Communication Systems based on Software Defined Radio (SDR)

Dr. Ing. Alejandro José Uriz

Introductory Concepts

Network of Competence on Internet of Things

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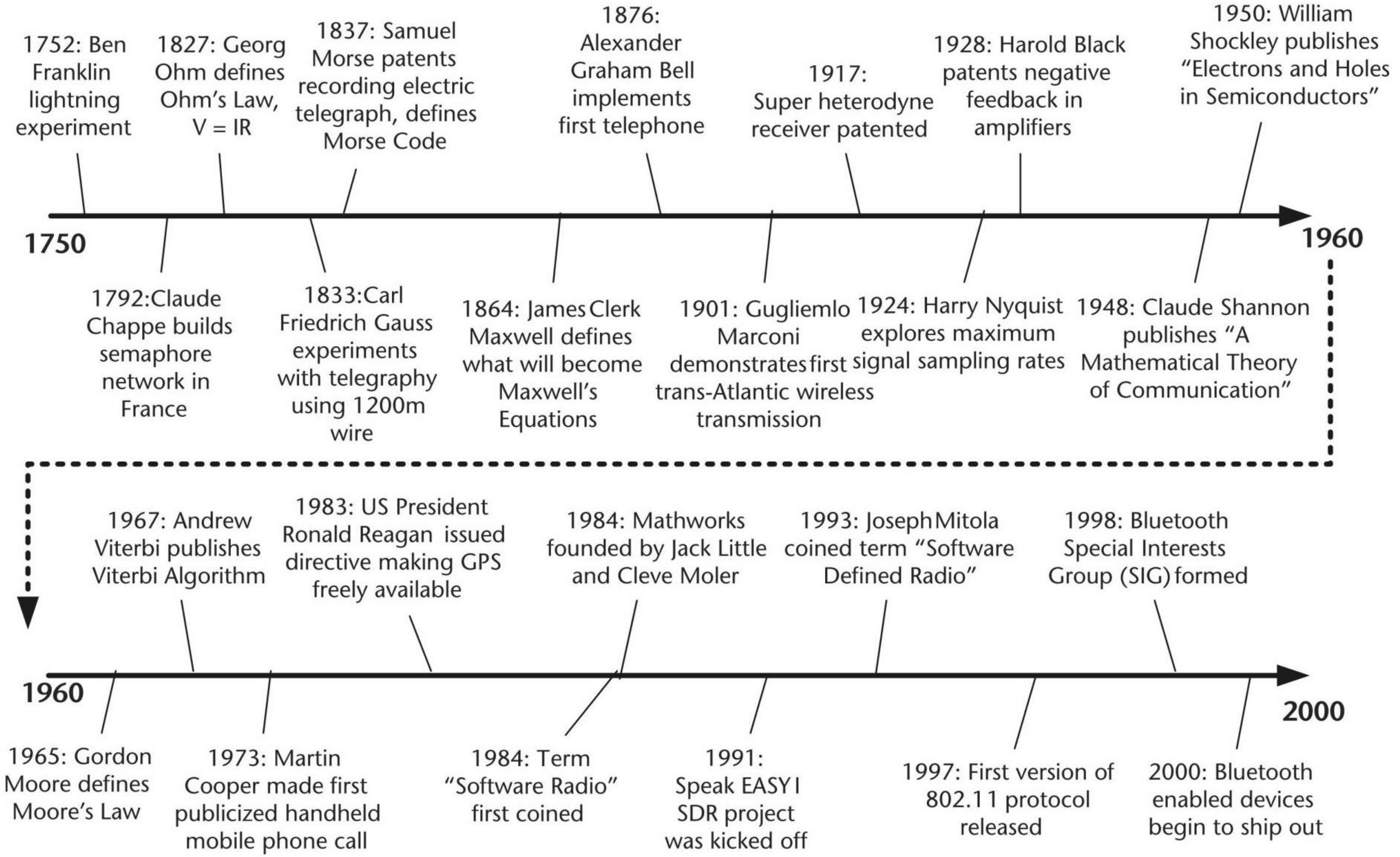

Figure 1.1 Timeline of several key milestones in communications.

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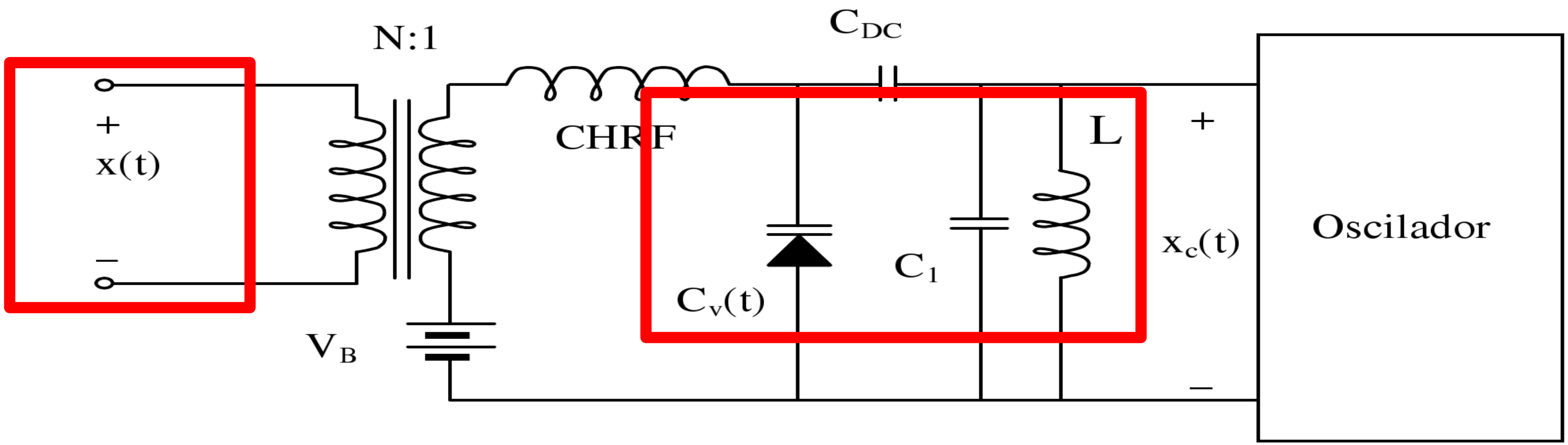
Source : https://www.analog.com/en/education/education-library/software-defined-radio-for-engineers.html

Direct method of FM generation



This circuit consists of a VCO. Its resonant frequency depends on L and C. The total capacity of the system is controlled by x(t).

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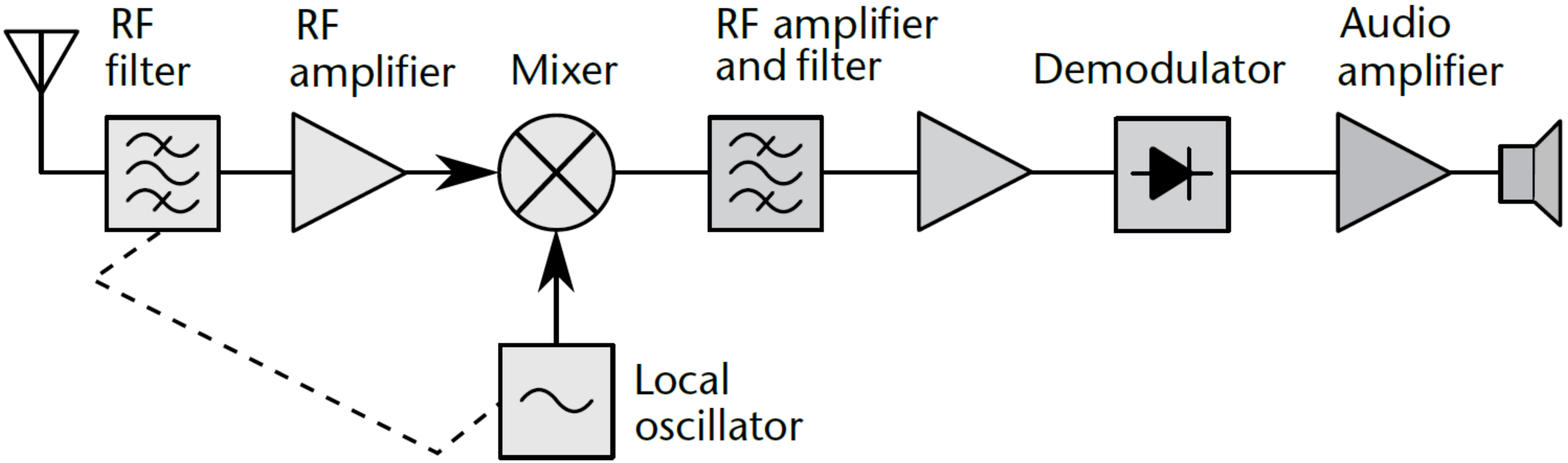

Figure A.3 Single-conversion superheterodyne radio receiver. The incoming radio signal from the antenna (left) is passed through an RF filter to attenuate some undesired signals, amplified in a radio frequency (RF) amplifier, and mixed with an unmodulated sine wave from a local oscillator. The result is a beat frequency or heterodyne at the difference between the input signal and local oscillator frequencies, a lower frequency called the IF. The IF signal is selected and strengthened by several IF stages that bandpass filter and amplify the signal. The IF signal is then applied to a demodulator that extracts the modulated audio signal. An audio amplifier further amplifies the signal, and the speaker makes it audible.

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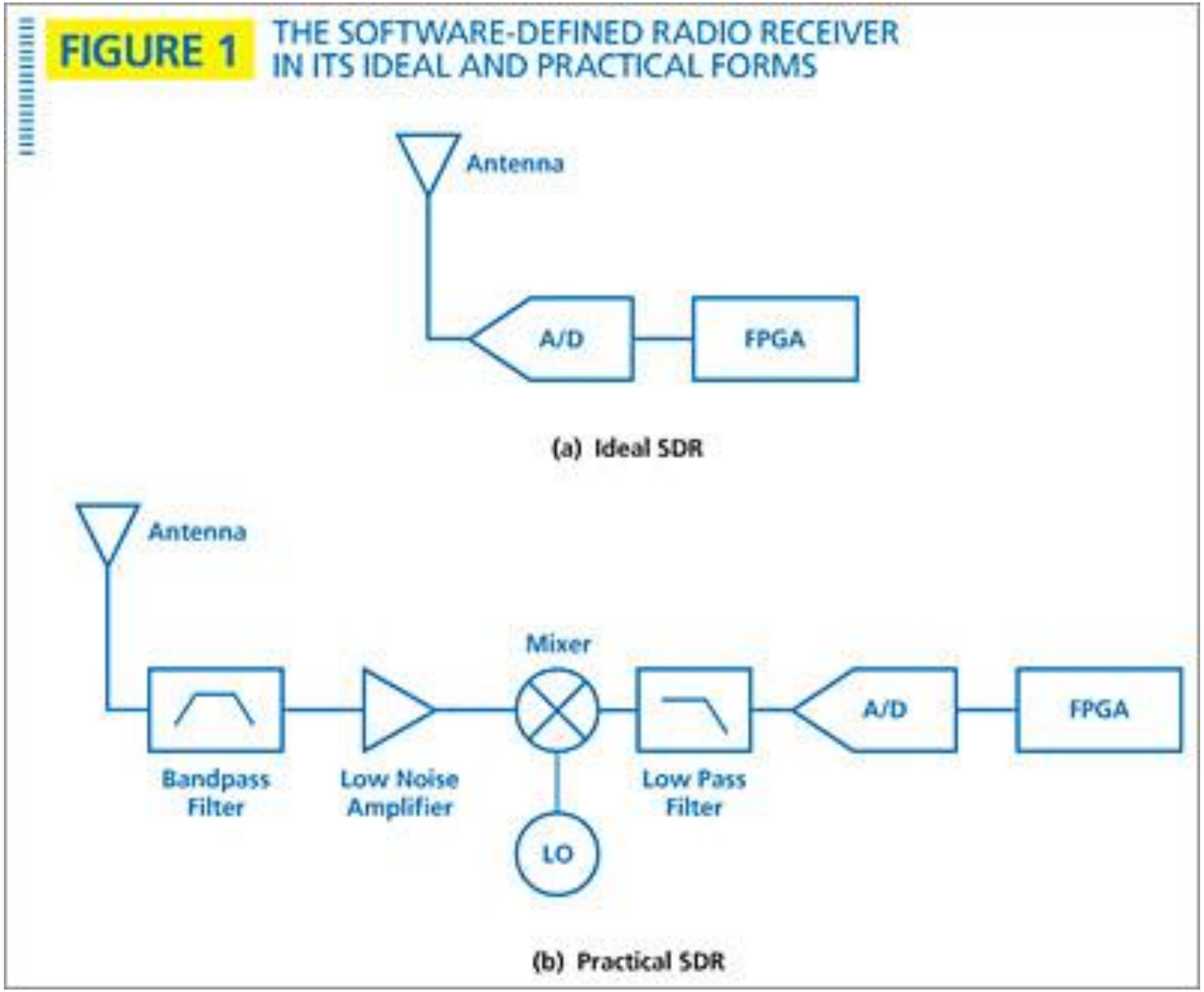
Source : https://www.analog.com/en/education/education-library/software-defined-radio-for-engineers.html



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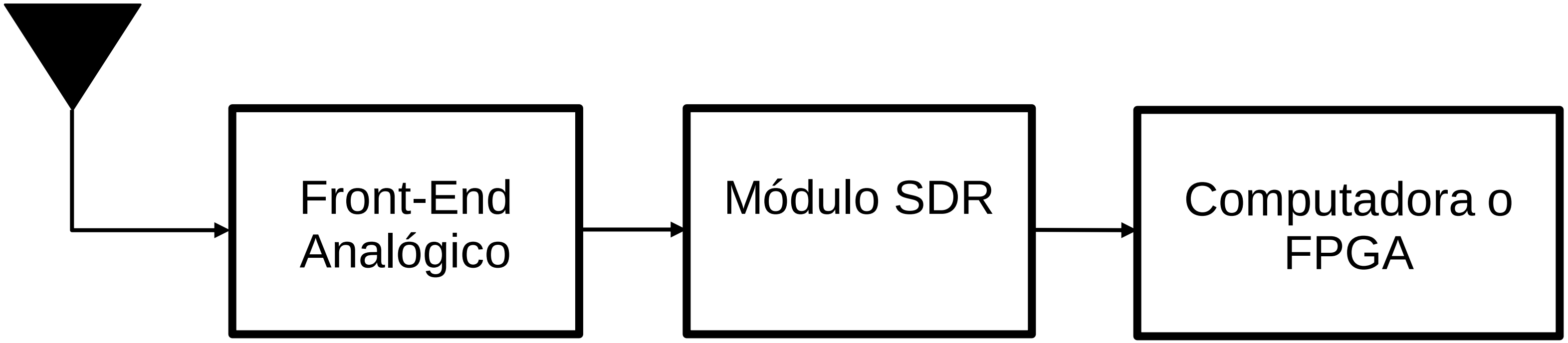
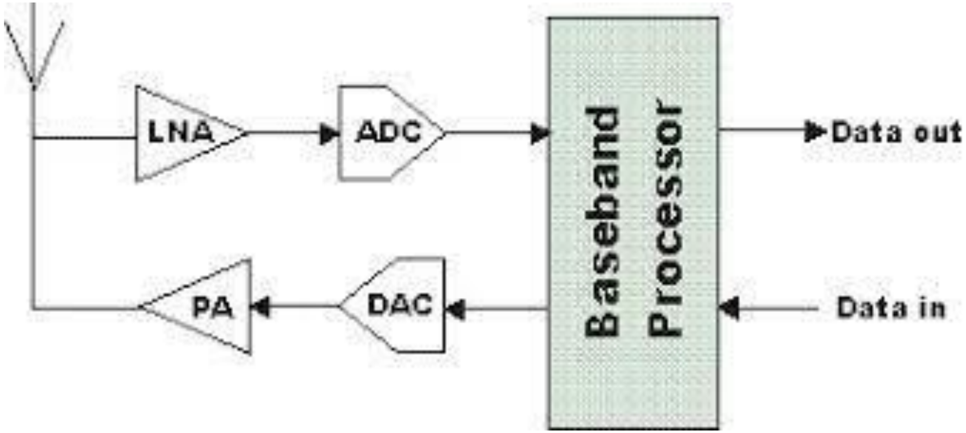
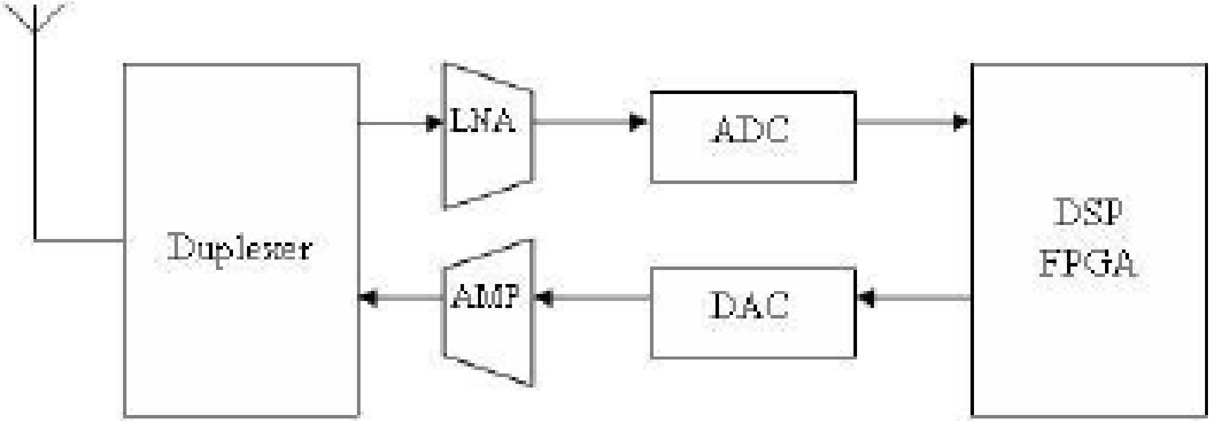

Front-End Analógico
Módulo SDR
Computadora o FPGA





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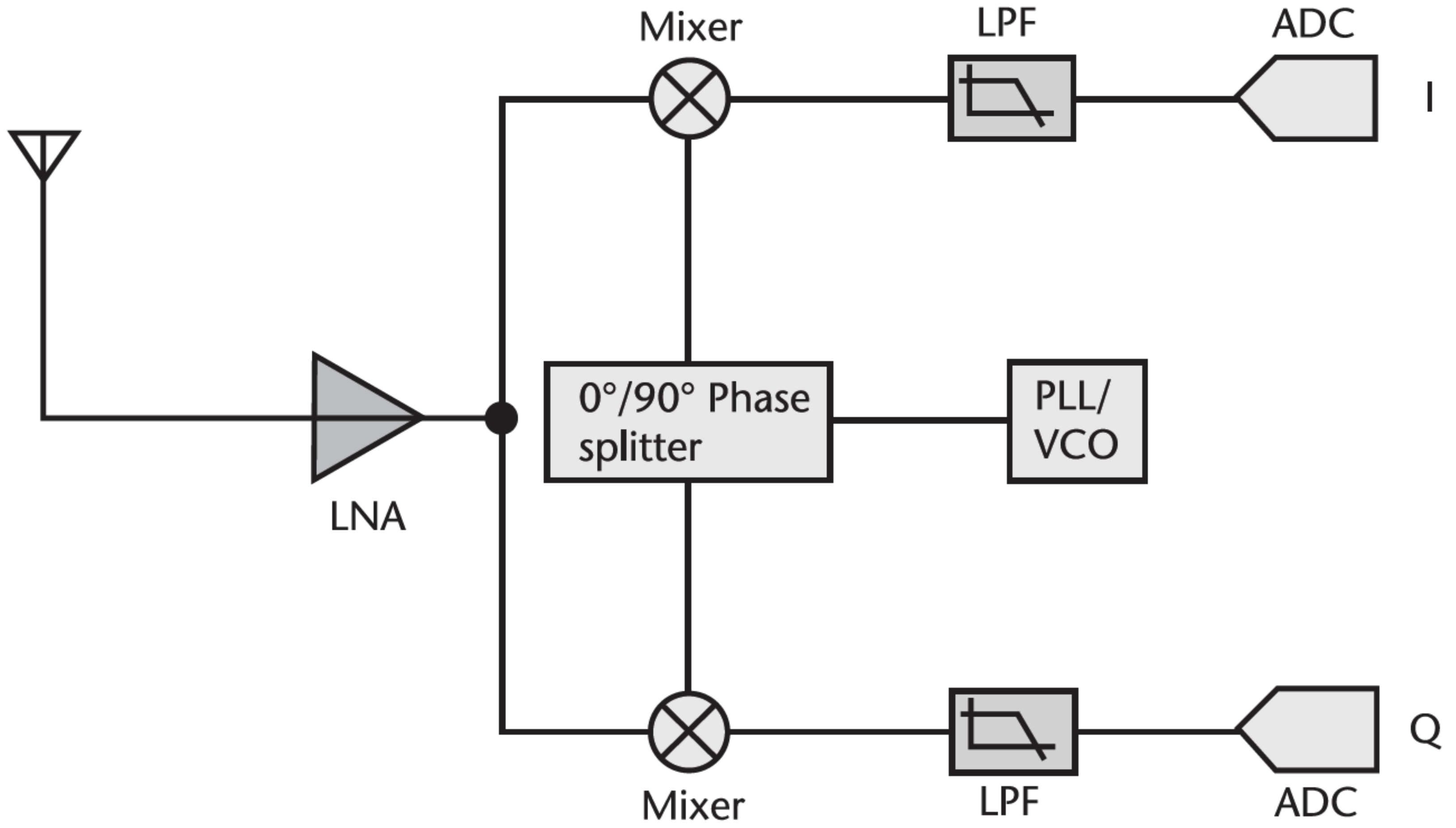
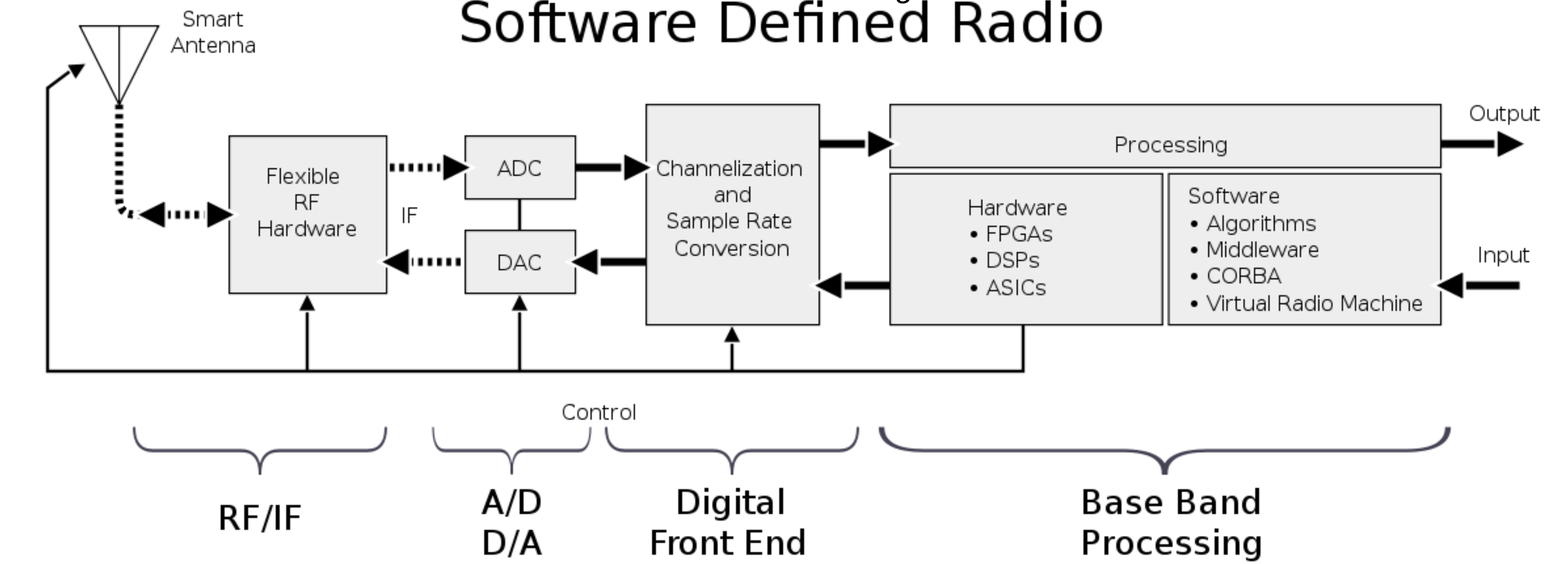
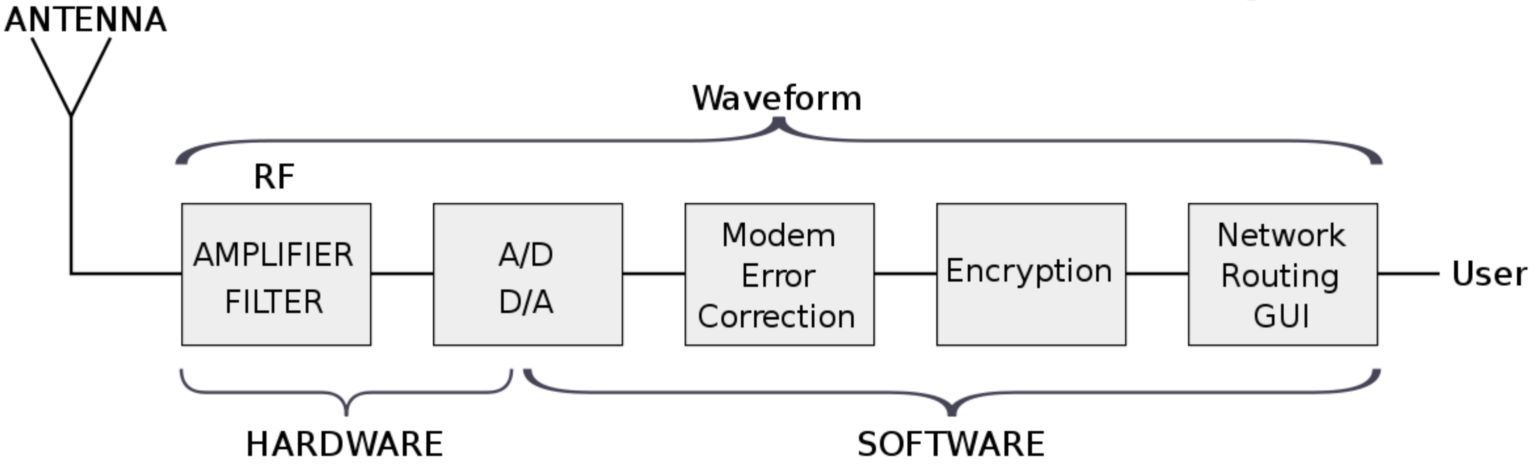


Figure 1.7 Zero IF architecture [4].

Source : https://www.analog.com/en/education/education-library/software-defined-radio-for-engineers.html

Software Defined Radio





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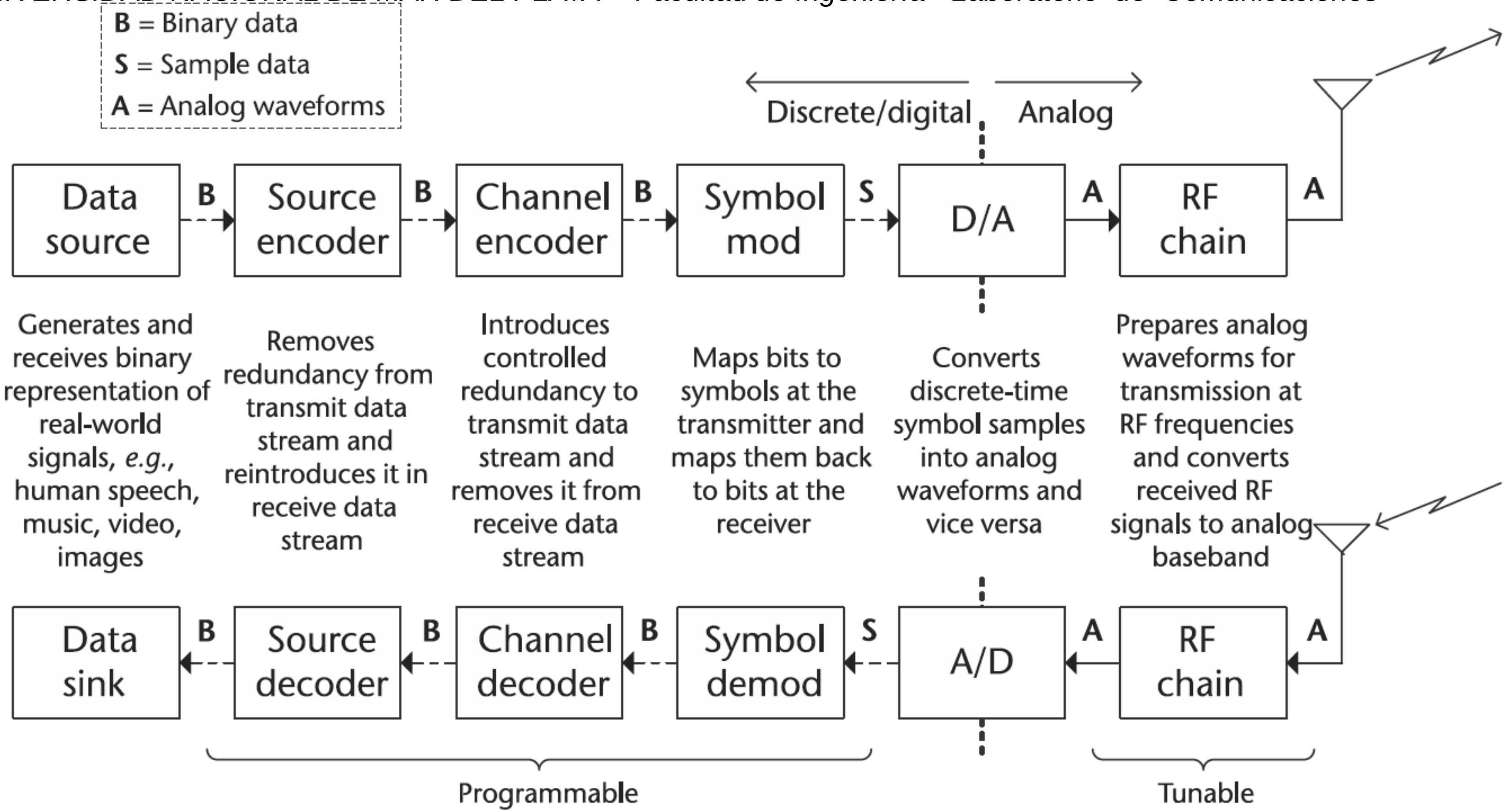

Figure 1.3 An illustration describing some of the important components that constitute a modern digital communications system. Note that for a SDR-based implementation, those components indicated as programmable can be realized in either programmable logic or software.

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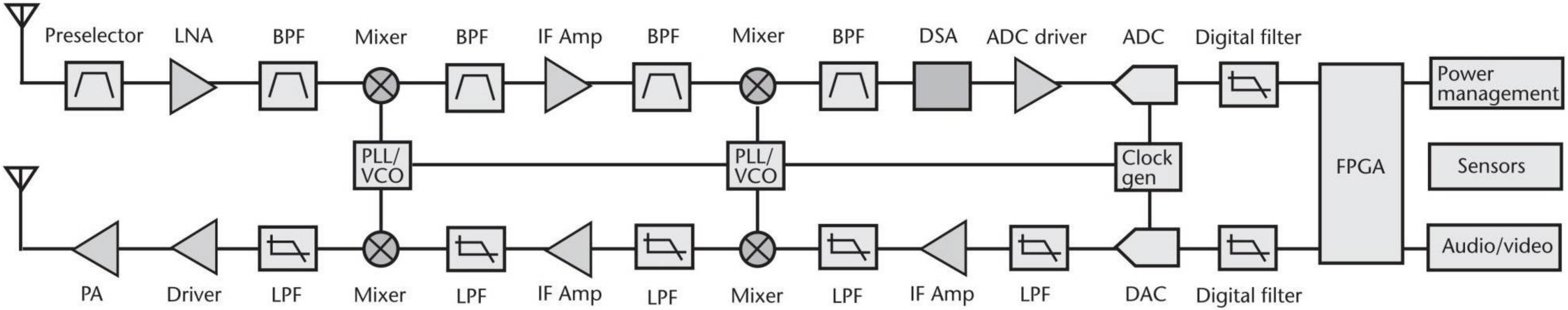
Source : https://www.analog.com/en/education/education-library/software-defined-radio-for-engineers.html



Source : https://www.analog.com/en/education/education-library/software-defined-radio-for-engineers.html

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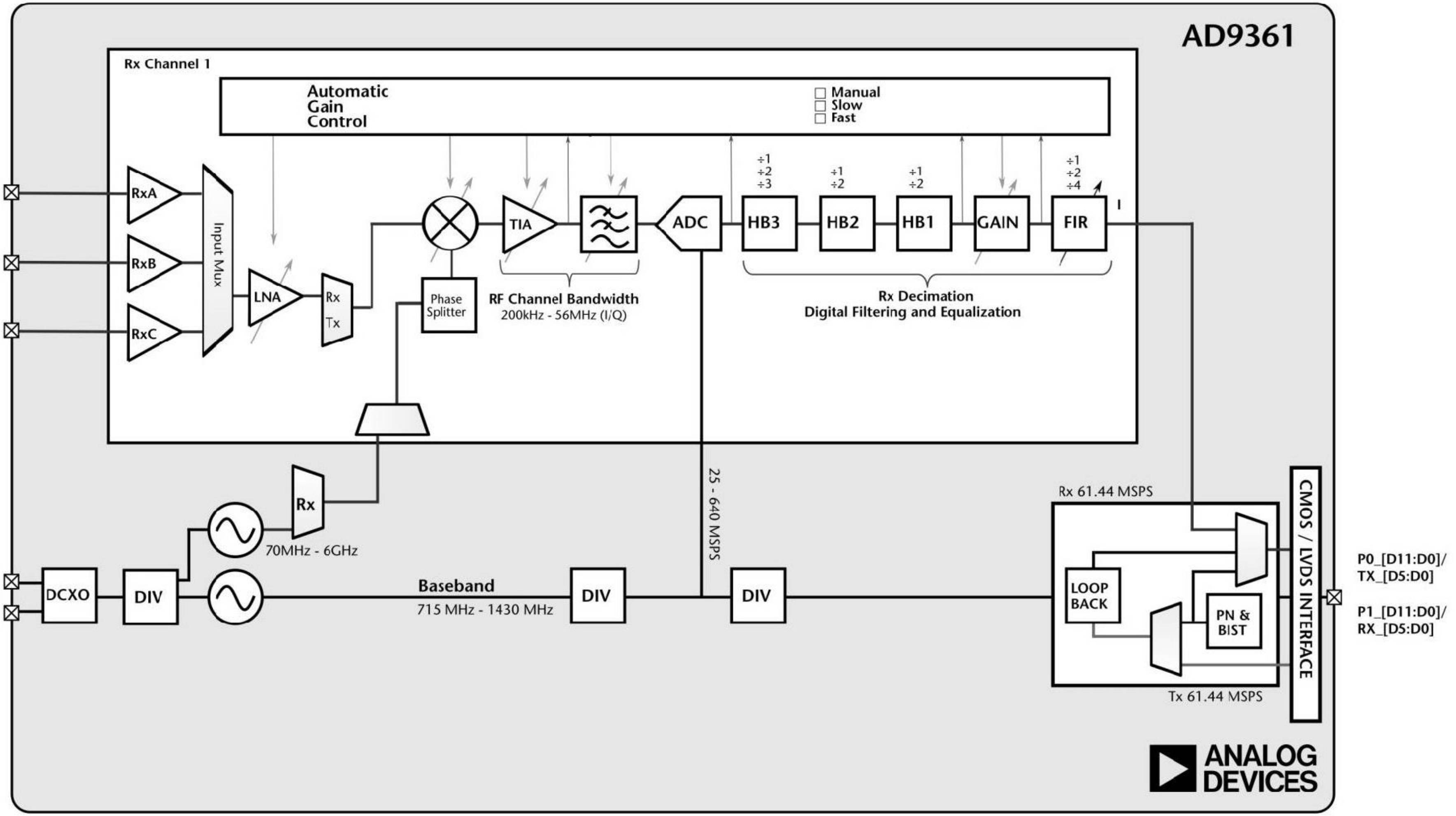

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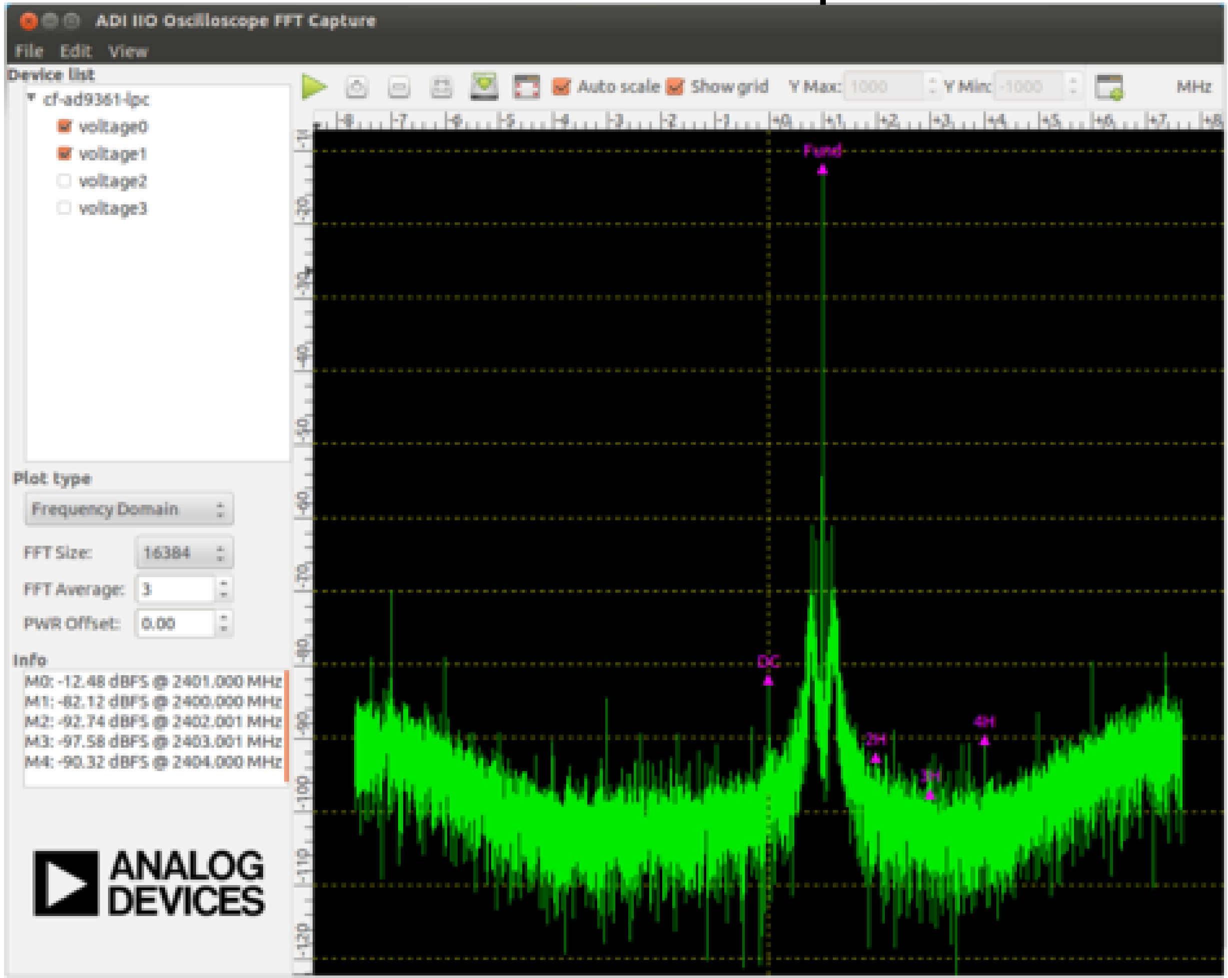
Source : https://www.analog.com/en/education/education-library/software-defined-radio-for-engineers.html

ADI IIO Oscilloscope



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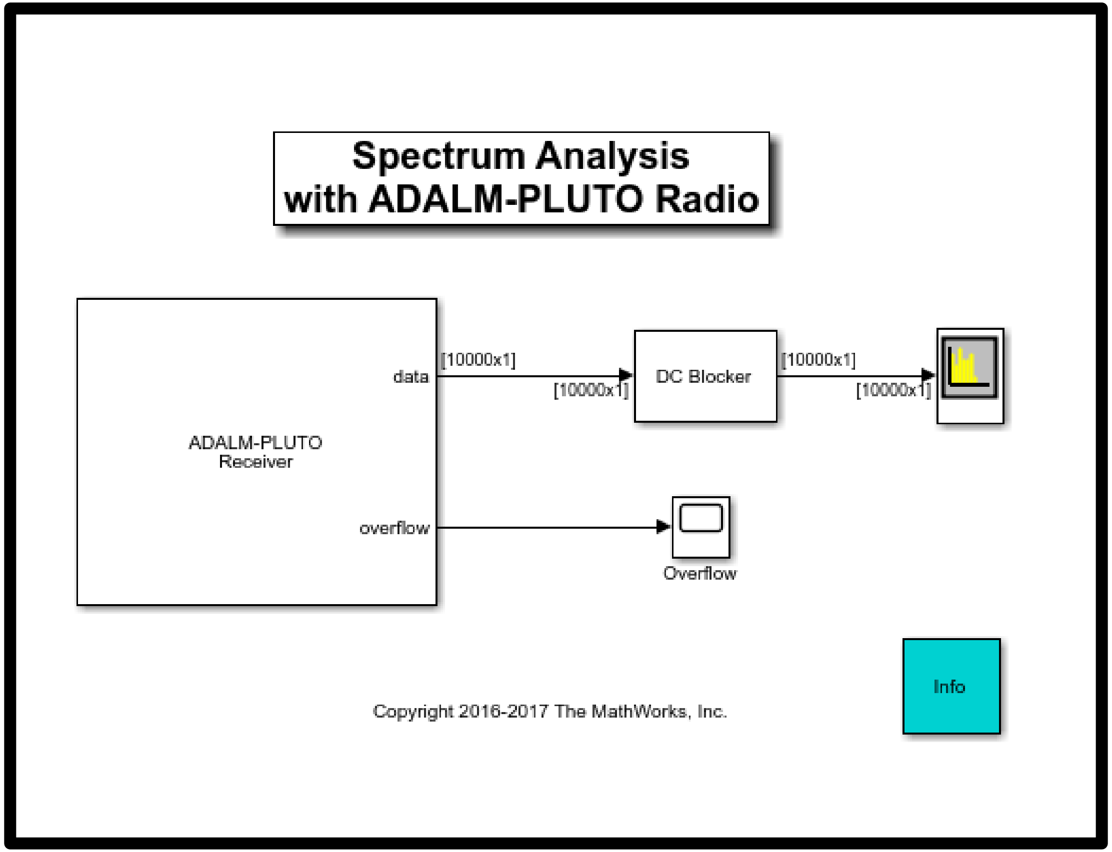
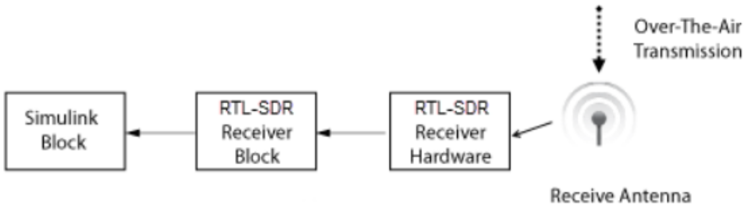
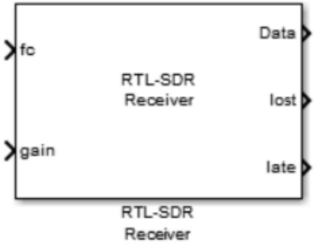
Source : https://www.analog.com/en/education/education-library/software-defined-radio-for-engineers.html

MatLab







Ports

Input

`fc` — Center frequency
positive scalar

`gain` — Receiver gain
scalar

Source : https://la.mathworks.com/

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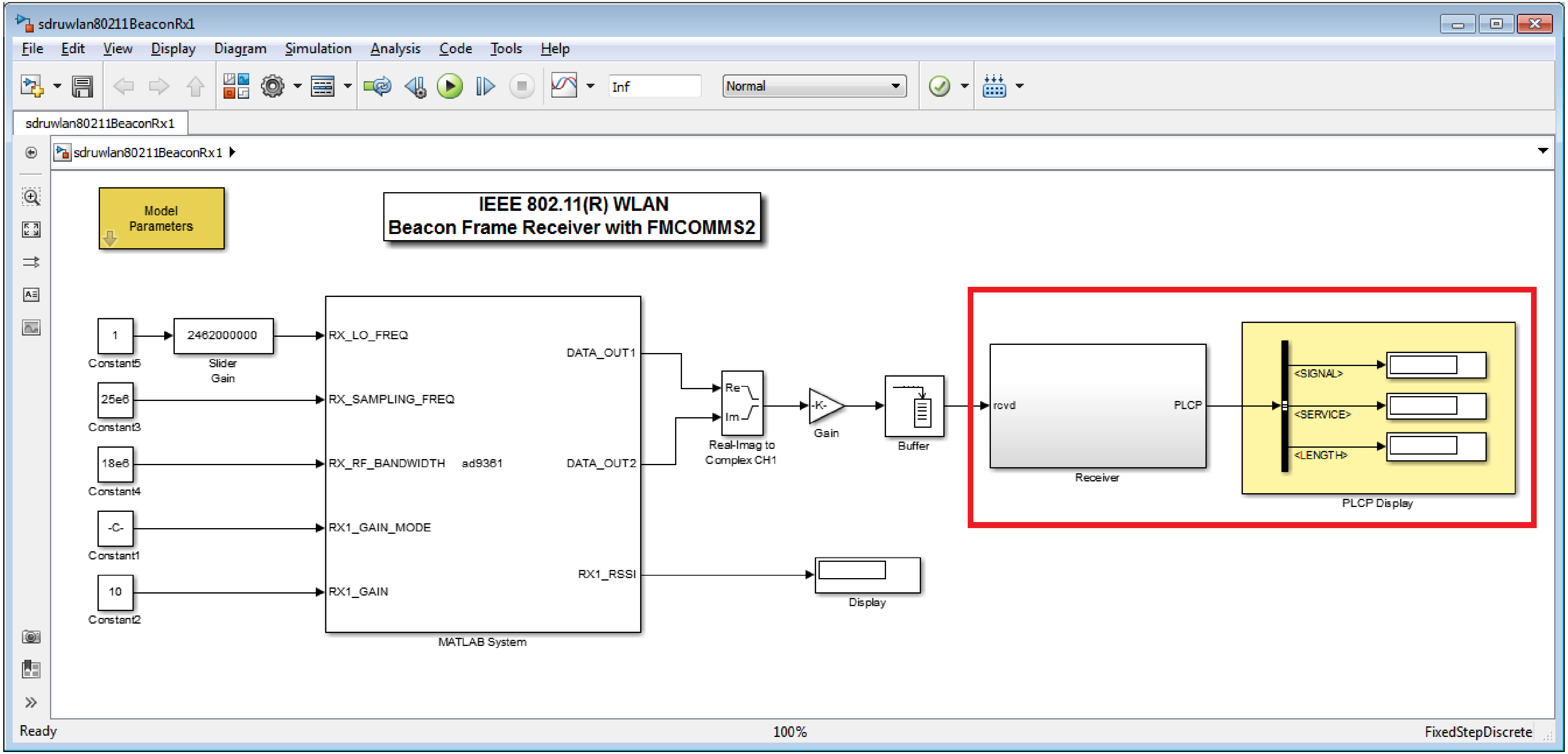

Source : https://la.mathworks.com/

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Model-Based Design

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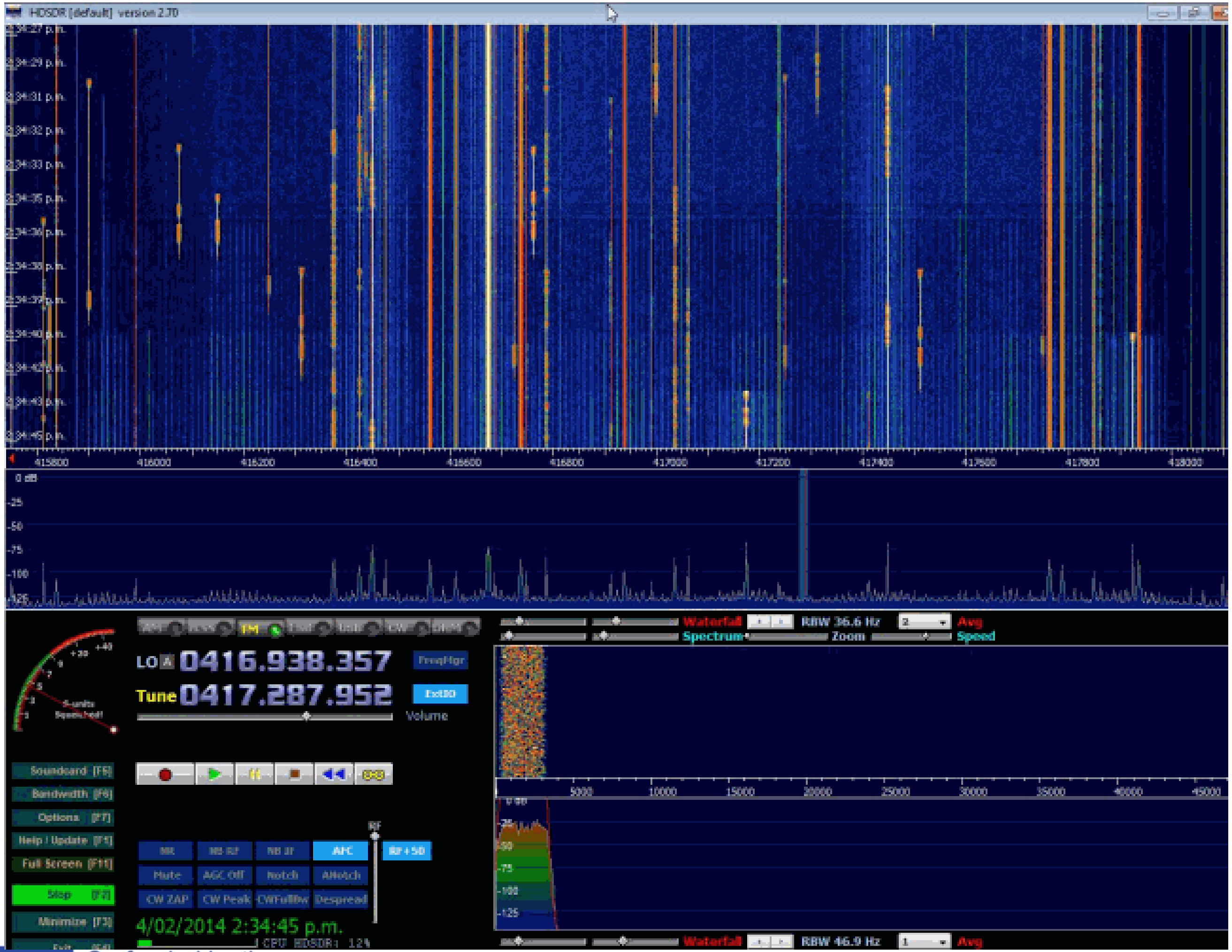
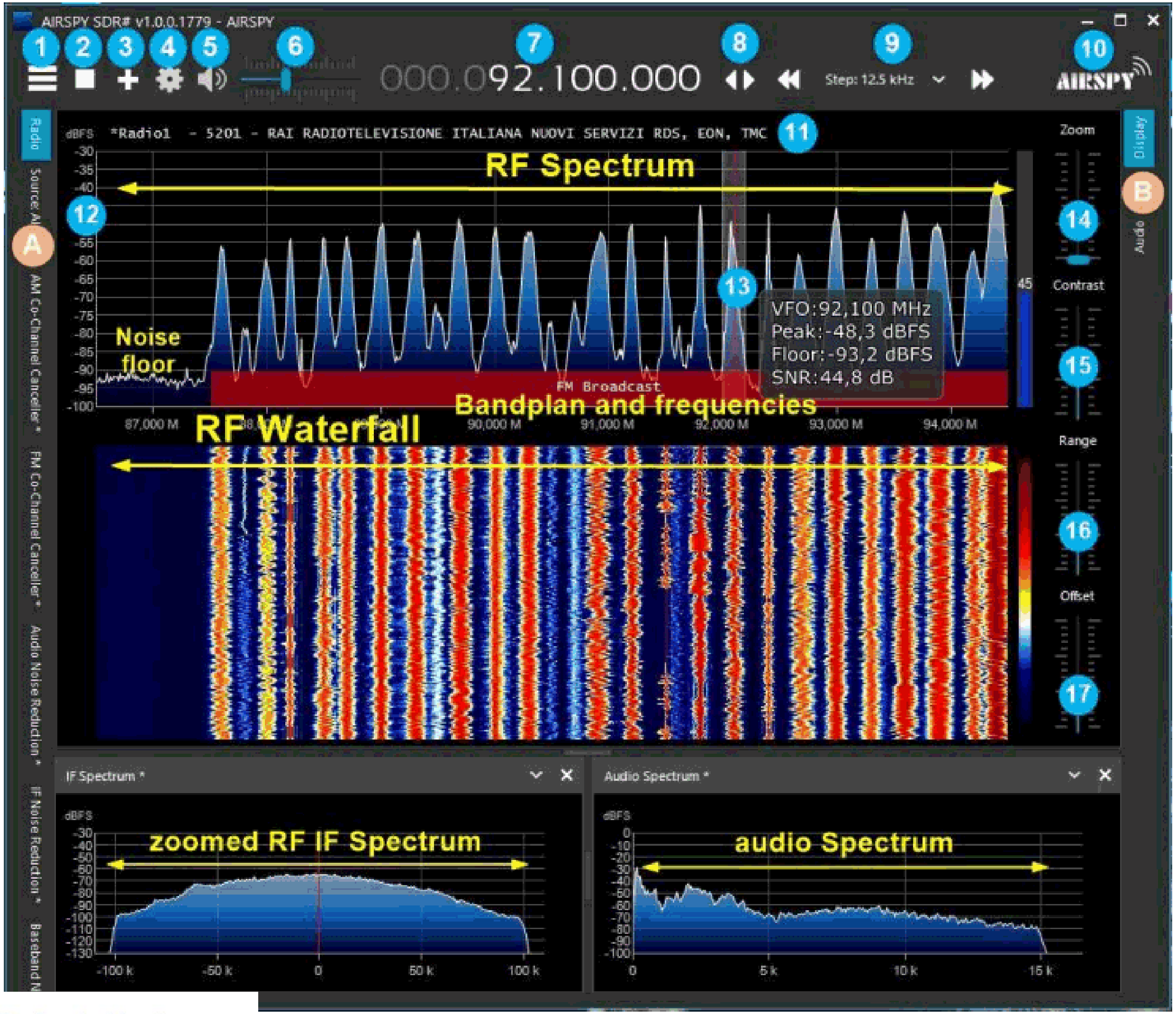
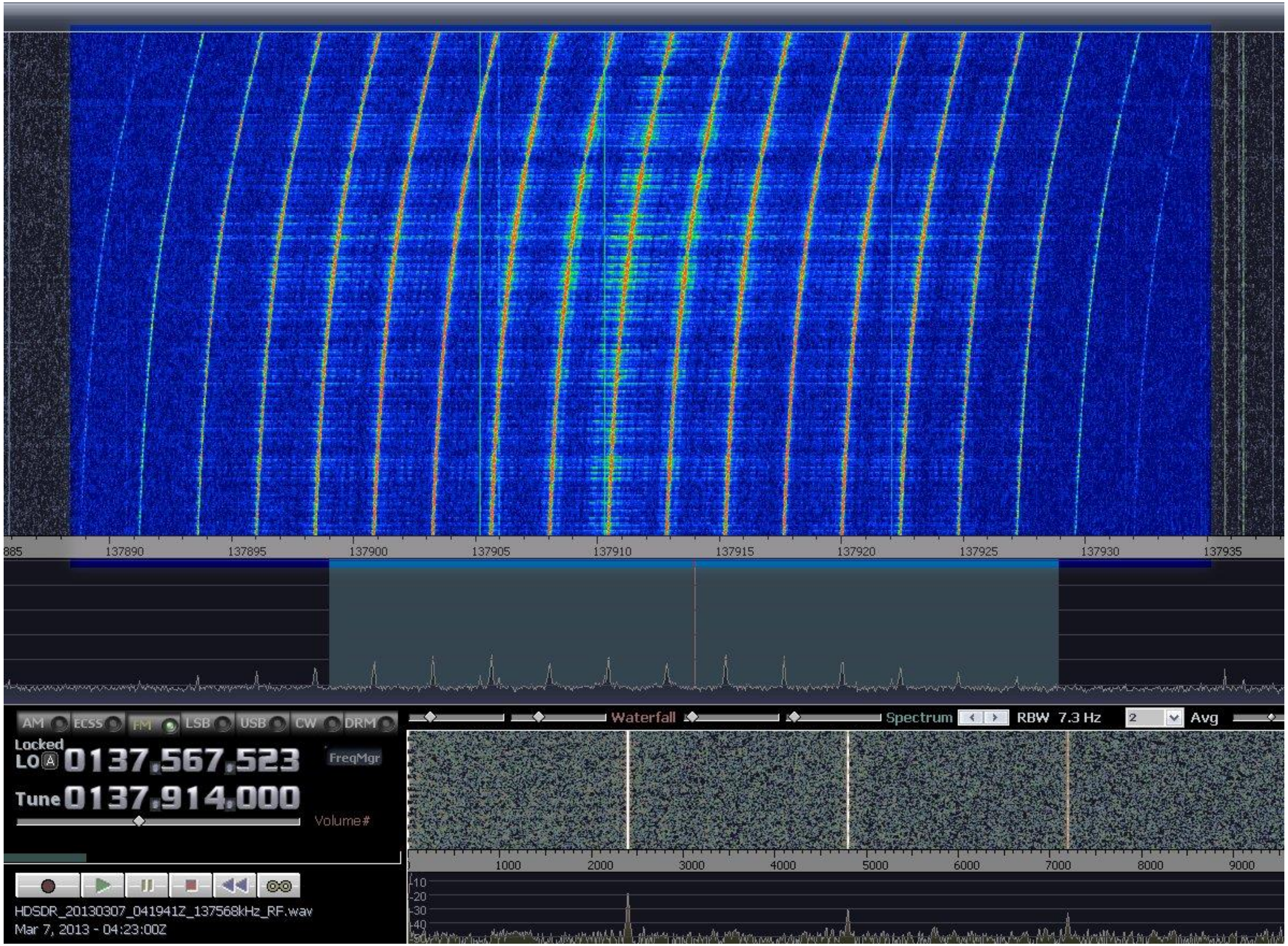
HDSDR



HDSDR [default] version 2.70
LO 0416.938.357
Tune 0417.287.952
Volume
FreqMgr
ExtIO
Waterfall
Spectrum
Zoom
Speed
Avg
RBW 36.6 Hz
RBW 46.9 Hz
Soundcard [F5]
Bandwidth [F6]
Options [F7]
Help / Update [F1]
Full Screen [F11]
Stop [F2]
Minimize [F3]
NR
NB RF
NB IF
AFC
RF+50
Mute
AGC Off
Notch
ANotch
CW ZAP
CW Peak
CWFullBw
Despread
4/02/2014 2:34:45 p.m.


AIRSPY SDR# v1.0.0.1779 - AIRSPY
000.092.100.000
Step: 12.5 kHz
AIRSPY
*Radio1 - 5201 - RAI RADIOTELEVISIONE ITALIANA NUOVI SERVIZI RDS, EON, TMC
RF Spectrum
Noise floor
VFO:92,100 MHz
Peak:-48,3 dBFS
Floor:-93,2 dBFS
SNR:44,8 dB
FM Broadcast
Bandplan and frequencies
RF Waterfall
Zoom
Contrast
Range
Offset
Radio
Display
Audio
AM Co-Channel Canceller *
FM Co-Channel Canceller *
Audio Noise Reduction *
IF Noise Reduction *
IF Spectrum *
zoomed RF IF Spectrum
Audio Spectrum *
audio Spectrum



https://www.creationfactory.co/2013/03/noaa-apt-satellite-night-time-weather.html

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Google Collab

Eye Diagram and ISI.ipynb

Archivo Editar Ver Insertar Entorno de ejecución Herramientas Ayuda Se editó por última vez: 25 de abril

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```python
#----------------- Transmitter configuration parameters -----------------

num_bits    = 2**13   # Number of transmitted bits
sps         = 8       # Samples per symbol
span        = 12      # The filter is truncated to span symbols
beta        = 1       # Excess-bandwidth parameter
sample_rate = 4e6     # Sample rate RX and TX paths[Samples/Sec]
```

```python
#----------------------------- SDR Parameter Configuration -----------------------------

Uri              = "ip:10.0.0.71"
SamplingRate     = sample_rate   # Sample rate RX and TX paths[Samples/Sec]
Loopback         = 1             # 0=Disabled, 1=Digital, 2=RF

TxLOFreq         = 910e6         # Carrier frequency of TX path [Hz]
TxAtten          = -40           # Attenuation applied to TX path, valid range is -90 to 0 dB [dB]
TxRfBw           = 2e6           # Bandwidth of front-end analog filter of TX path [Hz]

RxLOFreq         = TxLOFreq      # Carrier frequency of RX path [Hz]
GainControlModes = "slow_attack" # Receive path AGC Options: slow_attack, fast_attack, manual
RxHardwareGain   = 0             # Gain applied to RX path. Only applicable when gain_control_mode is set to 'manual'
RxRfBw           = TxRfBw        # Bandwidth of front-end analog filter of RX path [Hz]
RxBufferSize     = 2**20-1
```

```python
#------------------- Root Raised Cosine Filter Function -------------------

def rcosdesign(beta,span,sps):
    index     = np.arange(-(span*sps)/2,(span*sps)/2,1)
    Ts        = sps
    rrcFilter = np.array([])

    for n in index:
        if n == Ts/(4*beta) or n == -Ts/(4*beta):
            aux       = beta*((np.pi+2)*np.sin(np.pi/(4*beta))+(np.pi-2)*np.cos(np.pi/(4*beta)))/(np.pi*np.sqrt(2))
            rrcFilter = np.append(rrcFilter,aux)
```

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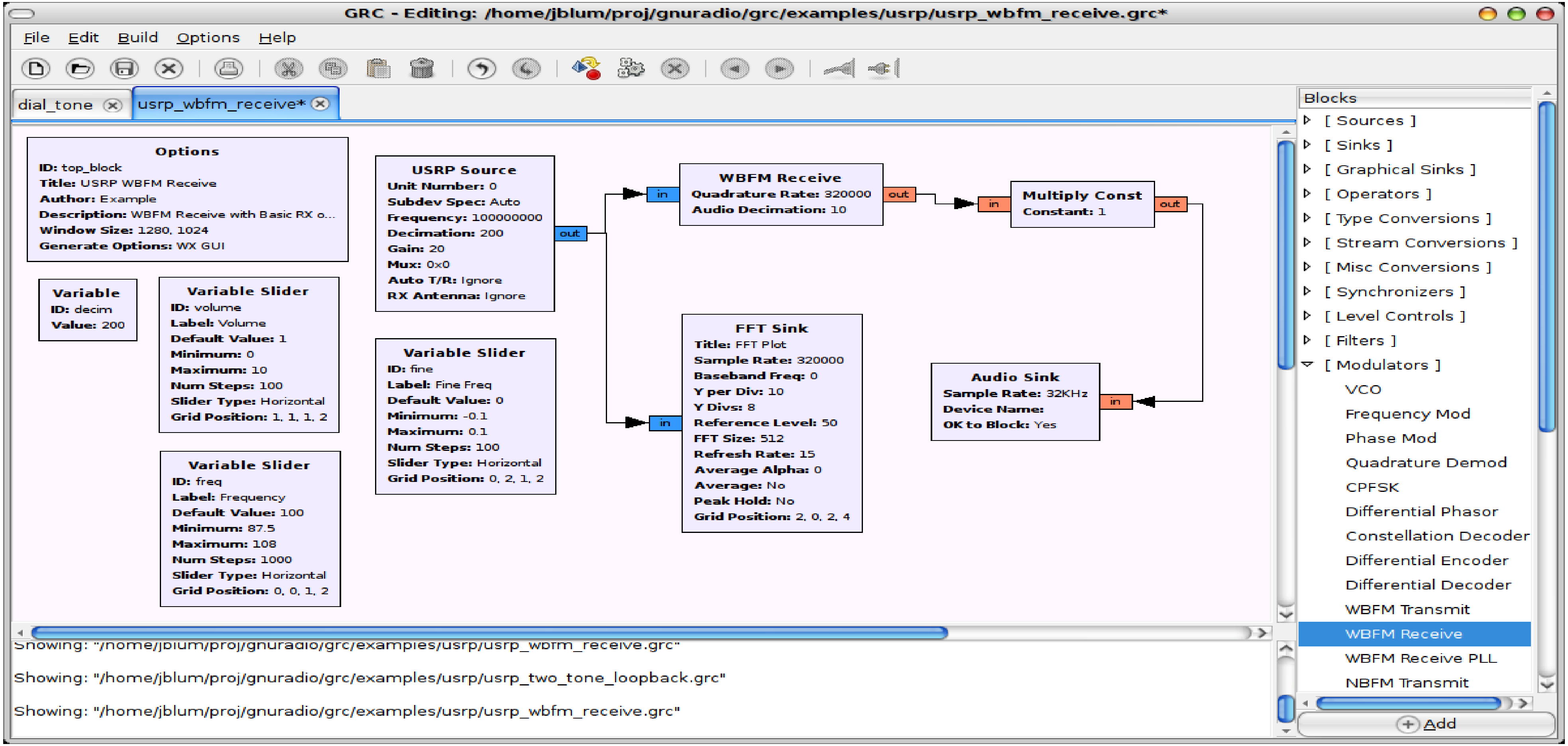
GNU RADIO



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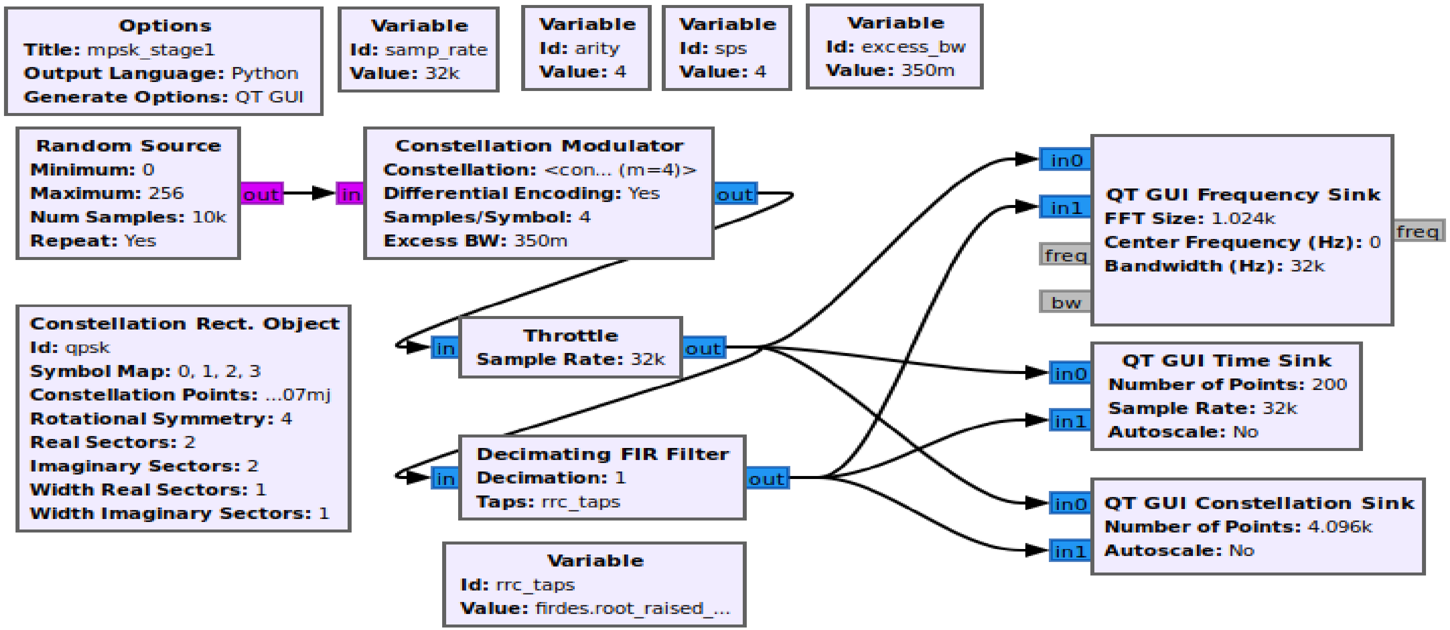
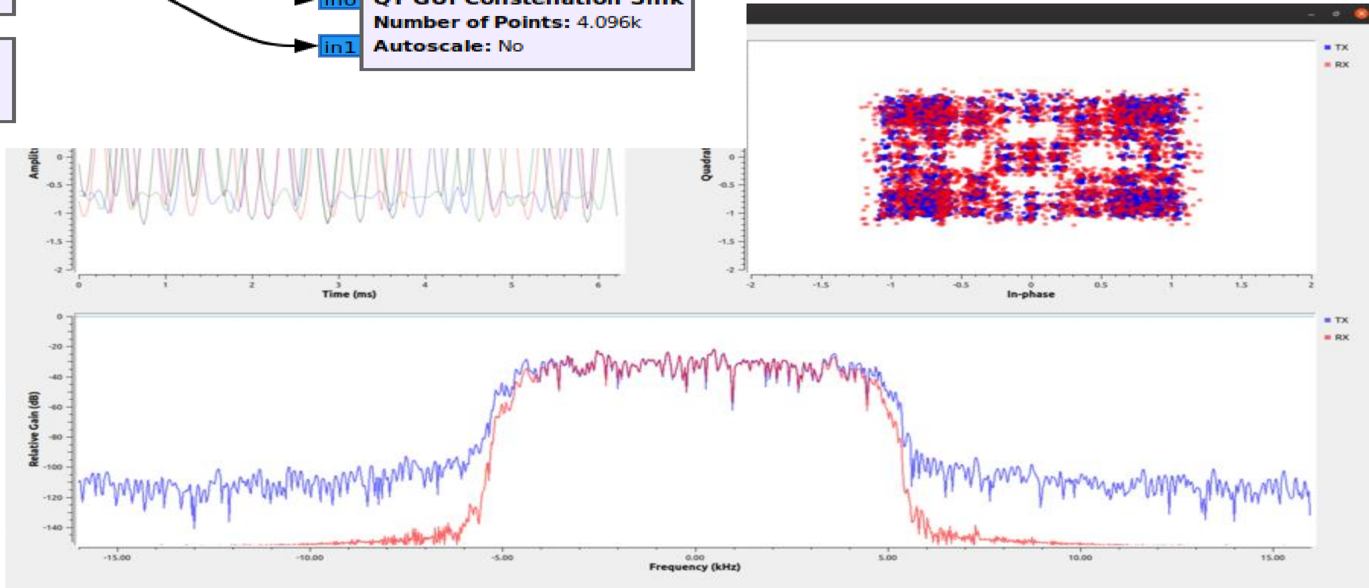
QPSK Example





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Some libraries of GNU Radio Companion

- gr-satellites
- gr-adsb
- gr-IEEE802-15-4
- gr-lora
- gr-gsm
- gr-isdtv
- gr-bluetooth
- gr-iridium
- gr-IEEE802-11

There are more in the website: https://www.cgran.org/

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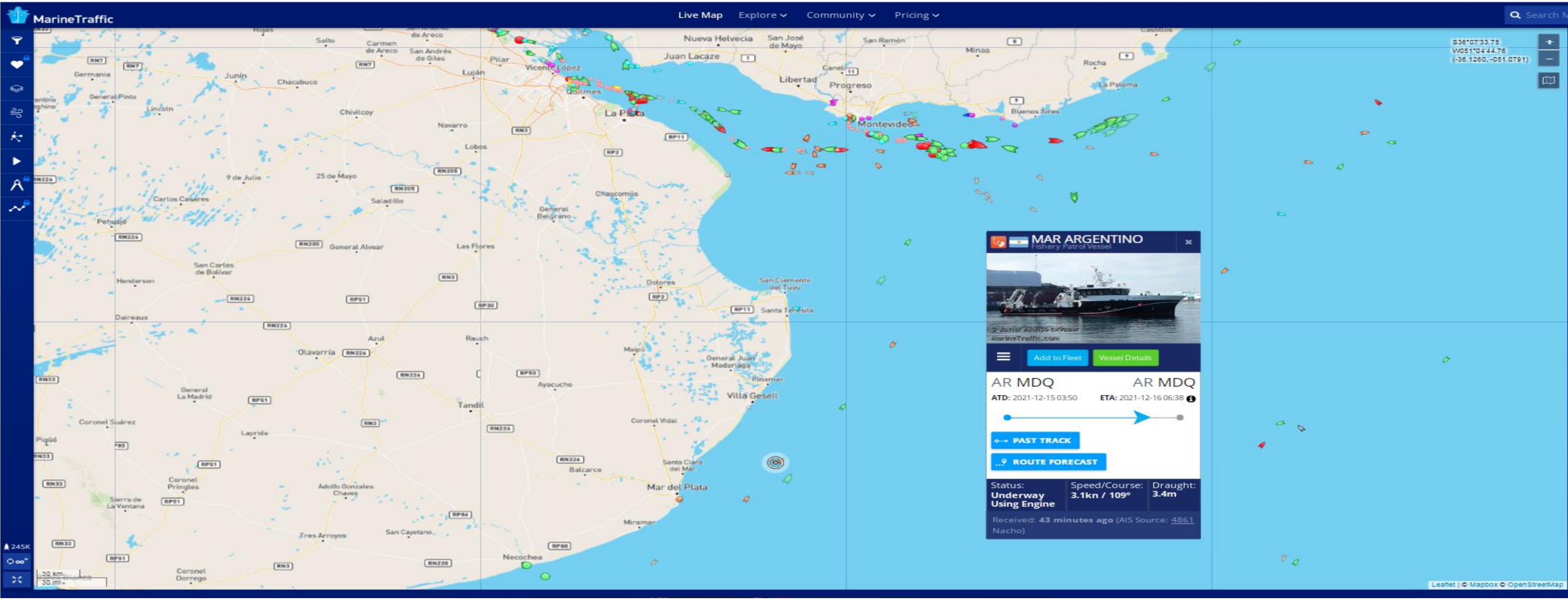
Advanced Example: AIS Receiver



Source: https://marinetraffic.com

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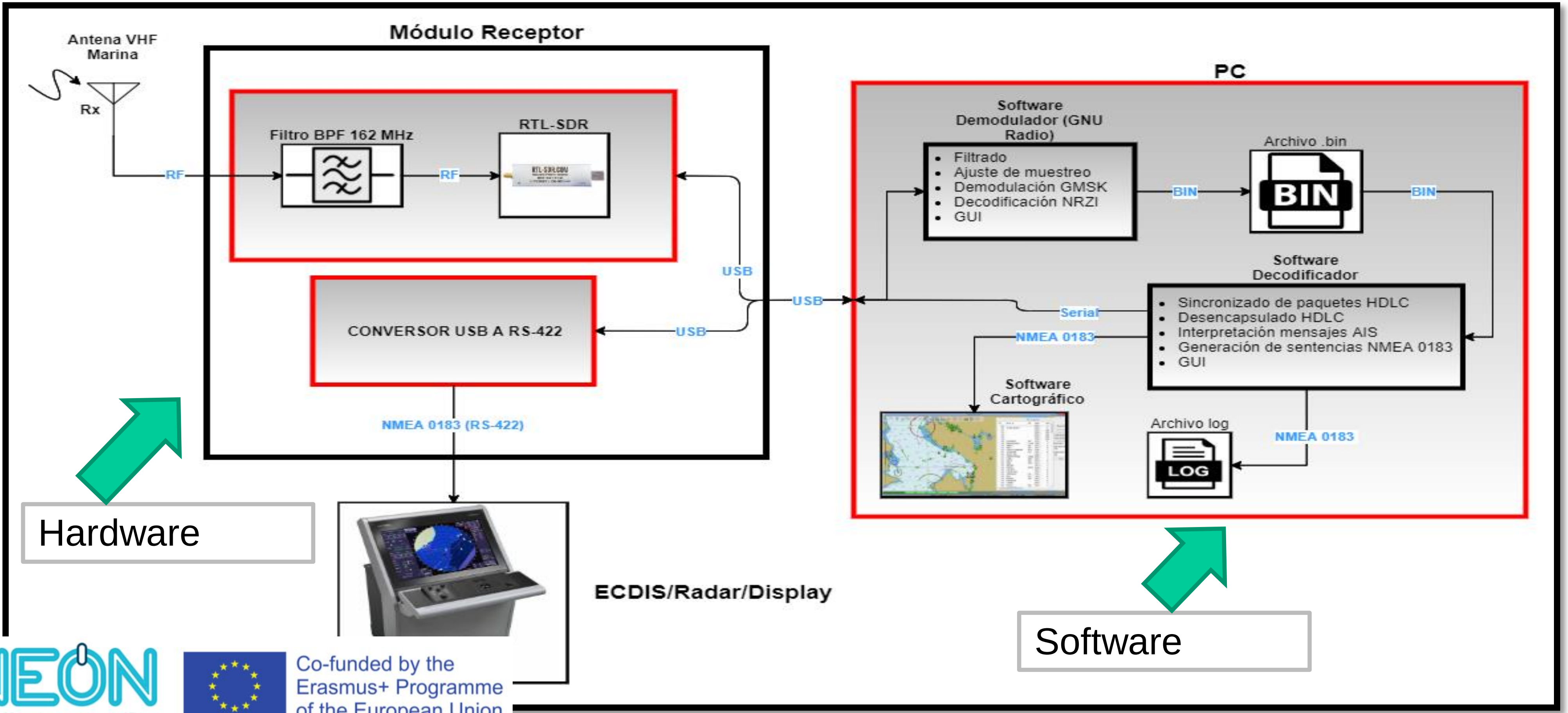
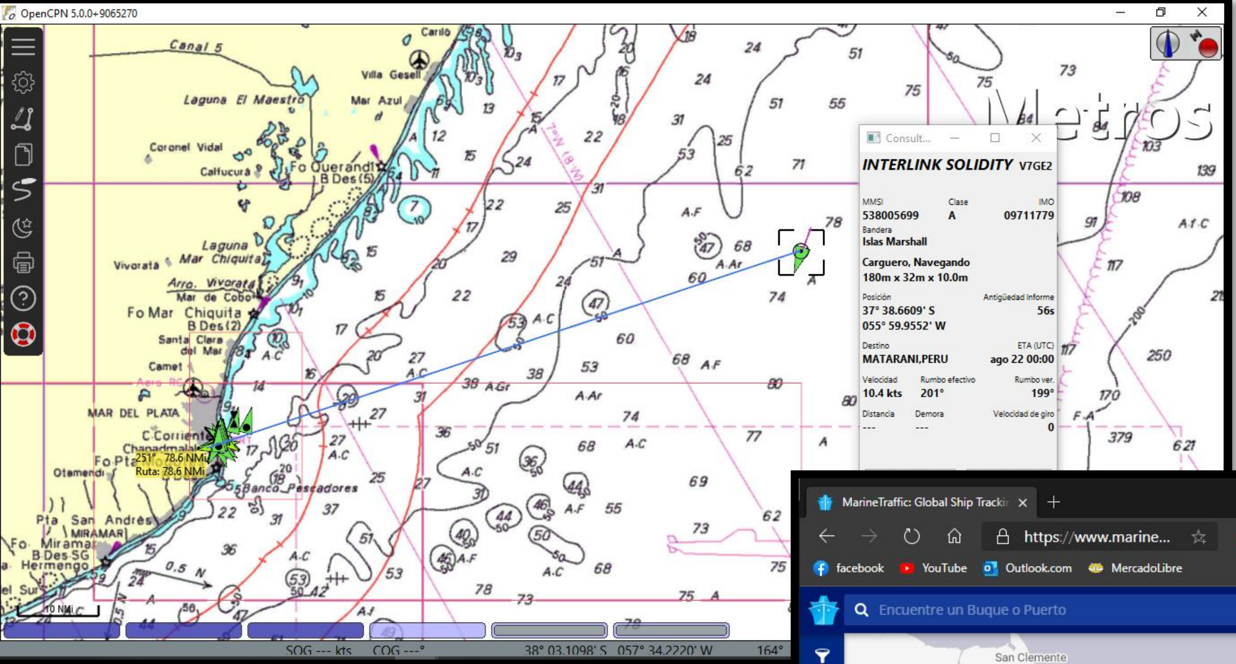
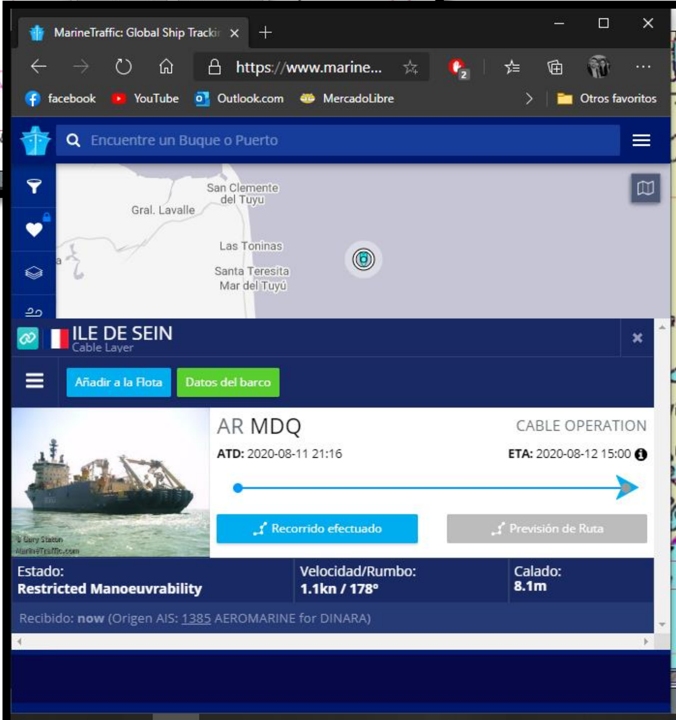
Advanced Example: AIS Receiver

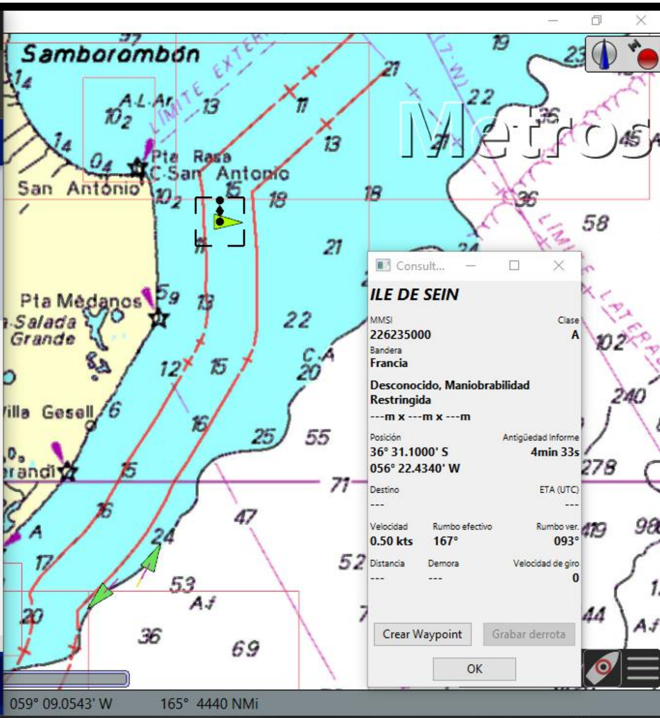
Receiver based on RTL-SDR dongle

Implemented on open software.




OpenCPN 5.0.0+9065270
Metros
Consult...
INTERLINK SOLIDITY V7GE2
MMSI 538005699
Clase A
IMO 09711779
Bandera Islas Marshall
Carguero, Navegando
180m x 32m x 10.0m
Posición 37° 38.6609' S 055° 59.9552' W
Antigüedad Informe 56s
Destino MATARANI,PERU
ETA (UTC) ago 22 00:00
Velocidad 10.4 kts
Rumbo efectivo 201°
Rumbo ver. 199°
Distancia ---
Demora ---
Velocidad de giro 0
MAR DEL PLATA
Laguna El Maestro
Coronel Vidal
Laguna Mar Chiquita
Villa Gesell
Banco Pescadores
251° 78.6 NMi
Ruta: 78.6 NMi
10 NMi
SOG --- kts
COG ---°
38° 03.1098' S 057° 34.2220' W
164°


MarineTraffic: Global Ship Trackin
https://www.marine...
facebook
YouTube
Outlook.com
MercadoLibre
Otros favoritos
Encuentre un Buque o Puerto
San Clemente del Tuyu
Gral. Lavalle
Las Toninas
Santa Teresita
Mar del Tuyú
ILE DE SEIN
Cable Layer
Añadir a la Flota
Datos del barco
AR MDQ
CABLE OPERATION
ATD: 2020-08-11 21:16
ETA: 2020-08-12 15:00
Recorrido efectuado
Previsión de Ruta
Estado: Restricted Manoeuvrability
Velocidad/Rumbo: 1.1kn / 178°
Calado: 8.1m
Recibido: now (Origen AIS: 1385 AEROMARINE for DINARA)

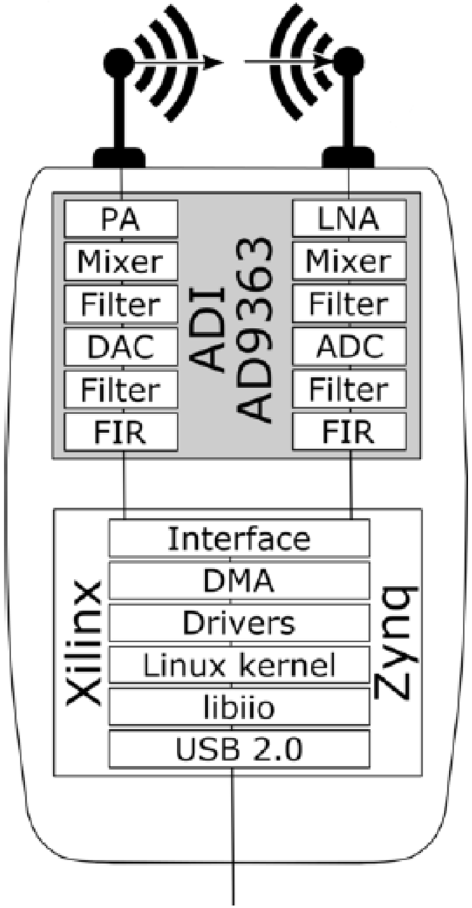

Samborombón
Metros
San Antonio
Pta Rasa
C.San Antonio
Pta Médanos
Salada Grande
Villa Gesell
Consult...
ILE DE SEIN
MMSI 226235000
Clase A
Bandera Francia
Desconocido, Maniobrabilidad Restringida
---m x ---m x ---m
Posición 36° 31.1000' S 056° 22.4340' W
Antigüedad Informe 4min 33s
Destino ---
ETA (UTC) ---
Velocidad 0.50 kts
Rumbo efectivo 167°
Rumbo ver. 093°
Distancia ---
Demora ---
Velocidad de giro 0
Crear Waypoint
Grabar derrota
OK
059° 09.0543' W
165° 4440 NMi

ADALM PLUTO

- **Full duplex / Half duplex.**
- **325MHz - 3,8GHz (extendible a 60MHz - 6GHz)**
- **ADC/DAC Sample Rate 65.2 kSPS to 61.44 MSPS**
- **ADC/DAC Resolution 12 bits**
- **Frequency Accuracy ±25 ppm**
- **RBW= 20MHz max (It cen be limited to 5MHz).**
- **50 Ohms Input.**

https://media.digikey.com/pdf/Data%20Sheets/Analog%20Devices%20PDFs/ADALM-PLUTO_Prod_Highlight.pdf

ADALM PLUTO



- Runs Linux inside the device
- Uses Linux's IIO framework to expose I/Q data and control
- Multi-Function Device
  - Native IIO over USB
  - Serial over USB
  - Ethernet over USB
  - Mass Storage
  - Device Firmware Update
- Host
  - USB dongles

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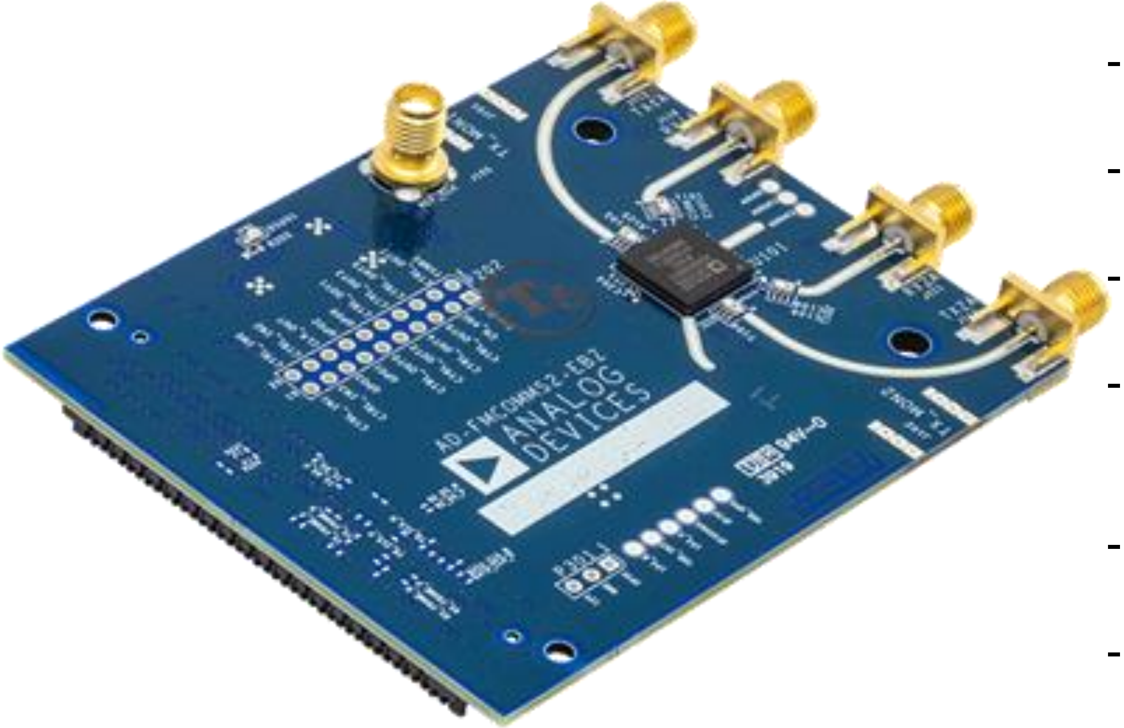
FSCOMMS4



- **Two outputs and two inputs full duplex**
- Frecuency range: 70 MHz – 6,0 GHz
- **RBW=** <200 kHz to 56 MHz
- **12 bits resolution**
- **Superior receiver sensitivity with a noise figure < 2.5 dB**
- **RX gain control**
- **Real-time monitor and control signals for manual gain**
- **Independent automatic gain control**

https://www.analog.com/en/products/ad9364.html#product-overview

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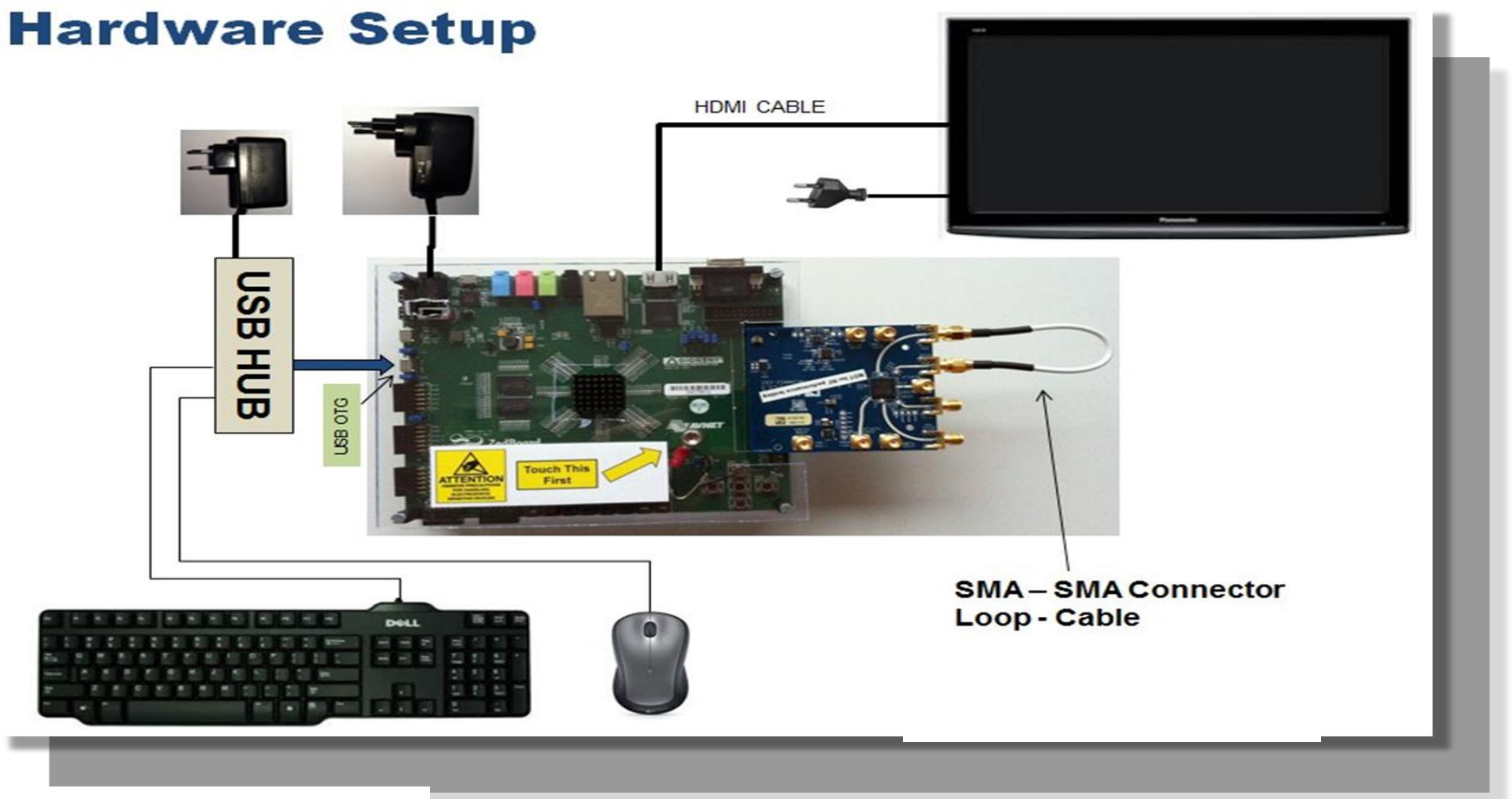
FSCOMMS2 + Zedboard

SDR platform: Xilinx Zedboard + Analog Devices FSCOMMS4 (60MHz - 6GHz)



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RTL2832U

- **Only receiver.**
- **Frequency range: 35MHz - 1,8GHz**
- **RBW=**
- **8 bits resolution.**

- Aluminum covering.

- Input impedance: 50 Ohms or 75 Ohms.

- <1 PPM temperature compensated oscillator (TCX)

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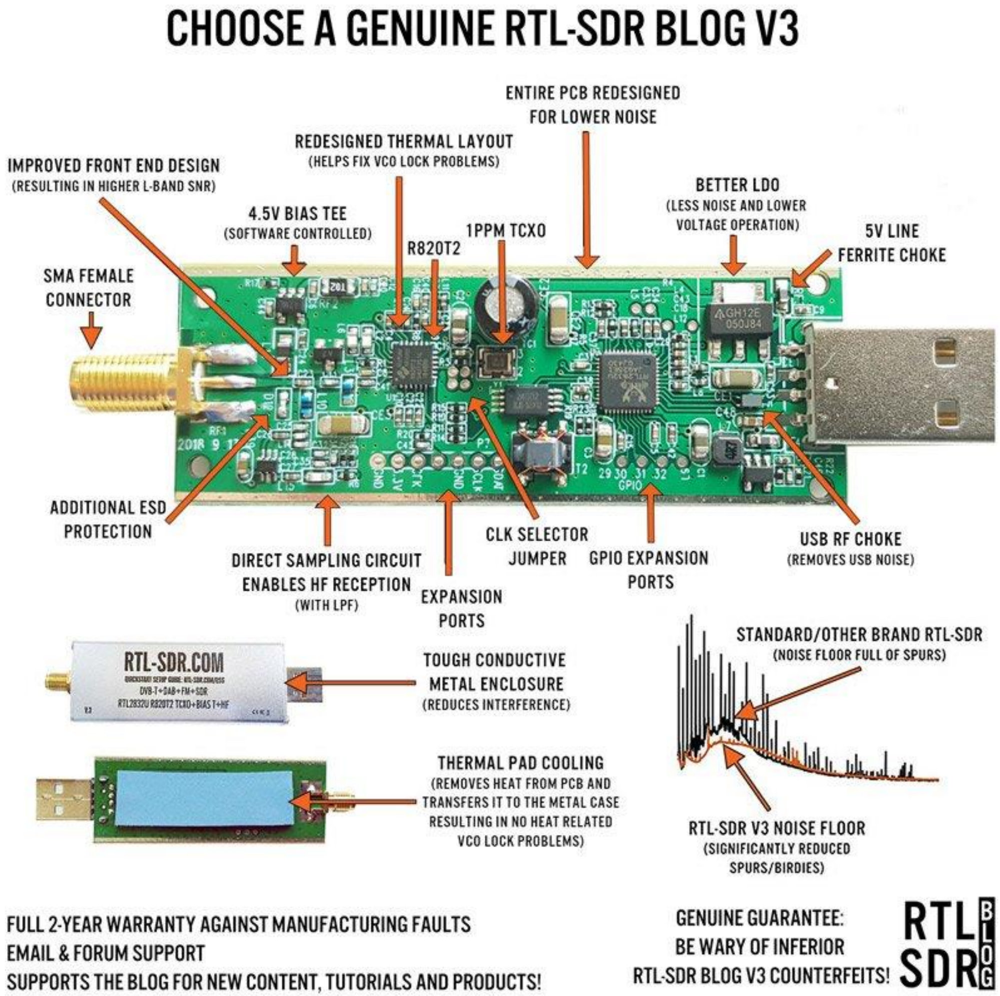
https://www.rtl-sdr.com/

RTL2832U

https://www.rtl-sdr.com/



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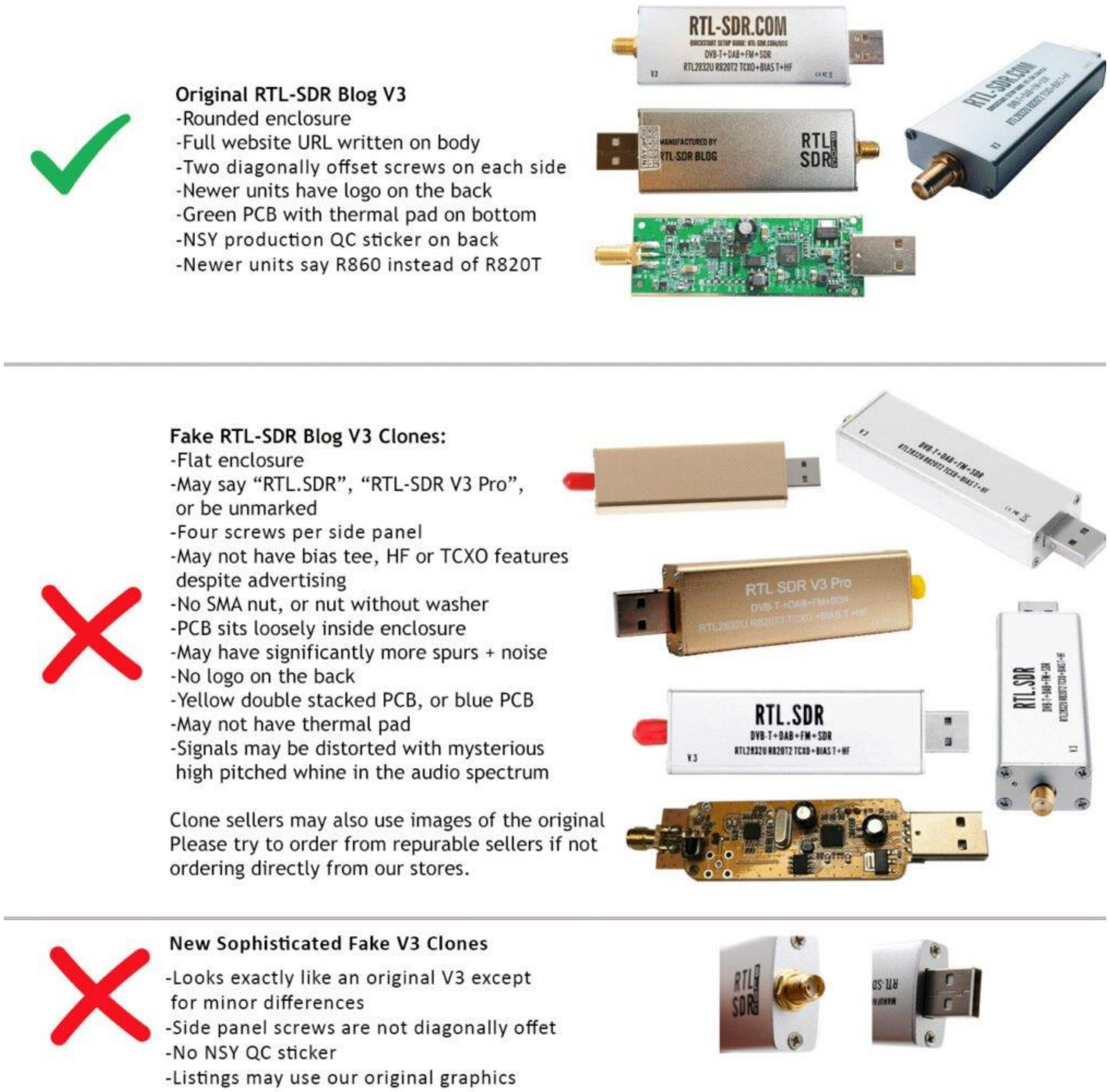

https://www.rtl-sdr.com/

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Hack RF ONE

- 1 MHz to 6 GHz operating frequency

- Half-duplex transceiver

- Up to 20 million samples per second

- 8-bit quadrature samples (8-bit I and 8-bit Q)

- SMA female antenna connector

- SMA female clock input and output for synchronization

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Relevant specifications

- Frequency range.
- receiver, half-duplex or full-duplex.
- Real band-width (RBW).
- ADC/DAC bits resolution.
- RF connectors.
- Covering.

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