RFTSat: Backscatter Radio for In-Orbit Distributed Sensing

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Introduction

The NNU RFTSat is a 3U CubeSat that will perform a technology demonstration of wireless, radio frequency (RF) sensor tags that harvest RF energy and communicate with the spacecraft using backscatter. The RF tags can be configured to sense many phenomena including radiation, temperature, acceleration, electric field strength, and magnetic field strength. During the mission, the RF tags will be deployed to demonstrate the range and effectiveness of the RF system.

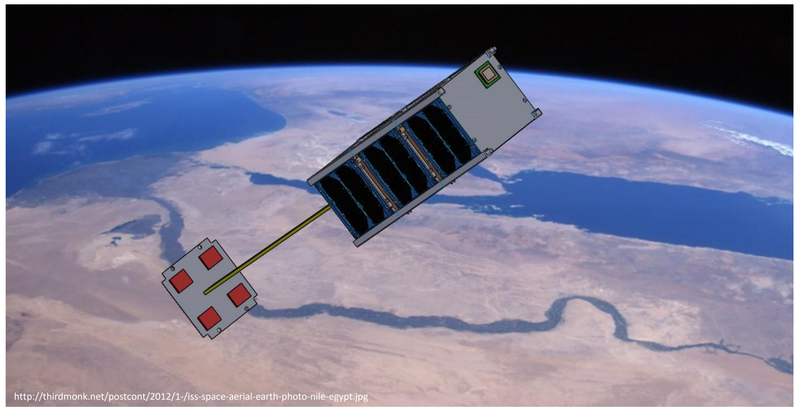

Figure 1: CAD Mockup of RFTSAT in Orbit

Because RF tags consume little power (e.g., a few 10s of microwatts), do not require a battery, and can wirelessly communicate sensor data over distance (e.g., a few 10s of meters), they have been used for distributed sensing in terrestrial applications including structural health monitoring, food-chain temperature sensing, and motion sensing. The RFTSat team believes that these same attributes would make RF tags applicable in the following space-related applications:

- Measure space weather (e.g., ionizing radiation, UV radiation, atomic oxygen interaction, micro-meter impacts).
- Monitor cumulative degradation of spacecraft components
- Provide a means to gather data from sensors that would be affected by long wires (e.g., electric or magnetic field measurements)
- Measure the antenna pattern of a spacecraft communications antenna in-flight

In the upcoming mission, RFTSat will focus measurements on space weather.

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Mission Objectives

NNU RFTSat expects to launch in 2017 with the objective of successfully measuring space weather using distributed, passive RF sensor tags. The objectives of the mission are:

- Collect space weather data wirelessly from an energy harvesting RF tag
- Demonstrate data collection with different distances between the reader and tag
- Provide sustained data throughout the satellite's life

RFTSat subsystems will be built primarily using commercial off the shelf (COTS) components. The CubeSat structure, electrical power system (EPS), radio, battery, and on-board computer (OBC) will all be chosen with the goal of conserving power to enable frequent use of the RF tag/reader system. Figure 2 shows top level diagram of RFTSAT. systems.

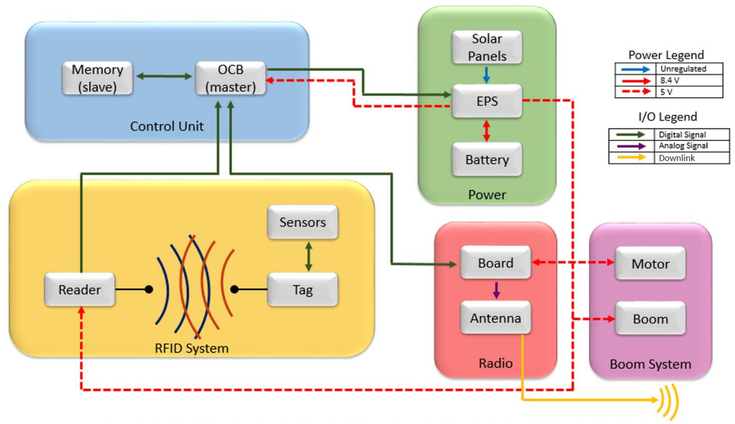

Figure 2: RFTSAT Systems Summarized in a Functional Block Diagram

Sensors

RF tags can be configured to contain different types of sensors. As energy harvesting RF tags are only active for short periods of time during a read, passive sensors are useful for lengthy total accumulation measurements. Alternatively, active sensors can be used to provide single data points, bu make no measurements until the tag is read.
Sensors types are limited only by size and power consumption.
Examples of sensor varieties included in RFTSat's RF Tag system are:

Passive

- MOSFET Radiation Dosimeter

Active

- Temperature
- Distance (derived from phase and magnitude of signal received from the tag)
- UV photodiode

RF Backscatter Technology

The RF tag system being used on the RFTSat's payload is a wireless, microwave (5.8 GHZ) system based on the design of tags that use backscatter radio to communicate. The RF system consists of two parts, a reader which broadcasts electromagnetic radiation, and a tag which harvests the radiated energy to perform sensor measurements. The tag communicates information back to the reader by modulating impedance to reflect the broadcast radiation in varying amounts. Backscattering the signal achieves the following advantages as a method of communication:

- Allows use of passive, energy harvesting RF tags.
- Eliminates risk of interference from stray currents on wires
- No battery required on tag – allows for more flexible and lightweight design
- No wires simplifies deployable boom design

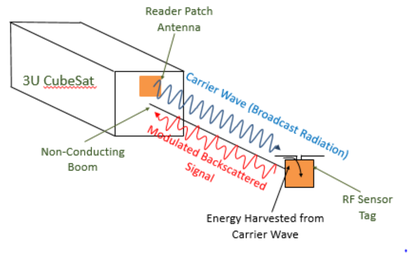

Fig 4: RF Backscatter Communication

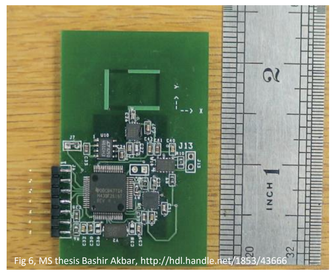

Fig 6, MS thesis Bashir Akbar, http://hdl.handle.net/1853/43666

Figure 3: 5.8 GHz RF Tag similar to those planned for use on RFTSAT.

Expected Results

RFTSat will be outfitted with a RF Tag mounted sensor capable of measuring total ionizing radiation dose. Trends in Dose rate will coincide with solar activity and orbital altitude. Additionally magnitude and phase of backscattered radiation will be recorded in order to calculate tag distance. Fig 5 shows expected data for reflected magnitude and phase parameters.

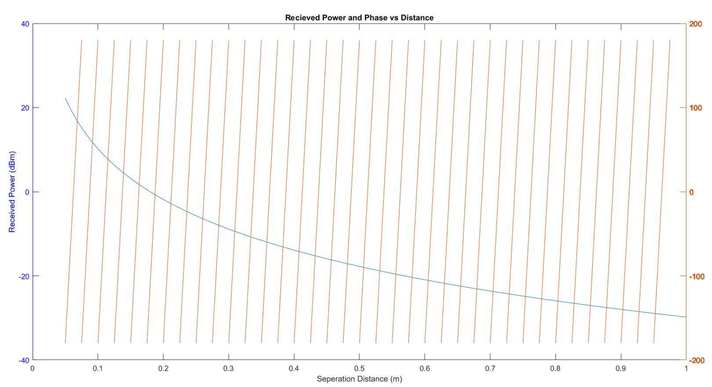

Fig 5: Received backscatter phase and magnitude. 1 watt radiated power starting at 5 cm separation distance.