A Study on DSB-AM Signal Generation and Signal Recovery Methods

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***Abstract*—This paper presents the generation and demodulation of Double Sideband Amplitude Modulation (DSB-AM) signals using both simulation in MATLAB and physical implementation on a breadboard. The theoretical foundation of amplitude modulation is discussed, followed by the generation of DSB-AM signals using a function generator and their demodulation observed via a Digital Storage Oscilloscope (DSO). MATLAB simulations include time-domain signal visualization, frequency spectrum analysis using FFT, and power spectral density estimation. This dual approach provides a comprehensive understanding of DSB-AM signal characteristics and their practical implications in analog communication systems.**

***Index Terms*—DSB-AM, Amplitude Modulation, MATLAB Simulation, Power Spectral Density, Frequency Spectrum, Demodulation, Analog Communication, Breadboard Implementation**

I. INTRODUCTION

Amplitude Modulation (AM) is one of the earliest and most fundamental modulation techniques used in analog communication systems. In particular, Double Sideband Amplitude Modulation (DSB-AM) is a method where the amplitude of the carrier wave is varied in proportion to the instantaneous amplitude of the modulating signal. Despite being simple and bandwidth inefficient compared to modern digital modulation techniques, AM remains a crucial concept in understanding signal transmission and recovery mechanisms.

This paper focuses on the generation and demodulation of DSB-AM signals through both simulation and practical hardware setup. The simulation is carried out in MATLAB where the time-domain waveform, frequency spectrum, and power spectral density of the modulated signal are analyzed. Additionally, the experiment is implemented on a breadboard using a function generator to produce the AM signal and a Digital Storage Oscilloscope (DSO) to observe and verify the results.

The objective of this work is to bridge the gap between theoretical understanding and practical implementation of AM techniques. This paper is organized as follows: Section II describes the general assumptions and notations used. Section III discusses the theory and working principle of DSB-AM. Section IV covers the signal generation in MATLAB and on hardware. Section V presents the demodulation method. Section VI includes simulation results and observations. Section VII concludes the study.

II. GENERAL ASSUMPTIONS AND NOTATION

In this study, the following assumptions and parameters are used for the generation and analysis of the DSB-AM signal:

- The modulating signal $m(t)$ is a single-tone cosine wave given by:
$$m(t) = A_m \cos(2\pi f_m t)$$
where A_m is the amplitude and f_m is the frequency of the modulating signal.
- The carrier signal $c(t)$ is defined as:
$$c(t) = A_c \cos(2\pi f_c t)$$
where A_c is the amplitude and f_c is the carrier frequency.
- The modulation index m_I is defined as the ratio of the amplitude of the modulating signal to the amplitude of the carrier:
$$m_I = \frac{A_m}{A_c}$$
- The DSB-AM modulated signal $s(t)$ is given by:
$$s(t) = A_c \left[1 + m_I \cos(2\pi f_m t)\right] \cos(2\pi f_c t)$$
- The sampling frequency f_s for MATLAB simulations is set significantly higher than the carrier and message frequencies to ensure accurate time-domain representation and FFT analysis:
$$f_s = 10^4 \text{ Hz}$$
- The length of the signal used for simulation is approximately 35 milliseconds, which is sufficient to observe multiple cycles of both carrier and modulating signals.
- Fourier analysis is applied using the Fast Fourier Transform (FFT) to observe the frequency components of the modulated signal.
- Power Spectral Density (PSD) is calculated using:
$$PSD = \frac{|\text{FFT}(s)|^2}{n \cdot (f_s/n)}$$
where n is the length of the time-domain signal vector.

These assumptions form the basis for the simulation and are consistent with the parameters used in the physical breadboard implementation, where equivalent values of f_m, f_c, and A_m, A_c were selected using the function generator.

III. Theory and Working Principle

Amplitude Modulation (AM) is a process in which the amplitude of a high-frequency carrier signal is varied in proportion to the instantaneous amplitude of the modulating signal. In Double Sideband Amplitude Modulation (DSB-AM), the carrier and both upper and lower sidebands are transmitted, making it a conventional form of AM.

A. Modulation Principle

Let the modulating signal $m(t)$ be defined as:

$$m(t) = A_m \cos(2\pi f_m t)$$

and the carrier signal $c(t)$ be:

$$c(t) = A_c \cos(2\pi f_c t)$$

In DSB-AM, the modulated signal $s(t)$ is formed by:

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

where $m_I = \frac{A_m}{A_c}$ is the modulation index. This signal contains three main frequency components:

- The carrier frequency f_c
- The upper sideband at $f_c + f_m$
- The lower sideband at $f_c - f_m$

B. Frequency Spectrum

The frequency spectrum of a DSB-AM signal shows prominent peaks at the carrier frequency and at both sidebands. The bandwidth required for DSB-AM transmission is:

$$BW = 2f_m$$

This makes DSB-AM less bandwidth-efficient compared to SSB (Single Sideband) or DSB-SC (Double Sideband Suppressed Carrier).

C. Demodulation Principle

The recovery of the original message signal from the modulated carrier can be achieved through envelope detection. For successful demodulation using this method, the modulation index should satisfy $0 < m_I \leq 1$ to avoid envelope distortion. If $m_I > 1$, over-modulation occurs, leading to signal distortion.

Envelope detection can be performed either using a diode-resistor-capacitor circuit (in hardware) or algorithmically (in MATLAB) by detecting the outer envelope of the modulated waveform.

D. Practical Implementation

In the hardware setup:

- The carrier and modulating signals were generated using a function generator.
- The resulting AM signal was visualized using a Digital Storage Oscilloscope (DSO).
- For demodulation, a simple envelope detector circuit was constructed using a diode and RC filter.

In MATLAB:

- The modulated signal was generated using the mathematical expression of DSB-AM.
- Frequency analysis was conducted using FFT.
- Power Spectral Density (PSD) was computed to examine power distribution across frequencies.

This dual implementation enables a strong conceptual and practical understanding of how AM systems function.

IV. Generation of DSB-AM

Double Sideband Amplitude Modulation (DSB-AM) is one of the most fundamental analog modulation techniques. It works by varying the amplitude of a high-frequency carrier signal in accordance with the instantaneous amplitude of the baseband message signal. This section explains the theoretical foundation of DSB-AM generation and its implementation through MATLAB simulation and hardware experiments.

A. Theoretical Basis

Let the message or modulating signal be a single-tone cosine wave given by:

$$m(t) = A_m \cos(2\pi f_m t)$$

where A_m is the amplitude of the message signal and f_m is its frequency.

Similarly, let the carrier signal be:

$$c(t) = A_c \cos(2\pi f_c t)$$

where A_c is the amplitude of the carrier and f_c is its frequency, with $f_c \gg f_m$.

In conventional amplitude modulation, the carrier's amplitude is modified based on the message signal. The resulting DSB-AM signal is:

$$s(t) = A_c \left[1 + m_I \cos(2\pi f_m t)\right] \cos(2\pi f_c t)$$

where $m_I = \frac{A_m}{A_c}$ is the modulation index. For effective modulation without distortion, $0 < m_I \leq 1$. If $m_I > 1$, overmodulation occurs, which leads to envelope distortion and loss of information during demodulation.

The frequency spectrum of this signal consists of three primary components:

- The carrier frequency at f_c
- The upper sideband (USB) at $f_c + f_m$
- The lower sideband (LSB) at $f_c - f_m$

Unlike DSB-SC (Double Sideband Suppressed Carrier), DSB-AM retains the carrier, which aids in simpler envelope-based demodulation.

B. MATLAB Simulation Overview

The DSB-AM signal was simulated using MATLAB. A high-resolution time vector was created to simulate the signal over a small interval. The message and carrier signals were generated using cosine functions, and the modulated signal was calculated using the theoretical formula.

The waveform of the DSB-AM signal was plotted in the time domain to observe the variation in amplitude (envelope) that mirrors the message signal. This visualization confirms the correct implementation of amplitude modulation.

To analyze the signal in the frequency domain, the Fast Fourier Transform (FFT) was applied to obtain the frequency spectrum. The three distinct peaks in the spectrum corresponding to f_c, $f_c - f_m$, and $f_c + f_m$ verified the theoretical expectations. Furthermore, the Power Spectral Density (PSD) was calculated to examine how the signal's power is distributed over frequency. The PSD plot shows that most power is concentrated at the carrier frequency and sidebands, as expected in AM.

C. Experimental Implementation

The generation of DSB-AM was also carried out physically in the communication laboratory using standard lab instruments. The setup included:

- **Function Generator:** Used to produce the low-frequency message signal (100 Hz) and the high-frequency carrier signal (1 kHz).
- **AM Modulation Circuit:** The two signals were fed into an AM modulator (either an IC-based circuit or a transistor-based modulator) implemented on a breadboard.
- **Digital Storage Oscilloscope (DSO):** Used to visualize the resulting AM waveform.

By adjusting the amplitude levels on the function generator, a modulation index of less than 1 was maintained. The modulated signal observed on the DSO exhibited the typical AM envelope structure, confirming successful DSB-AM generation.

This combination of simulation and physical implementation helped reinforce theoretical understanding and allowed practical verification of amplitude modulation concepts.

V. Demodulation of DSB-AM

Demodulation is the process of retrieving the original message signal from the modulated carrier wave. For DSB-AM, several demodulation methods are available depending on the availability of the carrier signal and the complexity of the system. In our study, we focus on **envelope detection**, which is a simple and effective method for demodulating conventional AM signals with an intact carrier.

A. Theoretical Background

For a conventional AM signal defined by:

$$s(t) = A_c \left[1 + m_I \cos(2\pi f_m t)\right] \cos(2\pi f_c t)$$

the envelope of the signal is:

$$|s(t)| = A_c \left|1 + m_I \cos(2\pi f_m t)\right|$$

When the modulation index $m_I \leq 1$, the envelope directly follows the shape of the message signal, and the message can be recovered using an envelope detector. The envelope detector typically consists of a diode, capacitor, and resistor. The diode rectifies the signal, and the capacitor-resistor (RC) pair filters out the high-frequency carrier, leaving behind the baseband message signal.

B. MATLAB Simulation Overview

In MATLAB, demodulation was simulated using a two-step process:

1) Rectification: The absolute value of the AM signal was taken to simulate the diode effect.
2) Low-pass filtering: A low-pass filter was applied to remove the carrier frequency and retain only the message signal.

This method effectively emulates envelope detection. The demodulated signal was plotted and compared with the original message signal to validate accuracy. The reconstructed signal closely matched the original modulating signal, demonstrating the effectiveness of the demodulation technique.

C. Experimental Implementation

The demodulation process was also tested in a practical hardware setup in the communication laboratory. The steps involved were:

- The DSB-AM signal generated previously was fed into an envelope detector circuit, consisting of a diode for rectification and an RC filter for smoothing.
- The RC time constant was carefully selected to ensure it allowed the message signal to pass while attenuating the carrier.
- The output of the envelope detector was visualized on a Digital Storage Oscilloscope (DSO).

The observed waveform on the DSO confirmed the successful extraction of the original message signal from the AM waveform. The results from the physical setup were in close agreement with the MATLAB simulation, confirming the validity of the theoretical approach.

D. Conclusion of Demodulation Stage

The study of demodulation using envelope detection demonstrates that for DSB-AM signals with an adequate carrier component and appropriate modulation index, the message signal can be reliably recovered. Both the simulated and experimental results validated the theory and emphasized the importance of correctly selecting the RC values in practical envelope detectors.

VI. Numerical Results

This section presents the numerical simulation results of the Double Sideband Amplitude Modulated (DSB-AM) signal. The simulations were performed using MATLAB, and the results include time-domain, frequency-domain, and power spectral density representations of the modulated signal.

A. Time-Domain Representation

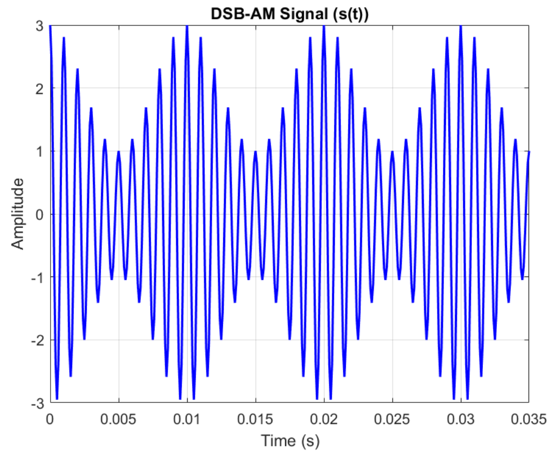

Fig. 1. Frequency spectrum of DSB-SC signal

Figure 1 shows the time-domain waveform of the DSB-AM signal. It can be observed that the high-frequency carrier signal is modulated in amplitude by the lower-frequency message signal. The envelope of this waveform follows the shape of the original message, confirming the successful modulation process. This visual representation confirms that the information is encoded in the varying amplitude of the carrier.

B. Frequency Spectrum of the DSB-AM Signal

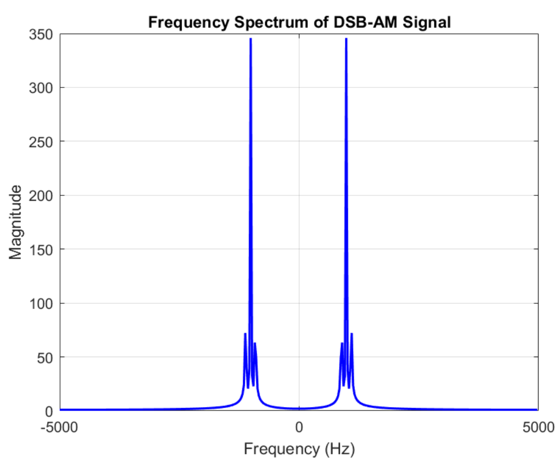

Fig. 2. Frequency spectrum of DSB-SC signal

Figure 2 illustrates the frequency-domain representation of the DSB-AM signal using the Fast Fourier Transform (FFT). The spectrum clearly shows two significant peaks centered around the carrier frequency, indicating the presence of upper and lower sidebands. These sidebands contain the actual message information. Since this is a double sideband suppressed carrier (DSB-SC) signal, there is no peak at the carrier frequency itself. The bandwidth of the signal is approximately twice the bandwidth of the message signal.

C. Power Spectral Density Analysis

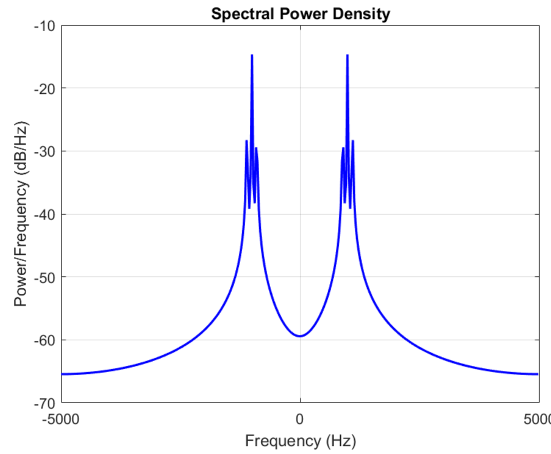

Fig. 3. Frequency spectrum of DSB-SC signal

Figure 3 shows the Power Spectral Density (PSD) of the DSB-AM signal. The PSD represents how the power of the signal is distributed with respect to frequency, measured in dB/Hz. The sharp peaks around the sidebands confirm the spectral characteristics of the DSB-AM signal. The logarithmic scale used in this plot highlights the concentration of power in the sidebands while attenuating lower power noise components. This plot is useful for understanding the spectral efficiency and helps in filter design for signal recovery.

D. Summary

The numerical results validate the theoretical analysis of DSB-AM modulation. The time-domain plot shows correct modulation of the carrier, while the frequency-domain and PSD plots confirm the expected spectral characteristics. These simulations demonstrate the fundamental principles of amplitude modulation and are consistent with theoretical expectations.

VII. Conclusion

This study explored the generation and recovery of Double Sideband Amplitude Modulated (DSB-AM) signals using both theoretical analysis and practical implementation. The signal generation was achieved in MATLAB using conventional modulation equations, and key signal characteristics were verified through time-domain and frequency-domain analysis. The Power Spectral Density (PSD) analysis further confirmed the concentration of power around the sidebands, consistent with DSB-AM theory.

Additionally, the experiment was implemented on a breadboard using discrete components and visualized using a Digital Storage Oscilloscope (DSO), validating the practical feasibility of the method. Demodulation was successfully carried out using envelope detection, both in MATLAB and in the hardware setup.

The results from the simulation and hardware experiment closely aligned with the theoretical expectations, demonstrating a solid understanding of DSB-AM signal behavior and recovery. This study not only reinforces the fundamental principles of amplitude modulation but also highlights its continued relevance in modern communication systems.

Future work may include exploring DSB-SC and SSB techniques, incorporating noise models, and comparing the performance of different demodulation methods under practical channel conditions.