**System Requirements Specification**

**Radio Frequency (RF) Direction of Arrival**

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**Section 1: Introduction**

**1.1 System to be Produced**

*<Include one paragraph to identify the product(s) to be produced. Refer the reader to the reference documents for more information.>*

This product will allow the user to track an illegal drone operating in the 33 cm RF band that extends from 902 to 928 MHz. The system will display the antenna gain relative to an ideal isotropic antenna and the angle at which the antenna picks up the strongest frequency of the drone. For development testing purposes, this system will simulate the drone using 915 MHz telemetry radios. The system will track the simulated drone using a rotating loop antenna.

**1.2 Applicable Standards**

*<You do not have to repeat the standards included in the project plan. Instead, cite any standards that are specific to the system requirements.>*

The system will adhere to the following standards:

* IEEE Standard 149: Standard Test Procedures for Antennas
* Radio Regulations of the International Telecommunication Union: Amateur Redio Operation Frequency

**1.3 Definitions, Acronyms, and Abbreviations**

*<Include any that are needed to read this document or "none" if document is self-explanatory and no acronyms or abbreviations will be used>*

DOA -Direction of Arrival

EECSE - Electrical Engineering and Computer Science

FAA - Federal Aviation Administration

MHz - Mega Hertz

NFM - Narrow-band FM

RF- Radio Frequency

SDR - Software Defined Radio

WFM - Wide-band FM

FHSS – Frequency Hopping Spread Spectrum

**Section 2: Product Overview**

**2.1 Assumptions**

*<List all the assumptions the developers are making. For example: assumptions about other systems this product will interface with; assumptions about the technological environment in which the product will operate (how much memory, what type of processor, ...); assumptions about availability and capability of COTS, GOTS, or other re-used products, ...>*

The following assumptions apply to our system:

* This system deals with a FHSS signal radiating from the telemetry radios.
* The FHSS signals will hop within the 33-cm RF band (902-928 MHz)
* The detected signal hops instantaneously across the frequency band.
* The point where the antenna gain is the highest represents the DOA of the simulated drone.
* The point here the antenna gain is the lowest represents a ±90° deviation from DOA.
* The characteristic impedance of the system is 50Ω.

**2.2 Stakeholders**

*<A stakeholder is anyone who has an interest in the system to be developed. For example, the customer, the various classes of users, applicable regulatory agencies, ... List each category of stakeholder and give a phrase or a sentence to describe their interest or concerns>*

Customer: Wants to detect where drones are coming from

FAA: Wants to detect illegally flying drones within restricted airspace (i.e. airports, military base, etc.)

Drone User: Wants to find lost drones or keep track of drones from far away

**2.3 Event Table**

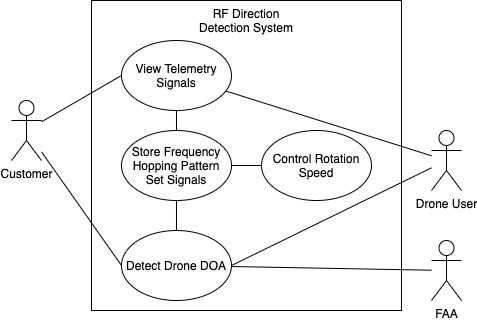
*<An event table identifies all the external events to which the system must respond. This is a first step in determining the required overall system functionality. The event list should be consistent with the context diagram and the interest of each stakeholder. Make sure that exceptions are considered.>*

*<Use the following table format>*

|  |  |  |  |
| --- | --- | --- | --- |
| Event Name | External Stimuli | External Responses | Internal data and state |
| No Signal | No drone in airspace | Antenna will receive no signal at all angles | SDR software discards data until signal appears. |
| Drone flying overhead | Drone communication in the 33-cm RF band | Antenna receives communication signal from 33-cm RF band | SDR processes the signal data and displays the strength of the signal at the given frequency |
| Frequency Hopping | Carrier frequency of signal hops into different frequencies | SDR software registers all signals from the frequency hopping pattern before changing angles | SDR registers each set of frequency hopping patterns and their correlating antenna angle |
| Antenna pointed in the DOA | The drone is parallel to the plane of the loop antenna | The measured antenna gain is the highest | SDR registers this frequency hopping set and angle as the DOA |
| Antenna pointed ±90° from DOA. | The drone is perpendicular to the plane of the loop antenna | The measured antenna gain is at its lowest | SDR registers this frequency hopping set and angel as ±90° away from the DOA |

**2.4 Use Case Diagram**

*<Include a use case diagram here. It should be consistent with all the above work. >*



**2.5 Use Case Descriptions**

*<Briefly describe each use case included in the above diagram. >*

* FAA - Will use the system’s location database to detect drones in illegal airspace.
* Drone Users - Will fly their drone that is communicating with the system. They may use the system’s location database to find lost drones or detect drones from far away.
* Customer - Will set up loop antenna and SDR software to view telemetry signals and detect the drones DOA.

**Section 3: Specific Requirements**

*<Use the following template for each requirement. >*

|  |
| --- |
| *No: <unique requirement number>* |
| *Statement: <the "shall" statement of the requirement>* |
| *Source: <source of the requirement>* |
| *Dependency: <list each other requirement on which satisfaction of this requirement depends. (May be "None")>* |
| *Conflicts: <list each other requirements with which this requirement conflicts. (May be "None")>* |
| *Supporting Materials: <list any supporting diagrams, lists, memos, etc.>* |
| *Evaluation Method: <How can you tell if the completed system satisfies this requirement? >* |
| *Revision History: <who, when, what>* |

**3.1 Functional Requirements**

* *< Describe the fundamental actions that the system must perform. Functional requirements can be partitioned into subfunctions or subprocesses. Note: the System design partition does not have to correspond with the functional requirements partition. Functional requirements include:*
  + *validity checks on the inputs,*
  + *exact sequence of operations,*
  + *responses to abnormal situations*
  + *relationship of outputs to inputs* 
    - *input/output sequences, formulas for input to output conversion, etc.*
  + *...>*
* **3.1.1 Antenna**
  + 3.1.1.1 The Antenna shall be able to rotate at least 180° and detect RF signals operating between 902-928 MHz.
  + 3.1.1.2 The user shall be able to connect the telemetry radios to each other using Mission planner.
  + 3.1.1.3 The Airspy software shall display the spectrum of the data exchanged between the Pixhawk, GPS and telemetry radios.
* **3.1.2 Stepper motor**
  + 3.1.2.1 The stepping motor shall be able to rotate at least 180 degrees clockwise.
  + 3.1.2.2 The stepping motor shall be able to rotate at least 180 degrees counterclockwise.
  + 3.1.2.3 The stepping motor shall be able to rotate at any numerical speed the user inputs.
  + 3.1.2.4 The stepping motor shall be able to stop when the end stop switch is pressed and held.
  + 3.1.2.5 The stepping motor shall be able to rotate the attached antenna.

**3.2 Interface Requirements**

* *< Describe the interactions of the system with other entities. Interface requirements include a precise description of the protocol for each interface:*
  + *what data items are input*
  + *what data items are output*
  + *what is the data type, the format, and the possible range of values for each data item? (i.e. what is the "domain" of this data item?)*
  + *how accurate must each data item be?*
  + *how often will each data item be received or sent?*
  + *timing issues (synchronous/asynchronous)>*
  + *how many will be received or sent in a particular time period?*
  + *how accurate must the data be?*
  + *...>*
* **3.2.1 User Interfaces**
  + 3.2.1.1 The user shall be able to connect the Pixhawk interface to Mission Planner via a connection though the computer’s USB ports.
  + 3.2.1.2 The user shall be able to specify the types of connection for the Pixhawk device in Mission Planner.
  + 3.2.1.3 The user shall be able to simulate a GPS-based flight path in Mission Planner.
  + 3.2.1.4 The user shall interface with Arduino to be able to control the rotation and direction of the stepping motor. The user shall change the following lines of code:
    - 3.2.1.4.1 Rotation (Line 12): This line controls the degrees the stepping motor turns in any direction.
    - 3.2.1.4.2 Speed (Line 13): This line controls the speed at which the stepping turn by adding a delay between each pause.
  + 3.2.1.5 The user shall use software Airspy to visualize the spectrum of data transferred at the selected frequency.
  + 3.2.1.6 The user shall use Simulink to convert the visualized data received by the SDR to magnitudes and phase angles.
    - 3.2.1.6.1 The highest printed magnitude gain shall represent the frequency and angle at which the signal is received.
* **3.2.2 Hardware Interfaces**
  + 3.2.2.1 The drone platform shall consist of the Pixhawk telemetry module and a GPS module.
  + 3.2.2.2 The system shall operate as followed:
    - 3.2.2.2.1 The PixHawk shall simulate the flight pattern of a drone.
    - 3.2.2.2.2 Mission Planner shall track the Pixhawk’s location and flight parameters using the GPS.
    - 3.2.2.2.3 The telemetry radios shall establish connections and data transfers between the PixHawk, laptop and Mission planner.
  + 3.2.2.3 The testing hardware shall be coordinated by a single-board computer.
  + 3.2.2.4 The testing hardware shall consist of the following:
    - 3.2.2.4.1 Software defined radio
    - 3.2.2.4.2 GPS module
  + 3.2.2.5 The base station shall consist of a laptop running Mission Planner, Airspy and Arduino.
  + 3.2.2.6 The base station shall consist of a stepping motor with a loop antenna design attached to the stepping motor.
  + 3.2.2.7 The loop antenna shall constantly be rotating 180/360 degrees through the stepping motor which is powered by Arduino.
  + 3.2.2.8 The stepping motor shall consist of the following:
    - 3.2.2.8.1 CNC Shield Board
    - 3.2.2.8.2 Arduino Uno Board
    - 3.2.2.8.3 1.5m USB cable for Board
    - 3.2.2.8.4 Nema 17 Stepper Motor 1.7A
    - 3.2.2.8.5 Mechanical Switch Endstop
    - 3.2.2.8.6 3 pin 70cm cable
    - 3.2.2.8.7 DRV8825 Stepper Motor Driver
    - 3.2.2.8.8 Aluminum heatsink
    - 3.2.2.8.9 12-volt battery supply
  + 3.2.2.9 The loop antenna shall consist of the following:
    - 3.2.2.9.1 The loop antenna shall operate in the 902-928 MHz range
    - 3.2.2.9.2 The antenna shall have a peak gain at 915 MHz
    - 3.2.2.9.3 The loop of the antenna shall be connected to a 50Ω coax cable
* **3.2.3 Software Interfaces**
  + 3.2.3.1 The operating software shall be able to process communication between all components.
  + 3.2.3.2 The system shall use the software Arduino to be able to run the stepping motor.
  + 3.2.3.3 The system shall use the software Airspy to be able to read and display the signal received by the loop antenna.
  + 3.2.3.4 The system shall use the software Mission Planner to be able to read and display the Pixhawk drone simulation.
  + 3.2.3.5 The system shall use Simulink to convert and print out complex data generated by the RTL-SDR to magnitude gain and phase angle.
* **3.2.4 Communications Interfaces**
  + 3.2.4.1 The system shall be able to detect signals operating in the 33-cm RF band.
  + 3.2.4.2 The system shall observe a minimal signal gain when the source is located in perpendicular to the plane of the loop.
  + 3.2.4.3 The system shall observe a maximum signal gain when the source is located in parallel to the plane of the loop.

**3.3 Physical Environment Requirements**

* *< Describe the environment in which the system must operate. Physical environment requirements include:*
  + *type of equipment/environment on which the system must run*
  + *location of the equipment*
  + *environmental considerations: temperature, humidity, ...*
  + *...>*
* 3.3.1 The system must operate outside.
* 3.3.2 The system must be able to operate in heat and humidity levels typical to central Florida.

**3.4 User and Human Factors Requirements**

* *<Describe the users and their constraints:*
  + *What different types of users must the system support?*
  + *What is the skill level of each type of user? What type of training and documentation must be provided for each user?*
  + *Do any users require special accommodations (large font size, ...)*
  + *Must the system detect and prevent misuse? If so, what types of potential misuse must the system detect and prevent?*
  + *...>*
* **3.4.1 User Requirements**
  + 3.4.1.1 The user shall have basic knowledge of telecommunications.
  + 3.4.1.2 The user shall have the technical knowledge required to set up the system.

**3.5 Documentation Requirements**

* *<Describe what documentation is required:*
  + *on-line, printed, or both?*
  + *what is the assumed skill level of the audience of each component of documentation?*
  + *...>*
  + 3.5.1 The documentation shall be in either PDF or .docx format

**3.6 Data Requirements**

* *<Describe any data calculations: what formula will be used? to what degree of precision must the calculations be made? >*
* *<Describe any retained data requirements: exactly what must be retained?*
* *...>*

**3.7 Resource Requirements**

* *<Describe the system resources:*
  + *skilled personnel required to build, use, and maintain the system?*
  + *physical space, power, heating, air conditioning, ...?*
  + *schedule?*
  + *funding?*
  + *hardware/software/tools?*
  + *...>*
* 3.7.1 The system shall require at least one person with sufficient knowledge to setup and operate the system.
* 3.7.2 The system shall require a source of power.

**3.8 Security Requirements**

**3.9 Quality Assurance Requirements**

* *<Describe quality attributes:*
  + *What are the requirements for reliability, availability, maintainability, security, portability ...?*
  + *How must these quality attributes be demonstrated?*
  + *Must the system detect and isolate faults? If so, what types of faults?*
  + *Is there a prescribed mean time between failures?*
  + *Is there a prescribed time the system must be available?*
  + *Is there a maximum time allowed for restarting the system after a failure?*
  + *What are the requirements for resource usage and response times?*
  + *...>*

**Section 4: Supporting Material**

* *<Here is where you put all your analysis work from which you derived the above requirements. It may include UML or other diagrams, notes, memos, etc.)*