Lab

To verify that the Decimating FIR Filter implements a discrete differentiator, I input a triangle wave to characterize the input/output (Fig. 1). The filter was configured with two taps [-1, 1] and no decimation, which gives the finite difference (y[n]=x[n]-x[n-1]) which approximates $\frac{\mathrm{dx}}{\mathrm{dt}}$ up to a scale of the sampling period. For a triangle wave with amplitude A and frequency f, the slope magnitude is $4Af$. After discrete differentiation at sample rate f_s, the expected output is a square wave with amplitude $|y| \approx \frac{4Af}{f_s}$ and the same fundamental frequency as the input. With $f_s = 100kS/s$ and $f = 10kHz$ the gain should be around $\frac{4Af}{f_s} = 0.4$. Figure 1 shows exactly the expected behavior, the blue trace (triangle input) becomes the red trace (square-wave output) with an amplitude of about 0.4 of the input and whose edges align with the triangle's rising/falling ramps. This shows that the FIR's taps perform the intended differentiation and validates the filter's in the FM slope detector.

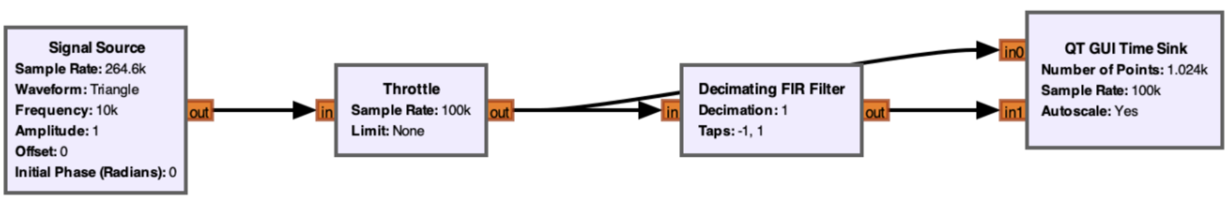

Figure 1: Simple differentiator with triangle wave input

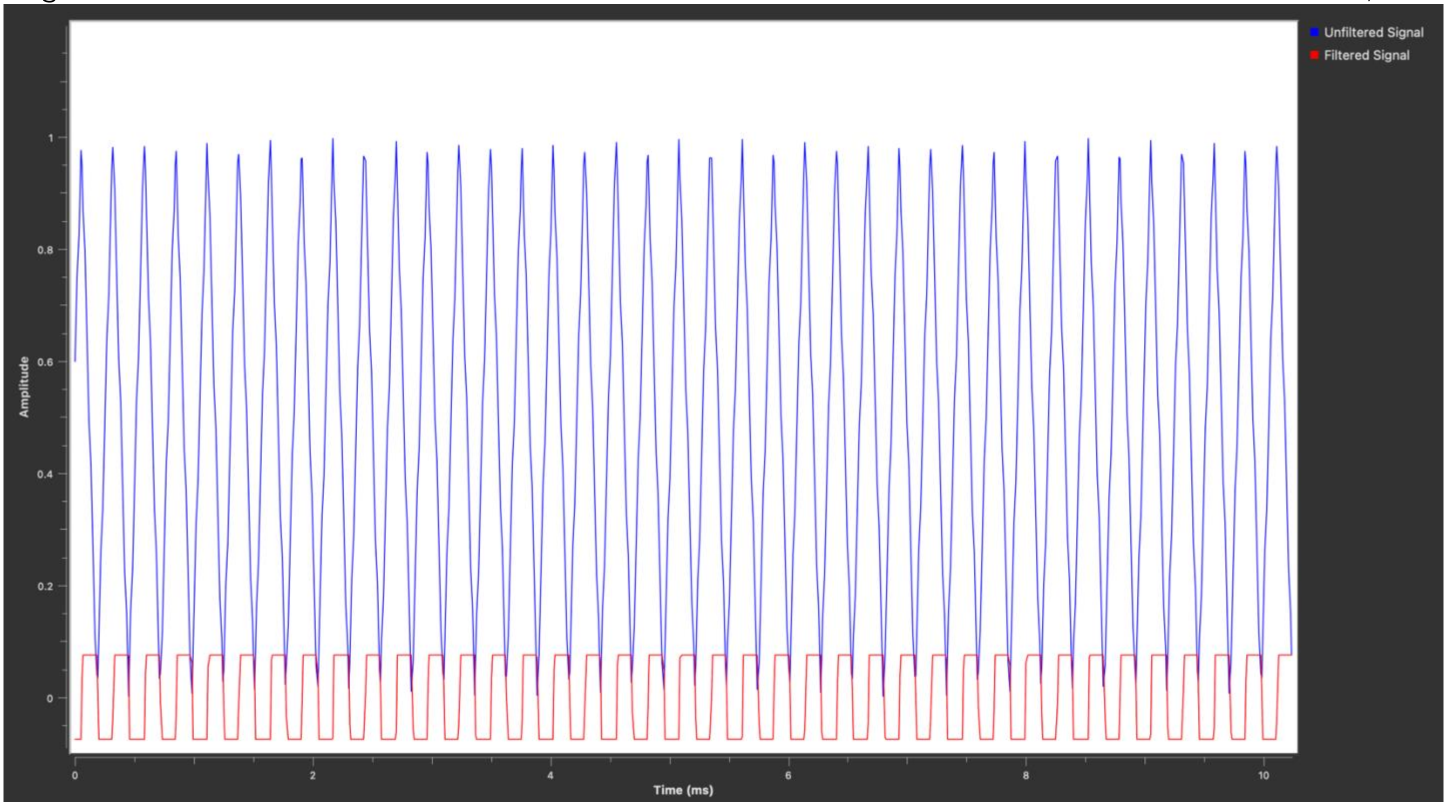

Figure 2: Input/Output of the differentiator

The design in Figure 3 converts a received FM broadcast into audio. The Osmocom Source delivers complex baseband IQ at 264.6 kS/s from the RTL-SDR. When tuned to a station, the content spans roughly a 200 kHz RF channel. The frequency is tunable and is used to select the station, rf_gain sets front-end amplification (where too little gives noise and too much results in clipping). This wideband FM stream then enters the discriminator stage.

The decimating FIR uses the taps [-1, 1] to implement the discrete differentiator just as before. For an FM signal differentiation produces an AM-like signal. The Complex-to-Magnitude block performs that envelope detection, giving a baseband audio waveform. A Low-Pass Filter retains mono audio while suppressing high-frequency noise; the DC Blocker removes the large constant term left by the envelope. Finally, a rational resampler converts the stream to 44.1 kS/s for the Audio Sink, producing audible mono audio.

The plot in Figure 4 shows the design working with a 100 kHz cutoff and 20 kHz transition filter. In the frequency plot is the FM channel spectrum centered near 0 kHz. The signal spans roughly ±100 kHz, and the rounded areas between about ±100 kHz and ±120 kHz are the filter's 20 kHz transition band. That shape is from the low-pass that keeps the ~200 kHz FM channel while tapering off outside it. The narrow notch at 0 kHz is from DC suppression, and the small ripples across the top are a mix of the discriminator and noise from the broadcast. The time plot shows the corresponding wideband waveform after discrimination/envelope. Because the channel filter is very wide (100 kHz), a lot of high-frequency content and noise gets through, so the waveform looks jagged with sharp excursions rather than smooth.

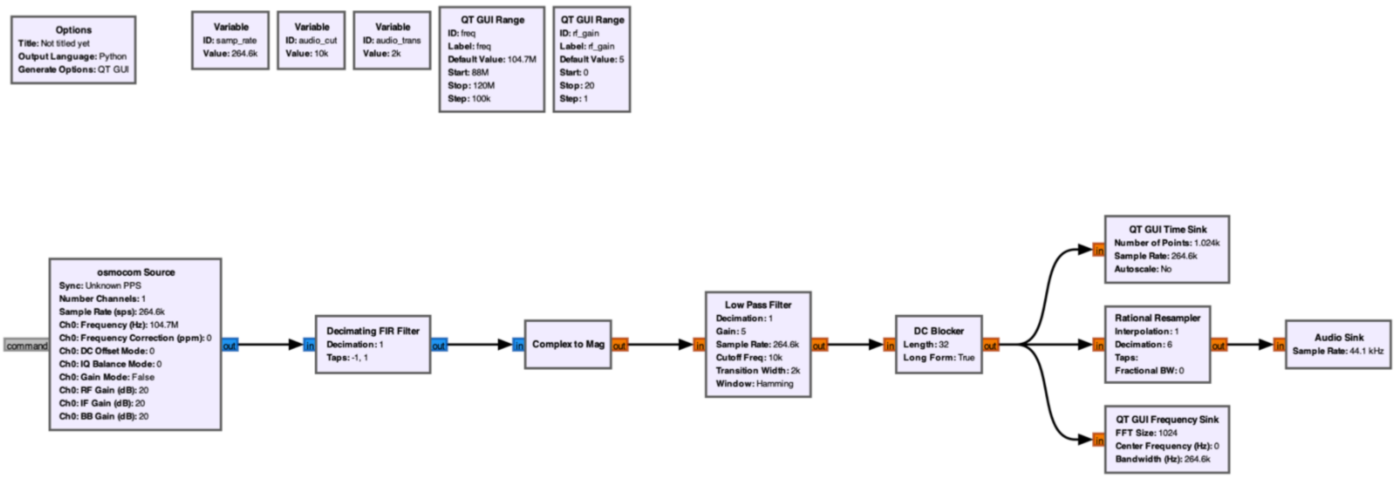

Figure 3: Block diagram of the FM demodulator

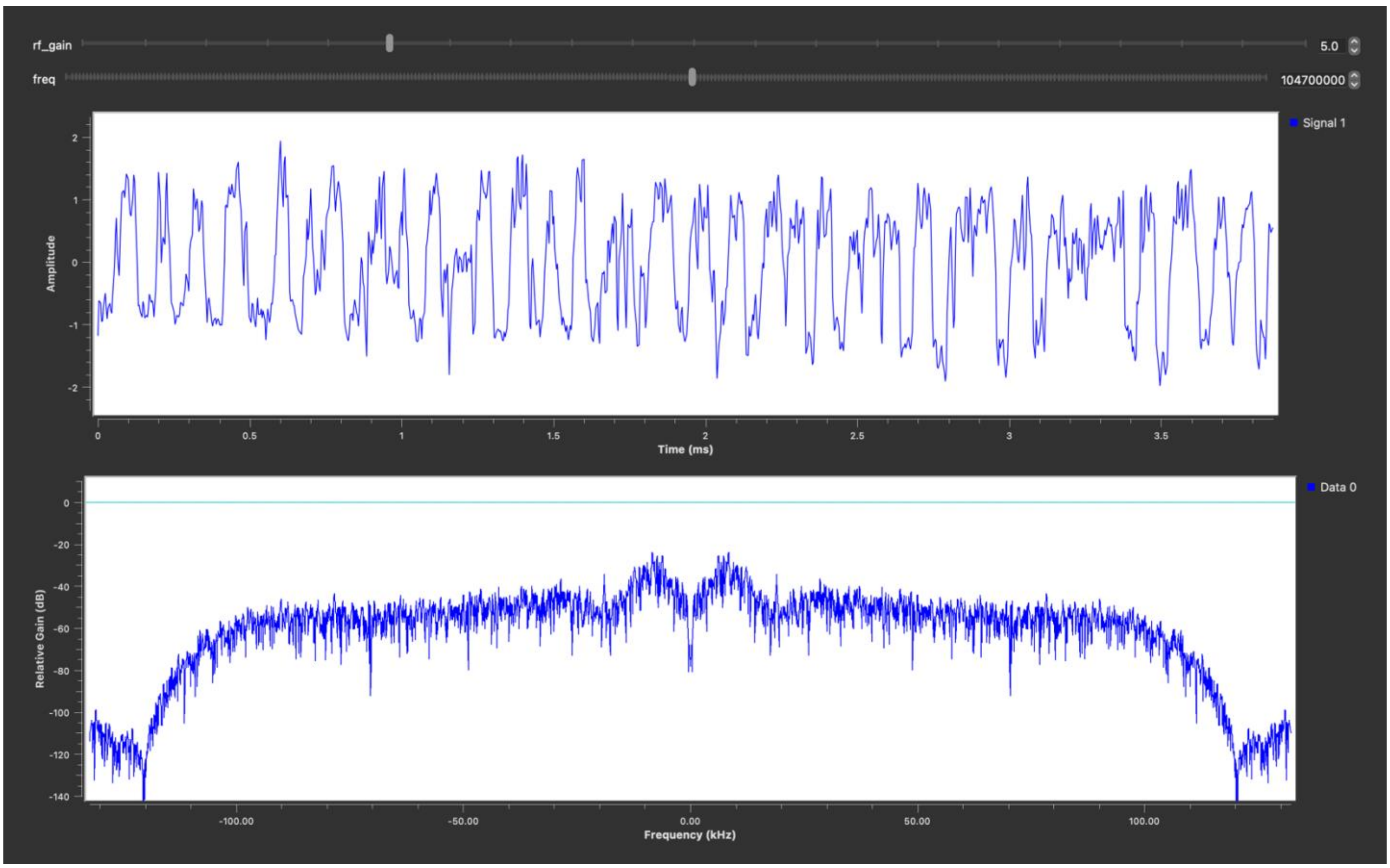

Figure 4: Time and spectral output of the FM demodulator