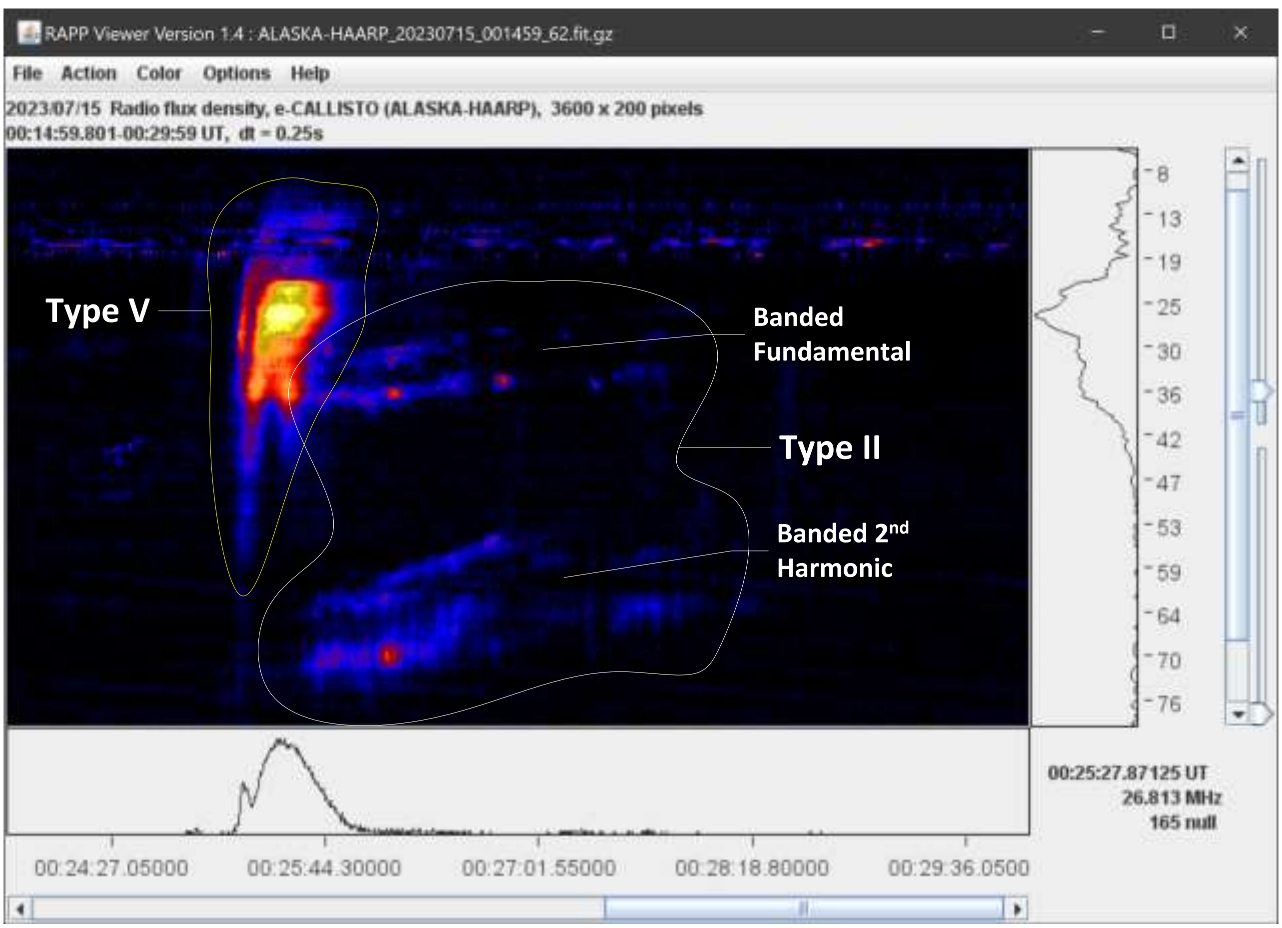
RADIO ASTRONOMY

Journal of the Society of Amateur Radio Astronomers
July-August 2023



Type II and V Solar Radio Bursts (July 15, 2023)

Dr. Richard A. Russel
SARA President and Editor

Bogdan Vacaliuc
Contributing Editor

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It is the mission of the Society of Amateur Radio Astronomers (SARA) to: Facilitate the flow of information pertinent to the field of Radio Astronomy among our members; Promote members to mentor newcomers to our hobby and share the excitement of radio astronomy with other interested persons and organizations; Promote individual and multi station observing programs; Encourage programs that enhance the technical abilities of our members to monitor cosmic radio signals, as well as to share and analyze such signals; Encourage educational programs within SARA and educational outreach initiatives. Founded in 1981, the Society of Amateur Radio Astronomers, Inc. is a membership supported, non-profit [501(c) (3)], educational and scientific corporation.

Cover Photo:
Whitham Reeve

Contents

President's Page

Another great year for SARA!

Membership has increased from 343 to 431 members (25.7%), from last year.

YouTube subscriptions have increased from 178 to 841.

Journal articles and YouTube videos have increased significantly.

The Western Conference was the first in-person conference since the pandemic and was a total success! Thanks David Westman!

Jay Wilson is doing a fantastic job organizing the Eastern conference. It will also be an in-person conference with approximately 30 members attending!

We are currently waiting for the ARRL Antenna book to be published. The SARA members were instrumental in writing the new Radio Astronomy chapter.

The new BALLOT for officers and board members is provided below. Please VOTE! I rely on these people to run the organization and provide sound counsel for decisions as well as ensuring the Journal is reviewed before distribution.

Thanks!
Rich
SARA President

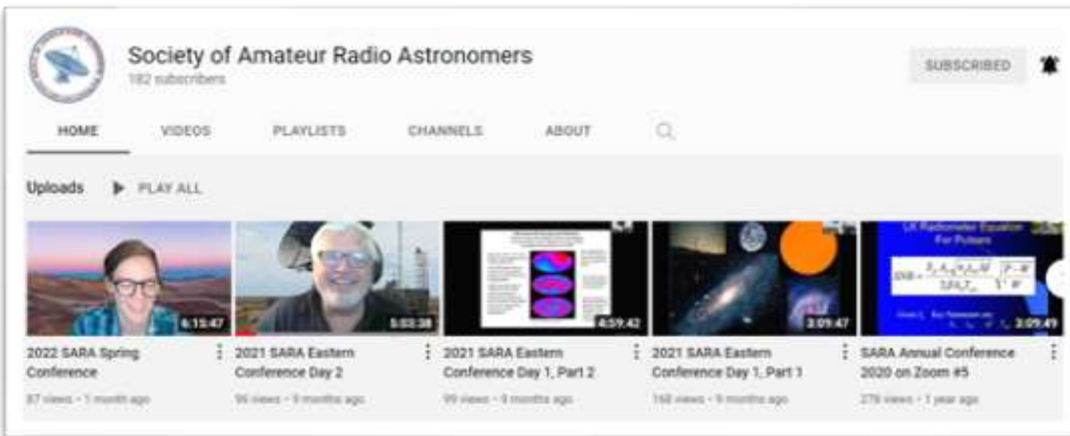
Editor's Notes

We are always looking for basic radio astronomy articles, radio astronomy tutorials, theoretical articles, application and construction articles, news pertinent to radio astronomy, profiles and interviews with amateur and professional radio astronomers, book reviews, puzzles (including word challenges, riddles, and crossword puzzles), anecdotes, expository on "bad astronomy," articles on radio astronomy observations, suggestions for reprint of articles from past journals, book reviews and other publications, and announcements of radio astronomy star parties, meetings, and outreach activities.

Subscribe to the SARA YouTube Channel

SARA has a YouTube channel at: https://www.youtube.com/channel/UC-SzptAQZ-20c9CkRb9ZPxw/videos

We are also looking to add content to the site. Anyone who wants to help produce a series of 5 - minute videos relating to radio astronomy technology or observations please contact me. (drrichrussel@netscape.net)



Observation Reports

We are now accepting 1-2 page observation reports. These reports should include the astronomical object's RA/DEC plus UTC of the observation. Also include the telescope configuration, process used to observe the object and results. Picture of the setup and plots of the observation are a plus to the report.

If you would like to write an article for Radio Astronomy, please follow **the newly updated Author's Guide** on the SARA web site:
http://www.radio-astronomy.org/publicat/RA-JSARA_Author's_Guide.pdf.

Let us know if you have questions; we are glad to assist authors with their articles and papers and will not hesitate to work with you. You may contact your editors any time via email here: edit@radio-astronomy.org.

The editor(s) will acknowledge that they have received your submission within two days. If they do not reply, assume they did not receive it and please try again.

Please consider submitting your radio astronomy observations for publication: any object, any wavelength. Strip charts, spectrograms, magnetograms, meteor scatter records, space radar records, photographs; examples of radio frequency interference (RFI) are also welcome.
Guidelines for submitting observations may be found here: http://www.radio-astronomy.org/publicat/RA-JSARA_Observation_Submission_Guide.pdf

SARA Election Ballot August 2023

Bruce Randall, Secretary

Treasurer: Vote for One (1)

_____ No current nominations
_____ Write-In_______________________________

Secretary: Vote for One (1)

_____ Bruce Randall
_____ Write-In _______________________________

Director: Vote for Two (2)

_____ Charles Osborne
_____ Ted Cline
_____ Write-In_______________________________
_____ Write-In _______________________________

Director at Large: Vote for Two (2)

_____ Dr. Wolfgang Herrmann
_____ Paul Butler
_____ Write-In _______________________________
_____ Write-In _______________________________

Members voting by e-mail should send their completed ballot to

SARA Secretary brandall@comporium.net

no later than August 21, 2023, 9:00 PM EDT.

Copying and pasting the ballot into the email will work. Then you can then mark your choices in the email.

SARA Student & Teacher Grant Program

All, SARA has a grant program that is, sad to say very underutilized. We will provide kits or money to students and teachers including college students to help them with a radio telescope project. SARA can supply any of the following kits:

[1] SuperSID
[2] Scope in a Box
[3] IBT (Itty Bitty Telescope)
[4] Radio Jove kit
[5] Inspire
[6] Sky Scan

We can also provide up to five hundred dollars ($500.00 USD) for an approved radio telescope project.

We have on occasion provided more money based on the merits of the project and the SARA Grant Committee approval.

More information on the grant program can be found at the URL below.
SARA Student and Teacher Project Grants | Society of Amateur Radio Astronomers (radio-astronomy.org)

All that is required is the SARA grant request form be filled out and sent in. If it needs more work for approval, we will work with the student to help ensure their success.

Please pass the word that SARA will fund any legitimate radio telescope project anywhere in the world.

If you have a question, contact me at crowleytj at hotmail dot com.
Tom Crowley - SARA Grant Program Administrator

NEW Drake's Lounge Australia

This new zoom forum is geared to the Melbourne, Australia time zone (UTC+10) in order to improve coordination with our Australia, New Zealand, and Japanese members. The meetings are scheduled for the 4rth Friday of every month, 9 AM Melbourne time (2000 UTC December 23). A zoom announcement will be sent out to all SARA members before the meeting.

Radio Telescope Observation Party (RTOP)

RTOP is designed to demonstrate how to take observations using various radio telescopes. It will also cover how to record and analyze data.

RTOP is every month on the 1st Sunday at 2 pm Eastern time (1800 UTC). ZOOM email notifications will be sent to all members.

Drake's Lounge

Join the SARA community as we discuss the latest astronomy and radio astronomy news. The lounge also provides a forum to share and get advice on your radio astronomy projects from very experienced amateur radio astronomers.

Drake's Lounge is every month on the 3rd Sunday at 2 pm Eastern time (1800 UTC). ZOOM email notifications will be sent to all members.

SARA 2023 Eastern/Annual Conference

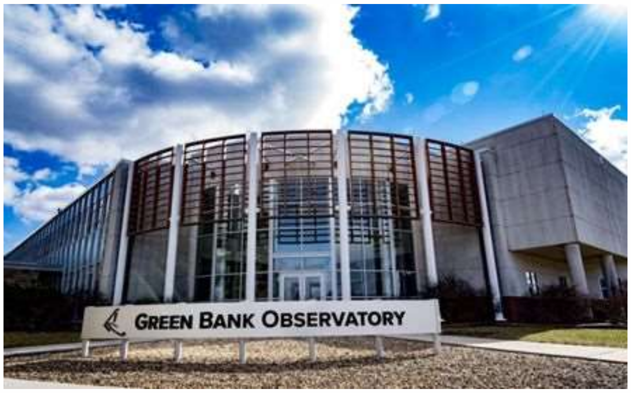
2023 SARA Eastern Conference and Global Radio Astronomy Symposium

Green Bank Observatory
Green Bank, West Virginia, 2023
20-22 August 2023

The 2023 SARA Eastern Conference and Global Radio Astronomy Symposium will be held at the Green Bank Observatory, West Virginia, Sunday through Tuesday, 20-22 August 2023. The conference will also be available as a fully interactive online event.

SARA has traditionally held our Eastern Conferences at GBO, and we are very pleased to return following a two-year hiatus due to the pandemic.

The first trailblazers of American radio astronomy called Green Bank Observatory (GBO) home over 60 years ago. Today, GBO is a world leader in advancing research, innovation, and education. Nestled in the mountain ranges and farmland of West Virginia, within the National Quiet Zone, radio astronomers are listening to the remote whispers of the universe, in order to discover answers to our most astounding astronomical questions.



Schedule: Conference meetings will be held in the main auditorium of the Jansky Laboratory at Green Bank Observatory with presentations by SARA members, GBO staff and distinguished speakers. Security and COVID restrictions permitting, tours of the facility, radio telescopes and laboratories will be conducted. Certain locations are open only to U.S. citizens who submit for a security review two weeks prior; however, other areas will be open to all attendees. ***Fully interactive online participation will be available for those who cannot attend in person.***

Key advantages of in-person attendance are training and hands-on use of the historical 40-foot radio telescope as well as user tutorial on the 20 Meter radio telescope.

Sunday through Tuesday evenings, round table discussions and refreshments are scheduled in the Drake’s Lounge, and there will be space outside for attendees to set up and display their own portable radio astronomy systems and optical telescopes.

Meals in the GBO cafeteria are included in the registration fee for in-person attendees.

Virtual online sessions are available for those who cannot attend in person.

Lodging is not included in the conference registration fee. No-frills rooms and RV/camping sites are available at the nearby Boyer Station Motel and Campground. The Elk Springs Resort is about 12 miles away. Numerous VRBO / Airbnb properties and private rentals are nearby. A list of many properties is at https://pocahontascountywv.com/lodging/ . Many chain accommodations are located about 30 miles away in Elkins, but that drive takes at least an hour due to mountainous roads. (A few on-site dormitory rooms may become available for conference presenters and SARA officers, but additional rooms for other conference attendees are not expected.)

Registration: Registration for in-person attendance by SARA members at the Conference is $275.00 (USD) if received by July 20, 2023, which includes meals but not lodging. The fee for family members or other guests who do not participate in conference sessions is $75.00, which includes meals amd evening activities. Registration by July 20th for non-members is $295.00, which includes a year's membership in SARA. SARA members wishing to renew their membership at the same time as they register may also pay $295 and should include a renewal comment with their payment.

Late registration after July 20, 2023, is $325.00. Walk-in registration at the conference is $350.00.

Online participation is $35.00

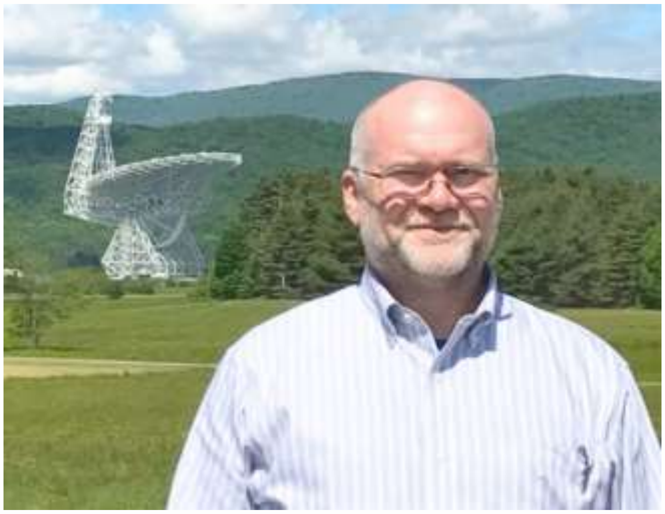
Payment can be made through PayPal, www.paypal.com by sending payment to treasurer@radio-astronomy.org Please include in comments that the payment is for the **2023 Eastern Conference.**

Registration is also available on the SARA Store at these links:

On-Site Participation or **Online Participation**

Keynote Address: Dr. James M. Jackson

Dr. Jackson has served as Director of Green Bank Observatory since 2021. Previously, he served as Associate Director for Research for the Stratospheric Observatory for Infrared Astronomy (SOFIA) with the Universities Space Research Association (USRA). Dr. Jackson has also led administration and research in astronomy and astrophysics for the University of Newcastle (Australia) and Boston University and served as Assistant Director for the Center for Astrophysical Research in Antarctica. He has co-authored 148 journal articles, with over 12,000 total citations.



Dr. James M. Jackson, Director of Green Bank Observatory

Dr. Jackson is widely recognized for his research into star formation, galactic processes and the study of deep-space molecular emissions. He has published extensive research on the observation and analysis of molecular clouds and has done in-depth study of the Milky Way’s Central Molecular Cloud Zone.

At ALMA, he was part of a distinguished research team that investigated G0.253+0.016, aka 'the Brick', one of the most massive (> 10^5 Msun) and dense (> 10^4 cm-3) molecular clouds in the Milky Way's Central Molecular Zone. Previous observations had detected tentative signs of active star formation, most notably a water maser that is associated with a dust continuum source. His team reported unambiguous evidence of active star formation within G0.253+0.016. They concluded that the sources are young and rapidly accreting and may potentially form intermediate and high-mass stars in the future. The masses and projected spatial distribution of the cores are generally consistent with thermal fragmentation, suggesting that the large-scale turbulence and strong magnetic field in the cloud do not dominate on these scales, and that star formation on the scale of individual protostars is similar to that in Galactic disc environments.

His Boston University lectures on “Fundamentals of Radio Astronomy” provide a foundation for understanding principles of antenna design and signal analysis. Of particular relevance is his explanations of beam patterns, directivity, gain, effective area, antenna temperature and sources of side lobes.

In his keynote address, Dr. Jackson will outline exciting new projects and research strategies now being undertaken at Green Bank and discuss long-term opportunities for the observatory.

Featured Presentation: Dr. Wolfgang Herrmann
President, Astropeiler Stockert, e.V., Germany

Dr. Herrmann's presentation will be on practical considerations for building small and medium-sized radio telescopes.

In recent years, the team at Astropeiler Stockert has been building and commissioning several radio telescopes varying in diameter from 3.2 meters to 1.2 meter. These are used mainly as instruments for lab courses and are designed to cover L-band to allow observation of hydrogen emission. The talk will cover the approach taken for each of these instruments for mount, feed horn, LNA and backend. Also, software designs will be discussed as well as performance parameters achieved for each design.

Dr. Herrmann received his PhD from the University of Bonn, where his thesis investigated laser spectroscopy, which was also the subject of his subsequent work at the IBM research labs in Zurich and the GKSS research center in Hamburg. He moved on to work in the telecommunication industry where he served as member of the board of a company that developed and produced advanced communication systems. Afterwards, he founded his own successful consulting company that supported major telecommunication carriers in the implementation of specialized radio and fixed line communication networks for the railway and aviation industry as well as high security networks for public administrations.

Currently, Dr. Herrmann serves as president of the Astropeiler Stockert group which operates one of the world's largest radio telescopes available to amateurs.

Conference Presentations

Introduction to Radio Astronomy
Ed Harfmann

The Sunday afternoon workshop session begins with an engaging and highly interactive presentation on the fundamentals of radio astronomy. Ed's presentation gives beginners all they need to know to get started yet will be informative to those who have spent years working in the field. This is both a "why to do it" and "how to do it" session.

Ed brings shares years of professional experience as he inspires and guides beginners and old-hands alike.

Hints and Kinks for Radio Astronomy
Charles Osborne

Immediately following the introductory session, Charles presents helpful guidance on how to set up and operate amateur radio telescopes with a view to avoiding the pitfalls which have frustrated many. Charles has managed large radio telescope research facilities and has designed and built his own amateur radio telescope systems at home, so his insight and advice can benefit everyone in the field.

40-Foot Radio Telescope Introduction and Operation
Hands-On Training and Workshop
Skip Crilly

For decades, the famous 40-foot radio telescope at GBO has been an important research and teaching instrument. Skip Crilly is one of the key volunteers at GBO responsible for maintaining this telescope and training others in its use. After a brief classroom introduction, Skip will move the session to the telescope control room where he will demonstrate how everything works before guiding the group as they learn to operate the telescope and interpret the data that is collected.

Twenty Meter Radio Telescope Introduction and Demonstration
Steve Tzikas

SARA has a user agreement with GBO which allows SARA members to remotely access and control the 20 Meter Radio Telescope. Certain security restrictions apply, but this telescope allows SARA members to conduct individual projects. Steve will cover:

- 20m Demo
- Interstellar Medium (ISM) Observations
- How to register and use the 20m radio telescope

Easy Radio Astronomy
ezRA
Radio Astronomy Team, Little Thompson Observatory
Berthoud, Colorado

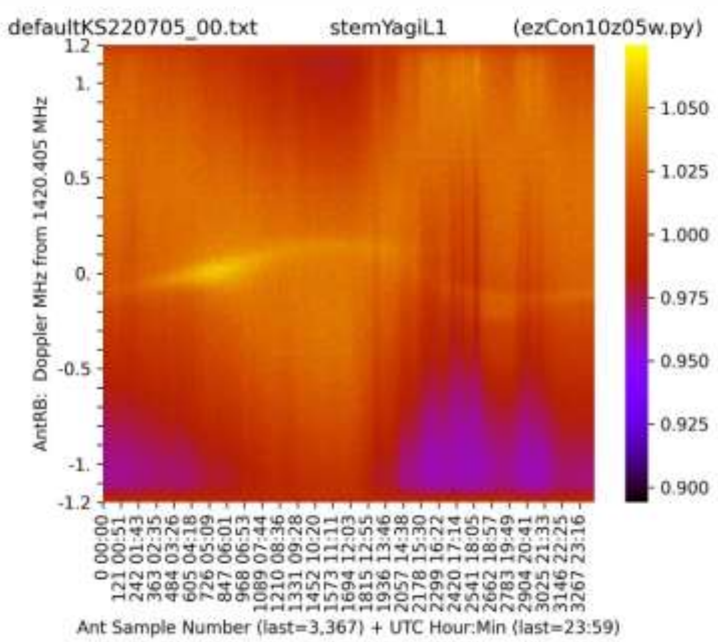
The software suite called ezRA (easy radio astronomy) is a free and easy way to get started in amateur radio astronomy. Ted Cline, N0RQV, developed this software and is a regular participant in SARA's online Drake's Lounge, where he is happy to answer questions and provide assistance.

Within minutes of powering on the system, an ezRA user can tell if her antenna is receiving HI (neutral Hydrogen emissions on 1420 MHz). Within a day, she may see the pattern of the Milky Way crossing overhead and verify antenna pointing accuracy and stability.

From a beginner's standpoint, it would be hard to make one's entry into radio astronomy easier.

As one gets more experienced with the software, ezRA has advanced features that allow researchers to plot complex galactic motions, structures, and anomalies.

The beauty of ezRA's graphics is dramatic and encouraging, even for a beginner in their first days.



ezRA sky map made on the first day by students with $5 antenna and $80 receiver

STEMSAT-1 Project Update
Dr. J. Wayne McCain, Athens State University

STEMSAT-1 (formerly known as SARA-SAT1) is manifested for launch late fourth quarter 2023 on a Vaya Space hybrid rocket from Cape Canaveral Space Force Station along with another commercial satellite.

First announced at the 2017 Western Conference, the primary objective of this 3U cubesat is to involve students from kindergarten through college level in various aspects of designing, building, launch, and mission control of the satellite as a STEM learning activity. The secondary scientific mission is to monitor VLF (50-200 KHz range) radio signals that won't otherwise penetrate the Earth's atmosphere and translate that data to a UHF, 430 MHz that is transmitted to ground stations world-wide. This paper will update the progress on STEMSAT including the project's collaboration with SARA and opportunities for global amateur radio astronomy participation and ground station support.

Modeling a Three-Element Interferometer System
Dr. Richard Russel

Dr. Russel presents a method for modeling interferometer systems which may be useful for planning small to medium-size systems and explains how this method can be applied.

Antenna Arrays in Interstellar Communication
Skip Crilly

A hypothesis has been proposed and tested suggesting that interstellar communication signals might contain pairs of close frequency/time-spaced narrow bandwidth pulses. In addition to detectability, an important requirement in interstellar communication systems is the measurement of angle of signal arrival. Phased array receiving antennas, and interferometry, provide a method to make and calibrate these measurements, and to reduce confounding radio interference.

A twelve-element phased array system is under construction to search for hypothesized pulsed signals, anomalous given an RFI-augmented random noise model. This presentation will summarize the presenter’s past multi-telescope observations and reports, describe the phased array radio telescope system under construction, explain reasoning behind the experimental methods, and seek ideas from conference attendees.

Skip presents both theoretical and practical approaches to radio astronomers interested in searching for evaluating signals that might indicate interstellar communications.

The Big Problem with Little c
B.J. Wilson, Little Thompson Observatory

Almost every calculation in astrophysics depends on an accurate determination of the speed of light, or "c." The problem is that the one-way speed of light has never been measured, and many theorize that it can never be measured by any means.

The importance of this issue was raised during a recent SARA conference when a high school STEM student in the audience asked our speaker, Nobel Laureate Dr. John C. Mather, challenging questions about distance to the source of cosmic microwave background radiation and whether conventional assumptions regarding the one-way speed of light in space could be defended scientifically. If, for instance, the one-way speed of light approached infinity, could the entire universe indeed be younger than 6,000 years? Without any reliable measurement of the one-way speed of light in space, the student asked, how could such a contrarian hypothesis of the universe be discounted?

This paper discusses the problem and proposes a global scientific initiative to find a method to definitively measure the one-way speed of light in deep space. The proposed mechanism is a "Reber Device."

Field Measurements and Front End Electronics for LWA Antennas
Whitham D. Reeve

Whit's presentation covers field measurements taken in New Mexico on the Long Wavelength Array system and provides technical and operational details for front end electronics.

<u>What Green Bank Observatory Visitors Need to Know</u>

COVID Restrictions. GBO reserves the right to impose requirements for vaccinations and masks. SARA will notify all registrants should GBO issue a policy statement. Should GBO policies adversely impact a conference registrant, they may change their registration from in-person to virtual / online and receive a refund for the difference. Should GBO close the campus for any reason, all registrations will be changed to virtual / online.

No Cellular Phone Service. GBO is in the National Radio Quiet Zone and there is no wireless phone service in the area. Use of wi-fi devices and satellite phones such as Iridium or Globalstar near the facility is not allowed, and severe restrictions are placed on digital cameras, although film cameras without electronic flash are allowed. There is a computer lab available during the day.

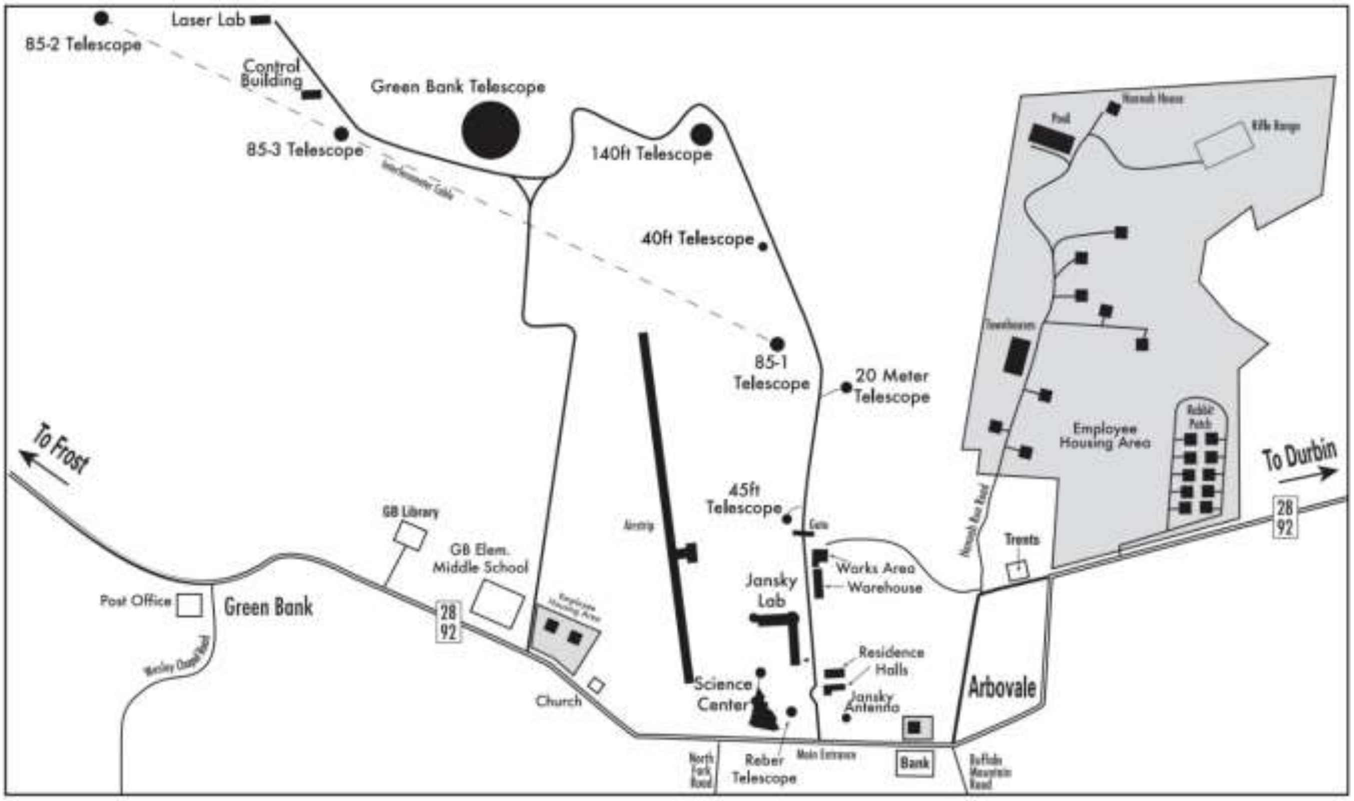
Pre-Conference Activities. Suggested pre-conference activities include free self-guided tours of the Green Bank Observatory Science Center and reasonably priced guided tours of the radio telescope area. Full details with a link for ticket purchase: https://greenbankobservatory.org/visit/
An overall guide to other activities and attractions in the area: https://pocahontascountywv.com/things-to-do/

Contact: Please contact the conference coordinator, B.J. Wilson, if you have any questions or if you would like to help with the conference: vicepresident@radio-astronomy.org

Additional Information: Additional details and updates will be published online at www.radio-astronomy.org and in the SARA journal, *Radio Astronomy*, as we get closer to the conference date.

National Radio Quiet Zone and Major Roads to Green Bank

Green Bank Observatory Site Map



2023 SARA Eastern Conference
and
Global Radio Astronomy Symposium

Note: Times are for Green Bank, WV, which is U.S. Eastern Daylight Time (UTC minus 4).

UTC TIME CONVERSION TABLE

EDT **US Eastern Daylight Time**	**UTC** **Same UTC Calendar Day for Conference Agenda Times**
0700	1100
0800	1200
0900	1300
1000	1400
1100	1500
1200	1600
1300	1700
1400	1800
1500	1900
1600	2000
1700	2100
1800	2200
1900	2300

2023 SARA Annual Conference
and
Global Radio Astronomy Symposium

DAY	TIME	SPEAKER	TITLE
Sunday 8/20/2023	**Preconference Activities and Workshops**		
	8:30-11:30 AM	On-your-own no-cost tours of Green Bank Observatory Science Center, exhibits, gift shop. Suggested lunch at the GBO Starlight Café. Bus tour tickets are sold at the gift shop, but online advance purchase is highly recommended.	
	12:00 Noon	Registration at Jansky Lab Building, just down the hill from Science Center. Ask at gift shop if you need directions. (Zoom session open at 1630 UTC)	
	12:45 PM	Jay Wilson, Chair	Administrative Announcements Safety, RFI Rules and Security Reminder
	1:00 PM	Ed Harfmann	Introduction to Radio Astronomy
	2:15 PM	Charles Osborne	Radio Astronomy Hints and Kinks
	2:45 PM	Break	
	3:00 PM	Skip Crilly	40 Ft. Radio Telescope Overview (End of day's online session)
	3:20 PM	Skip Crilly	40 Ft. Radio Telescope Hands-On Workshop
	5:15 PM	Dinner at GBO Cafeteria	
	6:30 PM	Set Up Outside Experiments and Demonstrations	
	6:30 PM	Steve Tzikas	20m GBO Skynet Robotic Radio Telescope Workshop
	8:00 PM	Social at Drake's Lounge Informal technical roundtable Outside equipment demonstrations. 40-foot radio telescope available for individual use.	

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	SARA Annual Conference and Global Radio Astronomy Symposium *In-Person at Green Bank Observatory with Interactive Online Sessions*		
	7:45 AM	Breakfast at GBO Cafeteria	
Monday 8/21/2019	8:30 AM		Registration at Jansky Lab Building
	9:00 AM	Jay Wilson, Chair	Administrative Announcements Safety, RFI Rules and Security Reminders
	9:15 AM	Dr. Rich Russel SARA President	Welcome and Conference Opening
	9:30 AM	Steve Tzikas	SARA Section Updates
	9:45 AM	David Westman	Western Conference Recap
	10:00 AM	Dr. Rich Russel	SARA Online Programs Online Drake's Lounge -- SARA RTOP SARA Drake's Lounge for Australia/New Zealand
	10:15 AM	Refreshment Break and Poster Session	
	10:30 AM	Dr. Wolfgang Hermann Astropeiler Stockert	Building Small and Medium Sized Radio Telescopes
	12:00 PM	Lunch at GBO Cafeteria	
	1:00 PM	Dr. James Jackson Director, Green Bank Observatory	Keynote Address
	2:15 PM	Dr. Rich Russel	Modeling a 3-Element Interferometer System
	3:00 PM	Refreshment Break and Poster Session	
	3:15 PM	Dr. Thankful Cromartie	NANOGrav
	4:00	Dr. Wayne McCain	Radio Astronomy STEMSAT Progress Report
	4:45 PM	Dr. Rich Russel SARA President	SARA Announcements
	5:00 PM	Bruce Randall SARA Secretary	Election Instructions (End of day's online session)
	5:15 PM	Dinner at GBO Cafeteria	
	6:15 PM	Flea Market in Dorm Parking Lot	
	6:15 PM	Setup Outside Experiments	

	7:00 PM	Social at Drake's Lounge. Outdoor experiments 40-foot radio telescope available for individual use	

Note: Times are for Green Bank, WV, which is U.S. Eastern Daylight Time (UTC minus 4).

SARA Annual Conference and International Radio Astronomy Symposium *In-Person at Green Bank Observatory with Interactive Online Sessions*			
Tuesday 8/22/2023	7:45 AM	Breakfast at GBO Cafeteria	
	9:00 AM	Jay Wilson	Administrative Announcements
	9:10 AM	Charles Osborne	Remembering Recently Passed Members and Friends Adrian Howell Bill Lord Paul Oxley Frank Drake Others we should honor? Please share.
	9:15 AM	Dr. Rich Russel SARA President	SARA Elections conducted by Bruce Randall Installation of Officers Business Meeting
	10:00 AM	Coffee Break and Poster Session	
	10:15 AM	Jay Wilson	The Big Problem with Little c
	10:30 AM	Skip Crilly	Antenna Arrays for Interstellar Communications
	11:15 AM	Ted Cline Little Thompson Obs.	ezRA Easy Radio Astronomy
	11:45 AM	Open Mic	Open Mic
	12:30 PM	Lunch at GBO Cafeteria	
	1:30 PM	Group Picture	
	1:45 PM	Whitham Reeve	Field Measurements and Front End Electronics for LWA Antennas
	2:30 PM	Rosalynn Daka	South Africa Square Kilometer Array
	3:15 PM	Refreshment Break and Poster Session	
	3:30 PM	Open Mic	Open Mic
	4:00 PM	Dr. Rich Russel	Online Conference Wrap-up
	4:15 PM	SARA Officers	SARA Board of Directors Meeting

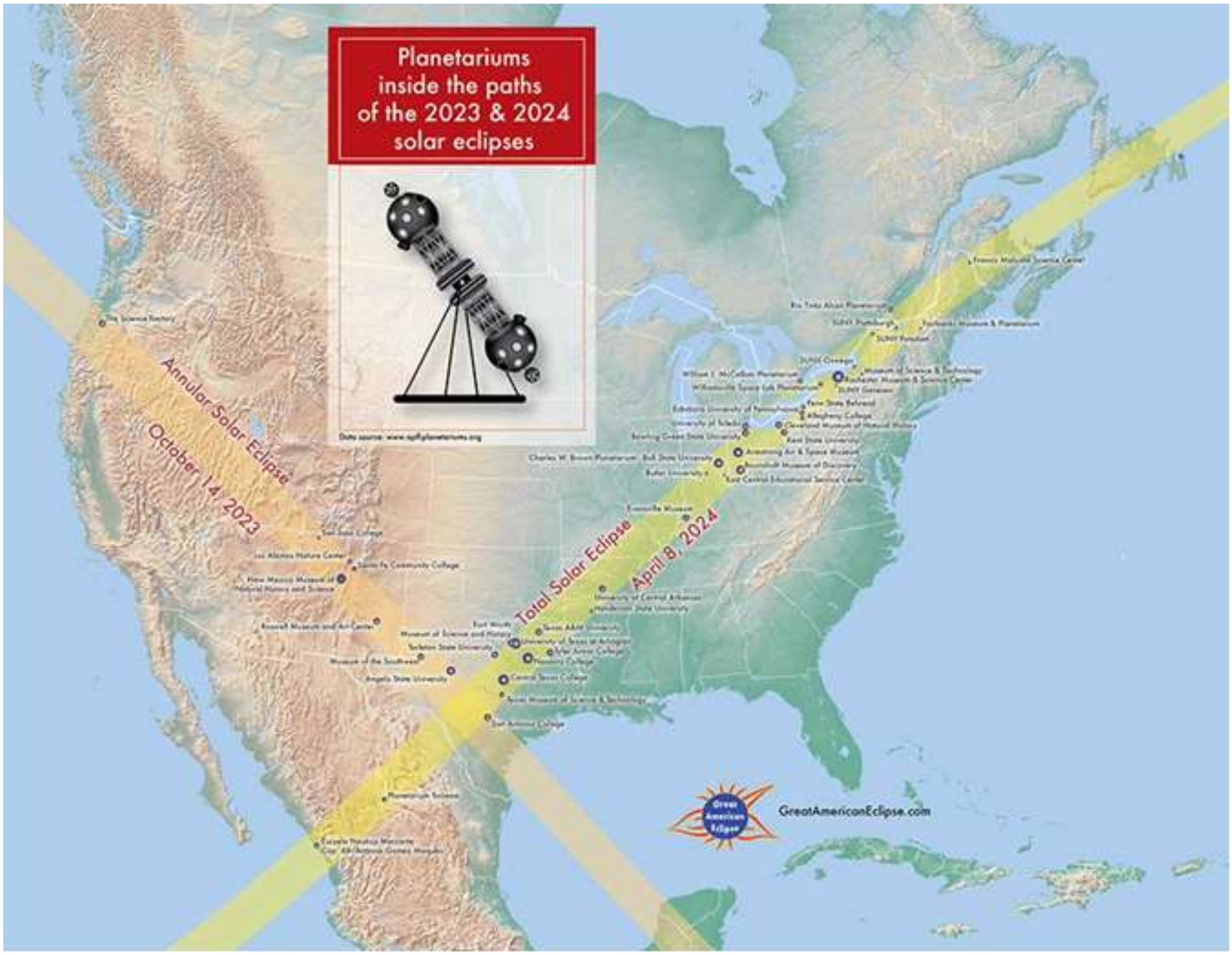
	5:15 PM	Dinner at GBO Cafeteria
	6:15 PM	Flea Market in Dorm Parking Lot
	6:15 PM	Set Up Outside Experiments
	8:00 PM	Social at Drake Lounge. Outdoor experiments 40 foot radio telescope available for individual use

Note: Times are for Green Bank, WV, which is U.S. Eastern Daylight Time (UTC minus 4).

SARA Annual Conference and International Radio Astronomy Symposium *In-Person at Green Bank Observatory Only*			
Wednesday 8/23/2023	7:45 AM		Breakfast at GBO Cafeteria
	9:00 AM	Jay Wilson	Administrative Announcements
	9:15 AM	Sue Ann Heatherly	Technical Area Tours
	11:45 AM	Dr. Rich Russel	Conference Wrap-Up
	12:30 PM		Lunch at GBO Cafeteria

Note: Times are for Green Bank, WV, which is U.S. Eastern Daylight Time (UTC minus 4).

News: (July-August 2023)



Sky & Telescope ~ *Where to See the Two Great North American Eclipses*
https://skyandtelescope.org/astronomy-news/where-to-see-the-two-great-north-american-eclipses/

Whitney Knitter - Discover Your Next USB Oscilloscope: The Analog Discovery 3

https://www.hackster.io/news/discover-your-next-usb-oscilloscope-the-analog-discovery-3-16c06078d05e
https://digilent.com/shop/analog-discovery-3

Michelle Starr - Physicists Conduct the Most Massive Test Ever of The Einstein-Podolsky-Rosen Paradox

https://www.sciencealert.com/physicists-conduct-the-most-massive-test-ever-of-the-einstein-podolsky-rosen-paradox

https://journals.aps.org/prx/abstract/10.1103/PhysRevX.13.021031

Carl Franzen - The AI feedback loop: Researchers warn of ‘model collapse’ as AI trains on AI-generated content.

https://venturebeat.com/ai/the-ai-feedback-loop-researchers-warn-of-model-collapse-as-ai-trains-on-ai-generated-content/

https://arxiv.org/abs/2305.17493v2

Scott Allen Johnston - These are the Fastest Stars in the Galaxy

https://www.universetoday.com/161915/these-are-the-fastest-stars-in-the-galaxy/

https://arxiv.org/abs/2306.03914

Les Pounder - $79 Raspberry Pi Alternative Comes with Built-in Touch Screen

https://www.tomshardware.com/news/dfrobot-unihiker-launches

https://www.unihiker.com/

Frederik Marin/CNRS/University of Strasbourg - Detection of an echo emitted by Sagittarius A* 200 years ago

https://phys.org/news/2023-06-echo-emitted-sagittarius-years.html

https://www.nature.com/articles/s41586-023-06064-x

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Mark Kaufmann - Webb telescope shows fantastic powers by zooming into alien planet

https://mashable.com/article/james-webb-space-telescope-trappist-planet

https://www.nature.com/articles/s41586-023-06232-z

Ben Turner - Neutrino map of the galaxy is 1st view of the Milky Way in 'anything other than light'

Two images of the Milky Way galaxy. The top was made with visible light and the bottom with neutrinos.
(Image credit: IceCube Collaboration/U.S. National Science Foundation (Lily Le & Shawn Johnson)/ESO (S. Brunier))

https://www.livescience.com/physics-mathematics/particle-physics/ghost-particle-image-is-the-1st-view-of-our-galaxy-in-anything-other-than-light

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Marianne Guenot – The sun has produced a record number of sunspots — and it could mean power outages, grounded flights, and beautiful auroras

NASA/SDO

https://www.businessinsider.com/sunspots-record-concerns-over-power-outages-grounded-flights-radio-blackouts-2023-7

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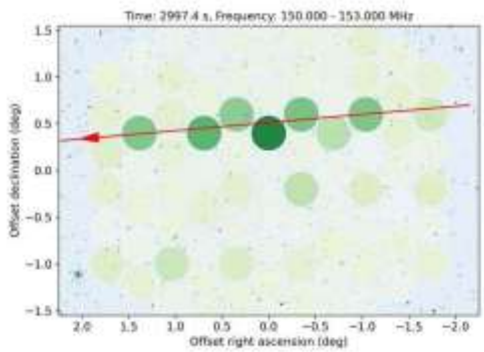

Max-Planck-Institut für Radioastronomie - New radio observations confirm unintended electromagnetic radiation emanating from large satellite constellations

https://dx.doi.org/10.1051/0004-6361/202346374

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https://scitechdaily.com/revolutionizing-cosmology-the-21-cm-forest-probes-role-in-deciphering-dark-matter/

https://www.nature.com/articles/s41550-023-02024-7

Christopher Plain – Impossible Quantum Drive that defies known laws of physics scheduled for "DO OR DIE" October space flight

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Michele Renda, "A sceptical (sic) analysis of Quantized Inertia," Preprint 6 August 2019, available=https://arxiv.org/abs/1908.01589

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European Southern Observatory - Building the World's Largest Eye: ESO's Extremely Large Telescope Reaches Construction Milestone

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https://phys.org/news/2023-07-particle-era-physics.html

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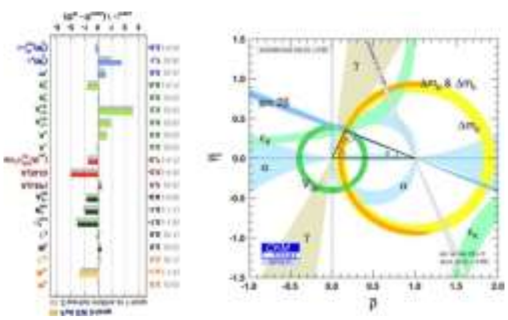

Jake Hertz – Qorvo Releases Free Circuit Simulation Software, QSPICE

https://www.allaboutcircuits.com/news/qorvo-releases-free-circuit-simulation-software-qspice/

Elizabeth A. Thomson - Team creates simple superconducting device that could dramatically cut energy use in computing

https://phys.org/news/2023-07-team-simple-superconducting-device-energy.html

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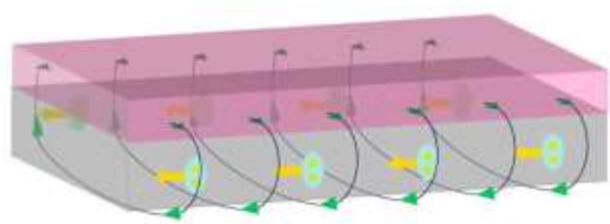
https://dx.doi.org/10.1103/PhysRevLett.131.027001



Rice University - Record-Breaking Solar Hydrogen Device: Turning Sunlight into Clean Energy

https://scitechdaily.com/record-breaking-solar-hydrogen-device-turning-sunlight-into-clean-energy/

https://www.nature.com/articles/s41467-023-39290-y

Robert Lea - Super-close supernova captivates record number of citizen scientists

https://www.space.com/supernova-closest-earth-ten-years-citizen-science

https://www.space.com/new-supernova-how-long-will-it-last

Technical Knowledge & Education: (July-August 2023)

Frank Martel - I'm a psychology expert in Finland, the No. 1 happiest country in the world—here's the real meaning of life in 5 words

https://www.cnbc.com/2023/06/09/psychology-expert-from-finland-the-worlds-happiest-country-shares-the-meaning-of-life-in-5-words.html

https://www.amazon.com/Wonderful-Life-Insights-Meaningful-Existence/dp/0062942778

SARA ~ ezRA – Easy Radio Astronomy Analysis Tutorials:
- *Simple Overview: https://youtu.be/sgid9zn9KkY*
- *Analysis 1- Introduction and Data Collectors*: https://youtu.be/ig_jPTuS8ZA
- *Analysis 2- Spreadsheet Analysis*: https://youtu.be/HkrIN9d6Hd8
- *Analysis 3- Signal Progression*: https://youtu.be/VIp7L6gIZPY
- *Analysis 4- More Plots and ezb file*: https://youtu.be/K02MADafOhc
- *Analysis 5- Interference Filters*: https://youtu.be/FeFk9EvITtc

SARA ~ *Radio Astronomy Video Series: Constants, Variables and Formulas, Radio Astronomy Formulas:*
- *Introduction to Radio Astronomy: https://youtu.be/AOgvjRXnins*
- *Lesson 1- Parabolic Dish Gain*: https://www.youtube.com/watch?v=2bx5K9jUc_w
- *Lesson 2 -Parabolic Dish Half Power Beamwidth*: https://www.youtube.com/watch?v=XWOMRrwjkl8
- *Lesson 3 -Thermal Noise*: https://youtu.be/MMJ6Xvapt10
- *Lesson 4 -Focal Length and f/D*: https://youtu.be/Am6t06KqFPE
- *Lesson 5 -Feed Illumination Angle*: https://youtu.be/4RZzPzVBSJ4
- *Lesson 6 -Pointing Offset Gain Loss*: https://youtu.be/dQ8wAaTtm40
- *Lesson 7 -Measuring System Temperature (TSys)*: https://youtu.be/4gVUFFxra-U
- *Lesson 8 -Coax Attenuation Interpolation*: https://youtu.be/3B8hV6vFyo8
- *Lesson 9 -Pulsar math including electron density, distance, and age*: https://youtu.be/Bymdp--_3JU
- *Lesson 10 -Distance Math - AU, Parallax, Parsecs and Light Years*: https://youtu.be/6fo0y3fDOZs
- *Lesson 11 -Doppler Frequency and Relative Velocity Calculations*: https://youtu.be/8zKloAVpnJc
- *Lesson 12 -Pointing to the Milky Way using a Compass and Protractor*: https://youtu.be/33xeUSji94U
- *Lesson 13 -Radiometer Equation Basics*: https://youtu.be/vAyypJ8f2z8
- *Lesson 14 -Noise Figure and Noise Factor Calculations*: https://youtu.be/GD6wZhW5NPA
- *Lesson 15 -Interpreting Stokes Parameters*: https://youtu.be/wUVsbfURIsg
- *Lesson 16 -Velocity Factor, Speed of Light in a Coax Cable: https://youtu.be/WWuqRyb4Ad8*

Announcements: (July-August 2023)

Petition against discontinuing the funding for the Leibniz Institute for Solar Physics (KIS)

Prof. Dr. Markus Roth

Dear Colleague,

The Leibniz Institute for Solar Physics (KIS, formerly known as Kiepenheuer Institute for Solar Physics) in Freiburg, Germany, is and has for many years been a leading solar physics institute in both theoretical and observational aspects. Moreover, the institute has provided valuable incentives and services for the growth of the solar physics research area and has been a centre for educating generations of scientists.

Despite these strengths, KIS is in serious danger of being closed: The senate of the Leibniz Association has recommended the German Federal Government and the German States, mainly the State of Baden-Württemberg, to end their joint funding for KIS.

This comes as a great shock for the solar physics scientific community, in particular because a recent independent scientific evaluation rated the scientific performance of KIS overall to be good to excellent. The loss of KIS would have an extremely negative impact on our community, undoing much of the progress in solar physics in the past years and setting back plans for the future of the field.

We as members of the solar and heliospheric community and related fields must speak up to ensure that KIS continues to be funded sufficiently in the future. Therefore, we would like to ask you to express your support for KIS and for its funding to be continued, if possible, at its current level and ideally with KIS remaining with the Leibniz Association, by signing an open petition at:

https://www.openpetition.eu/!kis

The petition will be handed to the relevant ministers stating your support. The online form allows you to provide specific reasons for your support, or simply to express your surprise or shock. Such additional information will make your signature even more impactful. Please keep the tone of any additional text mild. We need the support of the ministries and should not antagonize them. If you are not sure what to write, then even just putting your signature will be very valuable. Filling in the form takes just a few minutes. Please do take this time. Please note: the language of the website can be changed to English if needed, but the confirmation email with the link to verify your signature will always be in German. The more signatories, the stronger the case to keep KIS working. Thank you for giving this request the consideration it deserves.

Sincerely yours,
Laurent Gizon, Markus Roth, Sami K. Solanki, Klaus Strassmeier
Contact: Sami Solanki: solanki@mps.mpg.de

ASTROPEILER STOCKERT e.V.

Historische Radiosternwarte

European Conference on Amateur Radio Astronomy
EUCARA

Bad Münstereifel-Eschweiler, Germany
September 16th - 17th, 2023

Conference Announcement

Background

EUCARA has been initiated in 2014 and has been held at the Astropeiler Stockert. The next conferences took place in 2016 in Dwingeloo, 2018 again at Stockert, and 2021 as a virtual conference organized by the Dwingeloo team. Now it is time again to meet at Stockert.

The structure of the conference

EUCARA will be a two days conference on the weekend of September 16th and 17th, 2023. Saturday morning will be devoted to talks and the keynote speech by
Dr. Laura Spitler from the Max-Planck Institute for Radio Astronomy. After lunch, we will depart by bus to a visit of the Effelsberg radio telescope. In the evening, there will be a conference dinner.
On Sunday morning , there will be a second keynote address by Dr. Jürgen Kerp from the Argelander Institute of the Bonn Universtiy as well as further talks. After lunch, in the afternoon there will be tours of the Stockert site with various demonstrations of the telescopes as well as individual discussions. The conference will close in the late afternoon on Sunday.
For attendants arriving earlier on Friday, the conference site will be open for informal discussions and site tours.

The venue

The venue will be the facilities of the "Astropeiler Stockert" radio telescope, which comprises of several buildings and 6 radio telescopes (25-m, 10-m, 3-m, 2.3-m, 1.2-m and a Ku-band interferometer). Presentations will be held in our conference room. Another room is available for lunch, coffee and individual discussions.

The site is located near the town of Bad Münstereifel in the west of Germany. The distance to Cologne and Bonn is about 50km.

Registration

Important notice:
Due to the limited space at the Astropeiler Stockert and based on the experience from the previous conference, the number of attendants will be limited to a maximum of 40. Confirmation of registration will be on a first come, first serve basis. After reaching the maximum number of registrations, further requests will be put on a waiting list.

Registration is now open. Registrations are requested by sending an email to eucara2023@astropeiler.de, giving the following information:

- Full name
- Affiliation (if any)
- Full postal address
- Email address
- Ham callsign (if any)

Registration for online attendance

There is the option to participate at the conference via an online stream. Online participants will be able to listen to the talks both on Saturday and Sunday morning. Questions can be placed via a chat function. There will be no presentations by online participants, however, as all presentation slots are already allocated.
The afternoon sessions are devoted to visits and tours and will not be covered by the stream.

Registration fee

The conference fee for onsite participation is 100 EUR.
This will cover the transportation by bus for the visit to Effelsberg, lunch, coffee and drinks for both days and some material needed. Please note that the conference dinner is not included and will be paid individually.

The fee for online participants is 25 EUR.

The conference fee shall be paid via bank transfer to the account of Astropeiler Stockert e.V. Bank details are:

Raiffeisenbank Rheinbach Voreifel e.G.
IBAN DE88 3706 9627 0071 7580 10
BIC GENODED1RBC

Please give your name in the transfer so that we can allocate payments.

If bank transfer is not an option for you, we can provide the possibility to pay by PayPal. Please indicate in your registration if you want to use this option and we will provide you with the details.

Conference language

The conference language will be English. Assistance on site in other languages can be provided in German and French.

Website

A conference website has been set up at https://www.astropeiler.de/eucara/european-conference-on-amateur-radio-astronomy-2023/
Additional information will be provided there as they become available.

European Conference on Amateur Radio Astronomy
EUCARA

Bad Münstereifel-Eschweiler, Germany
September 16th - 17th, 2023

Preliminary Schedule

Note: All times are given in CEST (German local time). This is 2 hours ahead of UTC.

Friday, September 15th, 2023

This is the "unofficial" day. The Astropeiler site is open from 11:00 onwards for participants who arrive on that day and want to have an informal chat with other participants. This is also an opportunity to have a look at the various telescopes on site.

Saturday, September 16th, 2023

(Online participation will cover the time from 9:30 until 13:05)

9:00	Registration
9:30	Opening of conference, welcome and announcements; organizational matters
10:00	Keynote speech Fast Radio Bursts: an increasing complex astronomical mystery Laura Spitler, Max-Planck Institute for Radio Astronomy
11:00	Fast Radio Burst and Magnetar Observations with the Stockert Telescope Wolfgang Herrmann, Astropeiler Stockert e.V.
11:30	Coffee Break
11:45	Title to be determined Andrew Thomas

12:15	Status of the BRAMS and MOMSTER projects Hervé Lamy, Royal Belgian Institute for Space Aeronomy
12:45	Technical details of the Effelsberg radio telescope Gerhard Stramm, Astropeiler Stockert e.V.
13:05	Lunch
14:00	Departure for Effelsberg via Bus Guides at Effelsberg: Norbert Junkes, Max-Planck Institute for Radio Astronomy Gerhard Stramm, Astropeiler Stockert e.V.
17:00	Return from Effelsberg via Bus
19:00	Conference Dinner

Sunday, September 17th, 2023

(Online participation will cover the time from 9:00 until 12:45)

9:00	Cosmic Radiation detection by muon counting Paul Hearn
9:30	Keynote Speech On the way to the fifth Bonn survey: The Effelsberg-Bonn HI Survey (EBHIS) Jürgen Kerp, Argelander-Institute for Astronomy, University of Bonn
10:30	Mini maser telescope: observing astrophysical masers with a small backyard dish. Eduard Mol

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11:00	Coffee Break
11:15	Recent observing techniques at the Dwingeloo telescope Tammo Jan Dijkema and Thomas Telkamp, CAMRAS
11:45	PiRaTe - The Pi Radio Telescope: A modular, hard- and software open-source amateur radio telescope platform Hans-Georg Zaunick, II. Physikalisches Institut, Justus-Liebig-Universität Gießen
12:15	Overview of the Stockert Radio Telescopes Wolfgang Herrmann, Astropeiler Stockert

12:45 Lunch

14:00 Stockert site tour and demonstrations, Posters:
25-m dish
The smaller L-band dishes
The 10-m dish for Ku-/Ka band

Opportunity to measure the noise figure of LNAs

SuperSID

SuperSID
Collaboration of Society of Amateur Radio Astronomers and Stanford Solar Center

- Stanford provides data hosting, database programming, and maintains the SuperSID website
- Society of Amateur Radio Astronomers (SARA) sells the SuperSID monitors for 48 USD to amateur radio astronomers and the funds are then used to support free distribution to students all over the world (image below as of Fall 2017)
-
- Jonathan Pettingale at SARA is responsible for building and shipping the SuperSID monitor kits: SuperSID@radio-astronomy.org
- SuperSID kits may be ordered through the SARA SuperSID webpage: http://radio-astronomy.org/node/210
- Questions about the SuperSID project may be directed to Steve Berl at Stanford: steveberl@gmail.com
- Jaap Akkerhuis at Stanford is responsible for the SuperSID software and SARA has provided financial support for his efforts
- SuperSID website hosted by Stanford: http://solar-center.stanford.edu/SID/sidmonitor/
- SuperSID database: http://sid.stanford.edu/database-browser/
- The data is searchable by time, station, date, and multiple plots may be placed on the same graph for comparison.

Algeria - 2	Denmark - 3	Mexico - 21	Slovenia - 2
Antarctica - 1	Egypt - 3	Mongolia - 10	South Africa - 8
Australia - 7	Ethiopia - 14	Mozambique - 2	Spain - 1
Austria - 3	France - 9	Namibia - 1	Sri Lanka - 1
Azerbaijan - 2	Gabon - 1	Netherlands - 5	Sweden - 3
Bangladesh - 1	Germany - 30	New Zealand - 7	Switzerland - 4
Bhutan - 1	Greece - 7	Nigeria - 37	Taiwan - 4
Bolivia - 1	Guyana - 1	Pakistan - 4	Thailand - 5
Bosnia-Herzegovina - 2	Hungary - 1	Peru - 10	Tunisia - 9
Brazil - 11	India - 33	Philippines - 3	Turkey - 2
British Virgin Islands - 1	Indonesia - 2	Poland - 2	Uganda - 5
Bulgaria - 2	Iran - 4	Portugal - 3	UK - 32
Burkino Faso - 1	Iraq - 1	Rep of Congo - 3	Uruguay - 9
Canada - 33	Ireland - 9	Romania - 4	US Virgin Islands - 2
Chile - 1	Italy - 42	Russia - 3	USA - 491
China - 38	Kenya - 23	Rwanda - 1	Uzbekistan - 2
Columbia - 9	Korea (South) - 2	S Africa - 4	Venezuela - 2
Croatia - 7	Lebanon - 11	Senegal - 1	Vietnam - 1
Cyprus - 1	Libya - 1	Serbia - 1	Zambia - 2
Czech Republic - 1	Malaysia - 19	Singapore - 3	
D Rep of Congo - 4	Malta - 1	Slovak Repub - 2	

-

For official use only
Monitor assigned: ___________
Site name: _________________
Country: ___________________

SuperSID Space Weather Monitor

Request Form

	Your information here		
Name of site/school *(if an institution)*:			
Choose a site name: *(3-6 characters) No Spaces*			
Primary contact person:			
Email:			
Phone(s):			
Primary Address:	Name School or Business Street Street City State/Province Country Postal Code		
Shipping address, if different:	Name School or Business Street Street City State/Province Country Postal Code		
Shipping phone number:			
Latitude & longitude of site:	Latitude: ____________________________ Longitude: ___________________________		

I understand that neither Stanford nor the Society of Amateur Radio Astronomers is responsible for accidents or injuries related to monitor use. I will assure that a surge protector and other lightning protection devices are installed if necessary.

Signature: ____ Date: ____________________________

I will need:

What	*Cost*	*How many?*
SuperSID distribution USB Power	$48 (assembled)	
USB Sound card 96 kHz sample rate *(or provide this yourself)*	$40 *(optional)*	
Antenna wire (120 meters) *(or you can provide this yourself)*	$23 *(optional) with connectors attached and tested*	
RG 58 Coax Cable (9 meters) *(or provide this yourself)*	$14 *(optional) with connectors attached and tested*	
Shipping	US $12 Canada & Mexico $40 all other $60	
	TOTAL	$

____ **I have included a $_____________ check** (payable to SARA)

____ **I will make payment thru** www.paypal.com to treas@radio-astronomy.org

or

____ If you are a Minority-serving institution, in a Developing or economically deprived nation, and/or you are using the monitor with students for educational purposes, you may qualify for obtaining a monitor at reduced or no cost. Check here if you wish to apply for this designation. Then tell us how you want to use the SuperSID monitor. Include type of site, number of students involved, whether public or private school, grade levels, etc. and describe your program. The goal of the SuperSID project is to provide as many students with systems as possible. If you are able to pay for a system, even if you qualify for a free one, please do so and help support our goal.

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For more details on the Space Weather Monitor project, see: **http://sid.stanford.edu**

To set up a SuperSID monitor you will need:

1 Access to power and an antenna location that is relatively free of electric interference (could be indoors or out)

2 A **PC**** with the following minimal specifications:

a. A sound card that can record (sample) up to 96 kHz, or a USB port to connect such a sound card (for North and South America)
   i. All other countries can use AC97 sound card with 48 kHz record (sample) rate. Most computers made after 1997 will have AC97.
b. Windows 2000 or more recent operating system
c. 1 GHz Processer with 128 mb RAM
d. Ethernet connection & internet browser (desirable, but not required)
e. Standard keyboard, mouse, monitor, etc.

3 An inexpensive antenna that you build yourself. You'll need about 120 meters (400 feet) of **insulated** wire. Solid wire is easier to wind than stranded. Magnet wire will work but be more fragile. You can use anything from #18 to #26 size wire. The antenna frame can be made of wood, PVC pipe, or similar materials. We'll provide instructions. You can purchase the wire from us or obtain your own.

4 RG58 coax cable with a BNC connector at one end to run from the antenna to the SuperSID receiver. 9 meters is recommended, but the length will depend on where you place the antenna. You can purchase the coax from us or obtain your own.

5 Surge protector and other protection against a lightning strike

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Return this form to: SuperSID@radio-astronomy.org

or mail to: SARA
Brian O'Rourke, SARA Treasurer
337 Meadow Ridge Rd,
Troy, VA 22974-3256

Announcing Radio JOVE 2.0

The Radio JOVE Team

Radio JOVE students and amateur scientists from around the world observe and analyze natural radio emissions of Jupiter, the Sun, and our galaxy using their own easy to construct radio telescopes.

Our Project announces Radio JOVE 2.0, where participants assemble a 16-24 MHz radio spectrograph to observe solar, Jupiter, Galactic, and Earth-based natural radio emissions and share their observations with fellow participants.

In the Beginning

Radio JOVE started as a NASA sponsored educational outreach project in 1999. We developed a radio telescope kit suitable for receiving signals from Jupiter, the Sun, the Galaxy, and Earth-based radio emissions. The original kit comprised a radio receiver (RJ1.1) and a dual dipole antenna for 20.1 MHz. An important goal was to teach electronic principles including how to build, solder, and assemble the radio receiver and antenna.

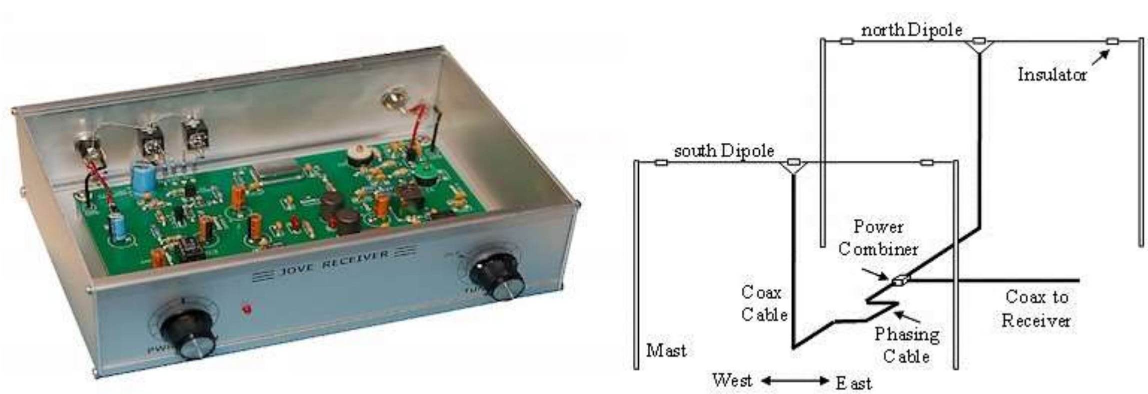

Figure 1. A Radio JOVE RJ1.1 receiver and a schematic of the dual-dipole antenna.

In addition to the hardware, three software packages were developed. These were Radio Jupiter Pro (Jupiter emission prediction program), Radio-SkyPipe (strip chart program) and Radio Sky Spectrograph (control and display of radio spectrograph data).

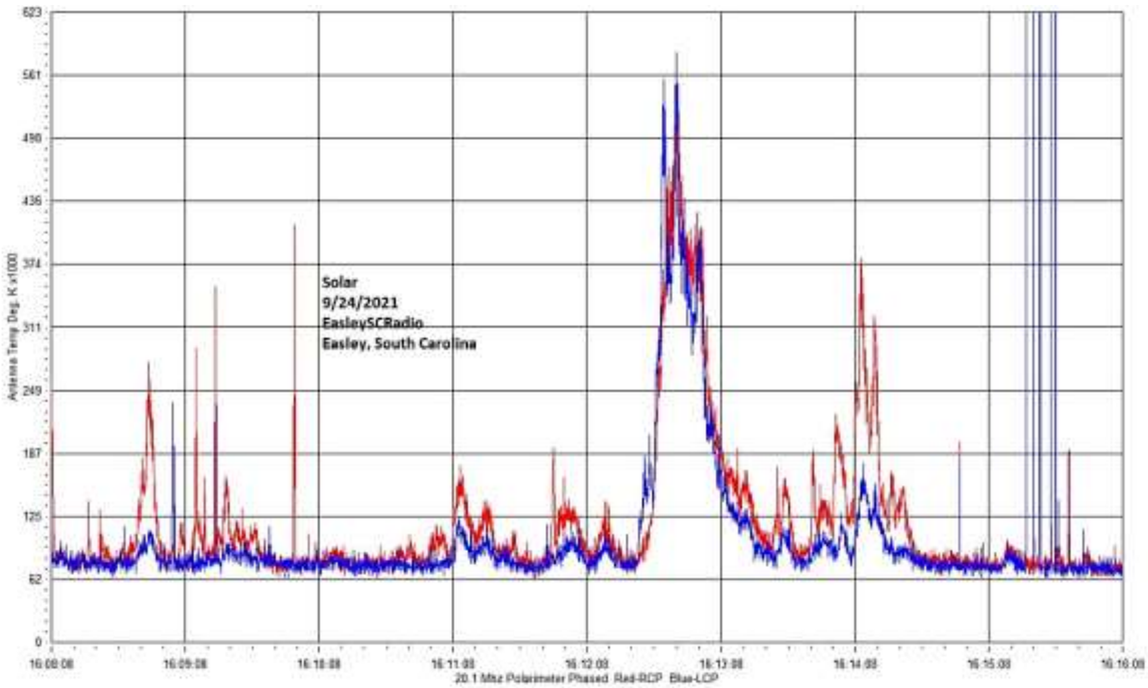

Figure 2. A SkyPipe strip chart showing multiple solar bursts using a JOVE receiver. John Cox, SC.

The Growth of Radio JOVE

As of Autumn 2021, over 2,500 kits have been sold at cost to schools and individuals around the world. Thousands of data submissions from observers have been made to the Radio JOVE data archive.

The Radio JOVE web site has always provided a wealth of information describing observation methods and various educational materials intended to teach radio astronomy techniques and scientific methods. Biannual newsletters are produced, and several telephone help sessions are held each year.

A sub-group of experienced observers known as the Spectrograph Users Group (SUG) evolved from the core JOVE group. These observers developed data collection and analysis techniques using more advanced equipment and techniques. SUG members have contributed to articles published in peer-reviewed scientific journals. This group remains active under the Radio JOVE listserv at https://groups.io/g/radio-jove/.

Moving Forward with New Technology

In the past, Radio JOVE provided the hands-on experience of building a radio kit. We have many RJ1.1 receivers in operation successfully contributing scientifically valuable data. It has, however, become increasingly difficult to obtain parts for the RJ1.1 receiver kits and we therefore decided to replace the RJ1.1 receiver with a new SDR-based design for the receiver portion of our radio telescope kits. While we continue to support the hardware and software for the original RJ1.1 receivers, the only kits now available for purchase from Radio JOVE contain this newly designed system.

In recent years, new technologies have made software defined radios (SDRs) ever more affordable. These radios can operate on a single frequency like the original JOVE receiver but can also generate spectrograms which depict radio activity as a function of both time and frequency. Such displays offer new insights into our studies of the Sun, Jupiter, the Galaxy, and both natural and artificial Earth-based radio emissions.

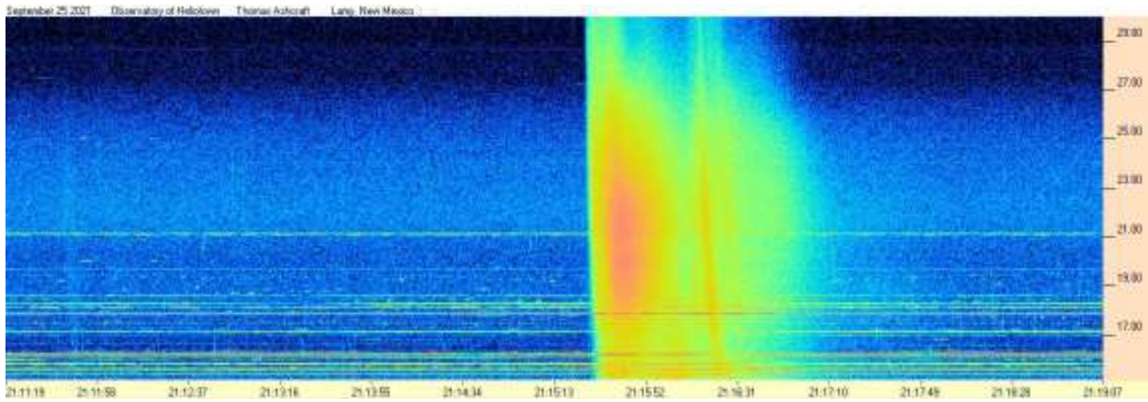

Figure 3. Radio spectrogram showing multiple solar bursts received by Tom Ashcraft in New Mexico. Horizontal scale is time, and the vertical scale is frequency. Amplitude is displayed using different colors corresponding to the strength of signals.

Radio JOVE continues to sell radio telescope packages including an antenna, receiver, and software; however, the receiver is now a commercially built SDR.

Figure 4. The JOVE team has had considerable success with the SDRPlay RSP1A unit and will provide support for using this instrument for our radio astronomy program. Not all SDR types can be supported, but it is our intent to provide support for some other SDRs as they become available during this period of rapid SDR development.

It continues to be our goal to introduce new observers to the scientific method and help them experience the thrill of receiving cosmic radio signals. Through a series of educational training modules and observing and analysis projects we aim to guide new observers to levels where they can contribute to Citizen Science projects.

We continue to support our large user base that uses JOVE RJ1.1 receivers – both in terms of technical support for the receivers but also with new and exciting observing projects for both RJ1.1 and SDR users.

We welcome both new and experienced observers to the JOVE 2.0 program as we share the excitement of receiving, studying, and understanding radio signals from our corner of the galaxy.

Please see the Radio JOVE web site at https://radiojove.gsfc.nasa.gov for more information.

RADIO JOVE 2.0 RADIO TELESCOPE KIT ORDER FORM

Order Online using PayPal™

* * * Please allow 2 to 3 weeks for delivery. * * *

IMPORTANT: Before you order the Jove receiver kit and/or the antenna kit, we suggest that you read the on-line manuals. You will need to provide additional materials and tools to complete the antenna. The cost of additional materials for the antenna support structure (masts, etc.) may be in the range of US$75 to US$100. Also note that the optimal antenna height can be up to 20ft, depending upon your latitude.

Item # RJK2u – Complete 2.0 Kit: Receiver + Unbuilt Antenna Kit + Software This kit includes an SDRplay RSP1A, USB Cable, SMA/BNC cable, F-adapter, unbuilt Antenna Kit (RJA), printed assembly manuals, and Radio-Sky Spectrograph (RSS) software. Note: Kit does not include antenna support structure. **Price: $215 + Shipping (See reverse for shipping)**	**Item # RJK2p** – Complete 2.0 Kit: Receiver + Professionally Built Antenna Kit + Software This kit includes an SDRplay RSP1A, USB Cable, SMA/BNC cable, F-adapter, Professionally Built Antenna Kit (RJA2), printed assembly manuals, and Radio-Sky Spectrograph (RSS) software. Note: Kit does not include antenna support structure. **Price: $384 + Shipping (See reverse for shipping)**
Item # RJA – Unbuilt Antenna Kit The RJA Radio JOVE Antenna Kit includes a printed construction manual, stranded copper easy-to-solder antenna wire, ceramic insulators, RG-59 easy-to-solder coax cable, screw-on Fconnectors, and a power combiner. Note: Kit does not include antenna support structure. Assembly requires a soldering gun and other tools. **Price: $90 + Shipping (See reverse for shipping)**	**Item # RJA2** – Professionally Built Antenna Kit The RJA2 Radio JOVE Antenna Kit includes a printed installation manual, two professionally assembled dipole antennas constructed of #14 Copperweld wire with Budwig center insulators and center support rope attachment points, high quality RG-6 coax with pre-installed commercial grade connectors, and a power combiner. Note: Kit does not include antenna support structure. **Price: $249 + Shipping (See reverse for shipping)**
Item # LTJ2 – Listening to Jupiter, 2nd Ed. by R. S. Flagg PDF download of Richard Flagg's book "Listening to Jupiter, 2nd Ed., 2005". The file is downloaded from a secure website. **Price: $10 + $0 shipping (PDF file download)**	**Item # RJR2** – Radio JOVE 2.0 Receiver-Only Kit This kit includes one SDRplay RSP1A SDR receiver, USB Cable, SMA/BNC cable, and F-adapter, printed assembly manuals, and Radio-Sky Spectrograph (RSS) software. **Price: $135 + Shipping (See reverse for shipping)**

RADIO JOVE 2.0 RADIO TELESCOPE KIT ORDER FORM (continued)

Order Online at https://radiojove.net/kit/order_form.html OR
Complete this form and mail with payment

Payment may be made by Credit Card via PayPal™, U.S. Check, U.S. Money Order, International Money Order in U.S. funds drawn on a U.S. bank, or Western Union Money Transfer made payable to **The Radio JOVE Project**. No bank-to-bank wire transfers are accepted. Purchase Orders are accepted from U.S. Institutions.

Send to: The Radio JOVE Project
1301 East Main St
MTSU Box 412
Murfreesboro, TN 37132, USA
email: chiggins@mtsu.edu
FEIN: 20-5239863

Item	Description	Quantity	Item Price	Shipping (see below)	Subtotal
RJK2u	Complete Radio JOVE 2.0 Kit Receiver + unbuilt Antenna		\$215		
RJK2p	Complete Radio JOVE 2.0 Kit Receiver + Professionally Built Antenna		\$384		
RJA2	Professionally Built Antenna-Only Kit		\$249		
RJA	Unbuilt Antenna-Only Kit		\$90		
RJR2	Receiver-Only Kit		\$135		
LTJ2	Listening to Jupiter, 2nd Ed., by R.S. Flagg (PDF download)		\$10	\$0	
				Total:	

Shipping Fees for Radio JOVE: We ship all packages using USPS Priority Mail flat rate boxes.
U.S.A.: \$17.00
Canada: \$57.00
All Other International Shipping: \$85.00

Ship to: (Please print clearly)

Name: ____

Address: ____

City, State, Postal Code: ____

Province, Country: ____

Email: ____

Visit the Radio JOVE web site and fill out the team application form at https://radiojove.net/sign_up_form.php even if you are just an interested individual so that you can receive important information about kit updates, online services, and activities within the project as they occur!

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BAA Radio Astronomy Section, Director: Paul Hearn

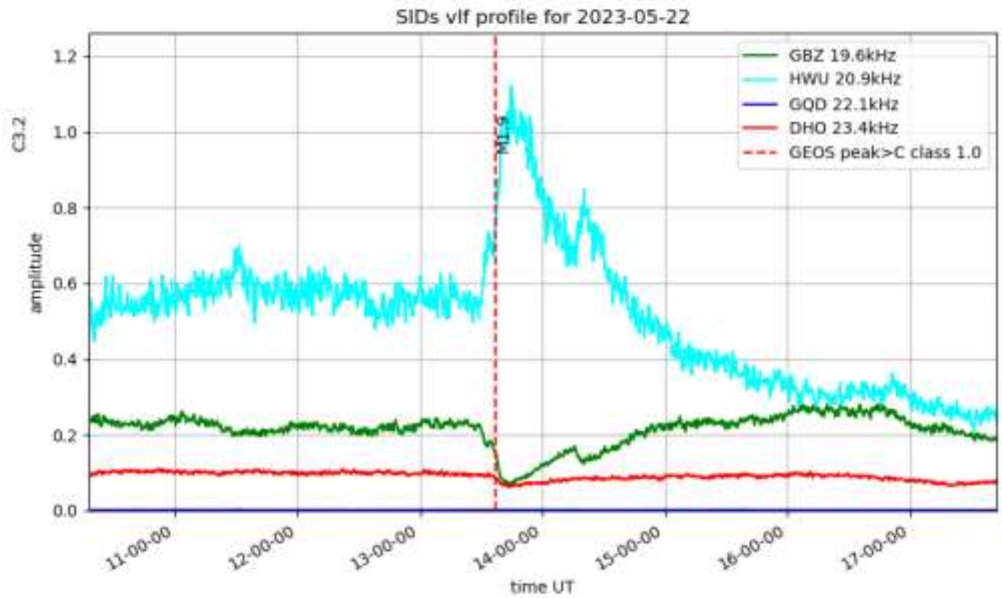
RADIO SKY NEWS **2023 MAY**

VLF SID OBSERVATIONS

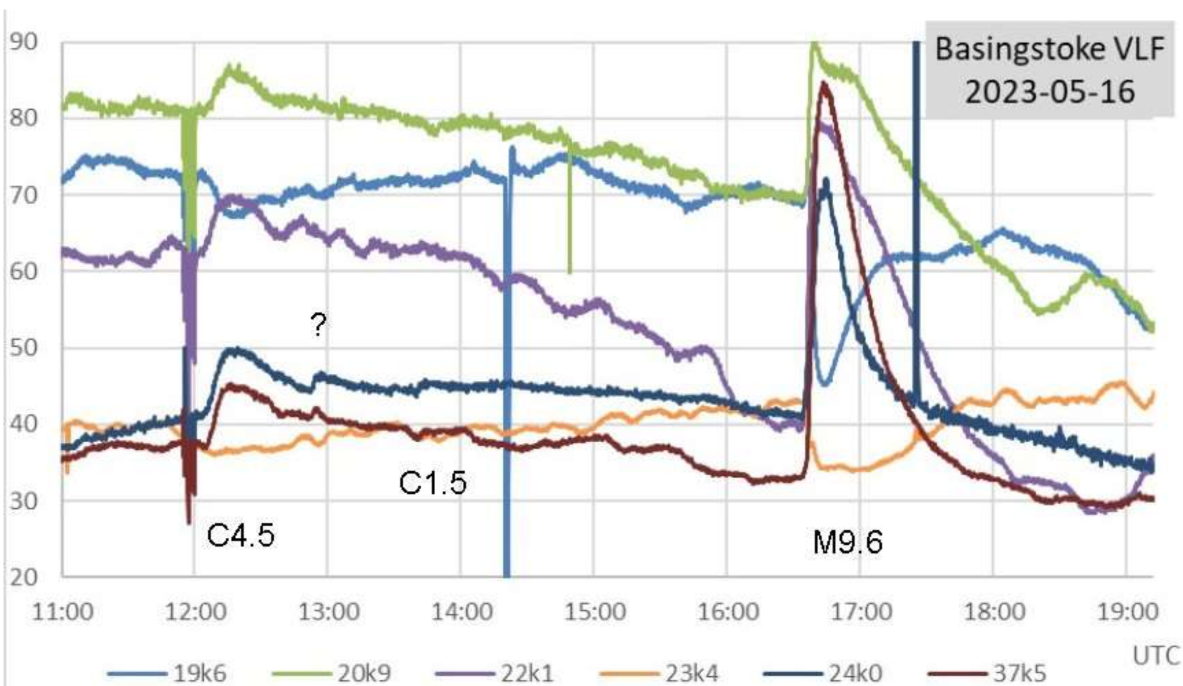
During 2023 May we recorded 227 individual SIDs, the largest number since we started recording in 2005 May. 175 of these were classified in the SWPC bulletins, again being the highest in our record. The previous peak was back in 2012 July, with 165 classified flares at the first peak of solar cycle 24. I have therefore had to alter the activity chart vertical axis in order to fit in the new peak. Cycle 25 looks to be as strong as cycle 24, if not potentially stronger; time will tell! It is also worth noting that we have gained more experience in analysing our recordings, as well as improving the equipment used. This may well bias our current observations compared to 10 years ago when comparing cycle activity.

We did not see any X-flares, but a number of the M-flares did come very close to the boundary. Some of these also occurred in active regions close to the solar limb, and so may well have reached X-class if they had been seen nearer head-on.

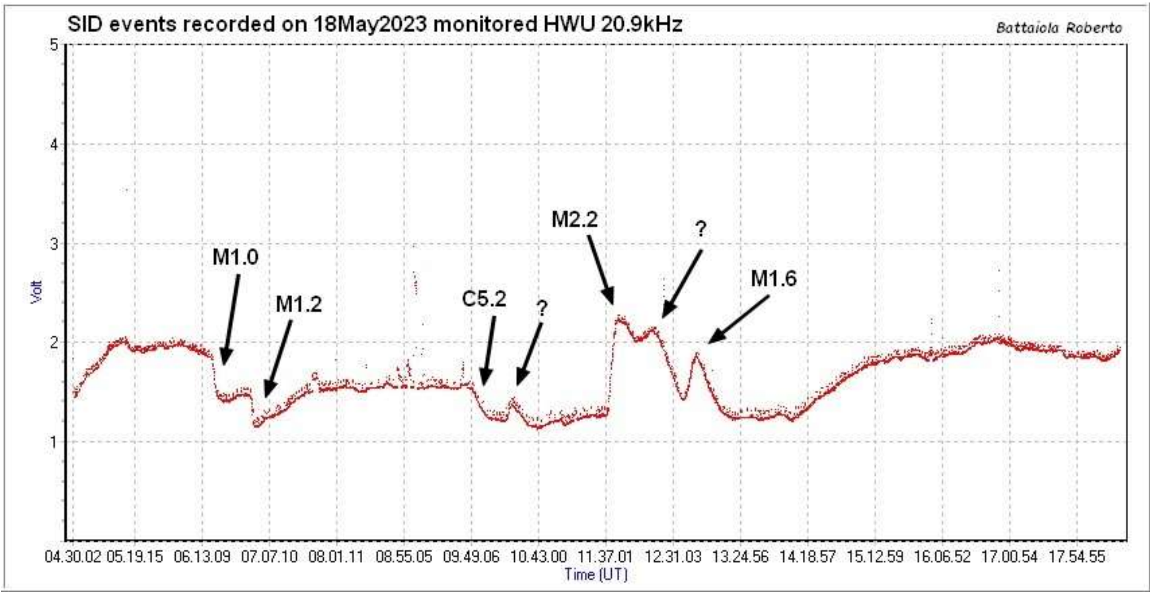
The M1.9 flare widely recorded peaking about 13:40UT on the 22nd was not particularly strong but is listed in the SWPC bulletin as two events. Both are listed with an X-ray peak of M1.9 at 13:37UT, but with end times of 13:43 and 06:55. The shorter flare was from AR13311, a fairly large and complex region, the second does not have a source, and seems to extend well into the following morning.



This recording from Mark Prescott shows a fairly ordinary SID at 19.6kHz and 20.9kHz, fading away as expected for an M1.9 flare. The C7.2 flare at the start of the main SID also does not have a source in the X-ray data, the C6.3 flare afterwards is also from AR13311.

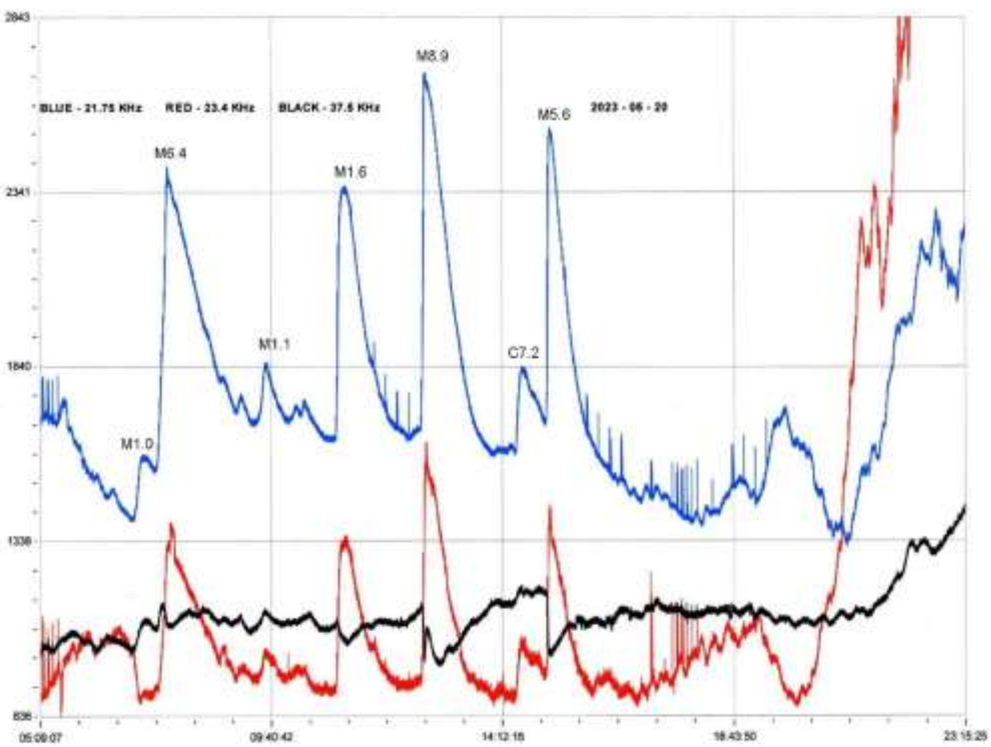


The M9.6 flare on the 16th was also widely recorded, shown here by Paul Hyde. Most of the signals show a very strong SID, although 23.4kHz looks rather subdued in comparison. Also visible is the earlier C4.5 flare with a strong and distinct SID. This is followed by the unclassified flare just before 13:00, and the small C1.5 flare. Both of these shows well at 37.5kHz, while 24kHz shows the unclassified event. There are some strong interference spikes, but luckily, they are clear of the activity.

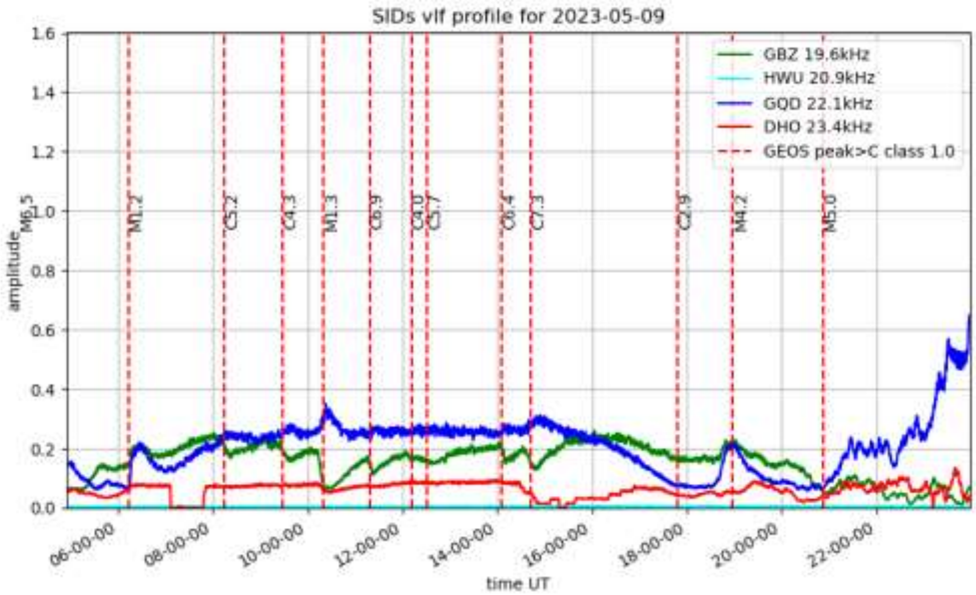


This recording by Roberto Battaiola shows activity on the 18th at 20.9kHz. The early M1.0 and M1.2 flares have produced negative going SIDs, while the later M2.2 and M1.6 are clearly positive going SIDs. The background signal also shows interference throughout the day. This was from the long-lasting thunderstorms in Italy. Luckily, no damage done, and the SIDs are mostly well defined. The C5.2 does have an unusual shape, and seems to be where the SID polarity changes.

May 20th was also busy with M-class flares, shown here by Colin Clements:



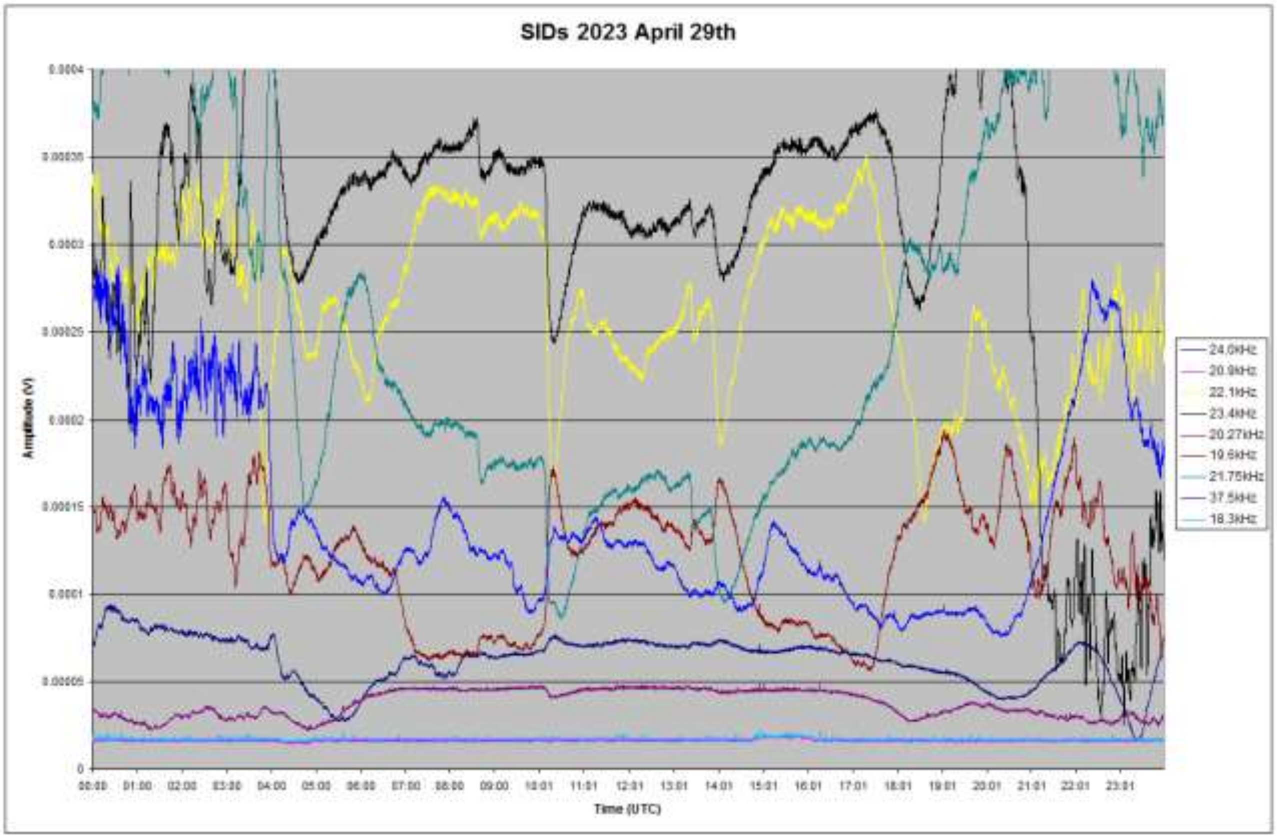
The chart shows most of the day from 05:09 to 23:15UT, with the stronger events labelled. Some of the smaller flares are also visible, superimposed on the larger ones. There is also some spiky local interference present. 37.5kHz does not seem to have responded much, while 21.75kHz shows plenty of detail.



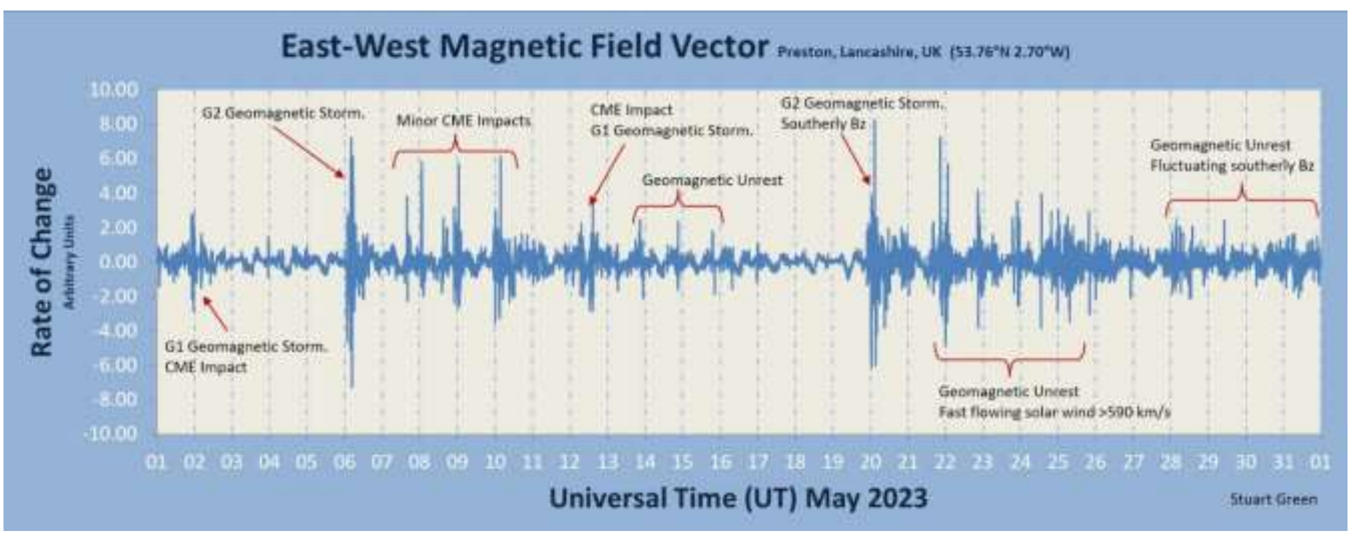
Mark Prescott's recording from the 9th shows plenty of activity, but from much weaker flares. 19.6kHz has produced the clearest SIDs, with 22.1kHz showing just the stronger events. Solar activity has been high throughout the month, with the background X-ray flux level correspondingly high. This means that many of the C-class flares represent only a small increase in flux, and so had have less effect on the ionosphere and produced smaller SIDs.

Over the past few years, some of the newer radio observations from professional observatories have been converted into sound so that we can hear what has been recorded rather than just looking at graphs and charts. This is of course ideal for the visually impaired. Mark Edwards has done this with his 19.6kHz data from the 20th, including all those M-class flares illustrated on the previous page. It covers 06:00 to 18:00UT, compressed into a much shorter time. Mark describes it as "sounding like a demented synthesiser," but the SIDS are easily heard as rises in the pitch for each flare.

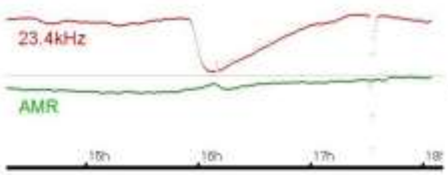
Last month's report included a rather unusual shaped series of SIDs on April 29th, recorded by Colin Clements at 21.75kHz. Mark Edwards has reported that he also saw a similar response at 19.6kHz (brown trace):

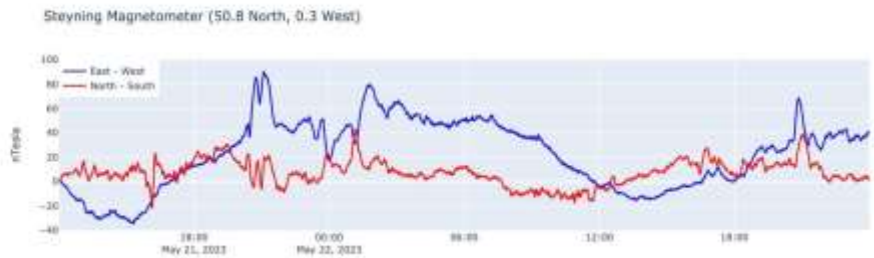


MAGNETIC OBSERVATIONS

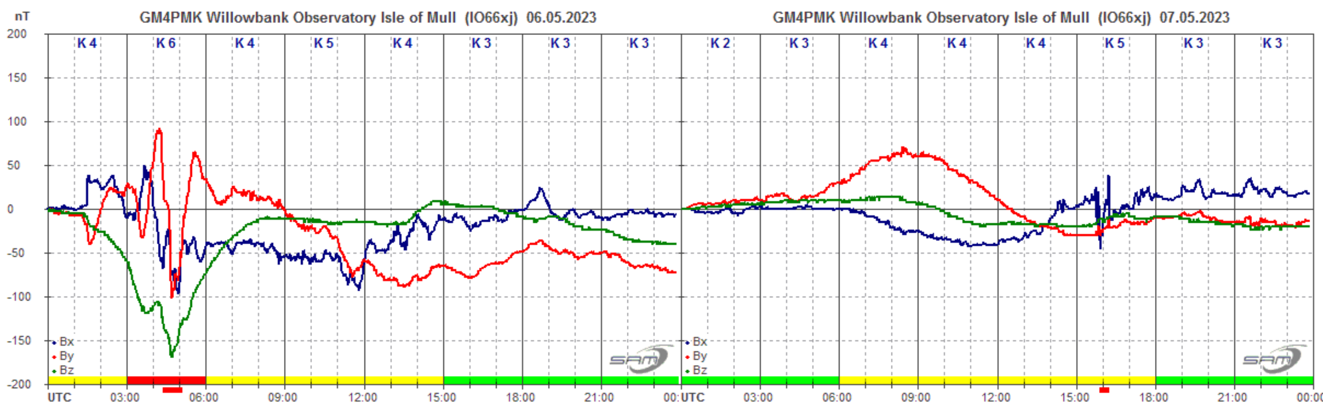


Many of the flares in May did have associated CMEs, but they were mostly not Earth-directed, and so produced only mild disturbances. There were some longer lasting high speed solar winds that resulted in periods of magnetic unrest. The M2.6 flare peaking just after 16:00 on the 20th does appear to have produced a small SFE:

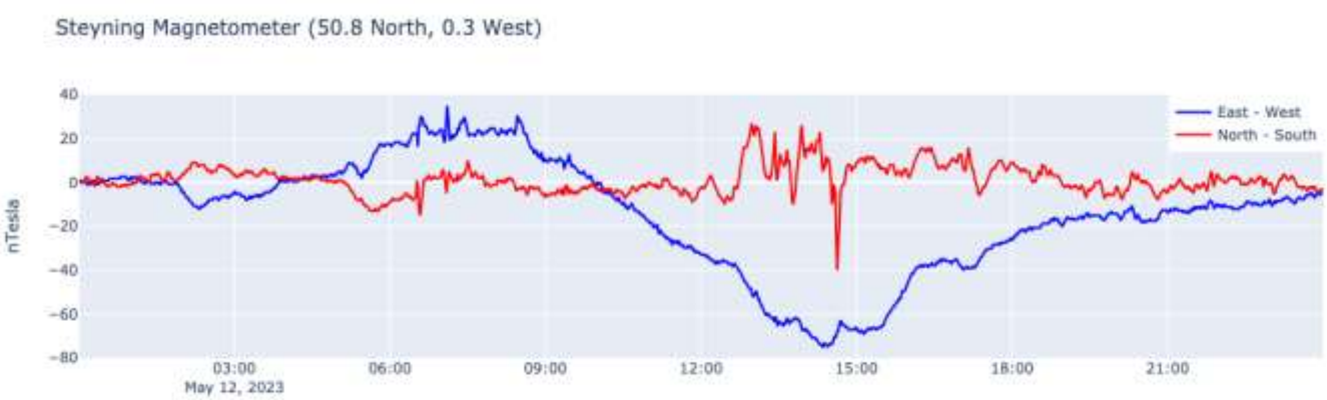




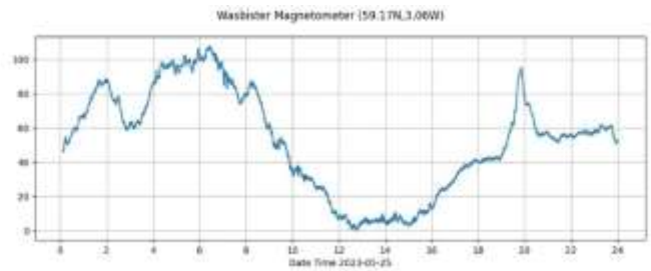
The chart on the left is my own recording showing the small (~16nT) magnetic pulse in green aligning well with the peak of the SID at 23.4kHz. Nick Quinn's chart on the right shows this pulse in the north-south component (red), followed by the disturbance overnight and through the morning of the 21st. The sensor shows a stronger magnetic pulse as it is aligned to the local magnetic field, while mine is mounted horizontally.



This recording by Roger Blackwell shows the short active period early on the 6th followed by more gentle activity through the rest of the day and into the 7th. The cause appears to be from a strong solar wind. There is also evidence of a CME impact around 16:00 on the 7th. There were a number of minor CMEs from the 7th to the 12th, so the precise cause is not known.



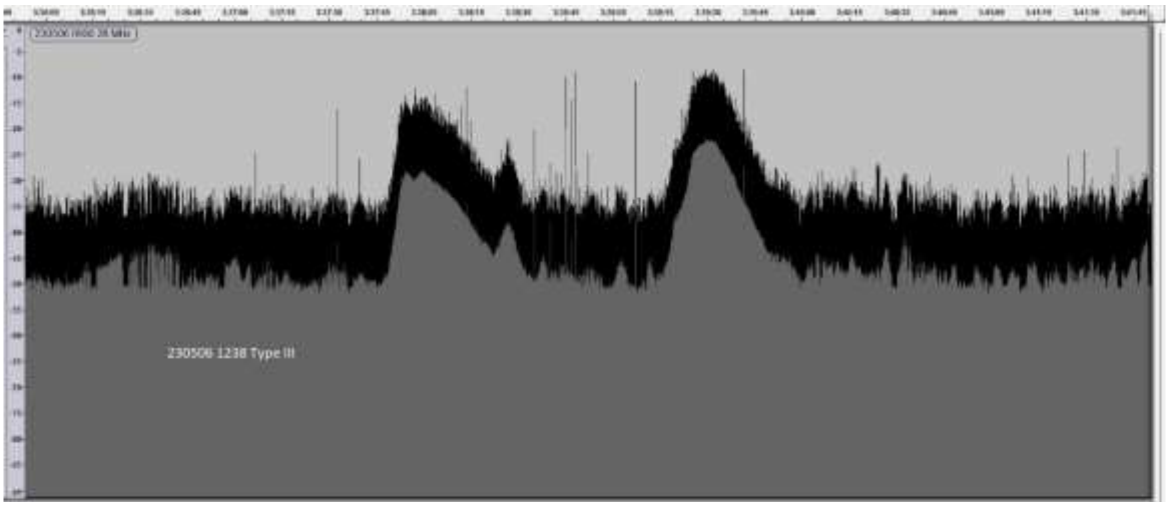
Nick Quinn's recording from the 12th shows another possible CME impact around 06:30. Satellite data suggests that this could be from a CME on the 9th, so with plenty to choose from, again the exact source is not known.



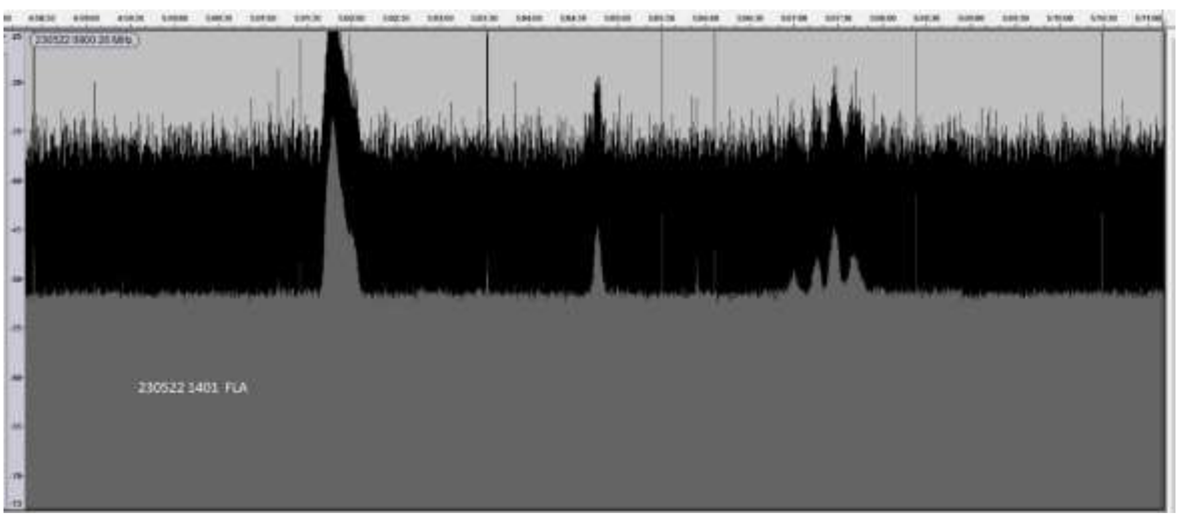
Recordings from Callum Potter on the 25th and 28th show some of the gentler activity that ended May. Callum had noticed some strange recordings earlier in the month and discovered that his fluxgate sensor had slipped within its mount. It has now been remounted and buried, giving some better results. He has provided a picture of the new mount, designed to fit into a plastic tube:

Magnetic observations received from Roger Blackwell, Stuart Green, Callum Potter, Nick Quinn, and John Cook.

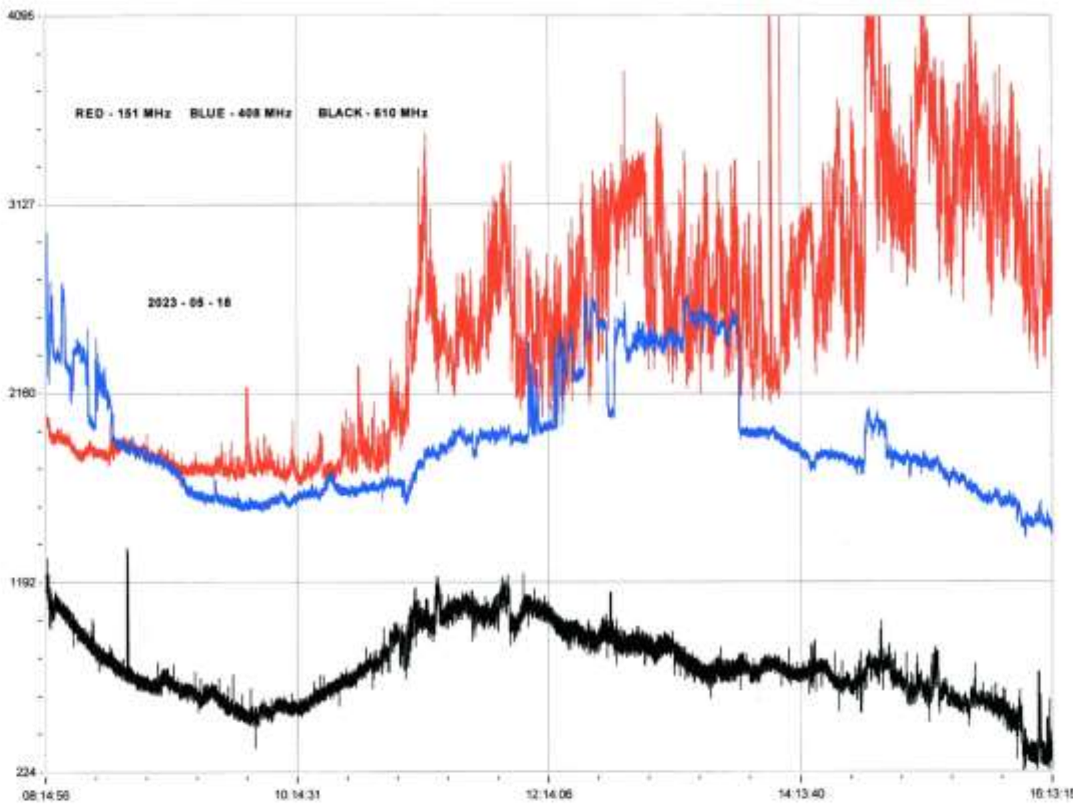
SOLAR EMISSIONS



This recording by Colin Briden shows a 28MHz type III double burst, starting at 12:38UT on the 6th.
These are both quite strong bursts, the second being a 27dB rise in noise level. The X-ray data does not show any significant flares around this time.

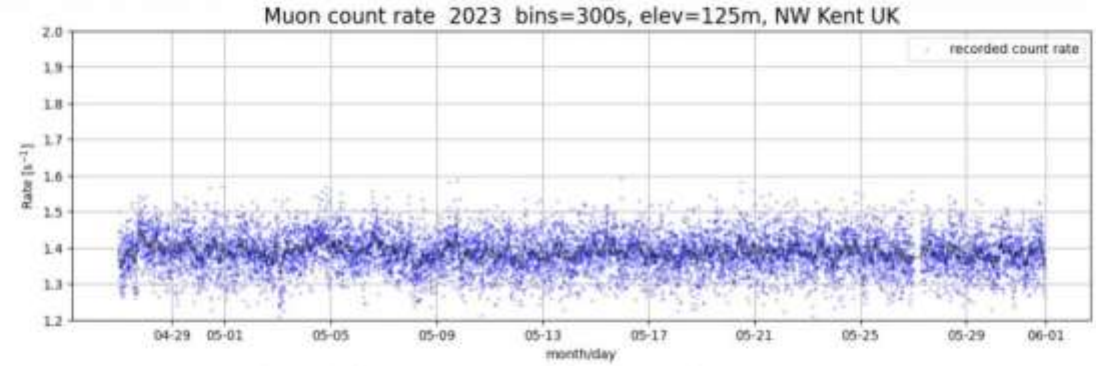


His recording from the 22nd shows a series of noise bursts, the strongest being at 14:01. The chart covers about 12 minutes. This could well be from the M1.9+M1.9 flare combination that we recorded at VLF.

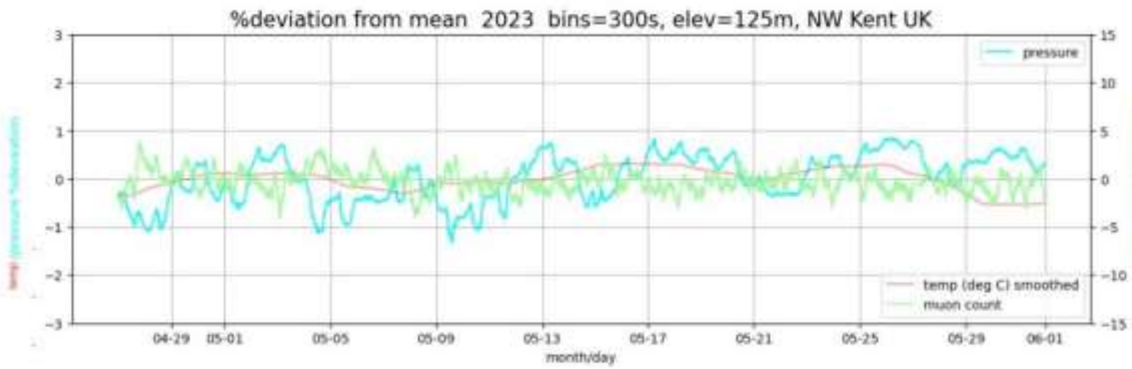


This VHF recording by Colin Clements shows activity on the 18th. 610MHz (black) has remained quiet all day, but 151MHz (red) has a very strong noise level for most of the day. There was plenty of flare activity on the 18th, including M2.2 and M1.6 flares around midday. They would match the 408MHz signal, which shows a sudden pulse of noise lasting almost two hours. Colin also recorded some strong signals on the 4th, 5th, 9th, 20th and 21st, mostly at 151MHz.

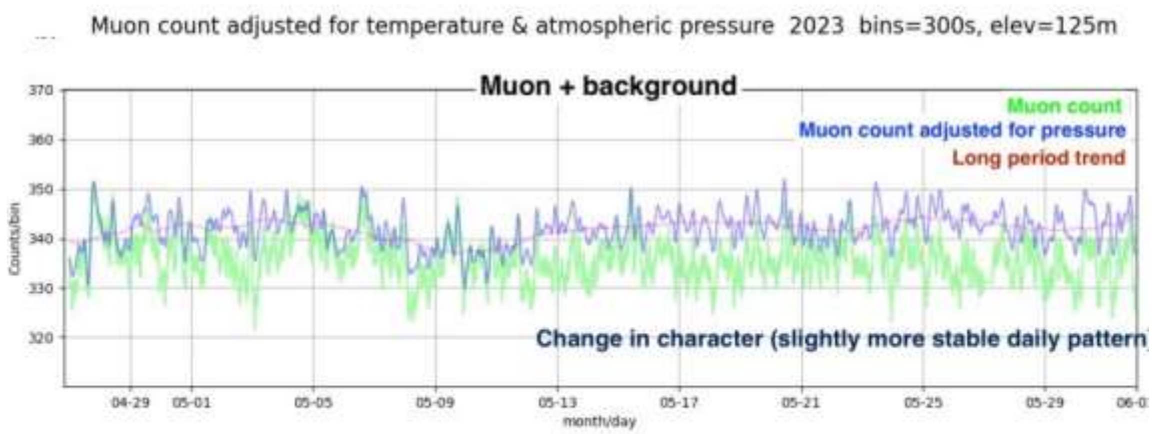
MUONS



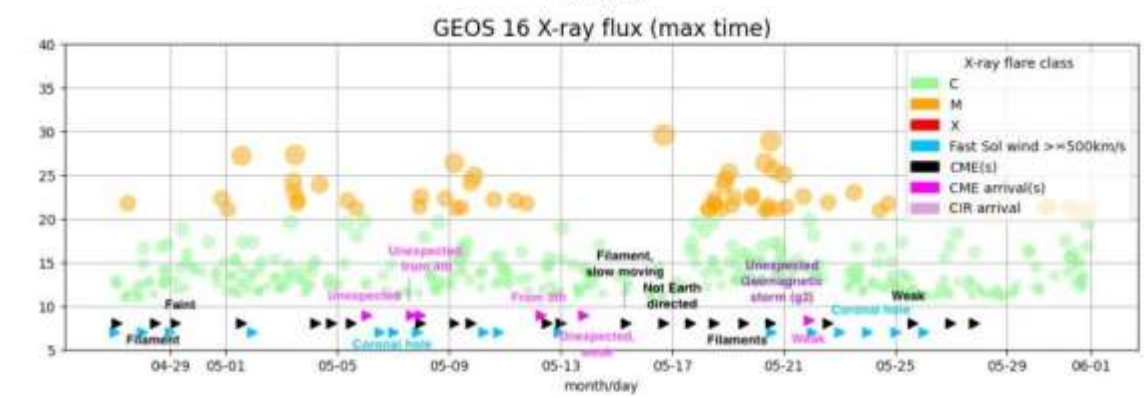
Muon count rate 2023 bins=300s, elev=125m, NW Kent UK
recorded count rate
Rate [s⁻¹]
month/day



%deviation from mean 2023 bins=300s, elev=125m, NW Kent UK
pressure
temp (deg C) smoothed
muon count
month/day

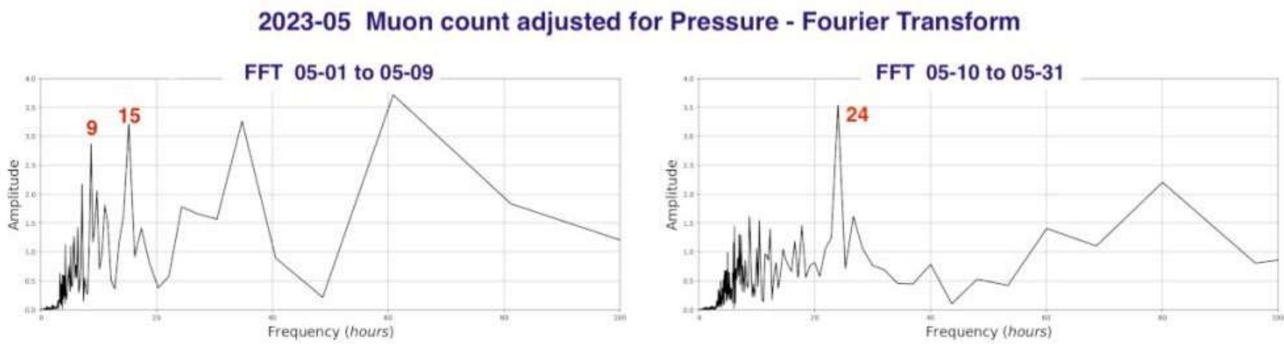


Muon count adjusted for temperature & atmospheric pressure 2023 bins=300s, elev=125m
Muon + background
Muon count
Muon count adjusted for pressure
Long period trend
Change in character (slightly more stable daily pattern
Counts/bin
month/day



GEOS 16 X-ray flux (max time)
X-ray flare class
C
M
X
Fast Sol wind >=500km/s
CME(s)
CME arrival(s)
CIR arrival
Faint
Filament
Coronal hole
Filament, slow moving
Not Earth directed
Filaments
Weak
month/day

Mark Prescott has provided his charts of Muon activity, raw data at the top and pressure corrected in the lower panel. He has been comparing this data against the Neutron counts from Oulu, Finland, and notes a fairly reasonable match. The lower panel also identifies some of the solar activity for comparison. Mark also noticed a change in the general diurnal pattern of activity through the month, and has made an analysis shown below:



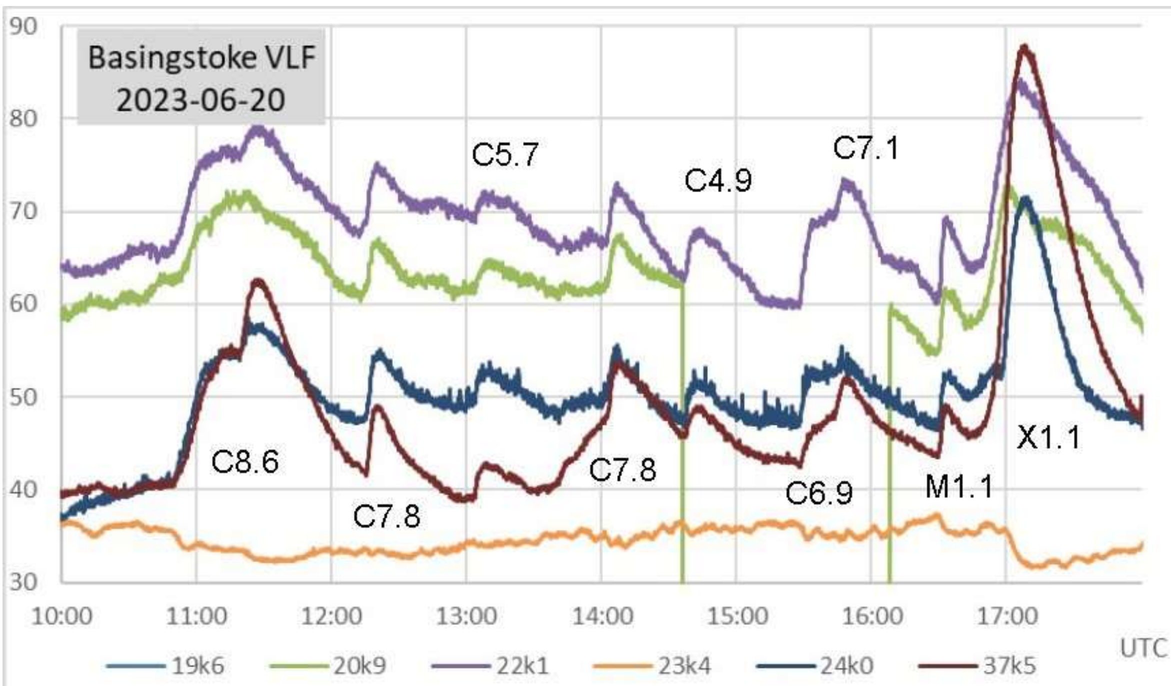
The left panel shows data from the 1st to 9th, showing periodicity peaks at 9 and 15 hours. The right panel covers the rest of the month, showing a strong 24-hour peak. Mark noted that this 24-hour diurnal pattern also became more prominent during the summer last year, so it may be a natural behaviour. Observations over the next few months will help to better understand this activity.

Mark Edwards has found a very interesting paper that summarises all of the various effects that we have seen in the ionosphere's D-layer, including one related to the timing of lunar tides. It would appear to result in only a small change in the reflection height, and so might perhaps be more easily detected during periods of lower solar activity.

https://hal.science/hal-02099868/file/Silber_Price2016.pdf

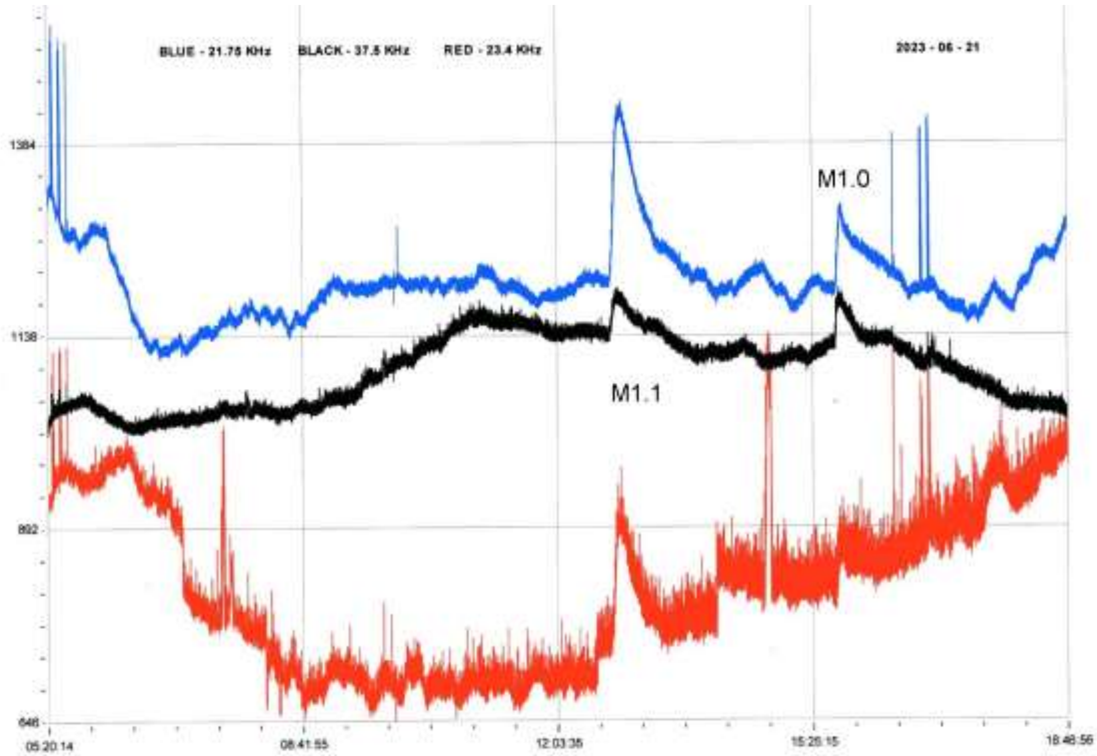
VLF SID OBSERVATIONS

June has been another very busy month for solar activity, with a total of 124 SIDs recorded from 105 flares. Many flares were again multi-peaked and overlapping, making analysis very tricky. We recorded another X-class flare, the fourth so far in 2023, just in time to be recorded before the mid summer sunset. It was also the only one shown in the GOES X-ray data.

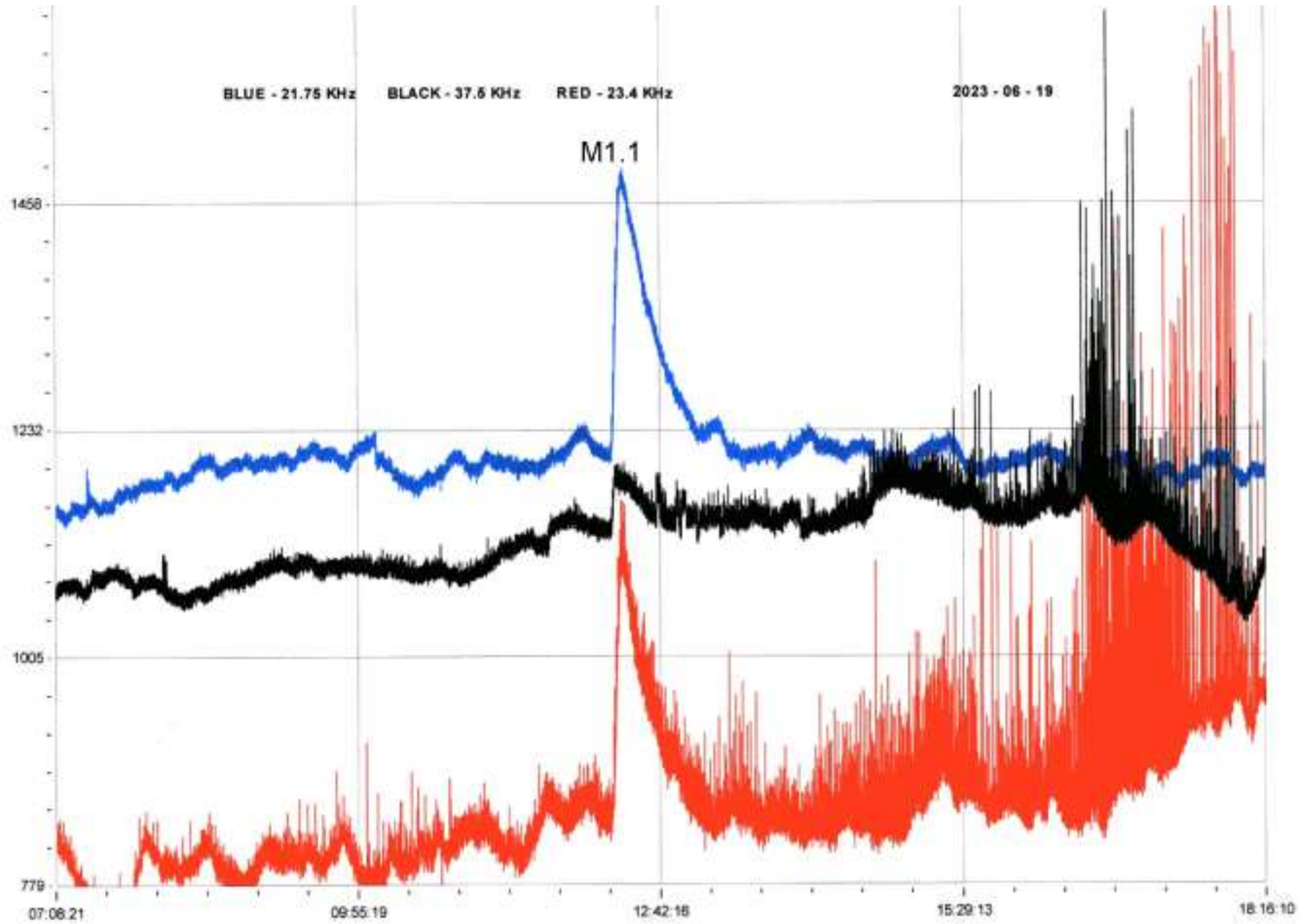


This recording by Paul Hyde shows activity on the 20th, ending with the X1.1flare. The first SID was from two flares, one unclassified, the other listed as C8.6. This has produced different SID shapes on the signals shown, appearing as a single event at 20.9kHz, and clearly twin at 37.5kHz. 23.4kHz has remained unaffected through most of this period. It does show a small dip aligned with the M1.1 flare, and a slightly larger dip for the X1.1. A total of four active regions were responsible for this activity.

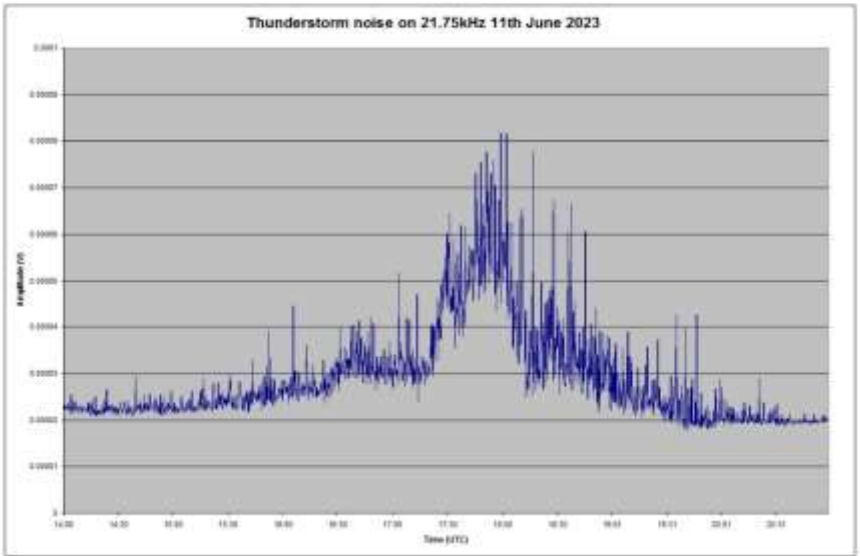
There were two M-class flares widely recorded on the 21st, shown in this chart by Colin Clements:



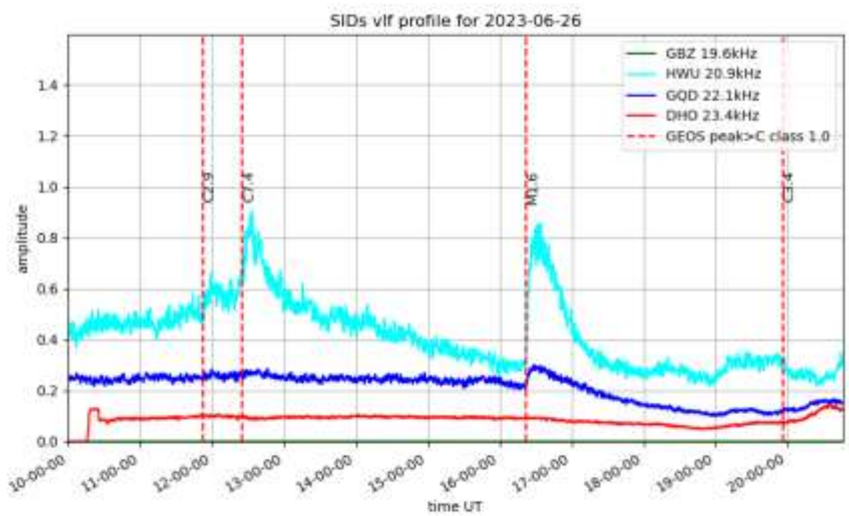
Both flares have produced clear SIDs at 21.75kHz and 37.5kHz, while 23.4kHz has been affected by long lasting thunderstorms. These caused interference over several days, although Colin was not aware of them at the time. His recording from the 19th shows much stronger interference:



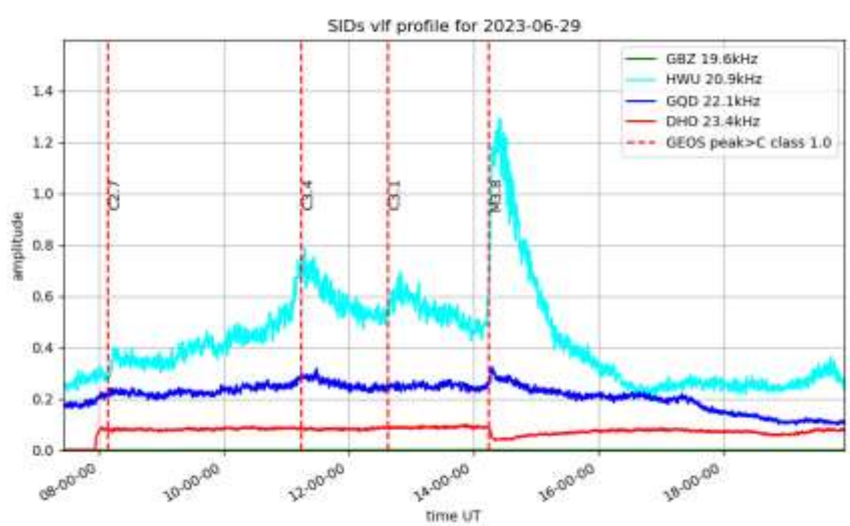
The M1.1 flare is well clear of the noise, which built up later in the afternoon. 37.5kHz also shows the storm. Colin's recording of the strong activity on the 20th was completely lost on these signals with even stronger interference from the storms. Most of the UK was affected by the storms sometime during this period, so Mark Edwards made a recording at 21.75kHz on the 11th. His recording shows the storm peaking between 17:30 and 18:30. This storm was local to Mark, rattling doors in the house! Lightning discharges around the globe are the classic source of 'spherics' recorded via D-layer propagation.



Thunderstorm noise on 21.75kHz 11th June 2023



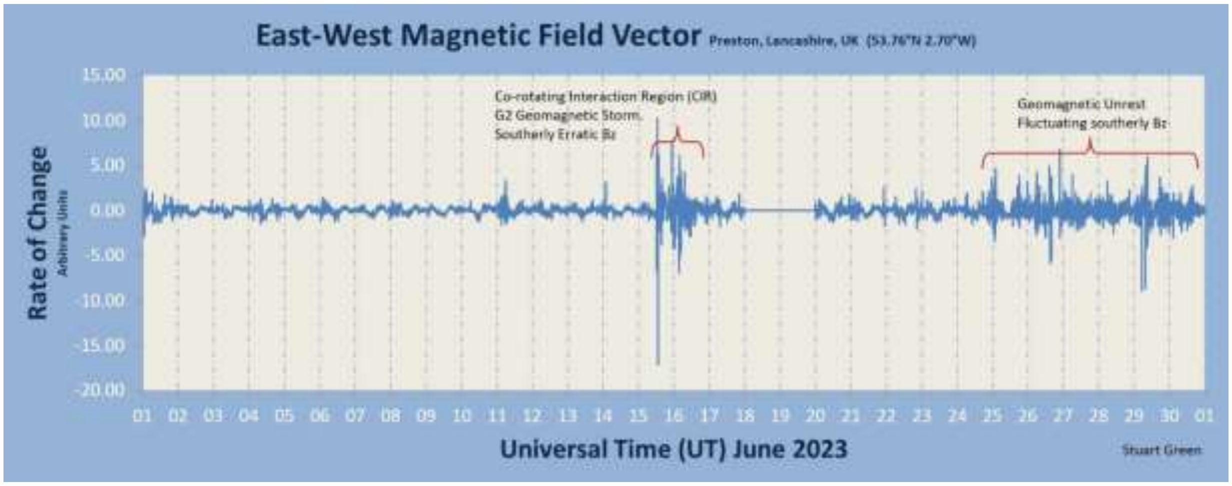
SIDs vlf profile for 2023-06-26
GBZ 19.6kHz
HWU 20.9kHz
GQD 22.1kHz
DHO 23.4kHz
GEOS peak>C class 1.0
C7.4
M1.6
C3.4
amplitude
time UT



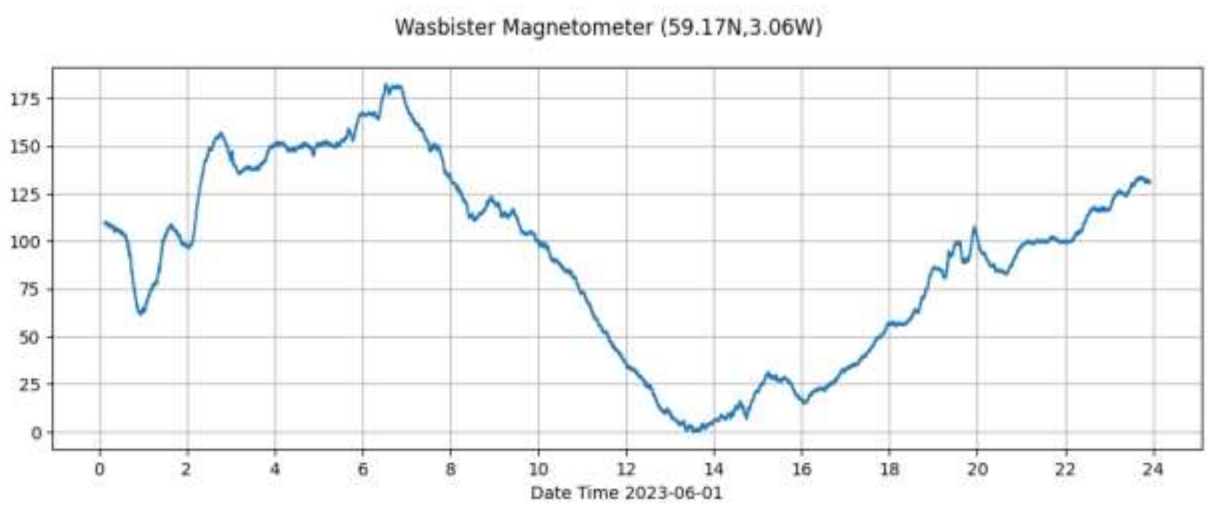
SIDs vlf profile for 2023-06-29
GBZ 19.6kHz
HWU 20.9kHz
GQD 22.1kHz
DHO 23.4kHz
GEOS peak>C class 1.0
C2.7
C3.4
C3.1
amplitude
time UT

The strong activity continued through to the end of the month, these two charts showing Mark Prescott's recordings from the 26th and 29th. 20.9kHz shows the strongest response to the flares, both of the M-class flares having very rapid rise times.

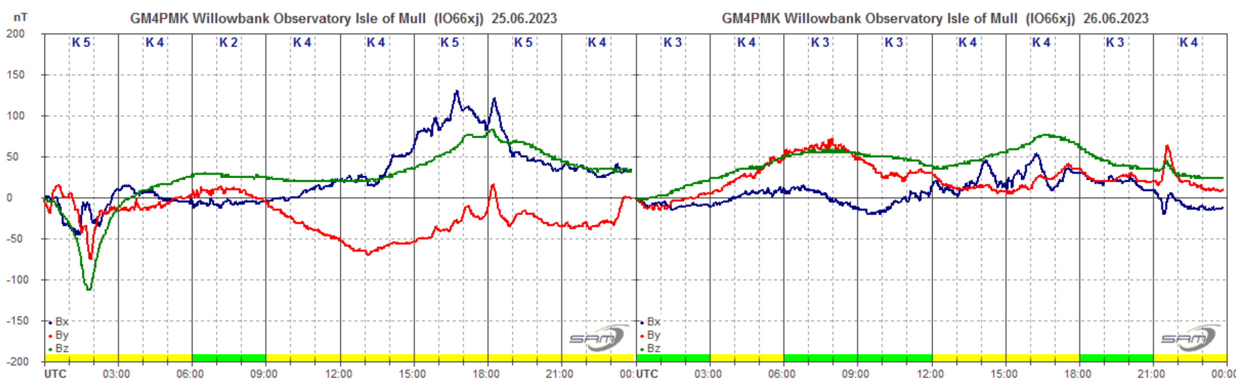
MAGNETIC OBSERVATIONS



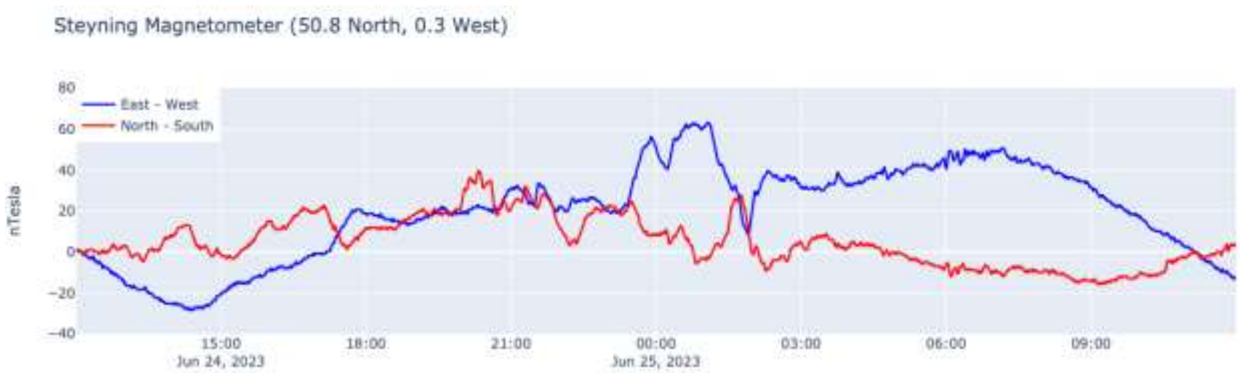
Stuart Green's monthly summary of magnetic activity is in great contrast to our list of energetic flares. Many of these, as well as some filament eruptions, did produce CMEs, but mostly directed well away from Earth. Stuart's chart shows the rate of change of the magnetic field over time, while our magnetometer recordings show the actual field over time. Looking at the Bartels diagram shows that there were periods of disturbance through most of the month, but fairly weak and not very turbulent. Callum Potter's recording from the 1st shows a sample:



Nick Quinn's recording from the 15th shows a more active period, produced by a high-speed wind rather than a CME. Nick also caught some aurora on a newly installed meteor / NLC camera. I suspect that this could have been seen elsewhere in the UK, given that Nick is located near the south coast. Sadly, light pollution probably prevents most of us from noticing it by eye.

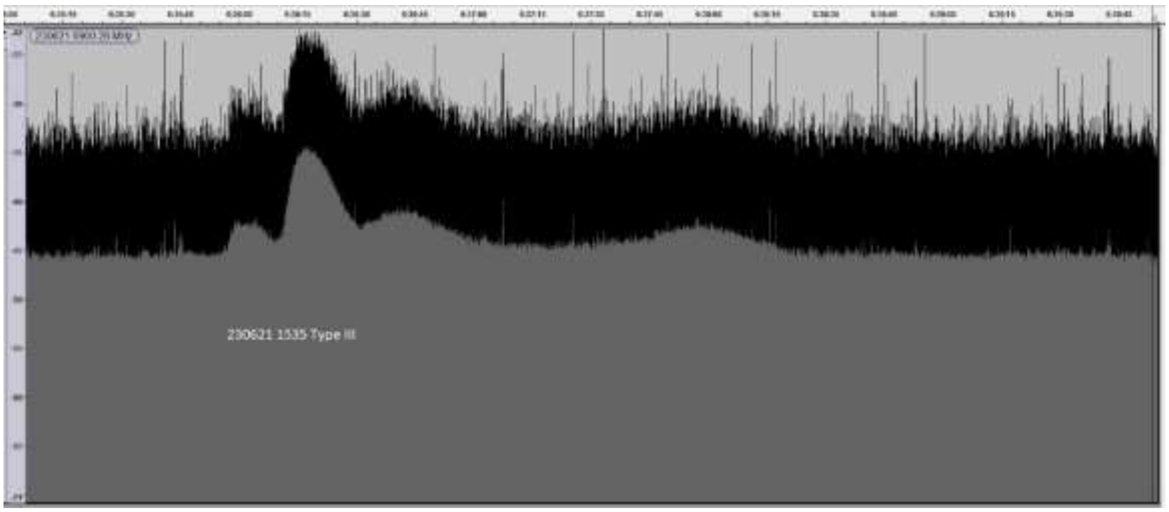


Roger Blackwell's recording from the 25th and 26th shows further disturbance from a combination of high-speed winds and glancing CMEs. The SID timing tables show many stronger flares around this time, including the X1.1 on the 20th. Nick Quinn's recording from the 24th / 25th also shows this activity:

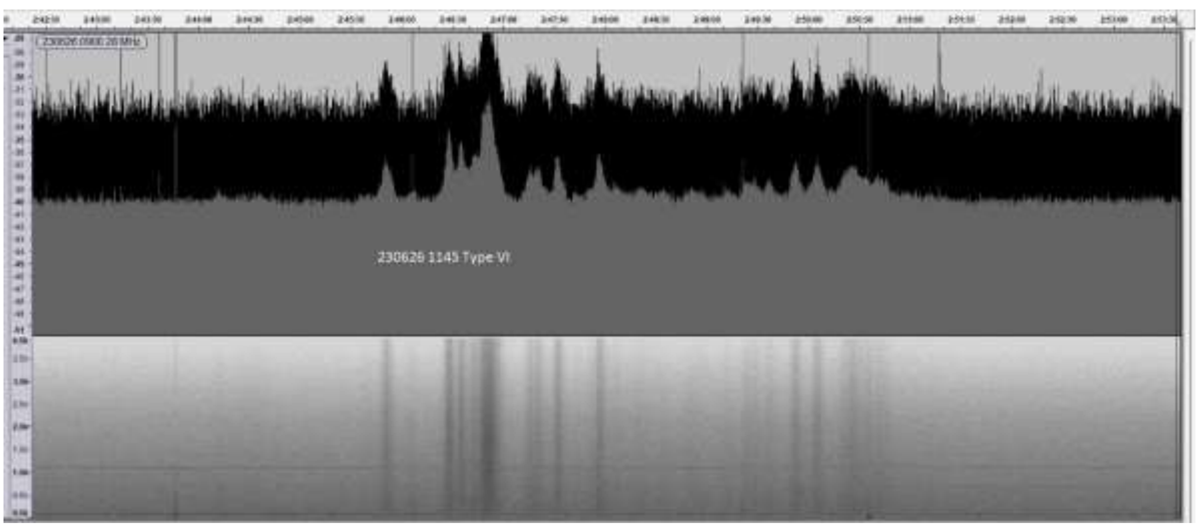


Magnetic observations received from Roger Blackwell, Stuart Green, Callum Potter, Nick Quinn, and John Cook.

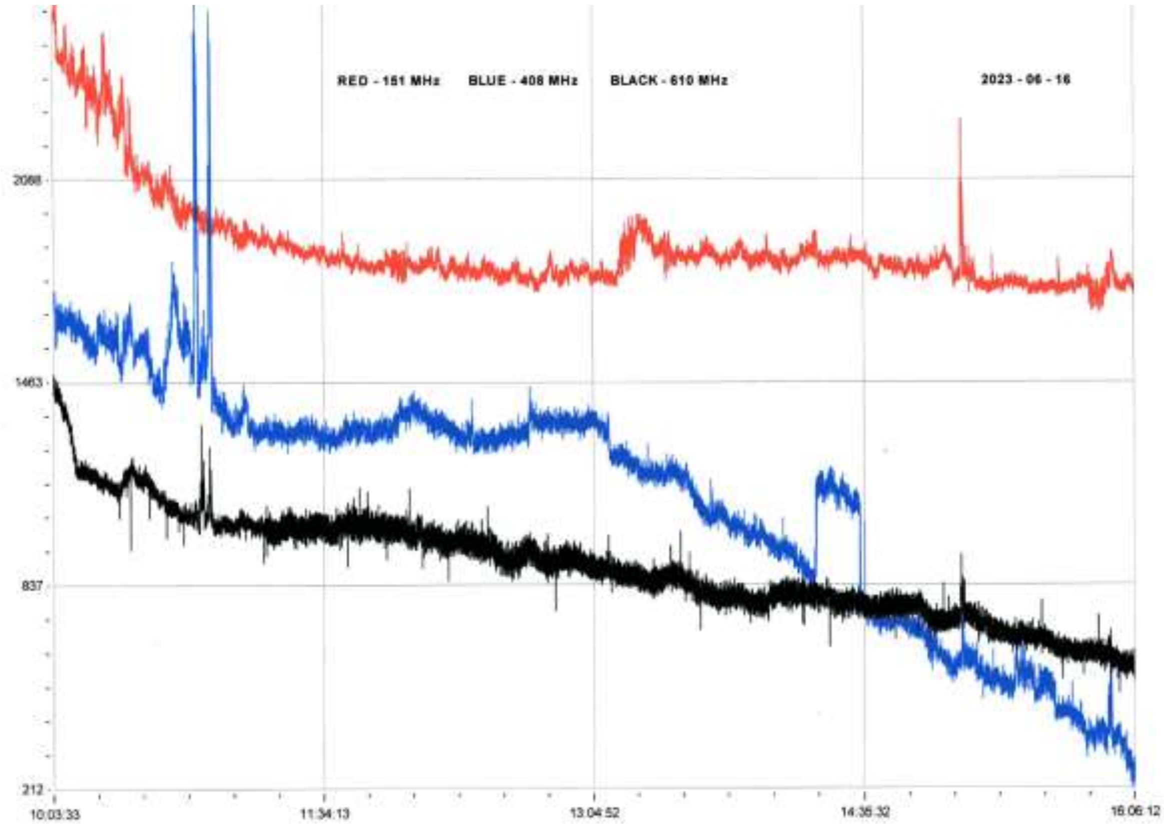
SOLAR EMISSIONS



This chart from Colin Briden shows a 28MHz type III burst matching the M1.1 flare recorded at 15:35 on the 21st. This lasts for about 1 minute, with an amplitude rise of about 10dB.

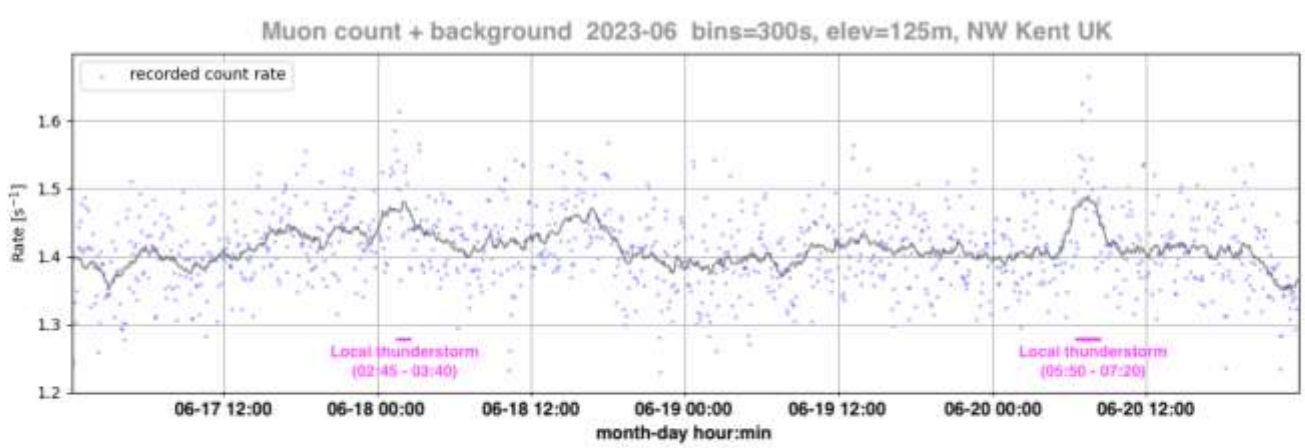


This recording shows a more complex type VI burst associated with the C2.9 flare at 11:45 on the 26th. Its multiple peaks last about 5 minutes, with an amplitude of about 8dB. The lower panel shows the spectrum recorded. The 28MHz data sampling rate gives a very large data file with a bandwidth of 24kHz. This is decimated down to 4kHz, enough to eliminate any non solar interference and save some memory space. This 4kHz bandwidth spectrum is shown in the chart, clearly identifying the individual spikes in the signal.

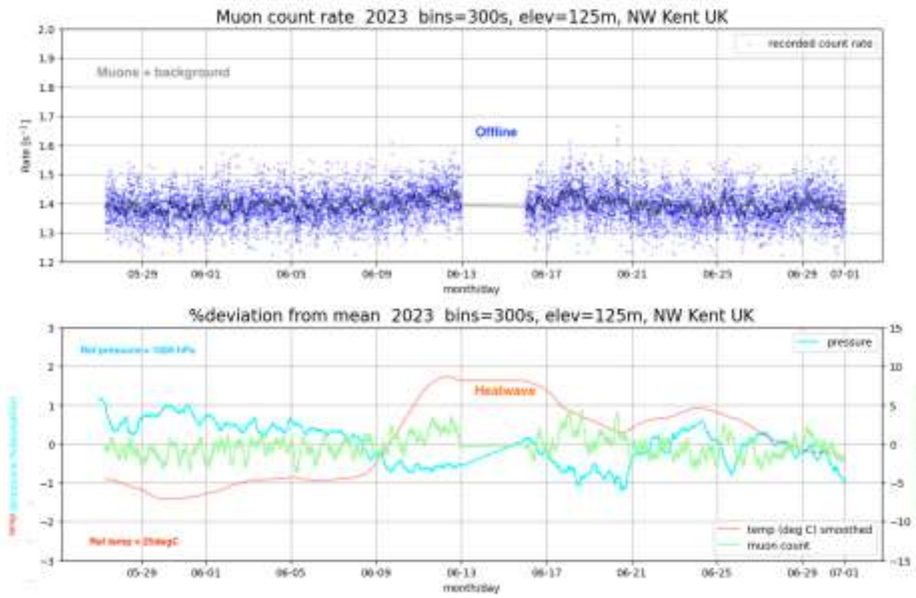


Colin Clement's VHF recording from the 16th shows a fairly small noise signal at 408MHz (blue) and 610MHz (black) possibly associated with the M1.0 flare peaking around 10:40. There is also a small-time difference between these signals. 151MHz (red) has not been affected, but does show a small signal at 13:20, matching the smaller C2.7 flare. The source of the 408MHz burst between 12 and 14UT is not clear. He also recorded a stronger 610MHz burst matching the C4.8 flare at 10:25 on the 8th.

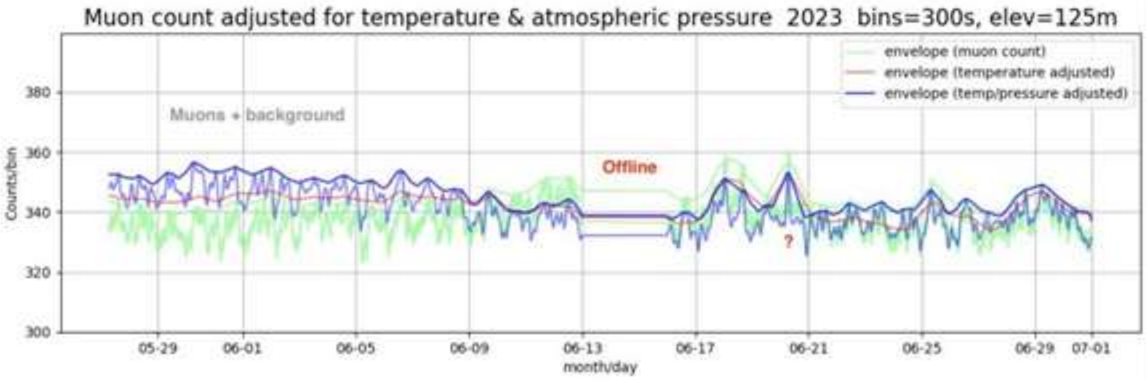
MUONS

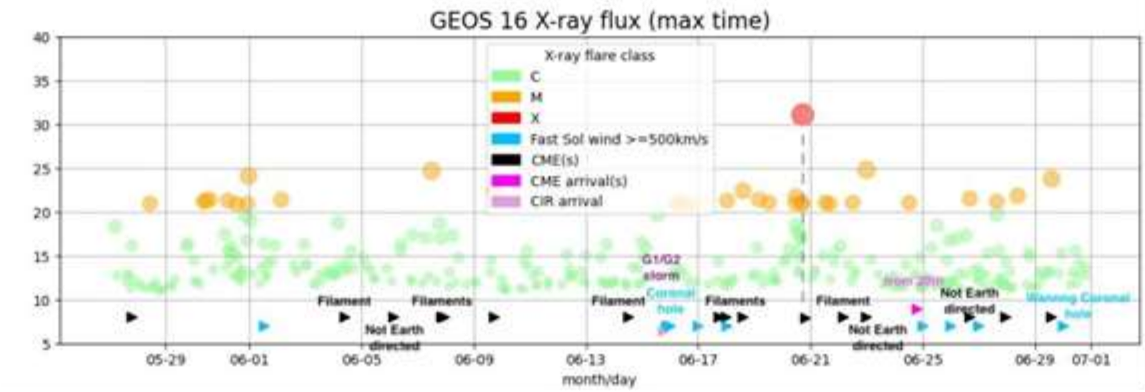


Thunderstorms have already been mentioned as a source of interference to our VLF recordings, but Mark Prescott has also noticed an effect in his Muon counts. A fairly strong local storm on the 20th produced a big increase in the muon count that initially caught his attention. A smaller increase was also noticed in the early morning of the 18th matching a local storm. Investigating, Mark has found work that shows that an increase or a decrease in muon counts can be associated with thunderstorms.



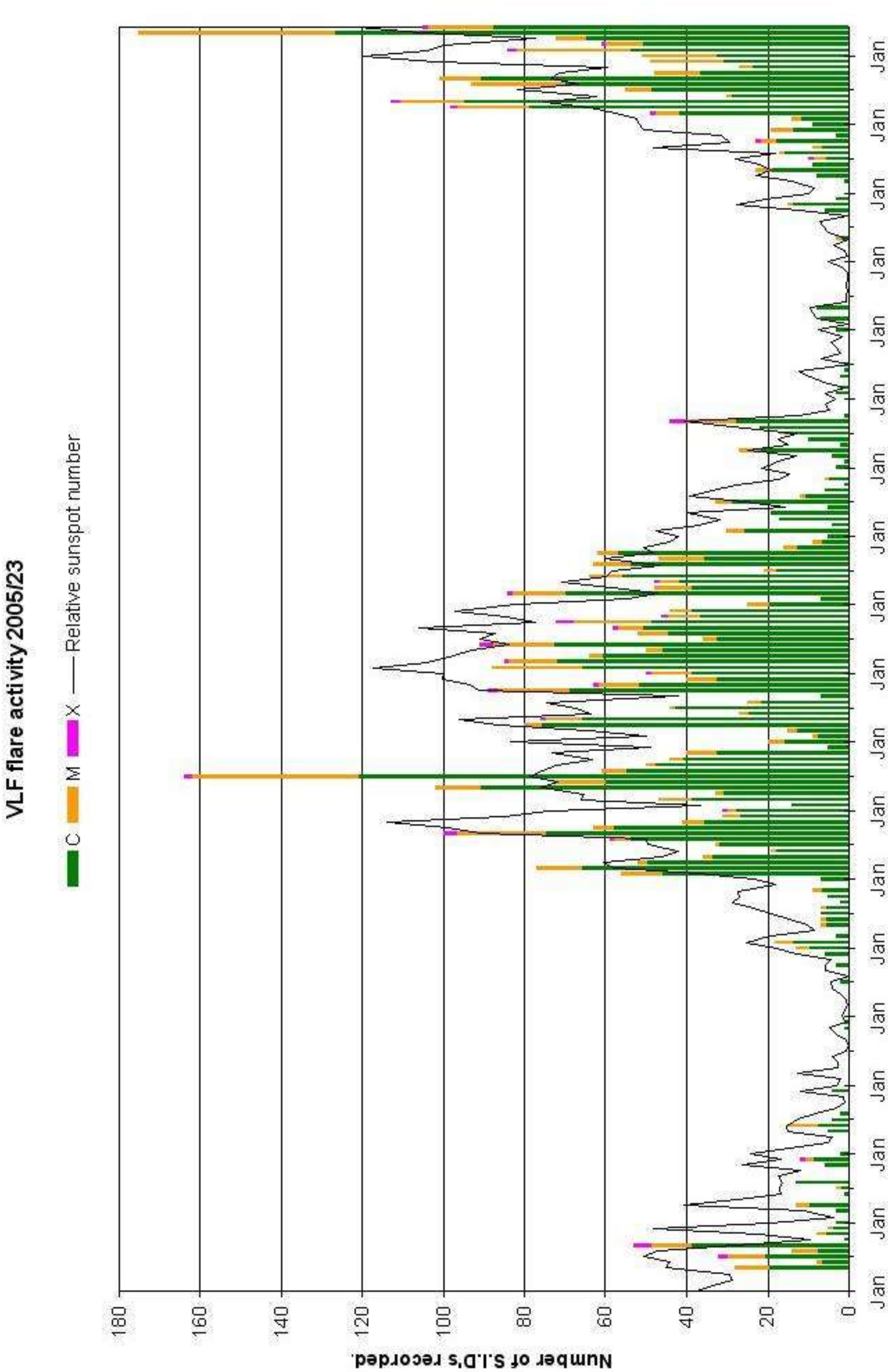
There was also a strong heatwave in the Southeast of the UK in mid June, marked in red on the lower panel, above. There was also a power failure that led to a loss of three day's data from the 13th. The thunderstorms followed the heatwave, seen as sharper spikes in the count data. The second half of the month was also magnetically more active, the 25th / 26th showing a small rise in muon counts.





The temperature and pressure adjusted chart shows just gentle variations up to the 13th, with much more activity from the 17th. The thunderstorms are clear, with the addition of the X1.1 flare just a few hours later on the 20th. The high-speed solar wind and glancing CMEs have created a little more variation through to the end of the month.

BARTELS CHART


VLF flare activity 2005/23
C
M
X
Relative sunspot number
Number of S.I.D's recorded.
0
20
40
60
80
100
120
140
160
180
Jan 2005
Jan 2006
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Jan 2017
Jan 2018
Jan 2019
Jan 2020
Jan 2021
Jan 2022
Jan 2023

British Astronomical Association
Supporting amateur astronomers since 1890
Radio Astronomy Section

BAA RA Section Autumn programme 2023

Fri. Sept. 1st. **19:30 BST (18:30 UTC)**	**Dr. Asayama, Shinichiro** Square Kilometre Array Observatory at Jodrell Bank National Astronomical Observatory of Japan	Square Kilometre Array Observatory at Jodrell Bank - an update and an innovative **and** a fun solution for hydrogen line reception.
Fri. Oct. 6th **19:30 BST (18:30 UTC)** **(15:30 EDT)**	**Marcus Leech** President. Canadian Centre for Experimental ***Radio Astronomy***	**Amateur SDR based interferometry**, hardware and software. (Getting started)
Monday Nov. 13th **19:30 GMT (19:30 UTC)**	**Prof. Sean Paling** STFC UKRI Boulby Underground Lab.	Deep Science at Boulby Underground Laboratory **The search for Dark Matter and Beyond**.
Christmas lecture **Fri. Dec. 1st.** **19:30 GMT (19:30 UTC)**	**Prof Clive Tadhunter** Department of Physics and Astronomy University of Sheffield	**Active Galactic Nuclei** (AGN) emit at least as much radiation by themselves as the integrated light of all the stars in a typical galaxy, yet this radiation is produced in a region that is smaller than the solar system.

Applications of CubeSats for Astrophysics Research
Detection of Radio Frequency Counterparts of High Energy Phenomena with Very Long Baseline Interferometry

Dave Hinzel

Abstract CubeSat systems have the potential to make significant contributions to multiple areas of astrophysics research, including detection of gravitational wave counterparts, Gamma Ray Bursts (GRBs) and GRB afterglow, X-ray and ultraviolet astrophysics, exoplanet studies, solar, ionospheric and space physics, and variable star astrophysics including pulsar detection, Active Galactic Nuclei (AGN) physics, transient, time domain, and multi-messenger astrophysics. Several of these areas of astrophysical research utilize the radio frequency (RF) spectrum between 10 MHz and 10 GHz. This spectrum accounts for significant opportunities for research with space-based CubeSat systems and networks. While other frequency ranges such as millimeter-wave bands are important for research, the 10 MHz to 10 GHz frequency bands are optimum for CubeSat applications. Given this wide frequency range, the question becomes how to incorporate this capability in small form factor CubeSats. Swarms or constellations of CubeSats can be configured to perform multi-aperture Very Long Baseline Interferometry (VLBI), which is a fundamental technique for radio astronomy. The applications of CubeSats for detection of radio frequency counterparts of high energy phenomena with VLBI will be the focus of this study.

1. Introduction

A CubeSat is a class of miniaturized satellite based around a form factor of 10 cm x 10 cm x 10 cm of useful volume (denoted 1U) as well as a weight of no more than 2 kilograms (or 4.4 pounds). Other satellite classifications are based upon their mass, ranging from large satellites of greater than 1000 kilograms to femto-satellites of less than 0.1 kilograms. CubeSats fall in the general category of nano-satellites which range from 1 to 10 kilograms. CubeSat architecture consists of several specialized subsystems including:

- Power: the electrical power system encompasses electrical power generation, storage, and distribution. Power generation technologies include photovoltaic cells, fuel cells, panels and arrays, and radioisotope thermoelectric or other nuclear power generators.
- In-space propulsion: in-space propulsion includes chemical (hydrazine based, warm/cold gas systems, and solid propellants), electric (electrothermal, ion thruster, Hall-effect, pulsed plasma, and vacuum arc systems), and propellantless (solar sails, electrodynamic tethers, and aerodynamic drag devices) propulsion technologies.
- Guidance, navigation, and control: these include reaction wheels, magnetic torquers, thrusters, star trackers, magnetometers, sun sensors, earth horizon sensors, inertial sensors (gyroscopes/accelerometers), GPS receivers, deep space navigation, and atomic clocks.
- Structures, materials, and mechanisms: modular frames, card slot systems, thermoplastics, radiation shielding and mitigation, charge dissipation, composites.
- Thermal control: passive thermal control includes paints/coats/tapes, multilayer insulation, thermal straps, conductive gaskets, sunshields, thermal louvers, radiators and heat pipes, phase changing

materials, and thermal switches and storage units. Active thermal control includes heaters, cryocoolers, thermoelectric coolers, and active thermal architectures.

- Spacecraft avionics: this includes command and data handling, avionics and on-board computing, highly integrated on-board computing, radiation hardened processors and Field Programmable Gate Arrays (FPGAs), memory, electronic functional blocks and components, bus electrical interfaces, and flight software.
- Communications: CubeSat transponder, uplink station, downlink station, antennas, radio frequency electronics, optical communications.
- Sensor payloads: Software Defined Radios (SDRs), optical sensors, radio frequency and microwave sensors, x-ray sensors, gamma ray sensors, infrared and ultraviolet sensors.

2. Background

CubeSat systems have the potential to make significant contributions to multiple areas of astrophysics research, including detection of gravitational wave counterparts, Gamma Ray Bursts (GRBs) and GRB afterglow, X-ray and ultraviolet astrophysics, exoplanet studies, solar, ionospheric and space physics, and variable star astrophysics including pulsar detection, Active Galactic Nuclei (AGN) physics, transient, time domain, and multi-messenger astrophysics. Several of these areas of astrophysical research utilize the radio frequency (RF) spectrum between 10 MHz and 10 GHz. This spectrum accounts for significant opportunities for research with space-based CubeSat systems and networks. While other frequency ranges such as millimeter-wave bands are important for research, the 10 MHz to 10 GHz frequency bands are optimum for CubeSat applications. Given this wide frequency range, the question becomes how to incorporate this capability in small form factor CubeSats. Swarms or constellations of CubeSats can be configured to perform multi-aperture Very Long Baseline Interferometry (VLBI), which is a fundamental technique for radio astronomy. The applications of CubeSats for VLBI will be the focus of this study. In particular, the emphasis will be on variable star astrophysics including pulsar detection, AGN physics, transient, time domain, and multi-messenger astrophysics (GRBs, gravitational wave counterparts, etc.). The 10 MHz to 10 GHz frequency bands are optimum for these CubeSat applications including:

2.1 Gravitational wave counterparts: Gravitational Wave (GW) radio frequency counterparts have been detected at approximately 150 MHz (Black Hole-Neutron Star mergers), 1.4 GHz/3 GHz (Double Neutron Star mergers), and 1-5 GHz (synchrotron radiation from post-merger events). Frequencies in the 10-240 MHz band are detected by LOFAR (Low Frequency Array) systems [Yancey, 2015; Hotokezaka, K., et al., 2016].

2.2 Pulsars: pulsars produce numerous radio frequencies, depending on the specific parameters of the pulsar. Frequencies in the 10-240 MHz band are detected by LOFAR systems while larger radio telescopes such as the JVLA (Jansky Very Large Array) detect pulsar emissions from approximately 1 GHz to 8.4 GHz [Tan, C.M, et al. 2018].

2.3 Active Galactic Nuclei: AGN activity has been detected by the JVLA at 610 MHz, 1.4GHz/L band, 5.0 GHz/C band, and 8.5 GHz/X band [Padovani, P., 2017; Padovani, P., et al. 2017].

2.4 Gamma Ray Burst afterglow and GRB jet RF signals span several bands including the 10-240 MHz LOFAR frequencies, 400 MHz, 1.5 GHz, 4.9 GHz, 8.5 GHz, and 0.7-1.8 GHz/0.58-14.5 GHz (GRB jets) [Hotokezaka, K., et al., 2016].

2.5 Transient, time domain, and multimessenger astrophysics radio frequency counterparts typically span the frequency range between 10 MHz and 10 GHz. The ground-based Square Kilometer Array (SKA), currently being developed for multi-messenger observations, will operate from 70 MHz to 500 MHz, 500 MHz to 1.5 GHz, and 800 MHz to 10 GHz in three arrays. [Padovani, P., et al. 2017].

3. Methods and concept of operations

Swarms or constellations of CubeSats can be configured to perform multi-aperture Very Long Baseline Interferometry (VLBI), which is a fundamental technique for radio astronomy. Figure 1 shows a three element VLBI constellation and Figure 2 shows a CubeSat swarm. Figure 2 illustrates the ability to communicate and share their data as a network. Each of the satellites is capable of communicating with a ground station and can relay all of the information gathered from the entire network.

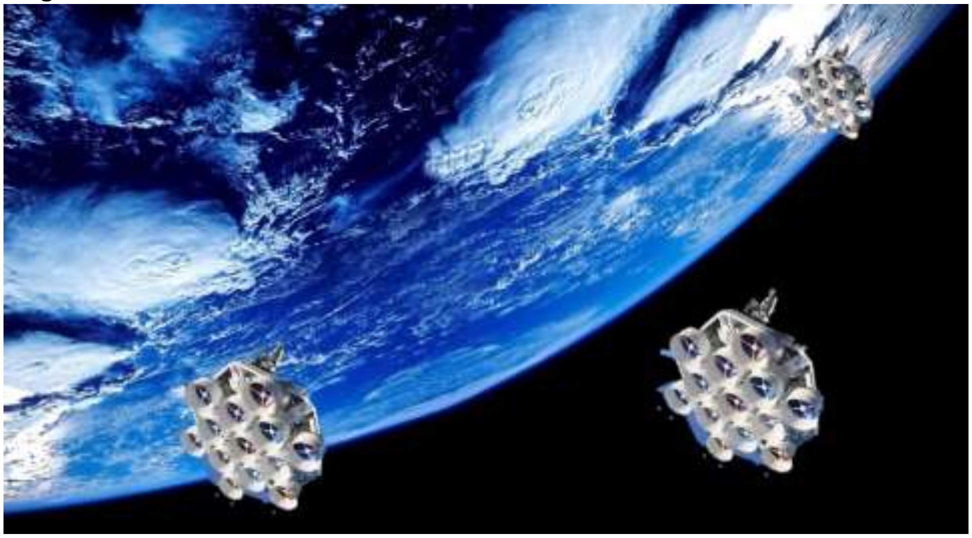

Figure 1. A Three Element VLBI CubeSat Constellation (Courtesy ASTRON & Joint Institute for VLBI)

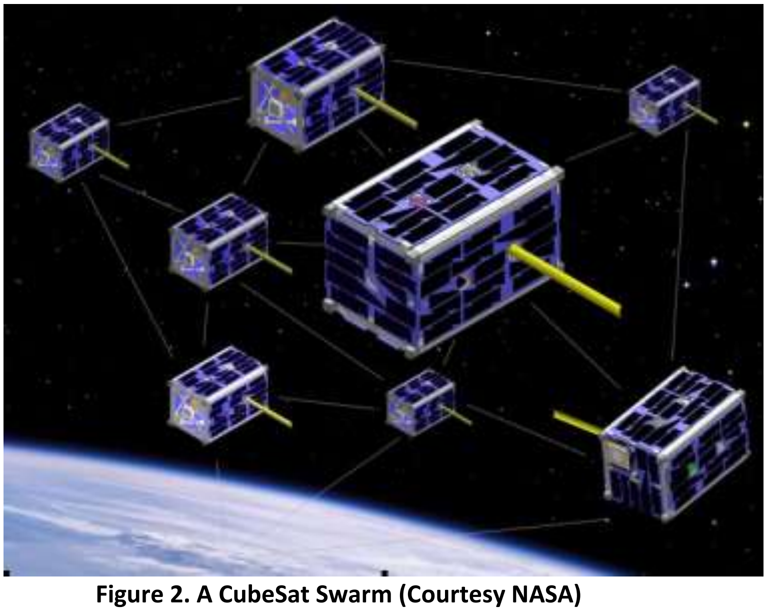

Figure 2. A CubeSat Swarm (Courtesy NASA)

CubeSat systems and networks can take advantage of their flexibility to dynamically configure the interferometer observing baseline length as well as network aperture geometry. For example, if the system is observing AGN activity at 1.4 GHz with the required baseline length and number of satellites and is retasked to observe a pulsar at 240 MHz, the network can reconfigure its baseline and satellite geometry to optimize operation for the pulsar mission. The specific configuration for a target depends on the required resolution which is a function of frequency (wavelength) and baseline length.

Telescopes in a traditional ground based interferometer are connected via cables so that their signals can be combined in real time. For a CubeSat network, the individual CubeSat units can be phase synchronized for coherent operation across the entire array (or subarray) in several ways depending on where they are deployed. In a low earth orbit application, GPS can be the timing mechanism. Alternatively, a ground based timing and synchronizing network could be employed, and signals uplinked to the array. For a deep space application such as around one of the LaGrange points, one or more of the CubeSat units would have to take on the role as the timing source. Another option is the use of pulsars themselves with the International Pulsar Timing Array (IPTA) which incorporates approximately 100 millisecond pulsars as a galactic system of highly accurate clocks. Each pulsar (a rapidly rotating neutron star) typically has a rotational period of less than 10 milliseconds with an accuracy of 100 nanoseconds.

3.1 Interferometry and aperture synthesis

Radio telescopes typically used in astronomical observations incorporate interferometry, specifically Very Long Baseline Interferometry, or VLBI. The resolving power of the interferometer (how small an object that can be seen) is a function of telescope size and wavelength of the electromagnetic energy. For a single telescope, the size is the diameter of the receiver dish while for an array of telescopes the size is the maximum distance between the individual telescope elements. VLBI provides high precision and good sensitivity (the weakest detectable radio emission) thereby making it an excellent tool for astrophysical objects such as AGNs, pulsars, and radio counterparts of gravitational wave events.

Important considerations for VLBI systems are sensitivity, type and length of the observing baseline, and the geometry of the VLBI array. For a single receiver antenna with a gain G and a system temperature T(sys), the overall antenna performance is defined as the System Equivalent Flux Density (SEFD)

$$SEFD = T(sys)/G \text{ in units of Janskys or Jy} \qquad \text{Equation (1)}$$

(1 Jy = 10 exp-26 Watts per meter squared per Hertz of bandwidth)

For a multielement interferometer with individual antenna performance as stated above, the sensitivity is

$$\Delta S\ (i,j) = 1/\eta \times \text{sqrt}\ [(SEFD\ (i) \times SEFD\ (j))/2 \times \Delta v \times \tau(acc)] \qquad \text{Equation (2)}$$

Here $\tau(acc)$ is the accumulation time, η is the system or array efficiency, and Δv is the collecting bandwidth of each antenna [Rioja, M., 2002].

Aperture Synthesis or synthesis imaging is a type of interferometry that mixes signals from a collection of telescopes to produce images having the same angular resolution as an instrument the size of the entire collection. At each separation and orientation, the lobe-pattern of the interferometer produces an output which is one component of the Fourier transform of the spatial distribution of the brightness of the observed object. The image (or "map") of the source is produced from these measurements. A two-element interferometer provides very limited information about the structure of a source unless the baseline is continually adjusted. However, if there are N telescopes, then their outputs can be combined to yield N(N-1)/2 unique baselines with each baseline adding improved sensitivity as well as a wider operating frequency range. Figure 3 shows the aperture improvement achieved by adding antennas, from two in 3 (a) to four in 3 (e) [Condon, J. J., and Ransom, S. M., 2010].

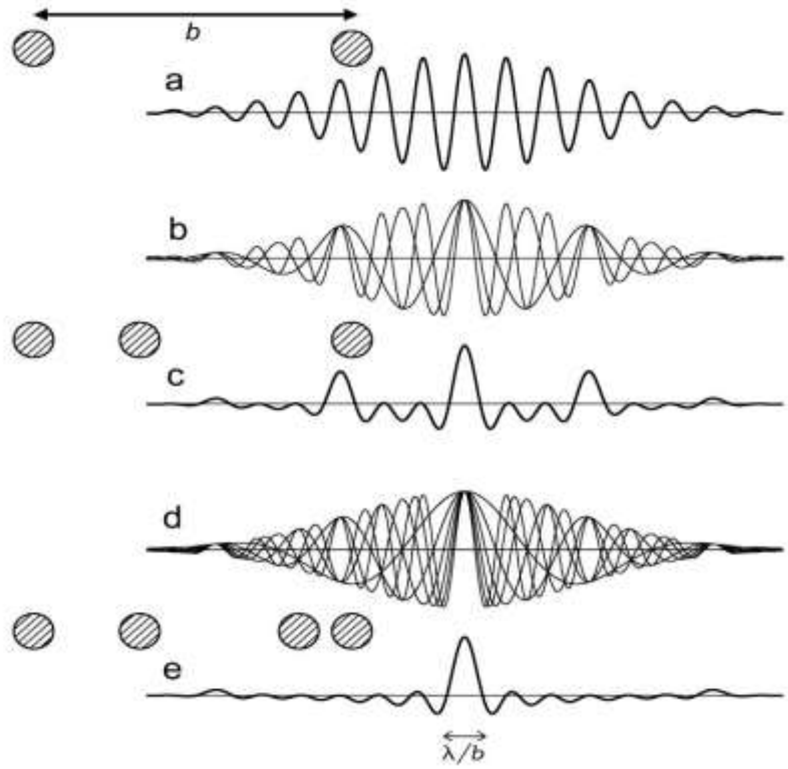

Figure 3. Aperture Synthesis

CubeSat systems and networks can take advantage of their flexibility to dynamically configure interferometer observing baseline length as well as network aperture geometry. Also, given the wide 10MHz-10GHz frequency range, the question becomes how to incorporate this capability in small form factor CubeSats. One approach is to apply the principles of fractal mathematics and geometry to both the individual CubeSat antennas and the overall array aperture of the antennas in the CubeSat constellation.

3.2 Fractal antennas and fractal arrays

Given the small form factor of CubeSat spacecraft, it is advantageous to keep the antenna structures similarly small. This runs counter to the requirements for a CubeSat system whose purpose is to study astrophysical phenomena that potentially covers a wide radio frequency spectrum. One solution to this is the use of fractal antennas on each CubeSat and fractal arrays of the CubeSat elements of the satellite constellation.

Fractal antennas have unique characteristics associated with the various geometries and mathematical properties of fractals. Fractals were first defined by Benoit Mandelbrot (1975) and published in his book (Mandelbrot, 1983) as a way of classifying structures whose dimensions were not whole numbers, but rather fractional dimensions (fractals). Application of fractal geometry to various antenna elements yields smaller antenna size, resonant frequencies that are wideband and multiband, and are optimized for antenna gain. Applying fractals to entire network antenna arrays also results in multiband/broadband performance. Therefore, fractal geometries are highly advantageous to both individual antenna elements and entire antenna arrays.

The key feature of fractal systems is self-similarity, that is, different parts of the antenna or antenna array are similar to each other at different physical scales (scale invariance). This makes it possible to design antennas and arrays capable of wideband and multi-band frequency response at a fraction of the size of conventional antennas. Figure 4 is a Cantor slot patch antenna. This fractal antenna operates from frequency f to frequency 32f all within one structure. Figure 5 is a Cantor linear fractal array and Figure 6 is the Cantor linear array factor. The array factor is a function of the positions of the individual antennas in the array and the relative weighting of each antenna. Figure 6 shows the various baselines that can be formed by combinations of the distances d (d1-d4) among the Cantor linear array elements shown in Figure 5. By varying the distances d, the beam can be steered over an angle $\boldsymbol{\theta}$ from approximately 0-180 degrees.

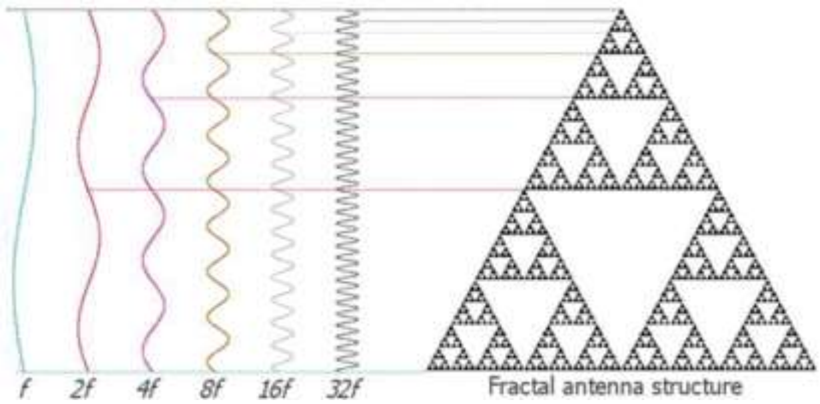

Figure 4. A Cantor Slot Patch Antenna

Figure 5. A Cantor Linear Fractal Array

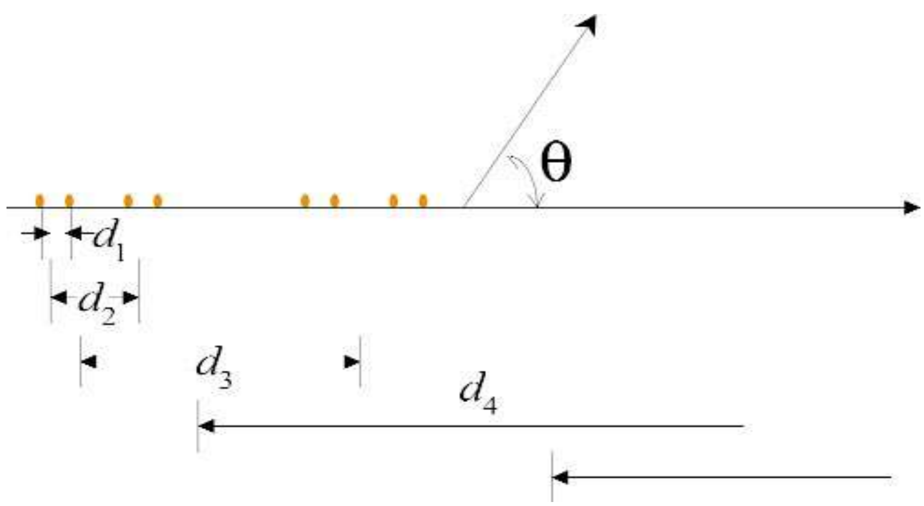

Figure 6. The Cantor Linear Array Factor
(Courtesy Yang, et al; Ponnapalli, et al)

3.3 Instrumentation, methods, and technologies

3.3.1 Software Defined Radios (SDRs)

The use of fractal-based antennas and antenna arrays as discussed above is a key consideration for CubeSat system flexibility in terms of wide frequency coverage and multi-aperture Very Long Baseline Interferometry. An additional degree of freedom for CubeSat operations is the implementation of Software Defined Radios (SDRs). A Software Defined Radio is a flexible technology that enables the design of adaptive communications systems. A generic hardware design can be used to address different communication needs, such as changing frequencies, modulation schemes and data rates. The hardware can be off-the-shelf technology, state-of-the-art technology, and a combination of the two. In its extreme, the entire CubeSat satellite could be considered to be a Software Defined Satellite. While the hardware remains essentially fixed, the flexibility is produced by the software that controls the hardware such that it can be rapidly reconfigured to meet the requirements of a particular mission. An example of an SDR is shown in Figure 7. The software functions are indicated as shown.

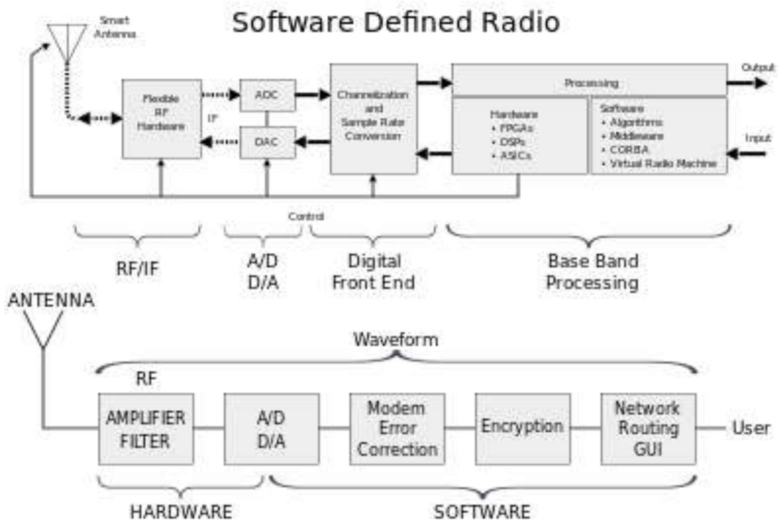

Figure 7. Software Defined Radio

3.3.2 Tunable filters, phase shifters, and switching networks

The flexibility in the SDR hardware can be further improved with the use of tunable bandpass filters, phase shifters, and switching networks to realize frequency band selection, tuning, and beam steering as required for the specific astrophysical applications and targets. These devices, integrated within the SDR digital receiver architecture, utilize the technology of Micro-Electro-Mechanical Systems (MEMS). Advantages of MEMS technology in CubeSat systems is that it requires very little electrical power, has very small size and weight, and can be integrated into higher order assemblies at the device level [Goldsmith, C.L., et al., 1999: Hinzel, D., et al., 2003].

Figure 8 shows a MEMS tunable bandpass filter including the basic filter structures, top view and cross section of the basic MEMS switch element, and a single pole four throw switch network implemented with the MEMS switches outlined above. Figure 8(e) shows the tunability of a bandpass filter implemented with the highly integrated MEMS technology. This filter tunes from approximately 200 MHz to approximately 525 MHz.

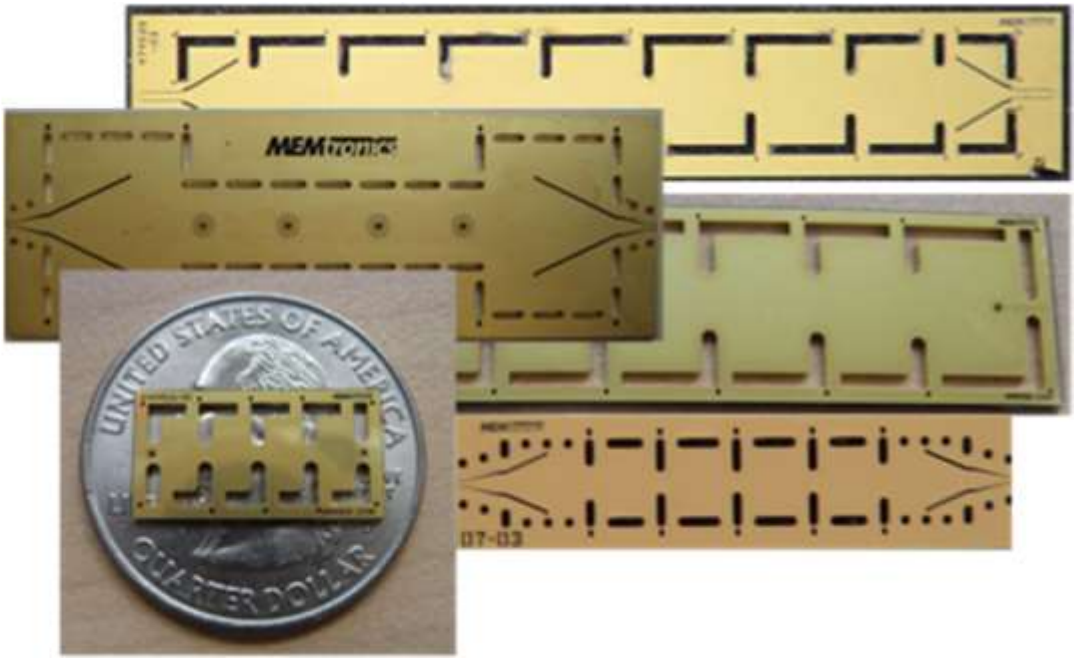

Figure 8a: Tunable Bandpass Filter Basic Filter Structures

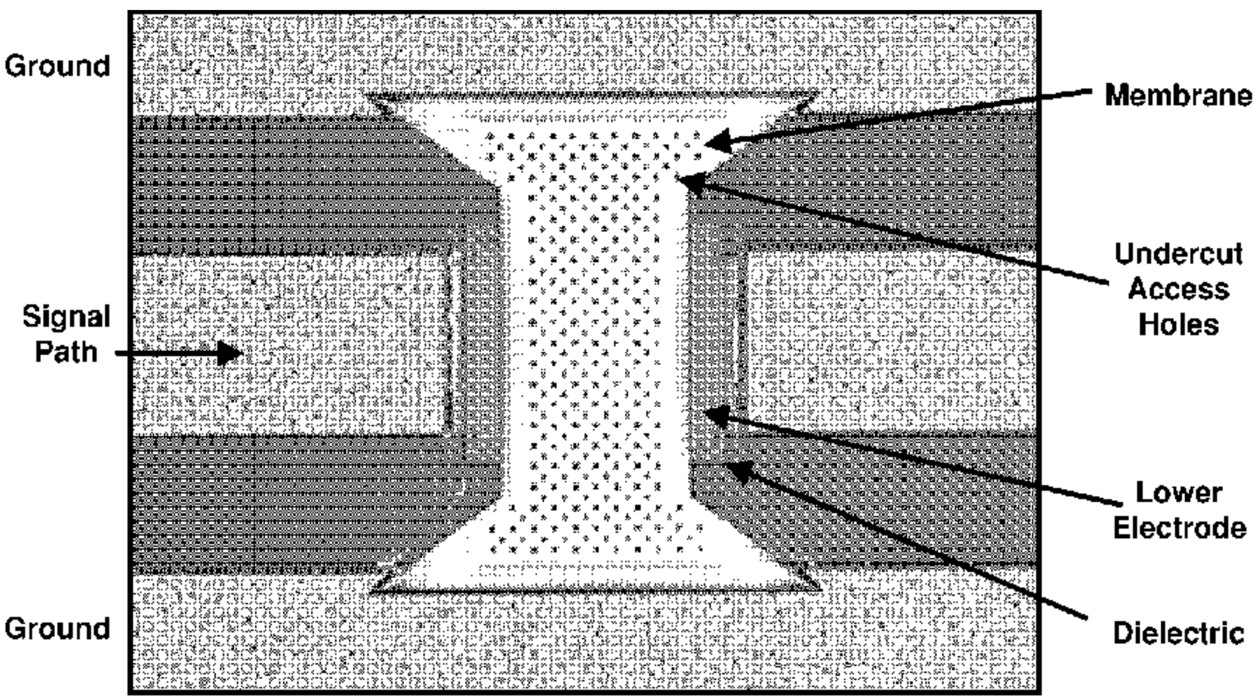

Figure 8b: Tunable Bandpass Filter MEMS Switch Element Top View

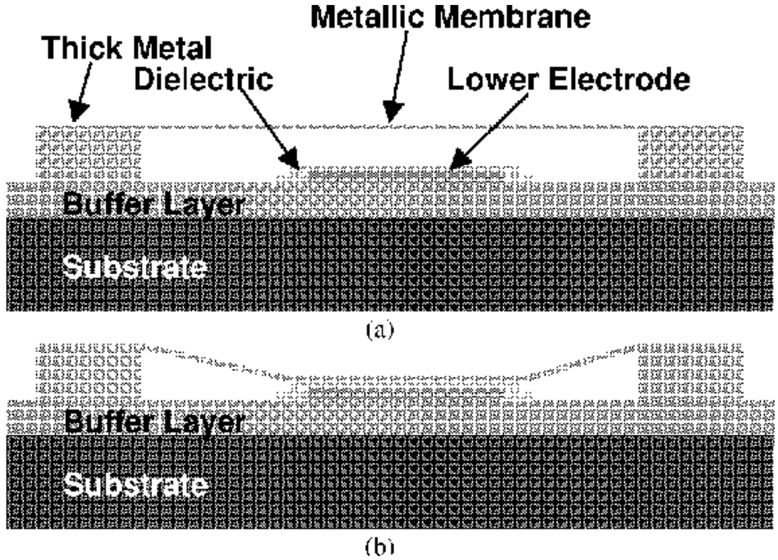

Figure 8c: Tunable Bandpass Filter MEMS Switch Element Cross Section

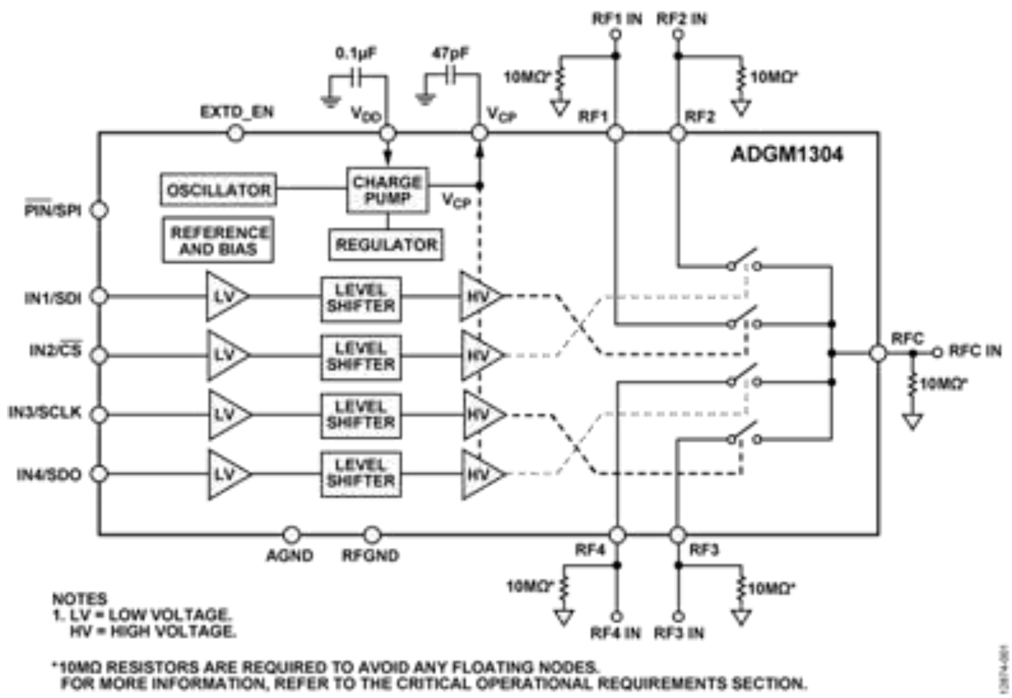

Figure 8d: Tunable Bandpass Filter MEMS Single Pole Four Throw Switch Network

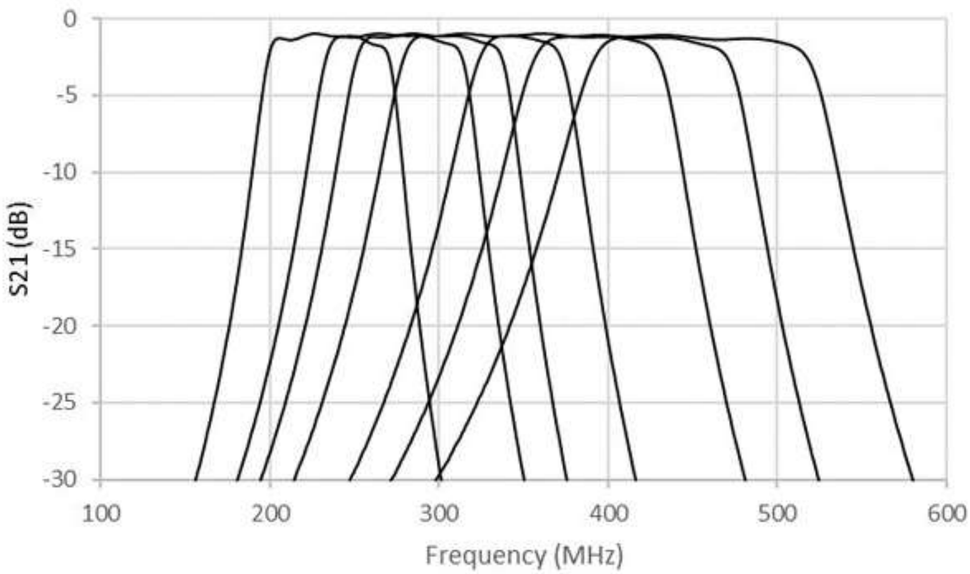

Figure 8e: MEMS Tunable Bandpass Filter Frequency Range (200 MHz-525 MHz)
(Courtesy MEMtronics Corporation)

This same MEMS technology can also be used to implement phase shifting functions for the purpose of antenna beam steering. This is shown in Figure 9. By steering the antenna beam, the CubeSat system can move from target to target very quickly. Here, eight MEMS phase shifters, with appropriate phase weighting in each element, can steer or scan the antenna beam by adjusting the equiphase front of the radiation pattern.

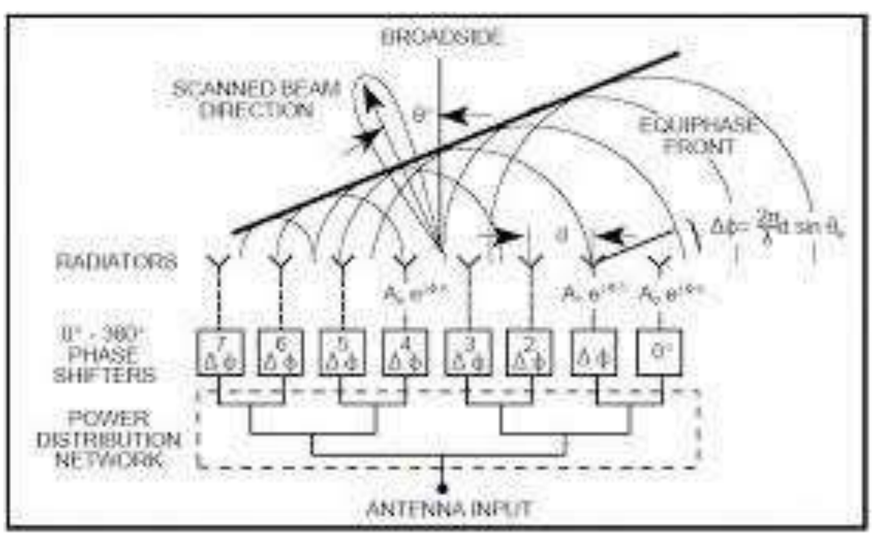

Figure 9. CubeSat Antenna Beam Steering Utilizing MEMS Technology
(Courtesy Elbanna, H., et al.)

4. Results

Figure 10 presents the results of implementing CubeSat systems for detection of the radio frequency counterpart of high energy events incorporating VLBI principles. It should be noted that Figure 10 is only a notional concept and not meant to represent an actual proposed system. Figure 10(a) indicates the notional placement of the Software Defined Radio used for detection of radio frequency counterparts of events, the fractal antenna as discussed above, and an RF link to other satellites in the array. Figure 10(b) is the Cantor linear fractal array as discussed above showing the beam steered to an angle **Θ**, and Figure 10(c) illustrates what a network of CubeSats in this type of array might look like on station.

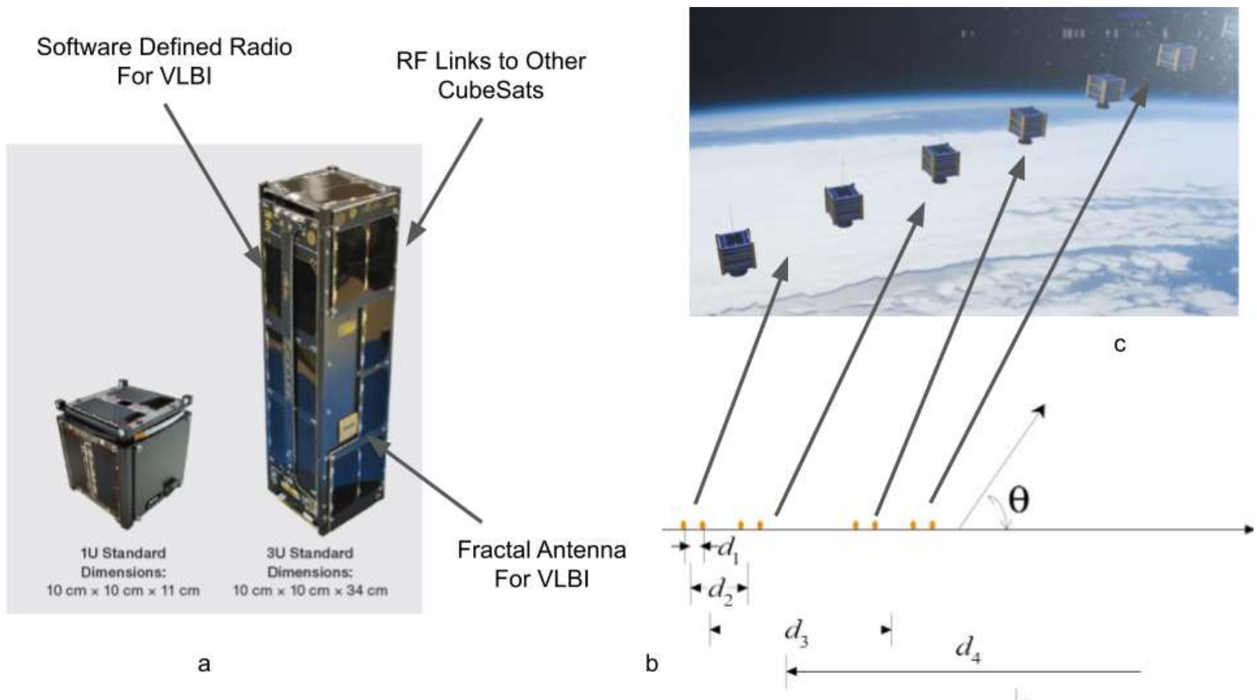

Figure 10. Notional Concept for CubeSat Array incorporating VLBI (Courtesy NASA)

5. Conclusions

CubeSat systems have the potential to make significant contributions to multiple areas of astrophysics research, including detection of gravitational wave counterparts, Gamma Ray Bursts (GRBs) and GRB afterglow, X-ray and ultraviolet astrophysics, exoplanet studies, solar, ionospheric and space physics, and variable star astrophysics including pulsar detection, Active Galactic Nuclei (AGN) physics, transient, time domain, and multi-messenger astrophysics. Several of these areas of astrophysical research utilize the radio frequency (RF) spectrum between 10 MHz and 10 GHz. This spectrum accounts for significant opportunities for research with space-based CubeSat systems and networks. Swarms or constellations of CubeSats can be configured to perform multi-aperture Very Long Baseline Interferometry (VLBI), which is a fundamental technique for radio astronomy. This can be achieved with the use of fractal antennas and fractal arrays, interferometry and aperture synthesis, Software Defined Radios, and MEMS tunable filters, switches, and phase shifters for agile frequency selection and antenna beam steering.

Researchers interested in CubeSat design, technology, and astrophysical applications should visit these links:

CubeSats
NASA's CubeSat Launch Initiative
NASA: CubeSat 101
CubeSat.org
CubeSats for Astrophysics and Astronomy Research
CubeSats for Astronomy and Astrophysics

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Biography

Mr. Hinzel is the Founder, President, and Chief Scientist of Argent Astro Research Institute (AARI). AARI, previously known as Engineering Tecknowledgey Applications, LLC (ETA) is a technical and business professional services firm established to provide high quality engineering, scientific, and business consulting, contracting, and research services to commercial, corporate, and government customers. He has a B.S. in Physics, a B.S. in Mathematics, and a B.S. in Electrical and Computer Engineering, an M.S. in Electrical Engineering, and has completed all course requirements for the Ph.D in Electrical Engineering.

Mr. Hinzel is a member of the American Association of Variable Star Observers (AAVSO) where he is the observing section leader for the AAVSO International High Energy Network (HEN). The HEN is dedicated to the study of high energy astrophysical phenomena in the universe, including Gamma Ray Bursts, Quasi-Stellar Objects, Active Galactic Nuclei, and gravitational waves. He is also a member of the American Astronomical Society (AAS) and the Society for Astronomical Sciences (SAS). He has written several research papers for the AAVSO and the AAS, including:

"Data Mining Analysis for Eclipsing Binary TrES-Cyg3-04450", D. Hinzel. The Journal of the American Association of Variable Star Observers, JAAVSO Volume 43, 2015.

"Unmanned Aerial Systems for Variable Star Astronomical Observations", D. Hinzel. The Journal of the American Association of Variable Star Observers, JAAVSO Volume 46, 2018.

Photometric Observations of Nine High Mass X-Ray Binaries and Analysis of Potential Periodicities and Variations 2022 Res. Notes AAS 7 15; DOI 10.3847/2515-5172/acb5a0

Light Curve Analysis of Nine Algol (EA) Eclipsing Binaries Discovered During the Dauban Survey 2022 Res. Notes AAS 6 231; DOI 10.3847/2515-5172/ac9d9e

Light Curve Analysis of Nine Algol (EA) Eclipsing Binaries Discovered During the Dauban Survey-additional Data 2022 Res. Notes AAS 6 239; DOI 10.3847/2515-5172/aca28f

Contact: argentastro22@gmail.com

RAS Re-Packaged Neutral Hydrogen Receiver Thermal Studies

Written by: Stephen Bentley (Astronomical Society of Victoria)

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Written: Stephen Bentley (Bachelor of Communication and Electronics Engineering R.M.I.T)
Date: 15th July 2023

1.0 Introduction

The Radio Astronomy Section of the ASV decided the purchased receiver for the study of neutral hydrogen required an electro-mechanical redesign. The intention was to significantly improve the thermal stability of the receiver. The original receiver as supplied by Radio Astronomy Supplies in the US placed the receiver Front End inside a 19" rack mount cabinet. The internal configuration of the rack enclosure employed a lining of polystyrene foam insulation and the internal air was cooled by a 48 Watt Peltier cell with the thermostat set to +23 degrees C.

The receiver also included a low noise amplifier which was housed inside its own diecast aluminium enclosure which was mounted directly to the output of the feed-horn antenna on the ASV 8.5 m radio telescope dish.
Both the low noise amplifier and the Front End were not reliably weatherproofed or thermally stable. The LNA was regularly in direct sunlight and exposed to the weather. The Front End electronics housing was better off in terms of weatherproofing as the 19" rack enclosure was located inside a custom fabricated enclosure (cabinet) mounted at the feed point on the dish antenna. The effectiveness however of the Peltier cell cooling system was found to be inadequate and only ever succeeded in stabilising the internal air temperature within a narrow range of ambient from +23 to +25 C. When the ambient temperature was below +23C or above +25C the receiver air temperature varied with the ambient.

This report describes the re-packaged components of the neutral Hydrogen receiver LNA and Front End and presents measured performance of the new Peltier cell cooling systems proposed on both the LNA and the Front End.

2.0 Re-Boxed Components

Shown in Figure 1 is the complete assembly of the re-boxed components of the neutral Hydrogen receiver LNA and Front End. The layout of the items is also to scale based on suitable mounting locations within the custom enclosure at the feed point on the ASV dish. This setup remained on the author's kitchen table for several weeks while the various interconnecting patch leads were fabricated to the correct length. Extensive use has been made of IP68 rated plugs and sockets and shielded wiring where possible.

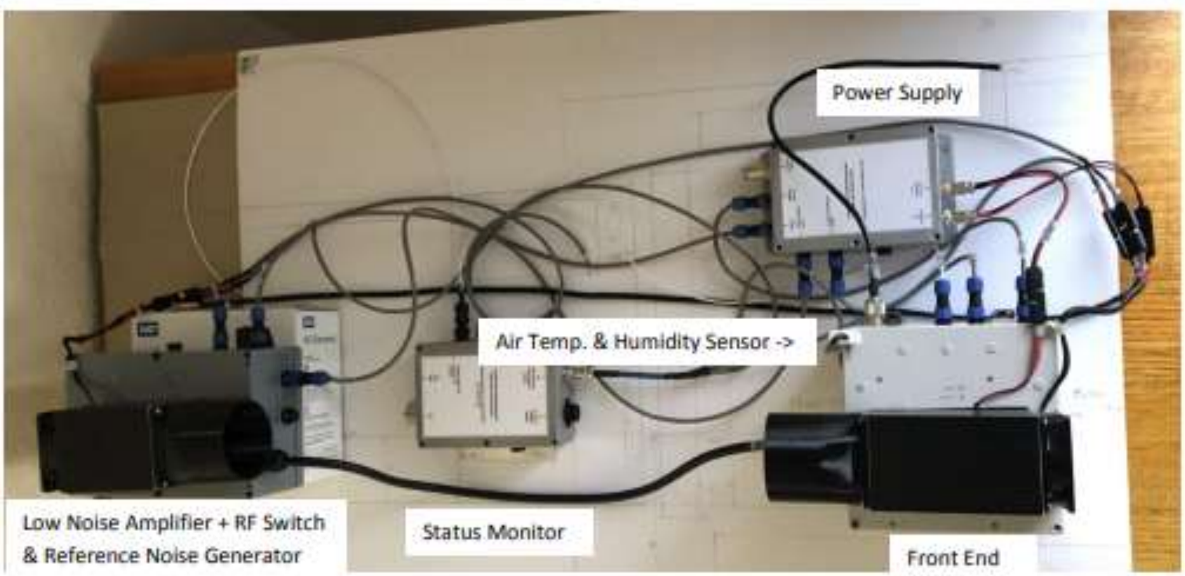


Figure 1. Neutral Hydrogen Receiver LNA and Front End Re-boxed Layout

As can be seen in Figure 1, both the LNA and the Front End are now housed in their own plastic waterproof box which also has individual Peltier cell cooling and heatsink. Each heatsink has an exhaust fan. The outlet of the heatsinks which are 3D printed plastic flanges fabricated by a fellow ASV member, Brian Mooney, will have ducts to send the heated air out and away from the custom cabinet. It is important to note the LNA is now located away from the feed-horn. Therefore a small additional RF loss will occur due to the short coaxial cable connection between the feed-horn and the LNA. This loss is expected to be small and less than 0.06 dB. The LNA enclosure also contains a low loss RF switch (measured loss -0.2dB) and a reference noise signal generator. The status monitor has been expanded to monitor the internal temperatures of the LNA and the Front End as well as the cabinet internal air temperature and humidity. In addition, both cooling fan speeds are also monitored.

Figure 2 provides a photo showing the internal view of the LNA enclosure.

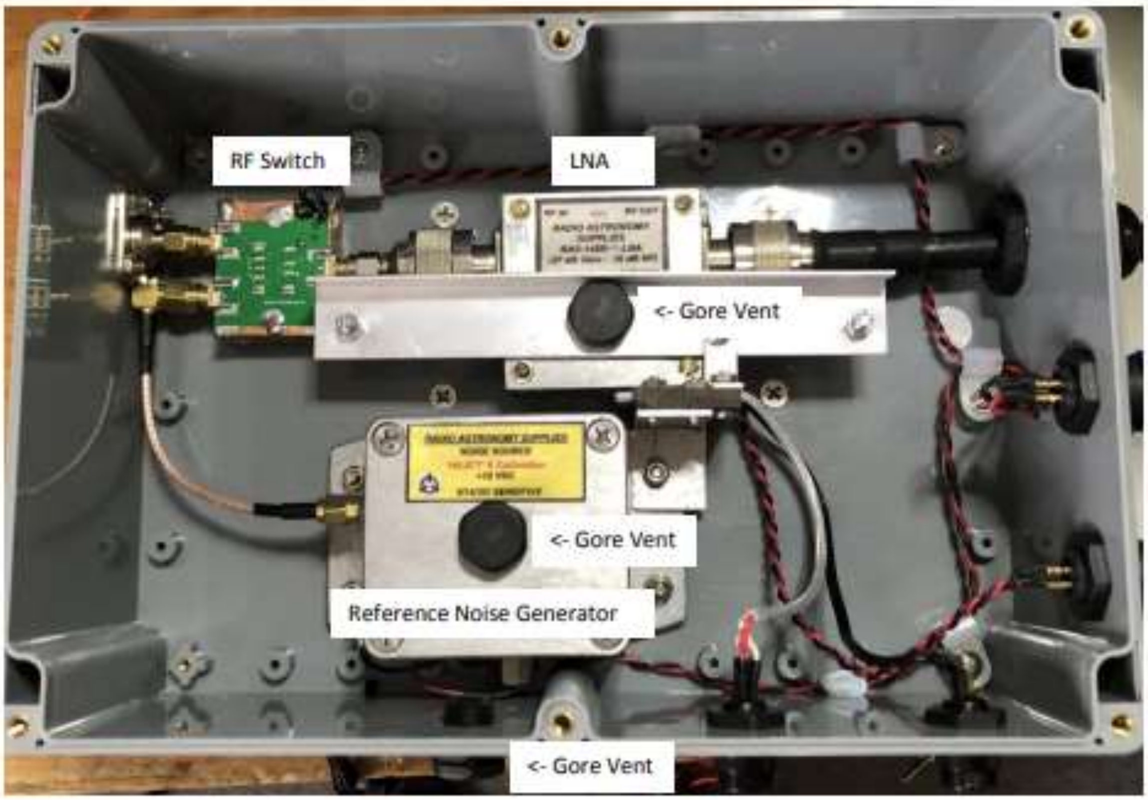


Figure 2. Neutral Hydrogen Receiver LNA Internal View

Within the LNA enclosure there are the 3 main components of the RF switch, the Reference Noise Generator and the LNA. The LNA enclosure and the Reference Noise Generator enclosure are both sealed and air-tight but each are fitted with a Gore-vent. In Figure 3 is a view showing the plastic enclosure lined with polystyrene foam to aid in temperature stabilisation of the LNA. The plastic enclosure is also sealed air-tight and fitted with a Gore-vent.

The LNA is mechanically coupled to a Peltier cell via a copper shim and thermal conductive compound. The Peltier cell has a rating of 12 Volts and 2.7 Amps (32 watts). The hot side is coupled to the external heatsink as seen in Figure 1. The external temperature of the LNA is monitored by a platinum 100 Ohm RTD probe as well as the thermistor probe connected to the thermostat.

Figure 3. Neutral Hydrogen Receiver LNA Thermal Insulation

Figure 4 provides a detail of the LNA temperature probes.

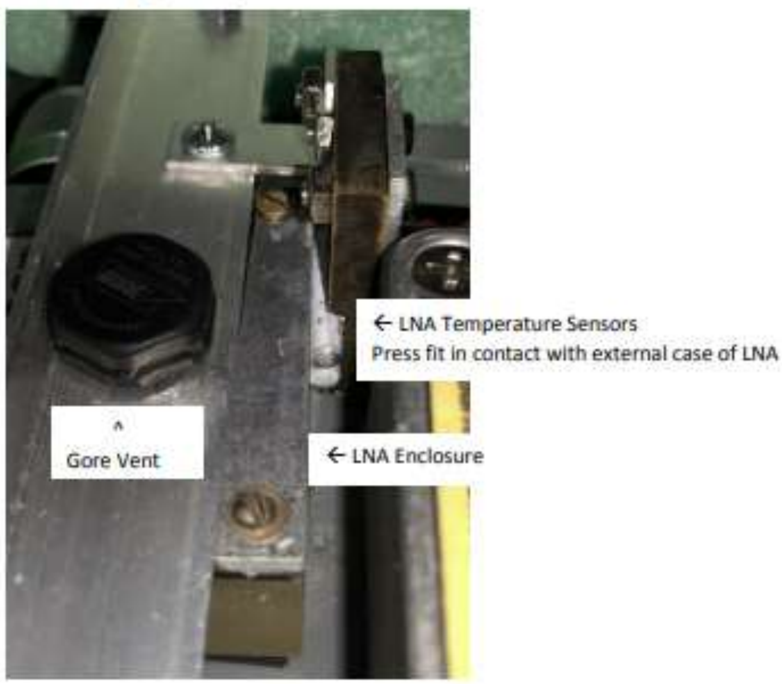


Figure 4. Neutral Hydrogen Receiver LNA Temperature Probes

Figure 5 provides an internal view of the Front end enclosure.

Figure 5. Neutral Hydrogen Receiver Front End Internal View (cover removed)

To enable the monitoring of the internal air temperature of the Front End enclosure, the 2 temperature probes are fitted to a custom mount on the inside of the diecast enclosure lid. See Figure 6 for the Front End temperature probes.

Figure 6. Neutral Hydrogen Receiver Front End Temperature Probes (inside cover)

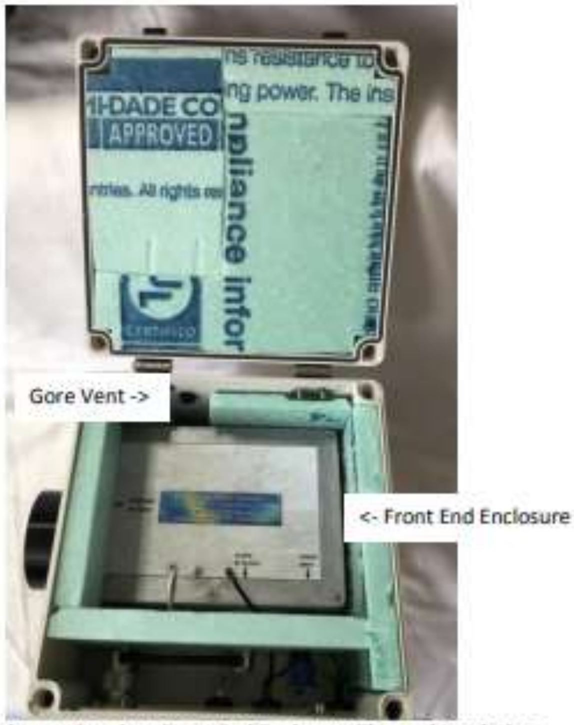


Figure 7. Neutral Hydrogen Receiver Front End Enclosure Thermal Insulation

To improve the thermal insulation of the Front End enclosure, the plastic box is further lined with a layer of polystyrene foam. See Figure 7 for the assembled Front End inside the plastic enclosure.

The power supply and Peltier cell components were removed from the original 19" rack enclosure and placed into a sealed diecast aluminium enclosure. An additional thermostat controller was added to this enclosure to control the new Peltier cell that cools the LNA. Figure 8 shows the internal view of the re-boxed power supply.

The power supply enclosure is also sealed airtight and fitted with a Gore vent.

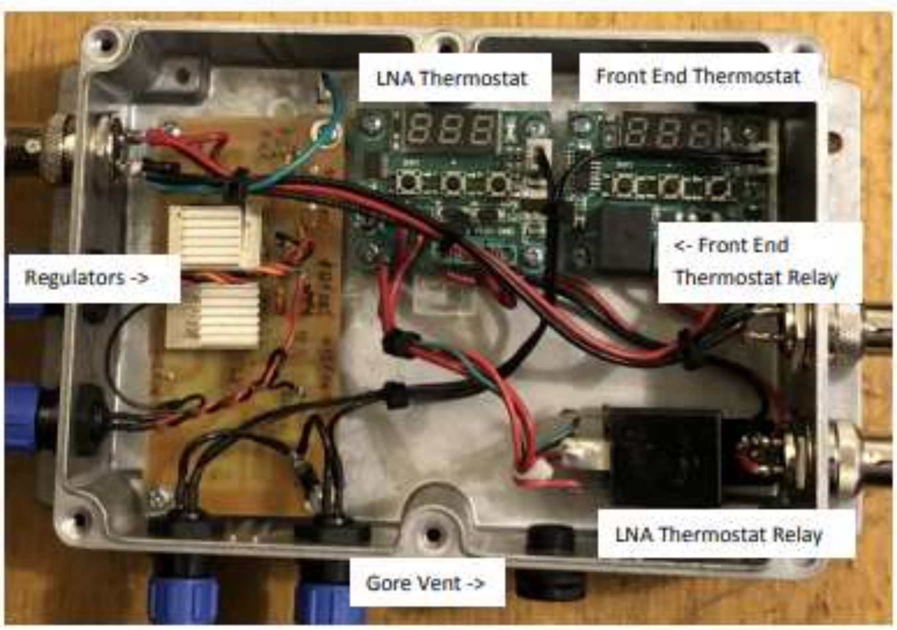


Figure 8. Neutral Hydrogen Receiver Power Supply Enclosure with Thermostat Controls

The thermostat circuits within the power supply enclosure can be set to a threshold temperature and a tolerance range. These values were varied during the experimental testing however it is recommended the LNA thermostat be set to +5C and +/- 1C range. The Front End thermostat is set to +13.5C with +/- 1C range. The Front End thermostat appeared to have about 1.5 degrees error when compared to the more accurate PT100 sensor which is located adjacent to the thermostat sensor (see Figure 6). Therefore by setting the thermostat to 13.5 the internal air temperature of the Front End stabilised more accurately to the target +15 degrees C.

The status monitor remained within its original diecast aluminium enclosure however additions were included on the circuit board to provide for temperature measurement of the LNA and the Front End. Provision for monitoring of the fan speed of the cooling fans on both the LNA and the Front End heatsink was included. The Arduino Nano software was upgraded to include the added features mentioned. Figure 9 provides an internal view of the status monitor.

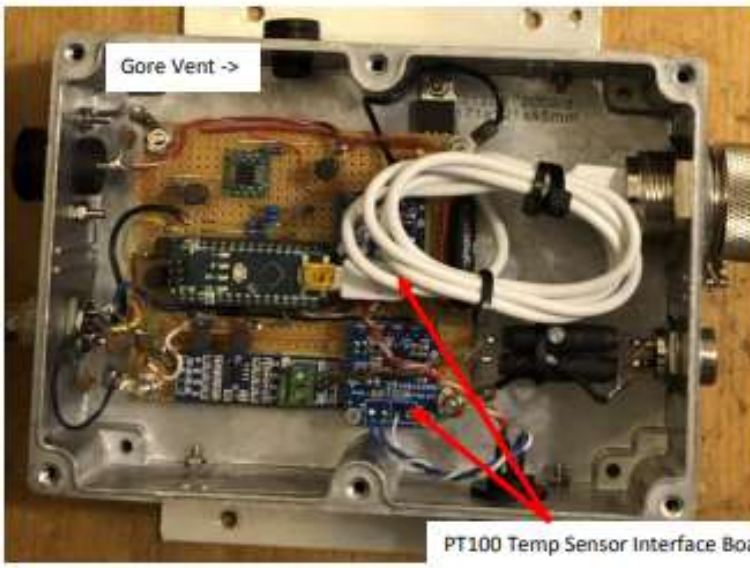


Figure 9. Neutral Hydrogen Receiver Revised Status Monitor

3.0 The Temperature Drift Problem

Shown in Figure 10 is a meteorological chart prepared by Weatherzone Australia, revealing the seasonal temperature variation for the district of Heathcote in central Victoria.

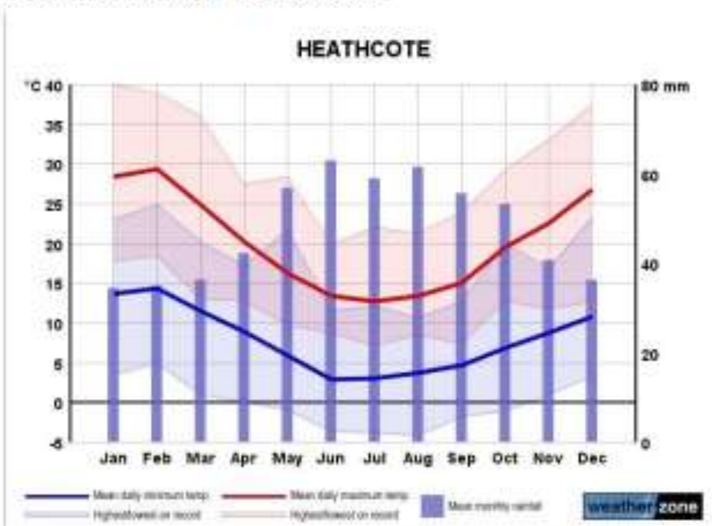


Figure 10. Heathcote Ambient Seasonal Temperature Variation

According to the Weatherzone chart, Heathcote will on average experience an ambient temperature variation from about +4 degrees C minimum (lowest point on the solid blue line) to about +30 degrees C maximum (highest point on the solid red line).
There are other extremes based on historical records. Observing the light blue shaded area the lowest temperature is about -4 C and from the light red shaded area the highest is about + 40 C. The author has visited the ASV property for more than 20 years and can confirm both extreme temperatures do occur.

Also presented in Figure 10 is the typical daily variation of temperature which is the spacing between the solid red and blue lines. This is typically 15 degrees during summer/autumn and 10 degrees during winter/spring.

The introduction of Peltier cell cooling on the receiver LNA and Front End enclosures presented a unique opportunity whereby the gain variation with temperature of these circuit components could now be measured in isolation and with some degree of accuracy.

Shown in Figure 11 is the gain variation with temperature of the LNA. To achieve this measurement, a signal of -80 dBm was injected at the input to the LNA (complete enclosure not just the LNA module) using a Marconi 2031 RF signal generator. The output of the LNA was observed using a HP8560A spectrum analyser. The spectrum analyser was adjusted to have a vertical scale of 1 dB per division and a peak marker was placed on the signal being measured. The marker was also set to track the signal peak to avoid any frequency drift during the measurement. The output of the LNA was typically 30 dB above the level of the signal generator which is consistent with the known gain of the LNA which is 37 dB. There is obviously loss in the coupling test cables used in the measurement however this loss is not relevant since only gain variation is being measured.

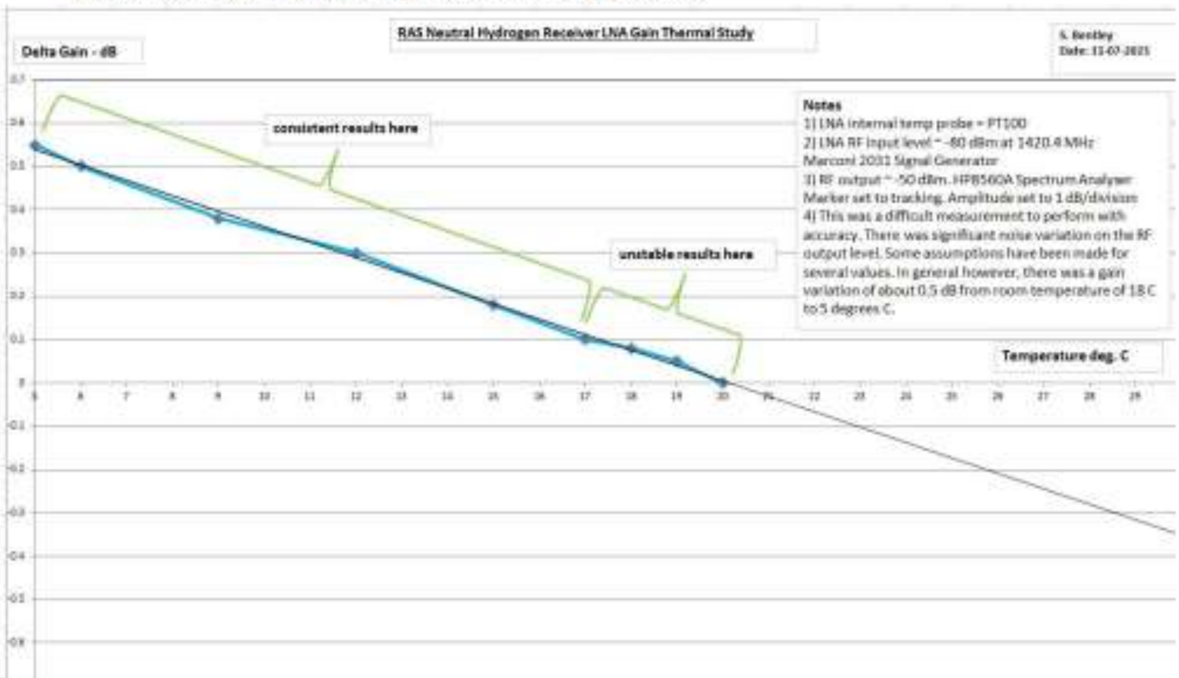


Figure 11. LNA RF Gain Versus Temperature

The measurement was difficult with a significant error and variation in levels on some of the results. However the levels over the temperature range of +5C to +17C were consistent and reliable. The LNA was stabilised at each temperature reading taken (shown by the markers on the blue line) for at least 5 minutes which is sufficient to also stabilise the small low mass LNA diecast box.
A linear trend-line was added to the curve for the measured results and this line was then extrapolated to the higher temperature of +30C. The result indicates the LNA has a negative temperature coefficient with a variation of
- 0.036 dB per degrees C.

The same process was performed on the receiver Front End however this time each measurement point was stabilised for at least 10 minutes since the Front End diecast aluminium box has a larger mass than the LNA. The frequency setting on the spectrum analyser was also adjusted to 70 MHz for this measurement which is the output frequency of the Front End with the input frequency of 1420.4 MHz.

The Front End RF gain is 37 dB based on a previous and accurate measurement, however based on the presented results in this report, an additional loss of 3 dB is evident (80 – 46 = 34dB) which is largely due to the few meters of RG58 coax test lead used between the RF signal generator at 1420.4 MHz and the input to the Front End.

Figure 12 shows the measured results.

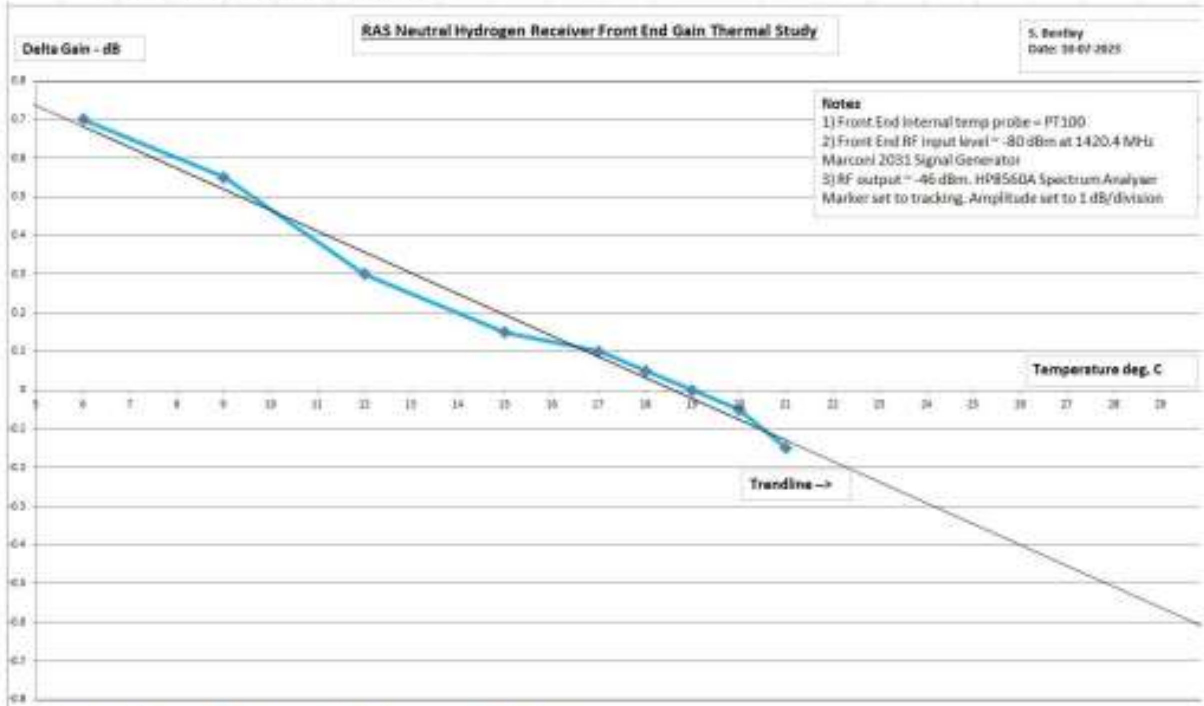


Figure 12. Front End RF Gain Versus Temperature

This measurement was somewhat more stable with less noise and variations seen during the measurement process.

The Front end gain also exhibits a negative temperature coefficient with the gradient of the superimposed trend-line being approximately **- 0.055 dB per degrees C.**

The LNA and Front End gain versus temperature combine to produce an overall coefficient of
-0.091 dB per degrees C.

Based on the receiver temperature sensitivities and the seasonal variation of Heathcote's ambient temperature, it is easy to see a receiver gain variation due to the LNA and Front end combined may cause the RF output level to change by **2.37 dB** typically (26 x 0.091) or in the worst case by **4 dB** (44 x 0.091) when the ambient temperature varies from -4 to + 40 Deg. C.

The fluctuations seen on many detailed sky surveys for neutral Hydrogen correspond to a variation of the RF signal strength of less than 1 dB. It can be seen therefore a fair bit of detail will be lost if the LNA and Front End components of the receiver are not temperature stabilised in some way, or their measured variation is not accounted for when performing any scientific survey.

4.0 Temperature Stabilisation Performance of Peltier Cell Cooling

4.1 LNA Peltier Cell Cooling

Shown in Figure 13 is the measurement setup for the LNA Peltier Cell cooling assessment.

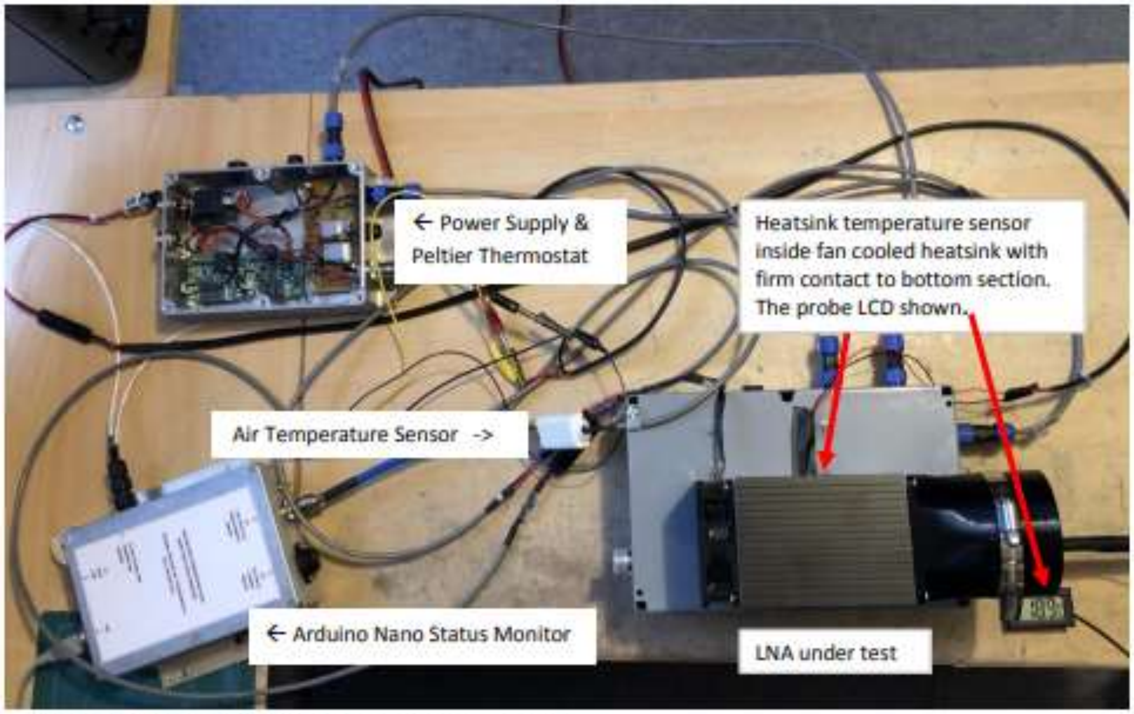


Figure 13. LNA Peltier Cell Cooling Measurement Setup

The measurement was performed by adjusting the Peltier cell thermostat to +5C with a hysteresis of +/- 1 deg. C. The system was allowed to operate for a period of 63 minutes to observe the thermal time constants and the cycling of the Peltier cell.

The specifications for the Peltier cell on this LNA test are listed in Table 1 below.

Model: TES1-12704
Voltage: 12 Volts DC
Current Consumption at 12 Volts: 2.7 Amp
Delta Temp. Maximum at 25 deg. C: 66 degrees
Size: 30 x 30 x 3.3 mm.

Table 1. LNA Peltier Cell Specifications

The cooling fan on the heatsink is a Jaycar product model YX2580 which has an airflow of 28 cubic feet per minute at a speed of 2000 rpm, current consumption 100 mA. This fan was initially chosen as the magnetic bearing design qualifies the expected lifetime of the fan to be 100,000 hours which is 11.4 years. It is intended to run the cooling fan continuously regardless of the cycling of the Peltier cell. This will ensure when the Peltier cell is off, any residual heat in the heatsink is dispersed away from the LNA as quickly as possible.

The status monitor was modified to sample the temperature probes on the LNA and the ambient air once per minute. The external heatsink temperature used a separate temperature probe intimately attached to the heatsink above the middle of the Peltier cell. This probe reading is read via the battery operated LCD as seen in Figure 13. The reading was recorded manually at each 1 minute cycle of the status monitor and required the author to remain diligent throughout the 63 minute period of the test.

At the commencement of the test the air temperature and the heatsink temperature were within 0.4 degree of each other however the LNA temperature was slightly higher. This is consistent as the LNA had its DC power applied and was dissipating a small amount of heat.

The thermostat temperature probe attached to the LNA was also monitored and recorded to determine the difference between this probe and the PT100 probe being monitored by the status monitor. Overall the 2 probes were quite close with the thermostat appearing to be about +0.5 deg. C higher than the PT100 probe.

4.1.1 LNA Thermal Test 1

Shown in Figure 14 the results are presented graphically. Each 1 minute data point is shown with a marker.

From the results in Figure 14 the following observations can be made.

1) The system including the heatsink stabilised within about 10 minutes. From the 10 minute mark until 63 minutes, there were only small variations on the heatsink temperature which appear to track with comparable changes in the ambient temperature. Home central heating cycles around +18C.
2) The LNA temperature stabilised within 5 minutes and was within the settings of the thermostat.
3) The on/off cycle of the Peltier cell settled down to 2 minutes on and 2 minutes off with the ambient temperature of +18 C.
4) The Delta T maximum of the Peltier cell was 26.7 degrees and below the specification limit for the device.
5) There appeared to be no difficulty for the 32 watt Peltier cell in stabilising the LNA to a temperature of +5 degrees C.
6) The difference between the LNA temperature and the ambient temperature is 13 degrees. Therefore this system should in principle be capable of keeping the LNA at +5 degrees for ambient temperatures up to +18C.

4.1.2 LNA Thermal Test 2

What is not known from test 1 is how well the LNA cooling system will operate with ambient temperatures up to +30 degrees C or indeed + 40C. A subsequent test was performed with the heatsink fan turned off. This potentially will create a thermal run-away situation however it may reveal what heatsink temperature is possible and still maintain +5C on the LNA. Figure 15 provides the LNA cooling test with the fan turned off.

From the results of test 2 shown in Figure 15 a thermal runaway condition has indeed occurred with the heatsink temperature continuing to rise after a period of 14 minutes where the temperature reached over +52C and was too hot to touch therefore the test was abandoned at this point. ***Clearly a cooling fan is an essential part of the design and it is also essential to monitor the operation of the fan and have a strategy to react quickly to any condition that will indicate deterioration or failure.***

Encouragingly, the LNA temperature remained at +5 degrees C within 5 minutes of the test activation and remained there until the end of the test at 14 minutes. The Peltier cell delta T reached a maximum of 47 degrees and was still within the limit of the device specification.

4.1.3 LNA Thermal Test 3

The choice of cooling fan on the heatsink was considered at this stage and further tests were performed with an alternative fan. The alternative fan is also a Jaycar product model YX2513 with ball bearings, operating speed of 3000 rpm, airflow of 34 cfm and expected lifetime of 100,000 hours, the only penalty being a higher current consumption of 200 mA compared to the YX2580.

From the results of test 3 shown in Figure 16 the most notable difference compared to Figure 14 where the slower 28 cfm fan was used, is the lower temperature of the heatsink. In LNA study-1 the heatsink reached a final average temperature of +28C with the ambient of +18C. In LNA study 3 the heatsink final average temperature was +25C for the same ambient temperature of +18C.

4.1.4 LNA Thermal Test 4

The LNA Peltier thermostat was set to the lower temperature of +1 degrees C. This was to determine if there was a limit where the Peltier cell could no longer cool below the ambient of +18C. The higher speed fan with airflow of 34 cfm was once again used in this experiment. The measured result is shown in Figure 17. The observations to note are:-

1) The LNA was able to be cooled close to + 1 degrees C.
2) The heatsink temperature stabilised at the slightly higher temperature of +27C.

4.1.5 LNA Thermal Test 5

A final evaluation was with the LNA thermostat setting at +1C but the cooling fan on the heatsink using the slower fan with airflow of 28 cfm. The measured result is shown in Figure 18. The observations to note are:-

1) The LNA was able to be cooled to close to 1 degrees C.
2) The heatsink temperature stabilised at the higher temperature of +30.5C.

The slow variation of the heatsink and LNA temperatures over time is related to the on/off cycles of the Peltier cell, however the periods are quite long being over several minutes. This is because the measurement samples as indicated by the tick marks on the graph lines are taken only once per minute and hence are intermittent samples of the faster on/off cycles which is typically 2 minutes on and 2 minutes off.

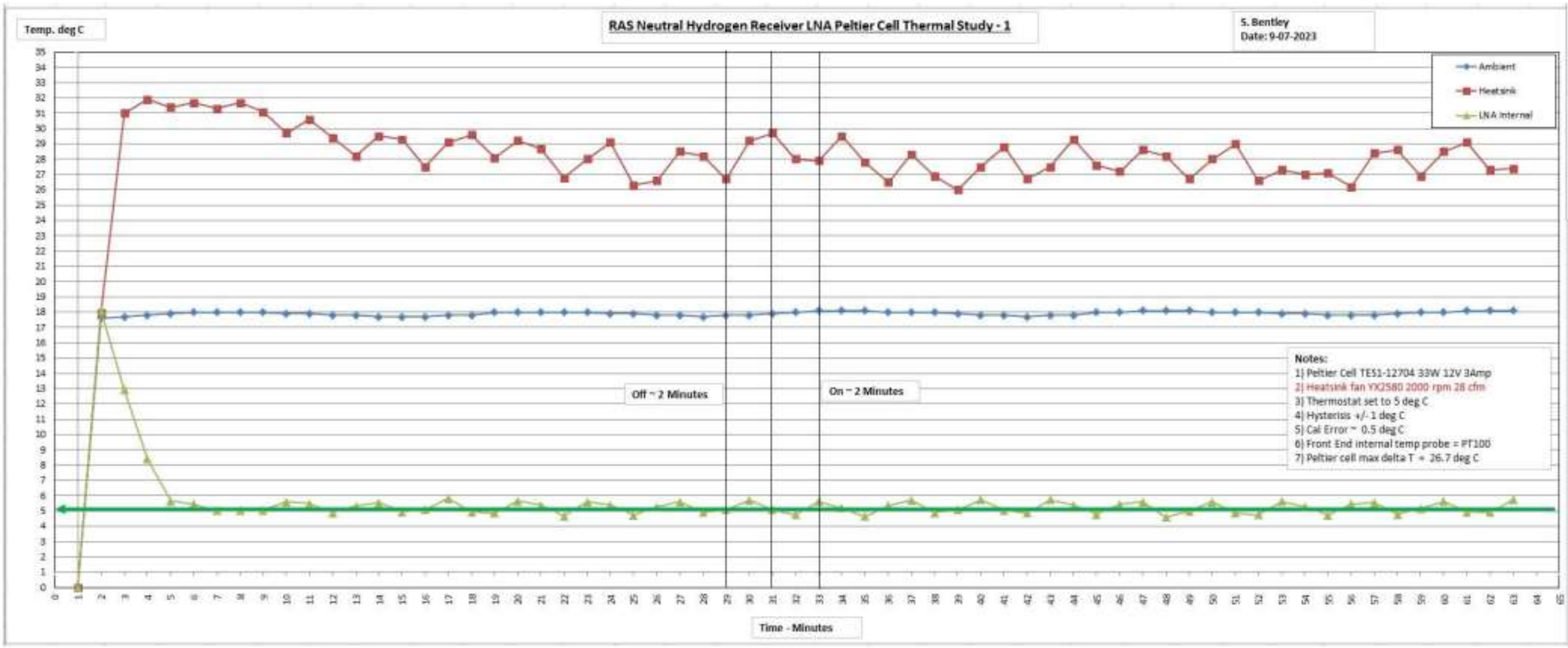


Figure 14. LNA Peltier Cell Cooling Measurement Study -1

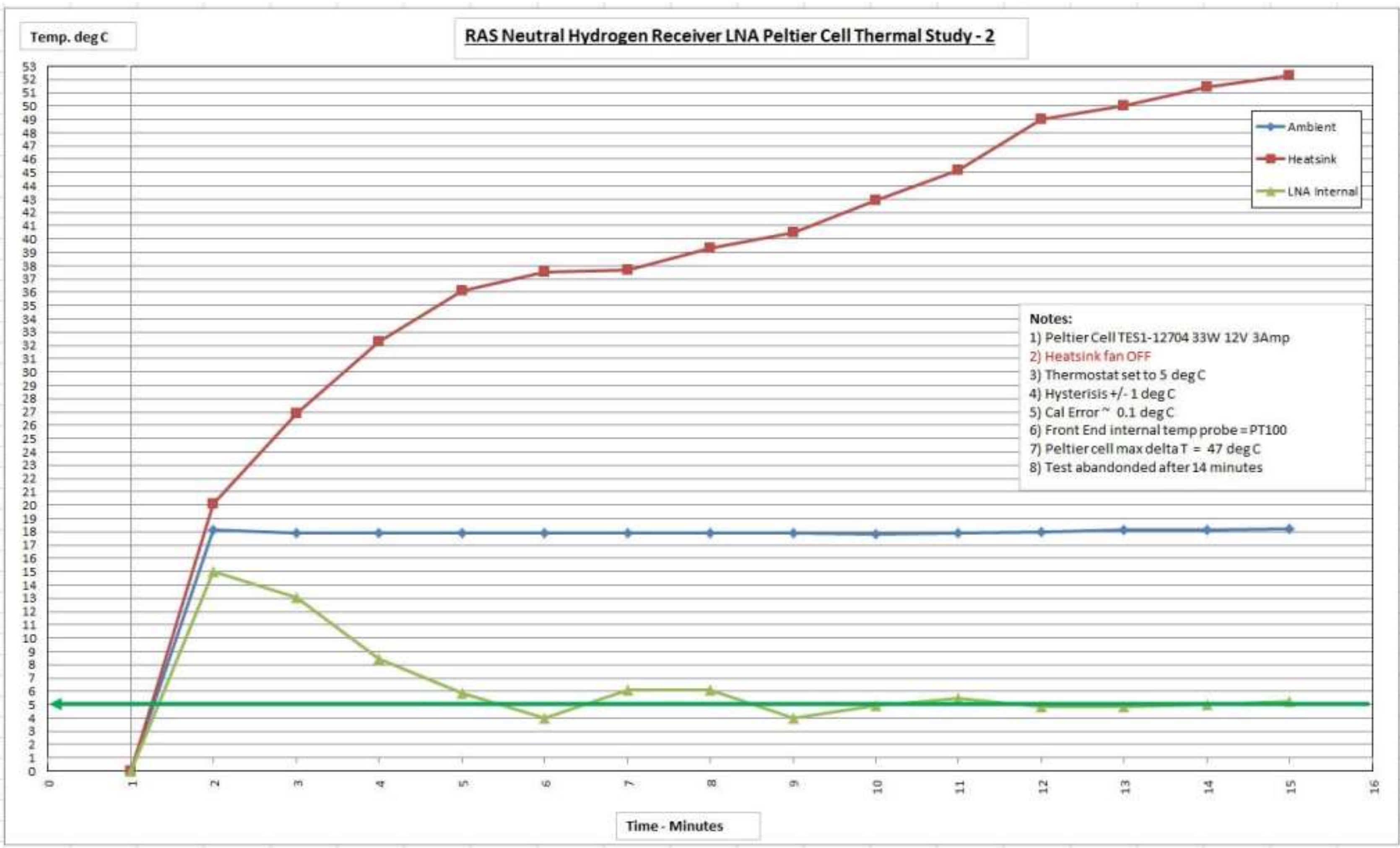


Figure 15. LNA Peltier Cell Cooling Measurement Study -2

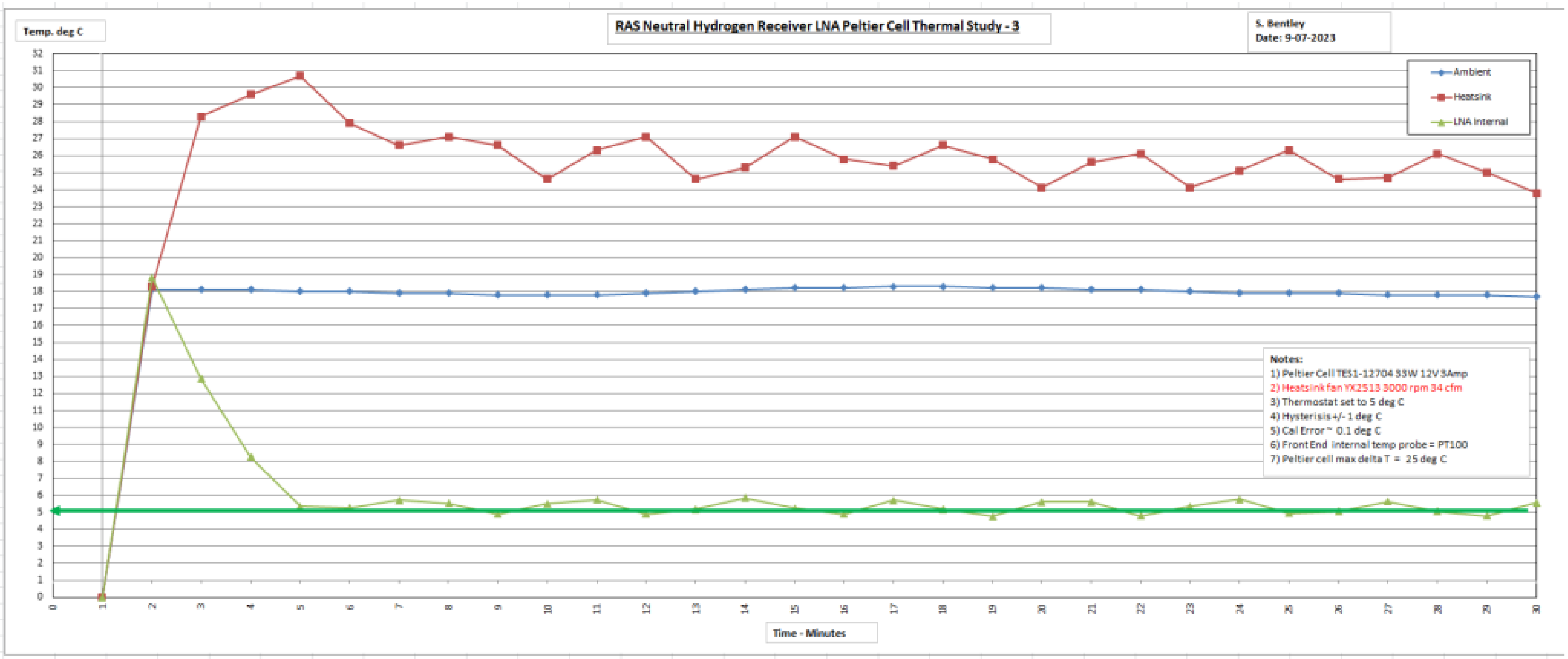


Figure 16. LNA Peltier Cell Cooling Measurement Study -3

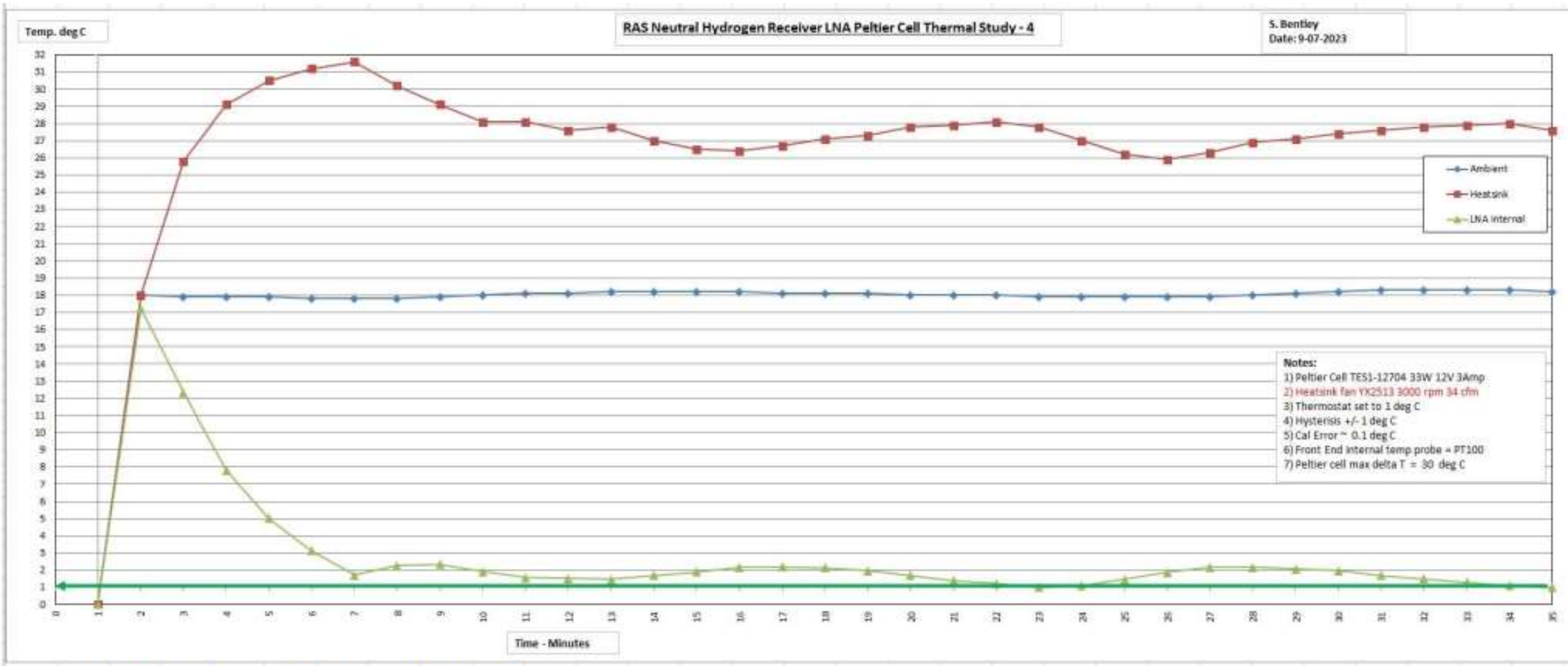


Figure 17. LNA Peltier Cell Cooling Measurement Study -4

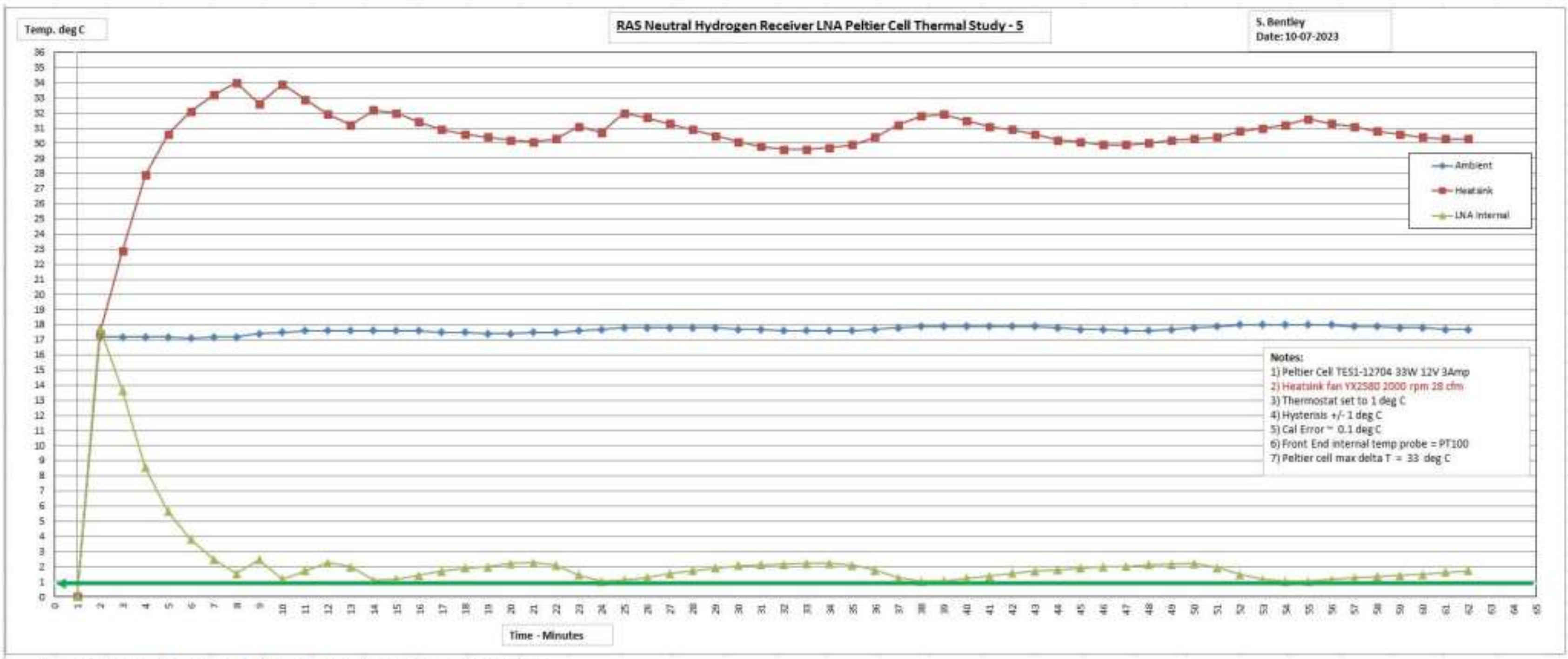


Figure 18. LNA Peltier Cell Cooling Measurement Study -5

4.2 Front End Peltier Cell Cooling

The test setup for the neutral Hydrogen receiver Front End thermal study is shown in Figure 19. The setup has essentially 4 temperature probes, these are listed below.

1) Ambient air
2) Front End internal air
3) Front End Heatsink
4) Thermostat

The Heatsink temperature probe was a PT100 sensor placed on the outside of the heatsink in a position just above the centre of the Peltier cell. The thermostat temperature sensor as shown in Figure 6 is adjacent to the Front End internal air temperature sensor. To monitor sensors 1 -3 the Arduino Status monitor was modified to record the readings from the 3 sensors once per minute. The Thermostat sensor was monitored manually by observing the display provided on the thermostat control circuit board.
The measurement was performed by adjusting the Peltier cell thermostat to +5C with a hysteresis of +/- 1 deg. C. The system was allowed to operate for a period of 69 minutes to observe the thermal time constants and the cycling of the Peltier cell. The specifications for the Peltier cell on the Front End test are listed in Table 2.

Model: ZP9100 (Jaycar)
Voltage: 12 Volts DC
Current Consumption at 12 Volts: 3 Amp
Delta Temp. Maximum: 68 degrees
Size: 40 x 40 x 4.2 mm

Table 2 Front End Peltier Cell Specifications

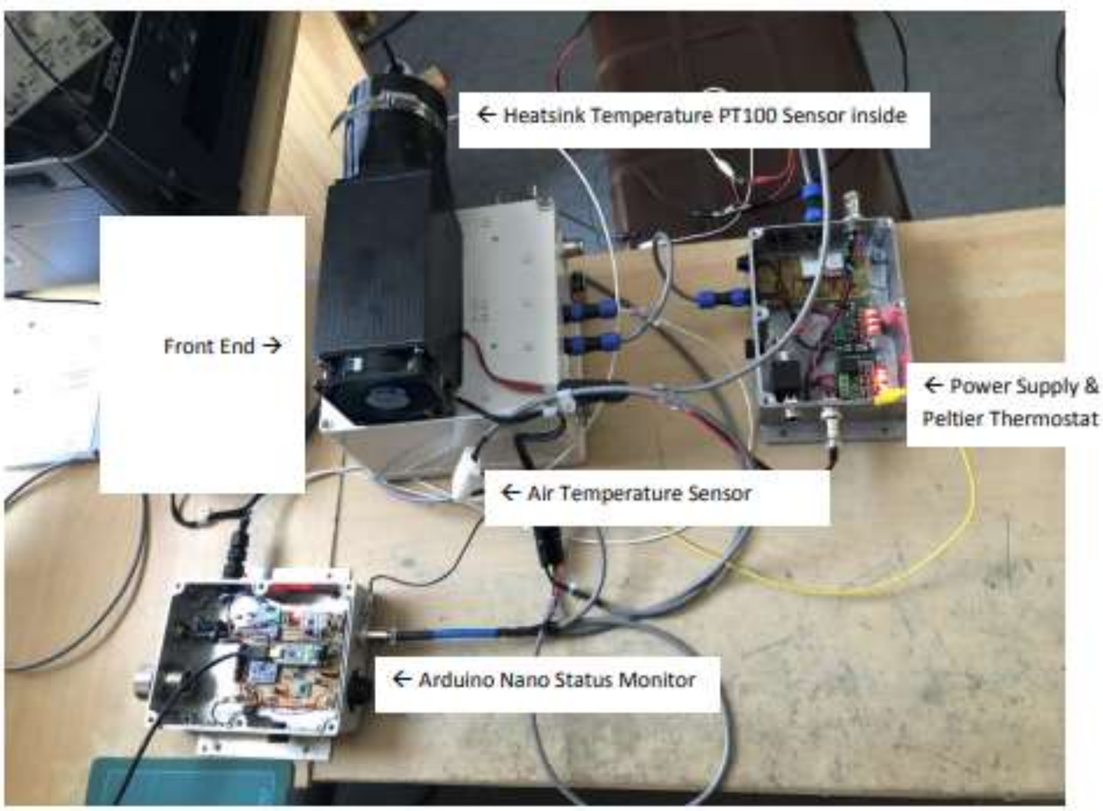


Figure 19. Front End Thermal Evaluation Test Setup

4.2.1 Front End Thermal Test 1

The first set of thermal studies on the Front End used the Jaycar fan, model YX2580 which has an airflow of 28 cubic feet per minute at a speed of 2000 rpm and current consumption of 100 mA.

The results of the first Front End thermal study is Shown in Figure 20 where the results are presented graphically.

From the results in Figure 20 the following observations can be made:-

1) The system including the heatsink stabilised within about 37 minutes. From the 37 minute mark until 69 minutes, the Peltier cell cycled on and off once the Front End internal air had stabilised based on the thermostat setting.
2) The on/off cycle of the Peltier cell settled down to 10 minutes on and 3 minutes off with the ambient temperature of +18 C.
3) The Front End internal air temperature stabilised at a mean temperature of +8C +/- 1degrees C.
4) There was evidence the Peltier cell thermostat was reading about 2 degrees C higher than the PT100 sensor located nearby.
5) The Delta T maximum of the Peltier cell was 29 degrees and below the specification limit for the device.
6) There appeared to be no difficulty for the 36 watt Peltier cell in stabilising the Front End to a temperature of +8 degrees C.
7) The difference between the Front End internal air temperature and the ambient temperature varied between 10 and 11 degrees.

4.2.2 Front End Thermal Test 2

As with the LNA test, a subsequent test was performed with the heatsink fan turned off. This potentially will create a thermal run-away situation but may reveal what heatsink temperature is possible and still maintain +5C on the Front End. Figure 21 provides the Front End cooling test with the fan turned off.

From the results of test 2 shown in Figure 21 a thermal runaway condition has indeed occurred with the heatsink temperature continuing to rise after a period of 22 minutes where the temperature reached over +59C, therefore the test was abandoned at this point. ***Clearly a cooling fan is an essential part of the design and it is also essential to monitor the operation of the fan and have a strategy to react quickly to any condition that will indicate deterioration or failure.***

The Front End internal air temperature was unable to drop to +5 Deg. C with the thermostat set to 0C, instead a temperature of +14 C was achieved. The delta T max between the hot to the cold side of the Peltier cell was 45 degrees. This was still within the Peltier cell specification.

4.2.3 Front End Thermal Test 3

A follow up measurement was again performed with the thermostat set to 0 degrees C. This was to determine the potential limit of performance of the Peltier cell cooling system. The measured result is shown in Figure 22.

From the results shown in Figure 22 the following observations can be made:-

1) The heatsink stabilised at +36 deg. C.
2) The Front End internal air continued to slowly cool even after 60 minutes of operation.
3) The Peltier cell never stabilised at the thermostat setting of 0 deg. C, instead the final temperature of about +5 Deg. C was obtained. This is also slightly above the 2 Deg. offset between the thermostat and the PT100. A temperature of about +2 C was expected.
4) The cooling system has reached its performance limit where the maximum differential between the ambient temperature and the Front End internal air temperature is about **12 Deg. C**, (17 – 5).

4.2.4 Front End Thermal Test 4

The higher speed fan was also tried on the Front End cooling system. For reference, this fan is the YX2513 with ball bearings, operating speed of 3000 rpm and airflow of 34 cfm. The thermostat was again set to 0C with the expectation the Front End internal air should reach +2C. The results of the measurement are shown in Figure 23.

Figure 23 provides the following observations:-

1) The Front End internal air stabilised at +3 degrees C.
2) The heatsink temperature stabilised at about 30.5 degrees C which is 6 degrees below the result with the slower speed fan and airflow of 28 cfm.
3) The Peltier cell did not cycle indicating the system has reached its achievable limit of performance.

4.2.5 Front End Thermal Test 5

It was never anticipated the large mass of the Front End diecast aluminium enclosure should be cooled to a temperature as low as +5 deg. C. The author anticipated a more realistic temperature would be about +15 Deg. C. Therefore a measurement was performed with the thermostat set to about +13.5 C which would cool the Front End to about +15 C due to the offset between the thermostat and the PT100 probe. The benefits of the higher speed fan with 34 cfm was also considered significant to redesign the system for the Front End cooling and continue to use this model fan. The measured results with the thermostat setting to obtain +15 C inside the Front End is shown in Figure 24. From Figure 24 the following observations can be made:-

1) The Peltier cell began cycling within 7 minutes of operation.
2) The Front End internal air temperature stabilised at +14.6 degrees C.
3) The heatsink temperature varied between +18 C and +30 C.
4) The thermostat cycle times were about 3 minutes on and 7 minutes off.

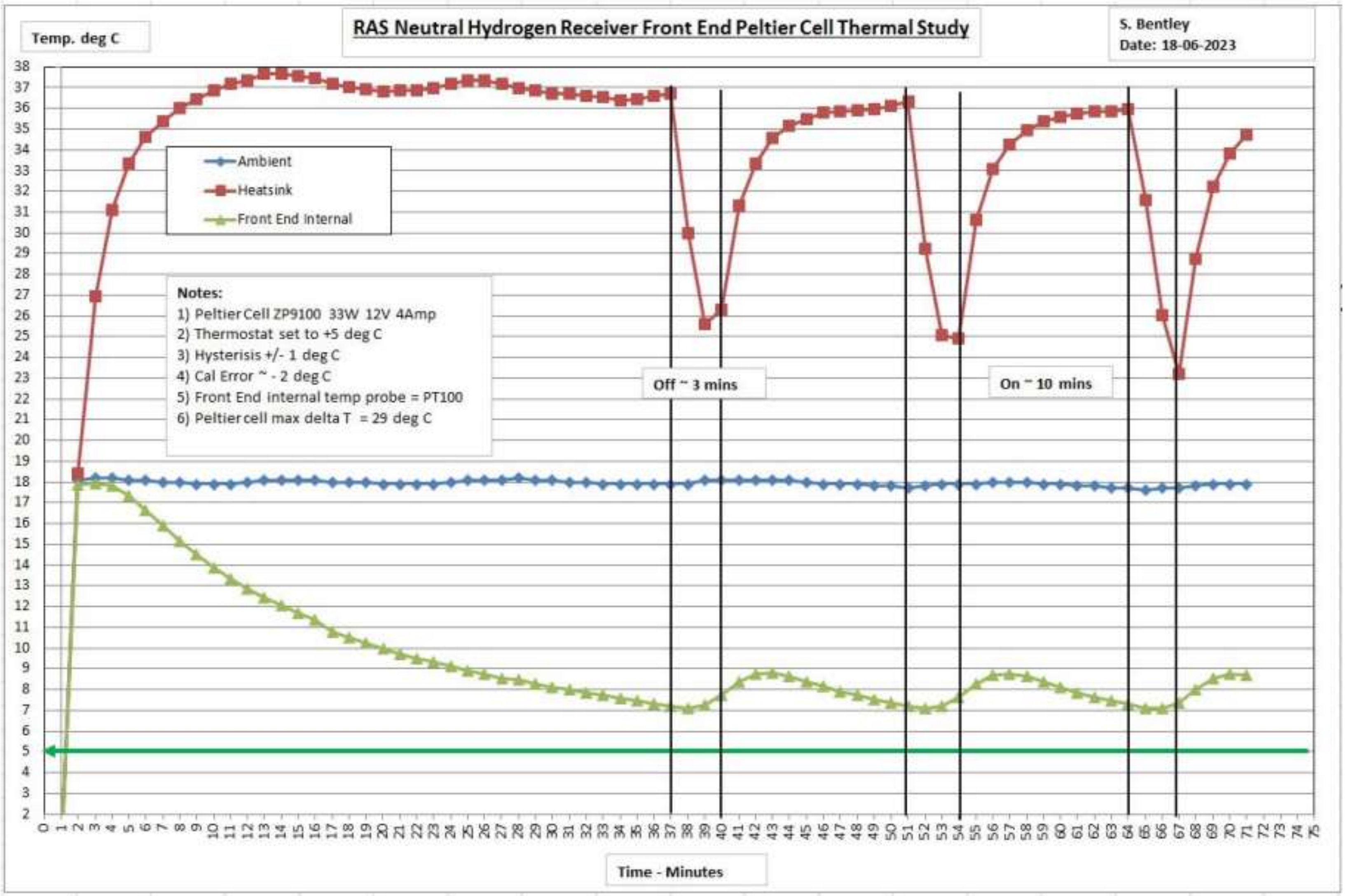


Figure 20. Front End Peltier Cell Cooling Measurement Study -1

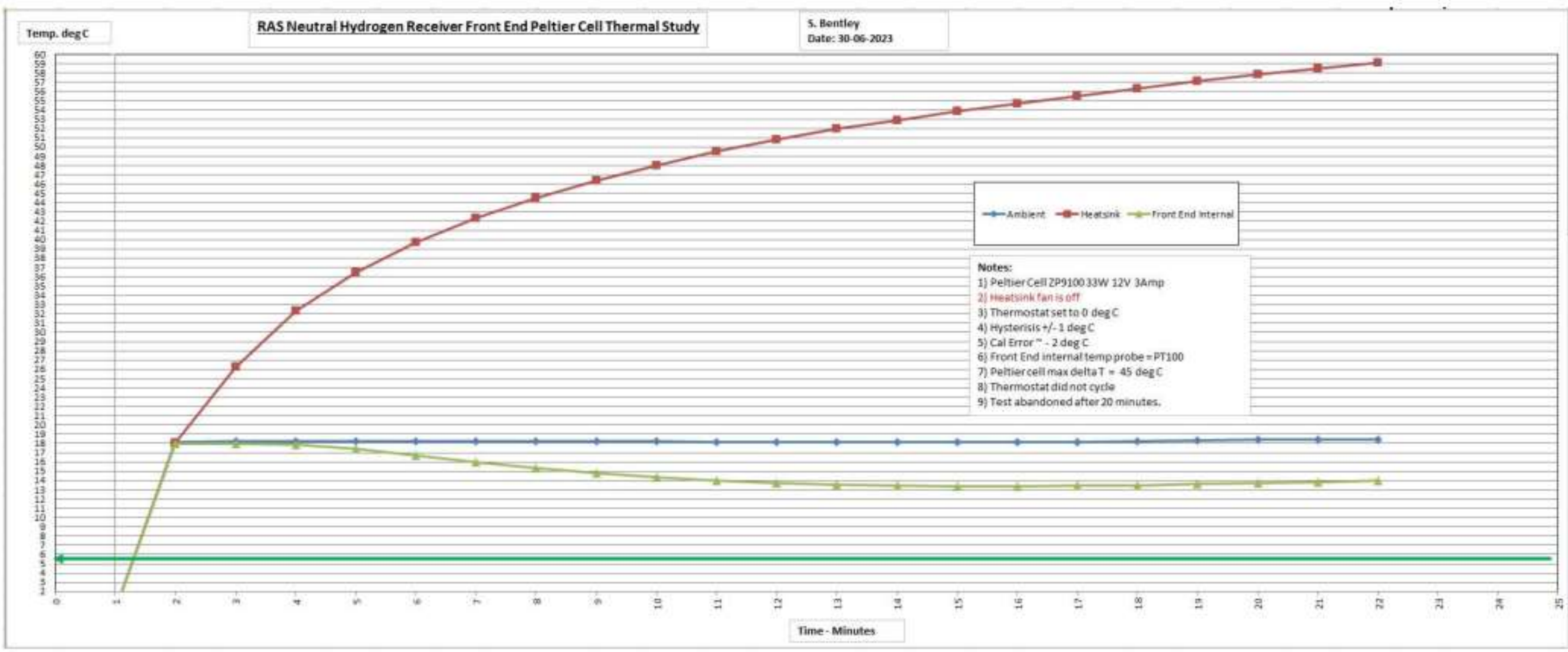


Figure 21. Front End Peltier Cell Cooling Measurement Study -2

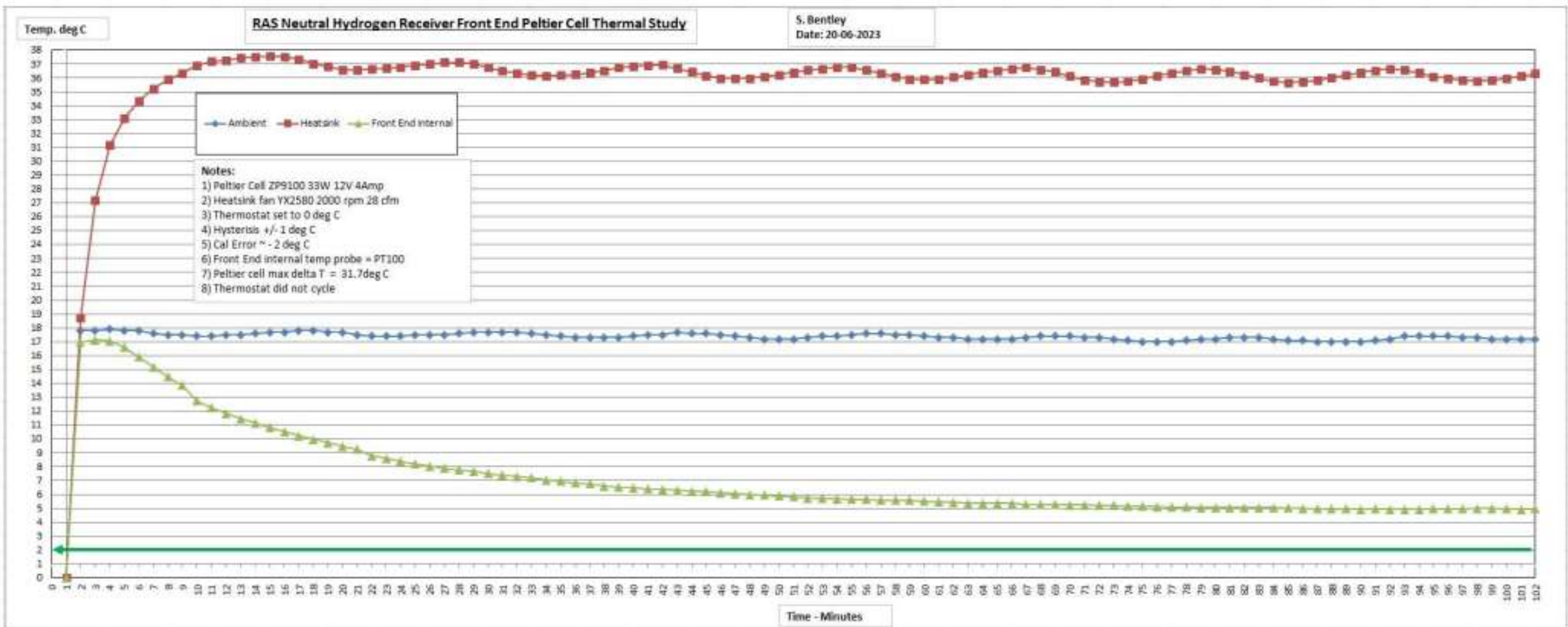


Figure 22. Front End Peltier Cell Cooling Measurement Study -3

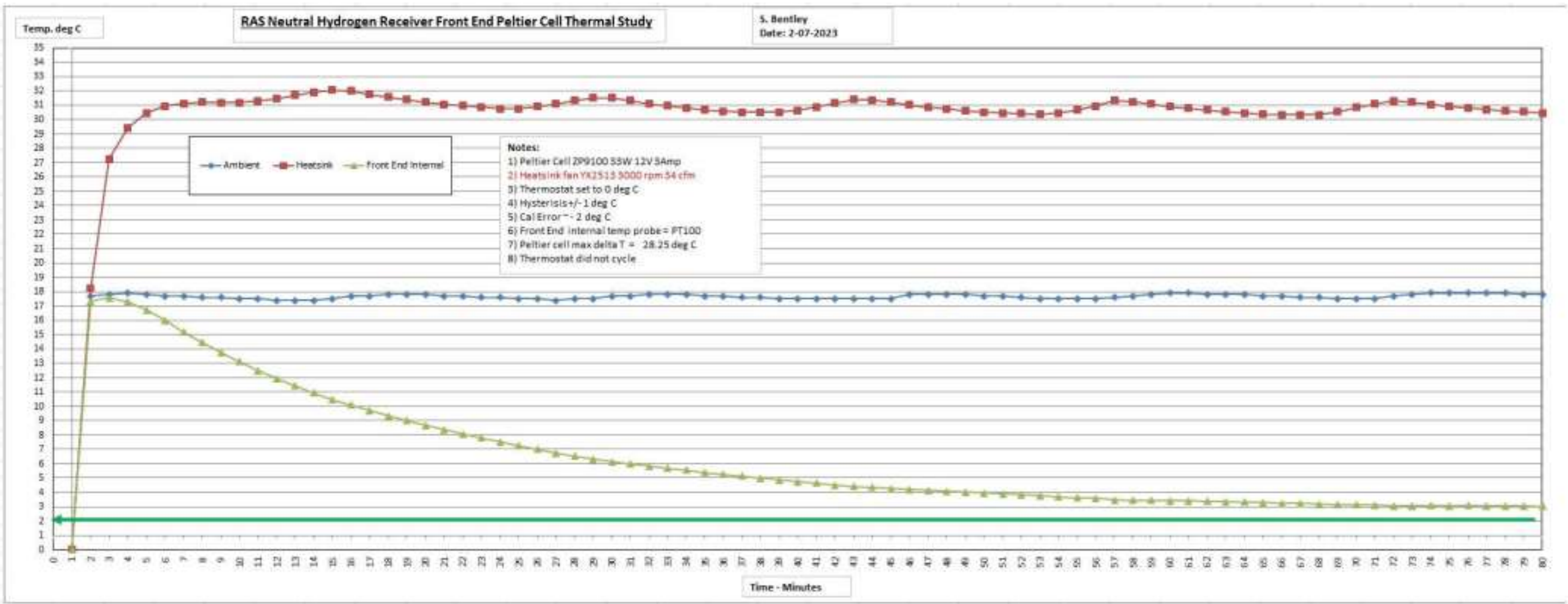


Figure 23. Front End Peltier Cell Cooling Measurement Study -4

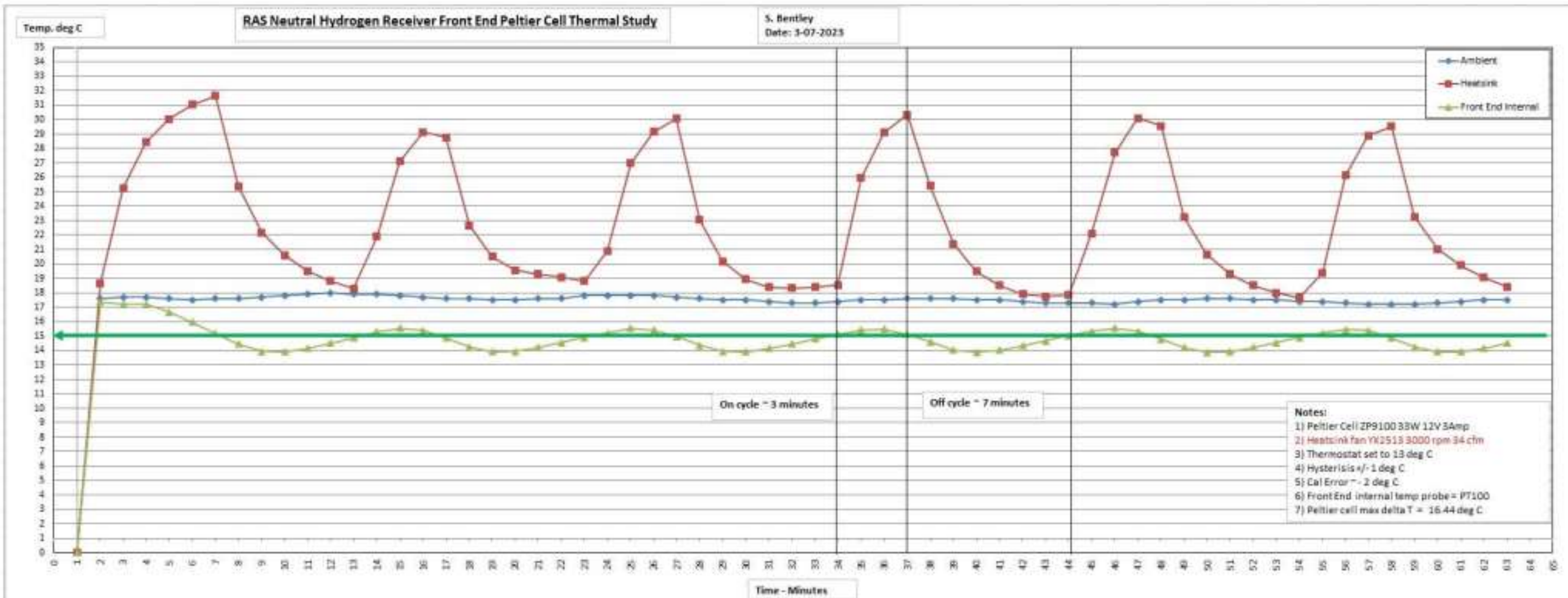


Figure 24. Front End Peltier Cell Cooling Measurement Study -5

5.0 Conclusions

The Peltier cell cooling system proposed for the neutral Hydrogen receiver LNA and Front End circuits will be effective at stabilising the receiver components which will be installed in the custom cabinet at the feed-point on the RAS dish antenna. The stabilisation however will have limitations. The LNA temperature differential between ambient can achieve better than 17 degrees therefore it is anticipated the LNA may be cooled to +5 degrees C and maintain that temperature up to at least an ambient temperature of +22 degrees C. The limit point of the Peltier cell was not found during the experiments in this report and it may be possible to maintain the LNA at +5 C for much higher ambient temperatures than +22C.
Based on the climate statistics at Heathcote, it is reasonable to expect on average the maximum air temperature will remain below +22 C between mid. March and mid. October or 8 months. During this period however the lowest temperature may drop below +5 C at night to as low as + 3 C. It is not yet clear if the LNA temperature will track the ambient below +5 C as the internal circuits of the LNA will generate a small amount of heat. This phenomenon was observed during the thermal experiments however not recorded. The LNA dissipation is about 1 watt.

The Front End Peltier cell cooling is less effective since the large diecast aluminium enclosure is more difficult to cool. However, based on the measured results it is reasonable to expect the Front End can be cooled by at least 12 degrees C below ambient. This means it should be possible to maintain +15 C up to an ambient of +27 degrees C. Based on the climate statistics at Heathcote, the average maximum ambient air temperature is below +27 degrees from mid Feb to early Dec (9.5 months). Of course when the ambient temperature drops below +15 C the Front End will begin to track the air temperature. Like the LNA, the Front End will self-heat since the internal power dissipation of about 4 watts will warm the enclosure. Therefore an extended range below an ambient of +15 C is anticipated.

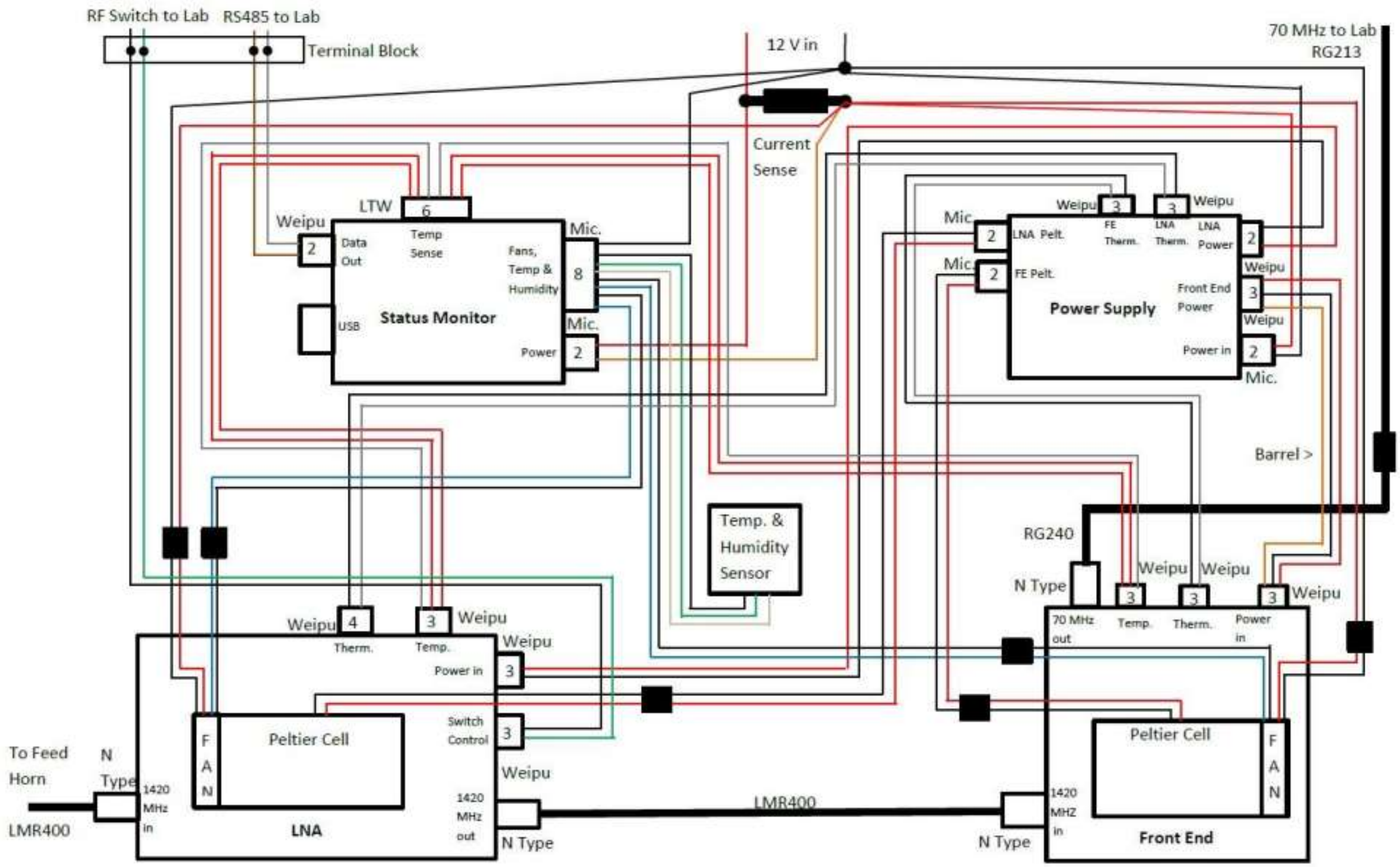
Left unchecked the temperature drift of the LNA and Front End combined will cause the receiver to vary in gain by up to 2.7 dB on average and up to 4 dB with extremes of ambient temperature.
If we assume neutral Hydrogen surveys are confined to the cooler months of the calendar year we can expect to perform very stable measurements for at least 8 months if not more. During the cooler months we have the potential to keep the component temperature drift to less than 5 degrees for the LNA and less than 19 degrees for the Front End.
Therefore the gain variation on the LNA can be kept below 0.18 dB (5 X -0.036) and 1 dB (19 X -0.055). In total this means the worst case drift would be 1.18dB. This is a significant improvement on 4 dB.

The application of the Reference Noise Generator will provide a highly temperature stable signal reference which is almost independent of temperature. Therefore the already reduced variation in receiver gain managed by the Peltier cell cooling can be enhanced further by regularly comparing a measurement with the Reference Noise Generator.
The slight offsets caused by the residual receiver temperature drift can therefore be virtually eliminated.

The weatherproofing techniques employed on each item of electronics should in principle avoid the ravages of water damage. The author has good experience with the application of the Gore-vent device on airtight enclosures and can confirm the absence of any sign of water damage to the internal circuits when the enclosure has been exposed to the weather at Heathcote for more than 5 years. In the re-boxed neutral Hydrogen receiver Gore-vents have been used extensively on any item that contained an electronic circuit. The novelty however is the LNA and Front End enclosures are to be cooled below ambient. There is the potential for condensation to occur however the claims by the Gore-vent manufacturers suggest this is much less of likely as the enclosure is always equal pressure with ambient. The self-heating effect of the circuits will also aid in minimising the formation of condensation. Finally, following the numerous temperature cycling performed on the Front End enclosure during the preparation of this report, the insides of the enclosure was inspected and there was no evidence condensation had formed inside the enclosure.

6.0 Appendix

6.1 Re-boxed RAS Neutral Hydrogen Receiver Wiring Schematic.



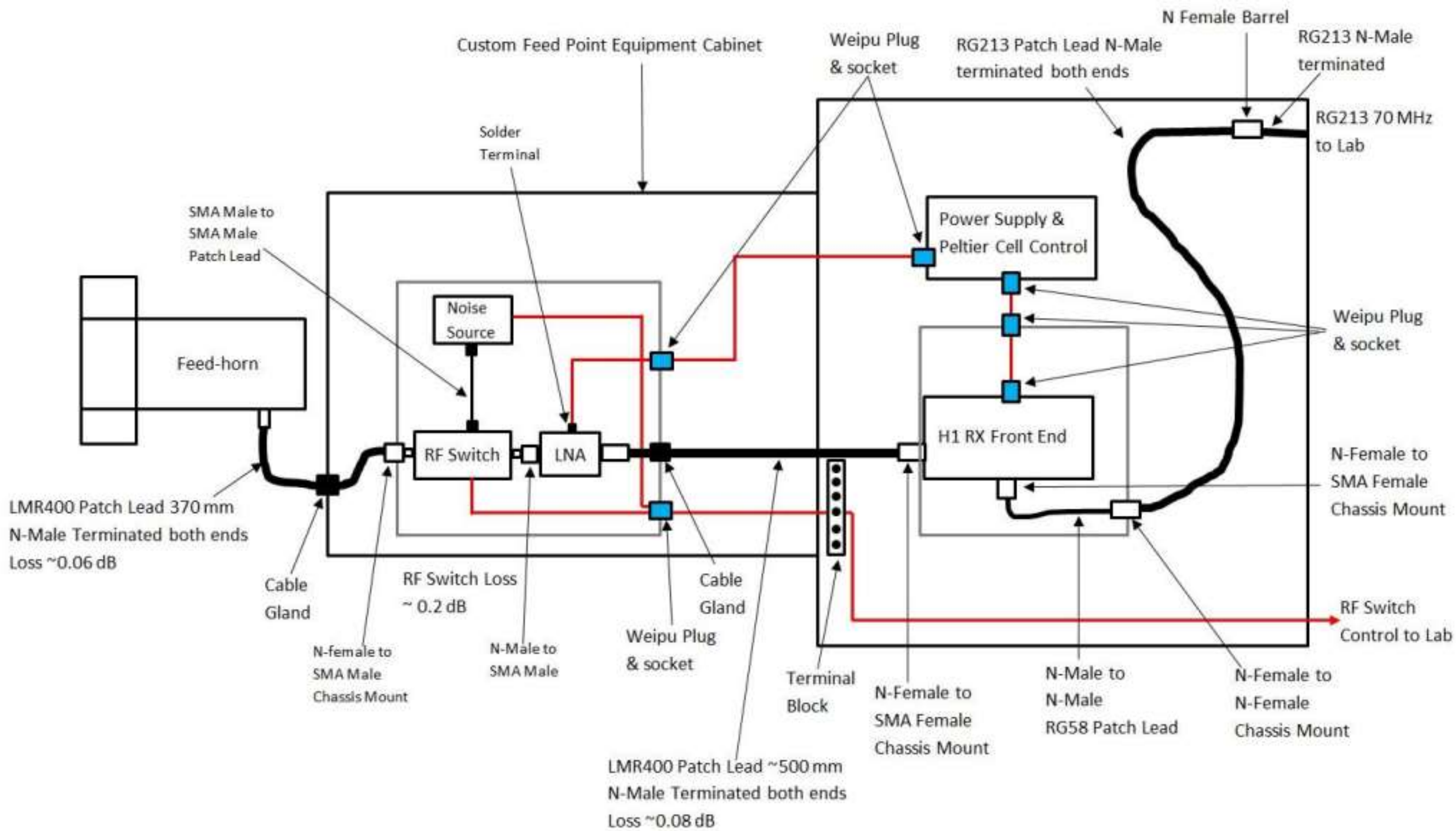
RAS Neutral Hydrogen Receiver Front End Wiring

Drawn: Stephen Bentley

Date: 7 April 2023

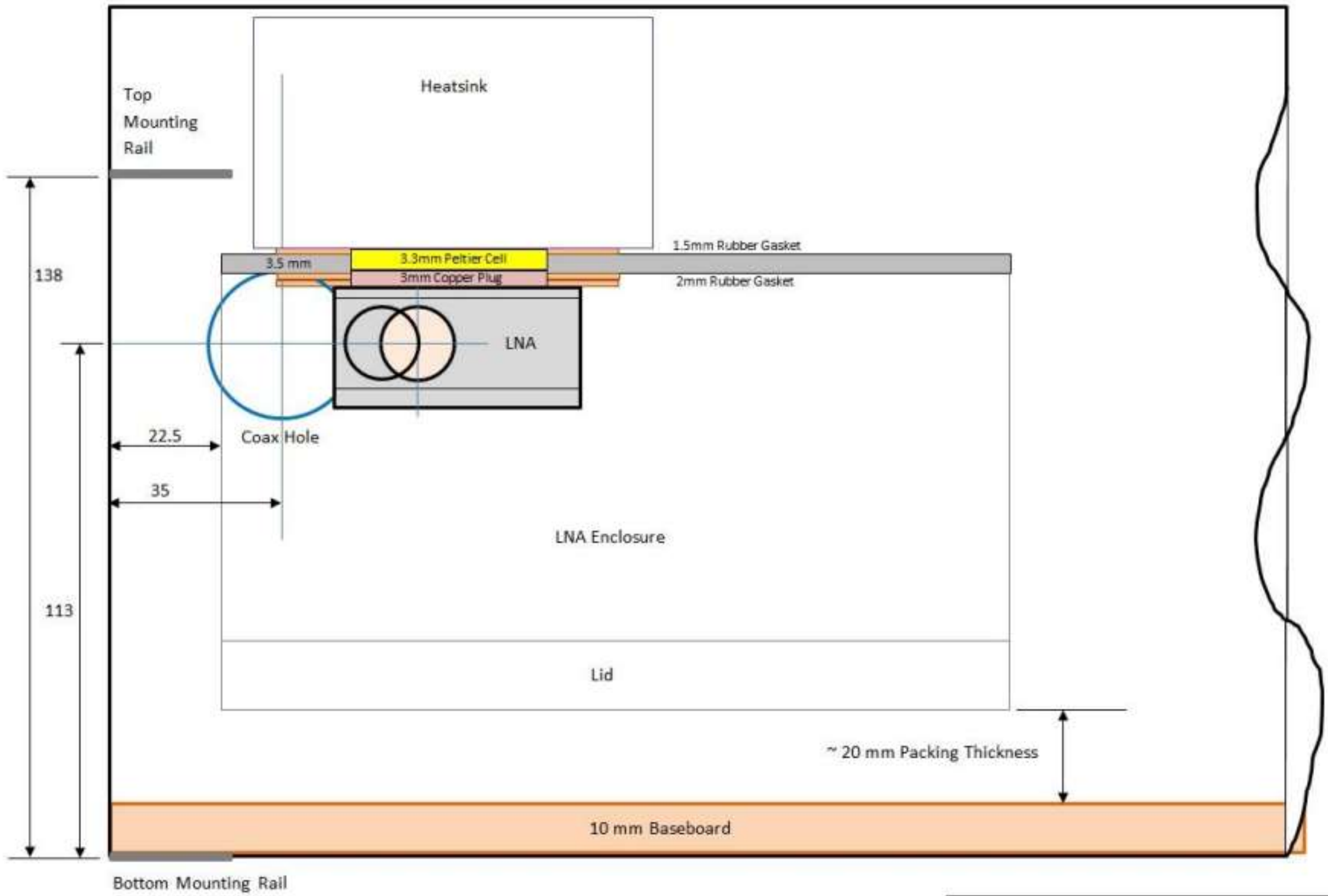
6.0 Appendix

6.2 Re-boxed RAS neutral Hydrogen receiver RF and power wiring in custom cabinet.



6.0 Appendix

6.3 LNA enclosure mounting plan within custom cabinet.



Scale: 1:1

RAS Neutral Hydrogen RX LNA Enclosure Mounting Plan
Drawn: Stephen Bentley
Date: 5th April 2023

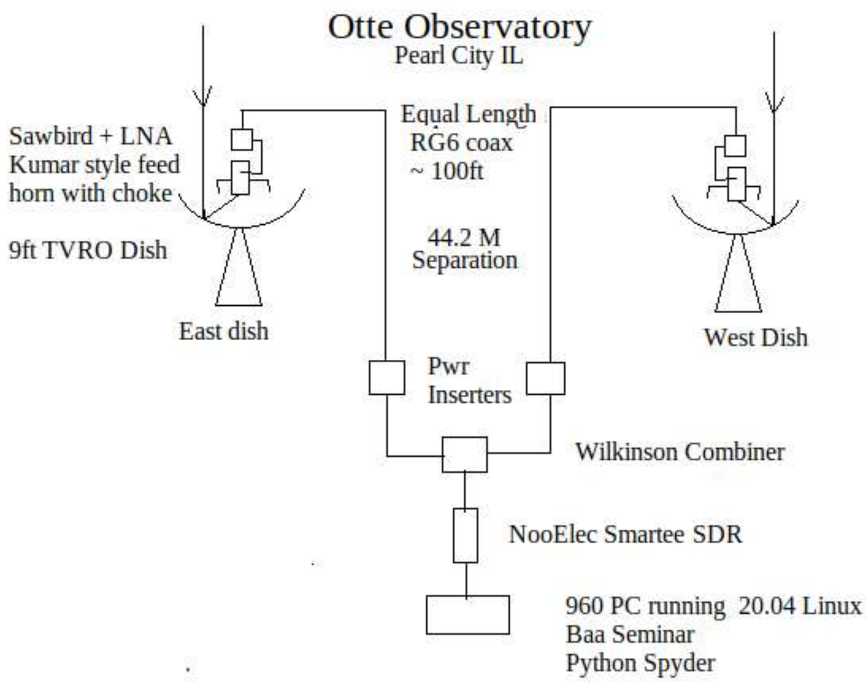
Observations

Simple Adding Interferometer Results

By Mike Otte
Otte Observatory
42.2N 89.9W
mike.otte96@gmail.com

Abstract:
These are the results from a 1950's style adding interferometer. Two TVRO 9ft dishes were spaced 44.2 meters apart in an E-W baseline and aimed south. At first only fringes of the Sun were possible but through development and tuning of the system several sources are now visible.

Description of Telescope:
The two dishes were mounted on solid bases with declination adjustable. One of the bases was movable for future experiments. Kumar style feeds were made and mounted on the dishes. Several LNA's were tried but the current results are using NooElec sawbirds+ mounted in a 1 lbs coffee can inches from the N connector probe on the circular feed horn. Two equal lengths (100 ft) of RG-6 cable bring the signal back to the observatory building and they also provide power to the sawbird+ LNA's. Power inserters are inline to send the 5vdc power out. Two short equal jumpers connect the power inserters to the Wlikison combiner where the signals are added. Finally, a short jumper sends the signal to the SDR. The SDR is mounted on a big piece of aluminum in a small Peltier refrigerator to control its temperature. A Dell 960 running Ubuntu Linux 20.04 takes the signal and stores it using BAA Seminar software. Python 3 using the Spyder IDE analyzes the data and graphs it.



Intro to Interferometry:
At the longer wavelengths of radio astronomy, it is harder to form an image of the sources we are trying to define. Visually we would be proud of a 1-meter optical telescope. Radio wise a 1 meter "scope in a box" has a 15 degree HPBW (half power Beam Width) which means what we are trying to measure is vaguely "somewhere over there". So, we need a bigger antenna. A 9 ft dish has a HPBW of ~ 5 degrees. The amateur can't afford a 100 meter dish which is about 9 arcminutes. By putting smaller antennas spaced out and covering the 100 meters, you lose sensitivity but gain the resolution. Now you can tell better where radio things are and how big they are.

What I am doing is exploring in the 1950's style simple adding interferometer and is just 2 dishes separated by a variable distance. When the signals are added together, they create a sinusoidal interference pattern just like the optical interferometer. By measuring the period and knowing the number of wavelengths in the baseline you can calculate the declination of the source. Also, by measuring the peak to peak of the response the "visibility" can be calculated. Where this visibility is highest is where the source is, and you can tell that to within a couple minutes of arc.

Some minor math:
Resolution of the interferometer in radians = 1.22 * wavelength / baseline

for the 3 M dish: $1.22 \times .21 \div 3 \times 57.3 = 4.89$ deg

for my interferometer with baseline of 44.2 M: $1.22 \times .21 \div 44.2 \times 57.3 = 0.33$ deg

Fringe rate = Baseline / wavelength *angular rotation of earth * cos declination

Fringe period = $(44.2\text{ M} / .21\text{M} * 7.3 \times 10^{-5} * \cos 40)^{-1} = 84.96$ sec

I have not done anything with visibility.

Source List

Source			RA	Dec	Flux	Fringe P
Cas A	W81	3C461	23:23	58:48	2240	126
	W80		20:55	44:03	550	94
Cyg A	W57	3C405	19:59	40:44	1255	86
Tau A	M1	3C144	05:34	22:00	926	69
NRAO608	W51	3C400	19:23	14:06	710	
Virgo A	M87	3C274	12:30	12.3	198	67
Orion A	W10,M42	3C145	05:35	-05:25	520	68
NGC6618	W38		18:20	-16:10	1060	68
Sag A	W24		17:45	-27	3650	73
Sun						

Most of the following graphs are made using Python and screen shot software.

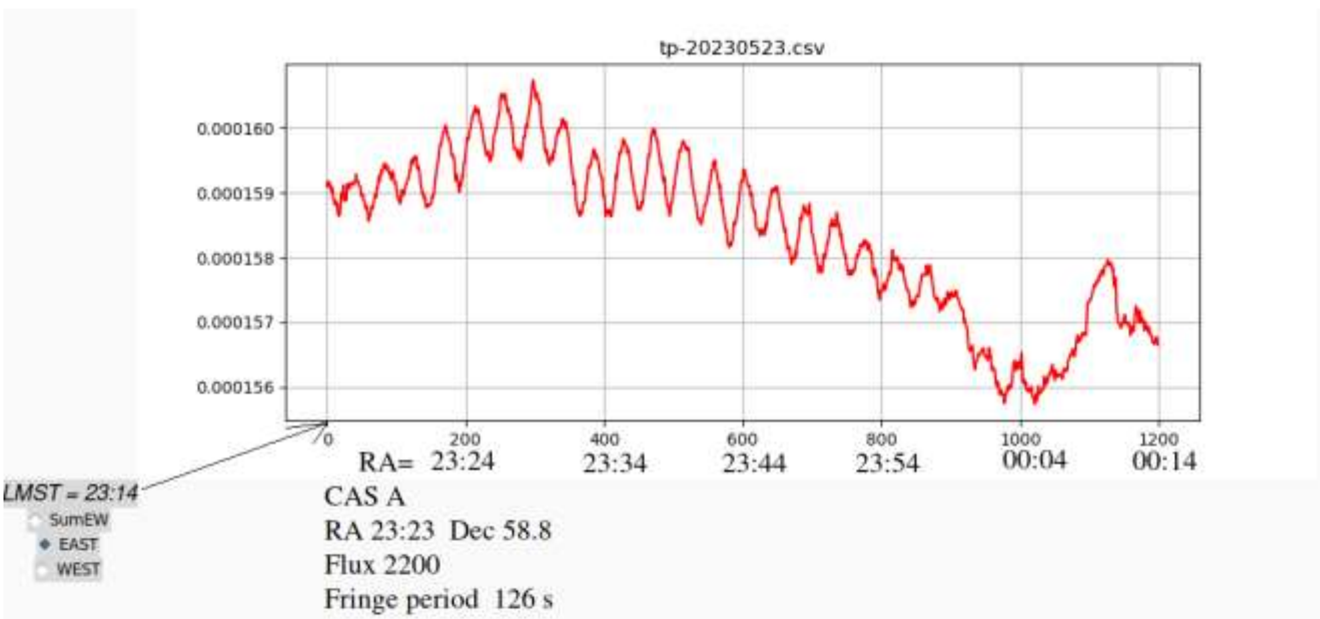


Image 1: The data below the graph is from the Source List. Sampling period is 3 secs so 200 samples equal 600sec or 10 minutes. So counting peaks or valleys between 2 ticks (10 minutes), I count about 4.75 which figures out to the 126 s Fringe Period. The change in power at 23:30 happened the previous day too and may be because of radio interference (desensing). The "brightness" is the peak-to-peak measurement not the "total power" measurement.

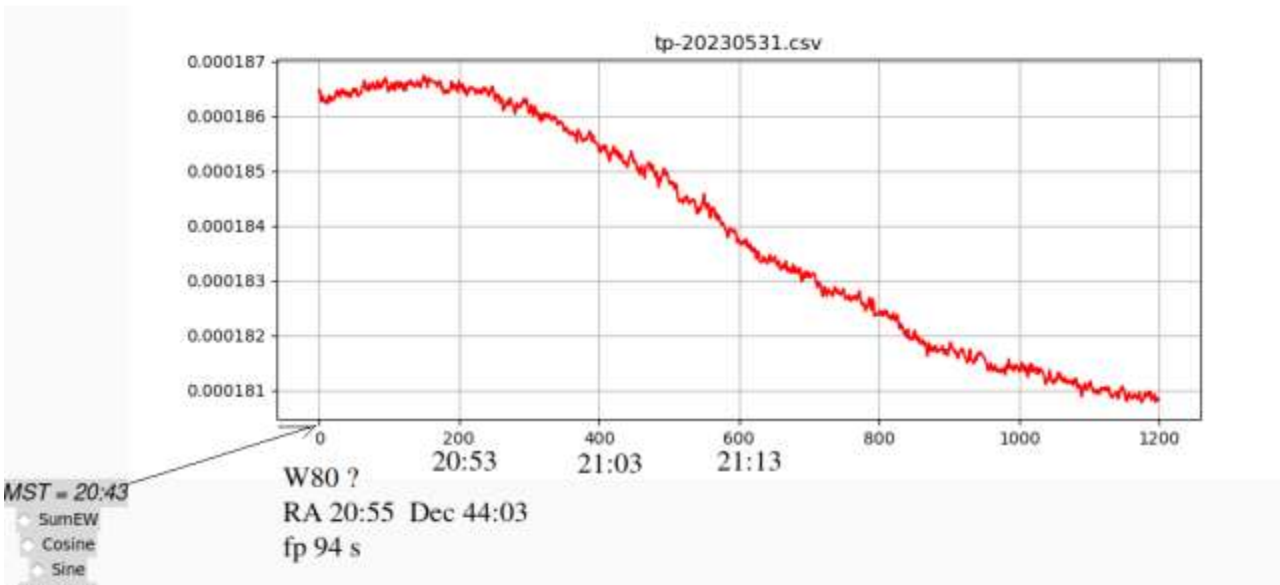


Image 2: This was an attempt to get W80 but W80 was shy. There is a wiggle after 21:03 and the interferometer is not calibrated for time, but it is close.

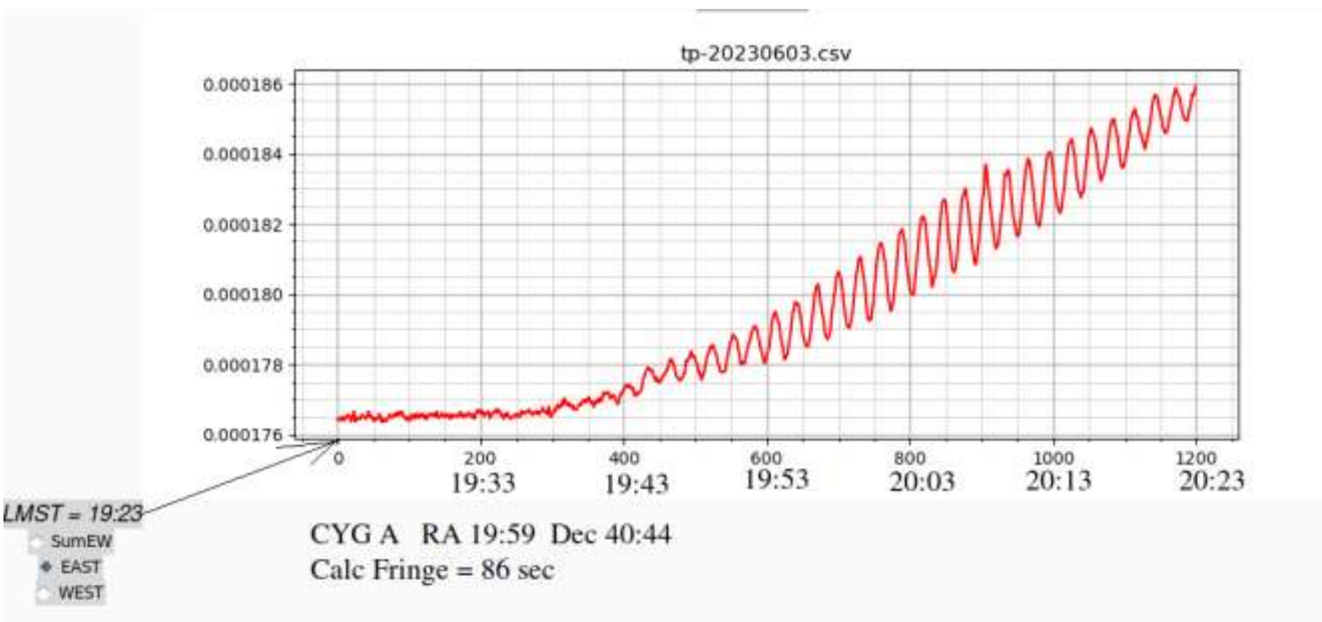


Image 3: Cyg A is showing in a fine example with features. Note at the beginning there is some noise in the signal, but it doesn't take long once the oscillations start for the noise to disappear. Counting valleys, I get 7 and 600 sec / 7 = 85.7sec which is the fringe period shown in the BAA seminar software. Also note the peak-to-peak amplitude increases and then decreases which is the "brightness" value. At 20:08 note the sharp top of that oscillation. This is where the phase reverses as the interferometer passes the source. It is not usually this apparent but shows up as a flaw in the trace.

Image 4: This is a little different graph presentation using a screen shot of BAA Seminar total power screen itself. Taurus A is not giving the "perfect" profile shot but all the features shown in the Cyg A graph are here also. The fringes are harder to count but I get between 8 and 9 so 600/8.5 = 70.5 s. The phase change imperfection is at about 1000 on the seconds scale or maybe the tall one at 500. Can't get much brightness data off of this.

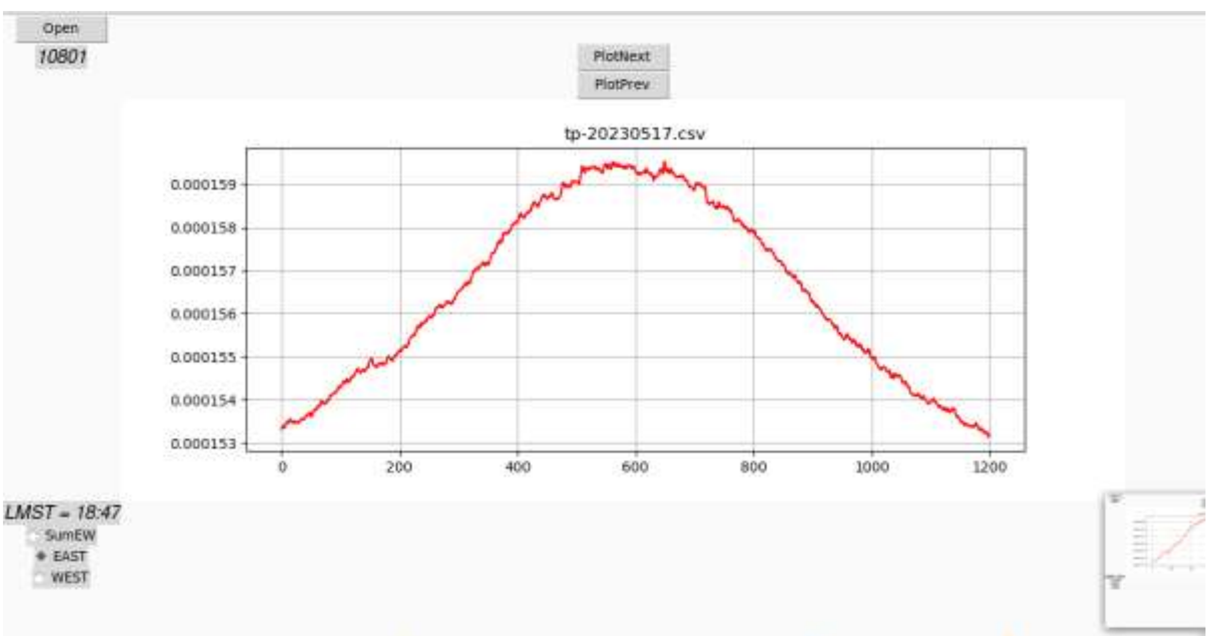


Image 5: NARO608 did not cooperate.

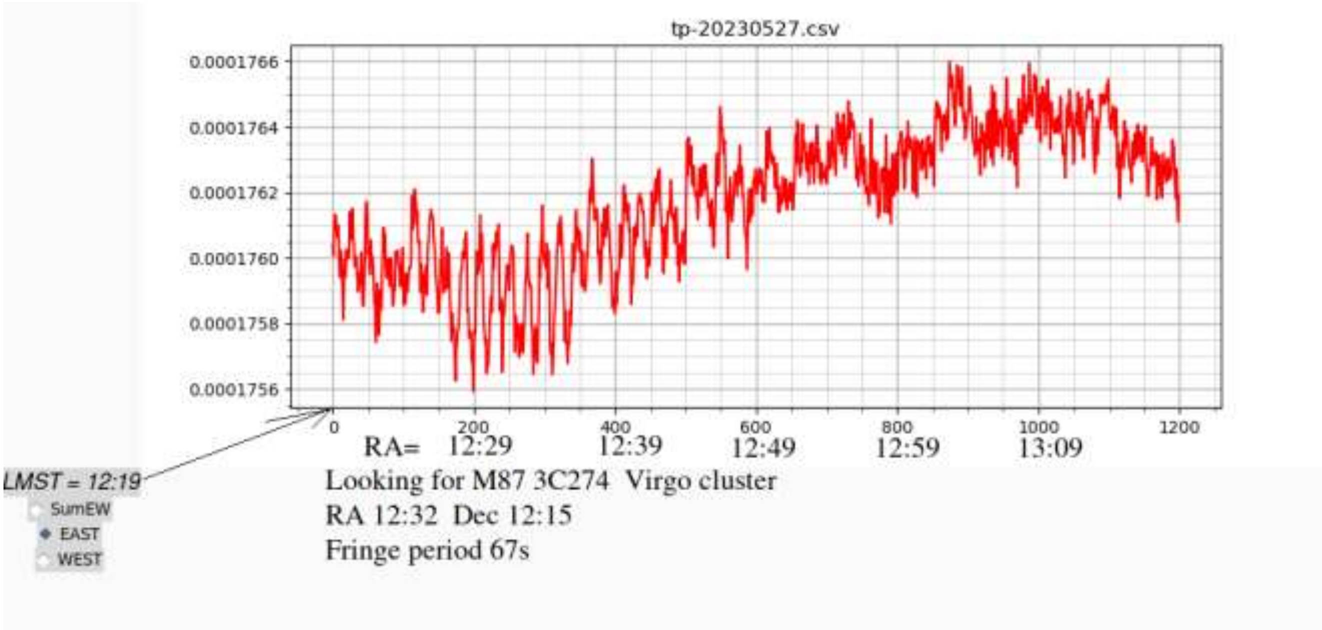


Image 6: Virgo is a weaker one in this group but definitely wants to be seen. I count about 9 peaks which gives the suggested fringe period.

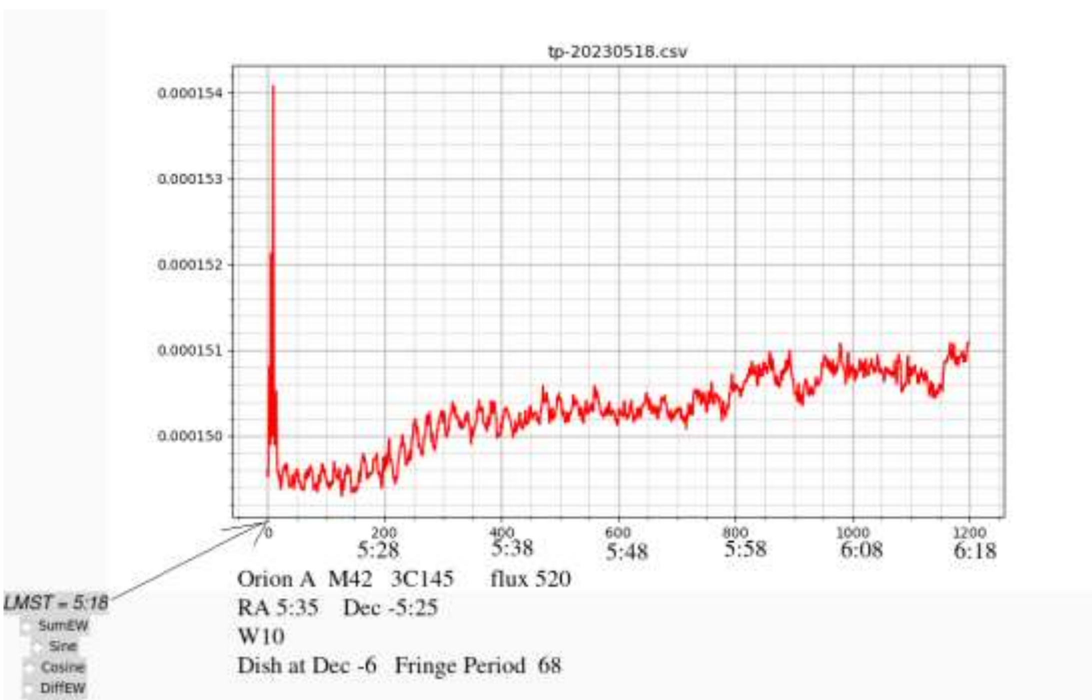


Image 7: Orion A is very apparent. Flux is not always an indicator of possible or impossible to catch.

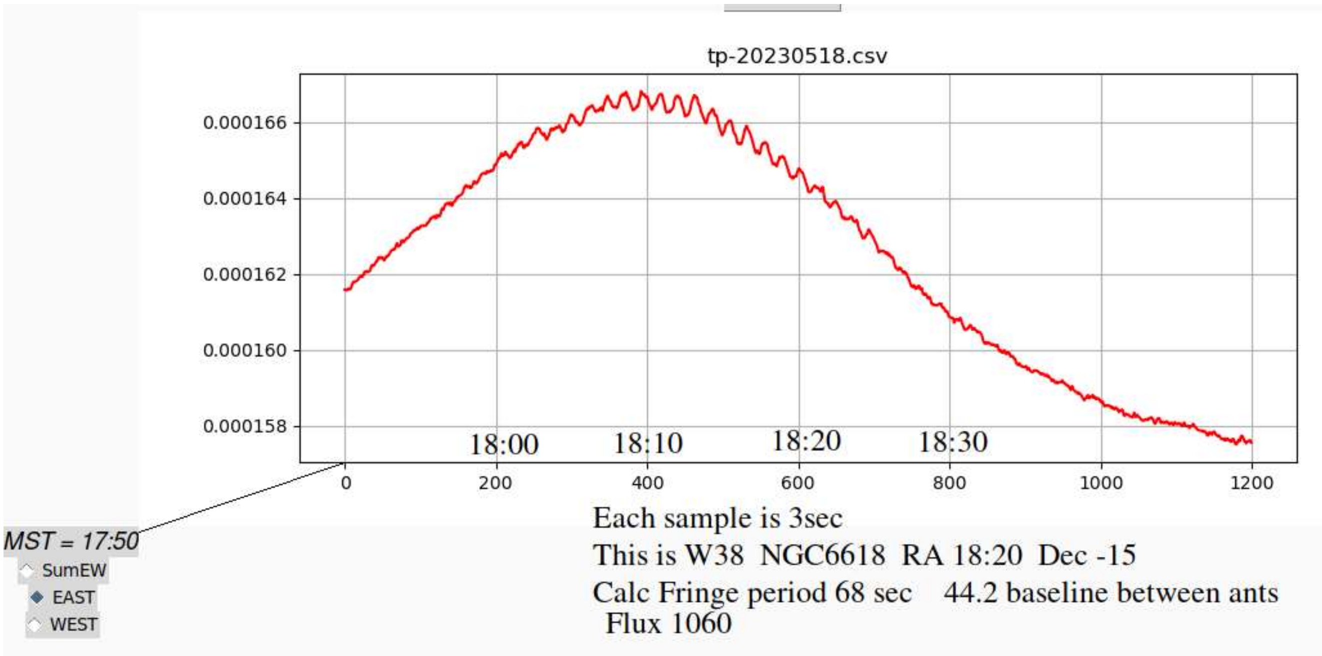


Image 8: NGC6618 is a nice catch.

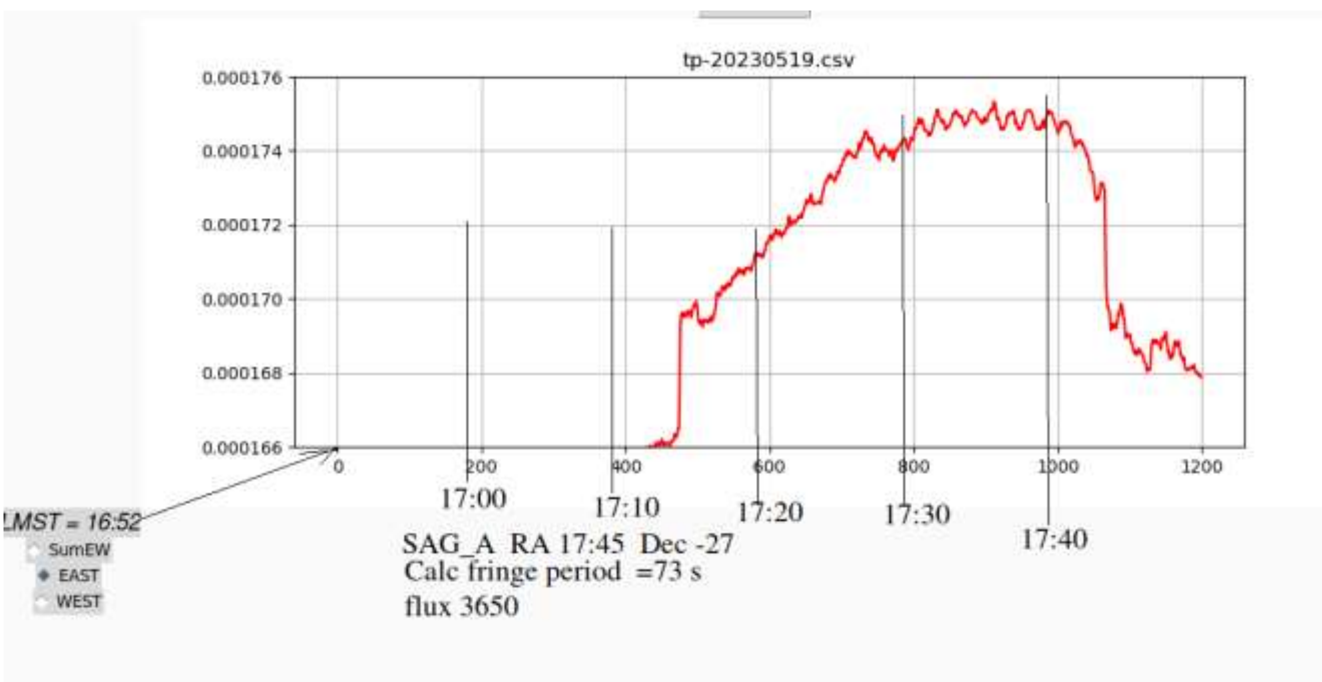


Image 9: Sag A is no easy catch.

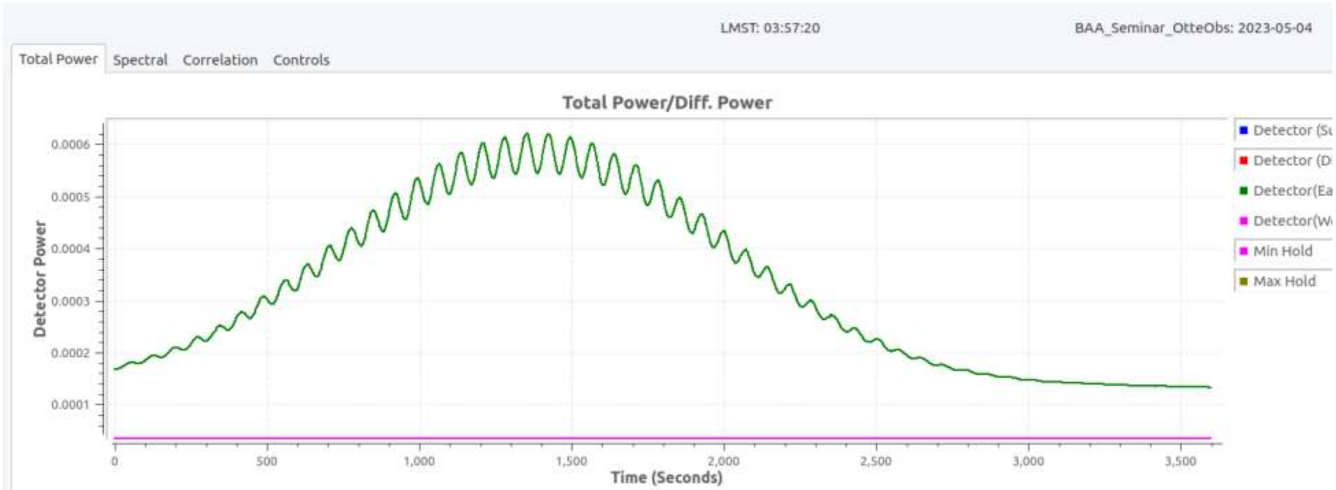


Image 10: The Sun is always a good performer.

So far these are drift scans of the various sources. So, I wondered if the interferometer geometry improved the declination resolution any? Also, would it be possible to make a raster scan image from a series of data? Moving declination in degree increments, I conducted the following series of observations. The interferometer locks on even at twice the HPBW of the individual dishes but the visibility definitely changes.

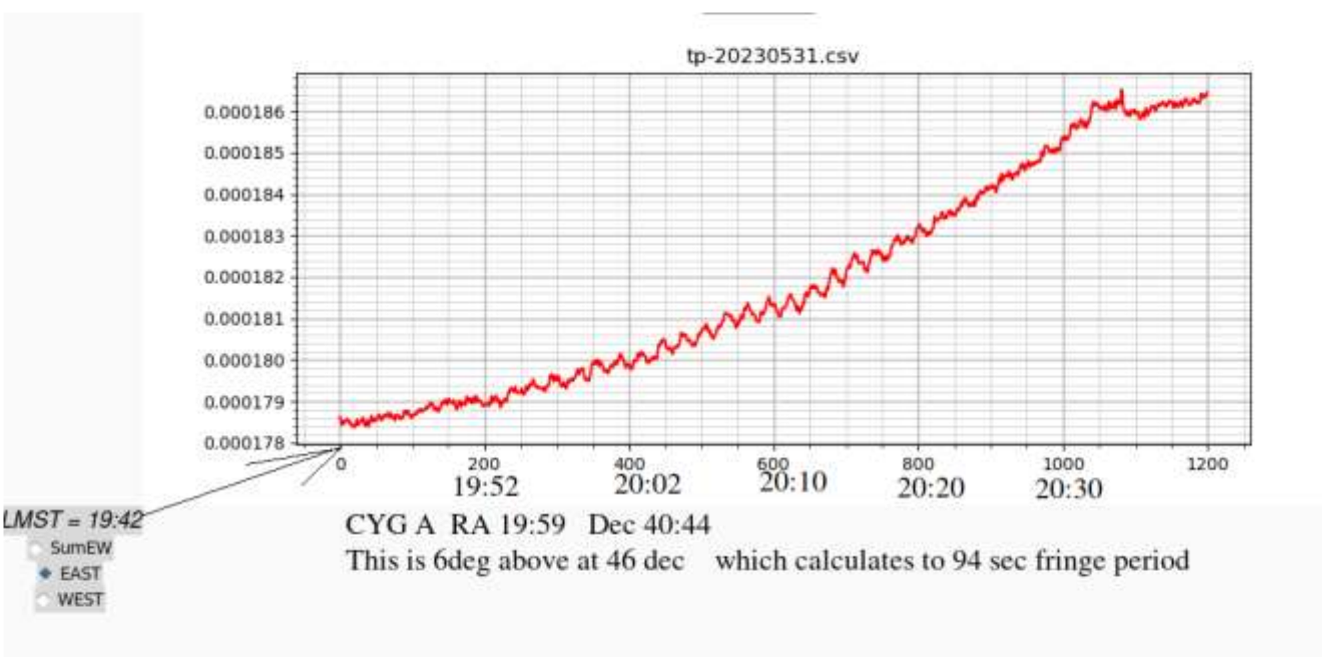


Image 11: This is 46 deg declination.

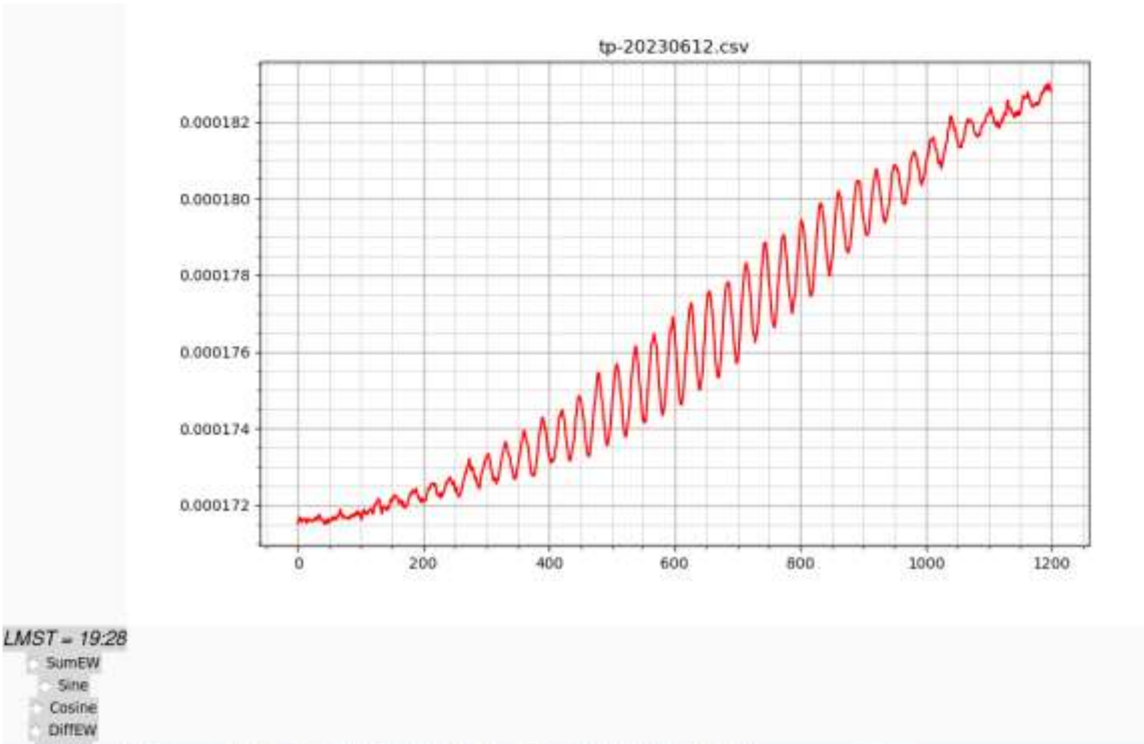


Image 12: This is 43 deg declination.

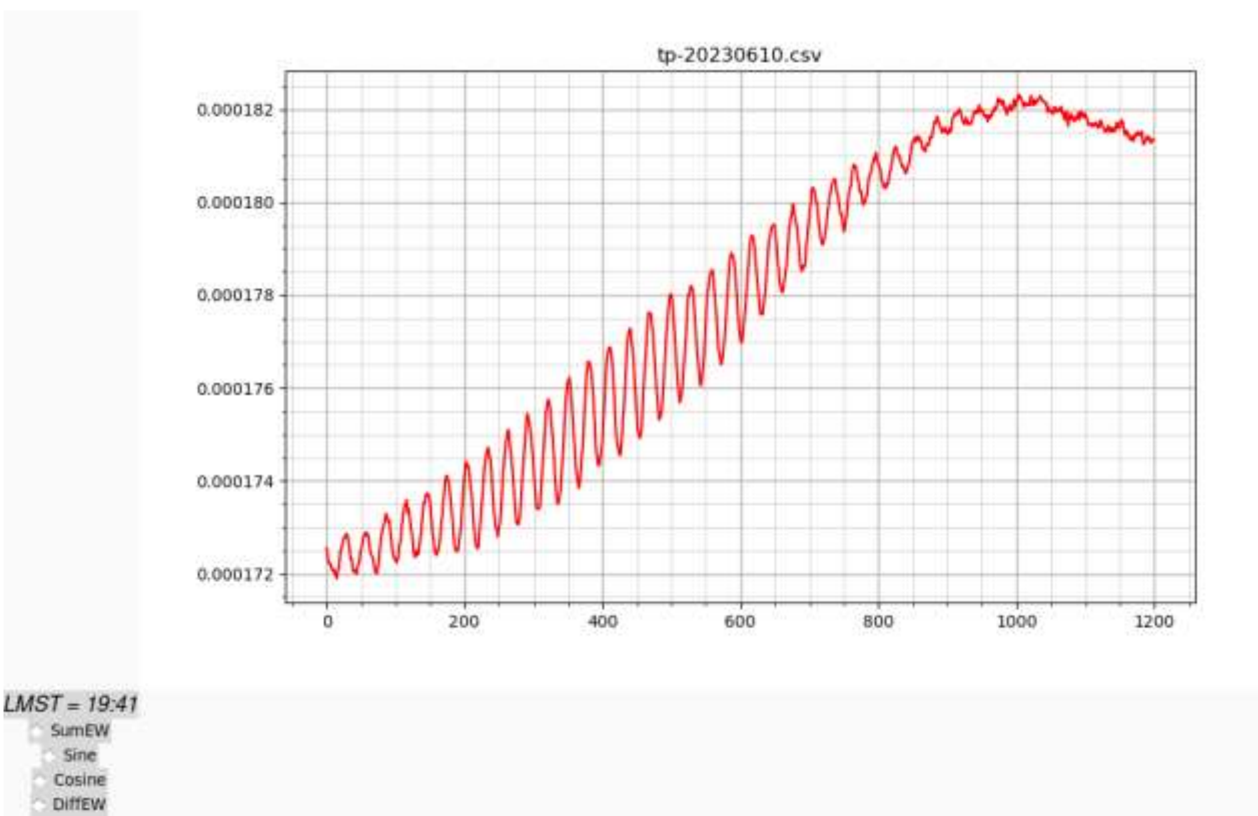


Image 13: This is 42 deg declination.

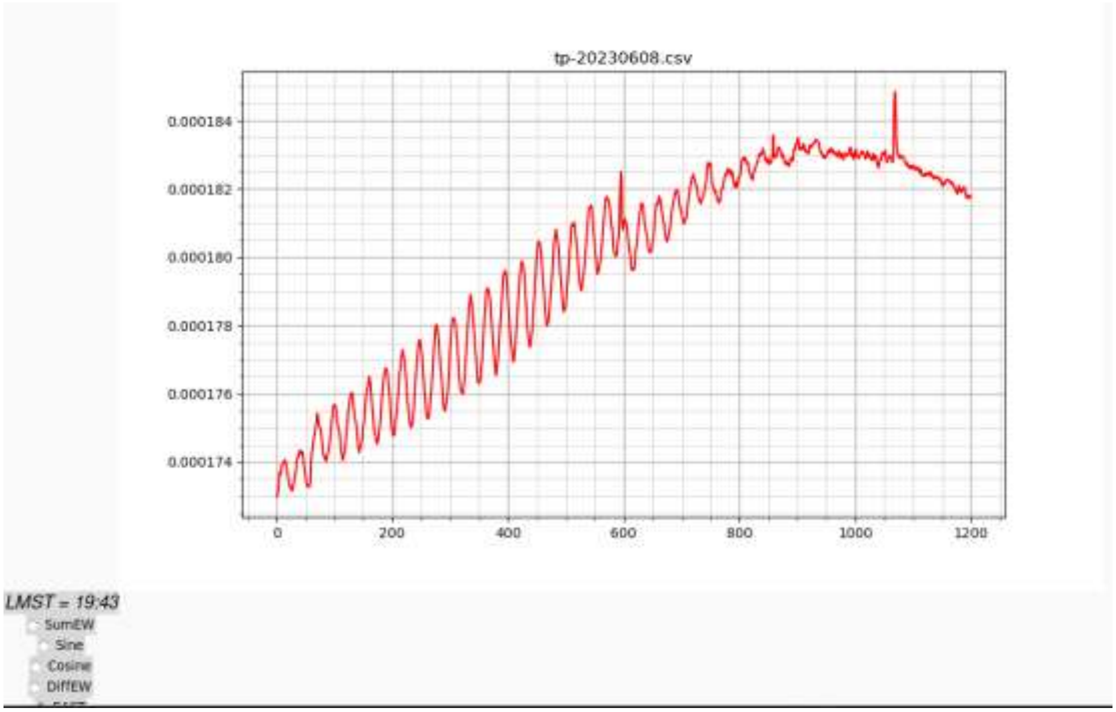


Image 14: This is 41 deg declination.

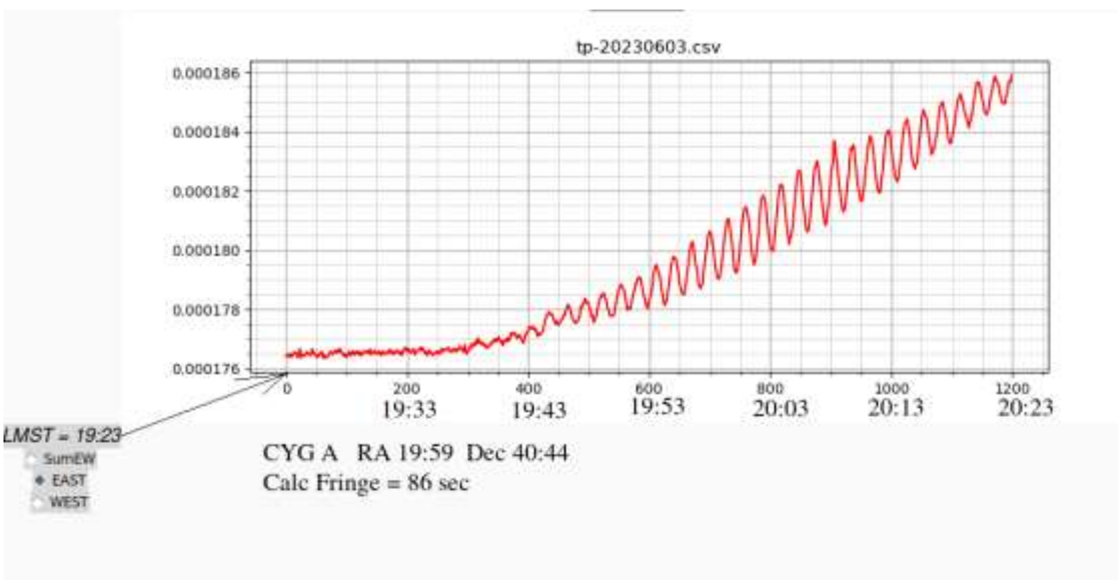


Image 15: This is 40 deg declination.

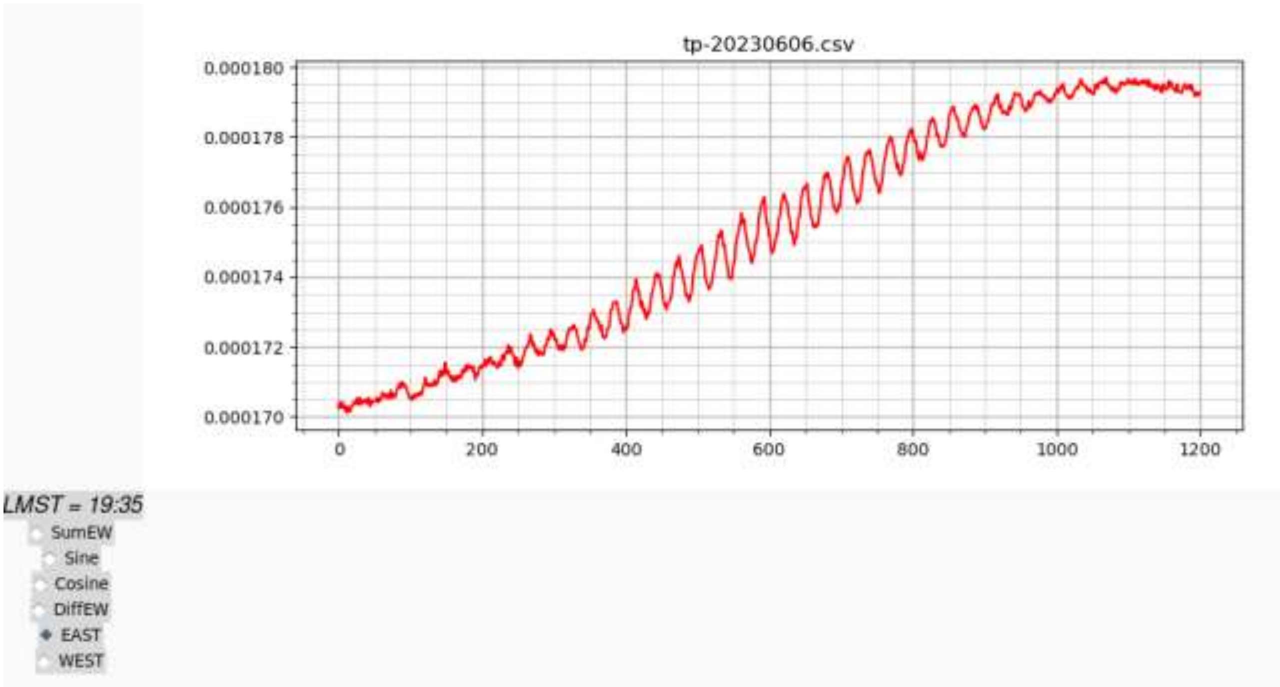


Image 16: This is 39 deg declination.

Type II and Type V Solar Radio Observed in Alaska

Whitham D. Reeve

Soon after the start of the UTC day on 15 July 2023, the Sun produced Type V and Type II radio bursts that were received at the HAARP Radio Observatory near Gakona (figure 1) and also at the Cohoe Radio Observatory, both in Alaska. The Type V consists of Type III fast sweep radio bursts followed by an interval of continuum emission. Type III radio bursts frequently precede Type II slow sweep radio bursts and did so here. In turn, Type II bursts may also involve Type IV emissions but, in this case, the Type IV did not exist or was too weak to be seen in the recorded spectra.

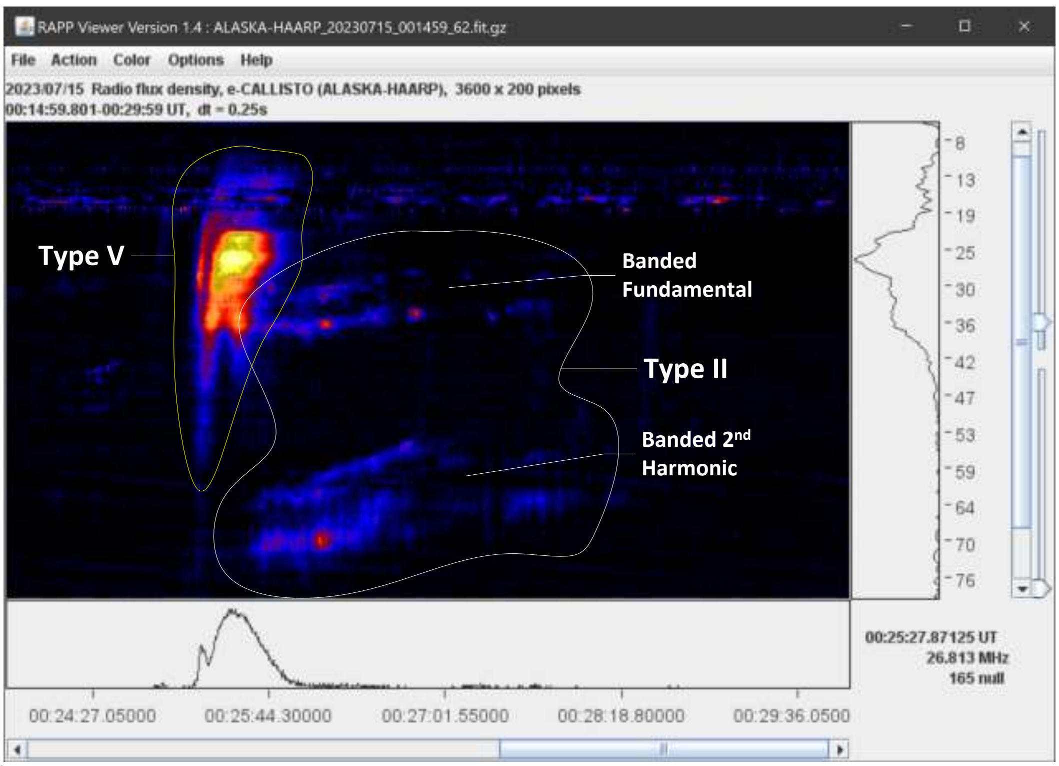


Figure 1 ~ Annotated spectrogram showing overlapping Type V (yellow line) and Type II (white line). The Type II has a fundamental and 2nd harmonic, both with a split-bands. The horizontal scale shows time in UTC and the vertical scale shows frequency in MHz. The cursor position (not visible) is at the center of the Type V with corresponding relative intensity traces below and to the right.

These radio phenomena are associated with solar flares, which are explosive events in the Sun's chromosphere. Flares most often are related to instabilities in the solar magnetic fields near or part of a sunspot. The frequencies of solar radio emissions produced by flares depend on the electron density (and associated plasma frequency) and magnetic field intensity where the emissions are produced; for emissions in the HF and VHF bands, such as those discussed here, the locations usually are above a sunspot in the Sun's corona. The emissions are mostly unpolarized.

The Type III bursts are thought to be produced by relativistic (near light-speed) electrons accelerated by flare energy release. These electrons tightly spiral around strong solar magnetic field lines and their accelerations produce a beam of electromagnetic emissions. As the disturbance moves outward through the corona, the frequency drifts from high to low in correspondence with the progressively lower coronal electron density. Sometimes a bulb or blob of continuum radiation is observed in the spectra with Type III bursts. The combination of the Type III with the continuum is called a Type V. The Type V follows in time the Type III bursts and may be a trace of the Type III's passage through the corona, or it may be a group of slower electrons that follows a different magnetic field configuration and emits a different spectral signature.

The Type II bursts are produced by the ejection of a huge amount of plasma (billions of tons of charged particles) that forms a magnetohydrodynamic (MHD) supersonic shockwave moving through the Sun's corona at velocities up to a few thousand kilometers per second. The cloud of particles is called a *coronal mass ejection* (CME). Type II bursts can include a 2nd harmonic. The harmonic ratio usually is around 10% less than 2. Band-splitting is often associated with Type II bursts in which the fundamental and 2nd harmonic seen in the dynamic spectra are each split into two distinct spectral regions. These split-bands are thought to be produced upstream and downstream of the MHD shock front. The Type II drifts from high to low frequency but at a much lower rate than the Type III owing to the former's lower velocity.

Instrumentation:

- HAARP Radio Observatory, Gakona, Alaska: 62° 23' 20.93"N, 145° 8' 15.51" W, 562 m AMSL
    - LWA Antenna (figure 2) connected through an LWA Power Coupler with quadrature coupler and RF power splitters
    - Dual up-converter, 5 – 85 MHz RF input, 205 – 285 MHz IF output
    - Two Callisto spectrometers, 205 – 285 MHz RF input, RHCP and LHCP, Callisto software with FITS file output
    - RAPPViewer software to produce the spectrogram from a Callisto FITS file

Figure 2 ~ LWA Antenna at HAARP Radio Observatory soon after installation in September 2021. The antenna is an active, tied-fork, crossed-dipole, 1.5 m high with the Front End Electronics (FEE) in the square hub enclosure at the top. The antenna and associated spectrometers are collocated on the science pad with the Modular UHF Incoherent Radar (MUIR) at the HAARP facility. The chain-link fence that surrounds the science pad can be seen in the background about 25 m away. Image © 2021 W. Reeve.

Resources:

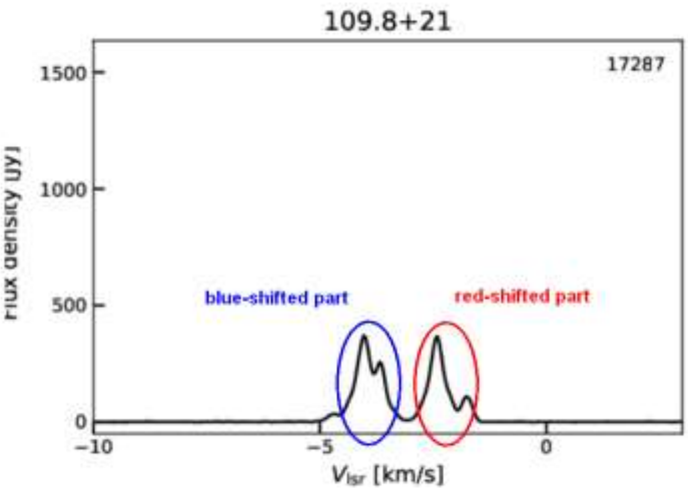
- Solar radio burst types: https://reeve.com/Solar/Solar.htm
- Type II Slow Sweep Radio Bursts: https://www.reeve.com/Documents/CALLISTO/Reeve_TypeII-Burst.pdf

Acknowledgements:
Callisto FITS files, credit: FHNW Brugg/Windisch and IRSOL Locarno, Switzerland, {Callisto}

Observations of Cepheus A methanol 6.7 GHz maser variability in June-August 2023
by Dimitry Fedorov UA3AVR

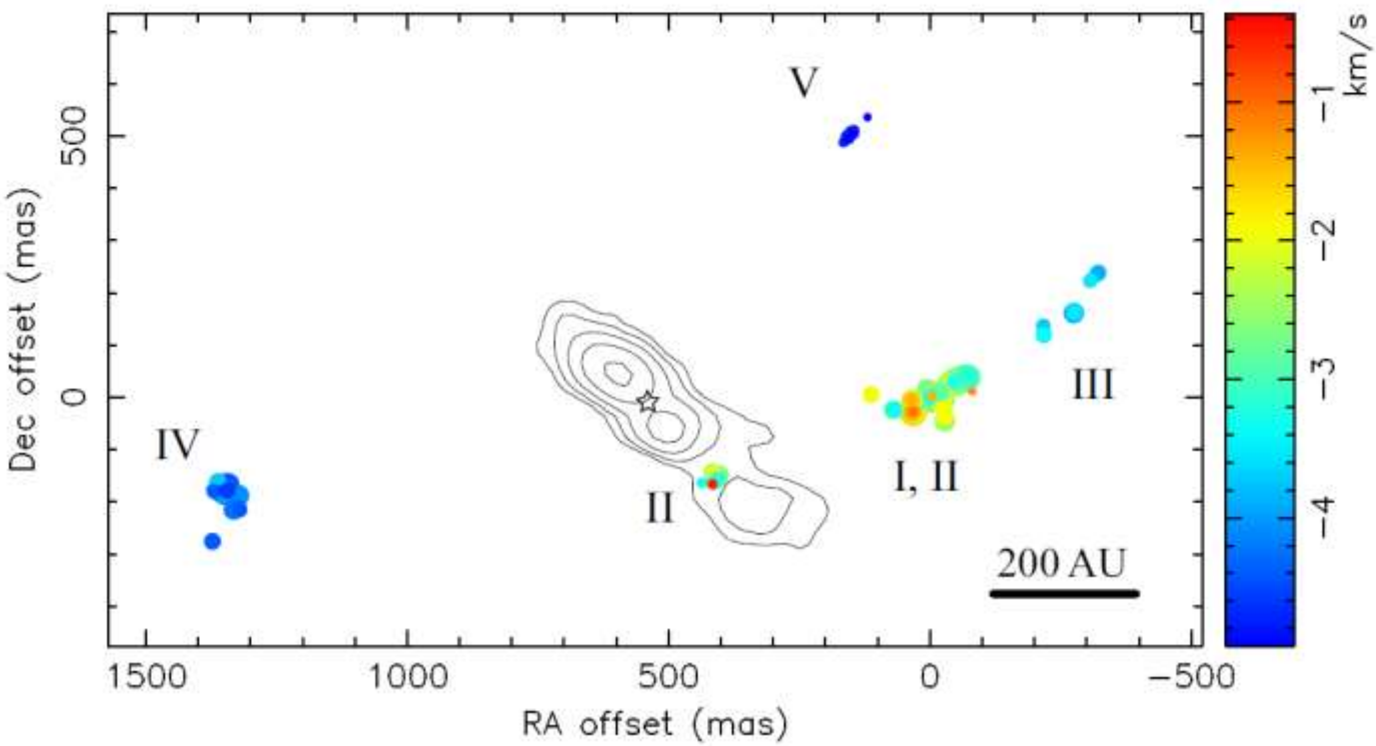
This report is based on results obtained for 6.7 GHz methanol maser line (transition $5_1 \rightarrow 6_0$, A^+ molecule type [1], accurate frequency 6668.5192 MHz) in June-August 2023 using a small dish radio telescope 1.8 m.

Cepheus A maser info



Source coordinates: RA 22:56:17, DEC +62:1:48 (J2000), G109.87078+2.11403. The spectrum consists of several lines; they can be divided into blue-shifted and red-shifted parts, see picture (the plot base is taken from [2]). Blue-shifted and red-shifted parts are usually inversely correlated (anti-correlated) in brightness [3]. A custom measure of their levels is a peak flux in Jy.

This maser belongs to Class II, i.e. a molecular cloud is pumped to inverse state by the infrared radiation from nearby stellar objects. The spatial structure of this maser is pictured below according to the data from Japanese VLBI Network (JVN) [3]:



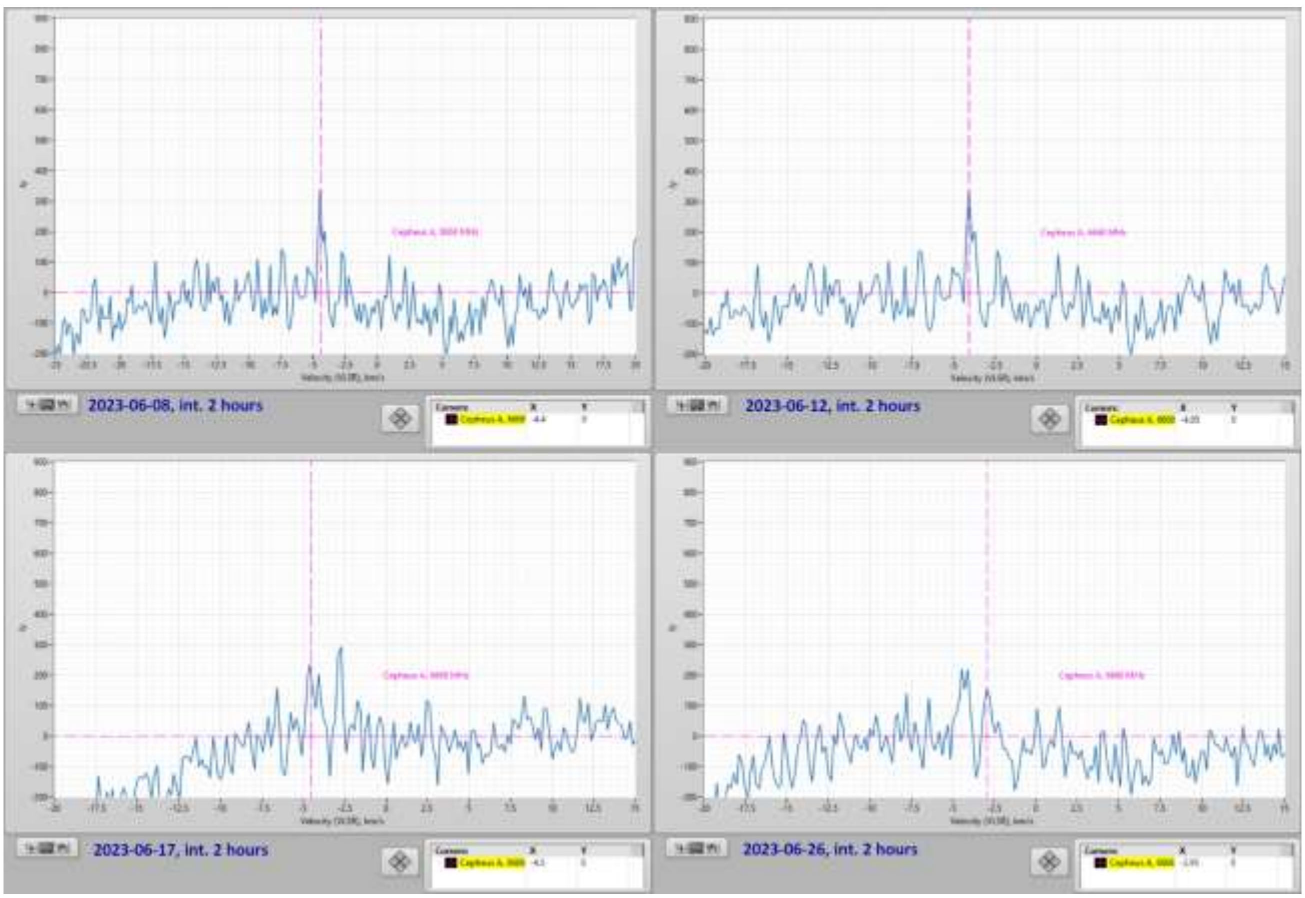
The spot sizes indicate the peak intensities in logarithmic scale; radial velocities are indicated at the color scale. Star denotes a supposed excitation source (founded peak of 43 GHz continuum radiation); contours (isophotes) around the star related to the 22 GHz continuum radiation by VLA (see Fig. 3 in [3]). Lines ("features") on this picture:

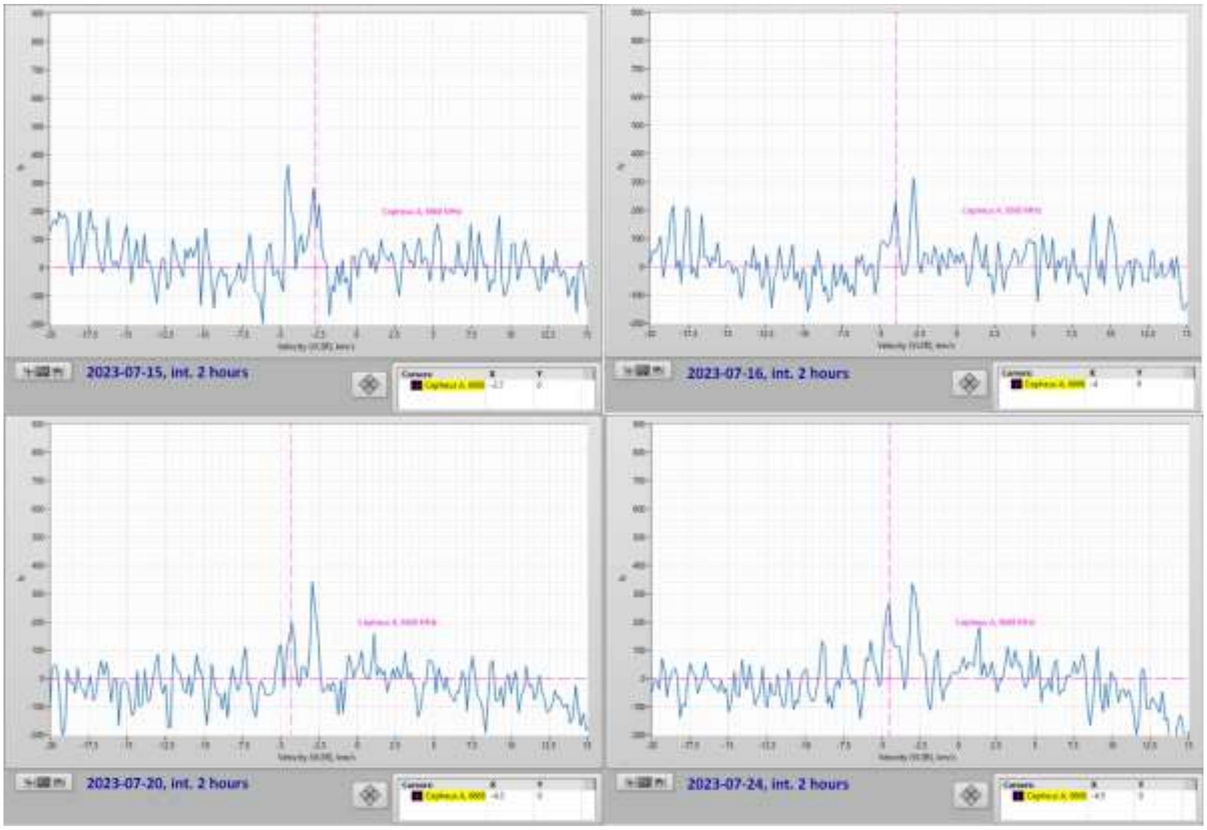
I	-1.9 km/s,	red-shifted part
II	-2.7 km/s	red-shifted part
III	-3.8 km/s	blue-shifted part
IV	-4.2 km/s	blue-shifted part
V	-4.9 km/s	blue-shifted part

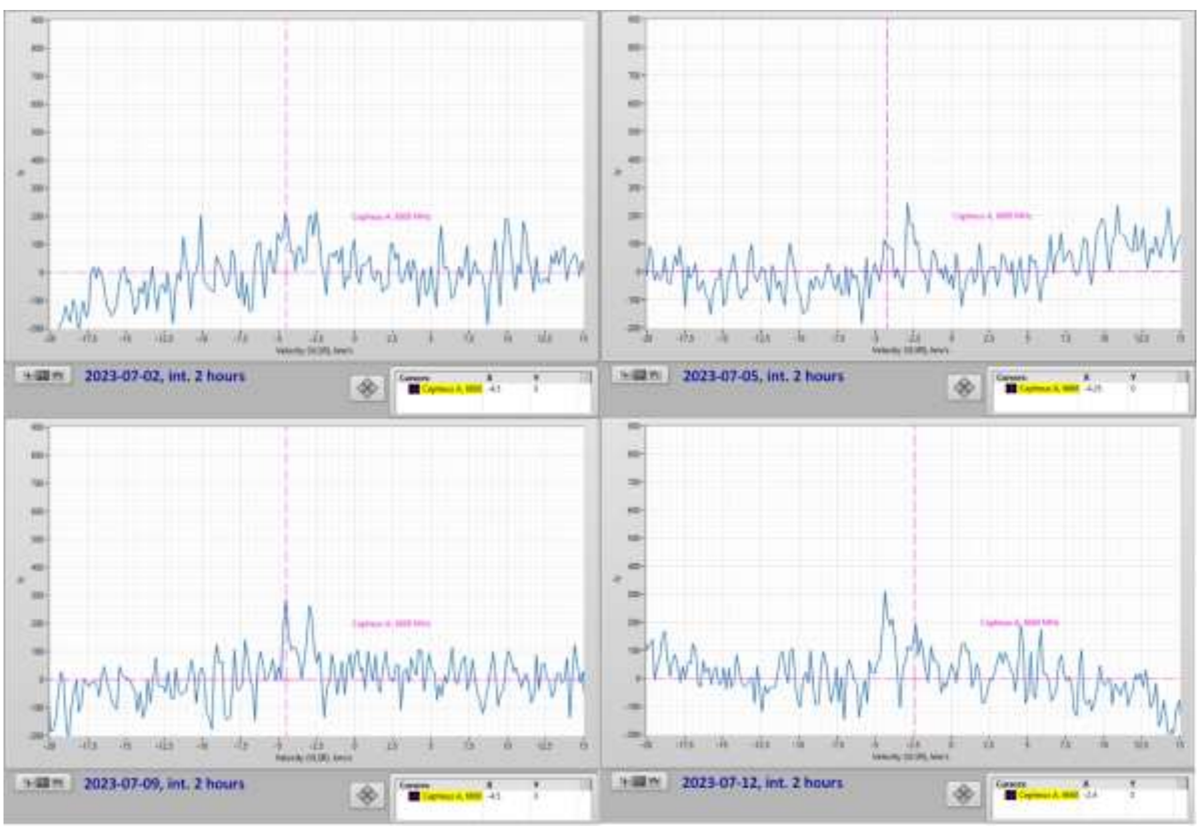
The anti-correlation of blue-shifted and red-shifted parts can be described by models with Keplerian rotation of the methanol cloud in the form of disk around the excitation center (see discussion in [4]); nevertheless, it is noted the radial movement with radial velocities ~1.3 km/s (not Keplerian rotation) of methanol clouds dominates.

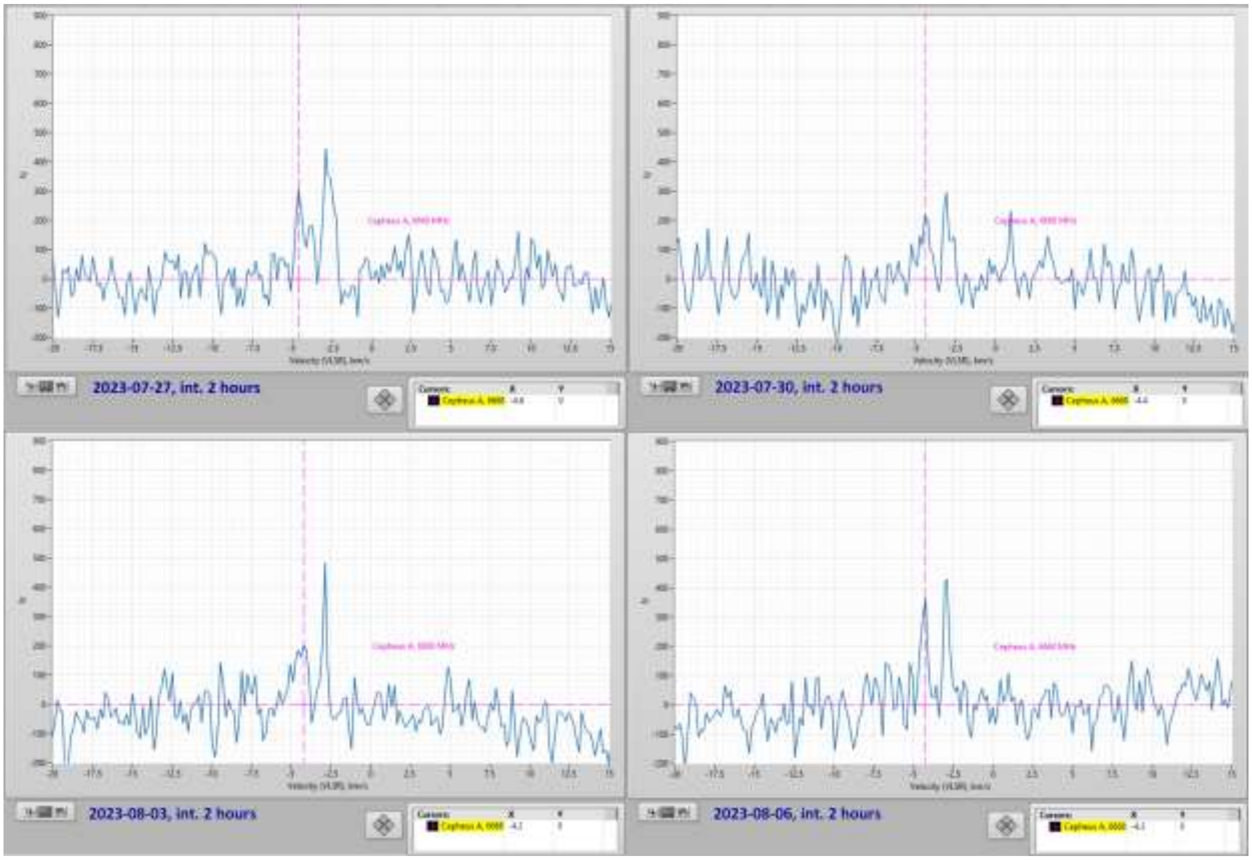
Results of spectrum observations

Observations were made in June, July and August 2023 with a small dish 1.8 m, see the ***Setup data*** in ***Appendix***. All spectrums are obtained with 2 hours of integration time.




2023-07-15, int. 2 hours
2023-07-16, int. 2 hours
2023-07-20, int. 2 hours
2023-07-24, int. 2 hours


2023-07-02, int. 2 hours
2023-07-05, int. 2 hours
2023-07-09, int. 2 hours
2023-07-12, int. 2 hours



The situation when one part is brighter then other can change rather fast, i.e. in one day, as it was seen in July 15, 2023 and July 16, 2023.

Variability characteristics

The data were obtained with rather low signal-to-noise ratio (S/N). The variability index *VI* for low S/N [4,5] is applied to estimate this maser variability for each of blue and red parts,

$$VI_i = \frac{\sqrt{S_i^2 - \sigma_{Noise}^2}}{\langle P \rangle_i}, \qquad \langle P \rangle_i = \frac{1}{N}\sum_{k=1}^{N} P_{i,k}\,, \qquad S_i^2 = \frac{1}{N-1}\sum_{k=1}^{N}\left(P_{i,k} - \langle P \rangle_i\right)^2, \qquad i = \text{blue}, \text{red}. \tag{1}$$

Here $P_{i,k}$ is the peak amplitude in Jy of *i*= blue or red parts for *k*-th day of observations, *N*=16 – is the number of observation days, $\langle P \rangle_i, S_i^2$ – are the statistical means and variances for the blue or red parts, corresponding deviations are $S_i = \sqrt{S_i^2}$, σ_{Noise}^2 – is the variance of background noise, corresponding value of the deviation, $\sigma_{Noise} = \sqrt{\sigma_{Noise}^2}$, was taken 50 Jy in calculations. The results for mean values, deviations and indexes VI_i are following:

Mean	Deviation	Variability index
$\langle P\rangle_{\text{blue}}$ = 261.5 Jy	S_{blue} = 70.3 Jy	VI_{blue} = 0.19
$\langle P\rangle_{\text{red}}$ = 285.3 Jy	S_{red} = 102.9 Jy	VI_{red} = 0.32

The correlation coefficients of the spectrum parts is calculated by

$$r = \frac{1}{S_{\text{blue}}\, S_{\text{red}}\, (N-1)} \sum_{k=1}^{N} \left(P_{\text{blue},k} - \langle P\rangle_{\text{blue}}\right)\left(P_{\text{red},k} - \langle P\rangle_{\text{red}}\right). \tag{2}$$

The result r = –0.104 is negative as expected, but unexpectedly low in its absolute value. This can be explained by rather high level of the background noise with deviation value $\sigma_{Noise} \approx$ 50 Jy.

Appendix. Setup data

Dish size D = 1.8 m;
Telescope characteristics:
Sensitivity (G, forward gain) – 0.63 mK/Jy;
System temperature $T_{sys} \approx$ 150 K (measured, see below);
Source automatic tracking during the integration time.

Outdoor downconverter: Terrasat 6.4-7.1 GHz
RX module (LO 5.7 GHz) + LNA (NF=1.1 dB)
Indoor IF receiver: USRP B200mini,
Receiver resolution – 5 kHz by noise bandwidth
(<0.2 km/s in VLSR), total bandwidth – 1.5 MHz;
Location near Moscow (N56.146254, E37.496530).

The indoor IF receiver USRP B200mini is controlled using LabVIEW software with on-fly averaging of spectrum during the integration time (no intermediate data are stored), see more details about the receiver and post processing procedures in [6].

References

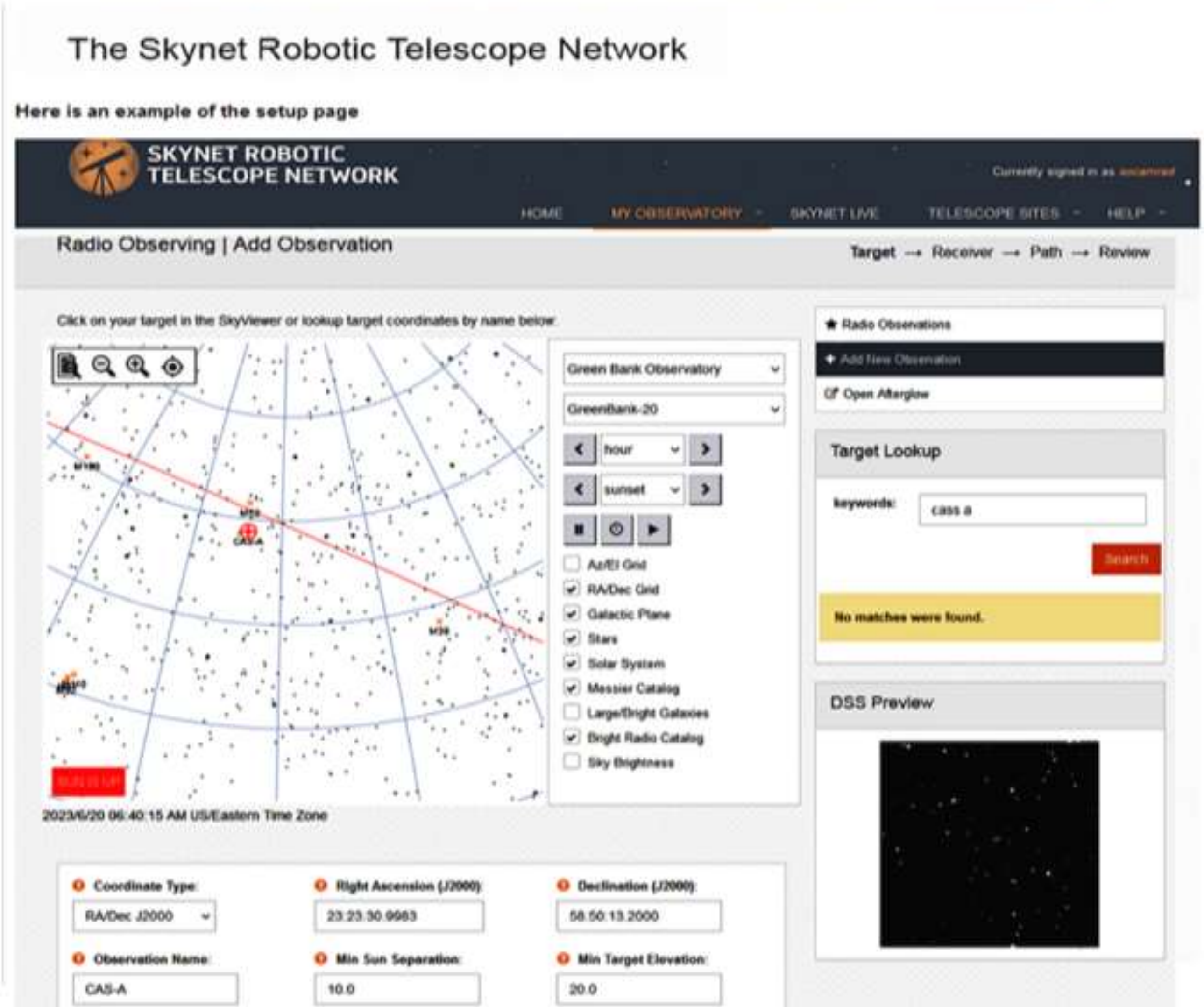
[1] H.S.P. Mueller et al, *Accurate rest frequencies of methanol maser and dark cloud lines*, arXiv:astro-ph/0408094 (2004)
[2] Ibaraki methanol maser line 6.7 GHz database iMet, http://vlbi.sci.ibaraki.ac.jp/iMet/, see Cepheus A page http://vlbi.sci.ibaraki.ac.jp/iMet/data/109.8+21/.
[3] Koichiro Sugiyama et al, *A Synchronized Variation of the 6.7 GHz Methanol Maser in Cepheus A*, arXiv:0804.4623v1 [astro-ph] (2008).
[4] M. Szymczak et al, *6.7 GHz methanol maser variability in Cepheus A*, MNRAS **439**, pp 407–415 (2014).
[5] Rick Edelson et al, *X-Ray Spectral Variability and Rapid Variability of the Soft X-Ray Spectrum Seyfert 1 Galaxies Arakelian 564 and Ton S180*, ApJ **568** p 610 (2002).
[6] D. Fedorov UA3AVR, *Methanol maser lines 12 GHz observations*, Radio Astronomy, Journal of the Society of Amateur Radio Astronomers, September – October 2022, page 71.

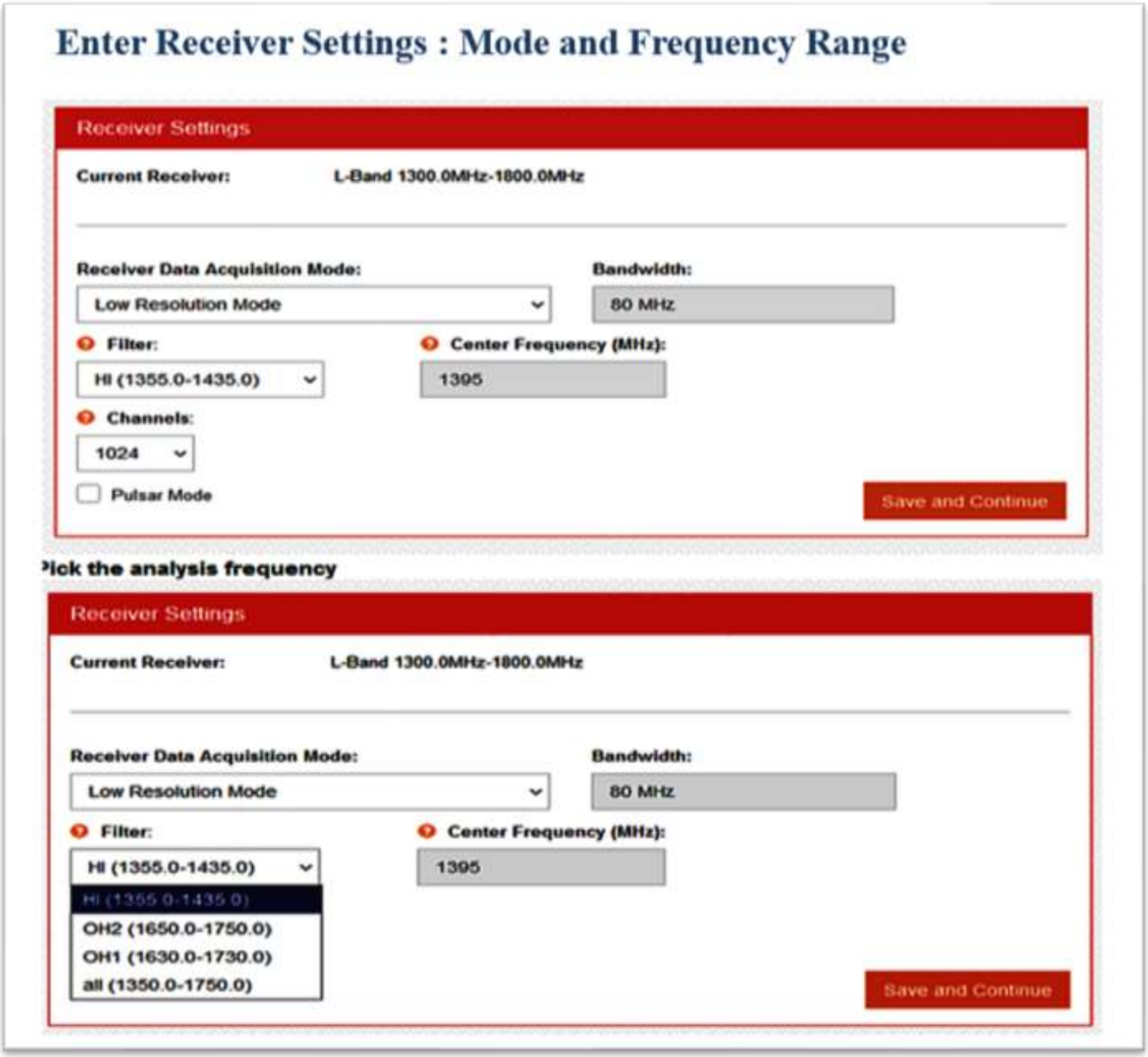
About the author

Dimitry Fedorov was first licensed as radio amateur since 1982, as UA3AVR since 1983. In 1990 graduated as MS in electronics in Moscow Power Engineering University. Now works as research and development engineer in wireless industry, LTE/5G NR, RF and microwave modules development. Previous scientific experience in nuclear and particle physics, worked in Moscow State University, Institute of Nuclear Physics and Universität Tübingen, Institut für Theoretische Physik, see profile blog at https://www.researchgate.net/profile/Dimitry-Fedorov-2. Radio Astronomy hobby since 2012, mainly in applications for weak signals reception. You can contact the author at ua3avr@yandex.ru.

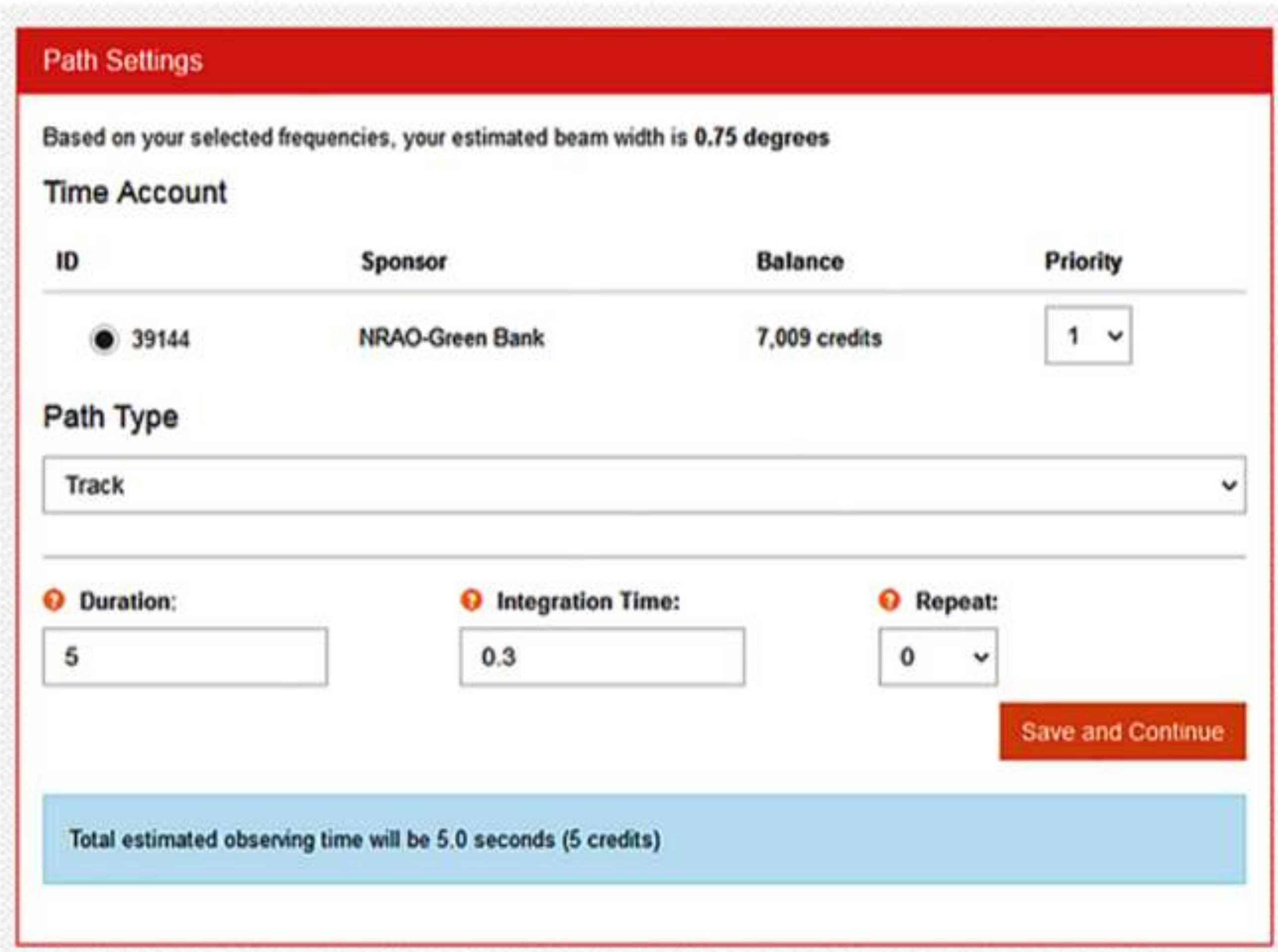
Users Guide: GreenBank Robotic 20m Radio Telescope – Alex Pettit

Select Target for Observation via coords or keyword look-up




Enter Receiver Settings : Mode and Frequency Range
Receiver Settings
Current Receiver:
L-Band 1300.0MHz-1800.0MHz
Receiver Data Acquisition Mode:
Low Resolution Mode
Bandwidth:
80 MHz
Filter:
HI (1355.0-1435.0)
Center Frequency (MHz):
1395
Channels:
1024
Pulsar Mode
Save and Continue
Pick the analysis frequency
Receiver Settings
Current Receiver:
L-Band 1300.0MHz-1800.0MHz
Receiver Data Acquisition Mode:
Low Resolution Mode
Bandwidth:
80 MHz
Filter:
HI (1355.0-1435.0)
Center Frequency (MHz):
1395
HI (1355.0-1435.0)
OH2 (1650.0-1750.0)
OH1 (1630.0-1730.0)
all (1350.0-1750.0)
Save and Continue

Select Measurement Parameters
Path Type " **Track** "



Select Measurement Parameters

Path Type multi pass " **Map** "

Path Settings

Path Type

Map

Map Size

Specified By: ○ Beam Widths ◉ Degrees

RA | Lng | Az Size: 12.860 beam widths 10 degrees

Dec | Lat | El Size: 13.31 beam widths 10 degrees

Maps should be at least 6 beam widths across in both directions and even larger if you wish to measure source brightness. Otherwise, only raw scan data will be returned.

Sampling Density

Direction: RA|Lng|Az

Gap Between Sweeps: 1/2 Beam Width

Gap Along Sweeps: ☑ same as gap between 1/2 Beam Width

Gaps should be the same in both directions and no greater than 1/4 of a beam width if you wish to measure source brightness. If not the same in both directions, only raw scan data will be returned.

Map Depth

Specified By: ◉ Integration Time ○ Slew Speed

Integration Time: 0.3 seconds

Slew Speed: 1.252 degrees/second

Note: The telescope's slew speed may not exceed 2.0 degrees / second.

Save and Continue

Total estimated observing time will be 3.5 minutes (208 credits) and consist of 26 sweeps each taking 8.0 seconds

Observation Parameter Summary

pre -acquisition

Radio Observing | Add Observation

OBSERVATION NAME:	CAS-A
COORDINATE TYPE:	RA_DEC_COORD
RA|LNG|AZ:	23:23:30.9
DEC|LAT|EL:	58:50:13.2
MIN SUN SEPARATION:	10.0 degrees
MIN TARGET ELEVATION:	20.0 degrees
RECEIVER MODE:	highres
FILTER:	N/A
CENTER FREQUENCY:	1406.25 MHz
SECONDARY FREQUENCY:	1421.875 MHz
# CHANNELS:	1024
PATH TYPE:	track
DURATION:	5.0
INTEGRATION TIME:	5.0
REPEAT:	0
TIME ACCOUNT:	39144 - NRAO-Green Bank

post-acquisition

Observation Info

Name:	CAS-A
Coordinate Type:	RA/DEC
Target:	23:23:30.839 | 58:50:13.2
Min Elevation:	20.0 degrees
Solar Separation:	10.0 degrees
Priority:	1
State:	completed
File Transfer:	pending
Submitted On:	2023-06-20 10:44:05
Receiver:	L-Band
Receiver Mode:	highres
Filter:	HI
Center Frequency:	1406.25 MHz
Secondary Frequency:	1421.88 MHz
Channels:	1024
Pattern:	track
Duration:	5.0 secs
Integration Time:	5.0 secs
Repeat:	0

Observation Acquisition Status Panel

Radio Observing | My Observations

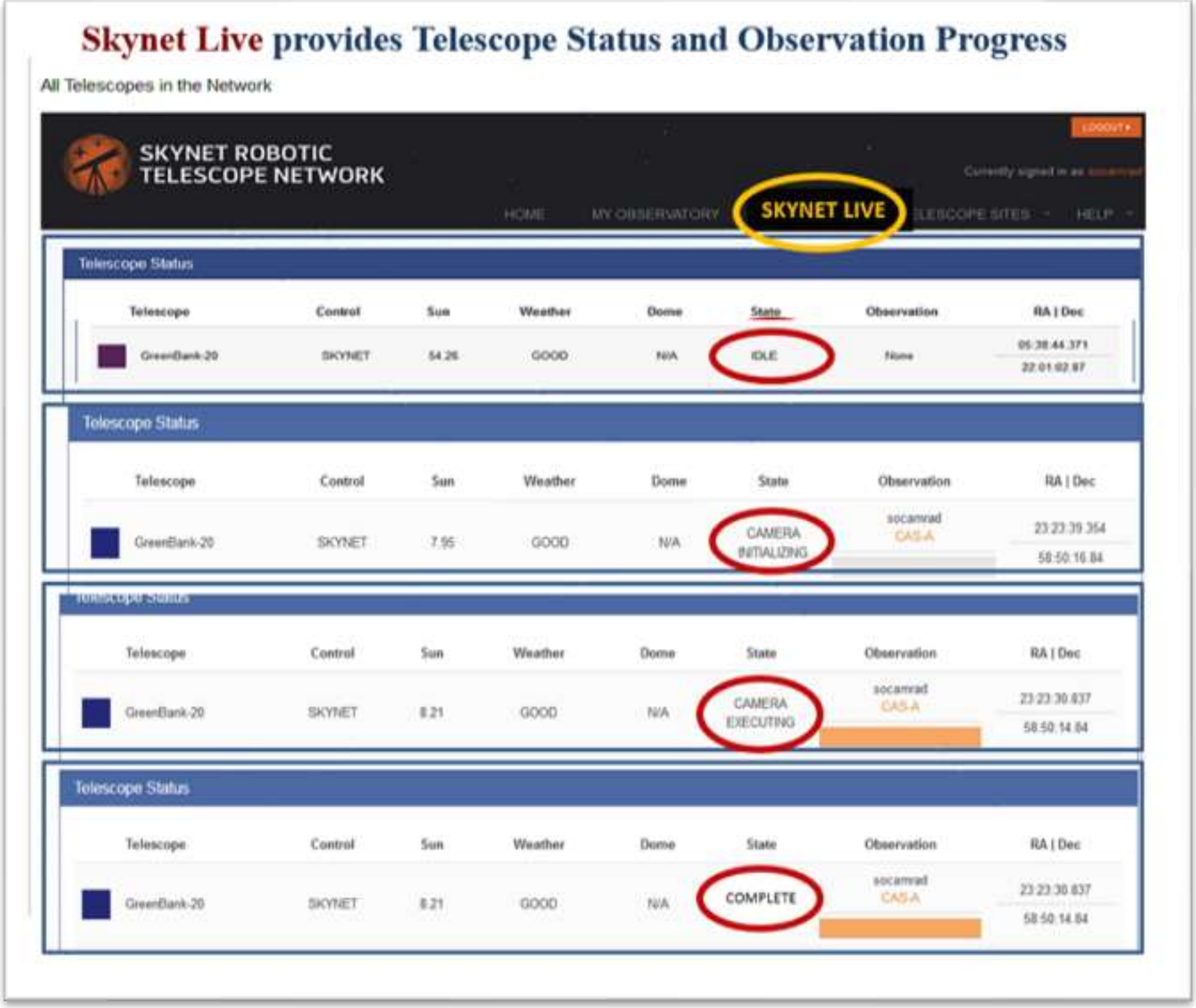
Previous Page 1 2 3 4 5 6 ... Next Page

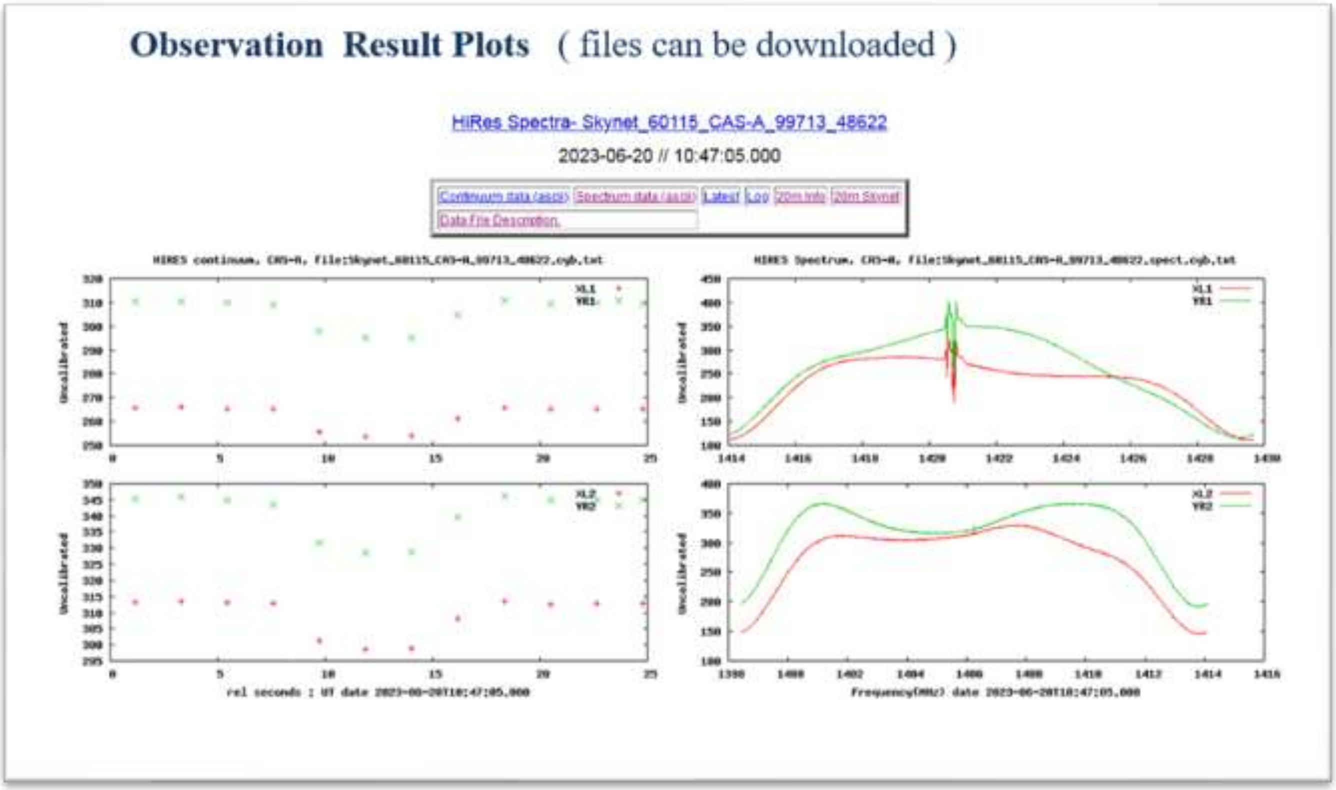
Radio Observations

ID	Name	Map Type	Target	State
99713	CAS-A	track	23:23:30.8 | 58:50:13.2	active
99594	bl lac-ST	track	22:02:43 | 42:16:39.7	archived
99593	mrk501-ST	track	16:53:52 | 39:45:36.7	archived
99592	3C279-ST	track	12:56:11 | -05:47:21.5	archived

Radio Observations

ID	Name	Map Type	Target	State
99713	CAS-A	track	23:23:30.8 | 58:50:13.2	completed

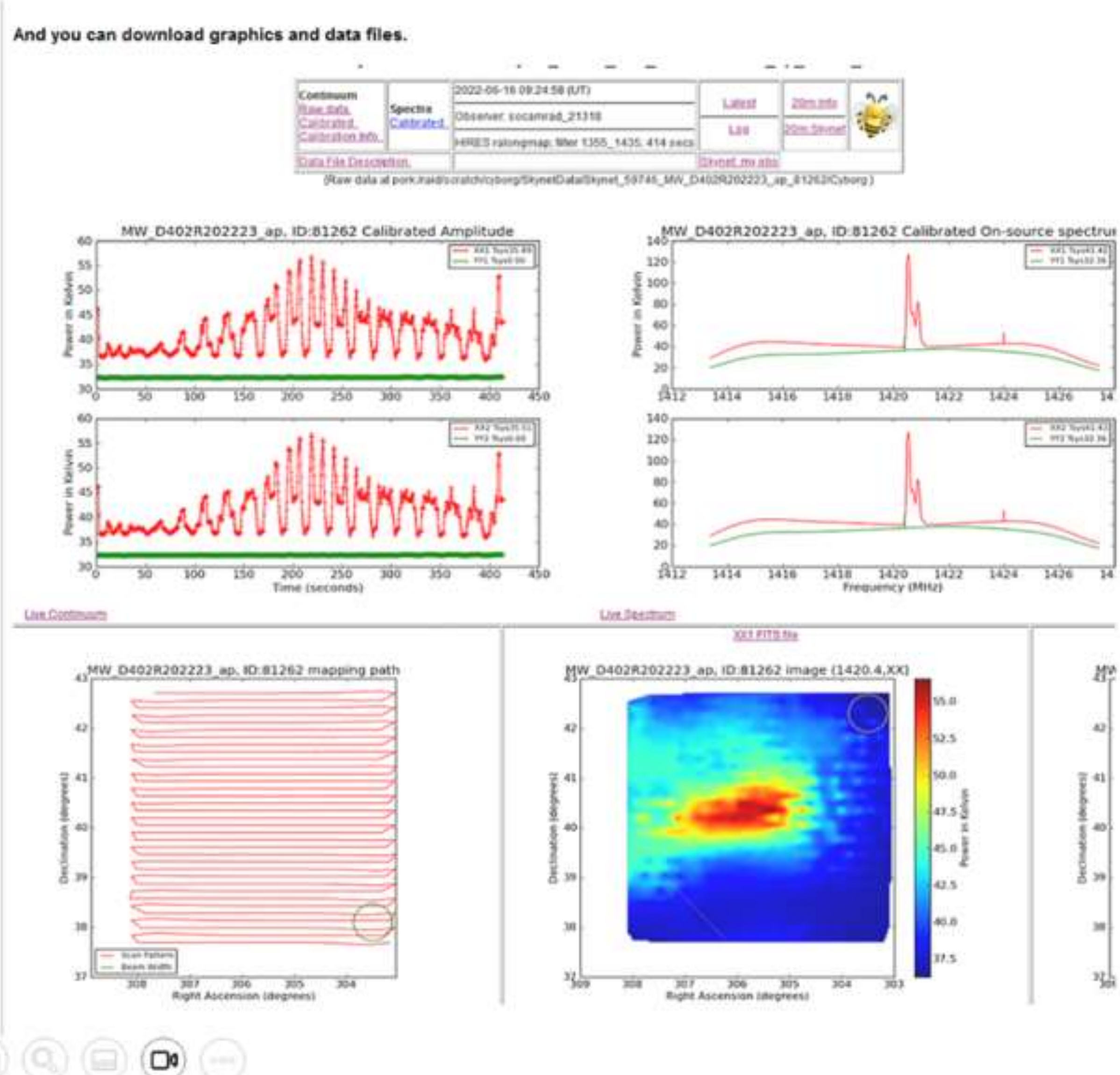

Skynet Live provides Telescope Status and Observation Progress
All Telescopes in the Network
SKYNET ROBOTIC TELESCOPE NETWORK
HOME
MY OBSERVATORY
SKYNET LIVE
HELP
Telescope Status
Telescope
Control
Sun
Weather
Dome
State
Observation
RA | Dec
GreenBank-20
SKYNET
54.26
GOOD
N/A
IDLE
None
Telescope Status
GreenBank-20
SKYNET
7.95
GOOD
N/A
CAMERA INITIALIZING
socamrad
CAS-A
23:23:39.354
58:50:16.84
GreenBank-20
SKYNET
8.21
GOOD
N/A
CAMERA EXECUTING
socamrad
CAS-A
58:50:14.84
Telescope Status
GreenBank-20
SKYNET
8.21
GOOD
N/A
COMPLETE
socamrad
CAS-A
58:50:14.84



Observation Result Plots (files can be downloaded)
HiRes Spectra- Skynet_60115_CAS-A_99713_48622
2023-06-20 // 10:47:05.000
XL1
YR1
XL2
YR2

Observation Result Plots (files can be downloaded)

this data from a raster scan of the Cygnus region of the Milky Way



NASA FITS File Plotting Software

FITS File PLOTTING SOFTWARE for more flexibility in the plotting

https://heasarc.gsfc.nasa.gov/docs/software/ftools/fv/pow/About.html

National Aeronautics and Space Administration
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Sciences and Exploration

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NASA's HEASARC: Software

FITSIO | FTOOLS | FV | HEASoft | Hera | Maki | PIMMS | PROFIT | Xanadu | Xselect | XSTAR | ASTRO-Update | FITS

Fv: The Interactive FITS File Editor

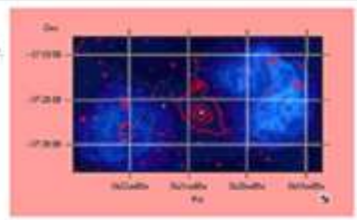
The latest version is 5.5.2, released April 2020

Fv is an easy to use graphical program for viewing and editing any FITS format image or table. The *Fv* software is small, completely self-contained and ready to run on

- Linux
- macOS
- Windows PCs (Fv v5.3 only)

Fv can be used with the DS9 image display.

Download Fv now...



Images and Contours

Fv also provides a portal into the new Hera data analysis service at the HEASARC:

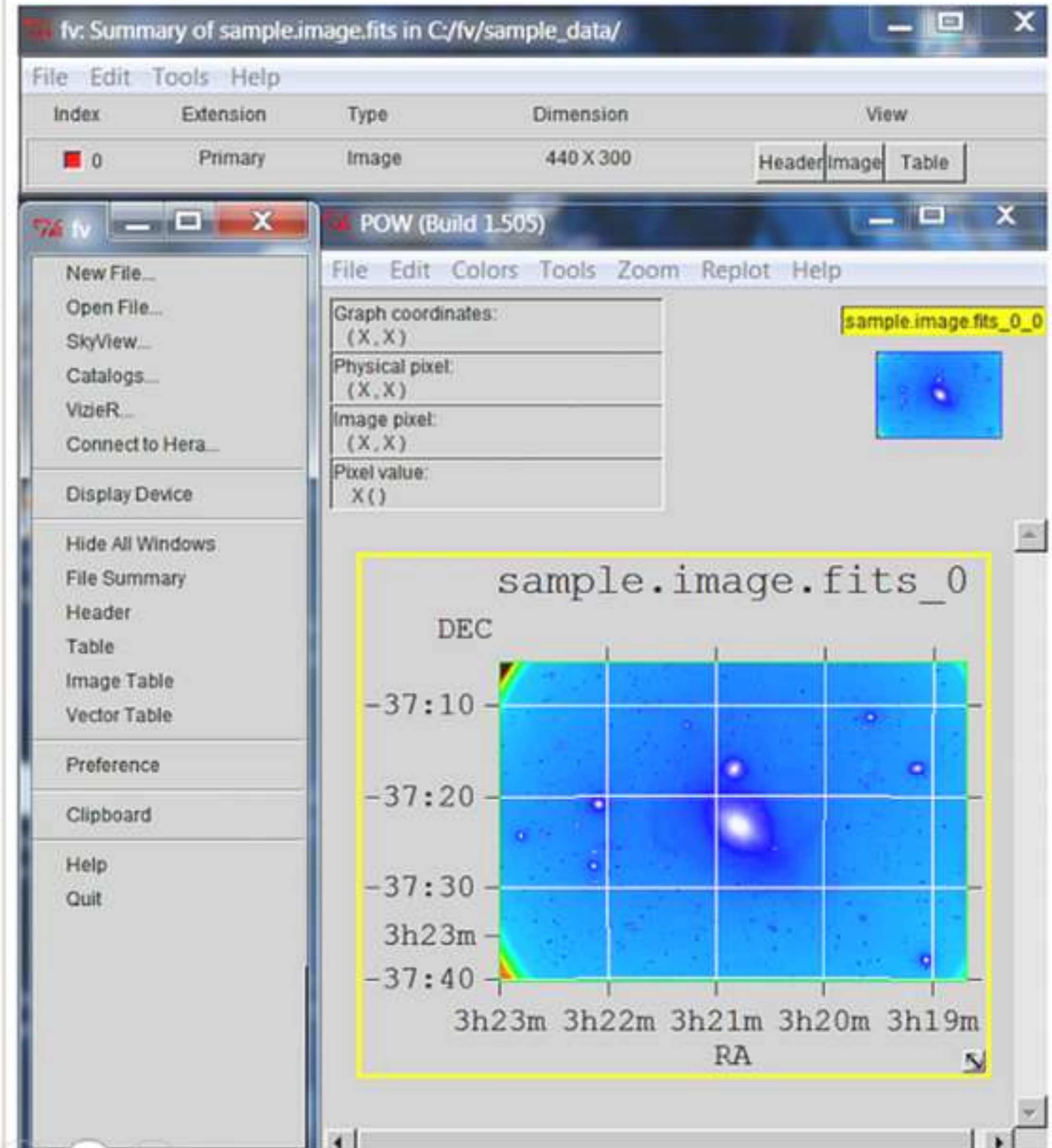
- Dozens of powerful utility program are available to manipulate local FITS file
  - Do general image arithetic using complex mathematical expressions
  - Sort, merge, join, or filter rows of a table
  - Compute statistics about images or table columns
  - Make ASCII listings of the contents of any image or table
- The programs run the same as if they were installed locally but they actually execute on the Hera servers.
- The input data files are transparently uploaded to the Hera servers where the program is executed, and any output FITS files and text output are transparently copied back to your machine after the program finishes.
- Hera tasks may be executed from the command line or using the special GUI built into *Fv*.
- For professional researchers, Hera provides the complete suite of data analysis programs from the FTOOLS, Chandra CIAO, and XMM SAS software packages.

Learn more about Hera...

Links to more *Fv* information:

- Download *Fv*
- Major *Fv* Features
- User's Guide
- Screen Shots
- *Fv* Help Files
- About fitsTcl

NASA FITS File Plotting Software



Journal Archives and Other Promotions

The rich and diverse legacy of member contributed content is available in the SARA Journal Archives. Table of contents for journals is available online at: SARA-Journal-Master-Index.xlsx (live.com)

The entire set of The Journal of The Society of Amateur Radio Astronomers is available by online download. It goes from the beginning of 1981 to the end of 2022 (over 6000 pages of SARA history!)

All SARA journals and conference proceedings are available through the previous calendar year.

SARA Store (radio-astronomy.org/store.)

SARA offers the above USB drives, DVDs, printed Proceedings and Proceedings on USB drive and other items at the SARA Store: http://www.radio-astronomy.org/e-store. Proceeds from sales go to support the student grant program. Members receive an additional 10% discount on orders over $50 US. Payments can be made by sending payment by PayPal to treas@radio-astronomy.org or by mailing a check or money order to SARA, c/o Brian O'Rourke, 337 Meadow Ridge Rd, Troy, VA 22974-3256

SARA Online Discussion Group
SARA members participate in the online forum at http://groups.google.com/group/sara-list. This is an invaluable resource for any amateur radio astronomer.

SARA Conferences
SARA organizes multiple conferences each year. Participants give talks, share ideas, attend seminars, and get hands-on experience. For more information, visit http://www.radio-astronomy.org/meetings.

What is Radio Astronomy?

Radio Astronomy is just what the name implies…. Astronomy observed at radio wavelengths instead of optical. But why do radio astronomy? Radio astronomy has expanded the knowledge of the universe about as much since its discovery in 1932 as optical has since humans first looked up at the sky. (The sky in the different frequencies or colors of radio are as different and varied as all of the flowers on Earth. Each frequency has its own information about what is happening in the universe.) This knowledge has been gained by both professional astronomers as well as amateurs with amateurs contributing to this day.

Do I need a big dish and expensive equipment?
No. Complete beginner projects are available at the SARA store at very reasonable prices. You can monitor the Sun's effects upon our planet with SuperSID. This information is gathered for Stanford for research into our ionosphere and radio signal propagation. Another project is the detection the hydrogen line just like Dr. Ewen had done in 1951 for a fraction of the cost using the Scope in a Box kit.

That said, radio astronomy is like optical astronomy in that you can spend as much as you want to. Many amateurs push the lower boundaries of cost by using very low-cost receivers and low-noise low-cost amplifiers that were not available even a few years ago. (See the Scope in a Box kit in the store for examples of both.)

Is everything 'plug and play' and boring?
The kits mentioned above are a starting point which are mostly plug-and-play… that gets you started. After you have mastered the basics, where you go from there depends upon your interests. Monitoring pulsars is done by amateurs. (One even noticed a pulsar glitch before the professionals!) These amateurs are pushing the boundaries of what can be done. Papers are being published and discussion had about pulsar detection as well detection of a MASER with a 50-inch dish. Techniques on new detection methods are posted in the SARA forum and elsewhere. You are free to build your own equipment to receive the signals as well as software to collect and analyze the data.

What is SETI?
SETI is the Search for Extra-Terrestrial Intelligence. Some amateurs scan the sky and search for signals that might be from aliens. To date no one has received a definitive alien signal (professional or amateur), but the search continues. The search has resulted not just in better receiving equipment but also wide and lively discussions about how aliens might communicate and how they might be trying to contact us. Some of these techniques have interesting ideas for our own communication techniques here on Earth!

What should I do to get started?
You should start with reading our Introduction to Radio Astronomy and joining our online SARA Forum. Look at the SARA store to get a project to get your feet wet without much expense and minimal risk. We will work with you so you can succeed.

Administrative

Officers, directors, and additional SARA contacts

The Society of Amateur Radio Astronomers is an all-volunteer organization. The best way to reach people on this page is by email with SARA in the subject line SARA Officers.

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Other SARA Contacts

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Resources

Great Projects to Get Started in Radio Astronomy

Radio Observing Program

The Astronomical League (AL) is starting a radio astronomy observing program. If you observe one category, you get a Bronze certificate. Silver pin is two categories with one being personally built. Gold pin level is at least four categories. (Silver and Gold level require AL membership which many clubs have membership. For the bronze level, you need not be a member of AL.)

Categories include
1) SID
2) Sun (aka IBT)
3) Jupiter (aka Radio Jove)
4) Meteor back-scatter
5) Galactic radio sources

This program is a collaboration between NRAO and AL. Steve Boerner is the Lead Coordinator and a SARA member.

For more information:
Steve Boerner
2017 Lake Clay Drive
Chesterfield, MO 63017
Email: sboerner@charter.net
Phone: 636-537-2495
http://www.astroleague.org/programs/radio-astronomy-observing-program

Radio Jove

The Radio Jove Project monitors the storms of Jupiter, solar activity and the galactic background. The radio telescope can be purchased as a kit, or you can order it assembled. They have a terrific user group you can join.
http://radiojove.gsfc.nasa.gov/

INSPIRE Program

The INSPIRE program uses build-it-yourself radio telescope kits to measure and record VLF emissions such as tweeks, whistlers, sferics, and chorus along with man-made emissions. This is a very portable unit that can be easily transported to remote sites for observations.
http://theinspireproject.org/default.asp?contentID=27

SARA/Stanford SuperSID

Stanford Solar Center and the Society of Amateur Radio Astronomers have teamed up to produce and distribute the SuperSID (Sudden Ionospheric Disturbance) monitor. The monitor utilizes a simple pre-amp to magnify the VLF radio signals which are then fed into a high-definition sound card. This design allows the user to monitor and record multiple frequencies simultaneously. The unit uses a compact 1-meter loop antenna that can be used indoors or outside. This is an ideal project for the radio astronomer that has limited space. To request a unit, send an e-mail to supersid@radio-astronomy.org

Radio Astronomy Online Resources

SARA YouTube Videos: https://www.youtube.com/channel/UC-SzptAQZ-20c9CkRb9ZPxw/videos	Pisgah Astronomical Research Institute: www.pari.edu
AJ4CO Observatory – Radio Astronomy Website: http://www.aj4co.org/	A New Radio Telescope for Mexico - ORION 2021 01 20. Dr. Stan Kurtz https://www.youtube.com/watch?v=Q9aBWr1aBVc
Radio Astronomy calculators https://www.aj4co.org/Calculators/Calculators.html	National Radio Astronomy Observatory http://www.nrao.edu
Introduction to Amateur Radio Astronomy (presentation) http://www.aj4co.org/Publications/Intro%20to%20Amateur%20Radio%20Astronomy,%20Typinski%20(AAC,%202016)%20v2.pdf	NRAO Essential Radio Astronomy Course http://www.cv.nrao.edu/course/astr534/ERA.shtml
RF Associates Richard Flagg, rf@hawaii.rr.com 1721-1 Young Street, Honolulu, HI 96826	Exotic Ions and Molecules in Interstellar Space -- ORION 2020 10 21. Dr. Bob Compton https://www.youtube.com/watch?v=r6cKhp23SUo&t=5s
RFSpace, Inc. http://www.rfspace.com	The Radio JOVE Project & NASA Citizen Science – ORION 2020.6.17. Dr. Chuck Higgins https://www.youtube.com/watch?v=s6eWAxJywp8&t=5s
CALLISTO Receiver & e-CALLISTO http://www.reeve.com/Solar/e-CALLISTO/e-callisto.htm	UK Radio Astronomy Association http://www.ukraa.com/
Deep Space Exploration Society http://DSES.science	CALLISTO software and data archive: www.e-callisto.org
Deep Space Object Astrophotography Part 1 -- ORION 2021 02 17. George Sradnov https://www.youtube.com/watch?v=Pm_Rs17KIyQ	Radio Jove Spectrograph Users Group http://www.radiojove.org/SUG/
European Radio Astronomy Club http://www.eracnet.org	Radio Sky Publishing http://radiosky.com
British Astronomical Association – Radio Astronomy Group http://www.britastro.org/baa/	The Arecibo Radio Telescope; It's History, Collapse, and Future - ORION 2020.12.16. Dr. Stan Kurtz, Dr. David Fields https://www.youtube.com/watch?v=rBZlPOLNX9E
Forum and Discussion Group http://groups.google.com/group/sara-list	Shirleys Bay Radio Astronomy Consortium marcus@propulsionpolymers.com
GNU Radio https://www.gnuradio.org/	SARA Twitter feed https://twitter.com/RadioAstronomy1
SETI League http://www.setileague.org	SARA Web Site http://radio-astronomy.org
NRAO Essential Radio Astronomy Course http://www.cv.nrao.edu/course/astr534/ERA.shtml	Simple Aurora Monitor: Magnetometer http://www.reeve.com/SAMDescription.htm
NASA Radio JOVE Project http://radiojove.gsfc.nasa.gov Archive: http://radiojove.org/archive.html https://groups.io/g/radio-jove	Stanford Solar Center http://solar-center.stanford.edu/SID/
National Radio Astronomy Observatory http://www.nrao.edu	

For Sale, Trade and Wanted

At the SARA online store: radio-astronomy.org/store.

SARA Polo Shirts

New SARA shirts have arrived.
We now have a good selection of X, XX, and XXX shirts available in all colors including white!
Shirts are $20 at the conference and $25 shipped.
Contact the treasurer at treas@radio-astronomy.org for availability and shipping.

Scope in a Box

radio-astronomy.org/store.

Kit of parts and software to build a working Radio Telescope to detect Hydrogen Line emissions. Available to USA addresses only at this time.

SuperSID Complete Kit
radio-astronomy.org/store.

SARA Publication, Journals and Conference Proceedings (various prices)
radio-astronomy.org/store.

SARA Journal Online Download
radio-astronomy.org/store.

The USB drive covers the society journal "Radio Astronomy" from the founding of the organization in 1981 thru 2020. Articles cover a wide range of topics including: cosmic radiation, pulsars, quasars, meteor detection, solar observing, Jupiter, Radio Jove, gamma ray bursts, the Itty Bitty Telescope (IBT), dark matter, black holes, the Jansky antenna, methanol masers, mapping at 408 MHz and more. This CD contains all of the above and more with over 4800 pages of articles on radio astronomy. Also included is a copy of Grote Reber's handwritten, 34-page document "Carriage and Mirror Detail" of his historic antenna now on display at the National Radio Astronomy Observatory (NRAO) in Greenbank, WV. You also get an electronic copy of the 109 page "Basics of Radio Astronomy" from JPL Goldstone-Apple Valley Radio Telescope. Also included is the NRAO 40-foot radio telescope "Operators Manual", which by the way, you get to operate if you attend the Eastern SARA conference in July.

SARA Advertisements

There is no charge to place an ad in Radio Astronomy; but you must be a current SARA member. Ads must be pertinent to radio astronomy and are subject to the editor's approval and alteration for brevity. Please send your "For Sale," "Trade," or "Wanted" ads to edit@radio-astronomy.org. Please include email and/or telephone contact information. Please keep your ad text to a reasonable length. Ads run for one bimonthly issue unless you request otherwise.

Membership Information

Annual SARA dues Individual $20, Classroom $20, Student $5 (US funds) anywhere in the world. Membership includes a subscription to Radio Astronomy, the bimonthly Journal of The Society of Amateur Radio Astronomers, delivered electronically (via a secure web link, emailed to you as each new issue is posted). We regret that printing and postage costs prevent SARA from providing hardcopy subscriptions to our Journal.

We would appreciate the following information included with your check or money order, made payable to SARA:

Name: ______________________

Email Address: ______________________
(required for electronic Journal delivery)

Ham call sign: ______________ (if applicable)

Address: ______________________

City: ______________________

State: ______________________

Zip: ______________________

Country: ______________________

Phone: ______________________

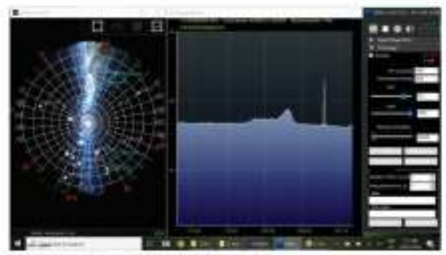
Please include a note of your interests. Send your application for membership, along with your remittance, to our Treasurer.

For further information, see our website at:

http://radio-astronomy.org/membership

How to get started?

SARA has a made a kit of software and parts to detect the Hydrogen line signal from space. This is an excellent method to get started in radio astronomy. It teaches the principles of antenna design, signal detection, and signal processing. Read more about this and other projects on our web site.



Society of Amateur Radio Astronomers, Inc.

Founded 1981

Membership supported, nonprofit [501(c) (3)] Educational and Radio Astronomy Organization

Knowledge through Common Research, Education and Mentoring

SARA members have been privileged to use this forty foot diameter drift-scan hydrogen line radio telescope every year at their annual meeting in Green Bank.

http://radio-astronomy.org

Why Radio Astronomy?

Because about sixty five percent of our current knowledge of the universe has stemmed from radio astronomy alone. The discovery of quasars, pulsars, black holes, the 3K background from the "Big Bang" and the discovery of biochemical hydrogen/carbon molecules are all the result of professional radio astronomy.

The Society of Amateur Radio Astronomers

SARA was founded in 1981, with the purpose of educating those interested in pursuing amateur radio astronomy.

The society is open to all, wishing to participate with others, worldwide.

SARA members have many interests, some are as follows:

SARA Areas of Study and Research:

- Solar Radio Astronomy
- Galactic Radio Astronomy
- Meteor Detection
- Jupiter
- SETI
- Gamma Ray/High Energy Pulse
- Detection
- Antennas
- Design of Hardware / Software

The members of the society offer a friendly mentor atmosphere. All questions and inquiries are answered in a constructive manner. No question is silly!

SARA offers its members an electronic bi-monthly journal entitled Radio Astronomy. Within the journal, members report on their research and observations. In addition, members receive updates on the professional radio astronomy community and, society news.

Once a year SARA meets for a three-day conference at the Green Bank Observatory in Green Bank West Va.

There is also a spring conference held at various cities in the Western USA. Previous meeting have been at the VLA in Socorro, NM and at Stanford University.

How do I get started?

Just as a long journey begins with the first step, the project you elect must start with a clear idea of your objectives. Do you wish to study the sun? Jupiter? Make meteor counts? Do you wish to engage in imaging radio astronomy? What you decide will not only determine the type of equipment you will need, but also the local radio spectrum.

How do amateurs do radio astronomy?

Radio astronomy by amateurs is conducted using antennas of various shapes and sizes, from smaller parabolic dishes to simple wire antennas. These antennas are connected to receivers and most of these receivers are software defined radios these days. Data from the receivers are collected by computers, and the received signals will be displayed as charts, graphs or maybe even sky maps. As diverse as the observed objects, so is are the instruments and tools used. SARA members will always be supportive to find good solutions for what one wishes to observe.

Is amateur radio astronomy instrumentation expensive?

Technical information freely circulated in our monthly journal helps amateurs to obtain good low noise equipment from off the shelf assemblies, or to build their own units. The actual cash investment in radio astronomy equipment need not exceed that of any other hobby.

What are amateurs actually looking for in the received data?

The aim of the radio amateur is to find something new and unusual. Just as an amateur optical observer hopes to notice a supernova or a new comet, so does an amateur radio observer hope to notice a new radio source, or one whose radiation has changed appreciably.

The Reber Telescope at NRAO. Constructed by Grote Reber in 1937 in his back yard in Wheaton, Illinois

SARA Members discussing the IBT (Itty Bitty Telescope)