SubLab: Software Defined Radio

We are bathed in an electromagnetic ocean. Transmitting devices like AM and FM radio, satellite communications, mobile phones, wifi hotspots, Bluetooth devices, aircraft positioning and communication signals, fill the air with all kinds of signals. Up until recently, the equipment needed to view this spectrum was expensive and difficult to use. Thanks to advances in computer radio receivers, we can now repurpose a simple, inexpensive device to view and listen in on a lot of this spectrum. Enter the world of Software Defines Radio.

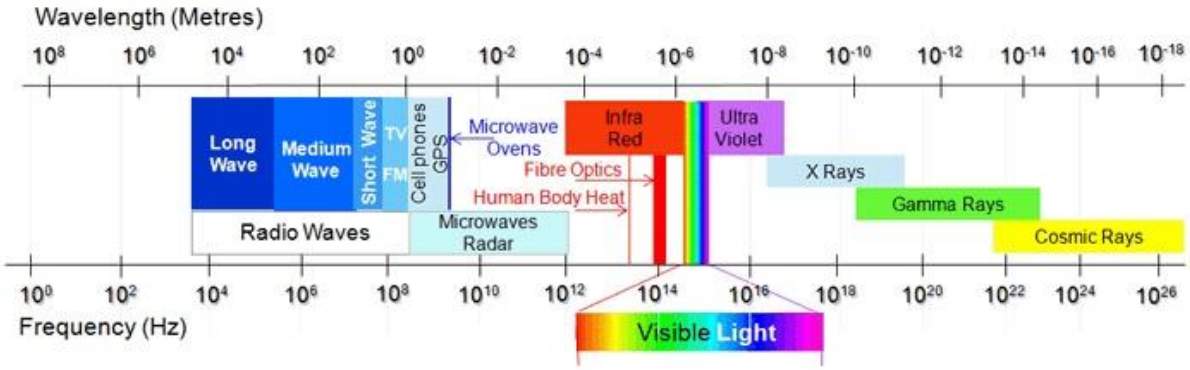


Figure 1: The Electromagnetic Spectrum

Software Defined Radio (SDR) is a radio communication method where many of the complex electronic circuits of radio transmitters and receivers are implemented in software instead of hardware. This allows very complex analysis of signals with just a very simple receiver or transmitter. If a receiver is hooked into a computer and provides a stream of data, the processing power of the computer can be used to analyze, format, and display the data.

One of the easiest ways to start experimenting with this type of communication technology is to repurpose a USB terrestrial television receiver. Using this receiver as the front end, we can then use computer software to process the data from this receiver.

One such receiver is shown below.

This system is made up of a wide band receiver and an external antenna. This setup was designed to be able to view over the air digital television broadcasts on your computer. This is a great enough reason to own one of these little devices. However, the included receiver is capable of much broader spectrum coverage than just digital television. You can grab the FM radio spectrum, aircraft chatter, and you can see the signals from beacons, satellites, and other transmitting bands. With additional software, antennae, and know how, you can even decode weather satellite pictures and track aircraft in your area.

In this lab, we just want to cover how to get started in this fascinating hobby of spectrum investigation.

How to Get Started

First thing you need is a USB digital TV receiver. Go to subsystems.us to purchase one that we have verified works with the below software. You could also try looking at other suppliers. Just make sure the radio chip is a R820T+2832U combination. This is a receiver and USB transceiver combination that has been a standard in the hobby SDR radio world.

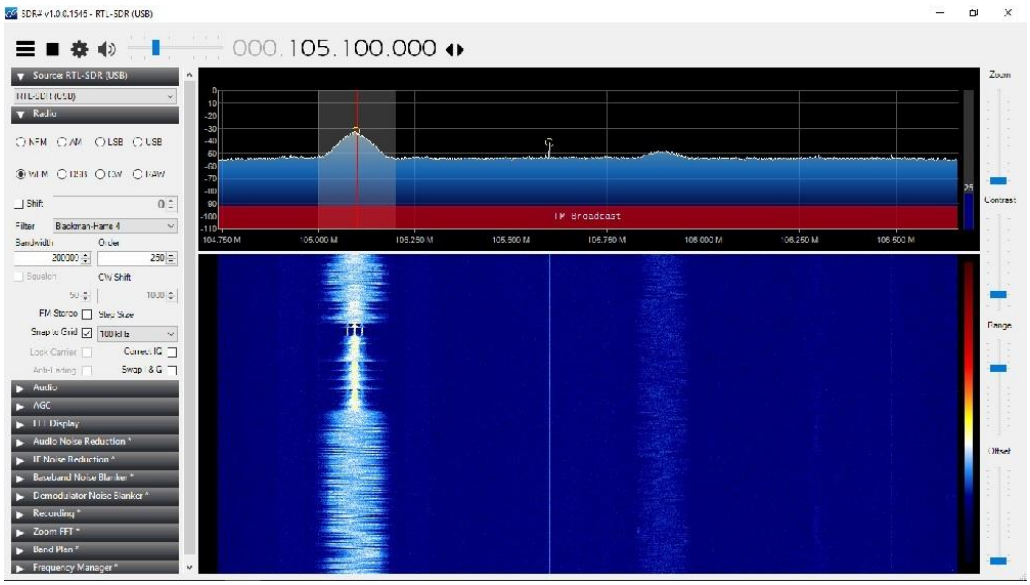
Next, head over to http://www.rtl-sdr.com/rtl-sdr-quick-start-guide/

They have a great tutorial on getting their software loaded and the USB device configured on your computer.

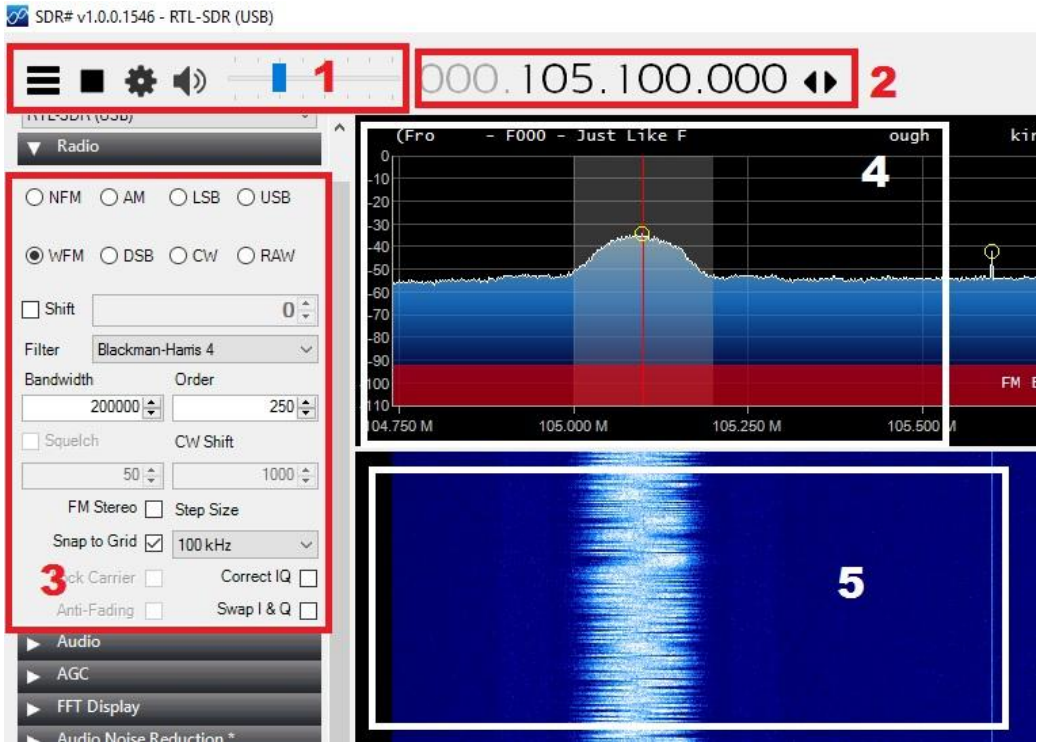
Since the USB device was meant to be used as a TV receiver, your computer may load the drivers that it determines are needed. What we need are special drivers that allow the receiver to be completely controlled by the computer. So pay

special attention to the section about replacing the installed driver for the USB receiver.

Once configured, start the software, select the correct receiver (as discussed in the tutorial) and press play. You should see a screen similar to that below:



There is a lot going on here so let's break down the display by functional area.



Section 1: This is the basic control block for the software. The first icon toggles the left side menu on and off. This gives more room for the displays when you do not need the menu for adjustments. The second icon turns the receiver on and off. You need to click this small “play” button to start the display and audio. The next icon (the gear icon) opens a window where you can adjust the settings of the receiver. Of note, this is where you set the gain of the receiver. Click on this button now and make sure the receiver gain is toward the high end of this scale. The final icon and slider control the audio. The speaker icon is the mute and the slider controls the volume.

Section 2: This is the frequency that the cursor is pointing to. You can change this value by hovering over the numbers with your mouse. On the lower part of each number a small blue box will appear. When you click the number, the number will decrement one number for each click. If you hover over the top of the number, a small red box will appear and mouse clicks will increment the number.

Section 3: This is a series of menus to customize the receiver, processing, and display. The “radio” section is an important section. I sets the type of receiver processing (AM, FM, SSB, etc), the frequency bandwidth and other important settings. One of the neat features of the software is that it defaults to setting the processing mode based on what frequency you have selected. At first, this takes some of the guess work out of setting up the software.

Section 4: This section shows a graph of frequency and signal strength. As the software pans across the frequency band, the signal strength is displayed. Areas of increased signal strength show potential signals. Left clicking on this display will move the cursor to the selected frequency.

Section 5: This section shows a time lapse of the signal strength. This is known as a waterfall display and is used in many signal analysis methods. It allows you to see a visual of signals over time and can help you determine signals that are coming in and out like air band and citizen band radios.

Let’s start using this software to explore the electromagnet spectrum. We will start with the easiest band. The FM radio band covers the frequency range of 88 to 108 MHz. Use the frequency display (section 2) to adjust the frequency to 100 MHz. Now, view the signal strength display. Look for humps in the signal strength. These are areas where the signal strength builds and then decays back down. Because FM stands for frequency modulation, there is not one set frequency that the station transmits on. There is a center frequency and then the modulated information (music, voice, data, etc) moves the transmitted frequency away from the center frequency. Receivers lock on to the center frequency and measure the deviation of the received frequency from this center.

This is the modulated signal recovered from the transmission. You will notice as you selected 100 MHz that the Radio mode setting automatically adjusted to WFM (wideband FM) and a banner on the bottom of Section 4 shows that you are in the FM band. These are helpful additions to the software.

Find a station (large hump in signal strength and a streak of color on the waterfall display) and left click on Section 4 at the center of the hump. If all goes right, you should see the cursor lock onto the station and you should hear the station audio.

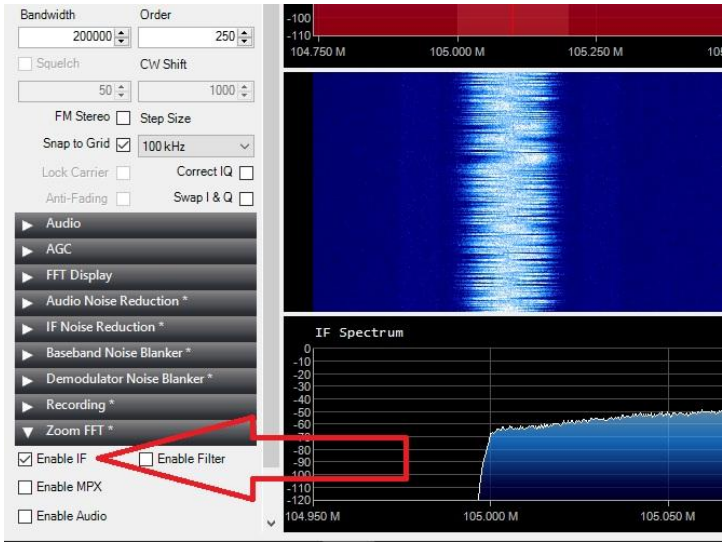
The signal strength graph can be grabbed and pulled by left clicking and dragging. Sometimes this is a convenient way to scan for new frequencies.

Some FM stations transmit data associated with the station (like current song and artist). If this information is available it will display at the top of the signal strength section.

Let's move on to some AM signals. AM stands for amplitude modulation. This is a transmission where the frequency of the transmission is fixed, but the signal strength is modulated with the desired information. The receiver need to sit on the frequency and watch the amplitude of the signal. The amplitude will have the information (music, voice, data) imposed on it. The frequency range of AM radio (that you would receive on a typical AM radio) is 540 to 1600 kHz. This is actually too low for the receiver which has a low frequency response of 25 MHz. But there are a lot of interesting AM radio transmissions in our receiving band.

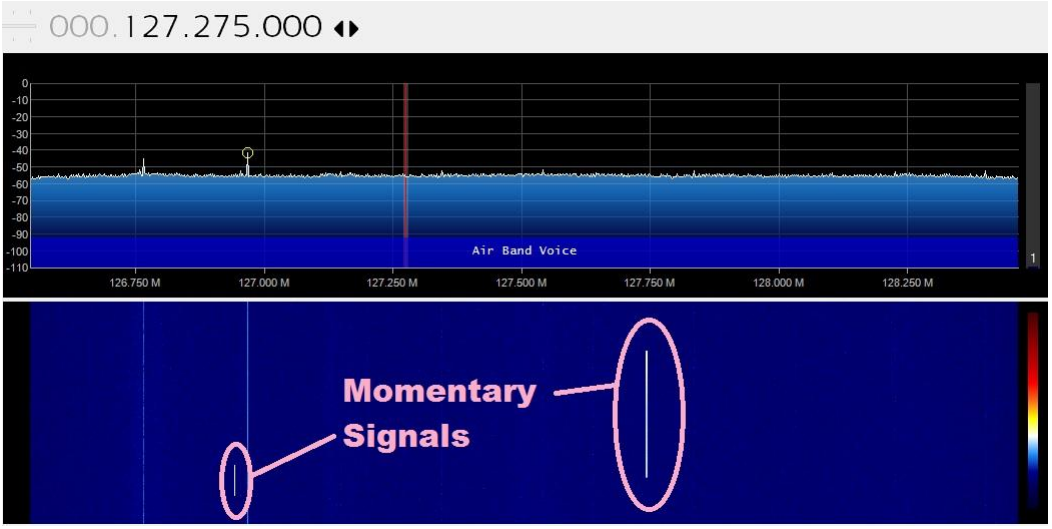
If you are near an airport, you will find a lot of chatter in the air band.

First, let's add a feature to the display. We want to be able to view an expanded view of the frequency we are receiving. Go to the left menu section and expand the section that is labeled "Zoom FFT."



Select the checkbox that says "Enable IF." This will add a display section to the lower part of the screen. This area is an expanded view of the signal strength section. This will allow you to tune and measure frequencies more accurately.

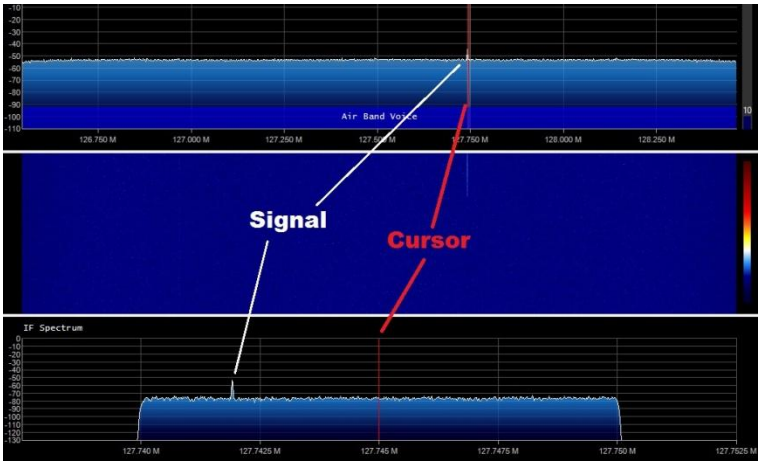
Tune the frequency to the air band. Select 127 MHz on the frequency section (section 2). The air band covers a pretty large frequency range so you may need to do some searching or look up local frequencies on the internet.



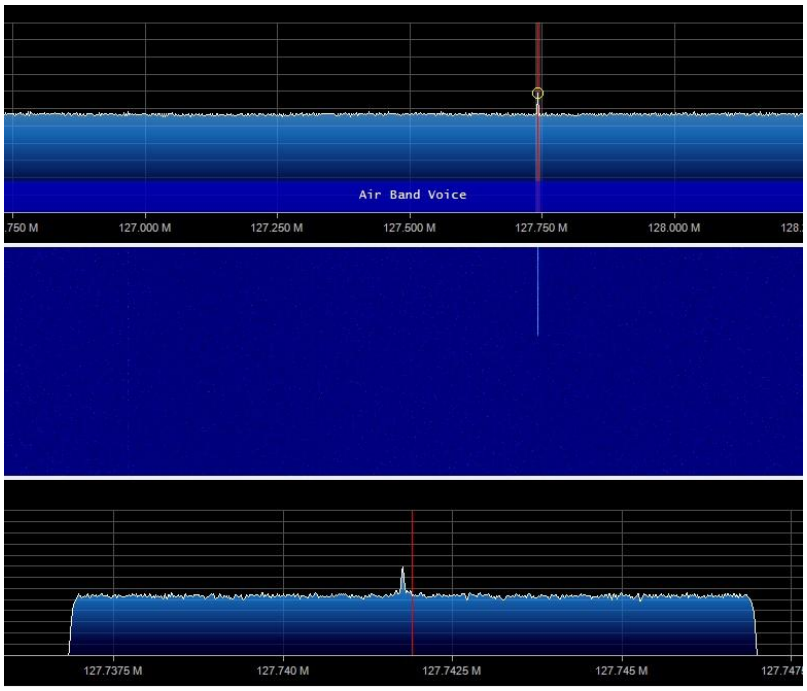
Here is where the value of the waterfall display comes in handy. There are some devices that transmit continuously like beacons and other navigational transmitters. But voice transmissions only transmit when the microphone is keyed. This will make the signal come in and out. You can see this easily on the waterfall display. A bright line will start burning in when the transmission starts and then will disappear when it ends. You can click on these frequencies in the waterfall section to hone in on the frequency.

Like before, when you changed the frequency to the air band, “Air Band Voice” appeared in the signal strength display and the radio mode was changed to AM.

Find one of these signals and set the cursor on it. Now when the transmitter is keyed, you should hear the communication. In the lower display, you may see the frequency peak not where your cursor is.



The bottom display acts just like the top. You can click and drag it. On the lower display when the signal is active, left click on the signal and drag it to your cursor. This will center the frequency on your cursor and give you the best reception and allow you to easily read the frequency of the received signal.



That is the basic information you need to get started. This software will allow you to peer into the vast electromagnetic spectrum that surrounds you. You may be surprised to see what is out there.

There are many great resources on the internet to expand the functionality of this software. You can actually add modules that can decode digital transmissions, display weather satellite pictures, and so much more. We encourage you to dive deep into this fun and informative hobby.