

Hudson Valley Digital Network | www.hvdsn.org /presentations

SDR & IoT: Sensing the world
around you with open source software

Presented at HV Open on November 6th 2019

About Hudson Valley Digital Network (HVDN)

Subpart A—General Provisions

§ 97.1 Basis and purpose.

The rules and regulations in this part are designed to provide an amateur radio service having a fundamental purpose as expressed in the following principles:

(a) Recognition and enhancement of the value of the amateur service to the public as a voluntary noncommercial communication service, particularly with respect to providing emergency communications.

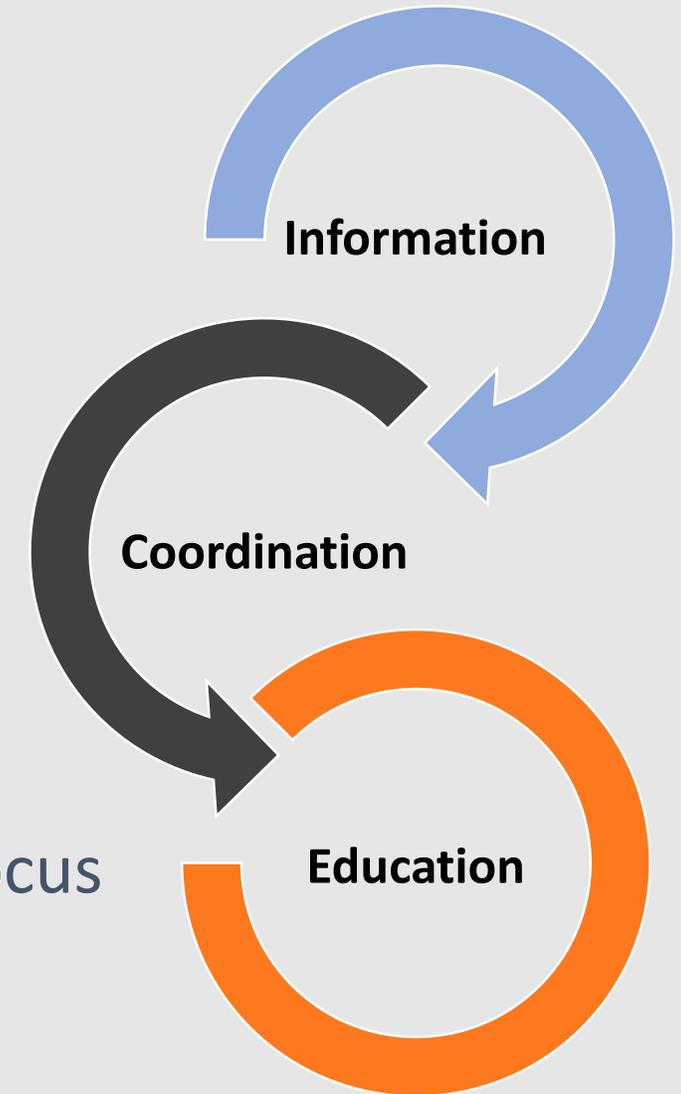
(b) Continuation and extension of the amateur's proven ability to contribute to the advancement of the radio art.

(c) Encouragement and improvement of the amateur service through rules which provide for advancing skills in both the communication and technical phases of the art.

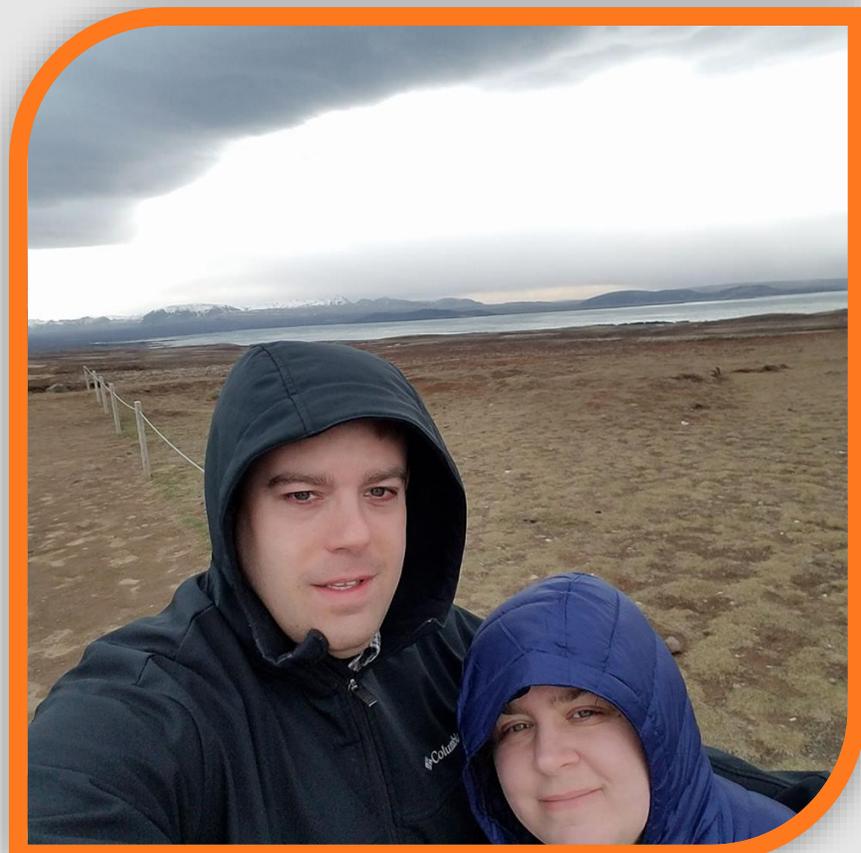
(d) Expansion of the existing reservoir within the amateur radio service of trained operators, technicians, and electronics experts.

(e) Continuation and extension of the amateur's unique ability to enhance international goodwill.

- HVDN founded 2017
- No, we are not “that” sort of network....
- Uphold FCC Part 97.1
- 3 pillar approach
- Deliberate modern & future focus
- Club call sign N2HVD



The “Biography” Slide....



Steve Bossert

K2GOG, Co-Founder HVNDN

Name:	Steve Bossert
First “Coding Experience”:	10 Years Old
Amateur Radio License Since:	1998 (21 Years Ago)
Hobby Funding Source:	Informa PLC
Top 3 Hobby Interests:	Hiking, Travel, Electronic Stuff
Fun Fact About Me:	Recently reviewed the Postal Service mailbox rules in detail

Presentation Goal

Demonstrate through the combined ethical use of software defined radio and open source software, illustrate converged ways different hobbies such as amateur radio, computers, makers, and electronics can be part of the “Internet of Things” by sensing the world around them.

Note: At the HV Open meeting, a customized video was used in lieu of the above statement for better audience engagement

What really is an SDR?

Sound Card



Wi-Fi Card



USB Oscilloscope



USB TV Tuner



Raspberry Pi



Smartphone



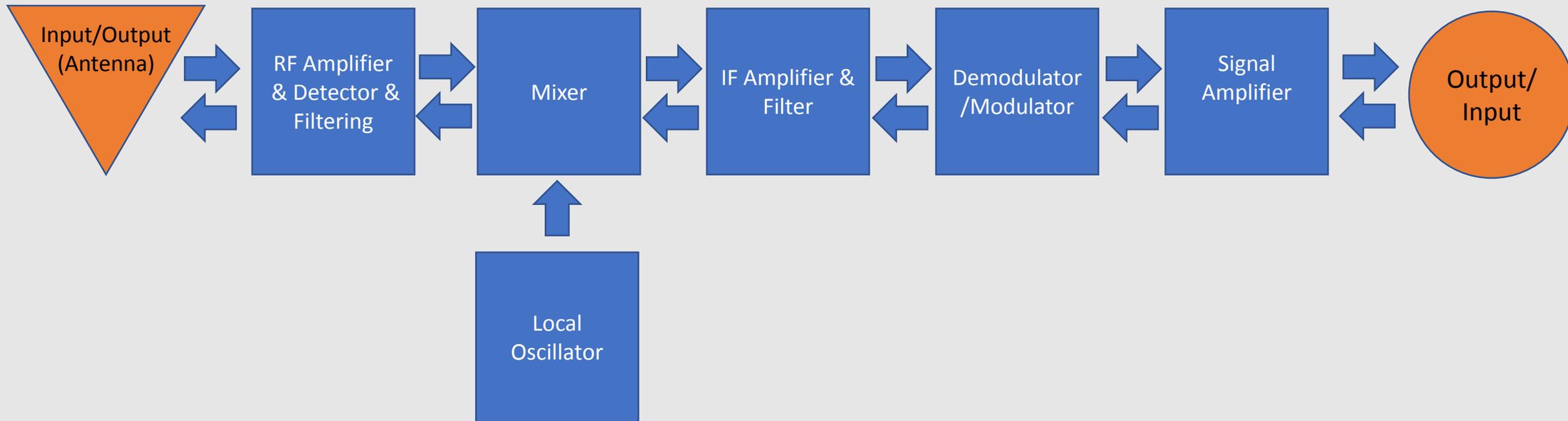
Lab Transceivers



0 Hz to 500 kHz+ 2.3 GHz to 6 GHz 0 Hz to 60 MHz+ 0 Hz to 1.9 GHz+ 0 Hz to 1.5 GHz+ 0 Hz to ?? GHz 0 Hz to 6.0 GHz+

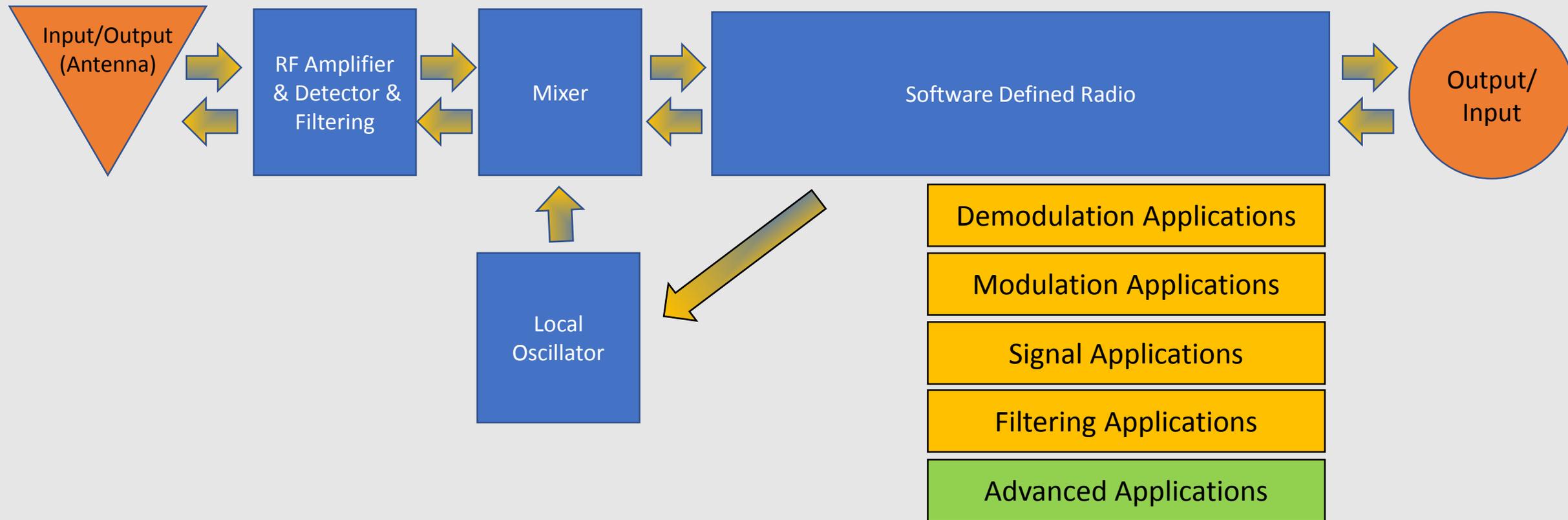
+ many more specialized and odd options too

SDR Basics: Traditional Radio Theory



Traditional Radio Systems are limited to hardware features and functionality (e.g. [mixers](#), [filters](#), [amplifiers](#), [modulators/demodulators](#), [detectors](#), etc.) There are applications where this still have benefits when very narrow needs are required.

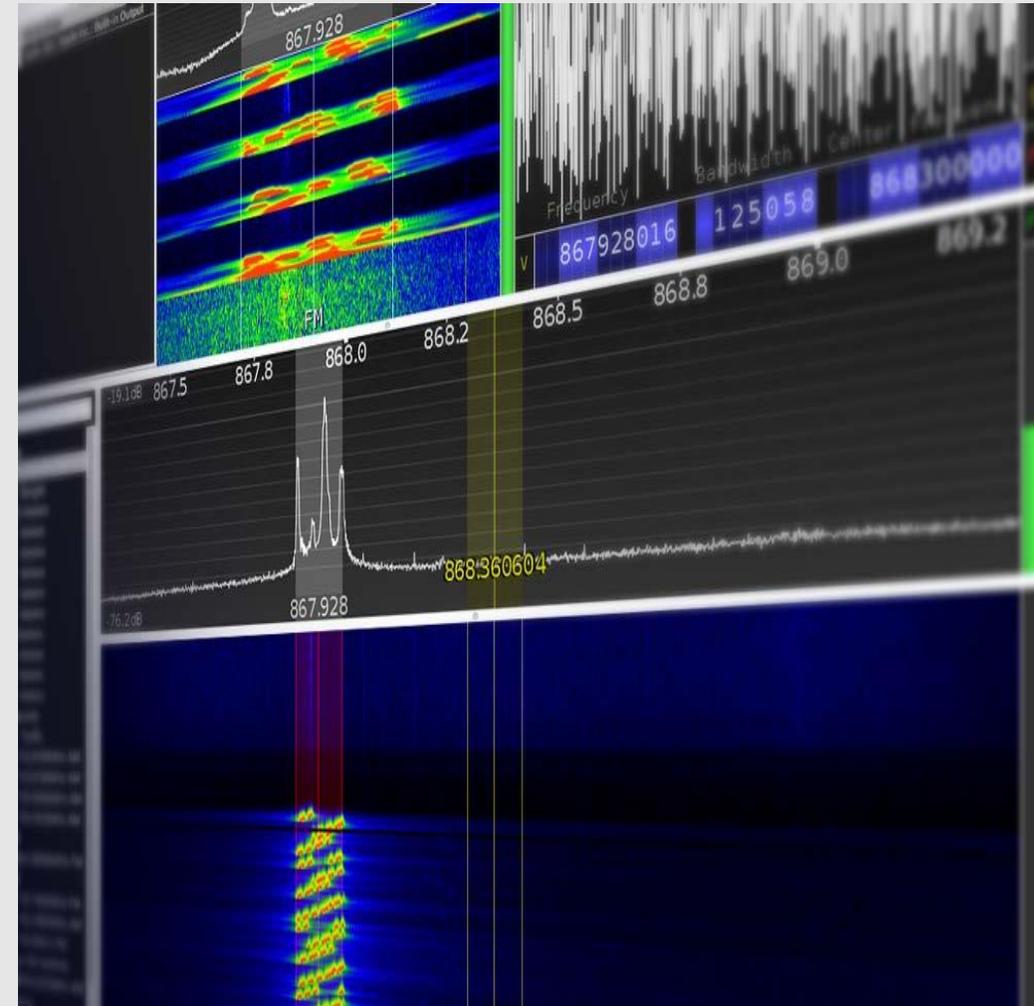
SDR Basics: New Radio Theory



Software-defined radio (SDR) is a [radio communication](#) system where components that have been traditionally implemented in hardware (e.g. [mixers](#), [filters](#), [amplifiers](#), [modulators/demodulators](#), [detectors](#), etc.) are instead implemented by means of software on a personal computer or [embedded system](#).

SDR and IoT combined

- “Internet of Things” devices can be found across the entire 1 to 6000+ MHz spectrum
- SDR Ethics: Not all of them are encrypted
- Many of them use proprietary software and hardware. Most are “hackable”.
- Using an SDR lets you sense, analyze and interact with the IoT world around you
- Explore simple “If this, than that” uses.



Open Source: SDR Software Summary (GUI)

GUI friendly open source options

-  Many open source options currently available
- Most users start with SDR#, HDSDR and SDRUno which are not open source
-  SDRangel, GNUradio and even SDR# offer much more....

Software Defined Radio Receiver Software

Application Name	Windows	Linux
	<i>Easy Scale (Less ★ is harder)</i>	
 SDR#	★★★★★	★★
  SDRangel	★★★★	★★★
HDSDR	★★★	★★
 GQRX	★	★★★★★
  GNUradio	★	★
 SDRconsole	★★★★	★★
 CubicSDR	★★★	★★
SDRUno	★★★★	★★
Linrad	★★	★★
 ShinySDR	★★	★★
Sodira	★★	★★★
 Qtradio	★	★★

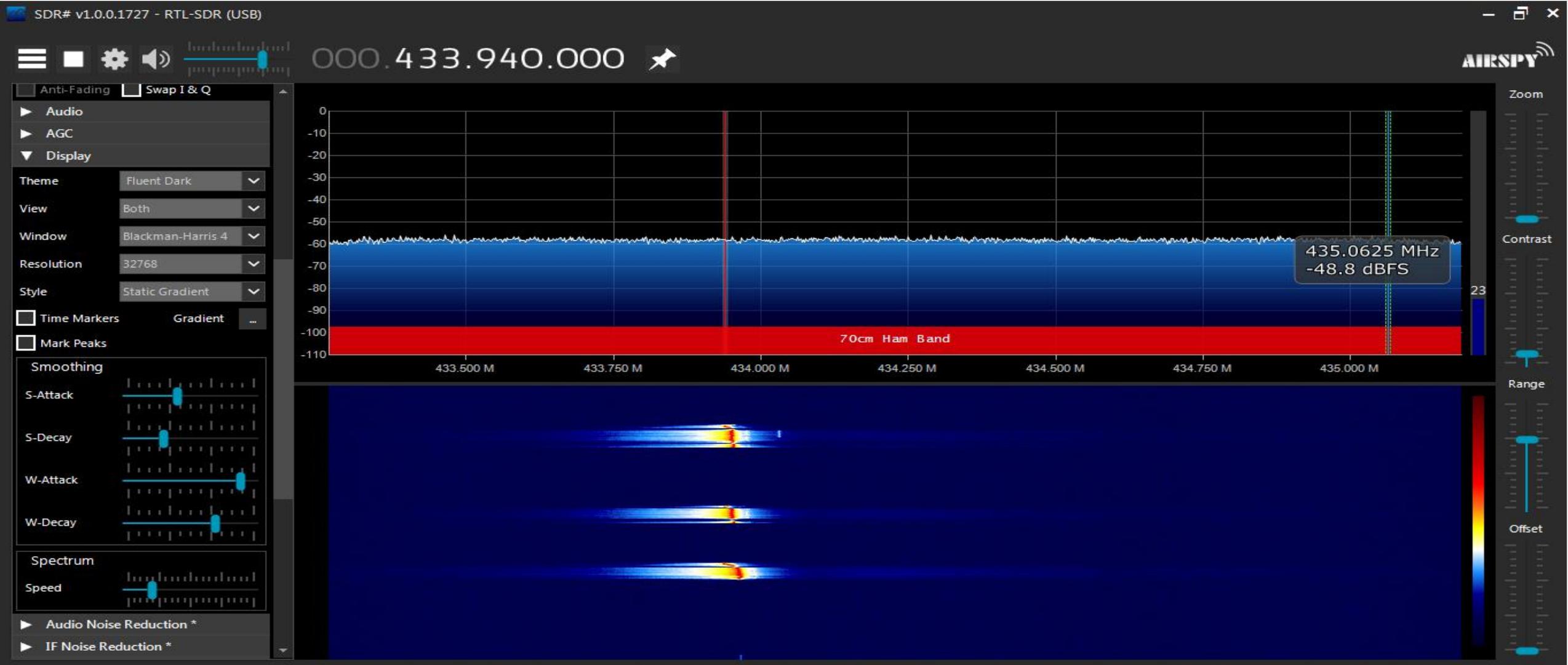
Courtesy of : hvdn.org/notebook

SDR Software: GUI Overview

The following 7 slides are photos of popular SDR software highlighted on slide 11.

These were further described/presented in the live discussion.

SDR Software: SDR# (Closed, but open plugins..)



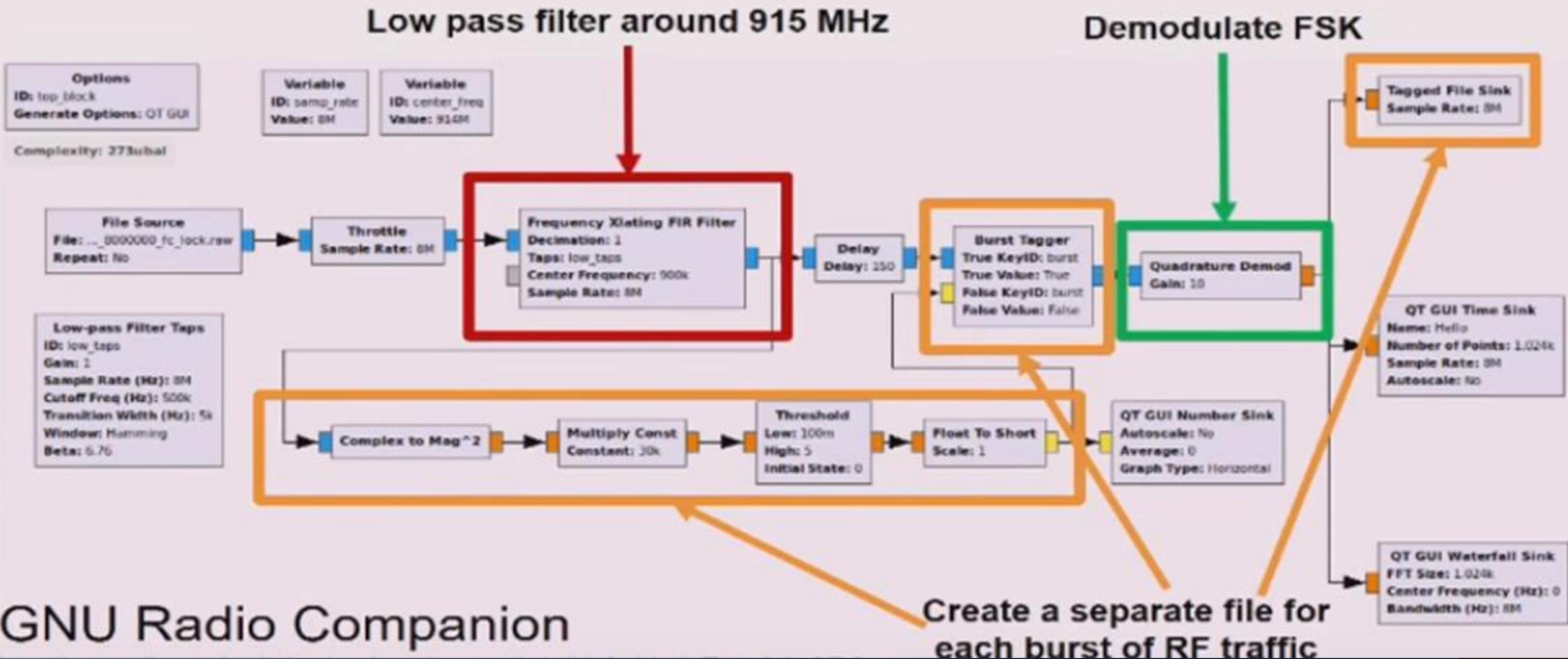
SDR Software: GNU Radio (Open Source)

The screenshot displays the GNU Radio Companion (GRC) interface. The main workspace shows a signal flow graph with the following components and connections:

- Variable** (ID: samp_rate, Value: 32k) is connected to the **Low Pass Filter**.
- Low Pass Filter** (Decimation: 1, Gain: 1, Sample Rate: 32k, Cutoff Freq: [blank], Transition Width: [blank], Window: Hamming, Beta: 6.76) is connected to the **WBFM Receive** block.
- WBFM Receive** (Quadrature Rate: [blank], Audio Decimation: [blank]) is connected to the **Audio Sink**.
- Audio Sink** (Sample Rate: 32k) is the final output block.
- RTL-SDR Source** (Mb0: Clock Source: O/B GPSDO, Sample Rate (sps): 32k, Ch0: Frequency (Hz): 101.5M, Ch0: Freq. Corr. (ppm): 0, Ch0: DC Offset Mode: Off, Ch0: IQ Balance Mode: Off, Ch0: Gain Mode: Manual, Ch0: RF Gain (dB): 20, Ch0: IF Gain (dB): 20, Ch0: BB Gain (dB): 20) is connected to the **Low Pass Filter**.

The right sidebar shows a search for "filter" and a list of filter types, with "Low Pass Filter" selected. The bottom status bar displays the text: "<<< Welcome to GNU Radio Companion 3.7.13.5 >>>".

SDR Software: GNU Radio (Open Source)



GNU Radio Companion

SDR Software: SDRangel (Open Source)

File View DeviceSets Window Preferences Help

Sampling devices

R0

1000k

LO ppm

Auto corr **DC** **IQ** Fp Cen X

L SR 1,000,000 S/s Dec 1

No-mod DS Ofs RFBW 1,000 kHz

Sampling devices Sampling devices control

Channels

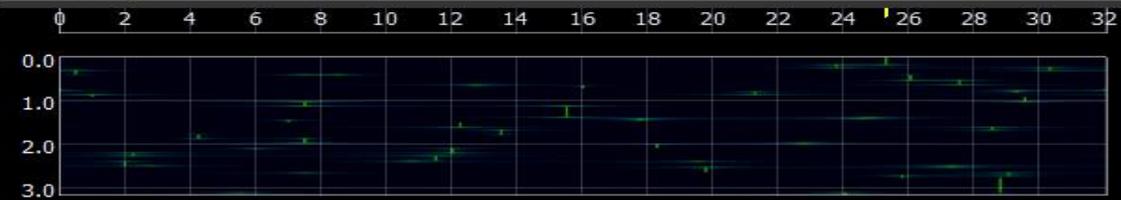
LoRa Demodulator

Settings

Bandwidth 20833 Hz

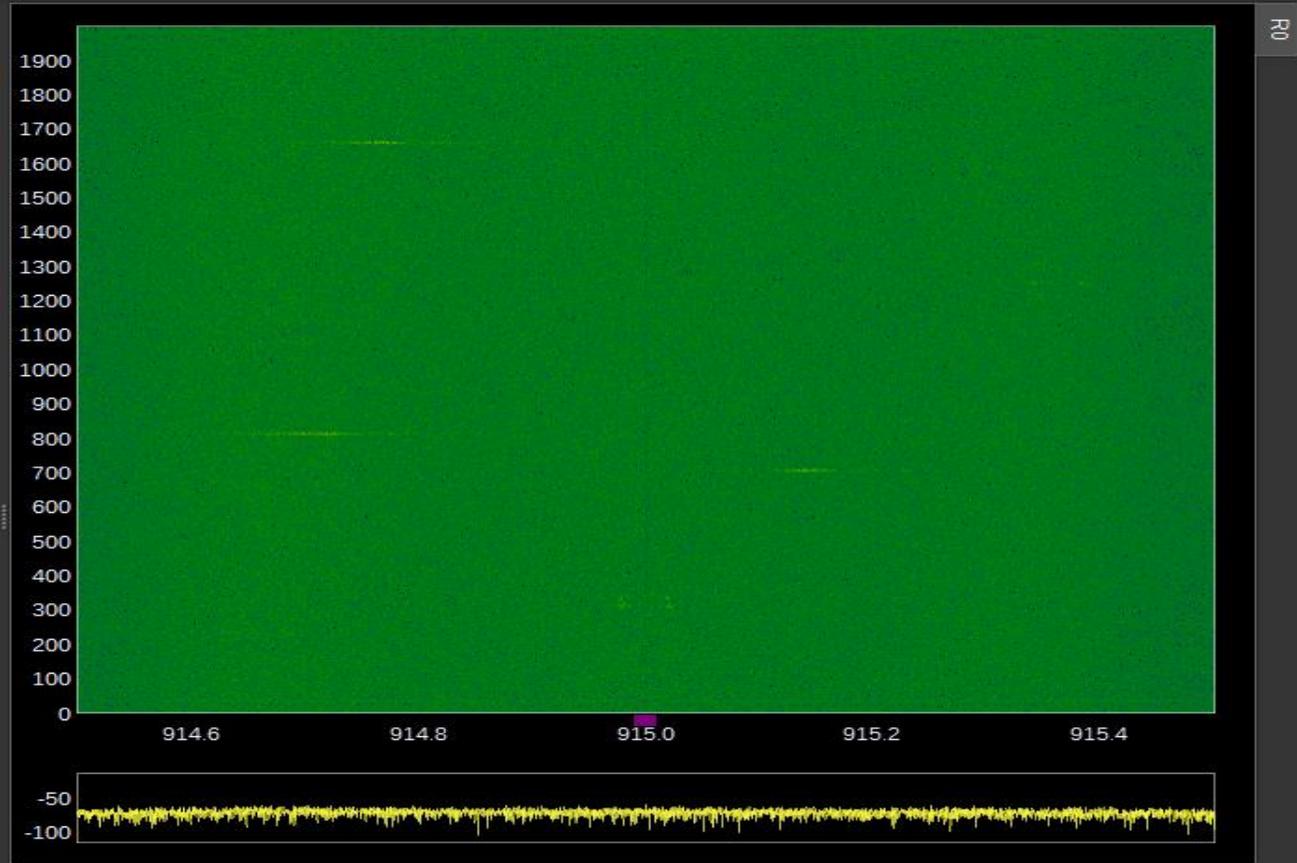
Spreading 6:4 2^8

Channel Spectrum



Han 1k -55 100 No 1

Channels Presets Commands



Spectrum Display

R0

Rec 4k -15 100 No 5k

SDRangel 4.11.12 Qt 5.12.1 x86_64 Windows 7 SP 1 (6.1) 2019-11-05 21:37:46 Eastern Standard Time

SDR Software: SDRangel (Open Source)

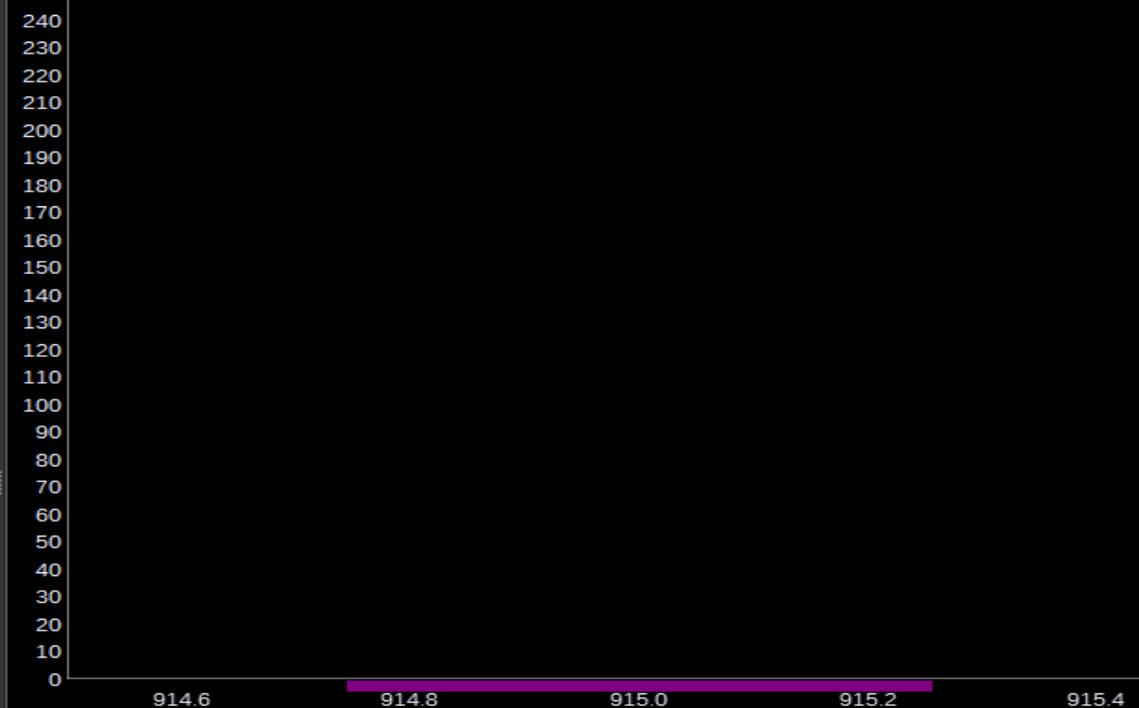
File View DeviceSets Window Preferences Help

Sampling devices control

R0

RTL-SDR[0] 00000001

- AM Demodulator
- ATV Demodulator
- Broadcast FM Demodulator
- Channel Analyzer
- DATV Demodulator
- DSD Demodulator
- Frequency Tracker
- LoRa Demodulator
- Local channel sink
- NFM Demodulator
- Remote channel sink
- SSB Demodulator
- UDP Channel Sink
- WFM Demodulator



Spectrum Display

R0

Rec 4k -15 100 No 5k

Buttons: [Gain] [Bandwidth] [Filter] [Sweep] [Grid] [Zoom]

SDRangel 4.11.12 Qt 5.12.1 x86_64 Windows 7 SP 1 (6.1) 2019-11-05 22:34:13 Eastern Standard Time

SDR Software: SDRangel (Open Source)

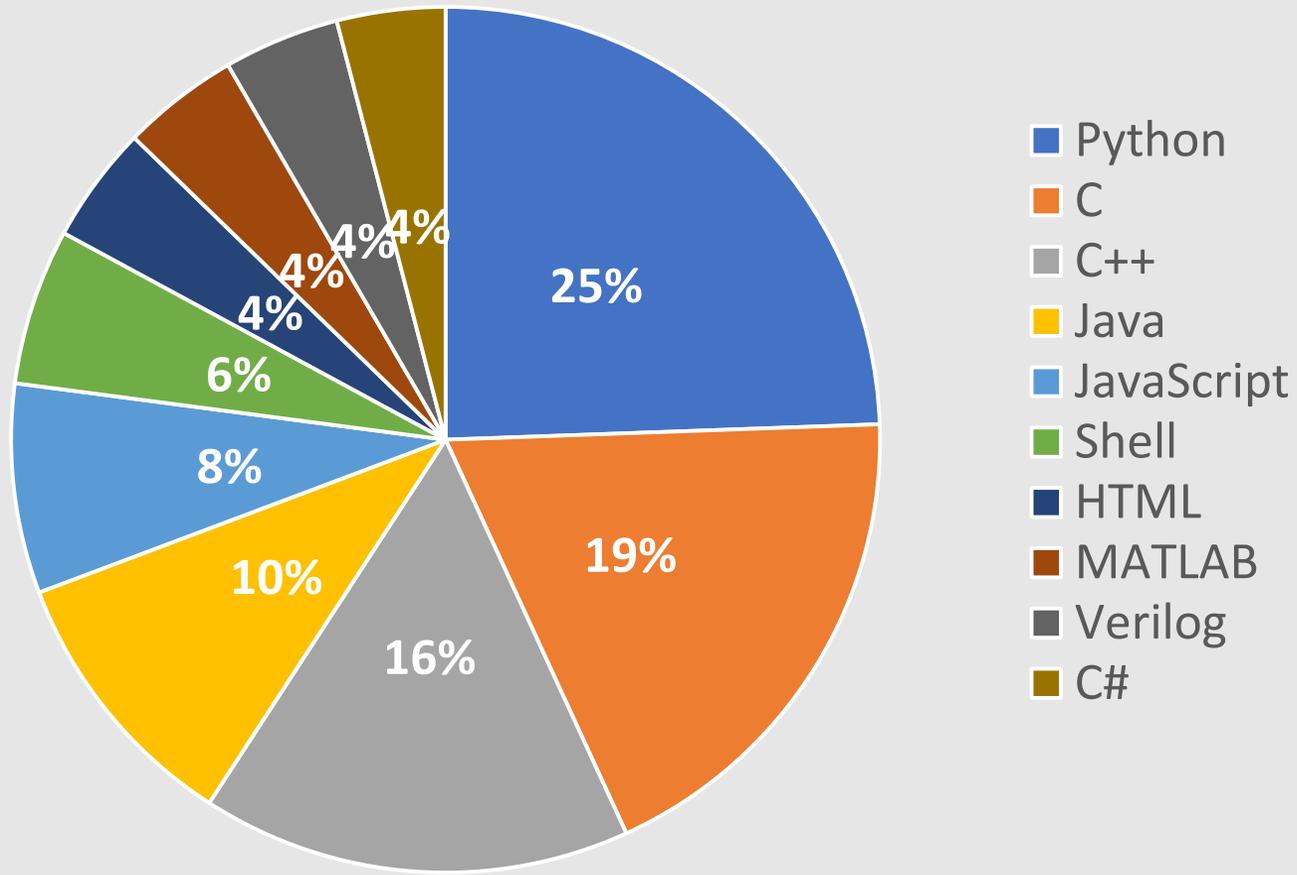
The screenshot displays the SDRangel software interface. On the left, the 'Spectrum Display' panel shows a green spectrum plot with a frequency range from 1.2480 to 1.2500 MHz. The 'DATV Demodulator' is selected, and the 'RF Settings' panel shows a frequency offset of +0,000,000 Hz, a bandwidth of 1,000,000 Hz, and a gain of -18.5 dB. The 'DATV' panel shows a video stream with the text 'MOIEB' overlaid. The video stream is identified as 'VIDEO Stream' with a PID of 256, a width of 320, and a height of 240. The service name is 'DTV-Express' and the service provider is 'MOIEB'. The codec is 'H.264 / AVC / MPEG-4 AVC / MPEG-4 part 10'. The video stream is currently playing, and the 'Full Screen' button is visible.

RTL-SDR[0] 00000001
DATV Demodulator
Spectrum Display
R0
Hamming 1k 0 100
Presets
Freq (MHz) M Description
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340
Presets Commands
FIR LINEAR
Data: 4.4 MB Speed: 2.3 Mb/s
Buffer: 0%
DATV Demodulator
RF Settings
 Δ +0,000,000 Hz BW 1,000,000 Hz -18.5 dB
DATV
VIDEO Stream
MOIEB
PID: 256 - Width: 320 - Height: 240
service_name: DTV-Express
service_provider: MOIEB
Codec: H.264 / AVC / MPEG-4 AVC / MPEG-4 part 10
Data
Transport
Video
Decoding
Video
Full Screen
SDRangel v3.14.7 Qt 5.5.1 x86_64 Ubuntu 16.04.4 LTS 2018-05-30 17:08:00

SDR Software Overview

By Language SDR projects on Git
(Updated - November 4th 2019)

3,600+ repositories involving SDR



Needed to receive signals + antenna

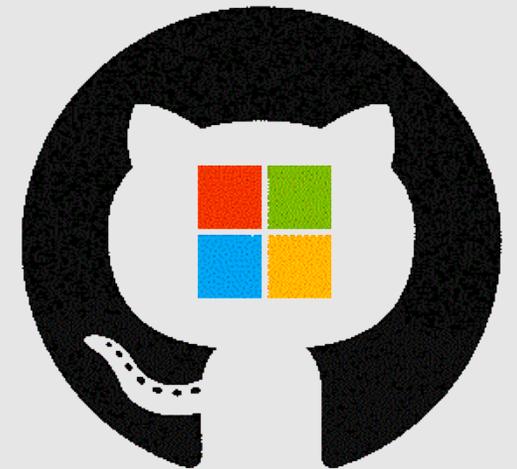
Open Source: SDR Software Summary (../)

Command line & other open source options

- Search for “SDR” on Git. Be amazed!
- Some for data, others for voice or video signals.
- rtl-sdr, RTL_433, dump1090 = 3 examples for IFTTT applications

GUI Analysis Tool Notable Mentions

- Inspectrum (Mike Walters)
- Kismet (Mike Kershaw)
- Audacity (Dominic Mazzoni/Roger Dannenberg)



SDR Software: Non-GUI Overview

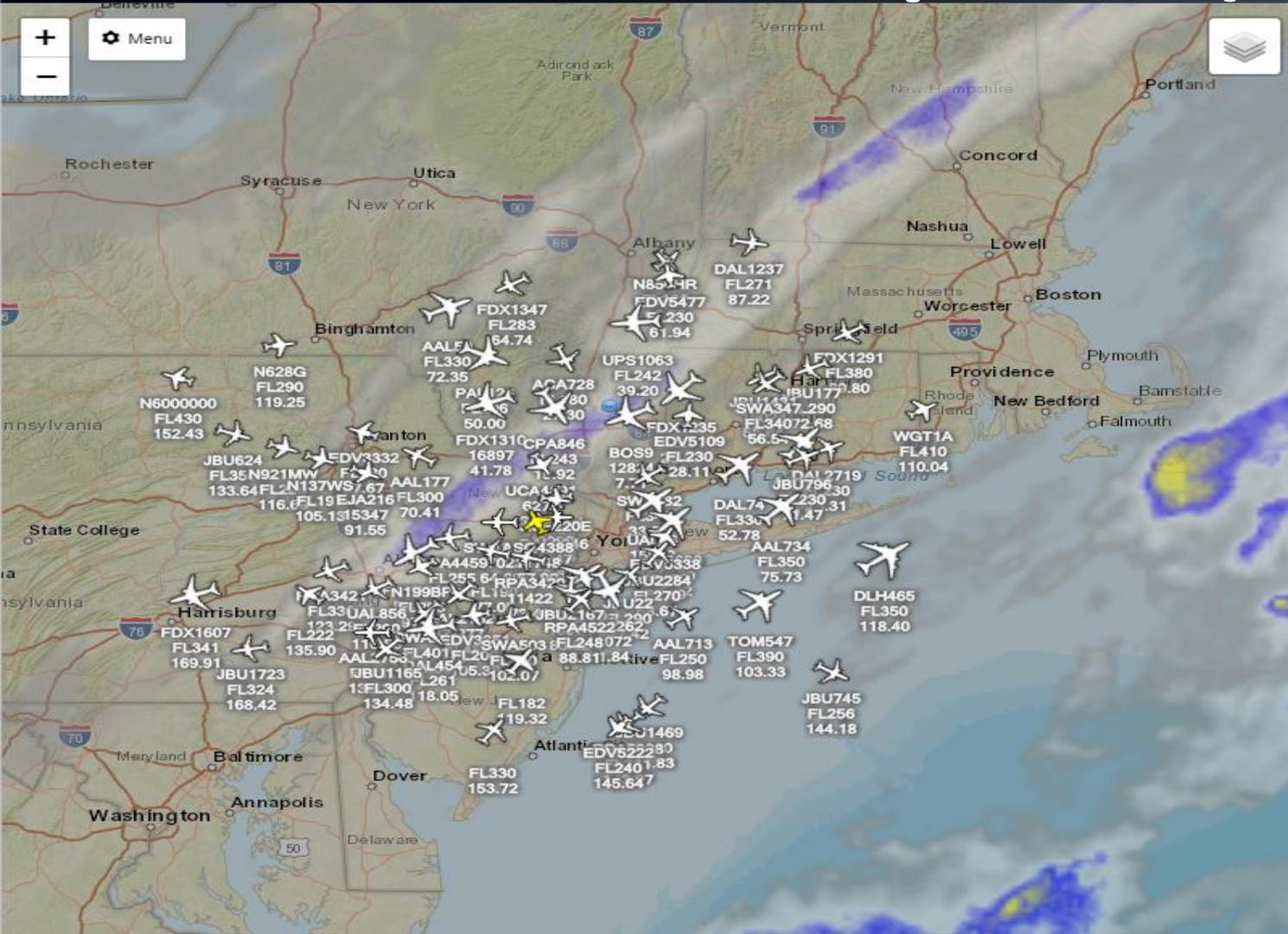
The following 6 slides are photos of popular additional SDR related software highlighted on slide 19.

These were further described/presented in the live discussion.

SDR Software: dump1090 (Open Source)

Hex	Mode	Sqwk	Flight	Alt	Spd	Hdg	Lat	Long	Sig	Msgs	Ti✓
AB3D41	S			33000					7	2	0
A3D75C	S			34675					8	6	1
AB30F2	S			23000	451	349			8	4	1
A301F3	S								4	3	1
A0F869	S			7775	242	198			8	12	1
780A89	S	7404	CPA846	28650	486	113	41.953	-74.691	10	65	0
A368C2	S		FDX1310	6825	249	318			9	16	4
A1E6B9	S	3536	SWA782	34000	350	234			9	85	1

SDR Software: dump1090 (output into VRS)



N14916 **A0C6B9**

United Express
United States
Embraer ERJ-145 LR

Altitude: 11500 ft Vertical Speed: 1472 ft/m Speed: 396.2 mph Heading: 336.2°
 Distance: 57.99 mi Squawk: 1724 Engines: Twin jet Species: Landplane

Wake Turbulence:
 Medium

Route:
 JAN Jackson Evers, United States
 IAH George Bush Intercontinental Houston, United States
 LIT Adams Field, Little Rock, United States

www.airport-data.com :: www.airliners.net :: www.airframes.org :: Database Editor
 Show on map :: Enable auto-select :: Submit route correction

Tracking 79 aircraft Pause :: List only visible

Civ/Mil	Silhouette	Flag	Reg.	ICAO	Callsign	Route	Altitude	Sp
Civil			N379CA	A4556D				
Civil		jetBlue AIRWAYS	N956JT	AD4BCB				
Civil			CS-EPE	491605	JME220E		2750 ft	274.9
Civil		DELTA	N121DU	A057C7	DAL2846	ATL-GRR	3775 ft	295.8
Civil		UNITED	N77537	AA7E7B			5750 ft	
Civil			N16147	A0F869	UCA4891	EWR-JAX	6000 ft	320.8
Civil			C-GLLJ	C062DC	CGLLJ		7825 ft	270.7
Civil		DELTA	N176DN	A12FCF	DAL2262	LAX-JFK	10800 ft	322.6
Civil			N649RW	A88836	RPA3429		11150 ft	323.0
Civil			N14916	A0C6B9	ASQ4388	JAN-*-LIT	11500 ft	396.2
Civil			F-HLVN	39AEAD	BOS9	ORY-EWR	12600 ft	328.1
Civil			N330PQ	A39723	EDV5338		12900 ft	467.3
Civil			N447SF	A56634			15025 ft	342.9
Civil		NETJETS	N216QS	A1D13B	EJA216		15075 ft	488.4
Civil		UNITED	N664UA	A8C4D8	UAL16	EWR-LHR	15300 ft	534.5

Leaflet | Tiles © Esri - Source: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2012, ©AerisWeather



SDR Software: dump1090 (output to MilSpot)

Telemetry for Aircraft Currently Being Received

Details

Hex Code: **AE1172**
 Call Sign: **POUGHKEEPSIE, NY**
 Altitude: **32750**
 Type: **C-17A - C17**
 BuNos: **02-1100**
 First Seen: **21:38:02**
 Home Base: **MEMPHIS INTL - MEMPHIS - TN**

Receiver Location:
POUGHKEEPSIE, NY
 Updated: **7 secs. ago**
 User: **TN ANG 164AW**
155AS [KMEM]

Altitude Profile



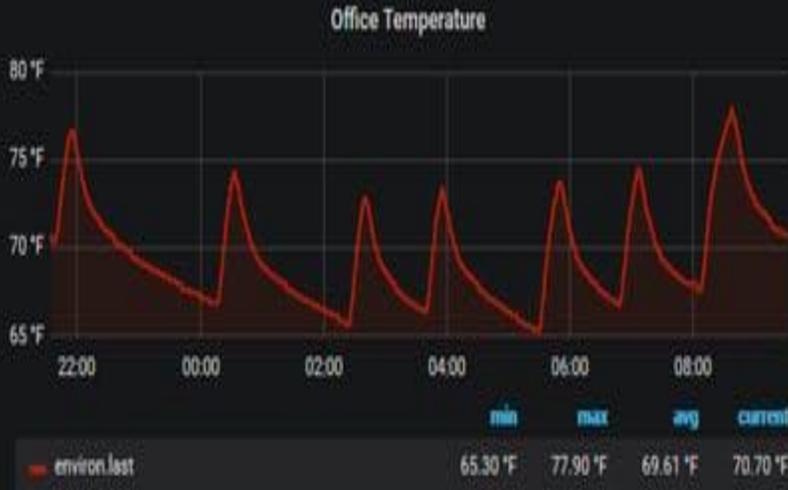
Last Seen (UTC)	HEXCODE	Altitude	Call Sign	Squawk	Aircraft BuNos	Aircraft Type & Operator	Receiver Location	Msgs Rcvd
11/06/19 21:39:27 <small>(First Seen: 21:38:02)</small>	AE1172	32750 ▼			02-1100	C-17A - C17 - TN ANG 164AW 155AS [KMEM] <small>Home Base: MEMPHIS INTL - MEMPHIS - TN</small>	POUGHKEEPSIE, NY	23
11/03/19 03:08:33 <small>(First Seen: 02:49:55)</small>	AE08CE	28650 ▼	RCH417	5613	00-0185	C-17A - C17 - USAF 3WG 517AS [PAED] <small>Home Base: RED DOG - RED DOG AK -</small>	POUGHKEEPSIE, NY	352
11/03/19 02:39:22 <small>(First Seen: 02:23:51)</small>	AE1457	34000	RCH527		05-5153	C-17A - C17 - USAF 15WG 535AS [PHIK] <small>Home Base: HICKAM AFB BASE OPS - HONOLULU - HI</small>	POUGHKEEPSIE, NY	89
11/03/19 02:32:36 <small>(First Seen: 02:19:19)</small>	AE0425	36975	BLUE21	6516	60-0342	KC-135T - K35R - USAF 92ARW [KSKA] <small>Home Base: FAIRCHILD AFB - SPOKANE - WA</small>	POUGHKEEPSIE, NY	163
10/21/19 00:52:01 <small>(First Seen: 00:27:35)</small>	AE0580	35000	RCH614	1020	87-0035	C-5M - C5 - USAF 436AW 9AS [KDOV] <small>Home Base: DOVER AFB - DOVER - DE</small>	POUGHKEEPSIE, NY	148
10/20/19 23:28:08 <small>(First Seen: 23:05:49)</small>	AE20C7	13650 ▼	RCH803		07-7186	C-17A - C17 - USAF 437AW [KCHS] <small>Home Base: CHARLESTON AFB/INTL - CHARLESTON - SC</small>	POUGHKEEPSIE, NY	Top
						KC 10A DC10 USAF 305AMW [KWRD]		

SDR Software: rtl_433 (Open Source)

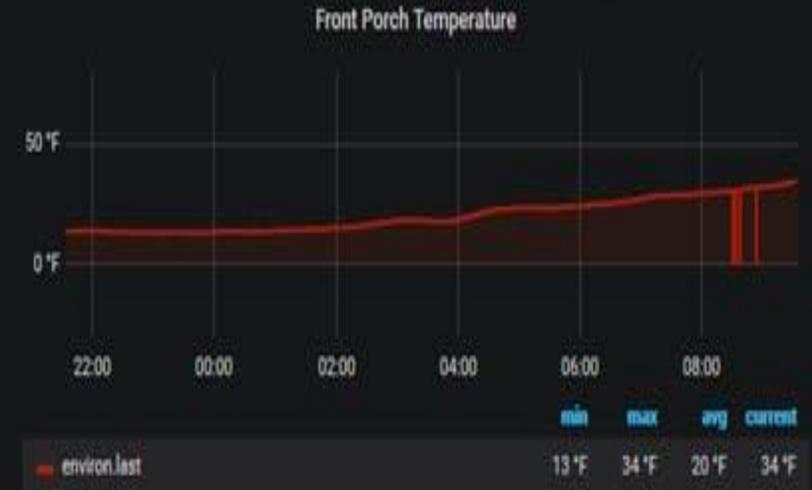
```
Using device 0: Generic RTL2832U OEM
Found Rafael Micro R820T tuner
Exact sample rate is: 250000.000414 Hz
Sample rate set to 250000.
Bit detection level set to 0 (Auto).
Tuner gain set to Auto.
Reading samples in async mode...
Tuned to 433920000 Hz.
2019-11-05 22:36:19 : Nexus Temperature/Humidity
    House Code: 147
    Battery: OK
    Channel: 1
    Temperature: 8.80 C
    Humidity: 17 %
2019-11-05 22:36:37 : Generic Remote
    House Code: 45523
    Command: 25
    Tri-State: ?10F1F010F?F
2019-11-05 22:36:37 : Generic Remote
    House Code: 45523
    Command: 25
    Tri-State: ?10F1F010F?F
2019-11-05 22:36:37 : Generic Remote
    House Code: 45523
    Command: 25
    Tri-State: ?10F1F010F?F
2019-11-05 22:36:37 : Generic Remote
    House Code: 45523
    Command: 25
    Tri-State: ?10F1F010F?F
2019-11-05 22:36:37 : Generic Remote
    House Code: 45523
    Command: 25
    Tri-State: ?10F1F010F?F
2019-11-05 22:36:37 : Generic Remote
    House Code: 45523
    Command: 25
    Tri-State: ?10F1F010F?F
2019-11-05 22:36:37 : Generic Remote
    House Code: 45523
    Command: 25
    Tri-State: ?10F1F010F?F
```

SDR Software: rtl433_influx + Grafana (Open Source)

Office Temperature



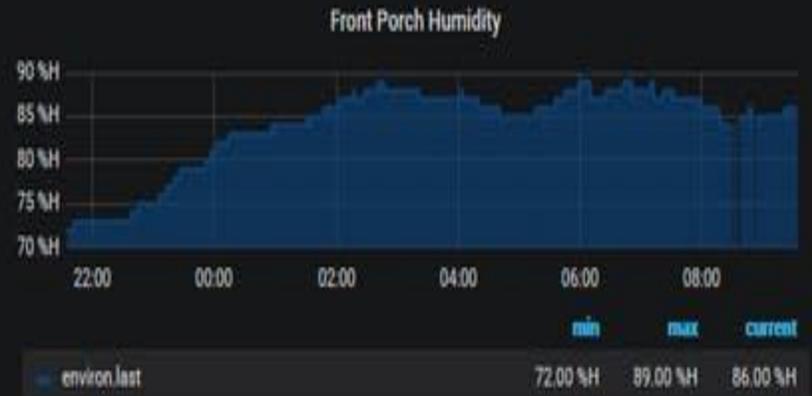
Front Porch Temperature



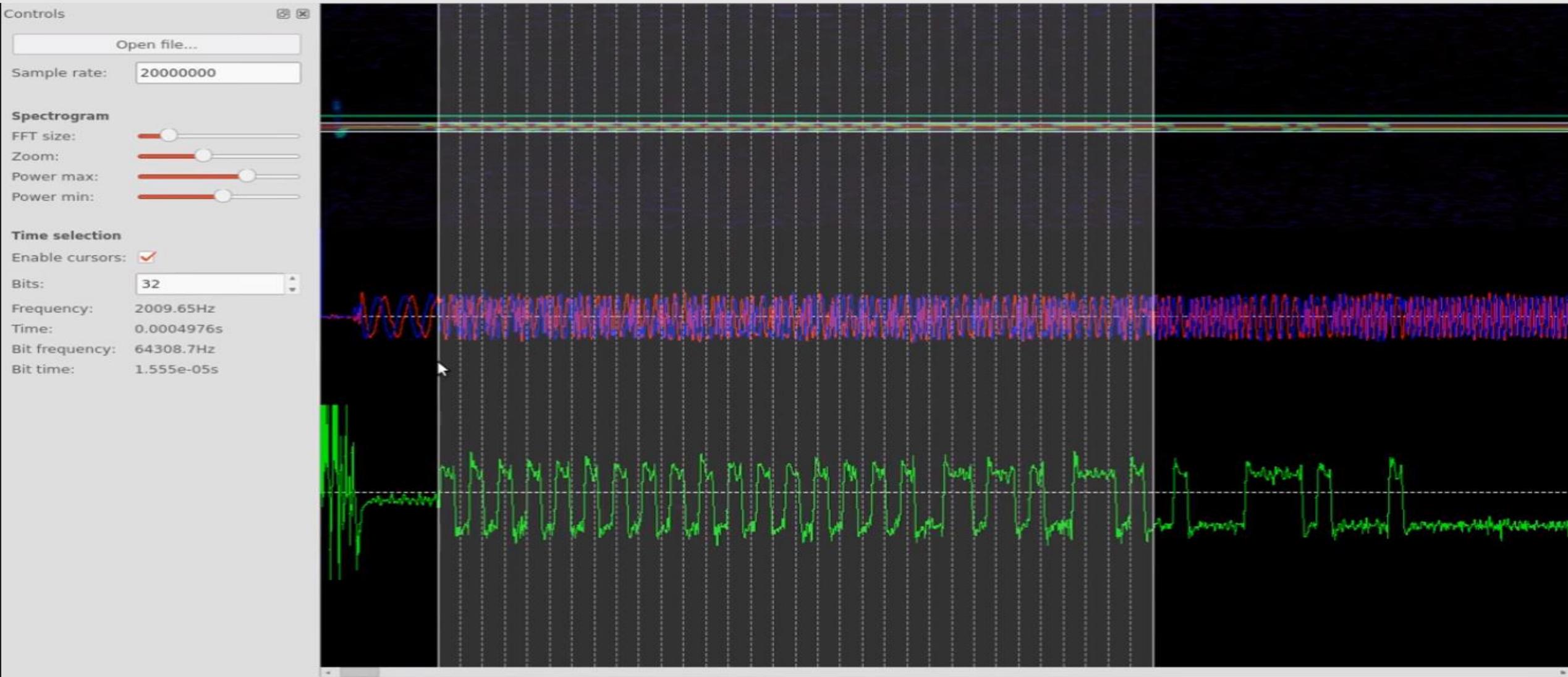
Office Humidity



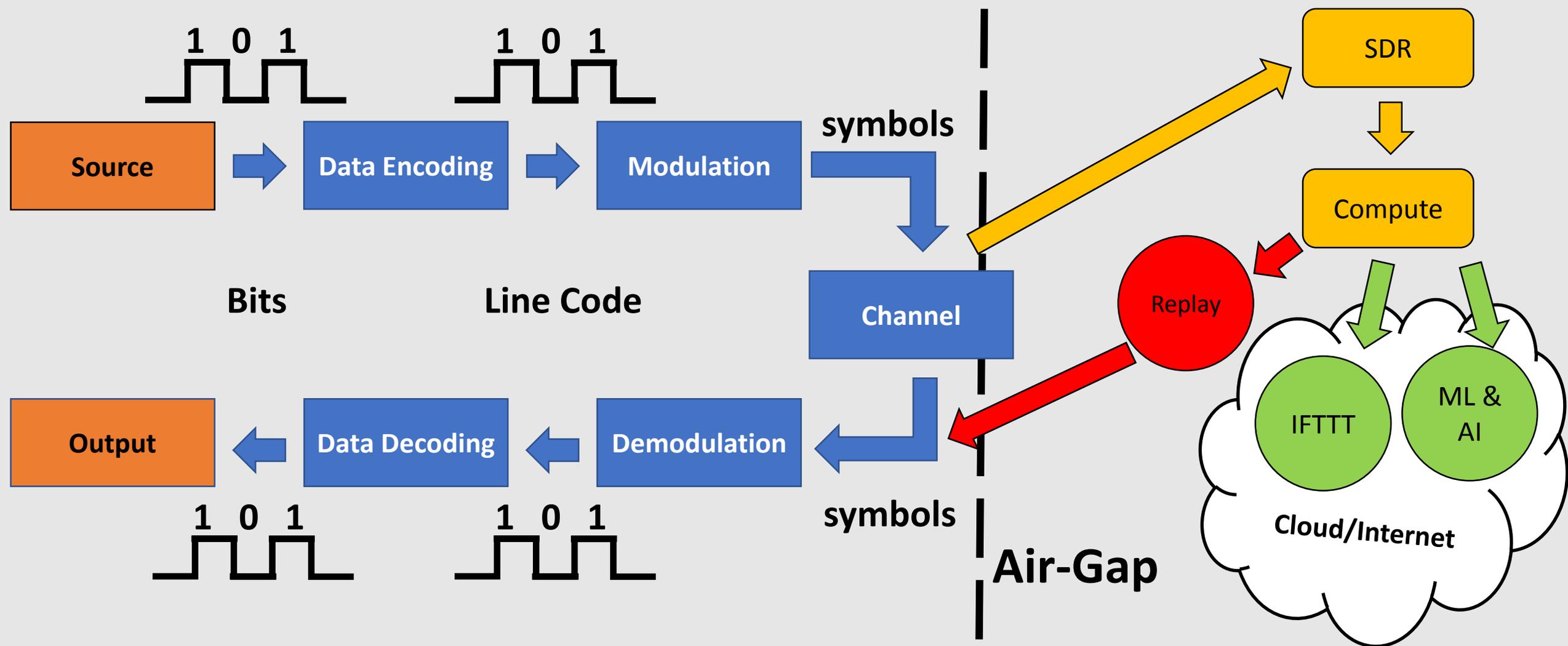
Front Porch Humidity



SDR Software: Inspectrum (Open Source)



Doing Stuff: First Understand Signals & Bits



Found Signal/Use Case: Review

- Step 1: Capture
 - Baseband, Audio or IQ Recording
 - Examples: SDR# & SDRangel
 - Step 2: Analyze
 - Step 3: Research Source
 - Step 4: Research Signal
 - Step 5: Replay, IFTTT, ML/AI
 - GNU Radio, MQTT/Mosquito, etc
 - Observe ethics in your next steps
- Center Frequency & Modulation Method
 - FSK Deviation & Bit Timing
 - Data encoding method (Manchester, etc.)
 - Symbol Rate & Symbol Time
 - Examples: Inspectrum, Audacity, SDRangel

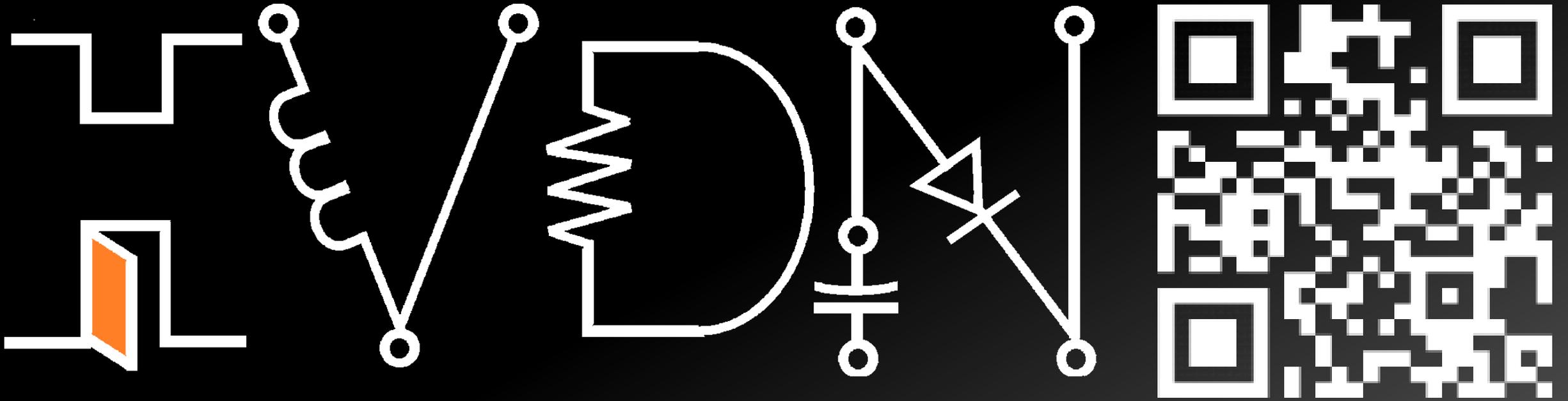
Found Signal/Use Case: Examples

Car remotes
Temperature sensors
Amateur radio hotspots
Pagers
Weather stations
Door alarms
RFID
Loss Prevention Devices
Industrial Control

Water spill alarm
Tire Pressure (TPMS)
Water meters
Smoke alarms
Toys
Security devices
Aircraft
Satellites
Environmental sensors

SDR Software: Capture & Playback (RX)

A live demonstration of a remote SDR connected to an OpenWRT router using `rtl_tcp` was demonstrated. Examples included receiving an FM broadcast, decoding RDS information, sensing and decoding 433 MHz IoT sensors and recording IQ files and playing them back for later analysis



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around you with open source software

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