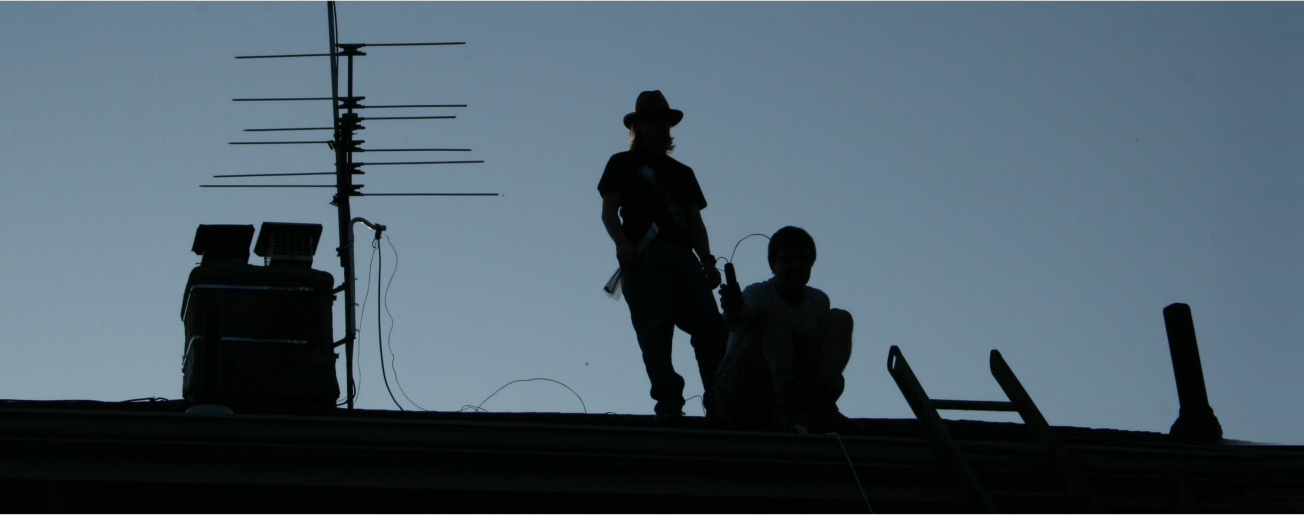

Low-Cost Low-Power Ionosonde

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Abstract

Ionosondes are a type of radar used to gather data about the height of the ionosphere. Typically, these systems can easily cost thousands of dollars and demand a lot of power. Using newer software defined radio technology, our goal is to develop a low-cost, low-power ionosonde.

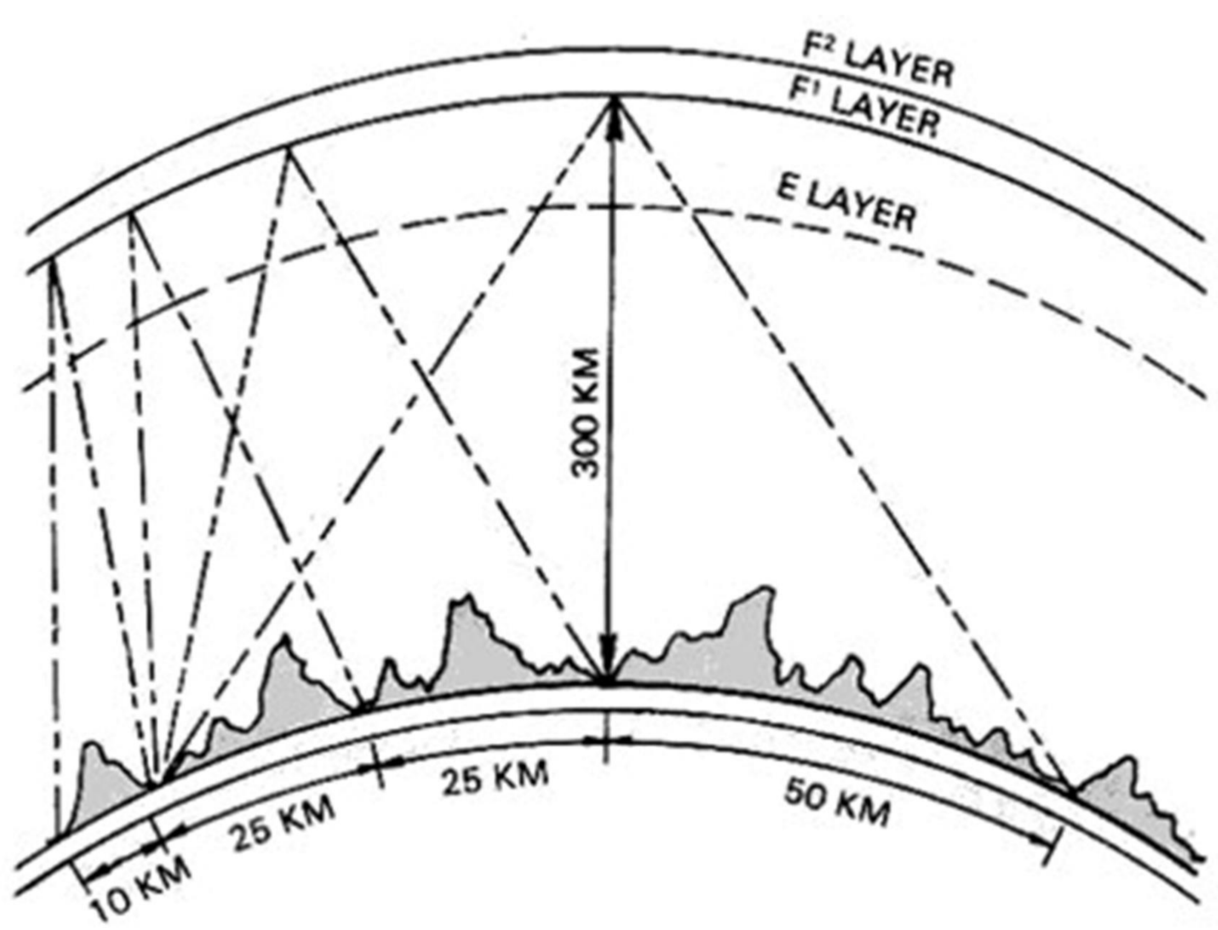
Introduction

The ionosphere is a region of the atmosphere made up of a high concentration of ions and free electrons. It is highly active and changes in size, electron density and height based on the energy absorbed from the sun. The ionosphere is capable of bending radio waves back towards the Earth, enabling long range communication. The ability of the ionosphere to propagate these radio waves, changes with the ionosphere, and a way to measure the ionosphere is with an ionosonde.

What is an ionosonde?

Ionosondes work by transmitting a signal towards the ionosphere, where it is then refracted back to the Earth's surface. It is then received, and the return echoes are timed. Using this and knowledge about the speed of light, the height profile of the plasma frequency of the bottomside ionosphere can be used to calculated and then be used to gather information about the electron density of the ionosphere.

There are two main kinds of ionosonde systems. Those being oblique and vertical instance. Oblique ionosondes require transmitting a signal that will be refracted by the ionosphere to be received by a separate antenna in a different location. This makes timing more difficult as the clocks need to be in sync, requires multiple systems, and can be more costly. Vertical instance ionosondes require one system and transmits a high frequency signal vertically into the ionosphere. This signal is between 3 MHz and 30 MHz, and it is refracted and picked up by the same system.



Low-Cost Low-Power

Ionosondes were originally designed in 1925 by Briet and Tuve. However, traditional ionosondes required large antenna systems, and the transmitter required high amounts of power. There has since been advancements in software defined radio (SDR) technology with advanced digital signal processing (DSP) and computational power. This enables the size, cost and power demands of an ionosonde system to be reduced significantly. This recently was demonstrated during the 2017 Great American Eclipse by sounding the ionosphere using an Ettus USRP N210 (*Lloyd*,2019). This system is still costly, currently more than US$3000, but newer, more affordable SDR systems, such as the Red Pitaya development board can provide similar functionality at a much lower price, less than $600 (*McGwier*,2018; *Lloyd*, 2019). More work still needs to be done, however, when complete the new system and software will be a valuable low-cost ionosonde system.

Red Pitaya

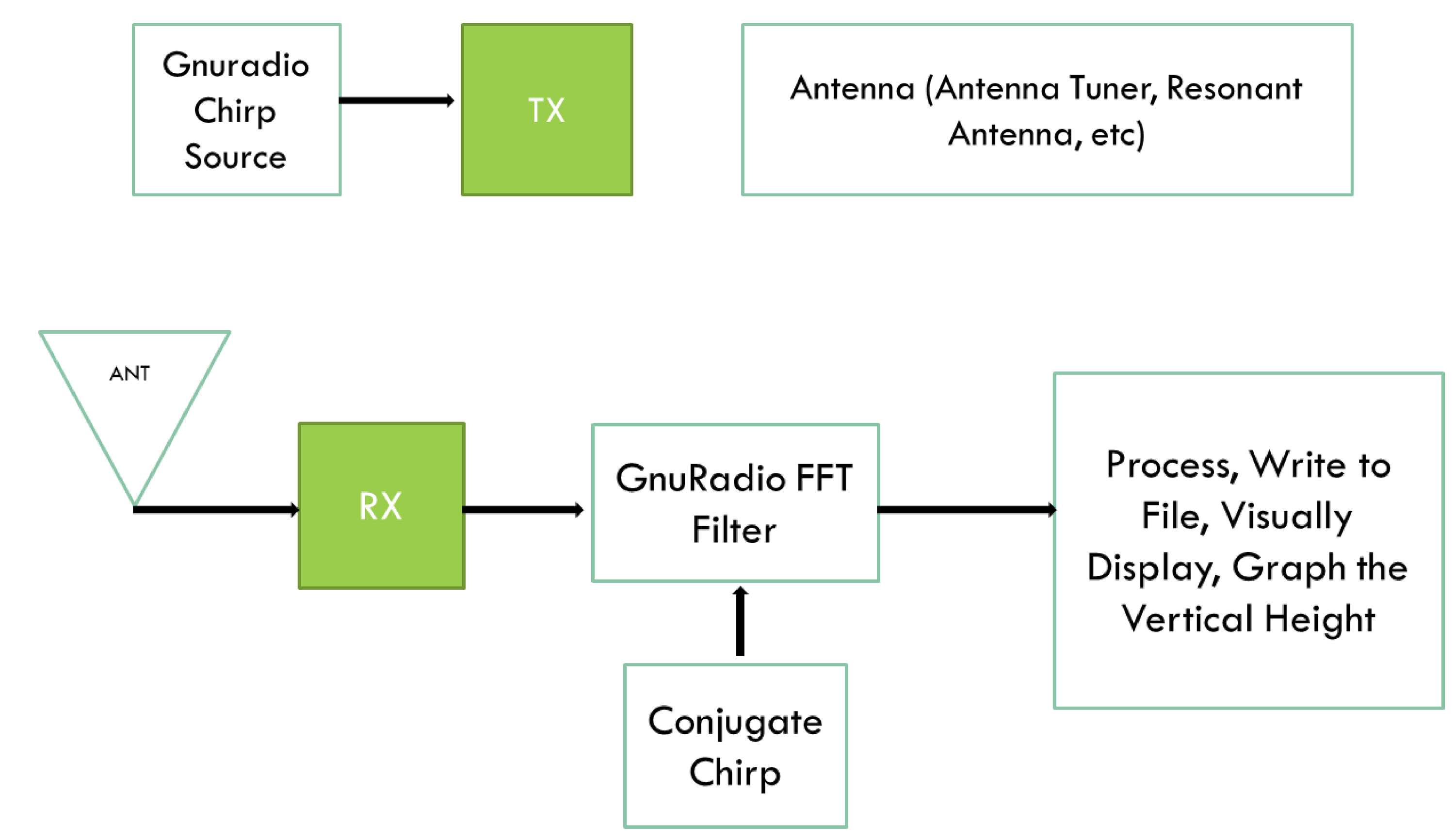
Previous versions of the Red Pitaya have faced issues that would make using the board in an ionosonde system less than ideal. These included not have a 50-ohm impedance, a high noise floor, and cross talk between the outputs and the data port. Additionally, there was not the ability to use a more accurate external clock. On the newer SDRlab 122-16 version, much of the issues with the older boards have been resolved. There is a lower noise floor, 50-Ohm impedance, no cross-talk, and there is a version that allows the user to use their own external clock. Additionally, Pavel Demin has created an image for the board that allows the Red Pitaya to be used with GNU radio as a transceiver, and currently a Leo Bodnar GPSDO reference clock is being used for the Red Pitaya.

Antenna

An experimental license has been obtained, enabling transmission on the desired frequencies (3-10 MHz), although the pitaya can achieve 60 MHz. The antenna design used will be an inverted-V fan dipole. This configuration will enable the ionosonde system to operate across the desired HF range easily, and as the fans will be near resonance, they will not interfere with each other.

Testing the board

So far, a good amount of testing has gone into the Red Pitaya. A significant part of this testing has been a trip to the MIT Haystack Observatory. The goal of visiting the observatory was to test the board so that it could be compared to the older version of the board, and to get a better understanding of the capabilities of the system. The testing included measuring the phase noise and Allen Deviation against a hydrogen maser. The results showed that there was still a deal of noise from the board, however, it was much cleaner than the older board.



Conclusion

The improved Red Pitaya development board offers a significantly more affordable option when constructing a low power ionosonde. There is still much work to be done in getting the ionosonde system up and running using the Red Pitaya. In the following months, the system will be able to be used to sound the ionosphere during the upcoming solar eclipses later in 2023 and in 2024. Currently Pavel Demin's image is working on the Red Pitaya SDRlab 122-16 and is enabling board to be controlled through GNU radio. Currently GNU radio code is being developed for the system to use. As the weather warms, setting up of the antenna will be able to begin, and testing can begin. This will be a great step in getting this type of low-cost low-power ionosonde out of its infancy.

References

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Acknowledgements

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