Lab 6: Amplitude Modulation

Week 8

In this lab, you will make an AM radio transmitter and test it by sending out signals to a receiver.

1 Background

AM, or amplitude modulation, is one of several modulation techniques used to transmit information via radio waves. In general, a modulation scheme consists of two parts: a carrier signal and a modulating signal. The modulating signal, which contains the information, modifies some aspect of the carrier, which usually oscillates at a much higher frequency; the altered carrier wave (or modulated signal) is what actually gets broadcasted into the air. At the receiving end of the communication channel, the modulating signal gets reconstructed through a demodulation process.

AM, in particular, changes the amplitude of the carrier wave. As can be seen in Fig. 1(a), the upper envelope of the modulated signal closely resembles the modulating signal. While this example is for a simple sinusoidal modulating signal, the same concept applies to more complex waveforms, such as voice. AM radio carrier frequencies range from 540 kHz to 1.6 MHz. Just for context, an FM (frequency modulation) scheme is shown in Figure 1(b); in this case, the frequency of the carrier gets modified, rather than its amplitude.

![Figure 1: (a) Basics of amplitude modulation, (b) Basics of frequency modulation (from http://ironbark.xtelco.com.au/subjects/DC/lectures/7/)](a) ![Figure 1: (a) Basics of amplitude modulation, (b) Basics of frequency modulation (from http://ironbark.xtelco.com.au/subjects/DC/lectures/7/)](b)

During this lab, you will analyze the AM scheme using two types of modulating signals: pure tones generated by an oscillator and music from one of your electronic devices.
2 Modulation with the Function Generator

The function generator has the ability to output the product of two different sinusoids and therefore can provide amplitude modulation by assigning one sinusoid to be the carrier and the other to be the modulating signal. Set the carrier amplitude to 1 Vpp. The carrier frequency will be assigned to you by the TA. Now press the Mod button, and adjust the AM parameters to reflect the values below.

- Type: AM
- Source: Int
- AM Depth: 100%
- Am Freq: 1 kHz
- Shape: Sine

Monitor the function generator output on the oscilloscope. *What frequency do you observe when the scope is zoomed in versus zoomed out? While zoomed out, what happens when you adjust the P-P voltage of the modulating signal?* Revert back to your original P-P value once you finish. Now observe the Fourier Transform. You can enable this feature by pressing the Math button and changing the function to FFT; change the center frequency to your carrier frequency, and adjust the span so that you can view near 0 Hz. *Where do you observe peaks in the spectrum? Do your observations match your expectations?*

Connect the output of the function generator to the leads on the loop antenna. Turn on the radio receiver and adjust the black tuning knob until you can hear the 1 kHz signal; for this step only, it may help to increase the carrier amplitude above 1 Vpp. To be sure the sound you hear is actually coming from the function generator, you can adjust the AM frequency to verify the sound changes pitch. *What orientation of the radio (with respect to the antenna) gives the best result?* Hint: think back to inductive coupling from Lab 2. *Approximately how far away can the receiver pick up the signal from the transmitter?* For fine tuning, it may be easier to adjust the carrier frequency (not the AM frequency) by small increments until the output sound is maximized. Your radio should now be tuned to your carrier frequency. Turn off the receiver and disable the Mod feature on the function generator.

3 Transmitter Circuit

Though the modulation feature on the function generator is quite instructive and easy to use, it does not have the ability to modulate arbitrary waveforms such as voice signals. Therefore in order to provide voice modulation, we must build a multiplying circuit, which is called a transmitter. The core of your transmitter will be based on a modulator IC (1496); since it is vital that this circuit works properly, it is provided in Fig. 2. Only connect the numbered pins shown in the figure; you will add the two input signals at a later step. Also, the symbol near the carrier input signifies a coaxial cable, which will be used in conjunction with the function generator. In addition, the carrier null potentiometer is not really important to this lab, so you can set the resistance to a medium value (~ 25 kΩ).
Creating a Radio Station

The goal of this step is to verify that the transmitter circuit works properly. You will do this by inputting two different sinusoids (the carrier and the modulating signal) into the circuit and then verifying that the circuit produces the correct output. Since each lab station is only provided with one function generator (which will be used to create the radio-frequency carrier signal), you will need to build a circuit that creates an oscillation at a frequency within the audible range.

4.1 Oscillator Design

There are many different types of oscillator circuits, but the one you will make is called a Wien Bridge Oscillator (see Fig. [3]). The Wien Bridge Oscillator outputs a sinusoidal voltage, but is powered entirely by an op-amp, which itself is powered by the DC power supply. Therefore, the Wien Bridge Oscillator is one of many ways to convert DC voltage into AC voltage. This circuit has a resonant frequency of $\omega_0 = 1/RC$. When noise enters the circuit (which happens continuously), it gets amplified by the op-amp, which then feeds the output back to both inputs after going through a few resistors and capacitors. Because the resonant frequency is impeded less than all other frequencies, it will continue to be amplified with each round of feedback, while all the other frequency components of the noise die out. Therefore in the steady state, this circuit can produce a sinusoidal signal with an angular frequency of $\omega_0 = 1/RC$.

Use a 50 kΩ potentiometer and let $R_i = 10$ kΩ. Here the potentiometer is being used as a variable resistor, so one of the end pins will not be connected to anything. Choose values of $R$ and $C$ so that this oscillator produces a cyclic frequency (not angular frequency!) of approximately 1 kHz. Supply the op-amp with $\pm 5$ V and monitor the output with the oscilloscope. Adjust the potentiometer until you observe a sinusoid. Note that the precision of your potentiometer may prevent you from easily obtaining a pure sinusoid; thus, it is acceptable if your signal has slight distor-
Figure 3: Wien bridge oscillator

...tions at the peaks and troughs. *Compare your theoretical and actual resonant frequencies.*

With the multimeter, measure the potentiometer resistance that gives the nicest-looking sinusoidal output. *What is this value? What happens to the output as you adjust the pot resistance above and below the desired resistance value (in terms of frequency and signal shape)? Offer potential explanations for why the signal’s shape changes.*

4.2 Transmitting Tones

Connect the output of the Wien Bridge Oscillator to the modulating signal input on your transmitter circuit. Use the function generator to produce a sinusoid in the AM radio frequency range (between 540 and 1600 kHz) with an amplitude of 1 Vpp, and connect it to the carrier input on your transmitter circuit. Now attach one antenna electrode to ground, and attach the other to the transmitter output. Turn on your radio transmitter and make sure it is tuned to your station. *What are you hearing?* Monitor the output voltage on the scope. *What are you seeing?*

4.3 Transmitting Music

It is now time to transmit more complicated signals. Disconnect the Wien Bridge Oscillator output from the modulating input. Add the microphone to your breadboard. Connect the middle pin (labeled “GND”) to ground and the right-hand pin (labeled “VCC”) to +5 V. Make sure this voltage is no more than +5 V, because these microphones burn out very easily!!! Connect the left pin (labeled “OUT”) to the modulating input on the transmitter circuit. Verify that your microphone is working by gently tapping it and listening to the radio receiver’s output.

Using your cellphone (or similar device), play music near the microphone; make sure the device’s speaker is close to the microphone. *How does the music sound from the radio speaker?* Use the oscilloscope to monitor the microphone’s output voltage while music is playing, and also
while gently tapping on the microphone. *What do you notice about the maximum amplitude of the signal? Can you think of a way to potentially improve the sound quality?*

5 Further Investigations

5.1 Human Antenna

Disconnect the coil antenna from the transmitter; stick one end of a wire next to the output capacitor. Try receiving the signal on the radio. Record your observations on the signal strength at various distances. Now, touch the exposed end of the wire. *Does the signal strength appear to change? What happens when you bring your other hand closer to the receiver? Explain what you think is happening.*

6 Write-Up

In your writeup, include answers to all of the questions asked throughout the lab, and provide any relevant data, graphs, pictures, calculations, etc.

Followup

If you are interested in learning more about this material, look into EECS 307 (Communications Systems), EECS 378 (Digital Communications), and EECS 380 (Wireless Communications).