Raspberry Pi SDR

Willem AC0KQ
willem@prinmath.com

What is SDR?

- High speed analog to digital converter (A2D)
  - RF front end
- Digital Signal Processing (DSP)
  - Heavy duty filters, processes
- Digital to analog converter (D2A)
  - Audio out
- Control interface
  - Putting it all together

ICOM
POWER
REMOTE
LOCAL
P.LOCK
TIMER
PHONES
DIAL A
SCAN
PRIO
DIAL B
D-STAR
FIL3
P.AMP ATT10 IP+
11:32
D-STAR CALL CH
1295.300.000
AFC
MEMO
1999
AGC-F
AN
NR
MONI
64.5 dBμ
TS
10k
SPECTRUM SCOPE
CENTER
Grid 20k/10dB
-100k
+100k
< 1 >
SPAN
HOLD
CENT/FIX
EXPD/SET
IC-R8600
DIAL C
▲GRP
V/M
▼GRP
MW
RECEIVE
LOCK
M-CH DIAL
MENU
FUNCTION
M.SCOPE
QUICK
EXIT
SPEECH
LOCK

Doing It Yourself

- Fast A2D converter
  - HackRF, SDR-IQ, RTL2832, FunCube, ...
- High speed CPU
  - A decent computer
- D2A converter
  - A sound card
- Control interface
  - rtl_fm, ...
  - SDR#, Gqrx, GNU Radio, ...

Why the Raspberry Pi?

- Very well supported
- Fast enough to do serious work
- Full multi-tasking GNU/Linux OS
- Model 3B ($35)
  - 1.2GHz Quad 64bit & 1GB SDRAM
  - 4xUSB, Ethernet, WiFi
- Model ZeroW ($10)
  - 1GHz Single & 512MB SDRAM
  - 1xUSB, WiFi

DVB-T USB

- Digital Video Broadcasting – Terrestrial
  - European digital television
- RF to USB A2D
  - MCX RF in
  - R820T tuner
  - RTL2832U demodulator
  - USB 2.0 output
- Cost about $20

Raspberry Pi + DVB-T

- Advantages
  - Simple to use
  - Widely supported
  - Can remotely mount DVB-T at antenna
  - Can stream audio or IQ data
- Disadvantages
  - Poor sensitivity and selectivity

RTL-SDR

- Linux library and code to support DVB-T
- librtlsdr.a – library that supports hardware
- rtl_test – test hardware
- rtl_fm – simple FM receiver
- rtl_sdr – IQ stream
- rtl_tcp – IQ stream via TCP/IP
- *IQ (**I**n-phase and **Q**uadrature) is SDR speak for a data stream of complex numbers which is the discrete samples of the analog signal*

Installing RTL-SDR

- Install prerequisites

```
sudo apt-get install -y cmake pkg-config libusb-1.0
```

- Download RTL-SDR

```
git clone git://git.osmocom.org/rtl-sdr.git
```

- Build RTL-SDR

```
cd rtl-sdr
mkdir build
cd build
cmake ../ -DINSTALL_UDEV_RULES=ON
make
sudo make install
sudo ldconfig
```

Remove default modules

- Prevent built-in modules from loading
  - sudo cat <<EOF >>/etc/modprobe.d/blacklist-rtlsdr.conf
  - blacklist dvb_usb_rtl28xxu
  - blacklist rtl2832
  - blacklist rtl2830
  - EOF
- Reboot to clean out modules

Simple Local Receiver

- Connect speakers to rPi audio
- Run rtl_fm to demodulate to stdout
- Play using aplay from stdin

Broadcast radio KYGO

```
rtl_fm -f 98.5e6 -M wbfm -s 200k -r 48k | aplay -r 48k -f S16_LE
```

rtl_fm

- -f 98.5e6   frequency 98.5MHz
- -M wbfm   wideband FM mode
- -s 200k   sample rate (twice the bandwidth)
- -r 48k   output rate

aplay

- -r 48k   input rate
- -f S16_LE Signed 16bit little endian

Ham Radio 146.550

```
rtl_fm -f 146.550e6 -s12500 -Edeemp | aplay -r 12500 -fS16_LE
```

rtl_fm

- -f 146.550e6   frequency 146.550 MHz
- -s12500   sample rate (twice the bandwidth)
- -Edeemp   deemphasis

aplay

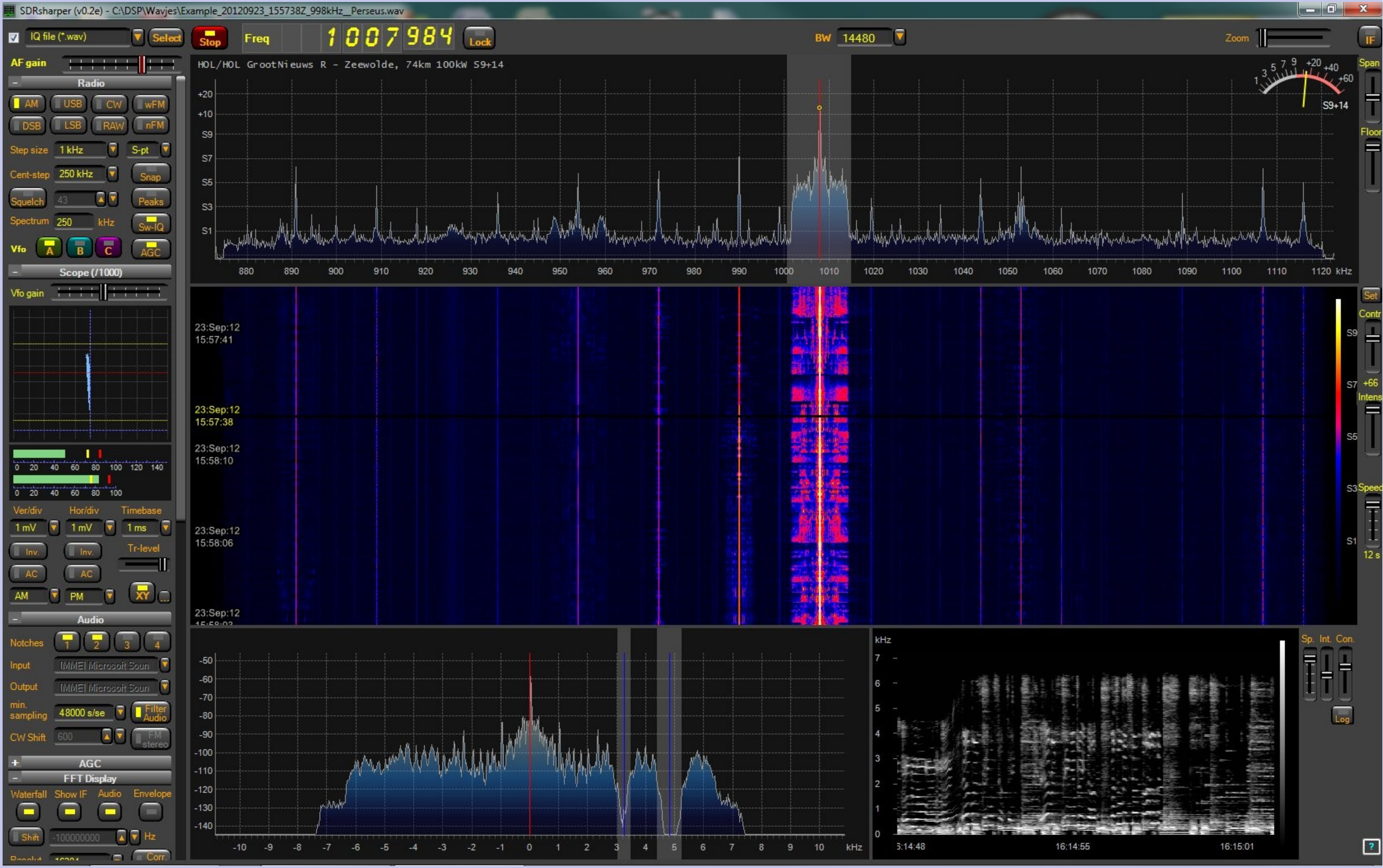
- -r 12500   input rate
- -f S16_LE   Signed 16bit little endian

Remote IQ spectrum server

- rtl_tcp -a *ip-address*
  - Remote IQ server
  - Provide the local external IP address
    - Default 127.0.0.1
  - rtl_tcp -a 192.168.99.30
- Decode this using an SDR program
  - SDR#
  - Gqrx
  - gnu-radio
  - many others

SDR#

- Excellent SDR software
- Supports many hardware types
- Windows Only
  - runs on Linux using mono
- Easy to use but very powerful
- Free and extensible via plugins



SDRsharper (v0.2e) - C:\DSP\Wavjes\Example_20120923_155738Z_998kHz__Perseus.wav

☑ IQ file (*.wav)

Freq 1007984

BW 14480

HOL/HOL GrootNieuws R - Zeewolde, 74km 100kW S9+14

Step size: 1 kHz

S-pt

Cent-step: 250 kHz

Squelch: 43

Spectrum: 250 kHz

Ver/div: 1 mV

Hor/div: 1 mV

Timebase: 1 ms

AM / PM

Input: [MME] Microsoft Soun

Output: [MME] Microsoft Soun

min. sampling: 48000 s/se

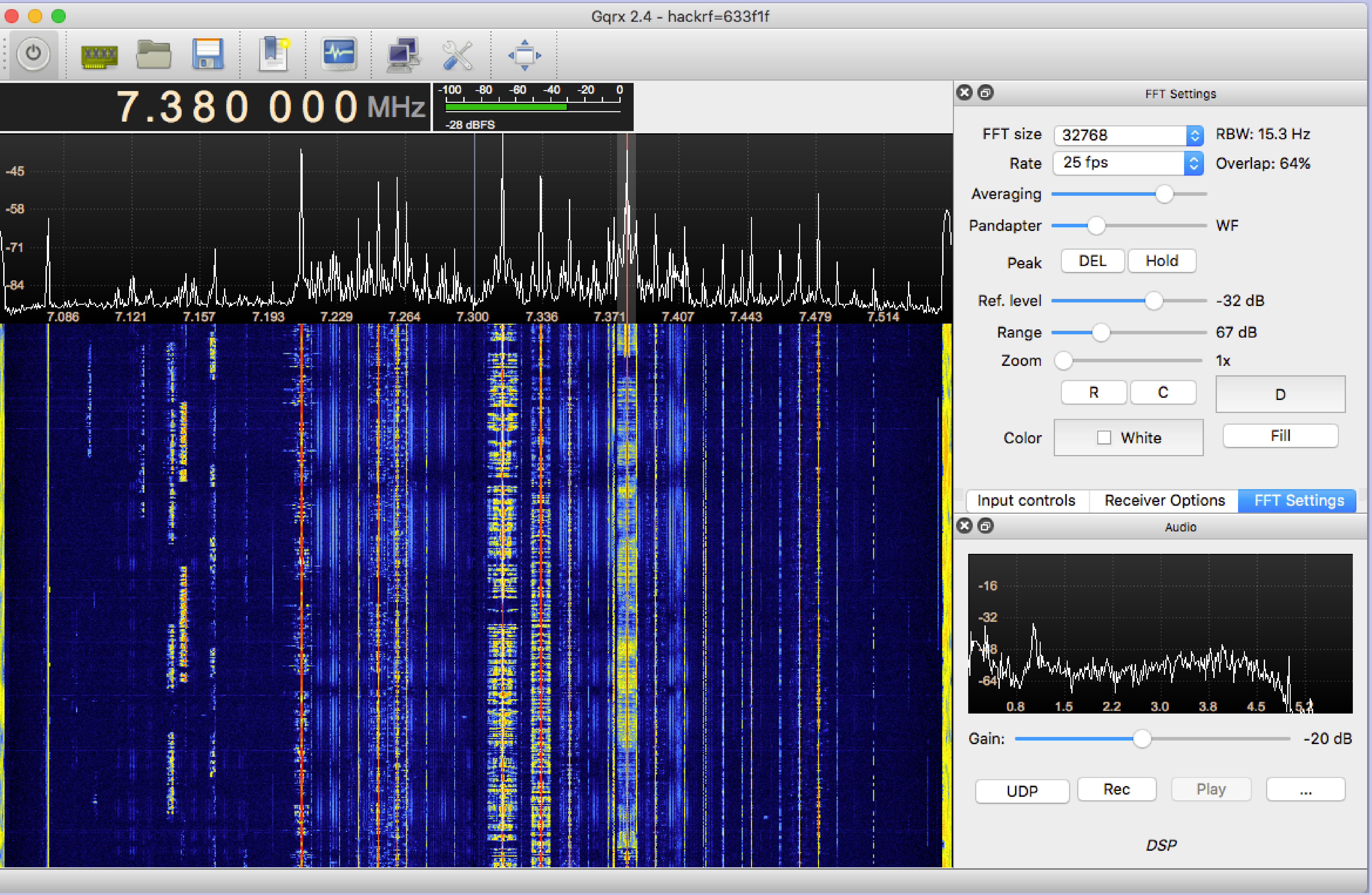
CW Shift: 600

Shift: -10000000 Hz

Resolut: 16384

Gqrx

- Pretty good SDR
- Supports many hardware types
- Runs on all platforms
- Easy to use
- Free



Gqrx 2.4 - hackrf=633f1f

7.380 000 MHz

-28 dBFS

FFT Settings

FFT size 32768

RBW: 15.3 Hz

Rate 25 fps

Overlap: 64%

Ref. level -32 dB

Range 67 dB

Zoom 1x

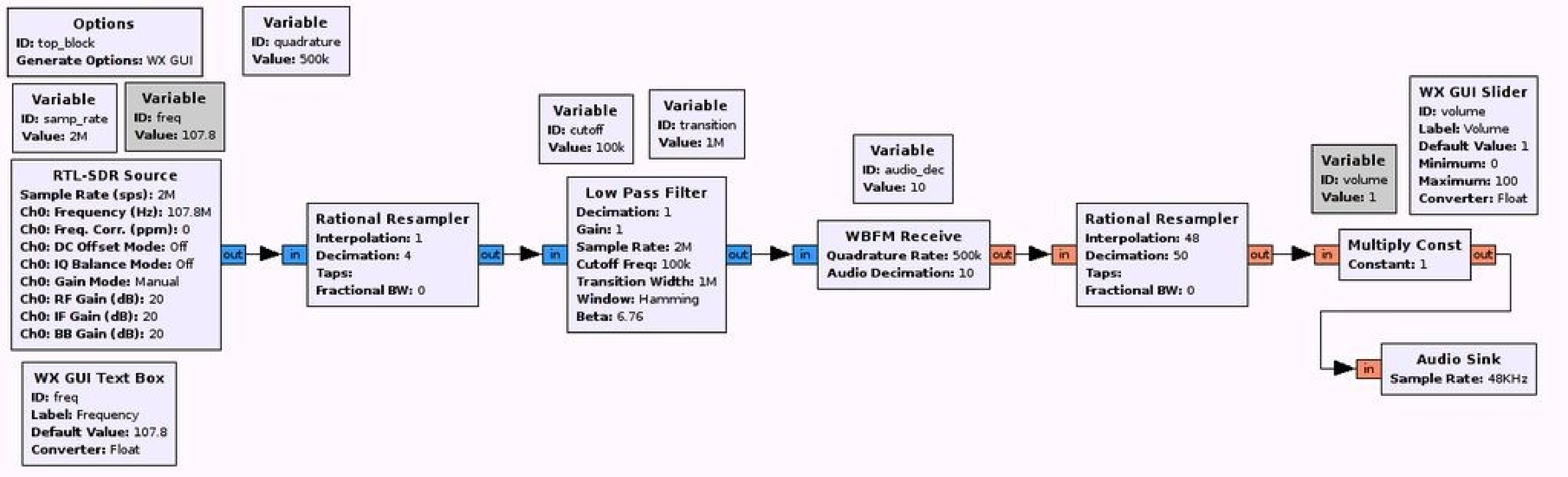
Color □ White

Audio

Gain: -20 dB

GNU Radio

- Extremely powerful
- Supports many hardware types
- Runs on all platforms
- gnu-radio-companion makes it easier to use
  - Python wrapper to connect components
  - Heavy on processor demands
  - Can be run natively on the Raspberry Pi
- Free and extensible



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: quadrature
Value: 500k

Variable
ID: samp_rate
Value: 2M

Variable
ID: freq
Value: 107.8

RTL-SDR Source
Sample Rate (sps): 2M
Ch0: Frequency (Hz): 107.8M
Ch0: Freq. Corr. (ppm): 0
Ch0: DC Offset Mode: Off
Ch0: IQ Balance Mode: Off
Ch0: Gain Mode: Manual
Ch0: RF Gain (dB): 20
Ch0: IF Gain (dB): 20
Ch0: BB Gain (dB): 20

WX GUI Text Box
ID: freq
Label: Frequency
Default Value: 107.8
Converter: Float

Rational Resampler
Interpolation: 1
Decimation: 4
Taps:
Fractional BW: 0

Variable
ID: cutoff
Value: 100k

Variable
ID: transition
Value: 1M

Low Pass Filter
Decimation: 1
Gain: 1
Sample Rate: 2M
Cutoff Freq: 100k
Transition Width: 1M
Window: Hamming
Beta: 6.76

Variable
ID: audio_dec
Value: 10

WBFM Receive
Quadrature Rate: 500k
Audio Decimation: 10

Rational Resampler
Interpolation: 48
Decimation: 50
Taps:
Fractional BW: 0

Variable
ID: volume
Value: 1

WX GUI Slider
ID: volume
Label: Volume
Default Value: 1
Minimum: 0
Maximum: 100
Converter: Float

Multiply Const
Constant: 1

Audio Sink
Sample Rate: 48KHz

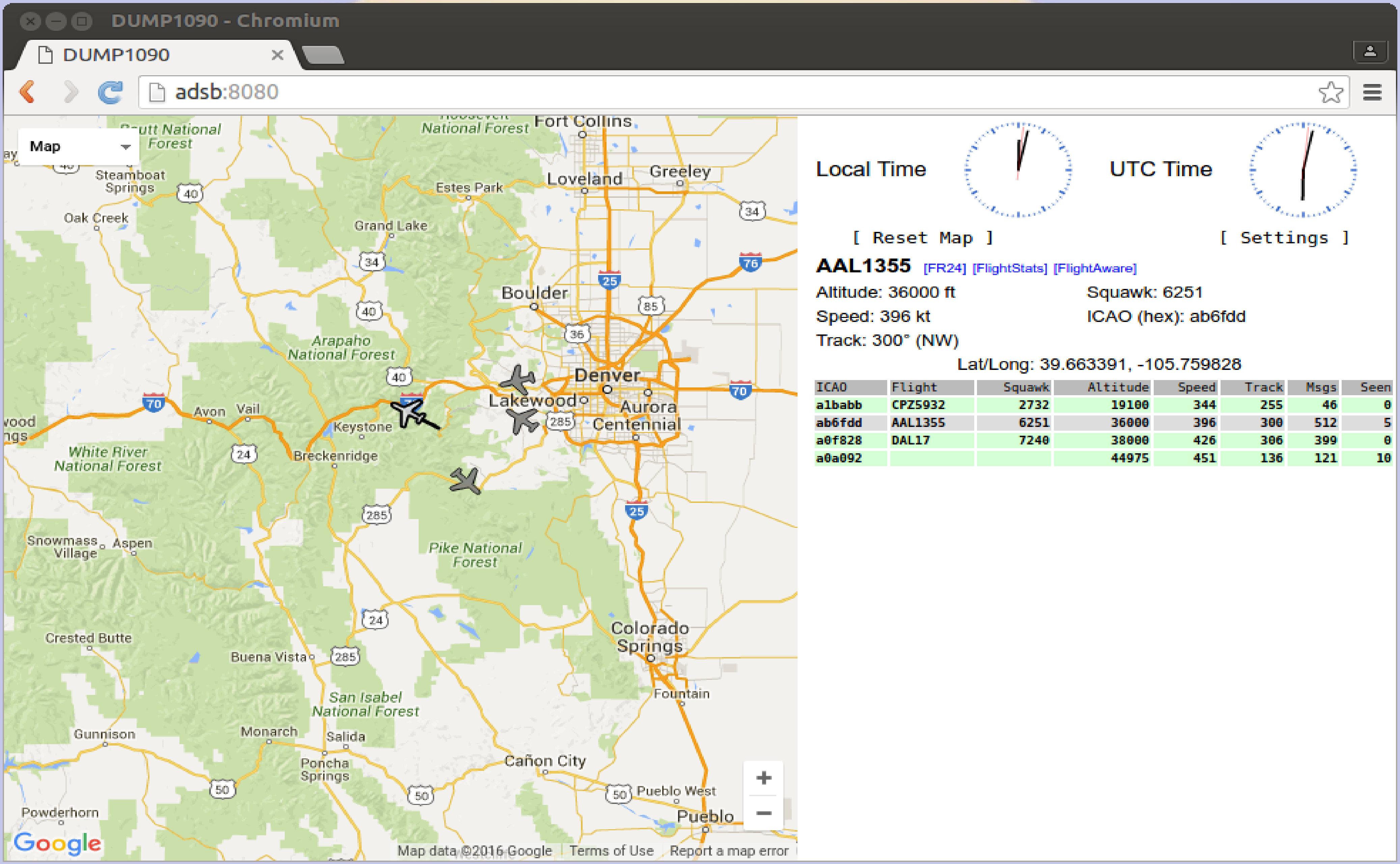
Where to go next

- Better hardware
  - Great Scott Gadgets HackRF
  - RFspace SDR-IQ
  - many others
- Transmitters
  - You really need to filter the output
- Specialized applications
  - ADSB
  - Freq Show

ADSB receiver

- Building the code
  - git clone git://github.com/MalcolmRobb/dump1090.git
  - cd dump1090
  - make
  - cd ..
- ./dump1090 --net --lon -105 --lat 39
  - --net enables web interface port 8080
  - --lon and –lat sets location

dump1090 ADSB web display



Local Time

UTC Time

[Reset Map]

[Settings]

AAL1355 [FR24] [FlightStats] [FlightAware]

Altitude: 36000 ft

Squawk: 6251

Speed: 396 kt

ICAO (hex): ab6fdd

Track: 300° (NW)

Lat/Long: 39.663391, -105.759828

ICAO	Flight	Squawk	Altitude	Speed	Track	Msgs	Seen
a1babb	CPZ5932	2732	19100	344	255	46	0
ab6fdd	AAL1355	6251	36000	396	300	512	5
a0f828	DAL17	7240	38000	426	306	399	0
a0a092			44975	451	136	121	10

Show and Tell