Team: Earth Remote Sensing
Year: Spring 2019
Team Members: Andrew Nguyen, Christina Lo, David Chen, Eric Smith, Jonathon Warnick, Leo Li, Nick Demsher

Earth Remote Sensing Final Report

Table of Contents

Introduction

The amount of water that is in soil is important information for several fields of study. In agriculture, this information is used to judge how much water is available to plants as they grow and what areas need more irrigation. Meteorology uses soil moisture measurements to better predict floods and droughts, and climatology tracks the long term trends of soil moisture and the impact of climate change.

One way this soil moisture can be measured is by looking at how radio waves are reflected off the ground. Currently, remote sensing such as this requires stationary towers or manned flights. By using an Unmanned Aerial Vehicle (UAV) mounted receiver and Signals of Opportunity (SoOp) from communication satellites, we can quickly take these measurements over a large area of land. The communication satellite signals are used to illuminate the ground, while the UAV mounted receiver is used to capture a direct signal from the satellite and a reflected signal from the ground. These two signals are then compared to determine the reflectivity of the soil, which relates to the soil moisture.

Objective

The objective for this team was to develop a system for collecting direct and reflected signals from ORBCOMM communication satellites, that could be mounted onto an Unmanned Aerial Vehicle (UAV). This included designing an antenna that would capture ORBCOMM signals, designing a lightweight power supply to power the receiver, and designing a lightweight mounting system to attach the receiver and antenna to the UAV. The final objective for our team was to be able to compare direct and reflected signals through cross correlation.

Antenna Design

Our team needed to design and construct a system composed of two antennas that would be mounted above and below the drone in order to obtain the satellite signals of opportunity. After initial research and getting acquainted with the overall goals of the project as well as the semester goals, the antenna design team created a list of criteria for developing our drone. While this list is not meant to be all-encompassing, it is the criteria we used to compare antenna designs during the course of the 2019 Spring semester. The criteria are as follows:

1. The design must be able to receive both direct signals originating from above the drone, as well as receive the reflected signals reflecting from below the drone.
2. The design must be volumetrically compact enough to avoid interfering with the drone's propellers or landing legs.
3. The design must be able to receive direct and reflected signals with uniform power regardless of the heading of the drone (design must be omnidirectional).
4. The design must be lightweight enough to avoid overloading the drone.

Several antenna concepts were researched to decide what would make the most sense mounted to a drone. The main categories of antennas considered were monopoles, dipoles, loops, patch antennas, and helical antennas. After researching the strengths and weaknesses of each antenna configuration and comparing them to our design criteria, our team decided that a full-wavelength loop antenna would be the best fit for our purposes. Referencing our target center frequency of 137.225MHz and accounting for the minor frequency shift as the signal traverses Earth's atmosphere, we determined that the necessary wavelength of our antenna would have to be 2.186 meters.

During the next phase of antenna design, our team focused on choosing a specific loop shape for our antenna. The first iteration was to build a circular loop, however we quickly ran into problems trying to develop a manufacturing technique for a perfectly circular loop antenna. Deciding that maximizing our cross-sectional area for the same perimeter was the most power-efficient shape (Prof. Garrison later explained this logic to be erroneous), we next decided to shape our antenna as a regular hexagon by purchasing and cutting straight copper rods and soldering them together, along with a support structure emulating the spokes on a bicycle wheel. However, we similarly ran into problems creating a 6-fold symmetric support structure presenting a manufacturing problem, and another iteration was necessary.

The design that was successfully constructed was actually a square loop, with three corners soldered together and the fourth corner connected to an SMA connector. The support structure had not been fully manufactured as designed by the end of the semester, so a rudimentary structure was created in an attempt to perform tests on the antenna before the semester ended. Guidelines for how to manufacture the intended support structure will be found in the Mounting Design & Instruction section of this report.

Antenna Testing

The exact materials, procedure, and results of each test is provided in the Test Report Forms section of the Lab Notebook. This section provides an overview of the objective and methods of each of the tests that we developed to test the antenna.

The Network Analyzer Test is the first of three tests to tell us if a certain antenna will work with our system. The network analyzer test is designed to tell us whether a certain antenna has the ability to capture signals in the frequency range that we need by looking at the resonance frequencies of the antenna. Using a Field Fox, network analyzer, we perform a S11 test on the antenna. The S11 test tells us the response of the antenna given a range of frequency inputs. If the response shows a dip at some frequency, that antenna is resonant at that frequency and will transmit/receive signals at that frequency. The range of frequencies that we are looking for is from 137 MHz to 138 MHz, if there is a dip in the response within this range, then the antenna has passed this test and can continue to the Lab Recording test.

The Lab Recording Test is used to make sure the radio can record signals in the range that we want with the antenna being tested. To do this we create a signal using a signal generator which is transmitted through a monopole antenna in the lab. The antenna being tested is attached to the radio receiver system and the radio is set to record the signal (see the User Manual developed by the Fall 2018 team in Google Drive > Previous ERS Team Files >Final Report and Presentation > Final Report or test documents in the Lab Notebook for instructions on how to record a signal). If the signal made in the signal generator can be recreated through the data recorded by the radio, then the antenna passes the lab recording test and is ready to be tested in a field recording.

The Field Recording Test is a test to make sure that the antenna can record actual ORBCOMM satellite signals. To do this, the antenna to be tested and the receiver system is taken to an open area so that we have good line of sight to satellites that may be overhead. The radio is set to record (following instructions for previous test) and left to record signals for at least 30 minutes in order to get enough data to analyze. While recording, we use a satellite tracking software, such as Orbitron or STK, to tell us whether active ORBCOMM communication satellites are overhead. One of the criteria for the test is that there is a visible signal when active satellites are overhead. When the power spectrum density of the recording is plotted, we expect to see signals that correspond to the ORBCOMM Satellite channels seen below.

Channel No.	Channel Freq. (MHz)	Channel Bandwidth (kHz)	Data rate (kbps)	Polarization
S-1	137.2000	25	9.6/4.8	RHCP
S-2	137.2250	25	9.6/4.8	RHCP
S-3	137.2500	25	9.6/4.8	RHCP
S-4	137.4400	25	9.6/4.8	RHCP
S-5	137.4600	25	9.6/4.8	RHCP
S-6	137.6625	25	9.6/4.8	RHCP
S-7	137.6875	25	9.6/4.8	RHCP
S-8	137.7125	25	9.6/4.8	RHCP
S-9	137.7375	25	9.6/4.8	RHCP
S-10	137.8000	25	9.6/4.8	RHCP
S-11	137.2875	25	9.6/4.8	RHCP
S-12	137.3125	25	9.6/4.8	RHCP
Gateway	137.5600	50	57.6	RHCP

Table D.1 - 137.0-138.0 MHz Downlink Channelization and Polarization Plan

Table. ORBCOMM Downlink Frequencies (From “ORBCOMM System Overview”)

We also expect to see a doppler shift in these frequencies due to the motion of the satellite relative to the receiver. According to “ORBCOMM System Overview” this doppler shift should be about 3 kHz or less. If the signals correspond to a valid ORBCOMM channel and have a doppler shift of 3 kHz or less when active satellites are overhead, then the antenna has successfully collected ORBCOMM signals and has passed the final test. These tests are necessary to make sure that the antenna being mounted to the UAV will actually collect the data that we need.

Power Supply Budget

Objective:

The objective is to determine the run time of the power supply,which the batteries in series configuration, during one full test to make see how much reserve is left.

Calculations:

The batteries are in series because the only way to output voltage that will power the electronic components, 15 V maximum. There needs to be some resistance load to keep the amount of voltage outputted to the correct voltage level for each electronic component.

Max Current Draw Calculation:

Max Current Draw = C rating x Amps

C = continuous discharge rate of a LiPo

Power = Voltage * Current

h = hours

Battery Data:

Turnigy 3 Cell 11.1 V 2200 mAh

Current Capacity: 2200 mAh

Voltage: 11.1 V

Constant Discharge: 25 C

Peak Discharge: 35 C

2.2 Ah * 25 C = 55 Ah for 1 battery

2*55 Ah = 110 Ah for 2 batteries

2.2 Ah * 11.1 V = 24.42 Wh for 1 battery

2 * 24.42 Vh = 48.84 Wh for 2 batteries

Reflective Switch:

MSP2T-18-12+

Voltage: 12 V

Max Current Draw: 230 mA

Max Power Consumption: 10 W

Amplifier:

ZFL-500LN

max current draw: 60 mA

Voltage: 15 V

Max Power Consumption: 0.9 W one amp

Max Power Consumption: 1.8 W two amp

2*60mA = 120 mA => 1.2A for 2 Amplifiers

Radio:

Max DC Voltage: 15 V

Max DC Current: 0.4 A

Max Power Consumption: 6 W

Reflective Switch

MSP2T-18-12+

Voltage: 12 V

Max Current Draw: 230 mA

Max Power Consumption: 10 W

Total Power Draw Needed by the Whole System:

6 W + 1.8 W +10 W =17.8 W (switch on)

6W + 1.8 W = 7.8W (switch out)

Total Run Time using 2 Batteries:

110 Ah / 4.2A = 26.19 h

48.84 Wh / 17.8 W = 2.74 h (switch on)

48.84 Wh / 7.8 W = 6.26 h (switch off)

Efficiency of the System:

[(Power Input - Power Output) / Power Input] * 100

[(48.84-17.8)/48.84] * 100 = 63.5% efficient (switch on)

[(48.84-7.8)/48.84] * 100 = 84% efficient (switch off)

Results:

Electronic Components	Max Power Draw	Number of Components
ZFL-500LN Amplifier	1.8 W	2
USRP E310 Radio	6 W	2
Reflective Switch	10 W	1
Power Supply	Max Power per Hour	
11.1 V LiPo Battery	24.24 Wh	2
Total Power Needed for Components	17.8	W
Total Power per Hour of Power Supply	48.84	Wh
Max Power Per Hour Run Time	2.74	h
Max Drone Flight Time for Single Test	1	h
Reserve Power After Single Drone Flight Test	1.74	h
Efficiency of the Power Supply (switch on)	63	%
Efficiency of the Power Supply (switch off)	84	%

Summary of Power Budget:

The results show that after 1 hour, full test time, the power supply will have at least 1.74 hours in reserve. The efficiency of the power supply is 63% when the reflective switch on and 84% when the reflective switch off.

Mounting Design and Instructions

Drone information

All the antennas, radio and other electrical components will be mounted on the UAV. The UAV we expect to use is a DJI Matrice 600 Pro. Some specifications of the UAV are shown in the following table.

Aircraft	DJI Matrice 600 pro
Weight	9.6 kg
Max takeoff weight	15.1 kg
Max wind resistant	8m/s
Hovering time (no payload)	40 min
Hovering time (max payload)	18 min

Table. DJI Matrice 600 Pro specifications

More specifications about the drone can be found in the Google Drive > Drone info > matrice_600.pdf, which is the user manual from DJI for this UAV.

Mass Budget

A major constraint for the mounting system is the mass of the payload that the UAV can lift. The payload specifications for the Matrice 600 Pro from the User Manual are displayed below.

Max Takeoff Mass(kg)	15.100
Drone Mass w/ Batteries (kg)	9.600

Max Payload Mass (kg)	5.5

Table. Payload Specifications for Matrice 600 Pro

This constraint of 5.5 kg payload mass includes all necessary electrical and structural components. The electrical components includes the radio, and any components the radio needs to collect the direct and reflected signals. The Structural components include any other components that would be used to attach the receiver to the UAV. The mass of each component is summed together to find out the total mass of the payload. Below is the table of all component masses, including the total masses for each category.

	Component Mass (kg)	System Mass Totals (kg)
Electrical Components		1.179
USRP E310	0.375	
2x Batteries	0.376	
Antenna	0.018	
2x Amplifiers	0.090	
Cables & Connectors	0.300	
2x DC Blocks	0.020	
Structural Components		2.235
12x Antenna Supports	0.360	

Aluminum Mounting Plate	0.375	
12x Antenna Mount Arms	1.200	
6 arm hub	0.3	

Table. Component Masses for both Electrical and Structural components

The total payload mass comes out to be 3.414 kg. The table below shows the total payload mass and our calculation for the remaining payload mass, which is the difference between the maximum payload mass and the total payload mass.

System Mass Budget (kg)	5.500
Total Payload Mass (kg)	3.414
Remaining Mass Budget (kg)	2.086

Table. Total Payload Mass and Remaining Mass Budget

Any future components should that are added to the system should also be added to this mass budget. Since the total mass of the payload is also related to the total flight time of the UAV, this system parameter should be limited as much as possible. If future teams find ways to decrease the payload mass, the system will be able to collect more data before having to land to recharge.

We have created a CAD for the drone for the convenience of future design. The CAD for the drone is located in the Drone info -> drone CAD folder and saved as a step file so it can be opened by any software. The Model is not allowed to be modified, but it can be used for measuring parameters and assembly.

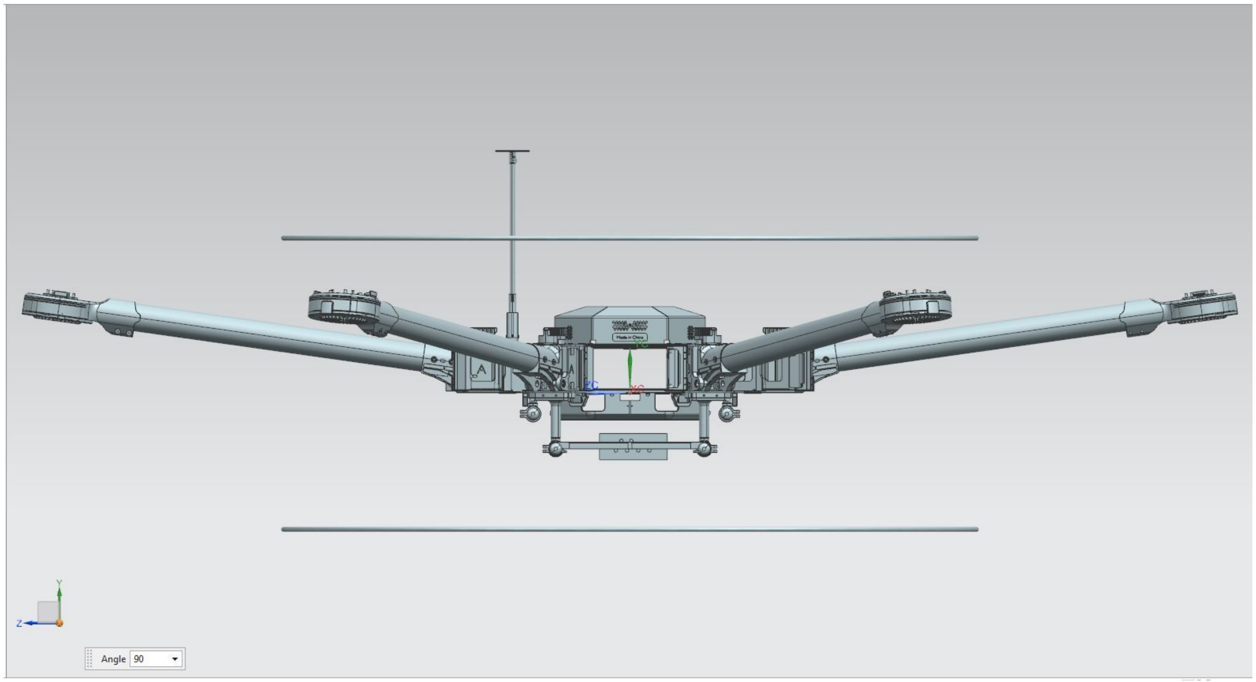


Fig. The CAD of the drone

Since the final antenna design has not done yet, we have to choose one of the designs from the alternative option. We have chosen the loop antenna for the mounting design. There will be two loop antennas on both the top and the bottom of the drone, they will receive the direct signal and the reflected signal. The loop antenna will be mounted above the GPS antenna so it won't affect the receive pattern. The loop antenna will be formed into a hexagon and each corner will be connected with the arm of the drone.

Manufacturing instruction:

The CAD for the mounting arms are made and stored in the folder drone info-> drone CAD -> arms.

All the things needed to purchase are shown in the

part	number	dimension	price	purchase link
carbon fiber tube	2	0.5inch dia* 72in/tube	103.25	https://dragonplate.com/Axially-Optimized-Braided-Carbon-Fiber-Tube-05-ID-x-72
carbon fiber connector	24	0.5 male clevis connector	7.6	https://dragonplate.com/05-Male-Clevis-Connector
socket head screw	12	M5*22mm	8.49	https://www.mcmaster.com/standard-socket-head-screws
rounded head screw	12	**M5 × 18 mm**	6.68	**https://www.mcmaster.com/standard-rounded-head-screws**
hex nut	24	M5	2.8	https://www.mcmaster.com/hex-nuts

The 3D model is made for the loop antenna. To edit or print the model, you have to use CREO Parametric to open the file, there are two parts need to be printed: hub.prt and antennacorn.prt. We need to print 12 of each part. The printing density needs to be above 25 below 30 to be strong enough for the structure and light enough.

The support arms will be made from carbon fiber. You will need to cut the carbon fiber tubes into shorter stages of 10 inches. There are a total of 12 tubes need to be made.

The mounting board needs to be manufactured. Holes need to be drilled on the the board and use zip ties to mount everything onto the board. The configuration is shown in the following picture. The board will be mounted to the the tubes on the bottom of the drone.

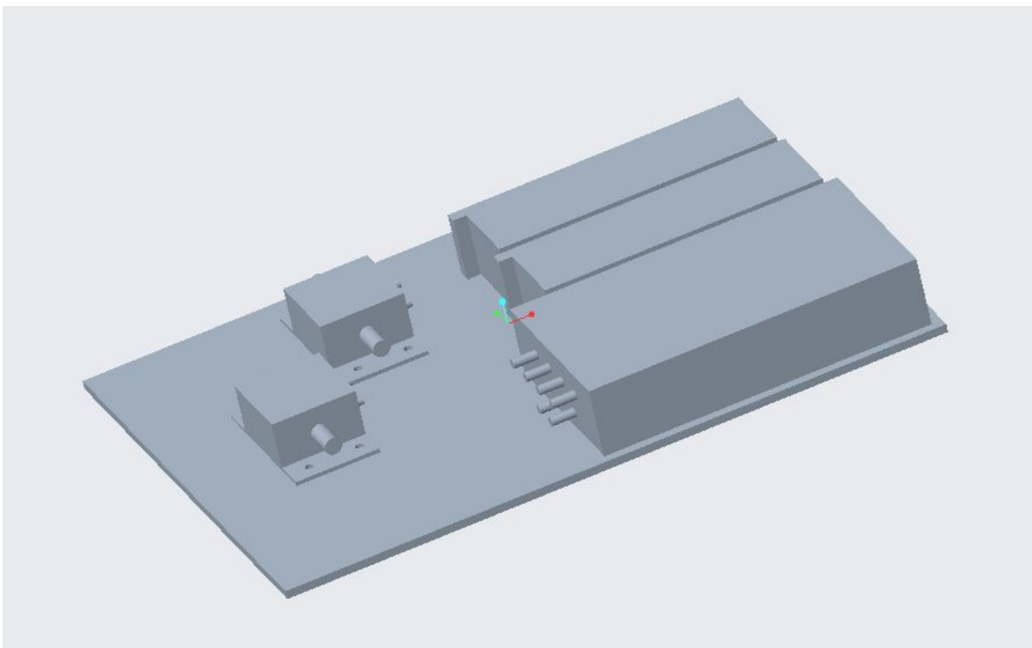


Fig. mounting configuration

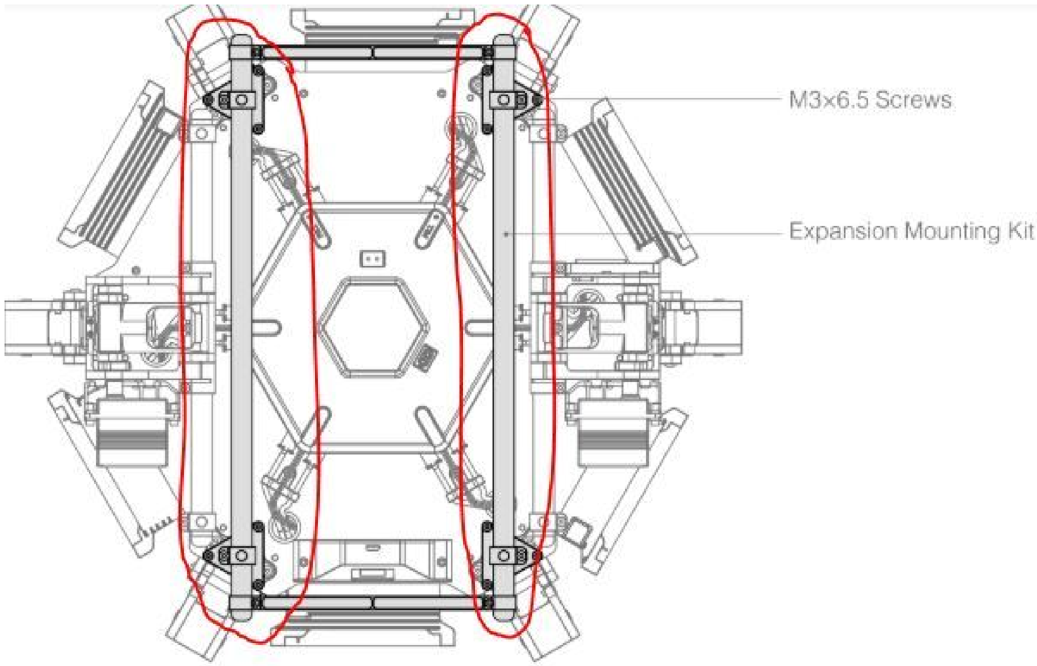


Fig. Mounting Set

Assembly instruction

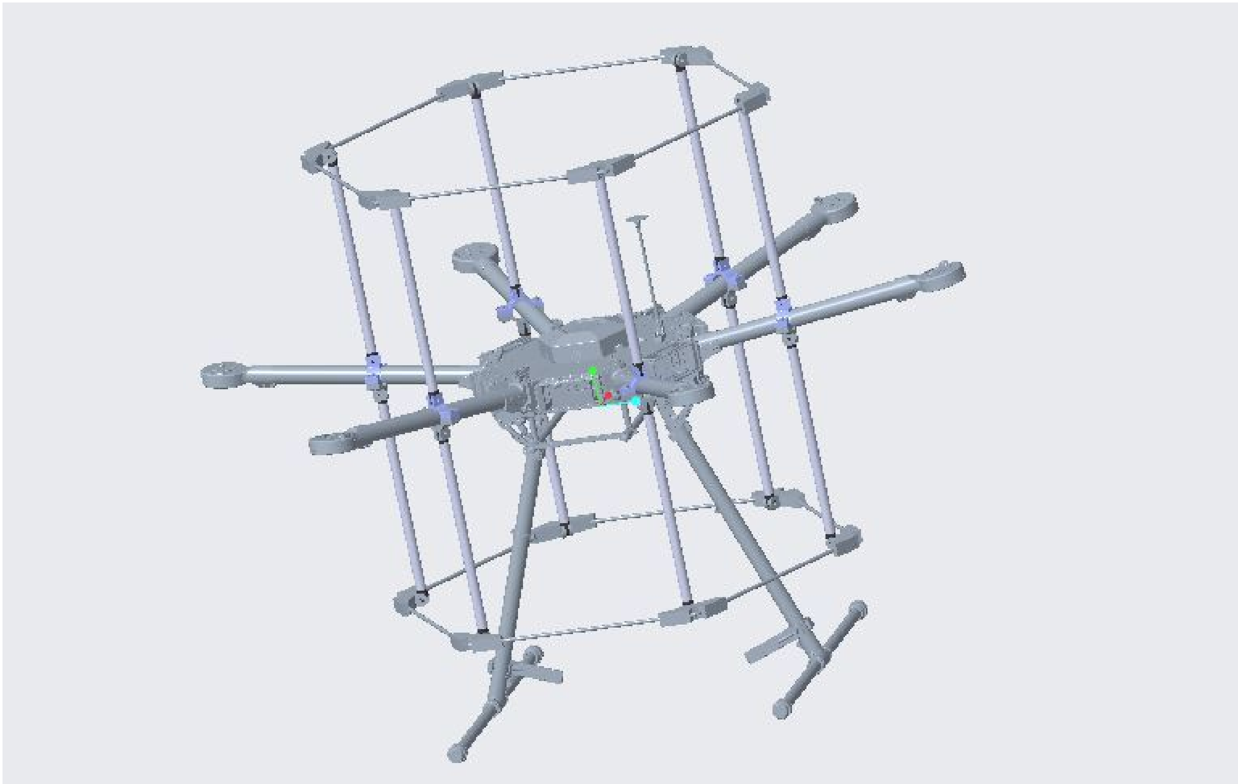


Fig. Full assembly diagram

1. Mount all the electrical component on the the mounting board. Connect them in sequence of radio->DC-block-> amplifier->antenna
2. Mount the board to the drone but do not connect the power supply until before the flight
3. Assemble the antenna

   For the loop antenna, cut the copper rod into six equally length road, and push them through the corner support. Solder the corners.

   For the monopole antenna, cut the ground plane into a hexagon and snap each corner into the corner support.
4. Assemble all the rods. Snap the end into the tube.

5. Assemble the hub. Take two pieces of the printed hub, get a piece of rubber in between them and use the screw to tighten the two hubs.
6. Assemble the hub with the rod.

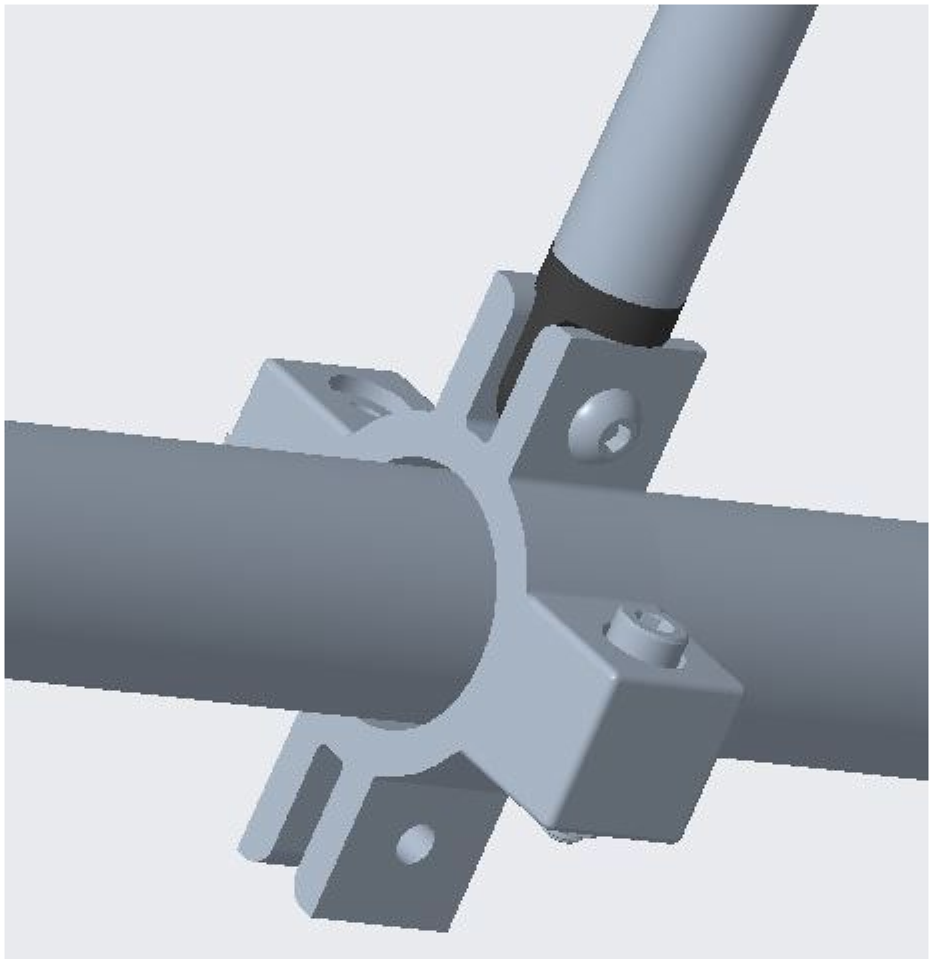


Fig. hub mounting instruction

7. Repeat step 4-6 for all six corners.
8. Assemble the antenna to the rods and connect it to the electrical board.

Link Budget Information

The link budget is needed to determine the net received power available for the system. The summation of the gains and losses determine this value. A system's link budget can be represented by the following logarithmically expressed equation

$$P_{RX} = P_{TX} + G_{TX} + G_{RX} - L_{TX} - L_{FS} - L_M - L_{RX}$$

Where: PRX - received power
PTX - transmitter output power
GTX - transmitter antenna gain
GRX - receiver antenna gain
LTX - transmitter losses
LFS - free space loss
LM - miscellaneous losses
LRX - receiver losses

all are expressed in unit of decibels (dB).

Where most of these values need to be calculated (such as free space loss), ORBCOMM provides many of these values on their datasheet as seen below.

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	

Other loss factors needed to be considered when calculated the link budget. Listed below are the miscellaneous losses through cables and the E310 radio system.

Content	Value	Unit	remarks
Power at Antenna	-111.9	dBm	converted from dBW
ERS Helical Antenna Gain	5.0	dBi	QFH Antenna Gain
Coax Losses	0.45	dB	10 ft RG58 @ 137 MHz
E310 Internal LNA Gain	60	dB	Adjustable in software
Final RX Signal Level	-46.45	dBm	

The main conclusion drawn from the information above is the final RX signal level. The next step is to determine the minimum threshold in which the system can operate.

Data Collection and Analysis

Cross-Correlation is a measurement of similarity of two signals. It is the way to analyze the direct and reflected signals captured from ORBCOMM. Through the result of cross-correlation, we get the time lag between two signal. The lag from cross correlation can furthermore be use to find the moisture level of soil, reflectivity of signal...etc.

cross_correlation.m

- Coding Process
    - Read each file(captured from ORBCOMM) stored inside the data path
    - Run the data for each
    - Apply Fast Fourier Transform for both signals
    - Using the property of discrete function:

      $$(f \star g)[n] \triangleq \sum_{m=-\infty}^{\infty} \overline{f[m]} g[m+n]$$

      (FFT of signal 1) * conjugate (FFT of signal 2) will equal to result of cross correlation
    - Convert the frequency domain back to time domain by inverse Fast Fourier Transform to create the cross-correlation plot
- Procedure
    - Open cross_correlation.m from the folder.
    - Change sampling frequency and integration time based on how data was conducted.
    - Change directory from where the file is collected, and make sure there’s one direct and reflect data file(*0.sc16 and *1.sc16) for each set.
    - Then run the program

- Simulated Data Test
  - Generate two signals:
    - The first plot: 100 samples of signal
    - The second plot: replication of first signal with delay of 10 units(pre-defined)
    - The third plot shows a cross-correlation result with a peak around 10 sample, showing the lag between two plots above. The lag can be converted from samples to time.

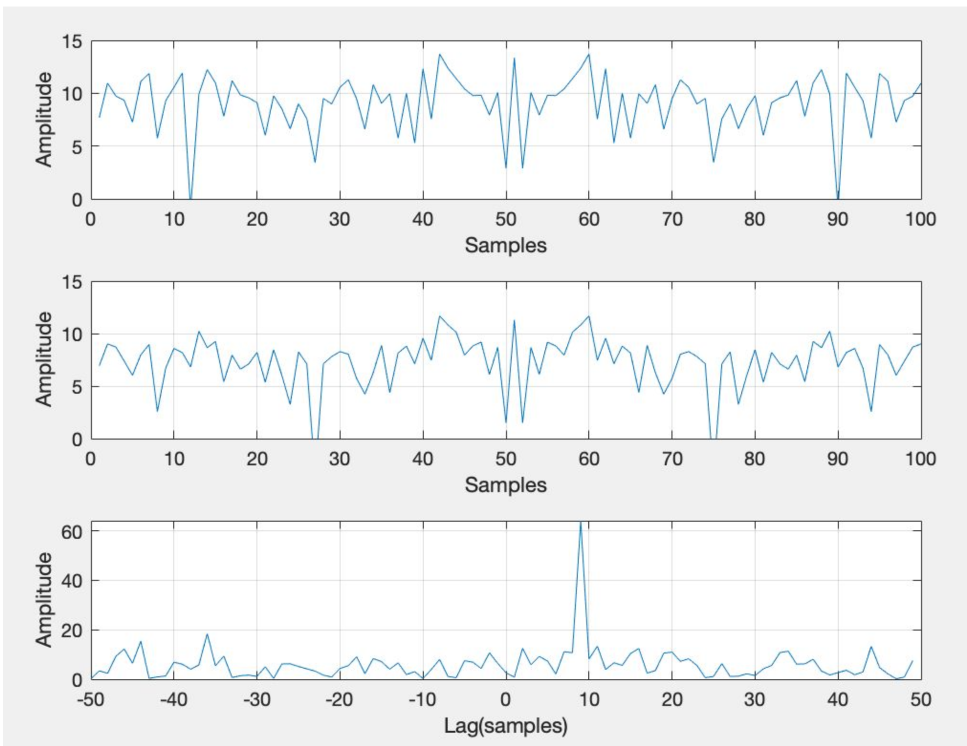


Figure 1: Simulated data test

- Collected Data Test
  - Two signals are collected from the same channel and file(collected on 3/22/2019).
    - The first two plot are the signals in frequency domain with power in dB.

- The third plot shows an auto-correlation result with a peak at 0 lag.

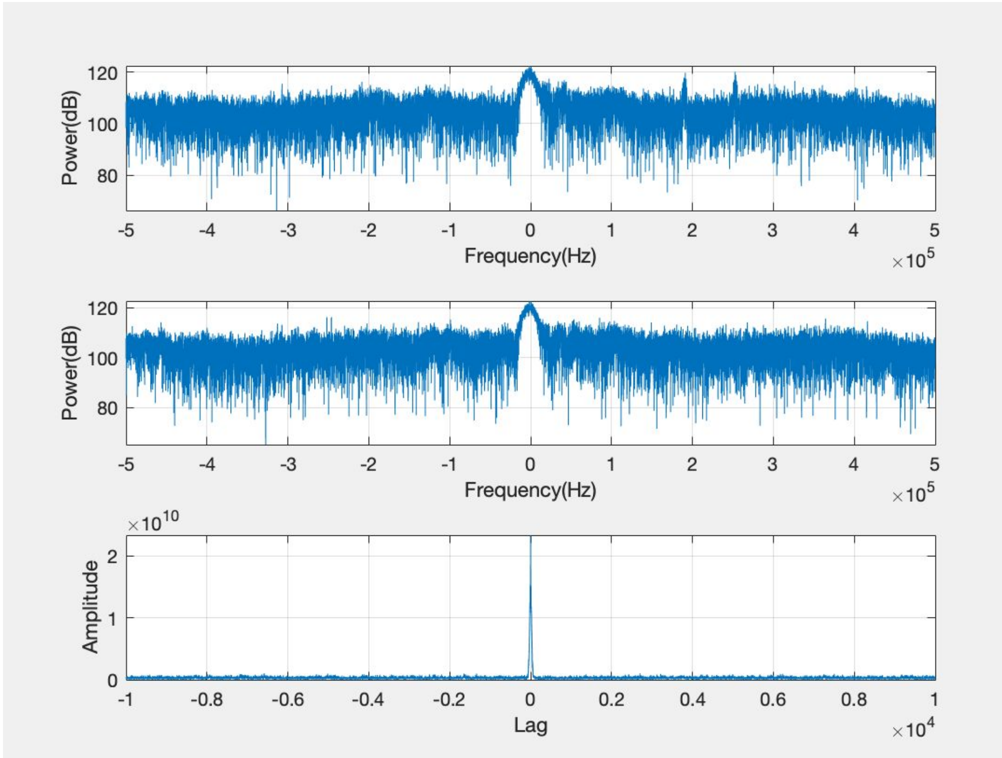


Figure 2: Collected data test

- Result

Overall, the code for cross-correlation is successfully functional, but filters are not applied to signals. From figure 1, the code presents cross-correlation between two given random signals. The lag shown in the result infers the time difference between two signals with similar signal structure. From figure 2, the collected data from field test are applied to the previous code with minor changes to read the files. The time lag is 0 because two signals are exactly extracted from the same file.

Conclusion

This team has made progress on the design of the UAV mounted receiver to measure soil moisture through remote sensing using Signals of Opportunity. Our achievements include creating a system for validating new antenna designs, a method for mounting the receiver and antenna to the UAV, and a program for cross correlation of two signals. We also have working link, mass, and power budgets that should be updated as future teams progress the design. The steps that we expect future teams to take include designing a “grey box” for the radio to work in conjunction with the power supply, testing new antennas for use with this system, manufacturing and assembly of the mounting system, and conducting further tests to prove that the cross correlation gives useful data.

Appendix

The following appendix contains all lab reports of all field testing done and reference information, and test report forms

LAB NOTEBOOK

Test Report forms

ERS-SPRING 2019: Network Analyzer Test

Test document last updated by E. Smith on 2/20/2019

Outline

This test is used to determine whether an antenna is capable of capturing signals at the proper frequency. If the antenna passes this test, then it can be tested with the radio to collect signals in the lab.

Required Equipment

FieldFox Microwave Analyzer N9918A 26.5 GHz

Antenna

Necessary Adapters

Procedure: FieldFox Microwave Analyzer N9918A 26.5 GHz

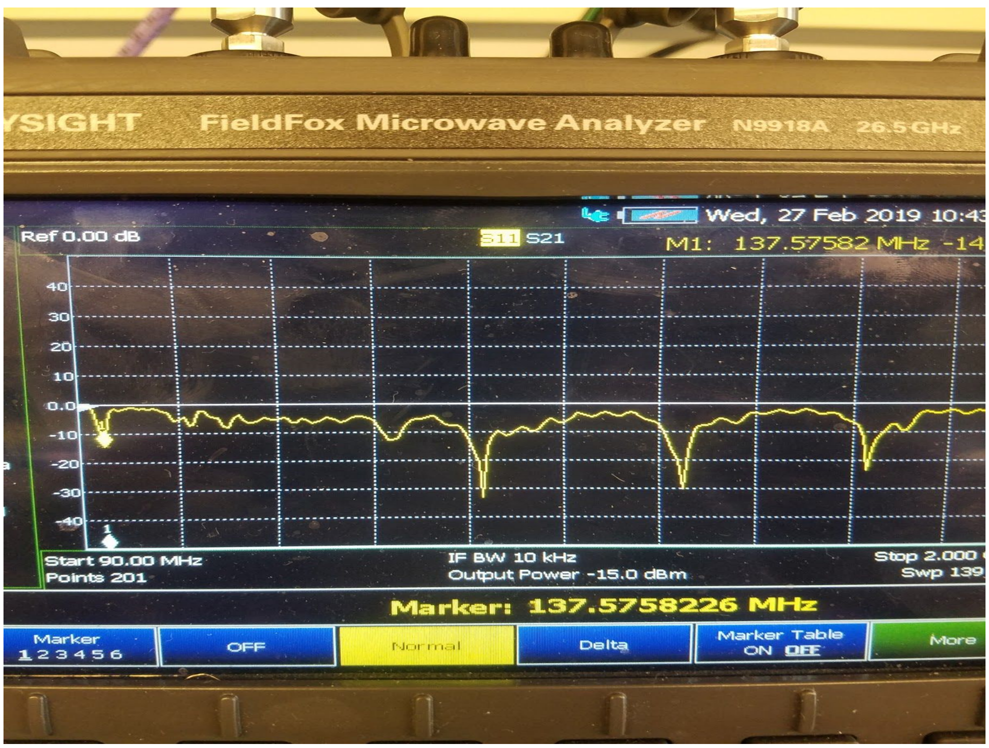
1. Connect the Antenna that needs to be tested to Port 1
    - SMA connector has red label
2. Select Mode
3. Select Network Analyzer which is labeled **N/A**
4. Select frequency:
    - set **Start** and **Stop** frequencies (large separation to see the null dip; **Example: 90 MHz to 150 MHz since we are looking for a frequency around 137.5 MHz**
5. Select measure: **S11**
    - Select **Format**
        - Impedance log to smith
            - In the top right corner the reading should be **50 ohms** for our testing
6. Must be **at least 4 feet back** to not interfere with the test
7. Select **Marker**
    - Select **Trace**

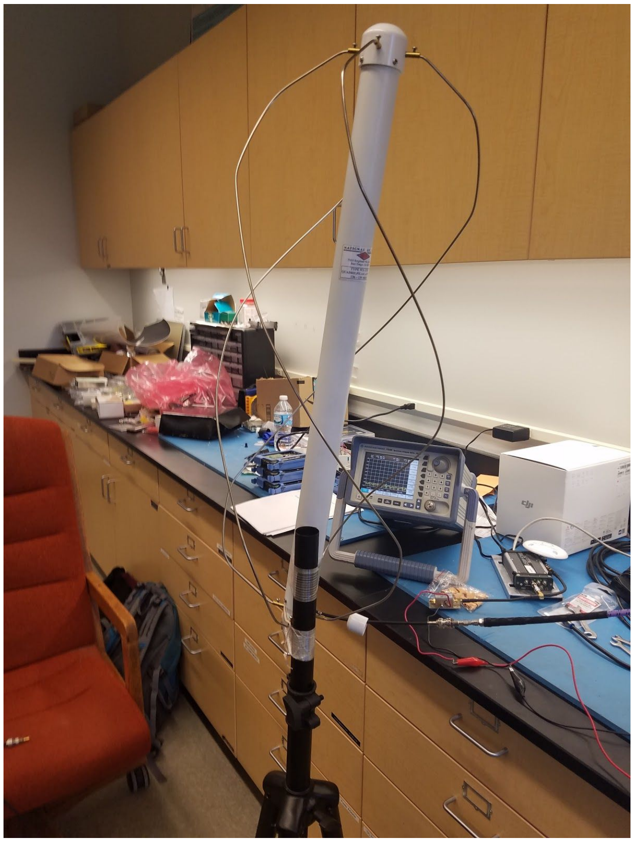
- Use this locate the signal

Analyzing the Signal:

- Null (the drop)
  - tells where the user the antenna **SHOULD** work within the specified range it is rated for
  - should not see noise floor jump

Results





Conclusion

The first image above shows that the null within the network analyzer results show that there is a null at 137.5 MHz which means the helix antenna shown in the second image does in fact receive signals with frequencies of 137 MHz to 138 Mhz.

ERS-SPRING 2019: Lab Signal Generator Recording Test

Test document last updated by E. Smith on 2/20/2019, A.Nguyen 02/28/2019

Outline

This test is used to determine if the radio/antenna combination can be used to collect signals at the desired frequency. A Signal Generator is used to broadcast a signal in the lab to the radio. The radio then runs the same recording program that would be used in field tests. If the signal can be recreated from the data produced by the recording program, then the radio will be ready to attempt to collect Orbcomm data in a field test.

Required Equipment

Ettus USRP E310 w/ Power Supply & Network Connection

SMA(F) to SMB(M) adapters [2x]

Ethernet Cable

External GPS Receiver

Antenna [2x]

Power Supply

DC Block

Coax Cable

Waveform Generator

Amplifier ZFL-500LN

Laptop

Test Setup

1. Set up in Lab 3105

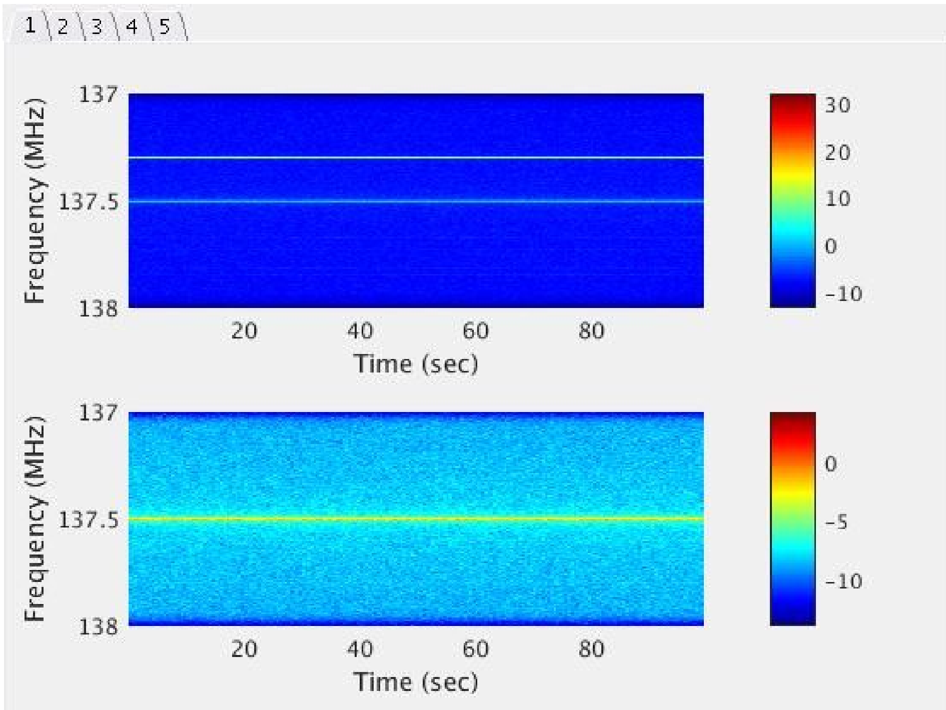
2. Turn on Signal Generator
    - Select Frequency
        - Set Frequency to **137.3 MHz**
            - Use a slightly different frequency then 137.5 MHz to avoid any confusion with the gain
        - Hit the back button to go back to menu
    - Select Level
        - Set dB to **-20 dB**
    - On the far right on the generator select the RF on/off
        - Make sure **RF is ON**
    - Attach the White PVC Helix Antenna to the output of the Signal Generator
3. Attach the DC block to **one of the receiver ports (Rx-2a) of the E310 Radio**
4. Attach the coax cable to the antenna then connect the other end to the Amplifier on the **INPUT** side
5. Attach the other end of the coax from the **OUTPUT** side of the Amplifier to **one of the receiver ports (Rx-2a) of the E310 Radio with the DC block already attached to it**
6. Connect the Power Supply and E310 Radio to the power outlet in the lab

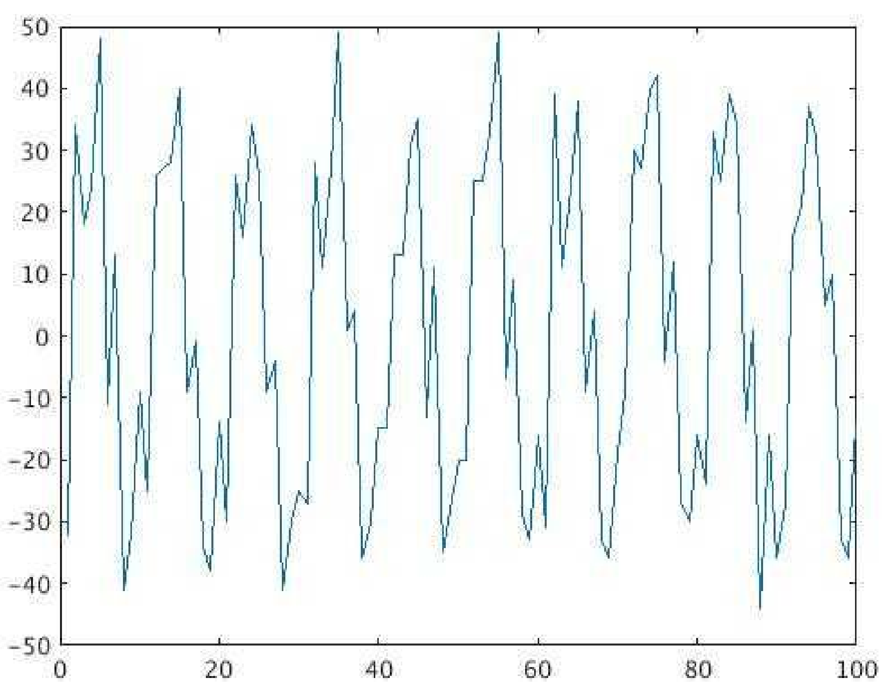
- Connect the **RED Wire** to the **POSITIVE PORT (+)** of Power Supply
- Connect the **BLACK Wire** to the **NEGATIVE** or **GROUND PORT (-)** of the Power Supply
- Set the Voltage to output **at least 15 Volts**

Procedure

1. Connect to Radio ssh
2. Use the Laptop to launch the program to collect data
    i. Use: **./orbcomm_test.bash**
    ii. 40 dB SDR channel gain
    iii. Run time must be a **minimum of 60 seconds for each test**
    iv. referencing p.19 of last semester report to record data
    v. using the radios internal clock to mark down start time; example: **1202 to 1203 (data below collected time stamps)**
3. Compare the data collected to the data collected from the Helix Antenna to last semesters data
    i. Confirmation Test p.31 (Last Group Final Report)

Results


1
2
3
4
5
Frequency (MHz)
137
137.5
138
20
40
60
80
Time (sec)
30
20
10
0
−10
Frequency (MHz)
137
137.5
138
20
40
60
80
Time (sec)
0
−5
−10


50
40
30
20
10
0
−10
−20
−30
−40
−50
0
20
40
60
80
100

Conclusion

The first plot is the frequency domain, therefore, the line is just showing that the antenna is receiving a strong signal at 137.3 MHz. Sample Rate is at 100 MHz. The second plot shows a sine wave within the time domain of the first 100 ms of the data recorded. Within the MatLab code at the ParFor loop, we took the Par out to create a For Loop. Next, we created a stopping point within the For loop after the data is created. Then we created a new variable of time with an interval of 1 to 100 which takes each sample note. Then created a separate variable to take the first 100 data points of the data recorded. Finally, we created a plot comparing the time variable and the first data 100 data points to plot the sine wave. The jagged edges are noise that may have been caused by the other signals reflecting in the lab or other noise within the background. In the end, we can collect a sine wave signal using the helix antennas.

Field Recording

ERS-SPRING 2019: ORBCOMM Recording Test

Test document last updated by E. Smith on 2/20/2019

Outline

This test is an attempt to capture ORBCOMM satellite signals. Open source software Orbitron shows a visual of what satellites are near current location. This information was used to keep track of what satellites were in range of the antenna. When running the captured data through Matlab the plot should show the downlink frequencies from satellites or noise along with a doppler shift.

Required Equipment

Ettus USRP E310 w/ Power Supply & Network Connection

SMA(F) to SMB(M) adapters [2x]

SMA cables [2x]

Ethernet Cable

External GPS Receiver

Antenna

LNA ()

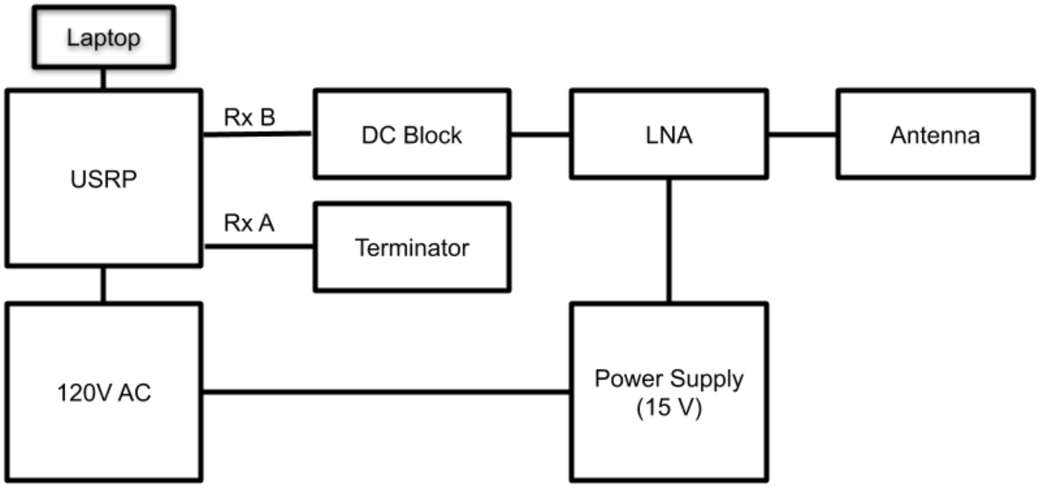
DC Block

Laptop

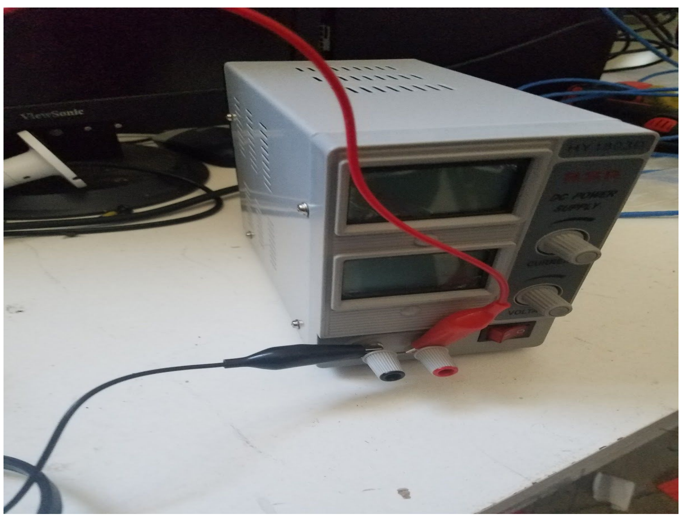
External power supply for LNA

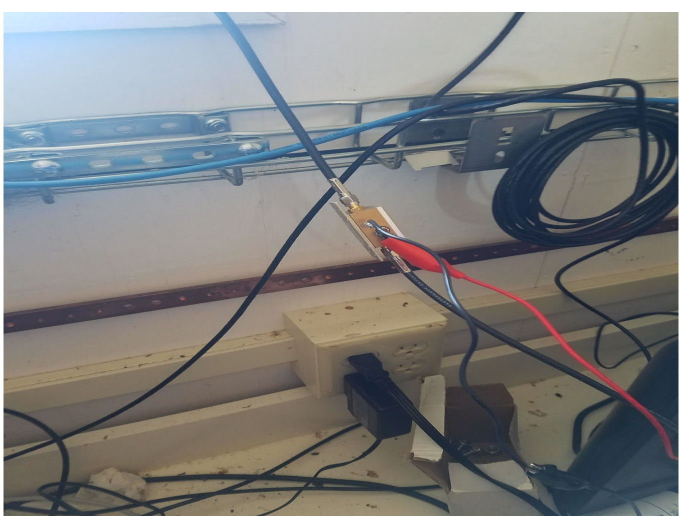
Test Setup

Connect the Ettus USRP E310 to a personal computer (laptop). Connect the E310 to an external GPS receiver using one of the SMA to SMA adapters. Connect the antenna to the LNA input. Connect the LNA output to one of the receivers (RXB) using an SMA to SMB adapter. This test was conducted at Purdue ACREs. The E310 and power supply for the LNA were connected to power in the shed. The LNA is attached to the power supply with voltage set to 15V. The antenna was connected with an SMA cable to the input of the LNA. The output of the LNA was attached to a DC Block with another SMA cable. The DC Block is then attached to the Receive input on the E310 with an SMA to SMB adapter.


Laptop
USRP
Rx B
Rx A
DC Block
Terminator
LNA
Antenna
120V AC
Power Supply
(15 V)


GPS
USRP E310





Use Orbitron (or any other satellite tracking program) to find ORBCOMM satellites in range. Record satellites in range and whether they are active. Find downlink frequencies of satellites in range. Write information down for reference looking at Matlab data plot.

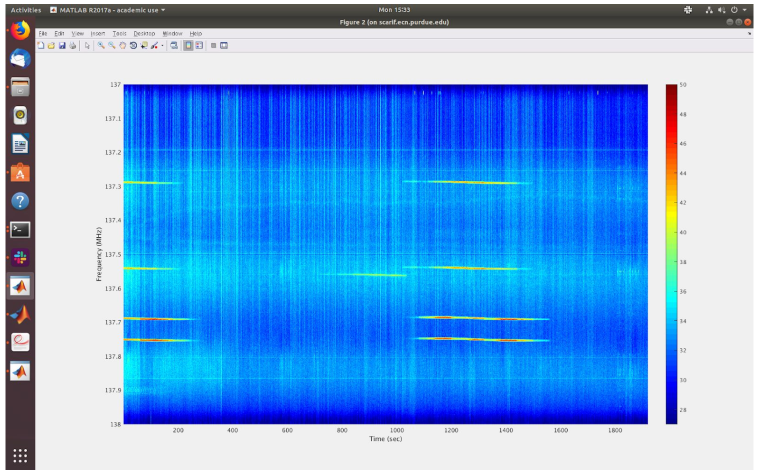
Procedure

Run a data capture using the orbcomm_test.bash script located on the E310 operating system. Make sure to compile the latest code before starting capture. Set recording time to 60 seconds and gain to 40 dB. Run the files through the Matlab script Read_and_plot_orbcomm.m. Verify that the transmitted frequency of the satellites appear on Matlab plot. Attach received plots to this report.

Results

White Antenna recording at UTC 2019-03-22 (20:33:00 - 21:09:13)

Test Requirement	Observation	Pass (Y/N)
Clear signal at frequency: of satellite (name): Operational FM34, FM111, FM38, FM108, FM35,FM107, Non-Operational FM29,FM02,FM10 5, FM39		Y

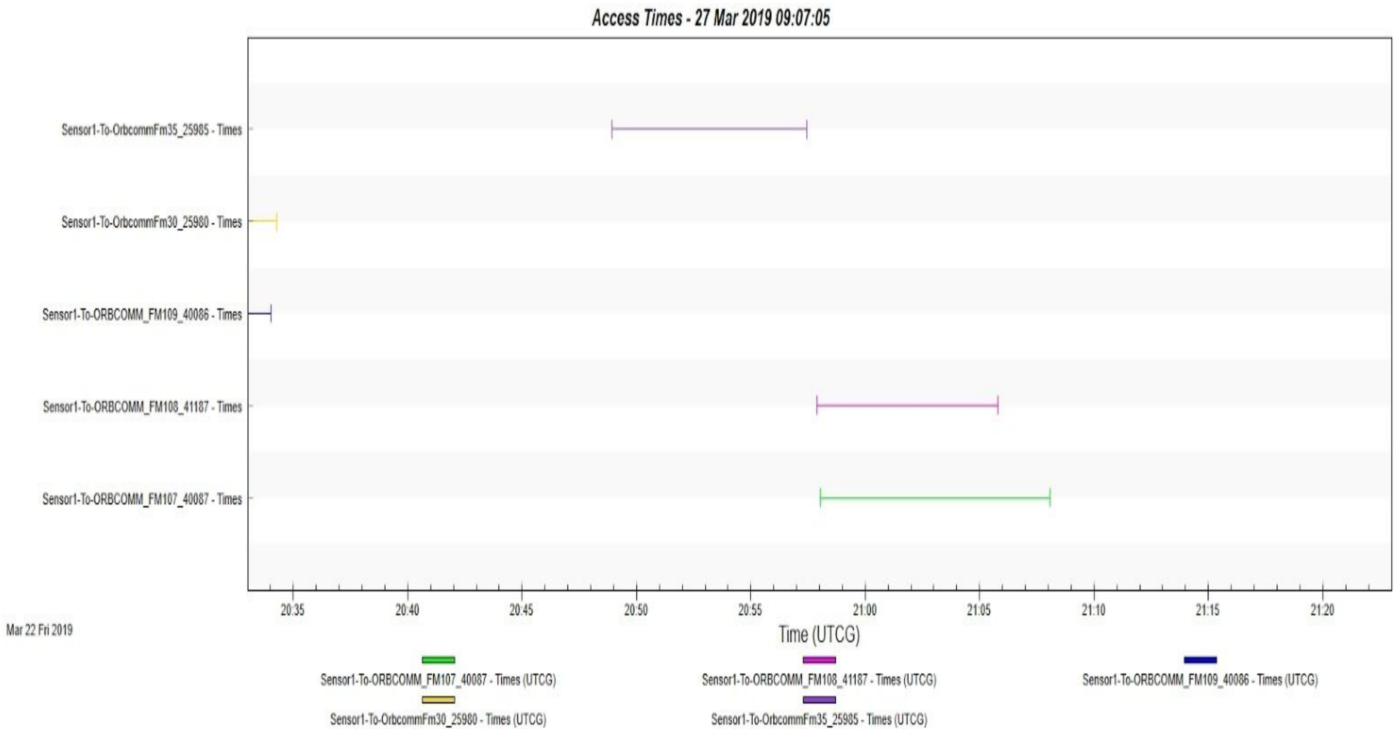
		

ORBCOMM Downlink Frequencies

Channel No.	Channel Freq. (MHz)	Channel Bandwidth (kHz)	Data rate (kbps)	Polarization
S-1	137.2000	25	9.6/4.8	RHCP
S-2	137.2250	25	9.6/4.8	RHCP
S-3	137.2500	25	9.6/4.8	RHCP
S-4	137.4400	25	9.6/4.8	RHCP
S-5	137.4600	25	9.6/4.8	RHCP
S-6	137.6625	25	9.6/4.8	RHCP
S-7	137.6875	25	9.6/4.8	RHCP
S-8	137.7125	25	9.6/4.8	RHCP
S-9	137.7375	25	9.6/4.8	RHCP
S-10	137.8000	25	9.6/4.8	RHCP
S-11	137.2875	25	9.6/4.8	RHCP
S-12	137.3125	25	9.6/4.8	RHCP
Gateway	137.5600	50	57.6	RHCP

Table D.1 - 137.0-138.0 MHz Downlink Channelization and Polarization Plan

Computed Access with a 10 degree cutoff (Due to Antenna Pattern)



ORBCOMM Satellites overhead during test

GPS Data Extraction

- **Procedure:**
    - Connect to the radio
        - Terminal type: **ssh -p 432 rnllab@128.46.6.93**
        - Password: **CaptainKirk!**
    - Run the bash file to extract GPS location
        - Terminal type: **./GPS_get.sh**
        - Type how long user wish to run the program (in seconds), and wait for completion.
        -

```
ettus-e3xx-sg3:~/SoOpAD_UAV$ ./GPS_get.sh
Seconds?
10
Log file created.
./GPS_get.sh: line 7:  1754 Terminated              gpspipe -w -o GPS_test.log
Done.
ettus-e3xx-sg3:~/SoOpAD_UAV$ 
```

    - File is saved as "**GPS_dat.txt"** in the same directory.
- **Programs:**

- **./GPS_get.sh**

- This bash script combines commands so data extraction can be easier. It first reads how many seconds the user wants the program to run. The coordinates is received by using "gpspipe" command, which connects to gpsd and collects data from the receiver. A log file is created with information, then removed after used in "GPS_location.py". **./GPS_location.py**

This python script opens the log file an translate into a text file with time (seconds), latitude (degrees), longitude (degrees), and altitude (meters). The time is in format with the date and time increment in seconds. The latitude and longitude only makes trivial errors. The altitude can be improved, because he vertical elevations can be hard to determined.

```
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
~
~
~
```

References

[01] ORBCOMM System Overview , Revision G. ORBCOMM LLC ,Dulles, VA , USA, December 2001. Accessed on: December, 15, 2018 . [Online]. Available:

https://www.ctu.cz/sites/default/files/cs/download/oznamene_typy_rozhrani/orbcomm-rozhrani_02_06_2010.pdf

[02] Cross-correlation. (2019, March 18). Retrieved from https://en.wikipedia.org/wiki/Cross-correlation