Pre-Lab

All diagrams were created using Miro

1.) For $r(t) = m(t)cos(2\pi f_c t + \theta)$

The I arm (Cos Lo):

$$LPF\{r(t)cos(2\pi f_c t)\} = LPF\{m(t)cos(2\pi f_c t + \theta)cos(2\pi f_c t)\}$$

$$= LPF\{\frac{m(t)}{2}[cos\theta + cos(4\pi f\_\{c\}t + \theta)]\}$$

$$= \frac{m(t)}{2}cos\theta$$

$$\boldsymbol{m_I(t) = m(t)cos\theta}$$

Q arm (sin Lo):

$$LPF\{r(t)sin(2\pi f_c t)\} = LPF\{m(t)cos(2\pi f_c t + \theta)sin(2\pi f_c t)\}$$

$$= LPF\{\frac{m(t)}{2}[sin(4\pi f\_\{c\}t + \theta) - sin\theta]\}$$

$$= -\frac{m(t)}{2}sin\theta$$

$$m_Q(t) = -m(t)sin\theta$$

2.)

$$m_I(t) = m(t)cos\theta \ \&\ m\_Q(t) = -m(t)sin\theta$$

If we want $am_I(t) + bm_Q(t) = m(t)$

Then if we use $a = cos\theta,\ b = -sin\theta$

We get $cos\theta m_I - sin\theta m_Q = m(t)(cos^2\theta + sin^2\theta) = m(t)$

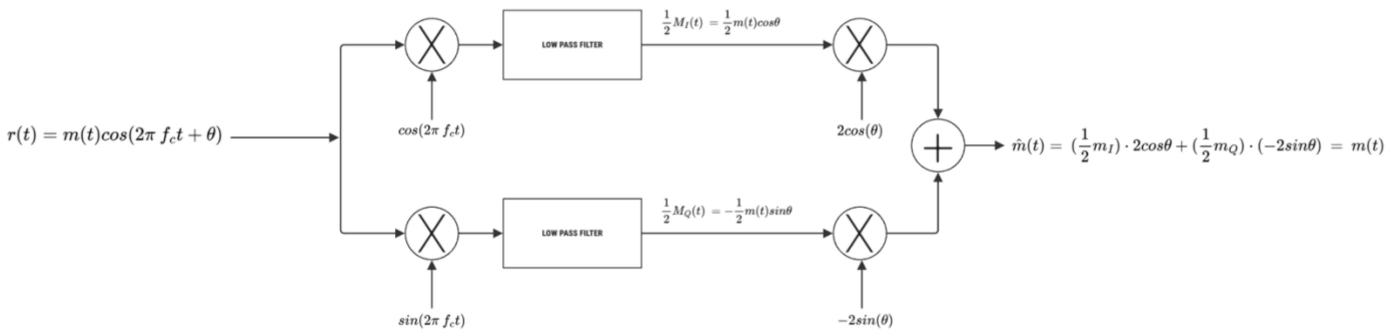


Figure 1: Quadrature coherent modulator (real LO)

3.) $r(t) = [A + m(t)]cos(2\pi f_c t + \theta)$

After the mixing and LPF: $I(t) = \frac{1}{2}[A + m(t)]cos\theta, Q(t) = -\frac{1}{2}[A + m(t)]sin\theta$

Square and add: $I^2(t) + Q^2(t) = \frac{1}{4}[A + m(t)]^2(cos^2\theta + sin^2\theta) = \frac{1}{4}[A + m(t)]^2$

Square root (envelope): $E(t) = \sqrt{I^2 + Q^2} = \frac{1}{2}|A + m(t)| = \frac{1}{2}[A + m(t)]$

Remove DC: $y(t) = E(t) - \frac{A}{2} = \frac{1}{2}m(t) = km(t), wherek = \frac{1}{2}$

$$m(t) = 2\sqrt{I^2 + Q^2}$$

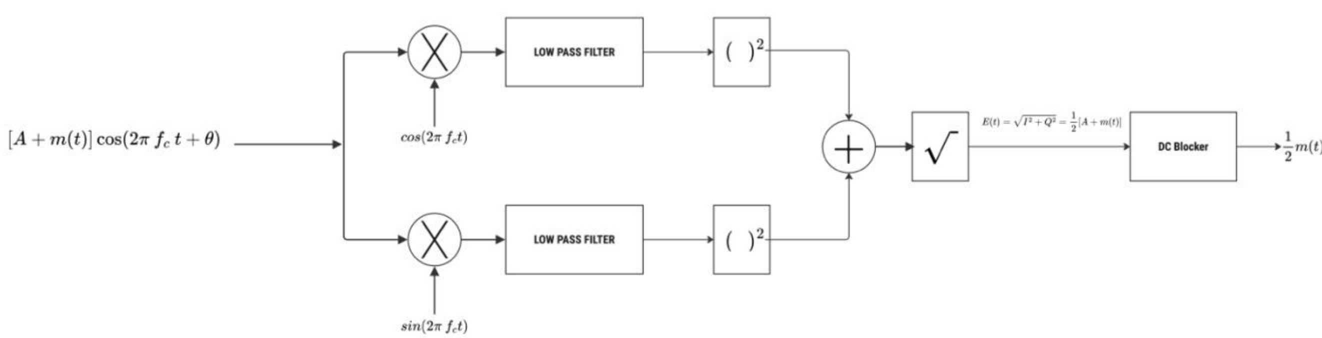


Figure 2: I/Q envelope detector for AM (real LO)

4.) Given $r(t) = m(t)cos(2\pi f_c t + \theta)$

$$r(t)e^{j2\pi f_c t} = m(t)\frac{e^{j2\pi f_c t+\theta} + e^{-j2\pi f_c t}}{2}e^{j2\pi f_c t}$$

$$= \frac{m(t)}{2}(e^{j4\pi f_c t} + e^{-j\theta})$$

After the LPF, the complex baseband output is as follows:

$$m_c(t) = \frac{1}{2}m(t)e^{-j\theta}$$

$$m_{REAL}(t) = \frac{1}{2}m(t)cos\theta, m_{IMAG} = \frac{1}{2}m(t)sin\theta$$

5.)

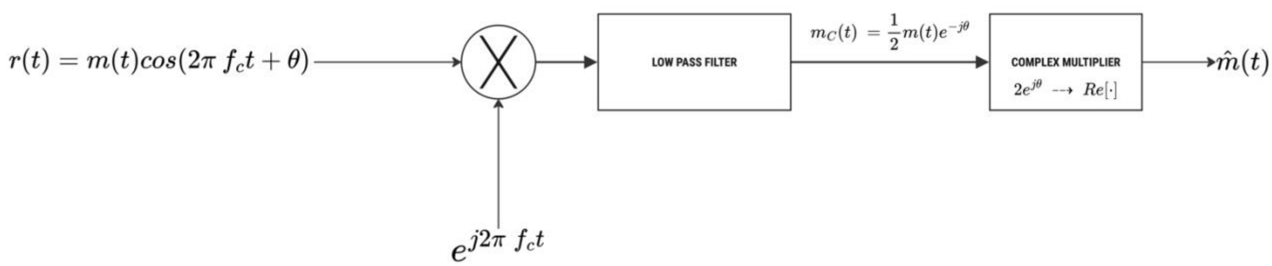


Figure 3: Coherent demodulator in complex baseband

6.)

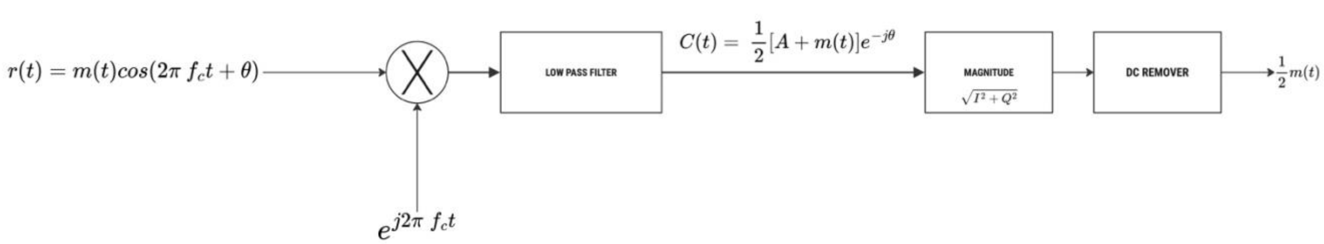


Figure 4: Complex signal envelope detector

Lab

In this lab I built an envelope receiver for a broadcast AM signal in the 915 MHz ISM band using an RTL-SDR with the osmosdr Source. The source produced I/Q samples at 264.6 kS/s while a tunable LO (≈ 916.99–917.01 MHz) mixed the RF to complex baseband with an unknown phase. To make the detector phase independent, I took the magnitude of the complex baseband (equivalent to $\sqrt{I^2 + Q^2}$) via complex to mag, then used a low pass filter with adjustable cutoff (≈ 1–50 kHz) and gain to pass the audio band. A DC Blocker removed the carrier/DC residue, and a rational resampler (decimating to 44.1 kS/s) fed the audio sink for listening. The PSD of the "Abs Output" showed a carrier at baseband with symmetric sidebands whose width tracked the audio bandwidth, and the time-domain plot displayed a clean audio waveform after filtering and gain adjustment. Overall, the quadrature-based envelope detection worked as expected without needing carrier phase recovery, and the adjustable LPF/gain allowed forbalancing fidelity and noise while successfully demodulating the AM transmission.

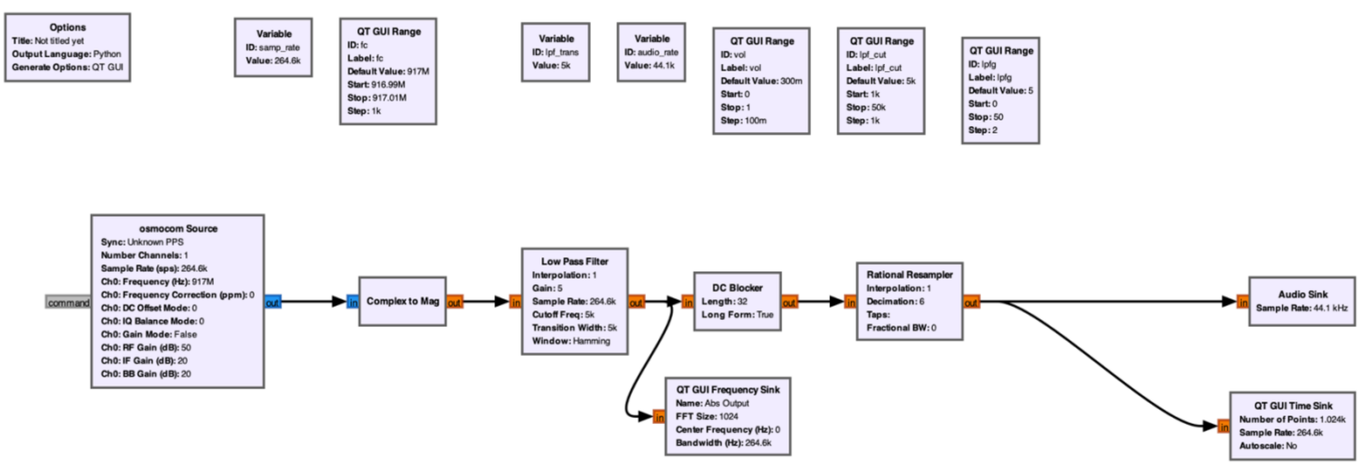
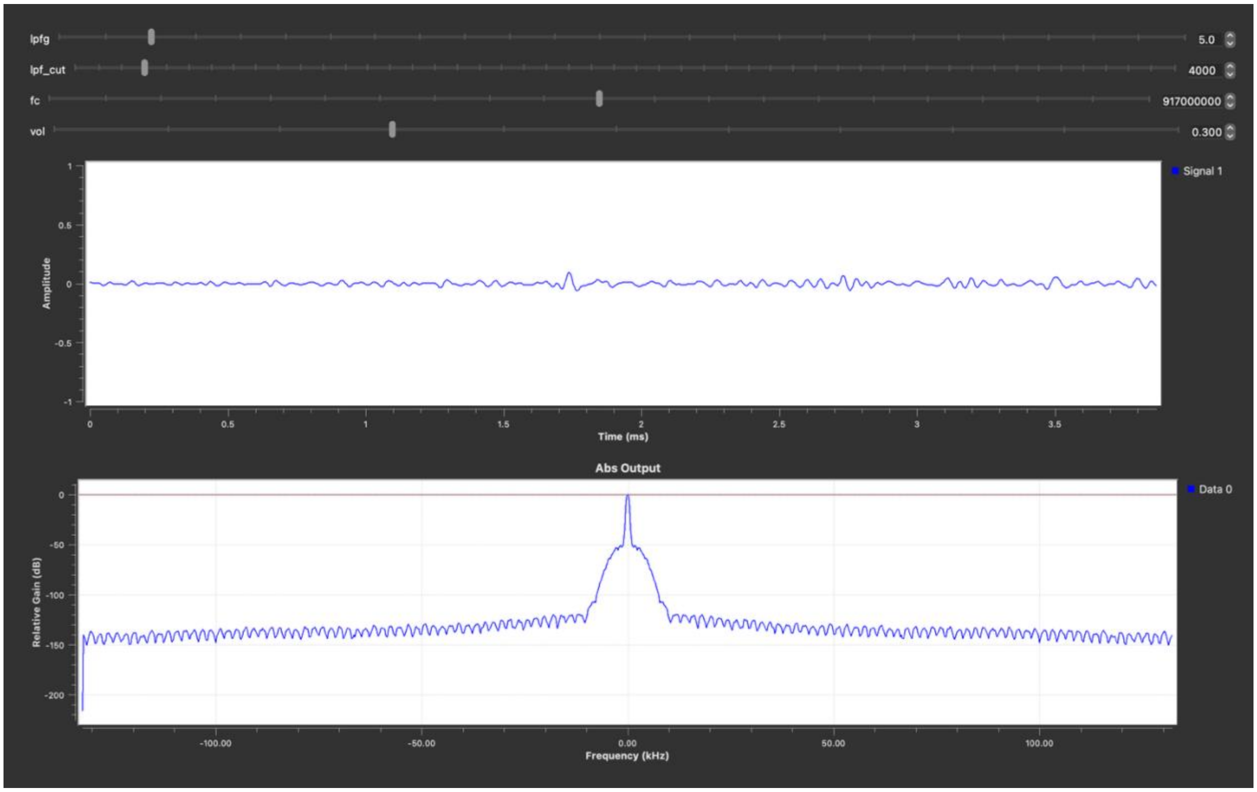


Figure 5: Block diagram of the envelope receiver



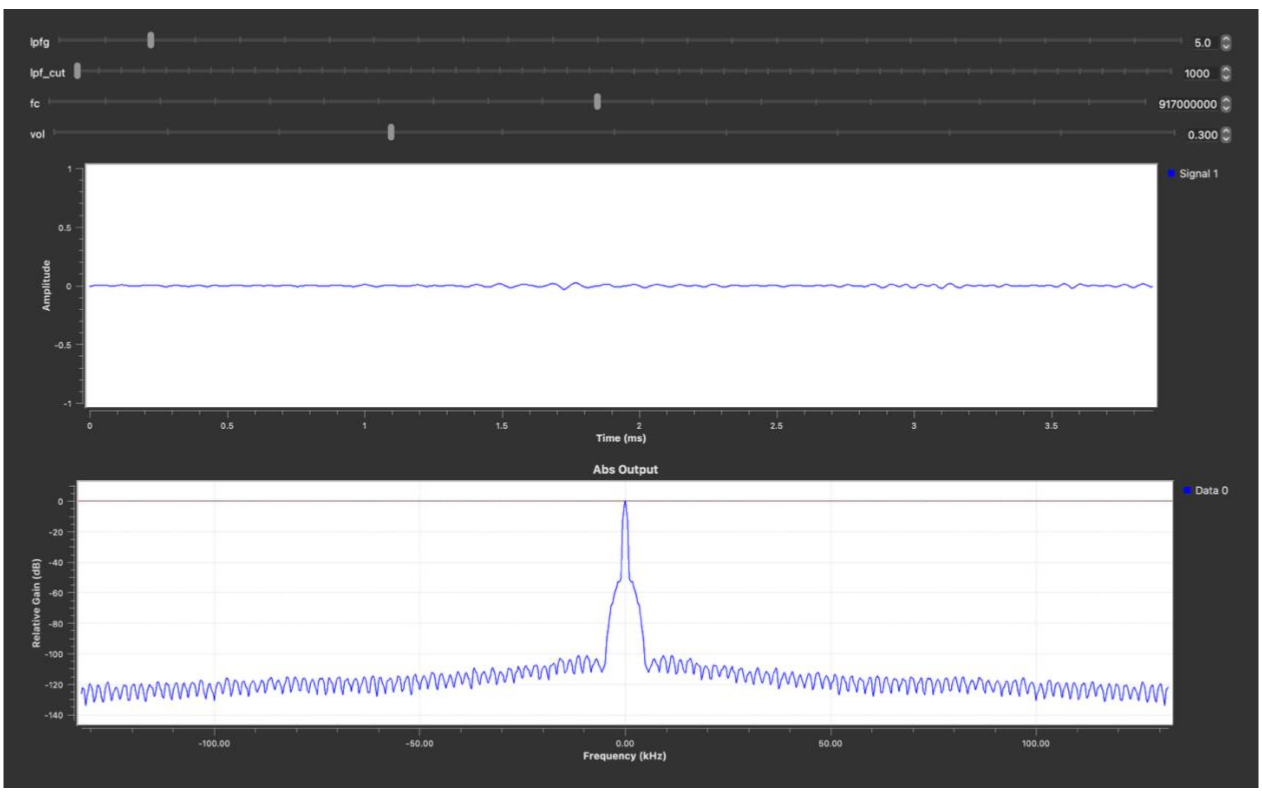


Figure 6: Envelope detector with tunable LPF — 4 kHz vs 10 kHz cutoff.