March 5th, 2008

Prof. Patrick Leung
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia.
V5A 1S6

Re: ENSC 440 Design Specification for the Wireless Item Label Locator (WILL)

Dear Prof. Leung:

The attached document from The Third Eye (TTE) provides a set of technical guidelines for the design of the Wireless Item Label Locator (WILL) . The WILL is an assistive device to guide the vision-impaired user to locate items. A remote will senses and audially indicate the range and distance of the radio-frequency identification (RFID) tag which is attached to the desired item.

The design specifications in this document describes the complete design criteria and testing plans for the proof-of-concept model. Also presented are some specifications which apply only to the final production version and will not be implemented in this stage of development.

If you have any questions or comments, please feel free to contact us by email at ensc440-spring08-tte@sfu.ca or by phone at (604) 779-6672.

Sincerely,

Tongxin Feng
President and CEO
The Third Eye Ltd.

Enclosure: ***Design Specification for a Wireless Item Labelled Locator***

THIRD EYE

DESIGN SPECIFICATION FOR A WIRELESS ITEM LABEL LOCATOR (WILL)

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Issued date: March 5th, 2008

Revision: 1.3

Executive Summery

The design specification for the Wireless Item Label Locator (WILL) provides a set of detailed descriptions for the design and development of the proof-of-concept model. Some specifications included in this document apply only to the final production model, and such specifications will be clearly indicated so. All of the functional requirements marked 1 or 2 and some marked 3, as specified in the document *Functional Specification for the Wireless Item Label Locator* [1], will be discussed.

This document outlines the design of the Wireless Item Label Locator and provides justification for our design choices. The user interface will consist of a set of buttons and speaker. The user button input is processed by the microcontroller which activates the radio frequency (RF) reader and antenna to send out ultral-high frequency (UHF) search signal. This signal powers up the passive RF identification (RFID) tags (consisting of a single IC chip and antenna) within the range. The tags then send back their respective IDs to the reader, which are passed to the microcontroller. Once it receives and identifies the ID of the desired tag, the microcontroller turns on the speaker to indicate that the item is located in the direction of the antenna within the given range. The microcontroller, RF reader and antenna, and the user interface will be built into one portable unit which will resemble a remote controller in its final production version.

A detailed description of the requirements and selection criteria for the components is provided. General software program process flow is also included. A description of test plans for the system and its subcomponents is provided at the end of the design specification.

Design improvements for future iterations and final production of the WILL are also discussed through out the document. The second phase will focus on accurately detecting tag proximity and directionas well as increasing the detection range from the initial 1-2m. The complete user interface model will be built with assistive features such as large buttons with LED backlighting and braille markings.

The development cycle of the proof-of-concept mode i s targeted for completion on April 6th, 2008.

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Acronyms

WILL	Wireless Item Labelled Locator
BIM	Button Input Module
SOM	Speaker Output Module
UIM	User Interface Module
CCM	Central Control Module
TIM	Tag Identification Module
RFCM	Radio Frequency Communication Module
RFID	Radio Frequency Identification

1 Introduction

The Wireless Item Label Locator (WILL) is an assitive device that will help a vision-impaired user in locating items. First, the user attaches the radio frequency identification (RFID) tags on the items. When locating a tagged item, the user presses the corresponding button on the remote and points it to various directions. The remote searches within the directions it points to, and when the particular tag (attached to the item) is located within a given range, signals the user with a beeping sound. The strength of the WILL is its passive, battery-free item tags. This takes away the frustration of losing tags without power and eliminates the hassle of replacing the tag batteries every few months. These features are especially conveninent for a vision-impaired user [2]. The design specification describes the technical details for the design of each component of the WILL.

1.1 Scope

The document specifies the design of the WILL and explains how the design meets the functional requirements as described in *Functional Specification for a Wireless Item Label Locator* [1]. The design specification includes all requirements for a proof-of-concept system and a partial set of requirements for a production model. As we are focusing on the proof-of concept system, only design considerations pertaining to the functional requirements marked 1 or 2 will be explicitly discussed.

1.2 Intended Audience

The intended audience of the design specification are the members of The Third Eye team. This document shall serve as the overall design guideline and and ensure all requirements are met in the final product. This document will also provide the test plan which the test engineers implement and confirm the completeness of the product.

2 System Overview

This section provieds a high-level overview of the entire design and an overall functional description of the system. Details specific to individual components can be found in their repective sections.

There are three main modules in the WILL and their functions: User Interface Module (UIM), Central Control Module (CCM), and Radio-Frequency Communcation Module (RFCM).

1) User Interface Module (UIM)

- Item Buttons
  - When pressed, each Item Button functions as a "Power On" button.
- Buzzer (Speaker)
- Volume Control
- Power Off Button

2) Central Control Module (CCM)

The Central Control Module is Atmel Microcontroller Atmega168. There are three submodules in the program architecture.

- Button Input Module (BIM)
  - Receives button input from UIM.
  - Turns off the speaker and reset the memory
  - Identifies which button has been pressed and stores the button ID
  - Sends "Search" command to RF Reader Unit.
- Tag Identification Module (TIM)
  - Receives tag input from RF Reader Unit.
  - Match the tag ID with the button ID
  - When MATCHED
    - Send "Stop" command to RF Reader Unit
    - Send "On" command to Speaker Output Module
  - When NOT MATCHED
    - Send "Search" command to RF Reader Unit
- Speaker Output Module (SOM)
  - Receives "On" command from TIM
  - Sends "On" command to the buzzer (speaker) in UIM
  - In the final production version, this module will change the rate of beeping sound according to the distance of the tag

3) Radio Frequency Communication Module (RFCM)

RFCM consists of three components: Radio Frequency (RF) Reader, RF Antenna, and RFID tags. These components are from Signal frequency range is 860Mhz ~ 960Mhz.

- Radio Frequency (RF) Reader
  - Receives signals and IDs from the tags
  - Convert tag IDs into binary codes and store them
  - Receives “Request” command from CCM
    - When there are already stored tag IDs, send the top ID back to CCM and wait
    - When there are no stored tag IDs, sends out radio wave signal to activate tags
- RF Antenna
  - Linearly polarized RF Antenna
- RFID Tags
  - Passive RFID tag – an IC chip and a antenna
  - When radio wave signal is received, powers up and sends back its ID

Figure 1 shows the system overview and how each module interact with each other.

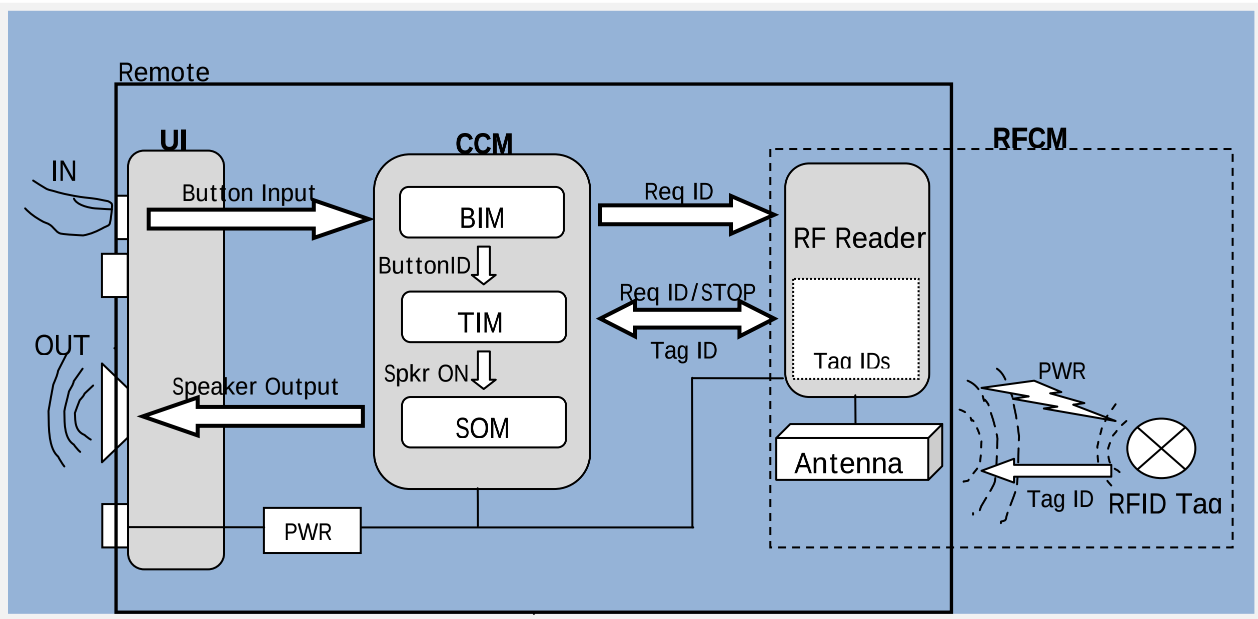

Figure 1. System Overview

System flowchart is included in Appendix.

3 Tags

The passive tag are used to eliminate the need for a battery power source . For the final product, customized design tag will be used to minimize the interference coming from specific material used in the item such as metal, liquid and chemicals. For metal, dielectric material can be used between the inlay and surface to reduce the reflection of RF signal. For glasses, the impedance of the tag antenna can be adjusted to give better performance [8].

3.1 Electronic construction

Tag is consisted of the overlay, RFID chip, substrate and antenna. The figure 2. is shown below.

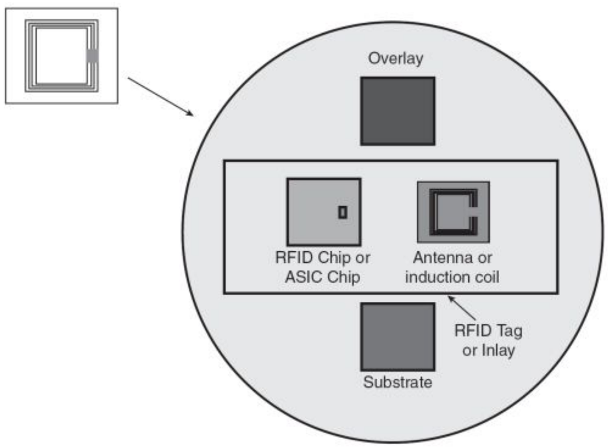

Figure 2. RFID construction [8]

3.2 Tag memory

Each type of tag has different memory. The memory structure of a typical class 1 gen2 tag is shown in Figure 3. Class 1 Gen 2 is the most common type of tag for UHF. Only reading memory is being used because there is no need to write the date on the tag.

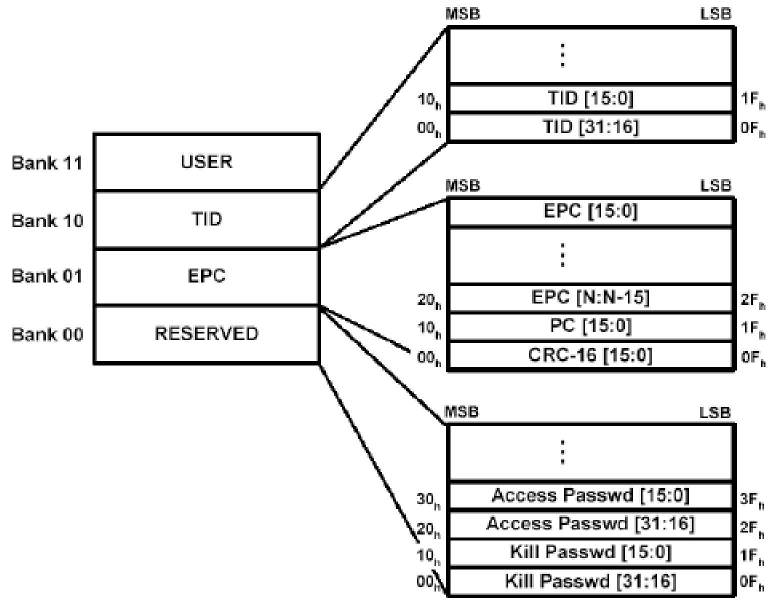

Figure 3. Tag data format [10]

In Bank 10, TID which represents the unique tag id which is used to identify the item. How tag Id is processed is explained in Section 5.

3.3 Tag communication

Passive tag uses passive backscatter method to communicate with the reader. When the reader sends out the RF signal, the tag receives the reader's signal. This RF signal can be demodulated in 0 and 1 in the tag, and tag follows the command embedded inside this signal. Tag sends back the RF signal to the reader. This process is shown below figure 4.

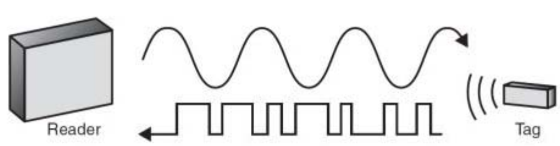

Figure 4. Passive Backscatter [8]

The tag will send its unique tag ID to the reader and the reader will process this data. The details of this process will be explained in the later section.

4 Antenna

4.1 Physical Design

The antenna is Skyetek UHF Broadband Antenna. Figure 2 shows the physical dimension of the antenna.

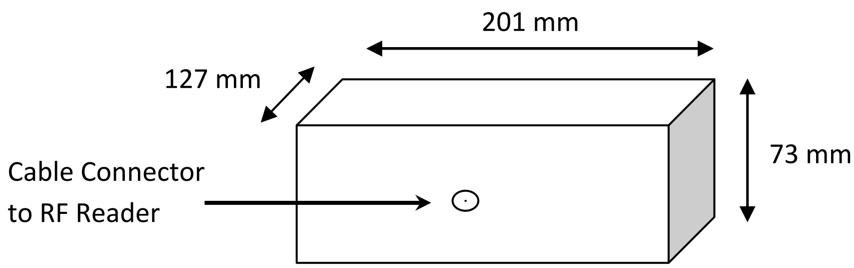

Figure 5. Physical Dimension of the Antenna

The antenna casing is plastic. The bottom of the casing is a metal plate with a rubber feet in each corner, and there is very little radiation on the bottom side. The antenna connects to the RF reader through a connector and a coaxial cable. The total weight of the antenna is 0.7 lb [3].

Inside the casing is a planar microstrip broadband dipole antenna printed on a PCB. The board is mounted approximately 60 mm above the metal plate bottom by a plastic leg fixed in each corner. Figure 3 shows a generalized PCB schematic of a (segment of) planar braodband dipole antenna.

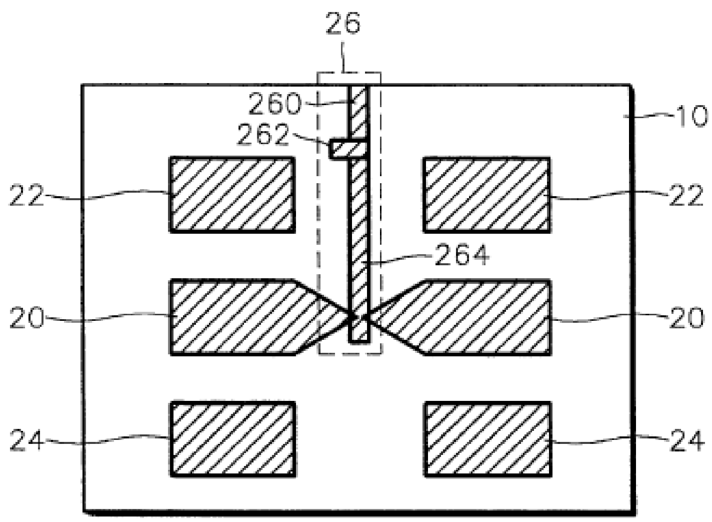

Figure 6. Top view of a planar broadband dipole antenna [4]

This is an abridged diagram of the antenna. In an actual dipole antenna, microstrips extend in both sides. This radiation plate includes a dipole element 20 for radiating waves, and a feeder 26 for feeding radio frequency signals. Parasitic elements 22 and 24 arranged on either side of the dipole element 20 prevent dispersion of waves radiated from the dipole element 20. The feeder 26 is comprised of a line-balance converter 260, a matching element 262, and a feed line 264. The line-balance converter 260 receives the radio frequency signals and achieves impedance balancing. The matching element 262 is connected to the line-balance converter 260 and achieves impedance matching. The feed line 264 feeds the radio frequency signals passed through the line-balance converter 260 and the matching element 262 to the dipole element 20. The feeder 26 and the dipole element 20 are formed of conductive strips [4].

4.2 Radiation field and Antenna Choice

Figure 4 shows the radiation field of a dipole antenna.

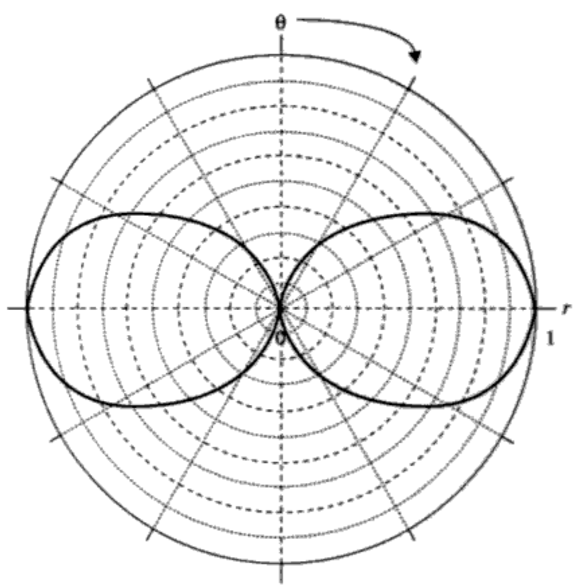

Figure 7. Radiation pattern of a dipole antenna [6]

In three-dimension, the radiation field is doughnut-shaped with the diple axis perpendicularly passing through the hole of the doughnut [6]. The antenna polarization

The main advantage of a dipole antenna is an almost constant directivity for a very wide frequency band [7]. This allows the antenna to operate in the frequency 860 ~ 960MHz. The RF reader can then utilizes frequency hopping spread spectrum in 902 ~ 928MHz according to the FCC guidelines [3], [9]. A spread-spectrum transmission requires a broadband antenna and has several advantages over a fixed-frequency transmission. Spread-spectrum signals are i) highly resistant to narrowband interference, ii) difficult to intercept, and iii) these can share a frequency band with many types of conventional transmissions with minimal interference [8].

4.3 Electrical Specifications

Table 1 summarizes the electrical specifications of the antenna.

Gain	6.5 dBi
Input Frequency	860 – 960 MHz
VSWR	< 2:1
Polarization	Linear
Input Impedance	50 Ohm (nominal)

Table 1. Antenna Electrical Specification [3]

Figure 5 and 6 show the change in voltage standing wave ratio (VSWR) and gain according to the change in frequency.

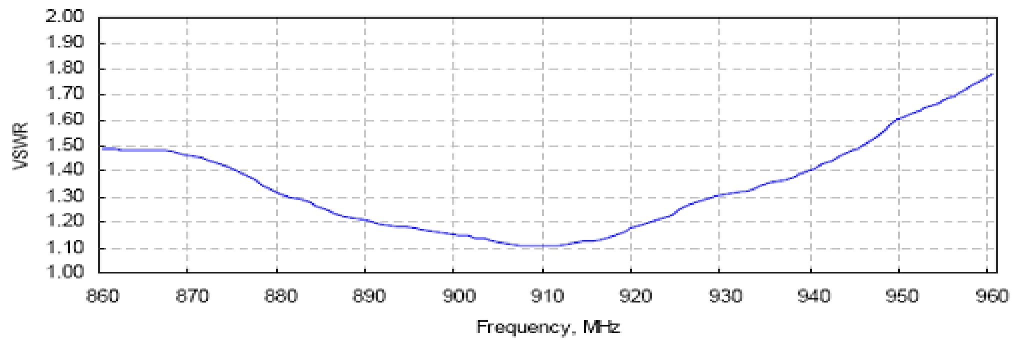

Figure 8. Frequency vs. Voltage Standing Wave Ratio (VSWR) [3]

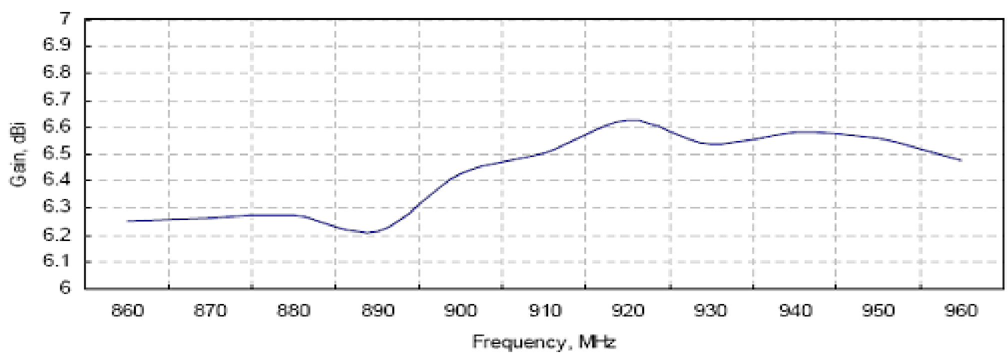

Figure 9. Frequency vs. Antenna Gain [3]

4.4 Design Concerns and Improvements

1) Size

The dimension of our antenna is large for a handheld device. While the area of the antenna is passable (120 mm x 200 mm), the problem is the height or thickness of the antenna (70 mm) . The size of the RF reader is similar to that of a credit card with less than 10 mm in thickness, and the area of the user interface and circuitry including the microcontroller is aimed to be approximately the area of a graphing calculator. Therefore, the main constraint for the size of the device comes from the antenna. Because the antenna size is generally proportional to the operation frequency and gain, an ultra-high frequency (UHF), high-gain antennas such as this has an intrinsic disadvantage in size. This is further supported by the fact that the majority of commercial passive UHF RF systems are large, permanant mount-on models designed for inventory or supply chain control.

There is a handful of handheld passive UHF RF readers available in the market. These are less common, more expensive than the larger ones ($1000 ~ $3000), and mostly of a size of a somewhat large version of a common graphing calculator. Some have an external antenna box attached, some have a circular antenna intergrated into a back handle, and some have internally intergrated antennas. All these require a cleverly customized design of the antenna, which is impossible for the current stage of our development due to limited knowledge and budget.

2) Reading range and interference

The reading range depends greatly on the environment and the tags. UHF signals have short wavelengths and this results in higher sensitivity to interference by reflection from surrounding objects (particularly metal) and walls. There is also interference from other electronic devices that operate in the similar frequency range such as a cordless phone. One possible solution is to increase the antenna gain by focusing the radiation in one direction and decreasing the beam width [3]. Figure 10 shows the radiation pattern of an antenna with antenna directors.

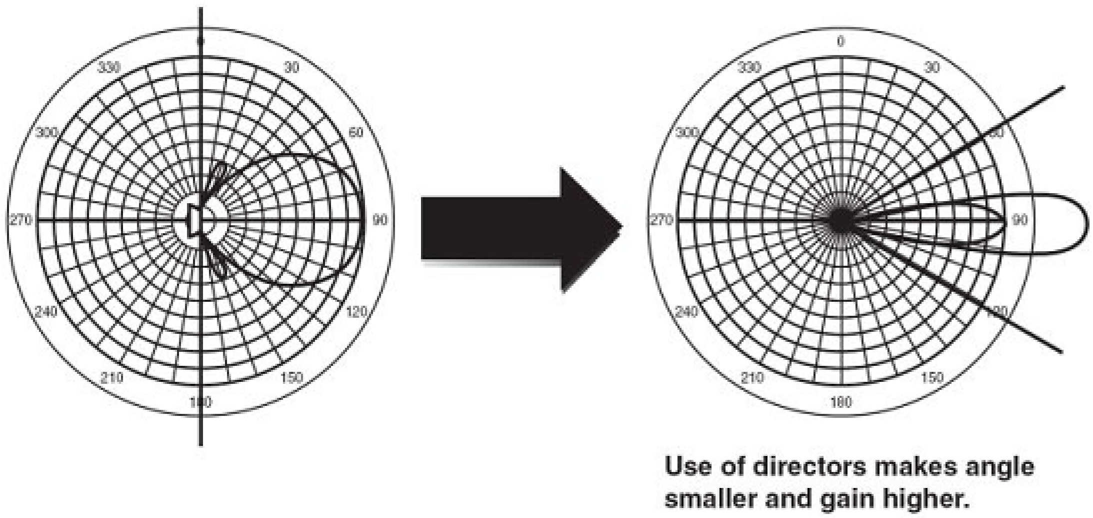

Figure 10. Directed radiation [3]

This is achieved by using a reflector and a director to focus the radiation in certain direction. Commonly used directional antennas are yagi-uda antenna and long-periodic antenna [10].
The financial and time constraint prevents us from purchasing and testing another antenna. In the final product, the antenna will likely be not a dipole but a more directional antenna with higher gain.

5 RF Reader Module

5.1 Electronic construction

Reader module is consisted of a transmitter, receiver, controller, and oscillator. The oscillator generates a carrier signal and sends it to the transmitter. The modulator inside the transmitter adds information to the carrier signal , and the power amplifier sends the signal to antenna. When the RF signal is received from the antenna, the receiver amplifies the signal for processing. The demodulator inside the receiver extracts the information and then controller communicates with the external devices. The figure 11 is shown below.

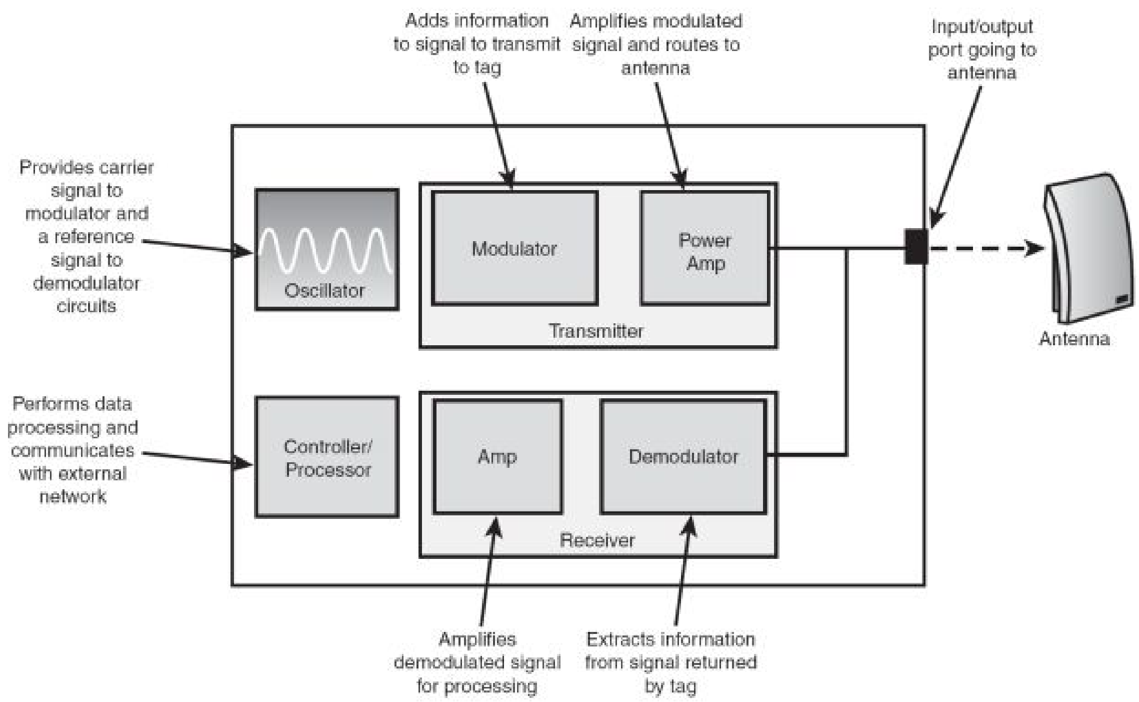

Figure 11. Reader construction [8]

5.2 Software design

Skyetek uses its own protocol called Skyeteck protocol V3. It uses C language to implement this protocol. C API is the interface used [8].

When the reader module receives the certain item to be identified from microcontroller in the remote, it acknowledges the tag ID associated with that item. The reader module goes to two step procedures.

1. Select type of tag: only one kind of tag such as gen1 class2 is identified [10].
2. Select TID: after step 1, only one tag ID is identified [skyetek ref]

There are two programming cycles to be controlled.

- Polling cycles has to be implemented. The reader determines the time interval of the tag searching time. [8]
- A repeat cycle is required to limit the number of attempt ion to read the tag. [8]

To send the tag ID to microcontroller when the requested tag ID representing the selected item is detected, reader module uses general I/O pin to send out the signal. The details are described section microcontroller.

5.3 Optimization design

The reader module has to be optimized to achieve the best performance.

1) Power level

Attenuation is adjusted to different environment and tag type [10]

2) Mux control

It allows using different kind of antenna to detect distance more accurately (product only not in prototype) [11]

3) Deterministic algorithm

For anti collision algorithm. When unique identification is defined for each tag, it searches the identification number which is stored in certain kind of database such as a binary tree and a node. [8] This algorithm achieves faster than other algorithm because the prototype only uses 3 items to detect therefore, do not waste much time searching for certain type of id in the binary tree.

4) Type of Tag

Only one kind of tag is used to provide consistent detection for each item and distance approximation [10]

6 Central Control Module

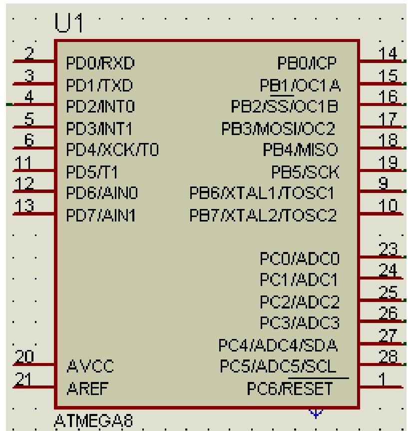

Figure 12: Microcontroller (U1)

- We use the Atmel microcontroller Atmega168 as the central control unit for controlling each modules
- Software for detecting input from Button Input Moduel (BIM) and output Speaker Output Moduel (SOM), and sending commend to Radio Frequency Communication Module (RFCM) are embedded in the microcontroller
- Module TIM - software algorithm of indentify tags is embedded in the microcontroller
- The microcontroller receives user input as interrupt when a button is pressed (through pin PD2/INT0), and also identifies which button is pressed from the (PC/ADC) input pins.
- The microcontroller processes the input signal and output signal to the reader through (PB/OC) the output pins
- The microcontroller sends commands to the reader to seach for the tags. The reader sendsback detected Tag IDs.
- Microcontroller decides if the ID is correct and activate the buzzer as needed

Microcontroller has Timer/Counter which will be used to control the buzzer beeping frequency. This indicates to the user that the tag is located in the direction s/he is pointing the device at.

7 User Interface Module

7.1 Input

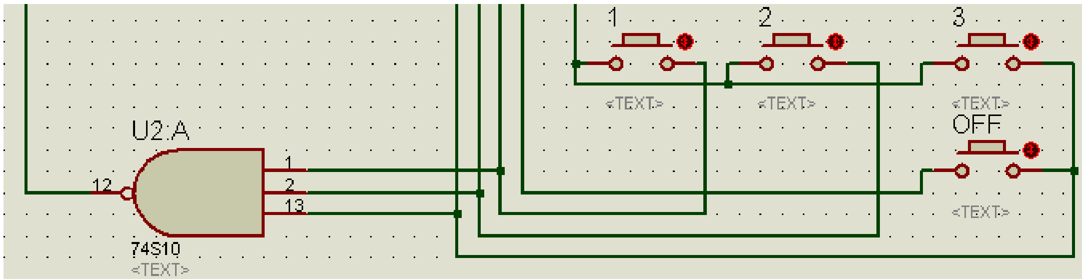

Figure 13. NAND Gate (U2) and Buttons

The final product can have 8 buttons. The prototype will have 4 buttons.

- Button 1-3 are for each item tag 1-3.
- Button 4 is the OFF button.
- User presses an item button associated with a tag to look for the item the tag is attached to.
- A NAND Gate is used for inputting a interrupt to the microcontroller when any button is pressed.

7.2 Output

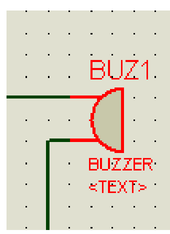

Figure 14. 555timer (U3) and Buzzer

When a button is pressed the buzzer will beep once to indicated the user turned the device on by pressing something

- Once the tag with the correct ID is found, the microcontroller activates the speaker to beep several times.
- The tag will be detected only when the tag is in the direction the device is pointing at.
- There will be also a volume control feature with the speaker using an analog voltage control. If the user doesn't hear very well, s/he may increase the volume of the beeping signal.

8 Connection between the Central Control Module (CCM) and the Radio Frequency Communication Module (RFCM)

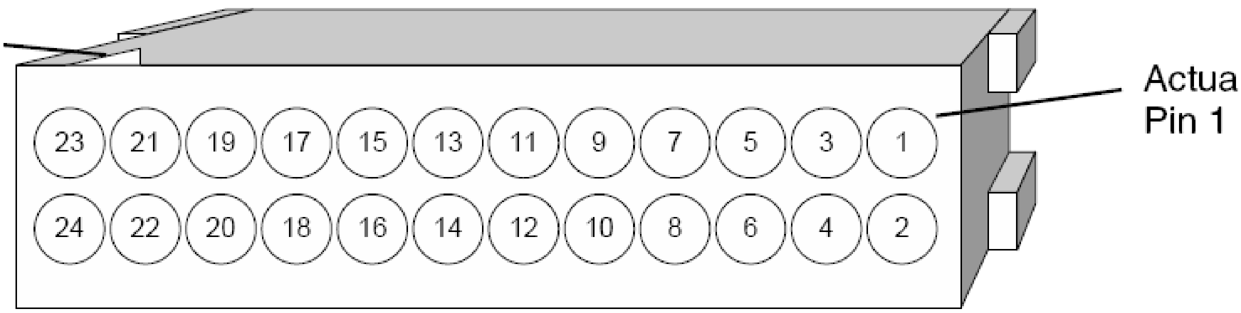

Figure 15. Ports of SkyeModule M9 RF Reader

Pin 17, 19, 21, 23 are general purpose I/O (GPIO) pins. Pin 17 also turns on the LED on reader board. The User Port Direction and User Port Value system parameters can be used to address the GPIO to set the user port direction (I/O) and the user port value (high/low). For our model, 19 and 17 are input pins, and 21 and 23 are output pins.

1) CCM -> RFCM

- When 19 is high, the reader starts to detecting tags.
- When 17 is high, the security mode is on.
- When 19 and 17 is low, the reader is off.

2) RFCM -> CCM

Reader will code the detected tag IDs and send these one by one.

- When 21 is high, and 23 is low, Tag 1 is detected. Once the microcontroller receives this information, it matches it with the button ID. If Button 1 has been pressed (i.e. a match), the microcontroller will decide this is the correct tag and signal the reader to a power-save

- When 21 is low, and 23 is high, then Tag 2 is detected and the same procedure follows as for Tag 1.
- When 21 is high and 23 is high, then Tag 3 is detected. and the same procedure follows as for Tag 1.

9 Power Supply

Figure 16. a 9V Battery to power the system

The battery will power up the microcontroller, the reader and the entire circuit.

- Voltage issue can be resolved by using LM9076 for our power supply.

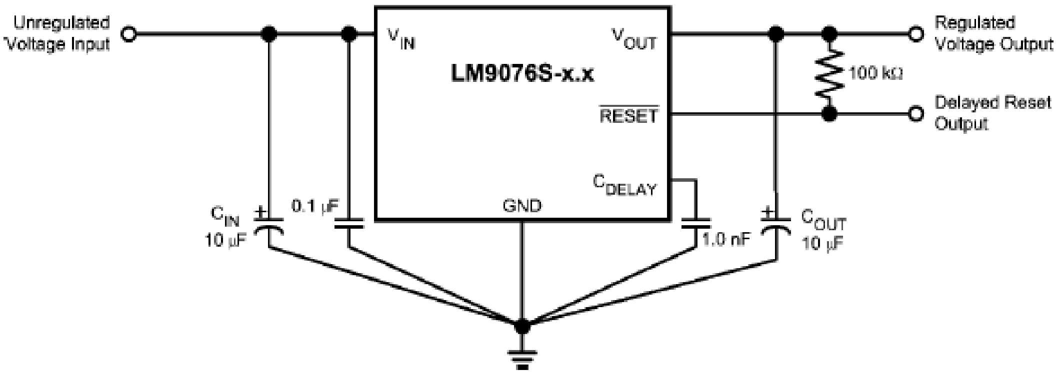

Figure 17. LM9076 Logic Controlled Voltage Regulator [12]

10 System Test Plan

10.1 Unit testing

Each unit is tested separately before all the parts are assembled fully. Each unit that has to be tested is listed below and the scenario of the most basic function is described below.

1) Microcontroller

i. Input: one button is pushed by the user
ii. Expected output: speaker alerts the user when the item is found

2) Reader

Required antenna for testing

i. Input: Command reader to read a tag
ii. Expected output: reader alerts whether the tag is detected or not

3) Antenna

4) Required reader for testing

i. Input: Command reader to read a tag in certain distance
ii. Expected output: reader alerts whether the tag is detected or not

Repeat the above steps in different distance and area and collect data

10.2 White Box testing

After the unit testing is done, each unit is fully assembled and white box testing starts

1) **Smoke test**

When any modification has made, quick testing for very basic functions

- on/off
- identify the item with the correct
- input/ output generated correctly

2) **Extreme cases**

The system should work on some unexpected cases but something that can happen in normal usage

- push all the buttons at once

- tags are keep moving
- disconnected accidently from power supply

3) Function test

Each function described in 10.1 section should be working in the fully assembled system.

Basic functions are described below.

- Identifying only one item selected by user
- Speaker make sounds when the item is identified

10.3 Black Box testing

Black box testing is performed by testers who do not know any details about the technology used for the product. And also the testers share similar characteristic as actual users such as vision impaired people, and seniors.

1) **Functional test**

- Same as 10.2 (3) function test.

2) User friendly

- Is it hard to use the buttons?
- Does any function do not make sense?
- Is the speaker too loud?
- Is the label big enough?

3) **Design**

- Is it disgusting?
- Does it offend any users?

11 Conclusion

The proposed design solution of the WILL have been discussed in this document. These design specifications provide clear goals for the development of the prototype.
The specification above will be adhered to as much as possible during the development stage. The test plans will be followed to ensure that all functional specifications are met

12 Appendix - System Flowchart

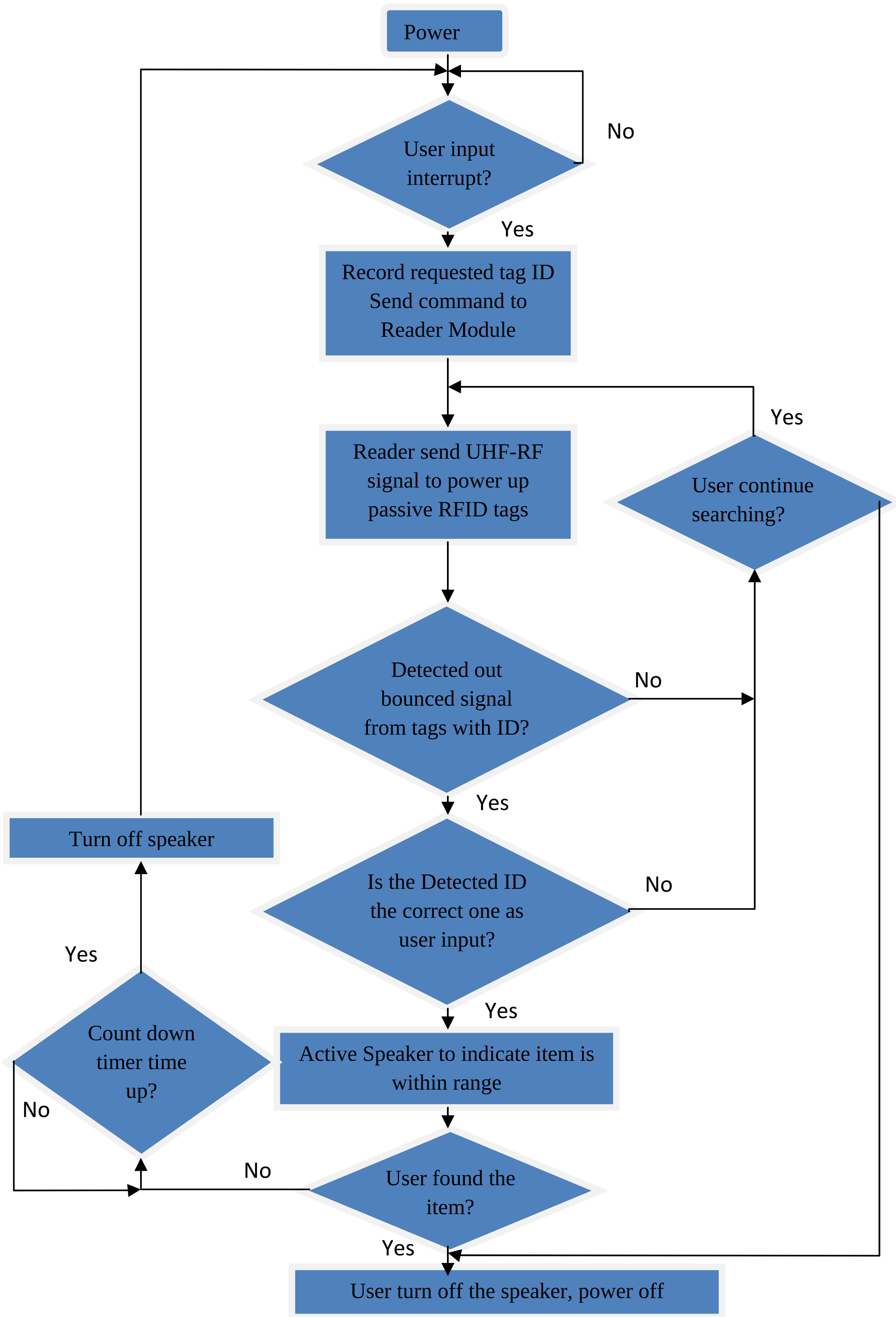

Figure 18 .System Flow Chart

13 References

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