Revision Matrix

Revision	Date	Description
1	12/6/2018	J Griffin -- created doc
2	2/19/2019	A Johnstone -- revised Globalstar antenna to NSL antenna and removed boom references
3	2/26/2019	J Griffin -- Removed boom references, updated figures, updated conops
4	5/20/2019	Removed deployable solar panels from figures and updated CONOPS

Radio Frequency Tag Satellite (RFTSat) Overview

Mission Summary

The Northwest Nazarene University Radio Frequency Tag Satellite (RFTSat) team is designing and building a 3U CubeSat to demonstrate the application of radio frequency (RF) energy harvesting and backscatter communication to the problem of distributed sensing in space. For this mission, a passive RF tag containing various space weather sensors will be mounted inside the satellite. The tag will not contain a battery, but will be powered by energy emitted from an RF reader onboard the satellite. The tag's sensor data will be wirelessly sent back to the reader via backscatter communication, and then to the Earth via a Globalstar satellite constellation link. RF tags equipped with sensors could be added to a spacecraft, like the ISS, without additional wires or power supplies and provide a means to monitor structural integrity, space weather, or make sensitive electric/magnetic field measurements.

Spacecraft Operations

The purpose of RFTSat is to demonstrate the use of RF energy harvesting and backscatter communication in space. The beauty of this type of backscatter system is that all of the complexity and power consumption is kept on the reader (powered by its own source) allowing the tag to be made very inexpensively and without batteries or wires. In such a system (shown in Figure 1), a reader communicates with a small tag that can be adhered to an object (such as a distant spacecraft surface) much like a postage stamp or barcode sticker. The tag does not contain a battery, but instead powers itself by harvesting energy from the RF signal incident on it from the reader. The tag communicates data back to the reader by modulating the RF signal that is scattered (i.e., reflected) from its antenna. The information transmitted from the tag could be any type of digital or analog information, including data from various sensors on the tag.

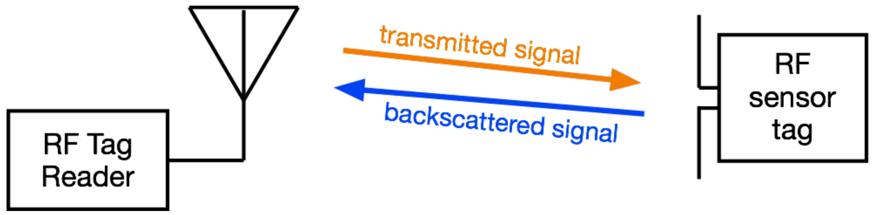

Figure 1:A backscatter RF tag system is divided into two parts: a reader and a tag. The transmitted signal is harvested to provide energy to the tag and the backscatter signal provides low-power communication from the RF tag back to the reader.

On RFTSat, the RF tag reader and tag will be housed in the body of the satellite about 4cm apart. The RF tag will contain a temperature sensor. The RF tag reader has two antennas: a transmitter antenna (microstrip patch antenna) that emits a continuous-wave signal at 5.8 GHz and a receiver antenna (microstrip patch antenna) that receives the modulated backscatter signal from the RF tag. These microstrip patch antennas are made on the same substrate with a slotted ground plane for increased isolation; they are not used as an array. The tag also contains two antennas: a harvester antenna (i.e., a two-element microstrip patch antenna array) that passes energy harvested from the continuous-wave signal emitted by the reader to the tag's energy harvester circuit and a communication antenna (microstrip patch antenna) that modulates the portion of the reader's transmitted signal that it scatters. This backscattered signal is modulated with the data from the tag's sensors.

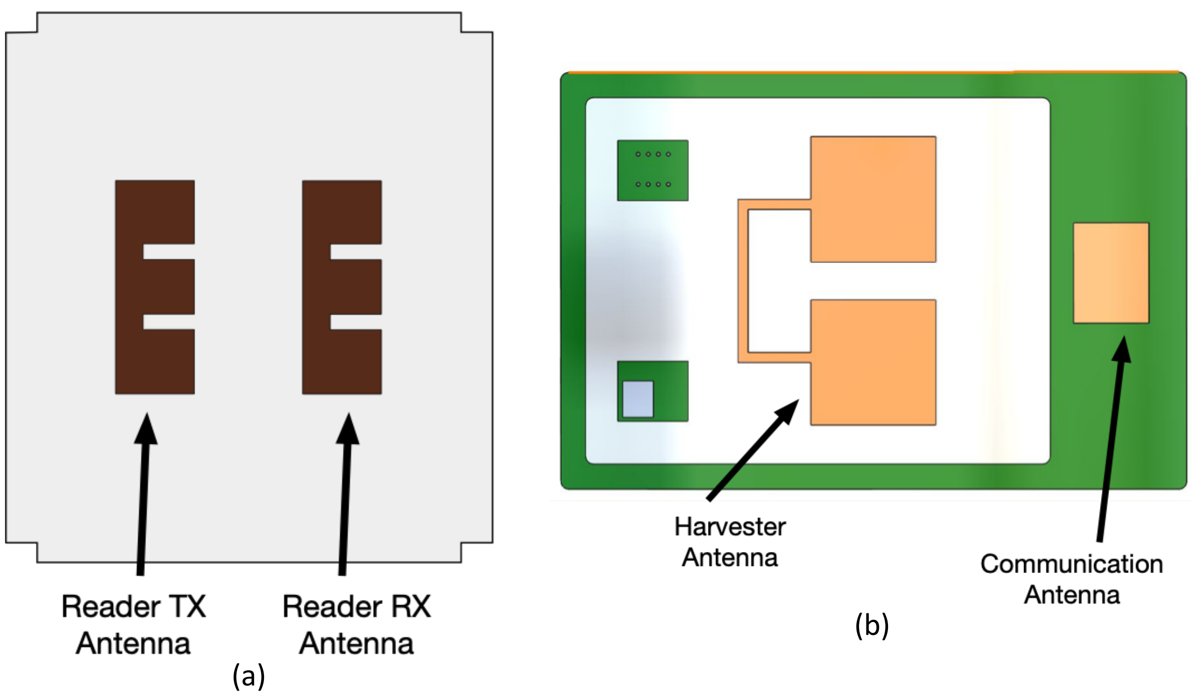

Figure 2: The (a) RF tag reader transmit and receive antennas and (b) the harvester and communication antennas of the RF tag.

The RF tag system described above is fundamentally different than many radio systems used on satellites. The RF tag system establishes an intra-satellite communication link that contains three parts: a reader transmitter, a reader receiver, and a passive RF tag. The RF tag transmitter emits a continuous-wave signal at 5.8 GHz that is absorbed by the tag's energy harvester antenna. The reader transmitter's continuous wave emissions are also scattered by the RF tag's communication antenna and received by the RF reader receiver. Communication between the tag and reader is achieved by the tag varying the phase of the signal scattered off its antenna. The RF tag is a passive device. It does not generate or emit an RF signal; instead, it simply changes the phase of the signal scattered by its antenna by changing the electrical impedance attached to the its communication antenna.

Once in orbit, the RF tag reader will begin to transmit an unmodulated signal at 5.8 GHz to the RF tag located approximately 4cm away from the reader. The RF tag will harvest energy from the 5.8 GHz signal and modulate the portion of the backscattered signal, which will be sampled by the RF tag reader receiver. The tag will be read repeatedly and the data from the tag downlinked via Eyestar Simplex radio from Near Space Launch. As done on previous missions, a Grid-eye horizon sensor will prevent the Eyestar radio from transmitting when facing earth. A Grid-eye horizon sensor has also been installed facing the bore-site direction of the RF tag reader transmitting antenna. It can be used to prevent the RF tag system from transmitting when facing earth, if required. As shown in Figure 3 and Figure 4, the tag is mounted on the side of the satellite and its antennas face inward towards the RF tag reader antenna that is housed in the frame of the satellite. Thus, the backscatter channel through which the RF tag system operates is located inside the satellite.

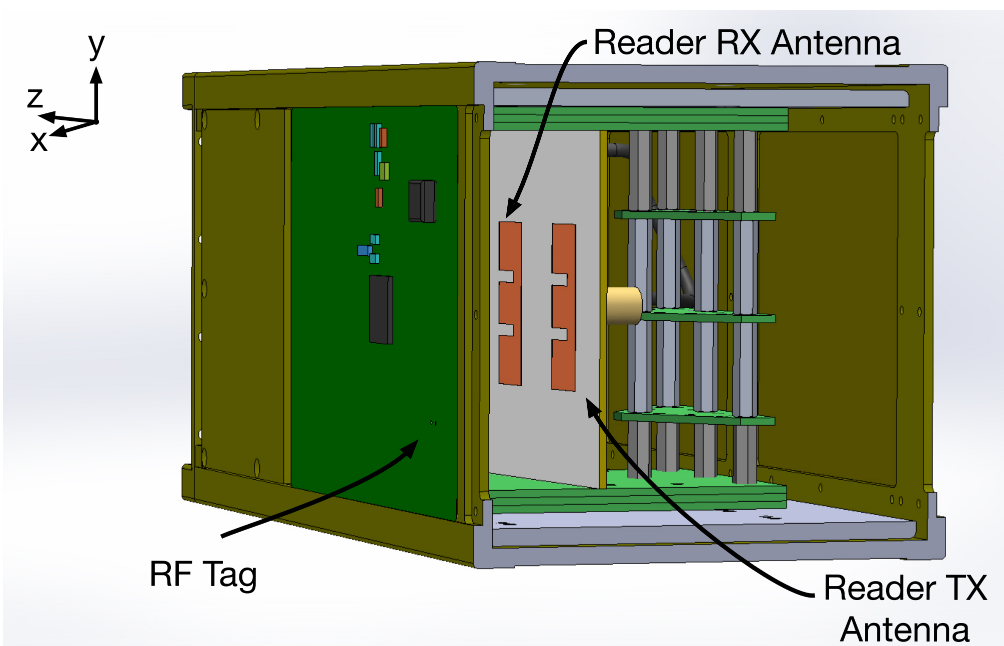

Figure 3: Cutaway view of RFTSat showing the RF tag mounted on the side of the satellite and the RF tag reader antennas housed within the satellite. The RF tag antennas face towards the inside of the satellite and harvest and backscatter energy transmitted from the RF tag reader.

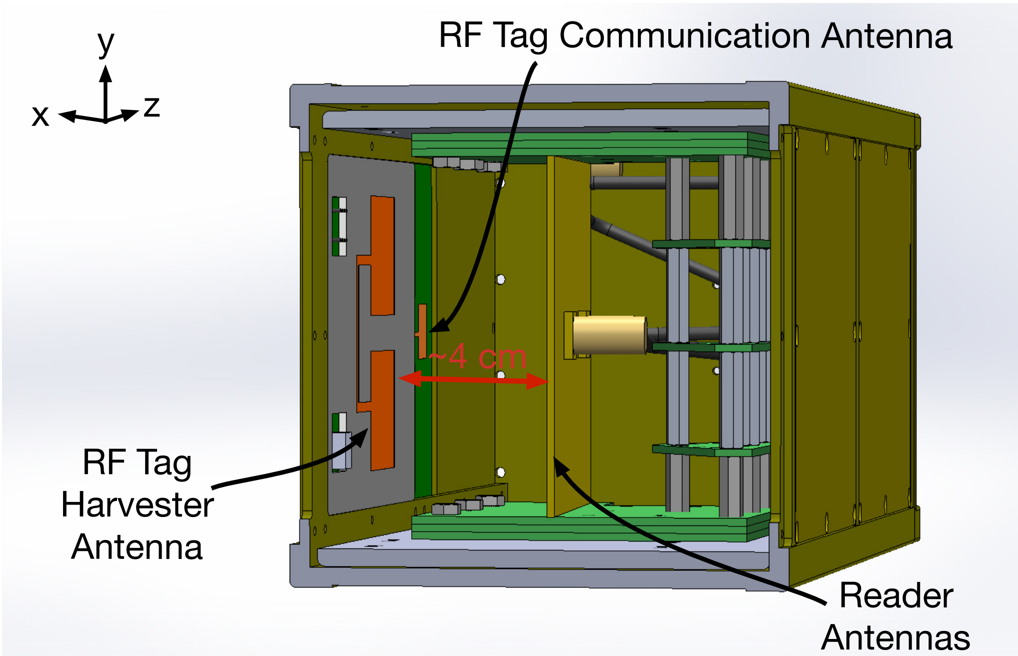

Figure 4: Cutaway view of RFTSat showing the RF tag mounted on the side of the satellite and the RF tag reader antennas housed within the satellite. The RF tag antennas face towards the inside of the satellite and harvest and backscatter energy transmitted from the RF tag reader.

CONOPS Overview

Phase 1: Startup (Day 1)

Upon deployment, RFTSat will power up and start a 30 minute countdown timer. At 30 minutes, the GlobalStar radio will activate and downlink 10 health beacons containing satellite telemetry data. Once the health packets have been sent, the burn wire mechanism will fire (even though the deployable panels have been removed, the firmware is still programmed to fire the burn wires), power will then be available to the payload; however, payload operations will not start for several orbits to allow the batteries to charge.

Phase 2: Conops (Weeks 1-8)

At this point, the satellite will enter its main conops mode. In the conops, the RF tag reader will be periodically powered (1-3 times every 2 days) and the data collected from the RF tag downlinked via the Eyestar Simplex radio (5-10 times every 2 days). The RF tag data will come from a temperature sensor and, possibly, a total dose ionizing radiation sensor (i.e., RadFET). Satellite health data will be downlinked via the EyeStar radio every 15 minutes. The RF tag system will operate for 8 weeks and will then be shut off by the NSL onboard computer.

Phase 3: NSL Phase (Weeks 9-Re-Entry)

During this phase, NSL will shut down the NNU payload and will use the remainder of the satellite's life to test the longevity of their hardware systems. NSL will continue to transmit satellite health beacons and data from their sensors (two 8x8 pixel infrared horizon sensors and pin diode particle detectors) to Globalstar periodically.

Deployables

RFTSat contains no deployables. The flight configuration of RFSat is shown the figure below.

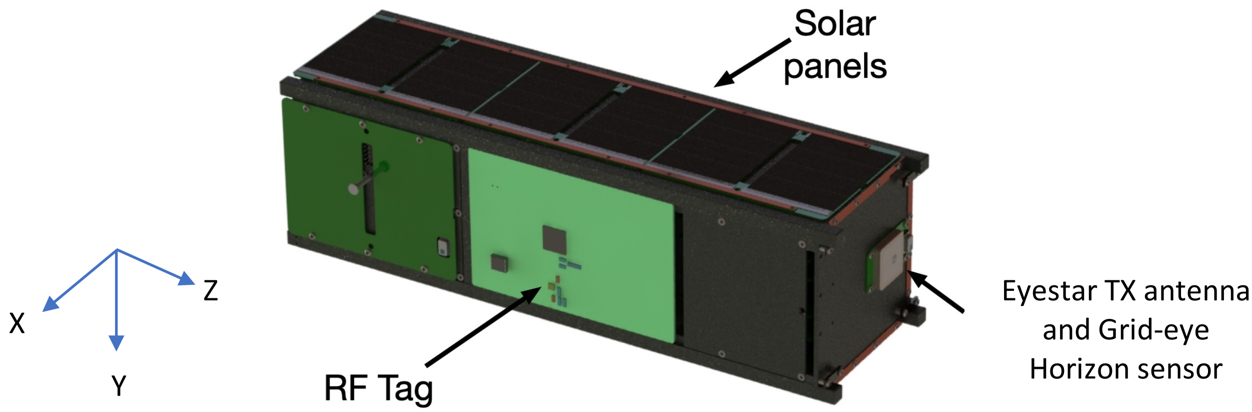

Figure 5: RFTSat in its flight configuration. Note ,the Eyestar RX antenna (not shown) is located on the Z- face of the satellite.