Experiment 02: Amplitude Modulation

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Abstract

In this second laboratory experiment, you will see Amplitude Modulation (AM). Its simplest form is accomplished by the multiplication between a bandlimited message signal and a cosine (called *carrier*), whose frequency is located at a much higher place in the spectrum. This multiplication will cause a shift of the bandlimited message spectrum to where the carrier is located. In the time domain, the envelope of the carrier signal will change (i.e. will be modulated in amplitude) proportionally to the voltage of the message signal.

Keywords

Modulation — Amplitude — Carrier — Demodulation — Coherent — XY mode

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Introduction

Amplitude modulation (AM), still used in commercial radio today, is one of the simplest ways that a message signal can modulate a sinusoidal carrier wave. The purpose of this lab is for you to gain familiarity with the concepts of amplitude modulation and demodulation. This will be done in three main steps:

- First, an amplitude modulation system will be created and simulated using Simulink;
- Second, you will implement an AM modulator or an AM demodulator on a DSP platform;
- Finally, you will pair up with a neighbouring group and create a full modulator/demodulator system.

Before coming to the lab, you must complete the preparation sheet. The preparation work should lead you to identify the equation for an AM-modulated signal, to understand the concept of overmodulation, to understand the time domain and frequency domain representation of an AM-modulated signal with (AM-DSB) and without (AM-DSB-SC) and to have a clear high-level picture of an AM modulator and demodulator.

Note that the **preparation** is to be done individually, whereas the lab **answer sheet** is to be done in groups of a maximum of two students. You should print the preparation and the answer sheet, fill out the preparation and bring them both to the lab. In the lab you will follow this procedure online and record your answers in the answer sheet.

1. Suggested Reading

There are many books and resources online to explain amplitude modulation. If your preference is to read from a (real) book, you can take a look at [1], [2] and [3], among others. The advantage you have in seeking for information online as well is that you can try to find out practical information about AM. For instances, where are the stations located in our area (example: 680News) and what kind of equipment do they use? Also, you may find interesting to read about Citizen Band (CB) radio, which is a very accessible form of communication to everyone and uses plain-old AM.

2. Experiment

It is expected that at this point you are familiar with the basic blocks of Simulink as well as the procedure to compile and run programs on the target DSP hardware. The pictures provided below should also guide you as to what is expected in the simulation.

2.1 Designing and Simulating an AM Modulator

The purpose of a simulation is to better understand what is expected from a system when it is actually implemented. You will simulate things first and then move to implementing them on the DSP hardware. Start, then, by building your AM modulator in Simulink. It should look like Figure 1 below.



Figure 1. Amplitude Modulator

For the initial simulation, use a DSP Sine generator as input, and for output use one time scope and put together your own frequency domain scope, as you did in the previous experiment. For your **message** signal, use a 1.5KHz, 0.5 peak Voltage (that is $1V_{pp}$) sinusoid. Use 48KHz as your sampling rate, and make sure you define the sampling rate for all blocks that need it.

As the block diagram shows, the input signal must be added to a DC component (use 1 as your DC component) and the signal resulting from this addition will be multiplied by the carrier frequency. The carrier frequency is generated by another discrete-time sine wave generator, with an amplitude of 1 (peak value) and 12KHz. Remember that you are multiplying your baseband signal by a carrier in order to shift it up in the spectrum.

Run your simulation, and observe the result on the Simulink scopes. Adjust the setting of your scopes appropriately (i.e, should you really start displaying your signal at -150dB?). At this point, the scopes should allow you to observe an AM signal similar to the one you drafted on your lab preparation sheet.

The pictures below shows a time-domain and frequency domain amplitude modulated signal similar to what you should observe. Your numbers may differ.

2.2 Designing and Simulating an AM Demodulator

Your modulator runs fine, but your objective is really to receive the message after it goes through modulator, amplifiers, antenna, channel and receiving antenna. You must then demodulate this received signal to extract the **modulating** signal, which is the signal containing the information you want. In your case, this information is a 1KHz, $1V_{pp}$ sine wave, or a single tone.

In this part of the experiment, you will utilize your previously tested AM modulator and implement a demodulator by adding a filter to the signal path, after the multiplication with the carrier. As you have seen in the theory, by multiplying the incoming (received) signal by the carrier frequency, one will have as a result the desired baseband signal as well as DC and other higher frequency components. If you remove the higher frequency components with a low-pass filter, you retrieve the



Figure 2. Simulated Time Domain and Frequency Domain Display for AM

original message signal which was transmitted, plus a DC component, as the model in 3. Since you do not have a capacitor to put in series and remove the DC, your option in software (firmware) is to create a bandpass filter. Design one now and run it. It should be similar to the one presented below, except for the filter.



Figure 3. Simulating Modulation and Demodulation

2.3 Implementing an AM Modulator and Demodulator

2.3.1 Modulator

You will now run a program on the DSP platform to implement the system(s) you have just simulated. Start by opening CCS. The program you are looking for is located on the left pane, and it is called ECE316_Exp02a_AM_MOD. All files related to the project should appear under the project tree. Inspect the files, identifying the most relevant routines, such as carrier generation, sample handling, adding DC, etc. When you click on it, the message [Active - Debug] should appear next to the project name. Right-click on it and select Build Project. Now click on the green bug (see below) and select Debug As -- Code Composer Debug Session.



This should connect to the target, load the executable and put everything ready to run. Make all the physical connections

and make the system run (press "play"). Answer the questions below, pertaining to the system you are running. Use a 3KHz, $0.5V_{pp}$ sine wave as input. Make sure your signal generators are adjusted to see a high-impedance load at the output. Also, take a good look at the code and make sure you understand what is going on. You will be required to change it.

One interesting point: when you run your modulator on the target hardware, you will notice that the **modulated** signal will **not** have the amplitude you read from your signal generator. This is due to a few reasons. One comes from the numerical values used in the code, that upon being translated back to volts will be scaled. For instance, if you use $0.7V_{pp}$ or more, the signal will be overmodulated. Take a look at the code to see what is being done to each input sample as it makes its way to the output. Also, there is an analog filter at the input of the CODEC, which starts to roll off at approximately 10KHz. Since your modulated signal presents a carrier at 12KHz, you can expect your output amplitude to be off by a certain margin (question for thinking only: how would you determine this margin?). The other detail that you will notice on the code is the presence of a DC blocking filter, applied to both channels. This is due to a spurious DC value that is passed to the DSP by the CODEC even without any input present. It is there and it must be removed right after the samples are passed to the program.

As a simple exercise to familiarize yourself with the code, make it implement AM-DSB-SC, and use as input a 1KHz, $0.5V_{pp}$ square wave. Now when you look at your results, think of it this way: you have **mixed** a carrier with a stream of bits. Remember that in communications, "mixing" is the multiplication between two signals, whereas in audio it is their addition. The 1KHz square wave message mimics alternating bits at 2Kbps. Notice how much bandwidth this signal is taking.

2.3.2 Demodulator

Click on ECE316_Exp02b_AM_DEMOD, which should make it active. Build the project and create a CCS debugging session (i.e., connect to the target and load the executable). Remember that now you are implementing a **demodulator**, which means that you will need an amplitude modulated signal to serve as input to your system. You will test your demodulator first by using an AM signal coming from the signal generator. Assuming you have now a sinusoid on your signal generator, you will proceed as follows:

- Set the existing sinusoid to 12KHz, $1.5V_{pp}$. This will be your sinusoidal carrier.
- Press Modulation on your signal generator (top buttons).
- Set the message, or modulating signal to be a 3KHz sinusoid. You want sine modulating sine.
- Set the modulation index (or *depth*) to be less than 100% (say, 80%).

Test to see which of the two input channels is the input to the demodulator. You can also try to change the input to a triangle or a square wave to see what happens. Can you explain why they look slightly different? Part of the clue is in your previous experiment.

2.4 The Full System: Sine Wave, Voice or Music

Now that you have tested both modulator and demodulator, pair up with the group next to you and have one group run the modulator and the other run the demodulator. Initially, your input to the modulator will be a 3KHz, $1V_{pp}$ sine. Set the system up, connect everything appropriately and run it, making sure it works for a sinusoid.

Now for the group running the **modulator**, connect one of the coax cables to the headphone jack of an mp3 player or smartphone. Use the scope to adjust the volume level to give you a voice or music signal of around (eyeball it) $1V_{pp}$. Now on the demodulator you should see the voice being demodulated after the AM transmission. If you are curious as to how it may sound at the receiving end, ask for some loudspeakers.

3. Accomplishments

In this experiment, you were presented with the key issues involved in designing, simulating and implementing an AM modulator and demodulator. This was done by using a simulation model, a DSP platform in which modulator and demodulator were implemented. You tried a software-defined and possibly an envelope detector as well for the demodulation of the AM signal. The experiment intended to guide you through the steps necessary to achieve a practical understanding of the concepts studied in the theory of Amplitude Modulation.

Acknowledgments

Thanks for all the students who have provided input on the previous versions of this experiment.

References

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