Labs in Information and Communication Technologies **Assignment 1**
Spring Semester
Telecommunications Circuits Laboratory
EPFL

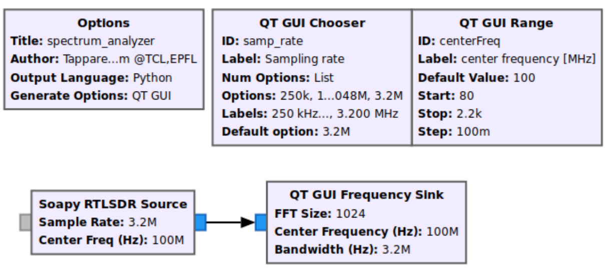
Exploring the Radio Spectrum with a Spectrum Analyzer

The objective of this lab session is to practice the use of a spectrum analyzer and to explore the radio spectrum. The lab also illustrates how to use the GNU Radio framework with software defined radio (SDR) hardware.
The lab session has three parts. In the first part you will familiarize yourself with the spectrum analyzer and its parameters/options. In the second part you will explore the spectrum and search for RF transmissions. Finally, you will build a simple FM receiver in GNU Radio.

Instrument Setup

- Start your computer on Ubuntu. When booting, you can choose to boot on the Ubuntu image by selecting the *Ubuntu Network Boot* when prompted (white screen with red text).
- Get an SDR and antenna set from the TA. Mount the antenna and connect the SDR to your computer. You do not need to fully extend the antenna.
- Download the lab files from Moodle and extract them on your machine.
- Open GNU Radio Companion and open the file *spectrum_analyzer.grc* that you just downloaded from Moodle (under File→Open).

You should see the following flowgraph being loaded:

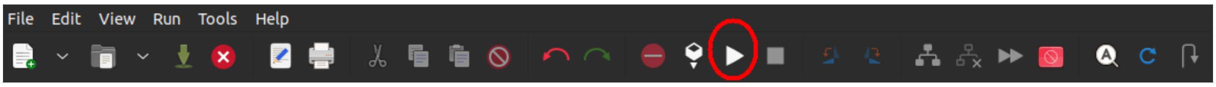


GNU Radio is a framework that enables users to design, simulate, and deploy real-world radio systems. It is a highly modular, ”flowgraph”-oriented framework that comes with a comprehensive library of processing blocks that can be readily combined to construct complex signal processing applications.

Each block has a specific function, some inputs, and some outputs. You can double click on the block to set their parameters.
In our first example have a very simple flowgraph composed of only a few blocks:

- The *Options* block defines some basic option for the whole flowgraph such as its executable name, output language, and other execution parameters.
- The block *QT GUI Range* allow to change variable values in a graphical interface generated during the flowgraph execution. We declared two useful variables here: the sampling rate and the center frequency.
- The *Soapy RTLSDR Source* will recover baseband samples from the SDR and output them as a stream of complex values.
- This stream is fed to a *QT GUI Frequency Sink* which will plot the frequency components of the signal provided at its input.

You can execute the flowgraph by pressing on the ”Play” button



Exploring the Spectrum Analyzer

We will now explore the different settings of the spectrum analyzer.

Task-1.1

Look at the spectrum between $88.4 - 91.6$ MHz. Provide a screenshot of the spectrum
Please use the *screenshot* application and not a picture of the screen in your report (Shortcut: prtSc).

Task-1.2

There are three ”Trace Options”: *Max Hold*, *Min Hold* and *Avg*. What are their effects?

Task-1.3

For the same frequency band as the first task, provide screenshots for the spectrum with the following frequency resolutions: 390.625 Hz, 25 kHz, and 100 kHz. Which parameter needs to be changed?

Exploring the Radio Spectrum

After getting to know the spectrum analyzer functions and its use, we can now explore the radio spectrum.

Task-2.1

In order to maximize the received signal strength, you need to change the antenna length to match the frequency of interest. For frequencies around 100 MHz and around 200 MHz what will be the antenna length you choose to use, knowing that each antenna segment is approximately 20 cm long.

Task-2.2

Can you find any RF transmission between 200 MHz and 220 MHz?
If yes, provide a screenshot of its spectrum. What is the bandwidth used?
Based on the official frequency band allocation Swiss Frequency Allocation Plan, what type of transmission did you found?

Task-2.3

Find the radio station "LFM" near Morges-Lausanne-Vevey and show its spectrum. Use the stations center frequency, a bandwidth of 1024 kHz. Report a picture of the spectrum with the station clearly visible. You find information on the radio stations in the area at: `https://ch.frequence-radio.com/frequences-canton-vaud.html`

Task-2.4

What is, approximately, the 10 dB bandwidth of the radio station "LFM"? Hint: The 10 dB bandwidth is the frequency range where the signal power is within 10 dB from the maximum power.

Task-2.5

Identify three radio stations in the range $[87, 108]$ MHz with a strong signal and mark their center frequencies (found with the spectrum analyzer). Provide a plot of their spectrum.

Listening to FM Radio

Besides being used only as a measurement instrument, we can also process (demodulate) received signals with an SDR. To verify if the frequencies identified in the previous task correspond to radio stations we will now implement a functional, yet simple, FM radio receiver.
First, open the flowgraph *fm_receiver_template.grc*. This template contains :

- A variable specifying the sampling rate of the SDR.

- A GUI elements allowing to change the center frequency of the SDR.
- A GUI element that you will use to set the output volume.
- A *Soapy RTLSDR Source* outputting the complex baseband samples received by the SDR.
- A *Multiply constant* to control the volume of the output signal.
- A *QT GUI Sink* to visualize the audio signal.
- An *Audio Sink* which forwards samples to the computer sound card.

In the current state, the flowgraph will not build nor execute. We will need to add the actual functionalities to go from a complex baseband signal to a real audio signal.
You can find blocks by searching for their name in the search bar on the right part of window or by pressing "Ctrl+f". These blocks have simple functionalities, but in case of doubt, they have a "Documentation" tab when double clicking on them.
Note that the colors of the input and output ports correspond to different type of data. In this exercise you will encounter blue for complex (float) numbers, orange for floats, and grey for asynchronous messages (which you won't have to use).

Task-3.1: FM Demodulator

When a signal is modulated using frequency modulation, the value of the input signal $x(t)$ changes the instantaneous frequency of the carrier wave as illustrated in Fig. 1.

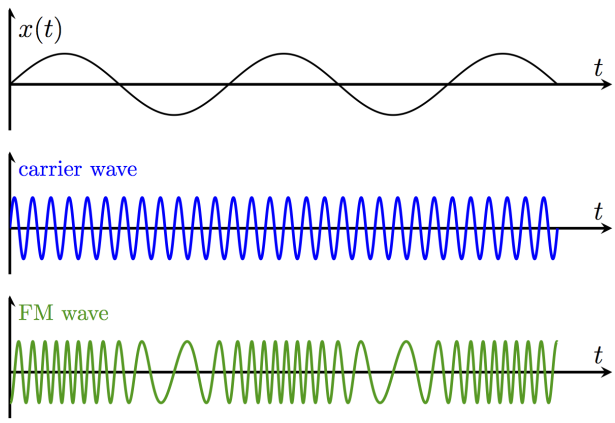


Figure 1: Illustration of FM modulation.

Add the block named *WBFM Receive* to the flowgraph. This block implement a wide-band FM receiver which takes complex IQ samples at the input and output a real audio signal.
This block has three parameters:

1. Quadrature Rate: This is the sample rate at the input of the block.

2. Audio Decimation: An integer ratio between the input and output rate. A value ≥ 4 is required for better sound quality.

3. Deemphasis Tau: A parameter of the FM modulation (75e-6 will work for local FM stations).

From the hardware configuration (radio and audio card), you have two constraints:

1. The sample rate of the audio sink should be 48 kHz.

2. The sample rate at the output of the SDR is 2048 kHz.

As the *WBFM* block imposes an integer ratio between its input and output, you need to resample the signal fed to its input (or output).
Add a block *Rational Resampler* to the flowgraph. This block allows you to resample a signal based on an interpolation and decimation value and telling what part of the output bandwidth is used (e.g 0.5 $\rightarrow$ signal over entire output bandwidth).

Using this block in addition to the FM demodulator, can you find a set of parameters that would allow you to go from the original 2048 kHz to 48 kHz? Give one possible combination and provide a screenshot of your flowgraph.

Task-3.2

Get a loudspeaker from the TA and connect it to your computer. If the loudspeaker is not recognized, log out of your account and log in again.
If the previous tasks are successful, you can now tune the center frequency of the receiver to the radio channels you identified in Task-2.3 and listen to the radio.
Fill the following table by helping you from the list of radio in Vaud and, for the emitter name, from the official swiss map here.
Hint: The official Swiss map provides many information on different radios technologies. In our case select only the *Radio and TV broadcasters* to only show radio towers. To find the list of station emitted by a broadcaster, click on it and follow the link *More info*. To find potential emitter, consider that a strong signal can come either from a closed-by location and/or a large transmit power.

Guessed frequency	Audible signal (yes/no)	Radio name	Actual radio frequency	Radio emitter name	Radiated power

Bonus: Exploring spectrum with CubicSDR

In this lab session, we used GNU Radio to build a simple spectrum analyzer and FM receiver. While GNU Radio is very powerful as it is very versatile, other software exist to perform specific tasks using SDRs. In this bonus task, you will use a software called CubicSDR to visualize and receive FM radio stations.

Task

Using CubicSDR, provide a screenshot showing the audio wave of three radio stations simultaneously.