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.

Objectives

Figure 1. Ettus Research N200 USRP Software Defined Radio

Our chirpsounder system is deployed in Springbrook Township, PA. The current algorithm can separate transmission received by the system into those which originate from Chesapeake, Virginia. However, the capabilities of this system extend far beyond this current use. The data derived from the generated ionogram can give valuable insight into the dynamics of the ionosphere that come into play with radio wave propagation. For example, this can include how these dynamics change in response to major events such as eclipses. Being able to observe ionospheric conditions around the globe from one receiver can advance our understanding and create a better model of the ionosphere. Our goal with this algorithm is to create a more accessible dataset that can organize signals based on locations. The above figure is the Software Defined Radio that is utilized for the GNU Chirpsounder software.
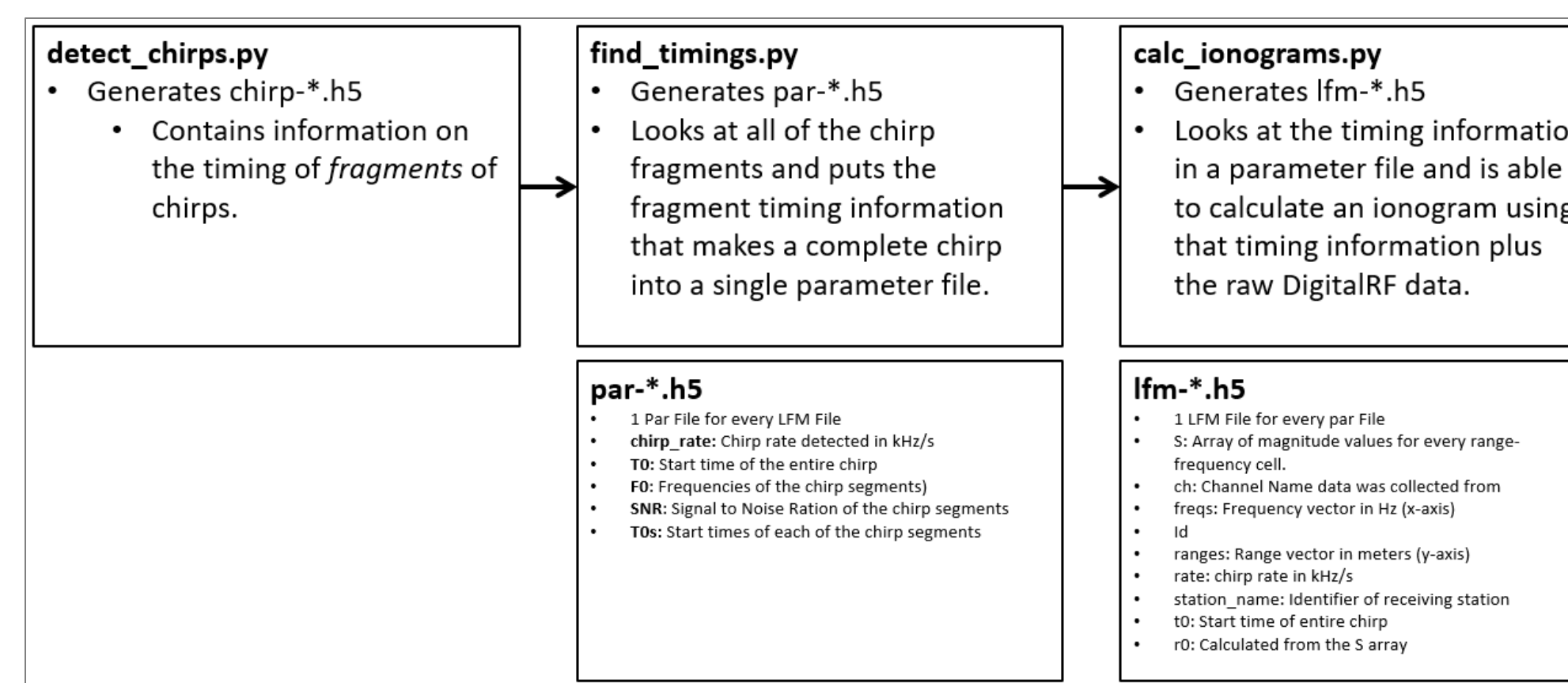
Current Software

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

The GNU Chirpsounder2 software makes use of various programs as shown in figure 2 above. The software relies on Digital HF recordings and these programs create various output files:

- Chirp.h5: includes the files that record the frequency, time, chirp rate, and SNR when a chirp is detected.
- Par.h5: Analyzes the chirp.h5 files which determines parameters to ensure the chirp is real.
- Lfm_ionogram.h5: Contain the generated ionograms.

There is a few variables within the algorithm that can be used to differentiate between transmitter sites. These include a chirp rate (kHz/sec) which measures the change in the signals frequency over time, the range (km) between the transmitter and receiver location, and a value called r0 which refers to the initial range or distance to the target at the start of the chirp waveform and can be calculated using the speed of light.

Pictured is an ionogram generated by the GNU Chirpsounder2 software. This ionogram a representation of the ionosphere's reflection and signals time delay against frequency. 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. 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.
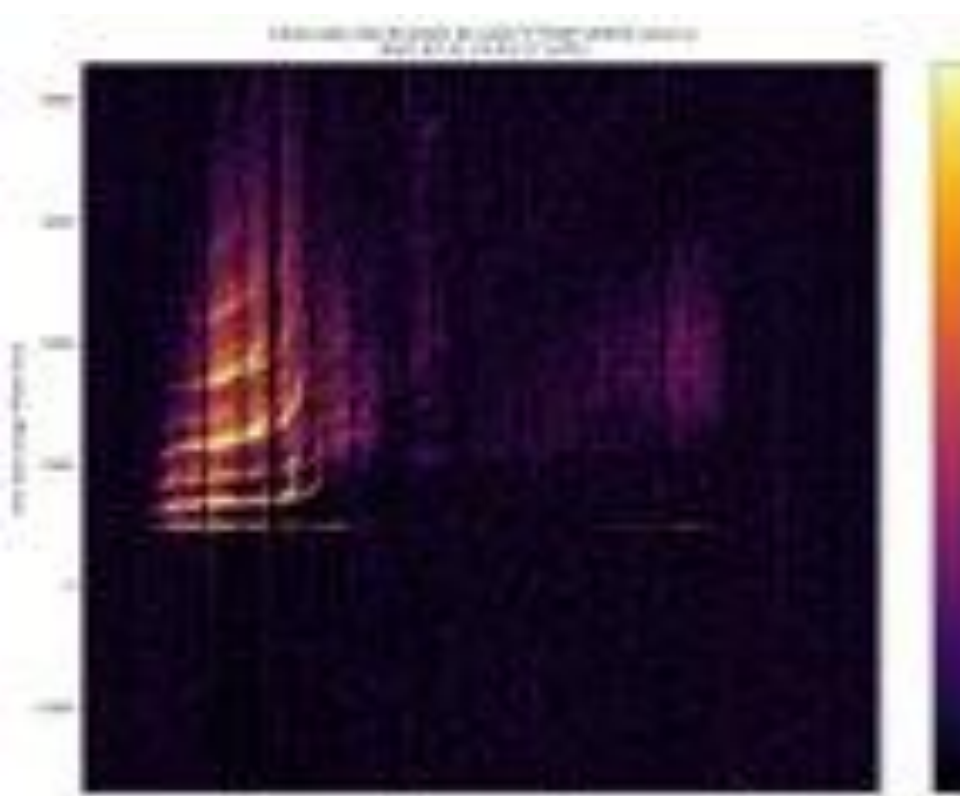

Figure 3. A calculated ionogram outputted by the GNU Chirpsounder2 software from a Chirpsounder located in SpringBrook, PA.

Web Based-Application

Figure 4. Screenshot of the filtered page of web-based application for analysis of chirpsounder data.

Above is a web-based application created by Nisha Yadav that allows of visualization and analysis of ionograms generated from GNU Chirpsounder2 software. This application classifies based on chirp rate and distances between RX and TX locations. Eventually, we will be able to implement our algorithm within this application so that users can select a transmitter location and be presented with all generated ionograms from the specific location. The above figure is a screenshot from the filtered page of the application (filtered for Chesapeake, VA) after the user selects a location. It is sorted based on day and the user can also download the lfm files as well as the ionogram on to their system.

References

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Acknowledgements

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