MATS Subsystem Test Plans

Mobile Antenna Tracking System (MATS)

9/28/2025

Zachary Murray, Dylan Vilcek, Ma Minghao

This document outlines the subsystem verification and test plan for the MATS. This document will outline the objectives of testing each subsystem, equipment and software required, as well as the procedures to verify the proper operation of the individual subsystems for successful integration into the overall system.

Revision	Date	Author	Description
0.1	9/26/2025	MATS Team	Initial draft created
0.2	9/27/2025	Zachary Murray	Added introduction, diagram, and system requirements. Revised receiver section.
0.3	9/27/2025	Zachary Murray	Added wiring schematic for user interface, adjusted formatting, added conclusion.
0.4	9/28/2025	Zachary Murray	Added information regarding antenna placement, software stack, and introductory paragraphs for power subsystem tests.
1.0	9/26/2025	Zachary Murray	Converted to PDF for Release.

Table of Contents

Table of Figures

Table of Tables

Introduction

The Mobile Antenna Tracking System relies on coordinated operation of the Receiver, Rotator, User Interface, and Power subsystem to track, receive, and decode satellite transmissions. To ensure reliable and proper operation in the field, each subsystem must be independently verified against its requirements before integration. This document outlines the test plan for each subsystem. The procedures described here validate that the hardware and software elements are correctly configured, and that each subsystem performs within specification under expected operation conditions.

The test plan is structed to provide clear subsystem overviews and requirements, defined objectives, step-by-step test procedures, and consolidated pass/fail outcome tables for traceability.

Successful completion of this test plan provides confidence that the subsystems are ready for integration into the MATS system.

System Overview

Functional Description

The MATS is designed for portable installations. The operation of the MATS includes deployment, setup, and reception. Once powered on via the user interface, the power distribution subsystem regulates the incoming 12-24VDC power to necessary voltages for each component: 5V for the receiver's single board computer, 5V for the microcontroller, and appropriate levels for the touchscreen and motors. The user interface provides immediate visual feedback through status LEDs indicating power and RF activity, while the touchscreen allows the user to configure satellite passes, view tracking status, and manage reception sessions using GPredict and SatDump.

System Diagram

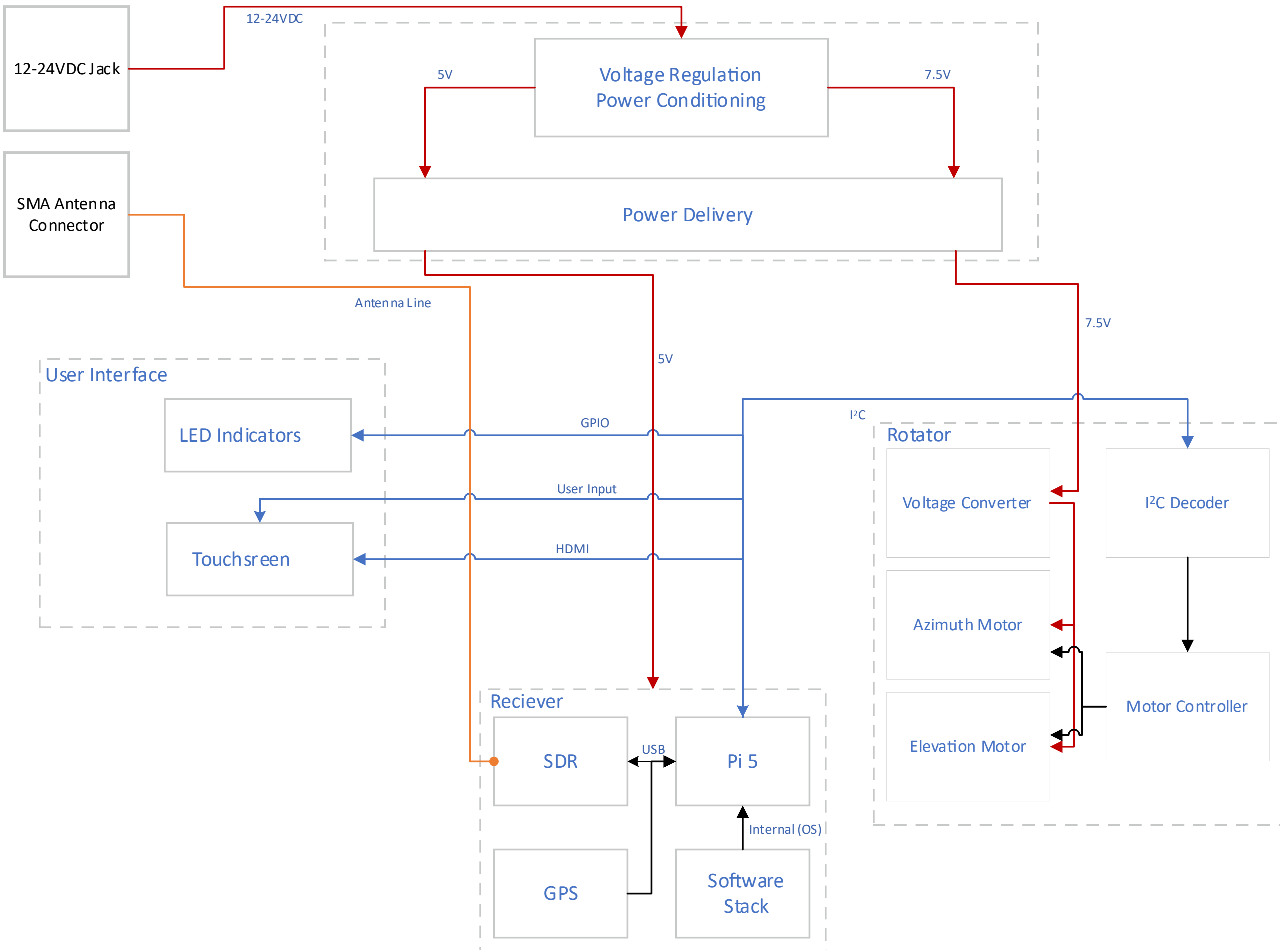

Figure 1: System Diagram

System Requirements

The system requirements for the MATS to successfully meet the needs of its stakeholders are shown below. These have been created to specifically address most of the concerns that are present in the needs of professionals that perform work in the fields that could benefit from the MATS.

Table 1: System Requirements

Requirement	**Expected Value**	**Importance**	**Verification**
The enclosure dimensions must fit within a defined volume.	22L x 14w x 9h in ±5%	2	Measure
The device must be lightweight for ease of transport and deployment.	≤25lbs	3	Measure
Enclosure must withstand accidental drops from a height of 3 feet without damage.	Deformation on enclosure ≤ 3cm	4	Physical Inspection
The device operates with commonly available power inputs.	12 - 24 ± 10% VDC	2	Test
The device operates with reasonable power requirements.	≤75W	3	Test
The system utilizes commonly available SDR components.	RTL-SDR V3	1	Datasheet
The system utilizes antenna lines that ensure antenna compatibility.	50Ω	1	Datasheet
Antenna connector must be standard for antenna compatibility.	utilizes SMA connectors.	2	Physical Inspection
The system can reliably track low earth orbit polar orbiting satellites.	±2 degrees on Low Earth Orbit meteorological satellites. (NOAA 15, 18, 19, METEOR M2-x)	1	Functional Testing
The system should function reliably in the expected environmental conditions.	-40C to 50C	2	Functional Testing
LEDs should indicate system status (power, RF.)	Red power LED indicator light Green RF LED indicator light	3	Demonstration

The system should be cost-effective.	≤ $400	1	Bill of Materials
The system utilizes free and open-source software for tracking and decoding.	Gpredict for tracking SatDump for decoding	1	Functional Testing
System contains screen for user interface and viewing of satellite data.	7" Touchscreen Display	2	Visual Inspection
System contains I/O for transferring software and imagery on and off the device.	Accessible USB-A 2.0 SDXC microSD card reader	3	Visual Inspection
Applicable Antennas	L-band Helical antennas Lightweight portable Dish Antennas	2	Demonstration
System follows applicable FCC regulations to avoid interference with other devices.	FCC Part 15 Class B	4	Circuit Review
System contains protections against overcurrent and overvoltage conditions.	Fuses and/or resettable breakers.	4	Circuit Review
System prevents user harm due to rotating/moving components.	Guards, covers, and/or occupancy detection.	3	Visual Inspection

Receiver

Subsystem Overview

The receiver is responsible for being the central processor for the MATS. Its duties include being able to track a satellite given the TLE's in Gpredict, receiving signals from the tracked satellites and decode the signals using SatDump. The receiver is equipped with an RTL-SDR for signal reception and utilizes a Raspberry Pi 5 running Raspian OS for its wide software support and community. Additionally, the Receiver subsystem will be equipped with GPS such that SatDump can accurately decode the received signals with map overlays and timestamps. To support the tracking of the satellite, the Receiver utilizes its GPS coordinates and the TLE data given by Gpredict and sends position data to the Rotator.

Subsystem Requirements and Specifications

To enable the Receiver to function accurately and be integrated into the MATS successfully, the Receiver has the following signal characteristics and requirements.

Table 2: Receiver Subsystem Requirements

Receiver Subsystem	
Power Requirement	5VDC 5A±0.5VDC
I/O Characteristics	USB2-A Interface (internal and external) HDMI 1.4 I2C
Receiving Equipment	50Ω Antenna line External SMA Antenna Connector 25MHz to 1.75GHz tuner
Software	Raspbian OS SatDump Gpredict Latest RTL-SDR V4 drivers
Cost	< $150

A detailed diagram for this system is provided below in Figure 2.

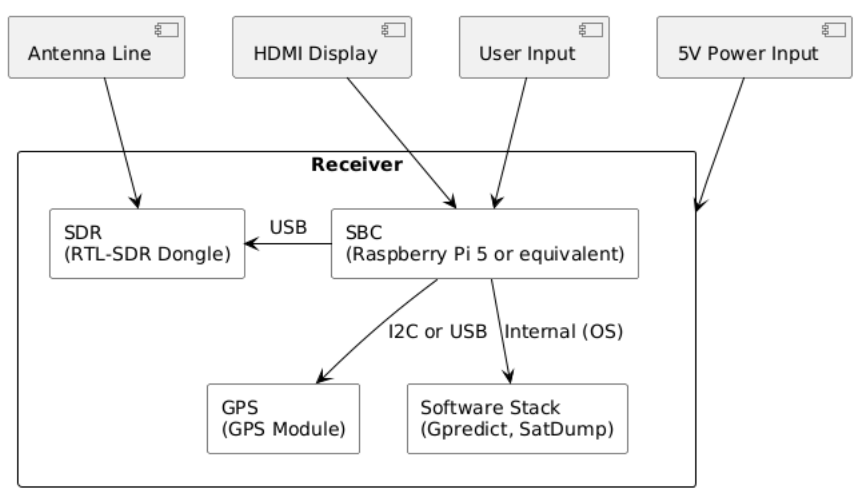

Figure 2: Receiver System Diagram

The objectives of these tests can be found below, outlining the high level checks that should be performed before the integration into MATS.

Objectives

The objectives for testing the receiver include verifying that the receiver has the correct drivers and software stack, being able to receive satellite communication downlinks, and decode these downlinks into meaningful data. Subsystem components that will be tested include:

- Installation of the correct RTL-SDR Drivers
- I2C enabled
- Correct software stack installed
    - SatDump
    - GPredict
    - GPS Driver
    - SDR++
- Reception of common satellites
- Satellite transmission decodes

These objectives ensure that the receiver can correctly send commands via I2C, receive and decode Satellite transmissions. Early testing to verify the I2C bus sends the correct 32 bits will also be executed, ensuring smooth integration with the rotator.

Required Equipment

The required equipment to test the Receiver can be found below. Additionally, the testing scripts and programs can be found at the project's GitHub[1]. Required hardware testing is as follows:

- Provided Receiver hardware
- Analog Discovery 2
- Provided 78MHz to 1GHz V-Dipole if testing VHF or equivalent 1.7GHz L-band antenna if testing using L-band (can substitute for other antennas as region requires.)
- 50Ω SMA RG58 coaxial cable
- Fluke 117 Multimeter

[1] https://github.com/ZacharyRMu/MATS

Optional equipment is listed below for use with certain testing scripts and hardware but not necessarily required:

- Laptop with serial port
- 3GHz NanoVNA
- Nooelec Sawbird+ NOAA LNA or L-band LNB for satellite reception (Satellite Dependent)

Testing Procedure

This section will walk the user through testing each individual section of the reciever's capabilities. Step by step instructions are

Correct Drivers Installed

Installation of the correct RTL-SDR drivers is crucial. The installer script should fetch the latest version, build, and install the correct driver. However, sometimes Udev rules can become a problem and not allow the correct RTL-SDR driver to initialize; it's important that it is checked to verify that the correct driver is installed, and the generic driver be disabled. To ensure that the correct drivers are installed, Table 3 outlines the procedure to be followed.

Table 3: Correct RTL-SDR Driver Install Test Procedure

Test	**Expected Result**	**Observed Result**
Check that DVB and rtl12832 drivers are not loaded using `lsmod`	Drivers not loaded	Correct drivers loaded
Plug in RTL-SDR V4 into Receiver	N/A	N/A
Run `lsusb` to confirm the device is detected	RTL-SDR found	device detected
Run `rtl_test -t` or `rtl_test -p` to verify the driver claims the device	No "usb_open error" message	driver claims device

I2C Interface Enablement

Verify that the Raspberry Pi's I2C interface is enabled by the installer script and accessible by user-space applications. Table 4 outlines this procedure.

Table 4: I2C Interface Testing

Test	Expected Result	Observed Result
Inspect `/boot/firmware/config.txt`		
Confirm `dtparam=i2c_arm=on` is present and not commented out	Line not commented out	present
Verify the invoking user has been added to the i2c group		
run the following: `groups $USER | grep i2c`	User Added	user added
Verify the kernel driver is loaded. Run: `lsmod | grep i2c_bcm`	Driver loaded	driver loaded
With the system booted, execute: `sudo i2cdetect -y 1`	A grid of addresses is displayed	0x20 (AD2)
Use the Analog Discovery 2 to verify I2C traffic using the provided `i2c_ad2_test.py` script.	I2C present on AD2	traffic present.

Installed Software Stack

The receiver must have the correct software stack for correct operation with the other subsystems. This test section ensures that the correct software, such as GPS drivers, SatDump, Gpredict, and SDR++ are installed on the system. The software stack has been provided in Figure 3 for reference. Table 5 shows the procedure for verifying all required software has been installed. A test script has been provided in the github repository for automated testing.

Table 5: Receiver Software Stack Test Procedure

Test	Expected Result	Observed Result
Run automated verification script	Script executes and prints results for each component.	
Check GPS drivers	Output shows: [+] Checking gpsd... PASS	PASS
Check SatDump installation	Output shows: [+] Checking SatDump... PASS	PASS
Check Gpredict installation	Output shows: [+] Checking Gpredict... PASS	PASS
Check SDR++ installation	Output shows: [+] Checking SDR++... PASS	PASS
Review summary	Script ends with === Verification complete === and no FAIL messages.	NO FAIL

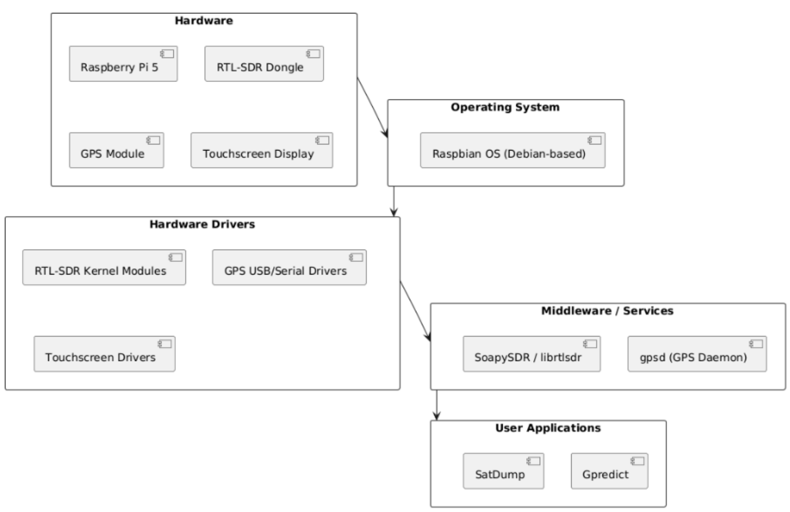

Figure 3: Software Stack for Receiver

Satellite Reception

Successful satellite reception is required for the MATS to perform it's core functionality. Shown below in Table 6, the testing procedure verifies that that SatDump can record a satellite transmission.

Table 6: Satellite Reception Test

Test	Expected Result	Observed Result
Connect RTL-SDR Blog V4 dongle to Pi USB 3.0 port and attach VHF antenna (QFH, V-dipole, turnstile, etc.) tuned for ~137 MHz as shown in Figure 4 [1] and Figure 5. For more information, refer to Antenna Information in the Appendix on Page 41.	Hardware connected firmly, antenna outdoors or with clear sky view.	
Use Gpredict to check upcoming Meteor-M2-4 pass (137.9 MHz). Record start time, max elevation, and pass duration.	Pass info visible, frequency: **137.900 MHz**.	Start time: 9:05 Max Elevation: 78 End Time: 9:21
Launch SDR++ and configure RTL-SDR input. Set center frequency to 137.9 MHz and sample rate to ~2.048 MSPS.	Device initializes without error, spectrum visible.	137.9 center (primary) 2.4 MSPS
Observe waterfall during predicted pass. An example has been provided in Figure 6.	Wideband (~140 kHz) signal appears centered at 137.9 MHz, rising above noise floor as pass begins.	wideband signal at 137.9
(Optional) Verify via SatDump spectrum mode without decoding.	Console/log shows device streaming, RF power increases near 137.9 MHz during pass.	N/A
Satellite passes last roughly 15 minutes. Monitor until end of pass.	Signal fades as satellite sets. No USB or driver errors reported.	reception for 13 minutes

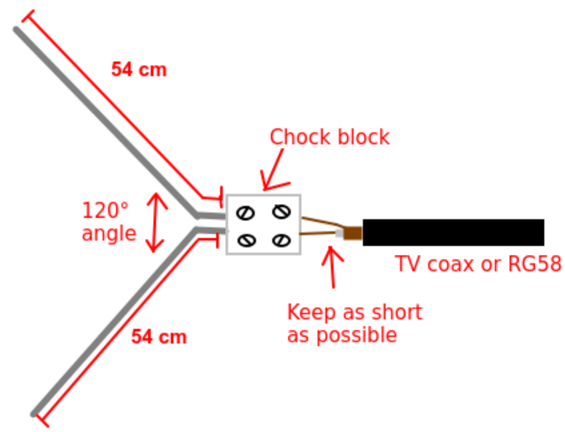

Figure 4: V-Dipole Antenna Setup [1]

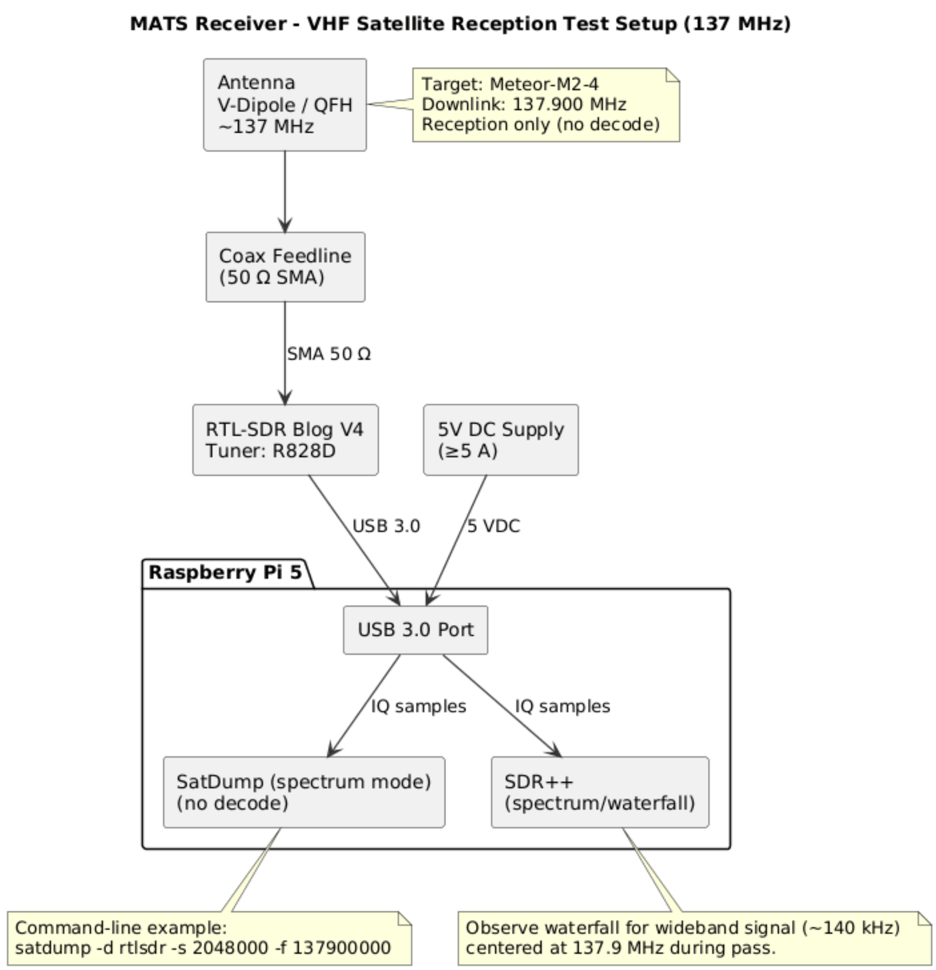

Figure 5: Test Setup for Satellite Reception.

Figure 6: Waterfall Example (SDR++) Source: Zachary Murray

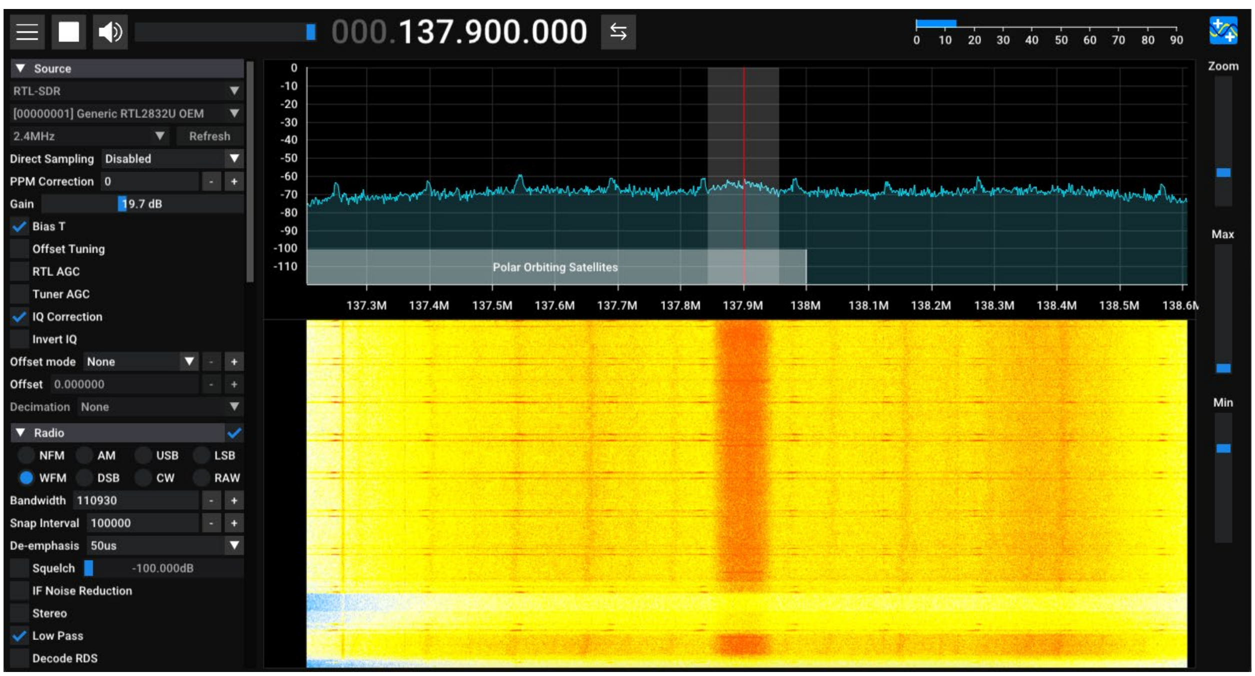

Figure 7: Waterfall Example (SatDump) Source: Zachary Murray

Satellite Transmission Decoding

Testing of the receiver's decoding stack ensures that satellite transmissions are accurately reconstructed with the correct GPS coordinates and map overlays. Table 7 below outlines the testing procedure.

Table 7: Satellite Transmission Decode Test

Test	Expected Result	Observed Result
Connect RTL-SDR Blog V4 dongle to Pi USB 3.0 port and antenna suitable for target satellite (e.g., QFH for VHF).	Hardware connected firmly, antenna with clear sky view.	Hardware connected firmly, antenna with clear sky view.
Use Gpredict to schedule and monitor an upcoming pass of a decodable satellite (e.g., NOAA APT at 137.1–137.9 MHz or Meteor-M2-4 at 137.9 MHz).	Pass data visible with start time, elevation, and duration.	N/A
Launch SatDump in live mode with correct frequency and sample rate.	SatDump initializes without error, SDR engaged.	137.9MHz, METEOR M2-3 2.4MSPS
Observe console/log during pass. Optionally, if using the GUI version of SatDump, Figure 7 shows an example waterfall.	Frames are received and decoded; progress messages visible.	figure 7 visible.
At end of pass, review generated products (e.g., map overlays, imagery, data files). An example is provided in Figure 8.	Output files (e.g., PNG, HDF5) are generated in SatDump output directory with valid content.	saved in ~/liveoutput

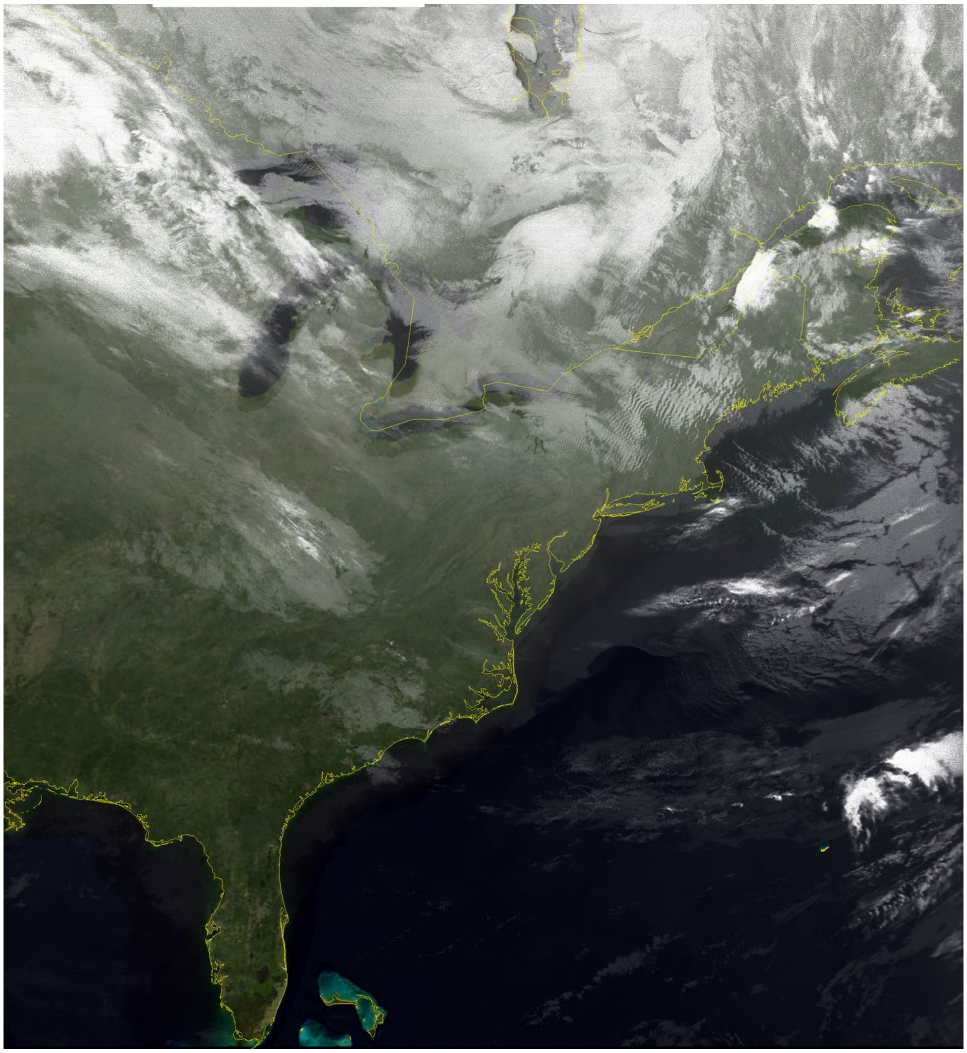

Figure 8: MCIR False Color Output. Source: Zachary Murray

Subsystem Test Results

After execution of all test sections (drivers, I2C, software stack, reception, and decoding), results should be consolidated in the following table.

Test Section	Pass/Fail	Notes
RTL-SDR Driver Install	PASS	Minor driver claiming issue. was resolved.
I^2C Interface Enablement	PASS	worked first try!
Software Stack Verification	PASS	stack verified
Satellite Reception (M2-4, 137.9 MHz)	PASS	PASS
Satellite Transmission Decoding	PASS	PASS

User Interface

Subsystem Overview

The User Interface subsystem provides the primary operator touchpoint within the MATS. It delivers feedback through a 7" touchscreen, communicates system status via LED indicators, and provides removable media access through USB and SD ports. The UI runs a lightweight Raspberry Pi OS desktop, auto-launching SatDump at startup. Status LED's are driven using a Python daemon that subscribes to SatDump telemetry, providing live feedback for RF lock, recording, and power state. A block diagram has been provided in **Error! Reference source not found.**.

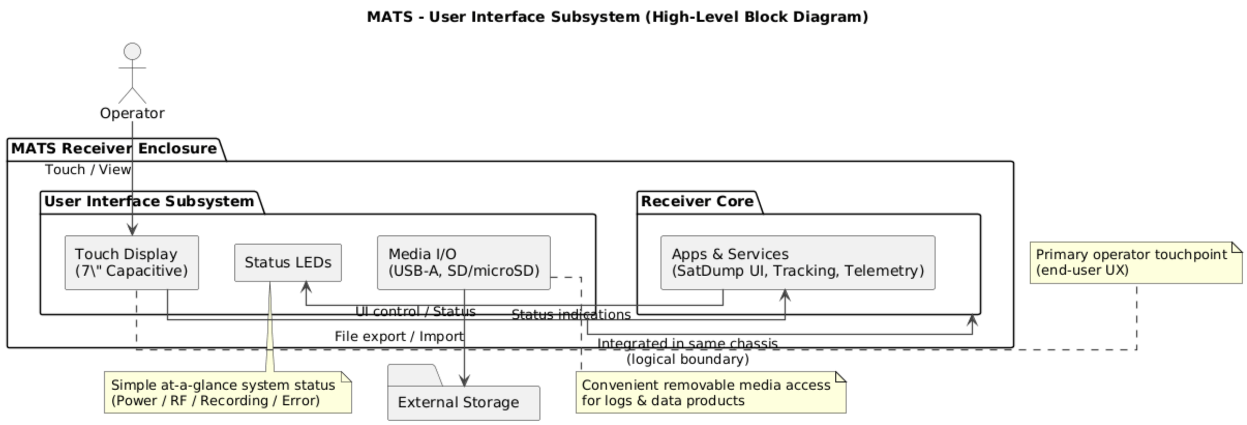

Figure 9: User Interface Subsystem Block Diagram

Subsystem Requirements and Specifications

Table 8: User Interface Subsystem Specifications

Category	Requirement
Display	7 Inch capacitive touchscreen with Linux driver support.
Inputs/outputs	≥ 1 USB-A user port, SD/microSD card reader, power switch, RF & Power status LEDs.
Environmental	Operating 0ºC-50ºC, front panel.
Splash Resistance	IP-54 splash resistance
Electrical	Single 5V DC rail, ≤2A steady-state draw
Software	GPIO LEDs
Mechanical	Front-panel mounting to aluminum chassis, maximum depth behind panel ≤ 45mm
Cost	< $140

Objectives

The testing objectives for the User Interface are:

- Verify touchscreen responsiveness and accuracy
- Confirm automatic startup and SatDump launch.
- Validate USB and SD card hot-plug enumeration
- Verify LED indicators function under scripted test
- Confirm LEDs respond correctly to SatDump Telemetry.

These objectives ensure the User Interface provides reliable control and feedback to operators.

Required Equipment

- Provided UI Hardware
- Test Media: 32 GB microSD card and 128 GB USB Flash drive
- Multimeter
- Python I2C test script (led_test.py
- Dupont jumper wires

A test setup has been provided in Figure 10 below.

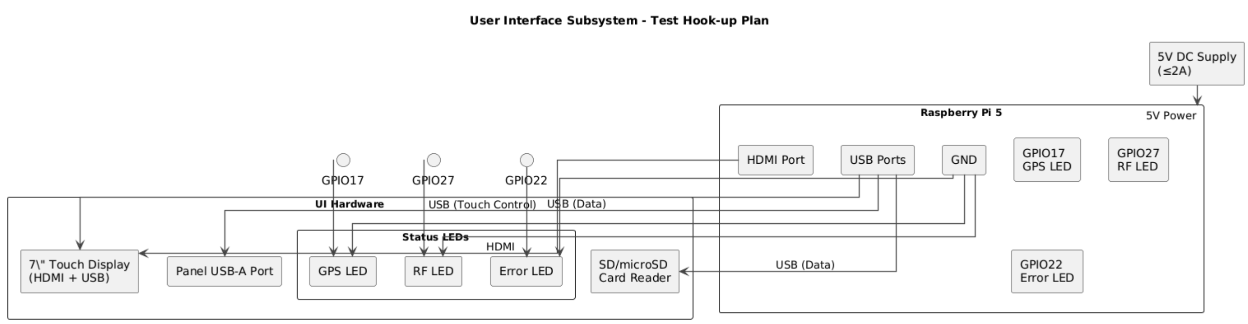

Figure 10: User Interface Test Setup

Testing Procedure

Testing of the user interface is primarily focused on the core functionality with interacting with the MATS. Table 9 shows the tests to be performed for successful verification.

Table 9: User Interface Testing

Test	Method	Expected Result	Observed Result
Display Touch Response	Run 10-point accuracy grid or calibration app	Touch deviation < 2 mm	about 1mm
SatDump Auto-Launch	Boot system and observe startup	Pi logs into desktop and SatDump auto-launches within ~15 s	pi boots in >10s
USB Enumeration	Hot-plug 128 GB USB drive	Drive mounts automatically.	drive did not
SD Card Enumeration	Hot-plug 32 GB microSD card via panel reader	Card mounts automatically.	SD card did not
LED Functionality	Run led_test.py scripted LED pattern test. See Figure 11 for script flowchart and pattern.	Each LED (Power, RF, Recording) cycles correctly through colors	LED's operate
LED Telemetry Response	Start/stop SatDump recording session	RF/Recording LEDs toggle in real time with telemetry	Operational

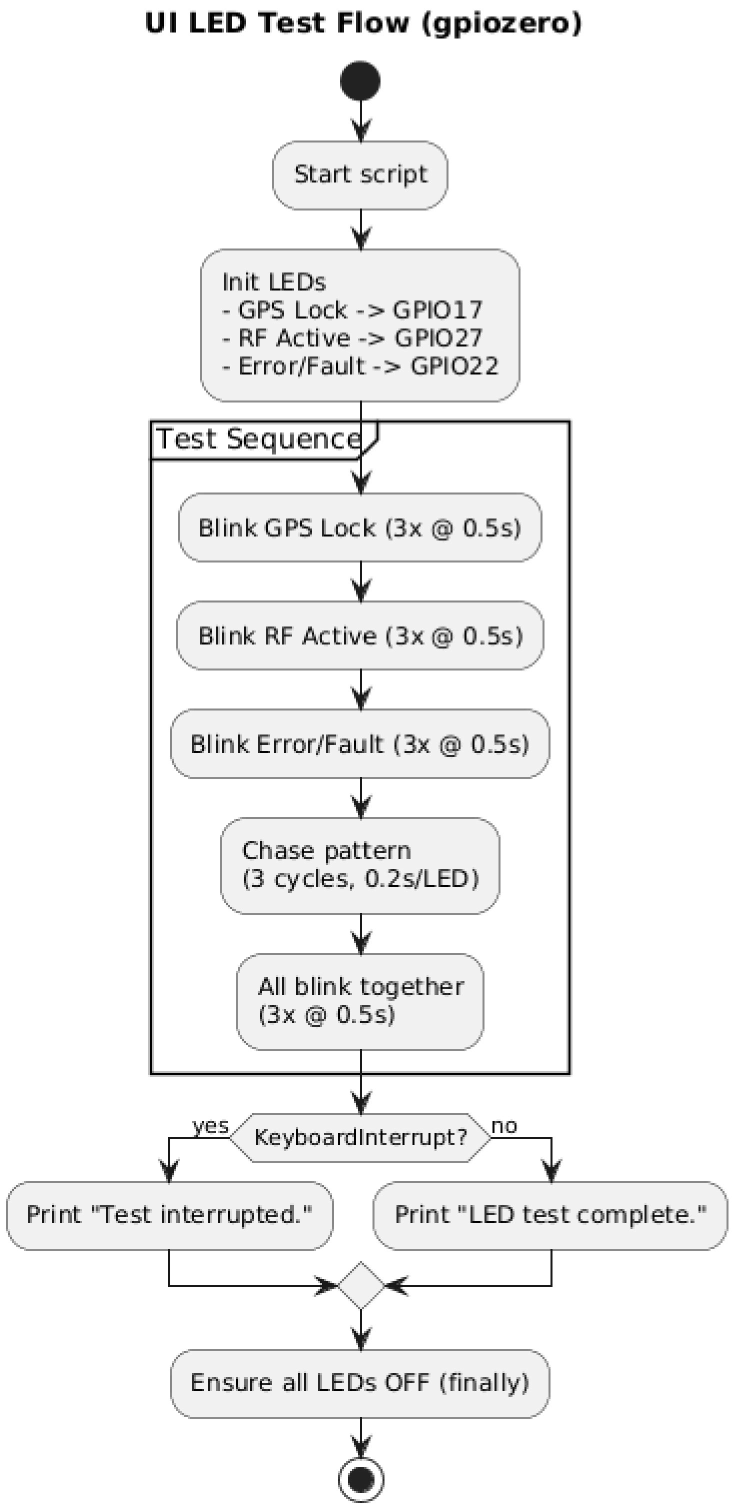

Figure 11: LED Test Script Flowchart

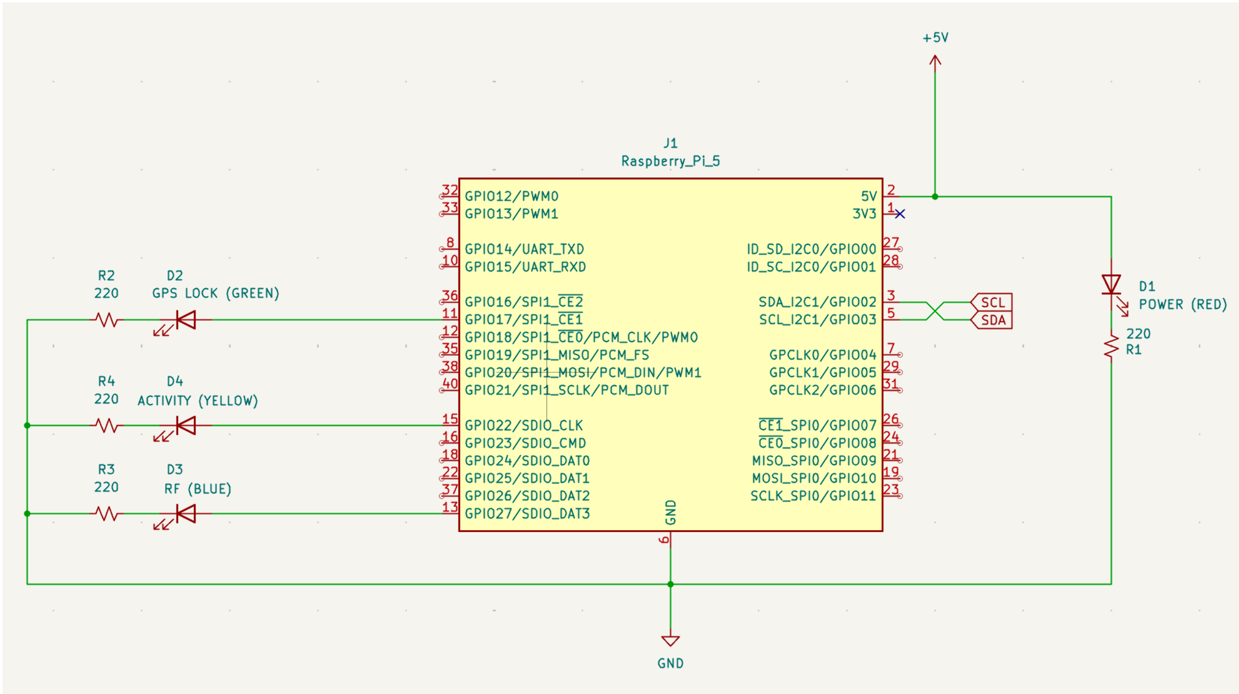

Figure 12: User Interface Wiring Schematic for LEDs.

Subsystem Test Results

Test Section	Pass/Fail	Notes
Touchscreen Accuracy	PASS	more subjective test
Auto-Launch of SatDump	PASS	launched
USB Enumeration	FAIL	Card reader unusable
SD Card Enumeration	FAIL	card reader unusable
LED Functionality	PASS	script works
LED Telemetry Response	PASS	PASS

Rotator

Subsystem Overview

The purpose of this subsystem verification plan is to establish a structured and repeatable process for verifying the performance, functionality, and compliance of the Rotator subsystem. This document provides a detailed framework for conducting verification activities, ensuring that all requirements are met before integration into the larger MATS. By following this plan, verification activities will be performed efficiently, ensuring the subsystem meets its design and functional requirements before proceeding to the next phase of system development. This subsystem was previously developed and testing. The verification has been included for completeness.

Subsystem Requirements and Specifications

The Rotator system is responsible for rotating the antenna, moving it to a position given by the receiver system to track low earth orbit satellites. Due to the requirements given by the receiver, this system needs to receive an I2C signal for obtaining the azimuth and elevation location required and positioning the antenna to the specific coordinate within the specific time. System requirements can be found in Table 17.

Table 10: Rotator Subsystem Requirements

Requirement	Expectation
Power Requirement	3V3, 12VDC
Interface	I^2C
Azimuth Accuracy	±1.6°
Elevation Accuracy	±1.6°
Power Consumption	< 75W
Cost	< $110

A diagram is provided in Figure 13 outlining the functional blocks and connections within the Rotator.

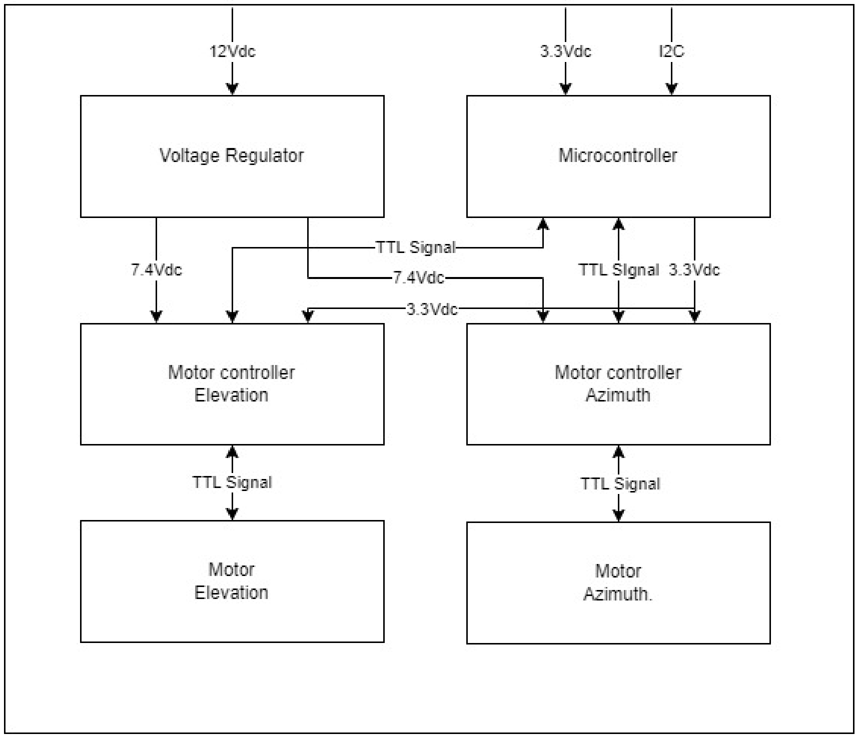

Figure 13: Rotator Block Diagram

These requirements ensure the proper operation of the Rotator, allowing the MATS to accurately track low earth orbit satellites.

Objectives

These tests are intended to test the Rotator for proper operation. The rest of this document outlines the equipment and tests required to confirm that the Rotator is working as intended, and ready to be integrated into the larger MATS system. In these tests, the functional tests include:

- System Self-Test
- Azimuth Mobility Test
- Elevation Mobility Test
- Command Response Verification Test
- Rotational Mobility Test
- Power Consumption Test

Required Equipment

For the following tests to be performed, some equipment should be obtained. This equipment is chosen for its simplicity of use and being readily available. The equipment required to perform these tests include:

- Laptop
- DMM
- Power Supply
- I^2C Generator (raspberry pi, microcontroller, analog discovery)
- Stopwatch
- Protractor
- Wattmeter
- Compass

Testing Procedure

This section details the verification procedures required to validate the Rotator. Each test ensures compliance with functional, performance, and reliability requirements. Data acquired from these tests should be documented in the provided tables.

System Self-Test

The system self-test's purpose is to verify that the azimuth and elevation motors start, perform the respective self-checks, and return to the original position. Table 11 outlines the procedure and measurements to be taken.

Table 11: System Self-Test Procedure

	Test/Verification Step	Expected Value	Measured Value	Pass or Fail
1	Connect power supply to Subsystem Under Test (SUT) as shown in Figure 14.	N/A	N/A	N/A
2	Using a protractor, take an initial position measurement at 90 degrees.	90	N/A	Pass
3	Turn on the power to the SUT and observe the behavior.	N/A	N/A	N/A
4	Verify the servo motors have performed their self-start checks.	Servo 1 and 2 online	both online	Pass
5	Using the protractor, measure the position deviation from original position measured in step 2.	< 1.8°	0	Pass

If the Rotator's motors successfully perform the startup self-checks and return to the original position, the Rotator should be tested for functional performance.

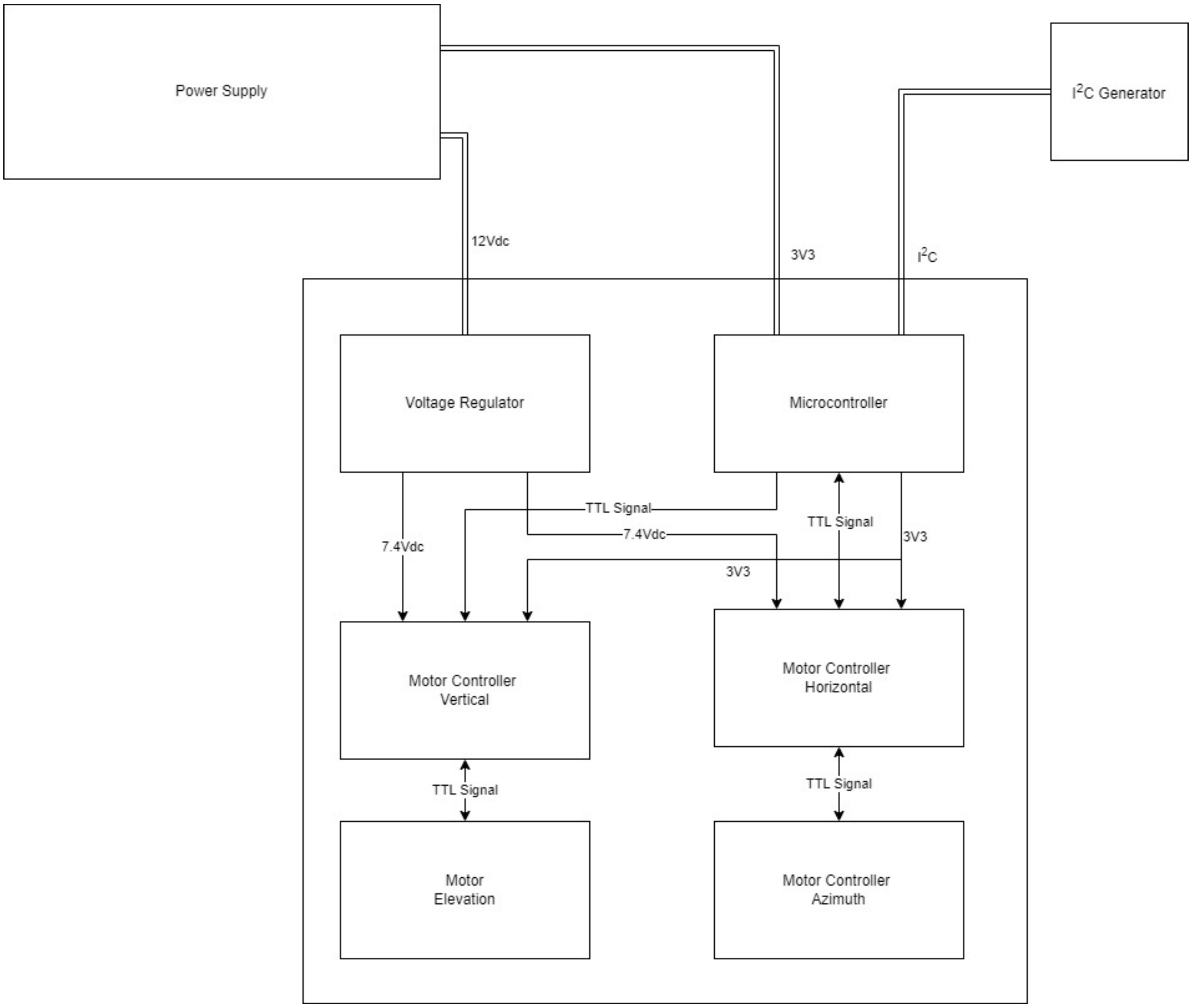

Figure 14: Mobility Test Setup

Azimuth Mobility Test

The Azimuth Mobility Test verifies that the Rotator is capable of completely rotating 360 degrees in Azimuth. This check ensures that the Rotator will not need to "flip" when the satellite is passing directly overhead. This ensures that the signal will not be impacted while tracking directly overhead satellites.

To perform this test, the system should still be connected to power and the following steps outlined in Table 12 are to be performed.

Table 12: Azimuth Mobility Test Procedure

	Test/Verification Step	Expected Value	Measured Value	Pass or Fail
1	Connect Test Equipment and power supply to Subsystem Under Test (SUT) as shown in Figure 14.	N/A	N/A	N/A
2	Using a compass, take an initial measurement position measurement.	N/A	N/A	N/A
3	Using the code provided in Figure 15, send a control input that moves the azimuth to rotate 90º.	N/A	N/A	N/A
4	Utilizing the stopwatch, measure the amount of time taken to complete the rotation.	<180s	1.8s	Pass
5	Using the compass, measure the azimuth angle after rotation.	90° ± 1.8°	90	Pass

```
Serial.println("Set 90(Azimuth) ");
delay(1000);
uservo_0.setRawAngle(0.0);   //Set servo 0 (Horizontal) angle
uservo_1.setRawAngle(0.0);  //Set servo 1 (Vertical) angle
delay(1000);
uservo_0.setRawAngle(90.0);   //Set servo 0 (Horizontal) angle
uservo_1.setRawAngle(0.0);  //Set servo 1 (Vertical) angle
delay(10000);
```

Figure 15: Azimuth Test Code

This check determines the freedom of movement of the Rotator subsystem's azimuth direction. Upon failure, determine failure cause and document accordingly.

Elevation Mobility Test

The Elevation Mobility Test determines the Rotator's freedom in elevation. The elevation is where the antenna is pointed and is primarily responsible for holding the antenna at a given height above the horizon. This operation is required for proper signal strength, as deviations in elevation can lead to signal loss.

The procedure to outline this test is shown in Table 13.

Table 13: Elevation Mobility Test Procedures

	Test/Verification Step	Expected Value	Measured Value	Pass or Fail
1	Connect Test Equipment and power supply to Subsystem Under Test (SUT) as shown in Figure 14.	N/A	N/A	N/A
2	Using a compass, take an initial Elevation measurement.	N/A	N/A	N/A
3	Using the code provided in Figure 16, send a control input that moves the elevation to 90º in elevation.	N/A	N/A	N/A
4	Utilizing the stopwatch, measure the amount of time taken to complete the rotation.	<180s	1.86s	Pass
5	Using a compass, measure the elevation angle after the rotation is complete.	90° ± 1.8°	90	Pass

```
//Set 90(Elevation Test)
Serial.println("Set 90(Elevation Test) ");
delay(1000);
uservo_0.setRawAngle(0.0);    //Set servo 0 (Horizontal) angle
uservo_1.setRawAngle(0.0);   //Set servo 1 (Vertical) angle
delay(1000);
uservo_0.setRawAngle(0.0);    //Set servo 0 (Horizontal) angle
uservo_1.setRawAngle(90.0);  //Set servo 1 (Vertical) angle
delay(10000);
```

Figure 16: Elevation Test Code

Verification of this system ensures that the Rotator has freedom of movement in elevation, which enables smooth movement allowing for the least amount of signal loss. Upon failure, determine failure cause and document accordingly.

Command Response Verification Test

The command response verification test ensures that the system can receive a command and move to the given coordinates. This test verifies that the Rotator can smoothly operate both the azimuth and elevation at the same time, ensuring that there is minimal signal loss during tracking.

To perform this test, follow the procedure outlined in Table 14.

Table 14: Command Response Verification Test

	Test/Verification Step	Expected Value	Measured Value	Pass or Fail
1	Connect Test Equipment and power supply to Subsystem Under Test (SUT) as shown in Figure 14.	N/A	N/A	N/A
2	Using a protractor, take an initial Elevation measurement at 0 degrees.	N/A	N/A	N/A
3	Using the protractor, take an initial azimuth measurement at 90 degrees.	N/A	N/A	N/A
4	Using the code provided in Figure 17, send a control input that moves 72º azimuth and 36º in elevation.	N/A	N/A	N/A
5	Utilizing the stopwatch, measure the amount of time taken to complete the movement	<180s	1.74	Pass
6	Using a compass, measure the elevation angle after the rotation is complete.	36 ± 1.8°	37	Pass
7	Using a compass, measure the azimuth angle after the rotation is complete.	72 ± 1.8°	71.8	Pass

```
//Set 36(Command Response Test)
Serial.println("Set 36(Command Response Test)");
delay(1000);
uservo_0.setRawAngle(0.0);   //Set servo 0 (Horizontal) angle
uservo_1.setRawAngle(0.0);  //Set servo 1 (Vertical) angle
delay(1000);
uservo_0.setRawAngle(36.0);   //Set servo 0 (Horizontal) angle
uservo_1.setRawAngle(36.0);  //Set servo 1 (Vertical) angle
delay(10000);
//Set 72(Command Response Test)
Serial.println("Set 72(Command Response Test)");
delay(1000);
uservo_0.setRawAngle(0.0);   //Set servo 0 (Horizontal) angle
uservo_1.setRawAngle(0.0);  //Set servo 1 (Vertical) angle
delay(1000);
uservo_0.setRawAngle(72.0);   //Set servo 0 (Horizontal) angle
uservo_1.setRawAngle(72.0);  //Set servo 1 (Vertical) angle
delay(10000);
```

Figure 17: Command Response Test Code

Completion of this test ensures that the Rotator is capable of smoothly tracking and positioning an antenna where it needs to be for obtaining a good signal. Upon failure, determine cause and document accordingly.

Rotational Mobility Test

The rotational mobility test will determine if the Rotator is capable of operating to the limit of azimuth and elevation required for accurate satellite tracking. This test will verify that the Rotator can move to more extreme values of azimuth and elevation.

To perform this test, follow the steps outlined in Table 15.

Table 15: Rotational Mobility Test

	Test/Verification Step	Expected Value	Measured Value	Pass or Fail
1	Connect Test Equipment and power supply to Subsystem Under Test (SUT) as shown in Figure 14.	N/A	N/A	N/A
2	Using a compass, take an initial Elevation measurement.	N/A	N/A	N/A
3	Using the compass, take an initial azimuth measurement.	N/A	N/A	N/A
4	Using code provided in Figure 8 And use Python code provided by Figure 9. send a control input that moves 172° azimuth and 86° in elevation.	N/A		
5	Utilizing the stopwatch, measure the amount of time taken to complete the movement	<180s	1.8s	Pass
6	Using a compass, measure the elevation angle after the rotation is complete.	86 ± 1.8°	86.5	Pass
7	Using a compass, measure the azimuth angle after the rotation is complete.	172 ± 1.8°	171	Pass

```
    //Set 360(Rotational Mobility Test)
    Serial.println("Set 360(Rotational Mobility Test)");
    delay(1000);
    uservo_0.setRawAngle(-180.0);   //Set servo 0 (Horizontal) angle
    uservo_1.setRawAngle(-180.0);  //Set servo 1 (Vertical) angle
    delay(1000);
    uservo_0.setRawAngle(180.0);   //Set servo 0 (Horizontal) angle
    uservo_1.setRawAngle(180.0);  //Set servo 1 (Vertical) angle
    delay(10000);
    //Set 86(Rotational Mobility Test)
    Serial.println("Set 86(Rotational Mobility Test)");
    delay(1000);
    uservo_0.setRawAngle(0.0);   //Set servo 0 (Horizontal) angle
    uservo_1.setRawAngle(0.0);  //Set servo 1 (Vertical) angle
    delay(1000);
    uservo_0.setRawAngle(36.0);   //Set servo 0 (Horizontal) angle
    uservo_1.setRawAngle(36.0);  //Set servo 1 (Vertical) angle
    delay(10000);
    //Set 172(Rotational Mobility Test)
    Serial.println("Set 172(Rotational Mobility Test)");
    delay(1000);
    uservo_0.setRawAngle(0.0);   //Set servo 0 (Horizontal) angle
    uservo_1.setRawAngle(0.0);  //Set servo 1 (Vertical) angle
    delay(1000);
    uservo_0.setRawAngle(172.0);   //Set servo 0 (Horizontal) angle
    uservo_1.setRawAngle(172.0);  //Set servo 1 (Vertical) angle
    delay(10000);
    //I2c rotation Code(not tested)
    //uservo_0.setRawAngle(horizonAngle);   //Set servo 0 (Horizontal) angle
    //uservo_1.setRawAngle(verticalAngle);  //Set servo 1 (Vertical) angle
}
```

Figure 18: Rotational Mobility Test

Completion of this test ensures that the Rotator is capable of operating at the limits of required angles for tracking low earth orbit satellites. Upon failure, determine cause and document accordingly.

Rotational Mobility Test by I2C

The rotational mobility test will determine if the Rotator is capable of operating to the limit of azimuth and elevation required for accurate satellite tracking by receiving system. This test will verify that the Rotator can receive correct messages from receive system and keep tracking right position.

To perform this test, follow the steps outlined in Table 15.

Table 7: Rotational Mobility Test

	Test/Verification Step	Expected Value	Measured Value	Pass or Fail
1	Connect Test Equipment and power supply to Subsystem Under Test (SUT) as shown in Figure 14.	N/A	N/A	N/A
2	Using a compass, take an initial Elevation measurement.	N/A	N/A	N/A
3	Using the compass, take an initial azimuth measurement.	N/A	N/A	N/A
4	Using code provided in Figure 18, send a control input that moves 172° azimuth and 86° in elevation.	N/A	N/A	N/A
5	Utilizing the stopwatch, measure the amount of time taken to complete the movement	<180s	1.8s	Pass
6	Using a compass, measure the elevation angle after the rotation is complete.	86 ± 1.8°	86.5	Pass
7	Using a compass, measure the azimuth angle after the rotation is complete.	172 ± 1.8°	171	Pass

```
if(newDataAvailable){
  newDataAvailable = false;
  //get angle value from recived value from I2C
  int horizonAngle = getValueForHorizontal(recivedValue);
  int verticalAngle = getValueForVerticalal(recivedValue);
  String message3 = "horizonAngle:"+String(horizonAngle) + " recivedValue " + "verticalAngle:"+String(verticalAngle) + " recivedValue ";
  DEBUG_SERIAL.println(message3);
  DEBUG_SERIAL.println(recivedValue);

//I2c rotation Code(not tested)
  uservo_0.setRawAngle(horizonAngle);   //Set servo 0 (Horizontal) angle
  uservo_1.setRawAngle(verticalAngle);  //Set servo 1 (Vertical) angle
  delay(10000);
}
```

Figure 8: Rotational Mobility Test

Completion of this test ensures that the Rotator can receive satellites location from receiver for tracking low earth orbit satellites. Upon failure, determine cause and document accordingly.

Power Consumption Test

The power consumption test verifies that the MATS has a power consumption that enables it to perform utilizing available power on board many aircraft, emergency vehicles, and maritime vessels. Table 16 outlines the procedure to successfully perform these checks, and Figure 19 shows the set equipment setup.

Table 16: Power Consumption Test Procedure

	Test/Verification Step	Expected Value	Measured Value	Pass or Fail
1	Connect Test equipment and the subsystem under test (SUT) as shown in Figure 19.	N/A	N/A	N/A
2	Connect Power Supply to SUT.	N/A	N/A	N/A
3	Using I^2C, send a control input that moves 90º azimuth and 45º in elevation.	N/A	N/A	N/A
4	Record power consumed by the SUT as measured by a wattmeter	< 50W	2.25W	Pass

The power consumption test validates that the rotator operates with a power consumption that will not damage fuses, wiring and other equipment on board airplanes, emergency vehicles and maritime vessels.

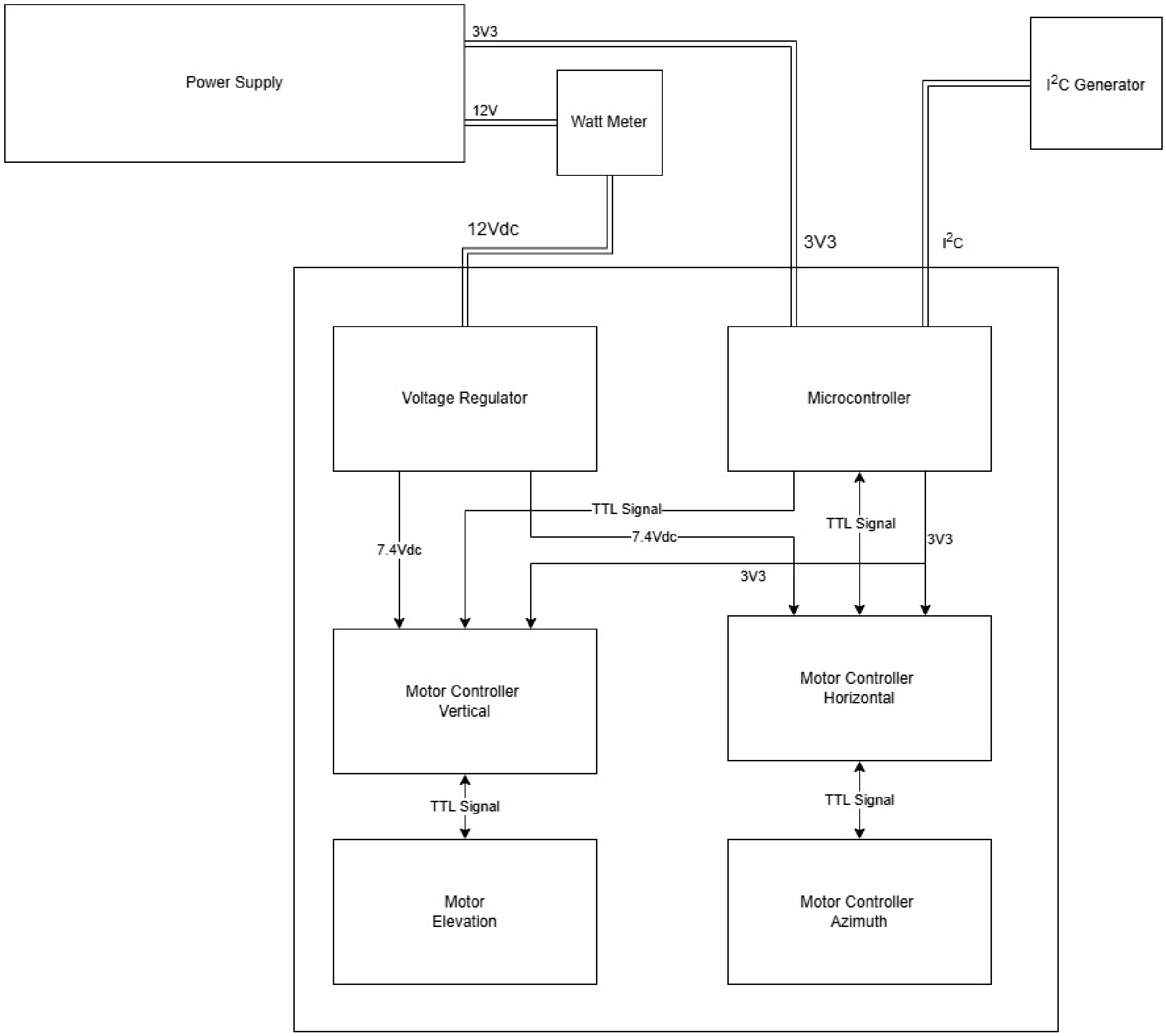

Figure 19: Power Consumption Equipment Setup

Subsystem Test Results

The successful execution of this subsystem verification test plan ensures that the Rotator subsystem meets all functional, performance, and reliability requirements before integration into the MATS. Following the verification procedures outlined in this document, a skilled technician can systematically validate the subsystem's compliance with the design specifications, identify potential issues, and document verification results accordingly.

Test Section	Pass/Fail	Notes
System Self-Test	Pass	previously tested
Azimuth Mobility Test	Pass	previously tested
Elevation Mobility Test	Pass	previously tested
Command Response Verification Test	Pass	previously tested
Rotational Mobility	Pass	previously tested
Power Consumption	Pass	previously tested

Power Delivery

Subsystem Overview

System overview and verification are critical to ensure that the MATS performs as intended. This document outlines the testing procedures for the Power Subsystem, which is responsible for converting the system's 12–24 V input into regulated voltage rails required by all other subsystems. The Power Subsystem provides 7.5 V, 5 V, and 3.3 V outputs to support the Rotator, Receiver, and User Interface subsystems. This test plan aims to verify the proper functionality and reliability of the Power Subsystem independently, prior to integration into the full MATS system.

Subsystem Requirements and Specifications

Using MP2329C buck converters, the design generates 7.5 V, 5 V, and 3.3 V outputs to supply the Rotator, Central Receiver, and User Interface. To ensure reliable operation, the subsystem must meet requirements for voltage accuracy, current delivery, ripple and noise, efficiency, and fault protection. System requirements can be found in Table 1.

Table 17: Rotator Subsystem Requirements

Requirement	Expectation
Input Voltage Range	12-24 V_{DC}
Output Rails	7.5V, 5V, 3v3
Maximum Current	6A, 5A, 5A
Voltage Accuracy	± 5% of nominal
Ripple Voltage	≤ 50 mV_{pp}
Protection	Overcurrent and short-circuit safe
Power Consumption	<85W

A block diagram is provided below in Figure 20.

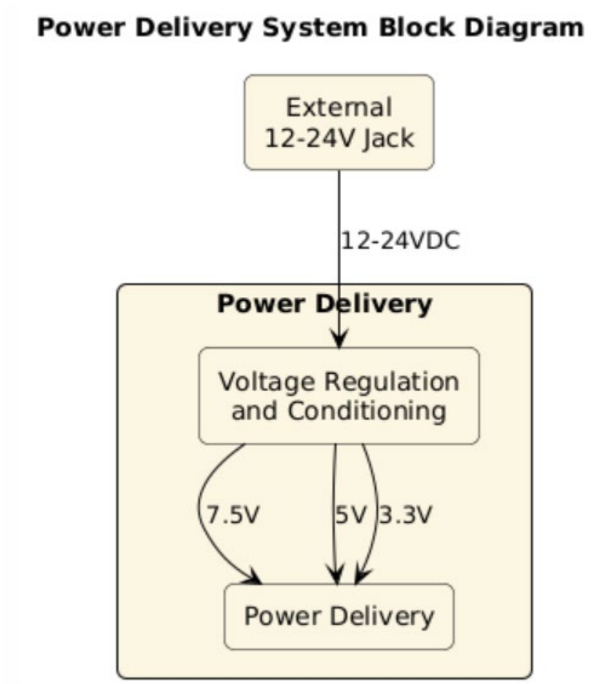

Figure 20: Power Delivery Block Diagram

Additionally, a circuit schematic is provided below in Figure 21.

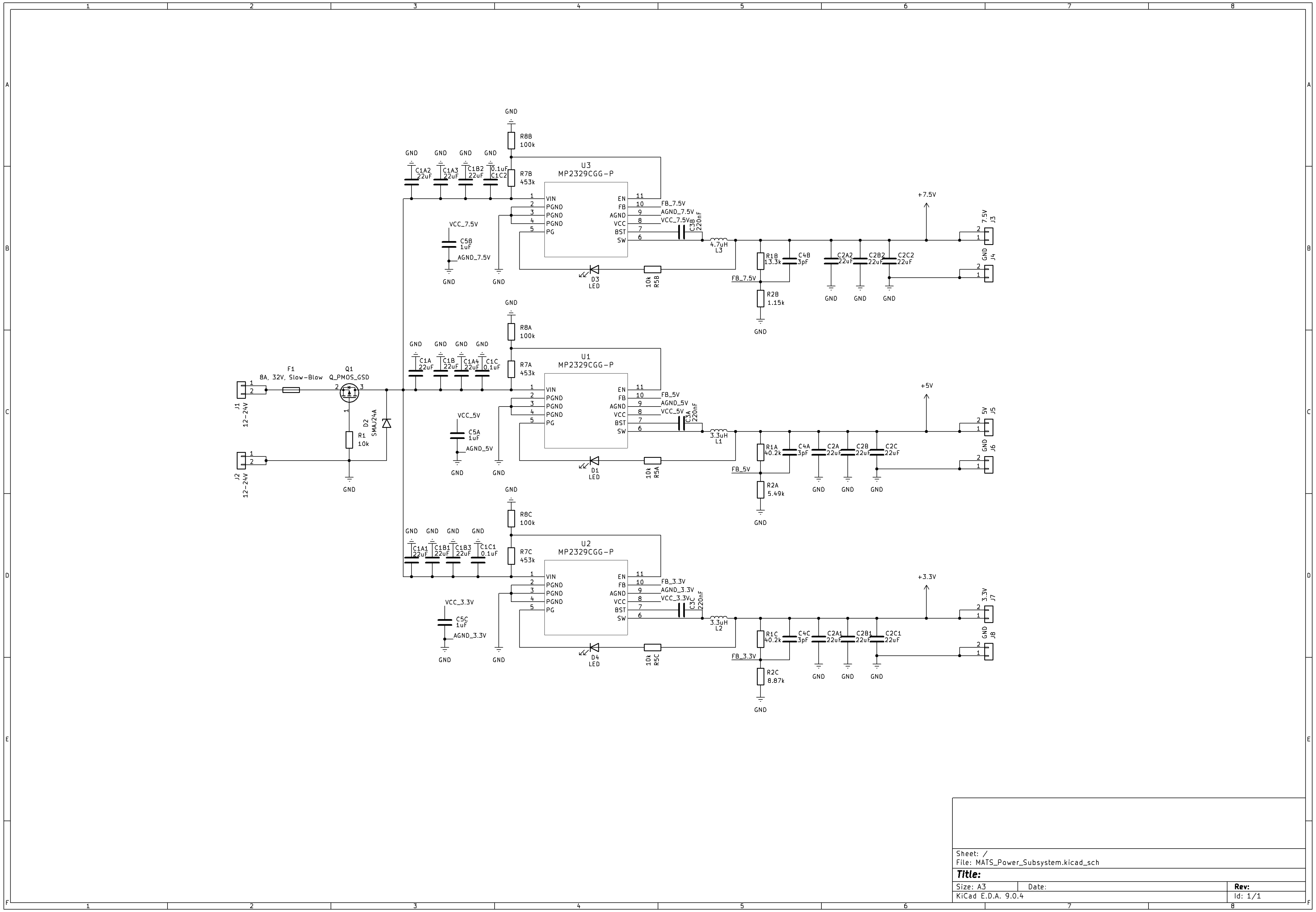

Figure 21: Power Delivery Electrical Schematic

Objectives

The objectives to test and verify operation for include:

- Verify each output rail maintains voltage within tolerance across the load
- Confirm maximum current delivery for each rail
- Measure and evaluate ripple/noise
- Validate startup, shutdown, and sequencing behavior
- Test protection circuitry to ensure safe fault handling

Required Equipment

The following is a list of the equipment needed to carry out the tests and verification plans for the Power Subsystem of the MATS.

- Programmable DC power supply
- Adjustable resistive loads
- Fluke 117 Digital multimeter
- Digital Oscilloscope

Testing Procedure

This section covers in detail the testing procedure for each part of the Power Subsystem.

Input Verification

The input verification test ensures that the Power Subsystem operates across its entire full specified input range of 12-24 VDC. The subsystem must power on reliably at each step and maintain stable outputs, both under no-load and loaded conditions. This test validates compatibility with the system's expected supply source and confirms the subsystem will start without fault across the entire input spectrum.

Table 18: Input Verification Test Procedure

Test	Expected Result	Observed Result
Connect programmable DC power supply to subsystem input.	N/A	N/A
Connect DMM to measure input voltage/current.	N/A	N/A
Apply 12 V input with no load attached.	Subsystem powers on.	
Increase input to 14 V, no load.	Subsystem remains powered.	

Repeat in 2 V increments up to 24 V, no load.	Subsystem remains powered.	
Apply representative load to each rail at 12 V input.	Subsystem powers on, outputs remain stable.	
Repeat input sweep (12–24 V) with load attached.	Outputs remain stable within tolerance across input range.	

Voltage Accuracy

The voltage accuracy test verifies each regulated output rail remains within its specific tolerance of $\pm5\%$ under both no-load and rated-load conditions. Accurate regulation is critical to ensure downstream subsystems receive stable power and perform as required.

Table 19: Voltage accuracy Test Procedure

Test	Expected Result	Observed Result
Connect DMM probes to each output rail (7.5 V, 5 V, 3.3 V). Apply nominal 12 V input, no load.	All rails within ±5% of nominal.	
Apply nominal input with rated load on 7.5 V rail, measure output.	Voltage within ±5% of nominal.	
Apply nominal input with rated load on 5 V rail, measure output.	Voltage within ±5% of nominal.	
Apply nominal input with rated load on 3.3 V rail, measure output.	Voltage within ±5% of nominal.	

Load Regulation and Current Capacity

The load regulation test evaluates the subsystem's ability to sustain rated load currents on each rail. It also verifies that voltage deviations remain within specification as load current increases, demonstrating proper load regulation.

Table 20: Load Regulation and Current Capacity Test Procedure

Test	Expected Result	Observed Result
Connect adjustable load to 7.5 V rail. Increase current gradually to rated limit.	Voltage deviation remains within spec.	
Repeat test for 5 V rail.	Voltage deviation within spec.	
Repeat test for 3.3 V rail.	Voltage deviation within spec.	
Load all rails simultaneously to rated current.	Subsystem remains stable, no shutdown/thermal fault.	

Ripple and Noise

The ripple and noise test characterizes the quality of the power rails by measuring the peak-to-peak voltage fluctuations using an oscilloscope under nominal load. Excessive ripple or noise can interfere with the SDR and digital circuits in the Receiver, resulting in signal loss.

Table 21: Ripple and Noise Test Procedure

Test	Expected Result	Observed Result
Connect oscilloscope probe across 7.5 V rail under nominal load. Measure Vpp.	Ripple ≤ 50 mVpp.	
Repeat for 5 V rail.	Ripple ≤ 50 mVpp.	
Repeat for 3.3 V rail.	Ripple ≤ 50 mVpp.	

Protection Testing

The protection test sequence validates that the subsystem safeguards against overcurrent and short-circuit conditions. By stressing the outputs beyond their rated limits, the test confirms that built-in protection measures activate without causing permanent damage.

Table 22: Protection Testing Test Procedure

Test	Expected Result	Observed Result
Connect electronic load, increase 7.5 V rail current above rated limit.	Overcurrent protection engages, subsystem safe.	
Repeat test on 5 V rail.	Protection engages safely.	
Repeat test on 3.3 V rail.	Protection engages safely.	
Briefly short 7.5 V rail using current-limited supply.	Subsystem shuts down or limits safely, recovers after fault.	
Repeat short-circuit test for 5 V rail.	Subsystem recovers after fault.	
Repeat short-circuit test for 3.3 V rail.	Subsystem recovers after fault.	

Subsystem Test Results

Test Section	Pass/Fail	Notes
Input Verification		
Voltage Accuracy		
Load Regulation & Current Capacity		
Ripple and Noise		
Protection Features		

Conclusion

The testing procedures for the receiver, user interface, and power subsystems have demonstrated that each unit performs within its design requirements and is ready for integration into the MATS. Verifying that each subsystem operates correctly ensures smooth integration, and eases challenges caused by overlooked items. With successful completion of robust system testing, the MATS project has established a strong foundation for achieving a fully functional, field-ready platform.

The recorded results should be compiled and compared against the expected values defined for each test. Any deviations should be documented, investigated, and resolved before the next test. Verified test logs and data serve as evidence of compliance with system requirements, ensuring traceability throughout the integration process.

Appendix

Antenna Information

For reception testing, the VHF Antenna (V-Dipole) must be placed outdoors or in a location with a clear, unobstructed view of the sky. The antenna elements are extended outward in a horizontal "V" shape parallel to the ground, and the antenna should be placed about 22 inches above the ground. The feedpoint is located at the junction of it's elements, with coaxial cable routed downward towards the receiver. This horizontal orientation provides a broad, near-omnidirectional coverage pattern across the horizon, while ensuring sufficient gain toward the sky for low-Earth orbit satellites such as METEOR.

The V-dipole operates with linear polarization, while many weather satellites transmit circularly polarized signals. As a result, some polarization loss is expected; however, the antenna's geometry and positioning provides a balance between simplicity, coverage, and signal strength.

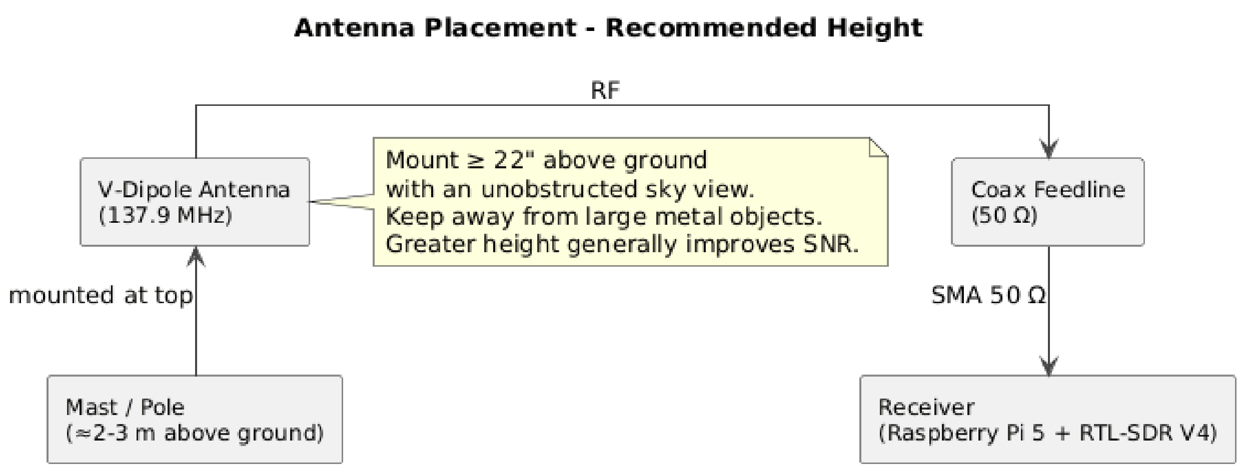

Figure 22: Antenna Placement Block Diagram

Below in Figure 23 is an example antenna placement.

Figure 23: V-dipole orientation picture. Source: Zachary Murray

Bibliography

[1] J. Lair, "METEOR-M (METEOR-M N2-3, METEOR-M N2-4) satellites reception," [Online]. Available: https://www.a-centauri.com/articoli/meteor-satellite-reception. [Accessed 27 9 2025].

[2] A. Blog, "Getting the most out of a V-dipole," 20 05 2020. [Online]. Available: https://apbouwens.github.io/V-dipole-rad-pat/. [Accessed 27 9 2025].