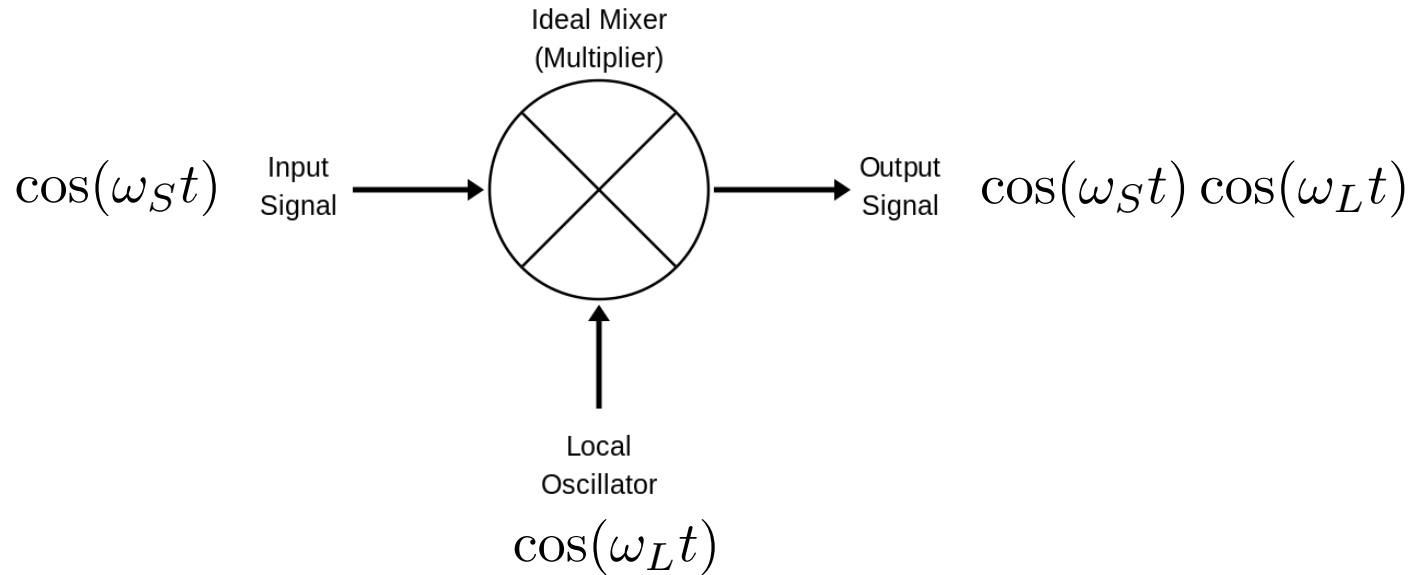# Software Defined Radio (SDR)
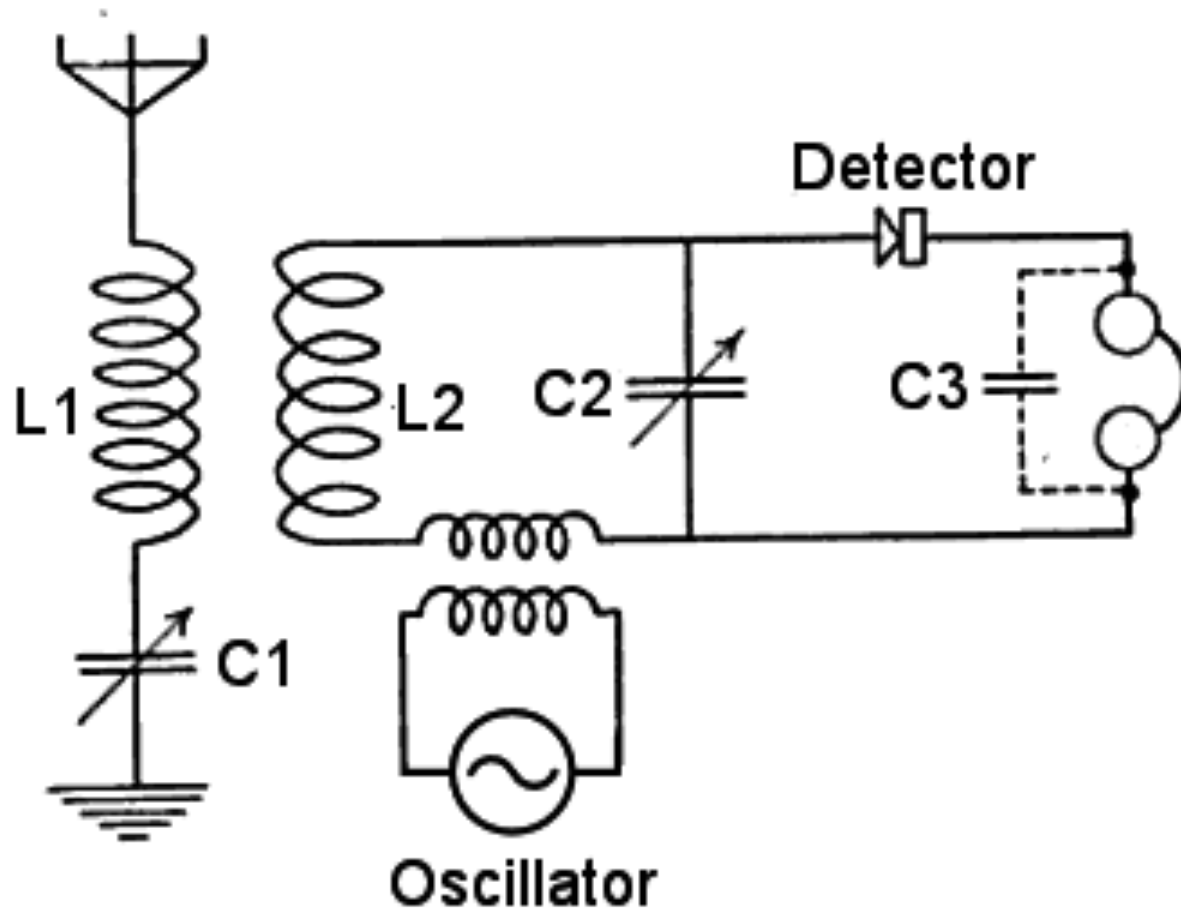
Edoardo Milotti

Fondamenti Fisici di Tecnologia Moderna
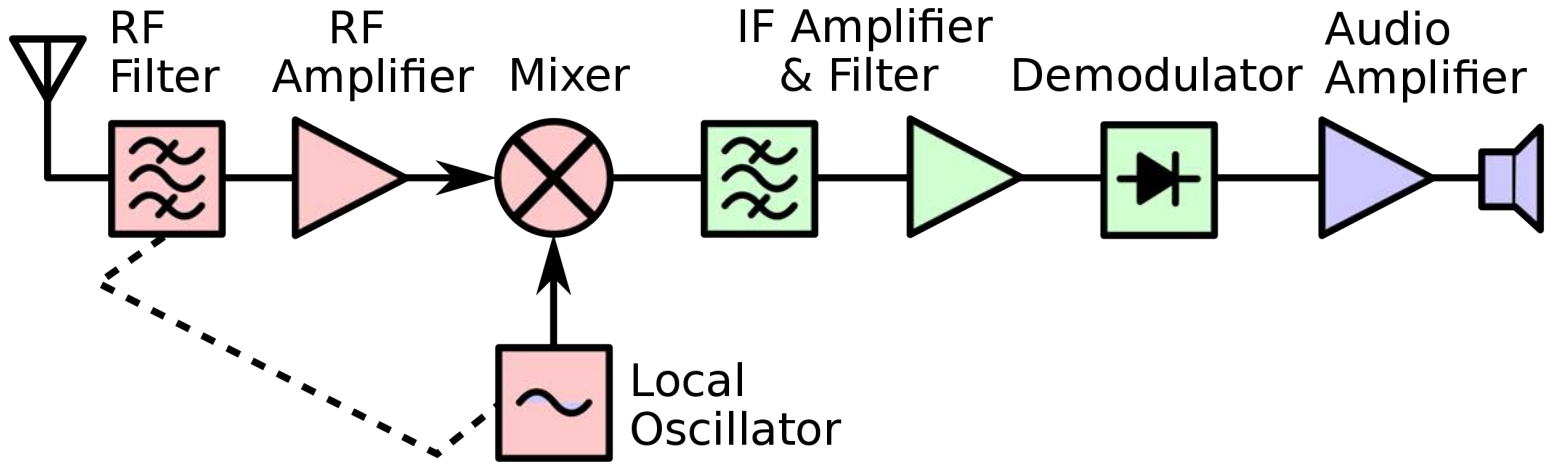
Rivelazione eterodina

$$\cos(\omega_S t)$$ Input Signal → **Ideal Mixer (Multiplier)** → Output Signal $$\cos(\omega_S t)\cos(\omega_L t)$$
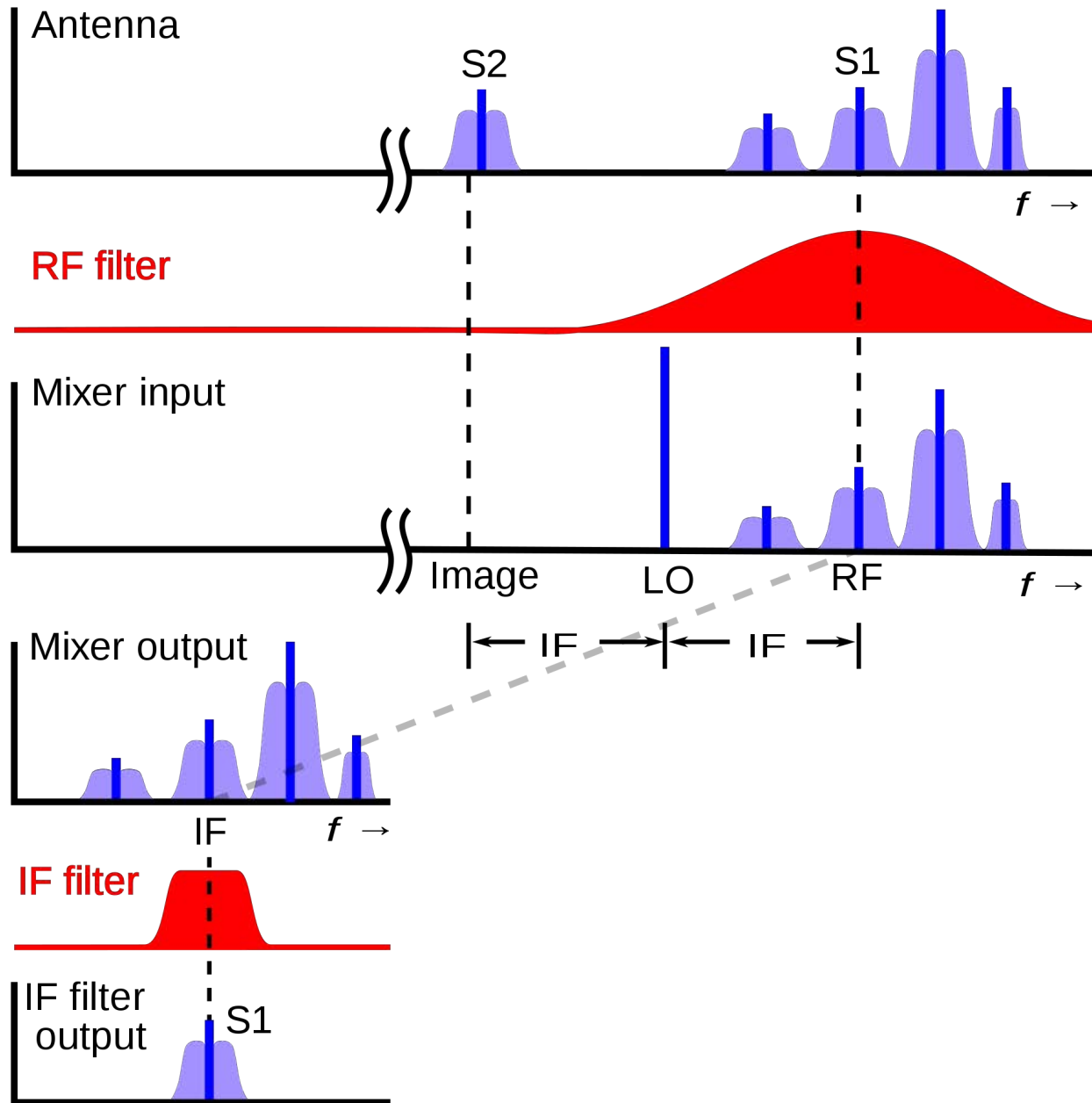
Local Oscillator $$\cos(\omega_L t)$$

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

Il ricevitore radio ad eterodina di Reginald Fessenden. Il segnale radio e l'oscillatore locale vengono miscelati nel diodo.

Schema a blocchi di un ricevitore a supereterodina (inventato nel 1918 da Edwin Armstrong). Le parti rosa sono quelle che lavorano alla frequenza del segnale radio originale (RF); quelle verdi operano alla frequenza intermedia (IF); quelle blu lavorano alla frequenza di modulazione (audio). La linea tra il filtro RF e l'oscillatore locale indica che i due devono essere regolati insieme.

Antenna

S2   S1

$f \rightarrow$

RF filter

Mixer input

Image   LO   RF $f \rightarrow$

|← IF →|← IF →|

Mixer output

IF $f \rightarrow$

IF filter

IF filter
output   S1

Importanza della fase

Consideriamo un segnale modulato in ampiezza e fase (questo comprende anche la modulazione di frequenza), allora l'eterodina produce il seguente risultato

I (in-phase)

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

dove la fase aggiunta corrisponde a frequenze di modulazione molto più piccole della frequenza della portante. Come si vede, se la fase aggiunta è vicina 90°, il segnale a bassa frequenza ha ampiezza molto piccola e viene quasi completamente perso.

Però se si moltiplica anche per un seno ...

Q (quadrature)

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

e si vede che il segnale a bassa frequenza in questo caso NON è piccolo per una fase vicina a 90°.

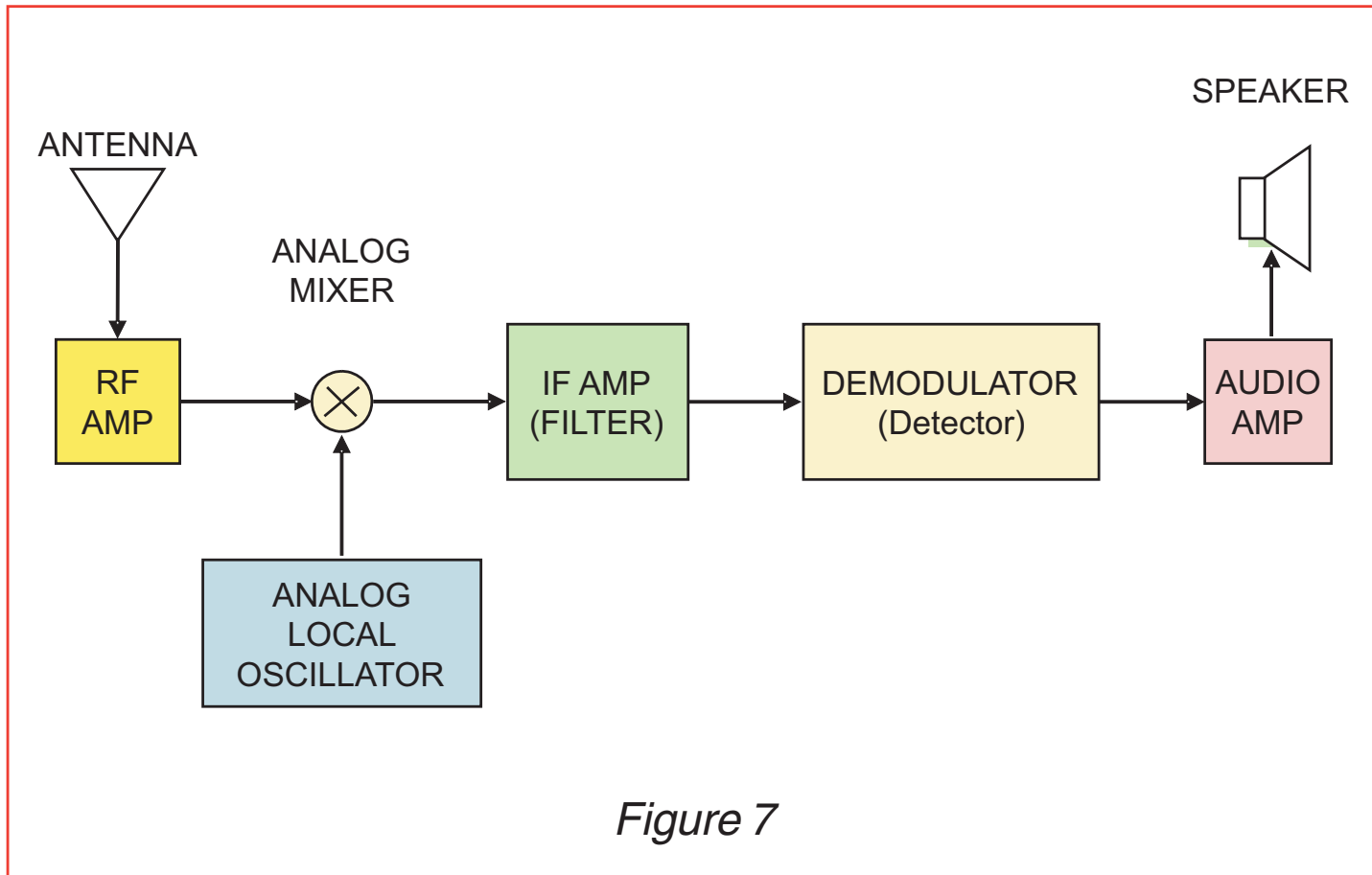A questo punto la modulazione di ampiezza si può recuperare in questo modo

$$x = \frac{A(t)}{2} \cos \varphi$$

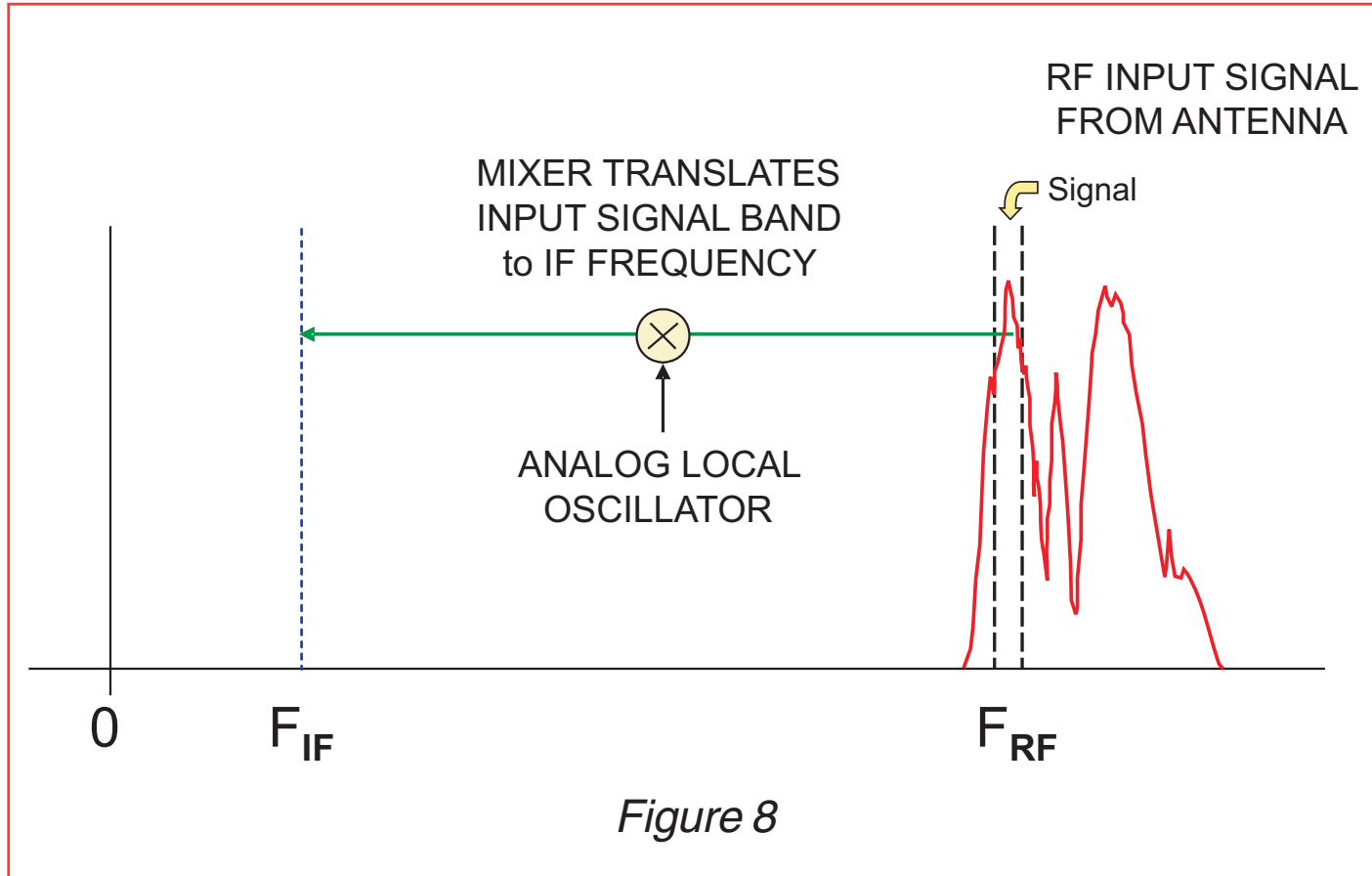$$y = -\frac{A(t)}{2} \sin \varphi$$

$$\Rightarrow A(t) = \sqrt{x^2 + y^2}$$

e la modulazione di fase o frequenza

$$\varphi(t) = -\arctan \frac{y}{x}$$

Analog Radio Receiver Block Diagram
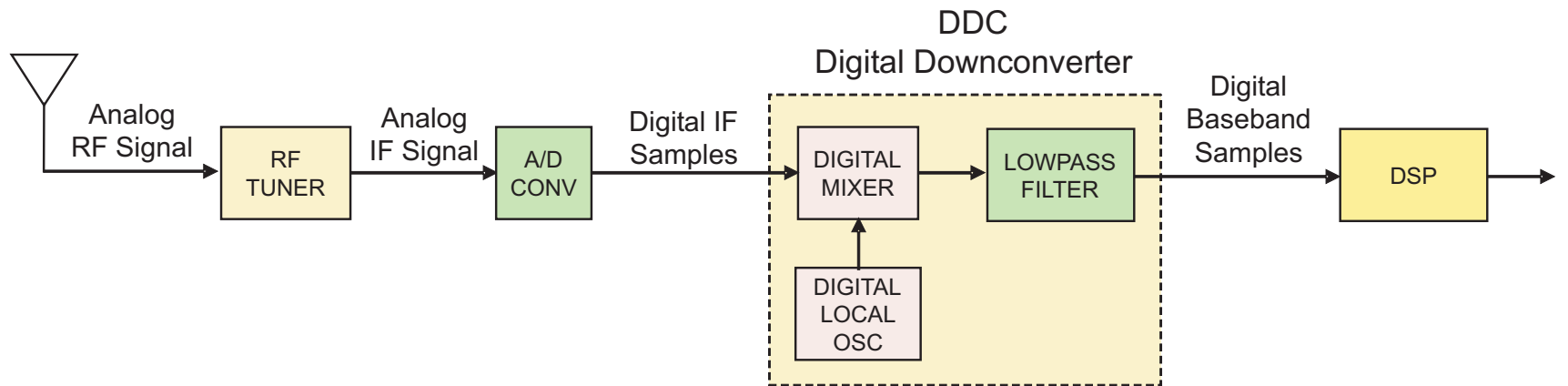

Figure 7

Analog Radio Receiver Mixer

RF INPUT SIGNAL
FROM ANTENNA

MIXER TRANSLATES
INPUT SIGNAL BAND
to IF FREQUENCY

Signal

$\otimes$

ANALOG LOCAL
OSCILLATOR

0   F_{IF} F_{RF}

Figure 8

SDR Receiver Block Diagram

...er

Digital Baseband Samples

s

DSP

Figure 9

SDR Receiver Mixer

CHANNEL BANDWIDTH

MIXER TRANSLATES INPUT SIGNAL BAND to DC

IF BW

Signal

DIGITAL LOCAL OSCILLATOR $F_{LO} = F_{SIG}$

MIXER TRANSLATES INPUT SIGNAL BAND to DC

IF BW

DIGITAL LOCAL OSCILLATOR $F_{LO} = F_{SIG}$

0

F_{SIG}

Figure 10

0

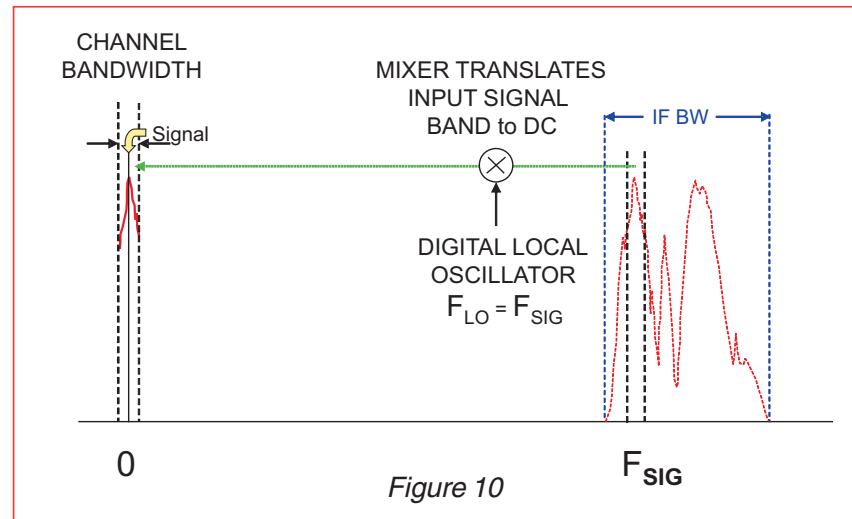F_{SIG}

DDC Local Oscillator and Decimation
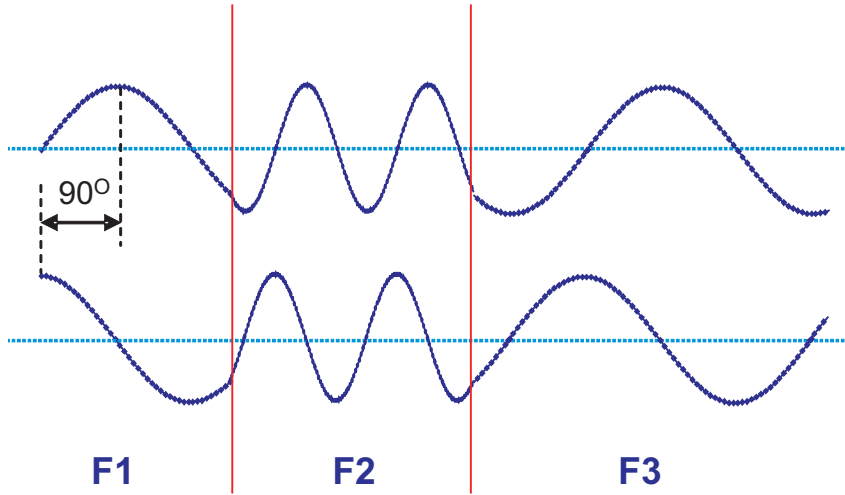

F1   F2   F3

Figure 11A Local Oscillator Frequency Switching

A
C

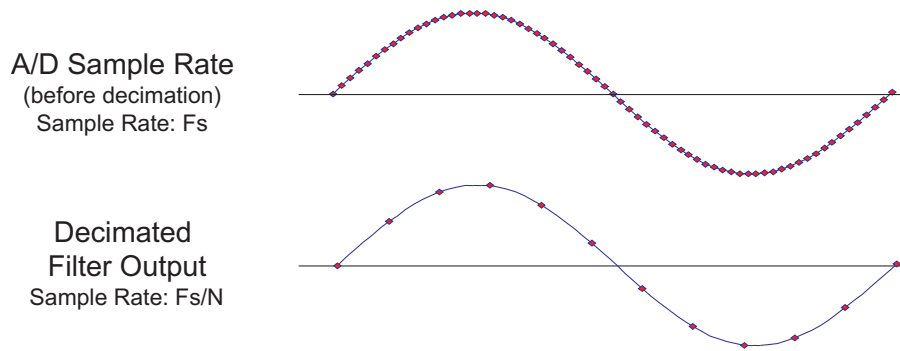*Figure 11B FIR Filter Decimation*

DDC Signal Processing

Translation   Filtering

Digital IF Samples

A/D CONV → DIGITAL MIXER → LOWPASS FILTER → Digital Baseband Samples
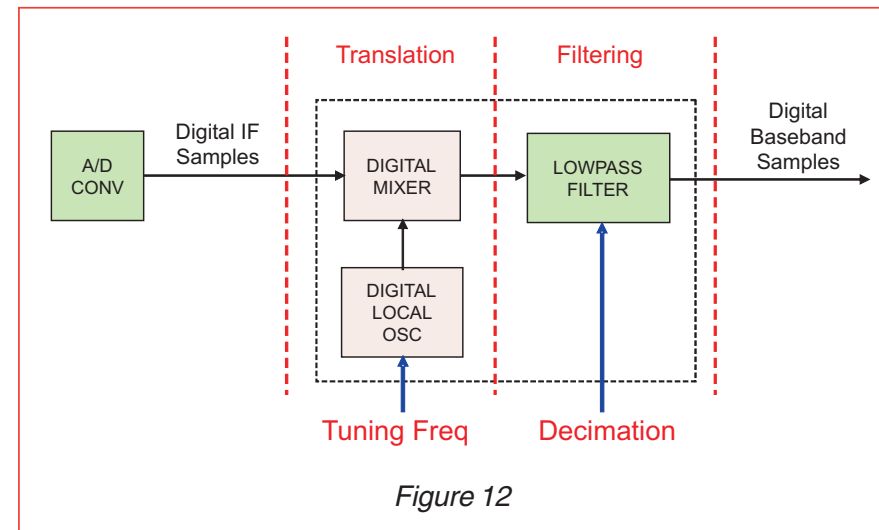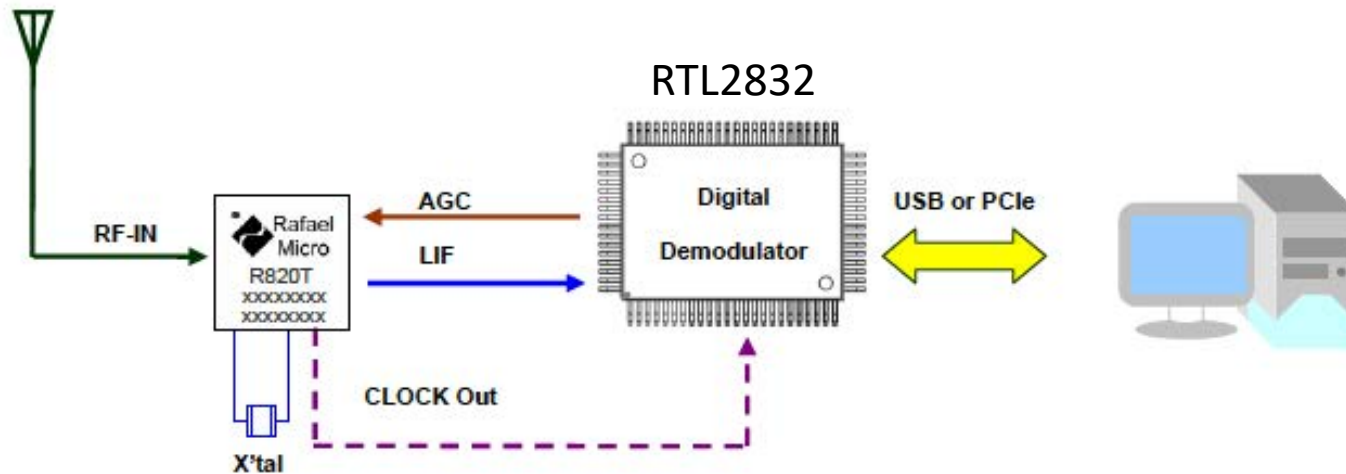
DIGITAL LOCAL OSC

Tuning Freq   Decimation

Figure 12

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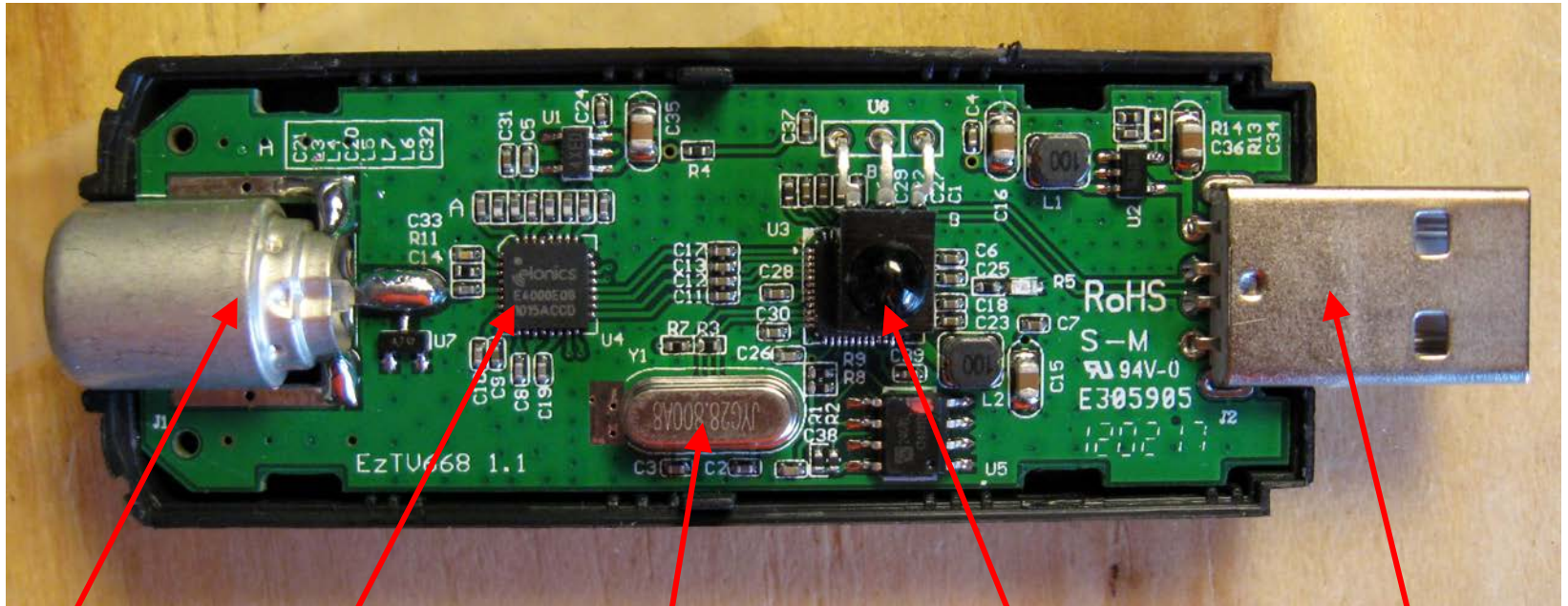
RTL2832

SDR Receiver Block Diagram

Figure 9
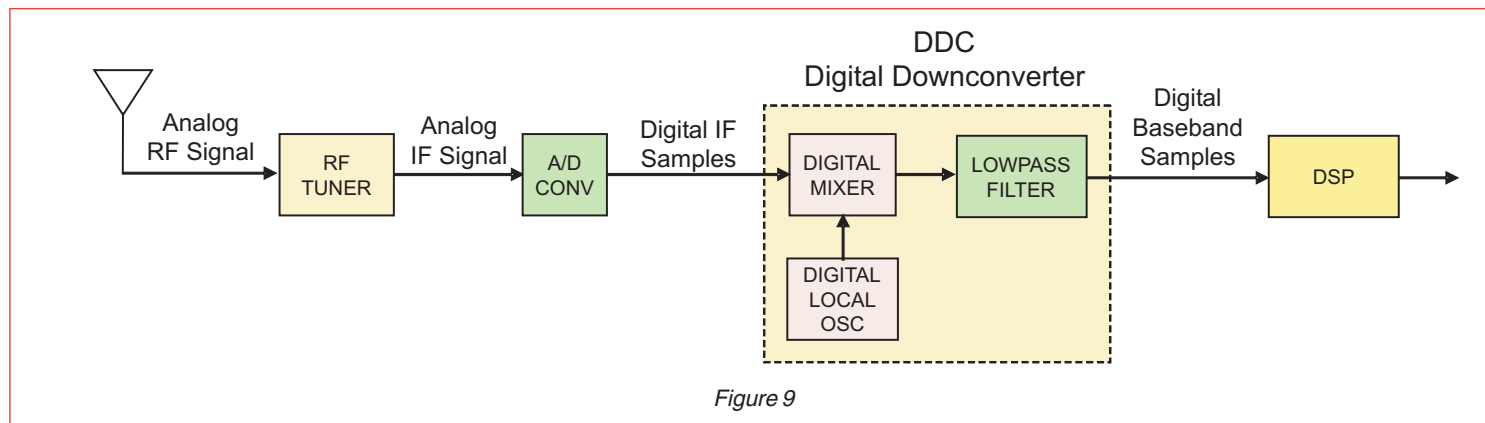
Struttura del microcircuito RTL2832
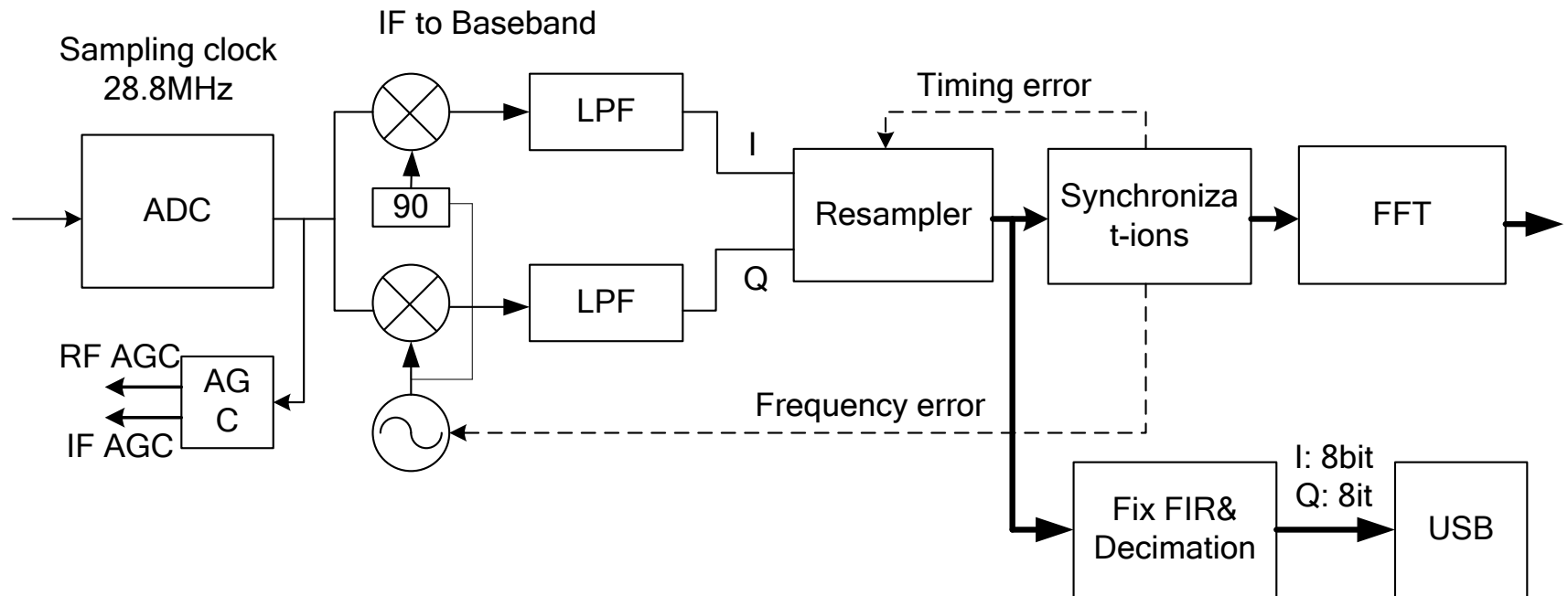
Ingresso
antenna

Tuner chip
(eterodina)

Risonatore
a quarzo

Demodulatore
digitale

Uscita
USB

https://www.gnuradio.org

What is GNU Radio?

GNU Radio is a free & open-source software development toolkit that provides signal processing blocks to implement software radios. It can be used with readily-available low-cost external RF hardware to create software-defined radios, or without hardware in a simulation-like environment. It is widely used in research, industry, academia, government, and hobbyist environments to support both wireless communications research and real-world radio systems.

What is Software Radio?

The Wikipedia page on software radio provides an excellent overview. In brief, a software radio is a radio system which performs the required signal processing in software instead of using dedicated integrated circuits in hardware. The benefit is that since software can be easily replaced in the radio system, the same hardware can be used to create many kinds of radios for many different communications standards; thus, one software radio can be used for a variety of applications!

What Does GNU Radio Do?

GNU Radio performs all the signal processing. You can use it to write applications to receive and transmit data with radio hardware, or to create entirely simulation-based applications. GNU Radio has filters, channel codes, synchronisation elements, equalizers, demodulators, vocoders, decoders, and many other types of blocks which are typically found in signal processing systems. More importantly, it includes a method of connecting these blocks and then manages how data is passed from one block to another. Extending GNU Radio is also quite easy; if you find a specific block that is missing, you can quickly create and add it.

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**

RTL-SDR.COM

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

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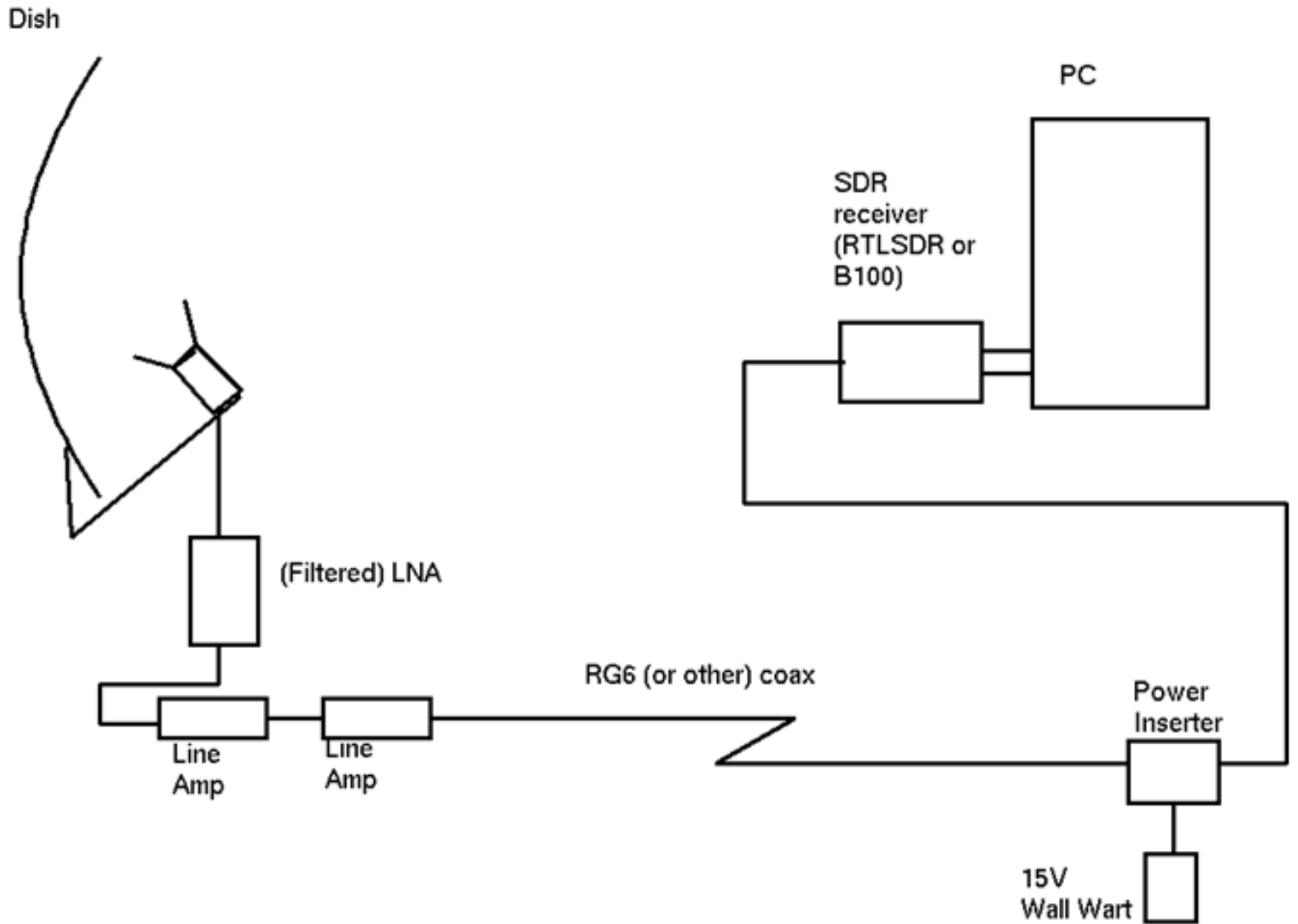
Marcus Leech of Science Radio Laboratories, Inc has released a tutorial document titled "*A Budget-Conscious Radio Telescope for 21cm*", (doc version) (pdf here) where he shows

> 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.
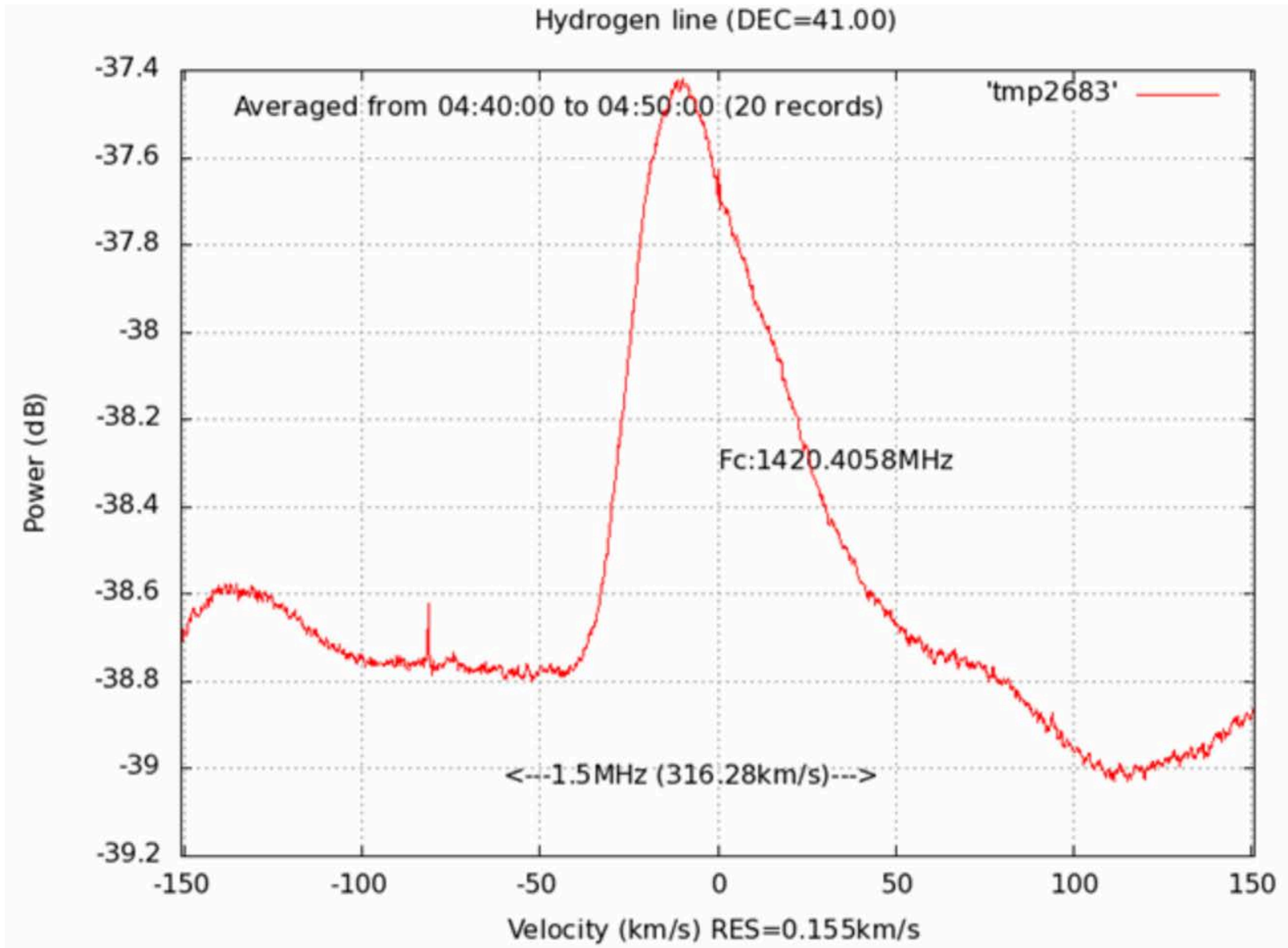
He uses the RTL-SDR as the receiving radio with an LNA (low noise amplifier) and a couple of line amps, a 93cm x 85cm offset satellite dish (potential dish for sale here, and here), and GNU Radio with the simple_ra application. In his results he was able to observe the spectrum of the Galactic Plane, 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

Line Amp

Line Amp

Power Inserter

15V Wall Wart

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

Hydrogen line (DEC=41.00)

Averaged from 04:40:00 to 04:50:00 (20 records)

'tmp2683'

Fc:1420.4058MHz

<---1.5MHz (316.28km/s)--->

Power (dB)

Velocity (km/s) RES=0.155km/s

The RTL-SDR Blog V3 is an improved RTL-SDR dongle. RTL-SDR dongles were originally designed for DVB-T HDTV reception, but they were found by hardware hackers to be useful as a general purpose SDR. The standard dongles are okay for DVB-T reception, but are just barely suitable for SDR users/experimenters. The RTL-SDR Blog V3 was redesigned with SDR user needs in mind, instead of DVB-T HDTV users who typically have more relaxed requirements.

Basic Information

- **Bandwidth:** Up to 2.4 MHz stable.

- **ADC:** RTL2832U 8-bits

- **Frequency Range:** 500 kHz – 1766 MHz (500 kHz – 24 MHz in direct sampling mode)

- **Typical Input Impedance:** 50 Ohms

- **Typical Current Draw:** 270 – 280 mA