System Requirements Specification

for

Microwave Tracking Ground Station

Version 6.1 approved

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WiDE LAB

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Revision History

Name	Date	Reason For Changes	Version
CO, JO, CE, IW, JS	09/28/2023	Document Creation	1.0
CO, CE, IW, JS	10/28/2023	Update for Sprint 2	2.0
CO, JO, CE, IW, JS,JW	11/21/2023	Update for Sprint 3	3.0
JO, CO	02/25/2023	Update during Spring Sprint 2 after contingency plan put in place, added section 4.4	4.0
JO, CE, IW, JW, CO, JS	03/03/2023	Many revisions, fixed a lot of formatting issues, rewrote sections for adjusted scope, fixed writing errors, added figures	5.0
CE	04/13/2024	Updates for version and final submission	6.0
JO, JS, IW	04/14/2024	Additional updates and rewording in multiple sections, as well as updates and additions of figures and diagrams	6.1

1. Introduction

This document serves as the Software Requirements Specification (SRS) for the Microwave-Tracking Ground Station. It outlines the functional and non-functional requirements of the system to be developed. The SRS provides a comprehensive understanding of the project's scope, purpose, and intended functionality.

1.1 Purpose

The Microwave Tracking Ground Station (MTGS) is designed to autonomously track satellites operating on S-band frequencies, and then analyze and record their signals using software-defined radio (SDR). This project addresses the challenges of radio frequency (RF) communication, including the design of antennas, combiners, filters, and amplifiers. It also navigates constraints such as size limitations, the implementation of tracking software for a dual-rotor positioner, and the stabilization of the system using a tripod pole mount.

As an ongoing project within the Embry-Riddle Aeronautical University WiDE Laboratory, the MTGS aims to innovate on the work of the previous team. By manipulating existing hardware, this iteration of the project introduces new tracking software, a complete RF block design, and utilizes the SDR to effectively record satellite signals.

1.2 Document Conventions

We will follow industry standard documentation and formatting. Each requirement is designed to have its own priority and may have sub requirements based on complexity.

1.3 Intended Audience and Reading Suggestions

The Microwave Tracking Ground Station is intended for Dr. Eduardo Rojas, Director of the WiDE (Wireless Devices and Electronics) laboratory, future students involved in microwave tracking design projects, as well as other members of the electrical engineering field focused on signal processing. The ground station and its systems can aid in the understanding of tracking software, signal processing, radio frequency block design, and satellite orbits.

1.4 Product Scope

The final iteration of the Microwave Tracking Ground Station is expected to be able to track a satellite through its visible orbit from the location of the ground station, utilizing tracking software to calculate its orbit with the satellite's two-line elements. Additionally, with the design and manufacturing of a radio frequency (RF) block, the ground station will be able to receive and display signals from Wi-Fi transmitters with the hope of receiving signals from the satellite that is being tracked, depending on atmospheric noise and the capabilities of the available antenna. The entire ground station will consist of the dish and antenna fixed on a mount, with the antenna feeding the received signals through the RF block and to the software-defined radio (SDR) which will connect to a computer to display the signals in SDR Sharp. The dish and antenna are also connected to a positioner which will be controlled by SatPC32, the tracking software, to point the antenna in the direction of the desired satellite.

1.5 References

1.8AEBP-1.8m elevation-over-azimuth antenna positioner - orbital systems. MA 101-113 1.8AEBP-1.8m Positioner Data Sheet C.01 print. (n.d.). http://www.orbitalsystems.com/wp-content/uploads/2020/06/1.8AEBP-1.8m-Positioner-Data-Sheet-C.01.pdf

AMSAT Satellite tracking for ISS. AMSAT. (n.d.). https://www.amsat.org/track/satloc.php?lang=en&satellite=ISS

Barth et al. (2018). Critical Design Review - University of Colorado Boulder. https://www.colorado.edu/aerospace/sites/default/files/attached-files/argus_cdr_0.pdf

Bevelacqua, P. (n.d.-a). *Antenna types*. List of Antennas (Antenna Types). https://www.antenna-theory.com/antennas/main.php

Bevelacqua, P. (n.d.-b). *The parabolic reflector antenna (satellite dish) - 3*. Antenna. https://www.antenna-theory.com/antennas/reflectors/dish3.php

Cassegrain reflector antennas: Antenna Design, gain & specs. Millimeter Wave Products | Waveguide Products | MM Wave Components. (n.d.). https://www.miwv.com/cassegrain-reflector-antennas/

Chamberlin, A. B. (Ed.). (n.d.). *Small-body satellites*. NASA. https://ssd.jpl.nasa.gov/sb/sats.html

Comly, D. (n.d.). *Parabolic Antennas and their Feeds*. dl7qy. https://www.dl7qy.eu/broadbandfeed/N3AOGpattern.pdf

Contact the ISS. ARISS. (n.d.). https://www.ariss.org/contact-the-iss.html

Gilani, A. S. (2019, August 7). *Images from the ISS and listening to hams with the RTL-SDR: Toptal®*. Toptal Engineering Blog. https://www.toptal.com/software/software-defined-radio-tutorial-rtl-sdr

Keslo, T. S. (n.d.). *Search of SATCAT*. CelesTrak. https://celestrak.org/satcat/table-satcat.php?INTDES=2001-018A&MAX=10000

Keslo, T. S. (n.d.). *Search of SATCAT*. CelesTrak. https://celestrak.org/satcat/table-satcat.php?NAME=QuetzSat+1&PAYLOAD=1&MAX=500

Krebs, G. D. (n.d.). *XM 1, 2 (XM Rock, roll)*. Gunter's Space Page. https://space.skyrocket.de/doc_sdat/xm-1.htm#:~:text=XM%201%20%5BBoeing%20BSS%5D%20Hughes%20Space%20and%20Communications,1%20and%20XM%202%20(nicknamed%20%22Rock%22%20and%20%22Roll%22)

Patel, S. (2023, October 26). *NASA Tech breathes life into potentially game-changing antenna design*. NASA. https://www.nasa.gov/directorates/stmd/nasa-tech-breathes-life-into-potentially-game-changing-antenna-design/

Quetzsat 1 - Gunter's Space Page. Gunter's Space Page. (n.d.). https://space.skyrocket.de/doc_sdat/quetzsat-1.htm

RocketDish RD-2G24 Quick Start Guide. Ubiquiti. (n.d.).

https://dl.ubnt.com/guides/rocketdish/RocketDish_RD-2G24_QSG.pdf

Satbeams - world of satellites at your fingertips. Satbeams Web and Mobile. (n.d.-a). https://www.satbeams.com/satellites?norad=37826

Satbeams - world of satellites at your fingertips. Satbeams Web and Mobile. (n.d.-b). https://www.satbeams.com/channels?norad=37826

Satellite finder. USRadioguy.com. (2023, January 16). https://usradioguy.com/satellite-finder/

SPX-01 - RF hamdesign. (n.d.). https://www.rfhamdesign.com/downloads/spx-01-specifications.pdf

SPX-01 azimuth & elevation rotor. SPX Standard Rotators - RF HAMSTORE. (n.d.). https://www.rfhamstore.com/webshop/antenna-rotators/spx-standard-rotators/detail/77/spx-01-azimuth--elevation-rotor.html

Technical details for satellite QUETZSAT 1. N2YO.com - Real Time Satellite Tracking and Predictions. (n.d.-a). https://www.n2yo.com/satellite/?s=37826#results

Technical details for satellite XM-2. N2YO.com - Real Time Satellite Tracking and Predictions. (n.d.-b). https://www.n2yo.com/satellite/?s=26724#results

2. Overall Description

2.1 Product Perspective

The Satellite Tracking Microwave Ground Station is a system designed to reliably receive satellite communications in the microwave frequency S-band. This band is used for communication by commercial and government satellites for a variety of missions. As seen in Figure 1, the ground station system comprises a dish antenna and two positioning motors for accurate satellite tracking. The parabolic dish optimizes signal reception by being able to receive all parts of a circularly polarized signal. The azimuth and elevation positioning motors, mountable on a ground plate or standing pole, enable flexibility in diverse work site conditions. Their role is to maintain antenna alignment with the desired satellite in order to produce the clearest communications.

A PC-based tracking system facilitates real-time adjustments for precise antenna alignment with changing satellite positions. The azimuth and elevation motors continuously update the antenna's orientation. The PC also hosts a Software-Defined Radio (SDR) Software for demodulating received signals into digital data, enhancing integration with communication protocols.

In operation, the dish antenna captures satellite signals, and the positioning motors adjust azimuth and elevation angles for accurate tracking. The tracking software processes real-time orbital data, calculating adjustments for optimal alignment. The SDR converts received signals into digital data for further analysis. This system is engineered for reliable communication links with satellites, suitable for applications like satellite communication and remote sensing, emphasizing uninterrupted and accurate satellite tracking for operational success.

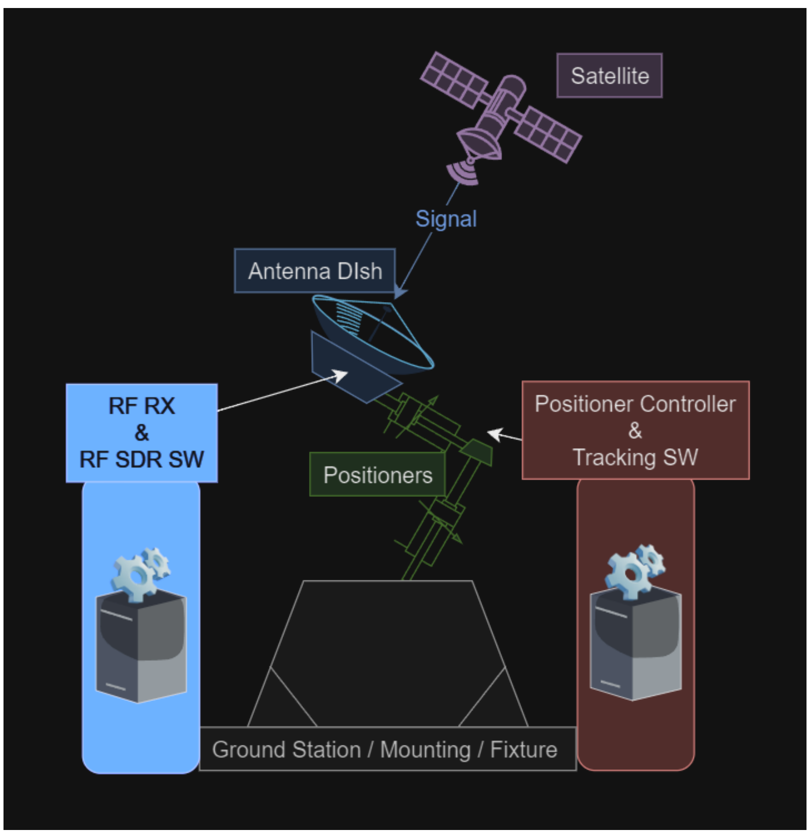

Figure 1 (Satellite-Tracking Microwave Ground Station Systems diagram)

2.2 Product Functions

REQ-2.2.1: The ground station shall be able to receive signals from a satellite

REQ-2.2.2: The ground station shall be able to detect signals in the Ku-Band frequency range

REQ-2.2.3: The ground station shall be portable and easy to move (smaller than existing prototype in WiDE lab)

REQ-2.2.4: The ground station's dish shall be able to turn in all directions in a hemispherical range of motion

REQ-2.2.5: The ground station shall be able to be controlled by directly connected controls as well as remotely by computer software

REQ-2.2.6: The ground station shall be able to track a specific satellite to receive constant signals

2.3 User Classes and Characteristics

Admins - Users with the highest privileges and authorization to use, test, or manipulate the ground station.

Admins shall have the following:

- A deep understanding of satellite tracking
- A deep understanding of radio frequency signals
- A deep understanding of electrical engineering
- A basic understanding of connected software and programming for alterations
- Access to WiDE lab and permission to use from Dr. Rojas if on team

Institute of Electrical and Electronics Engineers (IEEE) Community (focused on satellite tracking and/or digital signal processing) - The ground station should be something that anyone in the IEEE field, including engineers, computer scientists, and mathematicians, are able to use as long as they have a basic understanding of satellite tracking and RF signals. The system is meant to function easily for any user, but understanding the outputs and results of the system, as well as detecting success and error, will require basic knowledge in those areas.

IEEE Community members shall have the following:

- A basic understanding of satellite tracking
- A basic understanding of connected software
- Access to WiDE lab and permission to use from Dr. Rojas and team

No other users outside of the previous 2 user classes should have access to or use the ground station or any connected systems or parts.

2.4 Operating Environment

The tracking ground station is intended to operate outdoors to minimize interference, which would be more prevalent indoors. Preferable operation locations may include the roof of the MicaPlex and the Lehman building, both research and academic buildings located at Embry-Riddle Aeronautical University in Daytona Beach, FL. Additional design considerations will need to be given to mitigate any harm to the product from the elements, including but not limited to wind, humidity, uncontrolled climate (heat and cold), and direct sunlight/UV exposure. With this product being developed in Florida, rain is also a major concern for outdoor operation. In light of this, the ground station should be portable and only be put outdoors when weather conditions are favorable and testing is occuring.

In terms of software, along with connections to hardware, the different pieces of software being used will not interact with each other a significant amount. The tracking software, which will be run on any personal computer, all takes place in the SatPC32 program which will be communicating with the motor controller of the positioner. This will move the positioner to point the antenna in the direction of the desired satellite. SDR Sharp is the SDR software that displays the received signals from the antenna that come from the antenna and through the RF block to the SDR Pluto module and then to the laptop. Note that testing will only be done with personal computers running on the Windows 10 or Windows 11 operating systems.

2.5 Design and Implementation Constraints

2.5.1 Policies and Regulatory Compliance:

Corporate Policies:

There are no specific corporate policies that need to be adhered to for this project.

Regulatory Policies:

While not directly affected by regulatory policies, the system shall still operate within general industry and legal standards.

2.5.2 Hardware Limitations:

Power Requirements:

The hardware is designed to be plugged into a 120V 60Hz power outlet, adhering to USA standard electrical requirements.

Environmental Conditions:

The system is intended for outdoor use, but should be operated in dry conditions to ensure functionality and safety.

Signal Reception:

Hardware design shall account for the capacity to receive signals from a broad range of bands under 6 GHz (amplified 3.8 GHz Pluto), ensuring versatile and effective satellite communication.

Antenna Weight and Actuator Performance:

The weight of the antenna is a critical factor as it impacts the speed and accuracy of the actuators in positioning the dish. The antenna and dish cannot exceed the 66-pound weight limit of the positioner system. This necessitates a balance between antenna robustness and agility.

2.5.3 Timing Considerations:

The system's functionality heavily relies on precise timing. Users will input Keplerian coordinates of the target satellite and the ground station's current position, following which the actuators shall accurately and promptly orient the dish towards the satellite.

2.5.4 Software Requirements:

Memory Constraints:

Given the primary function of receiving and interpreting satellite signals, the project does not require significant memory storage capabilities.

Real-Time Processing:

Software shall be capable of processing input data in real-time to allow for immediate actuator response and signal reception.

2.5.6 Technology and Tools:

Specific technologies and tools required for the development will be selected based on their compatibility with the above constraints and the overall project goals.

2.5.7 Security Considerations:

While not primarily a concern, basic security measures to protect the system from unauthorized access and interference should be implemented.

2.5.8 Design and Programming Standards:

The project will adhere to industry-standard design conventions and programming standards to facilitate future maintenance and potential upgrades.

2.6 User Documentation

User documentation for Pluto SDR:
https://wiki.analog.com/university/tools/pluto

User documentation for SDR Sharp Software:
https://airspy.com/quickstart/

User documentation for SatPC32 Satellite Tracking Software:
https://www.dk1tb.de/indexeng.htm

User documentation for RocketDish 2, 2 GHz, 24dBi Antenna:
https://dl.ubnt.com/datasheets/rocketdish/rd_ds_web.pdf

2.7 Assumptions and Dependencies

2.7.1 Miniaturization Challenges:

The project assumes the feasibility of miniaturizing certain components of the prototype. However, this may be challenging due to limitations in the availability and suitability of motors and other parts. The assumption is that existing technologies can be effectively downsized without compromising functionality.

2.7.2 Timeline Constraints and Meeting Conflicts:

The progress of the project is contingent on adherence to the proposed timeline. There is an inherent assumption that project milestones align with the availability of team members. Conflicts in scheduling and meeting times could adversely affect project progression and deadlines.

2.7.3 Integration of Reused Software:

The project depends on the integration of software components reused from a previous team's work. There are potential challenges in incorporating or redesigning this software to fit the new prototype, given its unique requirements and specifications. This assumption underlines the necessity for flexibility in software adaptation and potential redevelopment.

2.7.4 Antenna Design and Part Availability:

A critical dependency of the project is the design or acquisition of a new dish that meets the goals of this SRS. This process might face obstacles due to the availability of suitable parts or challenges in custom designing an antenna that aligns with specific needs and constraints.

2.7.5 Hardware Compatibility:

The assumption that all selected hardware components, including SDRs, antennas, and positioning systems, will be compatible with each other. This includes both physical compatibility and the ability to communicate effectively through software interfaces.

2.7.6 Software Licensing and Third-Party Tools:

Dependence on third-party software tools or libraries, which might be subject to licensing terms and costs. This includes any software development kits (SDKs) or application programming interfaces (APIs) used in the project.

2.7.7 Environmental Tolerance:

The assumption that the hardware and software will perform reliably under various environmental conditions, such as temperature fluctuations, humidity, or electromagnetic interference, which might not have been fully tested.

2.7.8 Regulatory Compliance:

The project may be based on the assumption that it complies with all relevant regulations, such as those related to frequency use, power emissions, and operational safety. Changes in regulations or misunderstandings about compliance requirements could impact the project.

2.7.9 Data Availability and Accuracy:

Dependence on external data sources, such as satellite data or geographical information systems (GIS), assuming that this data will be available, accurate, and up-to-date.

2.7.10 Stable Power Supply:

Assuming a consistent and reliable power source that meets the system's requirements, especially if the system is intended for use in remote or varying locations.

2.7.11 Network Connectivity and Bandwidth:

If the system requires internet or network connectivity, there's an assumption regarding the availability and consistency of these connections, including sufficient bandwidth for data transmission.

2.7.12 Skilled Personnel Availability:

The project might depend on the availability of skilled personnel, such as software developers, engineers, and technical support staff. Changes in team composition or skill levels could affect the project.

2.7.13 Maintenance and Support:

Assuming that maintenance and technical support will be available for both hardware and software components over the life of the system.

2.7.14 Scalability and Future Upgrades:

Assuming that the system can be scaled up or modified in the future to meet evolving requirements or to incorporate new technology.

2.7.15 Budget Constraints and Funding Continuity:

The project is dependent on the assumption of a consistent budget and ongoing funding. Financial constraints or changes in funding could significantly impact the project scope or timeline.

3. External Interface Requirements

3.1 User Interfaces

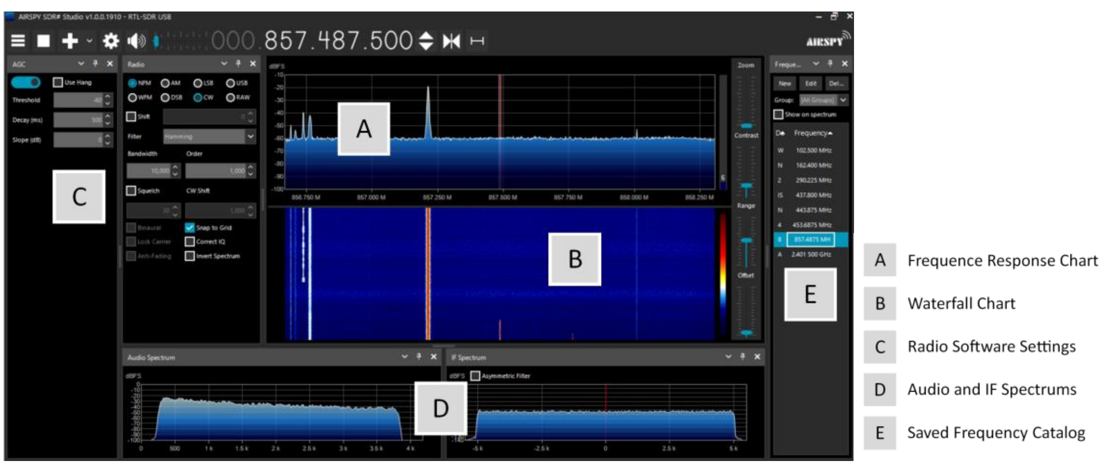

Figure 2 (SDR Software User Interface)

This device primarily connects to a computer digitally, although there are some physical aspects to consider. To enhance its portability and ease of maneuvering, it is affixed to a cart, significantly reducing the effort required for relocation. The digital interface encompasses both the SDR software and the positioner control software, both accessible via a computer. These software applications were selected with a strong emphasis on user-friendly design. The majority of user input will be to the SDR software pictured in Figure 2. This software has many features but is mainly used to manipulate the SDR settings and display the received signals.

3.2 Hardware Interfaces

The hardware interface requirements for this system comprise two key communication pathways: the antenna feed and the positioner control. The antenna feed is sourced directly from the dish antenna, featuring separate vertical and horizontal polarization ports. These signals are amalgamated into a circularly polarized signal, which subsequently passes through a coupled-line filter and low-noise amplifier (see Figure 3 below). The resultant signal is then directed into the Software-Defined Radio (SDR) for interpretation and visualization via the SDR software. Conversely, the positioner control signal is transmitted from the control software to an auxiliary module integrated with the motor controller. This specialized module is inherently designed to seamlessly interface with the motor controller, facilitating computer-based control. Both pathways require interfacing with an external computer that can run the software.

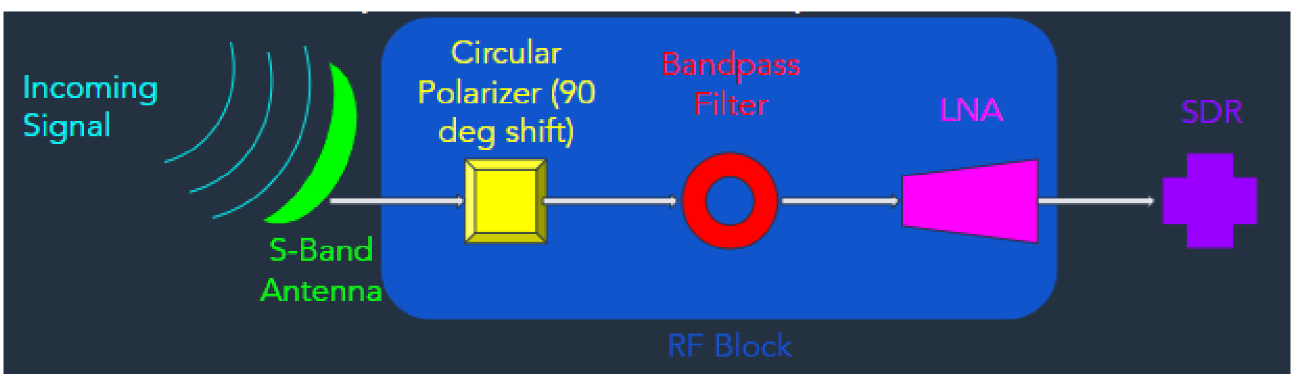

Figure 3 (Linear Connection Between Hardware Interfaces)

3.3 Software Interfaces

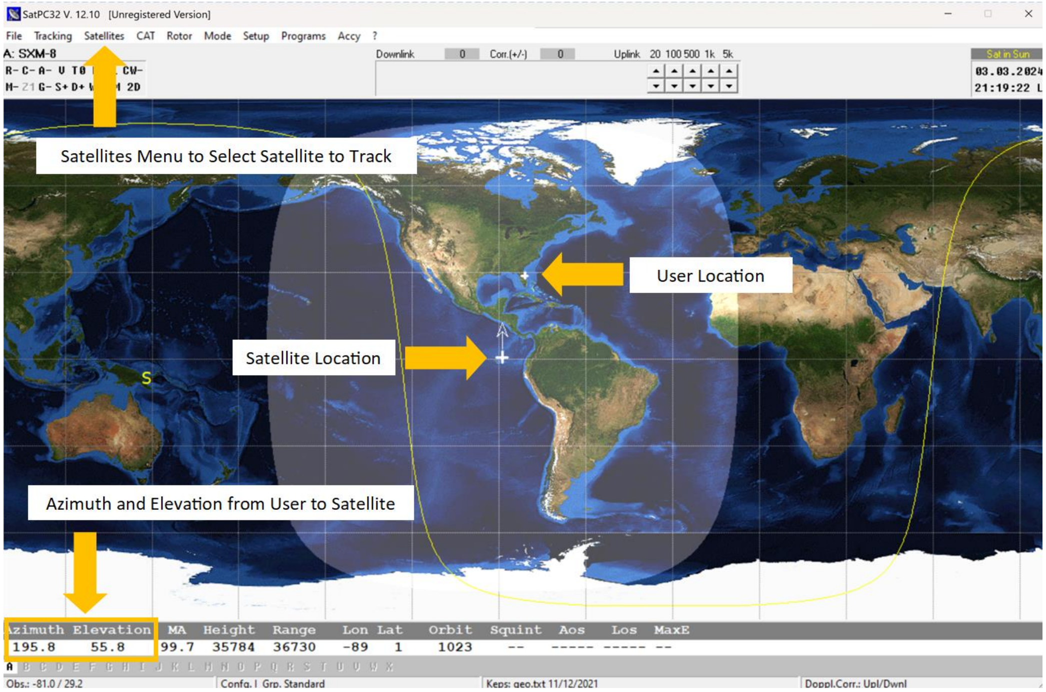

Figure 4 (Satellite Tracking Software User Interface)

The software interface requirements for this product revolve around two primary software components. The initial software component interacts with the positioner controller, ensuring precise alignment of the antenna with moving satellites as shown in Figure 4. It relies on input data, specifically the Keplerian elements of the satellite and the receiver's location, to regulate the positioner and achieve antenna alignment. This software has a built in database of these elements for easy satellite lookup and selection. It displays a map of the world and indicates both the satellite's and the user's locations. The second software component is the SDR receiver software shown in Figure 2, which serves as the intermediary between the system's Software-Defined Radio (SDR) and a computer. This software is responsible for visualizing the signals received by the antenna and fine-tuning the frequencies monitored by the SDR.

3.4 Communications Interfaces

The communication interface requirements for this system encompass three critical components. Firstly, the system shall support both vertical and horizontal polarization modes, combine them into a circularly polarized signal, and apply necessary signal processing filters before transmitting to the Software-Defined Radio (SDR) for further analysis. Secondly, a robust interface is needed to enable the positioner control software to communicate seamlessly with the motor controller's accessory module, ensuring real-time command and data transfer for precise antenna alignment with moving satellites. Lastly, the SDR software interface shall facilitate signal reception, interpretation, and frequency adjustments while offering a user-friendly display of received signals and data on a computer screen. These interface requirements are fundamental to the system's efficient and effective operation.

4. System Features

4.1 Dish Antenna

4.1.1 Description and Priority:

The Dish Antenna makes up the main hardware component responsible for collecting the RF signal from the satellite and transforming it into an electrical signal for the Radio Frequency Block. The Dish Antenna is of high priority to the system as it is critical to receiving satellite communications.

4.1.2 Stimulus/Response Sequences:

S/R Number	Stimulus	Response
1	Antenna is exposed to RF signals within its operating range	Antenna outputs electrical signal of the received RF signal
2	User adjusts Antenna direction.	System reorients the Antenna accordingly for optimal signal reception.
3	System detects signal interference.	System adjusts Antenna parameters to minimize interference.

4.1.3 Functional Requirements:

REQ-4.1.3.1: The system shall enable user-initiated power on of the Dish Antenna.

REQ-4.1.3.2: The system shall allow for user-initiated power off of the Dish Antenna.

REQ-4.1.3.3: The Dish Antenna shall be able to be mounted on the positioner.

REQ-4.1.3.4: The system shall automatically optimize the Dish Antenna position for optimal signal reception of the satellite that is actively being tracked.

REQ-4.1.3.5: The system shall monitor signal quality every second in real-time

REQ-4.1.3.6: The system shall adjust orientation (azimuth and elevation) to optimize signal reception.

REQ-4.1.3.7: The system will provide immediate feedback to the user interface, displaying the current signal quality and any adjustments made.

REQ-4.1.3.8: Adjustments will be triggered when signal quality drops below a predefined threshold, which is to be maintained above a signal-to-noise ratio (SNR) of 20 dB.

REQ-4.1.3.9: In the event of signal loss, the system shall immediately notify the user via the GUI.

REQ-4.1.3.10: Upon detection of signal loss, the system shall automatically initiate reconnection attempts.

REQ-4.1.3.11: The system will attempt to reconnect every 30 seconds.

REQ-4.1.3.12: Reconnection attempts will continue for a maximum of 5 minutes.

REQ-4.1.3.13: If reconnection is not successful within 5 minutes, the system will notify the user

REQ-4.1.3.15: The system shall log and report any issues related to the Dish Antenna for maintenance purposes.

4.2 Tracking Software

4.2.1 Description and Priority:

The tracking software for the ground station is the software that will be controlling the positioner and giving it instructions on how to position the antenna to track a satellite as it moves through its orbit. Its other main functionality is its graphical user interface for the user to choose their desired satellite to track and follow its data and view its position above the globe. This system is of high priority as without it, the product will not function. Receiving a signal from an orbiting satellite for an extended period of time is not possible without being able to track the satellite.

4.2.2 Stimulus/Response Sequences:

Stimulus	Response
The User inputs the desired satellite to track into the Tracking Software.	The Tracking Software calculates the satellite's orbit and determines the necessary adjustments to the antenna's position to align with the satellite.
The Tracking Software calculates and outputs the required azimuth and elevation adjustments, along with the corresponding voltage for the positioner motors.	The positioner motors receive these inputs and move the positioner to align with the calculated azimuth and elevation parameters.
The User inputs the longitude and latitude of the ground station's location into the Tracking Software.	The Tracking Software uses these coordinates to calculate the azimuth and elevation needed to align with the desired satellite.

4.2.3 Functional Requirements:

REQ-4.2.3.1: The system shall calculate the orbit of the satellite using the inputted two-line elements.

REQ-4.2.3.2: The system shall calculate the azimuth of the chosen satellite using the inputted two-line elements.

REQ-4.2.3.3: The system shall calculate the elevation of the chosen satellite using the inputted two-line elements.

REQ-4.2.3.4: The system shall send the chosen satellite’s degrees of azimuth and elevation to the positioner every 0.1 seconds.

REQ-4.2.3.4: The system shall use inputted GPS coordinates to calculate azimuth and elevation relative to the current location of the ground station on Earth.

REQ-4.2.3.5: The system shall update the satellite's position in real-time based on the current date and time.

REQ-4.2.3.6: The system shall allow the user to add a new satellite's data that will then be added to the library of available satellites.

REQ-4.2.3.7: The system shall allow the user to toggle on and off the path of the satellite view.

REQ-4.2.3.8: The system shall provide a global map on the graphical user interface to show where the chosen satellite is in relation to the globe, updating every 1 second.

REQ-4.2.3.9: The system shall allow the user to change the current global position of the ground station and display it within 1 second.

REQ-4.2.3.11:The system shall detect invalid input data and alert the user immediately.

REQ-4.2.3.12: The system shall detect errors in calculations and report these to the user.

REQ-4.2.3.13: The system shall monitor and detect communication issues with external data sources.

REQ-4.2.3.14: The system shall detect internal program errors and notify the user.

REQ-4.2.3.15: The system shall allow the user to center the map on the ground station or the desired satellite's current position.

4.3 Rotor Positioning System

4.3.1 Description and Priority:

The ground station positioner system features an Azimuth rotor and Elevation rotor. Controlled manually or via autonomous programming, the rotors may operate within 360 degrees of Azimuth and 180 degrees of Elevation. This system is of high priority as it is crucial to testing both tracking software and antenna design. Additionally, the specifications of the positioner shall be fast and accurate enough to maintain signal reception with tracked satellites.

4.3.2 Stimulus/Response Sequences:

Stimulus	Response
The Tracking Software sends an elevation angle to the Rotor Positioning System.	The Rotor Positioning System turns the elevation rotor to align it with the received angle.
The Tracking Software sends an azimuth angle to the Rotor Positioning System.	The Rotor Positioning System turns the azimuth rotor to align it with the received angle.
Using the manual controller, the user makes azimuth and elevation inputs.	The Rotor Positioning System turns the rotors to the angles directed by the user's manual control input.

4.3.3 Functional Requirements:

REQ-4.3.3.1: The system shall have an angle of resolution smaller than 1 degree.

REQ-4.3.3.2: The system shall have an accuracy greater than +/- 0.06 degrees within the set angle.

REQ-4.3.3.3: The system shall have a maximum azimuth rotation speed greater than 3°/s.

REQ-4.3.3.4: The system shall have a maximum elevation rotation speed greater than 3°/s.

REQ-4.3.3.5: The system shall be able to hold 30kg of vertical load at all angles of elevation between 0-1800.

REQ-4.3.3.6: The system shall be able to rotate 360 degrees of azimuth.

REQ-4.3.3.7: The system shall be able to rotate 180 degrees of elevation.

REQ-4.3.3.8: The system shall weigh less than 20kg.

REQ-4.3.3.9: The system shall remain still against 10lbs of horizontal force.

REQ-4.3.3.10: The system shall have a manual override for disabling or adding input to the positioning system.

4.4 Radio Frequency Block

4.4.1 Description and Priority:

The Radio Frequency Block is of ***high*** importance to ground station performance. Each component of the RF Block ensures signal reception, including a coupled-line bandpass filter, amplifier, and polarization converter.

4.4.2 Stimulus/Response Sequences:

Stimulus	Response

The antenna captures vertical and horizontal signal components and feeds them into the polarization converter through two coaxial cables.	The polarization converter merges these two signal inputs, producing a unified signal output directed towards the bandpass filter.
Then the signal will go through a wilkinson power combiner to combine these two into one coaxial cable.	The combiner will combine both signals that are now in phase thanks to the polarizer.
The unified signal reaches the bandpass filter.	The bandpass filter permits signals within the 2.2GHz to 2.5GHz range, attenuating those outside this spectrum, and forwards the filtered signals to the amplifier.
The filtered signals are input into the low noise amplifier.	The amplifier applies a 20 dB gain to the received signals and outputs the amplified signals to the Software-Defined Radio.

4.4.3 Functional Requirements:

REQ-4.4.3.1: The system shall attenuate signals between 2.2 GHz and 2.5 GHz at -5 dB and 0 dB.

REQ-4.4.3.2: The system shall attenuate signals below 2.2 GHz and above 2.5 GHz at -20dB or below.

REQ-4.4.3.3: The system shall amplify signals between 2.2 GHz and 2.5 GHz by 20 dB.

REQ-4.4.3.4: The system shall align the phases of the horizontal and vertical signal component within 1 degree.

5. Other Nonfunctional Requirements

5.1 Performance Requirements

These requirements exist so that the system will perform satellite tracking efficiently and effectively. The goal is for the system to adjust to a satellite's ever changing position and perform the necessary actions to consistently track them. The system also needs to accurately transmit and receive data because otherwise the operations would not be possible.

REQ-5.1.1: The system shall track the given satellite in real time.

REQ-5.1.2: The system shall continuously adjust its positioning to track the location of the specified satellite.

REQ-5.1.3: The system shall RX at the given frequencies of 2.1-2.4 GHZ at all times of operation.

REQ-5.1.4: The system shall perform adjusting movements without interfering with communications.

REQ-5.1.5: The system shall only use the necessary power required.

5.2 Safety Requirements

REQ-5.2.1: The system shall automatically halt operations under any conditions that pose a risk of damage to its components.

REQ-5.2.2: The system shall cease movement operations if the movement can not be performed.

REQ-5.2.3: The system must ensure uniform and steady movements throughout its operational lifespan.

REQ-5.2.4: The system shall not draw power while not in operation.

5.3 Security Requirements

REQ-5.3.1: The system shall not interfere with local communications.

REQ-5.3.2: The system shall not interfere with local laws regarding communication equipment.

REQ-5.3.3: The system shall be accessible by only the user.

REQ-5.3.4: The system shall not interfere in local first responder operations.

REQ-5.3.5: The system shall not interfere with the satellites or other satellite operations.

REQ-5.3.6: The system shall have a passcode for the user interface.

5.4 Software Quality Attributes

REQ-5.4.1: The software shall perform adjusting movements to within ± 1% accuracy to the known correct values (NORAD).

REQ-5.4.2: The software shall perform active tracking via the given frequencies and locations.

REQ-5.4.3: The software shall have reboot capabilities in the events of power cycling and or errors.

REQ-5.4.4: The software shall have adjustable operations in the event of loss communications.

5.5 Business Rules

REQ-5.5.1: There will be one operator of the vehicle controlling the system via software and or a mechanical adjustor.

REQ-5.5.2: System use approval shall be given before the commencement of operations.

6. Other Requirements

Currently, there are no other requirements for the Microwave Tracking Ground Station.

Appendix A: Glossary

Terms (A-Z)	**Meaning**
RF	Radio Frequency (wireless communication technology)
SDD	Software Design Document
SDR	Software Defined Radio *(a radio communication system utilizing software to modulate and demodulate received signals)*
SRS	Software Requirement Specifications (Document)
STMGS	Satellite-Tracking Microwave Ground Station
LEO	Low Earth Orbit
GHz	Gigahertz
GUI	Graphical User Interface

RX	Received Signal/Receive
RF	Radio Frequency
K-Band	Frequencies between 18-27 GHz
Ku-Band	Frequencies between 12-18 GHz
Ka-Band	Frequencies between 27-40 GHz
S-Band	Frequencies between 2-4 GHz

Appendix B: Analysis Models

Figure 1 (Satellite-Tracking Microwave Ground Station Systems diagram)

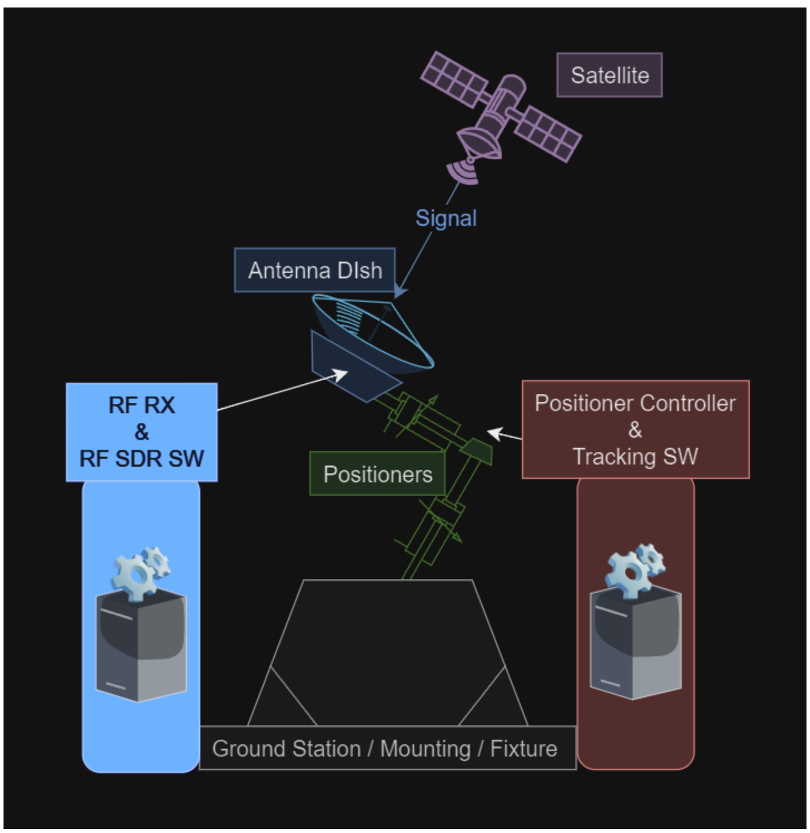

Figure 2 (SDR Software User Interface)

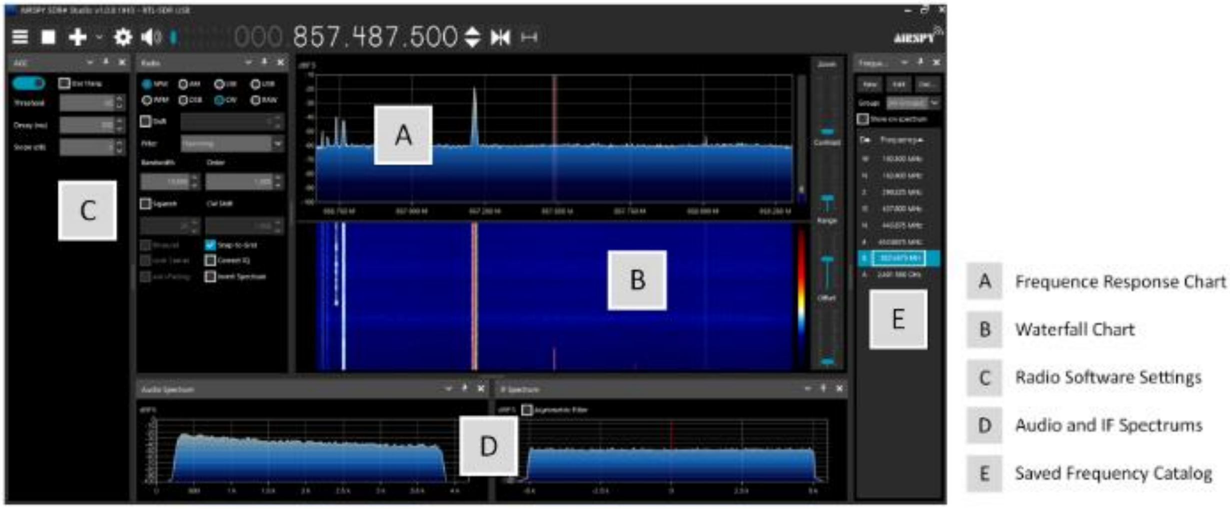

Figure 3 (Linear Connection Between Hardware Interfaces)

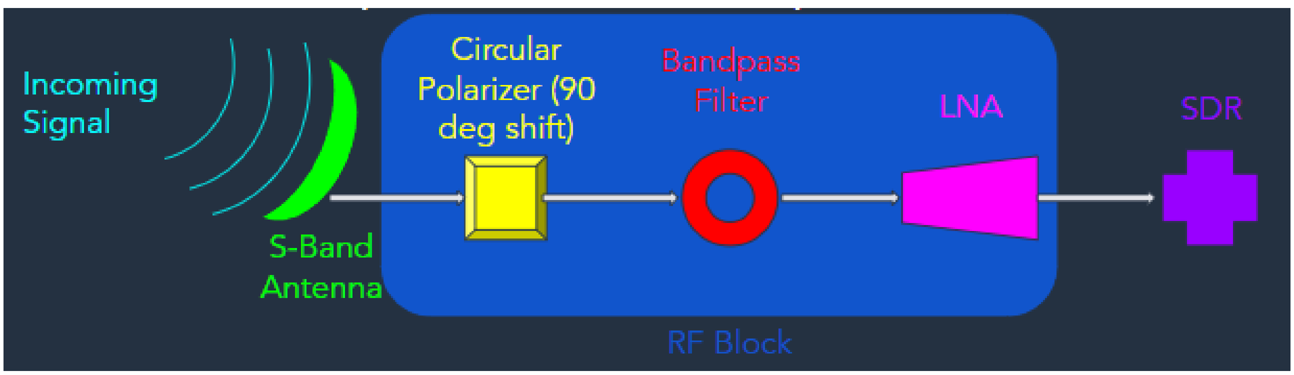

Figure 4 (Satellite Tracking Software User Interface)

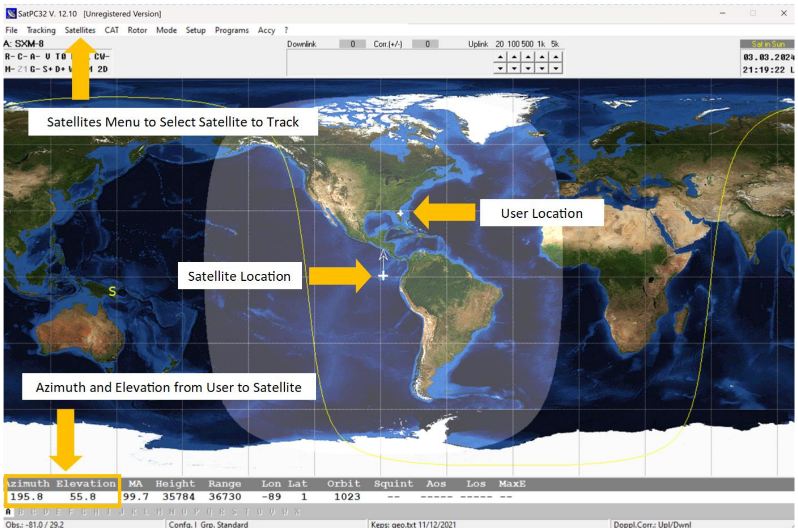

Figure 5 (Use Case Diagram)

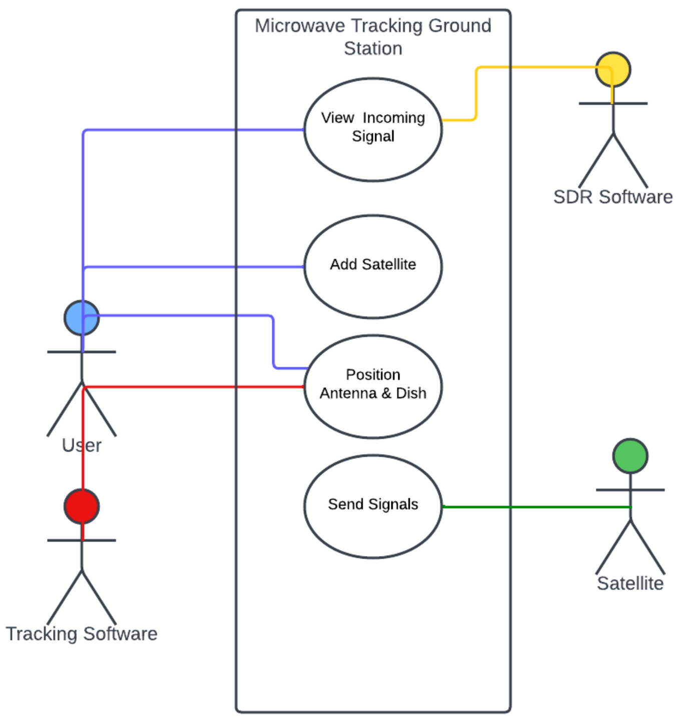

Figure 6 (Context Diagram)

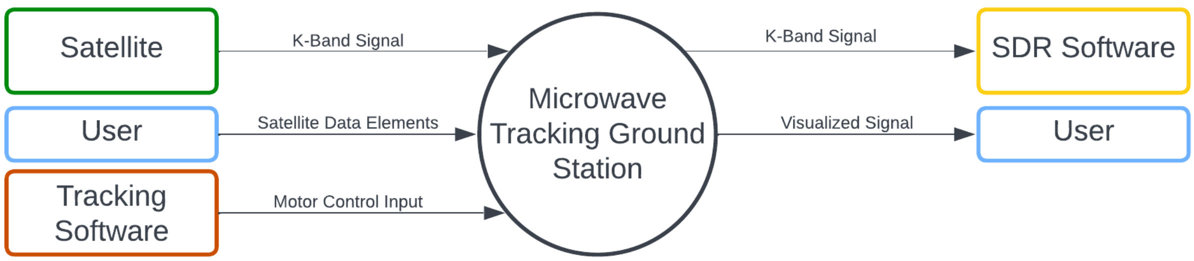

Figure 7 (Data Flow Diagram)