Messen und Funken mit GNU-Radio und Pluto

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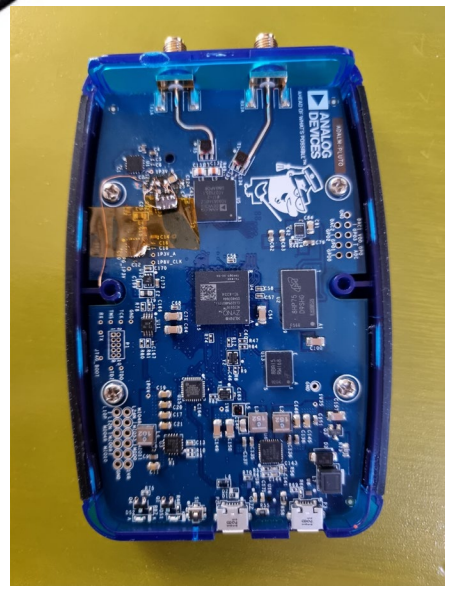
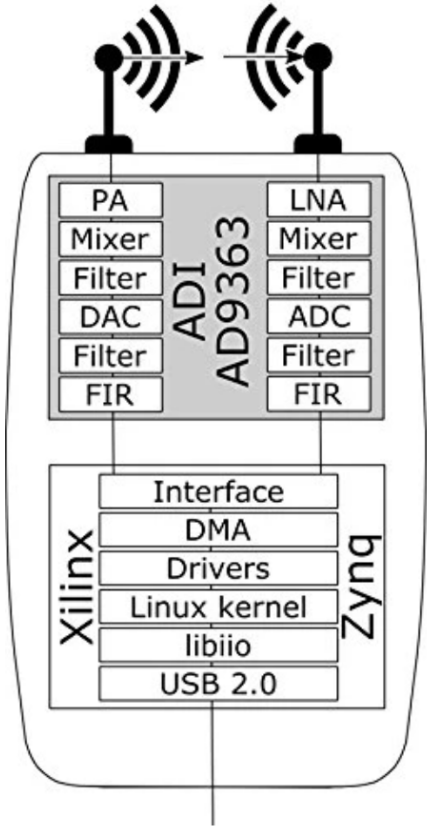
Institut für Elektrotechnik

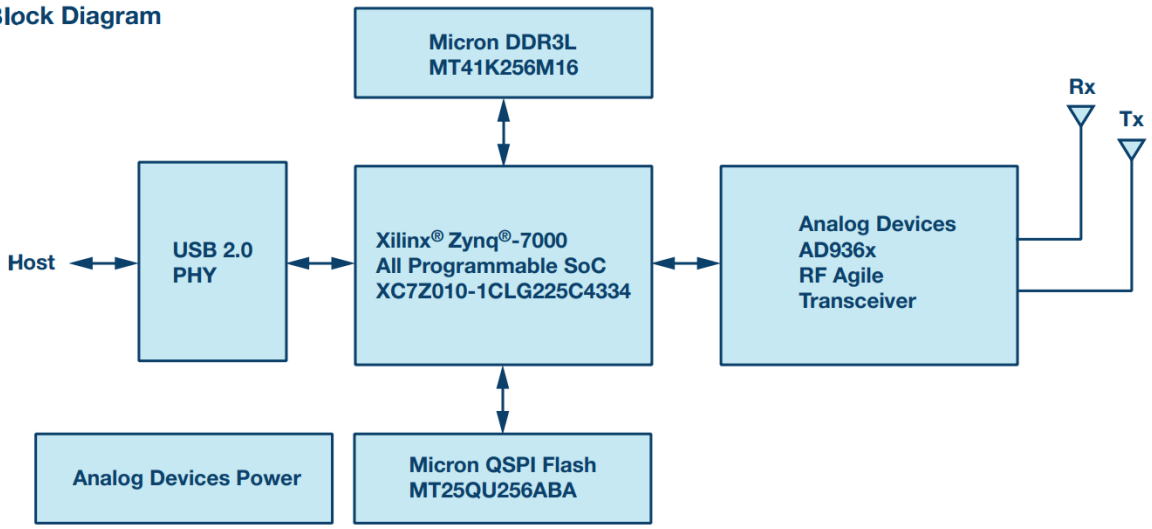
FFHS
Fernfachhochschule Schweiz
Mitglied der SUPSI

V 1.1

Was ist "Pluto" ?







ADALM-PLUTO =
Active Learning Module
& Education Tool

Was ist "GNU-Radio" ?

- GNU Radio ist ein freies **Programmierwerkzeug** für die Implementierung von Software Defined Radio (SDR), oder allgemeiner **Signalverarbeitung**.

- Möglichkeiten:
  - Beliebige digitale Modulations- und Demodulationsverfahren
  - Verfahren zur Manipulation von Signalen wie digitale Filter
  - verschiedene Anzeigen wie Darstellungen als Zeitsignal oder als Frequenzspektrum, Leistungsdichten und Konstellationsdiagramme
  - Ansteuern von Hardware
  - Grosse vorgefertigte Bibliothek an Baublöcken

Was wir heute neu kennen lernen:
Neue Technologien

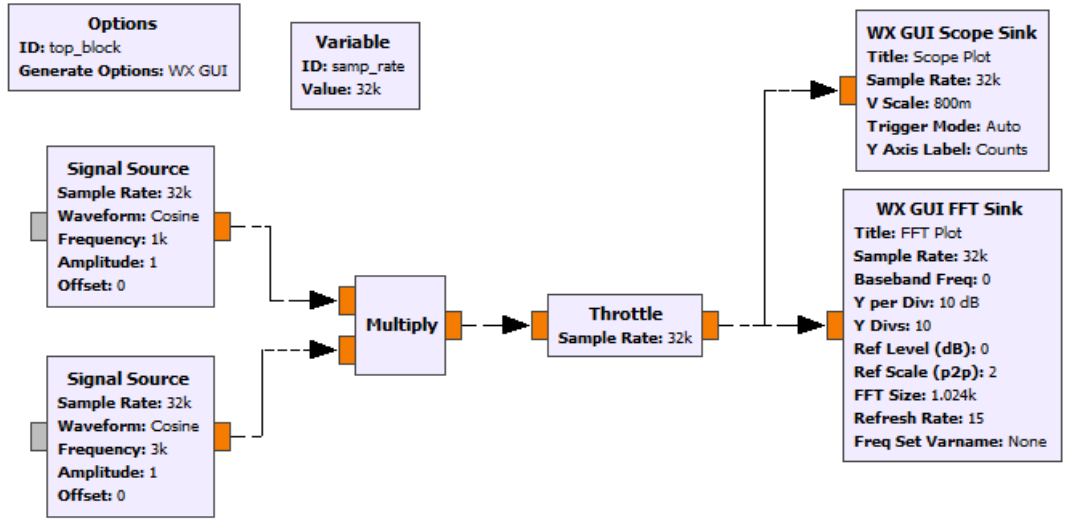
- Was ist die Kombination GNU + Pluto nicht:
  - Pre-Amplifier
  - Power Amplifier (0 dBm, 1 mW)
  - Eingangsfilter (breitbandig!)
  - Oberwellenfilter (oberwellenreich)

Aber: das sind ohnehin Kernkompetenzen eines Funkamateurs

"Die Zeiten ändern sich und wir ändern uns in ihnen." (Ovid)

Vorgestern

Heute



$$\cos\alpha \cdot \cos\beta = 1/2 \cdot \cos(\alpha + \beta) + 1/2 \cdot \cos(\alpha - \beta)$$

Adalm Pluto oder

Lime SDR

USRP B200 Oder …

Lernziele

Hauptziel:
Motivieren, wieder zu basteln, aber mit modernen Technologien.

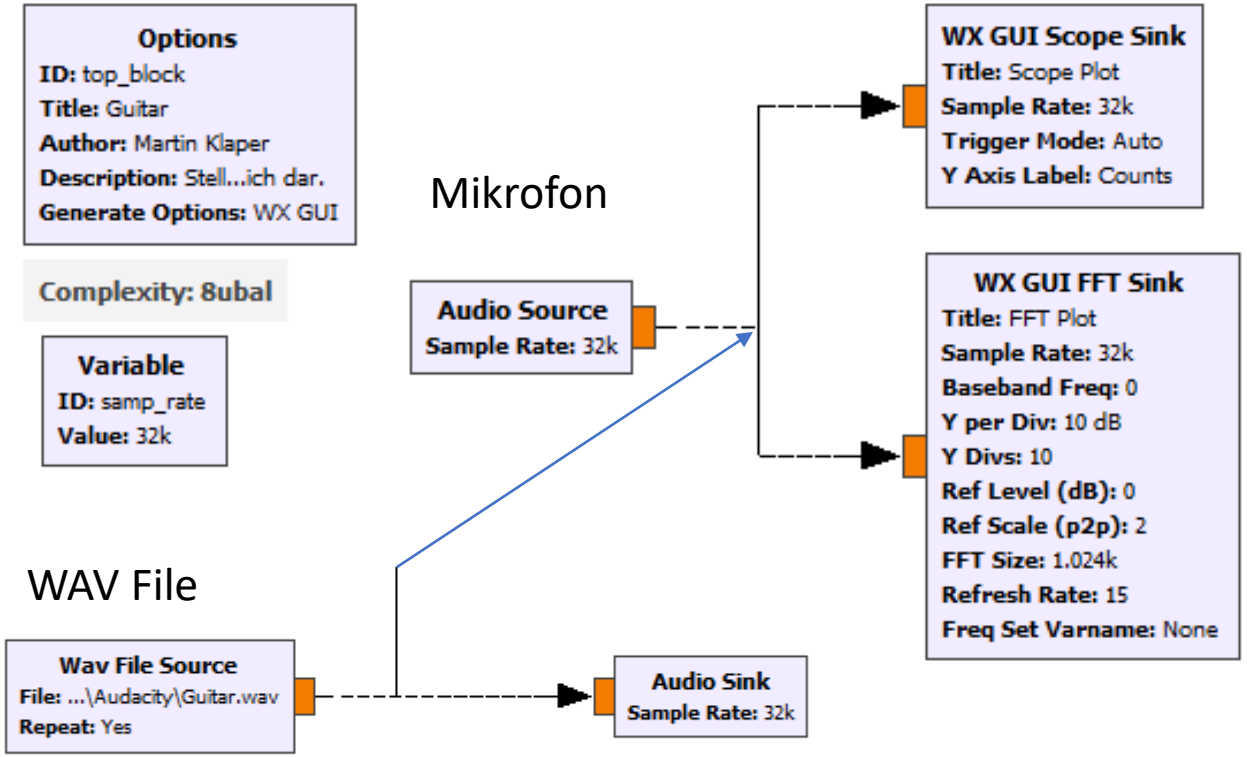
- **Spektrum Analysator** mit GNU Radio erstellen und anwenden.
- Einen "fertigen" Spektrum Analysator mit Pluto einsetzen können.
- SSB Signal mit GNU Radio erzeugen.
- SSB Sender mit GNU Radio und Pluto bauen.
- SSB Empfänger mit GNU Radio und Pluto bauen.
- Einen QO-100 Transceiver mit GNU Radio und Pluto bauen.
- Narrow-band FM Transceiver bauen.

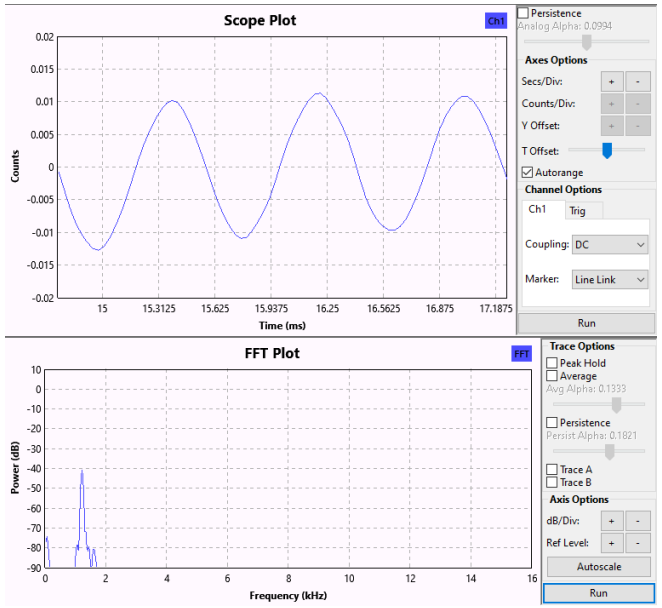
Inhalt

- Messen mit GNU Radio und Pluto
- Oszillograph
- Spektrum Analysator
- Signal Generator
- FM und SSB Tx und Rx
- QO-100 Ground Stations

Wer spielt ein Musikinstrument ?

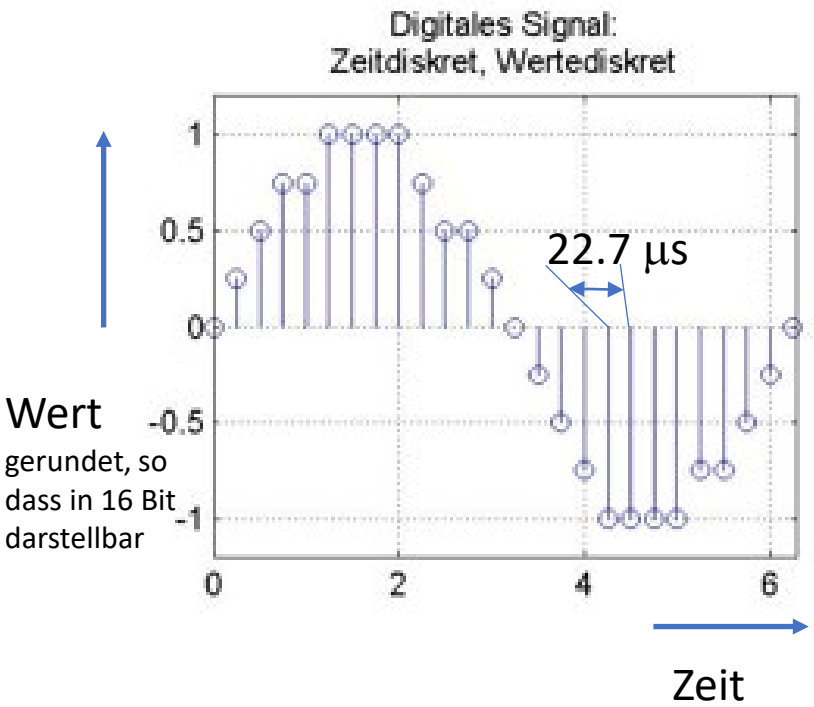
- Hast Du die Obertöne schon mal angesehen?
  In wenigen Schritten geht das mit GNU.

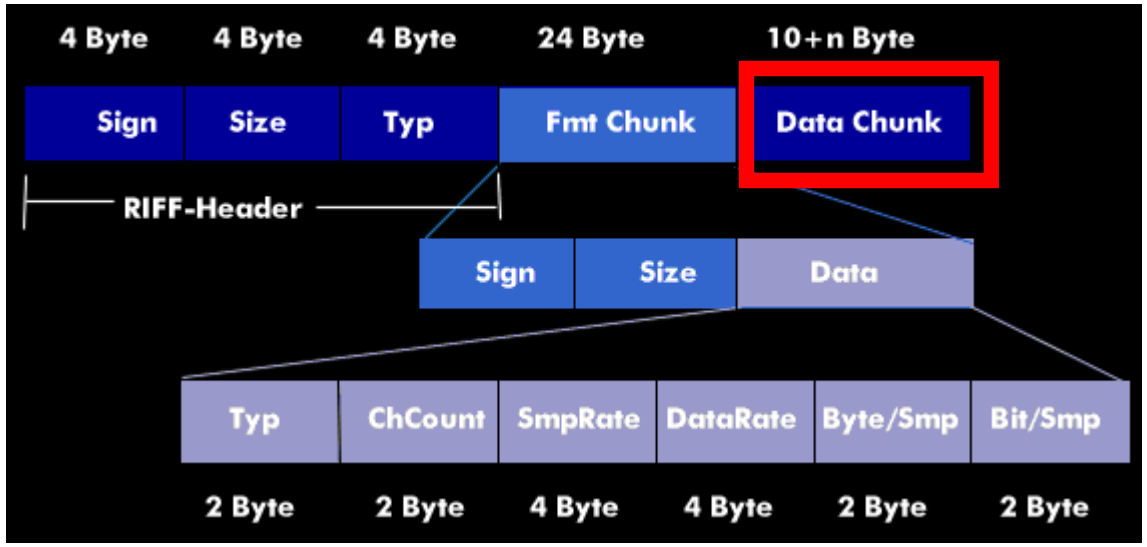


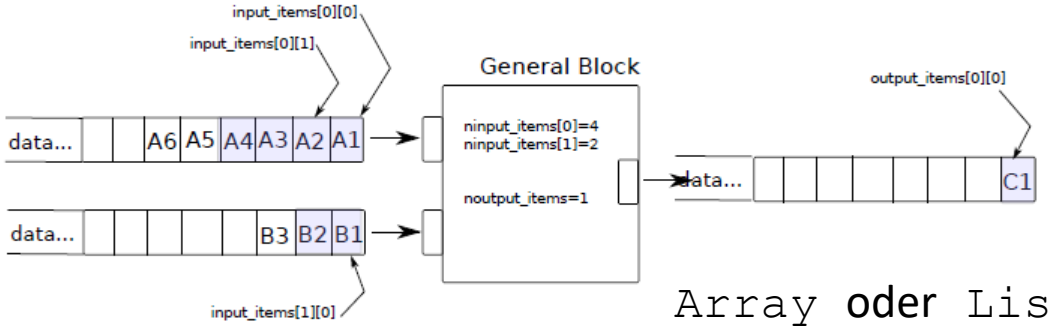


Pfeifen ins Mikrofon

Was steckt im WAV File?







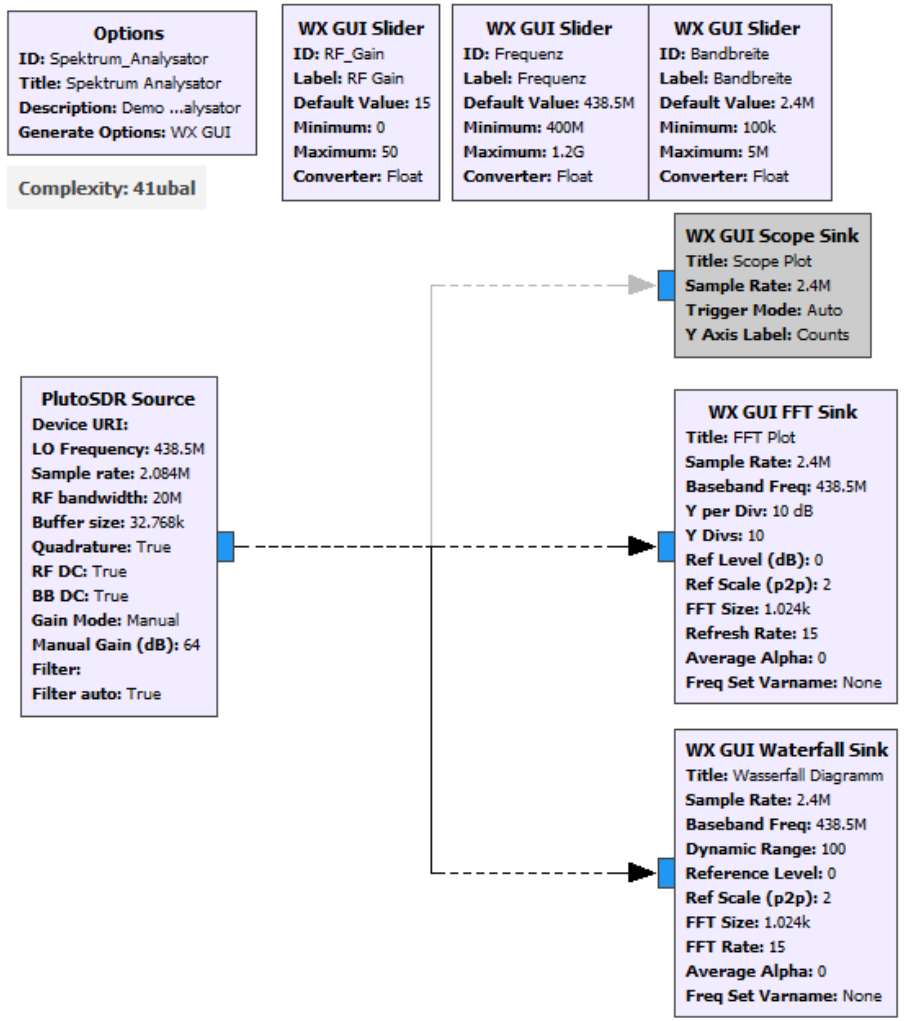
`Array` oder `Liste`

File Name	Guitar.wav
File Size	1518 KiB
File Type	WAV
File Type Extension	wav
Num Channels	2
Sample Rate	44100
Avg Bytes Per Sec	176400
Bits Per Sample	16
Time Base	1/44100

-> 22.7 µs

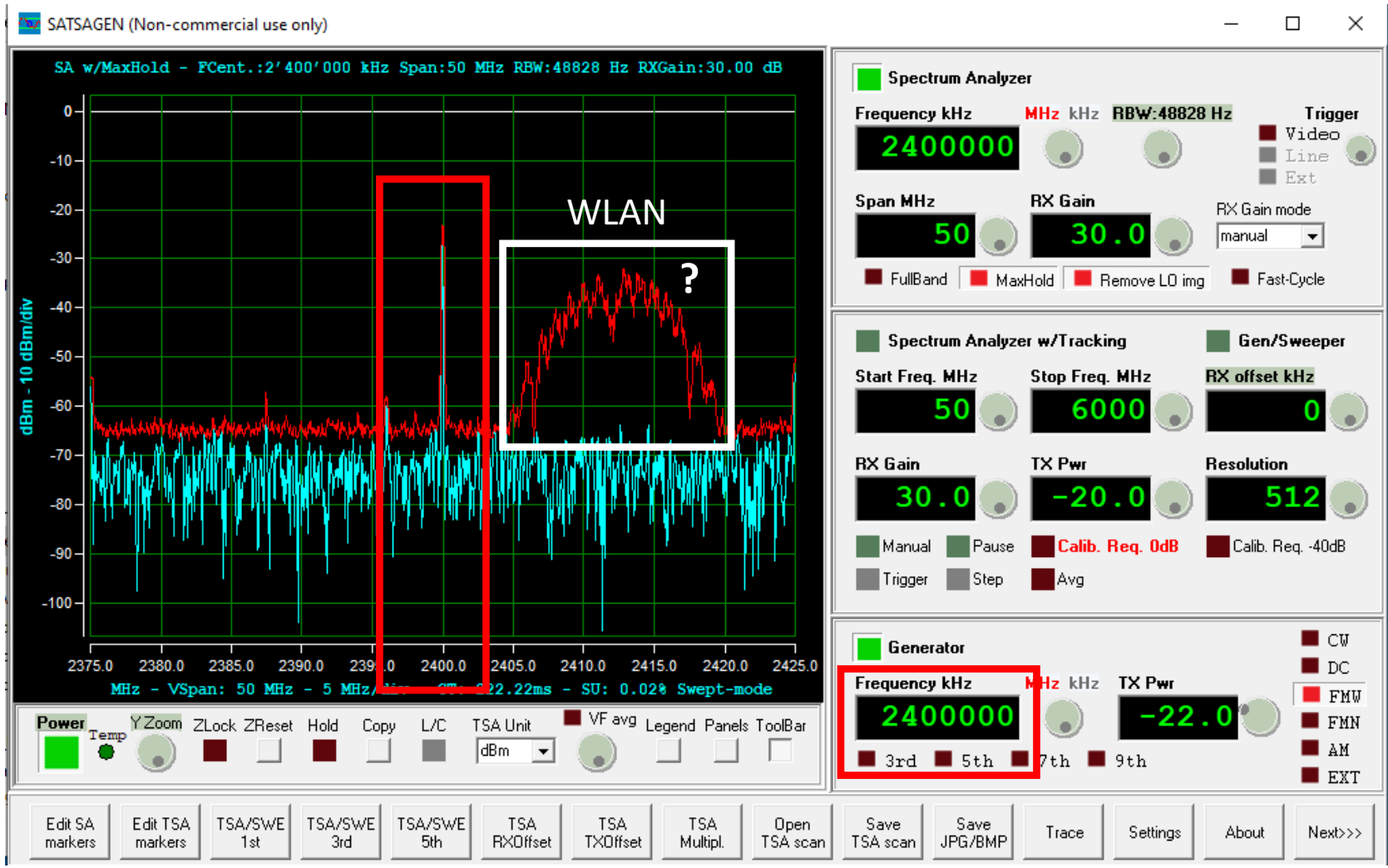
Ein "richtiger" (HF) Spektrumanalysator

DUT



Nicht GNU, aber Pluto: SATSAGEN

http://www.albfer.com/satsagen-download-page/#content

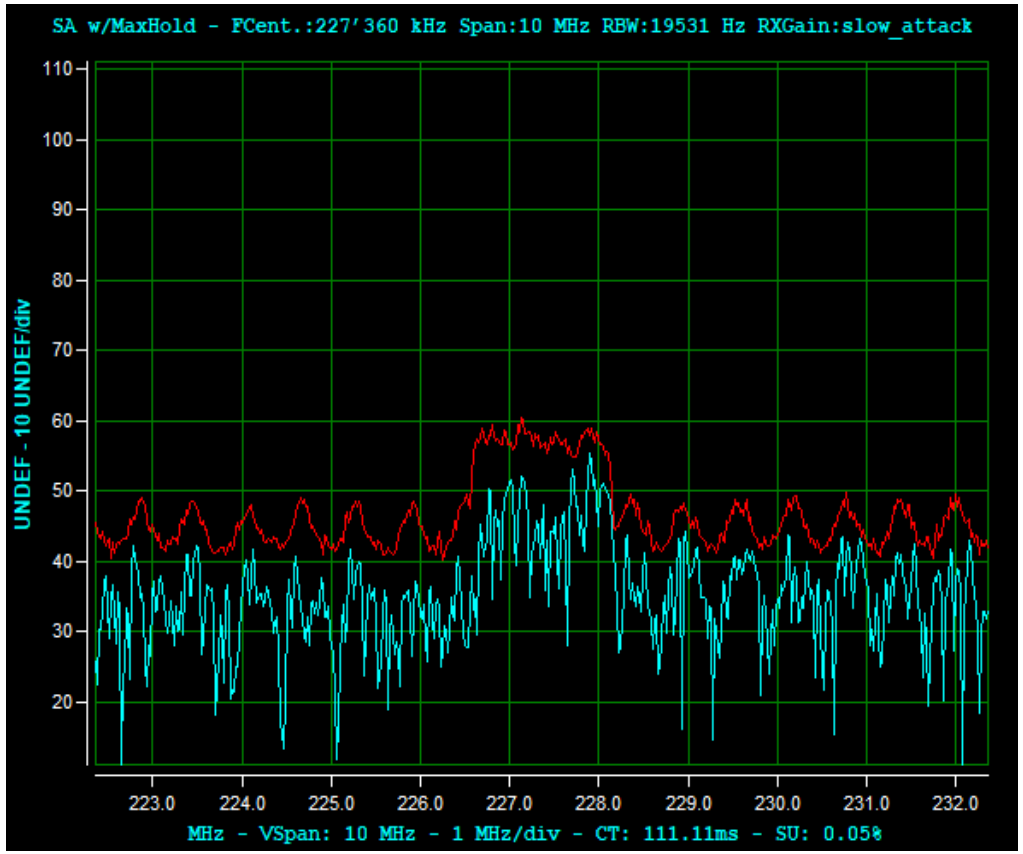


← Spektrum Analysator

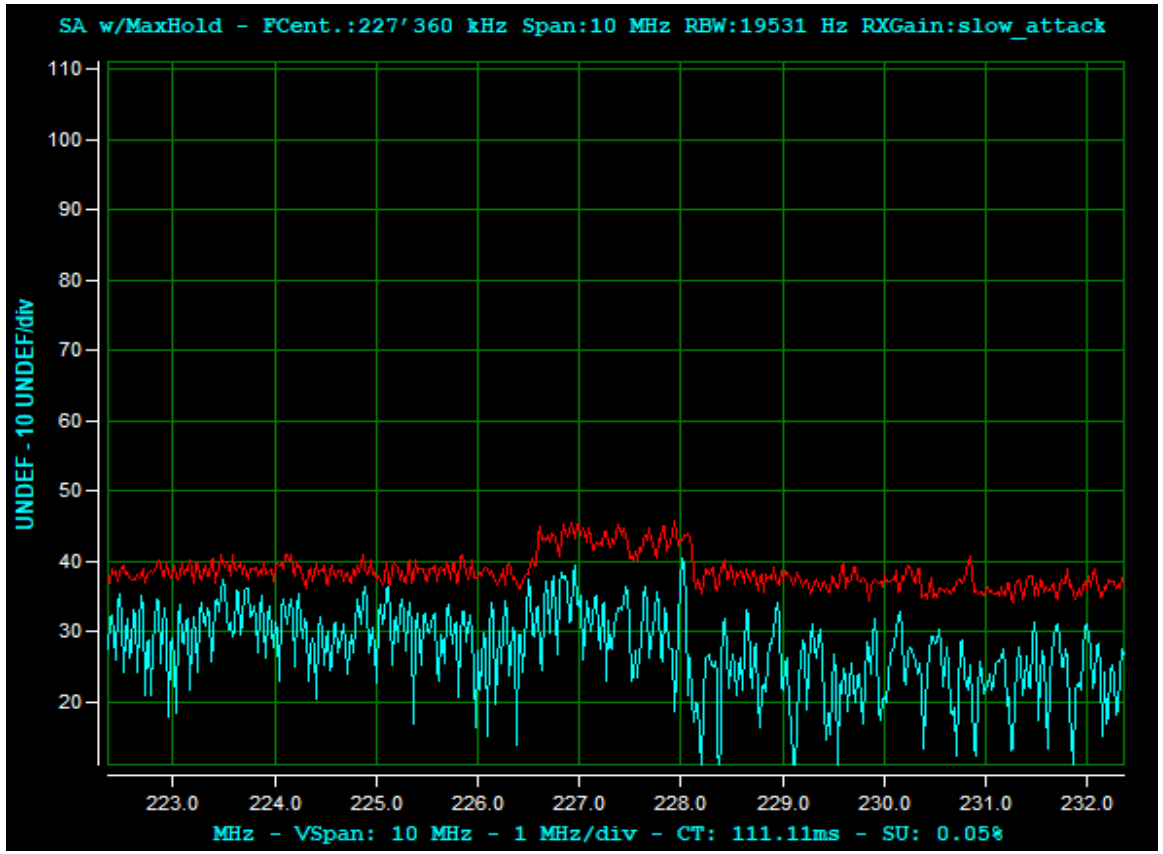
← Signalgenerator

Einsatz für DAB+ und LED-Lampen Störung

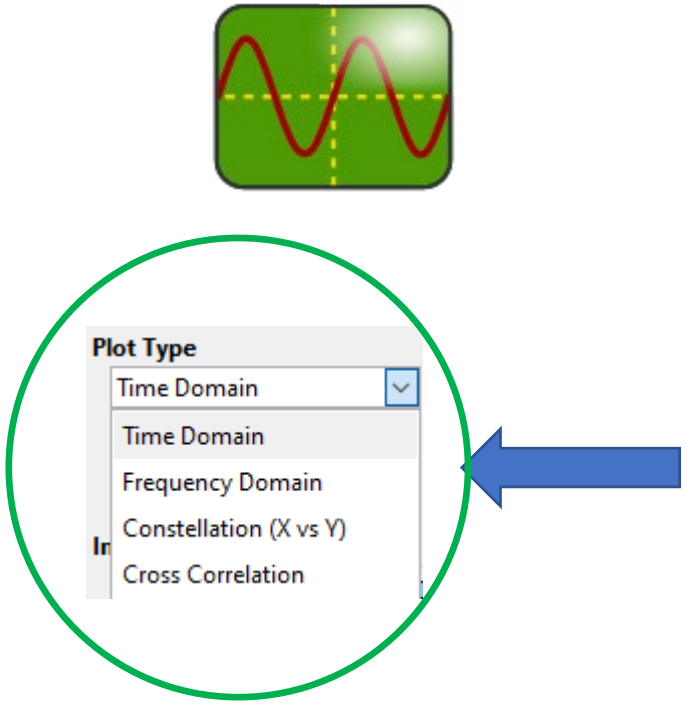
Lampe ausgeschaltet, Radio Empfang OK.
227.360 MHz DAB+ Signal

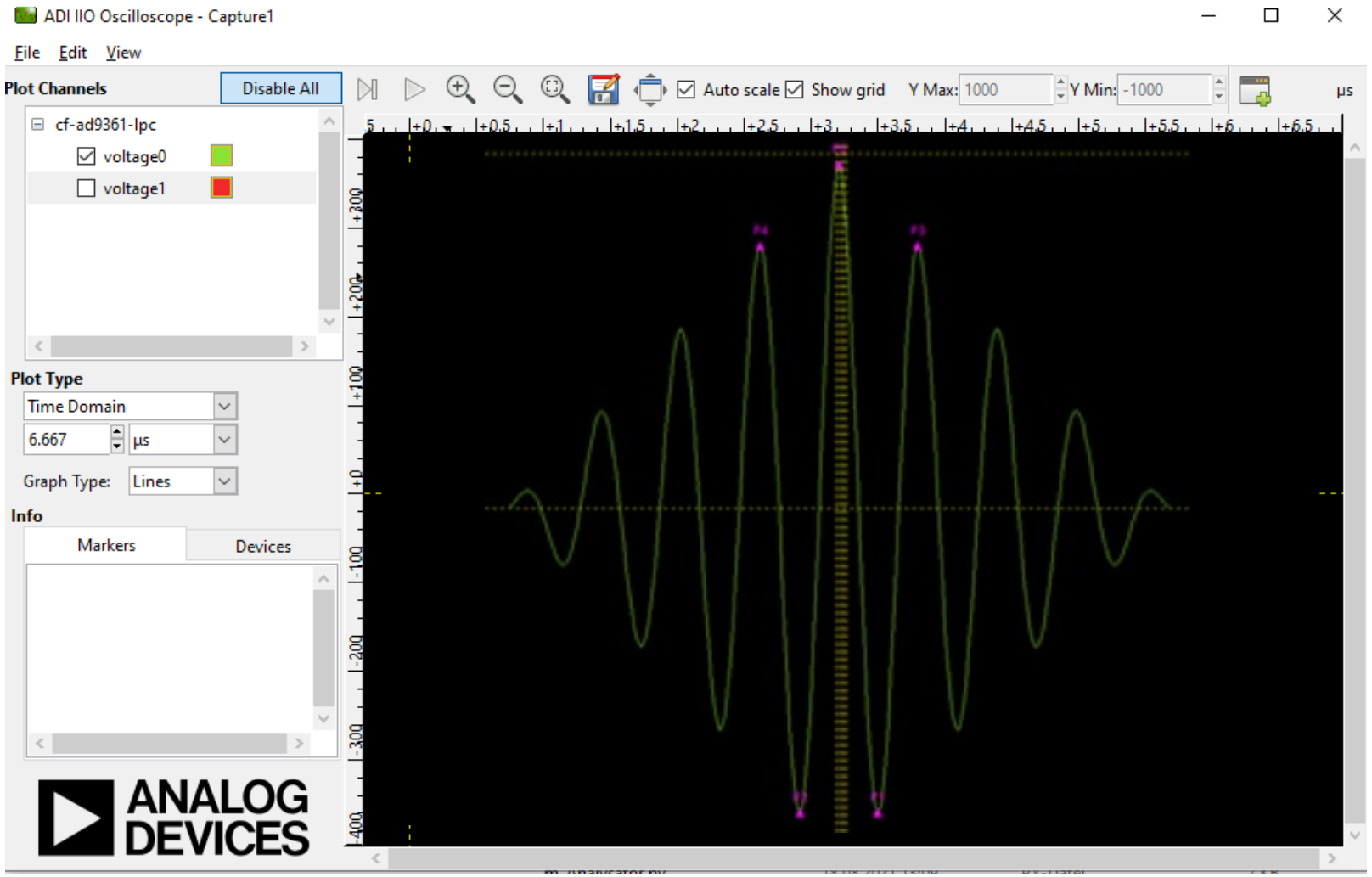


Lampe eingeschaltet, Kein Radio Empfang.
227.360 MHz DAB+ Signal



Nicht GNU, aber Pluto: IIO Osziloskope



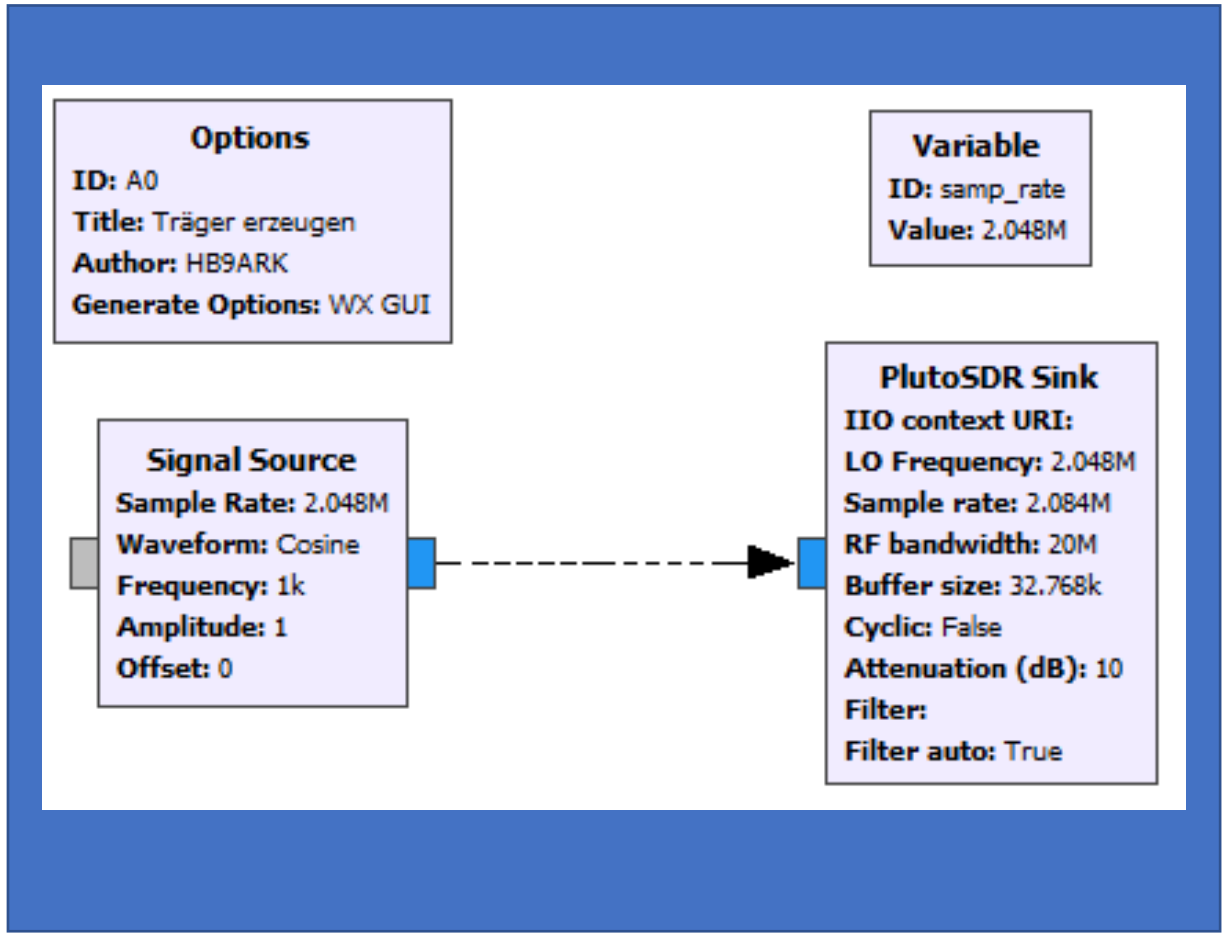


https://wiki.analog.com/resources/tools-software/linux-software/iio_oscilloscope

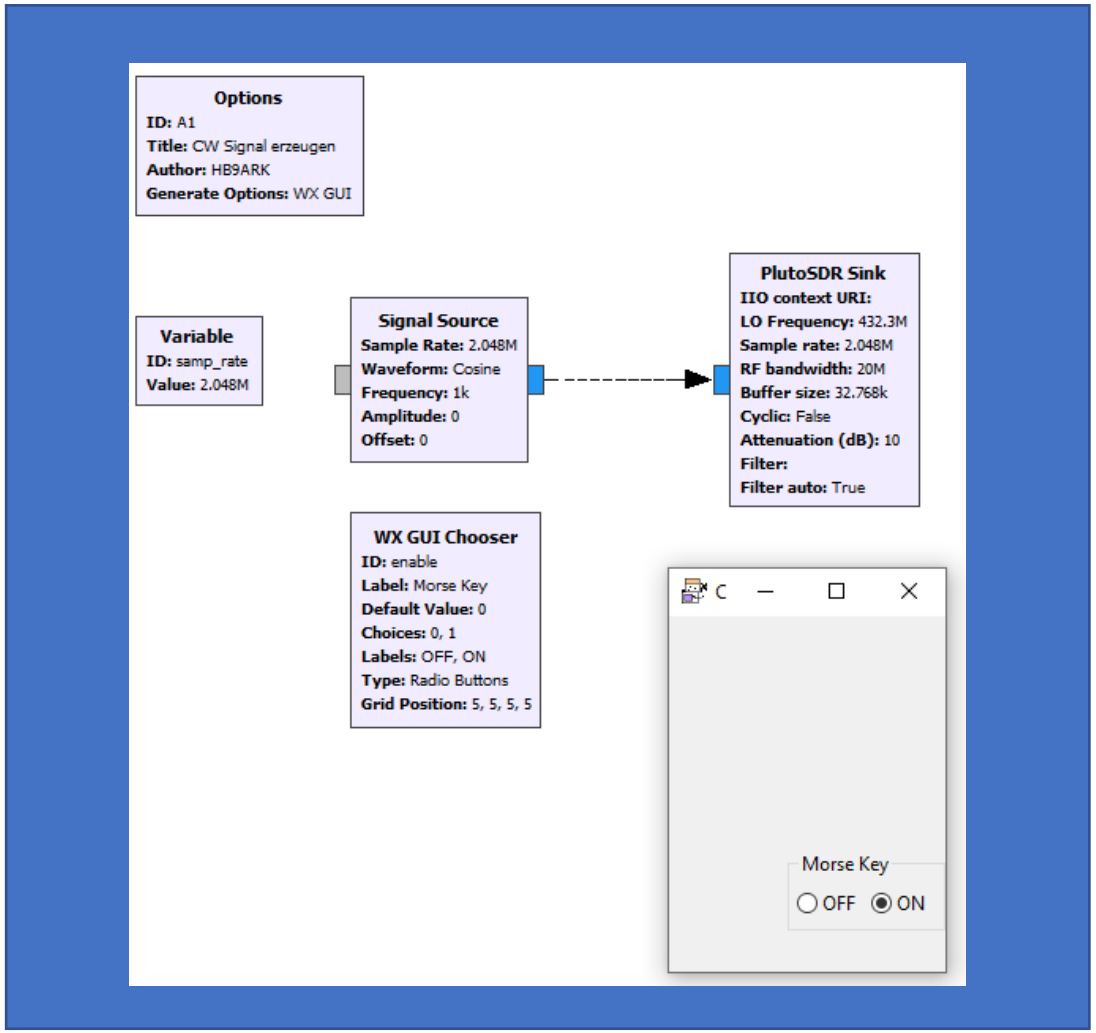
GNU Radio
GRC = GNU Radio Companion

A0, A1 Signal erzeugen

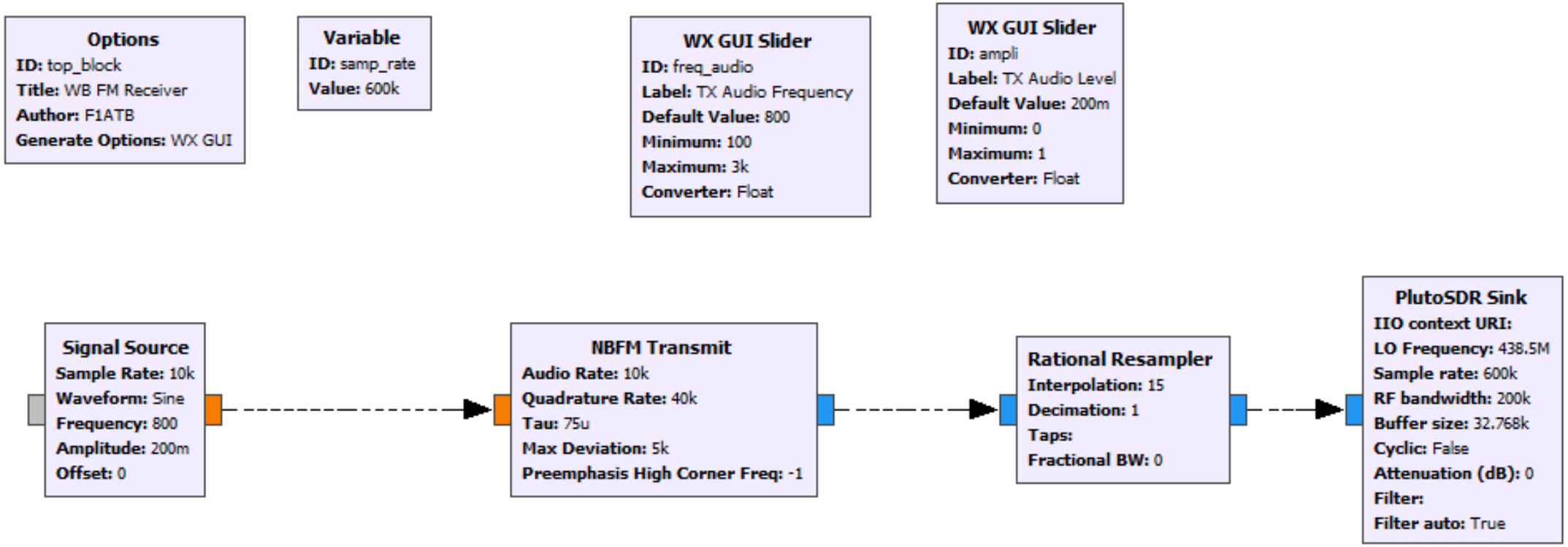
A0



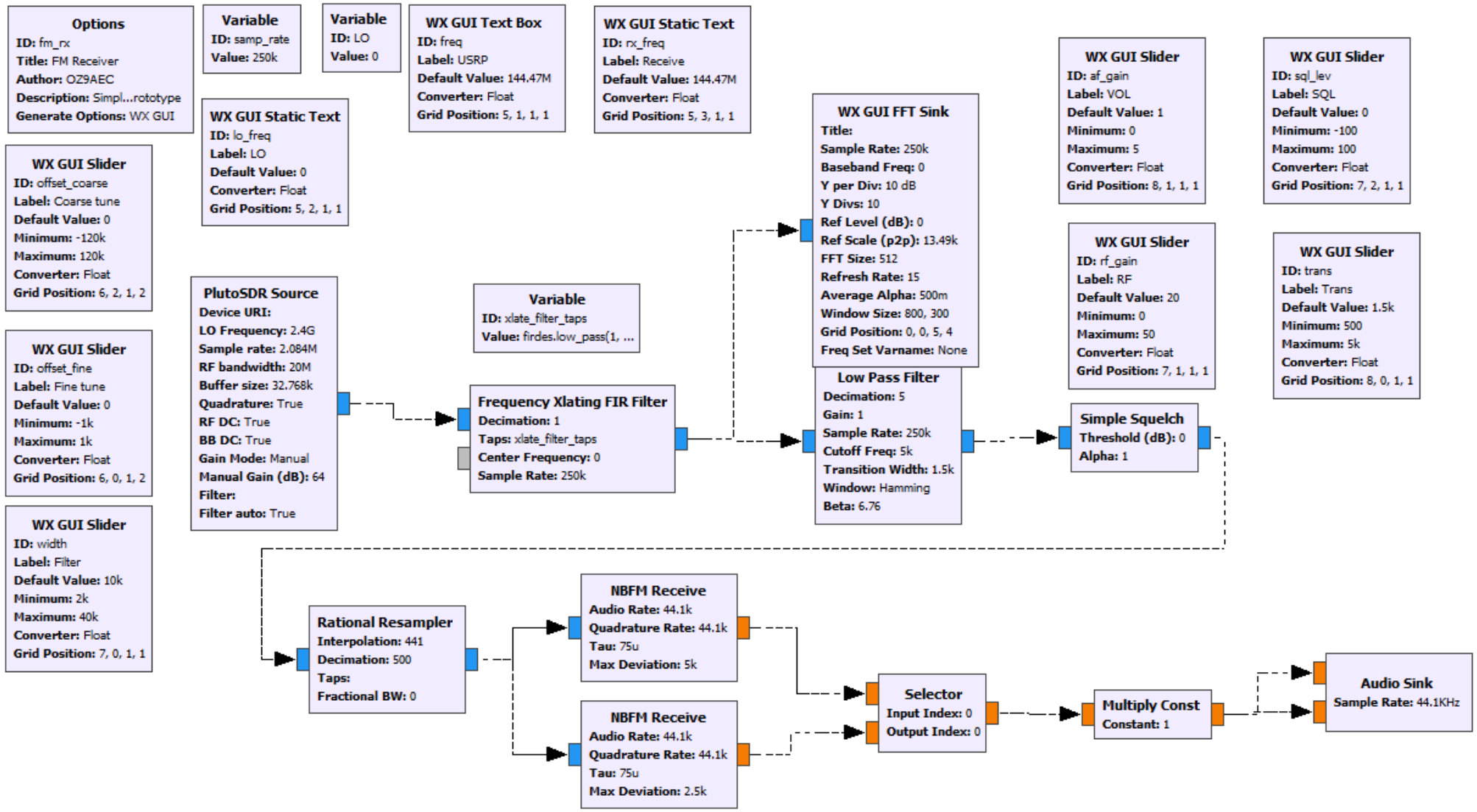
A1



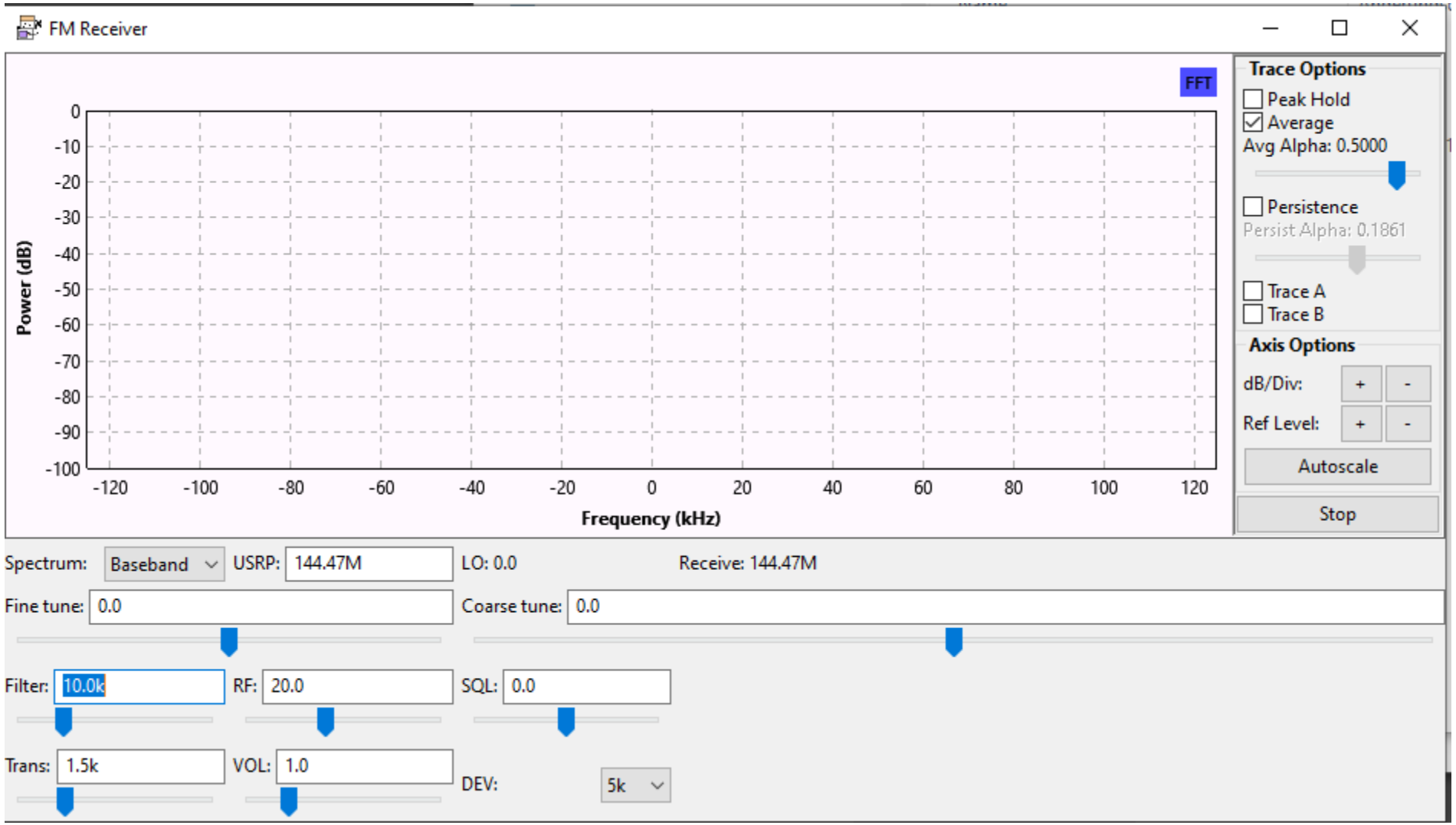
FM Tx


Options
ID: top_block
Title: WB FM Receiver
Author: F1ATB
Generate Options: WX GUI
Variable
ID: samp_rate
Value: 600k
WX GUI Slider
ID: freq_audio
Label: TX Audio Frequency
Default Value: 800
Minimum: 100
Maximum: 3k
Converter: Float
WX GUI Slider
ID: ampli
Label: TX Audio Level
Default Value: 200m
Minimum: 0
Maximum: 1
Converter: Float
Signal Source
Sample Rate: 10k
Waveform: Sine
Frequency: 800
Amplitude: 200m
Offset: 0
NBFM Transmit
Audio Rate: 10k
Quadrature Rate: 40k
Tau: 75u
Max Deviation: 5k
Preemphasis High Corner Freq: -1
Rational Resampler
Interpolation: 15
Decimation: 1
Taps:
Fractional BW: 0
PlutoSDR Sink
IIO context URI:
LO Frequency: 438.5M
Sample rate: 600k
RF bandwidth: 200k
Buffer size: 32.768k
Cyclic: False
Attenuation (dB): 0
Filter:
Filter auto: True

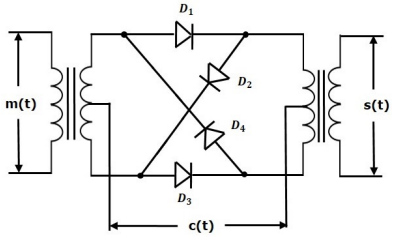
FM Rx

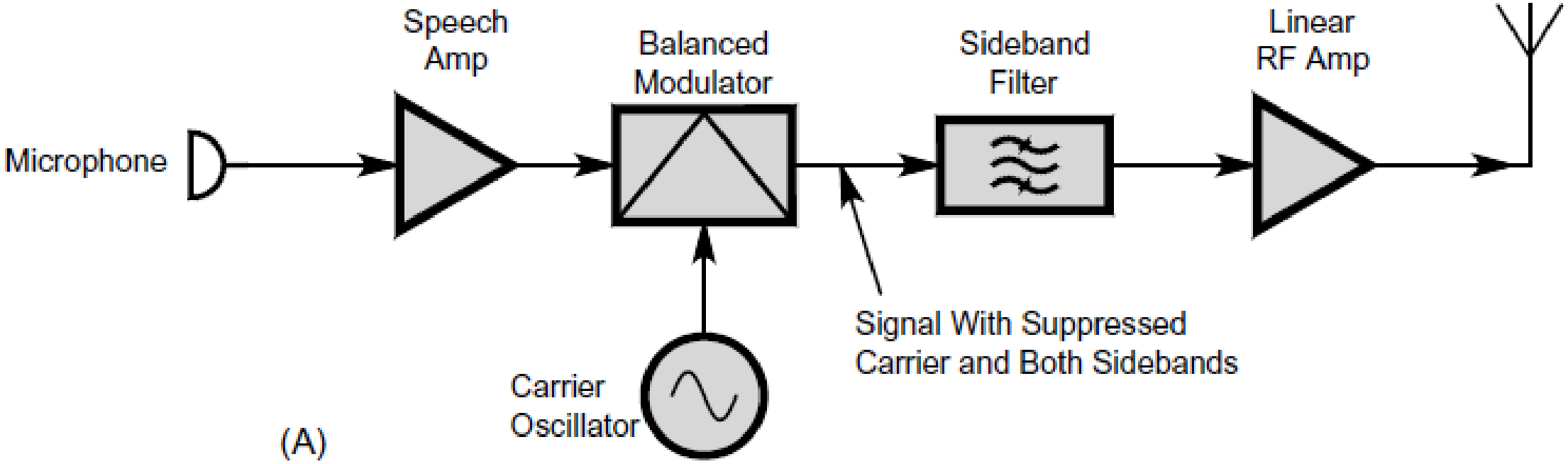

Options
ID: fm_rx
Title: FM Receiver
Author: OZ9AEC
Description: Simpl...rototype
Generate Options: WX GUI
Variable
ID: samp_rate
Value: 250k
Variable
ID: LO
Value: 0
WX GUI Text Box
ID: freq
Label: USRP
Default Value: 144.47M
Converter: Float
Grid Position: 5, 1, 1, 1
WX GUI Static Text
ID: rx_freq
Label: Receive
Default Value: 144.47M
Converter: Float
Grid Position: 5, 3, 1, 1
WX GUI Static Text
ID: lo_freq
Label: LO
Default Value: 0
Converter: Float
Grid Position: 5, 2, 1, 1
WX GUI Slider
ID: offset_coarse
Label: Coarse tune
Default Value: 0
Minimum: -120k
Maximum: 120k
Converter: Float
Grid Position: 6, 2, 1, 2
WX GUI Slider
ID: offset_fine
Label: Fine tune
Default Value: 0
Minimum: -1k
Maximum: 1k
Converter: Float
Grid Position: 6, 0, 1, 2
WX GUI Slider
ID: width
Label: Filter
Default Value: 10k
Minimum: 2k
Maximum: 40k
Converter: Float
Grid Position: 7, 0, 1, 1
PlutoSDR Source
Device URI:
LO Frequency: 2.4G
Sample rate: 2.084M
RF bandwidth: 20M
Buffer size: 32.768k
Quadrature: True
RF DC: True
BB DC: True
Gain Mode: Manual
Manual Gain (dB): 64
Filter:
Filter auto: True
Variable
ID: xlate_filter_taps
Value: firdes.low_pass(1, ...
Frequency Xlating FIR Filter
Decimation: 1
Taps: xlate_filter_taps
Center Frequency: 0
Sample Rate: 250k
WX GUI FFT Sink
Title:
Sample Rate: 250k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 13.49k
FFT Size: 512
Refresh Rate: 15
Average Alpha: 500m
Window Size: 800, 300
Grid Position: 0, 0, 5, 4
Freq Set Varname: None
Low Pass Filter
Decimation: 5
Gain: 1
Sample Rate: 250k
Cutoff Freq: 5k
Transition Width: 1.5k
Window: Hamming
Beta: 6.76
WX GUI Slider
ID: af_gain
Label: VOL
Default Value: 1
Minimum: 0
Maximum: 5
Converter: Float
Grid Position: 8, 1, 1, 1
WX GUI Slider
ID: sql_lev
Label: SQL
Default Value: 0
Minimum: -100
Maximum: 100
Converter: Float
Grid Position: 7, 2, 1, 1
WX GUI Slider
ID: rf_gain
Label: RF
Default Value: 20
Minimum: 0
Maximum: 50
Converter: Float
Grid Position: 7, 1, 1, 1
WX GUI Slider
ID: trans
Label: Trans
Default Value: 1.5k
Minimum: 500
Maximum: 5k
Converter: Float
Grid Position: 8, 0, 1, 1
Simple Squelch
Threshold (dB): 0
Alpha: 1
Rational Resampler
Interpolation: 441
Decimation: 500
Taps:
Fractional BW: 0
NBFM Receive
Audio Rate: 44.1k
Quadrature Rate: 44.1k
Tau: 75u
Max Deviation: 5k
NBFM Receive
Audio Rate: 44.1k
Quadrature Rate: 44.1k
Tau: 75u
Max Deviation: 2.5k
Selector
Input Index: 0
Output Index: 0
Multiply Const
Constant: 1
Audio Sink
Sample Rate: 44.1KHz

GUI des FM Rx


FM Receiver
FFT
Power (dB)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
Frequency (kHz)
Trace Options
Peak Hold
Average
Avg Alpha: 0.5000
Persistence
Persist Alpha: 0.1861
Trace A
Trace B
Axis Options
dB/Div:
Ref Level:
Autoscale
Stop
Spectrum:
Baseband
USRP:
144.47M
LO: 0.0
Receive: 144.47M
Fine tune:
0.0
Coarse tune:
0.0
Filter:
10.0k
RF:
20.0
SQL:
0.0
Trans:
1.5k
VOL:
1.0
DEV:
5k

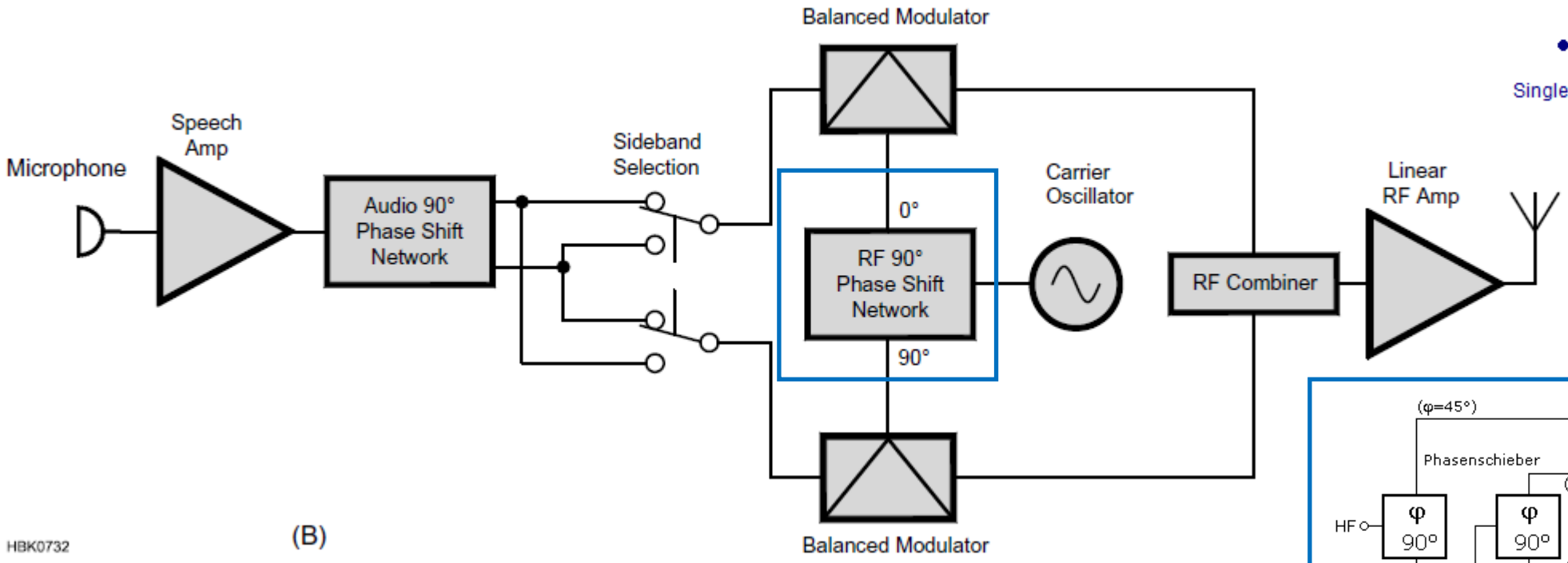
SSB mit der Filter Methode

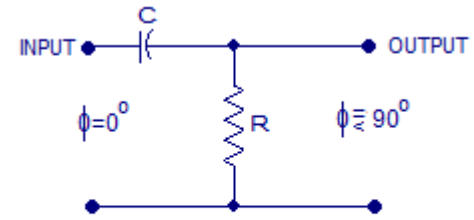




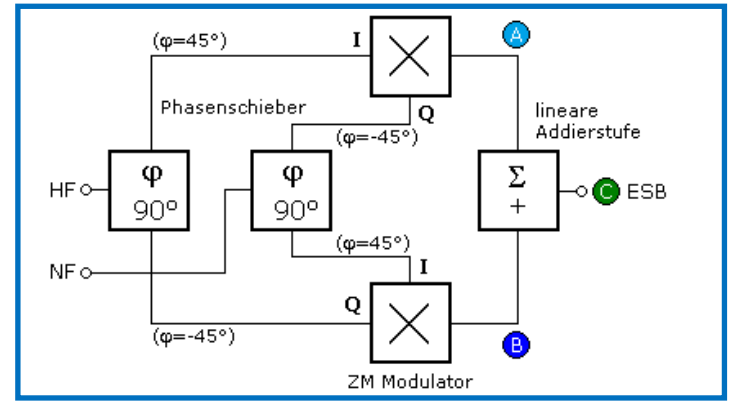
Quelle: Skizze ARRL Handbook, 2019, ergänzt mit Bildern

SSB mit der Phasen Methode





Single stage RC phase shift network



Quelle: Skizze ARRL Handbook, 2019, ergänzt mit Bildern

SSB mit der 3. Methode "Weaver", 1956 "erfunden"

1956 PROCEEDINGS OF THE IRE

A Third Method of Generation and Detection of Single-Sideband Signals*

DONALD K. WEAVER, JR.†, ASSOCIATE MEMBER, IRE

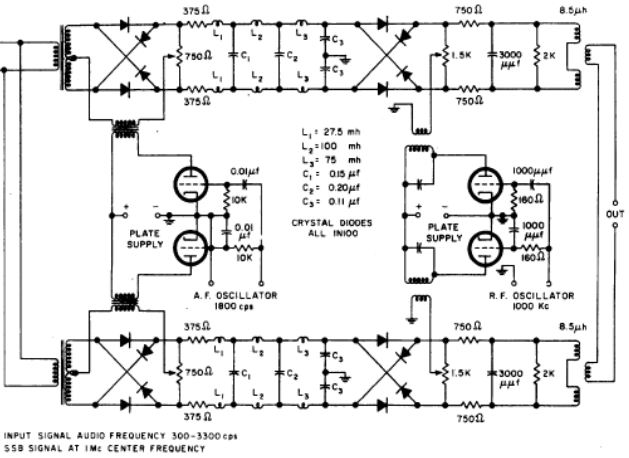
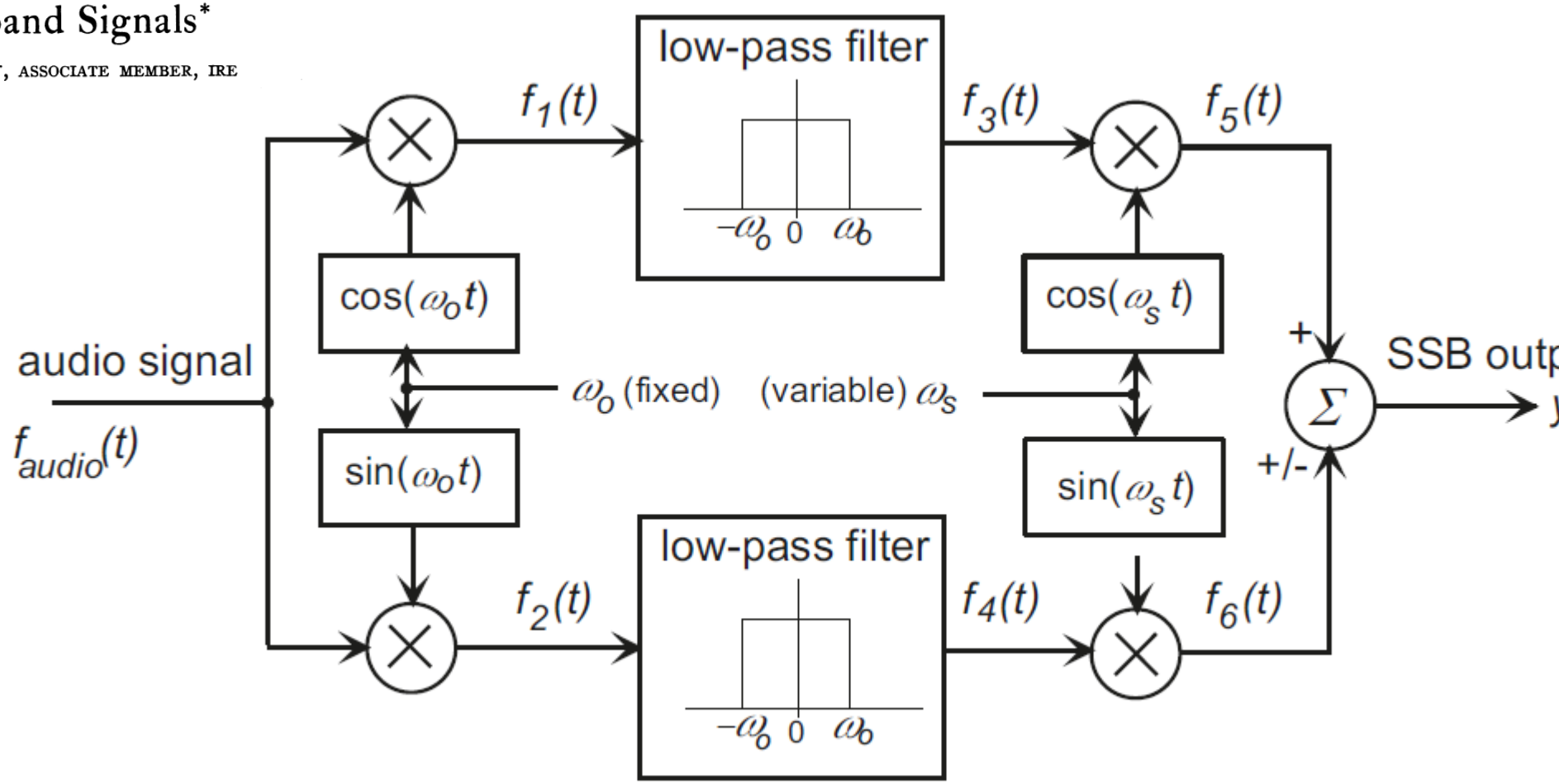
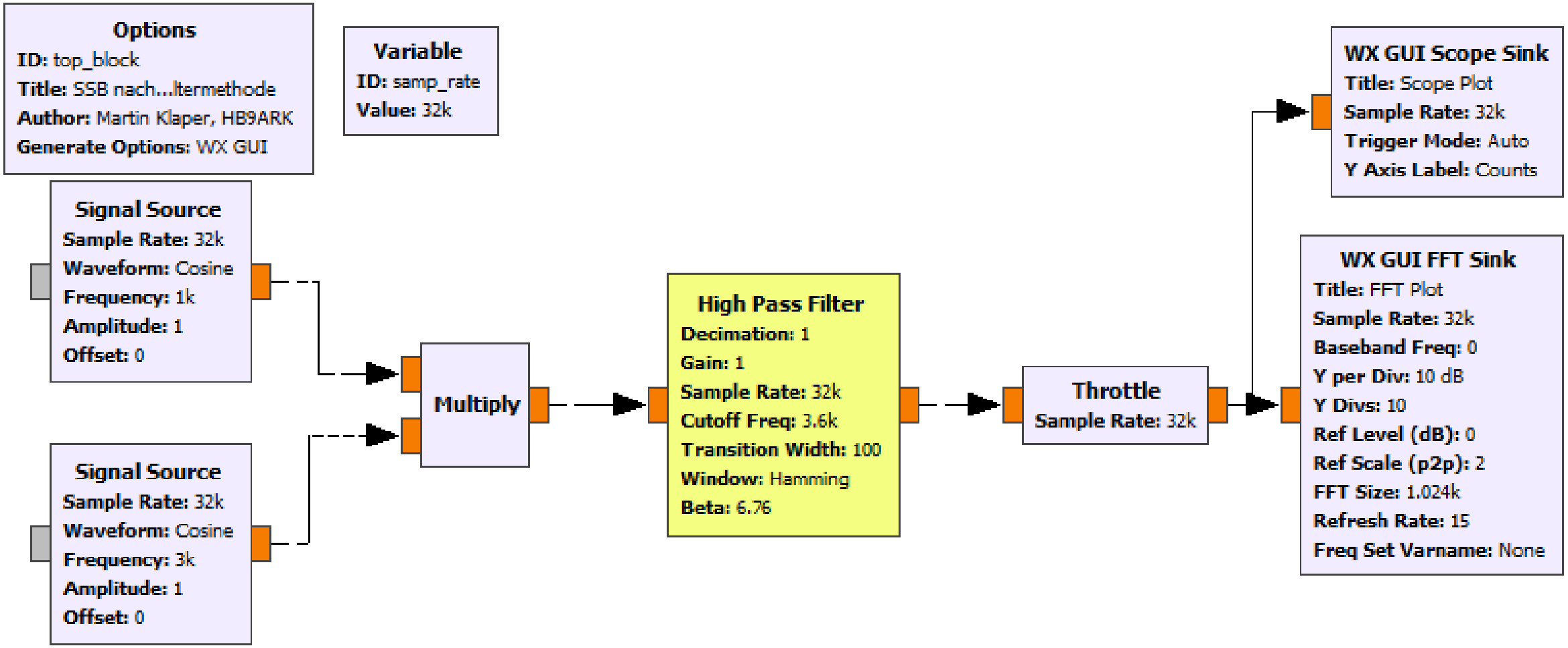


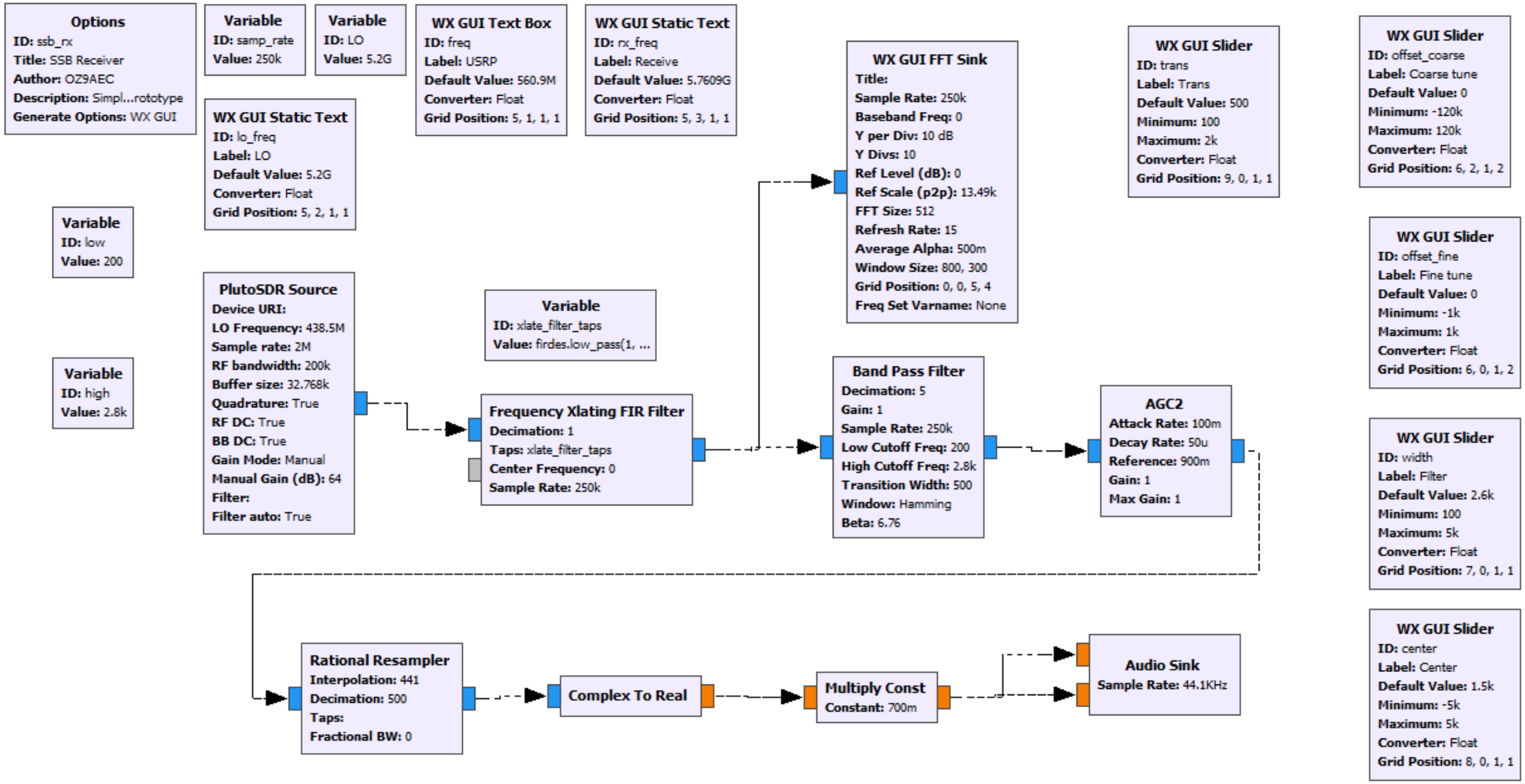
Fig. 7—Single-sideband generator.



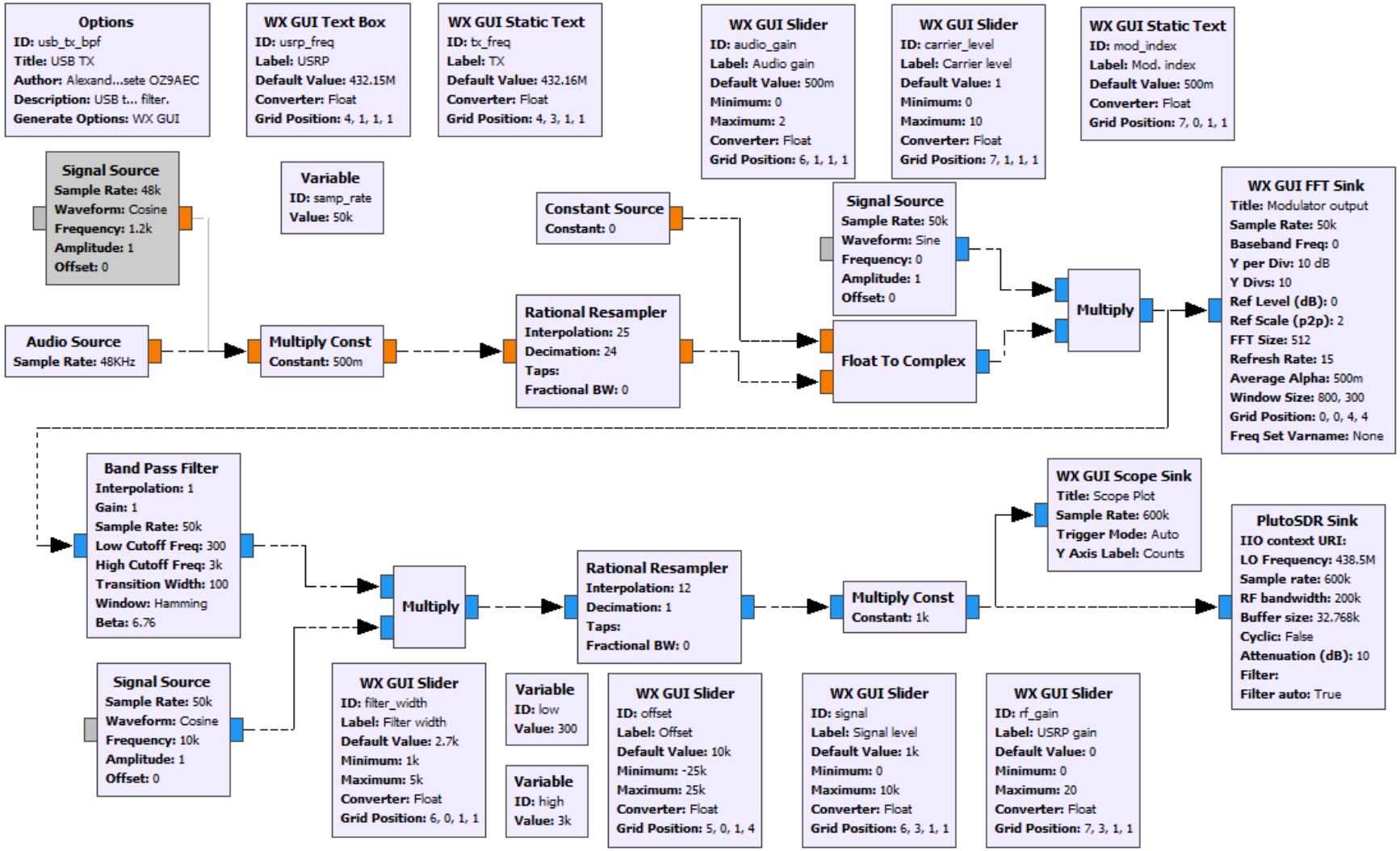
Filter Methode ("basics")



SSB Rx: ein SSB Signal empfangen



SSB Tx: ein SSB Signal erzeugen



Transceiver für QO-100: Langstone TRX

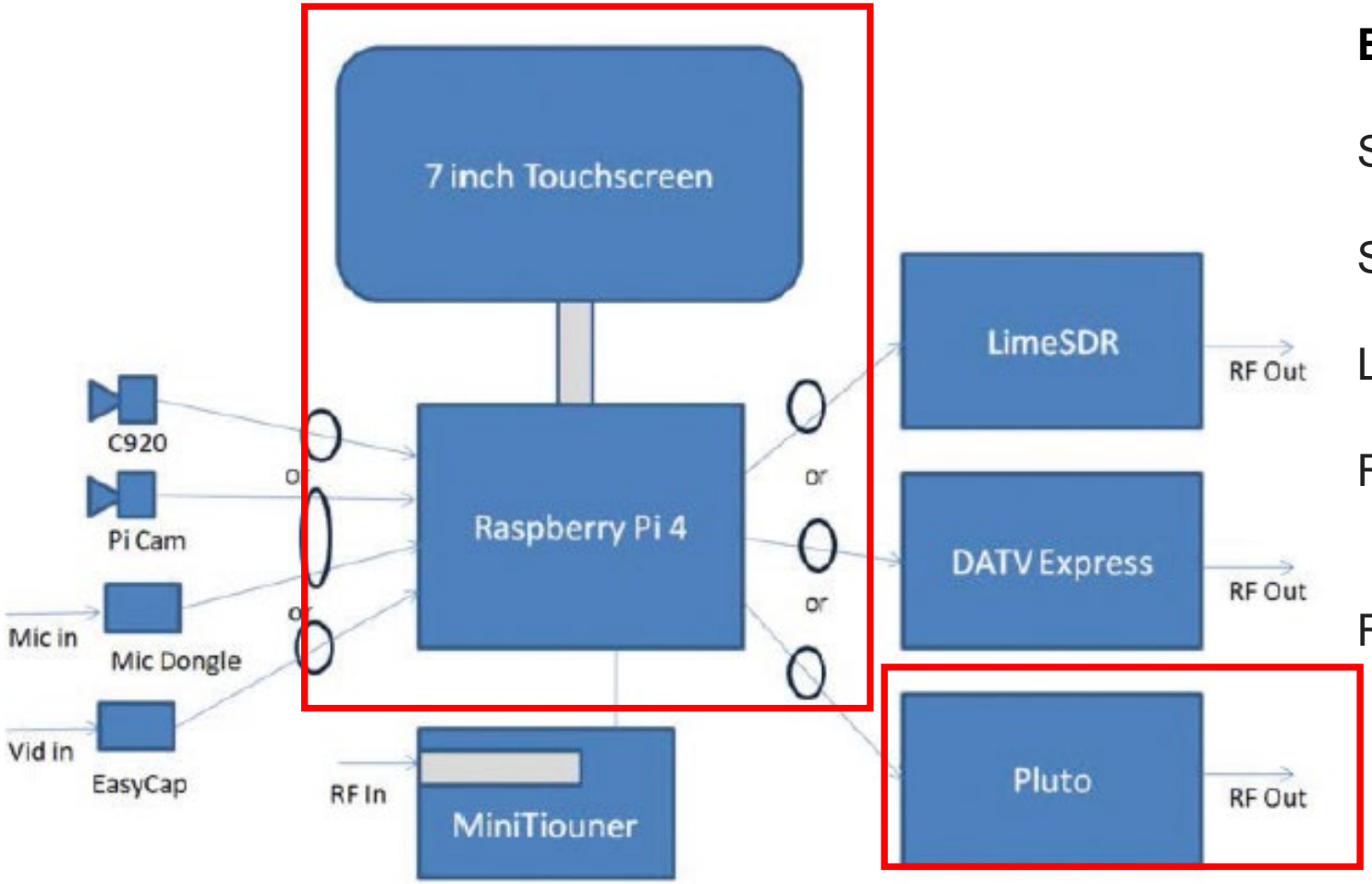
Langstone QO-100 SDR+++ Transceiver (Colin Durbridge G4EM)

70 MHz to 5.7 GHz (oder mehr) !!! , all mode, mit GNU GRC realisiert

Raspberry Pi + Touch Panel

Und eingebaut in ein Gehäuse

Portsdown/Langstone TRX mit QO-100 Funktionen



Portsdown 4 – Simplified Block Diagram

Berechnung der Offset Werte für QO-100

Satellite Downlink Frequency = 10489.6 MHz

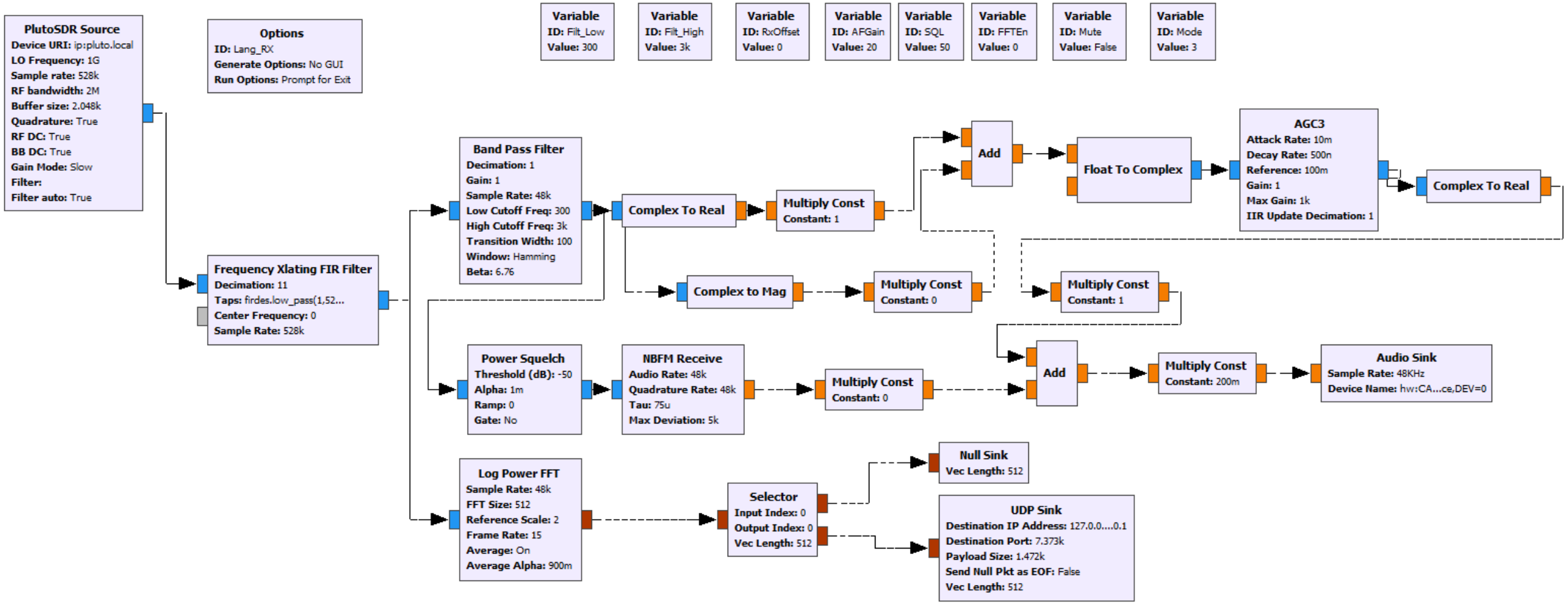
Satellite Uplink Frequency = 2400.1 MHz

LNB Local Oscillator Frequency = 9750 MHz

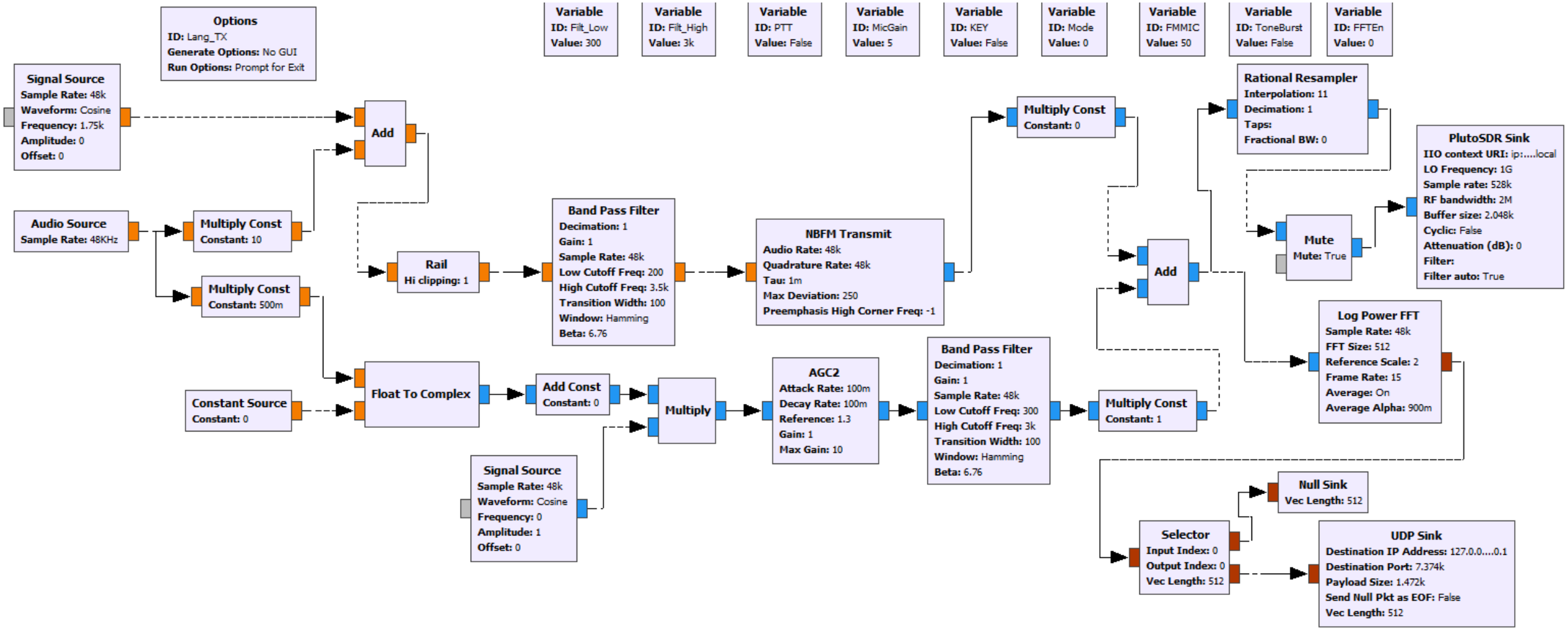
Required Tx offset =
= 2400.1 - 10489.6 = -8089.5 MHz

Required Rx offset = -9750 MHz

Transceiver für QO-100: Langstone Rx



Transceiver für QO-100: Langstone Tx

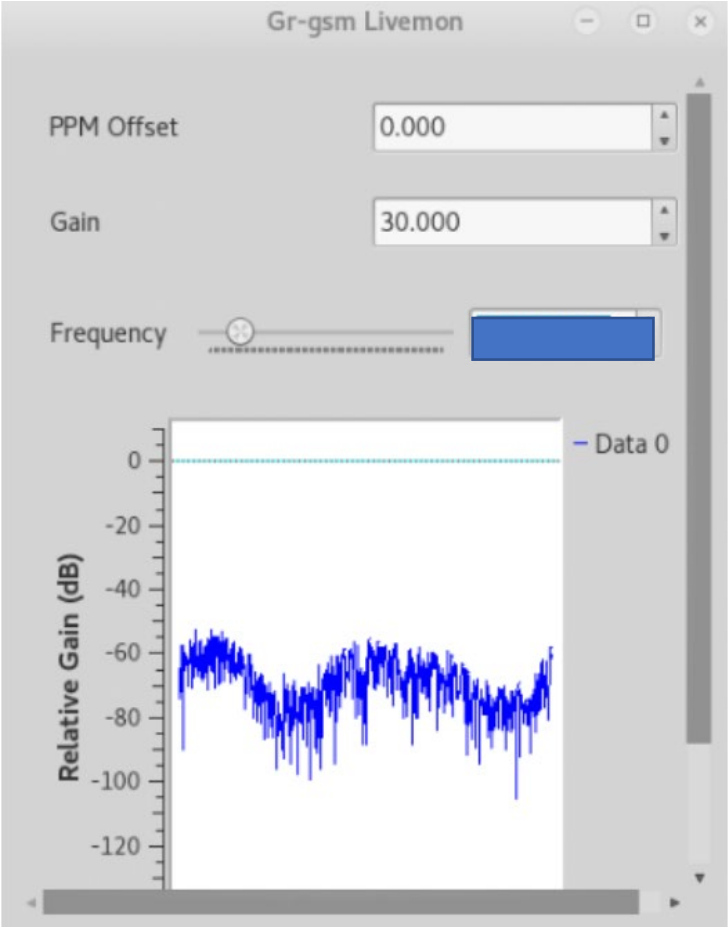


Langstone TRX

Kann man sonst noch was damit machen?

Vom Gebirg zum Ozean ….

Pluto + gr-gsm + Wireshark



WIRESHARK

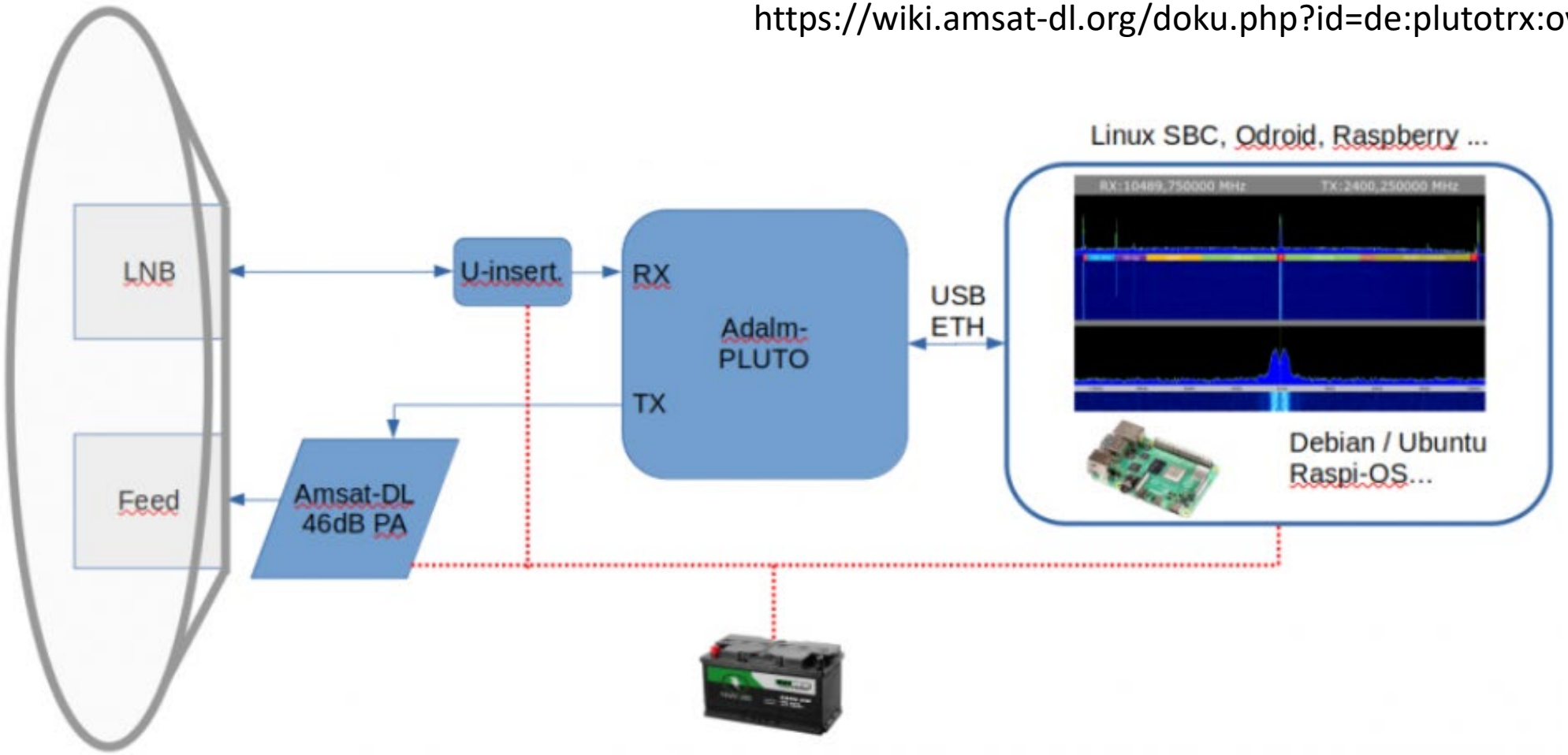
		ation	Protocol	Length	Info
		.1	GSMTAP	81	(CCCH) (RR) Paging Request Type 1
		.1	GSMTAP	81	(CCCH) (RR) Paging Request Type 1
		.1	LAPDm	81	U, func=UI(CCCH) (RR) System Informa
165	45.10434935	127.0.0.1	GSMTAP	81	(CCCH) (RR) Paging Request Type 1
166	45.14718509	127.0.0.1	GSMTAP	81	(CCCH) (RR) Paging Request Type 1
167	45.17253894	127.0.0.1	GSMTAP	81	(CCCH) (RR) Paging Request Type 1
168	45.19269615	127.0.0.1	LAPDm	81	I, N(R)=2, N(S)=1(DTAP) (MM) Authent
169	45.20137261	127.0.0.1	GSMTAP	81	(CCCH) (RR) System Information Type
170	45.22052841	127.0.0.1	GSMTAP	81	(CCCH) (SS)
171	45.24398545	127.0.0.1	GSMTAP	81	(CCCH) (RR) Paging Request Type 1
172	45.25849706	127.0.0.1	GSMTAP	81	(CCCH) (RR) Paging Request Type 1

```
▶Frame 53487: 81 bytes on wire (648 bits), 81 bytes captured (648 bits) on
▶Ethernet II, Src: 00:00:00_00:00:00 (00:00:00:00:00:00), Dst: 00:00:00_00
▶Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
▶User Datagram Protocol, Src Port: 56679, Dst Port: 4729
▶GSM TAP Header, ARFCN: 34 (Downlink), TS: 0, Channel: BCCH (0)
▼GSM CCCH - System Information Type 2
 ▶L2 Pseudo Length
 ▶.... 0110 = Protocol discriminator: Radio Resources Management messages
  Message Type: System Information Type 2
 ▼Neighbour Cell Description - BCCH Frequency List
   ..0. .... = EXT-IND: The information element carries the complete BA (0)
   ...0 .... = BA-IND: 0
   00.. 000. = Format Identifier: bit map 0 (0x00)
   List of ARFCNs = 47 46 45 44 42 40 38 35 34 33 32 31 29
 ▶NCC Permitted
 ▼RACH Control Parameters
   10.. .... = Max retrans: Maximum 4 retransmissions (2)
   ..11 10.. = Tx-integer: 32 slots used to spread transmission (14)
   .... ..0. = CELL_BARR_ACCESS: The cell is not barred (0)
   .... ...0 = RE: Call Reestablishment allowed in the cell (0)
   0000 0000 0000 0000 = ACC: 0x0000
```

SDR QO100 mit Pluto ohne GNU

QO-100 Linux SDR Transceiver (AMSAT-DL)

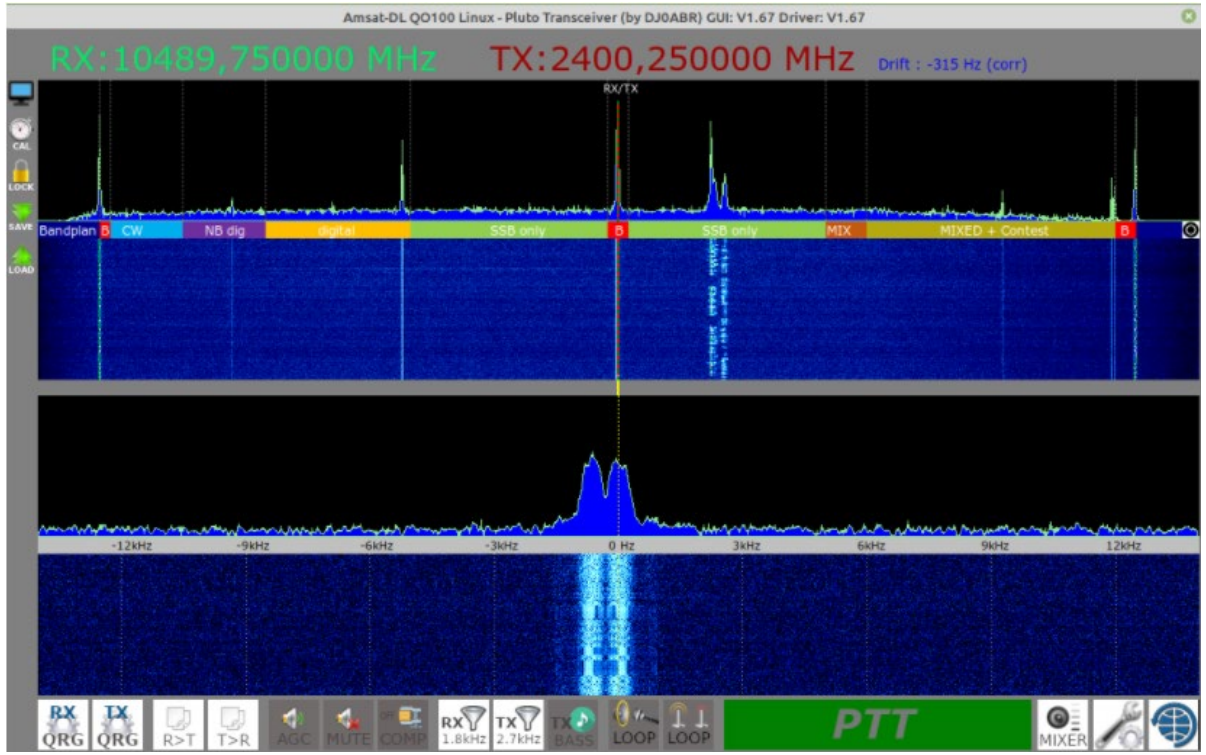
https://wiki.amsat-dl.org/doku.php?id=de:plutotrx:overview

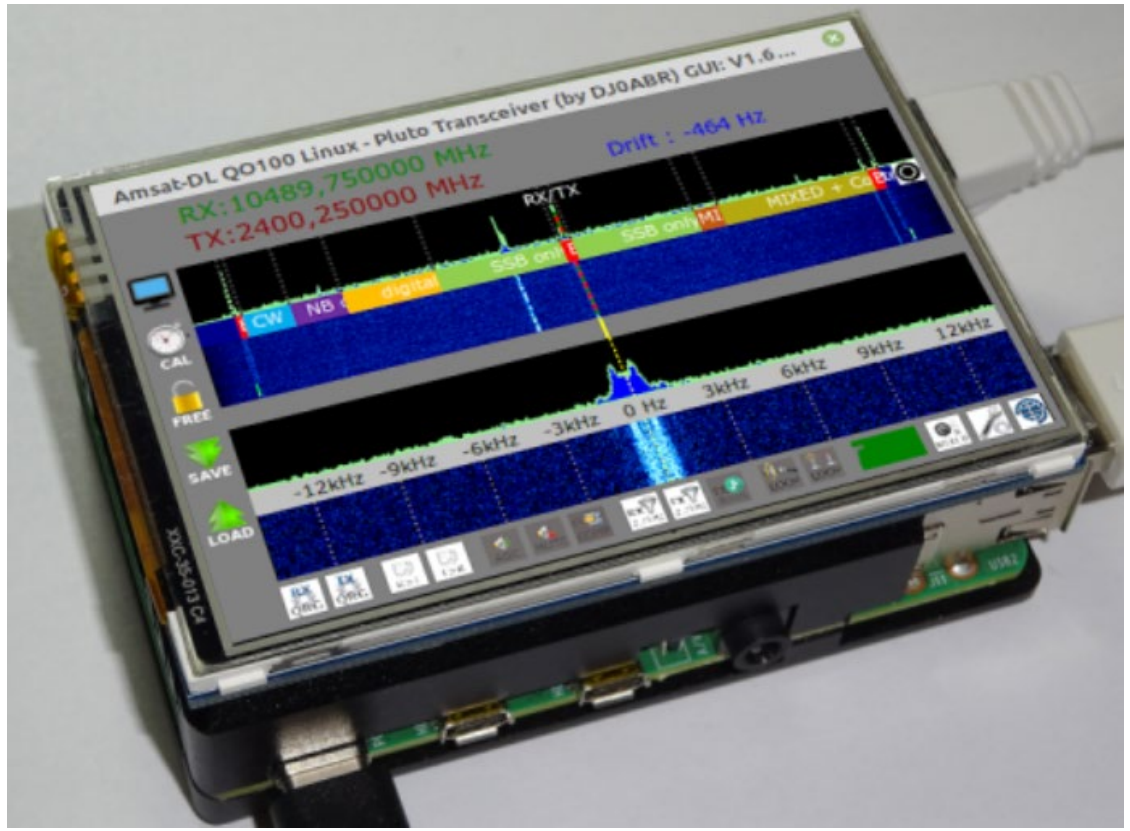



```
wget https://raw.githubusercontent.com/dj0abr/QO100_Transceiver/main/install chmod 755 install ./install
```

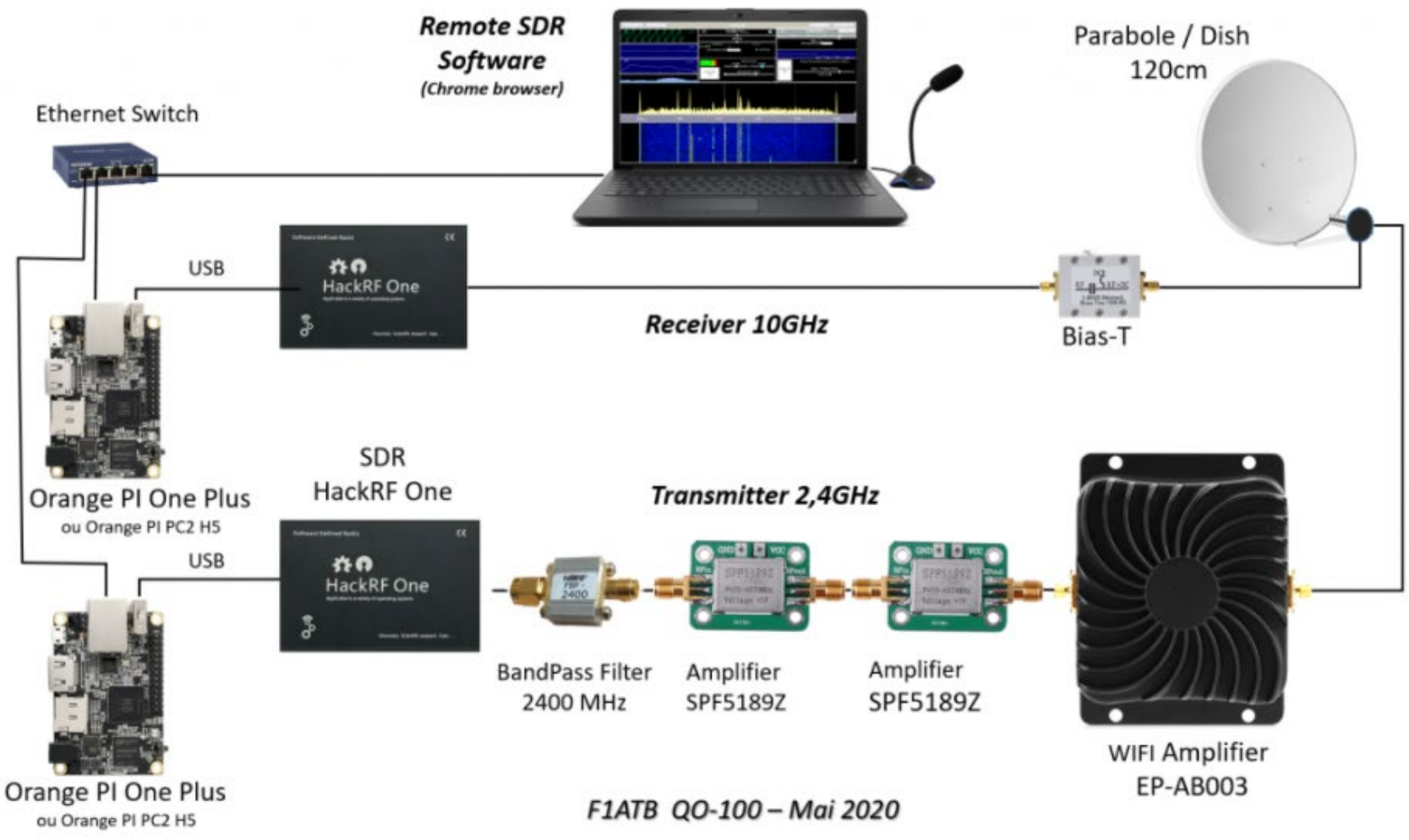
QO-100 Linux SDR Transceiver

https://wiki.amsat-dl.org/doku.php?id=de:plutotrx:overview





Mit Web Interface



Alternative: Selber programmieren

- Was in den GNU GRC Baublöcken "versteckt" ist, lässt sich natürlich auch "selber" programmieren.

- Das kann zu vertieften Kenntnissen führen.
- Man hat dann etwas selber gebaut. Programmieren ist wie Konstruieren, ein kreativer Prozess.

- Beispiel rechts: ein Lokaloszillator (noch nicht ganz perfekt, aber er zeigt das Prinzip!

- Wie funktioniert es? Aus einer Tabelle mit Sinuswerten wird der Wert herausgelesen. Die Phaseninkremente ergeben die Stützstellen (Bäumchen).

```
class Oscillator:
    TABLE_SIZE = 128

    def __init__(self, frequency, samples):
        self.freq = frequency
        self.sampleRate = samples
        self._phase = 0
        self._sinTable = self._init_table()
        self._phaseIncrement = self._calc_phase_inc(self.freq, self.sampleRate)

    def _init_table(self):
        table = []
        for n in range(0, self.TABLE_SIZE):
            table.append(math.sin(n*2.0*math.pi/self.TABLE_SIZE))
        return table

    def _calc_phase_inc(self, frequency, samplesPerSecond):
        return 2 * math.pi * frequency / samplesPerSecond

    def next_sample(self):
        self._phase = self._phase + self._phaseIncrement
        if (self._phase >= 2 * math.pi):
            self._phase = 0;
        idx = (int)((self._phase * self.TABLE_SIZE/(2 * math.pi))%self.TABLE_SIZE)
        value = self._sinTable[idx]
        return value
```

Wrap Up

- Software Defined Radio ist immer mehr ein aktuelles und spannendes Thema.
- Es eignet sich zum "basteln".

- GNU Radio ist ein zweckmässiges frei verfügbares Werkzeug zur Umsetzung.

- Erfolgreiche Beschäftigung mit Software Radio erfordert Fachwissen auf verschiedenen Gebieten.

- GNU Radio mit GRC verringert die Einstiegshürde deutlich.
- Von Grund auf selber programmieren ist durchaus machbar und kann Spass machen.

- … und noch bequemer geht’s mit einem Seminar der HamAcademy.

Verzeichnis der Programme

Datei	Beschreibung
SpektrumAnalysator.grc	Einfacher Spektrum Analysator
SimpleTx.grc	Konstanten Träger erzeugen, A0
SimpleCWTx.grc	Getasteten Träger erzeugen, A1
NarrowBandFMTX.grc	FM Sender für Voice
Demo Mischer usb_tx_bpf.grc	Live Vorführung SSB (USB) Sender für Voice nach der Filtermethode
LangRx.grc	Langstone Sender für QO-100 und vieles Andere
LangTx.grc	Langstone Empfänger für QO-100 und vieles Andere

Links und Quellenangaben I

- https://ez.analog.com/adieducation/university-program/f/q-a/111642/transmitting-a-continuous-wave-cw-signal-using-adalm-pluto-with-gnu-radio
- Chris Thompson, https://www.g0kla.com/sdr/index.php
- Alexandru Csete, OZ9AEC, https://oz9aec.net/
- Martin Klaper, HB9ARK, https://www.uska.ch/hamfest-2019/f2_hb9ark-gnu-radio-mit-grc/
- https://github.com/tfcollins/GNURadio_Windows_Build_Scripts/releases/download/1.5.0/gnuradio_3.7.11_iiosupport_win64.msi
- https://wiki.analog.com/resources/tools-software/linux-software/gnuradio_windows#gnu_radio_with_iio_for_windows
- https://www.analog.com/media/en/training-seminars/design-handbooks/Software-Defined-Radio-for-Engineers-2018/SDR4Engineers.pdf
- www.hb9hslu.ch

Links und Quellenangaben II

- https://docs.microsoft.com/de-ch/archive/blogs/dawate/intro-to-audio-programming-part-2-demystifying-the-wav-format
- https://www.codeproject.com/Articles/7906/A-simple-C-Wave-editor-part-1-Background-and-analy
- https://wiki.gnuradio.org/index.php/Tutorials
- https://github.com/analogdevicesinc/iio-oscilloscope/releases
- https://www.cgran.org/
- https://hexed.it/

USKA Online Angebot

- https://www.hamwebinar.ch/hamacademy/
- https://www.hamwebinar.ch/
- https://www.hamgroups.ch/

Danke für Eure Aufmerksamkeit