



Sensing the World Around You

A Windows-Based Technical Guide for the
RTL-SDR Activities



Acknowledgements

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Antenna base and antenna by Douglas Brown (2021).
SDR dongle by Douglas Brown (2021).

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Chapter 1: Materials and Resources

RTL-SDR Dongle-- Nooelec NESDR Smart HF Bundle. The guide was created with this one but others will probably work just fine.

A Windows PC with minimum

- Dual Processor with 1 GB or more of memory,
- Windows 7 or newer.
- USB 2.0 recommended Intel i3 or newer.
- Microsoft .NET 4.6 or newer,

*The software used in this module is incompatible with Windows XP and MAC OS.

Software (Links last checked 6/25/23)

Chapter 2

- .NET <https://dotnet.microsoft.com/en-us/download/dotnet/7.0/runtime>
- SDR# <https://airspy.com/download/>

Chapter 3

- RTL 1090 <https://rtl1090.com/>
- Virtual Radar Server <http://www.virtualradarserver.co.uk/Download.aspx>




Chapter 4

- VB Cable <https://vb-audio.com/Cable/index.htm>
- WXtoImg <https://www.wraase.de/wxtoimg/>

Chapter 2: Setting up SDR and the Antenna

Software-defined radio (SDR) is a radio communication system where information is received and decoded on a personal computer. This chapter contains instructions for the foundational SDR software and hardware set up.

Hardware Setup

<ol style="list-style-type: none">1.2.	<ol style="list-style-type: none">1. Assemble the antenna by screwing the telescoping monopole onto the threaded base (Figure 1).2. Remove the protective covers from the connectors on the SDR dongle	 A photograph showing a silver telescoping antenna with a black base. The antenna is extended and has a small black cap on its tip. The base is a black circular component with a threaded hole in the center.	<p>Figure 1 The telescoping antenna (above) and threaded base (below)</p>
<ol style="list-style-type: none">3.	<ol style="list-style-type: none">3. Screw the connector at the end of the antenna cable to the matching threaded connector on the dongle (Figure 2).	 A close-up photograph of the antenna's SMA connector on the left and the SMA connector on the SDR dongle on the right. The dongle is black with 'n0oelec' and 'NESDR SMART' printed on it.	<p>Figure 2: The ends of the antenna (left) and dongle (right) to be connected.</p>
<ol style="list-style-type: none">4.	<ol style="list-style-type: none">4. The completed assembly can be seen in figure 3.	 A photograph of the completed SDR setup. The antenna is attached to the base, which is connected to the SDR dongle via a black cable. The dongle has a USB-A connector on one end and the SMA connector on the other.	<p>Figure 3 The completed assembly.</p>

Installing Supporting Software

1. Download the most recent version of the .NET redistributable (currently 7.0) should be downloaded or installed before installing SDR# from <https://dotnet.microsoft.com/en-us/download/dotnet/7.0/runtime> (last accessed 6/25/23)

- From the “Run desktop apps” selection, click the “Download x86” version (Figure 4). As SDR# is a 32 bit application, there have been problems with the 64 bit version of .NET; the 32 bit “x86” version has been more reliable.

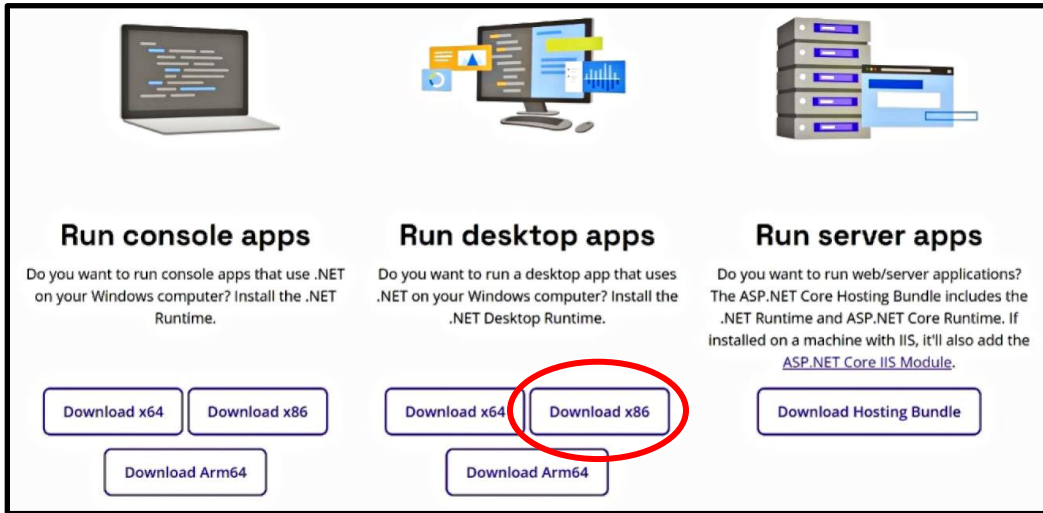


Figure 4 The .Net download screen. For best results select x86

- Once the file has downloaded, double click to run the installation.
- Restart computer

Installing Zadig Driver

Installing SDR#

- Go to <https://airspy.com/download/> and click on the “download” button.
- Extract (unzip) sdrsharp-x86.zip into the folder you created earlier.
- Double click on install-rtlsdr.bat from within the extracted folder (Figure 5). This will start a command prompt used to download all required drivers. The command prompt will automatically close.
- Plug in the dongle and wait for any plug and play pop up to complete installation.
- In the folder where the sdrsharp files were extracted to, find the file called zadig.exe. Right click the .exe file and select “Run as administrator”.
- In the Zadig application, in the menu bar navigate to Options
- In the pop up that appears: Ensure that “List All Devices” is checked.

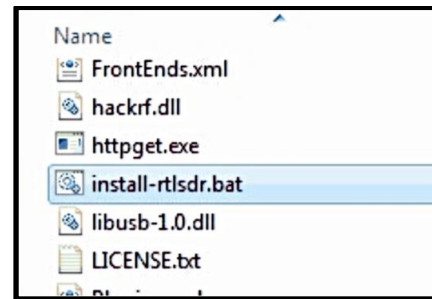


Figure 5 To install SDR# double click on “install-rtlsdr.bat”

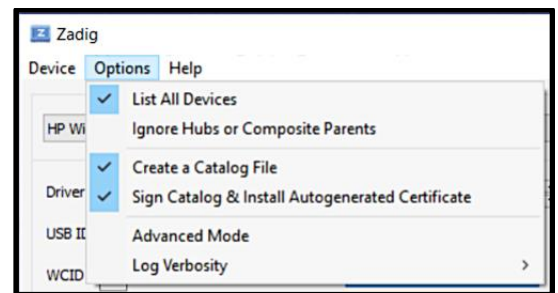


Figure 6 Correct configuration within the options menu.

Ensure that “Ignore Hubs or Composite Parents” is unchecked. (This is necessary to run the RTLSDR Scanner used in later steps.) (Figure 6)

8. Select RTL2832UHIDIR or RTL2832U from the drop down list in the center of the Zadig dialog box. Do NOT select “Bulk-In, Interface (Interface 0)”, “Bulk-In, Interface (Interface 1) ” or “USB Receiver (Interface 0)”. Also, ensure that WinUSB is selected in the box next to where it says driver. (Figure 7).

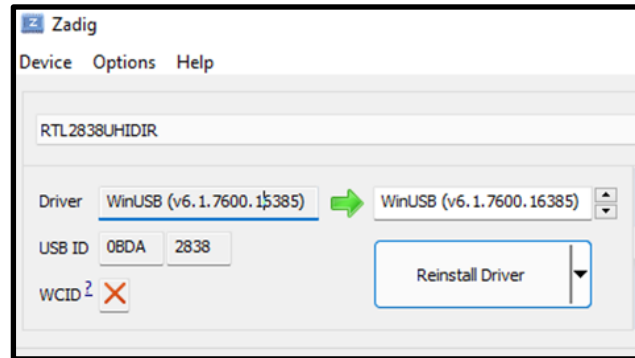


Figure 7 Correct configuration for driver selection.

9. Click Install Driver or Replace Driver. A warning may appear saying that the publisher cannot be verified, but click “Install this driver software anyway”. IMPORTANT: This driver has only been installed onto the USB port that the dongle is plugged into. Note which USB port has the dongle plugged into. If the dongle is moved to another port, or an additional dongle is used, zadig.exe will need to be installed for any USB port used.
10. Open SDRSharp by clicking on the SDRSharp application icon which is in the same folder as Zadig (Figure 8).

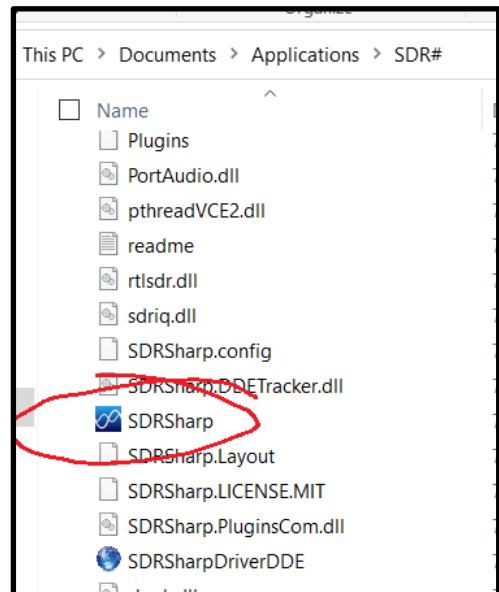


Figure 8 Doubleclick on the SDRSharp Application

- When SDR# opens, find the “Source” partition and from the drop down menu select RTL-SDR USB (Figure 9).

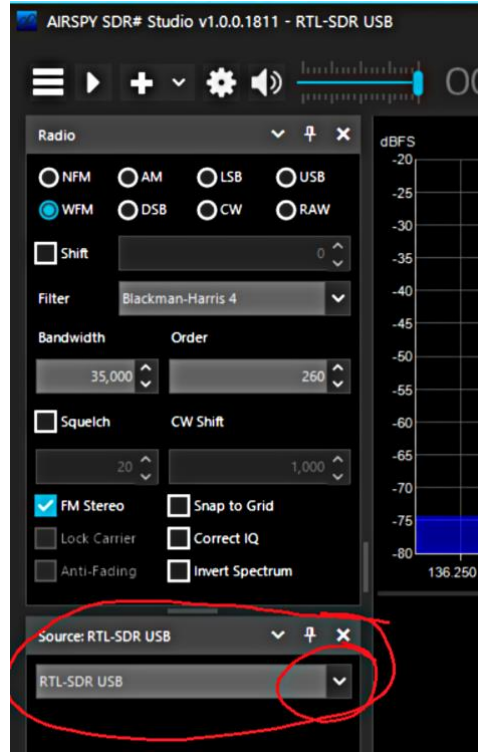



Figure 9 Select RTL-SDR USB from the drop down menu.

- Click on the Configure button  (shaped like a gear) at the top of the SDR# window to bring up the configure menu (Figure 10). By default the RTL-SDR's gain is set to zero. Increase this gain by moving the RF Gain slider up. Gain is an amplification factor—it is increasing the strength of signal so that the software can detect it. Gain values of around 40 are commonly used. Alternatively, the AGC (automatic gain control) option can be enabled.

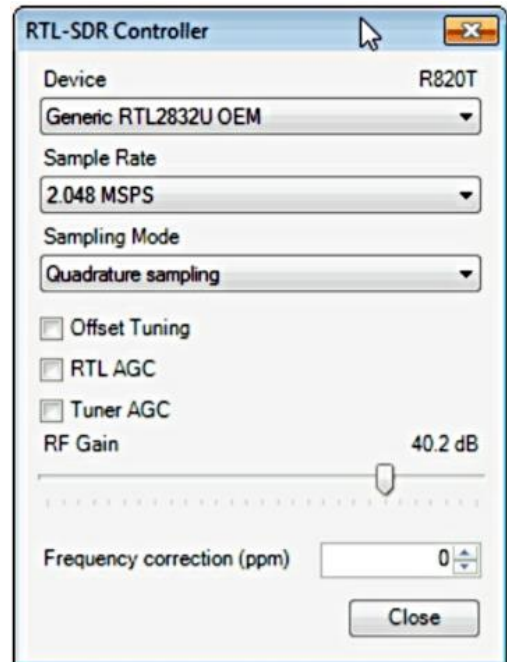


Figure 10 The SDR# configure menu. The RF Gain is circled

Press the Play button. The RTL-SDR software radio should now be playing some static and showing an RF spectrum and waterfall display (Figure 11). Using the frequency range at the top of the program window, tune to different broadcast signals.

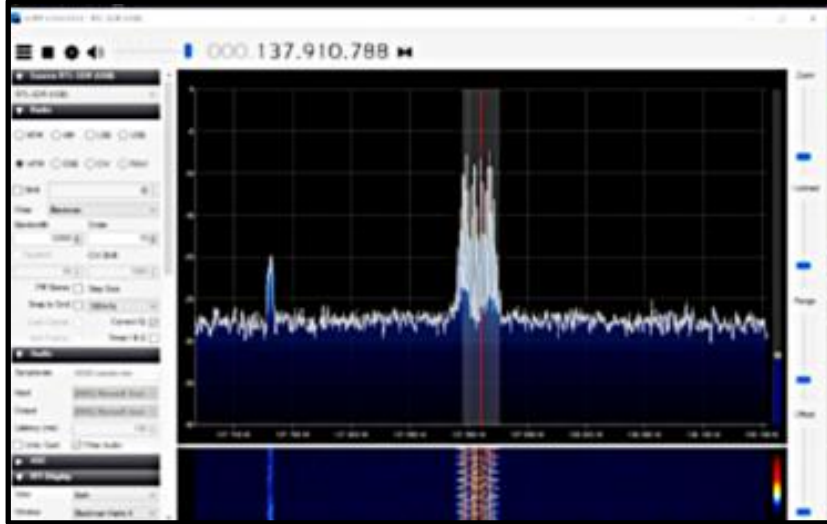


Figure 11 RTL-SDR RF spectrum and waterfall display

See the SDR# users guide at <https://www.rtl-sdr.com/sdrsharp-users-guide/> for more information on the use of SDR# and its various settings.

Improving Reception

Ground Plane

The performance of the monopole antenna can be improved by placing it on a flat metallic surface that has a radius similar to or larger than the length of the antenna (Figure 12). Even if the metal disc has a smaller radius, it will help in most cases to improve reception. The metallic surface could be anything - most easily it could be something like the lid from a coffee tin, or the tin cover of a metal cookie or chocolate box. Placing it on a metallic surface completes the antenna as a quarter wave ground plane.



Figure 12 An example of a ground plane made from a cookie sheet.

Coax Choke

Another improvement that can improve performance is to create a common mode coax choke. A choke will stop unwanted currents in the coax shield. This helps to remove the effect of the coax cabling becoming a part of the antenna and undesirably skewing the radiation pattern. To create

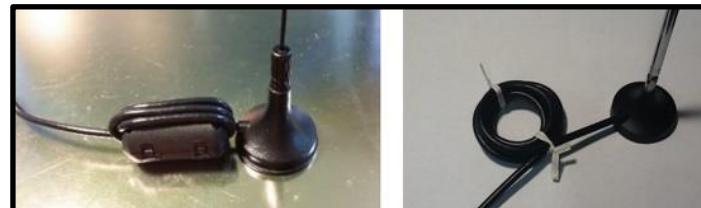


Figure 13 Examples of a simple coax choke. The image on the left uses a ferrite core while the one on the right is a simple coil.

a coax choke find cylindrical object about 2 - 3 cm in diameter, like a marker pen and create about 5 - 10 turns of coax cabling around it. A ferrite core can be used it as the winding center for even better performance. With a ferrite core there are fewer turns required for the same effect as with a non-ferrite core. Make the winding as close to the antenna base as possible. Below are examples of winding with and without a ferrite (Figure 13). This simple modification significantly lowers the noise floor.

Chapter 3: Installing and Scanning with RTLSDR

RTLSDR scanner generates a visual representation of received radio signal.

Installing the RTLSDR scanner

1. Go to <https://github.com/EarToEarOak/RTLSDR-Scanner/releases> and download the file `rtlsdr_scanner-setup-win32.exe` (Figure 14).

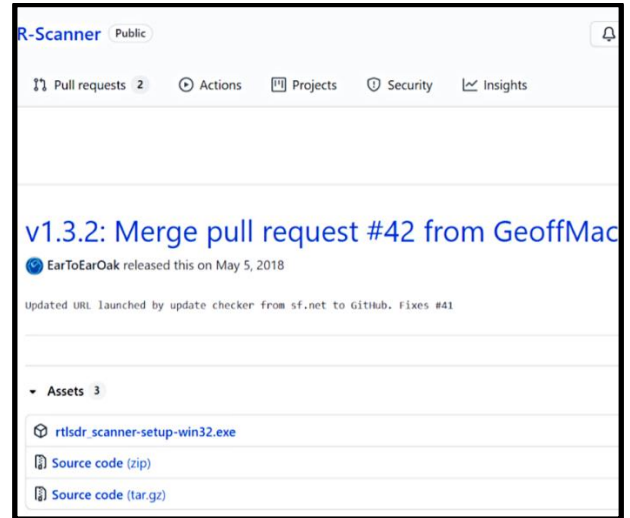


Figure 14 Download page for RTLSDR Scanner

2. Opening the downloaded file will run a Windows installer that will automatically download and install the various dependencies that are required for the software to run. Select the full install option. When the installer progresses to the "Choose components", make sure that all the dependencies are selected for installation (Figure 15).

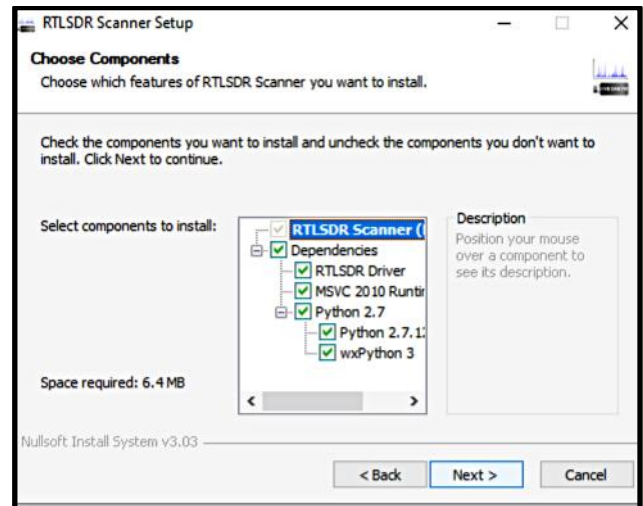


Figure 15 The Choose components window with all options selected.

- After installing RTLSDR Scanner, navigate to the newly created application folder (likely to be C:/Program Files (x86)/RTLSDR Scanner and open the BBCR2 file to run the application. A black box may appear while the program is loading. This program may take longer than expected to load.

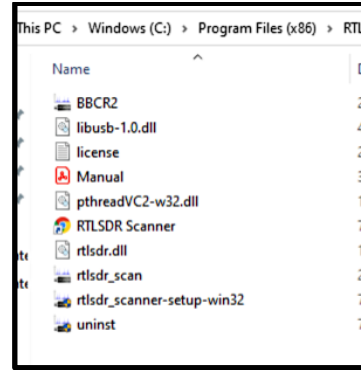


Figure 16 Double click to run BBCR2

- When RTLSDR Scanner opens, as a test scan the FM frequency band (88-108 MHz) to identify known FM stations in the local area. Enter the lower and upper bounds of the range of frequencies to be scanned in the Start and Stop boxes at the bottom of the window (Figure 16). Set the gain with the pull down menu. A value around 40 is generally appropriate (Figure 17).

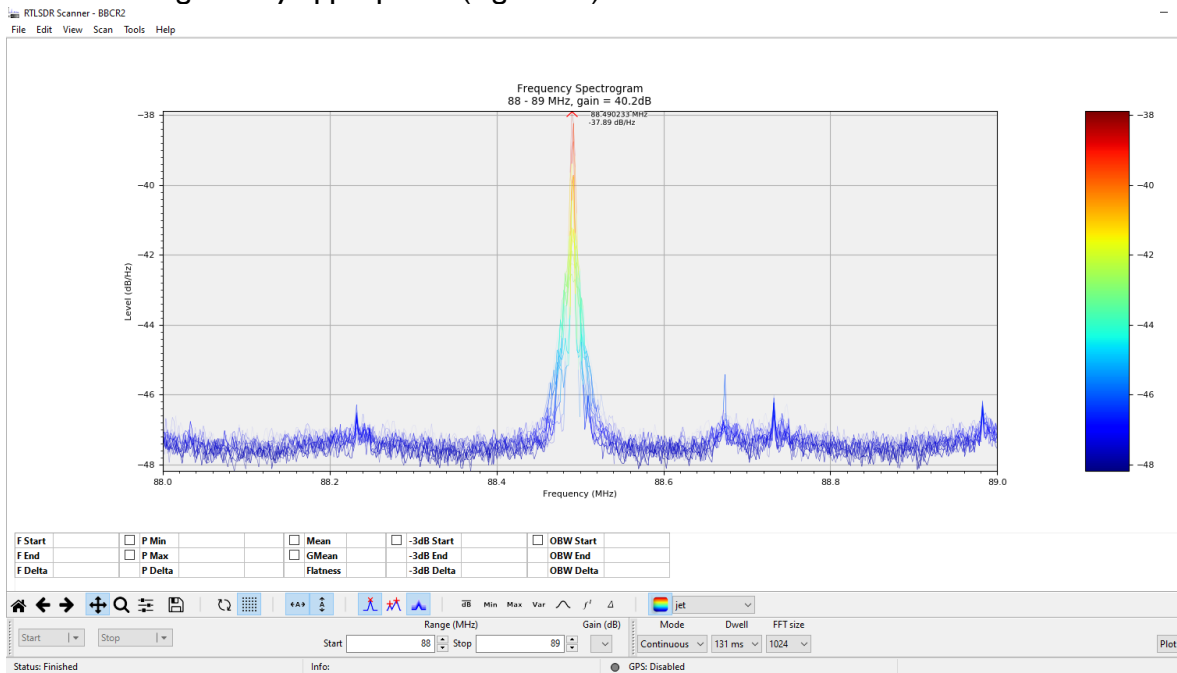


Figure 17 The start and stop boxes are circled in red. The gain box is circled in green.

- Press Start to begin scanning.

The mode can be set to either continuous or single. In continuous mode the scanner will

continuously refresh the spectrum every time it finishes one pass, in single mode the scanner will perform one scan and then stop. There are several things that can be done to improve the quality of the graph. The dwell time indicates how long the scanner will analyze the signal for a frequency range before recording the values. The longer the dwell time the cleaner the peaks in the graph. However, it will take the computer longer to create a graph from this data. Another value that will affect the cleanness of the graph is the FFT size. This value is the number of samples that are collected. The more samples collected the clearer the peaks in the graph. However, the greater the number of samples collected, the slower the computer will analyze the data to create a graph.

RTLSDR Scanner can also display the band scan as a spectrogram or 3D spectrograph by changing the settings in the Display pull down box.

Scanning at frequencies below the FM band will be limited by the efficacy of the provided monopole antenna. Reception above the FM band can be improved by extending the telescoping antenna to a length of approximately $\frac{1}{4}$ wavelength of the desired frequency. For example at 100 MHz

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8 \text{ m/s}}{100 \times 10^6 \text{ s}^{-1}} = 3 \text{ m} \quad \text{so: } \frac{1}{4} \lambda = 0.75 \text{ m}$$

To improve the reception of a particular signal, adjust the length of the antenna. First, use the speed of sound and the frequency to find the wavelength.

$$\lambda = \frac{c}{f}$$

Example: 100 MHz

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8 \text{ m/s}}{100 \times 10^6 \text{ s}^{-1}} = 3 \text{ m}$$

Now that the wavelength is known, the optimal length for the antenna can be found using the formula below.

$$\frac{1}{4} \lambda =$$

Example: Continuing with the 100MHz example from above we get

$$\frac{1}{4}\lambda = 0.75 \text{ m}$$

Depending on the chosen settings and the computer's capabilities, scanning bandwidths of 50 MHz should work reasonably well. Larger bandwidths can use a great deal of computer processing power, but performance may vary. To improve performance, scan in chunks, adjusting antenna length to the appropriate length for the chosen frequency range.

Chapter 3 – Using ADS-B Aircraft Tracking

ADS-B Aircraft Tracking receives and decodes signals from planes overhead

Background

Modern planes carry an Automatic Dependent Surveillance-Broadcast (ADS-B) Mode-S transponder. This transponder periodically broadcasts location and altitude information to air traffic controllers and other aircraft. The system replaced traditional RADAR systems which work by bouncing a radio signal off the plane and listening for the echo. ADS-B uses an accurate on-board GPS receiver and broadcasts the GPS location data to ground controllers and other aircraft via radio, thus providing more accurate and stable data. ADS-B is also used to help aircraft avoid collisions by sending a warning or taking automatic emergency action if the flight computer detects a possible collision from ADS-B data.

Currently, ADS-B data is not encrypted so an SDR can be used to decode these signals. The decoded data can then be used to create a live home aircraft radar system. ADS-B signals can be found at a frequency of 1090 MHz. ADS-B uses “Mode S” which provides the location data for ADS-B. Public websites including flightradar24.com and flightaware.com display ADS-B data through the internet as well. They receive ADS-B data through volunteers who have bought dedicated ADS-B receiver hardware or are using an RTL-SDR and feeder software.

Hardware Considerations

Antenna

With a good antenna an SDR could be capable of receiving aircraft ADS-B signals from over 250 nautical miles away, or about 460 km or 290 miles. Many people have found that in most cases the stock antenna that comes with the dongle can pick up ADS-B signals without modification. Its performance will depend on distance from the aircraft and local RF interference. ADS-B operates at 1090MHz with vertical polarization which just means that a vertically oriented antenna should be used. Frequencies in the gigahertz region are “line of sight” frequencies meaning there should be a clear unobstructed path between the antenna and the transmitter on the aircraft. Since ADS-B signals are generally quite strong and come from aircraft flying up high, reception is quite easy and even untuned antennas can work decently. The provided telescoping antenna at its shortest length on a suitable ground plane will likely provide adequate reception for most users. However, to increase ADS-B receiving range, place a properly tuned antenna at an elevation.

COAX Feed and Connectors

The coax feed line (the length of coaxial cable between the antenna and dongle) should be high quality, low loss and as short as possible. At gigahertz frequencies long runs of cheap coax tend to reduce signal strength significantly. Use coax cable intended for satellite TV installations such as RG-6 or RG-8 as these cables are designed to work well at gigahertz frequencies. Alternatively, use an active USB extension cable and place the dongle as close to the antenna instead of using coax cable. BNC, N or SMA connectors are recommended. Poor connectors at gigahertz frequencies could net up to 1-3 dB of loss per connector.

Low Noise Amplifiers (LNAs)

By simply placing an LNA in front of the SDR, ADS-B range can be significantly increased. This is because the noise figure (NF) of the RTL-SDR at 1090 MHz is approximately 5 dB. Using a high quality LNA can reduce the system noise figure down to 1 dB. Essentially this means that SNR will be about 5-6 dB's higher, resulting in significantly more ADS-B packets received. The additional benefit of using an LNA is that coax and connector losses can be overcome if the LNA is placed right by the antenna. To use ADS-B, the antenna should be placed on a roof or a mast for optimal performance. This means that many meters of coax cable will be needed. Even if high quality RG-6 coax is used, the loss at 1090 MHz for 10 meters (33ft) would be about 3.5 dB plus about 1 dB in connector losses. The LNA can be placed at the antenna and powered by a bias tee.

Filters

If there are strong interference broadcast stations nearby (e.g. FM, DAB, DVB-T, GSM) then these signals can cause the dongle to overload and desensitize ADS-B reception. Overloading becomes even more likely if an LNA is used. In these cases a filter should be. The FlightAware 1090 MHz filter can be used. This filter is found at rtl-sdr.com/store. In addition a ADS-B LNA + filter combination unit is available.

The filter or the LNA can be placed "first" or closest to the antenna. Place the LNA first, then the filter, if the LNA can handle strong signals (high linearity/OIP3) and there are not too many interfering signals. Most filters usually have an insertion loss of about 3 dB, and so placing the LNA first will nullify that insertion loss. On the other hand, if interfering signals are exceptionally strong, then they could overload the LNA. In this case, place the filter first. The easiest way to check is to view the spectrum in SDR#. If the signal quality decreases with the LNA in front, then put the filter first. If the signal quality looks similar with either the LNA or filter first, then put the LNA first.

Software Installation

Note that for the Windows based software the SDR drivers need to be installed via Zadig. The ADS-B decoder and a map display program must be downloaded. The best combination of decoder and display programs are RTL1090 and Virtual Radar Server.

RTL1090 can be downloaded from <https://rtl1090.com/>. Scroll down the page to find the IMU (Installer and Maintenance Utility). Selecting that option will automatically download all the required files (Figure 18)

Unzip the downloaded file, and run the resulting installation file. If Zadig has already been installed, that installation can be skipped. Windows security and/or antivirus software may suggest that the application not be run. Click “more info” and “run anyway”.

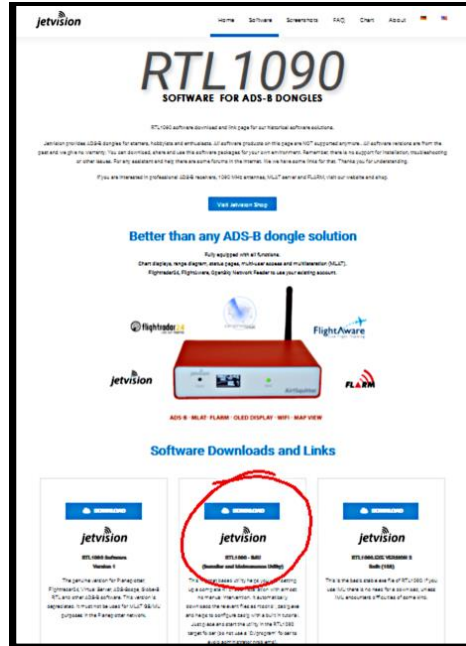


Figure 18 The download page for RTL1090. Select the circled option.

To run RTL1090 find the executable rtl1090 application in the folder it was installed to (Figure 19).

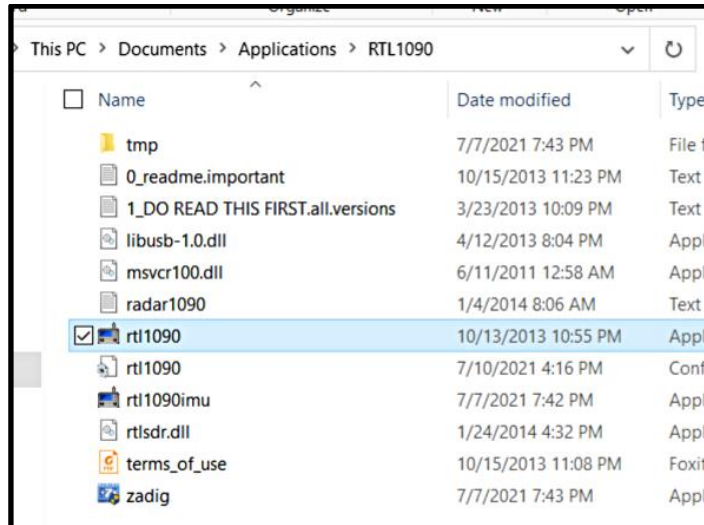


Figure 19 Double click on rtl 1090 to install

Upon opening a small square screen will appear. To start decoding press the start button (Figure 20)



Figure 20 Click Start to begin debugging

To visualize the decoded data on a map, the Virtual Radar Server is needed. VRS is Windows (and Linux compatible via Mono) based free software program which displays plane positions in a web browser using Google maps. The map can then be shared with other people over the internet if desired. Virtual Radar Server can be downloaded from <http://www.virtualradarserver.co.uk/Download.aspx>.

1. Download the VRS Windows installer from the website.
2. When installing selecting a port number for the web interface is required. Make sure that the chosen port does not conflict with another port that is being used by another web server. Then open VRS from the start menu. If by chance the VRS is installed with a port conflict, VRS won't run. If that happens, reinstall with a different port number.
3. It may be necessary to install an older version of the .NET application. This is necessary for VRS, accept and let the installer install the software.
4. VRS should install an icon in the Start menu. Click that icon to open the virtual radar server.
5. Go to Tools → Options.

- (Optional) Click on Receiver Locations and a box appears (Figure 21).

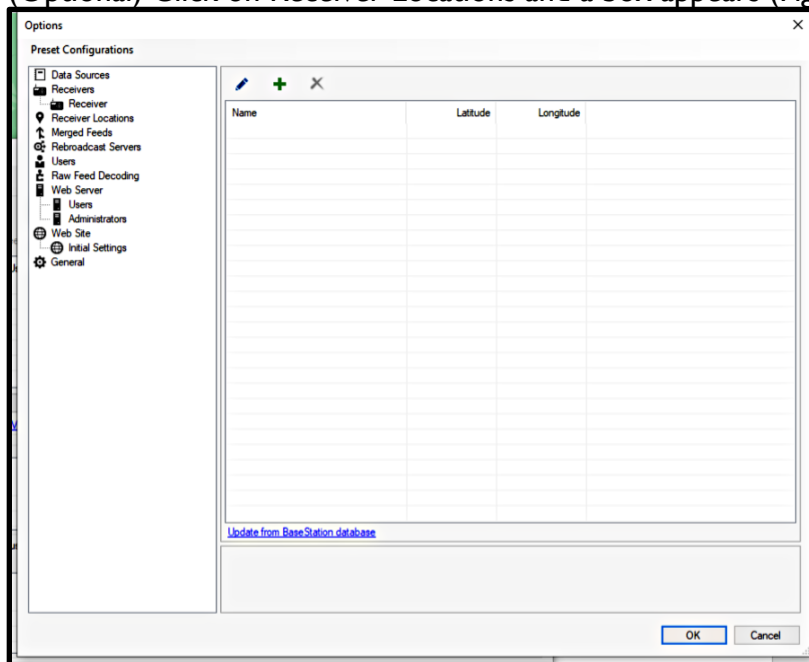


Figure 21 To add receiver location, click the "+" symbol

- Click the green + and add the name of location and coordinates of the receiver. Latitude and longitude can be determined by clicking on that location in a Google map.
- Remaining in the Options menu, in the left menu tree, click on Receivers, then click on the green plus icon to add a receiver.
- The properties of this receiver will show.
- Name the Receiver "RTL-SDR".
- Change Format to "AVR or Beast Raw Feed". Without this selection the software will decode messages but won't track planes.
- Choose the appropriate location in the drop down box next to Location.
- Keep the IP Address at 127.0.0.1 and set the port as 31001. 31001 is the output port for RTL1090 (Figure 22).

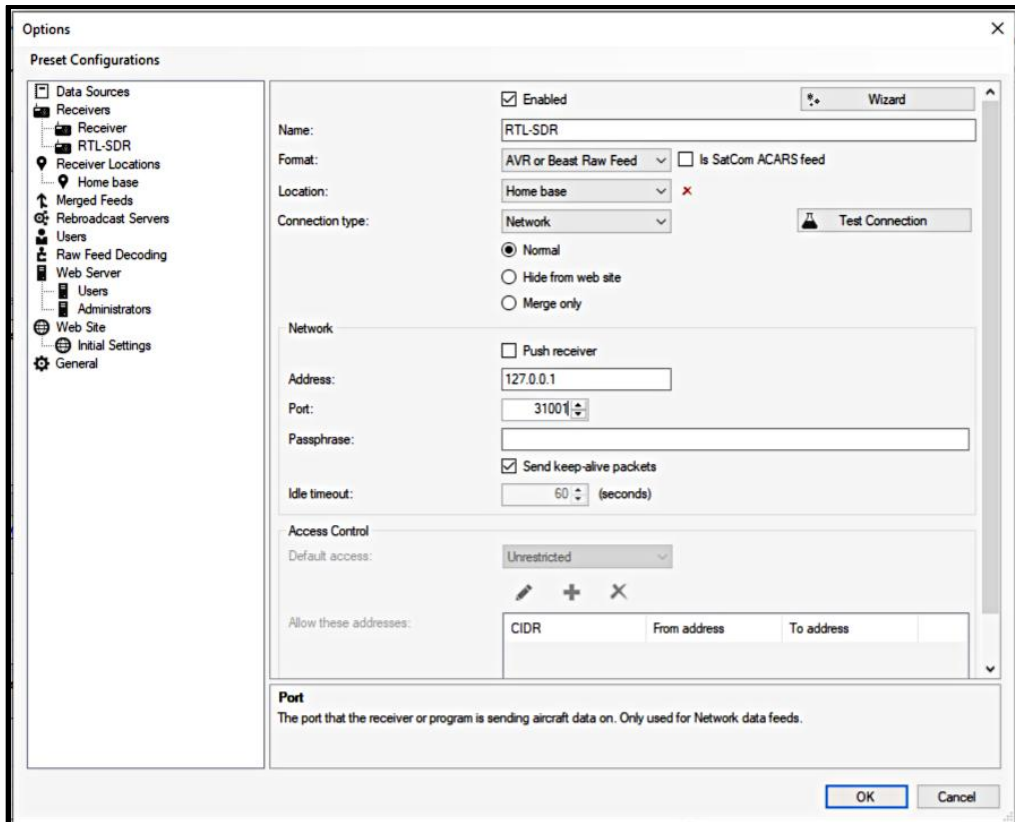


Figure 22 Correct settings for receiver location. Name and location are customizable. All other settings should match those displayed.

14. With RTL1090 running, click on Test Connection. A message showing that a connection can be made should appear
15. Click on Receivers again, and set the “Web site receiver”, “Closest aircraft receiver” and “Flight Simulator X receiver” to the RTL-SDR receiver just created (Figure 23). Press OK.

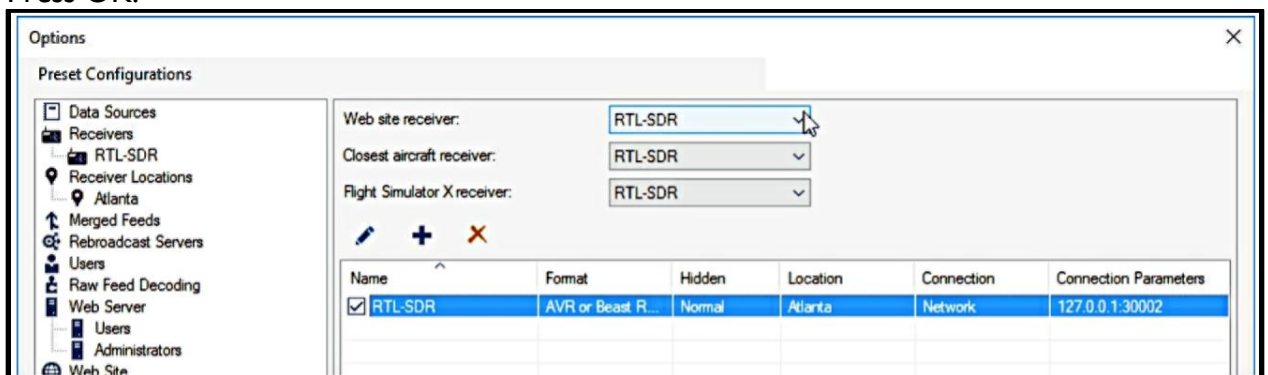


Figure 23 Setting the receivers to the local location.

Now click on the link to <http://127.0.0.1:8081/VirtualRadar> in the middle right of the VRS main window (Figure 24).

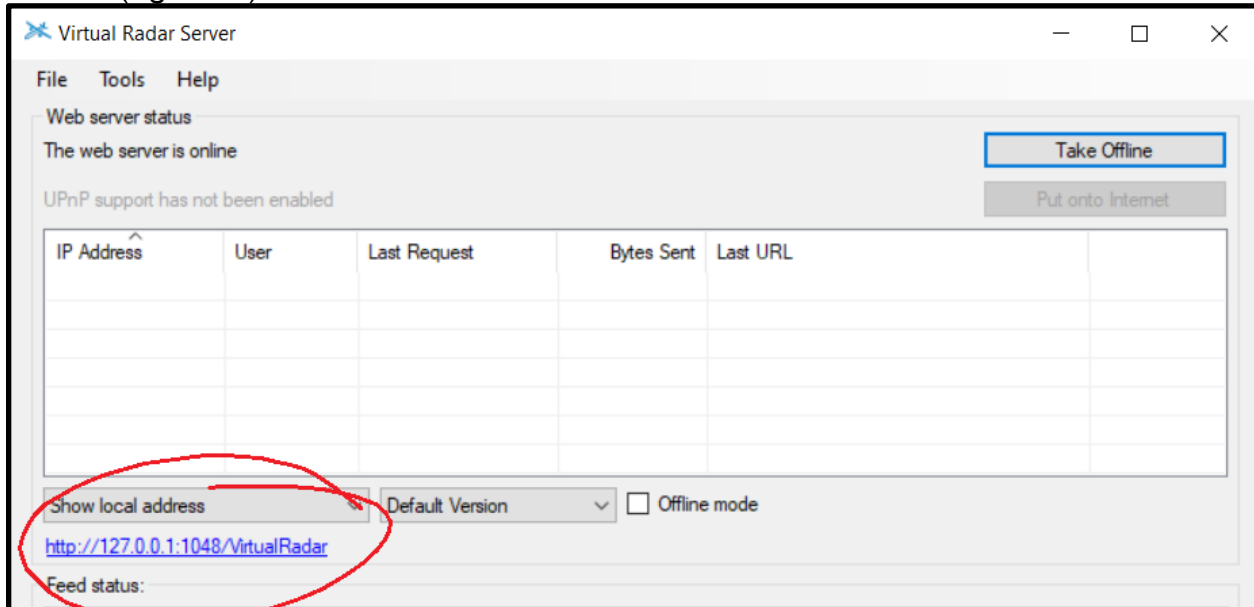


Figure 24 Click on the indicated link to connect to VRS Google Map

16. A web page with a special VRS Google map will load. Zoom out and scroll to your location on the map. Graphics of planes should appear as the ADS-B frame decodes from ADS-B decoder program.

To use Virtual Radar Server in the future simply start RTL1090 and then Virtual Radar Server.

Chapter 5 - Receiving Satellite Transmissions

Many satellite transmissions can be received by amateur radio enthusiasts. This section provides tips for modifying the basic set up to receive this data.

There are many satellites circling above the Earth that are communicating in frequencies all across the radio spectrum. There are a variety of satellite tracking applications available. Convenient web based trackers can be found at <https://www.n2yo.com> and <https://www.heavens-above.com>. These sites are a little different, but complementary. Some of the capabilities of these sites include:

- The ability to predict the times satellites will pass over your location, including identifying those passes that will be visible along with the relative brightness of the object.
- Detailed information about the orientation and altitude of the orbit of every satellite
- The ability to plot the ground tracks of satellite orbits. Heavens-above also has the ability to display orbits as viewed from above the orbital plane or from above the satellite.
- Downlink frequencies for transmissions from each satellite
- Historical information about each satellite
- Both websites include other interesting information, visualizations, and links to explore.

Many satellite transmissions can be received by amateur radio enthusiasts. Most of the signals from powerful commercial or governmental satellites require decoding to be understood. There are satellites such as amateur radio repeaters that don't require decoding, but these typically operate at lower powers and so generally require specialized antennas in order to receive an adequate signal. While both of these hurdles can be overcome by SDR users, they are beyond the scope of this introductory guide.

Nonetheless, there are a few types of satellite transmissions that may be receivable at your location with the hardware in the kit and/or some simple additional materials. Two such projects that we'll describe here are capturing NOAA weather satellite images and listening to "pirate" radio transmissions using US military communications satellites (MILSATCOM).

NOAA Weather Satellite Images

These satellites use a transmission protocol known as Automatic Picture Transmission (APT) which was developed specifically for use on weather satellites. It is an analogue transmission that is somewhat similar to the HF Fax mode used on the HF bands. APT is transmitted in grayscale, but software can be used to colorize the image.

The NOAA satellites only pass overhead at certain times of the day, broadcasting a signal. These signals appear at around ~137 MHz and only when a satellite is passing overhead. Each satellite uses a slightly different frequency. Their frequencies are shown below.

NOAA 15 - 137.6200 MHz

NOAA 18 - 137.9125 MHz
NOAA 19 - 137.1000 MHz

Satellite location can be tracked overhead using the tracking websites described above. With an appropriate antenna, transmissions can be received and identified using a dongle and SDR#. Processing the transmission to produce images requires the use of two more software applications. One to process the images and another to direct the output from SDR# to the image processing software. Installation and use of these applications will be discussed further below.

Hardware Setup

A specialized antenna is best for receiving satellite transmissions. Such antennas can be purchased, or home built with modest skills and supplies. Depending on location conditions, transmissions may be received with the supplied telescoping monopole antenna. Orient the antenna horizontally and adjust the length to $\frac{1}{4}$ wavelength long. At 137 MHz that is about 54 cm.

A likely improvement over the provided monopole can be obtained with a simple V-dipole antenna. NOAA satellites send signals with “right hand circular polarization” (RHCP), and thus a RHCP antenna is needed. A V-Dipole is the simplest antenna that can be made for receiving satellites. It is simply a dipole bent into the shape of a V, and mounted horizontally facing North-South. It is horizontally polarized, and not RHCP, but the difference is only 3dB. The wrong polarization can in fact be beneficial in this case, because a horizontally polarized antenna attenuates vertically polarized signals by 20 dB, and most terrestrial signals are vertically polarized. This can significantly reduce the effects of terrestrial interference.

A readily available V-dipole antenna is commonly known as “rabbit ears”. With a set of rabbit ears and a bit of coaxial cable, an antenna can be constructed that can receive the NOAA satellite transmissions. An example setup is shown below (Figure 25).



Figure 25 On the left is the complete rabbit ear set up. On the right is a close up of the connection.

Setups may vary depending on available hardware. Looping the coaxial cable into a balun as described in Chapter 1 will help improve the signal to noise ratio considerably. The coaxial connector shown is commonly provided with rabbit ear antennas and should be readily available in hardware stores.

The coaxial cable can then be connected to the SDR using one of the provided adaptors (Figure 26)

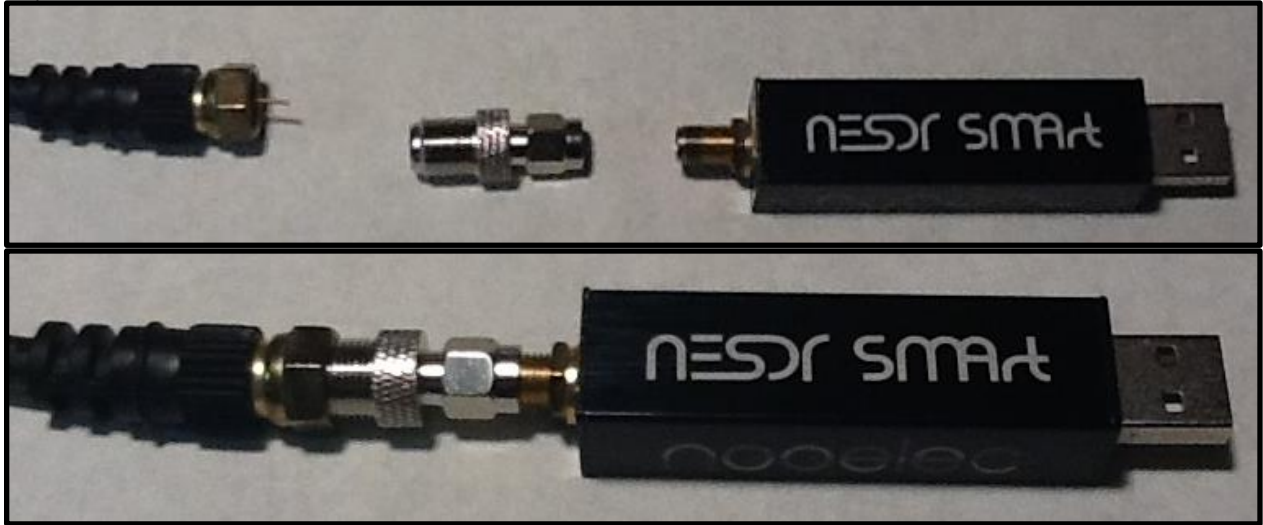


Figure 26 Connecting the antenna to the dongle. The picture above shows components before connection. The picture on the right shows three elements connected.

This setup introduces the potential for several impedance mismatches and consequently the received signal strength is likely to be attenuated significantly.

Rabbit Antenna Set up Instructions

1. Each arm should be $\frac{1}{4}$ wavelength long. At 137 MHz that is about 54 cm.
2. The V should be approximately 90 degrees
3. The antenna should be placed horizontally with the V opening towards the north.
4. At this point, it is possible to test the antenna and determine if it is receiving a satellite transmission. Attach the antenna and dongle to the computer and open SDR#.
5. Determine when one of the NOAA satellites is passing overhead and tune SDR# to the appropriate frequency and set the receive mode to WFM (Figure 27).

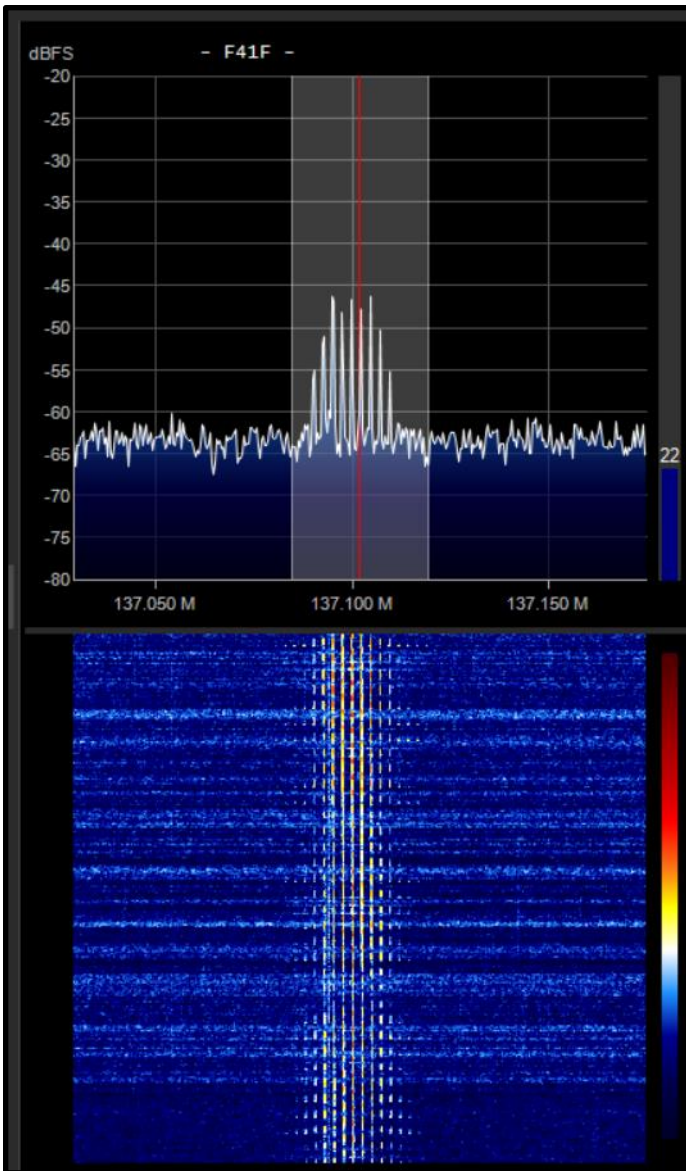


Figure 27 Example of SDR# waterfall image when receiving a satellite signal.

Software Setup

Before use image processing software can be used, audio pipe software to route the output from SDR# to the image processing application must be installed. We have used VB Cable audio pipe software successfully. To install VB Cable go to <https://vb-audio.com/Cable/index.htm>.

- I. Download the Windows version of VB Cable from the website (Figure 28).



Figure 28 Double click on the Download for windows icon

2. Extract all the files from the downloaded .zip file.
3. Right click on the VBCABLE_Setup or VBCABLE_Setup_x64 application and select “Run as administrator” (Figure 29).

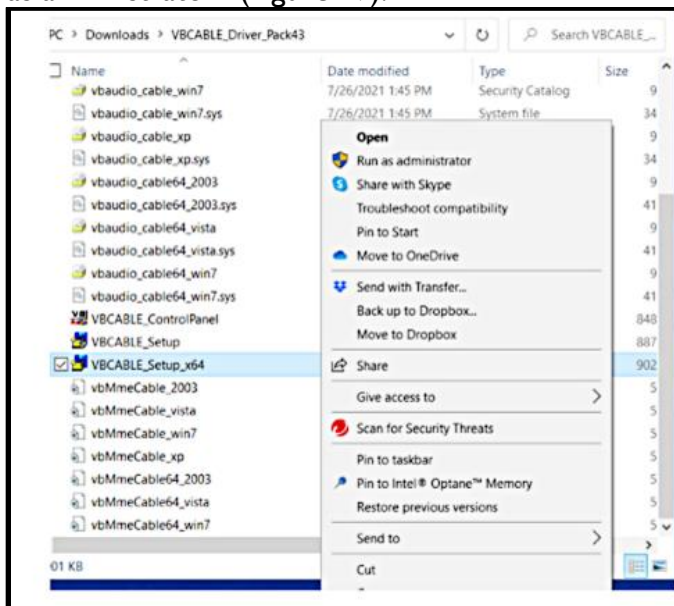


Figure 29 Right click on the VBCABLE_setup_x64 and select “Run as administrator”

4. Follow the prompts
5. **The computer must be rebooted before using VB Cable.**

After VB Cable the is installed, plug in the SDR and open SDR# and from the main menu open the “Audio” window and select “VB-Audio” as the output (Figure 30).

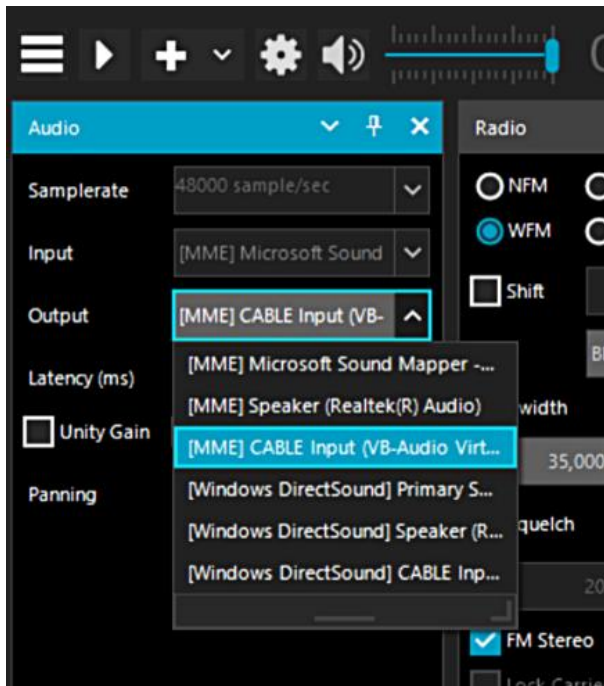


Figure 30 Select CABLE Input (VB-Audio Virt...)

Download the image processing software, WXtoImg.

1. Go to <https://www.wraase.de/wxtoimg/> and download the Windows preconfigured file.
2. Unzip the downloaded file and run the “install” batch file in the extracted folder.
3. Open WXtoImg and set Ground Station Location, by going to Options → Ground Station Location. Enter city and country, or latitude, longitude and altitude (Figure 31). The location information is used to determine when a satellite will pass over your sky.

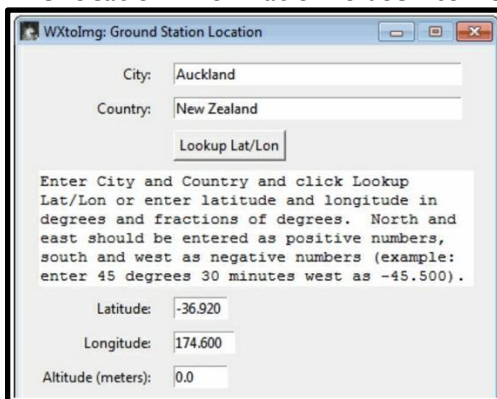


Figure 31 Setting up the location of the ground station.

4. Go to Options → Recording Options and select CABLE Output (VB Audio Virtual) from the Soundcard menu. (Figure 32).

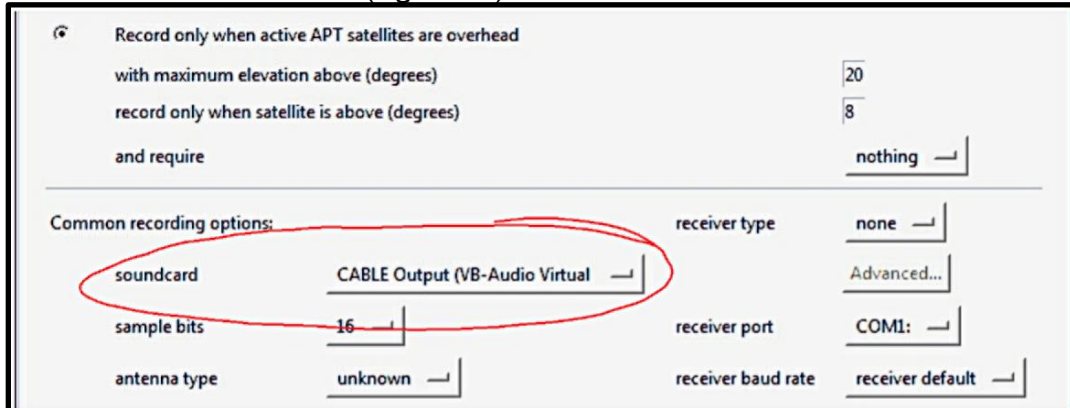


Figure 32 Setting the soundcard option. The sound card menu is circled.

5. There are options when it comes to receiving satellite transmission. The software can record continuously but that will run down the laptop battery. Alternatively, “Record only when active APT satellites are overhead” “with maximum elevation above (degrees)” and “record only when a selected satellite is above (degrees)” settings can be selected. The default values can be reduced if the antenna has a good view of the sky and WXtolmg stops recording or doesn’t start fast enough when the APT signal is present in SDR#. Because the satellite transmits directly downward, passes with higher maximum elevations will get better reception as they will pass directly overhead and there will also be less obstructions from trees/mountains etc. Elevation values should be set according to terrain.
6. The Kepler file contains the information about satellite locations which needs to be periodically updated because satellites drift in their orbit over time. Go to File → Update Keplers to do an update. An active internet connection is required for the update.
7. To view when a NOAA satellite is overhead, go to File → Satellite Pass List. Take note of the frequency of the pass as well.
8. When the time comes for the satellite to pass overhead, open WXtolmg and go to File→Record (Figure 33). Make sure that the radio button “Record only” is selected and then click on Auto Record. The recording and decoding will begin automatically when it is time for the satellite to appear on the horizon. It will automatically stop when it goes out of view according to the times in the satellite pass list. If for some reason the recording doesn’t start in time, click on the Manual Test button to immediately begin decoding.

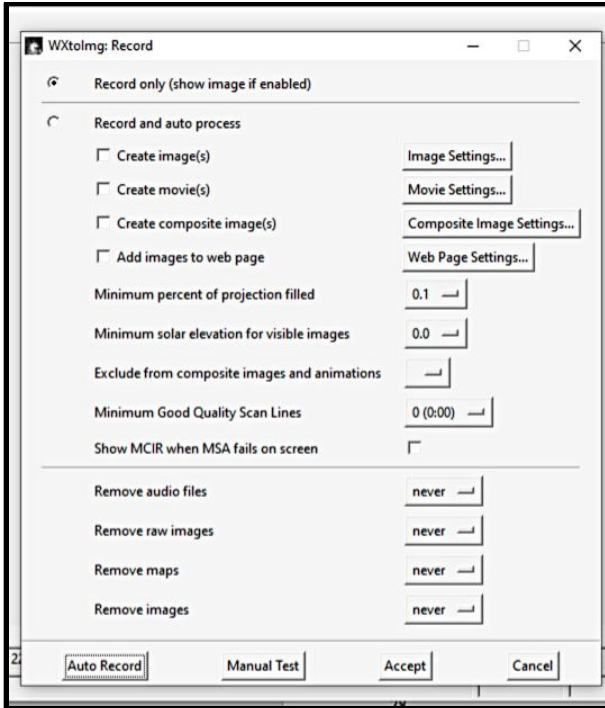


Figure 33 The Wxtolmg record window. Select the radio button. Click Auto Record.

- Open SDR# and select audio from the menu which is represented by three lines in the upper left hand corner. Then select MME Cable Input from the Audio Output drop down box. (Figure 34).

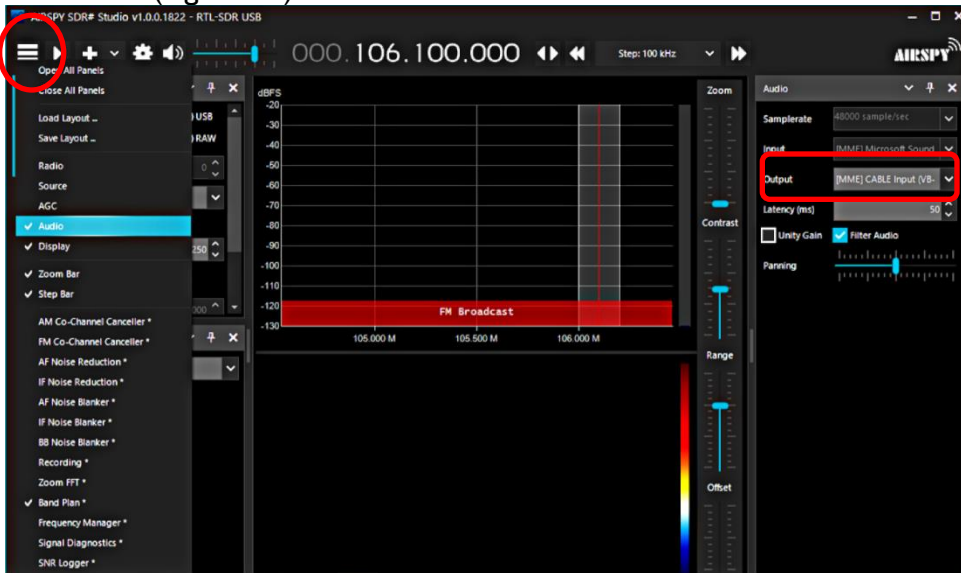


Figure 34 Audio has been selected from the menu on the left (highlighted). Then the output was selected from the drop down menu (in red).

- Next tune to the frequency that the satellite will be broadcasting at. The frequency is found at the top of SDR# in the middle of the box. In figure 33 the frequency is listed as

106.100. To tune to a specific frequency just click above or below a number. For example, if we were to tune the frequency in figure 33 to 137 we would click above the 6 to get 7 and above the 0 in 106 to get 3.

11. Click on the configure button and adjust the gain settings to optimize the signal to noise (Figure 35). Recall that increasing the gain to approximately 40 will make the signal appear more clearly and will reduce the effects of interference.

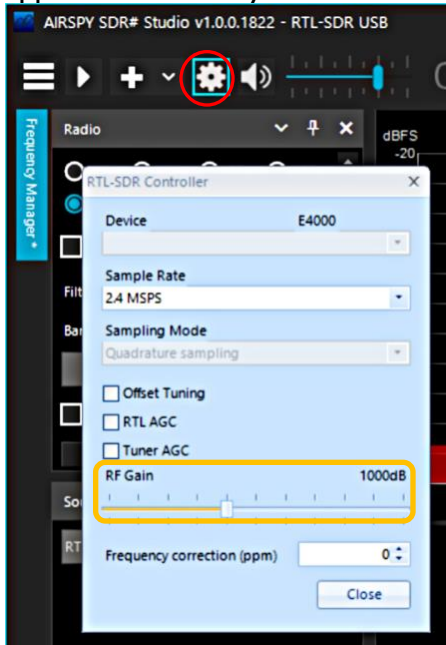


Figure 35 The Configure button is circled. In the pop-up box adjust the gain setting.

12. Adjust the volume in SDR# and/or Windows volume settings so that the volume bar in the bottom right hand corner of WXtollmg shows a green color.
13. WXtollmg should now be decoding and showing the weather satellite image as it is received. Set the filter bandwidth within the range of 36- 40 kHz so that the signal is received and is not affected by Doppler shift.
14. Once the image has been fully received, the options under the Enhancements and Projection menu can be adjusted in order to add false color and enhance the received image.

Military Satellite Communications (MILSATCOM)

From the late 1970s to the 1990's the US military launched "Fleet Satellite Communications System" (FLTSATCOM/FLTSAT or UFO) satellites into geosynchronous orbit (the satellites stay in the same spot in the sky at all times). The satellites were designed to allow for global communications between US Navy personnel at sea or on land. They operate in the frequency range of 243 – 270 MHz. Normally most military communications are encrypted, and nothing can be heard from them. However, these satellites are essentially unsecured repeaters in space, and they will sometimes unintentionally pick up and repeat signals from the earth. For example, in Russia and some parts of Asia long distance telephone calls in rural areas are made with UHF

radio transmissions. These satellites can pick these signals up and repeat them back down to a wide area. Sometimes radio stations from various parts of the world can be heard.

The signals are quite strong and often a standard $\frac{1}{4}$ wave ground plane antenna tuned to 255 MHz can receive the signals. Since these frequencies are quite close to broadcast FM or DAB/DVB-T frequencies, filtering may be required.

The SDR along with the telescoping monopole antenna tuned to the vicinity of 255 MHz (29 cm long) can receive signals from these satellites. Unencrypted transmissions are occasional and sporadic.

