Wild Game Tracking System

Team Members:

Travis Ribby, Jeffrey Beery and Clinton McElroy

Advisor's Name:

ENT 498 Dr. Mert Bal

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Executive Summary

The objective of this project was to design a mechanical carrier that attaches to the end of an arrow which was outfitted with a radio frequency transmitter placed inside of a potted housing. Once the arrow was fired, the mechanical carrier delivered the RF transmitter to the target and become detached upon impact. With the transmitter attached to the target, the user could use the RF receiver to follow the beacon and locate the target.

The mechanical carrier was designed out of a piece of 7075 aluminum 3/8 inch in diameter. A pocket was machined into the stock for the transmitter housing to fit inside. Threads to match that of a common arrow were also cut onto both ends of the carrier, for the carrier will be taking the place of a broadhead or a practice tip. With extra slots machined into the carrier to cut weight, the mechanical carrier came in under the required weight of 100 grains.

The transmitter is the part that is used to track the animal. The device consists of a housing, which for this project was 3D printed, with the circuitry contained therein. The housing had a metal hook on the end that attaches it to the targeted animal, as it breaks it off the arrow. The transmitter emits a radio frequency signal allowing it to be tracked by the receiver. The signal is 433.8 MHz and is generated by a specialized transmitter chip (Several prototypes were made with scratch-built transmitters, the construction of which is detailed below, but their inferior performance led to them being marginalized in favor of the prefabricated chip).

The receiver is the part that is used to receive the signal from the transmitter that is attached to the target. The device consists of a housing, which contains a power switch and LED indicators to display how close or far you are from the target. The circuitry consists of a prepackaged receiver module and a Arduino Nano Microprocessor. The Received Signal Strength Indicator (RSSI) pin is used to output a voltage level. We used this value to reflect a specific set of amplitude ranges in our code for the microprocessor. Each LED indictor represented one of those ranges. The stronger the amplitude, the greater number of LEDs are displayed, and the closer you are to the target. This proved to be successful and a rather simple way to receive the signal from the transmitting device.

Testing was performed to measure the RSSI at any given distance. It was expected that the RSSI would get lower as the transmitter got further away from the receiver. The RSSI was measured at five different distances and decreased with distance, as intended.

The *Wild Game Tracking System* used most of the material taught from within the Electro-Mechanical Engineering program at Miami University. The *Wild Game Tracking System* also used many electrical components to transmit a radio frequency that can be received from approximately 50 yards away from the receiver. The battery that will be embedded in the transmitter lasted approximately twenty-four hours with a continuous transmission. Our hope is that no more animals will die without a cause and this will open the door to miniature RF tracking devices.

Scope and Methodology

Mechanical Carrier:

The mechanical carrier is a device that attaches to the end of an arrow using the threads already incorporated in the arrow. The mechanical carrier is the device that carries the transmitter housing to the target and will separate upon impact. The mechanical carrier was designed out of a piece of 7075 round aluminum 3/8 inches in diameter. The aluminum stock was subject to three different CNC machining setups. In the first, one end of the carrier will be machined on a CNC lathe, during this process; the threads will be cut into the part allowing it to attach to the arrow. The part will then be flipped and put back into the lathe. During this process the part will have a hole drilled into the end in order the cut threads for an 8-32 screw which is the threads on all broad heads and practice tips. The final setup will utilize a CNC mill which will cut a pocket into the stock as a place for the transmitter housing to sit. During this process, extra slots will be cut into the stock in order to meet weight requirements of 100 grains (6.48 grams) or less. CAD models of the mechanical carrier can be found in Appendix 1.

Transmitter Housing:

The transmitter housing is what contains the transmitter circuitry and sits inside the mechanical carrier. When the arrow impacts the target, the barbed hook potted into the housing, will become lodged into the target, and allow the arrow to continue to fly as the housing becomes detached. With the barbed hook, the transmitter is forced to stay with the target as it runs off. Initially, the transmitter housing was to be molded, using electrical potting which would help minimize weight and help protect the transmitter. As the project continued, the team decided to simply 3D print the housing with a pocket inside to place the transmitter circuitry in and seal the pocket with hot glue (Figure 1). Though, not ideal, this process proved to be sufficient. Photos of the transmitter housing can be found in Appendix 1.

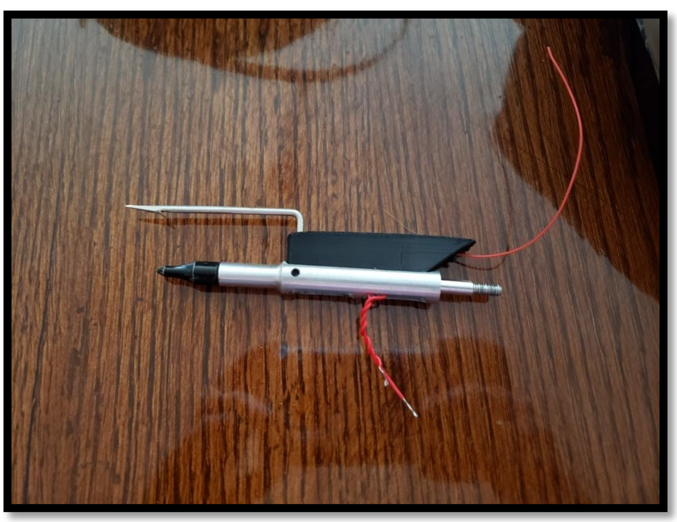

Figure 1: Transmitter Housing Attached to Mechanical Carrier.

Transmitter:

To track the animal, the probe must be equipped with some form of transmitter. To perform its function, the device must emit some form of signal that can be tracked by the receiver. The obvious choice is a radio frequency (RF) signal, which can be tracked over long distances, through obstacles, and can be generated with a compact circuit embedded in the tracking probe.

At the beginning of the project, several requirements for the transmitter were laid out:

- The transmitter must be detectable from 300 yards away.
- The device must be able to run on its power supply for at least several hours, ideally 24+
- The circuit must fit inside the probe's housing.
- The probe and transmitter circuitry should not exceed the weight limit.
- The transmitter should not require any form of license to be able to legally operate.

A proper transmitter circuit has three major components: the oscillator, the amplifier, and the antenna (Most RF transmitter designs have additional components used to encode information into the signal, this function is not required for this project). The oscillator is a circuit that, given a constant input voltage, produces a time varying output – a requirement for generating the RF waves. Multiple types of oscillators are available; for RF applications the oscillator must emit a sine wave. The amplifier is used to boost the output of the oscillator to a power level sufficient to run the antenna. The antenna is the component used to convert the electricity into radio waves; for this transmitter, an omnidirectional antenna (one which radiates energy in all directions roughly equally) is desirable.

Frequency:

Before designing or constructing the circuitry of the transmitter or receiver, it is required to know the frequency the devices will use. It was decided early on that the transmitter will use radio signals in the VHF (30 to 300 MHz) or UHF (0.3 to 3 GHz) regions. Frequencies below a certain point become impractical because the transmitting antenna would become excessively large. Very high frequencies, meanwhile, are impractical because of increasing attenuation by the surroundings. Additionally, issues such as parasitic capacitance and limitations of the components used makes designing circuitry for high frequencies increasingly difficult. Legal restrictions on the RF spectrum require the device to only use authorized frequencies. The frequencies considered are shown below:

ISM Bands – 40.7 MHz, 900 MHz, and 2.45 GHz:

It was considered early in the project to use an ISM band, a region in the frequency range with comparatively little regulation. There are three ISM bands in the United States for the range concerned: 40.7 MHz, 915 MHz, and 2.45 GHz. The 2.45 GHz band was rejected early in the project cycle, as it has an excessively high frequency and it finds frequent use in many other RF devices, increasing the risk of interference. The 915 MHz band was considered for a time, but due to the aforementioned issues of constructing the transmitter and the lower frequency antenna size problem not being seen as a major issue at that time, the 40.7 MHz band was – for a time – considered the most feasible. The ISM bands present an issue, however, in that they are comparatively narrow. For the relatively basic equipment used in this project, keeping the transmitter within the realm of legality would have been difficult.

49 MHz:

Later in the project, the 49 MHz band was discovered and for a while was the front runner in the frequency debate. It has a wider bandwidth, and many more specialized electronics are available for it. On the other hand, antenna size proved an issue. A proper half wave dipole antenna, tuned for the 49 MHz band, would be around ten feet long. While the antenna can be shortened, the efficiency drops greatly.

433 MHz:

There is another low regulation band in the RF spectrum, around 433 MHz Unlike the 49 MHz band, antenna construction is simple. The main drawback to this band is the difficulty of generating the high frequency signals needed. Nonetheless, this was the frequency chosen to be used for the project, partly due to a move towards more prefabricated components, lessening the difficulty of assembly.

Oscillator:

The oscillator is a circuit that, given a constant DC input, outputs an AC waveform. The oscillator has two subcomponents: the amplifier and the feedback system. The amplifier can be, among other things, a transistor, or an op-amp, while the feedback component can be a RLC circuit of varying type or a crystal. The first test models used an op-amp with a RC phase-shift oscillator circuit. This was used only for exploring the basic principles of oscillation and had several issues that would make it impractical for the final version. The RC phase shift component is not ideal as it is more difficult to adjust, and it is difficult to find op-amps with gain-bandwidth products (GBP) high enough for the needed circuit. Several physical versions of this circuit were constructed on a breadboard for the purpose of testing the circuit, this is detailed in a later section. Due to these issues, the feedback component was changed to that of a Hartley oscillator, and the amplifier changed to a BJT transistor circuit. These circuits were simulated on LT Spice (Appendix 2), a circuit simulation program. The circuit, in theory, outputs a pure sine wave, but due to imperfections in the system, multiple overtones distorted the signal. An 8^{th} order Chebyshev filter, low pass was added to the output to attenuate these undesired overtones. Upon later redesigns of the circuit, it was no longer needed and removed.

It was also considered for a time to use a crystal oscillator. Crystals were initially rejected due to the lack of higher frequencies and expense. While considering the lower frequency 40.7 and 49 MHz bands, however, interest in crystals grew. Crystal oscillators are more accurate at maintaining the desired frequency – which would have been important had the narrow 40.7 MHz ISM band been used. After the ISM band was ultimately rejected, the concept of a crystal fell by the wayside, as they are larger and more expensive.

Construction of the oscillator proved difficult. Various phenomena endemic to high frequency electronics were doomed to plague the system. These include parasitic capacitance – nearby conductors acting as sub-picofarad capacitors that allow unwanted current flow in the high megahertz range – and the finite GBP of both transistors and op-amps hindering operation above a given frequency. Due to these phenomena, as well as the general difficulty of translating simulation models into functioning prototypes, it was decided to instead use a prepackaged voltage-controlled oscillator (VCO). A VCO, given a constant voltage input, outputs an AC signal of predictable frequency. The output is of a lower current level, an amplifier was still required.

In addition to the oscillator, an astable multi-vibrator circuit is needed to manage the on/off pulses. This was accomplished with a 555-timer circuit. The system gave a one millisecond pulse on, and one second off. This theoretically reduces power consumption a thousandfold (actually less, as other components require power) without compromising signal strength. The oscillator circuit can be found in Appendix 2.

Amplifier:

Before transmission, the signal should be passed through a final amplification stage, optimized for delivering the required power to the antenna. In its simplest form, this is near-identical to the amplifying component of the oscillator, with similar possible implementations. A basic BJT amplifier design was used, with trimmer potentiometers in place of the fixed resistors, allowing simple post assembly tuning. The amplifier was rather primitive and had lower gain than desired.

While not implemented, a couple of ideas were considered to improve amplification. It was proposed that, during the one second quiescent period, power, after being converted to AC, would be diverted to a step-up transformer. This would have been rectified and used to charge a capacitor. When the 555 triggers a pulse, the power in the capacitor would run through the final amplifier and power the antenna. This could theoretically give voltages and power outputs an order of magnitude above the baseline. Basic, incomplete, schematics of the system were drawn up, but the idea was ultimately abandoned after being deemed too complex and unlikely to fit within the confines of the probe's housing.

Other Components:

The antenna ultimately used consisted of a simple pair of wires the appropriate length. While other, more complex ideas were proposed, none made it past the discussion stage.

The batteries used were a set of button cells. Rechargeability was not deemed to be a significantly important aspect of the project. Most prototype circuits were instead powered by external power supplies, due to the convenience.

Components were soldered on a premade generic breadboard. While a custom-built PCB was considered and designed, it was not pursued due to the inflexibility of the system; if a mistake was made on the design, or an alternate design was chosen later, a whole new order would have been required. Given the long shipping delay and expense, it was not deemed to be a worthwhile endeavor.

Prefabricated Transmitters:

As constructing the transmitter proved more difficult than anticipated, an alternate path was also pursued. Prebuilt transmitter and receiver chips were acquired and tested along with the original. These chips contained all the major components for transmission, power simply had to be applied to transmit. These components ultimately worked better than the scratch built and were used on the tests.

Receiver Circuitry:

It has been understood from the beginning that the receiver was going to be a challenge. With that being said, it was very important that a lot of research was to be done to gain confidence in the performance of the receiver. As difficult as the receiver is going to be, the first steps for us were constructing and testing what would be ideal in for the transmitter. Since we have completed that for the transmitter, it will allow us to start focusing on the functionality and testing of the receiver more than we have. Construction of the transmitter was the initial focus, so it has allowed me to really put that time into understanding the complexity of the receiver circuitry and narrow down how to approach this portion. With the selection of the of the 433 MHz frequency, it gives us some options with the receiver to increase the success rate of the receiver functionality. First being a ground up construction of the receiver circuitry. We understood the requirements for building one, but that really did not fit into our timeline, so we decided to use a prepackaged receiver. This left a lot of the decision making and final research on the antenna as it was the primary point for receiving the signal in the easiest and most efficient way possible.

The receiver is required to pick up the signal that the transmitter outputs for tracking purposes. The first step of the receiver is to pick up the transmitted signal. The initial part or input of the circuit would need to be the antenna and amplifier. Since this has a chance of being long range, the antenna is very important. After the antenna is the amplifier. This is going to increase or amplify the signal that was picked up before we can filter the signal. Once the desired radio frequency is detected and amplified, all the other radio frequencies will need to be filtered out. The first step is to narrow the frequency band as much as possible. This will be accomplished using bandpass filters. This will be comparable or match the filtering of the source to limit the amount of filtering required. Additional noise will be present so adjustable gain stages will be used to continuously maintain that signal of the required frequency.

Our main objective was to be able to have full control over the gain. Because there is a potential for larger distances that the transmitter will be sending the signal from, we will need as much control of the gain as possible. By obtaining one clear signal, we can use that to either output an audio signal or visual signal. We were not able to fit this design into the scope of our project, so we resorted to a prepackaged 433 MHz receiver. This limited the time and cost that went into the configuration of the receiver. This receiver module pinout consists of a power, ground, antenna, power down mode, Received Signal Strength Indicator (RSSI), and Data Output. Other than the obvious connections, we ended up using the antenna and RSSI pins. We decided to use a helical antenna as it provided the best performance for directional applications. The RSSI pin is used to output a voltage level that is proportional to the amplitude of the signal strength that is picked up by the antenna. We took that RSSI voltage and input into an Arduino. From there we were able to write a code to control the display range on the LED display.

The receiver contains a visual display with various LEDs that will light up the closer you get to the target. We wanted to include an audio signal as because alertness of your surroundings will be important when tracking so an audio. We were not able to incorporate that due to time constraints. We used an Arduino Nano for the output messaging to the user, with some coding that we constructed. The receiver, antenna, and display circuitry can be seen in Figure 2.

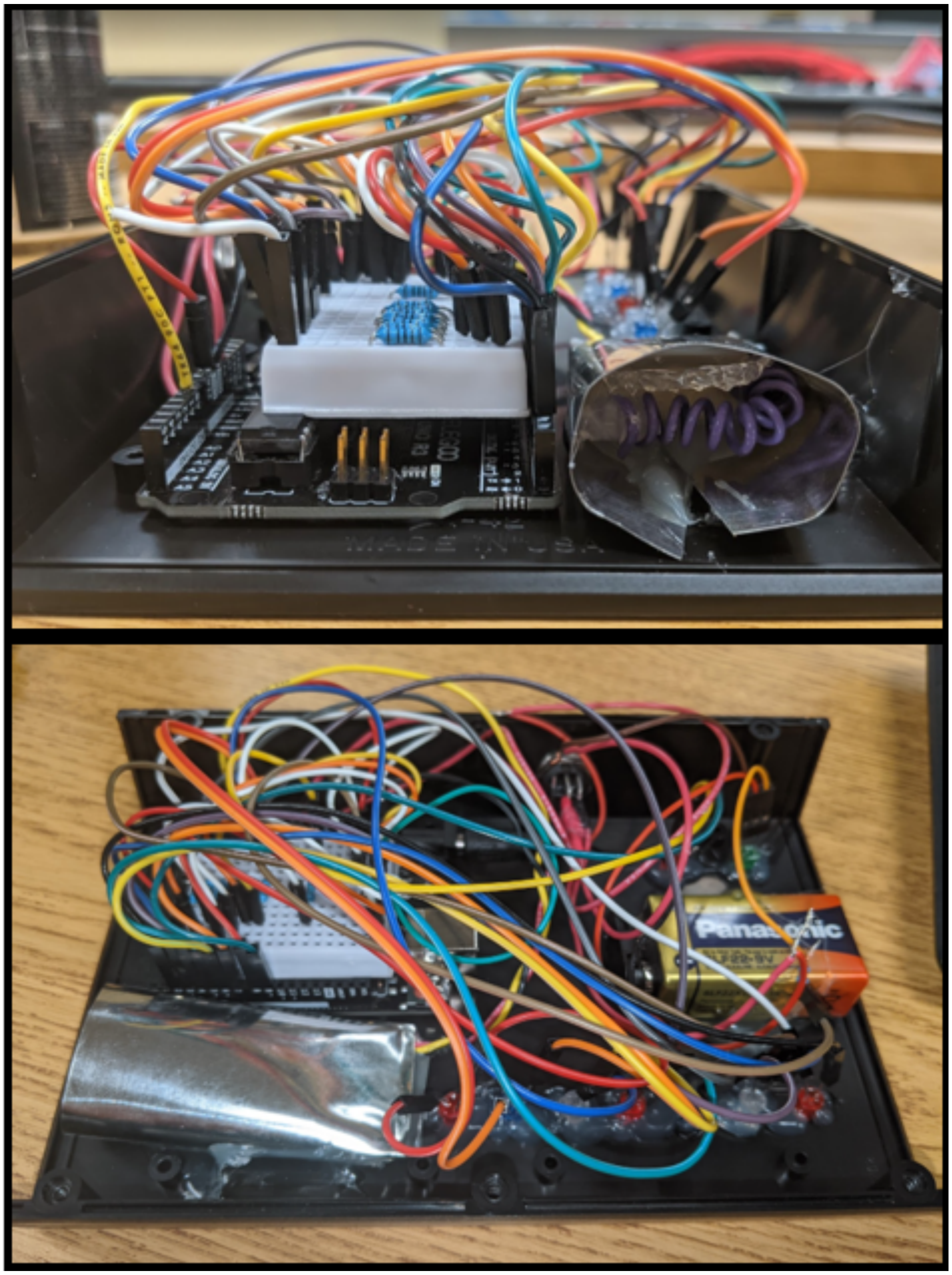

Figure 2: Receiver, Antenna and Display Circuitry.

Receiver Housing

The Receiver Housing is what contains the receiver circuitry and the Arduino Nano. The housing also doubled as a user interface. Since the Receiver housing was being held by the user, it was important to our team that the housing was ergonomically friendly and easy to use. Initially, the receiver housing was designed on SolidWorks and was going to be 3D printed for this project (Appendix 1). After printing a sample, the team decided that the quality and appearance of the housing was insufficient, thus, we decided to use a prefabricated housing (Figure 3).

Figure 3: Prefabricated Receiver Housing.

Arduino Nano:
To convert the analog signal received from the transmitter into a digital signal that could be used on the interface, the team decided to use an Arduino Nano. The receiver was wired to the Arduino microprocess using the analog in pins. The Arduino code then converted the signal into a digital signal which was then sent to the user interface, which is this case was a series of LEDs. The Arduino microprocessor was also used to power the receiver, which was tied into a simple on/off toggle switch and was indicated on with a separate LED. The Arduino code can be found in Appendix 3. An I/O Block diagram can be seen in Figure 4.

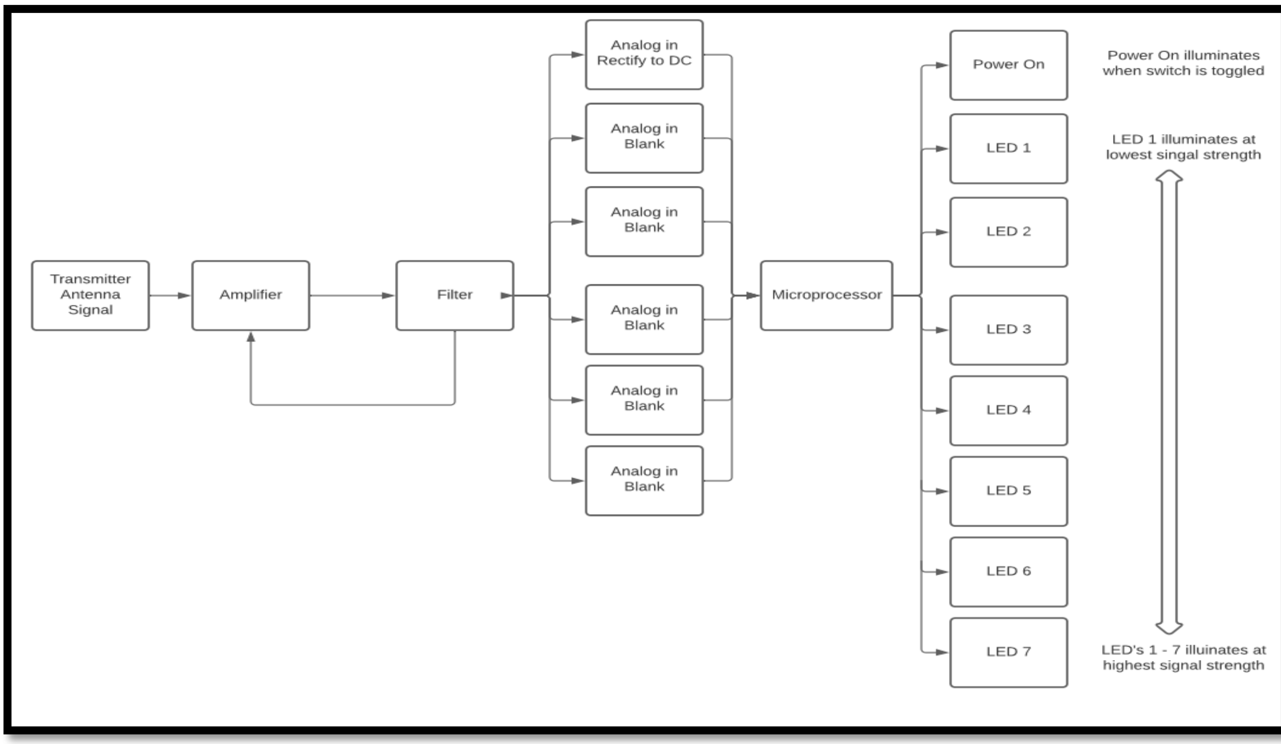

Figure 4: I/O Block Diagram.

Results

Testing was performed to measure the RSSI at any given distance. It was expected that the RSSI would get lower as the transmitter got further away from the receiver. The RSSI was measured at five different distances and decreased with distance. RSSI over Distance graph can be seen in Figure 5. It should be noted that because the Transmitter was not outfitted with an amplifier that maximum receivable range was limited to 50 yards.

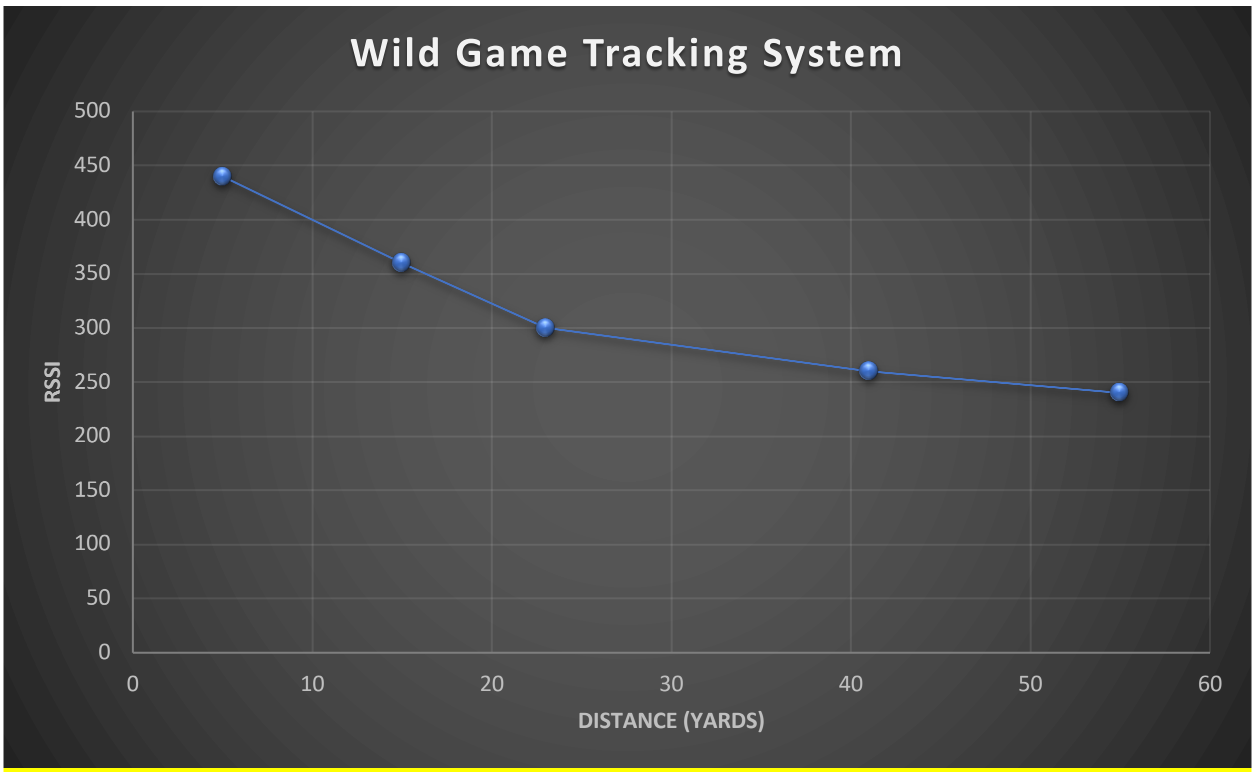

Figure 5: RSSI Over Distance.

Conclusions

There were multiple roadblocks in creating a working transmitter. The size of the circuitry for the scratch-built variants far exceeded the size of the housing. This issue is likely simply due to the bulky components we used; in a real-world engineering situation there likely would have been multiple avenues to downsizing (fabrication of an integrated circuit, machine assembly of an ultra-compact PCB, etc.) that were to cost prohibitive for a college engineering project. This is evidenced by the fact that the professionally assembled prefabricated transmitter fit within the casing.

Additionally, soldering of the components was difficult, either due to our inexperience or the difficulty of soldering surface mount parts onto a board made for through hole components. This may have impeded operation.

Receiver Housing contained more of a simplistic design than originally planned. We wanted to use an LCD display in junction with the Arduino as it would have looked more pleasing. In addition, with an audio signal so it was easier to view your surrounding when tracking. With that being said, we were still able to produce a very effective and professional looking design.

The initial design of wiring the system ourselves could have been done but was not logical upon review of our time and budget. We accomplished exactly what we needed from the prepackaged receiver and was only limited on range due to the transmitter. This made it a lot simpler and provided results.

The *Wild Game Tracking System* used a majority of the material taught from within the Electro-Mechanical Engineering program at Miami University. The *Wild Game Tracking System* also used many electrical components to transmit a radio frequency that can be received from approximately 50 yards away from the receiver. The battery that will be embedded in the transmitter lasted approximately twenty-four hours with a continuous transmission. Our hope is that no more animals will die without a cause and this will open the door to miniature RF tracking devices.

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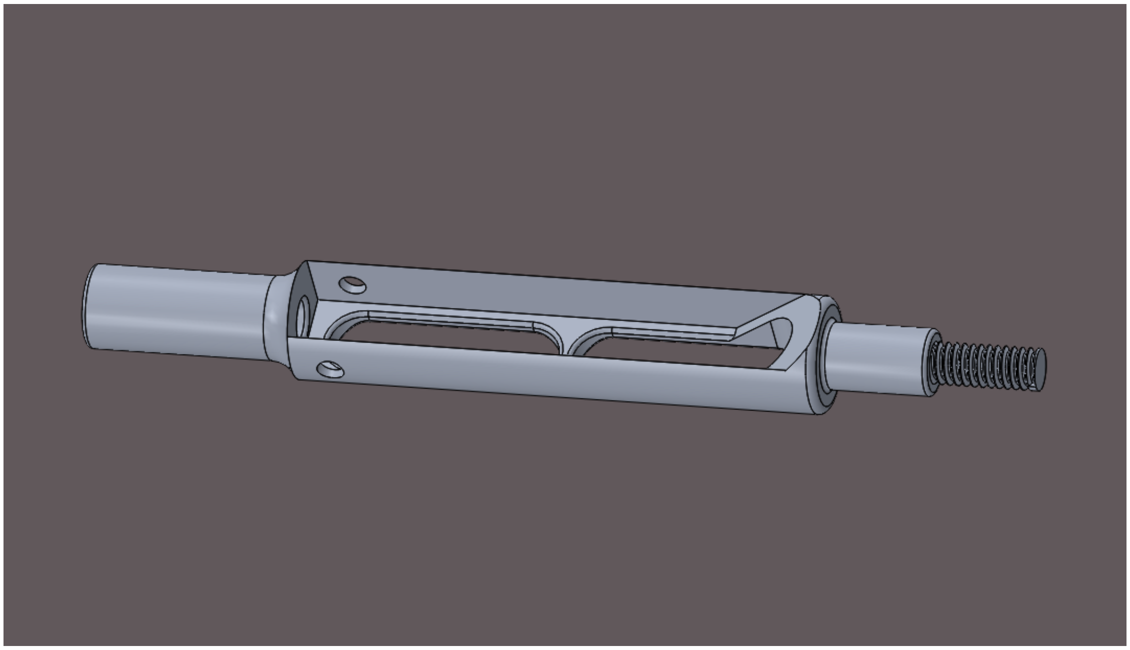
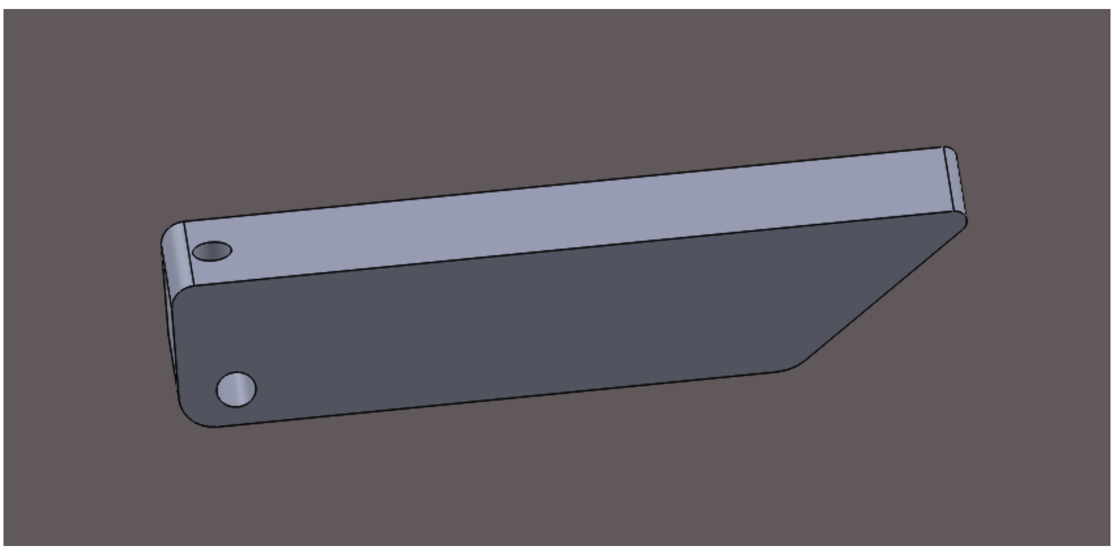
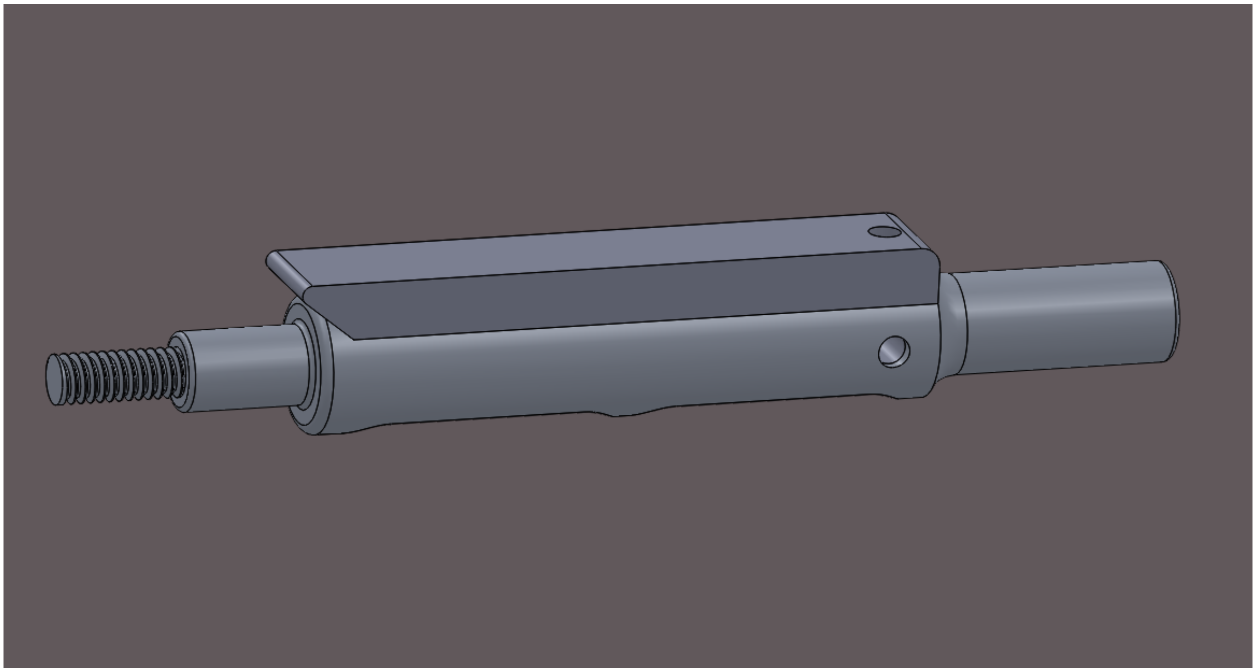
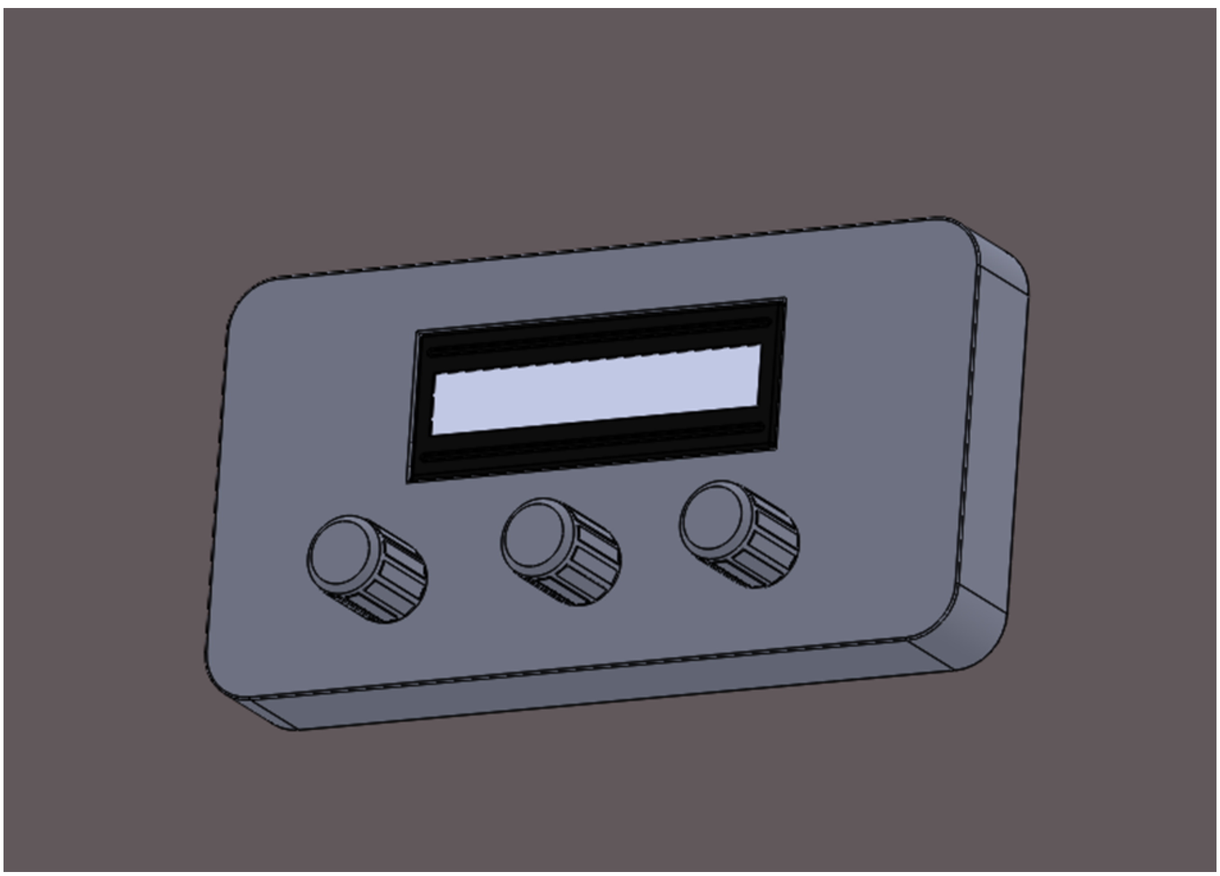
Appendix 1: CAD Models

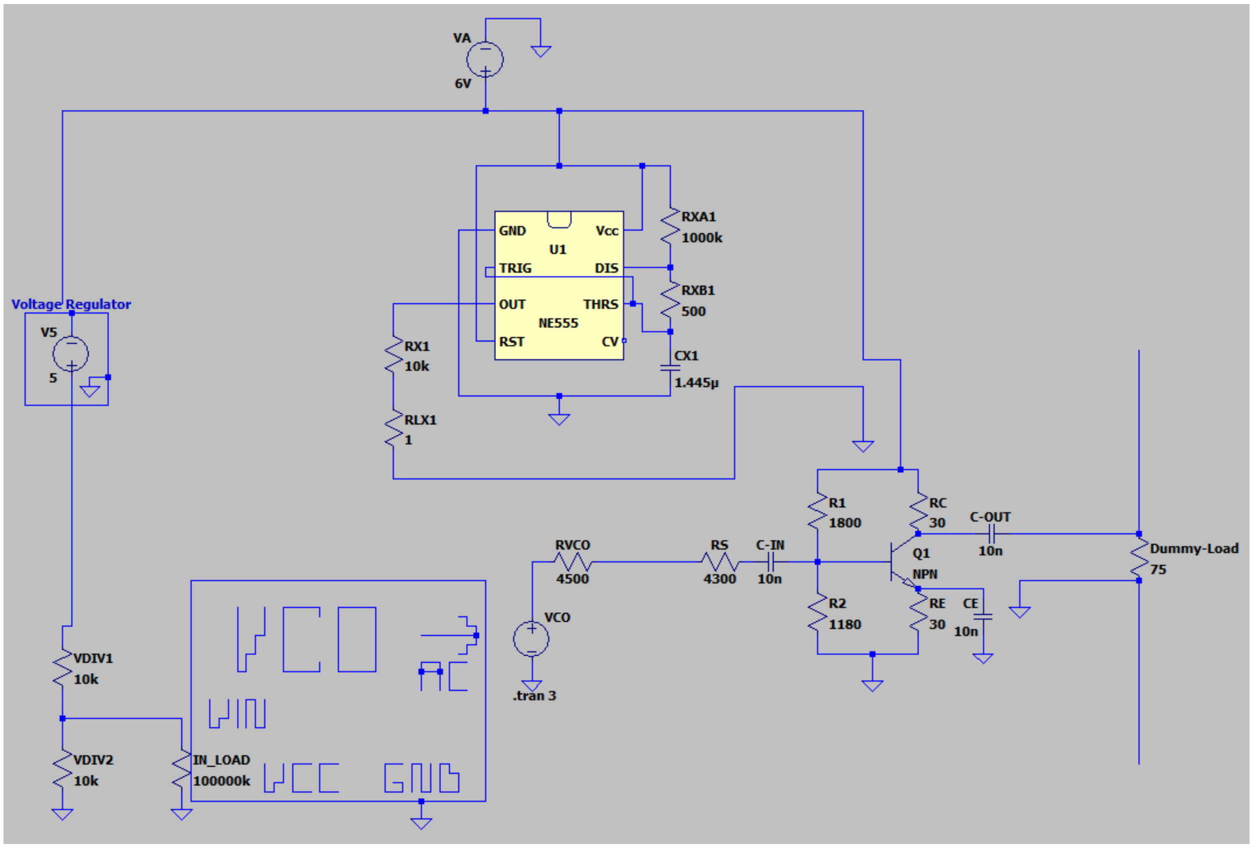








Appendix 2: Transmitter Circuit



Appendix 3: Arduino Code

```
int led8 = 8;
int led9 = 9;
int led10 = 10;
int led11 = 11;
int led12 = 12;
int volt = A0; //outside voltage//


void setup() {
  // put your setup code here, to run once:
Serial.begin(9600);
pinMode(led8, OUTPUT);
pinMode(led9, OUTPUT);
pinMode(led10, OUTPUT);
pinMode(led11, OUTPUT);
pinMode(led12, OUTPUT);
pinMode(volt, INPUT);
}

void loop() {
  // put your main code here, to run repeatedly:
volt = analogRead(A0);
if (volt > 240)digitalWrite(led8, HIGH); //condition for led1//
else digitalWrite(led8, LOW);
if (volt > 260)digitalWrite(led9, HIGH); //condition for led2//
else digitalWrite(led9, LOW);
if (volt > 300)digitalWrite(led10, HIGH); //condition for led3//
else digitalWrite(led10, LOW);
if (volt > 360)digitalWrite(led11, HIGH);
else digitalWrite(led11, LOW);
if (volt > 440)digitalWrite(led12, HIGH);
else digitalWrite(led12, LOW);


Serial.println(volt);
delay(50);
}
```