

# Introduction to Low-Cost Software Defined Radio



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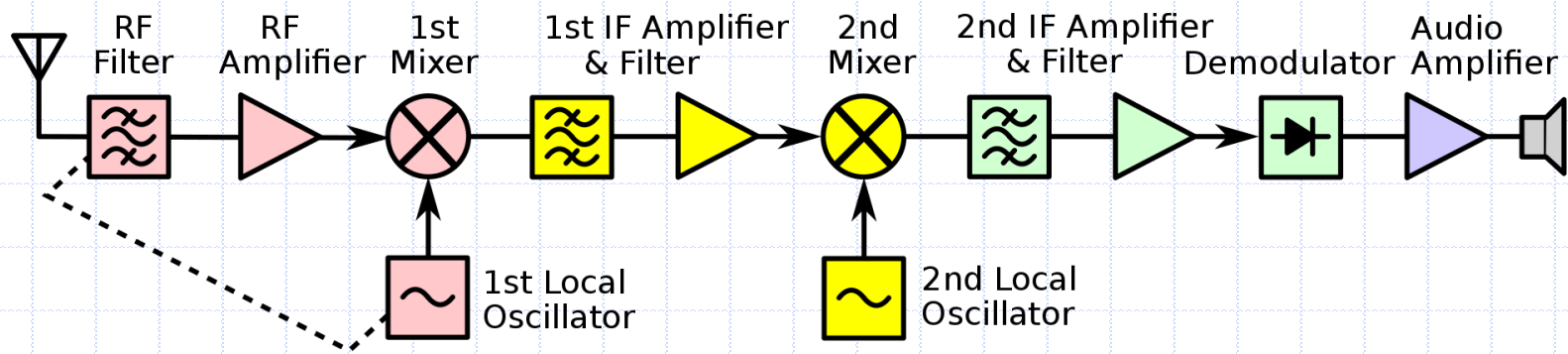


# Agenda

- Review HDR (Hardware Defined Radio)
- Arrival of DSP (Digital Signal Processing)
- What is SDR
- What is the RTL-SDR
- Setting it all up
- Many applications...

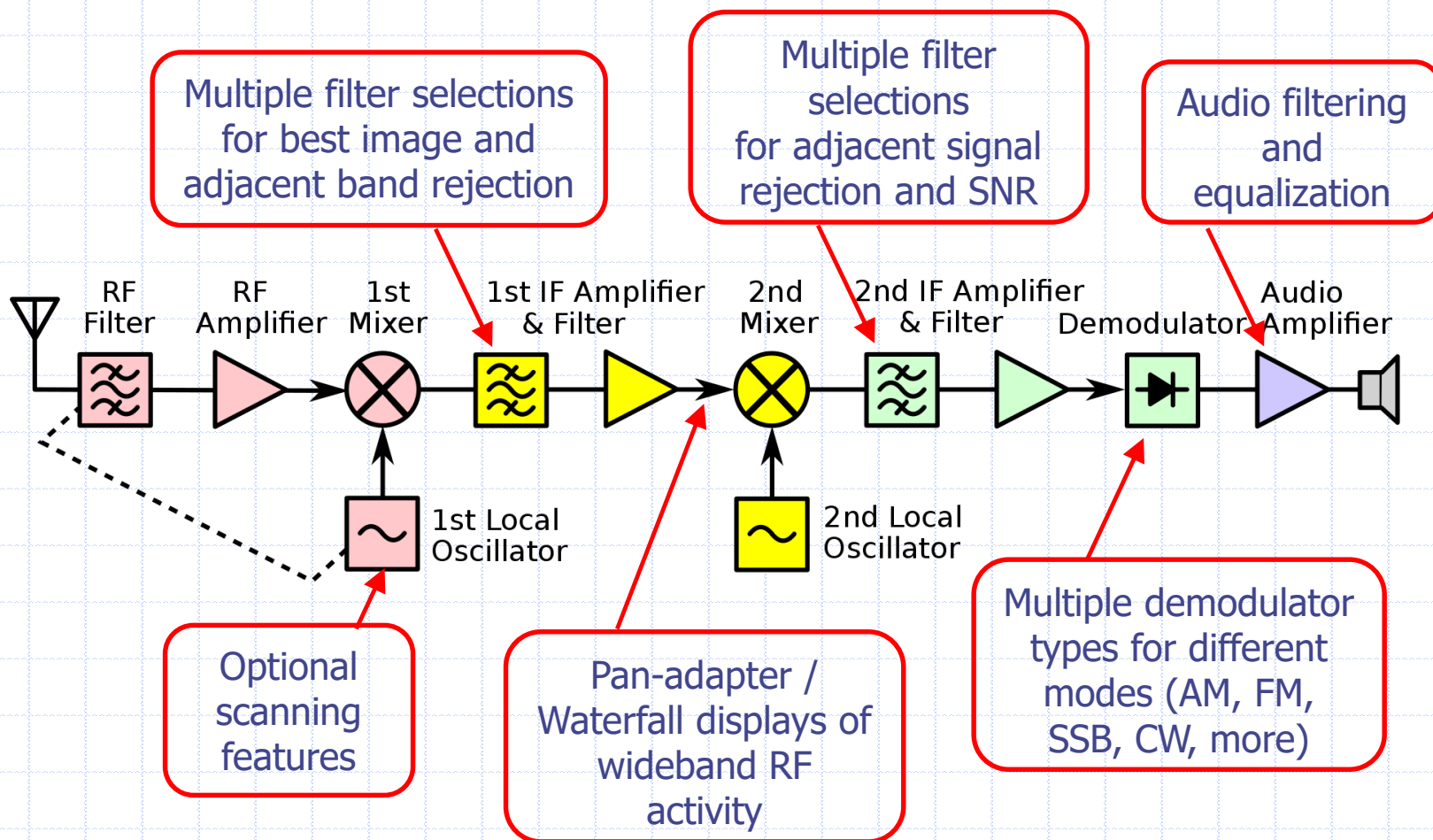


# Dual-Conversion Superhhet

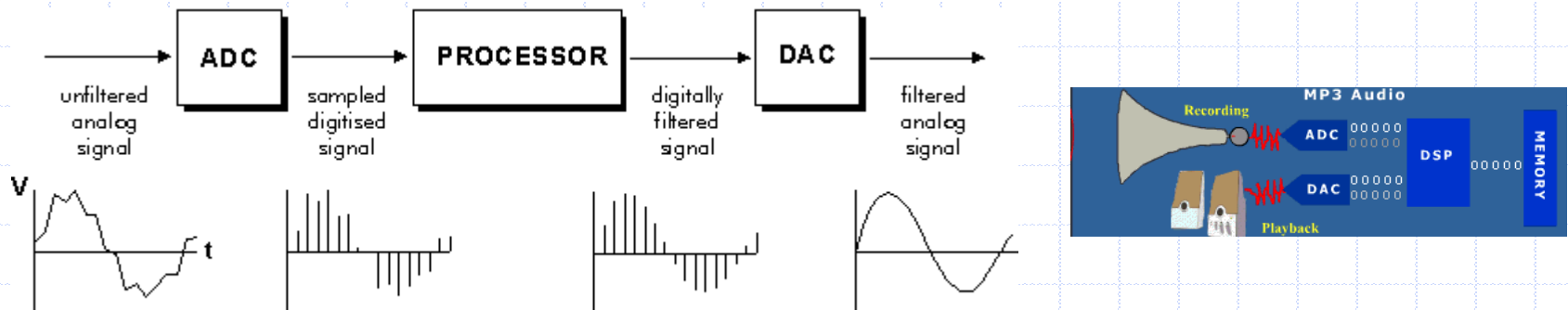


- Additional conversion stages for:
  - Image Rejection and Selectivity
  - Flexible filtering
  - Wider frequency coverage
  - Etc.

# All-Mode Receiver Features



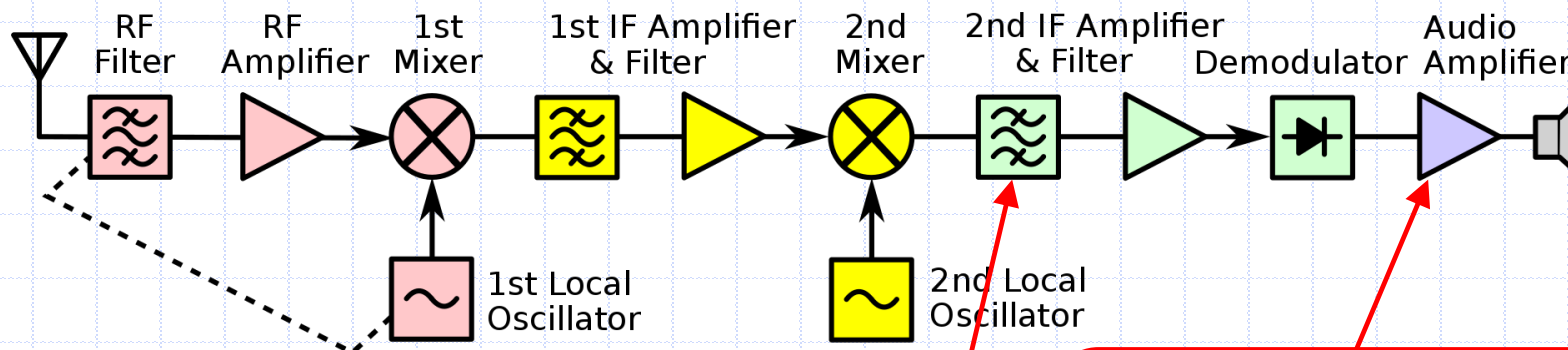
# What is DSP – Digital Signal Processing



- Signal is “sampled” – like movie snapshots
  - Sample rate must be  $>2x$  highest frequency
  - “Time Series of Binary numbers”
- Numeric samples can then be altered mathematically...
- Processed sampled reconverted back to analog

# First entrees into DSP

(Digital Signal Processing)



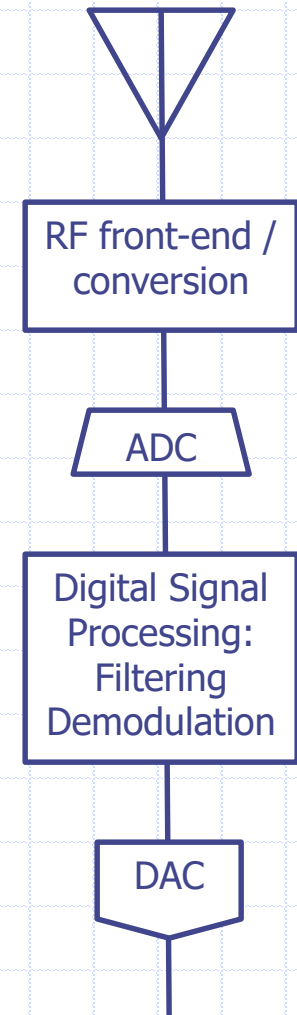
- Low-Frequency IF signal is digitized, then mathematically filtered with DSP
- ADC/DAC requirements are a little tougher

- Audio/Baseband is sampled, then filtering & equalization is applied digitally
- Easy ADC/DAC requirements

- As technology advances, the "bits" are moved closer and closer to the antenna
  - Faster ADC and DAC, faster processors to do the math
- More processing is done on the sampled signals vs. analog circuits
- As we incorporate more functions (filtering + demodulation, etc.) we begin to call this Software Defined Radio (SDR).

# SDR at a Glance

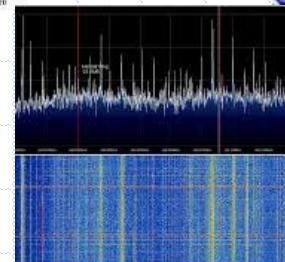
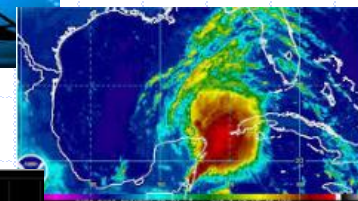
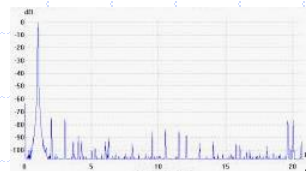
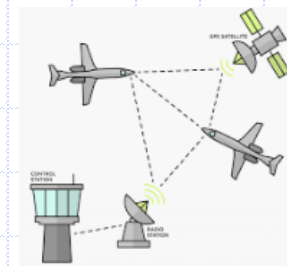
- Software **Defined** is more than simply Software **Controlled**
- Software implements the:
  - Filtering
  - Demodulation
  - RF and AF Spectrum and waterfall
  - Scanning
  - Decoding, and more





# A sampling of SDR Applications

- AM/FM Radio
  - All Mode Amateur Radio
  - Digital TV and Radio
  - Air Traffic Control
  - Police/Fire/Public Service Scanning
  - ADS-B Aircraft Tracking
  - Satellite Reception
  - NOAA Weather Image Reception
  - APRS
  - Spectrum Analysis
  - Etc.
- 
- Many (most) commercial RF applications such as cell phones, etc. are now SDRs



# RTL-SDR Dongle

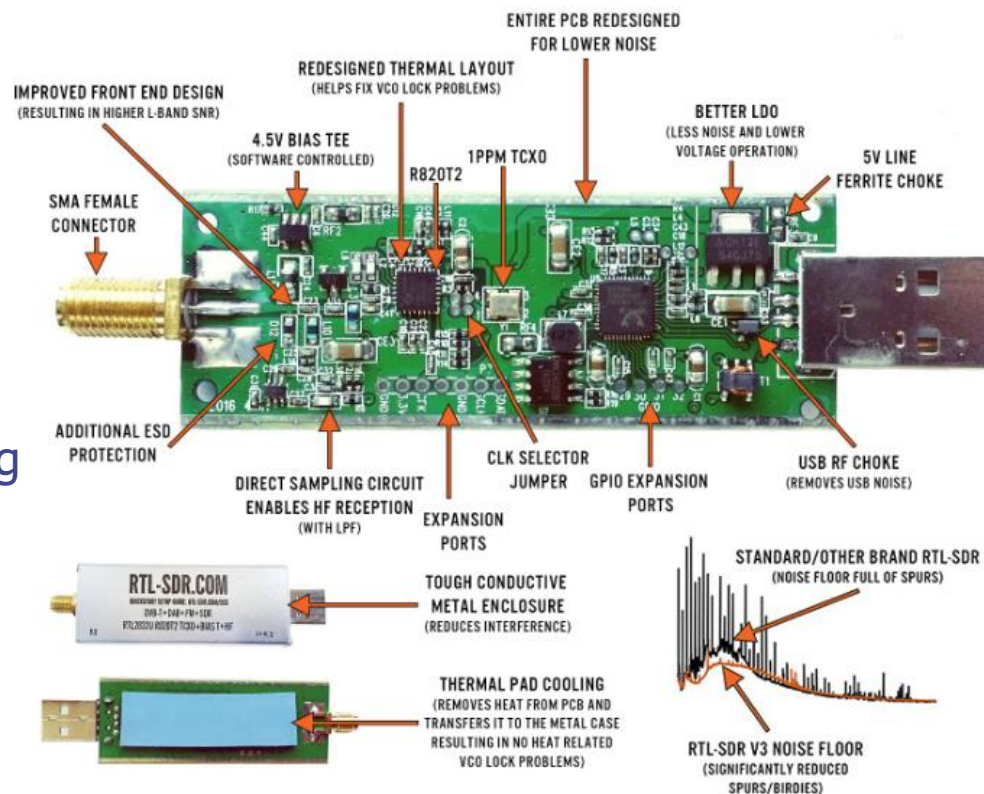
- “Ubiquitous” SDR Dongle
- About \$20 on Amazon
  - There are cheaper ones too
- Designed for DVB/DAB, but commonly used for many SDR applications
- Tunes 24MHz to 1.7GHz (Tuner)
  - Also 500kHz to 24MHz (Direct)
- RTL = RealTek, mfg of backend chip
  - Coupled with a Tuner-on-a-chip
- Provides sampled data to PC
- Software on PC controls unit, and completes the remaining receiver functionality



<https://www.amazon.com/RTL-SDR-Blog-RTL2832U-Software-Defined/dp/B0129EBDS2>

# The RTL-SDR V3

- The V3 version adds many improvements over earlier and cheaper designs
  - TCXO
  - Better Shielding
  - Better Heat Management
  - SMA Connector
  - Bias-Tee
  - Switchable Direct Sampling for HF reception
  - Lower Noise Design

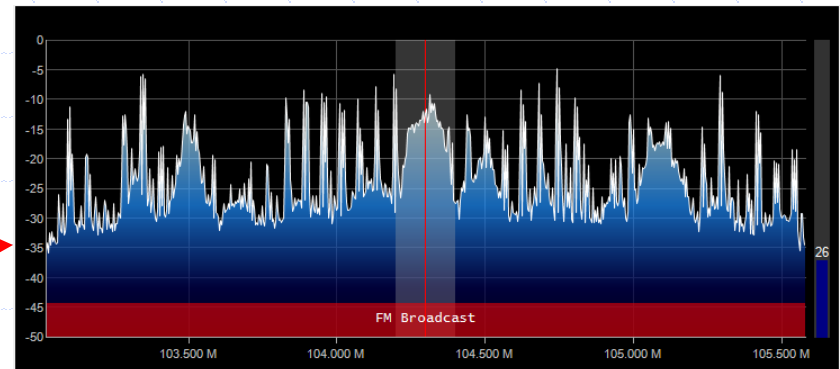


# “Wideband” Visibility

- Up to 2.4MHz of radio spectrum visible at any time
- Visualize all activity in this band using:

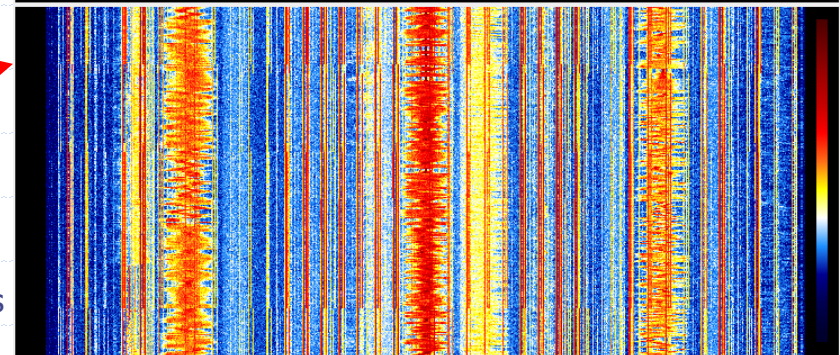
- Spectrum Display

- Signal Strength on vertical axis
- Frequency on horizontal axis



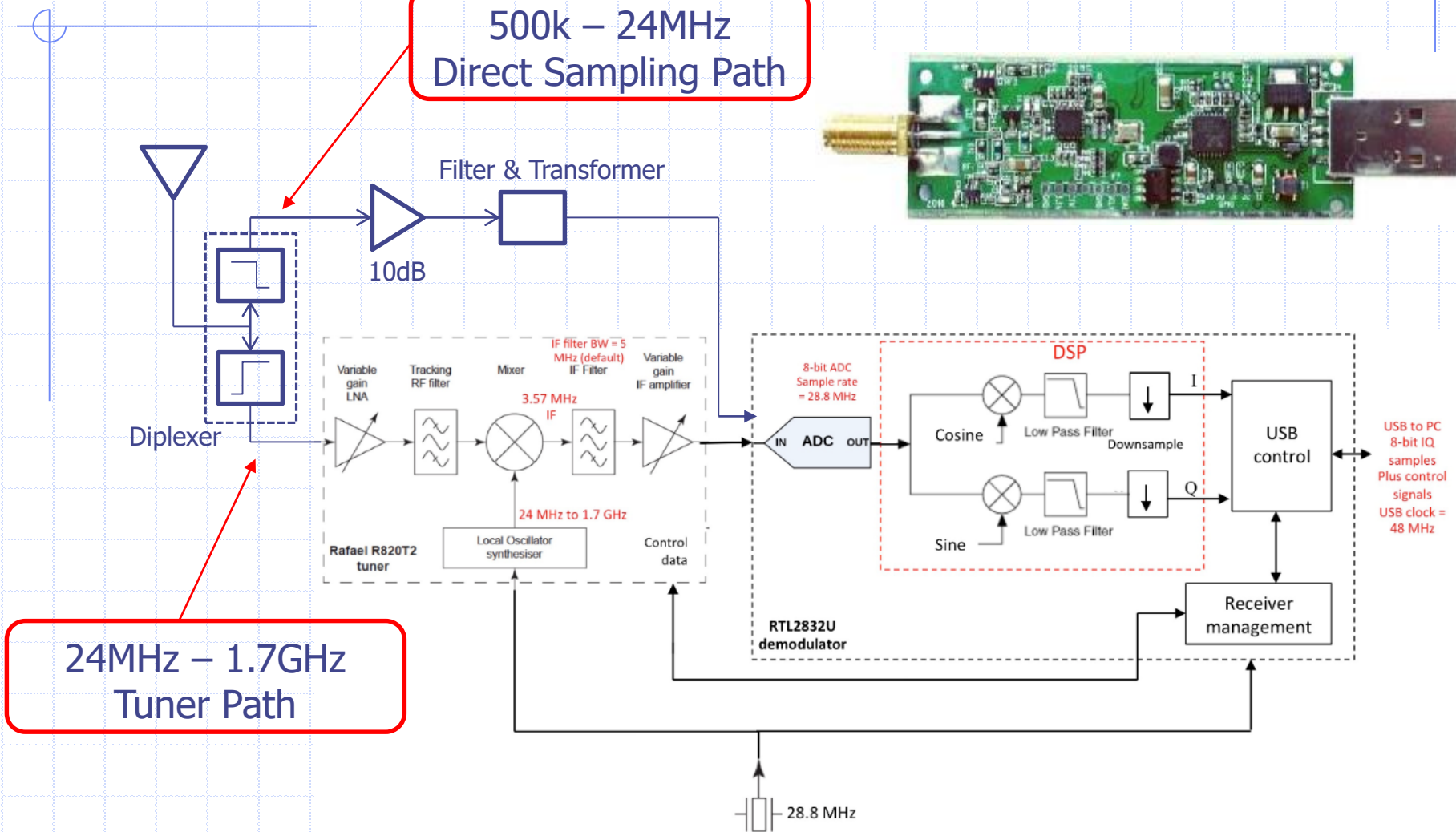
- Waterfall / Spectrogram

- “Strip chart” of spectral activity
- Each row of pixels is looking at the top of a spectrum trace
- Signal Strength shown by color – hotter is stronger (red)



# Under the Hood...

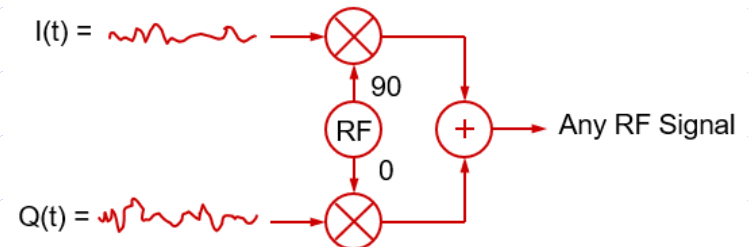
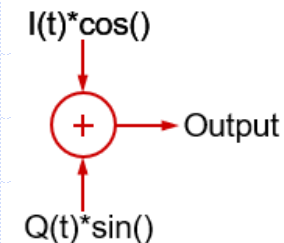
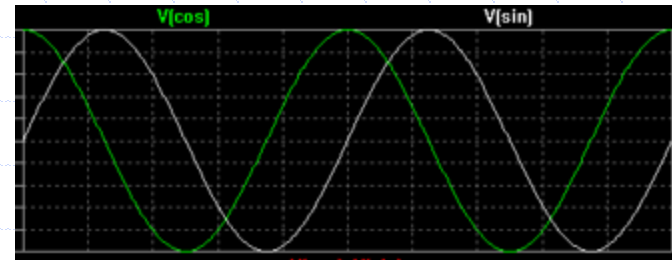
500k – 24MHz  
Direct Sampling Path



24MHz – 1.7GHz  
Tuner Path

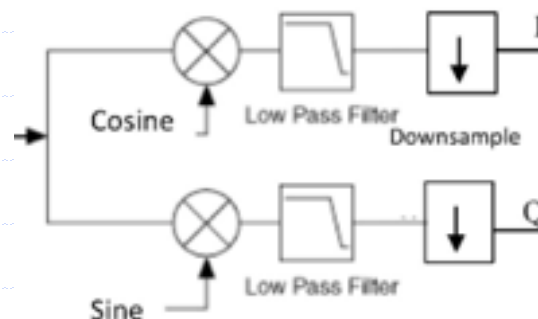
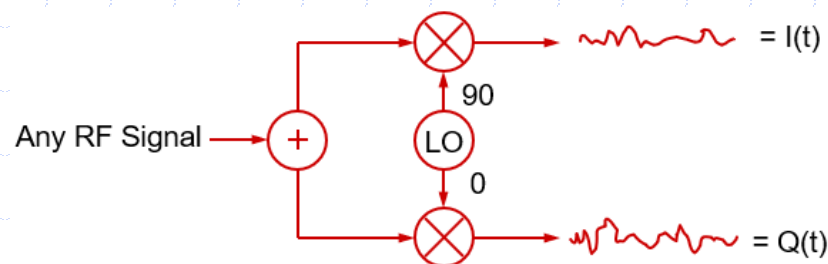
# What's all this I&Q Stuff?

- Quadrature Signals
  - Just 90° phase diff.
  - Like  $\sin()$  and  $\cos()$
- Adding IQ signals:
  - $I=1, Q=0$  : cosine
  - $I=0, Q=1$  : sine
  - $I=1, Q=1$  : sine + 45°
- Amplitude & Phase (and Frequency) vary by changing I and Q



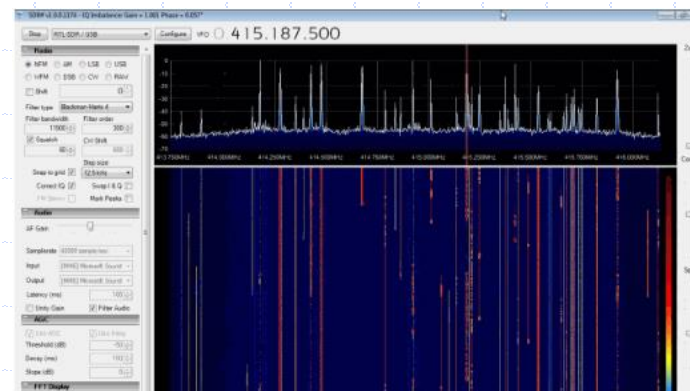
# IQ Signals in Receivers

- Same thing works in reverse...
- Most (all?) SDRs use Quadrature Down-conversion to create I and Q signal pairs
- Once you have I and Q vs. time...  
...you know **everything** you need to know about the signal!
  - Amplitude =  $\sqrt{I^2 + Q^2}$
  - Phase =  $\arctan(Q/I)$
  - Frequency =  $d(\text{Phase})/dt$
- Filtering and Demodulation is simply (well, not real simple) math on the IQ signals.



# SDR Software

- Many SDR Apps available
- Most common is SDR# (SDR-Sharp)
- Other popular ones:
  - HDSDR, SDR-Radio, Linrad, CubicSDR, more...
- Plus – specialty software:
  - Spectrum analysis, ADS-B monitoring, scanner apps, etc.

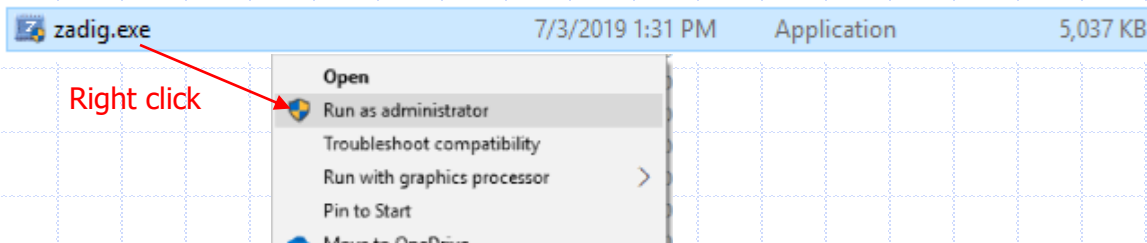
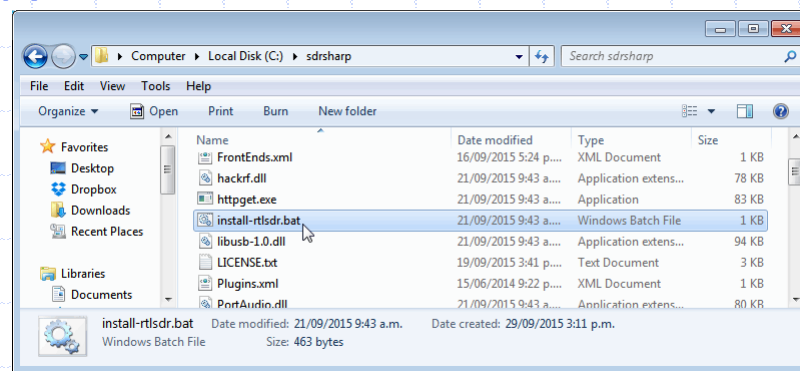


<https://www.rtl-sdr.com/big-list-rtl-sdr-supported-software/>



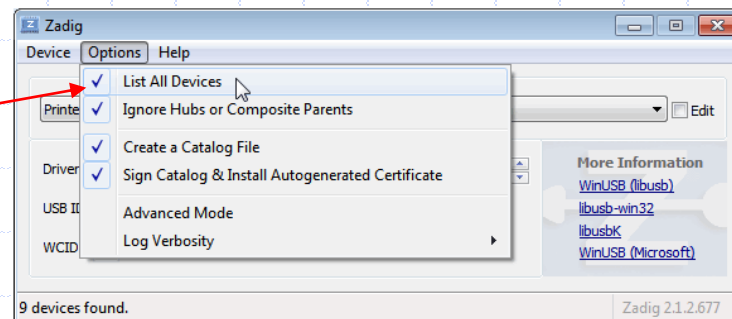
# Setting up SDR# for RTL-SDR

- Quick Start Guide: <https://www.rtl-sdr.com/rtl-sdr-quick-start-guide/>
- Download SDR# from: <https://airspy.com/download/>
  - Unzip the **sdrsharp-x86.zip** file
  - Run the **install-rtlsdr.bat** file
  - Your computer might also need:
    - Microsoft .NET 4.6 Redistributable
    - Visual C++ Runtime(see QSG for details)
- Plug-in your RTL-SDR Dongle!
  - Wait a few while Windows tries to install drivers (don't install any that come with it)
- In folder where you unzipped files, run **zadig.exe** as "admin"
  - Right click on **zadig.exe**, select "Run as Administrator"



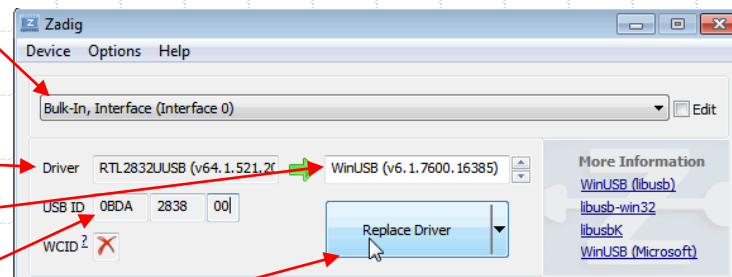
# Configure the Driver

- Under Options – select “List All Devices”




- Select “Bulk-In, Interface (Interface 0)”

- It may say “RTL2832UHIDIR or RTL2832U” instead of the bulk in interface on some PCs
- This shows currently installed driver
- Make sure it shows the **WinUSB** selection
- (this is what we’re replacing it with)
- Make sure USB ID says: **0BDA 2838 00**




- Click **Replace Driver**

# Setup SDR#

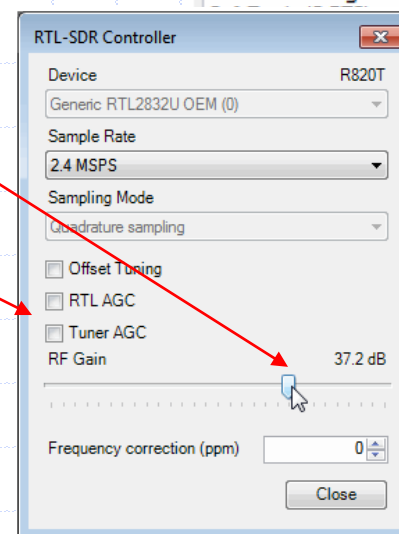
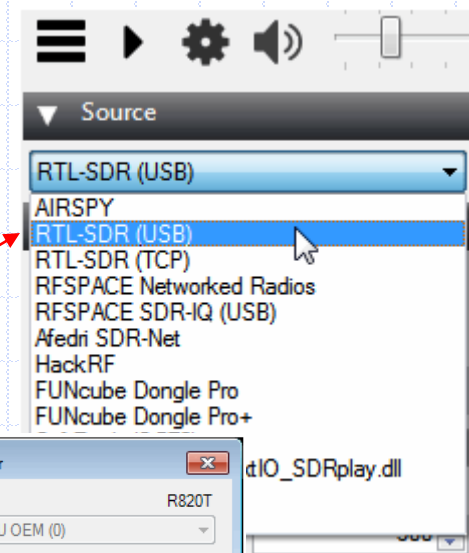
- Open SDR#
  - SDRSharp.exe in the unzipped folder
- Select **RTL-SDR (USB)** from the Source menu
- Press "Play"  and you're ready to roll!

- **Important!**



- You'll want to adjust the RF Gain to get good sensitivity...
- Or, enable the RTL and Tune AGC controls
- Click the Settings "cog"  to open the dialog

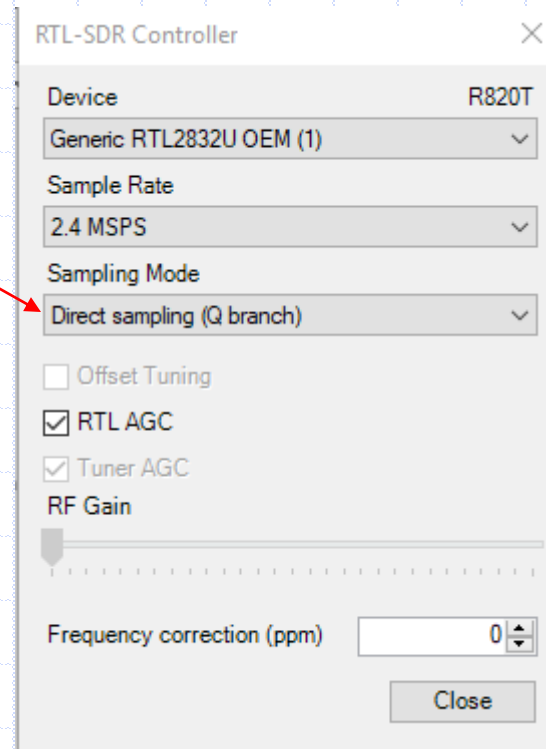
- You're now setup for tuning from 24MHz up to 1.7GHz.

- For LF/MF/HF reception, you need to use Direct Sampling...



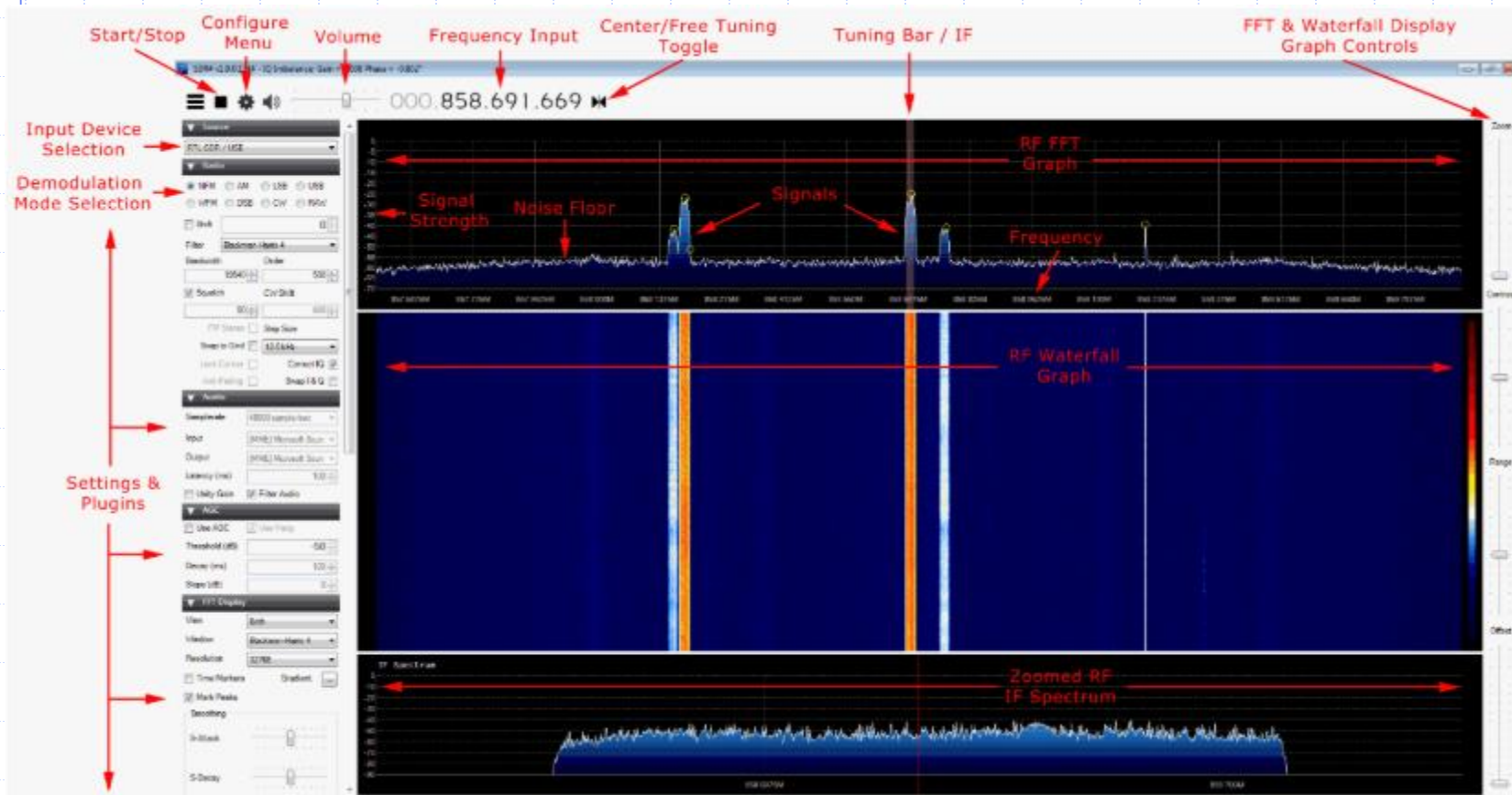
# Direct Sampling for LF/MF/HF

- If "running", hit Stop 
- Hit the Settings cog 
- Select "Direct Sampling (Q branch)"
- Now you can tune 500kHz to 28.8MHz
- Note:
  - Sample rate is 28.8MS/s
  - You may see images of signals <14.4MHz appearing between 14.4 to 28.8MHz, and vice-versa.
  - You may need to apply your own front end filters to avoid this.



- SDR# Users Guide:  
<https://www.rtl-sdr.com/sdrsharp-users-guide/>

# Overview of SDR#



# Live Demo

