Welcome to the $20 Software Defined Radio

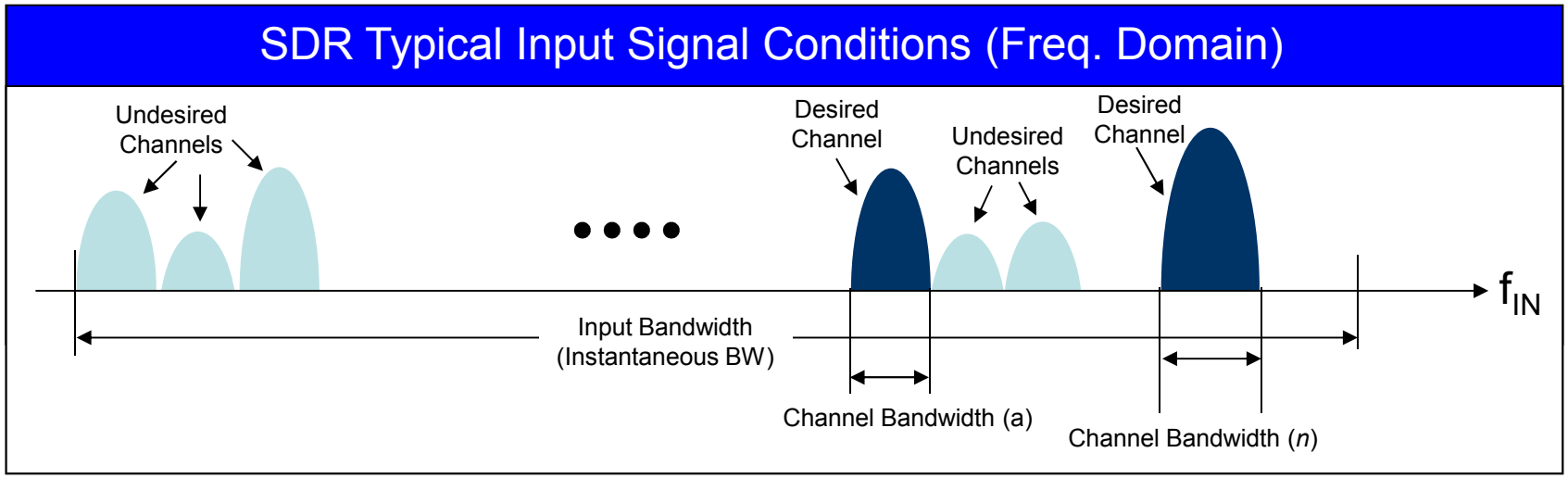
Presentation Overview

- Introduction to SDR Concepts
- SDR Block Diagram, Theory of Operation, Strengths and Weaknesses
- How to convert your $20 DVB-T Receiver into an SDR
- Available Software Options
- Installation of SDR# Sharp & Plugins
- RTL-SDR Applications Demonstration
- Q & A

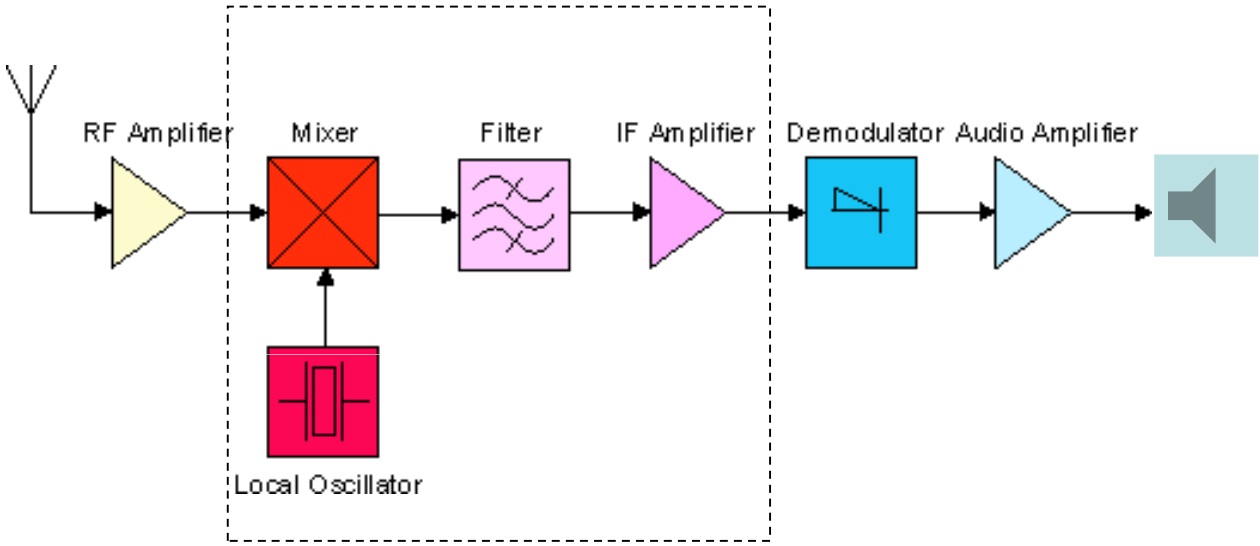
What is a Software Defined Radio ?

- ***Characteristics of Software Defined Radios:***

  - Primary stages defined in software (mixers, filters, amplifiers)
  - Analog Signals (RF) converted to Digital (I/Q)
  - Wide input bandwidth
  - Easily reconfigurable
  - Complexity shift from HW to SW



Heterodyne Receiver Block Diagram



SDR Receiver Block Diagram

Quadrature Sampling Detector (QSD)

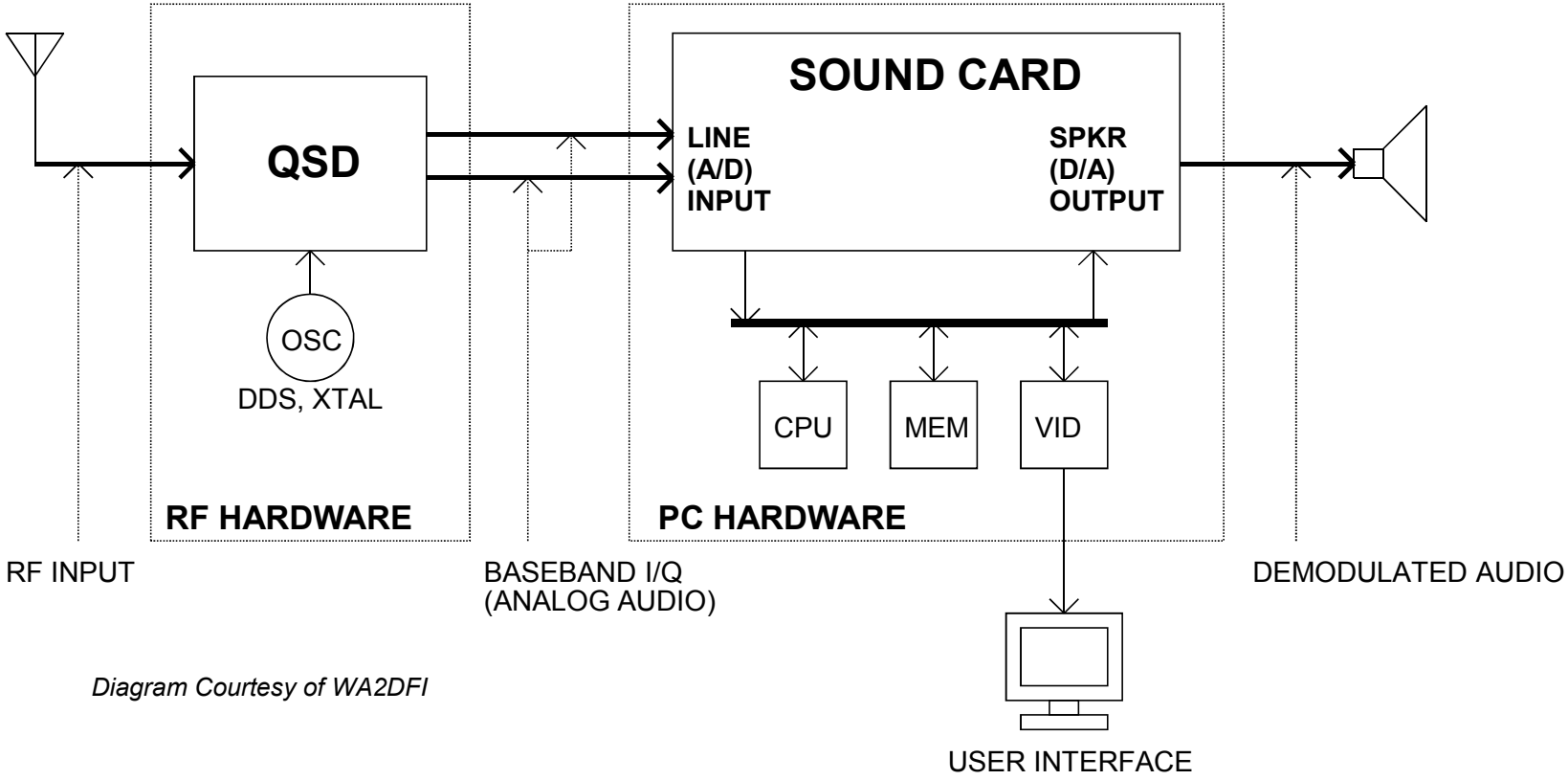
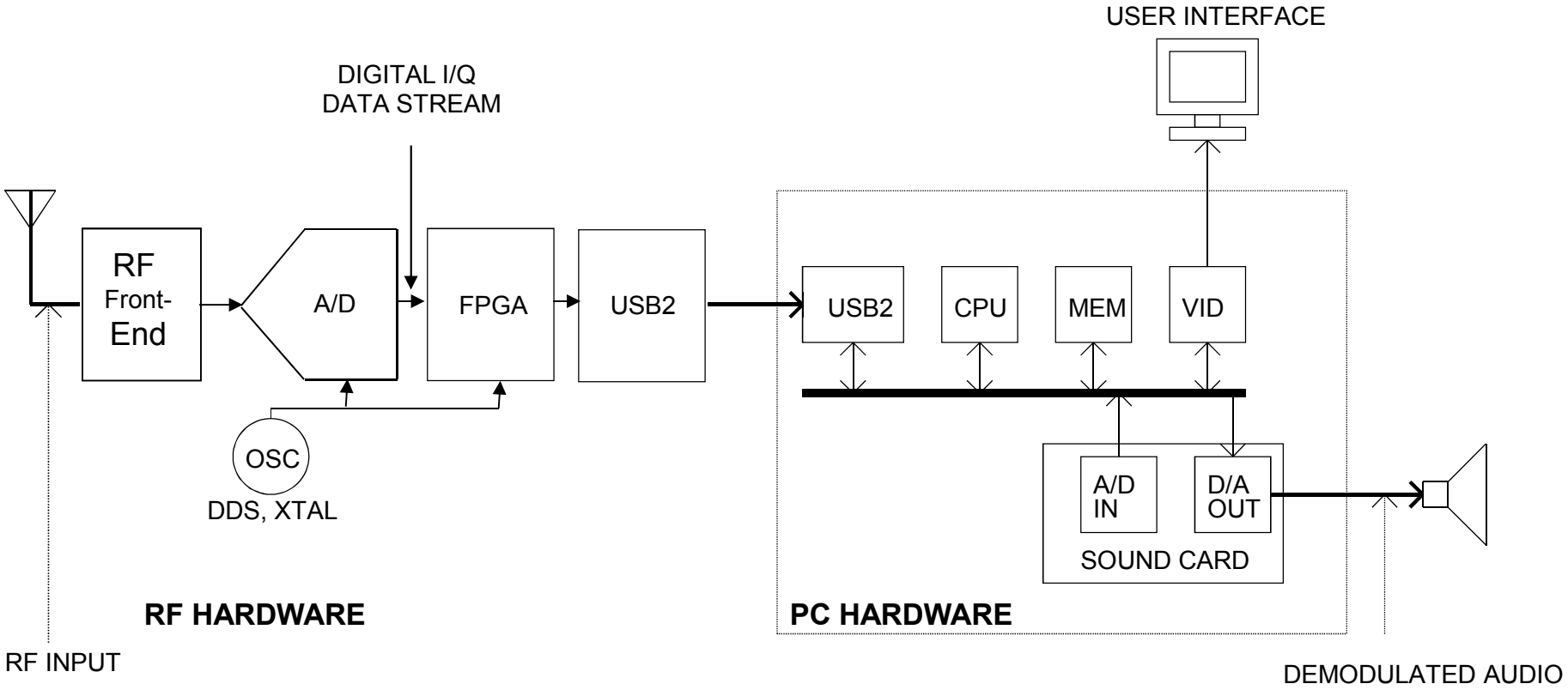


Diagram Courtesy of WA2DFI

SDR Receiver Block Diagram

Direct Sampling or Digital Down Converter (DDC)



Examples of Amateur Radio SDRs (2013)

- ELECRAFT KX3 XCVR (HF, QSD SDR, I/Q Output. ~$1450, loaded)
- AFEDRI SDR-NET RX (By 4Z5LV: HF, DDC SDR, 1.25 MHz BW, ~$250)
- RTL-SDR/DVB-T Dongle (QSD SDR, 22-2200 MHz, 2.8 MHz BW, <$20)
    - NooElec Upconverter (300kHz-50MHz+, $50)

ELECRAFT KX-3 Transceiver

Ateecs AFEDRI-SDR-Net Receiver

DVB-T Dongle/RTL-SDR

NooElec Upconverter

Software Defined Radio
Advantages & Disadvantages

- ***Key Benefits of Software Defined Radio:***
  - Flexible – “New” features/capabilities with each SW release !
  - Reprogrammable
  - Networkable
  - Enhances learning/experimentation
  - Conceptual shift from ‘Tuning’ for a station (VFO) to “Point-and-Click”

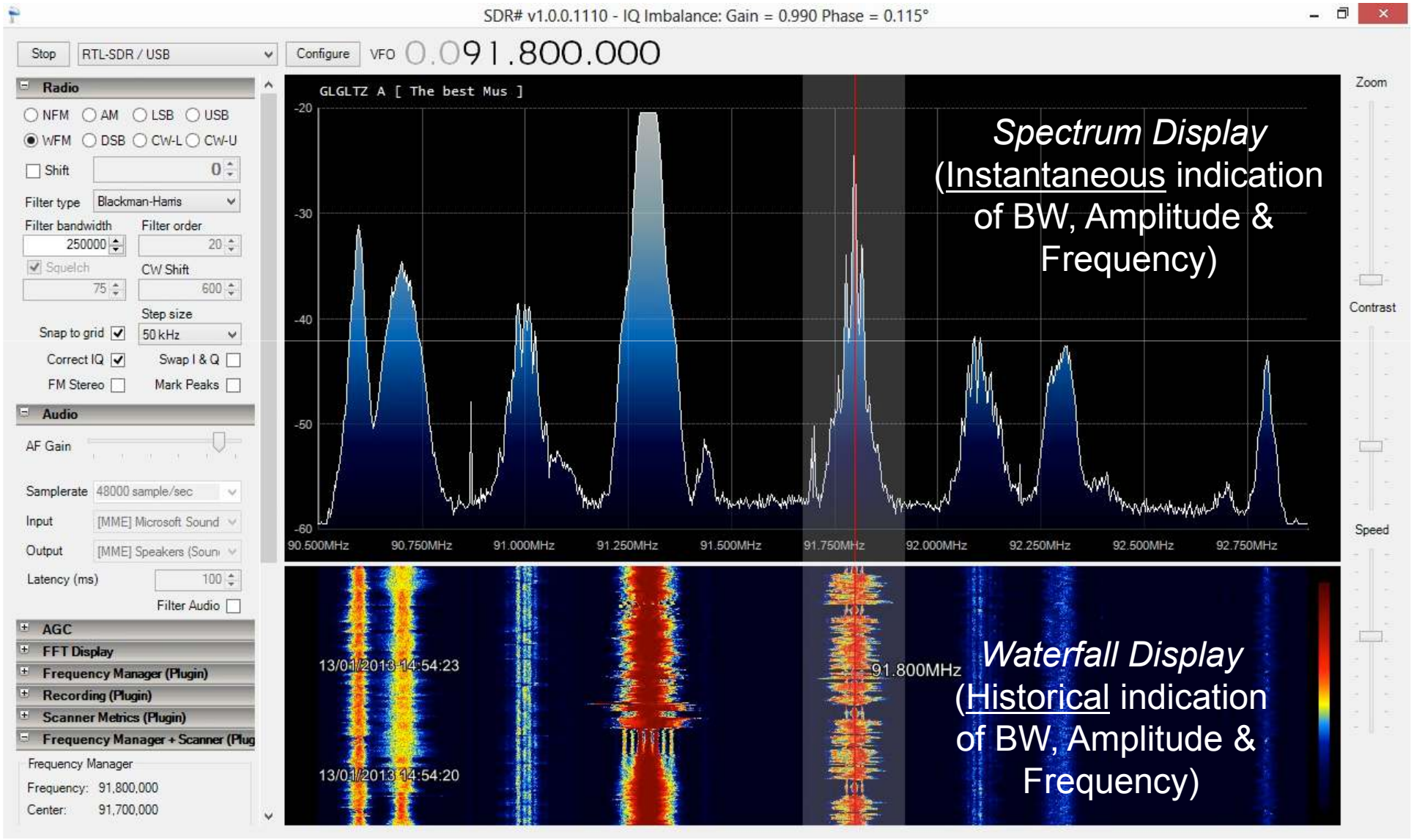
- ***SDR Disadvantages:***
  - PC required (for full GUI benefits)
  - Latency (Not recommended for full break-in CW, QSK)
  - Poor Dynamic Range/Mediocre Sensitivity earlier (e4K based) RTL-SDRs
  - Demands staying on top of developments; Constant Learning Curve

Conventional Tuning

“Seek, and Ye Shall Find” …Maybe

SDR Tuning

"Point and Click"



How It's Sold

ebay Browse by category | DVB-T R820T | Search in all | Search | Advanced

Back to home page | Listed in category: Computers/Tablets & Networking > Computer Components & Parts > Video Capture & TV Tuner Cards

Click to view larger image

New Designed FM+DAB USB DVB-T RTL2832U+R820T w/ MCX antenna Hotsale!

Like | Want | Own

Item condition: **New**

Quantity: 1 More than 10 available / 52 sold

Price: **GBP 5.51** Approximately **US $8.88** Buy It Now

Add to Watch list

Shipping: **GBP 1.00** (approx. US $1.61) Economy Int'l Postage | See details
International items may be subject to customs processing and additional charges.
Item location: **HongKong, Hong Kong**
Ships to: **Americas, Europe, Asia, Australia**

Delivery: Varies for items shipped from an international location
Seller ships within 1 day after receiving cleared payment.
Please allow additional time if international delivery is subject to customs processing.

Payments: PayPal | See details

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Registered as a Business Seller

How the Idea of an Ultra-Cheap SDR was Conceived?

From: Antti Palosaari <crope <at> iki.fi>
Subject: **SDR FM demodulation**
Newsgroups: **gmane.linux.drivers.video-input-infrastructure**
Date: 2012-02-09 15:01:12 GMT (48 weeks, 2 days, 22 hours and 16 minutes ago)
I have taken radio sniffs from FM capable Realtek DVB-T device. Looks like demodulator ADC samples IF frequency and pass all the sampled data to the application. Application is then responsible for decoding that.
Device supports DVB-T, FM and DAB. I can guess both FM and DAB are demodulated by software.

Here is 17 second, 83 MB, FM radio sniff:
http://palosaari.fi/linux/v4l-dvb/rtl2832u_fm/
Decode it and listen some Finnish speak ;)

Could someone help to decode it? I tried GNU Radio, but I failed likely because I didn't have enough knowledge... GNU Radio and Octave or Matlab are way to go.

I smell very cheap poor man's software radio here :)

regards
Antti
--
http://palosaari.fi/

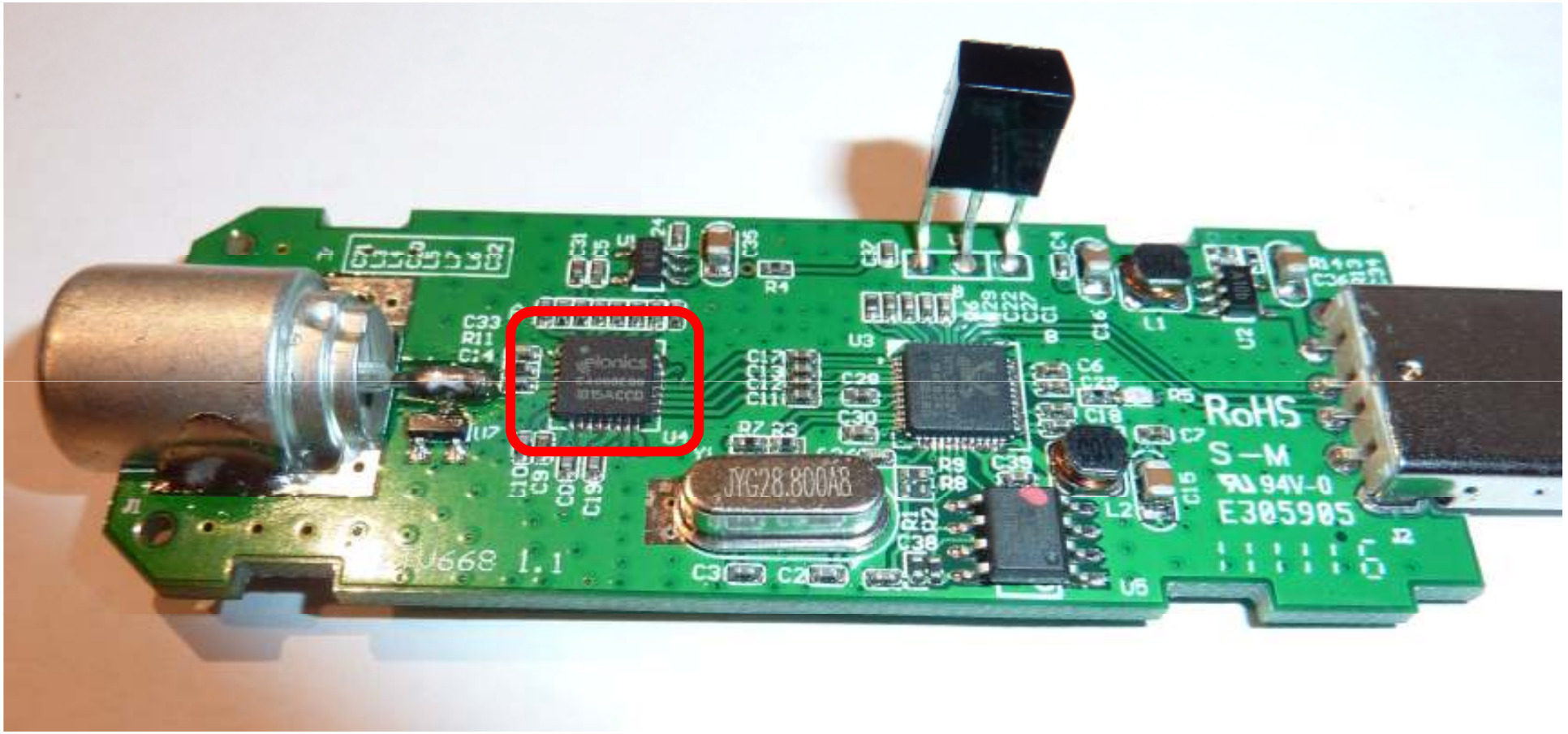
Converting Your DVB-T Dongle into and SDR

What You'll Need

- ***PC Minimum Requirements:***
  - Duo-Core Intel CPU @2.4GHz with at least 2GB RAM
  - USB 2.0

- ***DVB-T Dongle:***
  - R820T Tuner recommended
  - MCX (Male) to BNC (Female) Adapter
- ***Software:***
  - Latest ver. of Zadig
  - SDR# Sharp or HDSDR
  - rtlsdr.dll for SDR#
  - or ExtIO.dll for HDSDR
- ***Misc.:***
  - Accurate Frequency Source (For Initial Calibration)

Which Tuner?



RTL-SDR Tuner Specifications

Tuner	Frequency Range	Comments
Elonics E4000	52 - 2200 MHz with a gap from 1100 MHz to 1250 MHz (varies)	**1st version, now obsolete. Widest Freq. Range; Suffered from DC Offset 'hump', Images and Intermod from FM Broadcast band and strong pager xmtrs**
Rafael Micro R820T	24 - 1766 MHz	**Currently, most popular ver.; DC Offset 'hump' fixed; better sensitivity than e4K**
Fitipower FC0013	22 - 1100 MHz (FC0013B/C, FC0013G has a separate L-band input, which is unconnected on most sticks)	**Most sensitive on 144/430 MHz. May not be supported by all drivers/SW**
Fitipower FC0012	22 - 948.6 MHz	**May not be supported by all drivers/SW**
FCI FC2580	146 - 308 MHz and 438 - 924 MHz (gap in between)	**May not be supported by all drivers/SW. Nasty FM broadcast Intermod blocked out**

RTL-SDR Software Options

Popular UI Software (2/2013)

1.SDR# (Pronounced 'SDR Sharp') – Two versions available:

- *Development version – current is ver. 1114*
- *Autotuner (Hacked version with unique features)*

2.HDSDR

3.SDR-Radio

Loading SDR# Software [UPDATE]

http://sdrsharp.com/downloads/sdr-install.zip

1. Make sure the PC you will be installing the software on is connected to the Internet

2 . Create a Folder on your desktop called 'SDR'

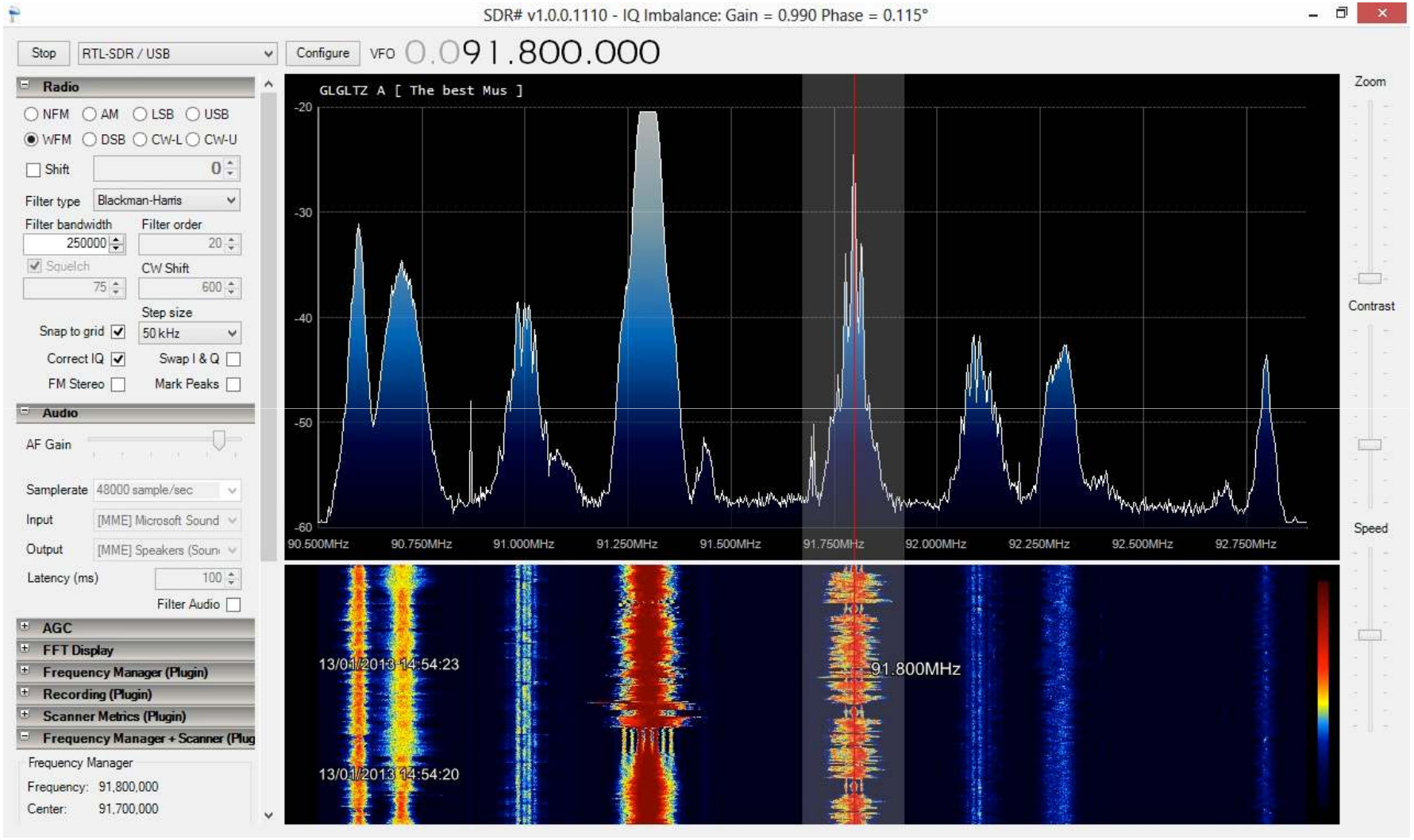
3. Download the link above and unzip to SDR folder

4. Plug the DVB-T dongle into USB port

5. Run install.bat

6. Done!

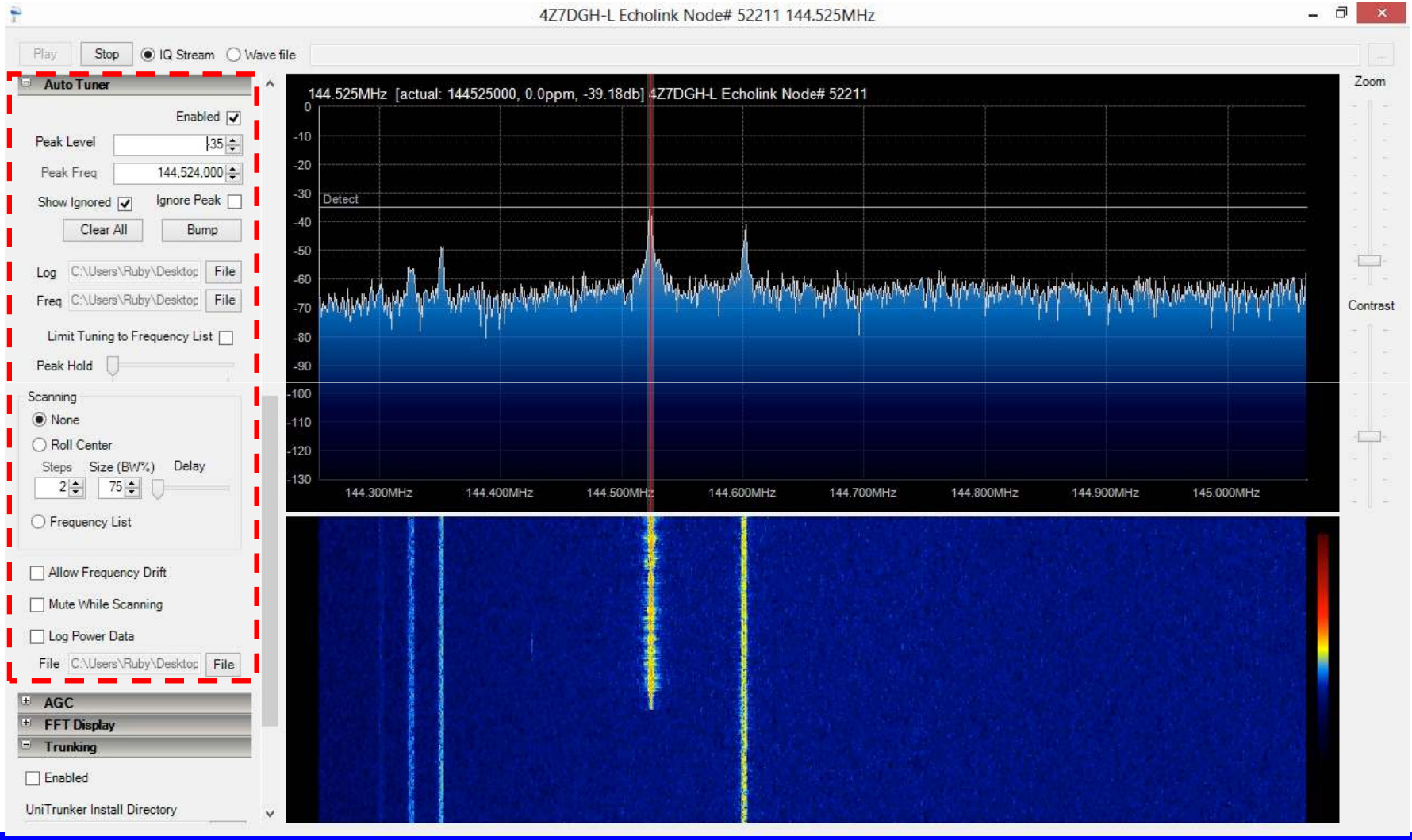
SDR# (Sharp)



Excellent DSP demod capabilities, especially for wide-band signals like WFM

SDR# (Sharp) Plugins

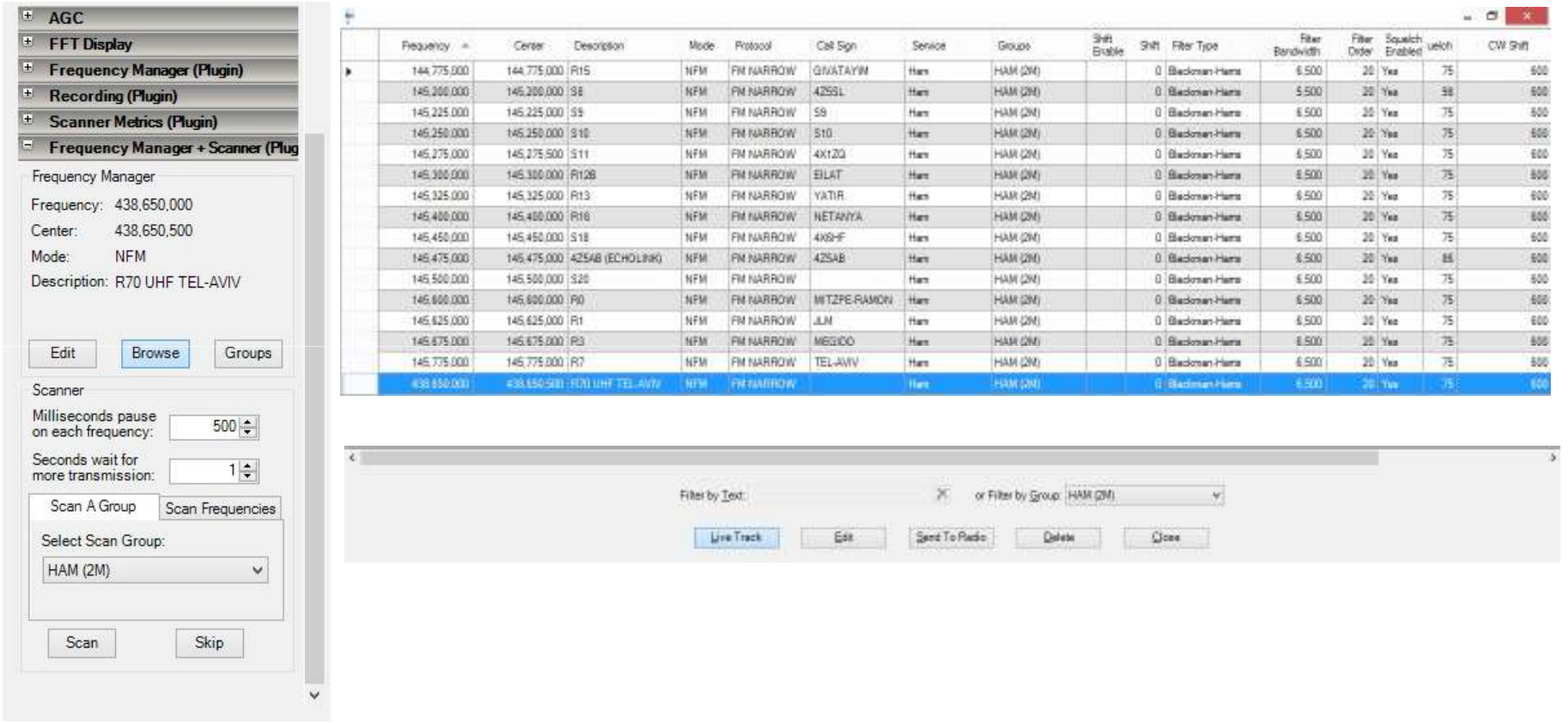
Autotuner



Autotuner can automatically search for and lock on a peak signal

SDR# (Sharp) Plugins

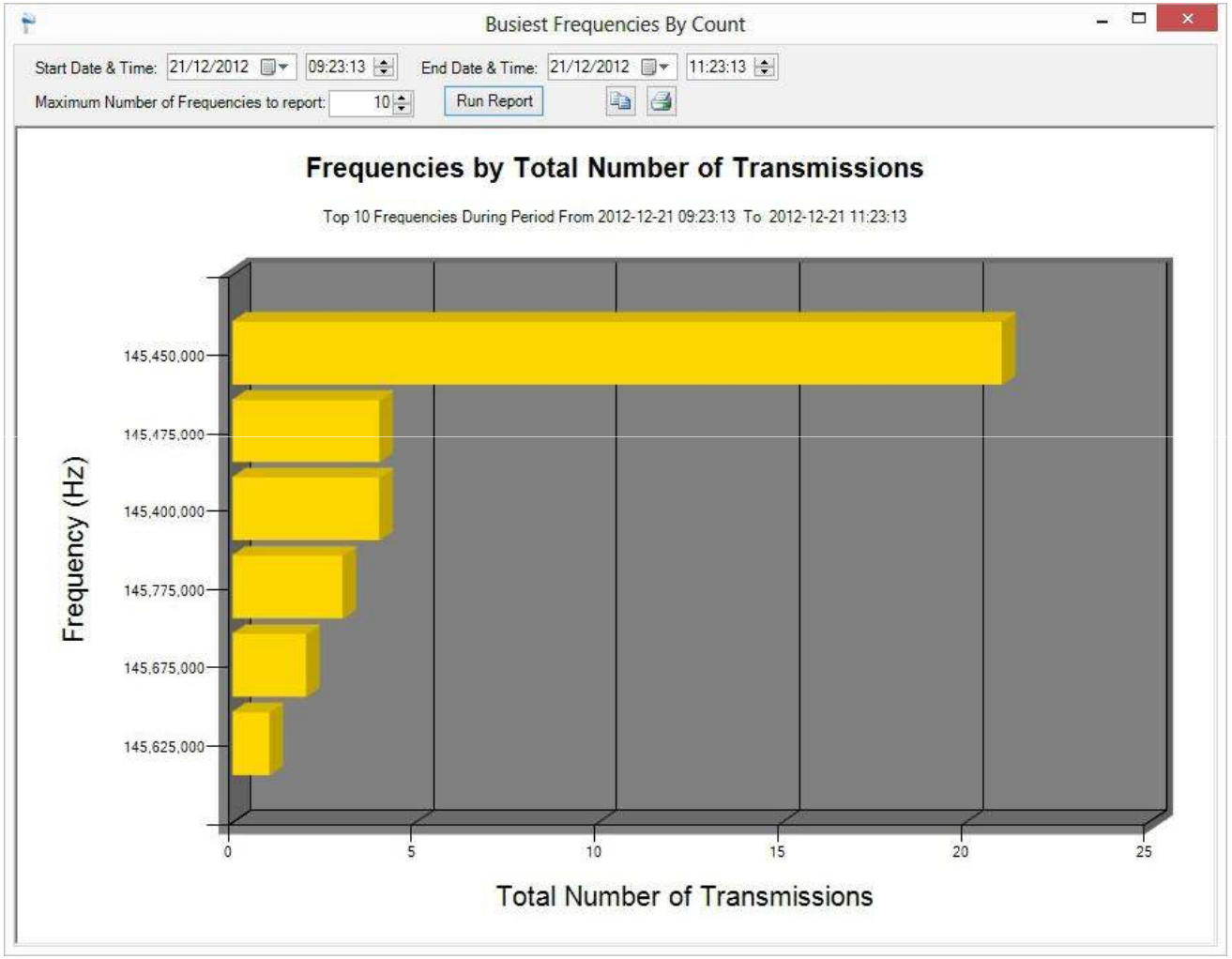
Frequency Manager



Frequency Manager's DB can be saved in Dropbox and shared dynamically between several users!

SDR# (Sharp) Plugins

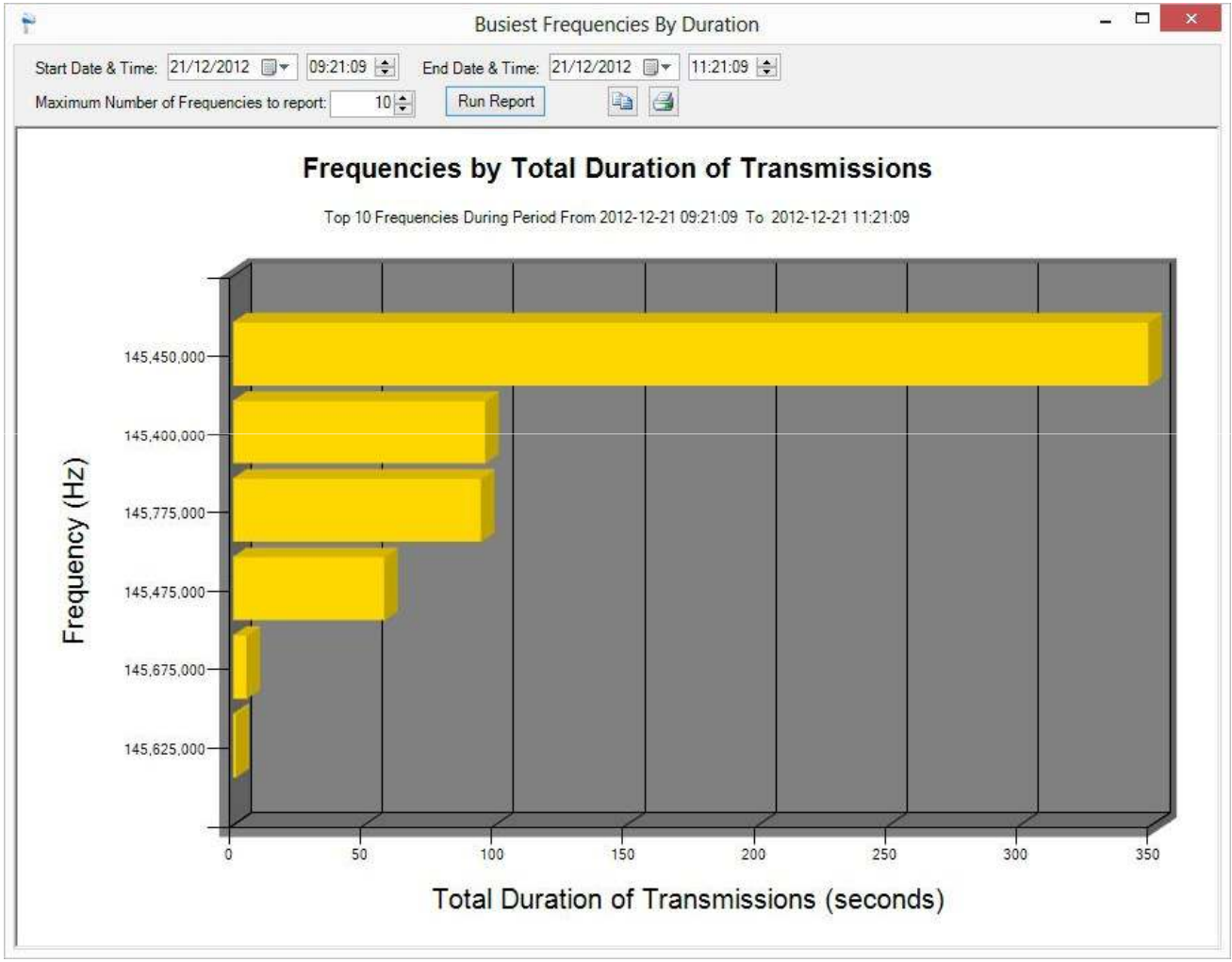
Frequency Manager Metrics



# of transmissions over two hour period/per frequency

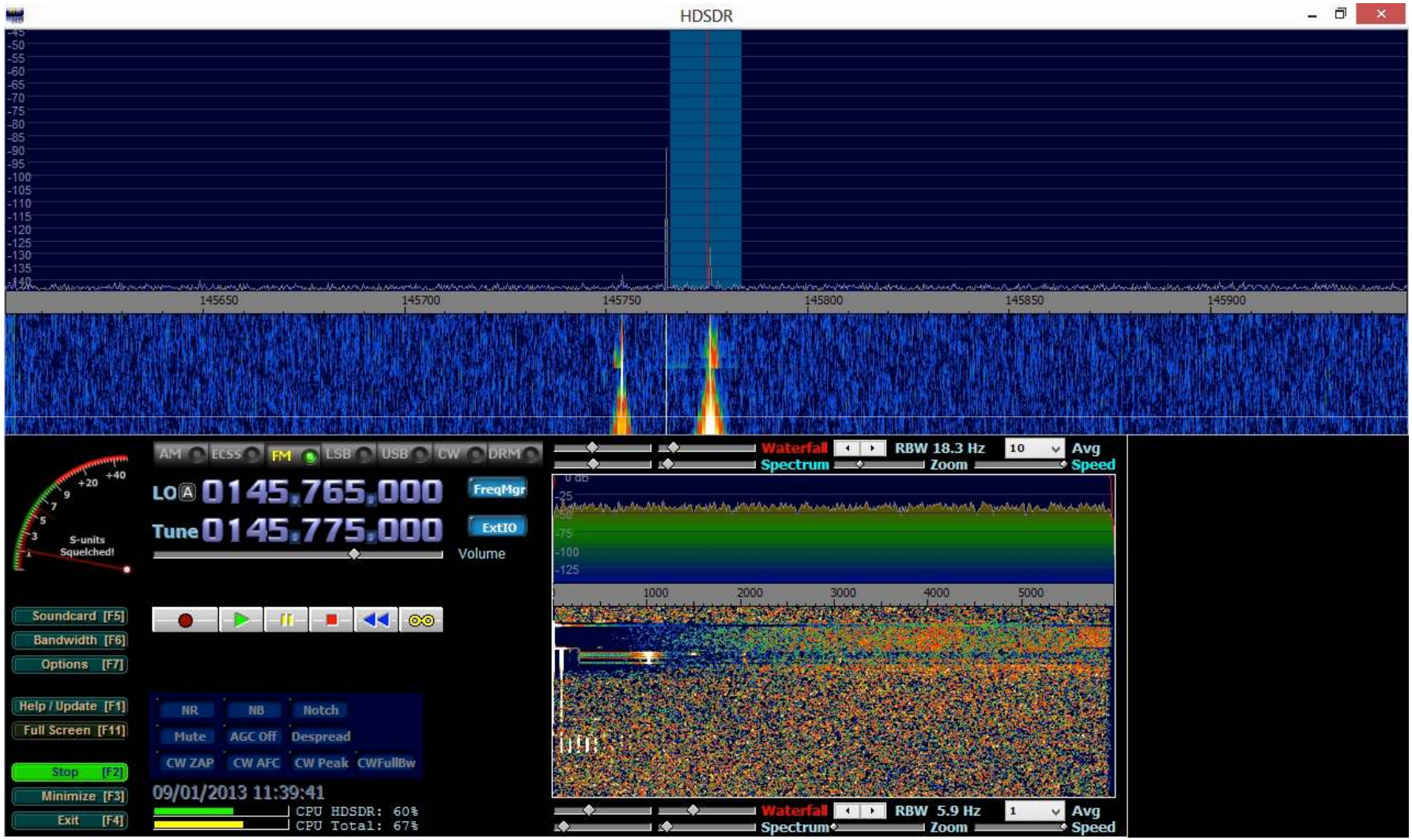
SDR# (Sharp) Plugins

Frequency Manager Metrics



Total duration of transmissions per channel

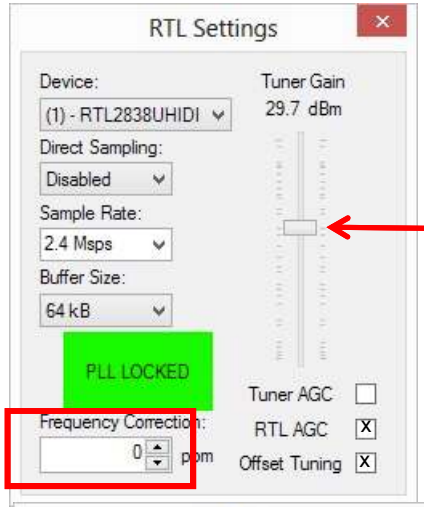
HDSDR



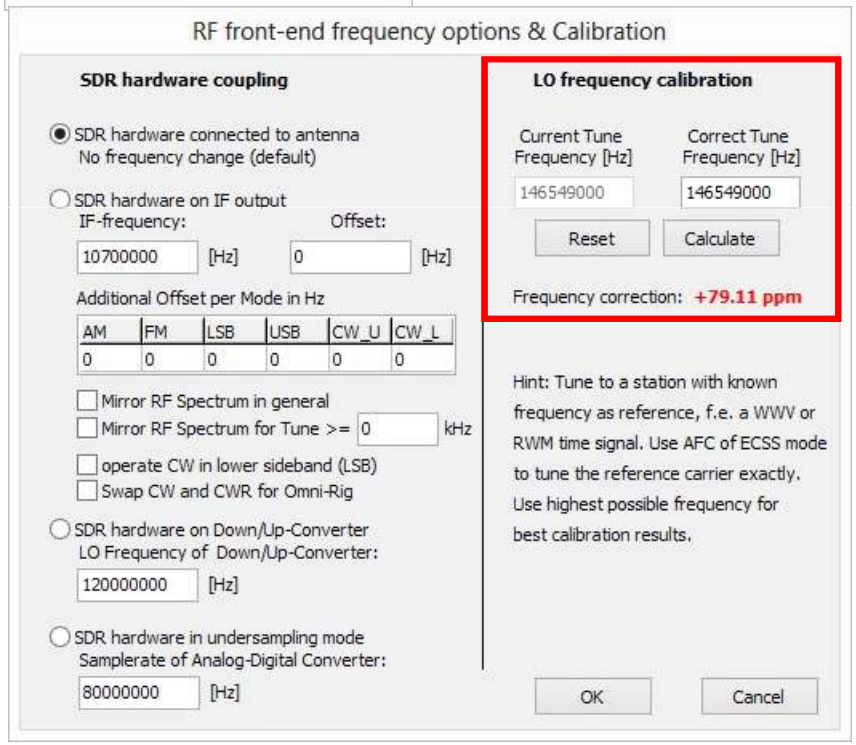
Rich in features; Unique recording capabilities; Use with ExtIO_RTL.dll

HDSDR
Frequency Calibration

- *In the RTL Settings window, keep the Frequency Calibration setting at 0 ppm*
- *Frequency Calibration in HDSDR is done through the Options, RF Front-End + Calibration menu*
- *Calibrate to a known frequency source; for most purposes, any modern VHF xcvr is 'good enough'*
- *Be sure to turn your xcvr's PL OFF when calibrating HDSDR*

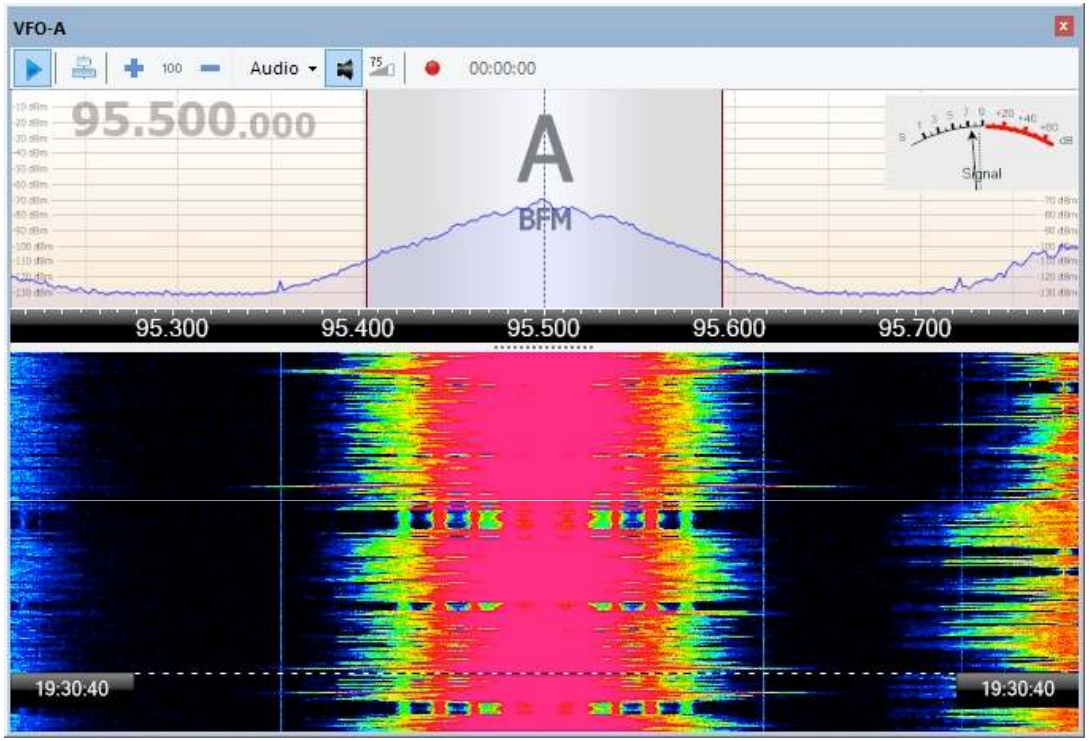


After calibration, use slider to set gain



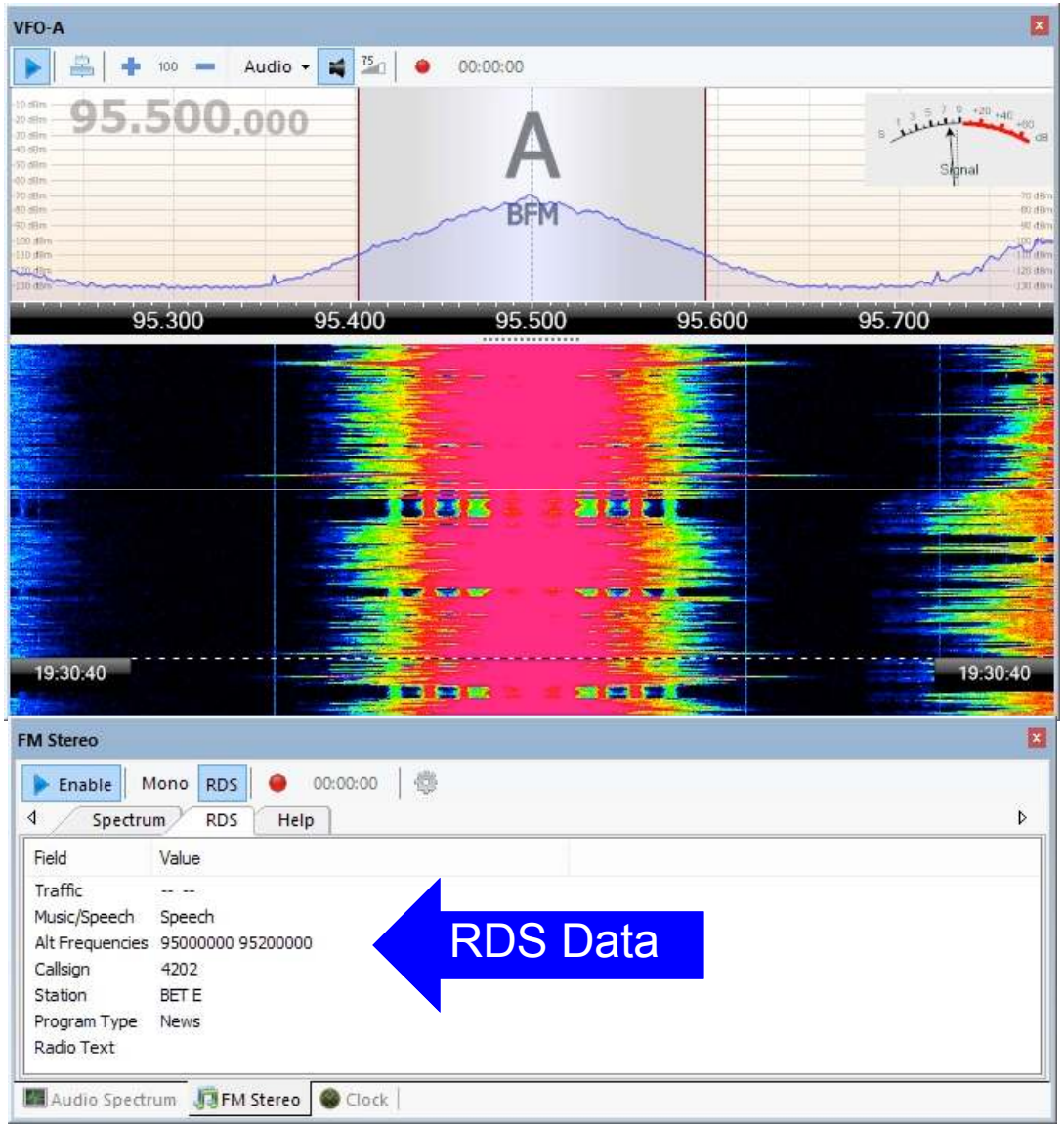
Make sure the ExtIO_RTL.dll file is installed in the same directory as HDSDR

SDR-RADIO 2.0



RTL-SDR is supported via rtl_tcp.exe or, via 3rd party dll (AA5SH)

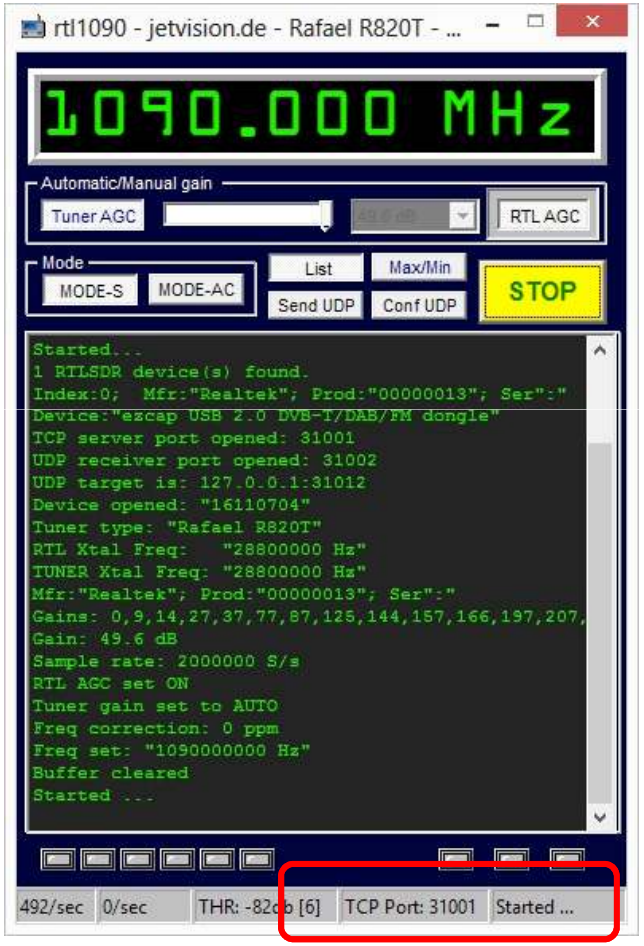
SDR-RADIO 2.0


VFO-A
Audio
00:00:00
95.500.000
A
BFM
Signal
95.300
95.400
95.500
95.600
95.700
19:30:40
19:30:40
FM Stereo
Enable
Mono
RDS
00:00:00
Spectrum
RDS
Help
Field
Value
Traffic
-- --
Music/Speech
Speech
Alt Frequencies
95000000 95200000
Callsign
4202
Station
BET E
Program Type
News
Radio Text
RDS Data
Audio Spectrum
FM Stereo
Clock

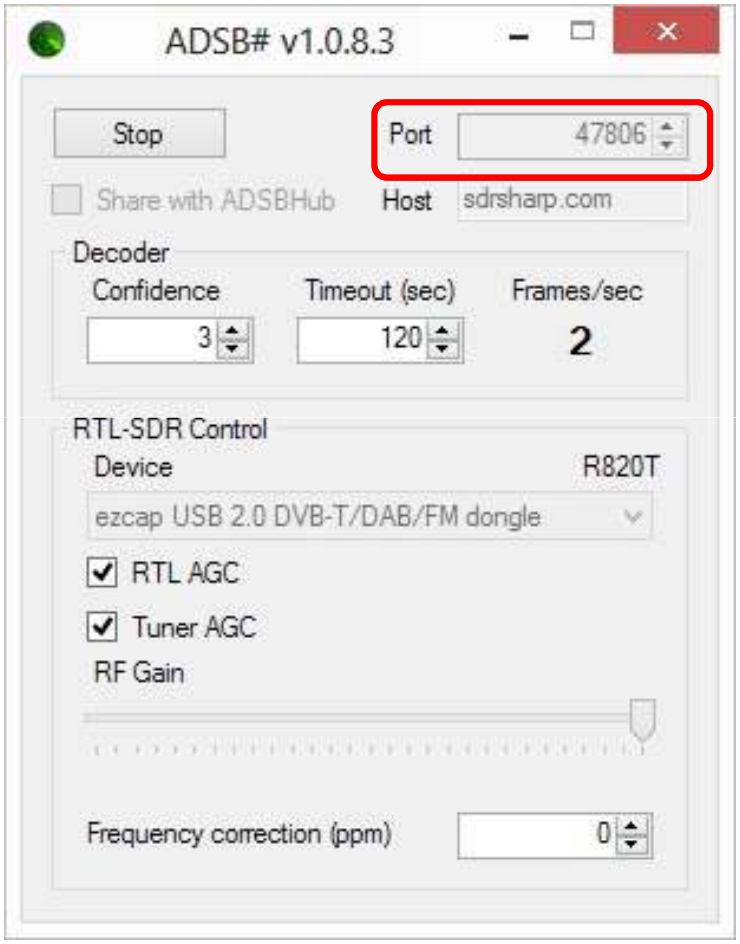
RTL-SDR Software Applications

ADS-B

Automatic Dependent Surveillance Broadcast

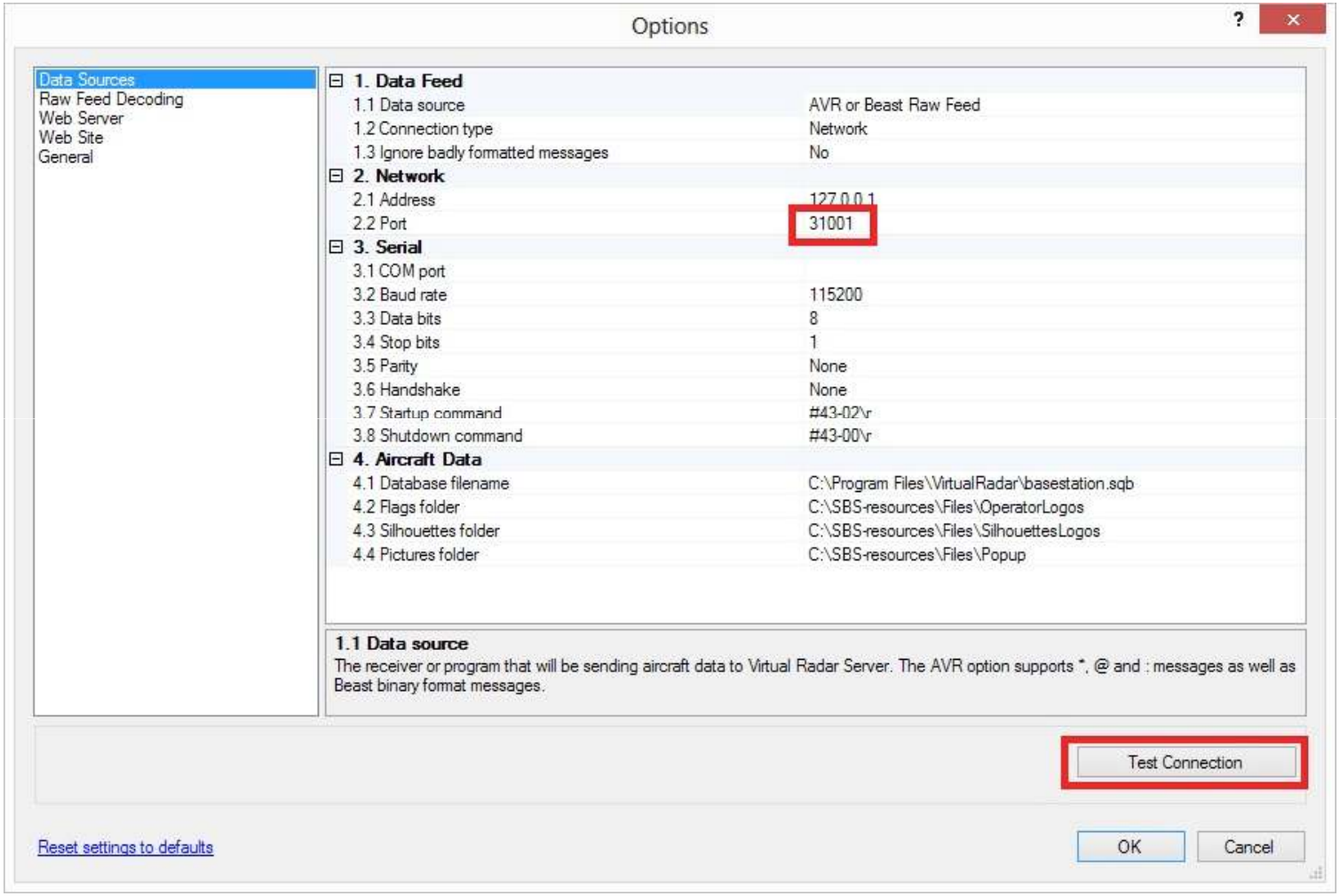


(or)



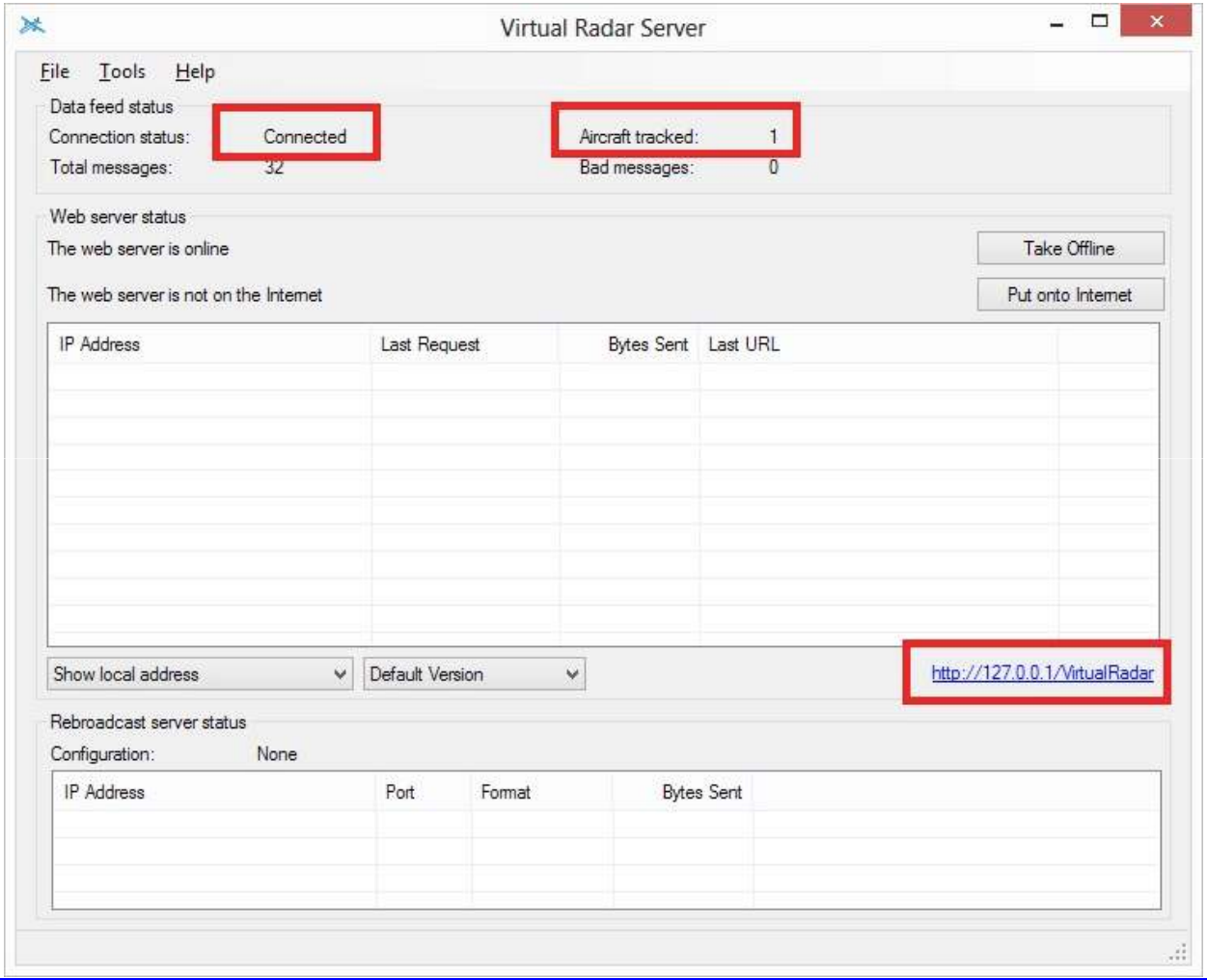
Two programs are available; either RTL1090 or, ADSB#.
Port# must talk to Virtual Radar Server

Virtual Radar Server



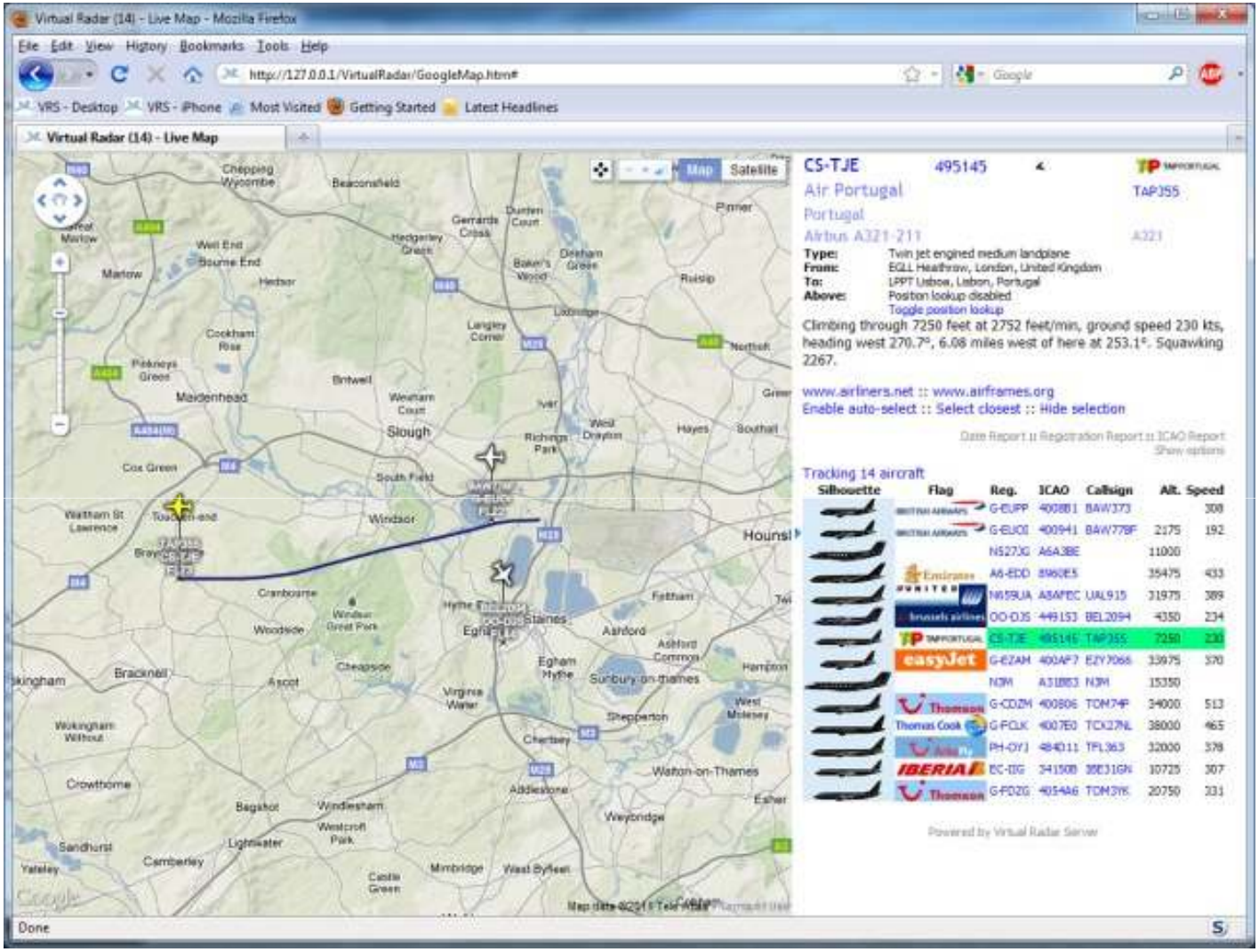
Set Port # to 31001 to communicate with RTL1090;
or 47806 to communicate with ADSB#

Virtual Radar Server



Click on URL to launch Web server locally or over the Web

Virtual Radar Server



VRS 'talks' to RTL1090 or ADSB# and tracks aircraft in Real-Time;
Compare data to flightradar24.com or Planefinder.net

Decoding Digital Transmissions

• Besides, SDR#, you will need three programs to decode digital transmissions

1. VAC (Virtual Audio Cable)
2. UniTrunker
3. DSD

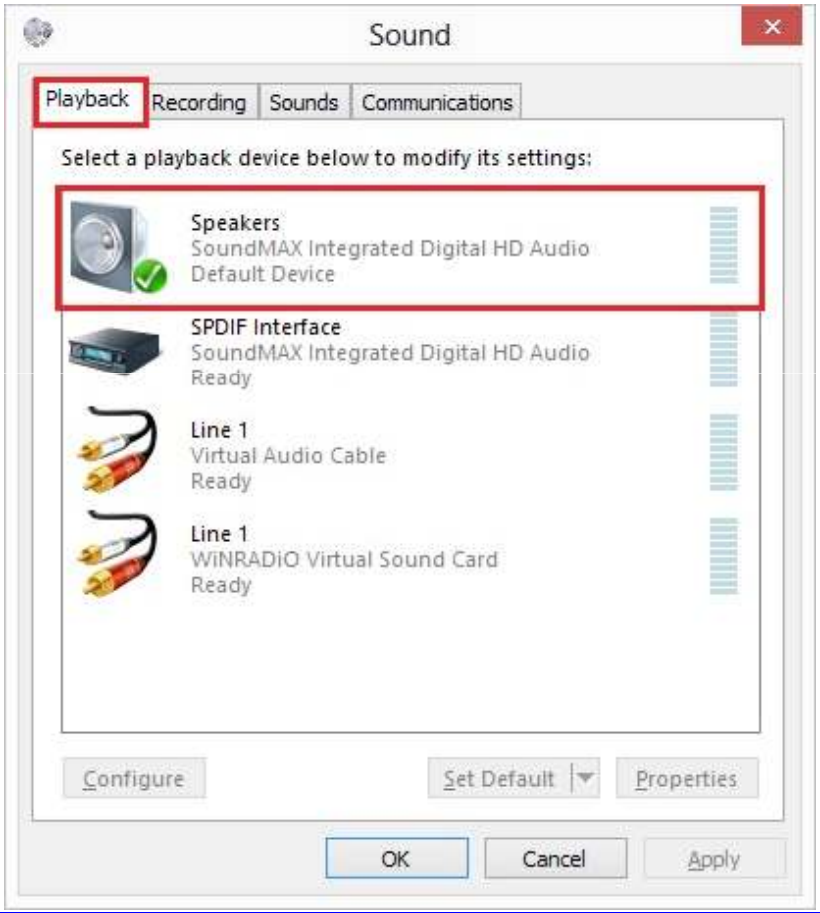
• **DSD can decode the following digital standards**

- ***P25 Phase 1***
- ***ProVoice -*** EDACS Digital Voice
- ***X2-TDMA -*** Motorola public safety TDMA system with P25 style signaling (mostly based on DMR)
- ***DMR/MOTOTRBO -*** Digital Mobile Radio standard
- ***NXDN***
- ***C4FM***
- ***GFSK***
- ***QPSK*** (sometimes marketed as "LSM")

Requires Recording Device set to VAC

Decoding Digital Transmissions

Sound Card Settings (1)



Playback set to normal default device

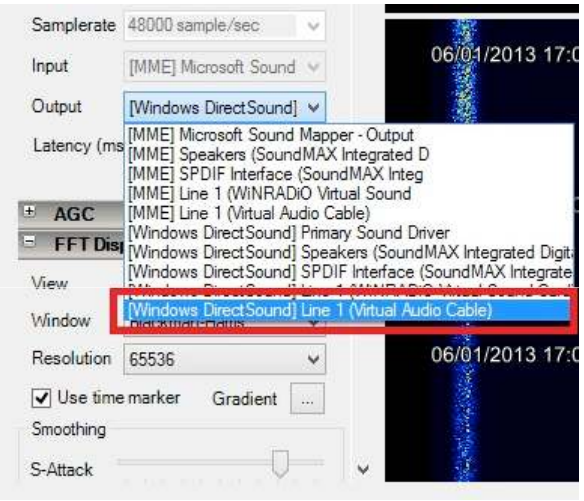
Decoding Digital Transmissions

Sound Card Settings (2)

Requires Recording Device set to VAC

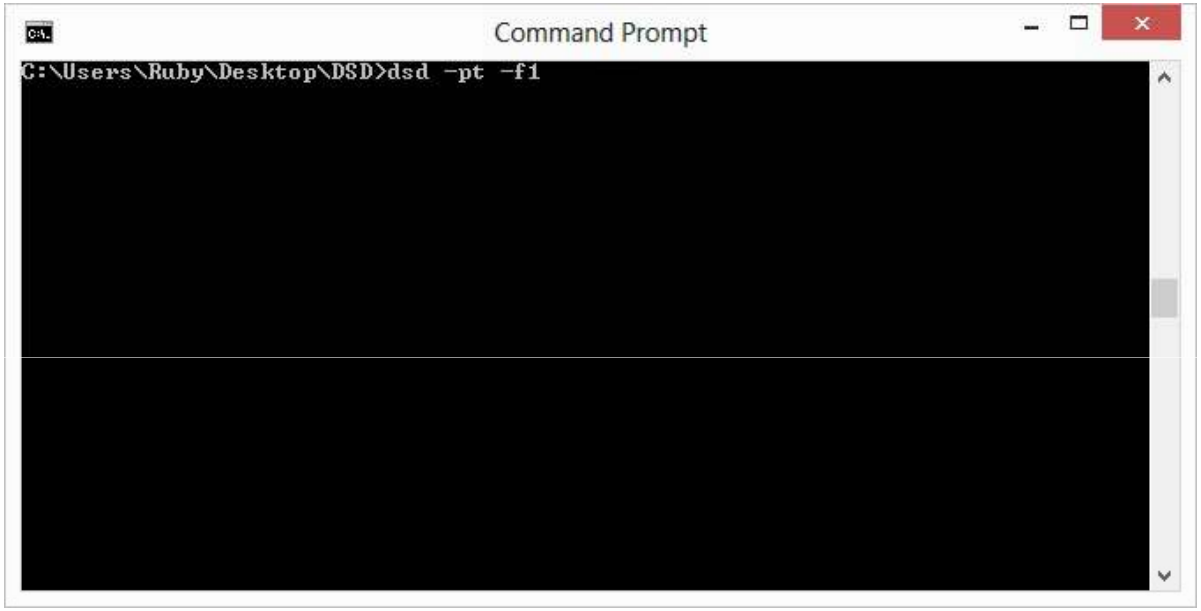
Decoding Digital Transmissions

Sound Card Settings in SDR#



In SDR#, set 'Output' to Virtual Audio Cable Line 1

Decoding Digital Transmissions
DSD (Digital Signal Decoder)



Latest ver. of DSD is 1.6; Use syntax –pt –f1 –w demo.wav
(Show P25 talkgroup info, decode only P25 Phase 1, Save audio to wav file)

Decoding Digital Transmissions

DSD (Digital Signal Decoder) Commands

```
C:\dsd4winv2>dsd -h
Digital Speech Decoder 1.4.1
mbelib version 1.2.3

Usage:
  dsd [options]           Live scanner mode
  dsd [options] -r <files> Read/Play saved mbe data from file(s)
  dsd -h                  Show help

Display Options:
  -e            Show Frame Info and errorbars (default)
  -pe           Show P25 encryption sync bits
  -pl           Show P25 link control bits
  -ps           Show P25 status bits and low speed data
  -pt           Show P25 talkgroup info
  -q            Don't show Frame Info/errorbars
  -s            Datascope (disables other display options)
  -t            Show symbol timing during sync
  -v <num>      Frame information Verbosity
  -z <num>      Frame rate for datascope

Input/Output options:
  -i <device>   Audio input device (default is /dev/audio)
  -o <device>   Audio output device (default is /dev/audio)
  -d <dir>      Create mbe data files, use this directory
  -g <num>      Audio output gain (default = 0 = auto)
  -n            Do not send synthesized speech to audio output device
  -w <file>     Output synthesized speech to a .wav file

Scanner control options:
  -B <num>      Serial port baud rate (default=115200)
  -C <device>   Serial port for scanner control (default=/dev/ttyUSB0)
  -R <num>      Resume scan after <num> TDULC frames or any PDU or TSDU

Decoder options:
  -fa           Auto-detect frame type (default)
  -f1           Decode only P25 Phase 1
  -fd           Decode only D-STAR* (no audio)
  -fi           Decode only NXDN48* (6.25 kHz) / IDAS*
  -fn           Decode only NXDN96 (12.5 kHz)
  -fp           Decode only ProVoice*
  -fr           Decode only DMR/MOTOTRBO
  -fx           Decode only X2-TDMA
  -ma           Auto-select modulation optimizations (default)
  -mc           Use only C4FM modulation optimizations
  -mg           Use only GFSK modulation optimizations
  -mq           Use only QPSK modulation optimizations
  -u <num>      Unvoiced speech quality (default=3)
  -xx           Expect non-inverted X2-TDMA signal
  -xr           Expect inverted DMR/MOTOTRBO signal

  * denotes frame types that cannot be auto-detected.

Advanced decoder options:
  -A <num>      QPSK modulation auto detection threshold (default=26)
  -S <num>      Symbol buffer size for QPSK decision point tracking
                (default=36)
  -M <num>      Min/Max buffer size for QPSK decision point tracking
                (default=15)

C:\dsd4winv2>
```

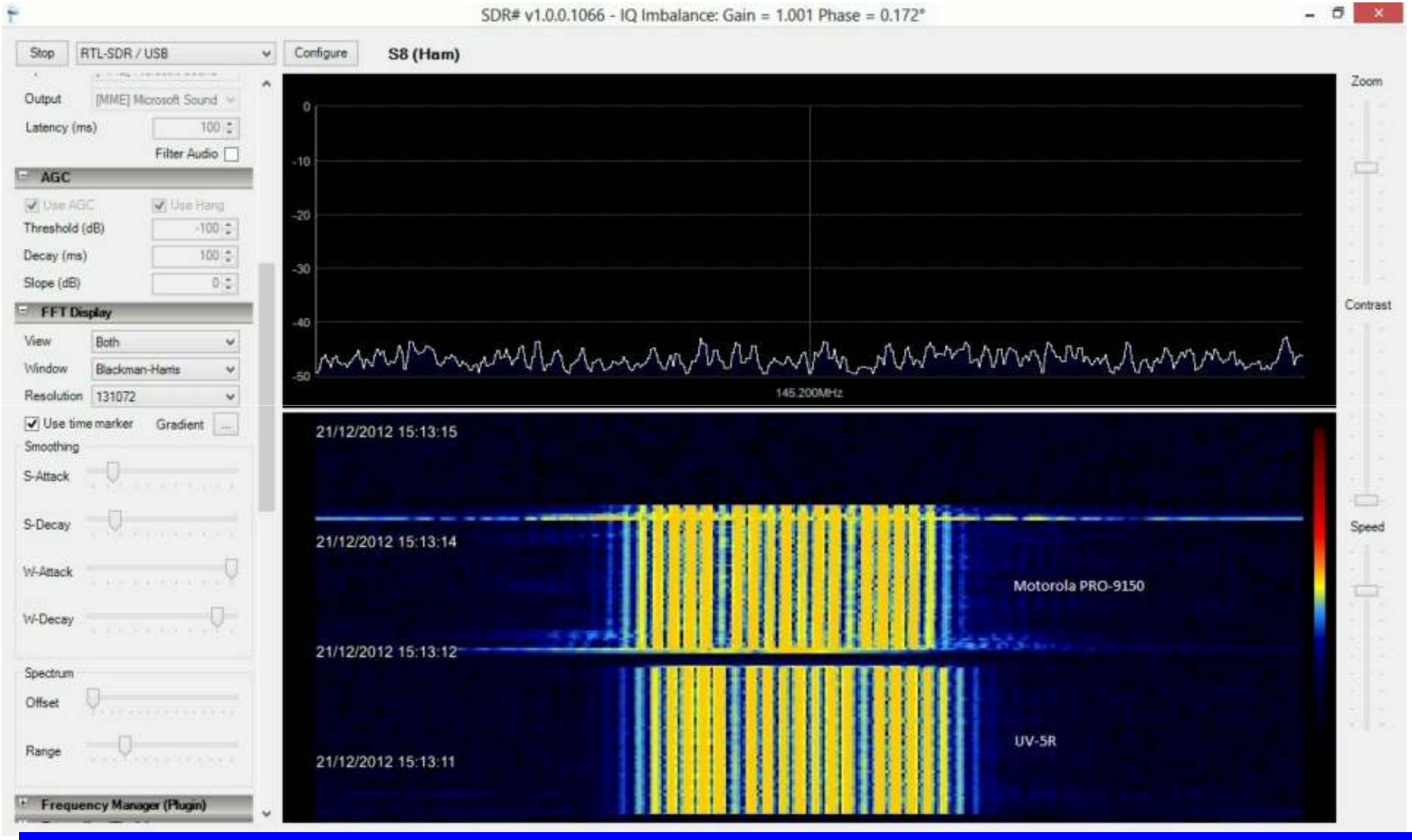
Decoding Digital Transmissions
DSD (Digital Signal Decoder) Fine Tuning

Don't expect your $20 RTL-SDR to sound as good as a $4500 P25 xcvr!

- **Set all soundcard and VAC devices to 48000 samples per second**
- **In SDR#:**
  - Set Mode to NFM
  - Set step size to 6.25 kHz in SDR#
  - Set BW to 12.5 kHz
  - Uncheck 'Filter Audio'
  - Adjust AF gain for 30% inlvl in DSD
  - Set FFT resolution to 65536
  - Increasing 'latency' from 100 to 200 or 300 may help decrease stutter

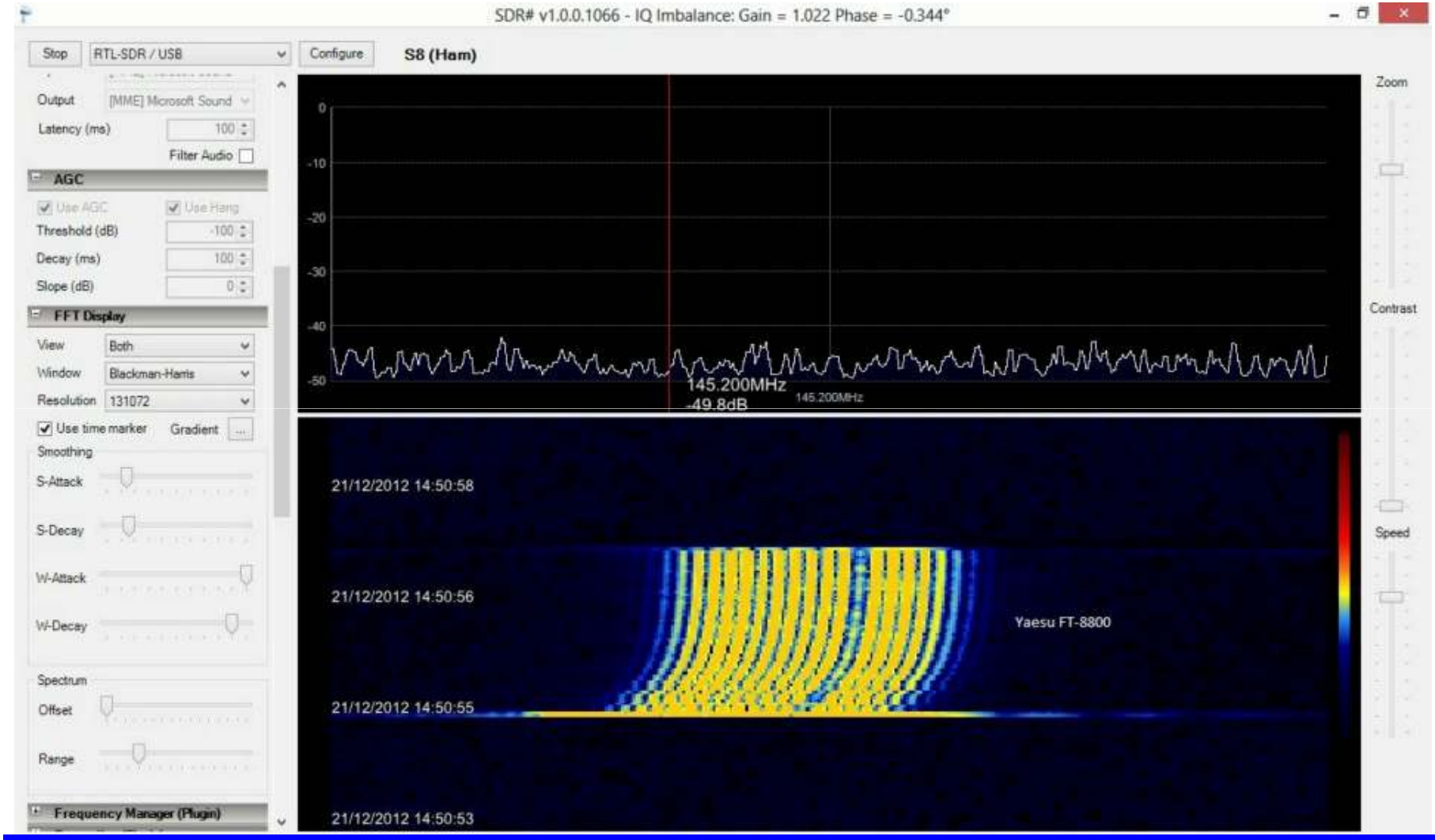
DSD CANNOT and will never support decoding of encrypted data

Transmitter ‘Finger-Printing’



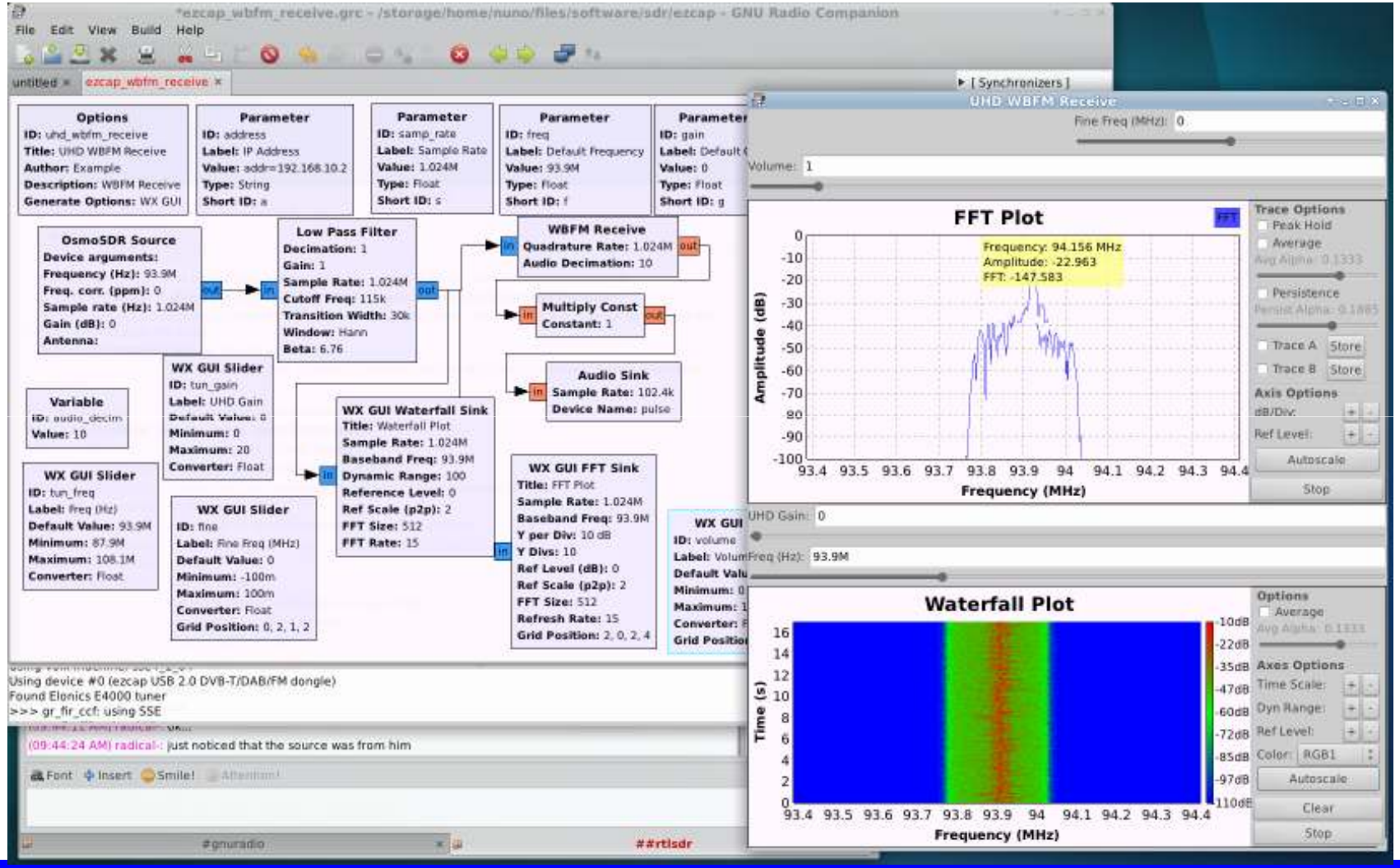
Every transmitter has it’s own unique characteristics – increase the FFT resolution and zoom in on the signal to identify them!

Transmitter ‘Finger-Printing’



…and identify anomalies in a waveform

RTL-SDR with GNU Radio

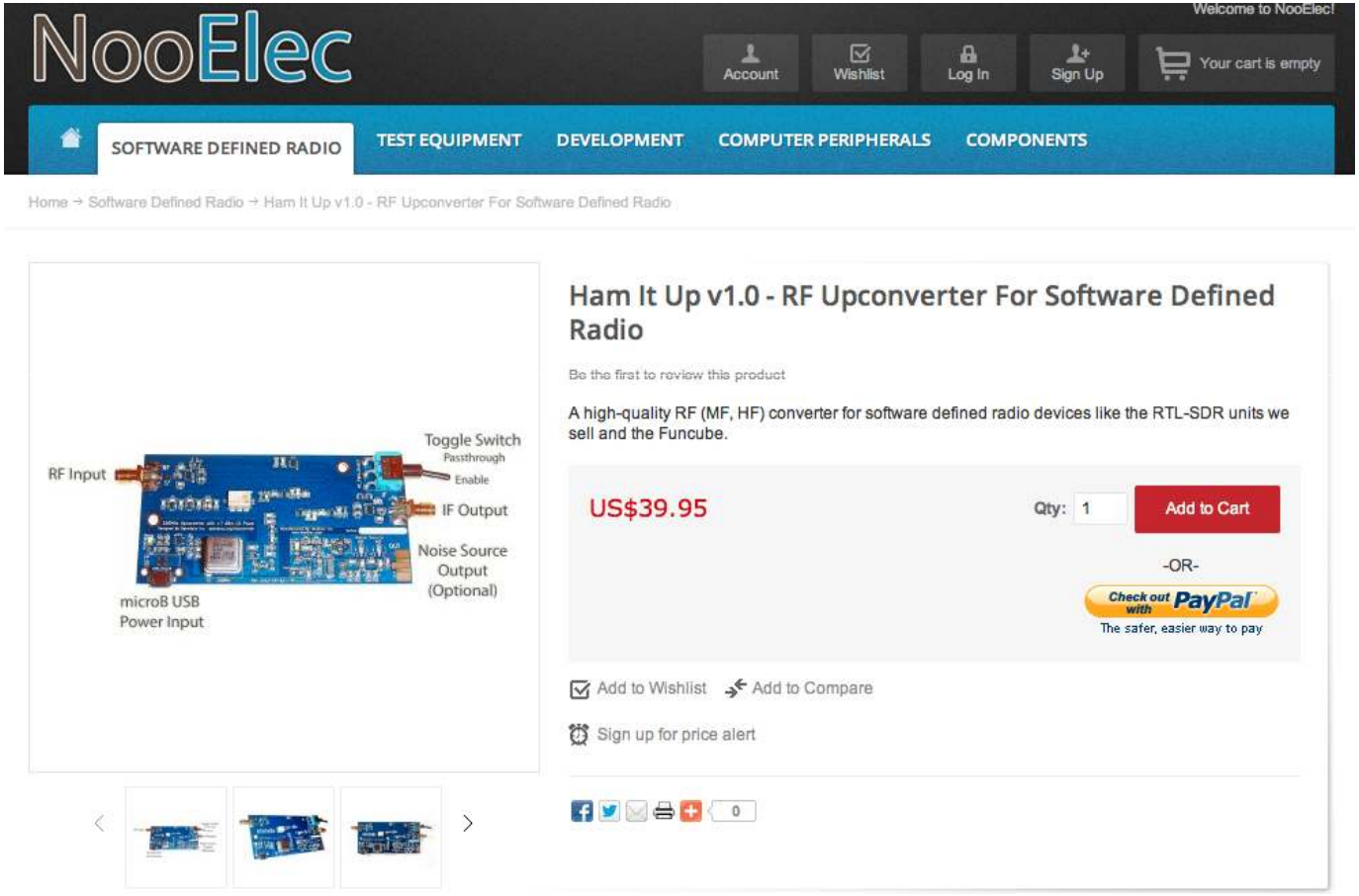


Run RTL-SDR in GNU Radio – on Linux

HF on the RTL-SDR

NooElec ‘Ham It Up’ v1.0

See YouTube demo here:
http://www.youtube.com/watch?v=VR0Lz4JOoBU

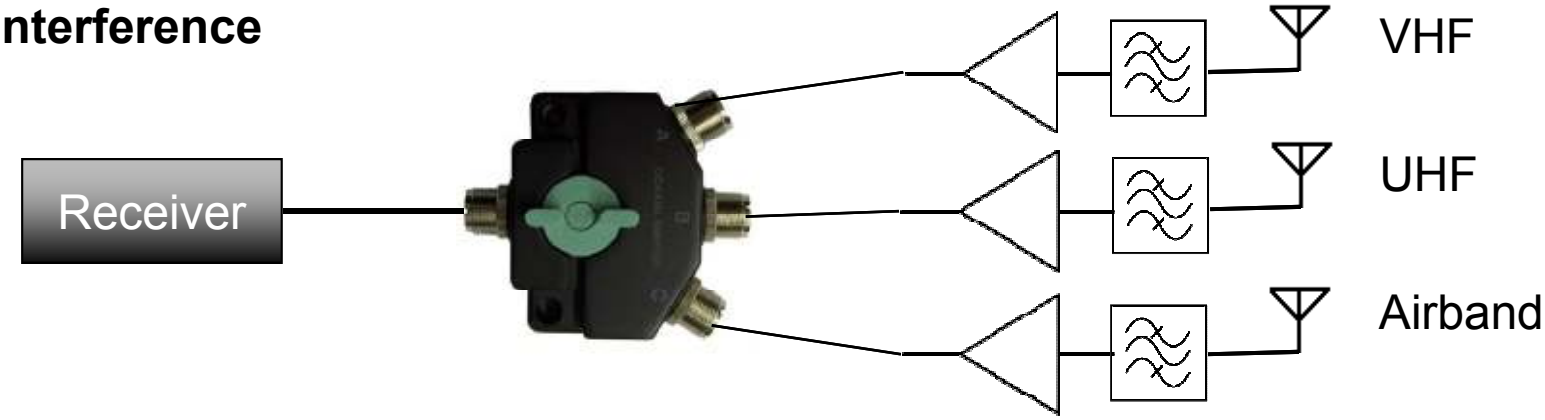


Interfaces between antenna and RTL-SDR Dongle; Powered by USB port; Bypass switch; On-board noise source; 300 kHz-50 MHz+

Hints and Tips

Antennas, Filters, Preamps

- **RTL-SDR has poor front end filtering and poor dynamic range**
- **As a result, they can suffer from de-sense from strong, out of band signals**
- **Narrow band antennas such as a Yagi can help reduce interference outside of the design frequency range**
- **A band specific LNA will significantly increase performance**
- **Band-pass and Band-stop filters can also be used to reduce interference**



LNA's for 50, 144 and 430 MHz are available from Down East Microwave

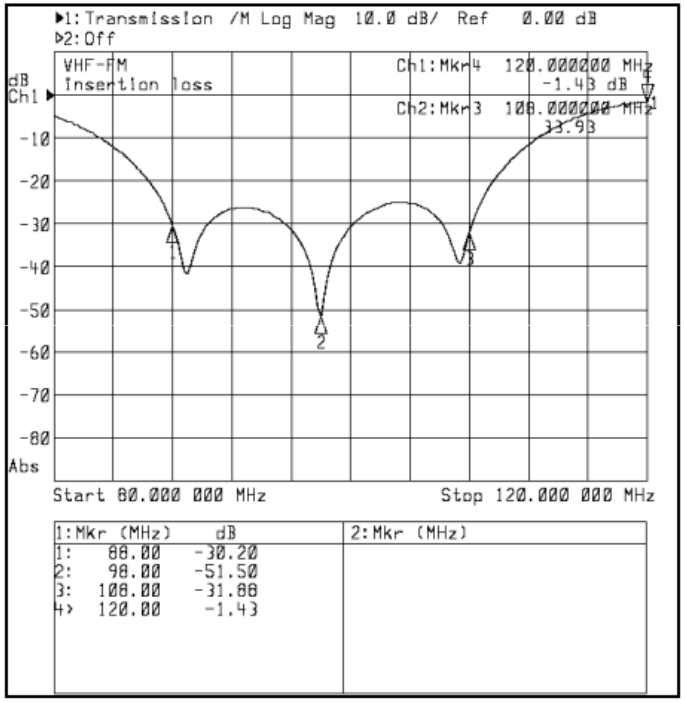
Hints and Tips

Coax-Stub Filter (Attenuates FM Broadcast Band)

Band stop filters can easily be constructed from coax and a T-connector (1/4 wave coax stub)

Hints and Tips

Antennas, Filters, Preamps



Commercial FM-Broadcast Band-Reject Filter

Probing Further (1)

Recommended Sites:

1.Ham Radio Science: A site focused on SDR and SDR Applications:
http://www.hamradioscience.com

2. Ultra Cheap SDR (Google Groups)
https://groups.google.com/forum/#!forum/ultra-cheap-sdr

Software:

1. Zadig download:
http://sourceforge.net/projects/libwdi/files/zadig/

2.SDR# (Sharp) Home Page:
http://sdrsharp.com/index.php/downloads

3. SDR# Yahoo Support page:
http://uk.groups.yahoo.com/group/SDRSharp/

4. HDSDR Home Page:
http://www.hdsdr.de/

5. SDR-RADIO Home Page:
http://sdr-radio.com/

6. SDR-RADIO Yahoo Support page:
http://groups.yahoo.com/group/sdr-radio-com/

7. SDR-RADIO Download Page:
http://www.ham-radio.ch/kits/sdr-radio.com/2.0/

Probing Further (2)

Software (cont.):

8. SDR# with Autotuner
https://public-xrp.s3.amazonaws.com/Release-latest.zip

9. ADS-B# Download
http://sdrsharp.com/index.php/downloads

10. RTL1090 Homepage and Download
http://rtl1090.web99.de

Drivers/DLLs:

1. OsmocomSDR sdr dll:
http://sdr.osmocom.org/trac/attachment/wiki/rtl-sdr/RelWithDebInfo.zip

(Unzip, then go to rtl-sdr-release/x32 - copy rtlsdr.dll to SDR# directory)

2. ExtIO_RTL.dll for HDSDR:
https://github.com/josemariaaraujo/ExtIO_RTL/blob/master/Release/ExtIO_RTL.dll

3. ExtIO_RTL.dll for SDR-RADIO:
http://www.aa5sh.com/?page_id=65

4. SDR# Auto-Install Utility:
http://sdrsharp.com/downloads/sdr-install.zip

(Unzip, then install the install.bat file)

Online FM Frequency DB tailored for your location:

1.http://fmscan.org/index.php

Probing Further (3)

DSD and UniTrunker:

1.DSD Decoder for Windows – Homepage and Download:
http://wiki.radioreference.com/index.php/Digital_Speech_Decoder_(software_package)

2. UniTrunker Homepage and Download:
http://unitrunker.com/

3. Using DSD, UniTrunker with SDR# and 2 RTL-SDR dongles (How to Guide):
http://public-xrp.s3.amazonaws.com/docs/sdrsharptrunk.htm

4. Virtual Audio Cable:
http://software.muzychenko.net/eng/vac.htm

SDR Sharp Frequency Manager + Scanner (v1.2)
http://uk.groups.yahoo.com/group/SDRSharp/message/5093

Reference Links

Dan Tayloe's Original Zero IF Quadrature Product Detector (QSD) Article
http://wb9ipa.qrpradio.com/60meter/exciter/Tayloe_mixer_x3a.pdf

Understanding I/Q Data
http://www.ni.com/white-paper/4805/en

A Software-Defined Radio for the Masses, Part 1-4
http://www.arrl.org/files/file/Technology/tis/info/pdf/020708qex013.pdf
http://www.arrl.org/files/file/Technology/tis/info/pdf/020910qex010.pdf
http://www.arrl.org/files/file/Technology/tis/info/pdf/021112qex027.pdf
http://www.arrl.org/files/file/Technology/tis/info/pdf/030304qex020.pdf

Questions?

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