SSODD

Sixth Sense Omnidirectional Drone Detection

High Level Design Document

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1 Introduction

Small Unmanned Aerial Vehicles (UAV) are becoming increasingly present on the modern battlefield. This growth in drone usage has become especially apparent in the war in Ukraine. The sophistication of these drones varies from coordinated swarms with integrated sensors and communication systems to hobby drones, explosives, and duct tape. Drones can be used for a multitude of purposes, from surveillance to explosive elimination. In the case of the latter, a three second warning could be the difference between the life and death of a soldier.

To solve this problem, Special Operations Command and MIT Lincoln Laboratory have a significant research interest focused on developing a system capable of detecting commercially available drones that are employed on the modern battlefield. This project aims to develop a preliminary system to meet the needs of operators dealing with the evolving battlefield.

2 Problem Statement and Proposed Solution

There is no current method for our armed forces to detect incoming drones. Special Operations Command has tasked us with creating a wearable device that could alert a soldier to the presence of an incoming UAV.

A detection device would have to be quick, reliable, and unobtrusive. Just like the detection of conventional ordnance, every millisecond counts. The sooner the user can receive the alert, the more time he or she has to react. False positives from the device would slow down operations and wear down the user's trust in the readings, while false negatives could result in injury or death of the user. The device should not interfere with the intended force's range of motion or add significant payload to their already significant fighting loads.

Our solution will integrate RF sensing and audio-based detection to quantify a likelihood of attack, and employ electro-stim as a method of notifying the operator of an incoming attack. The device will use an antenna mounted to the operator's helmet to detect RF waves within the range of the most common drone operation frequencies. Omnidirectional microphones will detect the distinct sound of spinning quadcopter blades. This data will be dynamically processed and analyzed to output a "Threat Level" from 1 to 10. A threat level lower than 5 will induce no stimulus. A threat level between 5 and 10 will administer a proportional electronic stimulation to the back of the neck. The stimulation will be generally mild, meant to simulate the feeling of the hair on the back of your neck sticking up. This feeling will naturally encourage awareness and response to danger. Applying a stimulus in this way will prevent wasted time from needing to check a smartwatch screen or obstructing valuable screen space on the operator's Android Team Awareness Kit (ATAK) with a pop-up alert. One central unit will conduct the data processing and send the threat level out to all other operators' electrostimulus units.

3 System Requirements

We must have reliable drone detection and sensory output with a few specific requirements. We require multiple sources of information to verify and weigh the likely presence of an enemy drone, RF and audio detection as described in our proposal. Another feature is the reliable sensory output which must be quiet and wearable. Our proposed solution is the TENS unit for prototyping purposes at the very least.

The product would be used and integrated with other field equipment necessary in a military environment. As such it must be unobtrusive and durable.

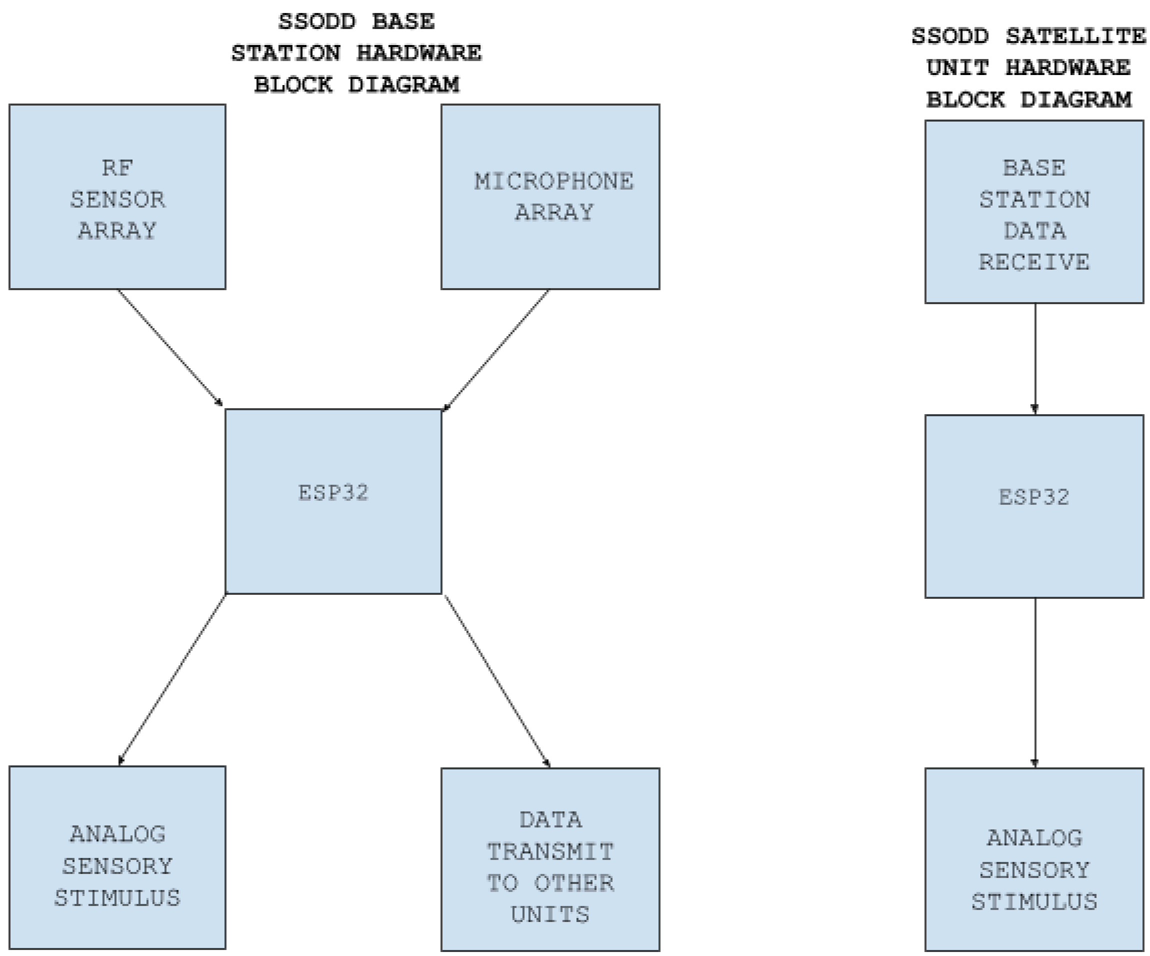
If there is a central “base” with satellite units, we need wireless communication between them. We would probably want up to 50 meters of range with around 10 units compatible with each other.

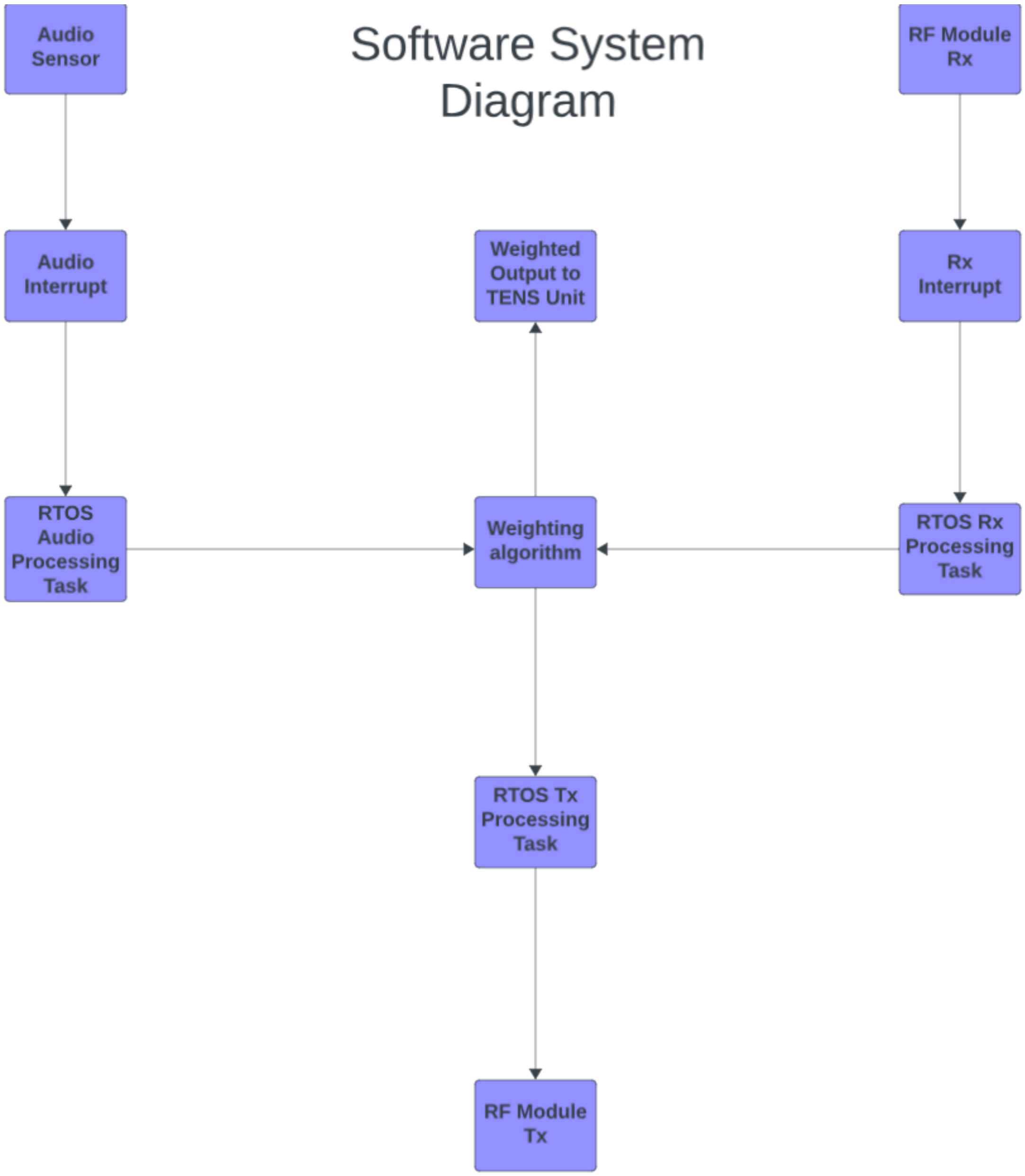
The units would be powered using individual users’ existing equipment loadout, eliminating the need for additional batteries. Ensuring this compatibility is an important requirement.

In terms of space and mechanical requirements, we look to compatibility with existing loadouts, ensuring the satellite units do not interfere and with a central unit probably to be worn on a helmet. The weight should not be burdensome on the users’ heads.

4 System Block Diagram

4.1 Overall System:





4.2 RF Array Subsystem and Interface Requirements:

- The RF array will be made up of one or perhaps several RF sensors, one of which will likely be made from a WiFi adaptor. We will research other potential ways of sensing RF emanations early in the project.
- The RF sensors will be tasked with transmitting the weighted output throughout the team and receiving RF data corresponding to the drone’s communication system
- The RF module will communicate with the EP32 via SPI

4.3 Microphone Array Subsystem and Interface Requirements:

- The microphone array will be built with several microphones pointing in various directions. We will perform tests to find the best number and positioning of microphones to get the best data at a reasonable price. The output from the microphones will be an analog audio signal that can be quantized and analyzed in the microprocessor.

4.4 Data Transmit and Receive Subsystem and Interface Requirements

- The ESP32 will be able to use its built-in wireless or bluetooth to communicate data from the SSODD sensing unit out to other receiver units worn by other special operators in the immediate vicinity.

4.5 Analog Sensory Stimulus Subsystem and Interface Requirements

- We intend to do tests to see if the TENS unit will be intrusive or inconvenient to wear as well as doing sound tests on vibrating watches to see if we could make a vibrating wearable that didn't risk creating noise that could compromise an operator.

4.6 Microprocessor Signal Processing Subsystem and Interface Requirements

- The microprocessor will take inputs from the RF and microphone arrays, and process each signal separately to determine the likelihood that a drone is approaching, outputting an alert value from 0 (no drones) to 10 (drone definitely incoming) for each subsystem. These two alert values will then be weighted based on which array is more accurate (we will determine this during testing) and output a single alert value, which will be output to our analog sensory stimulus subsystem and be transmitted to other receiver units with the TX/RX subsystem.

4.7 Future Enhancement Requirements

- Weight and volume optimization in order to maintain as unobtrusive to the operator as possible
- Distinguish friendly and enemy drones
- Collection of in-field data and results in order to dynamically improve threat level algorithm
- Increase range to satellite units to 200 meters

5 High Level Design Decisions

5.1 RF Array Subsystem

The RF array will include an antenna and an RF module, and will communicate to the processor via SPI. It will require 3.3 V, so this subsystem will need to be connected to our power path (voltage regulator, USB, Battery).

5.2 Microphone Array Subsystem

The microphone array includes multiple microphones at the base unit, facing multiple directions. Additional testing is required to determine the exact number and positioning.

5.3 Data Transmit and Receive Subsystem

We will use the WiFi module of the ESP32 in order to communicate between the base unit and satellite units. Satellite units will only need to receive the signal which translates directly to the analog output. There could be a transmission component to the satellites which confirms to the base that the signal was received and resulted in an output.

5.4 Analog Output Subsystem

The sensory output used will be a modified transcutaneous electrical nerve stimulation (TENS) unit. The unit will deliver a small electric pulse on the back of the neck. The amplitude will range from 0 to 100 mA in increments of 10 mA based on the received threat level. The TENS unit requires 1.5 volts to operate.

5.5 Microprocessor Signal Processing Subsystem

The signal processing subsystem will require an RTOS (Real Time Operating System). This system will assign tasks for our RF receiving, RF transmitting, audio receiving, and weighted output. It will employ interrupts to let the processor know when data has been received and compute a weighted output based on the received signals. Each task will filter and process the incoming data and pass to the weighting algorithm, which will compute an output. The microprocessor will be an ESP32 requiring 3.3 V, which will require a power path involving a voltage regulator, USB port, and potential battery port and a transistor.

6 Open Questions

1. Will the ESP32 have enough processing power to do the necessary signal processing?
2. How do we keep the TENS units applied through sweat and movement?
3. How do we prevent our device from picking up non-threatening devices, i.e. wifi routers?
4. There are multiple frequency bands with which commercial drones can operate, which will be the most effective for our use case?

7 Major Component Costs

Component	Cost ($)
Directional microphones	6
RF Sensors	125
TENS Unit	37
2x ESP32	20
Total:	**188**

8 Conclusions

Our device will collect RF and audio data, calculate a threat likelihood level, and administer a proportional electrostimulus alert to all nearby operators. We must have reliable drone RF detection while ignoring false flags from units like wifi modems. Our team has a clear path forward for all steps within our process. All components are within our budget. Challenges include practical aspects such as adhesion of TENS units and selecting a microprocessor with the appropriate power.