Update on the Personal Space Weather Station Project & HamSCI Activities for 2021

Nathaniel A. Frissell, W2NAF

The University of Scranton

Contest University 2021 Propagation Summit January 23, 2021



<u>Ham</u>SCI Ham radio Science Citizen Investigation



hamsci.org/dayton2017





Founder/Lead HamSCI Organizer: Dr. Nathaniel A. Frissell, W2NAF The University of Scranton

http://hamsci.org

A collective that allows university researchers to collaborate with the amateur radio community in scientific investigations.

Objectives:

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



HamSCI Activities

- Google Group (Over 350 Members)
- •Weekly Telecons
- Participation in
 - Professional Science Meetings
 - Amateur Radio Conventions
- Annual HamSCI Workshop
- Close collaboration with TAPR (tapr.org)

Join at https://hamsci.org/get-involved



Current Projects

- 1. Personal Space Weather Station
 - 1. Development and Engineering
 - 2. Science
- 2. Research using existing amateur radio observation networks.



HamSCI Personal Space Weather Station



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PSWS Teams





"Grape" Low Cost PSWS



"Grape Receiver" Generation 1 by J. Gibbons N8OBJ



Raspberry Pi 4 with Switching Mode Power Supply for Grape Receiver and GNSS Disciplined Oscillator



NIST Standards Station WWV in Fort Collins, CO is the primary signal source for Grape PSWS receivers. [https://www.nist.gov/image-23112]



Scientific SDR (TangerineSDR)



Developed as "TangerineSDR" by TAPR

Data Engine Specifications

- Altera/Intel 10M50DAF672C6G FPGA 50K LEs
- 512MByte (256Mx16) DDR3L SDRAM
- 4Mbit (512K x 8) QSPI serial flash memory
- 512Kbit (64K x 8) serial EEPROM
- µSDXC memory card up to 2TByte

Data Engine Features

- 11-15V wide input, low noise SMPS
- 3-port GbESwitch (Dual GbEdata interfaces)
- Cryptographic processor with key storage
- Temperature sensors (FPGA, ambient)
- Power-on reset monitor, fan header

RF Module

- AD9648 125 dual 14 bit 122.88Msps ADC
- 0dB/10dB/20dB/30dB remotely switchable attenuator
- LTC6420 20 20dB LNA
- Fixed 55MHz Low Pass Filter
- Optional user defined plug in filter
- On-board 50Ω calibration noise source
- On-board low noise power supplies
- Dual SMA antenna connectors

GNSS/Timing Module

- Precision timestamping (10 to 100 ns accuracy)
- Frequency reference (Parts in 10^{13} over 24 hr)

More Information at tangerinesdr.com



Why a New SDR?

- •Current commercial HF SDRs do not have:
 - •Dual, phase-locked, receive channels
 - •GPS precision timestamping
 - •GPSDO Frequency Stability
 - •Wide-band HF Signal Processing
 - Low cost
 - Integrated system for wide-scale scientific data collection



What are the science goals we are after?

- •Broadly, we are trying to design a general device that will be useful for many different science targets:
 - Solar Flare Impacts
 - •Geomagnetic/Ionospheric Storms
 - Internal Ionospheric Electrodynamics
 - •Short time scale/small spatial scale ionospheric variability
 - Connections with Lower Atmosphere



How does this help amateur radio?

- •The PSWS needs to have a direct benefit to amateur radio.
- •FT8 / WSPRNet monitor already implemented.
- •Working on best practices for having PSWS co-exist with amateur transmitting equipment
- •Looking for novel approaches to use the science data to help amateur radio.
- •What applications can you think of?

Hams

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wsprnet.org

Amateur Radio Frequencies and Modes



- Amateurs routinely use HF-VHF transionospheric links.
- Often ~100 W into dipole, vertical, or small beam antennas.
- Common HF Modes
 - Data: FT8, PSK31, WSPR, RTTY
 - Morse Code / Continuous Wave (CW)
 - Voice: Single Sideband (SSB)



	Frequency	Wavelength
LF	135 kHz	2,200 m
MF	473 kHz	630 m
	1.8 MHz	160 m
HF	3.5 MHz	80 m
	7 MHz	40 m
	10 MHz	30 m
	14 MHz	20 m
	18 MHz	17 m
	21 MHz	15 m
	24 MHz	12 m
	28 MHz	10 m
VHF+	50 MHz	6 m
	And more	

SAMI3-PHaRLAP Raytrace





Refraction as a Function of Frequency

http://hamsci.org





Space Weather From Above





Atmospheric Structure

http://hamsci.org



Whole Atmosphere Coupling



From Pedatella et al., (2018) (https://doi.org/10.1029/2018E0092441)



What affects the ionosphere?

Forcing from Above

- •Solar Origin
- Magnetospheric Origin

Forcing from Below

- Tropospheric Origin
- Stratospheric Origin



Traveling Ionospheric Disturbances

•TIDs are Quasi-periodic Variations of F Region Electron Density •Medium Scale (MSTID)

- *T* ≈ 15 60 min
- v_H≈ 100 250 m/s
- $\lambda_H^{"} \approx$ Several Hundred km (< 1000 km)
- Often Meteorological Sources

•Large Scale (LSTID)

- *λ*_h > 1000 km
- 30 < *T* [min] <180
- Often Auroral Electrojet Enhancement, Particle Precipitation

•Often associated with Atmospheric Gravity Waves

[Francis, 1975; Hunsucker 1982; Ogawa et al., 1967; Ding et al., 2012; Frissell et al., 2014; 2016]

•Typically thought to be caused by

- Auroral/Space Weather Activity
- Lower/Middle Atmospheric Disturbances



SuperDARN Radars

http://hamsci.org



14 MHz MSTID Simulation

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http://hamsci.org



[Frissell et al., 2016]



Example SuperDARN MSTID

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MSTIDs Nov 2012 – May 2013

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MSTID Active



Correlation with Polar Vortex

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MSTID Active



Amateur Radio Observation Networks



- Quasi-Global
- Organic/Community Run
- Unique & Quasi-random geospatial sampling



- Data back to 2008 (A whole solar cycle!)
- Available in real-time!

November 4, 2017

20171103.1200-20171104.0000_timeseries.png





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What is Total Electron Content (TEC)?

- TEC is a measure of the total number of electrons between a GPS/GNSS satellite transmitter and GPS/GNSS receiver.
- It is derived from the difference in phase delay of two different frequencies passing through the ionospheric plasma.





Estimated GNSS TEC LSTID Parameters

 $\lambda_{\rm h} \approx 1,100 \ {\rm km}$

 $v_{\rm p} \approx 950 \ \rm km/hr$

 $T \approx 70 \text{ min}$



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GNSS TEC Comparison 18:00 - 21:00



• Radio range is shortest when TEC is red (higher TEC)





Comparison with SuperDARN MSTID Statistics



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Measuring TIDs (and More) with Doppler Shifts

- •When the propagation path length changes as the refraction heigh moves up and down, the ionosphere imposes a Doppler shift on the signal.
- •Typical observed values are fractions of a Hz to a few Hz.
- •Causes include TIDs, Solar Flares, Eclipses, Dawn/Dusk Terminator

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Figure by Kristina Collins, KD8OXT

Measuring Doppler – Ham Rig?

•You can't use just any old Ham rig to measure Doppler shift!

- •A typical amateur receiver often has frequency stability and accuracy on the order of ±5-10 Hz.
 - Fine for normal communications.
 - •Not fine for ionospheric Doppler measurements, which are often smaller than ±3 Hz.



GPS Disciplined Oscillators (GPSDO)

- •Synchronizes to GPS Clocks
- •GPS Clocks use Cesium References
- •Long-term stability approaches 10^{-12} • ± 0.00001 Hz at 10 MHz

•Some, but not all amateur radios let you connect a GPSDO without modification.



Mini Precision GPS Reference Clock http://www.leobodnar.com/ ~\$135 USD



Icom IC-7610

HamSCI

http://hamsci.org



Icom IC-7610



10 MHz Reference In



Amateur Radio HF Doppler Measurements

- 1. GPSDO-lock receiver.
- 2. Put radio in USB mode.
- Tune dial 1 kHz below carrier to be measured (e.g. 9999 kHz for 10 MHz WWV)
- 4. Feed audio into Spectrum Lab by DL4YHF to record WAV files and visualize spectrum.



13 Oct 2019

Ft. Collins, CO 40.68°N, -105.04°E to San Antonio, TX 29.57°N, -98.89°W

Courtesy of Steve Cerwin WA5FRF


"Grape" Low Cost PSWS

- •The Grape Generation 1 mixes the incoming HF signal directly with the Leo Bodnar GPSDO reference.
- •This provides a relatively inexpensive way to make these precision measurements.



"Grape Receiver" Generation 1 by J. Gibbons N8OBJ



Raspberry Pi 4 with Switching Mode Power Supply for Grape Receiver and GNSS Disciplined Oscillator



Example Doppler Measurements

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by Steven Rever WWV 10 MHz Carrier Frequency, 8/20/17 (Control Day) WA9VNJ (SK) Received Near Milwaukee, WI. Mean=10,000,000.0022 Hz 10,000,000.30 10,000,000.20 Carrier Frequency (Hz) 10,000,000.10 10,000,000.00 9,999,999.90 9,999,999.80 9,999,999.70 15 16 17 18 19 20 21 22 14 Time (Hours, UTC)

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Measurements

Example Doppler Measurements

Measurements by Steven Reyer WA9VNJ (SK)





Example Doppler Measurements

Analysis by Steve Cerwin WA5FRF



WA9VNJ Frequency Record

WA9VNJ Frequency Record with Superimposed Envelope Estimation

Envelope estimation with 7.5 minute timing markers superimposed over data record to allow manual digitization for computer analysis.

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Path Length Change from Eclipse Computed Through Numerical Integration Procedure on Velocity Envelope

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KD8OXT SAMI3 Simulation Shows an F-layer Height Increase of 31 km From the Eclipse but No Change in E-layer Height

SAMI3 simulation generated by Kristina Collins KD8OXT using:

- PHaRLAP: Cervera & Harris, 2014, https://doi.org/10.1002/2013JA019247
- SAMI3: Huba & Drob, 2017, <u>https://doi.org/10.1002/2017GL073549</u>

Eclipse Study – Initial Observations

Analysis by Steve Cerwin WA5FRF

• The eclipse-induced increase in layer height inferred from WA9VNJ Doppler data was 40 km. The SAMI3 simulations performed by KD8OXT showed the increase to be 32 km.

Possible causes for the difference include:

- Error in the manually drawn Doppler envelope estimation.
- Inaccuracies in the actual Doppler data reported by the FLDIGI frequency measuring program.
- Error in the "flat earth" ray trace model used to calculate layer height from path length. This model does not take into account the curvature of the earth and assumes straight line propagation paths with geometric reflection from a virtual reflection height instead of curved ray paths and a rounded refraction in the ionization layer.
- The F layer depictions in the SAMI3 simulations were not continuous in the video from which they were captured. It is possible the frame captures were not taken at the right time and did not reflect the actual minimum height on the control day or the maximum height during the eclipse day. Also the maximum height on the simulations was 250 km and it is possible higher layer predictions were there but not displayed.
- The solar-terrestrial forecasts used for the simulation may not have been the actual numbers present during the eclipse.
- The data presented here assumes the measured frequency shift data resulted only from Doppler shift caused by the ascending-then-descending refraction layer. It is possible that the extra frequency shift may have been caused by wave velocity modulation. The passage of the eclipse shadow over the propagation path causes both layer height changes and rapid changes in free electron density that can decelerate and accelerate wave velocity.
- The SAMI3 simulations showed an eclipse-induced increase in F-layer height but no change in the E-layer. This prediction ties in nicely with many spectral recordings that show a steady frequency track along with mode splitting into multiple higher order modes during daily dawn and dusk transitions. This suggests that the frequency swings and mode splitting occur in the F layer while the steady track comes from the E-layer.

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Festival of Frequency (FoF) Measurements

- Kristina Collins KD8OXT has been leading the charge to run global campaigns to monitor HF Doppler shifts using both PSWS Grapes and Amateur gear.
- Initial results from October 1, 2019 FoF now submitted to IEEE GRSL.
- Preparing for December 4, 2021 Southern Hemisphere Eclipse

DEART FOR BEE ORONTEDER AND REMOTE PERSON LETTERS AS OF MOVEMBER 25 YOU

Citizen Scientists Conduct Distributed Doppler Measurement for Ionospheric Remote Sensing

Kristina Collins 🦰 , Aidan Montare 🕘 , Nathaniel Frissell 🕘 , David Kazdan 😔

Abstract-Doppler shift measurement using time standard grade observations of signals of opportunity scross (in HF stations as passive radar beacons is well-established as a means bands from volunteer citizen observers.

of estimating virtual ionospheric height. A community science experiment in distributed Doppler shift measurement was conducted in October 2019 using the time station WWV, on the event of that station's centennial. Participants were asked to collect Doppler shift data from the WWV 5MHz carrier via the open source software program fidigi. This experiment garnered participation from stations across the country, demonstrating sonsiderable volunteer interest: 45 recordings of WWV's 5 MHz seacon were collected. The novel element of this study is the use of distributed low-fidelity sensors in this geophysical domain, and the robust participation of the amateur radio community was enabled by inexpensive and readily available instrumentation. In this letter, we present an initial correlation analysis of the resultant data and discuss its implications for future long-term distributed Doppler networks. The data collected are in good agreement and, when examined together, offer some insight into egional trends. Despite the variety of equipment used by the amateur community, this community science approach shows promise for addressing the problem of undersampling in the more reden

Index Terms-Doppler shift, citizen science, time standard, PS-disciplined oscillator (GPSDO), distributed sensing. I. INTRODUCTION

MATEUR radio is a proven resource for the collection A of actentific data in inneghteric physics [1]. The popu-

ation of amateur radio operators is widely distributed, largely

Department at the University of Scrutten

Fig. 1: Map of participants in North America, some intermitional stations not shown. Squares denote stations with OPSDOs. The star indicates the location of WWV.

II. METHODOLOGY A. Doppler Measurement Via WWV

technically literate, and socially inclined, making the com-WWV is a radio station of the U.S. National Institute of munity well-solved for citizen science. As amateur radio has Standards and Technology (NIST) that transmits standard time secome more computerized, the number of licensed operators and frequency information. Located in Fort Collins, Colorado has increased; the same frend enables greater sophistication since 1966, WWV provides a stable, reliable, and traceable in scientific data collection at lower cost. The experiment reference for frequency and time that can be received with smdiscussed herein, undertaken in October 2019, leveraged the ple equipment. Signals from HF time standards stations like instrumentation and goodwill of the ansteur community for WWV propagate via the ionogohere, and the path length of the a large-scale data codlection exercise [2]. The event sought signal changes with ionospheric conditions These variations citizen scientists from the amateux radio community as well as occur on a daily basis, with the virtual ionospherio height at a those with HP listening equipment. Instructions were provided at https://hamaci.org/wwv-oentennial-festival-frequencymeasurements and publicized widely in the amsteur radio and shorter (e.g., minute) timescales. The frequency of the community. Data was made available in a public archive received signal is affected by Doppler shift, as shown in Figure [3]. This exercise was a pilot experiment for the Personal 2. For a ray indergoing a single hop, a movement upwards in Space Weather Station project, an effort by the Ham Radio the virtual ionospheric height at the point of reflection results Science Citizen Investigation (HamSCI) collective to create a m a drop in reseived frequency as the wavefronts are stretched distributed network of instruments which will gather scientific- farther spart. Conversely, if the virtual height decreases, the wavefronts move closer together and the received frequency is increased. Since WWV's carrier is extraordinarily precise, the change in received frequency may be used as a proxy

given location dropping during the day and rising during the night; they also undergo variation on longer (e.g., seasonal)

E. Collins (Millow/@case.edu), A. Montare (thilumd@case.edu) and D. Kantan (addy@case.edu) are in the Department of Electrical Engineering at Case Western Reserve University, N. Prinedl is in the Physical and Engineering for change in path length, and therefore change in virtual

Festival of Frequency Measurement

Ham

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WA5FRF Comparison Between Spectrogram and Single Frequency Formats During HamSCI Festival of Frequency Measurements

Path: WWV, Ft. Collins CO to WA5FRF, near San Antonio, TX 0000z – 2359z October 1, 2019

ams

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Slide Courtesy of Steve Cerwin, WA5FRF

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Chirp Ionosonde Studies

- •Science mode to take advantage of the TangerineSDR
- Make oblique ionograms using FM Chirp Ionosondes of opportunity
- Made possible by open source software and help from Dr. Juha Vierinen
- Science effort led by HamSCI/Scranton Post-Doc Dr. Dev Joshi, KC3PVE

An ionogram processed with **Chirpsounder2** software showing the single-hop and the multi-hop propagation of high-frequency (HF) radio waves transmitted from Relocatable Over-the-Horizon Radar site in Virginia to Spring Brook, Pennsylvania – the receiver station on Nov. 17, 2020.

KiwiSDR Capture of Chirp Ionosonde

Prototype Receive Station

The Universal Software Radio Peripheral (USRP) N200 kit. **Image Source:** https://ettus.com/all-products/un200-kit

The ZS6BKW Multiband HF Antenna employed in receiving the HF signals at the receiver station. **Image Source :** https://www.awarc.org/the-zs6bkw-multiband-hf-antenna/

- •Implemented on Intel Core i9 with 128GB RAM Ettus USRP N200
- •Receiver located in Spring Brook, PA (~10 miles from Scranton)
- •Antenna: ZS6BKW @ 30 ft Altitude (Dipole-Like)
- •A goal of TangerineSDR PSWS is to reduce the hardware requirements of this application substantially.

GNU Chirpsounder2 by Juha Vierinen

- The software Chirpsounder2 (https://github.com/jvierine/chirpsounder2) can be used to detect chirp sounders and over-the-horizon radar transmissions over the air, and to calculate ionograms from them. The software relies on Digital RF recordings of HF.
- This is a new implementation of the GNU Chirp Sounder. This new version allows to automatically find chirps without knowledge of what the timing and chirp-rate is.
- The process starts with a data capture with **THOR** (comes with DigitalRF), a USRP N2x0, a GPSDO, and a broadband HF antenna.

The following parts of the **chirpsounder2** software are then implemented to plot the ionograms from the collected data:

•detect_chirps.py # To find chirps using a chirp-rate matched filterbank

•find_timings.py # To cluster detections and determine what chirp timings and chirp rates exist

•calc_ionograms.py # To calculate ionograms based on parameters

•plot_ionograms.py # To plot calculated ionograms

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Chirp Ionosonde Studies

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[Joshi et al., 2020, https://github.com/jvierine/chirpsounder2]

Monday Night TangerineSDR Telecons

HamSCI Webseler

•Engineering-focused telecon to support

- •TangerineSDR development
- Magnetometer module development
- TangerineSDR-based PSWS
- Monday nights at 9 PM Eastern
- Hosted by TAPR and The University of Scranton
- •Zoom link, calendar, and archives at https://hamsci.org/get-involved

Thursday Morning Grape Telecons

"Grape Receiver" Generation 1 by J. Gibbons N8OBJ

Raspberry Pi 4 with Switching Mode Power Supply for Grape Receiver and GNSS Disciplined Oscillator

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- Engineering-focused telecon to support
 Low-cost PSWS engineering and science
- •Thursday mornings at 10 AM Eastern
- •Hosted by Case Western Reserve University and Case ARC W8EDU
- •Zoom link and calendar available at https://hamsci.org/get-involved

Thursday Bi-Weekly HamSCI Telecons

- •Science-focused telecon to support HamSCI Science
- •Every other Thursday 3 PM Eastern
- •Hosted by The University of Scranton
- •Contributed speakers are welcome!
- •Zoom link, calendar, and archives at <u>https://hamsci.org/get-involved</u>

HamSCI Workshop 2021 – Virtual!

We welcome papers related to:

- Development of the PSWS
- Ionospheric Science
- Atmospheric Science
- Radio Science
- Space Weather
- Radio Astronomy

Theme: Midlatitude Ionospheric Science

Abstracts are due February 15, 2021.

Visit hamsci.org/hamsci2021 for details.

Virtual HamSCI Workshop (March 19-20, 2021)

Friday AM	Saturday AM 1 Invited Tutorials
PSWS Engineering Orals	Saturday AM 2 Experiment Co-Design
Lunch Discussion	Lunch Discussion
Friday PM Science Orals	Saturday PM iPosters and Breakout Rooms
Friday 2200z (6 PM EST) Keynote: "History of Radio"	
<u>Ham</u> SCÏ	nathaniel.frissell@scranton.ed

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Invited Scientist Tutorial

Invited Scientist Tutorial

Midlatitude Ionospheric Physics

Dr. J. Michael Ruohoniemi

The midlatitudes are where the bulk of humanity live and radio amateurs operate, however this region has traditionally been considered "quiet" compared to the auroral zone and equatorial region and therefore has received less scientific attention.

In this tutorial, Dr. Ruohoniemi will present a review of the physics of the midlatitude ionosphere, discuss recent advancements and open questions at the frontiers of research, and consider means by which the amateur radio community can contribute to advancing scientific understanding and technical capabilities.

Dr. J. Michael Ruohoniemi is a professor of electrical engineering at Virginia Tech and Principal Investigator of the Virginia Tech SuperDARN Laboratory.

Invited Amateur Tutorial

Invited Amateur Tutorial Amateur Radio Observations and The Science of Midlatitude Sporadic E Joseph Dzekevich K1YOW

Amateurs may ask, "How are sporadic-E transatlantic VHF communications possible between North America and Europe?"

In his tutorial, Joe K1YOW will explain what Sporadic E is, how amateur operators use Sporadic E to enable long-distance VHF communications, current theories of Sporadic E formation, and how we might be able to better understand Es formation by examining amateur radio propagation logs.

Joe's studies of Sporadic E using amateur radio have been published both in <u>QST (2017)</u> and <u>CQ Magazine (2020)</u>.

Keynote Address

<u>http:</u>//hamsci.org

Keynote Address History of Radio Dr. Elizabeth Bruton

This talk will explore developments in the history, science, technology, and licensing of radio amateur communities from the early 1900s through to the present day, exploring how individuals and communities contributed to "citizen science" long before the term entered popular usage in the 1990s.

Dr. Brunton will also explore how these community-led developments can inspire the next generation's interest in science, technology, engineering, and mathematics (STEM), citizen science, and amateur radio.

Dr. Bruton is Curator of Technology and Engineering at the <u>Science</u> <u>Museum, London</u>, specializing in the history of communications. Her PhD dissertation is entitled *Beyond Marconi: the roles of the Admiralty, the Post Office, and the Institution of Electrical Engineers in the invention and development of wireless communication up to 1908.*

Acknowledgments

The authors gratefully acknowledge the support of NSF Grants AGS-2002278, AGS-1932997, and AGS-1932972. We are especially grateful to the amateur radio community who voluntarily produced and provided the HF radio observations used in this presentation, especially the operators of the Reverse Beacon Network (RBN, reversebeacon.net), the Weak Signal Propagation Reporting Network (WSPRNet, wsprnet.org), PSKReporter (http://pskreporter.info), grz.com, and hamcall.net. The Kp index was accessed through the OMNI database at the NASA Space Physics Data Facility (https://omniweb.gsfc.nasa.gov/). The SYM-H index was obtained from the Kyoto World Data Center for Geomagnetism (http://wdc.kugi.kyoto-u.ac.jp/). GOES data are provided by NOAA NCEI (https://satdat.ngdc.noaa.gov/). GPS-based total electron content observations and the Madrigal distributed data system are provided to the community as part of the Millstone Hill Geospace Facility by MIT Haystack Observatory under NSF grant AGS-1762141 to the Massachusetts Institute of Technology. We acknowledge the use of the Free Open Source Software projects used in this analysis: Ubuntu Linux, python, matplotlib, NumPy, SciPy, pandas, xarray, iPython, and others.

Thank You!

Acronym Glossary

AE	Auroral Electrojet Index
BKS	Blackstone, VA SuperDARN Radar
GNSS	Global Navigation Satellite System
HF	High Frequency (3-30 MHz)
LSTID	Large Scale Traveling Ionospheric Disturbance
MSTID	Medium Scale Traveling Ionospheric Disturbance
RBN	Reverse Beacon Network
SAMI3	SAMI3 is Another Model Ionosphere
SuperDARN	Super Dual Auroral Radar Network
Sym-H	Symmetric-H Index (For measuring geomagnetic storms)
TEC	Total Electron Content
TID	Traveling Ionospheric Disturbance
WSPRNet	Weak Signal Propagation Reporting Network

Abstract

The Ham Radio Science Citizen Investigation (HamSCI) is a platform to foster collaborations between the amateur (ham) radio and professional space science and space weather communities. Its mission is to (1) advance scientific research and understanding through amateur radio activities, (2) encourage the development of new technologies to support this research, and (3) provide educational opportunities for the amateur radio community and the general public. Similar to amateur astronomy, amateur radio allows individuals new to the avocation a path for learning, and those with years of experience a place to apply their advanced skills. This is accomplished through collaborative projects, coordinated experiments, workshops, telecons, and e-mail groups. In this presentation, we describe current HamSCI activities, available datasets, recent results, and future plans. This includes the HamSCI Personal Space Weather Station (PSWS) project, analysis of near-global communications monitoring networks such as the Reverse Beacon Network (RBN) and Weak Signal Propagation Reporting Network (WSPRNet), and analysis of observed Doppler shifts for high frequency signals of opportunity.

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Backup Slides

What is Amateur (Ham) Radio?

Hobby for Radio Enthusiasts

- Communicators
- Builders
- Experimenters

Wide-reaching Demographic

- All ages & walks of life
- Over 760,000 US amateurs; ~3 million Worldwide (http://www.arrl.org/arrl-fact-sheet)

Licensed by the Federal Government

- Basic RF electrical engineering knowledge
- Licensing provides a path to learning and ensures a basic interest and knowledge level from each participant
- Each amateur radio station has a government-issued "call sign"

Ideal Community for Citizen Science

http://hamsci.org

Note: A license is not required to operate a PSWS because it is receive only!

KD2JAO & WB2JSV at NJIT Station K2MFF

AB4EJ Home Station

N8UR multi-TICC: Precision Time Interval Counter

The Ionosphere

https://commons.wikimedia.org/wiki/File:IonosphereLayers-NPS.gif

TIDs in Blackstone SuperDARN

http://hamsci.org

Periods get longer...

PSWS Control Software and Database

Developed by University of Alabama

Primary objective

• Local Control Software for Tangerine SDR

Bill Engelke AB4EJ demonstrates early versions of the TangerineSDR Local Control Software and Simulator at 2020 HamCation in Orlando, FL.

Current Status

- Prototype of local control software exists
- Runs on Odroid N2 Single Board Computer
- Uses data from a TangerineSDR Simulator
- Can monitor up to 16 band segments at a time
- 4 types of data collection
 - **Snapshotter:** wideband high frequency spectrograms at a 1 second cadence.
 - **Ring Buffer:** Continuous local storage of IQ samples for 24 hours, then upload on request from Central Control (with throttling)
 - Firehose: Continuous transfer IQ samples to a local computer
 - **Propagation Monitoring:** Decoding of FT8 and WSPR amateur radio digital modes on up to 8 bands at a 1 minute cadence

Scientific SDR (TangerineSDR)

Developed as "TangerineSDR" byrF Module TAPR • AD9648 12

Data Engine Specifications

- Altera/Intel 10M50DAF672C6G FPGA 50K LEs
- 512MByte (256Mx16) DDR3L SDRAM
- 4Mbit (512K x 8) QSPI serial flash memory
- 512Kbit (64K x 8) serial EEPROM
- µSDXC memory card up to 2TByte

Data Engine Features

- 11-15V wide input, low noise SMPS
- 3-port GbESwitch (Dual GbEdata interfaces)
- Cryptographic processor with key storage
- Temperature sensors (FPGA, ambient)
- Power-on reset monitor, fan header

<u>http:</u>//hamsci.org

- AD9648 125 dual 14 bit 122.88Msps ADC
- OdB/10dB/20dB/30dB remotely switchable attenuator
- LTC6420 20 20dB LNA
- Fixed 55MHz Low Pass Filter
- Optional user defined plug in filter
- On-board 50 Ω calibration noise source
- On-board low noise power supplies
- Dual SMA antenna connectors

GNSS/Timing Module

- Precision timestamping (10 to 100 ns accuracy)
- Frequency reference (Parts in 10¹³ over 24 hr)

Current Status

- Prototypes expected by Fall 2020
- More information at tangerinesdr.com

Ground Magnetometer

Developed by TAPR and NJIT

Purpose

• To establish a densely-spaced magnetic field sensor network to observe Earth's magnetic field variations in three vector components.

Target performance level

- ~10 nT field resolution
- 1-sec sample rate (note: Earth's magnetic field ranges from 25,000 to 65,000 nT)

Sensors

- PNI RM3100 magnetometer module
 - 3 axis magneto-inductive measurement module
 - Low cost (≤ \$20) allows widespread deployment
 - Very small (25.4 x 25.4 x 8 mm)
- MCP9808 temperature sensor

http://hamsci.org

Prototypes have been made

Software driver development

- Current low-level software is rudimentary
- Both low-level and user facing software must be created to support further characterization and optimization of the sensors.

Planned Testing

- Testing at established quiet sites.
- Comparison with calibrated sensors of established quality.



Magnetometer prototype designed by David Witten KD0EAG at the 2020 HamCation conference in Orlando, FL

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Low-Cost PSWS Status

- Developed as the "Grape" Receiver by Case Western Reserve University and Case Amateur Radio Club W8EDU.
- **Primary objective** is to measure Doppler Shift of HF standards stations such as WWV and CHU.
- Cost target is ~\$100.
- Four stations are currently deployed, some with prototype receivers and some with amateur transceivers. Preparations are also underway to set up stations with several aspiring data collectors.
- Doppler shift data is collected via spectrographs and frequency estimation algorithms.
- The low-cost PSWS team is currently fine-tuning metadata fornats and automatic data upload.
 http://hamsci.org



"Grape Receiver" Generation 1 by J. Gibbons N8OBJ



Raspbery Pi 4 with Switching Mode Power Supply for Grape Receiver and GNSS Disciplined Oscillator

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What is Total Electron Content (TEC)?



[Tsugawa et al., 2007, doi:10.1029/2007GL031663]



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