

# SOFTWARE DEFINED RADIOS

GETTING STARTED WITH SDR

WØTLM SMALL GROUP SESSION

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# OUTLINE

- Software Defined Radio (SDR) background
  - SDR Hardware
  - How SDRs work (very basic)
- SDR software applications & demo
  - SDR# (SDR Sharp) with RTLSDR
  - Gnuradio with RTLSDR
  - OpenWebRX with RTLSDR
  - SDRuno with SDRplay

# CREDIT WHERE CREDIT IS DUE

- Numerous slides with permission from Rocky Mountain Ham University
  - Practical SDR With OpenWebRX, Ben Matthews KC2VJW, April 9, 2022
  - GNURadio, Willem Schreüder, ACØKQ , April 9, 2022

# SDR HARDWARE – EASY MODE

- Commercial Transceiver
- All self contained - No 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

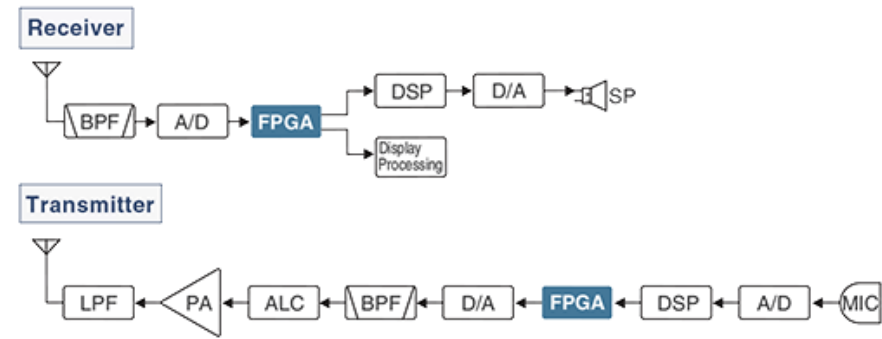
New technology is changing the way receivers are being designed and the IC-7300 is an industry first as an RF, Direct Sampling System is being used in an entry level HF radio. The ability to digitize RF before various receiver stages reduces the inherent noise that is generated in the different IF stages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

- Commercial Transceiver
- External Computer required but S/W included

The screenshot shows the FlexRadio website interface. At the top, there is a navigation bar with the FlexRadio logo and links for Products, Software, About Us, Support, and Community. Below this, a breadcrumb trail reads '< ALL RADIOS'. The main product title is 'FLEX-6700 Signature Series SDR Transceiver'. Underneath, it says 'FlexRadio Systems' and 'SKU: FLEX-6700'. A light blue box contains a shipping notice: 'Please allow up to 6-8 weeks for shipment. Payment(s) will not be processed until an order has been shipped.' The price is listed as '\$7,499.00'. To the left of the main product image, there are four add-on options: 'FLEX-6000 GPSDO Upgrade [+ \$749.00]', 'Rack Mount for FLEX-6500 and FLEX-6700', 'KNB-FlexControl USB Controlled Tuning Knob', and 'FLEX-6700 Extended Warranty [+ \$750.00]'. Below these options, there is a 'Quantity' dropdown set to '1' and a '+ WISHLIST' button. At the bottom left of the product area is a large blue 'ADD TO CART' button. On the right side of the screenshot is a large image of the FLEX-6700 hardware unit. The unit is black with a front panel featuring a digital display showing 'FLEX-6700', a central rotary knob with 'OK' in the center, and a power button. On the left side of the front panel, there are three ports labeled 'MIC', 'PHONES', and 'KEY'. The FlexRadio Systems logo and 'HF 50MHz Transceiver' are visible on the top left of the front panel, while 'FLEX-6700 Signature Series' is on the top right. The unit is supported by four black feet.

# SDR – HARDER MODE

- Range from very economical to \$\$\$\$
  - RTL-SDR
  - SDRPlay
  - HackRF
  - BladeRF
  - KrakenSDR
  - Airspy
  - ... Tons 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

- Utilize Digital Signal Processing (DSP) often performed by Field-Programmable Gate Array (FPGA)
- Nyquist Sampling Theorem
  - To digitize a waveform without aliasing, sampling must be at least TWICE the frequency of the waveform. (Aliasing: seeing a periodic event of one frequency occurring at a different frequency because of the ratio between sampling frequency and the actual behavior.)
- 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 signal processing was done at IF frequencies



# RTL-SDR BLOCK DIAGRAM

Front-end

Local Oscillator  
(not a DC SDR)

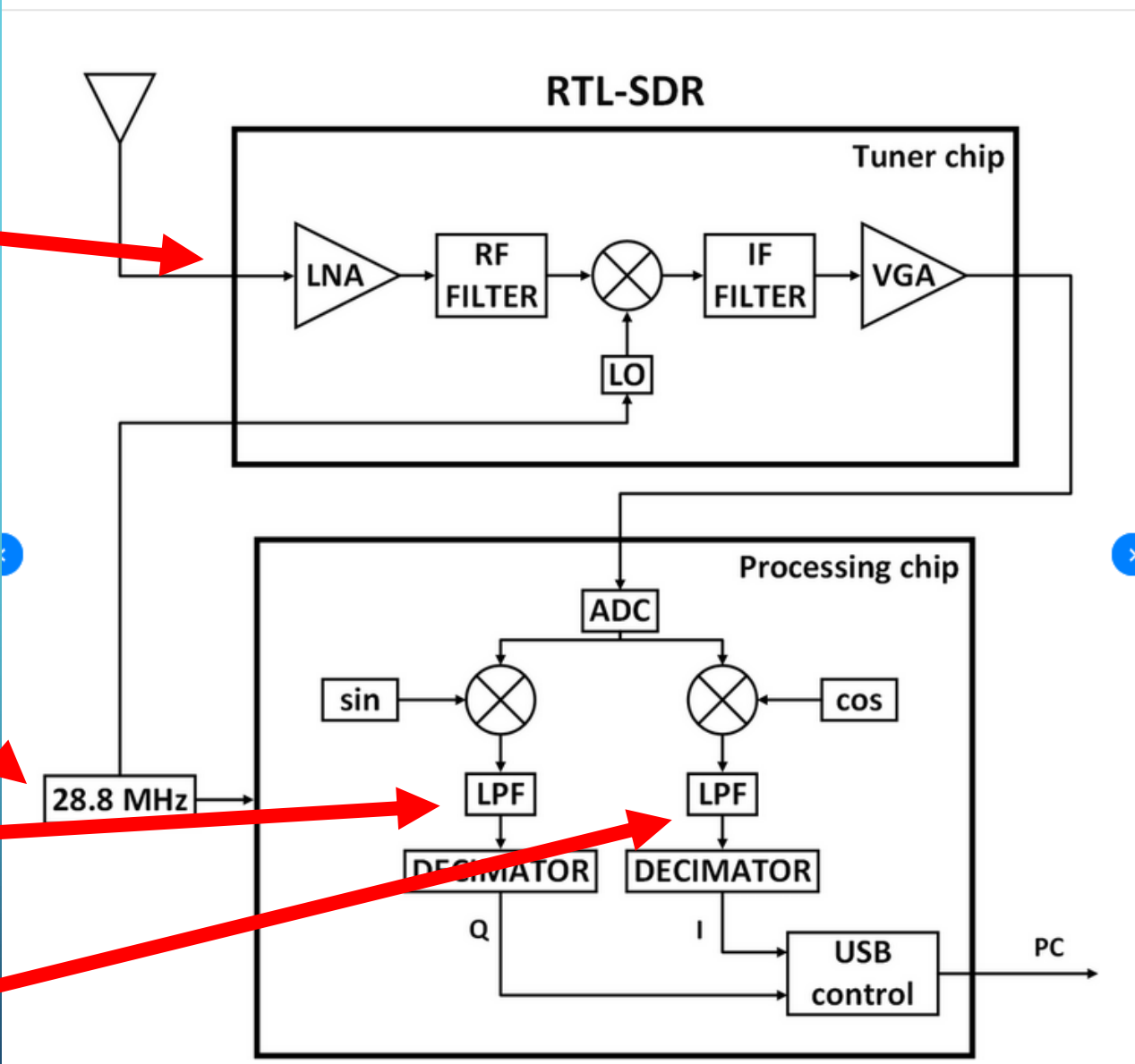
“Q” signal (quadrature)  
Q is phase shifted  $+90^\circ$  with respect to “I”

“I” signal (in-phase)

Fig 2 - uploaded by [Noori BniLam](#)  
Content may be subject to copyright.

Download

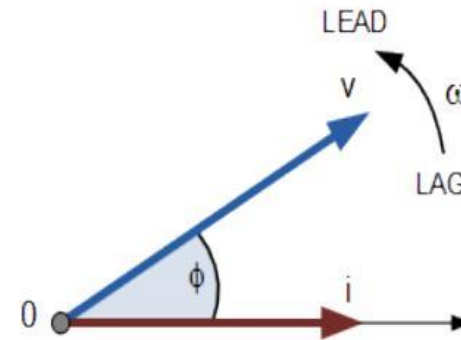
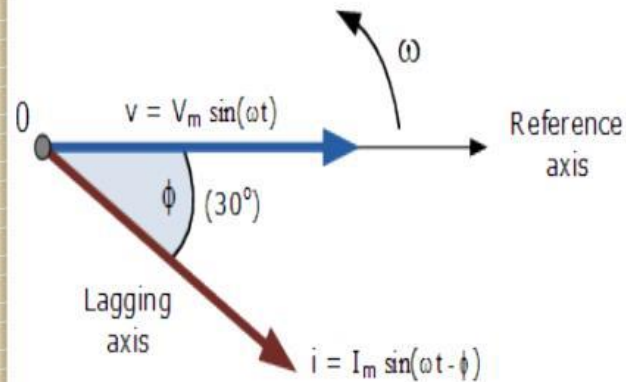
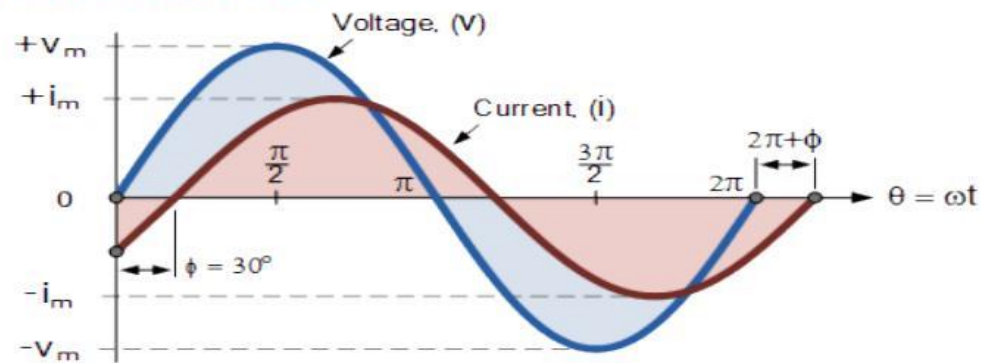
View publication



Block diagram of the RTL-SDR.

# REPRESENTING WAVEFORMS AS PHASORS

## Phasor Diagram of a Sinusoidal Waveform



# WHAT ARE THE I/Q SIGNALS?

- In-phase (I)/Quadrature (Q) simply means that the 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 easily handled by DSP
- Let's do some basic high school trigonometry. AM demodulation is simply 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:  $x(t) = \tan^{-1} \left[ \frac{q(t)}{i(t)} \right]$

# I/Q SIGNALS WITH NO AM MODULATION

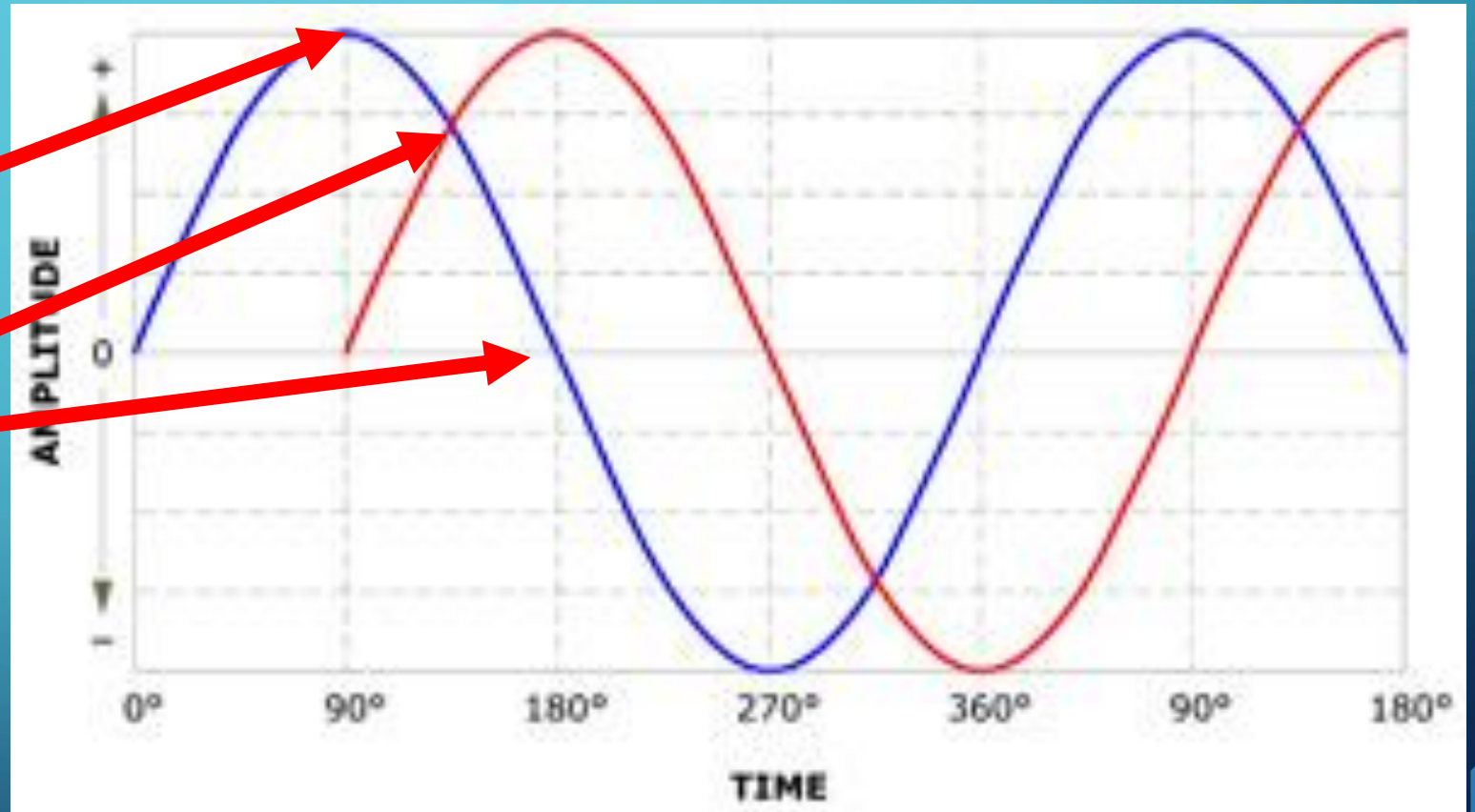
$$X = \sqrt{I^2 + Q^2}$$

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

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

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

X is always 1. No signal variation!



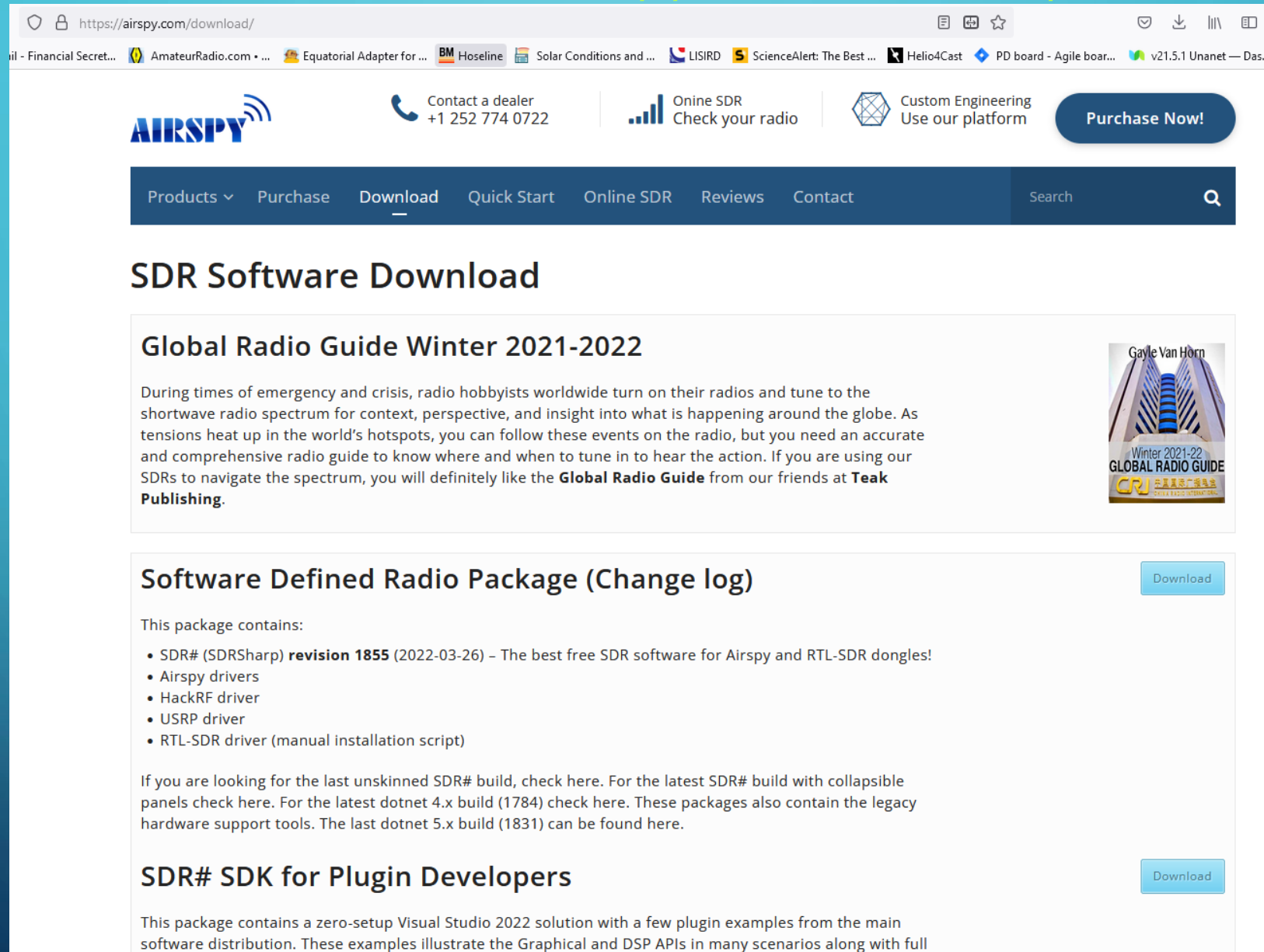


The background is a dark teal gradient. In the corners, there are white line-art illustrations of circuit traces and nodes. The top-left and bottom-left corners have more complex, branching circuit patterns, while the top-right and bottom-right corners have simpler, more linear traces.

SDR# (SDR SHARP)

# SDR# DOWNLOAD

[HTTPS://AIRSPY.COM/DOWNLOAD](https://airspy.com/download)



The screenshot shows the Airspy website's download page. At the top, there is a navigation bar with the Airspy logo, contact information (+1 252 774 0722), and links for 'Online SDR Check your radio' and 'Custom Engineering Use our platform'. A 'Purchase Now!' button is also present. Below the navigation bar, the main heading is 'SDR Software Download'. The first featured item is 'Global Radio Guide Winter 2021-2022', which includes a description of the guide and a 'Download' button. The second item is 'Software Defined Radio Package (Change log)', which lists the contents of the package (SDR#, Airspy drivers, HackRF driver, USRP driver, and RTL-SDR driver) and provides links to other software builds. The third item is 'SDR# SDK for Plugin Developers', which describes a Visual Studio 2022 solution for plugin development. Each item has a 'Download' button.

**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

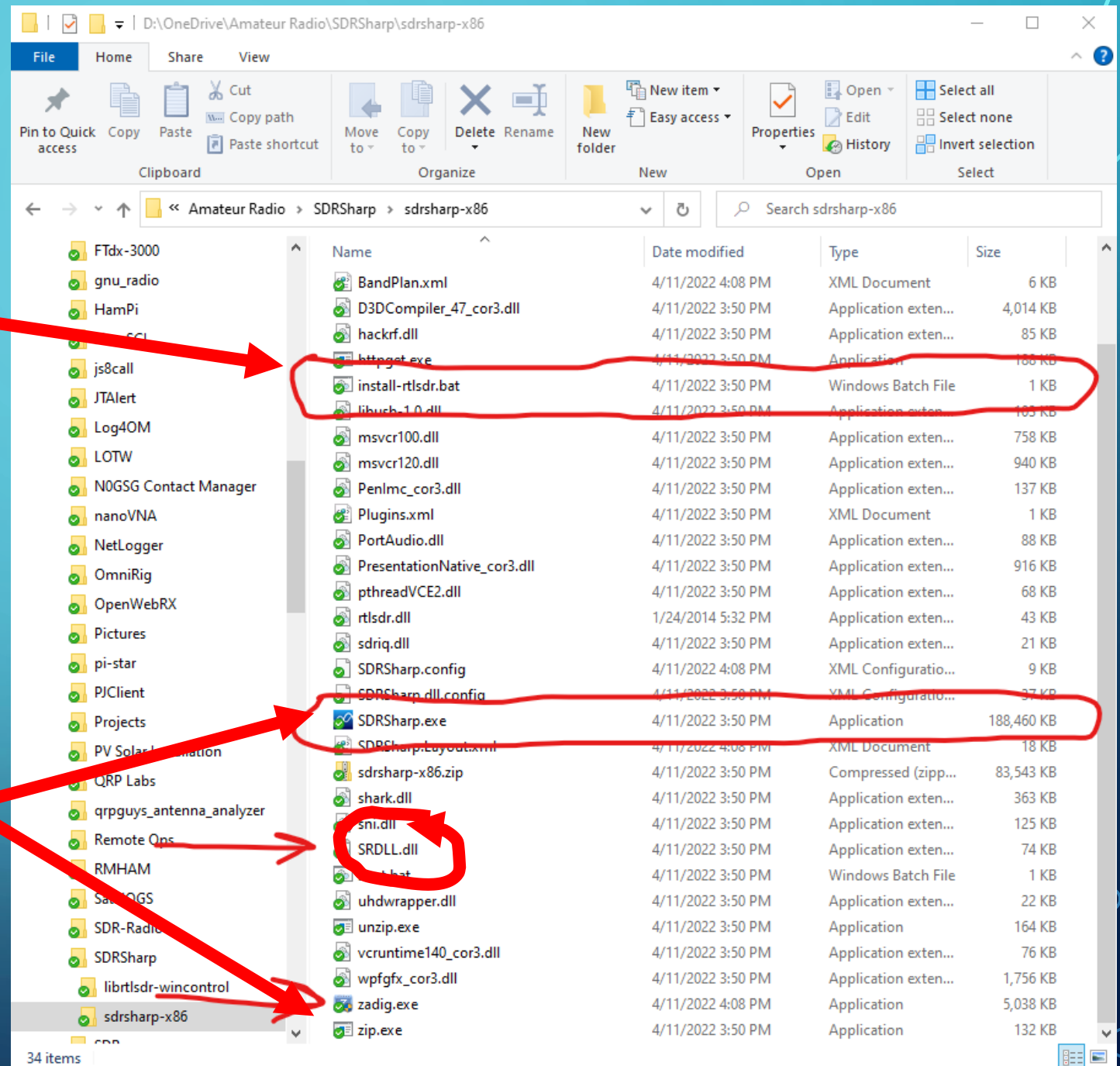
Windows installs driver that  
SDR# can't use

Run zadig.exe

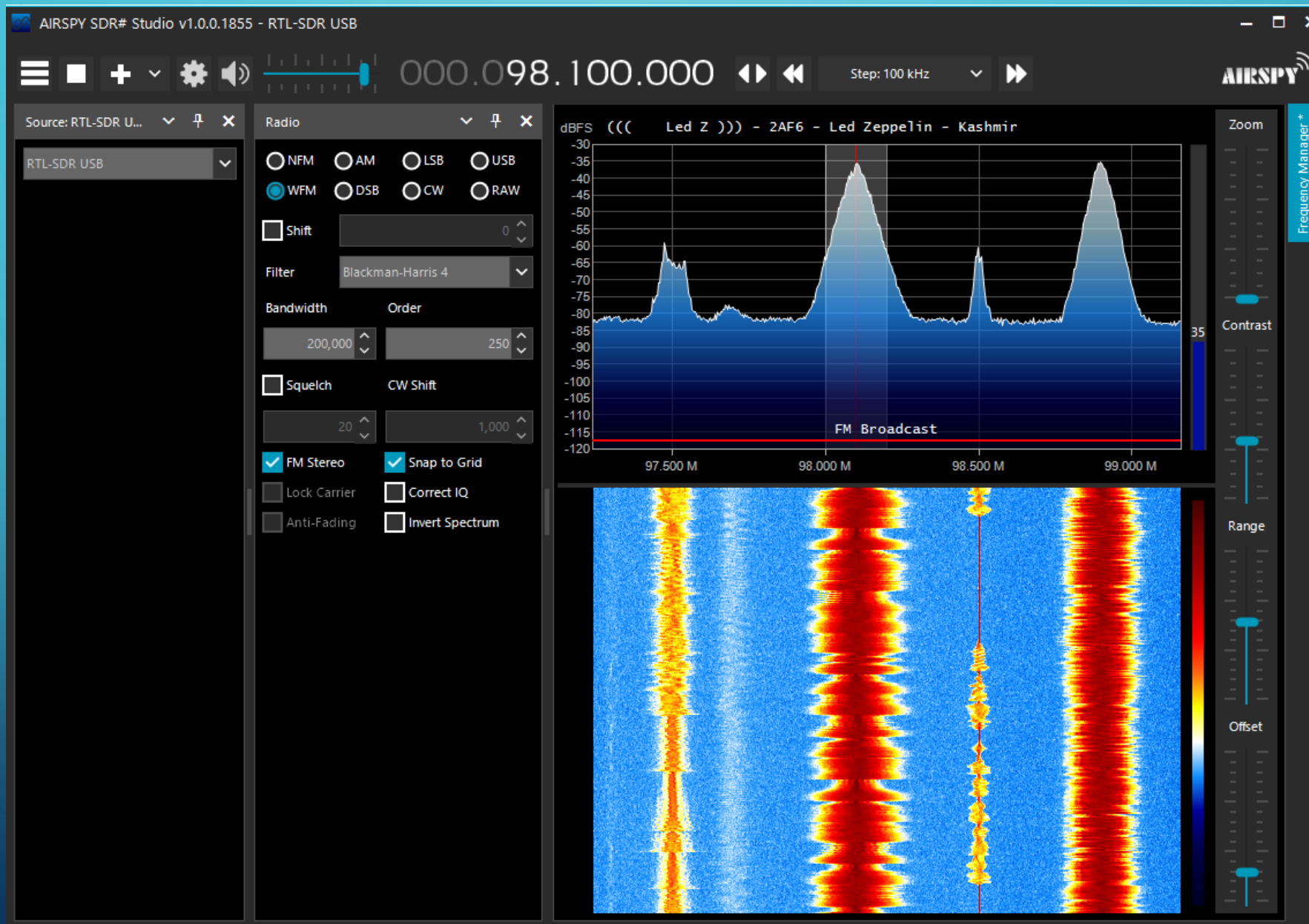
Replace driver

See [YouTube](#) video

Run SDR#

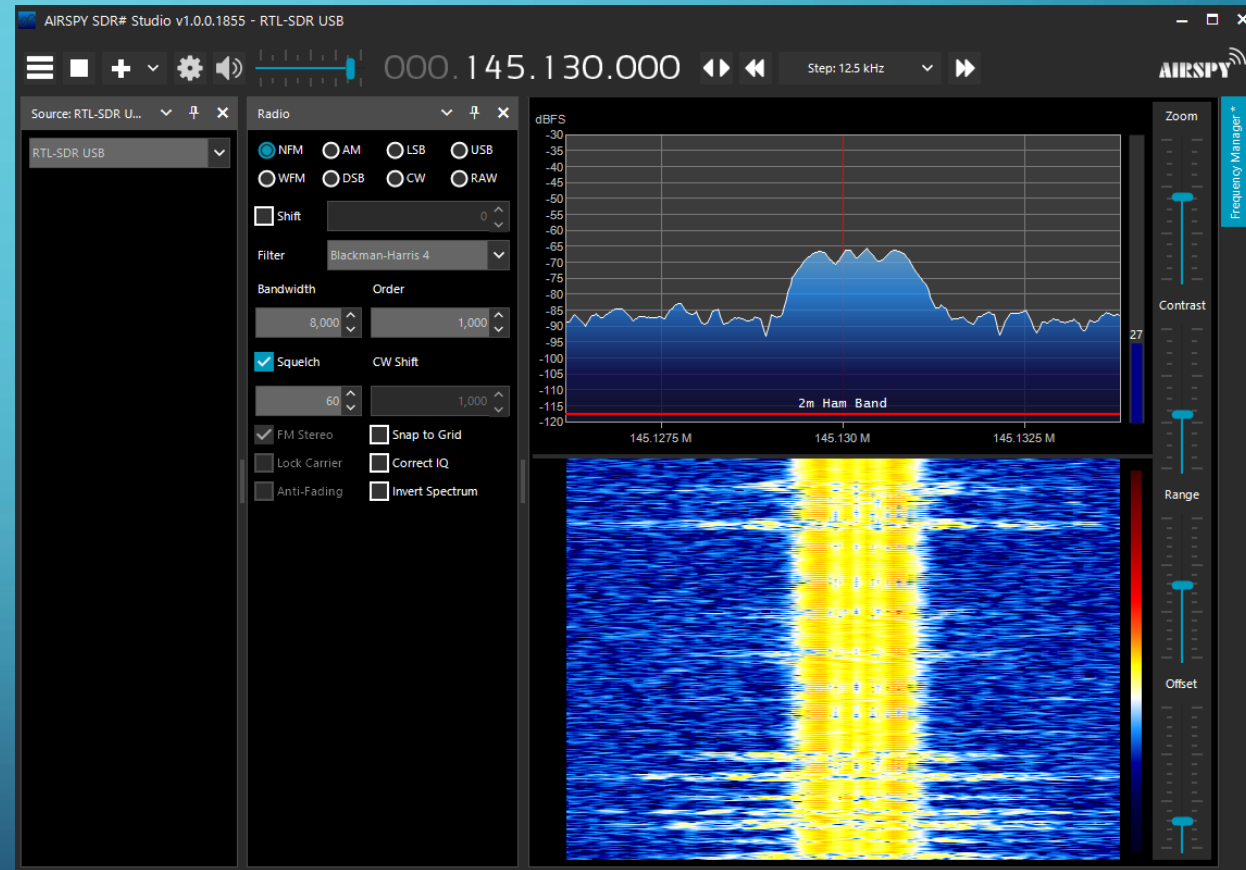
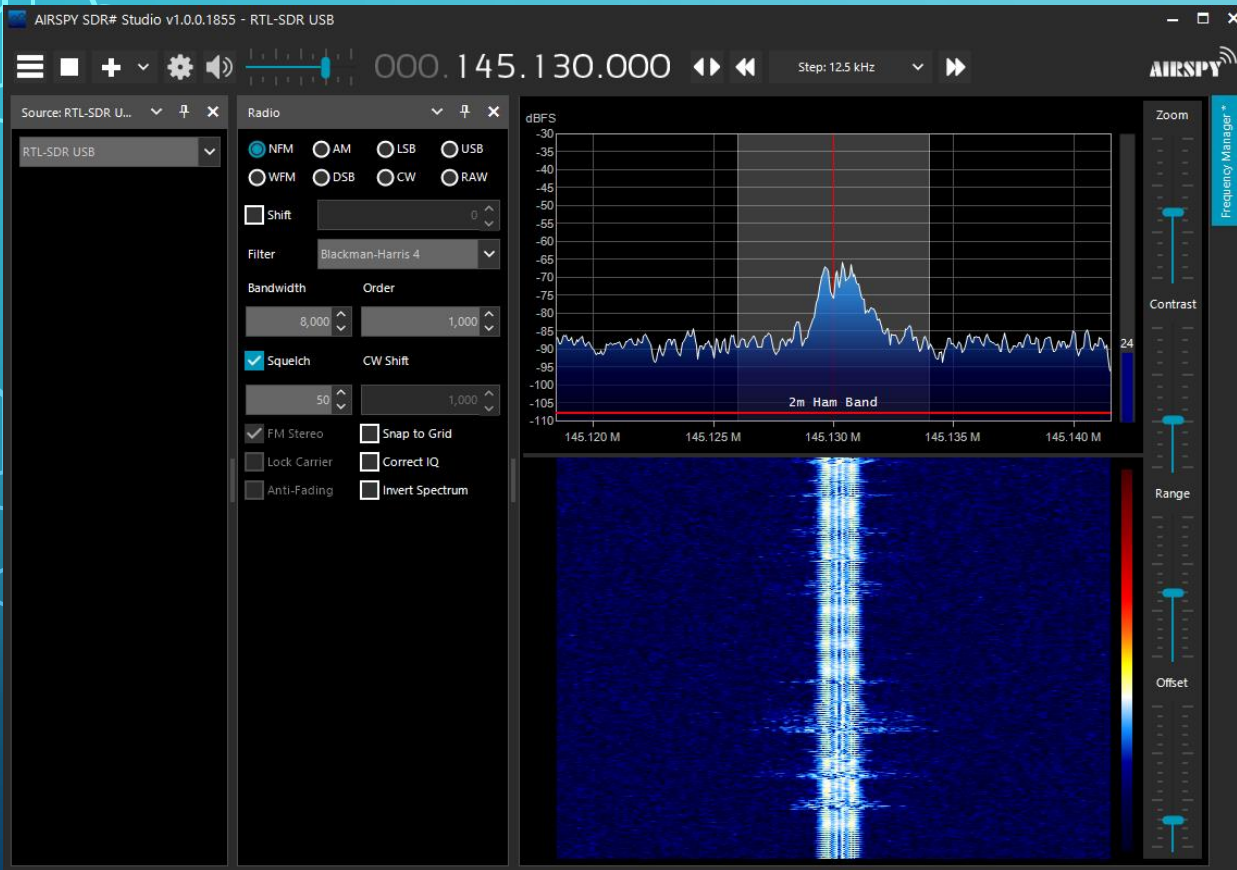


# SDR# FM BROADCAST RECEIVER





# RTL-SDR WITH SDR# (SDRSHARP) (WINDOWS)



The logo for GNURADIO is a circular emblem with a central gear-like shape and a smaller gear inside it, surrounded by a ring of dots. The entire logo is rendered in a light blue color against a dark blue background.

GNURADIO

# GNURADIO

- Software Radio Ecosystem
- Open-source (FREE!) 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)

<https://www.gnuradio.org/>

- GNU Radio Companion – GUI to manipulate signal processing blocks

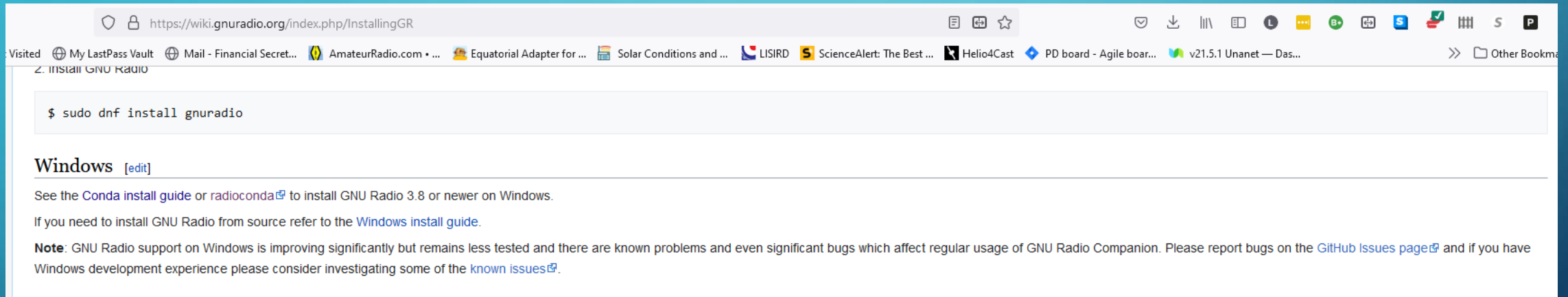
[Using GNU Radio Companion Part 1 YouTube video](#)

- Thanks to Willem Schreuder, AC0KQ & Rocky Mountain Ham University

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

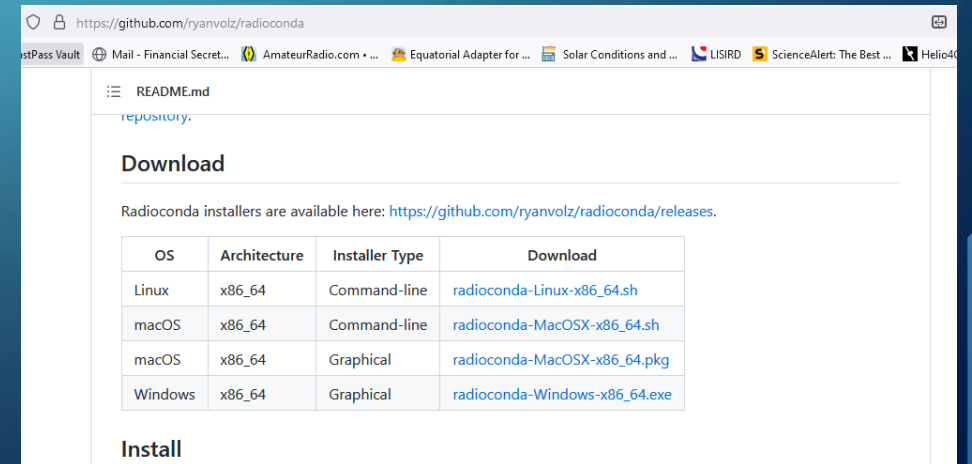
# GNURADIO INSTALLATION

- From <https://gnuradio.org> Getting Started
  - Select Installing GNU Radio



The screenshot shows a web browser window with the URL <https://wiki.gnuradio.org/index.php/InstallingGR>. The page content includes a terminal command: `$ sudo dnf install gnuradio`. Below the code, there is a section titled "Windows" with a link to [edit]. The text under "Windows" reads: "See the [Conda install guide](#) or [radioconda](#) to install GNU Radio 3.8 or newer on Windows. If you need to install GNU Radio from source refer to the [Windows install guide](#). **Note:** GNU Radio support on Windows is improving significantly but remains less tested and there are known problems and even significant bugs which affect regular usage of GNU Radio Companion. Please report bugs on the [GitHub Issues page](#) and if you have Windows development experience please consider investigating some of the [known issues](#)."

- <https://github.com/ryanvolz/radioconda>



The screenshot shows the GitHub repository page for <https://github.com/ryanvolz/radioconda>. The page includes a "Download" section with the text: "Radioconda installers are available here: <https://github.com/ryanvolz/radioconda/releases>." Below this is a table with the following data:

OS	Architecture	Installer Type	Download
Linux	x86_64	Command-line	<a href="#">radioconda-Linux-x86_64.sh</a>
macOS	x86_64	Command-line	<a href="#">radioconda-MacOSX-x86_64.sh</a>
macOS	x86_64	Graphical	<a href="#">radioconda-MacOSX-x86_64.pkg</a>
Windows	x86_64	Graphical	<a href="#">radioconda-Windows-x86_64.exe</a>

Below the table, there is an "Install" section.



# GNURADIO COMPANION – 2M NBFM RECEIVER

**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

Component Palette:

- 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

Id	Value
Imports	
Variables	

```
>>> Done
```

The background is a gradient of blue, darker at the bottom. In the corners, there are decorative white line-art patterns resembling circuit traces or fiber optic paths, with small circles at the end of the lines.

# OPENWEBRX

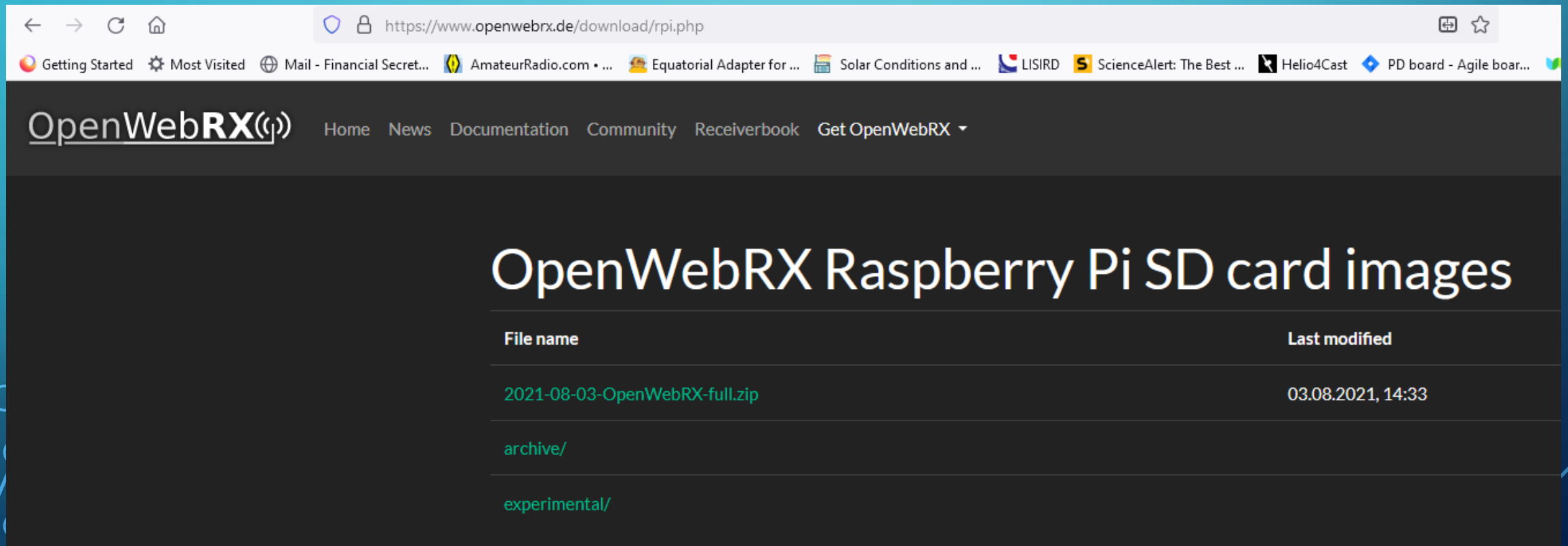
THANKS TO BEN MATTHEWS, KC2VJW, ROCKY MOUNTAIN HAM UNIVERSITY

# 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
- Thanks to Ben Matthews, KC2VJW & Rocky Mountain Ham University
- Detailed installation instructions for Raspberry Pi available at <https://www.rmham.org/wp-content/uploads/2022/04/PracticalSDR.pdf>

# OPENWEBRX SETUP

- OpenWebRX image loaded on SD card



The screenshot shows a web browser window with the URL <https://www.openwebrx.de/download/rpi.php>. The page title is "OpenWebRX Raspberry Pi SD card images". The navigation menu includes "Home", "News", "Documentation", "Community", "Receiverbook", and "Get OpenWebRX". The main content area displays a table of files and folders for download.

File name	Last modified
<a href="#">2021-08-03-OpenWebRX-full.zip</a>	03.08.2021, 14:33
<a href="#">archive/</a>	
<a href="#">experimental/</a>	



# OPENWEBRX SETUP CONTINUED

- This is a broad brush, not detailed instructions
- It may be useful to run your RPi at first 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”
  - Disconnect monitor, keyboard & mouse

# WEB APPLICATION

- Set up custom receiver
  - Select Center Frequency
  - Sample Rate
  - Starting Frequency
  - RF Gain

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=nfm,sql=-150`. The application header includes the OpenWebRX logo, a location indicator for 'N0SZ Westcreek, Colorado | Loc: DM79ma, ASL: 2700 m', and navigation icons for 'Receiver', 'Map', and 'Settings'. A red arrow points from the 'Settings' icon to the receiver settings panel on the right. The main area features a spectrum plot with a frequency range from 448.0 MHz to 450.0 MHz. A yellow signal peak is visible at 449.0 MHz. The receiver settings panel on the right shows the current frequency set to 449.0000 MHz and the mode set to FM. Other modes listed include WFM, AM, LSB, USB, CW, M17, FreeDV, and DRM. The panel also includes sliders for volume and signal-to-noise ratio (SQ), and a signal strength indicator at the bottom showing -45.4 dB. A red box highlights the mode selection area. At the bottom of the interface, there is a red 'Under construction' warning 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

The screenshot displays the OpenWebRX web interface in a browser window. The address bar shows the URL `10.30.115.147/#freq=449000000,mod=nfm,sql=-150`. 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 second bullet point in the list to the 'FM' mode button in the control panel. The control panel includes a frequency display at 449.0000 MHz, a dropdown menu for the receiver (currently 'RTL-SDR USB Stick 20m Repeater'), and buttons for various modulation modes: FM, WFM, AM, LSB, USB, CW, M17, and FreeDV. Below these are 'DIG' mode options and audio level sliders. At the bottom, a status bar shows 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]. A red 'Under construction' banner is also visible.

# OPENWEBRX DEMO







# SDRUNO WITH FTDX-3000



# SDR PLAY FOR FTDX-3000 PANADAPTER

- Instead of antenna providing signal source relying on transceiver to provide signal
- Using SDRuno software to do rig control
- Rig has RF and IF outputs (protected from transmitted signal)
  - RF output has wider bandwidth than IF so entire band can be seen
- SDRuno software for Windows
- Omnirig for rig control from SDRuno
  - I seldom touch the tuning knob
  - Tuning with mouse click on signal and fine tuning with mouse wheel
- Adaptable to any rig with CAT interface
- Logging software (Log4OM) automatically receives frequency and mode information and does QRZ lookup when callsign entered

# SDRUNO WITH FTDX-3000 RF OUTPUT

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

- Top Panel:** Includes 'SETT.', 'PWR & SNR TO CSV', 'SCREENSHOT', 'SDRuno MAIN SP', 'STEP LOCK 0:00', and 'STORE'.
- Spectrum Plot:** Shows a signal at 14.240000 MHz. The y-axis is labeled 'dBm' ranging from -140 to -20. The x-axis shows frequency from 14000 to 14360 kHz. A signal strength of -107.5 dBm and SNR of -- dB is indicated. Parameters: Span 388.9 kHz, FFT 8192 Pts, RBW 47.47 Hz, Marks 2 kHz.
- Waterfall View:** A 20m band framed waterfall view showing signal activity over time.
- SDRuno MEM. PANEL:** A table with columns: Frequency, S, Mode, Description.
- SDRuno SCANNER:** Includes 'SCANNER CONFIG', 'ADD LOCKOUT', 'SCAN MODE', 'RANGE', and 'MEM' buttons.
- Bottom Left Panel (MAIN):** Contains 'OPT', 'SCAN', 'SCHEDULER', 'SP1', 'SP2', 'RX', 'DEL VRX', 'LO LOCK', 'RF GAIN', 'STOP', 'MEM PAN', 'SDR Play', 'Sdr: 5%', 'Sys: 74%', and 'SAVE WS'.
- Bottom Middle Panel (RX CONTROL):** Shows 'STEP: 250 Hz', '14.240000', '-107.5 dBm', 'PEAK', 'I/Q OUT', 'MODE' (AM, SAM, FM, CW, DSB, LSB, USB, DIGITAL), 'VFO A', 'VFO B', 'QMS', 'QMR', 'MUTE', 'SQLC', 'VOLUME', and various filter and notch options.
- Bottom Right Panel (AUX SP):** Shows a smaller spectrum plot with 'Span 12 kHz', 'FFT 620 Pts', 'RBW 9.68 Hz', 'Marks 200 H'.
- Bottom Far Right Panel (EX CONTROL):** Includes 'BW', 'FREQ', 'AM SOFT FILTER', 'SOFT', 'FC', 'AGC', 'NR', 'CWPK', 'FM', 'DEEM', 'AFC', 'MONO', 'FMS-NR', 'PDBPF', 'RC', 'FMS-NR', and '40'.