Toward Developing an Algorithm for Separation of Transmitters of High Frequency Chirp Signals of Opportunity for the Purpose of Ionospheric Sounding

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Introduction

The ionosphere is a highly variable, ionized layer of the Earth's upper atmosphere. Extending from about 50-1000 km above the Earth's surface, the ionosphere consists of several regions each of varying altitudes and ionization. The ionosphere can be broken up into the D region, E region, and F region. The instruments utilized to make these ground-based observation of the ionosphere are known as ionosondes, or ionospheric sounders. Gaining a deeper understanding is essential to furthering our knowledge on ionospheric science and its role in the geospace system and neutral atmosphere. We focus primarily on chirp ionosondes, which is a type of ionospheric sounder that works by transmitting an HF signal that changes linearly in frequency with time from about 2 MHz to about 20 MHz. By using an HF Software Defined Radio (SDR) receiver and the GNU Chirpsounder2 software created by Juha Vierinen, it is possible to listen for chirp ionosonde signals of opportunity and decode these signals into oblique ionograms that can be used for scientific or operational purposes. The current algorithm created by Dev Joshi can separate and detect received transmissions from Chesapeake Virginia. We further their work by altering the algorithm so that it can separate the transmission of chirp signals based on numerous geographic locations.

Relocatable-Over-The-Horizon Radar

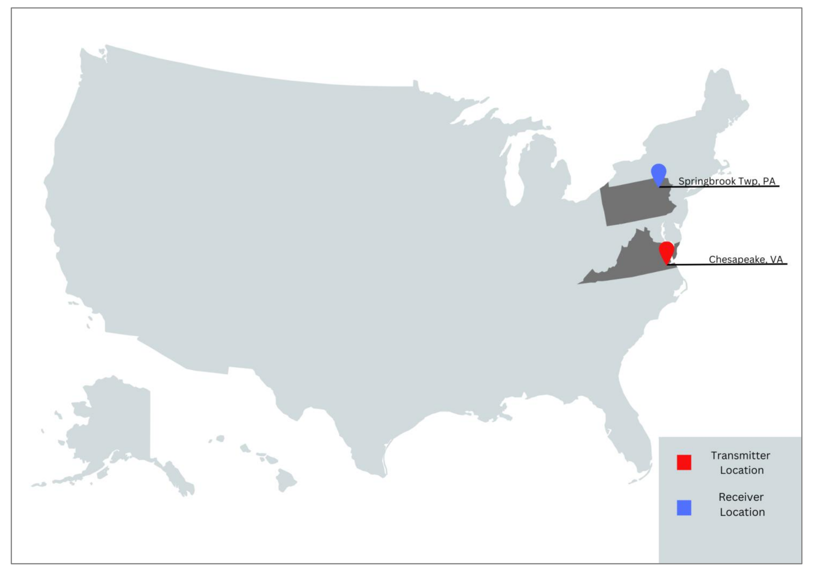

Figure 1. Map of current transmitter and receiver location

We utilize Chirpsounder data to pinpoint the location of transmissions being received by the Chirpsounder. These transmissions are from radars known as Relocatable-Over-The-Horizon-Radars or ROTHR. These radars are military instruments which emit chirp soundings and use the echoes to provide surveillance of targets such as aircrafts and ships. These echoes can help determine the size, type, and movement of the targets. There are multiple ROTHR's located across the United States most of which the exact locations are unknown. Our work will create an algorithm which can automate, and sort received signals of radars from the Chirpsounder.

GNU Chirpsounder2

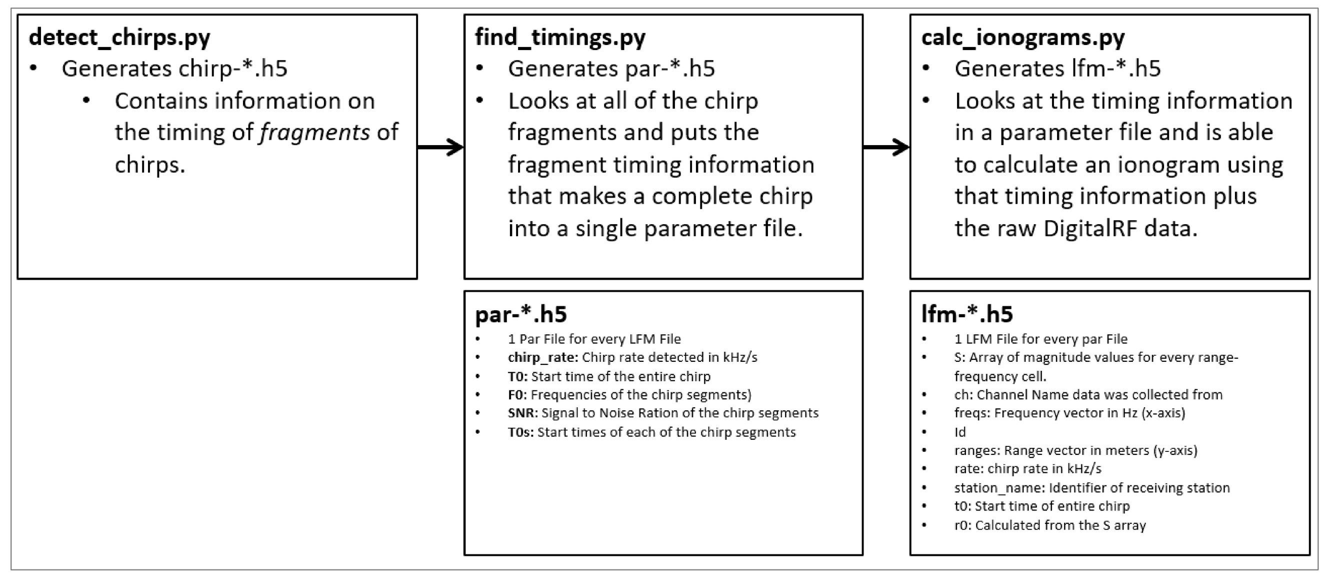

Figure 2. Block overview of the software architecture of the GNU Chirpsounder2

Figure 3. Ettus Research N200 USRP Software Defined Radio

The GNU Chirpsounder Receiver is a software defined radio (SDR) based instrument which can be utilized to make observations of the ionosphere and how it impacts radio wave propagation. It utilize the Ettus Research USRP N200 SDR as pictured in figure 3. Currently, an algorithm created by Dev Joshi as depicted in figure 1, uses the signal-to-noise ratio, chirp rate, and range to distinguish transmissions received by the Chirpsounder to those signals which are transmitted from a ROTHR located in Chesapeake Virginia.

Data & Analysis

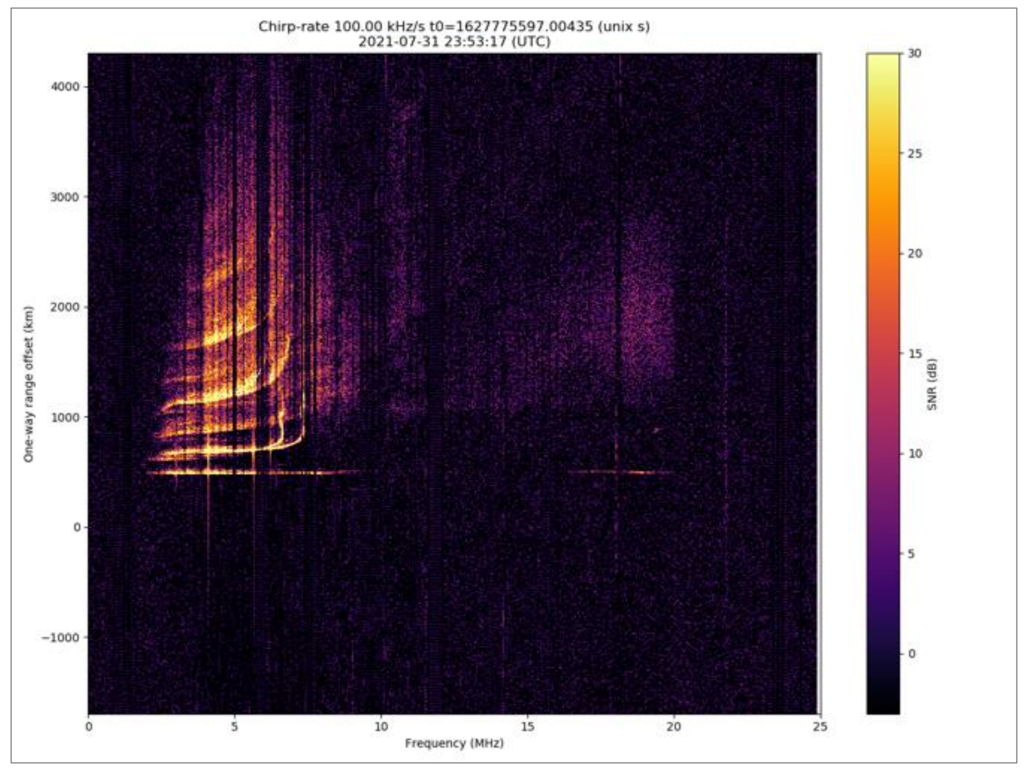

Figure 4. A calculated ionogram outputted by the GNU Chirpsounder2 softwarefrom a Chirpsounder located in SpringBrook, PA. The chirp signals are transmitted from the ROTHR located in Chesapeake, VA

The traces pictured in the oblique ionogram from the Chirpsounder ionosonde coincide with layers of the ionosphere, more specifically the E, F1, and F2 layers. The various hops between traces provide information about the electron density of the F-layer of the ionosphere (Bernhardt). In figure 3, the left signal cluster is an ordinary signal path, and the right is an extraordinary signal path. The cause of these paths are differences in polarization. The bistatic scatter noticed throughout the pulses are the result of reflected HF transmissions.

References

Bernhardt, P. A., et al., "Bistatic observations of the ocean surface with HF radar, satellite and airborne receivers," OCEANS 2017 - Anchorage, Anchorage, AK, USA, 2017, pp. 1-5.

Chen, Gang, et al. "Application of the oblique ionogram as vertical ionogram." *Science China technological sciences* 55.5 (2012): 1240-1244.

Davies, Kenneth. *Ionospheric radio*. No. 31. IET, 1990.

Ivanov, V. A., et al. "Chirp ionosonde and its application in the ionospheric research." *Radiophysics and Quantum electronics* 46 (2003): 821-851.

Joshi, D., N. Frissell, W. Liles, J. Vierinen and E. S. Miller, "Early Results from the Ionospheric Sounding Mode Using Chirp Ionosondes of Opportunity for the HamSCI Personal Space Weather Station," 2021 XXXIVth General Assembly and Scientific Symposium of the International Union of Radio Science (URSI GASS), Rome, Italy, 2021, pp. 1-3, doi: 10.23919/URSIGASS51995.2021.9560441.

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