International Institute of Information Technology
Bangalore

Principles of Communication Systems Lab

ECE 303P

Lab 4: DSB-SC Modulation and Demodulation

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Abstract

In this Lab report, we study DSB-SC modulation and demodulation. We plot the message signal, carrier signal and their frequency spectrum. We study DSB-SC modulation by plotting modulated signal and frequency spectrum. We also demodulate the transmission signal and study its various properties.

1 Introduction

1.1 Question 1

Consider a DSB-SC modulated signal $\phi(t) = A_c m(t) cos(2\pi f_c t)$ with message signal $m(t) = A_m cos(2\pi f_m t)$. Assume $A_m = A_c = 2$, $f_m = 200$ Hz and $f_c = 2$ KHz.

(a) Plot the message signal $m(t) = A_m cos(2\pi f_m t)$ for complete five cycles.

(b) Plot the carrier signal $c(t) = A_c cos(2\pi f_c t)$ for a duration equal to the duration of the message signal $m(t)$.

(c) Plot the DSB-SC signal $\phi(t)$.

(d) Plot the frequency spectrum of the signals in part (a) and (b) and identify the tones of carrier signal and the message signal.

(e) Demodulate the above DSB-SC signal using the synchronous detector discussed in the class for $\mu = 0.5,\ 1,\ 2$. Plot the demodulated signal and its spectrum. Assume that the receiver can generate a carrier $c(t) = A_c cos(2\pi f_c t)$.

1.2 Question 2

Consider a multi-tone signal $m(t) = A_1 cos(2\pi f_1 t) + A_2 cos(2\pi f_2 t)$ and a carrier signal $A_c cos(2\pi f_c t)$ with $A_c = A_1 = A_2 = 1$, $f_1 = 250$ Hz, $f_2 = 350$ Hz and $f_c = 2.5$ KHz.

(a) Plot the signal $A_1 cos(2\pi f_1 t)$ for complete five cycles.

(b) Plot the signal $A_2 cos(2\pi f_2 t)$ and the carrier signal $A_c cos(2\pi f_c t)$ over the duration of signal $A_1 cos(2\pi f_1 t)$.

(c) Plot the frequency spectrum of the message signal $m(t)$ and the carrier signal $c(t) = A_c cos(2\pi f_c t)$.

(d) Plot the frequency spectrum of the DSB-SC signal $\phi(t) = A_c m(t) cos(2\pi f_c t)$ and identify the tones of the message signal and the carrier signal.

(e) Demodulate the above DSB-SC signal using the synchronous detector discussed in the class and plot the demodulated signal and its spectrum. Assume that the receiver knows the the carrier signal perfectly.

2 Method

2.1 Question 1

To begin with, we first create a time vector followed by message signal vector, carrier signal vector and dsbsc vector as shown below:

```
Am = 2;         Ac = 2;     %Parameters
fm = 200;       fc = 2000;
fs = 50000;                 %Sampling frequency
t = [0:fs-1]*1/fs;          %Time vector

m_t = Am*cos(2*pi*fm*t);
c_t = Ac*cos(2*pi*fc*t);
dsbsc = c_t .* m_t;
```

Here, we take the sampling frequency as 50 KHz. We plot the message signal, carrier signal and DSB-SC signal using `plot(t, x)` command.

Using the following code, we find the frequency spectrum of DSB-SC signal, message signal and carrier signal to plot them:

```
fftD = fftshift(fft(dsbsc))/length(dsbsc);      %Find ffts of the signals
fftM = fftshift(fft(m_t))/length(m_t);
fftC = fftshift(fft(c_t))/length(c_t);
f = [-fs/2:fs/2-1]*df;
```

To demodulate the transmission signal, we use the concepts of synchronous detector. First we multiply the transmission signal by $A_c cos(2\pi f_c t)$. Then we pass it through a low pass filter. Finally, we divide the signal by $A_c^2/2$ to get the original signal. The code for this process is shown below:

```
x_t = dsbsc.*Ac.*c_t;                    %Multiply with Ac*Cos(2*pi*fc*t)
m1t = lowpass(x_t, 220, fs);             %Pass through low pass filter
m1t = m1t/(Ac^2);                        %Divide the signal by Ac^2
```

2.2 Question 2

We follow the same steps as question 1 to get the desired results.

3 Results and Analysis

3.1 Question 1

To solve the question, we create message signal, carrier signal vector and DSB-SC signal vector as shown below:

```
Am = 2;          Ac = 2;      %Parameters
fm = 200;        fc = 2000;
fs = 50000;      df = 1;
t = [0:fs-1]*1/fs;            %Time vector

m_t = Am*cos(2*pi*fm*t);
c_t = Ac*cos(2*pi*fc*t);
dsbsc = c_t .* m_t;
```

The MATLAB code to plot message and carrier signal (part (a) and part (b)) is as follows:

```
%≤===== 1(a) ======>
subplot(2, 1, 1);            %Plot the message signal
plot(t, m_t);
xlabel('---> time(s)');    ylabel('---> m(t)');
title('1(a) Message Signal: A_mcos(2\pif_mt)');
xlim([0 0.025]);
grid on;

%≤===== 1(b) ======>
subplot(2, 1, 2);            %Plot the carrier signal
plot(t, c_t);
xlabel('---> time(s)');    ylabel('---> c(t)');
title('1(b) Carrier Signal: A_ccos(2\pif_ct)');
xlim([0 0.025]);
grid on;
```

The plot of message and carrier signal (part (a) and part (b)) is as follows:

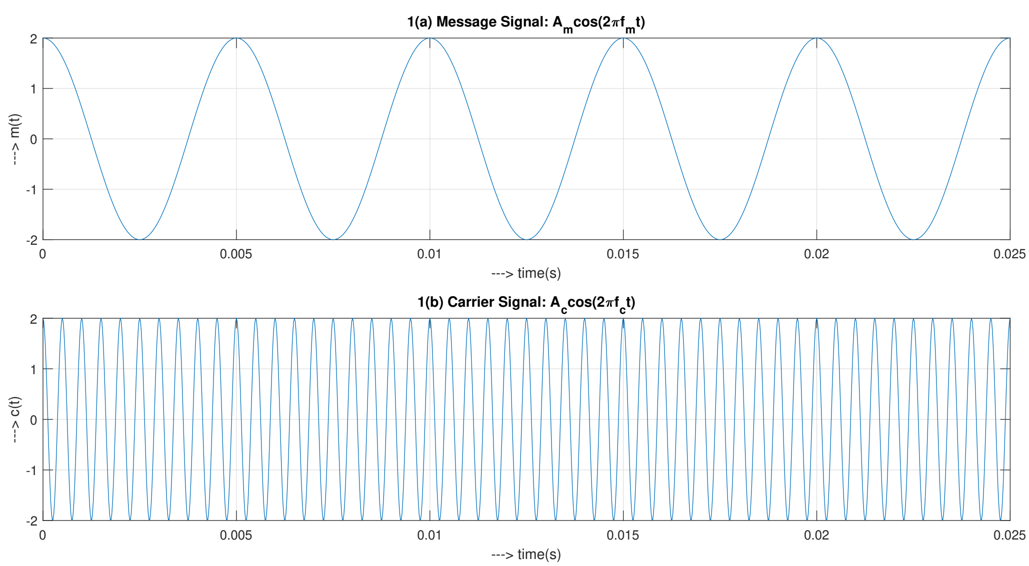

Figure 1: The message and the carrier signal.

The MATLAB code to plot DSB-SC signal (part (c)) and it's spectrum is as follows:

```
%≤===== 1(c) ======>
```

```
subplot(2, 1, 1);            %Plot the carrier signal
plot(t, dsbsc);
xlabel('---> time(s)');     ylabel('---> \phi(t)');
title('1(c) DSB-SC signal: A_c m(t) cos(2\pif_ct)');
xlim([0 0.025]);
grid on;

fftD = fftshift(fft(dsbsc))/length(dsbsc);      %Find ffts of the signals
f = [-fs/2:fs/2-1]*df;

subplot(2, 1, 2);                               %Plot frequency spectrum
plot(f, abs(fftD));
xlabel('---> Frequency(Hz)');     ylabel('---> \phi(f)');
title('1(c) Frequency Spectrum of DSB-SC signal');
xlim([-3000 3000]);
grid on;
```

The plot of DSB-SC signal and its frequency spectrum (part (c)) is as follows:

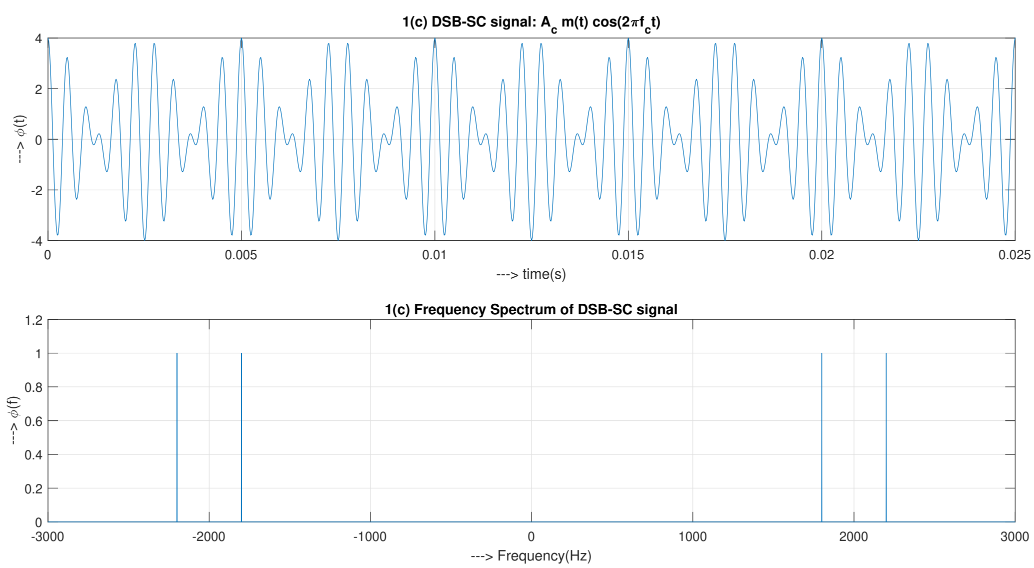

Figure 2: DSB-SC signal and its frequency spectrum.

The MATLAB code to plot the frequency spectrum of the signals (part (d)) is as follows:

```
%<===== 1(d) ======>
fftM = fftshift(fft(m_t))/length(m_t);      %Find ffts of the signals
fftC = fftshift(fft(c_t))/length(c_t);

f = [-fs/2:fs/2-1]*df;

subplot(2, 1, 1);                           %Plot frequency spectrum
plot(f, abs(fftM));
xlabel('---> Frequency(Hz)');     ylabel('---> M(f)');
title('1(d) Frequency Spectrum of Message Signal');
text(220, 0.8, 'Tone at 200 Hz');
xlim([-1000 1000]);
grid on;
```

```
subplot(2, 1, 2);                               %Plot frequency spectrum
plot(f, abs(fftC));
xlabel('---> Frequency(Hz)');    ylabel('---> C(f)');
title('1(d) Frequency Spectrum of Carrier Signal');
text(2100, 0.8, 'Tone at 2000 Hz');
xlim([-3000 3000]);
grid on;
```

The plot of the frequency spectrum is as follows:

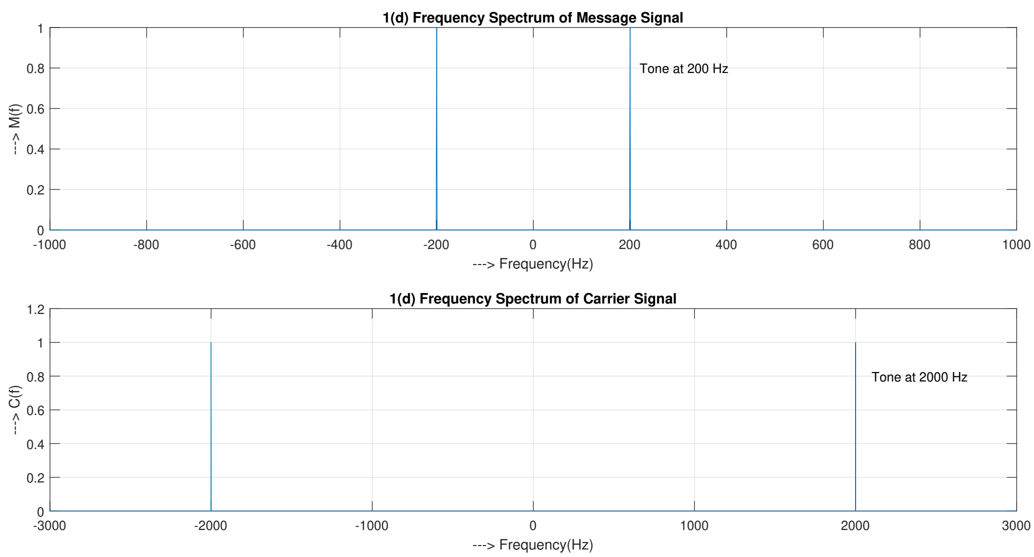

Figure 3: Frequency Spectrum of message and carrier signals.

For message signal, the tone is at 200 Hz. This is a single tone signal. For carrier signal, the tone is at 2000 Hz.

The MATLAB code to demodulate the DSB-SC signal (part(e)) is as follows:

```
%<===== 1(e) ======>
x_t = dsbsc.*Ac.*c_t;                       %Multiply with Ac*Cos(2*pi*fc*t)
m1t = lowpass(x_t, 220, fs);                %Pass through low pass filter
m1t = m1t/(Ac^2);                           %Divide the signal by Ac^2
subplot(2, 1, 1);
plot(t, m1t);
xlabel('---> time(s)');    ylabel('---> m(t)');
title('1(e) Demodulated Signal');
xlim([0 0.025]);
grid on;

fftS = fftshift(fft(m1t))/length(m1t); %Find fft of the signal
f = [-fs/2:fs/2-1]*df;
subplot(2, 1, 2);                     %Plot frequency spectrum
plot(f, abs(fftS));
xlim([-400 400]);
xlabel('---> Frequency(Hz)');    ylabel('---> M(f)');
title('1(e) Frequency Spectrum of the demodulated signal');
```

```
grid on;
```

The plot of the demodulated signal and its frequency spectrum is as follows:

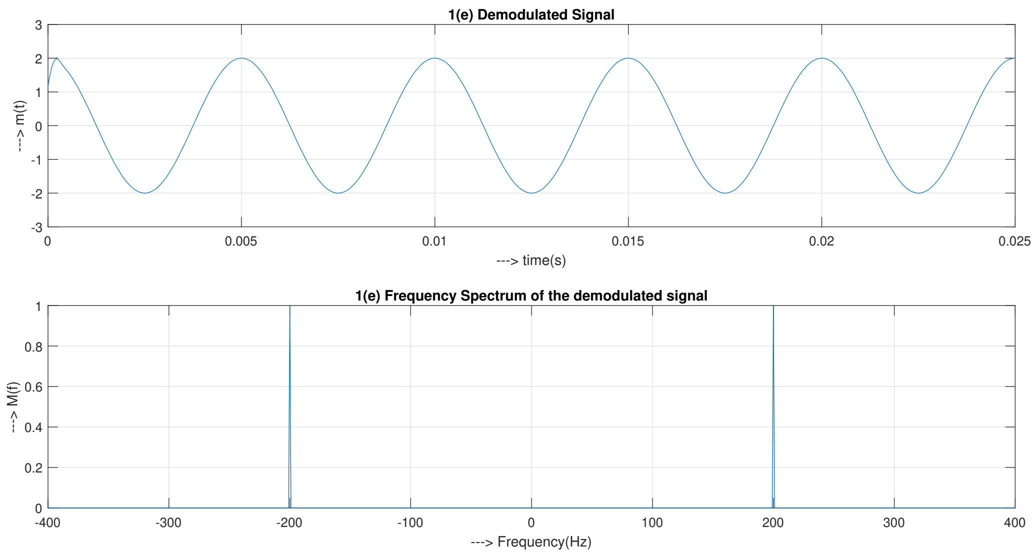

Figure 4: Demodulated signal and its frequency spectrum.

Here, we see that the demodulated signal matches with the original message signal. The frequency spectrum of the demodulated signal has tone at 200 Hz.

3.2 Question 2

To begin with, we first create the carrier signal vector and message signal vector as follows:

```
Ac = 1; A1 = 1; A2 = 1;
f1 = 250;   f2 = 350;
fc = 2500;  df = 1;
fs = 50000;                     %Sampling Frequency
t = [0:fs-1]*1/fs;              %Time vector

m1 = A1*cos(2*pi*f1*t);
m2 = A2*cos(2*pi*f2*t);
m_t = m1 + m2;
c_t = Ac*cos(2*pi*fc*t);
```

The MATLAB code to plot $A_1cos(2\pi f_1t)$, $A_2cos(2\pi f_2t)$ and carrier signal $A_ccos(2\pi f_ct)$ (part (a) and (b)) is as follows:

```
%<===== 2(a) ======>
subplot(3, 1, 1);               %Plot the signals
plot(t, m1);
xlabel('---> time(s)');    ylabel('---> Signal');
title('2(a) A_1cos(2\pif_1t) signal');
xlim([0 0.02]);
grid on;
```

```

%≤===== 2(b) ======>
subplot(3, 1, 2);
plot(t, m2);
xlabel('---> time(s)');    ylabel('---> Signal');
title('2(b) A_2cos(2\pif_2t) signal');
xlim([0 0.02]);
grid on;

subplot(3, 1, 3);
plot(t, c_t);
xlabel('---> time(s)');    ylabel('---> Signal');
title('2(b) Carrier signal: A_ccos(2\pif_ct)');
xlim([0 0.02]);
grid on;
```

The plots of $A_1cos(2\pi f_1t)$, $A_2cos(2\pi f_2t)$ and $A_ccos(2\pi f_ct)$ is as follows:

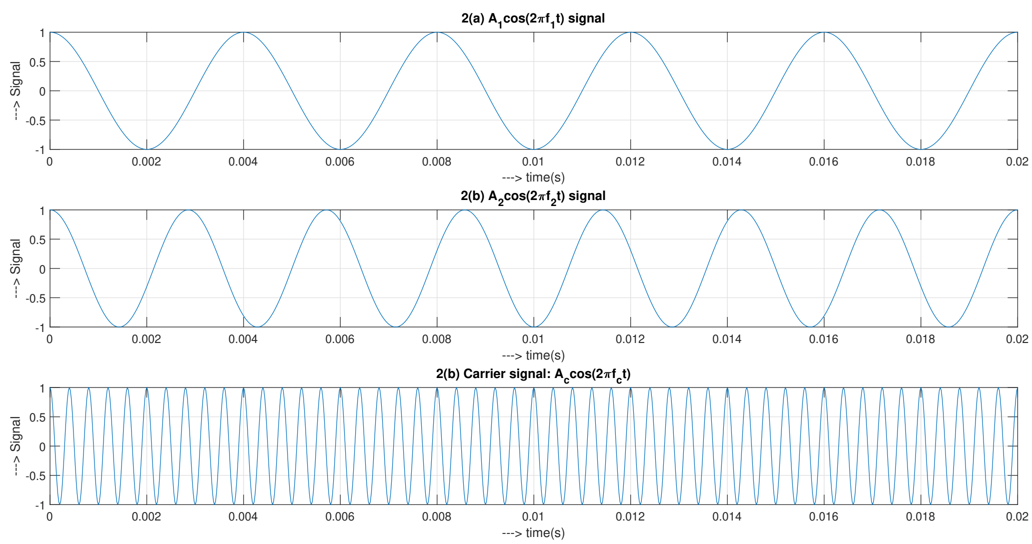

Figure 5: $A_1cos(2\pi f_1t)$, $A_2cos(2\pi f_2t)$ and $A_ccos(2\pi f_ct)$ signals.

The MATLAB code to plot the frequency spectrum of message signal, carrier signal and DSB-SC signal (part(c) and part (d)) is as follows:

```
%≤===== 2(c) ======>
fftM = fftshift(fft(m_t))/length(m_t);      %Calculate fft of the signals
fftC = fftshift(fft(c_t))/length(c_t);
fftD = fftshift(fft(dsbsc))/length(dsbsc);

f = [-fs/2:fs/2-1]*df;

subplot(3, 1, 1);                    %Plot the frequency spectrum
plot(f, abs(fftM));
xlabel('---> Frequency(Hz)');    ylabel('---> M(f)');
title('2(c) Frequency Spectrum of Message Signal');
xlim([-600 600]);
grid on;
```

```
subplot(3, 1, 2);                    %Plot the frequency spectrum
plot(f, abs(fftC));
xlabel('---> Frequency(Hz)');    ylabel('---> C(f)');
title('2(c) Frequency Spectrum of Carrier Signal');
xlim([-4000 4000]);
grid on;

%<===== 2(d) ======>
subplot(3, 1, 3);                    %Plot the frequency spectrum
plot(f, abs(fftD));
xlabel('---> Frequency(Hz)');    ylabel('---> \phi(f)');
title('2(d) Frequency Spectrum of DSB-SC signal');
text(-2000, 0.1, 'Tone of message signal at 2150, 2250, 2750, 2850 Hz');
xlim([-4000 4000]);
grid on;
```

The plot of the frequency spectrum of the signals are as follows:

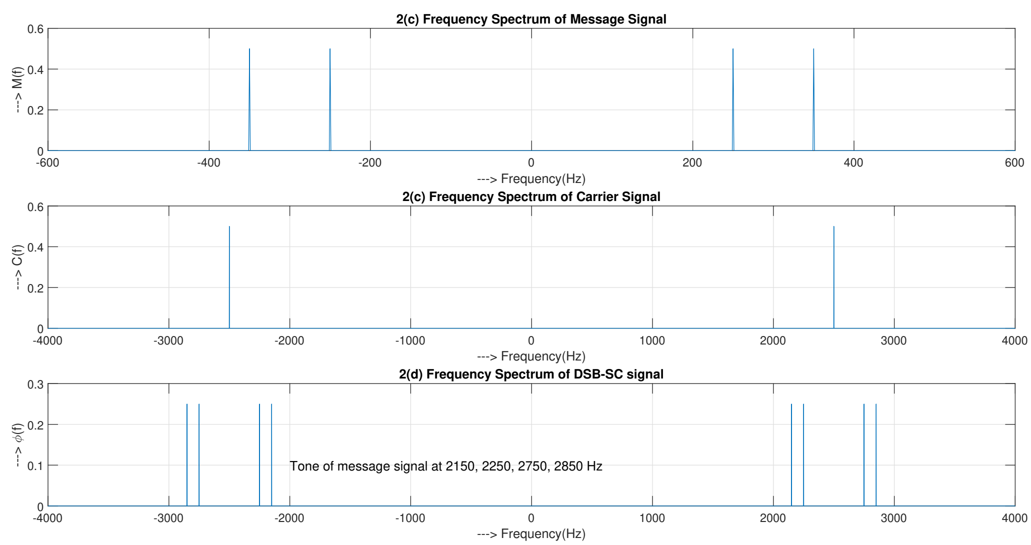

Figure 6: Frequency spectrum of message signal, carrier signal and DSB-SC signal

Here, in the frequency spectrum of DSB-SC signal, the frequency of carrier signal gets suppressed. The tone of message signal is at 2150, 2250, 2750 and 2850 Hz.

The MATLAB code to demodulate the DSB-SC signal (part(e)) is as follows:

```
%<===== 2(e) ======>
x_t = dsbsc.*Ac.*c_t;                %Multiply with Ac*Cos(2*pi*fc*t)
m1t = lowpass(x_t, 400, fs);         %Pass through low pass filter
m1t = m1t/(Ac^2);                    %Divide the signal by Ac^2
subplot(2, 1, 1);
plot(t, m1t);
xlabel('---> time(s)');    ylabel('---> m(t)');
title('2(e) Demodulated Signal');
xlim([0 0.025]);
grid on;
```

```
fftS = fftshift(fft(m1t))/length(m1t); %Find fft of the signal
f = [-fs/2:fs/2-1]*df;
subplot(2, 1, 2);                     %Plot frequency spectrum
plot(f, abs(fftS));
xlim([-500 500]);
xlabel('---> Frequency(Hz)');    ylabel('---> M(f)');
title('2(e) Frequency Spectrum of the demodulated signal');
grid on;
```

The demodulated signal and its frequency spectrum is shown below:

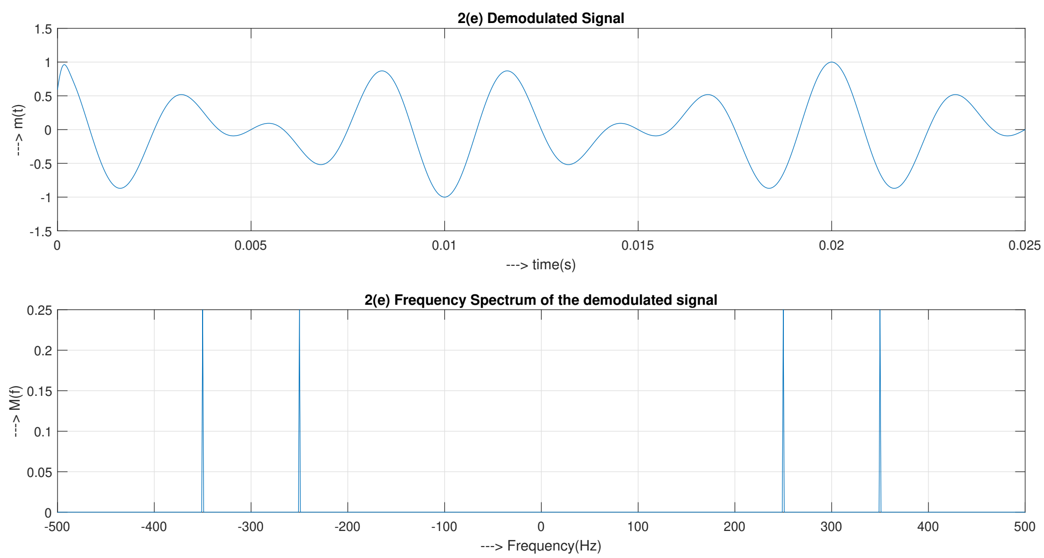

Figure 7: Demodulated signal and its frequency spectrum

Here, we observe that we get back the original signal by passing the transmission signal through synchronous detector. The demodulated signal has tone at 250 and 350 Hz.

4 Discussion and Conclusion

4.1 Question 1

We plotted the message and carrier signal along with its frequency spectrum. We also plotted the DSB-SC modulated signal with its frequency spectrum. Finally, we replicated the function of synchronous detector to demodulate the transmission signal and plotted the demodulated signal with its frequency spectrum.

Some of the noteworthy observations are as follows:

- The given message signal is a single tone signal.
- The tone of the message signal is at 200 Hz and that of the carrier signal is at 2 KHz.
- In DSB-SC signal, the tone of carrier signal gets suppressed. The tone of message signal is at 1800 and 2200 Hz.

- Using synchronous detector, we were able to get back the original signal from the transmission signal.

4.2 Question 2

For this question too, we plotted the message signal, the carrier signal and the DSB-SC modulated signal along with its frequency spectrum. We also demodulated the transmission signal and plotted its frequency spectrum.

Some of the noteworthy observations are as follows:

- The given message signal is a multi tone signal.
- In the frequency spectrum of message signal, the tones are at 250 and 350 Hz. Similarly, for carrier signal, the tone is at 2.5 KHz.
- In DSB-SC modulated signal, the tone of the carrier signal gets suppressed and tones of message signal are at 2150, 2250, 2750 and 2850 Hz.
- Using synchronous detector, we were able to get back the original signal from the transmission signal.