National Aeronautics and Space Administration

Operational Testing and Improvements of the ASU SmallSat Ground Station

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Strategic University Research Partnership

Objectives

- Development of a ground station which supports LEO and interplanetary CubeSat operations. Focused support for upcoming ASU and JPL missions, reducing DSN load.
- Designing of re-configurable communication systems via a software defined radio (SDR)
- Gain knowledge of CCSDS standards and other protocols for DSN communications. Develop a Universal X-Band and S-Band communication system that also allows for real-time data transfer and analysis.
- Platform for student training in CubeSat operations, ground station development and radio hardware development.
- Support UHF, S-Band and X-band communications.

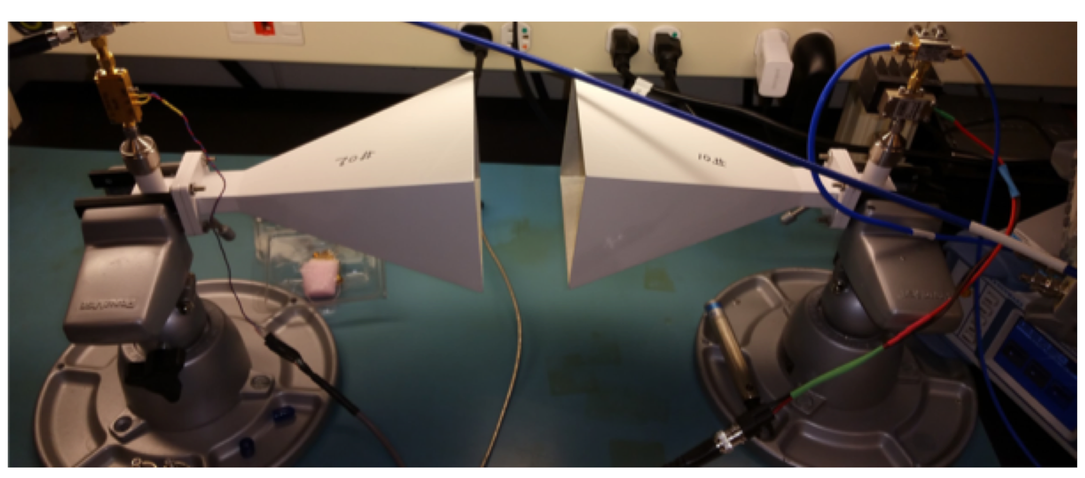

Figure 1: Testing the CCSDS 131.0-B-3 transponder by radiating the signal into free space via the horn and USRP. The signal is then received by the opposing horn and the TM signal is received and decoded.

Figure 2: Installation of revised ground station on the roof of an ASU building in February of 2018. Replaced parts include a steel-case rotor, 75% lighter dish. Upgrades include a new student-built power control box, and a weather station.

Ground Station Improvements

- Integration into the ASU mission operations center framework. This integration includes front-end software for future missions to interact with the dish in a user-friendly way. See figure 3.
- Performed general background noise measurements by capturing all of the signal levels seen between or perspective UHF (415-475MHz) and S-Band (2066-2660MHz) frequency ranges while performing 360 azimuth sweeps.
- Designed and fabricated amplifier protection circuit for the RF component power states and a 250W power distribution board.
- Implementation of a re-configurable communication system via an Ettus USRPN210 (SDR)
- Development of new, professional CCSDS code to be used in gnuradio.

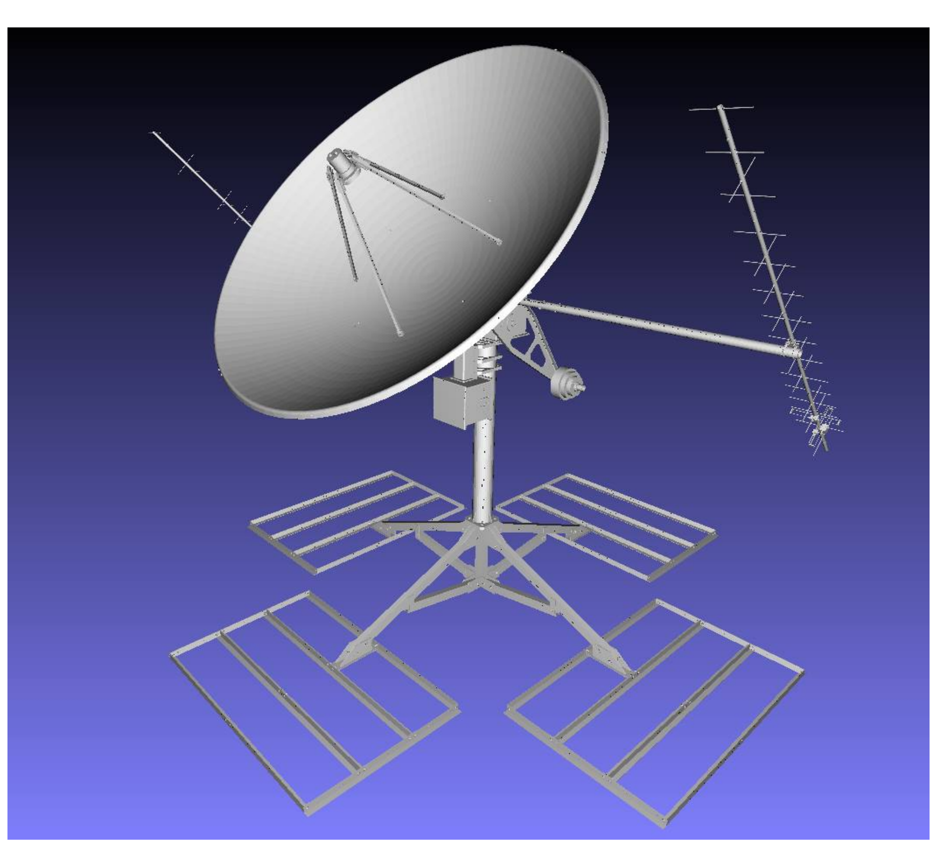

Figure 3: A centralized hardware framework gives the ground station a small footprint, supporting ease of installation and modification. This flexible design allows for easy hardware modifications, supporting the receiver research and design objectives.

Cryogenic Low Noise Amplification

- Overcoming small dish size through improved low noise amplification.
- Key Features:
  - Power Gain: 30dB
  - Gain Flatness: < 1 dB on 500-3000MHz band
  - Noise Temperature : 5-6 Kelvin (Noise figure 0.075 dB)
  - Input and Output Impedance: 50 OHM
  - Input Return Loss: < -10dB
  - Output Return Loss: < -10dB
  - Unconditionally stable with any input / output impedance .
  - Input 1dB Compression @ 2GHz: -36dBm
  - Power consumption: 10mW at 10K

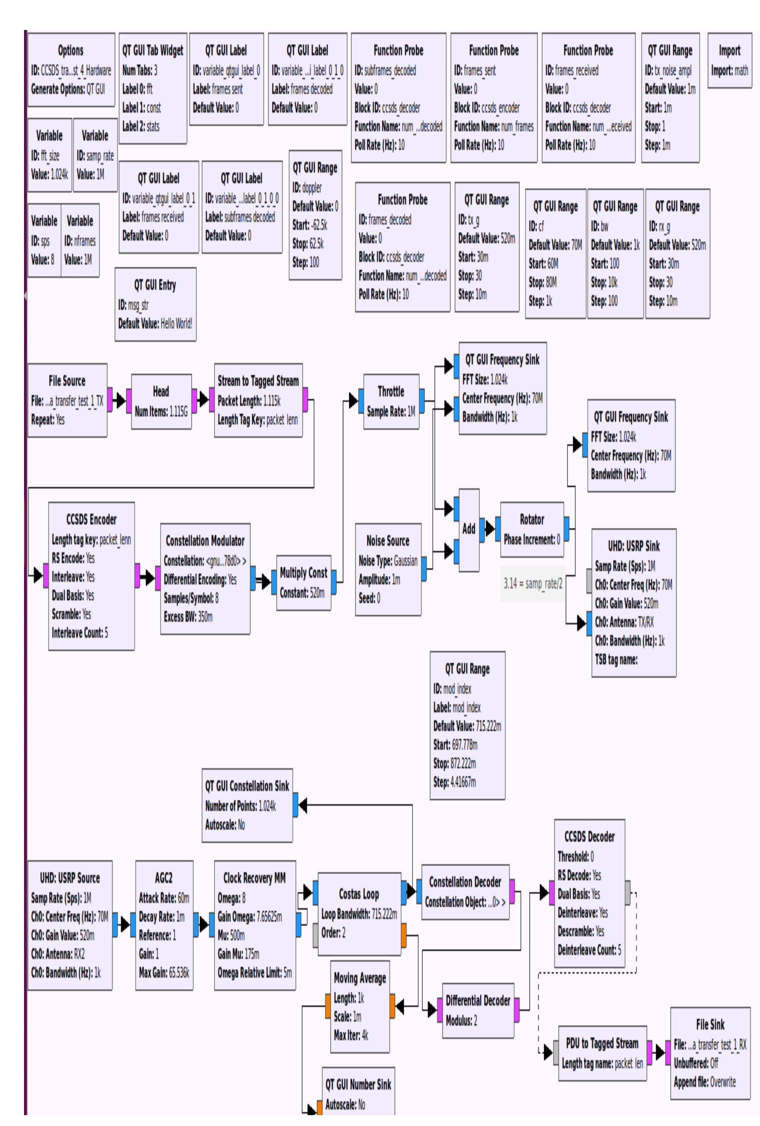

Figure 4: Block diagram in Gnuradio Companion (GRC) of our current Software Defined Radio transponder. The system is functional and operates using the CCSDS 131.0-B-3 for gathering telemetry data.

JPL Benefits

- X-band capabilities allow for interoperability with assets requiring DSN time.
- Offloading interplanetary CubeSat communications to university ground stations reduces DSN load.
- Increased CubeSat partnerships with ASU expands collaboration potential for operation of future JPL CubeSats.
- Provides a testbed location for the testing of future JPL radio receiver prototypes.
- Student training pathway provides JPL interns and ECH hires with real world experience and familiarity with JPL toolchains.
- Advancement of reconfigurable communication systems and SDR technology by expanding CCSDS code libraries for SDRs.

Next Steps

- Attempt signal collection from known LEO CubeSats. To-date only carrier signal have been collected.
- Develop a waveguide that is capable of cryogenically cooling the internal electronics of the feed system.
- Develop an X-band LNA/filter/switch/coupler, including down-conversion to UHF, circuit for new waveguide.
- Document and peer-review the process obtaining the system noise level temperature, G/T and supporting measurements of the ground station system with the new feed circuit. Show performance comparisons between passive and cryogenically cooled implementations.
- Demonstration of signal reception/processing and data forwarding for S-Band and X-Band signals using collaboration spacecraft (MarCO and LunaH-Map).
- Develop an SDR capable of communicating with swarms of CubeSats simultaneously without data loss or corruption.
- Software based system that does not rely on Cassy or commercial AIT/AMPCS hardware for TC and AOS CCSDS signal processing.

Figure 5: Dust storms pose great risk in the Phoenix metro area. Storm winds can reach 30 mph. The dish, positioned on the roof of an 8 story building, requires supplemental mechanical safeguards to ensure damage does not occur on the ground station gearing system. "birdbath mode" is used during storms to reduce the wind pressure on the dish.

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Poster No. RPC-236
CL#19-5931