The CubeSat Radiometer Radio Frequency Interference Technology Validation (CubeRRT) Mission: Status and Continuing Operations

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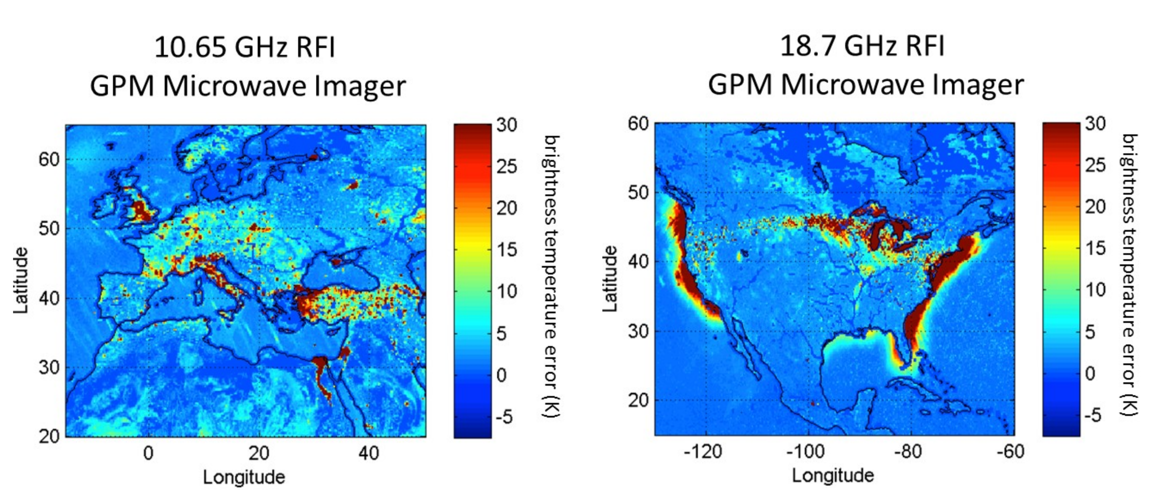
INTRODUCTION

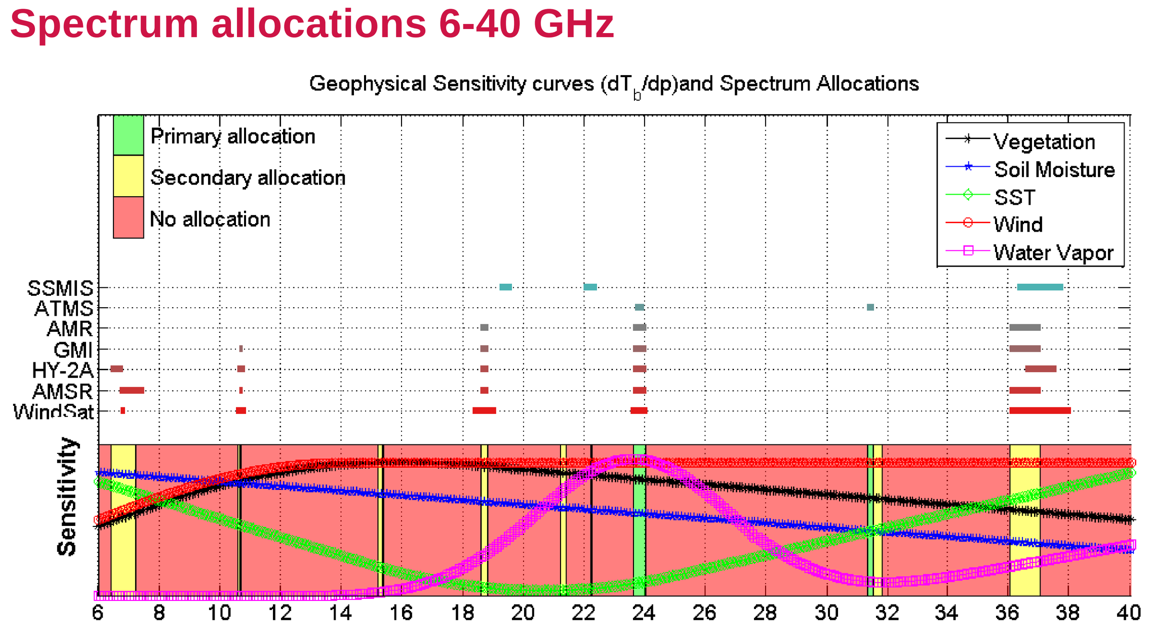
Passive microwave systems provide important data products for Earth science applications by measuring the naturally generated microwave thermal emission from Earth. Data from these highly sensitive instruments can be corrupted by radio-frequency interference (RFI). Recent measurements below 40 GHz have shown an increasing presence of RFI, making it more difficult to perform radiometry without an RFI mitigation capability. To address this challenge, the CubeRRT mission has demonstrated a real-time onboard RFI processor with low SWaP requirements operating on a 6U CubeSat.

RFI PROBLEM FOR MICROWAVE RADIOMETRY



Images from NASA's GMI radiometer (above) at 10.65 and 18.7 GHz show the clear corrupting influence of RFI. Ideally, radiometers avoid RFI by operating in bands where transmission is prohibited. In practice, radiometers must co-exist with RFI sources due to shared spectrum allocations or operation in unprotected bands. Co-existence in some cases may be possible provided that a subsystem for mitigating RFI is included in future systems.

Spectrum allocations 6-40 GHz

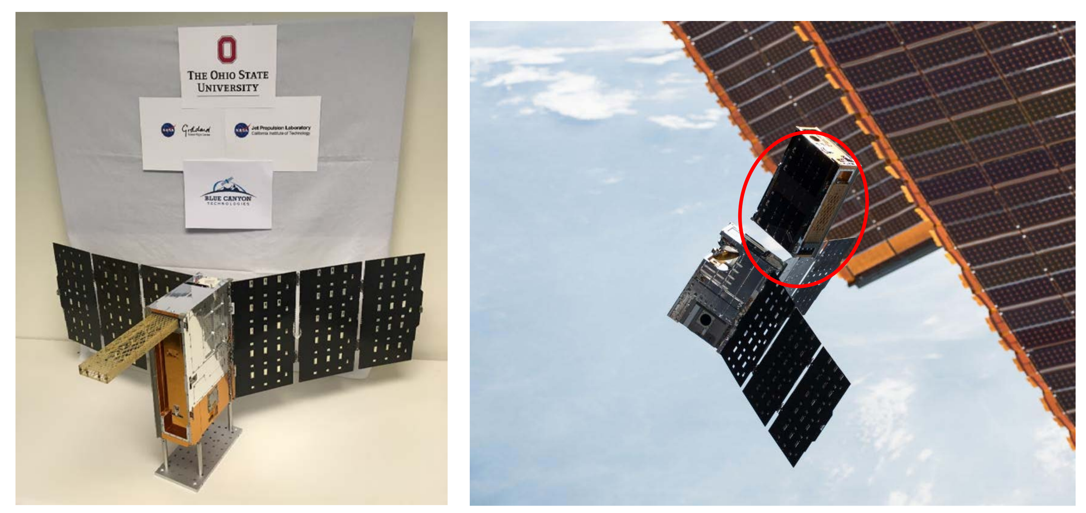


CUBERRT MISSION

The CubeRRT mission's primary objective is to demonstrate an RFI processor for future spaceborne microwave radiometers that provides real-time, onboard RFI filtering.

- 6U CubeSat (30 cm x 20 cm x 10 cm) housing radiometer front end, digital backend, and wideband antenna systems
- 1 GHz instantaneous bandwidth
- Real-time on-board RFI detection and removal using digital backend
- 6 to 40 GHz operational range, tunable
- CubeRRT launched to ISS on May 21st, 2018 and was deployed into orbit on July 13th

CubeRRT satellite and ISS Deployment

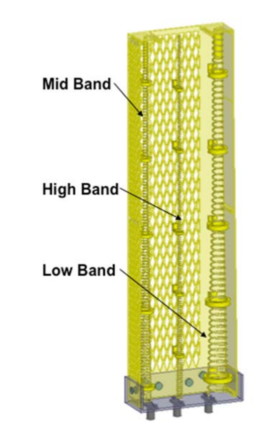


Mission Properties

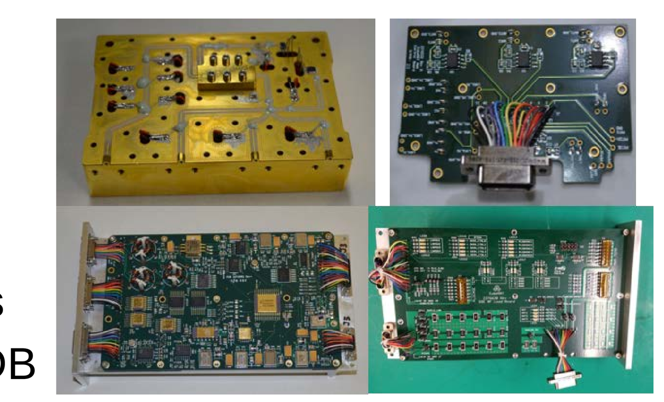
Frequency	**6 to 40 GHz Tunable, 1 GHz instantaneous**
Polarization	**Circular polarization**
Observation angle/Orbit (ISS launch)	**0° Earth Incidence Angle 400 km altitude, 51.6° orbit inclination**
Spatial Resolution	**80 km (40 GHz) to 240 km (6 GHz)**
Integration time	**100 msec**
Ant Gain/ Beamwidth	**12dBi/30° (6 GHz), 21 dBi/10° (40 GHz)**
Interference Mitigation	**On-board Nyquist sampling of 1 GHz spectrum; On-board real-time Kurtosis 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 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**

CUBERRT PAYLOAD SUBSYSTEMS

Subsystems include the 6-40 GHz antenna (ANT), the Radiometer Front End (RFE), and the Radiometer Digital Backend RFI (RDB) processor.

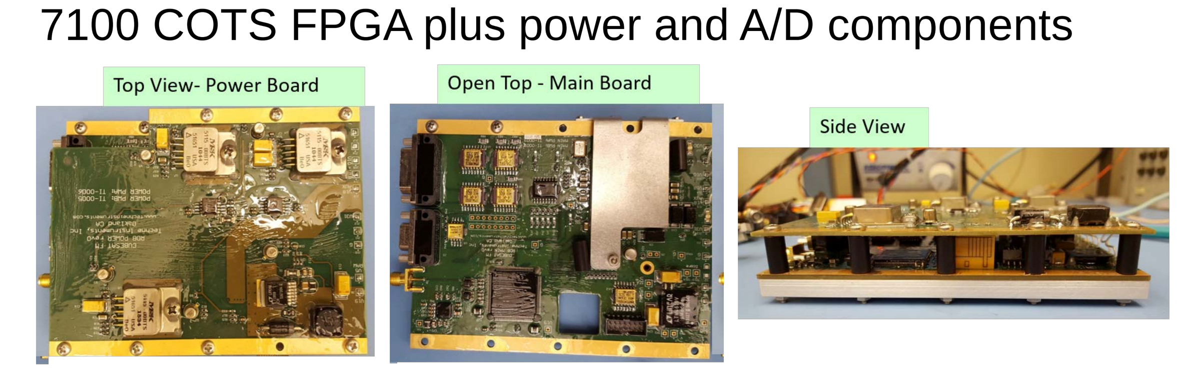


CubeRRT's payload antenna (left) includes 3 tapered helix elements to cover 6-40 GHz with gain 7 to 21 dBi in a 0.25U, 116g package

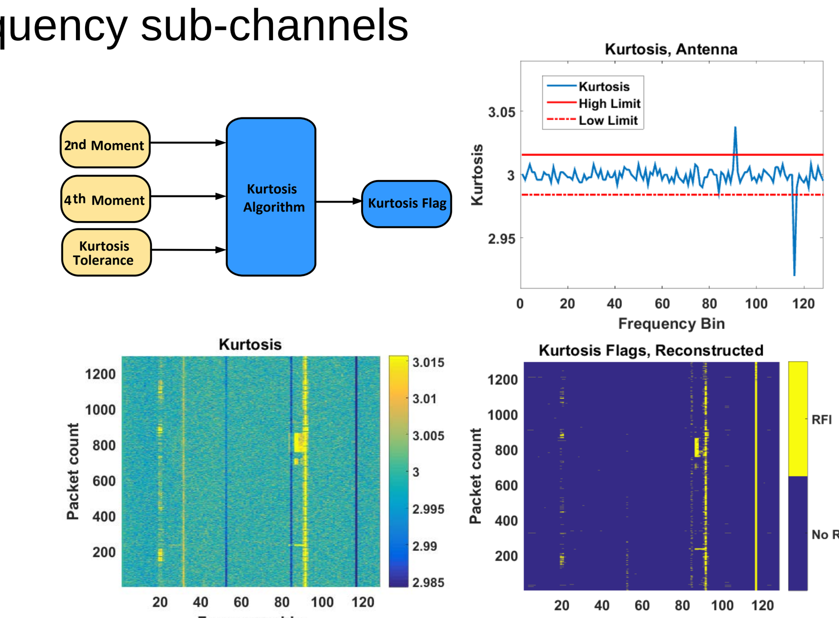


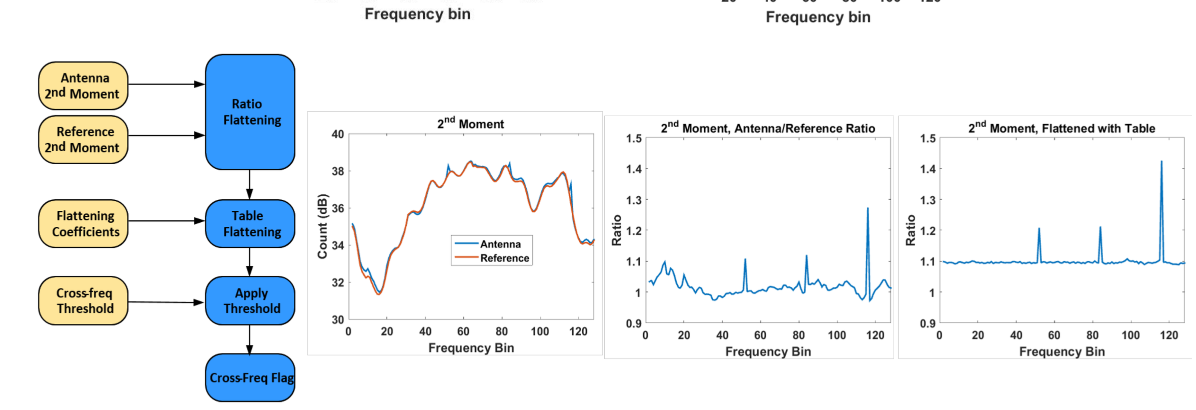
CubeRRT's RFE (right) tunes 6-40 GHz signals to 1-2 RF GHz IF of RDB

CubeRRT's RDB (below, ~ 0.25U, 170g, 10W) is the key technology, and is implemented using a Zynq 7100 COTS FPGA plus power and A/D components

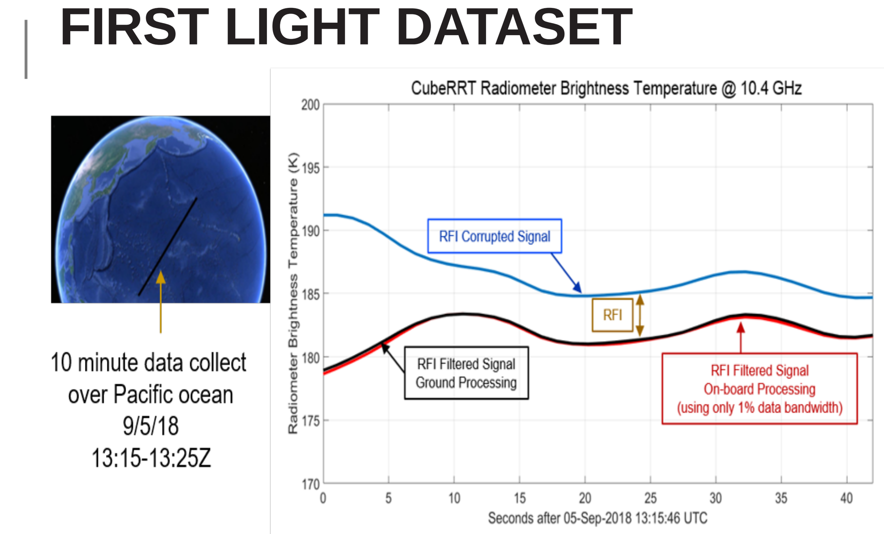


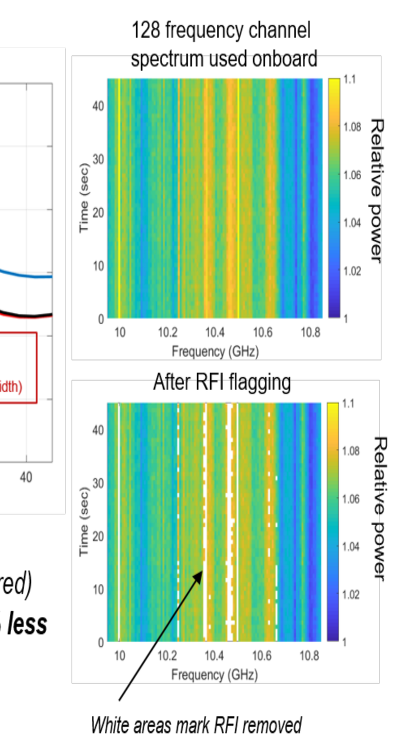
The RDB implements both kurtosis and cross-frequency methods for RFI detection using 128 frequency sub-channels





FIRST LIGHT DATASET





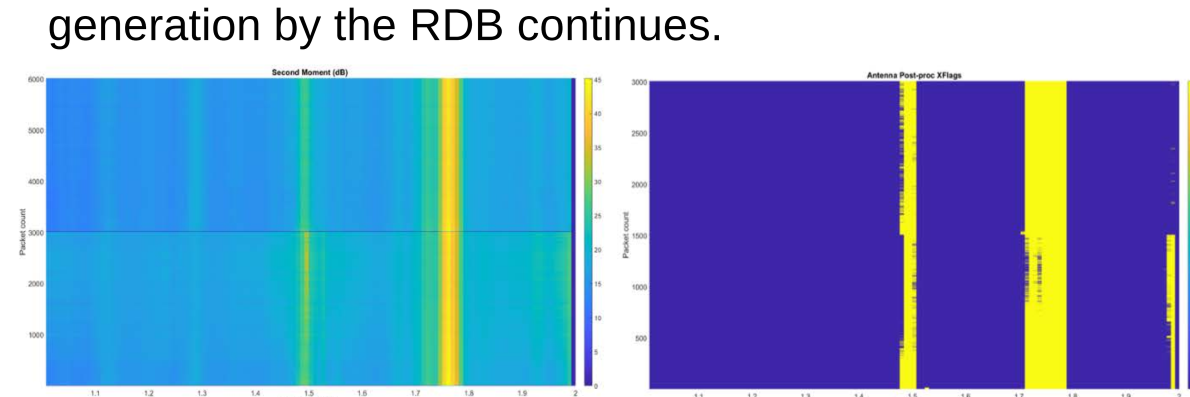
Smoothed CubeRRT radiometer brightness temperatures demonstrate on-board RFI filtering: original RFI corrupted signal (blue) corrected on-orbit to RFI filtered signal (red) that is validated with ground processed data (black). On-board filtering ***requires 99% less data to be downlinked.***

CubeRRT's first light dataset was acquired on September 5th, 2018, and demonstrates successful real-time onboard RFI flagging for the first time in space!

CURRENT STATUS AND CONCLUSIONS

CubeRRT has successfully met its mission objectives by demonstrating the RFI processor for over 400 hours of measurements in orbit with no evidence of radiation induced degradation. This is an important milestone for the use of COTS FPGA systems for radiometer RFI processing in space.

CubeRRT's RFE ceased operation on September 8th, 2018, limiting the range of observed RDB inputs to a self generated "test pattern". Ground processing nevertheless confirms that successful on-board flag generation by the RDB continues.



The success of CubeRRT's RDB paves the way for its adoption as an essential component of future Earth observing microwave radiometers to enable continued operation in the presence of RFI.

ACKNOWLEDGEMENTS

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