

# Raspberry Pi Radio Projects



**David Haworth**  
**WA9ONY**

[www.stargazing.net/david/RPi/hrrpi.html](http://www.stargazing.net/david/RPi/hrrpi.html)



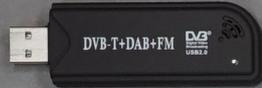
# SDRs with USB Interface



DVB-T: Digital Video Broadcasting — Terrestrial

DVB-T+DA3+FM

NESDR Mini



RTL

LimeSDR Mini



NESDR Smart



RTL-SDR Blog V3 R820T2 RTL2832U



RTL

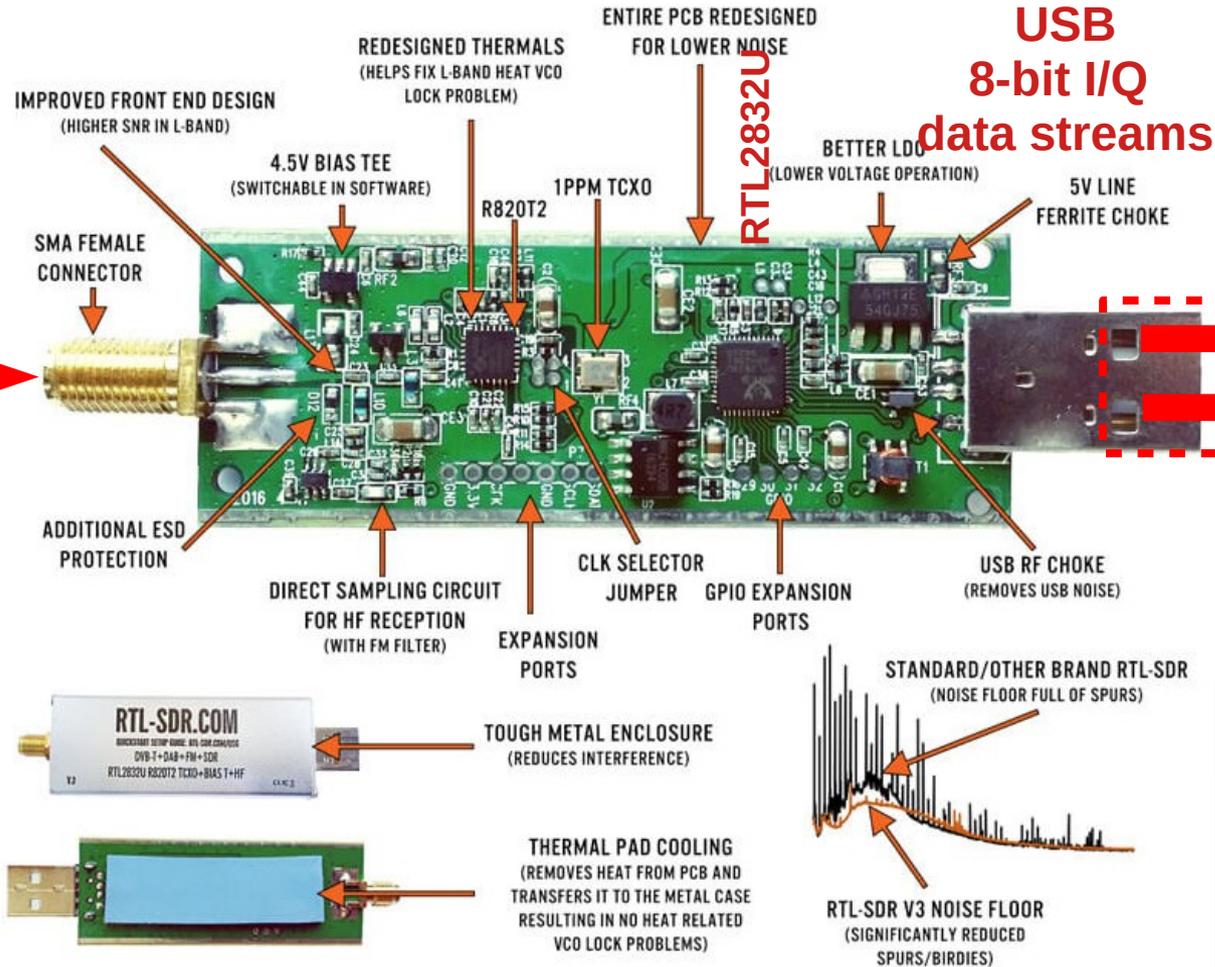


## Key Specs.

- Frequency range
- I/Q rate
- A/D bits
- Noise floor
- Transmit
- SW support
- Price

# WHAT MAKES OUR RTL-SDR V3 BETTER THAN OTHERS?

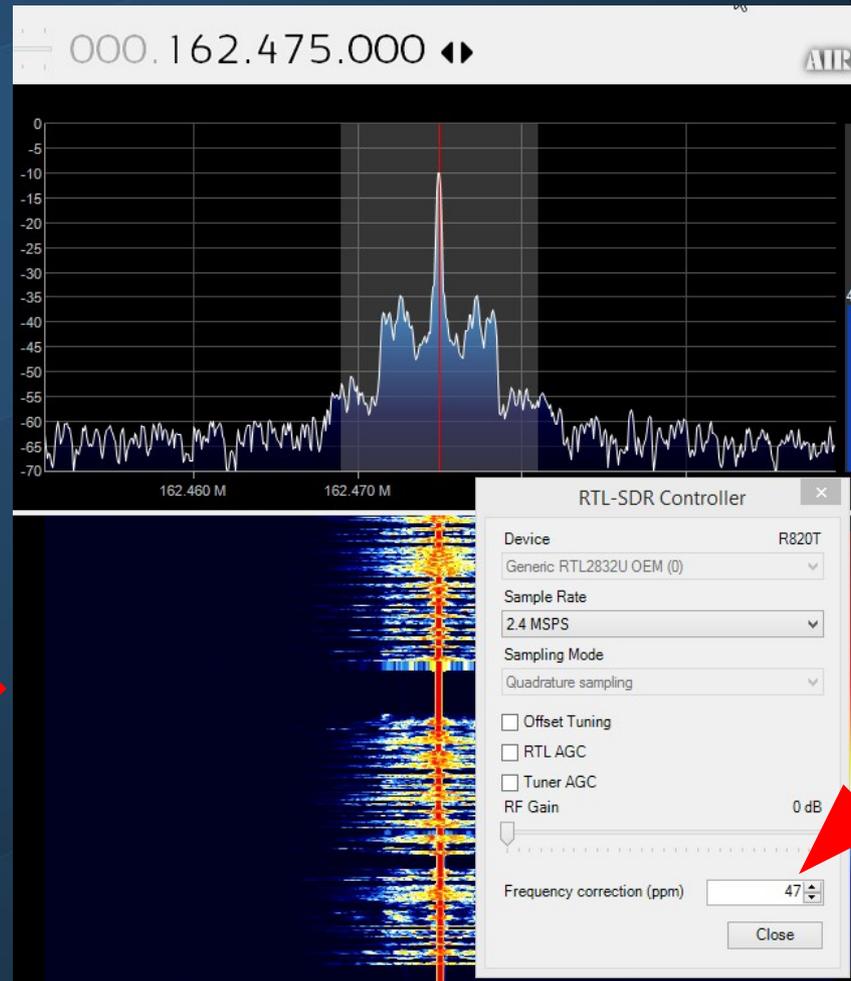
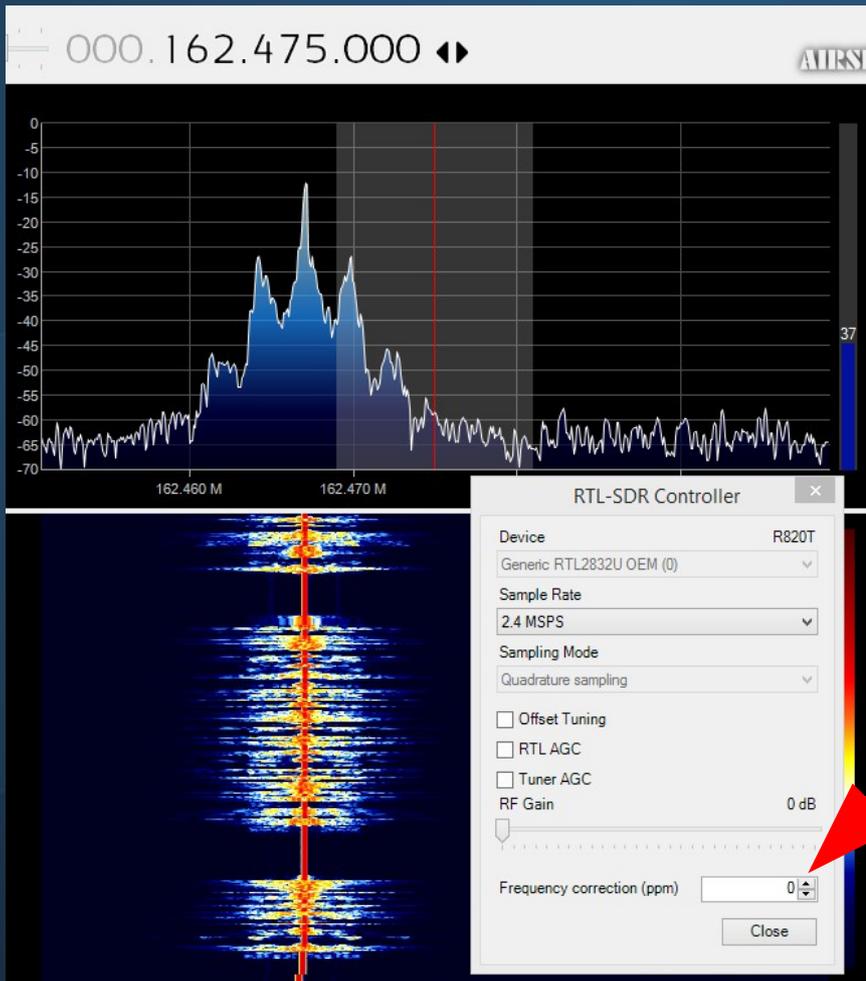
24-1766 MHz



<https://www.rtl-sdr.com/buy-rtl-sdr-dvb-t-dongles/>



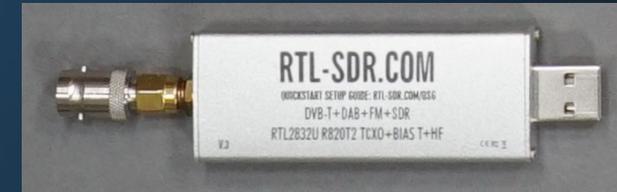
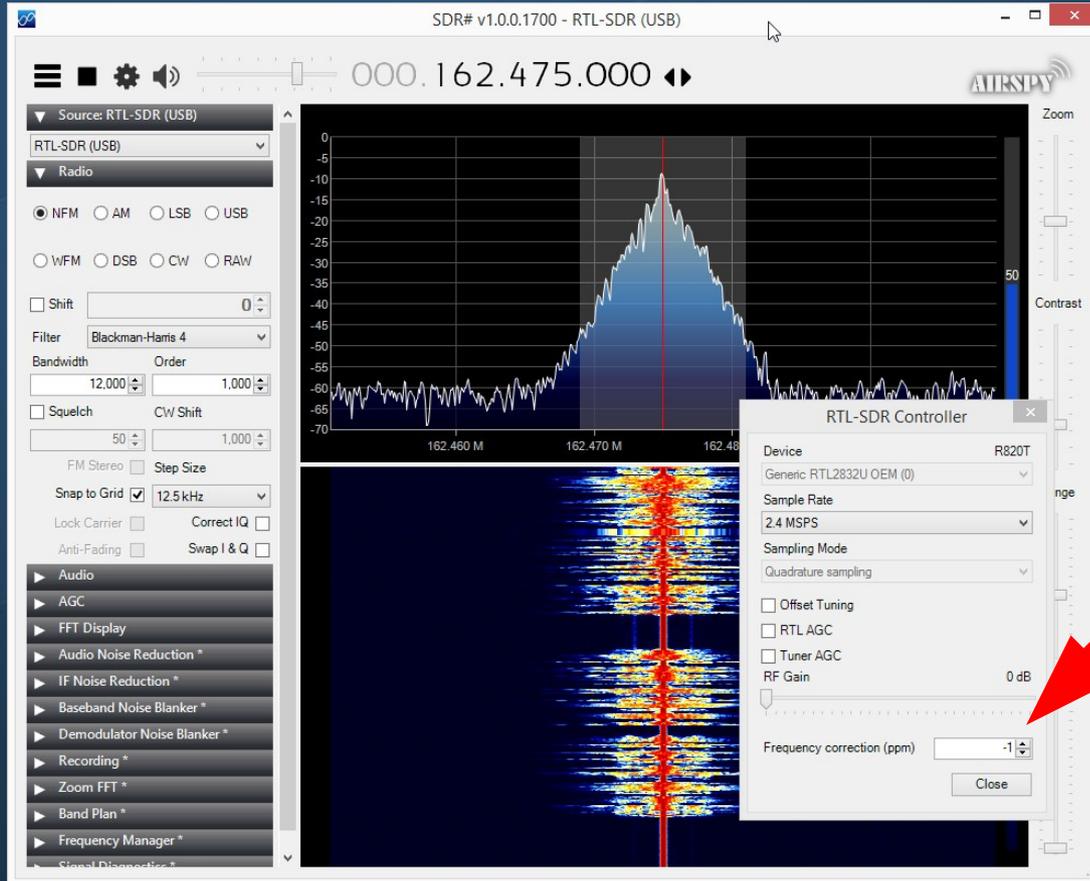
# SDR# Frequency Correction (47 ppm)



# SDR# Frequency Correction (<1 ppm)



- <1 PPM temperature compensated oscillator (TCXO) – Accurate tuning and almost zero temperature drift (2 PPM max. initial offset, 0.5-1 PPM temperature drift)



# Amazon RTL-SDR.COM Kit \$29.95



# www.amazon.com/gp/product/B011HVUEME/ ref=ppx\_yo\_dt\_b\_asin\_title\_o01\_s00?ie=UTF8&psc=1



## RTL-SDR Blog R820T2 RTL2832U 1PPM TCXO SMA Software Defined Radio with 2x Telescopic Antennas

by [RTL-SDR Blog](#)

★★★★☆ 666 customer reviews | 221 answered questions

Amazon's Choice for "rtl sdr"

Price: **\$29.95** ✓prime

📦 FREE One-Day Pickup. [Details](#)

Pay **\$29.95** \$0.00 after using available Discover Cashback Bonus®.

[Free Amazon tech support included](#) ▾

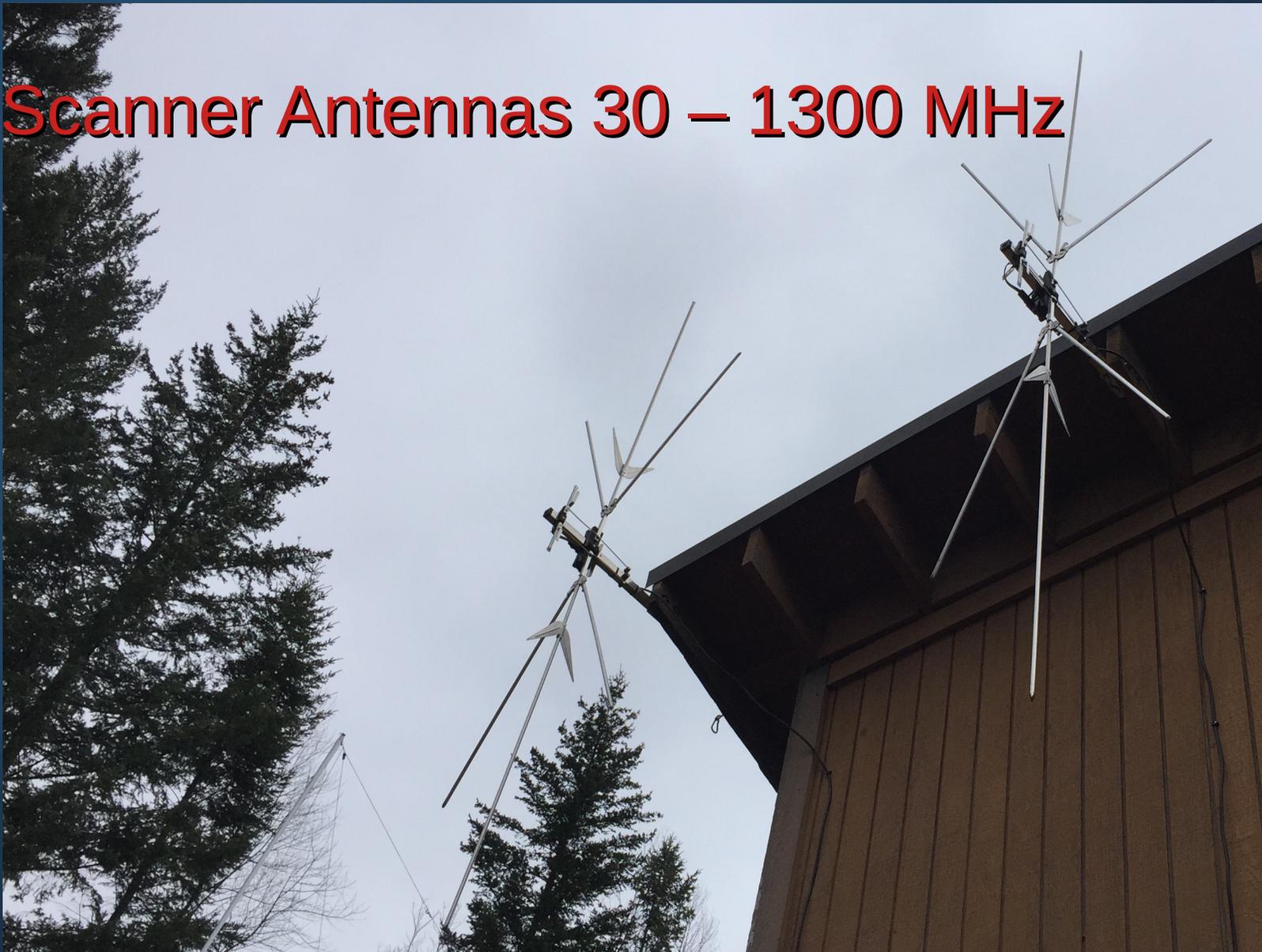
- Includes 1x RTL-SDR Blog brand R820T2 RTL2832U 1PPM TCXO HF Bias Tee SMA Dongle (V3), 1x portable multipurpose dipole antenna set. Dipole set includes 1x dipole base with 60cm RG174, 2x 23cm to 1m telescopic antenna, 2x 5cm to 13cm telescopic antenna, 1x 3m RG173 extension cable, 1x flex tripod mount, 1x suction cup mount.
- Great for many applications including general radio scanning, air traffic control, public safety radio, ADSB, ACARS, trunked radio, P25 digital voice, POCSAG, weather balloons, APRS, NOAA APT weather satellites, radio astronomy, meteor scatter monitoring, DAB, or for use as a low cost panadapter with a traditional ham radio.
- Several improvements over other brands including use of the R820T2 tuner, improved component tolerances, a 1 PPM temperature compensated oscillator (TCXO), SMA F connector, aluminium shielded case with thermal pad for passive cooling, activatable bias tee circuit and a much improved antenna set.
- Can tune from 500 kHz to 1.7 GHz and has up to 3.2 MHz of instantaneous bandwidth (2.4 MHz stable). (HF reception below 24 MHz in direct sampling mode). Please note RTL-SDR dongles are RX only.
- The multipurpose portable dipole kit is great for beginners! Use it either for terrestrial or satellite reception just by changing the orientation of the antenna. The mounts and extension cable allow you to temporarily place the antenna outside for improved reception.

[Compare with similar items](#)

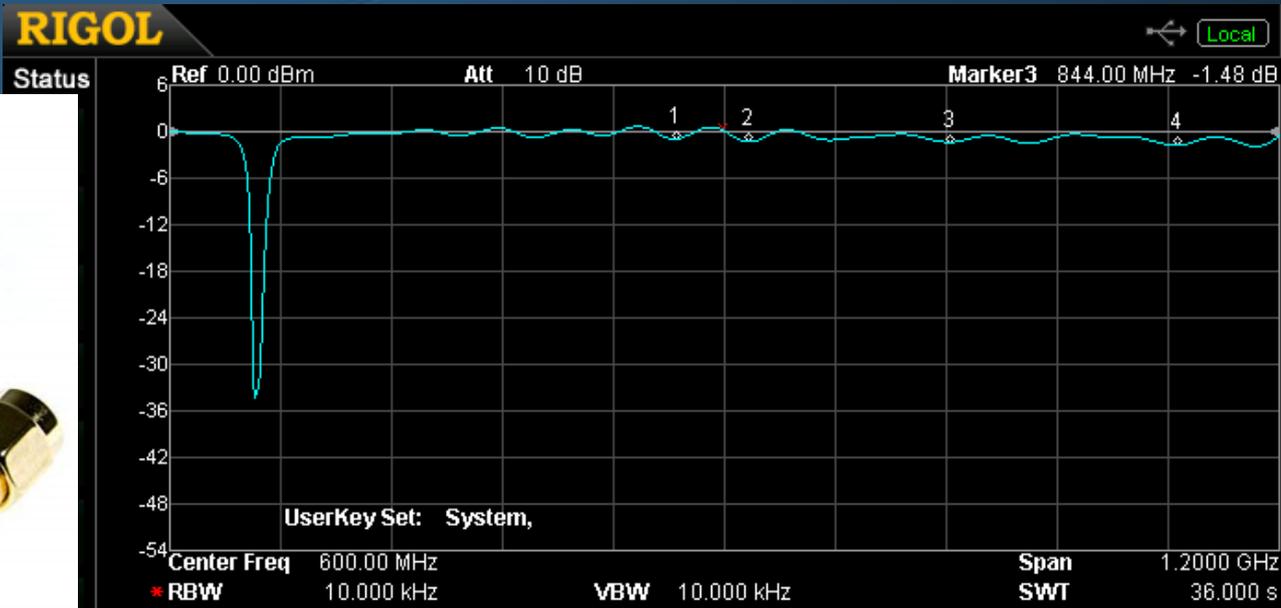
**New (1)** from **\$29.95** ✓prime

🚩 [Report incorrect product information.](#)

# Scanner Antennas 30 – 1300 MHz



# NooElec Broadcast FM Bandstop Filter



Marker Table

Marker	Trace	Type	X Axis	Amp
1D	3	Frequency	548.000000 MHz	-1.04 dB
2D	3	Frequency	626.000000 MHz	-1.41 dB
3D	3	Frequency	844.000000 MHz	-1.48 dB
4D	3	Frequency	1.090000000 GHz	-1.85 dB

# SMA RG142 Coax Cables Loss at 750MHz, 100'

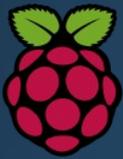


- RG-6 5.6 dB 75Ω
- **RG-142** **9.6 dB** 50Ω
- RG-8X 11 dB 50Ω
- RG-58 13 dB 50Ω
- RG-316 22 dB 50Ω
- RG-174 24 dB 50Ω

# Mini-Circuits Amp. ZFL-500LN+



MODEL NO.	FREQUENCY (MHz)		NOISE FIGURE (dB)	GAIN (dB)	
	$f_L$	$f_U$		Min.	Total Range
ZFL-500LN+	0.1	500	Typ. 2.9	Flatness Max. 24	±0.5



# AC Powered Speakers with Volume Control

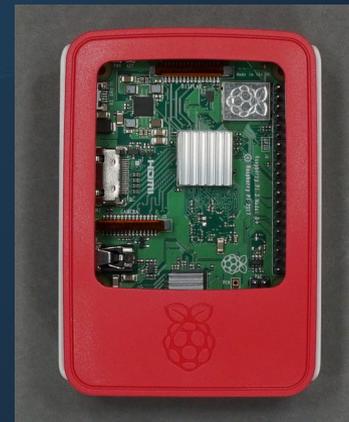




# SDR: Software Defined Radio



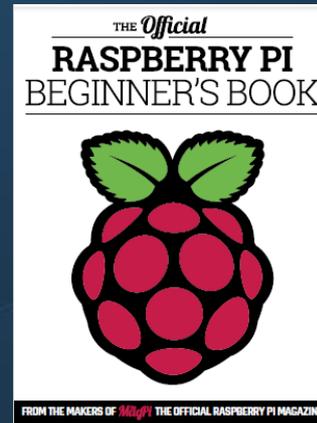
- RTL-SDR USB device
- Raspberry Pi computer
- Software
  - rtl\_sdr: demodulates RTL-SDR USB I/Q data stream
  - SoX: audio processing & recording
  - QSSTV: Slow scan TV decoder

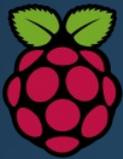




# Raspberry Pi Computer

- Low cost, \$35, small **single board computer (SBC)**
- Large ecosystem
  - 19 million sold 2012 to 2018
  - 1/3 to education, 1/3 to hobbyist & 1/3 to commercial
  - Websites, books, magazines, forums, etc.





# Raspbian Operating System



The Raspbian operating system – based on Debian Linux - is now being installed on your Raspberry Pi.



**debian**

This provides an easy-to-use desktop interface and includes a web browser, email and office applications.

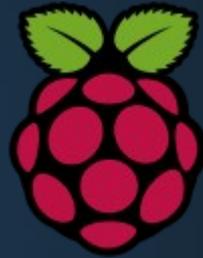
It also includes several programming languages, aimed at a range of users from absolute beginners to experienced developers.

Raspbian Full: Extracting filesystem

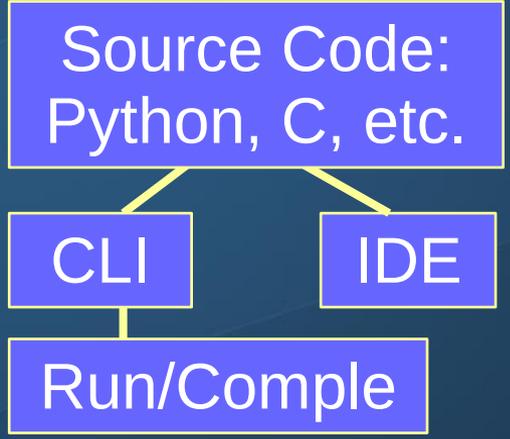
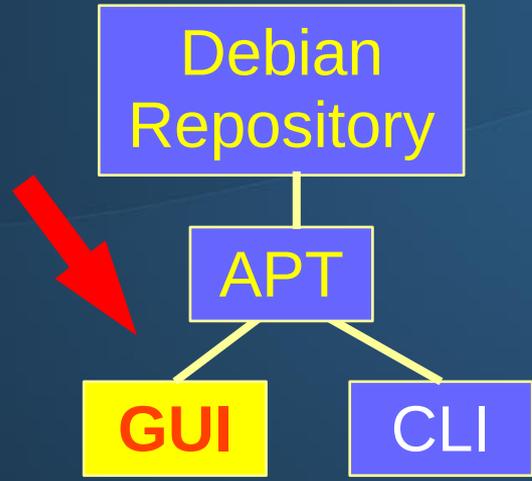
54%

2333 MB of 4279 MB written (7.7 MB/sec)

- 1970 UNIX, AT&T Bell Labs
  - Multitasking & Multiuser
  - Pipes, SW tools & Portable
- 1984 X Windows, MIT
- 1991 Linux, Linus Torvalds
  - An UNIX like kernel
- 1993 Debian - GNU/Linux
  - SW **repository** – >51,000 packages
- 2013 Raspbian based on Debian
  - For Raspberry Pi computers

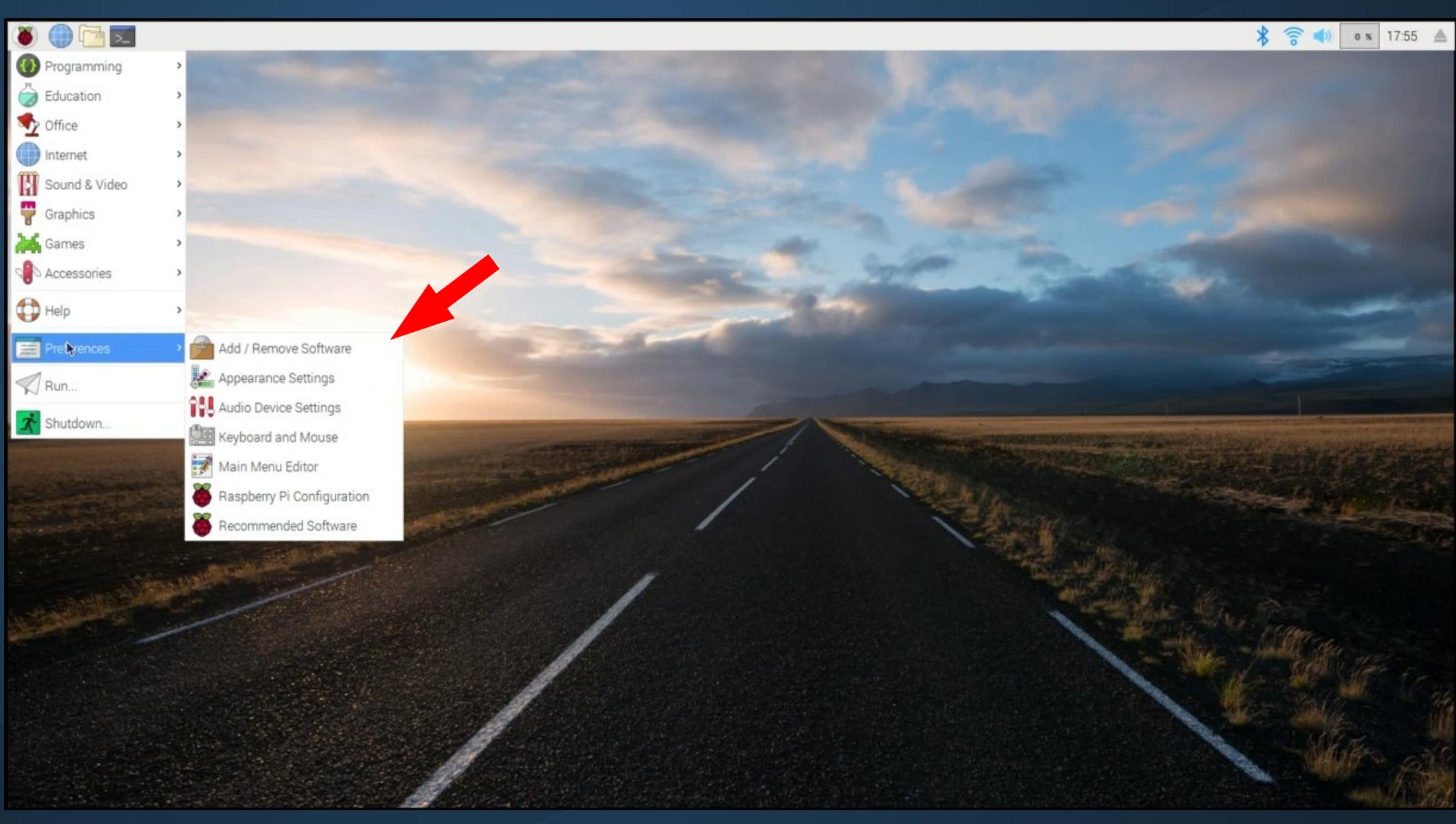


# Installing Raspberry Pi Software



## MicroSD image

- 01. USER GUIDE - IMPORTANT INFORMATION (PDF)
- 02. SoapySDRUtil (test RSP connection)
- 03. SoapyRemote
- 04. CubicSDR
- 05. Gnu Radio
- 06. GQRX
- 07. ADS-B (Interactive & Network)
- 08. QT-DAB DAB Receiver
- 09. RSP TCP Server
- 10. SoapySDR website - pothosware
- 11. CubicSDR website - Charles J Cliffe
- 12. QT-DAB website - Jan Van Katwijk
- 13. Gnu Radio website
- 14. GQRX website - Alex Csete
- 15. RSP TCP Server Github
- 16. RSP1 Datasheet (PDF)
- 17. RSP1A Datasheet (PDF)
- 18. RSP2 Datasheet (PDF)
- 19. RSPduo Datasheet (PDF)
- 20. API Specification (PDF)
- 21. ADS-B User Guide (PDF)
- 22. SDRplay website
- 23. Exit



- Programming >
- Education >
- Office >
- Internet >
- Sound & Video >
- Graphics >
- Games >
- Accessories >
- Help >
- Preferences >**
- Run...
- Shutdown...

- Add / Remove Software
- Appearance Settings
- Audio Device Settings
- Keyboard and Mouse
- Main Menu Editor
- Raspberry Pi Configuration
- Recommended Software



# Add / Remove Software: rtl\_sdr

Add / Remove Software

Options

rtl\_sdr

Accessories  
Admin tools  
Communication  
GNOME desktop  
KDE desktop  
Other desktops  
Fonts

 Software defined radio receiver for Realtek RTL2832U (tools)  
rtl-sdr-0.5.3-11+rpt1

Right click for website

rtl-sdr is a software defined radio (SDR) receiver software for certain low-cost DVB-T/DAB(+) USB dongles based on the Realtek RTL2832U chip. This package contains a set of command line utilities:  
\* rtl\_adsb: a simple ADS-B decoder for RTL2832 based DVB-T receivers  
\* rtl\_eeprom: an EEPROM programming tool for RTL2832 based DVB-T

Installed size 172.0 kB  
License unknown

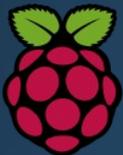
Cancel Apply OK

Shutdown options

Shutdown

Reboot

Logout



# Add / Remove Software: rtl\_sdr Website

Rtl-sdr - rtl-sdr - Open Source Mobile Communications - Chromium

APT-3000 x Rtl-sdr - rtl-sdr - Open So x +

https://osmocom.org/projects/rtl-sdr/wiki/Rtl-sdr

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SDR (Software Defined Radio) » Search:  rtl-sdr

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## rtl-sdr

DVB-T dongles based on the Realtek RTL2832U can be used as a cheap SDR, since the chip allows transferring the raw I/Q samples to the host, which is officially used for DAB/DAB+/FM demodulation. The possibility of this has been discovered by Eric Fry ( History and Discovery of RTLSDR). Antti Palosaari has not been involved in development of rtl-sdr.

### Specifications

The RTL2832U outputs 8-bit I/Q-samples, and the highest theoretically possible sample-rate is 3.2 MS/s, however, the highest sample-rate without lost samples that has been tested so far is 2.56 MS/s. The frequency range is highly dependent of the used tuner, **dongles that use the Elonics E4000 offer the widest possible range (see table below).**

Tuner	Frequency range
Elonics E4000	52 - 2200 MHz with a gap from 1100 MHz to 1250 MHz (varies)
Rafael Micro R820T	24 - 1766 MHz
Rafael Micro R828D	24 - 1766 MHz

#### Table of contents

- rtl-sdr
  - Specifications
  - Supported Hardware
  - Software
    - Mailing List
    - Building the software
      - rtlsdr library & capture tool
      - Gnuradio Source
      - Automated installation
    - Usage
      - rtl\_sdr
      - rtl\_tcp
      - rtl\_test
    - Using the data
    - Known Apps
    - Credits

#### Wiki

- Start page
- Index by title
- Index by date



# No SDR found by rtl\_test



```
pi@raspberrypi: ~/SDR | pi
pi@raspberrypi: ~/SDR
File Edit Tabs Help
pi@raspberrypi:~/SDR $ rtl_test
No supported devices found.
pi@raspberrypi:~/SDR $
```

Need to plug in the SDR



# CLI: rtl\_test at 2,048,000 S/s CTRL-C to exit

```
pi@raspberrypi:~/SDR $ rtl_test
Found 1 device(s):
 0: Realtek, RTL2838UHIDIR, SN: 00000001

Using device 0: Generic RTL2832U OEM
Detached kernel driver
Found Rafael Micro R820T tuner
Supported gain values (29): 0.0 0.9 1.4 2.7 3.7 7.7 8.7 12.5 14.4 15.7 16.6 19.7
 20.7 22.9 25.4 28.0 29.7 32.8 33.8 36.4 37.2 38.6 40.2 42.1 43.4 43.9 44.5 48.0
 49.6
[R82XX] PLL not locked!
Sampling at 2048000 S/s.

Info: This tool will continuously read from the device, and report if
samples get lost. If you observe no further output, everything is fine.

Reading samples in async mode...
^CSignal caught, exiting!

User cancel, exiting...
Samples per million lost (minimum): 0
Reattached kernel driver
pi@raspberrypi:~/SDR $
```



# CLI: rtl\_test at 2,700,000 CTRL-C to exit

```
pi@raspberrypi:~ $ rtl_test -s 2700000
Found 1 device(s):
 0: Realtek, RTL2838UHIDIR, SN: 00000001

Using device 0: Generic RTL2832U OEM
Detached kernel driver
Found Rafael Micro R820T tuner
Supported gain values (29): 0.0 0.9 1.4 2.7 3.7 7.7 8.7 12.5 14.4 15.7 16.6 19.7
 20.7 22.9 25.4 28.0 29.7 32.8 33.8 36.4 37.2 38.6 40.2 42.1 43.4 43.9 44.5 48.0
 49.6
Exact sample rate is: 2700000.160933 Hz
[R82XX] PLL not locked!
Sampling at 2700000 S/s.

Info: This tool will continuously read from the device, and report if
samples get lost. If you observe no further output, everything is fine.

Reading samples in async mode...
lost at least 68 bytes
lost at least 188 bytes
lost at least 68 bytes
lost at least 68 bytes
lost at least 68 bytes
lost at least 188 bytes
lost at least 68 bytes
lost at least 68 bytes
lost at least 68 bytes
lost at least 188 bytes
lost at least 68 bytes
^CSignal caught, exiting!

User cancel, exiting...
Samples per million lost (minimum): 0
Reattached kernel driver
pi@raspberrypi:~ $
```



# Add / Remove Software: SoX

Add / Remove Software

Options



- Accessories
- Admin tools
- Communication
- GNOME desktop
- KDE desktop
- Other desktops
- Fonts
- Games
- Graphics
- Internet
- Legacy

<input checked="" type="checkbox"/>		High quality 1D sample-rate conversion library libsoxr0-0.1.2-2
<input type="checkbox"/>		High quality 1D sample-rate conversion library (development files) libsoxr-dev-0.1.2-2
<input type="checkbox"/>		High quality 1D sample-rate conversion library (libsamplerate bindings) libsoxr-lsr0-0.1.2-2
<input checked="" type="checkbox"/>		Swiss army knife of sound processing sox-14.4.1-5+deb9u1

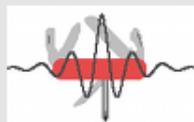
**Right click for website**

SoX is a command line utility that can convert various formats of computer audio files in to other formats. It can also apply various effects to these sound files during the conversion. As an added bonus, SoX can play and record audio files on several unix-style platforms. SoX is able to handle formats like Ogg Vorbis, MP3, WAV, AIFF, VOC, SND,

Installed size 194.6 kB  
License unknown  
Source

Cancel Apply OK

# SoX - Sound eXchange | HomePage

[Print Version](#) | [Search Site](#)


## Welcome

Welcome to the home of SoX, the Swiss Army knife of sound processing programs.

SoX is a cross-platform (Windows, Linux, MacOS X, etc.) command line utility that can convert various formats of computer audio files in to other formats. It can also apply various effects to these sound files, and, as an added bonus, SoX can play and record audio files on most platforms.

The screen-shot to the right shows an example of SoX first being used to process some audio, then being used to play some audio files.

For the list of all file formats, device drivers, and effects supported in the latest release, [click here](#). To see the complete set of SoX documentation, [click here](#).

If you find SoX to be useful, please consider supporting the project with a donation. We can accept PayPal donations through the SourceForge donation system, although currently a SourceForge login ID (or an openID), is required. Creating a SourceForge ID takes only a few seconds—click on the Paypal logo below to make a donation.

```
$ sox track1.wav track1-processed.flac remix - norm -3 highpass 22
gain -3 rate 48k norm -3 dither

Input File      : 'track1.wav'
Channels       : 2
Sample Rate    : 44100
Precision     : 16-bit
Duration      : 00:02:54.97 = 7716324 samples = 13123 CDDA sectors
Sample Encoding: 16-bit Signed Integer PCM
Endian Type   : little

Output File    : 'track1-processed.flac'
Channels      : 1
Sample Rate   : 48000
Precision    : 16-bit
Duration     : 00:02:54.97 = 8398720 samples ~ 13123 CDDA sectors
Sample Encoding: 16-bit FLAC

sox: effects chain: input      44100Hz 2 channels 16 bits (multi)
sox: effects chain: remix    44100Hz 2 channels 16 bits (multi)
sox: effects chain: norm     44100Hz 1 channels 16 bits
sox: effects chain: highpass 44100Hz 1 channels 16 bits
sox: effects chain: gain     44100Hz 1 channels 16 bits (multi)
sox: effects chain: rate     44100Hz 1 channels 16 bits
sox: effects chain: norm     48000Hz 1 channels 16 bits
sox: effects chain: dither   48000Hz 1 channels 16 bits
sox: effects chain: output   48000Hz 1 channels 16 bits (multi)

$ play *.ogg

01 - Summer's Cauldron.ogg:

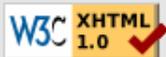
Encoding: Vorbis
```

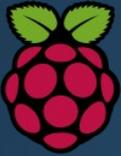
Home Page  
Features  
FAQ  
Documentation  
Mailing Lists  
Links

Project Page  
Browse git



[Hosted by](#)





Tip

# CLI: man rtl\_fm

```
pi@raspberrypi: ~/SDR
File Edit Tabs Help
rtl_adsb(1) User Commands rtl_adsb(1)
NAME
    rtl_fm - a simple FM demodulator for RTL2832 based DVB-T receivers
DESCRIPTION
    Uses a re-purposed DVB-T receiver as a software defined radio to receive narrow band FM signals and demodulate to audio. Written for and incorporated in the osmocom rtl-sdr project.

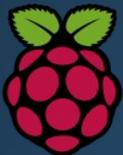
    Narrowband FM is commonly used by public service agencies and commercial dispatch operations in the VHF and UHF bands. Also can demodulate Wideband FM, as found in the 88-108 MHz FM broadcast band. Experimental options include AM, LSB, USB and DSB demodulation.

    Much software is available for the RTL2832. Most of the user-level packages rely on the librtlsdr library which comes as part of the rtl-sdr codebase. This codebase contains both the library itself and also a number of command line tools such as rtl_test, rtl_sdr, rtl_tcp, and rtl_fm. These command line tools use the library to test for the existence of RTL2832 devices and to perform basic data transfer functions to and from the device.

    Because most of the RTL2832 devices are connected using USB, the librtlsdr library depends on the libusb library to communicate with the device.
USAGE
    With a suitable antenna for receiving the signal attached to the rtl-sdr supported device, this program will output the digital audio data decoded from that signal. The data can be listened to by piping to Sox or aplay applications to play the stream on the computer sound card.
SYNOPSIS
    rtl_fm [-f freq] [-options] [filename]
OPTIONS
    -f frequency_to_tune_to [Hz]
        use multiple -f for scanning, (requires squelch)
        ranges supported, -f 118M:137M:25k

    [-M modulation (default: fm)]
        fm, wbfm, raw, am, usb, lsb
        wbfm == -M fm -s 170k -o 4 -A fast -r 32k -l 0 -E deemph
        raw mode outputs 2x16 bit IQ pairs

    -s sample_rate (default: 24k)
Manual page rtl_fm(1) line 1 (press h for help or q to quit)
```



Tip

# CLI: rtl\_fm -h

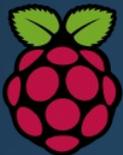
```
pi@raspberrypi: ~/SDR
File Edit Tabs Help
pi@raspberrypi:~/SDR $ rtl_fm -h
rtl_fm, a simple narrow band FM demodulator for RTL2832 based DVB-T receivers

Use:   rtl_fm -f freq [-options] [filename]
       -f frequency_to_tune_to [Hz]
           use multiple -f for scanning (requires squelch)
           ranges supported, -f 118M:137M:25k
       [-M modulation (default: fm)]
           fm, wbfm, raw, am, usb, lsb
           wbfm == -M fm -s 170k -o 4 -A fast -r 32k -l 0 -E deemp
           raw mode outputs 2x16 bit IQ pairs
       [-s sample_rate (default: 24k)]
       [-d device_index (default: 0)]
       [-g tuner_gain (default: automatic)]
       [-l squelch_level (default: 0/off)]
       [-p ppm_error (default: 0)]
       [-E enable_option (default: none)]
           use multiple -E to enable multiple options
           edge:  enable lower edge tuning
           dc:    enable dc blocking filter
           deemp: enable de-emphasis filter
           direct: enable direct sampling
           offset: enable offset tuning
       filename ('-' means stdout)
           omitting the filename also uses stdout

Experimental options:
       [-r resample_rate (default: none / same as -s)]
       [-t squelch_delay (default: 10)]
           +values will mute/scan, -values will exit
       [-F fir_size (default: off)]
           enables low-leakage downsampler filter
           size can be 0 or 9. 0 has bad roll off
       [-A std/fast/lut choose atan math (default: std)]

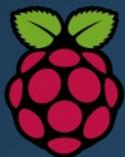
Produces signed 16 bit ints, use Sox or aplay to hear them.
rtl_fm ... | play -t raw -r 24k -es -b 16 -c 1 -V1 -
           | aplay -r 24k -f S16_LE -t raw -c 1
       -M wbfm | play -r 32k ...
       -s 22050 | multimon -t raw /dev/stdin

pi@raspberrypi:~/SDR $
```



# Google Search: rtl\_fm

The screenshot shows a Chromium browser window on a Raspberry Pi. The address bar contains the URL `https://www.google.com/search?q=rtl_fm&oq=rtl_fm&aqs=chrome..69i57.12298j0j8&sourceid=chrome&ie=UTF-8`. The search bar contains the text `rtl_fm`. Below the search bar, the search results are displayed. The first result is a link to `kmkeen.com/rtl-demod-guide/` with the title `Rtl_fm Guide: Updates for rtl_fm overhaul`. The description of the result states: `Rtl_fm is a little utility I wrote for the rtl-sdr project. The program was made to fill a gap in software defined radio: all the computers weaker than a Pentium 4. You've visited this page many times. Last visit: 4/22/19`. Two red arrows point to the search bar and the search results.



← → ↻ ⓘ Not secure | kmkeen.com/rtl-demod-guide/

📁 Apps 📁 Observational ... 🌹 RCA Forum - I... 📁 Imported From... ✨ SKY-MAP.ORG 📁 APT-3000

RSS

# Rtl\_fm Guide

Updates for rtl\_fm overhaul

[Original](#) [Editable](#)

version 2 of 2

ARCH LINUX  
BASH  
CODE  
ALBUMBLER  
AUTOCROSTIC  
CHATBOX  
CONTEXTFREEAUDIO  
FLASH RECOVERY  
GZ-SORT  
LoCoART  
LOCAL EULER  
NONOGRAMS  
PROJBOT  
QUICKBLOB  
RTL POWER  
**RTL\_FM GUIDE**  
SITE MIRRORS  
THIXOTROPICAL  
TINY CODE  
DF2TTF  
GALLERY  
MISC  
PYTHON

Rtl\_fm is a little utility I wrote for the [rtl-sdr](#) project. The program was made to fill a gap in software defined radio: all the computers weaker than a Pentium 4. Basically, an Atom processor processor does not have enough oomph to demodulate something as simple as narrow band FM using the [standard tools](#). (Recently a high performance FM demodulator was released, [Simple FM](#) but it works only passably on newer Atoms.) So rtl\_fm was written with one goal, efficiency, in mind.

<http://kmkeen.com/rtl-demod-guide/>



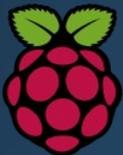
# Select & Copy Command From Website



## Music on the Radio



```
rtl_fm -M wbfm -f 89.1M | play -r 32k -t raw -e s -b 16 -c 1 -V1 -
```



# Copy Website Text



## Music on the Radio

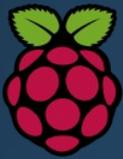
A screenshot of a web browser's context menu. The menu is open over a blue highlighted text area. A red arrow points to the 'Copy' option. The menu items are:

- Copy (Ctrl+C)
- Search Google for "rtl\_fm -M wbfm -f 89.1M | play -r 32k -t raw -e s..."
- Print... (Ctrl+P)
- Block element (with a red shield icon)
- Inspect (Ctrl+Shift+I)



# Paste Text in to Terminal



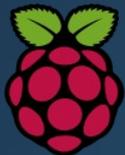


# FM Stations



[http://radiostationworld.com/locations/united\\_states\\_of\\_america/oregon/portland/radio\\_stations/](http://radiostationworld.com/locations/united_states_of_america/oregon/portland/radio_stations/)

102.5 10w	<b>K273AJ</b> -- CSN	Elwood (Clackamas) OR	religious	<a href="#">🔗</a> <a href="#">▶</a> <a href="#">+</a>
102.5 100w	<b>KIEV-LP</b> -- <b>Slavic Community Radio</b>	Camas (Clark) WA	community,religious	<a href="#">🔗</a> <a href="#">▶</a> <a href="#">+</a>
102.9 99w	<b>K275CH</b> -- <b>The Game</b> <small>KXTG-750</small>	Gresham (Multnomah) OR	sports	<a href="#">🔗</a> <a href="#">▶</a> <a href="#">+</a>
103.3 100kW	<b>KKCW</b> -- <b>K103</b>	Beaverton (Washington) OR	soft ac	<a href="#">🔗</a> <a href="#">▶</a> <a href="#">+</a>
	<b>KKCW-HD1</b> -- <b>K103</b>		soft ac	<a href="#">🔗</a> <a href="#">▶</a> <a href="#">+</a>
	<b>KKCW-HD2</b> -- <b>Smooth Jazz Network</b> <small>(satellite feed)</small>		smooth jazz	<a href="#">🔗</a> <a href="#">▶</a> <a href="#">+</a>
	<b>KKCW-HD3</b> -- Air1		worship music (CWM)	<a href="#">🔗</a> <a href="#">▶</a> <a href="#">+</a>
103.7 99w	<b>K279BO</b> -- <b>103.7 The Legend</b> <small>KFBW-HD3</small>	Portland (Multnomah) OR	classic country	<a href="#">🔗</a> <a href="#">▶</a> <a href="#">+</a>
104.1 7kW	<b>KFIS</b> -- <b>The Fish</b>	Scappoose (Columbia) OR	contemporary Christian	<a href="#">🔗</a> <a href="#">▶</a> <a href="#">+</a>
104.5 99w	K283BL -- Way FM <small>KFBW-HD2</small>	Portland (Multnomah) OR	contemporary Christian	
104.5 100w	<b>KVPB-LP</b> -- <b>The Sound</b>	Vernonia (Columbia) OR	new (->community)	<a href="#">🔗</a> <a href="#">+</a>



Change Freq. To 103.3 KKCW 100 kW  
Left Arrow, Backspace, 103.3



```
pi@raspberrypi: ~/SDR
File Edit Tabs Help
pi@raspberrypi:~/SDR $ rtl_fm -M wbfm -f 103.3M | play -r 32k -t raw -e s -b 16
-c 1 -V1 -
```

**103.3**



# Listening to 103.3 FM



rtl\_fm

play

rtl\_fm

play

```
pi@raspberrypi:~/SDR $ rtl_fm -M wbfm -f 103.3M | play -r 32k -t raw -e s -b 16
-c 1 -V1 -
Found 1 device(s):
 0: Realtek, RTL2838UHIDIR, SN: 00000001

Using device 0: Generic RTL2832U OEM

-: (raw)

  Encoding: Signed PCM
  Channels: 1 @ 16-bit
  Samplerate: 32000Hz
  Replaygain: off
  Duration: unknown

In:0.00% 00:00:00.00 [00:00:00.00] Out:0 [ | ] Clip:0 De
tached kernel driver
Found Rafael Micro R820T tuner
Tuner gain set to automatic.
Tuned to 103571000 Hz.
oversampling input by: 6x.
Oversampling output by: 1x.
Buffer size: 8.03ms
Exact sample rate is: 1020000.026345 Hz
Create UDP thread
Created UDP thread
Main socket started! :-) Tuning enabled on UDP/6020
Sampling at 1020000 S/s.
Output at 170000 Hz.
In:0.00% 00:00:41.22 [00:00:00.00] Out:1.31M [ =====|===== ] Clip:0
```



# CTRL-C to Exit Playing 103.3 FM



```
pi@raspberrypi: ~/SDR
File Edit Tabs Help
pi@raspberrypi:~/SDR $ rtl_fm -M wbfm -f 103.3M | play -r 32k -t raw -e s -b 16
-c 1 -V1 -
Found 1 device(s):
 0: Realtek, RTL2838UHIDIR, SN: 00000001

Using device 0: Generic RTL2832U OEM

-: (raw)

Encoding: Signed PCM
Channels: 1 @ 16-bit
Samplerate: 32000Hz
Replaygain: off
Duration: unknown

In:0.00% 00:00:00.00 [00:00:00.00] Out:0 [ | ] Clip:0 De
tached kernel driver
Found Rafael Micro R820T tuner
Tuner gain set to automatic.
Tuned to 103571000 Hz.
oversampling input by: 6x.
Oversampling output by: 1x.
Buffer size: 8.03ms
Exact sample rate is: 1020000.026345 Hz
Create UDP thread
Created UDP thread
Main socket started! :-) Tuning enabled on UDP/6020
Sampling at 1020000 S/s.
Output at 170000 Hz.
In:0.00% 00:03:21.22 [00:00:00.00] Out:6.43M [ -====|===== ] Clip:0 ^C
Signal caught, exiting!

User cancel, exiting...
Reattached kernel driver
In:0.00% 00:03:21.38 [00:00:00.00] Out:6.44M [ -====|===== ] Clip:0
Aborted.
pi@raspberrypi:~/SDR $
```





# NOAA Weather Frequencies

www.nws.noaa.gov/nwr/coverage/ccov.php?State=OR



**NOAA WEATHER RADIO ALL HAZARDS**  
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Home Español Coverage Outages Information FAQ Organization Search

## NWR County Coverage Listing for [Oregon](#)

**DEGRADED** - Indicates transmitter is experiencing a temporary degradation of service.

**OUT OF SERVICE** - Indicates transmitter is temporarily out of service.

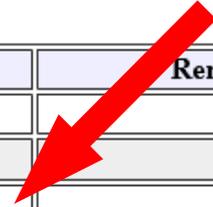
[State Selection for County Coverage](#)

162.400	162.425	162.450	162.475	162.500	162.525	162.550
---------	---------	---------	---------	---------	---------	---------

County Coverage as of April 21 2019 20:48:12. (UTC)

[Print](#)

County	SAME #	NWR Transmitter	Call Sign	Frequency	Remarks
Baker	041001	---No NWR Coverage---			
Benton	041003	Eugene	<a href="#">KEC42</a>	162.400	
Benton	041003	Salem	<a href="#">WXL96</a>	162.475	
Clackamas	041005	Portland	<a href="#">KIG98</a>	162.550	
Clackamas	041005	Salem	<a href="#">WXL96</a>	162.475	
Clatsop	041007	Astoria	<a href="#">KEC91</a>	162.400	





# WXL96 NOAA Weather 162.475 MHz FM



```
pi@raspberrypi:~/SDR $ rtl_fm -M fm -f 162.475M -s 24000 | play -r 24000 -t raw
-e s -b 16 -c 1 -V1 -
Found 1 device(s):
 0: Realtek, RTL2838UHIDIR, SN: 00000001

Using device 0: Generic RTL2832U OEM

-: (raw)

Encoding: Signed PCM
Channels: 1 @ 16-bit
Samplerate: 24000Hz
Replaygain: off
Duration: unknown

In:0.00% 00:00:00.00 [00:00:00.00] Out:0 [ | ] Clip:0 De
tached kernel driver
Found Rafael Micro R820T tuner
Tuner gain set to automatic.
Tuned to 162727000 Hz.
oversampling input by: 42x.
Oversampling output by: 1x.
Buffer size: 8.13ms
Exact sample rate is: 1008000.009613 Hz
Create UDP thread
Created UDP thread
Main socket started! ;-) Tuning enabled on UDP/6020
Sampling at 1008000 S/s.
Output at 24000 Hz.
In:0.00% 00:00:33.11 [00:00:00.00] Out:786k [ | ] Clip:0 [ ]
```



# WA7ABU 145.290 MHz FM Repeater



```
pi@raspberrypi:~/SDR $ rtl_fm -M fm -f 145.290M -s 24000 | play -r 24000 -t raw -e s
-b 16 -c 1 -V1 -
Found 1 device(s):
 0: Realtek, RTL2838UHIDIR, SN: 00000001

Using device 0: Generic RTL2832U OEM

-: (raw)

Encoding: Signed PCM
Channels: 1 @ 16-bit
Samplerate: 24000Hz
Replaygain: off
Duration: unknown

In:0.00% 00:00:00.00 [00:00:00.00] Out:0 [ | ] Clip:0 Detache
d kernel driver
Found Rafael Micro R820T tuner
Tuner gain set to automatic.
Tuned to 145542000 Hz.
oversampling input by: 42x.
Oversampling output by: 1x.
Buffer size: 8.13ms
Exact sample rate is: 1008000.009613 Hz
Create UDP thread
Created UDP thread
Main socket started! :-) Tuning enabled on UDP/6020
Sampling at 1008000 S/s.
Output at 24000 Hz.
In:0.00% 00:00:15.70 [00:00:00.00] Out:369k [ | ] Clip:0 [ ]
```



# rtl\_fm Command Parameters



```
pi@raspberrypi:~/SDR $ rtl_fm -M fm -f 145.290M -s 32000 | play -r 32000 -t raw -e s -b  
16 -c 1 -V1 -
```

- -M **fm** modulation
- -f **145.290** frequency
- -s **32000** audio sample rate
  - 8000, 11025, 22050, 32000, 44100 & 48000

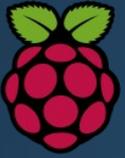


# Adding Fixed Gain & Squelch



```
pi@raspberrypi:~/SDR $ rtl_fm -M fm -f 145.290M -s 24000 -g 30 -l 80 | play -r 24000  
-t raw -e s -b 16 -c 1 -V1 -
```

- -g 30 gain level
- -l 80 squelch level is sensitive to gain level & preamp



# Linux Pipeline Function



```
pi@raspberrypi:~/SDR $ rtl_fm -M fm -f 145.290M -s 24000 | play -r 24000 -t raw -e s -b 16 -c 1 -V1 -
```

RTL-SDR USB data stream



rtl\_fm

stdout

pipe

stdin

play

speaker



# Sound eXchange: SoX **play** Command Parameters

```
pi@raspberrypi:~/SDR $ rtl_fm -M fm -f 145.290M -s 32000 | play -r 32000 -t raw -e s -b  
16 -c 1 -V1 -
```

- **-r**      **32000** audio sample rate, **must match rtl\_fm -s rate**
  - 8000, 11025, 22050, 32000, 44100 & 48000
- **-t**      **raw** audio data encoding
- **-e**      **s** for signed-integer encoding
- **-b**      **16** bits of audio data
- **-c**      **1** audio channel
- **-V1**     **-V1** SoX processing & only error messages are shown.
- **-**        **-** Use stdin pipeline

SoX 84 pages

```
In:0.00% 00:00:11.01 [00:00:00.00] Out:344k [ ==|== ] Clip:0
```



# WA7ABU 145.290 MHz SSTV Wed. 8:30 pm



```

pi@raspberrypi:~
File Edit Tabs Help
pi@raspberrypi:~$ rtl_fm -M fm -f 145.29M -s 48k | play -r 48k -t raw -e s -b 1
6 -c 1 -V1 -
Found 1 device(s):
 0: Realtek, RTL2838UHIDIR, SN: 00000001

Using device 0: Generic RTL2832U OEM

-: (raw)

Encoding: Signed PCM
Channels: 1 @ 16-bit
Samplerate: 48000Hz
Replaygain: off
Duration: unknown

In:0.00% 00:00:00.00 [00:00:00.00] Out:0 [ | ] Clip:0 De
tached kernel driver
Found Rafael Micro R820T tuner
Tuner gain set to automatic.
Tuned to 145542000 Hz.
oversampling input by: 21x.
Oversampling output by: 1x.
Buffer size: 8.13ms
Exact sample rate is: 1008000.009613 Hz
Create UDP thread
Created UDP thread
Main socket started! (-) Tuning enabled on UDP/6020
Sampling at 1008000 S/s.
Output at 48000 Hz.
In:0.00% 03:22:12.35 [00:00:00.00] Out:582M [ ----|---- ] Clip:0

```

QSSTV 9.2.4

File Options Help

Receive Transmit Gallery

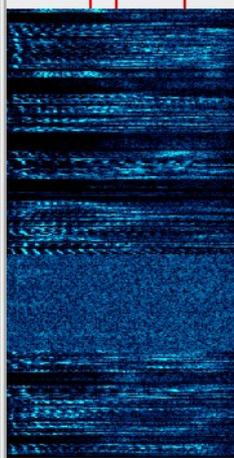
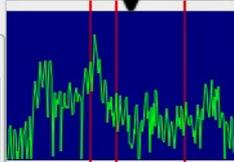
RX SSTV RX DRM TX SSTV TX DRM TX Stock Templates


Page 1 of 2

Max dB Range Avg  
-25 + 35 + 0.90 +

Saved: /home/pi/qsstv/rx\_sstv//S2\_20190418\_0

WF Text BSR WF ID CW ID PTT





# ISS SSTV 145.8 MHz FM



```
pi@raspberrypi:~  
File Edit Tabs Help  
User cancel, exiting...  
In:0.00% 00:00:49.32 [00:00:00.00] Out:2.36M [ | ] Clip:0  
Aborted.  
Reattached kernel driver  
Signal caught, exiting!  
pi@raspberrypi:~$ rtl_fm -M fm -f 145.8M -s 48k | play -r 48k -t raw -e s -b 16  
-c 1 -V1 -  
Found 1 device(s):  
 0: Realtek, RTL2838UHIDIR, SN: 00000001  
Using device 0: Generic RTL2832U OEM  
-: (raw)  
Encoding: Signed PCM  
Channels: 1 @ 16-bit  
Samplerate: 48000Hz  
Replaygain: off  
Duration: unknown  
In:0.00% 00:00:00.00 [00:00:00.00] Out:0 [ | ] Clip:0 De  
tached kernel driver  
Found Rafael Micro R820T tuner  
Tuner gain set to automatic.  
Tuned to 146052000 Hz.  
oversampling input by: 21x.  
Oversampling output by: 1x.  
Buffer size: 8.13ms  
Exact sample rate is: 1008000.009613 Hz  
Create UDP thread  
Created UDP thread  
Main socket started! (-) Tuning enabled on UDP/6020  
Sampling at 1008000 S/s.  
Output at 48000 Hz.  
In:0.00% 14:08:20.14 [00:00:00.00] Out:2.44G [ -====|====- ] Clip:0
```

OSSTV 9.2.4

File Options Help

Receive Transmit Gallery

SSTV DRM

- Use VIS
- Auto Slant
- Autosave

Signals: Normal

Mode: PD120

Default Image format: png

Save if Complete (%): 5

Call:  LOG QSO

No sync

Max dB Range Avg  
-25 + 35 0.90

WF Text BSR WF ID CW ID PTT



# NOAA18.sh Bash Shell



```
pi@raspberrypi: ~/SDR
File Edit Tabs Help
pi@raspberrypi:~ $ cd SDR
pi@raspberrypi:~/SDR $ ./NOAA18.sh
```

File Properties

General Permissions

Name: NOAA18.sh

Location: /home/pi/SDR

File type: shell script

Open with: Text Editor

Total size of files: 817 bytes (817 bytes)

Size on disk: 4.0 KiB (4,096 bytes)

Last modification: 05/15/2019 18:00

Last access: 05/08/2019 17:22

Last permissions change: 05/15/2019 18:00

Cancel OK

File Properties

General Permissions

Owner: pi

Group: pi

Access Control

View content: Anyone

Change content: Only owner

Execute: Anyone

Hidden file

Cancel OK



NOAA18.sh

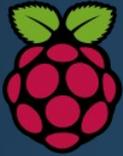
- □ ×

File Edit Search Options Help

```
#!/bin/bash
#
# David Haworth, WA90NY
# www.qrz.com/db/WA90NY
#
# $1 is gain parameter
#
gain=29.7
if [ $# -eq 0 ]; then
    echo 'Missing gain parameter 0 to 49.6, gain set to 29.7.'
else
    gain=${1}
fi
echo 'CTRL-C to stop'
echo 'NOAA-18 frequency 137,912,500 Hz WFM'
echo "Gain is $1"
echo 'Rafael Micro R820T tuner'
echo 'Supported gain values (29):'
echo '0.0 0.9 1.4 2.7 3.7 7.7 8.7'
echo '12.5 14.4 15.7 16.6 19.7'
echo '20.7 22.9 25.4 28.0 29.7'
echo '32.8 33.8 36.4 37.2 38.6'
echo '40.2 42.1 43.4 43.9 44.5 48.0 49.6'
echo
#
today=`date '+%Y_%m_%d_%H_%M_%S'`
filename="/home/pi/SDR/NOAA18_$today.wav"
rtl_fm -M fm -f 137912500 -g ${gain} -l 0 -s 150k -r 11025 -A fast -E deemo |
tee >( play -v 2 -r 11025 -t raw -e s -b 16 -c 1 -V1 - ) >( sox -v 2 -r 11025 -
t raw -e s -b 16 -c 1 - ${filename}| ) > /dev/null
```

Gain parameter with default  
Speaker  
Save to file with auto file name





# NOAA-18 Weather Satellite 137.9125 MHz WFM

A screenshot of a Raspberry Pi desktop environment. The desktop background is a landscape image. On the left side, there is a vertical dock with icons for 'Trash', 'Presentation', 'SSH RPi', 'Octave RTL', and 'SETTINGS'. The top of the screen shows a terminal window with the command 'pi@raspberrypi: ~/SDR' and a Chromium browser window titled 'APT-3000 - Chromium'. The browser window displays a webpage from 'jthatch.com/APT3000/APT3000.html'. The webpage content includes a search bar with the text 'NOAA18\_2019\_05\_09\_\_16\_57\_3' and three buttons labeled 'View A', 'View B', and 'View AB'. Below the buttons is a large, dark, grayscale image of a satellite view of a coastal region. At the bottom of the browser window, the URL 'http://jthatch.com/APT3000/APT3000.html' is visible.

APT-3000 - Chromium

APT-3000 - Chromium

Observational Astronom... x APT-3000 x +

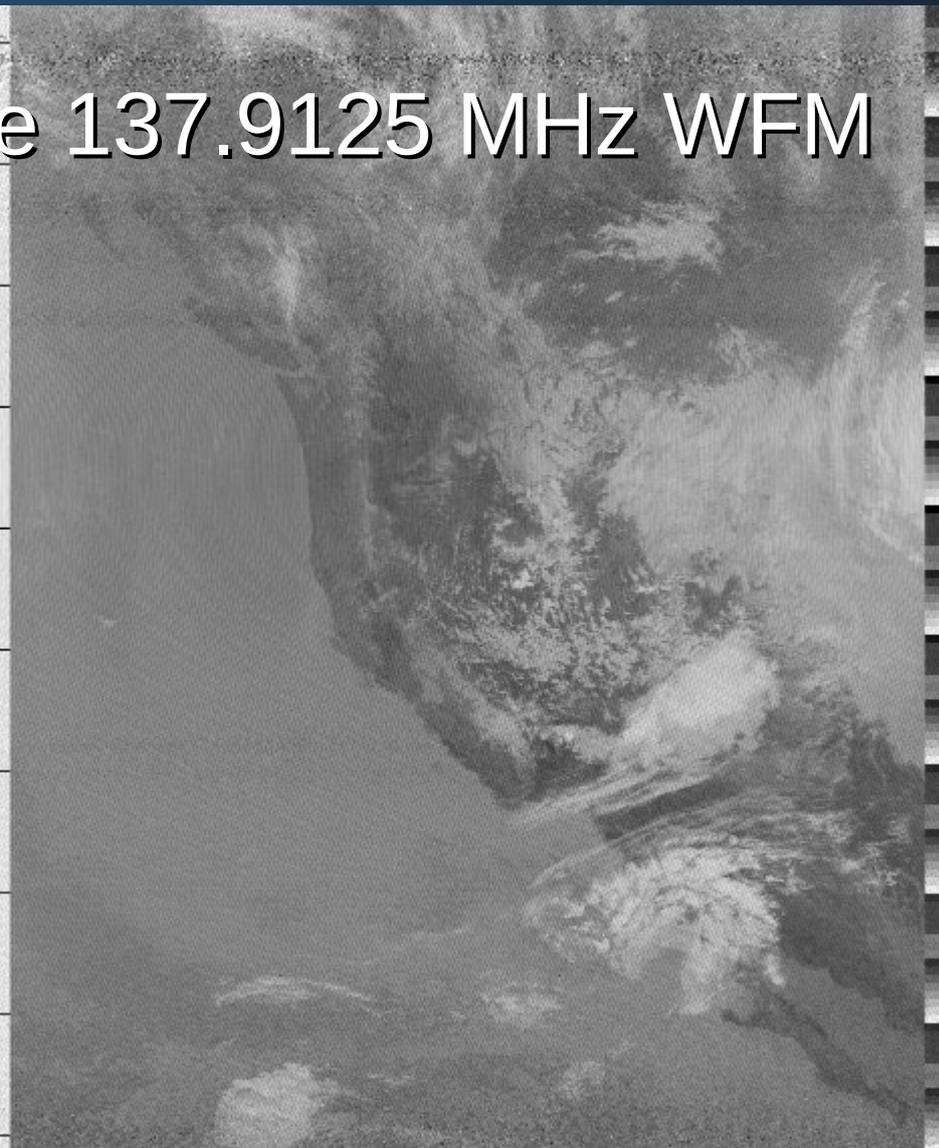
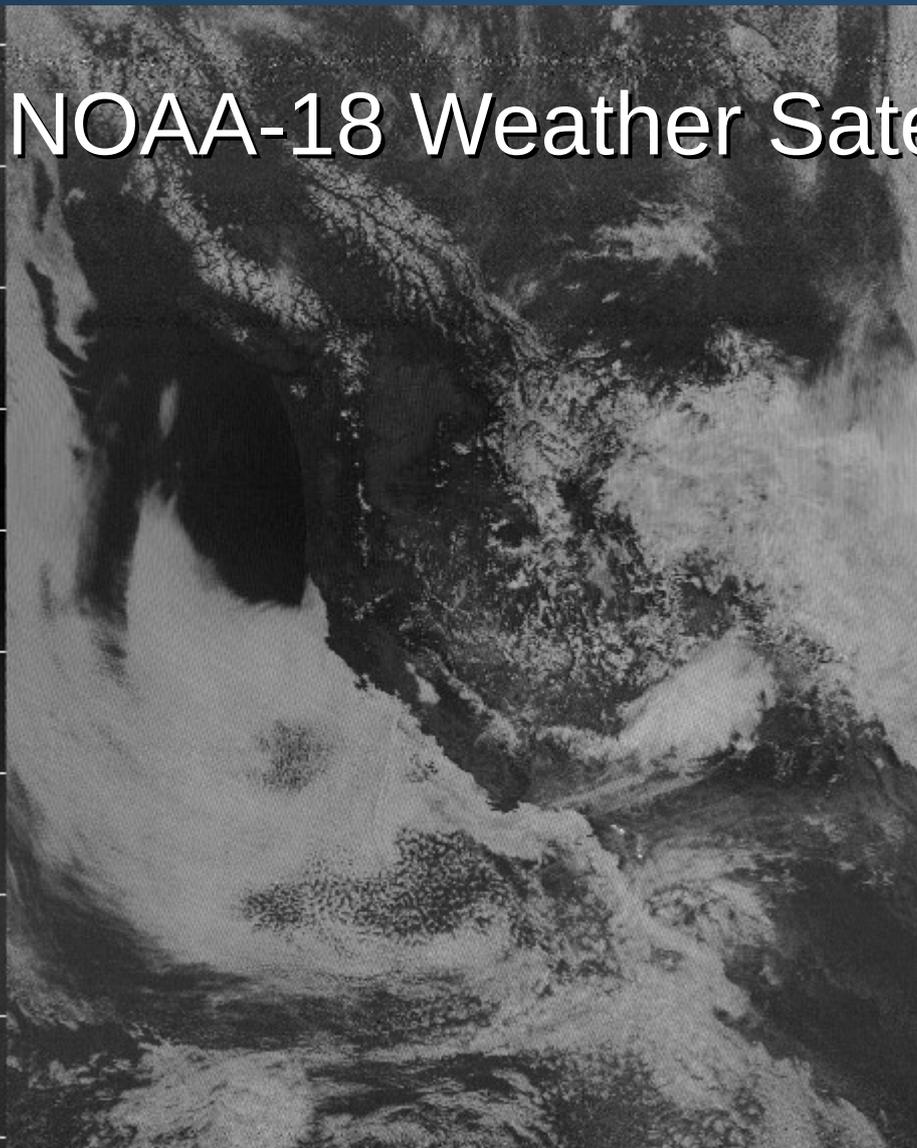
Not secure | jthatch.com/APT3000/APT3000.html

Apps Observational... Spektroskopie... spectro-aras Tools - Google... 100,000 Stars UNL Astronom...

Browse... NOAA18\_2019\_05\_09\_\_16\_57\_3 View A View B View AB

<http://jthatch.com/APT3000/APT3000.html>

# NOAA-18 Weather Satellite 137.9125 MHz WFM





# Raspberry Pi Headless Operation

## No Keyboard, No Mouse & No Monitor



- Enable SSH (**S**ecure **S**hell) on Raspberry Pi
  - *man ssh*
- SSH on Windows 8.1
- SSH on Mac OS/X
- SSH on Linux / Raspberry Pi





# Enable SSH



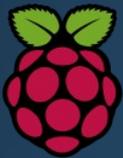
Raspberry Pi Configuration

System Interfaces Performance Localisation

Camera:	<input type="radio"/> Enable	<input checked="" type="radio"/> Disable
SSH:	<input checked="" type="radio"/> Enable	<input type="radio"/> Disable
VNC:	<input checked="" type="radio"/> Enable	<input type="radio"/> Disable
SPI:	<input type="radio"/> Enable	<input checked="" type="radio"/> Disable
I2C:	<input type="radio"/> Enable	<input checked="" type="radio"/> Disable
Serial Port:	<input type="radio"/> Enable	<input checked="" type="radio"/> Disable
Serial Console:	<input checked="" type="radio"/> Enable	<input type="radio"/> Disable
1-Wire:	<input type="radio"/> Enable	<input checked="" type="radio"/> Disable
Remote GPIO:	<input type="radio"/> Enable	<input checked="" type="radio"/> Disable

Cancel OK

A red arrow points from the top-right towards the 'Enable' radio button for the SSH option.



# Boot into CLI



Raspberry Pi Configuration

System Interfaces Performance Localisation

Password:

Hostname:

Boot:  To Desktop  To CLI

Auto login:  Login as user

Network at Boot:  Wait for network

Splash Screen:  Enable  Disable

Resolution:

Overscan:  Enable  Disable

Pixel Doubling:  Enable  Disable

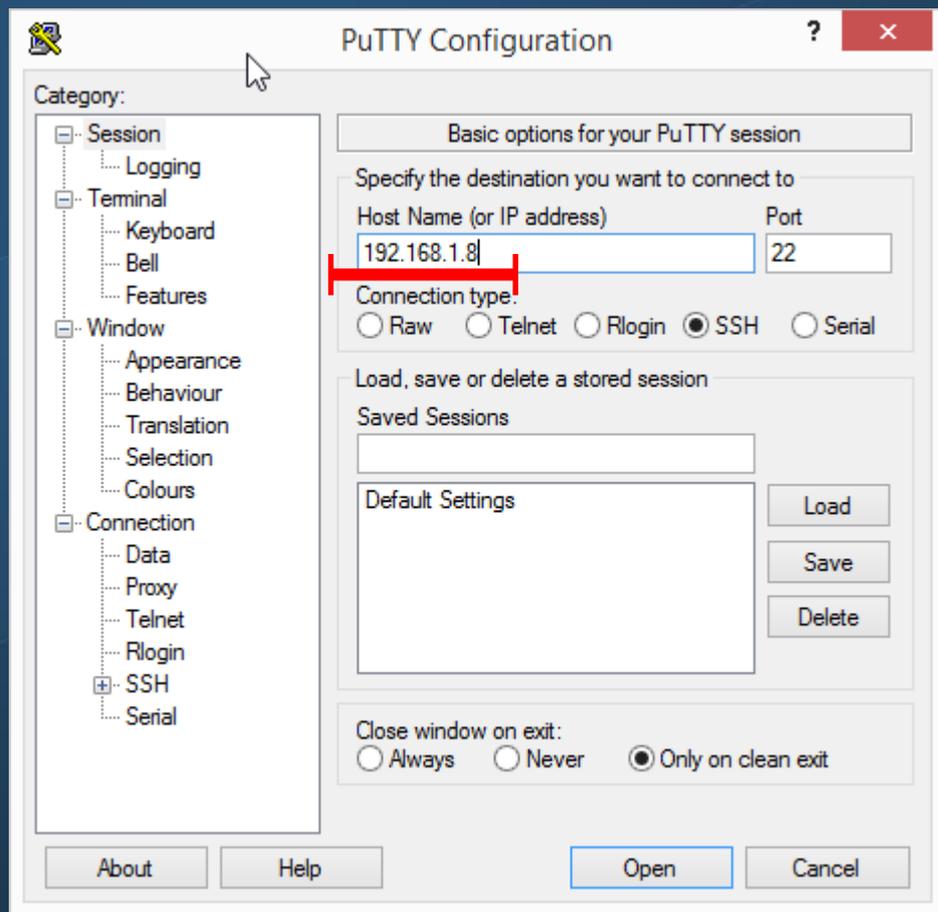
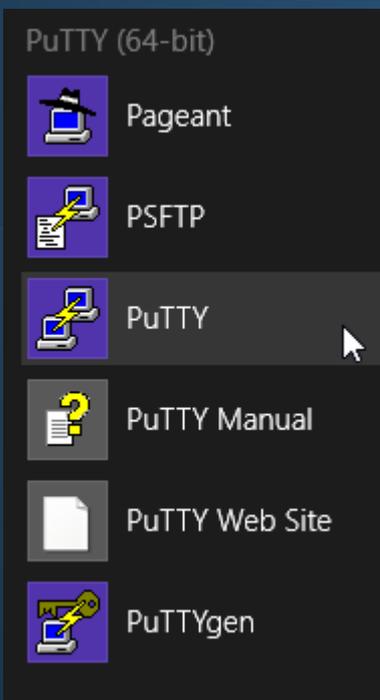
Downloads  
Installs1  
ISS  
MagPi  
Music  
Octave  
Pictures  
Public  
qsstv  
Screens1  
SDR  
Templates  
templates  
tx\_drm

audio  
desktop  
documents  
installs1  
ISS  
MagPi  
<No subfolders>  
music  
octave  
pictures  
<No subfolders>

Boot into a command line shell rather than the desktop



# SSH: Windows 8.1 with PuTTY



<https://www.putty.org/>



# SSH: Windows 8.1 with PuTTY

PuTTY (64-bit)

- Pageant
- PSFTP
- PuTTY**
- PuTTY Manual
- PuTTY Web Site
- PuTTYgen

```
pi@raspberrypi: ~  
login as: pi  
pi@192.168.1.8's password:  
Linux raspberrypi 4.14.98-v7+ #1200 SMP Tue Feb 12 20:27:48 GMT 2019 armv7l  
  
The programs included with the Debian GNU/Linux system are free software;  
the exact distribution terms for each program are described in the  
individual files in /usr/share/doc/*/copyright.  
  
Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent  
permitted by applicable law.  
Last login: Tue Apr 23 16:00:41 2019 from 192.168.1.9  
pi@raspberrypi:~ $
```



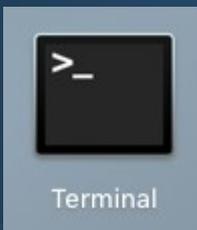
# SSH: Windows 8.1 with PuTTY

```
pi@raspberrypi: ~  
pi@raspberrypi:~ $ rtl_fm -M fm -f 162.475M -s 48k | play -r 48k -t raw -e s -b 16 -c ^  
1 -V1 -  
Found 1 device(s):  
 0: Realtek, RTL2838UHIDIR, SN: 00000001  
  
Using device 0: Generic RTL2832U OEM  
-: (raw)  
  
  Encoding: Signed PCM  
  Channels: 1 @ 16-bit  
Samplerate: 48000Hz  
Replaygain: off  
  Duration: unknown  
  
In:0.00% 00:00:00.00 [00:00:00.00] Out:0      [    |    ]      Clip:0   Detache  
d kernel driver  
Found Rafael Micro R820T tuner  
Tuner gain set to automatic.  
Tuned to 162727000 Hz.  
oversampling input by: 21x.  
Oversampling output by: 1x.  
Buffer size: 8.13ms  
Exact sample rate is: 1008000.009613 Hz  
Create UDP thread  
Created UDP thread  
Main socket started! :-) Tuning enabled on UDP/6020  
Sampling at 1008000 S/s.  
Output at 48000 Hz.  
In:0.00% 00:00:19.80 [00:00:00.00] Out:942k [  ==|==  ]      Clip:0   █
```

- PuTTY (64-bit)
- Pageant
- PSFTP
- PuTTY
- PuTTY Manual
- PuTTY Web Site
- PuTTYgen



# SSH: macOS



```

davidhaworth — pi@raspberrypi: ~ — ssh pi@192.168.1.8 — 80x24
Last login: Wed Apr 24 15:07:18 on console
[Dauids-MacBook-Pro:~ davidhaworth$ ssh pi@192.168.1.8 ]
The authenticity of host '192.168.1.8 (192.168.1.8)' can't be established.
ECDSA key fingerprint is SHA256:KiZNzMZ5qRTHU7o/NFTEGX7Hxiy3VXHvSfcxmjrmSgI.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '192.168.1.8' (ECDSA) to the list of known hosts.
[pi@192.168.1.8's password: ]
Linux raspberrypi 4.14.98-v7+ #1200 SMP Tue Feb 12 20:27:48 GMT 2019 armv7l

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Last login: Sun Apr 28 10:39:08 2019 from 192.168.1.4
pi@raspberrypi:~ $
```



# SSH: macOS



Terminal

```
[pi@raspberrypi:~ $ exit
logout
Connection to 192.168.1.8 closed.
Davids-MacBook-Pro:~ davidhaworth$
```

```
davidhaworth — pi@raspberrypi: ~ — ssh pi@192.168.1.8 — 80x30
[pi@raspberrypi:~ $ rtl_fm -M fm -f 162.475M -s 48k | play -r 48k -t raw -e s -b
16 -c 1 -V1 -
Found 1 device(s):
 0: Realtek, RTL2838UHIDIR, SN: 00000001

Using device 0: Generic RTL2832U OEM

-: (raw)

Encoding: Signed PCM
Channels: 1 @ 16-bit
Samplerate: 48000Hz
Replaygain: off
Duration: unknown

In:0.00% 00:00:00.00 [00:00:00.00] Out:0 [ | ] Clip:0 De
tached kernel driver
Found Rafael Micro R820T tuner
Tuner gain set to automatic.
Tuned to 162727000 Hz.
oversampling input by: 21x.
Oversampling output by: 1x.
Buffer size: 8.13ms
Exact sample rate is: 1008000.009613 Hz
Create UDP thread
Created UDP thread
Main socket started! :-) Tuning enabled on UDP/6020
Sampling at 1008000 S/s.
Output at 48000 Hz.
In:0.00% 00:00:53.76 [00:00:00.00] Out:2.57M [ ==|== ] Clip:0
```



# SSH: Another Raspberry Pi



```
pi@raspberrypi: ~  
File Edit Tab Help  
pi@raspberrypi:~ $ ssh pi@192.168.1.8  
pi@192.168.1.8's password:  
Linux raspberrypi 4.14.98-v7+ #1200 SMP Tue Feb 12 20:27:48 GMT 2019 armv7l  
The programs included with the Debian GNU/Linux system are free software;  
the exact distribution terms for each program are described in the  
individual files in /usr/share/doc/*/copyright.  
Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent  
permitted by applicable law.  
Last login: Sun Apr 21 10:21:59 2019  
pi@raspberrypi:~ $ ifconfig
```

# Future Raspberry Pi Radio Projects

- SDR DSP
  - rtl\_sdr with GNU Octave
- GNU Radio



This Presentation PDF URL is at  
[www.qrz.com/db/WA9ONY](http://www.qrz.com/db/WA9ONY)



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- 2018 [FT8 Digital Mode DX Fun with Modest Equipment Part 1](#)
- 2018 [FT8 Digital Mode DX Fun with Modest Equipment Part 2](#)
- 2016 [Fun with Satellites](#)
- 2015 [FUNcube-1 \(AO-73\) 2m Satellites Telemetry](#)

Oregon Tualatin Valley Amateur Radio Club ([OTVARC](#))

- May 16, 2019 7:00 PM: [\*\*Raspberry Pi Radio Projects presentation PDF\*\*](#)