EEE F311 COMMUNICATION SYSTEMS
Experiment 4: DSB-SC & SSB-SC Modulation and Demodulation

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Section: P1

Aim: This experiment is intended to make the student to perform experiments on DSB-SC and SSB-SC Modulation and demodulation using MATLAB.

A –Generation of a DSB-SC Modulated Signal

DSB-SC modulated signal is mathematically represented as $y(t) = A \cos(2\pi f_c t) \sin(2\pi f_m t)$, where f_c is the carrier frequency and f_m is the message frequency. Let the Message Signal be a 2 Khz Sinusoid and the Carrier be a 100 KHz Sinusoid. Let the peak-to-peak amplitude of the message and carrier signals be 2V and 4V, respectively.

1) Write a MATLAB code to implement DSBSC modulated wave and observe the modulated waveform. Plot the message and the modulated waveform one below the other in a single plot window. calculate the message power in the modulated signal and tabulate these in Table 1.

   Hint : Note down the message signal amplitude, carrier signal amplitude and calculate the power from the time domain equation of DSBSC modulated signal.

```
clear;
clc;
close all;

Fs = 400*1000;
T = 1/Fs;
L = 1000;
t = (0:L)*T;
Fm = 2000;
Fc = 100000;
Am = 1;
Ac = 2;

m = Am*sin(2*pi*Fm*t);
c = Ac*cos(2*pi*Fc*t);

subplot(3, 1, 1);
plot(t, m);
```

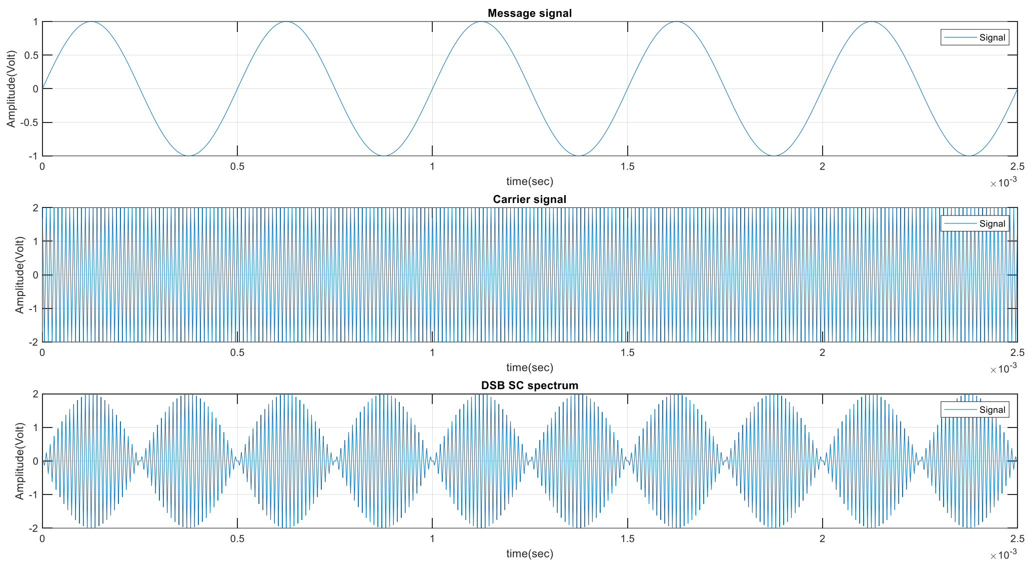
```
title('Message signal');
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
legend("Signal");
grid;

subplot(3, 1, 2);
plot(t, c);
title('Carrier signal');
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
legend("Signal");
grid;

y = m.*c;

subplot(3, 1, 3);
plot(t, y);
title('DSB SC spectrum');
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
legend("Signal");
grid;

%freq spectrums'
f = Fs*(-L/2:(L/2-1))/L;
figure;
M = fftshift(fft(m,L));
P2_1 = abs(M/L);
subplot(2,1,1);
plot(f,P2_1);

C = fftshift(fft(c,L));
P2_2 = abs(C/L);
hold on
plot(f, P2_2);
title('Spectrum of message & carrier signal');
xlabel("frequency(Hz)");
ylabel("Amplitude");
legend("Message","Carrier");
```

```
Y = fftshift(fft(y,L));
P2_3 = abs(Y/L);
subplot(212);
plot(f, P2_3);
title('DSB SC spectrum');
xlabel("frequency(Hz)");
ylabel("Amplitude");
legend("Signal");

figure;
subplot(211);
plot(f,P2_1.^2);
hold on
plot(f,P2_2.^2);
title('Power Spectrum of message & carrier signal');
xlabel("frequency(Hz)");
ylabel("Power(W)");
legend("Message","Carrier");

subplot(212);
plot(f,P2_3.^2);
title('Power Spectrum of DSB-SC wave');
xlabel("frequency(Hz)");
ylabel("Power(W)");
legend("Signal");
```

	Time Domain		Frequency Domain					Demodulated Signal (Time Domain)		Frequency Domain
Sl. No	Message Amplitude (V)	Message Power in modulated signal	Frequency of USB	Power in USB	Frequency of LSB	Power in LSB	Total Message Power	Message Amplitude	Message Power	Message Power
1.	1V	0.5W	102KHz	0.25W	98KHz	0.25W	0.5W	0.9963V	0.497W	0.494W
2.	2V	2W	102KHz	1W	98KHz	1W	2W	1.9935V	1.987W	1.976W
3.	1.5V	1.125W	102KHz	0.5625W	98KHz	0.5625W	1.125W	1.4951V	1.118W	1.1122W

Table 1: Message and Sideband Powers in DSB-SC

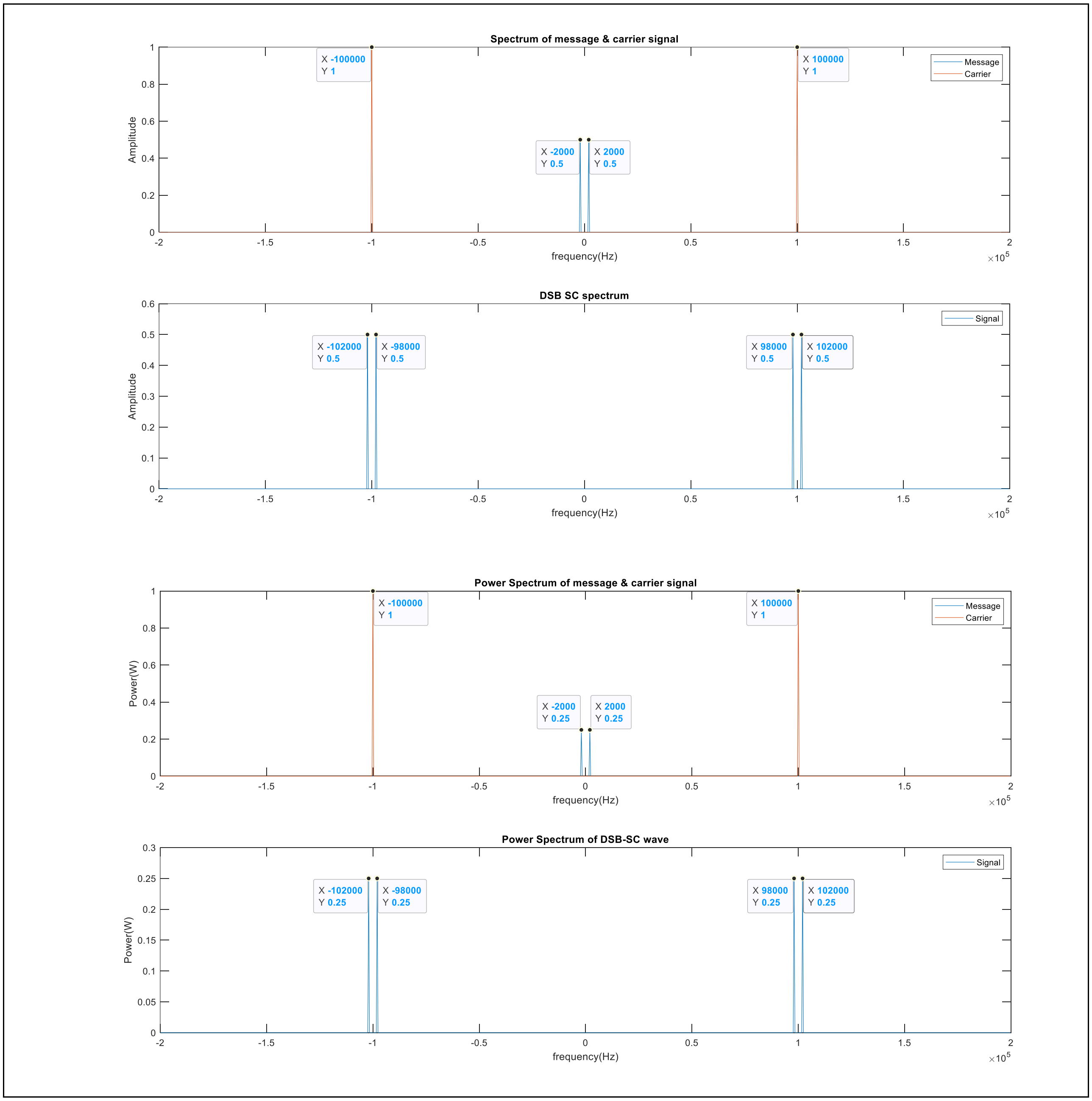
2) Screenshot of the obtained plot is to be noted in the report. How is this different from AM modulation with carrier? Is there a phase Reversal of the carrier at the notch points, where the waveform has decayed to zero amplitude? Why? Reason it out and note it in the report. Hint : Compare the efficiency of AM and DSBSC.



AM and DSB-SC are different in the sense the AM has a DC Bias attached to the signal which constitutes the major chunk of the power but this is not the case of DSB-SC where these types don't have a DC Bias.
Yes, there will a phase reversal at every notch point where the message signal comes to zero value.
It is due to the fact that in Amplitude Modulated signal the signal is added with a DC Bias with which the Phase reversal of the message signal is prevented but in DSB-SC there is no extra component of Carrier signal which constitutes of maximum power but minimum usage thereby decreasing the efficiency. Since it is not the case with DSB-SC efficiency doesn't deteriorate but at the cost of phase reversal.

3) Plot the spectrum of DSB-SC modulated signal. How many distinct spectral peaks are observed and what are their frequencies? Which of these, if any, pertain to the carrier component?

Ans: Two distinct peaks are observed on one side of the spectrum which are at 98kHz and 102KHz (fc ± fm), similarly on the negative side of the spectrum.
None of them pertain to the carrier component. Since the modulation is itself named as suppressed carrier one.



Measure the power in the side bands from the spectrum and tabulate them in Table 1. Check whether the total power in the side bands is equal to the calculated message signal power in the modulated signal from time domain.

Hint: Consider the amplitudes from time domain equations and calculate power.

Power is calculated and tabulated in table 1. Sum of side bands power is equal to message power.

4) Increase the message signal amplitude to 3V peak-to-peak and notice the effect on the DSB-SC signal. Measure and tabulate the results in Table1.

B – Demodulation of DSB-SC Signal:

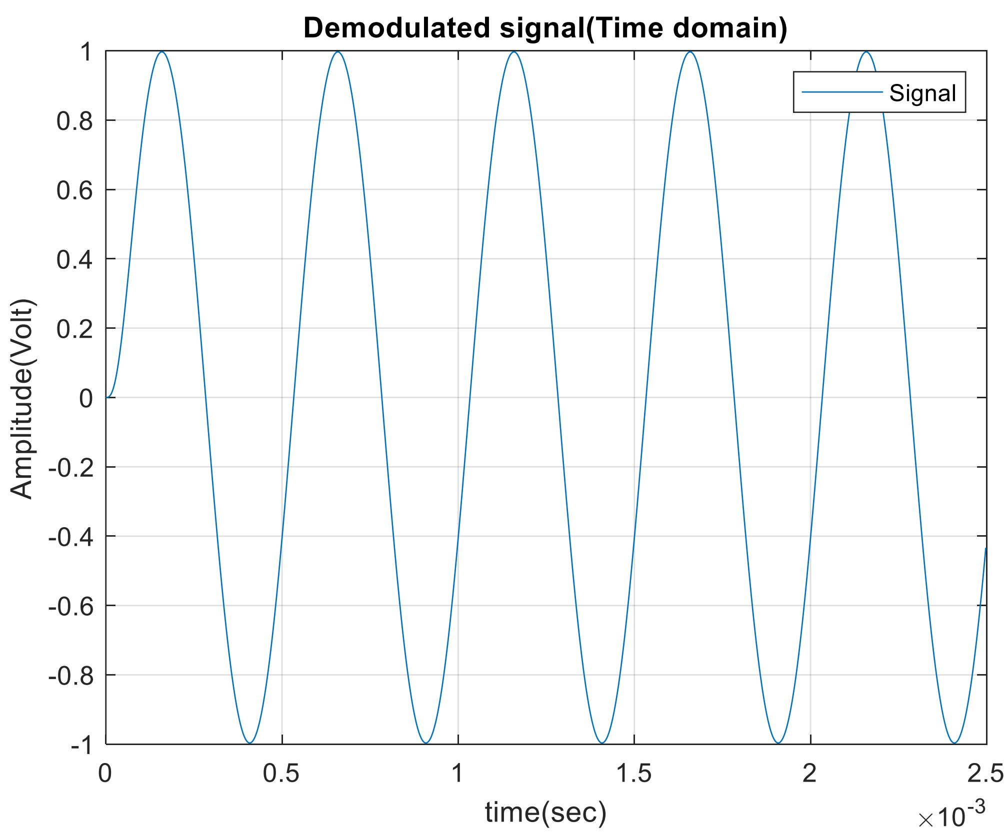
Demodulation of DSB-SC signal is accomplished by multiplying the DSB-SC signal with a local carrier that is perfectly synchronous to the carrier used for modulation.

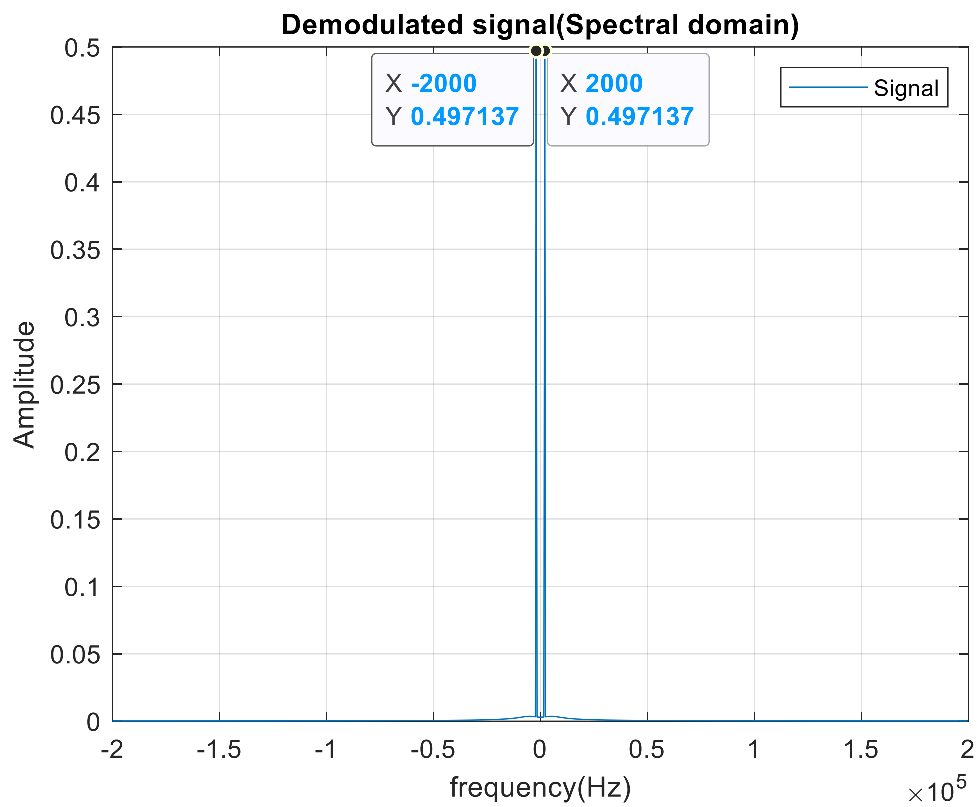
1. Write a MATLAB code to multiply the DSC-SC modulated wave with the carrier signal, and compute the spectrum of the product signal. What Frequency components you observe? Do they include a component corresponding to message signal? Measure and tabulate the power observed from the spectral domain in Table I.

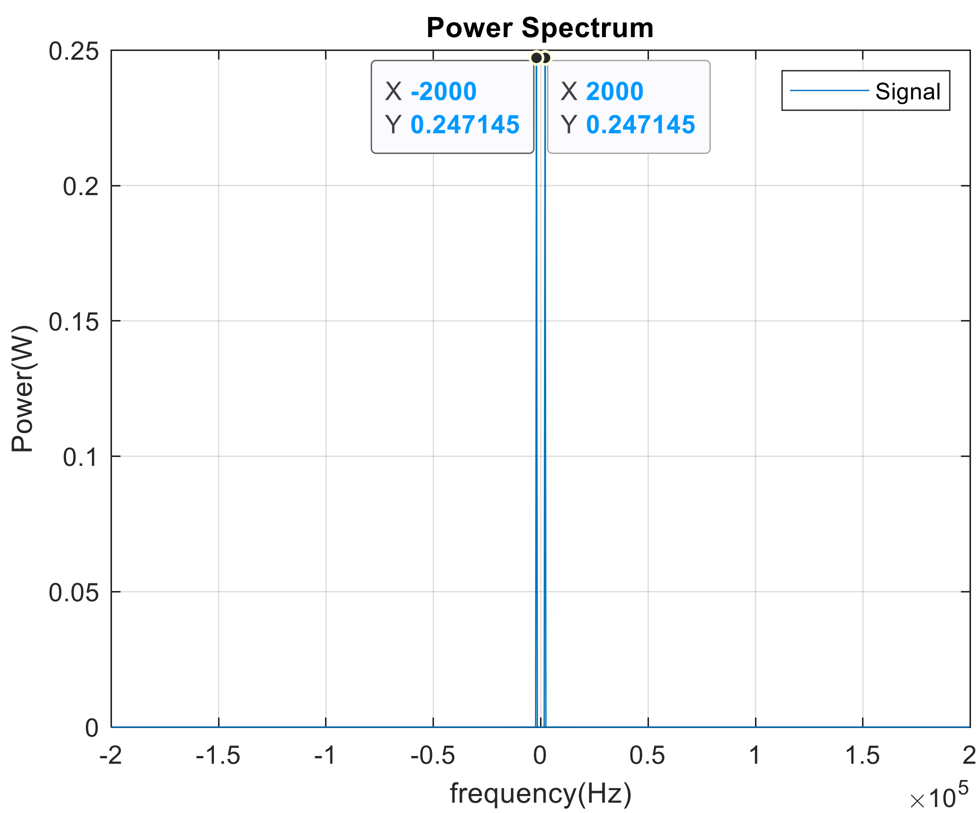
   Hint: after product modulating the modulated signal with the synchronous carrier, pass it through necessary filters to observe the proper demodulated signal. Commands like butter, filter can be used.

```
clear;
clc;
close all;

Fs = 400*1000;
T = 1/Fs;
L = 1000;
t = (0:L-1)*T;

Am = 1;
Ac = 2;

m = Am*sin(2*pi*2000*t);
c = Ac*cos(2*pi*100000*t);

[n,w] = buttord(2*2000/Fs,(8.4*2000)/Fs,.5,5);
[b,a] = butter(n,w,'low');

y = m.*c;

dms = (y.*c)./2;%./Ac^2;

%time domain
dms = filter(b, a, dms);
figure(1);
plot(t, dms);
title('Demodulated signal(Time domain)');
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
legend("Signal");
disp(max(dms));
grid;
```

```
%freq domain
DMS = fft(dms);
DMS = fftshift(DMS);
P2 = abs(DMS/L);

disp(max(P2));
f = Fs*(-L/2:(L/2-1))/L;
figure(2);
plot(f, P2);
title('Demodulated signal(Spectral domain)');
xlabel("frequency(Hz)");
ylabel("Amplitude");
legend("Signal");
grid;

%power spectrum
f = Fs*(-L/2:(L/2-1))/L;
figure(3);
plot(f, P2.^2);
title('Demodulated signal Power Spectrum');
title('Power Spectrum');
xlabel("frequency(Hz)");
ylabel("Power(W)");
legend("Signal");
grid;
```




Demodulated signal(Spectral domain)
Amplitude
frequency(Hz)
×10^5
X -2000
Y 0.497137
X 2000
Y 0.497137
Signal


Power Spectrum
Power(W)
frequency(Hz)
×10^5
X -2000
Y 0.247145
X 2000
Y 0.247145
Signal

2. Compare the demodulated output and the message signal. Is there a difference? Why?

Yes both the message signal and demodulated signal is different. The reason is that the Butterworth filter that we are using is not an ideal filter but comes close to the nature of an ideal filter.

3. Tabulate the demodulated message amplitude and the calculated power in Table 1.

Amplitude and Power are calculated and written in table 1.

4. Comment on the results in Table 1 with respect to the message powers, before modulation and after demodulation

The power of the signal is reduced slightly after demodulation due to filters being non-ideal.

C –Generation of a SSB-SC Modulated Signal

A popular method for generating SSB-SC signal is through phase shifting method (Hilbert Transform). SSB-SC modulated signal is mathematically represented as

$$\varphi_{SSB(t)} = \mathbf{m(t)\cos(2\pi f_c t) \pm \hat{m}(t)\sin(2\pi f_c t)},$$

where f_c is the carrier frequency and f_m is the message frequency, **m(t)** is the message signal and **m̂ (t)** is the Hilbert transform of **m(t).** ***It is well known that the Hilbert transform, for a narrowband signal can be implemented using a 90 degree phase shifter.***

$$\varphi_{USB(t)} = \mathbf{m(t)\cos(2\pi f_c t) - \hat{m}(t)\sin(2\pi f_c t)},$$

$$\varphi_{LSB(t)} = \mathbf{m(t)\cos(2\pi f_c t) + \hat{m}(t)\sin(2\pi f_c t)},$$

Let the Message Signal be a 2 KHz Sinusoid and the Carrier be a 100 KHz Sinusoid. Let the peak-to-peak amplitude of the message and carrier signals be 2V and 4V, respectively.

1. Write the code to generate the SSB-SC modulate signal, and plot the message and the SSB-SC modulated signal one below the other. Screenshot of this is to be pasted in the report. How is this different from AM modulation with carrier? Is there a phase reversal of the carrier at the notch points, where the waveform has decayed to zero amplitude? Why? Reason it out and note it in the report.

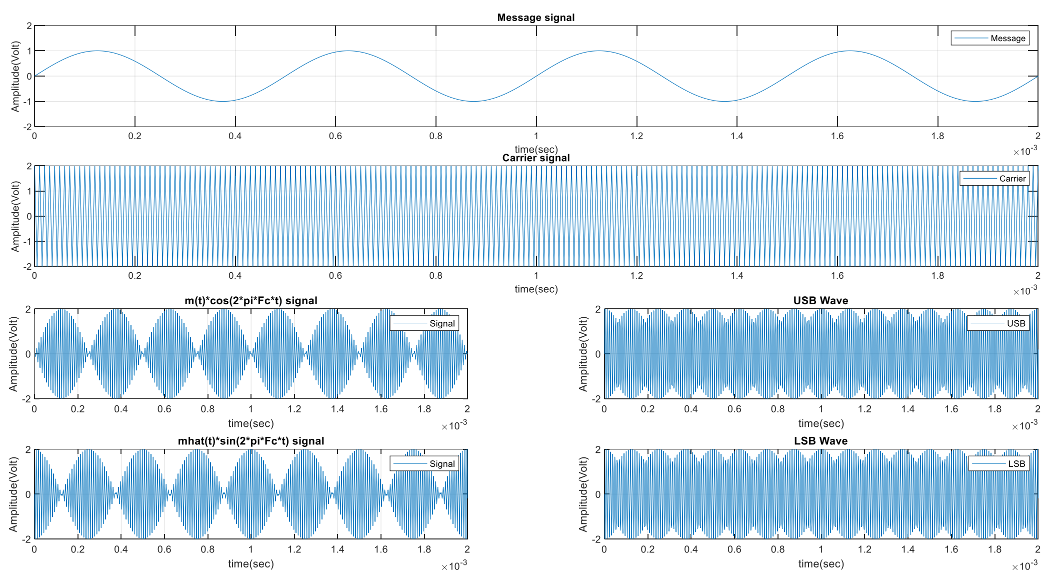
   Hint : Commands like imag, Hilbert needs to be used to generate SSB-SC equation.

```
clear;
clc;
close all;

Fs = 400*1000;
```

```
T = 1/Fs;
L = 1000;
t = (0:L-1)*T;
Fm = 2000;
Fc = 100000;

Am = 1;
Ac = 2;

m = Am*sin(2*pi*Fm*t);
c = Ac*cos(2*pi*Fc*t);

mhat = imag(hilbert(m));
c1 = Ac*sin(2*pi*Fc*t);

x1 = (m.*c);
x2 = (mhat.*c1);

figure(1);
subplot(4,2,[1 2]);
plot(t, m);
title('Message signal');
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
legend("Message");
axis([0 4/Fm -2 2]);
grid;

subplot(4,2,[3 4]);
plot(t, c);
title('Carrier signal');
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
legend("Carrier");
axis([0 4/Fm -2 2]);
grid;

subplot(4,2,5);
plot(t,x1);
title('m(t)*cos(2*pi*Fc*t) signal');
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
legend("Signal");
axis([0 4/Fm -2 2]);
grid;

subplot(4,2,7);
plot(t,x2);
title('mhat(t)*sin(2*pi*Fc*t) signal');
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
```

```
legend("Signal");
axis([0 4/Fm -2 2]);
grid;

yusb = x1-x2;
ylsb = x1+x2;
subplot(426);
plot(t, yusb);
title('USB Wave');
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
legend("USB");
axis([0 4/Fm -2 2]);
grid;

subplot(428);
plot(t, ylsb);
title('LSB Wave');
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
legend("LSB");
axis([0 4/Fm -2 2]);
grid;


%freq spectrums'

f = Fs*(-L/2:(L/2-1))/L;

figure(2);
M = fftshift(fft(m));
P2_1 = abs(M/L);
C = fftshift(fft(c));
P2_2 = abs(C/L);

subplot(211);
plot(f, P2_1);
hold on;
plot(f, P2_2);
title('Spectrum of message & carrier signal');
xlabel("frequency(Hz)");
ylabel("Amplitude");
legend("Message","Carrier");


Yusb = fftshift(fft(yusb));
P2_3 = abs(Yusb/L);
Ylsb = fftshift(fft(ylsb));
P2_4 = abs(Ylsb/L);

subplot(212);
```

```
plot(f, P2_3);
hold on;
plot(f, P2_4);
title('USB & LSB wave');
xlabel("frequency(Hz)");
ylabel("Amplitude");
legend("USB","LSB");


figure(3);
subplot(211);
plot(f,P2_1.^2);
hold on;
plot(f,P2_2.^2);
title('Power Spectrum of carrier signal');
xlabel("frequency(Hz)");
ylabel("Power(W)");
legend("Message","Carrier");

subplot(212);
plot(f,P2_3.^2);
hold on;
plot(f,P2_4.^2);
title('Power Spectrum of USB & LSB wave');
xlabel("frequency(Hz)");
ylabel("Power(W)");
legend("USB","LSB");
```



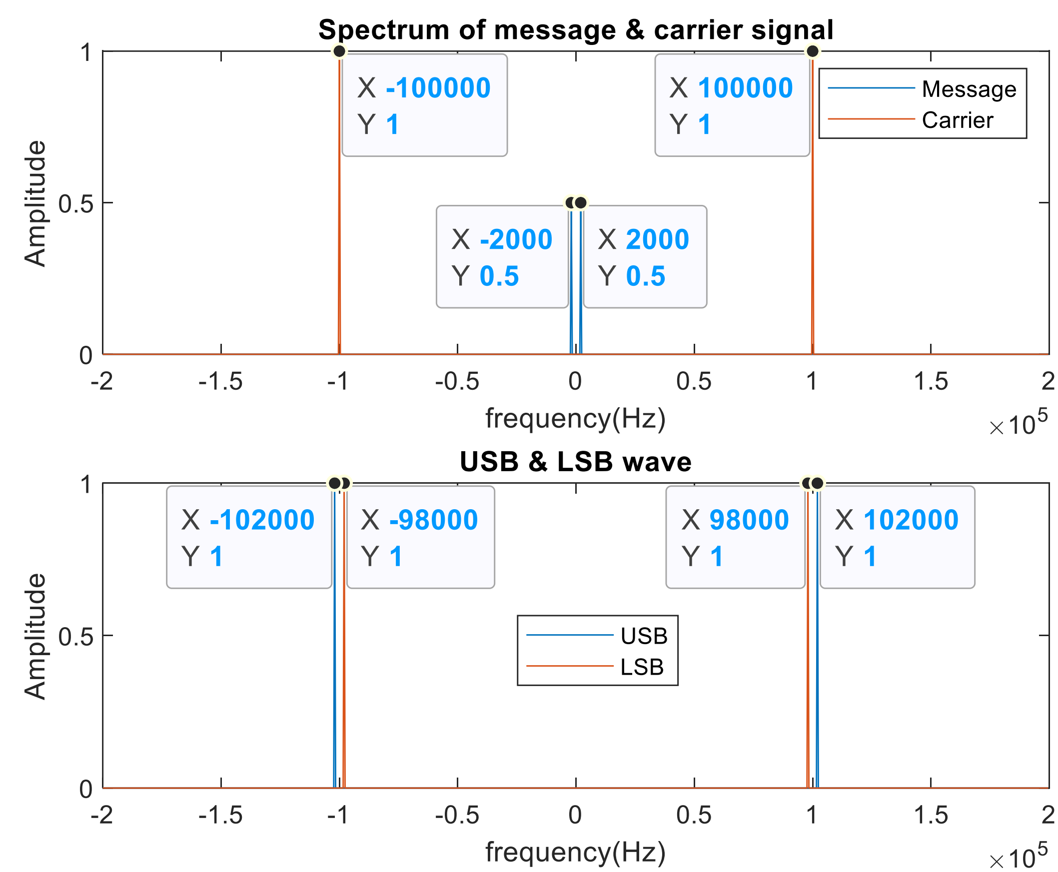
<u>Ans:</u> This is different from the AM because the SSB-SC modulation transmits only the upper spectral band or the lower spectral band but not both the bands since they carry the same information which might be redundant, and also the AM modulation has a DC Bias added to it but SSB-SC modulation doesn't have the DC Biasing.

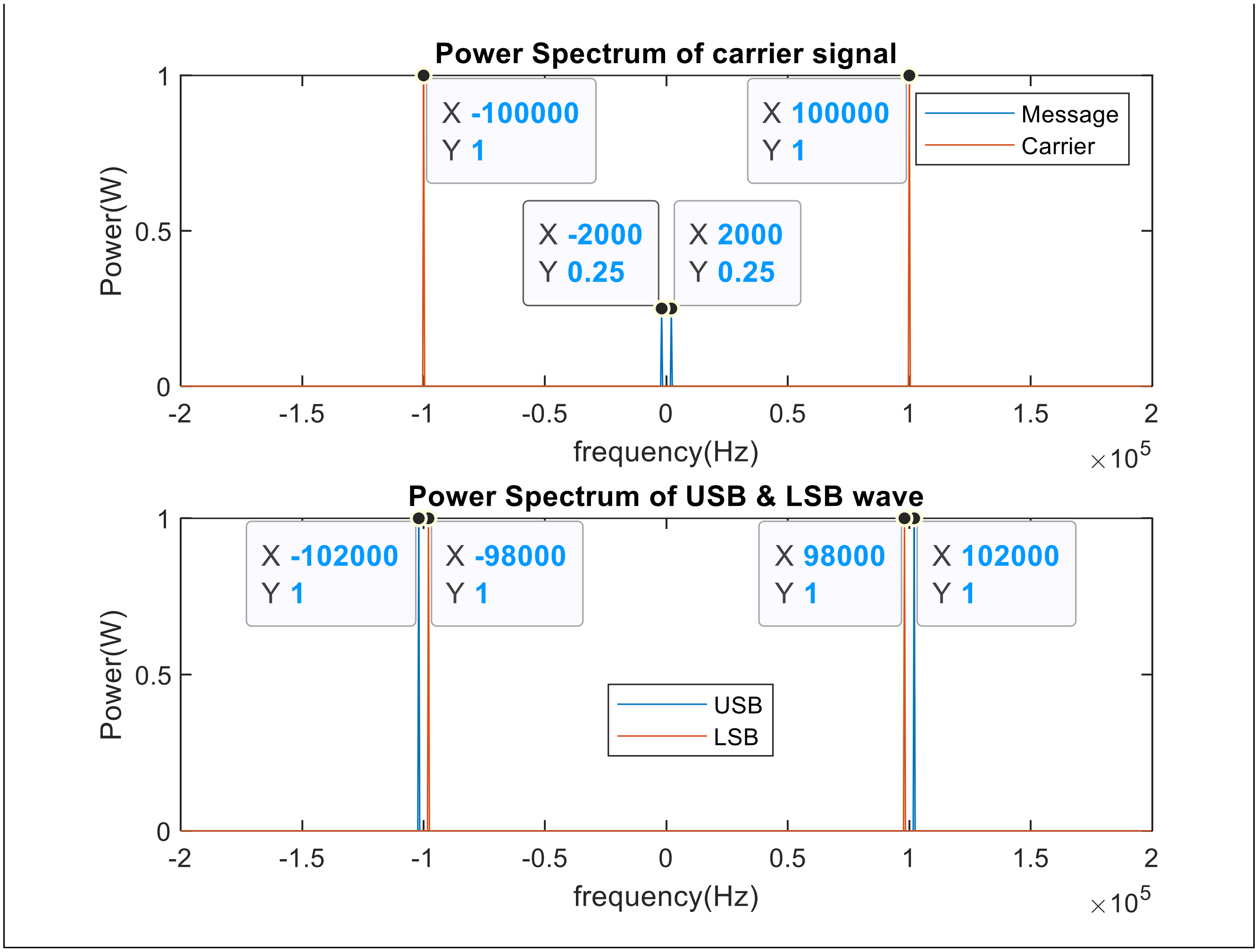
Due to this reason phase reversal happens in SSB Modulation too at message signal having zero amplitude.

2. Obtain and plot the spectrum of the SSB-SC signal. How many distinct spectral peaks are present and what are their frequencies? Is there any carrier component? Which side band do you find in the spectrum, USB or LSB?

Ans: For USB: There is one distinct peak on each side of the spectrum having frequency of 102KHz (or -102KHz) and no carrier component. We find right side band in positive frequency spectrum for the USB signal (and vice versa in negative frequency spectrum).

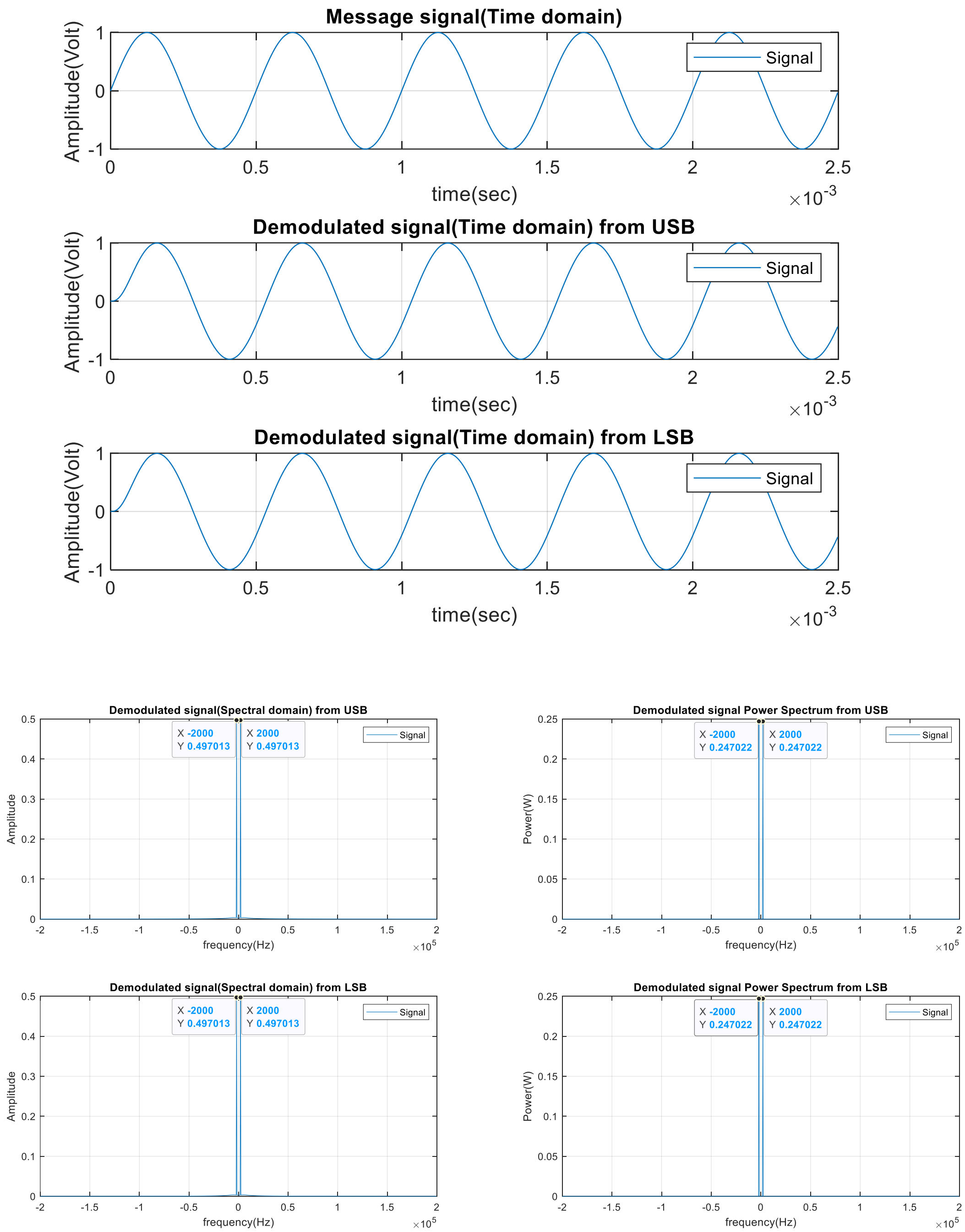
For LSB: There is one distinct peak on each side of the spectrum having frequency of 98KHz (or -98KHz) and no carrier component. We find left side band in positive frequency spectrum for the USB signal (and vice versa in negative frequency spectrum).




Power Spectrum of carrier signal
Power(W)
frequency(Hz)
Message
Carrier
X -100000
Y 1
X 100000
Y 1
X -2000
Y 0.25
X 2000
Y 0.25
Power Spectrum of USB & LSB wave
X -102000
Y 1
X -98000
Y 1
X 98000
Y 1
X 102000
Y 1
USB
LSB

D – Demodulation of DSB-SC Signal: Synchronous Demodulation

Demodulation of SSB-SC signal is accomplished by multiplying the SSB signal with a local carrier that is perfectly synchronous to the carrier used for modulation. Generate the demodulated signal, and plot it below the transmitted message signal. What is the relationship between the original message and the recovered message? Are they in the same phase? Why?



The relationship between the original and recovered message is that they both represent the message signal that we wanted to convey the recovered signal has some very small (negligible error) and the remaining signal is same.

Yes, they both are in the same phase since in the simulation we didn't take the delay and other channel defects into consideration.

E – Conclusions

Which modulation technique is efficient?

Ans: SSB-SC type of Modulation is efficient in consideration that it uses minimum power for transmission of same message signal compared to AM or DSB-SC Modulation.

Why do we use only synchronous detection?

Ans: We use Synchronous detection only because in this process the received signal is multiplied with the exact carrier wave frequency which is used during the DSB-SC or SSB-SC, then the low frequency message signal gets separated out from the high frequency carrier wave signal and thus it can be easily filter out using a low passband filter such as a Butterworth filter.

List out your learning's from the above experiments.

Ans: The learning outcomes from this experiment are:

1. Getting a good understanding of why use DSB-SC and SSB-SC when we have DSB-FC or AM modulation types and what are their advantages and disadvantages compared to AM modulation
2. Using the DSB-SC or SSB-SC the power consumption during the transmission of actual message decreased when compared to the actual AM Modulated signal thereby enhancing the efficiency of power consumption.
3. Demodulation the DSB-SC and SSB-SC signal differs from the normal envelope kind of demodulation that is used in the AM Modulated signal. Here we use Synchronous detection which done by modulating the received signal with the exact replica of the carrier wave thereby separating the actual low frequency message signal from the high frequency carrier wave which can be further filtered out for getting the actual message.