Data Collection and Visualization of the HamSCI Grape High Frequency Doppler Observations for the 2023 and 2024 North American Solar Eclipses

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Introduction

The HamSCI Grape Personal Space Weather Station citizen science project is designed to study ionospheric variability using a network of low-cost, high frequency (HF, 3-30 MHz) Doppler receivers. These receivers monitor highly stable signals broadcast by US and Canadian governmental standards stations WWV (Ft. Collins, Colorado), WWVH (Kauai, Hawaii), and CHU (Ottawa, Ontario). Due to the use of these highly-stable and carefully calibrated transmitters, paired with precision frequency measurement by the Global Navigation Satellite System (GNSS)-disciplined Grape receivers, variability of the received frequency can be attributed to ionospheric variability. To study the ionospheric and radio propagation impacts of the upcoming October 14, 2023 annular and April 8, 2024 total solar eclipses, a network of Grape receivers is being deployed to volunteer amateur radio operators and citizen scientists across the US. The data from these receivers will be sent to a central Personal Space Weather Station database and made available for public access via a web interface. In this presentation, we describe the current operation of this system, as well as planned improvements to public data access and visualization.

Objectives

- Data aggregation: Each Grape receiver is designed to output MIT Haystack's DigitalRF format (https://github.com/MITHaystack/digital_rf), a data format that enables the reading and writing of radio frequency data for efficient data archiving and rapid random access for data processing. This system plays a crucial role in establishing communication with remote Grape receivers and gathering their data into a centralized database managed by the University of Alabama. By consolidating data from multiple receivers, the aggregation process facilitates comprehensive analysis and exploration of the collected information.
- Data visualization: The accompanying web interface allows users to swiftly generate spectral plots encompassing any desired time period. Through an intuitive and user-friendly interface, researchers and scientists can easily visualize the collected data in the form of spectral plots, which offer valuable insights into the frequency distributions and patterns observed within the dataset. This visual representation aids in the identification of significant trends, anomalies, or patterns that may be present in the radio frequency data.
- Public data access: The web interface also offers public access to the collected data. Interested parties, including researchers, students, and enthusiasts, have the opportunity to utilize the web interface to download sets of raw data for their own analysis.

- Grape version 2 development: Recognizing a limitation of Grape version 1, which restricted monitoring to a single frequency at a time, the development team has undertaken the creation of Grape version 2. This system possesses the capability to simultaneously monitor up to three frequencies, thereby expanding the scope and versatility of data collection. Multiple hardware and software components are being refined and optimized to ensure seamless integration and reliable functionality. Notably, the developers are implementing the ability to package data into a format compatible with the data aggregating system. Once completed, this feature will facilitate the efficient integration of Grape version 2 into the broader data processing infrastructure.

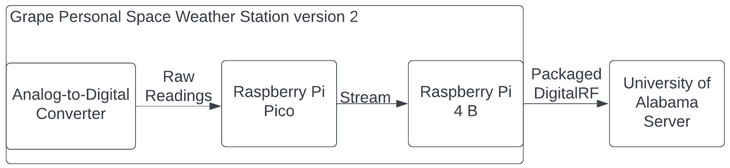

Figure 1. Proposed Data Flow Diagram of the Grape v2

- TangerineSDR integration: this system (under development) is a wideband software defined radio (SDR) version of Personal Space Weather Station. By leveraging wideband SDR architecture, the TangerineSDR will capable of conducting multiple scientific receive experiments simultaneously, including emulation of the Grape 2.

Operational Components

- Several Grape v1 receivers have been strategically deployed to engage volunteer amateur radio operators and citizen scientists throughout the United States. By distributing Grape v1 receivers to these dedicated volunteers, a wide geographic coverage is achieved, enabling comprehensive data collection across diverse locations and environments.
- Initial Grape 1 architecture and science results have been published by *Gibbons et al.* (2022) and *Collins et al.* (2023).
- The University of Alabama team led by Prof. William D. Engelke has developed an operational database system and user-friendly interface. Once a day, the server reaches out to the participating Grape receivers, retrieving their digitalRF data.

- *The web interface, created by the University of Alabama, serves as a portal to the data collected by the Grape receivers. This user-friendly interface has been developed using the Django web framework, which provides a foundation for building dynamic web applications. Accessible at https://psws.hamsci.org, the website offers a platform for users to explore and download data from all participating Grape receivers.*

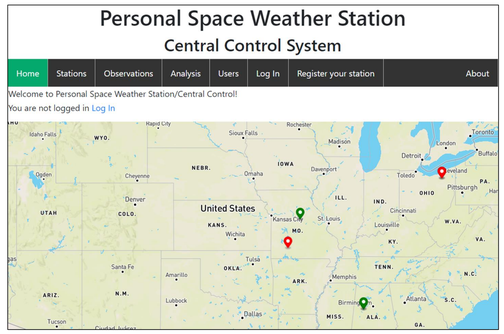

Figure 2. Web-Based Interface for Data Access and Visualization

- Significant progress has been made in the development of a preliminary plot generating function. These plots aid in identifying trends, patterns, and anomalies, assisting researchers in extracting meaningful insights from the complex radio frequency information.
- In the ongoing Grape v2 development, the handshake protocols between each individual component and the data format output of each component have been defined. The system is pending implementation.

Future Work

- We aim to increase the deployment of Grape v1 receivers across the country. Additionally, it would be ideal to fully implement Grape v2 and distribute these systems before the upcoming eclipse events.
- There is ample room for optimizations and refinements within the web data portal. Furthermore, the plot generating function needs to be integrated into the website.
- The Raspberry Pi 4B used in Grape v2 requires embedded software to effectively package raw digital data into the digitalRF format.

References

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