TAOSON

SIGNAL
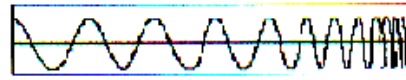

TAOSON Director-- David Fields N4HBO   ..   ..

Newsletter Editor --Bill Seymour KM4YL   - /.-/ ---/ …/ ---/ -. /…/ ../ --./ -./ .-/ .-..

                                                    …

                                                    ••••

Table of Contents

I. Welcome

Welcome to the **Tamke-Allan Observatory Solar Observation Network. TAOSON** was conceived in 2007 and operated for its first year as a student group directed by David Fields at TAO. Other members were Heather Fries, now President of the Student Astronomy Association and President of Sigma Pi Sigma at ETSU and Tyler Moore, now in Naval Intelligence. Both Heather and Tyler attended and presented papers at the SARA meeting. In 2008 we opened up the group to the larger local amateur radio astronomy community.

The primary purpose of TAOSON is to keep local radio astronomers in touch and help coordinate their activities as they maintain their radio astronomy research sites. To this end we maintain a server for storing and sharing data, schedule meetings each month, and assist each other when needed. Most members support the Society of Amateur Radio Astronomers (see www.radio-astronomy.org).

TAOSON participates in the TAO Academic Associates of colleges and universities where members share research and scientific goals. This is both science and a humanistic endeavor that encourages cultural exchange. TAOSON also helps advise the TAO Space Explorer Groups with a common goal of developing capable and motivated human beings that will serve the community and become future scientists and contributors to a better world.

Membership is free if you're actively doing radio astronomy. Otherwise, membership is still free and you are invited to help with our projects. Our major problem is lack of contributors to the Signal.

II. Meetings

TAOSON

TAOSON had a great meeting with Tom Crowley's visit (see below). Our meeting format will usually include a brief tutorial on a radio astronomy topic of interest, a work session on some chosen task or topic, a meal or refreshments, and a brainstorming session about projects.

Area Optical Astronomy Groups

Oak Ridge Isochronous Observation Network (Orion) meets at 7:00 P.M. on the first Wednesday of each month The Club Room, Oak Ridge Civic Center. See www.roanestate.edu/obs and www.orioninc.org.

ORION met on April 6 and considered cosmogenic gamma pulses (by John Mannone) and energy sources (Bob Edwards).

Save Roane Starry Skies had a meeting in Oak Ridge on April 6. Roane County kids are going to be invited to come to TAO with paint ball guns and use our (to be constructed firing range. Targets will have targets with images of Bad (glaring, sky-unfriendly) lamps, andGood (light-conserving) lamps. This will be the big event of the year for SRSS.

Barnard Astronomical Society (BAS) meets at 7:00 P.M. on the second Thursday of each month at the UT Chattanooga Clarence Jones Observatory. See BAS@chattanooga.net.

III. The TAOSON Signal

Our newsletter, the TAOSON Signal, will be published on a periodic basis as sufficient articles and other written contributions are received. Every effort will be made to protect the e-mail addresses on the distribution list and the privacy of their owners. Feel free to circulate and share copies of the Signal.

Items for the newsletter will be submitted by e-mail to Editor Bill Seymour at swafseymo@bellsouth.net and to David Fields at fieldsde@aol.com. We encourage each active member to submit at least a paragraph that summarizes site activities, goals, and ideas. Members are also invited to submit questions to the Editor to be considered in the newsletter and at meeting.

IV. Research Site Locations and Capabilities

TAOSON sites include those shown on the following map and identified in the following FACILITIES DIRECTORY.
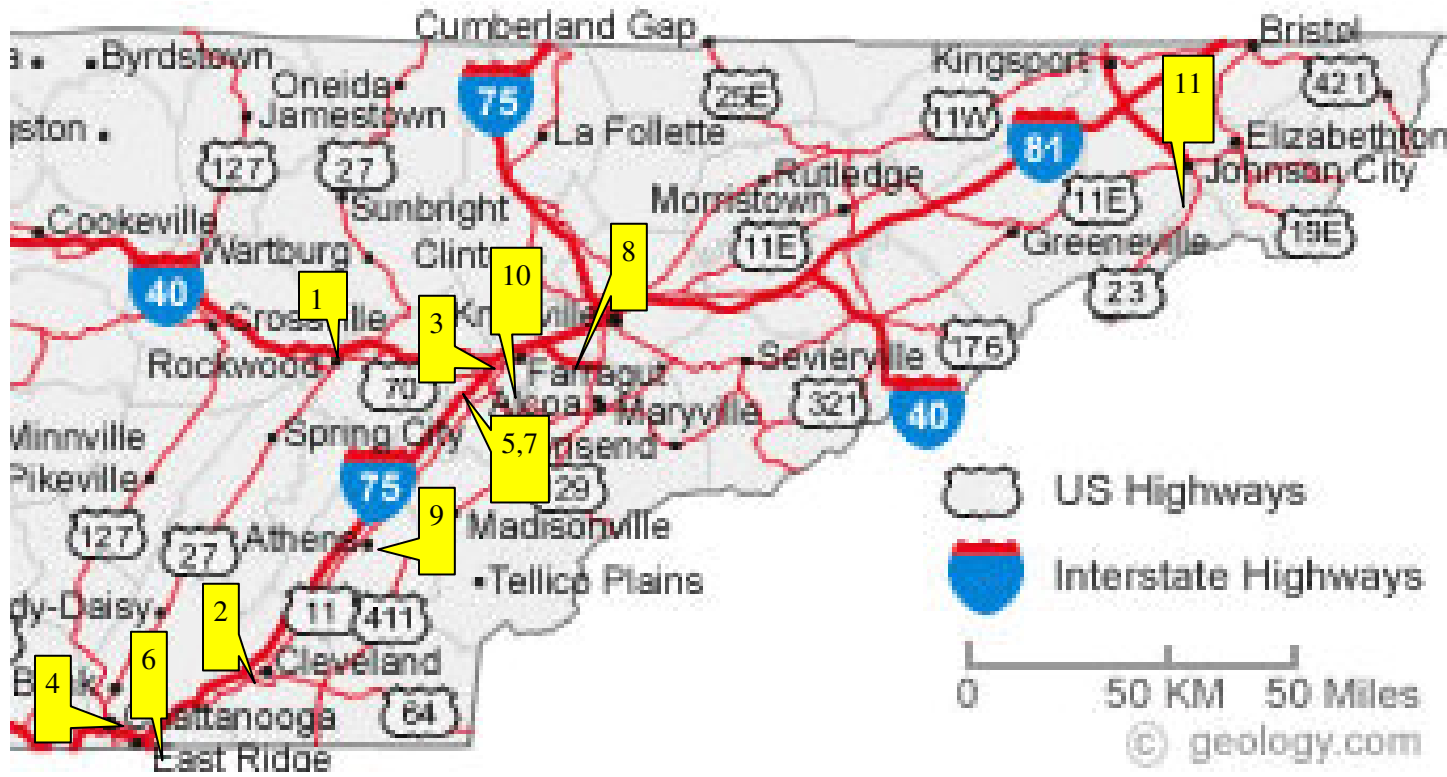
TAOSON FACILITIES DIRECTORY

| Site Location	Site Name	Code	Control Operator	Lat Long	Telephone	Operations
1 Rockwood	TAO	TAO	David Fields	35.8322 84.6175	865-376-1362	21 cm, 15m, optical, Ku, Spectracyber, Interferometer, IBT
2 Cleveland	SkyNet	SN	Bill & Melinda Lord	35.2427 84.8783	423-478-9043	21 cm, 15m, optical, Ku, Spectracyber, VLF (SID), FM Meteor, IBT
3 Solway	Solway	SOL	David Fields	35.9641 84.2021	865-927-5155	15m, Ku (2), optical, VLF, H-alpha
4 Hixson	Riverbend	RB	Dick Castle		423-870-4398	15m
5/7 Lenoir City	Lenoir City	LC	Aaron Haun		865-986-7153	Server, 15 m
6 Signal Mtn.	Mountain	MTN	Bill Seymour		423-870-8552	15m, optical, Ku, VLF (SID), IBT
8 Blue Meadow	Blue Meadow	BLM	Linda Fippin		865-539-0826	VLF
9 Niota	Niota	CL	John Mannone		423-337-2197	Ku, Optical, VLF, IBT
10 Karns	Karns	KA	Carl Lyster			Spectracyber, VLF
11 Johnson City	Johnson City	JC	Heather Fries			Quantitative optical, VLF (SID) planned
Puerto Rico	Puerto Rico	PR	Wanda Diaz			15 m, Spectracyber
UNAM, MX	Mexico	UN	Stan Kurtz			15m, Spectracyber, Homebrew IBT, SRT

V.Reports from The Sites

TAO Site Report   **David Fields**

Astronomers,

Our guest astronomer from Chiefland Astronomy Village, Tom Crowley, gave two excellent talks in April. We had a full crowd for both. The first presentation, "Advances in Amateur Radio Astronomy" covered recent advances in radio astronomy that permit amateur astronomers to contribute actively to astronomy research. Current observations showing changes in solar output were discussed. After this excellent talk, part of the afternoon (geeky) crowd went to Gondolier and we had a great meal. Here's part of the afternoon crowd. The night crowd was bigger but I haven't received anyone's photos yet. If you have any, please send me a copy.
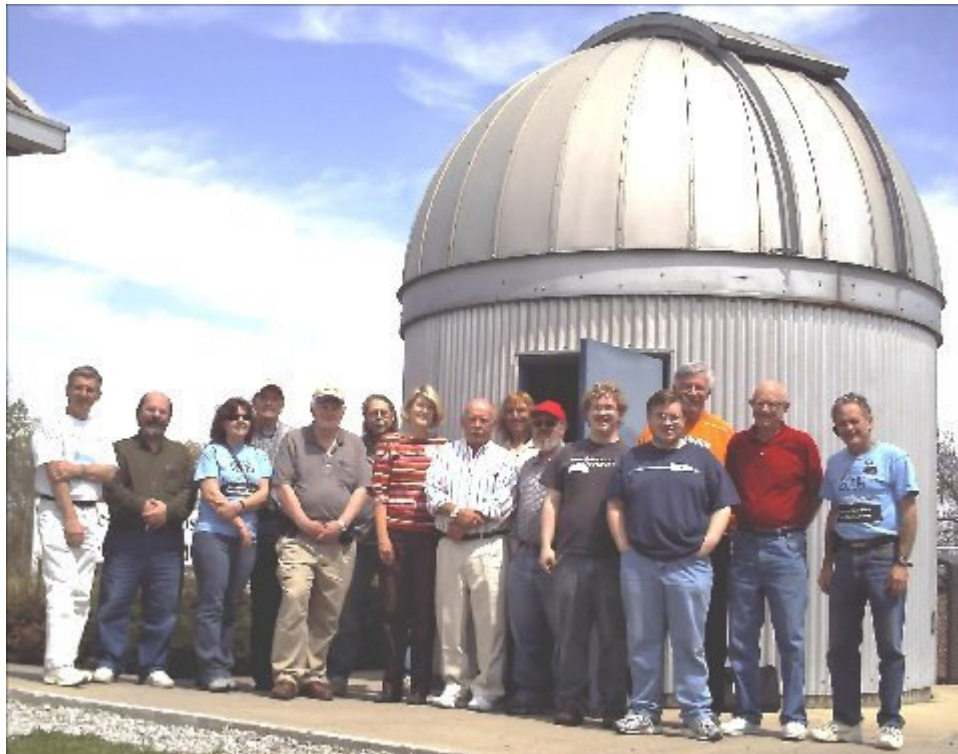
Tom's second presentation, "Searching for Super Novas," started at 7:30 PM. Tom is a member of the Puckett Observatory Super Nova Search Team and they have discovered over 170 super novas. This presentation covered different classifications of super novas; described how the amateur astronomer hunts

them, and what procedures need to be followed to report their discovery. Besides super nova hunting with his homebuilt 24" telescope, Tom does visual observing, CCD imaging and radio astronomy. Most of their photos are made using Jack Newton's scope for remote photos. The night talk was packed, but outside skies were cloudy -- not even sucker holes.

Roy Morrow has a western h ome near Jack Newton's and was over there last week. Roy, Heather, and the rest of you who asked if someone could video tape Tom's presentations -- we had 2 video cameras going (thanks to Dick Castle and Bill Seymour, both of Chattanooga) so I think that we'll be able to get a copy. Thanks to both of you!

Come to think of it, we had more Chattanooga people there than SMAS people (yes, that's even including the fact that I'm a paid-up SMAS member). That's not the first time that this has happened. Chattanooga is an active place! I was there a few weeks ago, when they had my friend Chuck Higgins speaking about observing Jupiter. Here we are admiring the historic telescope on the UTC campus.

We have some interest in the NASA LCROSS mission. Two lunar crater impacts are planned for Aug. or Sept., the first being a 2-ton Centaur rocket and the second, an instrumented probe. Analysis of the dust plume will provide composition data.

I speculate that there may be active radio emission with good signal/noise, based on the following considerations:

- we will know the impact time, so can look for a synchronous signal (pulse);

[7]

- active emission will be against a very low background, so S/N is good;

- the impact will be at night for us (I hope) so there will be no large competing solar signal;

- the impact vehicle would probably be charged from its journey, and an expected spark would send harmonics dependant on the size of the vehicle (fundamental resonance of 4xlength at max impact probe size. The probe is the 2300 kg spent Earth Departure Upper Stage (EDUS) -- about 10m for the Centaur rocket -- so the initial pulse might appear at 40 m wavelength, and higher frequencies;

- lunar dust probably has a stratified electric charge that would generate a noise pulse;

- lunar dust, like quartz, has triboelectric properties, etc. so electrical discharges would be expected; and

- lunar dust might accompanied by gaseous emission including water vapor, since the impact will be into a dark polar crater.

We must ask if eruptions of such dust can produce electrical effects. The answer is yes. Consider this, a 2006 photo of Chile's Chaitin volcano, which shows one or two lightning bolts;

Here is Alaska's Redout volcano on April 14:

So I expect that the LCROSS impact might yield a radio pulse with a lower frequency limit of about 7 MHz followed by a burst of white noise.

Our 15m (20 MHz) monitoring frequency would be an acceptable one to use for LCROSS monitoring, and using SkyPipe with accurate atomic clock synchronization, we would be able to identify any detected pulses.

We've time to do some planning, so start thinking!

UNAM, MEXICO   **Stan Kurtz**

The inclinometer that we bought is a tremendous help in pointing the telescope to the right elevation, and with its help we have finally succeeded in detecting the Moon! (see the figure) We got started a little late in the observing run that is shown, so we were still fiddling around with the sensitivity adjustment when the Moon started to go overhead. But we had everything set before it transited, and got a nice trace as it left the telescope beam. The vertical axis is in volts and the horizontal axis is in seconds. We were using

the Ku-band LNB at this point, and hence were observing at about 10 GHz, with a beam size of about 1
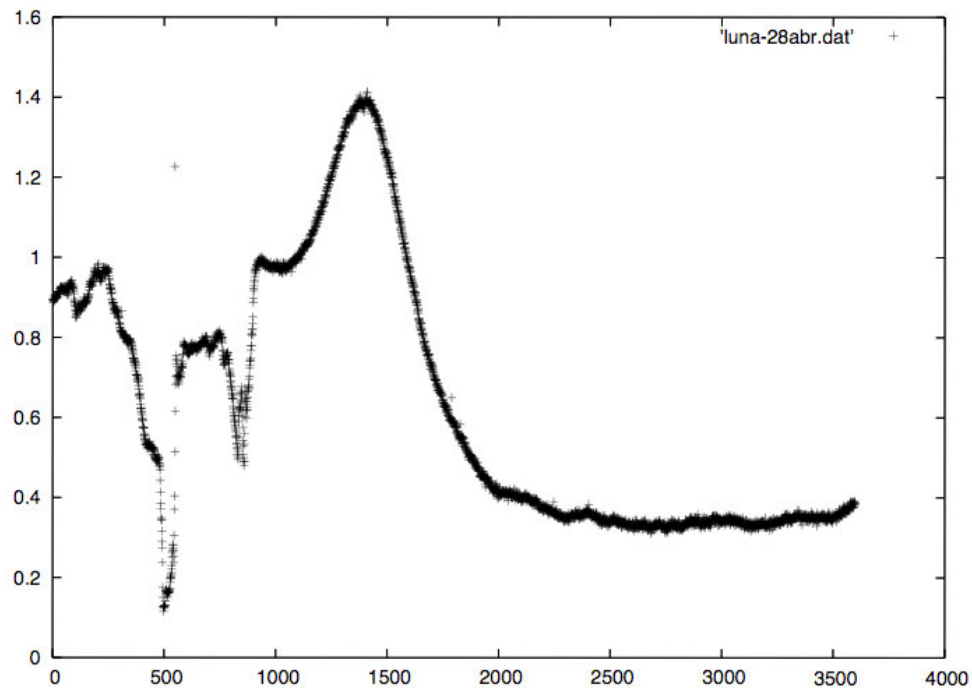
degree.

We are still using the satellite finder as our detector. The tunnel diode detector only needs to have some power connections finished, but the student who is working on that is busy with classes right now…. We are trying to locate some noise diodes to make a calibration system, and then measure the Allan variance of both the satellite finder and the tunnel diode detector.

VI.The Basics

Masers↑

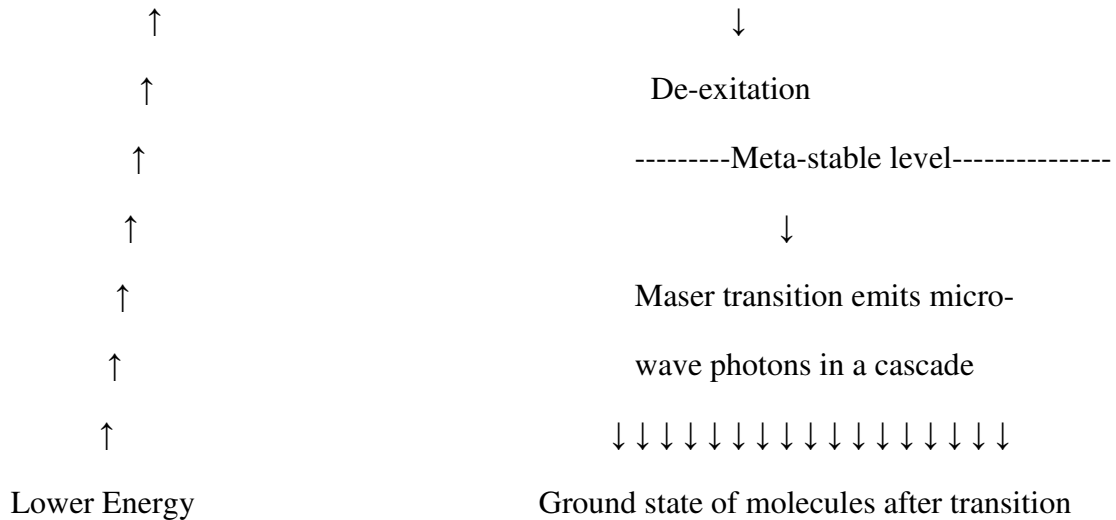The word is an acronym for **microwave amplification by stimulated emission of radiation.**

The OH and H20 molecules in a giant molecular cloud become powerful sources of microwaves as they are excited by radiation from newborn stars. The process starts when these molecules absorb photons, whose added energy makes the molecules spin faster. In the language of quantum mechanics, the OH and H_2O molecules jump from

[10]

their ground energy state to an excited rotational energy level, a process called "pumping."

Higher Energy from Pumping Radiation → Exited state of OH and H_2O Molecules

| ↑ | ↓ |

↑   De-exitation

↑   ---------Meta-stable level--------------

↑   ↓

↑   Maser transition emits micro-

↑   wave photons in a cascade

↑   ↓↓↓↓↓↓↓↓↓↓↓↓↓↓↓↓

Lower Energy   Ground state of molecules after transition

The excited molecules naturally drop back to a lower energy level by emitting photons. According to rules of quantum mechanics, some of these molecules will drop down into an energy level that is characterized as being "meta-stable," meaning that the molecule will remain in that level for an exceptionally long time.

As a result of the pumping process, regions develop in a giant molecular cloud where vast numbers of OH and H_2O molecules are stuck in metastable states. Now imagine one of these regions being traversed by a microwave photon whose energy equals the difference between the meta-stable excited level and the ground level. The electromagnetic field of this photon triggers many molecules along its path to lose energy by emitting identical microwave photons traveling parallel to the original one. These new photons stimulate still more molecules to lose energy, resulting in a cascade that releases a vast amount of energy at microwave frequencies. A single maser lasts for only a few weeks or months. Near a site of active star formation, new masers are continually being turned on while old ones, having depleted their supplies of excited molecules, simply fade away.

Reference: Universe, Fourth Edition; William J. Kaufmann III

VII. Notable Quote

"There are only two ways to live your life. One is though nothing is a miracle. The other is though everything is a miracle."

Albert Einstein (1879-1955); German-born American
Physicist and 1921 recipient of The Nobel Prize in Physics

VIII.   A Professional-Amateur Dialogue (Continued)

Rodney Howe writes:

"I read through the correspondence between Stan and David in the March TAOSON Signal. I have to agree with Stan on not having amateurs trying to compete with professional astronomers. I looked up Troland, and C. Heiles references, and can see just how much has already been done; http://www.pa.uky.edu/~aips/PAGELINKS/trol_publ.hmtl.

I also think it is a good idea to follow Stan's lead on looking at Mira masers, especially at the OH frequencies, around 1.612 GHz to 1.665 GHz. So, I thought I would put together a proposal for doing just that, as described below.

MIRA LASER PROPOSAL

The objective of this research will be to detect OH masers around old Mira stars, which in the Northern Hemisphere can be found around UHer, S CrB, W Hya, and R Cas. For radio measurements with amateur dishes, we'll have to use dark skies as a control measure of cold sky between 2 and 3 degrees off from these Miras. This will be a program for collecting data over a couple of years or more. Miras are old variable red giants with an average period of 331 days. However, their magnitudes may vary from a visual minimum magnitude to greater than 4 or 5 magnitude increase (very bright). The hope is that we can detect their OH masers at 1.612 GHz and 1.665 GHz.with circular polarization during the entire cycle of variability. If detection is possible with a sensitive receiver, perhaps the Spectracyber combined with the 18 meter dish, then data can be collected on the weekends or whenever the stars are above the horizon. Variable stars are normally done in the optical; however, these OH masers have been rated at greater than 1 Jansky in flux (see article: Astrometry of The OH Masers of Four Mira Stars). Previous calibrations with DSES SpectraCyber, 1.420 GHz receiverhave shown that this is about the limit of sensitivity for our 18 meter dish. But with suitable tracking capability, and dwell time, we may be able to detect these OH masers signatures. What we don't know is whether the sensitivities between the OH frequencies and the HI frequencies are comparable. Should our data be significant, the hope will be to submit our results to the AAVSO Mira Program:

. This would certainly be a first, since there are no radio observations of Mira stars in the AAVSO database of variable stars.

Below might be an observation schedule for the 'weekend warriors' at DSES:

ELEVATION OF MIRA STARS IN DEGREES AT 1:00 P.M. IN THE MIDDLE SUNDAY OF EVERY MONTH, 2009. (Values in Parentheses are Below The Horizon)

2009 Month	R Cas	RCrB	U Her	W Hya
January	46	40	42	(-7)
February	63	20	21	(-37)
March	77	(1)	(1)	(-58)
April	69	(-15)	(-19)	(-77)
May	52	(-21)	(-29)	(-65)
June	31	(-15)	(-27)	(-39)
July	17	(-2)	(-14)	(-19)
August	(6)	19	(2)	(3)
September	(2)	40	28	15
October	(5)	61	48	21
November	16	77	67	14
December	30	62	62	1

Perhaps we can get some ideas on how this might best be done. The difference between these studies and the ones at HRAO (http:www. Hartrao.ac.za/spectra/SP_Ohir.html) will be as follows: we would like to do this with a Vertical and Horizontal polarized feed. The science in this case would be to see if there are any detectable differences in the polarization among any of these Mira stars. And, if so, what does that mean? Any ideas on how to best approach this would be helpful. I think we will need to develop computer programs for the Stokes parameters to reduce this data. Can this be done effectively without interferometry. i.e. on a single dish? "

In response, Stan Kurtz and David Fields write their comments with some additional ideas from Rodney inserted.

Stan: In summary the proposal suggests the following: The objective of this research will be to detect OH Masers around old Mira stars. This will be a program for collecting data over a couple of years or more. Mira stars are old variable red giants with an average period of 331 days. However, their magnitudes may vary from a visual minimum magnitude to greater than 4 or 5 magnitude increase (very bright). The hope is that we can detect their OH masers at 1.612 GHz and 1.665 GHz with circular polarization during the entire cycle of variability. Should our data be statistically significant, the hope will be to submit our results to the AAVSO Mira program: http://www.aavso.org/vstar/vsots/archive.shtml.

Both David and Stan like this idea.

David: I like the suggestion of complementing the radio observations with optical data--I'm thinking that the Mira stars could be a nice challenge for Roy Morrow's new optical scope and that they would complement a radio effort. Heather is doing photometry on a Mira star; if we could extend this coverage to several other targets, then we could document photometric (optical vs radio) changes of Mira stars during a cycle or two.

Rodney adds to this: Heather, perhaps if you have a good telescope on a stable mount, you might think about using the SSP-4 IR photometer for these Mira maser stars. Comparing the IR response and the radio signatures might be more useful than just comparing the optical to the radio signatures.

There was also some discussion of which stars to observe.

Rodney: In the Northern Hemisphere these masers can be found around:

U Her, S CrB, W Hya, and R Cas.

Stan: Some sources that are a bit stronger (and might be good ones to start with) are R Crt, W Hya, and IRC+10420. Particularly the 1665/1667 lines in W Hya can be over 10 Jy. (Although when Chapman et.al. (1994) observed it in 1984, it also was down around 2 Jy. And IRC+10420 has been over 100 Jy in the 1612 line.

David: Up to 100 Jy emission intensity would be great, but the OH/IR stars might be challenging to see optically, which puts them more out of reach of the optical folks. Granted, they should show infra red emission.

Stan: Agreed. For the 'final' study it would be better to use more accessible sources, for which we can have a more complete data set. But the strong ones can at least serve as a test bed to get the radio observing techniques down, and as an on-going consistency check of the observations. It is probably the mid-IR that is pumping the OH masers, so it would be most interesting to extend the data coverage in that direction. But having the optical data would be good anyway, to have a stellar tracer.

Editor's Note: Others are invited to become involved in this project. Contact David Fields, who will be coordinating the various aspects of the study, if you are interested.

VIII. Article by Guest Contributor

Procedures for Making

Radio Spectrum Observations of the Sun

Employing the AR5000 Receiver & SDR-14 Spectrum Analyzer

by

Michael Rudolph

Abstract

This article describes a solar radio telescope and operating procedures that employ an AR5000+3 broadband radio receiver that is connected to an SDR-14 software-defined spectrum analyzer. It also describes procedures for displaying, recording, reviewing, and calibrating numerical data acquired there from.

Introduction

For an amateur radio astronomer with limited financial means, deciding which receiver and spectrum analyzer to incorporate in the radio telescope can be a challenging task. A professional radio astronomer, operating under a research grant or contract, does not usually have this problem because the intended study is defined, and the equipment needed to achieve it is also defined. What is more, the equipment is paid for by the grantor, so the way it may be used at the conclusion of the study is not an issue.

Not so with the amateur radio astronomer who typically purchases his equipment early in his scientific pursuit, at a time when he is not totally sure what his future studies and equipment needs will be. That, plus the fact that the burden of purchasing the equipment is his own, the amateur radio astronomer must think ahead, and purchase equipment that is not only affordable, but that has the greatest foreseeable application for future use.

I recently faced this decision. I knew I wanted to do spectral studies of the active sun, but I had not yet settled in on a specific study or on the range of frequencies I would be observing. Not only that! What if, in the future, I shifted my observing interest to something else – say to the emissions of Jupiter? I was reluctant to purchase equipment that was so specialized that it could not be used in a wide arena of possibilities.

It came to my attention that Richard Flagg recently purchased two items of equipment that, when working together, might have the breadth of possible uses I was looking for. What is more, Jim Sky had written software that could be used with those pieces of equipment to observe and record spectra of the sun,

[15]

Jupiter, and even deep space emitters. The equipment consisted of an AR5000+3 (AOR broad-band receiver), with its IF output fed into an SDR-14 (RF-Space's software-defined spectrum analyzer). After communicating with representatives of the two companies, and barraging Jim.Sky and Richard Flagg with questions, I concluded that the combination of those two pieces of equipment would most likely do the job and, if they didn't, at least I would be in good company.

So I took the plunge and purchased an SDR-14 and an AR5000+3, and very soon realized that I had been given very good advice, and had hit the jackpot of unbelievable versatility for a modest (by scientific equipment standards) cost. However, learning to use the equipment was another thing. As I poured over the various manuals that accompanied the two pieces of equipment, I perceived that it would take me a long time to learn all of their various features and ways they could be used, and that I needed to decide upon and become comfortable with one standard setup and one set of procedures that would get me started. I therefore decided to define an initial project, determine a setup and procedures for that one project, and leave the future to the future. When I accomplished that to my satisfaction, I decided to write this article describing the specifics of my setup, in the hope that I may spare others who acquire the same equipment, the time and anguish I experienced while trying to understand.

Equipment Overview

This article describes my setup for receiving and recording 10 MHz-wide solar spectra centered on a quiet frequency band chosen between 120 and 150 MHz. I chose to observe in the VHF region rather than in HF because of the convenience of using a smaller antenna, and also because most of the solar data thus far acquired has been at HF frequencies. I chose a 10 MHz bandwidth of study because the AR5000+3's IF bandwidth is nominally 10 MHz. The rate of spectrum captures per second is limited by which spectrographic software one uses to display and save the SDR-14's data output. Two software packages I compared were (1) "SpectraVue," developed by Moe Wheatley specifically for the SDR-14, and (2) "Rado-Sky Spectrograph," developed by Jim Sky for a different purpose, but later adapted for use with the SDR-14. My equipment also incorporates a log periodic antenna of suitable frequency, a "Yaesu" alt/az rotator driven by "Nova for Windows" solar-tracking software, an "Angle Linear" 21 dB low noise preamplifier, and a VHF signal calibrator designed and made by Richard Flagg.

Each of the spectrographic software applications mentioned has its strengths and its limitations, and each has different features. SpectraVue utilizes more of the features of the SDR-14, it can capture a greater number of FFT frequency channels in a given spectrum, its various displays are more varied and more refined, and it can be calibrated to display and save data in dBm units. It is, however, limited in ways that make it overall less suitable for spectral studies in radio astronomy -- ways such as its data-recording rate being no faster than 1 capture per second, and it's saved numerical data not being time-stamped. In comparison, Radio-Sky Spectrograph's capture rate is approximately 10 captures per second, and its saved numerical data is automatically time-stamped using the computer's clock. It has many other favorable features as well, especially its high-speed movie review feature. Its chief limitations are that it can only capture 200 FFT frequency channels of any given spectrum (this is far short of the number of FFT channels SpectraVue can capture), its displays are less refined, and its numerical data are not expressed in dB units and are not calibrated. In the balance of things, however, these deficits are a small price to pay, when you consider that Radio-Sky Spectrograph does so many other astronomy-related

things better than SpectraVue. My first choice of spectrographic software is therefore Radio-Sky Spectrograph, but I find SpectraVue very useful for supplemental tasks.

As I have said, the AR5000+3's 10 MHz IF bandwidth limits the observer to spectra that do not exceed 10 MHz in width. There is a way around it though; since the SDR-14 can display a 30 MHz bandwidth and the AR5000+3 has sophisticated channel-scanning capabilities, it is possible (albeit clumsy) to scan and record three adjacent 10 MHz wide spectra, and then piece them together to produce a spectrum 30 MHz wide. I did it successfully, but the labor of doing it is, in my opinion, prohibitive.

Hardware Connections

The log periodic antenna I use contains 10 elements, and is cut to present a relatively flat 50 ohms at received frequencies from 105 MHz to well over 1 GHz. The antenna is mounted on a Yaesu alt/az rotator that tracks the sun, and is connected, via 50-ohm low-loss coaxial cable, to a 120-150 MHz, 21 dB gain, low noise preamplifier that is situated adjacent to the other receiving electronics, in a relatively temperature-stable control room. The preamplifier is connected, via a short length of 50-ohm coaxial cable, to Antenna Input #1 of the AR5000+3, and the IF output of the AR5000+3 is, in turn, connected, via a short length of 50-ohm coaxial cable, to the SDR-14's Input Channel #1. Finally, the SDR-14 is connected, via a USB cable, to the observatory's Pentium 4 computer running Windows XP. Radio-Sky Spectrograph, Radio-Sky Pipe, and Microsoft Excel software reside on the computer.[1]

AR5000+3 Settings

The AR5000+3's receiving parameters are set as follows:

RF Gain: Squelch off, and RF Gain control fully rotated to the left (maximum gain)

AGC: Off

Step: 500 KHz

Ant: Set to "1"   (Assuming antenna connected to Antenna Input #1)

Att: 0 dB   (Unless attenuation is needed beyond that provided by the SDR-14)

Lamp: Off   (Use "Config" button) (Turned off to conserve light bulb)

Ext IF: 1   (Use "Config" button)

BPS: 9600   (Use "Config" button)

---

[1] Hint: Load Radio-SkyPipe on the computer before loading Radio-Sky Spectrograph 1.7.2; SkyPipe contains a needed file.
.

Setting other parameters is not needed.

SDR-14 / Radio-Sky Spectrograph Settings

Radio-Sky Spectrograph software (version 1.7.2) that is loaded on the computer controls the SDR-14; the software parameters are set as follows:

Menu Parameters

View: Show SDR-14 Controls

Color: Multiply

                Load Color File (blueyellowred.txt)

Mode: Stand Alone

Options: Identity: Fill in local data

                Radio: Select "SDR-14"

                Network: No selection

                File Saving: Save on Demand

                Data Directory: Browse and select directory for saved data files

                                 Select "Log Saved Files"

File Review: Above Normal

Auto Start Server: <No selection>

Stalls: 0

Parameters to Right of Chart 1

Hi F: 15.7 MHz (Center frequency of AR5000+3's IF output is 10.7 MHz.)

Lo F: 5.7 MHz (Center frequency of AR5000+3's IF output is 10.7 MHz.)

Radio: No entry

SDR-14 FFT Parameters

Size: [2]   32768

Avgs: [3]   25

---

[2] The smaller the FFT Size, the higher is the background level for a given signal, and the smaller is the signal-to-noise ratio.

<u>HF Gain</u>: -1 (But set to highest level that does not cause SDR-14's overload light to blink.)[4]

<u>Pre Amp</u>: Selected

<u>Max dB</u>: -10   (Experiment to achieve maximum dynamic range.)

<u>Min dB</u>: -130 (Experiment to achieve maximum dynamic range.)

Color Parameters

<u>Color Offset</u>:   Set according to preference (Try beginning at 472, and see following sections.)

<u>Color Gain</u>:   Set according to preference (Try beginning at 0.5, and see following sections)

Considerations for Setting Radio-Sky Spectrograph's Color Parameters

The color settings of Radio-Sky Spectrograph do not affect its saved raw data at all. However, the color appearance of the waterfall display is very important for noticing transient solar activity. No radio astronomer stares at his computer screen six to eight hours a day looking for color changes in real-time, so the technique of review that I use is to record a movie of the waterfall display and then, that evening, play the movie back at high speed so the day's observation can be reviewed in 15 to 20 minutes. This requires that the color resulting from normal background noise (as displayed by the waterfall) be such that the reviewer can easily notice when a signal of interest occurs, stop the movie, and investigate.

Various color schemes are possible with the Radio-Sky Spectrograph, but the default scheme "blueyellowred.txt" of version 1.7.2 is very adequate. That color scheme progresses from deep blue for the smallest signal strength, then lighter blue, then yellow, then light red, and finally dark red for the greatest signal strength. Because the AR5000+3 is not linear or frequency-independent in its signal strength reproduction from antenna to IF output, a flat galactic background that is received at the antenna will not produce a flat signal at the IF output across its 10 MHz bandwidth. Consequently, the waterfall display of the radio's IF will almost always show a gradation of color from its center to both edges, where the center is generally higher in signal strength. This is not a matter for concern because the calibration procedure described later in this article compensates for any lack of linearity.

As a day's observation is being replayed at high speed, I look for color changes from the background that would represent even brief bursts of solar activity. My task is therefore to adjust the waterfall's color so as to be able to see such activity at the lowest levels. With the "blueyellowred.txt" color scheme selected, I adjust the Color Offset and Color Gain until the center area of the waterfall display is substantially yellow with the briefest touches of red, and both its edge areas (top and bottom) contain some blue. The Gain parameter controls color intensity, and the Offset parameter controls color shift toward either blue or red; the settings are a matter of personal choice. The "Max dB" and "Min dB" parameters not only affect display color, but also the dynamic range of the saved numerical data; they are discussed in more detail below.

---

[3] The smallest Avgs setting is 1. The lower the Avgs, the greater and spikier the background noise (especially at low signal levels), but the better the spectrograph is able to capture and display a rapid change in signal strength. Setting Avgs to 5 and higher smooths out the background noise, and improves the signal-to-noise ratio. I find 25 the best.
[4] Additional RF gain and attenuation can be obtained via the AR5000+3's controls.

There is another color system that one may use that produces a single-color (no detail) waterfall when there is no signal of interest.[5] This is implemented by right-clicking Chart #2 (the lower display) during a time of no solar activity; immediately upon doing so, the color displayed by each FFT frequency channel offsets itself to the color of the channel exhibiting the lowest signal level; this immediately causes all channels to be displayed in the same color. The theory here is that an increase in signal in any channel will be seen in a contrasting, easily distinguishable color, so it is meant as an alternative to other color schemes. To reset all color offsets to zero, click the menu item of that name in the "Color" drop-down menu.

Starting and Stopping Data Capture and Waterfall Display

1. Power up the AR5000+3, the SDR-14, and the computer.

2. Open Radio-Sky Spectrograph 1.72 (or higher) on the computer.

3. In the View menu, click "Show SDR-14 Controls."

4. Set all parameters as previously indicated.

5. Click the "Start" button (Waterfall starts, but data is not recorded).

6. Click the "Start Saving" button (The waterfall has already begun; recording of data begins now).

7. When the observation is finished, click the "Stop Saving" button (Recording stops and data

  is saved as a file with an "SPS" extension).

8. Click the "Stop" button (The waterfall display stops moving).

High Speed Review of Data

As I have previously said, "No radio astronomer stares at his computer screen six to eight hours a day looking for color changes in real-time. The technique of review is to record a movie of the day's waterfall display and then, at the end of the day, play the movie back at high speed so that the day's observation can be reviewed in 15 to 20 minutes." When something is noticed in the fast-running movie that is of interest, the display is stopped, and the first and last time stamps on the display are noted for future reference. The movie is then resumed, stopped, and started, as many times as are needed until the movie ends.

If the movie is stopped because something is seen that is of interest, the next step is to load the data file (not re-run the movie), and look for the segment that contains the item of interest. The time stamps that were previously noted are used to find the segment and, when it is found, the data of just that segment is saved in a separate file. The importance of producing this separate and smaller file will become apparent when it comes time to analyze the data.

The procedural details to accomplish what has just been described are as follows:

---

[5] Do not perform the procedure while a signal of interest is visible; doing so will cause the signal to vanish from view.

Playing Movie to Find Data

9. With Radio-Sky Spectrograph 1.7.2 (or higher) loaded on the computer, click "Load Data as Movie" in the "File" menu.

10. Browse for the "SPS" file that contains the day's recorded data and double-click it; the movie begins to play at high speed.

11. Pressing <P> on the computer keyboard causes the movie to pause, and pressing <S> restarts it.

12. When something is seen in the movie that warrants further exploration, press <Esc>; this permanently stops the movie.

13. Take note of the time stamp on the extreme left of the display, and the one on the extreme right; these will be used to locate the same segment of data in the next steps.

Loading, Isolating, and Saving Data

14. In the "View" menu, deselect "Show SDR-14 Controls," and select "Chart Navigation." The "Chart Navigation" controls replace the "SDR-14" controls.

15. Click "Load Data" in the "File" menu; browse and select the "SPS" file of interest. The loaded file will appear in the waterfall display. This is the same file, but not in "Movie" mode.

16. Now click the left-hand button that contains the "pencil" icon. This launches a box in which you can manually enter "Start" and "End" times that were the end-points (time stamps) of the waterfall segment of interest you noted in the movie.

17. Enter the "Start" and "End" times you desire and click "Save" (This records the segment end-points; it does not save the file). Notice that the segment that was observed and noted earlier in the movie is now fully displayed, but the rest of the file is still there and can be observed by navigating left and right.

18. Navigate the timeline (left and right) of the displayed waterfall segment to more precisely determine the beginning and end of the data segment you want to study and save. This is done using the navigation buttons that are among other Chart Navigation controls.

19. Take note of the chosen segment end-points and their time stamps, add a few seconds to each end of the segment, and repeat instructions 16 and 17 above, except with this revised segment – not the one previously noted in the movie.

20. Save the displayed segment of data to a new "SPS" file by clicking the button to the far right in the Chart Navigation controls. You will be prompted to select a destination folder, and a name for the file that will be saved, and that will contain the data segment of interest. It will, of course, be smaller than the original "SPS" file from which it was taken; that is the point.

Exporting Spectrograph Data to an Excel Worksheet

The spectrographic data of interest has been saved as a new "SPS" file, but two additional steps are needed before the numerical data can be accessed for analysis. Those two steps are (1) export the "SPS" file to a "CSV" file, and (2) load the "CSV" file into a Microsoft Excel Worksheet.[6] To accomplish these, do the following:

21. In the "File" menu, click "Export to CSV File / Export All."

22. Browse for a suitable folder, type in a suitable file name, and click "Save."

23. Double-click the "CSV" File that was produced; it is displayed in the form of an Excel Worksheet, but the file still has a "CSV" extension.

24. To convert the displayed "CSV" file as an Excel 2007 Workbook file with an XLSX extension, click "Save As / Excel Workbook" in Excel's Office Button dropdown menu.

25. Browse for a suitable folder, type in a suitable file name, and click "Save." The data is now saved as an Excel 2007 Workbook.

Need and Procedure for Calibrating the Data

As I previously indicated, the numerical data contained in the "CSV" file that Radio-Sky Spectrograph produces is not calibrated. Not only that; the equipment used to receive, amplify, filter, digitize, and finally record the numerical data all contribute to nonlinearity of the final data as compared with the original signal; hence the need to calibrate the data against an external standard.

There are several approaches to this, but I chose to interpret the power data produced by Radio-Sky Spectrograph as equivalent radiation temperature using a VHF Calibrator that was made for me by Richard Flagg.[7]

The steps I take to calibrate my data are as follows:

26. Once the data segment of interest has been isolated, saved, and displayed in an array as previously described, I note the maximum and minimum numerical data (the data that ranges from the galactic background to the most intense signal of interest) in each FFT frequency channel I will be analyzing. Two hundred channels of data are automatically recorded, so if I want to use them all in any analysis, I must either calibrate them all or be willing to extrapolate over multiple contiguous channels. Extrapolation works reasonably well near the center of the 10 MHz wide recorded spectrum, but it does not work well toward the edges of the spectrum because there is less linearity near the edges.

27. Without altering the equipment, the equipment settings, or the software parameters with which I originally observed, I disconnect the antenna from the preamp and replace it with the Flagg VHF Signal

---

[6] Excel 2007 or later is recommended in order to have the advantage of its large number of rows and columns.
[7] Signal Calibrators for a variety of frequencies can be made to specification by Richard Flagg, through his company RF Associates.

Calibrator.[8] The Calibrator employs a known noise source and a pair of precision attenuators that can be dialed up or down in 1 dB steps to produce broadband noise of known temperature in the VHF band I am using.

28. With the noise generator of the calibrator turned on, I make short recordings in Radio-Sky Spectrograph adjusting the calibrator's attenuators so as to reproduce the range of numerical data that are of interest that appear in each of the FFT frequency channels to be analyzed.

29. From the above procedure, I generate a calibration table where each column is an FFT frequency channel that I intend to analyze, each row is a number that is in the range of expected data generated by a typical observation recorded with Radio-Sky Spectrograph, and each intersecting point is a corresponding temperature (in Kelvins) derived from the Flagg VHS Signal Calibrator.

30. Using the above table as a reference, I replace all of the Spectrograph-generated data numbers that are of interest in a particular observation with their corresponding Calibrator-generated temperatures.

The result is an array that contains calibrated temperature data of the spectrum segment of interest. The data can now be analyzed for spectral details or computed into a continuum.

Summary and Looking Ahead

I submitted this article for publication in the TAOSON Signal because I believe its details of equipment choice and operation will be appreciated by the Signal's hardware-oriented readership – especially those who own all or part of the equipment I have described, or who are currently in the process of choosing which equipment to purchase. To those who are deliberating on the purchase of equipment, I heartily recommend the AR5000+3 / SDR-14 combination for receiving, digitizing, and computer interfacing, Radio-Sky Spectrograph for spectrum capture, display and recording, and a Flagg Calibrator (or its equivalent) for signal calibration.

Although my target of interest is the sun and the spectra I am observing is in the VHF range, the equipment I am using and have described is fully adaptable to other targets and other frequencies. In my saying this, do keep in mind that, for applications below 30 MHz, the SDR-14 may be sufficient without the AR5000+3 as its front end.

I am now looking forward to the sun becoming more active so that my next article can be a report of interesting spectral data.

About the Author

Michael Rudolph is retired from the practice of law, and is currently in full time ministry in Northern Virginia. He holds doctorates in both law and ministry, and a bachelor's degree in applied mathematics. He observes the sun in both the radio spectrum and in Hydrogen-alpha light from his home observatory "Genesis Solar Observatory," located in Silver Spring, Maryland. He holds a General class Amateur Radio License, call-sign N3IRT.

---

[8] The Flagg VHF Signal Calibrator was itself calibrated prior shipping, and a chart of "dB" vs. "Temperature (Kelvin)" was provided for signals of 120 MHz, 130 MHz, 140 MHz, and 150 MHz.