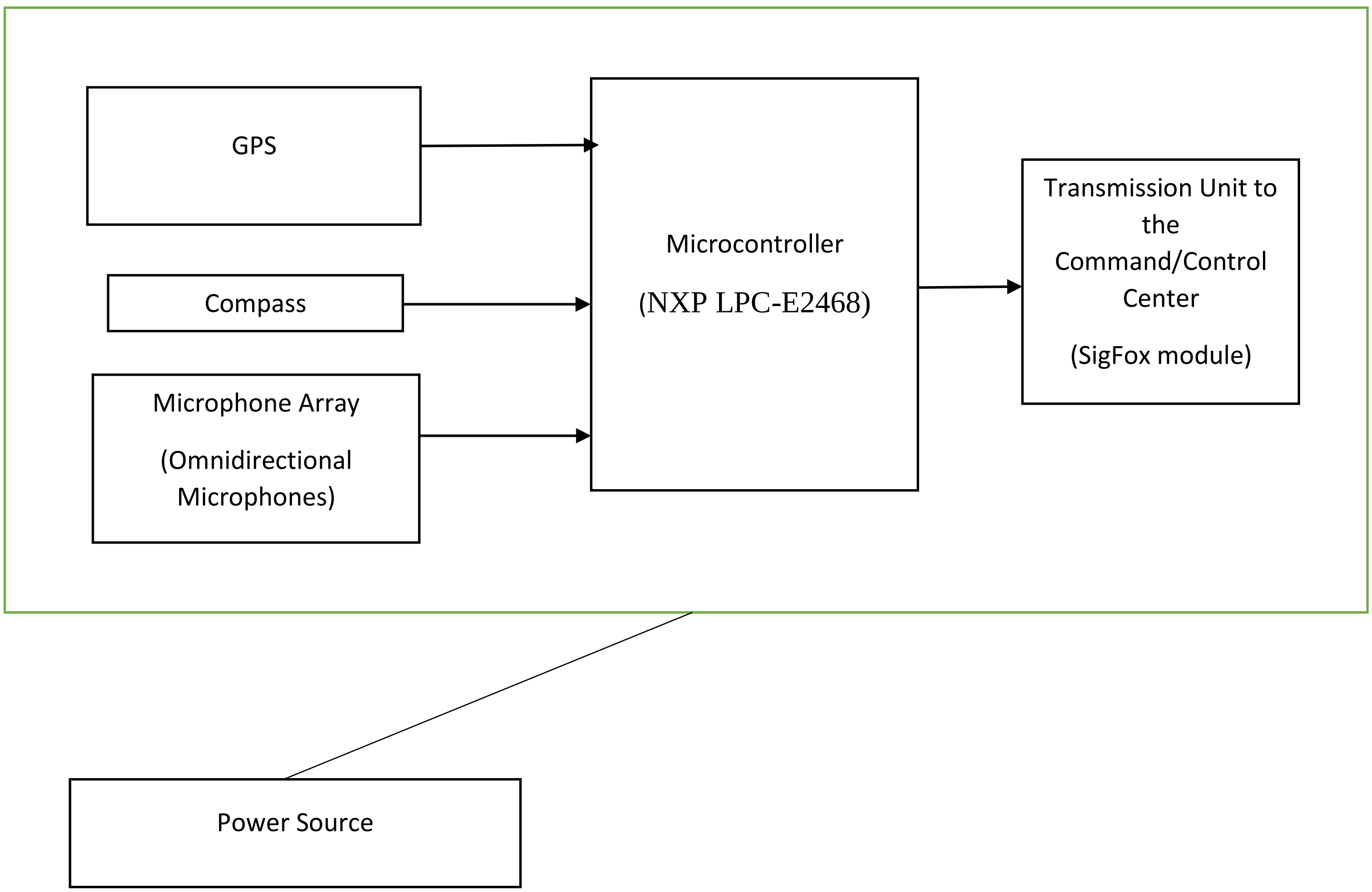
GUNSHOT DETECTION AND LOCATION SYSTEM(GDLS)

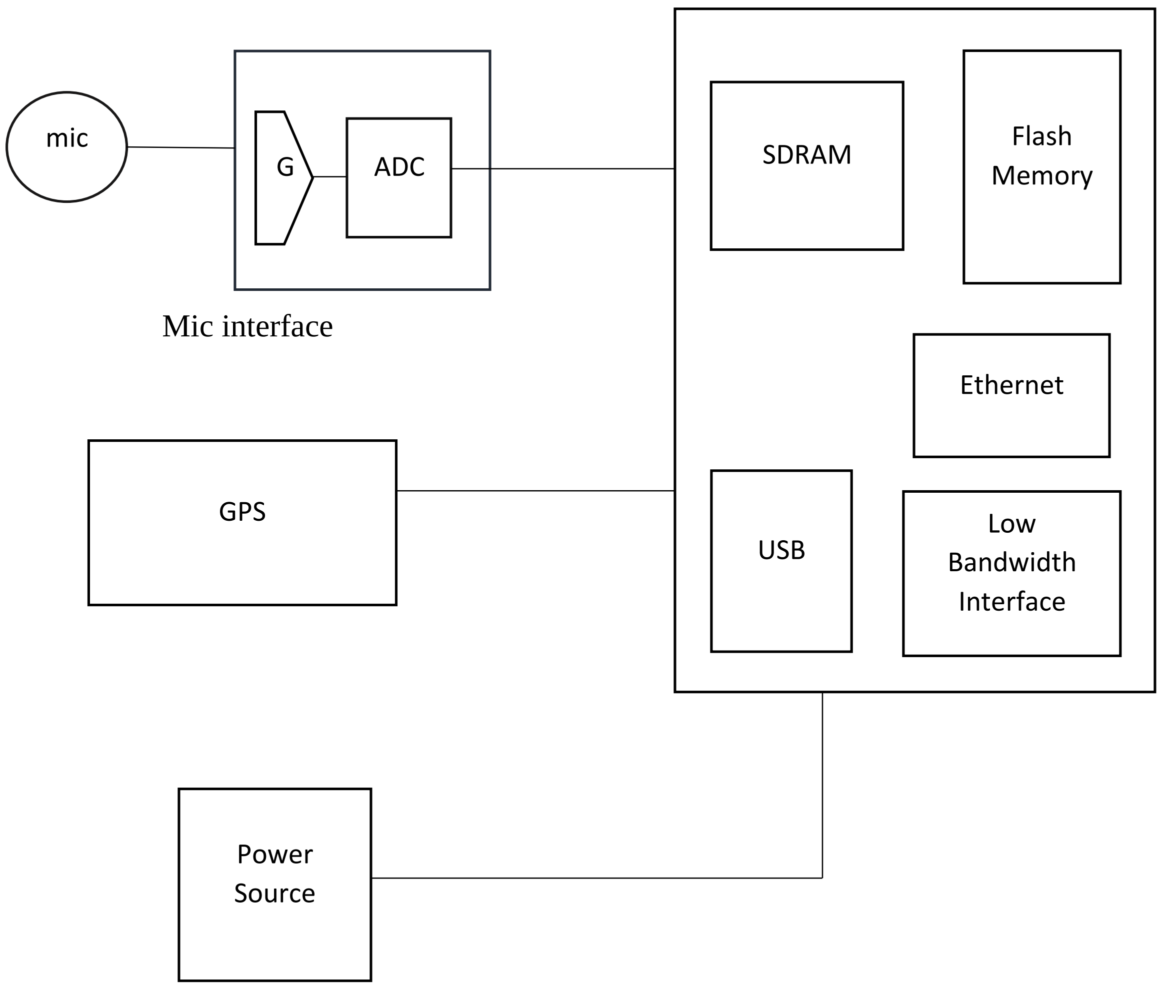
OBJECTIVE:

To design a mobile unit for inclusion into the equipment of each soldier on the battlefield that is used to

- Detect gunfire noise
- Relay the precise GPS time and location of the unit when the gunshot occurred, to the command center via a low bandwidth wireless connection

DESIGN:





Mic interface

COMPONENT DESCRIPTION:

Microphone Array:

The Microphone array is constructed and positioned on the wearer in such a way as to enable the gathering of data for an accurate detection of gunshot regardless of the origin of projectile or the direction that projectile is traveling relative to the wearer.

Omnidirectional Dynamic Microphones (Analog Condenser Microphones) are used for this application because of their sturdiness, resistance to moisture and they also do not break easily and require no external power which allows the usage of multiple microphones per array.

Amplifier:

Breakout Boards are used in this design as they are fairly cheap, and amplifies the signals from the microphone by a factor of one hundred. OPA344 operational amplifier is used which has an operating voltage from 2.7V to 5.5V and is specifically useful for precise low power application.

It also operates in a temperature range of -55 to 125 degree Celsius which is ideal for this use-case.

ADC:

During operation, the microphones will hear the event at different times which will trigger the microphones to produce a current that will be amplified by the breakout board. The microcontroller must be able to convert these analog signals to digital signals by having multiple ADC.

GPS:

The GPS is used to determine the exact coordinates of the unit at the time the sound event is detected. The GPS has a NMEA 0183 interface which is an ASCII serial communication protocol that defines how the data will be transmitted by the GPS.

Microcontroller:

The microcontroller must be able to process the signals quickly and relay an output to the command center. The main input and output signals the microcontroller will be dealing with are the microphones, the GPS and the transmission information. Each of these components will be combined to identify gunshots and relay GPS and time information to the command unit. The microcontroller must also be able to transmit signals via a low bandwidth connection. Also, the clock speed has to be taken into consideration, as precision depends on how fast we can sample the inputs. An NXP LPC-E2468 is used in this design because of its high computational power and the low operating voltage of the device allows it to be scalable to be solar powered. It also has a LCD 16*2 display with backlight that can be used to communicate with the soldier. It also has RS232 ports and Ethernet connectors that is needed for this design. It must also extract the accurate time and position information from the Serial NMEA streams from the GPS and construct them into appropriate packets that can be sent over the low bandwidth communication. The event detection and classification algorithm is programmed and burnt into the non-volatile memory for better performance.

The event classification algorithm consists of two parts: identifying the presence of Shock Waves and the presence of Muzzle blasts by the microphone. These two activities are extracted by using a Shockwave finder and a Muzzle Blast detector respectively and passed through a SVM classifier to get the type of gunshot detected.

Device Specs:

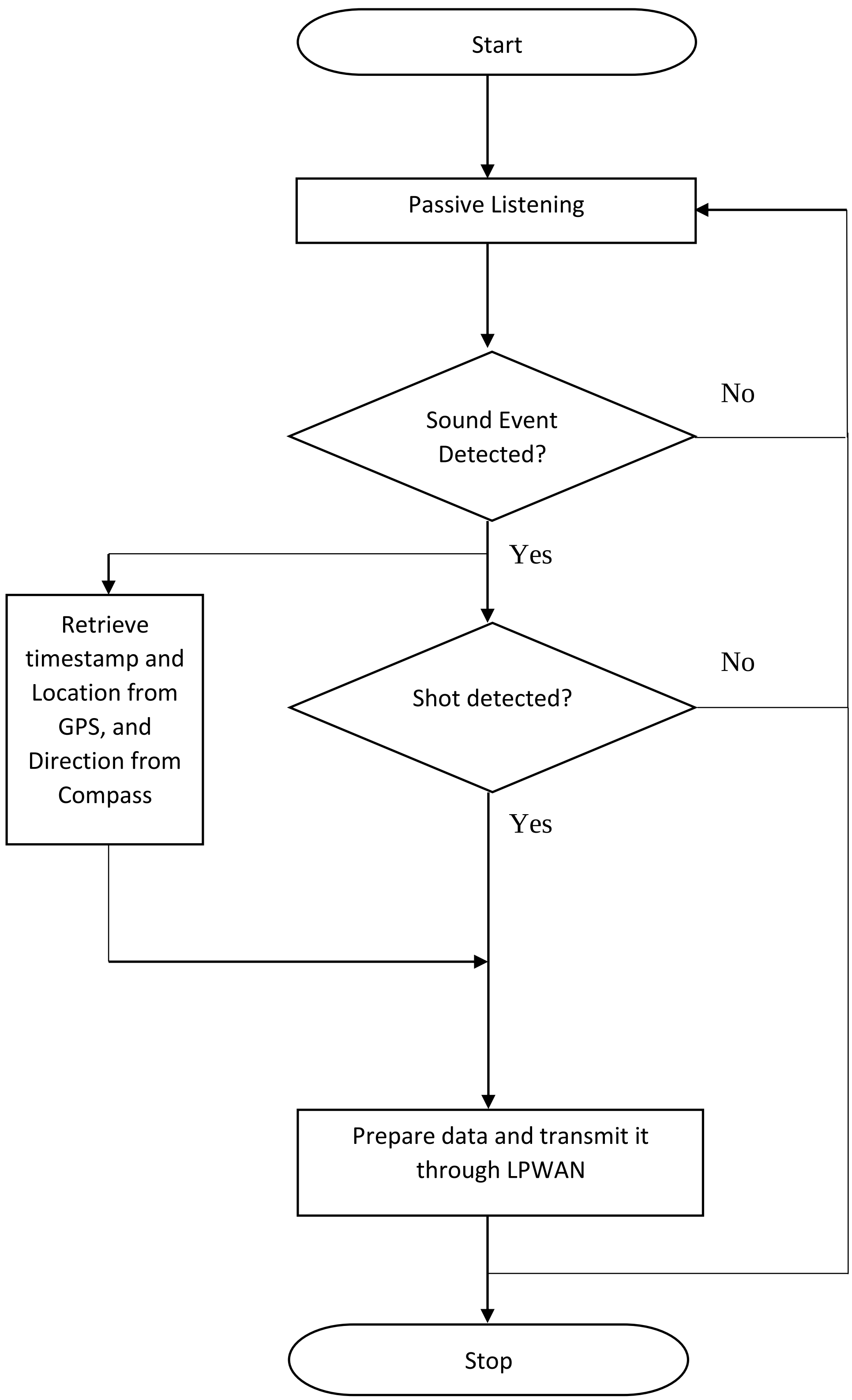
- 16MB SDRAM
- 128 MB NAN Flash
- standard JTAG connector with ARM 2x10 pin layout for programming/debugging with ARM-JTAG
- Ethernet 100MBit
- 2x USB hosts
- USB-to-RS232 converter device connected to LPC2468 UART
- SD/MMC card connector

- UEXT connector with I2C, SPI, RS232 and power supply for connecting add-on modules like RF link, MP3, etc available from Olimex
- trimpot connected to ADC
- RESET circuit with external control of Philips ISP utility via RS232 port
- two USER button
- RESET Button
- two onboard voltage regulators 3V and 5V with up to 800mA current
- Extension port connector for many of microcontrollers pins
- single power supply: External power supply, USB or JTAG connector
- Battery holder and connector for the RTC
- power supply led
- FR-4, 1.5 mm, red soldermask, component print
- Dimensions: 90x60mm (3.54 x 2.36")

Low Bandwidth Wireless Connection:

The microcontroller is also integrated with a module to transmit data via a low bandwidth wireless connection. For this design, Sigfox, a LPWAN technology, to relay the message to the command center, and will be fused with data from other mobile units using time-series data to localize the detected gunshot. This is interfaced with the microcontroller through one of the UART ports.

FUNCTIONAL FLOWCHART:



Software Overview:

1. The software for the system will have several main functions including functions to get GPS coordinates and the amplitude, frequency and time of arrival of the sound wave from the filter. The software must receive the event sound wave signal, convert it from Analog to Digital and process the digital signal to determine if there was a gunshot or not.
2. The microcontroller board has a large supply of software support. It has class libraries for accessing the analog, digital, RS232, UART and Ethernet ports through which the data can be transmitted and received easily through these ports.
3. The waves will be sampled and in each of these samples, the time and amplitude of the signal are saved. When combined, the wave can be reconstructed completely.
4. Once the digitized version of the wave is constructed, the corresponding time of arrivals is used to extract GPS coordinates that are relayed.
5. A separate function is used to convert the NMEA standard output string to output data and make it readable.
6. The system will also identify the event type based on the wavelets calculated from the saved waveform. Once the event is identified as a gunshot, another function will be triggered to construct a packet to transmit the timestamps and the GPS coordinates via the Low Bandwidth Wireless Connection.
7. Once the information is received at the Command center, it is fused with data from other units and the origin of the gunshot is triangulated.
8. The User Interface at the Command center consists of an online map database which is accessed to visualize the GPS locations transmitted by the mobile units and also the triangulated location.
9. A GUI is also designed to view the raw packets received and a logger is integrated into the design for keeping a record of all events.

Requirements:

- The microphones must be sturdy enough to withstand extreme weathers and must be small and easily replaceable.
- The microphones must have individual amplifiers and ADCs and must be directly interfaced with the Microcontroller.
- The gain, impedance, and other characteristics must be identical for all operational amplifiers.
- The GPS has to be integrated directly to the Microcontroller through the RS232 ports and must be highly accurate.
- The clock speed of the Microcontroller should be as high as possible to reduce the difference between arrival time and perceived arrival time to increase accuracy.
- The Microcontroller must be able to extract appropriate information and construct packets for transmission.

- The clock synchronization must be maintained across all the components by the Microcontroller so as to correlate between data from the microphone and the GPS units.

Testing:

Experiment 1: Verification and Validation of the system

Objective:

To verify the individual blocks/components in the system

Equipment:

GDLS

USB

Laptop/PC

External GPS

Description:

Before testing the operation of GDLS, all the components have to iterated individually to ensure accurate designing and integration with the microcontroller.

Experiment:

1. Connect the GDLS to a Laptop/PC with a USB to the Microprocessor. Iterate through each function blocks, components and interconnections and correlate the implementation with the design. Simulate sounds and ensure the proper functioning of the GDLS in a basic environment.
2. Set up the GDLS system and fire two shots at 400meter distance. Observe the result of the event classification algorithm. Record the corresponding timestamp and location information using an external GPS and compare it with the data obtained from the decoded packets at the command center that was transmitted for the particular trial.
3. Repeat the part one of the experiment and verify that the packets are being transmitted to the command center without being dropped and that the decoded values match the actual measurements.

Experiment 2: Accuracy of the system

Objective:

To evaluate the performance of the system in the presence of different gunshot sounds and in all orientations

Equipment:

GDLS

External GPS

Glock 22

44-Magnum

AK-47

Description:

The main component of the GDLS is the event classification algorithm and the accuracy of gunshot detection determines the effectiveness of the system

Experiment:

1. Set up the Glock 22 at a distance of 300 meters, from the GDLS. Fire two shots and check the event classification algorithm's results. Record the results.
2. Repeat part one for AK-47 and Magnum-44 and Record the results for each case.
3. Repeat the first two steps and change the orientation of the GDLS. Record the results and compare with the previous test cases and verify that the accuracy is uniform irrespective of the orientation of the device

Experiment 3: Effect of Signal Interference

Objective:

To determine the capability of the GDLS to detect gunshots in the presence of ambient and other acoustic sounds

Equipment:

GDLS

Glock 22, 44-Magnum, AK-47

Sprinkler

Ice bucket

Recorded audio of birds chirping, talk and other natural sounds

Recorded audio of other non-ballistic events (Road bumps, Door Slams, Wind noise, Tactical Radio Transmissions, Vehicle Traffic)

Fireworks

Description:

The main function of the GDLS is its ability to detect gunshot events irrespective of the gun type and bullet caliber and it should be accurate even in presence of acoustic events

Experiment:

1. Set up the Glock 22 at a distance equal to the maximum effective range of the microphones, from the GDLS. Play the recorded audio and fire two shots and check the event classification algorithm's results. Record the results.
2. Repeat the part one for AK-47 and 44-Magnum with the recording playing within 2 meters of the device. Compare the performance.
3. Repeat the part one for each one of the acoustic events listed (Road bumps, Door Slams, Wind noise, Tactical Radio Transmissions, Vehicle Traffic) in independent and individual trials and observe the event classification algorithm output and validate the results.
4. Repeat the part one and set off fireworks. Check the event classification algorithm output and verify the result.

Experiment 4: Range of the System

Objective: To determine the range up to which GDLS can provide accurate detection of gunshot events

Equipment:

GDLS

Glock 22

Measuring tape

External GPS

Description:

Since most of the sniper fire occurs at more than 700 meters, the accuracy of the GDLS has to calibrated with respect to distance. Despite the presence of the signal attenuation, interference due to obstacles (buildings, vehicles, etc.) and diffraction, the GDLS must be able to classify the events accurately.

Experiment:

1. Set up the Glock 22 at a distance of 300 meters, from the GDLS. Fire two shots and check the event classification algorithm's results. Record the results.
2. Repeat part one for 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300 and 1400 meters. Record the results for each case.
3. Based on these results, determine the maximum operating range of the GDLS.

Experiment 5: Durability of System

Objective:

To determine the GDLS's resistance to shock pressure, weather, and external interference and noise

Equipment:

GDLS

Sprinklers

Ice buckets

Glock G22

Recorded audio of birds chirping, talk and other natural sounds

Description:

The GDLS should be able to withstand extreme climatic conditions because of its use-cases. When the events occur, the device must still be able to record the sound waves accurate enough so that event classification can be done. It must also be resistant to impact both during transportation and usage in the field. It also must be shielded from external interference. The GDLS will be placed in an appropriate casing to protect from these factors, and the functionality is to tested after severe trauma.

Experiment:

1. Set up the GDLS and the Glock G22 at a distance of 200 meters and fire two shots. Compare and record the results.
2. Drop the device from 1.5 meters. Repeat part one of the experiment. Record the results and evaluate if there is any appreciable change in accuracy. Repeat for 2, 2.5 and 3 meters, and record the results.
3. Rain: Repeat part one with the peripherals of the device subject to water from sprinklers to simulate rainy weather. Fire two shots and check the event classification algorithm's results. Record the results. Vary the distance between the sprinkler and the GDLS and observe the results.
4. Snow: Repeat part two by replacing sprinkler with the ice bucket. Fire two shots and check the event classification algorithm's results. Record the results.
5. Noise: Repeat all three experiments in the presence addition noises in the environment. Play the recording and fire the gun. Observe the results in all the cases and record output.

Experiment 6: Multiple Gunshot Environment

Objective:

To determine the accuracy of the GDLS in multiple gunshot environment

Equipment:

GDLS

2- Glock G22

External GPS

Timer

Description:

The GDLS should be able to withstand extreme climatic conditions because of its use-cases. When the events occur, the device must still be able to record the sound waves accurate enough so that event classification can be done. It must also be resistant to impact both during transportation and usage in the field. It also must be shielded from external interference. The GDLS will be placed in an appropriate casing to protect from these factors, and the functionality is to tested after severe trauma.

Experiment:

1. Set up the GDLS and one Glock G22 at a distance of 200 meters and the other at 400 meters and fire two shots respectively. Record the timing of all the shots. Check the output of the event classification algorithm. Compare and record the results. Check the decoded packets and compare the corresponding data and record the results.
2. Repeat part one of the experiment by changing the time interval between consecutive gunshots and also using other gun types. Record the results and evaluate if there is any appreciable change in accuracy.
3. Evaluate the accuracy with which the packets are received at the base station and ensure the correctness of decoded data using the external GPS and timer correlated data.

Experiment 7: Effect of Interference on Communication with Command Center

Objective:

To determine the level of impact the external interference will have on the data transmitted to the command center

Equipment:

GDLS

Glock G22

Signal jammer

Description:

After a gunshot event is detected, it is critical that accurate time and location information are relayed to the command center so that the data can be used to triangulate the location of the gunshot.

Experiment:

1. Set up the GDLS and one Glock G22 at a distance of 400 meters and fire ten shots respectively. Record the timing of all the shots, and the location using external GPS. Record the transmitted packets after encoding and compare with the packets received at the base station. Check the decoded packets and compare the corresponding data and record the results.
2. Repeat part one of the experiment by having the signal jammer active. Record the results and evaluate the usefulness of the decoded data at the base station.

Experiment 8: Load Test

Objective:

To evaluate the capacity of the battery that is used in the GDLS and to gauge the lifetime of the device

Equipment:

GDLS

Stopwatch

Digital Multimeter

Recorded audio of gunshot

External GPS

Laptop/PC

Description:

In deployment scenarios, it is important to know the longevity of the batteries used in the GDLS and the frequency with which the batteries have to be replaced.

Experiment:

1. Set up the entire GDLS in a laboratory setting with an external GPS. Have the multimeter set up to monitor the output from the battery source. Connect the GDLS to a computer to monitor the output. Have the GUI of the Command center up and running and start the stopwatch as soon the battery is set up. Play the recording and enable the logger files at the GDLS and the command center. Run this configuration to the suggested battery life and terminate the experiment at this threshold. Observe the results from both the log files by syncing the time-series data and record the results. Use this data to determine the worst case lifetime of the GDLS.

2. Repeat the part one for different scenarios varying the environment in which the GDLS is deployed in and observe the results and compare them with the previous result. These two experiments are used as a benchmark to judge the lifetime of the device and frequency with which the batteries have to be replaced.

Experiment 9: Ease of Use

Objective:

To evaluate the complexity in use of the GDLS and to evaluate the amount of time it takes for an inexperienced user to setup the device

Equipment:

GDLS

Glock G22

Experienced User

Inexperienced User

Stopwatch

Description:

The goal of the design is for the device to be easy to set up and use. When the device is used in a real-world scenario, the initial setup time should be low because of the use case and also the equipment should not hinder the movement of the soldier.

Experiment:

1. Create a user guide for the mobile unit. It must be short and concise, describing only on how to get the device setup.
2. Interview both the users and record what they expect the setup time to be and how much it would hinder their movement. Record the time and use it to calibrate the experiment.
3. Let the users read over the guide and set up the Glock G22 and the timer. Tell the test users to set up the device and start the timer. Record the time taken and compare it with their suggested times.
4. Observe the way the test group go about setting up the device and take note of the steps they had trouble with. Re-edit the user guide and repeat the experiment with a different new user. Repeat the process until the setup time is lower than the pre-set threshold.