Lost Object Search Technology

Adithya Sairam - Cecil Macgregor - Brittany Joy
ECE 445 Project Proposal - Spring 2017
TA: Daniel Gardner

1 Introduction

1.1 Background and Objective

Lost Object Search Technology is designed to allow users with audio and visual impairment to easily detect and track down small lost objects. In every person's life, there are a handful of small objects which are critical for day to day life, such as car keys, cell phones, wallets, walking canes, etc. Thankfully, there are a number of products such as Tile which can be attached to these important objects and used to find them if they are misplaced. However, these products all share a common flaw: they are unusable by those with audio and visual impairment. The Tile's phone app is useless to the blind, and the deaf are unable to hear Tile's ringing. Nearly 15% of children experience low or high frequency hearing loss of at least 16-decibel hearing level in one or both ears[1]. Additionally, more than 3.4 million (3%) of Americans aged 40 years and older are either legally blind or are visually impaired[2]. All of these people are unable to use the existing lost object finders; clearly, something should be done.

Our goal is to solve this clear and evident problem by creating LOST, or Lost Object Search Technology. By redesigning the concept from the ground up, we will deliver a product which can be used easily and effectively by any user, regardless of any visual/audio impairments. LOST will incorporate a receiver which can connect to one of multiple transmitters. The receiver will then use tactile, audio and visual feedback to guide the bearer to the selected transmitter using the classic "Hot or Cold" method of pathfinding. The use of analog switches and multiple forms of feedback will make LOST easily usable by the deaf and the blind.

1.2 High Level Requirements

- Receiver must be able to connect to and evaluate the signal strength of up to three separate transmitters at a range of up to 300 feet.
- Receiver must be able to report the signal strength (i.e., distance to transmitter) to the user using tactile, visual and audio feedback.
- Transmitters must be small, light, and able to operate on battery power for long periods of time, ideally for months.

2 Design

LOST has four major modules that are a part of its design: the transmitters, the control unit, the feedback module, and the power supply module. The receiver unit has a master switch to turn off the power to the whole system when not in use.

There will be three RF transmitters, all transmitting signals in the 915 MHz ISM band. Each transmitter will have its own small battery supply, but will stay on the whole time. A stretch goal will be to implement a passive notification system which can turn on the transmitter remotely from the receiver, or a small solar panel (on the order of 10 to 30 mA) to slowly recharge the battery over.

The control unit is comprised of an antenna, a transceiver chip, and a microcontroller. This module determines the RF signal strength (i.e. distance from the lost object) and determines how to control the feedback module.

The feedback module contains 3 different systems used to interact with the user. The feedback module receives signals from the microcontroller that are fed into a speaker, a vibration motor, and LEDs. Each of these will indicate greater signal strength with an increased frequency of sound from the speaker, vibration from the motor, and blinks from the light.

The power supply module consists of a 9V battery and two voltage regulators to step the 9V battery down to 5V and 3V depending on each component's required voltage. We plan to use buck converters for our voltage regulators since they have better efficiency than linear regulators.

Refer to Figure 1 for a block diagram of LOST.

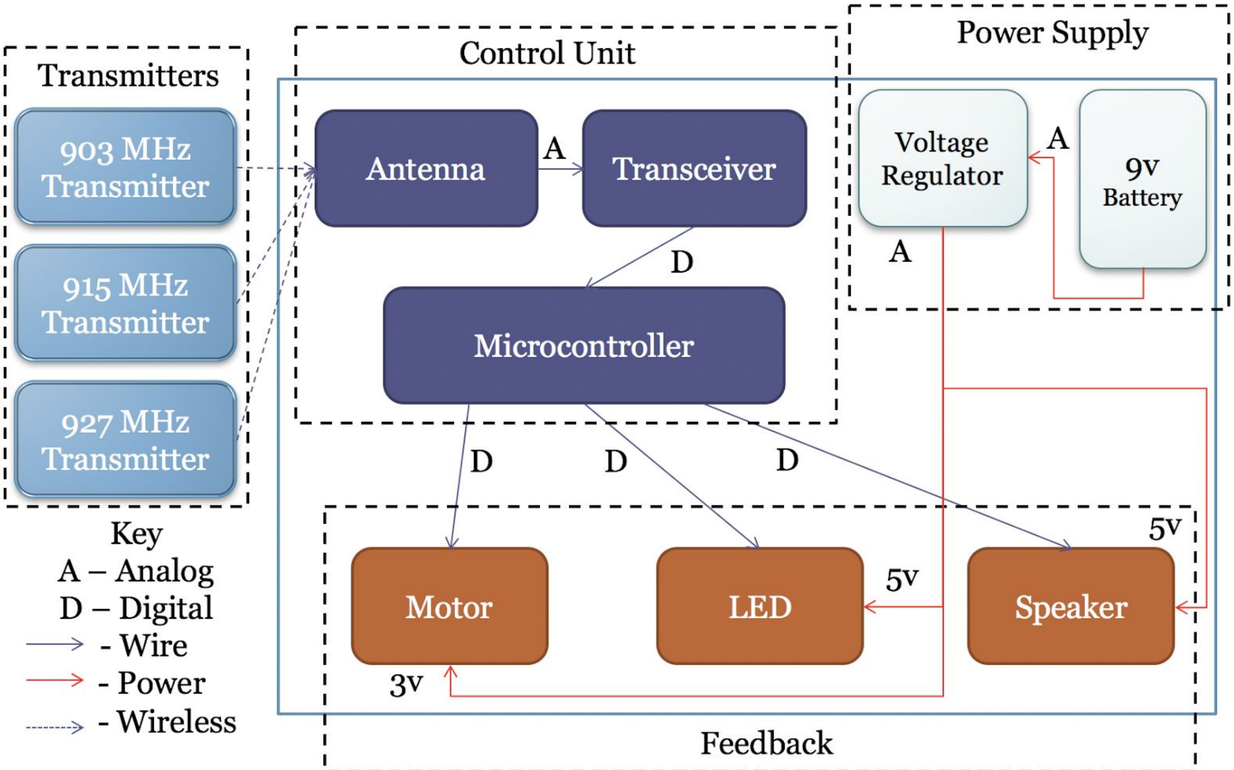

Fig. 1: LOST Block Diagram

2.1 The Transmitters

The three transmitters will transmit signals in the 915 MHz ISM band which will be picked up by the receiver when attempting to locate lost objects. Each of them will have their own transceiver chip, a low-power microcontroller, an antenna, and will be powered by a 3V lithium battery. Each transmitter will operate at a different frequency corresponding to different channels within the 915 MHz ISM band. We have selected carrier frequencies of 903 MHz, 915 MHz, 927 MHz for the transmitters to spread out along the band as much as possible. A stretch goal for the transmitters is to leave them in a low-power sleep mode where they “listen” for a signal from the receiver to turn on and begin transmitting a signal to the receiver to find the lost object. The purpose of this is to avoid constantly transmitting a RF signal to the receiver and decrease power consumption. Another stretch goal is to have a solar panel in tandem with a rechargeable lithium coin battery for portability and battery endurance.

Refer to Figure 2 for the block diagram for the transmitters.

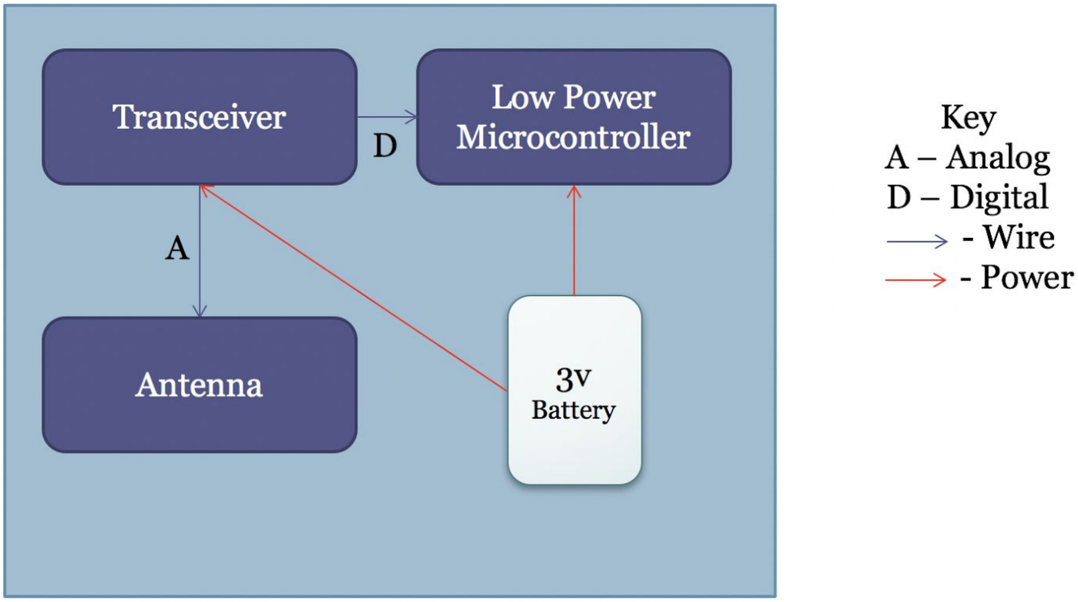

Fig. 2: Transmitter Block Diagram

2.1.1 Transceiver

The RF transmitters (that are connected to objects the user wants to track such as keys or phones) will be paired with a receiver that is kept on the user, and will operate with carrier frequencies of 903 MHz, 915 MHz, 927 MHz. The transmitters are always in TX (transmit) mode. In this mode, an RF signal at its respective frequency is sent to the receiver. To accomplish our stretch goal, an additional functionality needs to be implemented in order to achieve a sleep mode. This would mean that when the receiver is turned off, the transceiver on the transmitters is on RX (receive) mode and is “listening” for a signal from the receiver to start transmitting the RF signal. Once the transmitter receives the signal to turn on, it switches to TX mode and begins broadcasting an RF signal at its respective frequency.

Requirement 1: The three transmitter frequencies should differ enough so that they are not located on the same channel within the 915 MHz ISM band.

2.1.2 Low Power Microcontroller

In order to communicate with the transceiver, a low power microcontroller is used. It will be powered using the 3V battery and will consume approximately 200mA.

2.1.3 Antenna

This antenna is used to transmit the RF signal from the transceiver. In order to achieve best functionality, antenna impedance matching circuitry must also be implemented[3].

Requirement 1: An omnidirectional antenna will serve better for our purposes over a directional antenna because the transmitter can be in any direction away from the user.

2.1.4 Battery

The transmitters will be powered with a 3V battery. This will provide power to the internal transceiver and associated microcontroller.

Requirement 1: At 3V, the battery will power a microcontroller and a transceiver for several days.

2.2 Control Unit

The user will select one of the three transmitters using a switch on the receiver unit and the corresponding strength of the RF signal chosen by the user will be relayed to the feedback module.

2.2.1 The Antenna

This antenna is used to receive the RF signal from the transmitters. In order to achieve best functionality, antenna impedance matching circuitry must also be implemented.

Requirement 1: An omnidirectional antenna will serve better for our purposes over a directional antenna because the transmitter can be in any direction away from the user.

2.2.2 Transceiver

The transceiver will be connected to the antenna and microcontroller. The transceiver also gives the RSSI (Received Signal Strength Indicator) of the RF signal it is set to receive from the selected transmitter. This RSSI will be fed to the microcontroller and used to determine the appropriate level of feedback to the user.

2.2.3 Microcontroller

A microcontroller will be selected based on its small size and power-efficiency, ideally consuming approximately 500mA at 5V. This microcontroller will control the transceiver and feedback module. It will use the RSSI from the transceiver to output a clock signal to the feedback module. The frequency of this clock signal will vary directly with received signal strength.

Requirement 1: The microcontroller has more than enough memory for the operations required to determine output clock signal based on received signal strength, and to direct the operations of the transceiver.

Requirement 2: The microcontroller operates roughly between 1V to 5V, well within the range provided by the power supply.

2.3 Feedback

Since LOST is designed to work with people with audio/visual impairments, there are several methods of interacting with the receiver unit including sight, sound and touch.

2.3.1 The Vibration Motor

The vibration motor will buzz with faster frequency as the user approaches the transmitter of their choice, with constant intensity.

Requirement 1: A small motor capable of significant haptic feedback, ideally operating at 3V and consuming 20 to 30 mA of current

2.3.2 LEDs

There will be three LEDs which will blink with increasing frequency as the user approaches the transmitter. Each LED will be a different color to symbolize the different transmitter.

Requirement 1: 5V is enough to power the LEDs, along with a 1kHz pull-down resistor.

2.3.3 Speaker

There will be a speaker which will buzz with faster frequency as the user approaches the transmitter. This will work in tandem with the LEDs and vibration motors so all three are in sync.

Requirement 1: The speaker also operates with 5V, and can be transmitted to using a 3.5mm jack.

2.4 Power Supply

The receiver unit is operated with a 9V battery with several buck converter voltage regulators to bring the voltage down to 5V and 3V so every part of the circuit can be powered without being overloaded. There is also a master power switch which will turn the power off for the receiver unit when not in use.

2.4.1 9V Battery

The 9V battery is more than enough to power the circuit and will ensure a long-lasting life for the entire unit.

2.4.2 Voltage Regulators

There are two regulators to bring the voltage down from 9V to 5V for the microcontroller, LEDs and speaker in the feedback system, and to 3V for the vibration motor. As discussed previously, we will use buck converters.

Requirement 1: The voltage regulator must provide 5V and 3V with ± 10% error from the 9V battery source (which in reality will provide approximately 8.9V of power).

Requirement 2: The regulator should not heat up to unstable conditions so a heat sink will be added to ensure that the temperature is optimal for working conditions.

2.5 Risk Analysis

There are a couple risks we face in the completion of this project, the most significant dealing with the RF transmission and reception. The range of an RF signal is dependent on two main factors: the frequency and the antenna. Since portability is a major component for LOST, we want to transmit over a frequency range and use an antenna that will not take up too much space on the circuit board. Stronger signal transmission requires more power and for the antenna length to be longer, so we have to compromise and find the best combination of the two. High frequencies also penetrate walls a lot better, which is essential in finding lost objects.

The antenna is also a concern because the selection of choosing the proper type of antenna and the height depend on a lot of factors. Directional antennas provide better gain but for the purposes of this project, an omnidirectional antenna would provide better support to pick up the transmitter from all directions around the user. We will also ensure our PCB design does not interfere with the antenna.

3 Safety and Ethics

In accordance with the #1 of IEEE Code of Ethics, we “accept responsibility in making decisions consistent with the safety, health, and welfare of the public” and will “disclose promptly factors that might endanger the public or environment.” Our project is designed and intended to help people (especially those with audio/visual impairments) locate frequently misplaced objects easily and efficiently. The purpose of this section is to explain how we will commit to this.

No aspect of this project goes against any part of the IEEE or ACM Code of Ethics, and there is no way to misuse this project in a way that would be deemed unethical. To avoid any ethical breach, we will make clear any associated safety concerns with our project.

Our current design for the project utilizes 9V batteries and Lithium coin batteries. There are safety hazards associated with both of these types of batteries. The positive and negative terminals on a 9V battery are near each other. If metal or a conductive material connects the terminals it can cause a short circuit which can generate heat and possibly start a fire. During development, we will take caution in storing any 9V batteries by either leaving them in their original packaging, storing them upright, and not storing them in contact with other batteries or metal objects as well as covering the terminals with masking, duct, or electrical tape [5]. Information on 9V battery safety will be included with our project so that the user does not unintentionally put themselves at risk with the 9V batteries if the battery is removed or needs to be replaced.

Lithium coin batteries are less dangerous electrically than 9V batteries, but are a choking hazard for young children. If ingested, they can cause severe burns on the esophagus in as little as two hours and can cause ongoing medical concerns [6]. In development we should not have any issues with ingesting coin batteries. If the user removes the coin batteries they must be sure to keep out of reach of children and dispose of the batteries when they need to be replaced. We will follow the safe practice guidelines for Lithium batteries provided by the course [7].

In general, if the project is tampered with or taken apart, small pieces pose threat as a choking hazard to children and should be kept out of reach. This project will have RF emissions when on and in use. These RF emissions will be lower power than emissions from cell phones or microwave ovens and do not pose a health risk.

Our project can be classified as a low-power non licensed transmitter. Our project will comply with Part 15 of the FCC to avoid potential harmful interference with other RF signals. We intend to operate our project in the 902-928 MHz range which is a typical unlicensed part 15 band for devices of this type. Our project could potentially interfere with household devices such as cordless telephones, wireless toys, and baby monitors because these objects may also operate in this same frequency range [8]. Since the devices associated with our project are small and low-power, the field strength will not exceed the limit set by the FCC.

References:

[1] "Data and Statistics." Centers for Disease Control and Prevention. Centers for Disease Control and Prevention, 05 Dec. 2016. Web. 07 Feb. 2017. <https://www.cdc.gov/ncbddd/hearingloss/data.html>.

[2] "The Burden of Vision Loss." Centers for Disease Control and Prevention. Centers for Disease Control and Prevention, 25 Sept. 2009. Web. 07 Feb. 2017. <https://www.cdc.gov/visionhealth/basic_information/vision_loss_burden.htm>.

[3] "3 Factors That Limit Range in RF Applications." Laird Technologies Wireless Connectivity Blog. Laird Wireless Blog, 03 Nov. 2015. Web. 08 Feb. 2017. <.http://www.summitdata.com/blog/3-factors-limit-range-rf-applications/>.

[4] "Small Loudspeaker Circuit Diagram Using IC LM386." Small Loudspeaker Circuit Diagram Using IC LM386. Circuit Digest, n.d. Web. 08 Feb. 2017. <http://circuitdigest.com/electronic-circuits/small-loudspeaker-circuit-diagram>.

[5] "9V Battery." NFPA. N.p., n.d. Web. 7 Feb. 2017. <http://www.nfpa.org/~/media/files/public-education/resources/safety-tip-sheets/9voltbatterysafety.p>.

[6] "Coin Lithium Battery Safety." Coin Lithium Battery Safety. Energizer, n.d. Web. 08 Feb. 2017. <http://www.energizer.com/responsibility/coin-lithium-battery-safety/preventing-coin-lithium-battery-injury>.

[7] Spring 2016 Course Staff. "Safe Practice for Lead Acid and Lithium Batteries." (n.d.): n. pag. *ECE 445 Senior Design Laboratory*. ECE Illinois, 13 Apr. 2016. Web. 8 Feb. 2017. <https://courses.engr.illinois.edu/ece445/documents/GeneralBatterySafety.pdf>.

[8] "ARRL." Part 15 - Radio Frequency Devices. ARRL, n.d. Web. 08 Feb. 2017. <http://www.arrl.org/part-15-radio-frequency-devices>.