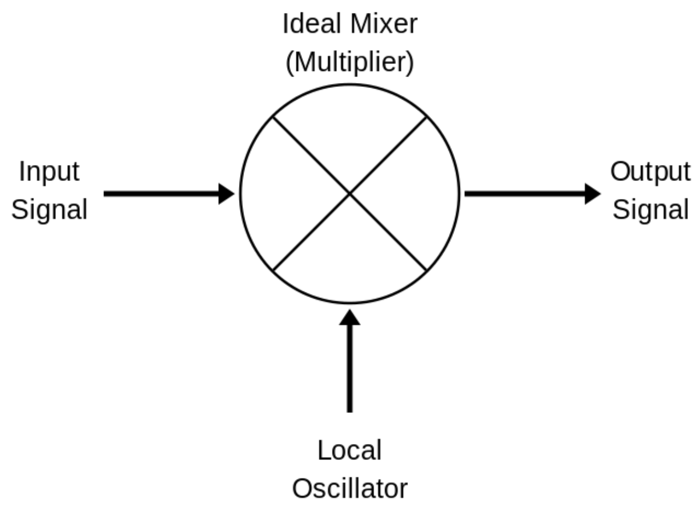
Software Defined Radio (SDR)

Edoardo Milotti

Corso di Metodi di Trattamento del Segnale

Rivelazione eterodina

$$\cos(\omega_S t)$$



$$\cos(\omega_S t)\cos(\omega_L t)$$

$$\cos(\omega_L t)$$

$$\cos(\omega_S t)\cos(\omega_L t) = \frac{1}{2}\left\{\cos[(\omega_S + \omega_L)t] + \underline{\cos[(\omega_S - \omega_L)t]}\right\}$$

Importanza della fase

Supponiamo che ci sia sfasamento tra portante e oscillatore locale

I (in-phase)

$$\cos(\omega_C t)\cos(\omega_C t + \varphi) = \frac{1}{2}\left[\cos(\varphi) + \cos(2\omega_C t + \varphi)\right]$$

come si vede, se la fase relativa è 90°, il segnale a bassa frequenza viene completamente perso.

Però se si moltiplica anche per un seno ...

Q (quadrature)

$$\cos(\omega_C t)\sin(\omega_C t + \varphi) = \frac{1}{2}\left[\sin(\varphi) + \sin(2\omega_C t + \varphi)\right]$$

e quindi la somma in quadratura delle due parti a bassa frequenza permette di ricostruire l'ampiezza originale (questo è analogo a quello che succede in uno strumento di laboratorio, l'amplificatore lock-in).

Analog Radio Receiver Block Diagram

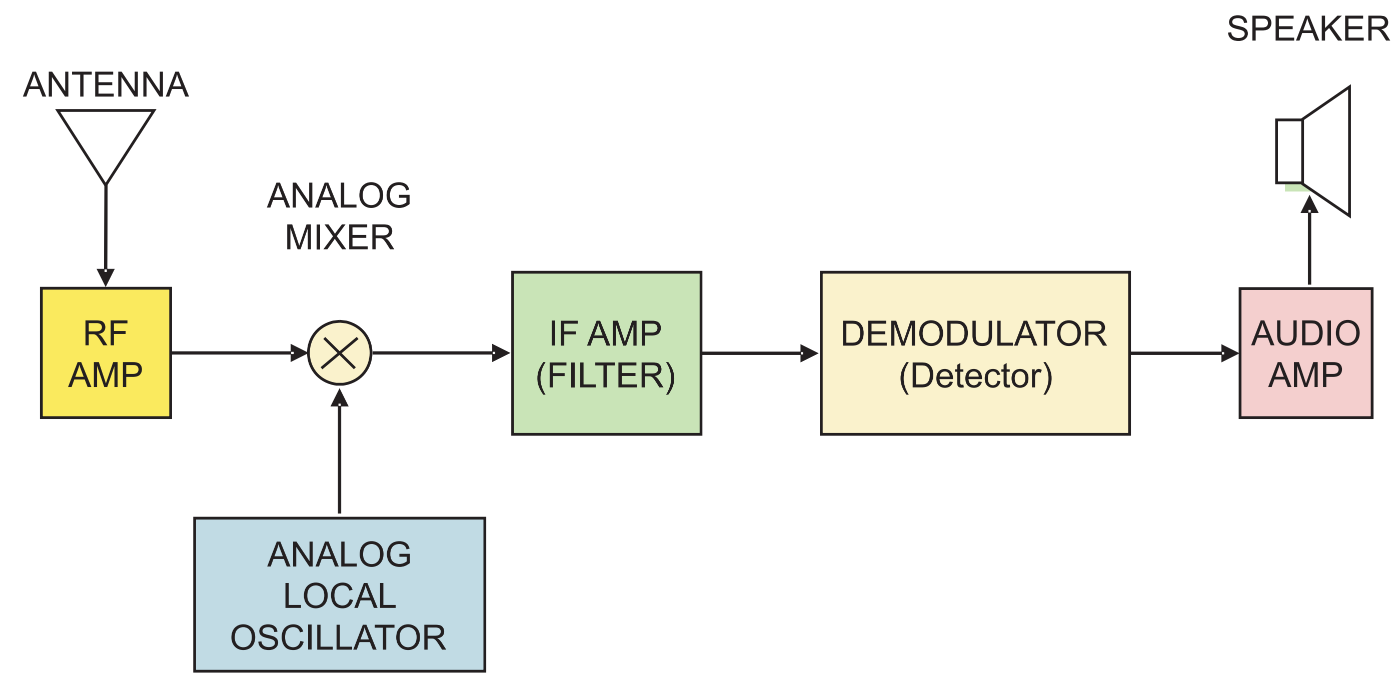


Figure 7

Analog Radio Receiver Mixer

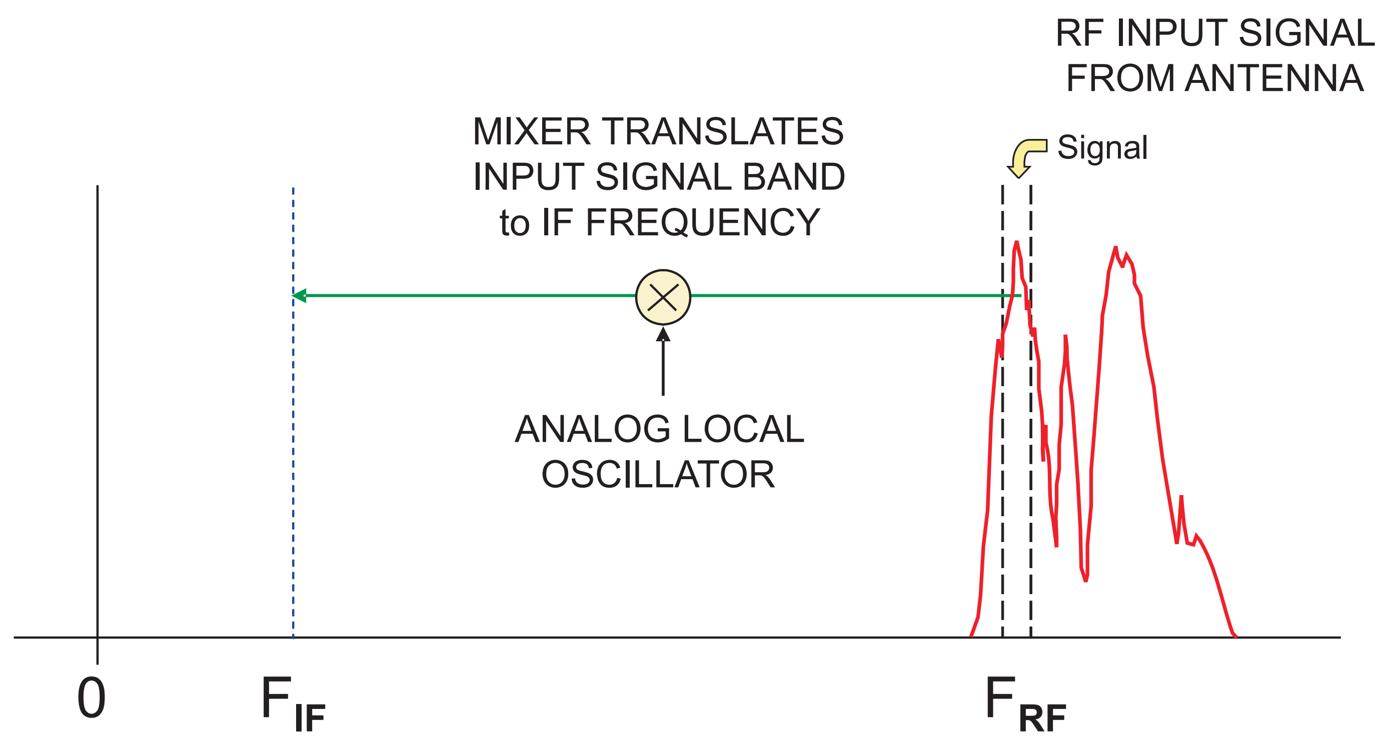


Figure 8

SDR Receiver Block Diagram

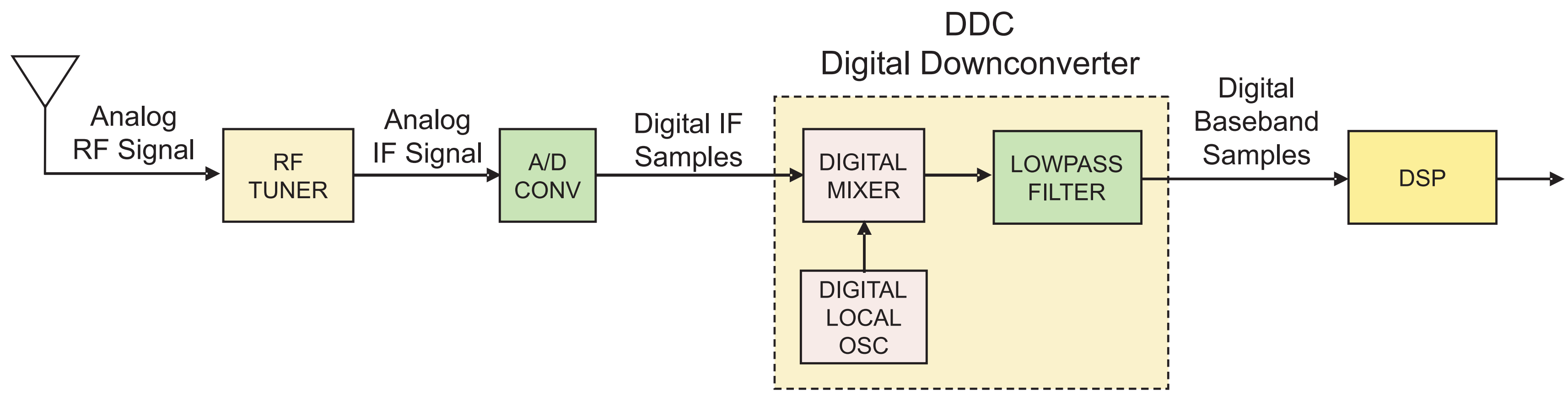


Figure 9

SDR Receiver Mixer

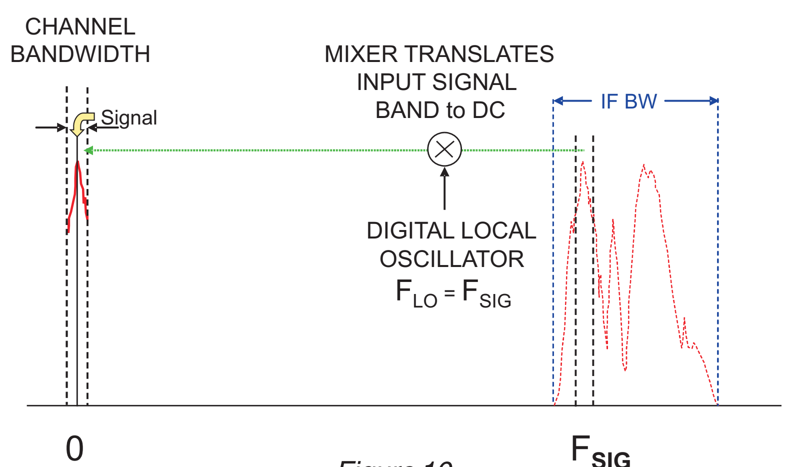


Figure 10

DDC Local Oscillator and Decimation

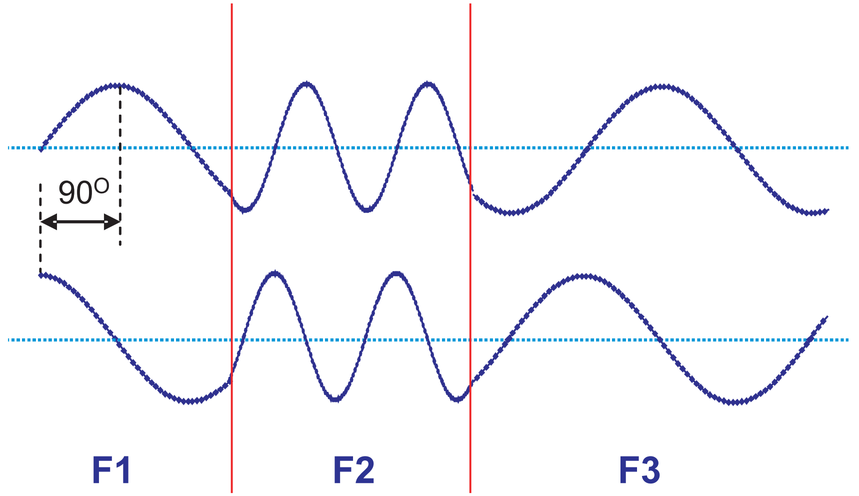


Figure 11A Local Oscillator Frequency Switching

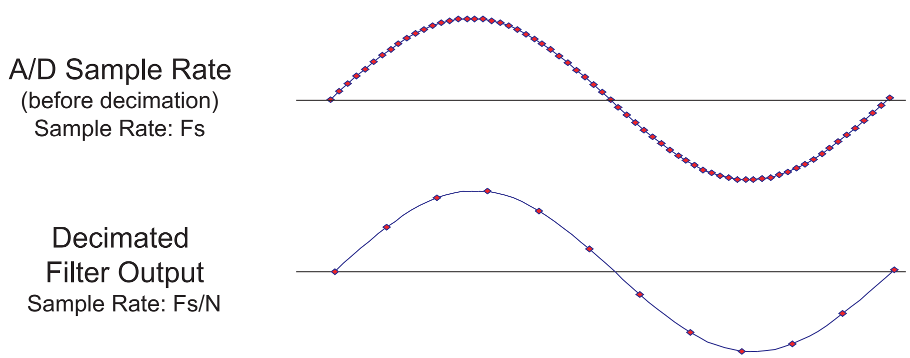


Figure 11B FIR Filter Decimation

DDC Signal Processing

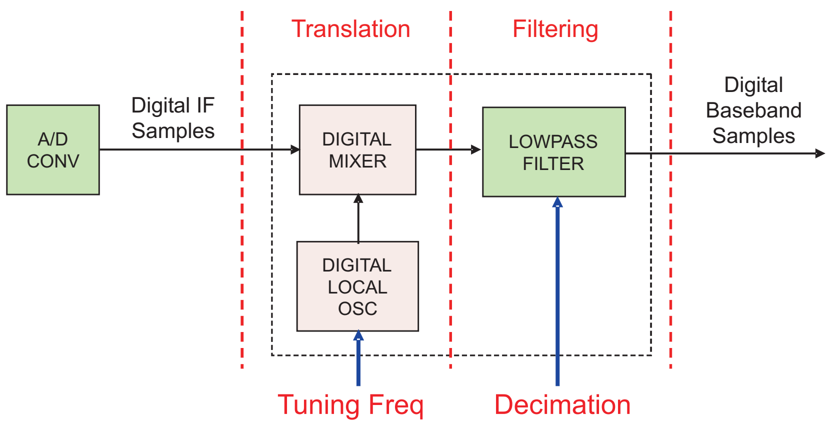


Figure 12

La trasformata di Hilbert

Si consideri il solito impulso esponenziale

$$h(t) = \begin{cases} \exp(-t/\tau) & t \geq 0 \\ 0 & t < 0 \end{cases}$$

la cui trasformata di Fourier è

$$H(\omega) = \int_0^{+\infty} \exp(-t/\tau) e^{-i\omega t} \, dt = \frac{1}{\frac{1}{\tau} + i\omega} = \frac{\tau}{1 + i\omega\tau}$$

In particolare si può anche scrivere

$$H(\omega) = \frac{1}{\frac{1}{\tau} + i\omega} = -\frac{i}{\omega - \frac{i}{\tau}}$$

Se la costante di decadimento tende all'infinito l'impulso esponenziale tende a diventare una funzione theta di Heaviside, e quindi la trasformata di Fourier della funzione theta è

$$\Theta(\omega) = \int_{-\infty}^{+\infty} \theta(t) e^{-i\omega t}\, dt = \lim_{\varepsilon \to 0^+} \frac{-i}{\omega - i\varepsilon}$$

e ovviamente vale anche la formula analoga che si ottiene con la sostituzione $\omega \to -\omega$

$$\int_{-\infty}^{+\infty} \theta(t) e^{i\omega t}\, dt = \lim_{\varepsilon \to 0^+} \frac{i}{\omega + i\varepsilon}$$

Adesso si noti che

$$\theta(t) = \int_{-\infty}^{t} \delta(t')\, dt' \quad \Rightarrow \quad \theta'(t) = \delta(t)$$

Ricordando che la rappresentazione di Fourier della funzione delta è

$$\delta(t-t_0)=\frac{1}{2\pi}\int_{-\infty}^{+\infty} e^{i\omega(t-t_0)}\,d\omega$$

e che

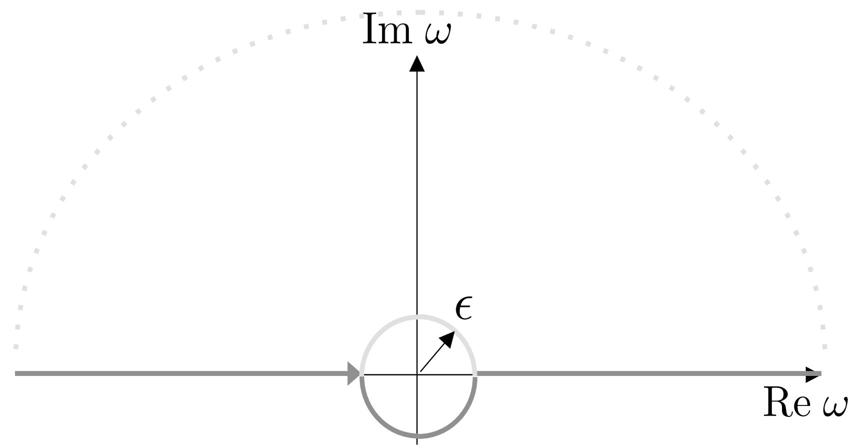
$$\frac{d}{dt}\frac{1}{2\pi}\int_{-\infty}^{+\infty} F(\omega)e^{i\omega t}\,d\omega=\frac{1}{2\pi}\int_{-\infty}^{+\infty} i\omega F(\omega)e^{i\omega t}\,d\omega$$

si trova la seguente espressione per l' antitrasformata di Fourier della funzione theta

$$\theta(t)=\frac{1}{2\pi}\int_{-\infty}^{+\infty}\frac{1}{i\omega}e^{i\omega t}\,d\omega$$

Questa espressione integrale ha un problema di definizione intorno all'origine (nel dominio della frequenza), e l'integrale può essere definito solo tramite un processo al limite.

Si segue il cammino di integrazione mostrato nella figura seguente, chiudendolo nel semipiano superiore, e passando sopra oppure sotto la singolarità nell'origine, che dà quindi (in media!) un contributo che è uguale a metà dell'integrale fatto su tutta la circonferenza che circonda l'origine



e quindi – notando che il residuo in 0 vale 1 – l'integrale può essere scritto come

$$\theta(t) = \frac{1}{2\pi}\int_{-\infty}^{+\infty}\frac{1}{i\omega}e^{i\omega t}\,d\omega = \frac{1}{2\pi i}\left[\left(\lim_{\varepsilon\to 0}\int_{-\infty}^{-\varepsilon}\frac{1}{\omega}e^{i\omega t}\,d\omega + \lim_{\varepsilon\to 0}\int_{+\varepsilon}^{+\infty}\frac{1}{\omega}e^{i\omega t}\,d\omega\right) + \frac{1}{2}2\pi i\right]$$

$$= \frac{1}{2\pi}P\int_{-\infty}^{+\infty}\frac{1}{i\omega}e^{i\omega t}\,d\omega + \frac{1}{2}$$

L'ultima formula può anche venire riarrangiata nel modo seguente

$$P\int_{-\infty}^{+\infty}\frac{1}{\pi t}e^{-i\omega t}dt = -i[2\theta(\omega)-1] = -i\,\mathrm{sgn}(\omega)$$

Infine questo significa che la trasformata di Hilbert, che è definita dalla formula

$$H(f)(t) = \frac{1}{\pi}\mathrm{P}\int_{-\infty}^{+\infty}\frac{f(\tau)}{t-\tau}d\tau$$

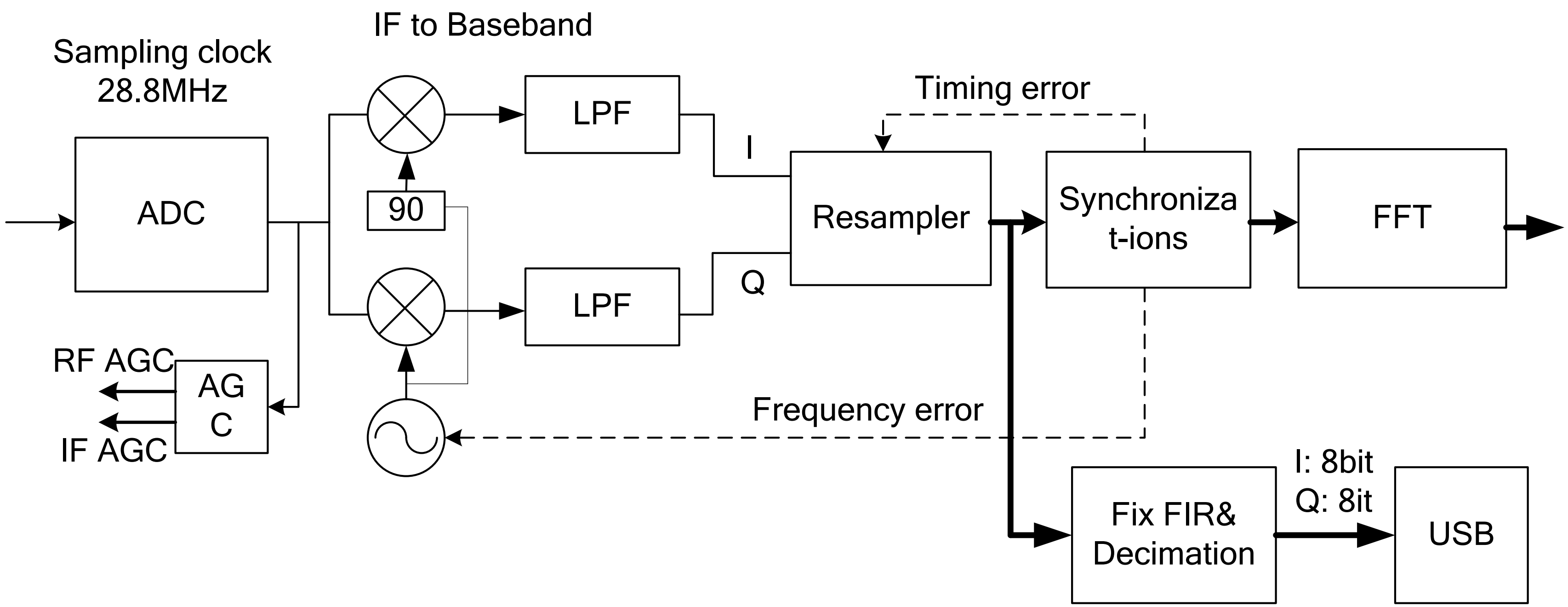
e che corrisponde ad una convoluzione, può essere scritta come segue nel dominio della frequenza

$$-i\,\mathrm{sgn}(\omega)F(\omega) = \begin{cases} e^{i\pi/2}F(\omega) & \omega < 0 \\ e^{-i\pi/2}F(\omega) & \omega > 0 \end{cases}$$

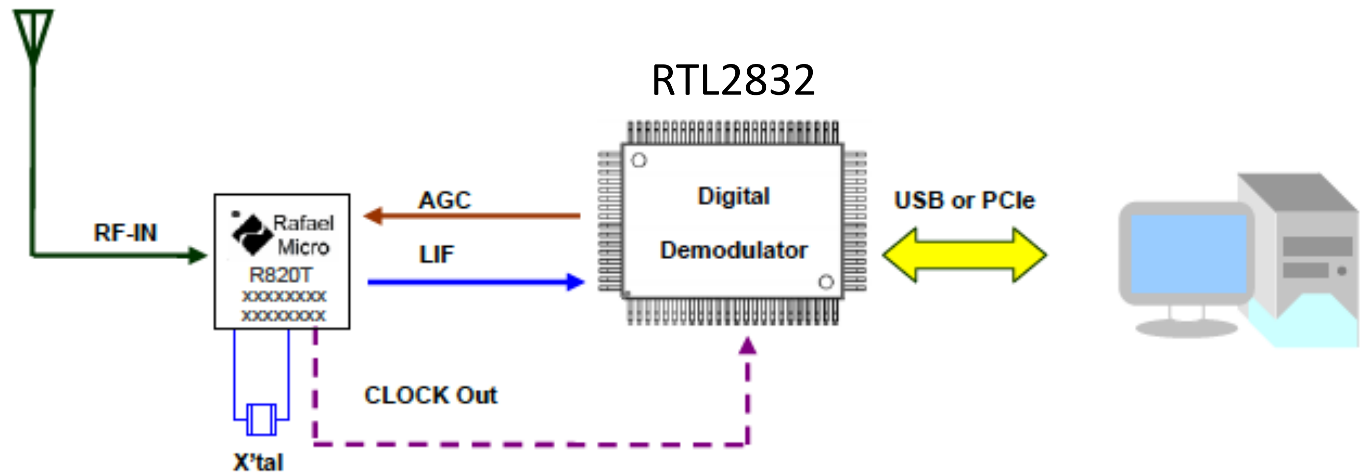
quindi la trasformata di Hilbert realizza uno shift di fase di ±90° che dipende solo dal segno della frequenza.

Modulazione SSB ... (v. nota di R. Lyons)

Struttura del microcircuito RTL2832



Radio digitale basata sul microcircuito RTL2832 (ADC veloce e demodulatore)



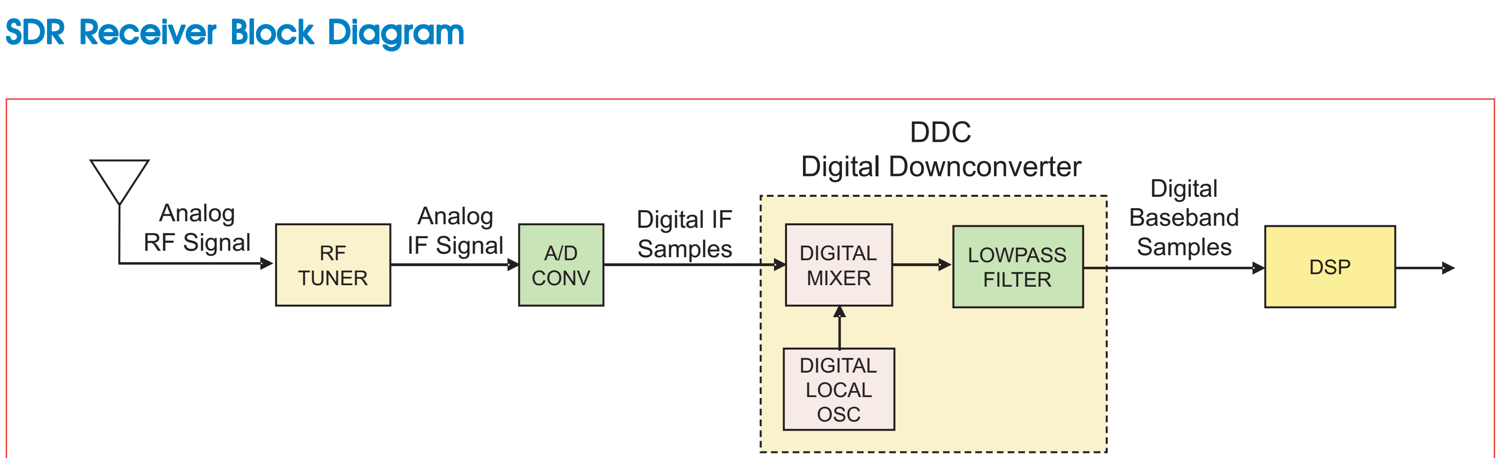
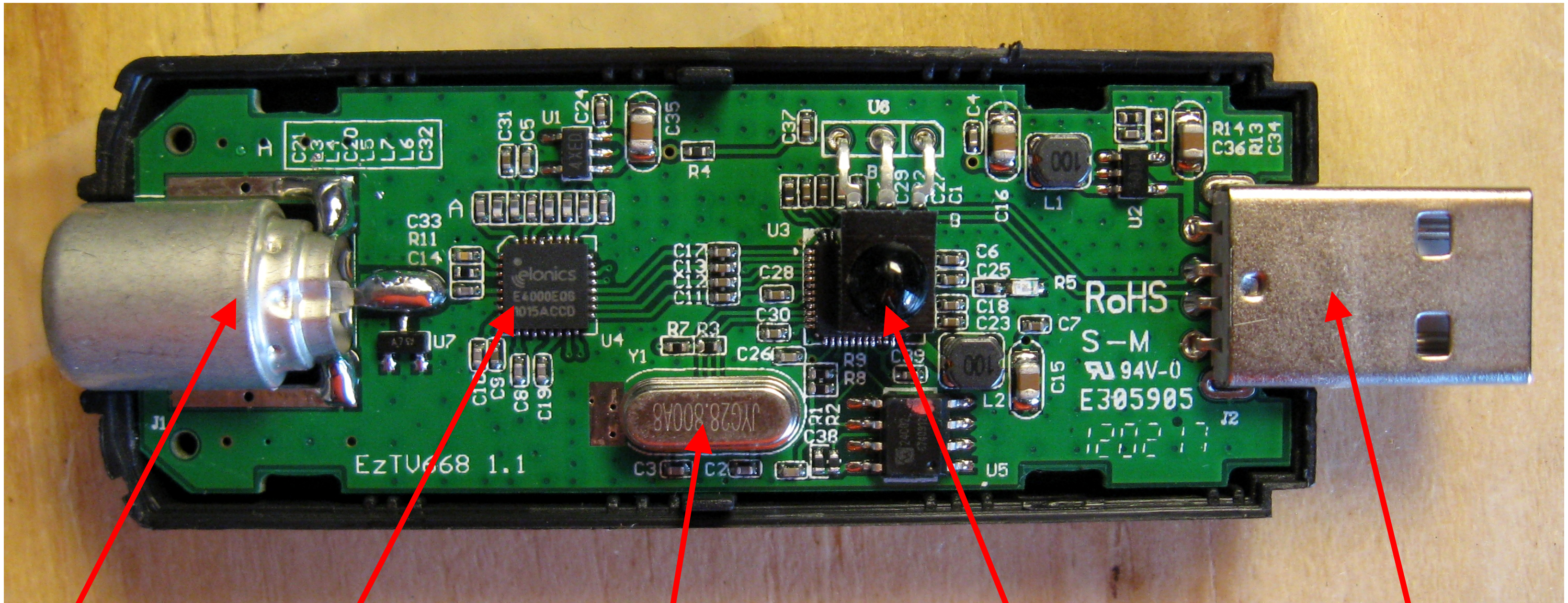


Figure 9



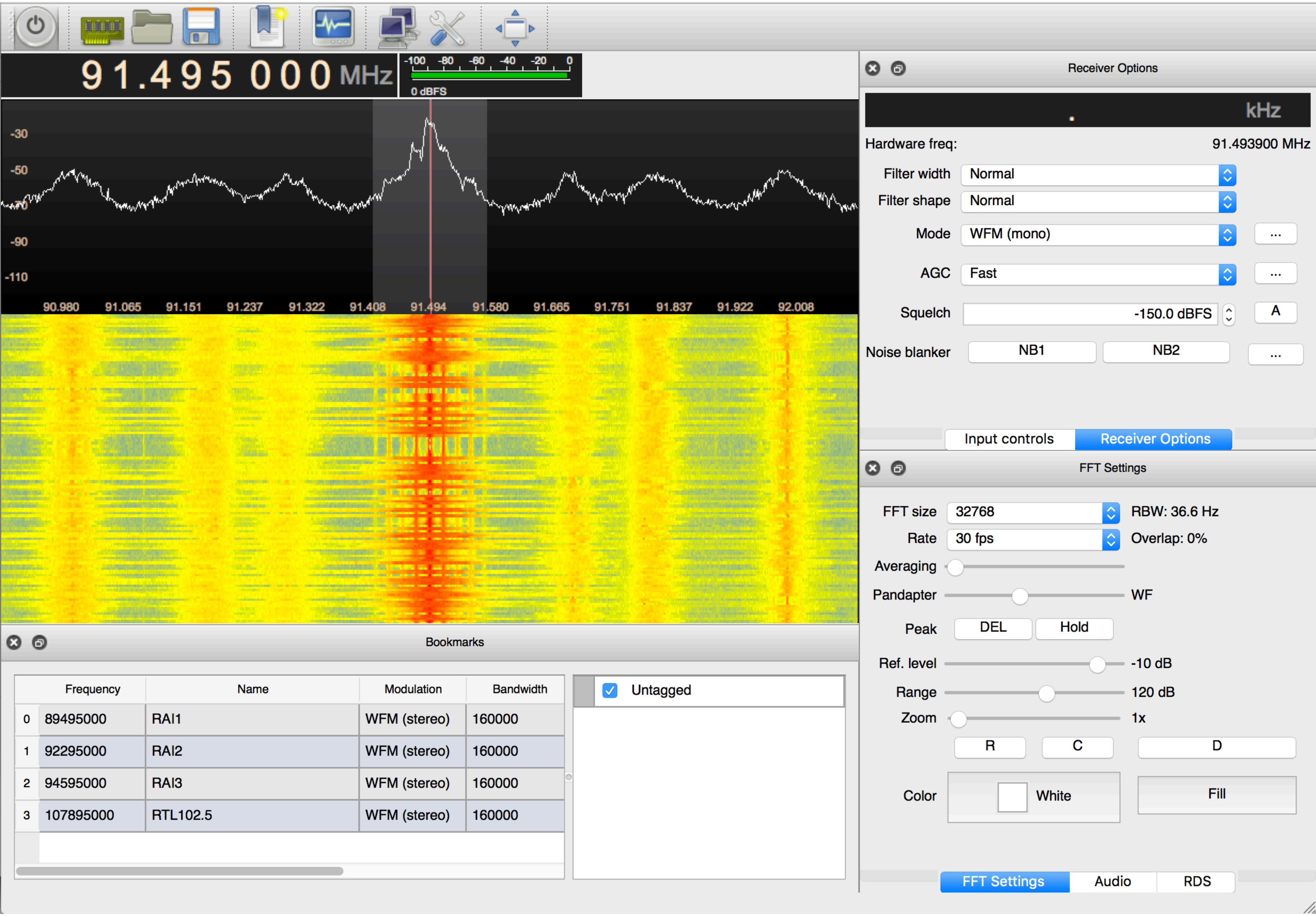
Ingresso antenna

Tuner chip (eterodina)

Risonatore a quarzo

Demodulatore digitale

Uscita USB


91.495 000 MHz
-100 -80 -60 -40 -20 0
0 dBFS
-30
-50
-70
-90
-110
90.980 91.065 91.151 91.237 91.322 91.408 91.494 91.580 91.665 91.751 91.837 91.922 92.008
Receiver Options
kHz
Hardware freq: 91.493900 MHz
Filter width Normal
Filter shape Normal
Mode WFM (mono)
AGC Fast
Squelch -150.0 dBFS
A
Noise blanker NB1 NB2
Input controls
Receiver Options
FFT Settings
FFT size 32768
RBW: 36.6 Hz
Rate 30 fps
Overlap: 0%
Averaging
Pandapter
WF
Peak DEL Hold
Ref. level -10 dB
Range 120 dB
Zoom 1x
R C D
Color White
Fill
FFT Settings Audio RDS
Bookmarks
Frequency Name Modulation Bandwidth
0 89495000 RAI1 WFM (stereo) 160000
1 92295000 RAI2 WFM (stereo) 160000
2 94595000 RAI3 WFM (stereo) 160000
3 107895000 RTL102.5 WFM (stereo) 160000
Untagged

http://www.rtl-sdr.com/big-list-rtl-sdr-supported-software/

RTL-SDR.COM

RTL-SDR (RTL2832U) and software defined radio news and projects. Also featuring Airspy, HackRF, FCD, SDRplay and more.

HOME | ABOUT RTL-SDR | QUICK START GUIDE | FEATURED ARTICLES | SOFTWARE | SIGNAL ID WIKI | FORUM | RTL-SDR STORE

FEBRUARY 11, 2014

THE BIG LIST OF RTL-SDR SUPPORTED SOFTWARE

There are now dozens of software defined radio packages that support the ultra cheap RTL-SDR. On this page we will attempt to list, categorize and provide a brief overview of each software program. We categorize the programs into general purpose software, single purpose software, research software and software compatible with audio piping.

If you know of a program that is missing please leave a comment in the comments section at the bottom of the page.

13/02/2014 – Added Sodira, gr-wmbus, rtlsdr-waterfall, QTRadio, multimon, sdrangelove, lte-scanner, rtl_tcp, rtl_sdr_FS20_decoder.
17/02/2014 – Updated the Linrad description.
28/04/2014 – Added Modesdeco and Trunk88.
30/05/2014 – Added RTL Panorama, RTL SDR Panoramic Spectrum Analyzer, Chrome Radio Receiver, SeeDeR, DAB Player, RTL SDR Installer, PD/Max Wrapper, SDRWeather, LTR Analyzer, softEOT/softDPU and ScanEyes.
26/07/2014 – Added PiAware, OOK-Decoder, rtl_fm_python, rtl_power heatmap viewer, RTL Bridge, threejs-spectrum, CANFI Software, PNAIS, FLARM Decoder, Xastir, RTLSDR-Airband, SDRTrunk.
13/11/2014 – Added Touchstone, RFAnalyzer, RTL1090 XHSI Interface, Parus Decoder, PlotRTL1090, LRPT Decoder.
05/02/2015 – Added rtl_tool_kit, CubicSDR, OregonWeather, FreqWatch.
15/04/2015 – Added ADSBox, YouSDR, FlightAware Flight Feeder, Frequensea, Track your flight EUROPE, QSpectrumAnalyzer, Doppler & Demod, Redsea, rtl_heatmap, gr-gsm, driveby, SDRecord.
23/12/2015 – Added Remote rtl_udp, AISRec, dump978, AISDeco2, SDRrecorder, OpenWebRX, dsame, RTL-Widespectrum,

ADS-B

ADS-B is a surveillance technology incorporating air and ground aspects that provide Air Traffic Control (ATC) with a more accurate picture of the aircraft's three-dimensional position in the enroute, terminal, approach and surface environments. The aircraft provides the airborne portion in the form of a broadcast of its identification, position, altitude, velocity, and other information.

The ground portion is comprised of ADS-B ground stations which receive these broadcasts and direct them to ATC automation systems for presentation on a controller's display similar in nature to a radar return. ADS-B is automatic because no external interrogation is required. It is dependent because it relies on onboard position sources and broadcast transmission systems to provide surveillance information to ATC.

ADS-B allows ATC to monitor and separate aircraft efficiently, and with more precision. Because it uses GPS signals, it expands surveillance services into areas where little or no radar coverage exists. The technology provides improved situational awareness to pilots and ATC.

Providing a flexible and expandable platform to accommodate future air-traffic growth, ADS-B is designed to improve the safety, capacity and efficiency of the airspace around the world.

ADS–B equipment is currently mandatory in portions of Australian airspace, the United States requires some aircraft to be equipped by 2020 and the equipment will be mandatory for some aircraft in Europe from 2017. Canada is already using ADS-B for air traffic control.

GNURadio
THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM

Overview

GNU Radio is a free software development toolkit that provides the signal processing runtime and processing blocks to implement software radios using readily-available, low-cost external RF hardware and commodity processors. It is widely used in hobbyist, academic and commercial environments to support wireless communications research as well as to implement real-world radio systems.

GNU Radio applications are primarily written using the Python programming language, while the supplied, performance-critical signal processing path is implemented in C++ using processor floating point extensions where available. Thus, the developer is able to implement real-time, high-throughput radio systems in a simple-to-use, rapid-application-development environment.

If you're looking for information on GNU Radio, **start with the wiki**. To browse the git repositories use **http://gnuradio.org/cgit**

- Subprojects: **GRCon14**

Issue tracking

- **Bug**: 59 open / 551
- **Feature**: 16 open / 277
- **Support**: 0 open / 0

Members

Manager: **Eric Blossom**, **Johnathan Corgan**, **Martin Braun**, **Matt Ettus**, **Nathan West**, **Tom Rondeau**

Developer: **Achilleas Anastasopoulos**, **Alexandru Csete**, **Balint Seeber**, **Ben Hilburn**, **Ben Reynwar**, **Dimitrios Symeonidis**, **Doug Geiger**, **John Malsbury**, **Martin Braun**, **Martin Dvh**, **Michael Dickens**, **Moritz Fischer**, **n4hy McGwier**, **Nathan West**, **Neel Pandeya**, **Nicholas Corgan**, **Nick Foster**, **Patrick Strasser**, **Philip Balister**, **Sebastian Koslowski**, **Seth Hitefield**, **Sylvain Munaut**, **Tim O'Shea**

Reporter: **Al Whaley**, **Alex Dusowitz**, **Alex Ruffell**, **Alexander Chemeris**, **Alexander Limonov**, **Alexandre Pierrot**, **Alexandru Csete**, **Alfredo Muniz**, **Alon Levy**, **Amarnath alapati**, **Andre Puschmann**, **Andrej Lajovic**, **andres lucena**, **Andrew Back**, **Andrew Davis**, **andy shi**, **Ankit Kaushik**, **anton komarov**, **Antonio Cantoni**, **Anupama Purohit**, **aravindan arun**, **Arturo Rinaldi**, **Asier Alonso**, **Axelle Apvrille**, **Ayman Shalaby**, **Balint Seeber**, **Bastian Bloessl**, **Ben Hilburn**, **Ben Reynwar**, **Bill Pretty**, **Brian Padalino**, **Catalin P**, **Cauresew Cauresew**, **Chaouki KASMI**, **Chris Paget**, **Christoph Hausl**, **Christophe Devine**, **Chí-Thanh Christopher Nguyễn**, **Daniel Bovensiepen**, **Daniel Mundall**, **David Burgess**, **David Lawrence**, **Devang M**, **Diane Bruce**, **Dick Carrillo**, **Dimitri Stolnikov**, **Don**

MAY 21, 2013

RTL-SDR FOR BUDGET RADIO ASTRONOMY

With the right additional hardware, the RTL-SDR software defined radio can be used as a super cheap radio telescope for radio astronomy experiments.

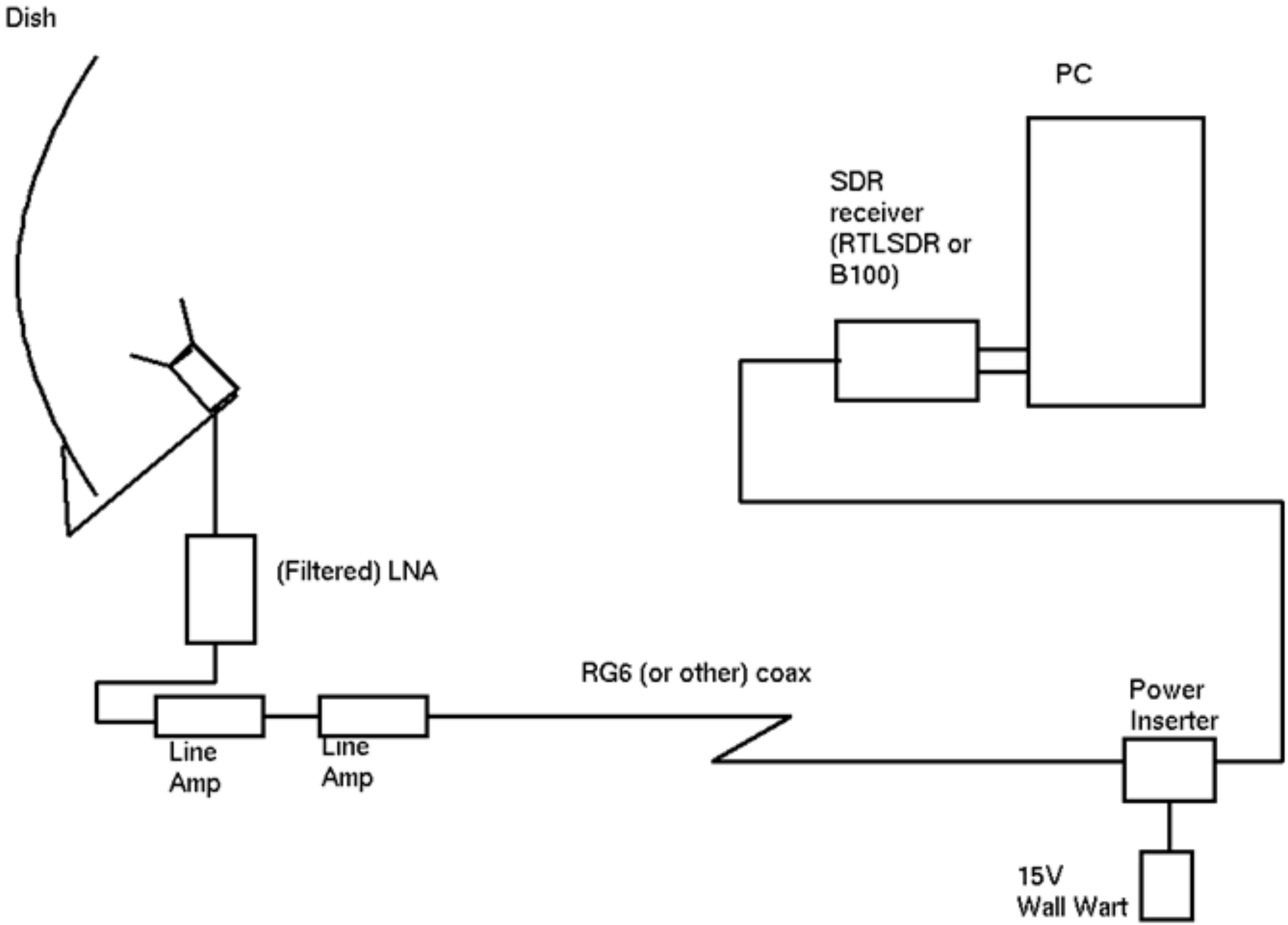
Marcus Leech of Science Radio Laboratories, Inc has released a tutorial document titled "*A Budget-Conscious Radio Telescope for 21cm*", (doc version) (pdf here) where he shows

> Two slightly-different designs for a simple, small, effective, radio telescope capable of observing the Sun, and the galactic plane in both continuum and spectral modes, easily able to show the hydrogen line in various parts of the galactic plane.

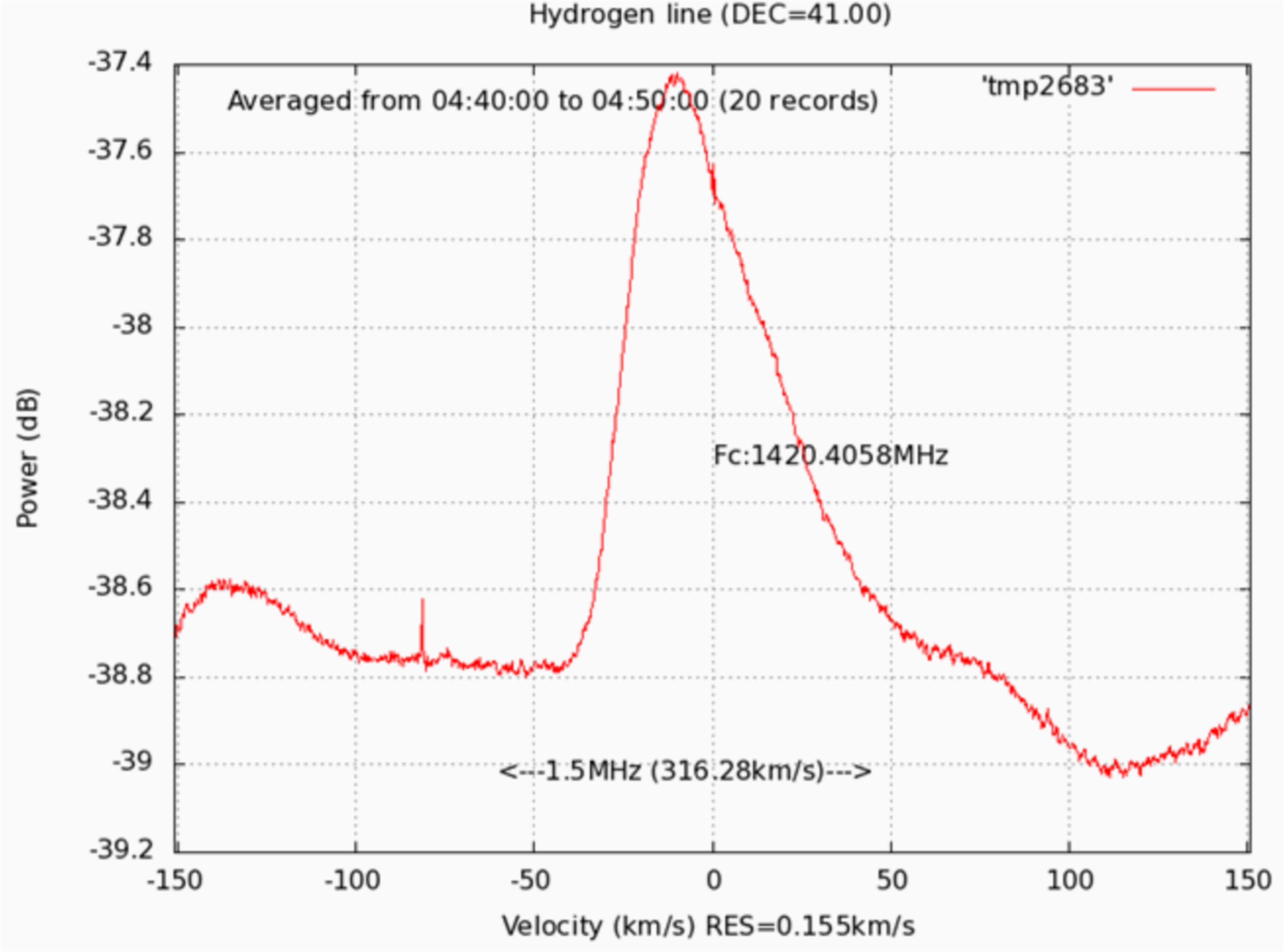
He uses the RTL-SDR as the receiving radio with an LNA (low noise amplifier) and a couple of line amps, a 93cm x 85cm offset satellite dish (potential dish for sale here, and here), and GNU Radio with the simple_ra application. In his results he was able to observe the spectrum of the Galactic Plane, and the Hydrogen Line. Some more information about this project can be found on this Reddit thread.

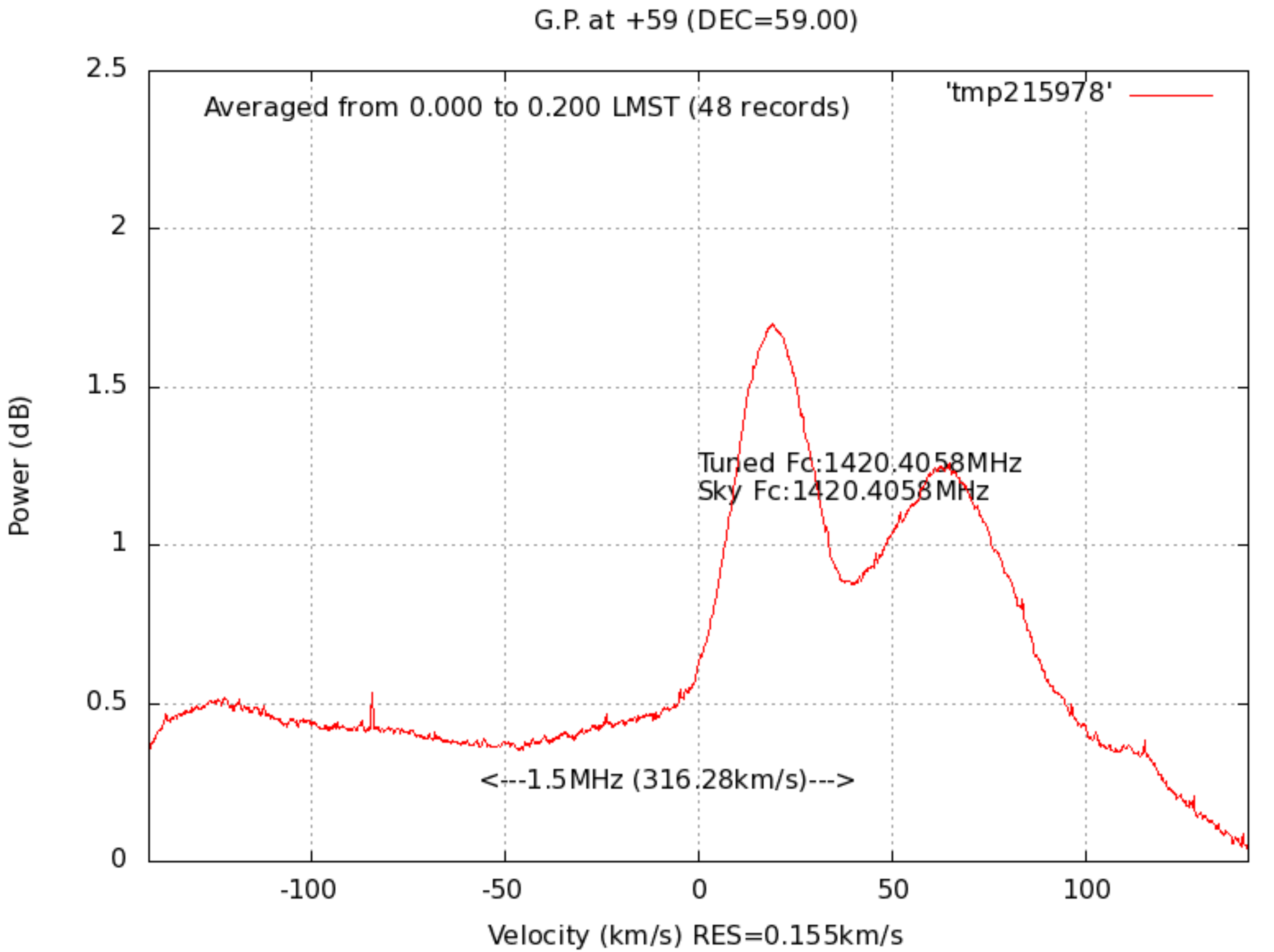
Here is a link to an interesting gif Marcus made with his RTL-SDR, showing a timelapse of recorded hydrogen emissions over 24 hours. Reddit user patchvonbraun (a.k.a Marcus Leech) writes on this thread an explanation of what is going on in the gif.

> Interstellar space is "full" of neutral hydrogen, which occasionally emits at photon at a wavelength of 21cm–1420.4058Mhz.


Dish
PC
SDR
receiver
(RTLSDR or
B100)
(Filtered) LNA
RG6 (or other) coax
Power
Inserter
Line
Amp
Line
Amp
15V
Wall Wart

And here is just one of his many resulting graphs shown in the document showing the Hydrogen line.





G.P. at +59 (DEC=59.00)
Averaged from 0.000 to 0.200 LMST (48 records)
'tmp215978'
Tuned Fc:1420.4058MHz
Sky Fc:1420.4058MHz
<---1.5MHz (316.28km/s)--->
Power (dB)
Velocity (km/s) RES=0.155km/s
2.5
2
1.5
1
0.5
0
-100
-50
0
50
100