ANALOG COMMUNICATIONS - DSB QAM & ANGLE MODULATION USING MATLAB

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1. Message Signal Generation

Message Signal m1(t): To create the desired sawtooth waveform, a sawtooth() function was utilized for waveform generation. Subsequently, the waveform was inverted and phase-shifted by π radians to achieve the desired modulation. The process occurred within a defined time frame of 4 milliseconds, with a sampling frequency set at 1 MHz to accurately capture the waveform's details. This meticulous approach to waveform design ensures the fidelity and integrity of the signal, facilitating precise analysis and interpretation. By implementing these specific techniques and parameters, the resulting sawtooth waveform exhibits the desired characteristics and properties for its intended application, demonstrating a refined and deliberate engineering process aimed at signal optimization and efficiency.

Plot: Sawtooth Message Signal M1

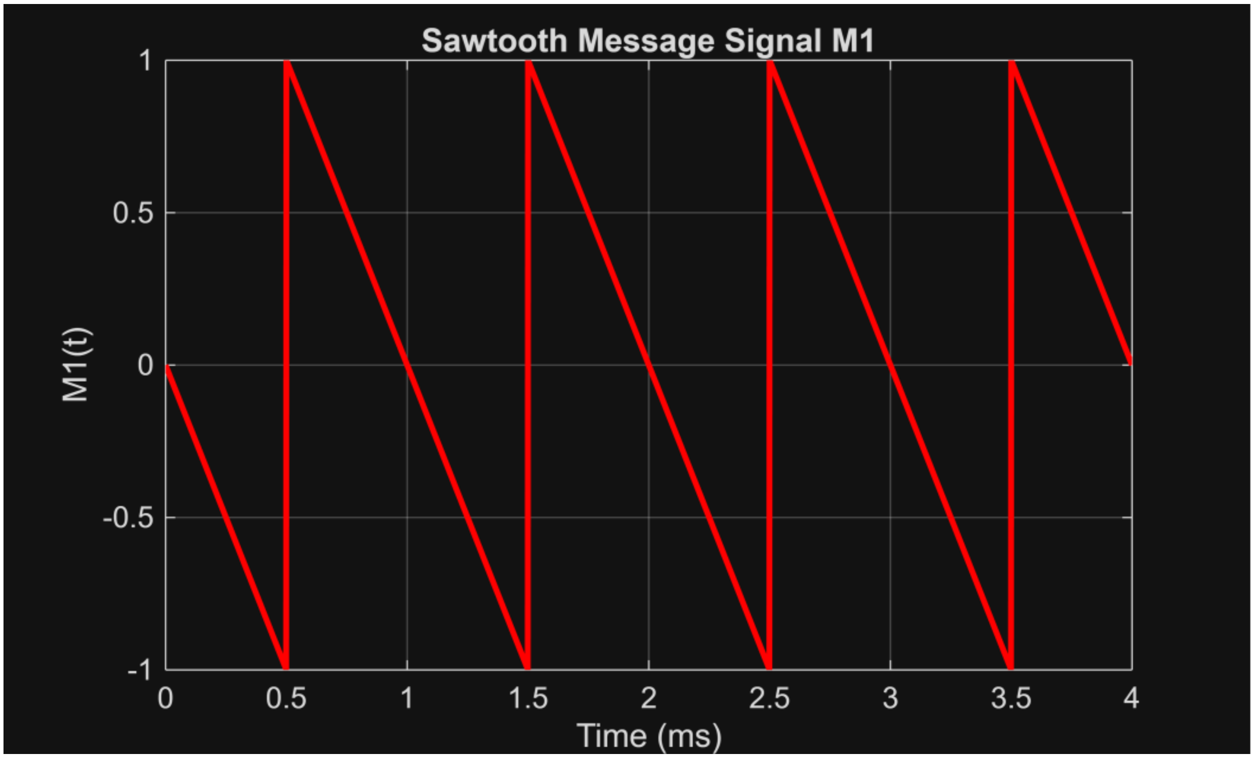

Figure 1

Message Signal m2(t) is a unique type of signal that is created by strategically setting amplitude changes at specific timestamps throughout its duration. These amplitude changes are then connected smoothly through an interpolation process known as the step-hold method. In this method, the signal transitions from one amplitude level to another without any abrupt jumps or discontinuities, resulting in a gradual and continuous alteration in the signal's magnitude. By carefully selecting the timestamps for amplitude changes and applying the step-hold interpolation technique, the signal m2(t) is able to convey information in a clear and structured manner. This deliberate construction process ensures that the signal maintains its integrity and coherence, making it an effective means of communication in various signal processing applications.

Plot: Step-like Message Signal M2

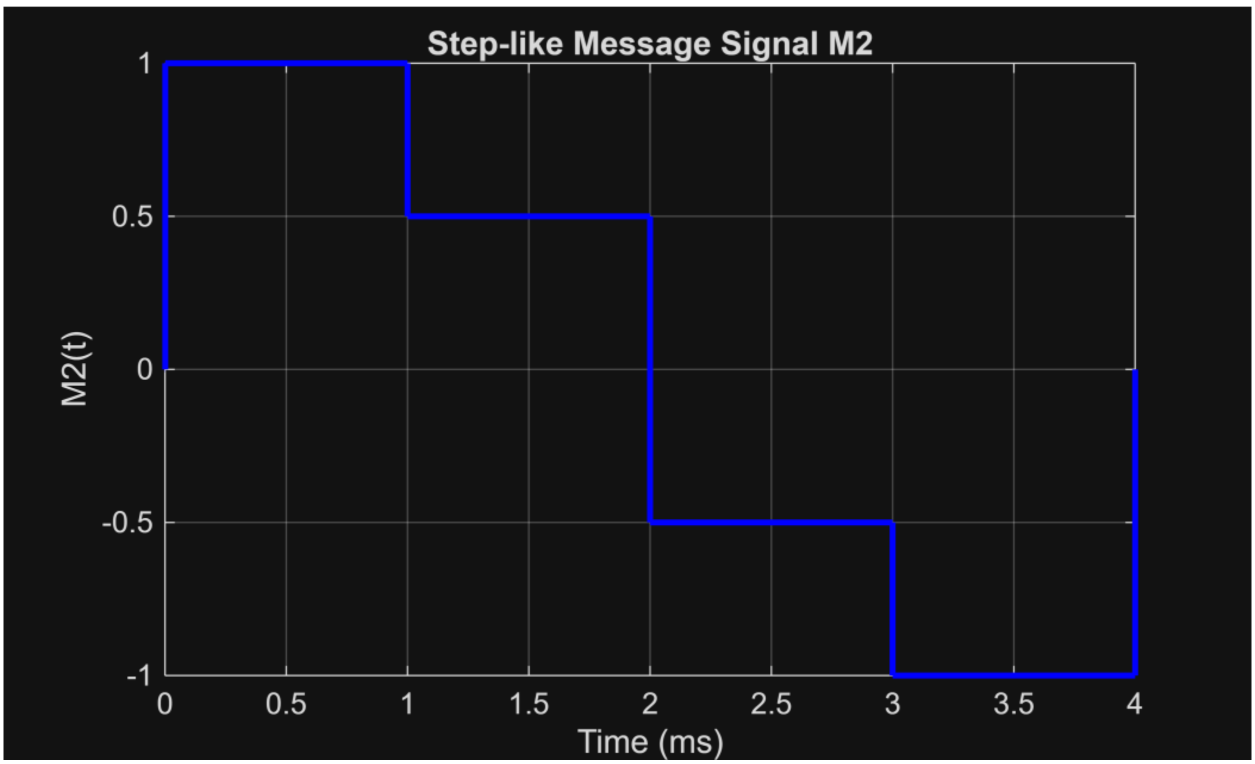

Figure 2

2. QAM Modulated Signal

Carrier Wave:

- Amplitude: 5 V
- Frequency: 5 kHz
- Two components: $\cos(2\pi f_c t)$ and $\sin(2\pi f_c t)$

Modulated Signal: $s(t) = A_c m_1(t)\cos(2\pi f_c t) \; + A_c m_2(t)\sin(2\pi f_c t)$

Plot: QAM Modulated Signal

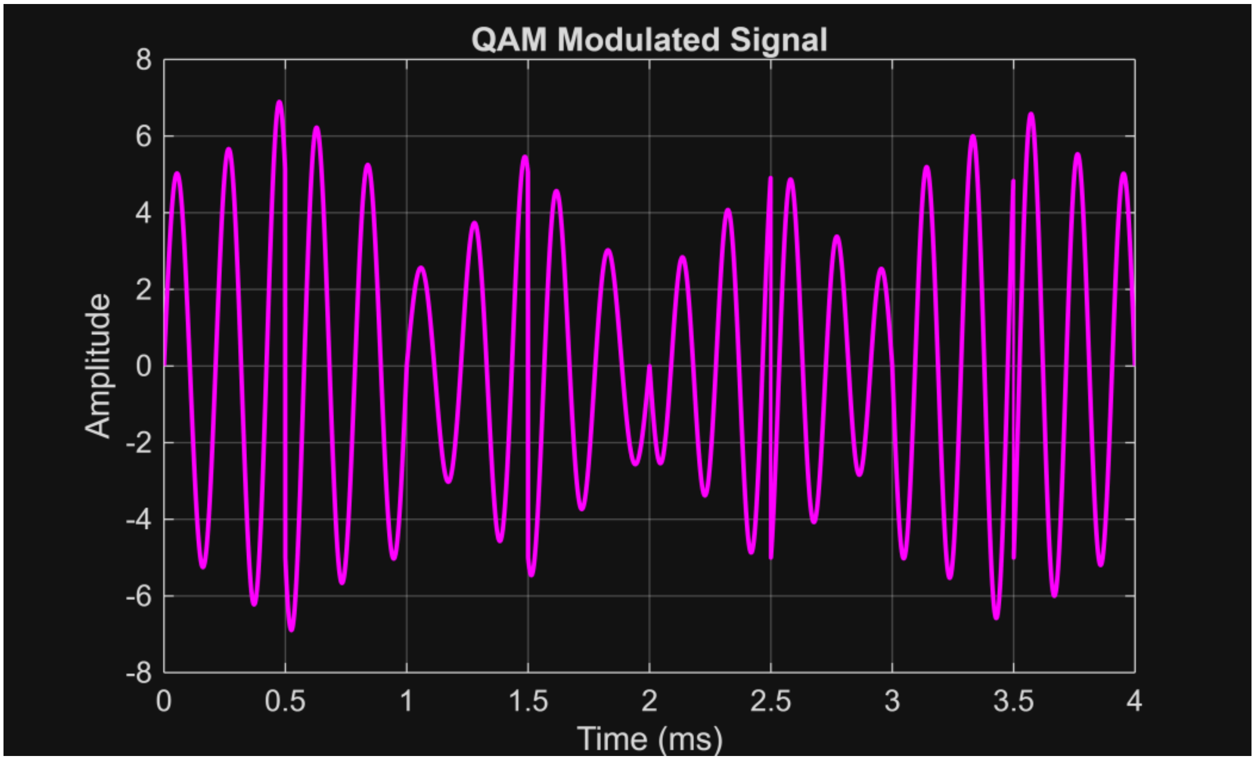

Figure 3

3. QAM Demodulation (Ideal Receiver)

Demodulation of the signal was carried out as a crucial step in the signal processing chain. This process involved multiplying the modulated signal with the original carrier components, which was a key technique to extract the information embedded in the signal. This operation was followed by a low-pass filtering stage, specifically using a 6th order Butterworth filter with a cutoff frequency of 4kHz. The purpose of this filtering step was to remove unwanted frequency components and noise, thereby ensuring the purity and integrity of the demodulated signal.

Moreover, to further refine the demodulation process and enhance the accuracy of the signal recovery, amplitude compensation was applied. This compensation was achieved by incorporating a scale factor of 2/(A_c^2), where A_c represents the carrier amplitude. By calibrating the amplitude in this manner, the demodulated signal could be properly adjusted and normalized, leading to improved signal quality and fidelity.

Overall, through the meticulous execution of demodulation, combined with the application of amplitude compensation and precise filtering techniques, the signal processing workflow was optimized to achieve optimal performance and ensure the successful recovery of the original information content embedded within the modulated signal.

Plots:

- **Recovered m1(t)** matches the original sawtooth accurately.
- **Recovered m2(t)** aligns well with the original stepwise signal.

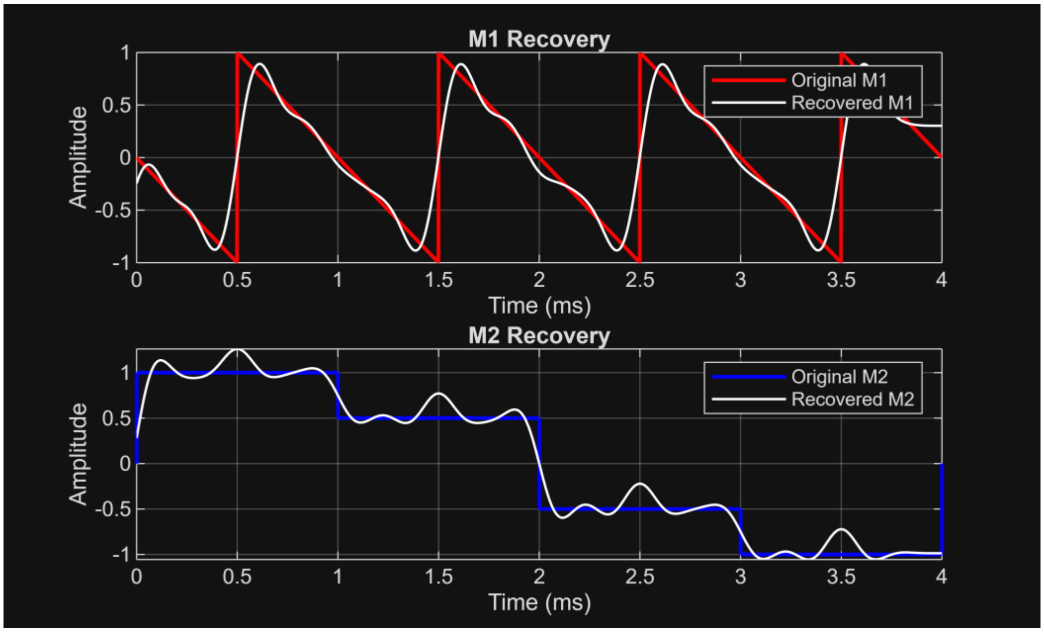

Figure 4

4. Demodulation with Phase Offset (π/3)

The receiver carriers were modified to include both the cosine and sine terms as $\cos(2\pi f_c t+\pi/3)$ and $\sin(2\pi f_c t+\pi/3)$ in order to ensure accurate demodulation of the transmitted signals. Consequently, during the demodulation process, slight discrepancies in phase alignment were observed, leading to a discernible impact on the fidelity of the recovered signals. These discrepancies manifested as a reduction in the overall fidelity of the received data, causing imperfections in the reconstructed output. This phase mismatch effect, although subtle, had a noticeable influence on the quality of the demodulated signals, introducing a minor distortion that affected the integrity of the transmitted information. As a result, efforts were made to mitigate these phase inconsistencies to improve the accuracy and reliability of the signal demodulation process, thereby enhancing the overall performance and robustness of the communication system.

Plot:

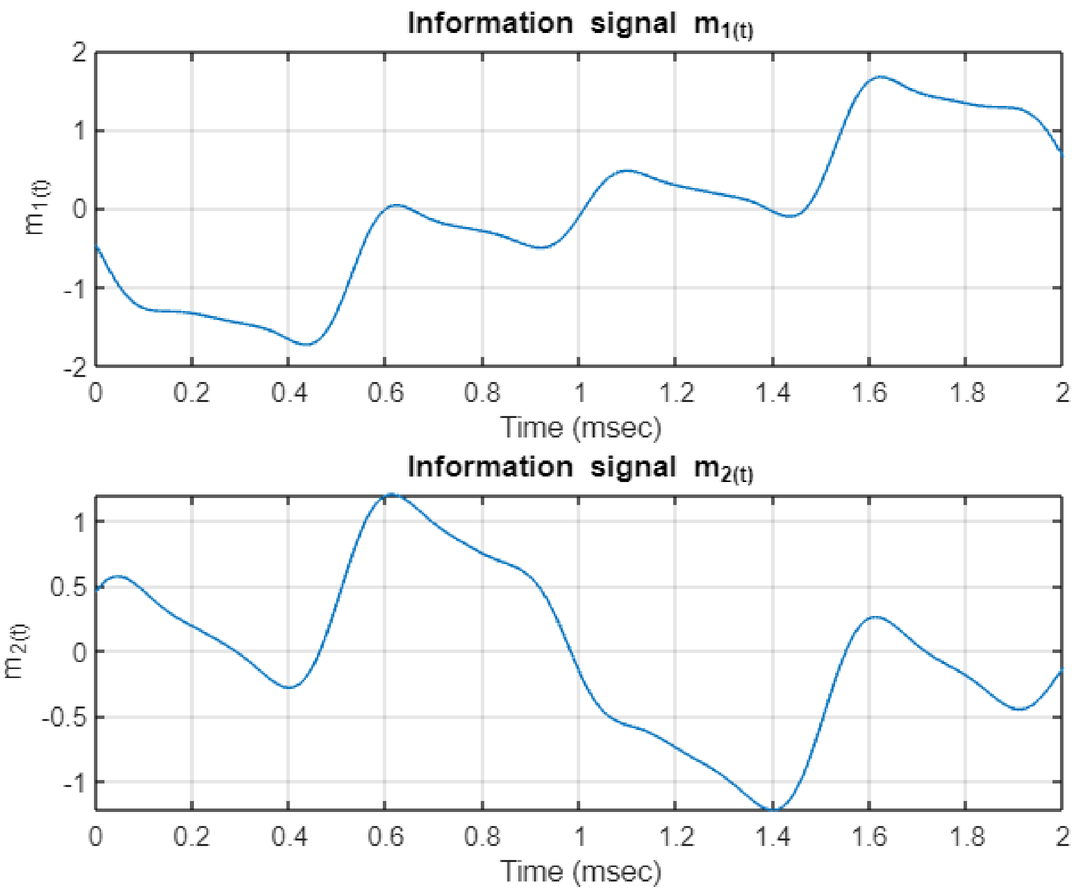

Figure 5

5. Demodulation with Frequency Offset (2.02πfc)

The carrier frequency at the receiver experienced a subtle alteration, which ultimately led to a notable decline in performance as a consequence of the frequency mismatch. This deviation in the carrier frequency picked up by the receiver caused a disruption in the signal processing, impacting the overall system's efficiency and accuracy. The slight change in the carrier frequency resulted in a discrepancy that affected the transmission quality, leading to a decrease in the system's effectiveness and reliability. The mismatch in frequency at the receiver level introduced inconsistencies in signal reception and processing, causing a decline in the system's ability to effectively transmit and decode information. The consequential performance degradation highlights the critical role that frequency alignment plays in ensuring optimal communication and signal integrity within the system, underscoring the importance of maintaining precise carrier frequency synchronization to sustain seamless and efficient operation.

Plot:

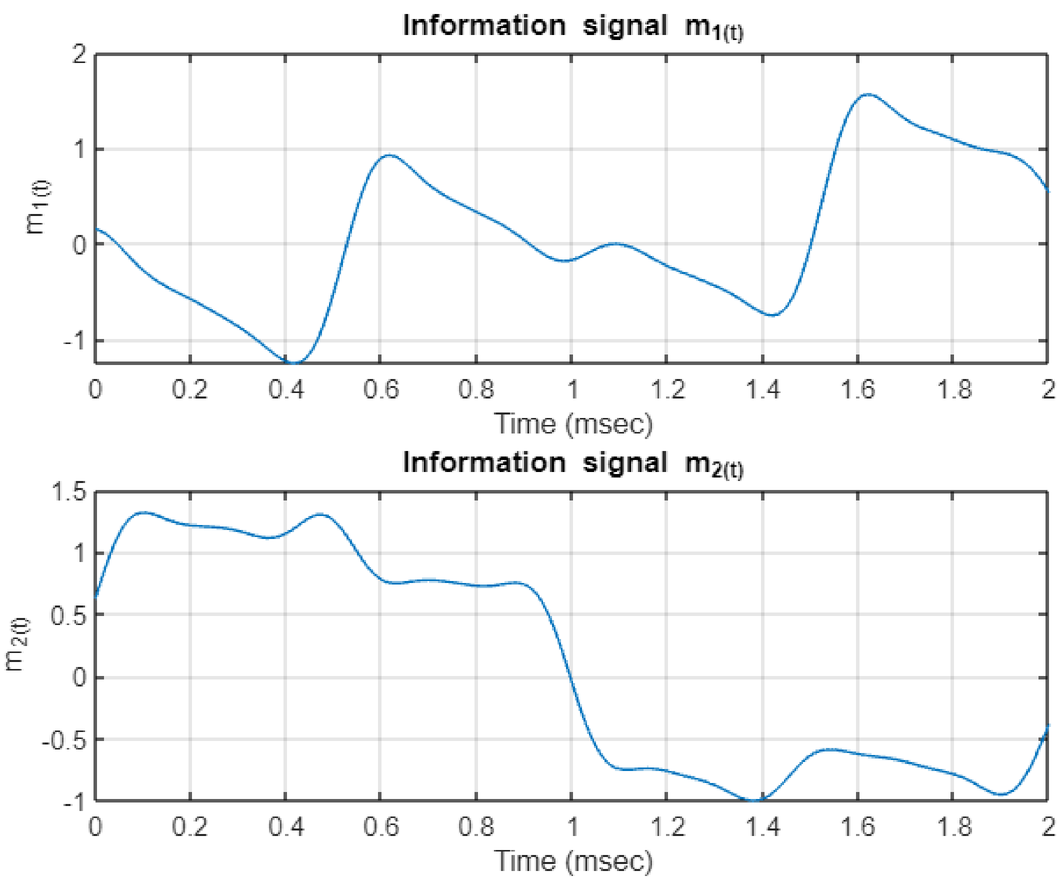

Figure 6

Comment: QAM is highly sensitive to both phase and frequency mismatches at the receiver.

Part B: Angle Modulation Using MATLAB

1. Message Signal Generation

m1(t) represents a waveform exhibiting a triangular shape which is produced through the utilization of the sawtooth() function. This particular function enables the formation of a pattern that resembles a triangle with its distinct upward slope and sharp downward descent. The triangular waveform portrayed by m1(t) exhibits a repetitive nature that is a characteristic feature of such waveforms, making it a valuable tool in signal processing and analysis. On the other hand, m2(t) depicts a stepwise signal that undergoes discrete amplitude changes occurring at precise 0.5 millisecond intervals. These step changes in amplitude create a distinct signal pattern, making m2(t) a unique and valuable asset in applications requiring discrete signal representation and manipulation. Overall, both m1(t) and m2(t) serve as essential components in various signal processing tasks due to their distinctive characteristics and functionality.

Plot:

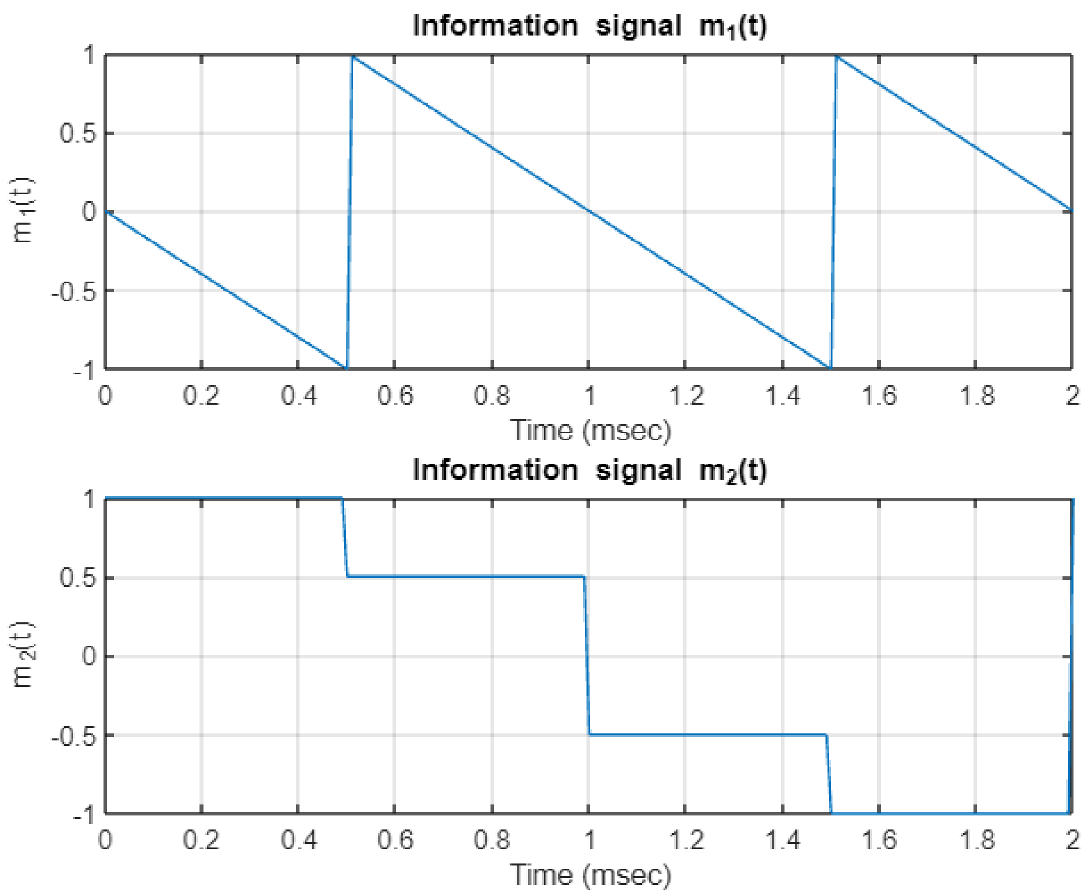

Figure 7

2. Phase Modulation (PM) - Kp = 0.05

Signal: $s_1(t) = A_C \cos(2\pi f_c t + K_p m_1(t))$

Plot:

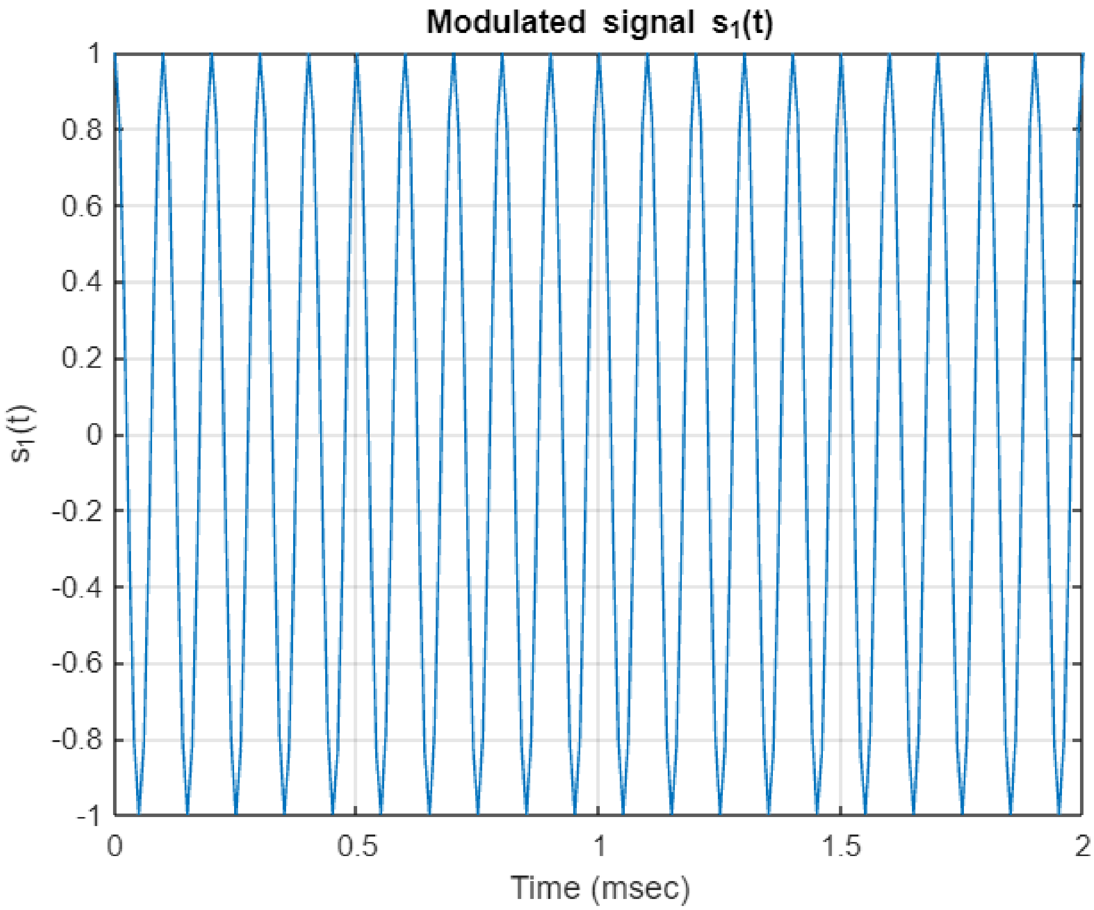

Figure 8

In the analysis of systems with small proportional gains (Kp), it can be observed that the modulated signal exhibits a striking similarity to the carrier signal. This phenomenon is particularly pronounced when the proportional gain is set to a low value, indicating that the influence of the modulation on the signal is minimal. The resemblance between the modulated signal and the carrier is a key feature that can be leveraged in various applications, such as signal processing and communication systems. Understanding this behavior provides insights into the dynamics of modulated signals under different control parameters. By exploring these nuances, researchers and engineers can fine-tune systems for optimal performance and efficiency, taking advantage of the delicate balance between the carrier and modulated signals to achieve desired outcomes.

3. PM with Kp = 1, 5, and 10

As the proportional gain, Kp, in a control system increases, the phase deviation also increases, leading to the generation of higher frequency components within the system and consequently causing the system to exhibit faster oscillations. This phenomenon is a direct consequence of the relationship between the controller's gain and the system's response characteristics. By adjusting Kp to higher values, the system becomes more sensitive to changes in input signals, causing the output to fluctuate more rapidly due to the increased influence of the proportional term in the control algorithm. This heightened responsiveness to variations in the input signal can result in faster oscillations as the system attempts to maintain stability while simultaneously adapting to changes. Therefore, an increase in Kp induces a cascading effect on the system's behavior, as the phase deviation grows in tandem with the gain value, ultimately impacting the frequency components present in the system's output. In essence, the relationship between incremental changes in Kp and the corresponding alterations in phase deviation underscores the interconnected nature of system dynamics, highlighting how control parameters can significantly influence the performance characteristics of a system by affecting its oscillatory behavior and response speed.

Plot:

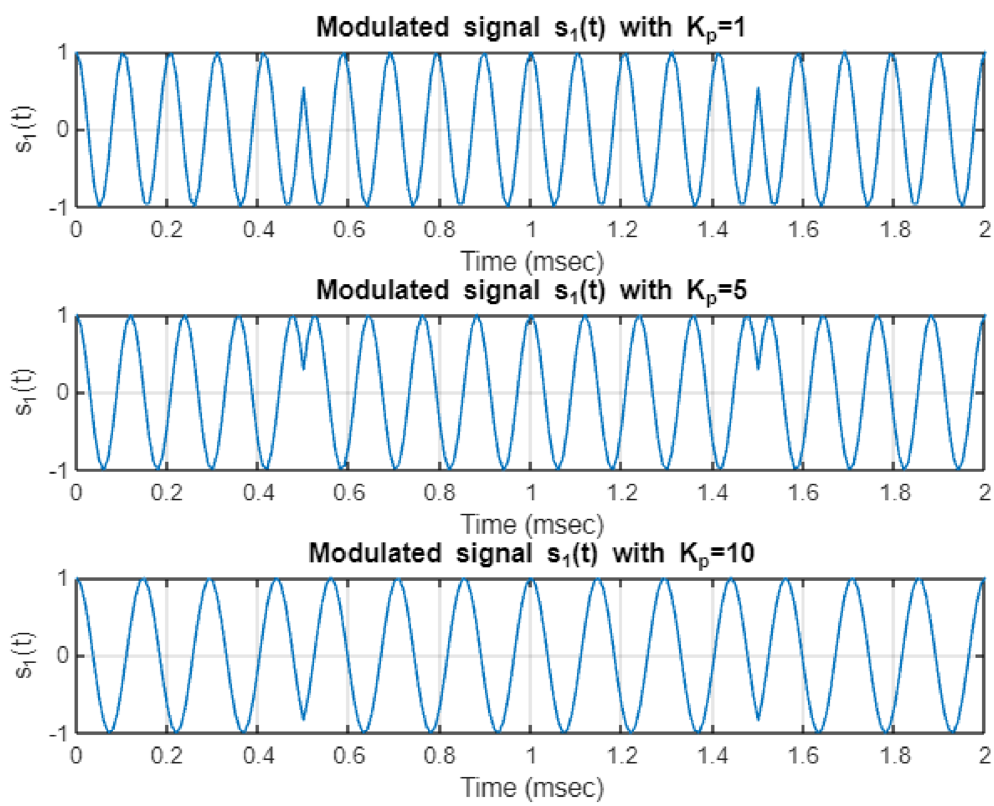

Figure 9

4. Frequency Modulation (FM) using m2(t)

Signal: $s_2(t) = A_c \cos(2\pi f_c t + K_f \int m_2(\tau)\, d\tau)$ with $K_f = 1000$

Plot:

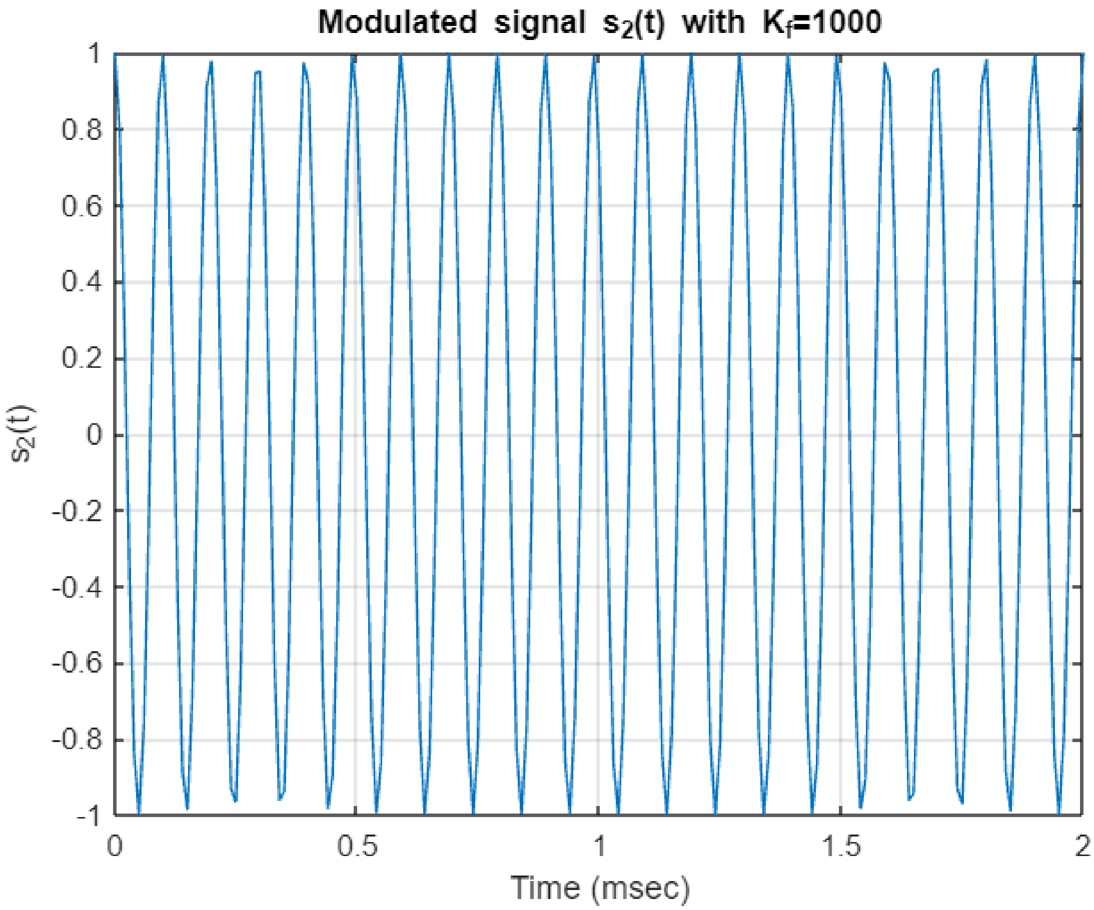

Figure 10

5. FM using m1(t)

Signal: $s_3(t) = A_c\cos(2\pi f_c t + K_f \int m_1(\tau)d\tau)$ with K_f = 2000

Plot:

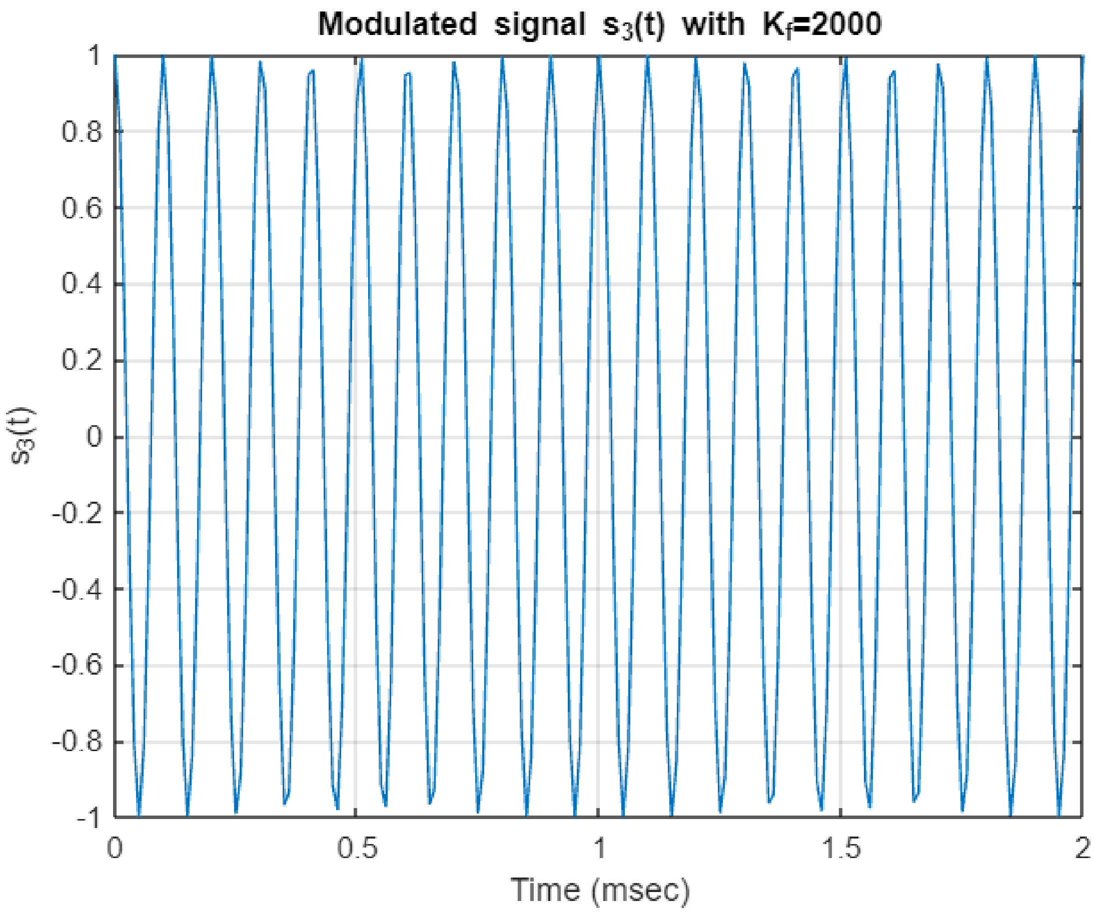

Figure 11

Summary and Observations

In the realm of digital communication, the dynamic nature of DSB-QAM modulation shines through its capacity to neatly segregate multiple message signals. Nevertheless, this technique's Achilles' heel lies in its susceptibility to phase and frequency discrepancies, which can inadvertently compromise the integrity of the transmitted data. On the flip side, the utilization of PM/FM techniques within the communication framework offers a robust and steadfast modulation approach. However, this method necessitates meticulous calibration in terms of Kp and Kf to achieve the intended spectral attributes, underscoring the critical importance of precision in adjusting these parameters. The pivotal role played by filtering and synchronization in the process of successful demodulation cannot be overstated. Both constituents act as linchpins in ensuring the accurate retrieval and interpretation of data, thus forming the cornerstone of effective demodulation strategies in digital communication systems. These reflections and deductions are grounded in the empirical evidence derived from the simulation outputs, which serve as the bedrock for analyzing and evaluating the efficacy and performance of these modulation schemes.

References

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