GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL of ELECTRICAL and COMPUTER ENGINEERING

ECE 2025 Spring 2001
Lab #12: AM Communication System

Date: 9 April – 26 April

This is *the official* Lab #12 description.

If you have a PC-compatible microphone (and headphones), please bring them to lab for the warm-up.

Lab Quiz #3 will be held during the week of 16–19 April.

Even though this lab is not due until the week of April 23-26, it is important to get your verifications done during the week of 9 April. You will not have time to complete both the verifications and the Lab Quiz during the week of 16–19 April.

During the week of (23-26 April), lab will be held. You will have to fill out surveys and also demonstrate your working AM system.

The lab report for this lab will be **INFORMAL**. Include explanations as well as spectrogram plots to illustrate the spectral content of the AM signals in Part 3.

The report will be **due during the week of 23 April at the start of your lab.**

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1 Introduction & Objective

The goal of this laboratory project is to illustrate the inner workings of a communication system based on AM (Amplitude Modulation). Ideally your lab report should demonstrate that you can produce a functional AM system that operates on a voice signal.

1.1 Think Independently

One objective of your education is to **"learn how to learn"** and how to extend your skills on your own. Thus the second goal in this lab is for you to demonstrate that you can "Think independently." As a result, the lab instructions are minimal, but should be well within your capability as an experienced MATLAB user.

Your written lab report should document that you can produce an interesting demonstration of AM. There are many ways to do this, so formulate your own plan of action.

2 Warmup

In this warm-up you must do four things:

(a) Download the file `Lab12_s01.mat` from WebCT. (It's actually inside of `Lab12_s01.zip`.) Verify that there are three items in this file: The vector `s` is a speech file sampled at 44.1 kHz sampling rate. The vector `b` is a set of FIR filter coefficients. The variable `fs` is the sampling rate.

(b) Demonstrate to your TA that you can record a few seconds of your voice at $f_s = 44.1$ kHz. Use the Windows Accessory called *Sound Recorder* and save the signal as a WAV file. When you need the signal in MATLAB, use the function `wavread()`.
Instructor Verification (separate page)

(c) Use `freqz( )` to compute the frequency response of the filter whose coefficients are the vector `b` that you just downloaded. Make a plot of the frequency response over a band of frequencies corresponding to $0 \leq f \leq 4$ kHz assuming that the sampling rate is $f_s = 44.1$ kHz.
Instructor Verification (separate page)

(d) First use `soundsc( )` to listen to the voice signal that you recorded. Then filter your voice signal through the lowpass filter and play out the result. It should sound similar to the original recording but qualitatively different. How would you describe the difference? Convince your TA that the output has no frequency components above 2 kHz (by using an appropriate spectrogram plot).
Instructor Verification (separate page)

3 AM Communication System

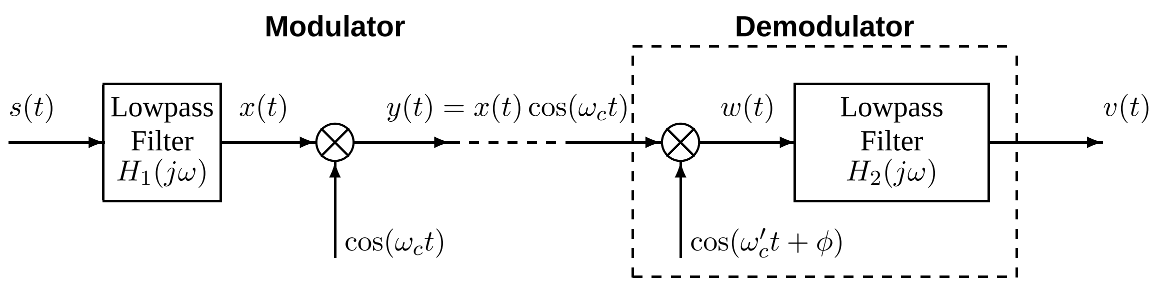

Figure 1: Block diagram of sinusoidal modulation followed by demodulation with variable phase.

In this part of the lab project, you must do an implementation of a single channel AM communication system (Fig. 1). Here are the steps:

1. Make an input signal by recording your voice for a one or two seconds. Use a sampling rate of 44.1 kHz. The best test signal would have lots of vowels. Plot the waveform using plot. Determine the beginning and end of significant speech activity and select only that region for processing. As a second test signal, use the vector `s` that is downloaded with `Lab12_s01.mat`.

2. Filter the voice signal with the given FIR lowpass filter.

3. Display the spectrogram of your filtered voice and *estimate* the bandwidth of the speech signal.

4. Make an AM signal by multiplying your voice by a cosine. Use a "carrier frequency" $f_c = \omega_c/(2\pi)$ that is between 8 kHz and 9 kHz.[1]

5. Simulate the demodulator for the AM signal. Write the demodulator as a MATLAB function with input arguments for the frequency and phase. In other words, implement a demodulator that can have a different carrier frequency $f_c' = \omega_c'/(2\pi)$ and non-zero phase ϕ. *Note: The analysis of this demodulator is done in Problem 12.1 of Prob Set #12. Work this problem before doing the experiment.*

6. First experiment with the effect of the phase difference. Set the demodulator carrier frequency exactly equal to the modulator carrier frequency. You can hear the effect of phase if you normalize your input signal $s(t)$ so that its maximum magnitude is 1. Then you can listen to the various signals using `sound( )` rather than `soundsc( )`. If you use `sound( )` you will hear amplitude differences

[1] To make your choice of frequency unique, pick the carrier frequency as follows: Add the last THREE digits of your SSN to 8,000 and round to the nearest multiple of 100.

because this function does not rescale the signal, however, it does assume that the signal amplitude is less than or equal to 1. Demonstrate how the demodulator output depends on the phase. Show that for one choice of the phase that you get zero output.

7. Next set the phase to zero and make the demodulator carrier frequency 10 Hz higher than the carrier frequency of the modulator. Listen to the demodulated signal. How do you characterize the output?

8. Demonstrate your working system to your lab TA.

Make spectrograms at the appropriate points to show what is happening to the signal in the frequency domain, e.g., show the spectrogram at each point in the demodulator.

3.1 Explanations

Explain using Fourier transforms, mathematics and sketches how your AM system works One aspect of this is to explain why “phase matters” in the receiver’s mixer, but it is also important to draw sketches of the Fourier transform to show where the signal’s spectrum lies at any point in the system. Make a spectrogram at certain key places in the system to explain what is going on. You don’t need every one, but you should use the Fourier knowledge that you gained in the previous part to decide which ones are useful. In particular, make a spectrogram of the AM signal $y(t)$. Point out the upper and lower sidebands in the spectrogram. Since the theory shows that the lower sideband comes from the “negative frequencies” in $x(t)$, this is in some sense a demonstration that those negative frequencies do indeed exist.

3.2 Note on Simulation Frequency

A true AM system is a continuous-time (or analog) system. However, in this lab we are using MATLAB to simulate the analog system. The simulation rate is 44.1kHz. Therefore, every signal in the simulation must be sampled at $f_s = 44.1$ kHz, and every digital filter must be designed for 44.1 kHz. Also, the sampling frequency places a limit on how high we can make the carrier frequency since modulation shifts the input spectrum to higher frequencies, we might incur aliasing if we shift too far. Also, in the demodulation process, we generate even higher frequencies. This is why we used a bandwidth of 2 kHz and a carrier frequency around 8 kHz.

Lab #12
ECE-2025 Spring 2001
Instructor Verification

For each verification, be prepared to explain your answer and respond to other related questions that the lab TA's or professors might ask. Turn this page in at the end of your lab period.

Name: ______________________________ Date of Lab: __________

Part 2(a): Record your voice and show a spectrogram in MATLAB of the resulting signal.

Verified:____________________ Date/Time:__________

Part 2(b): Use `freqz( )` to compute the frequency response of the filter whose coefficients are the vector `b` that you downloaded. Make a plot of the frequency response over a band of frequencies corresponding to $0 \leq f \leq 4000$ kHz assuming that the sampling rate is $f_s = 44.1$ kHz. Determine the stopband region from the plot.

Verified:____________________ Date/Time:__________

Part 2(c): Filter your voice signal. Convince your TA that it has no components above 2 kHz (approximately).

Verified:____________________ Date/Time:__________

Evaluation: Demonstrate your working system to you TA. Explain how it works. Listen to the output signal for the maximum output.

Verified:____________________ Date/Time:__________

Verify the output when the phase of the demodulator is changed to produce zero and demonstrate the effect of a mismatch between the modulator and demodulator carrier frequencies.

Verified:____________________ Date/Time:__________