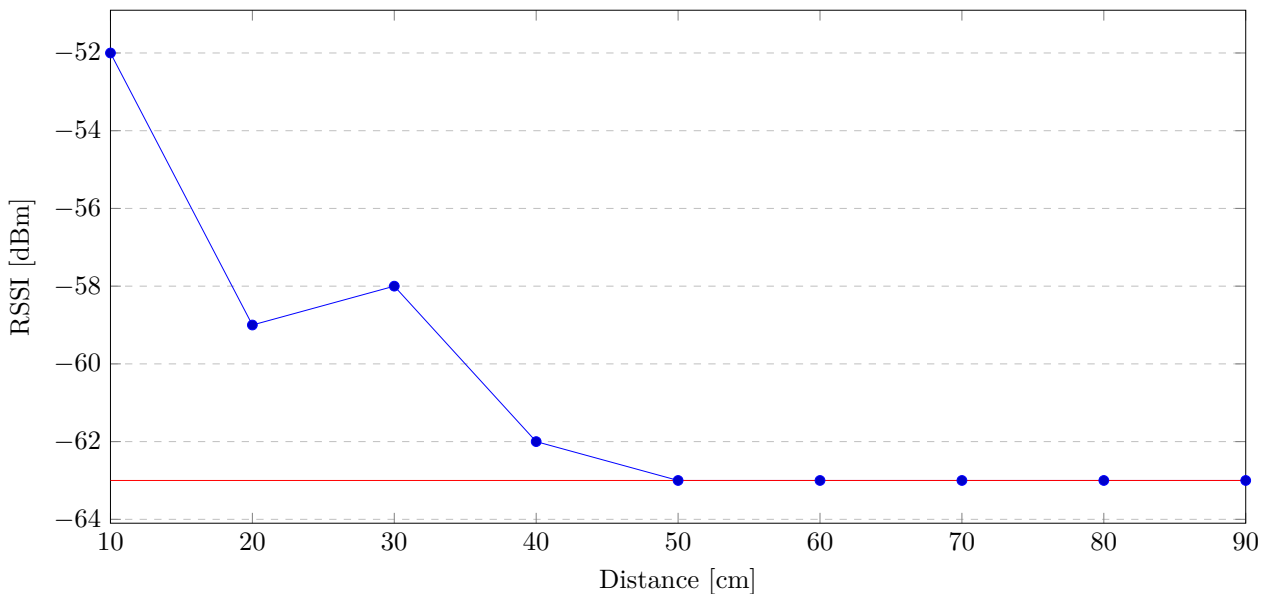


Figure 6.6: Power measurements received every 10 cm inside the backpack.

6.3. Tag orientation

It must be taken into account that the orientation of the tags with respect to the antenna will be impossible to establish in a certain one in real life since during an emergency situation it will not be a priority for the health workers nor would it be feasible to force them to orient the tags in one specific direction.

For this reason, a study has been carried out as shown in the figure 6.7 on the effect of orientation on the quality of reception of a signal since the polarization of a wave is a very important characteristic and its depolarization is one of the major causes of transmission loss.



(a) Approximate location of the RFID reader and antenna.



(b) Location of the two tags used in the backpack.

Figure 6.7: System configuration. [Own]

Although worse data (figure 6.8) have been obtained on the quality of the signal in the tag that was not correctly polarized with respect to the RFID reader antenna, the differences have not been noticeable or maintained over time, only in specific cases. Therefore, it is estimated that although not being polarized correctly degrades the measurement, it is a negligible degradation for the purpose of this work.

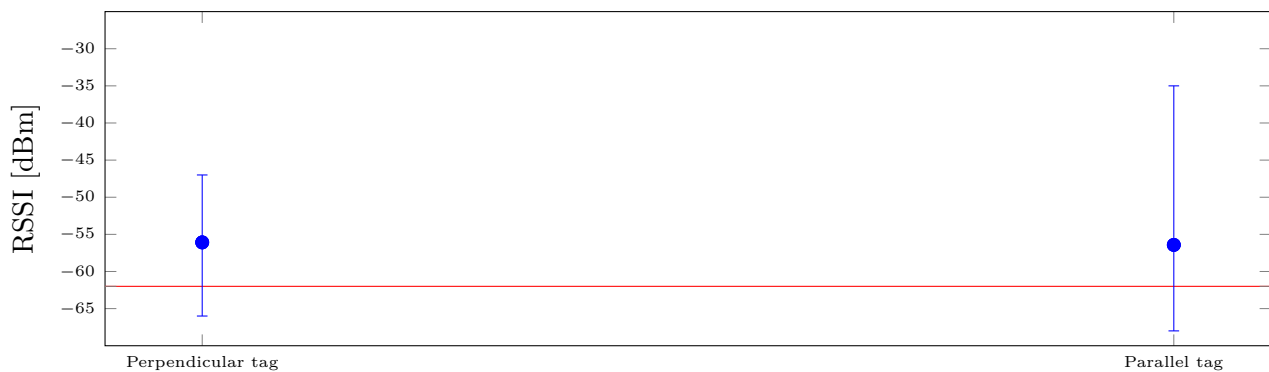


Figure 6.8: RSSI according to the orientation of the tag.

6.4. Range in non-ideal situations

Until now, the measurements taken were in situations that put the RFID reader in a very good position in terms of contact with the tags. In a real application these situations will not be the case so the next samples have focused on simulating a scenario as realistic as possible to analyze the behavior of the system and its development based on the requirements established by the health personnel.

6.4.1. Tags adhered to liquids

Liquids have a different dielectric constant and therefore a different conductivity than air or other transmission media. This fact supposes an important attenuation in the electromagnetic waves that circulate through them, being able to cancel the signal sent by the tag towards the receiver, or absorbing all the energy sent by the emitter to the tag.

For this reason, measurements have been carried out with the two most common elements in these kits, the 100 and 500 ml saline bags, placing them as shown in the figure 6.9. The 100 ml saline bag had the tags attached as the 500 ml one.

A first measurement has been made using for the 500 ml serum and three different tags, one located in the backpack, another located in the serum above the liquid, and the last located in the serum but outside the liquid. The results have been those obtained in figure 6.10.

In this measurement the three tags can be read with an average RSSI value of -55 dBm. Although the three tags are read, it must be taken into account that the measurements received in terms of the RSSI and the number of readings (as shown in the figure 6.11) is much lower in the one attached to the saline, having performed only 4 readings during the entire measurement time compared to more than 600 for the other tags.

The fact that a tag located below the physiological saline is read, but not that of the serum that is closest to the reader, is due to the absorption of the signal by the serum and to the multipath propagation that occurs by the material itself. Also the backpack allows the waves to travel to the tag attached to it.



Figure 6.9: Situation of the physiological saline of 500 ml. [Own]

Subsequently, the study has been repeated using a 100 ml physiological saline to evaluate whether the amount of liquid present in the system modifies the quality of the signal, influencing it in a positive or negative way. Again, the measurements have been taken with three different tags, as evidenced in figure 6.10.

In this second study we observed similar results to the previous ones, since there are hardly any variations in the number of readings or the RSSI of the tags attached to the backpack or those attached to the serum by the plastic part. The greatest difference is observed in the tag attached above the serum, in the figure 6.10, where it is evidenced that a greater amount of fluid implies greater attenuation and, therefore, worse RSSI.

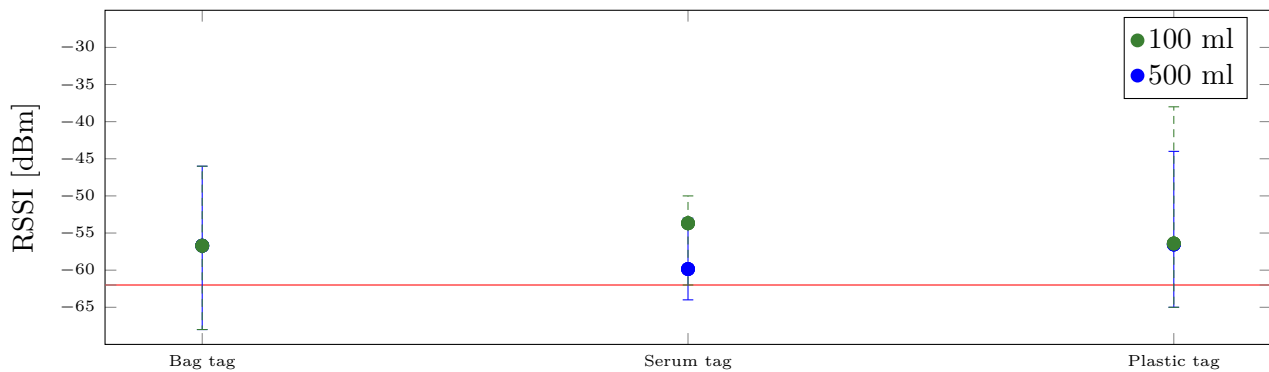


Figure 6.10: RSSI of the tags according to the attached serum.

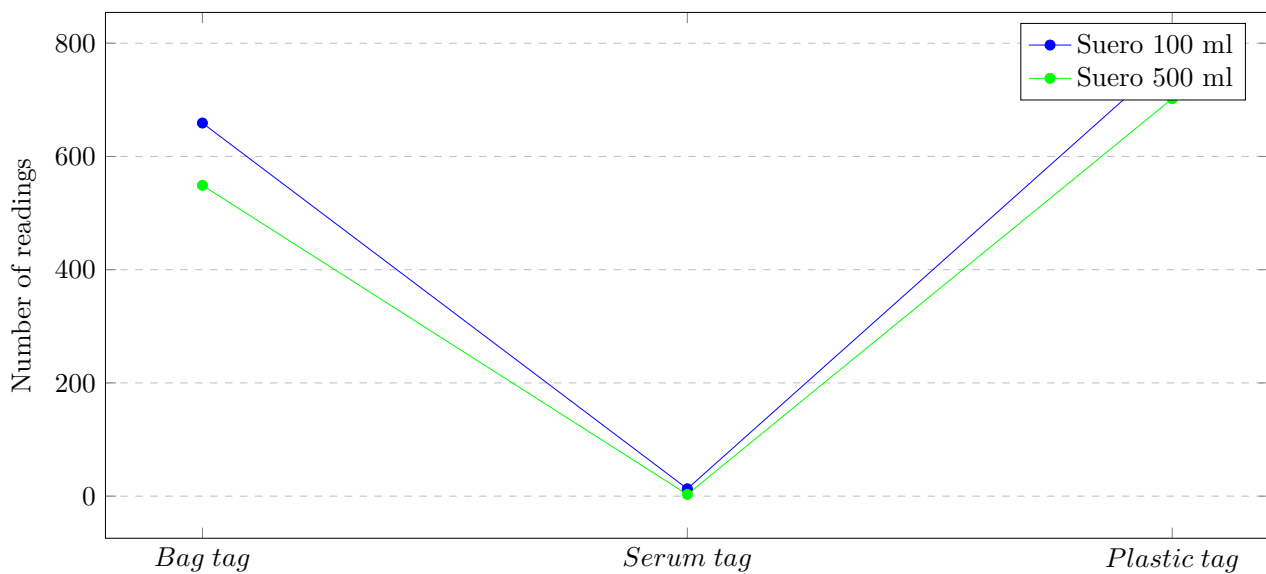


Figure 6.11: Number of readings according to serum.

6.4.2. Folded tags

It should be taken into account that the tags must have minimum dimensions, on the one hand due to physical needs in terms of the area of the antenna to capture enough energy, but also due to the increased cost of smaller size tags. Although, the size of the smallest tags found in the distributors that were accessed during the development of this work was greater than the surface presented by some item to be monitored, such as 1 milliliter drug ampoules.

This fact implied the need to place the tag in a non-recommended arrangement for capturing energy by the emitter, as shown in figure 6.12. Due to this anomaly it was decided to carry out measurements on how having the tag placed in this way affected the reception and subsequent response of the signal.

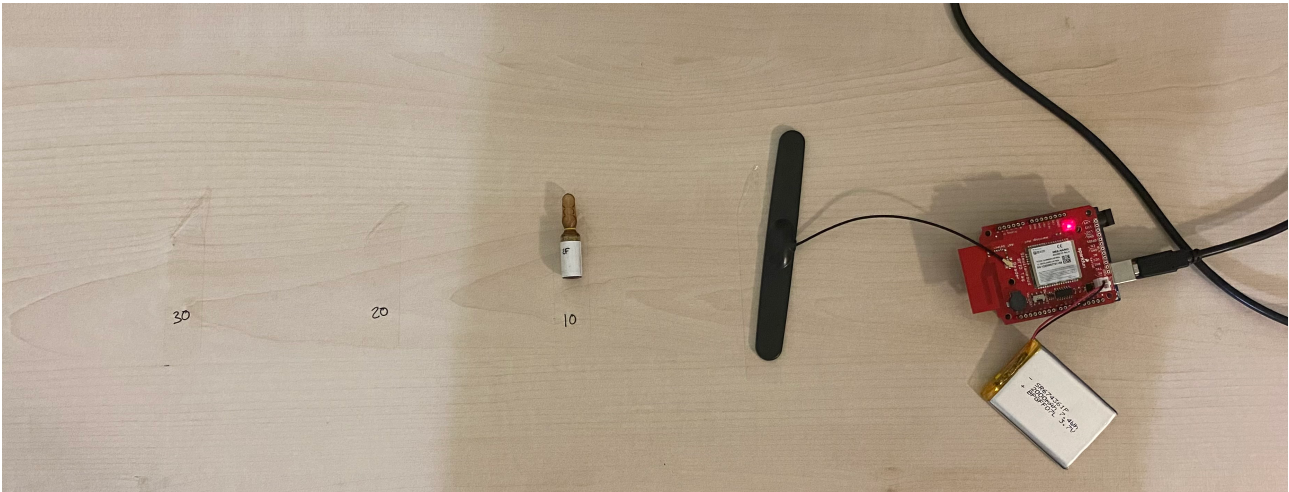


Figure 6.12: Configuration for 1 ml ampoule measurement. [Own]

In the graph 6.13 we observe a big difference in the obtained RSSI between the tag folded and the one that is in a correct position. These results will have to be taken into account when sizing the system and looking for possible solutions.

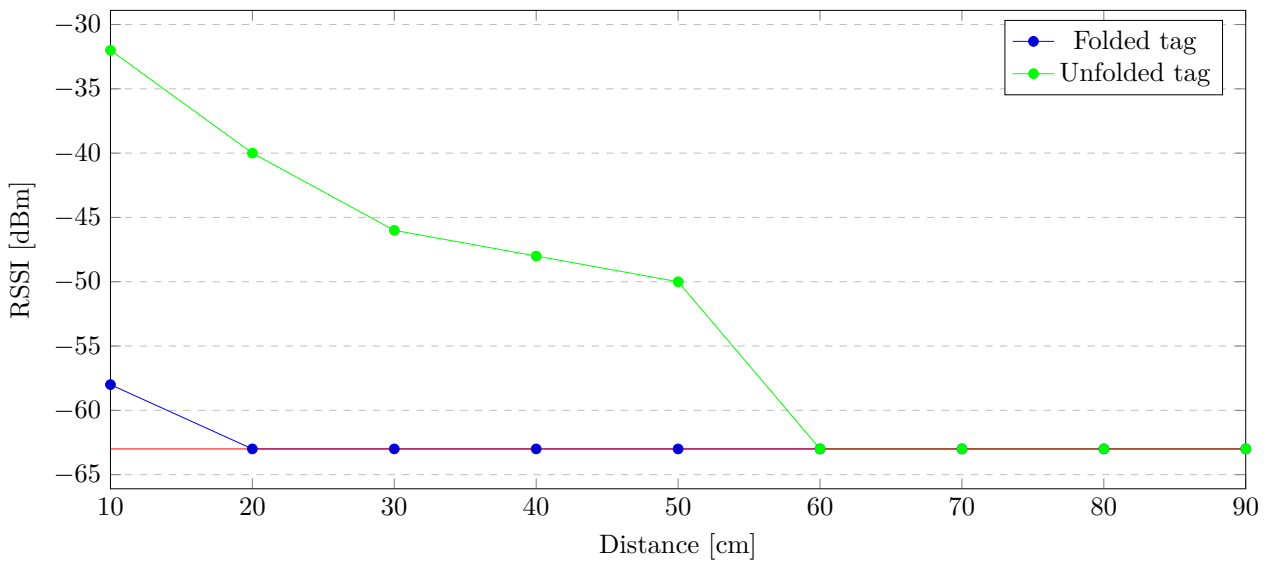
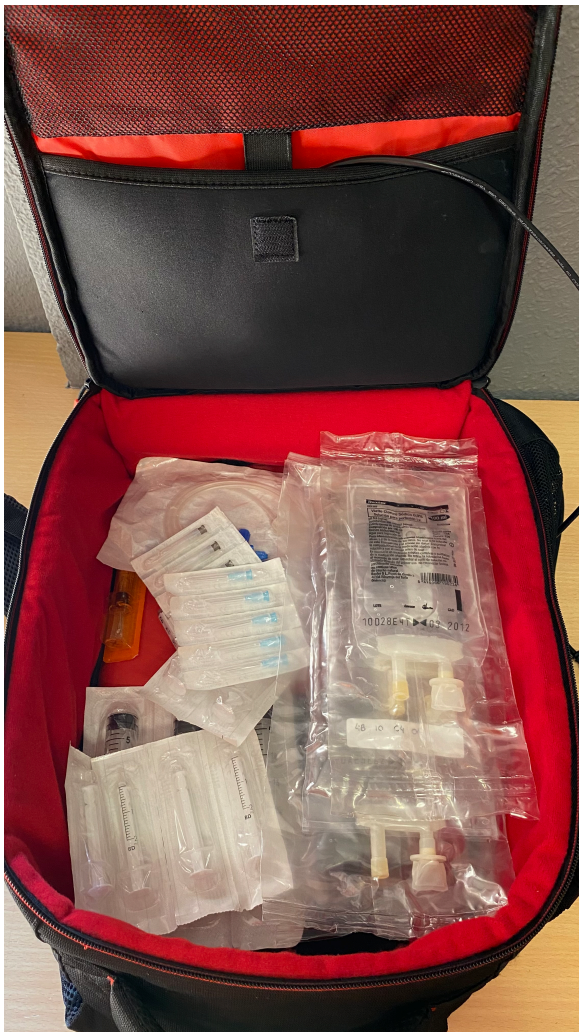


Figure 6.13: Power measurements received every 10 cm.

6.4.3. Multiple tags

Finally, a measurement was carried out with a large number of tags in all the previously commented cases in order to study the behavior of the system in this state since it will be similar to what can be found in a real situation. For this measurement, 10 tags were placed in different materials and more materials without tags as seen on figure 6.14. In this test, the 100 % of the tags were measured with an RSSI between -47 and -57 mostly.

In the figure 6.15 we observe that those tags adhered to a liquid are the ones with greatest variability as well as a lower number of readings as evidenced by the figure 6.16. In such figure, we observe two large groups, those with more than a thousand readings (the tags not adhered to any liquid) and the rest (those adhered to liquids) that present an average of 20 readings during the observation time. Thanks to this, we know that we will have to have long observation times to capture all the tags adhered to liquids.



The total number of items and tags included in the backpack for this test are the following:

- Items with RFID tag:
 - 1x Unleashed tag
 - 1x Bag tag
 - 1x Serum 500 ml (one tag above liquid and another above plastic)
 - 1x Serum 100 ml (one tag above liquid and another above plastic)
 - 1x Atropine ampoule 1 ml
 - 1x Eufiline ampoule 10 ml
 - 1x Three – way wrench
 - 1x Pre – charged adrenaline
- Items without RFID tag:
 - 1x Serum 500 ml
 - 1x Serum 100 ml
 - 5x Syringe 2 ml
 - 4x Syringe 10 ml
 - 10x Needles

Figure 6.14: Backpack with a multiple items.
[Own]

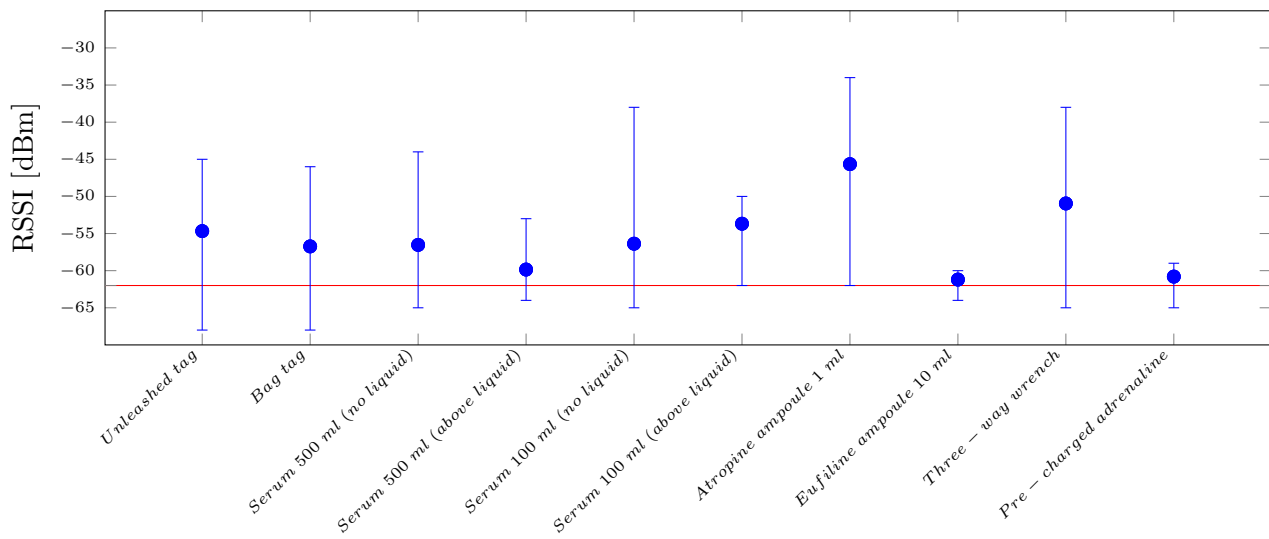


Figure 6.15: RSSI according to the orientation of the tag.

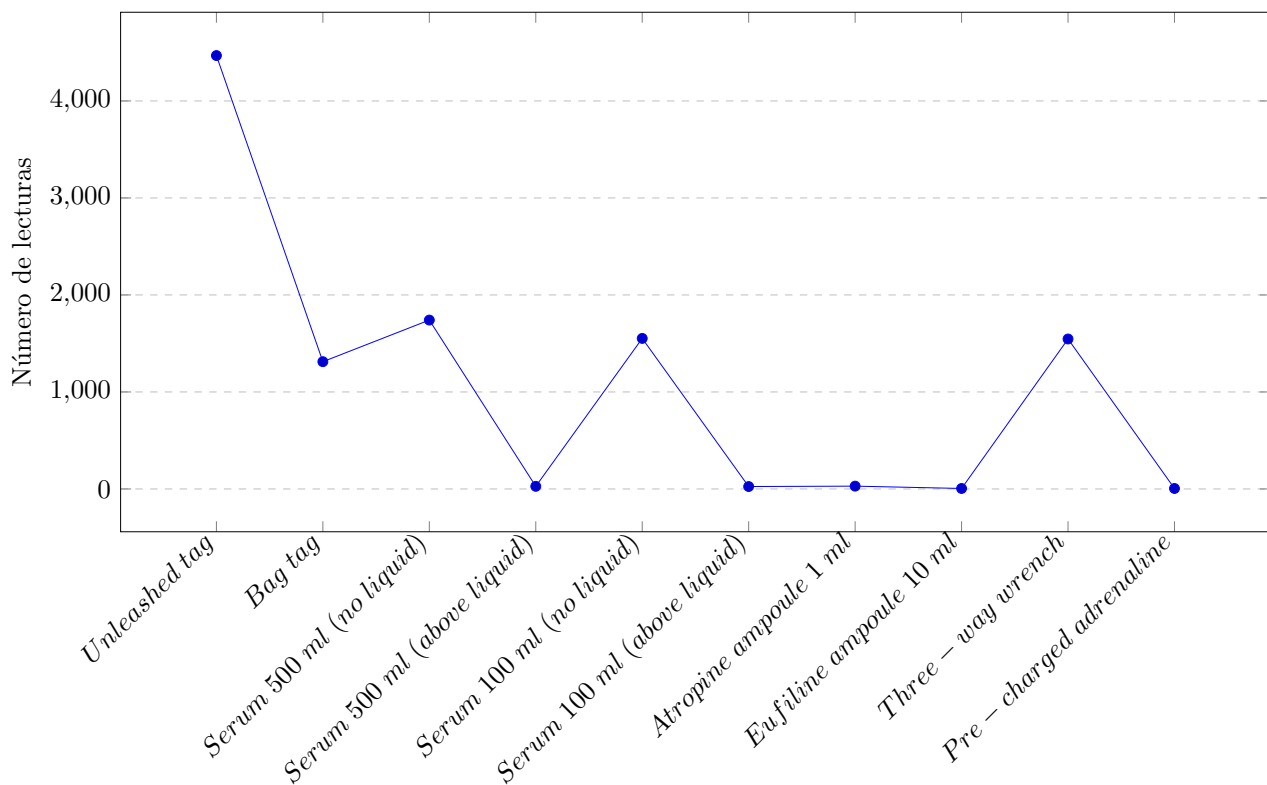


Figure 6.16: Number of reads based on tag location.

6.5. Power variation

Until now, the tests that had been carried out to verify the operation of the system and the application had used a transmit power of 27 dBm. This power is very high which would imply a large battery consumption and less ease of use by the health team.

For this, three measurements have been made to different tests, to compare them with the 27 dBm previously mentioned. The chosen powers have been 15, 20 and 23 dBm.

Thanks to this test in figure 6.17 we observe that with a higher power we can read more tags but lower RSSI. We should find an equilibrium between the two needs.

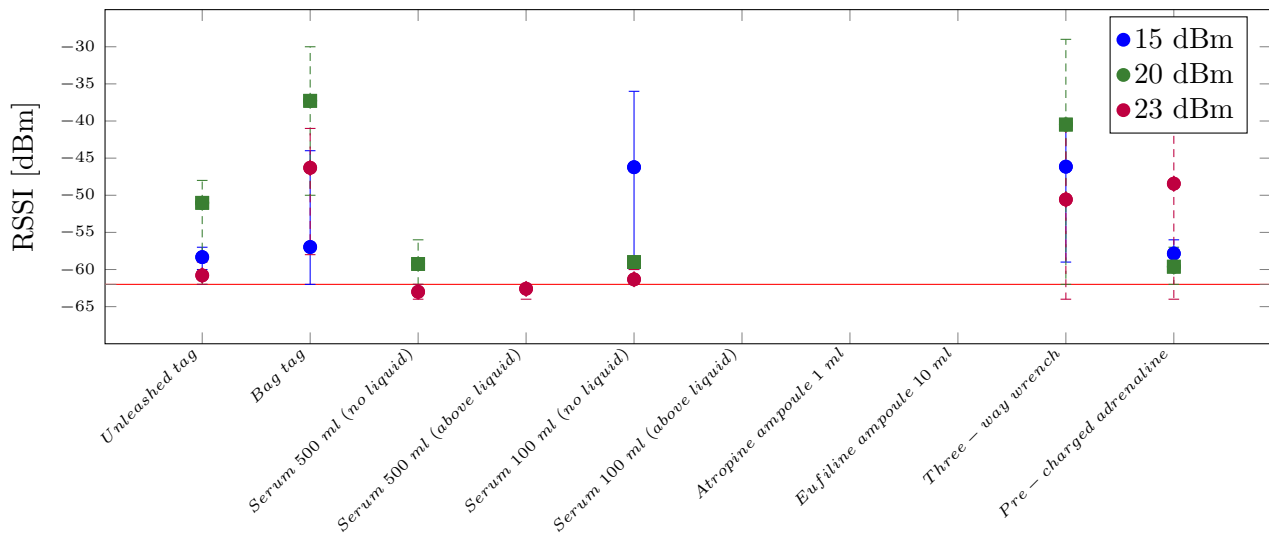


Figure 6.17: RSSI according to the emitted power.

7. Conclusions and future improvements

This chapter includes the conclusions and future improvements of the work. The conclusions summarize and reaffirm both the method and the development carried out in the present work.

On the other hand, future improvements establish interesting approaches on which the present work should continue to be developed, all of them based on the results and knowledge acquired during the development of the work. Most of these improvements are aimed at adapting the application to real needs and publishing the results obtained in scientific journals.

7.1. Conclusions

During the development of this FYP two well differentiated systems have been proposed: a multi-device application for the management of medicine backpacks, and the hardware necessary to add to said application the possibility of carrying out inventories.

For the development of the application, cutting-edge technologies have been used, including Flutter or Amazon Web Services. Flutter has been shown to be a great tool for application development and rapid prototyping, thanks to its shorter learning curve if you already have prior knowledge in similar frameworks such as Angular. The difficulty in using Flutter increases when developing marketable applications such as the present case, since it is necessary to achieve greater optimization of the resources consumed (both in API requests and the memory, battery and processor resources of the smartphone). Such optimization mainly lies in the efficient use of widget states, which requires a stronger learning curve.

On the other hand, thanks to the development of the hardware to be used, the previously established objectives have been delved into. It has been observed that the range of the RFID system depends directly on the antenna used and the amount of maximum power that the power supply can deliver. In addition, what was intuited has been confirmed and that is that liquids absorb a large amount of the signals, thus not allowing good communication. Finally, it can be concluded that within the framework of this work, the orientation of the tags and the fact of including a large number of them has not significantly degraded the quality of the signal.

In summary, what is stated in the present work can be considered a reality since no major flaws have been evidenced in the system or modifications have been proposed to correct them. The greatest drawback would be the final price per backpack, as stated in the Budget section .

7.2. Future improvements

Although the work is tailored to the needs of healthcare personnel raised at the beginning of the inDemand challenge, many improvements can be made to shape the current project.

It would be interesting to work on a plastic package to protect all the integrated circuits that are part of the project. With this, greater resistance and durability would be achieved, although the heat dissipation would have to be reviewed. In addition, it could incorporate buttons for the Bluetooth

connection and turning on or off of the equipment.

Besides that, it would be of huge assistance for health personnel to include the expiration dates of medicines, since if a medicine is expired it must be replaced immediately. Nowadays this characteristic has not been included because the information on the expiration date of each batch delivered to each healthcare unit could not be provided from the SNS warehouse.

The necessary steps will be followed to complement the range study carried out for this work and to write a paper to be presented to scientific journals of interest, thus contributing to common knowledge and the improvement of health. Also, a study to analyze why at higher emitting power we obtain more reads but worsen RSSI should be carried out.

Finally, the procedures for certain actions could be included in the application to guide the healthcare team in the tasks to be carried out during the application.

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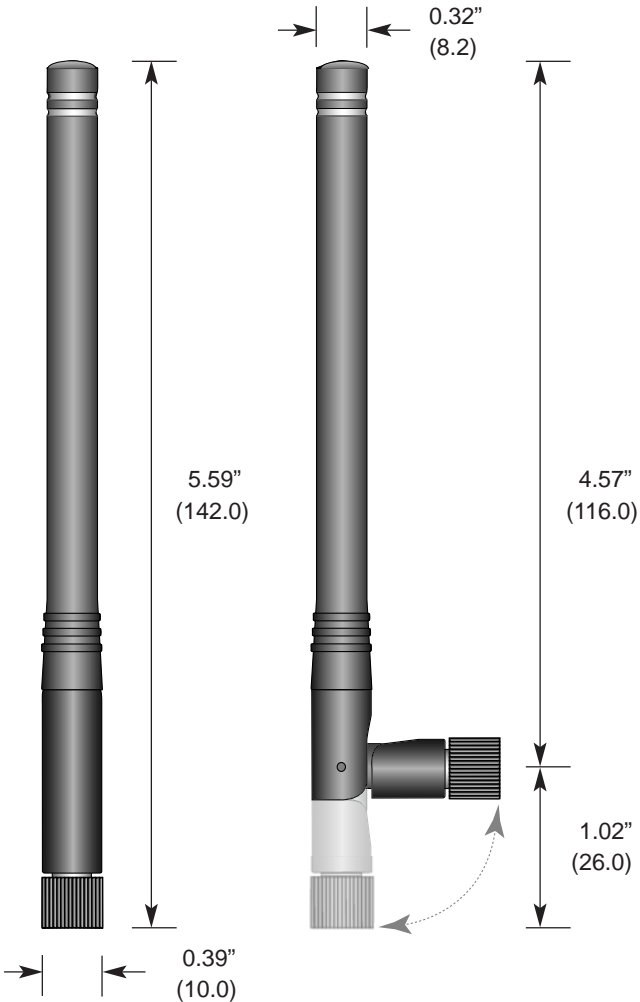
List of Acronyms and Abbreviations

ALS	Advanced Life Support.
ANE	Agencia Navarra de Emergencias.
API	Application Programming Interface.
BLS	Basic Life Support.
CPR	Cardiopulmonary Resuscitation.
DYA	Detente Y Ayuda.
EAS	Electronic Article Surveillance.
EMS	Emergency Medical Service.
FYP	Final Year Project.
HF	High frequency.
IEEE	Institute of Electrical and Electronics Engineers.
IoT	Internet of the Things.
LF	Low frequency.
MIT	Massachusetts Institute of Technology.
POH	Prevention of Occupational Hazards.
RFID	Radio Frequency IDentification.
RRU	Rapid Response Unit.
RSSI	Received Signal Strength Indicator.
SNS	Servicio Navarro de Salud.
SNU	Servicio Normal de Urgencias.
SUE	Servicio de Urgencias Extrahospitalarias.
SUR	Servicio de Urgencias Rurales.
UHF	Ultahigh frequency.
UPNA	Universidad Pública de Navarra.

A. Antennas' datasheets

This chapter includes the datasheets of the three antennas used in the development of FYP. These datasheets include all the information on the antennas, although the most important data related to this work were already indicated in their corresponding section of the report.

Product Dimensions



Description

HWR Series 1/2-wave center-fed dipole antennas deliver outstanding performance in a rugged and cosmetically attractive package. The articulating base allows the antenna to tilt 90 degrees and rotate 360 degrees. The antenna's internal counterpoise eliminates external ground plane dependence and maximizes performance. HWR Series antennas attach via a standard SMA or Part 15 compliant RP-SMA connector. Custom colors and connectors are available for volume OEM customers.

Features

- Low cost
- Internal counterpoise
- Tilts and rotates
- Excellent performance
- Omni-directional pattern
- Outstanding VSWR
- Flexible main shaft
- Rugged & damage-resistant
- Standard SMA or Part 15 compliant RP-SMA connector
- Custom terminations for volume OEMs
- Available in black or custom colors

Electrical Specifications

- Center Freq. 868MHz
- Bandwidth 30MHz
- Wavelength 1/2-wave
- VSWR <2.0 typ. at center
- Impedance 50 ohms
- Gain 2dBi
- Connector RP-SMA or SMA

Electrical specifications and plots measured on 4.00" x 4.00" reference ground plane

Ordering Information

- ANT-868-CW-HWR-RPS (with RP-SMA connector)
- ANT-868-CW-HWR-SMA (with SMA connector)

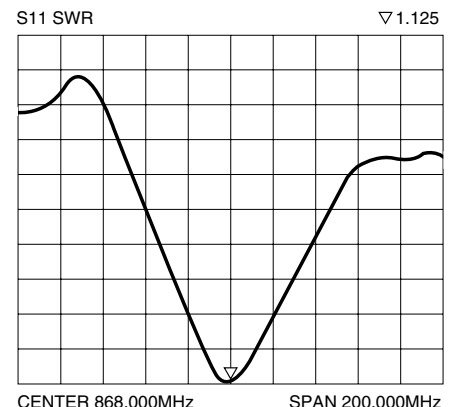
Polar Plots and VSWR Graph



Azimuth



Elevation



Typical VSWR





PENTABAND GSM-UMTS ADHESIVE MOUNT ANTENNA

Part Number 505

Applications

- Automotive
- Telemetry



Main features

- Wideband
- Easy to install
- Low weight
- RoHS compliant
- Good efficiency

Main Specifications GSM 850/900/1800/1900

GSM 850 (824–894 MHz)

Gain	<0 dBi
VSWR	<2
Impedance	50 OHM
Polarization	linear

GSM 900 (890–960 MHz)

Gain	<1 dBi
VSWR	<2
Impedance	50 OHM
Polarization	linear



PENTABAND GSM-UMTS ADHESIVE MOUNT ANTENNA

Part Number 505

Main Specifications GSM 850/900/1800/1900

GSM 1800 (1710–1880 MHz)

Gain	<1 dBi
VSWR	<2
Impedance	50 OHM
Polarization	linear

GSM 1900 (1850–1990 MHz)

Gain	<0 dBi
VSWR	<2,2
Impedance	50 OHM
Polarization	linear

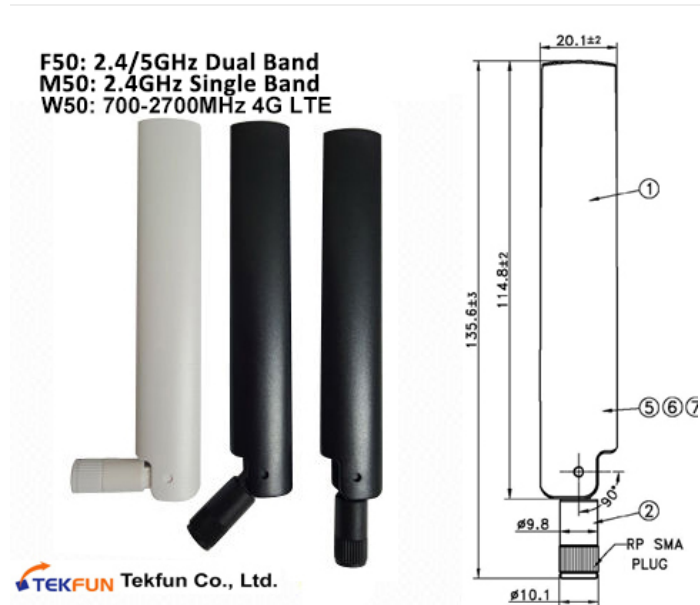
Main Specifications UMTS (1900–2200 MHz)

Gain	<0 dBi
VSWR	<2,5
Impedance	50 OHM
Polarisation	linear

Dimensions & Al.

Dimensions	130x16x5 mm
Cable	all coaxial cables Z_0 50 OHM diam < 3,6 mm
Cable length	custom
Connector	custom

868/915MHz Swivel Hinged Rubber Dipole antenna with SMA



Enlargement

Q'ty : [Inquiry](#)

Product Description

Part no.	Standard Male	Reverse polarity Male
SMA	I50-S	I50-SR

Product Character

Electrical:

- Type: Monopole antenna
- Frequency: 868/915MHz (862~870/902~928MHz)
- VSWR: ≤ 2.0
- Impedance: 50ohms
- Gain: 2dBi
- Radiation: omni
- Electrical Wave: 1/2
- Polarization: Vertical
- Max Power: 1W

Mechanical:

- Antenna length: 135.6mm
- Operating temp.: -20 to +60 degree
- Storage temp.: -30 to +75 degree
- Materials: ABS (Antenna Cover)
- Color: Black and White

Mounting:

- SMA Male (standard or RP - Reverse polarity)

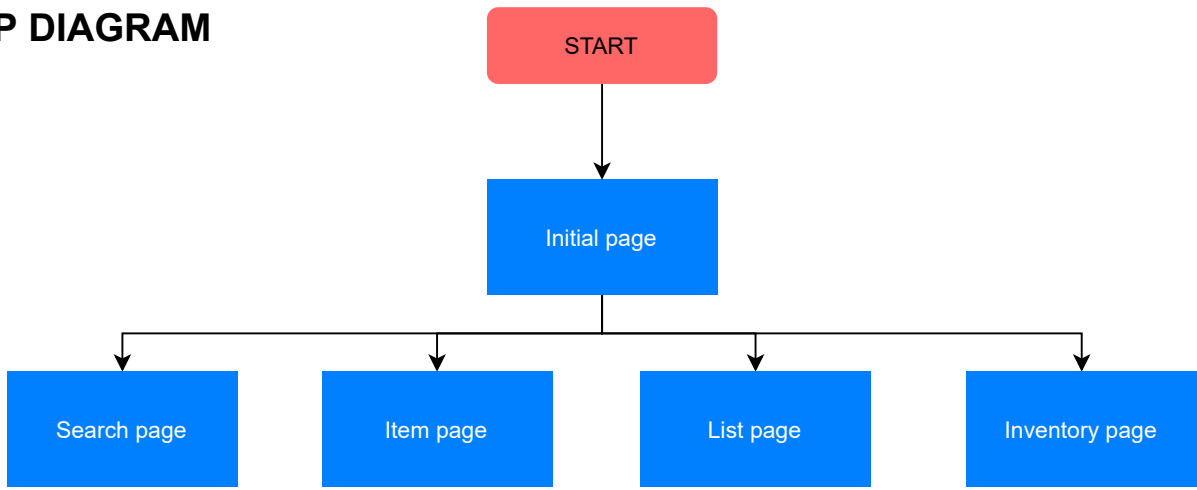
Made in Taiwan

OEM and ODM orders are welcome

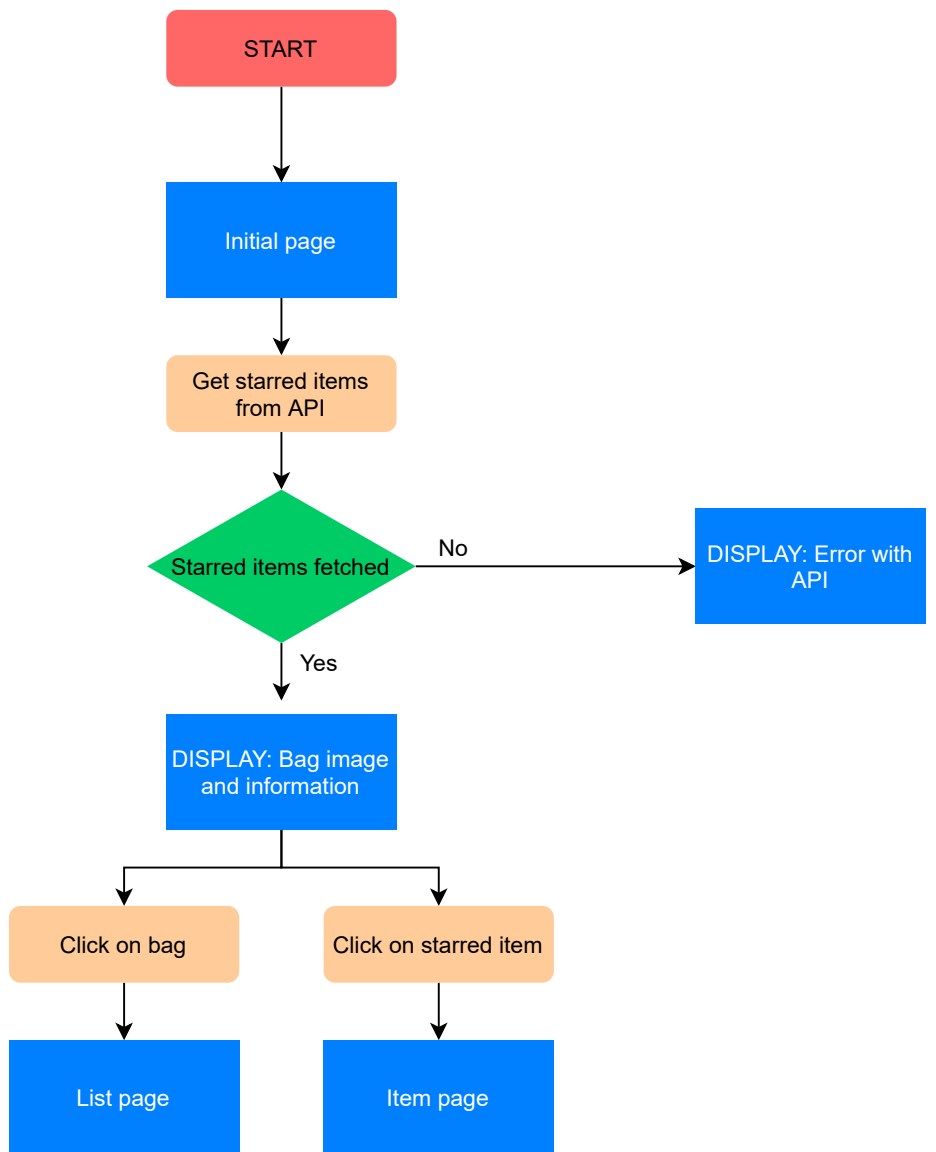
Compliant with RoHS Directive

Part II.
Diagrams

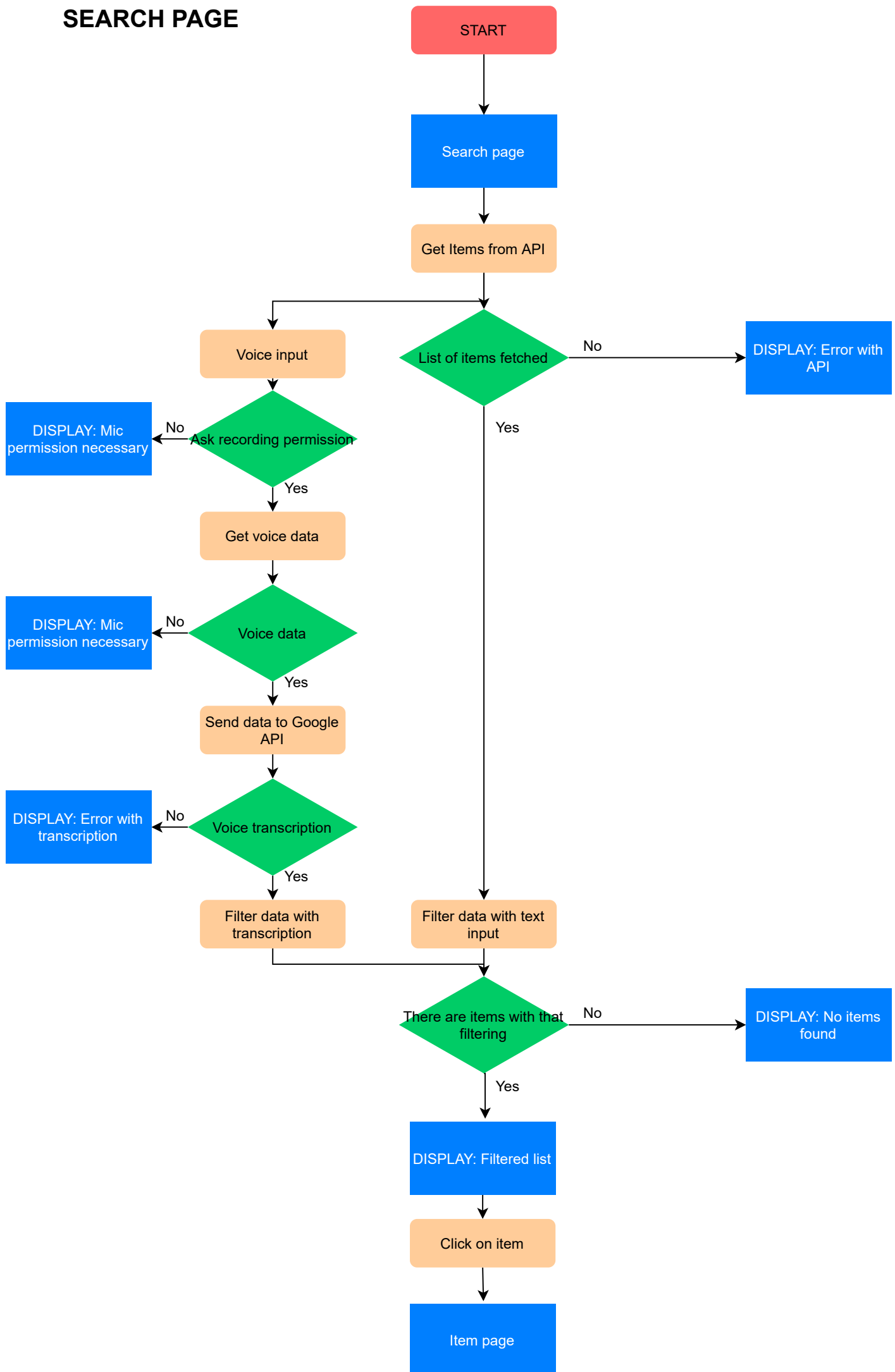
APP DIAGRAM



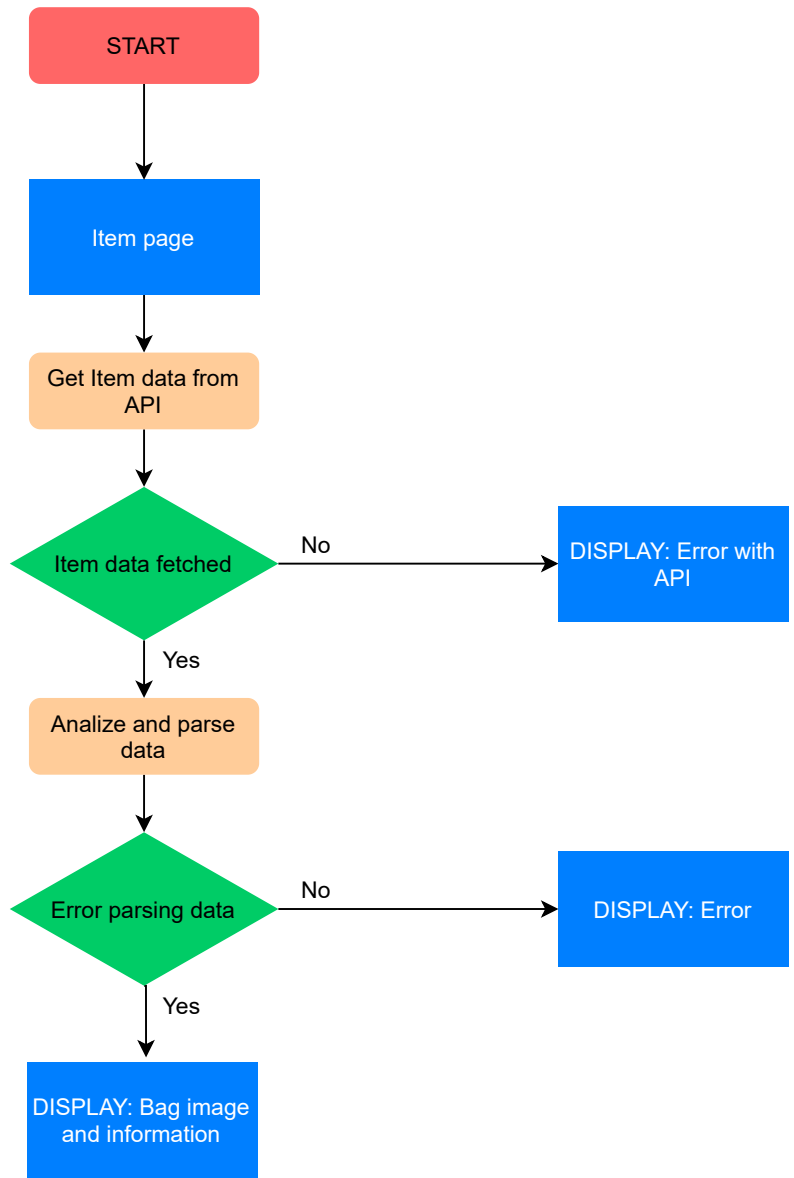
INITIAL PAGE



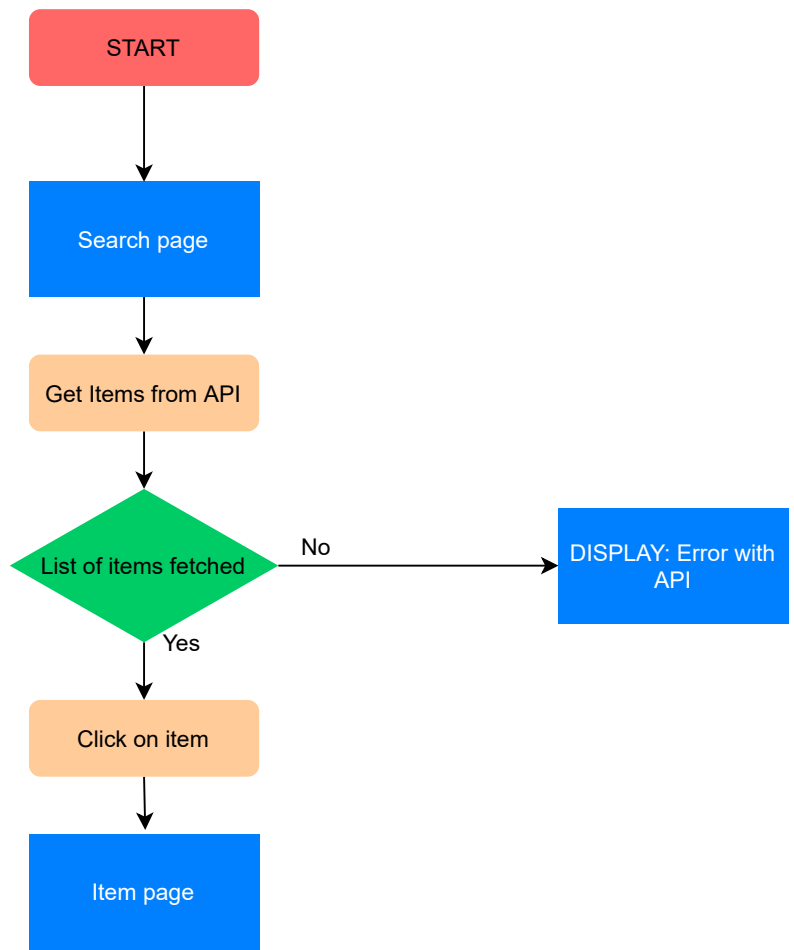
SEARCH PAGE



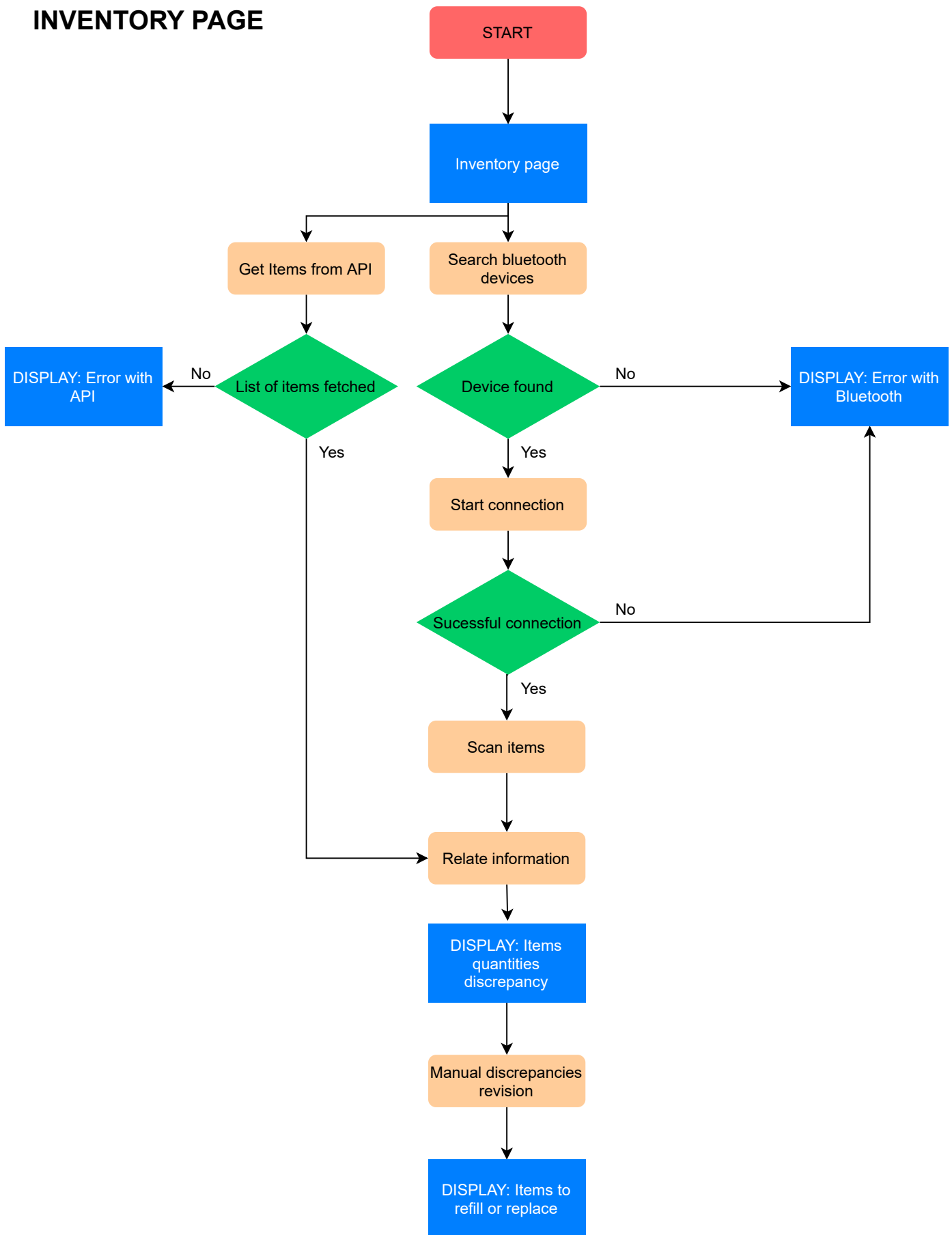
ITEM PAGE



SEARCH PAGE



INVENTORY PAGE



Part III.

Specifications

Specifications

This section describes the hardware and software needs that have arisen for the development of this project.

- **HARDWARE**

- MacBook Pro Personal

- * Processor: 2,7 GHz Intel Core i5 de double core
 - * RAM: 8GB 1867 MHz DDR3
 - * Graphics: Intel Iris Graphics 6100 1536 MB
 - * Hard disk: SSD 480 GB
 - * Operating system: macOS Big Sur Version 11.3 Beta

- ASUS X556UJ

- * Processor: Intel Core i7-6500U double core
 - * RAM: 8GB 1600 MHz DDR3L-SDRAM
 - * Graphics: NVIDIA GeForce GT920M 2 GB
 - * Hard disk: SSD 512 GB + HDD 1 TB
 - * Operating system: Microsoft Windows 10 Pro

- Monitor BENQ GW2480

- * Screen size: 23.8"
 - * Aspect proportion: 16:9
 - * Resolution (max): 1920x1080
 - * Consumption: 27 W

- **SOFTWARE**

- **Image processing:**

- * Adobe Photoshop (Mac)
 - Version: 21.0.3
 - Compatible OS: macOS Mojave (version 10.14) or later
 - Graphic card: GPU with Metal support and 2 GB of GPU memory
 - HD space: 4 GB of available hard-disk space; additional space is required for installation

- **Text processing:**

- * TEX Maker
 - Version: 5.0.4
 - Compatible OS: macOS, Windows and Linux

- Additional requirements: any LaTeX compiler
 - * MacTeX
 - Version: MacTeX-2020
 - Compatible OS: macOS 10.13 High Sierra or higher
 - Processor: both Intel and Arm processors
 - * Google Docs
 - : Additional requirements: Internet browser
 - Compatible OS: macOS, Windows and Linux
 - **Coding:**
 - * Visual Studio Code
 - Version: 1.54.3
 - Compatible OS: OS X Yosemite (10.10+) or higher
 - Processor: 1.6 GHz or faster processor
 - RAM: 1 GB of RAM
 - * Visual Studio Community 2019
 - Version: 16.9.2
 - Compatible OS: Windows 10 version 1703 or higher
 - Processor: 1.8 GHz or faster processor. Quad-core or better recommended
 - RAM: 2 GB of RAM; 8 GB of RAM recommended
 - * Arduino IDE
 - Version: 1.8.13
 - Compatible OS: macOS, Windows or Linux
 - Processor: Intel Pentium processor or equivalent running at 1 GHz or more.
 - RAM: 512 MB of RAM; 1 GB of RAM recommended
 - **Work organizing:**
 - * zoom.us
 - Version: 5.4.9
 - Compatible OS: macOS X with macOS 10.10 or higher
 - Processor: 2.5 GHz dual-core Intel Core i5 or higher desktop CPU (single screen) processor
 - Bandwidth: 2.0 Mbps up and down for single screen
 - * Trello
 - Compatible OS: macOS - 10.9 or higher
 - : Additional requirements: Internet browser
-

Part IV.

Budget

Development hardware

Concept	Quantity (u)	Price per unit (€/u)	Total price (€)
MacBook Pro Early 2015	1	1.100,00	1.100,00
BenQ GW2480	1	129,00	129,00
ASUS X556UJ	1	500,00	500,00
Subtotal			1.729,00€

Prototype hardware

Concept	Quantity (u)	Price per unit (€/u)	Total price (€)
Arduino UNO	1	15,00	15,00
Tag RF600598	25	0,29360	7,34
Tag RF600600	25	0,31680	7,92
Sparkfun RFID Reader	1	190,00	190,00
Rechargeable battery	2	15,00	30,00
HAMA 190 MIAMI bag	2	52,00	104,00
Tube's Bag	1	62,00	62,00
Subtotal			416,26€

Software

Concept	Quantity (u)	Price per unit (€/u)	Total price (€)
VSMicro for Microsoft VS	1	170,00	170,00
Apple Developer License	1	99,00	99,00
Subtotal			269,00€

Final budget

As can be seen in the following table, the highest development cost is due to the hardware for the development of the system. This expense is fixed regardless of the number of readers that are manufactured. Towards a possible commercialization the most important price would be the cost of the prototype.

Concept	Subtotal(€)
Development hardware	1.729,00
Prototype hardware	416,26
Software	269,00
Total	2.039,26€

The cost of the RFID reader and the rest of the equipment necessary for the operation of the application's inventory is approximately 250€ (not counting the backpack). Although it is not a very high expense, it must be taken into account that there are 59 health centers and at least three backpacks in each (the nursing, the medicine and the oxygen therapy) so the total price of implementing this solution throughout Navarra would be a considerable expense, even if better prices were obtained for large quantities. This is surely the biggest impediment to not implementing the technology in its entirety.

Concept	Quantity	Subtotal(€)
Development hardware	1	1.729,00
Prototype hardware	59 * 3	250,00
Software	1	269,00
Total		46.248,00€