Autonomous capturing of ORBCOMM satellite transmissions for Earth remote sensing (ERS)

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Introduction

Our team is tasked with utilizing Signals of Opportunity to determine changes in the coefficient of reflection of the surface of the earth. This data can then be used to determine soil moisture content several meters below the surface, in the root-zone of the farmland we are surveying. Previous attempts have been made in the EHF band, but these signals only penetrate a few centimeters into the ground. By receiving signals in the VHF band, we are able to calculate soil moisture content several times further beneath the surface, leading to more long-term measurements of soil moisture.

Previously, performing remote sensing with Signals of Opportunity was limited to stationary towers or manned flights. Stationary towers have limited range, and manned flights are expensive. By utilizing a Software Defined Radio and a commercial UAV, remote sensing using these signals can be done autonomously.

A USRP E310 Software Defined Radio has been configured to collect VHF signals from ORBCOMM communication satellites. The radio and RX antennas are attached to a DJI Matrice 600 Pro UAV such that the receiver can collect data from different locations autonomously.

Our team expects to measure various coefficients of reflection dependent upon the moisture content of the medium that the signal reflects off of. In the case of more torrid soil conditions, we would expect a low relative coefficient, properly irrigated soil would have a coefficient between 0.6-0.9, and a body of water would produce a coefficient ~1.0.

Objectives

- To collect orbcomm signal and GPS data
- To create antennas to collect a direct and reflected signals of the orbcomm satellite
- To create a mounting solution for the radio, power supply, and other electronic components onto the drone
- To be able to process cross correlation between direct and reflected signals

Materials

- Copper Rod ⅛”
- Helix Antennas Power Supply
- Laptop Inspiron 15
- DC Block
- Coax Cables
- Amplifier ZFL-500LN
- USRP E310 Radio
- Portable Power Supply 15V
- Drone DJI Matrice 600 Pro

Figure 1: USRP E310 Radio

Methods

- In Lab Network Analyzer Test of the helix antenna to prove that the antenna functions within the range it was built for, 135 MHz to 140 MHz
  a. Connect the helix antenna to the Network Analyzer
  b. Set Start Frequency to 130 MHz and Stop Frequency to 150 MHz
  c. Make sure antenna is at least 4 feet away from any other objects
  d. Check measurement reading to see the dip or null at the range the antenna should be receiving (137 MHz - 138 MHz for ORBCOMM Signal collection)

- In Lab Test , ARMS 3105, of the helix antenna to make sure it properly receives a signal before collecting the Orbcomm signal in the field
  a. Turn on Signal Generator
  b. Set Frequency to 137.3 MHz (setting slightly different frequency to see the signal that is different than the set DC offset)

Methods (cont.)

c. Attach a stick Antenna to the output of the signal generator

d. Attach the White PVC Helix Antenna to the coax cable to one end of the Amplifier

e. Attach the other end of the coax from the Amplifier to the DC Block

f. Attach the DC block to one of the receiver ports (Rx-2a) of the E310 Radio

g. Connect the Power Supply and E310 Radio to the power outlet in the lab

h. Connect the Amplifiers power cables to the Power Supply

i. Connect to Radio via SSH

j. Use the Laptop to launch the recording program to collect data for 1 minute

k. Recreate signal in Matlab using recorded data. The recreated signal should match the Sine wave created by the signal generator.

- In Field Test , ACRE 51, of the helix antenna to make sure it properly receives a signal for collecting the Orbcomm
  a. Connect the radio to the power outlet inside the shed
  b. Set up the PVC Helix Antenna outside the shed into the field about 20 feet
  c. Attach the White PVC Helix Antenna to the coax cable to one end of the Amplifier through the window of the shed
  d. Attach the other end of the coax from the Amplifier to the DC Block
  e. Attach the DC block to one of the receiver ports (Rx-2a) of the E310 Radio
  f. Connect the Power Supply and E310 Radio to the power outlet in the shed
  g. Use the Laptop to launch the program to collect data for 1 hour
  h. Use Orbitron (free Satellite Tracking Software) to keep track of active satellites overhead to
  i. Input data into Matlab program in the lab to check if any Orbcomm signals were collected from the field test. A successful test will show signals at some Orbcomm channels when Orbcomm Satellites are overhead along with a doppler shift (due to the satellite’s motion relative to the antenna)

- Figure 2 displays the configuration used to receive ORBCOMM signals with the helix antenna.

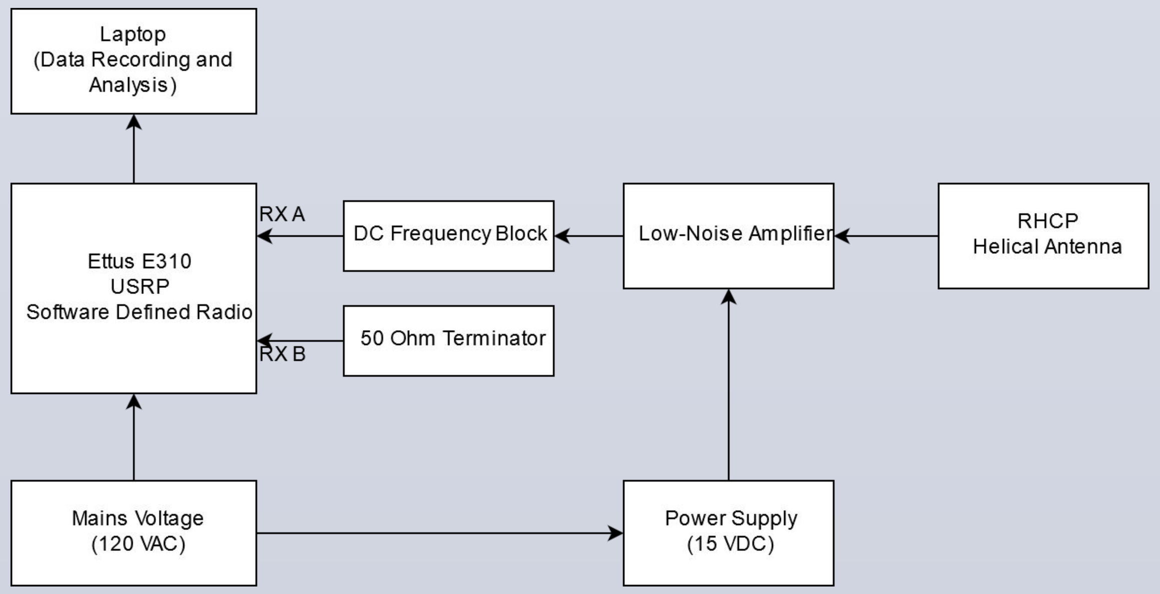

Figure 2: Helix antenna configuration

Methods (cont.)

- The table shown in figure 3 shows the values used to calculate a link budget. A link budget is a summation of all the gains and losses for the network to determine whether the system can receive and transmit efficiently.

Transmit EIRP	12.0	dBW	
Spreading Loss	-140.1	dBm^2	
Atmospheric Losses	0.2	dB	
Polarization Losses	4.1	dB	S/C 2 dB axial ratio, subscriber linear
Multipath Fade Losses	5.0	dB	
Satellite Pointing Loss	0.3	dB	5 degree off-nadir pointing
Area of an Isotrope	-4.2	dBm^2	
Power @ User Antenna	-141.9	dBW	

Figure 3: Values used to calculate link budget [1]

Results

- Figure 4 shows the team testing the helix antenna to receive ORBCOMM signals. The testing took place at Purdue ACRE 51.

Figure 4: Helix antenna testing (located at Purdue ACRE)

- Figure 5 displays the reception of ORBCOMM signals. Figure 6 is a zoomed in portion of the same graph displaying the expected doppler shift.

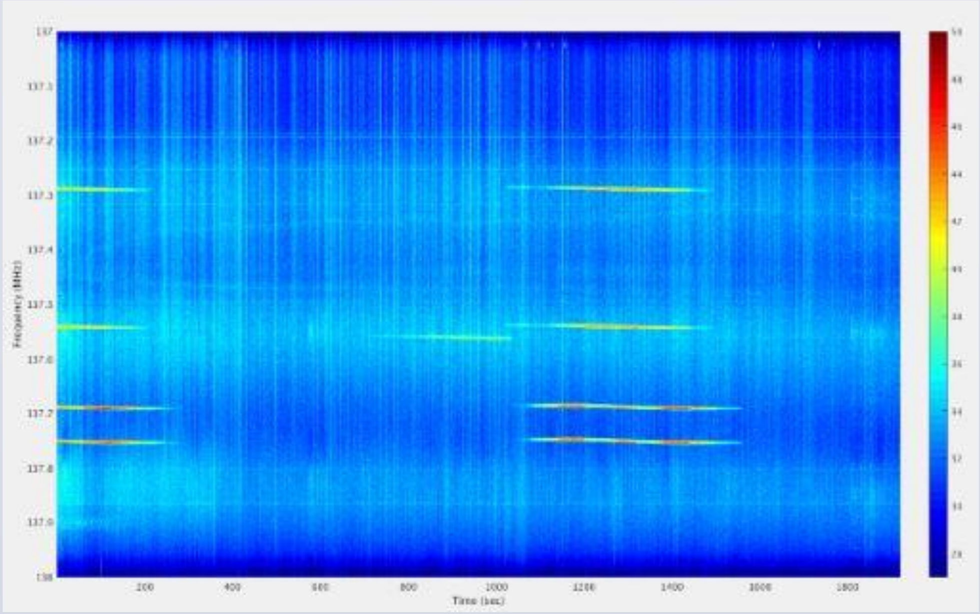

Figure 5: Received ORBCOMM signals

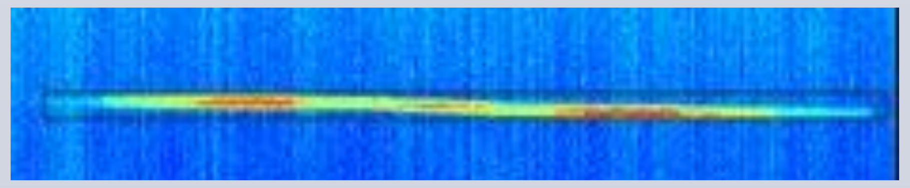

Figure 6: Doppler shift of a received ORBCOMM signal

Results (cont.)

- The table shown in figure 7 shows a file of the extracted GPS data from the GPS receiver. The goal for getting these extracted data is to plot the specular points (spots of reflection).

```
Time | Latitude | Longitude | Altitude
"2019-02-19T23:05:52.000Z" | 40.431052174 | -86.915269537 | 207.595
"2019-02-19T23:05:53.000Z" | 40.431052617 | -86.915269430 | 207.414
"2019-02-19T23:05:54.000Z" | 40.431053283 | -86.915269143 | 207.373
"2019-02-19T23:05:55.000Z" | 40.431054806 | -86.915268994 | 207.452
"2019-02-19T23:05:56.000Z" | 40.431055577 | -86.915268962 | 207.460
"2019-02-19T23:05:57.000Z" | 40.431056651 | -86.915268412 | 207.643
"2019-02-19T23:05:58.000Z" | 40.431057214 | -86.915268263 | 207.632
"2019-02-19T23:05:59.000Z" | 40.431058212 | -86.915267970 | 207.610
"2019-02-19T23:06:00.000Z" | 40.431059369 | -86.915267344 | 207.644
"2019-02-19T23:06:01.000Z" | 40.431060415 | -86.915267039 | 207.600
~
```

Figure 7: Extracted GPS data

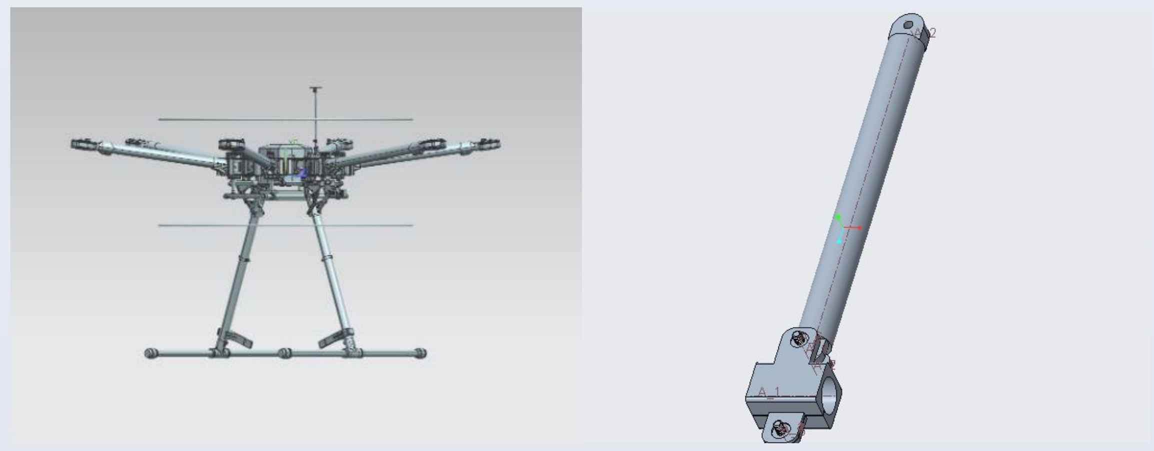

Figure 8: The drone CAD and the support arm

Mounting Plan

- Top and bottom of the drone. One for direct signal one for reflected signal
- 60 cm above and below the drone to avoid the drone GPS interference
- Attach support from drone arms to the corner of the drone
- CAD the drone, support arms and radio
- Manufacture all the parts and mount it on the drone

Conclusions

- Our tests have shown that ORBCOMM can be collected reliably with the USRP E310 through the helix antenna.
- We have created three tests that can be used to verify that a certain antenna will collect ORBCOMM signals with our USRP E310 setup.
- A Loop Antenna provides a low profile shape that is easily manufactured and attached to the DJI Matrice 600 Pro drone.
- The next steps for our team is to manufacture and perform our three tests before mounting the antenna onto the drone. Once the system is mounted to the drone, measurements can be taken of direct and reflected signals from ORBCOMM that can be analyzed to determine reflectivity of the ground, which relates to the Root Zone Soil Moisture (RZSM)

References

1. David M. Pozar “Microwave Engineering Fourth Edition” Hamilton Printing, 2012
2. Reid, Sarah. “ORBCOMM LABSAT MANUAL.” ORBCOMM LLC, 18 Dec. 2001.
3. DJI, Support team. “Matrice 600 pro User Manual .” DJI, Apr. 2018.

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