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February 6, 2012

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Functional Specifications for Portable Emergency Response FMCW Radar

Dear Dr. Rawicz,

Attached to this letter is our team's functional specifications for a Portable Emergency Response FMCW Radar, as per our Engineering Science 440 class. Our design will give emergency personnel the ability to enhance their vision in low-visibility environments. By interfacing the radar-hardware with an iPhone application, we will create a portable product that can be used in a variety of professions. What makes our product so appealing is its versatility- hand-held, durable, and adaptable to variable range scales. At Shift Technologies, we see this as the future "must-have" product for emergency response personnel.

In our functional specification, we will break-down our project into three distinctive components: radar hardware, user interface and visual display, and hardware packaging. Each section will outline both whether the requirement is regarded as a proof of concept, finished product, or both phases of our development process. This document will be used by both managers and engineers in order to bring our product to a realization.

Shift Technologies is composed of a five-member team whose knowledge and skill set is second to none. Borna Vojdani, Laurent Ye, Mehdi Stapleton, Nelson Meira, and Steve Rickards are all fourth-year engineering students majoring in electronics, computer, or systems engineering. Should you have any questions or concerns regarding our proposal, please feel free to contact myself via email at mps8@sfu.ca.

Sincerely,

Mehdi Stapleton

Mehdi Stapleton
President and CEO
Shift Technologies

Enclosure: *ERadar - Functional Specification for Portable Emergency Response FMCW Radar*

ERadar

Functional Specifications
Portable Emergency Response FMCW Radar

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Submitted to	Dr. Andrew Rawicz —ENSC 440 Steve Whitmore — ENSC 305 School of Engineering Science Simon Fraser University
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Executive Summary

At Shift Technologies, we aim to develop a Portable Emergency Response Frequency-Modulated Continuous Wave (FMCW) Radar System to help rescuers in low visibility situations because the visible spectrum used by our eyes can be easily absorbed or blocked. While many tools have been developed for low visibility situations, such as Infrared imaging or Light Detection and Ranging (LIDAR), their shortfalls- sensitivity to excessive environmental or the need for a direct line of sight- leaves much to be desired. At Shift Technologies, we employ short wave, high frequency radar technologies which are safe to the human body, in order to alleviate shortcomings of current solutions and provide imagery through a variety of obstacles. Our device will work for ranges up to one hundred and fifty meters and provide a resolution of approximately twelve and a half centimetres.

By analyzing and comparing multiple angular snapshots, our radar system is able to piece together a bird's eye view of the scanned terrain including the location of obstacles and the velocity of moving objects. Naturally, the system is broken down into hardware and software components. Functionally, the hardware consists of the radar which sends and receives microwave pulses; the processing unit which runs the algorithms to analyze the received pulses; and lastly, the LCD display which graphically represents obstacles. In addition, the software runs on the processing unit and consists of all the algorithms that interprets the received data and graphically outputs the scanned terrain.

As with any project, our functional requirements are broken down and prioritized. The highest priority requirements are essential and necessary for the function of our radar. This includes the ability to scan, detect and display obstacles. Next, the medium priority requirements are important for making a marketable device. This includes additional features such as variable range resolution as well as the appearance and packaging of the device. Lastly, the low priority requirements are for fine tuning and refining in order to create a final product. These three tiers represent the three distinct developmental cycles of our system. Furthermore, at Shift Technologies we strive for safe, complete and effective solutions; and thus our radar system will undergo a comprehensive testing to ensure compliance with regulations, functionally accurate results and ease of use.

In conclusion, Shift Technologies aims to use FMCW radar as an imaging device for rescuers in low visibility situations by creating an overhead view of the environment and map potential hazards and obstacles from many angular snapshots. When compared to current solutions, ours provides the best compromise between range, resolution and cost. The functional requirements for our radar system are prioritized into three tiers which help to chronologically sequence tasks from the completion a proof of concept device, to a marketable product and to a final product.

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Glossary

ESSEF	Acronym; Engineering Student Society Endowment Fund.
CCRS	Acronym; Canada Center for Remote Sensing.
FMCW	Acronym; Frequency Modulated Continuous-Wave.
LIDAR	Acronym; Light Detection and Ranging.
PD	Acronym; Pulse Doppler (radar methodology).
iOS	Apple's mobile operating system.
MATLAB	Mathworks' high-level technical computing language.
Radio frequency (**RF**)	Oscillations in the range of about 3 kHz to 300 GHz, which correspond to the frequency of radio waves and the alternating currents which carry radio signals.
Baseband	In telecommunications and signal processing, describes signals and systems whose range of frequencies is measured from close to 0 hertz to a cut-off frequency, a maximum bandwidth or highest signal frequency.
Voltage-controlled oscillator	An electronic oscillator designed to be controlled in oscillation frequency by a voltage input.
Electronic mixer	A device that combines two or more electrical or electronic signals into one or two composite output signals.
Radome	A structural, weatherproof enclosure that protects a microwave or radio-wave antenna.
HUD	Acronym; Heads-Up Display
GUI	Acronym; Graphical User Interface

1 Introduction

The Portable Emergency Response FMCW Radar system is a device that provides emergency response personnel with a detailed overhead image of a low-visibility environment. Regardless of the amount of light, smoke, or vegetation in a user's foremost direction, an accurate picture of the surroundings can be produced. This document lays out the functional requirements for our Portable Emergency Response FMCW Radar system in order to provide a comprehensive reference for this intricate product.

1.1 Scope

This document contains a complete list of functional requirements that must be met by Portable Emergency Response FMCW Radar system. The requirements are prioritized according to functional importance and the highest priority requirements fully describe a proof of concept device, while the full set of requirements encompasses a production device. This document will dictate the current design tasks as well as future development.

1.2 Intended Audience

This document will be used by all members of Shift Technologies throughout the development of our radar system and serves as a guideline for the design and implementation process. The President and CEO, Mehdi Stapleton, will use this as a measure of compliance and progress of our project and direct future tasks. For implementation, the engineers of Shift Technologies will refer to this document in order to ensure that the current design complies with the goal of our product. Lastly, during testing, this document will serve as a template against which the final product is evaluated.

1.3 Classification

This document uses the following convention to number and prioritize the functional requirements:

[Rn-p] A specific functional requirement.

The letter n is the number of the functional requirement and p is the priority of the functional requirement and is classified as follows:

A – These requirements are high priority and are essential and necessary for the function of our radar.
B – These requirements are medium priority and are important for making a marketable device.
C – These requirements are low priority and they represent fine tuning and refinements to our product.

2 System Requirements

2.1 System Overview

The ERadar Portable Emergency Response FMCW Radar system high-level block diagram is shown below in Figure 1.

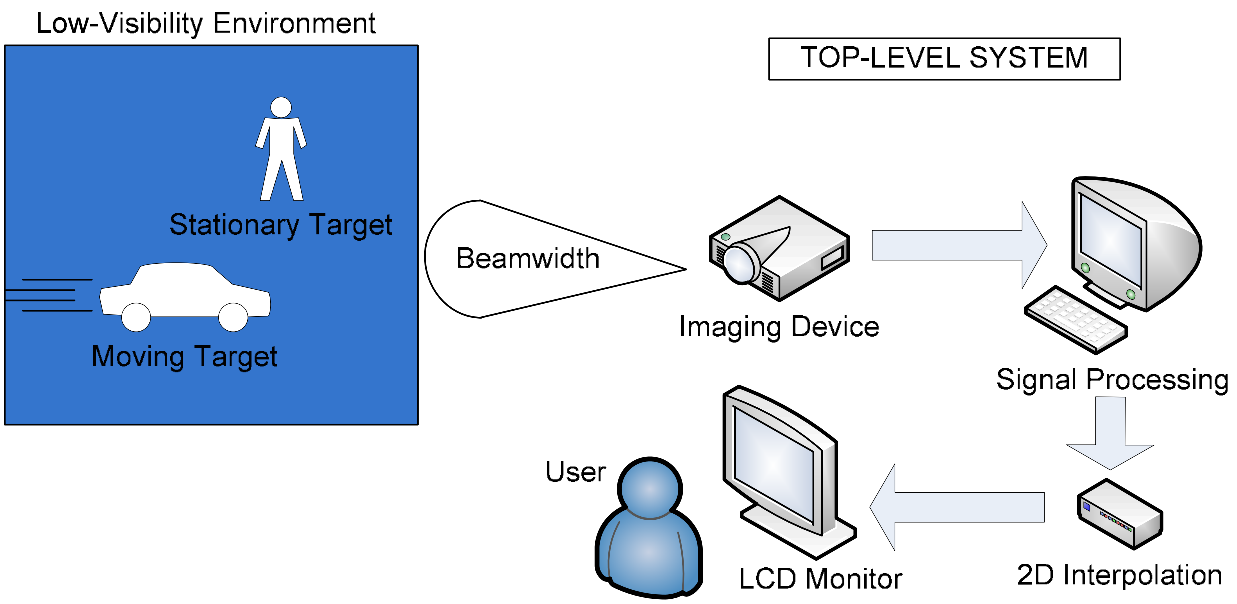

Figure 1: FMCW Radar system high-level block diagram

The product design consists of three main sub-systems: the imaging device, the real-time processing terminal and the user interface. The imaging device will comprise of a directional beam transmitting antenna and receiver capable of penetrating low-visibility environments in order to reveal targets within its beam-width. The transmitting antenna will be optimized for transmission of a 2.4 GHz (centre frequency) signal and capable of producing a sufficiently powerful signal to range profile moving and stationary targets at 150 meters from the hand-held radar system. The transmitter will be paired with a directional receiving antenna able of detecting return echoes from objects at ranges in excess of 150 meters. The antennas will be packaged compactly with the front-end function generation circuit and back-end analog filtering circuit alongside the signal processing terminal and user interface unit. The antennas will be light and unobtrusive to the personnel carrying the device.

The signal processing terminal will be able to filter undesirable artefacts and noise from the received echo and determine the range profile of the terrain within the field of view of the antenna. The processing will be able to parameterize the achievable range resolution given the proximity of the targets to the radar system as well as provide sufficient target-tracking to accommodate subsequent 2D interpolation of the radar range profiles – gathered at varying azimuthal angles relative a user-defined zero position.

The 2D interpolation hub and signal processing terminal must be compact and light -weight to reinforce the portability of the radar system. The terminal must also be capable of real-time processing of the incoming data in order to achieve tolerable processing delays of the target terrain.

The user interface unit will provide an intuitive and aesthetically pleasing representation of the signal processed target terrain. The interface will clearly identify targets (persons) of interest and both stationary and moving obstacles. The user interface will support display functions for the various range-resolution modes the signal processing hub will be capable of generating as well as guide the user in interpretation of the data.

For the proof of concept phase of the product, the antennas will service the minimum requirements in ranging profiling objects up to 150 meters with limited directionality or antenna gain. The signal processing will be able to meet the desired filtering characteristics of a final product; however, an optimally short processing delay will not be achieved until further into production.

Radio Frequency and Baseband Circuit

The circuit board for generating, amplifying, and analog-filtering the transmit and receive signal is composed into two subsections: the radio-frequency (RF) circuit and the baseband circuitry. The baseband circuit will generate the low-frequency modulating signal needed to create the linear FM signal. The aforementioned circuit will also boost and low-pass filter the received echo. The RF circuit pertains to the voltage-controlled oscillator (VCO) which uses the baseband modulating signal to frequency-modulate a microwave frequency carrier. The RF circuit also has high-frequency amplifiers for pre-antenna boosting, and a high-frequency mixer.

2.2 General Requirements

[R1-B] Must not have loose or cold-soldered wires
[R2-B] Must have easily accessible test points for trouble-shooting
[R3-B] The retail price of the ERadar must be under CDN$700
[R4-C] The final product must be aesthetically appealing
[R5-C] The circuit must be able to withstand a system vibration test

2.3 Physical Requirements

[R6-B] The ERadar must be able to withstand being rotated in any direction by a person holding it
[R7-C] The construction (i.e. the framing of the product) must be balanced so as to be easy to hold with one hand
[R8-C] The dimensions of circuit board must not exceed 7.5 cm by 7.5 cm in area

2.4 Electrical Requirements

[R9-A] The power supply must be portable and self-sufficient
[R10-B] The power supply must be easily accessible for replacement
[R11-B] The key voltage nodes must be easily accessible for debugging
[R12-C] The power supply must last at least at least 1 month before needing replacement

[R13-B] Must be electrically-isolated from interfering environmental signals (local or wide area networks)

2.5 Environmental Requirements

[R14-C] Circuit board must be able to withstand high temperature swings
[R15-C] Must be inflammable and fireproof
[R16-C] Must remain operable at ambient temperatures between - 50°C and 90°C
[R17-C] Must be able to withstand temperatures up to 300°C for at least 10 minutes [1]
[R18-C] Must be able to withstand a flux of 1.0 kW/m^2 to 10.0 kW/m^2 [1]
[R19-C] Must be operable at a relative humidity of at least 70%
[R20-B] Must be operable at altitudes between -75 m below sea level to 1000 m above sea level
[R21-C] Must be able to tolerate getting wet and remaining damp for periods up to 30 minutes

2.6 Standards

[R22-A] The ERadar will conform to IEEE 802.11 standards relating to wireless communications
[R23-A] The ERadar will conform to CSA standards [2]
[R24-A] The ERadar will conform to FCC regulations on Wi-Fi
[R25-C] The ERadar will conform to NIST Thermal Class I, II, and III [1]

2.7 Safety Requirements

[R26-B] The ERadar radiation power levels must lie within human safety limits
[R27-B] The ERadar power requirements must lie within human safety limits
[R28-C] The ERadar final product must not resemble a toy
[R29-C] The surfaces of the ERadar must remain cool enough to be held by fire suit gloves
[R30-C] The electrical components of the ERadar must not melt or emit toxic fumes
[R31-C] The ERadar must detect and clearly indicate mechanical or electrical failure

2.9 Performance Requirements

[R32-A] The ERadar must be able to detect objects between 1 m and 150 m away
[R33-A] For ranges up to 50 m, must have a detection resolution of 1 dm
[R34-A] For ranges between 50 m - 150m, must have a detection resolution of 1 m
[R35-A] Must be able to detect objects moving with velocities up to 17 m/s
[R36-A] The ERadar must be able to gather and process data within at least 3 s

2.10 Usability Requirements

[R37-A] The ERadar must have intuitive controls and methods for users to specify data parameters
[R38-B] The firmware must be easily updated by the user
[R39-B] The handle must be ergonomic and easily held by thickly-gloved hands
[R40-C] The frame must have a means to attach to a hook or other object in the case the user's hands are full
[R41-C] The GUI and the casing must clearly indicate which way the antennas point
[R42-C] The GUI must clearly indicate when the power source must be replaced

3 Antennas

The transmit and receive antenna elements will be able to send out a linearly frequency modulated continuous wave signal and detect the return echoes of pertinent targets in the field of view, respectively. The antennas must be configured for microwave frequency propagation and have sufficient antenna gain for directionality and azimuthal angle resolution.

3.1 General Requirements

[R43-C] Must cost less than $100 per antenna
[R44-C] Must be able to withstand a vibration test

3.2 Electrical Requirements

[R45-C] Optimized for 2.4 GHz transmission and reception
[R46-C] High gain for a 300 kHz bandwidth about the center frequency

3.3 Physical Requirements

[R47-C] Must be compact, not exceeding 6 inches in diameter and ten inches in length (for a cylindrical waveguide)
[R48-C] Must be lightweight, not exceeding a combined weight of 0.5 kg
[R49-C] Must have a radome on each to protect the propagating monopole element inside the waveguide

3.4 Safety Requirements

[R50-C] Level of exposure for personnel using the device must not exceed an output power density of 5mW/cm2
[R51-C] Level of exposure for general public which are targets of system must not exceed an output power density of 1mW/cm2 [3]

4 Hardware Packaging

The hardware packing of our system encompasses housing for the radar components, a mounting slot to secure the iPhone, and a handle for the user to hold. The enclosure will contain the battery supply, PCB, RF circuitry, and antennas. In order to fit the requirement of a *portable* radar system, the hardware packaging must be as compact as possible and be rugged enough to withstand general physical abuse.

4.1 General Requirements

[R52-A] Weigh less than 3 kg
[R53-A] Able to withstand a two-foot drop test
[R54-B] Dimensions of the case shall not exceed 35 cm x 30 cm x 20 cm

[R55-C] All electrical components will be mounted on the inside of the enclosure
[R56-C] Audio jack output of the circuit should be long enough to be pulled up to ten inches out of case
[R57-C] Two circular openings, approximate four inches in diameter at the front of the enclosure to allow electromagnetic waves to propagate without unnecessary attenuation
[R58-C] Case can be opened by removing fasteners in the event that any maintenance being required

4.2 Mechanical Requirements

[R59-A] Audio jack output of the circuit to be wound onto an automatic, retractable pulley system in order to prevent it from getting tangled
[R60-A] Ergonomically designed handle and mounting angle do not strain user's wrist
[R61-A] iPhone mounting is secure enough that the phone will not fall out when being jostled
[R62-B] Handle can be removed for storage purposes
[R63-B] On/Off slide switch mounted on the outside of the case
[R64-B] iPhone mounting should allow for easy installation and removal of iPhone

4.3 Physical Requirements

[R65-A] The effect from external interference is limited due to shielding on the PCB
[R66-A] Casing and electrical components able to operate within *momentary* external temperatures of between -10 °C and 80 °C
[R67-A] All openings to the interior of the case must be sealed with either chemical sealant or by use of an O-ring
[R68-B] Surface of the case and fasteners must not weather

5 Software Requirements

The primary function of the heads-up display (HUD) is to assist the user during the acquisition, processing and the presentation of data from the physical system, through a simple graphical interface. The HUD will guide the user through a simple and intuitive graphical user interface (GUI) in order to give the user feedback as to the state of the environment. The HUD allows the user to manipulate all adjustable aspects of the physical system within the GUI in order to interpret the data from the scans. Implemented in software, it is important that the HUD software is not only error free, but that all of its functions are mapped in a natural and cognitive arrangement as to minimize the probability of errors in emergency situations.

5.1 General Requirements

[R69-A] Graphically render the results of single/consecutive radar scan iterations
[R70-B] Allows for the selection of scan target range, prior to the processing of data
[R71-B] Will automatically select a range if no input by the user is made
[R72-B] Will detect the magnetic orientation of the radar for calculation use, and if selected to do

so report this bearing to the user as a compass heading

[R73-B] Must not allow the user to manipulate its functions during an active scan

[R74-B] Software must iterate any active task, if active and at all times, so to inform the user of its current availability and status

[R75-B] Must be capable of running on any iOS 5.xx iPhone device

[R76-B] Must run on any iOS 5.xx device with magnetometer capabilities.

6 User Documentation

6.1 General Requirements

[R77-A] A user documentation that will include graphics, text, and step by step operation instructions will be incorporated into a software feature in the device.

[R78-A] A quick start guide will be printed and included with the final product to allow the user to initially set up, configure, and access the user's documentation for the first time.

[R79-A] A special troubleshooting section will be included which will contain common pitfalls and technical issues involving software and hardware. This will include a "Q & A" section.

6.2 Usability Requirements

[R80-A] The user documentation will include a separate section to aid the user in the interpretation and identification of targets rendered by the radar system. This section will serve only to aid in the interpretation of radar data, and assumes that the user is acquainted with the basic function of the device.

6.3 Software Requirements

[R81-B] The HUD software will include automatic, real-time tips and directions overlaid throughout the software GUI. The optional guides will allow the user to quickly familiarize with the functions of the device, and can be disabled thereafter.

7 System Test Plan

In order to validate our portable emergency response radar system, Shift Technologies intends to implement a rigorous test plan in order to test both individual modules and the final product. Module tests will be conducted on both the radar hardware and iPhone application throughout the design process to verify basic functionalities. Once the basic signal processing of the radar system has been completed, we will begin testing trivial scenarios in an open field with stationary, moving, and multiple targets. As the project progresses to stitching together multiple scans to form a single image, tests will be conducted in an open field to verify its functionality. Once both basic ranging and velocity functions have been confirmed, the finished product will be put through a series of realistic scenarios simulating the professions of the intended users.

Individual module testing will be performed on each aspect of the project as they are completed. These tests include, but are not limited to:

- Basic MATLAB code: running the MATLAB code, provided by MIT's Lincoln Laboratories [4], with our constructed radar hardware to confirm radar's sending and receiving capabilities.
- Uploading a .wav file to the application: upload a simple .wav file into the iPhone app to test its response. Also, test not giving the application a .wav file during the loading period to observe its response.
- Attenuation from covered coffee can: scan the same environment once with the lids of the coffee cans on and once without. Compare the two images to confirm that it's viable to cover the cans for protection.
- Stitching together scans: combining two .wav files into a single set of usable data within MATLAB.
- Compass integration: utilizing the data from the compass tool within the iPhone for the signal processing.
- Hardware packaging drop-test: inspect the durability of the case by dropping it was various heights less than three feet.
- Once the radar hardware, signal processing, and iPhone app's basic ranging functionality has been validated, the components will then be integrated and tested. These tests will be completed in an open field to eliminate the possibility of confounding variables in the results. If required, the data obtained from these tests will be used to improve the algorithm of the signal processing. The situations that will be tested are:
- Single target test: stationary person starting at 25 m, 50 m, or 100 m and then begin to walk to or away from the radar. The exact velocity of the individual will not be known, however the target's change in distance with respect to the location of the radar will be noticeable.
- Multiple target test: stationary individuals all standing in line with the radar at 50 m, 100 m, and 150 m.
- Variable range resolution: stationary person standing 10 m away from the radar, and vary the range of the signal processing on the iPhone to observe the increase/decrease in resolution.

- Entering and leaving scanned area: person will run perpendicular to the emitting antenna in order to observe the data that is collected from someone running in and out of the area being scanned.
- As the project progresses to a radar system that can scan the azimuth angle (Do we need a reference from somewhere to talk about azimuth angle?), more complex and realistic tests will be conducted to observe the system's effectiveness in the intended fields. These situations will include, but are not limited to:
- Hidden skier in the snow: burry a person in a snow embankment and test the system's ability to locate the target.
- Hiker lost in the woods: stationary person within a wooded area and test the system's ability to locate the target. Also conduct the test with a moving target.
- Victim within a smoky room: fill a small room with steam from dry ice and test the system's ability to locate the target.
- Interference testing: observe any discrepancies when the radar is placed near a device that has a send or receive capability within the same transmission bandwidth (i.e. Wi-Fi networks).

Further tests that will also be conducted that evaluate the efficiency of the system: response time of the signal processing and the battery life of the radar. If the time that the user has to wait between when the .wav file is uploaded to when an image is produced is too long, major modifications must be done on the algorithm to decrease the wait time for the signal processing. As for the battery life, it would seriously hamper the system's effectiveness if the radar hardware drew too much power and depleted the batteries too quickly. If needed, components that draw less power would be researched and considered as replacements.

Conclusion

The functional specification detailed in this document clearly and concisely defines the requirements for our Portable Emergency Response FMCW Radar system. In addition, these requirements are prioritized by a three tier system and dictate the developmental phases for our radar system. With the completion of each phase, higher priority requirements are satisfied and the device evolves from a proof of concept, to a marketable product and to a final product. The proof of concept device is well under development and we are excited and confident in the completion of the final product by April 12, 2012.

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