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 ¼ 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 1 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 2 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 ¼ 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).

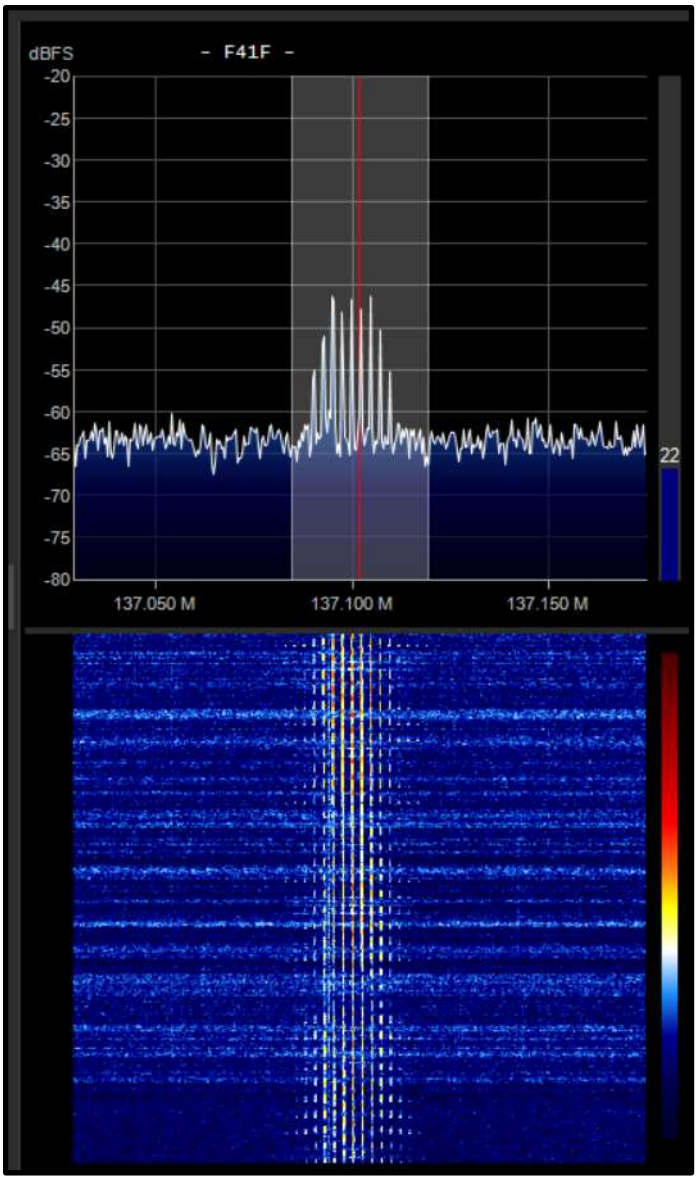

Figure 3 Example of SDR# waterfall image when receiving a satellite signal.

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.

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

Figure 4 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).

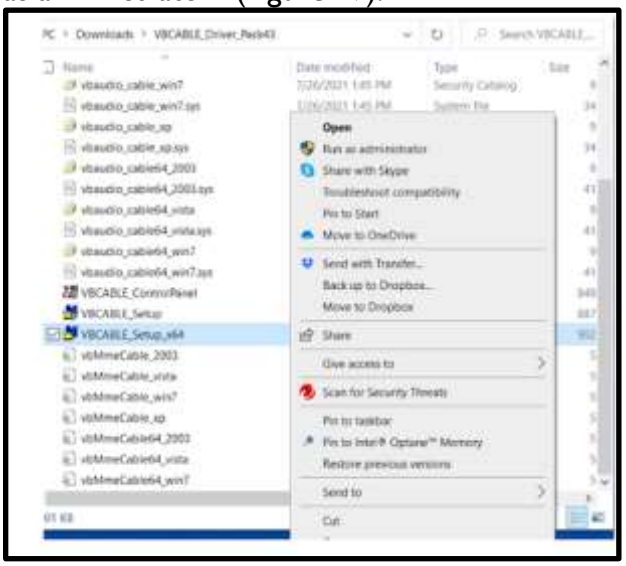

Figure 5 Right click on the VBCABLE_setup_x64 and select "Run as administrator"

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).

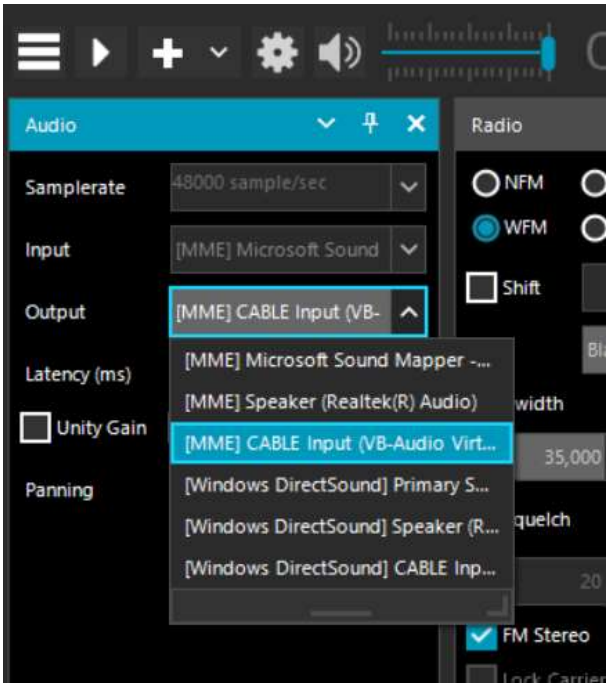

Figure 6 Select CABLE Input (VB-Audio Virt…)

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.

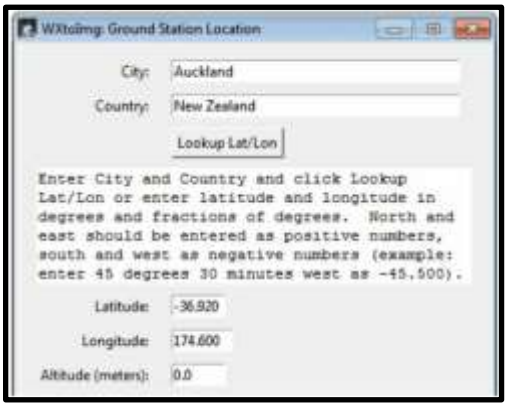

Figure 7 Setting up the location of the ground station.

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

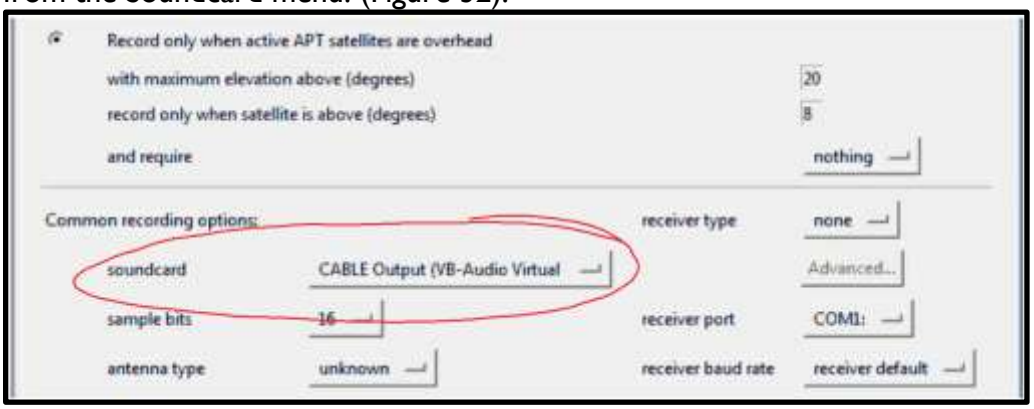

Figure 8 Setting the soundcard option. The sound card menu is circled.

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 WXtoImg 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 WXtoImg 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 9 The Wxtolmg record window. Select the radio button. Click Auto Record.

9. 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).

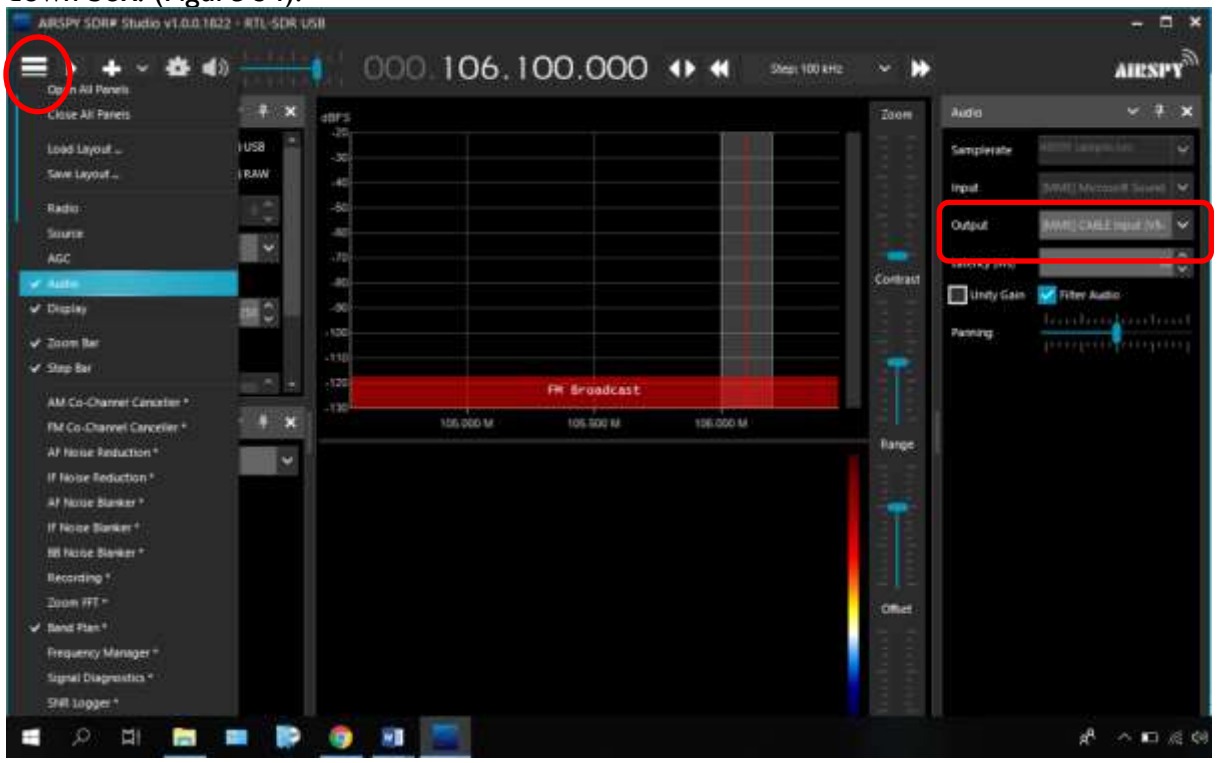

Figure 10 Audio has been selected from the menu on the left (highlighted). Then the output was selected from the drop down menu (in red).

10. 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.

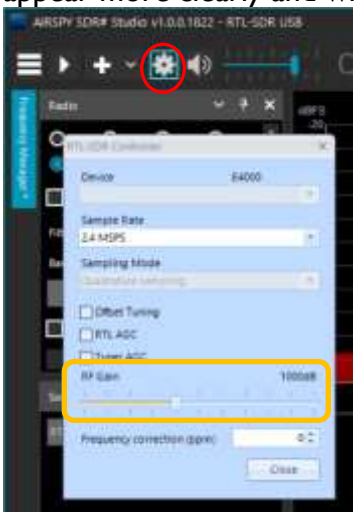

Figure 11 The Configure button is circled. In the pop-up box adjust the gain setting.

12. Adjust the volume in SDR# and/or Windows volume settings so that the volume bar in the bottom right hand corner of WXtoImg shows a green color.
13. WXtoImg 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 ¼ 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. Unecrypted transmissions are occasional and sporadic.