SOFTWARE DEFINED RADIOS

GETTING STARTED WITH SDR

LOREN ANDERSON KEØHZ

OUTLINE

Software Defined Radio (SDR) background

- SDR Hardware
- How SDRs work (very basic)

SDR software applications & demo(?)

- FlightAware with modified RTLSDR
- SDR# (SDR Sharp) with RTLSDR
- OpenWebRX with RTLSDR
- SDRuno with SDRplay
- Gnuradio with RTLSDR

TWO IMPORTANT RULES I LEARNED IN MY PROFESSIONAL LIFE

1. Never, ever rely on a live demo
2. If you're really confident that a live demo will work refer to Rule #1

But sometimes it's still worth a try!

CREDITS

Several slides copied with permission from Rocky Mountain Ham University

- Practical SDR With OpenWebRX, Ben Matthews KC2VJW, April 9, 2022
- GNURadio, Willem Schreüder, ACØKQ , April 9, 2022

Raise of hands if you've previously used or are currently using a Software Defined Radio?

Raise your hand if you have an IC-7300 and didn't previously raise your hand

SDR HARDWARE – EASY MODE

Popular Ham Transceiver

All self contained - No additional Computer or Software Required

The IC-7300 is an example of a Direct Conversion SDR

IC-7300 HF/50MHz TRANSCEIVER

Features

Specifications
Options
Product Gallery

Product Brochure
Instruction Manual
Hi-Resolution Image
Firmware/Software

The Innovative HF Transceiver

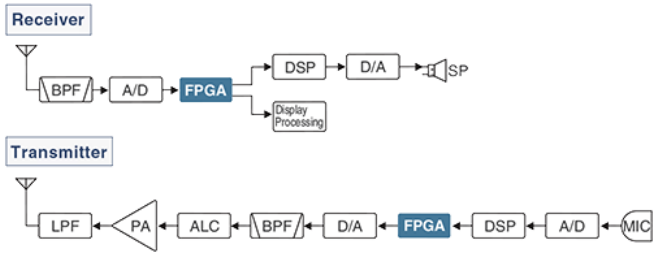
New technology is changing the way receivers are being designed and the IC-7300 is an industry first as an RF, Direct Sampling System is being used in an entry level HF radio. The ability to digitize RF before various receiver stages reduces the inherent noise that is generated in the different IF stages of a radio. We feel the performance of the '7300 will far exceed your expectations for a radio considered entry level.

Output Power:	100W (25W AM)
RX Frequencies:	0.030-74.800
Receiver Type:	Direct sampling

RF Direct Sampling System

The IC-7300 employs an RF direct sampling system, where RF signals are directly converted to digital data. Then processed in the FPGA (Field-Programmable Gate Array), making it possible to simplify the circuit construction as well as reduce noise that can mask weak signals.

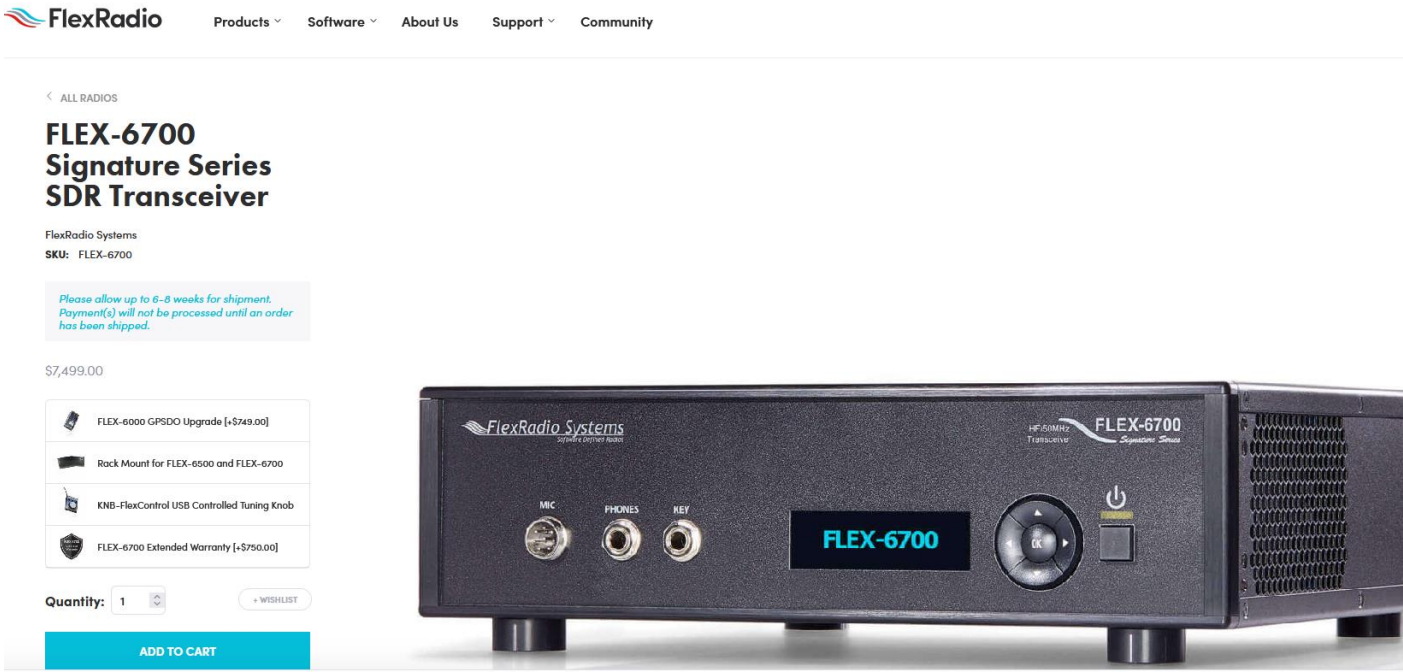
The new "IP+" improves the 3rd order intercept point (IP3) performance improving the ability to copy a weak signal that is adjacent to either a strong interfering signal. In this process, A/D converter is optimized to reduce or eliminate signal distortion.



SDR – SLIGHTLY HARDER MODE

Another Ham Transceiver

External Computer required but S/W app included



SDR – HARDER MODE

Harder but complexity varies from easy to ???

Range from $ to $$$$

- RTL-SDR ($29.95 (Amazon))
- SDRPlay ($117.00 (SDRplay))
- HackRF ($350.00 (Hackerwarehouse))
- Nooelec NESDR ($35.95 (Amazon))
- Airspy ($169.00 (Airspy.us))
- FlightAware Pro Stick ($68.74 (ebay))
- … many more to chose from

OTHER HARDWARE CONSIDERATIONS

- Antenna system as you would any other radio
- External filters can be a good idea
- Good quality cables (Computers/USB can be RF noisy)
- Faster computers are better, but it really depends on how much bandwidth you need

BRIEF BACKGROUND ON SDR

SDRs Utilize high speed Analog-to-Digital Converter (ADC), Field-Programmable Gate Array (FPGA), & Digital Signal Processing (DSP) components

Nyquist Sampling Theorem

- (Paraphrased) To digitize a waveform, sampling must be at least TWICE the frequency of the highest frequency component in the desired signal.

Sampling is performed with an analog-to-digital converter (ADC) with a sampling rate capability at least twice the input frequency.

- Direct Conversion did not become practical until the sampling speeds in the ADC increased significantly.
- In early days the RF signal processing was done at IF frequencies
    - Audio signal processing happened even earlier

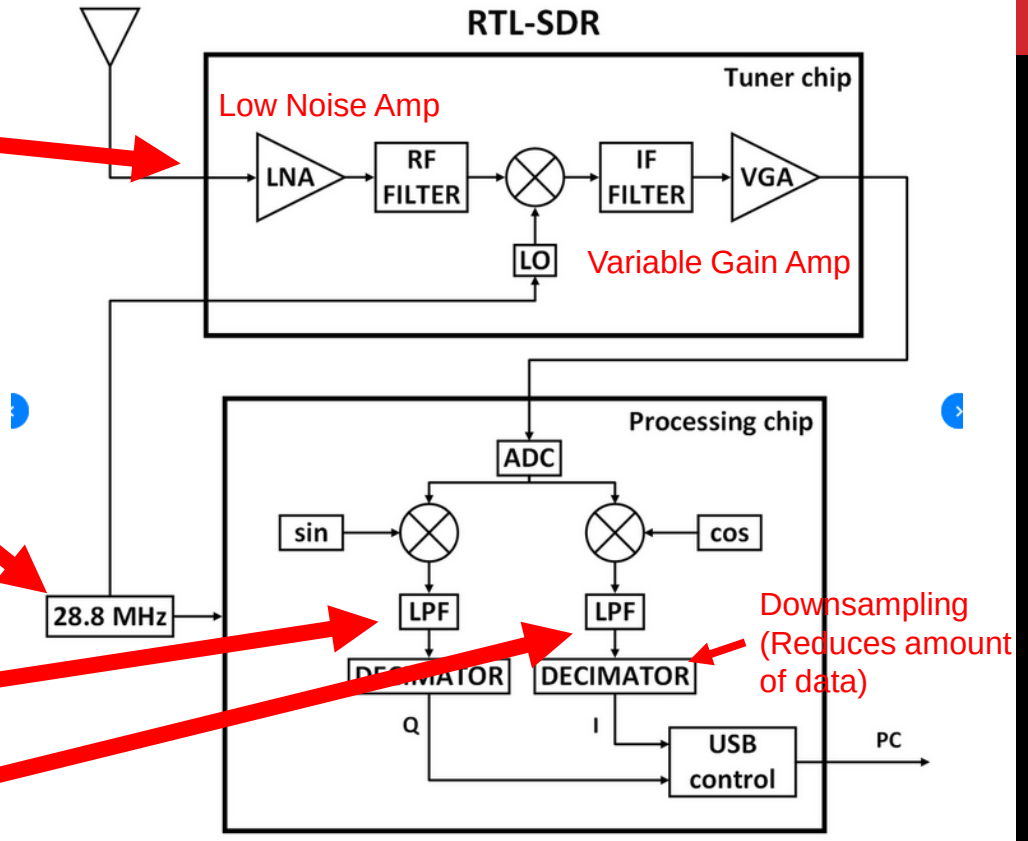
RTL-SDR BLOCK DIAGRAM

Front-end

Local Oscillator
(not a DC SDR)

“Q” signal
(quadrature)
Q is phase shifted +90˚
with respect to “I”

“I” signal (in-phase)



Block diagram of the RTL-SDR.

WHAT ARE THE I/Q SIGNALS?

In-phase (I)/Quadrature (Q) – input signal by definition is the I signal and the Q signal is shifted 90 degrees. I = Cosine/Q = Sine function

It doesn't matter if the input signal's phase is varying. The Q signal is always shifted 90 degrees from the input signal.

Demodulation equations are easily handled by DSP

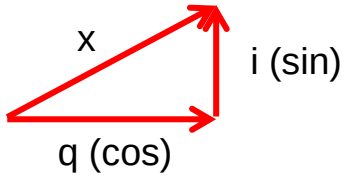
Let's do some basic high school trigonometry. AM demodulation is achieved by simply applying the Pythagorean Theorem

W8TLM Amateur Radio Club

DEMODULATION

9

- AM: $x(t) = \sqrt{i^2(t) + q^2(t)}$
- SSB: $x(t) = i(t)$
- FM: $x(t) = \left(\frac{1}{\Delta t}\right) \tan^{-1}\left[\frac{i(t)q(t-1) + q(t)i(t-1)}{i(t)i(t-1) - q(t)q(t-1)}\right]$
- PM: $x(t) = \tan^{-1}\left[\frac{q(t)}{i(t)}\right]$



$x^2 = i^2 + q^2$

I/Q SIGNALS WITH NO AM MODULATION

$X = \sqrt{(I^2 + Q^2)}$

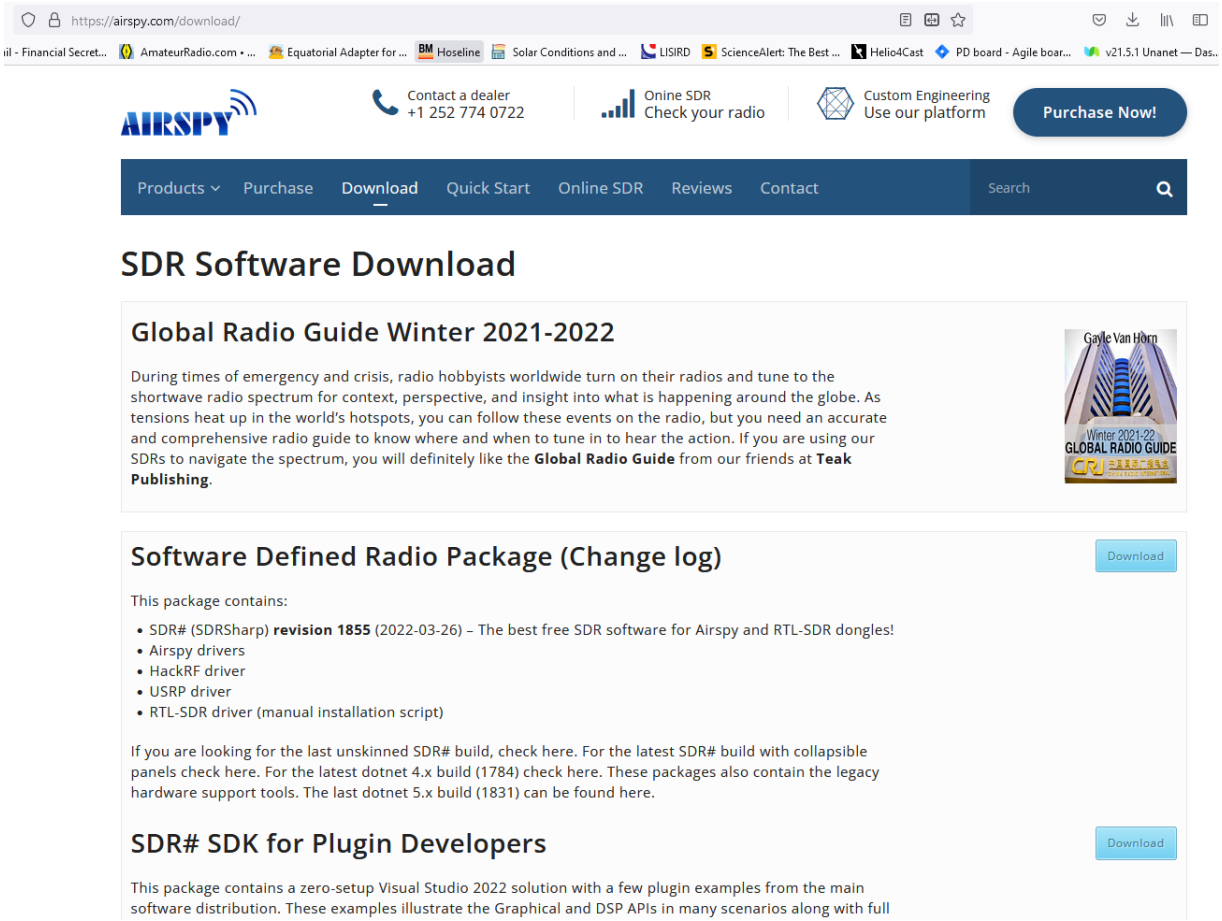
90°: I = 1, Q = 0, X = 1
120°: I = .5, Q = .866, X = 1
135°: I = .707, Q = .707, X = 1
180°: I = 0, Q = 1, X = 1

X is always 1. No signal variation!

But if there is a signal on the carrier, the Q value will be the value of the previous sample but the I value will have changed (+ or -) following the modulation. That value of X will be the demodulated signal.

SDR# (SDR SHARP) RECEIVER

HTTPS://AIRSPY.COM/DOWNLOAD



SDR#

Install Driver

Installs SRDLL.dll

Insert RTLSDR USB

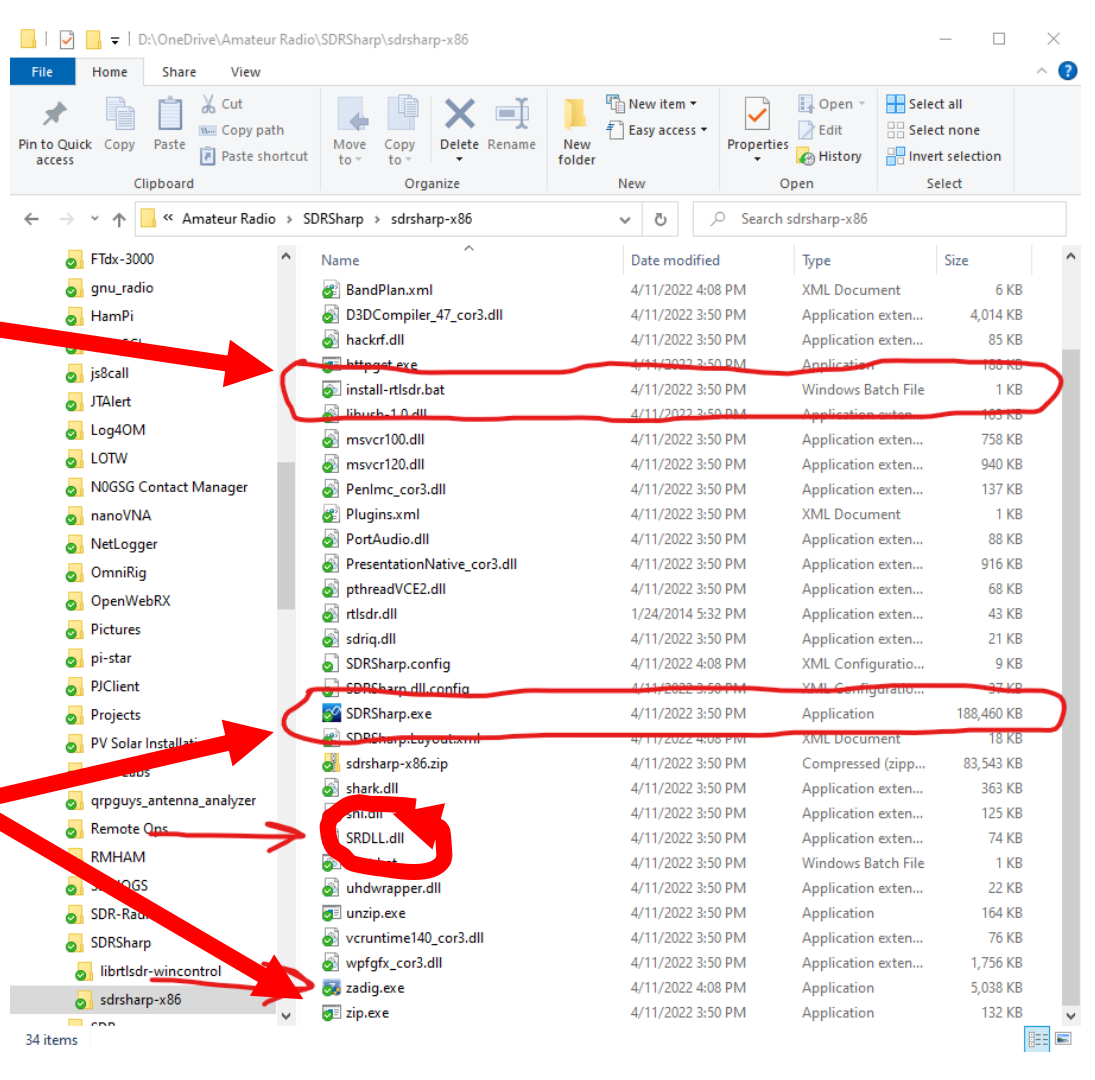
Windows installs driver that SDR# can't use

Run zadig.exe

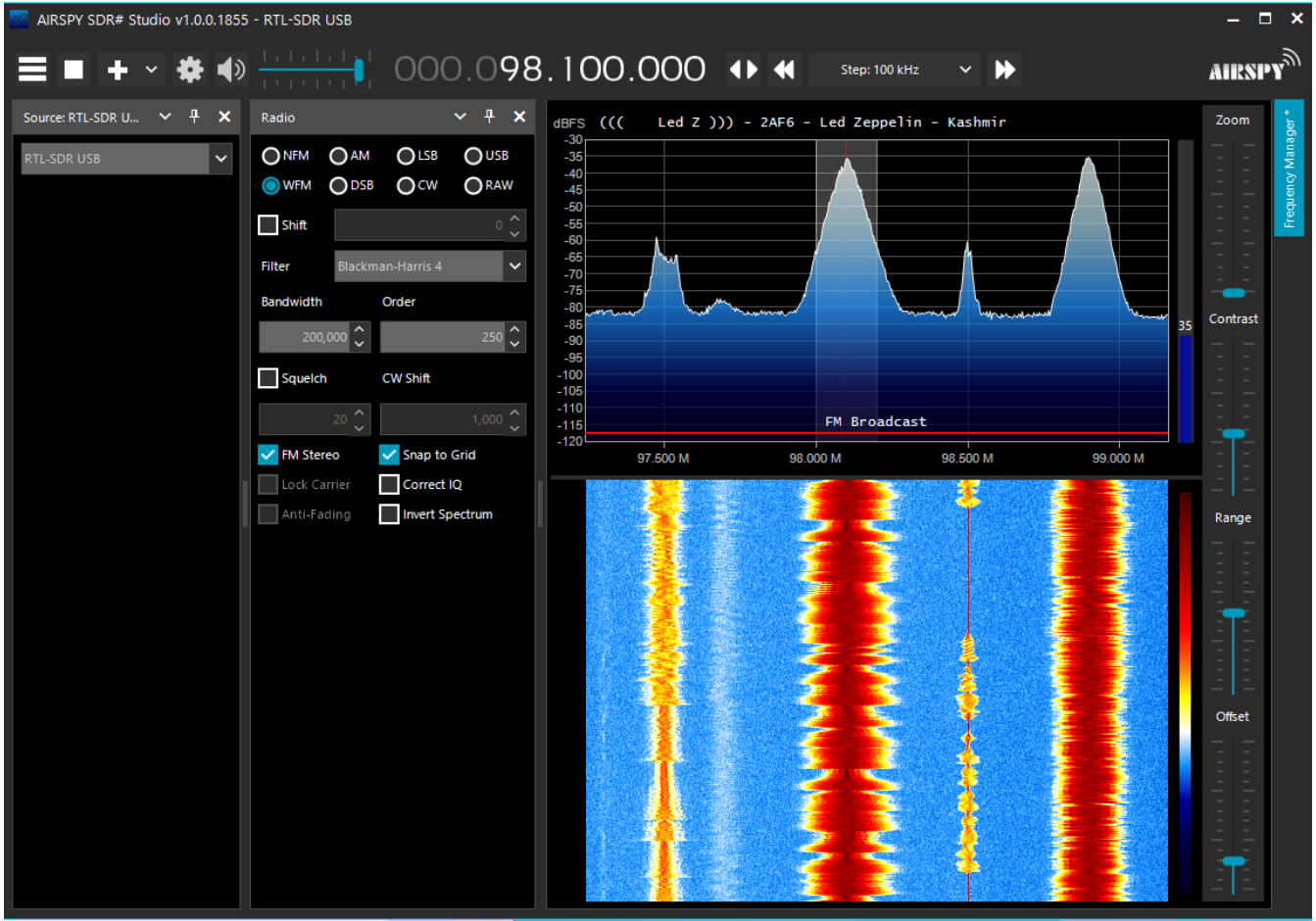
Replace driver

See YouTube video

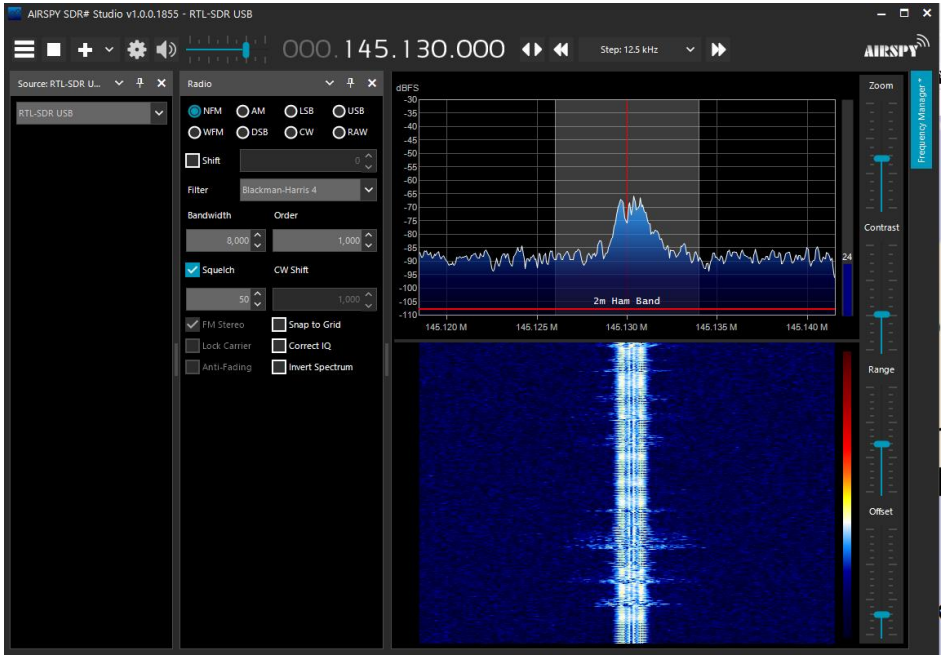
Run SDR#

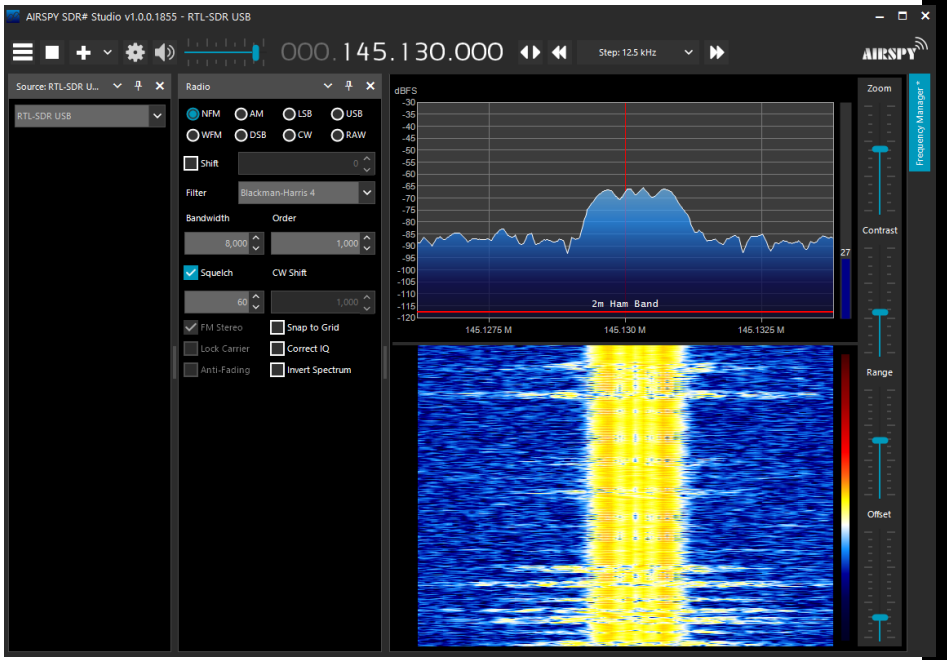


SDR# FM BROADCAST RECEIVER



SDR# 2M RECEIVER





SDR# DEMO

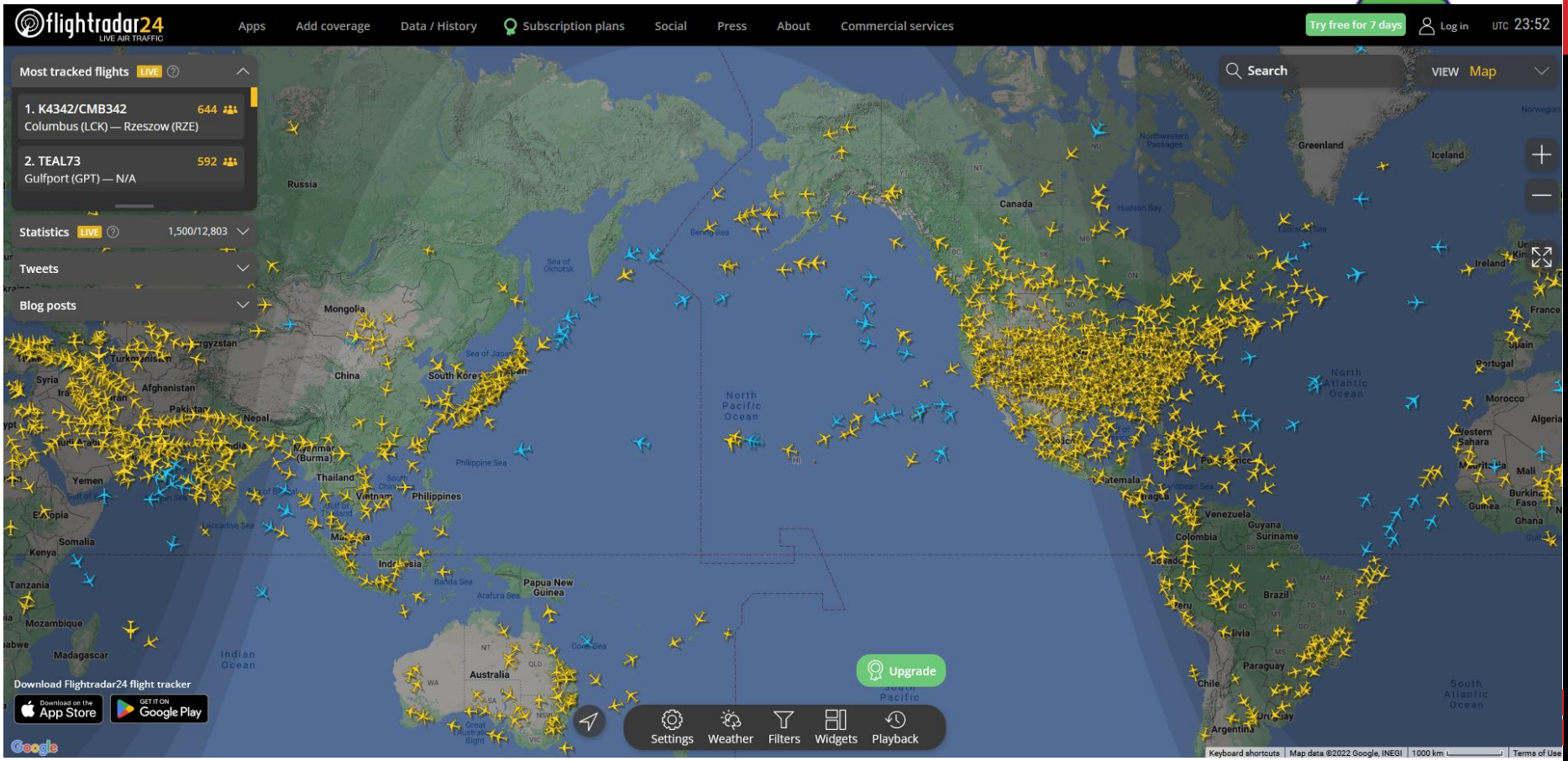
FLIGHTAWARE OR FLIGHTRADAR24 FEEDER

SIMPLE SETUP

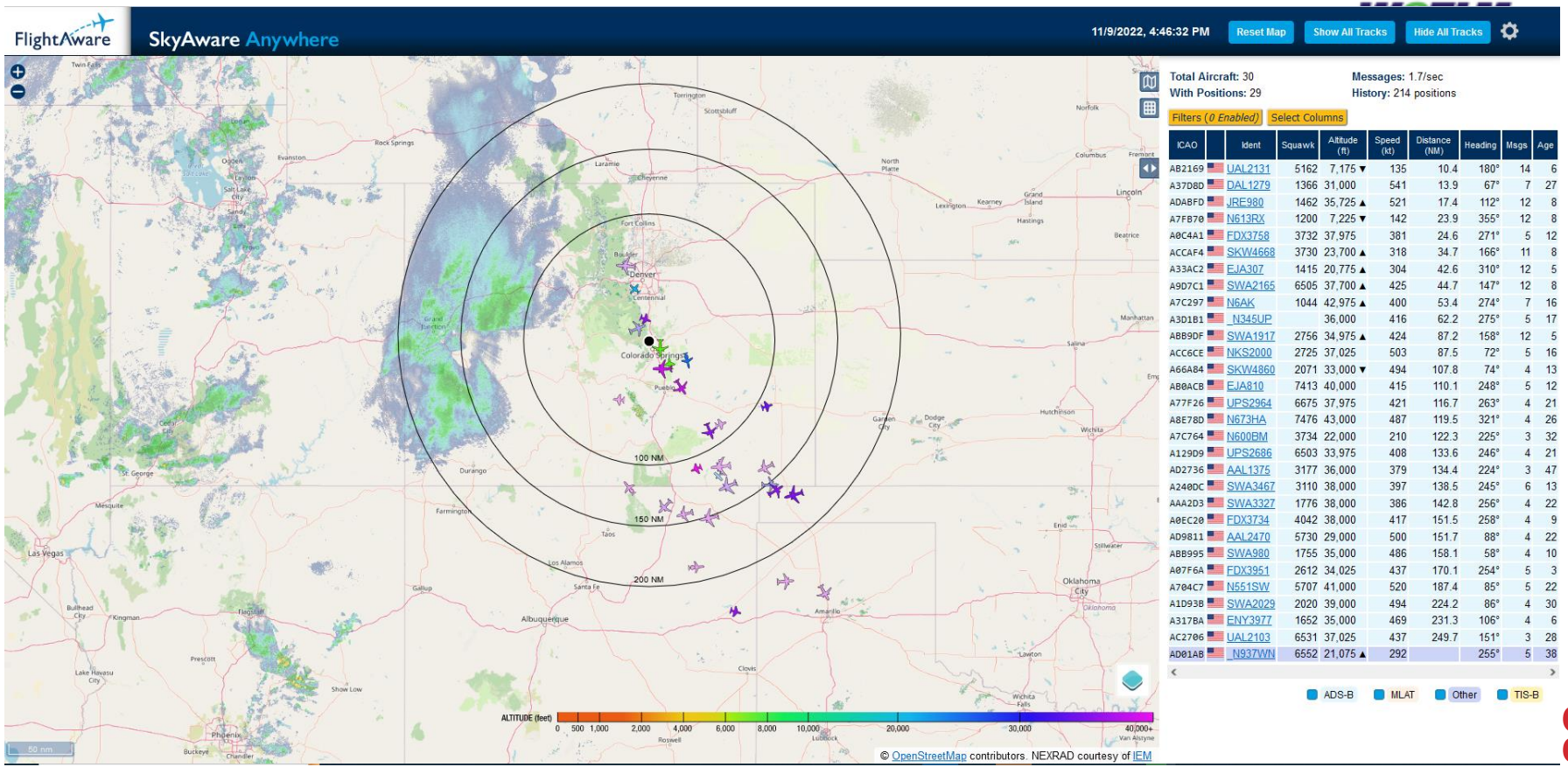
Hardware needed:

- **Raspberry Pi (at least a version 2, version 3 recommended)**
- **USB Dongle SDR (prefer a FlightAware custom version)**
- **Recommended – bandpass filter to reduce desensing due to strong local signals**
- **Antenna tuned for ADS-B signals**
  - Frequency
  - Insert picture

FLIGHTRADAR24

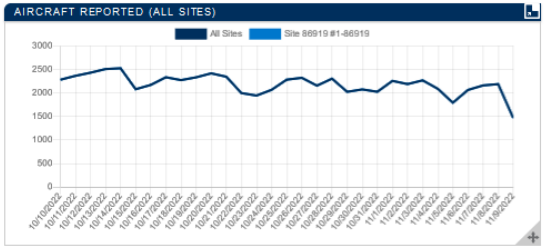


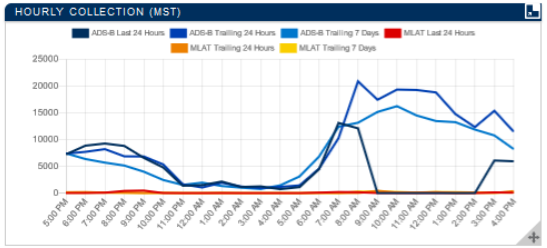
SKYAWARE ANYWHERE

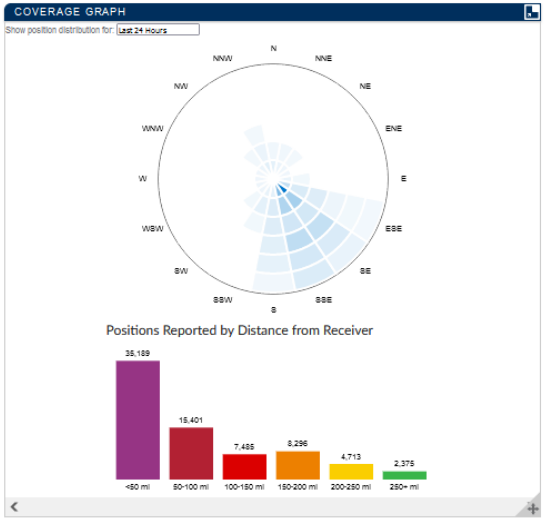


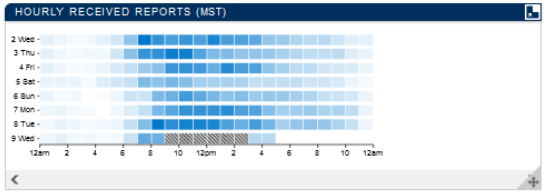
ICAO		Ident	Squawk	Altitude (ft)	Speed (kt)	Distance (NM)	Heading	Msgs	Age
AB2169		UAL2131	5162	7,175 ▼	135	10.4	180°	14	6
A37D8D		DAL1279	1366	31,000	541	13.9	67°	7	27
ADABFD		JRE980	1462	35,725 ▲	521	17.4	112°	12	8
A7FB70		N613RX	1200	7,225 ▼	142	23.9	355°	12	8
A0C4A1		FDX3758	3732	37,975	381	24.6	271°	5	12
ACCAF4		SKW4668	3730	23,700 ▲	318	34.7	166°	11	8
A33AC2		EJA307	1415	20,775 ▲	304	42.6	310°	12	5
A9D7C1		SWA2165	6505	37,700 ▲	425	44.7	147°	12	8
A7C297		N6AK	1044	42,975 ▲	400	53.4	274°	7	16
A3D1B1		N345UP		36,000	416	62.2	275°	5	17
ABB9DF		SWA1917	2756	34,975 ▲	424	87.2	158°	12	5
ACC6CE		NKS2000	2725	37,025	503	87.5	72°	5	16
A66A84		SKW4860	2071	33,000 ▼	494	107.8	74°	4	13
AB0ACB		EJA810	7413	40,000	415	110.1	248°	5	12
A77F26		UPS2964	6675	37,975	421	116.7	263°	4	21
A8E78D		N673HA	7476	43,000	487	119.5	321°	4	26
A7C764		N600BM	3734	22,000	210	122.3	225°	3	32
A129D9		UPS2686	6503	33,975	408	133.6	246°	4	21
AD2736		AAL1375	3177	36,000	379	134.4	224°	3	47
A240DC		SWA3467	3110	38,000	397	138.5	245°	6	13
AAA2D3		SWA3327	1776	38,000	386	142.8	256°	4	22
A0EC20		FDX3734	4042	38,000	417	151.5	258°	4	9
AD9811		AAL2470	5730	29,000	500	151.7	88°	4	22
ABB995		SWA980	1755	35,000	486	158.1	58°	4	10
A07F6A		FDX3951	2612	34,025	437	170.1	254°	5	3
A704C7		N551SW	5707	41,000	520	187.4	85°	5	22
A1D93B		SWA2029	2020	39,000	494	224.2	86°	4	30
A317BA		ENY3977	1652	35,000	469	231.3	106°	4	6
AC2706		UAL2103	6531	37,025	437	249.7	151°	3	28
AD01AB		N937WN	6552	21,075 ▲	292		255°	5	38

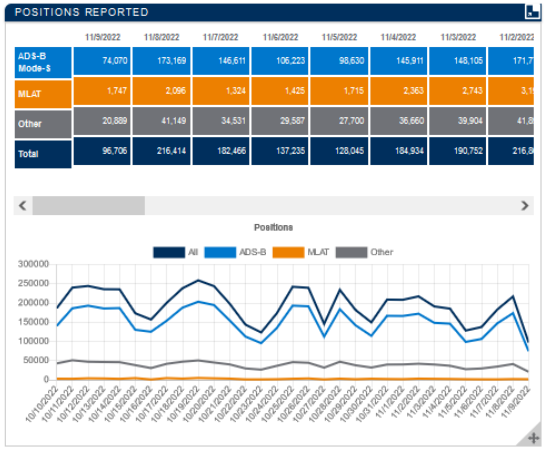
FLIGHTAWARE FEEDER STATS

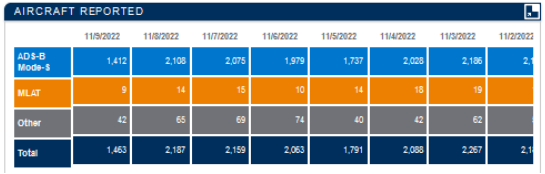


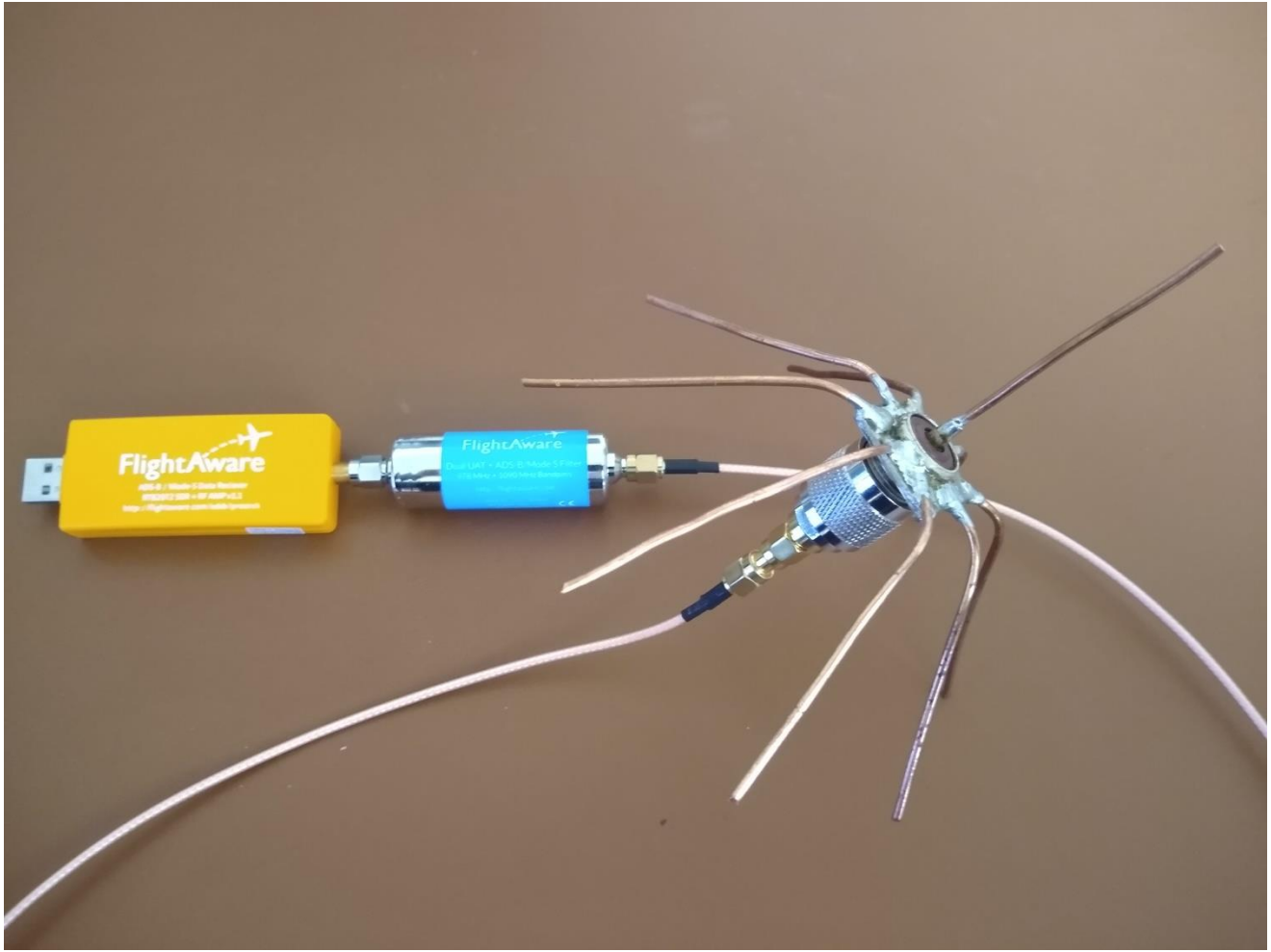












W8TLM
Amateur Radio Club

BENEFITS OF FLIGHT FEEDING

- **FlightAware Enterprise Account or flightradar24 Business Account**
- **When you see a contrail or the actual aircraft you can figure out who they are and where they are going**

ANOTHER DEMO?

OPENWEBRX

OPENWEBRX

Linux based but you don’t need to be a Linux expert

Runs on Raspberry Pi (3 or 4)

- More powerful computers required when more users are accessing via web server

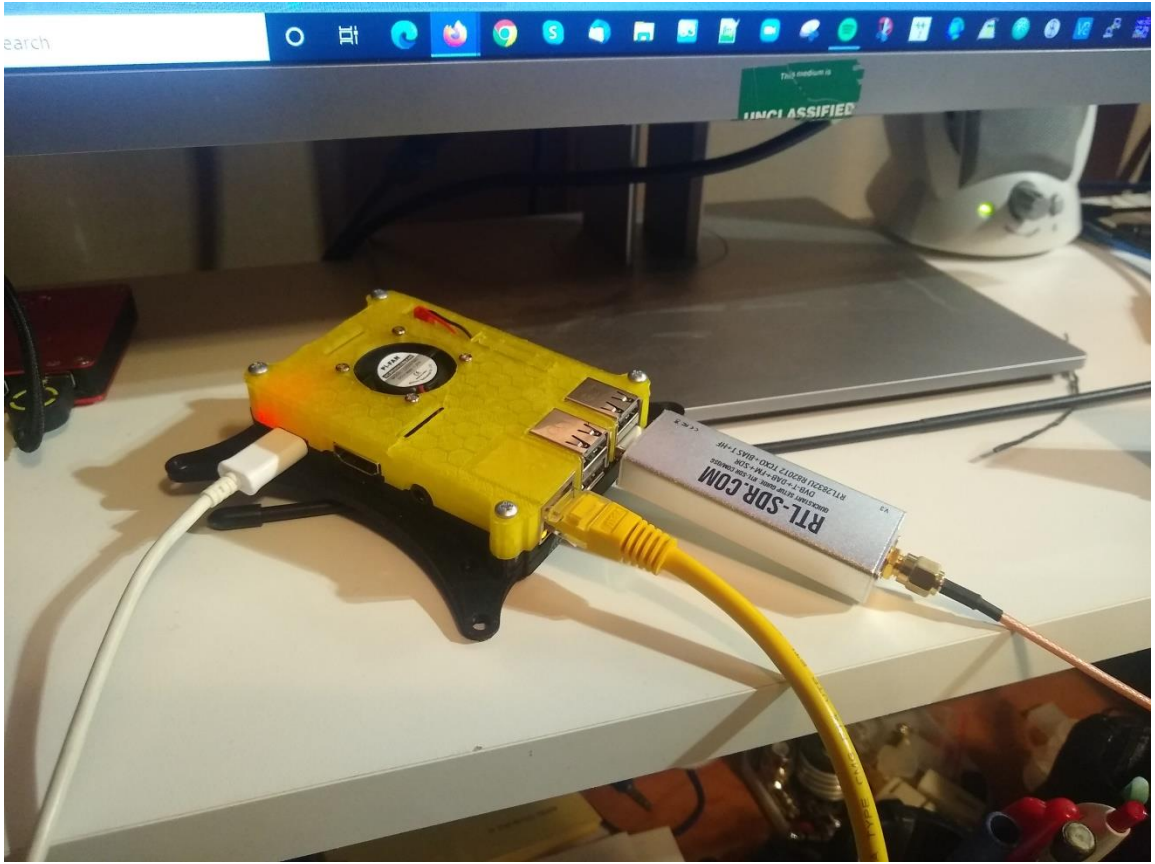
Interface via webserver

- Access from any computer with a web browser (laptop (Windows), notepad)
- May be opened to wider web beyond your home network

Lots of decoders available

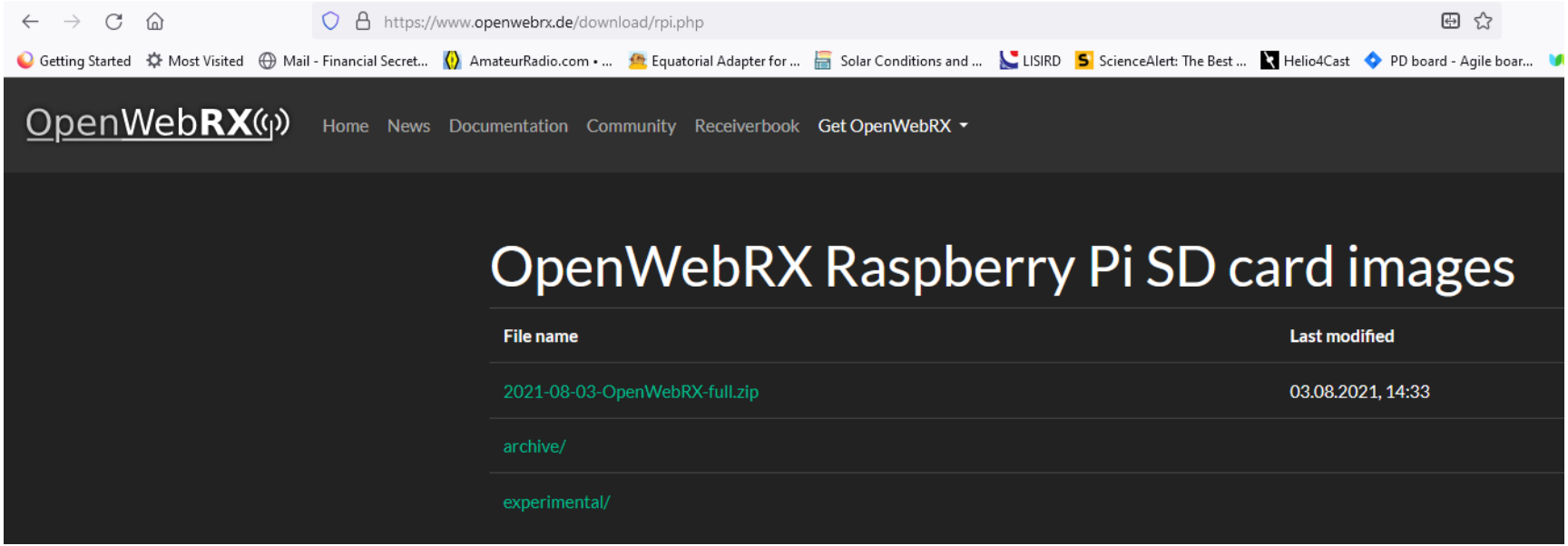
Detailed installation instructions for Raspberry Pi available at
https://www.rmham.org/wp-content/uploads/2022/04/PracticalSDR.pdf

OPENWEBRX SETUP



OPENWEBRX SETUP

OpenWebRX image loaded on SD card



OPENWEBRX SETUP, CONT'D

Initial setup with monitor, keyboard & mouse

- Update & Upgrade RPi
- Run raspi-config to enable SSH and reset your password
- Setup an OpenWebRX admin account to enable management of OpenWebRX application https://github.com/jketterl/openwebrx/wiki/User-Management
- Run ifconfig to determine IP address of RPi

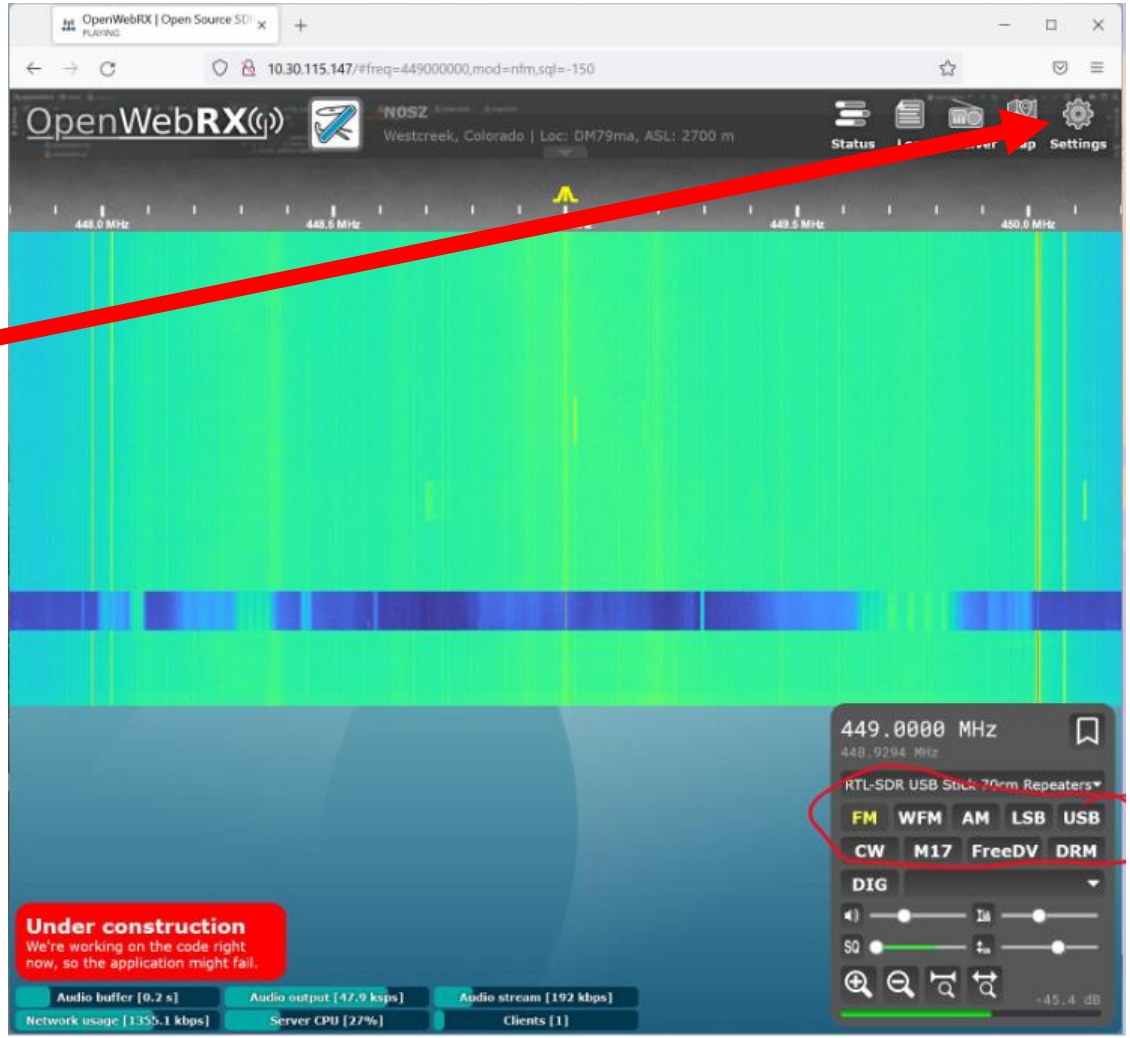
If you have comm program (e.g., Putty) for Windows computer you can now run the RPi "headless"

Lots of YouTube videos to help you

WEB APPLICATION

Set up custom receiver

- Select Center Frequency
- Sample Rate
- Starting Frequency
- RF Gain

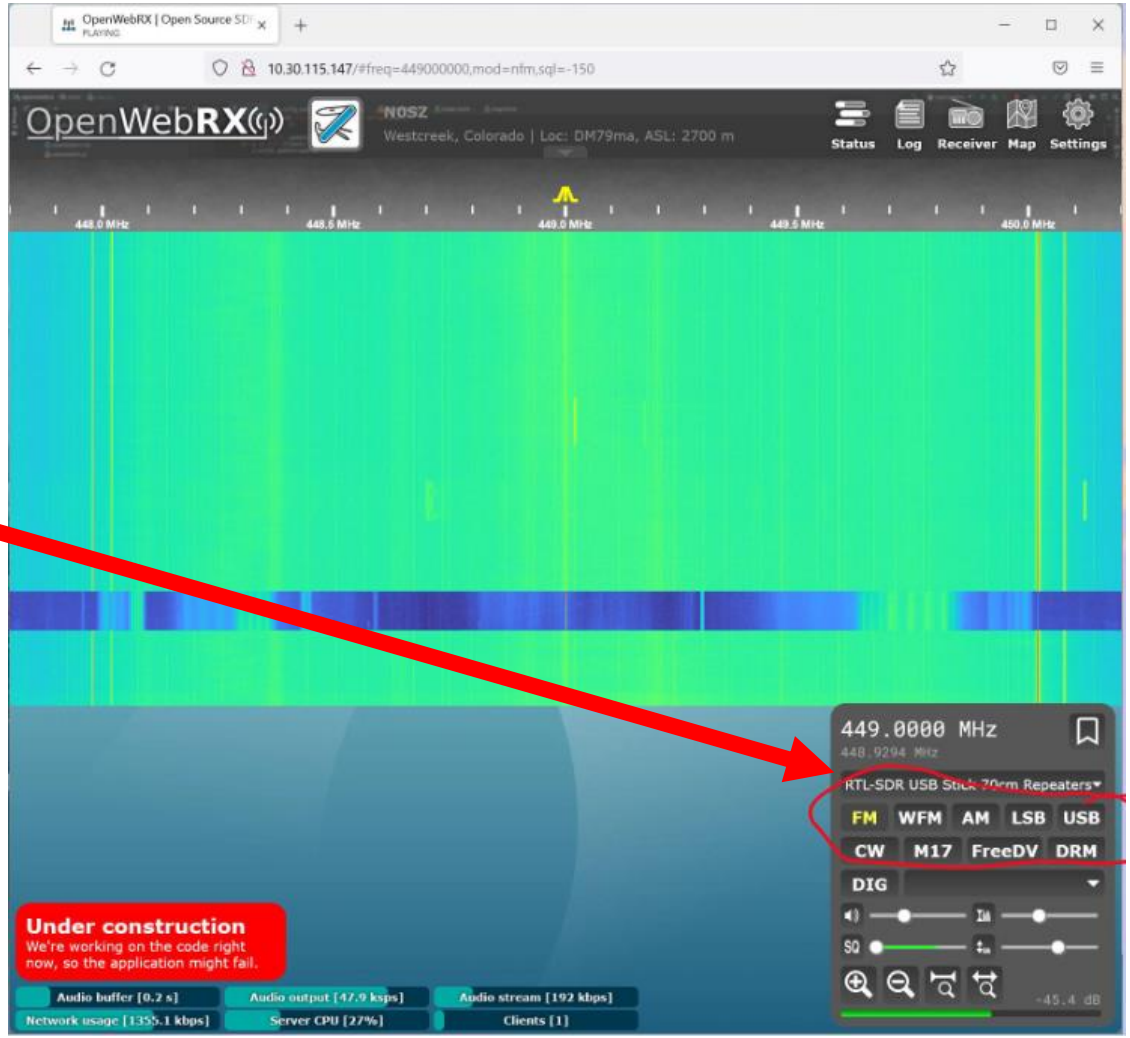


WEB APPLICATION

Select the receiver you just set up

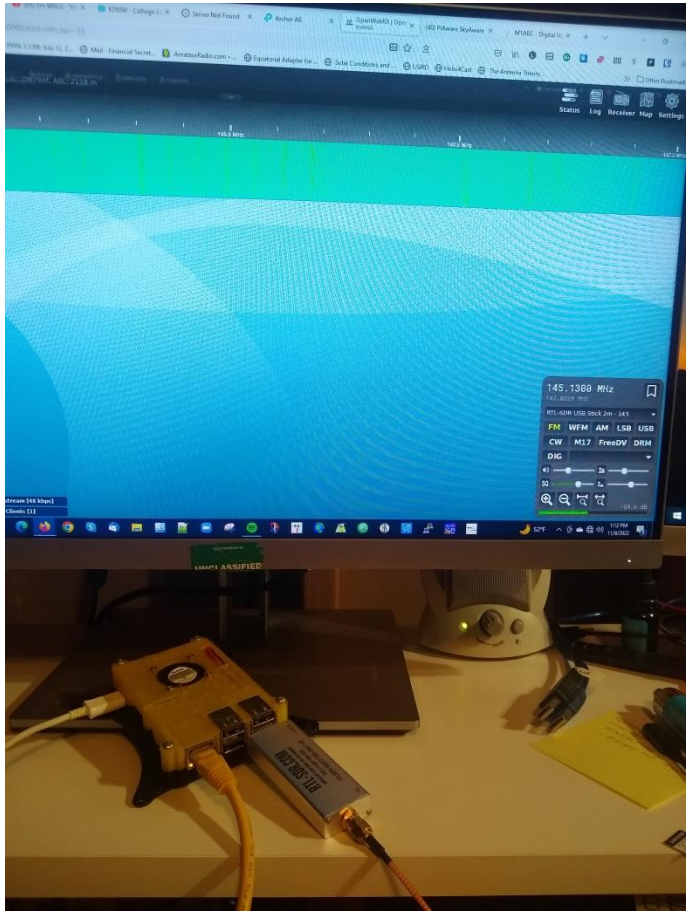
Select mode

Note digital modes available!



OPENWEBRX DEMO?

- **If away from your home network you need to use a Dynamic IP manager**
  - No-IP
  - DNS Duck
  - FreeDNS
  - Numerous others



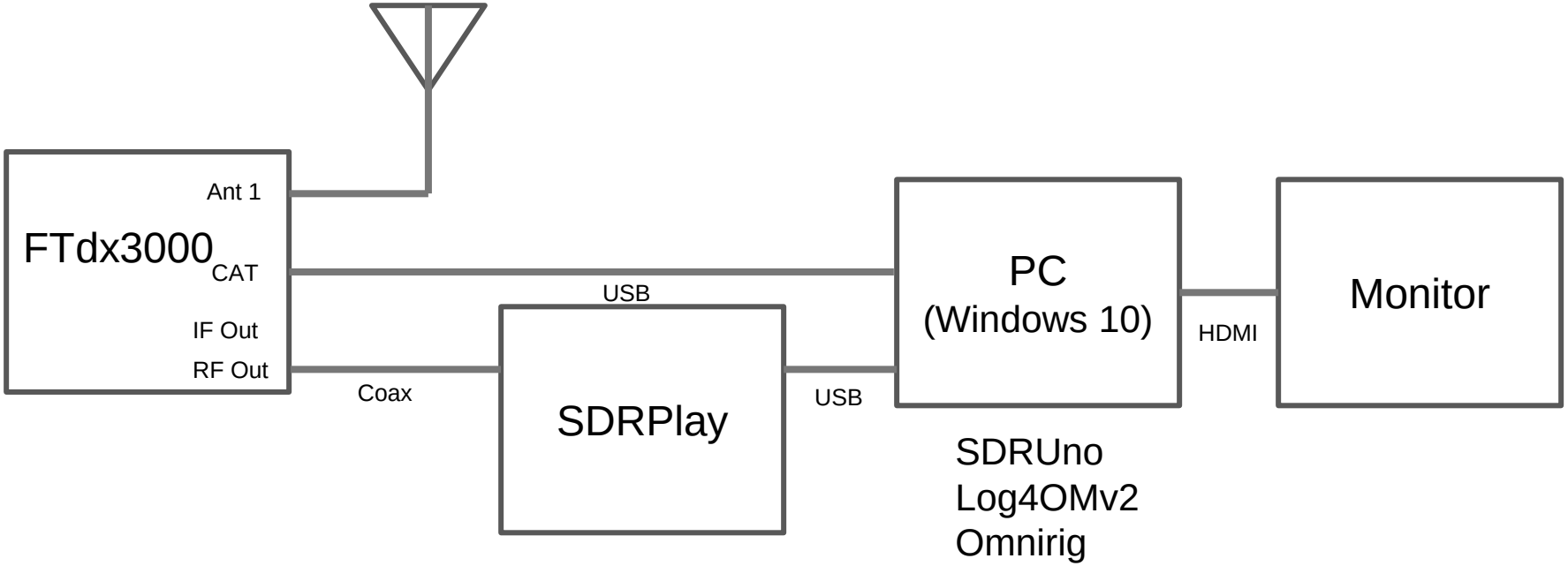
OPENWEBRX CONCLUSION

Why would I do this?

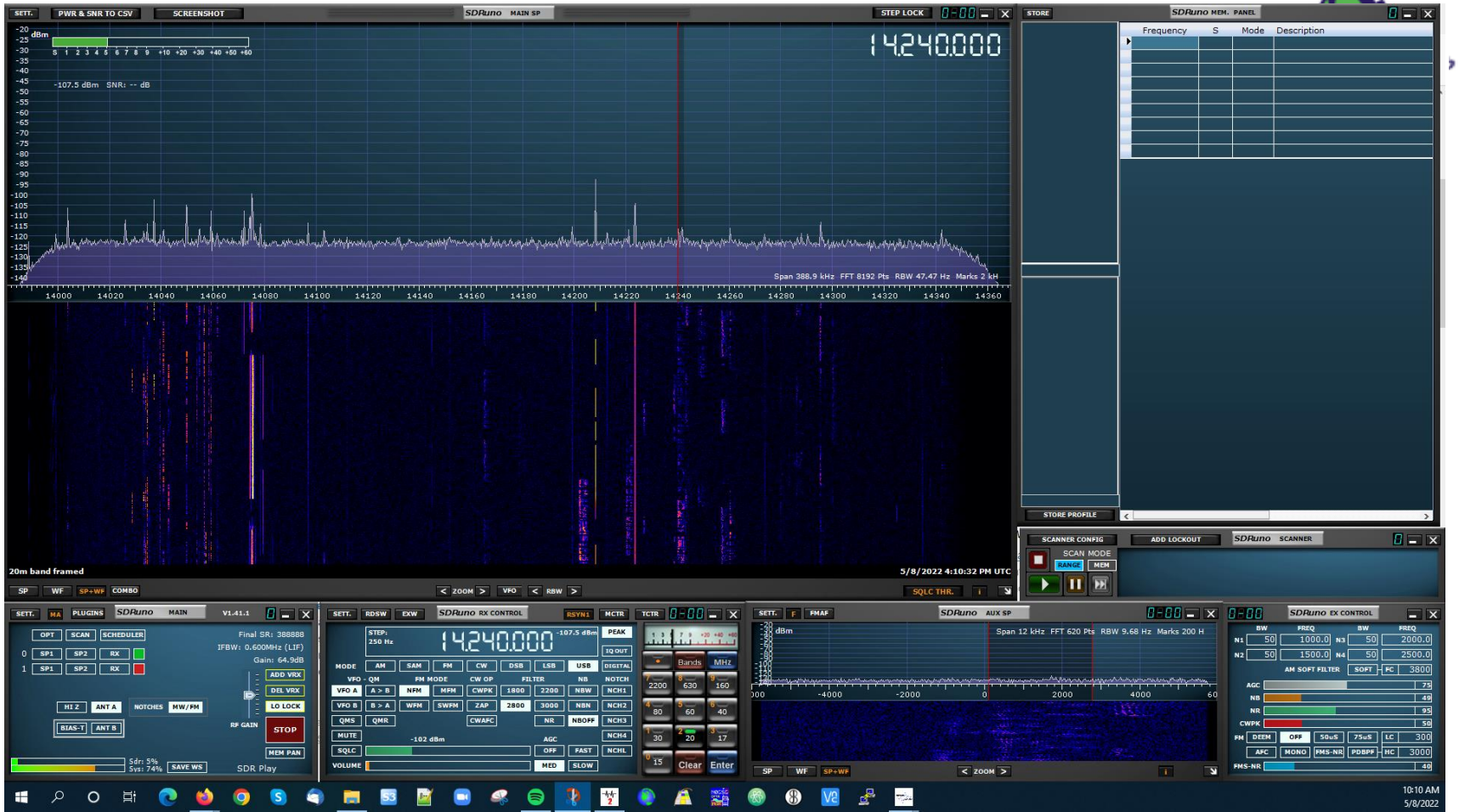
- **Observe local repeater activity without needing to scan**
- **Listen to activity from my recliner on phone or tablet without carrying HT (which has lousy coverage in my house)**
- **Does not need to be configured for public access within range of your home WiFi**

SDRPLAY AND SDRUNO WITH FTDX-3000

PANADAPTER CONFIGURATION



SDRUNO WITH FTDX-3000



FTDX-3000 PANADAPTER

Using RF or IF output from rig eliminates need for a TR switch to protect SDR. FTdx-3000 takes care of this. Pay special attention to this!!! You may need a TR switch to prevent blowing up your SDR

- RFout has wider bandwidth than IFout so entire band can be seen

SDRuno & Omnirig provide rig control

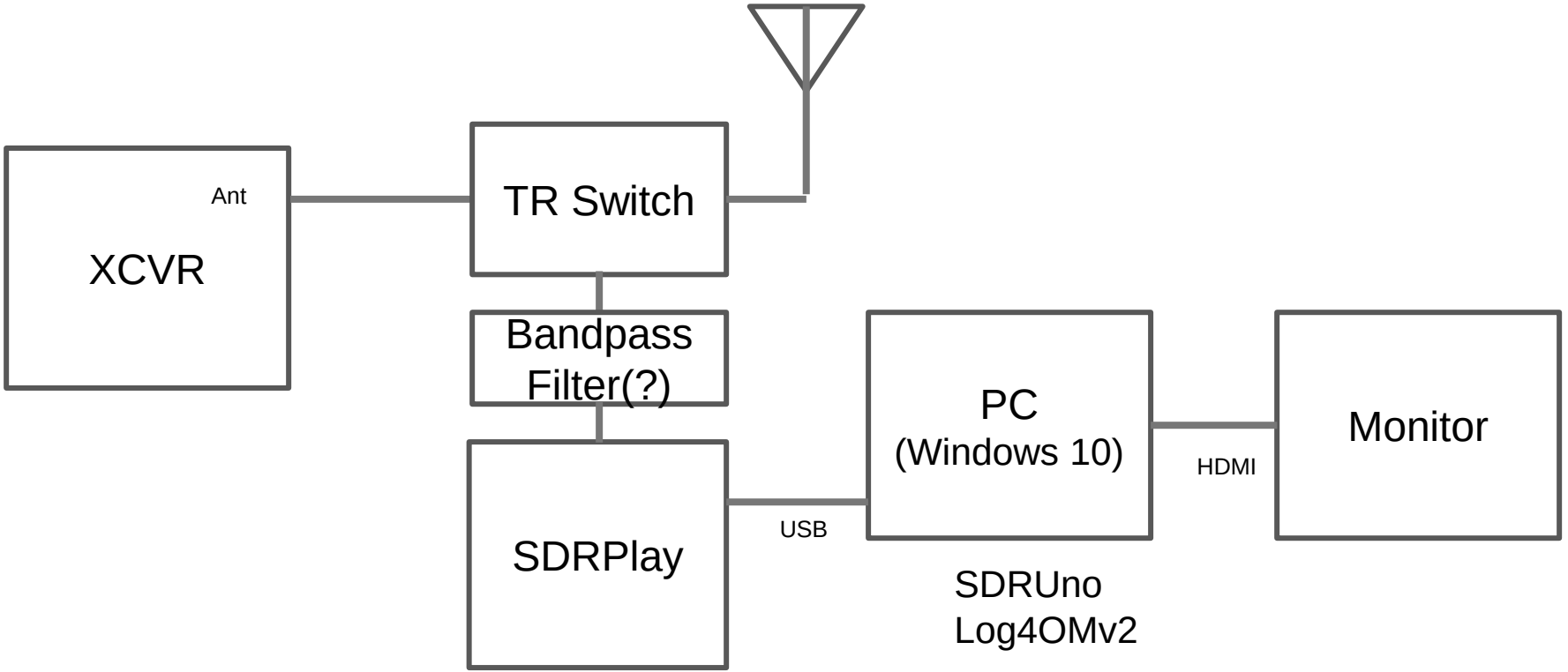
- I seldom touch the tuning knob or mode button
- Tune with mouse click on signal and fine tuning with mouse wheel

Easily adaptable to any rig with CAT interface

- If CAT I/F not available you need a TR switch and possibly bandpass filters

Logging software (Log4OM) automatically receives frequency and mode information making log entry easy

PANADAPTER CONFIGURATION WITHOUT SWITCHED XMIT & CAT I/F



GNURADIO

GNURADIO

Software Radio Ecosystem

Open-source software development toolkit that provides signal processing blocks to implement software radios

Written in Python

- Can be ported to microcontrollers avoiding need for a heavy operating system (e.g., Windows or Linux)

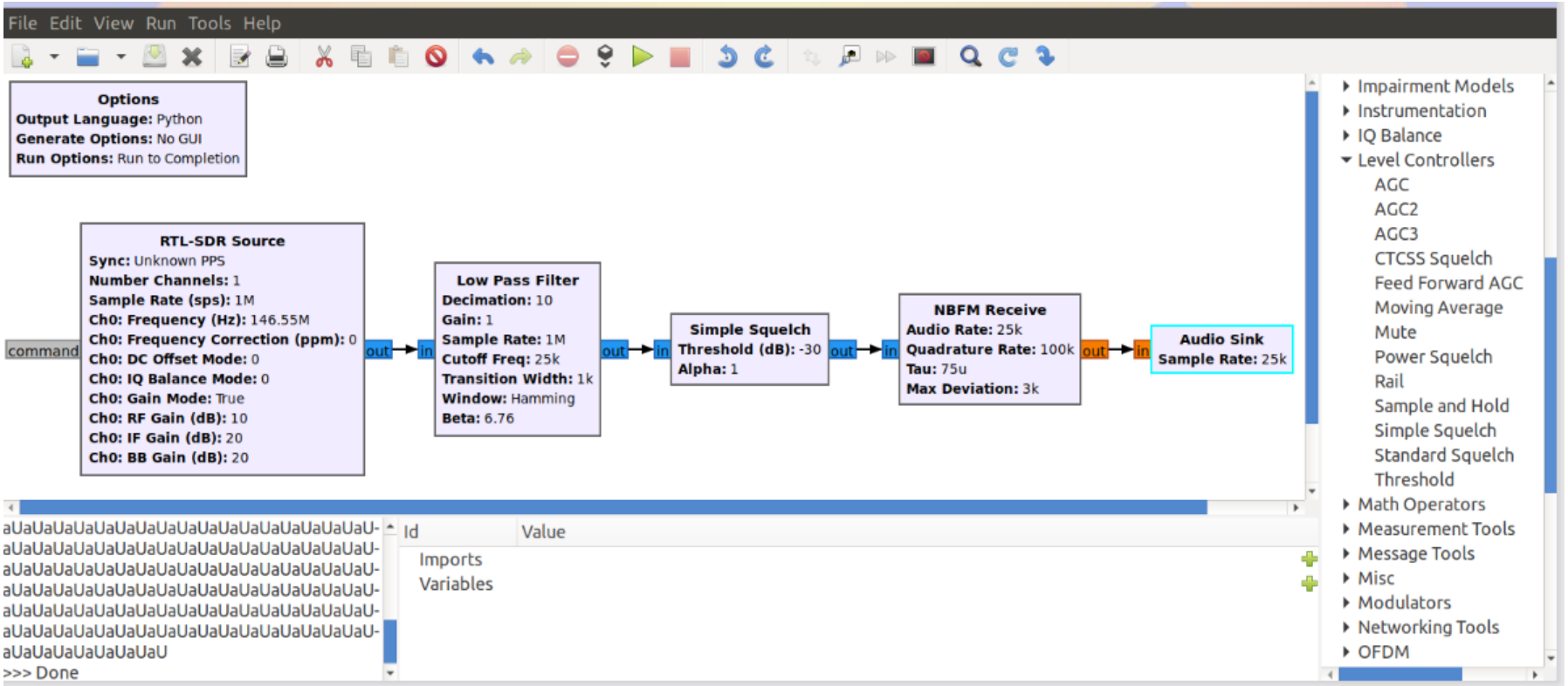
https://www.gnuradio.org/

GNU Radio Companion – GUI to manipulate signal processing blocks

Using GNU Radio Companion Part 1 YouTube video

https://www.rmham.org/wp-content/uploads/2022/04/gnuradio.pdf

GNURADIO COMPANION – 2M NBFM RECEIVER



BROADCAST RECEIVER