Heaven's Light is Our Guide

Rajshahi University of Engineering and Technology

Course Code
ECE 3208

Course Title
Communication Engineering Sessional

Experiment Date: January 7, 2025,
Submission Date: January 21, 2025

Lab Report 2: Study of Amplitude & DSB-SC Modulation & Demodulation

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Study of Amplitude & DSB-SC Modulation & Demodulation

Theory

Amplitude Modulation (AM) is a modulation technique used in electronic communication, most commonly for transmitting information via a radio carrier wave. In AM, the amplitude of the carrier signal is varied in proportion to that of the message signal, such as an audio signal. This technique is used in a variety of applications, including broadcasting and two-way radio communication [1].

Double Sideband Suppressed Carrier (DSB-SC) is a type of amplitude modulation that suppresses the carrier frequency, leaving only the upper and lower sidebands. This results in a more power-efficient transmission since the carrier does not need to be transmitted. DSB-SC is used in applications where bandwidth efficiency is crucial, such as in certain types of radio communication systems [2].

In this experiment, the principles of AM and DSB-SC modulation and demodulation are studied. AM and DSB-SC signals are generated, their spectra are observed, and they are demodulated to recover the original message signal. This experiment helps in understanding the advantages and disadvantages of each modulation technique and their practical applications.

AM Modulation

AM modulation involves varying the amplitude of a high-frequency carrier signal in accordance with the instantaneous amplitude of the message signal. The mathematical representation of an AM signal is given by:

$$s(t) = A_c[1 + m(t)]\cos(2\pi f_c t)$$

where A is the carrier amplitude, $m(t)$ is the message signal, and f_c is the carrier frequency.

DSB-SC Modulation

DSB-SC modulation is achieved by multiplying the message signal with the carrier signal. The mathematical representation of a DSB-SC signal is:

$$s(t) = m(t)\cos(2\pi f_c t)$$

This results in a signal that contains only the sidebands, with the carrier suppressed.

Demodulation

Demodulation is the process of extracting the original message signal from the modulated carrier. For AM signals, this can be achieved using an envelope detector. For DSB-SC signals, coherent detection is required, which involves mixing the received signal with a locally generated carrier signal that is synchronized in frequency and phase with the original carrier.

Required Apparatus

- AM/SSB/DSB-SC Board (ACT-02 AM DSB-SC/SSB Kit)
- Frequency Generator
- Oscilloscope
- Connecting Wires

Block Diagram

AM and DSB-SC Modulation Block Diagram

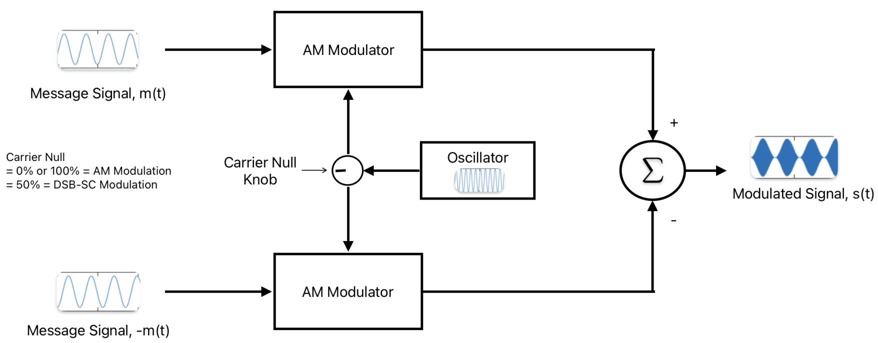

Figure 1: Block Diagram of AM and DSB-SC Modulation

AM and DSB-SC Modulation and Demodulation Block Diagram

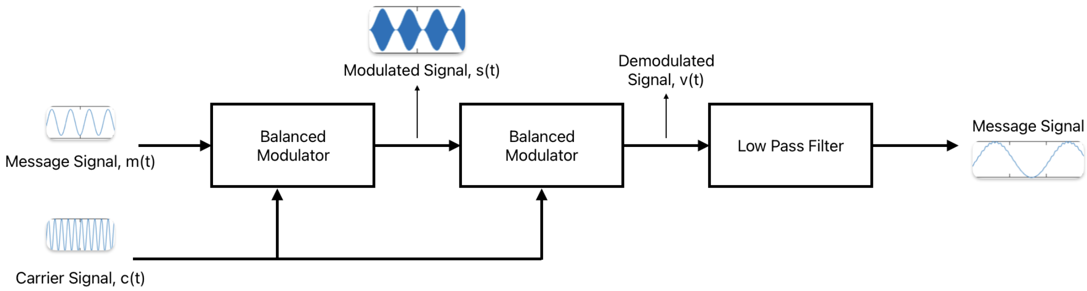

Figure 2: Block Diagram of AM and DSB-SC Modulation and Demodulation

Procedure

1. A function generator was used to generate two signals: a lower frequency message signal and a higher frequency carrier signal.

2. The AM/SSB/DSB-SC board (ACT-02 AM DSB-SC/SSB Kit) was used, specifically the balanced modulator portion of the board for the first experiment.

3. The message signal was passed to the balanced modulator, and the waveshapes of the message, carrier, and modulated signals were observed.

4. By adjusting the carrier null knob, AM and DSB-SC modulation were performed. Under, over, and 100% modulation were observed for AM modulation. For DSB-SC, the message amplitude was varied to observe cases similar to AM under or over modulation.

5. Another balanced modulator was used to pass the modulated signal through, and the output was then passed through a low pass filter to recover the original message signal for both AM and DSB-SC.

6. The waveforms were observed on the oscilloscope at each step.

Experimental Data

Modulation Type	$\mathbf{A_m}$	$\mathbf{F_m}$	$\mathbf{A_c}$	$\mathbf{F_c}$	$\mathbf{A_{max}}$	$\mathbf{A_{min}}$
AM Under Modulation	0.4V	1.75kHz	2.2V	298.8kHz	2.52V	0.5V
AM 100% Modulation	0.54V	1.762kHz	2.22V	301.5kHz	2.54V	0V
AM Over Modulation	0.9V	1.75kHz	2.24V	300.32kHz	2.64V	1.2V
DSB-SC Modulation 1	0.9V	1.75kHz	2.28V	300.3kHz	-	-
DSB-SC Modulation 1	1.88V	1.75kHz	2.28V	300.3kHz	-	-

Table 1: Experimental Data for Modulation Types

Calculations

The modulation index (μ) for AM can be calculated using the formula:

$$\mu = \frac{A_{\text{max}} - A_{\text{min}}}{A_{\text{max}} + A_{\text{min}}}$$

AM Under Modulation

Given:

$$A_{\text{max}} = 2.52V, \quad A_{\text{min}} = 0.5V$$

$$\mu = \frac{2.52 - 0.5}{2.52 + 0.5} = \frac{2.02}{3.02} \approx 0.668$$

AM 100% Modulation

Given:

$$A_{\text{max}} = 2.54V, \quad A_{\text{min}} = 0V$$

$$\mu = \frac{2.54 - 0}{2.54 + 0} = \frac{2.54}{2.54} = 1$$

AM Over Modulation

Given:

$$A_{\text{max}} = 2.64V, \quad A_{\text{min}} = 1.2V$$

$$\mu = \frac{2.64 - (-1.2)}{2.64 + (-1.2)} = \frac{3.84}{1.44} \approx 2.67$$

For DSB-SC modulation, the modulation index is not applicable as the carrier is suppressed.

Matlab Simulation

Code (AM):

The following Matlab code simulates the generation, modulation, and demodulation of an analog signal using Amplitude Modulation (AM).

```
% Parameters
% Amplitude of message signal in Volts
%Am = 0.4; % For Under Modulation
%Am = 0.54; % For 100% Modulation
Am = 0.9; % For Over Modulation
Fm = 1.761e3; % Frequency of message signal in Hz
Ac = 2.24; % Amplitude of carrier signal in Volts
Fc = 300.4e3; % Frequency of carrier signal in Hz
Fs = 1e6; % Sampling frequency in Hz
t = 0:1/Fs:1e-2; % Time vector for 1 ms
Ka = 1.87;

% Message signal
m_t = Am * cos(2 * pi * Fm * t);

% Carrier signal
c_t = Ac * cos(2 * pi * Fc * t);

% AM Modulated signal
s_t = Ac * (1 + Ka * m_t) .* cos(2 * pi * Fc * t);

% Demodulation
r_t = s_t .* cos(2 * pi * Fc * t);

% Low-pass filter design
[b, a] = butter(6, Fm/(Fs/2)); % 6th order Butterworth filter

% Filter the demodulated signal
m_rec = filter(b, a, r_t);

% Plotting the signals
figure;
subplot(4,1,1);
plot(t, m_t);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude (V)');

```

```
subplot(4,1,2);
plot(t, c_t);
title('Carrier Signal');
xlabel('Time (s)');
ylabel('Amplitude (V)');

subplot(4,1,3);
plot(t, s_t);
title('AM Modulated Signal');
xlabel('Time (s)');
ylabel('Amplitude (V)');

subplot(4,1,4);
plot(t, m_rec);
title('Demodulated Message Signal');
xlabel('Time (s)');
ylabel('Amplitude (V)');
```

Code (DSB-SC):

The following Matlab code simulates the generation, modulation, and demodulation of an analog signal using Double Sideband Suppressed Carrier (DSB-SC) modulation.

```
% Define parameters
Fs = 1000000; % Sampling frequency
t = 0:1/Fs:0.01; % Time vector

% Create message signal
Am = 1.88; % Amplitude of message signal
% Am = 0.9; % Amplitude of message signal
fm = 1750; % Frequency of message signal
message_signal = Am * sin(2 * pi * fm * t);

% Create carrier signal
Ac = 2.28; % Amplitude of carrier signal
fc = 300000; % Frequency of carrier signal
carrier_signal = Ac * sin(2 * pi * fc * t);

% Perform Double Sideband Suppressed Carrier (DSB-SC) Modulation
modulated_signal = message_signal .* carrier_signal;

% Demodulate the signal
demodulated_signal = modulated_signal .* carrier_signal;
[b, a] = butter(5, fm/(Fs/2)); % Design a low-pass filter
filtered_signal = filter(b, a, demodulated_signal);
```

```
% Plot the signals
figure;
subplot(4,1,1);
plot(t, message_signal);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');

subplot(4,1,2);
plot(t, carrier_signal);
title('Carrier Signal');
xlabel('Time (s)');
ylabel('Amplitude');

subplot(4,1,3);
plot(t, modulated_signal);
title('DSB-SC Modulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');

subplot(4,1,4);
plot(t, filtered_signal);
title('Demodulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');
```

Output

Experimental Output

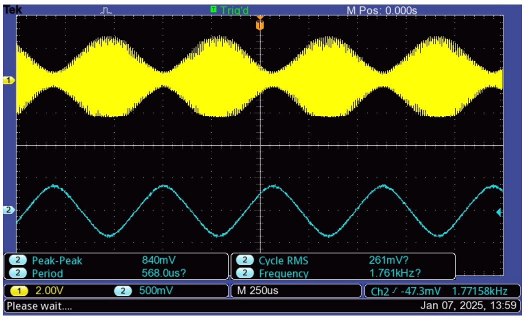

Figure 3: AM; Yellow: Under-modulated, Blue: Message

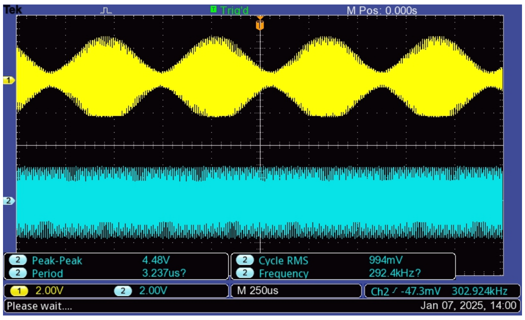

Figure 4: AM; Yellow: Under-modulated, Blue: Carrier

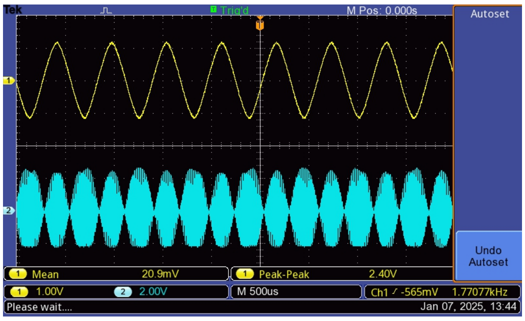

Figure 5: AM; Yellow: Message, Blue: 100% Modulated

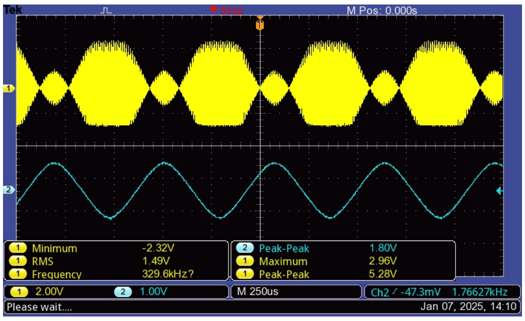

Figure 6: AM; Yellow: Over-modulated, Blue: Message

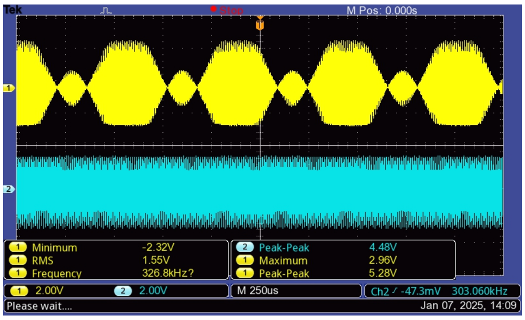

Figure 7: AM; Yellow: Over-modulated, Blue: Carrier

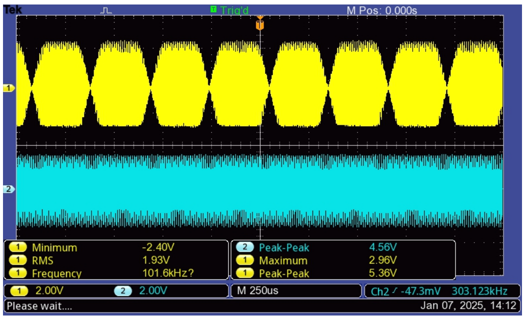

Figure 8: DSBSC; Yellow: Modulated, Blue: Carrier

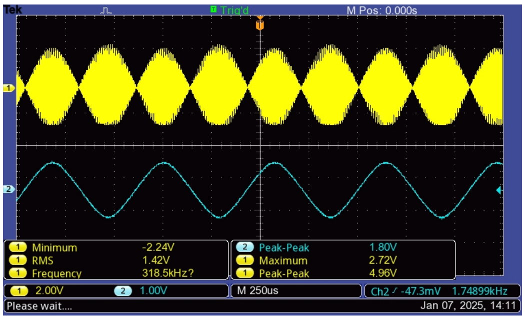

Figure 9: DSBSC; Yellow: Modulated, Blue: Message 1

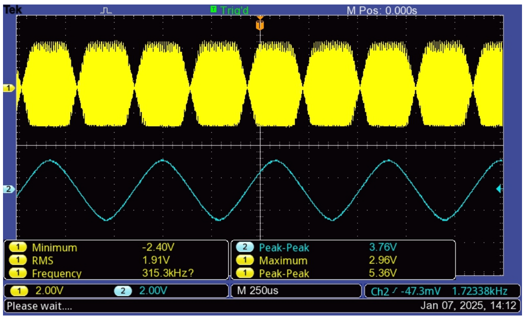

Figure 10: DSBSC; Yellow: Modulated, Blue: Message 2

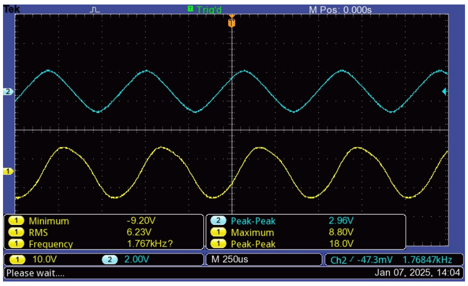

Figure 11: DSBSC; Yellow: Message, Blue: Demodulated Message

Matlab Simulation Output

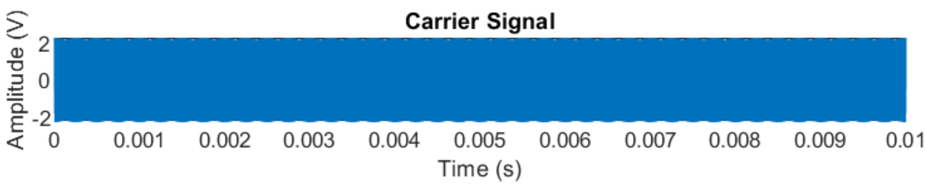

Figure 12: AM; Carrier

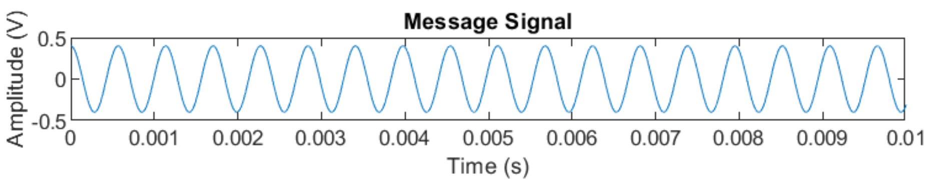

Figure 13: AM Under-modulated; Message Signal

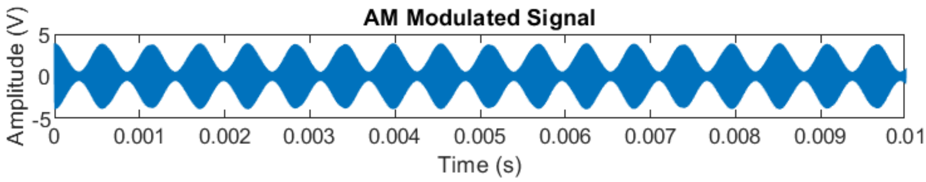

Figure 14: AM Under-modulated; Modulated Signal

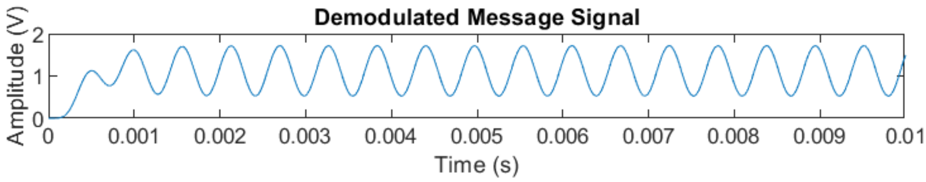

Figure 15: AM Under-modulated; Demodulated Signal

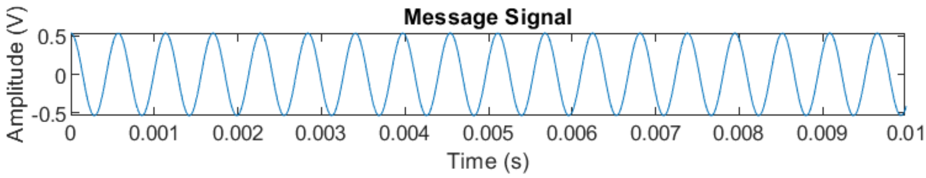

Figure 16: AM 100% Modulated; Message Signal

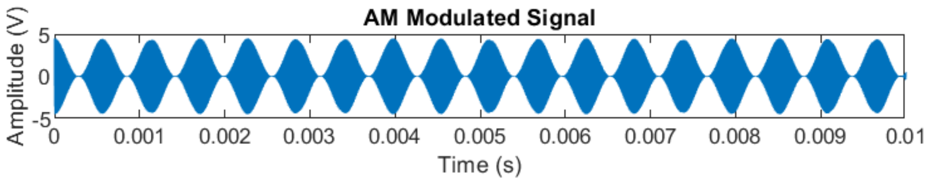

Figure 17: AM 100% Modulated; Modulated Signal

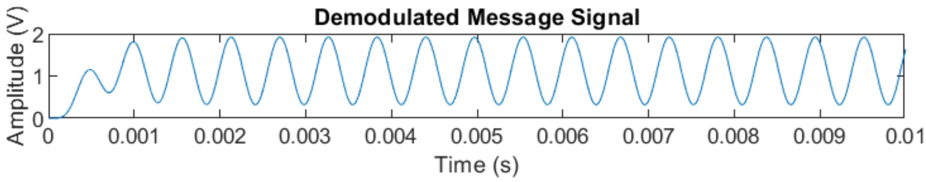

Figure 18: AM 100% Modulated; Demodulated Signal

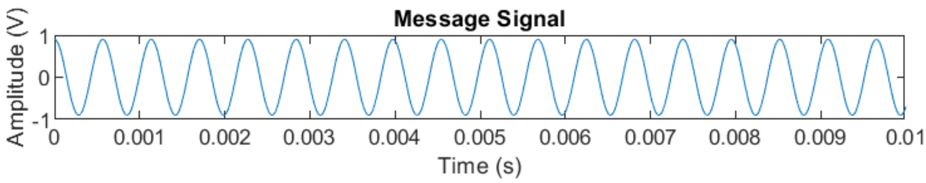

Figure 19: AM Over-modulated; Message Signal

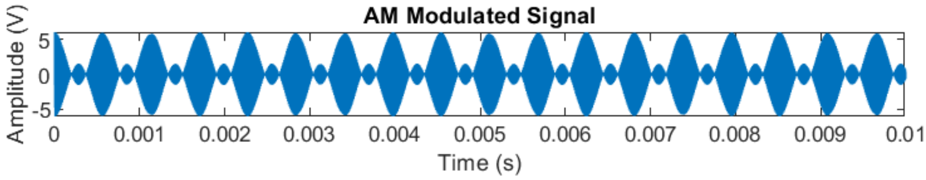

Figure 20: AM Over-modulated; Modulated Signal

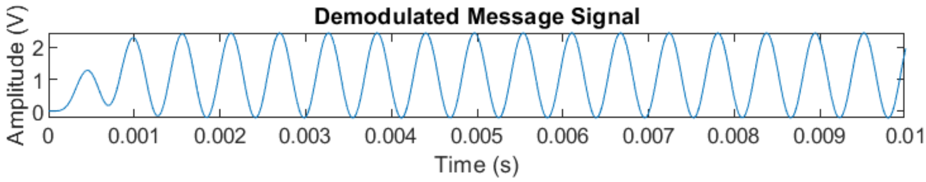

Figure 21: AM Over-modulated; Demodulated Signal

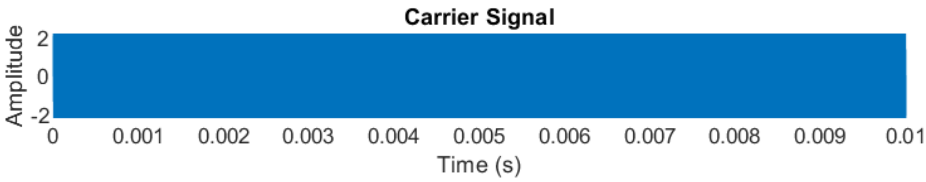

Figure 22: DSB-SC, Carrier Signal

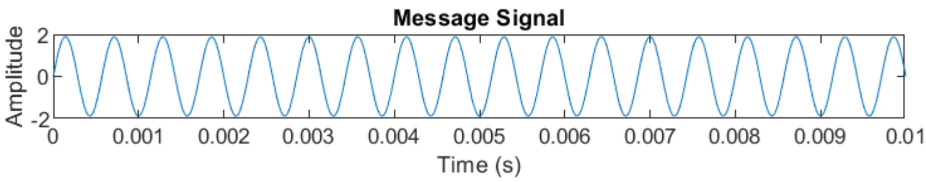

Figure 23: DSB-SC, Message Signal 1

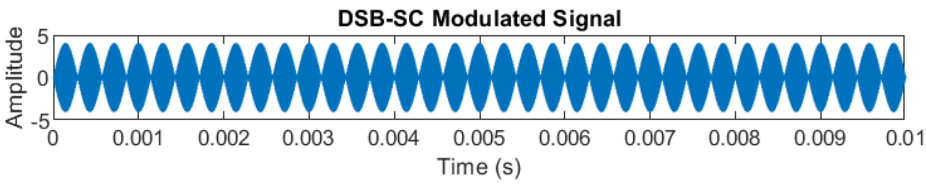

Figure 24: DSB-SC, Modulated Signal 1

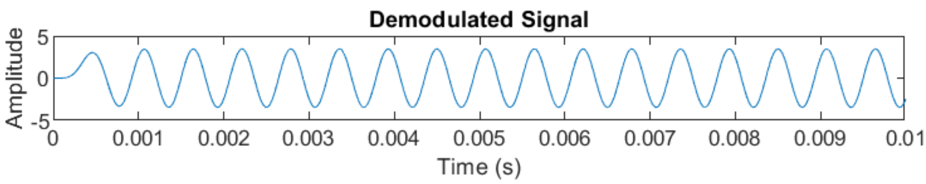

Figure 25: DSB-SC, Demodulated Signal 1

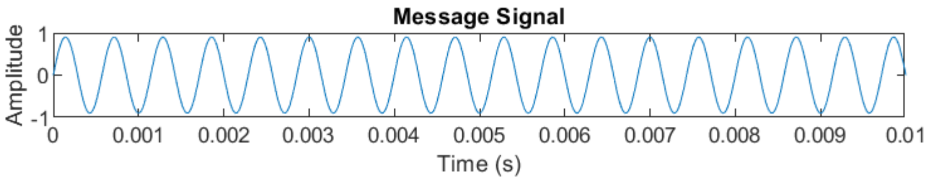

Figure 26: DSB-SC, Message Signal 2

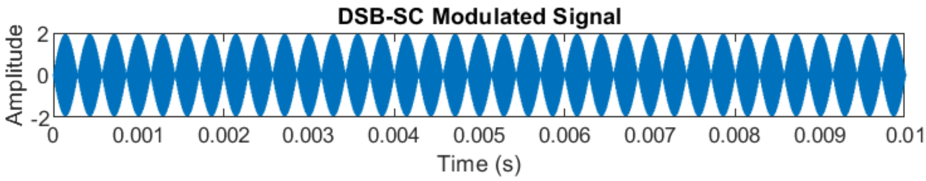

Figure 27: DSB-SC, Modulated Signal 2

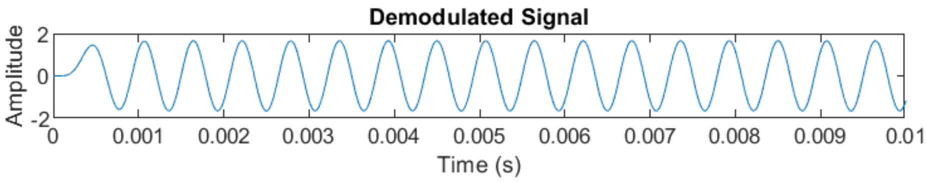

Figure 28: DSB-SC, Demodulated Signal 2

Discussion

In this experiment, the principles of Amplitude Modulation (AM) and Double Sideband Suppressed Carrier (DSB-SC) modulation and demodulation were explored. Experimental data and Matlab simulations provided insights into these modulation techniques under various conditions.

From the experimental data:

- For AM under modulation, the modulation index was approximately 0.668, indicating that the message signal's amplitude was less than the carrier's, resulting in a modulated signal with less variation in amplitude.

- For AM 100% modulation, the modulation index was 1, showing that the message signal's amplitude equaled the carrier's, resulting in a modulated signal with maximum amplitude variation without distortion.

- For AM over modulation, the modulation index was about 2.67, indicating that the message signal's amplitude exceeded the carrier's, resulting in significant distortion and envelope inversion in the modulated signal.

Matlab simulations supported these findings, visually representing the carrier, message, modulated, and demodulated signals for each modulation type. The effects of under, 100%, and over modulation on the AM signal and the successful demodulation of the original message signal were demonstrated.

For DSB-SC modulation, the carrier was suppressed, and only the sidebands were transmitted. Matlab simulations visualized the DSB-SC modulated signal and its demodulation, confirming the effectiveness of coherent detection in recovering the message.

This experiment highlighted the importance of the modulation index in AM and the efficiency of DSB-SC modulation in terms of power and bandwidth, reinforcing theoretical concepts through practical observations and simulations.

Conclusion

In conclusion, a comprehensive understanding of Amplitude Modulation (AM) and Double Sideband Suppressed Carrier (DSB-SC) modulation techniques was provided by this experiment. Through both experimental observations and Matlab simulations, the effects of different modulation indices on AM signals and the efficiency of DSB-SC modulation in terms of power and bandwidth were analyzed. The results demonstrated the importance of the modulation index in determining the quality of AM signals and highlighted the advantages of DSB-SC modulation for efficient communication. These findings are consistent with the theoretical concepts discussed in the literature [1, 2]. Overall, the practical applications and benefits of these modulation techniques in communication systems were reinforced by this experiment.

References

[1] S. Haykin, *Communication Systems.* Wiley, 2008.

[2] J. G. Proakis, *Digital Communications.* McGraw-Hill, 2007.