Personal Space Weather Station Software Development

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Abstract

As part of the Personal Space Weather Station (PSWS) project, our team has been developing the Central Control System and Central Database System that will be used to collect and store the data generated by the stations. The Central Control System functionality is being developed using Django, a Python based web framework. It is used to define how users will interact with the web server where their collected data will be uploaded, organized, and analyzed. It is also used to define models for the data being collected and how it will be stored in the Central Database System.

In the server's current state, users can register accounts and stations as well as view lists of uploaded observations. Observation data can also be downloaded individually for analysis. The availability of the PSWS will allow a much larger sample of data to be collected daily. With this data, more accurate models of the ionosphere can be created, granting a better ability to predict how radio waves will be precisely affected by the ionosphere at any given moment and supporting ionospheric science.

Introduction

The ionosphere can experience drastic changes over very short intervals of time in response to many variables:

- Radiation from the sun
- The time of day
- Weather on Earth
- The solar cycle

These rapid changes are known as ionospheric variability. This high level of variability makes it difficult to gather reliable data on the ionosphere's effects on radio communication using current methods.

The PSWS is a ground-based, multi-instrument device designed to remedy these difficulties. Once complete, the PSWS will be available for both professional researchers as well as amateur radio operators. Both groups will be able to collect data for different purposes.

- **Professional researchers**
  - Monitor and characterize the ionosphere's variability
  - Create more accurate models of the ionosphere
  - Predict its effects on radio waves more effectively
- **Amateur radio operators**
  - Contribute to official scientific research
  - Improve their understanding of how their equipment and radio signals interact with the ionosphere

Methods and Milestones

The PSWS consists of two main components: the Local Control Unit and the Central Control System.
The Local Control Unit is the physical PSWS device and the software that controls it. There are two versions of the device:

- **GrapeSDR**
  - Low-cost version
  - Less precision and storage
- **TangerineSDR**
  - High precision version
  - Fitted with more instruments and increased storage

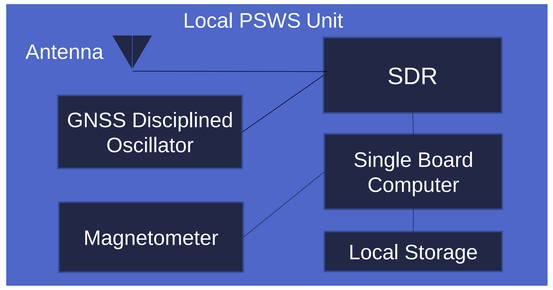

Figure 1– Component diagram of Local PSWS Unit

The Central Control System serves as the foundation for the PSWS network. It is a web server that allows users to create accounts, register stations, upload observations, and download data. The PSWS Network also houses the Database Control System, which receives and organizes all data uploaded for user analysis. The planned network layout is illustrated in Figure 2.

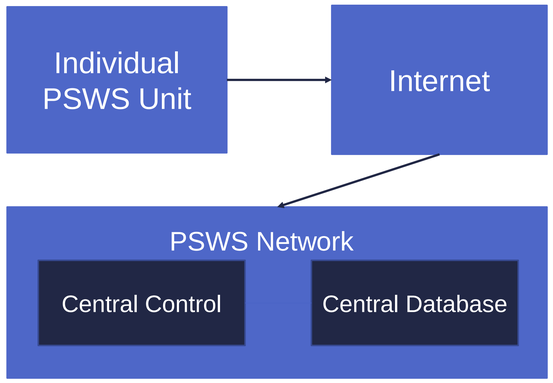

Figure 2 – Network composition between PSWS Unit, Central Control, and Central Database

Methods and Milestones

Currently, the focus of the project is the design, development, and integration of the Central Control and Central Database. Some of the key tools used:

- Django
- MariaDB
- Watchdog

Important use cases and features recently developed:

- Secure observation downloads
- Improved data table display and organization
- Filtering of tables for easier data access
- Enhanced map display system
- Beginning graphing and sonification analysis

Results and Example Data

Figures 3 and 4 contain a sample of data like what will be uploaded to the server. The data was collected by a simulation of the TangerineSDR based on a FlexRadio 6600 and two Odroid N2 microcomputers over the course of a single night in September 2020. Figure 3 shows the raw spectrum data, while Figure 4 is the same data transposed onto a more readable graph.

The data reveals multiple deviations from the carrier frequency that result from a phenomenon known as traveling ionospheric disturbances (TIDs.) TIDs can cause sudden changes in the ionosphere, even at times when the ionosphere is expected to exhibit decrease variations.

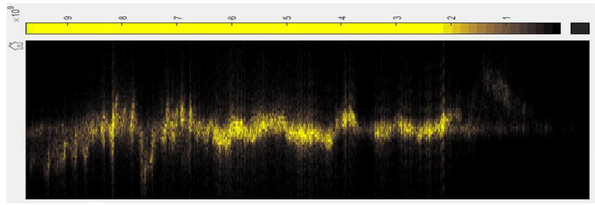

Figure 3 – Raw spectrum data recorded by a TangerineSDR in September 2020

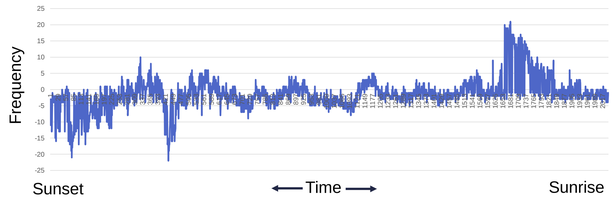

Figure 4 – The same September 2020 spectrum data but cleaned and graphed

Significance

Once completed, the PSWS will help both researchers and individuals improve their understanding of several scientific phenomena involving the ionosphere:

- Traveling Ionospheric Disturbances (TIDs)
- Long Delayed Echoes
- Sporadic E Propagation

In addition, improved understanding of the ionosphere and its activities will allow for more effective radio communication. By predicting ionospheric changes, ionospheric interference with radio signals can be better managed, potentially even allowing for radios to serve as a viable substitute for worldwide communication should current satellite communications ever fail.

Future Directions

In the short term, the team will continue development of the Central Control System. As it nears completion, the team will shift into testing and optimizing both the software and its interactions with the physical hardware.

The goal is to complete the PSWS Network and distribute individual PSWS units in time for the solar eclipse occurring in 2024. Ideally, hundreds of devices will be sent worldwide along the path of the eclipse to gather data on the ionosphere as it interacts with full and partial portions of the 2024 eclipse.

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