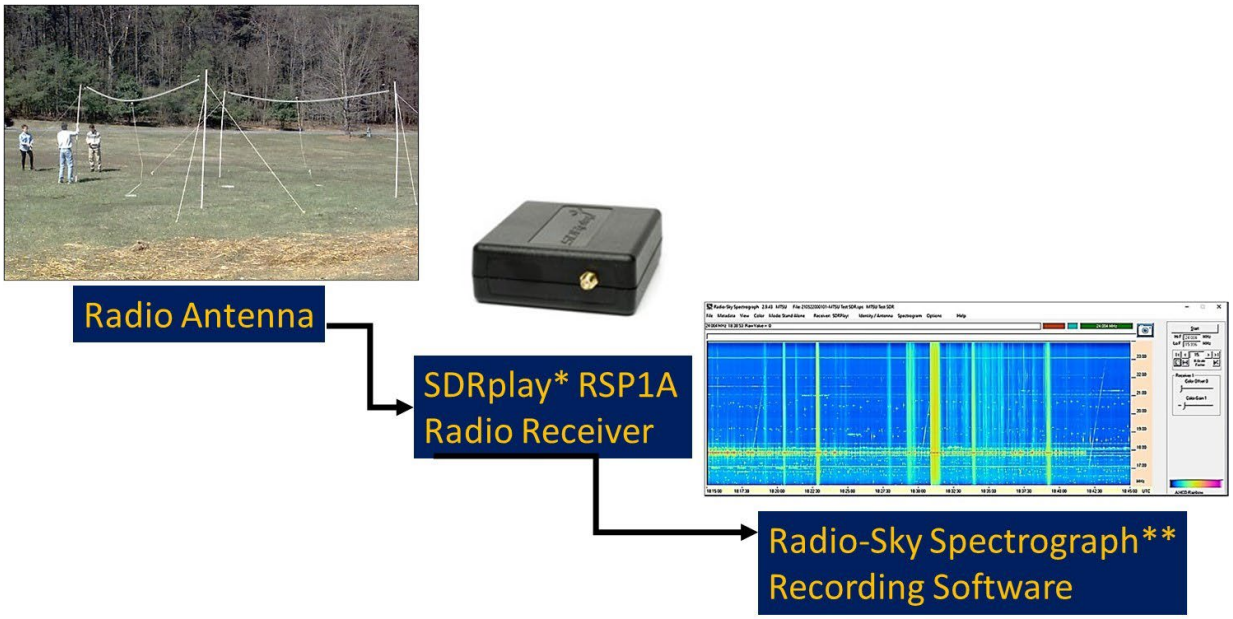
Radio JOVE 2.0

Radio Astronomy Telescope Kit using an SDRplay* RSP1A

Setup and Operation Manual



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Version 2.1

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

Contents

Introduction to Radio JOVE 2.0

Welcome to Radio JOVE 2.0, 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 2.0 is a follow-on to the successful Radio JOVE Project that distributed more than 2500 single-frequency radios allowing users to build their own radio receiver and antenna for education and outreach. Although no longer available for purchase, the original Radio JOVE receivers are still supported, and we have many in operation contributing data to our data archive.

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 2.0 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 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.

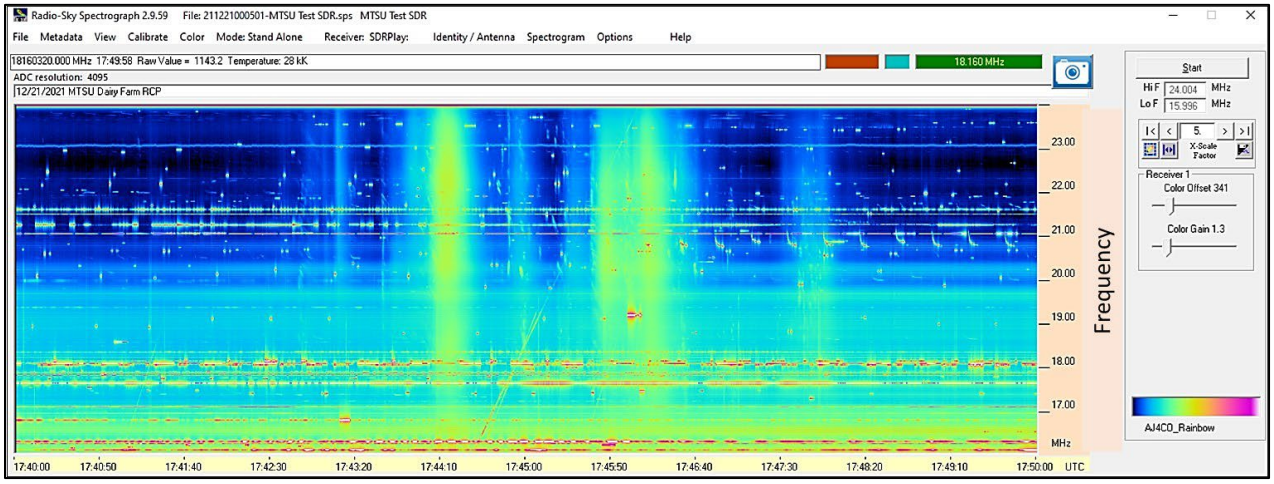

Figure 1. A frequency-time spectrogram showing multiple solar bursts on 21 December 2021. Data from C. Higgins, MTSU Dairy Farm.

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 must be amplified and filtered by the radio receiver (SDRplay model RSP1A). The SDR receiver, the accompanying software Radio-Sky Spectrograph (RSS), and the radio antenna, are designed to operate over an 8 MHz (megahertz) wide range 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 particular radio we are using is the SDRplay RSP1A. This radio 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 and its abilities.

Antenna

The antenna intercepts weak electromagnetic waves which have traveled hundreds of million 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 coaxial transmission line which minimizes losses and distortion.

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 wire, 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. Ideally, the computer should be dedicated to data collection when in operation, but it will depend on your computer's capabilities.

RADIO ANTENNA 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 spectrograph to help understand the hardware and software connections and the signal flow.

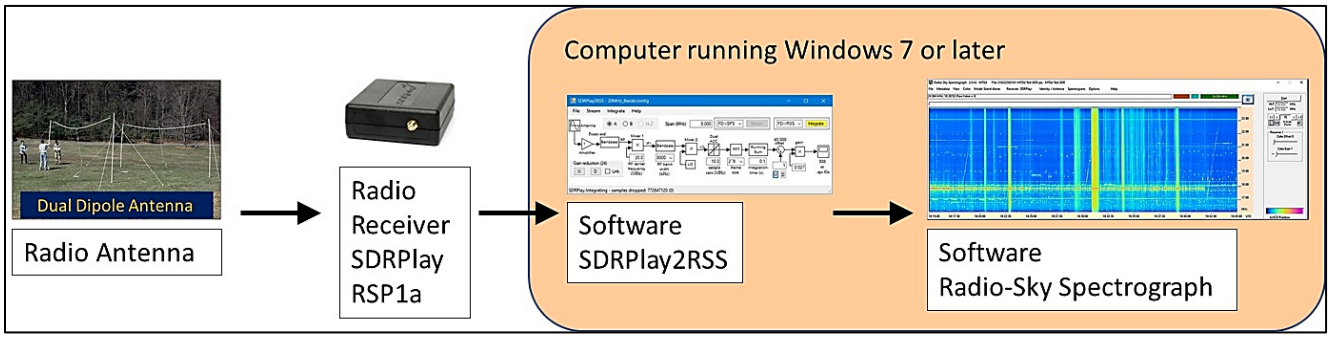

Figure 2. A block diagram of the Radio JOVE spectrograph.

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.

Table 1. Receiver Parts List

	Part Name	Suggested Part Supplier	Figure
1.	SDRplay RSP1A 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 or higher OS	Windows computer running Windows 7 or higher	

Part I. Radio JOVE SDRplay RSP1A Receiver Kit Setup Guide

Part I is an installation and setup guide. Part II is a Radio JOVE Software Supplement Guide.

A. Introduction – SDRPlay2RSS/Radio-Sky Spectrograph Software

This document will take you through the process of installing and configuring the software to get your Radio JOVE 2.0 kit working as a radio telescope. Three pieces of software are needed: (1) SDRuno is the commercial software to control the SDRplay radio, (2) SDRPlay2RSS software is custom-made intermediate software that controls the SDRplay receiver settings, and (3) the Radio-Sky Spectrograph (RSS) software displays and records the data as signal strength on a frequency versus time chart.

This document will take you through the process of installing and configuring SDRuno, Radio-Sky Spectrograph (RSS), and SDRPlay2RSS with the ultimate goal of utilizing a SDRplay receiver as a radio-science spectrograph. The Radio-Sky Spectrograph download also includes the SDRPlay2RSS software. These instructions were established using the SDRplay1A model receiver (they also work with the SDRplay2 model). *These instructions may not work for other SDR models*. Troubleshooting options are presented at the end of this section.

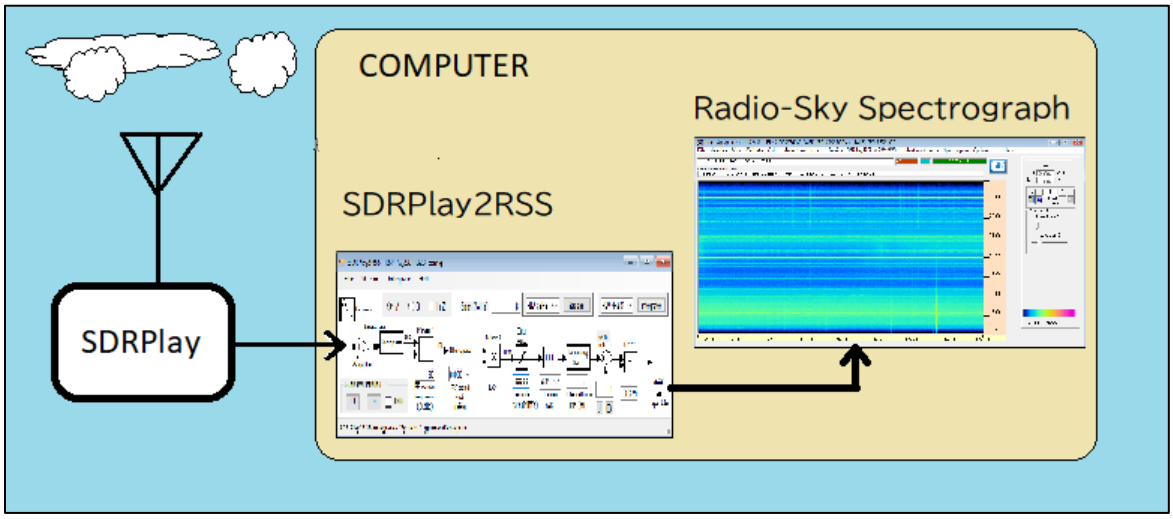

Figure 3. Diagram showing hardware and software connections.

RSS uses a separate program, SDRPlay2RSS, to gather spectral data from the SDRplay receiver and feed it to RSS for display and archiving (Figure 3). This

program, written by Nathan Towne, installs automatically along with RSS, and is our most tested tool for working with the SDRplay receivers.

Additional resources include:

a. Using SDRPlay2RSS
   http://radiojove.org/SUG/Pubs/Using%20SDRPlay2RSS,%20Sky%20(2021).pdf
b. The Radio-Sky Spectrograph Help File http://radiosky.com/spec/RSS_Help4.pdf
c. The SDRPlay2RSS Help File
   http://myplace.frontier.com/~nathan56/SDRPlay2RSS/doc/SDRPlay2RSS.html

B. Detailed Software and Hardware Setup

Important: follow these instructions in order. Do not connect the SDRplay radio to the computer until the software install routine tells you to connect it.

1. **Install SDRuno software**. Radio JOVE requires an older, working version of SDRuno and you can find the installer here: https://www.sdrplay.com/software/SDRplay_SDRuno_Installer_1.33.exe. [Radio-Sky Spectrograph software requires certain .dll files from an older version of SDRuno (i.e., from an older API); thus, we require SDRuno v1.41.1 or older. Version 1.33 is the oldest and smallest file version that SDRplay has for downloading on their website that works for us. If the above link does not work, you can find Ver 1.33 on Radio JOVE team member L. Dodd's website: https://tinyurl.com/SDRunoVer133.]
   a. For reference, the SDRplay website download page is found here: http://sdrplay.com/downloads. The *Legacy* Software is found at the bottom of the page https://www.sdrplay.com/dlfinishs/
   b. **Do not connect the SDRplay radio to the computer until the install routine tells you to connect it.** Connect the SDRplay radio to the computer using the USB cable and finish the software installation, and install all the plug-ins.

   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. **Connect** the SMA-to-BNC cable to the radio. **Connect** the antenna coaxial cable to the receiver using the F-to-BNC adapter (Figure 4). Figure 4 shows all the connections after the software is installed.

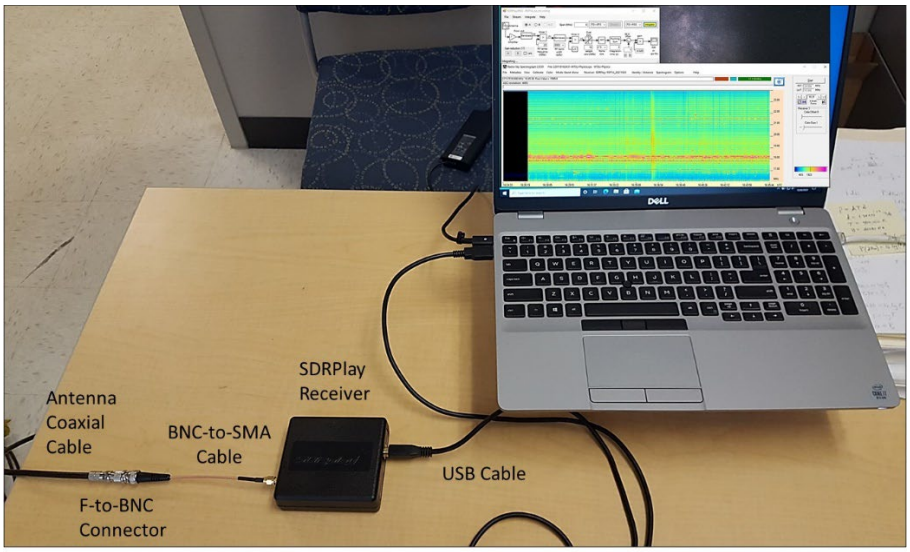

Figure 4. Receiver hardware setup showing the incoming antenna coaxial cable, the F-to-BNC connector, the BNC-to-SMA connector cable, the SDRplay receiver, the USB cable, and the computer.

3. **Start SDRuno** to verify that your radio is working.
    a. Click on the SDRuno icon on the desktop and multiple windows will open to let you control the radio. See Figure 5.
    b. The only requirements are Gain, Frequency, and Mode.
        i. (1) Set the Gain to Maximum, (2) Set the Mode to AM, and (3) Set the Frequency in Hertz (e.g., 1,080,000 Hz in Figure 5).
        ii. Unmute the audio and press “Play”. You should see a waterfall spectrum and you may hear the hiss of an untuned radio.

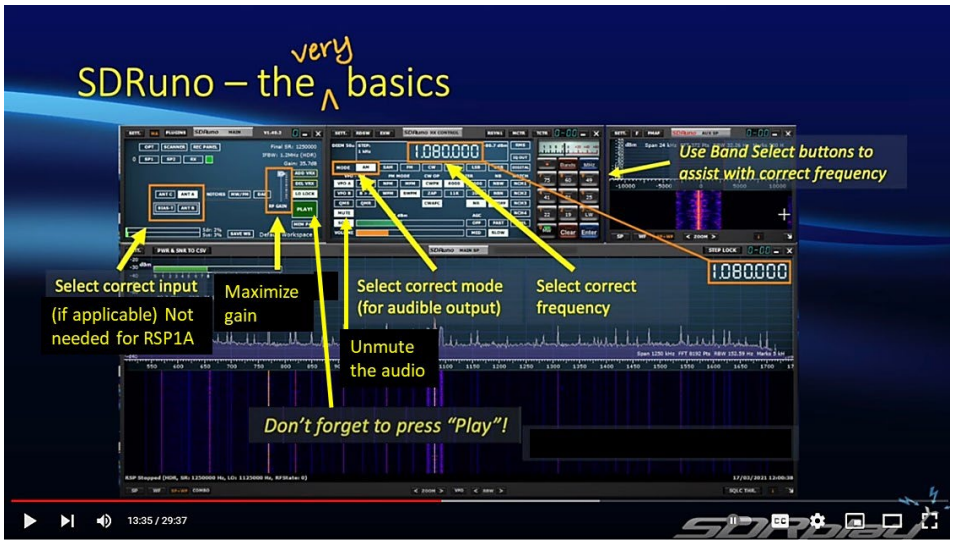

Figure 5a. A screenshot of the *SDRplay: SDRuno – The Basics* video highlighting the key settings to check that your radio is working.

4. After installing and successfully establishing that the SDRplay radio is working, **close SDRuno**. You may wish to use SDRuno as a flexible control program for your receiver and to test that the SDRplay receiver is functioning properly. However, SDRuno cannot be used when the SDRplay receiver is connected to Radio-Sky Spectrograph (RSS). You must close the RSS software to use the SDRuno software separately.

5. Download and install (in default directory!) Radio-Sky Spectrograph (RSS) **version 2.9.63** from https://www.radiosky.com/. The one-click download is here: http://radiosky.com/spec/Spectrograph_2_9_63.exe (This URL is case sensitive). If you get a warning, click *More Info* → *Run Anyway*. Proceed to download the software. *The Radio-Sky Spectrograph download also includes the SDRPlay2RSS software*.

6. After installing RSS on your Windows computer, it will automatically **run as *Administrator*** each time you run it. Select **Yes** in the User Account Control window to allow the software to run.

7. When you run RSS for the first time, click the ***Identity/Antenna*** menu and, at a minimum, fill in your name and observatory name (limit 20 characters), latitude, and longitude (Figure 7). Before sharing files, you should complete information thoroughly. Keeping good metadata is key to the usefulness of your observations.

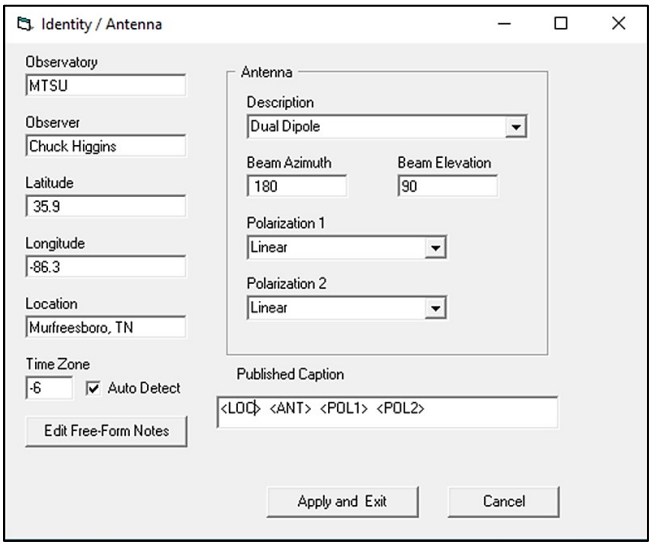

Figure 7. Set Identity and Antenna in the RSS software.

8. In RSS, Click on **Receiver** and select the **SDRplay** option. After selecting SDRplay option, open RSP1A_20211028.config from pop up window when asked to select new configuration. When you run the software thereafter you will see SDRPlay: RSP1A_20211028 (Figure 8).

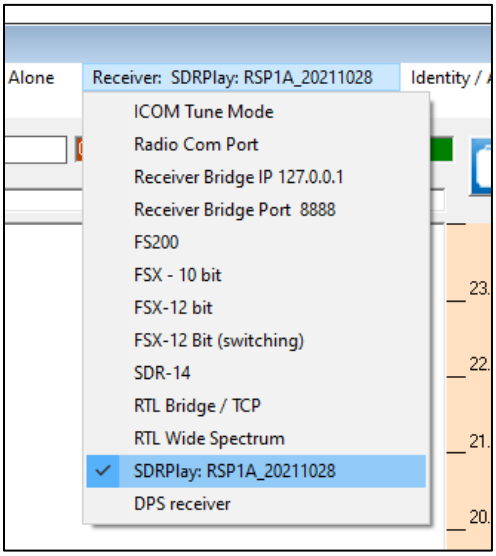

Figure 8. Receiver options in Radio-Sky Spectrograph

9. Select a configuration file for SDRPlay2RSS from the Windows File Explorer. Select the configuration file that corresponds to your receiver model *RSP1A_xxxxxxxx.config* or *RSP2_xxxxxxxx.config*. See Figure 9.

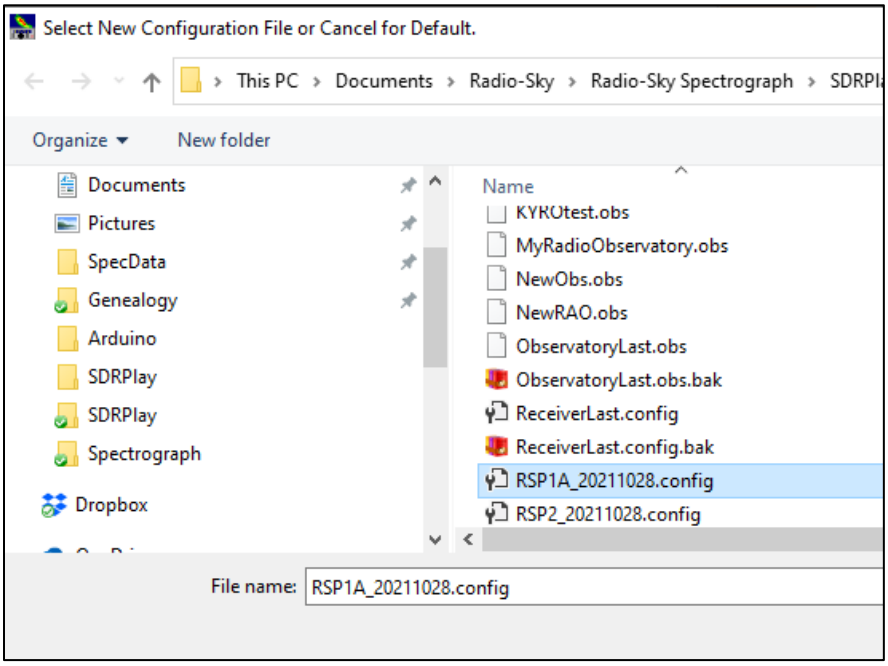

Figure 9. Configuration Files

10. Click the **Start** button in RSS. [You might get a Windows pop-up requiring a download of .NET Framework 3.5. Please download and let the .NET Framework 3.5 install. You might also be asked for observatory data requiring you to select a *.obs* file.]

    When an SDRplay receiver is selected in RSS and the **Start** button is pushed, RSS will check to see if SDRPlay2RSS is already running. After a few seconds the SDRPlay2RSS window will open and your spectrograph should begin taking data. The **Integrate** button in SDRPlay2RSS should be yellow and you should see the spectrogram scrolling in RSS (Figure 10). This can take several seconds. If this doesn't happen see the Troubleshooting section that follows.

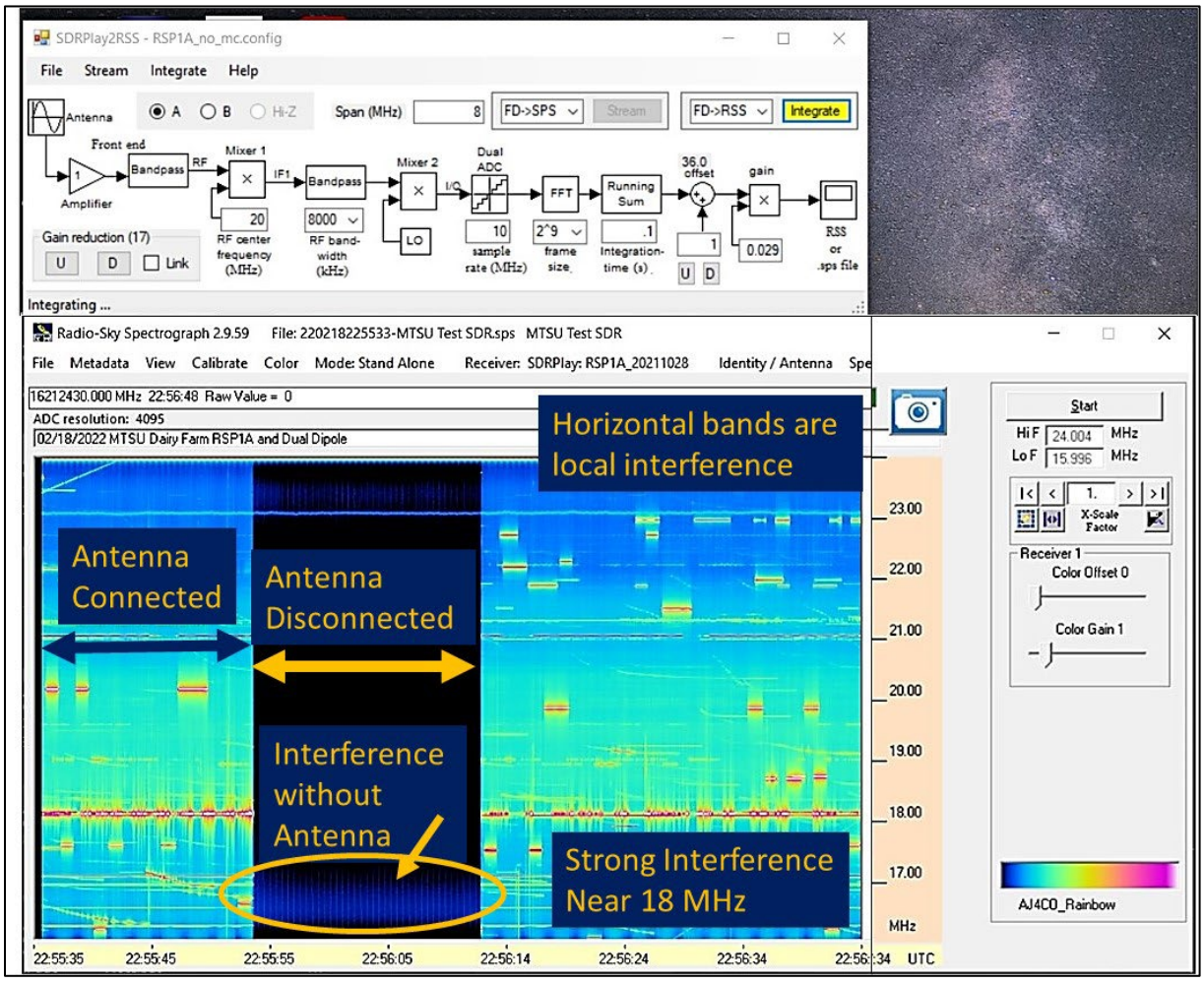

Figure 10. Example spectrograph output using RSS display software. Note the SDRPlay2RSS software window open with the Integrate button turned yellow. The antenna was disconnected and reconnected showing a good color spectrogram.

Some Key Tips for Normal Operation

a. Once the **Integrate** button turns yellow, there is no need to turn it off in SDRPlay2RSS every time you stop saving data. In other words, after the Integrate button turns yellow, RSS can start and stop collecting data without doing anything in SDRPlay2RSS.

b. *The configuration files used in this setup give the best settings within SDRPlay2RSS for a standard Radio JOVE setup.* However, the settings within SDRPlay2RSS may require some optimization for your particular radio and antenna. Understanding the various parameters that may be adjusted will help you produce the best observations. This information can be found below in Part 2A *Using SDRPlay2RSS* and in the **Help** menu in SDRPlay2RSS.

11. If you have not already done so, connect your radio antenna to your SDR receiver. Figure 10 shows a nearly blank spectrograph chart without an antenna connected from 19:38:01 to 19:39:31. At 19:39:31 the dipole antenna is connected, and a good color spectrogram is seen.

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 64 MB in size (about 2 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 the Setup

- "I get an 'ArgumentException' error."
  Possible sources of these errors are antivirus programs, computer and hardware anomalies, operating system versions, or software issues. A likely cause is if you do not have the correct version of the SDRuno software installed. The Radio JOVE January 2023 newsletter outlines steps that have proven effective in resolving these errors: https://radiojove.gsfc.nasa.gov/newsletters/2023Jan/index.html#3.

- "RSS won't start or ends with an error."
  Are you running RSS *As Administrator*? Running in administrator mode is essential for this program to function. See Step 4 above.

- "I don't see data scrolling but neither do I see errors displayed." To be sure that RSS isn't just saturated to one color (white). Look at the red status box above the upper spectrogram. This is the number of spectra or sweeps that have been received. If it is incrementing, data is being received. Try increasing the **Color Offset** control in RSS. This should make the spectrogram visible, if that is the problem. It is also possible that one of the settings in SDRPlay2RSS needs to be adjusted.

- "SDRPlay2RSS won't start. I don't see a window for it." There is a desktop icon for SDRPlay2RSS. Try starting it from there. No luck? SDRPlay2RSS.exe is probably already running in the background, just not displayed. The program did not close down properly the last time it was used. This seems to be common fault in Windows. You can open the **Windows Task Manager** and force the program to close with **End Task**. SDRPlay2RSS (32 bit) may appear in either *Apps* or *Processes* list in Task Manager.

- "I see both programs but nothing happens." Starting and stopping SDRPlay2RSS may sometimes result in a locked condition where SDRPlay2RSS is visible but refuses to resume "integrating". Try closing and re-starting RSS and SDRPlay2RSS. Stubborn cases may require rebooting.

- "SDRPlay2RSS runs but then stops with an error message in the status bar". When this happens, the most likely cause is that the computer processor failed to keep up with the data stream arriving from the SDRplay receiver.

This problem can be triggered by a human interaction with the program while it is running, such as selecting a menu item. Other programs running on the same computer may require too much of the CPU's attention and cause this crash. In SDRPlay2RSS, click on the Integrate menu item (not the button) and select the drop-down list for re-tries (may be unlabeled) and try selecting 3 or above. See Figure 11.

- "I don't see my problem here. Where can I look for clues?" SDRPlay2RSS produces two trouble logs that can be helpful in resolving an error. When the program stops select Help / SDRPlay2RSS.log. The text log will appear in Notepad. Scroll to the bottom for the most recent error. For example;

```
2021-10-30T22:56:24 ============================== ArgumentException
SDRPlay.integrating - ReadPacket failed 1 times, mir_sdr_HwError.
   at SDRPlay2RSS.SDRPlay.Integrating(Double integrationtime, Double recordfreqstart, Double
recordfreqend, rspConfig& devconfig, Double triggeredduration, ObservatoryData obs, DataSinkType
datasink, Int32 retries, String filepath, String tapspath, Double integrationblocksize)
   at SDRPlay2RSS.SDRPlay2RSS.IntegrateButton_Click(Object sender, EventArgs e)
```

While this log entry may seem formidable, the error description can be useful in troubleshooting the current problem. The error shown above is the typical result of data dropped because the computer could not keep up with incoming data. This "ReadPacket failed" error commonly occurs due to a busy state (increase Retries as above).

HELP! – if it still doesn't work – Contact Information

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.

Part II. Radio JOVE Software Supplement Guide

Part I above should get your radio telescope working with the best initial settings for the SDR software radio and the RSS spectrograph display. Part II is a supplement for those that need to fine tune their settings to get optimum performance out of the radio and the best spectrograph display.

A. Using SDRPlay2RSS

To gain full advantage of the software, you should familiarize yourself with some of the numerous settings in both SDRPlay2RSS and Radio-Sky Spectrograph (RSS) (see Figures 11 and 12). If you haven't already installed software, see the setup guide above in Part 1C Detailed Software and Hardware Setup.

In addition to the Part I Setup Guide and Part II Operations Guide, you may also access these Help Files:

1. The Radio-Sky Spectrograph Help File
   http://radiosky.com/spec/RSS_Help4.pdf
2. The SDRPlay2RSS Help File
   http://myplace.frontier.com/~nathan56/SDRPlay2RSS/doc/SDRPlay2RSS.html

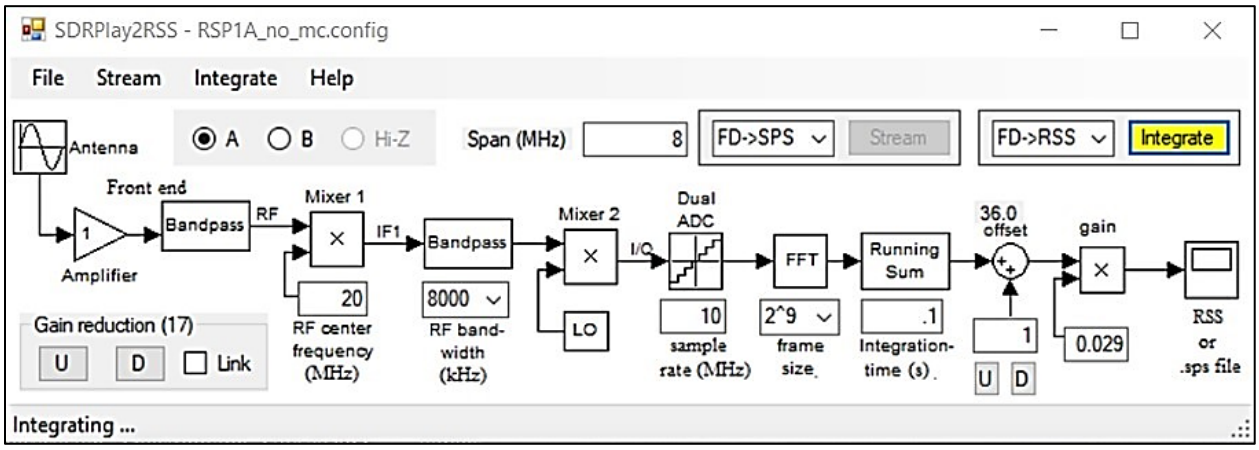

Figure 11. SDRPlay2RSS window showing the signal path of the radio and software with adjustments along the path. Note the yellow Integrate box.

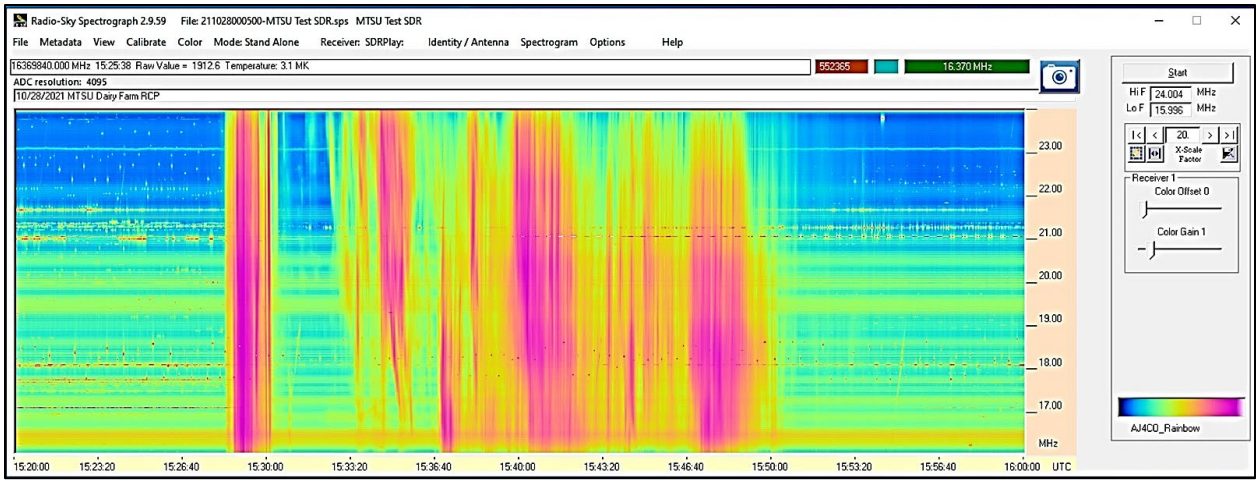

Figure 12. RSS window showing the menu of options at the top and to the right of the frequency versus time display. The display shows multiple solar bursts.

B. Starting SDRPlay2RSS

SDRPlay2RSS is a separate program (executable file) from RSS. The SDRPlay2RSS exe file lives in the SDRPlay sub-directory of Radio-Sky Spectrograph. ("*C:\Program Files(x86)\Spectrograph\SDRPlay*"). When an SDRplay receiver is selected in RSS and the **Start** button is pushed, RSS will check to see if SDRPlay2RSS is already running. If not, RSS will try to start SDRPlay2RSS. Once started, RSS will automatically press the **Integrate** button in SDRPlay2RSS to begin the data collection process. (If this process fails, see the troubleshooting section of Part I. Setup Guide.)

Once SDRPlay2RSS is running, it will stay open until it is manually closed. The **Integrate** button should stay yellow (= on) until it is manually pressed or an error occurs that disables it.

You may also want to start SDRPlay2RSS manually at times. To do this, you can use the desktop shortcut that was installed with RSS. If you manually open SDRPlay2RSS.exe this way, you will have to press the **Integrate** button to start the data streaming from the SDRplay receiver.

C. Configuration

As briefly described in Part I Setup Guide, SDRPlay2RSS saves its settings in a configuration file. Default configuration files are provided for the SDRplay1A

and SDRplay2 receivers (see Figure 10). These settings are the best settings for the standard Radio JOVE setup with a dual-dipole antenna.

However, advanced users may modify these settings for your particular location and different antenna. Getting the correct settings may require some patience and numerous trials.

D. Color

Before adjusting your SDRPlay2RSS settings, you should set color controls in RSS (see the right side of Figure 12). Set the **Color Offset** to zero and set the **Color Gain** control to one. These controls in RSS affect how the colors are mapped to the signal strength data received from SDRPlay2RSS.

1. **Color Offset** subtracts a given value from the incoming data, removing background environment and receiver noise.
2. **Color Gain** multiplies the remaining signal by some value so that small signal enhancements are spread over a wider range of colors.

The values saved in the RSS data files are those received from SDRPlay2RSS and are not affected by the RSS Color Gain and Offset. It is best to make adjustments in SDRPlay2RSS to display the range of colors you expect to see. *That is, the color and offset controls of RSS determine only the visual settings for the display and do not affect the raw data that is saved*.

The colors you see depend on a *color file* which you load into RSS, and several color files are provided to choose from. The default color file is “AJ4CO Rainbow” and using it will be helpful when comparing results with other observers (see Figure 12 lower right and Figure 13). 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.

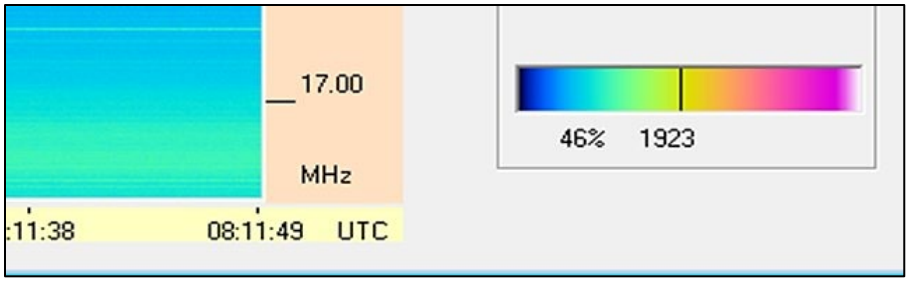

Figure 13. Color mapping of the data occurs in RSS. The AJ4CO Rainbow color palette is shown on the right. The 4096 colors are mapped to the 12-bit values coming from SDRPlay2RSS. Here you see where 1923 falls on the spectrum.

E. Receiver Dynamic Range

It is important to adjust the SDRPlay2RSS software controls so that the SDRplay achieves a wide receiver dynamic range **(RDR)**. By **receiver dynamic range,** we mean the difference in signal strength between the weakest and strongest received signals that can received. The Config files (Step 8 above and Figure 9) should give the best RDR for Radio JOVE system. Adjustments to the RDR should only be made by advanced users.

Here is an example of RDR: if the galactic background at the antenna feed point is 50kK (50 thousand Kelvin) and a very strong solar burst is 50 Mk (50 million Kelvin) we need a RDR of at least a thousand to one (30 dB). This represents the necessary dynamic range of the SDR receiver itself. If a signal exceeds the peak of the dynamic range the receiver will saturate – this means that as the input signal continues to increase in strength the output of the receiver will be maxed out and will not increase.

To repeat a point above, the controls in SDRPlay2RSS determine the dynamic range of the system and affect the raw data while the color and offset controls of RSS determine only the visual settings for the display and do not affect the raw data that is saved.

SDRPlay2RSS Controls affecting RDR include (see Figure 9):

1. **Gain Reduction** – applies attenuation to signals entering the receiver. **The recommended Gain Reduction setting is 17.** Increasing Gain Reduction lowers the amount of signal and allows you to receive stronger signals

without overloading (saturating) the receiver. At the same time, increasing Gain Reduction lowers the receiver's sensitivity to weak signals. To increase weak signal sensitivity, you lower Gain Reduction. *We recognize that this is confusing so be careful when adjusting the Gain Reduction.* Use the U and D buttons in the Gain Reduction box.

2. **Offset** – adds or subtracts a fixed value from the processed data. **The recommended Offset is 36.0.** Use the Offset adjustment to set the baseline level. You will likely adjust the Offset to counter or supplement the "brightness" affected by the Gain Reduction and Gain controls. Use the U and D buttons below the Offset icon. You can change the size of Offset steps in the associated text box.

3. **Gain** – is a signal strength multiplier. It is usually much less than one and is applied after the Offset is applied. **The recommended Gain setting is 0.029.** Increasing the Gain value will increase the signal output, making weak signals relatively stronger, while at the same time decreasing the RDR at the top end. You may type a Gain value at any time in the text box below the Gain stage however, the setting will not register your change until you press Enter.

F. Other Settings (see Figure 9)

1. **Center Frequency** – The center frequency you use will be determined by your research objective and by the bandpass characteristics of your antenna. The default center frequency in the Radio JOVE configurations is 20 MHz. The center frequency and width in SDRPlay2RSS determines the values that will appear in the Hi F and Low F boxes in RSS.

2. **RF Bandwidth** – For Radio JOVE leave at 8000 kHz (8 MHz).

3. **Sample Rate** - Must be higher than the RF Bandwidth. For Radio JOVE set to 10 MHz.

4. **Frame size** is the number of frequency channels generated in the spectrogram. The number of channels displayed in RSS is generally fewer than the number generated in the FFT. For reference, we normally use 300 channels in a custom-built analog sweeping spectrograph, each with a

bandwidth of 30 kHz. A frame size of 2^9 is suggested but no higher than 2^9. Higher values might seem to be working but Spectrograph (RSS) is not saving the data properly. If this setting causes the RSS display to exceed the vertical size of your monitor screen, then reduce the frame size to 2^8.

Frame size	Number of channels Generated	Number of channels Displayed	Channel width (kHz)
2^7	128	102	78.1
2^8	256	204	39.1
2^9	**512**	**410**	**19.5**

5. **Integration time** controls the number of transforms that are averaged together. The longer the integration time the better the sensitivity. For normal Jupiter and Solar observations an integration time of 0.1 seconds is recommended. Fast events such as Jupiter S-bursts may be resolved with shorter integration times (tens of milliseconds) and slowly varying features such as Cassiopeia-A radio scintillations will benefit from longer integration times (tens of seconds). For more information on Jupiter or Cassiopeia radio emissions, see the Radio JOVE website.

6. **Integration Menu** – The following settings are standard for Radio JOVE:

    a. The unlabeled (in version 1.0.39) drop-down list of numbers is for **Retries** and refers to the number of attempts made by SDRPlay2RSS to send data to RSS before giving up and terminating. On an average i5 level computer this problem can arise whenever the computer becomes busy. Setting the Retries to 3 seems to fix this problem (Figure 14).

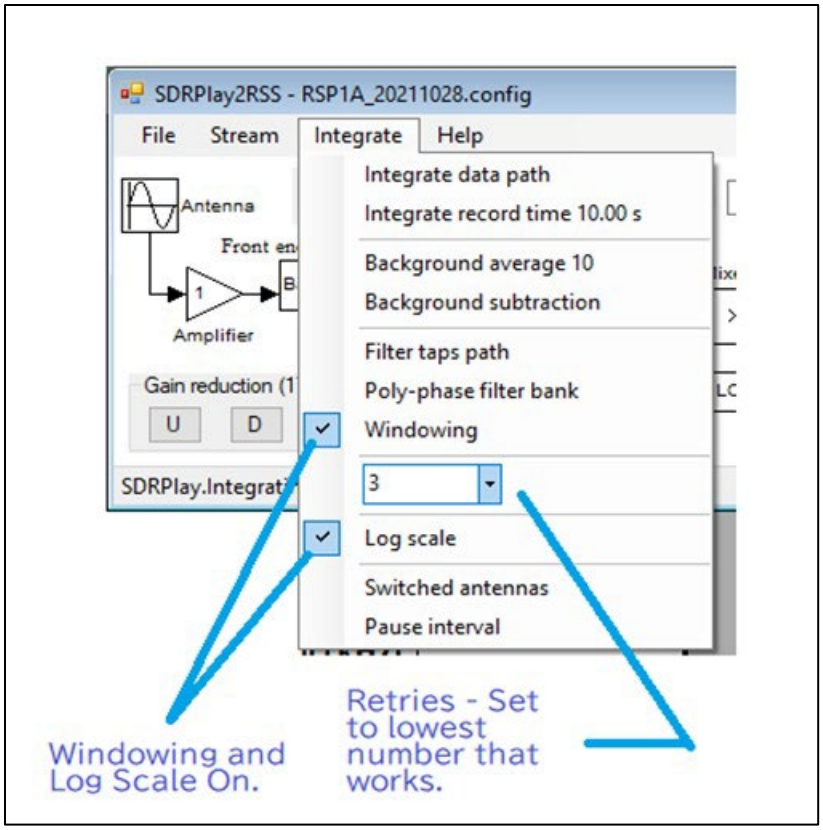

Figure 14. Integration menu with the settings for Radio JOVE.

b. **Windowing** and **Log Scale** should be turned on.

c. Your SDRplay receiver has the ability to supply a DC bias voltage on the coax for remote amplifiers. You will find the **Bias T** option under **File** in SDRPlay2RSS. For Radio JOVE antennas, the bias should be **off**.

7. **Important:** *Once you have established your settings, do a **File / Save As** and save your new configuration file with a new name. Select this file as the default SDRplay configuration in RSS. In case you need it, the original configuration file is saved as a .bak file.*

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 (SDRPlay2RSS with yellow Integrate button and RSS software Started) disconnect your antenna from the SDRplay receiver. The spectrograph will go nearly black (Figure 15). 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 15. Figure 15 shows many horizontal bands of interference and a particularly strong one near 18 MHz (see also Figure 12). Some horizontal banding is normal. Figure 15 shows a weak solar burst as the near vertical band in the spectrogram.

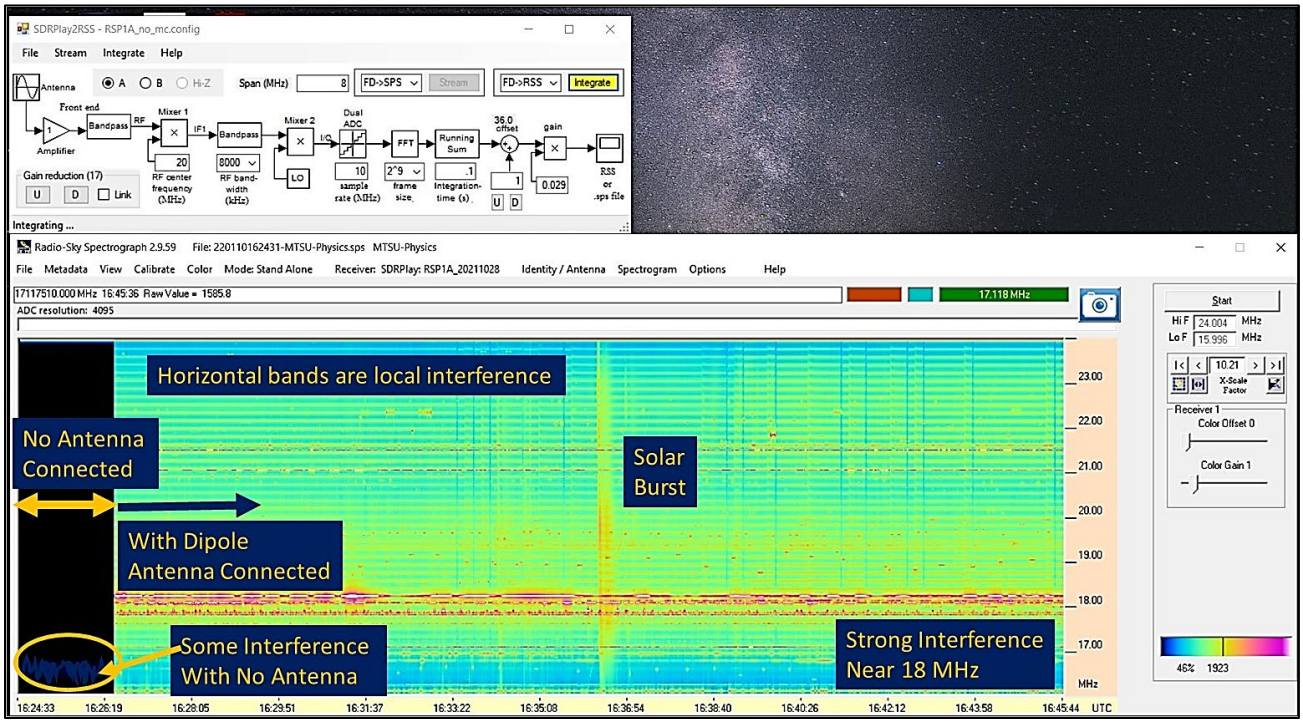

Figure 15. Example Radio JOVE spectrograph output using RSS display software.

2. **Second Test: Receiver test using the SDRuno software**

    a. **Start SDRuno** - Start this software separately without RSS software - Click on the SDRuno icon on the desktop and multiple windows will open to let you control the radio. See Figure 5.
    b. **Set the Gain, Frequency, and Mode** - The only requirements to check your receiver are Gain, Frequency, and Mode.
        i. Set the Gain to Maximum
        ii. Set the Mode to AM
        iii. Set the Frequency in Hertz (e.g., 1,080,000 Hz in Figure 5).
        iv. Unmute the audio and press "Play". You should see a waterfall spectrum and you may hear the hiss of an untuned radio.

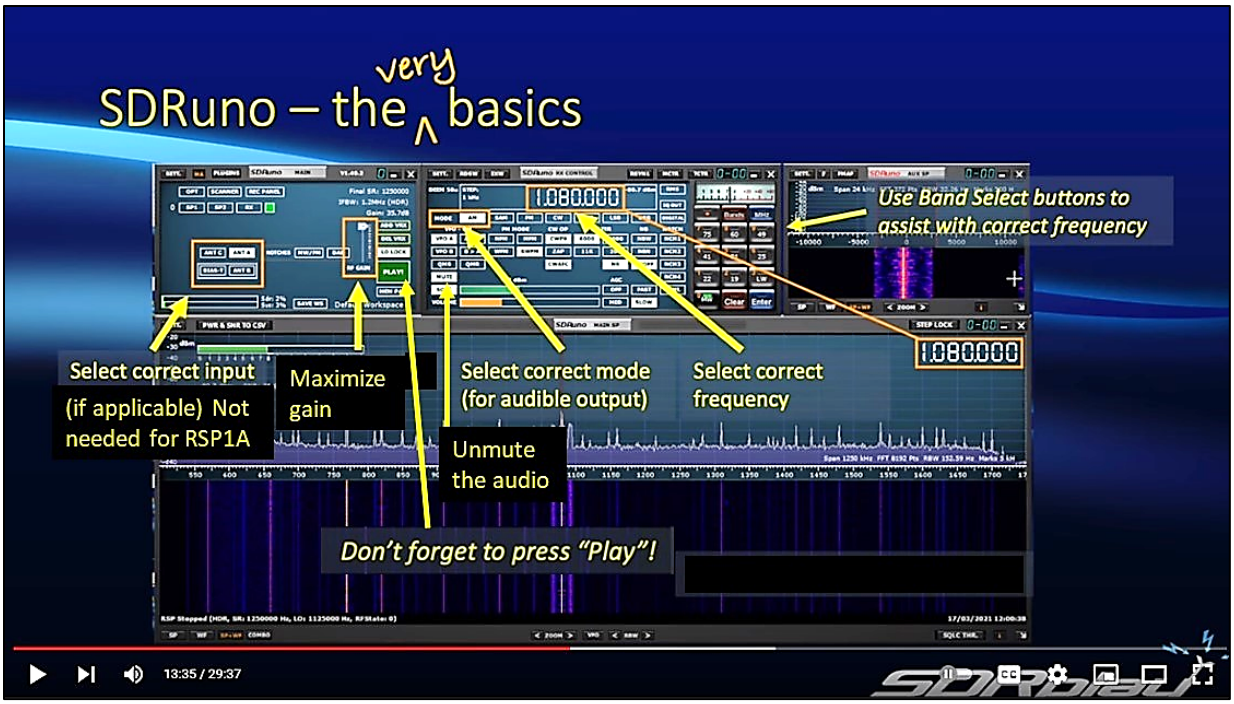

Figure 16. A screenshot of the *SDRplay: SDRuno – The Basics* video highlighting the key settings to check that your radio is working.

3. **Third 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

is a good sign you are picking up distant radio signals. The spectrogram in Figure 17 shows 3-4 sweepers and several solar bursts.

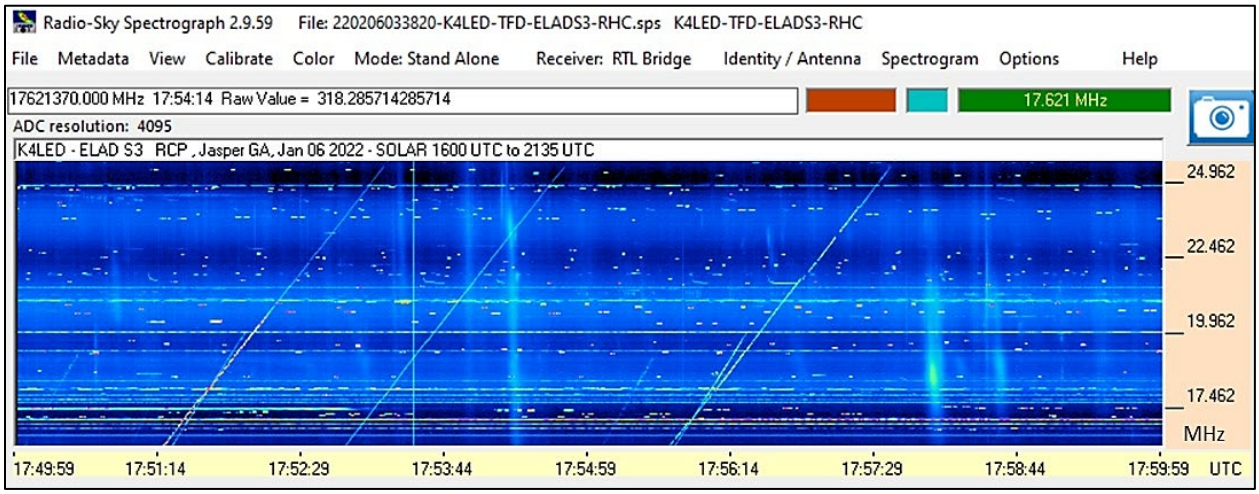

Figure 17. An SDR spectrograph showing several solar bursts as the near-vertical "wispy" bands. Several positively sloped "sweeper" radar signals are seen. (L. Dodd, 2022)

b. Interference – horizontal bands are local interference local radio stations or from electrical sources like power lines, lights, and HVAC systems. The spectrum in Figure 18 was obtained with an antenna very close to a building.

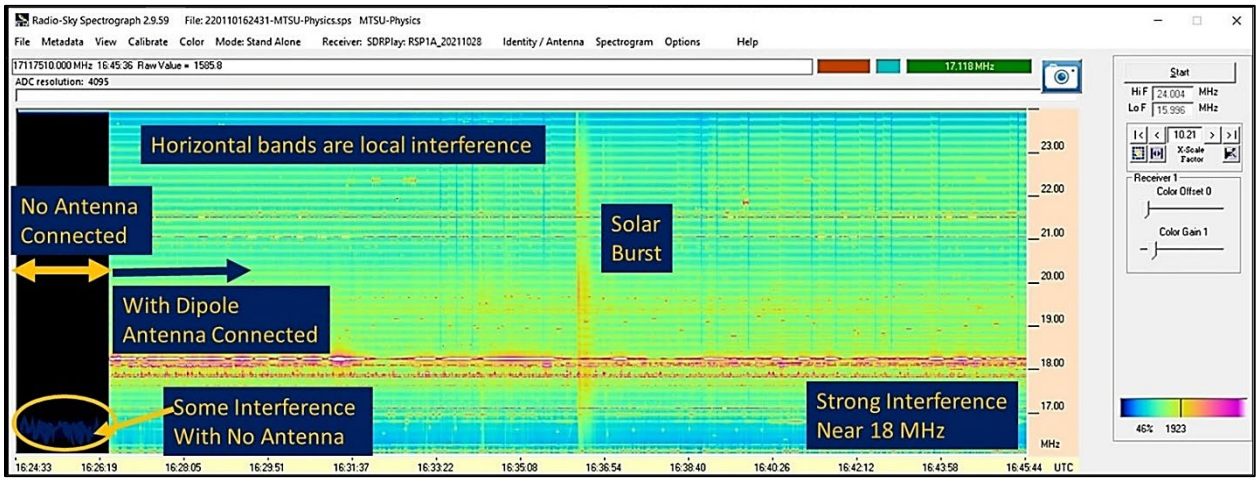

Figure 18. Example Radio JOVE spectrograph output using RSS display software. Note the large increase in signal denoted by the colored background after the antenna is connected. Horizontal bands are local interference, some very strong near 18 MHz. A solar burst is seen at the center as the near-vertical "wispy" band. (C. Higgins, 2022)

The spectrum in Figure 19 is a 24-hour graph showing the difference between nighttime and daytime interference. The conditions are fairly 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.

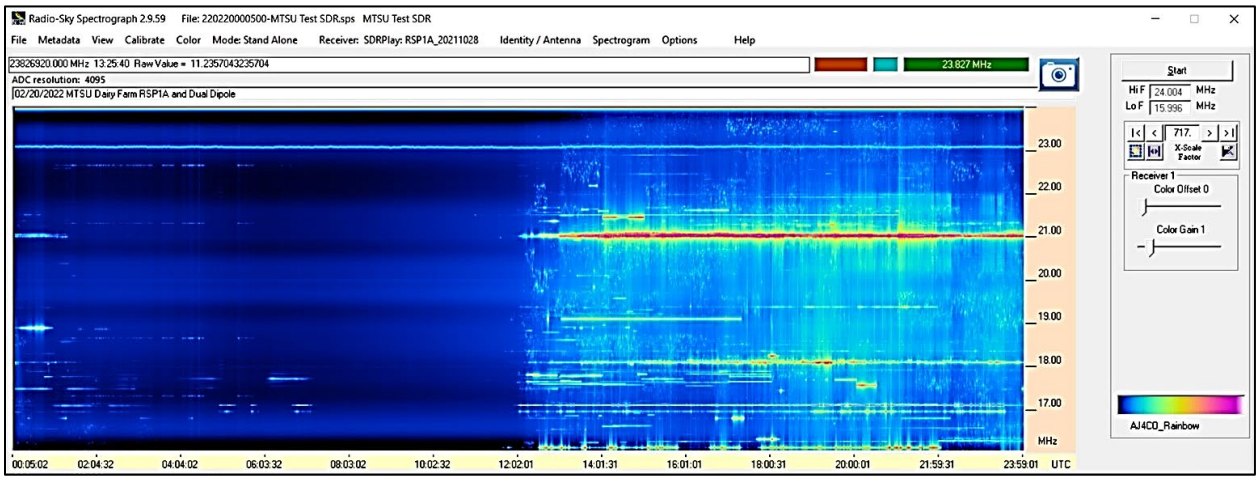

Figure 19. Example 24-hour Radio JOVE spectrograph output using RSS display software. Note the clear difference in the nighttime observations on the left and the daytime observations on the right. Local interference is more prevalent during the daytime. (C. Higgins, 2022)

c. Solar bursts show as broadband (near vertical) “wispy” signals on the spectrograms (Figure 20).

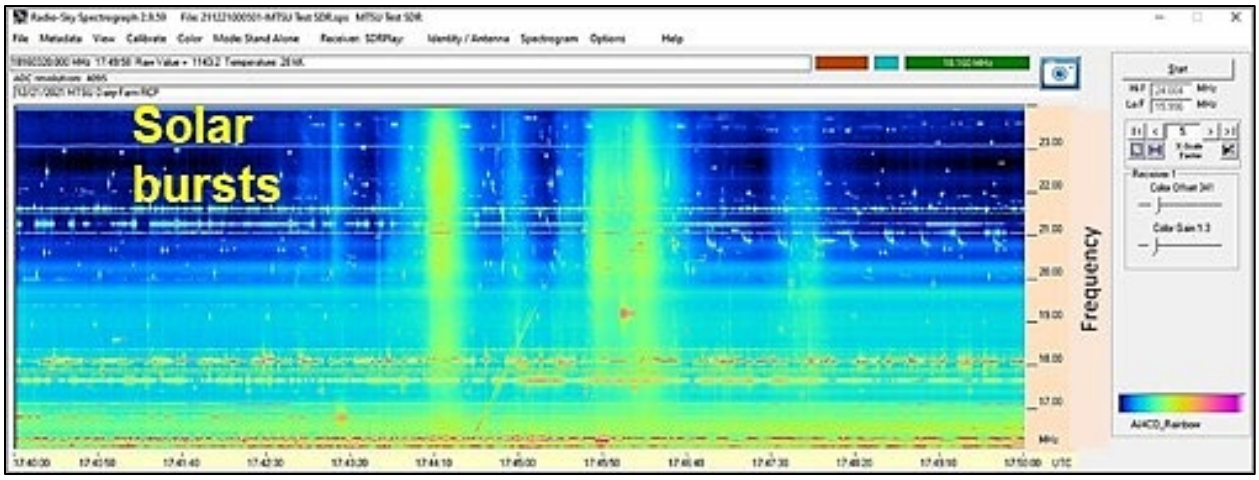

Figure 20. A Radio JOVE spectrograph showing multiple solar bursts as the near-vertical “wispy” bands. Spotty interference occurs at several frequencies, with more interference below about 18 MHz. A positively sloped “sweeper” radar signal is seen near the center of the spectrograph. (C. Higgins, 2021)

d. Jupiter bursts show as broadband bursts signals sometimes drifting upward or downward on the spectrograms (Figure 21). The signals are generally weaker than solar bursts, but usually show more spectral structure.

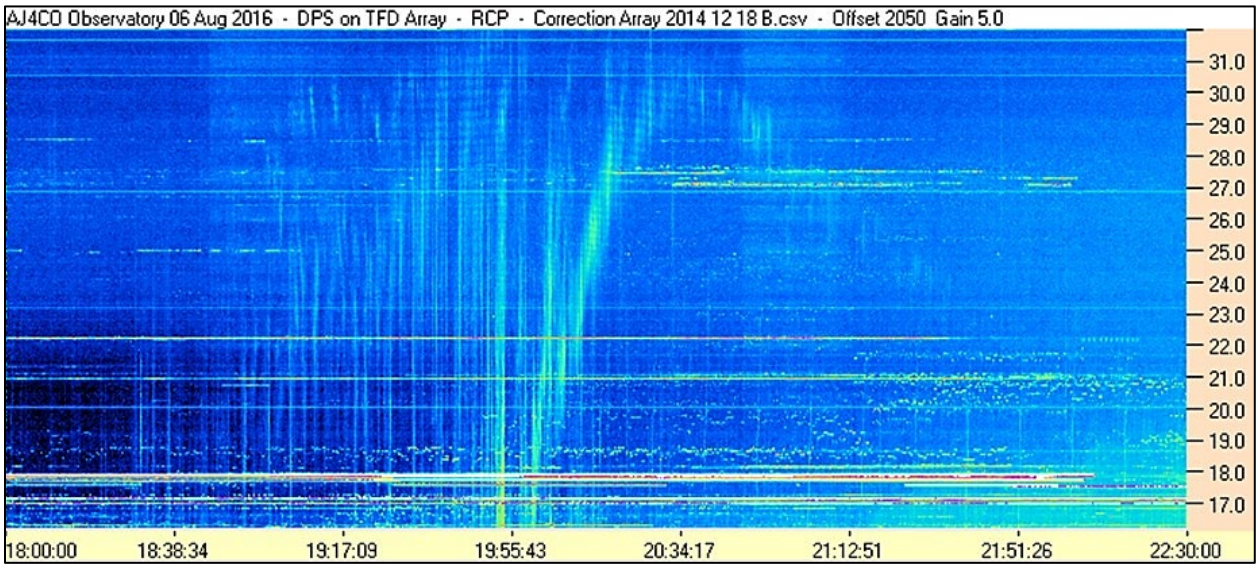

Figure 21. A custom built 16-32 MHz wide band spectrograph shows a Jupiter Io-B emission event over a span of 4.5 hours (D. Typinski, 2016).

APPENDICES

I. SDRplay RSP1A Receiver Specifications

The SDRplay RSP1A Specification Sheet is found here:
https://www.sdrplay.com/docs/RSP1Adatasheetv1.9.pdf

BANDWIDTH: the RF bandwidth is 10 MHz
NOISE FIGURE: 15 dB (at 20 MHz)
FREQUENCY RANGE: 1 kHz – 2 GHz

II. SDRuno Software Help

If you are new to SDR receivers, the SDRplay website has tutorials to help you learn how SDRuno software functions.

1. SDRuno software download: https://www.sdrplay.com/softwarehome
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/

III. Calibrating the Frequency Display

There is an easy procedure to use a WWV or CHU signal to calibrate the frequency display in SDRuno.
Using SDRuno to calibrate your RSP (3:34)
https://youtu.be/TjQLWPUR5us