Communication project: part 1

ECE233 – Fundamentals of Communications

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1 Introduction

This report presents the simulation and analysis of Single Sideband (SSB) and Quadrature Amplitude Modulation (QAM) systems using MATLAB. It includes implementation, demodulation, and the effects of carrier phase and frequency errors on signal recovery.

2 SSB Modulation and Demodulation

2.1 SSB

SSB is a form of amplitude modulation where only one sideband (upper or lower) is transmitted, reducing bandwidth and improving efficiency. It relies on the Hilbert transform to suppress one sideband.

2.2 Implementation Steps

1. Two message signals are defined: mt1 (cosine wave) and mt2 (sine wave).
2. Hilbert transforms of both signals are generated using a custom function hilbm (Helbert function we designed).
3. USB and LSB are modulated using standard SSB techniques.

2.3 SSB Modulator Code Overview

- mt1 is used to generate an Upper Sideband (USB) using:
  $$usb = mt1 .* cos(2 * pi * fc * t) - m1\_hilb .* sin(2 * pi * fc * t);$$
- mt2 is used to generate a Lower Sideband (LSB) using:
  $$lsb = mt2 .* cos(2 * pi * fc * t) + m2\_hilb .* sin(2 * pi * fc * t);$$

2.4 Demodulation

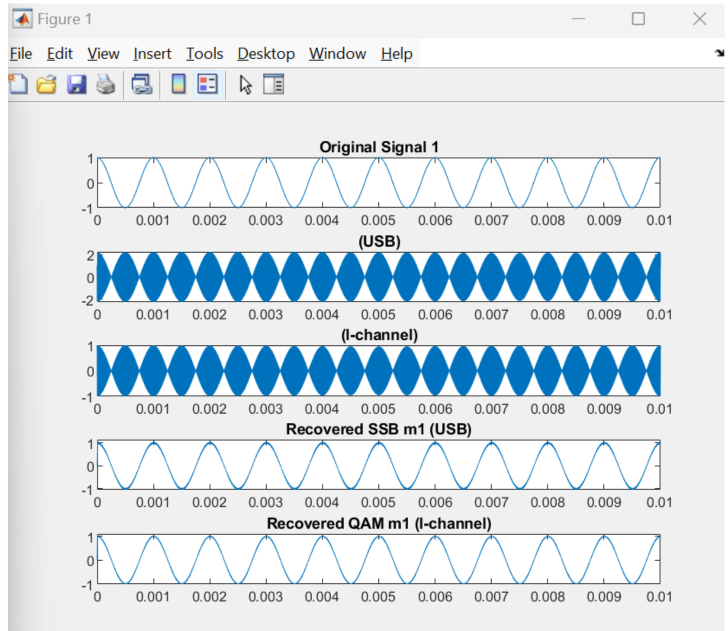
Demodulation is achieved by multiplying the received signal with a coherent carrier and applying a low-pass filter (LPF):

- $rec1\_ssb = filter(b, a, usb .* cos(2 * pi * fc * t)) * 2;$

- $rec2\_ssb = filter(b, a, lsb .* cos(2 * pi * fc * t)) * 2;$

2.5 Results

- The original signals mt1 and mt2 are accurately recovered from the USB and LSB, respectively.
- The time-domain plots show minimal distortion.



3 QAM Modulation and Demodulation

3.1 Theory

QAM combines two amplitude-modulated signals on orthogonal carriers (cosine and sine), enabling simultaneous transmission of two messages (I and Q channels).

3.2 Implementation

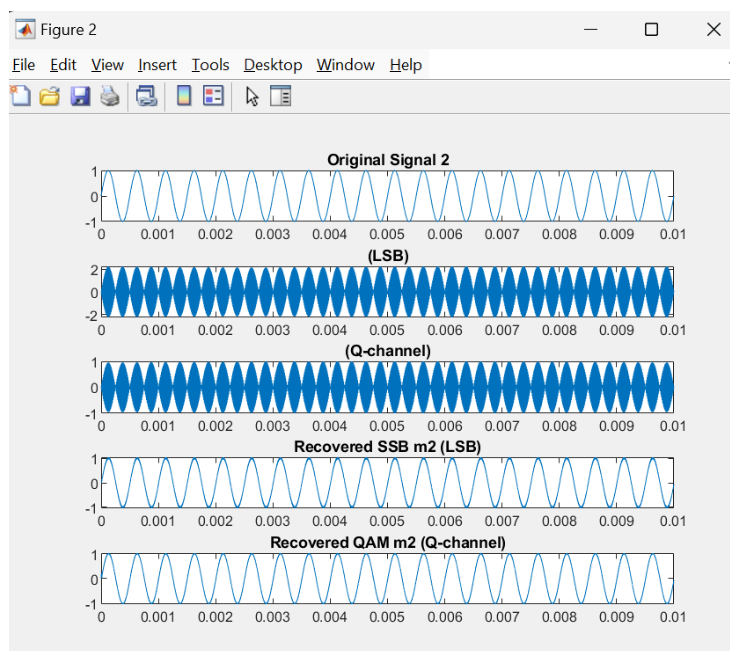
1. mt1 and mt2 are used as in-phase (I) and quadrature (Q) components.
2. QAM signal is generated:

$$qam\_signal = mt1 .* cos(2 * pi * fc * t) + mt2 .* sin(2 * pi * fc * t);$$

3.3 QAM Demodulator Code Overview

Demodulation is done by correlating with the carrier signals:

- $rec1\_qam = filter(b, a, qam\_signal .* cos(2 * pi * fc * t)) * 2;$
- $rec2\_qam = filter(b, a, qam\_signal .* sin(2 * pi * fc * t)) * 2;$



3.4 Results

- Recovered I and Q channels closely match the original signals.

- Demonstrates QAM's efficiency in utilizing bandwidth.

4 Effect of Phase and Frequency Errors

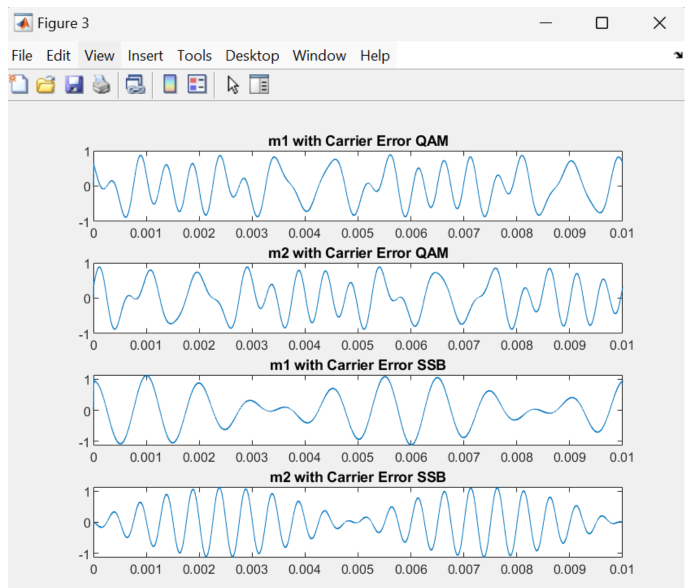
4.1 Phase Offset

Carrier offset in phase (pi/6) and frequency (+100 Hz) are added during demodulation. The corrupted carriers are:

- $cos\_e = cos(2 * pi * (fc + freq\_error) * t + phase\_error);$
- $sin\_e = sin(2 * pi * (fc + freq\_error) * t + phase\_error);$
  This leads to distortion in both I/Q and USB/LSB recovered signals.

4.2 Frequency Offset

Frequency shift leads to poor alignment between transmitter and receiver frequencies, creating beat interference and reducing signal recovery quality. And this resulted in a rotation of the signal constellation and noticeable distortion in the demodulated output, impacting signal fidelity.



- Distorted signals are observed in plots m1_errI, m2_errQ (QAM) and m1_erru, m2_errl (SSB).

4.2 Frequency Offset

Frequency shift leads to poor alignment between transmitter and receiver frequencies, creating beat interference and reducing signal recovery quality. A frequency deviation of ±100 Hz was simulated to represent carrier drift. And this caused beating effects and led to greater distortion in the recovered signal, demonstrating the system's sensitivity to frequency synchronization errors.

- Distorted signals are observed in plots m1_errI, m2_errQ (QAM) and m1_erru, m2_errl (SSB).

6 Conclusion

This simulation demonstrates the implementation of SSB and QAM modulation schemes and highlights their performance under ideal and non-ideal conditions. Both are sensitive to phase and frequency offsets, emphasizing the importance of carrier synchronization in communication systems.