Search And Find Emergency Drone

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SAFE

ABSTRACT

Search and rescue (SAR) teams are regularly deployed in part due to outdoor recreation, winter sports, and many other high risk activities. These activities include, but are not limited to hiking, mountain climbing/rappelling, rafting, snowboarding, skiing, hang gliding, hunting, camping, and even flying personal aircraft. Most individuals are predisposed to carry a smartphone for pictures, even if they don't suspect service will be available. Even without service, any cell phone in a remote area will continually attempt to discover and connect to a tower. This fact gives rise to a very well characterized emergency 'beacon' that we attempt to detect from the air. The cell phone will generally transmit with a maximum power of 2 watts when searching for a tower. All of this is assuming, of course, that the cell phone is powered on. With this knowledge, there exists an excellent opportunity to engineer a search and rescue operation leveraging radio hardware already on the person(s) and commercial off the shelf quad-rotor copter hardware.

BLOCK DIAGRAM

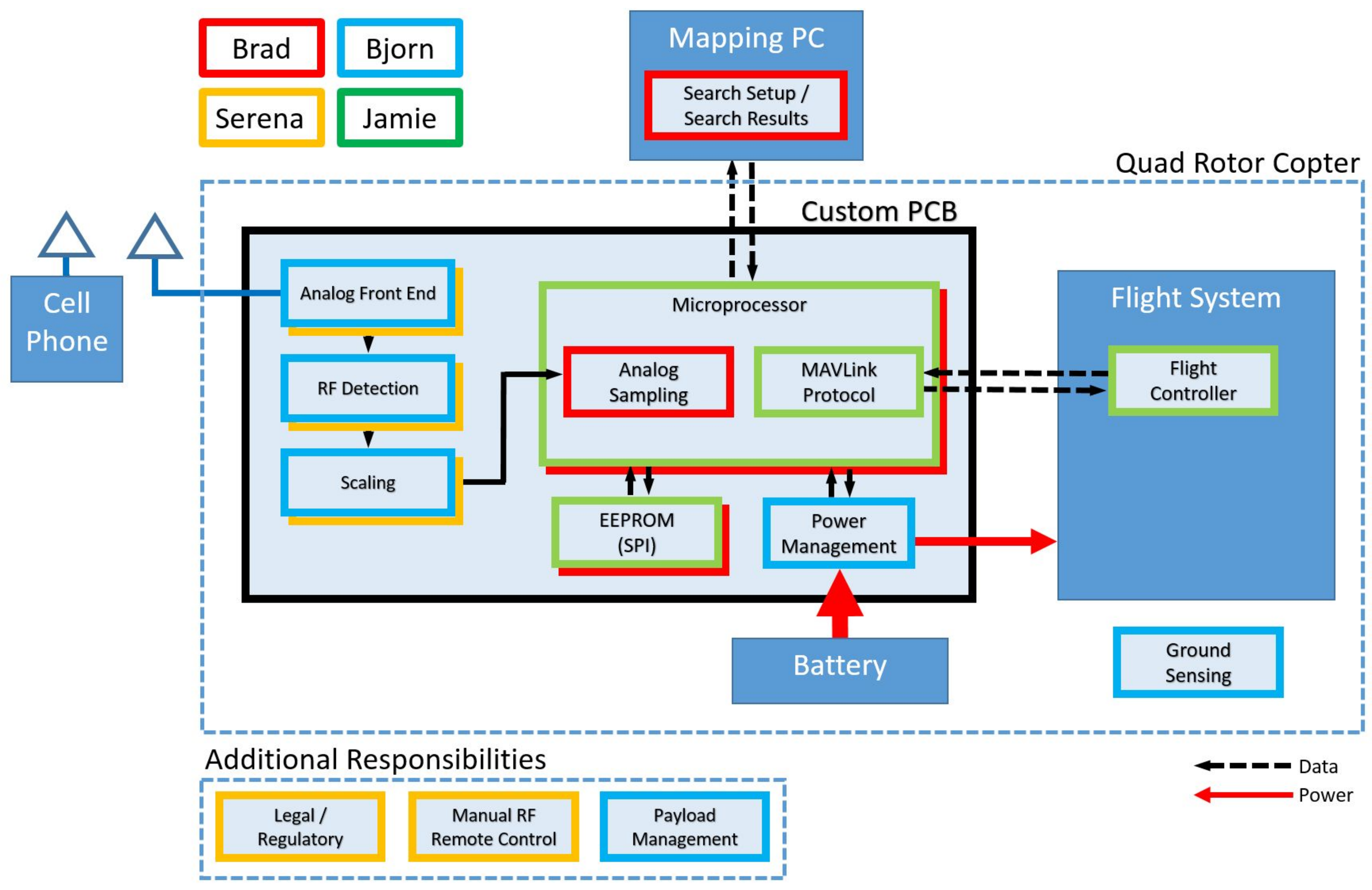

Figure 1: *System Block Diagram*

Our approach utilizes a custom circuit board which works in conjunction with a commercial off the shelf flight controller. Through serial communication, we make use of data streams (GPS data for example) already available to the flight controller. To facilitate the cellular signal detection, a remote signal strength indicator, tuned to the 900MHz cellular band is used. Because we are operating in an assumed radio-quiet region, any received power within this band can be attributed to cellular activity in the area. The current flight GPS coordinates are paired with this signal strength, stored in the external EEPROM, and then made available to search teams via the Mapping PC when the quad-rotor copter returns to point-of-launch.

SPECIFICATIONS

Specification	Value	Unit
Min Flight Time	10	[Minutes]
Max. Speed	30	[MPH]
Max. Sample Speed	200	[Ksps]
Max Samples	12,000	[samples]
Coordinate Accuracy	< 12	[inches]
Input Signal Intensity Range	-70 to 5	[dBm]
Frequency Range	835 to 915	[MHz]
Assumed Distance to Freq. Source	<100	[ft]

SYSTEM OVERVIEW

System usage starts by loading a defined search area/path onto the flight controller. The quad-rotor copter then flies autonomously to the area, executes a search pattern while sampling signal intensities, and then returns to the point of launch with the sampled data. The data is then download to a PC for analysis. The PC interface software allows for a heat map to be created from the sampled data showing the most likely location of the signal source.

The system works by using a remote signal strength indicator tuned to the cellular band which correlates the received dBm to an analog voltage level. The voltage level is then sampled by an ADC on the microcontroller to a digital integer representation. At the same time GPS coordinates are being streamed into the microcontroller from the flight controller. Every time a GPS coordinate is received by the microcontroller, the integer representation of the signal intensity is mapped to it and saved to EEPROM. Upon mission completion the device makes the data available for download by a host PC running the SAFE python program. The SAFE program downloads the data and creates a heat map representation of it which is then overlaid onto a satellite image of the area exposing the location of the signal source.

RESULTS

Test results show that the system is able to:

- Autonomously fly to & scan a predefined, tree covered area
- Sample a 900MHz signal
- Measure the signal intensity at an altitude of 100ft
- Map GPS Coordinates to the sampled intensity & save the data
- Autonomously return to home base
- Make data available for download
- Create heat map from the data that shows the location of sampled signal source

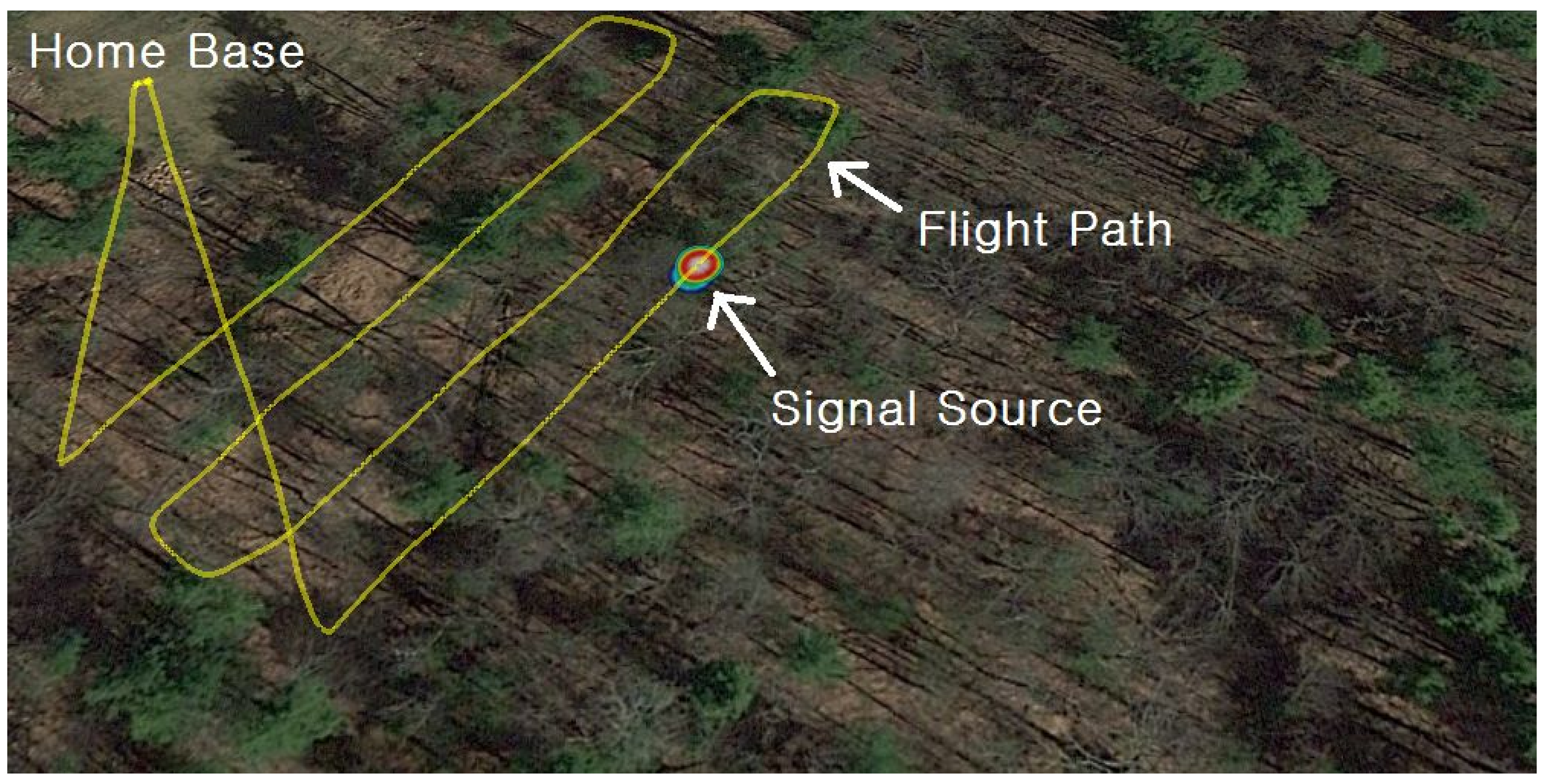

Figure 2: *Heat map with deviation factor of 2 from data collected from actual flight . Shows true location of 900MHz signal source, sampled from altitude of 100ft.*

ACKNOWLEDGEMENTS

We would like to take this time to say thank you to Andrew and team Otto for allowing us to build upon their previous project's platform. We would also like to say thank you to our evaluators, Professors Vouvakis and Janaswamy, whose valuable insight has helped move our project forward. Lastly, we would like to thank our advisor, Professor Leonard, for keeping us on track and offering his knowledge and expertise.

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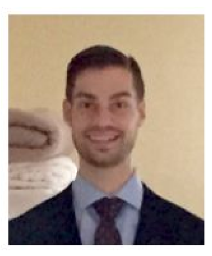
SENIOR DESIGN PROJECT 2017

College of Engineering - University of Massachusetts Amherst



FLIGHT CONTROL SYSTEM

Flight control and navigation was achieved using a commercial off the shelf flight controller and flight frame. This flight controller interfaced directly with the motor speed controllers, GPS module, onboard gyros, accelerometers, and magnetometers, to handle all the dynamics of flight control. This approach allowed us to drastically reduce development time by leveraging mature flight control hardware and software. Motors, propellers, and battery were careful chosen to provide the necessary balance of thrust, runtime, and throttle response required for this project.

SUPERVISORY CONTROL SYSTEM

In order to perform the signal acquisition and processing a companion board was designed around a 32-bit Atmel UC3 microcontroller. Onboard battery current sensing provides total power management functionality to the flight controller, enabling autonomous return at critical power levels. In addition an onboard switching regulator was designed for maximum efficiency, with downstream linear regulator to provide clean ripple-free power to the critical sensing and processing circuits. The microcontroller interfaced with numerous external peripherals, including serial EEPROM, a USB-to-USART bridge adaptor, and the flight controller serial link.

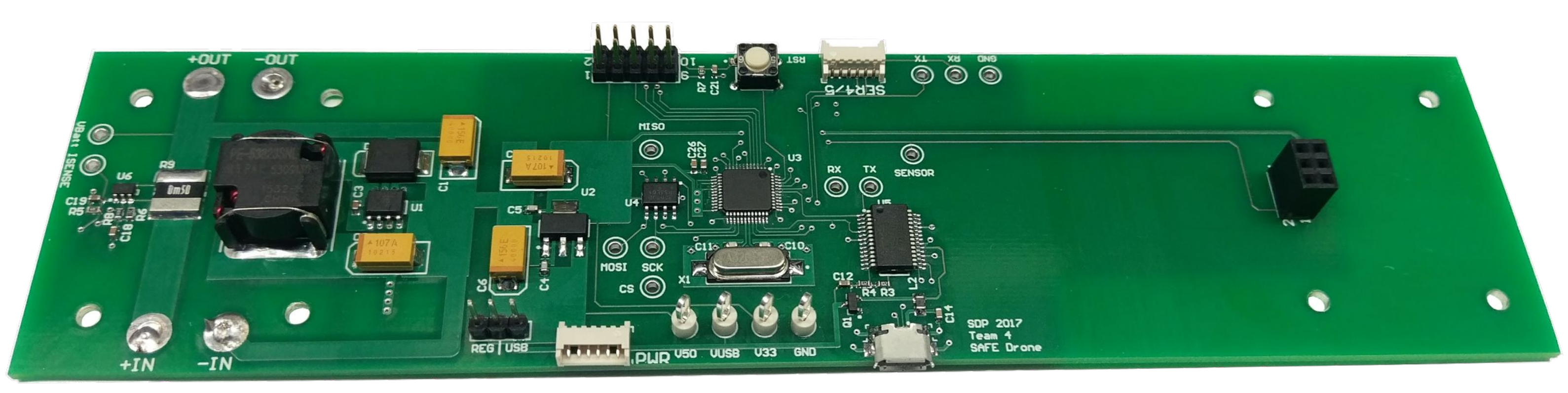


Figure 3: *Custom supervisory control system PCB*

The state machine that runs the sampling portion of the system has three states: Idle, Sampling, and Linked. The initial state on power is Idle where it subscribes to the flight controller in order to receive mission data. Once the mission has started it switches into the Sampling state where it continually maps signal intensities to GPS coordinates and writes them to EEPROM until the mission is complete. Upon completing the mission it switches back into Idle. While in Idle state and a PC is connected, it switches into the linked state where it starts streaming the data points to the PC. Once all sample points have been sent it switches back into the Idle state, ready for another mission.

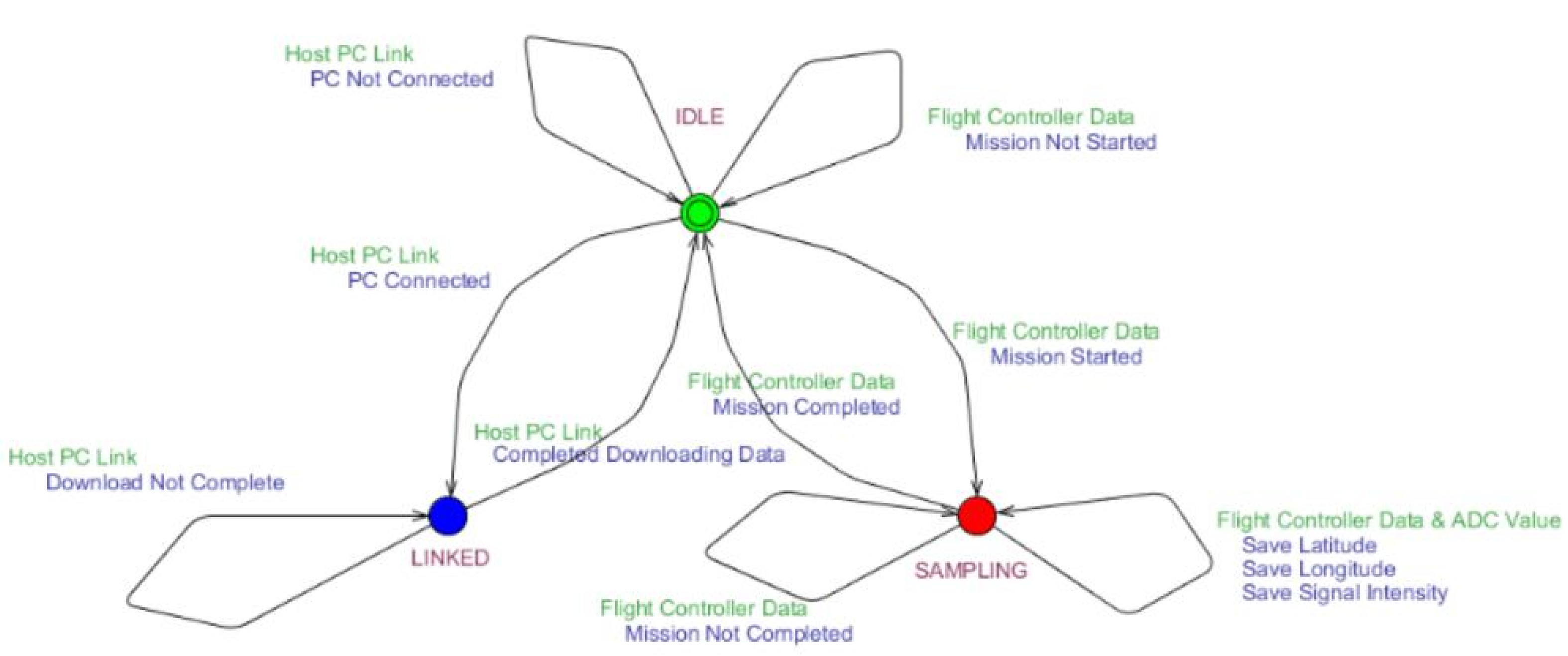


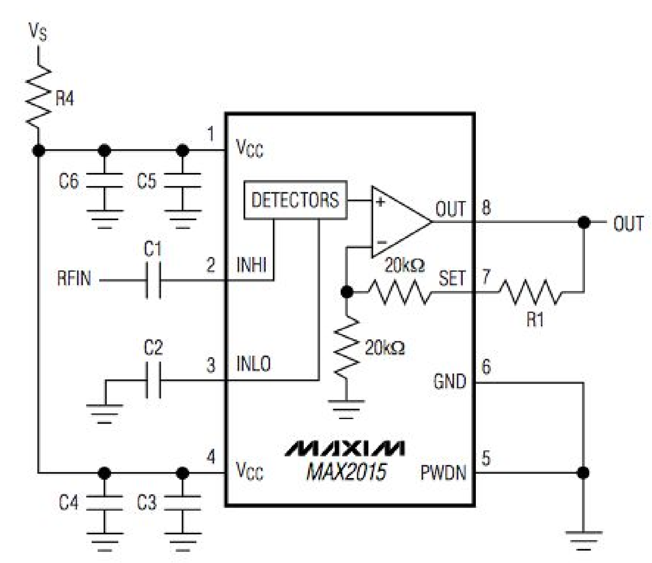
Figure 4: *State Machine Logic*

Serial communication with the flight controller was implemented using serial receive interrupts and a 256 Byte circular buffer. The hardware-based interrupts allow for the near immediate handling of received Bytes while also freeing the processor up to perform other tasks in the meantime. The buffer assured that the processor had adequate time to handle and process these bytes, and to reconstruct the received flight controller packets.

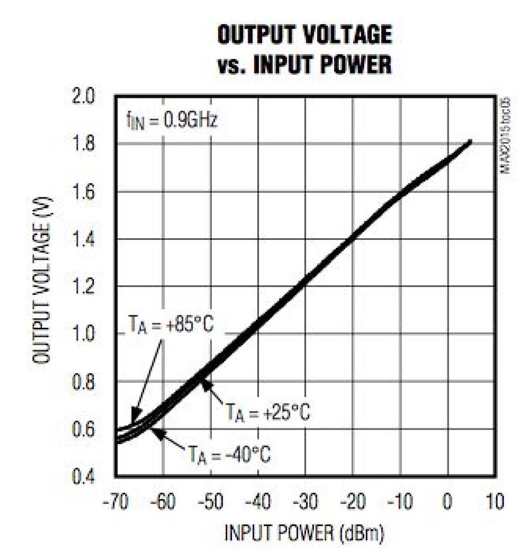
COST

Part	Development Price (1)	Production Price (1000)
Flight Controller	$70	$20
Frame, motors	-	$25
Propellers	$16	$2
Radio Control	$52	$5
PCB	$48	$9
Components	$267	$25
Total	$453	$86

SIGNAL STRENGTH DETECTION



For signal strength detection, we used the Maxim Integrated logarithmic detector in Received Signal Strength Indication (RSSI) mode. It accepts input signals from 100MHz-3GHz with an input power ranging from -65 dBm to 5 dBm.
The drone transmitter is in this detectable range (2.4GHz), so a 900MHz low pass filter was installed with the antenna.
Antenna reflector mesh analysis was done to possibly increase the signal strength detected.



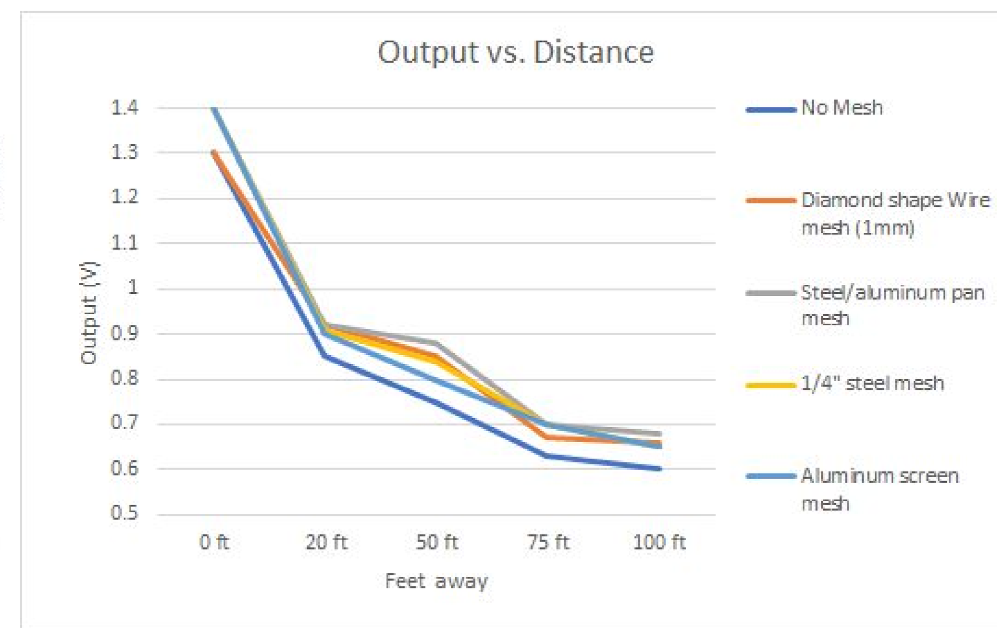
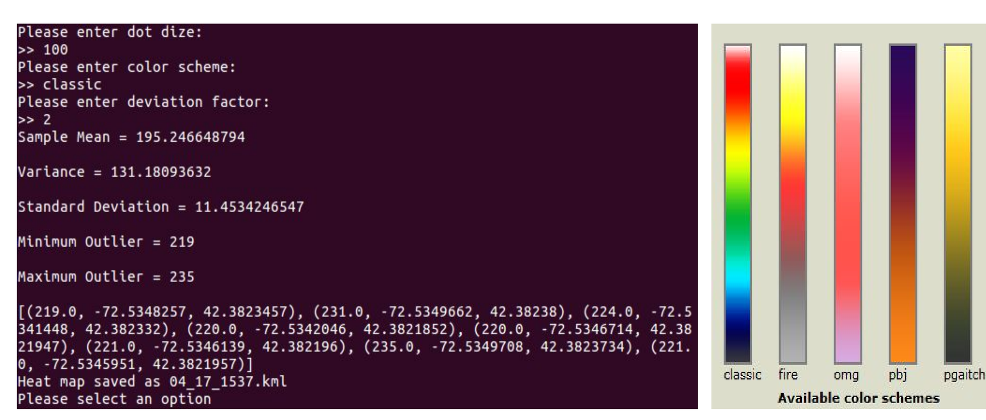


Figure 5: *Received Signal Strength Response Graphs*

HOST PC & HEAT MAP

To make the heat map the device is connected via micro usb to the host pc and the SAFE program is run. The program downloads the data (samples) in raw format, converts it to ASCII text, and then calculates the sample mean, variance, and standard deviation. Based on this information, and the deviation factor given, it uses the outlier formula to decide which points to make a heat map from. Points with higher measured signal intensities are shown as hotter points.



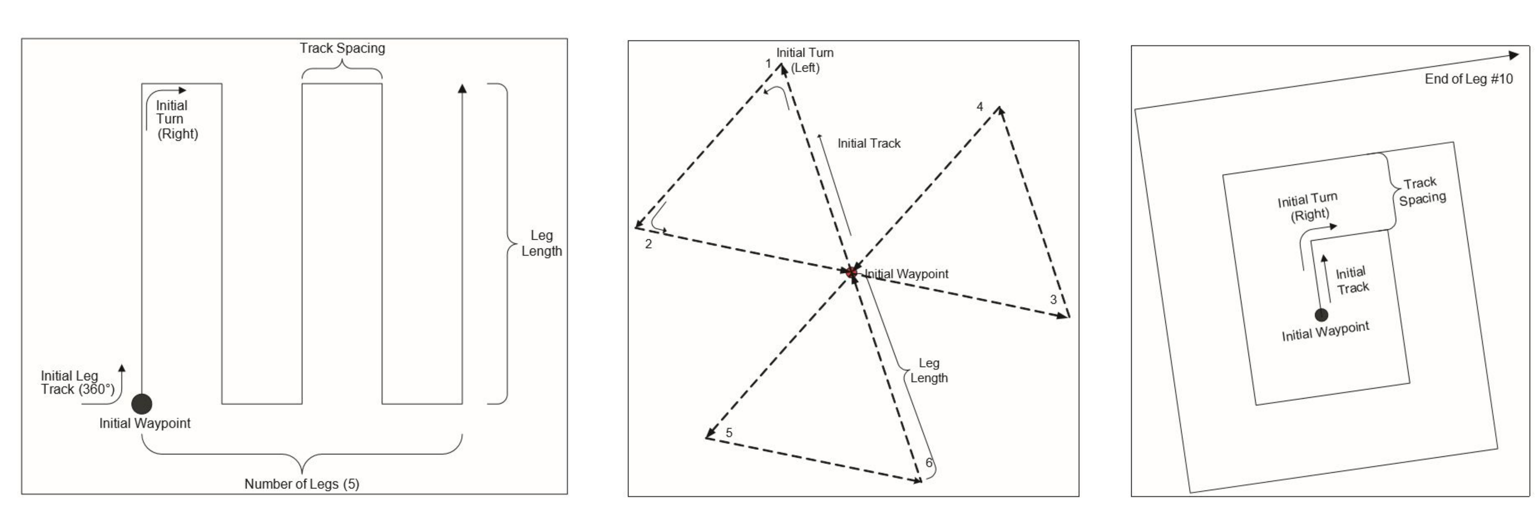
$$s_x = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

$n =$ The number of data points

$\bar{x} =$ The mean of the x_i

$x_i =$ Each of the values of the data

Outliers > $\bar{x}$ + (DF * s_x)



Parallel Track Search Pattern

Sector Search Pattern

Expanding Square Search Pattern

Search and Rescue Flight Patterns

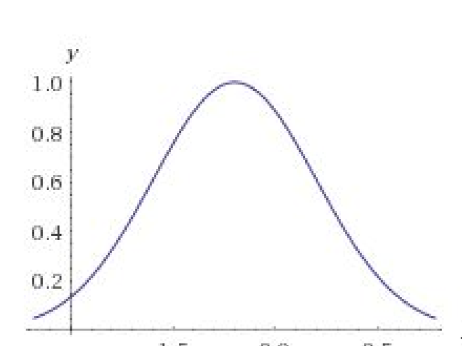
https://www.capmembers.com/media/cms/G1000SAR_Pilots_Guide_36A7F9D9CD4D5.pdf

There are three most efficient search and rescue flight patterns. The search and rescue teams pick one of these patterns depending on the terrain they are searching. In our experiments, we chose to use the Parallel Track Search Pattern.

ADDITIONAL FUNCTIONS

$$f(x) = \frac{1}{\sigma}\sqrt{2\pi}\exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$$

where f(x) is the probability, σ= 1/√2π, and μ is the highest output voltage when directly over a cellphone, assumed here to be 1.8V



- when given a power level as x, the probability that a person is at those coordinates is f(x)