RITA: A 1U multi-sensor Earth observation payload for the AlainSat-1

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Abstract

The Remote sensing and Interference detector with radiomeTry and vegetation Analysis (RITA) is one of the Remote Sensing payloads selected as winners of the 2nd GRSS Student Grand Challenge in 2019, to fly on board of the 3U AlainSat-1. This CubeSat is being developed by the National Space Science and Technology Center (NSSTC), United Arab Emirates University.

RITA has been designed as an academic mission, which brings together students from different backgrounds in a joint effort to apply very distinct sensors in an Earth Observation mission, fusing their results to obtain higher-accuracy measurements. The main payload used in RITA is a Total Power Radiometer such as the one on board the FSSCat mission. With these radiometric measurements, soil moisture and ice thickness will be obtained. To better characterize the extensive Radio-Frequency Interferences received by EO satellites in protected bands, several RFI Detection and Classification algorithms will be included to generate a worldwide map of RFI. As a novel addition to the ^{3}Cat family of satellites and payloads, a hyper-spectral camera with 25 bands ranging from 600 to 975 nm will be used to obtain several indexes related to vegetation. By linking these measurements with the soil moisture obtained from the MWR, pixel downscaling can be attempted. Finally, a custom-developed LoRa transceiver will be included to provide a multi-level approach to in-situ sensors: On-demand executions of the other payloads will be able to be triggered from ground sensors if necessary, as well as simple reception of other measurements that will complement the ones obtained on the satellite. The antennas for both the MWR and the LoRa experiments have been developed in-house, and will span the entirety of one of the 3U sides of the satellite. In this work, the latest development advances will be presented, together with an updated system overview and information about the operations that will be conducted. Results obtained from the test campaign are also presented in the conference.

Keywords

Microwave Radiometry, Hyper-spectral camera, CubeSat, RFI, LoRa, GRSS

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1. Introduction

Desertification and flooding events are becoming more extreme, and sea level is steadily rising. It is very important to acquire accurate measurements of Essential Climate Variables (ECVs) related to the water cycle such as the soil moisture (SM), and the ocean surface salinity to be able to provide better decisions and informed solutions. For vegetation and water-related measurements, L-band Microwave Radiometry (MWR) is the most accurate technique, and despite the coarse resolution, it can be used by pixel downscaling techniques **[1]**.

Currently, four satellite missions have used L-band MWR payloads to monitor these changes (SMOS **[2]**, AQUARIUS **[3]**, SMAP **[4]** and FSSCat **[5]**), but L-Band measurements are often hindered by Radio Frequency Interference (RFI) **[6]**, corrupting them. Hyper-spectral imagers are used to retrieve soil and vegetation-related measurements with enhanced resolution and resiliency, but are costly and difficult to integrate due to the size of the lenses. The RITA payload will attempt to provide a cost-effective solution by integrating all of the aforementioned instruments in a 1U space inside of a 3U CubeSat (**Figure 1**) using commercial off-the-shelf products to keep the cost low, and to develop it in an academic environment.

Figure 1. Section view of the AlainSat-1, with the MWR and LoRa antennas in ocre, and the RITA payload shown in the foreground.

2. System Design

The RITA payload's processor is based on a System-on-Module (SoM) containing a Zynq-7000 Field-Programmable Gate Array (FPGA) with an embedded ARM Cortex-A9. Through the Interface Board, it controls the hyper-spectral camera and the RF Front-Ends and communicates with the platform. The image sensor is a 2048x1088 CMOS pixel array with an integrated 5x5 Fabry-Pérot filter array that filters to a narrow spectral band from 600 nm to 975 nm (Red to NIR), packaged by Photonfocus AG. On the same board as the FPGA, an Analog Devices 9364 Software-Defined Radio (SDR) is used for MWR, LoRa communications, Radio-Frequency Interference (RFI) detection and S-Band downlink. The overall configuration can be seen in **Figure 2**.

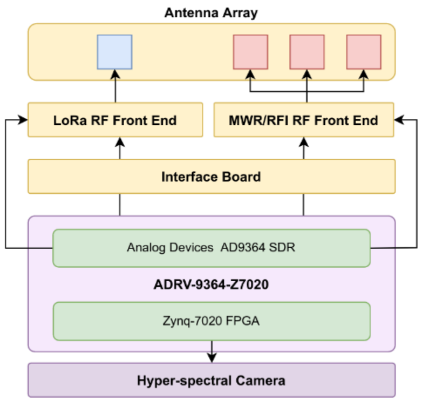

Figure 2 Block diagram of the payload components. In orange, the parts developed in-house. In purple, COTS components.

The payload also integrates a hyper-spectral camera instrument, that is composed of three parts: a 16 mm fixed focal length optics, an in-house manufactured C-mount and internal baffle, and a hyper-spectral image sensor integrated into a set of two PCBs with an additional third board that interfaces with the SoM/FPGA. The combination of the selected lenses and sensor size set a horizontal field-of-view (FoV) of ~38.8º, which matches the radiation pattern of the MWR antenna array.

Table 1: Summary table of the main characteristics of the MWR and Hyper-spectral camera payloads

Hyper-spectral camera	
Ground Sampling Distance (GSD)	206 m
Swath	224,4 km
Focal Length	16 mm
SNR	40,4 dB
Dynamic Range	60 dB
Shutter time range	0,013-349 ms
Pixel resolution	2048x1088
Filter Layout	SSM 5x5
Microwave Radiometer	
Radiation pattern	120º x 31.6º
Swath	317 km
Δ T	100ms
RFI Detection Algorithms	Kurtosis, Spectrogram
Receiver Noise Temperature	237,35 K

The cross-track swath is aligned with the 2048-pixel array, whereas the along-track swath is aligned with the 1088-pixel array, thus translating to a Ground Sample Distance (GSD) of 206 m/px. More information about the Hyper-spectral camera can be found in **Table 1**.

The mount to fix the lenses to the structure has been designed to match the C-type mount diameter and flange with a focal distance of 17.526 mm, and it also incorporates an internal structure to act as a baffle, blocking and reducing the possible internal reflections in the space between the sensor and the lens.

3. Mission Analysis

As a hosted payload, the mission analysis for RITA is tightly coupled with that of the platform and the other payloads. Every experiment in the RITA payload has a different requirement in terms of consumed power and data generated. Due to the high data yield from the hyper-spectral camera, a custom S-Band transmitter has been developed in-house exclusively for the scientific data downlink.

Table 2: Mission analysis focusing on the Hyper-spectral Camera

Limited by download capacity	Picture periodicity	11	s / picture
	Mean CAM oper. power	4.43	W
	CAM acq. allowed	4.5	pic. / orbit
	CAM duty cycle	0.891	% orbit
	Mean CAM power/orbit	39.4	mW / orbit
	Mean S-band power	4.42	W
	S-Band duty cycle	3.1	% orbit
	Mean S-Band power/orbit	135.9	mW / orbit
	Total avg. power/orbit	175.3	mW / orbit
Limited by target areas	Mean time over targets	233	s / orbit
	CAM duty cycle	4.19	% orbit
	CAM acquisitions	21.2	pic. / orbit
	Mean CAM power/orbit	185.3	mW / orbit
	Mean S-Band power/orbit	135.9	mW / orbit
	Total average power/orbit	321.2	mW / orbit
	Data rate required	2296	kbps

The other experiments are similar in terms of power consumption, as they use the same SDR platform, and also produce comparable amounts of data. They have been explored separately to obtain the worst-case scenario for the mission analysis. **Table 2** contains a summary of the different scenarios, with the limiting modes and results in bold type.

3.1. Camera mode

This mode includes only the use of the hyper-spectral camera, allowing for non-overlapping snapshot-based operation and acquisition of the 25 optical bands between 600 and 975~nm. In this acquisition mode both the FPGA and the hyper-spectral camera are powered on. The FPGA is responsible of the high-speed communications with the camera, both for control and for image retrieval, and it needs to be powered on continuously, whereas the hyper-spectral camera can be powered on and off only when needed due to the fast booting times. In terms of data generation, each picture occupies around 2~MB.

3.2. MWR and RFI Detection

The lowest-power operational mode includes only the L-Band MWR and the RFI detection and mitigation algorithms. Information about this mode can be found in **Table** *1*. In this mode, continuous acquisitions can be performed, including a mapping of RFI events over the ground track. It needs to power the FPGA, SDR, and RF Front-End during the entire acquisition. This mode is also the one which generates the smallest amount of data, since the MWR is storing only the total power received, and the calibration values.

3.3. Camera, MWR, and RFI Detection

In this operational mode hyper-spectral imaging, L-band radiometry and RFI detection and mitigation are performed. All the remote sensing instruments are powered on and operate in their nominal mode, taking measurements and simultaneously storing them into the payload memory. This makes this mode the most demanding one in terms of power-consumption and data generation.

3.4. LoRa experiment

The LoRa experiment will communicate with ground sensors using a novel LoRa transceiver implemented in an SDR. Due to the transmission mode, it will consume more power than the other RF experiments. In terms of data generation, it will only store logs and metadata of the transactions with ground sensors, and occasionally the collected scientific data.

3.5. Target Areas

Several target areas have been selected either due to their interest for continued scientific monitoring, or because their brightness makes them suitable for hyper-spectral camera calibration. Each area has an associated operational mode, that allows to, once in orbit, decide which areas the mission will take measures according to the

Table 3: Extract of the target areas planned for the RITA Payload

Area	Operational Mode	Main purpose	Secondary purpose
African Evergreen Forest	MWR+RFI	Vegetation	
Amazonas	CAM+MWR+RFI	Vegetation	Soil moisture
Arabian Sea	CAM+MWR+RFI	Algae Blooms	
Australian Forests East	CAM+MWR+RFI	Vegetation	
Bangladesh	CAM+MWR+RFI	Soil moisture	Vegetation
Borneo	CAM+MWR+RFI	Vegetation	
Cocos Island	CALIBRATION	Calibration	
Gulf Mexico	CAM+MWR+RFI	Oil spills	Algae blooms
Japan and Coast	MWR+RFI	Vegetation	
Lake Erie	CAM+MWR+RFI	Algae blooms	
Netherlands	CAM+MWR+RFI	Soil moisture	
Panama	CAM+MWR+RFI	Oil Spills	
Persian Gulf	CAM+MWR+RFI	Oil Spills	Algae blooms
Sahara Desert	CALIBRATION	Calibration	
Salt Lake City	CAM+MWR+RFI	Soil moisture	
Spain	CAM+MWR+RFI / LORA	Soil Moisture	Vegetation

power and data downlink capacity available. All areas have a scientific purpose associated to them, allowing for flexibility in the acquisition depending on the associated study. The number of target areas and execution times that will finally be executed will depend on both the Data Budget, which depends on the characteristics of the S-Band downlink, and the Power Budget, which depends on the platform. Examples of purposes associated to the areas would be RFI detection over East Asia, where RFI events are very common, soil moisture monitoring over the Amazonas, to monitor vegetation health of one of the largest nature's reservoirs, algae bloom detection over lakes such as Erie or Urmia for human safety, and oil spills detection over the Gulf of Mexico and Panamá. Some of these target areas and their planned operational mode can be seen in **Table 3**.

4. Conclusions

RITA is a miniaturized payload incorporating a number of instruments and devices for soil moisture, vegetation analysis, and RFI detection and monitoring. RITA is currently under development and is scheduled for completion in June 2022. The low-cost approach taken by this payload aims to pave the way for further educational missions in the field of Earth Observation. The project has provided an opportunity for training and engaging multicultural and multidisciplinary student teams. The payload will be launched aboard the AlainSat-1 in Q4 2022.

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