

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

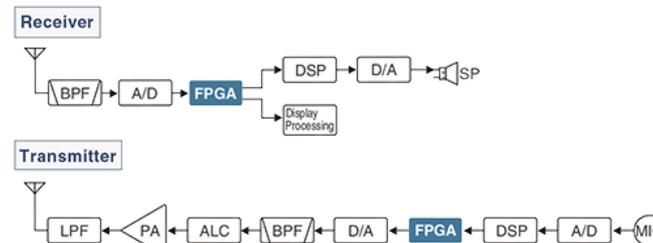
New technology is changing the way receivers are being designed and the IC-7300 is an industry first as an RF, Direct Sampling System is being used in an entry level HF radio. The ability to digitize RF before various receiver stages reduces the inherent noise that is generated in the different IF stages 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

 FlexRadio [Products](#) [Software](#) [About Us](#) [Support](#) [Community](#)

[← ALL RADIOS](#)

FLEX-6700 Signature Series SDR Transceiver

FlexRadio Systems
SKU: FLEX-6700

*Please allow up to 6-8 weeks for shipment.
Payment(s) will not be processed until an order
has been shipped.*

\$7,499.00

-  FLEX-6000 GPSDO Upgrade [+ \$749.00]
-  Rock Mount for FLEX-6500 and FLEX-6700
-  KNB-FlexControl USB Controlled Tuning Knob
-  FLEX-6700 Extended Warranty [+ \$750.00]

Quantity:

[+ WISHLIST](#)

[ADD TO CART](#)



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

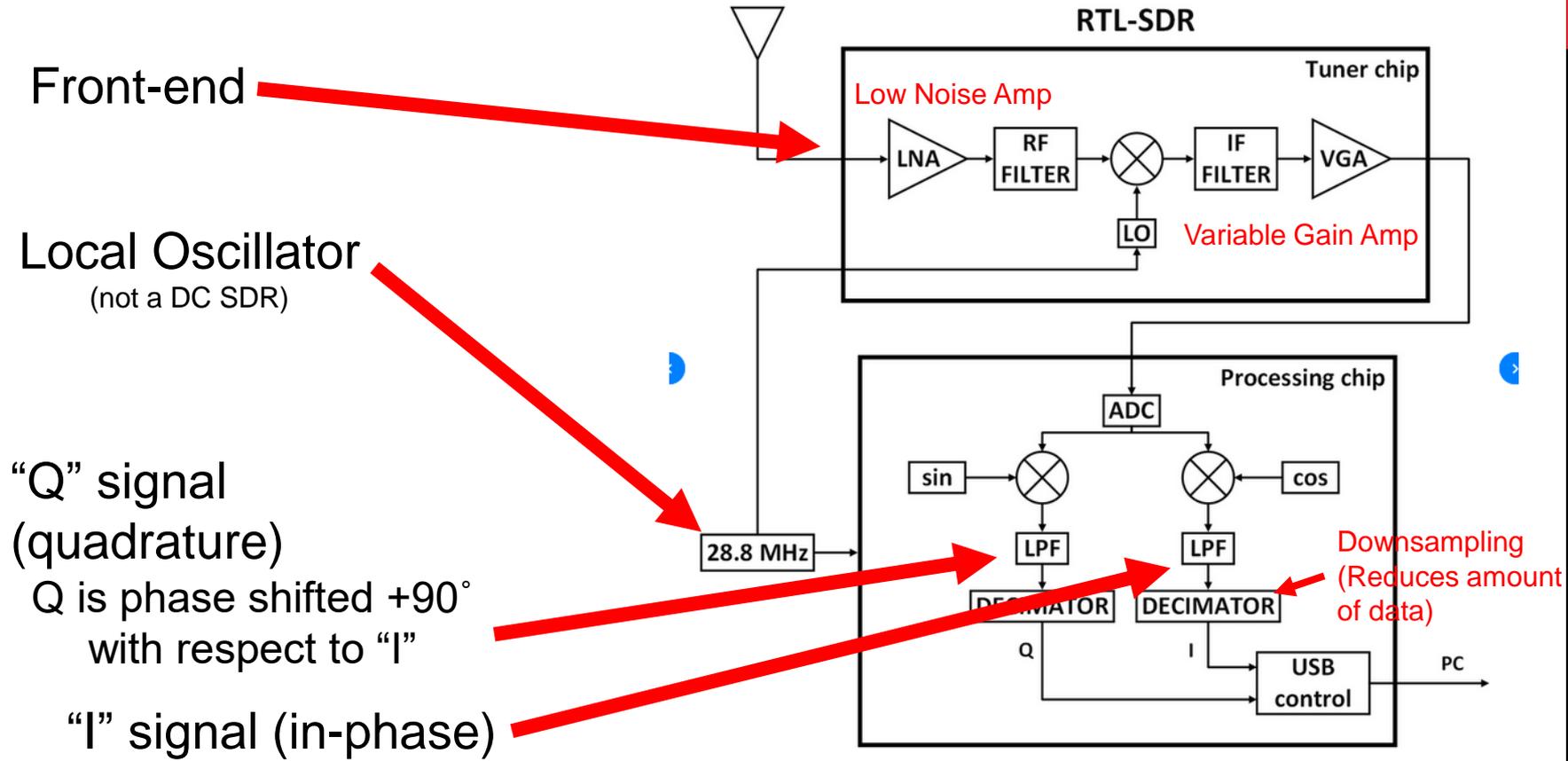
Nyquist Sampling Theorem

- (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



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.

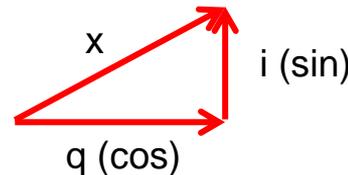
Demodulation equations are easily handled by DSP

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

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



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

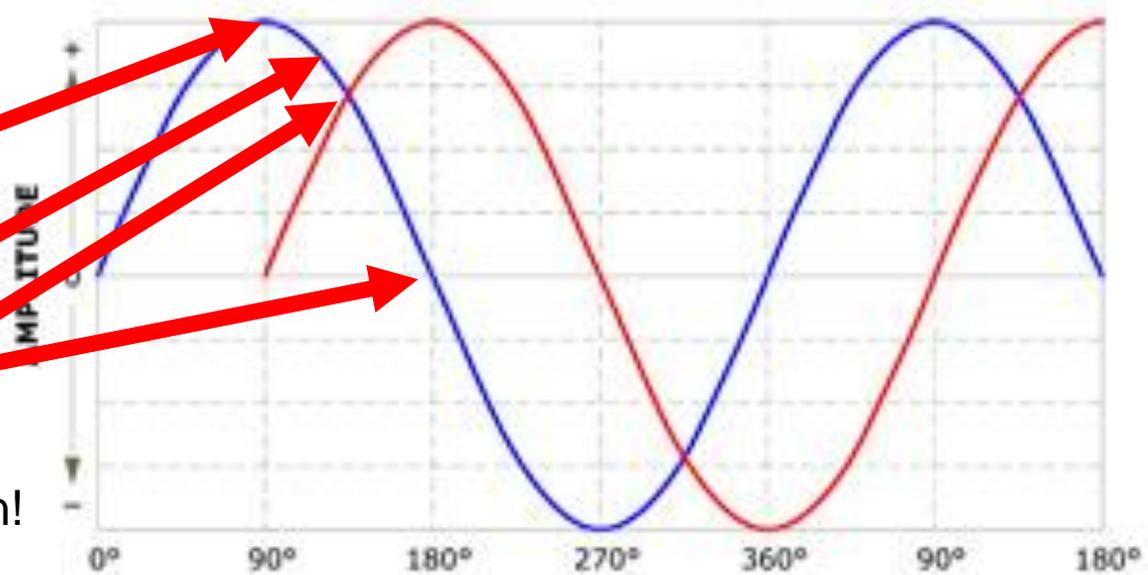
$$90^\circ: I = 1, Q = 0, X = 1$$

$$120^\circ: I = .5, Q = .866, X = 1$$

$$135^\circ: I = .707, Q = .707, X = 1$$

$$180^\circ: I = 0, Q = 1, X = 1$$

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



Contact a dealer
+1 252 774 0722

Online SDR
Check your radio

Custom Engineering
Use our platform

Purchase Now!



SDR Software Download

Global Radio Guide Winter 2021-2022

During times of emergency and crisis, radio hobbyists worldwide turn on their radios and tune to the shortwave radio spectrum for context, perspective, and insight into what is happening around the globe. As tensions heat up in the world's hotspots, you can follow these events on the radio, but you need an accurate and comprehensive radio guide to know where and when to tune in to hear the action. If you are using our SDRs to navigate the spectrum, you will definitely like the **Global Radio Guide** from our friends at **Teak Publishing**.



Software Defined Radio Package (Change log)

Download

This package contains:

- SDR# (SDRSharp) **revision 1855** (2022-03-26) - The best free SDR software for Airspy and RTL-SDR dongles!
- Airspy drivers
- HackRF driver
- USRP driver
- RTL-SDR driver (manual installation script)

If you are looking for the last unskinned SDR# build, check here. For the latest SDR# build with collapsible panels check here. For the latest dotnet 4.x build (1784) check here. These packages also contain the legacy hardware support tools. The last dotnet 5.x build (1831) can be found here.

SDR# SDK for Plugin Developers

Download

This package contains a zero-setup Visual Studio 2022 solution with a few plugin examples from the main software distribution. These examples illustrate the Graphical and DSP APIs in many scenarios along with full

SDR#

Install Driver

Installs SRDLL.dll

Insert RTLSDR USB

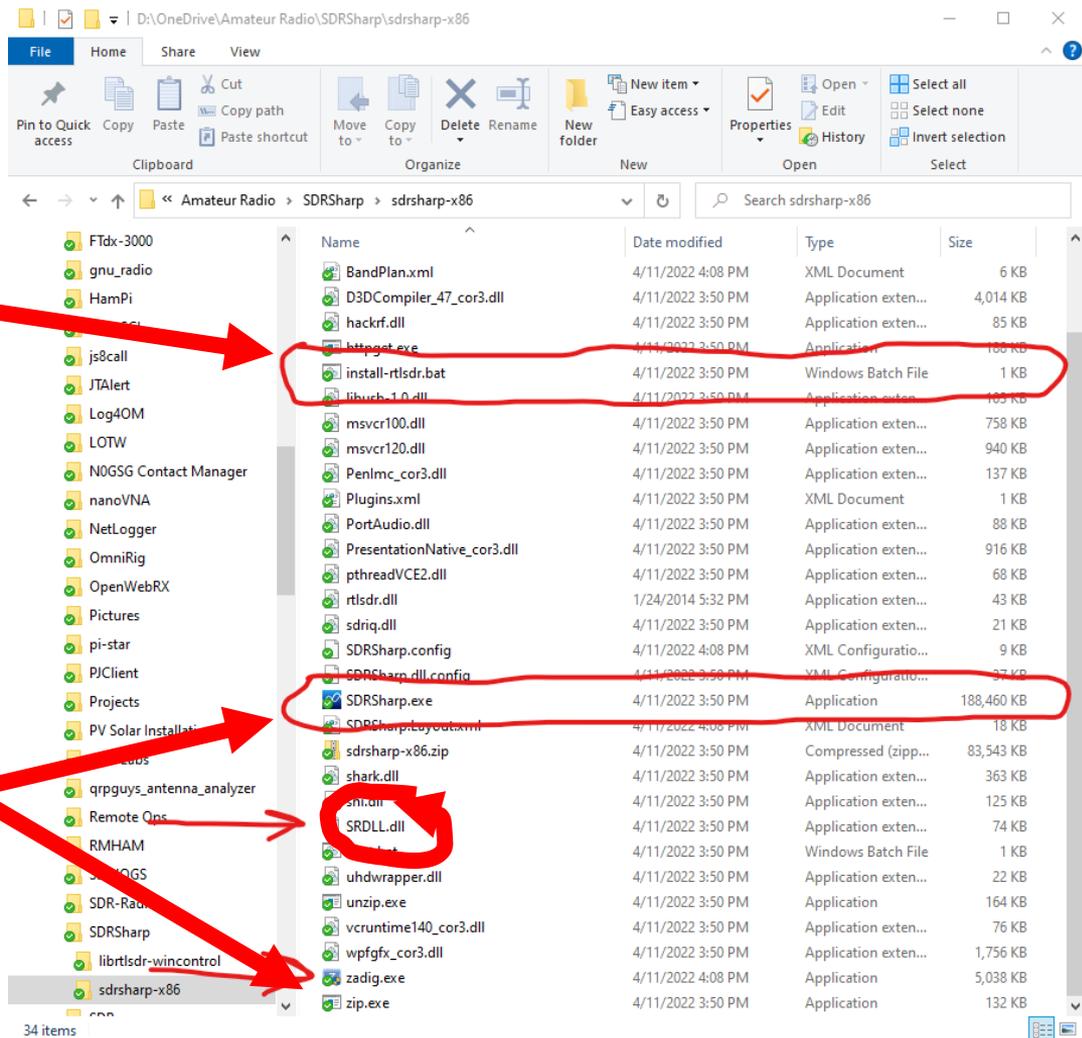
Windows installs driver that SDR# can't use

Run zadig.exe

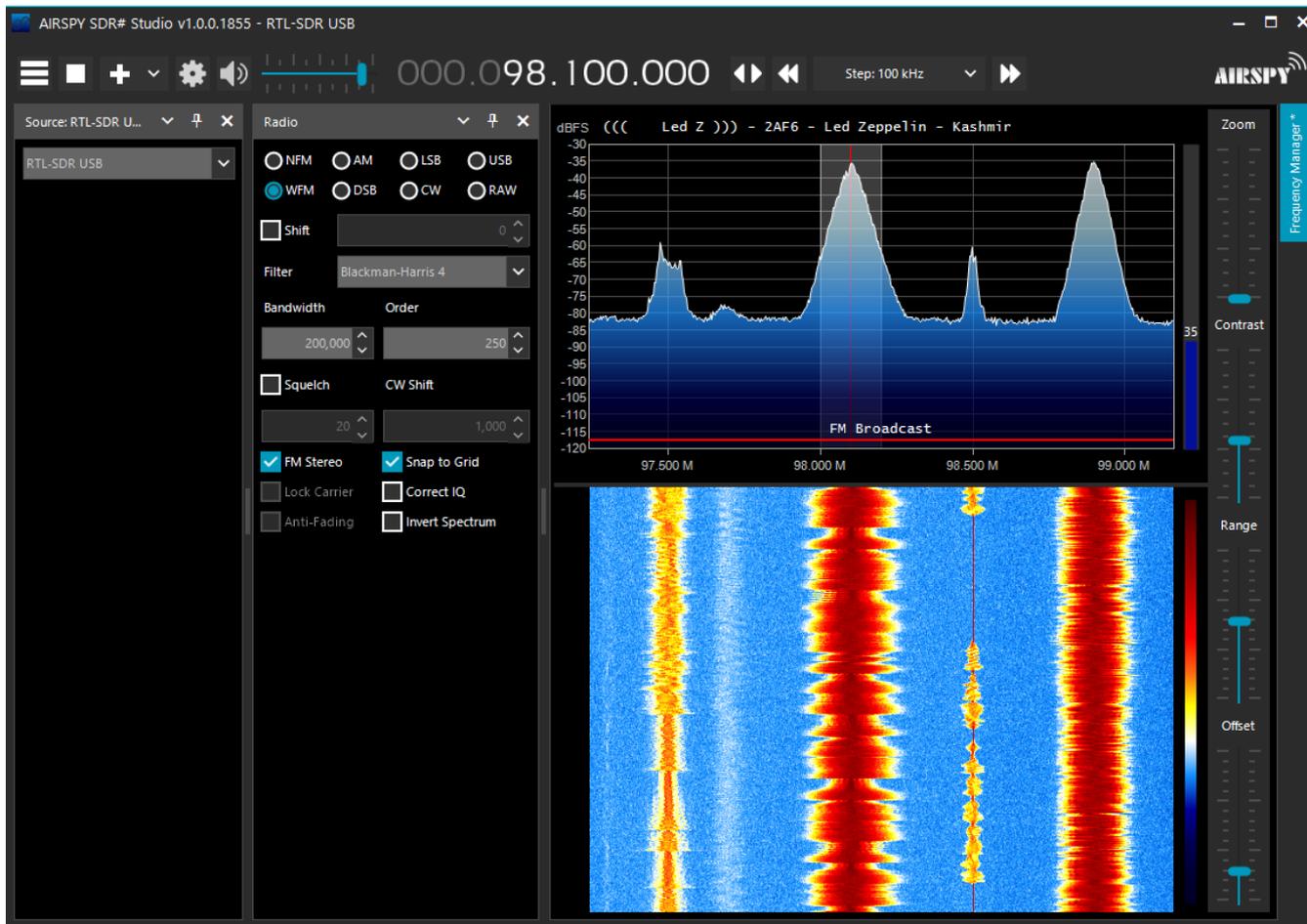
Replace driver

See [YouTube](#) video

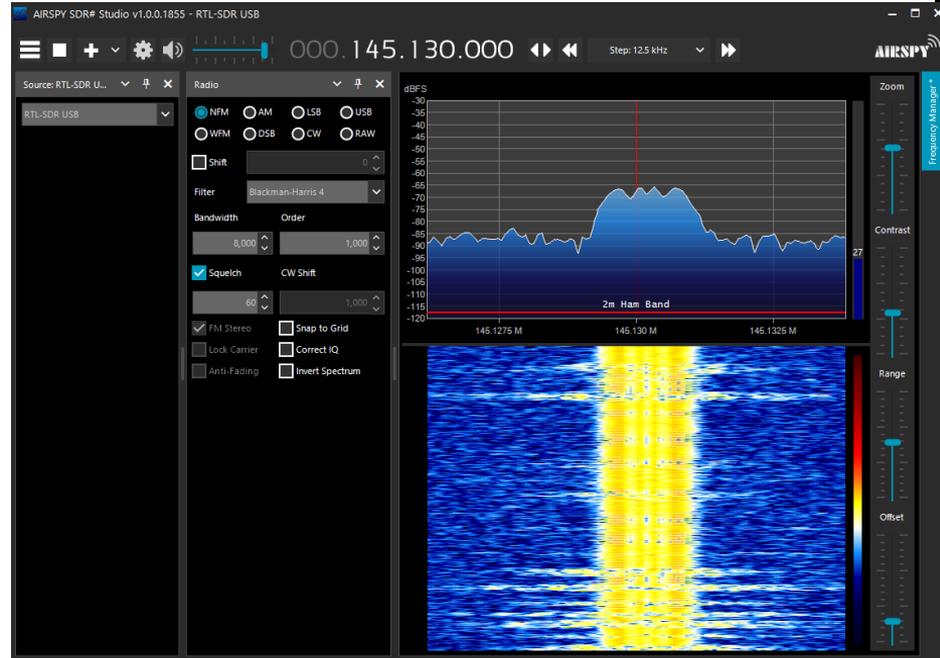
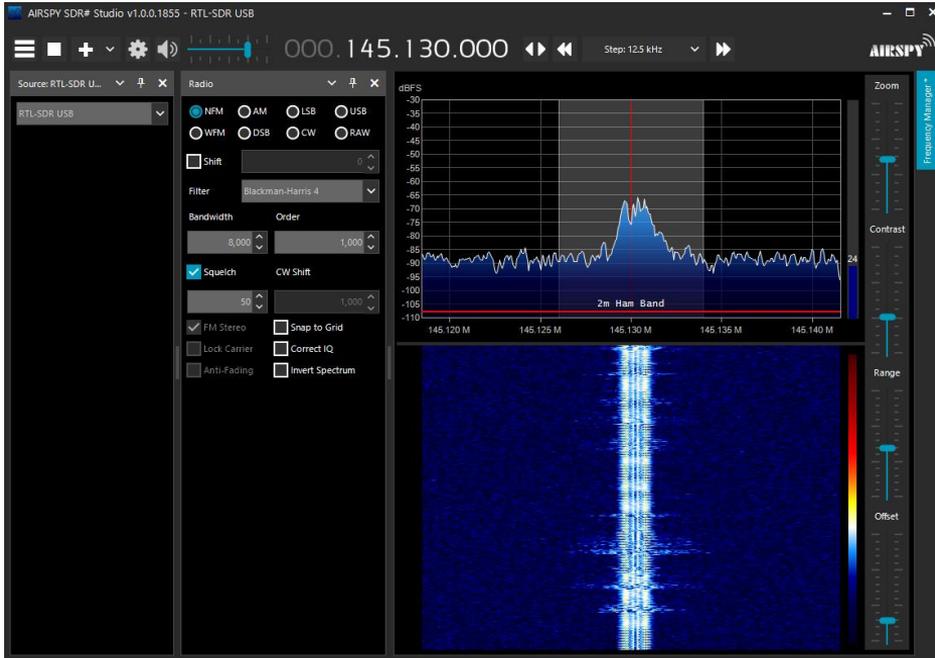
Run SDR#



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



flightradar24
LIVE AIR TRAFFIC

Apps Add coverage Data / History Subscription plans Social Press About Commercial services

Try free for 7 days Log in UTC 23:52

Most tracked flights **LIVE**

1. K4342/CMB342 **644** ✈️
Columbus (LCK) — Rzeszow (RZE)
2. TEAL73 **592** ✈️
Gulfport (GPT) — N/A

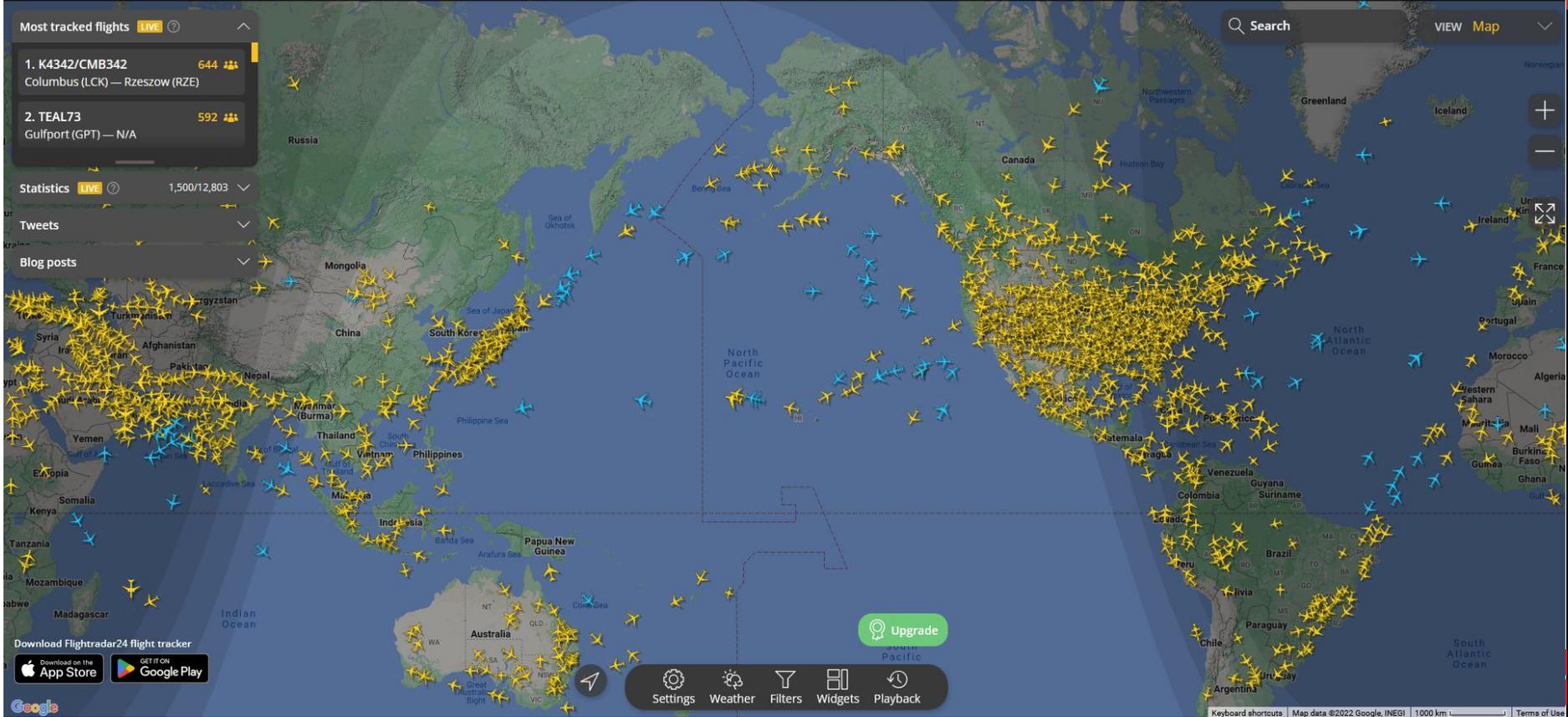
Statistics **LIVE** 1,500/12,803

Tweets

Blog posts

Search

VIEW Map



Download FlightRadar24 flight tracker



Upgrade
to Global Pacific

- Settings
- Weather
- Filters
- Widgets
- Playback

SKYAWARE ANYWHERE



FlightAware

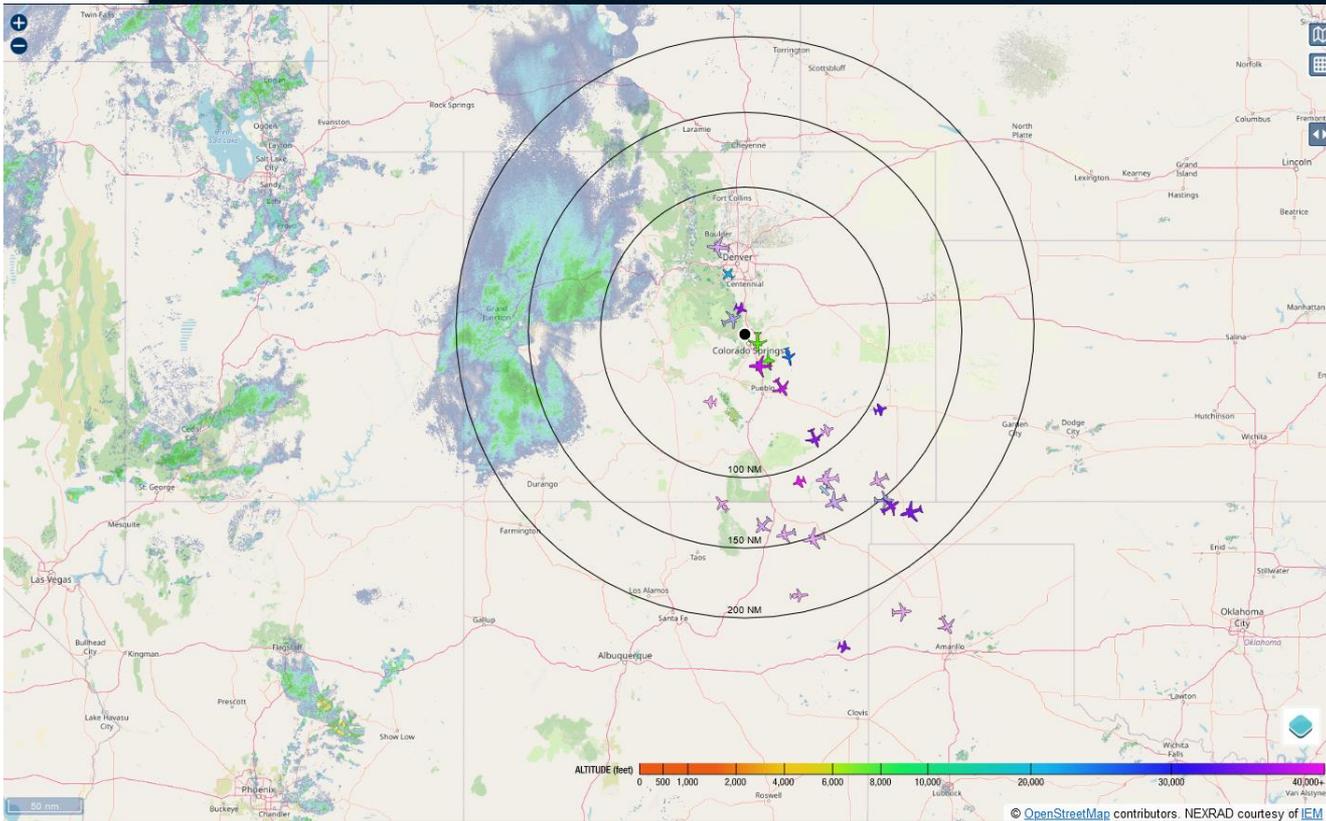
SkyAware *Anywhere*

11/9/2022, 4:48:32 PM

Reset Map

Show All Tracks

Hide All Tracks



Total Aircraft: 30
With Positions: 29

Messages: 1.7/sec
History: 214 positions

Filters (0 Enabled) Select Columns

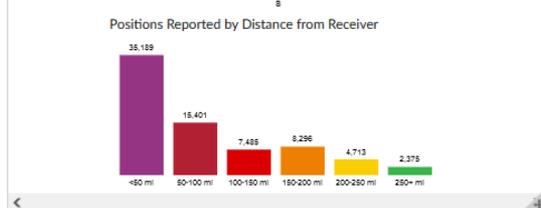
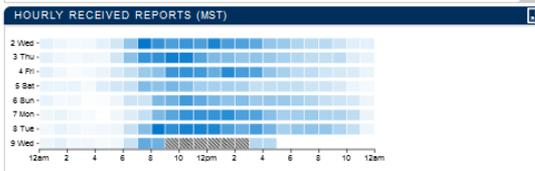
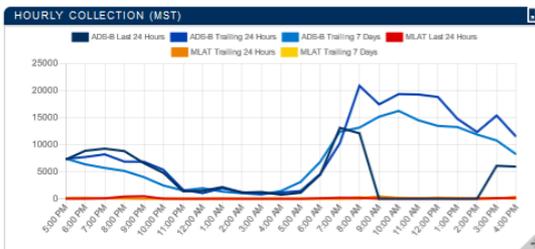
ICAO	Ident	Squawk	Altitude (ft)	Speed (kt)	Distance (NM)	Heading	Mags	Age	
AB2169	UAL2131	5162	7,175	135	10.4	180°	14	6	
A3708D	DAL1279	1366	31,000	541	13.9	67°	7	27	
ADABFD	JRE980	1462	35,725	▲	521	17.4	112°	12	8
A7FB70	N613RX	1200	7,225	▼	142	23.9	355°	12	8
A0C4A1	FDX3758	3732	37,975	381	24.6	271°	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	
A66AB4	SKW4060	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	
ABE78D	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	17	
A2400C	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	
A1D938	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	

ADS-B MLAT Other TIS-B



© OpenStreetMap contributors. NEXRAD courtesy of IEM

FLIGHTWARE FEEDER STATS



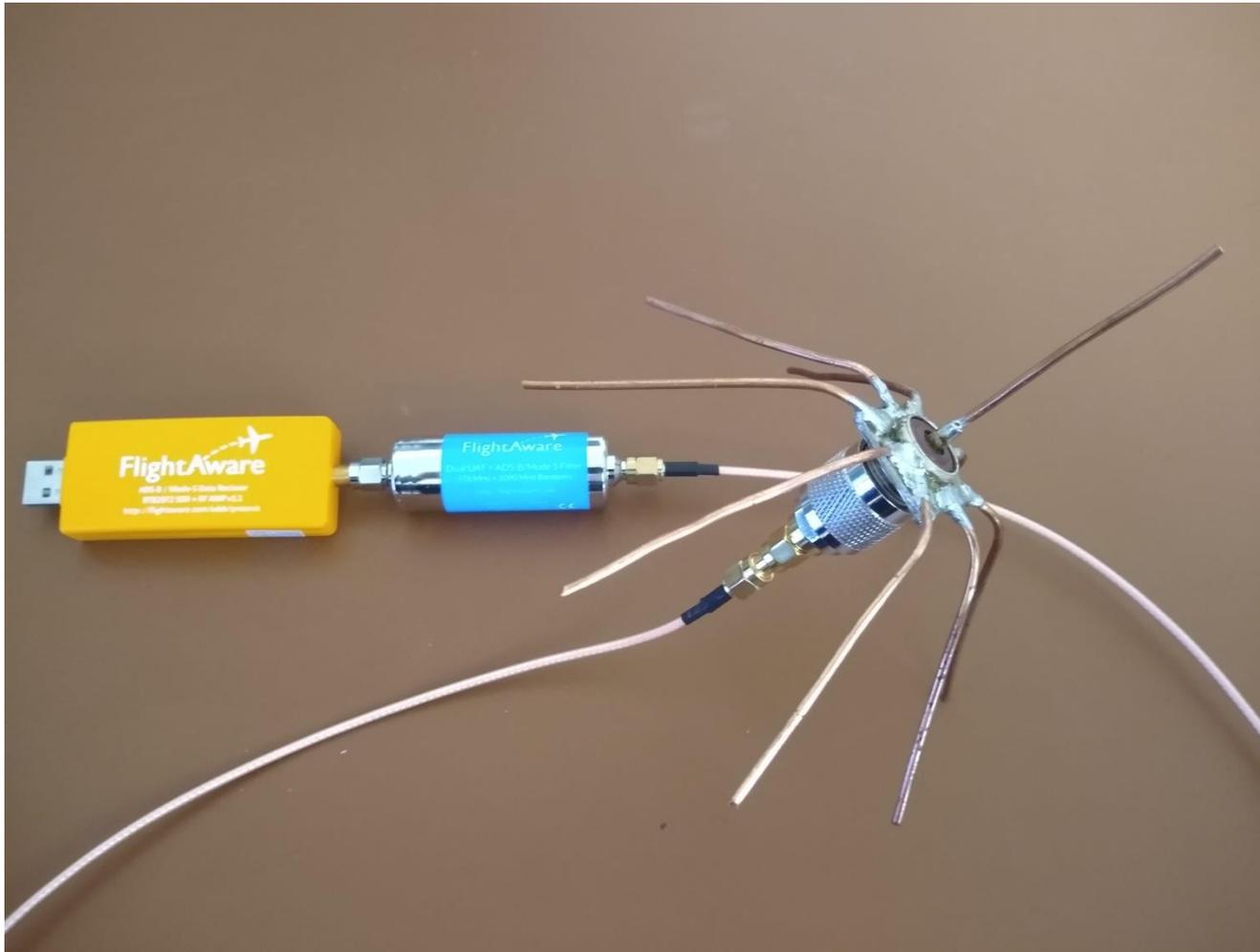
POSITIONS REPORTED

	11/9/2022	11/8/2022	11/7/2022	11/6/2022	11/5/2022	11/4/2022	11/3/2022	11/2/2022
ADS-B Mode-S	74,070	173,169	146,611	106,223	98,630	145,911	148,108	171,717
MLAT	1,747	2,098	1,324	1,405	1,715	2,363	2,743	3,111
Other	20,889	41,149	34,531	29,587	27,700	36,660	38,904	41,818
Total	96,706	216,414	182,466	137,235	128,045	184,934	190,752	216,646



AIRCRAFT REPORTED

	11/9/2022	11/8/2022	11/7/2022	11/6/2022	11/5/2022	11/4/2022	11/3/2022	11/2/2022
ADS-B Mode-S	1,412	2,108	2,075	1,979	1,737	2,030	2,186	2,111
MLAT	9	14	15	10	14	16	19	19
Other	42	65	69	74	40	42	62	62
Total	1,463	2,187	2,159	2,063	1,791	2,088	2,267	2,192



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

A screenshot of a web browser displaying the OpenWebRX website. The browser's address bar shows the URL "https://www.openwebrx.de/download/rpi.php". The website's navigation menu includes "Home", "News", "Documentation", "Community", "Receiverbook", and "Get OpenWebRX". The main heading on the page is "OpenWebRX Raspberry Pi SD card images". Below this heading is a table with two columns: "File name" and "Last modified".

File name	Last modified
2021-08-03-OpenWebRX-full.zip	03.08.2021, 14:33
archive/	
experimental/	

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

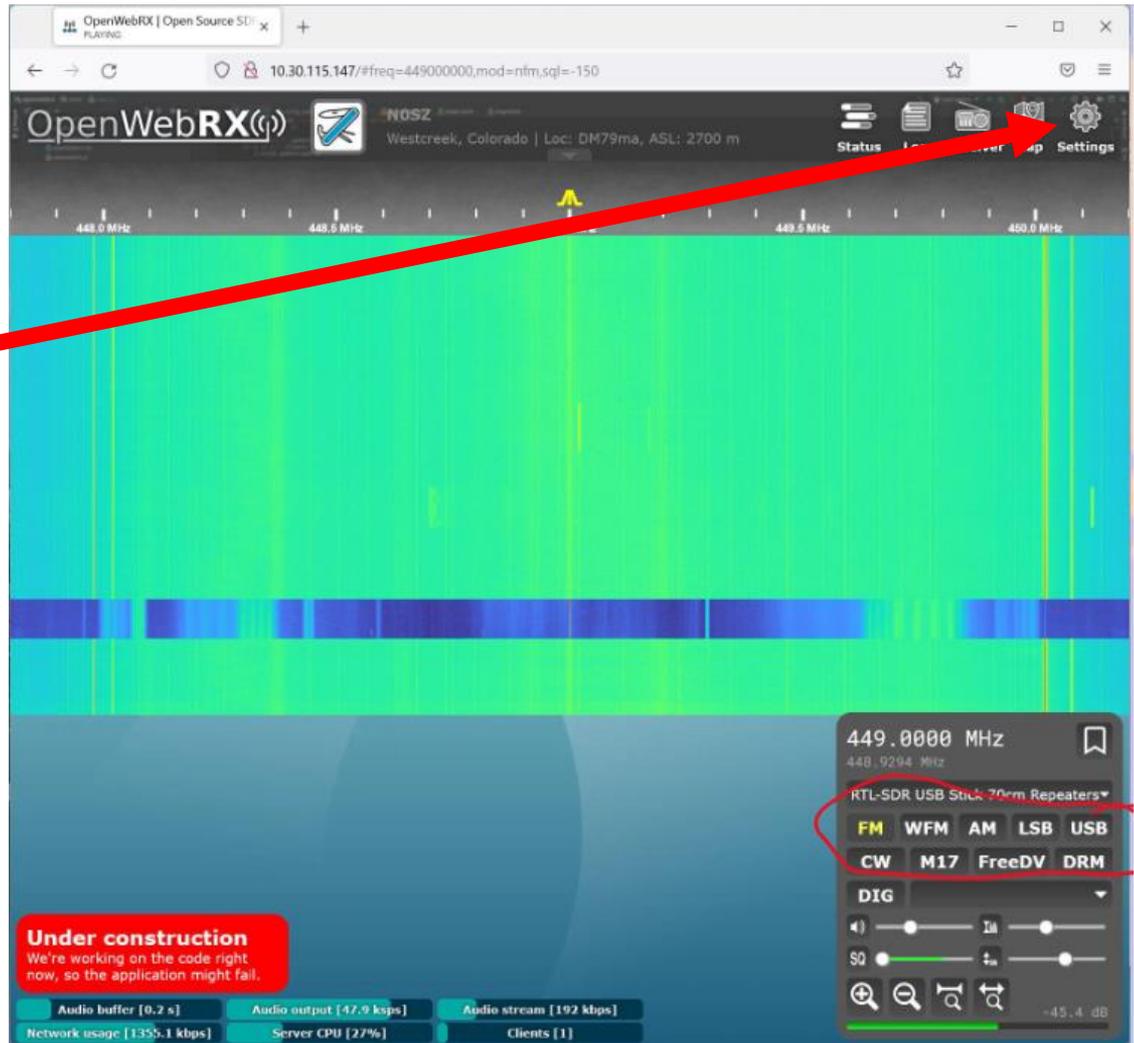
If you have comm program (e.g., Putty) for Windows computer you can now run the RPi “headless”

Lots of YouTube videos to help you

WEB APPLICATION

Set up custom receiver

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



The screenshot displays the OpenWebRX web application interface. The browser address bar shows the URL `10.30.115.147/#freq=449000000,mod=ntm,sql=-150`. The application header includes the OpenWebRX logo, a location indicator for 'Westcreek, Colorado | Loc: DM79ma, ASL: 2700 m', and navigation icons for Status, Log, and Settings. A red arrow points from the 'Settings' icon to the 'Settings' panel in the bottom right corner. The main area features a spectrum plot with a frequency range from 448.0 MHz to 450.0 MHz. A red circle highlights the 'Settings' panel, which shows the current frequency set to 449.0000 MHz and the device selected as 'RTL-SDR USB Stick 70cm Repeater'. The modulation mode is set to 'FM'. At the bottom, there is a red 'Under construction' warning box and a status bar displaying system metrics: Audio buffer [0.2 s], Audio output [47.9 kbps], Audio stream [192 kbps], Network usage [1355.1 kbps], Server CPU [27%], and Clients [1].

WEB APPLICATION

Select the receiver you just set up

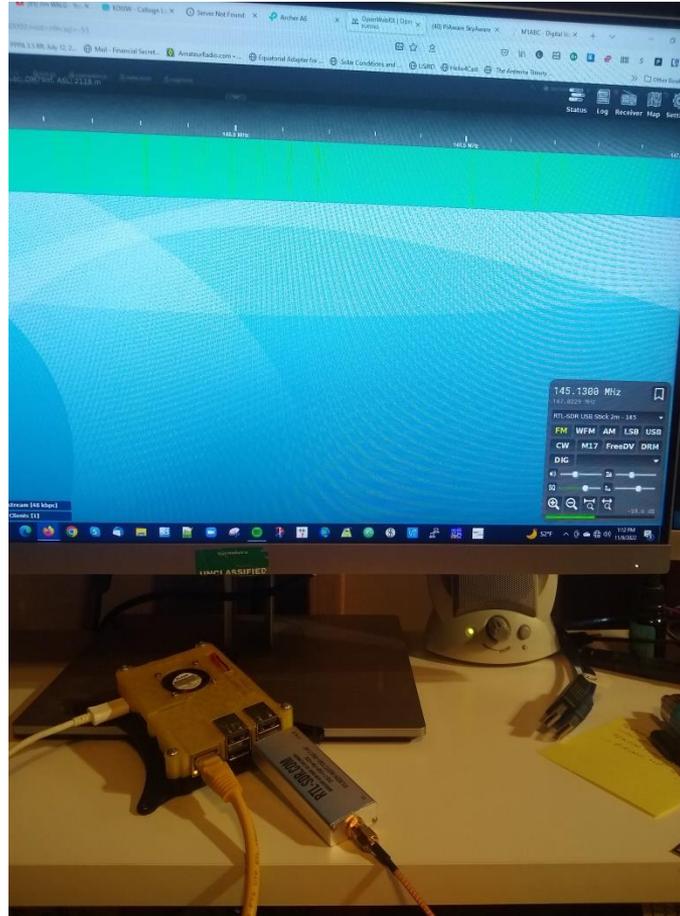
Select mode

Note digital modes available!

The screenshot displays the OpenWebRX web application interface. At the top, the browser address bar shows the URL `10.30.115.147/#freq=449000000,mod=ntm,sql=-150`. The application header includes the OpenWebRX logo, a location indicator for 'Westcreek, Colorado | Loc: DM79ma, ASL: 2700 m', and navigation buttons for 'Status', 'Log', 'Receiver', 'Map', and 'Settings'. The main area features a waterfall plot with a frequency range from 448.0 MHz to 450.0 MHz. A red arrow points from the text 'Select the receiver you just set up' to the 'RTL-SDR USB Stick 70cm Repeaters' dropdown menu in the control panel. The control panel shows the current frequency as 449.0000 MHz and offers various modulation modes: FM, WFM, AM, LSB, USB, CW, M17, FreeDV, and DRM. A 'DIG' dropdown menu is also visible. At the bottom, a red 'Under construction' banner states: 'We're working on the code right now, so the application might fail.' Below this, system status bars show 'Audio buffer [0.2 s]', 'Audio output [47.9 kbps]', 'Audio stream [192 kbps]', 'Network usage [1355.1 kbps]', 'Server CPU [27%]', and 'Clients [1]'.

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



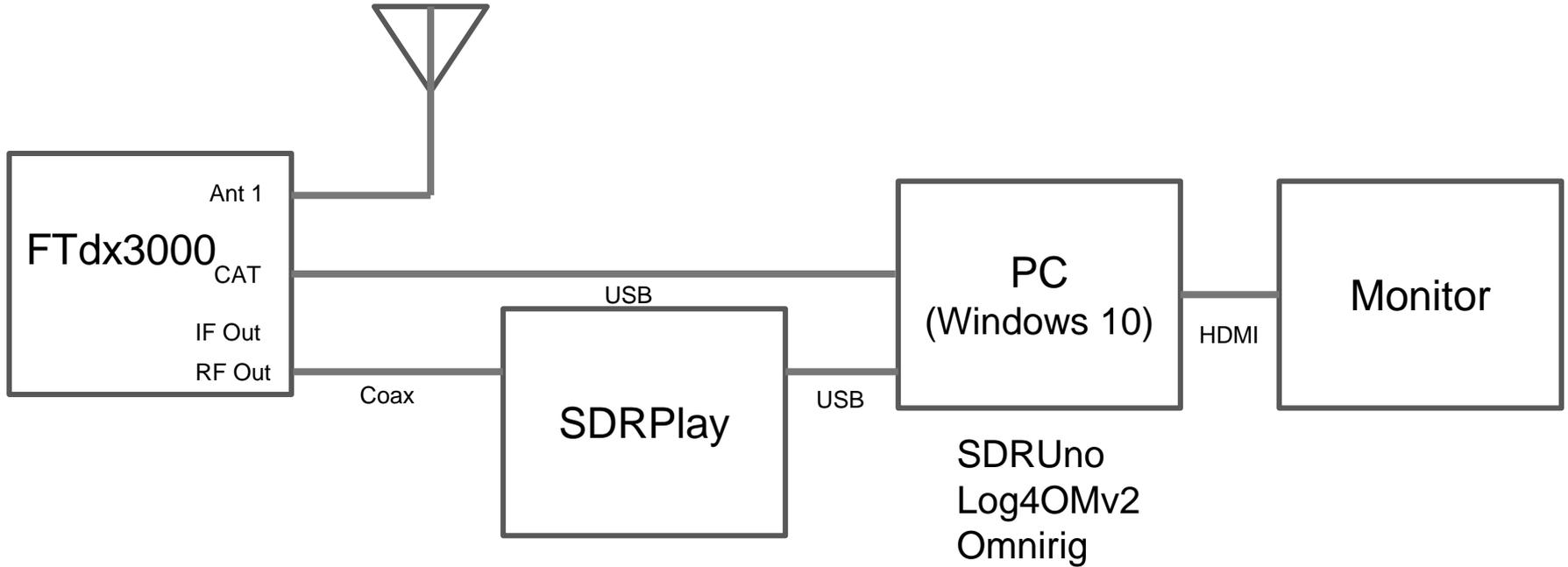
Why would I do this?

- **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



The screenshot displays the SDR# software interface with the following components:

- SDR# MAIN SP:** Shows a spectrum plot of the 20m band. The frequency range is from 14000 to 14960 kHz. The power scale is in dBm, ranging from -140 to -20. A signal is visible at 14.240 MHz, with a power level of -107.5 dBm and SNR of -- dB. The plot parameters are Span 388.9 kHz, FFT 8192 Pts, RBW 47.47 Hz, and Marks 2 kHz.
- SDR# MEM. PANEL:** A table for storing profiles with columns for Frequency, S, Mode, and Description.
- SDR# SCANNER:** A window for scanner configuration, currently in SCAN MODE.
- SDR# MAIN:** The main control panel for the SDR. It includes buttons for OPT, SCAN, SCHEDULER, and various filter and mode settings. The current mode is AM, and the frequency is 14.240 MHz. The signal strength is -107.5 dBm.
- SDR# RX CONTROL:** A panel for receiver control, showing the current frequency (14.240 MHz) and power level (-107.5 dBm). It includes settings for VFO, MODE, FILTER, and various receiver parameters.
- SDR# AUX SP:** A secondary spectrum plot showing a span of 12 kHz, FFT 620 Pts, RBW 9.68 Hz, and Marks 200 H.
- SDR# EX CONTROL:** A panel for external control, showing various settings for BW, FREQ, and other parameters.

The Windows taskbar at the bottom shows the system time as 10:10 AM on 5/8/2022.

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

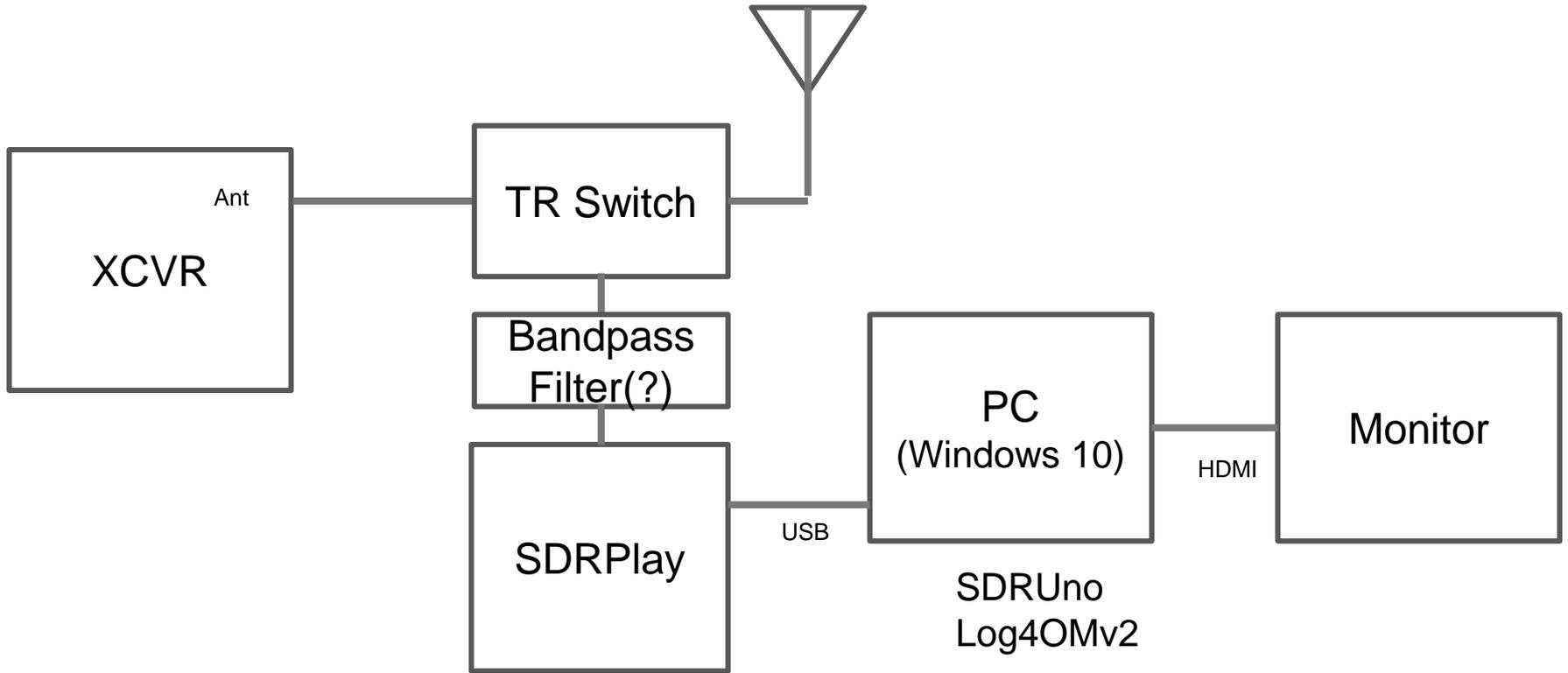
- I seldom touch the tuning knob or mode button
- Tune with mouse click on signal and fine tuning with mouse wheel

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



File Edit View Run Tools Help

Options
Output Language: Python
Generate Options: No GUI
Run Options: Run to Completion

RTL-SDR Source
Sync: Unknown PPS
Number Channels: 1
Sample Rate (sps): 1M
Ch0: Frequency (Hz): 146.55M
Ch0: Frequency Correction (ppm): 0
Ch0: DC Offset Mode: 0
Ch0: IQ Balance Mode: 0
Ch0: Gain Mode: True
Ch0: RF Gain (dB): 10
Ch0: IF Gain (dB): 20
Ch0: BB Gain (dB): 20

Low Pass Filter
Decimation: 10
Gain: 1
Sample Rate: 1M
Cutoff Freq: 25k
Transition Width: 1k
Window: Hamming
Beta: 6.76

Simple Squelch
Threshold (dB): -30
Alpha: 1

NBFM Receive
Audio Rate: 25k
Quadrature Rate: 100k
Tau: 75u
Max Deviation: 3k

Audio Sink
Sample Rate: 25k

command

Id	Value
Imports	
Variables	

>>> Done

- Impairment Models
- Instrumentation
- IQ Balance
- Level Controllers
 - AGC
 - AGC2
 - AGC3
 - CTCSS Squelch
 - Feed Forward AGC
 - Moving Average
 - Mute
 - Power Squelch
 - Rail
 - Sample and Hold
 - Simple Squelch
 - Standard Squelch
 - Threshold
- Math Operators
- Measurement Tools
- Message Tools
- Misc
- Modulators
- Networking Tools
- OFDM

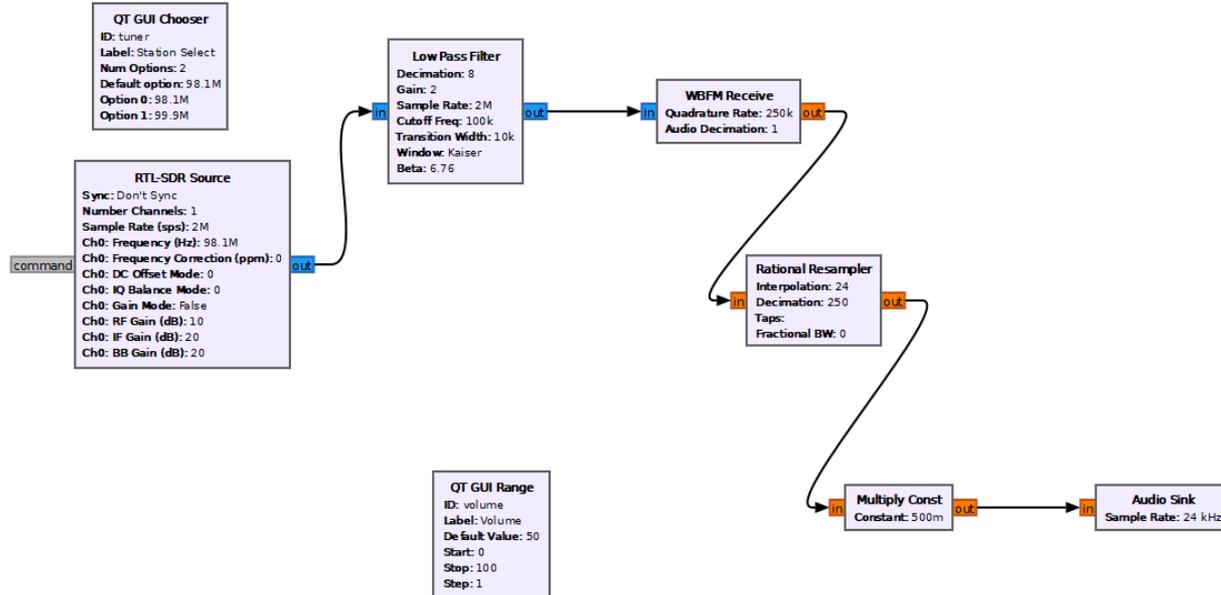
BROADCAST RECEIVER



Options
Title: FM Receiver
Output Language: Python
Generate Options: QT GUI

Variable
ID: samp_rate
Value: 2M

Variable
ID: down_rate
Value: 250k



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