



Scanning the Spectrum

An Intro to Software-Defined Radio with Gqrx



*a do-it-yourself guide
from Iffy Books*



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software-defined radio for beginners

Electromagnetic (EM) energy moves in waves.
Here's a wave with high frequency:



Here's a wave with low frequency:



And here's one cycle of a wave:



The word "hertz" means "cycles per second." So sending a radio signal at 91.7 megahertz (MHz) means generating an EM wave with a frequency of 91,700 cycles per second.

Some EM waves can be seen as visible light (roughly 400–790 THz). EM waves in the infrared range (300 GHz–430 THz) are absorbed by your body, and you feel them as heat.

The radio frequency (RF) spectrum is the range of EM frequencies used for carrying radio, TV, cell phone, and wi-fi signals (30 Hz–300 GHz).

Radio communication is possible because EM waves at different frequencies don't interact with each other. So you can send a radio signal at 91.7 MHz and a different one at 91.9 MHz, and each signal will stay in its lane.

If you've ever tuned an AM or FM radio, you've scanned through a small segment of the RF spectrum. When you turn the radio's tuning knob, you can hear static on some frequencies and clear signals on other ones.

Using software-defined radio (SDR), you can tune in to a wider range of frequencies than a conventional AM/FM radio. You can also set the modulation mode (AM, FM, etc.) manually.

And compared to a conventional radio, SDR lets you see what's happening on a wider slice of the RF spectrum. You can visualize a range of frequencies using a spectrum plot and a waterfall display, and choose which frequency to listen to based on what you see.

★ Choose an SDR device ★

SDR devices have become pretty cheap in recent years. One of the most popular is the RTL-SDR, a USB device can receive frequencies from 500 kHz to 1.75 GHz. You can get an RTL-SDR kit with a dipole (V-shaped) antenna for about \$40. Learn more at <https://rtl-sdr.com>



If you're looking for something small, check out the NooElec NESDR Nano series. You can get a Nano 3 kit with an antenna for about \$35, or a Nano 2+ kit for around \$25. Learn more at <https://nooelec.com>



★ Install gqrx ★

Gqrx is a program that lets you visualize, listen to, and record radio signals from an SDR device.

If you're using Linux or macOS, go to the following URL and download Gqrx for your system:

<http://gqrx.dk/download>

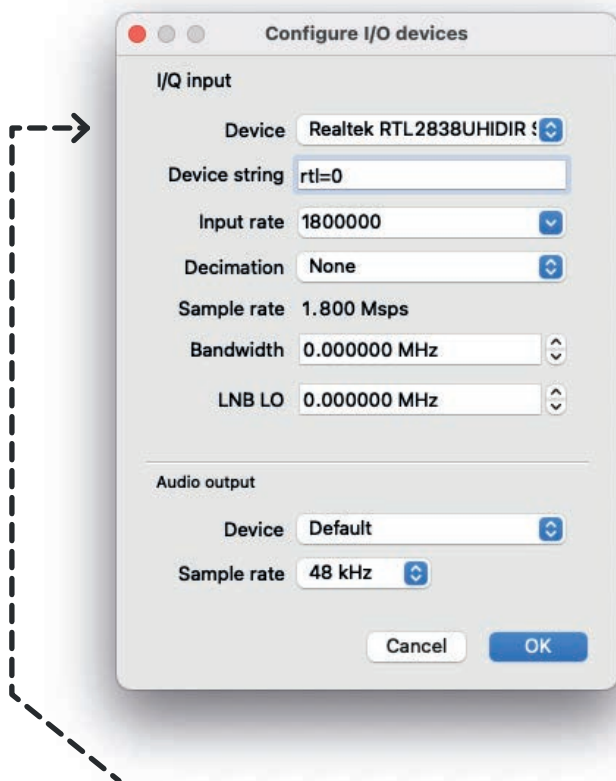
If you're using Windows, try SDR# instead:

<https://airspy.com/download>

Note for Mac: The macOS version of Gqrx isn't updated very often, but it should still run OK. The first time you open it, you'll need to right-click (or control+click) the application icon and give permission to run a program by an "unidentified developer." If it doesn't work on the first try, right-click the application and try again.

★ Configure hardware ★

Plug your SDR device into your computer and open Gqrx. You'll see a window that looks like the one below:



Under the **Device** dropdown menu, a device called "Realtek" should be selected by default. That's most likely the correct option.

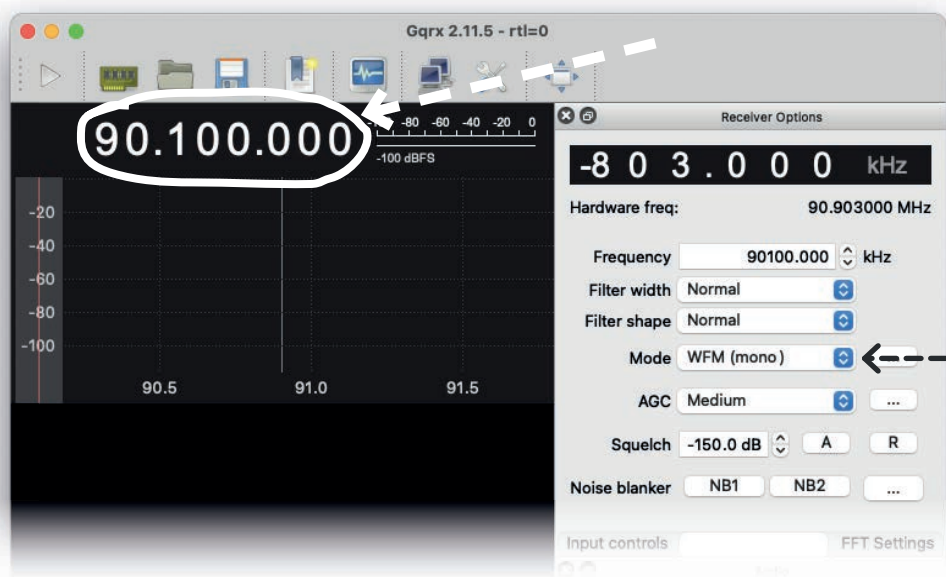
Alternately, select **Device > Other...** and update the options to match the example above.

Click **OK** to continue.

★ Listen to FM radio ★

In a moment, you'll click the play button to start processing audio from your SDR device.

But first, select the frequency of a nearby FM radio station with a strong signal. The frequency you're tuned to appears near the top of the window. The example below is tuned to 90.1 MHz.

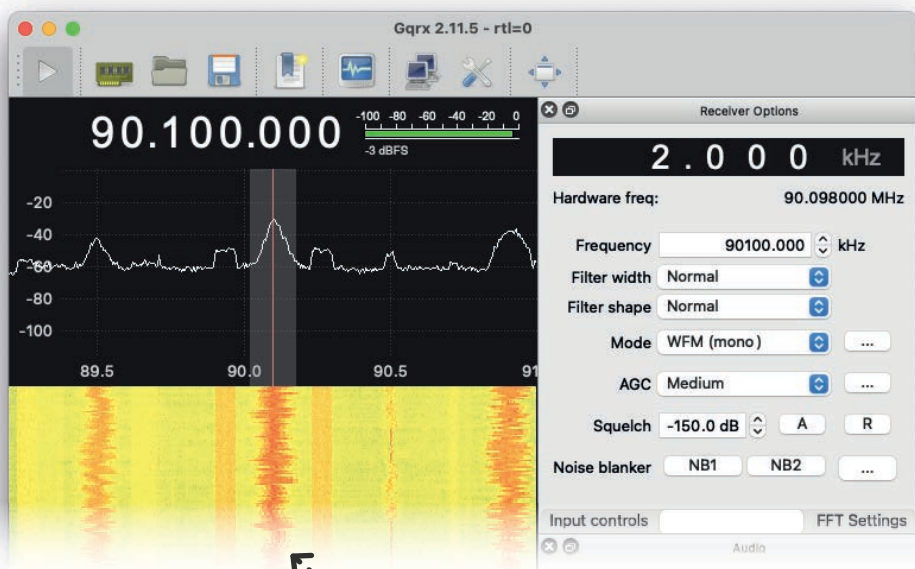


Adjusting the frequency in Gqrx is a little tricky. Click the top half of any digit to tune up, and click the lower half of a digit to tune down. You can also click a digit and type a number on your keyboard to replace it.

Next, click the **Mode** dropdown menu and select **WFM (mono)** or **WFM (stereo)**. "WFM" stands for "wideband frequency modulation."

Make sure your computer volume is at a reasonable level. You may want to avoid using headphones when starting out with SDR, because unexpected volume spikes can hurt your ears.

Click the play button at the top left corner of the window to start processing input from your SDR device. You should hear the radio station you chose.

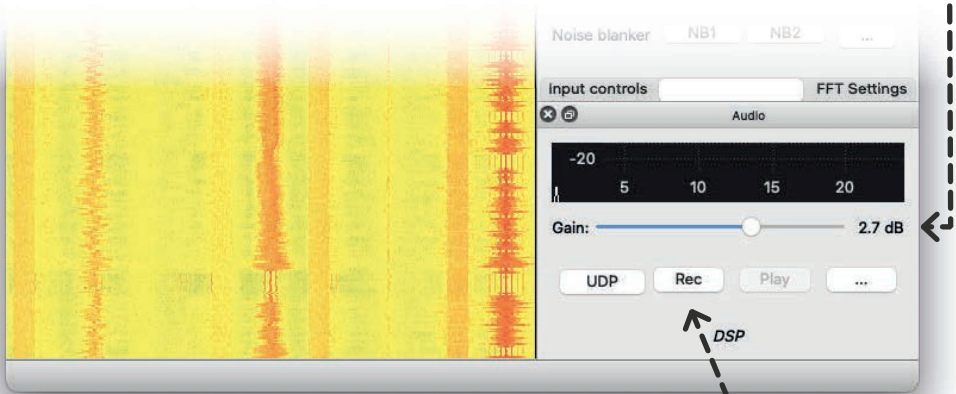


The window with the bouncing white line is called the **spectrum frame**, showing how much energy is present at various points along the RF spectrum. In the example above you can see three large peaks, corresponding to three different FM stations.

The **waterfall display** contains the same information as the spectrum frame, but plotted over time. The colors range from red (high energy) to yellow (medium energy) to blue (low energy).

Clicking within either of the visualization frames will tune to the corresponding frequency.

If the volume is too low, you can use the **Gain** slider to turn it up.



★ Record audio ★

To record audio from the radio, click the **Rec** button. Click it again to stop recording.

By default, your recordings will be saved to your home directory (the one that contains Documents, Desktop, etc.).

To save audio somewhere else, click the "..." button on the same line as **Rec**. In the window that pops up, switch to the **Recording** tab and click **Select** to choose a new save location.

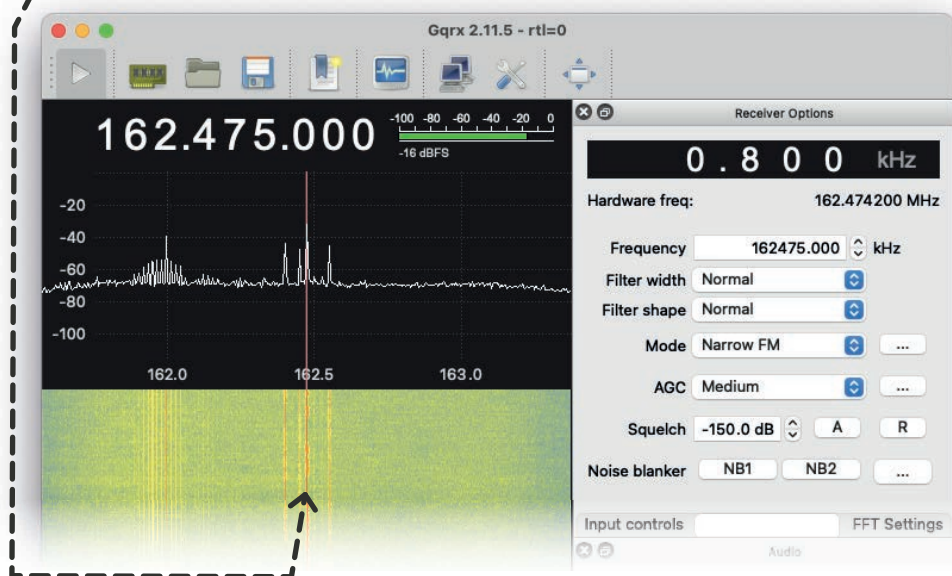
★ Listen to weather radio ★

In the U.S., the National Oceanic and Atmospheric Administration (NOAA) broadcasts automated 24-hour weather reports from a network of transmitters around the country. NOAA Weather Radio (NWR) broadcasts can be found at the following frequencies (MHz):

162.400	162.425	162.450	162.475
162.500	162.525	162.550	

Click the play button to stop the audio, then click the **Mode** dropdown menu and select **Narrow FM**. Tune to one of the frequencies above, then press play to start the audio again.

If the frequency you chose isn't coming in clearly, try another one. Or check the waterfall display and click on the frequency with the strongest signal.

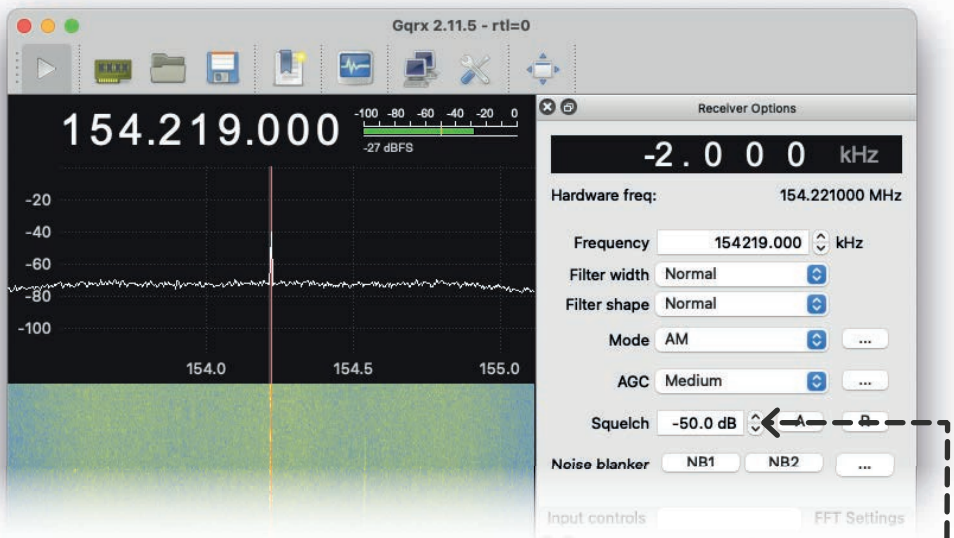


★ Listen to emergency services ★

From **150 to 157 MHz**, you'll find several channels used for public safety services (e.g., fire and EMS), as well as walkie-talkie channels for businesses and civilians. You'll want to use **Narrow FM** mode for this frequency range.

Turn down your volume and tune Gqrx to any frequency from **150 to 157 MHz**. You'll probably hear static. Watch the waterfall display for a minute and you'll see some faint lines scroll by, indicating transmissions at specific frequencies.

Try to tune to a channel while it's being used, and see if the signal is strong enough to understand. When you find a channel with a good signal, park there for a while and listen.



To turn off the audio when there isn't a strong signal, you can adjust the **squelch threshold**. Start at -30 dB and look for a value that lets signals through while silencing the noise.

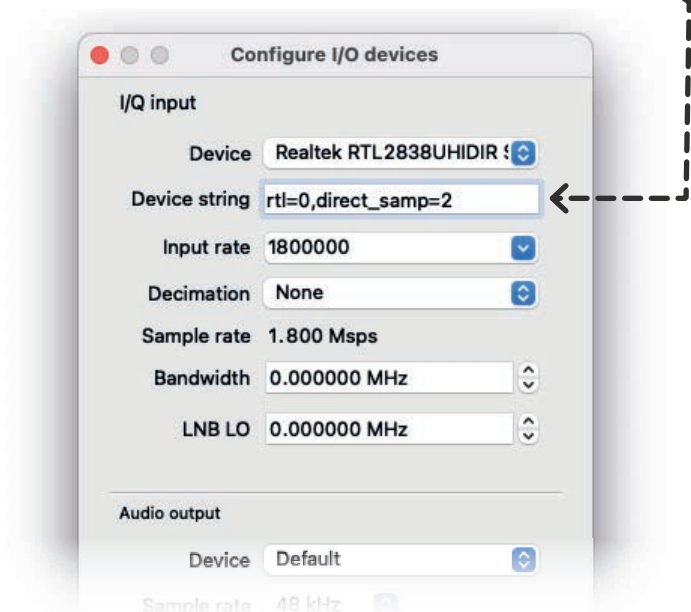
★ Listen to shortwave stations ★

The shortwave band, spanning **3 to 30 MHz**, is used for long-range broadcasting. Because shortwave signals bounce off the ionosphere, they can travel all around the globe.

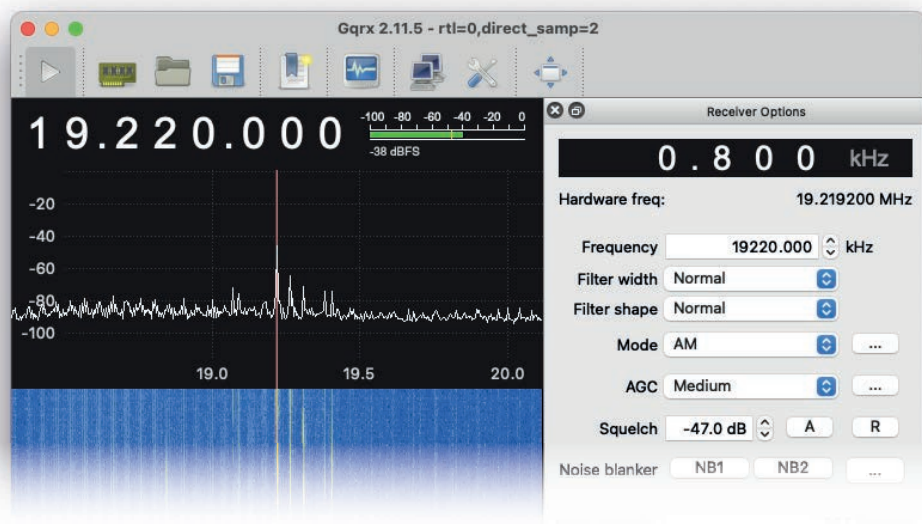
If you scan through the shortwave band, you'll find lots of religious stations, news/propaganda broadcasts from various governments, and even a few commercial music stations.

In order to tune to frequencies on the shortwave band, you'll need to switch Gqrx to **direct sampling mode**.

In the menu bar, go to **File > I/O Devices**. Set the device string to "**rtl=0,direct_samp=2**" and click **OK**. Then quit Gqrx and reopen it.



In the **Mode** dropdown menu, select **AM**. Then click the play button to start processing input from your SDR device.



Tune to a frequency from 3 to 30 MHz and see if you notice any active signals in the waterfall display. When you find one, click on it and see if the signal is strong enough to hear.

If you see a signal on the spectrum frame and waterfall display, but you don't hear anything when you tune to it, try lowering your squelch threshold.

Many shortwave stations only broadcast for a few hours per day, and reception varies depending on weather.

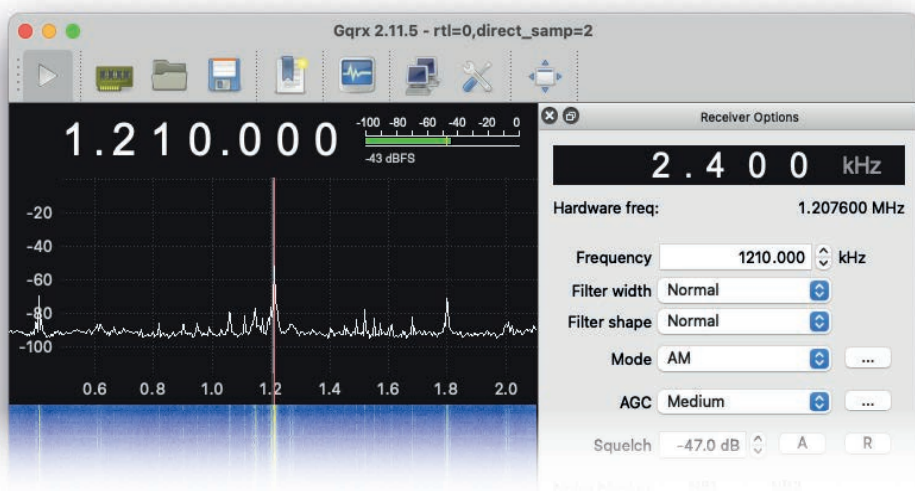
To learn more about who's broadcasting on the shortwave band, check out this Wikipedia page:

https://en.wikipedia.org/wiki/List_of_shortwave_radio_broadcasters

★ Listen to AM stations ★

While you're in **direct sampling** mode (see the previous section), you can also tune to conventional AM stations. Make sure your modulation mode is set to **AM**.

AM stations' frequencies are usually given in kilohertz. So a station at 1210 AM broadcasts at 1,210 kilohertz, or 1.21 megahertz. Here's what that looks like in Gqrx:



When you're done listening to AM and shortwave stations, you'll want turn off direct sampling mode. Go to **File > I/O Devices**, set the device string to "**rtl=0**", and click **OK**. Then quit Gqrx and reopen it.

★ Listen to ham frequencies ★

Certain segments of the RF spectrum are reserved for amateur radio, a.k.a. ham radio. Transmitting on a ham frequency requires a license from the FCC (in the U.S.), and operators follow strict rules about what they can do.

There are ham radio allocations spread across the RF spectrum, but you'll probably have the best luck in the VHF (very high frequency) band. The following VHF frequency ranges are reserved for hams:

50–54 MHz 144–148 MHz 220–225 MHz

To listen to VHF ham frequencies, set your modulation mode to **Narrow FM**.

To find more ham radio frequencies, go to the following URL:

<http://www.arrl.org/frequency-allocations>

★ Listen to airplanes ★

To listen to radio communications from airplanes and air traffic control, set your modulation mode to **AM** and scan around in the **123–136.00 MHz** range.

★ Learn more ★

To learn about Gqrx's other features, check out the following article:

<https://gqrx.dk/doc/practical-tricks-and-tips>

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