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Test Plan: RCA Radio Telescope System

A testing procedure for the RCA Radio Telescope System should ensure the functionality and accuracy of all components, as well as the system's ability to detect and process celestial signals. Here is an outline of a potential testing procedure.

Testing Procedure for the RCA Radio Telescope System:

- **Visual Inspection:**
  - Check the parabolic dish for physical damage, misalignment, or debris.
  - Inspect the feed horn, low-noise amplifier (LNA), and software-defined radio (SDR) for proper connections and secure mounting.
  - Verify the integrity of all cables and connectors, ensuring that there are no breaks or loose connections.

- **Power and Signal Flow Check:**
  - Power on the system components (LNA, SDR, laptop/PC).
  - Verify that the LNA receives power and amplifies signals by checking voltage levels or using a signal generator and oscilloscope.
  - Confirm that the SDR is initialized correctly and interfaces with the laptop or PC without errors.

- **Calibration:**
  - Use a known signal source (e.g., a calibrated signal generator) to simulate a weak signal within the 1 to 2 GHz range.
  - Adjust the system to ensure that the detected signal matches the input frequency, amplitude, and characteristics.
  - Record and verify the system's response to signals of varying strengths and frequencies to confirm linearity and sensitivity.

- **Antenna Alignment Test:**
  - Point the antenna at an orbital source, such as a geostationary satellite, with a known signal (e.g., weather satellites or communication satellites within the L-band frequency range of the system).
  - Measure the signal strength and manually adjust the antenna to verify the alignment process and optimize reception.

- **Celestial Signal Detection:**
    - Point the telescope toward a strong celestial source, such as the Sun, to confirm that it detects expected signals.
    - Test the system's ability to observe the hydrogen 21-cm line at 1.42 GHz by pointing it toward the Milky Way's plane.
    - Log signal strength, frequency spectrum, and any detected features.

- **Software and Data Analysis Verification:**
    - Open the SDR software on the laptop or PC.
    - Confirm that the software processes and displays the signal data in real-time (e.g., frequency spectrum, time-domain signals).
    - Analyze the displayed data to ensure accurate representation of input signals.

- **Long-Term Stability Test:**
    - Operate the system continuously for a set period (e.g., 24–48 hours) to monitor stability and detect any thermal drift or noise issues.
        - If time doesn't permit testing for long durations, a shorter test may be more appropriate. (10-20 min)
    - Evaluate signal consistency and identify potential interference or environmental factors affecting performance.

- **Outreach and Educational Simulation:**
    - Simulate an educational event by guiding users through the setup, alignment, and signal analysis process.
    - Verify the ease of use and the ability to detect and interpret meaningful signals.

- **Documentation and Reporting:**
    - Record all test results, including screenshots of the software interface and any measured values.
    - Identify any issues or inconsistencies, and propose solutions or adjustments.

- **Final Performance Verification:**
    - Revisit all critical tests (e.g., signal detection, software processing, and alignment) to confirm optimal performance before operational use.

The key requirements include:

1. Must display real-time signal data on a laptop/PC interface.
2. Must generate data for weak celestial signals with SNR ≥ 20:1.
3. Must interface with an SDR for signal acquisition.
4. Must have an LNA with noise figure ≤ 0.7 dB at 1-2 GHz.
5. Must provide an intuitive software interface for real-time data visualization and analysis.
6. Must consume ≤ 50 watts per hour, with total consumption ≤ 600 watts over 12 hours of continuous use.
7. Should have an LNA with a gain ≥ 30 dB for 1-2 GHz.
8. Should utilize a 12V DC (with 120V AC inverter).
9. Should use cross-compatible SDR software.

Top Down Test Plan v1.0 for RCA Radio Telescope

Date of Test:	
Tester:	

Purpose

To test the entire Radio Telescope System against its requirements by performing a top-down test, ensuring all components work together as an integrated system.

Equipment Needed

- System Equipment
  - Main Components
    - Pluto SDR
    - LNA (ZX60)
    - Power/Data PCB
    - Feed Horn with Antenna Inside
    - RF Board with Bandpass Filter
    - 3-meter Parabolic Dish
  - Accessories
    - 120V AC Wall Outlet
    - SMA Cable Connectors
    - USB A to USB B Micro Cable
    - Ethernet to USB Dongle
    - USB A to Micro USB B OTG Adapter
    - 120V to 12V Wall Adapter
    - Barrel Jack Cable
    - PoE Injector/Splitter
- Test Equipment
  - Spectrum Analyzer (capable of 1-2 GHz range)
  - Signal Generator (capable of 1-2 GHz range)
  - Virtual Network Analyzer
  - Digital Multimeter
  - Wattmeter/Power Meter
  - Laptop with SDRangel Software Installed (to test Ethernet connectivity)
  - Ethernet Cables (2 short/1 very long)
  - Stopwatch or Timer
- Other Equipment
  - Small Flathead Screwdriver
  - Allen Wrench Set
  - Cable Ties
  - Electrical Tape
  - Compass (for alignment)
  - Thermometer (for environmental testing)

Pre-Test Setup

1. User/Laptop Side
    a. Plug the barrel jack from the wall into the PoE injector on the side that says INPUT. The amber Ethernet activity light on the OUTPUT side should turn on, but not flash.
    b. On the same side that has the barrel jack input, plug in a short Ethernet cable to the side that says INPUT, and connect the other end to a laptop.
    c. (One Time) Configure the Pluto SDR's IP assignment by plugging in the SDR to a laptop, changing its configuration file in file explorer to an IP subnet that isn't used, and saving the configuration.
    d. (One Time) Configure the Laptop to a manual IP assignment and enter an IP address that shares the same subnet as the Pluto SDR.
    e. (One Time) Configure the Laptop's SDRangel installation and create a new device instance for the Pluto SDR with the expected IP address of the SDR.
2. Dish Side
    a. Connect the other end of the PoE-powered Ethernet cable coming out of the PoE injector to the PoE splitter's INPUT side.
    b. Connect a barrel jack cable from the barrel receptacle of the OUTPUT side of the PoE splitter to the barrel receptacle of the POWER/DATA PCB.
    c. Connect a USB cable from the POWER/DATA PCB to the Pluto SDR's POWER INPUT (right micro USB receptacle).
    d. Connect the power leads from the LNA to the POWER/DATA 3V Output Screw Terminal.
    e. Plug in a short Ethernet cable from the PoE splitter, and attach the Ethernet-to-USB dongle to the other end of the cable.
        i. On the dongle, attach the OTG adapter to the USB A connector of the dongle, and connect the whole assembly to the SDR's USB Data/Power USB input (middle micro USB receptacle).
3. Antenna + RF Signal Chain Setup
    a. Attach the Antenna/Feed horn assembly to an SMA cable. Connect the other end of the SMA cable to the RF Board.
    b. From the RF Board, attach another SMA cable to the LNA's RF input port.
    c. From the LNA's RF output port, attach another SMA cable to the RX RF port of the Pluto SDR.

Top Down Test Steps

1. Turning on the System/ Power-On and Voltage Test
    a. Plug in the 12V wall adapter to turn on the system.
    b. After a moment, the SDR should have booted up. The Ethernet activity signals should start flashing on both the PoE injector/splitter and Ethernet dongle.
    c. Measure the 9V-12V input of the POWER/DATA PCB: _____ V (should read ~12V±5%).
    d. Measure the 5V output of the POWER/DATA PCB: _____ V (should read ~5V±5%).
    e. Measure the 3V output of the POWER/DATA PCB: _____ V (should read ~3V±5%).
    ☐ Tests: Power delivery requirement
2. Data Connection Test/Establish a Data Connection from the Laptop to SDR
    a. Open up SDRangel and open up a new Receiving device. Use the configuration that was set up in the pre-test.
    b. Start pulling from the SDR by pressing the play/pause button. The FFT graph visual should start displaying noise and/or signals on the screen.
    ☐ Tests: SDR interface requirement, real-time display requirement
3. Power Consumption Test
    a. Connect the wattmeter between the wall outlet and the 12V adapter.
    b. Record the power consumption with the system in idle state: _____ W (should be ≤50W).
    c. Start a timer and monitor the power consumption for one hour, recording the total energy usage: _____ Wh.
    d. Based on the 15-minute reading, multiply reading by 4 to get an estimate of an hour's worth of power consumption, calculate the projected 12-hour consumption: _____ Wh (should be ≤600W).
    ☐ Tests: Power consumption requirement
4. LNA Performance Test
    a. Disconnect the LNA from the Antenna and RF Board, and connect the virtual network analyzer
    b. Configure the virtual network analyzer to a frequency range of 1-2 GHz with an output power signal that doesn't exceed 14 dBm input to the LNA (see LNA datasheet specifications for more details), and won't exceed the input power max to the virtual network analyzer. If the virtual network analyzer cannot be adjusted to transmit such a lower power signal, then an attenuator may need to be used.
    c. Measure $|S_{21}|$ (dB) such that the gain of the amplifier meets the specifications listed in the datasheet.
    ☐ Tests: LNA gain requirement

5. Signal-to-Noise Ratio Test
    a. Using the signal generator, input a weak signal (-110 dBm) at 1.42 GHz.
    b. Using a spectrum analyzer, measure the signal level and the noise floor.
    c. Calculate the SNR (signal level minus noise floor): _____ dB (should be ≥20dB).
        ☐ Tests: SNR requirement
6. Bandpass Filter Test
    a. Using the signal generator, input signals at 0.9 GHz, 1.42 GHz, and 2.1 GHz with equal power.
    b. Using a spectrum analyzer, measure and record the relative signal strengths.
    c. Verify that the 1.42 GHz signal is passed with minimal attenuation while signals outside the 1-2 GHz range are attenuated.
        ☐ Tests: Frequency selectivity
7. Software Interface Test
    a. In SDRangel, verify the following functions:
        i. Frequency tuning: Adjust the center frequency to 1.42 GHz.
        ii. Bandwidth adjustment: Set to an appropriate value for observing the hydrogen line.
        iii. Recording functionality: Start and stop a recording session.
        iv. Visualization options: Switch between different display modes (FFT, waterfall).
    b. Assess the intuitiveness of the interface by asking a non-team member to perform basic operations.
        ☐ Tests: Software interface requirement
8. Cross-Platform Test
    a. If available, connect the system to a different computer running another supported OS.
    b. Install and configure the SDR software.
    c. Verify basic reception and display functionality.
        ☐ Tests: Cross-platform software requirements
9. 12V DC Compatibility Test
    a. Disconnect the system from the wall power.
    b. Connect the system to a 12V battery or an alternative 12V power source.
    c. Verify all components are powered on and function properly.
        ☐ Tests: 12V DC compatibility requirement
10. Hydrogen Line Detection Test (conditions permitting)
    a. Align the dish toward the galactic plane.
    b. In SDRAngel, tune to 1.42 GHz and set appropriate bandwidth and gain settings.
    c. Observe for at least 10 minutes, recording any detection of the hydrogen line.
    d. Take screenshots of the FFT display as evidence.
        ☐ Tests: Weak celestial signal reception

Post-Test Teardown

1. Stop pulling from the SDR on SDRangel by pressing the play/pause button.
2. Close the SDRangel software.
3. Unplug the 12V wall adapter from the 120V source.
4. Disconnect all cables and store components properly.

Top-down Test Plan Conclusions / Discussion

The one-time configuration steps in the pre-test setup will be more detailed in the User's Manual. The steps to do so have many more details, but it didn't seem appropriate to put these in here.

Bottom Up Test Plans

Test Author: Truong Le				
	Test Case Name:	PoE/Laptop Test	**Test ID #:**	#1
	Description:	Tests the PoE setup and Connection to the SDR	**Type:**	□ white box □ black box □ _____
Tester Information				
	Name of Tester:		**Date:**	
	HW/SW Version:	1.0	**Time:**	
	Setup:	Need to have PowerData Board set up and connected to SDR for Data Connection testing; *PoE system should be connected for these tests.		

TEST	**INPUTS**	**EXPECTED OUTPUTS**	**PASS**	**FAIL**	**N/A**	**Comments**
1	12V Wall Adapter into PoE Injector	• Amber Ethernet Activity Light on Output Ethernet Receptacle				
2	Powered PoE Ethernet Cable into PoE Splitter	• 12V Output from Barrel Receptacle • Amber Ethernet Activity Light on Output Ethernet Receptacle				
3	Ethernet Cable from PoE Injector connected to Laptop *	• Ethernet Activity Lights flashing on all Ethernet components (Ethernet Dongle)				
4	Press the Play/Pause button on SDRangel*	• Noise Readings on the FFT graph when taking in samples				
	Overall test result:					

Test Author: Paul Nguyen							
	Test Case Name:	PowerData PCB Test		**Test ID #:**		#2	
	Description:	Testing Power Board PCB		**Type:**		□ white box □ black box □ _____	
Tester Information							
	Name of Tester:			**Date:**			
	HW/SW Version:	1.0		**Time:**			
	Setup:	Need Power from a source					
TEST	**INPUTS**	**EXPECTED OUTPUTS**		**PASS**	**FAIL**	**N/A**	**Comments**
1	9 - 12 V Input to the Buck Converter	● Maintain a 5V Output on the rail					
2	5V Output on rail	● 3V Output on Screw Terminal					
3	USB from Power/Data Board to SDR	● Powers SDR when the PCB is powered, indicated by activity lights on SDR					
4							
	Overall test result:						

Test Author: Bradley Glaubitz				
	Test Case Name:	RF Board Test	**Test ID #:**	#3
	Description:	Testing the RF board	**Type:**	□ white box □ black box □ _____
Tester Information				
	Name of Tester:		**Date:**	
	HW/SW Version:	1.0	**Time:**	
	Setup:	The testing procedure requires a virtual network analyzer or an antenna/signal generator with a spectrum analyzer.		

TEST	**INPUTS**	**EXPECTED OUTPUTS**	**PASS**	**FAIL**	**N/A**	**Comments**
1	Inject a known power signal at the input of the RF Board with the frequency of 800 MHz using a signal generator with a spectrum analyzer connected to the output of the RF board while viewing the frequency of the injected signal.	At the frequencies of 800 MHz ● Measure the output power and calculate the attenuation of the RF board based on the ratio of output divided by input power. Expect to see 28.71 dB attenuation.				
2	Use a VNA calibrated to 1-2 GHz to measure return loss and insertion loss of.	At the frequencies of 1.2 GHz, 1.42 GHz, and 1.6 GHz ● See if the insertion loss is $0 \geq (\lvert S_{21} \rvert) \geq$ -1 dB ● See if return loss ($\lvert S_{11} \rvert$) < -10 dB				
	Overall test result:					

Test Author: Bradley Glaubitz				
	Test Case Name:	Antenna Test	**Test ID #:**	#4
	Description:	Determining the functionality of the antenna	**Type:**	□ white box □ black box □ _____
Tester Information				
	Name of Tester:		**Date:**	
	HW/SW Version:	1.0	**Time:**	
	Setup:	Using a VNA and connecting an SMA cable to the antenna		

TEST	**INPUTS**	**EXPECTED OUTPUTS**	**PASS**	**FAIL**	**N/A**	**Comments**
1	Utilize a VNA calibrated to 1-2 GHz to measure into the N-type to SMA connector input terminal of the antenna.	Measure $\|S_{11}\|$ (dB) and determine if the value is less than -10 dB at 1.2 GHz, 1.42 GHz, and 1.6 GHz.				
2						
3						
4						
	Overall test result:					

Test Author: Bradley Glaubitz				
	Test Case Name:	Power Consumption Test	**Test ID #:**	#5
	Description:	Test the power consumption of the whole system to see if it meets the specs of: "Must consume ≤ 50 watts per hour, with a total power consumption of ≤ 600 watts over 12 hours of continuous use."	**Type:**	□ white box □ black box □ _____
Tester Information				
	Name of Tester:		**Date:**	
	HW/SW Version:	1.0	**Time:**	
	Setup:	Set up the whole system		

TEST	INPUTS	EXPECTED OUTPUTS	PASS	FAIL	N/A	Comments
1	Measure input power to the PoE system (outlet to PoE injector). PoE output power is max 30W.	The efficiency $\frac{P_{out}}{P_{in}}$ > 60% ($P_{out\ max}$ = 30W given by PoE+ standards) for the spec to be met.				
2						
3						
4						
	Overall test result:					