ECE478 Lab 3 Report

Amplitude Modulation using MATLAB

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ABSTRACT:

The following lab explores amplitude modulation (AM) schemes, and how they would operate for single-tone and multi-tone signals.

EXAMPLES

Exercise 1: Single-Tone Amplitude Modulation

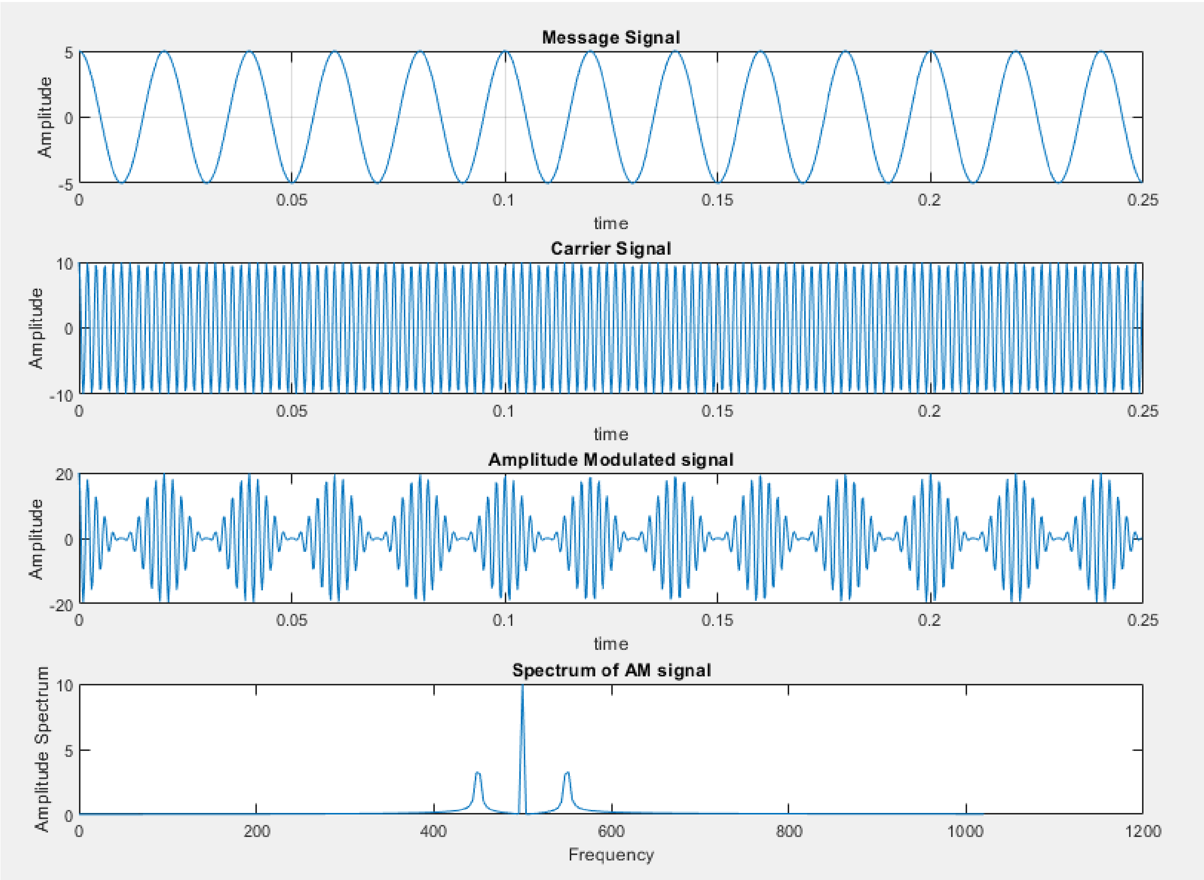

Figure 1: 100% Modulation, 50Hz Single-Tone Message, 500Hz Carrier

From Figure 1, we can by inspection see that a 200-Hz window is required to capture the majority of the frequency content of our modulated signal; non-idealities due to a unit-impulse being practically unrealizable force the transmitted signal to spread more in the frequency-domain.

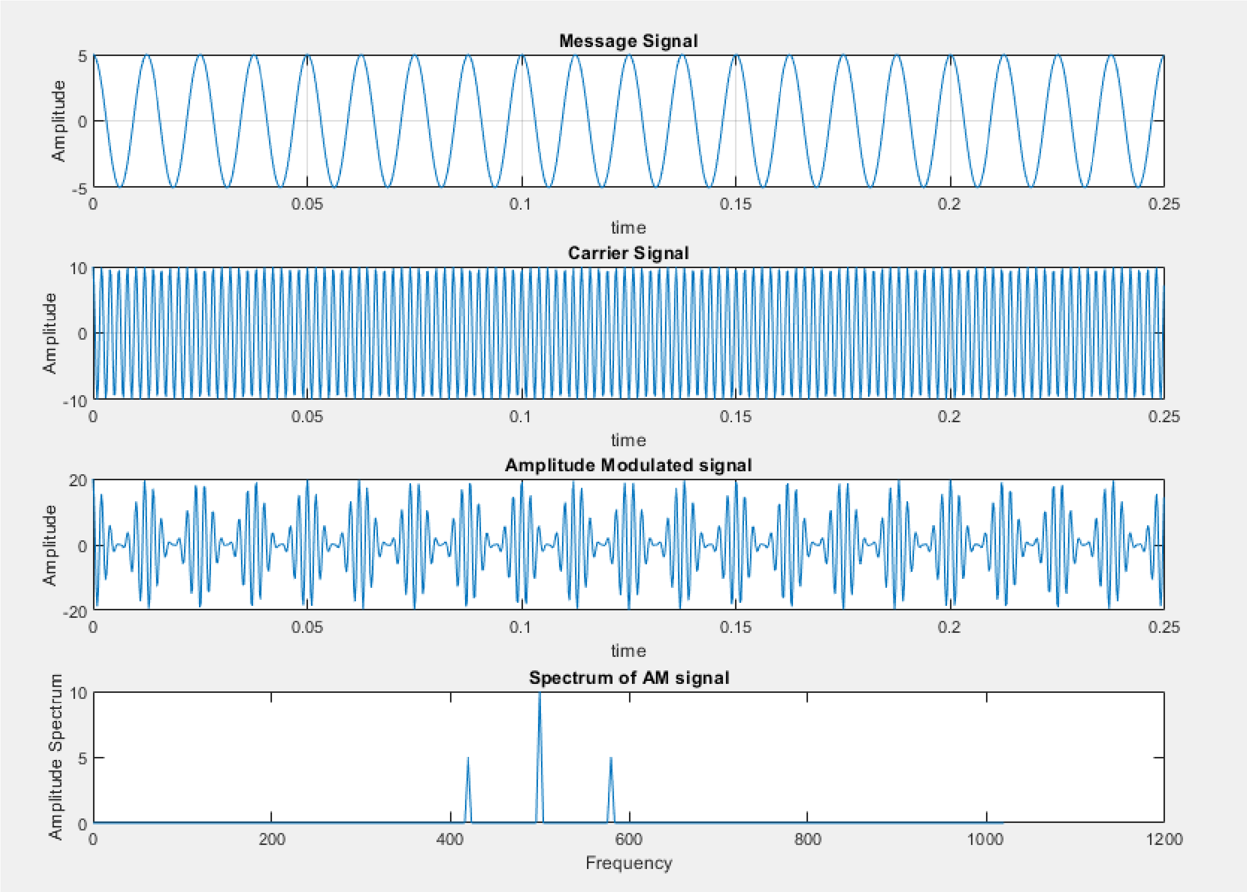

Figure 2: 100% Modulation, 80Hz Single-Tone Message, 500Hz Carrier

Here we can see instead an 80-Hz single-tone message sent over the same 500-Hz carrier.

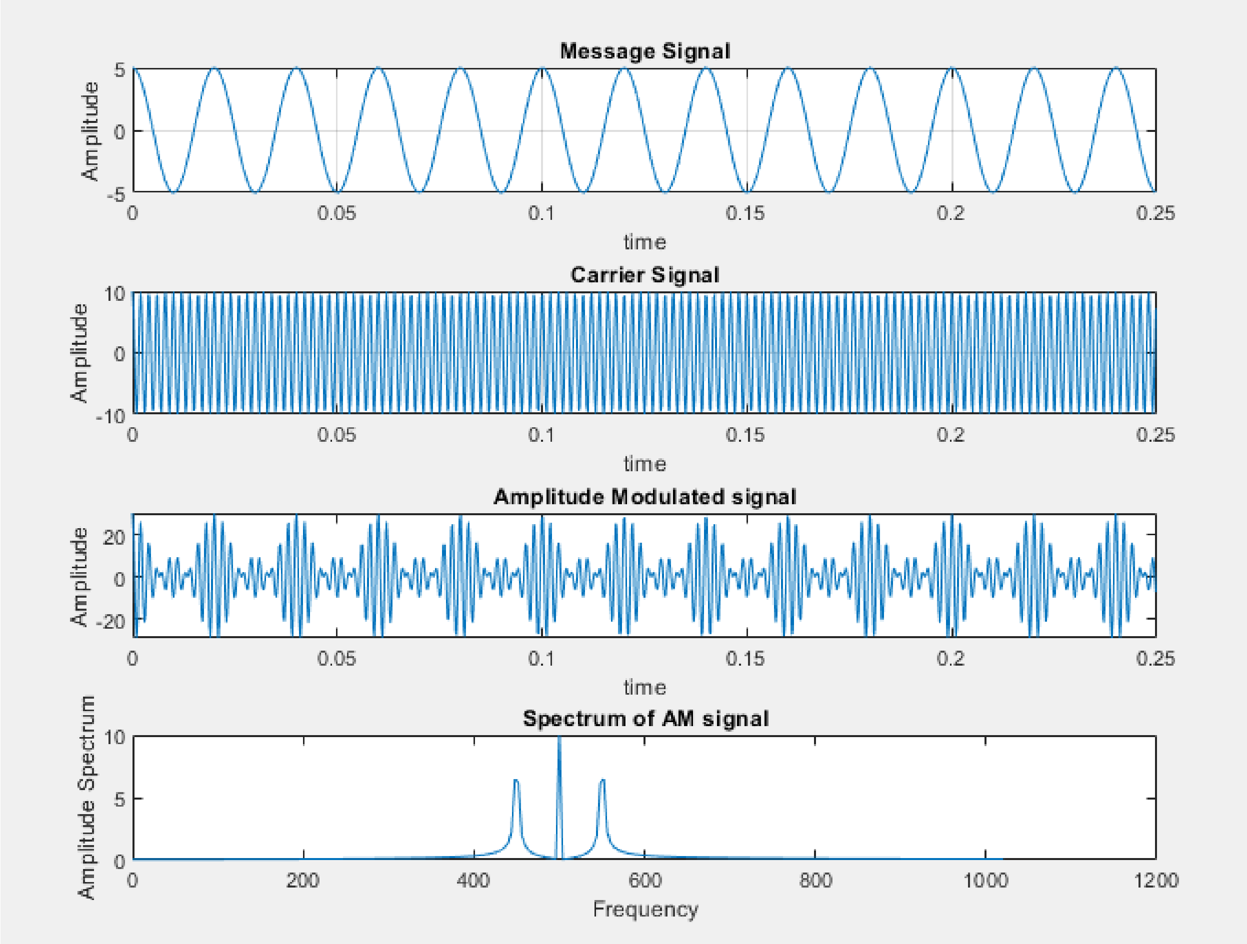

Figure 3: 200% Modulation, 50Hz Single-Tone Message, 500Hz Carrier

Here, instead, we can see the 50-Hz message signal sent over the 500-Hz carrier, but with 200% modulation. Observe, though subtle, the envelope on the Amplitude Modulated Signal does not follow a clean sinusoidal shape, but instead there are zero-crossings (or phase-reversals) that happen.

LAB EXERCISE:

```
% ECE478 - MATLAB Lab 3
% Amplitude Modulation of Multi-Tone
% Chase Lotito

% Defining AM modulation Index
mu1 = 0.5;
mu2 = 1;
mu3 = 1.25;

% Defining frequencies of message signal
f1 = 50;
f2 = 75;
f3 = 100;

% Defining frequency of carrier signal
fc = input('Enter carrier frequency (fc) (fc>>fm) (e.g. fc = fm*10) =
');

N = 2048;    % N point FFT N>fc to avoid freq domain aliasing
fs = 8192;    % sample frequency
t = (0:N-1)/fs;

% Generating modulating signal (message signal)
A1 = 5;
A2 = 5;
A3 = 5;
mt = A1 * cos(2 * pi * f1 * t) + A2 * cos(2 * pi * f2 * t) + A3 *
cos(2 * pi * f3 * t);    % generating the message signal
figure(1)
subplot(8,1,1);
plot(t, mt), grid on;    % A plot for the message signal
title('Message Signal');
xlabel('time');
ylabel('Amplitude');

% Generating carrier signal
Ac = 5;    % Amplitude of carrier signal
ct = Ac * cos(2 * pi * fc * t);    % generation of carrier signal
subplot(8,1,2);
plot(t, ct), grid on;    % A plot for the carrier signal
title('Carrier Signal');
xlabel('time');
```

```
ylabel('Amplitude');

% Generating 50% AM Modulated signal
st1 = Ac * (1 + mu1 * mt) .* cos(2 * pi * fc * t);    % AM wave
subplot(8,1,3);
plot(t, st1);    % a plot for the AM signal
title('50% Amplitude Modulated signal');
xlabel('time');
ylabel('Amplitude');

% Generating spectrum of 50% AM wave
Sf = 2 / N * abs(fft(st1, N));
f = fs * (0 : N/2) / N;    % fft is symmetric, only the positive half
is sufficient
subplot(8,1,4);
plot(f(1:256), Sf(1:256));    % a plot for the AM signal
title('Spectrum of 50% AM signal');
xlabel('Frequency');
ylabel('Amplitude Spectrum');


% Generating 100% AM Modulated signal
st2 = Ac * (1 + mu2 * mt) .* cos(2 * pi * fc * t);    % AM wave
subplot(8,1,5);
plot(t, st2);    % a plot for the AM signal
title('100% Amplitude Modulated Signal');
xlabel('time');
ylabel('Amplitude');

% Generating spectrum of 100% AM wave
Sf = 2 / N * abs(fft(st2, N));
f = fs * (0 : N/2) / N;    % fft is symmetric, only the positive half
is sufficient
subplot(8,1,6);
plot(f(1:256), Sf(1:256));    % a plot for the AM signal
title('Spectrum of 100% AM signal');
xlabel('Frequency');
ylabel('Amplitude Spectrum');



% Generating 125% AM Modulated signal
st3 = Ac * (1 + mu3 * mt) .* cos(2 * pi * fc * t);    % AM wave
subplot(8,1,7);
plot(t, st3);    % a plot for the AM signal
title('125% Amplitude Modulated signal');
```

```
xlabel('time');
ylabel('Amplitude');

% Generating spectrum of 125% AM wave
Sf = 2 / N * abs(fft(st3, N));
f = fs * (0 : N/2) / N;    % fft is symmetric, only the positive half
is sufficient
subplot(8,1,8);
plot(f(1:256), Sf(1:256));    % a plot for the AM signal
title('Spectrum of 125% AM signal');
xlabel('Frequency');
ylabel('Amplitude Spectrum');
```

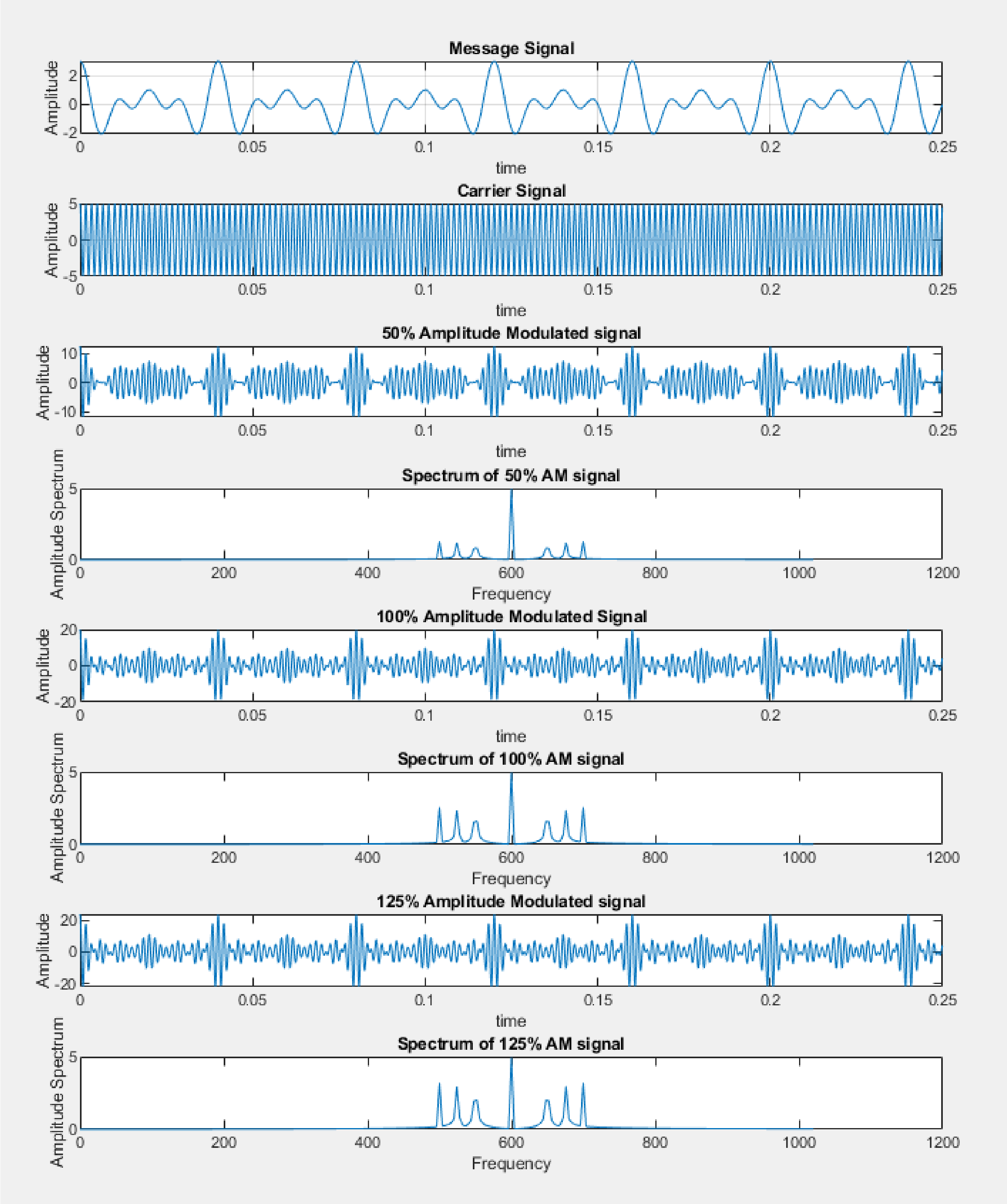

Figure 4: Question 1 Signals; 50%, 100%, 125% Modulation; 600-Hz Carrier

Here is the plot for different modulation levels for a multi-tone signal containing 50-Hz, 75-Hz, and 100-Hz harmonics.

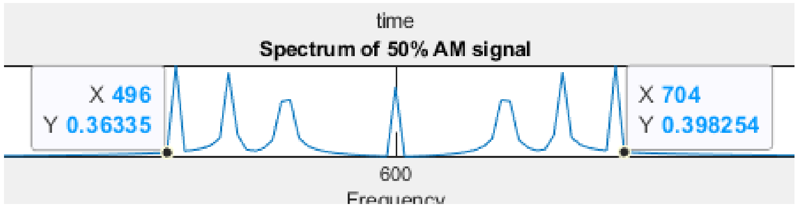

Figure 5: 50% Modulation AM Amplitude Spectrum

Here, for the 50% AM signal, ***we need a 300-Hz bandwidth***. Ideally, we would require 200-Hz, if we could realize non-casual cosine waves which have impulse frequency spectrums.

The power requirements of this AM signal is determined by the square of its amplitude spectrum, this being determined by the impulse power spectrum of the multi-tone signal. Power can be found by:

$$P_{tot} = \frac{1}{2}A_c^2 + \frac{6}{8}\mu^2 A_c^2$$

Where the 6 comes from the 6 sidebands in the signal.

Since $A_c = 5$, we should get this total power for each modulation level:

Table 1: Power Requirements for Multi-Tone AM Modulation

μ	P_{tot}	P_{sb}	P_{sb}/P_{tot}
0.5	17.188	4.688	27.27%
1	31.250	18.750	60.00%
1.25	41.797	29.297	70.09%

Overall, this is the simplest possible modulation scheme that I, as a design engineer, could create a communications system that can transmit the multi-tone signal, and because it is so simple, it is also inefficient. At 100% modulation, we have 60 % of the power needed to transmit be for the sidebands, which means that there is 40% of the power just for the carrier. And this gets worse for modulation levels under 100%, so if we design a buffer to ensure the integrity of the envelope of the message signal, we dive deeper into inefficiency. If we chose to sacrifice simplicity for efficiency, I could instead choose to modulate with a DSB-SC modulation scheme, where we can save nearly 1/3 of the power required for transmission. However, that would make it harder to implement, teach about, and service the design, as it requires a more complex coherence detector, and not a simple rectifier that can extract the envelope. But it is better economically and societally to have more efficient design, as it would allow for more to benefit from it and reduce the negative impacts of wasteful products.

Globally, this inefficient system, for one, has allowed for the greatest connection of people in history, but for a modern globe it needs to be made more efficient if it is to keep growing sustainably.