THE RADIO JOVE PROJECT: AMATEURS WORKING WITH PROFESSIONALS

J. Thieman[‡], R. Flagg[§], J. Sky[¶], C. Higgins[‖], L. Garcia[**], F. Reyes[††], W. Greenman[‡‡], B. Pine[§§], J. Gass[¶¶] and K. Imai[***]

Abstract

The Radio JOVE project (`http://radiojove.gsfc.nasa.gov`) is an education and outreach program intended for students to interactively perform basic radio astronomy observations. The equipment and the observers have increasingly become more sophisticated and the real-time and archived data are now a resource for scientific studies of Jupiter and the Sun. With the kit ($155 + shipping) students create a radio telescope by building a receiver and antenna that operate at a frequency of 20.1 MHz. They can then receive signals from Jupiter, the galaxy, the Sun, and a variety of manmade and terrestrial radio noise. The kits appeal to individuals of all ages who want to learn about radio astronomy. Radio JOVE began with NASA funding over seven years ago and has distributed more than 800 kits worldwide. People can also participate by accessing remote radio telescopes through the internet. Chart recorder emulation software, called Radio Skypipe, comes on a CD with the kit, but is also available as a free download from `http://radiosky.com`. This software allows anyone to monitor, in real time, others who are sending out their signals using Skypipe. The chart recording values are saved in a file that can be archived and analyzed with the software. An enhanced version of Radio Skypipe enables chart image capture and sound recording. An archive (`http://jovearchive.gsfc.nasa.gov`) of the chart files, images, and recordings now has over 3,000 records contributed from individuals worldwide. As a new aspect of the project, spectrographs covering 200 frequencies from 18 to 28 MHz have been developed and connected to professional radio telescopes in Florida and Hawaii. Spectrograph monitoring software is available as a free download that provides research quality data in real time. These data will also be archived on a continuous time basis. The possibilities of this network contributing to the professional radio studies of the Sun and Jupiter will be discussed.

[‡] *NASA Goddard Space Flight Center, Greenbelt, MD, USA*
[§] *RF Associates, 1721-I Young St., Honolulu, HI 96826, USA*
[¶] *Radio-Sky Publishing, PMB 242 P. O. Box 7063, Ocean View, HI 96737, USA*
[‖] *Middle Tennessee State University, Dept. of Physics and Astronomy, Murfreesboro, TN 37132, USA*
[**] *QSS Group, Inc./NASA/GSFC, Greenbelt, USA*
[††] *Univ. of Florida, P.O. Box 112055. Dept. of Astronomy. Gainesville, FL 32611-2055, USA*
[‡‡] *Wes Greenman Consulting*
[§§] *Chaffey High School, 1245. N. Euclid Ave., Ontario CA 91762, USA*
[¶¶] *Raytheon ITSS, NASA GSFC, Greenbelt, MD 20771-0001, USA*
[***] *Dept. of Electrical Engineering, Kochi National College of Technology, Kochi 783-8508, Japan*

1 What is Radio JOVE?

The Radio JOVE project is a hands-on educational activity teaching inquiry-based science through radio astronomy. The project began more than seven years ago as an educational activity proposed to the NASA Goddard Space Flight Center's Director's Discretionary Fund (DDF). The DDF fund is used for projects that might be risky and do not have a strong potential for receiving funding through more traditional forms or proposal solicitations. The idea is to have students (either high school or middle school level) build a radio telescope from an inexpensive kit. The original cost of the kit was about $100 but has since inevitably grown to a cost of $155 plus the shipping costs. The kit has a manual for building a radio receiver and for constructing two dipole antennas which are connected together by a power combiner and then connected to the receiver with standard coaxial cable. The manual is similar to Heathkit step-by-step instructions for building electronics projects. The double dipoles together with the receiver are made for observations at a center frequency of 20.1 MHz, but the receiver is tunable over the range from roughly 19.8 MHz to 20.4 MHz. Figure 1 shows an image of the receiver and the double dipoles. This setup has sufficient sensitivity to detect radio emissions from the galaxy, the Sun, Jupiter, as well as natural and man-made terrestrial radio emission.

Figure 1: The standard Radio JOVE Double Dipole Antenna and 20.1 MHz RJ1.1 Receiver

We knew that not all people interested in learning radio astronomy would have the willingness or the facilities to build and deploy the Radio JOVE telescope. So, we also made it possible for anyone to monitor remote professional radio telescopes through the internet. Two radio telescopes are particularly intended for this purpose: a steerable 17–30 MHz log-periodic antenna at the Windward Community College on the island of Oahu in Hawaii, and a 16–element 18–30 MHz antenna array at the University of Florida Radio Observatory near Old Town, Florida. Figure 2 shows pictures of these two telescopes.

Since the beginning of the project more than 800 kits have been distributed to 45 states and more than 27 countries around the world. This constitutes a network of amateur observers that can monitor Jupiter, the Sun, and the galaxy around the clock from all parts of the world - north, south, east and west. Figure 3 shows a map of the world with dots in countries where at least one kit has been distributed. Also, the map of the United States shows the zip code locations where each of the U.S. kits have been received.

Figure 2: The 17–30 MHz steerable log periodic antenna in Hawaii (left) and the 16–element 18–30 MHz TP Array at the University of Florida Radio Observatory.

Clearly there is a potentially large network of observers available.

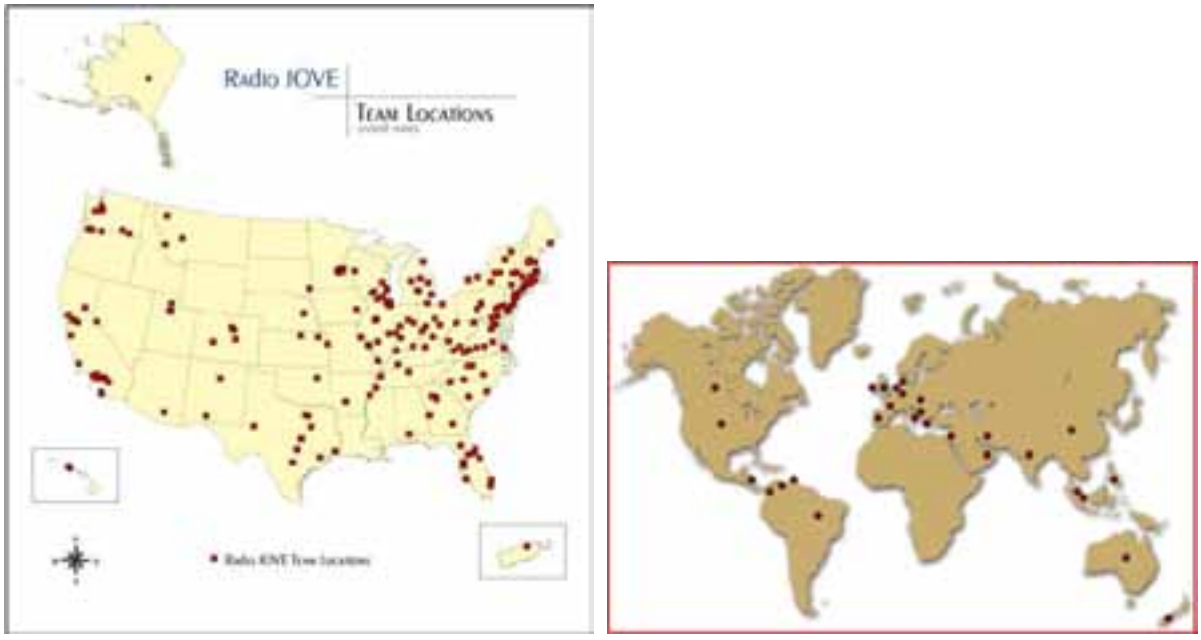

Figure 3: Kit distribution locations in the United States and countries around the world to which at least one Radio JOVE kit has been shipped.

2 Radio JOVE Observations

Once the Radio JOVE kit is built and set up, the observers can listen for radio emissions by connecting a standard speaker or set of headphones to the audio output jack of the

radio receiver. The radio signals from the antenna are converted to the audio range by the receiver. Listening to the signals provides immediate feedback to observers of the nature of the radio noise and is useful especially to distinguish manmade radio signals with voice, music, monotonic signals, morse code, etc. from the natural white noise hiss or "pops" usually heard from natural radio sources. However, a more scientific use of the data can be made by measuring the power of the radio signals. For this reason the kit comes with a CD that has Radio Skypipe software on it which can be installed on standard PC computers with Windows operating systems. Unfortunately the software will not work on Macintosh computers without PC emulation programs. The audio output of the radio receiver is simply plugged into the line input or microphone input jacks of the computer and the computer's sound card converts the analog signal to a digital signal that is picked up by the Skypipe software.

The Radio Skypipe software emulates a chart recorder and plots the signal strength of the antenna vs. time. The software has many capabilities for adjusting the display both horizontally and vertically, changing the sampling rate, looking at earlier data, recording the data on hard disk, etc. Even more important, however, if the computer is connected to the internet, the data values can be sent out through the network to others around the world and they can choose to view the same data plots in near real time in a separate chart window. Observers choose which stations to monitor through a list of "published" stations available in Skypipe. The data rate for this transmission is low, so the interchange through the internet works for high speed or low speed connections – even through modem dialup connections. Thus widely-scattered observers can monitor each others results within seconds of receipt of the data. This method is often used to verify that a radio signal is extraterrestrial in origin if it is received at many different stations simultaneously. Skypipe also features a "chat window" capability that allows the observers to type messages to each other while they are making the observations. Figure 4 shows a sample pair of Skypipe plots on the left-hand side, one for the observers own data and one monitoring someone elsewhere. The chat window is also shown as well as an information table about the other observers location, setup, etc. Skypipe contains software for recording data files, reloading old data files, analyzing the data, making images of the plots, and many other useful features. Since some people may not wish to build the kit but still wish to learn about radio astronomy it is also possible for the Radio Skypipe software to be freely downloaded through the network. The software can be obtained at the website `http://radiosky.com`. It can then be used to monitor the output of any of the JOVE telescopes around the world that are sending out their signal using Skypipe. This includes the two professional radio telescopes in Florida and Hawaii. Thus, anyone can participate even without the kit.

On the right hand side Figure 2 also shows a second chart recording emulation from the Internet Jupiter Radio Observatory. As mentioned earlier, the Skypipe software is written only for PC's and some interested individuals may only have Macintosh or UNIX computers. We also knew that in many cases schools have restrictions on software being downloaded and installed on school computers. Consequently, it is also possible to participate in Radio JOVE even if all a person has is a computer with a web browser. The signals from three frequencies received by the University of Florida TP array antenna

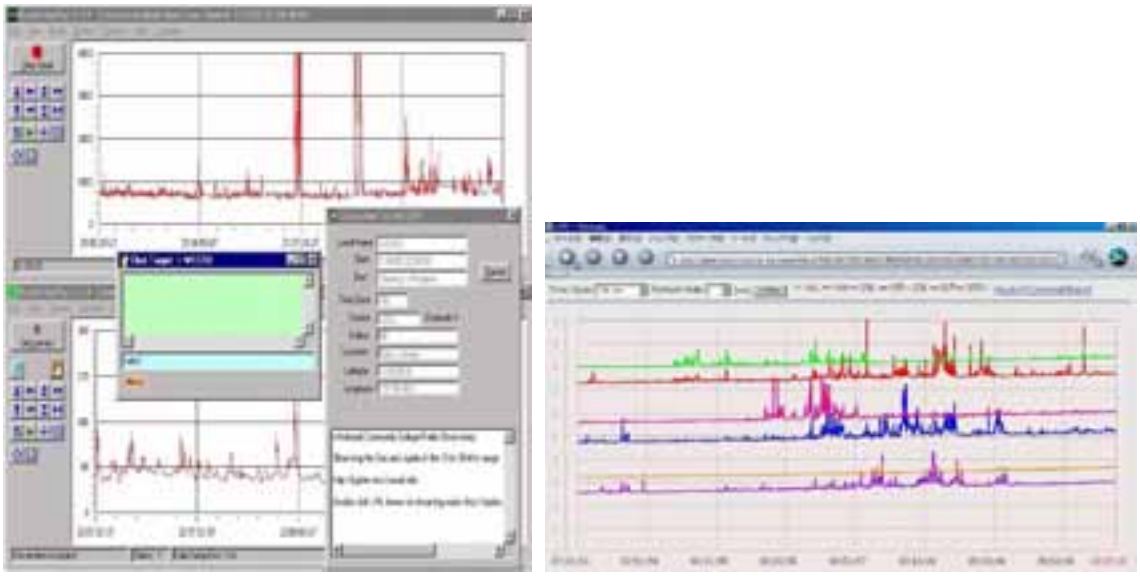

Figure 4: Sample Radio Skypipe chart emulation screens, chat window, and information display. The web-based Internet Jupiter Radio Observatory output is shown on the right.

are encoded and sent through the network to Japan where they are displayed in a chart recorder emulation program available to anyone as seen in Figure 2. The instructions for using this display may be found at `http://jupiter.kochi-ct.jp`. In this way, nearly anyone can participate as an observer in Radio JOVE.

Another lesson to be learned by JOVE participants is the importance of sharing data so that all can use the data to test theories and build on the total body of knowledge about the phenomena being observed. With Radio JOVE we encourage observers to contribute their data files to an archive that is maintained at Goddard Space Flight Center (`http://jovearchive.gsfc.nasa.gov`). Upon request anyone can gain access to upload their data to the archive. The contributed data can be in the form of Skypipe data files, images of the plots, sound files of what was being heard, and even general text reports of what was happening. In the five years or so that the archive has been in existence more than three thousand entries have been contributed. Anyone is welcome to browse the archive and download data from it. The usual method is to search for data on a particular day, but there are a variety of ways to search the archive. This set of observations has been used for student and professional research projects and represents a valuable database of potential use for multiple research purposes.

3 Spectrographs and Multi-Frequency Data

In the beginning Radio JOVE participants observe at a single frequency at or near 20.1 MHz. As had been intended, the project inspires some observers to go deeper into radio astronomy. Some have built additional antennas and used other radio receivers to make observations at other frequencies. Radio Skypipe has the capability of displaying

multiple traces in a single chart emulation and several observers use this capability to send out their multi-frequency observations. In order to provide a path for more professional studies of the decameter-wavelength radio regime we obtained funds to build two spectrographs and attach them to the multi-frequency telescopes in Hawaii and Florida.

Software was created to display 200–channel spectrograms from these instruments covering the 18–28 MHz frequency range in real time. This software is freely downloadable from `http://jupiter.wcc.hawaii.edu/spectrograph_software.htm` and can be used to monitor the spectrographs anywhere on the network. Again, like Radio Skypipe, the software uses Visual Basic and therefore is intended for use on PC's. Barring problems, the spectrographs are working 24 hours per day, seven days per week. The Florida observatory, however, is shut down during the summer due to very high probabilities of frequent thunderstorms. Figure 5 shows sample spectrograms of Jupiter data on the left and solar data on the right. Note that the top panel in each of the spectrograms is a full resolution display while the bottom panel is a 10:1 averaged compression of the top panel. An archive of the continuous observations made in Florida will be stored and distributed by the National Space Science Data Center at NASA/Goddard Space Flight Center in the near future. These spectrograph data are well–suited for research and the hardware and software could be used for other telescopes elsewhere. If you have further interest in the hardware or the software please contact the authors.

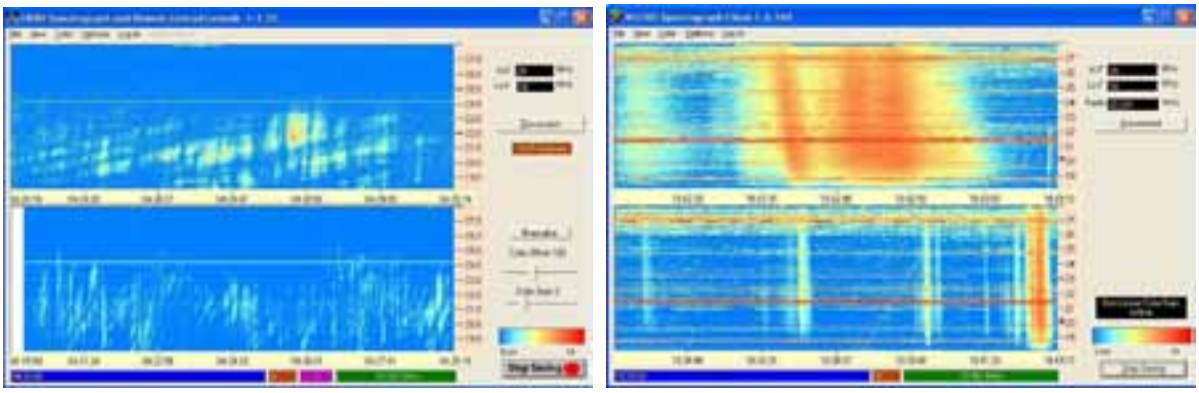

Figure 5: Spectrograms of Jupiter's Io-A related emission in the right hand panel and Type III solar bursts in the left panel as observed by the TP array in Florida.

4 Summary

In conclusion we believe that Radio JOVE is accomplishing its purpose of inspiring students in hands–on science. We also believe that Radio JOVE telescopes, Radio Skypipe software, spectrographs and associated spectrogram software can be valuable collaborative real–time tools for research. There is a worldwide network of observers ready to help. The archive of past observations can be mined for research purposes also. If you have ideas for how to use these resources we are interested in the best approaches that can further engage this next generation of explorers.