

Bat Migration Monitor

ECE 445

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Senior Design Project Proposal

Team 35

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1. Introduction

1.1 Problem

The population of bats, whose presence provides pest control, pollination, and seed dispersal has been on decline due to various reasons such as WNS, habitat destruction, and wind turbines (>400,00 hoary bats are killed by wind turbines annually). Due to the unawareness of their migratory path, minimum support has been provided in order to protect them. At the moment, there are VHF & Untraceable GNSS tags currently available in the market, however, they both have their own downsides. The VHF tags are very labor intensive and only are beneficial when the bat is stationary. Untraceable GNSS tags are unable to be retrieved which creates a lot of data loss of the paths. Additionally, both tags have a pricey dollar tag attached to both. In order to aid in bat conservation efforts, we need to learn more about the bats' migration habits, which calls for the need of a new low-cost tracking product, such that it can improve the devices that are currently in the market in order to preserve the current population of bats.

1.2 Solution

Our design is aimed to have low-cost VHF & GNSS technology that can store the bat's movement as well as send a signal for tracking data. This information will help us gather data for the bats' winter-summer migration paths, and use it to prevent the further increase in bats' casualties.

For our design from a high level perspective, it is essential to construct a device that incorporates a GNSS tag integrated with VHF tracking capabilities to resolve issues that current devices have in the market. The construction of the device must ensure a weight below 1.5g and have an approximately 21x13x5 mm dimensions, such that the device would have no interference with the flight capabilities of bats.

1.3 Visual Aid

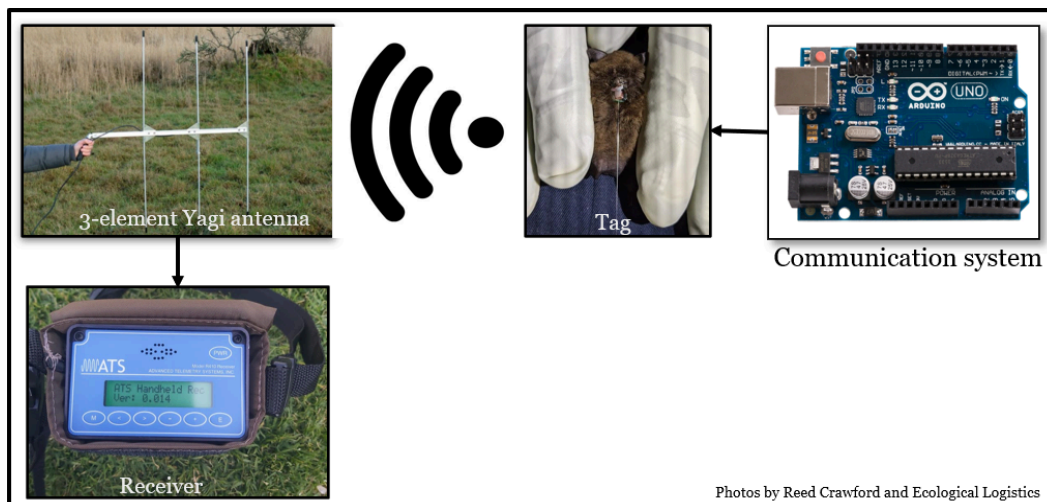


Figure 1- Visual Aid

1.4 High Level Requirements List

- Our design will need a GNSS module that will monitor the daily paths of a bat, which will provide insights of the movement patterns bat take throughout the day. Our device should be able to collect location data every 5-10 minutes over a 6 hour timeframe for a 3 day interval.
- In order to retrieve the device we have constructed, we require a tracking system such that we would be able to pinpoint the exact location of the device and be capable of collecting the data that was provided by the GNSS module. Thus, our device will utilize a VHF transmitter in the 148-152 MHz band, this band matches the receiver already in use by the lab. The transmitter should be able to be detected if it is within a 1 km range.
- We must be able to integrate the GNSS and VHS modules such that it would not interfere with the bats normal functionalities. Therefore, the weight of the device should be approximately less than 1.5 grams and have a maximum dimension of 21x13x5 mm.

2. Design

2.1 Block Diagram

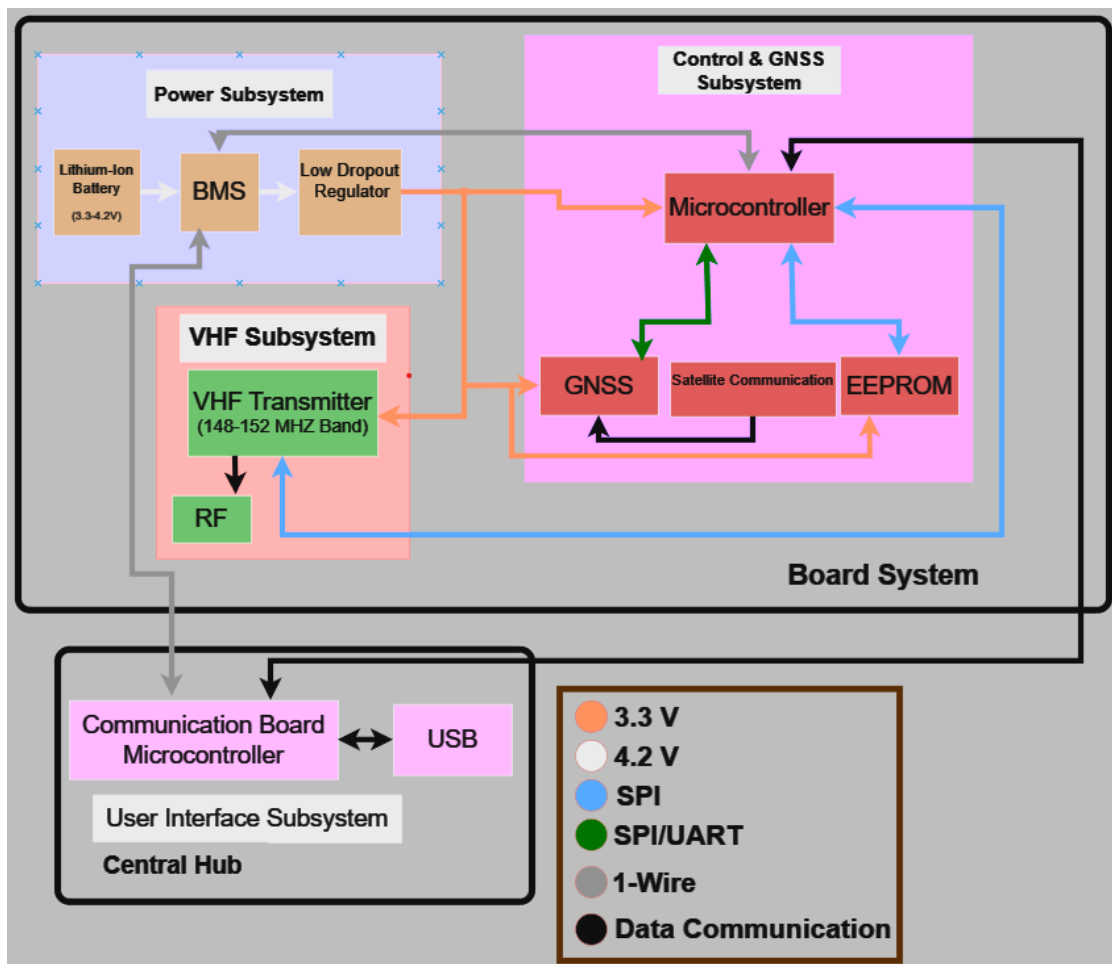


Figure 2 - Block Diagram

2.2 Subsystem Overview

2.2.1 Power Subsystem

The power subsystem needs to consist of a portable voltage supply such that it can supply the different modules that are a part of the constructed device that will be attached to the bat. The LOD regulator has the primary function of regulating the voltage from the battery source to the GNSS and VHF systems. The design will require the reduction of voltage from the battery to the GNSS and VHF systems in order for them to properly function. Overall, The power subsystem will be connected to the VHF, GNSS, and the microcontroller subsystems so that the modules receive the necessary voltage in order to function properly.

2.2.2 Control & GNSS Subsystem

For our project it is essential to have a device that is able to provide accurate position data of the bat in the measurement of longitude and latitude in order to track the migration path that the bat takes throughout the day. The GNSS section will need to communicate with the microcontroller and EEPROM such that the data can be transferred and stored until the device is retrieved from the bat. In order to store the location data of the bats migration path, the microcontroller and EEPROM is essential for our design. The overall subsystem will be required to be connected to the power subsystem in order to obtain the necessary power to function properly.

2.2.3 VHF Subsystem

In order to access the data generated and stored by our constructed device, it is necessary to establish a tracking system that can find the device's location. For the tracking system for this project, a VHF transmitter system will be used. The system will be capable of transmitting frequency signals which will be captured by an external VHF receiver. This module may be provided initial programming by the microcontroller through SPI, as well as receiving power from the 3.3v supply.

2.2.4 User Interface Subsystem

This system is contained on a separate board and will not be placed on the bat. After retrieving the device off of the bat with the help of the VHF subsystem, the user interface subsystem will allow the user to obtain the location data off of the device to help determine the migration path that the bat followed throughout the day. The communication will be done using 1-wire protocol. The reason for this choice is simple, once complete the tag will be very small and encased in a water proof resin. Therefore we need minimal external connections that must handle unreliable signal integrity, as those connections will be used after being exposed to nature and water for long periods of time.

2.3 Subsystem Requirements:

The system has two independent boards, the tag board and User interface board. The tag board has modularity, but is governed by the following equation to meet specifications:

$$Q_{batt} \geq i_{GPS, avg\ on} * (18\ hours) + i_{VHF, avg\ on} * (168\ hours)$$

2.3.1 Power Subsystem

The power subsystem will require a rechargeable battery voltage supply of 4.2-3.7V. The Low Dropout Regulator to bring the voltage down to 3.3V +/- 0.1 V as well as providing a max output current of 30mA +/- 1mA for the supply to the GNSS, VHF, EEPROM, and the Microcontroller. The BMS must manage a single cell battery in the 4.2-3.7v range.

2.3.2 Control & GNSS Subsystem

The GNSS subsystem must run from a 3.3 +/- 0.1 V supply, have an accuracy range of at least 10m, with an ON current of 10 mA or less and standby current of less than 100uA. The time to fix from standby must be 30 seconds or less. The GPS must have an OFF current of 100nA or less. The microcontroller must be capable of communicating using 1-wire, SPI, and UART. It must run off 3.3V +/- 0.1v and have an ON current of 8 mA or less and a standby current of less than 10uA. The EEPROM chip must work off 3.3V +/- 0.1v and store at least 16KBytes of data.

2.3.3 VHF Subsystem

The VHF transmitter system will be in the 148-152MHz band and needs to have a range of at least 1 km. The receiver used by the lab has a minimal detectable limit of -150dBm and -133dBm with the DSP using a 3-pole Yagi antenna with a gain of 7.7 dBi. Given the Wavelength of 2-meters and the incredibly small form factor requirements and omnidirectional need the antenna will be electrically small giving a predicted gain around 1.76 dBi. This means the transmitter will need to output at least 13 dBm to be detected by the receiver and overcome inefficiencies in the antenna. The modulation scheme is a simple pulse of width 12ms and fundamental frequency of 1.0 - 0.1 Hz. Table 1 summarizes our goals for our VHF system.

Input Voltage	3.3v +/- 0.1v
Peak Input current, max	30mA @13dBm
TX output power, min	13dBm
Frequency Range	148-152 mHz
Modulation type	OOK/On-Off
Pulse length	12ms
Standby current	<100nA

Table 1: VHF Data

2.3.4 User Interface Subsystem

The microcontroller must run off a 5.0 +/- 0.1 V supply and be capable of communicating over 1-wire to the tag microcontroller and usb to a host computer.

2.4 Tolerance Analysis

There are two great risks to our project not being usable by the lab, those are weight and charge usage. These are not independent issues and need to be at the forethought of any decisions we make on the tag board. Currently we are confident enough to move forward, but it's close. The GNSS module weighs about 0.6 grams, and while still not fully decided we predict the battery will be at most the same weight given a 25 mAh battery is 0.62 grams. This gives the rest of the GNSS and VHF a ~0.3 gram weight limit(worst case scenario). Unfortunately, It is not possible to figure out any information about chip and component weights as they aren't included in the data sheets, so this is something we will have to determine after physically having a working system. However we can mitigate this unknown through Charge analysis, as battery weight can be lowered if our charge consumption is lessened. Currently, given the component we are planning to purchase and using the limit of the electrical spec range we get, our average charge use per system can be calculated as follows:

$$Q_{tot} = \int_{T_{experiment}} i(t)dt$$

$$Q_{batt} \geq i_{GPS, avg on} * (18 \text{ hours}) + i_{GPS, avg off} * (150 \text{ hours}) + i_{VHF, avg on} * (168 \text{ hours})$$

$$i_{GPS, avg on} \leq \frac{1}{600 \text{ sec}} \left(\int_0^{30} (18 \text{ ma}) dt + \int_{30}^{600} (110 \text{ uA}) dt \right) \leq 0.93876 \text{ mA}$$

$$i_{VHF, avg on} \leq \frac{1}{600 \text{ sec}} \left(\int_0^{.012} (30 \text{ ma}) dt + \int_{.012}^{600} (100 \text{ nA}) dt \right) \leq 36 \text{ uA}$$

$$i_{GPS, avg off} \leq 100 \text{ nA}$$

$$Q_{batt} \geq .93876 \text{ mA} * (18 \text{ hours}) + 100 \text{ nA} * (150 \text{ hours}) + 36 \text{ uA} * (168 \text{ hours})$$

$$Q_{batt} \geq 22.9 \text{ mAh}$$

These numbers were calculated using the upper threshold of current draw (least efficient system) and the lower threshold for specifications. This analysis means that even if we have the worst implementation of our system, we are predicted to make weight given what we currently know.

The VHF receiver used by the lab has a minimal detectable limit of -150dBm and -133dBm with the DSP using a 3-pole Yagi antenna with a gain of 7.7 dBi. Given the Wavelength of 2 meters and the incredibly small form factor requirements and omnidirectional need the antenna will be electrically small giving a predicted gain worse case of 1.76 dBi. Using the antenna power formula we can see that even with a very inefficient antenna we can still be detected, using a 0.1% efficient antenna, which given an electrically small antenna isn't improbable, we get -83 dBm which still well exceeds the receiver reception at 1km.

$$Pr = \frac{Pt * (Gr * .001) * Gt * \lambda^2}{(4\pi r)^2} = -83.5 \text{ dBm}$$

3. Ethics & Safety

We recognize the importance, and commit ourselves, to the highest ethical and professional conduct that surrounds our profession. We understand the IEEE Code of Ethics[1] and recognize that the technology we create may impact our profession, our fellow teammates, and the communities we serve. We acknowledge there's another project that will attempt the same problem, and we will not tolerate a violation of privacy towards either group.

One major ethical concern our group faces is relating to the conflict between the desire of this course and the desires of the lab to whom the idea belongs. This conflict is due to the necessity of the weight limit imposed by the lab compared to the electrically focused nature of the course.

To be blunt, there may be a point in which our group is faced with a decision to choose making a more useful product for the lab at the expense of our grade in the course due to not meeting a proposed electrical specification to instead hit the weight spec.

A particular issue our team faces in this project is that we are making a tracking monitor for animal research, and unfortunately that type of device could also be used to track and monitor people. Given this is a pitched project and open source, there is very little we can do to combat potentially nefarious actors from reproducing this tag.

References

- [1] IEEE, "IEEE Code of Ethics," *ieee.org*, Jun. 2020.
<https://www.ieee.org/about/corporate/governance/p7-8.html>