THE CUBESAT RADIOMETER RADIO FREQUENCY INTERFERENCE TECHNOLOGY VALIDATION (CUBERRT) MISSION

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ABSTRACT

The CubeSat Radiometer Radio Frequency Interference Technology Validation (CubeRRT) mission is developing a 6U CubeSat system to demonstrate radio frequency interference (RFI) detection and mitigation technologies for future microwave radiometer remote sensing missions. CubeRRT will perform observations of Earth brightness temperatures from 6-40 GHz using a 1 GHz bandwidth tuned channel, and will demonstrate on-board real-time RFI processing. The system is currently under development, with launch readiness expected in 2018 followed by a one year period of on-orbit operations. Project plans and status are reported in this paper.

Index Terms— Microwave radiometry, radio frequency interference, CubeSat

1. THE CUBERRT PROJECT

Recent passive microwave measurements below 40 GHz have shown an increase in the amount of man-made interference [1]-[2], corrupting geophysical retrievals in a variety of crucial science products, including soil moisture, atmospheric water vapor, sea surface temperature, sea surface winds, and many others. Spectrum for commercial use is becoming increasingly crowded, accelerating demand to open the bands reserved for passive microwave Earth observation and radio astronomy applications to general use. Due to current shared spectrum allocations, microwave radiometers must co-exist with terrestrial RFI sources. Figure 1 illustrates the 6-40 GHz portion of the spectrum, along with the frequency ranges used in several past radiometer missions; the sensitivity to environmental effects in each of these frequencies is also shown in the lower curves. Passive microwave observations are allocated primary-use only in a small number of bands (those shown as green vertical bars), with shared-use in those marked in yellow. Due to the high sensitivity of radiometer measurements, shared allocations offer little protection from RFI corruption, as amply demonstrated in numerous past missions. As active sources expand over larger areas and occupy additional spectrum, it will be increasingly difficult to perform radiometry without an RFI mitigation capability. Co-existence in some cases may be possible provided that a subsystem for mitigating RFI is included in future systems.

Initial progress in RFI mitigation technologies for microwave radiometry in space has been achieved in the SMAP [3]-[5] mission. The SMAP radiometer utilizes a digital subsystem that operates on a 24 MHz bandwidth, centered at the protected 1413 MHz frequency allocation. Digital subsystems for higher frequency microwave radiometry, over the 6-40 GHz range, require a larger bandwidth, so the bandwidth, processing power, and on-board operation capabilities for RFI mitigation must also increase accordingly. Table 1 summarizes current issues in RFI processing for radiometers, and highlights the capabilities that future missions will require. While the SMAP mission is demonstrating RFI mitigation in a single 24 MHz channel, all RFI processing is performed on the ground following downlink of high data rate products such as a spectrogram of the received signal and its kurtosis. The multiple channels and much larger bandwidths of current and future radiometer missions operating 6-40 GHz do not allow downlink of this data volume to occur, so RFI processing on the ground is not possible. Real-time on-board RFI processing is therefore an important technology needed for future missions.

To demonstrate on-board, real-time RFI processing from 6-40 GHz, the CubeSat Radiometer Radio Frequency Interference Technology Validation (CubeRRT) mission has been proposed and selected under NASA's In-space Validation of Earth Science Technologies (InVEST) program.

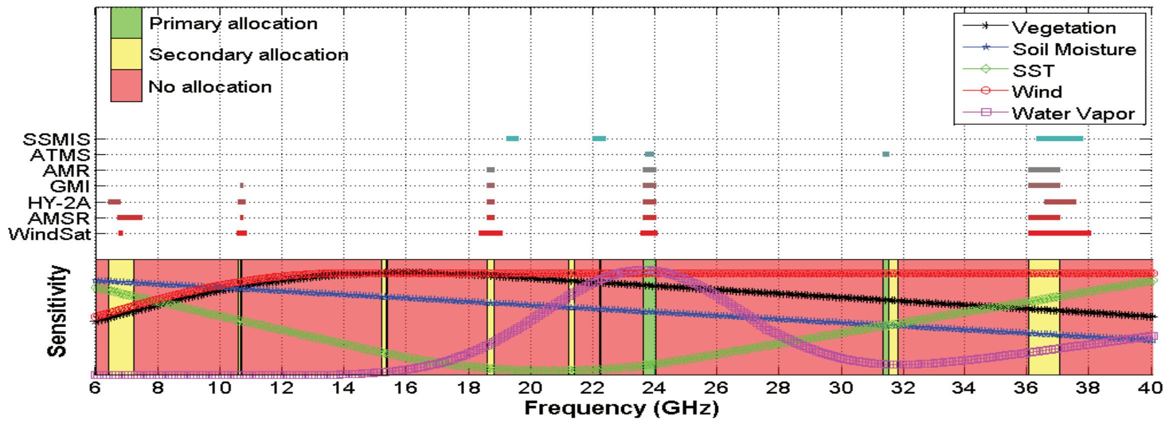

Figure 1: Frequency ranges allocated for microwave radiometer observations (green=primary, yellow=shared) in the 6-40 GHz range. Spectral ranges used by several past missions also indicated, as well as curves of sensitivity to environmental parameters vs. frequency.

2. CUBERRT DESIGN

The enabling CubeRRT technology is a digital Field-Programmable Gate Array-based spectrometer with a bandwidth of 1 GHz that is capable of implementing advanced RFI mitigation algorithms that use the kurtosis and cross-frequency RFI detection methods in real-time on board the spacecraft [6]. Though the technology can be demonstrated for any frequency band from 1 to 40 GHz, CubeRRT will integrate this backend with a wideband radiometer operating over a 1 GHz bandwidth tunable from 6-40 GHz to demonstrate RFI detection and mitigation in microwave radiometry bands that are fundamentally significant for Earth remote sensing. The CubeRRT payload will be integrated into a 6U CubeSat for deployment in space (expected launch from the International Space Station). Although the spatial resolution to be achieved by CubeRRT will be coarse (~120-300 km, due to the limited antenna size possible), the goal of demonstrating observation, detection, and mitigation of RFI should be achievable in this configuration.

The CubeRRT payload consists of 3 subsystems: a wideband dual-element antenna system, a tunable analog radiometer subsystem, and a digital backend performing real-time RFI detection and mitigation in a 1 GHz bandwidth. The dual-element antenna system is composed of a conical antenna (6-20 GHz) and a helical antenna (20-40 GHz), to provide a gain ranging from 15 dBi (at 6 GHz) to 23 dBi (at 40 GHz) in a single, circular polarization. The tunable analog radiometer subsystem is being developed by NASA-GSFC, and will provide internal calibration references as well as amplification, filtering, and downconversion functions. The digital subsystem is being developed by NASA-JPL, and will perform real-time computation of the kurtosis spectrum and power spectrum of the observed signals in 128 frequency channels. The digital subsystem will also conduct on-board RFI detection and mitigation using a variety of RFI algorithms, so that the resulting observed scene thermal noise power can be reported both before and after RFI mitigation is performed. Table 2 provides a summary of current CubeRRT design goals. The CubeRRT project schedule plans for completion of the satellite by late 2017 with availability for launch beginning 2018.

3. REFERENCES

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Table 1: Challenges in current and future missions

	SMAP	Future
Number of bands	1	6 or more
Bandwidth	20 MHz	100's of MHz in each channel
RFI Processing on ground?	Yes (limited downlink volume)	Not possible (downlink volume too high)
RFI Processing on-board spacecraft?	No; not necessary	Yes; only way to address RFI challenge for future systems

Table 2: Summary of CubeRRT properties

Frequency	6 to 40 GHz Tunable, 1 GHz instantaneous Operations emphasize nine bands commonly used for microwave radiometry
Polarization	Single polarization (Left Hand Circular)
Observation angle/Orbit (ISS launch)	0° Earth Incidence Angle 400 km altitude, 51° orbit inclination
Spatial Resolution	120 km (40 GHz) to 300 km (6 GHz)
Integration time	100 msec
Ant Gain/Beamwidth	15dBi/40° (6 GHz), 23 dBi/16° (40 GHz)
Interference Mitigation	On-board Nyquist sampling of 1 GHz spectrum; On-board real-time Kurtosis, Pulse, and Cross-Frequency Detection Downlink of frequency resolved power and kurtosis in 128 channels to verify on-board performance
Calibration (Internal)	Reference load and Noise diode sources
Calibration (External)	Cold sky and Ocean measurements
Noise equiv dT	0.8 K in 100 msec (each of 128 channels in 1 GHz)
Average Payload Data Rate	9.375 kpbs (including 25% duty cycle) ~102 MB per day,~ 37 GB over 1 year mission life
Downlink	135 MB per daily ground contact [6 minute contact with 3 Mbps UHF cadet Radio] 32% margin over payload data