

Amateur Radio Astronomy Projects

The author participated in a variety of activities during the International Year of Astronomy in 2009.

As my IYA 2009 (International Year of Astronomy) activities come to a close, I would like to share some of my favorite radio astronomy projects with you in the hope that you will enjoy them as much as I have.

I am a science teacher in Connecticut. I have long thought that too much stress is placed on visual science, and I've always tried to expose students to non-visual experiences. With this in mind, I started exploring radio astronomy in the early '80s and joined the Society of Amateur Radio Astronomers (SARA). I got lots of help building projects and have been at it ever since (check out SARA at radio-astronomy.org).

The first project I will discuss, a solar radio in the VLF range, is one I started many years ago. It is very simple and yet yields data that can be reported to a national organization and is used to do "real science!" It studies the reaction of Earth's ionosphere to solar activity by measuring the intensity of a received signal. These radios are known as SID (Sudden Ionospheric Disturbance) monitors, since they are measuring the changes in intensity of a radio signal due to ionospheric disturbance caused by solar flare activity.

Ionosphere

This region of the atmosphere is ionized by solar and cosmic radiation. It ranges from 70 to 1000 km (about 40 to 600 miles) above Earth's surface, and is generally considered to be made up of three regions D, E, and F. Some also include a C region and most experts split the F region into two (F1 and F2) during the daylight hours. Ionization is strongest in the upper F region and weakest in the lower D region, which basically exists only during daylight hours. This is because the number of free electrons increases as

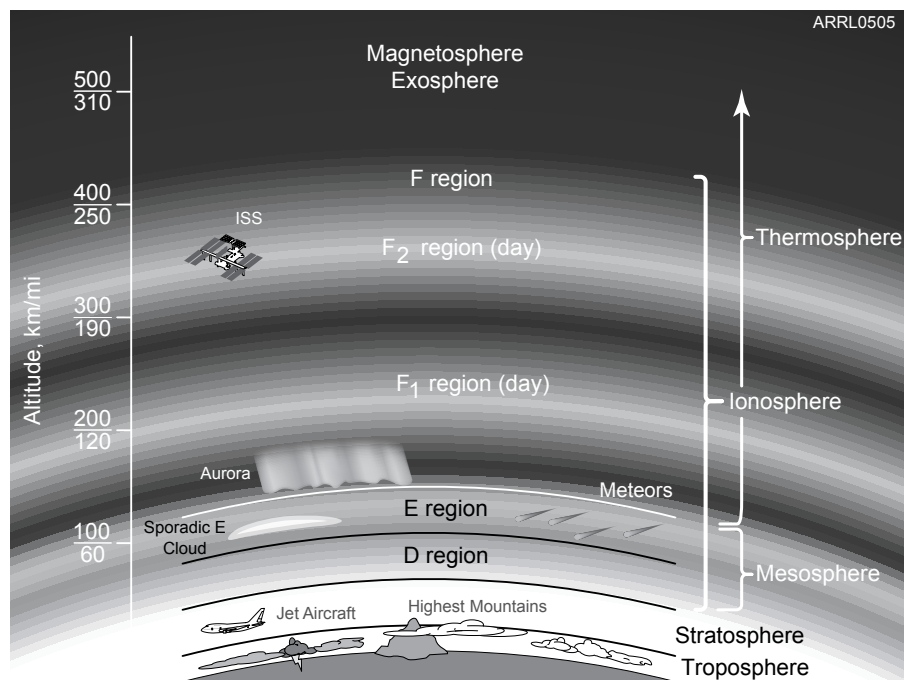


Figure 1 —Earth's atmosphere, including regions of the ionosphere.

you rise through the atmosphere, reaching radio significance at about 70 km. You also have lower pressure at higher elevation. These conditions lead to the production of more monatomic gases and ionization that lasts longer because of the distance between atoms/molecules. Most of the ionization we are discussing is due to ultraviolet light, but at lower altitudes X-rays are needed to produce the ionization seen. Figure 1 is an illustration of the Earth's atmosphere, including the ionosphere.

Solar Flares

Flares are enormous explosions that

occur near sunspots on the surface of the sun, lasting roughly an hour and heating the region to millions of kelvins. See Figure 2. Most astronomers believe these events are caused by the sun's magnetic field. Since the sun is a fluid, magnetic field lines can get twisted. Near sunspots, the field lines get so twisted and sheared that they cross and recombine releasing an explosive burst of energy that can travel tens of thousands of miles off the surface of the sun. Obviously, as this energy makes its way to Earth, ionization in the atmosphere is greatly enhanced.

Flares are thus closely tied to the 11 year sunspot cycle. The sunspot cycle relates to

a solar magnetic cycle, which runs for 22 years. During the first 11 years, sunspot frequency increases to a maximum and then decreases. At this point the magnetic poles flip polarity and the cycle begins again for the next 11 years. We are currently coming out of the Cycle 23 minimum and some sunspots from Cycle 24 have been detected. Figure 3 shows how the positions of sunspots on the Sun's surface create a butterfly pattern, with 12 sunspot cycles represented.

Flares that can be detected with VLF radios are generally caused by X-ray flares and have various flux levels associated with them. Figure 4 explains the classification of these flares.

The flares we can detect with VLF radios are C, M and X. C flares and below are fairly weak disturbances, with little effect on communications. M flares are medium sized flares that can cause short periods of radio blackout and minor radiation storms. X flares are large events that cause major planetary blackouts and radiation storms. When I'm not sure whether or not I've detected a flare, I always check "The Solar Events Report" at the NOAA Space Weather Prediction Center (www.swpc.noaa.gov/ftp-menu/indices/events.html). Here they list events by day and time, which allows you to check your results.

VLF and the Ionosphere

During the daylight hours, VLF signals generally pass through the D region and are refracted by (or reflect off) the E region, thus leading to a weakened signal. During a flare event, the D region is strengthened and acts as a wave guide for VLF signals, since the wavelength of the signal we are monitoring is a significant part of

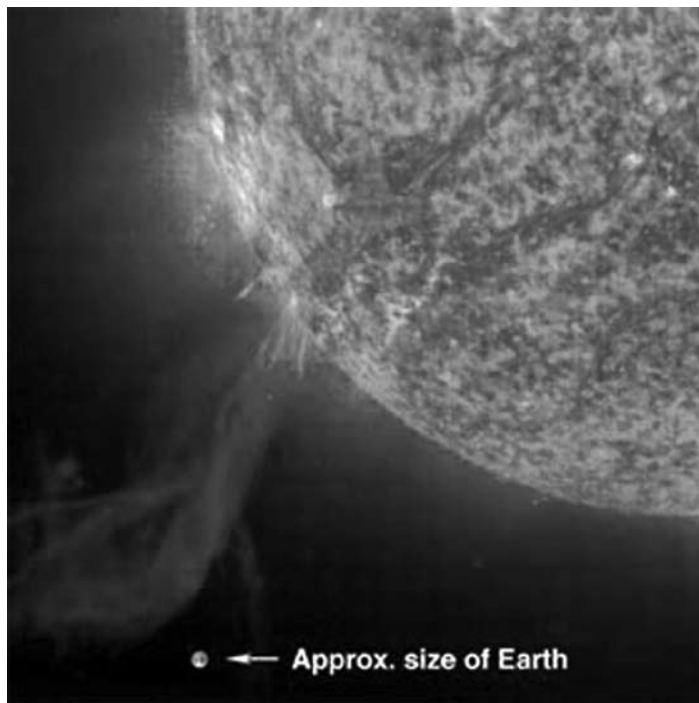


Figure 2 — A large solar flare, as shown at www.suntrek.org/images/big-solar-flare.jpg.

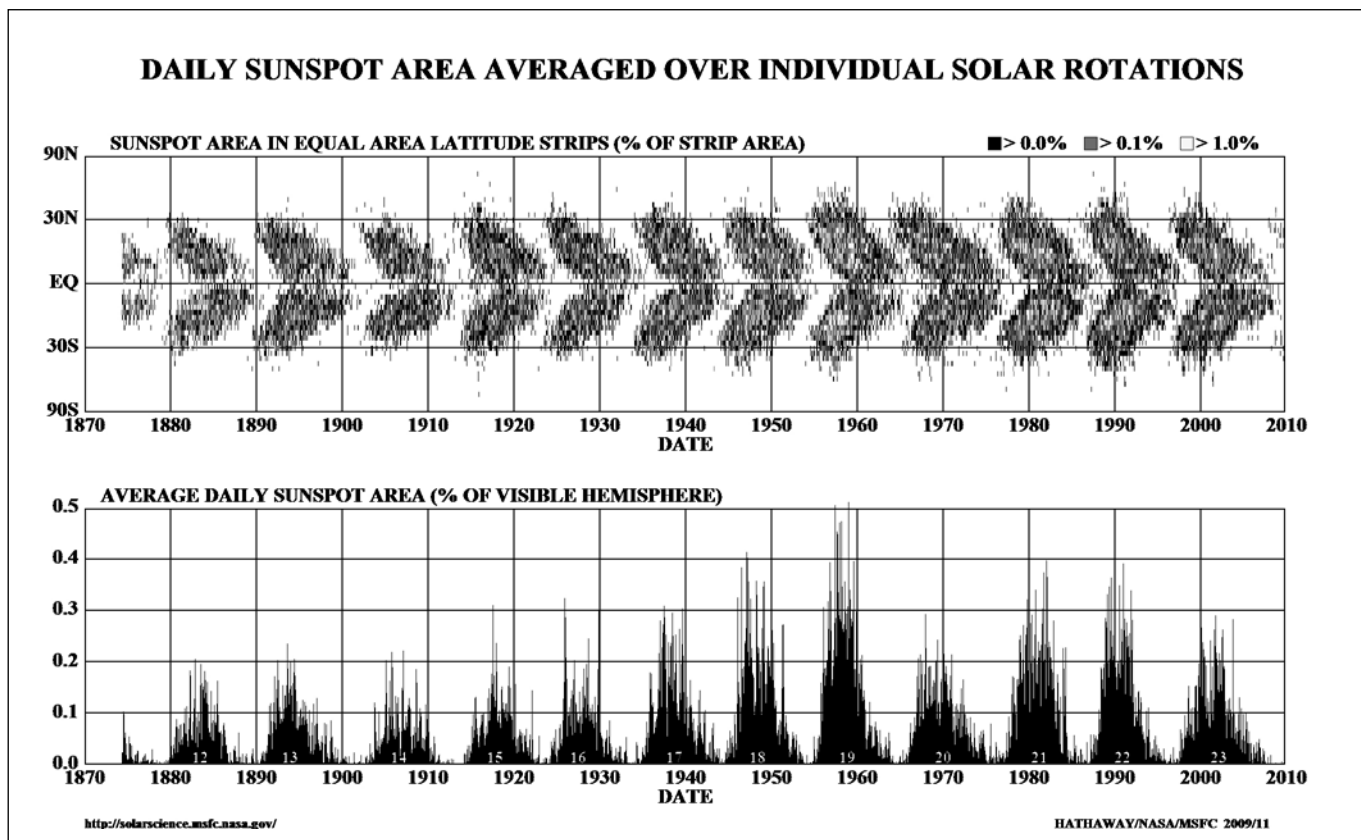


Figure 3 — This graph of multiple sunspot cycles shows how the positions of the sunspots move from the polar regions towards the equator as the cycle progresses. This creates a butterfly pattern. The image is from http://upload.wikimedia.org/wikipedia/commons/9/93/Sunspot_butterfly_with_graph.jpg.

the height of the D region. (Remember that $\lambda = c / f$, thus $300,000 \text{ (km/s)} / 20,000 \text{ Hz} = 15 \text{ km}$). In addition, the signal refracts in the D region now, and less loss is experienced since it no longer passes through the D region to refract in the E region. This generally leads to a sudden increase in VLF signal, called SID (Sudden Ionospheric Disturbance). Sometimes the VLF signal could be reduced (as with my particular VLF radio) because the low refractions have more collisions of waves and this leads to increased destructive interference.

A quick way to check the performance of your VLF radio is to monitor sunrise and/or sunset. Remembering that the D region

X-Ray Flare Classes

Rank of a flare based on its X-ray energy output. Flares are classified by the order of magnitude of the peak burst intensity (I) measured at the earth in the 1 to 8 angstrom band as follows:

Class	(in Watt/sq meter)
B	$I < 1.0 \times 10^{-6}$
C	$1.0 \times 10^{-6} \leq I \leq 1.0 \times 10^{-5}$
M	$1.0 \times 10^{-5} \leq I \leq 1.0 \times 10^{-4}$
X	$I \geq 1.0 \times 10^{-4}$

Figure 4 — Solar flares are classified according to the X-ray energy released in the flare. This chart is from www.swpc.noaa.gov/info/glossary.html#RADIOEMISSION.

is dependent on solar energy, our radios can detect the changes in the D region at both times of day as the sun passes over the transmitter/receiver path. There is generally a small peak produced at both points on the charts (see Chart 2 for a clear example). The effect lengthens with an increase in distance (east/west) between the transmitter and receiver.

The Radios

Mark Spencer spent a lot of time in a Sep/Oct 2008 *QEX* article describing a VLF radio system, which he designed and built, so I will merely provide some basic information about my system here.¹ The radio I chose uses a design by the American Association of Variable Star Observers (AAVSO). Since the sun is a variable star and easy to observe, it is an ideal source. I use the 24.0 KHz signal from Cutler, Maine, but there are signals throughout the country you can monitor. Check out the AAVSO Web site for all the relevant information and schematics: www.aavso.org/observing/programs/solar/sid.shtml (follow the links on this page to equipment and data recording).

I built the Gyrator II radio using a circuit

¹Mark Spencer, WA8SME, "SID: Study Cycle 24, Don't Just Use It," *QEX*, Sep/Oct 2008, pp 3-9.

board from Far Circuits (www.farcircuits.net/receiver1.htm) made for this device, making it much easier to build. Most parts are available from RadioShack and are simply positioned on the circuit board and soldered into place. Figure 5 is the schematic diagram of the Gyrator II VLF receiver.

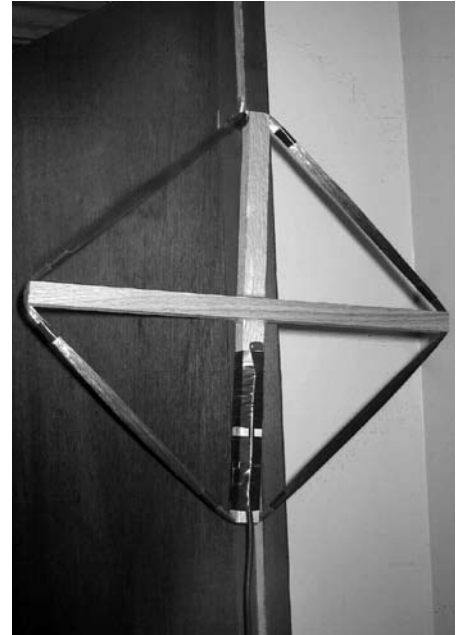


Figure 6 — Here is a photo of my loop antenna.

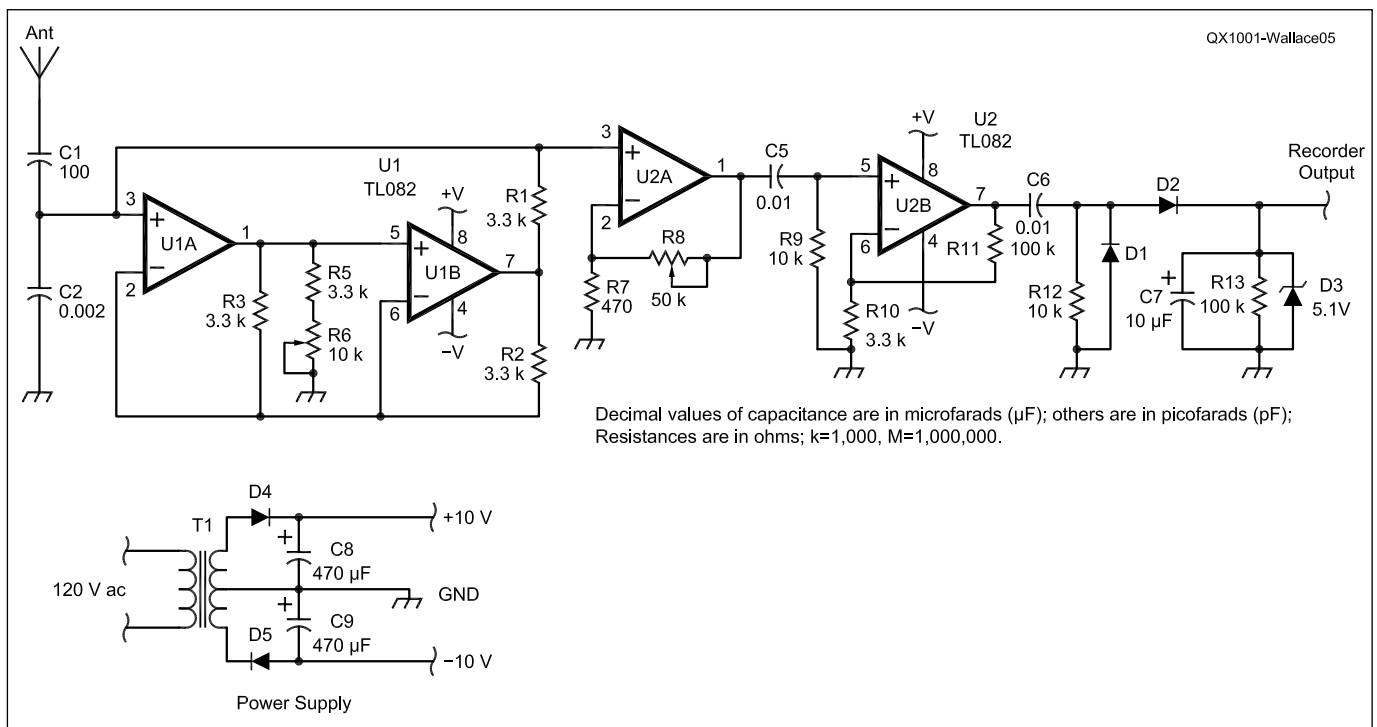


Figure 5 — This schematic diagram shows the Gyrator II VLF receiver, with parts list. There is more information at www.aavso.org/images/fullgyrator.gif.



Figure 7 — This photo shows my complete system, with the loop antenna at top left, a computer on a shelf and the VLF radio and analog to digital converter device in a box below the computer.

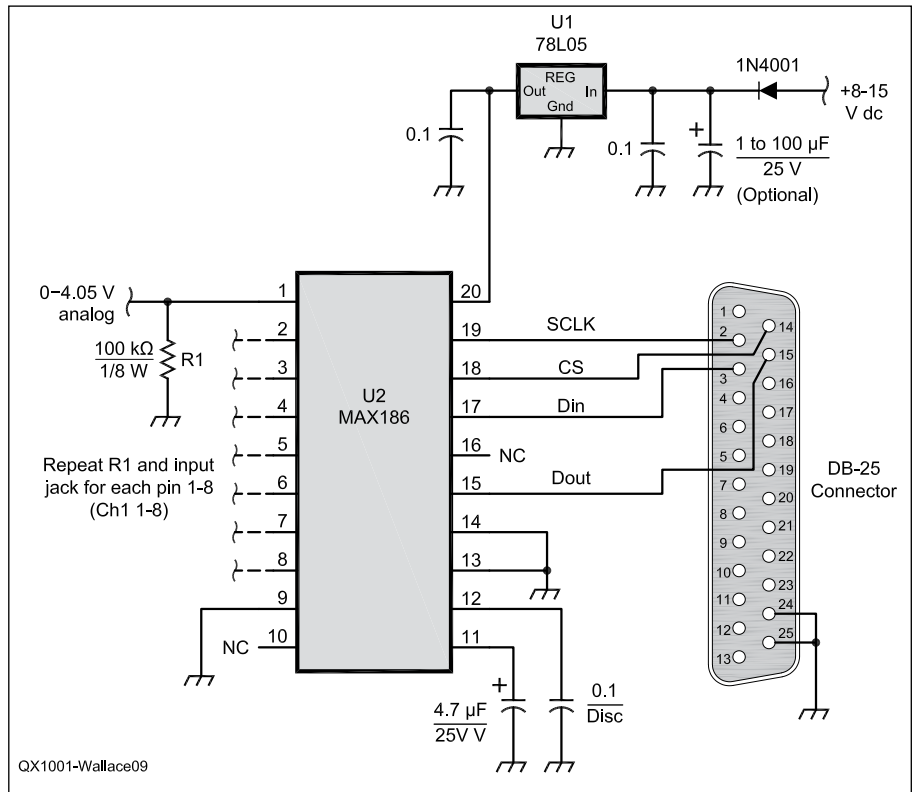


Figure 9 — This schematic is the ADC device from Jim Sky at his Radio Sky Web site: www.radiosky.com/skypehelp/skype8channelADC.html.



Figure 8 — Here is a photo of the antenna field for station NAA in Cutler, Maine.

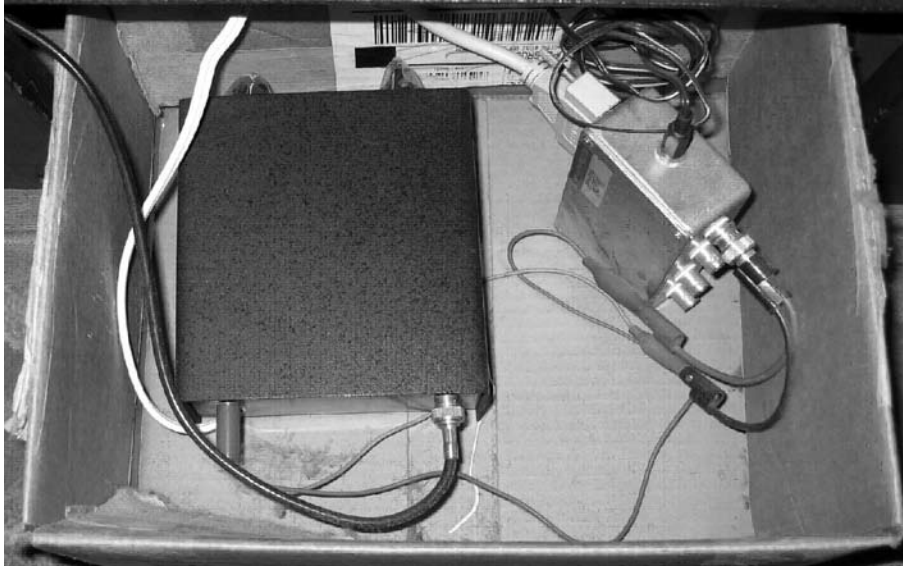


Figure 10 — Here is a close-up photo with my VLF radio on the left and the ADC device on the right.

Stanford Radio - By Bill and Melinda Lord (SARA)

Tim Huynh of Stanford University has designed a simple system to monitor Sudden Ionospheric Disturbances (SID). He uses a preamp that feeds a signal into a sound card, which records at up to 96 kHz to collect data at very low frequencies. The preamp is connected to a one meter loop antenna made of 400 feet of solid copper wire. The software can be easily configured to monitor multiple frequencies. Commonly monitored frequencies used in the US range from 21.4 kHz to 25.2 kHz. The unit can monitor from 7.5 kHz to 43.7 kHz.

Since the system can collect several frequencies, the antenna is not tuned. The early designs required an 8 foot loop antenna made of 720 feet of solid copper wire, but the current design works with a compact one meter antenna. You can increase the sensitivity with a larger antenna if you wish. Stanford is producing 100 units with the assistance of the Society of Amateur Radio Astronomers (SARA) and will be distributing them to schools all over the world.

used an IC socket so I wouldn't be soldering the IC directly; construction was very fast and easy. I used an antenna design from Mike Hill — "A Tuned Indoor Loop." See Figure 6. It is easy to make but consists of 125 turns of magnet wire! Keeping count can be a challenge. The wire is wound around a small frame (I made mine out of wood). This is an easy project, well within the skills of any ham. Figure 7 shows my complete receiving system.

Another very interesting monitor is available from Stanford University for about \$270 (nova.stanford.edu/~vlf/IHY_Test/pmwiki/pmwiki.php?n=Main.HomePage). It uses multiple frequencies to monitor flare activity. I have included a short summary at the end of this article.

Tuning

I found that using a coil of wire attached to a signal generator set to the station frequency (24.0 kHz for Cutler Maine) provided a great tuning device. Simply turning the potentiometer for gain and then tuning the radio, searching for the peak voltage output, made short work of it.

NAA

The NAA transmitter is located in Cutler Maine, and is maintained by the Navy for communication with submarines. It operates at 24.0 kHz and has a sister station at 24.8 kHz called NLK in Jim Creek, Washington. The NAA station occupies 3,000 acres and used 90,000 cubic yards of concrete and 15,000 tons of steel in its construction. It produces a 2 MW signal. The antenna consists of 13 towers, the center



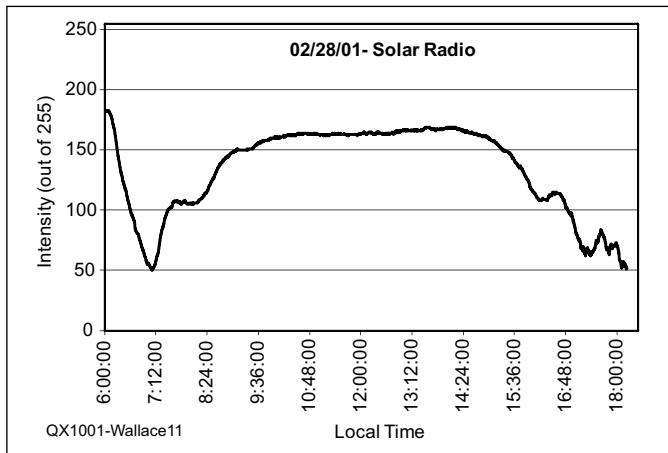


Figure 11 — This graph represents data collected on a quiet day, when no flares occurred.

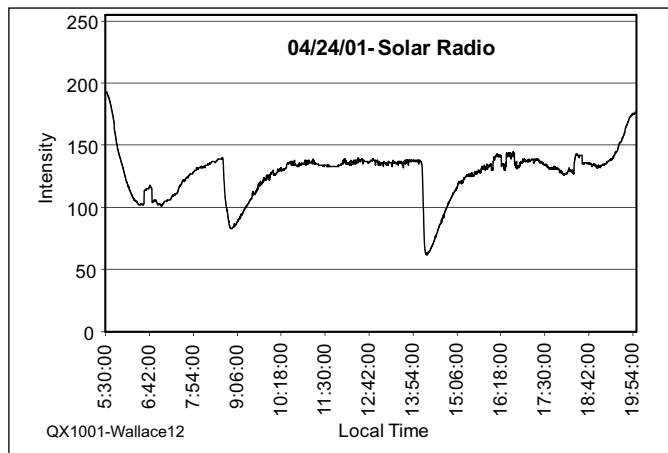


Figure 12 — This graph shows a day with several large solar flares. Also notice the peaks at both ends of the graph, representing the sunrise/sunset effect.

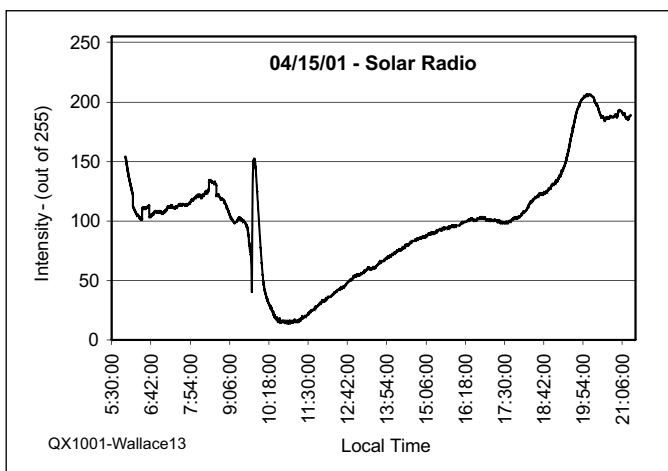


Figure 13 — This graph is from a day that had an amazing X 14.4 flare.

at 980 feet above ground, the next six at 875 feet and the last six at 800 feet. The antenna consists of 75 miles of 1 inch phosphor bronze wire above ground. See Figure 8 for a picture I took on a recent visit.

Data Recording/Charts

I record my data through an analog to digital converter (ADC) I built using plans at Jim Sky's Web site (www.radiosky.com/skypipehelp/skypipe8channelADC.html). The schematic is shown in Figure 9. It is a simple device that allows you to gather data through the printer port of any computer using Jim's software called *Radio-SkyPipe*. Figure 10 is a photo of my receiver and the ADC in separate project boxes. I use an old laptop with *Windows 3.1*. I then export the data to floppy disk and bring it to my main computer and make the final charts in Microsoft *Excel*. In Figure 11, a quiet day with no flares present is shown. Note the peaks on both ends — the sunrise/sunset effect. Figure 12 shows a day with several large flares. Flares usually appear as upward peaks, but on my receiver they appear as downward troughs. These are M1.6 and M2.3 flares respectively. Figure 13 shows a day with an amazing X 14.4 flare! Data can be reported each month to AAVSO through a simple log program, in which you enter the date and begin, peak and end times of each flare.

Conclusion

I hope you will try this simple radio and send your results to AAVSO. If you have any questions, comments or concerns, feel free to contact me.

Jon Wallace is a long-time ARRL Associate Member.

For further information check out:

Society of Amateur Radio Astronomers (SARA) — www.radio-astronomy.org/

AAVSO — www.aavso.org/observing/programs/solar/sid.shtml

Stanford's SID Program — solar-center.stanford.edu/SID/sidmonitor/

Ian Poole, G3YWX, *Radio Propagation — Principles & Practice*, available from your local ARRL dealer or from the ARRL Bookstore. Telephone toll free in the US: 888-277-5289, or call 860-594-0355, fax 860-594-0303; www.arrl.org/shop; pubsales@arrl.org.