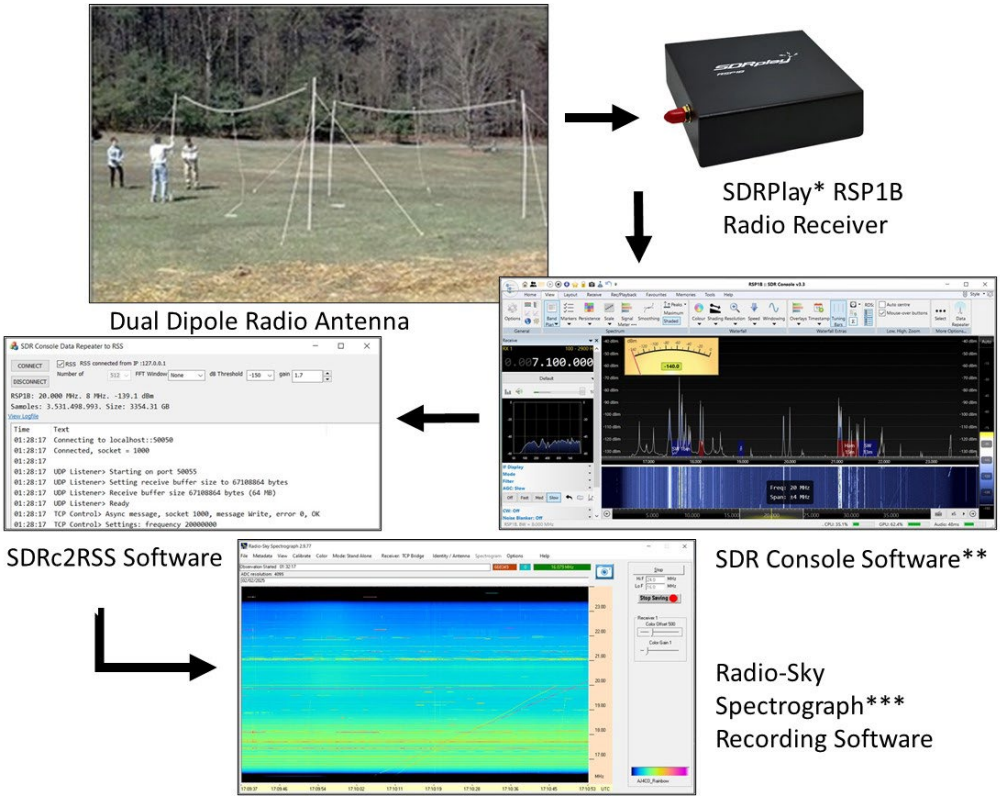
Radio JOVE 2.1

Radio Astronomy Telescope Kit using an SDRplay* RSP1B

Set-up and Operation Manual



Version 1.0, March 2025

*SDRplay (www.sdrplay.com) is a UK-based company that manufactures Software Defined Radio (SDR) radios.
**SDR Console Software from Simon Brown (https://www.sdr-radio.com/console)
***Radio-Sky Spectrograph from Radio-Sky Publishing (https://www.radiosky.com)

Contents

Acknowledgment: A special thanks goes to Larry Dodd (K4LED) for his great efforts to help Radio JOVE incorporate and beta test the SDR Console software and for making videos and instructions for this manual.

Introduction to Radio JOVE 2.1

Welcome to Radio JOVE 2.1, an exciting NASA Partner citizen science project that allows participants to assemble and operate a multi-frequency radio astronomy telescope to gather data from Jupiter, the Sun, the Milky Way Galaxy, and Earth-based radio emissions for scientific analysis and archiving. Radio JOVE 2.1 is a follow-up to the successful Radio JOVE Project 1.0 allowing users to build their own radio receiver and antenna for education and outreach, and Radio JOVE 2.0 that introduced multifrequency radios to our community. Although no longer available for purchase, Radio JOVE 1.0 and 2.0 kits are still supported, and we have many in operation contributing data to our data archive.

The reason for the change from Radio JOVE 2.0 to 2.1 is that the SDRplay SDR radio receiver model RSP1A was replaced by the RSP1B, and this also required a change in software. Radio-Sky Spectrograph (RSS) is still the standard Radio JOVE recording and analysis software; however, intermediary software is required to convert the data output from the radio to the preferred radio astronomy frequency-time display in RSS. The older SDRplay2RSS intermediary software for RJ 2.0 only works with the RSP1A radio. The newer software for RJ 2.1, called SDR Console, works with the RSP1B radio but is versatile enough to work with many radios.

This document is a guide to help you make a low-frequency radio telescope from a commercially available Software Defined Radio (SDR). This hands-on project requires working with both hardware (wires, coaxial cable, connectors), a Windows computer (Windows 7 operating system or higher), and software (download, installation, operation). Mac and Linux operating systems are not supported by Radio JOVE specific software at this time.

To function as a radio astronomy telescope, the receiver requires connection to a proper radio antenna. For a simple and effective radio antenna, Radio JOVE recommends a single or dual dipole antenna. Antenna plans are found on our website, Building the Telescope: https://radiojove.gsfc.nasa.gov/radio_telescope/building_testing.php.

Software-Defined Radios (SDRs) offer newer technology capable of receiving a wide bandwidth of radio frequencies. Therefore, the Radio JOVE 2.1 radio astronomy telescope is technically a radio spectrograph instrument, an

instrument that can receive radio signals over a wide range of the radio spectrum. Combined with Radio-Sky Spectrograph (RSS) software, a radio spectrograph can generate spectrograms which depict radio activity as a function of both time and frequency.

Radio JOVE is partnering with SDRplay (www.sdrplay.com), a UK-based company that manufactures Software Defined Radio (SDR) radios.

Figure 1 is an example of a radio frequency vs. time spectrogram showing multiple solar bursts. The solar burst signatures are the enhanced yellow-red vertical features occurring over timespans of seconds to minutes.

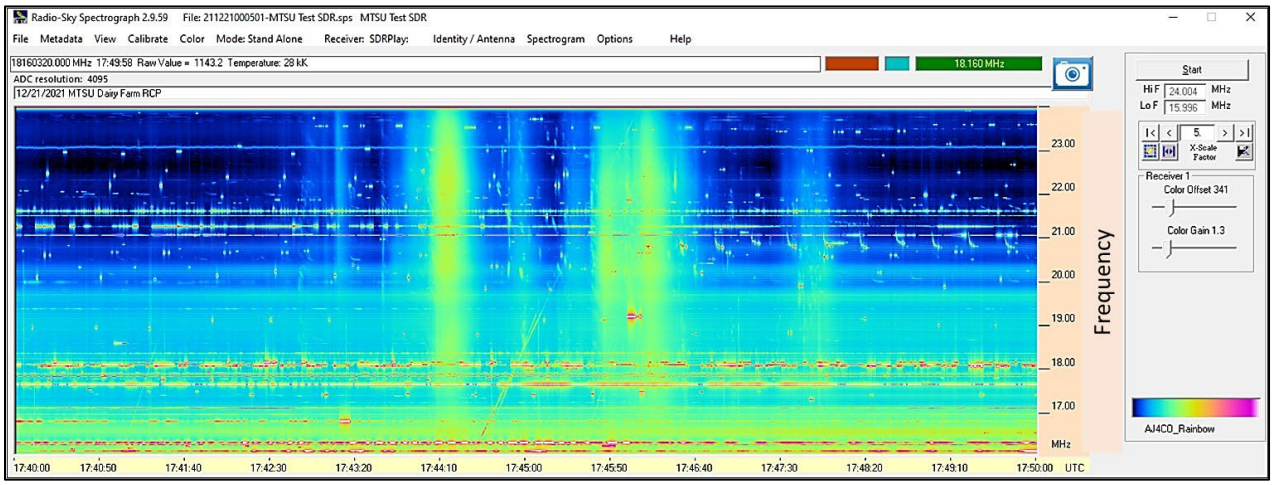


Figure 1. A frequency-time spectrogram showing multiple solar bursts on 21 December 2021. Data from C. Higgins, MTSU Dairy Farm.

TIME ESTIMATES FOR ASSEMBLY

Reading Documents	approx. 1.0 hr.
Software Installation	approx. 1.0 hr.
Receiver connections	approx. 0.5 hr.
Total Time for Receiver/Software Setup	approx. 2.5 hr.
Antenna Construction	approx. 6.0 hr. (See Antenna Manual)

BASIC THEORY OF OPERATION

Receiver

Radio signals from Jupiter are very weak - they produce less than a millionth of a volt (1 microvolt, 1µv) at the antenna terminals of the receiver. These weak radio frequency (RF) signals are amplified, digitized, and processed by the radio receiver and computer software. Signal processing includes the use of the Fast Fourier Transform (FFT) to generate a spectral display (signal amplitude vs frequency and time) from time sampled data.

The Radio JOVE 2.1 radio telescope comprises an antenna, an SDR receiver, and software: SDR Console, SDRuno, SDR Console to RSS (SDRc2RSS), and Radio–Sky Spectrograph (RSS). JOVE observers typically operate the radio telescope over an 8 MHz (megahertz) wide band of frequencies centered on 20 MHz. This frequency range is optimum for detecting Jupiter radio signals, and is excellent for detecting solar radio emissions, the galactic background from the Milky Way, and natural and artificial Earth-based radio emissions.

The SDRplay RSP1B radio we are using is incredibly versatile, and with the right antenna, it can detect radio frequencies over a very broad range, from 1.0 kHz – 2.0 GHz including the radio bands VLF, LF, MW, HF, VHF, UHF and L-band. For example, it will detect longwave and shortwave radio communications, AM and FM radio stations, and aircraft beacons. See https://www.sdrplay.com/ for more information about this radio.

Antenna

The antenna intercepts weak electromagnetic waves which have traveled hundreds of millions of miles to the Earth. When these electromagnetic waves strike the wire antenna, a tiny RF voltage is developed at the antenna terminals. Signals from the antenna are delivered to the antenna terminals of the receiver by a low loss coaxial cable.

The radio antenna recommended, and included with the kit, is two half-wave dipole antennas (see cover image). A single dipole requires about 15 x 30 ft (approx. 4 x 8 m) of space; it is the minimum needed to detect solar bursts, and the strongest Jupiter emissions. Two dipoles are required to detect weaker Jupiter and solar emissions. Note that the masts, hardware, guy ropes, and stakes are not included with the antenna kit, but are easily obtained from a hardware store. See

the antenna construction manual for details (https://radiojove.gsfc.nasa.gov/radio_telescope/ant_manual.pdf).

Computer and Software

The computer and software will record and provide a real-time display of the strength of the digital radio signal on a frequency vs. time graph (a spectrogram). We require a computer running Windows 7 or later operating system because the SDR requires a reasonable CPU speed to process the signals [**Recommended computer specifications: Windows 7 or higher, 64-bit system recommended (32-bit is okay), i3 processor or better, and 4GB RAM or better**]. Ideally, the computer should be dedicated to data collection when in operation, but it will depend on your computer's capabilities.

RADIO TELESCOPE COMPONENTS

Antenna – collects the radio waves
Antenna cable and connector – connects the radio antenna to the receiver
Receiver – detects, amplifies, and filters the radio signals
USB Cable – transmits the signal to the computer and powers the radio
Computer and software – record and display the radio signals for analysis

Figure 2 is a block diagram of the Radio JOVE 2.1 spectrograph to help understand the hardware and software connections and the signal flow.

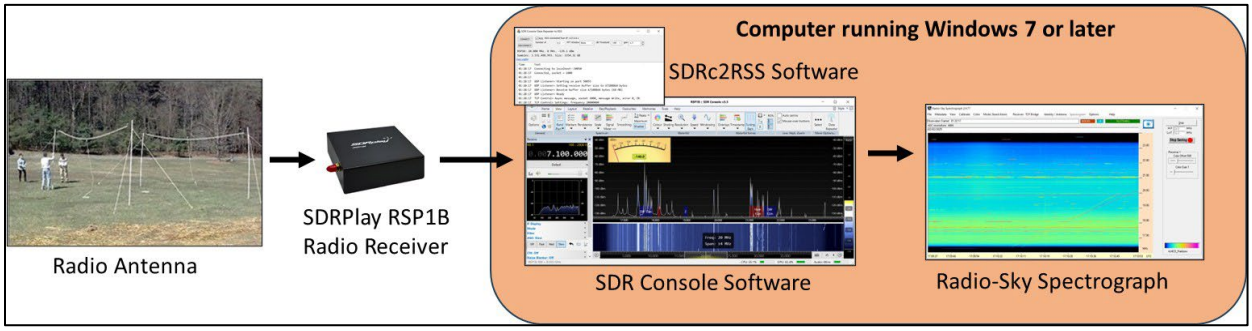


Figure 2. A block diagram of the Radio JOVE 2.1 spectrograph.

TOOLS

No tools are required for the receiver. See the Antenna Manual for a list of tools required to build the antenna.

RECEIVER PARTS

A list of parts is given in Table 1. Check the parts you have received against the list in Table 1. You must provide a computer running Windows 7 or higher with recommended specifications in Table 1.

Table 1. Receiver Parts List

	Part Name	Suggested Part Supplier	Figure
1.	SDRplay RSP1B receiver	https://www.sdrplay.com/	
2.	USB 2.0 type B socket to USB 2.0 type A socket (6-foot cable)	Any electronics store. https://www.digikey.com/en/products/detail/tripp-lite/U023-006/4439389	
3.	SMA male-to-BNC male Cable (6-inch cable)	https://www.digikey.com/en/products/detail/cinch-connectivity-solutions-johnson/415-0028-006/457089	
4.	BNC-female-to-F-female connector (50-ohm)	https://www.mouser.com/ProductDetail/678-3328505	
5.	Antenna Parts	See Antenna Manual https://radiojove.gsfc.nasa.gov/radio_telescope/ant_manual.pdf	
6.	Computer running Windows 7 OS or higher	Recommended specifications: 1. Windows 7 or higher 2. 64-bit system (32-bit is okay) 3. i3 processor or better 4. 4GB RAM or better	

Radio JOVE 2.1 SDRplay RSP1B Receiver Kit Setup Guide

A. Introduction

This document will take you through the process of installing and configuring the software to get your Radio JOVE 2.1 kit working as a radio telescope. For those that prefer a video guide to the software setup you can find a YouTube video here. Use the QR Code or the link for RSP1B on SDR Console SDRc2RSS and RSS (10:41): https://youtu.be/Om7348g3ULk. It is a good idea to watch the full video before you begin the installation to get a good overview of the entire process. *These instructions will work for other SDRplay models*.

RSP1BCONSOLE YouTube

Four pieces of software are needed: (1) **SDRuno** is the Windows platform commercial software to control the SDRplay radio --- this installs all the required plugins and SDRplay API service for the radio, (2) **SDR Console** program, written by Simon Brown is intermediate software to connect and control the SDRplay radio, (3) **SDRc2RSS** (SDR console to RSS) is intermediate software to send the signal to the RSS spectrograph display, and (4) **Radio-Sky Spectrograph (RSS)** software displays and records the data as signal strength on a frequency versus time chart.

Figure 3 shows all the hardware connections after the software is installed.

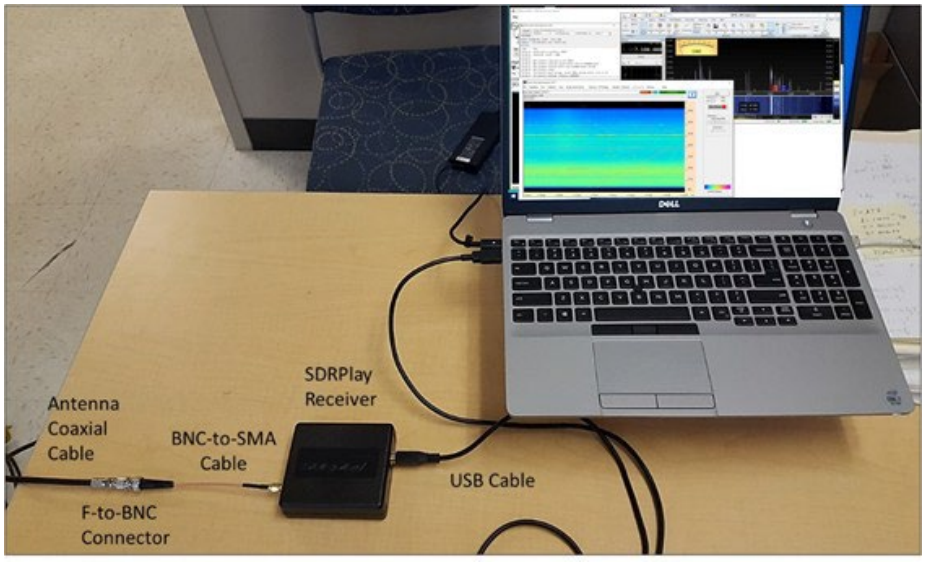


Figure 3. Receiver hardware setup showing the incoming antenna coaxial cable, the F-to-BNC connector, the BNC-to-SMA connector cable, the SDRplay receiver, the USB cable, and the computer.

B. Detailed Software and Hardware Setup

1. **Download and Install SDRuno software**. Radio JOVE requires SDRuno V1.42 or newer (Figure 4). Download here: https://www.sdrplay.com/sdruno/
    a. **Do not connect the SDRplay radio to the computer until the install routine tells you to connect it.** Run the installer and let it make updates to other software like C++ and SDRplay API service.
    b. Connect the SDRplay radio to the computer using the USB cable and finish the software installation, including the plug-ins.
    c. C**lose SDRuno**. SDRuno should not be running while the other programs are running. Installing SDRuno simply updates the drivers and the proper plug-ins for the other software to run properly.

    For first time users, here is a great help video from *SDRplay: SDRuno - The Basics* (29:37) https://www.youtube.com/watch?v=k8p106BpSXU

2. **Download and Install SDR Console software,** SDR-Radio v3.3 (Figure 4)**.** This software will connect and allow control of the SDRplay radio.
    SDR Console (64-bit) download: SDRConsole_64bit
    SDR Console (32-bit) download: SDRConsole_32bit
    SDR Console website: https://www.sdr-radio.com
    a. **Unplug your SDR radio from your computer.**
    b. **Do not connect the SDRplay radio to the computer until the install routine tells you to connect it.** Run the installer and allow updates.
    c. Connect the SDRplay radio to the computer using the USB cable and finish the software installation.

Figure 4. SDRuno, SDR Console, SDRc2RSS, and Radio-Sky Spectrograph (RSS) desktop icons.

3. **Download and install the SDRc2RSS software**, this will use the SDR Console data repeater to send the signal to the RSS spectrograph display software (Figure 4). Download here: http://www.101science.com/RJ/SDRc2RSS.exe.

4. **Download and install (in default directory!) Radio-Sky Spectrograph (RSS)** from https://www.radiosky.com/. The one-click download is here: http://radiosky.com/spec/Spectrograph.exe (This URL is case sensitive). If you get a warning, click *More Info* → *Run Anyway*. Proceed to download the software (Figure 7). After installing RSS on your Windows computer, it will automatically **run as *Administrator*** each time you run it.

Starting the Software

1. **SDR Console Program**.
    a. Start the SDR Console program; wait for the program to load (Figure 5).

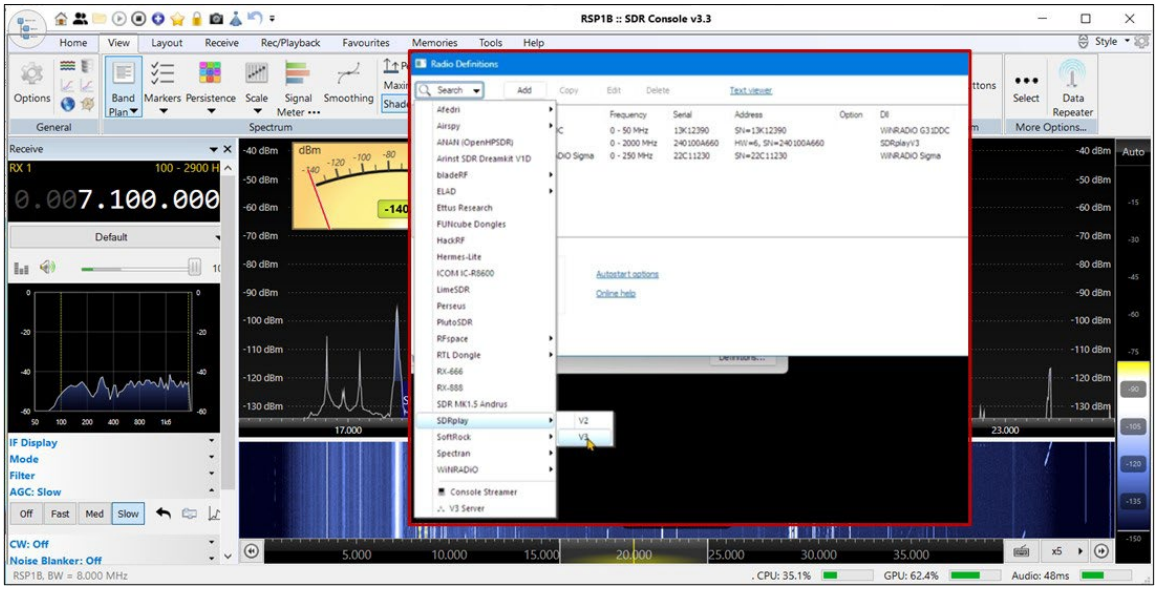


Figure 5. SDR Console program and Search for SDRplay V3 option (inset).

    b. In the select radio window, click on the definitions button. Click the search button at the top, then go to the pull-down list. Then select and click on SDR play. Select Version 3 since we are using an RSP1B (Figure 5 Inset). Click on add the version definition. Click on SDR play RSP1B. Then click on save. In the Select Radio window, click on SDR play RSP1B to highlight it.

c. Select a bandwidth of 8 Mega Hertz when using the RSP1B. Click start.

d. Open the view menu in the top SDR Console toolbar. Go to the far right-hand end of the toolbar and ensure the data repeater is activated. If it has not started, click on it to start it (Figure 6). You only need to do this once, as the SDR Console software will normally remember all your menu settings.

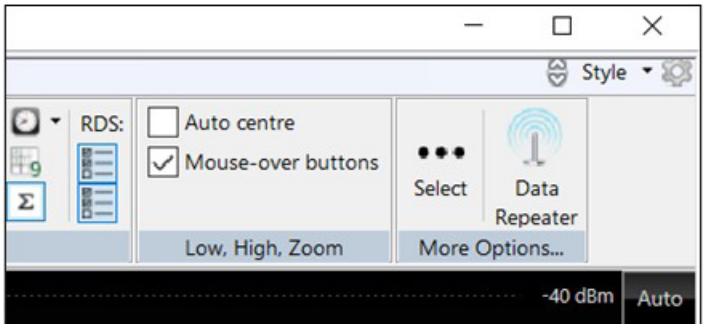


Figure 6. SDR Console Data Repeater option shown activated.

e. Go back to the home menu. In the top home toolbar, set RF gain to 9 Max, set IF gain to minus 40 dB, and Visual Gain to minus 40 dB (Figure 7).

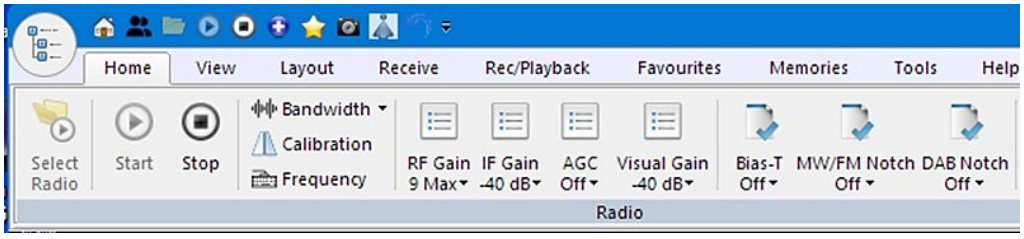


Figure 7. Set the RF, IF, and Visual Gain controls in SDR Console.

f. At the bottom of the SDR Console window, set the left side of the gray slider to 16 Mega Hertz. Then, set the right-hand side to 24 Mega Hertz (see Figure 5). These are the typical frequencies for Radio JOVE work on 8 Mega Hertz bandwidth receivers like the RSP1B. SDR Console software will remember all these settings even after a computer restart.

g. Leave all other SDR Console settings not mentioned at their default settings.

h. Go to the right side of the SDR Console spectrograph and adjust the top red slider and the bottom blue slider to see a spectrograph with a dark blue background and some white signals during the daytime (see Figure 5). This is not a critical item. These settings only affect the SDR Console display you see on your screen. They will not affect your RSS spectrograph in any way.

i. This completes the settings in the SDR Console for the RSP1B. Place the SDR Console window toward the bottom of your screen.

2. SDRc2RSS Interface Program.

a. Open the SDRc2RSS program. Click on Connect (See Figure 8). Click on Connect again. The SDRc2RSS program takes the digital data from the SDR Console data repeater feature and repeats it in the form and protocols required by Radio Sky Spectrograph (RSS).

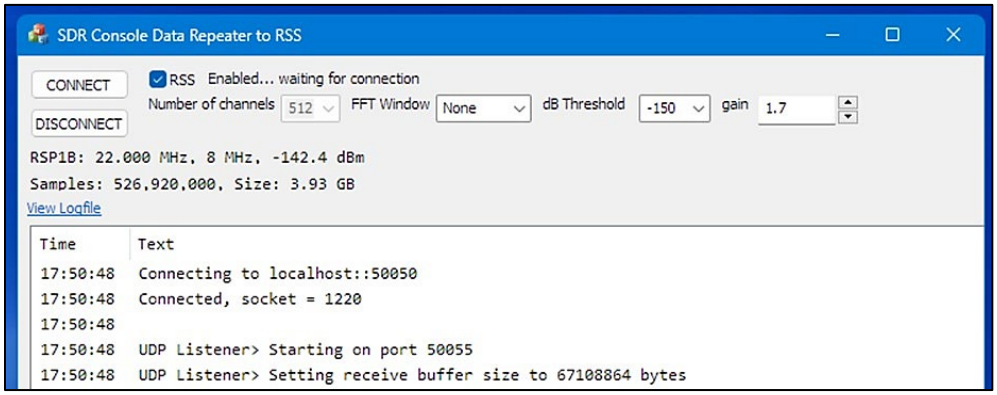


Figure 8. SDRc2RSS Software.

b. Set the number of channels to 512. Set the FFT window to none. If you have RFI issues, try setting it to Blackman. Set the dB threshold to minus 150. Set the gain to 1.7 (see Figure 8).

c. All settings in SDRC2RSS are not remembered, so you must reenter them each time the program is restarted.

d. Check the tiny RSS box in the upper left corner of SDRc2RSS to checkmark it. This setting is very easy to miss, so make sure it is

checked (see Figure 8). If it is not checked, data will not be sent to RSS. Place the SDRc2RSS interface program window on the upper left-hand side of your screen.

3. Radio-Sky Spectrograph (RSS)

a. Open the Radio Sky Spectrograph (RSS) program (Figure 9). Place the program on the upper right side of your screen. After you start the software, select **Yes** in the User Account Control window to allow the software to **run as *Administrator***.

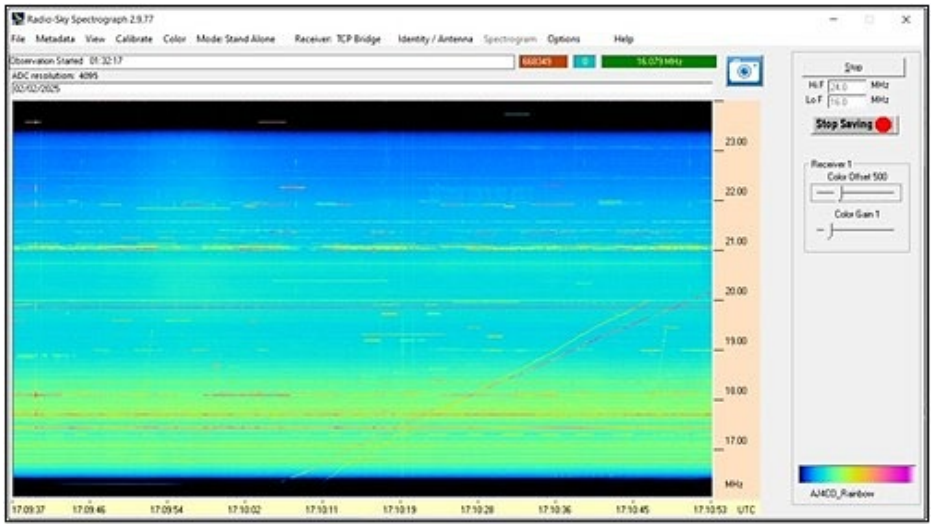


Figure 9. Radio-Sky Spectrograph software.

b. Set the receiver type to RTL Bridge slash TCP (Figure 10a).

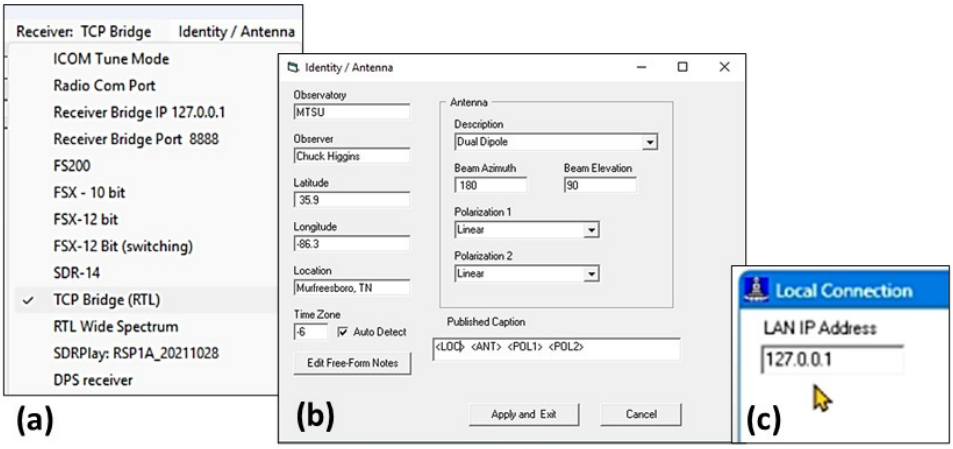


Figure 10. RSS Software Selections (a) receiver selection, (b) Identity/ Antenna options, and (c) Options/Network/Local Connection settings. For RSS help: http://radiosky.com/spec/RSS_Help4.pdf.

c. Click on the Identity/Antenna menu (Figure 10b). When you run RSS for the first time, at a minimum, fill in your name and observatory name (limit 20 characters), latitude, and longitude. Before sharing files, you should complete information thoroughly. Keeping good metadata, that is, basic information about your observatory, is key to the usefulness of your observations. When completed, click on apply and exit.

d. In the Options menu, network, local connections, ensure the Lan IP address is set to 127.0.0.1 (Figure 10c). Click on OK.

e. In the options menu, file saving, activate the items by clicking on them. Save on demand, start saving on connection and the next to last item, append local name to the file names. Activated items will now have a check mark in front of the item.

f. Please make note of the data directory path. This is where your **spectrograph.sps** data files are stored. You can change this location if needed.

g. In the options menu, program priority, set to high.

h. In RSS on the right-hand side, set RSS color offset to 500 and RSS color gain to 1 (see Figure 9). Later, you can further adjust these two settings as needed to obtain a dark blue background with some white signals for an acceptable uncalibrated spectrograph. These last two RSS settings do not affect the data file you save. They only affect what you see on your computer monitor screen.

   Color Offset subtracts a given value from the incoming data, removing background environment and receiver noise.

   Color Gain multiplies the remaining signal by some value so that small signal enhancements are spread over a wider range of colors.

i. Open the RSS color menu tab. It is recommended that you load the AJ4CO color file. The AJ4CO rainbow icon will appear at the bottom

right of the spectrograph (see Figure 9). However, you may want to try other color files that may make features more visible in any given chart. Later when making actual observations you will use the color controls in RSS to visually enhance features in the spectrogram.

j. Start RSS. You can use a schedule file to start RSS or simply click the RSS start button in the upper right corner. If RSS does not start painting a spectrograph after a few seconds, ensure the tiny RSS box in the upper left corner of SDRc2RSS is checked (Figure 8).

Congratulations! You are now ready to make radio astronomy observations.

Please check the Radio JOVE website periodically for any updates on the hardware and software**.**

Radio JOVE Data Archive

A key component of data analysis and research is archiving your data. By doing so, it preserves interesting observations and makes it easier to compare data with other observers. The Radio JOVE Data Archive accepts data files up to 128 MB in size (about 4 hours of spectrograph data). Good discussions and data comparisons happen on our Groups.io group - https://groups.io/g/radio-jove. Please join us.

Troubleshooting

HELP! – if it still doesn't work –
RJ Team Contact Information: https://radiojove.gsfc.nasa.gov/contacts.php
If you need to ask one of the Radio JOVE team for assistance it is much easier for us to help if you have documented exactly what the problem is, what measurements you have made, and their results.

If you have been unsuccessful in getting your receiver working by this point, please feel free to contact us on the Radio JOVE listserv: radio-jove@groups.io. However, to send an email, you must register with our Groups.io group - https://groups.io/g/radio-jove and receive emails from the Radio JOVE project.

Testing the Receiver and Antenna Together

Before making your first observations of the Sun or Jupiter it is a good idea to set up the antenna and receiver to confirm that everything is working properly. For this test you can set up either a single dipole or the dual dipole array.

1. **Basic test: Disconnect and reconnect your antenna.**

    a. **Disconnect your antenna** - With the software running disconnect your antenna from the SDRplay receiver. The spectrograph will go nearly black (Figure 11). You might see some small interference at the bottom or top of your chart.

    b. **Connect your antenna** - you should see a good color spectrogram like Figure 11. Figure 11 shows many horizontal bands of interference and a particularly strong one near 18 MHz. Some horizontal banding is normal.

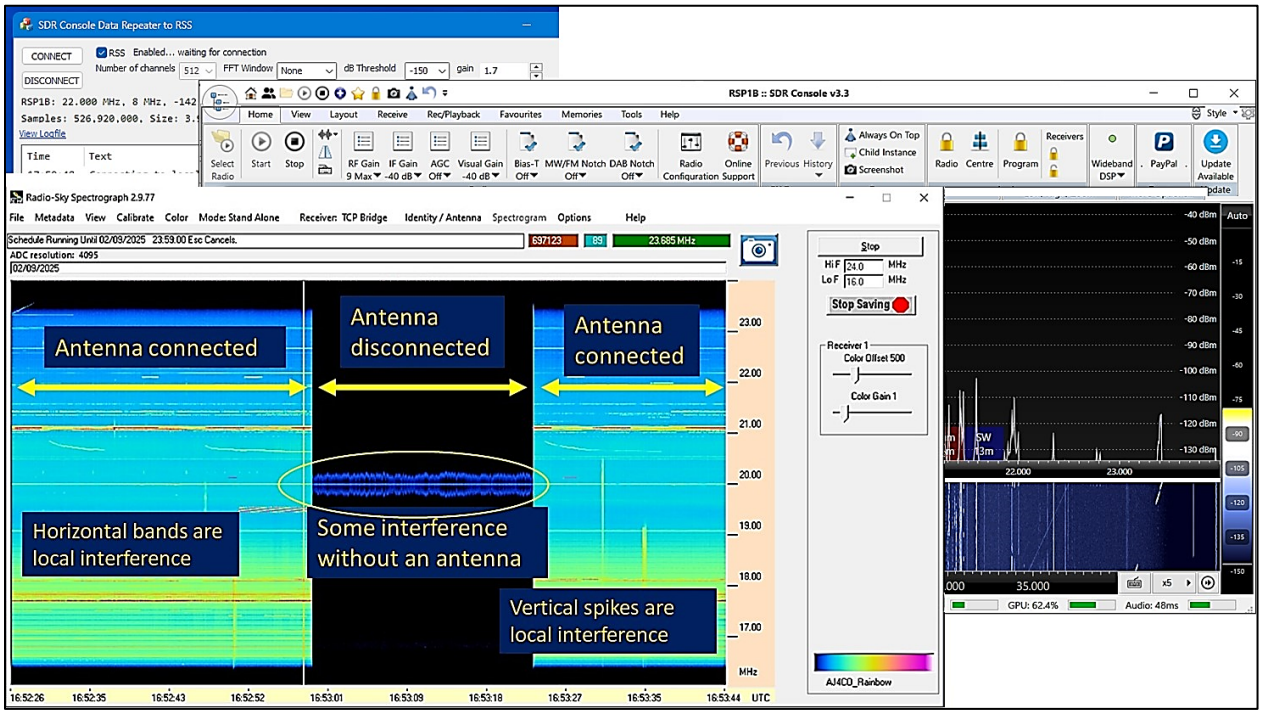


Figure 11. Example spectrograph output using RSS display software. Note the SDRc2RSS software window open with the RSS checkbox enables. The antenna was disconnected and reconnected showing a good color spectrogram.

2. Second test – Compare your data with Example Spectrograms.

a. Radar sweeps - A spectrogram of the ionospheric “sweepers” caused by distant radar used to sound the ionosphere. These appear as diagonal lines on spectrograph graphs from low frequency to high frequency and are a good sign you are picking up distant radio signals. The spectrogram in Figure 12 shows 3-4 sweepers and several solar bursts.

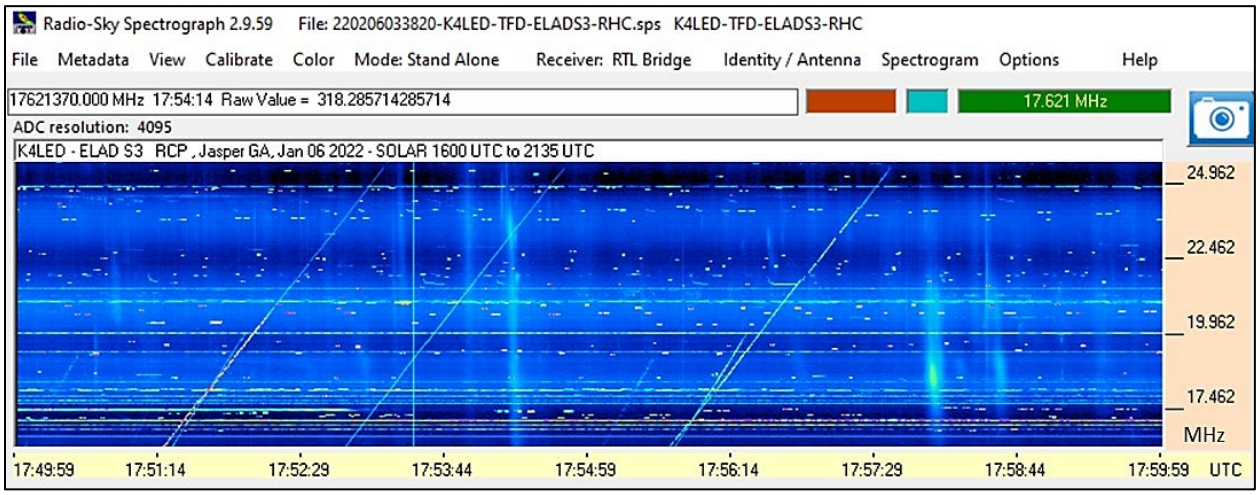


Figure 12. An SDR spectrograph showing several solar bursts as the near-vertical “wispy” bands. Several positively sloped “sweeper” radar signals are seen. (L. Dodd, 2022)

b. Interference – horizontal bands are local interference local radio stations or from electrical sources like power lines, lights, and HVAC systems (see Figure 11). Figure 13 is a 24-hour spectrum showing the difference between nighttime and daytime interference. The conditions are mostly quiet at night, but there is more electrical noise during the day, and the ionosphere reflects more radio signals during the daytime. The strong horizontal bands are local broadcast radio stations.

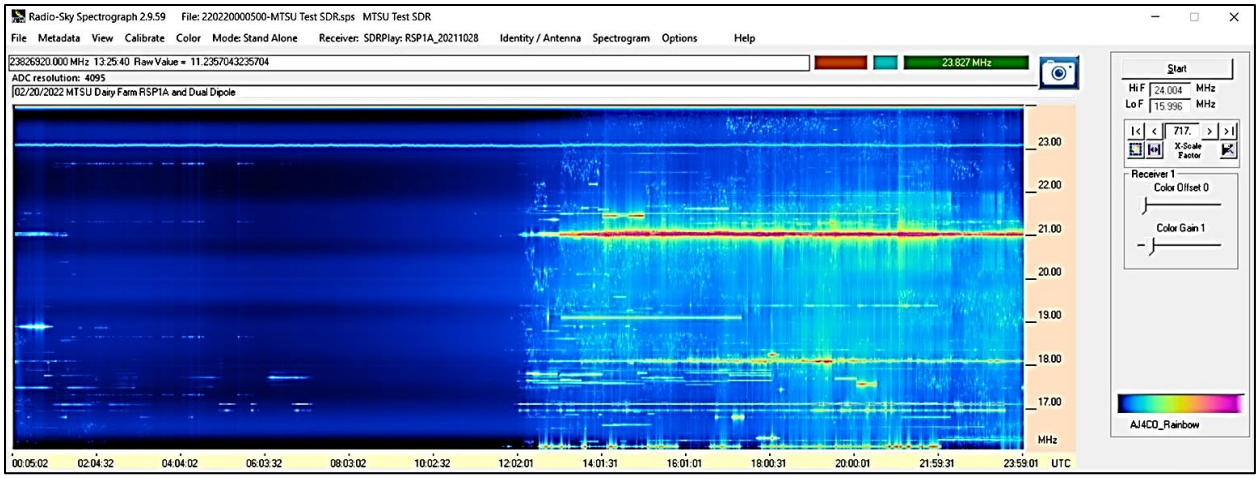


Figure 13. Example 24-hour Radio JOVE spectrograph output using RSS display software. Note the clear difference in the nighttime observations on the left and the daytime observations on the right. Local interference is more prevalent during the daytime. (C. Higgins, 2022)

c. Solar bursts show as broadband (near vertical) “wispy” signals on the spectrograms (Figure 14).

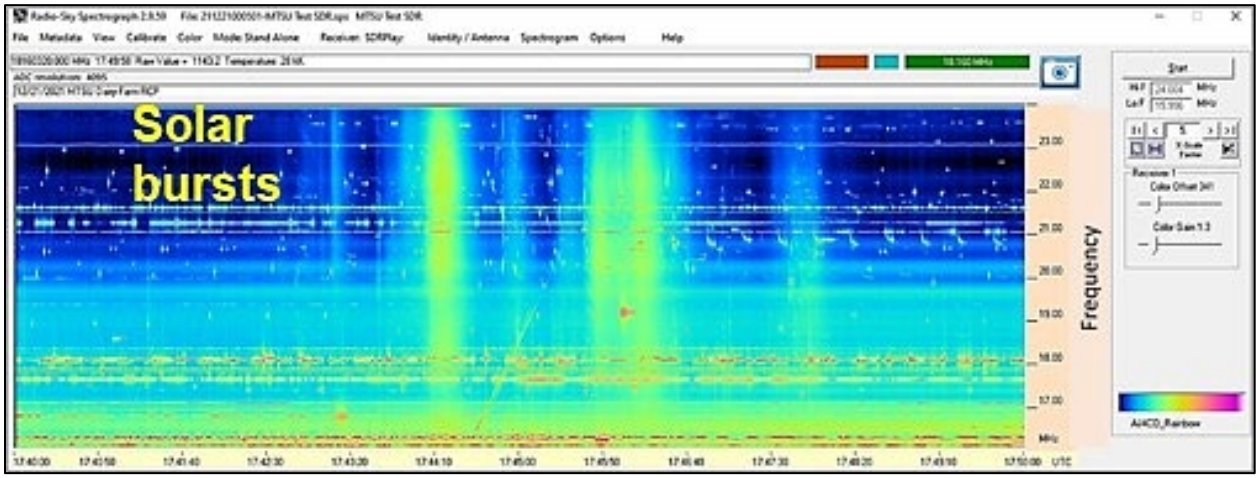


Figure 14. A Radio JOVE spectrograph showing multiple solar bursts as the near-vertical “wispy” bands. Spotty interference occurs at several frequencies, with more interference below about 18 MHz. A positively sloped “sweeper” radar signal is seen near the center of the spectrograph. (C. Higgins, 2021)

d. Jupiter bursts show as broadband bursts signals sometimes drifting upward or downward on the spectrograms (Figure 15). The signals are generally weaker than solar bursts but usually show more spectral structure.

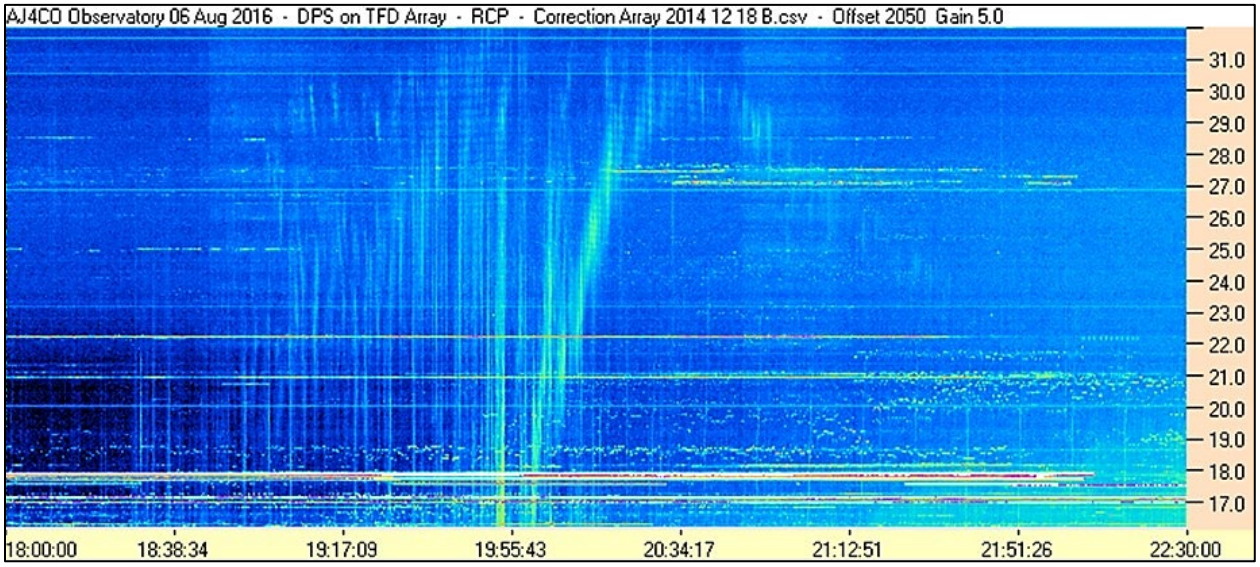


Figure 15. A custom built 16-32 MHz wide band spectrograph shows a Jupiter Io-B emission event over a span of 4.5 hours (D. Typinski, 2016).

APPENDIX

I. SDRplay RSP1B Receiver Specifications

The SDRplay RSP1B Specification Sheet is found here:
https://www.sdrplay.com/resources/RSP1BDatasheet.pdf

II. SDRuno Software Help

The SDRplay website has tutorials to help you learn how SDRuno software functions.

1. SDRuno software download: https://www.sdrplay.com/sdruno/
2. SDRplay SDRuno User's Manual: https://www.sdrplay.com/docs/SDRplay_SDRuno_User_Manual.pdf
3. SDRuno - The Basics (29:37): https://www.youtube.com/watch?v=k8p106BpSXU
4. SDRplay: Antennas and Signals for newcomers to SDR receivers (15:46): https://youtu.be/KpBkRrjjph4
5. All Documentation videos from SDRplay: https://www.sdrplay.com/apps-catalogue/

A LIST OF HELPFUL LINKS AND SOFTWARE

1. **The RSP1BCONSOLE.mp4 YouTube video, "RSP1B on SDR CONSOLE and RSS":** https://m.youtube.com/watch?v=Om7348g3ULk
2. SDR Console: https://www.sdr-radio.com/download (NOTE: Click on RELEASE then download)
3. SDRc2RSS Program: http://www.101science.com/RJ/SDRc2RSS.exe
4. Radio Sky Spectrograph: https://radiosky.com/spec/Spectrograph.exe
5. AJ4CO Color File: 12 bit https://101science.com/AJ4CO-Rainbow.txt
6. AJ4CO Color File: 14 bit https://101science.com/AJ4CO-Rainbow-14-bit(RSS).txt
7. RSS Schedule Files: https://www.youtube.com/watch?v=iYTEyFukxMM
8. Radio Sky Spectrograph RSS HELP: http://radiosky.com/spec/RSS_Help4.pdf