DSBSC Signal Generation and Demodulation

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***Abstract*—This paper presents the analysis, design, and practical implementation of Double Sideband Suppressed Carrier Amplitude Modulation (DSBSC). The DSB-SC signal was generated using three different modulation techniques: balanced modulator, ring modulator, and switching modulator. For signal recovery, a coherent detection method was employed for demodulation. The theoretical concepts were validated through MATLAB simulations, including time-domain analysis, frequency spectrum, and power spectral density calculations. Furthermore, the entire experiment was implemented on a breadboard using discrete components and a function generator, with signal observation carried out using a digital storage oscilloscope (DSO). This study highlights the comparative behavior of various modulator circuits and demonstrates the effectiveness of coherent detection for DSB-SC demodulation in practical scenarios. The results confirm the theoretical predictions and offer insights into the strengths and limitations of each method used.**

***Index Terms*—DSB-SC, Balanced Modulator, Ring Modulator, Switching Modulator, Coherent Detection, Amplitude Modulation, Breadboard Implementation, MATLAB Simulation.**

I. Introduction

Amplitude Modulation (AM) is a fundamental technique in analog communication systems, where the amplitude of a high-frequency carrier signal is varied in accordance with the instantaneous amplitude of the baseband message signal. Among various AM techniques, Double Sideband Suppressed Carrier Amplitude Modulation (DSBSCAM) is widely used due to its more efficient use of power and bandwidth compared to conventional AM with carrier. In DSB-SC, the carrier component is suppressed, resulting in a signal that consists only of the upper and lower sidebands, which carry the information. The generation and demodulation of DSB-SC signals are critical tasks in communication system design. Various modulation methods can be employed to generate DSB-SC signals, including balanced modulators, ring modulators, and switching modulators—each with distinct advantages and implementation complexities. Similarly, demodulation techniques such as coherent detection and envelope detection offer different trade-offs between complexity and performance. In particular, coherent detection provides an accurate and efficient method for demodulating DSB-SC signals by using a locally generated carrier synchronized in frequency and phase with the transmitted carrier. This paper focuses on the analysis, simulation, and practical implementation of DSB-SC signal generation using three different modulation techniques—balanced modulator, ring modulator, and switching modulator—and the demodulation of the generated signals using a coherent detector. MATLAB simulations are used to study the time-domain signals, frequency spectra, and power spectral densities to validate the theoretical models. The practical implementation is carried out on a breadboard using discrete components and function generators, with observations made using a digital storage oscilloscope (DSO).

The remainder of the paper is organized as follows: Section II presents the theory and working principle of DSB-SC modulation and demodulation. Section III discusses the generation of DSB-SC AM signals using various modulation techniques. Section IV explains the coherent demodulation process in detail. Section V provides numerical results and simulation outputs. Finally, Section VI concludes the paper by summarizing the findings and suggesting future directions.

II. Theory and Working Principle

Modulation is the process of encoding information on a carrier wave for efficient transmission over long distances. Among different modulation techniques, Amplitude Modulation (AM) is widely used, where the amplitude of a high-frequency carrier signal varies according to the message signal. However, in standard AM, a significant portion of the transmitted power is wasted in the carrier, which does not carry useful information.

To improve power efficiency, Double Sideband Suppressed Carrier modulation (DSB-SC) is used, where the carrier is completely removed and only the upper and lower sidebands are transmitted. This ensures that the transmitted power is concentrated in the useful part of the signal.

A. Mathematical Representation of DSB-SC AM

A general AM signal is expressed as:

$$s(t) = A_c[1 + m(t)]\cos(\omega_c t) \tag{1}$$

where:

- A_c is the carrier amplitude,
- $m(t)$ is the message signal,
- $\omega_c = 2\pi f_c$ is the angular carrier frequency.

In DSB-SC, the carrier component is eliminated, and the transmitted signal is:

$$s(t) = A_c m(t)\cos(\omega_c t) \tag{2}$$

B. Frequency-Domain Representation of DSB-SC

Applying the Fourier Transform to the DSB-SC signal yields:

$$S(f) = \frac{A_c}{2} \left[M(f - f_c) + M(f + f_c) \right] \tag{3}$$

where $M(f)$ is the Fourier transform of the message signal $m(t)$.

This shows that DSB-SC consists of two frequency-shifted versions of the baseband signal, centered at $\pm f_c$, with no spectral content at the carrier frequency due to suppression.

C. Bandwidth Consideration

The bandwidth of a DSB-SC signal is:

$$BW = 2f_m \tag{4}$$

where f_m is the maximum frequency component of the message signal. This is identical to the bandwidth of standard AM, but with better power efficiency due to carrier suppression.

D. Demodulation Principle

Demodulation of DSB-SC requires a coherent detector, which involves multiplying the received signal with a locally generated carrier signal that is **synchronized** in both frequency and phase with the original carrier. This allows for the retrieval of the original message signal after low-pass filtering, as detailed in Section **??**.

III. Generation of DSB-SC AM Signal

Double Sideband Suppressed Carrier (DSB-SC) modulation is a technique wherein a baseband message signal is multiplied by a high-frequency carrier, effectively removing the carrier component and retaining only the sidebands. This section explains the theoretical foundation of DSB-SC modulation and describes three practical methods of implementing it using discrete components.

A. Mathematical Basis

The DSB-SC signal can be mathematically expressed as:

$$s(t) = m(t) \cdot A_c \cos(2\pi f_c t) \tag{5}$$

Here, $m(t)$ represents the message signal, A_c is the carrier amplitude, and f_c denotes the carrier frequency. The product of the message and carrier signals results in a spectrum comprising two sidebands located at frequencies $f_c \pm f_m$, where f_m is the frequency content of $m(t)$. The carrier component at f_c is significantly reduced or entirely suppressed.

B. Balanced Modulator Method

A balanced modulator uses a differential amplifier configuration to suppress the carrier. This is typically realized using matched bipolar junction transistors (BJTs) or analog multipliers. Due to the circuit's symmetrical structure, the carrier components cancel out, allowing only the modulated sidebands to appear at the output.

In the experimental setup, a pair of matched NPN transistors was used to construct the modulator on a breadboard. A 1 kHz sine wave served as the message signal, while a 100 kHz sine wave functioned as the carrier. Proper DC biasing and symmetry ensured the cancellation of the carrier. The output waveform, observed using a digital storage oscilloscope (DSO), clearly displayed DSB-SC characteristics with minimal carrier leakage.

C. Ring Modulator Method

The ring modulator, or diode bridge modulator, uses four diodes arranged in a ring structure. This configuration enables polarity inversion of the carrier signal, synchronized with the instantaneous value of the message signal, thereby achieving signal multiplication.

The circuit was built using four 1N4148 diodes, with transformers used to provide signal coupling and phase balancing. When tested with the same message and carrier frequencies as the previous method, the output exhibited a clean DSB-SC signal, as verified on the DSO. The symmetry of the ring topology contributes to effective carrier suppression.

D. Switching Modulator Method

In this method, DSB-SC modulation is approximated by switching the polarity of the carrier based on the sign of the message signal. This is commonly implemented using transistor switches controlled by a square wave version of the message.

The output of this method can be mathematically described as:

$$s(t) = \mathrm{sgn}(m(t)) \cdot A_c \cos(2\pi f_c t) \tag{6}$$

Although this is an approximation, it still yields a spectrum centered at the carrier frequency with suppressed carrier content.

The circuit was realized using NPN transistors operating as electronic switches. A square wave derived from the message signal was applied to control the switching of the carrier signal. The observed waveform on the oscilloscope confirmed the presence of sidebands and the effective suppression of the carrier.

The generation of DSB-SC signals can be accomplished using various hardware techniques, each based on the fundamental principle of multiplying the message signal with a carrier. Among the three methods studied, the balanced modulator offers precise carrier suppression when constructed with well-matched components. The ring modulator provides a diode-based alternative with good spectral results, while the switching modulator offers a simpler approach that approximates DSB-SC behavior effectively.

All three methods were successfully implemented and verified using a digital oscilloscope. The observed waveforms aligned closely with theoretical expectations, demonstrating that practical analog circuits can reliably achieve DSB-SC modulation with proper design and component selection.

IV. Demodulation of DSBSC

Double Sideband Suppressed Carrier (DSBSC) demodulation requires **coherent detection**, where the received signal is multiplied by a locally generated carrier.

A. Mathematical Analysis

The transmitted DSBSC signal is given by:

$$s(t) = m(t) A_c \cos(2\pi f_c t) \tag{7}$$

where:

- $m(t)$ is the message signal,
- A_c is the carrier amplitude,
- f_c is the carrier frequency.

At the receiver, we multiply $s(t)$ with a locally generated carrier $\cos(2\pi f_c t)$:

$$r(t) = s(t) \cos(2\pi f_c t) \tag{8}$$

Substituting $s(t)$:

$$r(t) = (m(t) A_c \cos(2\pi f_c t)) \cos(2\pi f_c t) \tag{9}$$

Using the trigonometric identity:

$$\cos^2 x = \frac{1 + \cos 2x}{2}, \tag{10}$$

we get:

$$r(t) = m(t) A_c \frac{1 + \cos(4\pi f_c t)}{2} \tag{11}$$

$$r(t) = \frac{A_c}{2} m(t) + \frac{A_c}{2} m(t) \cos(4\pi f_c t) \tag{12}$$

The second term is a high-frequency component at $2f_c$, which is removed using a **low-pass filter (LPF)**. This gives:

$$m_{\text{dem}}(t) = \frac{A_c}{2} m(t) \tag{13}$$

To fully recover $m(t)$, we scale by $2/A_c$:

$$m(t) = \frac{2}{A_c} m_{\text{dem}}(t) \tag{14}$$

For proper demodulation, the locally generated carrier must:

- Have the **same frequency** as the original carrier (f_c).
- Be **phase-aligned** with the transmitted carrier.

If there is a phase mismatch, the recovered signal will be distorted.

V. Numerical Results

This section presents the simulation results of Double Sideband Suppressed Carrier (DSB-SC) amplitude modulation carried out using MATLAB. The parameters used in the simulation are as follows: the message signal frequency f_m is 100 Hz, the carrier frequency f_c is 1000 Hz, the message amplitude A_m is 1, the carrier amplitude A_c is 2, and the sampling frequency f_s is 10 kHz. The simulation time duration is 35 ms.

Algorithm 1 DSBSC-AM Modulation and Demodulation

Initialize Parameters:
Define message signal frequency f_m and carrier frequency f_c
Set amplitudes: Message (A_m) and Carrier (A_c)
Define sampling frequency f_s and time vector t
Generate Signals:
Generate message signal: $m(t) = A_m \cos(2\pi f_m t)$
Generate carrier signal: $c(t) = A_c \cos(2\pi f_c t)$
Modulation (DSBSC-AM):
Multiply message with carrier: $s(t) = m(t) \cdot c(t)$
Demodulation (Coherent Detection):
Generate synchronized carrier at receiver: $c'(t) = 2\cos(2\pi f_c t)$
Multiply received signal with $c'(t)$: $y(t) = s(t) \cdot c'(t)$
Low-Pass Filtering:
Apply LPF to remove high-frequency components: $m'(t) = \text{LPF}(y(t))$
End Process

A. Time-Domain Representation

Figure 1 illustrates the time-domain waveform of the modulated DSB-SC signal. The waveform shows amplitude variations that correspond to the baseband message signal, while the carrier component is effectively suppressed. The signal exhibits a typical double-sideband suppressed-carrier modulation pattern, where the envelope reflects the shape of the message signal without the presence of a continuous carrier.

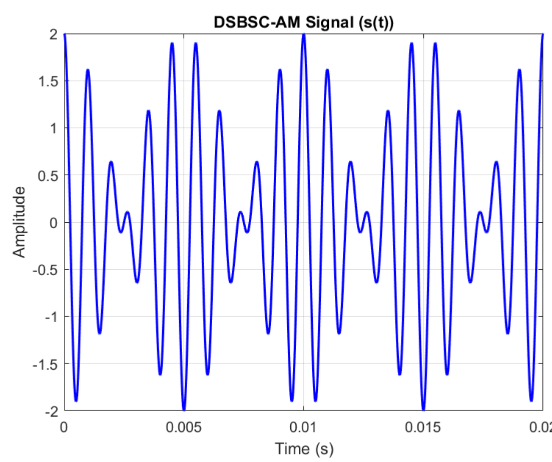

Fig. 1. Time-domain waveform of DSB-SC signal

B. Frequency Spectrum Analysis

The frequency domain representation of the modulated signal is obtained using the Fast Fourier Transform (FFT). As shown in Figure 2, the spectrum contains two prominent peaks located at $f_c - f_m = 900$ Hz and $f_c + f_m = 1100$ Hz. The carrier frequency component at 1000 Hz is notably absent, confirming that the carrier is suppressed and only the sidebands are transmitted.

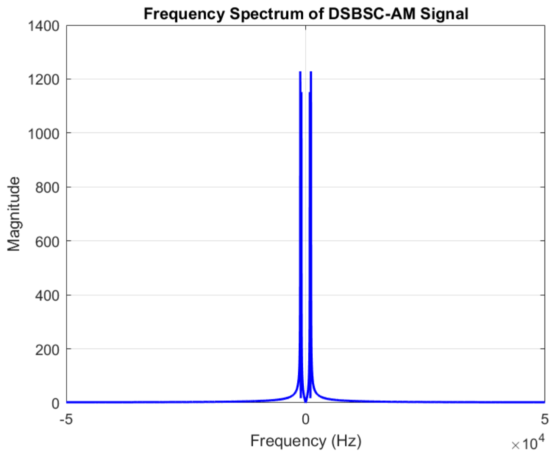

Fig. 2. Frequency spectrum of DSB-SC signal

C. Power Spectral Density

Figure 3 shows the Power Spectral Density (PSD) of the DSB-SC signal. The PSD plot reveals energy concentration primarily in the vicinity of 900 Hz and 1100 Hz, which corresponds to the lower and upper sidebands. The logarithmic scale (in dB/Hz) highlights the spectral shape and confirms that no significant energy is present at the carrier frequency, indicating efficient spectral usage.

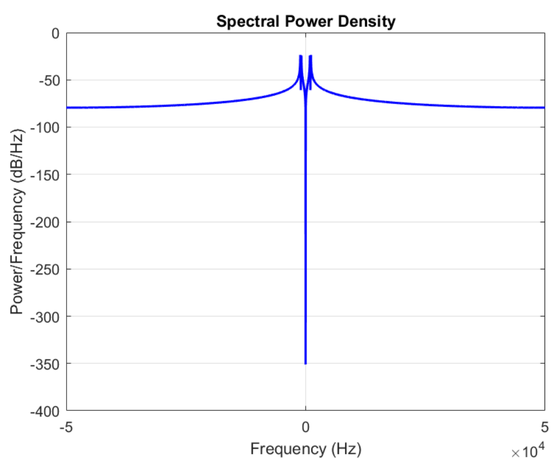

Fig. 3. Power Spectral Density of DSB-SC signal

D. Discussion

The simulation results confirm the theoretical principles of DSB-SC modulation and demodulation. In the time-domain plot, the modulated signal exhibits the characteristic envelope of the message signal, with the carrier component suppressed as expected. The frequency spectrum shows two distinct sidebands at 900 Hz and 1100 Hz, and the absence of a spectral peak at 1000 Hz verifies the suppression of the carrier. The PSD plot further emphasizes efficient spectral utilization, with energy concentrated around the sidebands.

During demodulation, the use of a synchronized carrier in coherent detection allows accurate retrieval of the message signal. The low-pass filter effectively removes the high-frequency components, resulting in a demodulated output that closely resembles the original message. These results demonstrate the reliability of DSB-SC in both frequency and time domains

VI. Conclusion

In this study, the principles and practical implementation of Double Sideband Suppressed Carrier (DSB-SC) amplitude modulation were explored through both simulation in MATLAB and hardware experimentation. The modulation and demodulation processes were successfully carried out using coherent detection, which was further enhanced by low-pass filtering to recover the original message signal.

The time-domain analysis confirmed the suppression of the carrier signal and preservation of the modulated waveform envelope corresponding to the message signal. The frequency-domain and power spectral density analyses revealed distinct sidebands at expected frequencies (i.e., $f_c \pm f_m$) and confirmed the absence of carrier energy, validating the spectral efficiency of the DSB-SC technique.

The simulation results aligned closely with theoretical expectations and provided a clear understanding of the signal characteristics in both time and frequency domains. The practical implementation using a breadboard further reinforced the conceptual understanding, though it also highlighted real-world considerations such as component limitations and synchronization issues in carrier recovery.

Overall, the study demonstrates that DSB-SC modulation is a bandwidth-efficient modulation technique suitable for various analog communication systems. The MATLAB simulation provides a valuable tool for analyzing and visualizing signal behavior, while the hardware implementation offers hands-on insights into real-time signal generation and recovery.