THE UNIVERSITY OF BRITISH COLUMBIA
Department of Electrical and Computer Engineering

ELEC 391 – Electrical Engineering Design Studio II

Lab Assignment 2 – Amplitude Modulation

1 Introduction

This lab assignment is concerned with practical issues associated with the implementation of modulators and demodulators for Double-Sideband Suppressed Carrier (DSB-SC) and Double-Sideband Large Carrier (DSB-LC) modulation.

The test and measurement equipment (and measurement accessories) used in Lab 1 will be used again here. Two new devices are introduced: the Mini-Circuits ZAD-1 double-balanced mixer that will form the basis for the DSB modulators and demodulators and an op-amp-based low-pass filter that will be used in the synchronous demodulator.

As in Lab 1, we place particular emphasis on accurate and honest comparison between theoretical predictions and experimental results. Where discrepancies exist, possible and realistic explanations should be offered.

1.1 Performance Objectives

Upon completion of this lab assignment, ELEC 391 students will be able to:

1. Explain the function and operation of DSB modulators and demodulators using simple mathematical models and use MATLAB to generate numerical predictions based upon those models.

2. Design, implement, and evaluate the performance of DSB modulators and demodulators using standard components, test and measurement equipment, and measurement accessories.

1.2 Tasks

Completing this lab assignment will involve the following steps:

1. *Before your first assigned lab period:* Review the lab assignment and begin the prelab assignment in Section 2 on your own! Although the assignment will not be formally marked, it will be checked for completeness and correctness and will be considered when your mark for this lab assignment is assigned.

   Meet with your lab partners to discuss the lab assignment and to assign responsibilities during the lab session.
2. *During the scheduled lab period:* Submit your individual prelab assignment and work with your lab partners to complete the four experiments described in the lab assignment handout.
3. *During the few days after your first assigned lab period:* Meet with your lab partners to plot and/or reduce your data, to draw conclusions, and to the group lab report.
4. *Three days after your second assigned lab period:* Submit your group lab report for marking.

1.3 Test and Measurement Equipment

The following test and measurement equipment will be used in this lab session. Where applicable, please record the serial numbers of each unit.

1. RF Signal Generator (Agilent, model 8648B, 9 kHz – 2 GHz)
2. Function/Arbitrary Waveform Generator (Rigol, model DG1022, 2 Channel, 20 MHz, 100 MSa/s)
3. Spectrum analyzer (Rigol, model DS 815), 9 kHz-1.5 GHz)
4. Dual-channel oscilloscope (Tektronix, model TDS 2012C, 100 MHz)
5. 2-input combiner (Mini-Circuits, model ZSC-2-1, 0.1-400 MHz)
6. 20 dB attenuator (Mini-Circuits, HAT-20 (DC-2 GHz))
7. Low-pass filter (Mini-Circuits BLP-5)

Be certain to consult the equipment operating manuals that are posted on the ECE Engineering Services website.

In order to protect the input of the spectrum analyzer, please make absolutely certain that the signal at the output of the signal generators does not exceed 5 V_{p-p}

1.4 Notes

1. Be aware of the limitations on the power that can be safely applied to the LO, RF, and IF ports of the ZAD-1 mixer. If you overdrive the mixer, the output will be severely distorted. For full technical specification, please refer to the complete Mini-Circuits data sheet available on the Mini-Circuits website.

   L-port (LO port): +7 dBm (*i.e.,* 0.5 V rms across 50Ω).
   R-port (RF port): +1 dBm (*i.e.,* 0.22 V rms across 50Ω).
   I-port (IF-port): +1 dBm (*i.e.,* 0.22 V rms across 50Ω).

2. Recall that the input impedance of the spectrum analyzer is 50 Ω, while the input impedance of the oscilloscope is much higher (> 1 MΩ). Ensure that the output impedance of the function generator is set to 50 Ω.

2 Prelab Assignment

Before you come to the lab, please review this entire lab assignment in detail and complete the following pre-lab assignment:

2.1 DSB-LC Modulation

1. Derive mathematical representations for a DSB-LC signal in both the frequency and time domains where the modulating (message) signal is $m(t)=A_m cos(2\pi f_m t)$ and the carrier signal is $c(t)=A_c cos(2\pi f_c t)$.
2. Using MATLAB and the frequency and time domain representations derived above, plot the time and frequency representations of DSB-LC signals with A_c=1V and modulation indices μ of 25%, 66.7% and 100%, respectively. Choose the other parameters so that you can easily compare these results with those that you measure in the lab.

2.2 DSB-SC Modulation

1. Derive mathematical representations for a DSB-SC signal in both the frequency and time domains where the modulating (message) signal is $m(t)=A_m cos(2\pi f_m t)$ and the carrier signal is $c(t)=A_c cos(2\pi f_c t)$.
2. Using MATLAB and the frequency and time domain representations derived above, plot the time and frequency representations of a DSB-SC signal with A_m=2V and A_c=1V. Choose the other parameters so that you can easily compare these results with those that you measure in the lab.
3. Briefly explain (using mathematical derivations as appropriate) how one might coherently demodulate (*i.e.,* recover) a replica of the original modulating (message) signal $m(t)$.

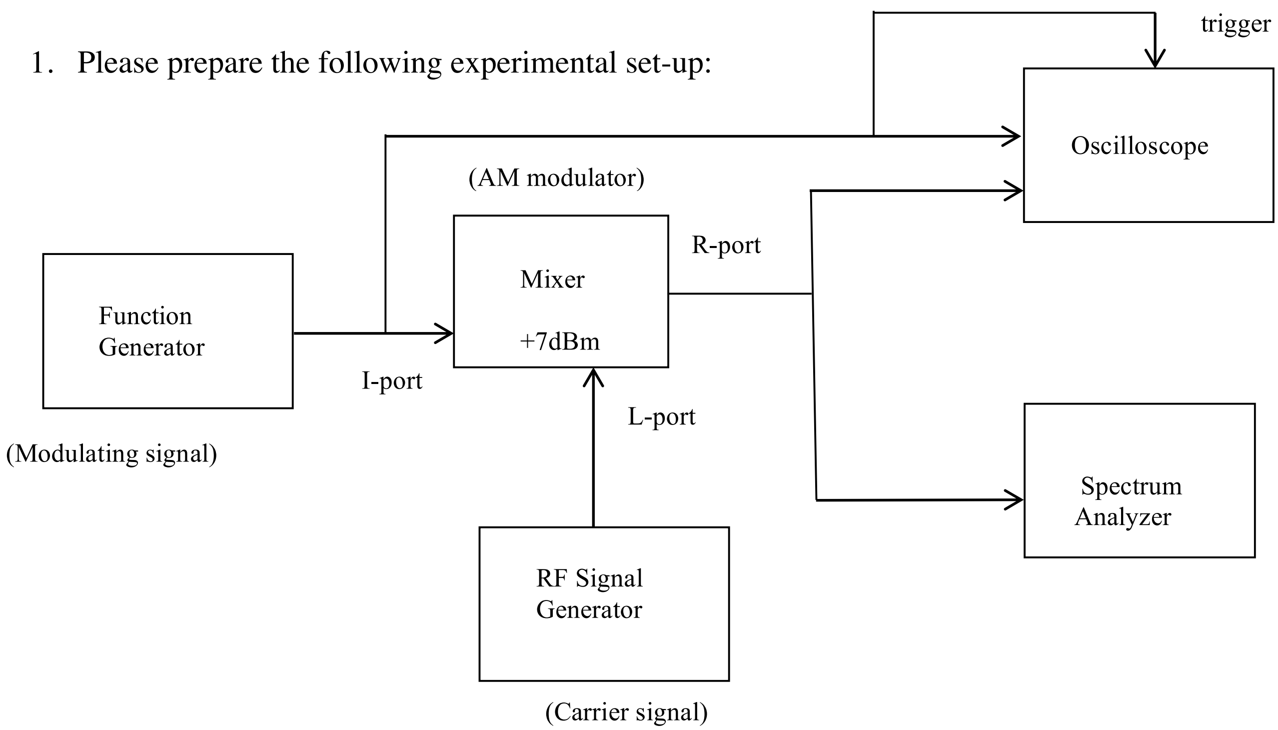
2.3 DSB-SC Demodulation

1. Devise and implement an op-amp-based low-pass filter that will eliminate the unwanted frequency component at the output of the second mixer. A Sallen-Key filter will likely provide the desired performance.

3 Experiment 1: Implementation of a DSB-LC Modulator

3.1 Procedure

1. Please prepare the following experimental set-up:



2. Apply a +7dBm (*i.e.,* 0.5V rms) sinusoidal signal with a frequency of 2 MHz to the mixer's L-port. Observe the radio frequency (RF) output of the mixer on the spectrum analyzer and verify that there is simply a spectral line at 2 MHz. Are there any other signals which you can observe in the frequency domain? If so, explain the origin of such signals. For example you could check for any harmonics which might exist.
3. Apply a sinusoidal modulating signal of 50 kHz to the mixer's baseband frequency (IF) input. Adjust the appropriate signal levels (both modulating signal amplitude and DC offset) in order to obtain at the output of the mixer DSB-LC signals with modulation indexes μ equal to $25\%, 66.7\%$ and 100%. In all cases observe and record the measured signals in both the time and frequency domain.

3.2 Issues for Discussion

1. In both the time and frequency domains, compare the theoretical predictions derived in the prelab assignment and the corresponding measurements obtained during the lab session. Report and suggest explanations for any discrepancies that were observed.
2. Comment on the relative accuracy of measurements obtained in the time and frequency domain.
3. Based upon your results, estimate the conversion gain of the ZAD-1 mixer.

4 Experiment 2: Implementation of a DSB-SC Modulator

4.1 Procedure

1. Using the experimental set-up and following the procedure described in Experiment 1, generate a DSB-SC signal using a sinusoidal modulation signal (message signal) with a frequency of 50 kHz and a carrier signal of 2 MHz.
2. Observe the modulated signal both in the frequency and time domain. By a small adjustment of the modulating signal frequency, "freeze" the relative motion of the carrier and signal envelope in the time domain. Note and record the 180-degree phase reversal of the carrier at the zero-crossing instants.

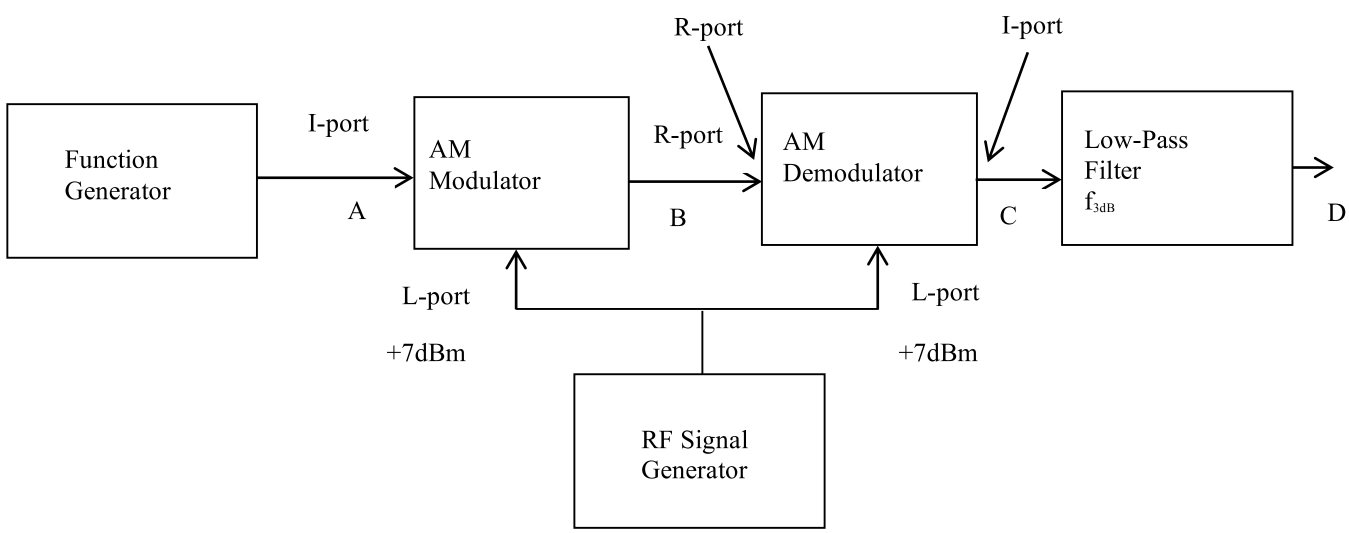
4.2 Issues for Discussion

1. Compare the theoretical results and the equivalent measurements in the time and frequency domain. Report any discrepancies and suggest possible explanations.
2. Comment on the relative accuracy of the measurements collected in the time and frequency domains, respectively.
3. Based upon your results, estimate the conversion gain of the ZAD-1 mixer. Does the result agree with the estimate that you obtained in Experiment 1?

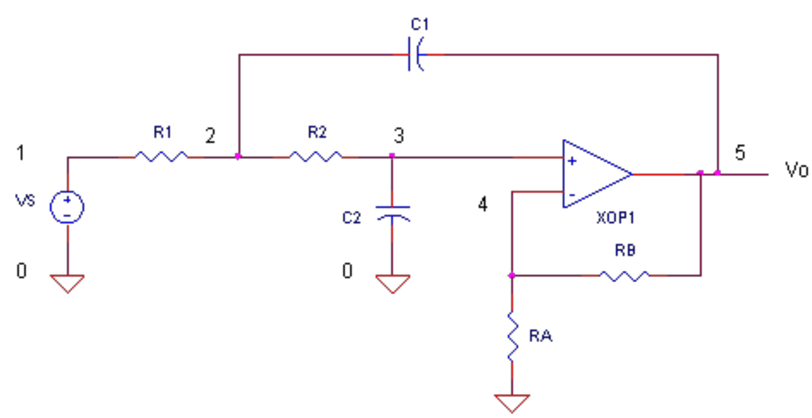
5 Experiment 3: Demodulation of DSB-SC Signals

5.1 Procedure

1. Please prepare the following experimental set-up. A power splitter should be used to drive the two mixers.



2. Devise and implement an op-amp-based low-pass filter that will eliminate the unwanted frequency component at the output of the second mixer. A Sallen-Key filter will likely provide the desired performance. You will need to determine the best value of the f_{3dB} of the low pass filter (LPF) that will allow accurate recovery of an accurate replica of the modulating signal.



3. Apply a 50 kHz sinusoidal modulating signal to the I-port and a 2 MHz sinusoidal carrier signal to the L-port as in the previous experiments. Determine the appropriate

range for the value of the f_{3dB} of the low pass filter (LPF) that is necessary to recover an accurate replica of the modulating signal.

3. In both the time and frequency domains, observe and record the signal at points *A, B, C* and *D*. Pay appropriate attention to the output impedances of the devices and the input impedances of the instruments.
4. Maintaining the same frequencies and amplitudes, change the message signal to a triangular and a square wave signal in turn. In each case, compare the message signal with its replica.

5.2 Issues for Discussion

1. Comment on the factors that affect the optimal choice of the value of the f_{3dB} of the low pass filter (LPF) that is necessary to recover an accurate replica of the modulating signal.
2. Was the output of the DSB-SC demodulator similar to the original modulating signal? If not, please describe the differences and suggest explanations.