EEL 4514C: Communication Systems and Components (Fall 2025)

Lab 5: AM Envelope Detection

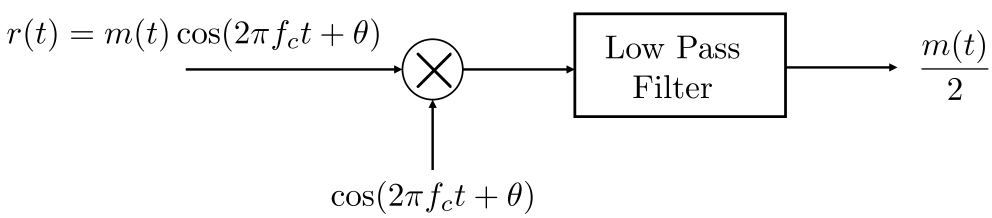
Deliverables Due: At 11:59pm on October 20, 2025.

Introduction and Pre-Lab

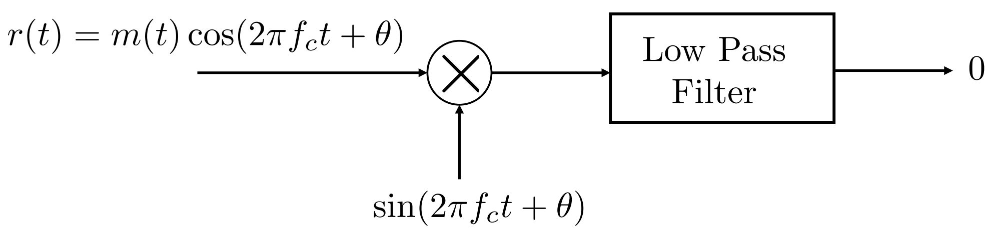
Goals:

- Learn about quadrature receivers
- Learn about complex representations of signals
- Understand the meaning of the complex output of the `osmocom Source` block in GRC
- Build an envelope detector for an AM signal using GRC

Consider again the problem of detecting an incoming amplitude-modulated signal. In a **heterodyne receiver**, the signal is mixed with an oscillator at the same frequency as the incoming signal. For instance, if the signal is DSB-SC and the phase can be matched (for instance, using a phase-locked loop), the resulting receiver structure looks like:

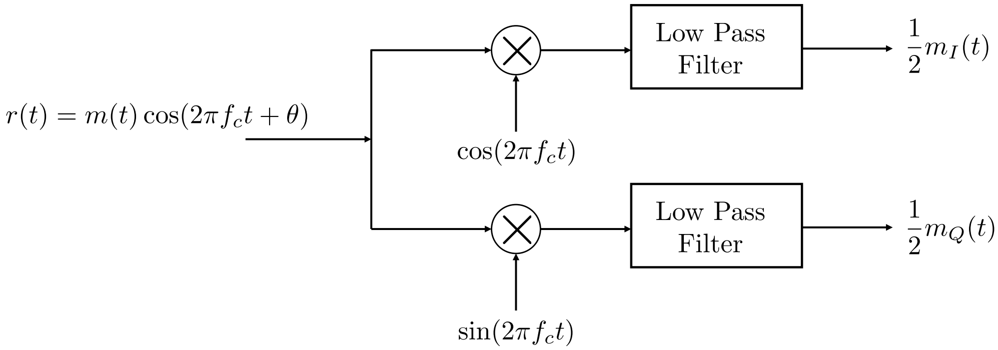


But what if the phase is unknown? By the orthogonality of sine and cosine, we can see that



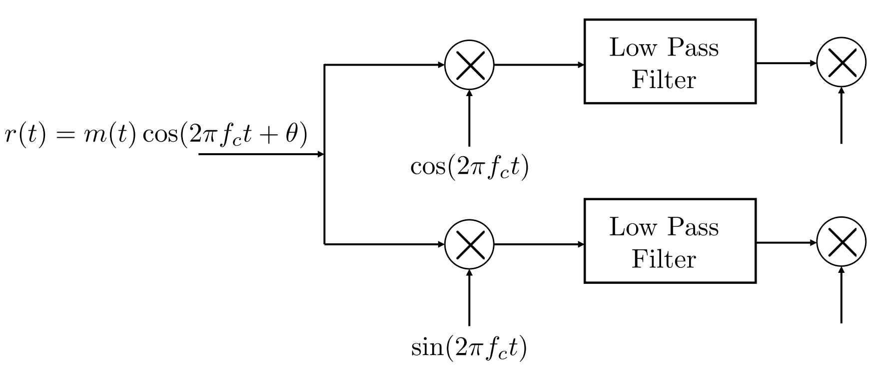
However, that might generate an idea. What if we correlate with both a cosine and a sine carrier?

1. Determine the output signals $m_I(t)$ and $m_Q(t)$ for both of the matched filters in the picture below.



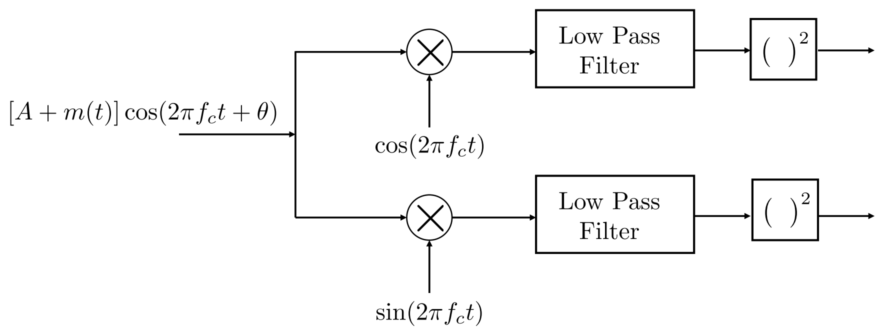
This is a **quadrature receiver**.

2. If we can estimate θ, we can recover the signal $m(t)$ as a linear combination of $m_I(t)$ and $m_Q(t)$. Determine the values a and b (as functions of θ) such that $am_I(t) + bm_Q(t) = m(t)$. Using this idea, complete the block diagram below.



Thus, we can perform coherent detection on the baseband quadrature signal.

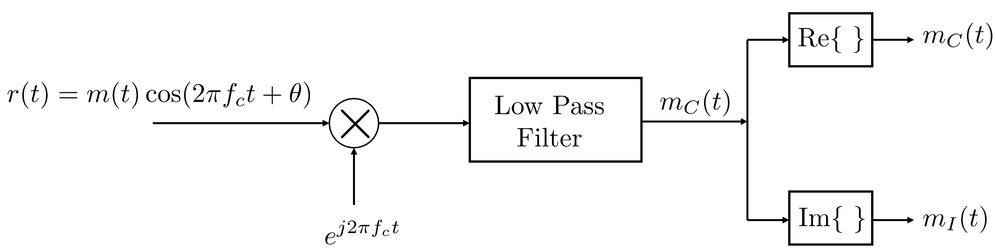
3. Similarly, if $r(t)$ is AM modulation, we can perform envelope detection using $m_I(t)$ and $m_q(t)$ without knowing θ. Consider the partial demodulator shown below. Draw the additional blocks needed to output $km(t)$, where k is some constant that is independent of θ and f_c.



Complex Representation

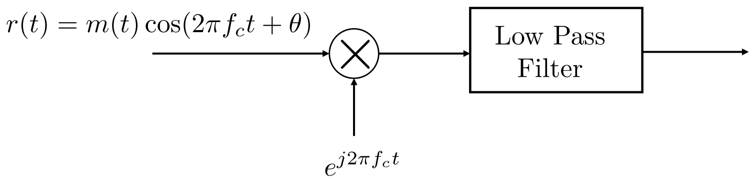
Now we introduce the idea of a complex carrier as a way to make this approach more concise and general.

4. Consider the receiver below.

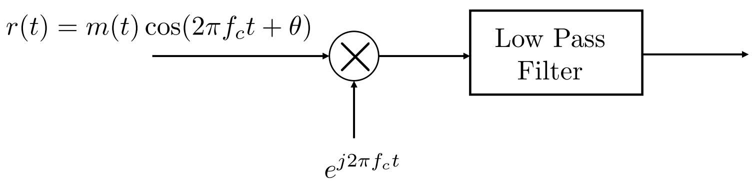


Determine the complex output of the low pass filter, $m_C(t)$, and the real and imaginary parts of that signal, $m_R(t)$ and $m_I(t)$. Compare your answers to your answers for problem 1.

5. Based on your coherent demodulator design from part 2, complete the following block diagram to implement a coherent demodulator on the complex signal.



6. Based on your envelope detector design from part 3, complete the following block diagram to implement an envelope detector on the complex signal.



Lab Experiments

GRC components:

- 1 osmocom Source block
- 1 Rational Resampler block
- 1 Complex to Mag block
- 1 Low Pass Filter block
- 1 DC Blocker block
- QT GUI Range blocks
- 1 QT GUI Time Sink block
- 1 QT GUI Frequency Sink block
- 1 Audio Sink block
- Any other blocks as you see fit

Design Requirements:

1. AM radio broadcasts in the US do not fall within the normal frequency range of the SDR dongle. So the TA will send out our own AM signal in the 915MHz ISM band. **You will need to go to the lab sessions to receive this signal.**

   Direct sampling (not tested yet!): If you have one of the RTL SDRs that support direct sampling, you may be able to receive a broadcast radio AM signal by using the RTL-SDR source and setting the parameter `direct_samp=1` in the `Device Arguments` field (visible when you double click on the block). If your device supports direct sampling, you may also be able to modify the directions below to receive a broadcast radio station, such as WRUF 850 (kHz). Note in particular, that you will have to use a higher sampling rate to capture the AM radio signal. With direct sampling, the RF signal has *not* been mixed with carrier signals, so any mixing needs to be done as part of your flowgraph.

2. Construct a signal flowgraph to implement an envelope receiver based on quadrature detection. Set the sampling rate of the `osmocom Source` block to 264.6 kHz. The `osmocom Source` block mixes the received signal with a local reference carrier whose frequency is set by you. For example, if you set the frequency of local reference carrier to f_c and the received signal is $y(t)$, then the mixer output is $y(t)\cos(2\pi f_c t + \theta)$, where θ is the unknown phase offset of the local carrier reference w.r.t. the transmitted carrier. Since the phase offset is unknown, this mixer output may have very small magnitude. To circumvent this problem, the `osmocom Source` block actually implements another mixer with the sine carrier reference, i.e., $y(t)\sin(2\pi f_c t + \theta)$. The mixer outputs from the cosine and sine references are respectively provided as the real and imaginary parts of a complex signal $z(t)$. The magnitude of $z(t)$ gives us the envelope of the AM signal.

3. The carrier frequency of the broadcast AM is set to 917 MHz. Your receiver needs to allow adjustment of its carrier frequency over the range from 916.990 to 917.010 MHz.

4. The LPF bandwidth in your receiver should be made adjustable over the range from 1 to 50 kHz. You may also want to make its gain adjustable.

5. Take screen captures that show the PSD of the broadcast AM signal and the time-domain waveform of the demodulated signal.