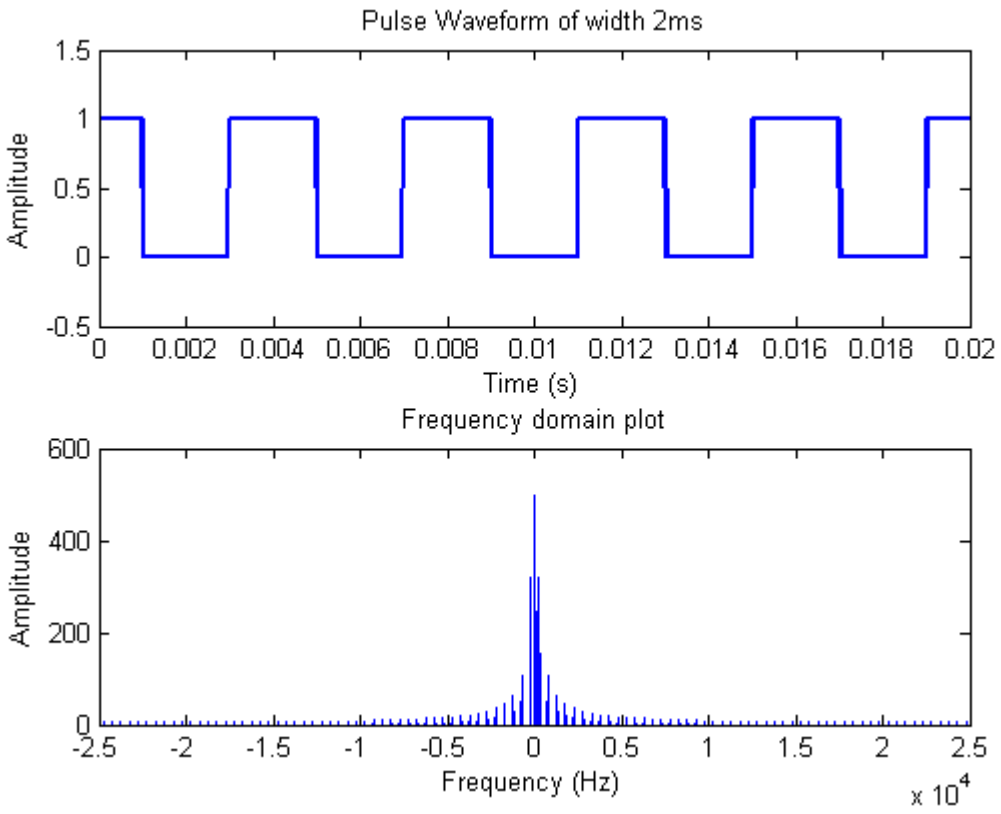
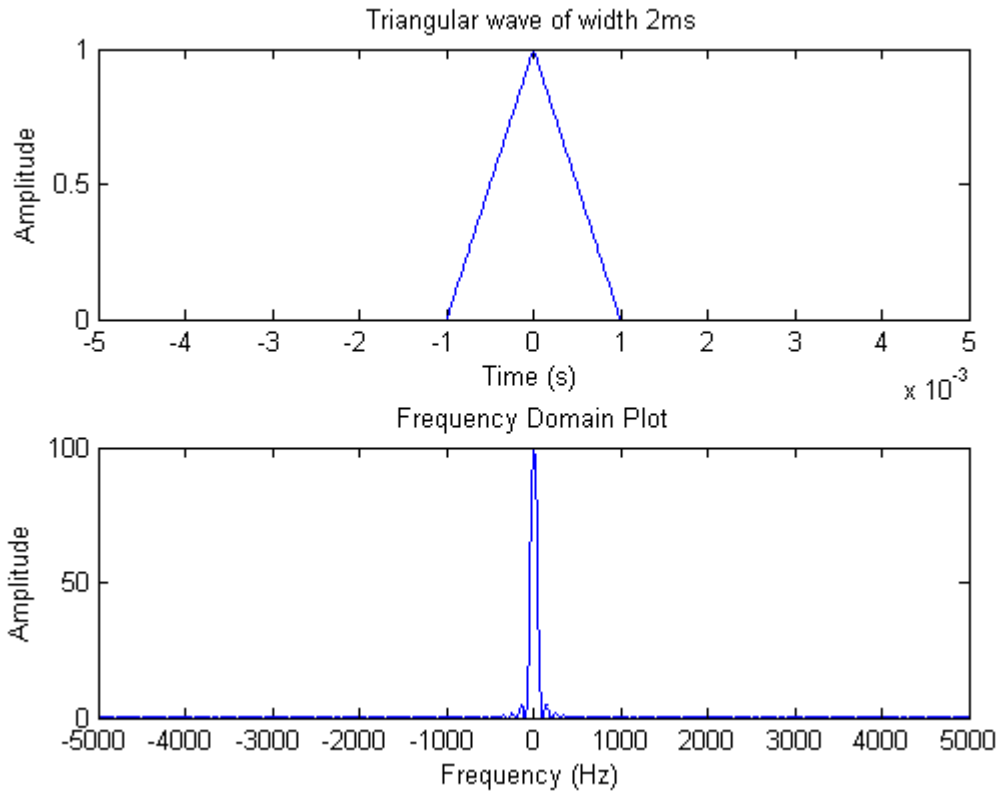
Assignment-1

ANALOG COMMUNICATION LAB

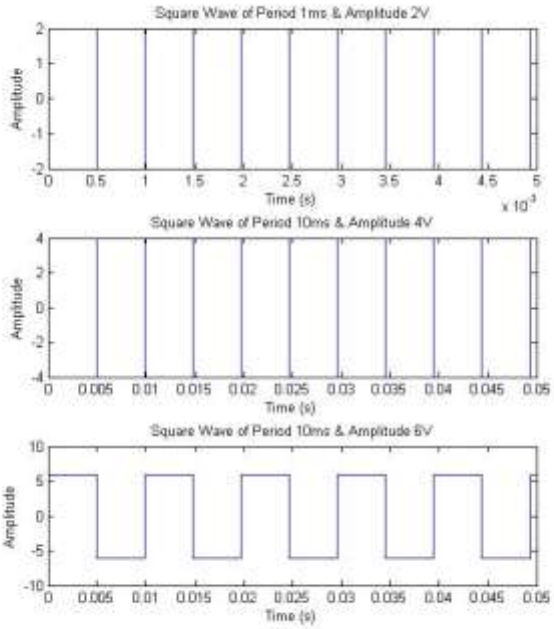
```
% 1. Pulse waveform of width 2ms
% ------------------------------
%
% -by Subhajit Sahu, 110EC0181
%

clc;
clear all;
close all;

t = linspace(0,0.02,1000);
d = 0 : 0.02/5 : 0.02;
y = pulstran(t,d,'rectpuls',0.002);

subplot(2,1,1);
plot(t,y, 'LineWidth', 2);
title('Pulse Waveform of width 2ms');
xlabel('Time (s)');
ylabel('Amplitude');
ylim([-0.5 1.5]);
fs = linspace(-25000,25000,1000);
y1 = abs(fftshift(fft(y)));
subplot(2,1,2);
plot(fs,y1);
title('Frequency domain plot');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
```

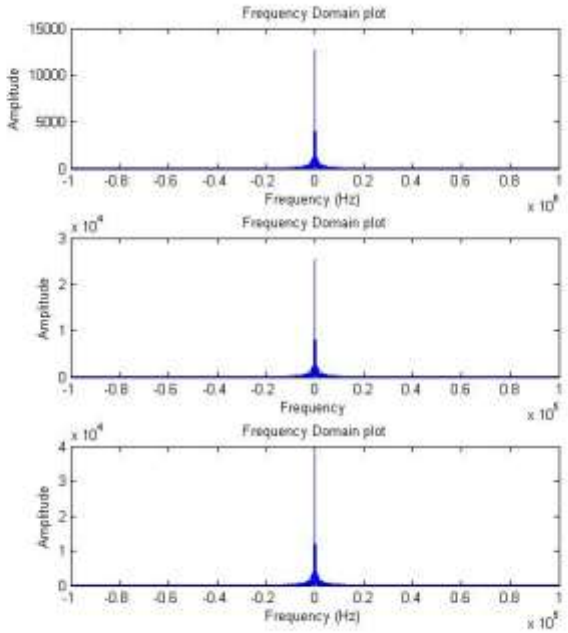


```
% 2. Triangular Wave of width 2ms
% ------------------------------
%
% -by Subhajit Sahu, 110EC0181
%

clc;
clear all;
close all;

t = linspace(-0.005,0.005,1000);
w = 0.002;
y = tripuls(t,w);
subplot(2,1,1);
plot(t,y);
title('Triangular wave of width 2ms');
xlabel('Time (s)');
ylabel('Amplitude');

fs = linspace(-5000,5000,1000);
y1 = abs(fftshift(fft(y)));
subplot(2,1,2);
plot(fs,y1)
title('Frequency Domain Plot');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
```

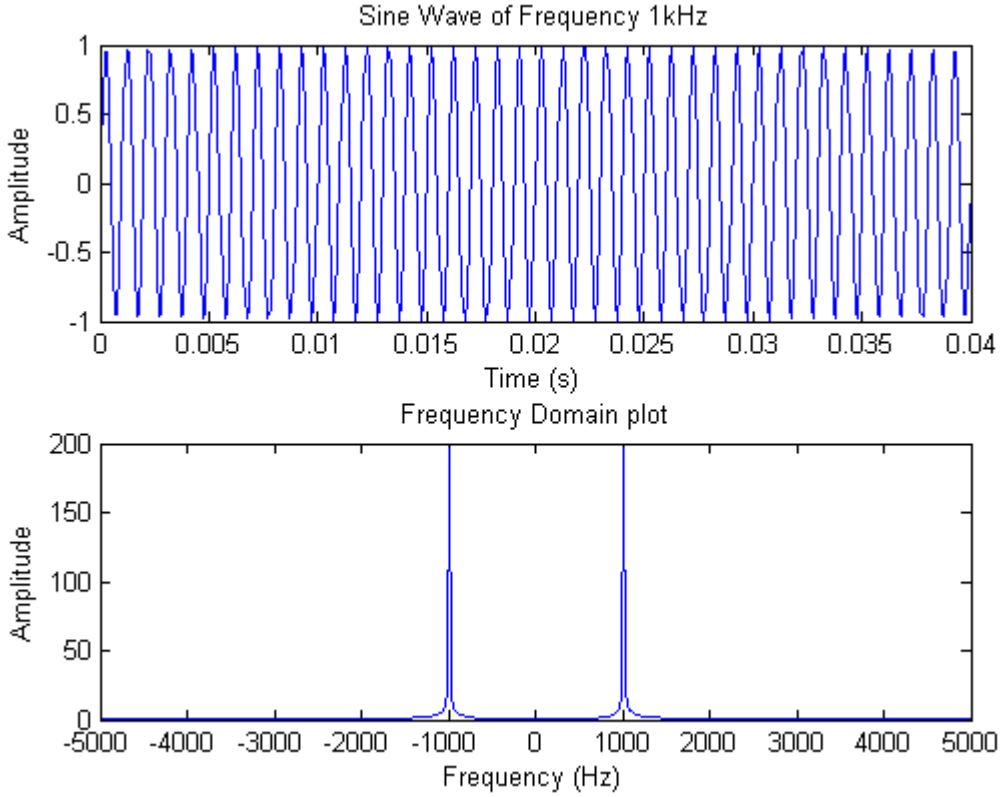


```
% 3. Square Wave of different amplitude and period
% ------------------------------------------------
%
% -by Subhajit Sahu, 110EC0181
%

clc;
clear all;
close all;

t = linspace(0,0.005,10000);
x = 2*square(t/(0.000025*2*pi));
subplot(3,2,1);
plot(t,x)
title('Square Wave of Period 1ms & Amplitude 2V');
xlabel('Time (s)');
ylabel('Amplitude');

fs = linspace(-1000000,1000000,10000);
y1 = abs(fftshift(fft(x)));
subplot(3,2,2);
plot(fs,y1);
title('Frequency Domain plot');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

t = linspace(0,0.05,10000);
x = 4*square(t/(0.00025*2*pi));
subplot(3,2,3);
plot(t,x)
title('Square Wave of Period 10ms & Amplitude 4V');
xlabel('Time (s)');
ylabel('Amplitude');

fs = linspace(-100000,100000,10000);
y1 = abs(fftshift(fft(x)));
subplot(3,2,4);
plot(fs,y1);
title('Frequency Domain plot');
xlabel('Frequency');
ylabel('Amplitude');

t = linspace(0,0.05,10000);
x = 6*square(t/(0.00025*2*pi));
subplot(3,2,5);
plot(t,x)
title('Square Wave of Period 10ms & Amplitude 6V');
xlabel('Time (s)');
ylabel('Amplitude');

fs = linspace(-100000,100000,10000);
y1 = abs(fftshift(fft(x)));
subplot(3,2,6);
plot(fs,y1);
title('Frequency Domain plot');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
```






```
% 4. Sine wave of frequency 1kHz and sampling frequency 10kHz
% ------------------------------------------------------------
%
% -by Subhajit Sahu, 110EC0181
%

clc;
clear all;
close all;

t = linspace(0,0.04,400);
x = sin(2*pi*t*(1000));
subplot(2,1,1);
plot(t,x);
title('Sine Wave of Frequency 1kHz');
xlabel('Time (s)');
ylabel('Amplitude');

fs = linspace(-5000,5000,400);
y1 = abs(fftshift(fft(x)));
subplot(2,1,2);
plot(fs,y1);
title('Frequency Domain plot');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
```


Sine Wave of Frequency 1kHz
Amplitude
Time (s)
Frequency Domain plot
Amplitude
Frequency (Hz)

Assignment – 2

CONTENTS

By Subhajit Sahu

110EC0181

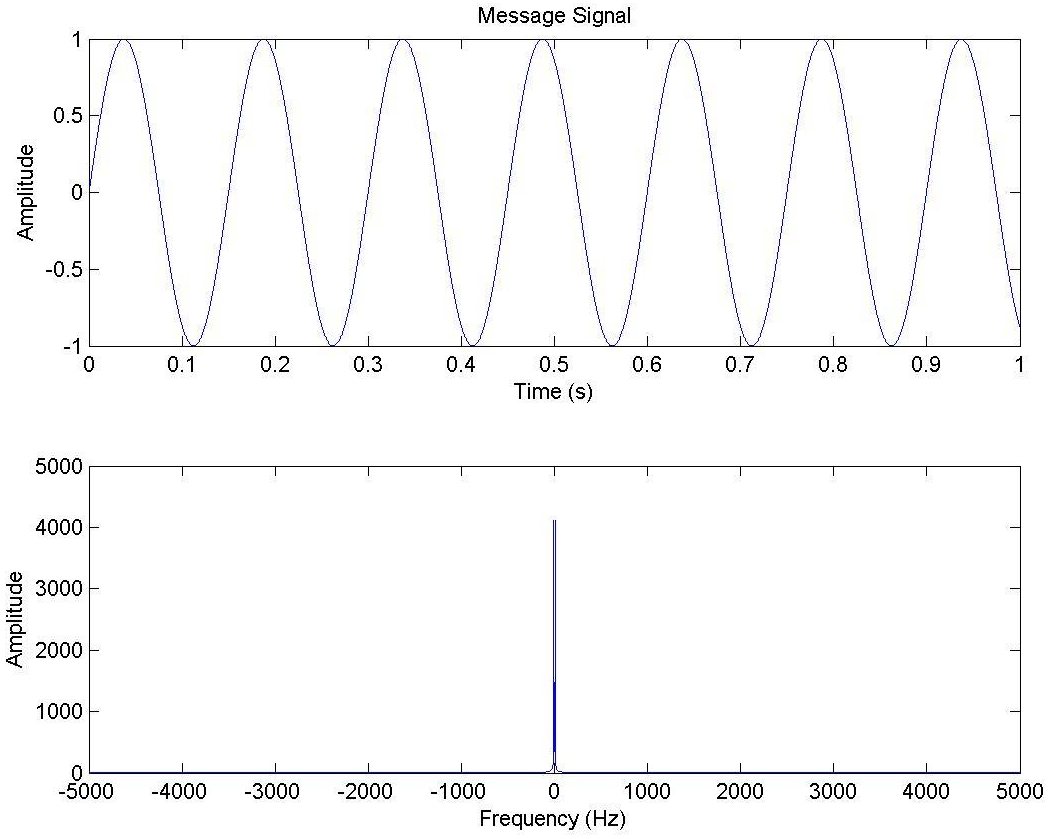
Under Prof. Shrishail Hiremath

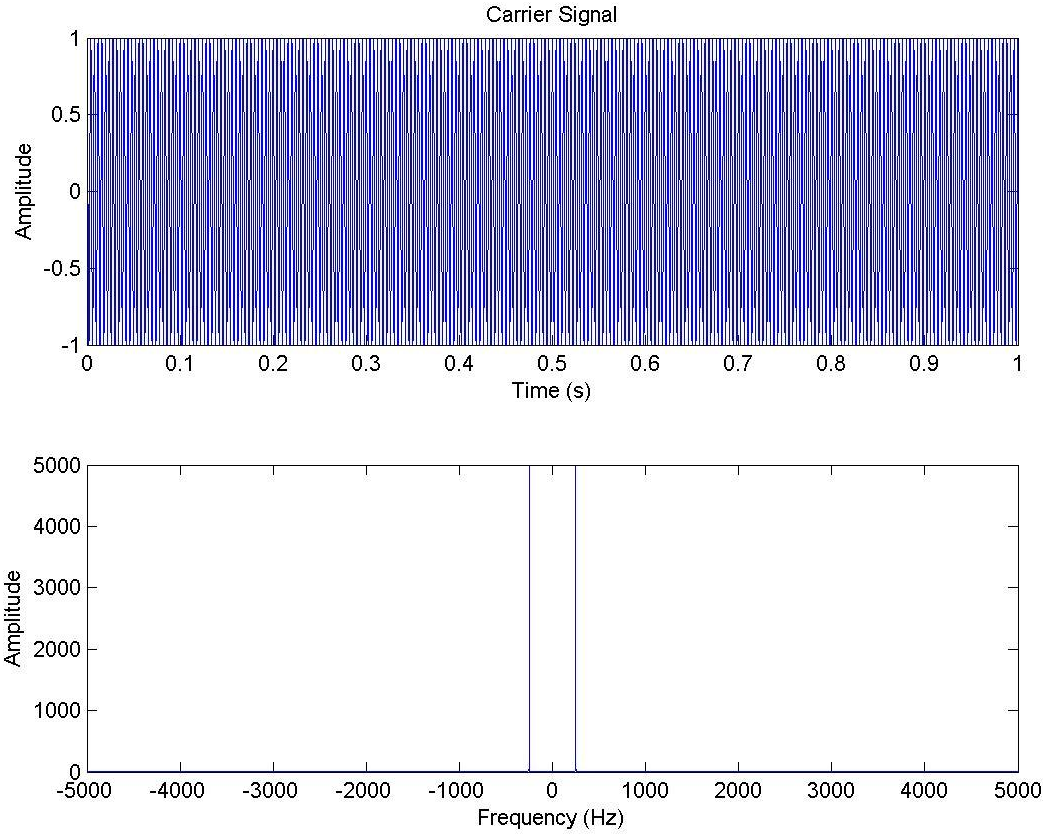
1. Main Program

```
% Assignment - 2
% --------------
%
% Determine the spectra of the message signal m(t) and amplitude-modulated
% signal s(t) (AM with carrier + both side bands) and plot them. Plot also
% the waveform of the message signal. Carrier  signal is cos (2*pi *250*t)
% and modulation index m = 0.33, .5, 0.85,1. The message signal is a
% sinusoidal signal of 6.67 Hz.
%

clc;
clear all;
close all;

% Generate the Message and Carrier Signals
[m_t, t] = sig_sin(1, 2*pi*6.67, 0, 0, 1, 10000);
c_t = sig_sin(1, 2*pi*250, pi/2, 0, 1, 10000);
tLen = length(t);
m_f = abs(fftshift(fft(m_t)));
c_f = abs(fftshift(fft(c_t)));
f = linspace(-10000/2, 10000/2, tLen);

% List of Modulation indexes for which to plot
m = [0.33, 0.5, 0.85, 1];
mLen = length(m);

% Get the DSB-FC Modulated signals
s_t = zeros(mLen, tLen);
s_f = zeros(mLen, tLen);
for i = 1 : mLen
    s_t(i, :) = Mod_dsb_fc(m_t, 1, c_t, m(1, i));
    s_f(i, :) = abs(fftshift(fft(s_t(i, :))));
end

% Plot all figures
h = figure;
name = 'Message Signal';
subplot(2,1,1); plot(t, m_t);
title(name);
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2); plot(f, m_f);
xlabel('Frequency (Hz)');
ylabel('Amplitude');
saveas(h, [name '.jpg']);

h = figure;
name = 'Carrier Signal';
subplot(2,1,1); plot(t, c_t);
title(name);
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2); plot(f, c_f);
xlabel('Frequency (Hz)');
ylabel('Amplitude');
```

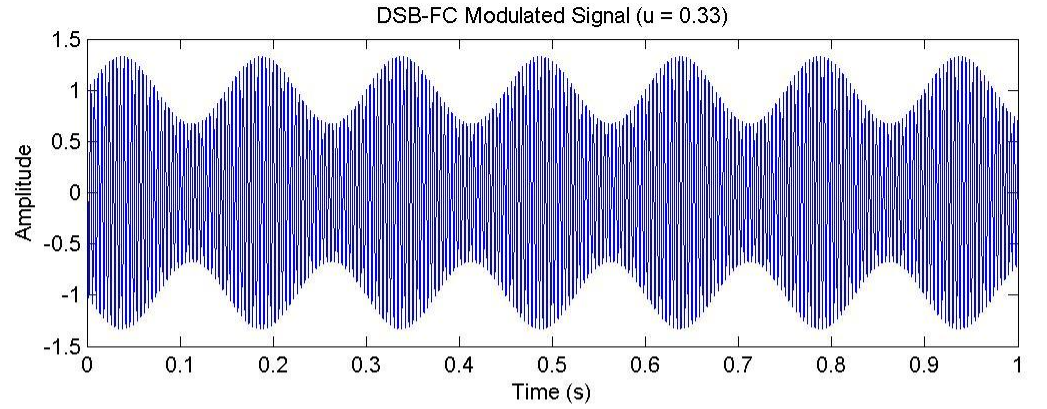
```
saveas(h, [name '.jpg']);

for i = 1 : mLen
    h = figure;
    name = sprintf('DSB-FC Modulated Signal (u = %1.2f)', m(1, i));
    subplot(2,1,1); plot(t, s_t(i, :));
    title(name);
    xlabel('Time (s)');
    ylabel('Amplitude');
    subplot(2,1,2); plot(f, s_f(i, :));
    xlabel('Frequency (Hz)');
    ylabel('Amplitude');
    saveas(h, [name '.jpg']);
end
```

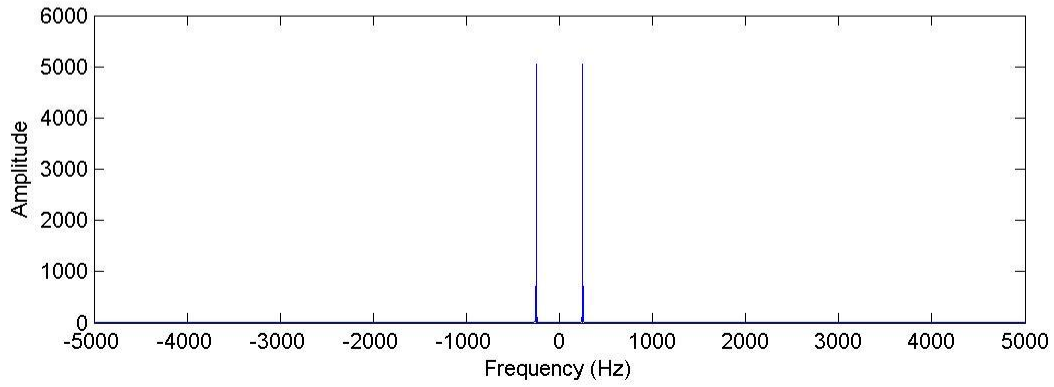
2. Outputs

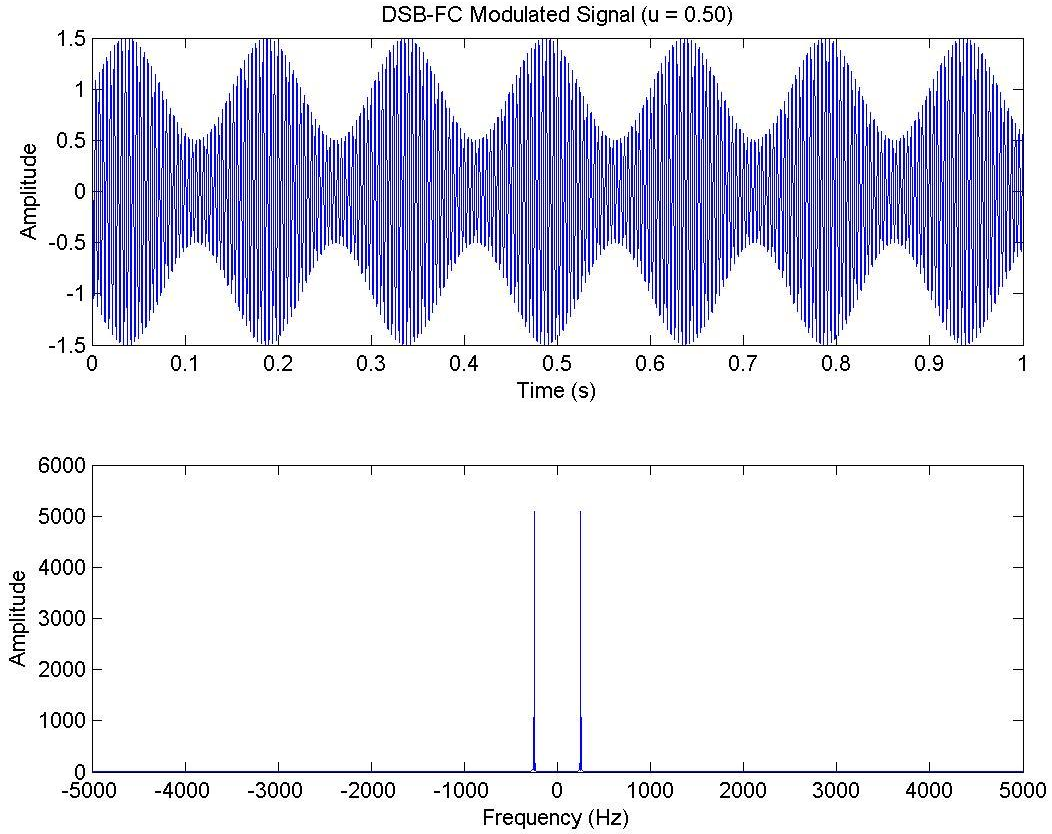


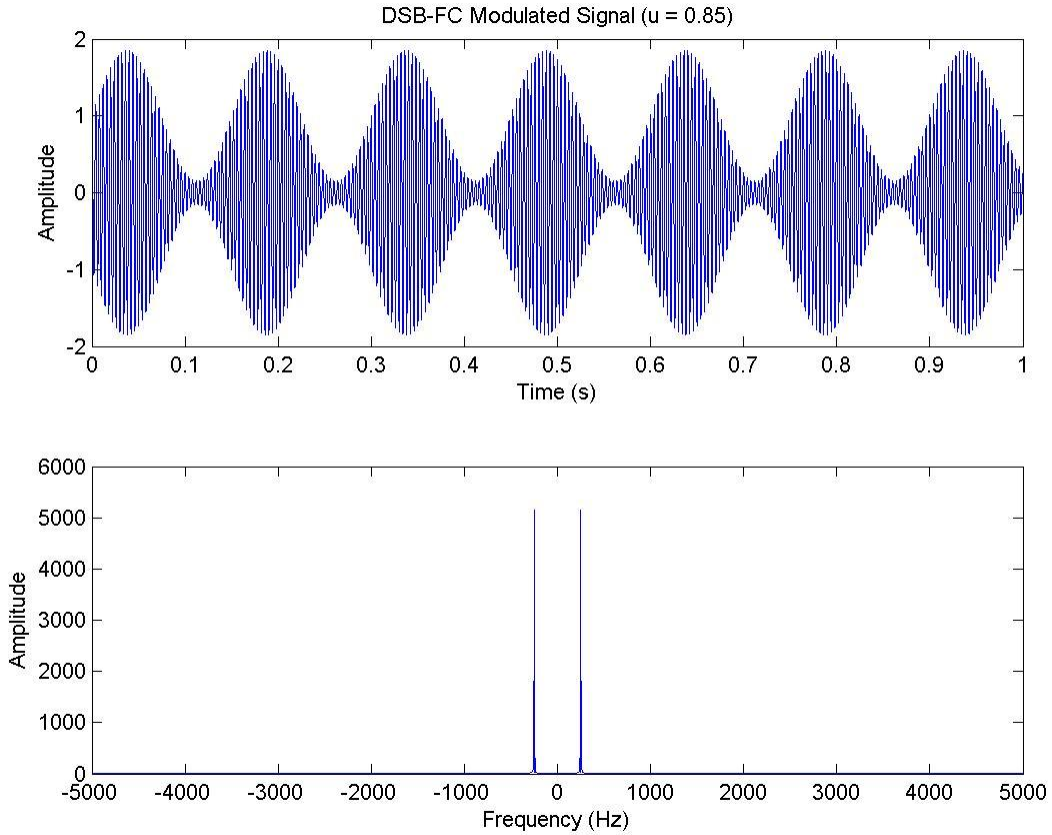

Carrier Signal
Amplitude
Time (s)
1
0.5
0
-0.5
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

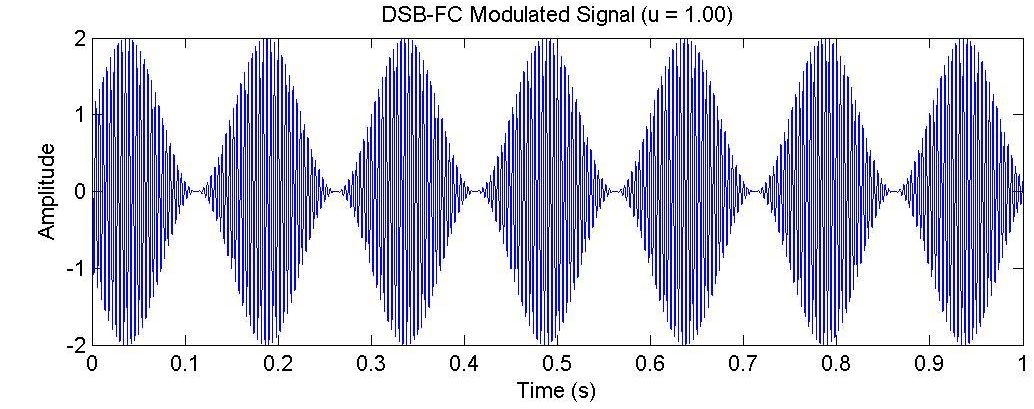
Amplitude
Frequency (Hz)
5000
4000
3000
2000
1000
0
-5000
-4000
-3000
-2000
-1000
0
1000
2000
3000
4000
5000

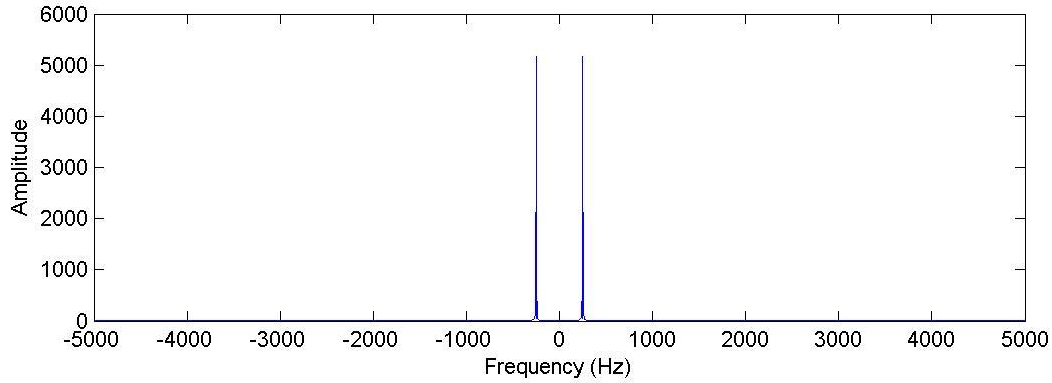

DSB-FC Modulated Signal (u = 0.33)
Amplitude
Time (s)
1.5
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Amplitude
Frequency (Hz)
6000
5000
4000
3000
2000
1000
0
-5000
-4000
-3000
-2000
-1000
0
1000
2000
3000
4000
5000


DSB-FC Modulated Signal (u = 0.50)
Amplitude
Time (s)
Amplitude
Frequency (Hz)


DSB-FC Modulated Signal (u = 0.85)
Amplitude
Time (s)
Amplitude
Frequency (Hz)





3. Function: Mod_dsb_fc()

```
function y = Mod_dsb_fc(x_m, A_m, x_c, u)
% x_m  = Input Message signal
% A_m  = Amplitude of Message Signal
% x_c  = Carrier Signal
% u    = Modulation Index
% y = Acos(wct) + Aum'(t) cos(wct)

y = x_c + u * (x_c .* (x_m / A_m));
end
```

4. Function: sig_sin()

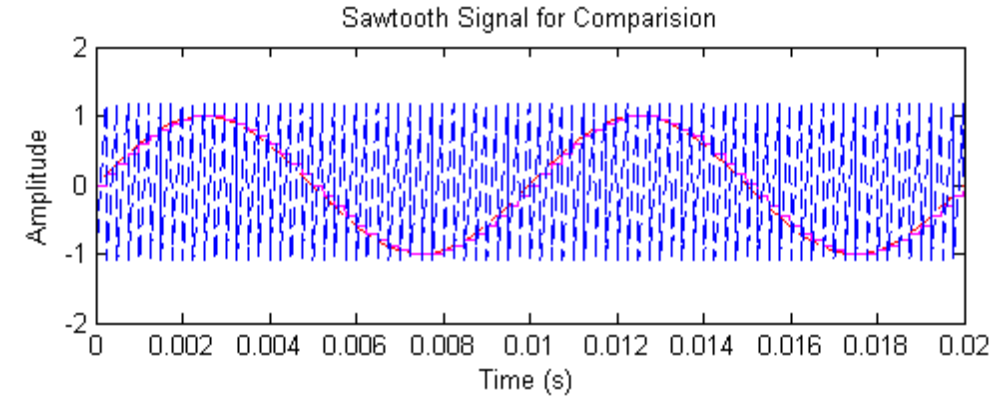
```
function [x, t] = sig_sin(A, b, c, tStart, tStop, Fs)
% x = Asin(bt+c)

Ts = sign(tStop - tStart) * (1/Fs);
t = tStart : Ts : tStop;
x = A * sin(b*t + c);
end
```

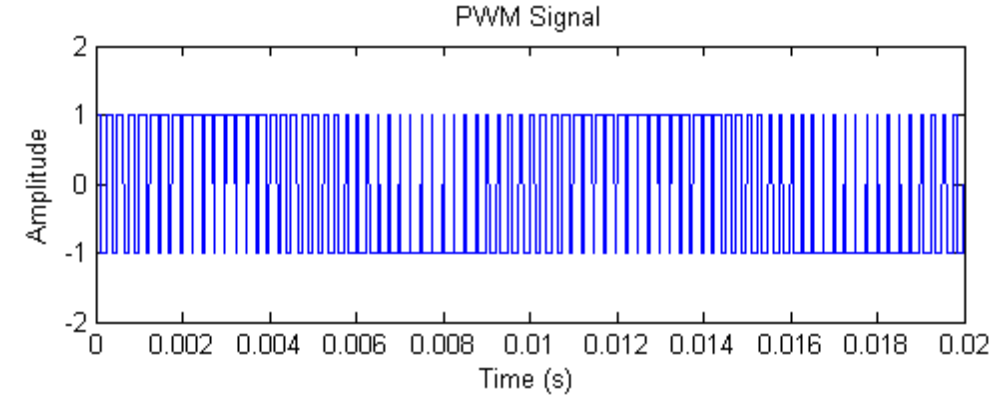
```
% Assignment - 5
% --------------
clc;
clear all;
close all;

% Details given in the question
f = 100;
vFs = 4000;

% Assumed values
Fs = 80000;
Tstart = 0;
Tstop = 0.02;
sAmp = 2.4;
sAdd = -1.1;
ppmWidth = 1;

% Generating time
vTs = 1 / vFs;
Ts = 1 / Fs;
t = Tstart : Ts : Tstop;
N = length(t);

% Generating the message signal
m_t = sin(2*pi*100*t);
subplot(2,1,1);
plot(t, m_t, '--r');
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');
hold on;

% Generating sample-hold signal (PAM)
oldTime = vTs;
oldMsg = 0;
M_t = m_t;
for i = 1 : N
    t0 = mod(t(1, i), vTs);
    if(t0 < oldTime)
        oldMsg = m_t(1, i);
    else
        M_t(1, i) = oldMsg;
    end
    oldTime = t0;
end
subplot(2,1,1);
plot(t, M_t, 'm');
title('Sample-hold message signal');
xlabel('Time (s)');
ylabel('Amplitude');

% Generating the sawtooth signal (for PWM)
s_t = sAdd + sAmp * (mod(t, vTs) / vTs);
subplot(2,1,1);
plot(t, s_t, '--b');
ylim([-2 2]);
title('Sawtooth Signal for Comparision');
xlabel('Time (s)');
ylabel('Amplitude');

% Generating the PWM signal
p_t = 2 * (M_t > s_t) - 1;
```

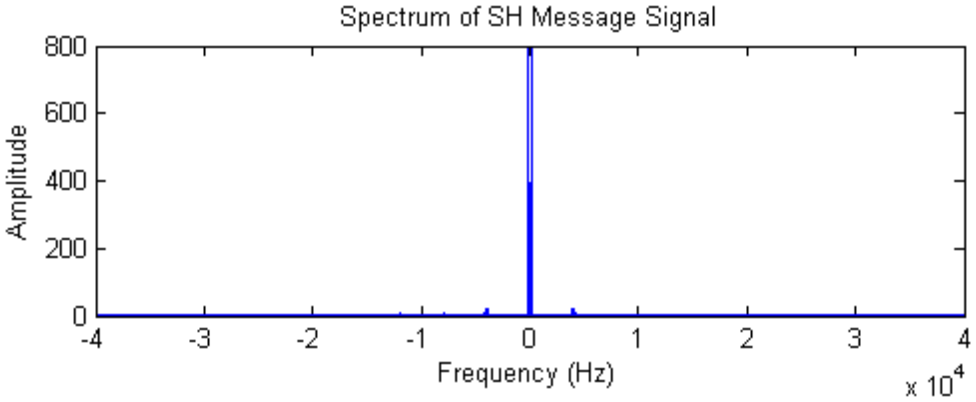
```
subplot(2,1,2);
plot(t, p_t, 'b', 'LineWidth', 1);
ylim([-2 2]);
title('PWM Signal');
xlabel('Time (s)');
ylabel('Amplitude');

% Plot Spectra
figure;
subplot(2,1,1);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(M_t))));
title('Spectrum of SH Message Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(p_t))));
title('Spectrum of PWM Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Low pass Filter the PWM Signal (PWM demodulation)
Fc = 150;
p_f = fft(p_t);
ClrStart = floor((2 * Fc / Fs) * N);
ClrStop = N - ClrStart;
p_f(1, ClrStart:ClrStop) = zeros(1, 1+ClrStop-ClrStart);
m0_t = ifft(p_f);
figure;
subplot(2, 1, 1)
plot(t, m0_t, 'b', 'LineWidth', 1);
ylim([-2 2]);
title('Demodulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(m0_t))));
title('Spectrum of Demodulated Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Generating the PPM signal
ppmAdd = 2*ones(1, ppmWidth);
pp_t = zeros(1, N)-1;
oldMsg = 0;
for i = 1 : N
    if(oldMsg > p_t(1, i))
        pp_t(1, i:(i+ppmWidth-1)) = pp_t(1, i:(i+ppmWidth-1)) + ppmAdd;
    end
    oldMsg = p_t(1, i);
end
figure;
subplot(2,1,1);
plot(t, p_t);
ylim([-2 2]);
title('PWM Signal');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(t, pp_t, 'r');
ylim([-2 2]);
title('PPM Signal');
xlabel('Time (s)');
ylabel('Amplitude');

% Plot Spectra
```

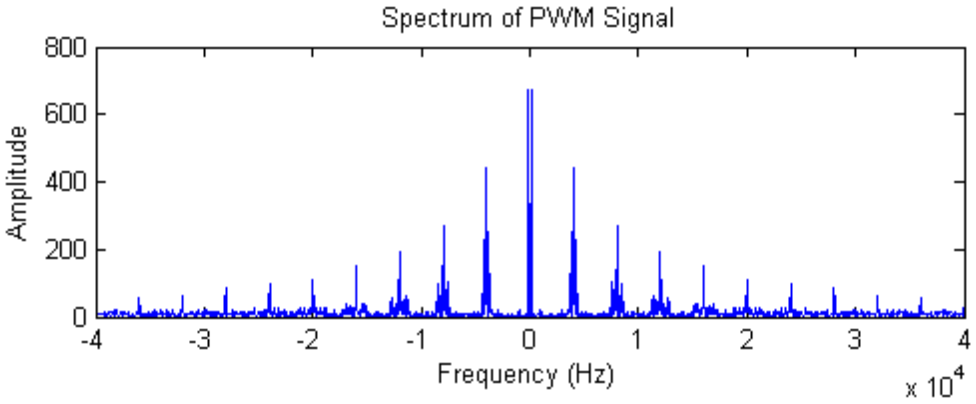
```
figure;
subplot(2,1,1);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(M_t))));
title('Spectrum of SH Message Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(pp_t))));
title('Spectrum of PPM Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% % PPM demodulation
% Fc = 150;
% p_f = fft(p_t);
% ClrStart = floor((2 * Fc / Fs) * N);
% ClrStop = N - ClrStart;
% p_f(1, ClrStart:ClrStop) = zeros(1, 1+ClrStop-ClrStart);
% m0_t = ifft(p_f);
% figure;
% subplot(2, 1, 1)
% plot(t, m0_t, 'b', 'LineWidth', 1);
% ylim([-2 2]);
% title('Demodulated Signal');
% xlabel('Time (s)');
% ylabel('Amplitude');
% subplot(2,1,2);
% plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(m0_t))));
% title('Spectrum of Demodulated Signal');
% xlabel('Frequency (Hz)');
% ylabel('Amplitude');
%
```

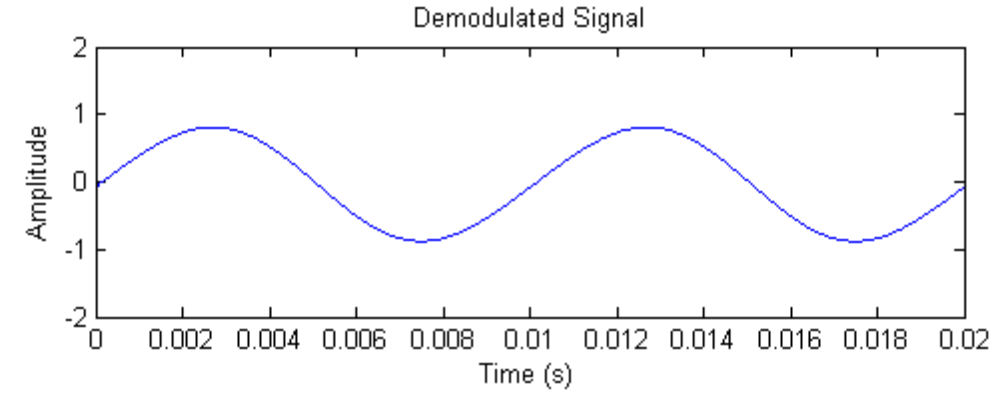
Warning: Imaginary parts of complex X and/or Y arguments ignored

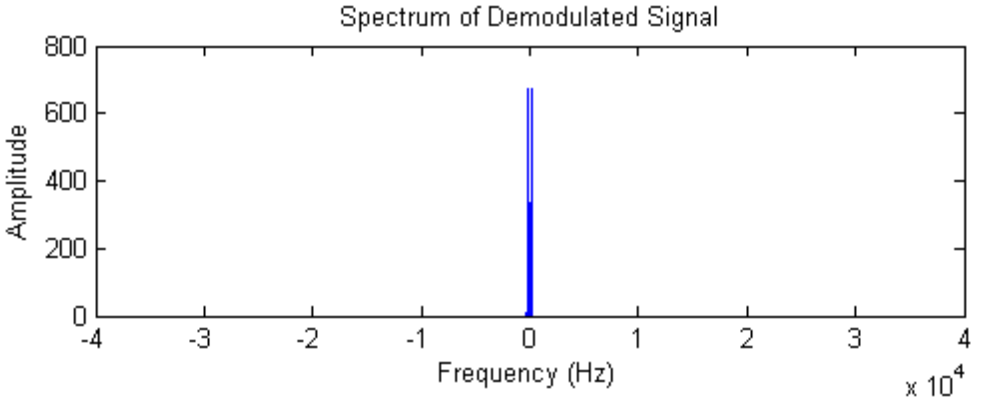

Sawtooth Signal for Comparision
Amplitude
Time (s)
2
1
0
-1
-2
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0.02

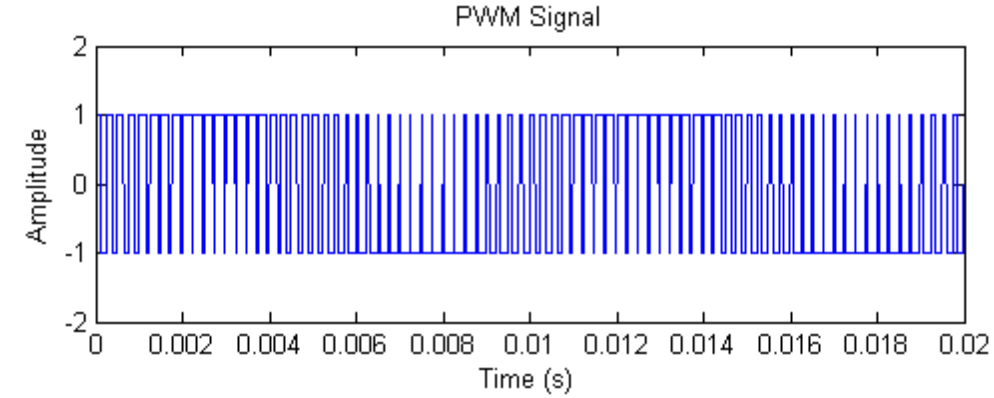

PWM Signal
Amplitude
Time (s)
2
1
0
-1
-2
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0.02

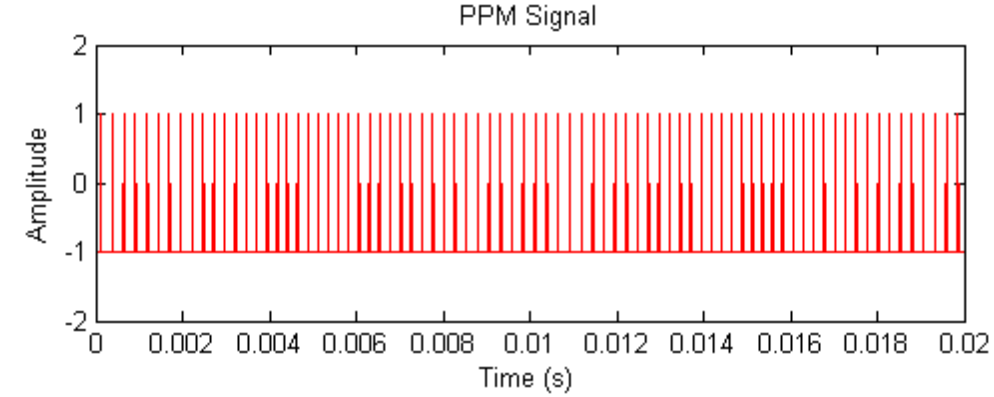

Spectrum of SH Message Signal
Amplitude
Frequency (Hz)
x 10^4
800
600
400
200
0
-4
-3
-2
-1
0
1
2
3
4

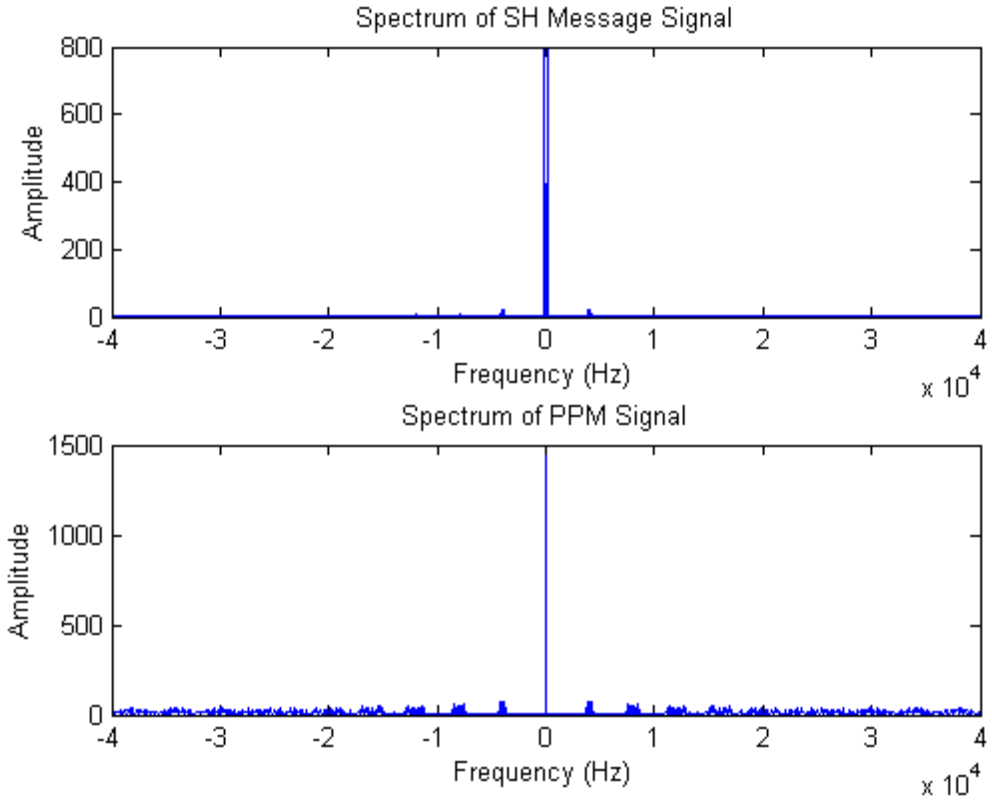

Spectrum of PWM Signal
Amplitude
Frequency (Hz)
x 10^4
800
600
400
200
0
-4
-3
-2
-1
0
1
2
3
4


Demodulated Signal
Amplitude
Time (s)
2
1
0
-1
-2
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0.02


Spectrum of Demodulated Signal
Amplitude
Frequency (Hz)
x 10^4
800
600
400
200
0
-4
-3
-2
-1
0
1
2
3
4


PWM Signal
Amplitude
Time (s)
2
1
0
-1
-2
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0.02


PPM Signal
Amplitude
Time (s)
2
1
0
-1
-2
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0.02



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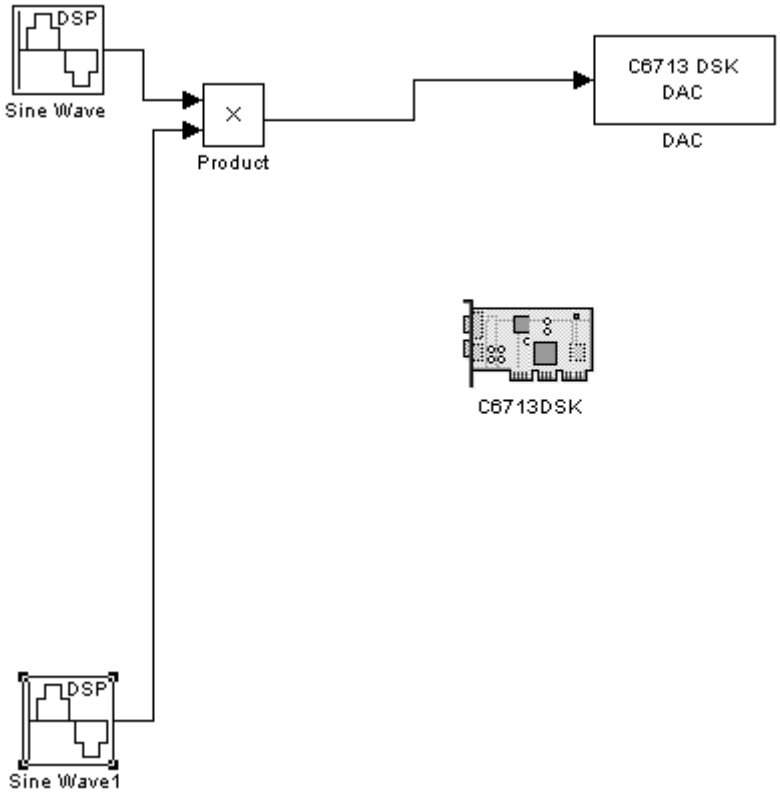
DSP PROCESSOR PROJECT

DSB – SC:

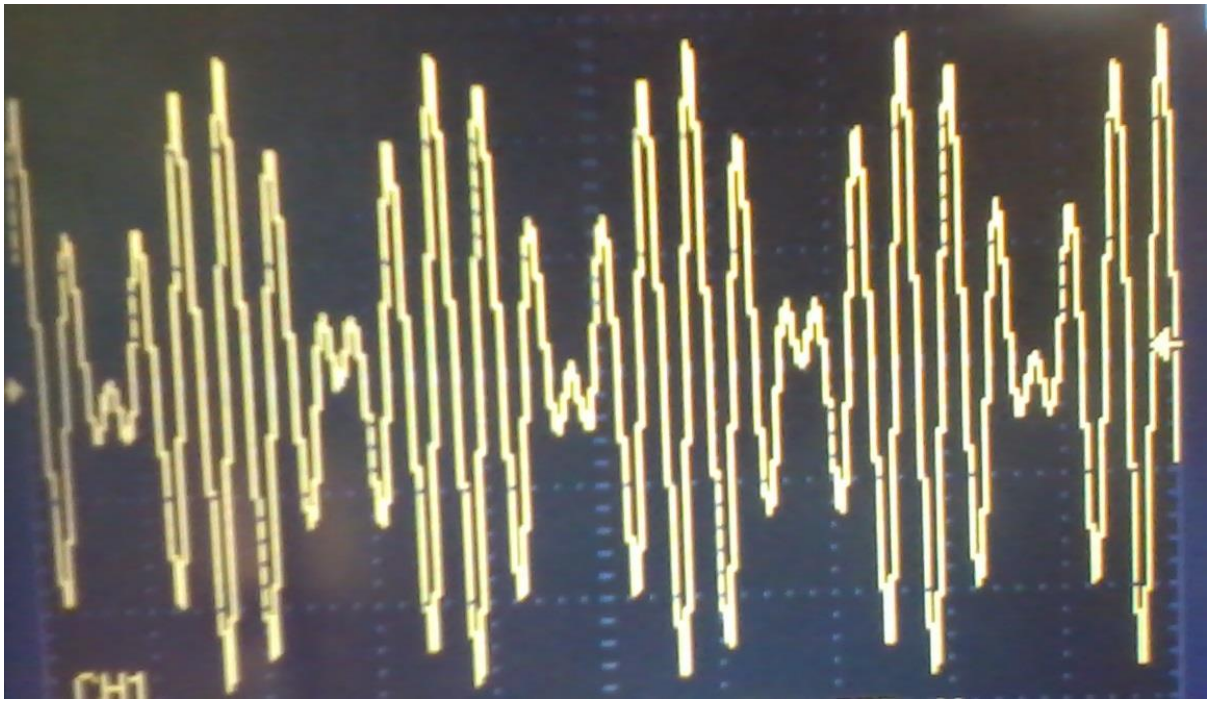
Modulation

Message: 100 Hz

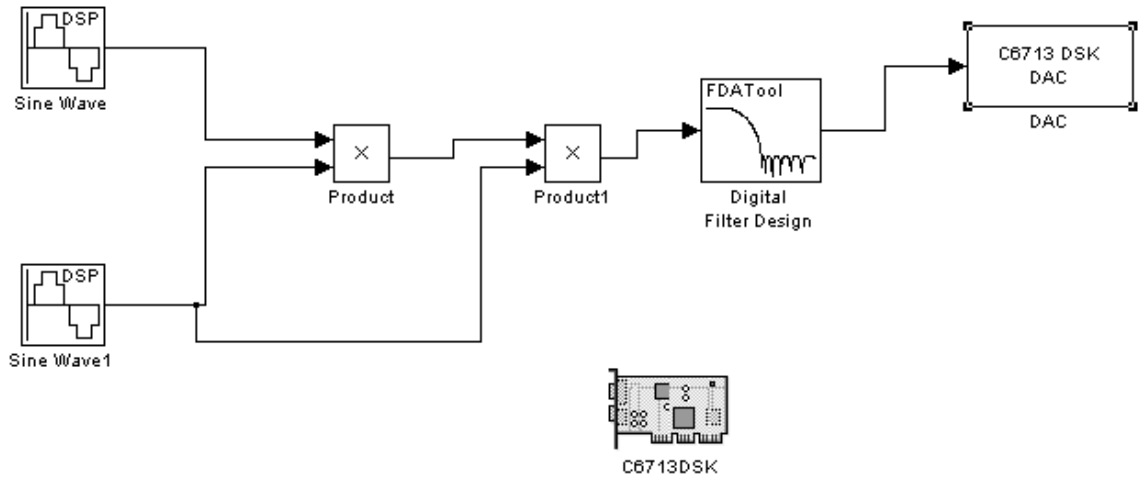
Carrier: 1 kHz



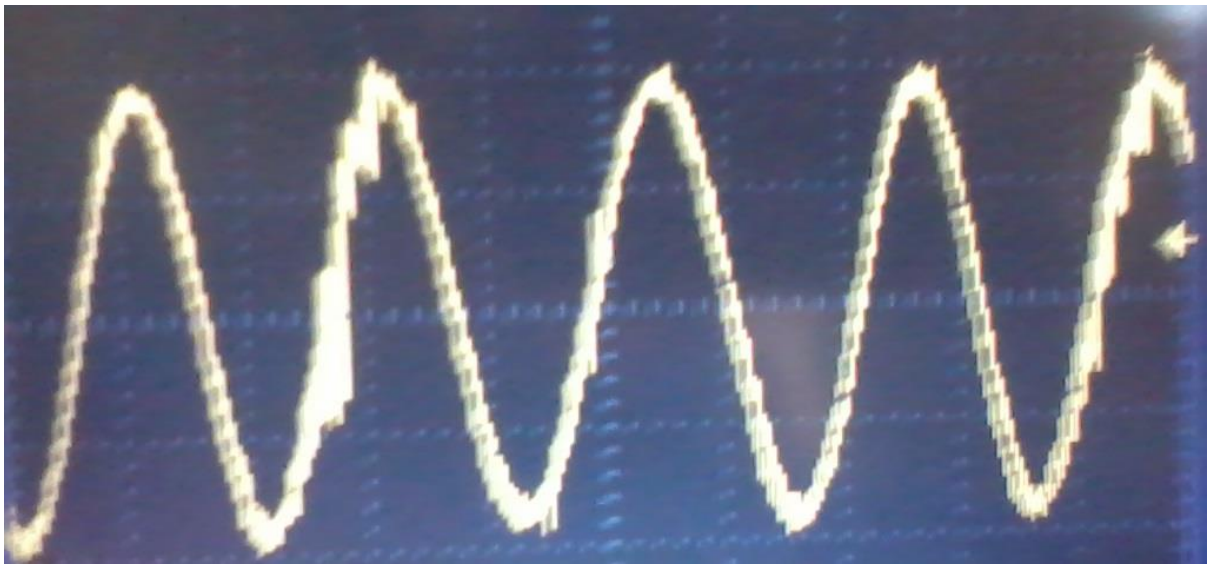
Signal



Demodulation



Demodulated wave

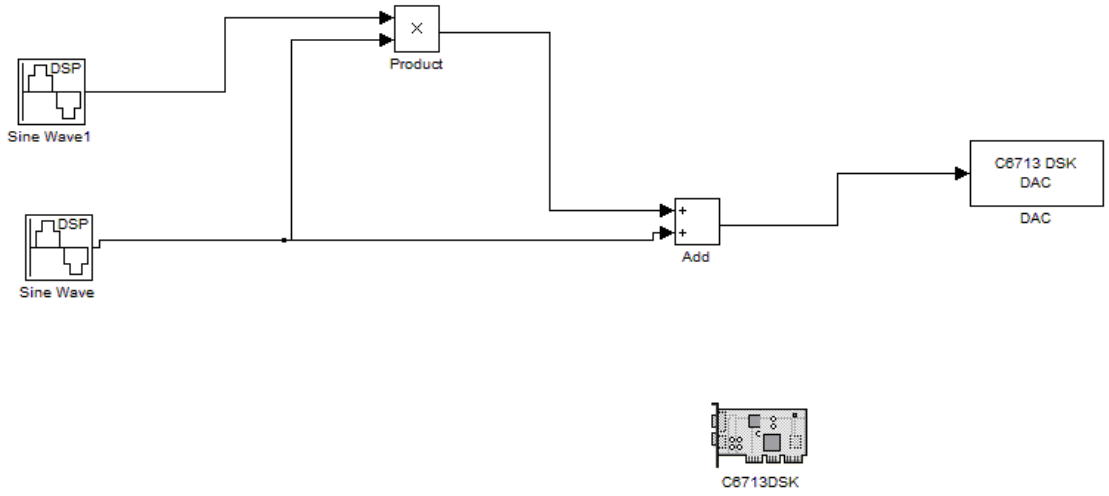


DSB – AM :

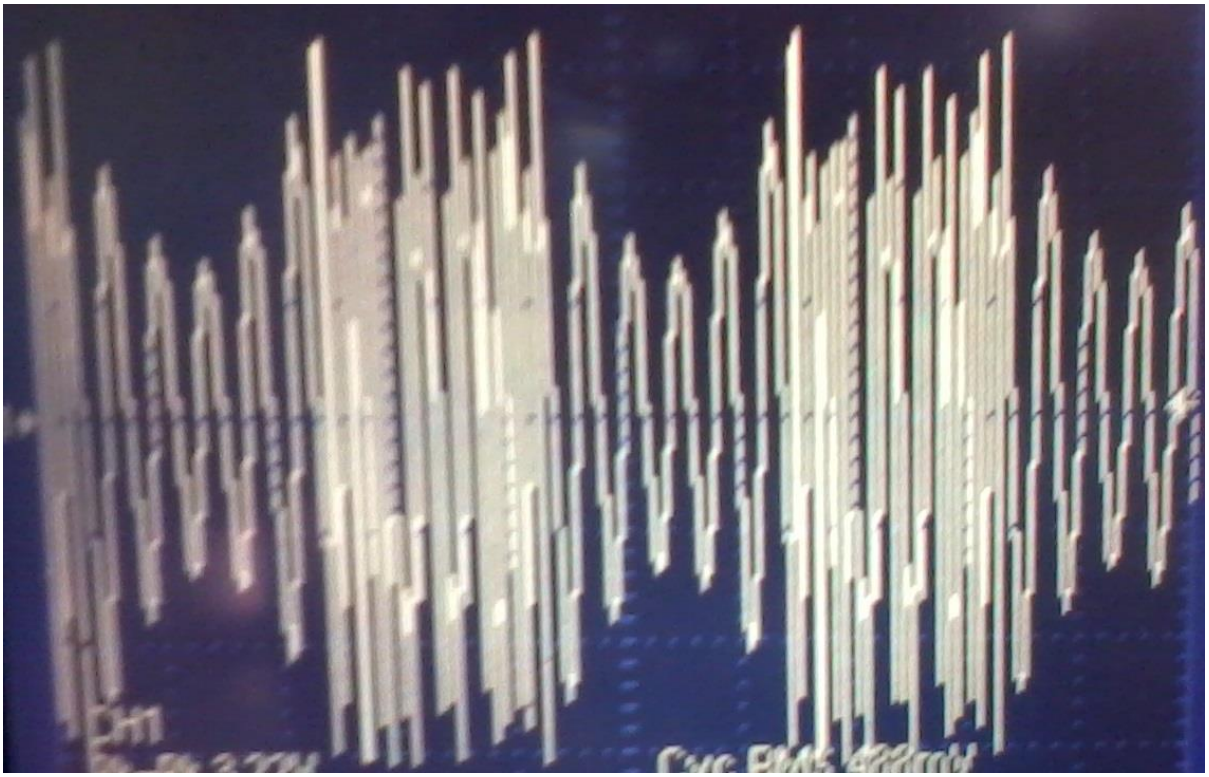
Modulation:

Message: 100Hz

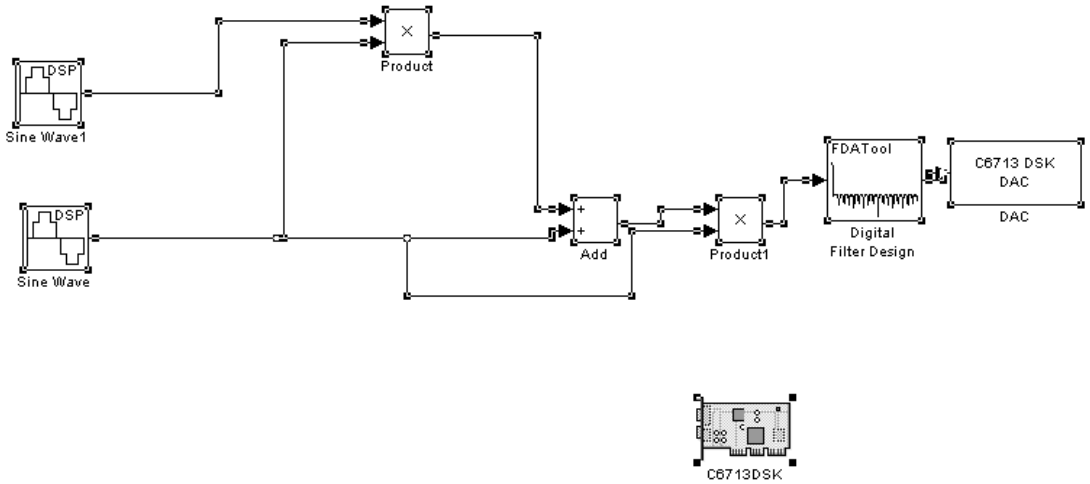
Carrier: 1 kHz



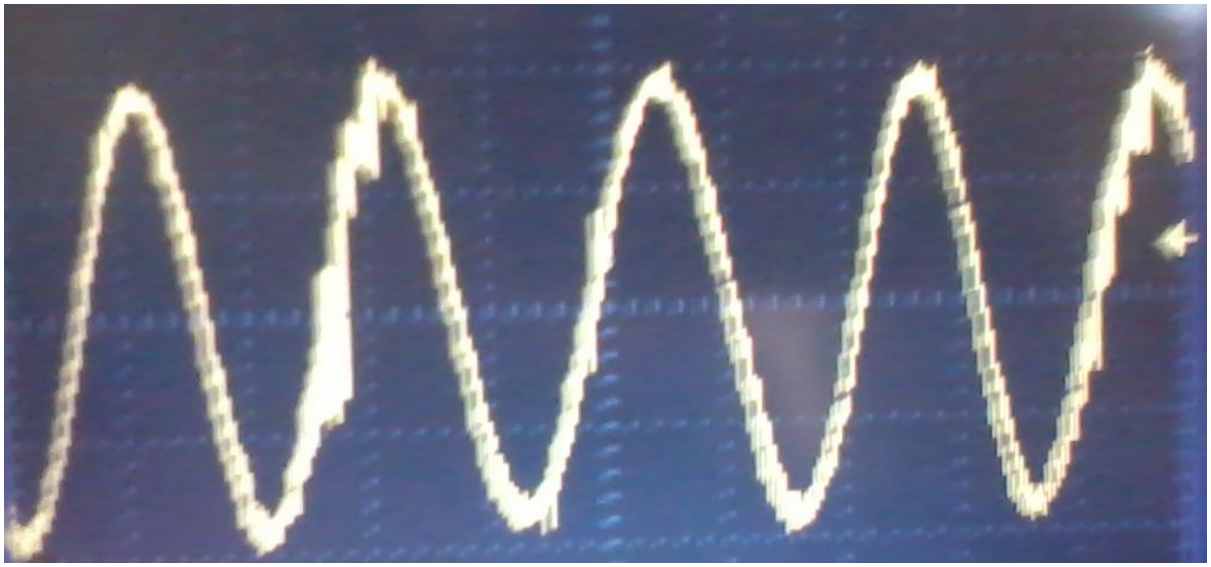
Signal



Demodulation



Demodulated wave

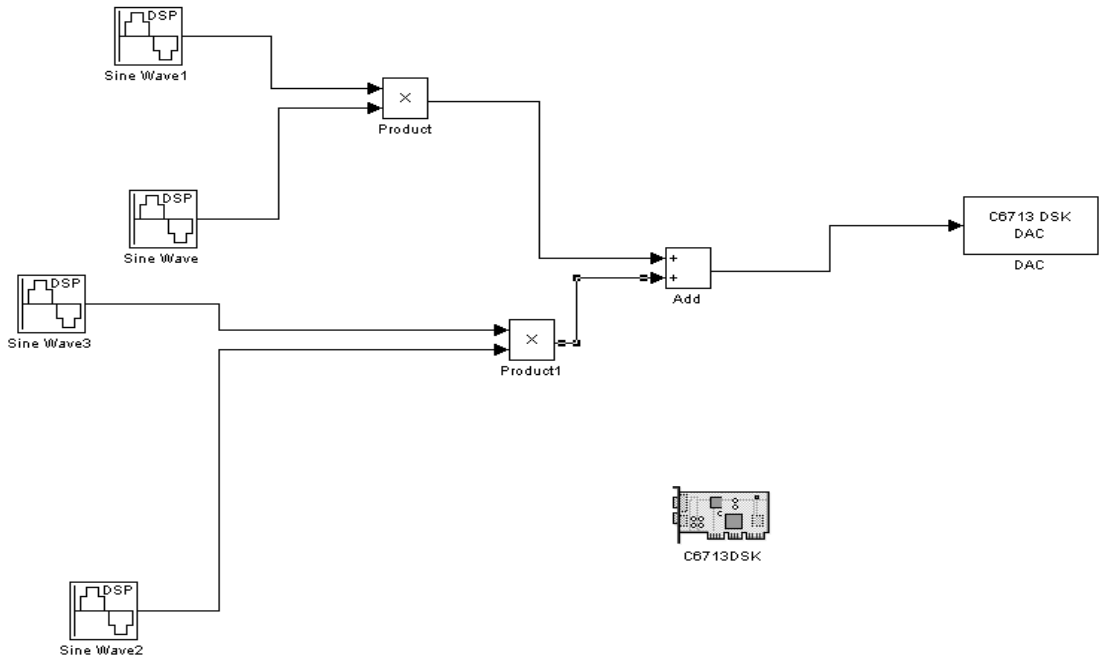


SSB:

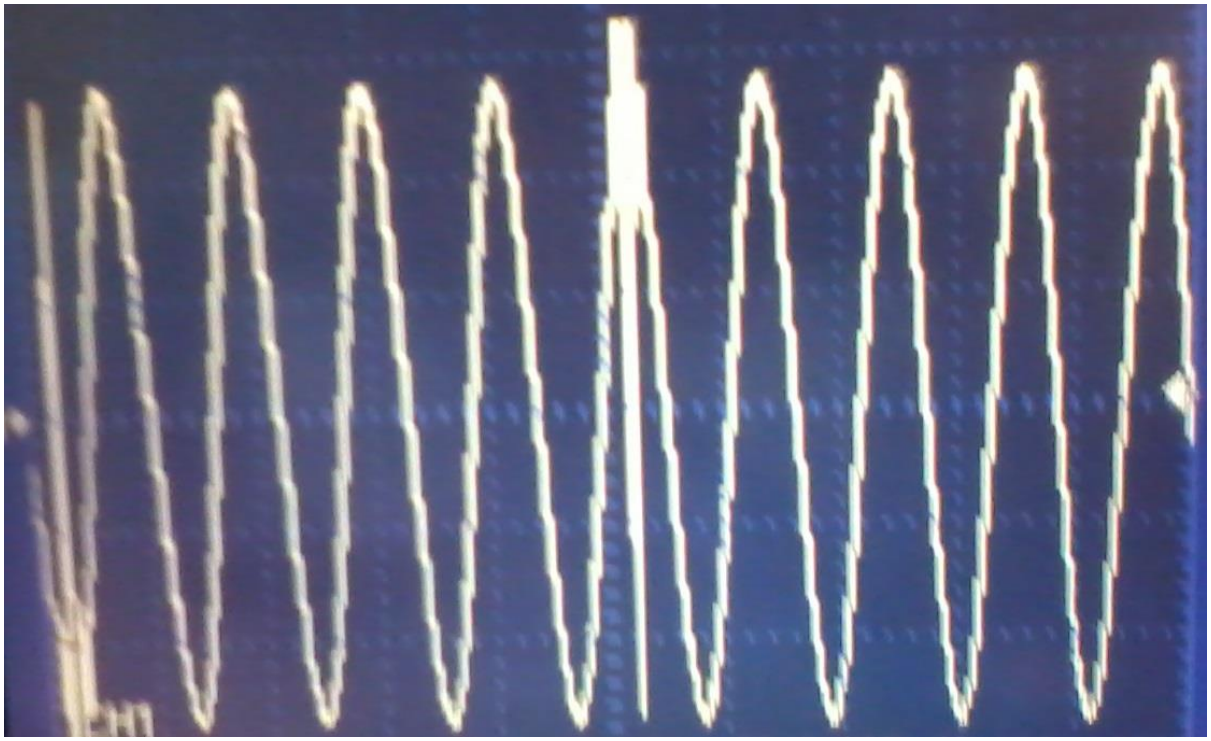
Modulation

Message: 100Hz

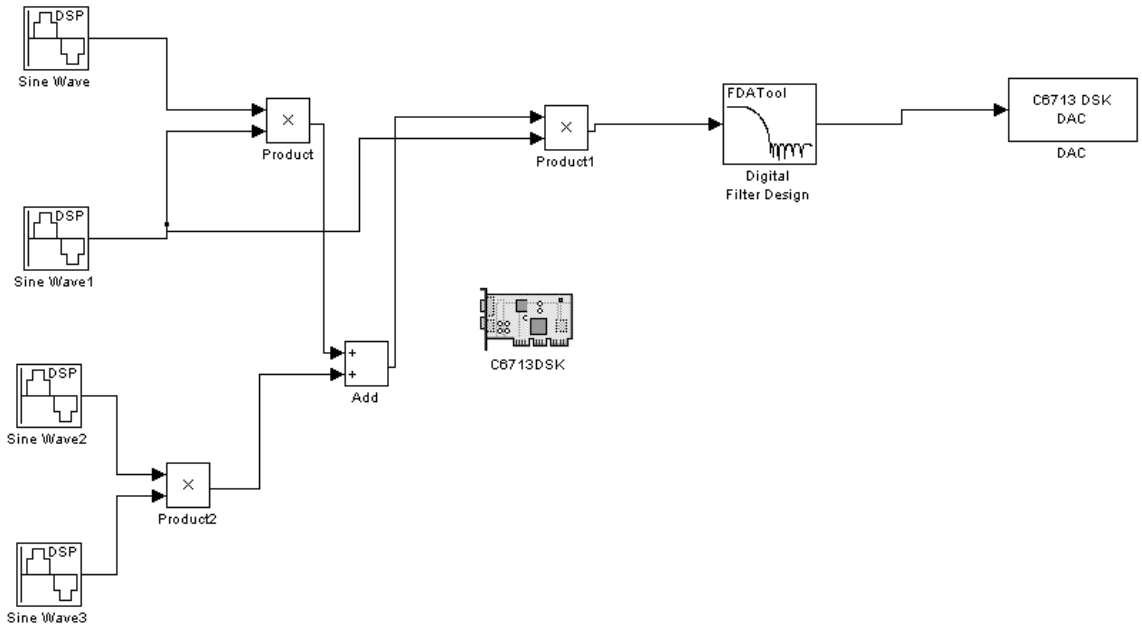
Carrier: 1 kHz



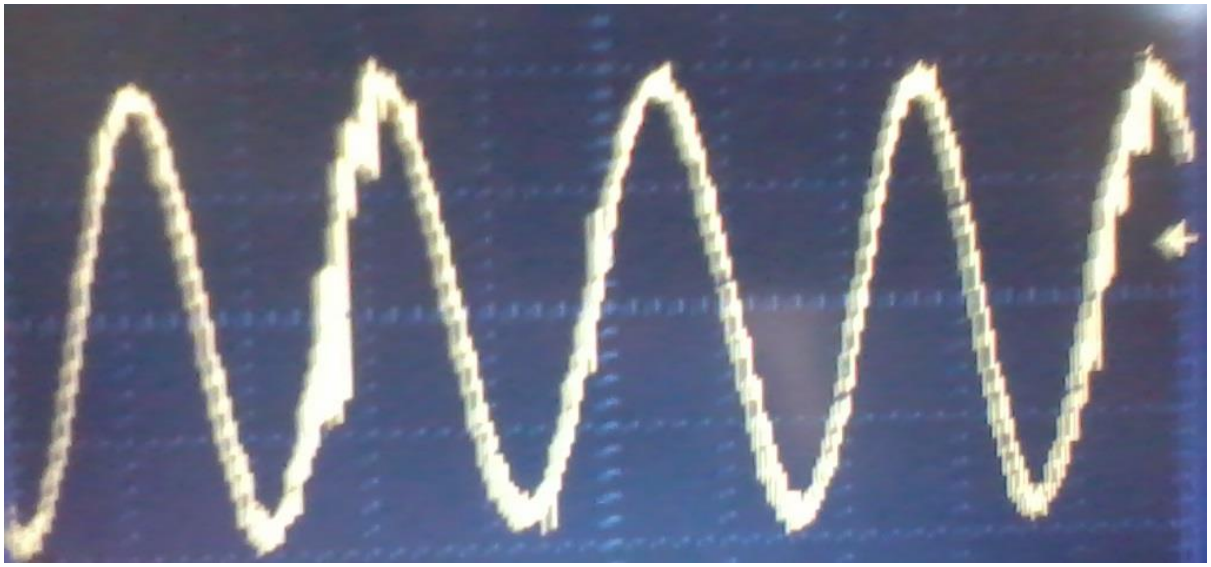
Signal



Demodulation



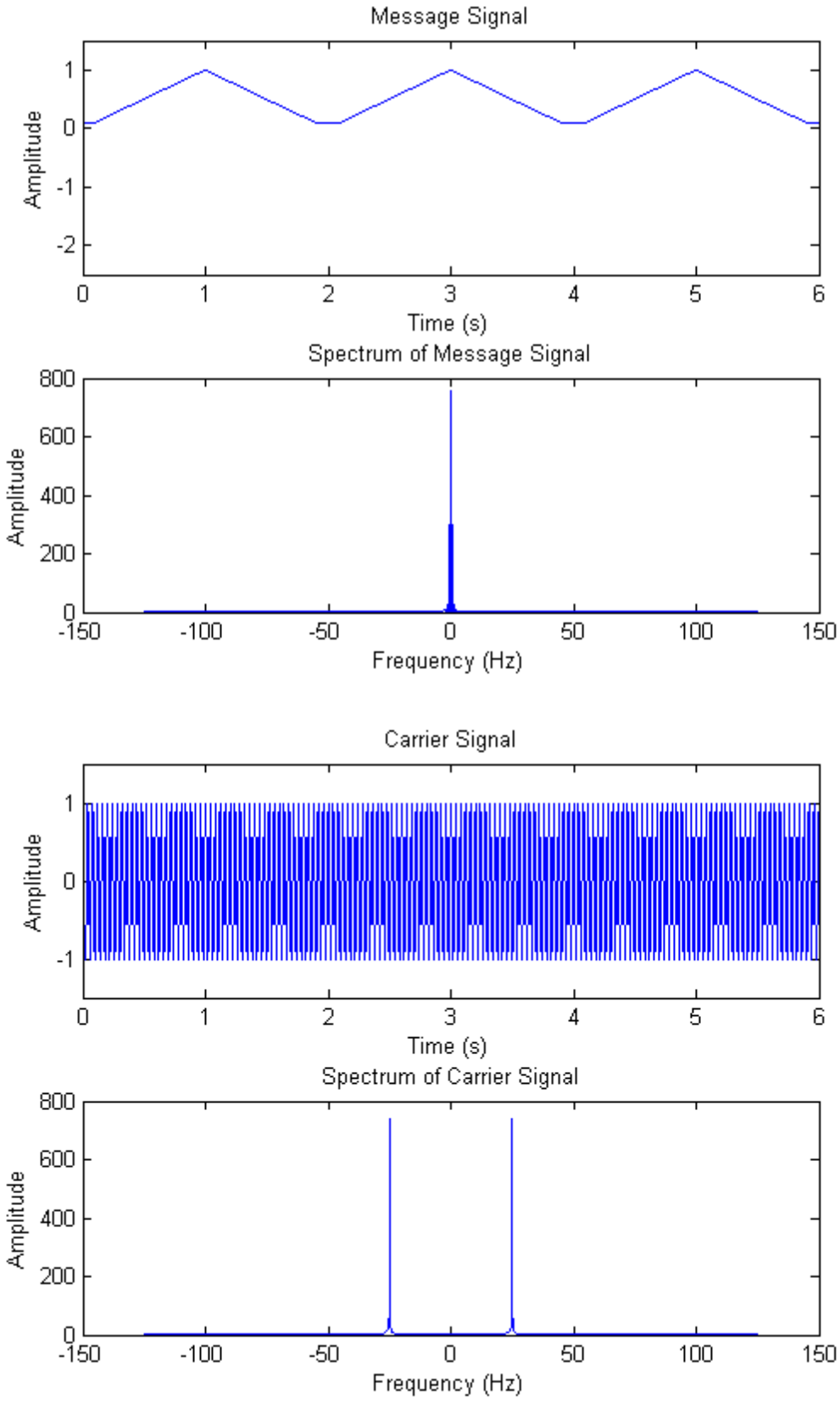
Demodulated signal

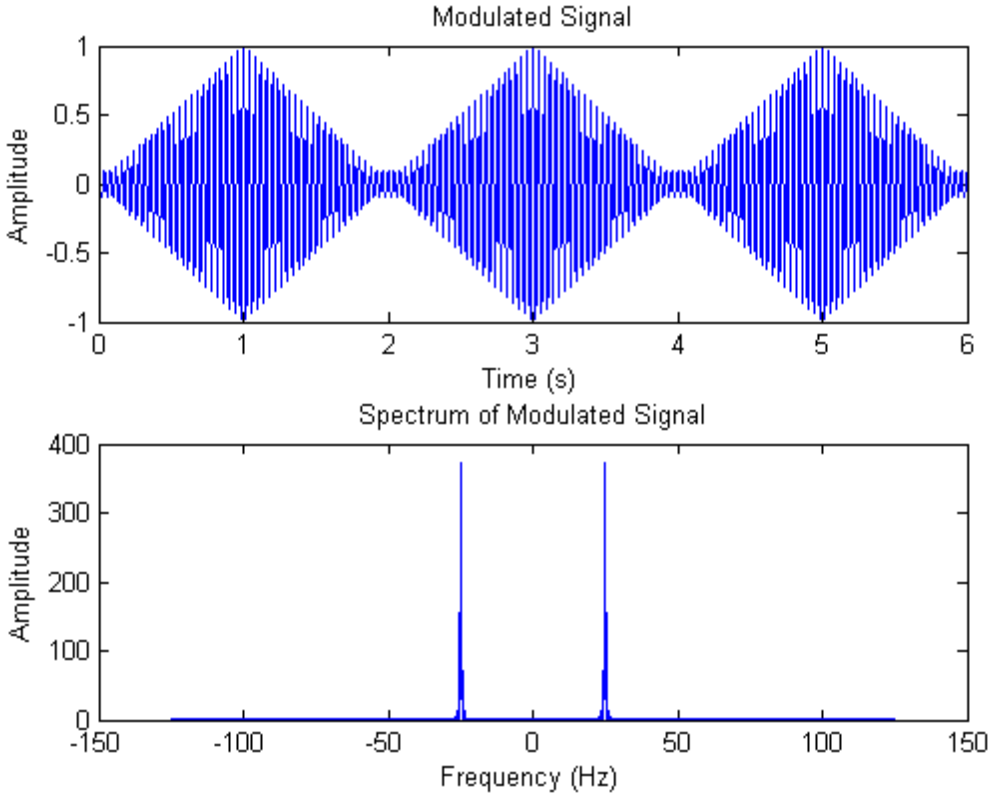


```
% Exercise Problem 3.1
% --------------------
clc;
clear all;
close all;

% Details given in the question
Fc = 25;
t0 = 2;

% Assumed values
Tstart = 0;
Tstop = 6;
Fs = 250;

% Generating time
Ts = 1 / Fs;
t = Tstart : Ts : Tstop;
N = length(t);

% Generating the message signal
m_t = zeros(1, N);
tk = mod(t, t0);
for i = 1 : N
    tk = mod(t(1, i), t0);
    if((tk >= 0.1) && (tk < 1))
        m_t(1, i) = tk;
    elseif((tk >= 1) && (tk <  1.9))
        m_t(1, i) = -tk + 2;
    else
        m_t(1, i) = 0.1;
    end
end
figure;
subplot(2,1,1);
plot(t, m_t);
ylim([-2.5 1.5]);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(m_t))));
title('Spectrum of Message Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Generating the carrier signal
c_t = cos(2*pi*Fc*t);
figure;
subplot(2,1,1);
plot(t, c_t);
title('Carrier Signal');
```

```
xlabel('Time (s)');
ylabel('Amplitude');
ylim([-1.5 1.5]);
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(c_t))));
title('Spectrum of Carrier Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Generating the modulated signal
u_t = m_t .* c_t;
figure;
subplot(2,1,1);
plot(t, u_t);
title('Modulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(u_t))));
title('Spectrum of Modulated Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Calculate power
u_pow = sum(u_t .^ 2) / N;
fprintf(1, 'Power of modulated signal u(t) = %f\n', u_pow);
u_f_pow = sum(abs(fft(u_t)) .^ 2) / N;
m_f_pow = sum(abs(fft(m_t)) .^ 2) / N;
fprintf(1, 'Power spectral density of modulated signal u(f) = %f\n', u_f_pow);
fprintf(1, 'Power spectral density of message signal m(f) = %f\n\n', m_f_pow);
```

```
Power of modulated signal u(t) = 0.166907
Power spectral density of modulated signal u(f) = 250.527430
Power spectral density of message signal m(f) = 501.013600
```


Message Signal
Amplitude
Time (s)
Spectrum of Message Signal
Amplitude
Frequency (Hz)
Carrier Signal
Amplitude
Time (s)
Spectrum of Carrier Signal
Amplitude
Frequency (Hz)



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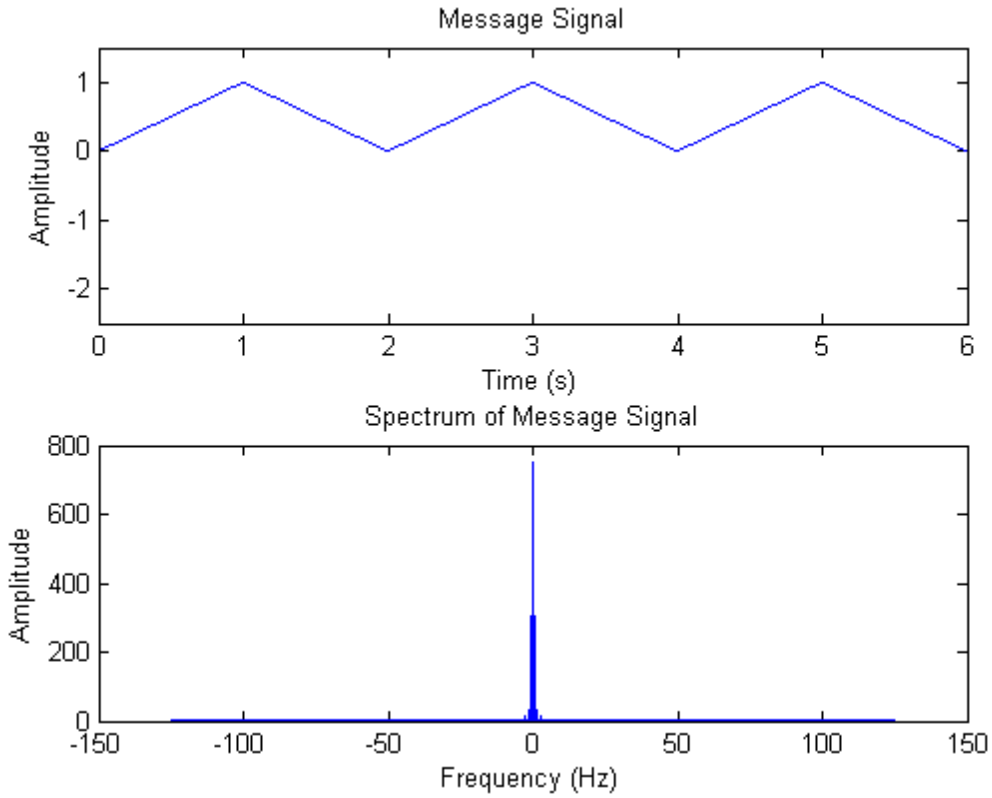
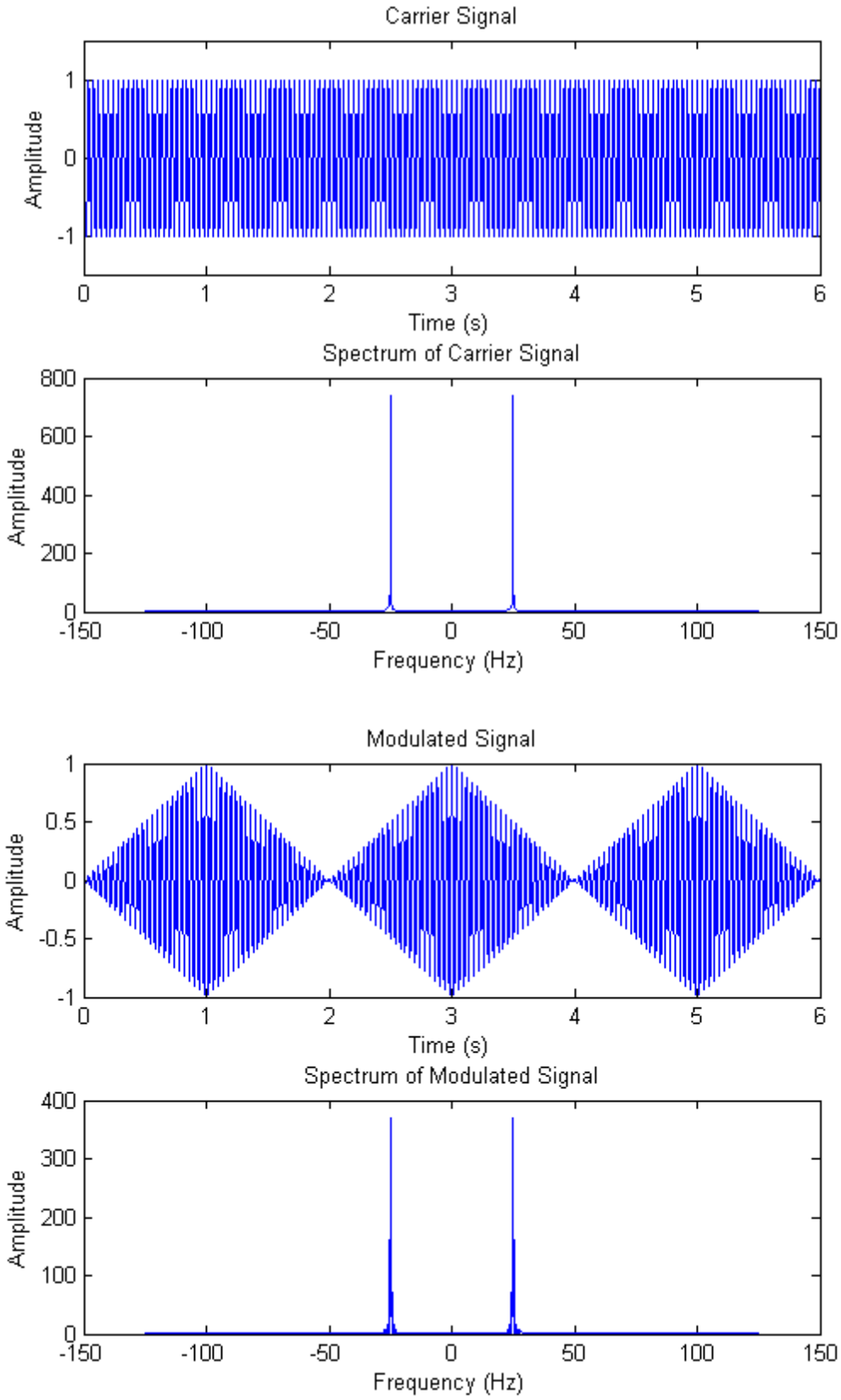
```
% Exercise Problem 3.2
% --------------------
clc;
clear all;
close all;

% Details given in the question
Fc = 25;
t0 = 2;

% Assumed values
Tstart = 0;
Tstop = 6;
Fs = 250;

% Generating time
Ts = 1 / Fs;
t = Tstart : Ts : Tstop;
N = length(t);

% Generating the message signal
tk = mod(t, t0);
m_t = tk.*(tk < 1) + (-tk+2).*((tk>=1).*(tk<=2));
figure;
subplot(2,1,1);
plot(t, m_t);
ylim([-2.5 1.5]);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(m_t))));
title('Spectrum of Message Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Generating the carrier signal
c_t = cos(2*pi*Fc*t);
figure;
subplot(2,1,1);
plot(t, c_t);
title('Carrier Signal');
xlabel('Time (s)');
ylabel('Amplitude');
ylim([-1.5 1.5]);
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(c_t))));
title('Spectrum of Carrier Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Generating the modulated signal
```

```
u_t = m_t .* c_t;
figure;
subplot(2,1,1);
plot(t, u_t);
title('Modulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(u_t))));
title('Spectrum of Modulated Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Calculate power
u_pow = sum(u_t .^ 2) / N;
fprintf(1, 'Power of modulated signal u(t) = %f\n', u_pow);
u_f_pow = sum(abs(fft(u_t)) .^ 2) / N;
m_f_pow = sum(abs(fft(m_t)) .^ 2) / N;
fprintf(1, 'Power spectral density of modulated signal u(f) = %f\n', u_f_pow);
fprintf(1, 'Power spectral density of message signal m(f) = %f\n\n', m_f_pow);
```

```
Power of modulated signal u(t) = 0.166569

Power spectral density of modulated signal u(f) = 250.019367
Power spectral density of message signal m(f) = 500.004000
```




Carrier Signal
Amplitude
Time (s)
Spectrum of Carrier Signal
Amplitude
Frequency (Hz)
Modulated Signal
Amplitude
Time (s)
Spectrum of Modulated Signal
Amplitude
Frequency (Hz)

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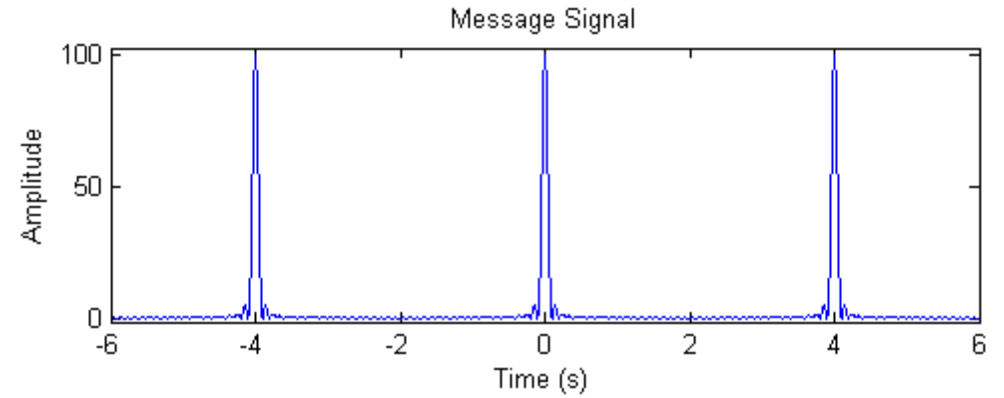
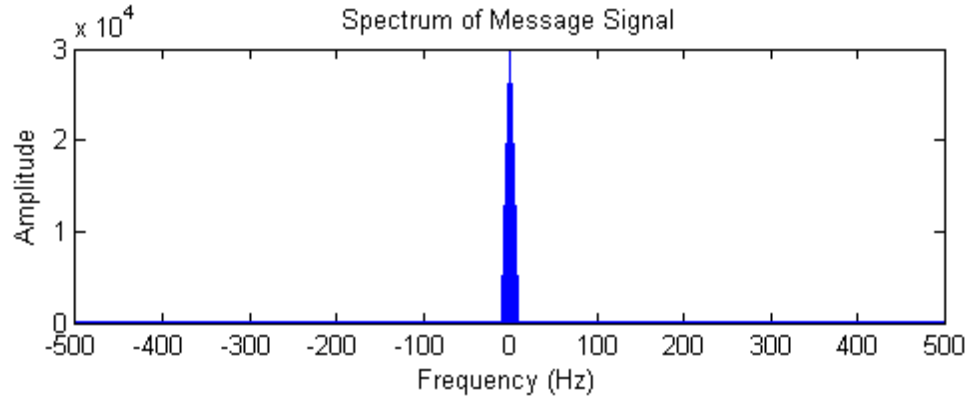
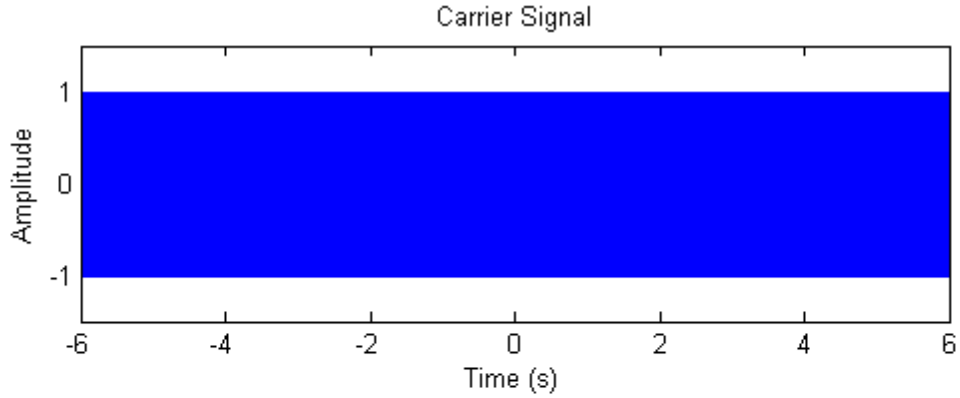
```
% Exercise Problem 3.3
% --------------------
clc;
clear all;
close all;

% Details given in the question
Fc = 100;
t0 = 4;

% Assumed values
Tstart = -6;
Tstop = 6;
Fs = 1000;

% Generating time
Ts = 1 / Fs;
t = Tstart : Ts : Tstop;
N = length(t);

% Generating the message signal
tk = mod(t - (t0/2), t0) - (t0/2);
m_t = (sin(pi*10*tk) ./ (pi*tk)) .^ 2;
for i = 1 : N
    if(isnan(m_t(1, i)))
        m_t(1, i) = 100;
    end
end
figure;
subplot(2,1,1);
plot(t, m_t);
ylim([-1.5 102.5]);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(m_t))));
title('Spectrum of Message Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Generating the carrier signal
c_t = cos(2*pi*Fc*t);
figure;
subplot(2,1,1);
plot(t, c_t);
title('Carrier Signal');
xlabel('Time (s)');
ylabel('Amplitude');
ylim([-1.5 1.5]);
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(c_t))));
```

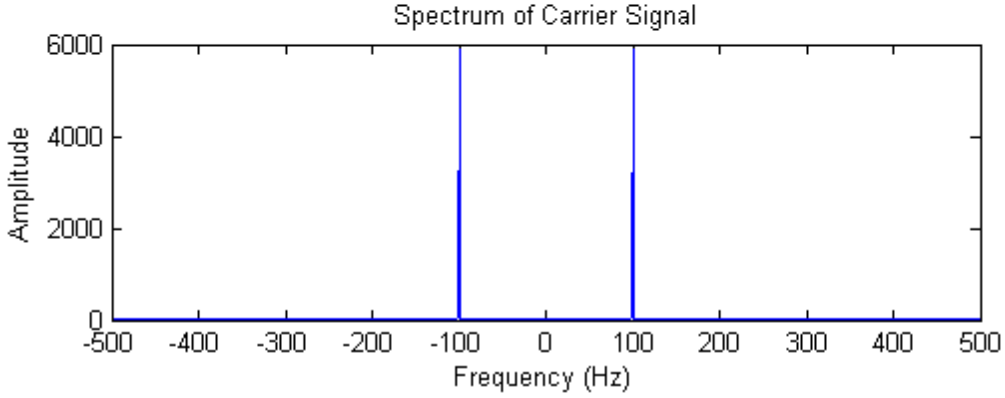
```
title('Spectrum of Carrier Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Generating the modulated signal
u_t = m_t .* c_t;
figure;
subplot(2,1,1);
plot(t, u_t);
title('Modulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(u_t))));
title('Spectrum of Modulated Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Calculate power
u_pow = sum(u_t .^ 2) / N;
fprintf(1, 'Power of modulated signal u(t) = %f\n', u_pow);
u_f_pow = sum(abs(fft(u_t)) .^ 2) / N;
m_f_pow = sum(abs(fft(m_t)) .^ 2) / N;
fprintf(1, 'Power spectral density of modulated signal u(f) = %f\n', u_f_pow);
fprintf(1, 'Power spectral density of message signal m(f) = %f\n\n', m_f_pow);
```

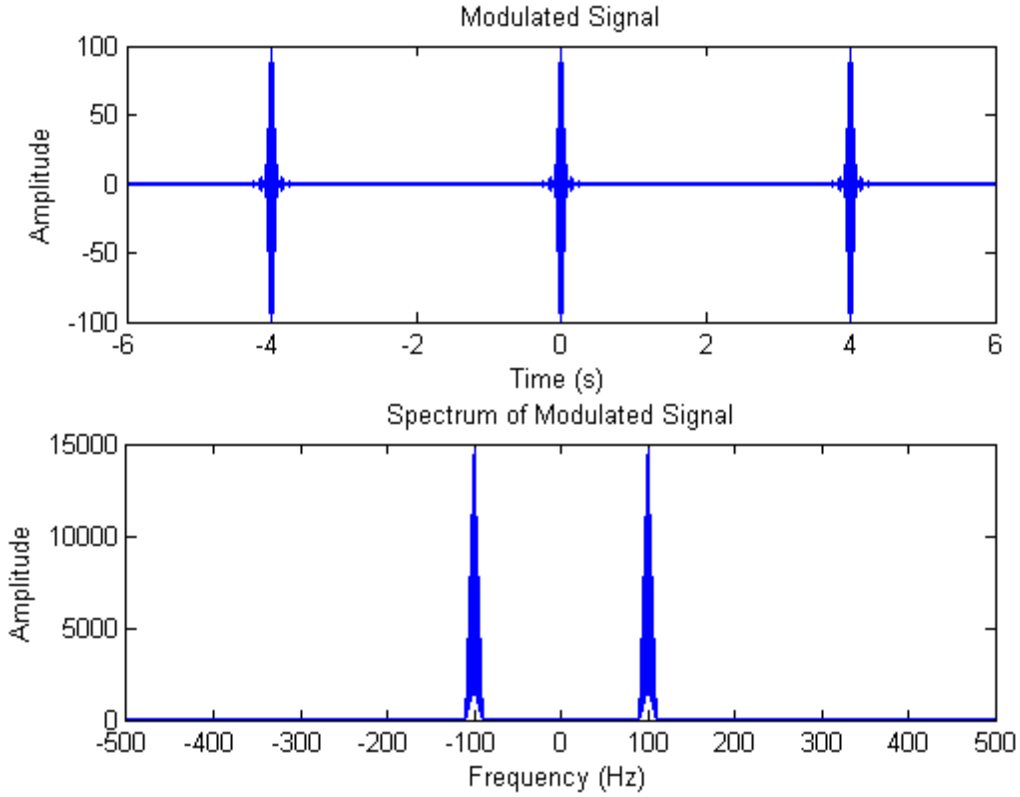
```
Power of modulated signal u(t) = 83.326349
Power spectral density of modulated signal u(f) = 999999.519238
Power spectral density of message signal m(f) = 1999999.038477
```


Message Signal
Amplitude
Time (s)


x 10^4
Spectrum of Message Signal
Amplitude
Frequency (Hz)


Carrier Signal
Amplitude
Time (s)


Spectrum of Carrier Signal
Amplitude
Frequency (Hz)



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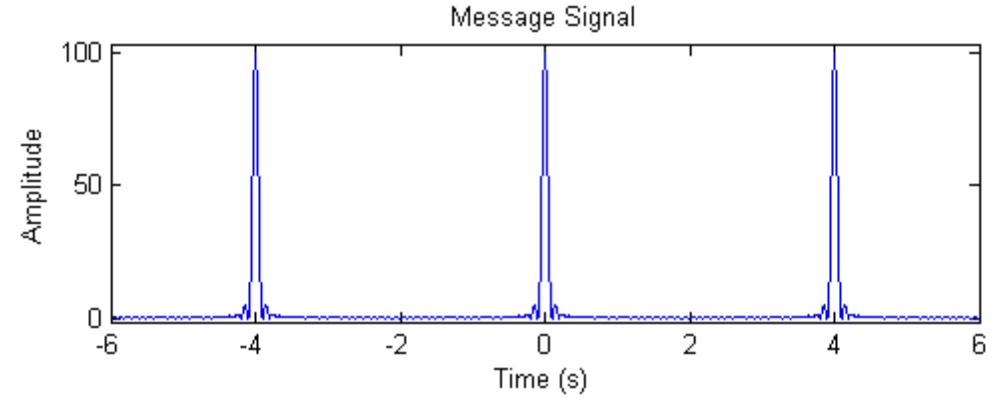
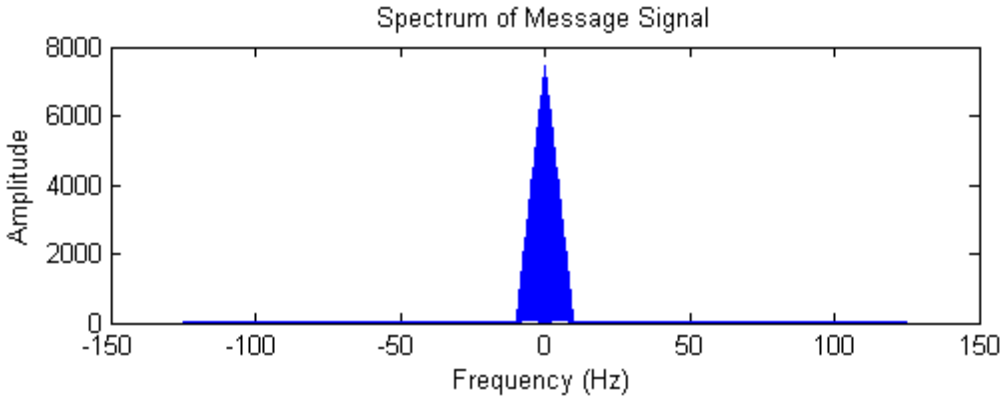
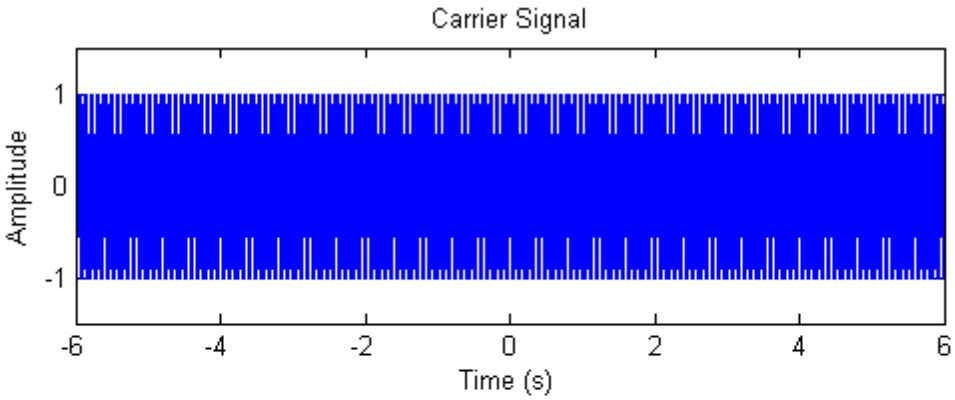
```
% Exercise Problem 3.4
% --------------------
clc;
clear all;
close all;

% Details given in the question
Fc = 25;
t0 = 4;
a = 0.1 : 0.01 : 0.9;

% Assumed values
Tstart = -6;
Tstop = 6;
Fs = 250;

% Generating time
Ts = 1 / Fs;
t = Tstart : Ts : Tstop;
N = length(t);

% Generating the message signal
tk = mod(t - (t0/2), t0) - (t0/2);
m_t = (sin(pi*10*tk) ./ (pi*tk)) .^ 2;
for i = 1 : N
    if(isnan(m_t(1, i)))
        m_t(1, i) = 100;
    end
end
figure;
subplot(2,1,1);
plot(t, m_t);
ylim([-1.5 102.5]);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(m_t))));
title('Spectrum of Message Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Generating the carrier signal
c_t = cos(2*pi*Fc*t);
figure;
subplot(2,1,1);
plot(t, c_t);
title('Carrier Signal');
xlabel('Time (s)');
ylabel('Amplitude');
ylim([-1.5 1.5]);
subplot(2,1,2);
```

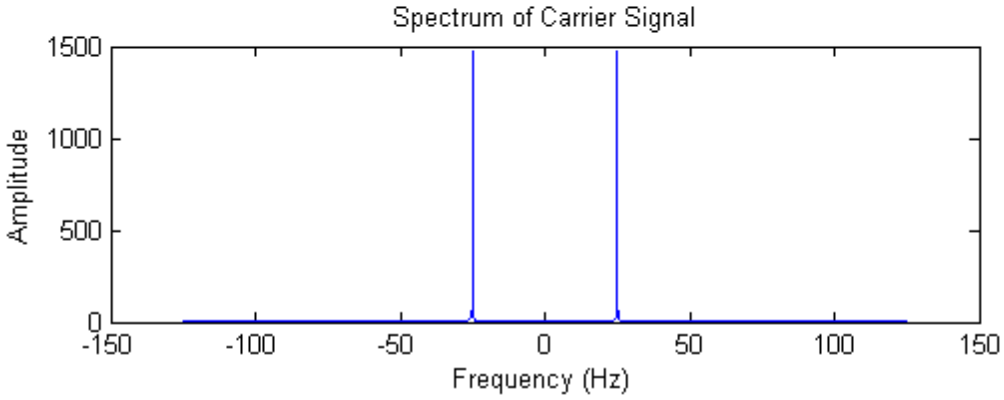
```
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(c_t))));
title('Spectrum of Carrier Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Generating the modulated signal
ratio = zeros(1, length(a));
for i = 1 : length(a)
    if(mod(a(1, i), 0.1) == 0)
        u_t = (2/a(1, i))*c_t + m_t.*c_t;
        figure;
        subplot(2,1,1);
        plot(t, u_t);
        title(sprintf('Modulated Signal (a = %f)', a(1, i)));
        xlabel('Time (s)');
        ylabel('Amplitude');
        subplot(2,1,2);
        plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(u_t))));
        title(sprintf('Spectrum of Modulated Signal (a = %f)', a(1, i)));
        xlabel('Frequency (Hz)');
        ylabel('Amplitude');
    end
    ratio(1, i) = (a(1, i) ^ 2) / 2;
end
figure;
plot(a, ratio);
title('Power Content ratio of Sideband to Carrier');
xlabel('Modulation index (a)');
ylabel('Ratio');


% Calculate power
u_pow = sum(u_t .^ 2) / N;
fprintf(1, 'Power of modulated signal u(t) = %f\n', u_pow);
u_f_pow = sum(abs(fft(u_t)) .^ 2) / N;
m_f_pow = sum(abs(fft(m_t)) .^ 2) / N;
fprintf(1, 'Power spectral density of modulated signal u(f) = %f\n', u_f_pow);
fprintf(1, 'Power spectral density of message signal m(f) = %f\n\n', m_f_pow);
```

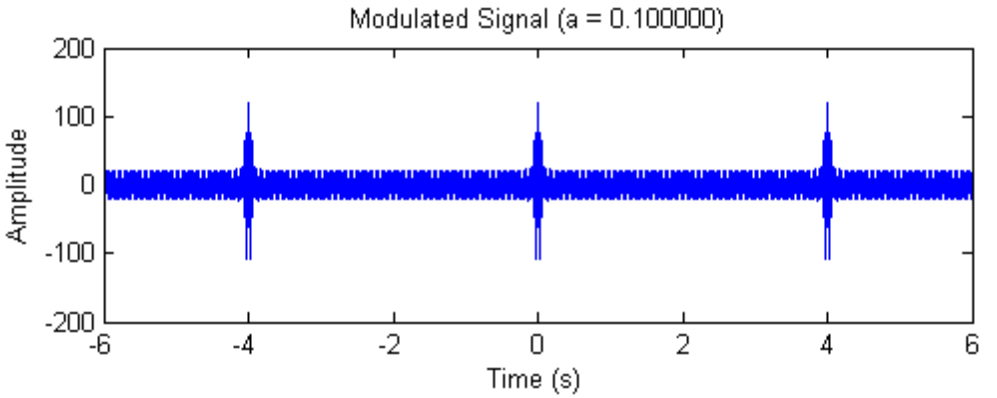
```
Power of modulated signal u(t) = 91.301056
Power spectral density of modulated signal u(f) = 273994.468576
Power spectral density of message signal m(f) = 499999.759619
```

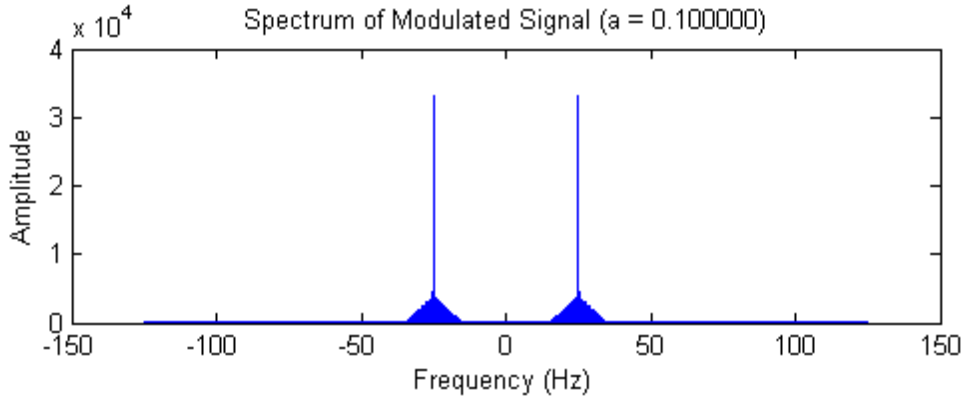

Message Signal
Amplitude
Time (s)

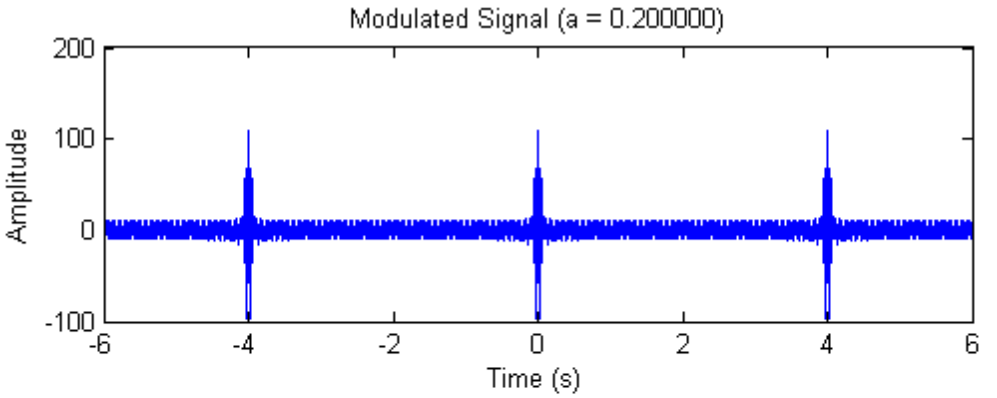

Spectrum of Message Signal
Amplitude
Frequency (Hz)

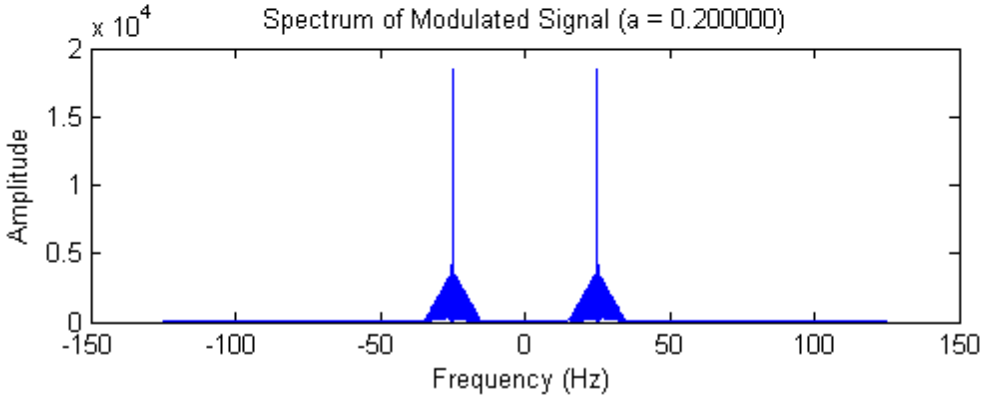

Carrier Signal
Amplitude
Time (s)

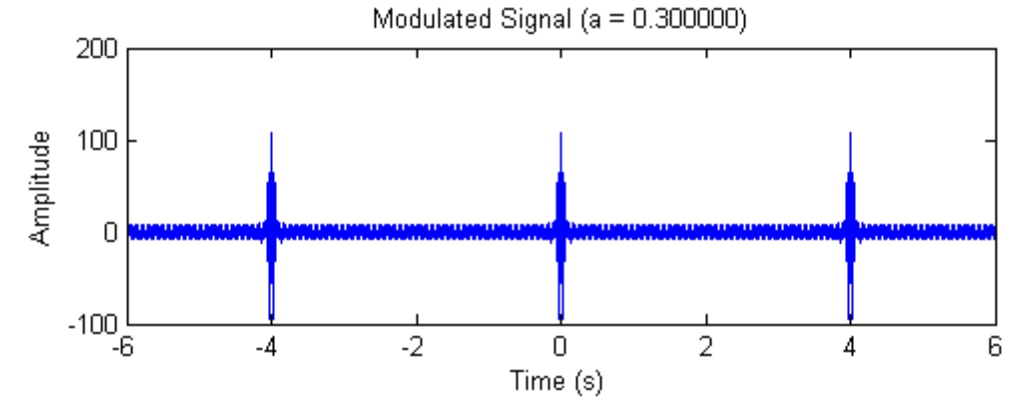

Spectrum of Carrier Signal
Amplitude
Frequency (Hz)

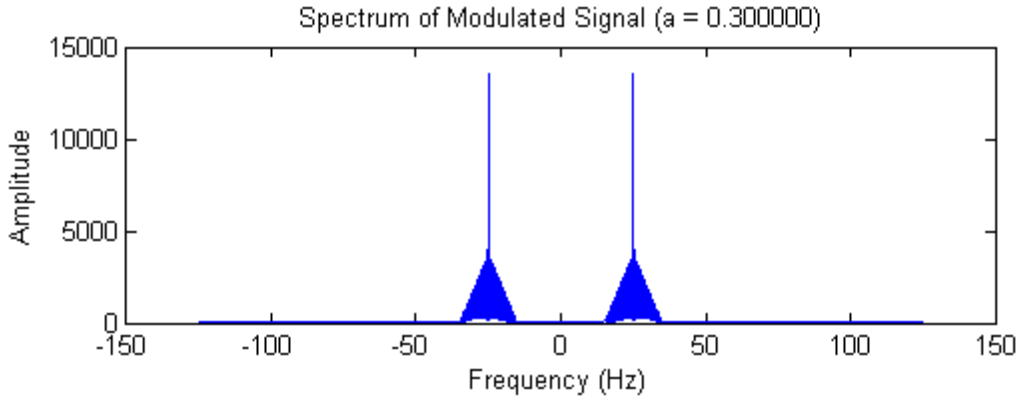

Modulated Signal (a = 0.100000)
Amplitude
Time (s)
200
100
0
-100
-200
-6
-4
-2
0
2
4
6

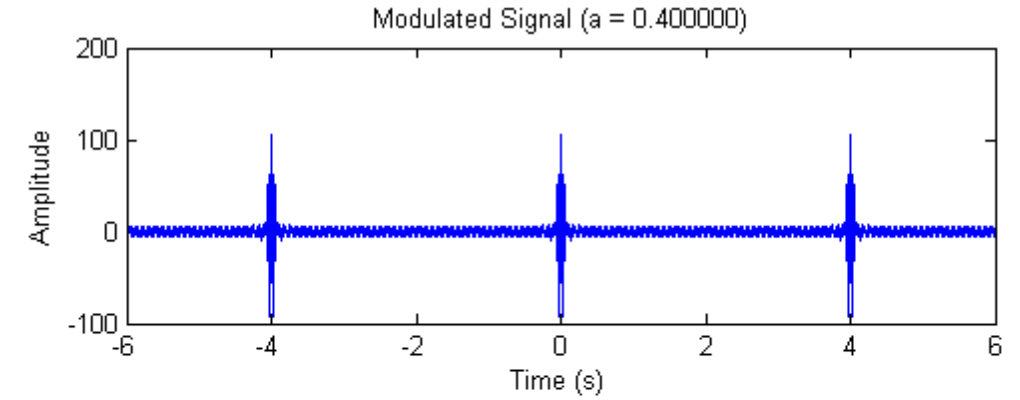

Spectrum of Modulated Signal (a = 0.100000)
x 10^4
Amplitude
Frequency (Hz)
4
3
2
1
0
-150
-100
-50
0
50
100
150

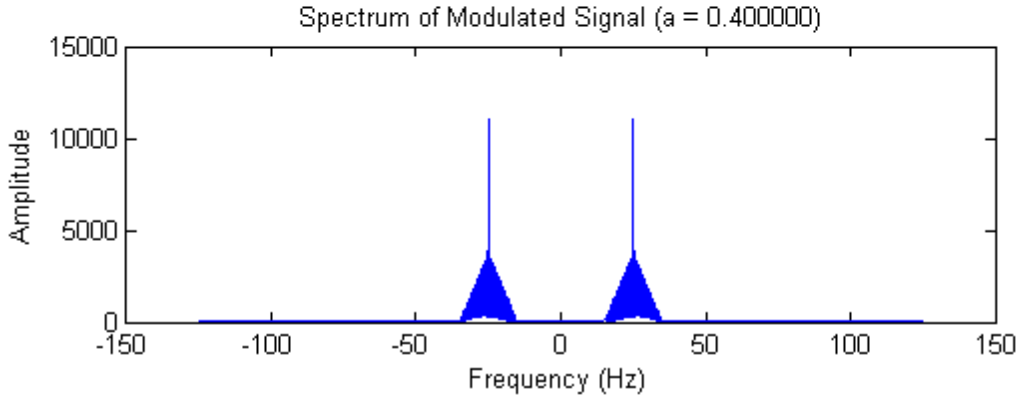

Modulated Signal (a = 0.200000)
Amplitude
Time (s)
200
100
0
-100
-6
-4
-2
0
2
4
6

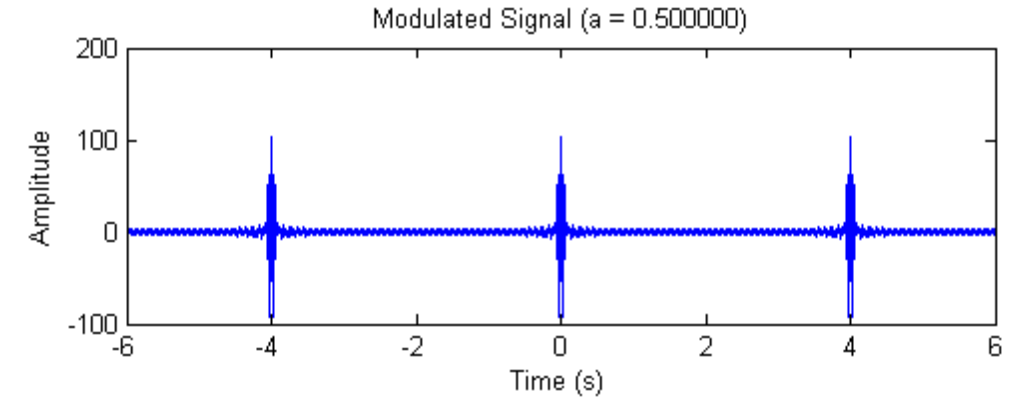

Spectrum of Modulated Signal (a = 0.200000)
x 10^4
Amplitude
Frequency (Hz)
2
1.5
1
0.5
0
-150
-100
-50
0
50
100
150

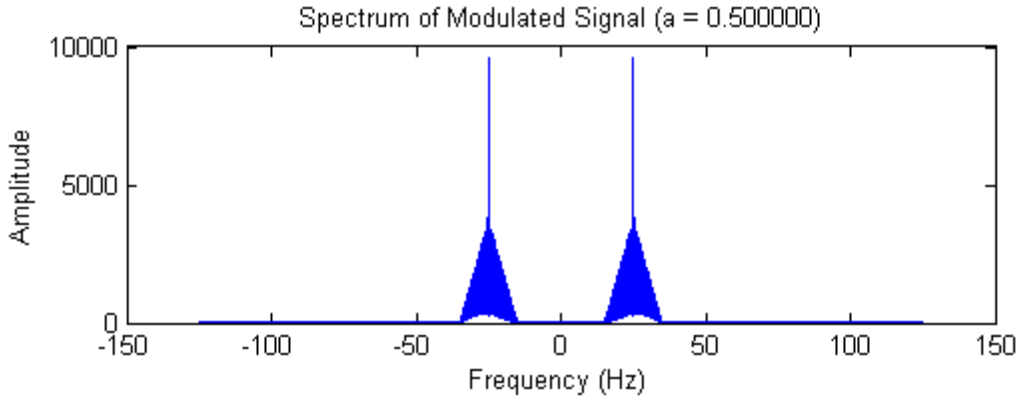

Modulated Signal (a = 0.300000)
Amplitude
Time (s)
200
100
0
-100
-6
-4
-2
0
2
4
6

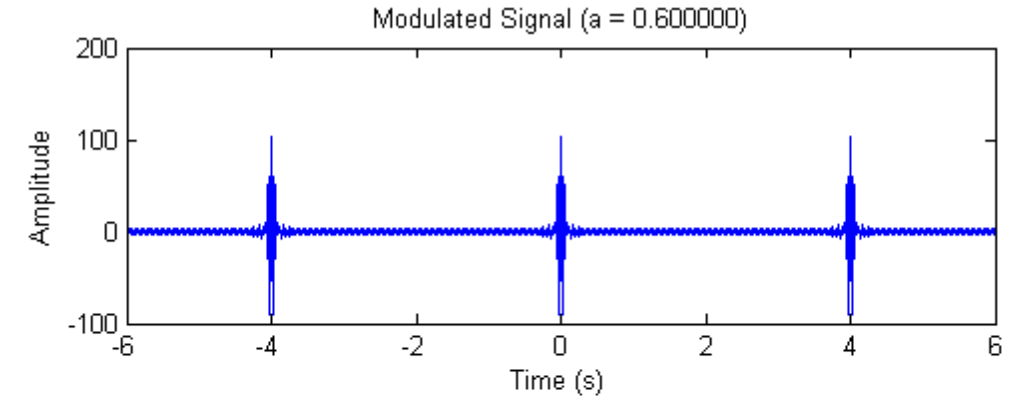

Spectrum of Modulated Signal (a = 0.300000)
Amplitude
Frequency (Hz)
15000
10000
5000
0
-150
-100
-50
0
50
100
150

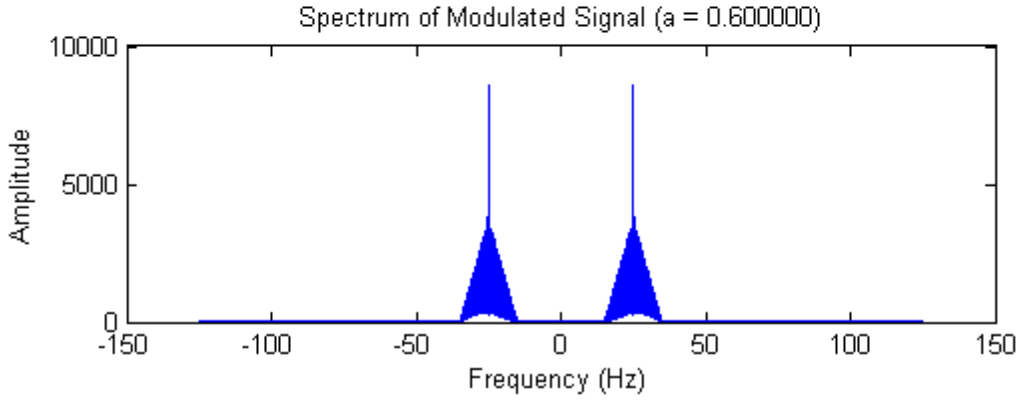

Modulated Signal (a = 0.400000)
Amplitude
Time (s)
200
100
0
-100
-6
-4
-2
0
2
4
6

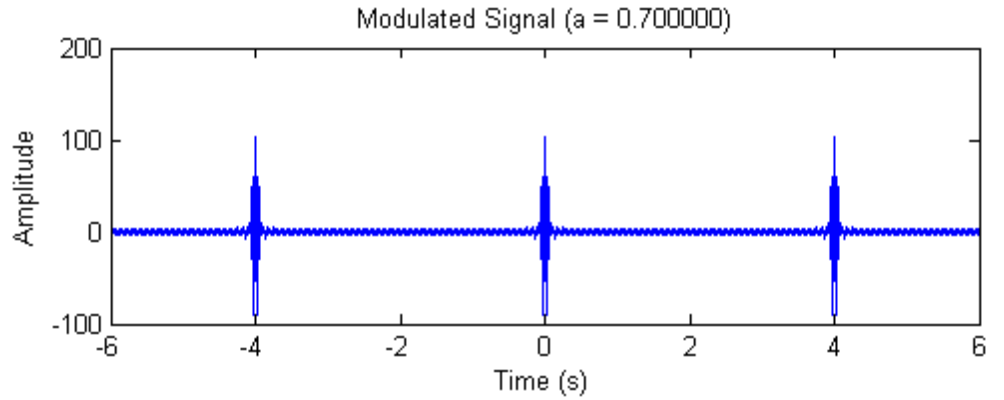

Spectrum of Modulated Signal (a = 0.400000)
Amplitude
Frequency (Hz)
15000
10000
5000
0
-150
-100
-50
0
50
100
150

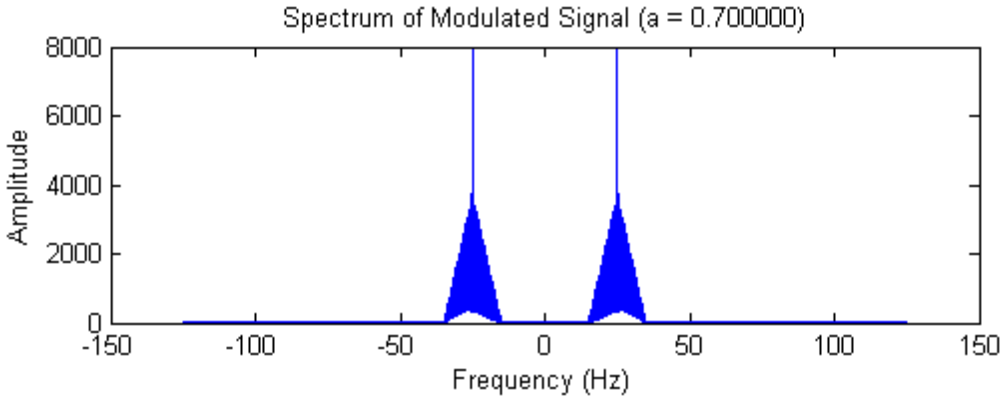

Modulated Signal (a = 0.500000)
Amplitude
Time (s)
200
100
0
-100
-6
-4
-2
0
2
4
6

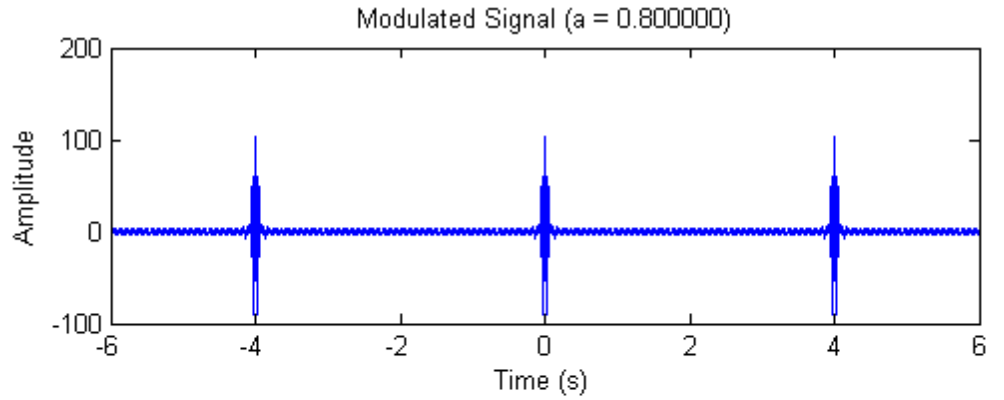

Spectrum of Modulated Signal (a = 0.500000)
Amplitude
Frequency (Hz)
10000
5000
0
-150
-100
-50
0
50
100
150

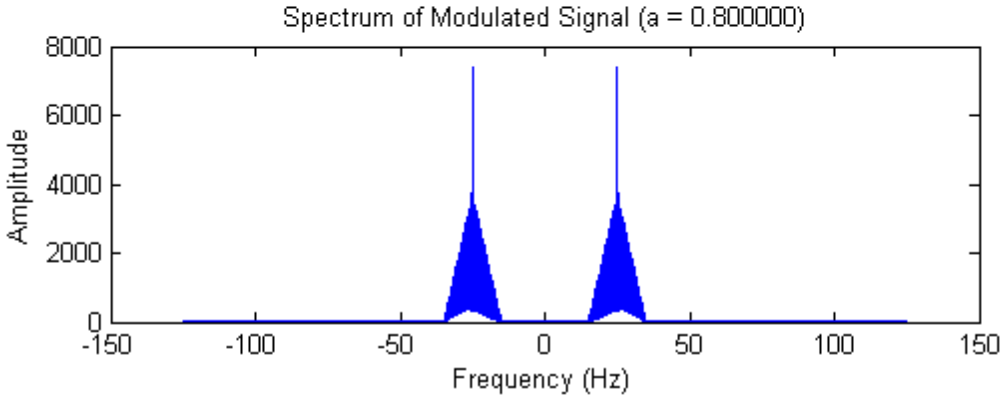

Modulated Signal (a = 0.600000)
Amplitude
Time (s)
200
100
0
-100
-6
-4
-2
0
2
4
6

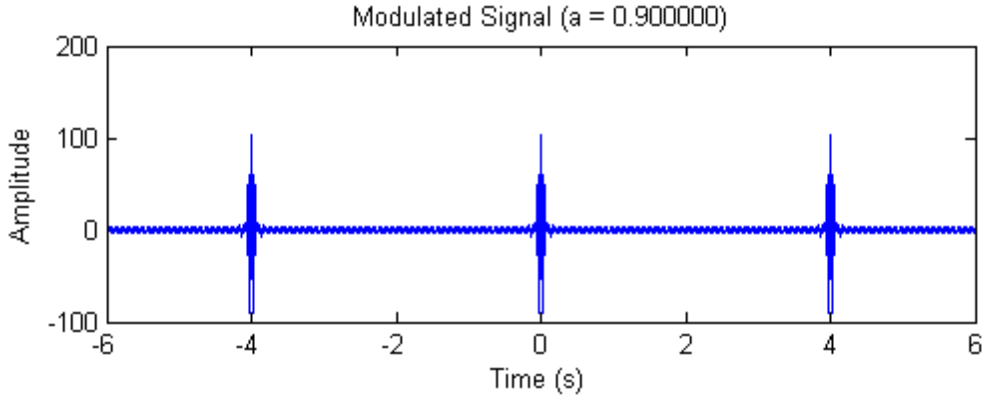

Spectrum of Modulated Signal (a = 0.600000)
Amplitude
Frequency (Hz)
10000
5000
0
-150
-100
-50
0
50
100
150

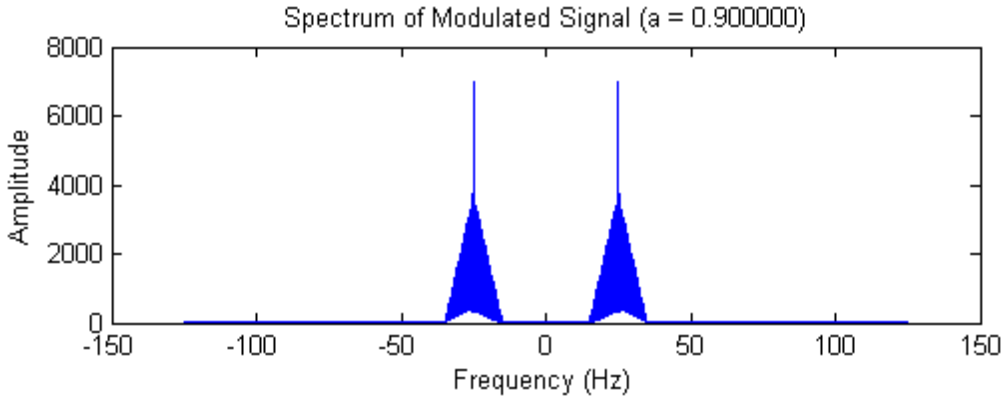

Modulated Signal (a = 0.700000)
Amplitude
Time (s)
200
100
0
-100
-6
-4
-2
0
2
4
6

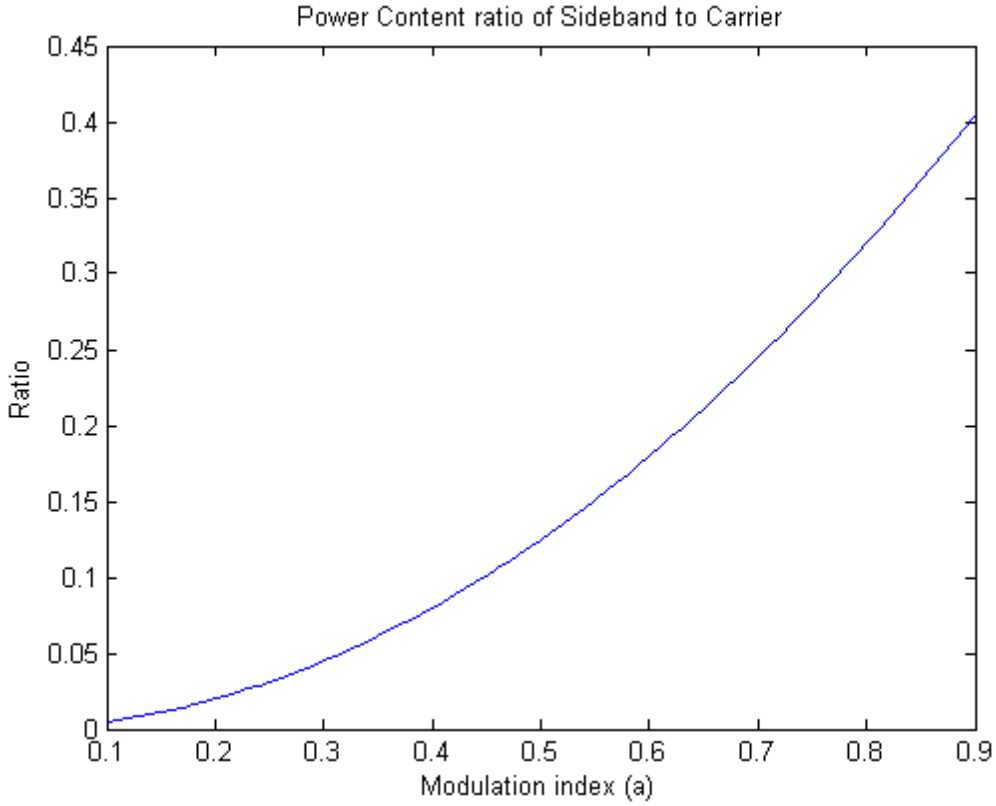

Spectrum of Modulated Signal (a = 0.700000)
Amplitude
Frequency (Hz)
8000
6000
4000
2000
0
-150
-100
-50
0
50
100
150


Modulated Signal (a = 0.800000)
Amplitude
Time (s)
200
100
0
-100
-6
-4
-2
0
2
4
6


Spectrum of Modulated Signal (a = 0.800000)
Amplitude
Frequency (Hz)
8000
6000
4000
2000
0
-150
-100
-50
0
50
100
150


Modulated Signal (a = 0.900000)
Amplitude
Time (s)
200
100
0
-100
-6
-4
-2
0
2
4
6


Spectrum of Modulated Signal (a = 0.900000)
Amplitude
Frequency (Hz)
8000
6000
4000
2000
0
-150
-100
-50
0
50
100
150


Power Content ratio of Sideband to Carrier
Ratio
Modulation index (a)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

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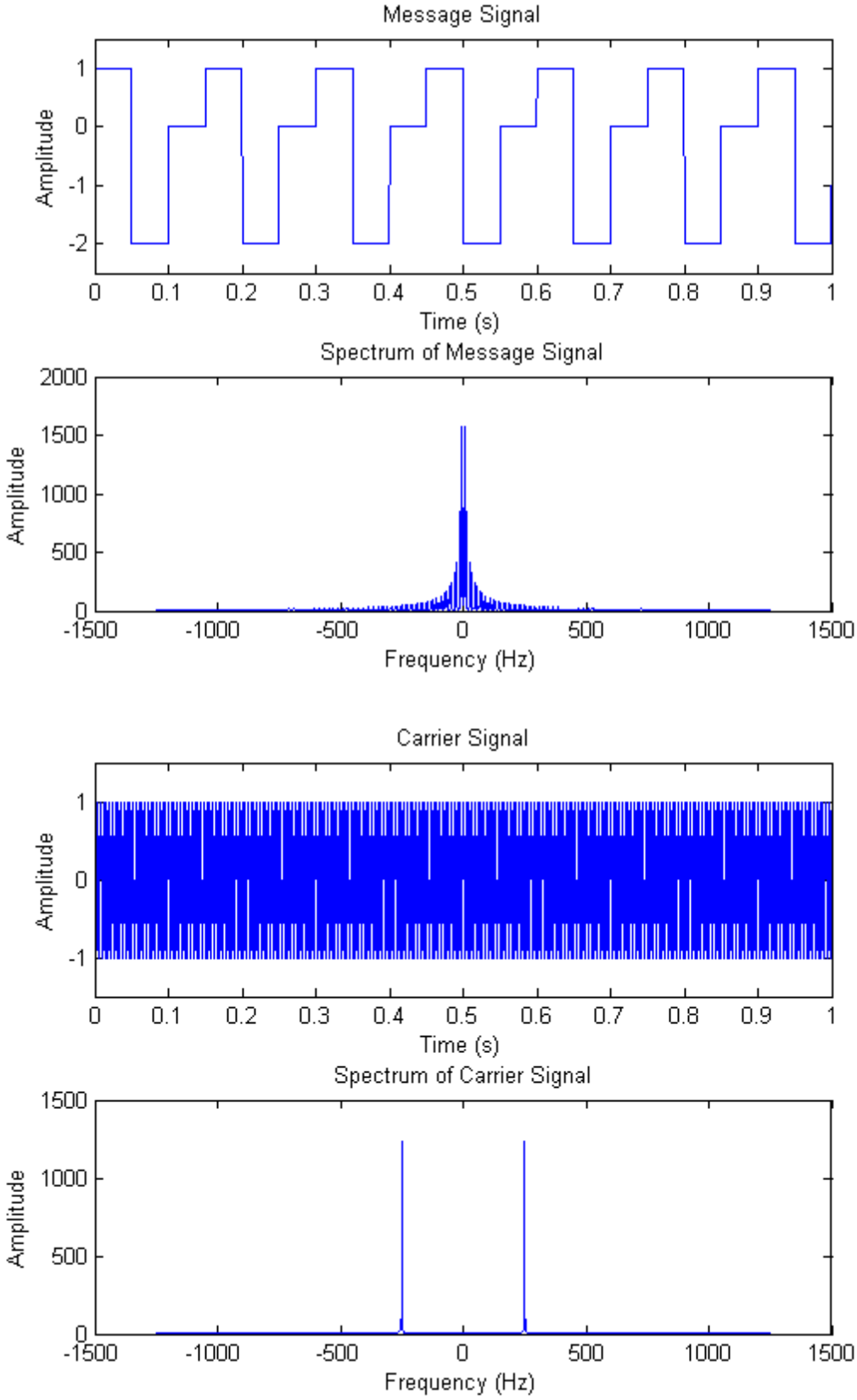
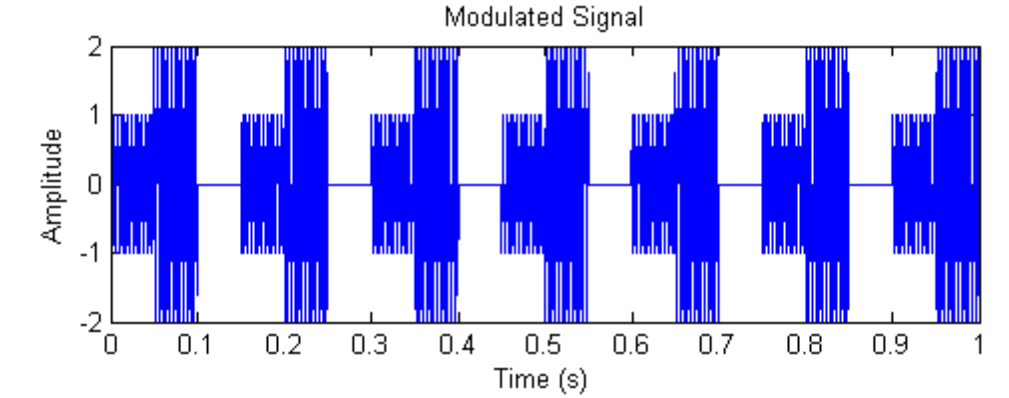
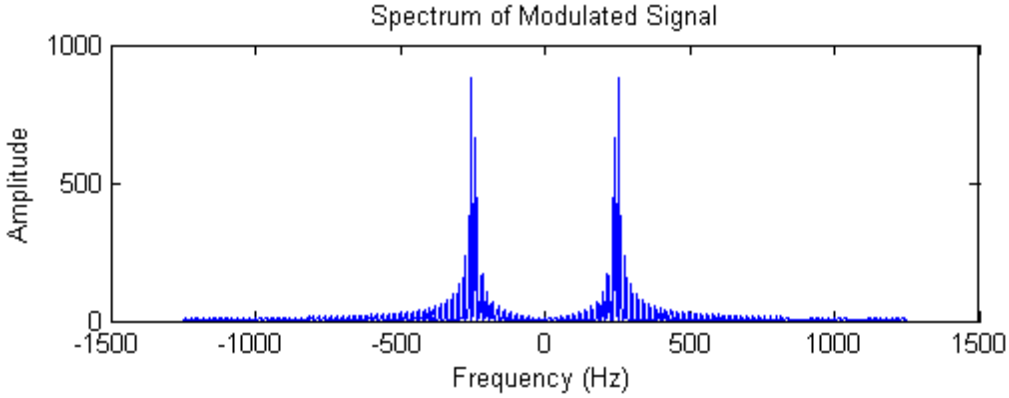
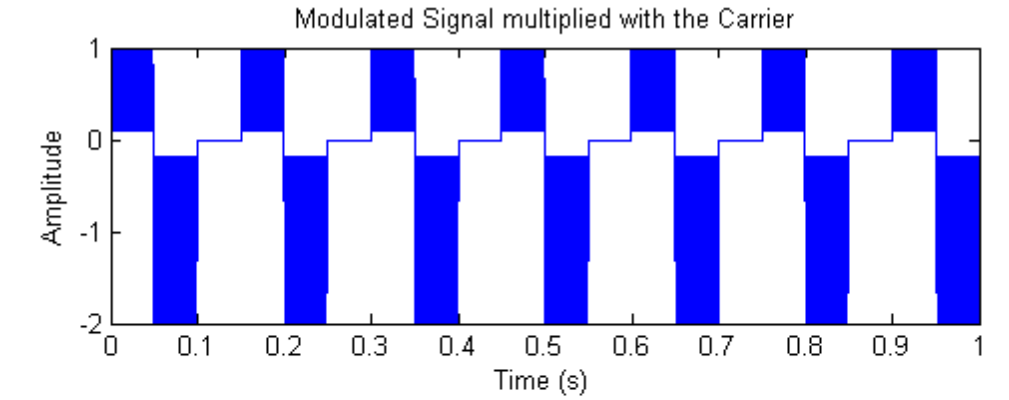
```
% Illustrative Problem 3.5
% ------------------------
clc;
clear all;
close all;

% Details given in the question
lpf_Fc = 250;
t0 = 0.15;

% Assumed values
Tstart = 0;
Tstop = 1;
Fs = 2.5 * 10^3;

% Generating time
Ts = 1 / Fs;
t = Tstart : Ts : Tstop;
N = length(t);

% Generating the message signal
tk = mod(t, t0);
m_t = (tk <= (1/3)*t0) - 2*((tk > (1/3)*t0) .* (tk <= (2/3)*t0));
figure;
subplot(2,1,1);
plot(t, m_t);
ylim([-2.5 1.5]);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(m_t))));
title('Spectrum of Message Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Generating the carrier signal
c_t = cos(2*pi*lpf_Fc*t);
figure;
subplot(2,1,1);
plot(t, c_t);
title('Carrier Signal');
xlabel('Time (s)');
ylabel('Amplitude');
ylim([-1.5 1.5]);
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(c_t))));
title('Spectrum of Carrier Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Generating the modulated signal
```

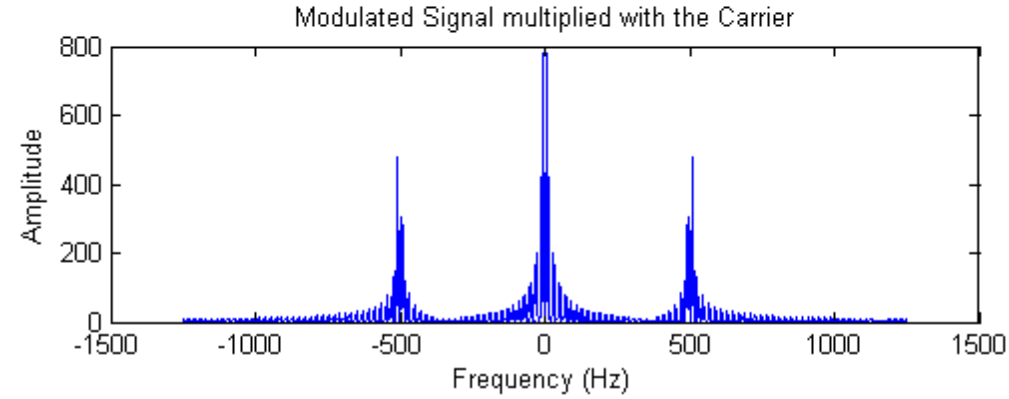
```
u_t = m_t .* c_t;
figure;
subplot(2,1,1);
plot(t, u_t);
title('Modulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(u_t))));
title('Spectrum of Modulated Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Create a Low Pass Filter
lpf_N    = 128;      % Order
lpf_Fc   = 250;      % Cutoff Frequency
lpf_flag = 'scale';  % Sampling Flag
lpf_h    = fir1(lpf_N, lpf_Fc/(Fs/2), 'low', blackman(lpf_N+1), lpf_flag);
lpf_sz   = length(lpf_h);
lpf_sz2  = floor(lpf_sz / 2);

% Demodulate the modulated signal
md1_t = u_t .* c_t;
md2_t = conv(md1_t, lpf_h);
md_t = 2 * md2_t(1, (1 + lpf_sz2) : (length(md2_t) - (lpf_sz - lpf_sz2 - 1)));

% Plot the demodulated signal
figure;
subplot(2,1,1);
plot(t, md1_t);
title('Modulated Signal multiplied with the Carrier');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(md1_t))));
title('Modulated Signal multiplied with the Carrier');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
figure;
subplot(2,1,1);
plot(t, md_t);
title('Demodulated Signal (after passing through LPF)');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(md_t))));
title('Spectrum of Demodulated Signal (after passing through LPF)');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
```

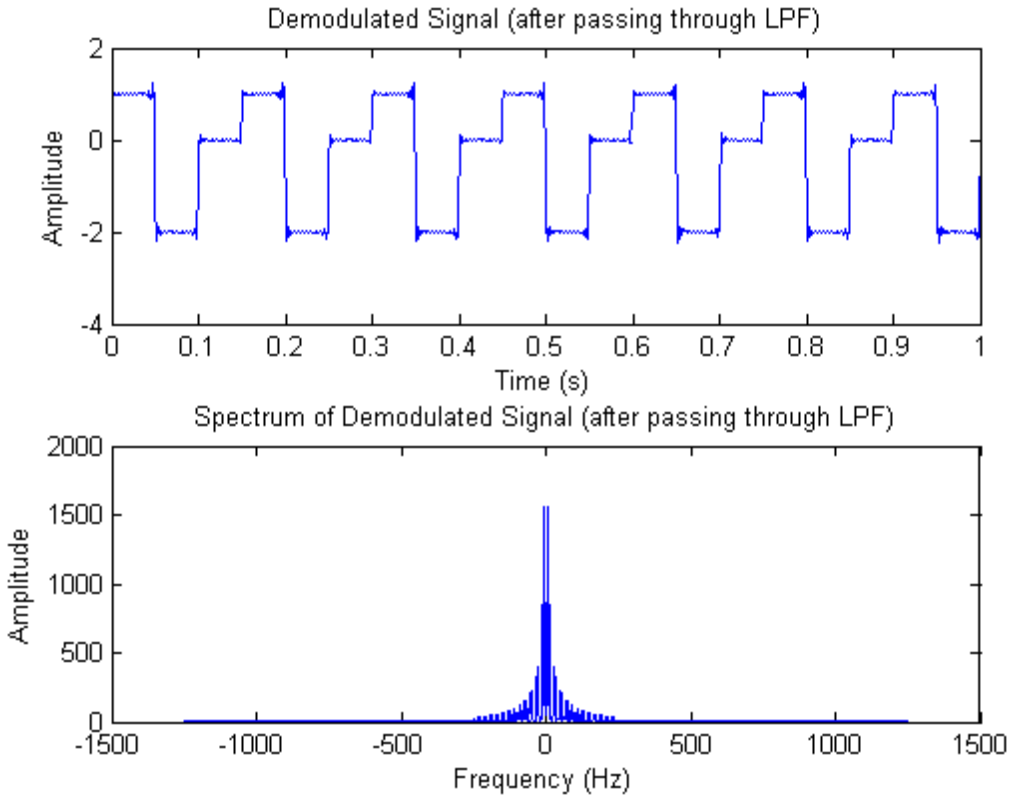

Message Signal
Amplitude
Time (s)
Spectrum of Message Signal
Amplitude
Frequency (Hz)
Carrier Signal
Amplitude
Time (s)
Spectrum of Carrier Signal
Amplitude
Frequency (Hz)


Modulated Signal
Amplitude
Time (s)


Spectrum of Modulated Signal
Amplitude
Frequency (Hz)


Modulated Signal multiplied with the Carrier
Amplitude
Time (s)


Modulated Signal multiplied with the Carrier
Amplitude
Frequency (Hz)



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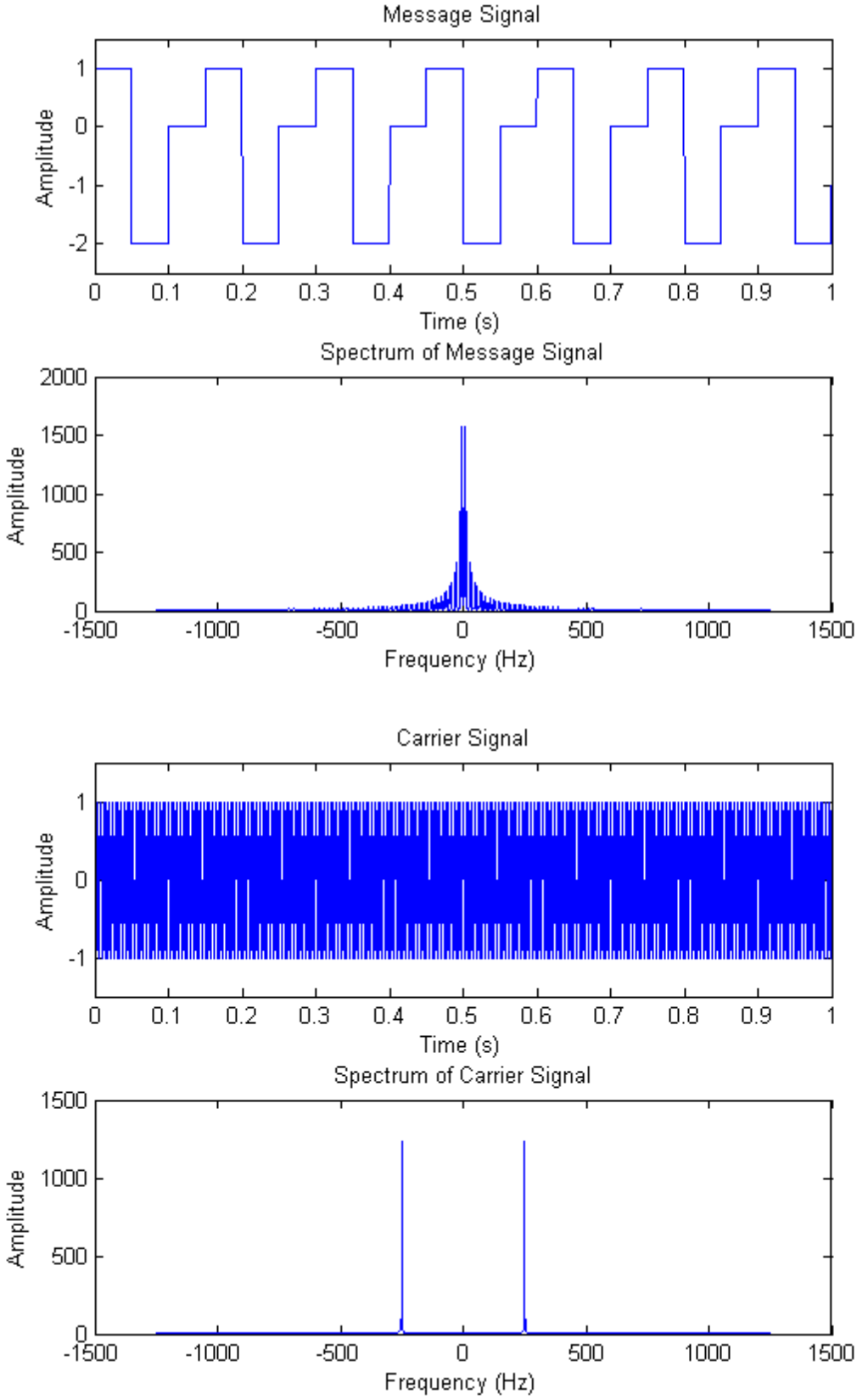
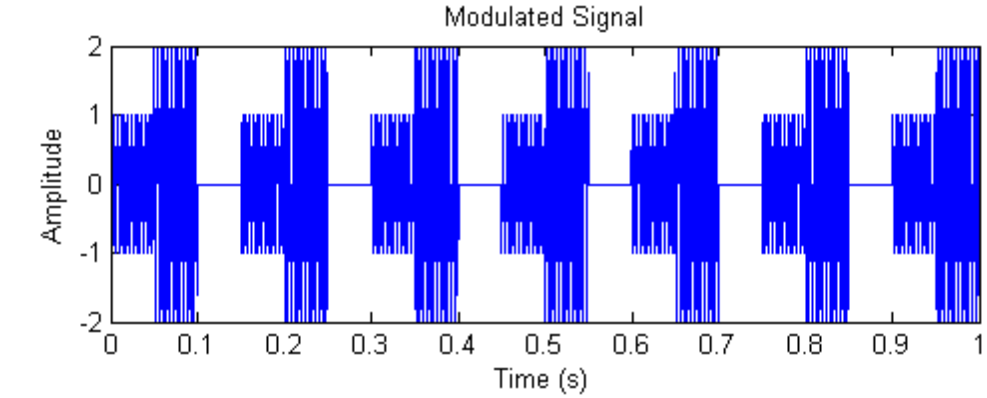
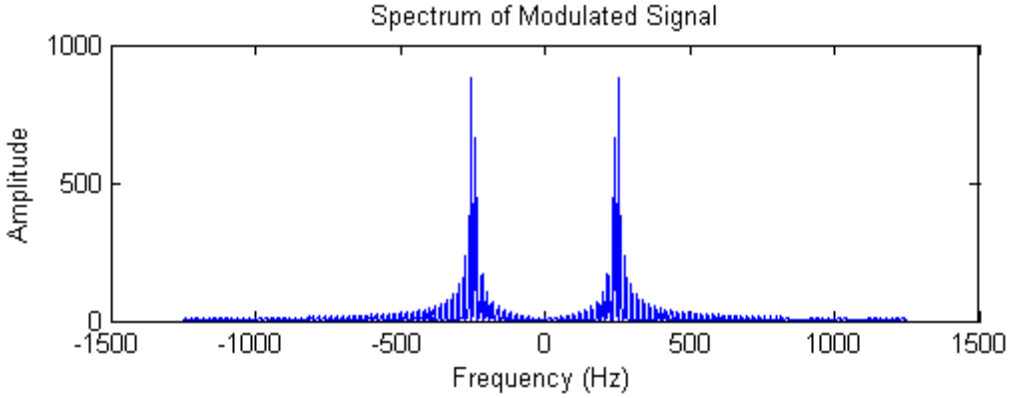
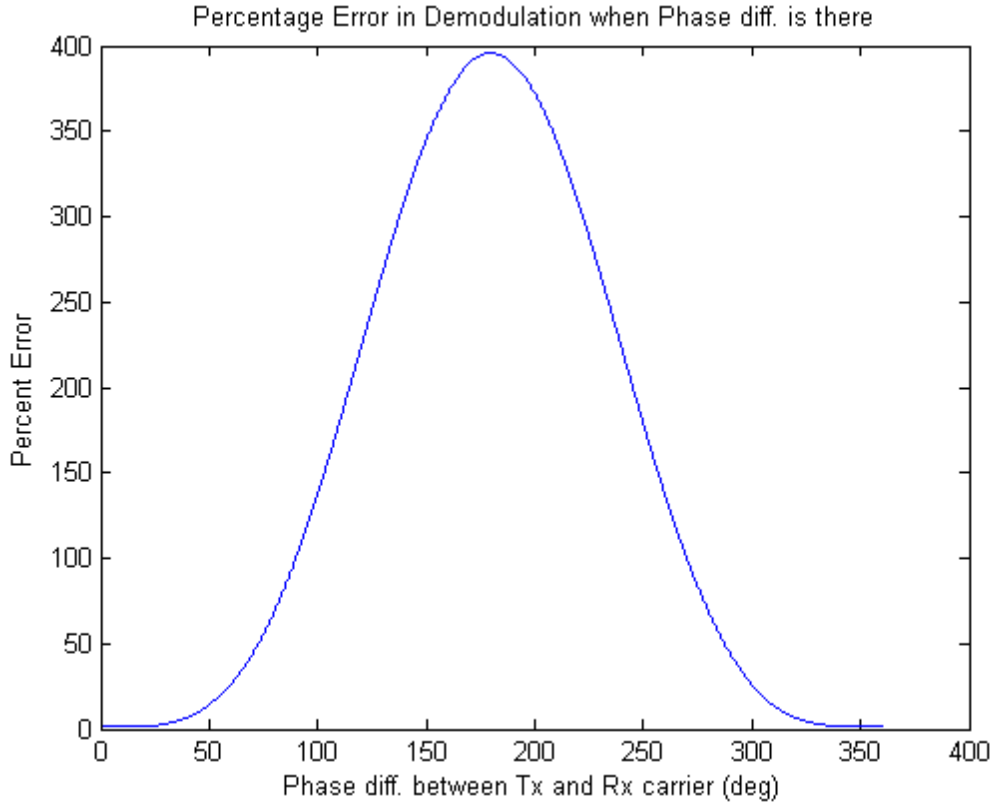
```
% Illustrative Problem 3.6
% ------------------------
clc;
clear all;
close all;

% Details given in the question
Fc = 250;
t0 = 0.15;

% Assumed values
Tstart = 0;
Tstop = 1;
Fs = 2.5 * 10^3;

% Generating time
Ts = 1 / Fs;
t = Tstart : Ts : Tstop;
N = length(t);

% Generating the message signal
tk = mod(t, t0);
m_t = (tk <= (1/3)*t0) - 2*((tk > (1/3)*t0) .* (tk <= (2/3)*t0));
figure;
subplot(2,1,1);
plot(t, m_t);
ylim([-2.5 1.5]);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(m_t))));
title('Spectrum of Message Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Calculate Message Power
m_pow = sum(m_t .^ 2) / N;

% Generating the carrier signal
c_t = cos(2*pi*Fc*t);
figure;
subplot(2,1,1);
plot(t, c_t);
title('Carrier Signal');
xlabel('Time (s)');
ylabel('Amplitude');
ylim([-1.5 1.5]);
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(c_t))));
title('Spectrum of Carrier Signal');
xlabel('Frequency (Hz)');
```

```
ylabel('Amplitude');

% Generating the modulated signal
u_t = m_t .* c_t;
figure;
subplot(2,1,1);
plot(t, u_t);
title('Modulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(u_t))));
title('Spectrum of Modulated Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Create a Low Pass Filter
lpf_N    = 128;      % Order
lpf_Fc   = Fc;       % Cutoff Frequency
lpf_flag = 'scale';  % Sampling Flag
lpf_h    = fir1(lpf_N, lpf_Fc/(Fs/2), 'low', blackman(lpf_N+1), lpf_flag);
lpf_sz   = length(lpf_h);
lpf_sz2  = floor(lpf_sz / 2);

% Calculate Percentage Error in Demodulation
phi = 0 : 0.1 : 360;
phi_N = length(phi);
p_err = zeros(1, phi_N);
for i = 1 : phi_N

    % Demodulate the modulated signal
    md1_t = u_t .* cos(2*pi*Fc*t + (phi(1, i) / 180) * pi);
    md2_t = conv(md1_t, lpf_h);
    md_t = 2 * md2_t(1, (1 + lpf_sz2) : (length(md2_t) - (lpf_sz - lpf_sz2 - 1)));

    % Calculate Error Power
    e_pow = sum((md_t - m_t) .^ 2) / N;

    % Calculate Percentage Error
    p_err(1, i) = (e_pow / m_pow) * 100;
end

% Plot the percent error in demodulation
figure;
plot(phi, p_err);
title('Percentage Error in Demodulation when Phase diff. is there');
xlabel('Phase diff. between Tx and Rx carrier (deg)');
ylabel('Percent Error');
```


Message Signal
Amplitude
Time (s)
Spectrum of Message Signal
Amplitude
Frequency (Hz)
Carrier Signal
Amplitude
Time (s)
Spectrum of Carrier Signal
Amplitude
Frequency (Hz)


Modulated Signal
Amplitude
Time (s)
2
1
0
-1
-2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Spectrum of Modulated Signal
Amplitude
Frequency (Hz)
1000
500
0
-1500
-1000
-500
0
500
1000
1500


Percentage Error in Demodulation when Phase diff. is there
Percent Error
Phase diff. between Tx and Rx carrier (deg)
400
350
300
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400

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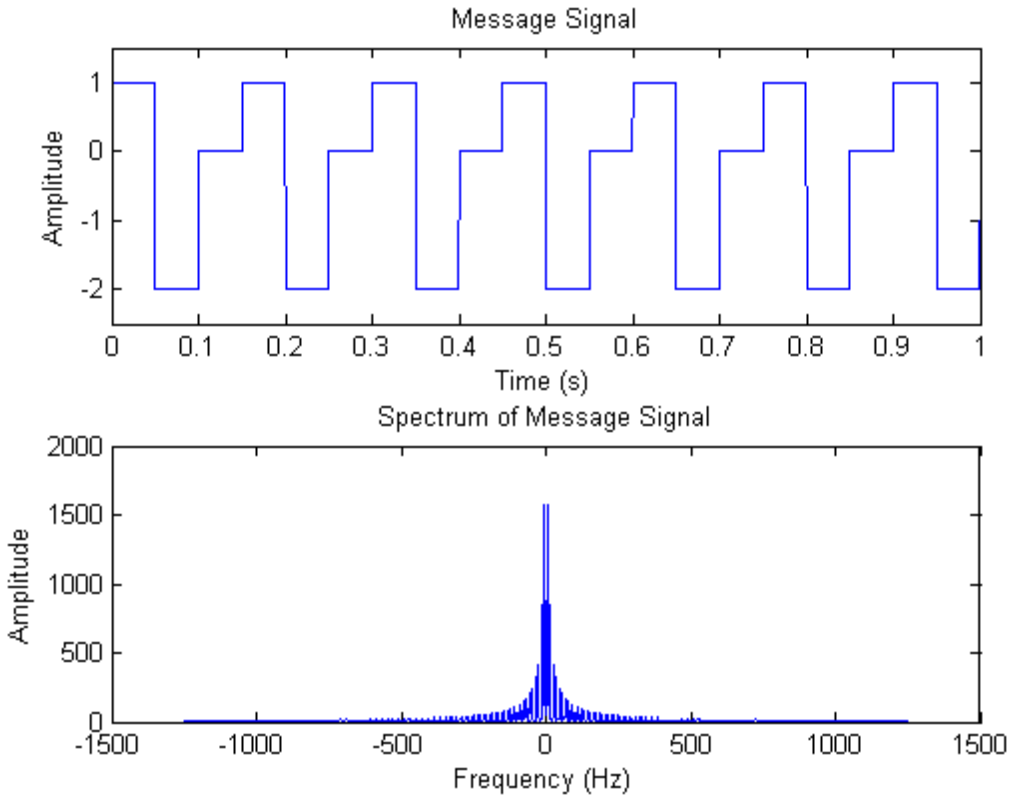
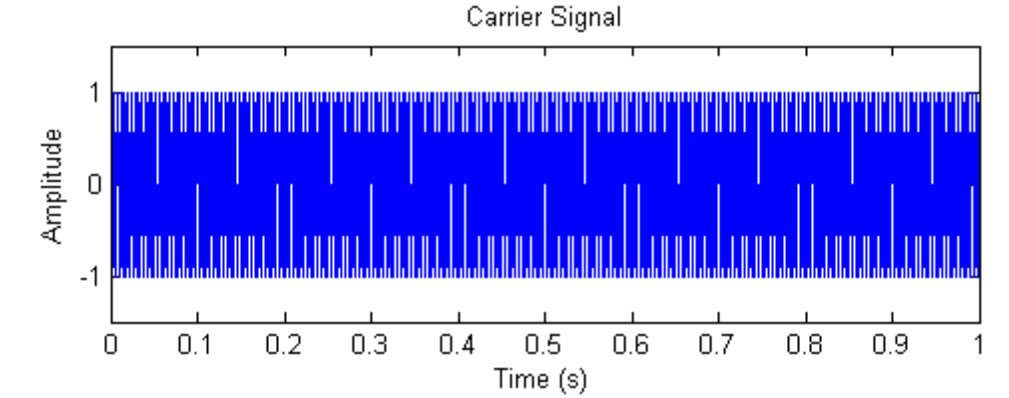
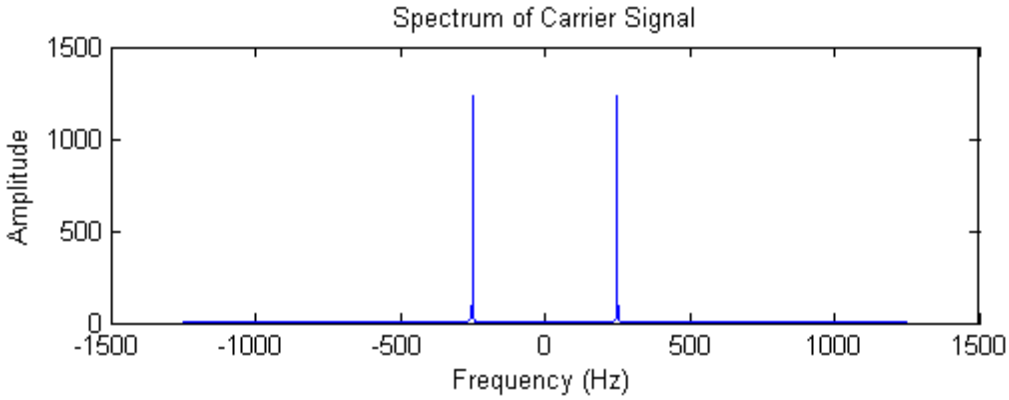
```
% Illustrative Problem 3.9
% ------------------------
clc;
clear all;
close all;

% Details given in the question
Fc = 250;
t0 = 0.15;
a = 0.85;

% Assumed values
Tstart = 0;
Tstop = 1;
Fs = 2.5 * 10^3;

% Generating time
Ts = 1 / Fs;
t = Tstart : Ts : Tstop;
N = length(t);

% Generating the message signal
tk = mod(t, t0);
m_t = (tk <= (1/3)*t0) - 2*((tk > (1/3)*t0) .* (tk <= (2/3)*t0));
figure;
subplot(2,1,1);
plot(t, m_t);
ylim([-2.5 1.5]);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(m_t))));
title('Spectrum of Message Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Generating the carrier signal
c_t = cos(2*pi*Fc*t);
figure;
subplot(2,1,1);
plot(t, c_t);
title('Carrier Signal');
xlabel('Time (s)');
ylabel('Amplitude');
ylim([-1.5 1.5]);
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(c_t))));
title('Spectrum of Carrier Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
```

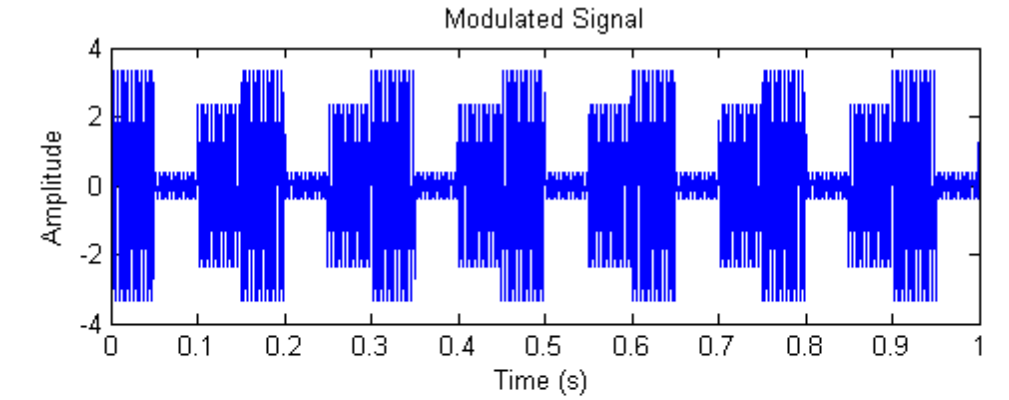
```
% Generating the modulated signal
u_t = (2/a)*c_t + m_t.*c_t;
figure;
subplot(2,1,1);
plot(t, u_t);
title('Modulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(u_t))));
title('Spectrum of Modulated Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Demodulate the modulated signal
md_t = am_envelope_detect(u_t, 1/Fs, 1/50);

% Plot the demodulated signal
figure;
subplot(2,1,1);
plot(t, md_t);
title('Demodulated Signal (using Envelope Detector)');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(md_t))));
title('Spectrum of Demodulated Signal (using Envelope Detector)');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Demodulate the modulated signal with noise
un_t = awgn(u_t, 20);
mdn_t = am_envelope_detect(un_t, 1/Fs, 1/50);

% Plot the demodulated signal with noise
figure;
subplot(2,1,1);
plot(t, mdn_t);
title('Demodulated Signal (with noise, SNR = 20dB)');
xlabel('Time (s)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(mdn_t))));
title('Spectrum of Demodulated Signal (with noise, SNR = 20dB)');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

%
% function y = am_envelope_detect(x, Ts, time_const)
% % Function to simulate envelope detection
% N = length(x);
% y = zeros(1, N);
% amp = 0;
% tp = 0;
```

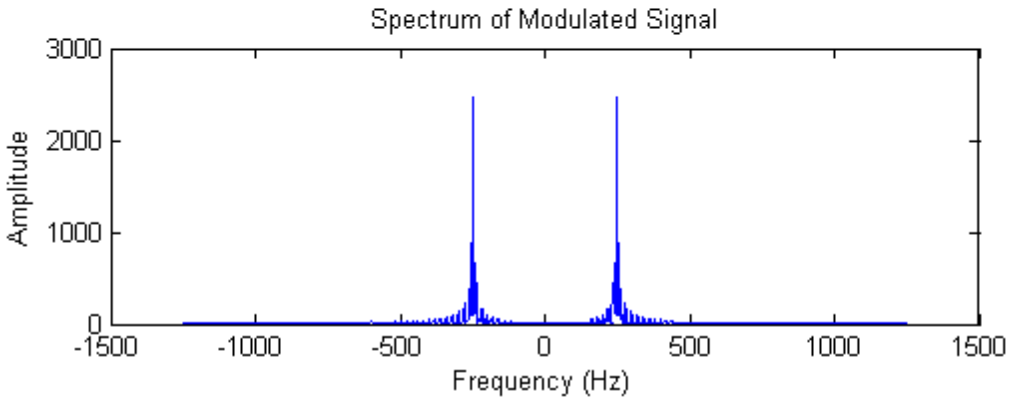
```
% for i = 1 : N
%     if(x(1, i) > (amp * exp(-tp / time_const)))
%         amp = x(1, i);
%         tp = 0;
%     else
%         tp = tp + Ts;
%     end
%     y(1, i) = amp * exp(-tp / time_const);
% end
% end
%
```

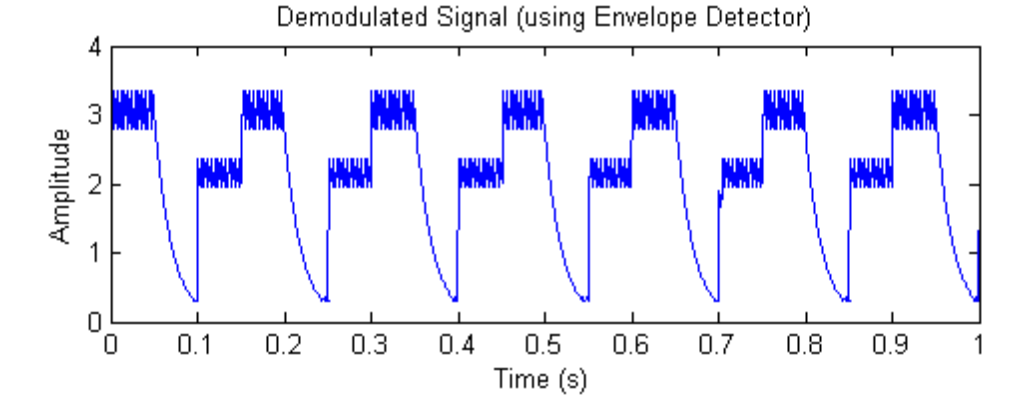


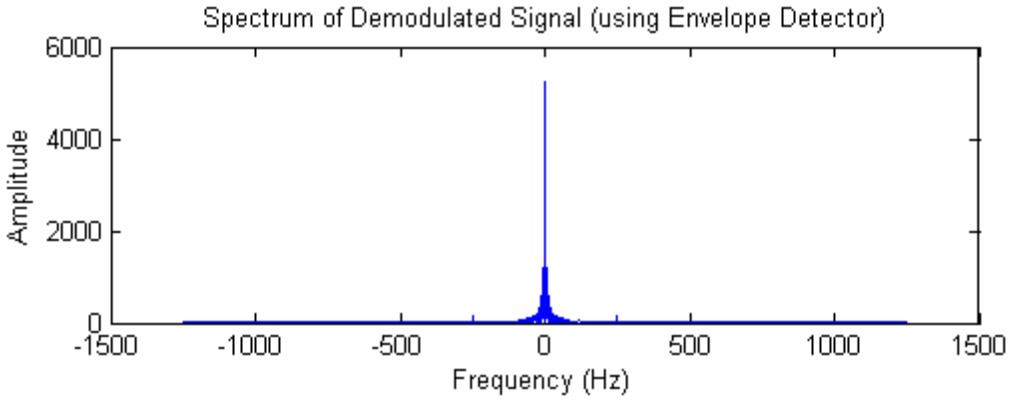

Carrier Signal
Amplitude
Time (s)

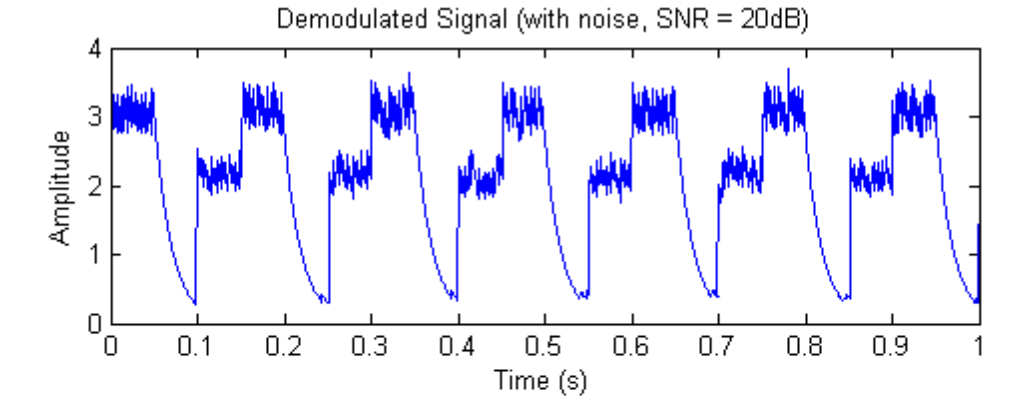

Spectrum of Carrier Signal
Amplitude
Frequency (Hz)

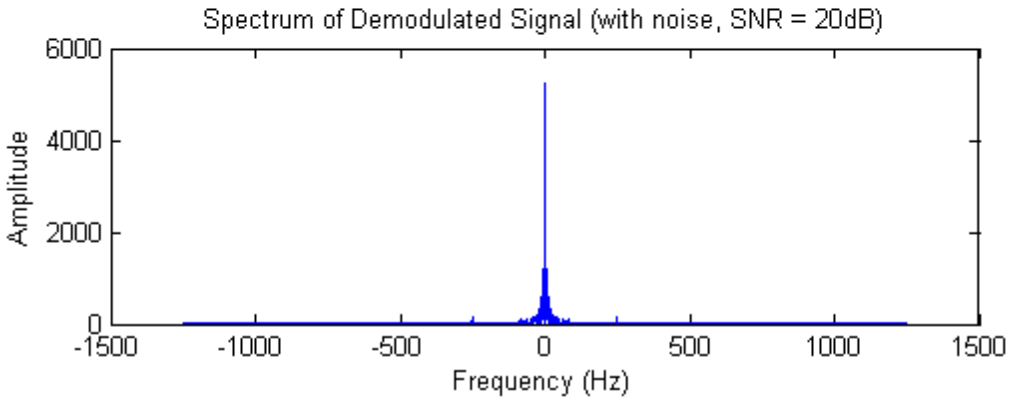

Modulated Signal
Amplitude
Time (s)


Spectrum of Modulated Signal
Amplitude
Frequency (Hz)


Demodulated Signal (using Envelope Detector)
Amplitude
Time (s)
0
1
2
3
4
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9


Spectrum of Demodulated Signal (using Envelope Detector)
Amplitude
Frequency (Hz)
0
2000
4000
6000
-1500
-1000
-500
500
1000
1500


Demodulated Signal (with noise, SNR = 20dB)
Amplitude
Time (s)
0
1
2
3
4
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9


Spectrum of Demodulated Signal (with noise, SNR = 20dB)
Amplitude
Frequency (Hz)
0
2000
4000
6000
-1500
-1000
-500
500
1000
1500

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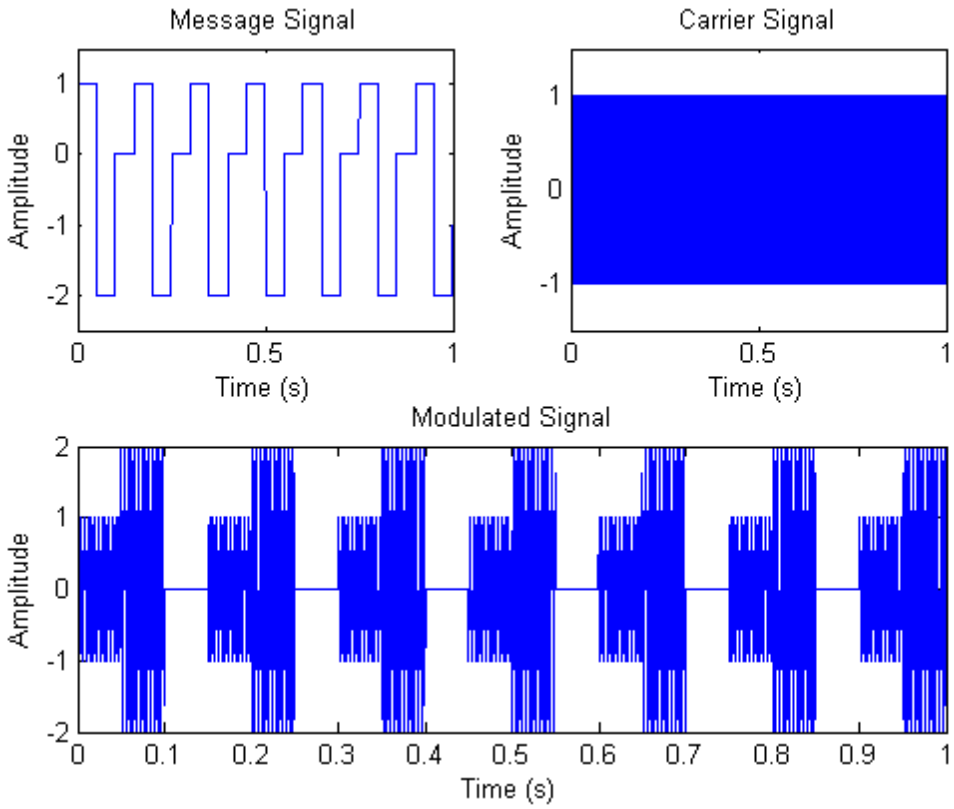
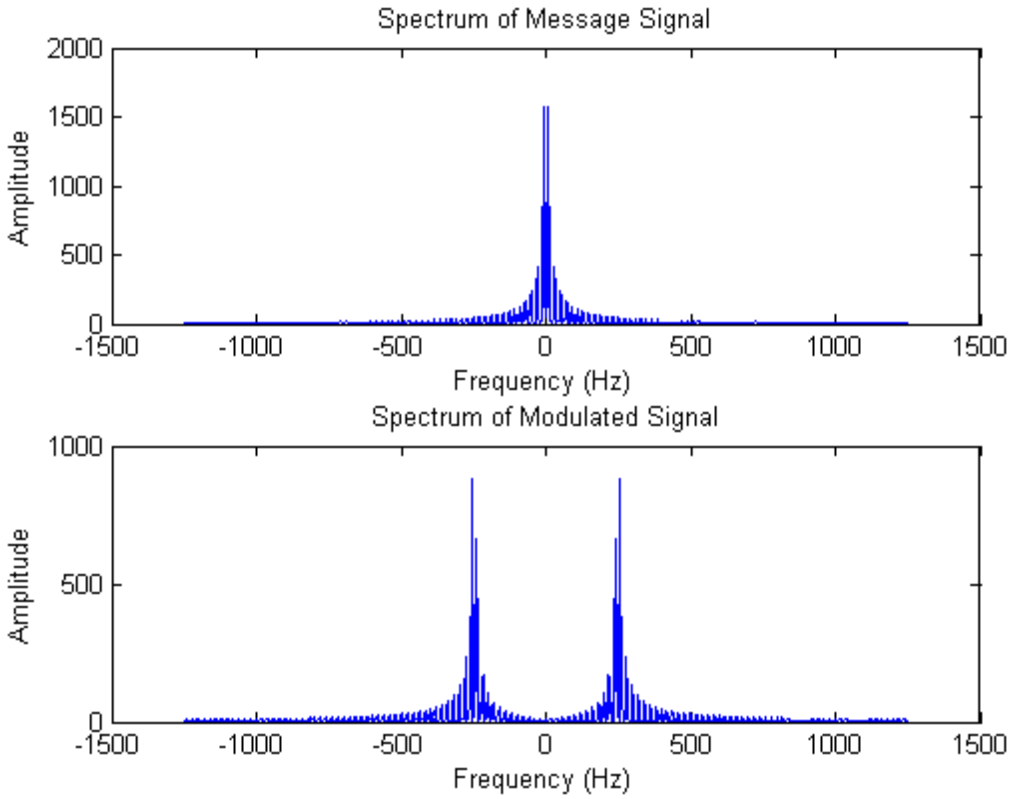
```
% Illustrative Problem 3.1
% ------------------------
clc;
clear all;
close all;

% Details given in the question
Fc = 250;
t0 = 0.15;

% Assumed values
Tstart = 0;
Tstop = 1;
Fs = 2.5 * 10^3;

% Generating time
Ts = 1 / Fs;
t = Tstart : Ts : Tstop;
N = length(t);

% Generating the message signal
tk = mod(t, t0);
m_t = (tk <= (1/3)*t0) - 2*((tk > (1/3)*t0) .* (tk <= (2/3)*t0));
subplot(2,2,1);
plot(t, m_t);
ylim([-2.5 1.5]);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');

% Generating the carrier signal
c_t = cos(2*pi*Fc*t);
subplot(2,2,2);
plot(t, c_t);
title('Carrier Signal');
xlabel('Time (s)');
ylabel('Amplitude');
ylim([-1.5 1.5]);

% Generating the modulated signal
u_t = m_t .* c_t;
subplot(2,2,3:4);
plot(t, u_t);
title('Modulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');

% Plot Spectra
figure;
subplot(2,1,1);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(m_t))));
title('Spectrum of Message Signal');
```

```
xlabel('Frequency (Hz)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(u_t))));
title('Spectrum of Modulated Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Calculate power
u_pow = sum(u_t .^ 2) / N;
fprintf(1, 'Power of modulated signal u(t) = %f / %f\n\n', u_pow);

% Calculate Noise Power
SNR = 10;
n_pow = u_pow / (10 ^ (SNR/10));
fprintf(1, 'Noise power = %f\n\n', n_pow);
```

Power of modulated signal u(t) = 0.873850 / Noise power = 0.087385





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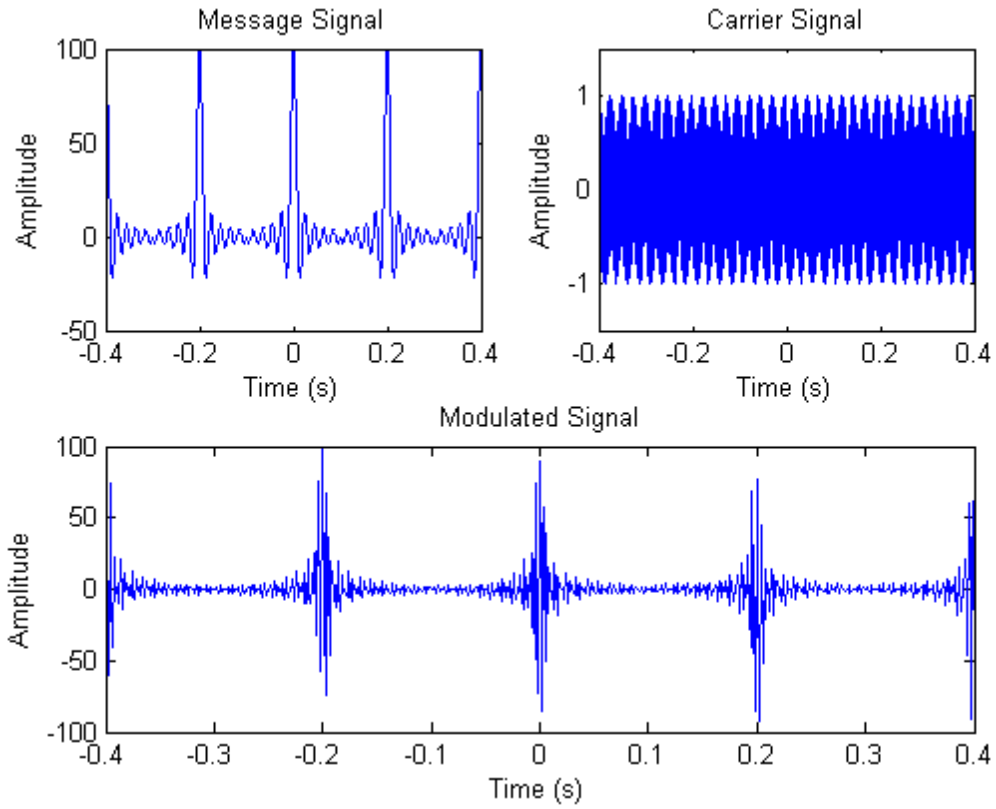
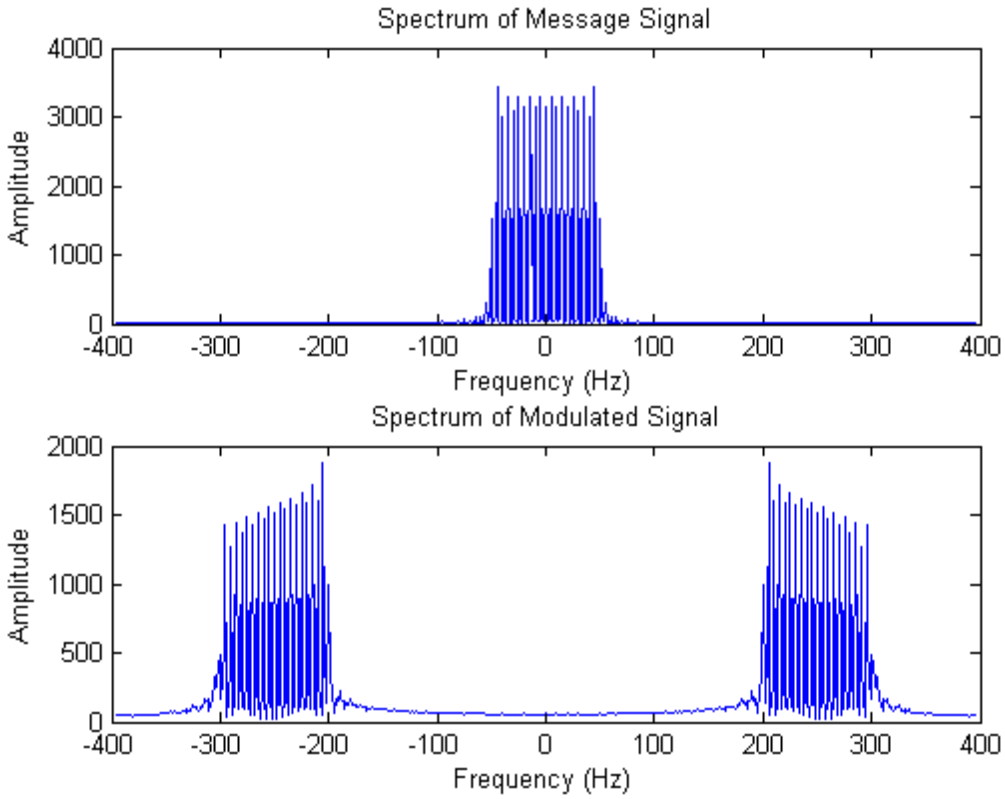
```
% Illustrative Problem 3.2
% ------------------------
clc;
clear all;
close all;

% Details given in the question
Fc = 250;
t0 = 0.1;
T0 = 0.2;

% Assumed values
Tstart = -0.4;
Tstop = 0.4;
Fs = 2.5 * 10^2.5;

% Generating time
Ts = 1 / Fs;
t = Tstart : Ts : Tstop;
N = length(t);

% Generating the message signal
tk = mod(t - (T0/2), T0) - (T0/2);
m_t = (sin(pi*100*tk)./(pi*tk));
for i = 1 : N
    if(isnan(m_t(1, i)))
        m_t(1, i) = 100;
    end
end
subplot(2,2,1);
plot(t, m_t);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');

% Generating the carrier signal
c_t = cos(2*pi*Fc*t);
subplot(2,2,2);
plot(t, c_t);
title('Carrier Signal');
xlabel('Time (s)');
ylabel('Amplitude');
ylim([-1.5 1.5]);

% Generating the modulated signal
u_t = m_t .* c_t;
subplot(2,2,3:4);
plot(t, u_t);
title('Modulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');
```

```
% Plot Spectra
figure;
subplot(2,1,1);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(m_t))));
title('Spectrum of Message Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(u_t))));
title('Spectrum of Modulated Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Calculate power
u_pow = sum(u_t .^ 2) / N;
fprintf(1, 'Power of modulated signal u(t) = %f\n\n', u_pow);

% Calculate Noise Power
SNR = 10;
n_pow = u_pow / (10 ^ (SNR/10));
fprintf(1, 'Noise power = %f\n\n', n_pow);
```

Power of modulated signal u(t) = 256.285285

Noise power = 25.628529





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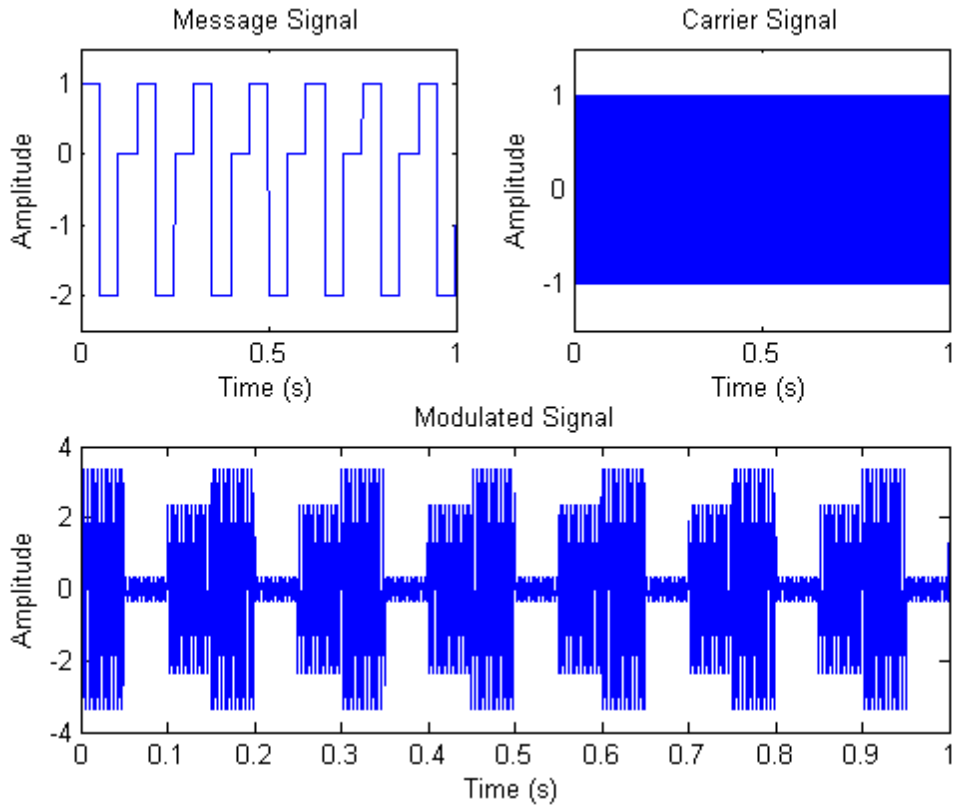
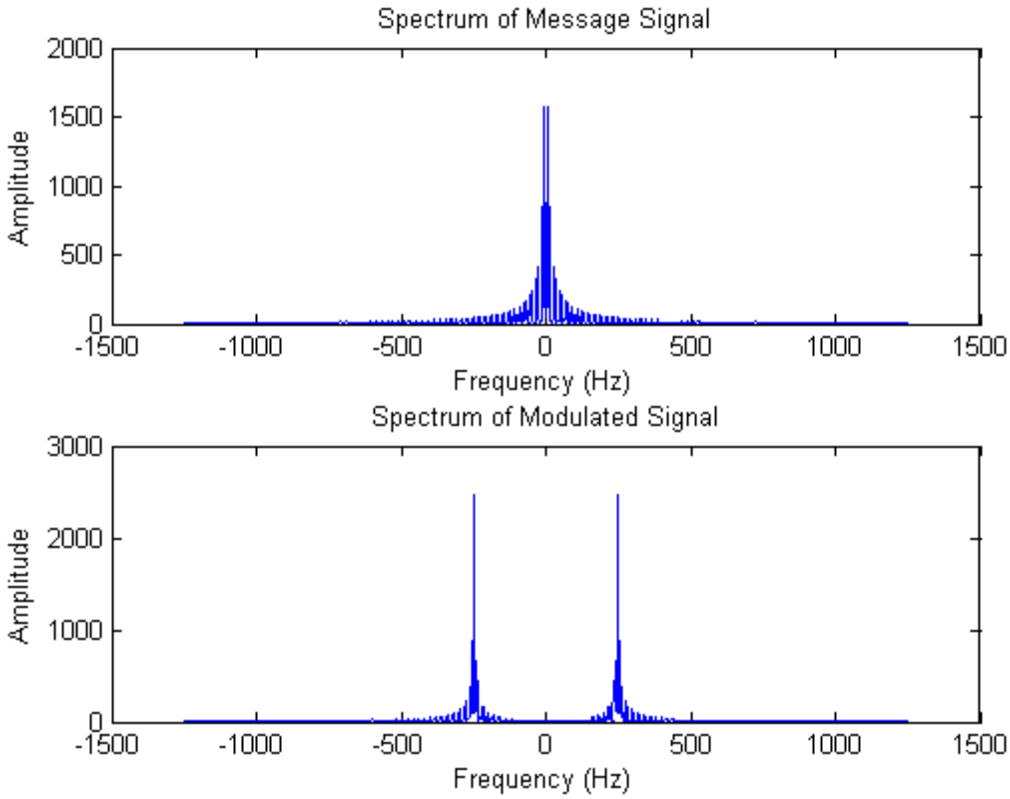
```
% Illustrative Problem 3.3
% ------------------------
clc;
clear all;
close all;

% Details given in the question
Fc = 250;
t0 = 0.15;
a = 0.85;

% Assumed values
Tstart = 0;
Tstop = 1;
Fs = 2.5 * 10^3;

% Generating time
Ts = 1 / Fs;
t = Tstart : Ts : Tstop;
N = length(t);

% Generating the message signal
tk = mod(t, t0);
m_t = (tk <= (1/3)*t0) - 2*((tk > (1/3)*t0) .* (tk <= (2/3)*t0));
subplot(2,2,1);
plot(t, m_t);
ylim([-2.5 1.5]);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');

% Generating the carrier signal
c_t = cos(2*pi*Fc*t);
subplot(2,2,2);
plot(t, c_t);
title('Carrier Signal');
xlabel('Time (s)');
ylabel('Amplitude');
ylim([-1.5 1.5]);

% Generating the modulated signal
u_t = (2/a)*c_t + m_t.*c_t;
subplot(2,2,3:4);
plot(t, u_t);
title('Modulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');

% Plot Spectra
figure;
subplot(2,1,1);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(m_t))));
```

```
title('Spectrum of Message Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(u_t))));
title('Spectrum of Modulated Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');

% Calculate power
u_pow = sum(u_t .^ 2) / N;
fprintf(1, 'Power of modulated signal u(t) = %f\n', u_pow);
m_pow = sum(m_t .^2) / N;
u_eff = m_pow / u_pow;
fprintf(1, 'Efficiency of modulated signal u = %f\n', u_eff);

% Calculate Noise Power
SNR = 10;
n_pow = u_pow / (10 ^ (SNR/10));
fprintf(1, 'Noise power = %f\n\n', n_pow);
```

Power of modulated signal u(t) = 2.827450

Efficiency of modulated signal u = 0.618402
Noise power = 0.282745





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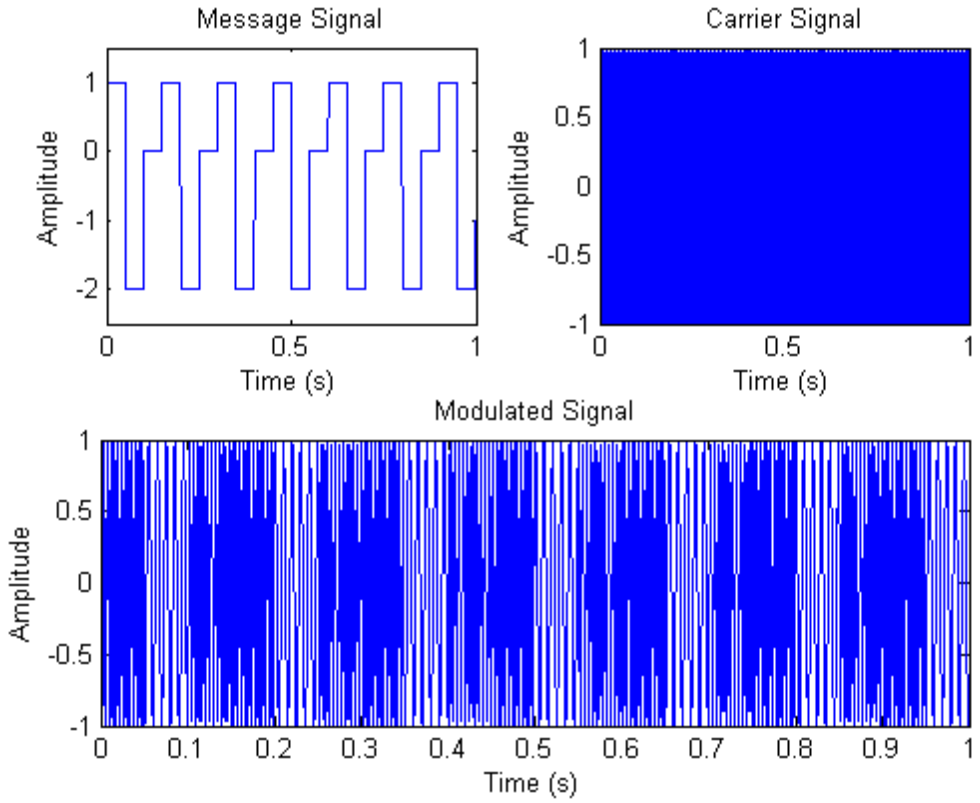
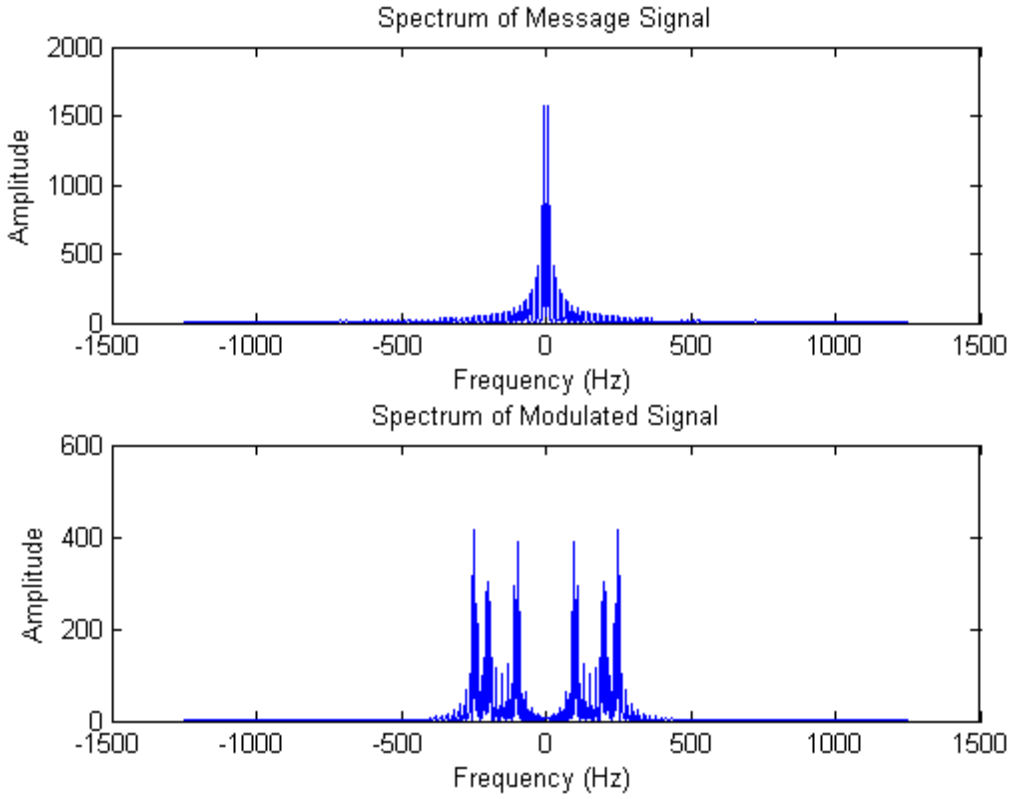
```
% Question 3.10
% -------------
clc;
clear all;
close all;

% Details given in the question
Fc = 200;
t0 = 0.15;
kf = 50;

% Assumed values
Tstart = 0;
Tstop = 1;
Fs = 2.5 * 10^3;

% Generating time
Ts = 1 / Fs;
t = Tstart : Ts : Tstop;
N = length(t);

% Generating the message signal
tk = mod(t, t0);
m_t = (tk <= (1/3)*t0) - 2*((tk > (1/3)*t0) .* (tk <= (2/3)*t0));
subplot(2,2,1);
plot(t, m_t);
ylim([-2.5 1.5]);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');

% Generating the carrier signal
c_t = zeros(1, N);
for i = 1 : N
    c_t(1, i) = 1 * cos(2*pi*Fc*t(1, i));
end
subplot(2,2,2);
plot(t, c_t);
title('Carrier Signal');
xlabel('Time (s)');
ylabel('Amplitude');

% Generating the modulated signal
u_t = zeros(1, N);
sum = 0;
for i = 1 : N
    sum = sum + m_t(1, i);
    u_t(1, i) = 1 * cos(2*pi*Fc*t(1, i) + 2*pi*kf*(sum / Fs));
end
subplot(2,2,3:4);
plot(t, u_t);
title('Modulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');

% Plot Spectra
figure;
subplot(2,1,1);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(m_t))));
title('Spectrum of Message Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
subplot(2,1,2);
```

```
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(u_t))));
title('Spectrum of Modulated Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
```





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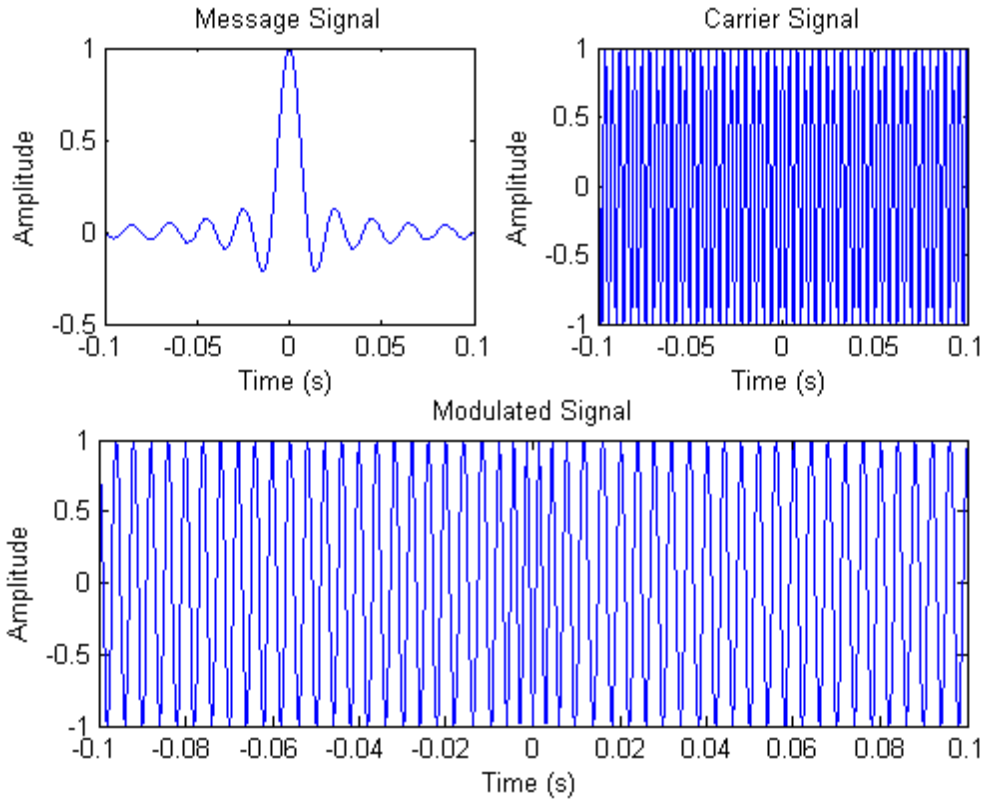
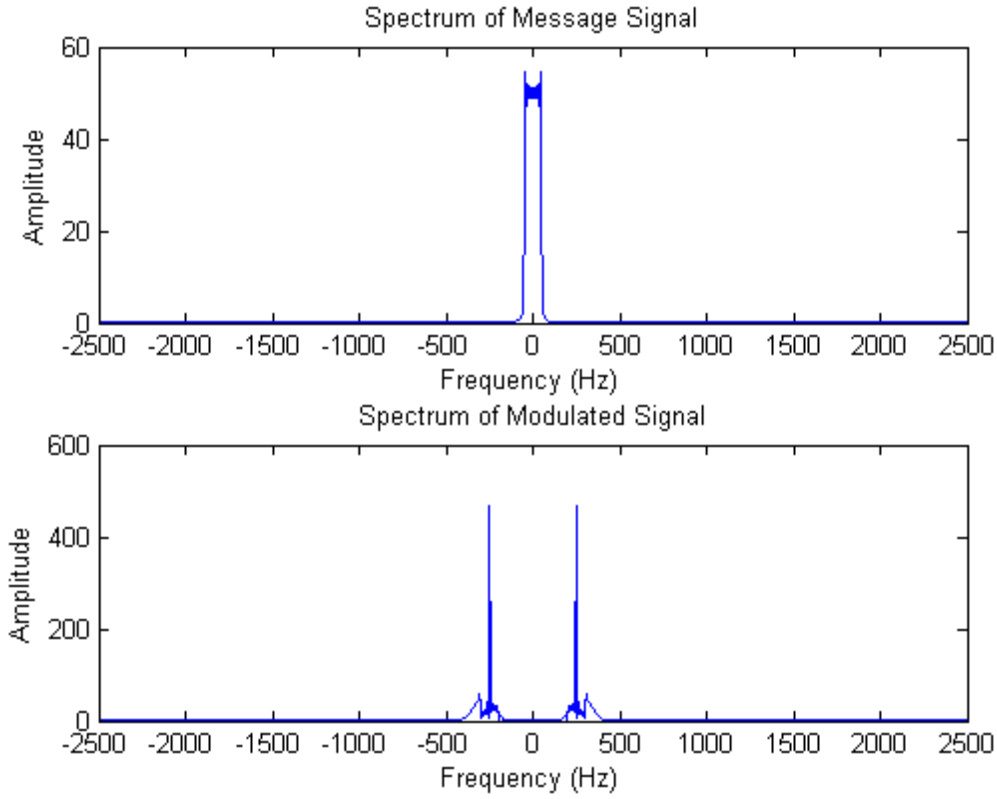
```
% Question 3.11
% --------------
clc;
clear all;
close all;

% Details given in the question
Fc = 250;
t0 = 0.1;
kf = 100;
T0 = 2*t0;

% Assumed values
Tstart = -0.1;
Tstop = 0.1;
Fs = 5000;

% Generating time
Ts = 1 / Fs;
t = Tstart : Ts : Tstop;
N = length(t);

% Generating the message signal
tk = mod(t - (T0/2), T0) - (T0/2);
m_t = sinc(100*t);
for i = 1 : N
    if(isnan(m_t(1, i)))
        m_t(1, i) = 100;
    end
end
subplot(2,2,1);
plot(t, m_t);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');

% Generating the carrier signal
c_t = zeros(1, N);
for i = 1 : N
    c_t(1, i) = 1 * cos(2*pi*Fc*t(1, i));
end
subplot(2,2,2);
plot(t, c_t);
title('Carrier Signal');
xlabel('Time (s)');
ylabel('Amplitude');

% Generating the modulated signal
u_t = zeros(1, N);
sum = 0;
for i = 1 : N
    sum = sum + m_t(1, i);
    u_t(1, i) = 1 * cos(2*pi*Fc*t(1, i) + 2*pi*kf*(sum / Fs));
end
subplot(2,2,3:4);
plot(t, u_t);
title('Modulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');

% Plot Spectra
figure;
subplot(2,1,1);
```

```
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(m_t))));
title('Spectrum of Message Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
subplot(2,1,2);
plot(linspace(-Fs/2, Fs/2, N), abs(fftshift(fft(u_t))));
title('Spectrum of Modulated Signal');
xlabel('Frequency (Hz)');
ylabel('Amplitude');
```





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