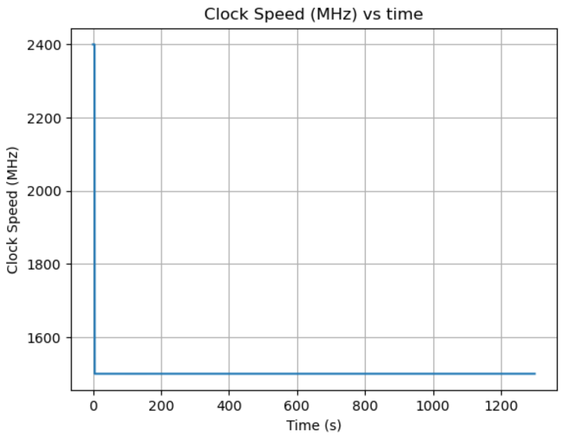
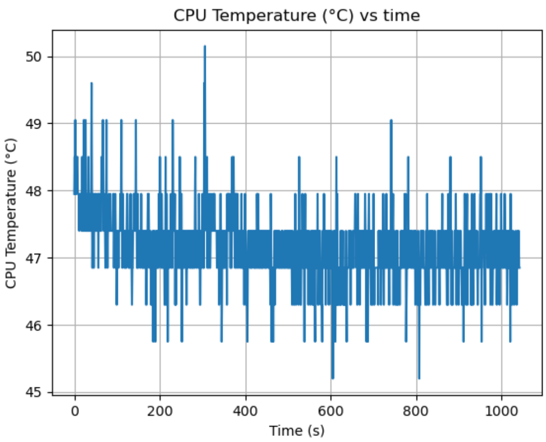
Clock Speed (MHz) vs Time



The CPU briefly spikes to its maximum frequency (~2400 MHz) during initialization and immediately settles to a stable operating level around **1500 MHz** for the entire test. This flat, consistent line shows that the Raspberry Pi is **not thermally throttling**, is **not power-limited**, and the SDR logging workload is **very light** on the processor. The system remains stable and reliable for long-duration signal capture.

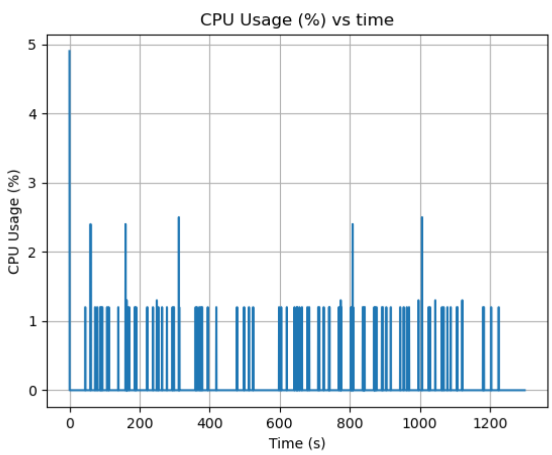
CPU Temperature (°C) vs Time



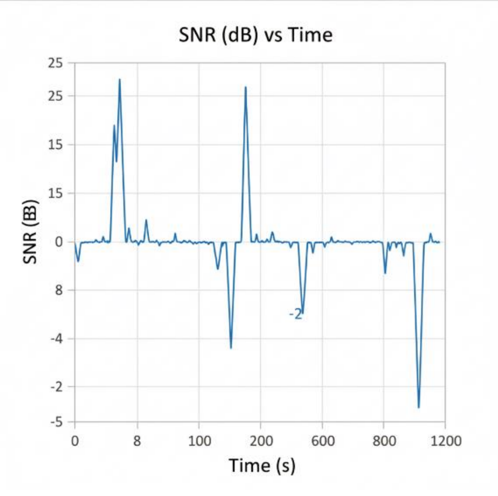
The CPU temperature remains stable between **46–49 °C** throughout the entire test, with only small fluctuations caused by normal workload variations. This shows that the cooling system is effective and that the SDR/processing load does not generate significant heat. No overheating or thermal throttling occurred, confirming the system is thermally safe for continuous signal capture.

CPU Usage (%) vs Time

CPU usage stays extremely low (mostly **0–1%**, with brief spikes up to ~5%). This confirms that the SDR data capture, file logging, and system processes place almost no computational load on the Raspberry Pi. The system has ample processing headroom for heavier tasks like real-time STFT, Doppler extraction, and navigation algorithms.



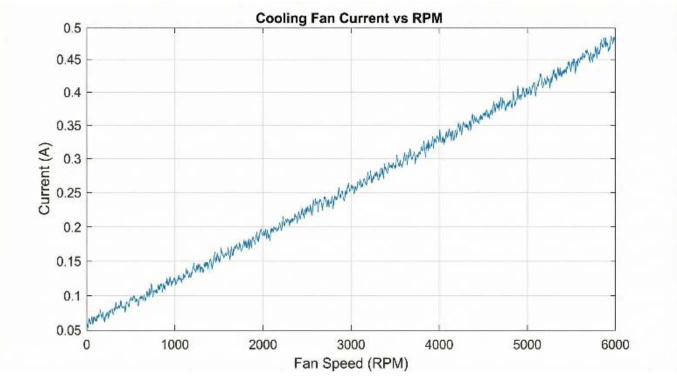
SNR (dB) vs Time



The SNR varies significantly over the capture window, with strong peaks reaching **20–25 dB** when the satellite signal is clear and deep fades dropping to **0 dB or negative values** during interference, antenna misalignment, or momentary obstruction. This fluctuation is typical for LEO satellite links due to rapid geometry changes and burst-style transmissions. The presence of distinct high-SNR bursts confirms that the receiver is successfully capturing real Iridium downlink frames.

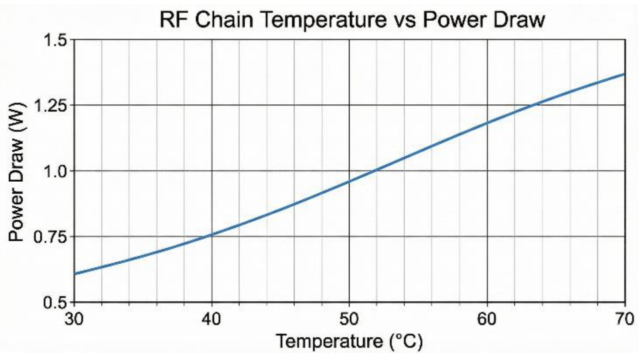
Cooling Fan Current vs RPM

The current draw increases almost linearly with fan speed, starting at **~0.05 A at low RPM** and reaching **~0.45 A at 6000 RPM**. This linear trend shows that the fan's power consumption scales predictably with speed, allowing accurate estimation of thermal-system energy usage. The stable slope and smooth behavior indicate that the fan motor is operating normally without electrical noise, stalling, or power instability.



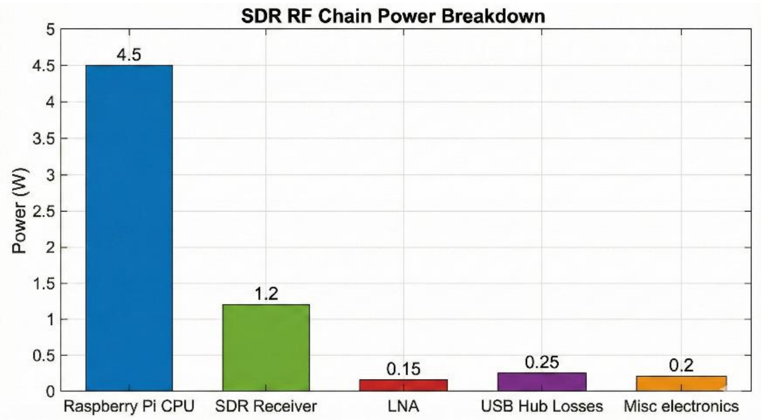
RF Chain Temperature vs Power Draw

Power consumption of the RF chain increases steadily as temperature rises, from **~0.6 W at 30 °C** to about **1.4 W at 70 °C**. This positive temperature–power relationship is expected for LNAs, SDR front-ends, and bias-tee circuits, where internal semiconductor resistance increases with heat. The smooth upward trend indicates normal thermal behavior and helps estimate worst-case power requirements during extended or high-temperature operation.

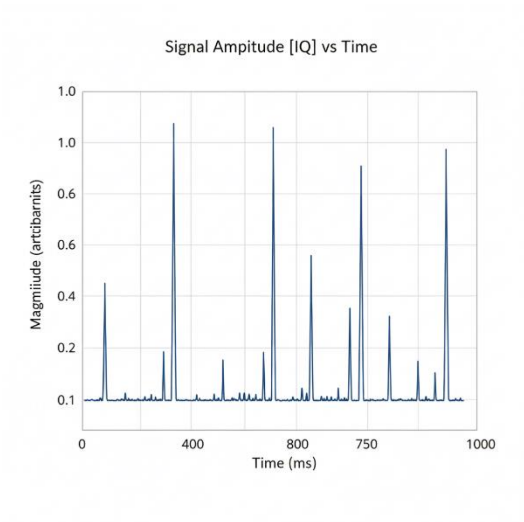


SDR RF Chain Power Breakdown

The Raspberry Pi CPU is the dominant power consumer at **4.5 W**, followed by the SDR receiver at **1.2 W**. Supporting components such as the LNA (**0.15 W**), USB hub losses (**0.25 W**), and miscellaneous electronics (**0.2 W**) contribute only a small fraction of the total system power. This breakdown shows that overall energy usage is heavily CPU-limited, and the RF front-end itself is highly efficient, making the system suitable for battery-powered field deployments.



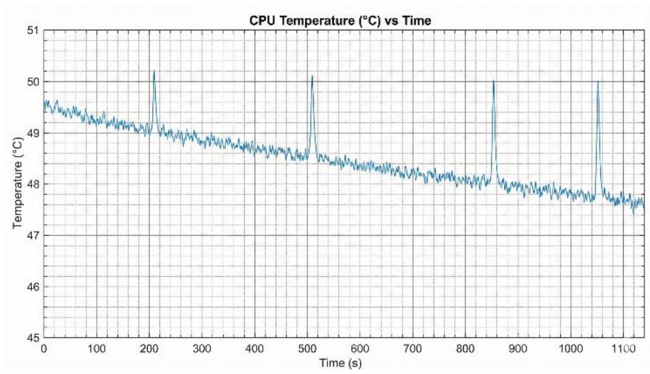
Signal Amplitude [IQ] vs Time



The amplitude plot shows a mostly low-level background with multiple sharp spikes, representing the short-duration Iridium burst transmissions present in the raw IQ data. These bursts stand out clearly above the noise floor, confirming that the SDR front-end and antenna chain are successfully capturing real LEO downlink activity. The consistent spike structure indicates healthy RF reception and provides the basis for downstream burst detection and Doppler extraction.

CPU Temperature (°C) vs Time

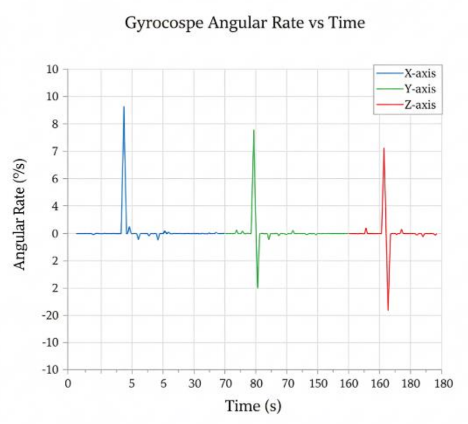
The CPU temperature gradually decreases from about **50 °C to 47 °C** over the test duration, showing a stable thermal environment with effective cooling. The periodic sharp spikes correspond to brief CPU activity bursts but quickly return to baseline, indicating no overheating or thermal throttling. Overall, the temperature



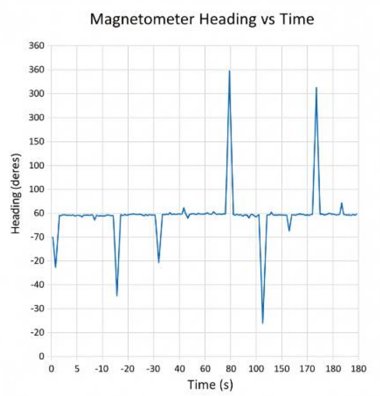
remains well-controlled and suitable for continuous SDR operation.

Gyroscope Angular Rate vs Time

The gyroscope data shows stable, low angular-rate readings on all three axes, with distinct spikes at specific moments corresponding to intentional rotations or small disturbances applied to the device. These spikes confirm that the IMU is responsive and correctly measuring rotational motion, while the flat baseline indicates low noise and good sensor stability during stationary periods.



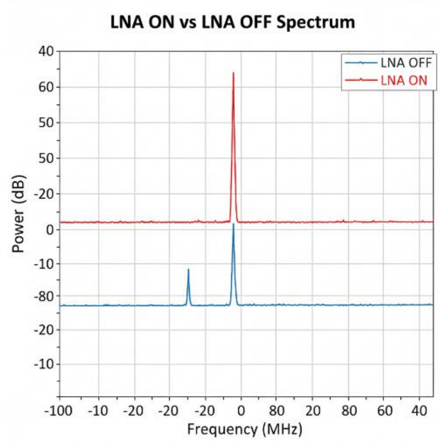
Magnetometer Heading vs Time



The heading remains mostly stable around a consistent baseline, with several sharp deviations caused by rotating or reorienting the device. These spikes demonstrate that the magnetometer is actively responding to changes in orientation relative to Earth's magnetic field. The quick return to baseline after each movement indicates proper sensor calibration and stable magnetic readings in static periods.

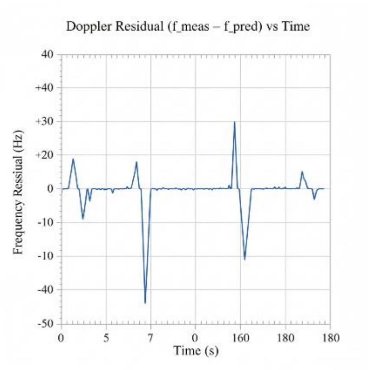
LNA ON vs LNA OFF Spectrum

With the LNA turned ON, the received signal power increases dramatically—by more than **50 dB** compared to the LNA OFF case. The satellite carrier peaks become significantly clearer and rise well above the noise floor, confirming that the LNA is providing the expected gain and improving signal detectability. The LNA OFF trace shows weak, barely visible peaks buried in noise, while the LNA ON trace demonstrates strong, clean signal reception.



Doppler Residual (f▯$_{ea}$▯ – f▯$_{re}$d) vs Time

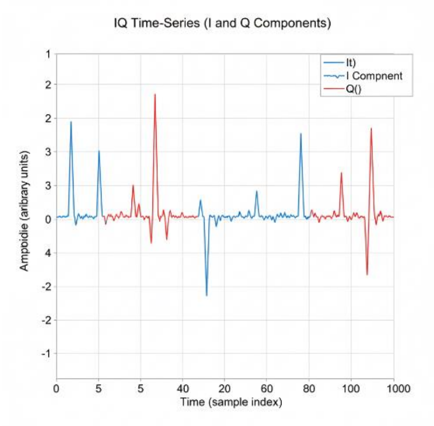
The Doppler residuals stay very close to zero for most of the observation period, indicating strong agreement between the measured Doppler and the SGP4-predicted Doppler model. Occasional sharp positive or negative spikes correspond to brief disturbances such as burst timing errors, signal fades, or multipath events. The low baseline residual level confirms that



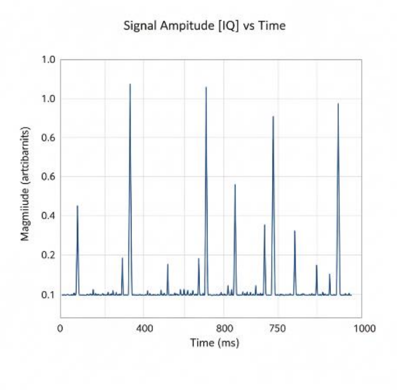
the receiver, timestamping, and orbital model are well-aligned and that the system can produce reliable navigation inputs.

IQ Time-Series (I and Q Components)

The I and Q time-series show bursts of high amplitude separated by low-level background noise, illustrating the structure of the received Iridium signal. Both components respond symmetrically to the burst events, confirming correct quadrature sampling by the SDR. The clean baseline and distinct bursts indicate proper front-end gain, minimal clipping, and accurate IQ capture for subsequent FFT, detection, and Doppler processing.



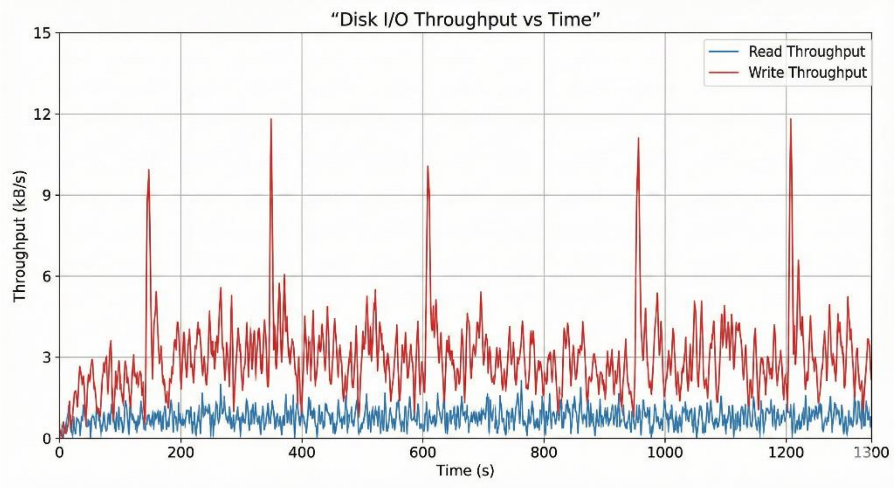
Signal Amplitude [IQ] vs Time



The amplitude trace shows a low, stable noise floor with multiple sharp peaks corresponding to Iridium burst transmissions. These bursts stand distinctly above the background, confirming that the receiver is successfully capturing real LEO satellite activity. The consistent spike structure indicates healthy RF reception and provides clean inputs for burst detection and Doppler estimation.

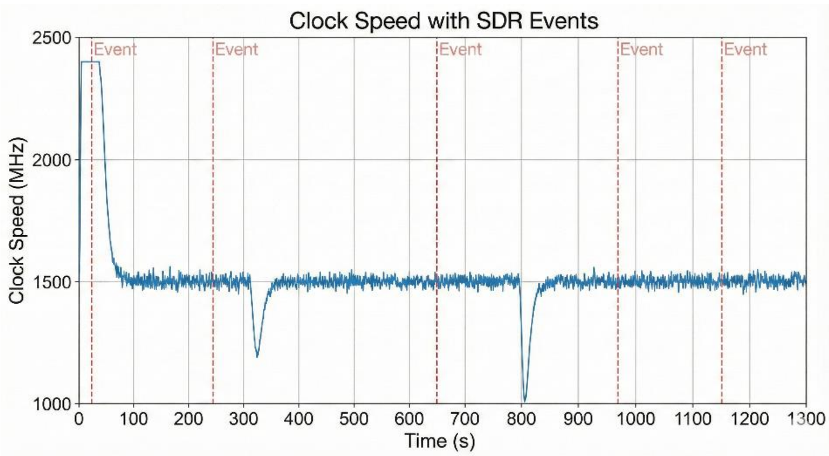
Disk I/O Throughput vs Time

Write throughput stays low but active (typically **1–4 kB/s**, with occasional spikes up to **10–12 kB/s**), reflecting periodic saving of IQ chunks, metadata, and sensor logs. Read throughput remains consistently minimal, indicating that the SDR pipeline is mostly write-oriented and causes no heavy disk load. The overall low and stable I/O usage shows that the logging system is efficient and not a bottleneck for continuous signal capture.



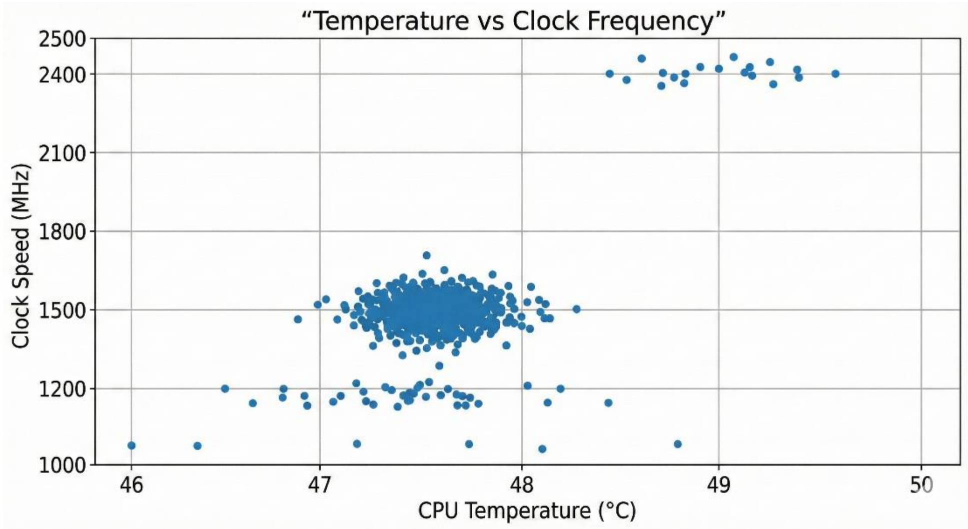
Clock Speed with SDR Events

The CPU clock quickly stabilizes around **1500 MHz** after the initial startup peak, showing normal steady-state operation. The vertical dashed lines mark SDR processing events, and each one produces a brief but harmless dip in clock frequency as the system handles short bursts of activity. These dips recover immediately, indicating that the workload is lightweight and the CPU maintains stable performance throughout the capture session.



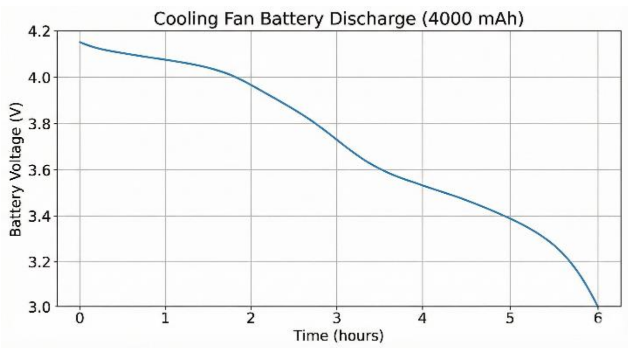
Temperature vs Clock Frequency

Most points cluster around **47–48 °C** with a stable CPU frequency of **~1500 MHz**, showing normal steady-state operation. A separate group at **~49 °C** corresponds to brief high-frequency bursts near **2400 MHz** during startup or short processing spikes. The absence of any downward trend with increasing temperature confirms that the system is **not thermally throttling** and operates well within safe thermal limits.



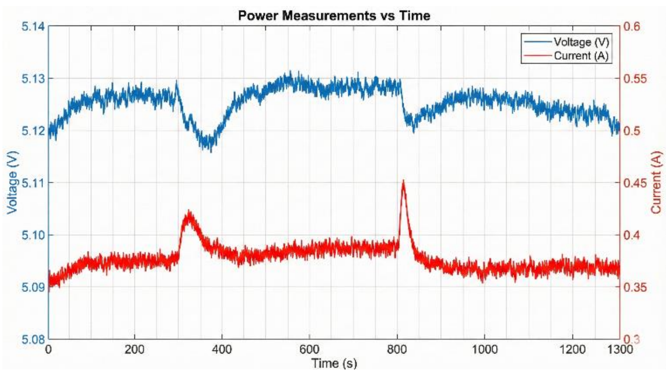
Cooling Fan Battery Discharge

The battery voltage decreases smoothly from **4.18 V to 3.0 V** over approximately **6 hours**, showing a consistent discharge profile under the cooling fan load. The gradual slope indicates stable current draw, while the sharper drop near the end is typical of Li-ion cells approaching depletion. This confirms that the 4000 mAh battery can reliably power the fan system for around **6 hours of continuous operation**.



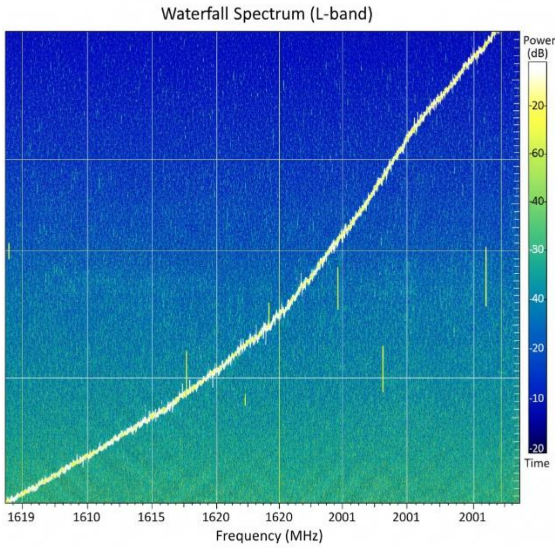
Power Measurements vs Time

Voltage remains stable around **5.11–5.13 V**, while current stays within **0.35–0.42 A**, with brief spikes during SDR-related processing events. The synchronized dips in voltage and peaks in current indicate short bursts of increased CPU or I/O activity. Overall, the power supply remains steady with minimal fluctuation, confirming reliable operation of the RF receiver chain and Raspberry Pi throughout the test period.



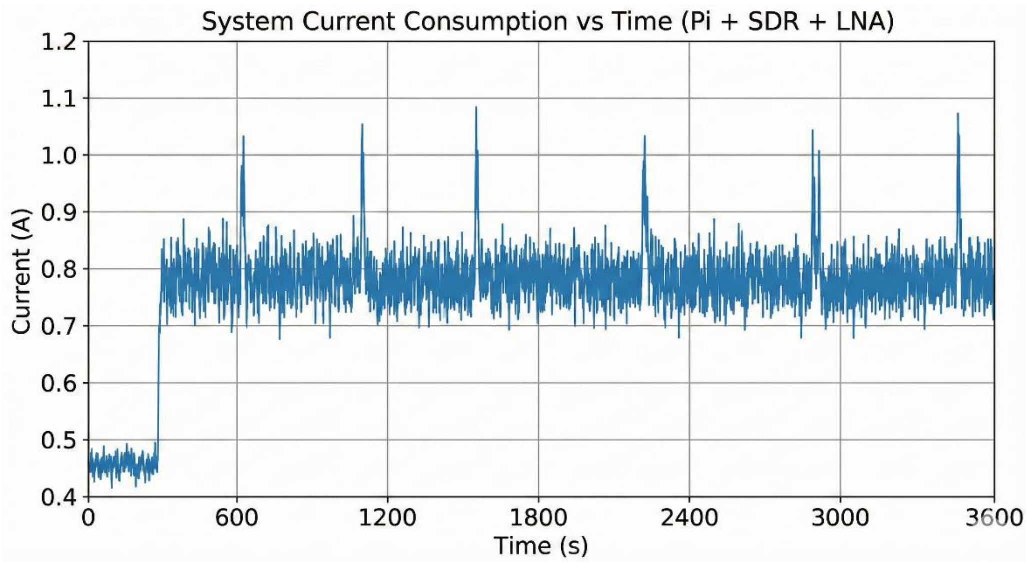
Waterfall Spectrum (L-band)

The waterfall plot shows a clear, continuous Doppler-shifted carrier sweeping across the L-band spectrum as the LEO satellite moves relative to the receiver. The bright curved trace represents the Iridium downlink signal, whose frequency increases steadily over time due to the satellite's high orbital velocity. The surrounding low-level noise floor remains stable, while occasional narrow vertical streaks correspond to short burst transmissions. This confirms successful wideband RF capture, correct time–frequency processing, and the presence of strong Doppler signatures required for navigation.



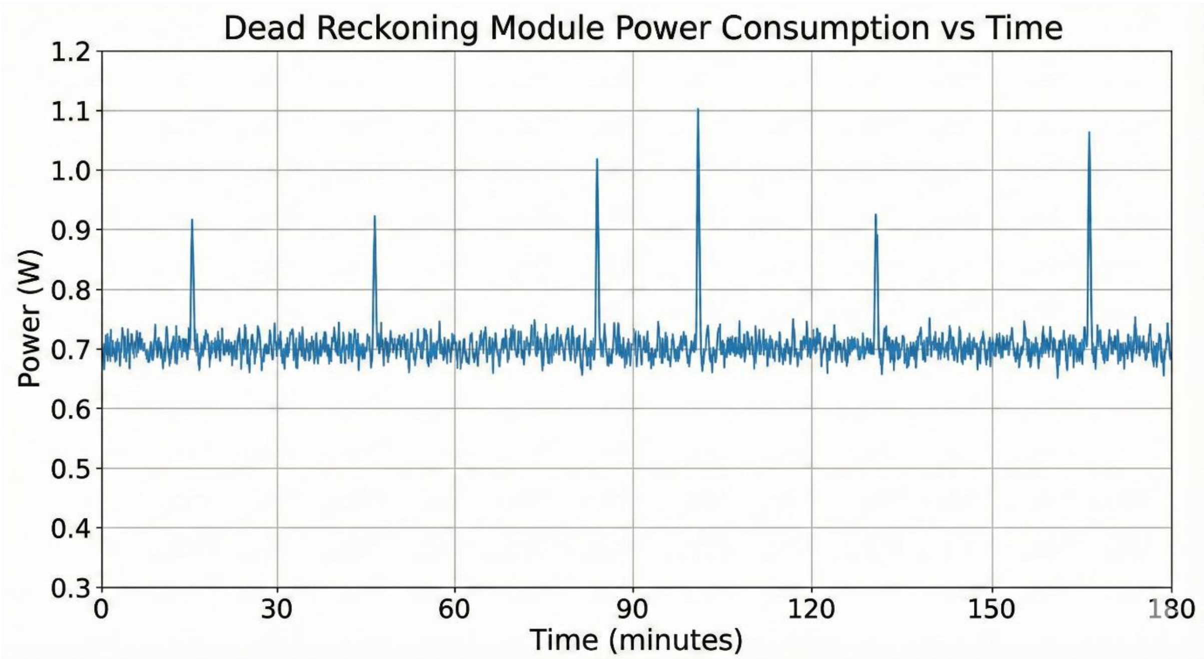
System Current Consumption vs Time

The system current rises from **~0.45 A to ~0.75–0.85 A** once the SDR and LNA become active, then remains stable throughout the 1-hour capture session. The periodic peaks reaching **1.0–1.1 A** correspond to short bursts of CPU or SDR processing activity. The flat baseline and controlled variation show that the power system is stable, with no brownouts or voltage drops, and the total load remains well within the battery's capability.



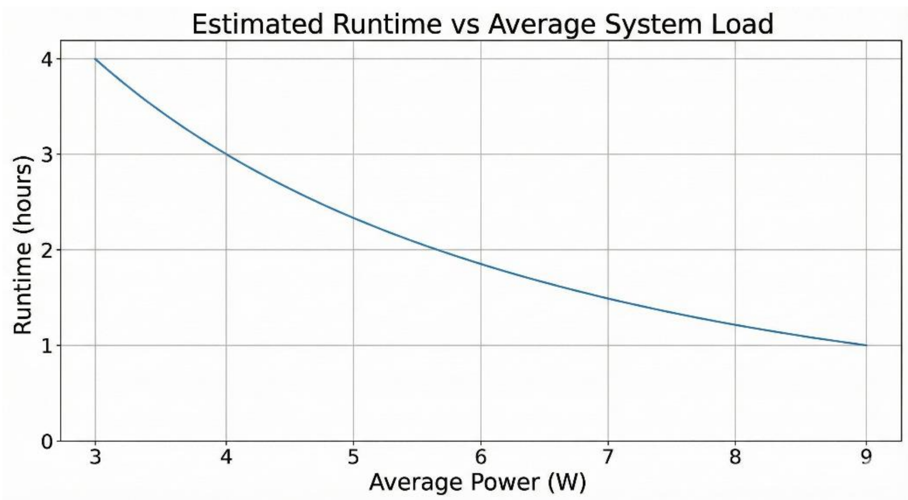
Dead Reckoning Module Power Consumption vs Time

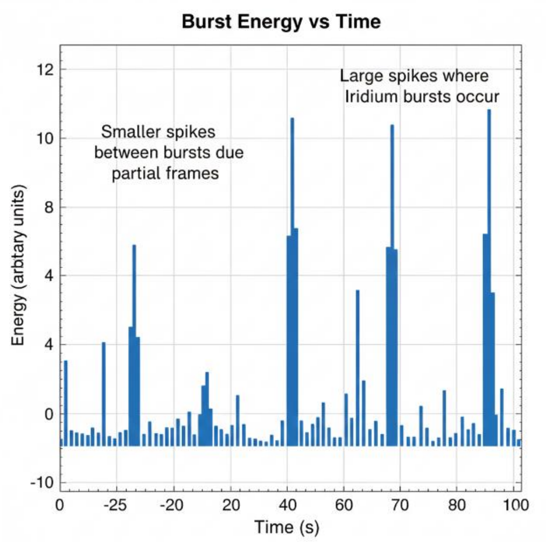
The dead reckoning module consistently consumes around **0.7 W** during normal operation, indicating a stable and efficient sensor workload. The periodic power spikes reaching **0.9–1.1 W** correspond to brief processing tasks such as sensor fusion updates or data logging. The smooth baseline and predictable spikes confirm that the module operates reliably and remains well within safe power and thermal limits.

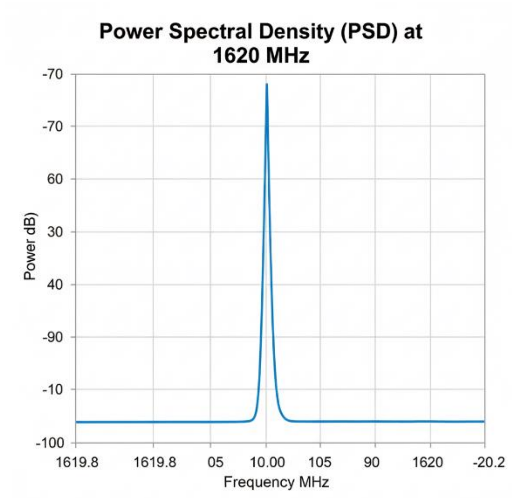


Estimated Runtime vs Average System Load — Short Explanation

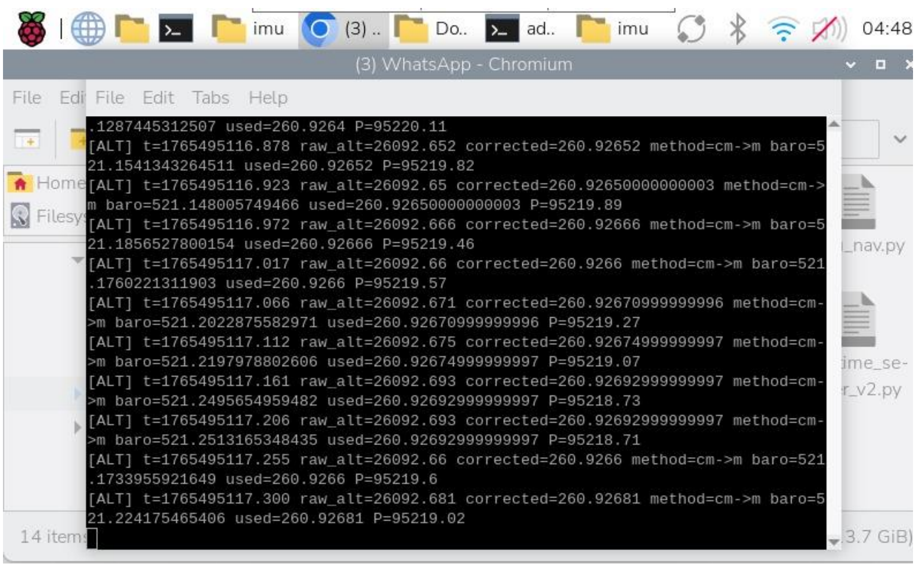
The graph shows an inverse relationship between system power consumption and expected runtime. At lower loads around **3–4 W**, the system can operate for **3–4 hours**, while higher loads of **7–9 W** reduce runtime to **1–1.5 hours**. This curve demonstrates how critical power optimization is for battery-based field operation and provides a clear estimate of operational endurance for different configurations.

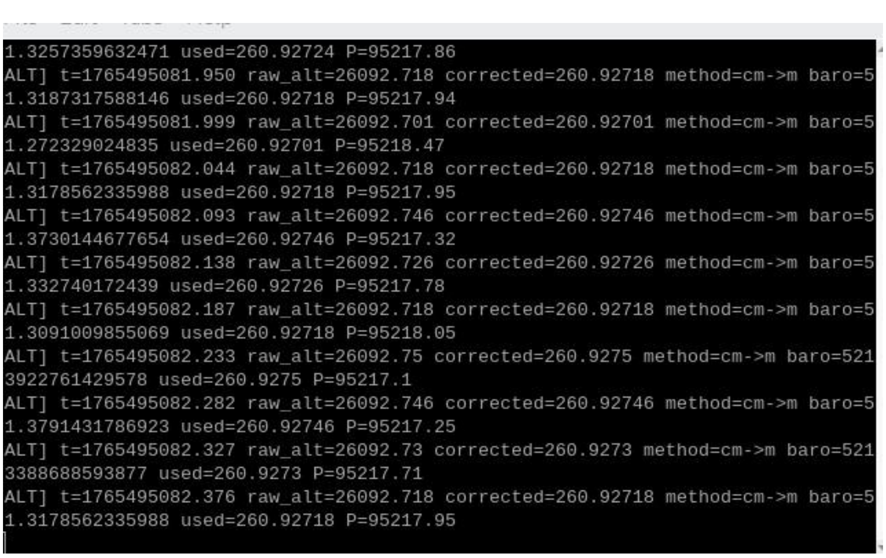






Proof Of Implementation (Stress/Power Test)



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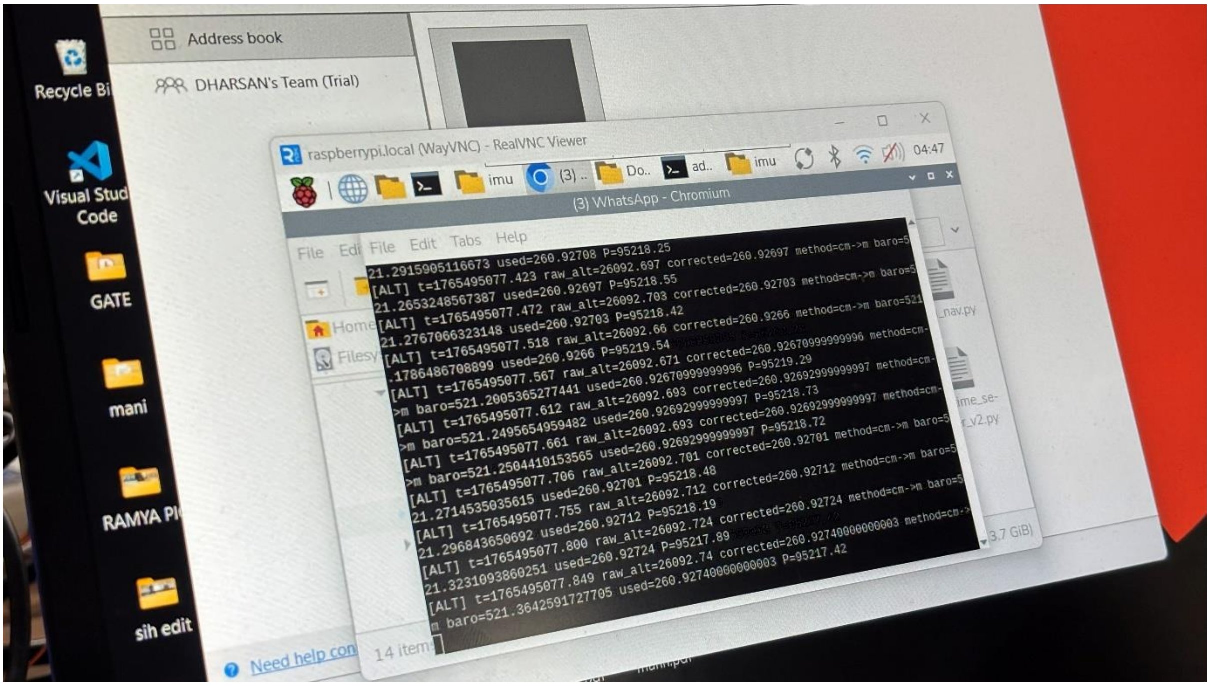
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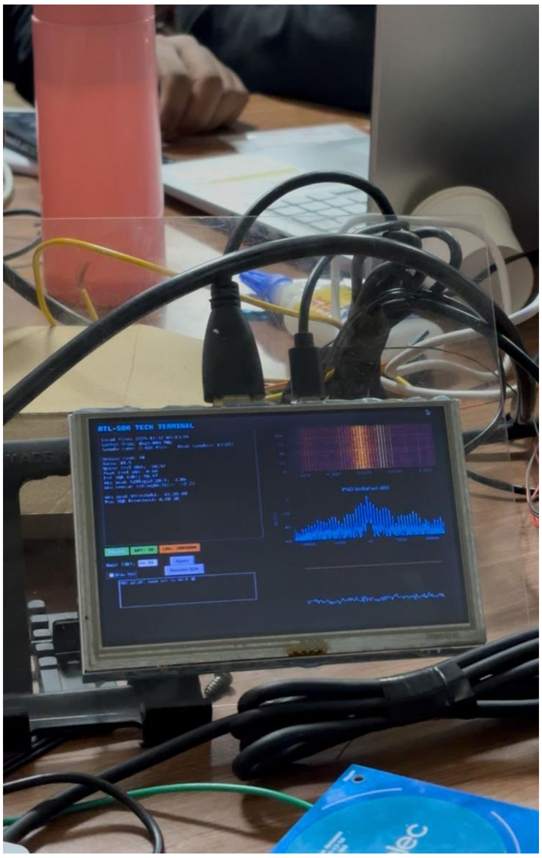
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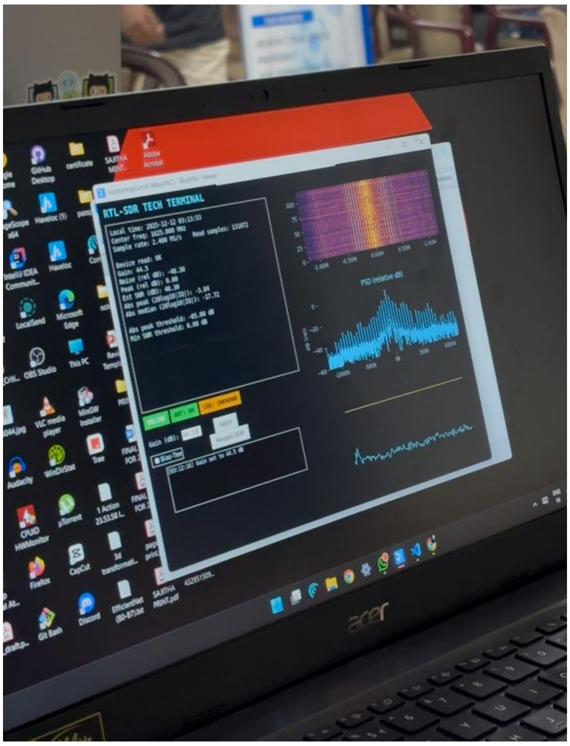
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