Wireless Signal Processing in GNU Radio Environment

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1 Introduction

This chapter presents a GNU Radio — an open source software package aimed to be used as an environment for wireless signal processing. Such application could be useful for computer science students during their education process in the courses related with data transmission, telecommunications, radio communications etc.

2 What is GNU Radio?

GNU Radio [2]:

1. is a free and **open-source** software development toolkit that provides signal processing blocks to implement software radios;
2. can be used with readily-available low-cost external RF hardware (such as RTL-SDR or HackRF) to create software-defined radios;
3. or even without hardware — in a simulation-like environment;
4. is widely used in hobbyist, academic and commercial environments to support both wireless communications research and real-world radio systems;
5. is a framework that enables users to design, simulate, and deploy highly capable real-world radio systems;
6. is a highly modular, "flowgraph"-oriented framework that comes with a comprehensive library of processing blocks that can be readily combined to make complex signal processing applications;
7. has been used for a huge array of real-world radio applications, including mobile communications, tracking satellites, radar systems, GSM networks, Digital Radio Mondiale, and much more — all in computer software;
8. can be used to develop implementations of basically any (band-limited) communication standard.

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3 Why would I want GNU Radio?

Formerly the engineer had to develop a specific circuits for detection, decoding, encoding of a specific signal and debug all of them using costly equipment. Software-Defined Radio (SDR) approach moves the analog radio signal processing — as far as physically and economically feasible — to a computer, using algorithms in software. The engineer had to self-implement all DSP algorithms while in GNU Radio environment a user is capable of using highly optimized and peer-reviewed scalable implementations along with GUIs.

GNU Radio:

1. is a framework dedicated to writing signal processing applications for general purpose computers;
2. wraps functionality in easy-to-use reusable blocks;
3. offers excellent scalability;
4. provides an extensive library of standard algorithms;
5. is heavily optimized for a large variety of common platforms;
6. comes with a large set of examples to get you started from.

4 A flowgraph-based approach to Digital Signal Processing

In GNU Radio framework individual processing stages such as filtering, correction, analysis, detection etc. are represented by processing blocks; these blokcs are connected using simple flow-indicating arrows — see example in Fig. 4

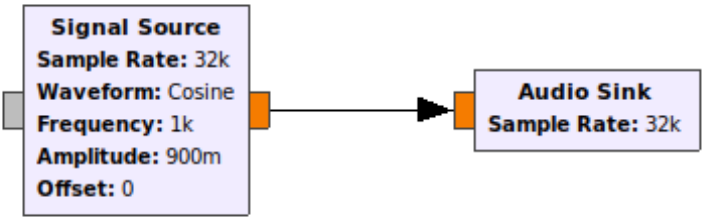

Fig. 1: *GNU Radio — two blocks (**Signal Source** and **Audio Sink**) connected with an arrow showing flow of the signal data*

A digital signal processing application is a complete graph of blocks, in GNU Radio called as **flowgraph**. Fig. 4 shows an example of flowgraph.

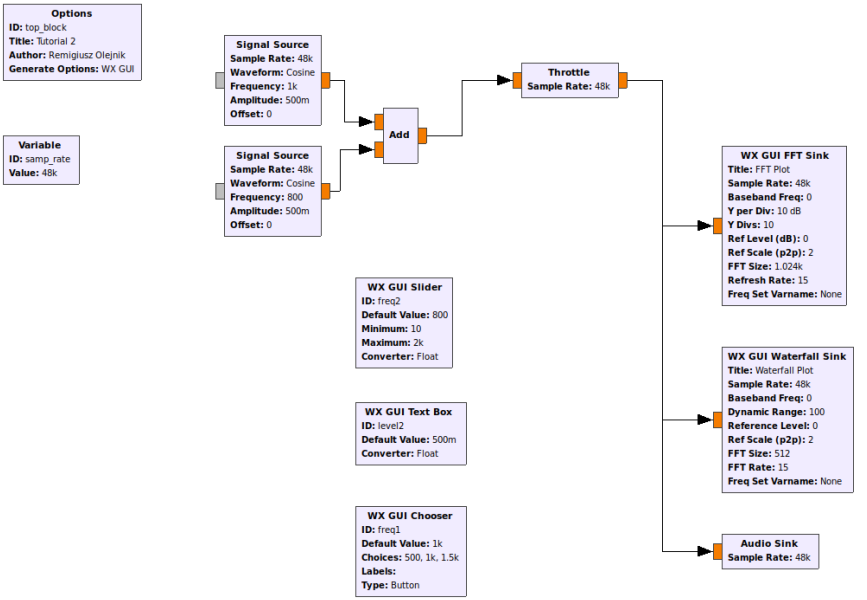

Fig. 2: *GNU Radio — seven blocks connected together form a flowgraph*

GNU Radio framework allows developing these processing blocks and creating flowgraphs, which comprise radio processing applications. Existing blocks could be combined into a high-level flowgraph.

5 Most popular GNU Radio blocks

GNU Radio comes with a large set of existing blocks. Most popular ones are presented below.

- Waveform Generators
  - Constant Source
  - Noise Source
  - Signal Source (e.g. Sine, Square, Saw Tooth)
- Modulators
  - AM Demod
  - Continuous Phase Modulation

  - PSK Mod / Demod
  - GFSK Mod / Demod
  - GMSK Mod / Demod
  - QAM Mod / Demod
  - WBFM Receive
  - NBFM Receive
- Instrumentation
  - Constellation Sink
  - Frequency Sink
  - Histogram Sink
  - Number Sink
  - Time Raster Sink
  - Time Sink
  - Waterfall Sink
- Math Operators
  - Abs
  - Add
  - Complex Conjugate
  - Divide
  - Integrate
  - Log10
  - Multiply
  - RMS
  - Subtract
- Channel Models
  - Channel Model
  - Fading Model
  - Dynamic Channel Model
  - Frequency Selective Fading Model
- Filters
  - Band Pass / Reject Filter
  - Low / High Pass Filter
  - IIR Filter
  - Generic Filterbank
  - Hilbert
  - Decimating FIR Filter
  - Root Raised Cosine Filter
  - FFT Filter
- Fourier Analysis

- FFT
- Log Power FFT
- Goertzel (Resamplers)
- Fractional Resampler
- Polyphase Arbitrary Resampler
- Rational Resampler (Synchronizers)
- Clock Recovery MM
- Correlate and Sync
- Costas Loop
- FLL Band-Edge
- PLL Freq Det
- PN Correlator
- Polyphase Clock Sync

6 RTL-SDR based WFM receiver example

In Fig. 6 a simple example of the broadcast WFM receiver is resented. It consists of **RTL-SDR Source** block as a radio signal source, **FM Demod** block as a FM demodulator, **Multiply Const** block supplying a volume value for the audio level and **Audio Sink** block that allows playing audio signal.

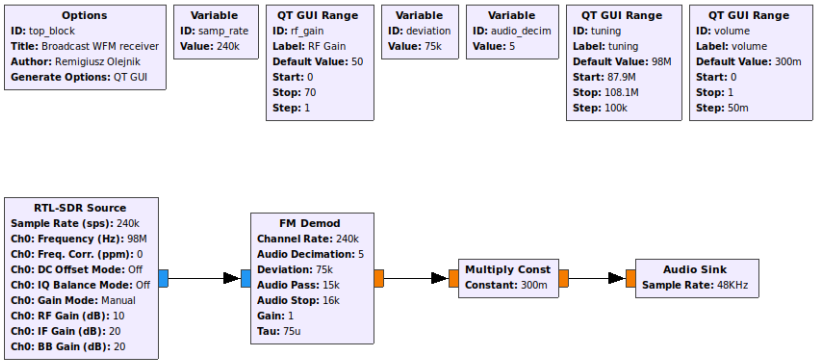

Fig. 3: *An example of the broadcast WFM receiver in GNU Radio*

7 Summary

GNU Radio is a free and open source software development toolkit that provides signal processing blocks to implement Software Defined Radios (SDRs). It is a highly mod-

ular, „flowgraph”-oriented framework, that comes with a large set of existing blocks. GNU Radio can be used with readily-available low-cost external RF hardware (such as RTL-SDR or HackRF) to create software-defined radios.

References

1. http://ioscs.zut.edu.pl/
2. GNU Radio, https://www.gnuradio.org/

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