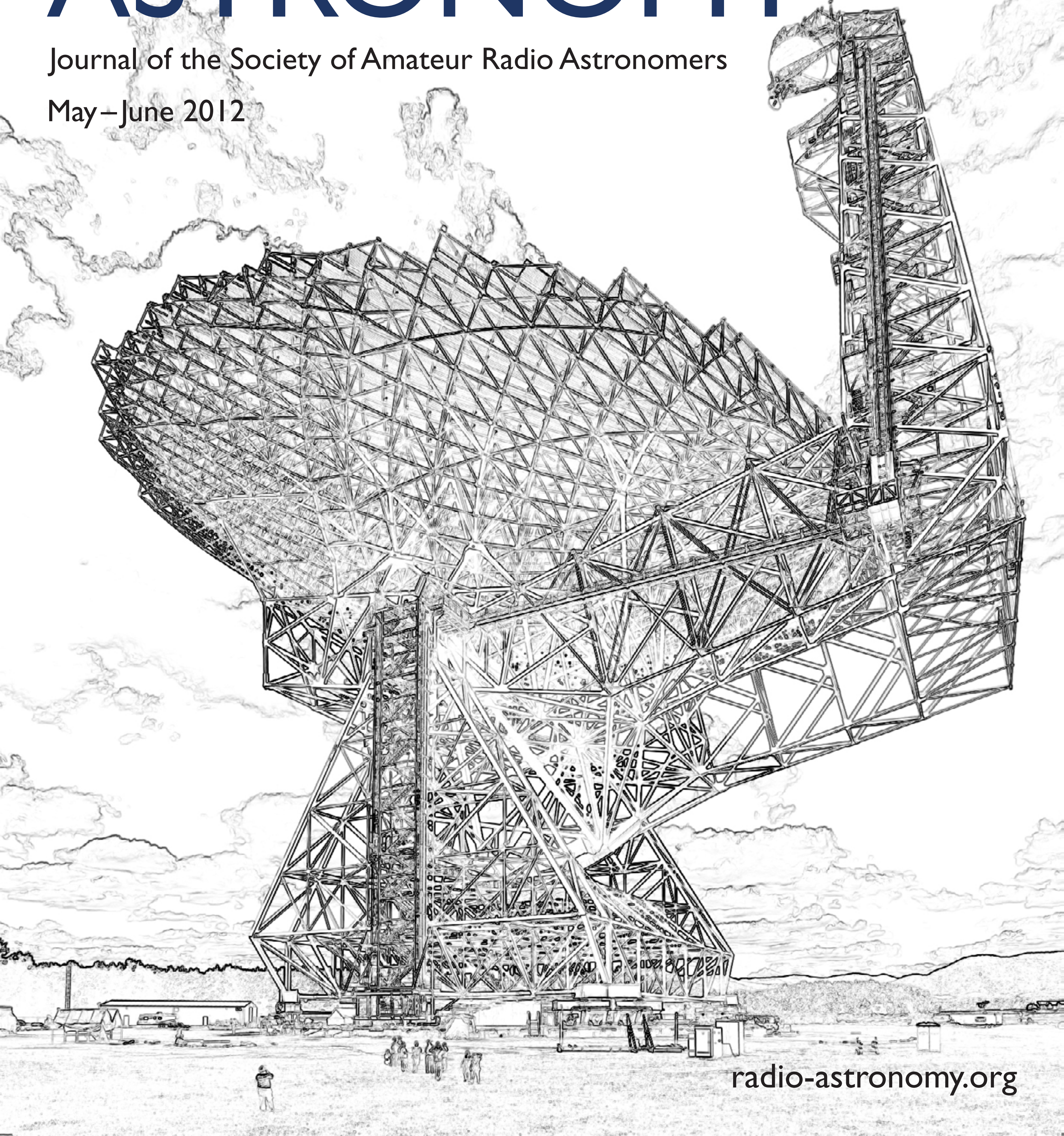
RADIO ASTRONOMY

Journal of the Society of Amateur Radio Astronomers

May – June 2012



radio-astronomy.org

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SARA

radio-astronomy.org

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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.

On The Cover – The Robert C. Byrd Green Bank Telescope, or GBT, is the world's premiere single-dish radio telescope. Its enormous 100-meter diameter collecting area, its unblocked aperture, and its excellent surface accuracy provide unparalleled sensitivity. Public domain image courtesy Wikipedia.

Radio Waves

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President's Page

I returned from the Western Conference held at Stanford in March impressed with the projects our members are pursuing. Curt Kinghorn is using off the shelf components to monitor 608 to 614 MHz. He gave the project a lot of thought before starting and showed us charts of drift scans and detection of Cassiopeia A at 610 MHz.

If you have been following the SARA E-list, you have read discussions about the FUNcube Dongle (**http://www.funcubedongle.com**) that has a design frequency range of 64~1700 MHz. Ray Fobes explained how it might be used with an amateur Long Wavelewngth Astronomy project he, Jim Campbell and Neal Vinson are developing in Arizona.

I was very excited to have three young students making presentations on radio astronomy and analyzing data. If radio astronomy is going to progress, we need to inspire students to get involved. The SARA student and teacher grants support this objective. We need our members to help promote this program (**http://www.radio-astronomy.org/node/142**).

The upcoming Annual SARA Conference will be held to June 24 to 27 at the National Radio Astronomy Observatory (NRAO) in Green Bank, West Virginia. We will have some great papers presented this year on a wide variety of topics. Hands-on astronomy projects will be set up Saturday and Monday night to include Radio-Jove, SuperSID, Inspire, and the IBT. You are invited to bring your project to demonstrate on the lawn. The swap meet is scheduled for Sunday night this year.

This year we are adding an optional extra session on Wednesday June 27 for more in depth hands-on workshops on Radio Jove, SuperSID, and other topics. Let me know what you are interested in and if you are willing to lead a group.

I know fuel prices are high, but the experience you will have at Green Bank, West Virginia is one you will not soon forget. It is impressive site to see the valley full of dishes, including the largest offset fed dish in the world, the 100 meter Green Bank Telescope. In addition to seeing these big dishes we are given complete access to operate the 40 ft dish during the conference.

Members will be voting on officers and directors at the annual summer conference. Nominations are listed in this issue of *Radio Astronomy* for the positions of President, Vice-President, three Directors, and one Director-at-Large. A ballot is included for members to use for voting. Ballots must be sent to **secretary@radio-astronomy.org** no later than 12:00 am Eastern Daylight Time on Monday, June 25, 2012 in order to be counted.

Until next time, happy monitoring,

Bill Lord
KJ4SKL

Editors' 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 and other publications, and announcements of radio astronomy star parties, meetings, and outreach activities.

If you would like to write an article for *Radio Astronomy*, please follow the Author's Guide on the SARA web site: **http://www.radio-astronomy.org/publicat/RA-JSARA_Author's_Guide.pdf**. Please note that the new version of the Author's Guide includes several changes, mostly dealing with article images.

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: **editor@radio-astronomy.org**.

Dave Typinski
Editor

Bill Seymour
Editor

Whitham D. Reeve
Contributing Editor

Christian Monstein
Contributing Editor

Tentative *Radio Astronomy* due dates and distribution schedule

Issue	Articles	Radio Waves	Review	Distribution
Jan – Feb	January 12	January 23	January 25	February 1
Mar – Apr	March 12	March 23	March 25	April 1
May – Jun	May 12	May 23	May 25	June 1
Jul – Aug	July 12	July 23	July 25	August 1
Sep – Oct	September 12	September 23	September 25	October 1
Nov – Dec	November 12	November 23	November 25	December 1

News from the World of Radio Astronomy

EVLA Rededicated as the Karl G. Jansky Very Large Array

On March 31, 2012, the Expanded Very Large Array (EVLA) in Socorro, New Mexico was rededicated as the Karl G. Jansky Very Large Array. With the upgrades installed over the last decade, the Jansky VLA is a much more powerful instrument than the original VLA built in the 1970's.

http://www.nrao.edu/pr/2012/rededicate/
http://www.nrao.edu/pr/2012/jansky/
http://www.nrao.edu/explorer/vla/TheVLAExplorer.php

Hat Creek Now Operated by SRI International

Built in 2007 by UC Berkeley and SETI, the Hat Creek Radio Observatory is now managed by SRI International. SRI, which also manages Arecibo, will use the Hat Creek observatory for monitoring space junk (a contract with the US Air Force) and will also allow SETI to continue to use the site.

http://www.sri.com/news/releases/041312.html
http://newscenter.berkeley.edu/2012/04/13/uc-berkeley-passes-management-of-allen-telescope-array-to-sri/

IBM and ASTRON to Develop Exabyte-Scale Computer Platform for SKA

IBM and the Netherlands Institute for Radio Astronomy (ASTRON) are teaming up to develop the systems necessary to handle the large volume of data that will be produced by the proposed Square Kilometer Array (SKA). The system will be able to process in excess of one exabyte per day, equivalent to about 12 terabytes per second or several times today's global internet traffic.

http://www-03.ibm.com/press/us/en/pressrelease/37361.wss
http://www.astron.nl/about-astron/press-public/news/astron-and-ibm-collaborate-explore-origins-universe/astron-and-ibm-co

Observation of Coolest Radio Star

A team from Penn State has detected the coolest star yet observed by radio. Using the Arecibo radio telescope, they observed flares at 4.65 GHz coming from 2MASS J1047+21, a type T6.5 methane brown dwarf about 33 light years away in the constellation Leo. The star has a surface temperature of only 900 K and is roughly the size of the planet Jupiter.

http://phys.org/news/2012-04-astronomers-coolest-radio-star.html
http://arxiv.org/abs/1202.1287

ALMA Observations Provide Constraints to Fomalhaut Planetary System

The first extrasolar planet directly imaged by the Hubble Space Telescope, Fomalhaut b, was until now thought to be a gas giant roughly the size and mass of Jupiter. New observations at 350 GHz by a team led by the University of Florida using the Atacama Large Millimeter Array (ALMA) telescope in Chile indicate that Fomalhaut b is slightly smaller to several times larger than Earth.

http://www.nrao.edu/pr/2012/fomalhaut/
http://arxiv.org/abs/1204.0007

Two First-Time Observations of Molecules in Space

Observations of deuterated hydroxyl (OD) at 1.3915 THz and mercapto radical (SH) at 1.383 THz have been made using the German Receiver for Astronomy at Terahertz Frequencies (GREAT) instrument aboard the Stratospheric Observatory for Infrared Astronomy (SOFIA) airborne observatory.

http://phys.org/news/2012-05-od-sh-molecules-space.html
http://arxiv.org/abs/1203.2825
http://arxiv.org/abs/1202.3142

South Africa, Australia, and New Zealand to Host SKA

South Africa, Australia, and New Zealand have been chosen to host the Square Kilometer Array (SKA), a €1.5 billion project to build the world's most sensitive radio telescope.

http://www.skatelescope.org/
http://www.ska.ac.za/
http://www.ska.gov.au/Pages/default.aspx

New African–European Radio Astronomy Organization Formed

Soon after the announcement that South Africa would host part of the SKA, the The African-European Radio Astronomy Platform (AERAP) was formed. The new organization will foster partnerships between Africa and Europe for radio astronomy.

http://www.aerap.org/
http://astroafricaeu.com/event.php?id=11

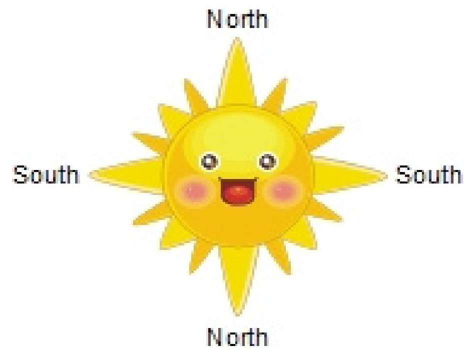
Blinded by Science

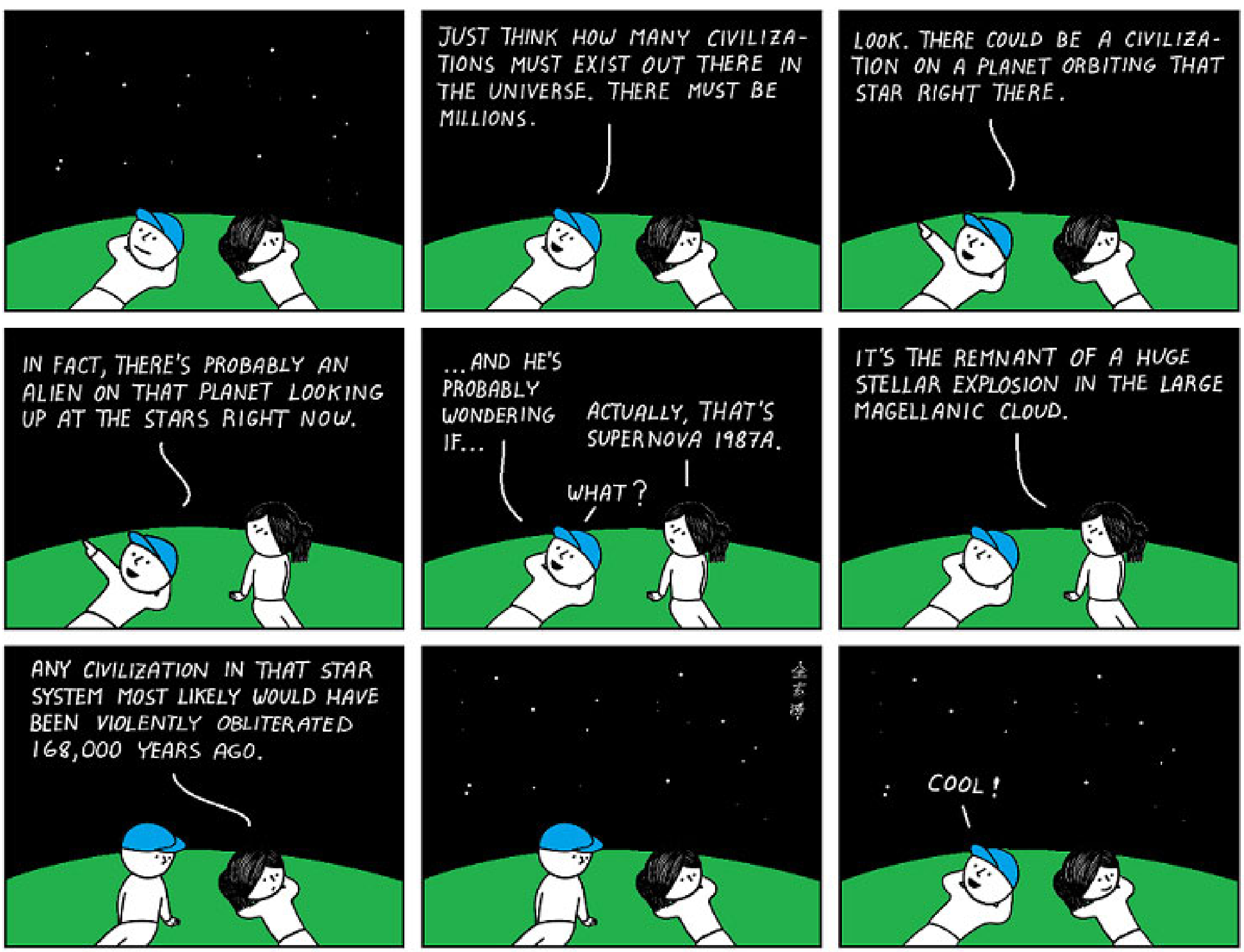
A San Bruno, California woman claims she hit two pedestrians with her car because she was blinded by the May 21st solar eclipse.

http://blog.sfgate.com/crime/2012/05/21/san-bruno-woman-blames-car-crash-on-eclipse/

Sun's Magnetic Field Scheduled to Reverse in May–June 2012, Julian Jove reporting

Approximately every 11 years, our Sun reverses its magnetic field. The last reversal, which took place during the early morning hours of 4 July, 2000, caused everything from crop failures in the Libyan Desert to continuous streams of Category F6+ tornados in Liberal, Kansas USA, where the Wizard of Oz was filmed, to the computer Y2K problems. Scientists from the Institute of Hot Science (IHS) have predicted the next reversal, but the prediction is for no ordinary reversal. In a press release, former criminal mastermind turned lead scientist, Dr. Duke Mantee said "We crunched the numbers and our results show the next reversal will occur within 1 or 2 nanoseconds of midnight, 31 May, 2012. However, rather than simply reversing itself, the Sun's magnetic field will morph into a quadrupolar field with two south poles and two north poles. There no longer will be an east or west. Furthermore, due to the interaction between the solar plasma and the interplanetary magnetic field, known as the 'oscillating two-stream instability,' ordinary solar compasses will no longer work and we believe all satellites and spacecraft will lose their way and spin out of orbit." He added, "Our studies show the Sun's behavior will definitely affect Earth's climate, but we will not release our current doomsday hypothesis until we receive additional government funds." In an accompanying press release, IHS reports "Our reversal calculations have a confidence factor of 2 parts per quadrillion (ppq), easily placing our studies in the top five for 2012. We expect to receive the Hobart Prize for Accuracy and Precision" Asked if IHS staff has any special plans for the day of the reversal, co-lead investigator Professor Cody Jarrett said "The first thing we are going to do is buy a boatload of SPF1000 sunscreen lotion."





A little knowledge makes everything a little cooler.

Courtesy Abstruse Goose **http://abstrusegoose.com/451**

Summary of 2012 SARA Western Conference, 24 – 25 March

Julian Jove

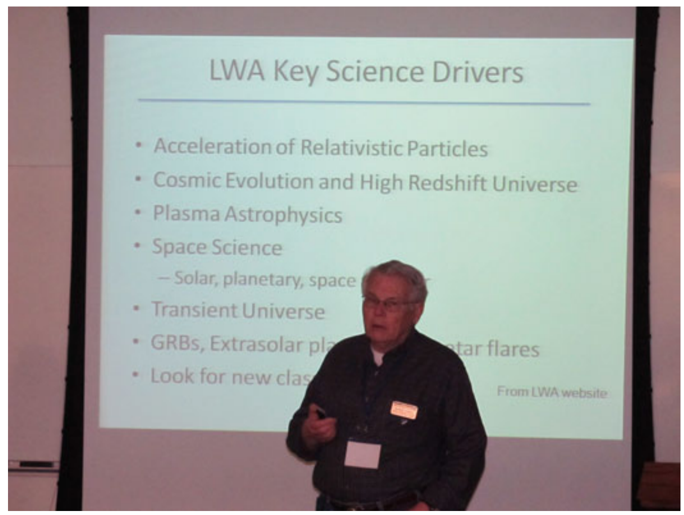
The SARA 2012 Western Conference was held at Stanford University in Palo Alto, California, USA (aerial photo right © aerialarchives.com/ Alamy). Debra Scherrer, Coordinator of the Stanford Solar Center, helped us obtain facilities at the Physics and Astrophysics building on the Stanford campus. We used the same room as the 2010 Western Conference, so we were in a familiar setting. Bill and Melinda Lord, SARA president and treasurer, respectively, kept us organized and out of trouble for the most part. I did see the Stanford Sheriff speaking sternly to a couple of attendees on Sunday morning but I kept my distance (for security reasons) and did not hear what it was all about. We had about 18 attendees. If you did not attend, you missed some interesting talks and discussions, which are described following.

Group photo: Back, l-r: Oliver Pitterling, Ray Fobes, Dave Westman, Debbie Scherrer, Curt Kinghorn, Keith Payea, Whit Reeve, Jim Campbell, Richard Sanders
Seated, l-r: Bill Lord, Bob Lash, Anne Driscoll, Larry Lu, Neal Vinson and Fred Miles.
Not pictured: Monica Bobra, Pavel Kosovichev and Melinda Lord (photo courtesy Melinda Lord)

The first day of conference, Saturday, was a rainy northern California day. We had opening remarks and announcements by SARA president Bill Lord. We then heard from Curt Kinghorn of San Deigo, California, who described his total power radio telescope that operates in the protected radio astronomy frequency band of 608~614 MHz. This also is known as Channel 37 in the UHF television band. Although no TV stations actually use this channel, it is bracketed by active stations and, as Curt discussed, it is not entirely free from radio frequency interference (RFI). Curt was inspired by a presentation made by Shad Nygren at the 2010 SARA Western Conference (what Curt called "Shad Nygren's great idea"). Shad described using the AntennaCraft U4000 and U8000 dipole arrays, originally designed for the UHF television band, on channel 37 (see write-up of that conference here: http://

www.radio-astronomy.org/node/155). Shad's plan was to build an array of arrays using these antennas but we never heard back from him. Curt decided to try this out after experiencing what he called "paralysis by analysis" – the process used by a newcomer to amateur radio astronomy to decide what to observe and how to observe it. In addition to the U8000 antenna, he used a pre-owned Icom R-7000 wideband receiver, a preamplifier designed for the television band, Radio-SkyPipe charting software and a laptop PC. Curt's total investment was slightly under US$900. He showed us charts of drift scans and detection of Cassiopeia A at 610 MHz. Curt's next plan is to build an interferometer based on this work, and we hope he lets us know about his results.

Next, Pavel Kosovichev and Anne Driscoll presented their plan to use AWESOME ionospheric propagation data in an attempt to find precursors to large earthquakes. AWESOME, which means Atmospheric Weather Electromagnetic System for Observation, Modeling and Education, is a Stanford Solar Center project that records and studies VLF transmissions around the world. It is similar in concept to the SuperSID but much more sophisticated and expensive. AWESOME has been in operation since 2007. Pavel and Anne described previous studies that showed promising evidence of VLF propagation anomalies prior to very large earthquakes. Their project is just now underway and no actual analysis has been completed. We hope to hear more about this in the future.



After a break, we heard from Ray Fobes (right, photo courtesy W. Reeve), Jim Campbell and Neal Vinson on Long Wavelength Astronomy: A Collaboration Proposal for the Amateur Radio Astronomy Community. They described a scaled-down version of the Long Wavelength Array (also called LWA) collocated with the Very Large Array (VLA) near Socorro, New Mexico, USA. Ray provided an overview of long wavelength astronomy, which he defined as observing the whole sky at frequencies below 300 MHz. Ray showed images and illustrations of a drooping crossed-dipole antenna and an active balun used with the antenna. This antenna is very similar to those used in the LWA near Socorro. Neal discussed a proposed system consisting of a software defined radio (SDR) receiver, global positioning system (GPS) receiver for accurate time stamping and correlation, calibration facilities and a PC. Jim discussed observations that could be made with this setup. This project has great potential for amateur radio astronomers and there was some discussion on SARA's participation.

Next, Whitham Reeve described the e-CALLISTO solar radio spectrometer network, the CALLISTO Receiver used in the network and modifications that may be made to the receiver to expand its usefulness for radio astronomy and other purposes. The CALLISTO Receiver was originally designed by Christian Monstein at ETH-Zurich, Switzerland, and has been used for many years. The receiver has a tuning range of 45 to 870 MHz and can sweep up to 800 channels per second within that range with a resolution of 62.5 kHz. Two modifications have been recently developed to allow the CALLISTO Receiver to be used as a narrowband (300 kHz bandwidth) or wideband (7 MHz bandwidth) tunable front-end for software defined radio receivers. CALLISTO Receivers originally were distributed by ETH-Zurich through the efforts of Christian Monstein. However, funds for this activity are in very short supply and Whit now produces the receiver and sells user-built and ready-built/tested versions.

Larry Lu, a student at Riverside High School in Riverside, California, and originally from China, discussed the SID program in China. He and two friends obtained a SolarSID (the red box that is the predecessor to the SuperSID) from Stanford Solar Center. They built progressively larger loop antennas for receiving VLF transmissions, and they used Audio Analyzer 2010 software to record and analyze the data.

Toward the end of the day we had an open forum. Bob Lash (famous for the "Bob and Mike's Big Investment," or BAMBI, interferometer project), under threat of extreme duress, provided a description of the "Radio Sundial" project. This consists of the removal and relocation of ten antenna support foundations, or piers, from Ronald Bracewell's old antenna farm on the Stanford campus to the VLA site in New Mexico. Bracewell is well-known in long wavelength and solar radio astronomy. The piers originally supported an array of 32 dish antennas built by Bracewell (shown at right). Once moved to New Mexico, the piers will be arranged in a special physical pattern so that visitors can determine the location of a number of cosmic radio sources by measuring the Sun's shadow cast by the piers. For additional information and to contribute to the project: **http://www.razoo.com/story/Bracewell**.

At additional open forum discussions, the group discussed mentoring opportunities and the need for advocacy and volunteers in amateur radio astronomy and associated education. Another suggestion is to connect newcomers with experienced observers in their area so they can go see actual installations and setups. This would help them overcome problems we all have had in determining methods and materials. As my old friend Alfred E. Neuman used to say "An on-site visit is worth ten thousand words."

On Sunday, the weather had much improved. Bill and Melinda Lord provided an update on SARA's collaboration with Stanford Solar Center on the SuperSID. SuperSID has been an immensely successful project. SARA first became involved in fall 2008. So far, over 340 units have been shipped to the USA and 46 other countries from Antarctica to Zambia. One very important reason for SuperSID's success is Bill and Melinda's very hard work.

During our scheduled open forum on Sunday morning, Neal Vinson discussed a "Space Exploratorium" project (**http://www.space-exploratorium.com/**), which he co-founded with Jim Campbell and Ray Fobes. The Space Exploratorium is an online resource that supports faculty, students, and teachers with a goal to improve K-12, undergraduate and graduate education in space physics and astronomy education. To round out our open forum, Ray Fobes made a presentation on the FUNcube Dongle SDR (**http://www.funcubedongle.com/**) and its application to amateur radio astronomy and the Long Wavelength Astronomy project described the day before. This appears to be a very interesting device from the UK, about the size of a fat USB drive stick, with a decent price tag (about US$185 delivered to USA, depending on currency exchange rates). The FUNCube has a design frequency range of 64~1700 MHz.

Our last presentation was by Monica Bobra of Stanford University, in which she described solar studies using the Solar Dynamics Observatory (SDO) spacecraft. This project was first described to us by Phillip Scherrer at our 2010 Western Conference. Monica showed very interesting imagery from SDO at various wavelengths. We were not able to obtain a copy of Monica's presentation but she provided the following links to all the material she covered in her presentation and much more:

http://www.youtube.com/littlesdohmi
http://solar-center.stanford.edu/
http://sdowww.lmsal.com/
http://www.skyandtelescope.com/skytel/beyondthepage/111380164.html

Monica also provided a link to a neat phone app called SDO:
http://www.appbrain.com/app/sdo%3A-solar-dynamic-observatory/com.astra.solarapp

After lunch, several of us headed up to Stanford's 150 ft radio telescope (check Google Earth at

37-24-30.86N, 122-10-46.50W) for a tour by Mike Cousins. Mike has worked at the site for 42 of the telescope's 52 years. Attendees of this year's conference will remember him from the tour he provided us after the 2010 conference. Mike is a great guy and we very much appreciated his time on a Sunday.

In addition to its regular radio astronomy duties, Stanford's 150 ft scope also serves industry by assisting with calibration and testing of GPS and other types of spacecraft. The top photo at right shows the dish antenna and equipment room on the day of the tour (photo courtesy W. Reeve). The antenna feeds are changed by rotating the dish so that it is about 1 deg. below horizontal. The tripod feed support at the top is then released. The bottom two supports are hinged and the end can be lowered so that it almost touches the ground. Work can then be done safely at ground level. The regular feed (pointing up at top of picture) can be replaced by a sub-reflector and another feed may be installed flush with the dish at center.

All radio telescope equipment is located and controlled on-site; this is not a remotely controlled scope like many others. The picture at right shows Mike Cousins at the control console (photo courtesy W. Reeve). The control room can be seen from the outside at the center-bottom of the previous picture. Mike demonstrated mechanical operation of the antenna by rotating it in azimuth and elevation, during which none of the many local prairie dogs were harmed (well, actually, I am not too sure about that, but it did make me think about setting up a trapline on-site).

All presentations, except as noted above, have been printed as PDF files and will be sent to attendees on CD.

Tour group at base of Stanford's 150 ft radio telescope: l-r, Curt Kinghorn, Bill Lord, Melinda Lord, Fred Miles, Mike Cousins (photo courtesy W. Reeve)

Sky Scan Project Update

David Cleary

The Sky Scan Science Outreach Program is a collaboration between the Edmonton Centre of the Royal Astronomical Society of Canada (RASC) and the Department of Physics at the University of Alberta. Sky Scan is using optical and radio telescopes to supplement the learning programs of Grade 6 and 9 science teachers for the sky science and space exploration units of their curriculum.

Staff and volunteers from the project visit science classes during regular school hours to introduce concepts of astronomy using hands on models and instruments to demonstrate such things as the phases of the Moon, spectroscopy, and FM radio meteor detection. The Astronomer in the Classroom program and field trips to the Department of Physics' observatory have involved more than 1500 students from 33 schools.

The radio astronomy component has proved to be the most challenging element to implement due to the relative complexity of the project, involving equipment and software installation, teacher training, and frequent followup with teachers to ensure meaningful results.

Originally forecast to reach 20 schools, 57 schools signed up in 2011. We managed to respond to 33 schools in the end. Our plan is to reach out beyond the city of Edmonton to under-served neighboring communities as well as meet the existing demand within Edmonton during the 2012/2013 school year, the second of a four year project.

Grade	Schools	Students	Astronomer visits (Schools)	Astronomer visits (Students)	Loaner scopes	Observatory day (Schools)	Observatory evening (Schools)	Students to Observatory	FM meteor detector in class
6	44	1689	36	1401	26	25	16	1245	Gr 9 only
9	15	1181	13	941	9	9	6	1013	11
Total	59	2870	49	2342	35	34	22	2258	11
Completed	33	1541	23	1189	5	21		380+	2
Scheduled			0	0	0	0		?	1
Outstanding	26	1329	22	1168	25	35		?	8

The table above is a summary of our Sky Scan astronomy project in Edmonton area schools as of Mar 31, 2012. It includes a program currently running in 2 Grade 9 science classes using the FM radio meteor detector as described in two *Radio Astronomy* articles in the Fall of 2011 (August-September and October-November). The upper portion of the table shows the requests we have for the program. The lower part shows what we've managed to do so far. We've had a lot more requests than we could handle this year.

The project is supported by grants from the Edmonton Centre of the RASC, the Department of Physics, the PromoScience program of the Natural Sciences and Engineering Research Council of Canada, and by volunteers from the RASC and the Northern Alberta Radio Club.

RASDR Update – May 2012

Paul Oxley, Bogdan Vacaliuc, David Fields, Stan Kurtz, Marcus Leach, and Joe Teague

Introduction

SARA members are building a Software Defined Radio (RASDR) that is optimized for Radio Astronomy. RASDR has the potential to be a common digital receiver interface that is useful in many applications. All SDRs use an analog front end, a digital interface and a back end computer that can be functionally reprogrammed for a variety of projects. Unfortunately, existing SDR products are some combination of expensive, difficult to use, or optimized for the communications market (and lack many capabilities useful for radio astronomy).

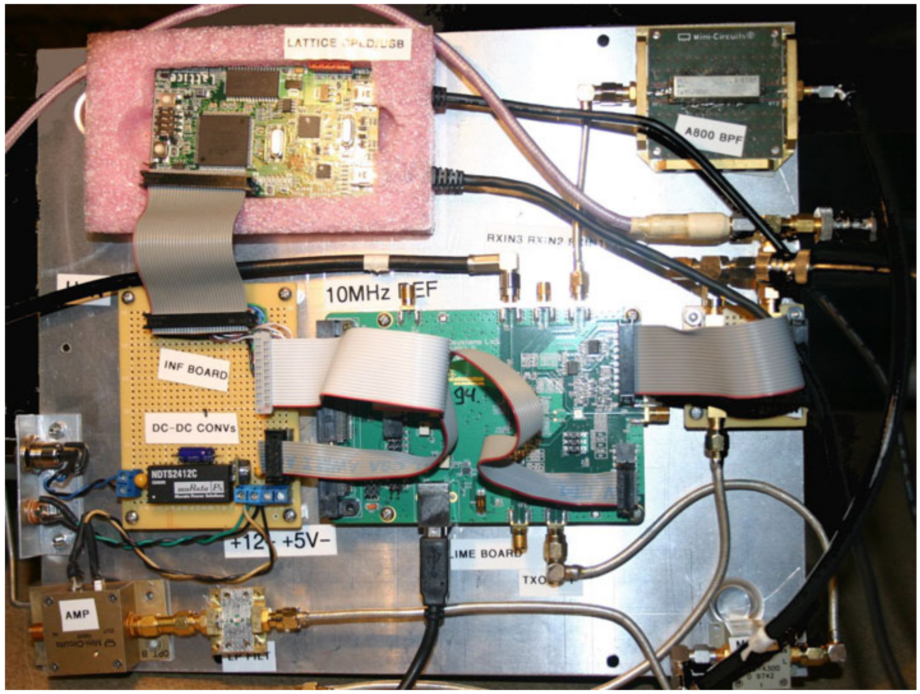


Figure 1 – the benchtop RASDR. The Lime board (green) is in the center, while the Lattice digital board is shown at the upper left.

RASDR progress is being tracked in *Radio Astronomy*, on the SARA website , on the RASDR Yahoo group , and on Sourceforge .

Since our last progress update, we have completed our analog benchtop front end and have interfaced it to the Lattice board. We are resolving difficulties with data transfer through the Lattice board (the CPLD). We have started discussions that should lead to licensing of an 'official' USB connection protocol for RASDR.

Hardware developments are more successful, in two areas: We have developed a working RASDR analog breadboard, and we have made a useful hardware upgrade to our Lattice board.

RASDR Front End (Analog section) Progress

Considerable progress has been made, with the breadboard configuration completed and testing ongoing. We have been able to extend the low frequency response of this board to below 100 kHz.

We are making analog measurements on the benchtop board. Specific RASDR status notes are as follows:

◊ Build Data Pipe generator/RASDR waterfall analysis codes for multiple OS (complete)

◊ Share front end design process on Sourceforge (ongoing)

◊ Spectrum Lab /vlfrx-tools development and testing (50%)

◊ Program Cypress chip on Lattice board (complete)

◊ Develop Lattice/computer data flow (80%)

◊ Codify (Frequency & Configuration) to Lime control parameters (25%)

◊ Hardware bench prototype with Lime/Lattice interface (75%)

◊ Develop Low/Intermediate Frequency Input boards (complete) and build (complete)

◊ Develop data flow – Lime/Lattice/back end hardware and programming (ongoing)

◊ Design and build RASDR board based on bench prototype (0%)

For optimal SARA member support, RASDR should provide coverage that goes significantly lower than the low-frequency cutoff (400 MHz) of our Lime femtocell chip. Our current measured performance is from 100 kHz through the low GHz region. We are starting to develop a set of operating specifications.

At this point, we are able to achieve 7.68 MHz of RF bandwidth across the tuning spectrum.

RASDR Lattice (Software) Progress

We are completing a significant effort to program the Lattice board to accept digital baseband data from the Lime board and pack it for transfer to the back end computer via USB. This is a first version of the Lattice CPLD/Cypress approach. The USB interface achieves 41MB/sec of sustained bandwidth without error, operating and tested on two different Linux computers. This equates to a peak RF bandwidth of 13.6MHz, if maximally packing bits. The design of the Lattice board is such that one bit of every byte is not usable for USB transfers, hence the current reduction in bandwidth and data packing. When we respin the Lattice interface board, this limitation will be eliminated.

All firmware source code, computer software and notes are on the Sourceforge link above and may be freely downloaded at any time.

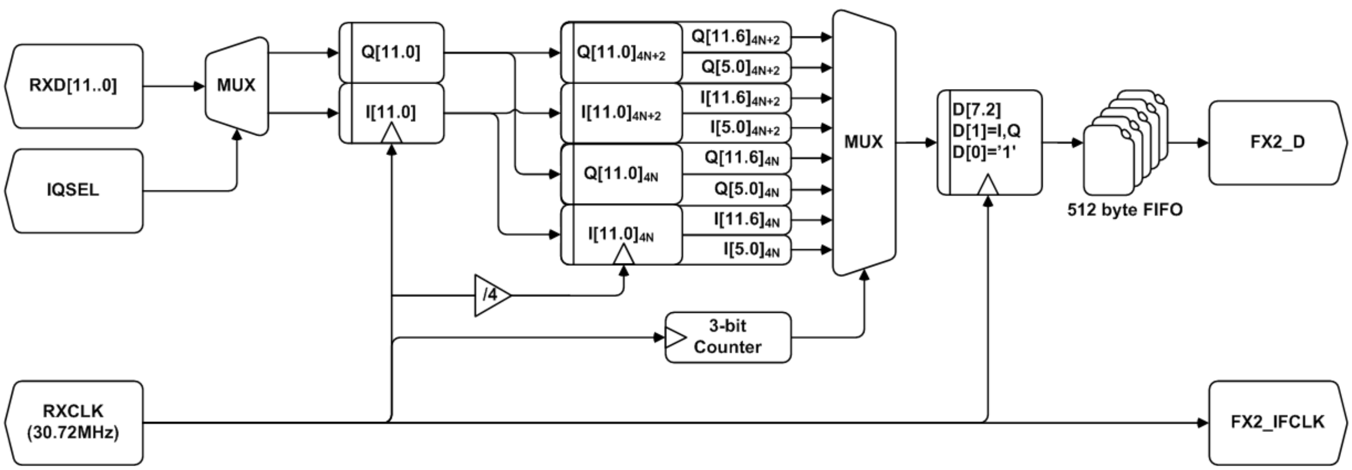


Figure 2 – shows the design of the packing pipeline implemented in the Lattice CPLD.

Finally, we have made hardware modifications to the Lattice board to permit cooling and allow switching the functionality of one of the header pins. This allows us to alternate between the intended JTAG function, and our preference to use the pin to accept another bus line of information from the Lime board. Figure 3 shows the modified Lattice board.

RASDR Back End (Computer Software) Progress

We are addressing software issues of data flow and timing.

RASDR Documentation

As described previously, progress is being tracked on the web and in *Radio Astronomy*. A RASDR User's Guide has been prepared that shows how to select frequencies in the low and intermediate frequencies. Two papers are being prepared for the SARA annual meeting.

References

[1] http://www.radio-astronomy.org
[2] rf-sampler@yahoogroups.com -- interested SARA members are invited to join
[3] http://sourceforge.net/scm/?type=svn&group_id=537344
[4] http://www.qsl.net/dl4yhf/spectra1.html
[5] http://abelian.org/vlfrx-tools/

Figure 3 – Modified Lattice board permits upgraded connectivity to the Lime board. Implementation of this connectivity will be address after we resolve programming challenges.

SARA Annual Conference in Green Bank

Conference and Registration Fees

The SARA Annual Conference and Meeting will be held at NRAO Green Bank, West Virginia from June 24 to 27, 2012 (Sunday to Wednesday).

The fee for the 2012 Conference has been set at $165 for all registered participants. This fee includes Conference registration, payment of your 2012 SARA membership dues, and one copy of the published Conference Proceedings (to be distributed at the meeting), morning coffee breaks, afternoon snack breaks, evening refreshments, and eight meals, as indicated below. Please note that all SARA 2011 memberships expire on June 15, 2012. Since SARA Membership Dues are now inseparable from Conference registration, all registered attendees automatically become SARA Members in Good Standing through June 15, 2013.

SARA Life Members, or those who have already paid their 2012 membership dues prior to registering, may deduct $20 from the above amount. Those registered for the 2012 Conference who subsequently purchase a Life Membership anytime during the 2012~2013 membership year may deduct $20 from the Life Member Fee (currently set at $400). And, because SARA offers a special membership rate of $5 for students, all full time students under the age of 18 may deduct $15 from the Conference registration fee.

The attendance fee for an accompanying family member (non-participating spouse, child, or companion of a registered Conference attendee) is $80, which includes morning coffee breaks, afternoon snacks, evening refreshments, and meals. The cited fees are calculated on a break-even basis and apply only to advance registrations received prior to May 31, 2012. All registrations received thereafter are subject to an additional late registration fee, as indicated below.

Included Meal Plan

Green Bank is a small community with few dining establishments. Thus, SARA has arranged for conference registration to include a meal plan at the NRAO employee's cafeteria, to include:

- Dinner Sunday night
- Breakfast / Lunch / Dinner Monday and Tuesday
- Breakfast on Wednesday

The NRAO Cafeteria is not a public dining facility, does not sell individual meals to visitors, and is doing SARA a favor by allowing the Conference group to use their cafeteria. Thus, the Meal Plan is an integral part of Conference Registration. Please note that in addition to the meals listed above, the Conference fee (or Accompanying Person fee) includes refreshments and coffee breaks during the Conference presentations, and snacks and beverages in the Drake Lounge in the evenings.

In general, one should consider the cost of meals to be inseparable from the conference registration fee except under unusual circumstances. For those with special dietary requirements, exceptions to the meal plan will be considered on a case-by-case basis. Please contact our Treasurer directly with your specific requests.

Conference Proceedings

Once again this year, a formal Proceedings is being professionally published. One printed copy of the Proceedings is included with Conference registration. (Please note that Proceedings are not provided to accompanying family members.) A limited number of additional copies of this year's and previous years' Proceedings will be available at Green Bank for $20 each. You may, if you wish, reserve and prepay additional Proceedings copies, by including the appropriate amount in your check to the SARA Treasurer.

Advance Registration Deadline

SARA Conferences require advance planning, thus early registration is encouraged. To register for the 2012 SARA Conference at the rates shown above, your remittance in full must be received by our Treasurer (not simply postmarked) not later than May 31, 2012. All registrations received after that date, including walk in registrations, will be assessed an additional 15% late registration fee.

Payment of Conference Fees

All prices are in US dollars.

Payment via check, in US dollars only, drawn on a US bank, should be sent in advance to:

SARA
Melinda Lord
2189 Redwood Ave
Washington, IA 52353
USA

You may also make payment by going to **http://www.paypal.com** and sending your payment, in US dollars, to **treasurer@radio-astronomy.org**.

Additional Information

Additional information about the conference may be found at **http://www.radio-astronomy.org/?q=node/181**.

2 Meter Repeater Available

SARA has received the following letter from the local amateur radio club in Green Bank:

President
Society of Amateur Astronomers
Feb. 2012

The 8 Rivers ARC welcomes the radio-astronomers to Greenbank, WV area during your conference in June. Knowing the difficulty of cell phone communication inside the Quiet Zone, we welcome all your members to use our repeater at 145.110 + tone 107.2.

This repeater has good coverage in the Greenbank area and beyond. Please inform your members that they are welcome to use the repeater any time. We also have a net Sunday evenings at 9pm.

Regards

Pat Schaffner KC8CSE
President, 8 Rivers Amateur Radio Club
Pocahontas County, WV

SARA Annual Conference
Abstracts Received as of May 13, 2012

Keynote Speaker

Dr. Namir E. Kassim

Dr. Namir E. Kassim received his B.Sc. from MIT in 1980 in physics, and his Ph.D. from the University of Maryland in 1987 in astronomy. His thesis research was a survey of our Milky Way Galaxy at a wavelength of 10 meters under the supervision of low frequency radio pioneer Professor William C. Erickson. His scientific interests include low frequency radio astrophysics, large HF/VHF arrays, and HF/VHF Adaptive Optics. He has authored over 100 refereed journal articles in low frequency astronomy, several books and book chapters, and numerous conference proceedings. Dr. Kassim is a pioneer in the resurgent field of low frequency radio interferometry, and has served as project scientist for the Low Frequency Array (LOFAR) in Europe, and is currently the project scientist for the Long Wavelength Array (LWA) under development in New Mexico. He also serves as Chief Scientist for the LWA1 Radio Observatory, led by the University of New Mexico. He currently works in the Remote Sensing Division at the Naval Research Laboratory in Washington, DC and is Head of the Radio Astrophysics and Sensing Section.

A Renaissance in Low Frequency Radio Astronomy

Dr. Namir E. Kassim, Naval Research Laboratory, Washington, DC.

Many of the greatest technical and scientific innovations in radio astronomy, including discovery of the field itself, were achieved at low frequencies. Jansky's detection of a long wavelength radio sky, as hot during the day as at night, was a shock to optical astronomers, and the Nobel-award winning discovery of pulsars near 81 MHz in 1968 was a milestone across astrophysics. But rather than catapulting the field to new heights, low frequency radio astronomy thereafter entered a period of dormancy relative to cm- and mm-wavelengths for several decades. With the emergence of an exciting suite of developing low frequency instruments across the world today, the field is undergoing

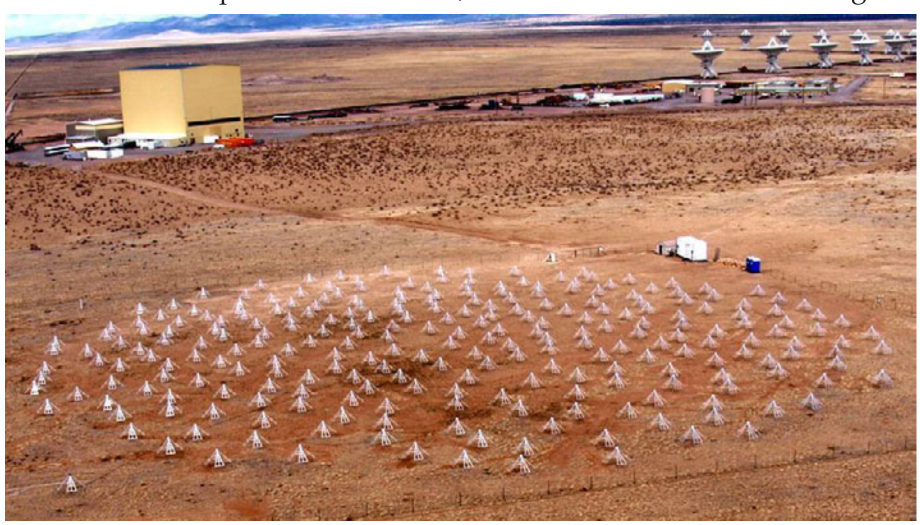


Figure 1: Aerial view of LWA1, the first station of the Long Wavelength Array (LWA), located near the center of the National Radio Astronomy Observatory's Jansky Very Large Array (VLA) telescope in New Mexico. LWA1 operates over 10-88 MHz and consists of 256 cross-dipole antenna stands arranged in a semi-random pattern. The diameter of the station is approximately 100 meters. Parabolic VLA antennas appear in the background at top right. The LWA1 is led by the University of New Mexico and supported by the National Science Foundation as a University Radio Observatory.

a bold resurgence. My talk will explore the reasons for this evolution in a historical, technical, and scientific context. I will briefly review the new telescopes and the scientific goals motivating their development, including for the Long Wavelength Array (**http://lwa.unm.edu**) project in New Mexico.

RASDR Development Status

Bogdan Vacaliuc[1], David Fields[2], Paul Oxley, Marcus Leech[3], and Stan Kurtz[4]

SARA members are working on designs for a Software Defined Radio (SDR) that is optimized for Radio Astronomy. The resulting receiver design, RASDR, has the potential to be a common digital receiver interface useful to many SARA members. A benchtop version of RASDR has been completed. This "Phase 0" RASDR provides digitized radio data to a back end computer through a USB 2.0 interface. One component of RASDR is the Lime Microsystems Femtocell chip which tunes from a 0.4-4 GHz center frequency with several selectable bandwidths from 0.75 MHz to 14 MHz. A second component is a board with a Complex Programmable Logic Device (CPLD) chip that connects to the Femtocell and provides two USB connections to the back end computer. A third component is an analog matching network that enables antenna connections to the Femtocell chip whose unique design allows upconversion of low frequency bands. Together these three components enable the RASDR to tune from 0.015 MHz thru 3.8GHz of the RF spectrum. The computer software used is based on vlfrx-tools[5] and Spectrum Lab[6], both of which are available to SARA members as free downloads. We will demonstrate the breadboard system and SARA members will be able to operate the unit hands-on throughout the workshop.

What is the "Epoch of Reionization" and How Can We Look at It?

David Westman

Research into the "Epoch of Reionization" has become an important area of cosmology over the past few years. Studying this period early in the history of the universe is crucial for the understanding of how the formation of atoms of the elements above hydrogen takes place, and how the galactic structure that we see has formed. It may seem that these facts of everyday life are too obvious to really investigate as they are now, but as we think about it more, the questions of "why are there so many complex kinds of atoms, which have the subatomic structure that we have discovered, exist?" and "why are there galaxies and clusters of galaxies of the kind that we see?" do not have self-evident answers. So, having discovered the "big bang", which is the origin of the universe, and having determined that this origin was approximately 13.7 Gyr ago, what took place between now and then to bring about the features of today's reality as we see them? A crucial part of defining this timeline is the "epoch of reionization", and evidence of this epoch can be detected with suitably designed radio astronomy antennas. This paper will describe how the existence of this epoch was discovered, why it is important, what kinds of signals we can expect to find from this epoch, and what the difficulties are in seeing these signals.

Taming the Ten Foot Dish for Radio Astronomy

Tom Crowley, Past President SARA

The ten foot TVRO dish appears to be the main stay in amateur radio astronomy. In the rural communities you'll still find the dishes everywhere. Most are no longer being used and have been replaced by Dish or DirecTV network dishes. This paper will discuss converting the TVRO dish for radio astronomy use. It will provide the necessary equations to determine gain, and find the correct focal point required to set the Feed horn. It will show how to set and calibrate the dish on the Southern Meridian and automating dish pointing for declination for approximately one hundred US dollars. This will allow pointing to the bright objects and the Moon and Sun. It can also be used for Hydrogen I surveys. It uses a "nudge" command for fine tuning. The talk will use the 21 cm line as an example, but the equations can be used to setup any dish.

Demonstration Devices and Audio Recordings for Radio Astronomy Presentations

Jon Wallace

Many of us are asked to give presentations to school groups and/or astronomy clubs and though we have tools such as the IBT, this usually isn't enough. The author has developed and built a number of devices over the last 30 years to help him teach about various topics that we as radio astronomers might want to talk about in a presentation. The author has also been trying to keep a record of all the recordings that he can find and many lend themselves to presentations. During this talk the author will show how to build and use the devices as well as share many of the audio clips he feels lend themselves to radio astronomy presentations.

Teaching About Black Holes

Jon Wallace

This past year the Peabody Museum at Yale hosted and helped develop a traveling program on black holes. Part of the exhibit was designed by students and had some interesting video clips and activities. The author was lucky enough to attend a teacher training session at Yale on this topic and then he developed materials to present to the Connecticut Association of Physics Teachers (CAPT) to help physics teachers teach about black holes. During this presentation the author will give participants a disk with many materials to aid in teaching about this popular topic and provide some guidance into using them.

Drift Scan Radio Astronomy Sky Mapping using an Articulating Parabolic Antenna

Michael T. M ruzek

The objective of this experimental setup and observing program was to create a sky map of the entire visible radio sky in one Sidereal day (1436 minutes, ~24 hours). Normally in drift scan observing the antenna is fixed in the declination axis during the data collection, and the rotation of Earth sweeps the field of view through the progressive hour angles. We endeavored to add articulating motion in the declination axis such that the field of view was swept from North (Pole Star) to South (Southern Horizon) every 2 minutes, while concurrently drift scanning for a Sidereal day. Consequently we could plot the observations as graphical 'pixel' regions on a 2 dimensional map to create a picture of the entire radio sky in a single day.

Operating a Remote Radio Astronomy Observatory

Chuck Forster

What does it take to construct and operate a remote radio astronomy observatory? There are many items to consider:

◊ Choosing the site location including property access and land ownership.

◊ How will you obtain electrical power supply, backup electrical power and Internet access?

◊ How will you provide basic RA equipment, heating and cooling systems, insurance and pay for electric power?

◊ How will you provide shelter, site safety, protection from vandalism and lightning damage?

◊ How will you construct safe antenna systems so unauthorized persons do not injure themselves?

◊ Who will have access to the site and equipment, and pay for the cost to/from site for repairs and restarting stalled computer equipment?

◊ How will you provide a remote control system?

◊ Who will you chose to use the system effectively, and what will they pay towards the cost of the system?

The author has installed and operated a remote observatory. The purpose of the talk is to share his experience with you to help you decide if you should do the same.

Low and Intermediate Frequency Inputs for RASDR

Paul L. Oxley, Vice President, SARA

The paper describes the design of the low and intermediate frequency inputs for the RASDR Phase 0 Breadboard layout. The selected LIME LMS6002D evaluation board provides inputs in the range of 400 to 3000 MHz Since it is desirable to extend this range to as low of frequency as possible, the project involved the selection and evaluation of alternative means of extending the low frequency input using a up conversion step to bring the signal to a frequency within the LIME board range. Two alternatives were considered namely, image cancelling up conversion and a frequency offset double sideband suppressed carrier (DSB-SC) scheme that uses digital filtering to suppress one of the two sidebands. The results indicate that it appears likely that the low frequency input range can be extended to 15 KHz using the DSB-SC alternative.

Observing Neutral Hydrogen (HI) in the Milky Way Galaxy

Tom Crowley, Past President SARA

Hydrogen comes in many forms. Neutral Hydrogen is a very cold form of Hydrogen. If it remains cold for a long period of time, and if the electron is spinning in the same directions as the proton, then the electron eventually does a spin flip, reversing direction and emitting a Photon at 1420.406 MHz. While it takes an average of ten million years for the spin flip to occur, there is a sufficient supply of neutral hydrogen to make it detectable in a small L band radio telescope. We'll look at the velocities of the clouds of Hydrogen in the arms of the Milky Way, map the velocities of the clouds and over the course of twenty four hours of Right Ascension. The importance of making the Geocentric observation, Heliocentric will be discussed and the technique will be demonstrated.

Annual Conference Video Stream Information

The annual conference at the National Radio Asttonomy Observatory in Green Bank, West Virginia will be available at Video Stream address: **mms://cod.nrao.edu:1800**

The video streaming format is Windows Media Video; playable on Windows, Macs or Linux computers with the required codec installed (e.g., in Windows Media Player, VLC for Mac/Linux, or mplayer on Linux).

The broadcast will run from 9:00 am Eastern Daylight Savings Time (EDST) until about 5:00 pm EDST on Monday June 25 and Tuesday June 26. There will be no broadcast during the lunch break.

SARA Annual Conference Tentative Schedule

June 24, 2012

Sunday	Topic / Activity	Speaker	Duration
12:30 PM	Conference Registration Dorm Lobby	Melinda Lord - Treasurer	As Req
1:00 PM	Radio Astronomy - Beginner Session- In the Visitors Center Conference Room	Tom Crowley - Past President	2
3:00 PM	40 foot Radio Telescope Familiarization Workshop - Meet in the Dorm Parking Lot	Tom Crowley - Past President	2.25
5:15 PM	Dinner in NRAO Cafeteria		2
7:15 PM	Hands on Radio Astronomy on the Lawn		
7:15 PM	Impromptu Presentations / Social in the Drake Lounge		
7:15 PM	Beginners Session - Welcome Center Conference Room	Jon Wallace	

June 25, 2012

Monday	Topic / Activity	Speaker	Duration
7:45 AM	Breakfast in the NRAO Cafeteria		1.25
9:00 AM	Welcome and Introduction	Paul Oxley - Vice President	0.25
9:15 AM	SARA Announcements	Bill Lord - President	0.25
9:30 AM	What is the "Epoch of Reionization" and how can we look at it?	David Westman	0.75
10:15 AM	Coffee Break & Poster Session in Lobby		0.5
10:45 AM	Teaching About Black Holes	Jon Wallace	0.75
11:30 AM	RASDR Development Status	Bogdan Vacaliuc - et al.	0.75
12:15 PM	Open Discussion		0.25
12:30 PM	Lunch in NRAO Cafeteria		1
1:30 PM	Call for Nominations of Officers and Directors	Bill Lord - President	0.5
2:00 PM	Observing Neutral Hydrogen (HI) in the Milky Way Galaxy with a 3 Meter Radio Telescope	Tom Crowley - Past President	0.75
2:45 PM	Operating a remote radio astronomy observatory	Chuck Forester	0.75
3:30 PM	Coffee Break & Poster Session in Lobby		0.5
4:00 PM	Low and Intermediate Frequency Inputs for RASDR	Paul Oxley - Vice President	0.75
4:45 PM	KEYNOTE SPEAKER - A Renaissance in Low Frequency Radio Astronomy	Dr. Namir E. Kassim, Naval Research Laboratory, Washington DC	0.75
5:30 PM	Dinner in the NRAO Cafeteria		1.25
6:45 PM	SARA Board Meeting in the conference room and Flea Market in Parking Lot and Dorm Lobby		1
7:45 PM	Impromptu Discussions and Social in Drake Lounge - Namir Kassim available for Informal Discussion		

SARA Annual Conference Tentative Schedule

June 26, 2012

Tuesday	Topic / Activity	Speaker	Duration
7:45 AM	Breakfast in the NRAO Cafeteria		1.25
9:00 AM	SARA Elections	Bill Lord - President	0.5
9:30 AM	SARA Business Meeting	Bill Lord - President	0.25
9:45 AM	Drift Scan Radio Astronomy Sky Mapping using Articulating Parabolic Antenna	Michael T. Mruzek	0.75
10:30 AM	Coffee Break and Poster Session		0.5
11:00 AM	Taming the Ten Foot Dish for Radio Astronomy	Tom Crowley - Past President	0.75
11:45 AM	Spectral Analysis: A Probe to the Ionosphere	John C. Mannone	0.75
12:30 PM	Lunch In NRAO Cafeteria		1.25
1:45 PM	Group Photo	Location to be announced	0.25
2:00 PM	NRAO High Tech Tour	Sue Ann Heatherly	1.5
3:30 PM	Coffee Break and Poster Session		0.5
4:00 PM	Demonstration Devices and Audio Recordings for Radio Astronomy Presentations	Jon Wallace	0.75
4:45 PM	2013 Conference Planning & Awarding of Door Prizes	Paul Oxley - Vice President & Incoming Vice President	0.5
5:15 PM	Dinner in NRAO Cafeteria		1.25
6:30 PM	Drake Lounge Open for Impromptu Presentations, Social and Hands-on Astronomy on the Lawn		
6:30 PM	RASDR Breadboard Demonstration	RASDR Development Team	

June 27, 2012

Wednesday	Topic / Activity	Speaker	Duration
7:45 AM	Breakfast in the NRAO Cafeteria		1.25
9:00 AM	Pay Room Bills in the NRAO Business Office		1
10:00 AM	Informal Calibration Session	Charles Osborne	2
12:00 PM	Conference Ends		

Nominations for SARA Officers and Directors

As required by the SARA bylaws (see below), this is the official call for nominations for SARA officers and directors. If you are interested in running for office and would like to know more about the positions, please contact a board member or SARA President Bill Lord (**president@radio-astronomy.org**). The requirement to be on the board is to attend the board meetings at the annual meeting and to actively participate in board-related activities. If you are unable to attend the annual meetings, then the director at large position may be for you. This position is a full board position except that attending the annual meeting is not required.

The following positions will be up for election in June 2012: President, Vice President, one Director at Large and three regular Directors. If you would like to run for one of the available SARA officer or board positions please send a note to Secretary Bill Seymour (**secretary@radio-astronomy.org**) copying President Bill Lord. Contact information also is listed in the Administrative Info tab on the SARA website (**http://www.radio-astronomy.org**) and in the Administrative section of *Radio Astronomy*.

SARA bylaws, Article VII, Section 3:

> Elections of Directors and Officers will be accomplished by the President placing an initial call for nominations in "The Journal" no less than ninety (90) days prior to the regular scheduled meeting. Two (2) nominations from different members will be required to nominate a member for an office.
>
> No less than thirty (30) days prior to this meeting (in a newsletter issued prior to the meeting), the President will place a notice of the results of the nominations in "The Journal", along with a ballot for the members to use to vote for the nominee of their choice. This ballot will be forwarded to the Secretary for collection and counting at the regular meeting.

Nominees for SARA Officers and Directors

Nominations received as of the date of this publication are listed here. A short write-up of each nominee's experience and reasons for running for an officer or director position follows along with a ballot and voting instructions.

Nominated for Director at Large

Whit Reeve

Nominated for Director

Chuck Forster
Scott Lansdale
Charles Osborne
Dave Typinski

Nominated for President

Bill Lord

Nominated for Vice-President

Tom Crowley

Nominated for President: Bill Lord

I have had the pleasure of serving as your President these past two years and am willing to stay on for another term.

During my tenure, our membership has grown to over 300 members. *Radio Astronomy* is a premier publication serving our membership thanks to the leadership and hard work of Whit Reeve and his team of Bill Seymour, Dave Typinski and Christian Monstein.

We have formed a solid partnership with Stanford Solar Center thru the SuperSID program. Stanford hosted us for the 2010 Western Conference and again for the 2012 Western Conference because of our relationship.

We are also working closely with the Radio Jove team by providing grants to students and teachers. Radio Jove and SARA have shared booths at Dayton Hamvention and Orlando Hamcation. The Radio Jove team was our keynote program for the 2010 Annual Conference at my request.

We have built a relationship with Dave Cleary and Sky Scan of Canada. This group is working to put radio astronomy in schools by using meteor detection. Dave has written articles for *Radio Astronomy* detailing their work and progress.

I plan to keep moving SARA forward and encourage our members to share their ideas, progress, successes and yes, even failures so we can all continue to learn and expand this hobby we all enjoy so much.

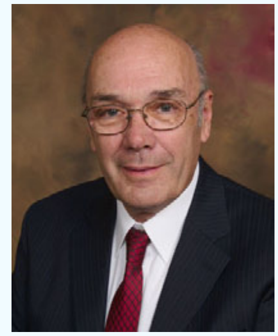
Nominated for Vice President: Tom Crowley

Tom is running for SARA Vice President; he has been a member of SARA for over 20 years and has served as President, Vice President and Treasurer. His goals as VP will be to continue the improvement of our annual meeting and to add to the value of SARA for its members.

Tom has had a long interest in astronomy both visual and radio. During the winter months he and his wife Lynn spend their time at the Chiefland Astronomy Village in Florida enjoying radio, visual and imaging astronomy. Tom has discovered 8 Supernovas over the past 6 years. He has also served the Atlanta Astronomy Club as Director and Chairman of the Board. Tom is also an avid ham radio operator, KT4XN, first licensed in 1957.

Tom retired from a long career working in computers and computer networks. After taking early retirement from IBM, Tom was VP, Network Planning in New York City while at the joint venture between MetroMedia Fiber Network and Racal Telecom in the UK. Tom returned to Atlanta and joined ATT Global Network Services as a Division Manager until retirement in 2002.

Nominated for Director: Chuck Forster



Joined SARA around 1985. Presently a Life Member.

President of SARA from 1991 to 1995.

Journal editor from 1994 to 2000.

Constructed and distributed SARA 408 MHz receivers in 1996-1997.

Don't forget the design work of Jim Carroll and Hal Braschwitz!

Presently employed to detect and evaluate high frequency, short duration impulse's in dairy farm environments.

At the age of 69, I am planning to retire sometime, not sure when.

Nominated for Director: Scott Lansdale

Scott Lansdale was born in Maryland and moved to Virginia as a teenager. His interest in astronomy grew in high school, which continued in college. He graduated from Randolph-Macon College in Virginia with a Bachelor's in Physics. For his Senior Project

(2001), he constructed a 10-ft hydrogen-line radio telescope operating at 1420 MHz, which he described at the 2002 SARA Conference. He called his project "the Center of the Universe Radio Telescope (CURT)." He said, "The SARA organization was pivotal in the success of the project as I had many questions along the way." Scott now serves as a SARA Mentor for Virginia & Washington, DC and he currently works as a software systems engineer.

Nominated for Director: Charles Osborne

I'm seeking the office of Director in SARA because I feel I can best make a contribution there without exceeding my available time. In the past I was:

SARA President from 2002–2008

SARA Vice President from 1999–2002

SARA Board of Directors from 1994–1999

In 1982 I Co-founded the Southeastern VHF Society. I have been President of the Southeastern VHF Society since 2010, and have been a Director for much of the past 15 years. I hold Extra class ham callsign K4CSO. I was licensed in college in 1977 where I was the President of the NC State Amateur Radio Club W4ATC and was elected as Electrical Engineering Representative to the Student Senate multiple terms.

I was Technical Director of the Pisgah Astronomical Research Institute from 1999~2007. This involved a wide variety of engineering and teaching roles as we retooled a NASA/NSA facility into a radio and optical astronomy not for profit public foundation. I brought many SARA oriented aspects of our hobby to the job including developing / building instruments for: seismometry, magnetometer, 12GHz IBT, HF antennas for RadioSkyPipe, 327 / 407 MHz pulsar receiver for the 26meter antennas, front ends / feeds for 1.4/2.4/3.3/4.8/6.7/8.4/12GHz for the 26m antennas, feeds/front end for 1.4/4.8/12GHz for "Smiley" the facilities' 4.6meter remote controllable teaching dish, VLF antenna / receiver, assisted with the fiber optic networking of the facility for remote control via the Internet for the optical telescopes, and opened the facility for volunteers to have hands on experience with all aspects of PARI.

My day job today with Rockwell Collins Government Systems is more a continuation of the type of satellite communications systems engineering design jobs I held in the 1980's and 1990's. I've worked for: ITT, AT&T, Scientific Atlanta, and Electromagnetic Sciences as Product Engineer, Lead Engineer, R&D RF Engineering Manager, and Division Test Engineering Manager.

My present city location isn't conducive to my: seismometry, geomagnetism, VLF, or HF Radio-Jove interests. But I have a 7ft dish for which I'm designing an 8.4 GHz feed and back end. But I've also had a 6.668 GHz methanol spectral line receiver online at times over the years. My interests tend toward the design and building of microwave LNAs, downconverters, and time / frequency references.

Nominated for Director at Large: Whit Reeve

Whitham Reeve was born in Anchorage, Alaska and has lived there his entire life. He became interested in electronics in 1958 and worked in the airline industry in the 1960s and 1970s as an avionics technician, engineer and manager responsible for the design, installation and maintenance of aircraft electronic equipment and systems. For the next 38 years he worked as an engineer in the telecommunications and electric utility industries with the last 34 years as owner and operator of Reeve Engineers, an Anchorage-based consulting engineering firm. Mr. Reeve has been registered as a professional electrical engineer and has BSEE and MEE degrees. He has written a number of books for practicing engineers and enjoys writing about technical subjects. Since 2008 he has been observing electromagnetic phenomena associated with the Sun, Earth and other planets and presently is a SARA Director at Large and an Editor of *Radio Astronomy*.

Nominated for Director: Dave Typinski

Dave Typinski is a professional businessman and amateur scientist who has been tinkering with things electrical and mechanical since he was old enough to hold a soldering iron and a Crescent wrench. His primary scientific interests are radio astronomy, mathematics, and the history of technology. Dave is an amateur radio operator, call sign AJ4CO, and is Co-Editor of *Radio Astronomy*, the journal of the Society of Amateur Radio Astronomers. He is an active member of the Radio Jove project and serves as part of the management group. He operates AJ4CO Observatory which provides real time strip charts and spectrograms of interference with a little bit of solar and Jupiter mixed in. Dave enjoys writing about science and technology; he sees SARA not only as an organization to serve the interests of amateur radio astronomers, but as an excellent vehicle to foster science and math education among young people. Dave lives in High Springs, Florida with his wife, daughter, and the cats—all of whom graciously pretend he is normal.

SARA 2012 Ballot

Members unable to attend the annual conference and meeting can email this ballot no later than 8:00 AM Eastern Daylight Time, Tuesday, 26 June to the SARA Secretary: secretary@radio-astronomy.org. This is one hour prior to voting at the annual meeting at 9:00 AM and will provide time for the Secretary to tally the emailed votes.

If your PDF reader does not allow copy & paste, write the position and name in the body of an email addressed to the Secretary and put "SARA Ballot" in the subject line. Be sure to sign your name as shown in your membership records.

President: Vote for One (1)

___ Bill Lord

___ Write In ________________________________

Vice President: Vote for One (1)

___ Tom Crowley

___ Write In ________________________________

Director: Vote for Three (3)

___ Chuck Forster

___ Scott Lansdale

___ Charles Osborne

___ Dave Typinski

___ Write In ________________________________

Director at Large: Vote for One (1)

___ Whit Reeve

___ Write In ________________________________

Agenda for Board of Directors Meeting – June 25, 2012

Reports from Officers

- ◊ President
- ◊ Vice-President
- ◊ Treasury
- ◊ Secretary

Other Reports

- ◊ Grant Committee
- ◊ Education Outreach
- ◊ Mentor Program

Old Business

1. Progress on a SARA Policy and Operations document
2. Beginner course on web/CD
3. ARRL Affiliation
4. RASDR Update

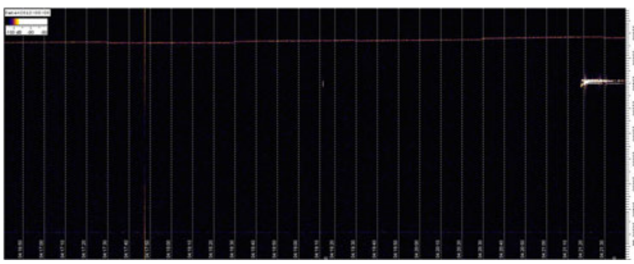
New Business

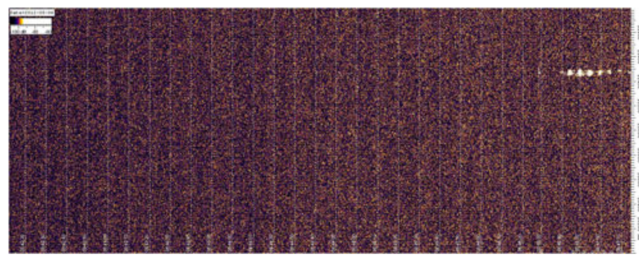
1. Annual meeting location and time
2. Change the director and officer attendence to at least one in person and one by Skype/ teleconference
3. Increase participation requirements of directors
    - ◊ Write or solicit one article per year for *Radio Astronomy*
    - ◊ Respond to discussion requests by the President at least 70%
    - ◊ Vote on motions brought to the BOD at least 70% (can be a undecided vote)
    - ◊ Actively assist with conference, Dayton Hamvention, Orlando Hamcation and/or other SARA functions.
    - ◊ Offer ideas to improve SARA, increase membership, etc.

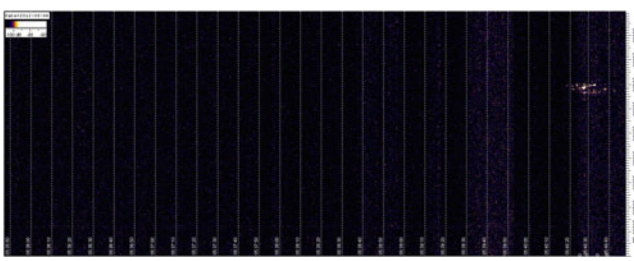
SARA Members Monitor the Radio Sky

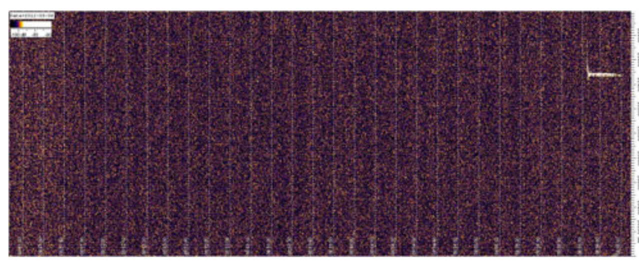
Meteor Trail Reflections Observed at Basingstoke, Hampshire, England

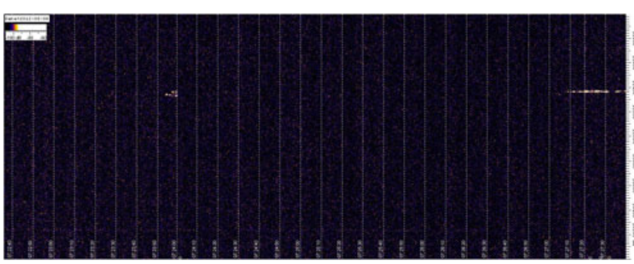
Paul Hyde captured meteor trail reflections shown below on 5 and 6 May, 2012. The reflected signals are seen as short, white traces on the right side of the spectrograms. Frequency is shown on the vertical scale and time on the horizontal scale. Each time tick is 10 seconds. Paul's hardware consisted of a home-constructed 3-element Yagi-Uda antenna and a FUNcube Dongle software defined radio (SDR) receiver. The software was SpectrumLab. The source of the reflected signals was the GRAVES radar system at Dijon, France, which transmits on 143.05 MHz and is 648 km from Paul's receiver location.

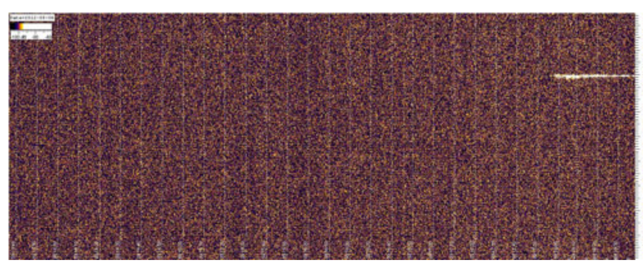










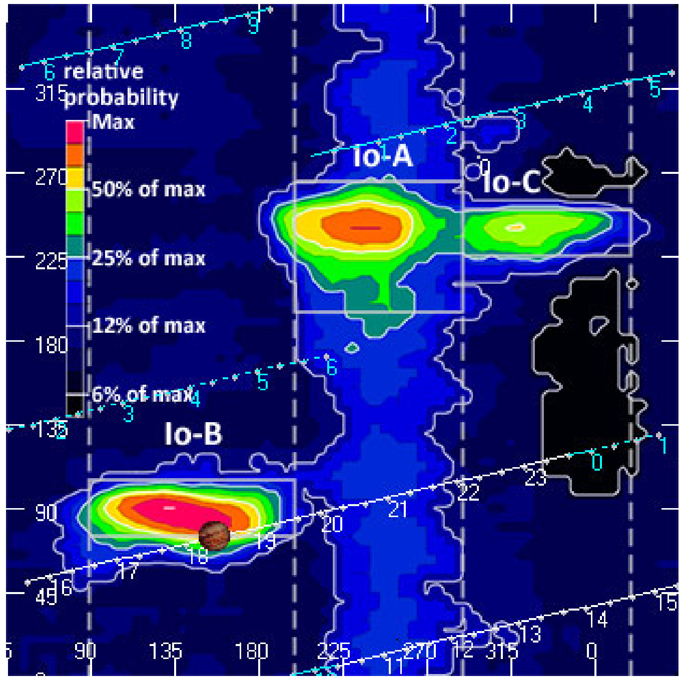


Jupiter Behind the Sun

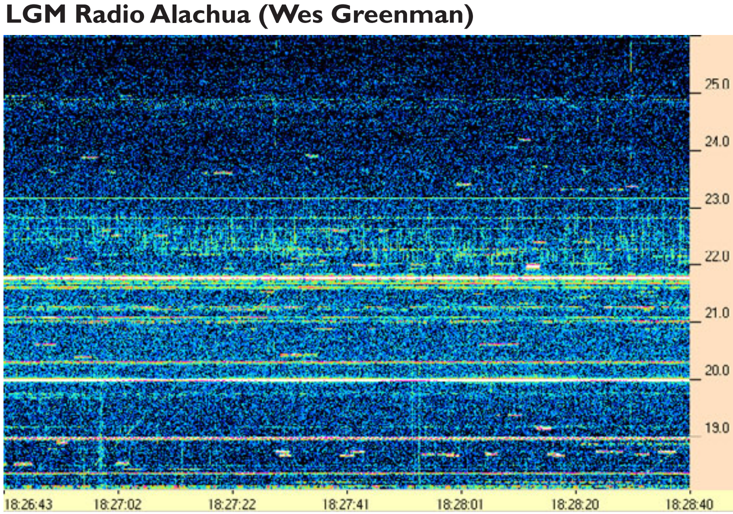
Wes Greenman and Dave Typinski observed a rare Jupiter burst from behind the Sun on May 21, 2012 at 1827 UTC (roughly one hour past local solar noon). This kind of observation is rare because the Sun was only 6° away from Jupiter at the time, meaning the ionosphere blocked most of the Jovian emission. This was an Io-B event, and it must have been particularly strong to make it through the ionosphere. The spectrograms reveal S-bursting at around 22 MHz.

Shown at right is the Radio Jupiter Pro phase plane display for the time in question. The phase plane shows the position of Jupiter's magnetic field on the horizontal axis (Jupiter's System III Central Meridian Longitude) and the position of Io in Jovian orbit relative to superior geocentric conjunction on the vertical axis.

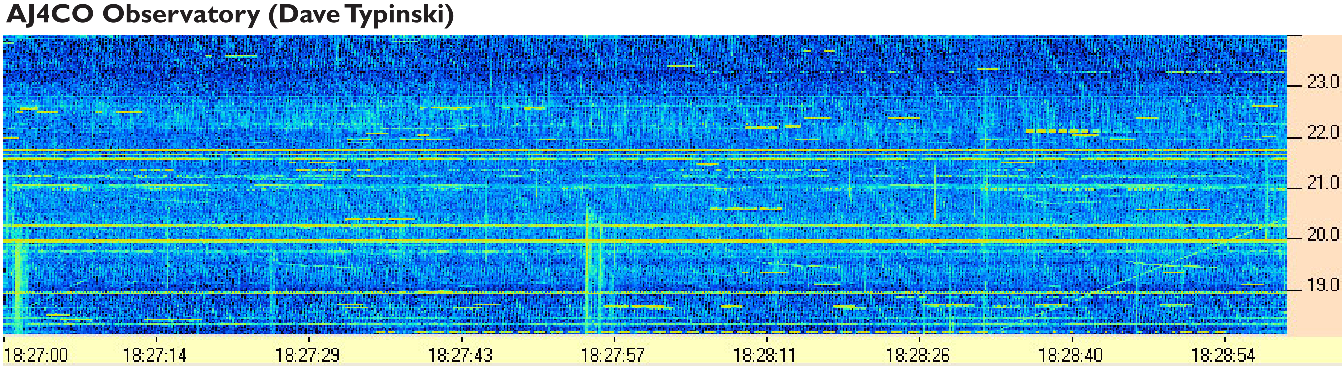
Wes was using an FS-X spectrograph on a dual-dipole 26 MHz Carr array; Dave was using an FS-200 spectrograph on a 4-dipole 20 MHz SuperJove array.



LGM Radio Alachua (Wes Greenman)



AJ4CO Observatory (Dave Typinski)



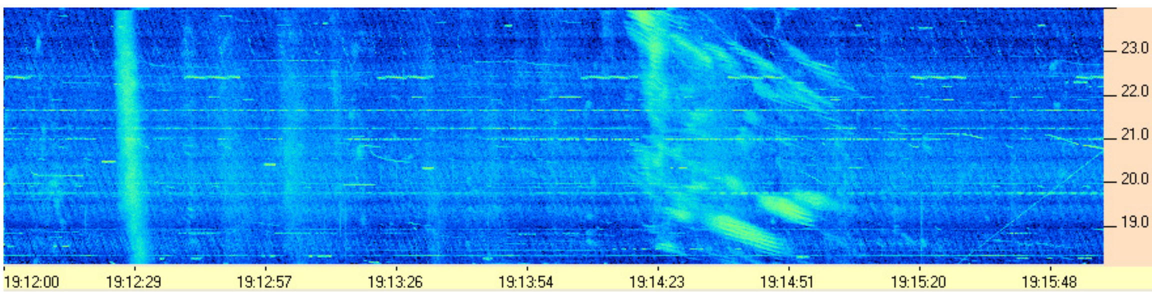
Rare Features Observed in Solar Spectra

On May 10, 2012 at 19:14:30 UTC, several observers (Dave Typinski, Wes Greenman, Jim Brown, Richard Flagg, and Jim Sky) recorded solar burst spectra with some very strange and rare features. There appear to be sloping diagonal lines in the spectra, which would normally indicate either a linearly polarized emission undergoing Faraday rotation in the ionosphere and being received by a linearly polarized antenna or some sort of modulation effect somewhere between the source and receiver.

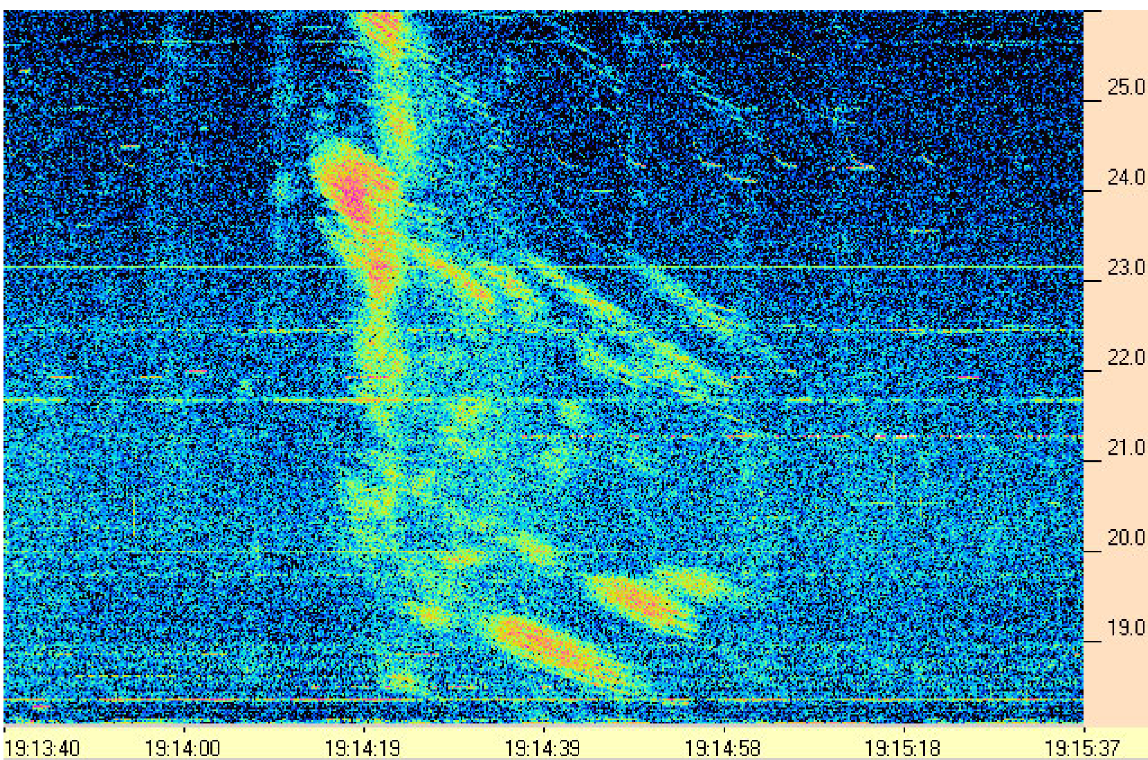
It is not clear whether these features represent terrestrial Faraday rotation, modulation lanes, or emission or absorption features. The Sun generally does not emit linearly polarized RF, preferring random polarization instead. The Sun also generally emits across a wide bandwidth, not in narrow channels. The slope of the lines indicates that if it were Faraday rotation, the amount of rotation is changing very rapidly with time, which generally doesn't happen with the ionosphere. If it were Faraday rotation, the lines should be closer together at lower frequencies—but these don't seem to follow that rule.

So, emission features or absorption features? Linear or random polarization? Rotation near the emission source, perhaps? We do not know.

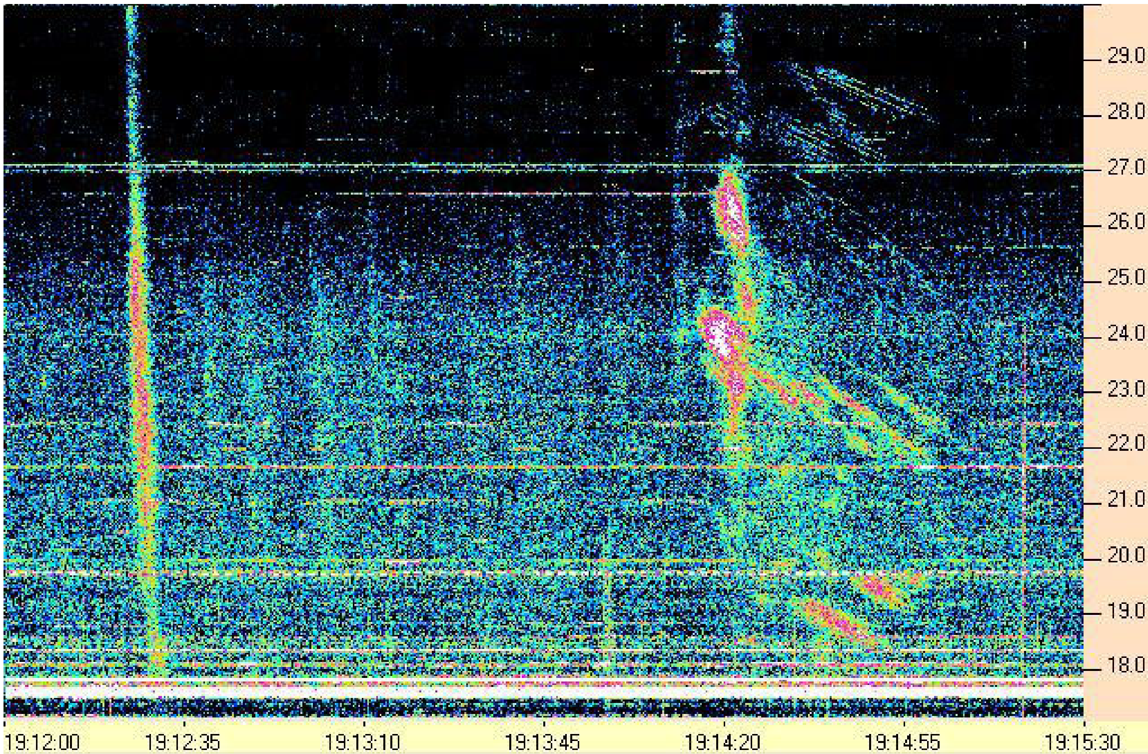
Our ignorance notwithstanding, this is one *very* interesting event.



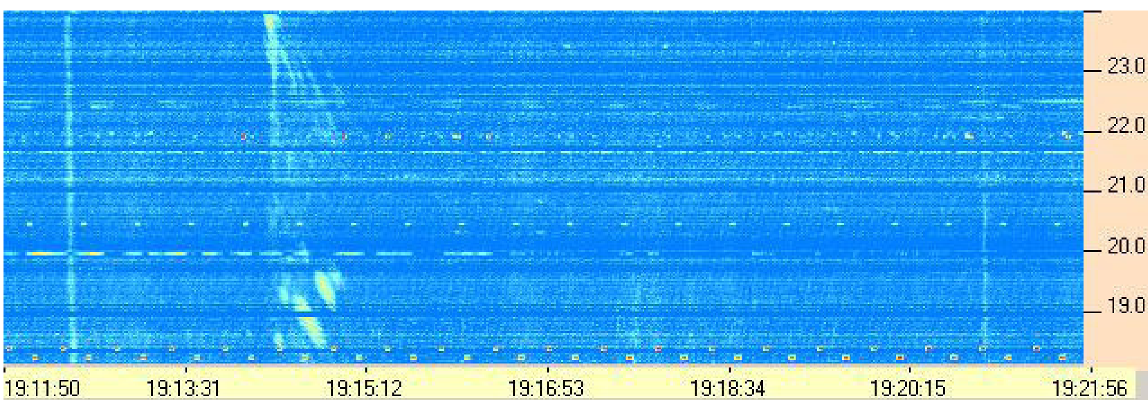
AJ4CO Observatory (Dave Typinski, Florida) – FS-200 spectrograph on 4-element, 20 MHz SuperJove array.



LGM Radio Alachua (Wes Greenman, Florida) – FS-X spectropgraph on dual dipole, 26 MHz Carr array.



Hawk's Nest Radio Observatory (Jim Brown, Pennsylvania) – FS-X spectrograph on a combination of a 20 MHz RadioJove dual-dipole array, a set of 24 MHz dipoles, and a 3 element Yagi.



Windward Community College Radio Observatory (Richard Flagg, Jim Sky, Hawaii) – FS-200 spectrograph on a 17 to 30 MHz log periodic.

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.

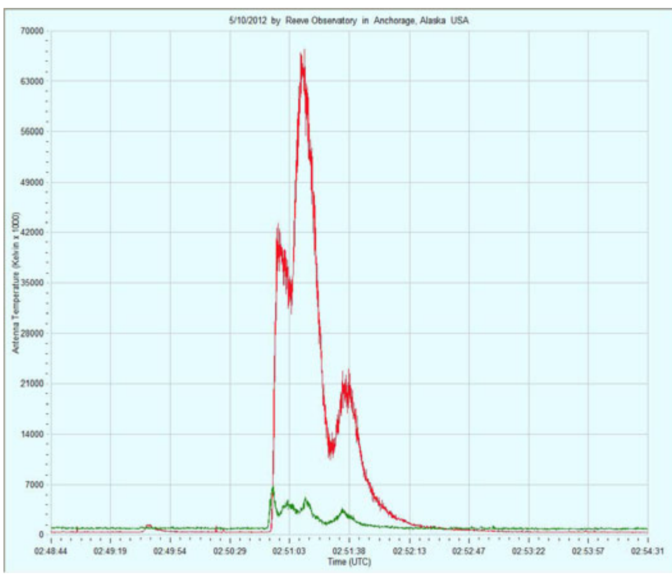
Guidelines for submitting observations may be found here: **http://www.radio-astronomy.org/publicat/RA-JSARA_Observation_Submission_Guide.pdf**.

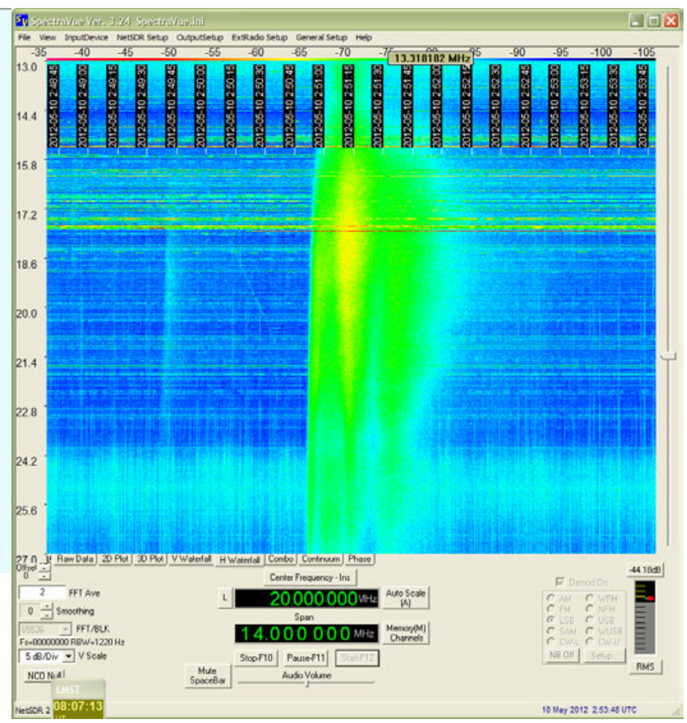
Solar Bursts Received at Reeve Observatory in Anchorage, Alaska USA

The Sun was very active on 10 and 11 May 2012, and representative records obtained by Whitham Reeve are shown below For all records, the hardware consisted of two Icom R-75 general coverage receivers and an RFSpace NetSDR software defined radio receiver, all connected through a receiver multicoupler to a Sun-tracking, 8-element log periodic antenna that is about 13.8 m above ground. The Radio-SkyPipe charts show the audio outputs from the R-75 receivers and the SpectraVue spectrograms show the output from the NetSDR. The charts and spectrograms have approximately the same time scale, covering a period of 5 minutes.

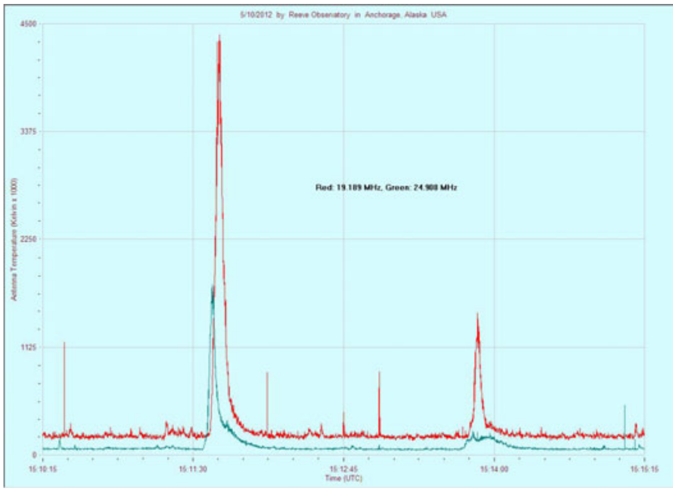
The Radio-SkyPipe charts show two very narrow slices of spectrum, or discrete frequencies, with a plot of receiver audio output power (in terms of noise temperature) along the left vertical scale versus time along the horizontal scale at the bottom. The receivers were set to lower sideband (LSB) at the indicated frequencies. The R-75 audio bandwidth for the LSB mode is approximately 2.8 kHz. The spectrograms from the NetSDR show the received power over a range of frequencies versus time. The spectrogram frequency is indicated along the left vertical scale and time is indicated by the stamps along the top horizontal scale. Just above the time-stamps is a color scale for the received power, from blue (low) to red (high). Below the spectrogram itself are SDR receiver settings including center frequency and frequency span. Spans of 14, 18 and 24 MHz are used in these spectrograms. For example, if the center frequency is 21 MHz and the span is 18 MHz, the spectrogram shows a frequency range of 12 to 30 MHz, or center frequency ± (frequency span/2).

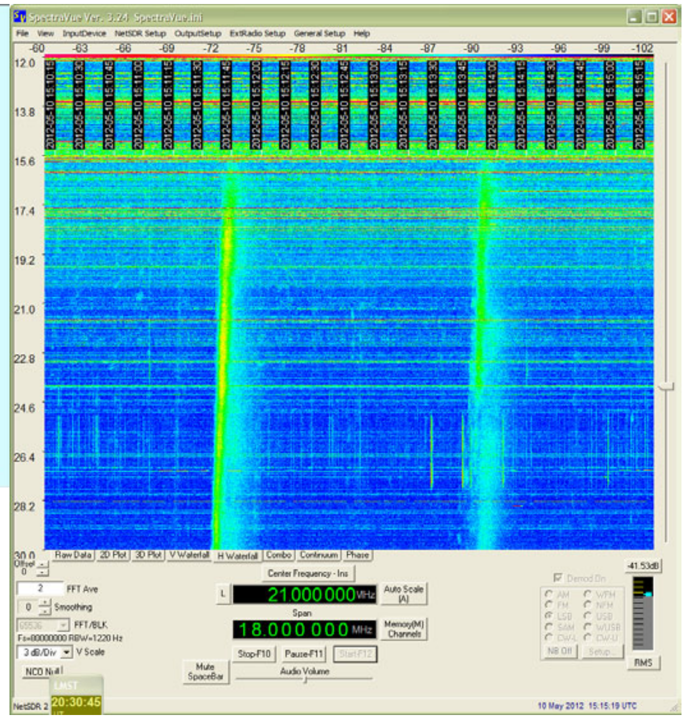
The two records immediately below show a powerful solar burst at about 0251 UTC on 10 May, 2012. The burst reached about 65 million kelvin at 19.2 MHz (red trace) but was considerably muted at 24.9 MHz (green trace), reaching only 7 thousand K. The spectrogram indicates the burst covered at least 13 to 27 MHz.



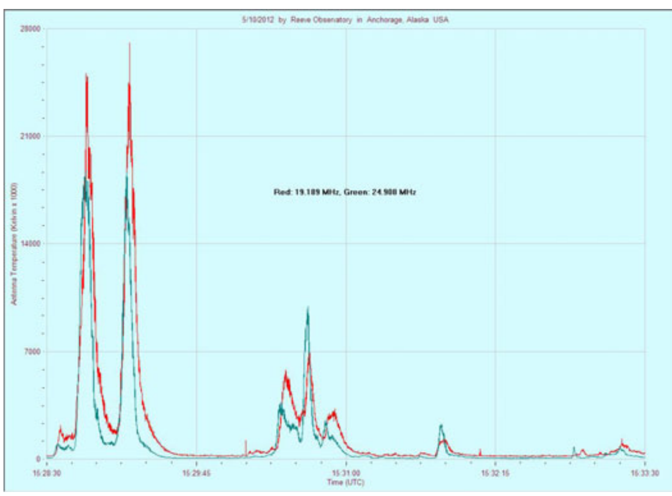


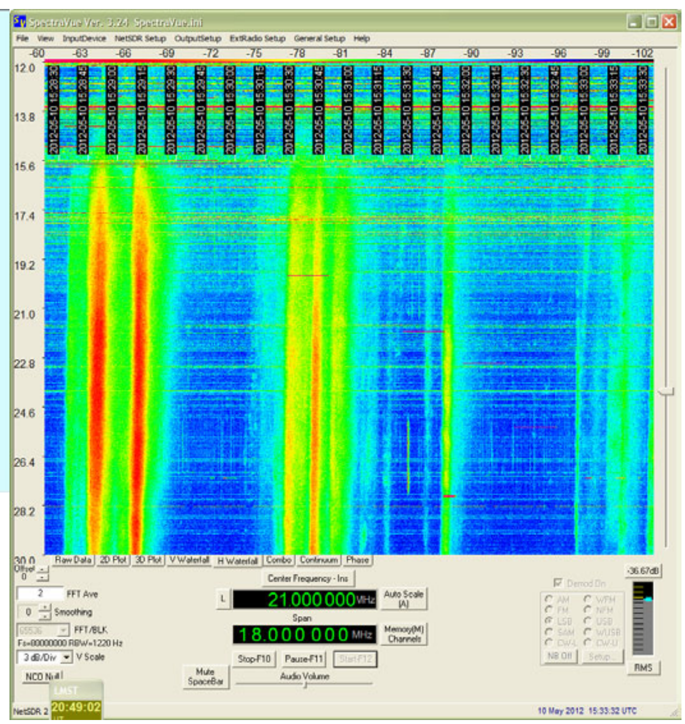
Reeve also received a pair of very short solar bursts at about 1512 and 1514 UTC on 10 May, 2012. As seen in the spectrogram below, these bursts covered a frequency range of at least 16 to 30 MHz, but they were not as powerful as some other bursts received on the same day.



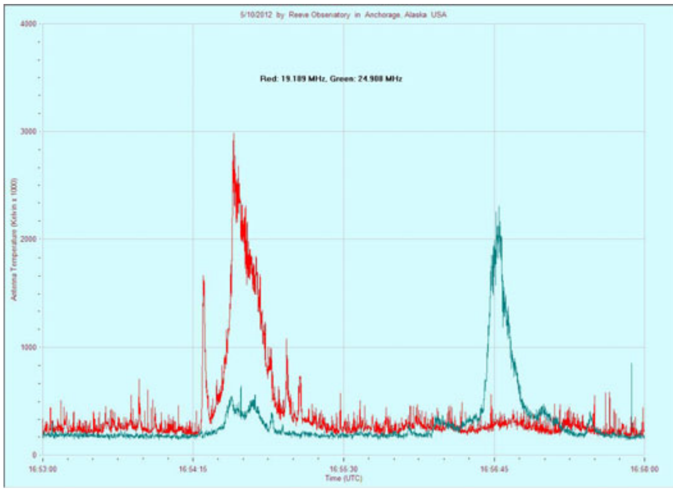


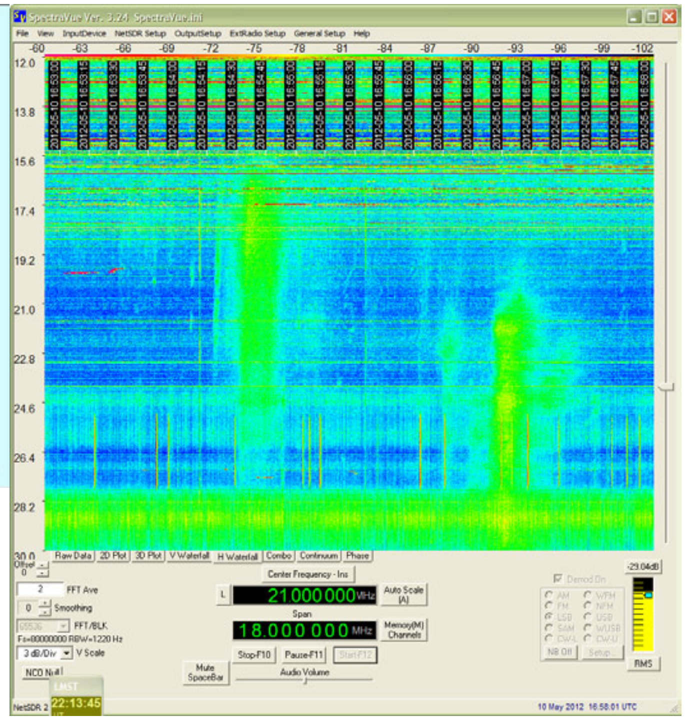
About 15 minutes after receiving the pair of bursts described previously, Reeve received a series of bursts shown below during the period 1528 to 1533 UTC on 10 May, 2012.



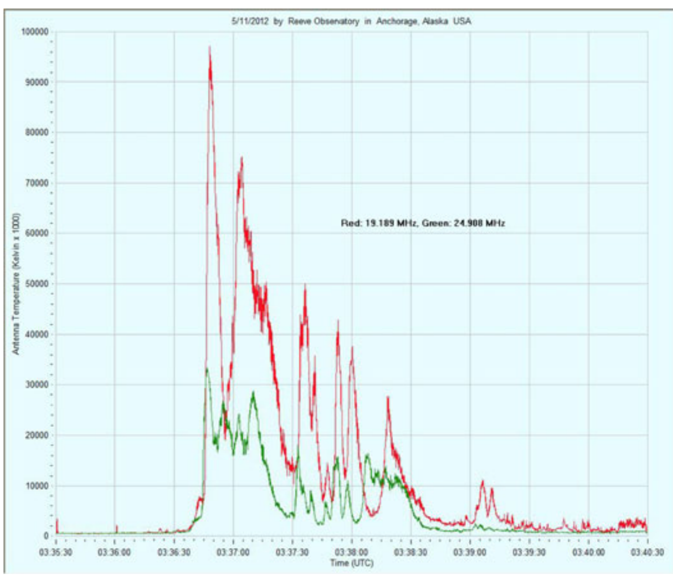


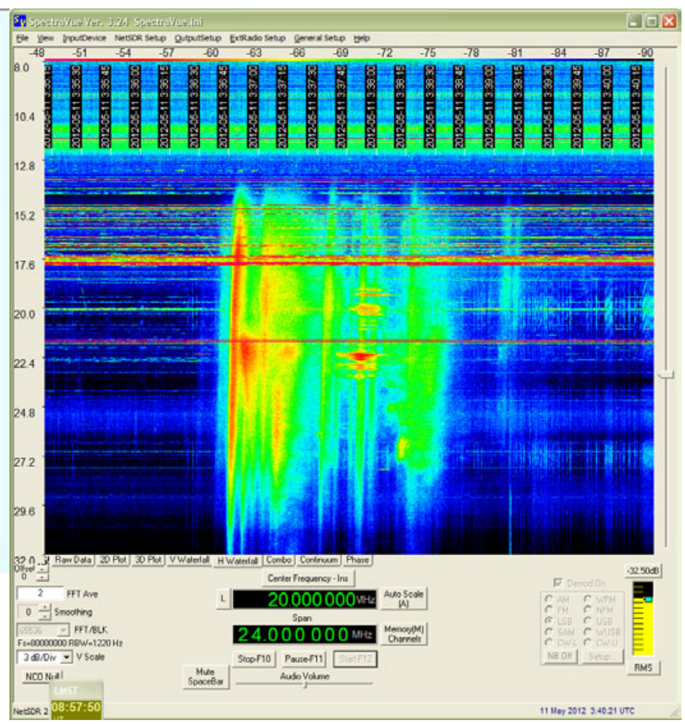
About 30 minutes later, Reeve received two bursts shown below, one indicated at 19.2 MHz followed one minute later by one at 24.9 MHz. The spectrogram reveals more complexity, with the higher frequency burst spectrogram looking somewhat like a saguaro cactus. The lower bright band at the bottom of the spectrogram is radio frequency interference (RFI).





Finally, Reeve received a very strong solar burst at about 0337 on 11 May 2012. This burst reached almost 100 million K at 19.2 MHz (red trace) and 34 million K at 24.9 MHz (green trace).





Long Wavelength Astronomy – A Collaboration Proposal for the Amateur Radio Astronomy Community

Ray Fobes[1],N eal Vinson[2], and Jim Campbell[3]

This paper was presented at the SARA Western Conference, Stanford, 24-25 march 2012.

Introduction

The professional radio astronomy community is beginning to build arrays to observe and study the universe at long wavelengths. Recent advances in electronics and computer power have opened up this relatively little explored region. We propose a simple version of these professional arrays taking advantage of all their testing and design work to create an amateur radio astronomy version of the long wavelength astronomical observatories.

Long wavelength astronomy studies the electromagnetic spectrum below about 300 MHz. Arrays are constructed out of dipole antennas connected together to create stations which in turn feed central computing processing facilities. The entire sky can be imaged to arc-second resolution and milli-Jansky sensitivity. Key science drivers range from studying relativistic particles, pulsars, the high red-shift universe and the transient universe.

The system proposed starts with a simple single broadband active HF dipole and an SDR and continues to expand with GPS timing and beam forming delay lines. Once several terminals are constructed collaboration between the sites will allow for multiple antenna observations, thereby significantly increasing the sensitivity and increasing the resolution allowing actual imaging of the radio sky to be accomplished.

What is Long Wavelength Astronomy

Recent advances in electronics and software processing and data analysis have opened up a new spectral window to exploitation at the lowest energy extreme of the spectrum by radio astronomers. To capture these extremely low energy “photons” long wavelength radio telescopes need large arrays of dipole antennas.

The primary reason why this long wavelength region has been ignored by radio astronomers was due to the high levels of noise created by the ionosphere and the low resolving powers of existing arrays. Most radio telescopes in use were large curtain arrays or single dipoles like the NRAO Solar Radio Burst Spectrometer at Green Bank or the numerous Radio Jove dipoles familiar to SARA members.

As we know we can increase the resolving power of a telescope by enlarging the aperture. In our case by increasing the distance between receiving elements of the array. This in effect increases the baseline of the telescope, and at long wavelengths useful resolutions require baselines of hundreds of kilometers. However, the limiting function is the ionosphere and its variation over time. One benefit of the long baseline is that it can be used to reduce the effect of local noise on the received signal. These irregularities in the ionosphere produce noise in the radio images similar to those produced in optical frequency images by atmospheric turbulence.

Over the past several years there has been several programs to develop more sophisticated active antenna designs. One of the goals was to be able to reduce the inherent noise produced in the active components. Spurred on by the development activities of the SKA a design emerged for the construction of hundreds of low-frequency active dipole antennas being operated simultaneously, capable of forming several simultaneous narrow beams. Using software control these beams can track multiple objects or scan different regions of the sky simultaneously.

The other major advance leading to ability to see through the ionosphere has been the increase in computing power and the development of calibration algorithms allowing the capturing of wide fields of view over short timescales to monitor and correct for ionospheric disturbances.

Observing at Long Wavelengths

Generally long wavelength astronomy operates at frequencies below 300 MHz and uses large arrays of dipole antennas rather than dishes. The dipoles have morphed over the past decade to a drooped dual dipole close to the ground. The crossed dipole antenna produces the two orthogonal components of the signal which can be used independently or cross polarized for circular patterns. The droop of the dipoles is generally 45 degrees. There is still work being done to determine the design of the dipole, from single wire to filled plane.

Long wavelength astronomy opens up a whole new range of sources, from space weather to pulsars and large scale structures of the universe not previously seen. Key science projects of the large long wavelength observatories include:

◊ Understanding the physics of active galactic nuclei and the acceleration of relativistic particles.

◊ Studying the interstellar medium and magnetic fields in nearby galaxies.

◊ Evolution of the universe by studying clusters of radio sources, baryonic oscillation and gravitational lensing.

◊ Studying galactic sources, including supernova remnants, HII regions, and exo-planets.

◊ Detailed solar studies including the initiation of CMEs, formation and development of shocks in the corona, and the generation of energetic particles in the Sun's atmosphere.

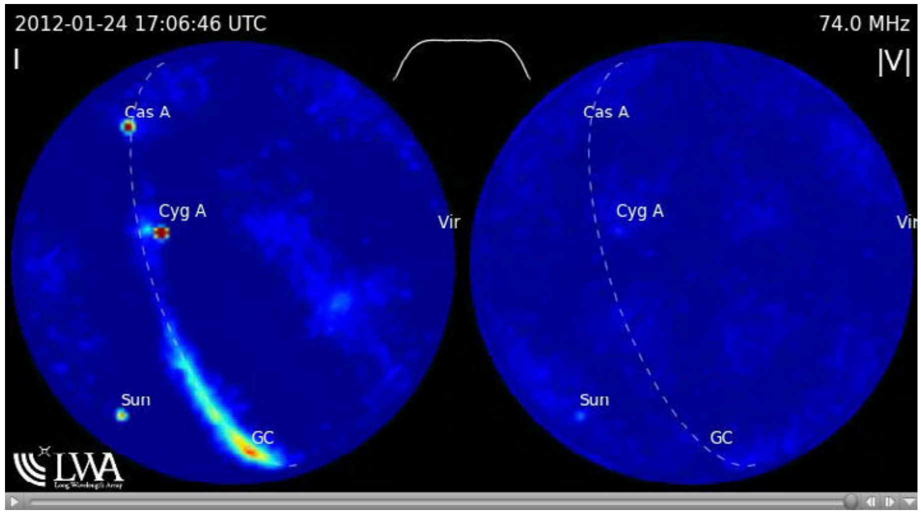
◊ Transient phenomenon of the dynamic universe, monitoring large portions of the sky for variable sources like pulsar flares and other types of flare phenomenon.

Some of the major work done to date includes studying the Epoc of Reionization regime in the high red-shifted universe from Z=4 to 12 time frame. The first examination of the epoch of reionization for the 21-cm hydrogen line was performed by Dr. Bowman, et al observing the spectrum from 100 to 200 MHz, corresponding to a redshift of $6 < z < 13$. The experiments were part of the EDGES test at Mileura Station. [4]

The Long Wavelength Array (LWA), Socorro, NM

The LWA has commissioned its first antenna station (shown at right), located adjacent to the VLA site. The station was completed in April 2011 and is composed of 256 dual-polarization dipoles. These dipoles operate as a single telescope, not as an interferometer. By phasing their signals very narrow beams can be formed to point over large regions of the sky.

The LWA operates from 10 to 88 MHz. It is envisioned that the complete system will contain hundreds of stations similar to the first one. Most will be located in New Mexico but serious consideration is being giving to expanding the system throughout the southwest. One of the major capabilities of the first station is to produce continuous all sky observations at specific frequencies. An example of these observations are shown in the adjacent figure to the right.

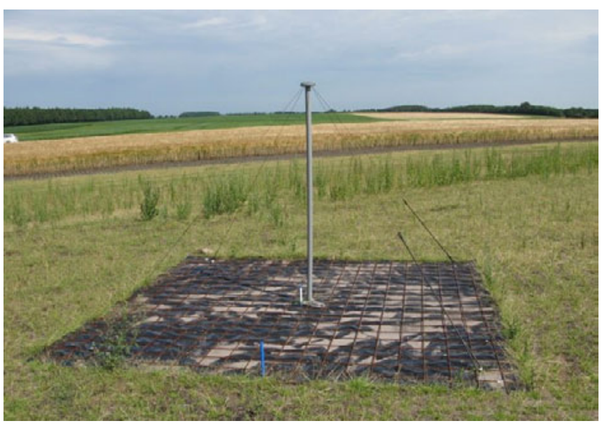


The Low Frequency Array (LOFAR), Netherlands

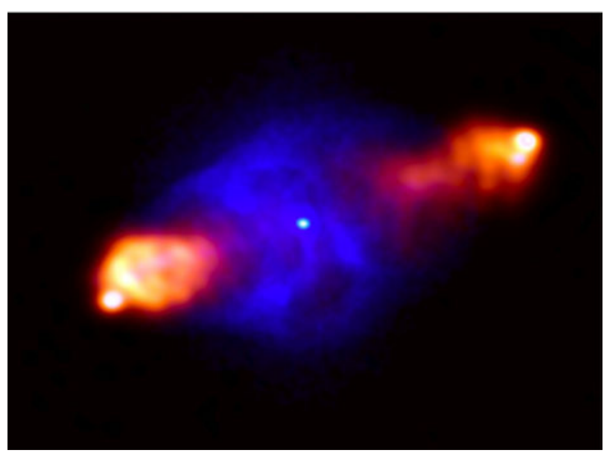
The LOFAR system is being constructed in Europe by a consortium of universities and industrial partners led by ASTRON (Netherlands Institute for Radio Astronomy). Now called the International LOFAR Telescope (ILT), stations will be located throughout northern Europe and the United Kingdom.

The design of LOFAR is a little different from the LWA primarily in that it has two sets of dipole antennas, one for the low band of 15 to 80 MHz and another set of bow-tie dipoles for the high band from 110 to 240 MHz. [5]

The initial station has seen first light and observations have begun in an all-sky survey at low frequencies called the Multi-frequency Snapshot Sky Survey (MSSS).



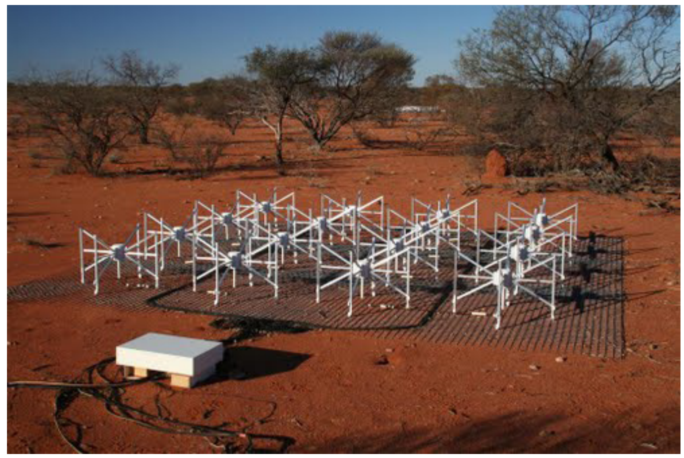
Shown above at left is one low band array element (30 to 80 MHz, crossed inverted V dipole arrangement); above at right is a pair of high band elements (110 to 240 MHz, crossed bowtie dipole arrangement). One of the first high band observations was of the Cygnus A region at 240 MHz. The resulting observation showed jets extending far beyond the visual part of the active galaxy as seen in the image at right.



Deep field observation by S. Yatawatta of ASTRON have been made at 150 MHz to image the universe EoR at a red shift of Z=6 or when the universe was about 2 By years old. The resulting 10 hour image shows galaxies to 6 arc-second resolution with 120 micro-Jansky's per beam in a 13 by 13 degree field.

The Murchison Widefield Array (MWA), Murchison, Western Australia

As a pathfinder for the SKA, the MWA is located in the outback of the Western Australian desert where the background and ionospheric noise is very low. The MWA is part of the Murchison Radio-astronomy Observatory (MRO) which is managed by CISRO. RFI studies have shown that there are wide portions of the VHF spectrum that are essentially noise free and the limiting noise is just galactic background. The MWA will, when completed, consist of 2048 dual-polarization dipole antennas similar to the LOFAR high band operating from 80 to 300 MHz. The telescope is constructed of 128 antenna platforms or tiles consisting of 16 dipoles in a 4 x 4 array on each tile. The tiles will be located out to 1500 meters. [6]

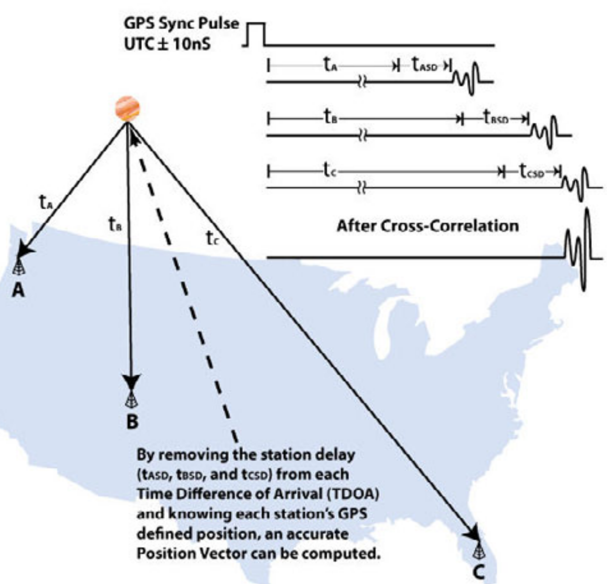


Field trials of the first tiles were conducted in 2006 by Bowman, et al. and showed the instrument to be as sensitive as expected. [7] Observations with just three tiles operational were conducted in 2007 and detected the giant pulses from the Crab Nebula pulsar at 200 MHz . Observations to date include spectroscopic imaging of the Sun which even with the limited set of tiles available (32T) have shown dense instantaneous monochromatic radio images with rapid temporal variation.

The above photo of one tile of the MWA shows the 16 dual-polarization bow-tie antennas in the 4 x 4 array. The 32 outputs are fed by coax to the tile control box.

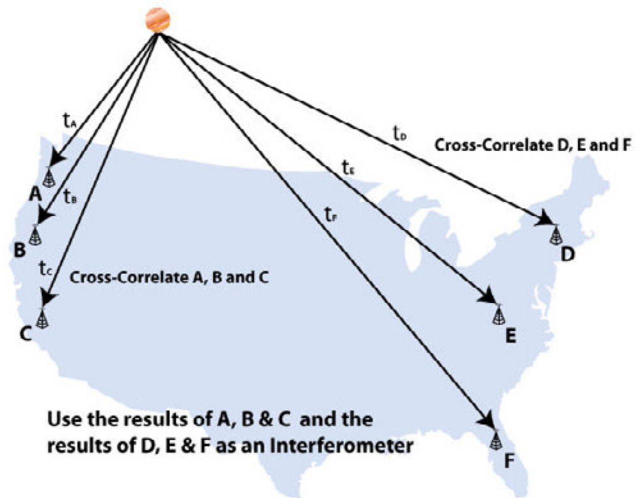
The Amateur LWA Station

Can the advances used by these professional radio telescopes be applied to the small radio telescopes operated by members of SARA? We believe they can be of enormous help in a variety of ways. Granted we will not be able to purchase the very high speed multiple channel, high density A/D converters, but on a limited scale we should be able to field simpler versions, thereby increasing our observing ability significantly.



We have developed what we call the Amateur LWA Station. Each individual station will consist of one or more of the low frequency active dipole antennas. The station will also have the capability of digitizing the signal, storing the data and posting the files to the internet if desired. Stations can also perform FX correlation [that is, cross correlation performed in the frequency domain –eds.] with collaborating stations to gain the benefits of multiple antennas separated by long baselines.

In our scenario we have developed a master station concept where observations can be directed from a single source. Available stations can chose to perform part of the tasked observation by using their station to set frequency, bandwidth and recording time. This data is recorded locally in real time then sent via FTP or other suitable means to the master station where post processing and FX correlation can be performed with the goal of producing an actual u,v image of the observed target. The master station would then make these observations available to the community.



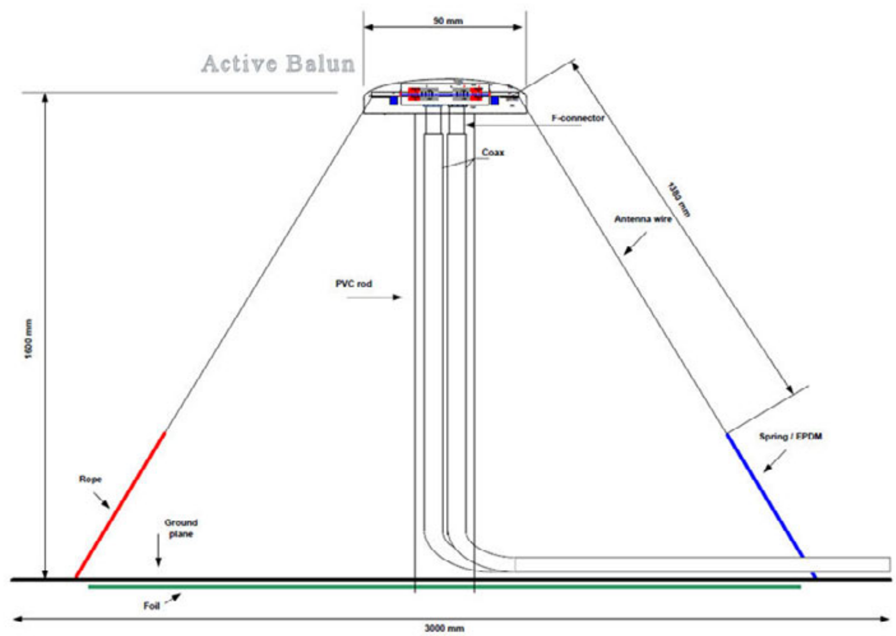
Tests controlling software defined radios over the internet have been conducted by a number to people. One such example is the W4AX station in Georgia, which allows participating remote internet connection to tune channels in the receiver.

Cross-correlation and position vector resolution will be by using GPS timing and sync (see figure bottom of preceeding page). GPS currently provides a sync pulse better than 10 nS which is sufficient to cross-correlate multiple stations, removing the a-priori station delay and the observational positional vector.

Sets of multiple stations can be used to perform cross-correlation and operate as an interferometer in a similar manner (see figure above).

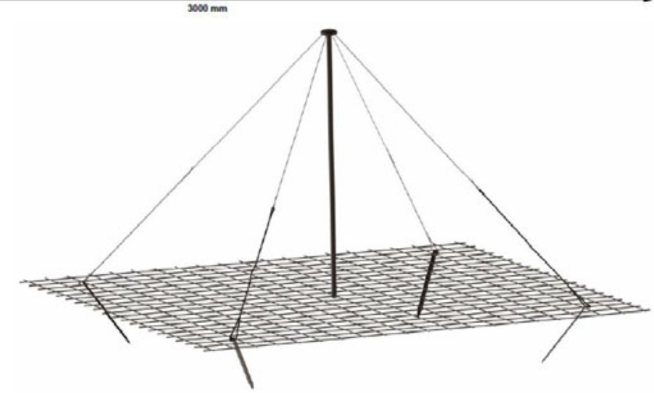
The LWA Station Components

The most important aspect of the long wavelength station is the active antenna where the dipole antenna is connected to an active balun. The antenna is based on the most recent LWA and LOFAR designs where each HF dual dipole is designed to operate from 10 to 80 MHz. The antenna can be either single or dual polarized and is in a fixed position with no moving parts. The figure at right shows the dipole antenna based on the LOFAR design. [8]



The active balun chosen is the NRL designed low frequency version adopted by the LWA telescope. Each leg of the dipole is amplified and fed to a HF Magic Tee. The sum output is grounded and the difference output is sent to the receiver. The balun provides 24 dB gain and a noise temp less than 150 K.

The antenna is based on the LOFAR low frequency crossed, inverted V, dual dipole antenna with wire mesh ground plane (shown at right).



Dipole Specifications are:

Arm length	54.3 inches (1380 mm)
Height of feed point	63 inches (1600 mm)
Gap at feed point	2.75 inches (70 mm)
Droop angle	45 deg
Conductor diameter	1/4 inch (6.35 mm)

It is envisioned that the antenna and balun would be provided as a kit with the balun pre-built using surface mount devices. This better guarantees that all the antennas will act similarly. It will also ease construction of the antenna station. Procurement of the ground plane should be done locally, but it is very important that each antenna have a welded ground plane.

Station Receiver

The simplest approach is to use a software defined receiver that provides sufficient bandwidth and A/D capability. This is a very active area of development and several SDR's on the market could be used. The major drawback is the expense. We believe that a detailed study needs to be undertaken to find the appropriate SDR.

On the low end of performance there are the 8-bit SDR's like the FUNcube and the DVB-T, both of which are extremely inexpensive and are built on a USB dongle. These operate with open software and run under windows and LINUX. The FUNcube has an onboard audio processor and outputs an audio signal as a microphone input to any windows program. This makes it extremely versatile, however the drawback is that it is very narrowband with an output bandwidth of less than 96 KHz. The DVB-T on the other hand uses the RTL2836 A/D processor which outputs and I and Q signal at just under 3 MS/s.

Although the 8-bit processors should work fine for general radio astronomy studies and in the scholastic environment as shown by Dr David Morgan's experiments for the British Astronomical Association, RAG and presented by the authors at the SARA Western Conference. [9,10] For scientific work the following are the minimum SDR requirements:

- 12 - 16 bits each for I and Q
- 100 MS/s
- 24 - 32 bits per antenna
- Minimum instantaneous RF bandwidth of 8 MHz
- External clock reference

The minimum requirements for a radio astronomy software defined radios are still a work in progress and several organizations, including SARA are developing products.

In addition to the SARA SDR several very sophisticated devices are now available. These include:

- The RFspace family [11]
- HPSDR [12]
- USRP [13]

GPS Disciplined Frequency Standard

To do any kind of cross correlation, the accuracy of the time stamp is critical. The receiving stations should have a time stamp associated with each observation with an accuracy of less than 1/4 wavelength (with 1/10 wavelength preferred). For 30 MHz or 10 meter wavelength, 1/4 wavelength is 2.5 meters. Light travels approximately 0.3 meters in one nanosecond so to travel 2.5 meters will take 8.33 nanoseconds. Hence, the accuracy of the time stamp should be < 8.33 nanoseconds. For a 14.9 meter wavelength (Radio Jove at 20.1 MHz), 1/4 wavelength is 3.725 meters which equates to 12.4 nanoseconds. Hence, the accuracy of the time stamp should be < 12.4 nanoseconds.

For station timing we propose a simple GPS disciplined frequency standard. The following characteristics are required:

- 12-channel parallel tracking

10 MHz reference oscillator, GPS disciplined
Frequency stability of 1.5 x 10-12 for a 24 hour average
Output a 1 pps sync signal to UTC +/- 10 ns, (+/- 5 ns preferred)

The sync output would be used as an observation trigger and providing the UTC stamp at the start and finish of the observation.

Relatively inexpensive GPS timing modules are available. One such is the Trimble Thunderbolt 12 channel GPS receiver designed to provide a 10 MHz output as well as 1 PPS. However it is only accurate to 15 ns.

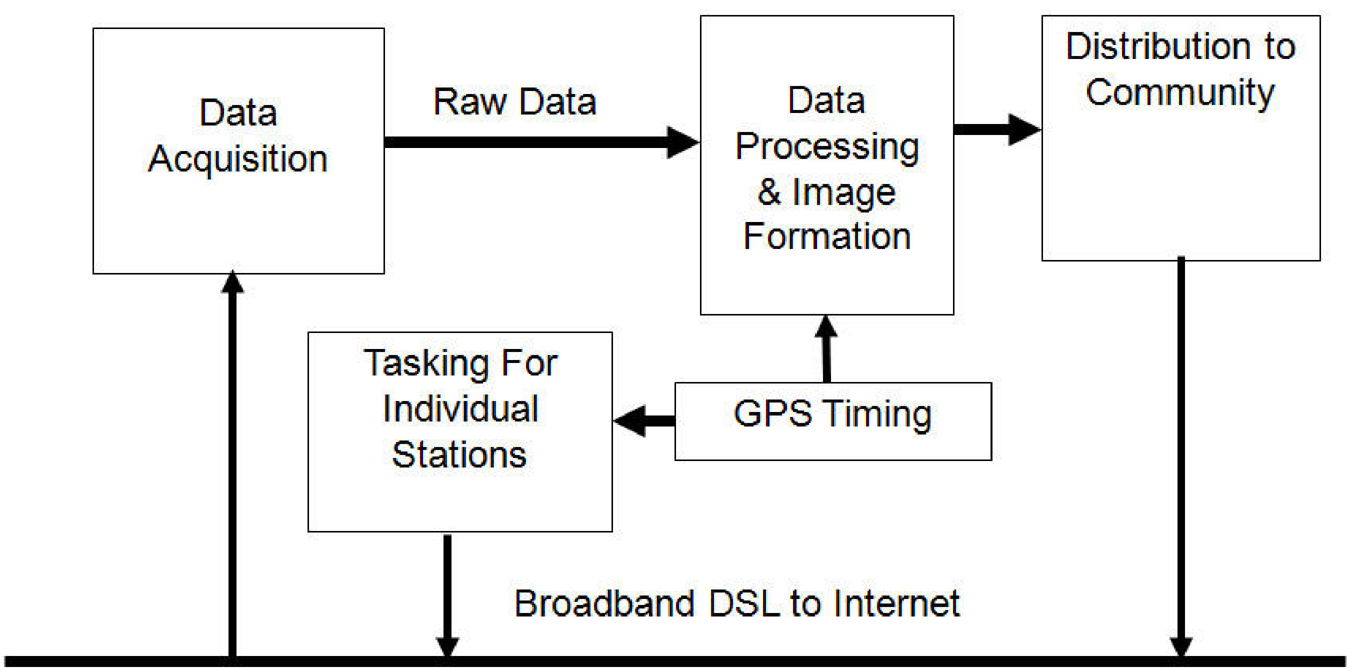
Computer

Basically any modern fast computer that can accept the output of the receiver and has internet connectivity could work. The SDR output sample rate will be about 6.4 megasamples per second for full real-time operation.

Software

In addition to the many free sdr software drivers Excel can be used to perform a Fast Fourier Transform (FFT) for Spectral Display and Signal Correlation, complex number multiplication and Inverse Fast Fourier Transform (Fringe Display).

Master Station Architecture



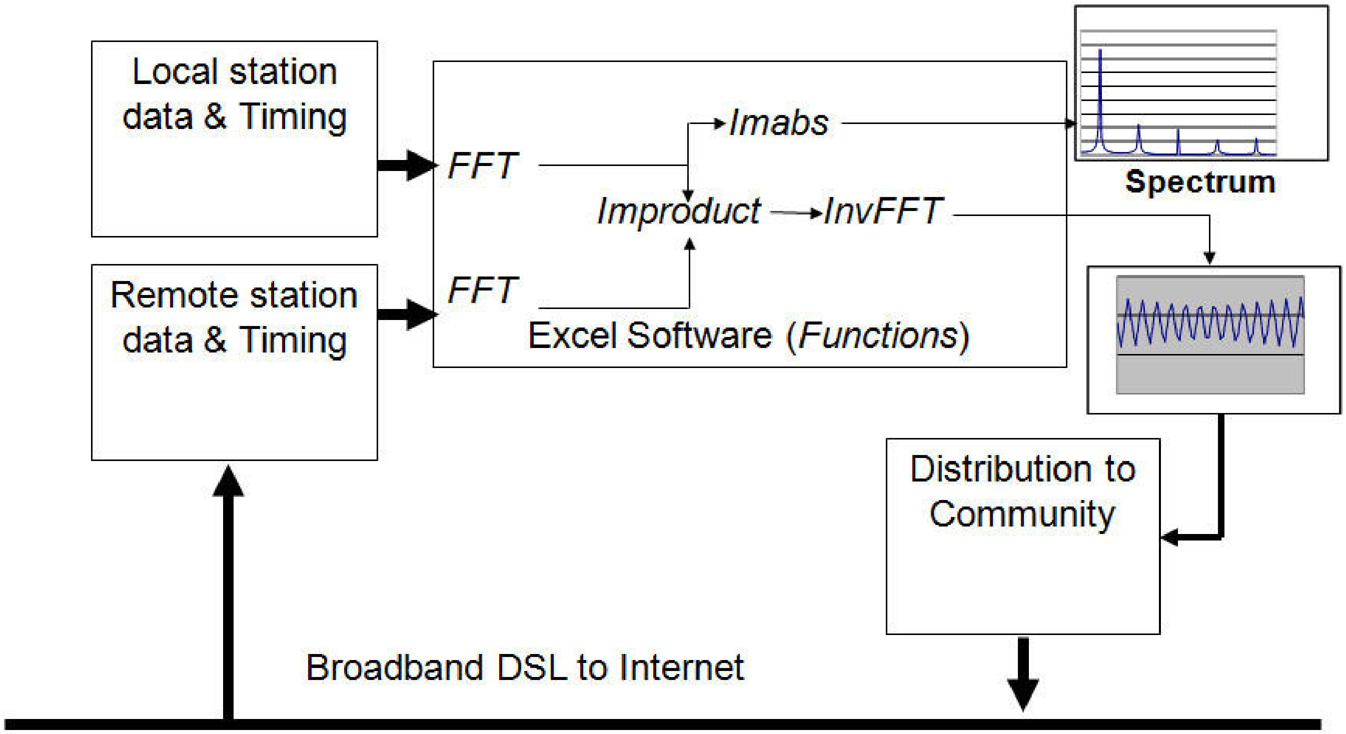
Interface to Community

Basically a station receives tasking from the master station daily and passes setup instructions to the station computer. Each station collects raw data and outputs it to the master station IP address as real time data stream or FTP.

In addition each station can perform an FFT on the raw data from the station and output it to the master station IP address to be multiplied with FFT data from other stations to complete correlation and produce baseline interferometer data.

Two Station Data Processing

An example of how two stations in the network can combine their observations and perform post observational data processing is shown in the following graphic:



The end result is a high performance, very flexible, radio observatory. This observatory can be utilized by various organizations/individuals for many different types of investigations. The stations can be tasked and controlled remotely through the Internet. In addition the station outputs can be processed at a master station for enhanced imaging and data analysis.

Observing with the LWA

A station with a single antenna can perform basic radio astronomy. It is envisioned that this type of radio telescope can be made available for a reasonable cost to schools and individuals who want to learn the basics of radio astronomy. One advantage is that you don't need to install a dish or large dipole should your environment prohibit it. It should be possible to conduct solar noise burst measurements and spectrographic studies, monitor for Radio Jove signals and monitor the HF band for transient signals.

One major function of each station is the calibration procedure. To operate as a single station just to understand radio astronomy the calibration can be as simple as testing the system sensitivity periodically. However to include the station in collaboration with other stations for joint observations calibrations of the ionosphere must be made before and after each run. Some of the calibrations would only need to be performed periodically like, signal delay from the antenna to the digital output, precise location of the antenna based on GPS or precise geographical knowledge and local interferes which can be pre-selected for removal.

Each station can perform auto-correlation on the received signal for improved signal to noise. With appropriate software multiple narrow band signals can be observed or wideband signals for spectrograms.

When operating in the multi-station environment another level of observations can be accomplished. Depending on the number of stations performing the observation high resolution simultaneous phased array beam steering operations can be performed.

Some of the areas that we would like to see studied include advanced space weather observations, studies of magnetic properties of planets other than Jupiter, better understanding the CODAR signals for ionospheric studies. Possible wide area meteor tracking and even GRB detection might be possible. In general we need to better understand the transient nature of the 5 to 80 MHz band rf environment.

Conclusion

We believe that it is practical using the latest hardware and software available to begin to construct an amateur very long baseline array at the long wavelengths. Initially targets would be the usual strong HF emitters, the Sun and Jovian radiation as well as other natural ionospheric phenomenon. Then as more stations join the array the effective aperture and sensitivity will increase and various all sky objects can be attempted.

One of the major benefits from the program is to have amateurs get involved in constructing state of the art radio telescopes that they can use individually as well as combined with other amateurs. It is hoped that some amateurs take on the construction of the central computer able to accept data from many sites and correlate it into finished products.

We are continuing to develop the detailed design of the active antennas and receivers and will publish the details as they develop.

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Maintain Your Time

Whitham D. Reeve

The email blared, *"M-class solar burst right now: 18h30 TU"* and it included a Radio-SkyPipe chart showing a burst peak at 1821 and a rising peak at 1828 on the chart's right edge. I received the email at 1731, about 1 hour *before* the stated time – was this a time traveling email? Probably not, but this event demonstrates why I wrote this article. One more thing, I am pretty sure the author of that email meant UT, Universal Time, and not "TU".

This article discusses two aspects of time—the basis for proper time keeping from an amateur radio astronomer's point of view and methods that help ensure computer-generated data are properly time stamped. In particular, since most amateur radio astronomers use a personal computer (PC) to record data, I will discuss methods used to maintain reasonable accuracy of a PC time-of-day, or TOD, clock (also called real-time clock).

Abbreviations in this article:
- CPU: Central Processing Unit
- GMT: Greenwich Mean Time
- GPS: Global Positioning System
- LAN: Local Area Network
- NIST: National Institute of Standards and Technology
- PC: Personal Computer
- NTP: Network Time Protocol
- PTP: Precision Time Protocol
- RFI: Radio Frequency Interference
- SID: Sudden Ionospheric Disturbance
- SNTP: Simple Network Tine Protocol
- TOD: Time Of Day
- UT: Universal Time
- UTC: Coordinated Universal Time
- WAN: Wide Area Network

When did that happen?

The event described above actually occurred near 1730 UT and not 1830 as claimed, a 1 hour error. It is clear that in our endeavors to receive celestial radio emissions we need to know not only what was detected but when it was detected. Knowing when is very important because sometimes the only way to verify reception of certain emissions is to compare charted times with other astronomers. For example, Jupiter emissions can be easily confused with ordinary radio frequency interference (RFI) but if other radio astronomers at different locations received similar emissions at the same time, then the time correlation helps confirmation. The same is true of many solar emissions and sudden ionospheric disturbances (SID) due to solar flares.

Most charted data and sampled data have a time/date stamp or time of day information associated with them (Figure 1). For the purposes of time correlation, it is necessary that the TOD clocks used by all parties involved in an observation are synchronized to a common time reference. Synchronization of multiple PCs, whether in the same city or spread around the world,

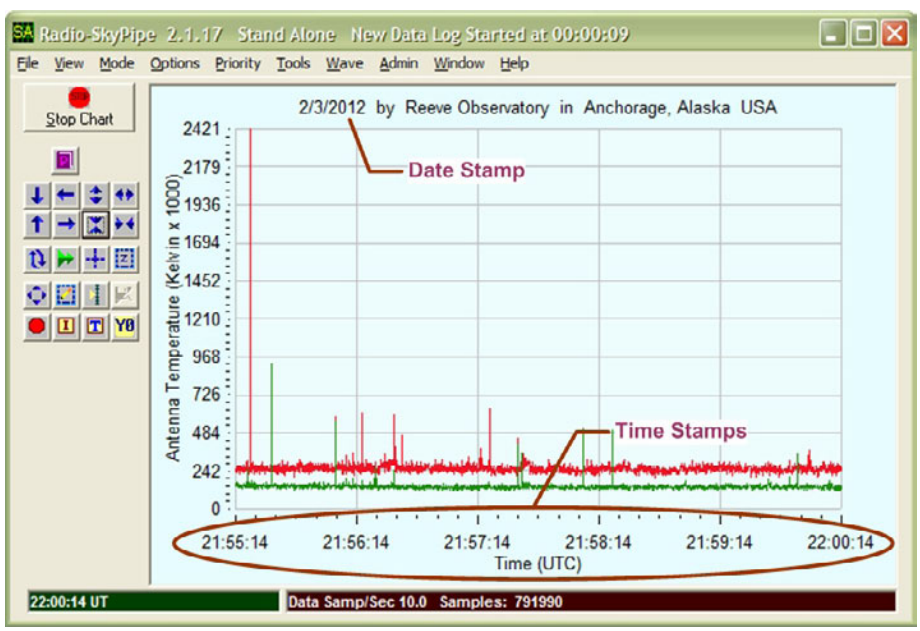


Figure 1 – Radio-SkyPipe chart with time information along the horizontal axis and date at the top.

is no easy task, especially when humans are involved. I am always surprised by data published on the various amateur radio astronomer technical groups that have grossly incorrect time stamps. Adding to the problem is at least one software application used by many amateur radio astronomers that does not always correctly time-stamp the data (I will briefly discuss this later).

In addition to the obvious error mentioned at the beginning of this article, here are some other reasons I have seen for erroneous time stamps: "*My chart is off by 1 hour because I forgot to reset the clock for daylight savings time*" and "*I have not set the PC clock for several months and it is wrong by something between 30 minutes and 2 hours*" and "*my PC clock probably has not been set since the day I bought it.*"

It takes time to set the time

Clock accuracy can be viewed as the ability of a hardware clock to prevent deviation and drift once it has been set to a particular time reference, and synchronization is the ability of the clock to get accurate time from a reference time source. The physical accuracy and stability of a given clock is directly related to its cost. PC clocks are inexpensive by design. A typical PC uses a quartz crystal oscillator that is mass produced and costs a tiny fraction of a US dollar. Crystal oscillators are sensitive to temperature and they drift with age. A TOD clock based on this technology must be regularly updated or resynchronized if useful accuracy is to be achieved.

Synchronization is not simple. It requires protocols, algorithms, estimations and interfaces to negotiate with a reference clock in another location. When a computer process is called to update the clock, it must know or at least estimate or assume when it sent the update request, the time it took the request to get to the reference, the time it took to be processed at the reference, the time it took for the response to get back and the time it took to process the response and set the PC clock. To some extent a PC clock must depend on its own accuracy to set itself accurately. Small errors in assumptions and estimates accumulate. A few milliseconds here and there quickly add up to a second, and a hundred milliseconds here and there quickly add up to 10 seconds. Before long the error can have a magnitude of minutes or hours.

Time protocols

The Network Time Protocol (NTP) is widely used for time distribution and to ensure time accuracy in local area networks (LAN) and wide area networks (WAN, for example the internet). NTP was developed as an internet protocol for synchronizing clocks in distributed time servers and clients to a "standard" time. NTP exchanges messages between a time server and client that are used to calculate time offsets and delays. NTP is capable of providing synchronization at the sub-tens of millisecond level in the WAN. Tens of thousands of NTP servers exist in the internet and many (but not all) of them are accessible by public users. A detailed description of NTP can be found at **http://www.ntp.org/**, and a list of National Institute of Standards and Technology (NIST) time servers in the USA can be found at **http://tf.nist.gov/tf-cgi/servers.cgi**.

A more recent timing protocol implementation is the Precision Time Protocol (PTP), which is defined in Institute of Electrical and Electronics Engineers (IEEE) Standard 1588 (*Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*). It has been deployed in industries that use packet networks and depend on synchronization at the sub-microsecond level, for example, telecommunications and manufacturing. More information on PTP is here: **http://www.ieee1588.com/**.

NTP and PTP are not the only time protocols that have been used over the years. For example, a simplified version of NTP, Simple NTP or SNTP, is used in some computer operating systems. The design of most time protocols are directly related to their end-use and the transmission media used to transport them.

What time is it?

Most of us live our daily lives based on the local time. Local time is an adjusted time scale consisting of two elements, a time reference and a time zone, where Local time = Time Reference ± Time Zone. The legal basis for time-keeping and the time reference used in most countries is Coordinated Universal Time (UTC), which is defined in International Telecommunications Union – Radio Communications Sector (ITU-R) Recommendation TF.460. [1] In most other countries UTC also is used even though it may not be legally adopted at the national level. One nice thing about UTC is that the time, in UTC, is the same around the world.

Time zones are a confusing mess based on geography, government jurisdictions and political whims and in rare cases on geographic longitude. For example, Alaska at one time had four time zones because of its size. Nowadays, because politicians are so smart, most of the state is in one time zone and the far reaches of the Aleutian Islands are in another. The Aleutians are partly on the other side of the international dateline (whatever that is). The two present Alaska time zones have no correlation whatsoever with longitude or solar time.

In most places in the USA and many other parts of the world, there is a requirement, with demonstrably dubious benefits, to shift to a daylight savings time during certain times of year. This means the local time shifts by one hour twice a year, forward in the spring and backward in the fall.

One quirk with UTC is that it has to be adjusted every so often with "leap seconds". The UTC time scale is the atomic standard of time. It is based on the emissions frequency of certain atoms (cesium) when their electrons jump from one energy level to another (see **http://www.bipm.org/en/si/si_brochure/chapter2/2-1/second.html**). However, commerce and almost all other human activities are based on daylight and darkness – the position of the Sun in the sky – so we have a generalized time scale called Universal Time (UT), which is based on Earth's rotation rate. There are three variations of UT: [1]

◊ UT0 is the mean solar time of the prime meridian obtained from direct astronomical observation;

◊ UT1 is UT0 corrected for the effects of small movements of Earth relative to the axis of rotation (polar variation). UT1 is the one most commonly seen and used and often is simply denoted UT;

◊ UT2 is UT1 corrected for the effects of a small seasonal fluctuation in the rate of rotation of Earth.

Because of the variations in Earth's rotation rate, UT1 and UTC would drift apart over time. To minimize the time difference, leap seconds were implemented in 1972 to compensate and to keep UT1 and UTC within about 1 second of each other. If leap seconds are not used, Earth rotation time, UT1, would differ from UTC, for example, by 2 or 3 minutes in 2100 and 30 minutes in 2700, and a lot of bus and train schedules would be disrupted. There have been many discussions among scientists around the world for many years about eliminating the leap second. I will discuss this topic in more detail in a future article.

For now, how do we correlate our observations with observers in other time zones or other places in the world? The answer is that we should stamp all of our observations with times and dates based on UTC and never use local time or any other time scale. Whenever we post an observation or discuss it, we should never use local times or dates except perhaps parenthetically to put certain observations in proper context (for example, when it is relevant that the observation was made during daytime or nighttime). To be sure, UT1 and UTC are not the only time scales used in radio and optical astronomy, but the others are beyond the scope of this article. The next question is how can you set the time on your PCs to UTC and keep it reasonably accurate? I will answer that in the following sections.

Microsoft Windows environments

Many amateur radio astronomers use PCs with various versions of the Windows operating system.

In the following discussion, I will concentrate on Windows XP and Windows 7. PCs running Windows XP and 7 by default use the Windows Time service (Figure 2). In Windows a "service" is a piece of software that performs a certain task. If the PC is in a local area network, the Windows Time service starts automatically. Windows Time service uses NTP and strives to ensure that all PCs in the network use the same time. Whether or not it is the correct time depends on the circumstances. The setting may not be accurate but at least the interconnected computers use the same nominal time.

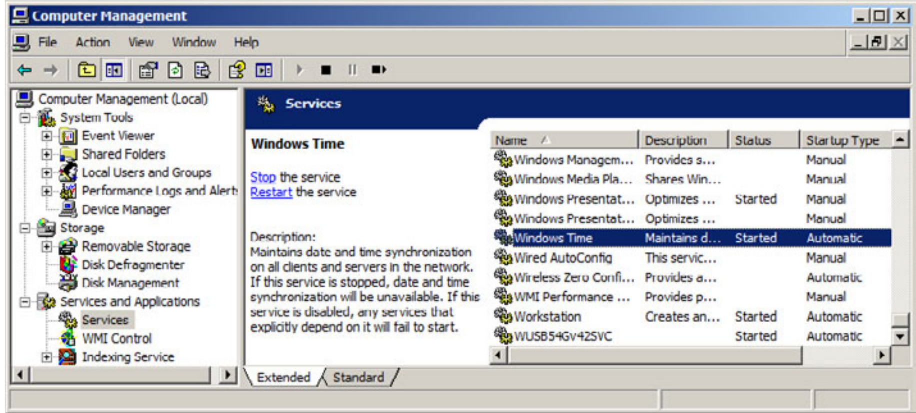


Figure 2 – Windows Time service is an underlying service on all modern Windows-based PCs.

If the PC is connected to the internet, and Windows Time service is properly configured, it will attempt to contact a time server to set the clock accurately. However, if the PC is not part of a network or is not connected to the internet, the Windows Time service may not be started, in which case the user must figure out how to use it or to use some other method. Additional information on the Windows Time service can be found here: http://technet.microsoft.com/en-us/library/bb490605.aspx.

Time setting alternatives

I have found that Windows Time service can be unreliable, possibly because of my network configurations – I really have no idea why. Rather than monkey with it, I use a free alternative, which I have found over the last several years to be non-intrusive and to always work very well. The time application program I use is Symmetricom's free SymmTime program (http://www.symmetricom.com/resources/downloads/symmtime/). Other application programs are available that reliably maintain and synchronize PC clocks, but I have not used anything but SymmTime for around the last 10 years. However, I discuss another worthwhile PC time-keeping alternative called NISTime and provide a link to a list of time-keeping software in a sidebar. Next, I will describe the Windows setup and then the SymmTime setup.

Windows Time service setup

The following provides specific setup for Windows XP but the Windows 7 setup is very similar. First, the PC clock should be set to Coordinated Universal Time (UTC) and not local time. This greatly reduces the possibility of incorrect time stamps. To set the PC clock to UTC click on Start – Control Panel – Date and Time. Select the Time Zone tab. From the drop-down list select (GMT) Coordinated Universal Time (Figure 3) and then OK. After setting the PC to UTC, it may be necessary to adjust the time zone or offset settings in your various software applications that do the

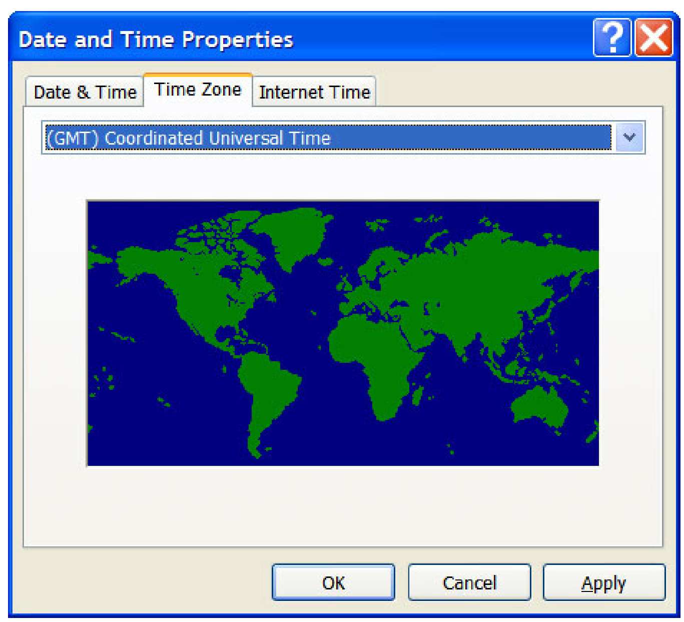


Figure 3 – Windows Date and Time Properties.

actual time stamping on your observations.

It is very important that the PC clock is accurate at all times, especially during data collection. As mentioned above Windows has built-in *Internet Time* synchronization capability but it may not be turned on. First, make sure your PC is connected to the internet, and then determine if your system has Internet Time synchronization capability, then click Start – Control Panel – Date and Time. Select the Internet Time tab, if it exists, and then check the box labeled *Automatically synchronize with an Internet time server*. If available, select *time.nist.gov* server and then *Update Now*. Wait a moment. If the update is successful you will see a screen similar to Figure 4–left. If not, you will see an error similar to Figure 4–right. The update could fail for any number of reasons and you could either troubleshoot or install an alternative software tool as described in the next section.

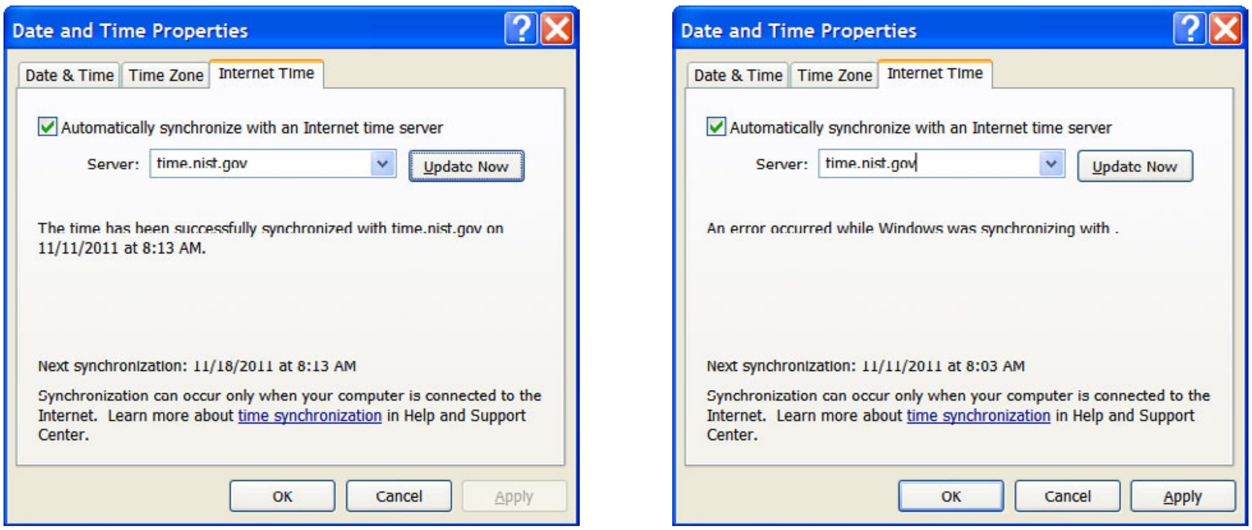


Figure 4 – Additional Windows Date and Time Properties settings.

If you decide to use the Windows Time service to update your PC clock, you should beware of its default settings. The default update interval is 604800 seconds, or 7 days. This is not nearly frequent enough for most PCs and useless for data collection. The default update interval can be changed through a Registry edit as follows:

◊ Start – Run...

◊ Type Regedit – OK

◊ Select: *HKEY_LOCAL_MACHINE\SYSTEM\ControlSet001\Services\W32Time\TimeProviders\NtpClient*

◊ Right-click *SpecialPollInterval* and select *Modify*

◊ Select the *Decimal* radio button in Base

◊ Change the default decimal value from *604800* seconds to some other value. The value to be used depends on the drift rate of the PC clock. Typically, you would set it to update the clock at 10 to 60 minute intervals (example, for 15 minutes update rate, set the value to 900)

◊ Click OK

SymmTime setup

Your version of Windows may not have the *Internet Time* tab described above or it may not be reliable or you may not want to use it. In those situations, I suggest SymmTime by Symmetricom. If you choose not to use the Windows Time service, you should uncheck *Automatically synchronize with an internet time server* in Windows Date and Time properties. You still should set your PC's clock to GMT/UTC as previously described regardless of the application that handles time synchronization. You can configure SymmTime to display both UTC and local time.

After downloading and installing the SymmTime application, it should start and run. You should see a small round clock icon on the Windows taskbar. Right-click the SymmTime window and select *Sync Options*.... Under the *Synchronize with Server* setting select the radio button *Periodically, every xx minutes*, where xx is your desired update interval, typically 10 to 60 minutes (Figure 5-left). Click OK when done.

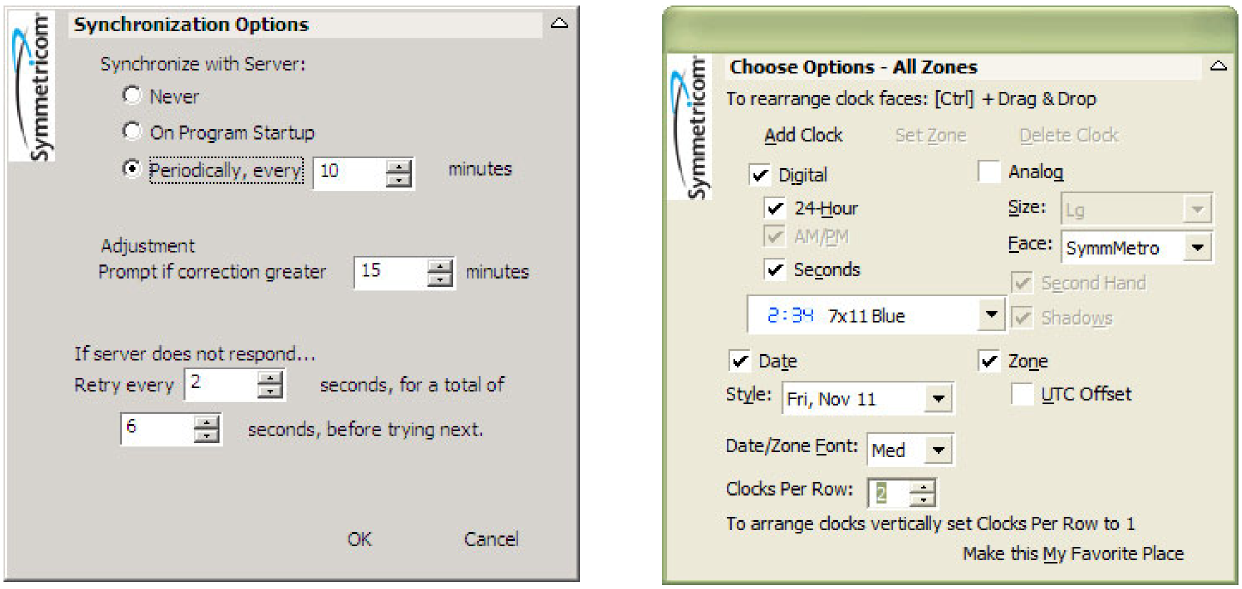


Figure 5 – SymmTime Option settings.

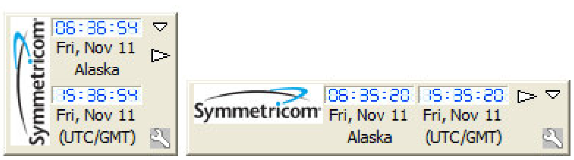


Figure 6 – SymmTime vertical and horizontal display configurations.

Right-click the SymmTime window again and select View Options... (Figure 5-right). Setting up various time zone displays is self-explanatory (or you can use the Help... function), but you should setup two time displays, one to show UTC/GMT and another to show your local time. Note that the time zone displays are simply that – displays. The PC TOD clock itself is governed according to the settings described at the beginning of the previous section. You can setup the two time displays in a horizontal or vertical format (Figure 6).

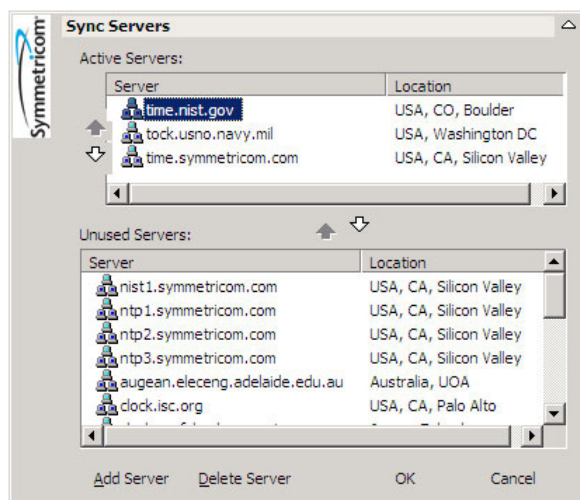


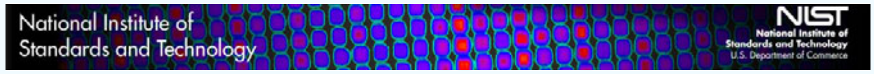
Figure 7 – Time Server selection in SymmTime.

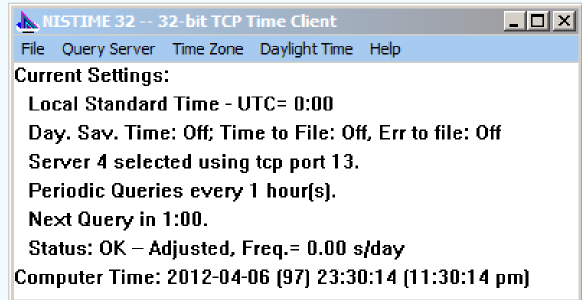
SymmTime can access any public time server. The default time server settings should be fine but you can change them. Right-click the SymmTime window and select *Sync Servers*.... You will see a scroll-list of Unused Servers in the bottom frame (Figure 7). You can customize the list by using the *Add Server* and *Delete Server* selections at the bottom. You also can add or delete servers to the Active Servers in the top frame by selecting a server and then clicking on the arrows between the two frames. The individual servers are quite reliable but you can place several in the *Active Server* list. This way, if SymmTime is unable to contact the first one on the list, it will attempt to contact the next one, and so on. It has been my experience that, if SymmTime cannot contact one of the listed public servers, the problem lies in the PC or its access to the internet and all other times servers are similarly inaccessible. When SymmTime is unable to contact the servers the clock icon in the Windows taskbar will flash red.

The last step is to place SymmTime in the Windows Startup folder. This will ensure that SymmTime starts automatically when the PC is rebooted. One way of doing this is to go to the Program Files folder where SymmTime is installed (typically c:\Program Files\Symmetricom\Symmtime\). Right-click and drag the file GeTTime.exe to Start – All Programs – Startup. That places a shortcut in the Startup folder, and it will automatically run whenever the PC reboots or is started.

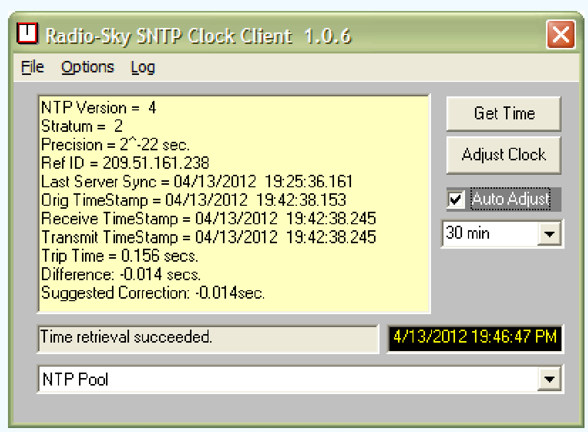
One minor inconvenience with SymmTime is that, when you have setup a local time display, it does not automatically compensate for daylight savings time. For data collection purposes this does not matter since your PC TOD clock is set to UTC anyway. However, if your location uses

PC Time-Keeping Alternatives





The National Institute of Standards and Technology (NIST) in the USA provides a list of publishers of time and frequency software: **http://www.nist.gov/pml/div688/grp40/softwarelist.cfm**. NIST also has available for free their own PC time-keeping software called NISTime: **http://www.nist.gov/pml/div688/grp40/its.cfm**. NISTime is very simple to setup and use and I recommend it as an alternative to SymmTime described in this article. However, NISTime does not have the same features, for example, it does not provide statistics and its minimum update interval is 1 hour, but it is very reliable and non-intrusive (above). NIST also has a browser "widget" that may be used to indicate the correct time on a webpage: **http://www.nist.gov/pml/div688/time_010511.cfm**.



Another time-keeping alternative is Radio-SkyPipe Pro (**http://www.radiosky.com/**), a very popular charting program with a built-in feature that uses SNTP to the set the PC TOD clock (at right). This feature is found in the Tools menu – Atomic Time. However, Atomic Time updates the PC clock only when RSP is running. Note that the free version of Radio-SkyPipe does not have the Atomic Time feature.

daylight savings time and you have setup SymmTime to display the local time, the display will be off by one hour during spring, summer and fall. For example, Alaska Standard Time (AST) is nine hours earlier than coordinated universal time, or UTC–9. On the first Sunday in March, we switch to daylight savings time, UTC–8, and on the second Sunday in November we switch back to standard time. In order for SymmTime to display the correct time, it is necessary to Choose New Time Zone – New Zone and then setup the 8 hour difference. This new Zone is applied to the local display until standard time goes into effect. It is simple to do. If you encounter any problems with SymmTime or have questions on it, Symmetricom provides a support contact on their website (and, yes, they do respond!).

PC time statistics

After SymmTime setup is completed, you can check the amount of correction made when SymmTime queries the time server. You should let SymmTime run at least 24 hours before making this check. Right-click on the SymmTime window and select *Sync Status*.... The window that opens shows some statistics including the average clock offset and recent history (Figure 8). Just below the *Avg Offset* value is a *Recent History* frame. It shows the correction made during each time query. It also will indicate if the time server is unreachable for any reason. If you find that the update rate is too frequent or too infrequent, adjust the *Synchronize with Server* setting in *Sync Options*.... as previously described.

If the PC is runs only during observations or during certain hours, it is necessary to resynchronize the PC TOD clock each time the PC is started. If you use SymmTime and set it up as described above, it will automatically resynchronize the clock within the interval specified in *Sync Options... – Periodically, every xx minutes*. Therefore, if your setting (xx) is 10 minutes, the program will resynchronize the PC clock within 10 minutes after SymmTime is loaded.

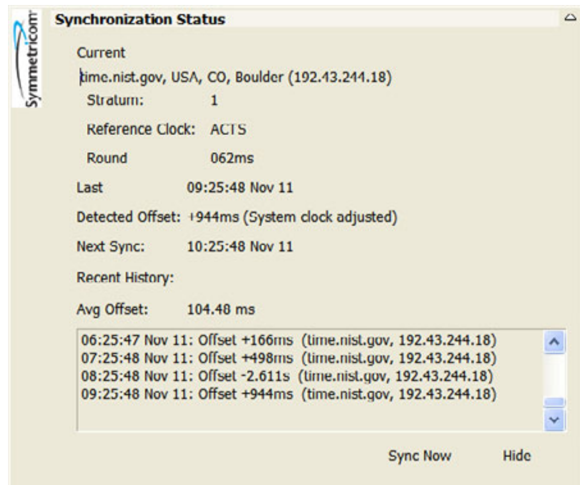


Figure 8 – Time statistics available in SymmTime. The update rate in Sync Options... for the PC shown here is 60 minutes. The maximum offset during the previous 24 hours was 2.6 seconds and the average offset was a little more than 100 ms.

What do you expect?

A typical commercial-grade crystal has a frequency tolerance of, say, ±50 parts per million (ppm) at 25° C and ±100 ppm frequency stability over a temperature range of 0 to 70° C. For example, a new 1.0 MHz crystal may operate between 0.999975 and 1.000025 MHz at 25° C and may drift between 0.999900 and 1.000100 MHz over the given temperature range. To see what this means, let us assume the TOD clock in a PC drifts no more than 25 ppm when averaged over 1 day. At the end of a 24 hour time period, the clock would be fast (or slow) by about 2.2 seconds ($25 \times 10^{-6} \times 24$ h/d $\times$ 3600 s/h). If that 25 ppm average offset is sustained for 30 days, the clock will drift by slightly more than 1 minute in a month. This is not especially bad, but it is my experience that most PC clocks drift much more rapidly than 1 minute per month. For one thing, tolerances of crystals used in PCs could be much worse than those used in this example. For another, the inside of some PCs can easily exceed 70° C and cause the crystal oscillator to operate outside of its specified range. I cannot even say with any confidence that the crystals used in high-quality PCs are better than in low-quality PCs (presumably they are, but I would not go to the bank on it).

I operate a number of PCs at my receiver stations, lab and office. I run SymmTime on all of them and use various update intervals. I took a snapshot of the Sync Status windows on each PC for comparison and summarized the information in table 1. The Lightning and Receiver PCs are used for data collection so their update intervals are relatively short. It is seen that I can expect my PC clocks to be accurate within a few tens of milliseconds. This assumes the clock accuracy read by SymmTime is not degraded by application software that actually collects and stores the data or by some other applications running on the PC; if there is no degradation then the stated accuracy is more than adequate for my types of radio astronomy.

PC name	Mfr and Model	Update interval	Average Offset	Typical correction	Round-trip Delay	Purpose
Lightning	Shuttle K45	5 min	+19.08 ms	6 ~ 54 ms	109 ms	Data collection
Lightning2	Shuttle K48	5 min	+14.92 ms	8 ~ 21 ms	109 ms	Data collection
ReceiverA61e	Lenovo A61e	10 min	–1.95 ms	0 ~ 8 ms	109 ms	Data collection
LenovoT61	Lenovo T61	10 min	–8.95 ms	3 ~ 10 ms	140 ms	Laptop
LabA61eNo1	Lenovo A61e	15 min	–3.15 ms	0 ~ 133 ms	109 ms	Lab
LabA61eNo2	Lenovo A61e	15 min	+33.62 ms	32 ~ 35 ms	78 ms	Lab
LabA61eW7	Lenovo A61e	60 min	+242 ms	74 ~ 84 ms	124 ms	Lab
AV8-MX	Custom	60 min	+156.62 ms	152 ~ 169 ms	109 ms	Office

Table 1 – PC time of day clock statistics at my observatory in Anchorage. All PCs had been running at least 24 hours prior to readings, all use SymmTime time update software, and all are in an ordinary environment in terms of temperature and humidity. The column "Round-trip Delay" is SymmTime's measure of the delay determined by NTP time for queries to the time server.

Application software

The question of TOD accuracy degradation by application software is of interest. I mentioned earlier that at least one popular radio astronomy software application sometimes applies incorrect time stamps to data. According to Deborah Scherrer, Director of the Stanford Solar Center, the SuperSID software obtains its initial time each day from the PC TOD clock. However, as the software collects data over the next 24 hours it assumes that each data point occurs 5 seconds after the one before it. It does not refer to the TOD clock and, as has been observed by many users, may drift away.

If you do not observe sudden ionospheric disturbances (SID) with the SuperSID software, this is not a problem for you. However, there are other problems waiting to strike. Everyone who uses a PC based on the Windows operating system has observed freezes and stalls, in which the PC seems to stop running momentarily, maybe for a few seconds, tens of seconds or several minutes. What happens to time stamps associated with data collection during these periods? I have not investigated this question but can guess there is loss in accuracy. Probably the most notorious applications that lead to these kinds of problems are anti-virus (AV) and software firewall programs.

The amateur radio astronomer is well advised to try different brands of AV software – there are several high-quality free programs available, and paid programs seldom are the best. It also is obvious that what works well on one PC may not work well on another, making experimentation necessary. I use the free Microsoft Security Essentials (MSE) along with the built-in Windows Firewall (my LAN router also has a firmware firewall). Even though I set MSE's CPU usage during scans to 10% and to run only at certain times, I still see occasional stalls of a few seconds, but these are not pervasive enough to be a problem for me. I do not know their source, anyway, except that MSE seems to be involved. For serious data collection it is important that only the bare minimum essential applications be running, and it is unfortunate that anti-virus software is essential for any PC connected to the internet.

Conclusions

Amateur radio astronomers wishing to compare data and observations collected by their PCs must have reasonably accurate time-of-day clocks. With very little effort and no extra cost it is possible to achieve 100 ms or better time-of-day clock accuracy by using simple software applications that regularly update the PC clock using publicly available time servers.

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Whitham Reeve was born in Anchorage, Alaska and has lived there his entire life. He became interested in electronics in 1958 and worked in the airline industry in the 1960s and 1970s as an avionics technician, engineer and manager responsible for the design, installation and maintenance of aircraft electronic equipment and systems. For the next 38 years he worked as an engineer in the telecommunications and electric utility industries with the last 34 years as owner and operator of Reeve Engineers, an Anchorage-based consulting engineering firm. Mr. Reeve has been registered as a professional electrical engineer and has BSEE and MEE degrees. He has written a number of books for practicing engineers and enjoys writing about technical subjects. Since 2008 he has been observing electromagnetic phenomena associated with the Sun, Earth and other planets and presently is a SARA Director at Large and a Contributing Editor of the SARA journal, *Radio Astronomy*.

Courtesy **http://xkcd.com/1061/**

Development of a Flexible Software Defined Radio for Radio Astronomy

David Lonard

This This article describes the development of a modular and flexible software defined radio (SDR) based receiver for radio astronomy, SETI, or Earth-Moon-Earth use (Flexible SDR for Radio Astronomy– FSRA). Its design allows for high performance capabilities at frequencies ranging from 10 kHz to 4400 MHz (excluding 62.5–137.5 MHz) with frequency accuracy (Allan Variances) of better than 10^{-11} using a GPS disciplined time source. This frequency stability should allow for very long baseline interferometry (VLBI) and other applications that require high frequency accuracy and stability. All of the hardware components comprising FSRA are commercial off-the-shelf (COTS) items that require almost no microelectronics assembly and should be a cost sensitive solution for amateurs or small academic programs. Importantly, FSRA renders all data in the digital domain where it can be manipulated through post processing routines for averaging, heliocentric velocity correction, correlation, dedispersion, de-chirping and other analyses. Examples of software routines to perform basic processing of FSRA data are discussed and improvements in signal data processing are currently being pursued.

Introduction

Advances in SDRs have been significant in recent years and a number of low cost commercially available options are now available that largely exceed the capabilities of analog-based receivers. Along with their large receiver bandwidth which is well suited to radio astronomy, the ability to store quadrature sampled signal data in a digital form opens up a broad range of post-processing schemes to extract relevant information from astronomical radio sources. For instance, digital signal streams could be analyzed by dedispersion routines such as PRESTO to identify pulsars that would otherwise be undetectable or to de-chirp narrow band carriers for SETI projects using the Baudline signal analysis tool. [1,2] While the advantages that exist with SDRs for radio astronomy applications are obvious, only a limited number of software-based tools exist to take advantage of their capabilities at this time. Nevertheless, once software solutions are developed, they can be distributed easily with no extra cost. Also, distributed processing by different end users makes it possible to achieve different research goals from the same recorded data. As an example, FSRA data sets could be posted to a common server where other users could analyze data for total power while other users could attempt to look for pulsar signals while yet other users could do SETI-related analyses like that being done by SETIQUEST with the Allen Telescope Array, but of course on a much smaller scale. [3]

Performance Parameters of FRSA for Observations of HI

Observations of neutral hydrogen from galactic and extra-galactic sources have been extensively characterized. [4] While FSRA is intended for a wide range of applications, its capabilities are very well suited to studies of HI emissions. Neutral hydrogen surveys such as the GALFA-HI surveys have revealed many important features about the characteristics of neutral hydrogen in space. [5] These and other professional surveys typically cover a ± 700 km/s velocity range and have frequency resolutions of ~0.1 km/s across their observation bandwidth. The QS1R's 2.5 MHz bandwidth allows for ± 211 km/s velocity Doppler shifts which is large enough to characterize the vast majority of galactic sources of HI, but will miss HI from many extra-galactic sources if observations are centered on 1420.405 MHz. Using a 4096 point FFT to process I/Q data from the system (see below), individual spectrogram bins have a width of 0.129 km/s, closely matching the resolution chosen for these established surveys.

Another key feature of FSRA that should greatly enhance the ability to study HI comes from its frequency stability. Because the FSRA utilizes a high quality time source, it should be possible to resolve HI velocities well within the velocity widths of each spectrogram bin at the velocity resolutions used by professional observers. Frequency accuracy of 1 in 10^{-11} corresponds to an error of less than 0.02 Hz at 1420.405 MHz. Velocity-based profiling of neutral hydrogen in the GALFA-HI surveys reveal striking differences at specific velocities and it will be important to maintain good frequency stability across and within observation runs. Even with broad beam width antennas, details of neutral hydrogen at very specific red-shifts should be possible with an FSRA-based system.

Hardware:

SDR: While many suitable SDRs are available, I chose the QS1R SDR for this project due to its 16 bit sample depth, large frequency range and the ability to accept an external clock source input. [6] The QS1R can also be controlled through TCP or UDP sockets, allowing for Python-based control scripts to record data from the system which I have already written. [7] The SDRMAXV server application used to communicate with the SDR can save quadrature (I&Q) data as 24 bit WAV files for future processing while the SDRMAXV client GUI allows for real time tuning and control of the radio. Ultimately, the effective signal bandwidth of the QS1R is limited to 2.5 MHz (2.5 million IQ sample pairs per second (MSPS)) through the USB2 communication port of the host computer. The QS1R possesses its own internal 125 MHz TCXO-based clock, which is sufficient for many users but can be disabled for those who wish to do VLBI or require high frequency accuracy and precision. More information about handling of data generated by the radio will be discussed later, but a computer with ample hard drive space should be used. I have opted for an i7 Core, 1 Tb HDD, 16 GB RAM system for this project; one hour of recording at 2.5 MSPS consumes 60 GB of hard drive space.

Clock source: For VLBI work, a highly accurate and precise time source is required. Thankfully, GPS disciplined oscillator (GPSDO) 10 MHz clock sources are now widely available as surplus. I acquired a Thunderbolt GPSDO, power supply and antenna from an EBay vendor and set it up according to information from other amateurs on the internet. [8] Short term frequency accuracy of 0.5 x 10-12 is typical from these clocks which makes them suitable for low frequency VLBI below 100 MHz and possibly at higher frequencies as well.

To externally drive the QS1R with a Thunderbolt GPSDO, a DDS-based frequency synthesizer (Valon 5007) and divider (Valon 3008) produced by Valon Technology was purchased. [9] The Valon 5007 is a computer controlled two channel signal generator capable of generating signals between 137.5 and 4400 MHz using either an internal or external signal reference. It possesses low phase noise and can essentially replace older, more costly signal sources. A 250 MHz signal was generated by one channel of the Valon 5007 synthesizer and directed to the Valon 3008 divider to produce a 125 MHz signal. The 125 MHz CMOS level 3.3V output signal from the Valon 3008 divider was used to provide a clock source for the QS1R. (The two SMA 50 Ohm outputs from the Valon 3008 can not be used to drive the QS1R; an SMA connector will need to be soldered to the +3.3V CMOS output and ground pins on output #3.)

Signal down conversion: The other channel of the Valon 5007 can be independently controlled to generate a suitable local oscillator (LO) signal for a mixer used to down convert 1420 MHz signals to an intermediate frequency (IF) suitable for reception by the QS1R. Through the use of a suitable mixer such as the Mini-Circuits ZEM-4300, it is possible to down convert signals across almost all of the range of the Valon frequency synthesizer. [10] Importantly, because the QS1R clock and the down conversion LO are derived from the same reference signal, the ability of the radio to achieve exceptionally good frequency accuracy and precision is preserved.

Receiver front end: The front end of the FSRA will be familiar to most amateur radio astronomers.

The QS1R requires a fairly high level signal be delivered to it, requiring the use of a second stage amplifier after the first stage LNA. I am currently using a Down East Microwave 1420 MHz LNA followed by a Mini Circuits SHP-800, 800 MHz high pass filter, then by a Mini Circuits ZX60-2534M amplifier to achieve enough amplification for my system. [11] 75 Ohm RG-6U coax with F connectors is sufficient to send a signal to the receiver 75 meters away. A schematic that details the FSRA at the hardware level is shown in Figure 1. Currently, I am using a SETI "Horn of Plenty" pyramidal horn antenna mounted on a Losmandy GT-11 mount. [12] This allows for tracking of celestial objects for long term integration. A transition to an improved horn and LNA is being pursued at this time, however this basic setup is more than adequate to generate results.

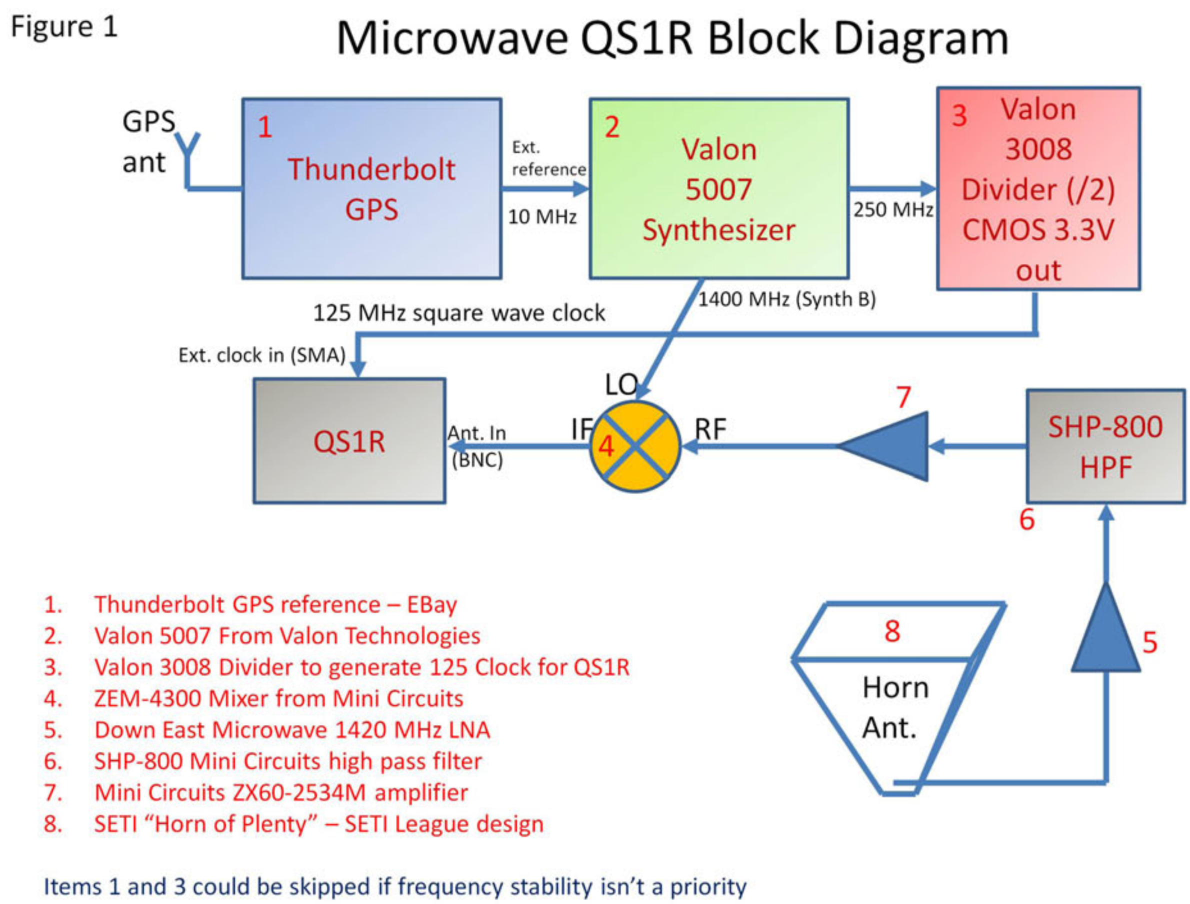

Figure 1 – Schematic of the FSRA.

The Digital Domain and Software

The realization of the FSRA at the hardware level is straightforward. Greater challenges await the user in the processing of the data that it generates however. In spite of this, the benefits of the FSRA are still compelling. First is the advantage that the FSRA has a 2.5 MHz instantaneous bandwidth that allows for full duty cycle sampling of signals of interest. The advantages in sensitivity compared to a scanning receiver design for measurement of the 1420 MHz hyperfine line are very significant. Compared to a classic total power receiver, FSRA provides frequency information and post processing can be used to remove radio frequency interference from the signal pass band. Different types of signal integration (averaging, median smoothing and sigma clipping) can be achieved as well. More ambitious forms of signal processing including dedispersion and de-chirping are also possible. A disadvantage is the very larges amounts of data that need to be stored on the computer's hard drive and significant amounts of CPU time will be needed. Note that the programming portions of this project are a work in progress and are constantly evolving. The examples provided below and their code are preliminary and could be updated or changed at any time.

Signal processing: I have already written some routines to transform 24-bit WAV signal streams into a suitable format for launching into other processing tasks. This part of the project is in its infancy, but once robust programs are in place, this part of the process should become routine. I decided at an early point to use the Python programming language and the NumPy array handling library to work with this data. [13,14] Python has become the language of choice for astronomy applications and is significantly easier to program in than C++. Once in NumPy arrays, data can easily be stored in Flexible Image Transport (FIT) files and retrieved for later analysis and imaging. This task is accomplished using the PyFITS Python library available from the Space Telescope Science Institute. [15] Python and all the dependencies described here are available for free and function across multiple operating system platforms. It is probably best to describe how to accomplish these processing steps by example:

Step 1 – Install Python and its version-matched dependencies onto your system. I am using Python 2.7 at the present time on a Windows 7 computer. Installations issues are beyond the scope of this article and familiarization with Python will be helpful. While it is a bit involved, Python and NumPy are very powerful tools that are worth getting to know better.

Step 2 – Record data: Point your antenna at your target of interest and record signals using the WAV file recording feature in SDRMAXV or apply a Python recording script such as 'qs1r_timed_file_recorder.py' that I have written (7). After this, point the antenna into the ground to obtain a reference signal for signal 'flattening'.

Step 3 – Generate signal flat file: Run the program called 'flat.py' (7) using the ground signal WAV file. This will generate a time averaged one dimensional 4096 long array with the ground signal to correct for gain variation in the receiver chain. This data will be saved as 'flat.fits'.

Step 4 – Convert 24 bit WAV files into a spectrogram: I have written a program called 'wavereader.py' (4) that will open a SDRMAXV/QS1R generated WAV file and process 10 million I/Q sample pairs from the WAV file. It does an overlapping Short Time Fourier Transform (STFT) that avoids signal loss due to FFT windowing on the data stream and generates a two dimensional

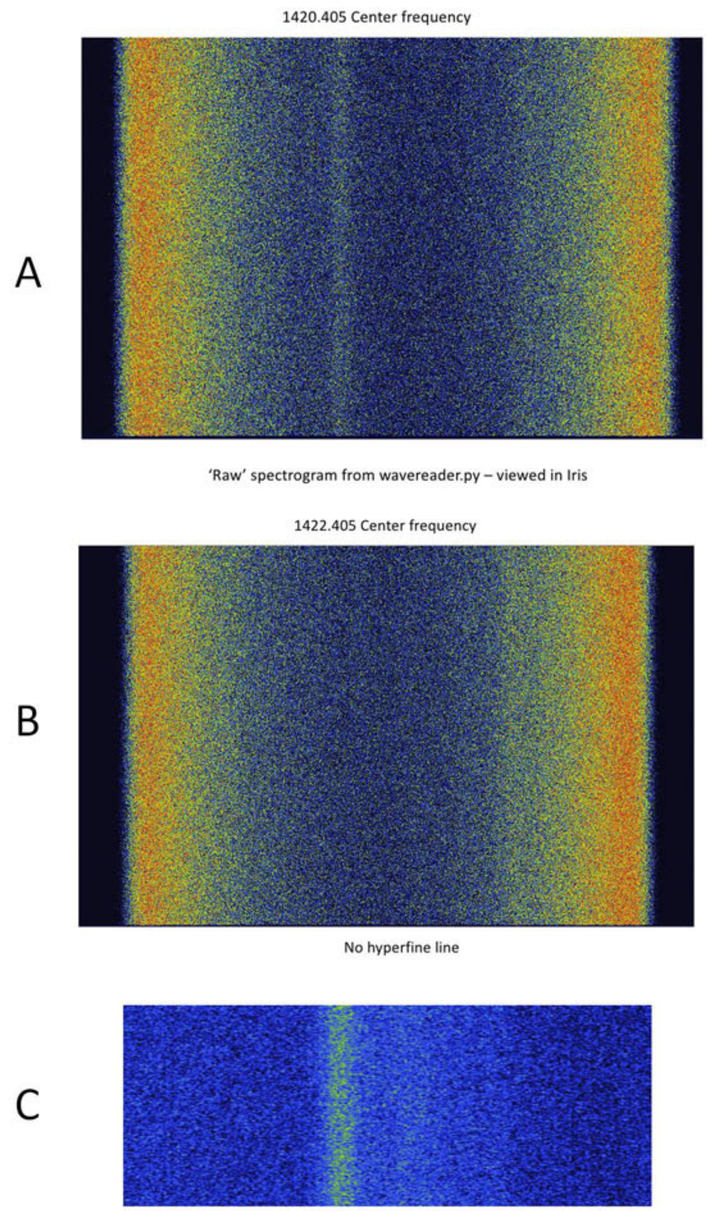

Figure 2 – Visualization of signal data. (A) Spectrogram of 'raw' hydrogen hyperfine signal. (B) Spectrogram of continuum signal. (C) Spectrogram of flat fielded hydrogen hyperfine spectrogram.

spectrogram NumPy array and saves it as a 16-bit FITs file.[16] At 2.5 MSPS, this is only four seconds worth of data but little signal information is lost. These spectrograms will be saved as FITs files that can be retrieved later for further processing or visualized with a FITs file viewer (see below). Alternatively, data can be converted using the program 'wavereaderiq.py' that saves WAV file data as a I/Q data stream where no signal data is lost.[7] Here, it could be possible to reduce sample bit depth to a 2-bit quantization to reduce file size for instance or analyze signals in the time domain.

Alternatively, I have written another program called 'bigreader.py' that will read five minutes worth of WAV file data (750 million samples) and perform median value integration to generate a spectrogram with a better signal to noise ratio.[7] This will generate nice spectrograms of the hydrogen hyperfine signal and can clearly reveal sources at different Doppler shifts. This program is best suited to basic analysis of the hydrogen hyperfine signal.

Step 5 – Visualize the data (see Figure 2): In Python, you can visualize the spectrogram using the commands from the matplotlib library (plt.imshow(array) and plt.show() commands). This is easy, but a better way to handle the data visually is to use a FITs file viewer/editor such as IRIS that is available for free.[17] Simply open a FITs file spectrogram and play with the contrast until the image looks good.

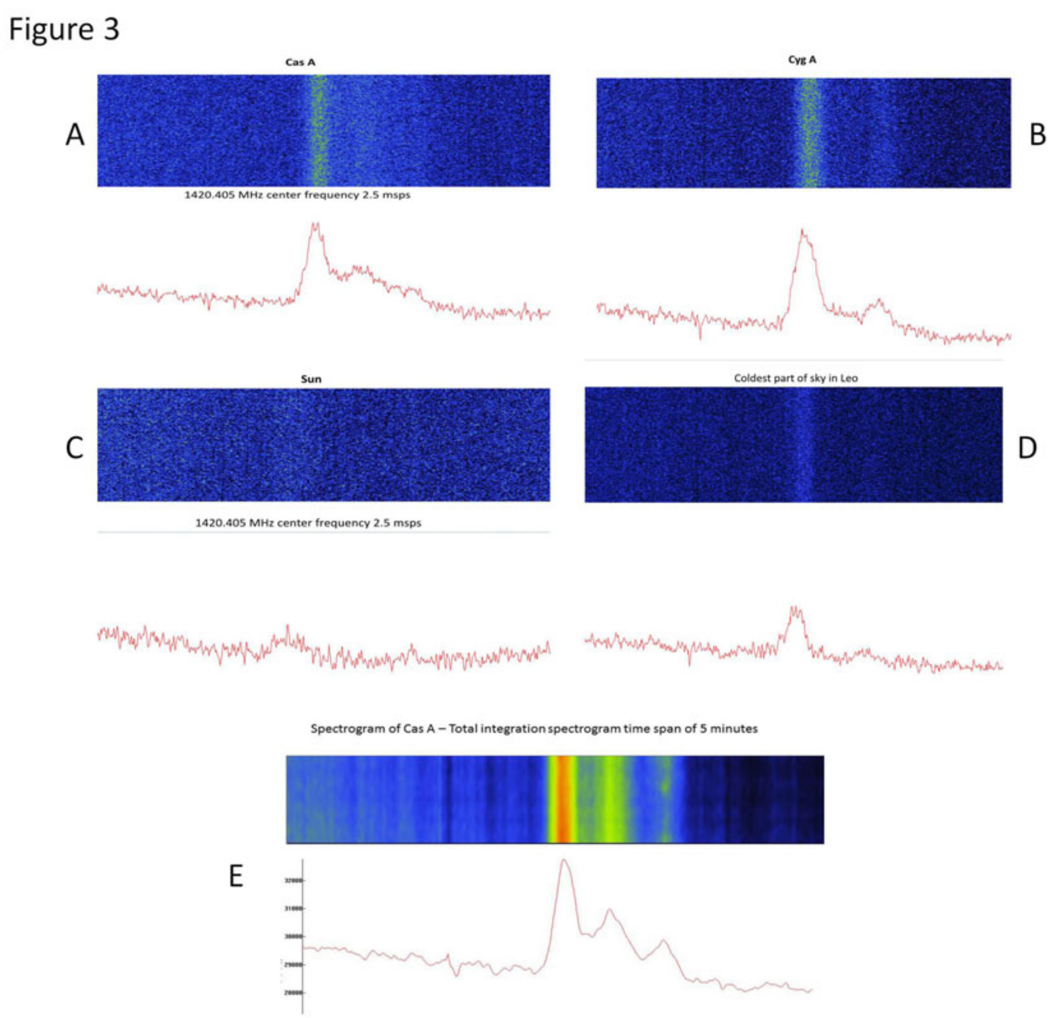

Figure 3 – Hydrogen hyperfine signals while pointing in the sightline of several radio sources. It should be noted that the neutral hydrogen signals emanate from cold hydrogen gas that is independent of the indicated sources. (A) Cas A; (B) Cyg A; (C) Neutral hydrogen signal from sources in the sightline of the sun (The sun does not produce its own neutral hydrogen signal) (D); Constellation Leo; (E) 5 minute integrated spectrogram neutral hydrogen in the sightline of Cas A.

If it is grainy, Gaussian blurring or wavelet filtering can usually reveal weak signal features. IRIS is designed for optical astronomy, but I have found it to work well for radio astronomy as well. In particular, IRIS possesses a variety of commands for spectrophotometry that are very useful for signal analyze.

Results

Preliminary results from the FSRA are encouraging. Initial tests revealed that a 9 dB signal difference exists between pointing my horn antenna at the ground (25 °C) and into the constellation Leo (data not shown). While these are primarily continuum sources and emit broadband radio energy, it was possible to detect neutral hydrogen signal from gas that was in the sightline of these sources. I aimed the antenna at the Sun, Leo, Cas A and Cyg A and manually recorded 4 seconds worth of data at 2.5 MSPS. Instantaneous spectrograms (no integration) using 'wavereader.py' of all sources (except the Sun) showed the hydrogen hyperfine line, before gain normalization. Gain normalization improved the signal levels and integration of the 4 second spectrograms revealed strong signals (see Figure 3). Finally, I recorded 5 minutes worth of data while in the sightline of Cas A and processed the signal data using 'bigreader.py'. This revealed a very strong signal and the presence of distinct Doppler shifted populations of hydrogen hyperfine radiating gas in the galactic plane sightline of Cas A (not from Cas A itself).

Conclusions

The FSRA is operational and can detect the hydrogen hyperfine signal even from regions of the sky known to have the lowest flux. I have constructed two FSRAs and plan to test them in a VLBI configuration in the near future and with additional users, FSRA's could be combined into a low cost VLBI network. The flexibility of FSRA makes it a useful platform for more than just hydrogen hyperfine observations. Suitable front ends for 406 MHz would be well suited to pulsar searches when combined with a signal dedispersion scripts in development or with PRESTO (7). My initial goals were to use the QS1R SDR for low frequency interferometry below 50 MHz like that being pursued by the LOFAR group where it has strong potential as well.[18] Large bandwidth observations of Jupiter decametric radiation are also easily achieved with the QS1R IF making the FSRA (or portions of it) an all-in-one solution as a radio astronomy receiver.

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Biography

David Lonard is a long-time amateur radio operator (N5OIQ) and amateur (optical) astronomer. He presently lives in suburban Pearland, Texas where he works on his hobbies under light polluted and RFI-hostile conditions. Contact information: David Lonard, email: dmlonard@gmail.com .

CALLISTO AS A WIDEBAND DOWN-CONVERTER

Whitham D. Reeve

Abbreviations in this article:
EME: Earth-Moon-Earth
IF: Intermediate Frequency
PC: Personal Computer
RF: Radio Frequency
SAW: Surface Acoustic Wave
SDR: Software Defined Radio
UHF: Ultra-High Frequency
VHF: Very High Frequency

In a previous issue of *Radio Astronomy*, Christian Monstein described the e-CALLISTO solar radio spectrometer network and a simple modification of the CALLISTO Receiver for operation as a narrowband (~300 kHz) single-frequency down-converter that works as a frontend to a software defined radio. [1] In this issue I will describe a modification that allows the CALLISTO Receiver to operate as a wideband down-converter.

When modified as a wideband down-converter, the CALLISTO Receiver provides a 10.7 MHz intermediate frequency (IF) output with a bandwidth of about 7 MHz. The new IF output may be connected to any software defined radio (SDR) capable of being tuned to 10.7 MHz and able to process that bandwidth. Two SDRs with this capability are the RFSpace SDR-14 and NetSDR (http://www.rfspace.com/) but there are others. The IF output also may be connected to a narrowband SDR, such as the RFSpace SDR-IQ or an SDR that uses a PC soundcard, but signal processing bandwidths will be much less. In the case of the SDR-IQ, the processing bandwidth is 190 kHz, and PC soundcards are limited to 48 or 96 kHz.

Applications

The modified CALLISTO Receiver can be used in many applications including observing satellites at very high frequencies and ultra-high frequencies (VHF/UHF) to derive Doppler-information., receiving meteor trail reflections and echoes from the Moon or satellites related to space radars and amateur radio Earth-Moon-Earth (EME) transmissions on 6 m, 2 m and 70 cm wavelengths, participating in VHF-SETI activities, and observing VHF/UHF solar radio bursts with extremely high frequency resolution.

Frequency Conversion

The CALLISTO Receiver is a superheteroydyn (superhet) radio receiver that covers the frequency range from 45 MHz to 870 MHz (for a tutorial on how a superhet radio works, see reference [2]). When used as a down-converter in front of an SDR, the CALLISTO Receiver effectively expands the tuning range of the SDR for signal processing purposes.

The modified CALLISTO Receiver operates at a single center frequency within its operating range. For example, the receiver could be tuned to 610.0 MHz. The RF frontend in the receiver has a bandwidth of around 7 MHz, as determined by the surface acoustic wave (SAW) filter built into it, so the tuner actually is working over the frequency range of 606.5 to 613.5 MHz. When the center frequency is converted by the tuner’s internal mixer to an intermediate frequency (the CALLISTO Receiver’s 1st IF), the bandwidth is retained. The tuner is connected to a 2nd mixer in the receiver with an IF output frequency of 10.7 MHz (2nd IF). In our example, the RF input frequency 610.0 ± 3.5 MHz appears at the 2nd IF output as 10.7 ± 3.5 MHz.

Wideband Modification

The wideband modification consists of tapping the output of the 2nd mixer just ahead of the 2nd IF bandpass filter (figure 1). The mixer output includes the 10.7 MHz intermediate frequency plus other mixing products such as the 2nd oscillator frequency and its harmonics. A lowpass filter is used to eliminate undesired mixing products prior to connection to the SDR.

Schematically, the modification is quite simple (figure 2). The wideband modification requires only a few passive components, a lowpass filter, a short piece of coaxial cable (figure 3) and a BNC-connector mounted on the front or rear panel of the CALLISTO Receiver (figure 4). All components can be mounted inside the receiver (figure 5).

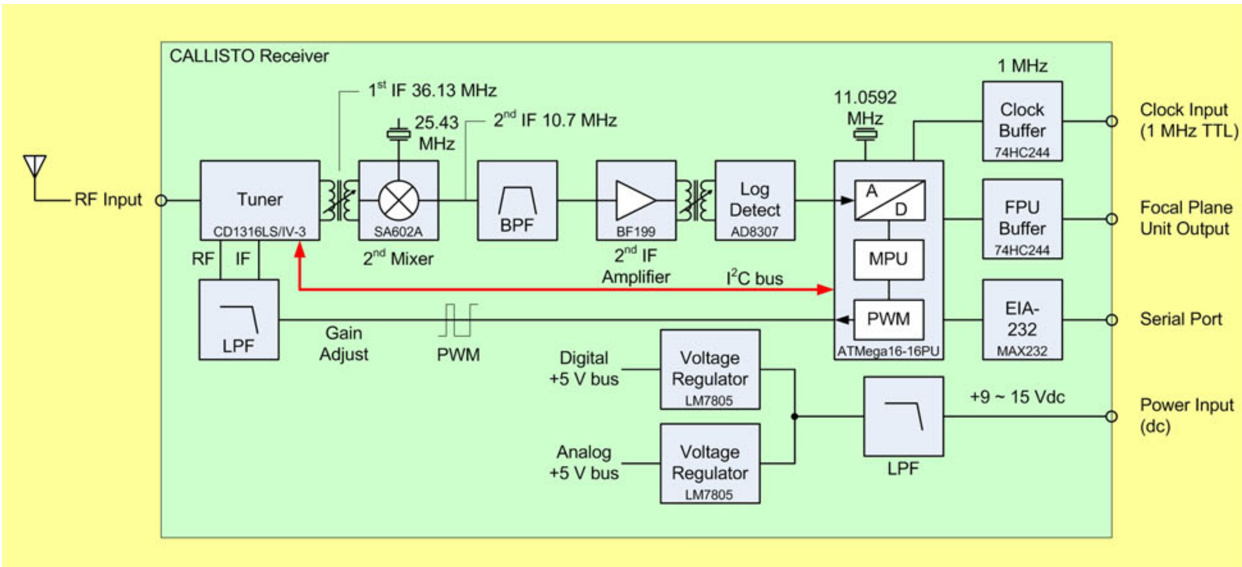

Figure 1 – Block diagram of the CALLISTO Receiver showing modifications, one wideband at the output of 2nd mixer – the subject of this article – and the other narrowband at the secondary of the 2nd IF output transformer.

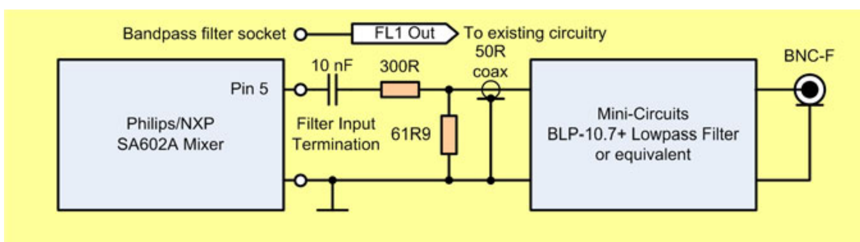

Figure 2 – Schematic of wideband modifications. The resistive divider provides impedance matching and the capacitor provides dc isolation. The lowpass filter eliminates undesired mixing products. A Mini-Circuits connectorized filter (http://www.minicircuits.com/pdfs/BLP-10.7+.pdf) is shown but any filter with comparable characteristics may be used. See text for discussion of the bandpass filter socket.

Figure 3 – Components required for the wideband down-converter modifications. In my experimental radio, I used pluggable interfaces and a commercial lowpass filter because it was available in my lab. A home-made filter may be used but the IF output response may differ from that shown later in this article. The cost of the parts shown here is about US$40.

Figure 4 – Panel modifications of a CALLISTO Receiver showing the BNC connector added to the rear panel to the right of the Clock Input connector. This connector also can be used with both the wideband and narrowband modifications.

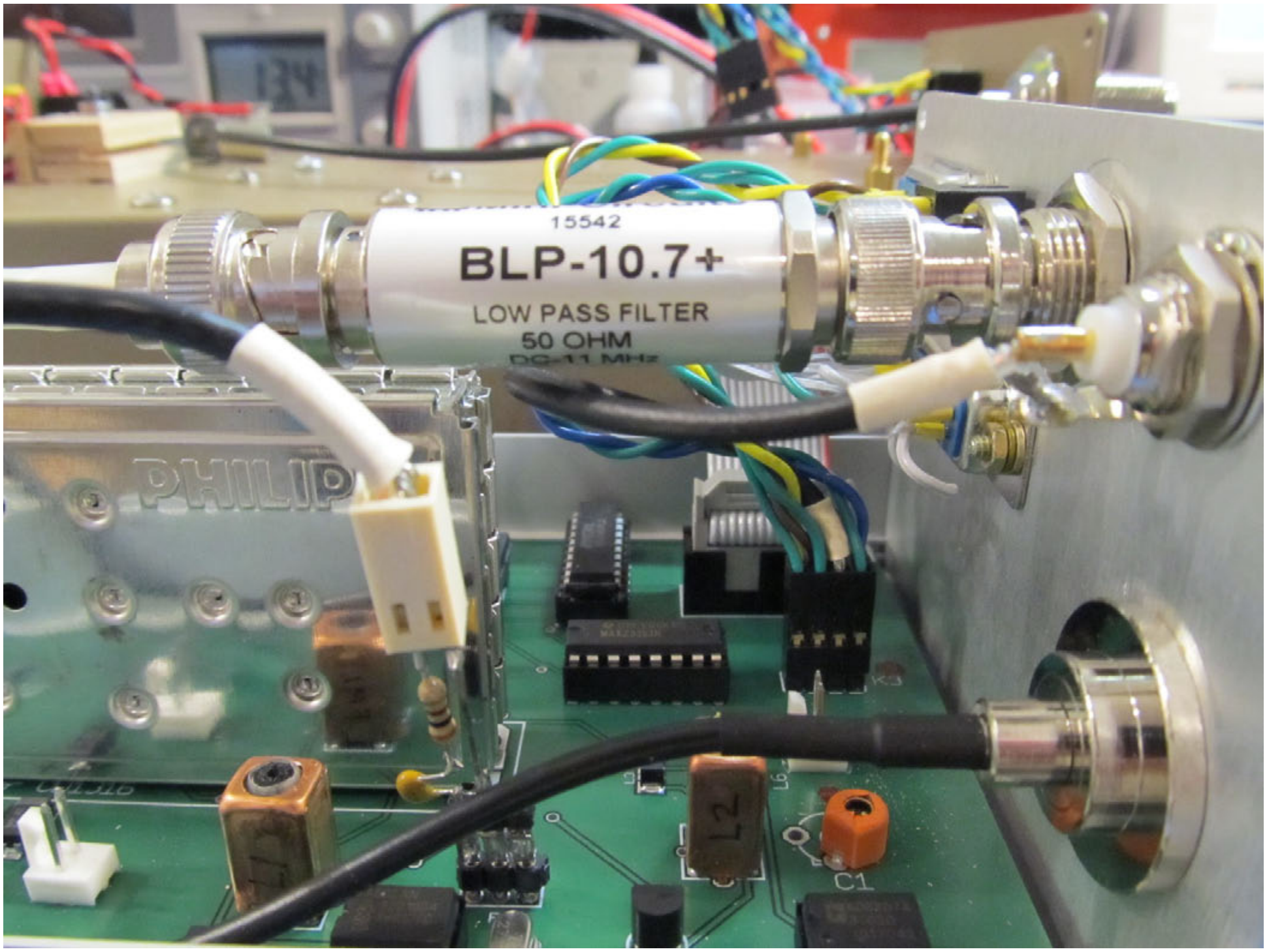

Figure 5 – The interface circuit shown just to the left of center is plugged into a 3-terminal socket, which I installed to allow the original 2nd IF bandpass filter to be reinstalled. The lowpass filter for the down-converter is at the top of the picture; it plugs into a bulkhead-type BNC-F to BNC-F feed-through connector on the rear panel. The small connectorized coaxial cable between the filter and interface circuit also can be used with the narrowband down-converter modification described in Christian Monstein's article by installing a 2-pin header on the PCB (partially visible behind the lower coaxial cable in the picture).

For experimental purposes and to allow the CALLISTO Receiver to be re-used in its original form, I installed a 3-terminal single-inline socket for the original bandpass filter FL1. This way I could remove the bandpass filter and plug-in the impedance matching network interface and lowpass filter to use the receiver as a wideband down-converter. To return the receiver to its original setup, I simply remove the interface and replace the bandpass filter. With this setup, the wideband modification is non-disruptive and does not preclude normal operation of the CALLISTO Receiver. However, the two modes, down-converter and normal, cannot be used simultaneously. The overall response, or transfer function, of the down-converter is quite linear (figure 6). The gain of the CALLISTO Receiver from the radio frequency (RF) input port to the wideband IF output port is adjustable through software and at maximum setting exceeds 40 dB.

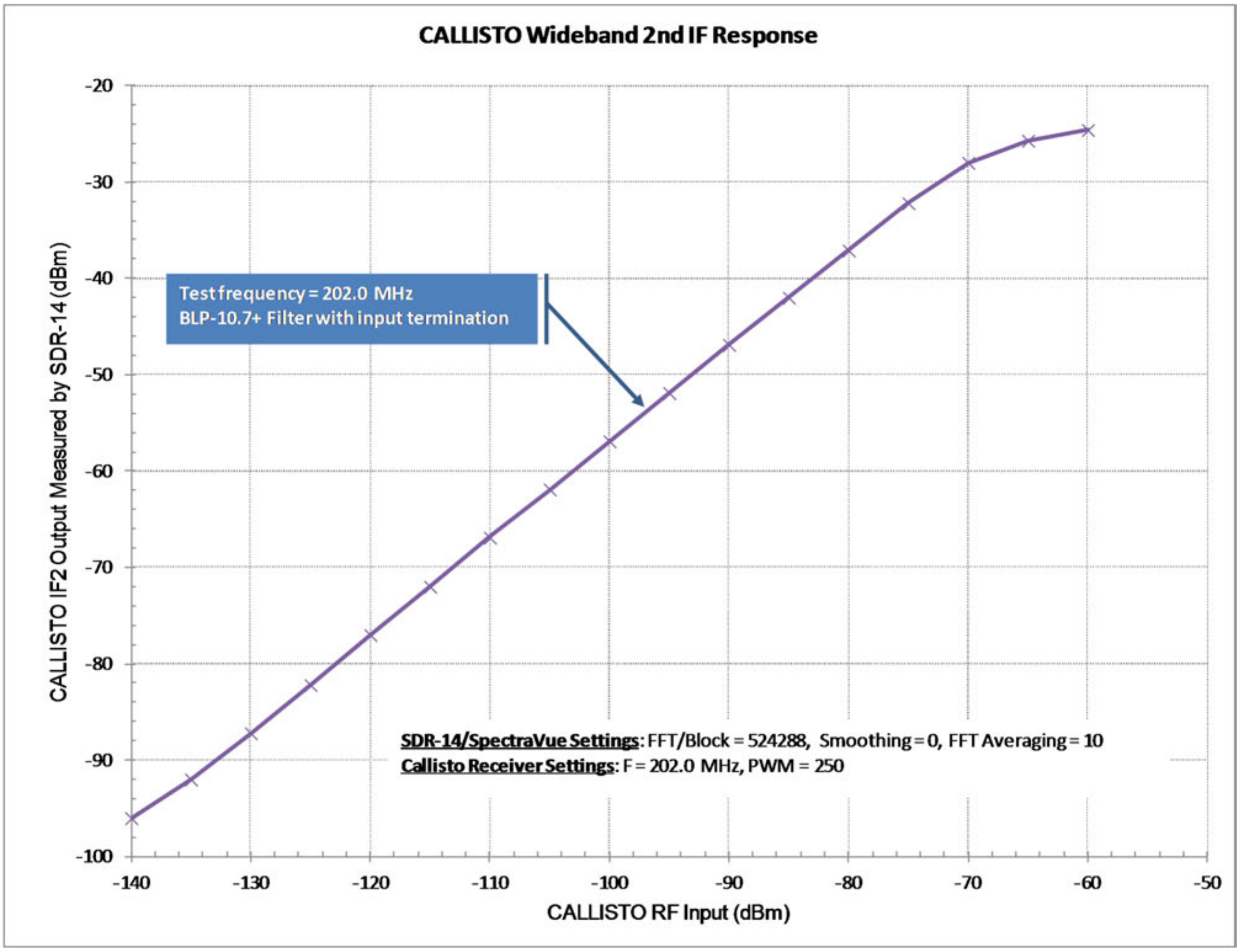

Figure 6 – Overall transfer function of CALLISTO down-converter. The x-axis is the RF output power from the RF signal generator applied to Callisto RF input port. The y-axis displays the 2nd IF output power (SDR-14 RF input power) as measured by the SpectraVue software. The response is linear over an input power range of approximately -135 dBm to -70 dBm.

Software control

To use the CALLISTO Receiver as a wideband down-converter, its filtered 2nd IF output signal is connected to the RF input of an SDR via a 50 ohm coaxial cable (figure 7). The frequency and gain of the CALLISTO Receiver is controlled by the Simple software application as described in Christian Monstein's article (figure 8).

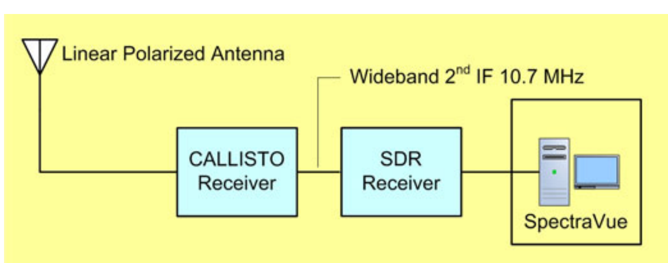

Figure 7 – CALLISTO down-converter connections. The SDR is operated with its normal software.

The SDR is controlled by its own software, which is used to set the SDR center frequency to 10.7 MHz and the bandwidth to the desired range (figure 9). I have used the SDR-14 with SpectraVue (http://www.moe-tronix.com/), Radio-Sky Spectrograph (http://www.radiosky.com/) and SDR-Radio (http://sdr-radio.com/), and I have used the NetSDR with SpectraVue and SDR-Radio. If you use a narrowband SDR with a PC soundcard, there are many software choices.

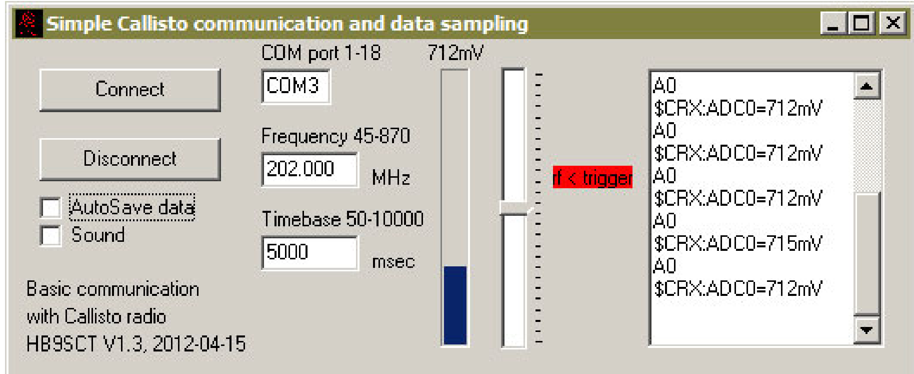

Figure 8 – Screenshot of the Simple V1.3 software tool with a frequency setting of 202.0 MHz. Simple originally was designed as a receiver alignment and test aid but has evolved into a more generalized frequency control tool.

Conclusions

The CALLISTO Receiver may be easily and inexpensively modified to work as a wideband down-converter. The modified receiver has a frequency range of 45 to 870 MHz and a bandwidth of about 7 MHz. With a software defined radio connected to the intermediate frequency output, celestial emissions or signals within that bandwidth may be analyzed through the SDR signal processing software.

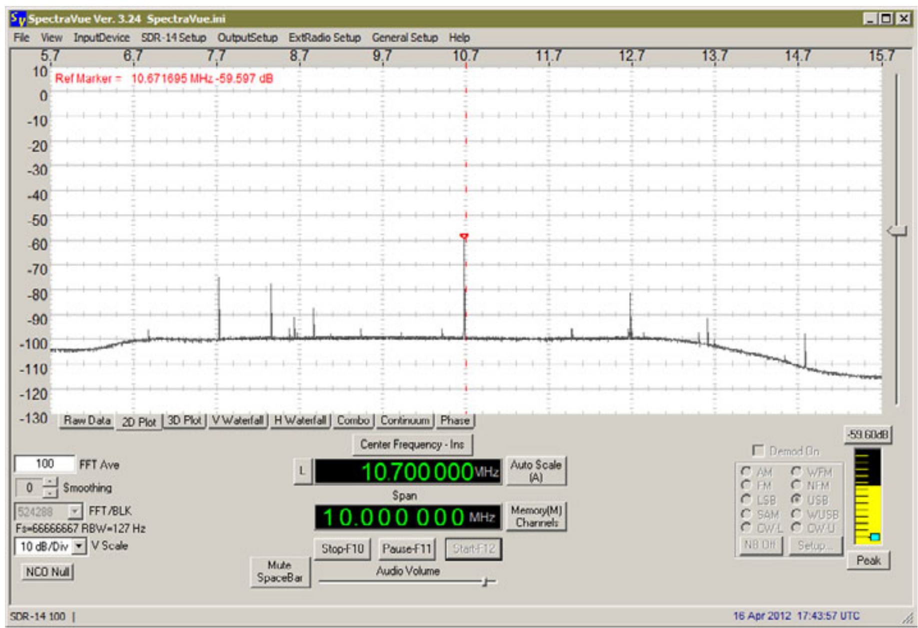

Figure 9 – CALLISTO Receiver 2nd IF output spectrum as seen on SpectraVue with SDR-14 tuned to 10.7 MHz center frequency and 10 MHz bandwidth. The IF output spectrum, which is shown by the slight hump in the background noise, ranges from about 6.7 to 13.7 MHz. The CALLISTO receiver was tuned to 202.0 MHz and connected to an RF signal generator tuned to the same frequency and with an output level of -100 dBm. This carrier is indicated by the center spike with (red) triangular peak marker.

References

[1] Monstein, C., Callisto as a Programmable Single-Frequency Down-Converter, Radio Astronomy, March-April 2012.

[2] Radio-Electronics, The Superhet or Superheterodyne Radio Receiver, http://www.radio-electronics.com/info/rf-technology-design/superheterodyne-radio-receiver/basics-tutorial.php

ALLAN TIME

Christian Monstein

Stability tests based on the Allan variance method have become a standard procedure for the evaluation of the quality of radio-astronomical instrumentation. They are very simple and simulate the situation when detecting weak signals buried in large noise fluctuations. Here a practical example will be presented on the basis of the Callisto frequency agile radio spectrometer. The result will be a numerical value called Allan-time which defines the suggested period of calibration.

Introduction

All radio-astronomical measurements are affected by instabilities of the gain, the transmission function, and the internal system noise changing the absolute scale of the measured signal. To compensate for these drifts, one switches between the astronomical source and a reference signal—a known internal calibrator or a point on the blank sky—on a time scale short compared to the instabilities. Because of the overheads introduced by switching to the calibration source, the optimum strategy is not to switch as fast as possible, but only as fast as necessary to suppress the drift noise. Therefore the characteristic time scales of the instabilities have to be measured. This can be done in terms of the Allan variance, a powerful technique to determine the stability of general radioastronomical equipment, in particular for systems consisting of heterodyne receivers and spectrometer back ends. [1] The Allan variance plot can be computed from any sufficiently long time series of spectrometer dumps (light curve) taken at fixed instrumental settings, provided that the integration times for the individual dumps are small compared to all instabilities. Allan variance in general is the method of analysis of stochastic processes in a time domain. It was originally designed for the statistics of atomic frequency standards. [1] The main advantage of Allan variance in a comparison with power spectral density is a lower computational complexity. On the other hand, there is a problem in interpretation of some kinds of noises, which appear in the same way. However, a solution is using the modified Allan variance. Because of the problem analogy, the Allan variance method can be used for the investigation of all periodic sampling devices like digital multimeters, frequency counters, radios, radiometers, and spectrometers as well. For detailed theory, mathematical background and explanations I refer to literature below.

Theory

The longer we average the better the result? The answer is no. But from theoretical point of view a measuring result should get more and more precise the longer we integrate or average the incoming signal. The resolution σ of any result is proportional to

$$\sigma \propto \frac{1}{\sqrt{N}} \qquad (1)$$

where N denotes the number of measurements. If we average N = 100 measurements, the resolution σ is getting 10 times better. [2] But this is only true if the measured signal follows purely statistical behavior (Gaussian distribution). Any nonlinearity or systematical error in the incoming signal or in the signal path (typically introduced by temperature changes or aging processes) cannot be improved by simply averaging. To compensate for systematical errors we need a periodic calibration process. To find out the time period for calibration we need to know how long the system is stable enough without any calibration.

What is the expected rms? We can analyze the Allan Time of our receivers with a program called ALAVAR (see Relevant Internet Addresses for Download and Further Reading at the end of this article). However, before we do the analysis, we should have an idea about the expected rms (root mean square) or sigma of the original signal.. Again according to Kraus, we get:

$$\sigma = \frac{\delta I}{I} = \frac{1}{\sqrt{B\tau}} \tag{2}$$

where I stands for any kind of intensity or power or flux or antenna temperature. Variable B stands for bandwidth, which is 300 kHz in case of Callisto. And τ defines the integration time, which in case of Callisto is about 1 ms. We express σ in dB, then we get:

$$\sigma_{dB} = 10 \log\left(1 + \frac{1}{\sqrt{B\tau}}\right) \tag{3}$$

In addition we know in case of Callisto the detector slope g = 25.4 mV/dB. Knowing this, we may express δI_{dB} now in mV .

$$\sigma_{mV} = 10 \log\left(1 + \frac{1}{\sqrt{300\,\text{kHz} \cdot 1\text{ms}}}\right)\left(\frac{25.4\,\text{mV}}{1\text{dB}}\right) = 6.2\,\text{mV} \tag{4}$$

In a recent measurement, W. Reeve obtained with one of his new series Callisto σ = 5.7 mV while I got with my own series σ =5.8 mV; both are slightly too small compared with theory. The meaning of these results is that either the bandwidth is slightly higher than 300 KHz or the integration is slightly higher than 1 msec or the detector slope is slightly lower than 25.4 mV/dB or some combination thereof. But the result as such proves that the low pass filtering of the detector signal is satisfactory (a measured value larger than the theoretical value, would indicate an inadequate low pass filter).

Practical process

Measurement setup: Here I report about getting the Allan-time based on the Callisto frequency agile radio spectrometer. The procedure is the same for any other radio, radiometer or spectrometer. The whole process has to be repeated for each frequency of interest. In my case I decided first for f = 610.0MHz because it's the only frequency at my current location in the whole sky spectrum within the Callisto receiver frequency range of 45 MHz and 870 MHz that is more or less free from interference. In addition it is a protected frequency for radio astronomy. Another method is to measure a 50 Ω termination resistor at constant temperature instead of a defined sky-position (Cas A, CygA, Tau A, Moon, etc.) with a lot of radio frequency interference coming from the the side lobes of the antenna. First I let the whole system warm up for at least one hour such that all components have the same temperature. During the test no component of the system should be touched to avoid temperature gradient or other electromagnetic influence to the receiver system. The receiver is then set to the frequency of interest and the signal is sampled and saved in a systematic way, e.g. one measurement every τ = 500 msec. This sam-

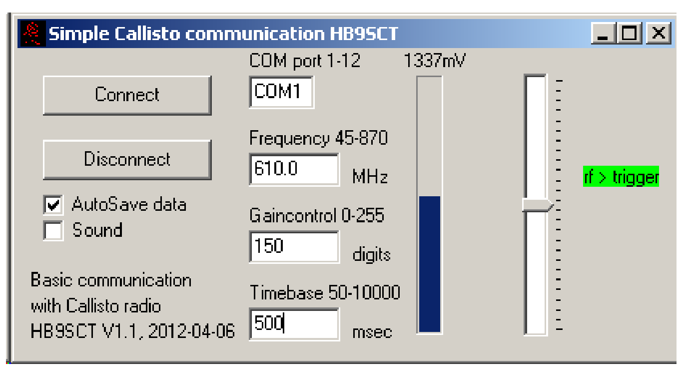

Figure 1 – Setup of software tool simple.exe to control serial communication port, receiver frequency, receiver gain and sampling rate of the Callisto frequency agile radio spectrometer.

pling can be done with the free tool simple.exe, which controls Callisto and collects the measured data samples. See Figure 1. Any digital multimeter with a serial or an USB connection to a PC can be used in a similar way.

Observation: The observation needs to be done for at least one hour. In many cases, the observation should go on for 24 hours or even longer to capture all possible interfering inputs. The longer the better. After sampling sufficient data points (from my experience at least 30,000), typically in an ASCII file, we put the signal-file into the software application ALAVAR. The application can be downloaded freely from the web (for web-link see end of this article). Install it on the hard disk of your PC. The installation-drive and path can be selected during the installation. Start the application ALAVAR from the desktop and select the function File → Load Data and select the data file. Normally the first row of the data file is interpreted as title text and is shown in the top memo field of ALAVAR. For the "Choose number column to load" field, select 2 and then press Validate. See Figure 2.

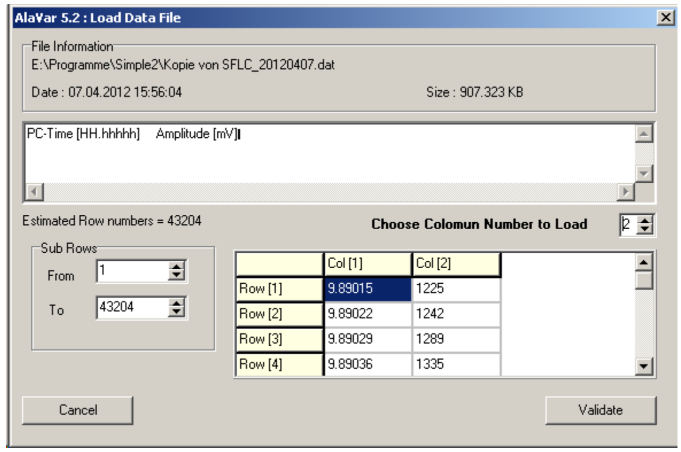

Figure 2 – Reading the ASCII data file and defining its data structure. Here column (1) contains observation time in UT and column (2) contains the amplitude of the signal to be analyzed in mV.

Analysis: If you are suffering from a lot of outliers from a *known* reason or source the you may tick the option Remove Outliers and press the button PreProcess. But this action needs to be mentioned in the final report, otherwise the report will look too good. If you know that there is no interference coming into the receiver then you may skip the function Remove Outliers (but you still must press PreProcess). Then we immediately get the light curve plot (a plot of intensity over time) as shown in Figure 3. The light curve plot should appear random with no periodic indications.

As the next step we should not forget to enter the sampling time Tau, in my case 0.5 s. Then tick ADEV (overlapping Allan standard deviation in red) and Error Bar but leave MDEV (modified Allan standard deviation), TDEV (Allan time standard deviation) and HDEV (overlapping Hadamard variance) un-ticked. The tool ALAVAR offers different statistical methods for analysis. As amateur radio astronomers we stick with ADEV (overlapping Allan standard deviation in red) because it is the most common statistical method, although there is no large difference between it and the other

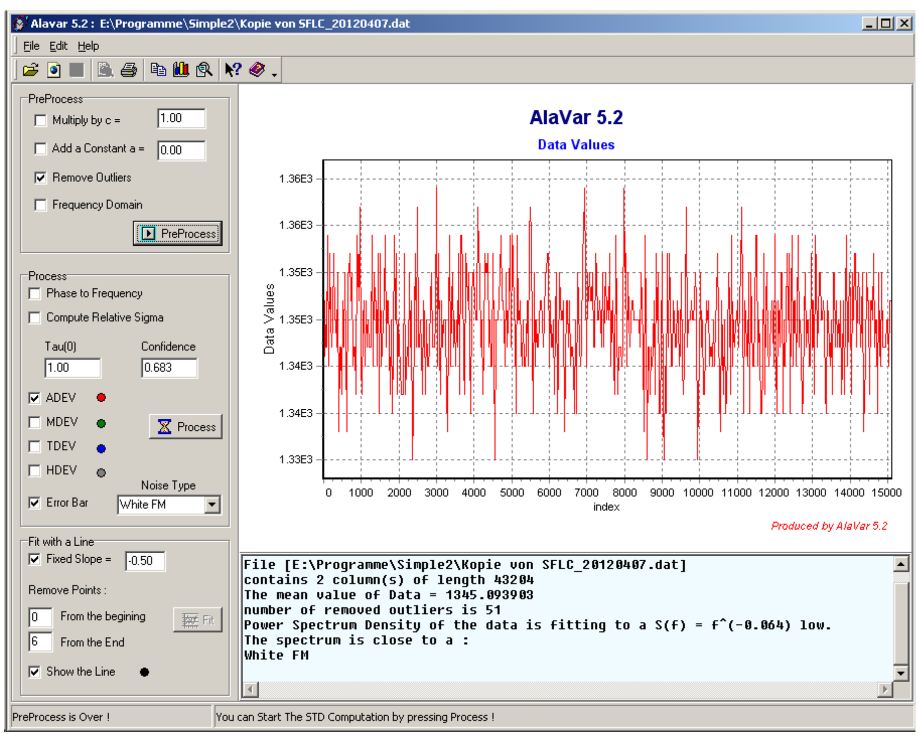

Figure 3 – PreProcess of sampled data at one single frequency channel and generating light curve. The plot shows noise with rather low interference (no large spikes or gaps). The x-axis shows the sample number and the y-axis the measured voltage in millivolts.

methods. ADEV is fine for our purposes, which is to get an idea about stability in time of the receiver. For more information, go to the ALAMATH-website of ALAVAR (link below). Then press the Process button.

One immediately gets the Allan plot as shown in Figure 4. Now set the Fixed Slope to -0.50 (purely theory) and press button Fit. Then one should get the theoretical linear fit plot for purely statistical noise. In practice, the measured situation (red) will differ from theory (gray). Therefore, one needs to cancel several points from the end of the plot, in my case six points, such that the measured plot follows in parallel as long as possible the theoretical linear fit trace. Press the Fit button again.

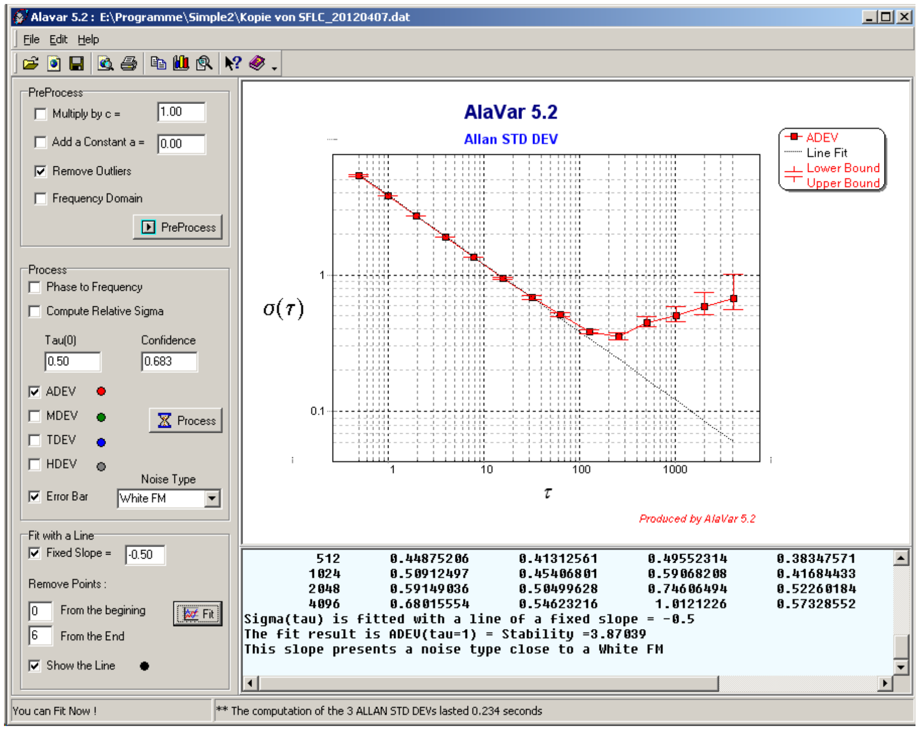

Figure 4 – Allan Variance plot for Callisto at *f* = 610.0 MHz. The x-axis shows the integration time τ expressed in seconds over an observation time of 6 hours and 3 minutes, the y-axis the variance σ of the signal, both in logarithmic scale.

Result/Conclusion

In my example based on Callisto, the Allan-time is on the order of 250 seconds, as indicated by the minimum in the red trace in Figure 4. That means we can measure and integrate up to this time and we still get results with improving precision. If we integrate longer than the Allan time (250 s for my receiver) the result will get worse, the red plot increases again. Therefore, in practice we need to re-calibrate the whole system about every 4 minutes to compensate for systematical errors. Appropriate calibration methods and a calibration unit will be presented in a future article.

Relevant Internet Addresses for Download and Further Reading

CALLISTO, **http://www.e-callisto.org**

ALAVAR, **http://www.alamath.com/**

Allan Time, **http://en.wikipedia.org/wiki/Allan_varianc**e

NIST Technical Note 1337, Characterization of Clocks and Oscillators, **http://tf.nist.gov/general/pdf/868.pdf**

Allan's paper at NIST, **http://tf.nist.gov/timefreq/general/pdf/7.pdf**

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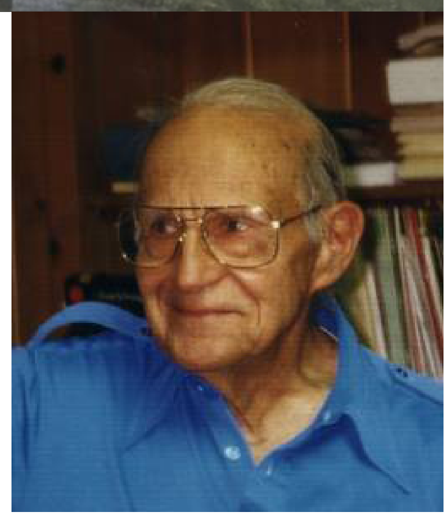
John D Kraus (1910–2004)
Modern Pioneer of Radio Astronomy

BIO

Bill Seymour, KM4YL

John Daniel Kraus was an American physicist known for his contributions to electromagnetic theory, antenna theory, and radio astronomy. His inventions included the helical antenna, the corner reflector, and several other types of antennas. He designed the Big Ear Antenna at Ohio State University (OSU), which was constructed mostly by a team of OSU students and was used to carry out the Ohio Radio Sky Survey. Kraus held a number of patents and was widely published. Two of his books, *Radio Astronomy*, and *Antennas*, are so comprehensive that they are still considered to be definitive texts in these areas. The brilliant radio/ radio astronomy work performed by Kraus during his tenure at OSU definitely places him in the innovative tradition of Karl Jansky and Grote Weber as a pioneer in the field.



Images courtesy NRAO and bigear.org.

Kraus was born in Ann Arbor, Michigan on June 28, 1910. He received the Ph.D. in physics from the University of Michigan in 1933. Following the completion of his doctorate, Kraus joined the research team in nuclear physics at the University of Michigan, helping to design and build the school's new 100-ton cyclotron. During World War II, he worked on degaussing ships for the U.S. Navy and on radar countermeasures at Harvard University. After the war, Kraus joined the faculty of OSU, where he later became Director of The Radio Observatory and McDougal Professor (Emeritus) of Electrical Engineering and Astronomy.

His work with the Sputnik satellites was an example of the creativity he brought to investigations involving radio and radio astronomy throughout his career. In 1958, while he was at OSU, Dr. Kraus used the signal of radio station WWV to track the disintegration of Russian satellite Sputnik I. Kraus knew that a meteor entering the upper atmosphere leaves in its wake a small amount of ionized air molecules. These ions reflect a stray radio signal back to Earth, strengthening the signal for a few seconds. This effect is known as "meteor scatter." Kraus predicted that what remained of Sputnik would exhibit the same effect—but on a larger scale. His prediction was correct: WWV's signal was noticeably strengthened for durations lasting over a minute. In addition, the strengthening came from a direction and at a time of day that agreed with predictions of the paths of Sputnik's final orbits. Using this information, Dr. Kraus was able to draw a complete time-line of Sputnik's disintegration. His data also led him to conclude that satellites do not fail as one unit, but rather that spacecraft break apart into their component units as they move closer to Earth.

He was a long-term advocate of SETI research, and the Big Ear antenna probed the farthest reaches of the known universe.

His book, *Antennas*, first published in 1950 by McGraw-Hill, was a monumental work in which the helical antenna Kraus invented is described in detail (Chapter 7). Even though the mathematical rigor and the attention to detail was typical of the time, the book set standards and was referred to by many as the "Antenna Bible." The shorter second edition, published in 1988, was a major upgrade but referenced the first edition for details of mathematical deductions. For the publication of the third edition in 2002, Ronald J. Marhefka joined Kraus as author/editor, with many chapters written by renowned experts in their fields. The book was also updated with respect to computer modeling and terahertz waves. The title was changed to *Antennas for All Applications* (ISBN 007123201X).

His book, *Radio Astronomy*, published by Cygnus-Quasar (ISBN 0070353921) is often referred to as "a classic text and reference book."

He is also the author of *Electromagnetics*, *Big Ear*, and *Our Cosmic Universe*. (Editor's note: *Big Ear Two* was reviewed in the April–May 2011 issue of *Radio Astronomy*.)

His honors and awards include U.S Navy Meritorious Civilian Service Award, Elected to Fellow of the IEEE, elected to National Academy of Engineering, Joseph Sullivan Medal from OSU, Outstanding Achievement Award from The University of Michigan, IEEE Centennial Medal, IEEE Edison Medal, IEEE Heinrich Hertz Medal, Twice the Distinguished Achievement Award from the IEEE Antennas and Propagation Society.

When he died at the age of 94, John Kraus had finished his final achievement—that of great personal longevity.

Listed below are excerpts from an article about Kraus by Reporter Barry Kawa in the *Cleveland (Ohio) Plain Dealer* Sunday Magazine section, September 18, 1994 :

> "If ever there is a radio astronomer's hall of fame, one of the first inductees would be Ohio State University professor emeritus Dr. John Kraus.
>
> Kraus emerged as one of the country's leading radio telescope pioneers in the 1940's. His contemporaries included Karl Jansky, a Bell Telephone Laboratories engineer who invented the radio telescope in the 1930s. A good friend, Grote Reber, another radio engineer, helped mold the science.
>
> In radio astronomy circles, Kraus is revered. His textbook *Radio Astronomy*, published in 1966, is the bible in the field.
>
> 'I think John is a prime mover in SETI [Search for Extraterrestrial Intelligence],' says Dr. Paul Horowitz, director of his own long-running search at Harvard University's Oak Ridge Radio Observatory. 'I think John is such a gentleman, too. In fact, John had made a personal contribution to our search, and not an unsubstantial amount.'
>
> He updated his textbook *Electromagnetics*, now in its fourth edition, a year ago. He still carries out electromagnetic experiments at the home he shares with his wife, Alice.
>
> Kraus is a pioneer, but he's not willing to predict the future of radio astronomy. 'It's very hard to say,' he says. 'New discoveries will undoubtedly come. It has been said the greatest discoveries are yet to be made.' "

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Kawa, Barry: 'Big Ear' Designer A Pioneer in The Field; *The Plain Dealer*; September 18, 1994.
Kraus, John D.; W8JK, SK, American Radio Relay League; July 21, 2004.
"Science Notes: Death of a Sputnik Traced by New Radio System", *The New York Times*; pp.E11, January 19, 1958.

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http://www.reeve.com/Solar/e-CALLISTO/e-callistoTMA.htm
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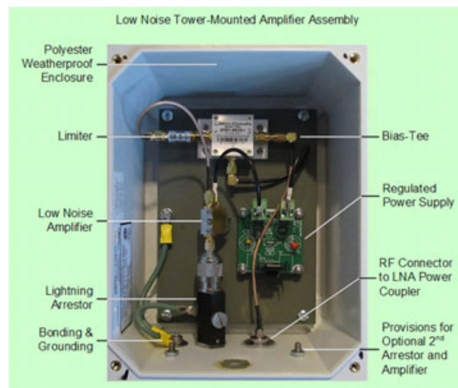

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Website dedicated to antenna theory: **http://www.antenna-theory.com/**

Spectrum analyzer tutorial and basics: **http://www.radio-electronics.com/info/t_and_m/spectrum_analyser/rf-analyzer-basics-tutorial.php**

Using radio atmospherics (sferics) to measure daytime D-region ionosphere variations: **http://people.ee.duke.edu/~cummer/reprints/119_Han10_JGR_DayDRegion.pdf**

For the mathematically inclined: Determination of Wave Mode Contribution into the ULF Pulsations from combined radar and magnetometer data: Method of Apparent Impedance: **http://cirrus.mail-list.com/iswinewsletter/Pilipenko_JASTP12_impedance.pdf**

Software Defined Radio Handbook, about 72 pages long of which 12 pages contains a tutorial and the rest contains product information: **http://www.pentek.com/deliver/TechDoc.cfm/DgtlRcvrHbk43.pdf?Filename=DgtlRcvrHbk43.pdf**

Low noise microwave monolithic integrated circuit (MMIC), 0.8 dB noise figure, 20 dB gain, 0.05~6 GHz frequency range for a buck-forty-nine each,
Mini-Circuits **PMA-545: http://www.minicircuits.com/pdfs/PMA-545+.pdf**
Evaluation board (US59.95 each): **http://www.minicircuits.com/pcb/WTB-501+_P02.pdf**

Another LNA with construction information: **http://www.newsvhf.com/hemt-mmic-wideband-lna.pdf**

73 magazine online archive from October 1960 to September 2003: **http://archive.org/search.php?query=collection%3A%2273-magazine%22**

Find the April 1997 issue of 73 magazine from the previous link and see the article on page 10 "The Hale-Bopp Comet and Its Controversial Tale – Build the Cosmic Crystal Set and Listen In!" Ignore the baloney at the beginning concerning alien communications and go to construction details for horn and parabolic dish antennas

Find the March 1966 issue of 73 magazine and see the article on page 6 "Circular Polarization." This is a good introductory article if you want to build circular polarized antennas with switching between left-hand and right-hand circular polarization.

Many of the old classic radio astronomy books by the pioneers (Piddington, Jennison, Hyde, Graham-Smith, Lovell, Clegg, Van de Hulst, Pawsey, Bracewell, Smith and many others), in PDF format: **http://www.google.com/url?sa=D&q=http://archive.org/search.php%3Fquery%3D%2522radio%2520astronomy%2522%2520AND%2520collection%253Aopensource&usg=AFQjCNHw48c5I-ZNV2SBYIz5-Inj_clu4g**

Fourier Series Tutorial: **http://www.fourier-series.com/**

NASA's Mysteries of the Sun: **http://missionscience.nasa.gov/sun/**

Online Resources

British Astronomical Association – Radio Astronomy Group
http://www.britastro.org/baa/

CALLISTO Receiver & e-CALLISTO
http://www.reeve.com/Solar/e-CALLISTO/e-callisto.htm
CALLISTO data archive: **http://e-callisto.org**

Deep Space Exploration Society
http://dses.org/index.shtml

European Radio Astronomy Club
http://www.eracnet.org

GNU Radio
http://www.gnu.org/licenses/gpl.html

Inspire Project
http://theinspireproject.org

Jamesburg Earth Station volunteer group
http://www.jamesburgdish.org
http://www.bambi.net/jamesburg.html

NASA Radio Jove Project
http://radiojove.gsfc.nasa.gov
Archive: **http://jovearchive.gsfc.nasa.gov**

National Radio Astronomy Observatory
http://www.nrao.edu
NRAO Essential Radio Astronomy Course
http://www.cv.nrao.edu/course/astr534/ERA.shtml

Pisgah Astronomical Research Institute
http://www.pari.edu

Radio Astronomy Supplies
http://www.radioastronomysupplies.com

Radio Sky Publishing
http://www.radiosky.com

RF Associates
Richard Flagg, **rf@hawaii.rr.com**
1721-I Young Street, Honolulu, HI 96826

RFSpace, Inc.
http://www.rfspace.com

SARA Email Forum and Discussion Group
http://groups.google.com/group/sara-list

SARA Web Site
http://radio-astronomy.org

SARA Facebook page
http://www.facebook.com/pages/Society-of-Amateur-Radio-Astronomers/128085007262843

Shirleys Bay Radio Astronomy Consortium
marcus@propulsionpolymers.com

Simple Aurora Monitor Magnetometer
http://www.reeve.com/SAMDescription.htm

Stanford Solar Center
http://solar-center.stanford.edu/SID/

SETI League
http://www.setileague.org

Tamke-Allan Observatory (David Fields)
http://www.roanestate.edu/obs

UK Radio Astronomy Association
http://www.ukraa.com/www/

For Sale, Trade, and Wanted

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 **editor@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.

For sale

RFSpace SDR-14, S/N KI001026, new in box, asking $975
Price negotiable, includes postage. Contact Dave Typinski, **davetyp@typnet.net**.

For sale

Items listed below. Send request to SARA by email to **supersid@radio-astronomy.org**.
For more information: **http://www.radio-astronomy.org/node/142**.

Description, items for sale by SARA	Price (US$)
SuperSID VLF receiver (assembled)	$48.00
PCI soundcard, 96 kHz sample rate	$40.00
Antenna wire (120 m)	$23.00
Coaxial cable, RG58 (9 m)	$14.00
Shipping (United States)	$10.00
Shipping (Canada, Mexico)	$25.00
Shipping (all other)	$40.00

For sale

Description, items for sale by SARA	Price (US$)
New-in-box DATAQ DI-194RS data logger starter kit with RS-232 serial port connection, 10 available.	$20.00/each
New-in-box twist-on male TNC Connector for RG-58 cable, 23 available.	$1.00/each
New Berk-Tek twist-on male TNC Connector for RG-59 cable, 10 available.	$1.00/each
New twist-on male BNC connector 1-Piece 50 ohm for RG-6 cable, 21 available.	$1.00/each

All are plus shipping. Will consider offers. Items are surplus and all proceeds go to support the SARA/Stanford SuperSID project. Contact Bill Lord (319)591-1131 or email **ap_guardian@yahoo.com**.
