2019 HamSCI Workshop Report

March 22-23, 2019

Case Western Reserve University, Cleveland, OH

Science/Program Committee

- Dr. Nathaniel Frissell, W2NAF, NJIT, Chair
- Dr. Phil Erickson, W1PJE, MIT Haystack Observatory
- Dr. Ethan Miller, K8GU, JHU/APL
- Mr. Bill Liles, NQ6Z, HamSCI Community

Local Organizing Committee

- Ms. Kristina Collins, KD8OXT, CWRU, Chair
- Dr. David Kazdan, AD8Y, CWRU, Advisor
- Mr. Nathaniel Vishner, CWRU, KB1QHX

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HamSCI Workshop 2019 Participants (Photo by Laura Gooch, N8NFE)

Introduction

The Ham Radio Science Citizen Investigation (HamSCI, hamsci.org) is an international collective of professional researchers and amateur radio operators working together to simultaneously advance the fields of space science and amateur (ham) radio activities. The 2nd US HamSCI meeting was held March 22-23, 2019, organized by Nathaniel Frissell of the New Jersey Institute of Technology (NJIT) and hosted by the Case Amateur Radio Club (Case ARC) at Case Western Reserve University (CWRU) in Cleveland, OH. The theme of this year's meeting was "Ionospheric Effects and Sensing," which includes the use of amateur radio techniques for the characterization and observational study of ionospheric phenomena such as traveling ionospheric disturbances, sporadic E, response to solar flares, geomagnetic storms, and other space weather events.

The annual HamSCI meeting is designed to provide an opportunity for both the amateur radio and professional research communities to come together and share ideas. There are over 730,000 hams in the United States, and about 3 million worldwide, ranging in age from very young to very old, and in experience from neophyte to highly experienced with advanced technical degrees. Hams are federally licensed and identified by a station call sign, such as W8EDU, the Case ARC call. Many hams have significant amounts of practical experience using their radios to communicate under all sorts of geophysical conditions, and have developed a keen observational ability to maximize their enjoyment and communications ability. This quality provides a unique perspective and excellent citizen science potentials when asking scientific questions or even analyzing observations. Conversely, the professional research community brings to the table a deep knowledge of space and ionospheric physics based on years of research, an understanding of where the boundaries of that knowledge lie, what science questions are of greatest interest in the field, and the rigor of the scientific process.

Every aspect of the HamSCI 2019 meeting was designed to create a forum that was both interesting and accessible to both the amateur and professional communities. The meeting took place on a Friday and Saturday, allowing both professionals and amateurs to attend at least one day. Friday was organized in the format of a traditional science workshop, with a full day's program of oral technical and scientific presentations. The Saturday program departed from this

convention, consisting of invited tutorials, more oral presentations, a demonstration room, tours of the Case Amateur Radio Station and think[box], and a panel discussion on the HamSCI Personal Space Weather Station Project. A banquet with a keynote speaker H. Ward Silver, N0AX, was held on Friday night.

Invited Tutorials

In order to help bring the professional research and amateur radio communities together, the HamSCI workshop featured a pair of invited tutorials, one given by a distinguished member of the amateur radio community, and the other given by a distinguished member of the space science community. For the 2019 HamSCI Workshop, Carl Luetzelschwab (K9LA). was selected to present *Ham Radio for Space Scientists.* Luetzelschwab has been a ham since 1961, is an amateur radio author, retired Raytheon RF design engineer, and AGU member. Larisa Goncharenko, a research scientist at the MIT Haystack Observatory, was selected to represent the space science community and present *Space Science for Ham Radio Operators.* Goncharenko is an extensively published ionosphere and neutral atmosphere scientist and expert, whose major areas of interest are the coupling, dynamics, and electrodynamics of the ionosphere and thermosphere with an emphasis on processes in the lower thermosphere and coupling at lower altitudes.

Ham Radio for Space Scientists

In his tutorial, Luetzelschwab talked about the early history of the amateur radio service, reviewed contributions hams have made throughout history to the science and technology, and presented open questions regarding radio science that hams can contribute to. In the US, Amateur Radio started as a licensed service with the Radio Act of 1912, at which point hams were relegated to wavelengths less than 200 m (> 1.5 MHz) because at the time these were considered useless. Over time, hams helped develop technologies and knowledge proving the worth of the long-distance HF (3-30 MHz) bands and the value of even higher frequencies.

Hams have a history of contributing to propagation science and collaborating with professional scientists. Key ham radio discoveries include transequatorial propagation (TEP) (Cracknell, 1959; Whiting, 1963), and Long Delayed Echoes (LDE) (Villard, 1969, 1970). The US Bureau of Standards requested hams participate in fading tests in the summer of 1920, and the American Radio Relay League participated in the International Geophysical Year with the ARRL-IGY Propagation Research Project. This project generated nearly 300,000 individual reports from ~600 observers in 50 countries, collected reports of possible 50, 144, and 220 MHz ionospheric propagation, and is tied to the discovery of TEP. This research also resulted in lots of sporadic E data showing motion of ionized patches. Today, ham radio activities such as DXPeditions (hams traveling to exotic locales to make contacts with the rest of the world) and tools such as RBN and WSPRNet provide ham radio data that can be used for ionospheric studies.

Luetzelschwab stated that today a primary research question is why and how does the ionospheric F2 region vary so considerably on a day-to-day basis. It is known that solar radiation, geomagnetic field activity, and events in the lower atmosphere all couple up the ionosphere, but current treatment results primarily in monthly median ionospheric models. A better understanding regarding both geomagnetic field activity (STORM model is current) and events in the lower atmosphere is needed. In addition to F2 region variability, Luetzelschwab also highlighted the importance of D region research. Current understanding of the D region is based on rocket flights, incoherent scatter radar, analysis of lightning discharges at VLF, and models involving ionospheric chemistry. The D region is the driver of propagation on the lower bands, especially on 630, 160, and 80 m.

Space Science for Ham Radio Operators

Goncharenko began her tutorial by introducing the Atmosphere-Ionosphere-Magnetosphere system. She emphasized that average ionospheric behavior well known, including the strong correlation with solar activity, strong diurnal and seasonal variations, and the location of the peaks of the equatorial ionization anomaly at +/- 15° magnetic latitude. The monthly mean behavior is well described by the empirical International Reference Ionosphere (IRI), which outperforms first principles models. What is not well known are the smaller temporal and spatial scale variability associated with impacts from geomagnetic storms and ionospheric waves of all types.

Goncharenko then explained that we are just beginning to understand the influences the lower atmosphere has on the ionosphere, especially in the form of waves carrying upward momentum and energy. Planetary waves, tidal waves, and gravity waves are generated in the lower atmosphere, increase in amplitude with altitude, and have a strong impact on the E-region and bottom side ionosphere. Understanding the lower thermosphere-ionosphere connection is a direct pathway to future multi-day predictions of the ionospheric state, as stratospheric parameters can be predicted 8 to 10 days in advance.

In her tutorial, Goncharenko presented observations from multiple professional instruments, including GNSS TEC, research satellites, incoherent scatter radars (ISRs), and SuperDARN. Still, she noted that the ionospheric system remains strongly undersampled by professional instrumentation due to the ionosphere's strong electrodynamic control requiring observations over huge distances, and that there is a great need for bottomside ionospheric measurements. HF signals are particularly well suited for this type of measurement, and data from existing commercial and military operational HF systems are not publicly available for research. Networks developed by amateur radio operators can provide critical information with a potential to advance physical understanding of near-Earth space environment. She left the hams with a charge: In years from now, we will look at the weather forecast on the ground to predict what happens in space. Can you help us to make it happen?

Ionospheric Variability

Much work has already begun in developing methods for measuring ionospheric variability with amateur radio techniques and summaries of these efforts were presented in the Friday morning session. Some of these presentations used data from multiple large-scale radio observation networks created and operated by the ham radio community, including the Reverse Beacon Network (RBN), PSKReporter, and WSPRNet. These networks observe and log amateur HF communications on a near-global scale and are saved to databases that date back to ~2008. William Engelke (AB4EJ, University of Alabama) presented plans for a machine learning study using these datasets to study the relationship of Sporadic E formation to upper level low pressure weather systems. Nathaniel Frissell (W2NAF, NJIT) presented a study of the ionospheric response to the storms and solar flares of Sept 2017 as observed by WSPRNet and the RBN (Frissell et al., 2019). Ethan Miller (K8GU, JHU/APL) presented methodologies for deriving foF2 and hmF2 estimates using RBN observations.

The strengths of the RBN, WSPRNet, and PSKReporter is that they make real-time global scale observations covering almost a solar cycle; however, these systems were not specifically designed for ionospheric studies and their observations are noisy and can be difficult to interpret. Another key group in the amateur radio community is the Frequency Measuring Test (FMT) community, a group of amateurs who compete in a bi-annual contests to see who is able to make the most accurate frequency measurement of a signal transmitted on an unspecified frequency. Some of these amateurs have the capability to measure frequency extremely accurately. Very sophisticated amateurs own their own expensive high-precision reference standards (Cesium, Rubidium), but now similar levels of precision can be obtained using $100 GPS Disciplined Oscillators (GPSDOs), which make this type of work much more accessible. Traditionally, ionospheric variability was a source of noise for the FMT community as something that the participants would have to estimate and remove from their signal. A feature commonly noted by FMT participants is short time-scale ionospheric variability effects on HF propagation path length and unpredictable Doppler shifts on the received signal.

In particular, these Doppler shifts are useful scientifically as they can provide information regarding the changing height of the ionospheric refraction point or periodicities of Traveling Ionospheric Disturbances (TIDs) passing through the communication path. Multiple presentations utilized a methodology in which Doppler shifts imposed on signals transmitted by governmental standards stations were observed to study ionospheric variability. The studies typically make use of signals transmitted by the US government time and frequency reference stations WWVB (60 kHz) and WWV (2.5, 5, 10, 15, 20, and 25 MHz) in Fort Collins, CO. Steve Cerwin (WA5FRF, HamSCI Community) presented WWV/WWVB Doppler and Amplitude observations of the August 21, 2017 Solar Eclipse as measured in Mico, TX. David Kazdan (AD8Y, CWRU) presented WWV Doppler shift observations from Cleveland, OH using a new, low-cost multi-band WWV Doppler receiver CWRU is developing. These observations showed wave-like perturbations in the received frequency. Phil Erickson (W1PJE, MIT Haystack Observatory) presented a different approach to WWV ionospheric variability observations by examining the temporal variability of the WWV time tick signal, rather than the Doppler shift of the carrier. Erickson compared trans-ionospheric WWV observations made in Massachusetts with coincident line-of-sight observations recorded in Colorado and found that the ionospheric path imparted a significant spread on the timing signal.

The majority of these presentations focused on ionospheric variability as observed using HF radio techniques. William Liles (NQ6Z, HamSCI Community) presented “Plans for EclipseMob

2024”, an update on a citizen radio science project using low frequency (LF, 30 – 300 kHz) signals of opportunity to study the ionospheric response to solar eclipses. LF propagation below ~500 kHz is qualitatively different from higher frequencies, and geographically distributed data is needed to explain this. EclipseMob aims to provide LF receivers to citizen scientists across the United States to observe propagation changes during an eclipse, and have that data returned to scientists for analysis. EclipseMob first ran during the 21 August 2017 total solar eclipse, but technical problems made much of the citizen science data unusable. EclipseMob will run another campaign during the 2024 total solar eclipse, but will implement lessons learned from the 2017 eclipse. Changes for the 2024 eclipse includes developing the receiver kit earlier, allowing for more testing time. The team will get expert advice for critical tasks like app development, and will design the kit to be Raspberry Pi-based rather than rely on hardware of smartphones, which vary widely and rapidly change with time. The kit will be simplified while preserving the build experience at block diagram level in order to reduce build errors and questions while still allowing participants to learn about and build their own receiver. The initial design is completed, and testing is underway. EclipseMob 2024 plans aims to have 1000+ participants.

Personal Space Weather Station

The HamSCI Personal Space Weather Station (PSWS) is a project is to create a network of ground-based observatories for the purpose of characterizing the ionospheric and geomagnetic response to space weather events and to determine the impact that ionospheric variability has on terrestrial HF communications systems. The PSWS will be a multi-instrument platform that can be deployed by both citizen and professional scientists alike, and will report observations to a central server to enable analysis of the large-scale observations. It should provide coverage similar to the existing amateur radio observation networks, but be designed for scientific usability from the ground up. Its base configuration will include an HF scientific radio receiver instrument, a ground magnetometer, and a GNSS receiver for accurate time stamping and stability. Nathaniel Frissell started the PSWS session with a presentation of the vision and scientific objectives of the PSWS.

Science and technical requirements for the PSWS magnetometer were presented by Hyomin Kim (KD2MCR, NJIT). The ground magnetometer will provide critical information about how solar activities impact the earth’s magnetosphere and ionosphere. In particular, geomagnetically induced currents (GIC) due to temporal changes in magnetic fields (dB/dt) are a very important issue in space weather. Three types of inexpensive, simple, mid-grade magnetometers utilizing the anisotropic magneto-resistive (AMR), magneto-inductive and fluxgate technologies were compared. The PSWS magnetometer will be designed to measure large- and medium-scale geomagnetic activities from a few to hundreds of nT.

High school student Ethan Scott Grace proposed the inclusion of a Very Low Frequency Sudden Ionospheric Disturbance (VLF SID) monitor on the PSWS. SIDs are detected as sudden enhancements in observed VLF signal strength in response to EUV and X-Ray solar flares. The SID monitor can be implemented using an appropriate computer sound card and home-built VLF receive antenna, or by using a kit from the Stanford Solar Center and the Society of Amateur Radio Astronomers (SARA).

The Scientific Software Defined Radio (SDR) Instrument will be a critical component of PSWS ionospheric monitoring. This will a 0.1-30 MHz multi-band SDR radio capable high-precision time stamping of samples and Doppler shift measurements that is within the budget of interested citizen scientists/amateur radio operator. HamSCI is collaborating with TAPR (tapr.org), a well-known amateur radio electrical engineering organization, to lead the development of this SDR. An open question is whether a new receiver design is needed, or if a commercial product would suffice. John Ackermann (N8UR, TAPR) presented a review of currently available commercial SDR hardware that might fulfill the PSWS requirements. A number of offerings come close, but it was determined that none of them met all of the requirements and a fresh design was in order. Rob Robinett, AI6VN, gave a more detailed look at the KiwiSDR, a commercially-available Ethernet-enabled SDR that most closely meets all of the requirements.

An overview of PSWS SDR technical requirements was presented by Tom McDermott (N5EG, TAPR). He found that range resolution of the target drives the cost and complexity of the hardware and storing of immediate results. Range resolution also drives most of the time, frequency, and stability requirements. Additionally, timing resolution and accuracy depends on GPS timing accuracy, oscillator smoothing and stability, and phase noise. Additional hardware issues include sensitivity, dynamic range, channel isolation. Scotty Cowling (WA2DFI, TAPR) presented early views of a TAPR-designed modular scientific SDR. This modular design could potentially meet the needs of not only the PSWS, but other applications as well. The core of the design would be a data engine board with a Field Programmable Gate Array (FPGA) for SDR computations, gigabit Ethernet, a clock module for a precision oscillator and time stamping, and RF modules to allow for different frequency and TX/RX capabilities. The TAPR PSWS SDR effort has been named the TangerineSDR (tangerinesdr.com).

Contributed Talks

With an open call for papers to both the amateur radio and science community, the HamSCI workshop received talks on a wide variety of topics. This included talks on history, education and outreach, antenna design, communications and precision timing support for scientific missions, and propagation research.

High school students Frances Bonte (KE8HPA) and Seamus Bonte (KE8GTT) spoke about the history of hams as being the first “Makers,” or people who revel in the creation of new devices, as well as tinkering with existing ones. Nancy Hall (KC4IYD, NASA Glenn Research Center) presented “ARISS: Talking to the astronauts via ham radio and how it inspires students.” In this presentation, Ms. Hall explained how youth could talk directly with astronauts on the ham radio though the Amateur Radio on the International Space Station (ARISS) program, and what types of associated activities could be done to teach students about science and technology, and encourage them to pursue STEM careers.

Antenna design presentations were presented by Jim Breakall (WA3FET, Penn State) and Bob Romanofsky (KE8ERX). Dr. Breakall presented his design of the new ionospheric HF frequency heating antennas at the Arecibo Observatory, to replace the system that was destroyed by Hurricane Georges in 1998. The new system is a Cassegrain system with the subreflector suspended from the upper platform being fed by a phased array of cross dipoles located close to the main dish. Operating frequencies are centered on 5.1 MHz (99.6 MW ERP) and 8.175 MHz (212.9 MW ERP). Dr. Romanofsky presented “Crazy Antennas,” which described a number of unusual antennas for particular communications scenarios that have been developed at the NASA Glenn Research Center over the past decade or so.

Additional contributed talks included “Digital Mobile Radio Support of High Altitude Balloons for a 2017 Total Solar Eclipse Cloud Formation Experiment,” by Mike Pappas (W9CN), “GPS Time Synchronization and Radio Detection for Ultra High Energy Cosmic Rays” by Rob Halliday (KD9HVY, CWRU), “Doppler Shift from Earth-Orbiting Satellites” by Mic Miller (N8ZYL), and “Conquering The Skip Zone: Short Range Voice and Digital NVIS Communication” by Stephen Hamilton (KJ5HY, West Point).

Demonstration Room

The Saturday Afternoon Demonstration room provided an opportunity for hands-on demonstrations of technologies useful to the HamSCI effort that meeting participants have been designing, building, and using. Many of the demos involved a wideband SDR component, that would be appropriate for providing ideas to the Personal Space Weather Station radio. Multiple commercially-produced options were demonstrated, including the HackRF One (John Ackerman, N8UR), the KiwiSDR (Rob Robinett, AI6VN), and a Red Pitaya-based system used to make HF radio observations at McMurdo Station, Antarctica (Nathaniel Frissell, W2NAF, NJIT). Scotty Cowling (WA2DFI, TAPR) demonstrated a homebrew FPGA-based HF transceiver. The Case Western group demonstrated their purpose-built receiver for multi-band Doppler shift monitoring of the WWV and CHU standards stations. These demonstrations included not only solutions for RF monitoring, but also data recording and processing.

Additional PSWS-related hardware included ground magnetometers and the VLF SID monitor. The Moldwin Magnetics Laboratory at the University of Michigan presented a prototype consisted of a high precision, low cost magnetometer package combining GPS time keeping, data logging, real time graphing, and Wi-Fi data distribution (Regoli et al., 2018). The system includes a Solar panel, 12V lead acid battery, and a charge controller. All electronics are enclosed in a weatherproof plastic case, except for the magnetometer, which is housed separately to reduce noise. This Raspberry Pi-based prototype was designed with the goal of keeping costs low to make it accessible to Citizen Scientist. Hyomin Kim of NJIT demonstrated multiple magnetometer sensors that would be appropriate for the citizen science use case. Ethan Grace and George Lemaster demonstrated the VLF Sudden Ionospheric Disturbance Receiver.

Not all of the demonstrations were hardware-based. NJIT undergraduate students Diego Sanchez (KD2RLM) and Evan Markowitz (KD2IZW) worked with Nathaniel Frissell to produce a prototype of web-based visualizations of RBN and WSPR Data that place the observations as a function of time and frequency in context of Kp, Sym-H, and GOES X-Ray Flux data. These visualizations are accessible from hamsci.org/data.

W8EDU, think[box], and Amateur Radio License Exams

As part of the mission of the HamSCI meeting, the collective wanted to show resources and facilities that help bring together science, technology, and the ham radio and academic communities. Therefore, tours of the W8EDU Case ARC Ham Radio station and the CWRU think[box] to meeting participants were offered during the Demonstration Room. The Case Amateur Radio Club, W8EDU (w8edu.wordpress.com), provides amateur radio education and resources to CWRU and the surrounding community, and emphasizes the integration of amateur radio in university curriculum and research. think[box], CWRU's manufacturing center (thinkbox.case.edu), provides makerspace resources and support to CWRU and all members of the public. Part of a growing wave of academic makerspaces, think[box] offers prototyping resources including 3D printers and scanners, laser cutters, and PCB routers, as well as a complete machine shop and startup incubator for student entrepreneurs. After the demonstration room and the tours, the Case Amateur Radio Club administered ham radio license examinations to those who wanted them.

Keynote Address

The keynote address at the Friday night banquet was presented by H. Ward Silver, N0AX. Silver, a ham since 1972, is well known as a leader and motivator in the ham radio community. An electrical engineer by training, he is the lead editor of the ARRL Antenna Book and Handbook, the author of the ARRL ham radio license manuals, winner of the ARRL Bill Orr Technical Writing award, and a CQ Contest Hall of Fame member.

"Science, Service, and Skill" are the words with which Silver began his address to the HamSCI banquet. Like a number of talks presented during the workshop, he recounted "Ham Radio 1.0" - the history of ham radio and its contributions of the past. But, he charged change is important, and it is the HamSCI group that has both an opportunity and an obligation to bring about change to the hobby and to science that will further both.

Silver stated that the direction of this change should follow the "Good Arrow." It understands radio's physical environment, improves efficiency, accuracy, and breadth of expertise. The "Good Arrow" encourages technical learning about communication, develops new radio services and techniques, and creates new opportunities for building and innovation. Finally, it builds a worldwide community of hams. Silver noted that HamSCI is among the groups like YOTA

(Youngsters on the Air) and CARI (The Collegiate Amateur Radio Initiative) that are bringing about these positive changes. “Opportunities are Obligations,” he said, and that the people at the HamSCI Workshop have the skills and desire to make meaningful contributions to science and create “Ham Radio 2.0.”

Summary

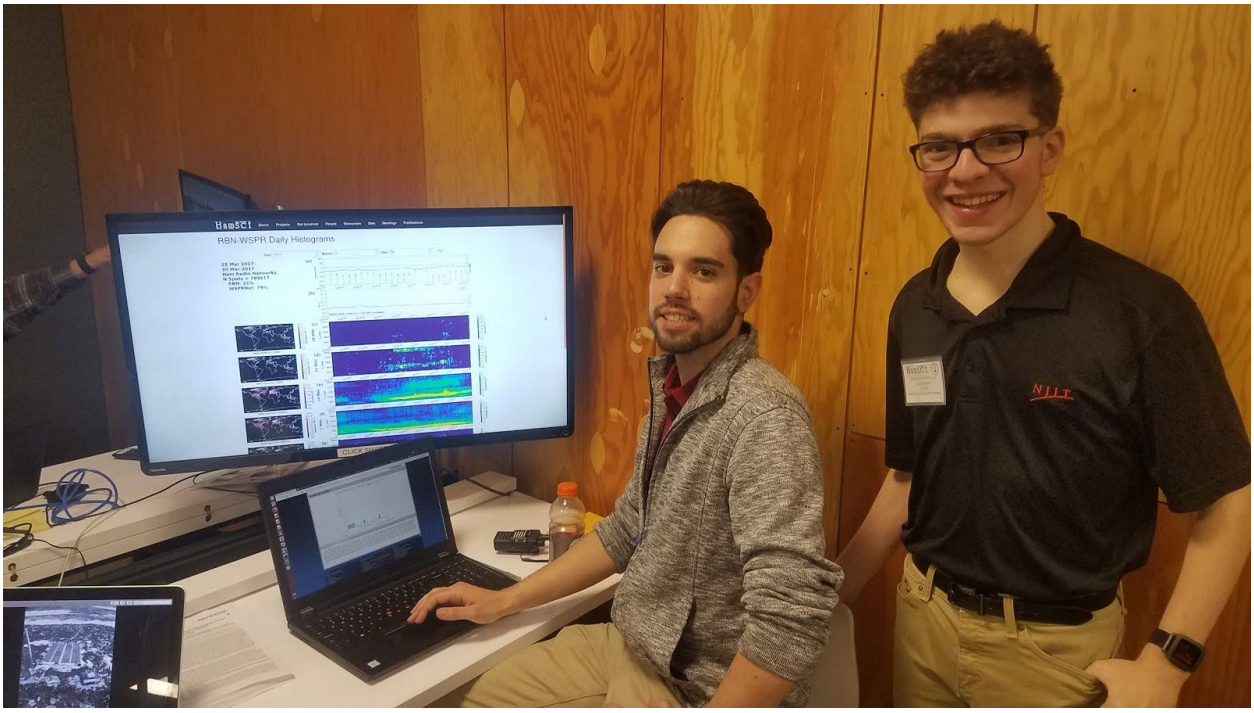
Space and radio science are at a very exciting point in history right now. These fields now have over 100 years of solid development, and they are at a point where large-scale, average behavior is reasonably well understood. However, this knowledge is by no means a comprehensive understanding of the upper atmosphere, as understanding of short-term, day-to-day variability and fine spatial scale structure and dynamics on a global scale are critical to true understanding and predictive capabilities in the geospace environment. Additionally, the significance of the impact of the lower atmosphere on the ionosphere has only recently been realized and conclusively demonstrated. For advances in these fields to continue, more resources need to be invested in terms of both observations and analysis, including (and especially) novel observation networks employing different strategies compared to professionally deployed assets.

The amateur radio community has both the technical skillset and the desire to make these contributions, but need to work with professional scientists to know where and how to direct their efforts. The 2019 HamSCI Workshop was able to successfully bring together leading members of both communities to share ideas on how to best make use of the observations that are already available, such as those made by large-scale observing networks such as the Reverse Beacon Network, WSPRNet, and PSKReporter, and the development of new techniques, such as those provided by the Frequency Measurement Community and the development of the HamSCI Personal Space Weather Station. This workshop also has brought in young people at the high school, undergraduate, and graduate levels to contribute to and learn from the experienced people in the HamSCI community. The 2019 HamSCI Workshop proved to be a fertile ground for the sharing and development of ideas between the amateur and professional communities.

Acknowledgements

The 2019 HamSCI Workshop was hosted by the Case Amateur Radio Club W8EDU and Case Western Reserve University. The local organizing committee consisted of Kristina Collins (KD8OXT, Chair), David Kazdan (AD8Y, Advisor), and Nathaniel Vishner (KB1QHX). The Science/Program Committee comprised of Nathaniel Frissell (W2NAF, Chair, NJIT), Phil Erickson (W1PJE, MIT Haystack Observatory), Ethan Miller (K8GU, JHU/APL), and William Liles (NQ6Z, HamSCI Community). Audio and video support was provided by George Byrkit, (K9TRV, TAPR). We gratefully acknowledge the support of NSF Grant AGS-1916690.

Dr. Phil Erickson (W1PJE, MIT Haystack), Larisa Goncharenko (MIT Haystack) learn about Dr. Nathaniel Frissell's (W2NAF, NJIT) HF Receiver System used for McMurdo Station Observations and PSWS Prototyping.



NJIT Undergraduate Students Diego Sanchez (KD2RLM) and Evan Markowitz (KD2IZW) demonstrate web-based scientific visualizations of RBN and WSPRNet ham radio observations.

Dr. Phil Erickson (W1PJE, MIT Haystack) and Dr. David Kazdan (AD8Y, CWRU) look at observations made by the prototype CWRU WWV HF Doppler Receiver Instrument.

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Agenda

Friday, March 22, 2019

Friday March 22, 2019	Title	Presenter	Organization	Home QTH
7:30 AM	**Breakfast/Registration**			
8:30 AM	Opening Remarks *Location: Dively Premier Lecture Hall - Room 202*	Dr. Jim McGuffin-Cawley, Senior Associate Dean, Case School of Engineering Nathaniel Frissell, W2NAF David Kazdan, AD8Y		
9:00 AM	Ionospheric Disturbances at Dawn, Dusk, and During the 2017 Eclipse	Steve Cerwin, WA5FRF		Mico, TX
9:20 AM	IonTV: Using WWV Timing Reference Signals to Observe Ionospheric Variation	Phil Erickson, W1PJE	MIT Haystack Observatory	Westford, MA
9:40 AM	WWV Doppler Shift Observations	David Kazdan, AD8Y Aidan Montare, KB3UMD Skylar Dannhoff, KD9JPX John Gibbons, N8OBJ	CWRU	Cleveland, OH
10:00 AM	Plans for EclipseMob 2024	Bill Liles, NQ6Z		Reston, VA
10:20 AM	**Coffee Break**			
10:50 AM	Sudden Ionospheric Disturbances (SIDs) and Personal Space Weather stations	Ethan Scott Grace	George Marshall HS	Falls Church,VA
11:10 AM	Doppler Shift from Earth-Orbiting Satellites	Mic Miller, N8ZYL	amateurgeophysics.com	Millersburg, OH

Friday March 22, 2019	Title	Presenter	Organization	Home QTH
11:30 AM	New Directions in Sporadic-E Research	Bill Engelke, AB4EJ	University of Alabama	Tuscaloosa, AL
11:50 AM	High Frequency Communications Response to Solar Activity in September 2017 as Observed by Amateur Radio Networks	Nathaniel Frissell, W2NAF	NJIT CSTR	Newark, NJ
12:10 PM	**Hot Lunch**			
1:20 PM	Science Questions for a Personal Space Weather Station	Nathaniel Frissell, W2NAF	NJIT CSTR	Newark, NJ
1:40 PM	HamSCI Magnetometer Network for Space Weather Monitoring	Hyomin Kim, KD2MCR	NJIT CSTR	Newark, NJ
2:00 PM	HamSCI HF Receiver Requirements	Tom McDermott, N5EG	TAPR	Medford, OR
2:20 PM	Review of SDR Hardware for the Personal Space Weather Station	John Ackermann, N8UR	TAPR	Dayton, OH
2:40 PM	Introduction to the KiwiSDR	Rob Robinett, AI6VN		Berkeley, CA
3:00 PM	**Coffee Break**			
3:30 PM	A Modular SDR for HamSCI and Other Users	Scotty Cowling, WA2DFI	TAPR	Tempe, AZ
3:50 PM	Conquering The Skip Zone: Short Range Voice and Digital NVIS Communication	Stephen Hamilton, KJ5HY	Army Cyber Institute	West Point, NY
4:10 PM	Crazy Antennas	Bob Romanofsky, KE8ERX	NASA Glenn Research Center	Cleveland, OH
4:30 PM	GPS Time Synchronization and Radio Detection for Ultra High Energy Cosmic Rays	Rob Halliday, KD9HVY	CWRU	Cleveland, OH
4:50 PM	Sounding the Ionosphere with Signals of Opportunity in the High-Frequency (HF) Band	Ethan Miller, K8GU	JHU APL	Laurel, MD
7:00 PM	**Banquet at Nighttown Restaurant**			
	Keynote Address: "Ham Radio 2.0 - Science, Service, Skill"	Ward Silver, N0AX		St. Charles, MO

Saturday, March 23, 2019

Saturday March 23, 2019	Title	Presenter	Organization	Home QTH
7:30 AM	Breakfast/Registration			
8:30 AM	History of Case ARC and W8EDU Location: Dively Premier Lecture Hall - Room 202	Jim Galm, W8WTS	CWRU	Cleveland, OH
9:00 AM	Invited: Ham Radio for Space Scientists	Carl Luetzelschwab, K9LA		Fort Wayne, IN
9:40 AM	Invited: Space Science for Ham Radio Operators	Larisa Goncharenko	MIT Haystack Observatory	Westford, MA
10:20 AM	Coffee Break			
10:50 AM	Hams: The First Makers	Frankie Bonte, KE8HPA Seamus Bonte, KE8GTT	DeSales High School	Columbus, OH
11:10 AM	ARISS: Talking to the astronauts via ham radio and how it inspires students	Nancy Hall, KC4IYD	NASA Glenn Research Center	Cleveland, OH
11:30 AM	The New Arecibo Ionospheric Modification HF Facility Dual Array Cassegrain Antenna – History and Design	Jim Breakall, WA3FET	Penn State/Arecibo Observatory	State College, PA
11:50 AM	Digital Mobile Radio Support of High Altitude Balloons for a 2017 Total Solar Eclipse Cloud Formation Experiment	Mike Pappas, W9CN	Edge of Space Sciences	Parker, CO
12:10 PM	Boxed Lunch Pickup			
2:00 PM	Lightning Talks & Demo Room Introductions Location: think[box]			
Demo Room	Case Western ARC W8EDU Station Tour	Case ARC Members	CWRU	Cleveland, OH
	think[box] Tour	Case ARC Members	CWRU	Cleveland, OH
	HF Spectrum Playback using Gnuradio	John Ackermann, N8UR	TAPR	Dayton, OH
	Wideband Spectrum Analyzer using HackRF One	John Ackermann, N8UR	TAPR	Dayton, OH

Saturday March 23, 2019	Title	Presenter	Organization	Home QTH
	FPGA-based HF transceiver running on an RPi with a MW loop antenna that works well indoors	Scotty Cowling, WA2DFI	TAPR	Tempe, AZ
	KiwiSDR	Rob Robinett, AI6VN		Berkeley, CA
	WWV Doppler Receiver	David Kazdan, AD8Y	CWRU	Cleveland, OH
	Red Pitaya SDR Recorder for Antarctica	Nathaniel Frissell, W2NAF	NJIT CSTR	Newark, NJ
	N2PK Vector Network Analyzer; A sophisticated portable HF VNA for field work	Robert Melville, WB3EFT	NJIT CSTR	Newark, NJ
	VLF Sudden Ionospheric Disturbance Receiver	Ethan Scott Grace George Lemaster, WB5OYP	George Marshall HS	Falls Church, VA
	Affordable Scientific Grade Ground Magnetometer	Hyomin Kim, KD2MCR	NJIT CSTR	Newark, NJ
	A Research Quality, Low Power and Cost Magnetometer Package for use in Citizen Science	Kit Ng, N9KIT Maya Pandya Leonardo Regoli	University of Michigan	Ann Arbor, MI
	Web-Based Scientific Visualizations of RBN/WSPR Data	Diego Sanchez, KD2RLM Evan Markowitz, KD2IZW Nathaniel Frissell, W2NAF	Essex County College NJIT CSTR NJIT CSTR	Newark, NJ
	GPS-disciplined MEMS oscillators for amateur radio applications (Poster)	Mohammad S. Islam	CWRU	Cleveland, OH
4:15 PM	PSWS Science Requirements Panel Discussion	Moderator: Ward Silver, N0AX 1. Phil Erickson, W1PJE, MIT Haystack Observatory, Radio, Ionospheric, & Magnetospheric Science		

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		2. Nathaniel Frissell, W2NAF, NJIT, Radio, Ionospheric, & Magnetospheric Science 3. Hyomin Kim, KD2MCR, NJIT, Magnetospheric Physics 4. Bill Liles, NQ6Z, VLF Science 5. John Ackermann, N8UR, TAPR, Radio Engineering 6. Scotty Cowling, WA2DFI, TAPR, Radio Engineering 7. Tom McDermott, N5EG, TAPR, Radio Engineering		
5:00 PM	Dinner at think[box] Catered by Ohio City Burrito Ham Radio License Exam Session/VE Session (Laurel VEC - Free!)			
6:30 PM	Closing Remarks *Location: Strosacker Auditorium*			
7:00 PM	Movie: Contact at CWRU Film Society			

Papers Submitted but Not Presented

Title	Author	Home QTH
Meteor scattering communication using JS8CALL and its possibilities	Dai Nagakura, JF2IWL/ND1R	Takayama City, Gifu, Japan