Analog Communication Final Project Report

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1. Introduction

This project investigates fundamental analog modulation techniques including Double Sideband (DSB), Single Sideband (SSB), and Narrowband Frequency Modulation (NBFM). MATLAB simulations are used to analyze modulation, demodulation, noise effects, and synchronization errors.

2. Experiment 1: Double Sideband Modulation

2.1 Original Audio Signal

The original audio signal was recorded at a sampling frequency of 48 kHz. This signal contains frequency components across the full audio spectrum.

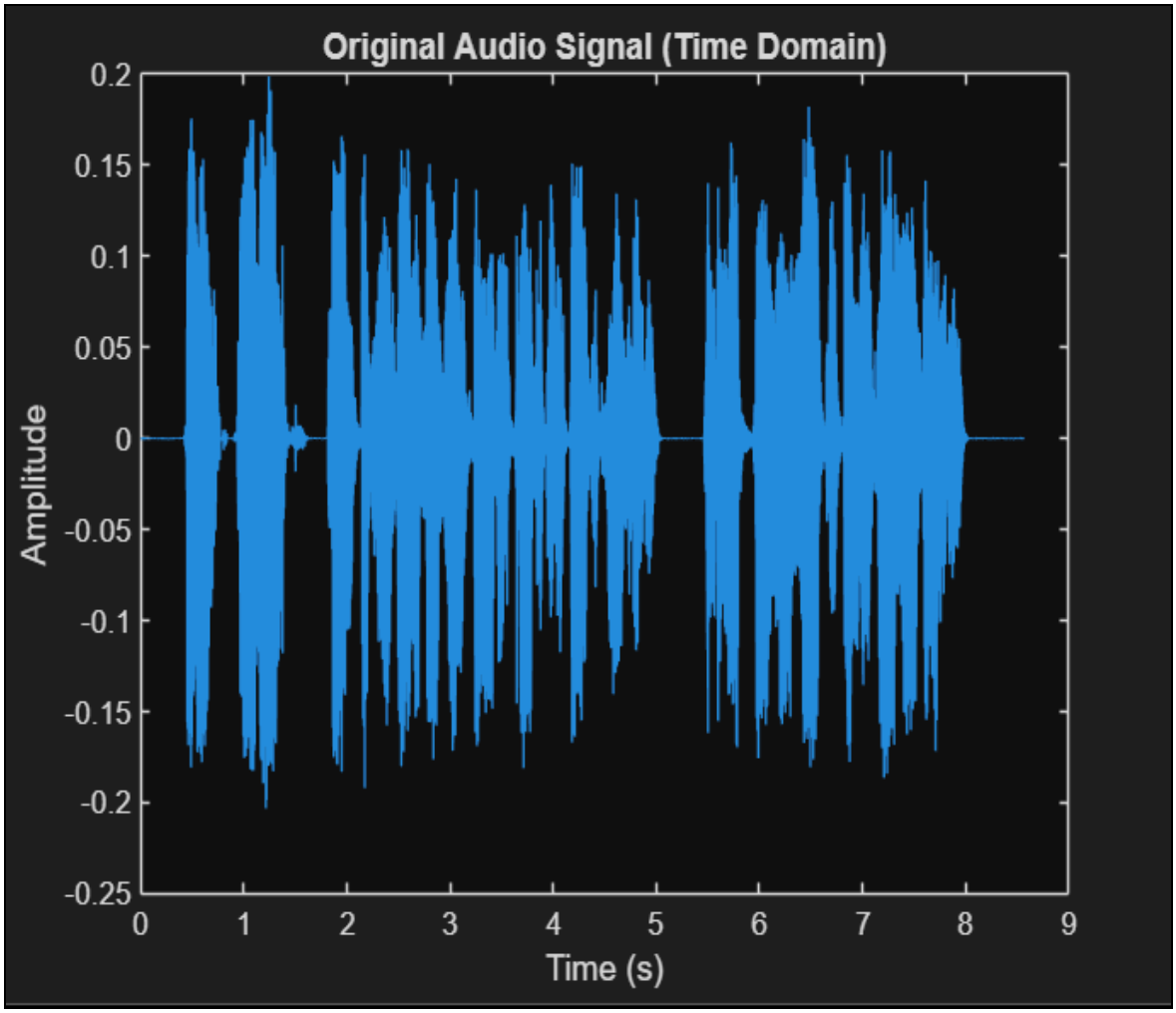

Figure 1: Original audio signal in time domain

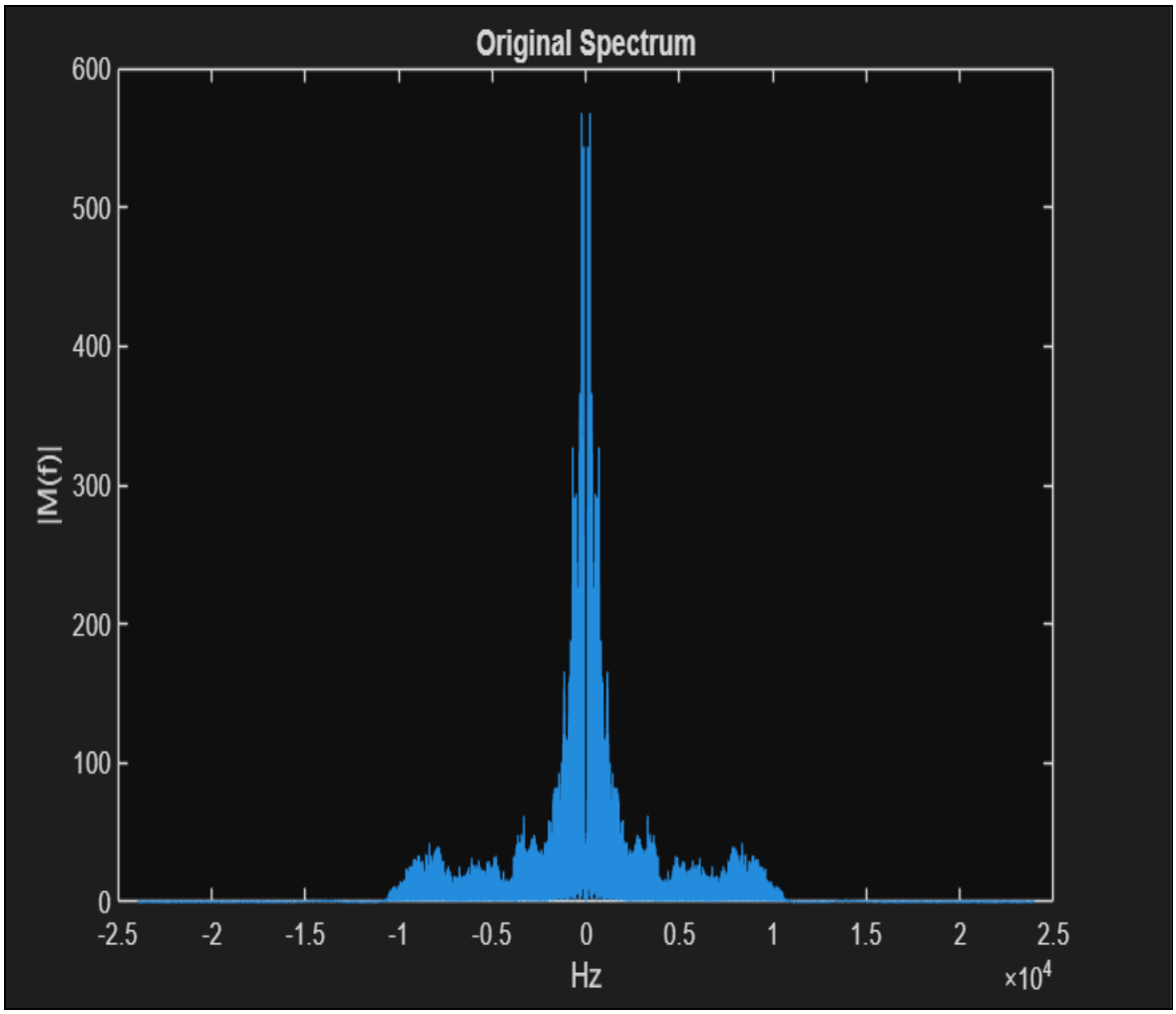

Figure 2: Spectrum of original audio signal (full bandwidth)

2.2 Filtered Message Signal

The original audio signal (Fs = 48 kHz) was low-pass filtered to limit the bandwidth to 4 kHz.

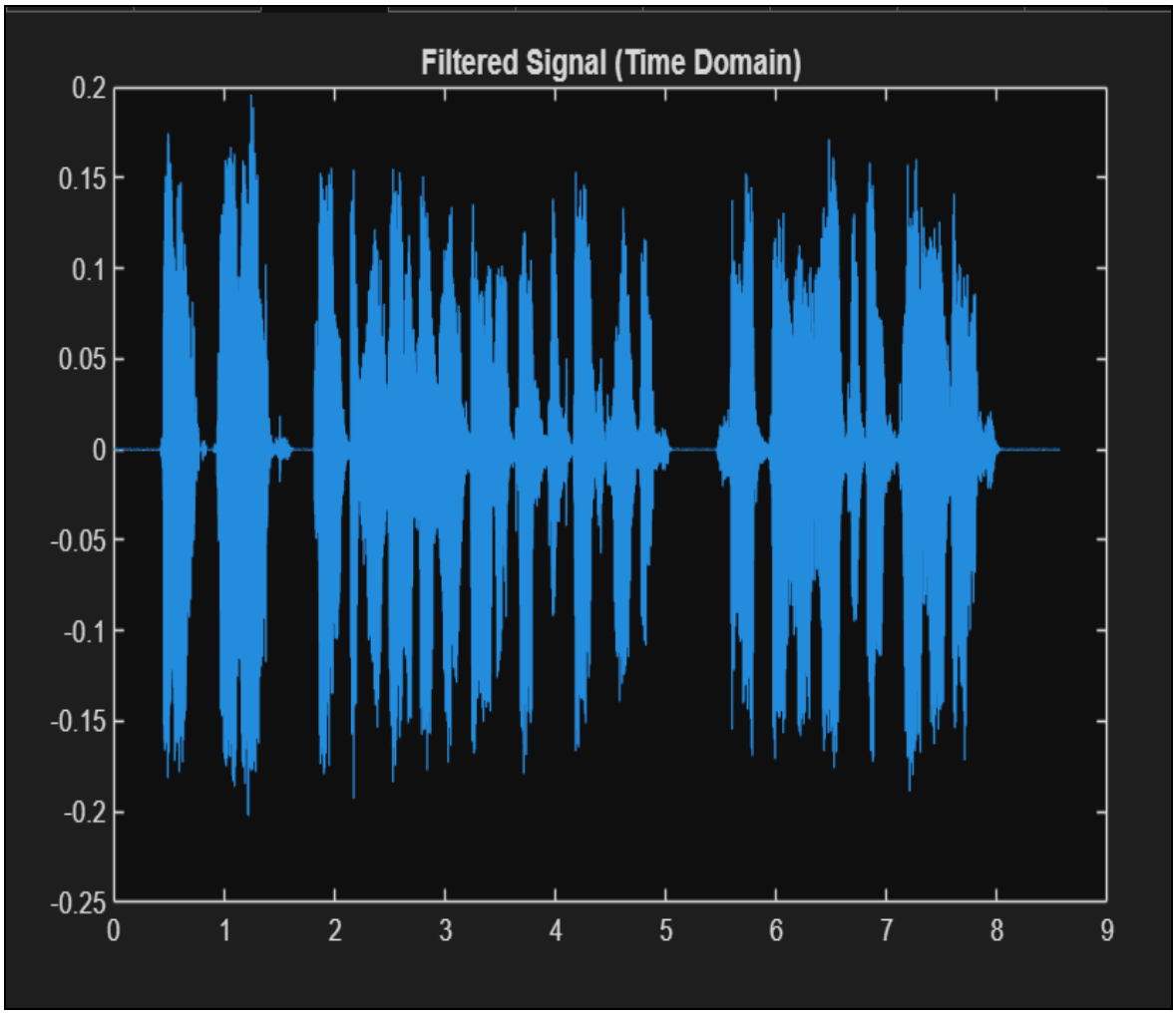

Figure 3: Filtered audio signal in time domain (BW = 4 kHz)

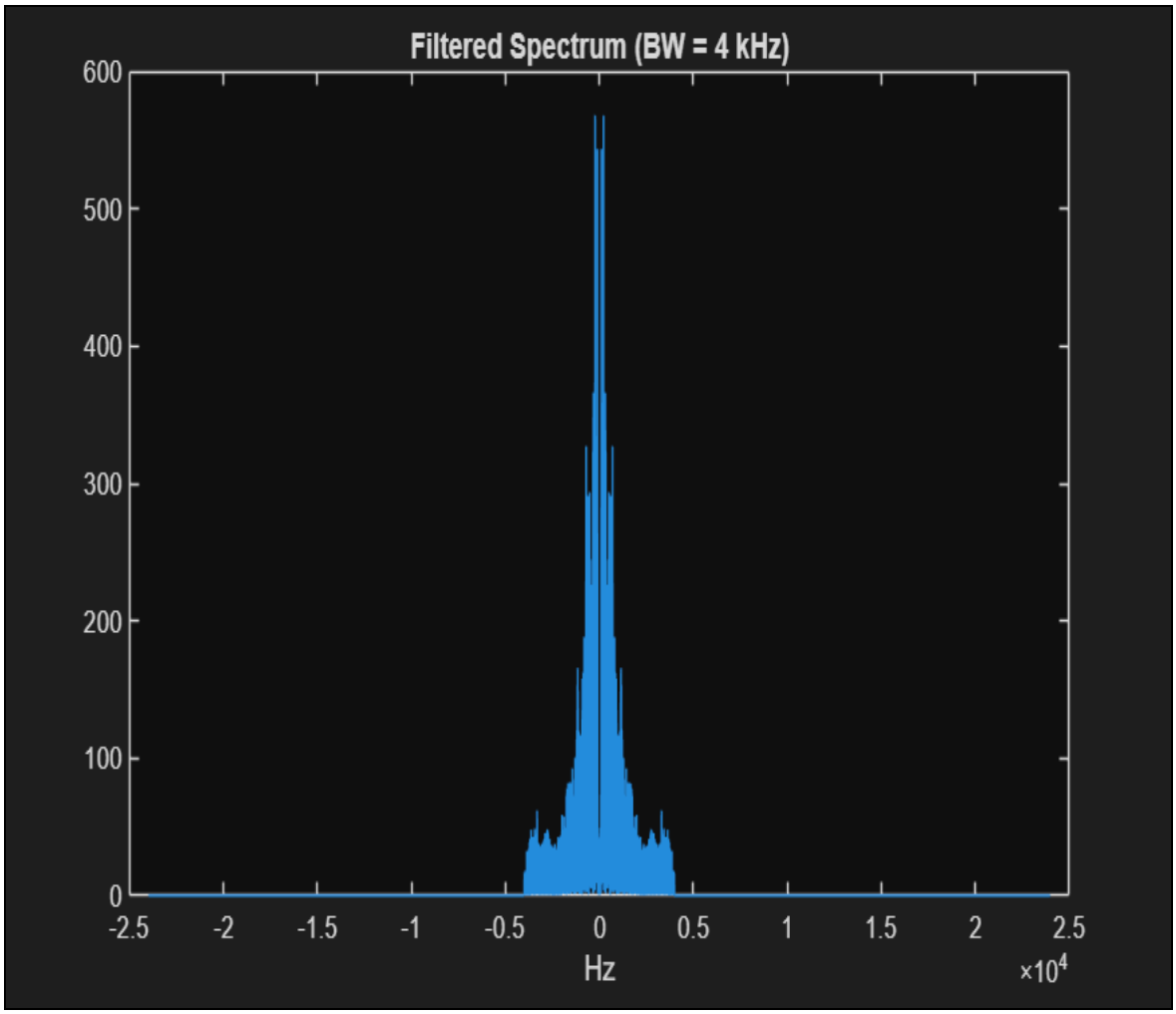

Figure 4: Spectrum of filtered audio signal

2.2 DSB-SC and DSB-TC Modulation

The carrier frequency was chosen as 100 kHz and the sampling frequency was increased to 500 kHz using resampling.

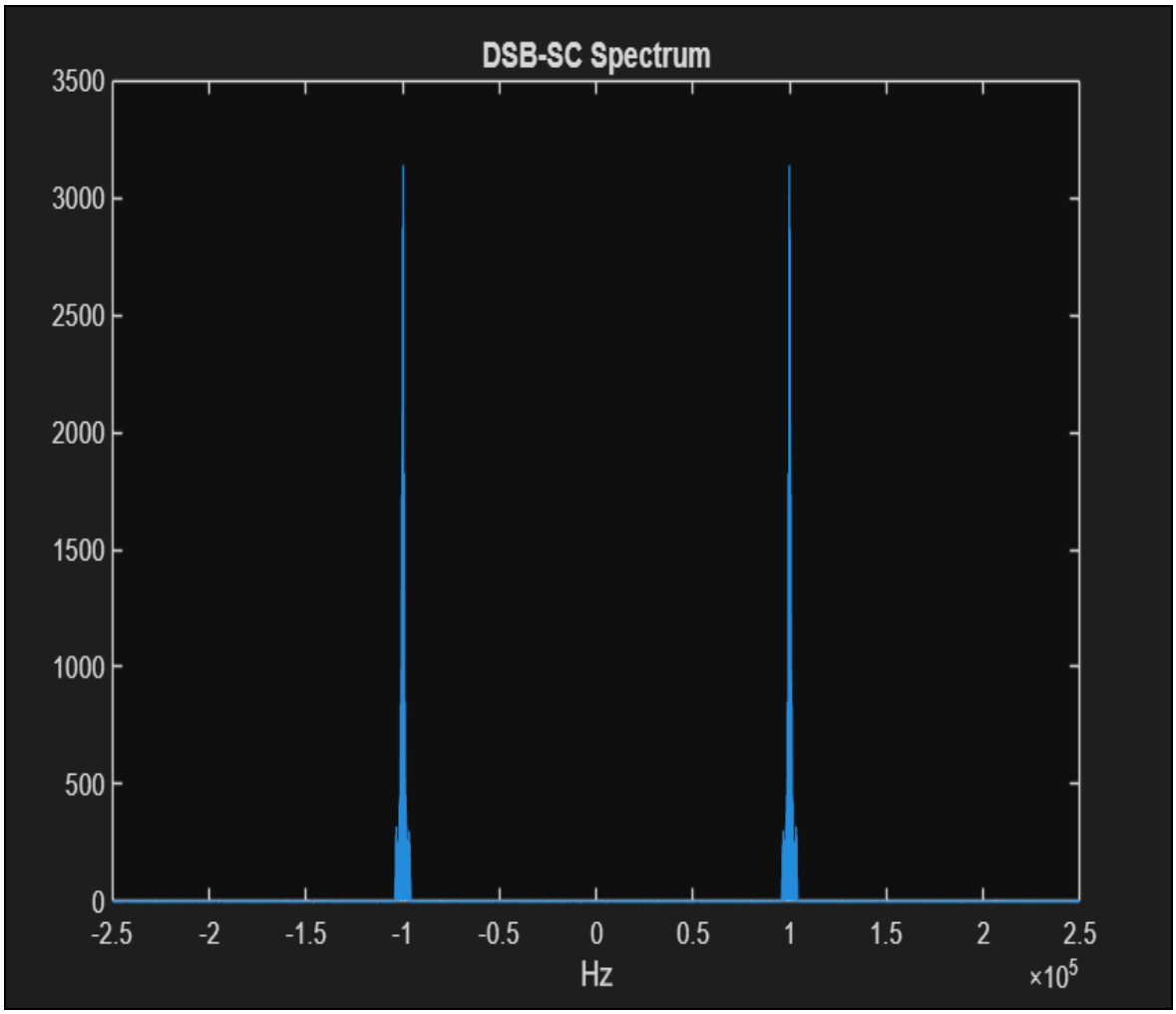

Figure 5: Frequency spectrum of DSB-SC signal

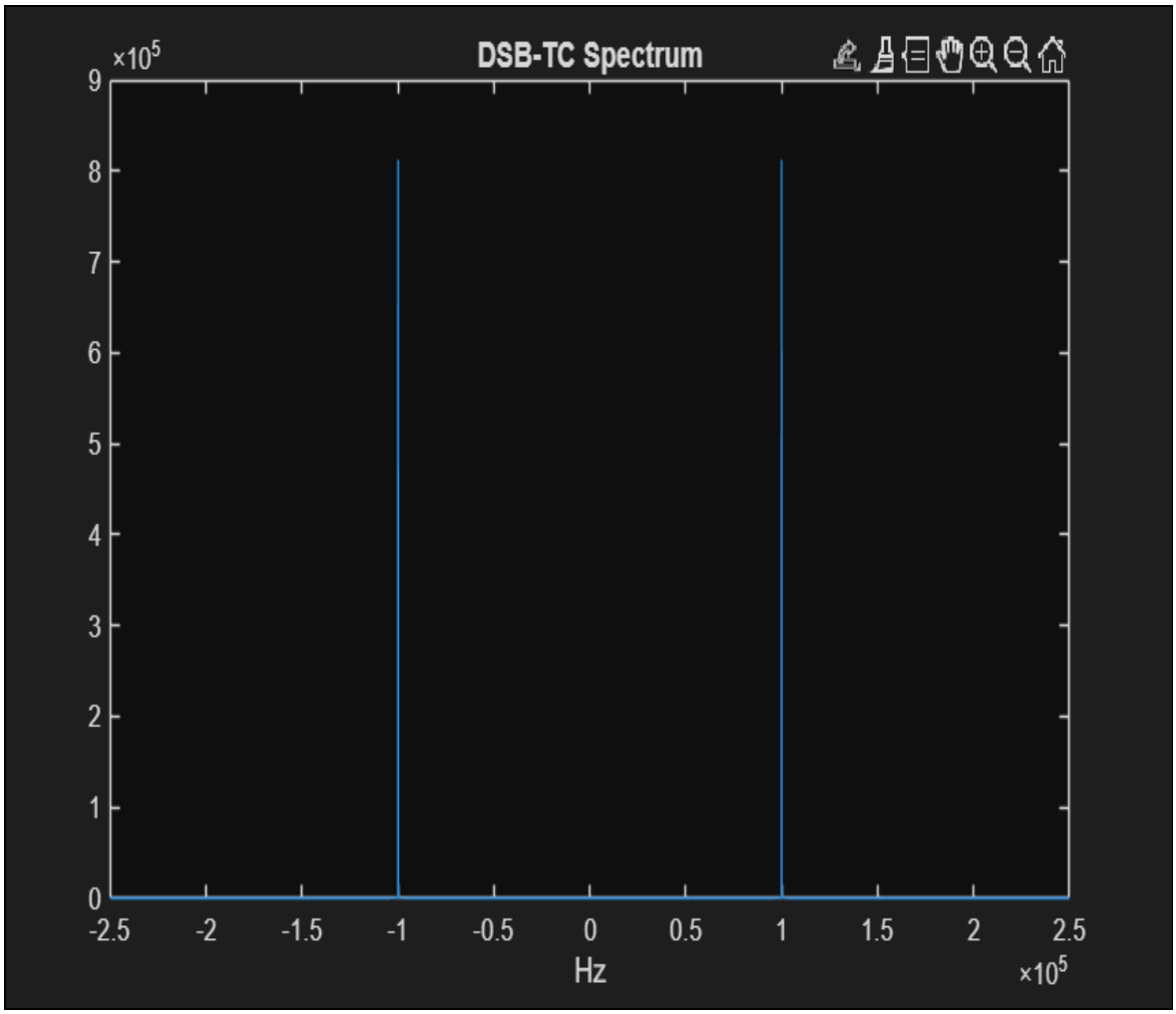

Figure 6: Frequency spectrum of DSB-TC signal showing carrier component

2.3 Envelope Detection

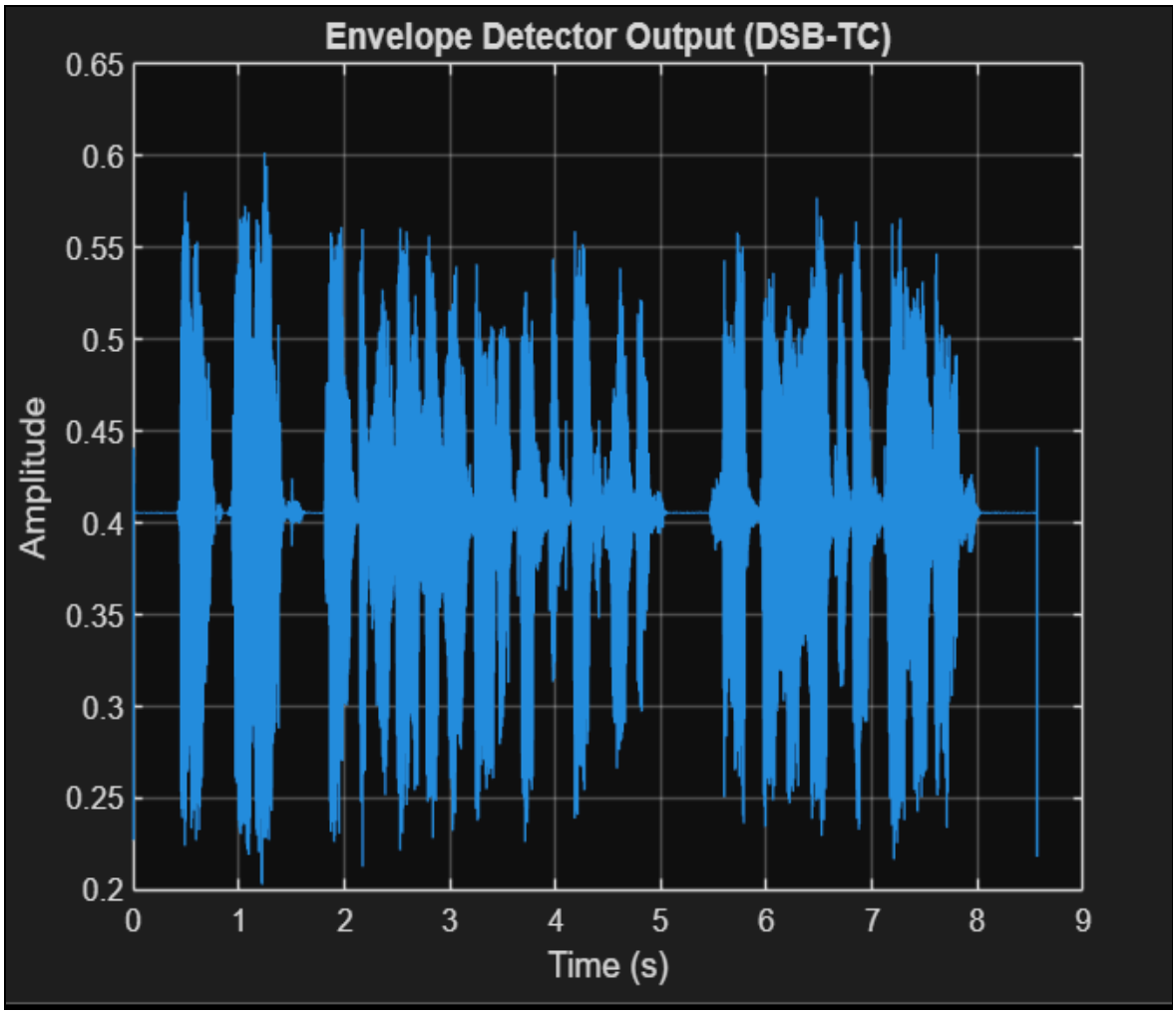

Figure 7: Envelope detector output for DSB-TC

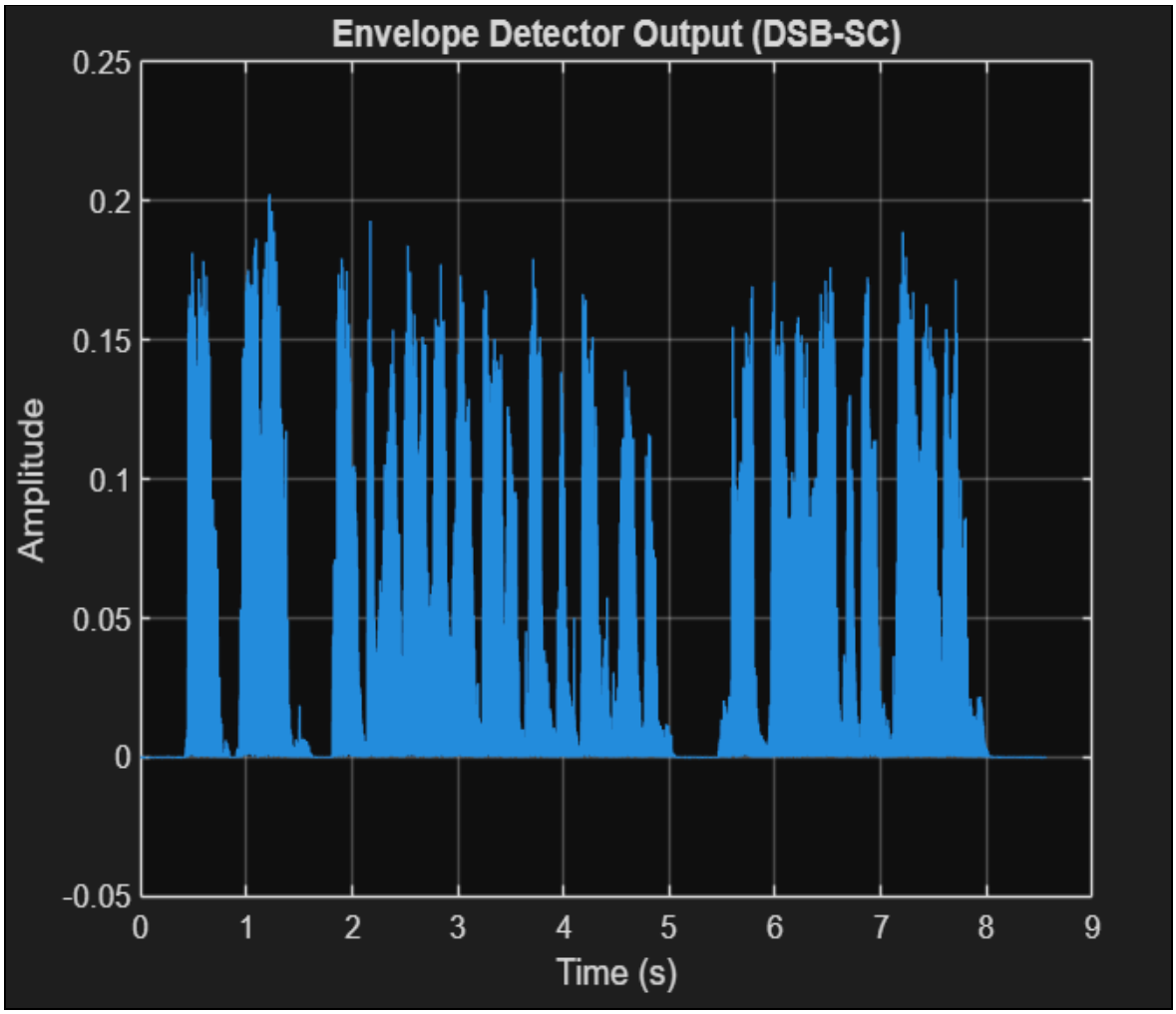

Figure 8: Envelope detector output for DSB-SC (distorted)

> Envelope detection succeeds only for DSB-TC because the carrier component preserves the envelope shape.

2.4 Coherent Detection with Noise

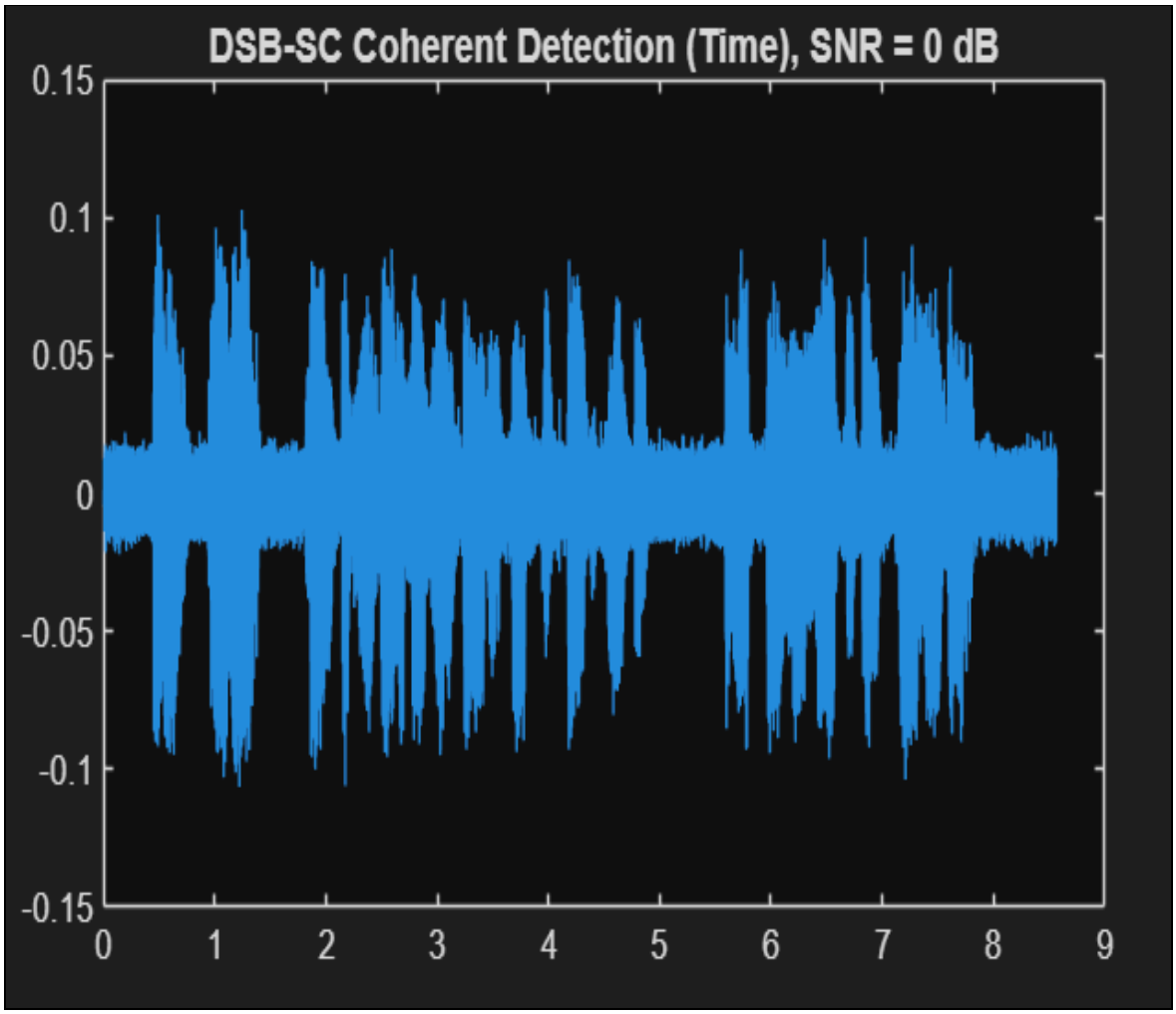

Figure 9: Coherent detection waveform of DSB-SC at SNR = 0 dB (time domain)

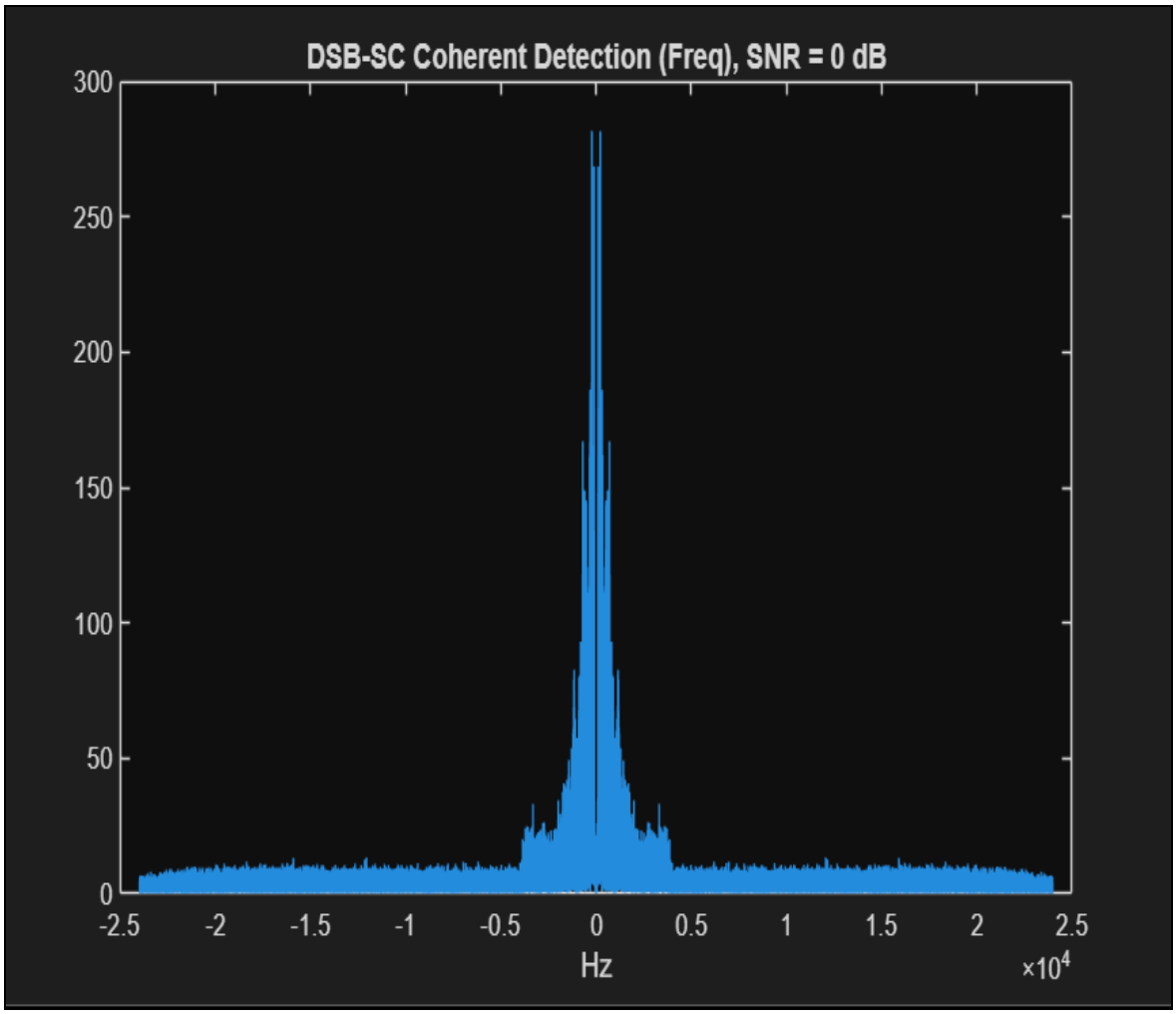

Figure 10: Coherent detection spectrum of DSB-SC at SNR = 0 dB (frequency domain)

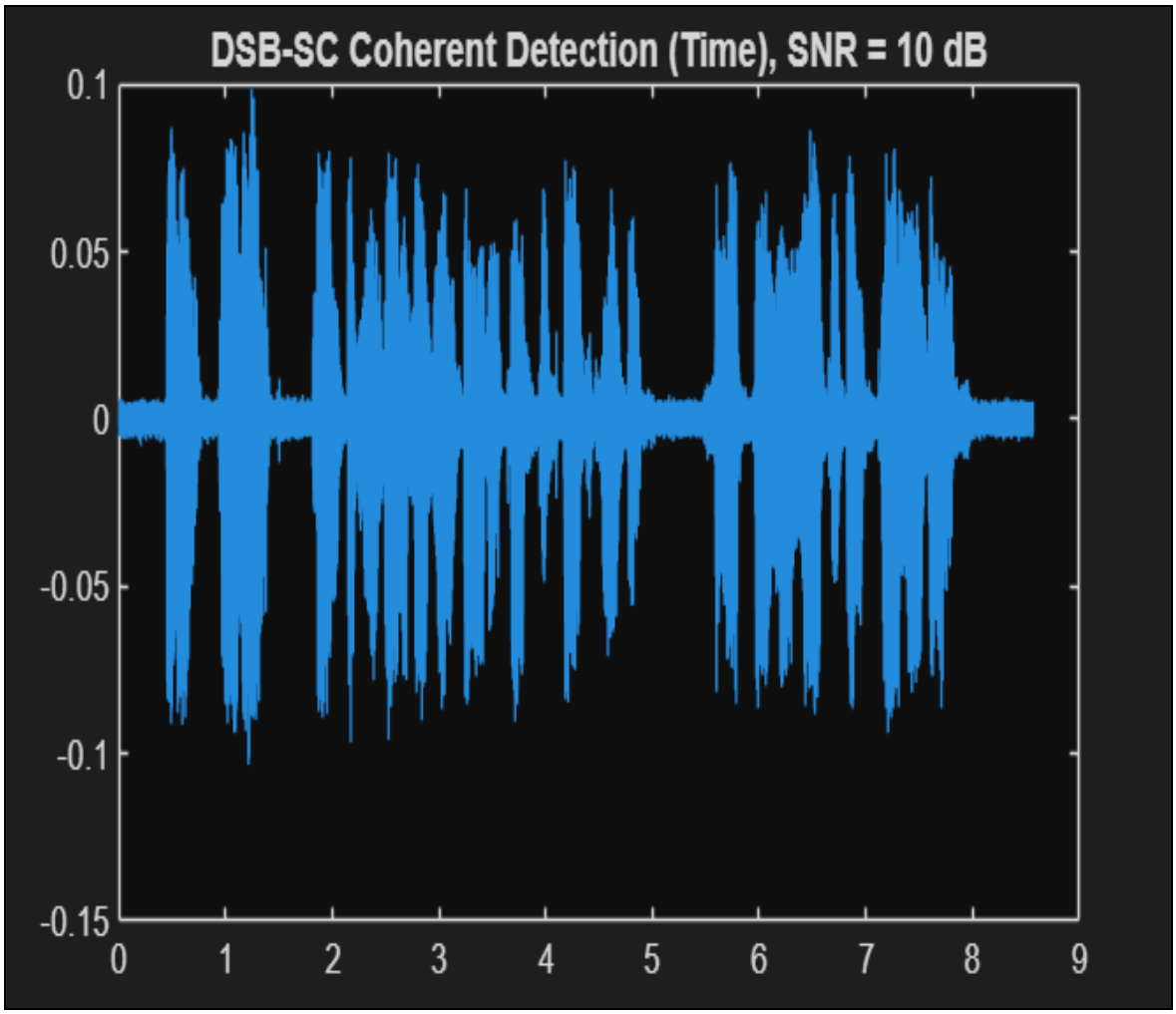

Figure 11: Coherent detection waveform of DSB-SC at SNR = 10 dB (time domain)

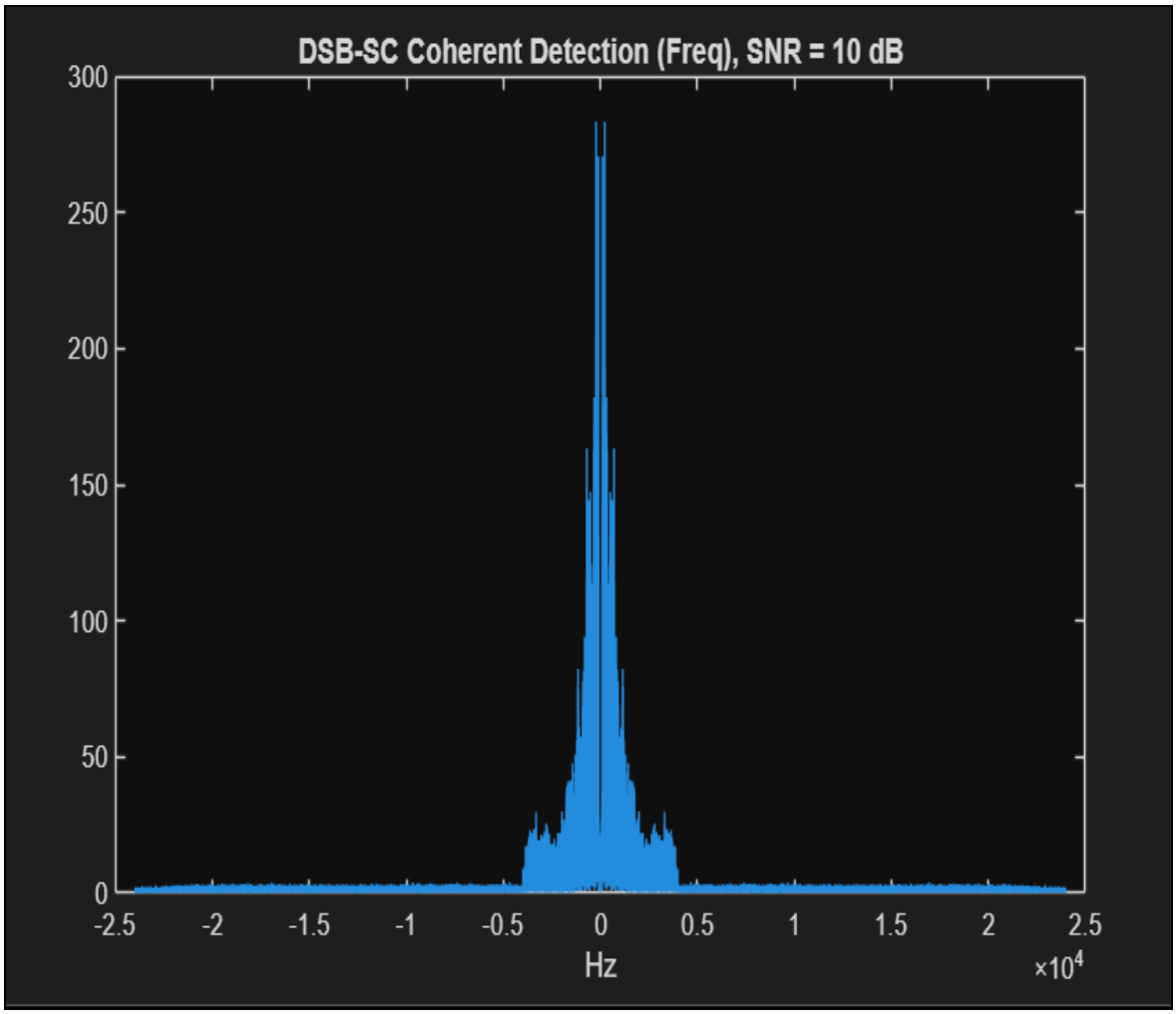

Figure 12: Coherent detection spectrum of DSB-SC at SNR = 10 dB (frequency domain)

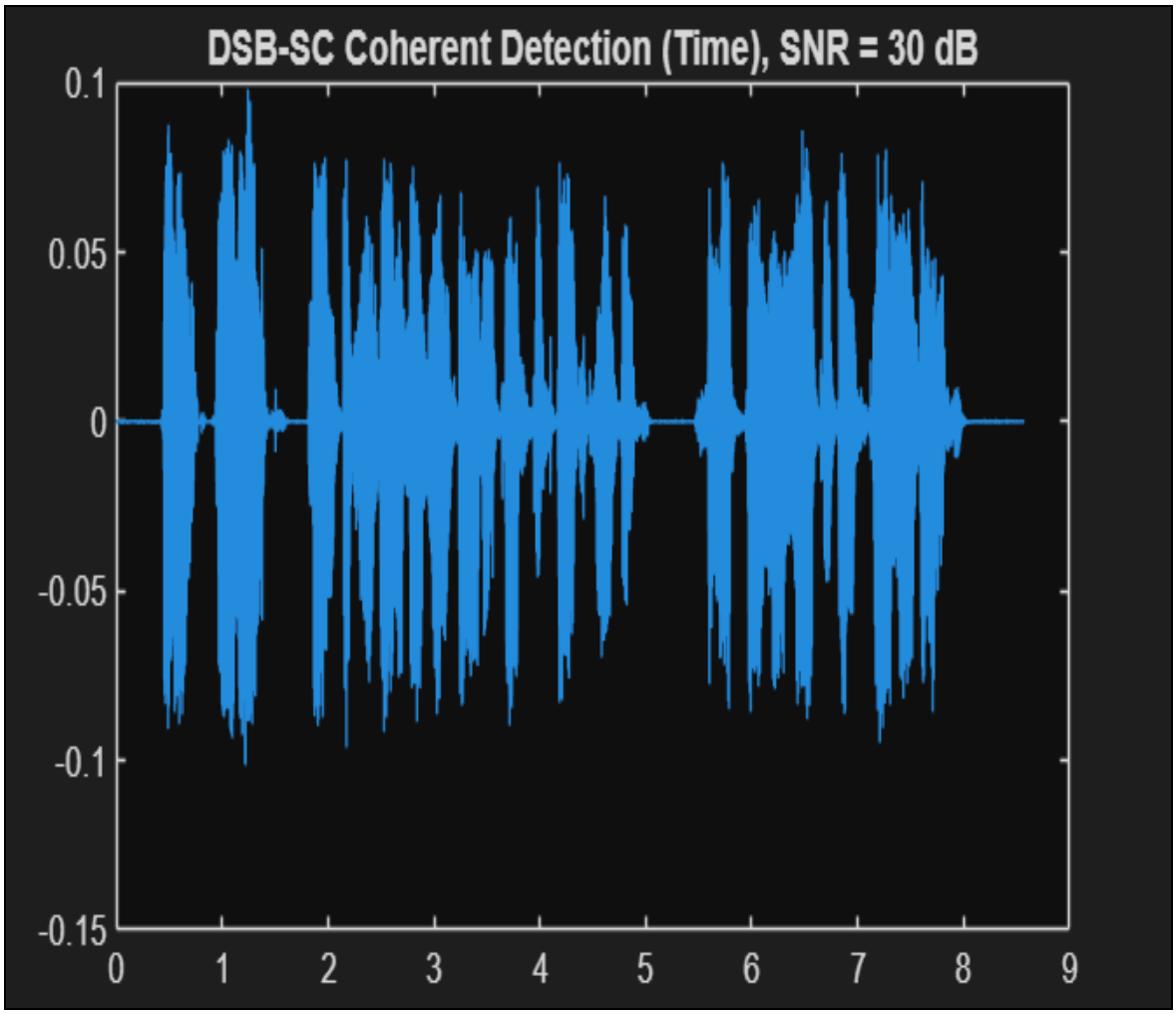

Figure 13: Coherent detection waveform of DSB-SC at SNR = 30 dB (time domain)

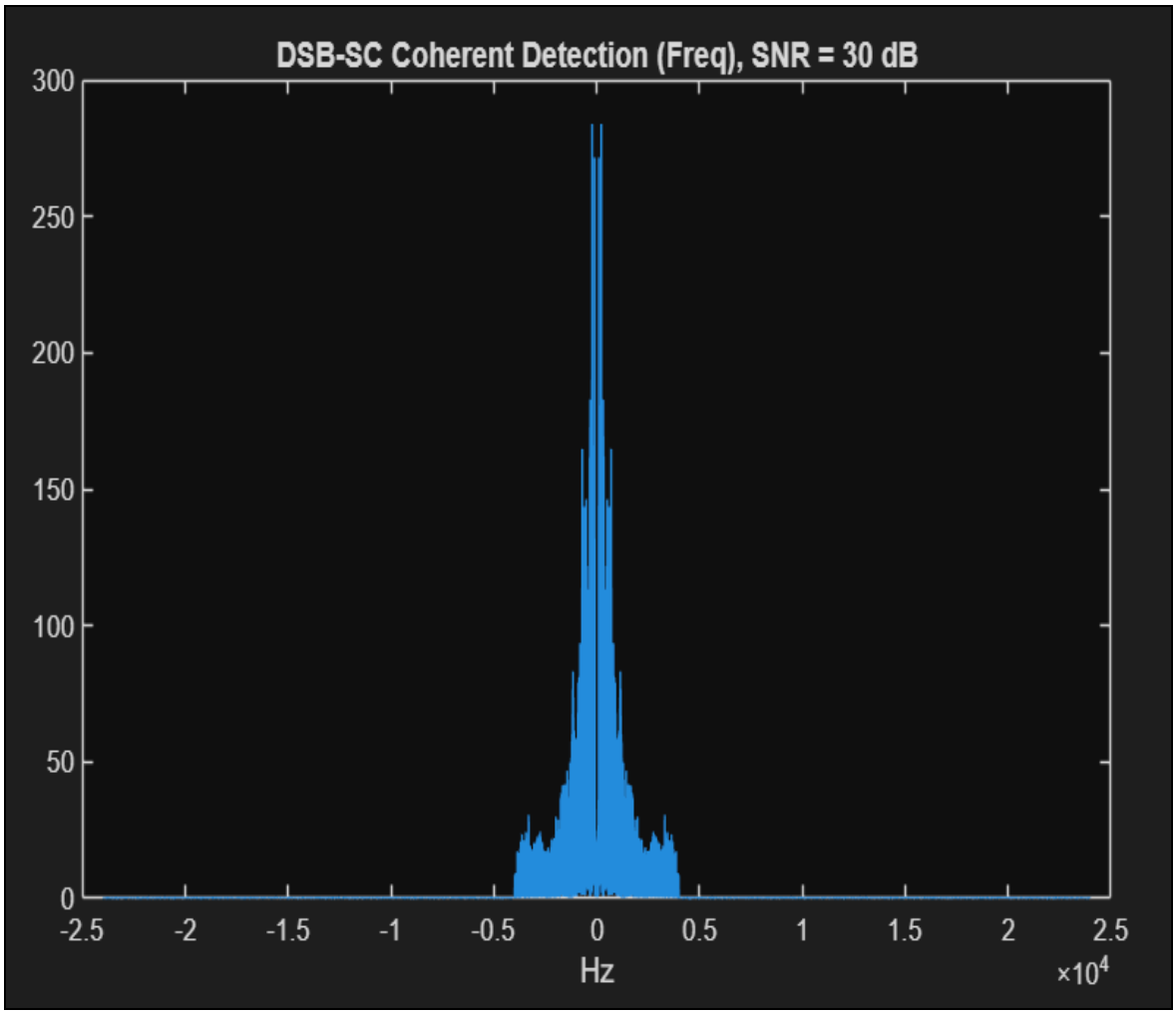

Figure 14: Coherent detection spectrum of DSB-SC at SNR = 30 dB (frequency domain)

2.5 Frequency and Phase Errors

When frequency and phase errors are introduced in the coherent detector, the recovered signal becomes distorted. A frequency offset of 100 Hz and a phase error of 20° were applied to demonstrate these effects.

```
        freq_err = dsb_sc .* cos(2*pi*100100*t_up);
        phase_err = dsb_sc .* cos(2*pi*Fc*t_up +
deg2rad(20));

        sound(resample(freq_err,Fs,Fs_new),Fs); pause(3);
        sound(resample(phase_err,Fs,Fs_new),Fs); pause(3);
```

3. Experiment 2: Single Sideband Modulation

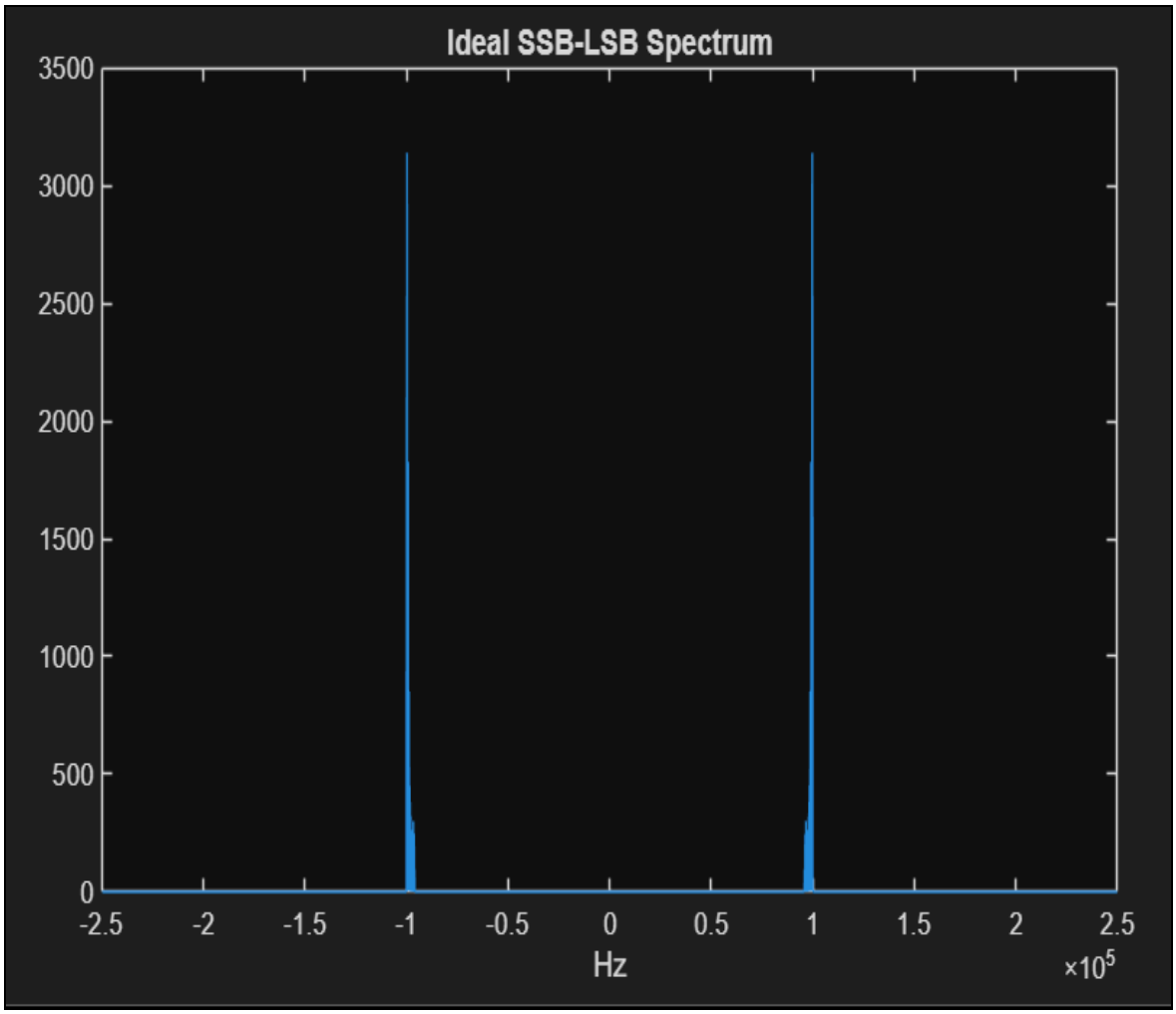

Figure 17: Spectrum of SSB-LSB signal (ideal filter)

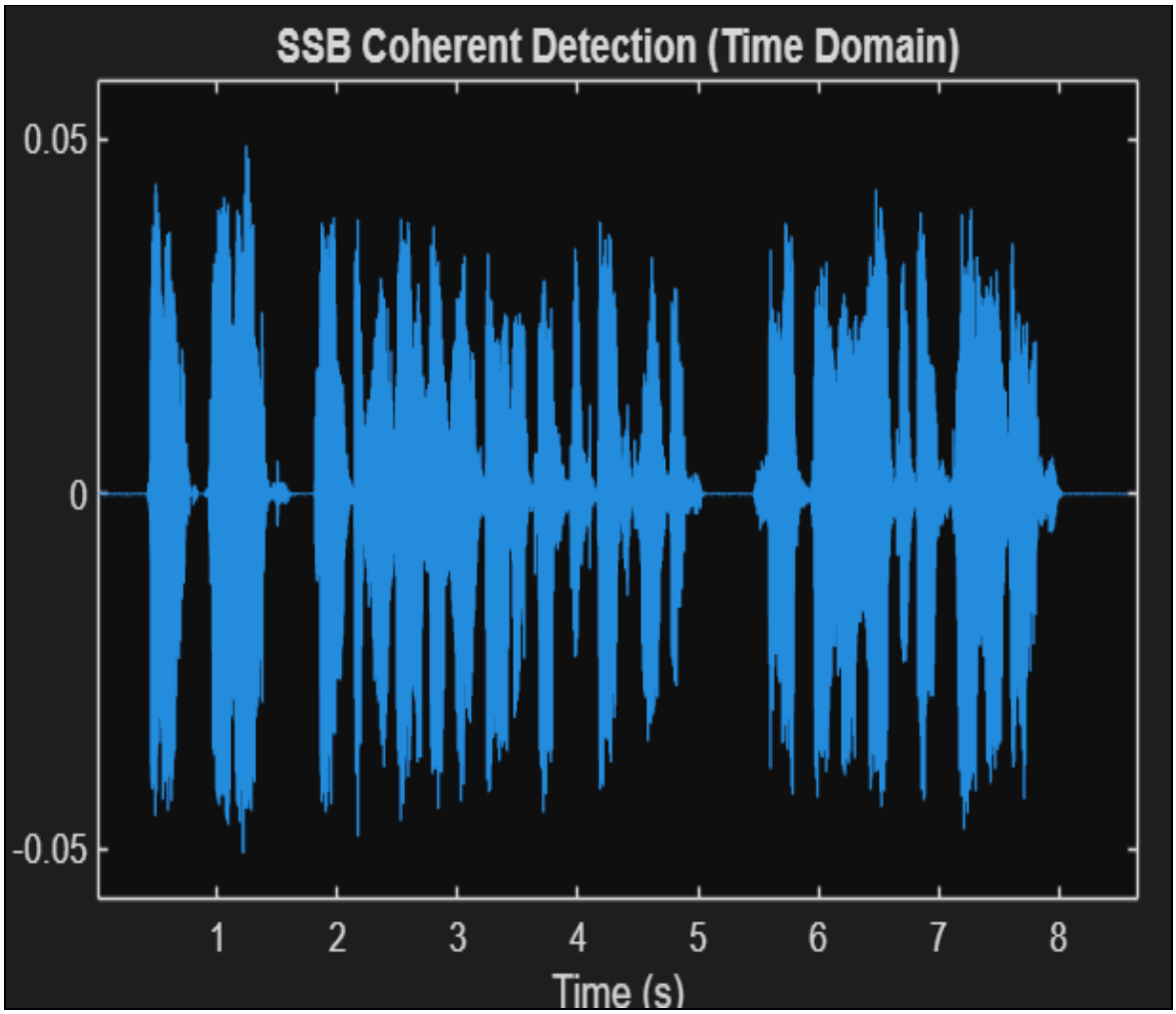

Figure 18: Demodulated SSB signal waveform using coherent detection

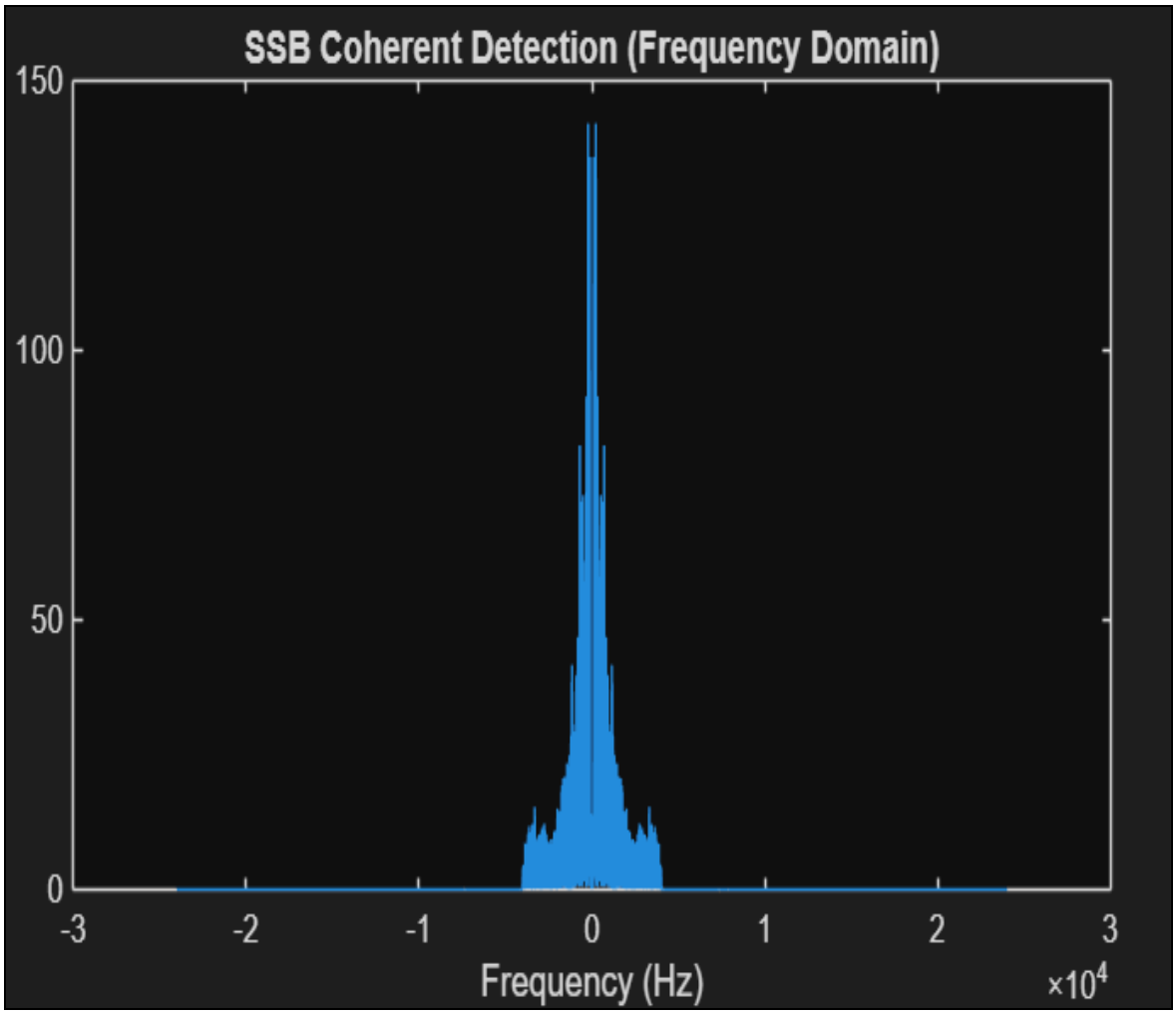

Figure 19: Demodulated SSB signal spectrum using coherent detection

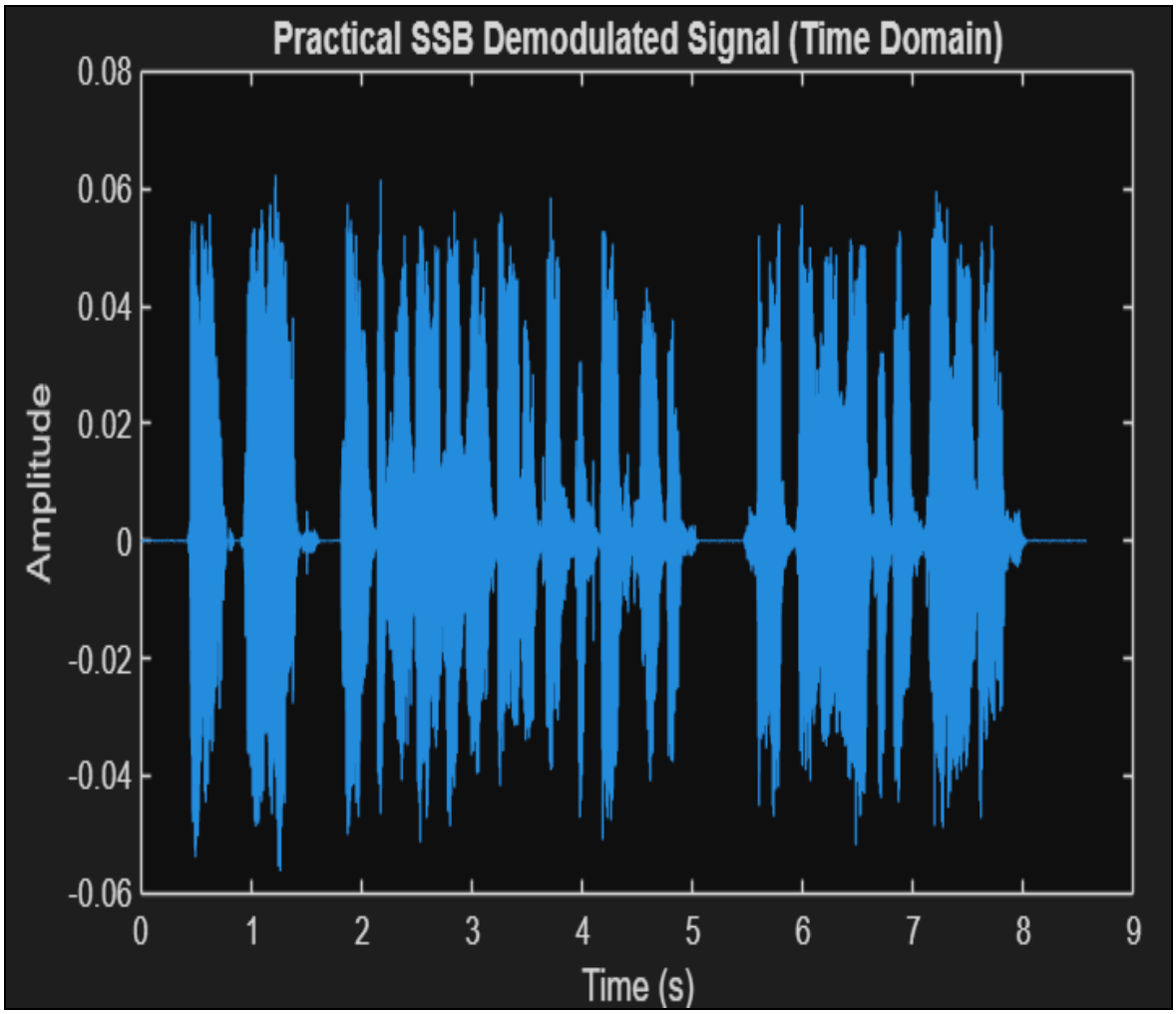

Figure 20: Practical SSB demodulated signal waveform (Butterworth bandpass)

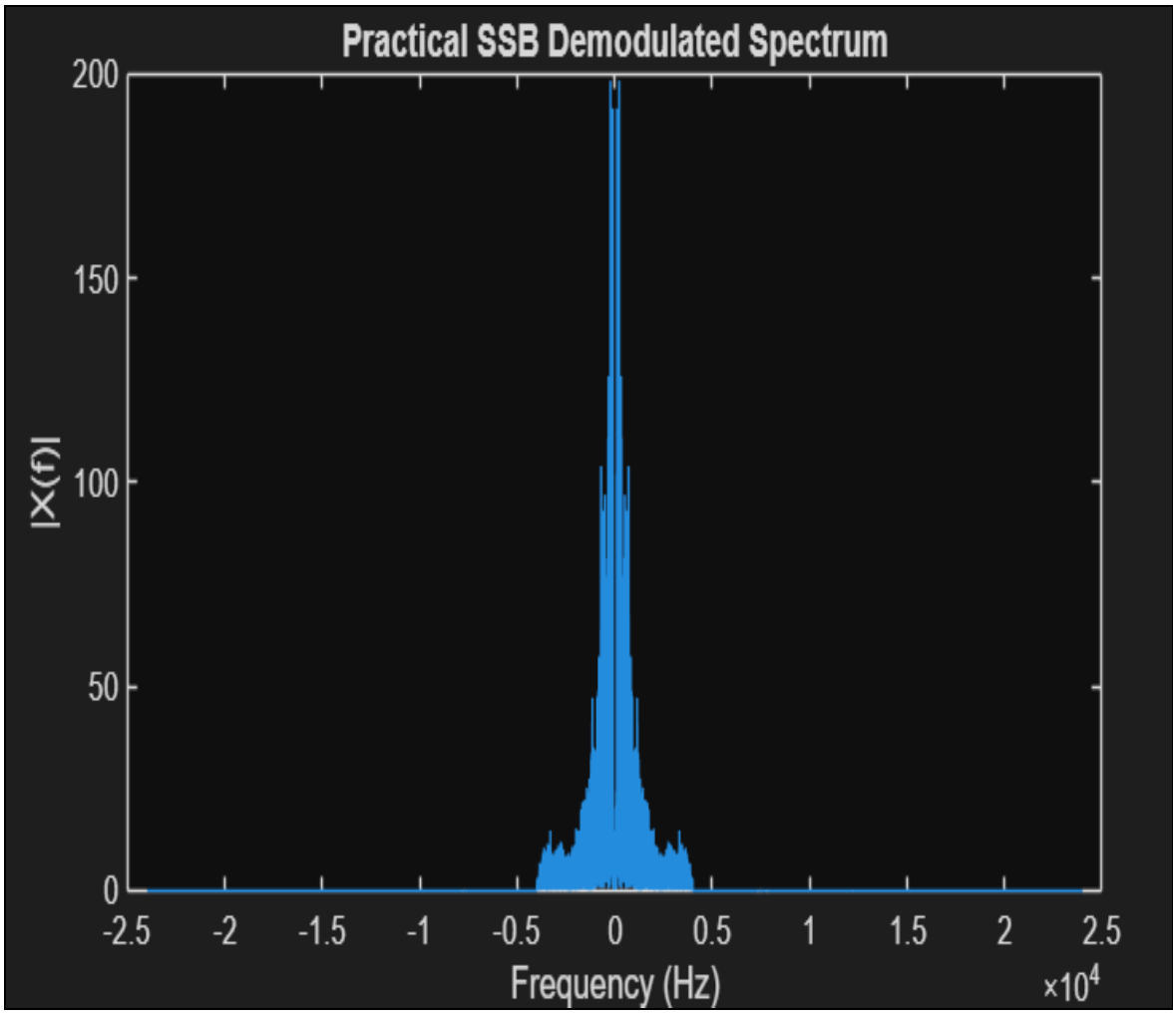

Figure 21: Practical SSB demodulated spectrum (Butterworth bandpass)

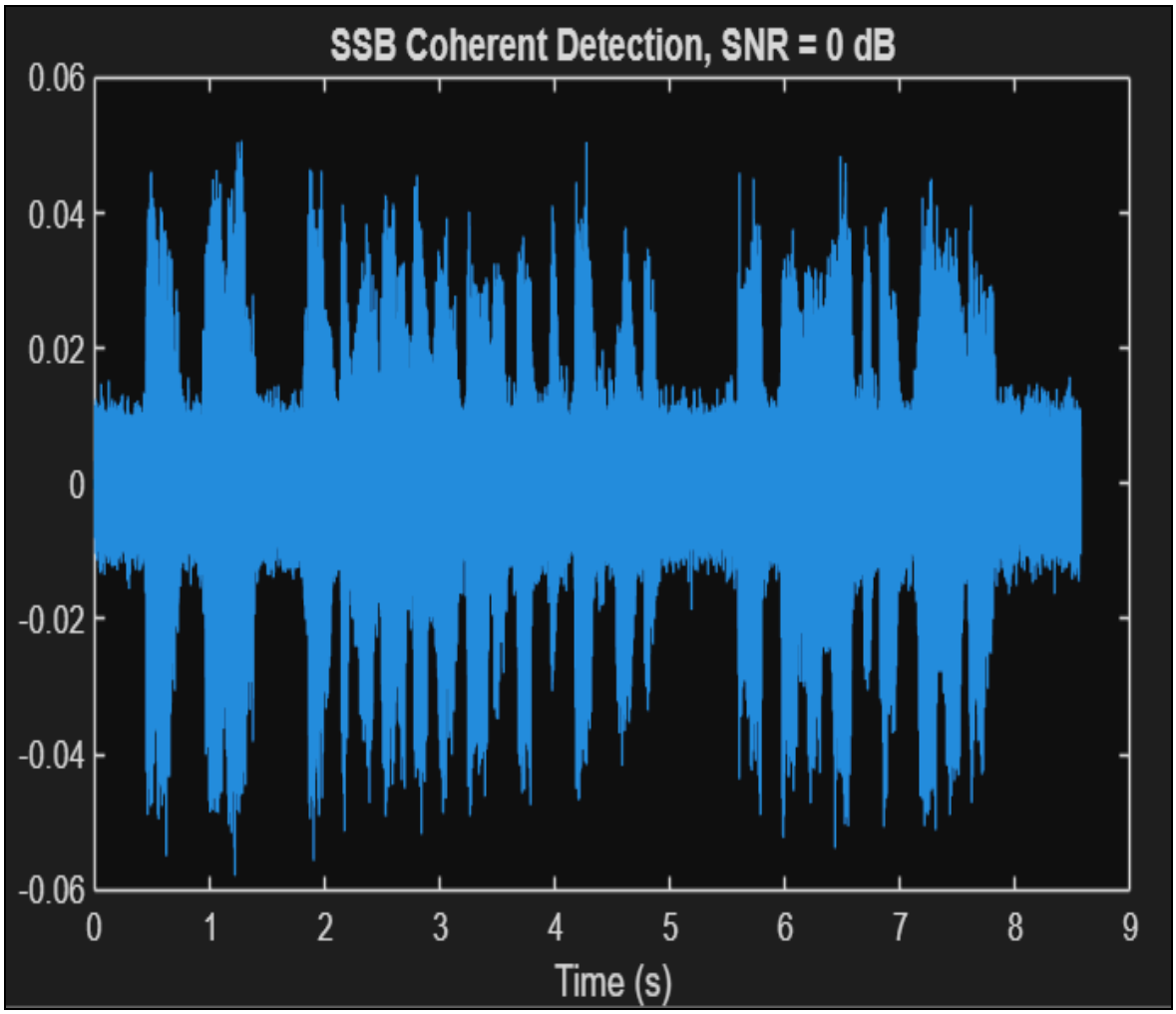

Figure 22: SSB coherent detection waveform at SNR = 0 dB

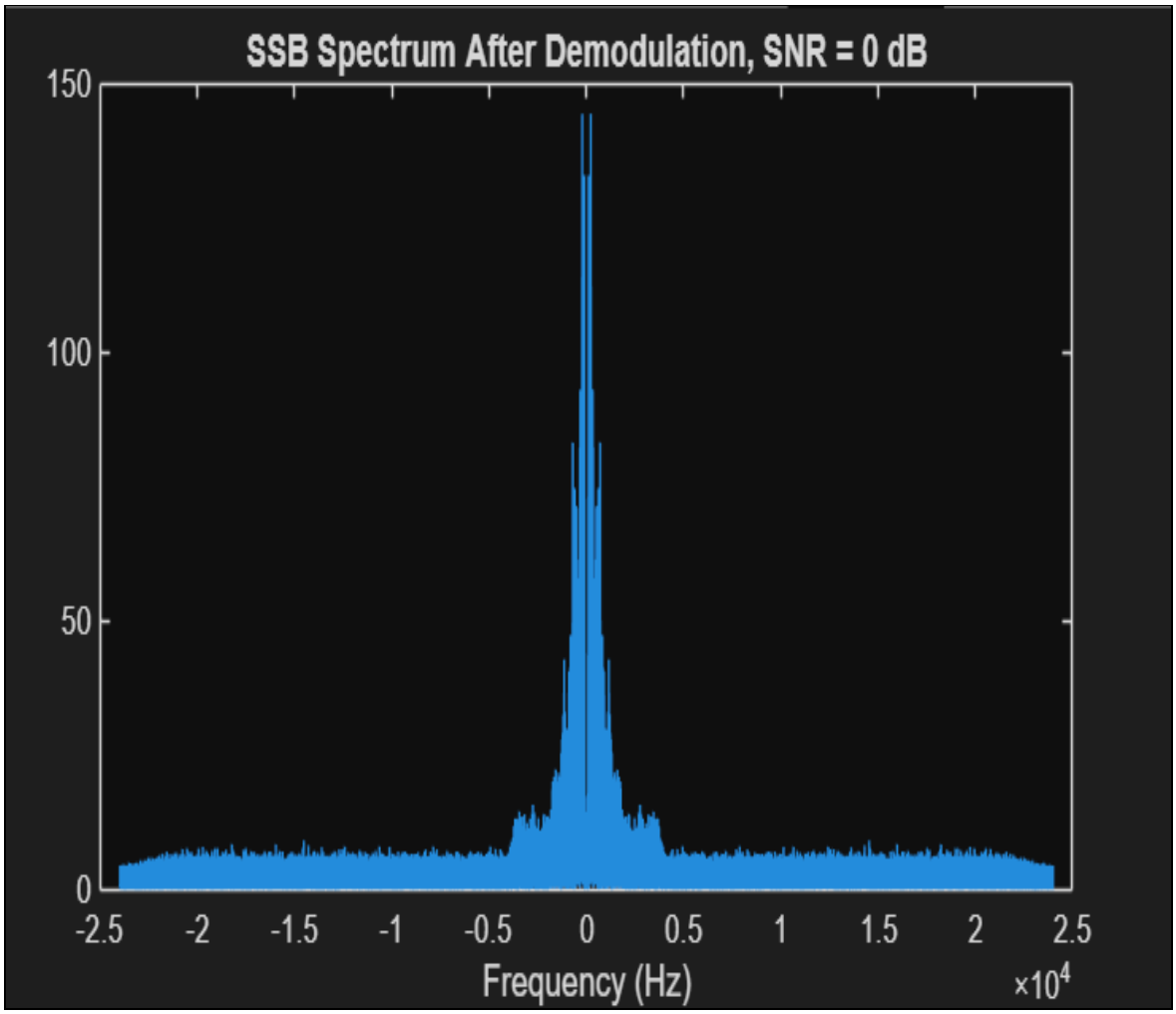

Figure 23: SSB coherent detection spectrum at SNR = 0 dB

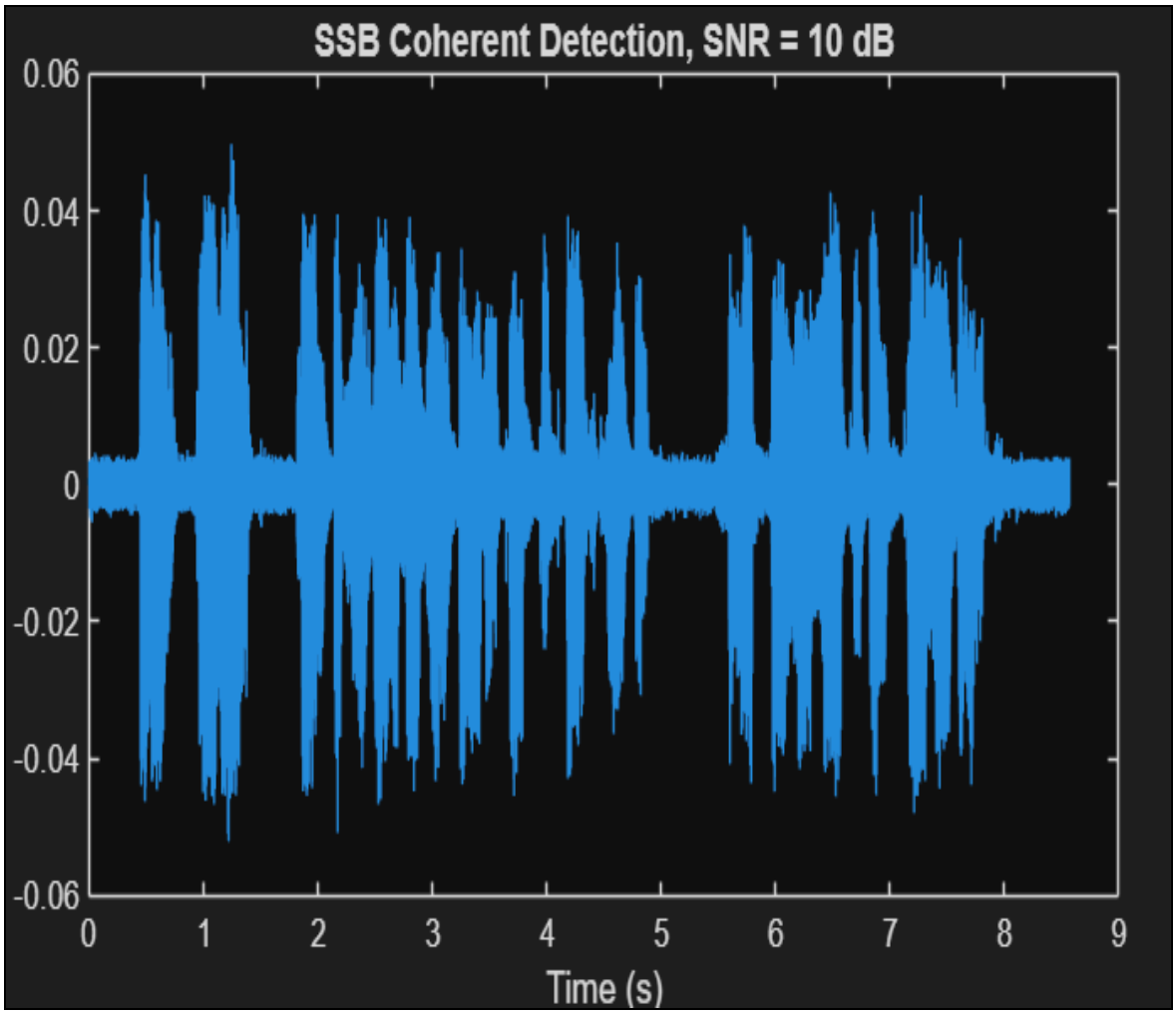

Figure 24: SSB coherent detection waveform at SNR = 10 dB

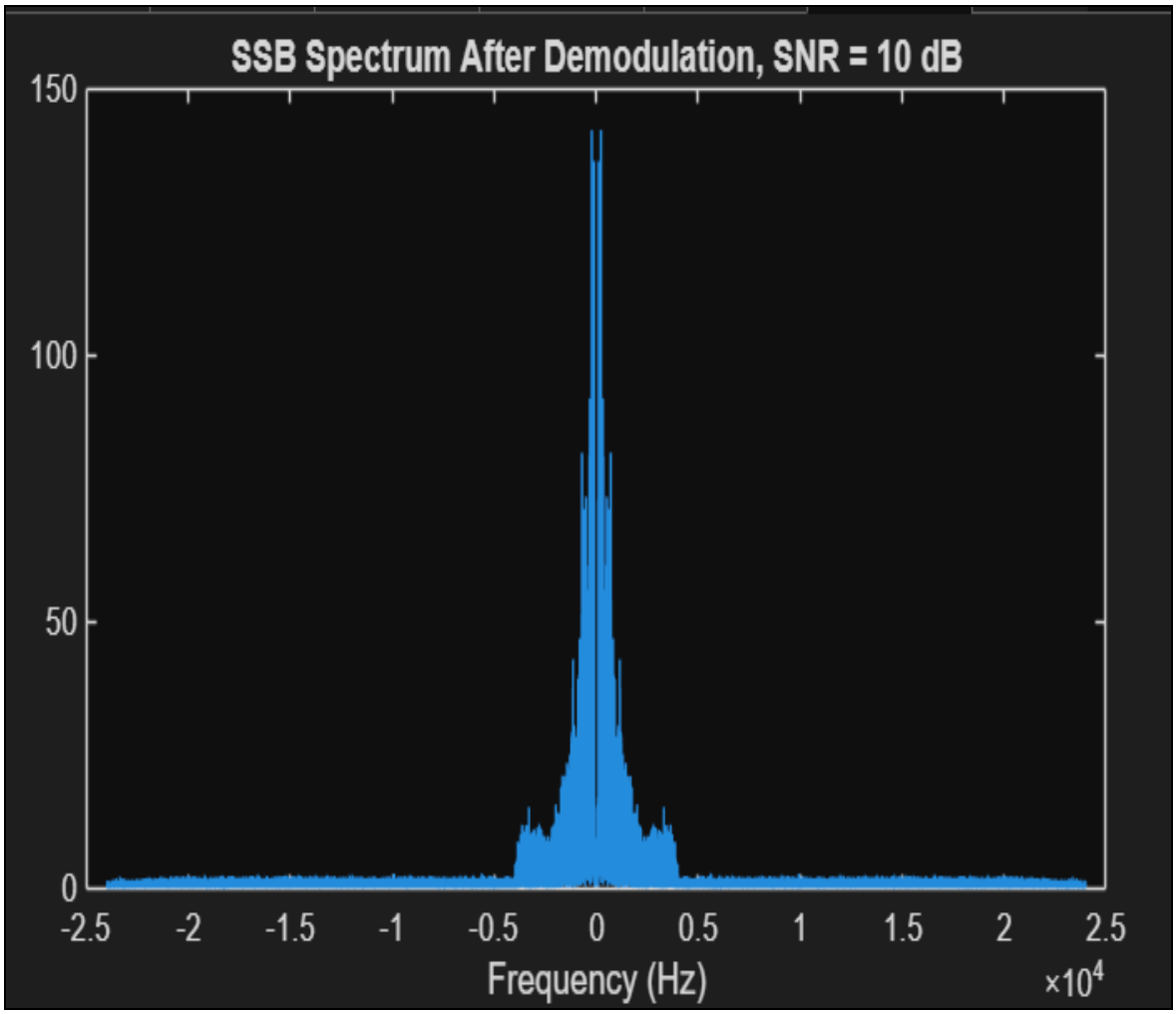

Figure 25: SSB coherent detection spectrum at SNR = 10 dB

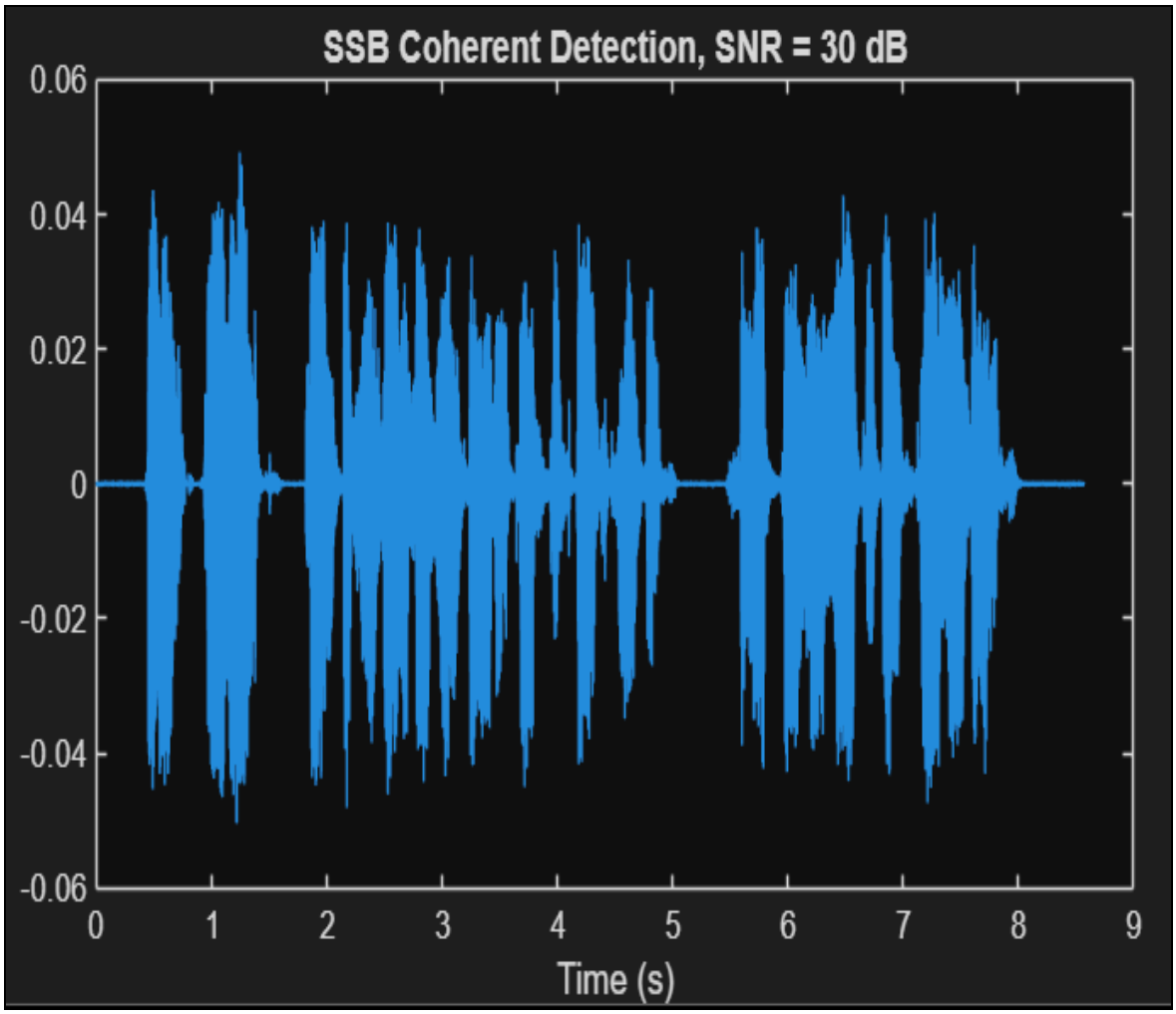

Figure 26: SSB coherent detection waveform at SNR = 30 dB

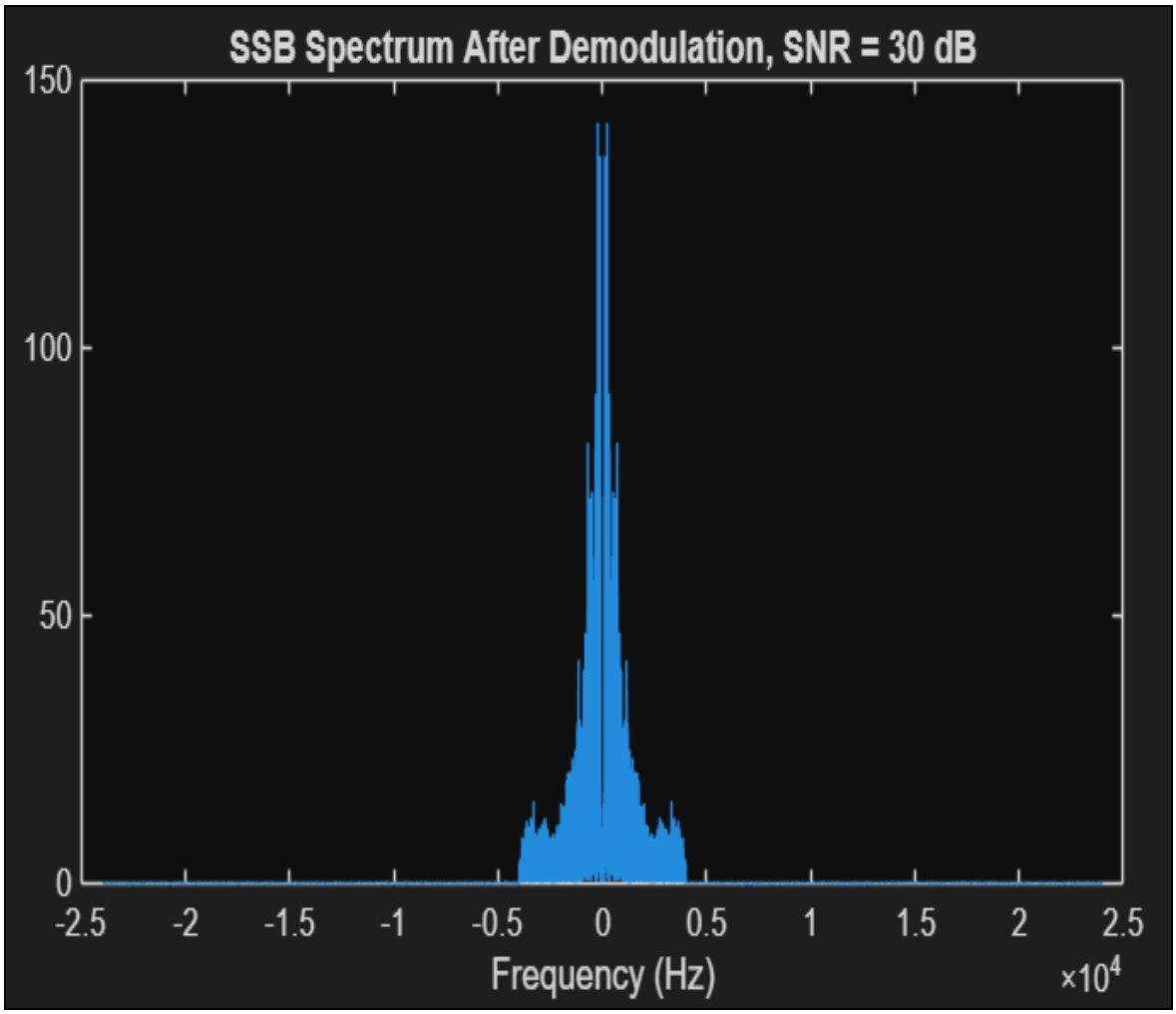

Figure 27: SSB coherent detection spectrum at SNR = 30 dB

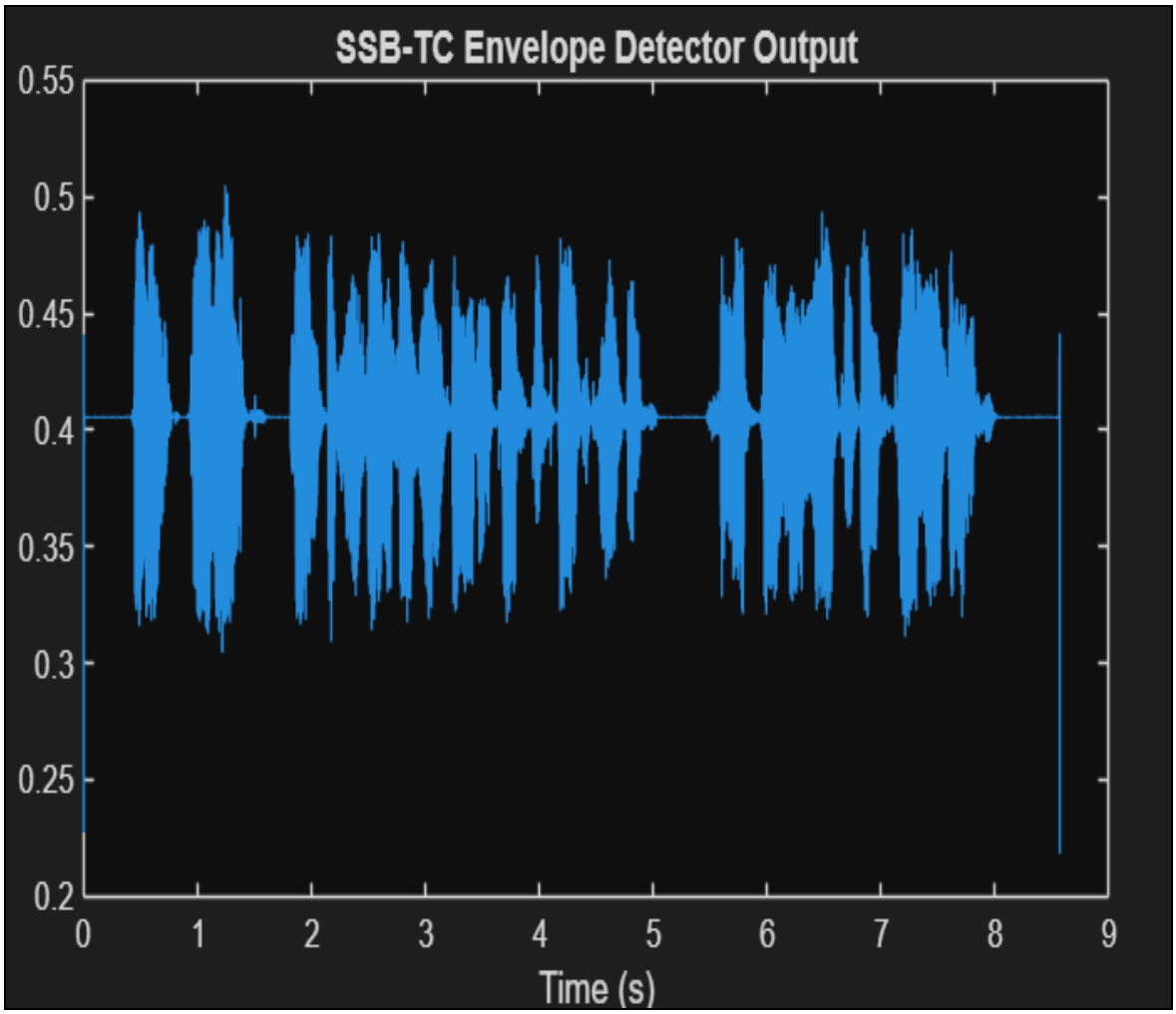

Figure 28: SSB-TC demodulated signal using envelope detector

4. Experiment 3: Narrowband Frequency Modulation

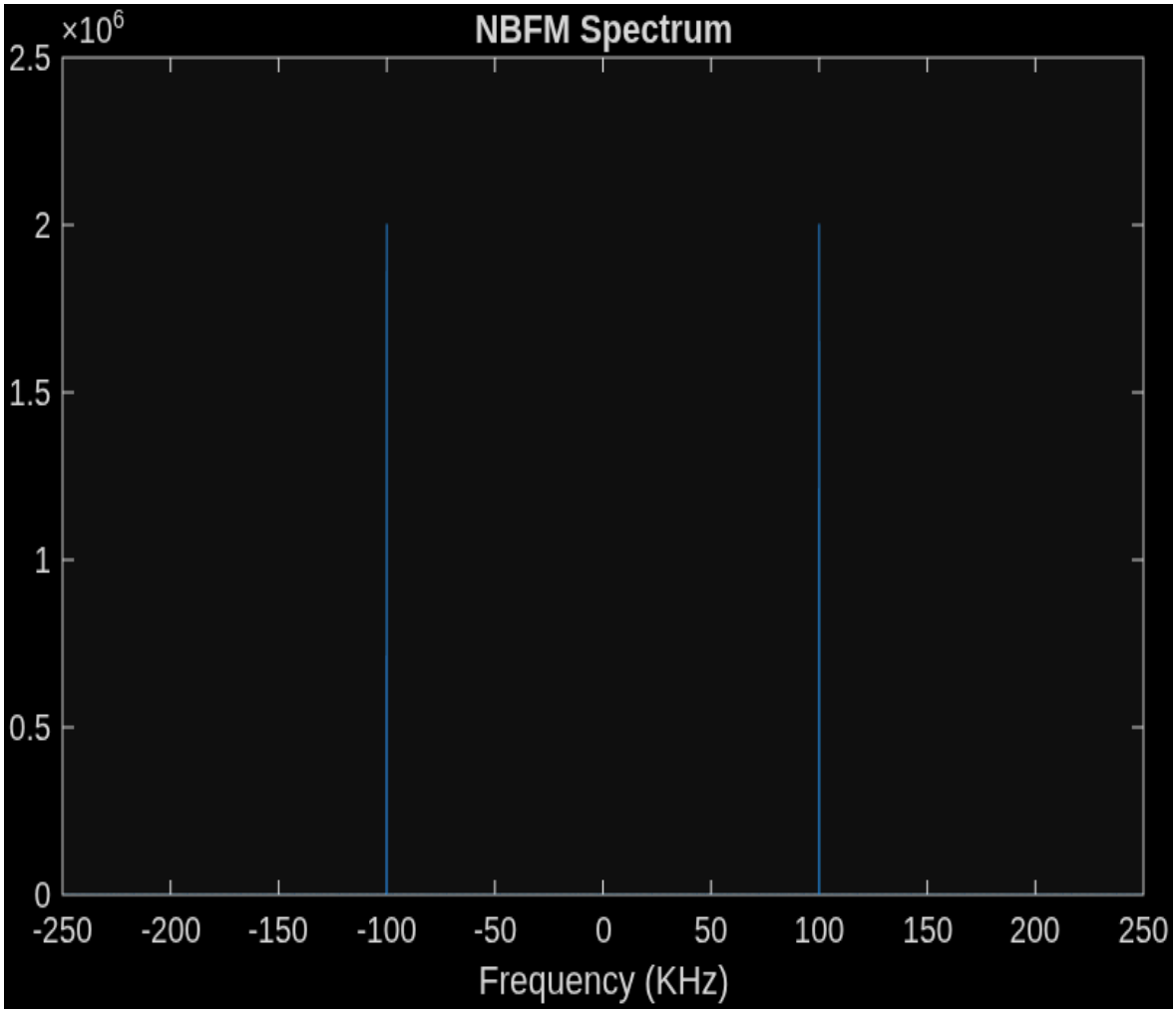

Figure 29: Spectrum of Narrowband FM signal

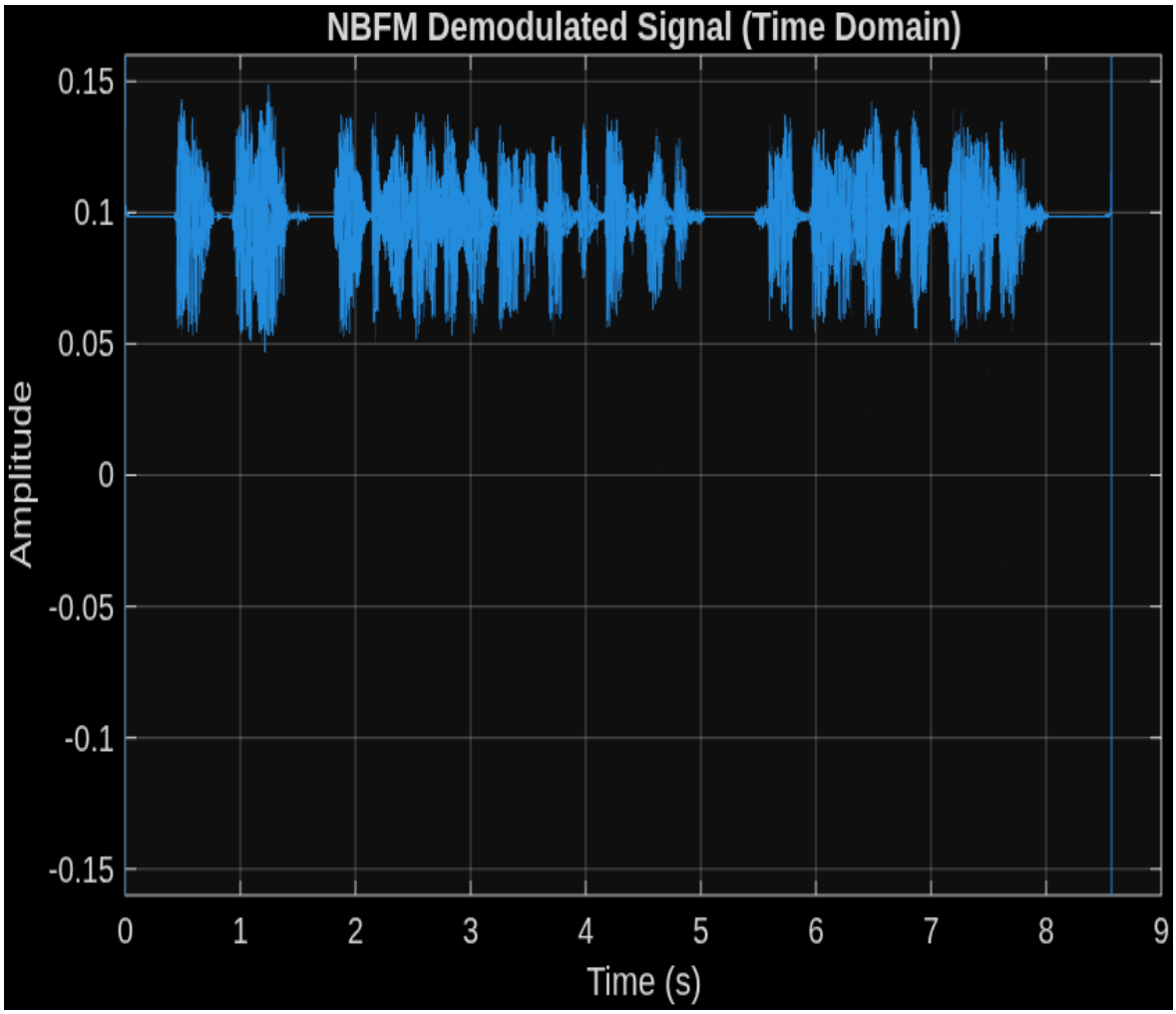

Figure 30: Demodulated NBFM signal using differentiator and envelope detector

5. Conclusions

The experiments demonstrate the trade-offs between bandwidth efficiency, power efficiency, and receiver complexity across different analog modulation schemes. DSB-TC allows simple envelope detection, SSB achieves superior bandwidth efficiency, and NBFM provides improved noise immunity.