Advanced topics in computer networks

UNIVERSITY OF
THESSALY

Semester Project Report

Angelis Marios, AEM: 2406

Charmanis Georgios, AEM: 2443

Brief Concept Description

The objective of our project was to create an FM station and an FM receiver using our laptops' microphone as input and speakers as output. Finally, we had to be able to decode the FM-RDS packets.

Extra objective: Implement a Stereo FM receiver and transmitter.

Implementation process

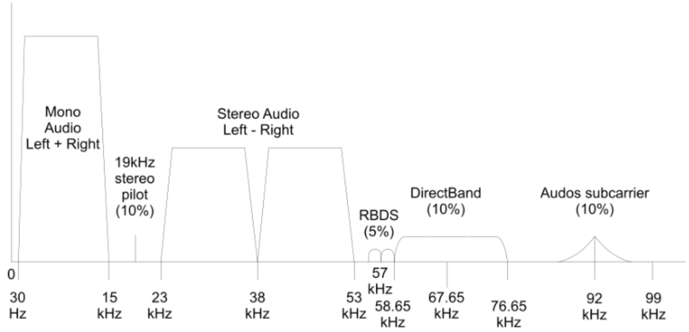
1. Build the FM receiver and make it able to listen to our local existing FM radio frequencies.
2. Build the FM radio transmitter on the second device and achieve communication between the two components.
3. Add all the RDS setting to the receiver from the existing radio stations.
4. Add all the RDS setting to the transmitter and configure it.
5. Implement the STEREO mode on the receiver from existing stereo stations.
6. Implement the STEREO mode on the transmitter and configure it.

Detailed functionality analysis

FM receiver: At first, we have a Pluto-SDR Source component with a fixed frequency of the desired radio station. We added a chooser to the GUI component to easily change frequencies, even during the runtime. We have set the bandwidth to 300 kHz with a sample rate of 768 kHz. After capturing the incoming signal, it is processed by a low-pass filter to cut a frequency of 80 kHz in the baseband. The remaining signal is FM demodulated with the use of a WBFM receiver, reducing the sample rate by half (384 kHz). Then, another low pass filter is used to reduce the frequency to 15 kHz, followed by a reduction of the sample rate to 48 kHz. The output signal is connected to an audio-sink, so that it can be played as sound from our laptop's loudspeakers. The same signal (after the demodulation) is used for the configuration of the RDS packets. The RDS packets have a central frequency of 57 kHz and a simple sideband bandwidth of 2.6 kHz.

FM transmitter: We use a WAV file as input to test our transmission. A rational re-sampler increases the initial sample rate from 48 kHz to 384 kHz and the signal is filtered to 13 kHz using a baseband low-pass filter. The output signal is the sound signal. After that, the RDS encoder module provides us with the RDS message in the form of a float sequence. We multiply that sequence with a sin wave of a 57 kHz central frequency. The sample rate of both signals (sound and RDS) is 384 kHz. Then, we add these two signals and perform FM modulation using a WBFM transmitter, we filter the signal to 80 kHz with a low-pass filter and transmit using the Pluto-SDR sink component with a final sampling rate of 768 kHz.

STEREO FM transmitter: As we can see from the image below, in stereo fm broadcasting, we transmit two signals. The first signal is called mono audio and it is placed in the range 30 Hz-15 kHz in the frequency domain and the second signal is called stereo audio and it is placed in the range 23 kHz - 53 kHz in the frequency domain. The mono audio contains an addition of two signals generated by the audio source and the stereo audio contains a subtraction of the same two signals generated by the audio source. Thus, the only difference from the basic FM transmitter is that we do not get only one input signal from the WAV file, but two. We then transmit two signals, the products of addition and subtraction of the two input signals.



STEREO FM receiver: The only difference from the basic FM receiver is that we receive two signals and we will use them to recreate the products of addition and subtraction of the two initial signals.

Each of the above components has the RDS functionality.

Sources of information and tools used for the implementation

As a first step of approaching this project, we had to search and thoroughly study various similar implementations and scientific publications. We used the IEEE library and Google Scholar as our sources.

To implement the forementioned topology, we used 2 Adalm-Pluto devices, one to operate as an FM transmitter and the other as an FM receiver. GNU Radio software was used for the implementation of both functionalities, as well as a testing environment. Some of the libraries we used are:

- gr-iio
- gr-rds
- libiio
- libad9361

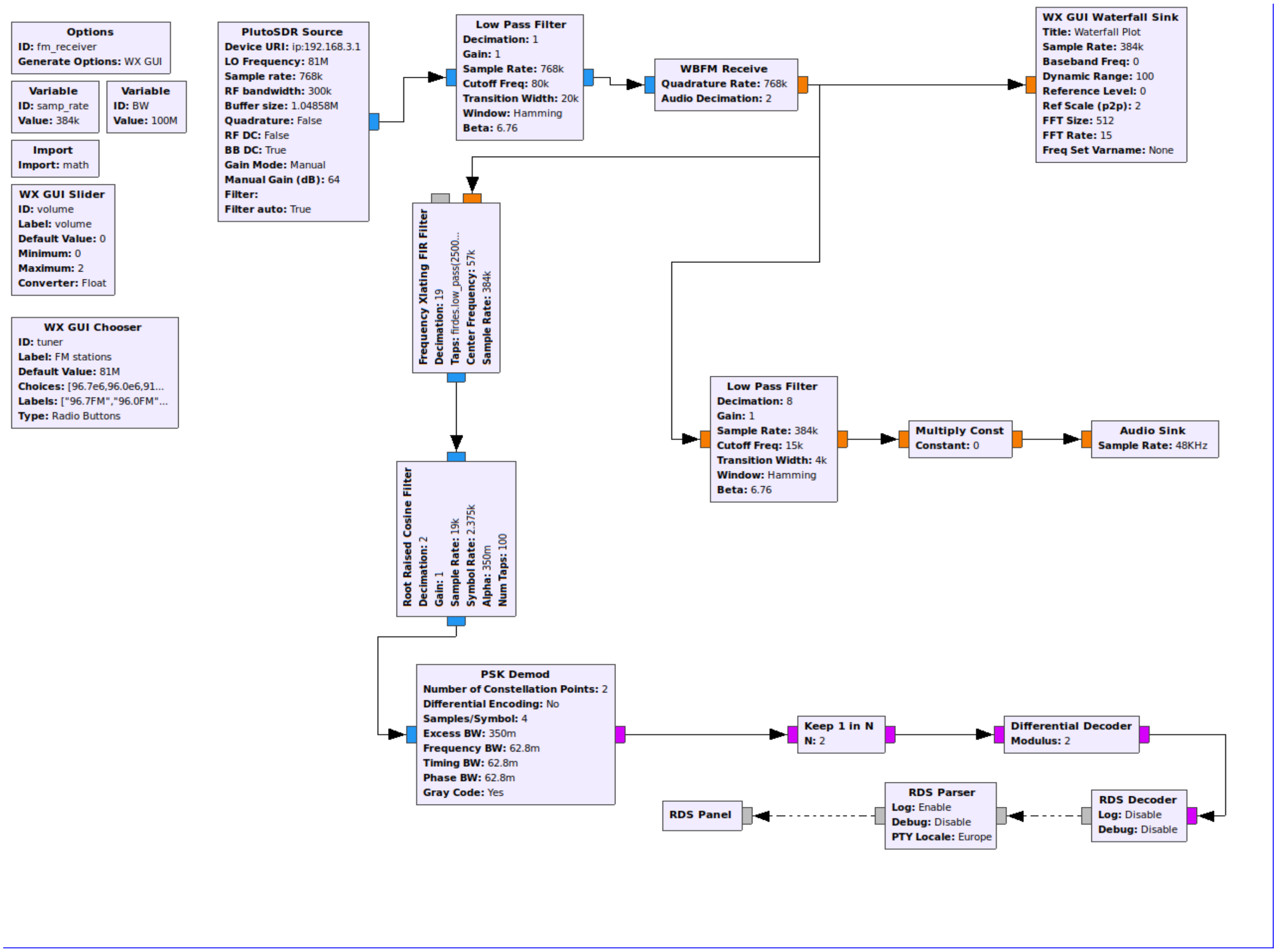
We also consulted the list of frequencies of all the public Greek FM Radio Stations, to test the functionality of the receiver and later, our implementation of RDS decoder.

Critical problems occurred and troubleshooting

- We did not use the proper sample rate values, which resulted in that we could not properly decode the captured signals.
- We did not make a proper use of the low pass filters; thus our transmission had a lot of interference.

Gnuradio implementations

FM receiver with rds



Options
ID: fm_receiver
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 384k

Variable
ID: BW
Value: 100M

Import
Import: math

WX GUI Slider
ID: volume
Label: volume
Default Value: 0
Minimum: 0
Maximum: 2
Converter: Float

WX GUI Chooser
ID: tuner
Label: FM stations
Default Value: 81M
Choices: [96.7e6,96.0e6,91...
Labels: ["96.7FM","96.0FM"...
Type: Radio Buttons

PlutoSDR Source
Device URI: ip:192.168.3.1
LO Frequency: 81M
Sample rate: 768k
RF bandwidth: 300k
Buffer size: 1.04858M
Quadrature: False
RF DC: False
BB DC: True
Gain Mode: Manual
Manual Gain (dB): 64
Filter:
Filter auto: True

Low Pass Filter
Decimation: 1
Gain: 1
Sample Rate: 768k
Cutoff Freq: 80k
Transition Width: 20k
Window: Hamming
Beta: 6.76

WBFM Receive
Quadrature Rate: 768k
Audio Decimation: 2

WX GUI Waterfall Sink
Title: Waterfall Plot
Sample Rate: 384k
Baseband Freq: 0
Dynamic Range: 100
Reference Level: 0
Ref Scale (p2p): 2
FFT Size: 512
FFT Rate: 15
Freq Set Varname: None

Frequency Xlating FIR Filter
Decimation: 19
Taps: firdes.low_pass(2500...
Center Frequency: 57k
Sample Rate: 384k

Root Raised Cosine Filter
Decimation: 2
Gain: 1
Sample Rate: 19k
Symbol Rate: 2.375k
Alpha: 350m
Num Taps: 100

Low Pass Filter
Decimation: 8
Gain: 1
Sample Rate: 384k
Cutoff Freq: 15k
Transition Width: 4k
Window: Hamming
Beta: 6.76

Multiply Const
Constant: 0

Audio Sink
Sample Rate: 48KHz

PSK Demod
Number of Constellation Points: 2
Differential Encoding: No
Samples/Symbol: 4
Excess BW: 350m
Frequency BW: 62.8m
Timing BW: 62.8m
Phase BW: 62.8m
Gray Code: Yes

Keep 1 in N
N: 2

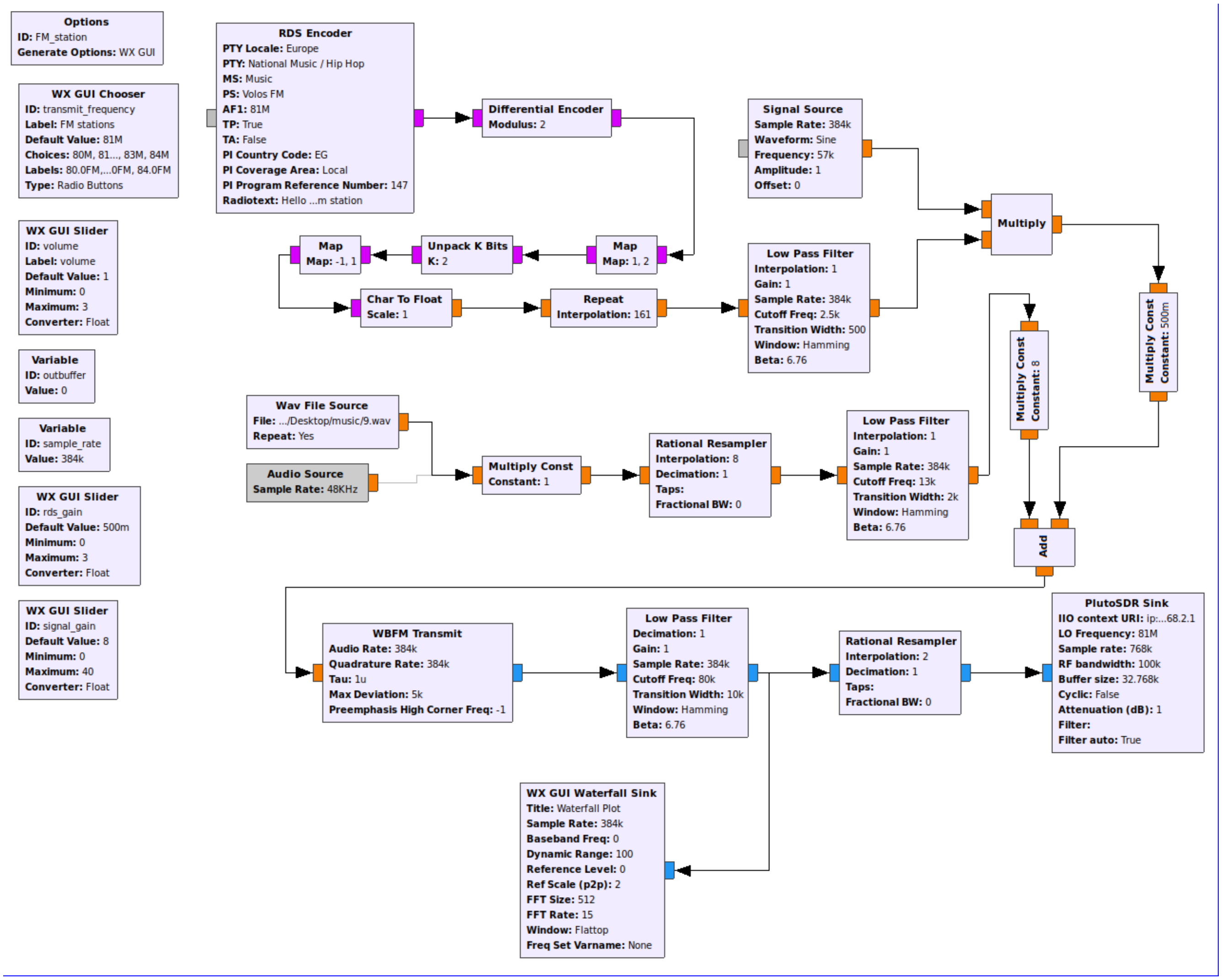
Differential Decoder
Modulus: 2

RDS Decoder
Log: Disable
Debug: Disable

RDS Parser
Log: Enable
Debug: Disable
PTY Locale: Europe

RDS Panel

FM transmitter with rds



Options
ID: FM_station
Generate Options: WX GUI

WX GUI Chooser
ID: transmit_frequency
Label: FM stations
Default Value: 81M
Choices: 80M, 81..., 83M, 84M
Labels: 80.0FM,...0FM, 84.0FM
Type: Radio Buttons

WX GUI Slider
ID: volume
Label: volume
Default Value: 1
Minimum: 0
Maximum: 3
Converter: Float

Variable
ID: outbuffer
Value: 0

Variable
ID: sample_rate
Value: 384k

WX GUI Slider
ID: rds_gain
Default Value: 500m
Minimum: 0
Maximum: 3
Converter: Float

WX GUI Slider
ID: signal_gain
Default Value: 8
Minimum: 0
Maximum: 40
Converter: Float

RDS Encoder
PTY Locale: Europe
PTY: National Music / Hip Hop
MS: Music
PS: Volos FM
AF1: 81M
TP: True
TA: False
PI Country Code: EG
PI Coverage Area: Local
PI Program Reference Number: 147
Radiotext: Hello ...m station

Differential Encoder
Modulus: 2

Map
Map: 1, 2

Unpack K Bits
K: 2

Map
Map: -1, 1

Char To Float
Scale: 1

Repeat
Interpolation: 161

Signal Source
Sample Rate: 384k
Waveform: Sine
Frequency: 57k
Amplitude: 1
Offset: 0

Low Pass Filter
Interpolation: 1
Gain: 1
Sample Rate: 384k
Cutoff Freq: 2.5k
Transition Width: 500
Window: Hamming
Beta: 6.76

Multiply

Multiply Const
Constant: 500m

Wav File Source
File: .../Desktop/music/9.wav
Repeat: Yes

Audio Source
Sample Rate: 48KHz

Multiply Const
Constant: 1

Rational Resampler
Interpolation: 8
Decimation: 1
Taps:
Fractional BW: 0

Low Pass Filter
Interpolation: 1
Gain: 1
Sample Rate: 384k
Cutoff Freq: 13k
Transition Width: 2k
Window: Hamming
Beta: 6.76

Multiply Const
Constant: 8

Add

WBFM Transmit
Audio Rate: 384k
Quadrature Rate: 384k
Tau: 1u
Max Deviation: 5k
Preemphasis High Corner Freq: -1

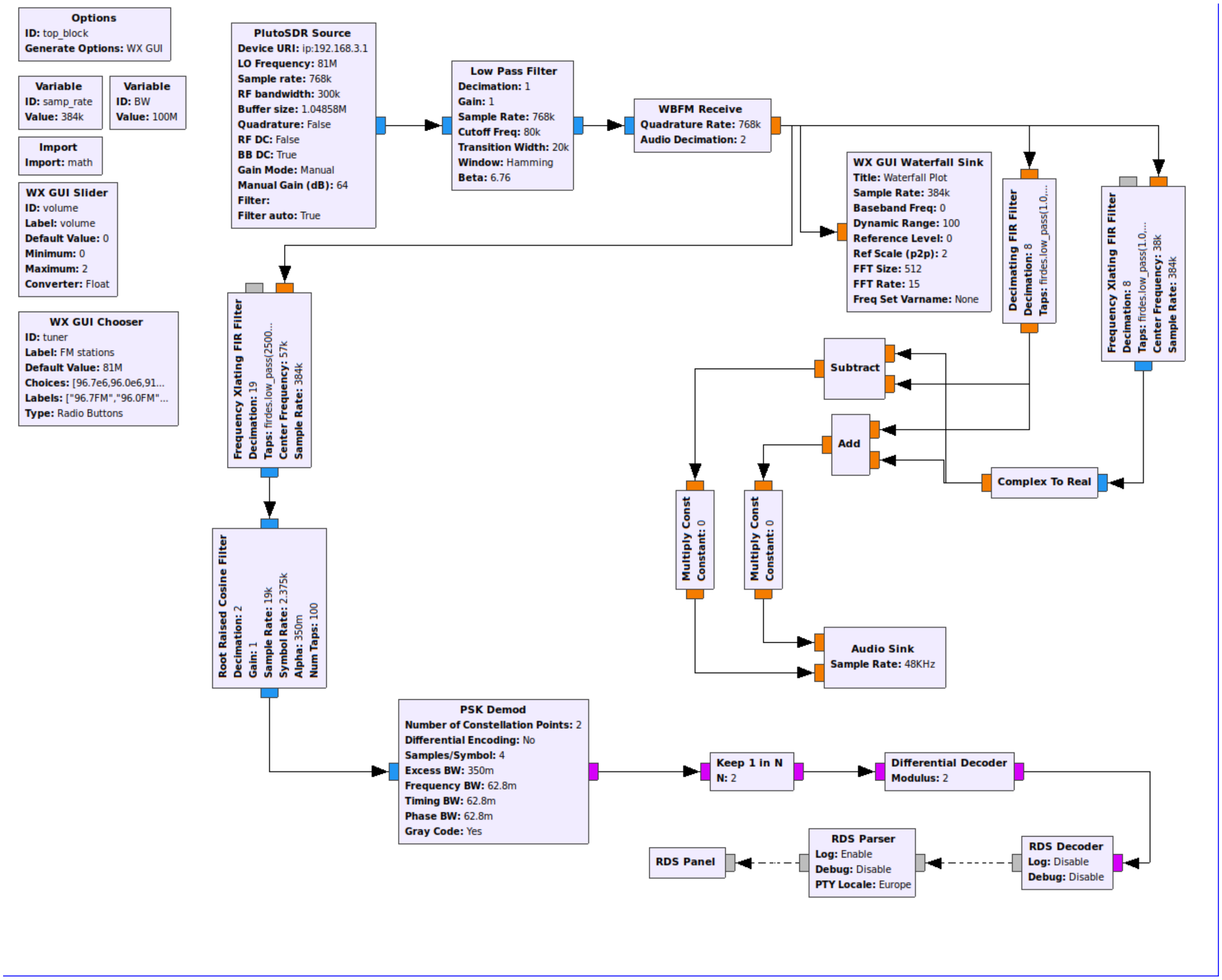
Low Pass Filter
Decimation: 1
Gain: 1
Sample Rate: 384k
Cutoff Freq: 80k
Transition Width: 10k
Window: Hamming
Beta: 6.76

Rational Resampler
Interpolation: 2
Decimation: 1
Taps:
Fractional BW: 0

PlutoSDR Sink
IIO context URI: ip:...68.2.1
LO Frequency: 81M
Sample rate: 768k
RF bandwidth: 100k
Buffer size: 32.768k
Cyclic: False
Attenuation (dB): 1
Filter:
Filter auto: True

WX GUI Waterfall Sink
Title: Waterfall Plot
Sample Rate: 384k
Baseband Freq: 0
Dynamic Range: 100
Reference Level: 0
Ref Scale (p2p): 2
FFT Size: 512
FFT Rate: 15
Window: Flattop
Freq Set Varname: None

STEREO FM receiver with rds



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 384k

Variable
ID: BW
Value: 100M

Import
Import: math

WX GUI Slider
ID: volume
Label: volume
Default Value: 0
Minimum: 0
Maximum: 2
Converter: Float

WX GUI Chooser
ID: tuner
Label: FM stations
Default Value: 81M
Choices: [96.7e6,96.0e6,91...
Labels: ["96.7FM","96.0FM"...
Type: Radio Buttons

PlutoSDR Source
Device URI: ip:192.168.3.1
LO Frequency: 81M
Sample rate: 768k
RF bandwidth: 300k
Buffer size: 1.04858M
Quadrature: False
RF DC: False
BB DC: True
Gain Mode: Manual
Manual Gain (dB): 64
Filter:
Filter auto: True

Low Pass Filter
Decimation: 1
Gain: 1
Sample Rate: 768k
Cutoff Freq: 80k
Transition Width: 20k
Window: Hamming
Beta: 6.76

WBFM Receive
Quadrature Rate: 768k
Audio Decimation: 2

WX GUI Waterfall Sink
Title: Waterfall Plot
Sample Rate: 384k
Baseband Freq: 0
Dynamic Range: 100
Reference Level: 0
Ref Scale (p2p): 2
FFT Size: 512
FFT Rate: 15
Freq Set Varname: None

Decimating FIR Filter
Decimation: 8
Taps: firdes.low_pass(1.0,...

Frequancy Xlating FIR Filter
Decimation: 8
Taps: firdes.low_pass(1.0,...
Center Frequency: 38k
Sample Rate: 384k

Frequency Xlating FIR Filter
Decimation: 19
Taps: firdes.low_pass(2500...
Center Frequency: 57k
Sample Rate: 384k

Root Raised Cosine Filter
Decimation: 2
Gain: 1
Sample Rate: 19k
Symbol Rate: 2.375k
Alpha: 350m
Num Taps: 100

Subtract

Add

Complex To Real

Multiply Const
Constant: 0

Multiply Const
Constant: 0

Audio Sink
Sample Rate: 48KHz

PSK Demod
Number of Constellation Points: 2
Differential Encoding: No
Samples/Symbol: 4
Excess BW: 350m
Frequency BW: 62.8m
Timing BW: 62.8m
Phase BW: 62.8m
Gray Code: Yes

Keep 1 in N
N: 2

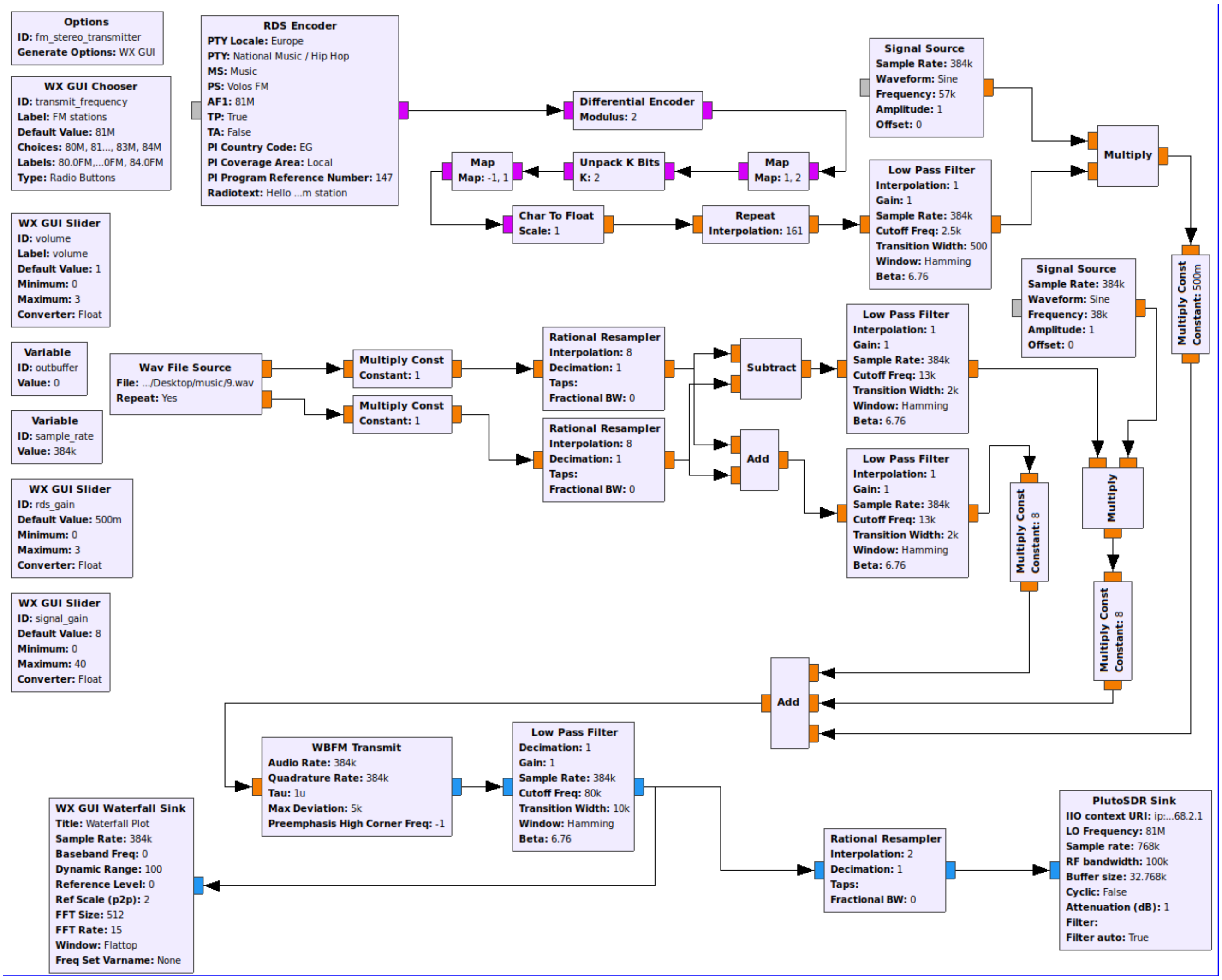
Differential Decoder
Modulus: 2

RDS Decoder
Log: Disable
Debug: Disable

RDS Parser
Log: Enable
Debug: Disable
PTY Locale: Europe

RDS Panel

STEREO FM transmitter with rds



Options
ID: fm_stereo_transmitter
Generate Options: WX GUI

WX GUI Chooser
ID: transmit_frequency
Label: FM stations
Default Value: 81M
Choices: 80M, 81..., 83M, 84M
Labels: 80.0FM,...0FM, 84.0FM
Type: Radio Buttons

WX GUI Slider
ID: volume
Label: volume
Default Value: 1
Minimum: 0
Maximum: 3
Converter: Float

Variable
ID: outbuffer
Value: 0

Variable
ID: sample_rate
Value: 384k

WX GUI Slider
ID: rds_gain
Default Value: 500m
Minimum: 0
Maximum: 3
Converter: Float

WX GUI Slider
ID: signal_gain
Default Value: 8
Minimum: 0
Maximum: 40
Converter: Float

RDS Encoder
PTY Locale: Europe
PTY: National Music / Hip Hop
MS: Music
PS: Volos FM
AF1: 81M
TP: True
TA: False
PI Country Code: EG
PI Coverage Area: Local
PI Program Reference Number: 147
Radiotext: Hello ...m station

Differential Encoder
Modulus: 2

Map
Map: -1, 1

Unpack K Bits
K: 2

Map
Map: 1, 2

Char To Float
Scale: 1

Repeat
Interpolation: 161

Signal Source
Sample Rate: 384k
Waveform: Sine
Frequency: 57k
Amplitude: 1
Offset: 0

Low Pass Filter
Interpolation: 1
Gain: 1
Sample Rate: 384k
Cutoff Freq: 2.5k
Transition Width: 500
Window: Hamming
Beta: 6.76

Multiply

Multiply Const
Constant: 500m

Wav File Source
File: .../Desktop/music/9.wav
Repeat: Yes

Multiply Const
Constant: 1

Multiply Const
Constant: 1

Rational Resampler
Interpolation: 8
Decimation: 1
Taps:
Fractional BW: 0

Rational Resampler
Interpolation: 8
Decimation: 1
Taps:
Fractional BW: 0

Subtract

Add

Low Pass Filter
Interpolation: 1
Gain: 1
Sample Rate: 384k
Cutoff Freq: 13k
Transition Width: 2k
Window: Hamming
Beta: 6.76

Low Pass Filter
Interpolation: 1
Gain: 1
Sample Rate: 384k
Cutoff Freq: 13k
Transition Width: 2k
Window: Hamming
Beta: 6.76

Signal Source
Sample Rate: 384k
Waveform: Sine
Frequency: 38k
Amplitude: 1
Offset: 0

Multiply Const
Constant: 8

Multiply

Multiply Const
Constant: 8

Add

WBFM Transmit
Audio Rate: 384k
Quadrature Rate: 384k
Tau: 1u
Max Deviation: 5k
Preemphasis High Corner Freq: -1

Low Pass Filter
Decimation: 1
Gain: 1
Sample Rate: 384k
Cutoff Freq: 80k
Transition Width: 10k
Window: Hamming
Beta: 6.76

WX GUI Waterfall Sink
Title: Waterfall Plot
Sample Rate: 384k
Baseband Freq: 0
Dynamic Range: 100
Reference Level: 0
Ref Scale (p2p): 2
FFT Size: 512
FFT Rate: 15
Window: Flattop
Freq Set Varname: None

Rational Resampler
Interpolation: 2
Decimation: 1
Taps:
Fractional BW: 0

PlutoSDR Sink
IIO context URI: ip:...68.2.1
LO Frequency: 81M
Sample rate: 768k
RF bandwidth: 100k
Buffer size: 32.768k
Cyclic: False
Attenuation (dB): 1
Filter:
Filter auto: True