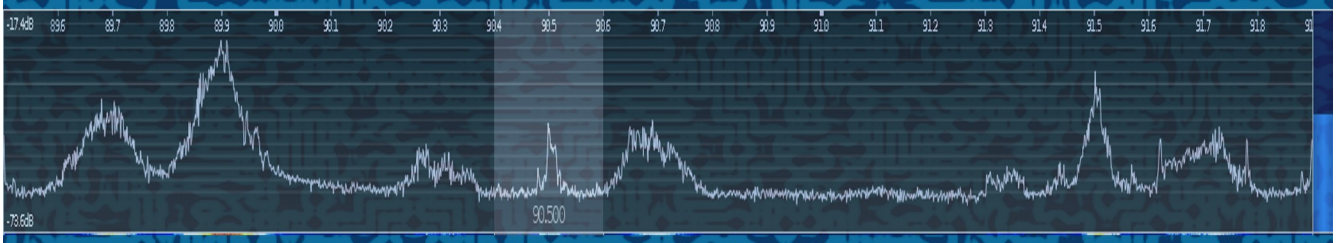
RTL-SDR for Linux
Quick Start Guide



Third Edition-2020

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Introduction:

If you've installed Linux on your PC hopefully you'll find this guide quick and easy. Created for Linux Mint v19.3 on a PC, I'll cover the software I've found to be complete and working as of this writing and O.S. If you have some amateur radio background but are new to SDR many of the controls will be familiar. If not, you'll learn as you go.

First, a quick primer on what RTL-SDR is. In Europe, TV uses the DVB-T standard. Inexpensive USB receivers are available to tune in on a computer. Based on the RTL2832 demodulator & USB interface chip, tuning is done by the R820T2 chip. By installing specialized drivers and software, these devices can be used as a **S**oftware **D**efined **R**adio capable of receiving 24 – 1800 MHz in blocks of ~2.4 MHz at a time. Bypassing the tuner chip by switching the receiver to direct sampling mode enables DC – 24 MHz reception.

A few caveats: North American TV is on the ATSC standard so these devices can't be used to watch TV. Also, the RTL hardware was originally designed to receive strong broadband signals. It lacks the sensitivity and selectivity of expensive receivers, so it can be over-loaded by strong signals such as FM Broadcast and pagers. They're also susceptible to RFI. Filters and pre-amplifiers are available to overcome some of these limitations.

The unit used here is version 3 of the RTL-SDR.com dongle. It has a 820T2 tuner, TCXO, anti-static diode, and a metal enclosure with heat-sink. It can be switched into direct sampling mode via software, no hardware mods needed. Use a good quality USB extension cable with ferrite cores on both ends. Try to position the dongle away from the computer and other sources of electrical noise to minimize interference.

PC system requirements are modest. A dual-core CPU with 2GB RAM or better will do. None of the applications here are highly demanding of Video or HDD.

Antennas & Feedlines:

Regardless of cost, any radio is only as good as it's antenna. There's an abundance of information on-line and in ARRL publications, so I'll be brief.

- Rule #1, there is no such thing as the perfect antenna for all situations. It does not exist. Like anything, there's compromises and trade-offs. A broadband antenna may be more useful across a wider swath of spectrum, but it won't gather as much signal as antenna designed for a specific frequency. Also, a broadband antenna collects unwanted signals which may overload the receiver.
- Rabbit ears are a good starter antenna. It's easy to adjust the length and orientation.
- Attic or outdoor antennas for TV may work well. Note they are usually in the horizontal plane, hence they are horizontally polarized. Ham, Public Service, NWR and similar services tend to use vertical antennas and so emit vertically polarized waves. Because of this difference, they may not be stellar performers. Newer TV antennas designed for HDTV may lack the ability to pull in FM radio. TV antennas are broadband by design.
- Discone antennas are broadband and work well for general purpose use.
- Turnstiles and Folded Dipoles excel at FM broadcast reception.
- For ADS-B a 12 element Coaxial Collinear is notably superior to a discone.
- Dipoles and long wires work well for the HF bands. (<30MHz)
- Ground planes, J-poles, dipoles, yagis, quads and log periodic antennas can offer superior performance when designed for a specific band.
- RG-6 coax and type F connectors, the same type used for cable and satellite TV is perfectly acceptable to use. It performs well up to several GHz, is inexpensive and commonly available. Type F connectors are probably the easiest type of connector to work with. Compression fittings are preferred, but a good quality side-crimp properly done is just fine. SMA to Type F connectors are available online.

In summary, VHF/UHF frequencies tend to be line-of-sight and can be blocked by some building materials, especially metal. Higher is better and outdoors is best.

Watch out for those power lines!

Installing the drivers:

1. Open a terminal and confirm you're in your home directory. This is the preferred convention and will be assumed throughout this text. Text highlighted in gray is exactly what you want to type or copy/paste to the command line. Yes it's case sensitive.

2. Update your distribution.

```
sudo apt-get update
```

3. Install the tools needed to retrieve (git), compile (cmake) and build (build-essential).

```
sudo apt-get install git
sudo apt-get install cmake
sudo apt-get install build-essential
```

4. Install libusb-1.0-0-dev which is a C library that provides generic access to USB devices.

```
sudo apt-get install libusb-1.0-0-dev
```

5. Retrieve, build and compile the RTL2832U Osmocom drivers from the source.

```
git clone git://git.osmocom.org/rtl-sdr.git
cd rtl-sdr/
mkdir build
cd build
cmake ../ -DINSTALL_UDEV_RULES=ON
make
sudo make install
sudo ldconfig
sudo cp ../rtl-sdr.rules /etc/udev/rules.d/
```

6. Blacklist the default driver that is automatically loaded for using the dongle as a TV device as it doesn't work for SDR purposes and clashes with the new Osmocom drivers we just installed.

A. Open your /etc/modprobe.d folder as (right-click) an administrator.

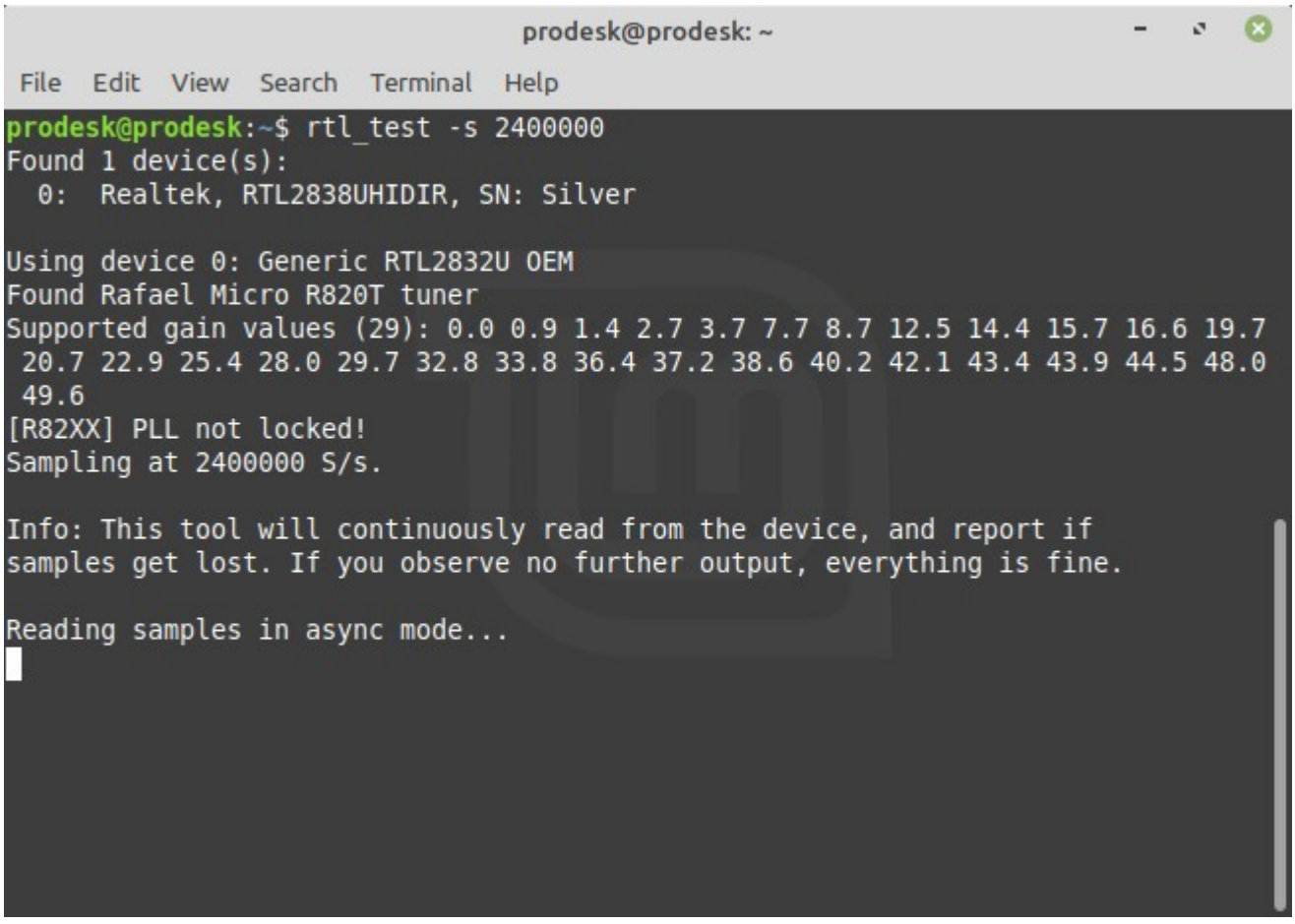
B. Create a new file 'blacklist-rtl.conf' and add this one line:

```
blacklist dvb_usb_rtl28xxu
```

C. Save the file, close the editor and restart the machine.

7. Test that the dongle is working by opening a terminal and typing:

```
rtl_test -s 2400000
```



If you get dropped samples, lower the -s number. Don't worry about messages like PLL not locked or E4000 tuner not found or that it says R820T and not R820T2. If you're seeing the above then your drivers and dongle are working. You're now ready to install some applications.

Gqrx General Purpose Radio/Spectrum Analyzer:

Gqrx continues to be the best spectrum analyzer for Linux. It’s configurable and accurate enough to earn a place on any test bench or radio shack. It can be found in the Synaptic Package Manager, but to get the latest version, visit http://gqrx.dk for instructions on how to add their PPA's (Personal Package Archive) to your system and install. They've made it pretty easy.

On first startup you'll see the Configure I/O devices box. If it doesn't appear, click the circuit board icon on the toolbar and check the following:

Device: Realtek RTL2838xxx

Device String: rtl=0 [Normal use >24MHz]*

Device String: rtl=0,direct_samp=2 [Direct Sample mode <24MHz]*

Input rate: 2400000 [aka Sample Rate]**

Decimation, Bandwidth, LNB LO: 0

** Note you're choosing one of the above Device Strings on startup, the first for VHF/UHF OR the latter for HF/MF.*

*** This is the amount of radio spectrum you'll see. When tuning in the HF/MF bands it's sometimes helpful to select a lower value. A higher value means you can view a larger slice of spectrum, but go too high and it gets choppy.*

Click OK then the > Power Button in the upper left corner to start receiving. Click or mouse wheel on the digits to change frequency. On the right under Receiver Options select the appropriate demodulator. (ie Narrow FM for NOAA Weather Radio or WFM for broadcast FM).

Hover over each item to see what it does. Under Input controls, toggle hardware AGC and adjust LNA gain to maximize the signal but not so high that static or distortion takes over. Adjust for a noise floor of -60db to -70db. Note that you'll need to alter gain settings as you tune around the spectrum.

If the audio sounds choppy, try reducing the sample rate. Also check under the FFT Settings tab and reduce the FFT size and Rate fps. You may also need to adjust your PPM as described next. You can also bookmark favorite frequencies and organize them by category.

Frequency Correction with GQRX:

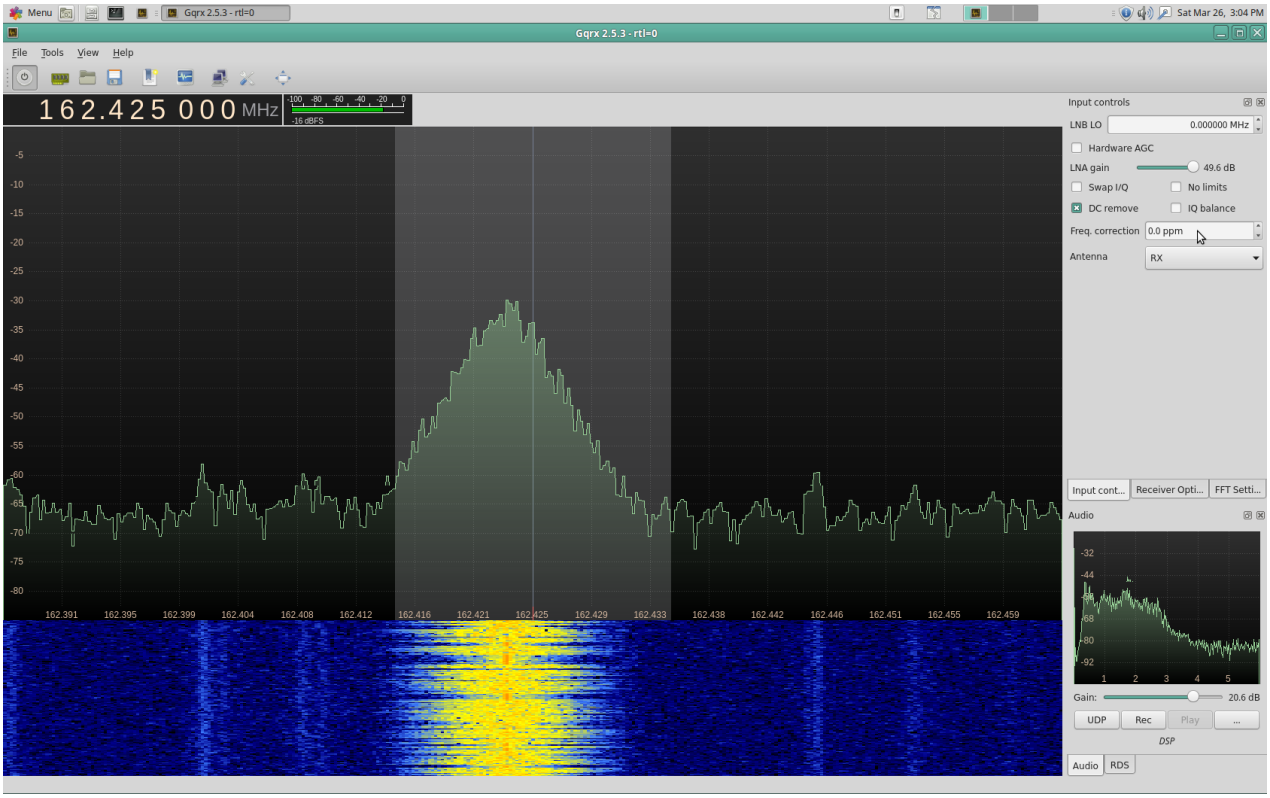
Later model dongles such as RTL-SDR's v3 have improved TXCO's for accurate frequency readouts regardless of temperature. For most uses in normal mode no calibration is needed.

However, older dongles and ones in direct sampling mode may need PPM adjustments. Once you've determined your PPM error correction factor you can use that value in most other RTL software. As long as the dongle doesn't overheat, this value should remain reasonably constant.

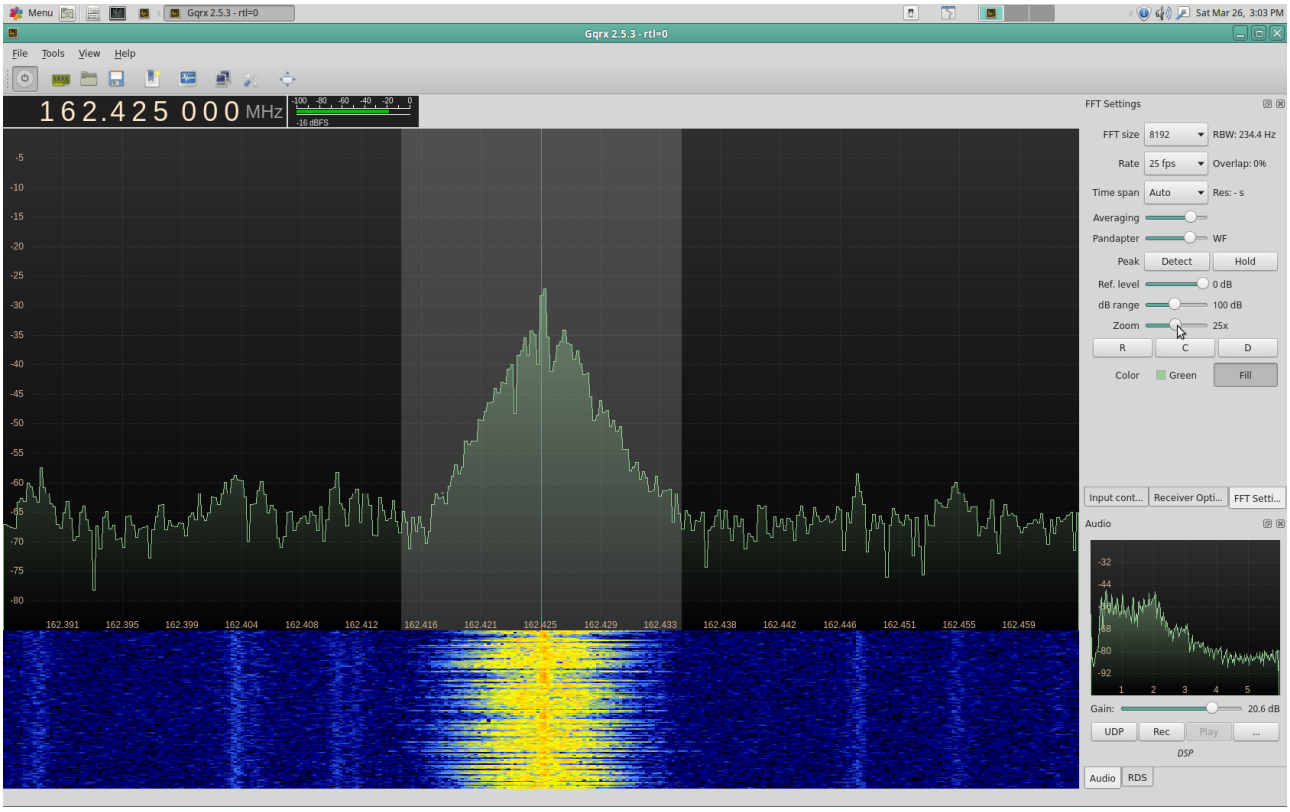
To determine your dongles PPM, launch GQRX and tune your SDR to one of the National Weather Radio frequencies. Give the unit at least 15 minutes to warm up.

162.400	162.425	162.450	162.475	162.500	162.525	162.550

Zoom in on the signal and adjust your PPM until the tuning line is centered on the signal. See the next two images for details.



Uncorrected PPM error.



Adjust your PPM + or – until tuning line is centered on signal.

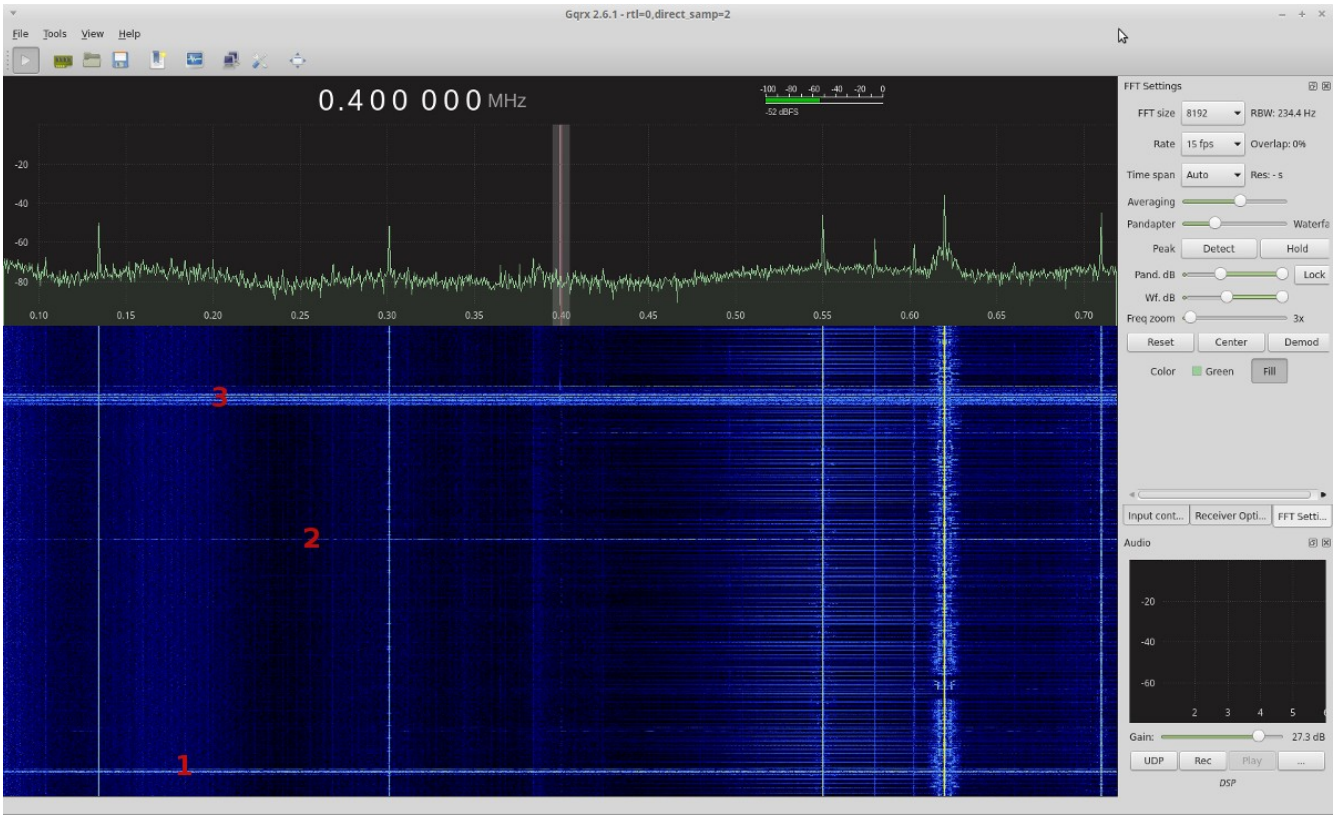
To check and adjust your PPM in Direct Sampling mode in the HF bands, tune to one of the NIST time stations on 2.5, 5.0, 10.0, 15.0 or 20.0 MHz. Choose whichever station comes in best. These transmitters are very frequency accurate.

The NIST WWV is quite the resource and worth the time for any radio enthusiast to know about.

https://www.nist.gov/pml/time-and-frequency-division/radio-stations/wwv

Lightning Detection with SDR:

What follows is an informal experiment to detect approaching lightning. Here I'm using GQRX and CubicSDR in direct sample mode but any spectrum analyzer software and dongle that can tune VLF should do it. Many dedicated lightning detectors work by listening to frequencies below the AM broadcast band, hence I chose to monitor 0 to 600kHz. The antenna is a 1/2 wave trapped dipole for HF but any bit of wire at least a few meters long will work.



The waterfall display speed is set to represent ~30 seconds. Event #3 in this image was several rapid-fire and rather close by. I found that by tuning to a quiet part of the spectrum and setting squelch, lightning discharges produce an audible crackle, hence an audible alert without needing to listen to constant static or needing to watch the screen.

Spectrum Plotting with Spektrum:

This app functions a bit differently than GQRX. It does not decode so there is no sound output. It's designed to rapidly scan a defined range of frequencies from 24MHz to 1800MHz and display the power level of any signals found. It's perfect for identifying the frequency of a transmitter when you've no idea what it might be. It's very handy for finding the source of RFI, such as a strong local transmitter or RF-noisy lighting.

Installation is simple, just visit https://github.com/pavels/spektrum/releases and download the latest tar.gz file. Extract it anywhere you like and dbl-clk to run.

Of particular interest is the Relative Mode feature. It allows you to zero any noise created by the computer or the dongle itself. Here's how to use it:

Launch Spektrum with a dummy load connected to the dongle.

Set desired frequency range.

Click 'Relative Mode' and wait several sweeps.

Click 'Set Relative' to set the current captured spectrum as reference. You should now see a fairly straight line around 0db.

Remove the dummy load and connect the antenna. The spikes you now see on the graph represent RF emissions minus noise created by the computer or dongle.

It's also very useful for measuring filter characteristics. To do that:

Launch Spektrum with a noise source connected to the dongle.

Set desired frequency range.

Click 'Relative Mode' and wait several sweeps.

Click 'Set Relative' to set the current captured spectrum as reference. You should now see a fairly straight line around 0db.

Insert the filter between the noise source and the dongle. You should see a reasonably accurate curve representing what ranges the filters blocks and passes.

Eeprom flashing:

You may have noticed a generic serial number appear when you ran rtl_test. That value can be changed to a more meaningful value. For example, I have several dongles and have flashed their serial number to indicate by color which one I have plugged in. At a terminal, type:

`rtl_eeprom` to display current configuration

`rtl_eeprom -s Silver` to change the serial number to 'Silver'

Resources:

http://sdr.osmocom.org/trac/wiki/rtl-sdr – *Source of the RTL-SDR drivers.*

http://rtl-sdr.com – *Great place to buy and learn about RTL-SDR*

http://distrowatch.org – *A one-stop index of the top 200 Linux distributions*

http://linuxmint.com – *A stable & refined Linux distribution*

qsl.net/na4it/dbgp.html – *A cheap, easy & good dual-band ground-plane antenna*

wikipedia.org/wiki/Electromagnetic_spectrum – *A primer on radio waves*

radioreference.com/ - *Excellent database of frequencies & radio info*

www.sigidwiki.com/wiki/Signal_Identification_Guide – *ID that waveform*

qsl.net/kb5wck/antenna.html – *A good source of antenna design calculations*

http://sdr.hu – *A network of shared SDR's around the world.*

In Closing:

Feel free to copy or distribute this guide as you see fit. My goal here is to consolidate and share my notes so others can bypass hours of annoying research and just get to the fun stuff. :) Unfortunately things change quickly so what works today may not work after the next update. I've found keeping up with it to be time consuming so I've shifted the focus of this guide to just the basics, centered around radio and test bench use.

Thanks for tuning in!

- Kenn