A Low-Cost Low-Power Chirp Ionosonde for Studying Eclipse Ionospheric Impacts

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Introduction

The ionosphere is a highly active region of the atmosphere characterized by both ions and electrons. It experiences changes in parameters such as electron density at different altitudes, based on the energy absorbed from the sun. Ionosondes are a type of radar used to gather data about the height of the ionosphere by transmitting a signal towards the ionosphere. This signal is refracted back to the Earth's surface and received in such a manner that return echoes can be timed and using knowledge about the speed of light, the height profile of the plasma frequency of the bottomside ionosphere can be calculated.

The way an ionosonde functions depends largely on the system. The main types are oblique and vertical instance. Oblique requires two separate geographic locations and separate systems. This introduces difficulties in timing, and it requires more space. Vertical instance ionosondes require one system using high frequency signals between 3 MHz and 30 MHz. This allows the ionosonde to be contained to one system and allows the transmitter and receiver to rely on the same clock. Additionally, traditional ionosondes require large antenna systems and high amounts of power. Recent advancements in software defined radio (SDR) technology, advanced digital signal processing (DSP), and computational efficiency enable the size, cost, and power demands of an ionosonde system to be reduced. In this poster, we present our recent efforts to implement a low-cost, low power ionosonde.

Methodology

Two systems are currently used in this project: the Ettus N200 Universal Radio Peripheral (USRP) and the newer Red Pitaya (RP) SDRlab 122-16. The RP system is still being developed while the Ettus enables us to test the rest of the hardware and collect data during the 2024 eclipse. Using amateur radio fan dipoles and GNU Radio code, the system will sound the ionosphere during the upcoming eclipse. We currently have a special temporary authorization from the FCC to transmit with the desired power on the necessary frequencies. This license enables up to transmit between 2 and 10 MHz. We plan to use the system to sound the ionosphere during the upcoming 2024 total solar eclipse. Over the following weeks the system will be refined in preparation for the upcoming eclipse.

By utilizing newer SDR technology we are able to make ionospheric sounding systems smaller, cheaper and less power demanding. This was demonstrated during the 2017 Great American Eclipse by sounding the ionosphere using an Ettus USRP N210 (*Lloyd*, 2019). The Ettus USRP still costs over US$3000, but newer SDR systems such as the RP development board cost less than US$600 (*McGwier*, 2018; *Lloyd*, 2019). Our RP system is still being developed, but we are using an Ettus N200 to develop and test the rest of the hardware in the system.

Hardware

The intention is to utilize the capabilities of a Red Pitaya SDRlab 122-16. Older versions of this board had issues in a few areas including cross talk and a lack of 50-Ohm impedance. The SDR 122-16 has a lower noise floor, proper impedance and eliminates crosstalk. The board requires an external clock with proper specifications in order to properly function. While this is being taken care of, an Ettus USRP N200 is being used to test the function of the antenna system and its ability to transmit and receive chirps reliably. Apart from the SDR in use the system can remain largely unchanged allowing easily switching from testing with the Ettus to the Red pitaya.

The system uses two fan dipole antennas. One is used to transmit a chirp, and the other receives, listening for the return echo. This method is more straightforward than utilizing one antenna to both transmit and receive since timing need to be precise. The Red Pitaya can transmit up to 60 MHz, which will provide plenty of room to transmit within.

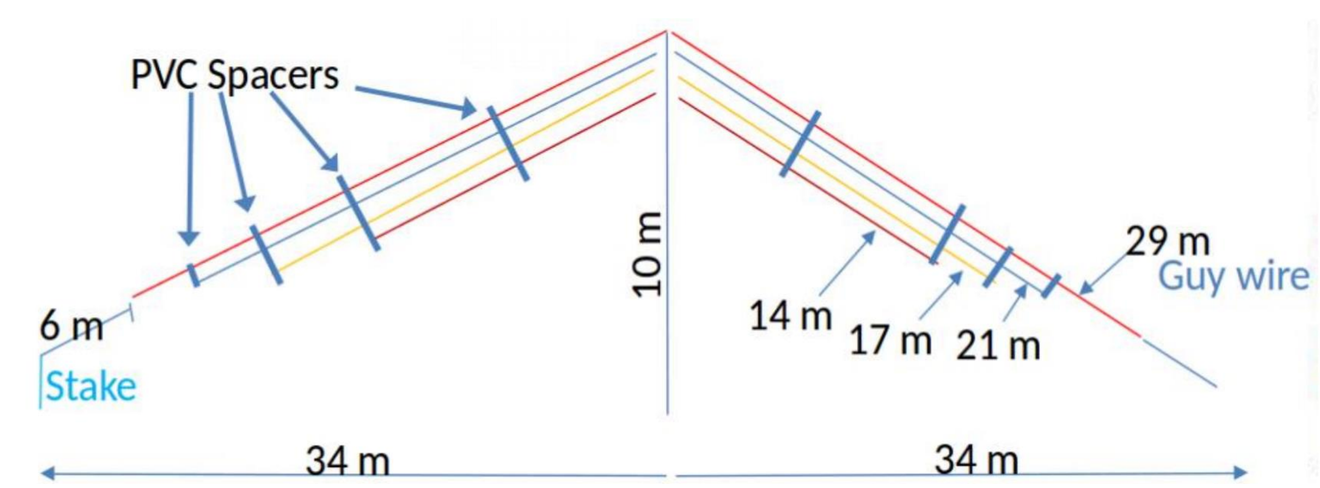

Figure 1. Antenna setup

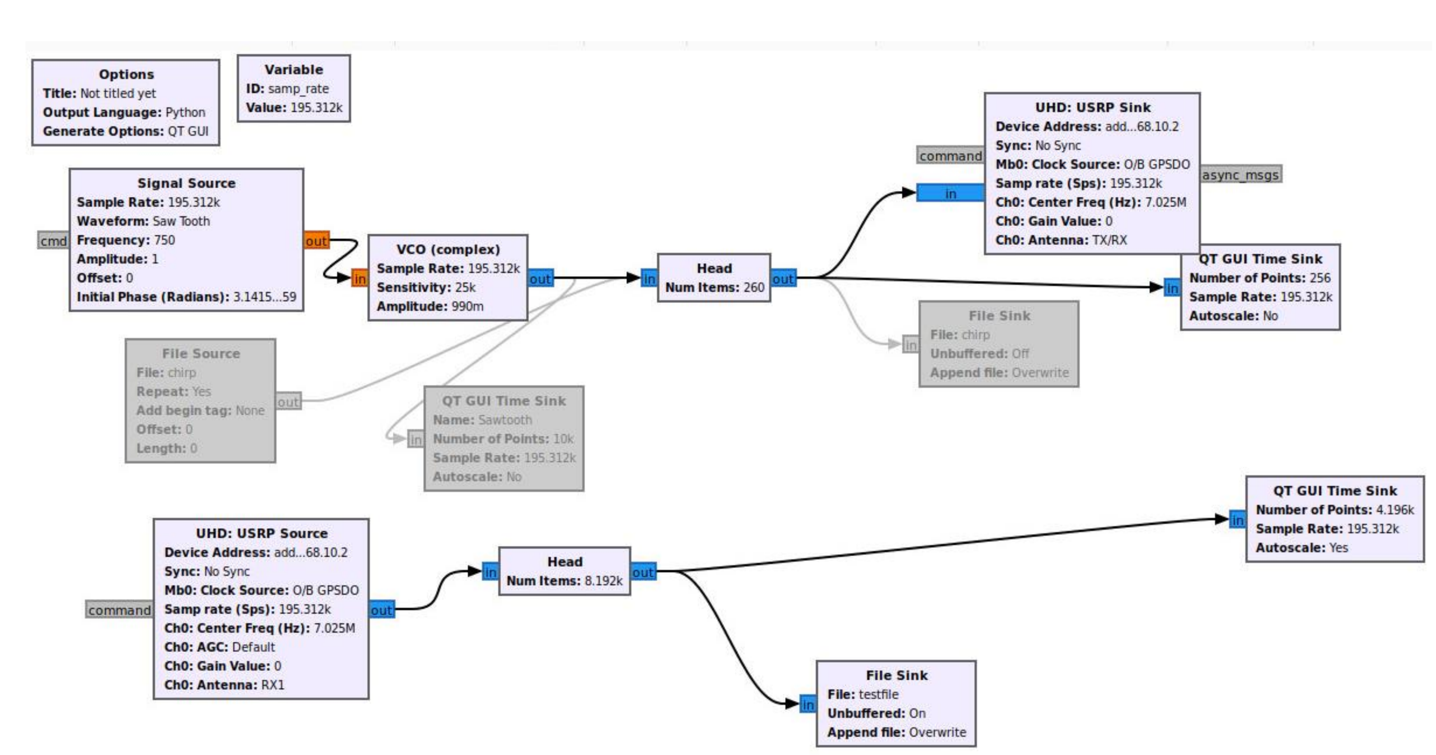

Figure 2. GNU radio flowgraph outputting a chirp and recording the return.

Software

GNU radio is used to configure the system. The system emits a chirp vertically and listens for the return echoes. The Ettus already has an established GNU radio environment, and Pavel Demin has developed an image for the Red Pitaya that enables the board to be controlled through GNU radio. This will make transitioning from operation with the Ettus to the Red Pitaya straightforward as much of the GNU radio code can be transferred as well.

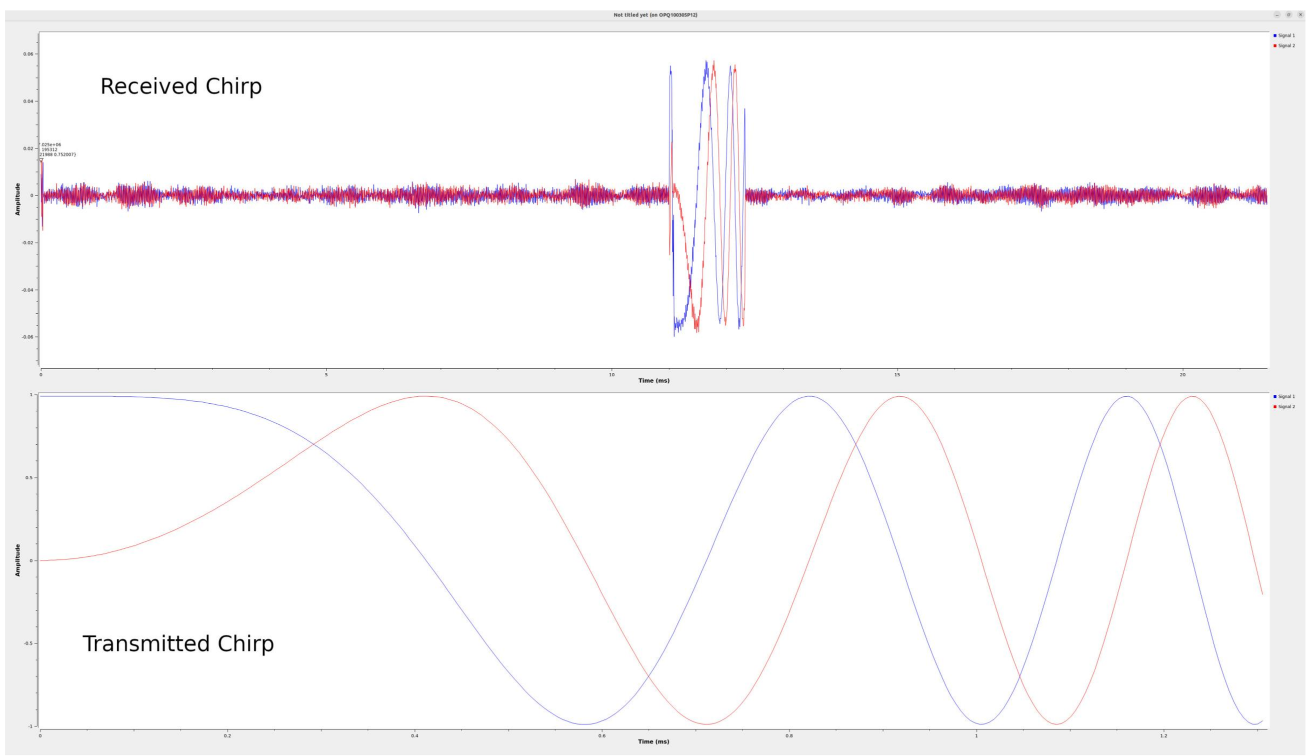

Figure 3. Sample chirp

Conclusion

The use of newer SDR technology significantly reduces the power demands and cost of an ionosonde system. A more affordable ionospheric sounding system enables more ionosondes to be set up for similar costs. This lesser cost supports citizen science as more people will be able to set up an ionosonde. This will lead to a greater area over which ionospheric data is being collected. Ideally this system will be able to sound this ionosphere during the upcoming 2024 total solar eclipse.

References

Lloyd, William C. (2019). Ionospheric Sounding During a Total Solar Eclipse. Master's Thesis, Virginia Tech Department of Electrical and Computer Engineering, http://hdl.handle.net/10919/89951.

McGwier, Robert (2018). "Using GNU Radio and Red Pitaya for Citizen Science" in *GNU Radio Conference 2018*, Las Vegas, NV, https://www.gnuradio.org/grcon/grcon18/presentations/Using_GNU_Radio_and_Red_Pitaya_for_Citizen_Science/.

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