Receiver System Design for Crowdsourced Experiments on the Effects of a Solar Eclipse on Low-Frequency Radio Wave Propagation

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***Abstract*—The goal of this project is to conduct the first geographically distributed, low-frequency skywave propagation measurements during a solar eclipse. There is a lack of knowledge about how radio waves below frequencies of 500 kHz are affected by a total eclipse and a lack of experimental data reflecting these low-frequency radio wave transmissions at geographically diverse locations during an eclipse. A low-frequency band receiver system for people across the United States to assemble and use is designed, allowing for a crowd-sourced collection of measurements of relative signal strength of the WWVB and Dixon low-frequency station signals during the eclipse over North America on August 21, 2017.**

A. Introduction

A solar eclipse will be visible from North America on August 21, 2017. This will be an opportune event to measure how skywave propagating, low frequency (LF) radio transmitted signals are affected by the varying magnitudes of eclipse at different geographical locations across North America, as seen in Fig. 1. There have been many experiments performed on the effects of a solar eclipse on the propagation of waves in the high frequency (HF) band. However, a limited number of experiments have been done measuring the propagation of LF waves during an eclipse. Furthermore, there is only one known previous attempt by the *Scientific American* magazine involving crowdsourced measurements of radio wave propagations during an eclipse using various geographically distributed receivers [1].

This project is a joint effort between the University of Massachusetts Boston and George Mason University. The goal of the project is to take measurements of LF radio wave propagation under varying magnitudes of the eclipse at different geographical locations. For this to be done, a receiver design is to be made available online so that pre-college students and hobbyists can participate in the measurement. Senior design teams at both institutions are developing receiver designs. This paper will discuss the efforts of the University of Massachusetts Boston design team.

Fig. 1. Map of North America showing the varying magnitude of the prognosticated eclipse of August 21, 2017 [2]

In order to attain the greatest amount of data during the eclipse, this project is being designed to be crowdsourced. The target audience to build these receivers and carry out the measurements are hobbyists, radio enthusiasts, researchers, and educational programs. Furthermore, by engaging school programs throughout the United States, we can engage students who are interested in the STEM fields and give them hands on experience with LF radio wave propagation.

The receiver system is designed to measure the strength of two transmitted signals during the eclipse, store the data, and upload it to the project servers after the eclipse. This receiver is designed to be inexpensive, easy to build, and easy to use, such that anyone ages 12 and up can easily build and use the equipment. A backend system is designed to receive and process the data collected by the users. A website is hosted on this backend system, displaying the processed data in different formats and all instructions needed for assembling the receiver.

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B. Receiver System Design

The receiver system is composed of an antenna, a low-noise amplifier (LNA), a digital signal processor (DSP) and controller, a mixer, a global positioning system (GPS) receiver, a GPS-disciplined oscillator (GPSDO), and an analog to digital converter (ADC). A simplified system diagram is shown in Fig. 2. In order to simplify the building process for the users, all of the receiver components are available to purchase online through the listed vendors on the project website. The signals to be received by the receivers during the eclipse are the 60-kHz radio wave signal transmitted by the WWVB, a National Institute of Standards and Technology time signal radio station in Colorado, and a 55.5-kHz radio wave signal transmitted by a LF station in Dixon, California [3].

The antenna is a ferrite rod loop antenna that is designed to receive the WWVB signal but will be used to receive both signals. The receiver is designed to be externally noise limited by using a low-noise, high gain amplifier. The DSP and controller are a Raspberry Pi A+. This microcontroller controls all of the active components of the receiver, processes the signal digitally, and stores the recorded measurements onto an SD card. Considering the sampling rate capabilities of the microcontroller, analog downconversion of the measured signal is done with a mixer module and a GPSDO. The GPS receiver module, shown in the upper right corner of Fig. 2, gives the GPSDO a clock signal and provides a timestamp and GPS location to the DSP. The mixer passes the downconverted measured signal to an ADC which then passes the converted digital signal to the DSP. After the measurements have been taken, processed, and stored, the DSP is able to upload the data to the project servers through a WIFI module.

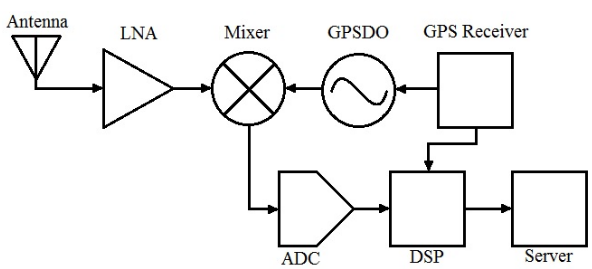

Fig. 2. Simplified system diagram.

C. Server Design

The server is designed using a multi-service architecture including data collecting API's and storage as well as the ability to serve web pages. The server exists as a central location for all documentation and other information related to the project. It is designed to be rugged and reliable, as the mass collection event happens within a limited timeframe. The server uses Socket.IO, a WebSocket library, in order to pass messages between the receivers and central servers. The server is programmed in JavaScript using the NodeJS platform. By design, the server has a single entry point, known as a load balancer, which accepts and routes connections to an unlimited number of "worker" servers based on geo-spatial location and other factors. This enables the services to be live and reliable for all locations and easily scalable as the demand grows.

D. Test Design

In preparation for the eclipse, a number of tests will be done by the design teams and the users. The design teams will test the receivers by receiving and parsing the time data sent by the WWVB station. Test cycles will be run on the receivers to test the receiving of data and sending of data to the server, as well as having the data be displayed on the webpage. Before the final set of instructions are sent to the participants, they will be sent to a group of beta testing teams which will try to follow the given instructions to verify the correct operation of a functional receiver. Prior to the eclipse, each user will test their receiver systems by following a set of instructions provided on the website. This will guarantee proper working functionality of each of the receiver system modules. After all modules pass the tests, the entire receiver will be tested to make sure it can measure and process the signal, then upload the data. Since the WWVB signal is broadcast year round, this signal will be used for testing both day and night signal strengths.

On the day of the eclipse, the users will use the receivers to measure the signal strength of the two signals before, during, and after the eclipse for approximately 10-min windows each. Within the few days following the eclipse, all users will be uploading the measurements to the servers. From there, the measurements will be made available online for future analysis to further understand the specifics of how the ionization of the ionosphere due to a solar eclipse affects skywave propagating radio wave transmissions.

E. Conclusion

Due to the crowdsourcing aspect of this project, its success depends on the collaboration and work by the users that will be assembling and using the receivers during the eclipse. This project will not only be a valuable contribution to ionospheric and radio wave propagation research, but also a great learning experience for the hobbyists and school programs that participate in it. Furthermore, the devices themselves can be reused in future iterations of similar projects or redesigned for recreational use as radio receiving devices.

Project Radio Eclipse invites the scientific community to participate in this project. Comments and questions pertaining to the project are also welcome.

References

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