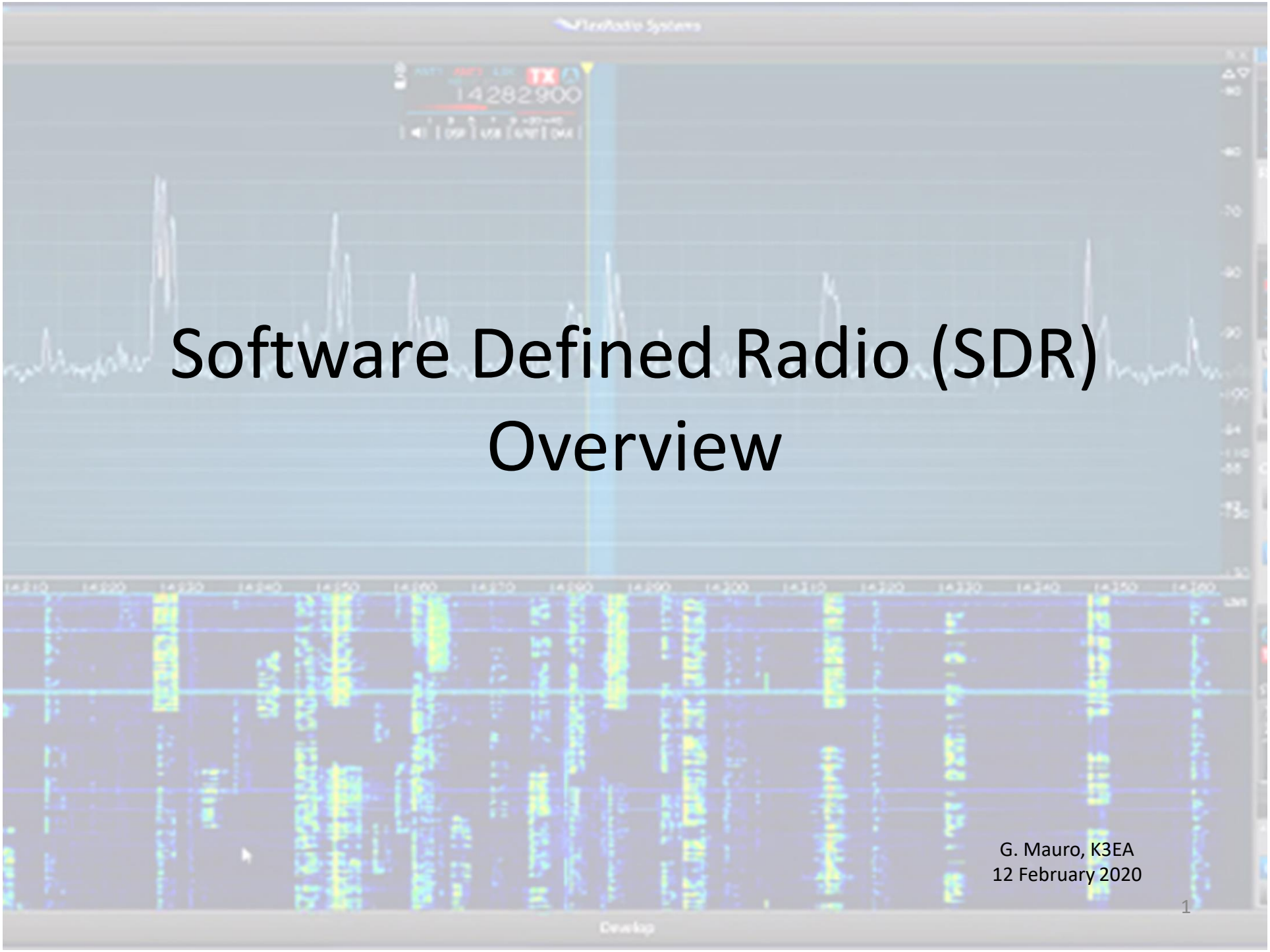


Software Defined Radio (SDR) Overview

G. Mauro, K3EA
12 February 2020

Software Defined Radio Overview

- SDR intro
- Architecture
- Early SDR implementation
- What can I do with SDR?
- Pros and Cons
- Current SDR Examples
- SDR Summary
- Questions?

SDR intro

- What is SDR?
- An SDR utilizes software to perform filtering and modulation / demodulation functions.
  - Not to be confused with radios that:
    - are computer controlled
    - utilize Digital Signal Processing (DSP) for audio or IF filtering
- SDR's are among the top performers in modern receiver designs
  - In particular, selectivity performance as measured with strong signals adjacent to the passband.

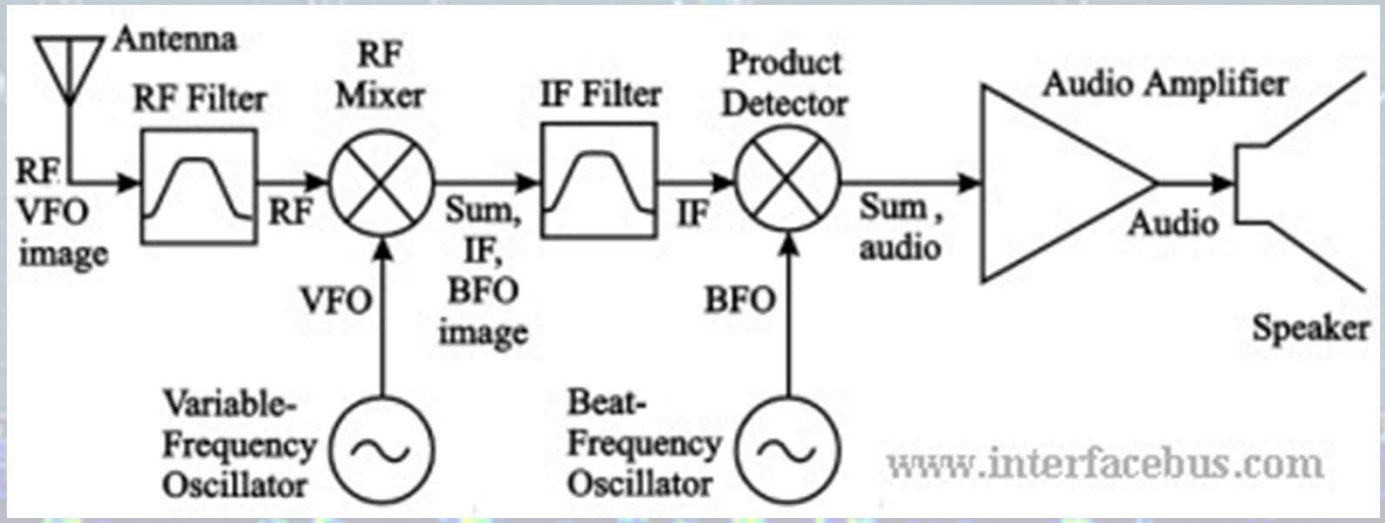
"Software Defined Radio", Andrew Barron

SDR Architecture

- Computer / software
  - The main feature of SDRs are software driven panadapter displays that allow the viewing of wide frequency ranges.
  - The user interface is the discriminator between SDRs
- Direct conversion – RF goes in, audio comes out
  - Single Conversion with a Quadrature Sampling Detector (QSD)
    - Panadapter display bandwidth a function of soundcard sampling rate
  - Digital Down Conversion (DDC)
    - Wider panadapter bandwidths possible
- Analog to Digital Converters (ADC's)
  - SDR display bandwidth is dictated by # of bits and sampling rate
- Filtering is performed by software in the processor.
  - Less complex, better performance than analog filters, no ringing.

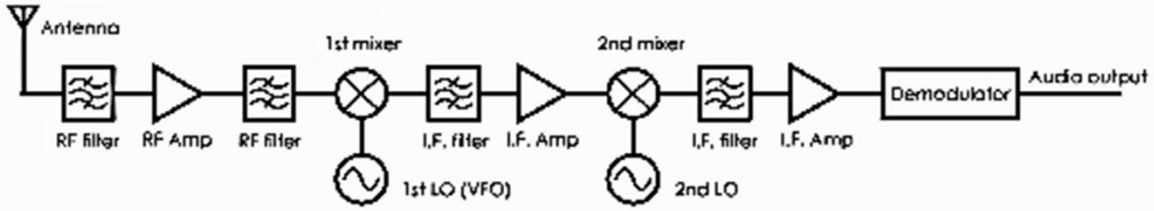
Progression of Receiver Technology

Typical Heterodyne Receiver Block Diagram

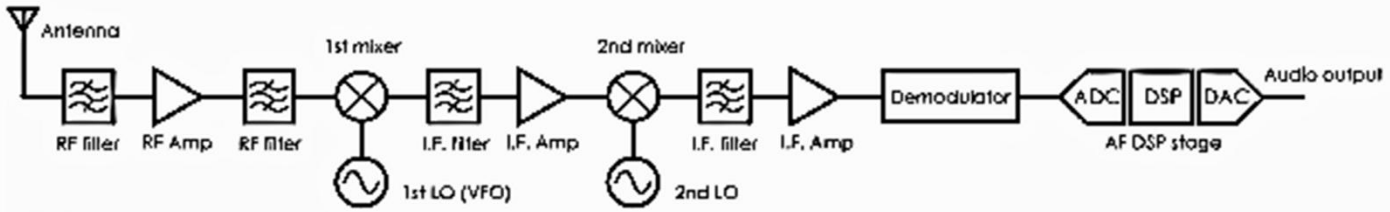


Most modern heterodyne receivers implement two, cascaded IF stages with a second oscillator / mixer stage. While improving selectivity performance, it adds complexity and introduces other unwanted characteristics.

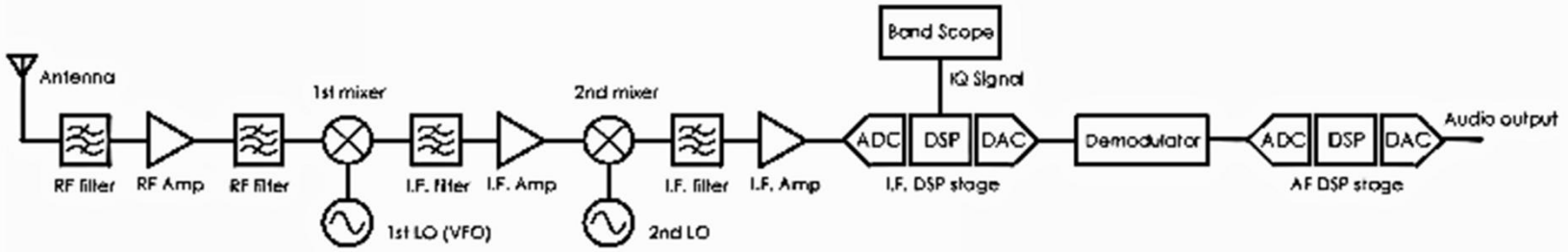
Progression of Receiver Technology (cont.)



A) Double conversion Superhetrodyne receiver

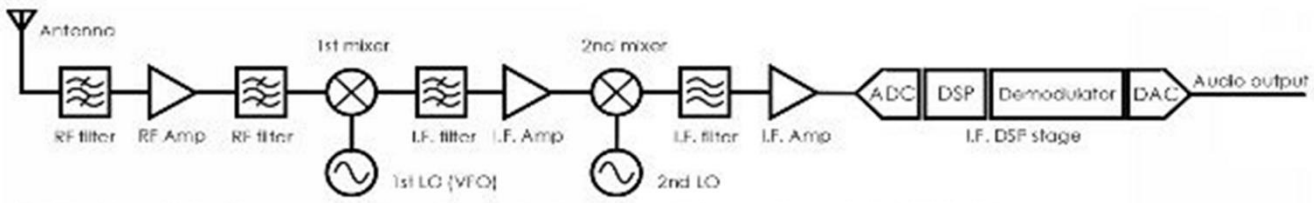


B) Double conversion Superhetrodyne receiver with AF DSP

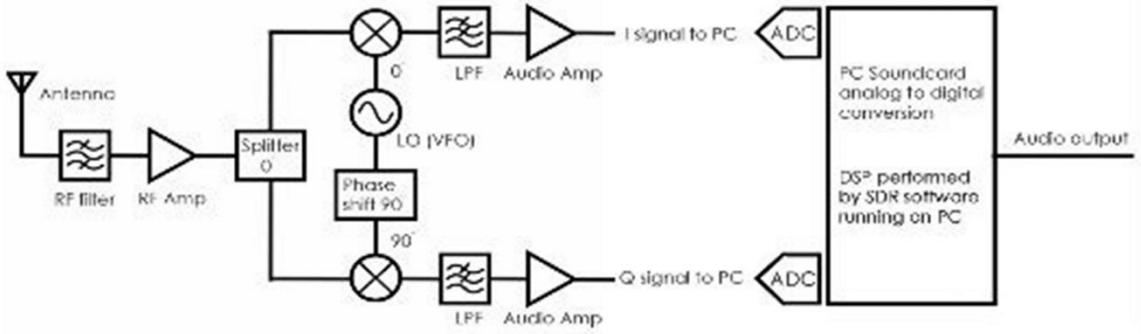


C) Double conversion Superhetrodyne receiver with I.F. DSP

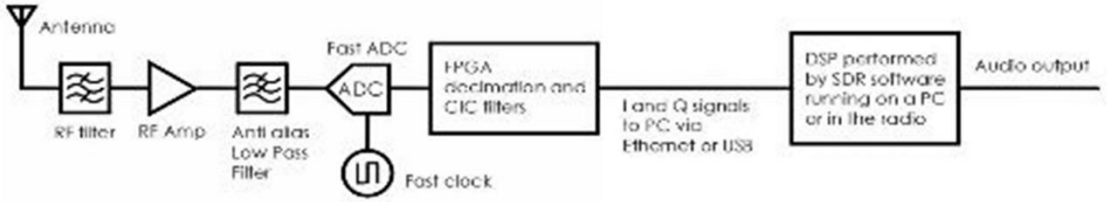
Progression of Receiver Technology (cont.)



D) Typical double conversion Superhetrodyne HF receiver with I.F. DSP



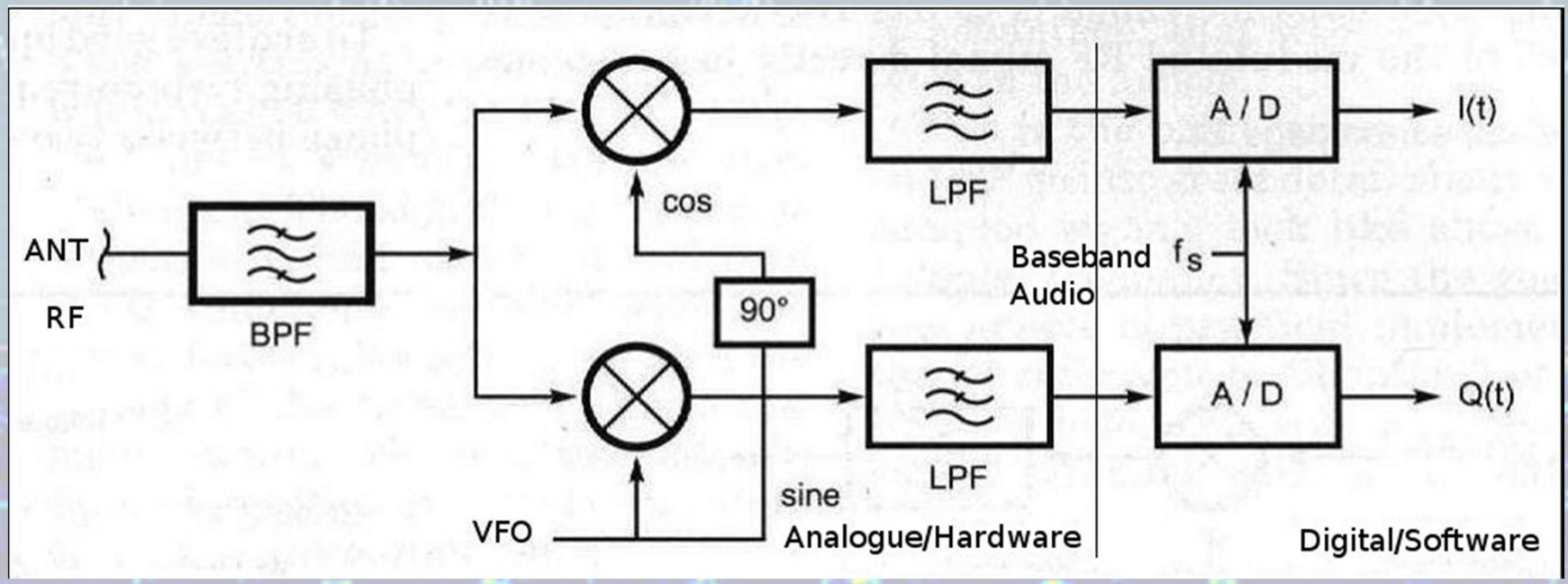
E) Single conversion QSD (quadrature sampling detector)HF receiver



F) DDC (direct down conversion) SDR HF receiver

DDC uses a clock, not an oscillator

SDR Down Conversion QSD Block Diagram



Band pass filter used on front end to avoid overload to ADC's

Early SDR ham radio implementation

- Kits / experimenters …….. early kits were complicated with multiple Printed Circuit boards.
  - Computers required
  - Specialized sound cards utilized with high sampling rates
- Receive only
  - Kits
  - Dongles, mostly VHF/UHF
    - (converted from European standard TV dongles)
  - Wide band HF receivers (expensive, $300+)
- Transceivers
  - Commercially manufactured (Flex SDR1000, Flex 1500)
    - Parallel port and Firewire connections on early models

“High-Performance, Single-Signal Direct-Conversion Receivers” – from 1993 QST

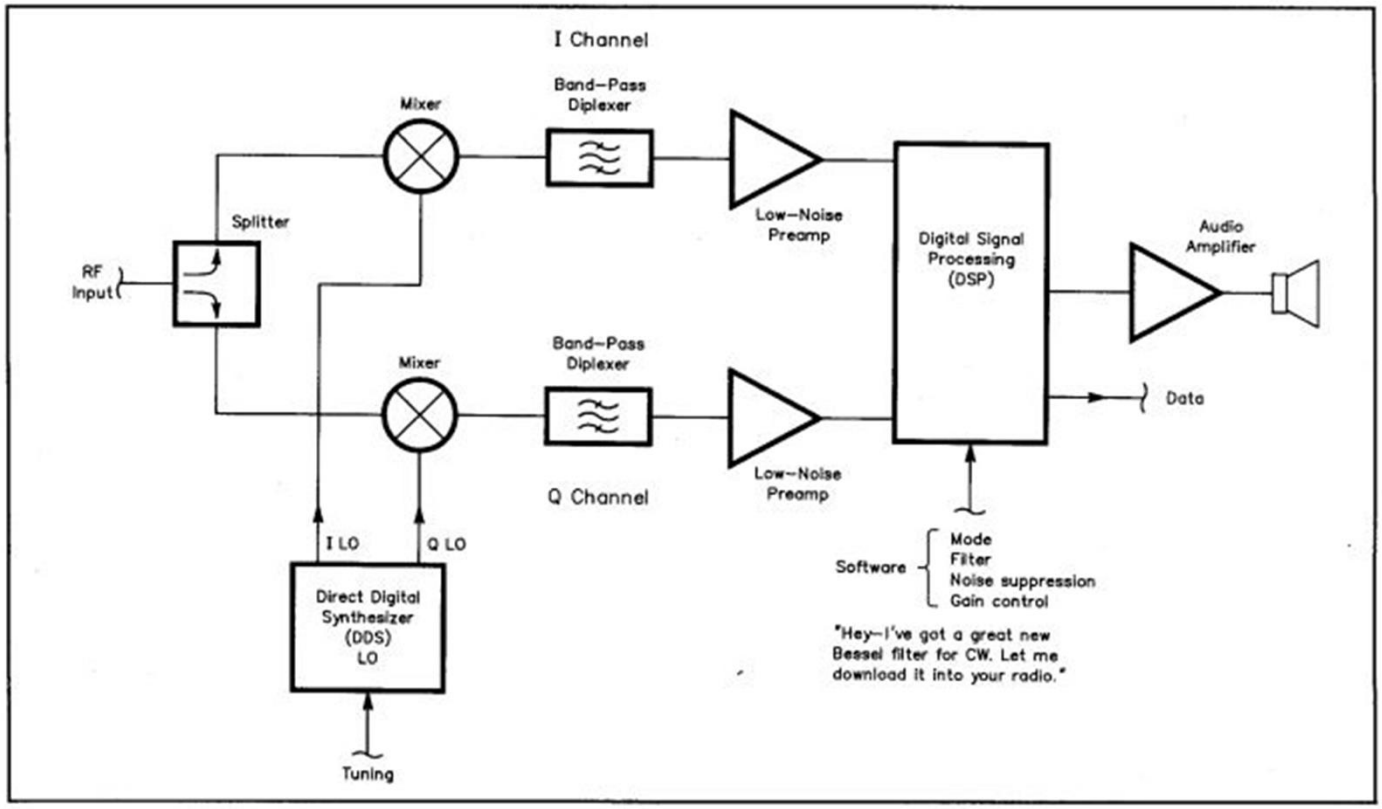


Fig 7—The R2 board can serve as a basic building block for a receiver of the future. Just add a direct-digital synthesizer for the LO and digital signal processing for the audio processing.

January 1993 39

What can I do with an SDR?

- Intuitive panadapter / waterfall display on a large monitor
  - Wide bandwidth display
  - Interactive / touch screen: point, click, drag, finger gestures
  - multiple frequency monitoring (hardware permitting)

- Configurable software
  - Sharp, constantly variable passband filtering
  - Noise reduction algorithms configurable & versatile
  - Rx and Tx audio tailoring
  - Operational memories
    - band, mode, power, filtering, etc. can be stored into individual memories

WHAT ELSE CAN I DO?

- Add a panadapter and waterfall display to an existing conversion receiver with an external SDR Rx

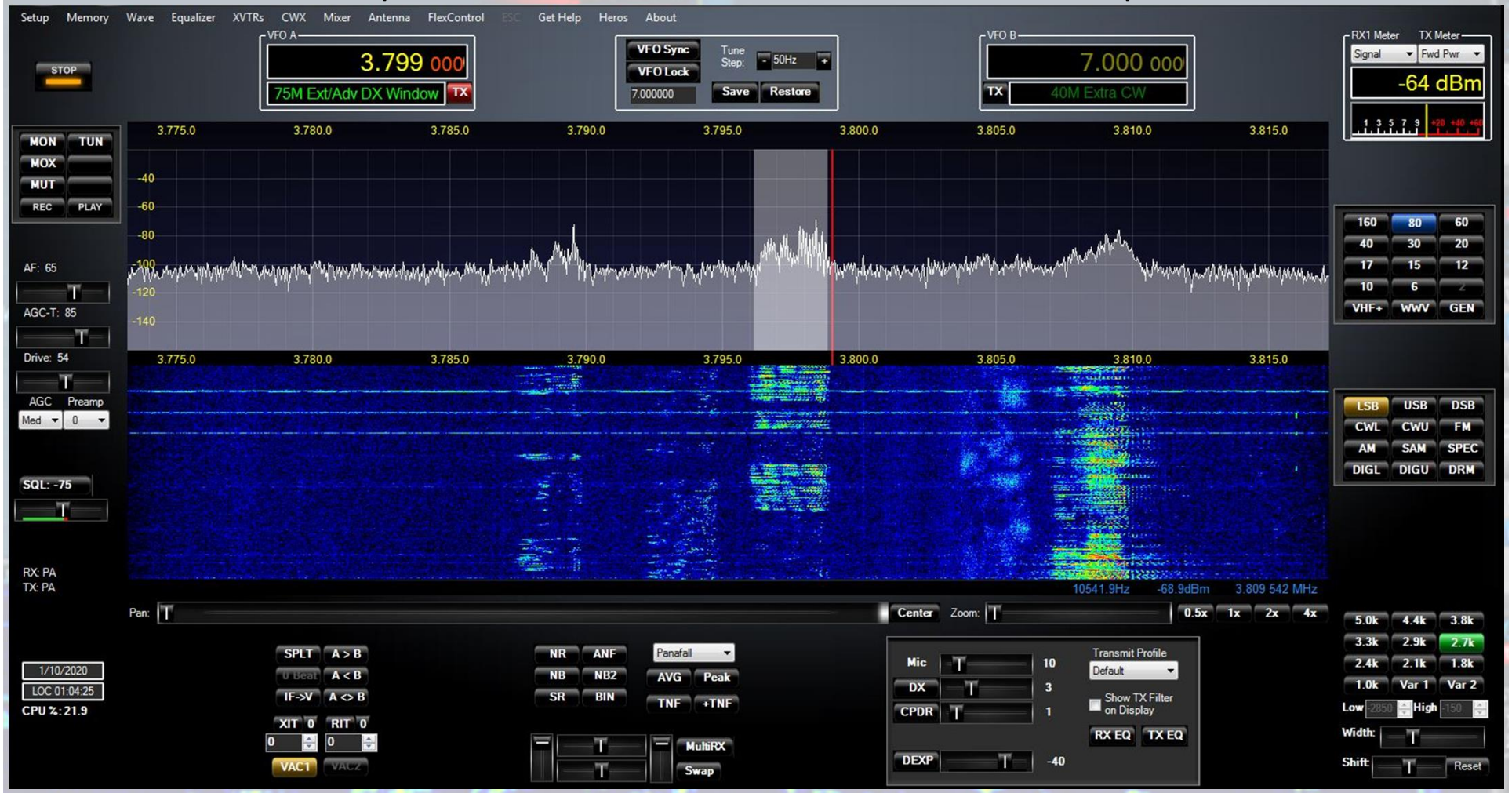
- Listen to or “broadcast” an SDR on the internet
  - Take advantage of a receiver at a remote, possibly more quite, location

- Advanced receiver and instrumentation applications
  - See list on slide 26

PANADAPTER EXAMPLES

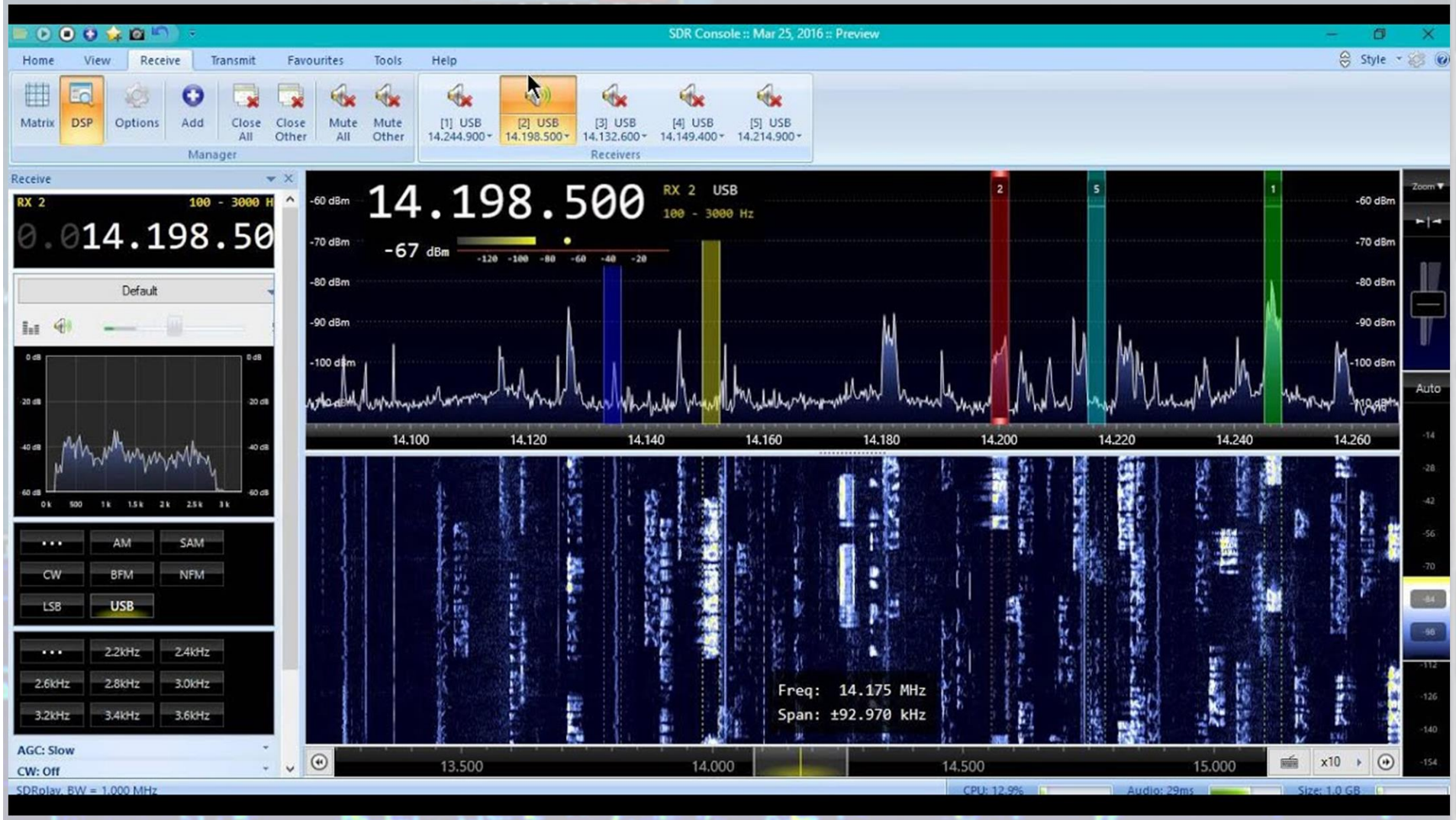
Panadapter display

(no knobs SDR - Flex1500 HF transceiver)



- Panadapter display - 48 KHz max. Passband shown at 2.7Khz is fully adjustable
- Power SDR software running on Win7 – Tune by click, fine tune w/ mouse scroll,
  - Typical, full set of controls on main screen
  - Hidden menus are typical of most modern radios, plus many more features

SDR console software



SDR Console is compatible with most dongles and many commercial SDRs

Panadapter display with 2 receivers

(Flex 6000 HF transceiver with Maestro controller)

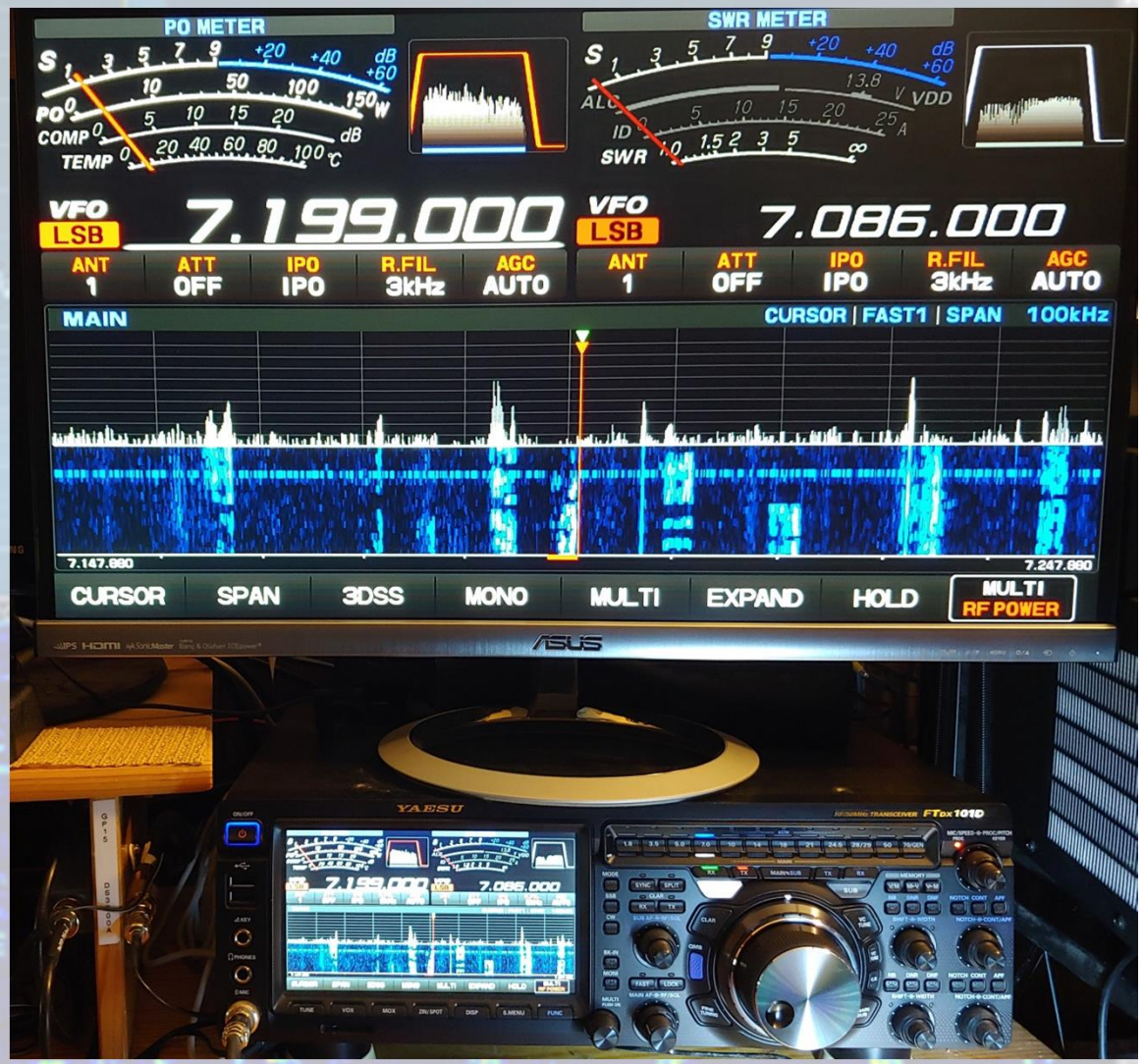
- 8 inch touch screen + manual tune, volume, AGC knobs, filter bandpass control, etc.
- Smart SDR software running on an embedded processor (no external computer required)
- Touch screen: Frequency tune by tap/swipe, band spread control with finger gestures
  - Wider display bandwidth enables user to see entire band at a glance
- Dual receive shown: VFO A on 7Mhz, VFO B on 3.8Mhz

New video.mp4

“All knobs” SDR and monitor

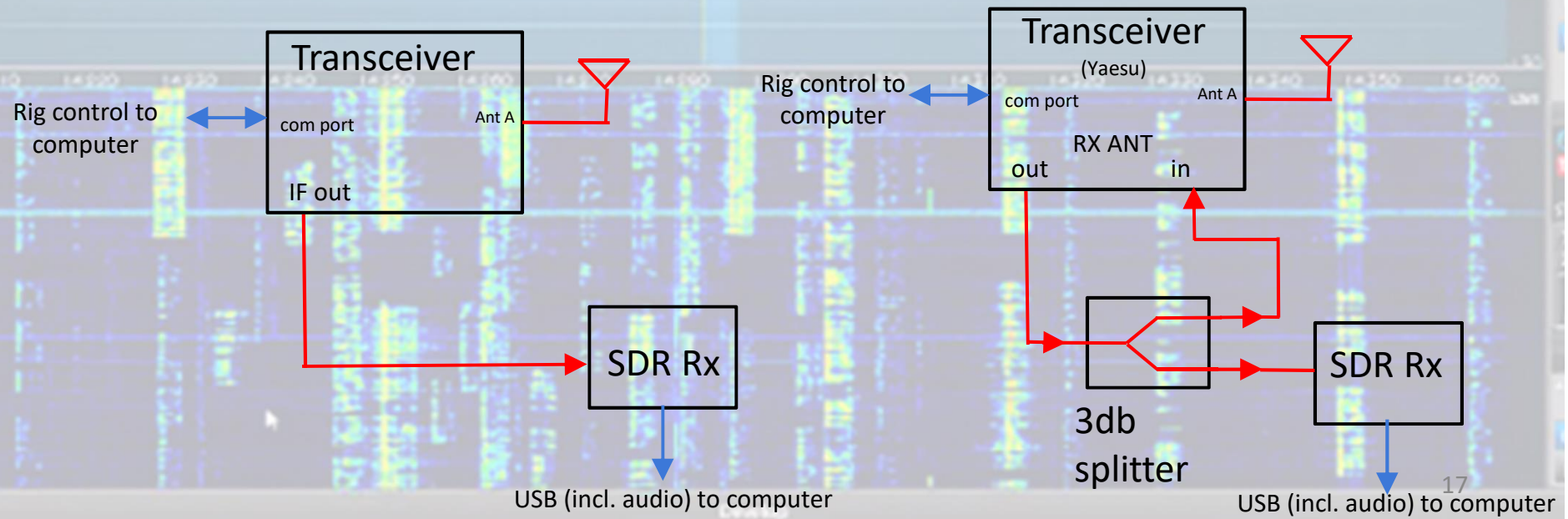
(Yaesu FTDX101D HF transceiver)

- Superhet/SDR hybrid (with IF filters)
- 7” menu driven, touch screen
- Shown with a 27” monitor that mirrors the radio display
- #1 on Sherwood Rx listing



External Panadapter Implementation

- Input to Radio and SDR Rx need to be the same
  - Some radios have an external IF output (preferred method)
  - Received signal can be split (some radios can route the received RF to the RX ANT “out” port)
  - Software needed to sync and control the two radios – i.e. “Omnirig”
  - Software needed to run the SDR – i.e. SDR console or HDSDR

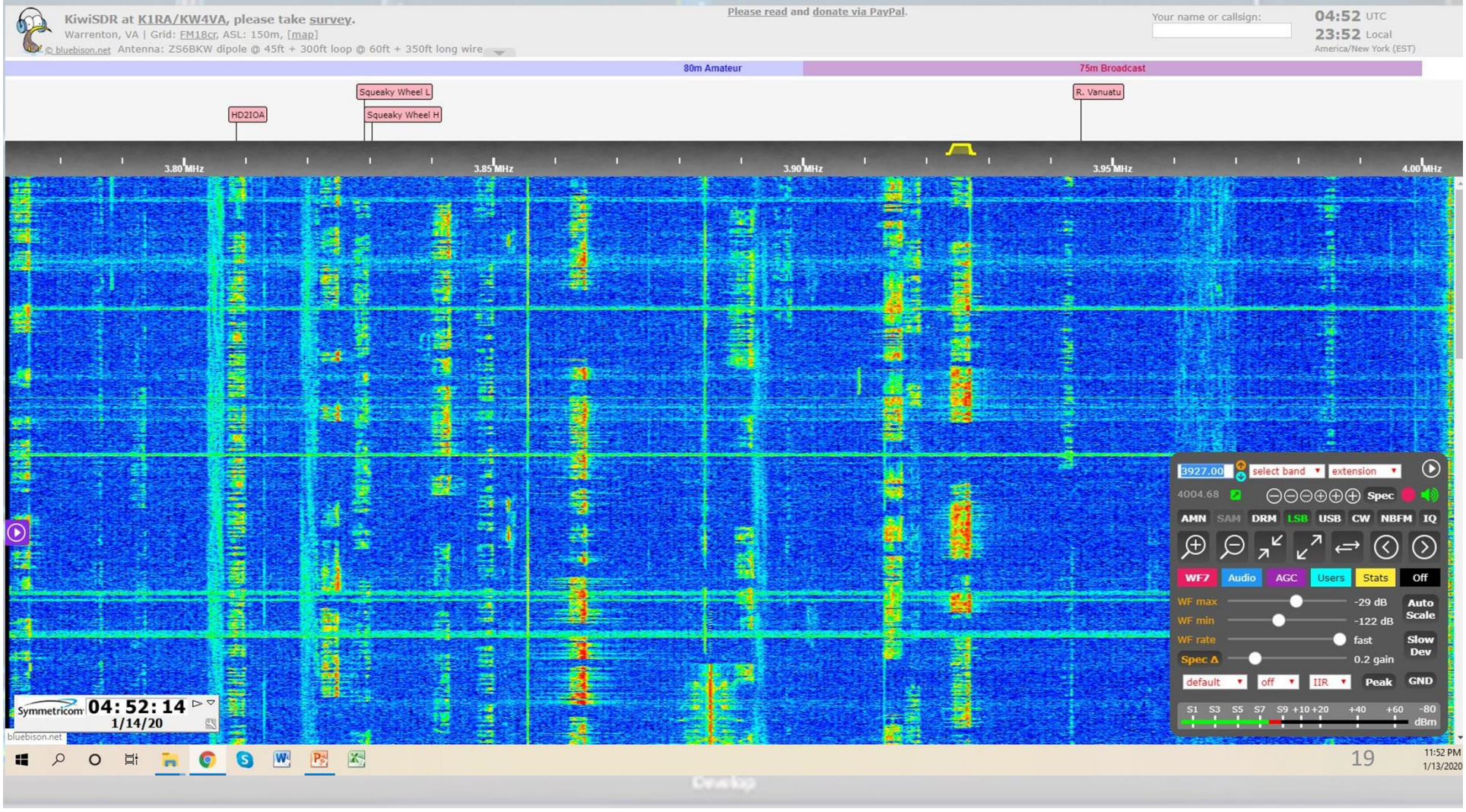


SDR dongle/ICOM panadapter at W2ZQ

- 64.455Mhz IF is brought out to an SDR dongle from an internal connector
- HDSDR software used for panadapter
- OmniRig software used to “synchronize” Icom with dongle

SDR on the internet

- Monitor your signal
- Receive outside your skip zone
- Receive from a less noisy location
- Kiwi SDR shown below



Pros and Cons of SDR

- PROS
  - Panadapter/Waterfall capabilities available on all SDRs
    - Click/touch screens with wide bandwidths and multiple band displays
  - Receiver performance – SDR meets or beats standard superhet receiver performance for key parameters
    - Noise: Digital signals can be amplified, filtered and demodulated without adding noise.
    - Interference: conversion and demodulation performed without introducing IMD, birdies and images.
    - Filtering: Digital filters avoid ringing and are continuously variable.
  - Cost vs Performance favors the SDR
    - SDR utilizes DSP computer chips vs expensive analog components
    - Firmware/software is easily improved, updated and revised into the SDR
  - Custom tailoring of Tx & Rx audio and noise reduction algorithms
  - Easily configured for remote operation
- CONS
  - Need computer / firmware upgrades
    - Added complexity for setup
    - hidden menus
    - slow startup / computer boot up
  - Latency for CW operation (early models)

Appendix, Sherwood Rx ratings

Sherwood Engineering Inc.
1268 South Ogden Street Denver, Colorado 80210 USA
email Phone: 303-722-2257 FAX: 303-744-8876
9 a.m. - 5 p.m. MST Monday - Friday

Look in on part of SEI's Laboratory

Receiver Test Data

(Terms Explained: DOC PDF)

Sorted by Third-Order Dynamic Range Narrow Spaced - or- ARRL RMDR (Reciprocal Mixing Dynamic Range) if Phase Noise Limited

Note: The term blocking only applies to a superhet radio. For a direct sampling radio the value in the blocking column is the ADC overload point reference receiver noise floor.

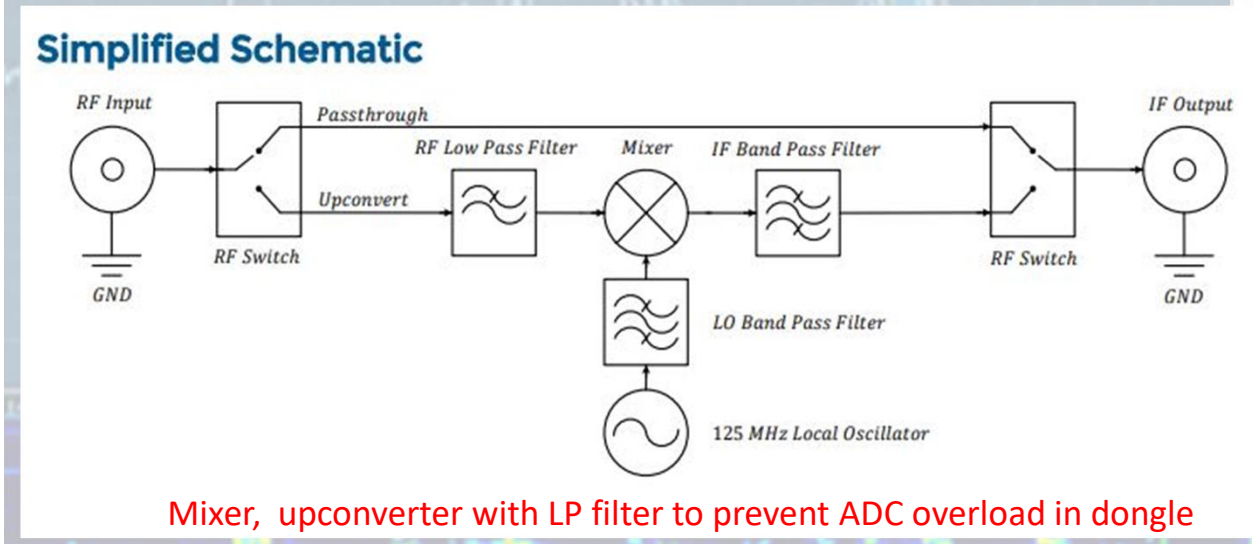
Updated 1 November 2019. Added Kenwood TS-2000X 2m data. 70cm and 23cm available in long form report.

Device Under Test	Noise Floor (dBm)	AGC Thrshld (uV)	dB	100kHz Blocking (dB)	Sensitivity (uV)	LO Noise (dBc/Hz)	Spacing kHz	Front End Selectivity	Filter Ultimate (dB)	Dynamic Range Wide Spaced (dB)	kHz	Dynamic Range Narrow Spaced (dB)	kHz
LO Noise Corrected 05/10/19 Yaesu FTdx-101D	-127 -136[b] -141[6]	4.5 1.6[b] 0.58[b1]	3	>147	0.60 0.20[b] 0.12[b1]	154 155	10 50	A Trk Presel	>115	110	20	110	2
Added 9/29/14 FlexRadio Systems 6700 Hardware Updated	-118 -135[b2]	3.0 1.0[b2]	Var	130 preamp Off	2.0 0.25[b2]	145 155	10 50	B Band Pass	115	99	20&2	108[y]	20&2
Added 02/11/18 Icom IC-R8600 Second sample S/N 02001177	-131 -142[b] -130[ab]	2.40 0.67[b]	3	125	0.40 0.12[b] 0.49[ab]	144 148	10 50	B Half Octave	>100	109[ab] 88[ac]	20	107[ab] 88[ac]	2
Added 11/10/15 Elecraft K3S	-135 -138[b] -145[10]	1.5 0.45[b]	3	150	0.27 0.20[b] 0.08[10]	144 146	10 50	B Band Pass	110	107[q]	20	106[p] 106[q]	2
Added 3/17/17 Elecraft K3S 2nd Sample 10 meter data	-135 -138[b] -145[10]	1.5 0.45[b]	3	150	0.27 0.20[b] 0.08[10]	144 146	10 50	B Band Pass	110	106[ah]	20	105[ah]	2
Added 02/23/15 Elecraft K3 (RX Gain Recal) New Synthesizer	-136 -139[bq]	1.0 0.3[b]	3	141	0.27 0.20[b]	145 147	10 50	B Band Pass	108	105[q]	20	107[p] 104[q]	2
Added 04/25/16 Icom IC-7851	-123 -135[b] -141[b1]	8.5 1.85[b] 1.16[b1]	3	149	0.65 0.16[b] 0.11[b1]	148 153	10 50	A Trk Presel	100	110[aa]	20	105[aa]	2
Added 10/15/18 Kenwood TS-890S	-131 -140[b] -141[6]	2.1 0.53[b] 0.14[b1]	3	>151	0.39 0.13[b] 0.10[b1]	155 156	10 50	B Half Octave	>118	106	20	105	2

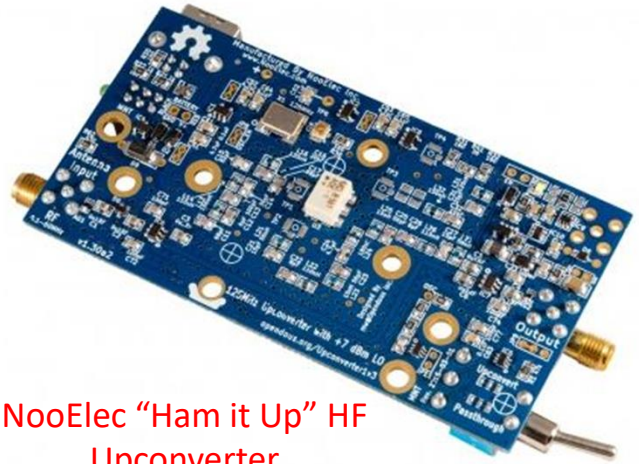
Receivers are listed in order of best selectivity. Of the top 20 rated, 14 are SDRs or SDR hybrids

Current SDR Examples

- Receivers (best way to start)
  - Dongles - mostly VHF/UHF
    - RTL2832U/R820T , $20
    - Fun Cube, $100
    - Add an inexpensive upconverter, $40:



Mixer, upconverter with LP filter to prevent ADC overload in dongle



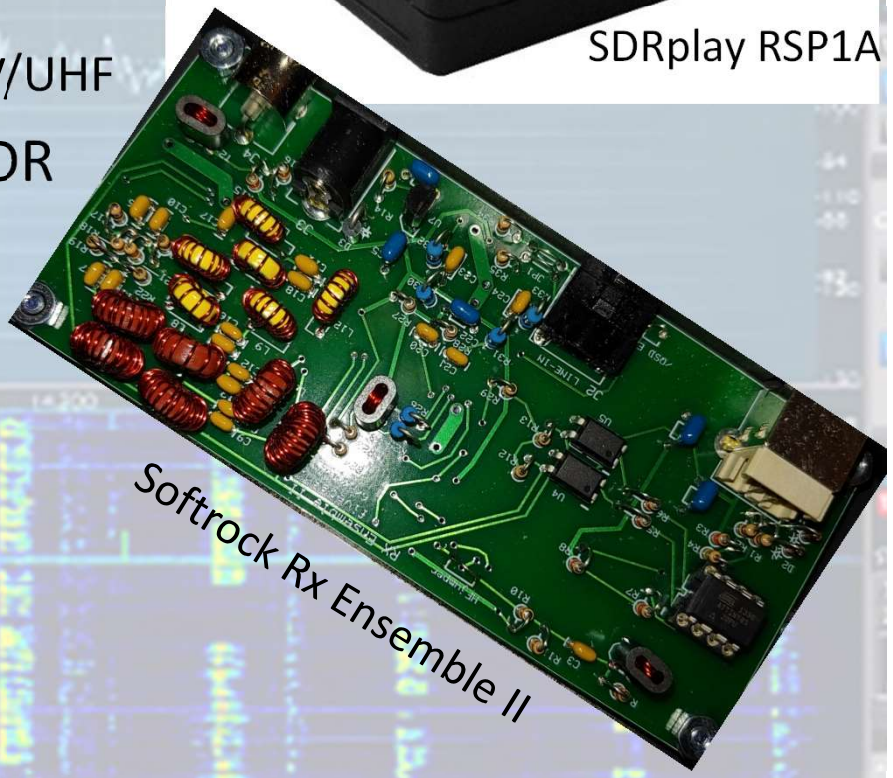
NooElec "Ham it Up" HF Upconverter

- Online receivers (FREE!!)
  - WebSDR.org
  - SDR.hu

Current SDR Examples (cont.)

- Receivers (cont.)
  - Small receivers: SDR Play, RF Space, Perseus, WinRadio, Quicksilver, many others, ~$100+
    - HF receivers, some models also V/UHF
  - Kits: Softrock, SDR Cube, KiwiSDR (network radio), others - $65+
  - Icom ICR8600 (10Khz – 3 GHz receiver w/ knobs, $2200)

SDRplay RSP1A



Softrock Rx Ensemble II

Icom ICR8600

Current SDR Examples (cont.)

- Transceivers w/ external computers
  - Interfaces are typically USB or Ethernet
  - Can use as large of a display as possible/practical
    - Flex – 6400/6600/6700, $2000+
      - » Maestro remote display, $1200
    - Apache – Anan7000, $2800+
    - Zeus – 15W, QRP, $1200
    - QRP Kits: SoftRock, $100 ; SDR Cube, $299

Anan7000

- Transceivers with embedded SDR hardware and I/Q output for external computer processing
  - Xiegu G90, $429 (knobs radio, 10W QRP, I/Q output)
  - Alinco DXSR9T, $565 (knobs radio, superhet Rx with 48 KHz I/Q output)

Xiegu G90

Current SDR Examples (cont.)

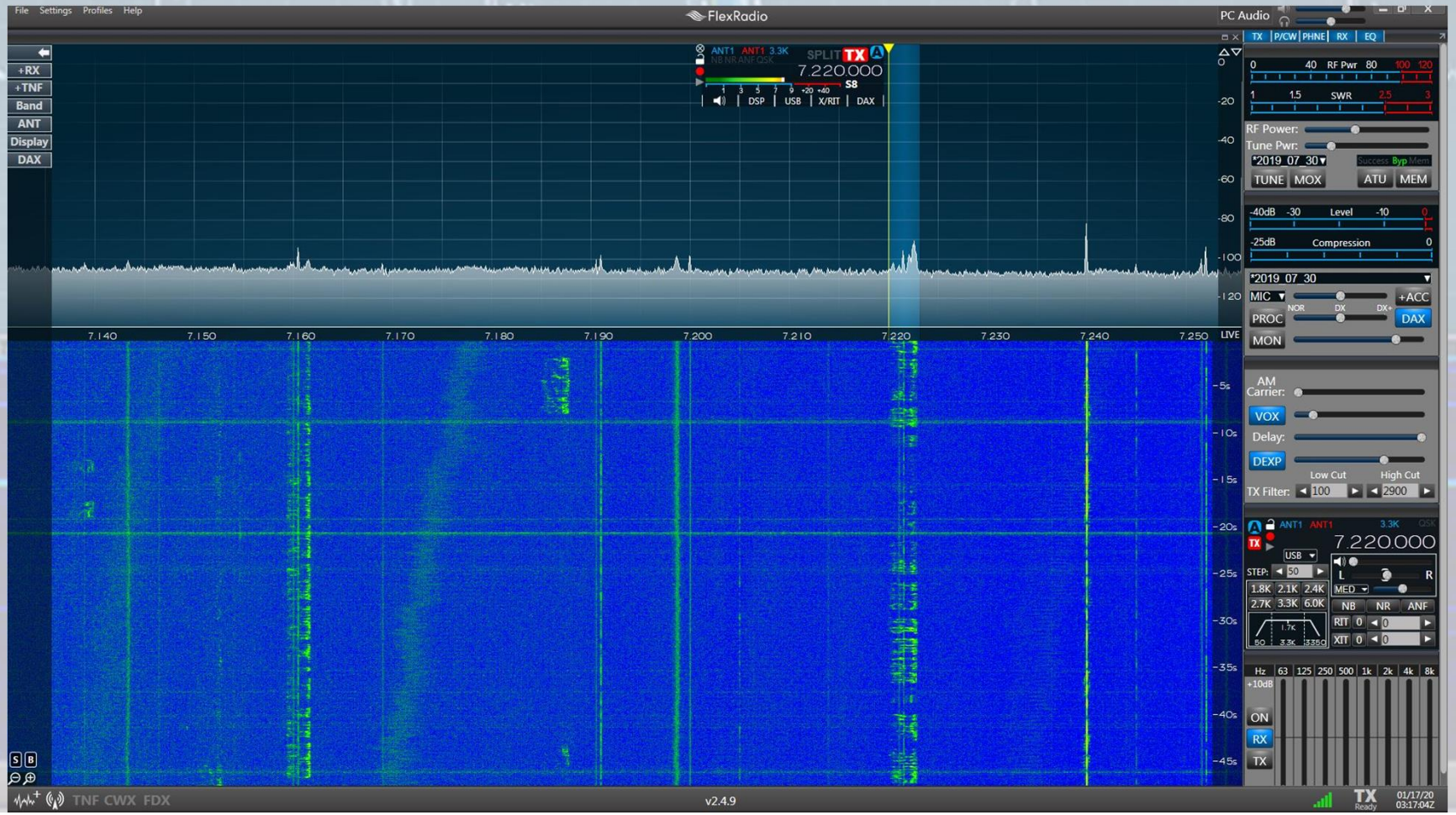
- Transceivers with internal processor/firmware
  - Looks like a conventional radio, - the processor and firmware are embedded
    - » Elecraft – K3S (hybrid), KX3 (QSD, 10W QRP, + I/Q output)
    - » Icom (DDC) – IC7300, $900; IC7610, $2900
    - » Yaesu – FTDX101D (hybrid), $3500
  - Some radios also have the option for an external display

Icom IC-7300

Many other units are commercially available…..

Popular SDR Software

- HDSDR (multiple radio support)
- SDR console (multiple radio support)
- SDR# (basic operation, multiple radio support)
- Power SDR (Flex, others)
- Smart SDR, shown below (Flex)
- SDR Touch (for Android phones)
- Many other options exist



Additional SDR Applications

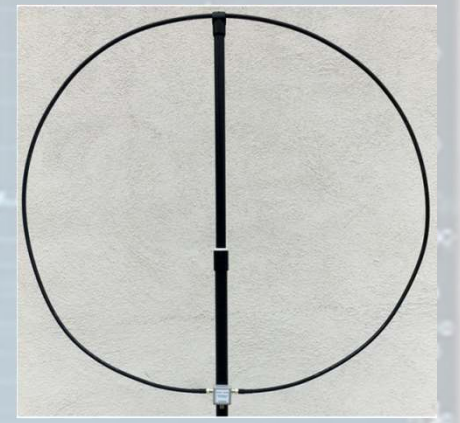
- Using rtl-sdr as a spectrum analyzer.
- Receiving NOAA weather satellite images.
- Listening to satellites and the ISS.
- Radio astronomy.
- CW skimmers
- ADS-B flight radar tracking
- Monitoring meteor scatter.
- Listening to FM radio, and decoding RDS information.
- Listening to DAB broadcast radio.
- Decoding taxi mobile data terminal signals.
- Use rtl-sdr as a high quality entropy source for random number generation.
- Use rtl-sdr as a noise figure indicator.
- Reverse engineering unknown protocols.
- Triangulating the source of a signal.
- Searching for RF noise sources.
- Characterizing RF filters and measuring antenna SWR.

One more thing…….Antennas

An outside antenna is a must!

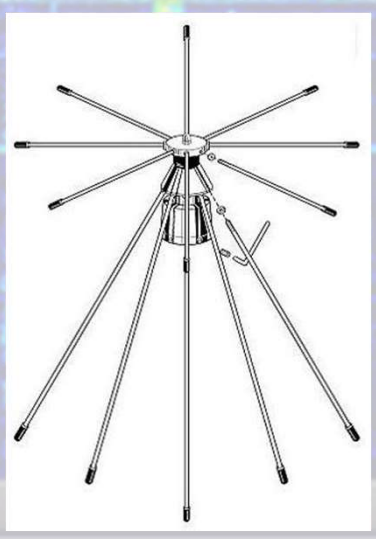
HF: any antenna tuner + a dipole or random length wire

or a wideband Rx magnetic loop
(W6LVP loop, from $225)



VHF: Discone antenna – wide frequency coverage and transmits on ham bands

JETSTREAM JTD1, $35
25-1300Mhz



Summary

- Try it……
  - Utilize online SDR receivers – for free
  - Start with a $20 RTL2832U dongle and monitor VHF/UHF
    - Add a downconverter for HF ($40) or……
  - Try an inexpensive stand-alone Rx for HF
  - Add a panadapter to an existing radio
    - Try the panadapter on W2ZQ Station B
  - NEED HELP? Many DVRA members have experience with SDR's and can assist or give demo's on their equipment

QUESTIONS?