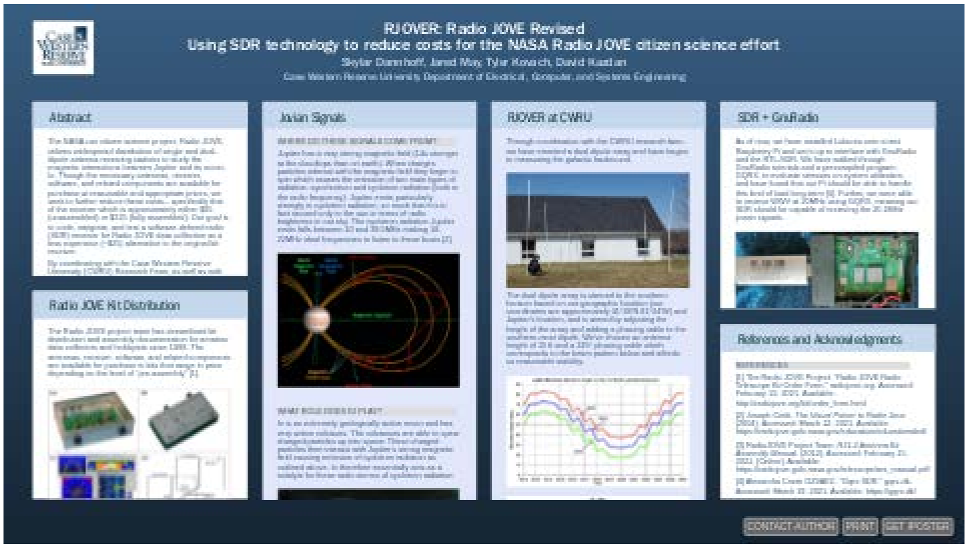
RJOVER: Radio JOVE Revised Using SDR technology to reduce costs for the NASA Radio JOVE citizen science effort



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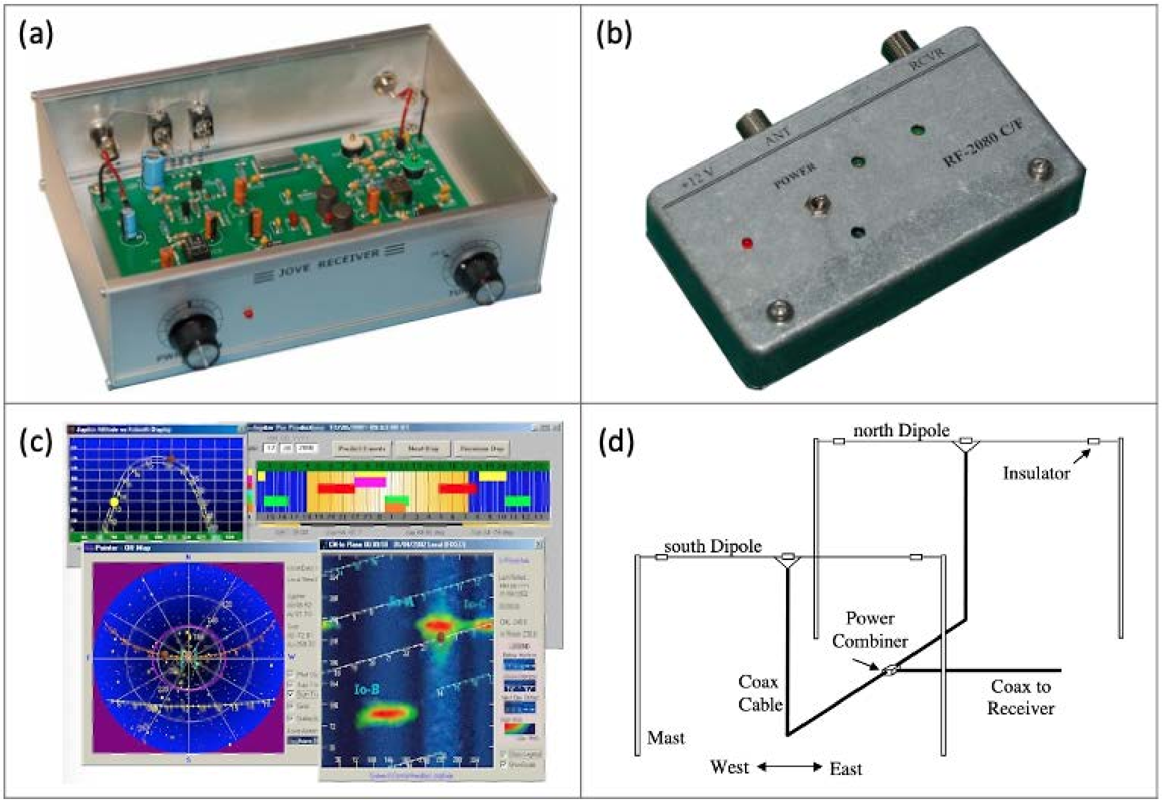
ABSTRACT

The NASA-run citizen science project, Radio JOVE, utilizes widespread distribution of single and dual-dipole antenna receiving stations to study the magnetic interactions between Jupiter and its moon, Io. Though the necessary antennas, receiver, software, and related components are available for purchase at reasonable and appropriate prices, we seek to further reduce these costs-- specifically that of the receiver which is approximately either $95 (unassembled) or $225 (fully assembled). Our goal is to code, integrate, and test a software-defined radio (SDR) receiver for Radio JOVE data collection as a less expensive (~$25) alternative to the original kit receiver.

By coordinating with the Case Western Reserve University (CWRU) Research Farm, as well as with guidance from faculty in the CWRU Electrical, Computer, and Science Engineering (ECSE) department and the Radio JOVE Project Team, we hope to establish a Radio JOVE receiving station at CWRU whereupon we can test our alternative SDR receiver for Jovian signal collection. Ultimately we hope to document a cheaper, more modern and digital age approach that could appeal to a wider audience including those working with a tighter budget and those interested in software-defined radio.

RADIO JOVE KIT DISTRIBUTION

The Radio JOVE project team has streamlined kit distribution and assembly documentation for amateur data collectors and hobbyists since 1998. The antennas, receiver, software, and related components are available for purchase in kits that range in price depending on the level of “pre-assembly” [1].



a) We estimate that the prices of unassembled and fully assembled kit receivers are approximately $95 and $225, respectively.

b) The noise calibration source is used to convert signal magnitudes to antenna temperature in kilo Kelvins to standardize signal collection between stations. The RF2080 Calibrator/Filter is priced at $100.

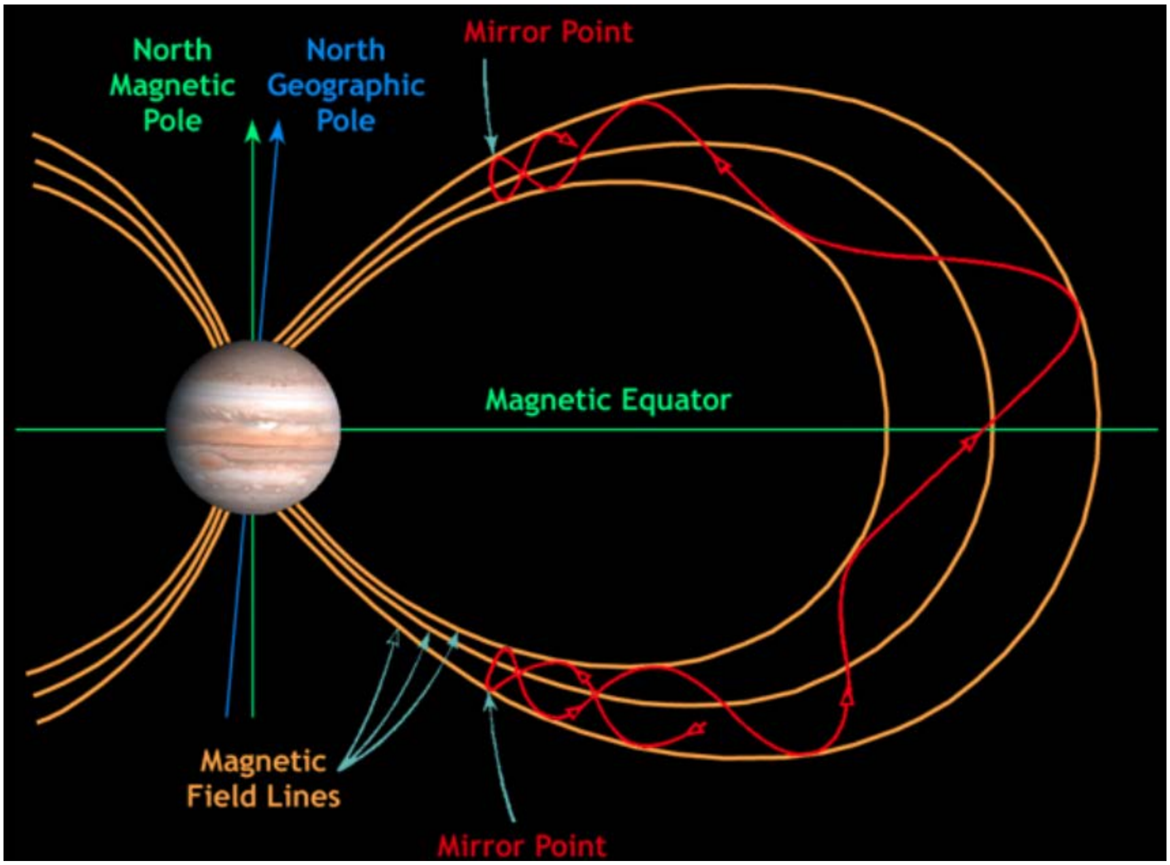
c) The recieved signals are collected and processed by the software Radio Sky-Pipe II ($49.95 for the Pro version), and it is also recommended to have Radio Jupiter Pro software ($19.95), which keeps track of Jupiter and Io's location and behavior.

d) The dual dipole array antenna materials, including copper wiring, coaxial cabling, connectors, power combiner, and insulators are available for $65. Not included is the antenna structural components such as PVC masts, nuts/bolts, guy ropes, and ground stakes, all of which cost ~$90 at local hardware stores.

JOVIAN SIGNALS

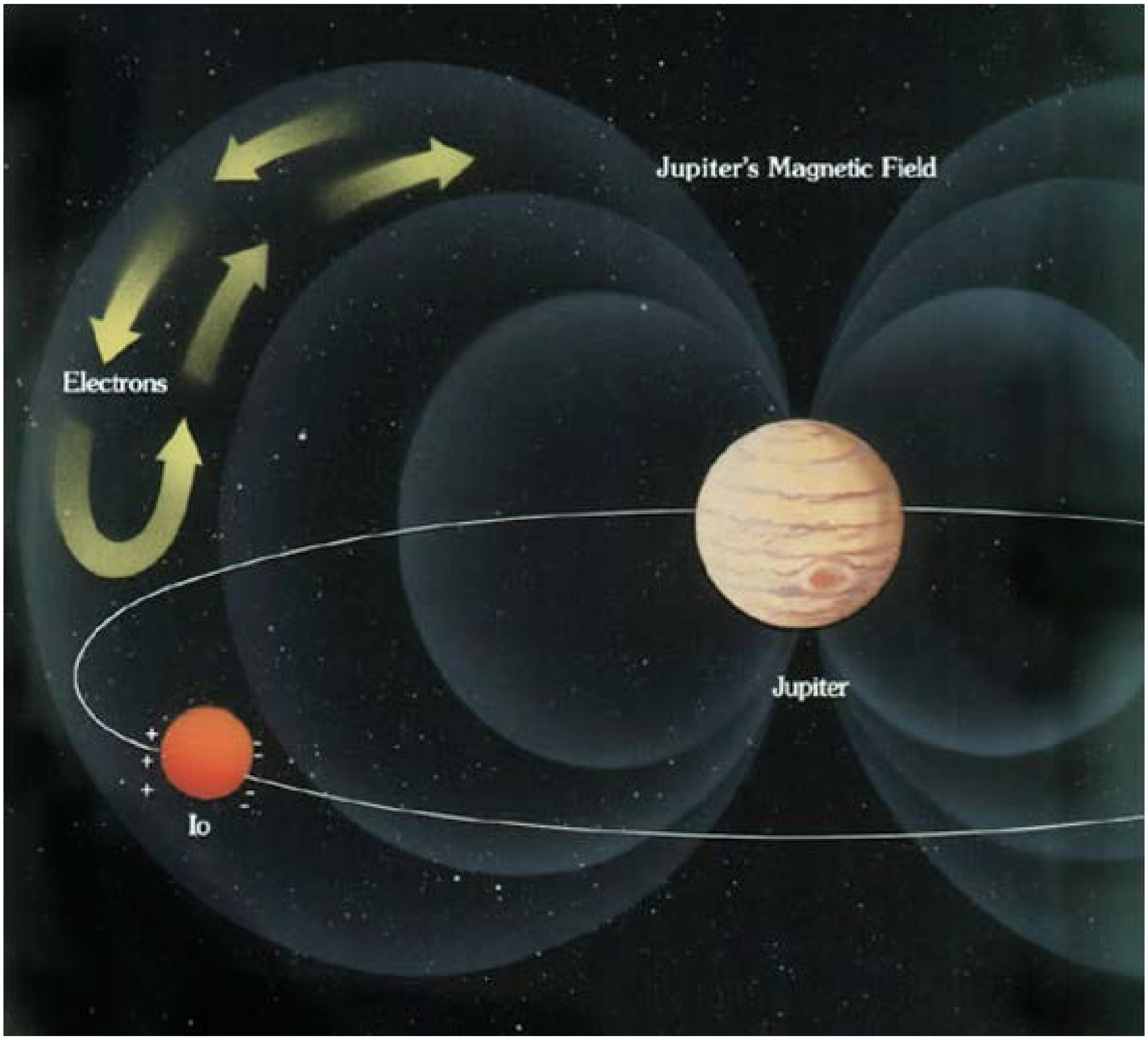
WHERE DO THESE SIGNALS COME FROM?

Jupiter has a very strong magnetic field (14x stronger at the cloudtops than on earth). When charges particles interact with the magnetic field they begin to spin which causes the emission of two main types of radiation: synchrotron and cyclotron radiation (both in the radio frequency). Jupiter emits particularly strongly in cyclotron radiation, so much that it is in fact second only to the sun in terms of radio brightness in our sky. The cyclotron radiation Jupiter emits falls between 10 and 39.5MHz making 18-22MHz ideal frequencies to listen to these busts [2].



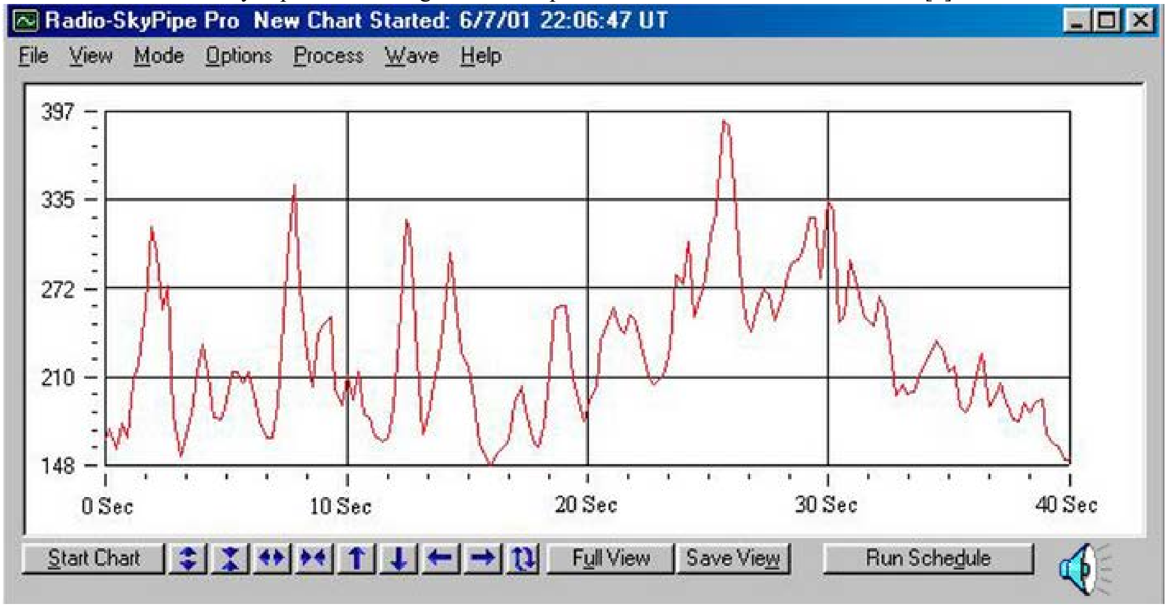
WHAT ROLE DOES IO PLAY?

Io is an extremely geologically active moon and has very active volcaoes. The volcanoes are able to spew charged particles up into space. These charged particles then interact with Jupiter's strong magnetic field causing emission of cyclotron radiation as outlined above. Io therefore essentially acts as a catalyst for these radio storms of cyclotron radiation.

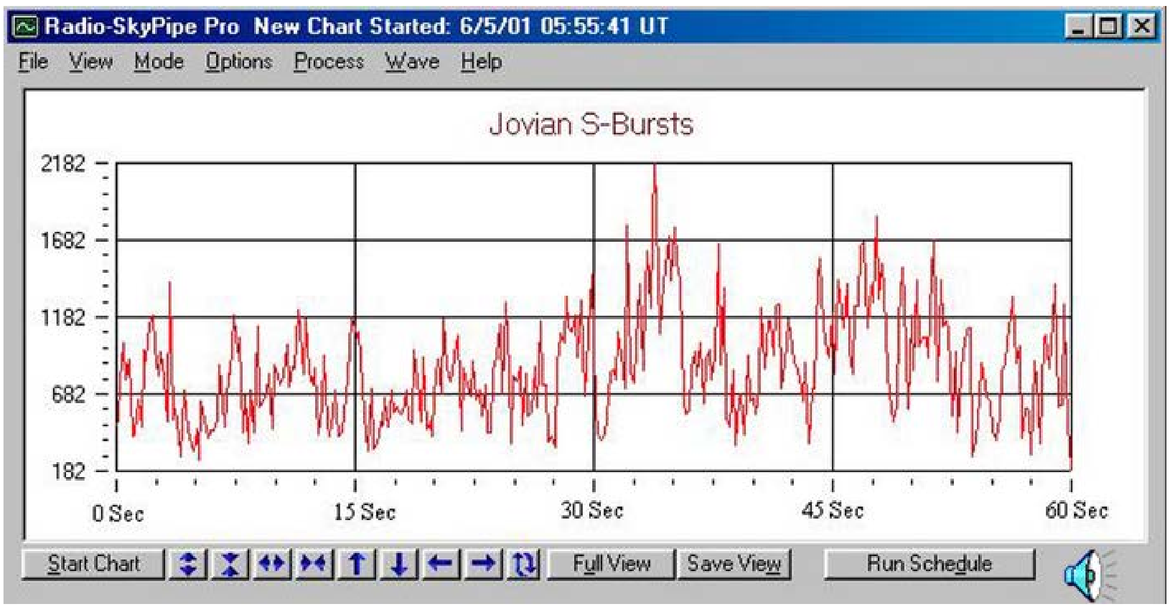


WHAT KINDS OF SIGNALS MAKE IT TO EARTH?

The signals that make it to the earth are classified into two categories: L-bursts and S-bursts. The former of these sounds like ocean waves breaking on a shoreline and the latter sounds like the crackling of a campfire. Jupiter itself has three primary emission points deemed Io-A, Io-B, and Io-C. Each of these three emission points rotate around Jupiter with its magnetic field. Each of these signals differs by the angle that Io makes between Jupiter and the earth. Each of these emission points and corresponding signals have varrying amounts of L and S-burst sound components. These radio storms that are sourced by Jupiter are so bright that a simple wire antenna is able to detect them [2].



Above: Strip chart and audio file of an example L-Burst [2].



Above: Strip chart and audio file of an example S-burst [2].

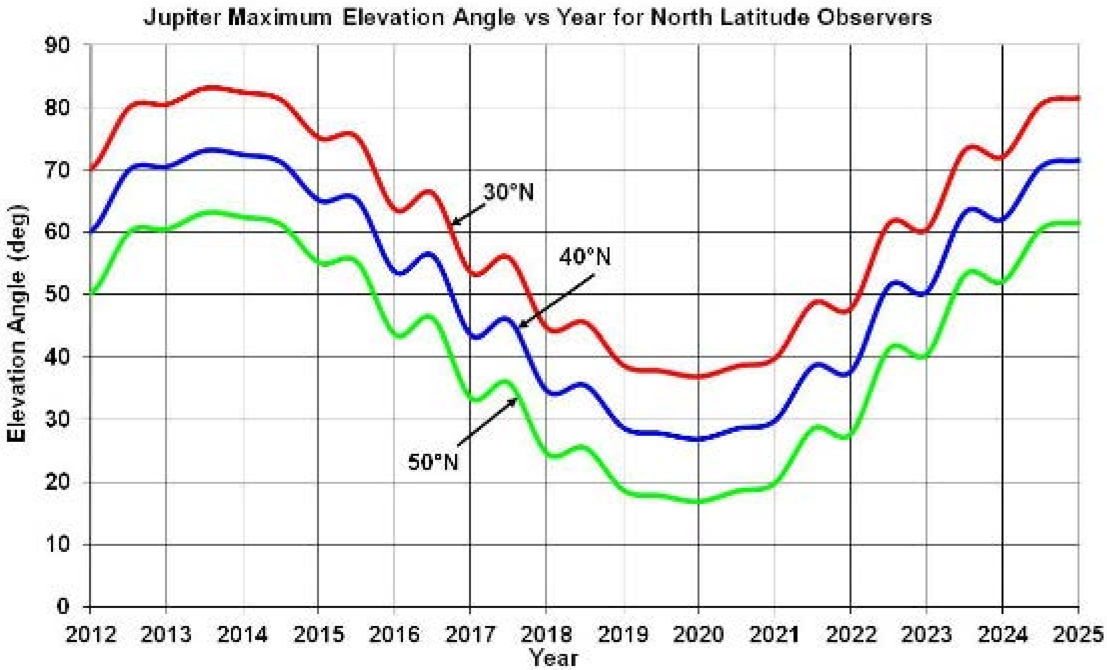
WHAT ARE THESE SIGNALS USED FOR?

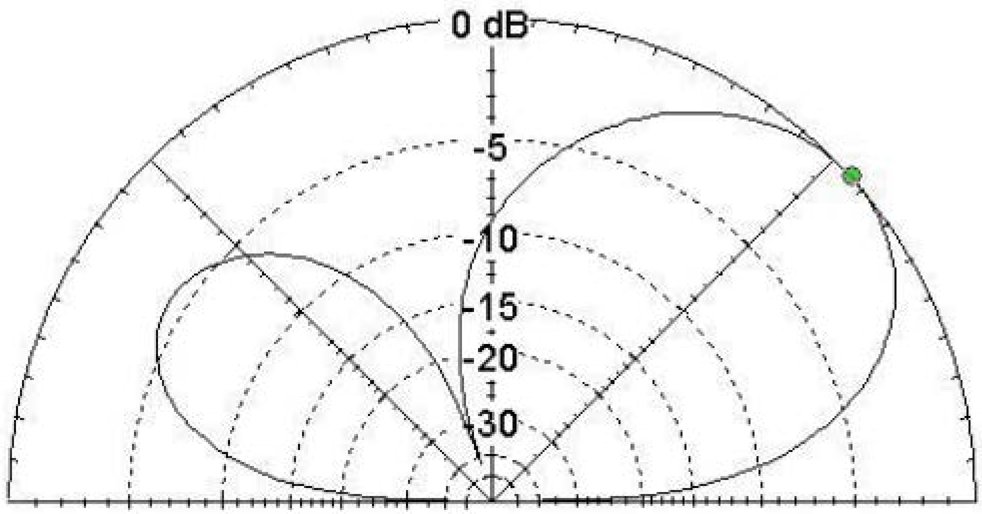
In general, these signals can be used for studying the current conditions of Io and examining Jupiter's magnetic field.

RJOVER AT CWRU

Through coordination with the CWRU research farm, we have errected a dual dipole array and have began to measuring the galactic backround.

The dual dipole array is steered to the southern horizon based on our geographic location (our coordinates are approximately 41°28′N 81°24′W) and Jupiter's location, and is aimed by adjusting the height of the array and adding a phasing cable to the southern-most dipole. We've chosen an antenna height of 15 ft and a 135° phasing cable which corresponds to the beam pattern below and affords us reasonable stability.

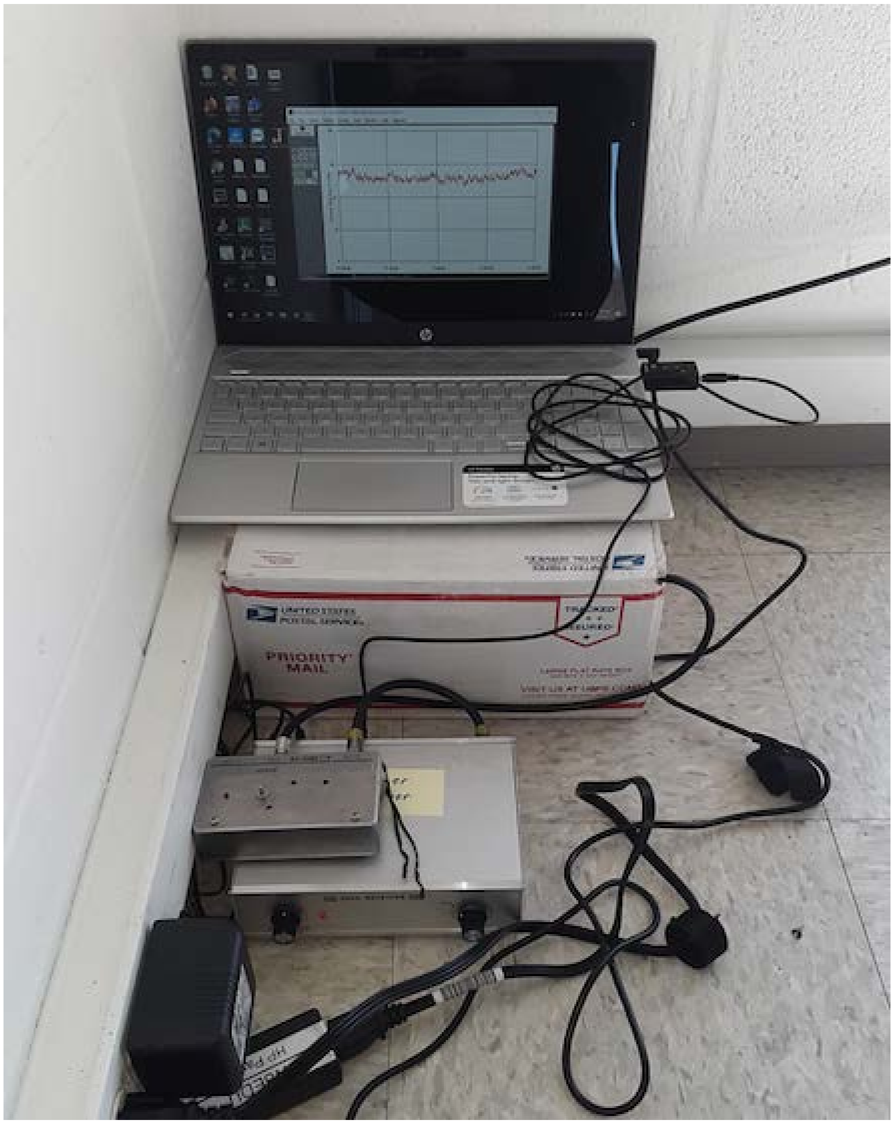




Dual dipole, 15 ft, 135 deg phasing, gain = 9.1 dBi at el = 42

Pictured Above: Charts describing Jupiter's elevation angle relative to our geographic lattitude and an antenna beaming pattern for a15 ft tall dual dipole array with 135° phasing cable [3].

The first phase of our project is to collect galactic background signals using the standard distributed kit to evaluate how RF quiet our station site is.

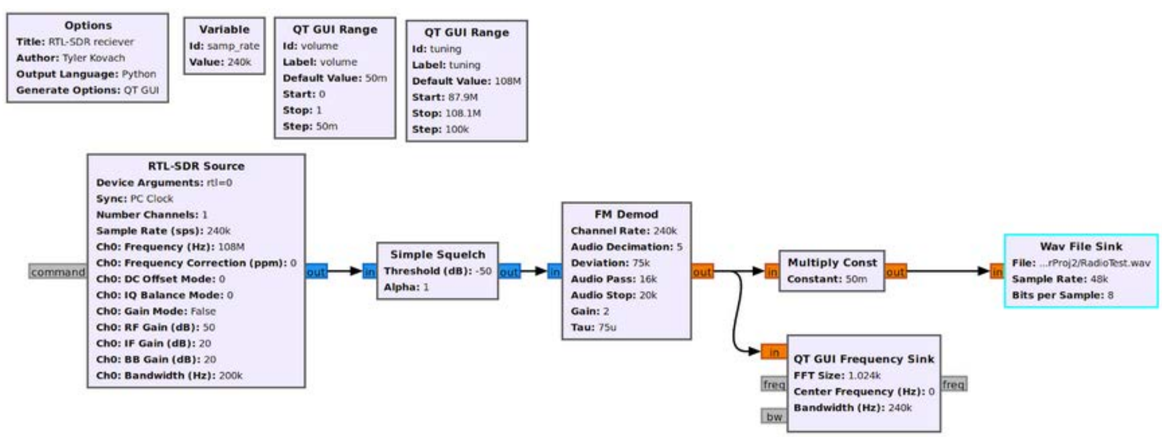


The next phase will be to replace the kit reciever with an RTL-SDR coded with GnuRadio and running off a Raspberry Pi.

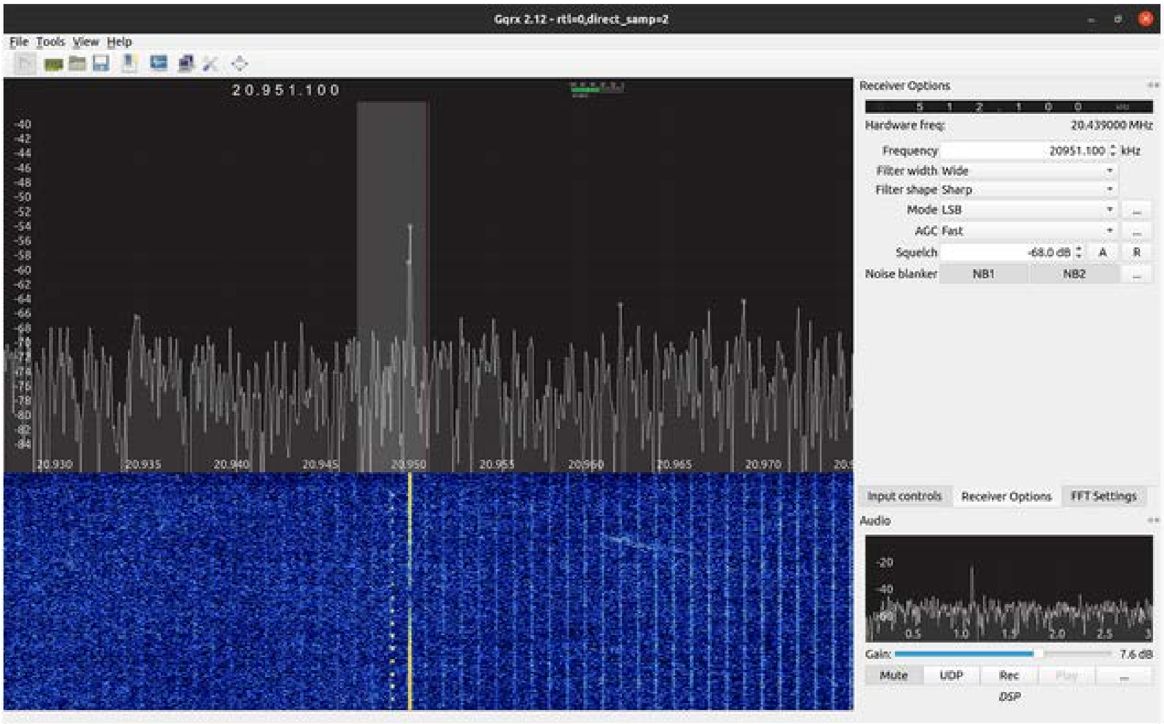
SDR + GNURADIO

As of now, we have installed Lubuntu onto a test Raspberry Pi and set it up to interface with GnuRadio and the RTL-SDR. We have walked through GnuRadio tutorials and a precompiled program, GQRX, to evaluate stresses on system utilization, and have found that our Pi should be able to handle this kind of load long-term [4]. Further, we were able to recieve WWV at 20MHz using GQRX, meaning our SDR should be capable of recieving the 20.1MHz jovian signals.

Picutred above: Our RTL-SDR connected to our Rasberry Pi with heatsink.



Pictured above: the GnuGradio precompiled program GQRX.



Pictured above: waterfall chart of our SDR's reception of WWV on 20MHz using GQRX.

We are also exploring how we can use our SDR and Raspberry Pi to calibrate, collect, and process recieved cosmic signals in a useful way without using the Radio Sky-Pipe software. This could further save costs, and could make data handling more convenient.

REFERENCES AND ACKNOWLEDGMENTS

REFERENCES

[1] The Radio JOVE Project. “Radio JOVE Radio Telescope Kit Order Form.” radiojove.org. Accessed: February 15, 2021. Available: http://radiojove.org/kit/order_form.html

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[3] RadioJOVE Project Team. *RJ1.2 Antenna Kit Assembly Manual.* (2012). Accessed: February 15, 2021. [Online]. Available: https://radiojove.gsfc.nasa.gov/telescope/ant_manual.pdf

[4] Alexandru Csete OZ9AEC. "Gqrx SDR." gqrx.dk. Accessed: March 19, 2021. Available: https://gqrx.dk/

ACKNOWLEDGMENTS

We'd like to thank Dr. Chuck Higgins of Middle Tennessee State University for his guidance and coordination and for loaning us a Radio JOVE kit for the semester. We'd also like to acknowledge our advisor, Dr. David Kazdan for his guidance, radio insights, and encouragement, and the facilities managers at the CWRU farm for their patience, help, and encouragement.