

An Amateur's amateur guide to Software Defined Radio (SDR)

Presented by Ethan Waldo

KF5UFH

About Me

- Learned from a co-worker about the existence of amateur satellites and Cubesats around December 2012
 - <http://science.slashdot.org/story/12/12/19/2310252/ask-slashdot-how-would-you-build-a-microsatellite>
- Joined AMSAT on 1/23/2013
 - Learned about the importance of amateur radio communication
- Ordered a Realtek TV Tuner commonly used for SDR on 2/3/2013
- Ordered the ARRL Tech license manual on 2/11/2013
- Took and passed the Tech exam on 3/2/2013 and received FCC license on 3/7/2013
- Defined a functioning NFW SDR and successfully listened to the Swapfest at 146.94 on 3/23/2013

What is Software Defined Radio (SDR)?

- A software-defined radio system, or SDR, is a radio communication system where components that have been typically implemented in hardware (e.g. mixers, filters, amplifiers, modulators/demodulators, detectors, etc.) are instead implemented by means of software on a personal computer or embedded system. -Wikipedia
http://en.wikipedia.org/wiki/Software-defined_radio

Why SDR?

- Provides a very low cost entry in to amateur radio
- Takes up little physical space
 - Portability
- Mature software variety and operating flexibility
- Wide range of radio spectrum
- Can appeal to the novice all the way up and beyond the radio engineer
- Usage is increasing in space
 - FOX-1 in US
 - Funcube in UK

Equipment

- Realtek RTL2832U+R820T
 - A USB device primarily intended for receiving DVB-T, FM, and DAB, but Antti Palosaari discovered sample data was unlocked and demodulation is performed in software
 - <http://thread.gmane.org/gmane.linux.drivers.video-input-infrastructure/44461/focus=44461>
 - 24Mhz to 1.85Ghz range
 - Lower HF bands available with upconverters
 - <http://www.nooelec.com/store/software-defined-radio/sdr-accessories/ham-it-up-v1-0-rf-upconverter-for-software-defined-radio.html#.UVMdvBl8s4M>
 - http://www.george-smart.co.uk/wiki/FunCube_Upconverter
 - \$10-\$12 including shipping on Ebay
 - Most sold directly from China so 1-2 week wait typically
 - Discontinued E4000 tuner very popular but frequency range not quite as wide
 - USB connection can be extremely flaky

Equipment



Record Live TV **R820T**
HDTV & SD TV
MPEG-4



Equipment

- Opek VU-1510 VHF/UHF Dual Band Magnet Monopole Antenna from AARadio for about \$20
- SMA Male to UHF Female jumper cable from AARadio for about \$15 (out of stock of the \$6 connector and I couldn't wait)
- GlobalSat MCX-to-SMA Female jumper cable from Amazon for about \$8 (sadly AARadio doesn't carry much MCX currently)
- Acer C7 Chromebook running ChrUbuntu \$200
- Char-Broil Red grill for ground plane: Priceless (or about \$400)

Total Cost sans Laptop and grill: \$50-60

Equipment

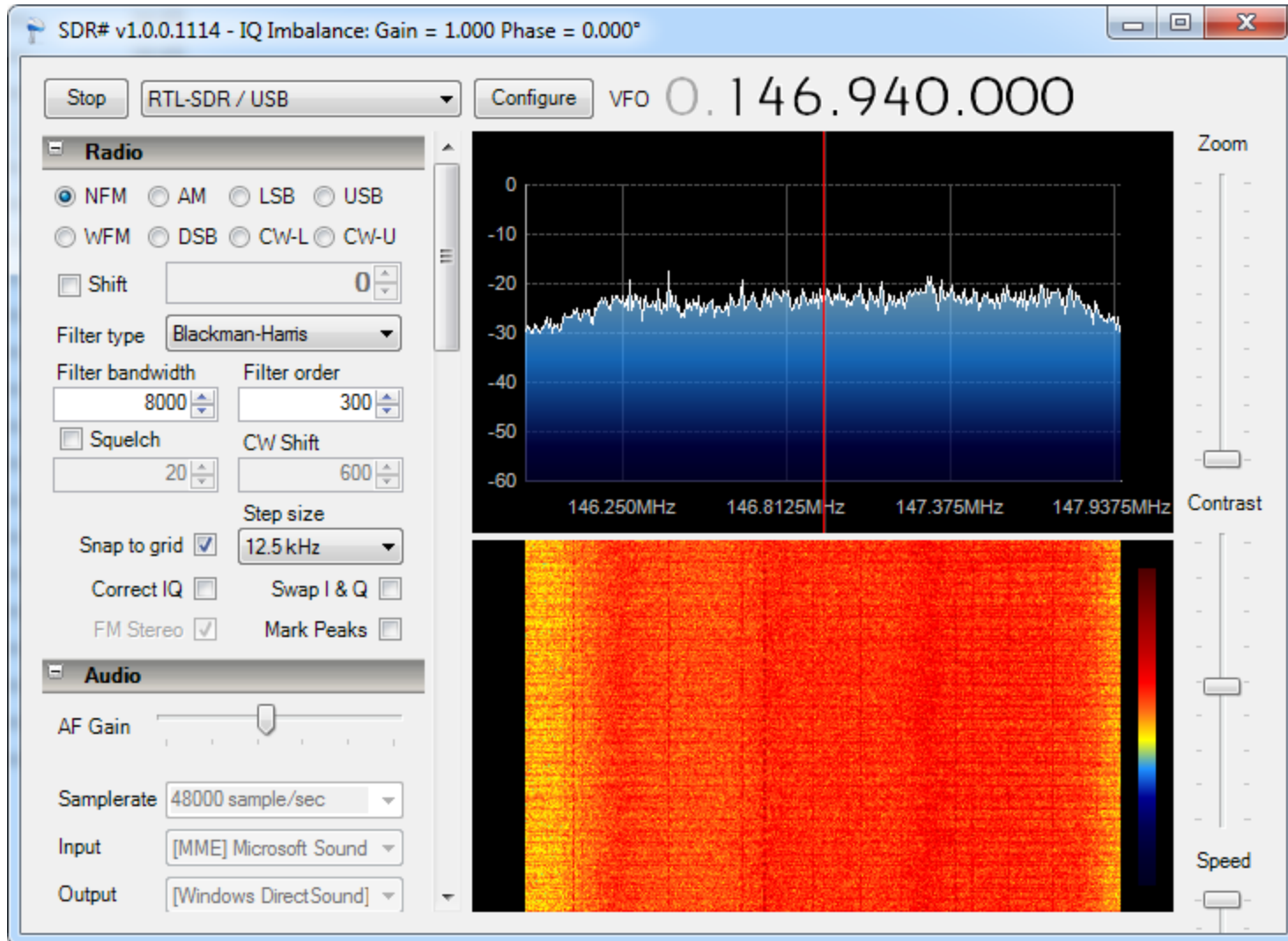


Equipment Disclaimer

- Bought BAOFENG UV-5RE and USB programming cable from Amazon for about \$65 to serve as reference device
 - recommendation from co-worker and a couple of Austin Hams who can remain anonymous if they like
- Was difficult to verify my SDR was working
 - 14cm monopole that came with RTL not great for picking up 2m
 - Didn't expect 146.94 repeater to be so quiet
 - sometimes no chatter for days at a time
 - Knowledge from Internet and ARRL books not clear on whether amateur 2m used WFM or NFM

Microsoft Windows Software

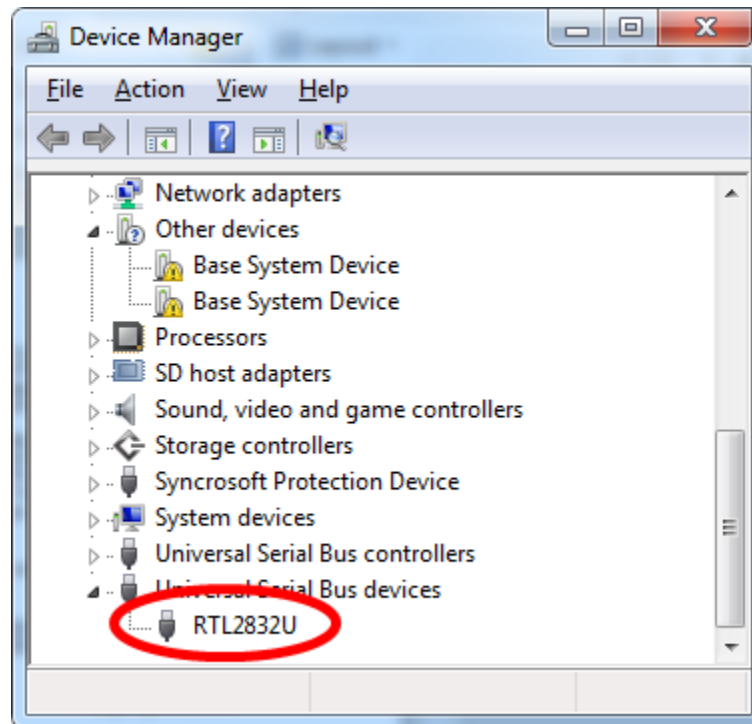
Software (SDRSharp)



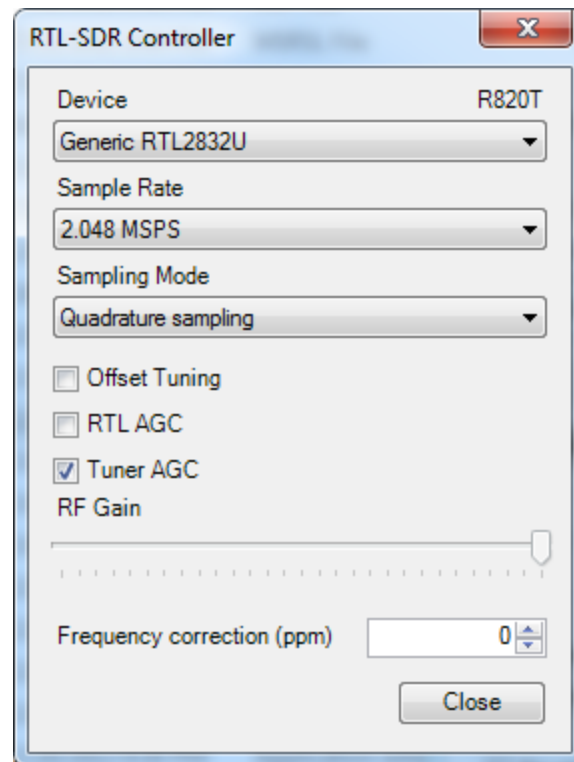
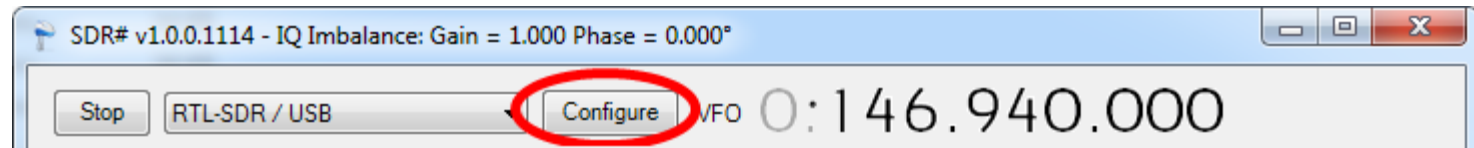
Software (SDRSharp)

- Somewhat Open Source SDR software
 - GUI and plugin parts under MIT license
 - DSP under MS-RSL (Boooo!)
- Download and install from <http://sdrsharp.com>
 - Under “Important note for RTL-SDR users” download <http://sdrsharp.com/downloads/sdr-install.zip> instead for quick install
- Follow instructions at <http://rtlsdr.org/softwarewindows> for Zadig to install special windows driver

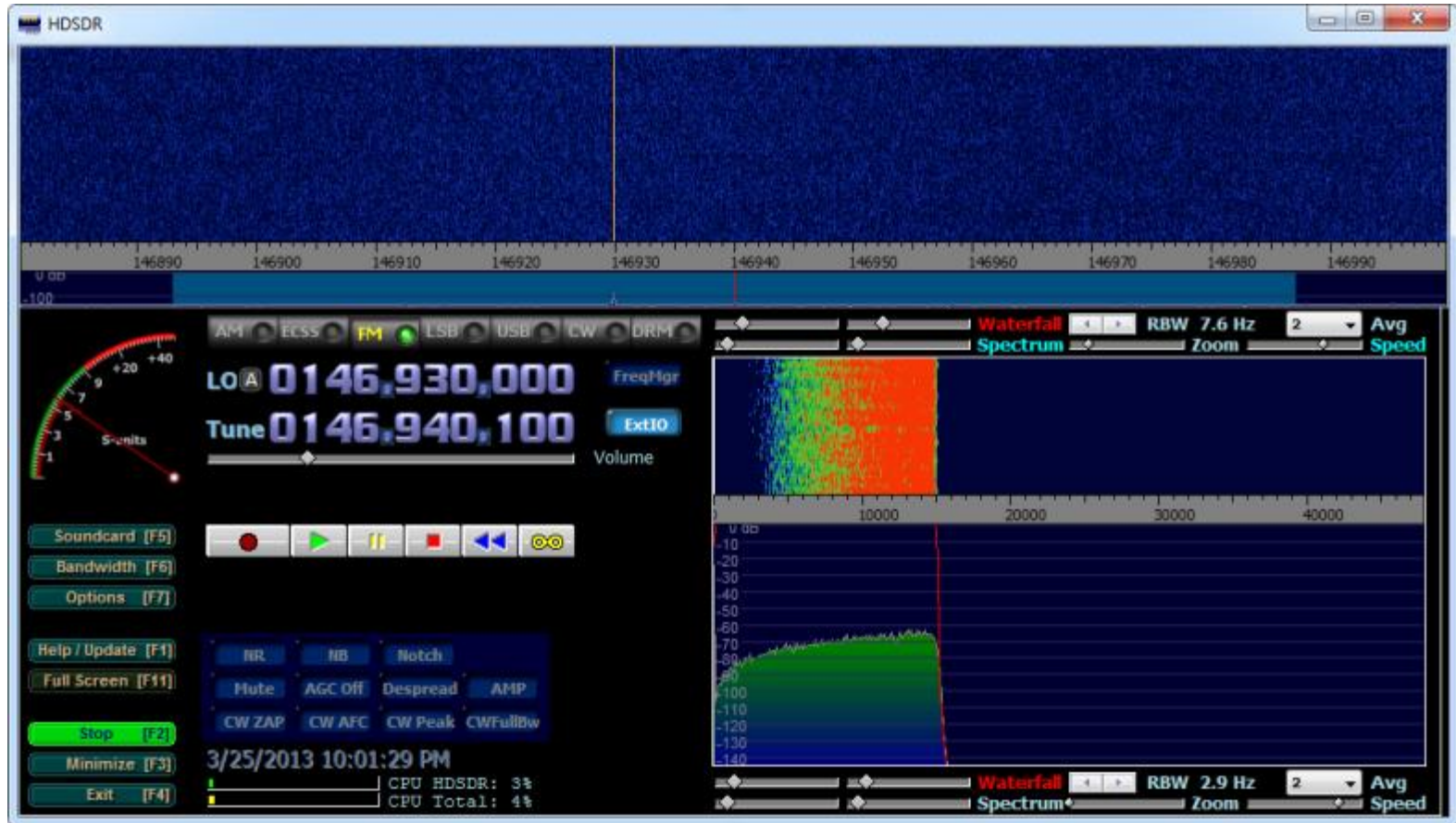
Software (SDRSharp)



Software (SDRSharp)



Software (HSDR)

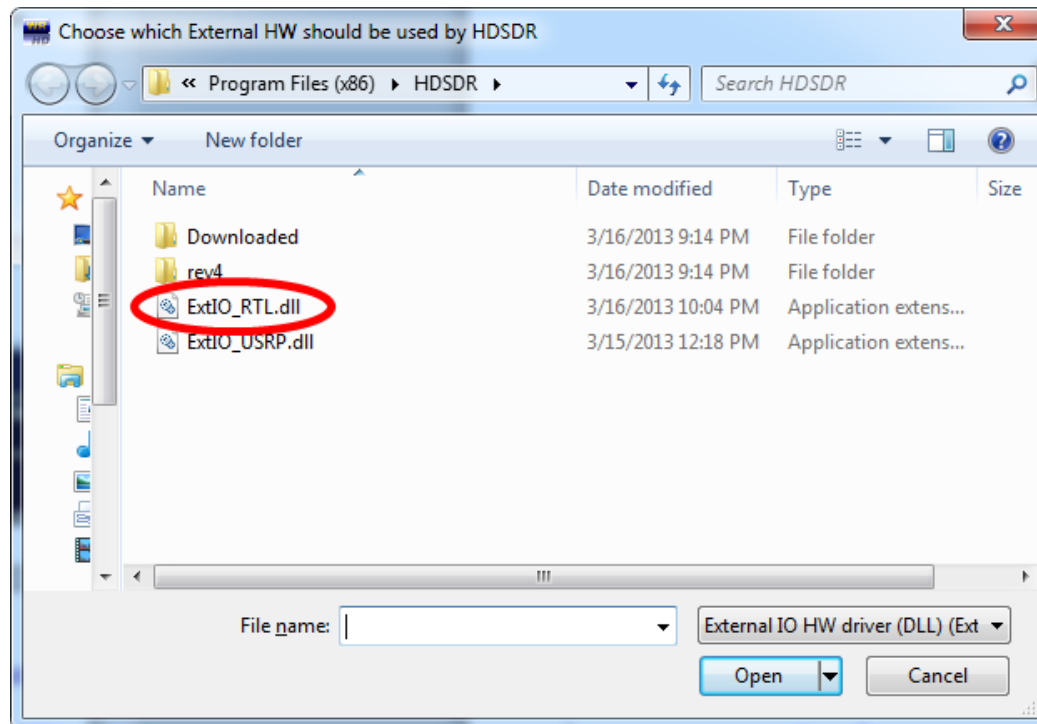


Software (HDSDR)

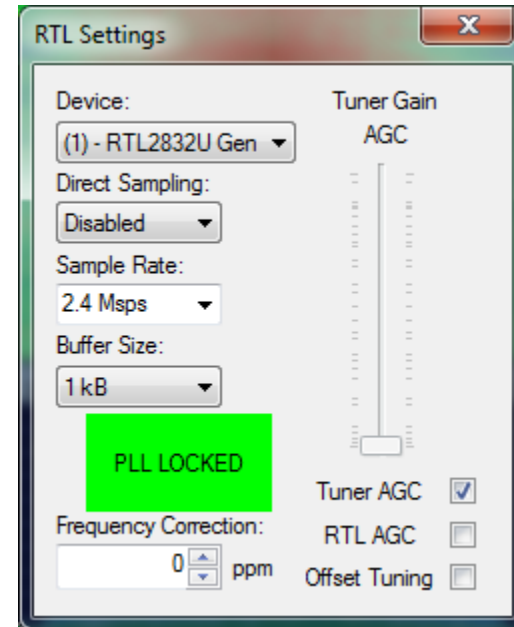
- Freeware closed source SDR software
 - Formerly WinRad
- http://wiki.spench.net/wiki/USRP_Interfaces
 - Click Download
 - Download from Mirror
 - http://users.on.net/~balint/ExtIO_USRP+FCD+RTL2832U+BorIP_Setup.zip
 - Unzip and install
 - Choose at least libusb, VC++ Runtime, EXTIO_USRP+FCD+RTL2832U + BorIP, and HDSDR
 - Skip over Zadig installation since we already installed from SDRSharp

Software (HSDR)

- Download EXTIO_RTL.dll from https://github.com/josemariaaraujo/ExtIO_RTL and copy to HSDR folder
 - https://github.com/josemariaaraujo/ExtIO_RTL/blob/master/Release/ExtIO_RTL.dll and click “Raw”



Software (HDSDR)



Linux Software

Software (GnuRadio)

The screenshot displays the GNU Radio GUI with the following components:

- Top Toolbar:** Standard software navigation icons including file operations, undo, redo, and zoom.
- Block Palette (Right):** A list of available blocks categorized into: Level Controls, Modulators, Sources, Synchronizers, Probes, Sinks, Message Tools, Operators, Type Conversions, Stream Conversions, Misc Conversions, Filters, Error Correction, Line Coding, Variables, Misc, Sources (New), Sinks (New), File Meta Sink, Math Operations (New), Boolean Operations (New), Stream Type Conversions, Stream Operations (New), Digital, Digital Modulators, OFDM, Extras, and FFT.
- Flow Graph (Center):**
 - RTLSDR Source:** Sample Rate (sps): 2M, Ch0: Frequency (Hz): 146.94M, Ch0: Freq. Corr. (ppm): 0, Ch0: Gain Mode: Manual, Ch0: RF Gain (dB): 50, Ch0: IF Gain (dB): 24.
 - Frequency Xlating FIR Filter:** Decimation: 8, Taps: xlate_filter_taps, Center Frequency: 0, Sample Rate: 250k.
 - Low Pass Filter:** Decimation: 5, Gain: 5, Sample Rate: 250k, Cutoff Freq: 12.5k, Transition Width: 1.5k, Window: Hamming, Beta: 6.76.
 - Simple Squelch:** Threshold (dB): -10, Alpha: 1.
 - Rational Resampler:** Decimation: 500, Interpolation: 441, Taps: Fractional BW: 0.
 - NBFM Receive:** Audio Rate: 44.1k, Quadrature Rate: 44.1k, Tau: 75u, Max Deviation: 5k.
 - Selector:** Input Index: 0, Output Index: 0.
 - Multiply Const:** Constant: 3.
 - Audio Sample Rate:** Sink block for audio output.
- Left Sidebar (GUI Sliders):**
 - WX GUI Slider (offset_fine):** Label: Fine tune, Default Value: 0, Range: -1k to 1k.
 - WX GUI Slider (width):** Label: Filter, Default Value: 25k, Range: 2k to 40k.
 - WX GUI Slider (trans):** Label: Trans, Default Value: 1.5k, Range: 500 to 5k.
- Bottom Status Window:**

```
8000 NO
16000 NO
22050 NO
32000 NO
44100 YES
48000 YES
96000 YES
192000 YES
audio_alsa_sink[hw:0,0]: using S32_LE
audio_alsa_sink[hw:0,0]: sample resolution = 32 bits
```

Software (GnuRadio)



Software (GnuRadio)

- Completely Free/Open Source SDR software
- <http://gnuradio.org/redmine/projects/gnuradio/wiki/InstallingGR>
 - Recommended: Using the build-gnuradio script
 - Fedora and Ubuntu distros, Debian on the way
 - `wget http://www.sbrac.org/files/build-gnuradio && chmod a+x ./build-gnuradio && ./build-gnuradio`
 - Build dependency requirements may vary but unfortunately outside the scope of presentation

Software (GnuRadio)

- <http://sdr.osmocom.org/trac/wiki/rtl-sdr> (<http://osmocom.rtlsdr.org>)
 - Install Git
 - “apt-get install git” for Ubuntu
 - “yum install git” for Fedora
 - `git clone git://git.osmocom.org/rtl-sdr.git`
 - Follow building the software section
- Gr-baz for additional GnuRadio blocks
 - <http://wiki.spench.net/wiki/Gr-baz>
 - `git clone https://github.com/balint256/gr-baz.git`
 - <http://wiki.spench.net/wiki/RTL2832U>
- GRC for example RX/TX radios
 - <http://www.oz9aec.net/index.php/gnu-radio/grc-examples>
 - `git clone https://github.com/csete/gnuradio-grc-examples.git`
- CGRAN for free open source 3rd party unsupported GnuRadio applications
 - <https://www.cgran.org/wiki/Projects>
- 146.94 compatible NFW receiver completed by Ethan Waldo (KF5UFH)
 - <http://bit.ly/14rEhoj> (Right-click <>/View Raw and save link to download)
- <http://www.youtube.com/watch?v=hGNT1w-jig>

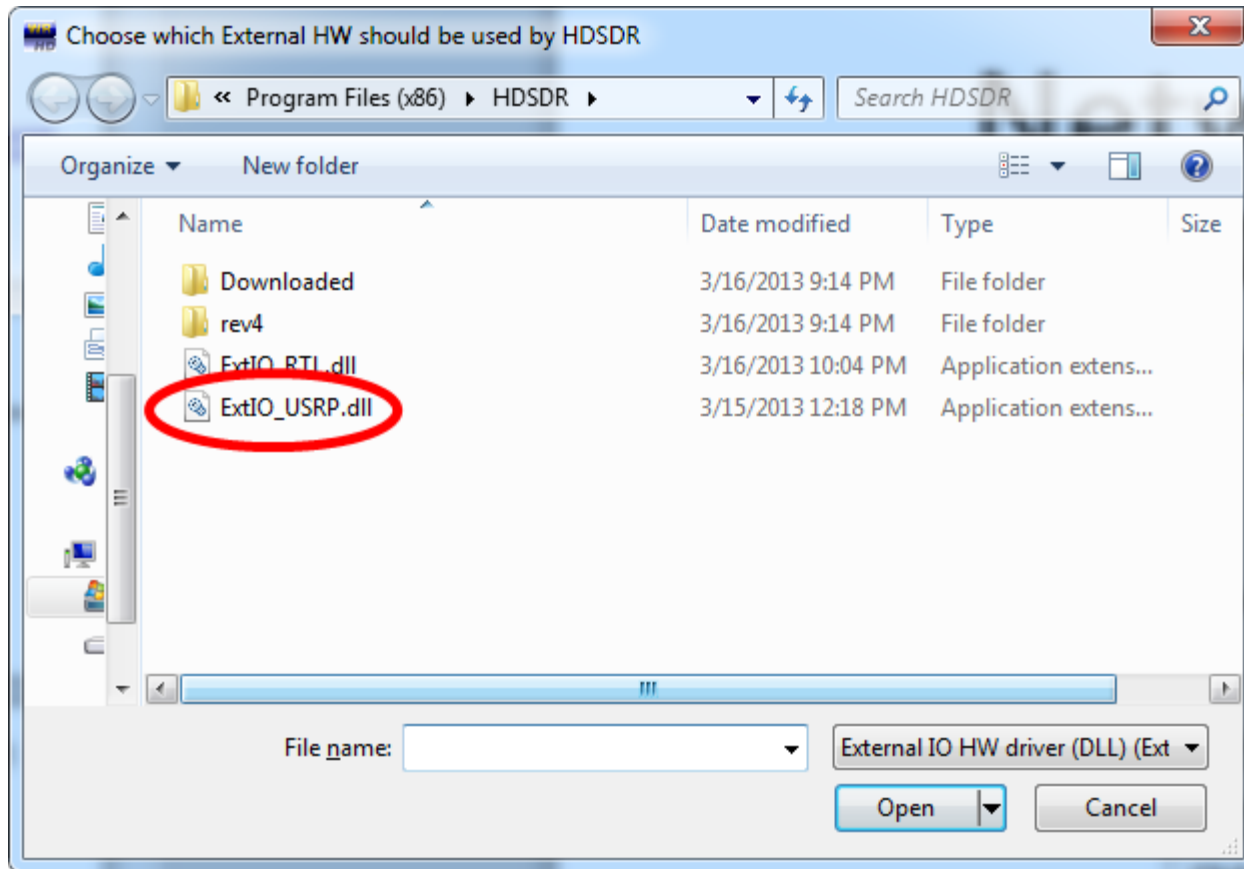
Networking Radio

- Allows the physical radio device and antennae/coax cable run to be located at a different location from where the SDR software runs without additional dB loss
- Wifi latency too high, recommend using wired Ethernet or equivalent
- BorIP for GnuRadio and HDSDR
- rtl_tcp for GnuRadio and SDRSharp

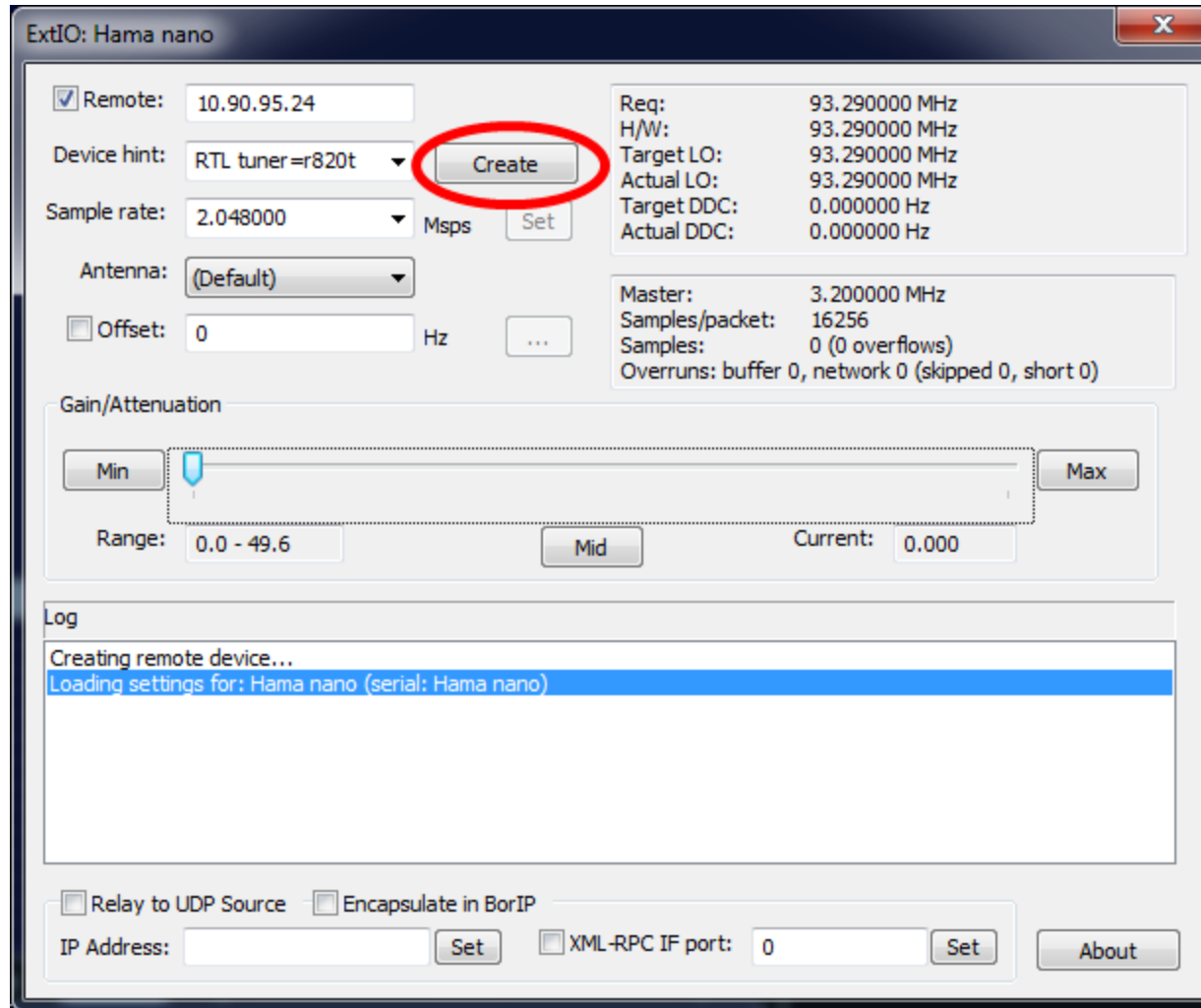
Networking Radio (BorIP)

- <http://wiki.spench.net/wiki/Gr-baz>
 - git clone <https://github.com/balint256/gr-baz.git>
- Needs Python 2.7+
- Run “lsusb” to get VID/PID from RTL device
 - i.e. Bus 002 Device 008: ID **0bda:2382** Realtek Semiconductor Corp. RTL2832U DVB-T
 - **0bda** is VID, **2382** is PID
- Under gr-baz/apps modify borip_RTL.py
 - self.source.set_vid(0xFFFF) #Where FFFF is VID
 - self.source.set_pid(0xFFFF) #Where FFFF is PID
 - self.source.set_sample_rate(2000000)
 - Run “python borip_server.py -vrgc”

Networking Radio (HSDR + BorIP)



Networking Radio (HDSDR + BorIP)



Networking Radio (rtl_tcp)

- rtl_tcp should be installed when rtl-sdr is installed
 - <http://sdr.osmocom.org/trac/wiki/rtl-sdr>
- Run “rtl_sdr -a <IP Address>” where <IP Address> is the bound IP of the local ethernet adapter you want the server to run on

```
Found 1 device(s).  
Found Rafael Micro R820T tuner  
Using Generic RTL2832U  
Tuned to 100000000 Hz.  
listening...
```

Networking Radio (GnuRadio + rtl_tcp)

Properties: OsmoSDR Source

Parameters:

ID	osmosdr_source_c_0
Output Type	Complex float32
Device Arguments	rtl_tcp=127.0.0.1:1234
Num Channels	1
Sample Rate (sps)	samp_rate*8
Ch0: Frequency (Hz)	freq
Ch0: Freq. Corr. (ppm)	offset_coarse + offset_fine
Ch0: Gain Mode	Manual
Ch0: RF Gain (dB)	rf_gain
Ch0: IF Gain (dB)	24
Ch0: Antenna	

Documentation:

The OsmoSDR Source block:

Cancel OK

What next for me?

- Listen to my first satellite QSO
- Start recording and deciphering satellite telemetry
- Research RX/TX capable SDRs and make more serious purchasing decision
 - Funcube Dongle Pro+ (<http://www.funcubedongle.com>) \$200
 - 150kHz – 250Mhz & 420Mhz – 1.9Ghz at 192kHz bandwidth
 - Noctar (<http://www.pervices.com>) \$750-\$850
 - 100kHz – 4Ghz at 200Mhz RX/250Mhz TX bandwidth
 - USRP (<https://www.ettus.com/product/>) \$650+-\$1,700+
 - DC – 6Ghz RX/TX with various daughterboards
 - http://en.wikipedia.org/wiki/List_of_software-defined_radios
- Continue to improve the audio quality and power usage of my SDR configurations
- Select a design and build a directional Yagi antennae from scratch
 - Continue learning about antennae design
 - Model my own antennae in EZNEC or appropriate software
- Build an operable ground station at my place of residence
- Upgrade to General Class and Extra Licenses
- Start making Satellite and Terrestrial contacts

Questions or Recommendations???

Thank You

I would like to thank Andrew Duhan, Austin Hams, ARRL, AMSAT, and various Internet denizens for making this all possible. Feel free to contact me for any questions or assistance and I will gladly help as I have time available.

Ethan Waldo

KF5UFH

ewaldo@arrl.net

<http://bit.ly/10sCkTG>