LAB 4

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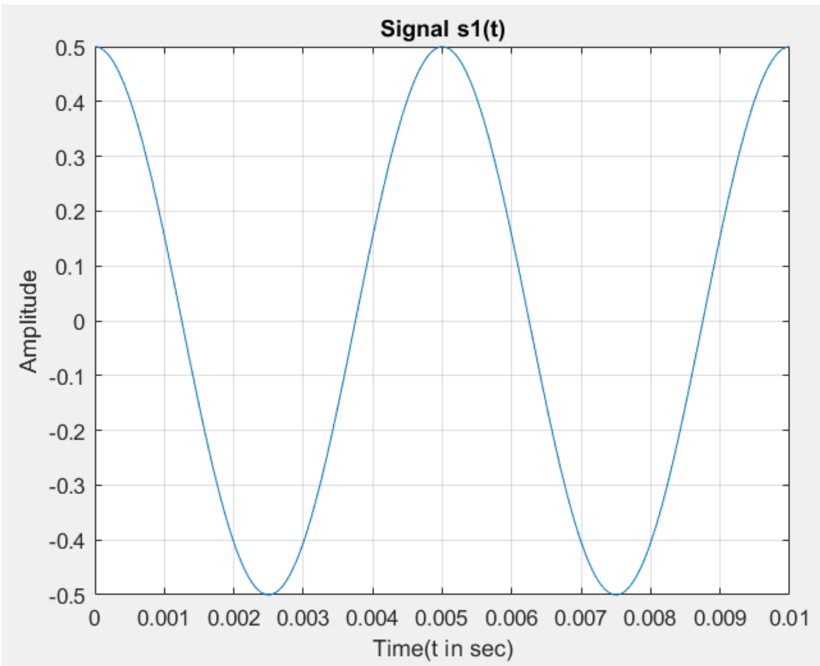
CONTENTS

1 QUESTION 1

1. Modulation & demodulation of Double sideband with suppressed carrier (DSB-SC) signal using MATLAB
   a) Generate and plot the sinusoidal waveform S1(t) with amplitude of 0.5V and frequency of 200 Hz for two complete cycles.
   b) Generate and plot the sinusoidal waveform S2(t) with amplitude of 1V and frequency of 2000 Hz for the same time duration as S1(t).
   c) Using S1(t) as the message signal and S2(t) as the carrier signal, generate and plot the DSB-SC signal, S31(t).
   d) Plot the power spectrum of the DSB-SC signal, S31(t).
   e) Using (d), find the lower sideband and upper sideband power of the modulated signal, S31(t).
   f) Find the bandwidth and total power of the modulated signal, S31(t). Display all these values. Also compare these values obtained from simulation with theoretical values based on formulas.
   g) Demodulate the DSB-SC signal, S31(t) and plot it.
   h) Consider transmission of modulated DSB-SC signal, S31(t) over a noisy channel with AWGN noise and then demodulate it assuming SNR=5dB. Plot and compare the demodulated signal with message signal, S1(t).
   i) Consider transmission of modulated DSB-SC signal, S31(t) over a noisy channel with AWGN noise and then demodulate it assuming SNR=15dB. Plot and compare the demodulated signal with message signal, S1(t). Write your observation with respect to this increase in SNR.

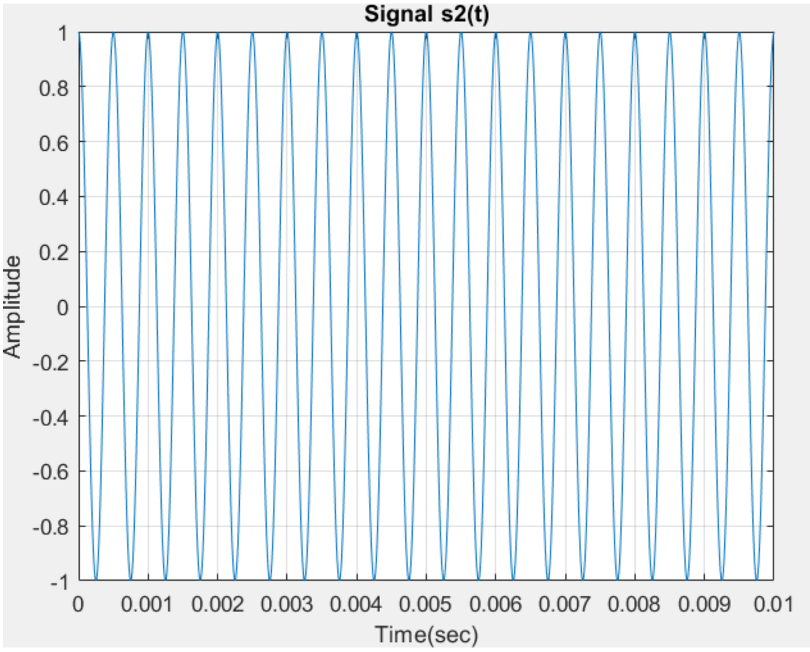
For all the plots a Sampling frequency of 100KHz is used

1.1 Plotting of signal s1(t)



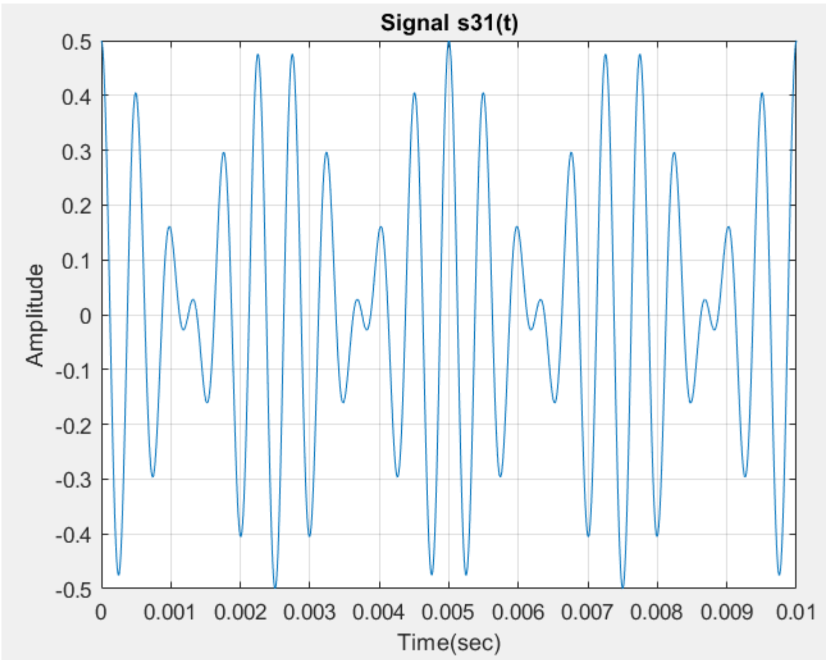
This plot shows 2 cycles of the signal s1(t) = 0.5*cos(2*pi*200*t).
This is a sinusoidal wave with frequency 200Hz(Time period = 0.005s). It has maximum amplitudes of +0.5, -0.5.

1.2 Plotting of signal s2(t)



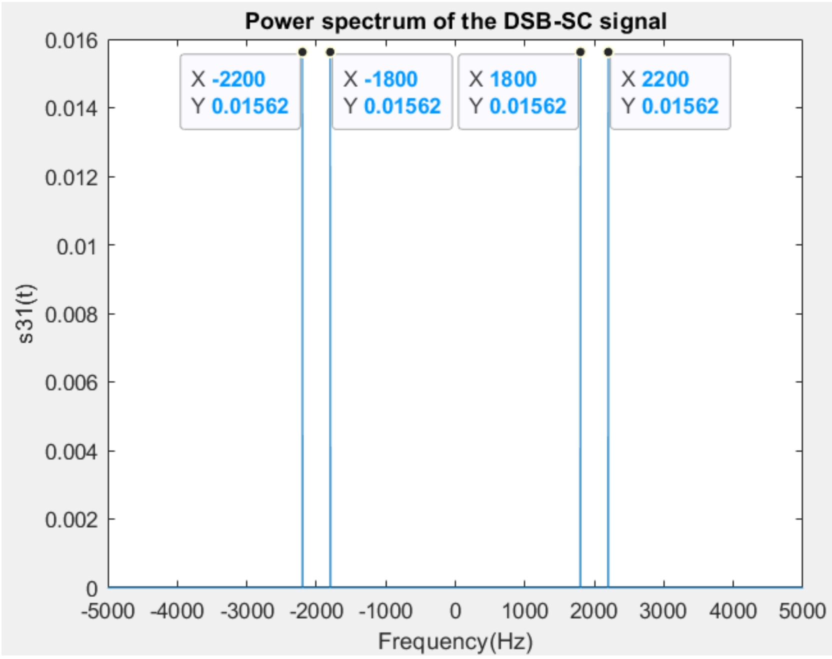
This plot shows 20 cycles of the signal s1(t) = cos(2*pi*2000*t).
This is a sinusoidal wave with frequency 2000Hz(Time period = 0.0005s). It has maximum amplitudes of +1, -1.

1.3 Plotting of DSB-SC signal, s31(t)



This is the plot of Double side band with suppressed carrier modulation result.
The signal with 2000Hz(s2) acts as the carrier signal.
This plot is basically also the outcome of s1.*s2.

1.4 Plotting of power spectrum of DSB-SC signal, s31(t)



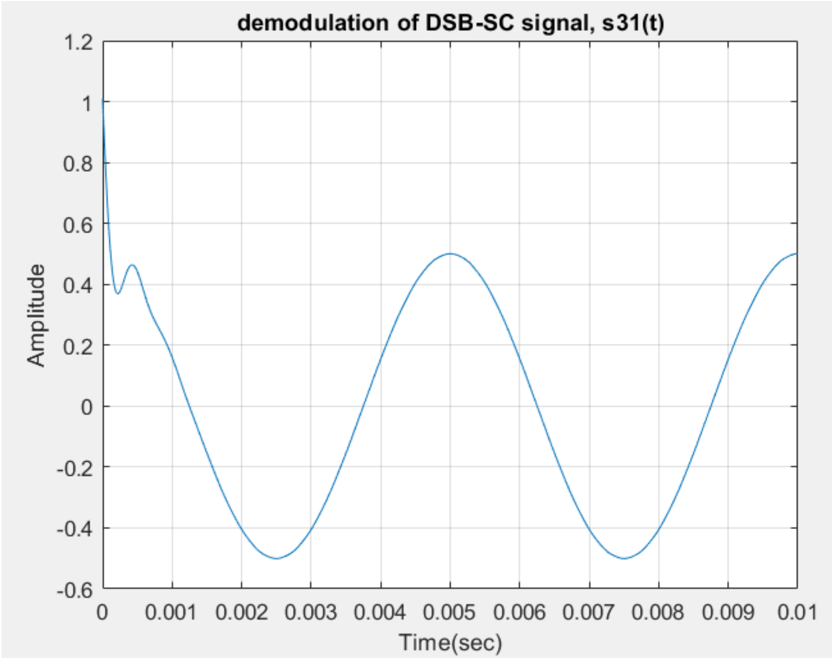
1.5 Lower and Upper side band power of the modulated signal

From above plot it is clear that Lower side bands are at -1800Hz, 1800Hz and upper side bands are at -2200Hz, 2200Hz
Lower side band power = Sum of powers at -1800 and 1800
=> Lower side band power = 0.01562 + 0.01562
=> Lower side band power = 0.03124 Watts
Upper side band power = Sum of powers at -2200 and 2200
=> Upper side band power = 0.01562 + 0.01562
=> Upper side band power = 0.03124 Watts

1.6 Bandwidth and Total Power of the modulated signal

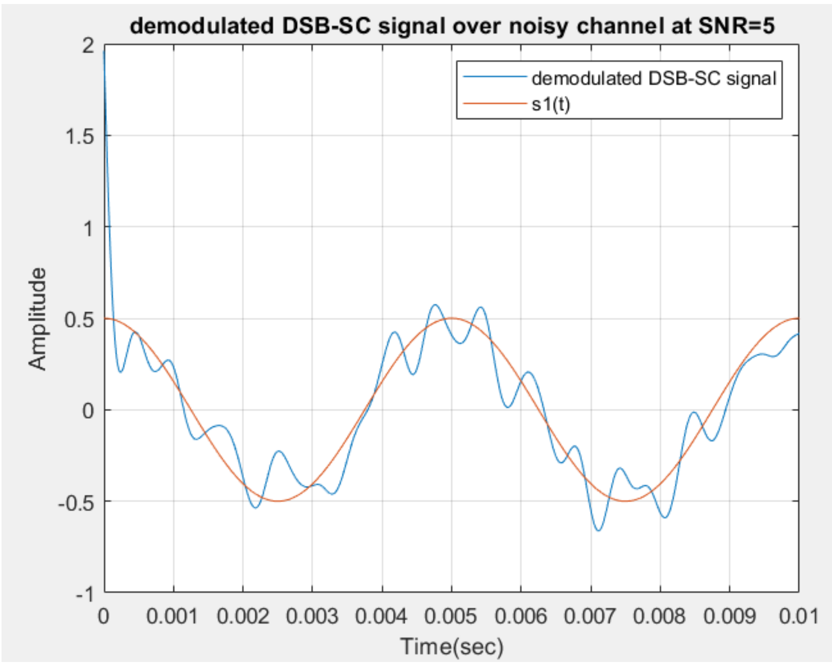
Bandwidth = f(Upper band)-f(Lower band)
=> Bandwidth = 2200Hz - 1800Hz
=> Bandwidth = 400Hz
Theoretically, **Bandwidth = 2*fm** (fm = frequency of message signal which is 200Hz in this case)
=> Bandwidth = 2*200Hz = 400Hz
Total power of modulated signal = Lower side band power + Upper side band power
=> Total power of modulated signal = 0.03124 + 0.03124
=> Total power of modulated signal = 0.06248 Watts.
Theoretically, **Total power of modulated signal = Am/2 * Ac/2** (Am = Amplitude of message signal = 0.5 here and Ac= Amplitude of carrier signal = 1 here)
=> Total power of modulated signal = 0.5/2 * 1/2
=> Total power of modulated signal = 0.0625 Watts.
Hence In both theoretical and observed methods our readings are correct and verified.

1.7 Plotting the demodulation of DSB-SC signal, s31(t)



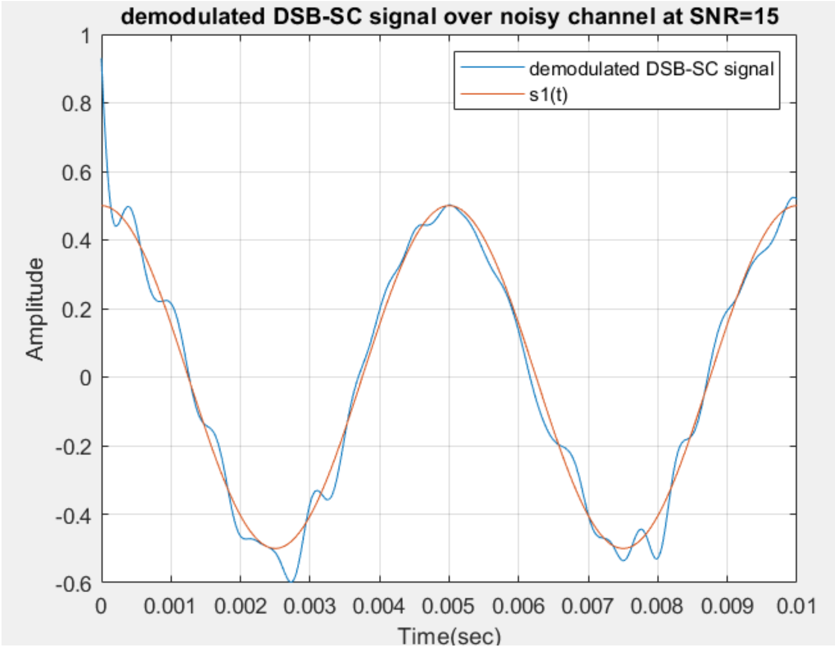
After demodulation, we get back the original signal. This demodulated signal except the few initial milliseconds is exactly the same as the signal s1. This is because we do not have any noise in this case.

1.8 Plotting the demodulated DSB-SC signal over noisy channel at SNR=5



After demodulation, we get back heavily distorted original signal.
This is because we do have any noise in this case.
With signal to noise ratio being low, The noise can have high impact on outcome.
We observe exactly the same in the plot.

1.9 Plotting the demodulated DSB-SC signal over noisy channel at SNR=15



After demodulation, we get back mildly distorted original signal.
This is because we do have any noise in this case.
With signal to noise ratio being high, The noise can have little impact on outcome.
We observe exactly the same in the plot.

1.10 Code

```
close all; clc;

fs = 100000;
t = 0:1/fs:10-1/fs;

s1 = 0.5*cos(2*pi*200*t);
s2 = 1*cos(2*pi*2000*t);

s31 = ammod(s1,2000,fs,0);
s31_demod = amdemod(s31,2000,fs,0);

s31_fts =fftshift((fft(s31)));
N = length(s31_fts);
freq = -fs/2: fs/length(s31_fts): fs/2-fs/length(s31_fts);
Gn=(abs(s31_fts/N).^2);

display(var(s31))

noise1 = awgn(s31,5);
demod_noise1 = amdemod(noise1,2000,fs,0);

noise2 = awgn(s31,15);
demod_noise2 = amdemod(noise2,2000,fs,0);
%% plot of s1(t)
figure
plot(t,s1)
title('Signal s1(t)')
```

```
xlabel('Time(t in sec)')
ylabel('Amplitude')
xlim([0 0.01])
grid on
%% plot of s2(t)
figure
plot(t,s2)
title('Signal s2(t)')
xlabel('Time(sec)')
ylabel('Amplitude')
xlim([0 0.01])
grid on
%% plot of DSB-SC signal, s31(t)
figure
plot(t,s31)
title('Signal s31(t)')
xlabel('Time(sec)')
ylabel('Amplitude')
xlim([0 0.01])
grid on
%% Plot of power spectrum of the DSB-SC signal, s31(t)
figure
plot(freq,Gn)
xlabel('Frequency(Hz)')
ylabel('s31(t)')
title ('Power spectrum of the DSB-SC signal')
xlim([-5000 5000])
%% plot of demodulated DSB-SC signal, s31_demod(t)
figure
plot(t,s31_demod)
title('demodulation of DSB-SC signal, s31(t)')
xlabel('Time(sec)')
ylabel('Amplitude')
xlim([0 0.01])
grid on
%% plot of demodulated DSB-SC signal over noisy channel at SNR=5
figure
plot(t,demod_noise1)
title('demodulated DSB-SC signal over noisy channel at SNR=5')
xlabel('Time(sec)')
ylabel('Amplitude')
xlim([0 0.01])
grid on
hold on
plot(t,s1)
hold off
legend('demodulated DSB-SC signal','s1(t)')
%% plot of demodulated DSB-SC signal over noisy channel at SNR=15
figure
plot(t,demod_noise2)
title('demodulated DSB-SC signal over noisy channel at SNR=15')
xlabel('Time(sec)')
```

```
ylabel('Amplitude')
xlim([0 0.01])
grid on
hold on
plot(t,s1)
hold off
legend('demodulated DSB-SC signal','s1(t)')
```

2 QUESTION 2

2. Modulation & demodulation of Amplitude Modulated signal (Double sideband with carrier) using MATLAB
   a) Using $S_1(t)$ as the message signal and $S_2(t)$ as the carrier signal, generate and plot the amplitude modulated signal, $S_3(t)$.
   b) Plot the amplitude and power spectrum of the amplitude modulated signal, $S_3(t)$.

c) Using (b), find the carrier power, the lower sideband and upper sideband power of the modulated signal, $S_3(t)$.

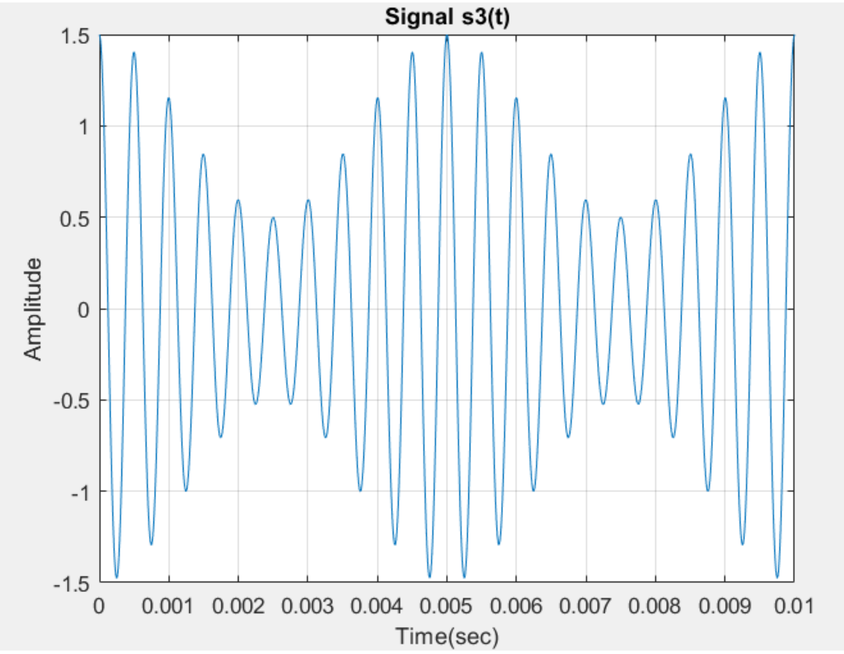
d) Find the modulation index, bandwidth and total power of the modulated signal, $S_3(t)$. Compare these values obtained from simulation with theoretical values based on formulas.

e) Demodulate the amplitude modulated signal, $S_3(t)$ and plot it.

f) Plot the graph between the total AM power normalized to carrier power and modulation index. Consider modulation index varying from 0 to 1.5.

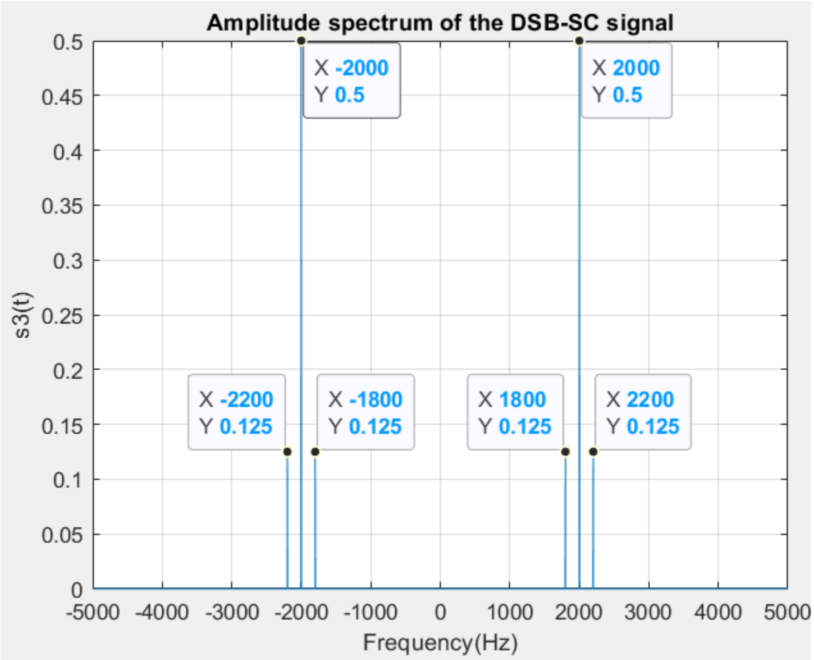
For all the plots a Sampling frequency of 100KHz is used

2.1 Plotting the Amplitude modulated signal s3(t)



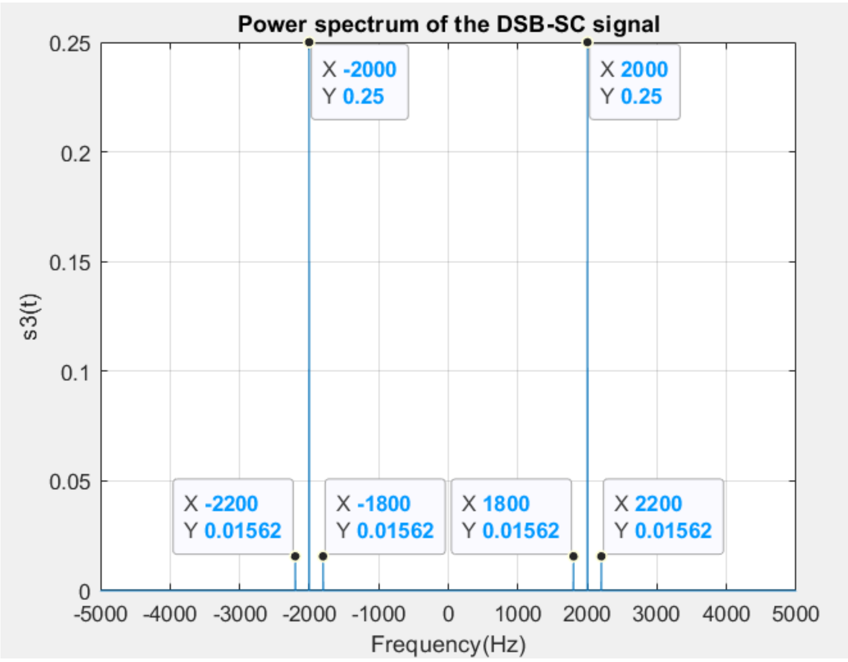
This plot is of Amplitude modulated signal for the message signal s1(t) = 0.5*cos(2*pi*200t) with carrier s2(t) = cos(2*pi*2000t).

2.2 Plotting the Amplitude Spectrum of Amplitude modulated signal, s3(t)



In the Amplitude spectrum we observe three peaks at ±1800Hz, ±2000Hz, ±2200Hz. Their respective amplitudes are 0.125, 0.5, 0.125.

2.3 Plotting the Power Spectrum of Amplitude modulated signal, s3(t)



In the power spectrum we observe peaks at ±1800Hz, ±2000Hz, ±2200Hz.
Their respective values are 0.01562, 0.25, 0.01562.
In comparison to earlier case here we see an additional carrier power.

2.4 Carrier power, the Lower and Upper side band power of the Modulated Signal

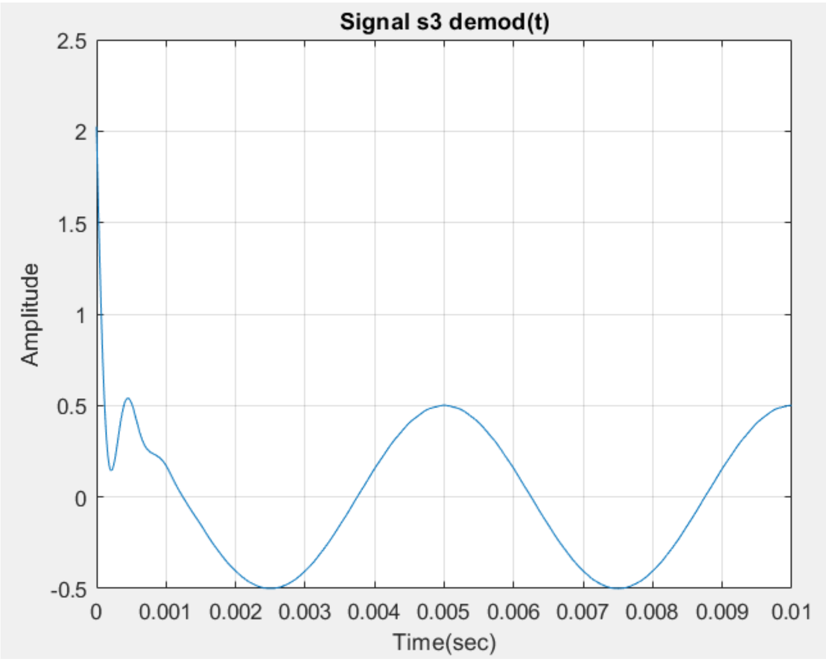
Lower side band power = 0.01562 + 0.01562 = 0.03124 Watts(Sum of powers at ±1800Hz)
Upper side band power = 0.01562 + 0.01562 = 0.03124 Watts(Sum of powers at

$\pm$2200Hz)
Carrier power = 0.25 + 0.25 = 0.5 Watts(Sum of powers at $\pm$2000Hz)

2.5 Modulation index, Bandwidth and Total Power of the Modulated Signal

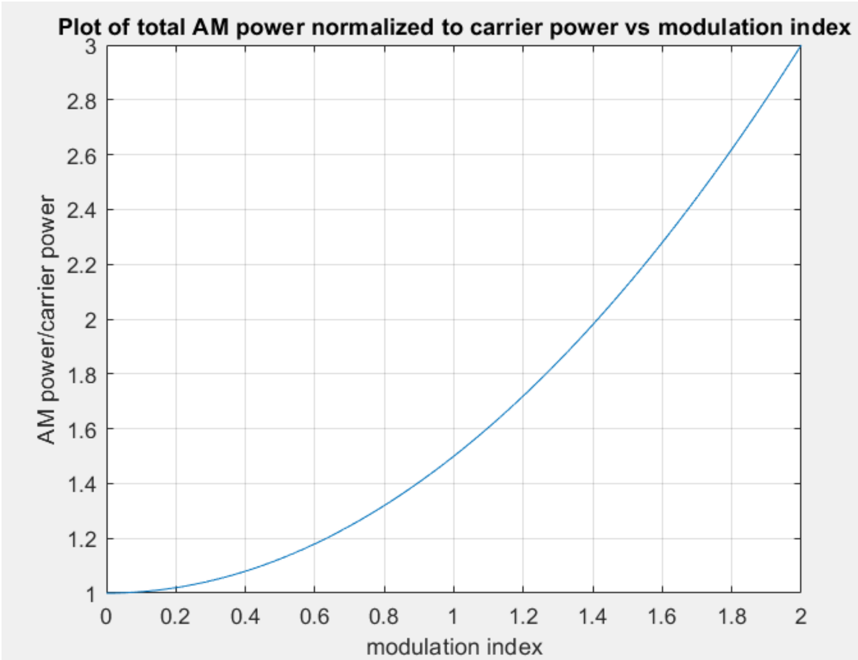
Theoretically modulation index of AM signal(m) = Am/Ac =0.5/1 =0.5 From plot,
m = (Amax *Amin)/(Amax+Amin)
=> m =0.475
Theoretically bandwidth = 2*fm(Here fm =200)
=> bandwidth = 400Hz
From plots, we can again infer, Bandwidth = 2200-1800 = 400Hz.
From the power spectrum we can say, Total power = 0.5+0.03124+0.03124 = 0.5623 Watts.
Again theoretically, total power = ((1*1)/2+((1*1)/2*(0.5*0.5)/2)
=> Total power = 0.5625 Watts.
therefore both theoretically and observed values are verified.

2.6 Plotting the demodulated output of the Amplitude modulated signal



After demodulation we got back the original message signal s1(t).

2.7 Plotting the graph between the total AM power normalized to carrier power and modulation index



Pm = Pc(1+(m*m)/2) is used to obtain the required exponential plot.

2.8 Code

```
close all; clc;

fs = 100000;
t = 0:1/fs:10-1/fs;

s1 = 0.5*cos(2*pi*200*t);
s2 = 1*cos(2*pi*2000*t);

s3 = ammod(s1,2000,fs,0,1);
s3_demod = amdemod(s3,2000,fs,0,1);

s3_fts =fftshift((fft(s3)));
N = length(s3_fts);
freq = -fs/2: fs/length(s3_fts): fs/2-fs/length(s3_fts);
Gn=(abs(s3_fts/N).^2);

m = 0:1/fs:2;
norm = (1+m.^2/2);
%% plot of Amplitude modulated signal, s3(t)
figure
plot(t,s3)
title('Signal s3(t)')
xlabel('Time(sec)')
ylabel('Amplitude')
xlim([0 0.01])
grid on
%% Plot of Amplitude spectrum of the Amplitude modulated
    signal signal, s3(t)
```

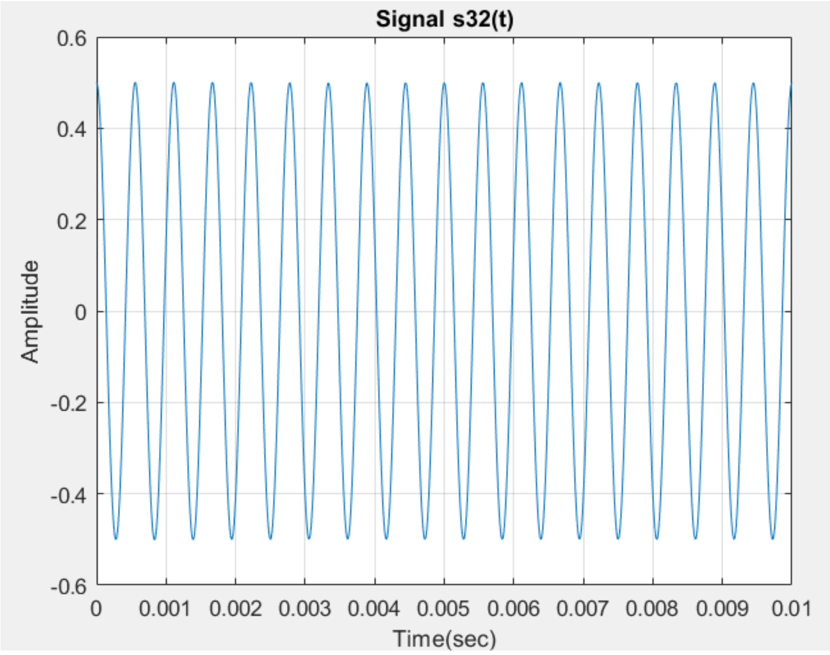
```
figure
plot(freq,abs(s3_fts/N))
xlabel('Frequency(Hz)')
ylabel('s3(t)')
title ('Amplitude spectrum of the DSB-SC signal')
xlim([-5000 5000])
grid on
%% Plot of power spectrum of the Amplitude modulated signal,
    s3(t)
figure
plot(freq,Gn)
xlabel('Frequency(Hz)')
ylabel('s3(t)')
title ('Power spectrum of the DSB-SC signal')
xlim([-5000 5000])
grid on
%% plot of demodulated signal, s3_demod(t)
figure
plot(t,s3_demod)
title('Signal s3 demod(t)')
xlabel('Time(sec)')
ylabel('Amplitude')
xlim([0 0.01])
grid on
%% Plotting the graph between the total AM power normalized
    to carrier power and modulation index
figure
plot (m,norm);
xlabel('modulation index');
ylabel('AM power/carrier power');
title ('Plot of total AM power normalized to carrier power vs
    modulation index');
grid on
```

3 QUESTION 3

3. Modulation & demodulation of Single sideband with suppressed carrier (SSB-SC) signal using MATLAB
    a) Using $S_1(t)$ as the message signal and $S_2(t)$ as the carrier signal, generate and plot the SSB-SC signal, $S_{32}(t)$.
    b) Plot the power spectrum of the SSB-SC signal, $S_{32}(t)$.
    c) Using (b), find the sideband power of the modulated signal, $S_{32}(t)$.
    d) Calculate the bandwidth and total power of the modulated signal, $S_{32}(t)$. Display all these values calculated above.
    e) Demodulate the SSB-SC signal, $S_{32}(t)$ and plot it.
    f) Consider transmission of modulated SSB-SC signal, $S_{32}(t)$ over a noisy channel with AWGN noise and then demodulate it assuming SNR=15dB. Plot and compare the demodulated signal with message signal, $S_1(t)$.

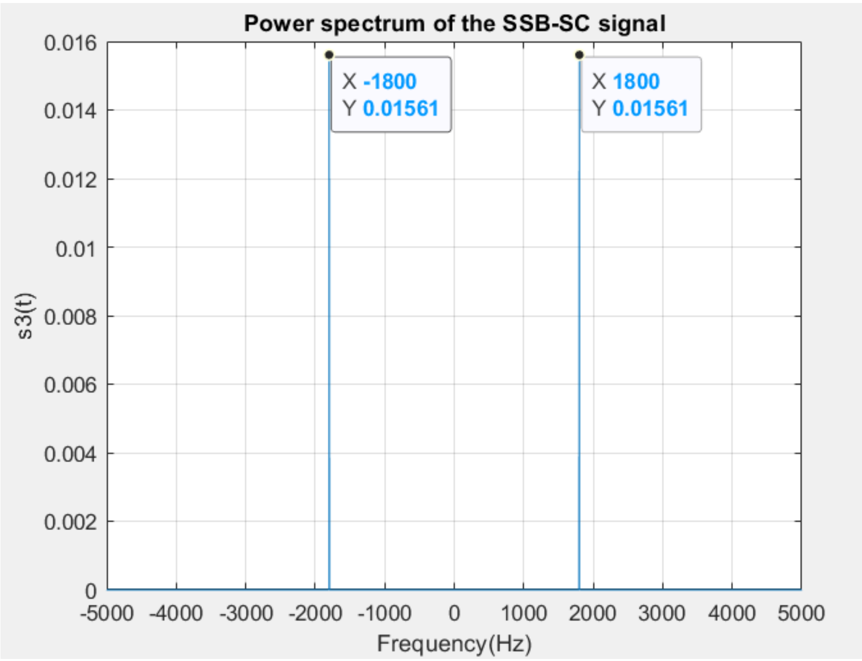
For all the plots a Sampling frequency of 100KHz is used

3.1 Plotting the SSB-SC signal, s32(t)



This plot shows the SSB-SC signal generated from the given message and carrier signals.

3.2 Plotting the Power Spectrum of SSB-SC signal, s32(t)



The power spectrum shows peaks at $\pm$1800Hz.
Both have the same amplitude, 0.06243 Watts.
As this is SSB signal, it will have only one frequency term and thats why we see peak at only one value.

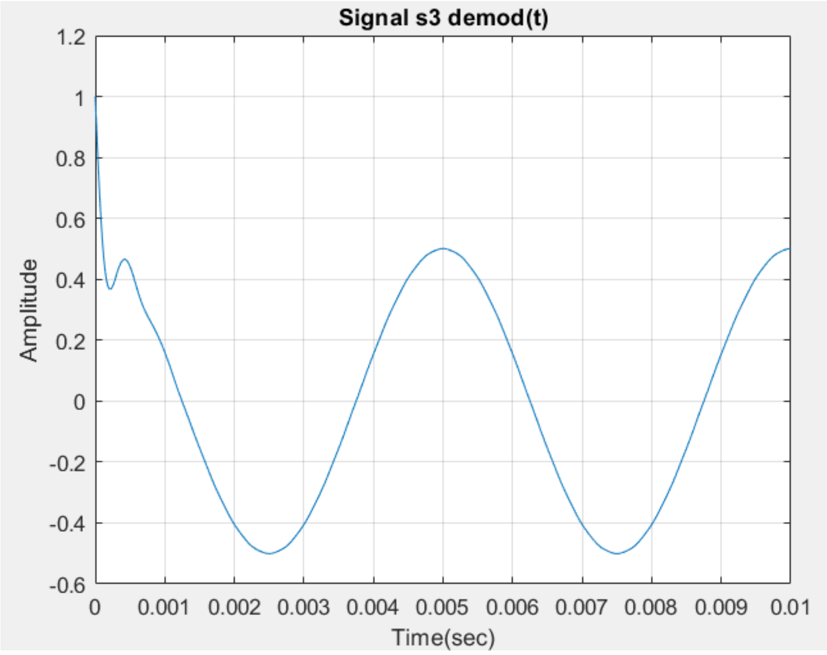
3.3 Side band Power of the modulated signal

Side band power = 0.01561 + 0.01561 = 0.03122 Watts = Total Power

3.4 Bandwidth and Total Power of the Modulated signal

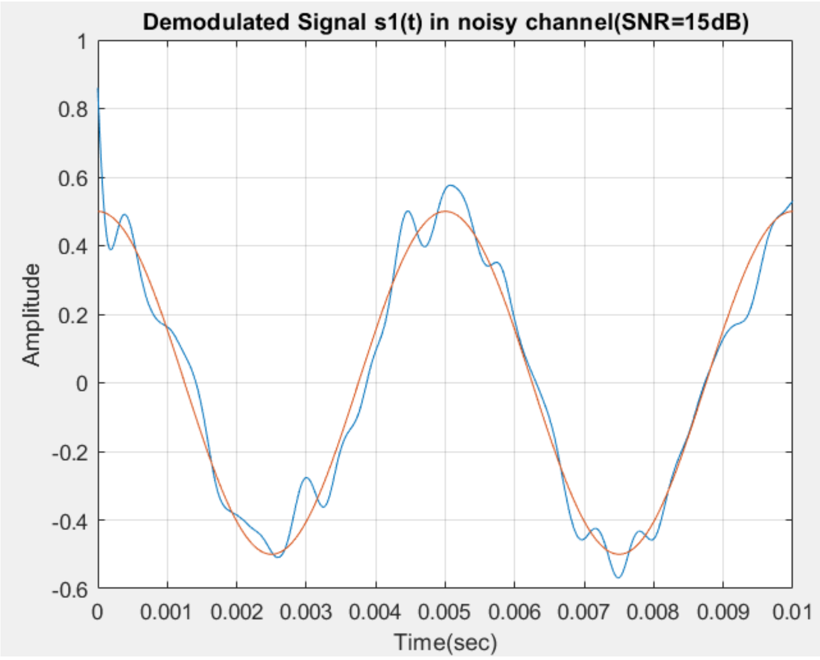
Bandwidth = fm = 200Hz
Theoretically, Total power = ((Am/2)*(Am/2))*((Ac/2)*(Ac/2))
For us, Am = 0.5, Ac = 1
=> Total power = 0.03125 Watts
Therefore again we have verified theoretically and practically

3.5 Plotting the demodulated SSB-SC signal



Demodulated signal looks same like message signal s1(t).

3.6 Plotting the demodulated SSB-SC signal over noisy channel at SNR=15



Demodulated signal has noise. But due to greater SNR, it didn't have considerable impact on message signal.

3.7 Code

```
close all; clc;

fs = 100000;
t = 0:1/fs:10;

s1 = 0.5*cos(2*pi*200*t);
s2 = 1*cos(2*pi*2000*t);

s32 = ssbmod(s1,2000,fs,0);
s32_demod = ssbdemod(s32,2000,fs,0);

s32_fts =fftshift((fft(s32)));
N = length(s32_fts);
freq = -fs/2: fs/length(s32_fts): fs/2-fs/length(s32_fts);
Gn=(abs(s32_fts/N).^2);

display(var(s32))

noise = awgn(s32,15);
demod_noise = ssbdemod(noise,2000,fs,0);
%% plot of SSB-SC signal, s31(t)
figure
plot(t,s32)
title('Signal s32(t)')
xlabel('Time(sec)')
ylabel('Amplitude')
xlim([0 0.01])
grid on
%% Plot of power spectrum of the Amplitude modulated signal, s3(t)
figure
plot(freq,Gn)
xlabel('Frequency(Hz)')
ylabel('s3(t)')
title ('Power spectrum of the SSB-SC signal')
xlim([-5000 5000])
grid on
%% plot of demodulated signal, s3_demod(t)
figure
plot(t,s32_demod)
title('Signal s3 demod(t)')
xlabel('Time(sec)')
ylabel('Amplitude')
xlim([0 0.01])
grid on
%% plot of demodulated DSB-SC signal over noisy channel at SNR=15
figure
plot(t,demod_noise)
title('Demodulated Signal s1(t) in noisy channel(SNR=15dB)')
xlabel('Time(sec)')
ylabel('Amplitude')
xlim([0 0.01])
grid on
```

```
hold on
plot(t,s1)
hold off
```