HamSCI and the 2017 Total Solar Eclipse

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On 21 August 2017, a total solar eclipse will cause the shadow of the moon to traverse the United States from Oregon to South Carolina in just over 90 minutes. The sudden absence of sunlight due to the eclipse, especially solar UV and x-rays, provides an impulse function to the upper atmosphere that modifies the neutral dynamics, plasma concentrations, and related properties. In spite of more than 60 years of research, open questions remain regarding eclipse-induced ionospheric impacts. Ham radio operators' advanced technical skills and inherent interest in ionospheric science make the amateur radio community ideal for contributing to and and participating in large-scale ionospheric sounding experiments. This paper describes the Solar Eclipse QSO Party (SEQP), the HF Wideband Recording Experiment, and the Eclipse Frequency Measurement Test (FMT), three amateur radio experiments designed to study the 2017 total solar eclipse. These experiments are coordinated by HamSCI, the Ham radio Science Citizen Investigation, a citizen science organization that connects the amateur radio community to the professional space science research community for mutual benefit.

Keywords. HamSCI, eclipse, SEQP, ionosphere

1 Introduction

On 21 August 2017, a total solar eclipse will cause the shadow of the moon to traverse the United States from Oregon to South Carolina in just over 90 minutes. As shown in Figure 1, this will be the one of most significant solar eclipses traversing the continental United States for 100 years. In addition to their stunning visual display, eclipses have a significant impact
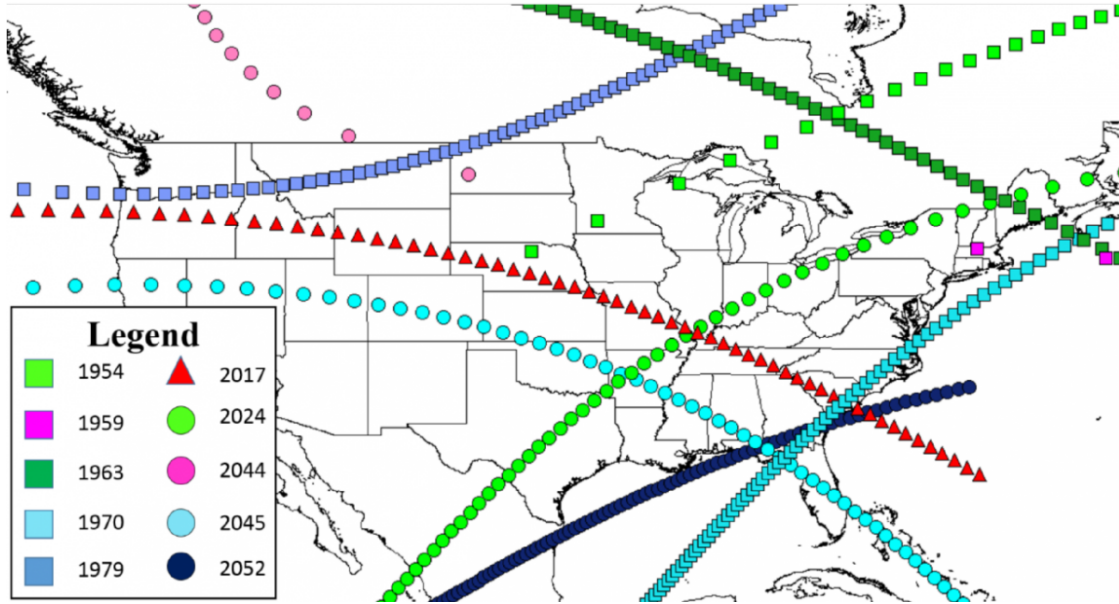
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Figure 1: Total solar eclipses over the continental United States from 1950 to 2052.

on the Earth's coupled thermosphere/ionosphere system. The sudden absence of sunlight, especially solar UV and x-rays, provides an impulse function to the upper atmosphere that modifies the neutral dynamics, plasma concentrations, and related properties. The predicted scale of these changes is evident in Figure 2, which shows NRL-SAMI3 model differential electron densities (eclipsed - non-eclipsed) at 302 km altitude on 21 August 2017 at 1815 UT [*Huba and Drob*, 2017].

The ionospheric effects of eclipses have been studied for more than 60 years [e.g., *Benyon and Brown*, 1956; *Anastassiades*, 1970; *Evans*, 1965; *Roble et al.*, 1986; *Krankowski et al.*, 2008; *Bamford*, 2000], but due to the rarity of such events in [often-times] under-instrumented locations, the spatial and temporal extent of ionospheric eclipse effects are still not fully understood. Thus, the 2017 total solar eclipse over the United States is an unprecedented opportunity to address open questions regarding eclipses and their impact on the ionosphere.

The Continental United States is well-instrumented to study eclipse-induced ionospheric effects, as it contains a suite of instrumentation including GPS Total Electron Content (GPS-TEC) receivers, ionosondes, Super Dual Auroral Radar Network (SuperDARN) radars, and other ionospheric instruments capable of obtaining data at an unprecedented level of detail. Even so, the ionosphere is vast and remains under sampled, and therefore additional data sources are welcome complements to existing measurement systems.

Amateur (ham) radio operators are hobbyists interested in radio and licensed by their respective federal governments to transmit and communicate on approved amateur radio frequencies. Hams often communicate on medium and high frequency (MF and HF, 1.8 – 30 MHz) bands that allow over-the-horizon communication due to signal refraction by the ionosphere. These communications are directly impacted by the ionospheric state, and it has been shown that systems designed to monitor HF amateur communications, such as the Reverse Beacon Network (RBN, http://reversebeacon.net), can serve as a data source

for ionospheric sounding [*Frissell et al.*, 2014]. Additionally, ham radio operators' advanced technical skills and inherent interest in ionospheric science make the amateur radio community ideal for contributing to and and participating in large-scale ionospheric sounding experiments.

This paper describes HamSCI, a citizen science organization that connects the amateur radio community to the professional space science research community, and its experiments related to the study of ionospheric effects induced by the 2017 Total Solar Eclipse. These experiments include the Solar Eclipse QSO Party (SEQP), the Eclipse HF Wideband Recording Experiment, and the Eclipse Frequency Measurement Test (FMT).
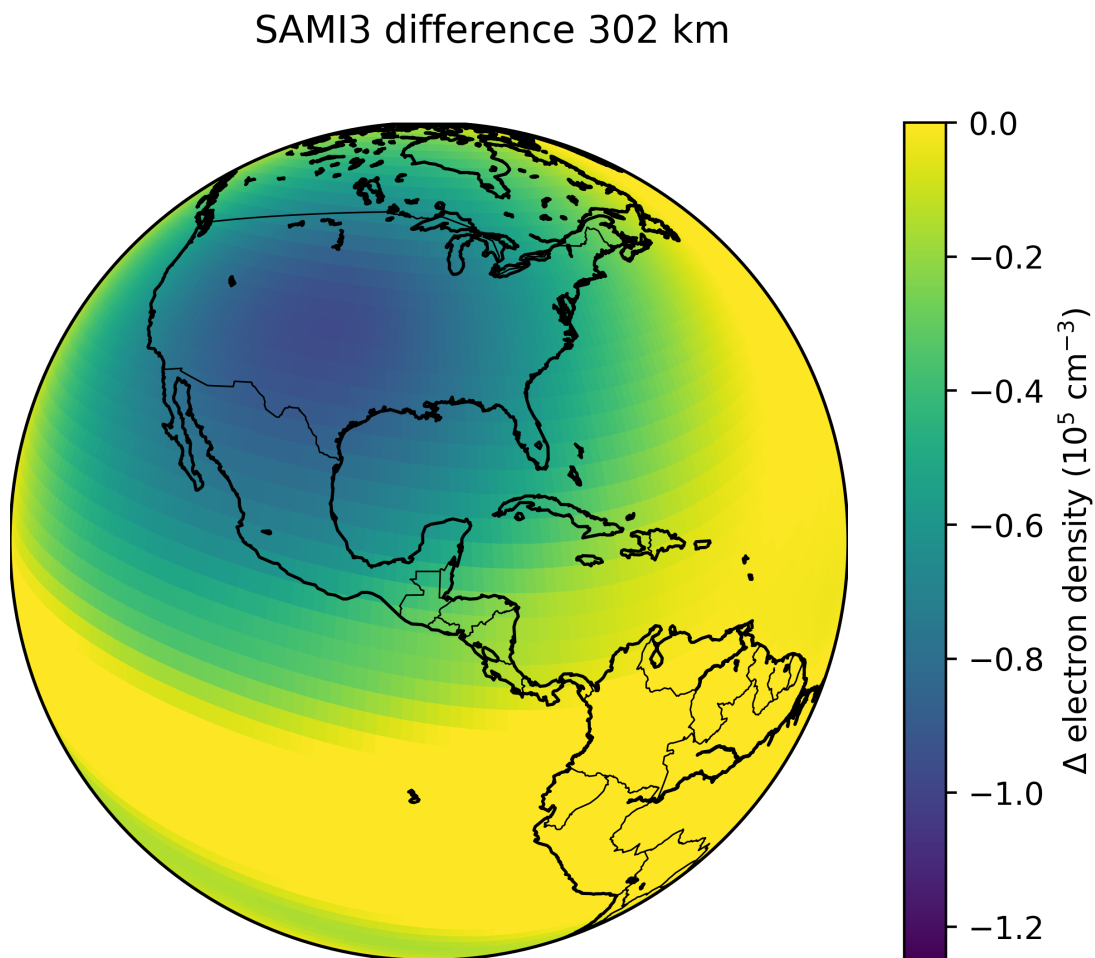
SAMI3 difference 302 km

Figure 2: Differential (eclipsed - non-eclipsed) electron densities at 302 km altitude as computed by the NRL-SAMI3 ionospheric model for 21 August 2017 at 1815 UT. A large electron density depletion caused by the eclipse shadow is observed over the United States.

2 HamSCI

The Ham radio Science Citizen Investigation (HamSCI, http://hamsci.org), is a citizen science organization that aims to bring the amateur radio and professional space science

research communities together for a mutual benefit. HamSCI has three primary objectives:

- Advance scientific research and understanding through amateur radio activities.
- Encourage the development of new technologies to support this research.
- Provide educational opportunities for the amateur community and the general public.

HamSCI was started by people who are both ham radio operators and space physicists and consists of participants from over 20 organizations in multiple countries. HamSCI's current primary leadership is based at the New Jersey Institute of Technology. HamSCI seeks to develop activities that are both engaging to the amateur radio community and are beneficial to the research community, with results of this research ultimately leading to publication.

3 HamSCI-Eclipse Radio Experiments

3.1 Solar Eclipse QSO Party

The Solar Eclipse QSO Party (SEQP) is a contest-like event that will be held before, during, and after the 2017 total solar eclipse in order to illuminate the ionosphere with HF radio contacts for the purpose of generating data to study the eclipse. The SEQP was designed with the intent of creating an enjoyable operating event that leverages the skills of the ham radio contest community while also providing useful scientific returns. The American Radio Relay League (ARRL) is working with HamSCI to promote the SEQP [*Silver*, 2017].

3.1.1 SEQP Data Sources

The SEQP is designed to generate data from many different sources. These data sources are summarized in Table 1. The largest source of data will be spot observations and QSOs automatically logged by the major automated digital ham radio networks. This includes observations by the Reverse Beacon Network (RBN), PSKReporter, and the Weak Signal Propagation Reporting Network (WSPRNet). Spots from the manual DX Cluster network will also be considered.

In addition to spots from automatic networks, SEQP participant logs, and detailed station information such as station location, antenna characteristics, local terrain profile, ground conductivity, and station Effective Radiated Power relative to a Dipole (ERPD) may be submitted directly to HamSCI via a submission form available from http://hamsci.org/seqp. Similarly, operators of RBN receive nodes and transmitting beacons may also submit station information though this site. Finally, participants who wish to record SEQP activity may provide wideband recordings in IQ format by following the instructions at http://hamsci.org/eclipse-wideband. These data will be uploaded to the HamSCI community on the open data sharing website http://zenodo.org.

3.1.2 SEQP Rules

The SEQP rules have been written to give the feel of a typical amateur radio contest while also guiding operating procedure to provide maximum scientific benefit. The official rules are published online at http://hamsci.org/seqp-rules/ and are reprinted here in Appendix A. This narrative will highlight selected rules and explain why certain rule choices were made.

Reverse Beacon Network http://www.reversebeacon.net/	Passive receiving stations automatically listen primarily for Morse code transmissions.
PSKReporter http://pskreporter.info/	Passive receiving stations automatically listen for digital amateur radio transmissions, including Phase Shift Keying 31 Hz (PSK31), radioteletype (RTTY), and many others.
WSPRNet http://wsprnet.org/	Weak Signal Propagation Reporting Network. This is an active mode specifically designed for evaluating ionospheric communication links. Member stations typically transmit and receive.
DX Cluster e.g. http://www.dxwatch.com/	Network where radio operators manually report on stations they have contacted and heard. This is the oldest digital amateur reporting network; it remains active today.
Participant Logs http://www.hamsci.org/seqp/	Participants may submit SEQP logs, detailed station information, and RBN and Beacon information directly to HamSCI.
HF Wideband Recordings http://www.hamsci.org/eclipse-wideband/	Radio operators may submit SDR recordings of SEQP recordings to zenodo.org by following the instructions on hamsci.org.

Table 1: Data sources used for the Solar Eclipse QSO Party (SEQP).

The SEQP will take place Monday, 21 August 2017 from 1400 – 2200 UTC. Partial eclipse begins in Oregon at about 1600 UTC and ends at about 2015 UTC in South Carolina. Therefore, this allows for coverage of the entire time the eclipse is over the continental United States plus about 4 hours of control time.

The SEQP aims to sample as much of the amateur HF spectrum as possible. All of the standard contest bands (160, 80, 40, 20, 15, 10, and 6 m) will be valid for SEQP QSOs. SEQP QSOs for points will not be allowed on the World Amateur Radio Conference (WARC) bands (30, 17, and 12 m) and the 60 m bands, as is customary for all contesting activity. Although any QSOs on these bands will not be eligible for points, spots and QSO data collected from these bands may be used in eclipse research. Additionally, bonus points will be given to SEQP participants who run automated monitoring stations on these bands.

Phone, CW, and all digital modes will be permitted during the SEQP. Because CW and digital transmissions may be detected automatic monitoring systems (i.e. RBN, PSKReporter), contacts on these modes will be given twice the point value of phone QSOs which cannot be automatically detected.

The SEQP exchange asks participants to exchange their six-character grid square and a real signal report. For phone and CW, the signal report will be the standard RS(T), while for digital both the SNR in dB (preferred) and the RSQ (readability - strength - quality) should be used. This exchange information will assist researchers in analyzing the logs post-event. This information may be easily recorded using the N1MM+ (https://n1mm.hamdocs.com/) logging software, which includes built-in support for the SEQP by selecting log-type "ECLIPSE".

Certain scoring practices have been implemented to generate additional data for the eclipse. First, a 4-character grid square multiplier is counted once per band. This is designed to increase the geographic coverage of the SEQP. Next, unlike normal contests, duplicate contacts are allowed on the same band and mode as long as 10 minutes has elapsed between QSOs. This rule is intended to increase the amount of data and allow for repeated testing of propagation paths.

Additionally, bonus points will be given for being spotted by systems such as the RBN, PSKReporter, etc., even if no QSO is made. This will encourage hams to test bands that otherwise appear closed. Bonus points are given to participants who submit detailed station information, such as antenna design characteristics, effective radiated power relative to a dipole (ERPD), and ground conductivity. These will be used to help researchers interpret QSO and spot data.

3.1.3 Analysis

Post-eclipse analysis will focus on three areas: (1) testing of numerical models, (2) study of propagation changes, (3) addressing of fundamental open scientific questions. The primary numerical model to be tested will be an eclipsed version of the first-principles Naval Research Laboratory Sami3 is Also a Model of the Ionosphere (NRL-SAMI3) [*Huba and Drob*, 2017] in conjunction with the HF PHaRLAP ray trace toolkit [*Cervera and Harris*, 2014]. The tools to couple these models and simulate SEQP activity has been done by *Vega et al.* [2017]. These models will be tested by determining how many of the observed SEQP QSOs are supported by the predicted SAMI3 eclipsed ionosphere.

Next, propagation changes will be studied by examining SEQP data for changes in prop-agation characteristics (usable frequency, SNR, path length distance) as the eclipse shadow traverses the United States. Additionally, the SEQP simulation conducted using PHaR-LAP to ray trace through both the eclipsed and non-eclipsed SAMI3 model will be used to determine how propagation differs during the eclipse compare to normal, non-eclipsed conditions.

Finally, the SEQP data will be used in conjunction with other traditional scientific in-struments such as ionosondes, GPS-TEC receivers, Incoherent Scatter Radars, SuperDARN radars, and others to help address open scientific questions. These include questions related to the spatial and temporal scale of eclipse ionospheric effects.

3.2 HF Wideband Recording Experiment

Modern Software Defined Radio (SDR) technology allows large portions of radio spectra to be recorded and replayed or studied at a later time. Some SDR implementations, such as the TAPR Hermes radios and the Red Pitaya development boards, allow multiple slice receivers to operate simultaneously. This enables the majority of HF amateur radio bands to be recorded in their entirety using a single receiver, antenna, and computer.

The HamSCI Eclipse HF Wideband Recording Experiment aims to capture all of the amateur HF spectra, and possibly some non-amateur HF spectra from locations spread across the North America. The wideband recording experiment will take place during the SEQP. Therefore, these recordings will allow for the study of eclipse-induced propagation changes use signals generated by the SEQP, as well as examine changes in noise floor measurements throughout the time of the eclipse. This experiment has been developed with input from the TAPR community.

3.2.1 Data Sources and Procedure

The official procedure for the HF Wideband Recording Experiment is published at http://hamsci.org/eclipse-wideband and has been reprinted here in Appendix B. The wide-band recording experiment will take place from 1400 – 2200 UTC on 21 August 2017. This includes approximately 2 hr of recording before partial eclipse reaches Oregon and about 2 hr of recording after partial eclipse leaves South Carolina.

Participating stations are encouraged to record as many of the HF amateur SEQP bands as possible, prioritizing the lower bands as they like see a larger effect. As resources permit, stations are also encouraged to record and submit other portions of the HF bands. Partic-ipants may use any radio and software that is capable of generating IQ recordings of HF spectrum that can be properly time-stamped and frequency-stamped. We recommend using MIT Haystack's Digital RF software[1] for this purpose, as it is will record observations to the proper IQ format and provide the required time- and frequency- stamping.

All participants are asked to upload all data generated by this experiment to the HamSCI community at https://zenodo.org/communities/hamsci/. By uploading to zenodo.org, a per-manent, citable, centralized record of the data that is openly available to both researchers and the general public will be created. Participants are asked to upload all IQ/HDF5 recording files, as well as any station and procedural information necessary for interpreting the data.

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[1]`https://github.com/MITHaystack/digital_rf`

3.2.2 Analysis

After the eclipse, the HF Wideband recording data will be used to identify changes in propagation during the event, support SEQP research, and find noise floor variations that may be eclipse-induced. These recordings can be used to recreate observed eclipse effects across a broad geographic area and range of frequencies.

3.3 Eclipse Frequency Measurement Test

Rapid changes in ionospheric electron density caused by the motion of the shadow of an eclipse is known to cause Doppler shifts on HF ray paths propagating through the eclipsed region. *Boitman et al.* [1999] observed Doppler shifts of over 1 Hz on an HF path between Irkutsk and Tory in Russia over a 2 hr period during the 9 March 1997 total solar eclipse. This experiment gives information regarding how much and how fast the ionosphere changes in height along a particular path.

Twice each year, the ARRL sponsors a Frequency Measurement Test (FMT, http://www.arrl.org/frequency-measuring-test) in which participants compete to make the most accurate frequency measurements of a HF signal with an unknown but highly stable frequency. The FMT community is highly skilled and well instrumented. Receive stations may use GPS Disciplined Oscillators (GPSDOs), rubidium, and cesium standards in conjunction with sophisticated data processing to achieve frequency measurement accuracy better than 0.001 Hz. These receive stations are distributed across the United States and are capable of measuring eclipse-induced Doppler shifts similar to those measured by *Boitman et al.* [1999]. This section describes a HamSCI experiment run in conjunction with the amateur frequency measurement community to observe these Doppler shifts.

3.3.1 Data Sources and Procedure

The official Eclipse FMT procedure is published online at http://hamsci.org/eclipse-fmt. The procedure is reprinted here in Appendix C. This narrative will highlight selected portions of the procedure and comment on why certain choices were made.

The Eclipse FMT will take place over two days: 20 and 21 August 2017 from 1400-2200 UTC each day. The August 20th experiment will serve as a control day, while August 21st is the eclipse day. Like the SEQP, the Eclipse FMT will start approximately 2 hours before partial eclipse begins in Oregon and will end about 2 hours after partial eclipse leaves South Carolina.

Two transmitters have been chosen as source signals for the Eclipse FMT: WWV in Fort Collins, Colorado and CHU in Ottawa, Ontario (Figure 3). These were chosen because they are HF standard stations capable of providing the stable signals needed to make the Doppler shift measurements. In order to measure Doppler shifts across the eclipse path, stations north of the path of totality are asked to monitor WWV while stations south of the path of totality are asked to monitor CHU. WWV transmits on 2.5, 5, 10, 15, and 20 MHz. CHU transmits on 3.330, 7.850, and 14.670 MHz. Receive stations should aim to measure as many frequencies as possible continuously and simultaneously, and not frequency-hop or otherwise alternate between frequencies. Because the greatest effect is expected at the lowest frequencies, participants are asked to prioritize the lower bands.

For making measurements and recording data, participants are encouraged to use a procedure in which either the received signal is beat against a sideband local oscillator that has been locked to an external stable frequency reference, or by mixing in a local, stable reference oscillator 1 kHz below the signal-under-test to a radio in AM mode. The output of the radio can then be recorded and processed using the Spectrum Lab Software. Detailed instructions are available at http://hamsci.org/eclipse-speclab. Alternative procedures may also be used, as long as it is technically sound and the procedure can be adequately described in the final data submission to allow for proper interpretation of measurements.

To allow for proper archiving and data sharing, all Eclipse FMT data will be submitted the Zenodo HamSCI community at https://zenodo.org/communities/hamsci/. Zenodo is a general-purpose open access data repository created by OpenAIRE and CERN that is capable of ensuring the amateur radio community has access to this submitted data into the foreseeable future. Participants are asked to upload their Spectrum Lab data file, the WAV recording of the measured station, and station and procedural information necessary for interpreting the data.

3.3.2 Analysis

Analysis of Eclipse FMT data will focus on understanding how the propagation path length, and hence the ionosphere, change with time on a variety of HF paths. Similar to the SEQP, these observations can be used to test ionospheric models such as the SAMI3 eclipse model, study propagation changes, and address eclipse scientific questions. An appropriate question for this data set is to determine whether or not traveling ionospheric disturbances (TIDs) are generated by the eclipse, and what is the process by which they are created. Eclipse FMT data can be used in conjunction with traditional ionospheric sounding data sources to address these questions.

4 Summary

On 21 August 2017, a total solar eclipse will cause the shadow of the moon to traverse the United States from Oregon to South Carolina in just over 90 minutes. The sudden absence of sunlight due to the eclipse, especially solar UV and x-rays, provides an impulse function to the upper atmosphere that modifies the neutral dynamics, plasma concentrations, and related properties. In spite of more than 60 years of research, open questions remain regarding eclipse-induced ionospheric impacts.

Ham radio operators' advanced technical skills and inherent interest in ionospheric science make the amateur radio community ideal for contributing to and and participating in large-scale ionospheric sounding experiments. HamSCI, the Ham radio Science Citizen Investigation, is coordinating experiments to study these eclipse-induced ionospheric effects.

The Solar Eclipse QSO Party (SEQP) is a contest-like event that will take place from 1400 – 2200 UTC on 21 August 2017 in order to illuminate the ionosphere with HF radio contacts for the purpose of generating data to study the eclipse. The SEQP was designed with the intent of creating an enjoyable operating event that leverages the skills of the ham radio contest community while also providing useful scientific returns.

The Eclipse HF Wideband Recording Experiment will take place from 1400 – 2200 UTC on 21 August 2017 and aims to capture all of the amateur HF spectra, and possibly some

non-amateur HF spectra from locations spread across the North America. This will allow for the study of eclipse-induced propagation changes use signals generated by the SEQP, as well as examine changes in noise floor measurements throughout the time of the eclipse.

The Eclipse Frequency Measurement Test (FMT) will take place 1400 – 2200 UTC on both 20 and 21 August 2017. In this experiment, participants will measure frequency changes along HF ray paths between their station and either WWV or CHU in order to better understand eclipse-induced Doppler shifts similar to those previously reported in the literature.

It is hoped that the SEQP, the HF Wideband Recording Experiment, and the Eclipse FMT will be both engaging to the amateur radio community and valuable to the scientific research community. Specific scientific returns include a better understanding of eclipse-induced propagation changes, ionospheric spatio- and temporal- dynamics, and the ability to test numerical ionospheric models of the eclipse.

Appendix A: SEQP Rules

A.1 Date and Time

21 Aug 2017 1400 – 2200 UTC (Partial eclipse begins at about 1600 UTC in Oregon ends at about 2015 UTC in South Carolina)

A.2 Objective

To generate observations of propagation by the Reverse Beacon Network (RBN, `http://www.reversebeacon.net/`), PSKReporter (`https://pskreporter.info/`), WSPRNet (`http://www.wsprnet.org`), and event logs before, during, and after the eclipse on the amateur bands for the purpose of ionospheric sounding.

A.3 Bands

160, 80, 40, 20, 15, 10, and 6 meter bands

The 60, 30, 17, and 12 meter bands will not be used for scoring purposes because contest QSOs are not allowed there. You may earn bonus points by monitoring non-contest QSOs on these bands with automated receive nodes such as RBN receivers.

We anticipate plenty of activity. On CW and Phone, tune for stations calling "CQ SEQP" toward the middle and lower portions of the various license class allocations. Activity on RTTY, PSK, and JT modes will be close to the usual activity centers but - please - spread out! With many stations active, assist the receiving decoder stations to make accurate and quick measurements by leaving a little space between signals. You can find band planning information at

- `http://www.arrl.org/band-plan`
- `http://www.ciarc.org/downloads/Digital_Mode_Band_Plan.pdf`
- `http://wsprnet.org/drupal/node/218`

A.4 Modes

The SEQP accepts CW, digital (all varieties), and phone QSOs.

A.5 Station Requirements

- All transmitting and receiving equipment used to make contacts must be no more than 1 km apart.
- RBN and other automatic receive spotting nodes can be any distance apart.

A.6 Categories (listed separately in the results)

- Single-operator (one transmitted signal permitted at any time)
- Multioperator (one transmitted signal per band and mode permitted at any time)

A.7 Exchange

Call Sign, Signal Report, 6-Character Grid Square

Example CW Exchange: If NØAX responds to a CQ by W1AW, NØAX receives "NØAX 579 FN31PR W1AW" and sends "W1AW 589 EM48SS NØAX".

Notes

1. On CW, call "CQ CQ TEST DE [your call] [your call] K" using a single code speed during the transmission. This maximizes the ability of the automated receivers to decode and spot your transmission.
2. To find and determine your grid square, visit `http://www.arrl.org/grid-squares`.
3. Signal Report

   - *CW/Phone:* The strength (S) value of RS(T) signal reports should represent the approximate peak S meter reading. (Readings greater than S9 should be sent as S9.)
   - *Digital:* The preferred digital signal report is the SNR in dB as provided by the digital mode software. Alternatively, give the operator-determined RSQ (Readability - Strength - Quality) value. Note that you can enter SNR values directly into the N1MM+ *Snt* and *Rcv* signal report entry boxes directly. Researchers will assume any CW or digital signal report not in three-digit RST/RSQ format is an SNR [dB] value.

A.8 Notes on Digital Modes

A.8.1 PSK Reporter Spotting

Many digital mode packages such as the open-source fldigi program and Ham Radio Deluxe/Digital Master 780 have options for automatically sending spots to PSKReporter. Please enable this option to send additional data to PSKReporter.

A.8.2 JT-Type Digital Modes (Such as WSJT)

1. Operate normally.
2. Make sure software is configured with the proper station location information. This is especially important if you are operating portably.
3. Use an internet connection for time sync and spotting if possible. Smart phone hotspots and public WIFI may provide internet in portable locations.

4. Use CAT control if possible.
5. In your Cabrillo soapbox, please note the type and version number of software used e.g. WSJT-X 1.8.0.
6. Optionally sign SEQP to attract other participating operators (e.g., "KV4PC SEQP 73").

A.8.3 WSPRNet

Because of the primarily one-way nature of WSPR QSOs, they should not be logged as two-way QSOs in the SEQP. WSPR reception reports *will* be logged on WSPRNet (wsprnet.org) and so WSPR operation during the entire SEQP period is encouraged on the usual WSPR frequencies on any band. In addition, bonuses are offered for operation of WSPR receive nodes as described in the bonus section below. You can further contribute WSPR data to the Eclipse project by recording the full data and sending it to us for post-processing. Please see `https://www.scivision.co/wspr-save-raw-wav-data/` for details on saving WSPR data. We ask that upload all data related to the SEQP to the HamSCI community on zenodo.org. Once your data has been posted to Zenodo, you will be provided with a DOI (Digital Object Identifier) that you can include in your SEQP score submission to associate your data with your submitted SEQP log.

A.9 Scoring

Score = (Multipliers x QSO Points) + Bonus Points

1. 2 points for CW or Digital; 1 point for phone
2. Multipliers: 4-character grid squares counted once per band.
3. Bonus points earned (see Bonus Points section)

Duplicate contacts on the same band and mode as a previous QSO with a station are allowed after 10 minutes have elapsed since the previous QSO with that station. The same station may be worked on all SEQP bands and modes.

The final score, including bonuses, will be calculated by the HamSCI data processing team. Claimed Scores are not required to be accurate.

A.10 Logging Requirements

Frequency, Mode, Date, Time (UTC, not local), Sent Call, Sent Signal Report, Sent Grid, Received Call, Received Signal Report, Received Grid

Example QSOs (or click here for full example log):

```
QSO:  7030 CW 2017-07-20 2241 K2MFF 579  FN20VR N3AO   599  EM97SG
QSO:  1816 PH 2017-07-20 2243 K2MFF 59   FN20VR KC2LRC 59   FN13WA
QSO:  3590 RY 2017-07-20 2249 K2MFF 599  FN20VR W1AW   599  FN31PR
QSO: 14070 PK 2017-07-20 2305 K2MFF 30   FN20VR AD0AE  24   CM97WL
```

- Use the following mode codes in the log. N1MM+ should automatically generate logs with the correct codes.

Mode	Cabrillo Code
LSB/USB/AM	PH
CW	CW
RTTY	RY
PSK31	PK
JT65	JT65
JT9	JT9
FT8	FT8

- 6-character grid locator is preferred, but 4-character grid locator is acceptable.
- Include station power level, 6-character grid square, antenna type, equipment list, and extra comments in the log soapbox. Please use the example format for easy post-event processing.

Example soapbox:

```
SOAPBOX: power=100 W, grid=FN20Vt, antenna=dipole, equipment=IC7410,
SOAPBOX: comments=Totality was beautiful!
```

- Use any software that supports the Solar Eclipse QSO Party. The N1MM+ contest logger natively supports the SEQP as log type "ECLIPSE". Any logging software that supports the ARRL VHF contest exchange format can also be used.

A.11 Log and Score Submission

SEQP Log submission instructions will be available at `http://hamsci.org/seqp`. Participants who submit through the web interface will immediately receive a downloadable PDF Certificate of Participation.

1. Please submit logs using the Cabrillo format standard. Paper logs and non-Cabrillo logs may be converted to Cabrillo format using WA7BNM's online Cabrillo form. Cabrillo files will be used for both scoring and research purposes and is the preferred log format.
2. Participants may alternatively submit ADIF or (other format) logs. These will not be scored but may be used for research purposes.
3. Any additional supporting files you believe would be useful to research may be posted to the public HamSCI zenodo.org community. You will be provided a DOI (digital object identifier) you can include on the SEQP log submission page.
4. Logs must be submitted by 2359 UTC Saturday, September 30, 2017.

A.12 Bonus Points

All bonuses will be calculated after the SEQP and included with the final scores.

1. Operated during totality (or the time of greatest shadow at your QTH) – add 100 points.
2. Operate outdoors (so you can see the eclipse) – add 100 points
3. Operate at a public venue – add 100 points

4. Provide detailed station operation information – add 50 points each:

    a. Antenna design characteristics (orientation, E and H plane patterns, height above ground
    b. HFTA terrain profile. See K6TU service at `http://www.k6tu.net/?q=TerrainProfiles`. It is not necessary to be a subscriber to K6TU.net.
    c. Ground conductivity (estimated from online conductivity maps, see `https://www.fcc.gov/media/radio/m3-ground-conductivity-map`
    d. Station Effective Radiated Power relative to a Dipole (ERPD) on each band.

5. Operate a wideband RBN, PSKReporter, or WSPRNet node during the contest

    a. 50 points per band and mode (including 60, 30, 17, and 12 meters).
    b. 50 points per band for providing the I/Q data file after the event by following instructions at `http://hamsci.org/seqp`.
    c. Multiple receive sites may be claimed, provided receive sites are spaced at least 100 km apart.

6. One bonus point will be awarded for each band and clock hour during which your signal was spotted in a grid square other than your own by the RBN, PSKReporter, or DX spotting network. There are eight clock hours and 7 bands available for receiving bonus points. A spot of your signal on any mode will qualify for the bonus point.

7. Bonus points items will be submitted and claimed via the SEQP Log Upload page. The link to this page will be posted at hamsci.org/seqp by the SEQP date.

Appendix B: HF Wideband Recording Procedure

Total solar eclipses are known to cause changes to the ionosphere and high frequency propagation. During the 2017 American Total Solar Eclipse, numerous HF radio sources will be on the air to help study these effects. We request that amateur radio stations capable of making wideband (e.g., 192k or higher sample rate) digital HF recordings participate in this experiment and publish their data to the HamSCI community on the open-data sharing site zenodo.org.

Research Question

- How does the 2017 Total Solar Eclipse affect HF propagation paths?
- How much of the ionosphere is affected by a solar eclipse?
- For how long is the ionosphere affected by a solar eclipse?

B.1 Objective

- Observe changes in HF propagation caused by the eclipse by making recordings of large portions of the HF band from multiple locations, most importantly across the North American continent.
- Provide wideband recordings of HF spectra to support SEQP log/RBN/PSKReporter/WSPR data.

B.2 Times

- 21 August 2017, 1400 – 2200 UTC

Note: Partial eclipse begins 21 Aug 2017 at about 1600 UTC in Oregon ends at 21 Aug 2017 at about 2015 UTC in South Carolina.

B.3 Frequencies

Please prioritize recording of frequencies that correspond with Solar Eclipse QSO Party (SEQP) operation, especially the lower frequencies, as these should see the largest eclipse effect. This consists of the standard HF contest bands (see table below). In addition, we welcome observations from as much of the LF, MF, and HF spectrum as possible. The capabilities of different HF receivers vary widely, and some modern HF SDRs are capable of multiple slice receivers. Note that it is possible to simultaneously make wideband recordings and act as a RBN skimmer node. See N6TV's How-To Guide for Running a Combined CW-RTTY Red Pitaya Skimmer for instructions on how send SDR data streams to multiple programs simultaneously.

Table 3: Solar Eclipse QSO Party (SEQP) Frequencies

Band	Frequency
160 m	1.800 - 2.000 MHz
80 m	3.500 - 4.000 MHz
40 m	7.000 - 7.300 MHz
20 m	14.000 - 14.350 MHz
15 m	21.000 - 21.450 MHz
10 m	28.000 - 29.700 MHz

B.4 Procedure

You may use any radio and software that is capable of generating IQ recordings of HF spectrum that can be properly time-stamped and frequency-stamped. We recommend using MIT Haystack's Digital RF software for this purpose, as it is will record observations to the proper IQ format and provide the required time- and frequency- stamping.

A number of SDR radio and software combinations allow real-time wideband recording of the HF spectrum. The spectrum width that can be recorded is usually a bit less than the radio sample rate. For example, a 384k sample-per-second receiver can record around 375 kHz of bandwidth, which is enough to include the entire 40, 30, or 20M band. A number of SDR receivers, including RTL-SDR "dongles", Red Pitaya, and "HPSDR" compatible radios such as the Anan 10/100/200 series and the original Hermes board, are capable of this.

An Open Source Software script using Gnuradio under Linux will shortly be available through TAPR that allows receiving and recording four bands simultaneously with HPSDR or six with the Red Pitaya hardware. (Note that multiple receivers will require a fairly fast PC such as an i7 with solid-state disk; using fewer receivers reduces the computer resources needed. Check `https://github.org/TAPR/N8UR/GnuRadio` for updates.

We encourage you to make the most careful measurements possible. If you are capable of stabilizing your receiver with a high-stability frequency reference or provide amplitude calibration characteristics for your system, please do so. You may describe your methodology in the Zenodo Data Description box and upload supporting documents if necessary (such as block or antenna pattern diagrams).

B.5 Uploading to Zenodo

We ask that all data generated by this experiment be uploaded to the HamSCI community on zenodo.org. By uploading to zenodo.org, a permanent, citable, centralized record of the data that is openly available to both researchers and the general public will be created.

To upload your data create an account on https://zenodo.org. You can create a login using your github account or via their account creation. Once you have an account and you are logged into the service visit "`https://zenodo.org/deposit/new?c=hamsci`". Select your file(s), click "Start Upload", select "Dataset" as your upload type, fill in all relevant information regarding contributors, and finally click "Save" and then "Publish" in the bottom right.

B.5.1 Data Files

Please submit the following items:

- IQ File for each band recorded (Will be encapsulated in a HDF5 file if using MIT's Digital RF)
- Supporting data files (i.e. any files needed to help interpret the raw data, such as a block diagram of the receive station)

Use the
<Callsign>_wideband_<start_freq>_<stop_freq>kHz_<YYYYMMDD>_<HHMM>UT.<ext>
filename convention for uploaded where HHMM is the UT start time of that particular file. Examples:

- K2MFF_wideband_3500_3692kHz_20170821_1400UT.hd5 (for a HDF5 IQ recording of 3500-3692 kHz made at K2MFF on 21 Aug 2017 starting at 1400 UT)
- K2MFF_wideband_supporting_20170821_1400UT.pdf (for a PDF of supporting material to help in interpreting the data)

B.5.2 Data Description

In the data description box, please include:

- Your Name and Callsign
- Latitude and Longitude of the Recording(s)
- A description of station hardware configuration, including

    - Antenna type
    - Antenna pointing direction (if applicable)
    - Receiver type

- Any other information you believe would be necessary for proper scientific interpretation of your measurements

B.5.3 Data Notes

In the Notes box, you may include your personal comments regarding your observations.

B.5.4 Data License

Please license your data as:

- Open Source
- Creative Commons Attribution 4.0

Appendix C: FMT Procedure

Rapid changes in ionospheric electron density caused by the motion of the shadow of an eclipse is known to cause Doppler shifts on HF ray paths propagating through the eclipse region. For example, see Figure 7 in Boitman et al. [1999]. We request that all amateur radio stations capable of making high-quality HF frequency measurements participate in this experiment and publish their data to the HamSCI community on the open-data sharing site zenodo.org.

C.1 Research Question

- How does the 2017 Total Solar Eclipse affect HF propagation paths?

C.2 Objective

- Measure HF path Doppler shifts caused by the motion of the eclipse shadow across the ionosphere.

C.3 Times

- **Control Day: August 20, 2017, 1400 − 2200 UTC**
- **Eclipse Day: August 21, 2017, 1400 − 2200 UTC**

Note: Partial eclipse begins 21 Aug 2017 at about 1600 UTC in Oregon ends at 21 Aug 2017 at about 2015 UTC in South Carolina.

C.4 Beacons

WWV in Fort Collins, CO

- 2.5 MHz
- 5 MHz
- 10 MHz
- 15 MHz
- 20 MHz

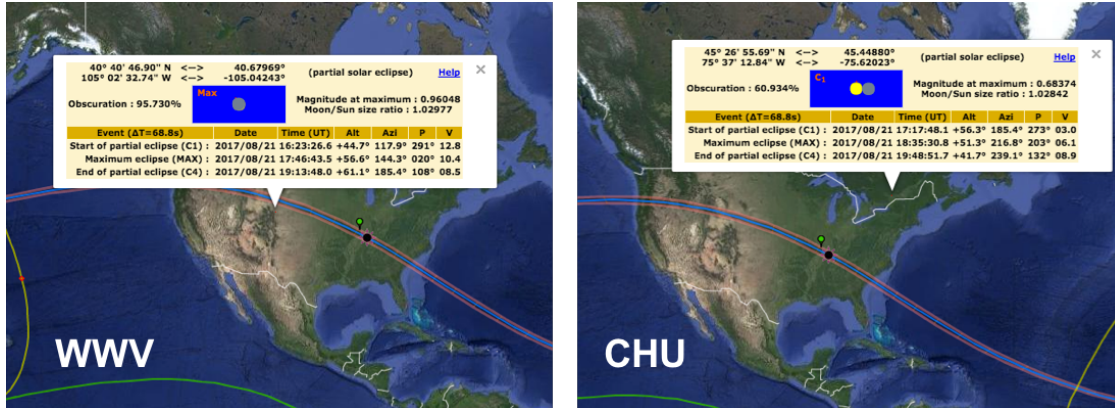CHU in Ottawa, Ontario, Canada

- 3.330 MHz
- 7.850 MHz
- 14.670 MHz

Figure 3: Locations of (left) WWV and (right) CHU relative to the 21 August 2017 eclipse path of totality.[2]

C.5 Receivers

Any and all observations that can unambiguously measure the characteristics of the beacon signal are welcome. Recommendations for participation are listed below; please choose an option that matches your interest, equipment capabilities, and skill level.

- To make narrow-band, precision frequency observations of the beacons, we recommend following the instructions on the Spectrum Lab Solar Eclipse Instructions Page. Please note that we understand that there are multiple ways of making accurate Doppler shift measurements. Please feel free to use an alternative procedure as long as it is technically sound and can adequately describe the procedure you used in your final data submission so that others will be able to properly interpret your measurements.
- Receive stations south of the eclipse path should monitor CHU, while receive stations north of the eclipse path should monitor WWV. This will ensure that the signal path crosses the eclipse. You can find your location relative to the eclipse path with Xavier Jubier's Eclipse Map (`http://xjubier.free.fr/en/site_pages/solar_eclipses/TSE_2017_GoogleMapFull.html`).
- Measure as many frequencies as you are able continuously and simultaneously.
- Do not frequency-hop or otherwise alternate between frequencies.
- The greatest effect is expected at the lowest frequencies, therefore prioritize measuring the lowest frequencies.

C.6 Uploading to Zenodo

We ask that all data generated by these experiments be uploaded to the HamSCI community on zenodo.org. This includes observation period data from the control day and the eclipse day. By uploading to zenodo.org, a permanent, citable, centralized record of the data that is openly available to both researchers and the general public will be created.

To upload your data create an account on https://zenodo.org. You can create a login using your github account or via their account creation. Once you have an account and

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[2]`http://xjubier.free.fr/en/site_pages/solar_eclipses/TSE_2017_GoogleMapFull.html`.

you are logged into the service visit "`https://zenodo.org/deposit/new?c=hamsci`". Select your file(s), click "Start Upload", select "Dataset" as your upload type, fill in all relevant information regarding contributors, and finally click "Save" and then "Publish" in the bottom right.

Here is an example completed Zenodo FMT upload: `https://doi.org/10.5281/zenodo.834948`

C.6.1 Data Files

For each observation period, please submit the following items:

- Raw Audio Recording(s)
- Processed Spectrum Lab Text File(s)

Use the <Callsign>_<freq>kHz_<YYYYMMDD>_<HHMM>UT.<ext> filename convention for uploaded where HHMM is the UT start time of that particular file. Examples:

- K2MFF_2500kHz_20170821_1400UT.wav (for a audio recording made at K2MFF on 2500 kHz on 21 Aug 2017 starting at 1400 UT)
- K2MFF_2500kHz_20170821_1400UT.txt (for a Spectrum Lab data file made at K2MFF on 2500 kHz on 21 Aug 2017 starting at 1400 UT)

C.6.2 Data Description

In the data description box, please include:

- Your Name and Callsign
- Latitude and Longitude of the Recording
- Start time of the WAV file
- A description of station hardware configuration, including

  - Antenna type
  - Antenna pointing direction (if applicable)
  - Receiver type
  - Frequency reference type
  - Frequency measurement technique

- Any other information you believe would be necessary for proper scientific interpretation of your measurements

C.6.3 Data Notes

In the Notes box, you may include your personal comments regarding your observations.

C.6.4 Data License

Please license your data as:

- Open Source
- Creative Commons Attribution 4.0

Acknowledgments

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Biography

Nathaniel A. Frissell, Ph.D., W2NAF

Nathaniel A. Frissell, W2NAF, is an Assistant Research Professor with the New Jersey Institute of Technology Center for Solar-Terrestrial Research (NJIT-CSTR). He earned his Ph.D. from the Virginia Tech SuperDARN Laboratory in 2016 with a dissertation entitled "Ionospheric Disturbances: Midlatitude Pi2 Magnetospheric ULF Pulsations and Medium Scale Traveling Ionospheric Disturbances." Nathaniel has participated in ionospheric field work in McMurdo Station, Antarctica, Adak Island, Alaska, and Longyearbyen, Svalbard. Each of these trips included amateur radio operations. Nathaniel's interest in ionospheric science and ham radio began in middle school when he was introduced to amateur radio through scouting. Nathaniel served as director of the Forestburg Scout Reservation Technology Center from 2002-2007 and remains active as the trustee of W2FSR. He holds an Extra class amateur radio license and initiated the citizen-science Ham Radio Science Citizen Investigation (HamSCI) project. Nathaniel is the associate advisor of the NJIT Amateur Radio Club, K2MFF.

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