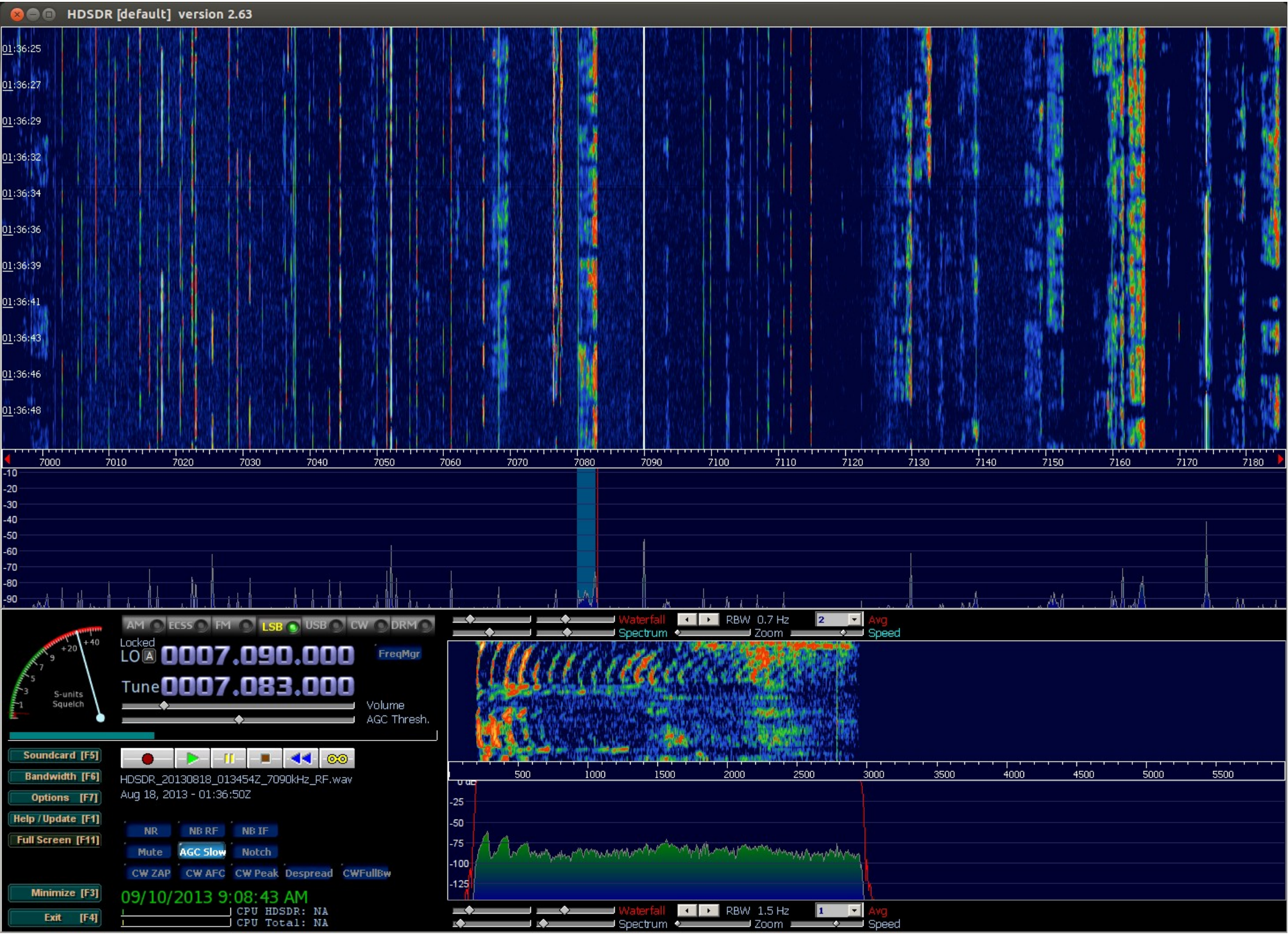
Building SDR Projects with

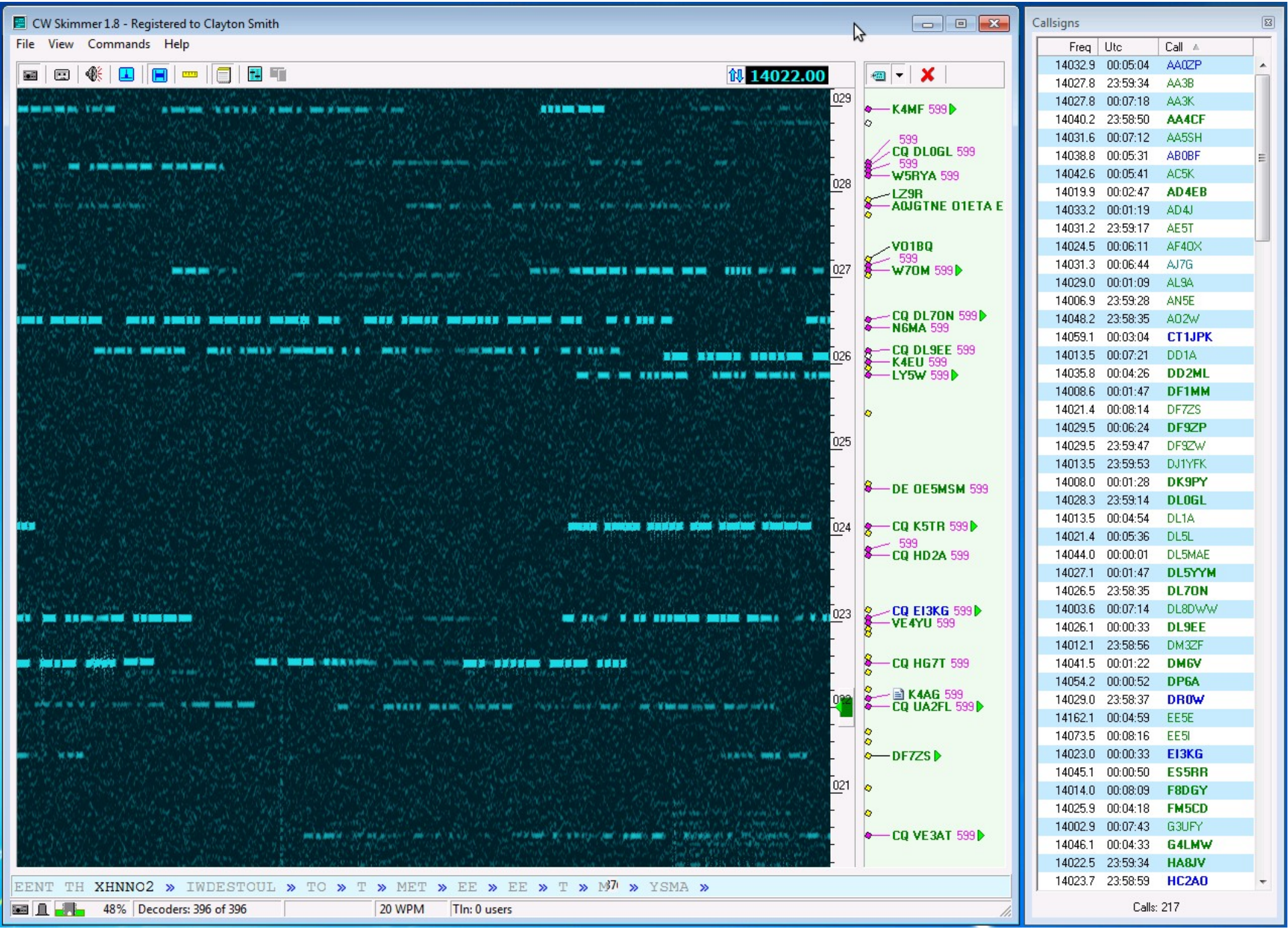
Clayton Smith (VE3IRR)
2014-09-16

Agenda

1. Why SDR?
2. SDR Architecture
3. Hardware
4. GNU Radio
5. Applications

WHY SDR?

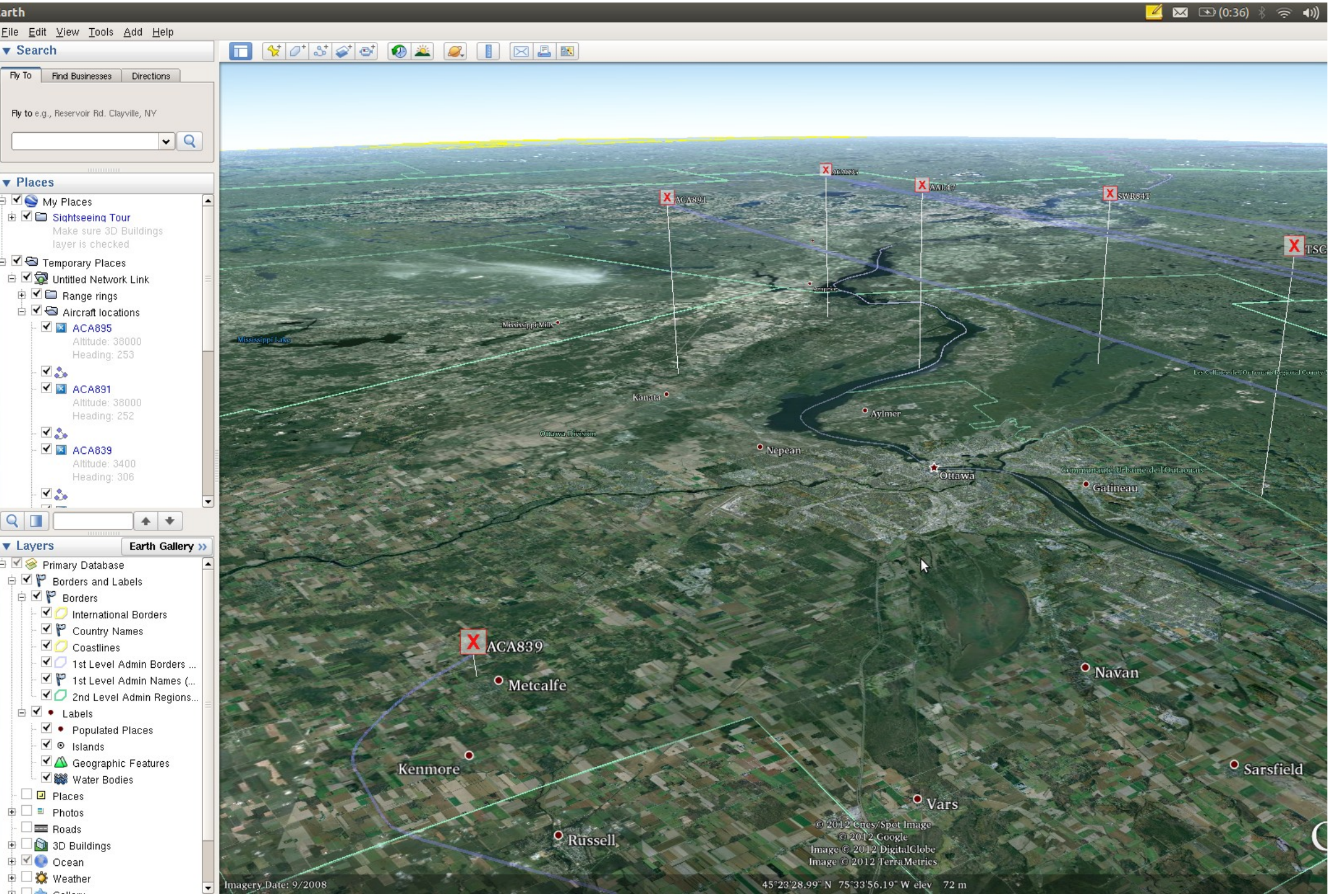

HDSDR [default] version 2.63
01:36:25
01:36:27
01:36:29
01:36:32
01:36:34
01:36:36
01:36:39
01:36:41
01:36:43
01:36:46
01:36:48
7000 7010 7020 7030 7040 7050 7060 7070 7080 7090 7100 7110 7120 7130 7140 7150 7160 7170 7180
-10 -20 -30 -40 -50 -60 -70 -80 -90
AM ECSS FM LSB USB CW DRM
Locked
LO A 0007.090.000
FreqMgr
Tune 0007.083.000
Volume
AGC Thresh.
S-units Squelch
Waterfall RBW 0.7 Hz Avg
Spectrum Zoom Speed
Soundcard [F5]
Bandwidth [F6]
Options [F7]
Help / Update [F1]
Full Screen [F11]
HDSDR_20130818_013454Z_7090kHz_RF.wav
Aug 18, 2013 - 01:36:50Z
500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500
0 dB -25 -50 -75 -100 -125
NR NB RF NB IF
Mute AGC Slow Notch
CW ZAP CW AFC CW Peak Despread CWFullBw
Minimize [F3]
09/10/2013 9:08:43 AM
Exit [F4]
CPU HDSDR: NA
CPU Total: NA
Waterfall RBW 1.5 Hz Avg
Spectrum Zoom Speed



Callsigns

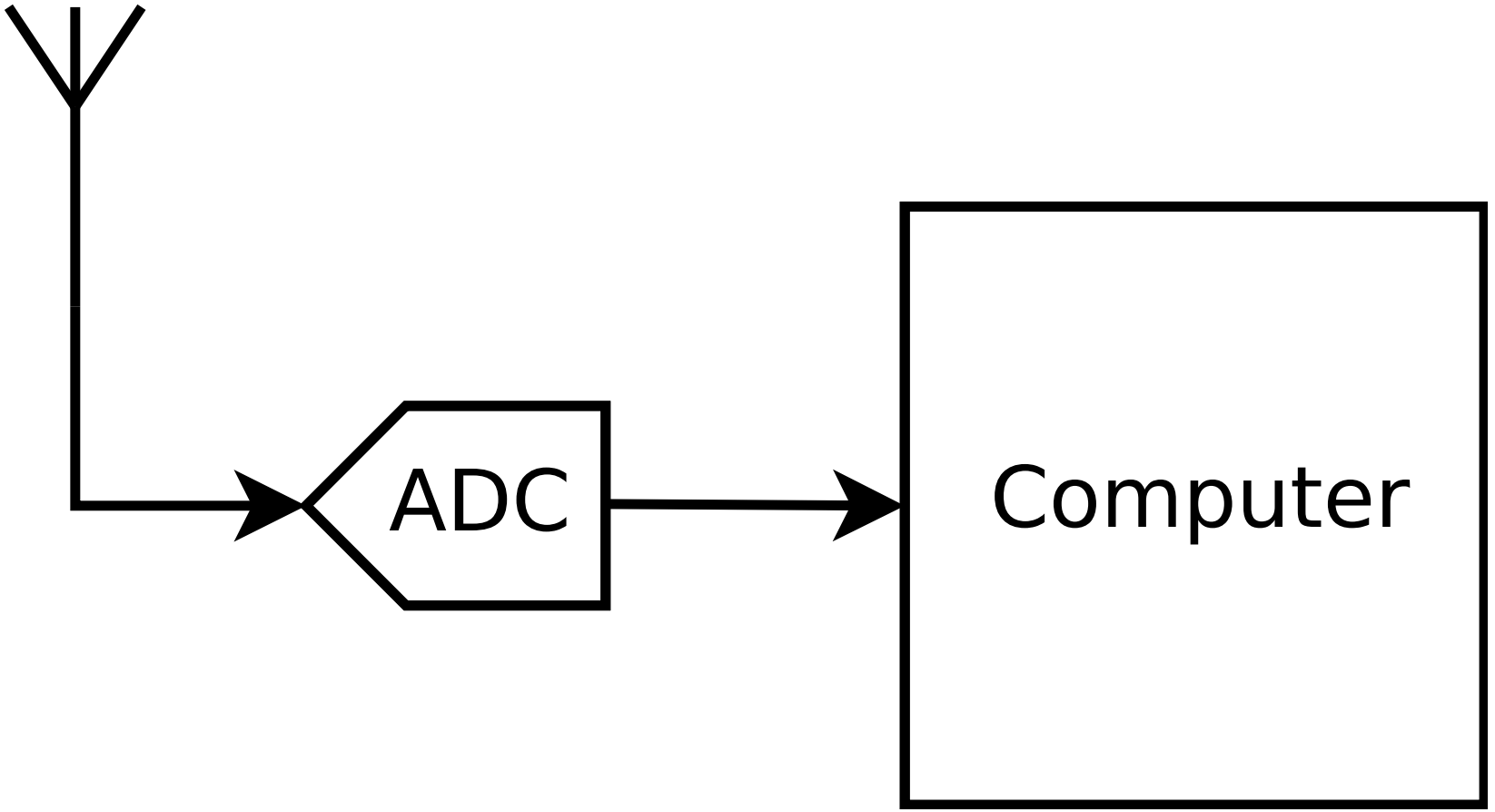
Freq	Utc	Call
14032.9	00:05:04	AA0ZP
14027.8	23:59:34	AA3B
14027.8	00:07:18	AA3K
14040.2	23:58:50	AA4CF
14031.6	00:07:12	AA5SH
14038.8	00:05:31	AB0BF
14042.6	00:05:41	AC5K
14019.9	00:02:47	AD4EB
14033.2	00:01:19	AD4J
14031.2	23:59:17	AE5T
14024.5	00:06:11	AF4OX
14031.3	00:06:44	AJ7G
14029.0	00:01:09	AL9A
14006.9	23:59:28	AN5E
14048.2	23:58:35	AO2W
14059.1	00:03:04	CT1JPK
14013.5	00:07:21	DD1A
14035.8	00:04:26	DD2ML
14008.6	00:01:47	DF1MM
14021.4	00:08:14	DF7ZS
14029.5	00:06:24	DF9ZP
14029.5	23:59:47	DF9ZW
14013.5	23:59:53	DJ1YFK
14008.0	00:01:28	DK9PY
14028.3	23:59:14	DL0GL
14013.5	00:04:54	DL1A
14021.4	00:05:36	DL5L
14044.0	00:00:01	DL5MAE
14027.1	00:01:47	DL5YYM
14026.5	23:58:35	DL7ON
14003.6	00:07:14	DL8DWW
14026.1	00:00:33	DL9EE
14012.1	23:58:56	DM3ZF
14041.5	00:01:22	DM6V
14054.2	00:00:52	DP6A
14029.0	23:58:37	DR0W
14162.1	00:04:59	EE5E
14073.5	00:08:16	EE5I
14023.0	00:00:33	EI3KG
14045.1	00:00:50	ES5RR
14014.0	00:08:09	F8DGY
14025.9	00:04:18	FM5CD
14002.9	00:07:43	G3UFY
14046.1	00:04:33	G4LMW
14022.5	23:59:34	HA8JV
14023.7	23:58:59	HC2AO

Calls: 217

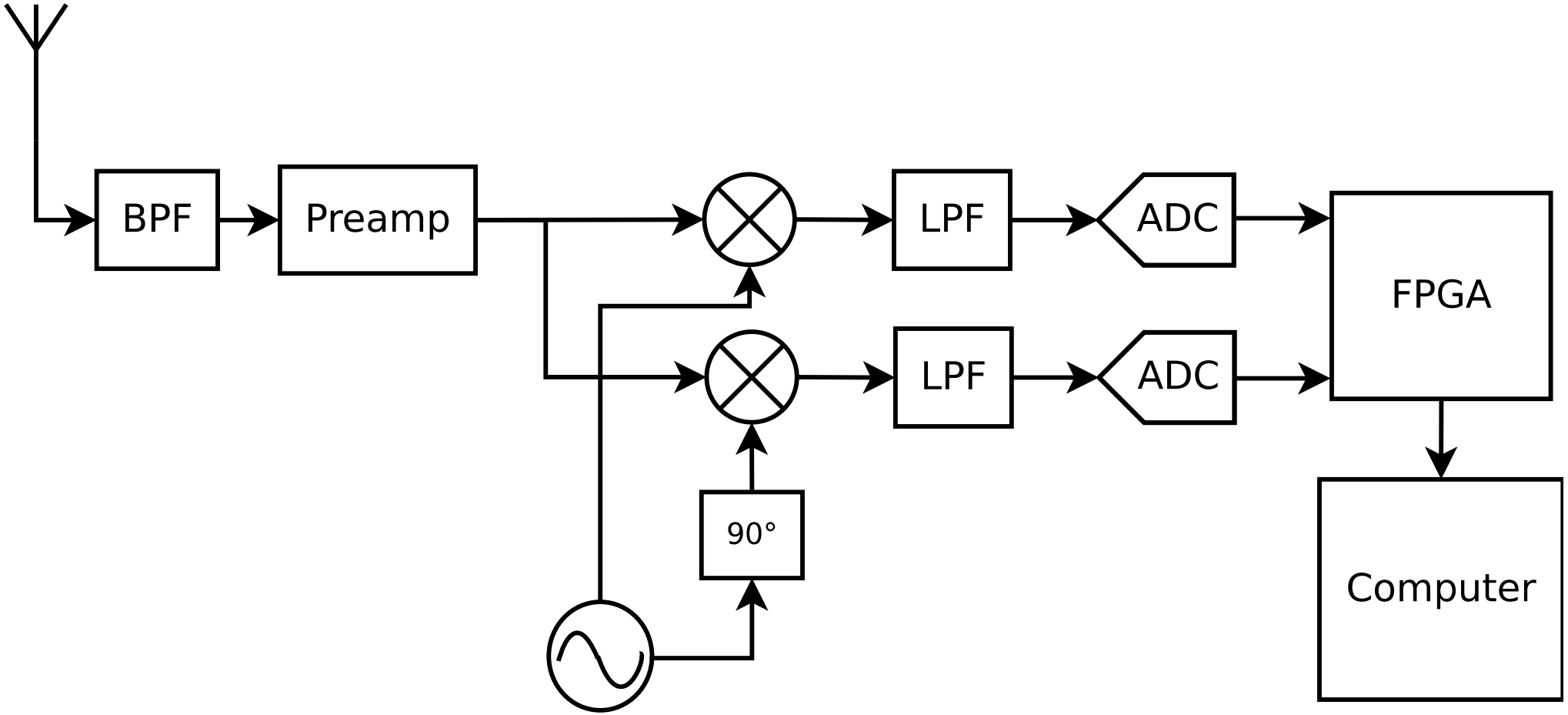

arth
(0:36)
File Edit View Tools Add Help
Search
Fly To
Find Businesses
Directions
Fly to e.g., Reservoir Rd. Clayville, NY
Places
My Places
Sightseeing Tour
Make sure 3D Buildings layer is checked
Temporary Places
Untitled Network Link
Range rings
Aircraft locations
ACA895
Altitude: 38000
Heading: 253
ACA891
Altitude: 38000
Heading: 252
ACA839
Altitude: 3400
Heading: 306
Layers
Earth Gallery
Primary Database
Borders and Labels
Borders
International Borders
Country Names
Coastlines
1st Level Admin Borders ...
1st Level Admin Names (...
2nd Level Admin Regions...
Labels
Populated Places
Islands
Geographic Features
Water Bodies
Places
Photos
Roads
3D Buildings
Ocean
Weather
ACA891
SWR834
ACA839
Kanata
Aylmer
Nepean
Ottawa
Gatineau
Metcalfe
Navan
Kennmore
Sarsfield
Vars
Russell
© 2012 Cnes/Spot Image
© 2012 Google
Image © 2012 DigitalGlobe
Image © 2012 TerraMetrics
Imagery Date: 9/2008
45°23'28.99" N 75°33'56.19" W elev 72 m

SDR ARCHITECTURE

“Ideal” SDR Receiver



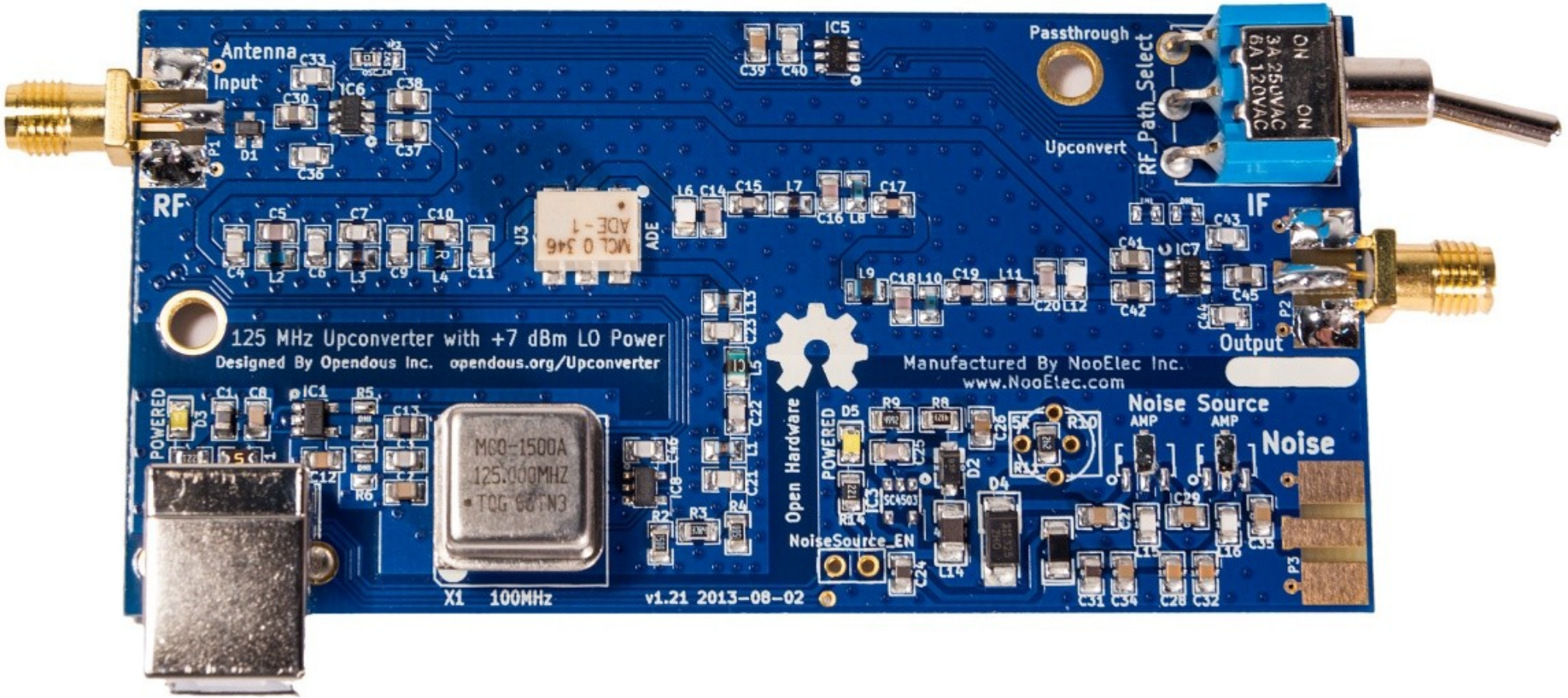
Practical SDR Receiver



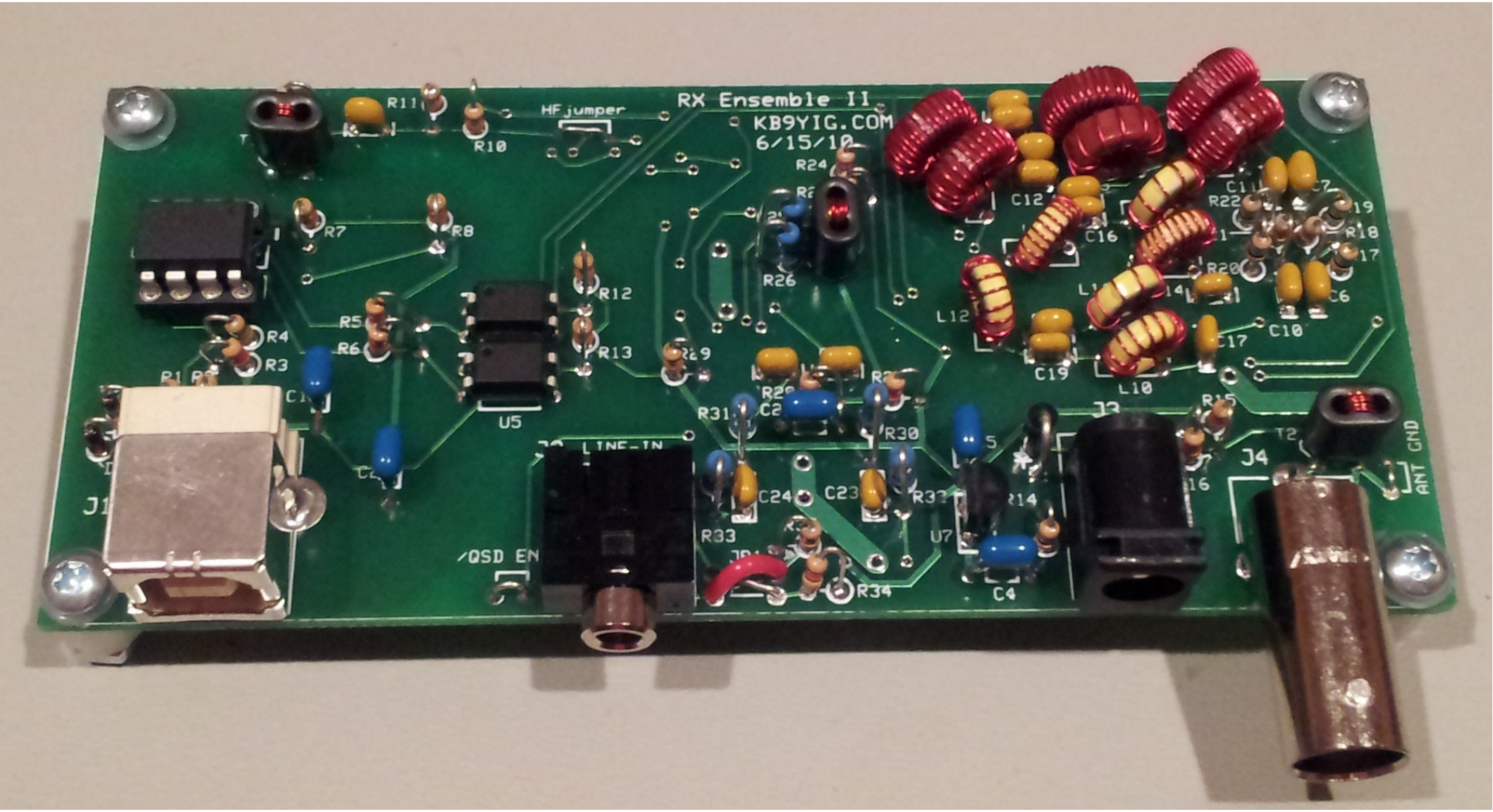
HARDWARE

RTL-SDR

Ham It Up


Antenna
Input
RF
IF
Passthrough
Upconvert
RF_Path_Select
ON
3A 250VAC
6A 120VAC
Output
125 MHz Upconverter with +7 dBm LO Power
Designed By Opendous Inc. opendous.org/Upconverter
Manufactured By NooElec Inc.
www.NooElec.com
Noise Source
AMP
AMP
Noise
Open Hardware
POWERED
NoiseSource_EN
MCQ-1500A
125.000MHZ
X1 100MHz
v1.21 2013-08-02

SoftRock / Peaberry

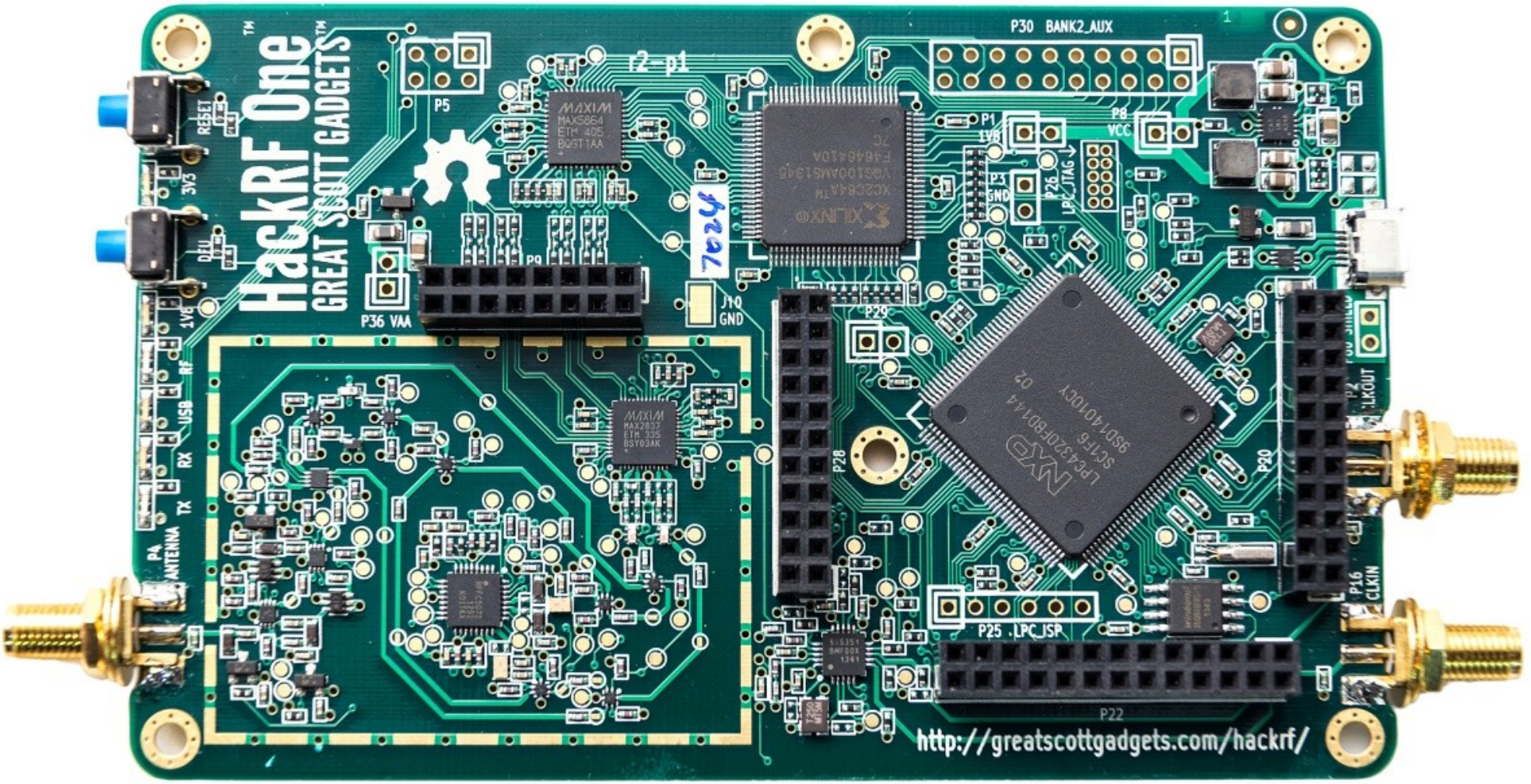


Funcube Dongle Pro+

HackRF

RESET
3V3
DFU
1V8
RF
USB
RX
TX
ANTENNA
HackRF One™
GREAT SCOTT GADGETS™
CLKOUT
CLKIN

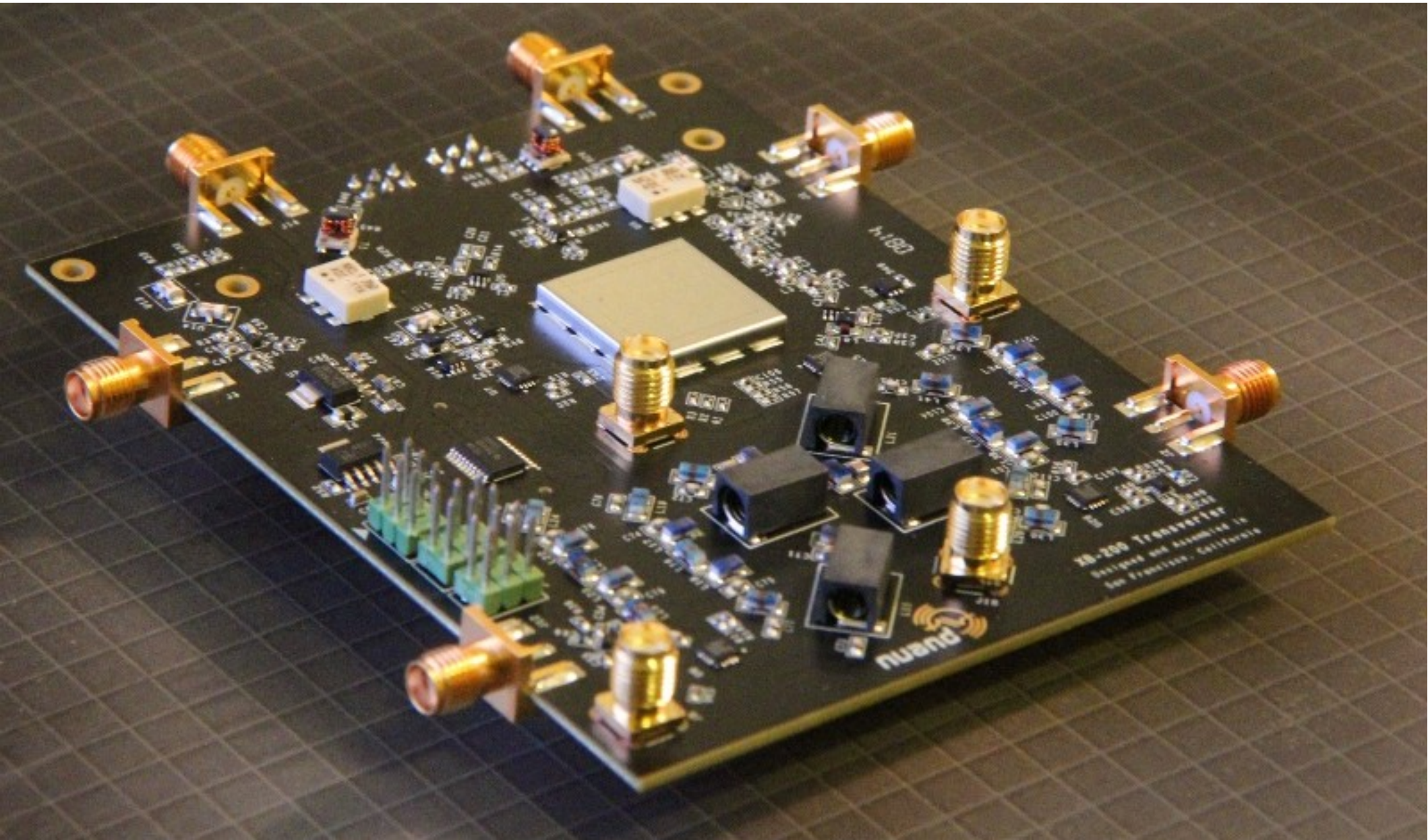
HackRF


HackRF One
GREAT SCOTT GADGETS
P30 BANK2_AUX
P5
P36 VAA
P25 LPC_ISP
P22
http://greatscottgadgets.com/hackrf/

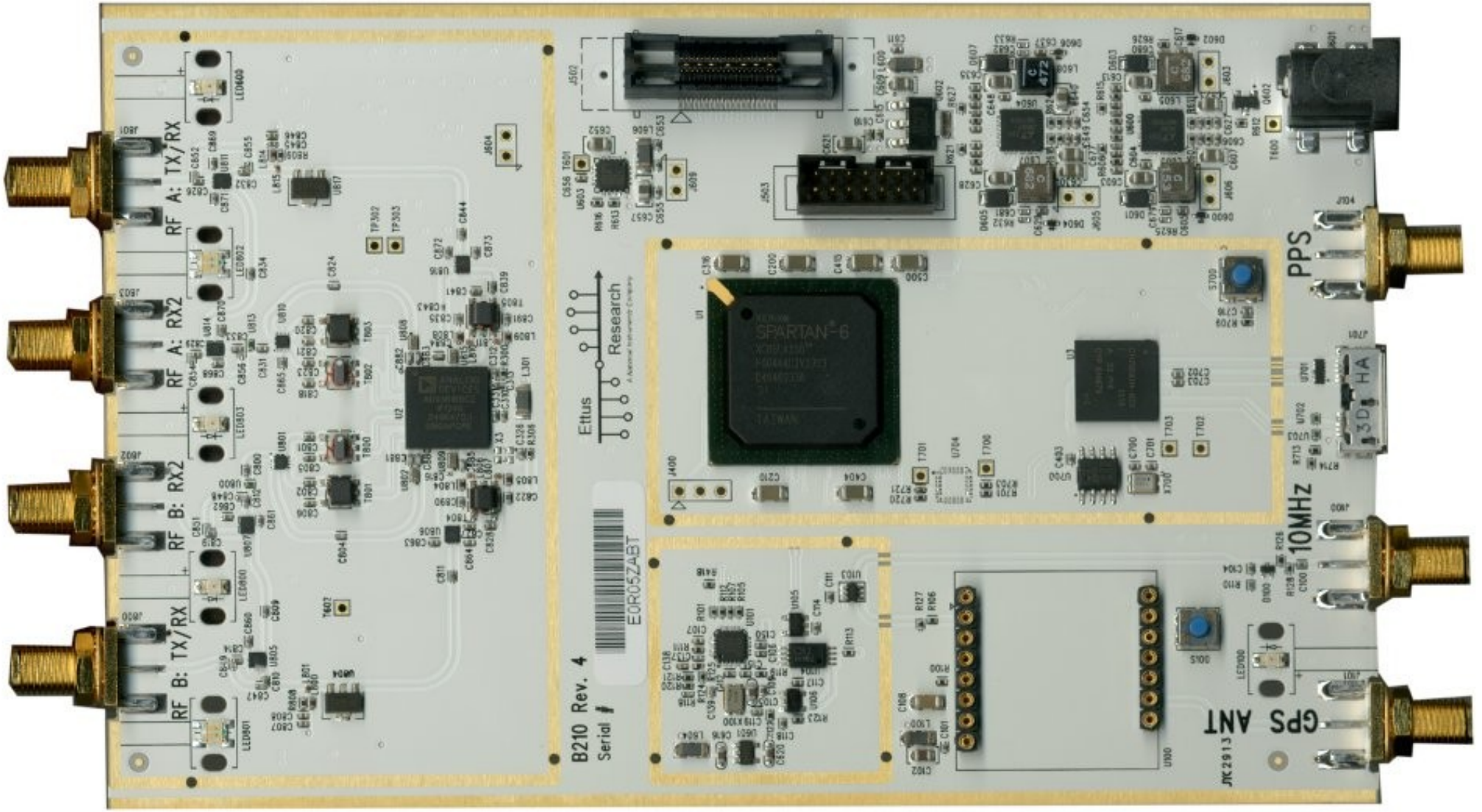
WSPR with HackRF

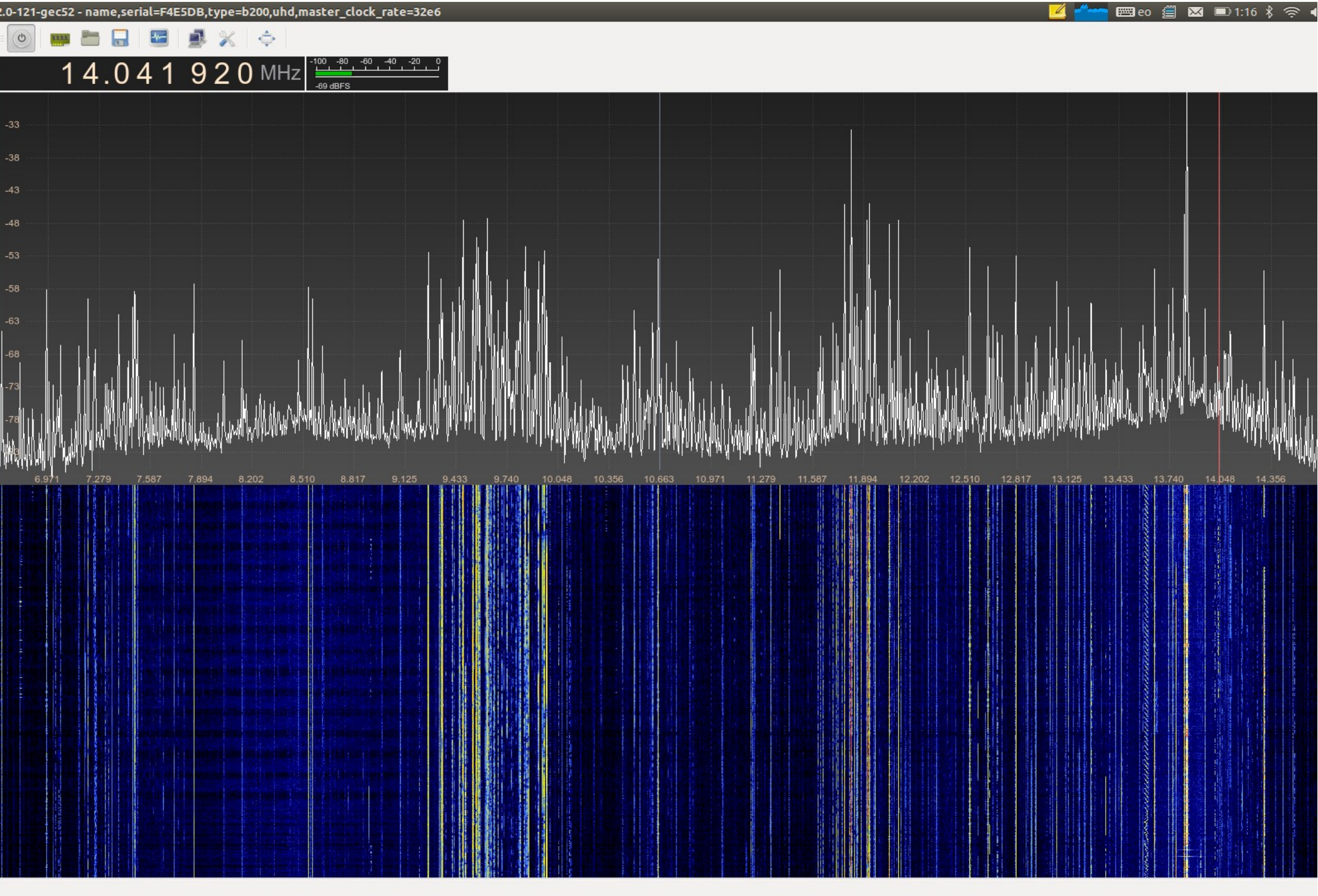
Nuand BladeRF

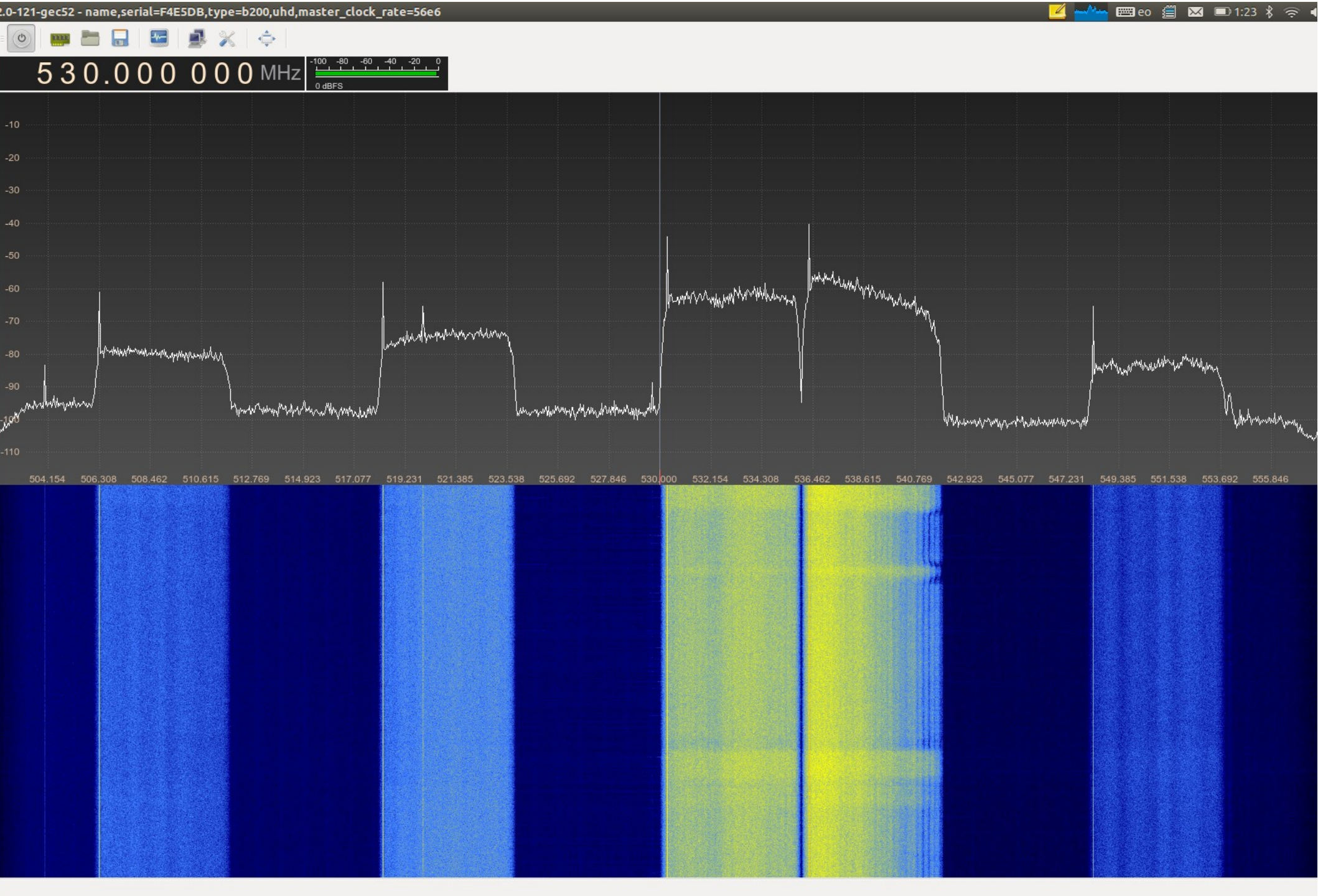
VHF/HF/MF/LF transverter for BladeRF

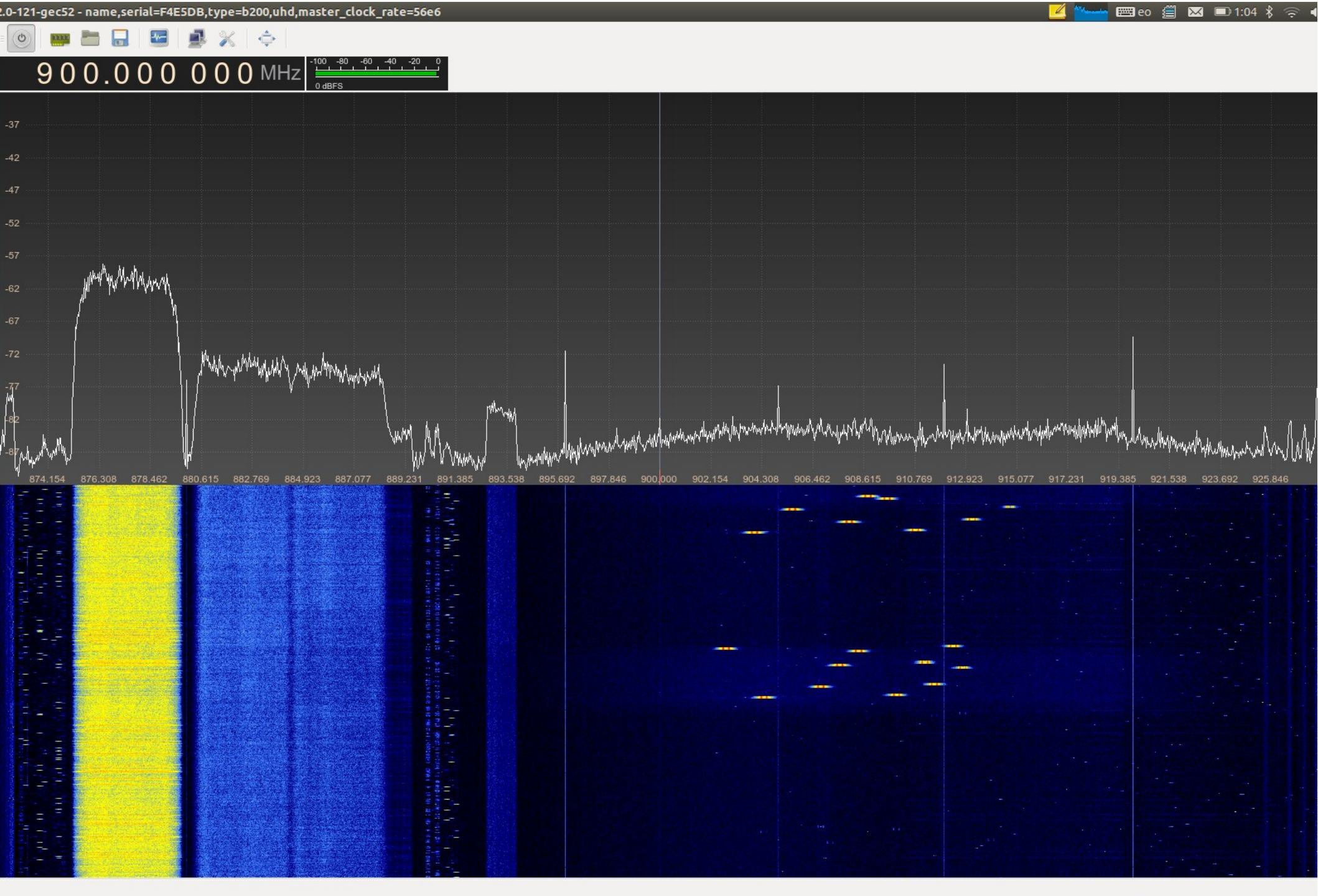


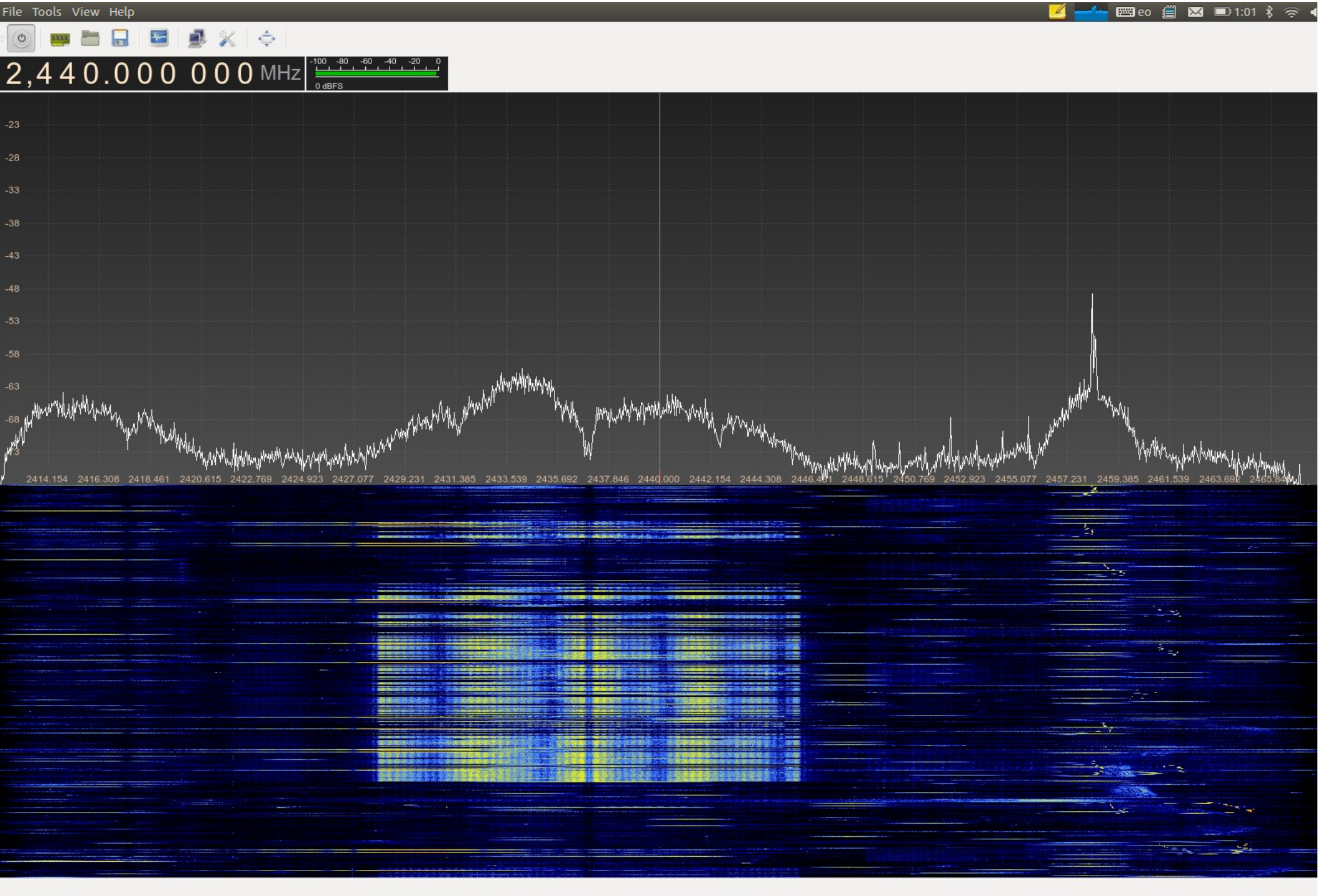
Ettus Research USRP B200/B210

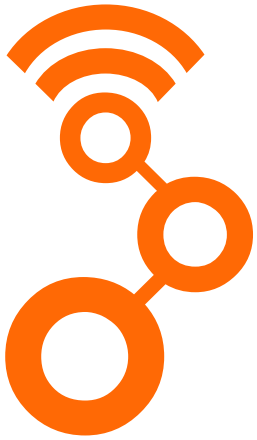



2.0-121-gec52 - name,serial=F4E5DB,type=b200,uhd,master_clock_rate=32e6
1:16
14.041 920 MHz
-100 -80 -60 -40 -20 0
-69 dBFS
-33
-38
-43
-48
-53
-58
-63
-68
-73
-78
6.971 7.279 7.587 7.894 8.202 8.510 8.817 9.125 9.433 9.740 10.048 10.356 10.663 10.971 11.279 11.587 11.894 12.202 12.510 12.817 13.125 13.433 13.740 14.048 14.356


2.0-121-gec52 - name,serial=F4E5DB,type=b200,uhd,master_clock_rate=56e6
1:23
530.000 000 MHz
-100 -80 -60 -40 -20 0
0 dBFS
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
504.154 506.308 508.462 510.615 512.769 514.923 517.077 519.231 521.385 523.538 525.692 527.846 530.000 532.154 534.308 536.462 538.615 540.769 542.923 545.077 547.231 549.385 551.538 553.692 555.846


2.0-121-gec52 - name,serial=F4E5DB,type=b200,uhd,master_clock_rate=56e6
1:04
900.000 000 MHz
-100 -80 -60 -40 -20 0
0 dBFS
-37
-42
-47
-52
-57
-62
-67
-72
874.154 876.308 878.462 880.615 882.769 884.923 887.077 889.231 891.385 893.538 895.692 897.846 900.000 902.154 904.308 906.462 908.615 910.769 912.923 915.077 917.231 919.385 921.538 923.692 925.846


File Tools View Help
eo
1:01
2,440.000 000 MHz
-100 -80 -60 -40 -20 0
0 dBFS
-23
-28
-33
-38
-43
-48
-53
-58
-63
-68
2414.154 2416.308 2418.461 2420.615 2422.769 2424.923 2427.077 2429.231 2431.385 2433.539 2435.692 2437.846 2440.000 2442.154 2444.308 2446.461 2448.615 2450.769 2452.923 2455.077 2457.231 2459.385 2461.539 2463.692



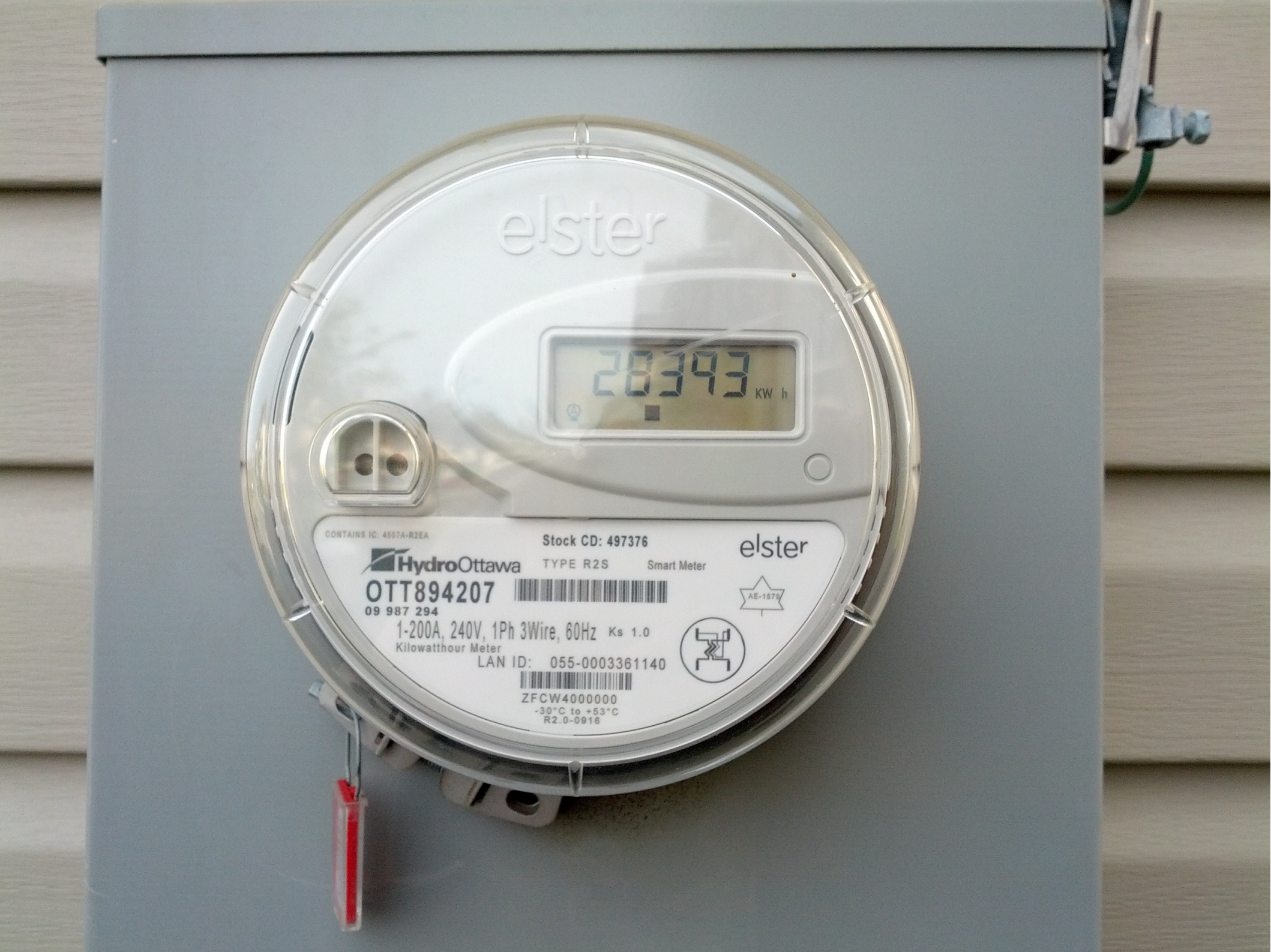
GNU Radio

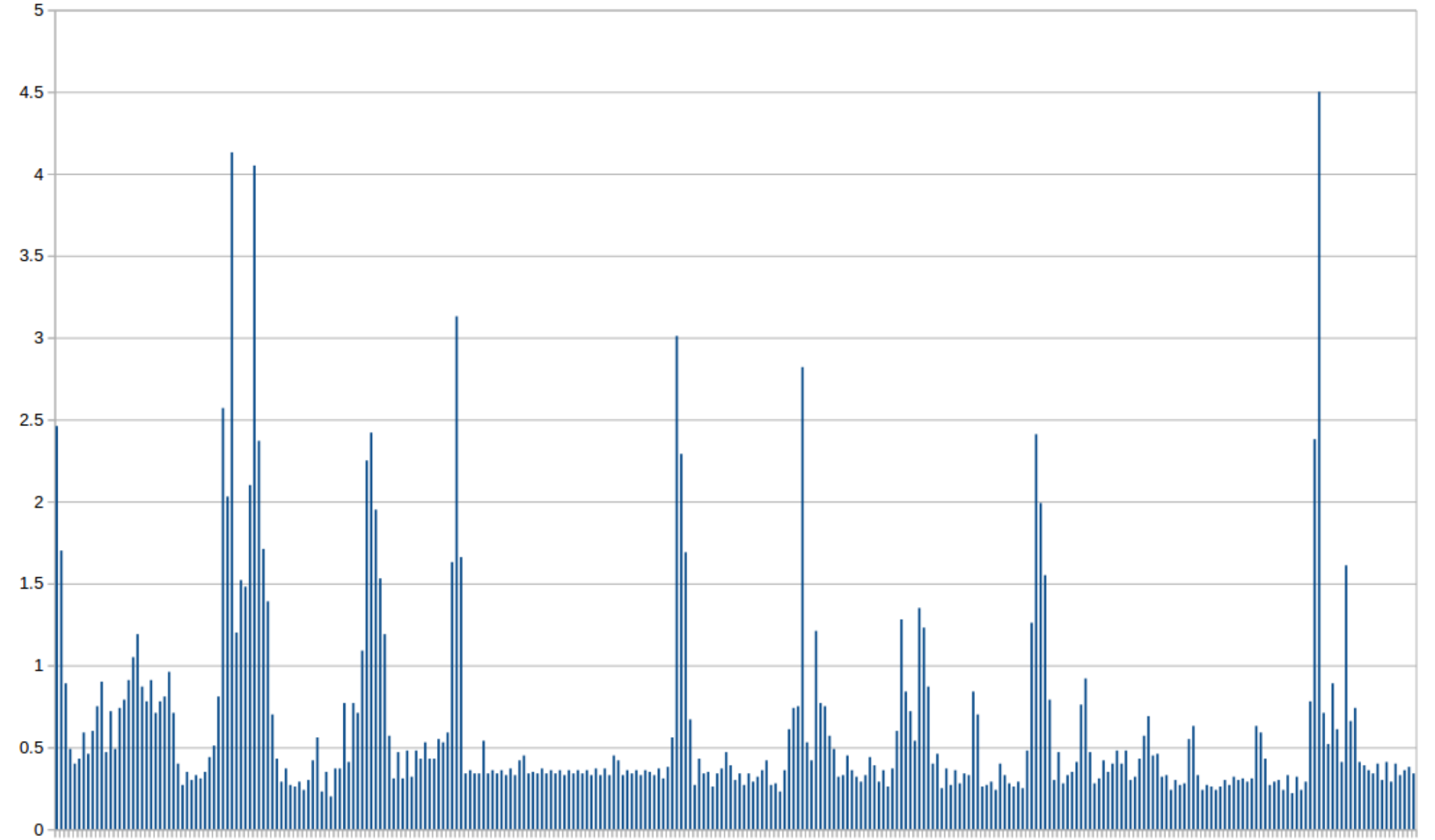
THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM

- Open Source project
- Founded in 2001
- Written in Python, C++
- Runs best under Linux
- Connect signal processing blocks to form a flow graph

DEMO

HYDRO METERS

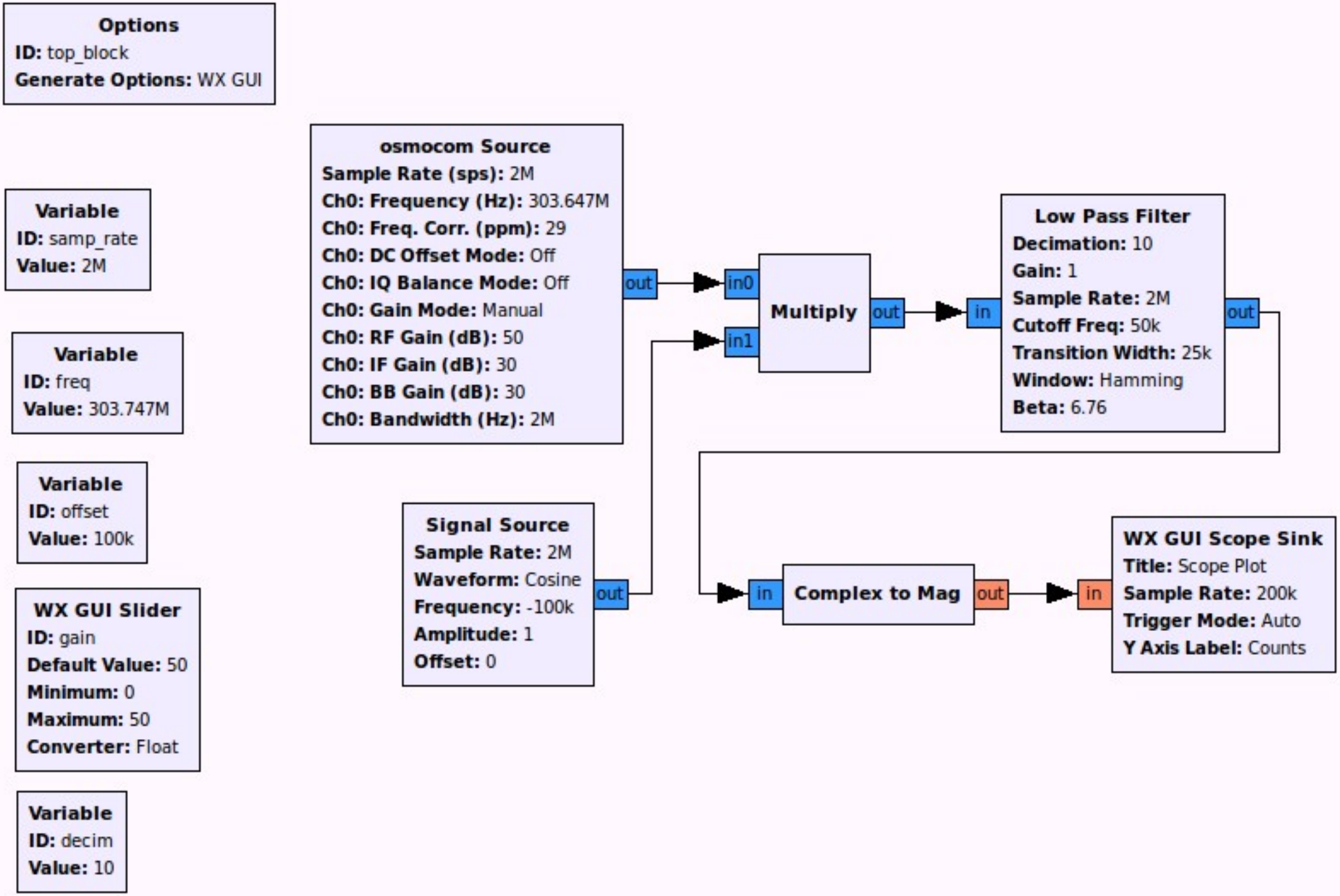

elster
28393 KW h
CONTAINS IC: 4557A-R2EA
Stock CD: 497376
elster
HydroOttawa
TYPE R2S
Smart Meter
OTT894207
09 987 294
AE-1579
1-200A, 240V, 1Ph 3Wire, 60Hz Ks 1.0
Kilowatthour Meter
LAN ID: 055-0003361140
ZFCW4000000
-30°C to +53°C
R2.0-0918

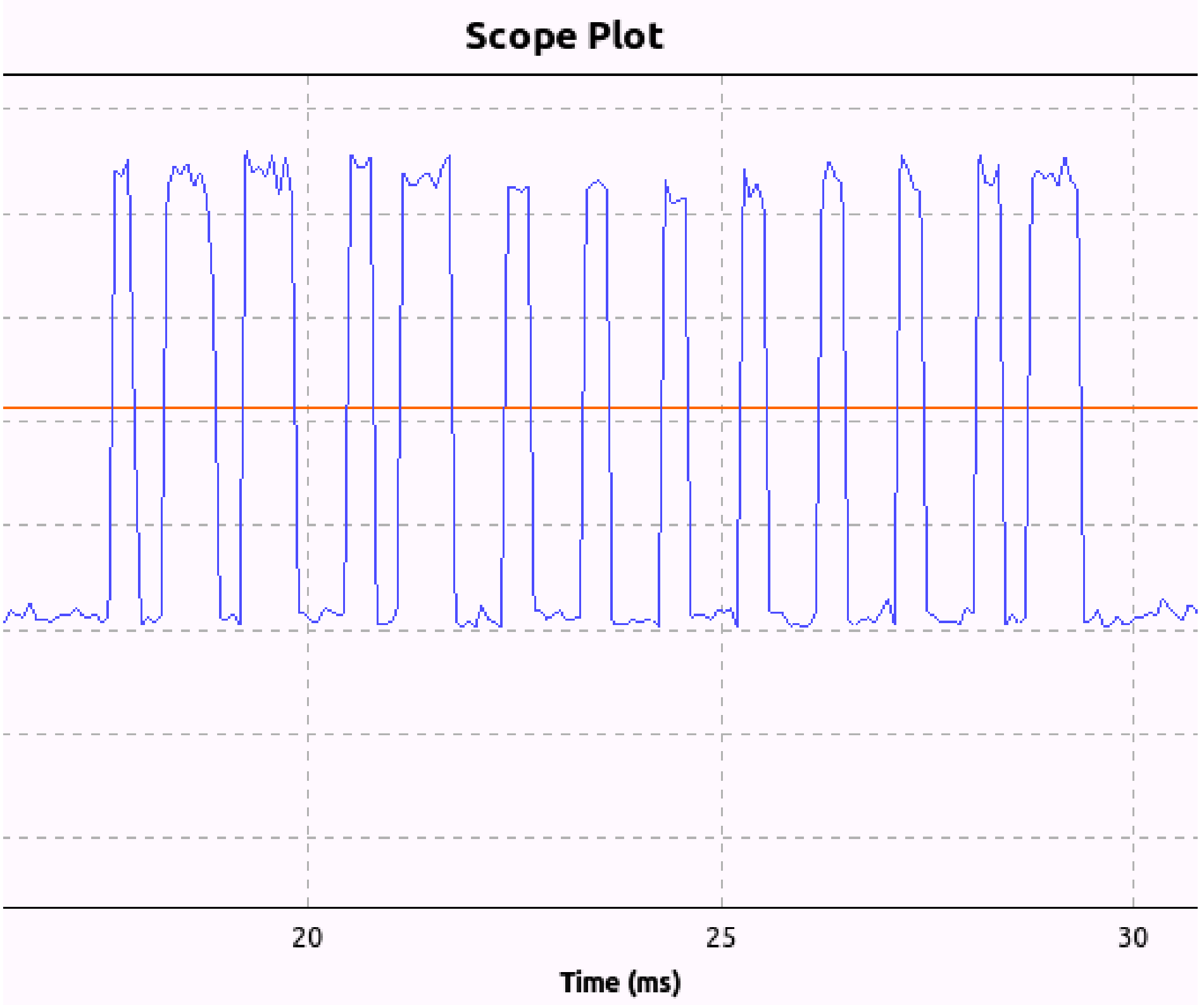

5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

000921f5
00092471
001e76bb
0008ce97
000923ed
003349a3
0008ced1
002bdd3f
000dfa6b
804d8024
0008ced2
00023b63
006ea1bc
00092428
0003f219
00334972
0003f21c
00092412
003349b7
00091e25
00150129
002bd76f
0033575e
0008ced3
0009241f
000bfc6e
002dc512
0080c424
0008cc4b
000923e0
00211aca
00232ae5
00208fda
0042248f

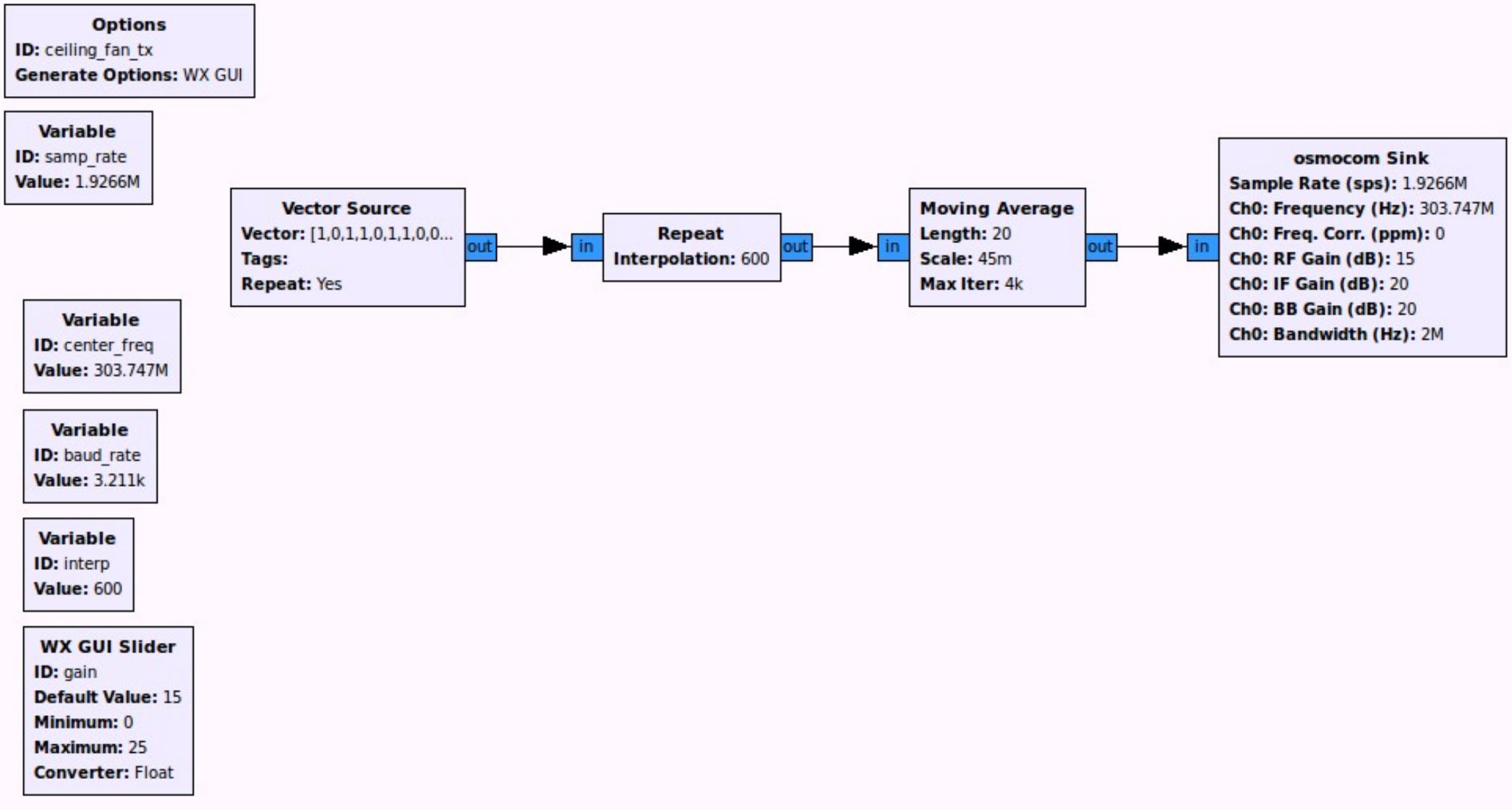
CEILING FAN

EAST WALL PLUG
HI
LIGHT
MED
LOW
FAN OFF
OFF
ON


Options
ID: top_block
Generate Options: WX GUI
Variable
ID: samp_rate
Value: 2M
Variable
ID: freq
Value: 303.747M
Variable
ID: offset
Value: 100k
WX GUI Slider
ID: gain
Default Value: 50
Minimum: 0
Maximum: 50
Converter: Float
Variable
ID: decim
Value: 10
osmocom Source
Sample Rate (sps): 2M
Ch0: Frequency (Hz): 303.647M
Ch0: Freq. Corr. (ppm): 29
Ch0: DC Offset Mode: Off
Ch0: IQ Balance Mode: Off
Ch0: Gain Mode: Manual
Ch0: RF Gain (dB): 50
Ch0: IF Gain (dB): 30
Ch0: BB Gain (dB): 30
Ch0: Bandwidth (Hz): 2M
out
in0
in1
Multiply
out
in
Low Pass Filter
Decimation: 10
Gain: 1
Sample Rate: 2M
Cutoff Freq: 50k
Transition Width: 25k
Window: Hamming
Beta: 6.76
out
Signal Source
Sample Rate: 2M
Waveform: Cosine
Frequency: -100k
Amplitude: 1
Offset: 0
out
in
Complex to Mag
out
in
WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 200k
Trigger Mode: Auto
Y Axis Label: Counts


Scope Plot
20
25
30
Time (ms)

```
light: 01101000000001
off:   01101000000010
low:   01101000001000
med:   01101000010000
high:  01101001000000
```


Options
ID: ceiling_fan_tx
Generate Options: WX GUI
Variable
ID: samp_rate
Value: 1.9266M
Vector Source
Vector: [1,0,1,1,0,1,1,0,0...
Tags:
Repeat: Yes
out
in
Repeat
Interpolation: 600
out
in
Moving Average
Length: 20
Scale: 45m
Max Iter: 4k
out
in
osmocom Sink
Sample Rate (sps): 1.9266M
Ch0: Frequency (Hz): 303.747M
Ch0: Freq. Corr. (ppm): 0
Ch0: RF Gain (dB): 15
Ch0: IF Gain (dB): 20
Ch0: BB Gain (dB): 20
Ch0: Bandwidth (Hz): 2M
Variable
ID: center_freq
Value: 303.747M
Variable
ID: baud_rate
Value: 3.211k
Variable
ID: interp
Value: 600
WX GUI Slider
ID: gain
Default Value: 15
Minimum: 0
Maximum: 25
Converter: Float

Digital TV in GNU Radio

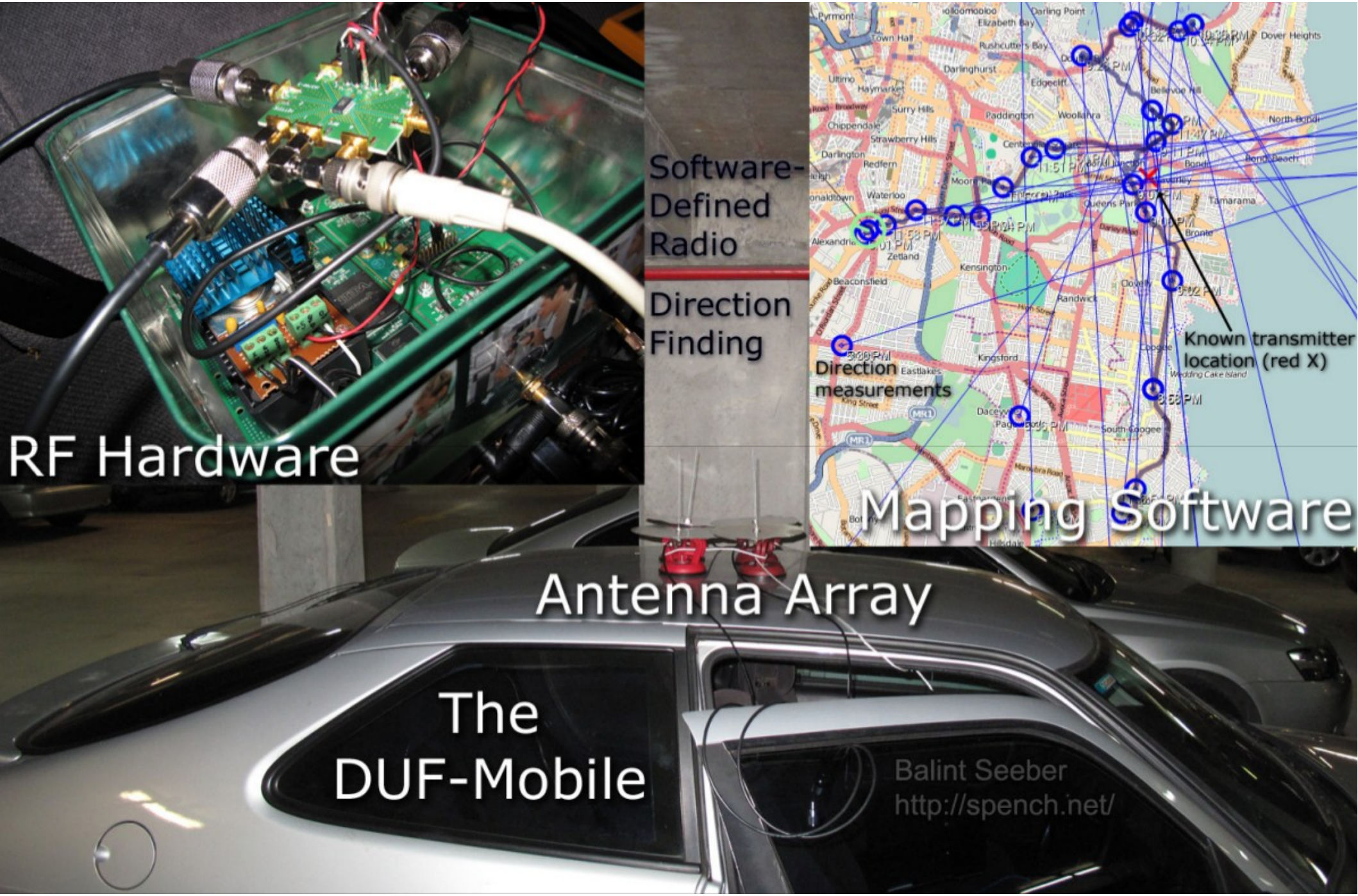
- ATSC – North America terrestrial
- QAM – North America cable
- DVB-T – Europe etc. terrestrial
- DVB-S – Satellite
- DVB-S2 – Satellite

Digital Voice in GNU Radio

- P25 Phase 1
- ProVoice EDACS digital voice
- X2-TDMA
- DMR / MOTOTRBO
- NXDN / NEXEDGE
- D-STAR

Other GNU Radio Projects

- GPS receiver
- LTE (cellular)
- ADS-B (aviation)
- AIS (marine)
- Trunked radio
- Restaurant pagers
- Tire pressure monitoring
- & many more...


RF Hardware
Software-Defined Radio
Direction Finding
Mapping Software
Known transmitter location (red X)
Direction measurements
Antenna Array
The DUF-Mobile
Balint Seeber
http://spench.net/

Resources

- Michael Ossmann's SDR tutorial series: greatscottgadgets.com/sdr
- Software Receiver Design by Johnson, Sethares & Klein
- Code and examples on my Github site: github.com/argilo
- Hardware: NooElec (nooelec.com)

Questions?