Chapter 3

Problem 3.1

1) Figures 25 and 26 present the message and modulated signals, respectively.
2) Spectrum of $m(t)$ and $u(t)$ are given in Figures 27 and 28, respectively.
3) Figures 29, 30, 31 and 32 present the message signal, modulated signal, spectrum of the message signal and the spectrum of the modulated signal for $t_0 = 0.4$.

The MATLAB script for this problem follows.

```
% MATLAB script for Computer Problem 3.1.
% Matlab demonstration script for DSB-AM modulation. The message signal
% is m(t)=sinc(100t).
echo off
t0=.4;                     % signal duration
ts=0.0001;                 % sampling interval
fc=250;                    % carrier frequency
snr=20;                    % SNR in dB (logarithmic)
fs=1/ts;                   % sampling frequency
df=0.3;                                      % required freq. resolution
t=[0:ts:t0];               % time vector
snr_lin=10^(snr/10);             % linear SNR
m=sinc(100*t);                 % the message signal
c=cos(2*pi*fc.*t);             % the carrier signal
u=m.*c;                    % the DSB-AM modulated signal
[M,m,df1]=fftseq(m,ts,df);                   % Fourier transform
M=M/fs;                                      % scaling
[U,u,df1]=fftseq(u,ts,df);                   % Fourier transform
U=U/fs;                                      % scaling
f=[0:df1:df1*(length(m)-1)]-fs/2;            % frequency vector
% plot the message signal
figure;
plot(t,m(1:length(t)))
xlabel('Time')
% plot the modulated signal.
figure;
plot(t,u(1:length(t)))
xlabel('Time')
% plot the magnitude of the message and the
% modulated signal in the frequency domain.
figure;
plot(f,abs(fftshift(M)))
xlabel('Frequency')
axis([-1000 1000 0 9*10^(-3)]);
figure;
plot(f,abs(fftshift(U)))
xlabel('Frequency')
axis([-1000 1000 0 4.5*10^(-3)]);
```

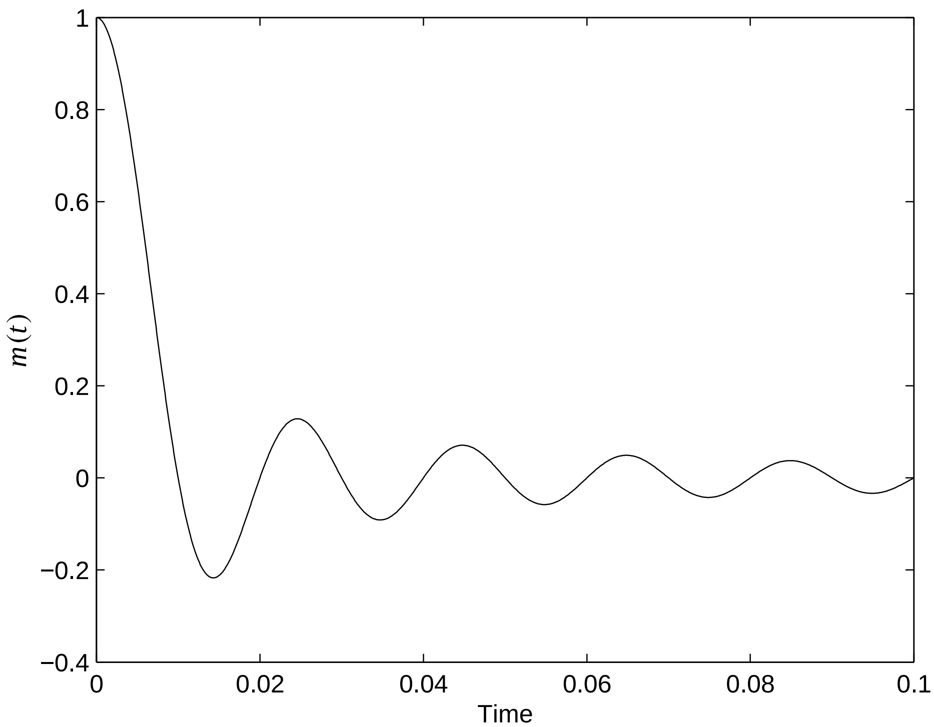

Figure 25: The message signal $m(t)$

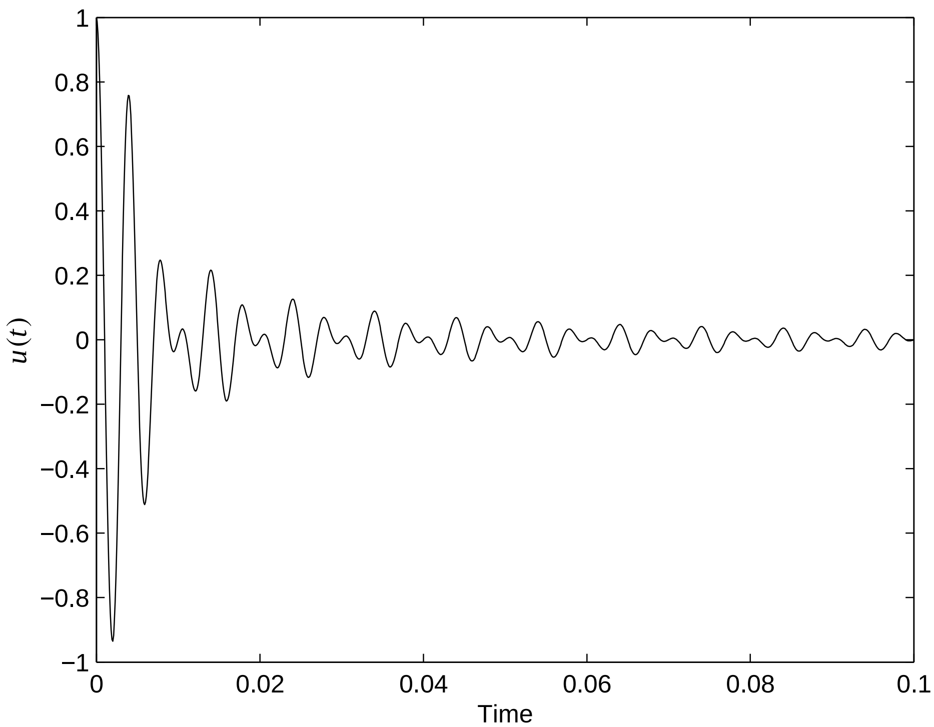

Figure 26: The modulated signal $u(t)$

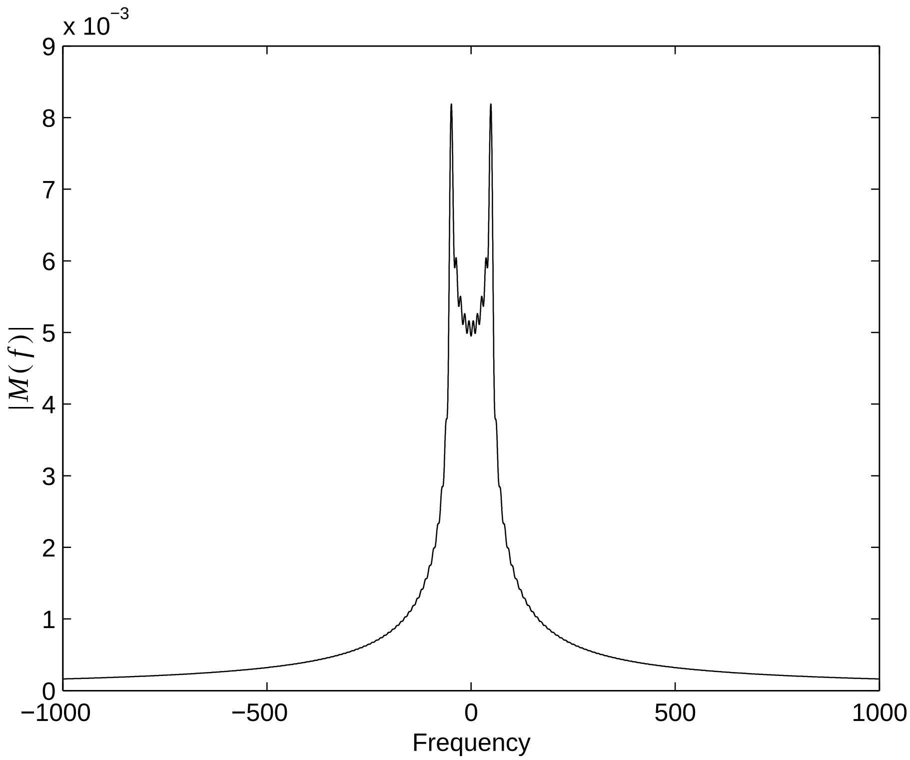

Figure 27: The spectrum of the message signal

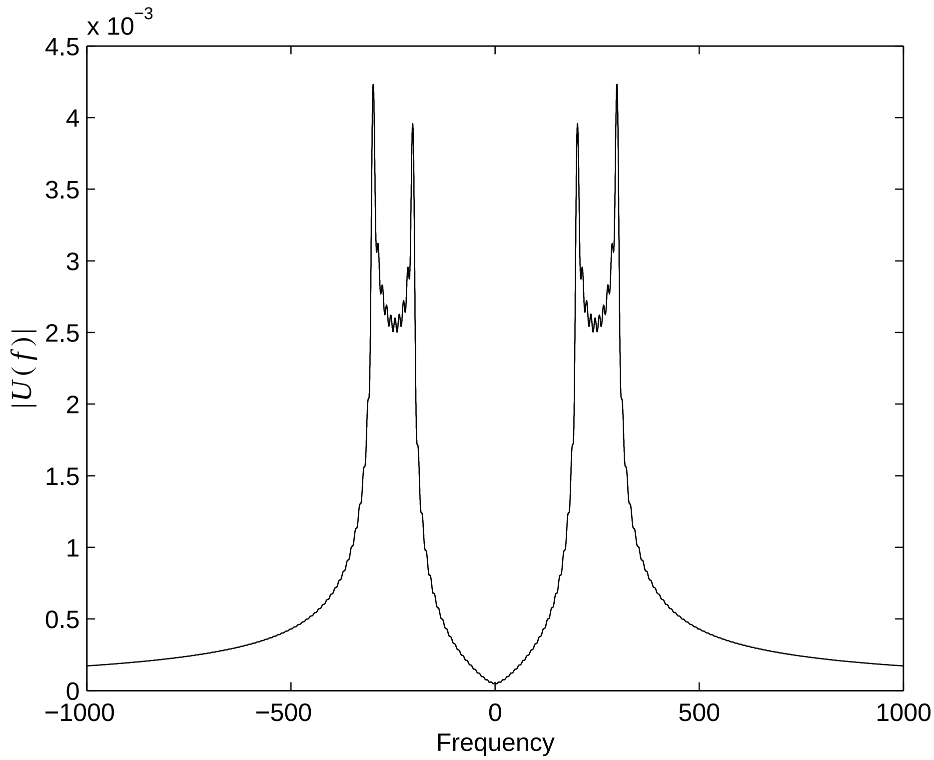

Figure 28: The message of the modulated signal

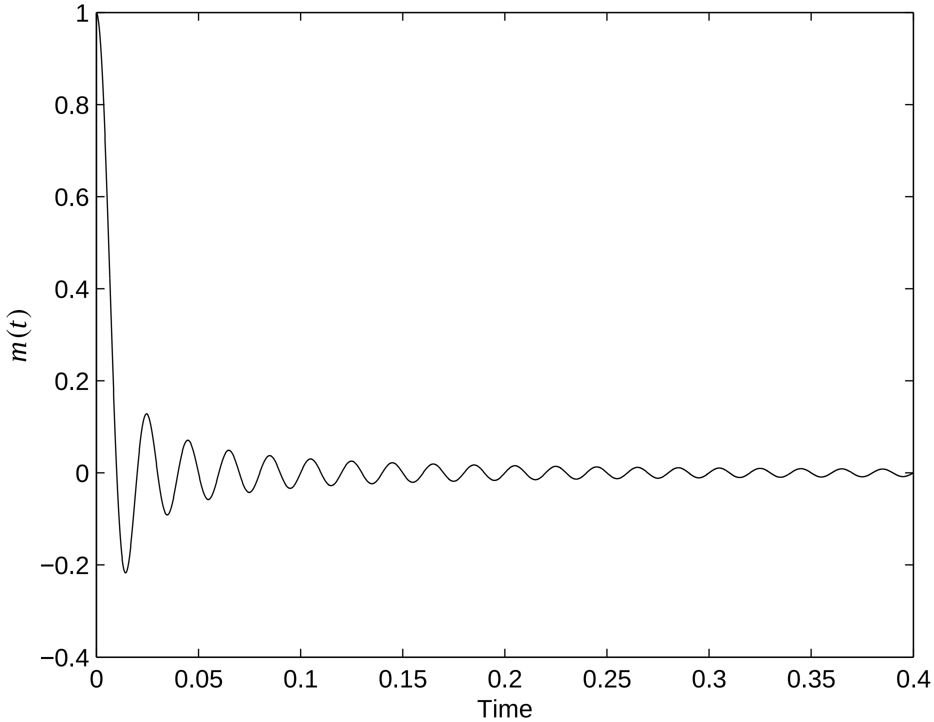

Figure 29: The message signal $m(t)$ for $t_0 = 0.4$

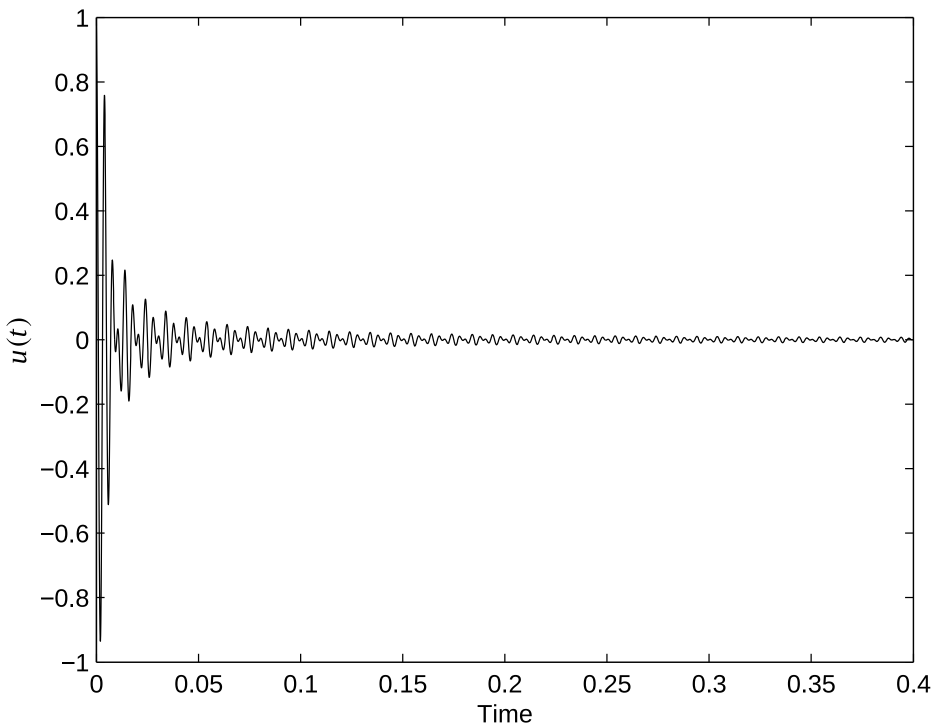

Figure 30: The modulated signal $u(t)$ for $t_0 = 0.4$

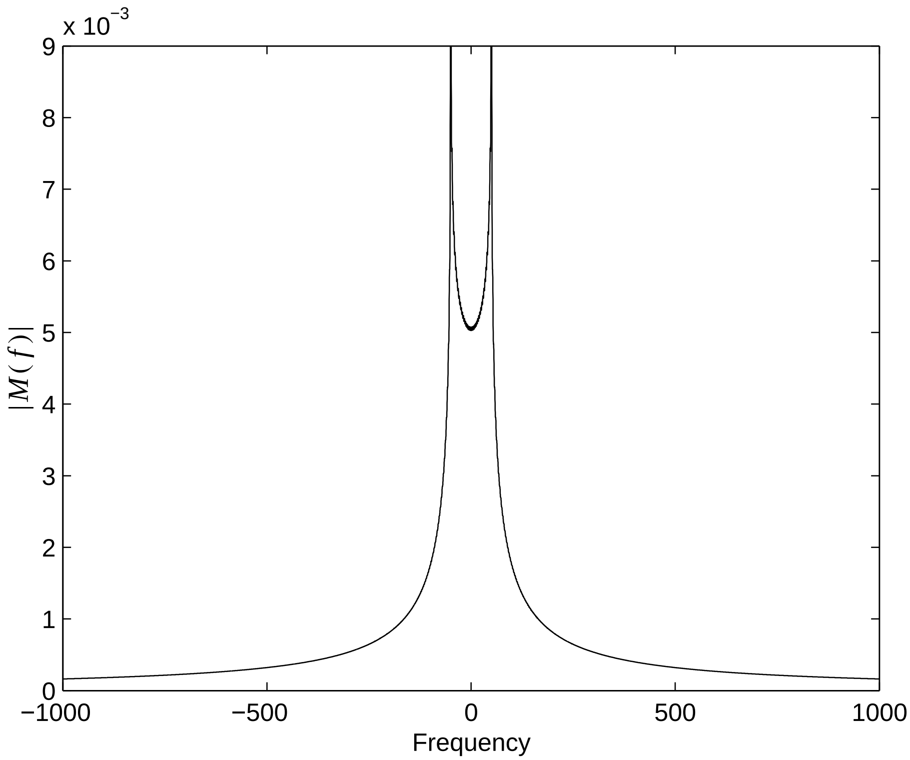

Figure 31: The spectrum of the message signal for $t_0 = 0.4$

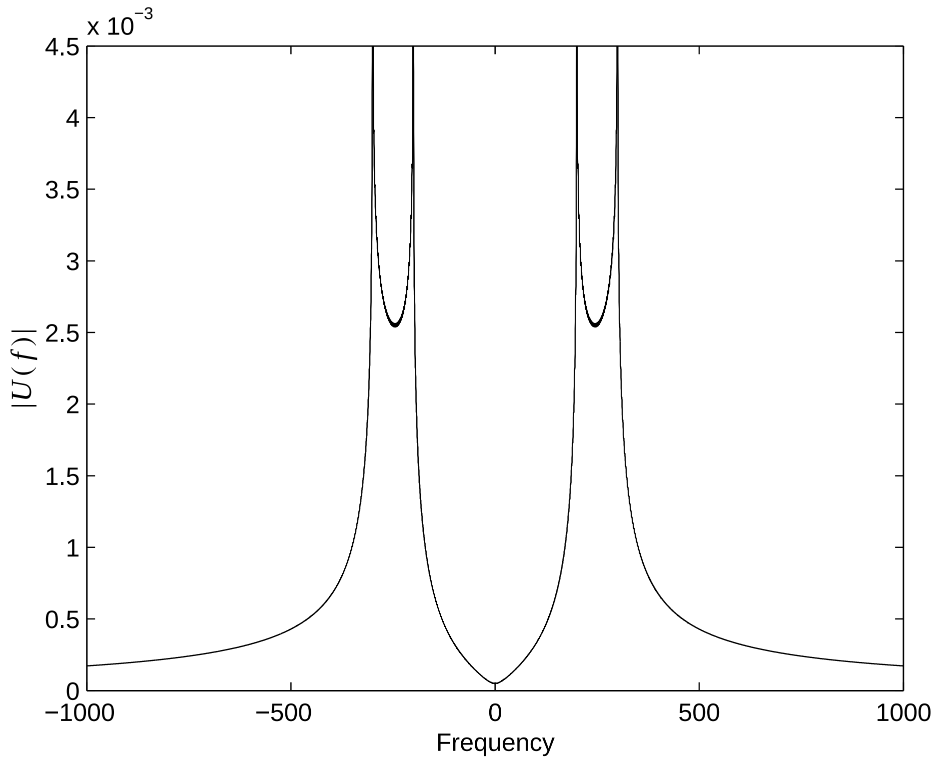

Figure 32: The spectrum of the modulated signal for $t_0 = 0.4$

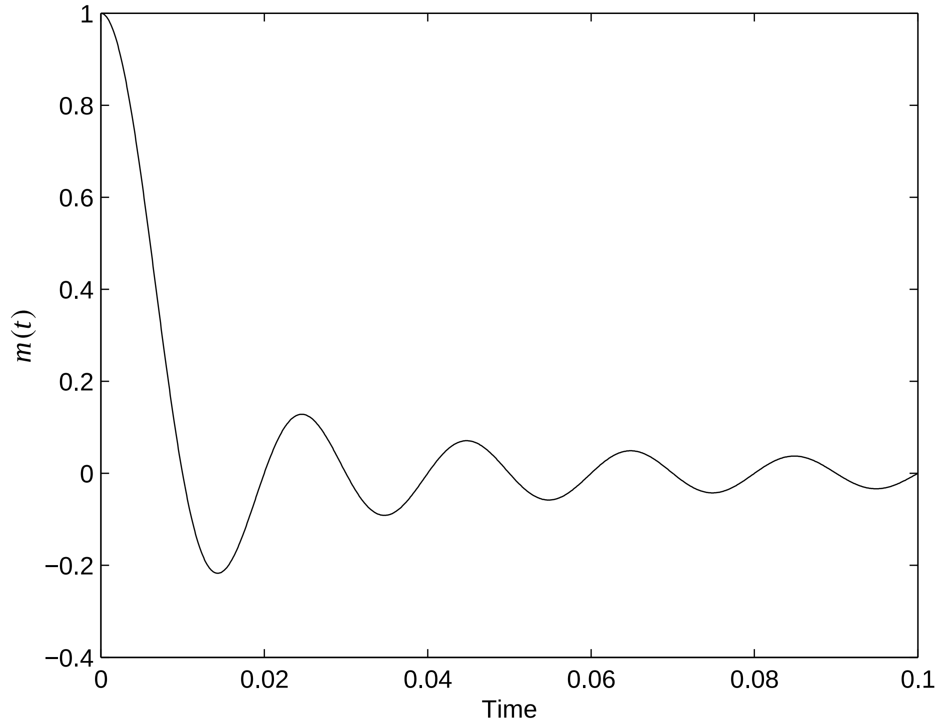

Figure 33: The message signal $m(t)$

Problem 3.2
The message signal $m(t)$ and the modulated signal $u(t)$ are presented in Figures 33 and 34, respectively.
2)The spectrum of the message signal is presented in Figure 35. Figure 36 presents the spectrum of the modulated signal $u(t)$.
3) Figures 37, 38, 39 and 40 present the message signal, modulated signal, spectrum of the message signal and the spectrum of the modulated signal for $t_0 = 0.4$.
The MATLAB script for this problem follows.

```
% MATLAB script for Computer Problem 3.2.
t0=.1;                          % signal duration
n=0:1000;
ts=0.0001;                      % sampling interval
df=0.2;                         % frequency resolution
fs=1/ts;                        % sampling frequency
fc=250;                         % carrier frequency
a=0.8;                          % modulation index
t=[0:ts:t0];                    % time vector
m = sinc(100*t);                 % message signal
c=cos(2*pi*fc.*t);              % carrier signal
m_n=m/max(abs(m));              % normalized message signal
[M,m,df1]=fftseq(m,ts,df);      % Fourier transform
M=M/fs;                         % scaling
```

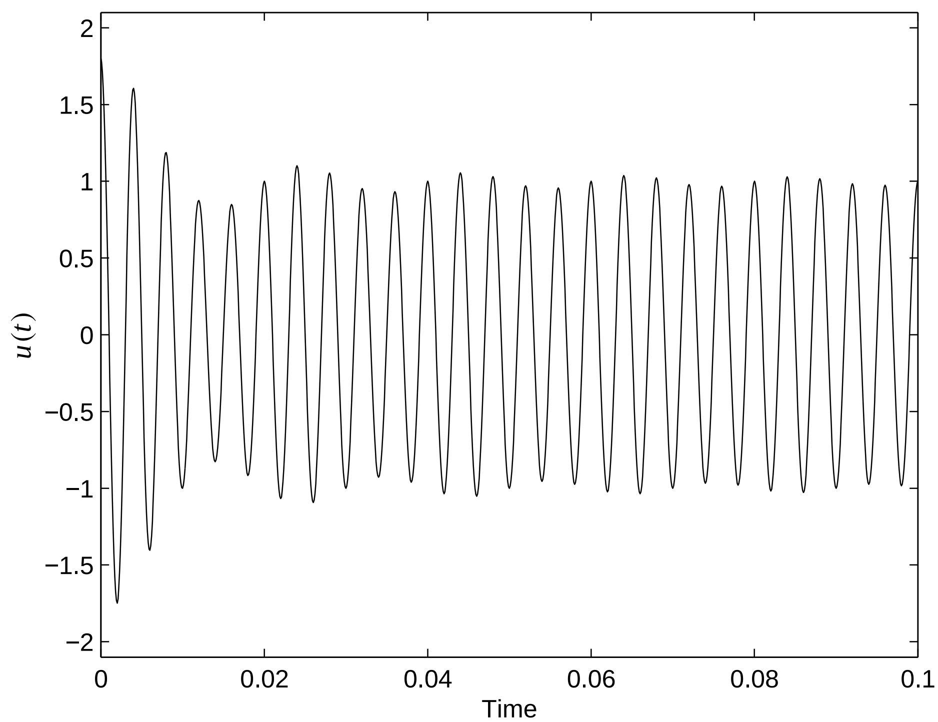

Figure 34: The modulated signal $u(t)$

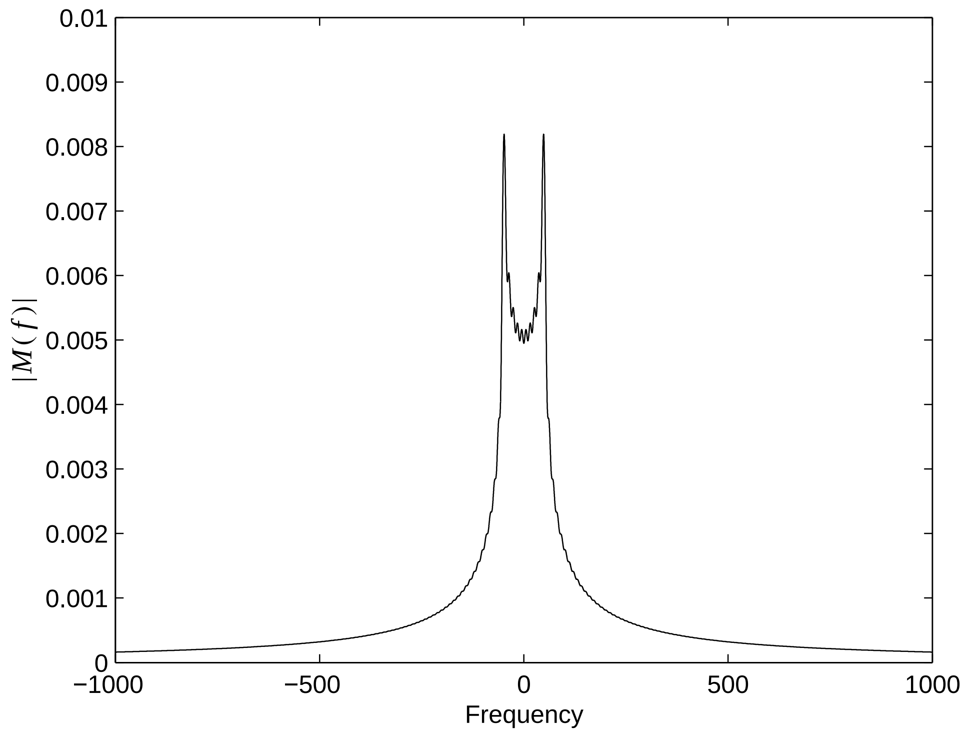

Figure 35: The spectrum of the message signal

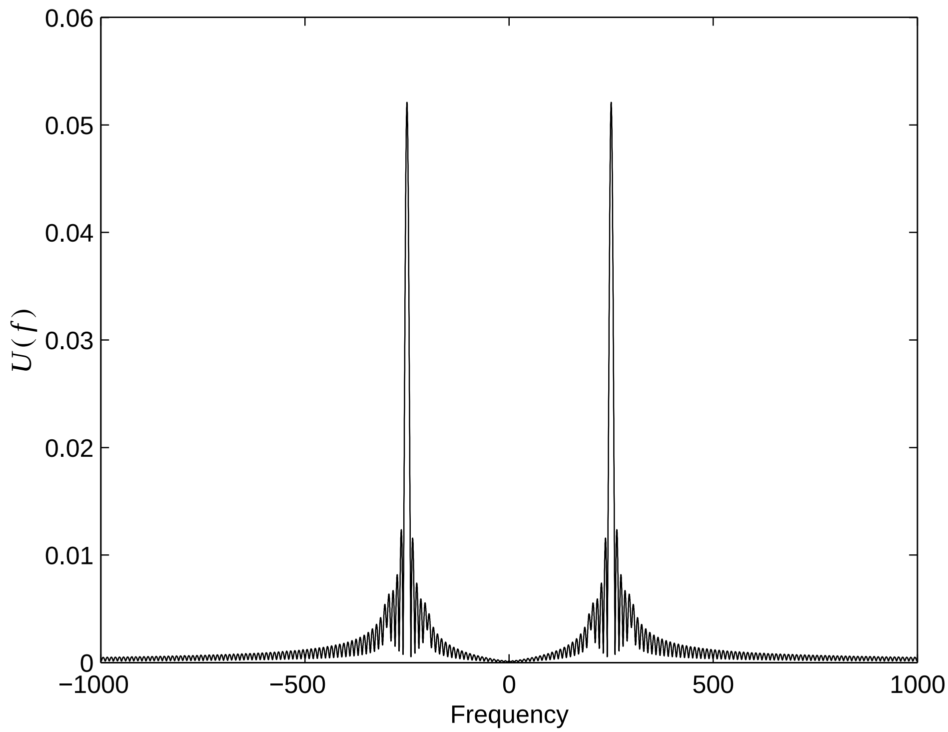

Figure 36: The spectrum of the modulated signal

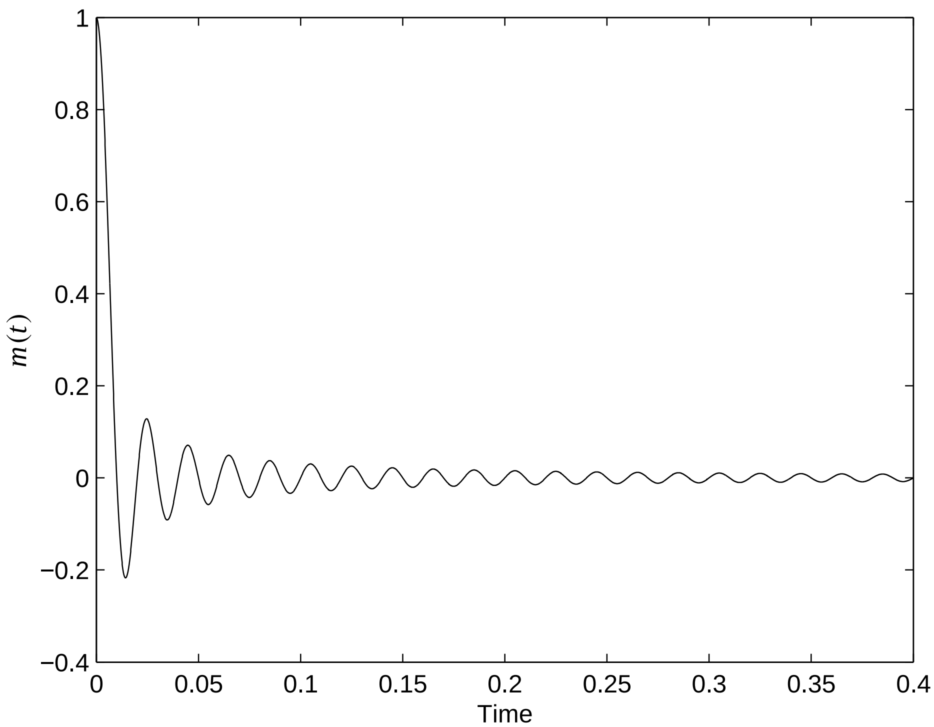

Figure 37: The message signal $m(t)$ for $t_0 = 0.4$

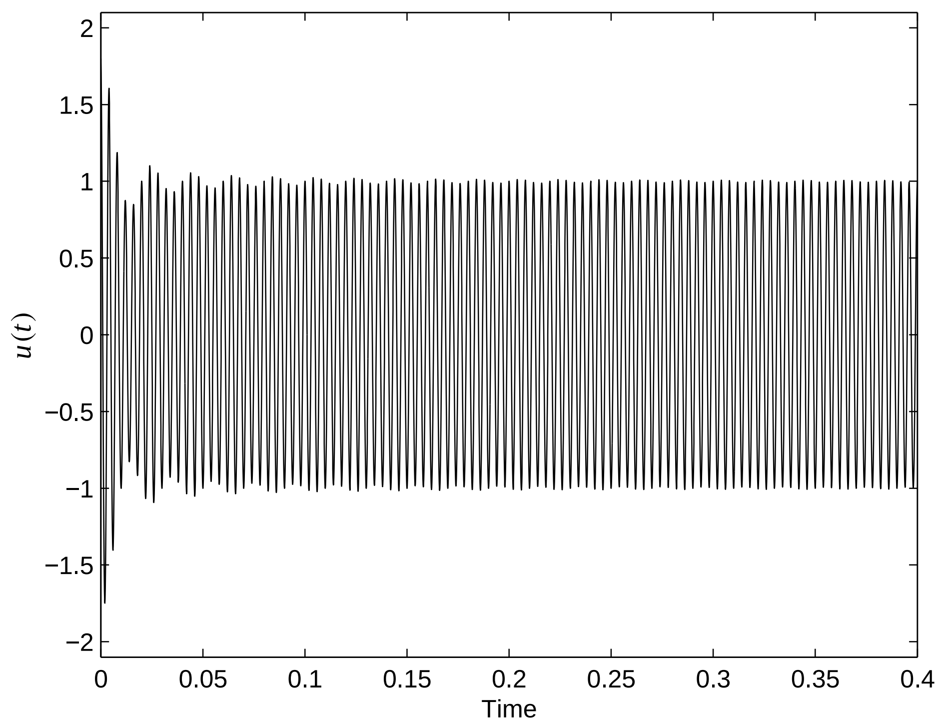

Figure 38: The modulated signal $u(t)$ for $t_0 = 0.4$

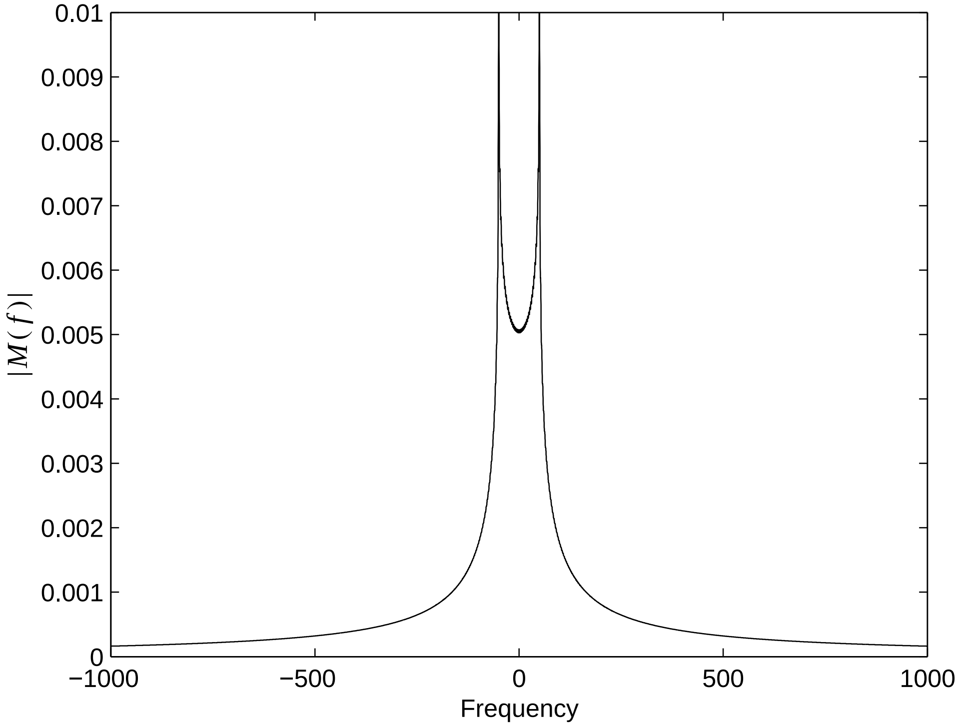

Figure 39: The spectrum of the message signal for $t_0 = 0.4$

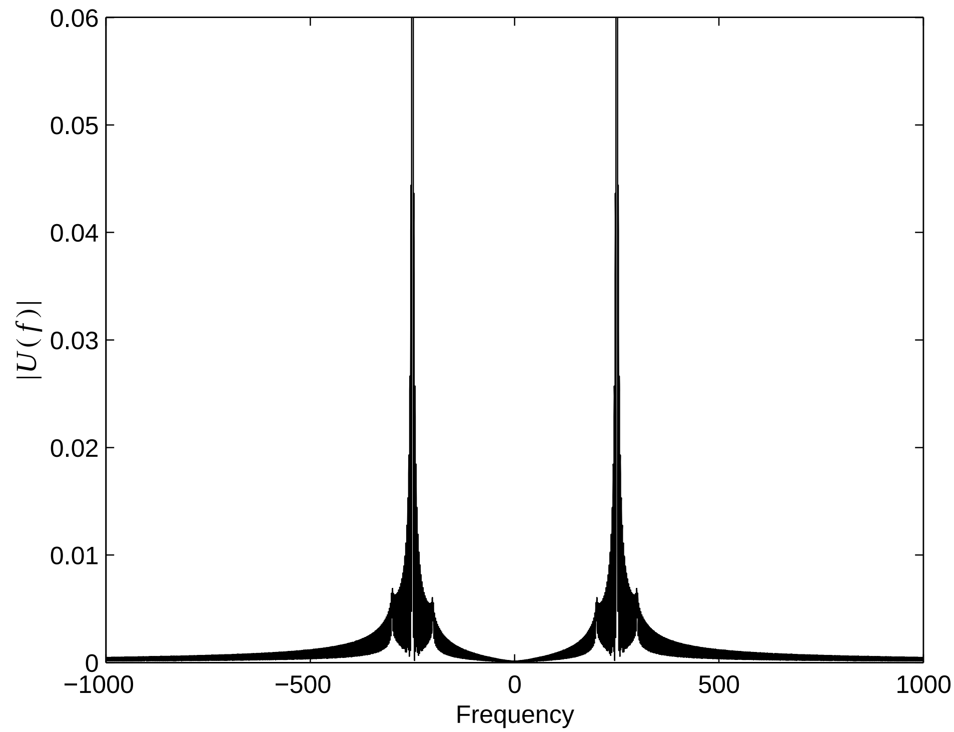

Figure 40: The spectrum of the modulated signal for $t_0 = 0.4$

```
f=[0:df1:df1*(length(m)−1)]−fs/2;  % frequency vector
u=(1+a*m_n).*c;                    % modulated signal
[U,u,df1]=fftseq(u,ts,df);         % Fourier transform
U=U/fs;                            % scaling
figure;
plot(t,m(1:length(t)))
xlabel('Time')
figure;
plot(t,u(1:length(t)))
axis([0 t0 −2.1 2.1])
xlabel('Time')
figure;
plot(f,abs(fftshift(M)))
xlabel('Frequency')
axis([−1000 1000 0 0.01]);
figure;
plot(f,abs(fftshift(U)))
xlabel('Frequency')
axis([−1000 1000 0 0.06]);
```

Problem 3.3

1) Figures 41 and 42 present the message signal and its Hilbert transform, respectively. The modulated signal is presented in Figure 43.

2) The spectrum of the message signal $m(t)$ and the modulated LSSB signal $u(t)$ are presented in Figures 44 and 45, respectively.

3) Figures 46, 47, 48, 49 and 50 present the message signal, its Hilbert transform, modulated signal, spectrum of the message signal and the spectrum of the modulated signal for $t_0 = 0.4$, respectively.

The MATLAB script for this problem follows.

```
% MATLAB script for Computer Problem 3.3.
t0=.4;                             % signal duration
n=0:1000;
ts=0.0001;                         % sampling interval
df=0.2;                            % frequency resolution
fs=1/ts;                           % sampling frequency
fc=250;                            % carrier frequency
t=[0:ts:t0];                       % time vector
m = sinc(100*t);                   % message signal
c=cos(2*pi*fc.*t);                 % carrier signal
udsb=m.*c;                           % DSB modulated signal
[UDSB,udssb,df1]=fftseq(udsb,ts,df); % Fourier transform
UDSB=UDSB/fs;                        % scaling
f=[0:df1:df1*(length(udssb)−1)]−fs/2; % frequency vector
n2=ceil(fc/df1);                     % location of carrier in freq. vector
% Remove the upper sideband from DSB.
UDSB(n2:length(UDSB)−n2)=zeros(size(UDSB(n2:length(UDSB)−n2)));
ULSSB=UDSB;                          % Generate LSSB-AM spectrum.
[M,m,df1]=fftseq(m,ts,df);           % Fourier transform
M=M/fs;                              % scaling
u=real(ifft(ULSSB))*fs;              % Generate LSSB signal from spectrum.
%Plot the message signal
figure;
plot(t,m(1:length(t)))
```

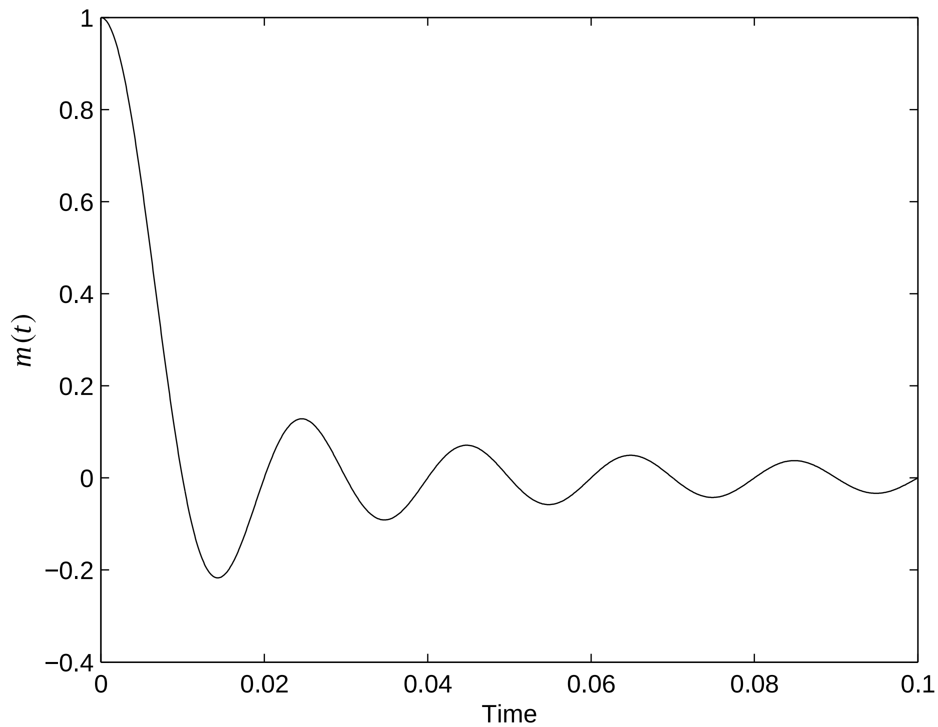

Figure 41: Message signal $m(t)$

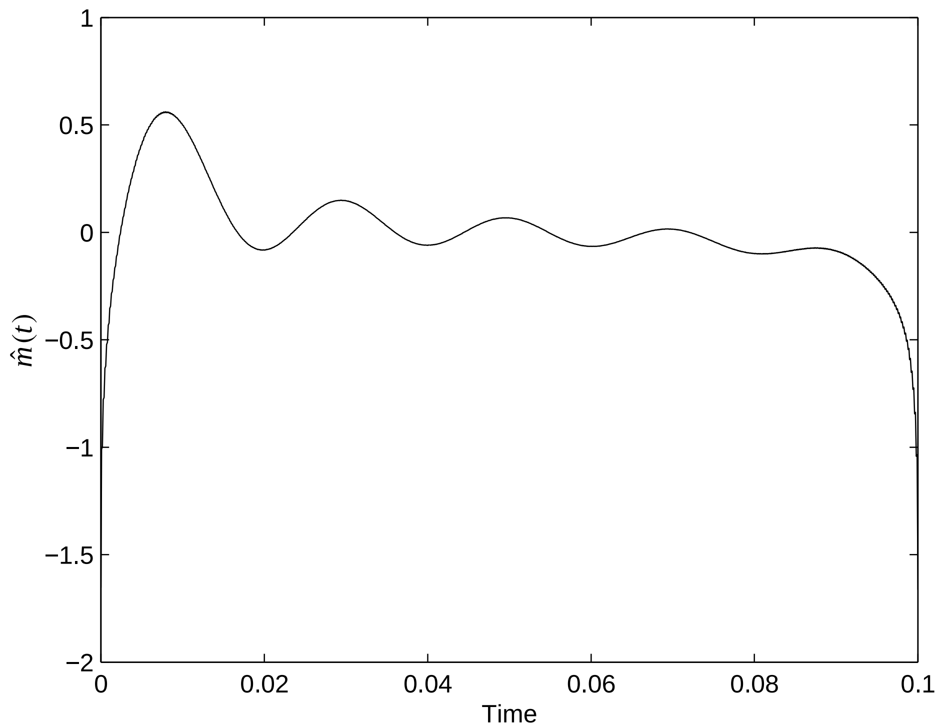

Figure 42: Hilbert transform of the message signal $m(t)$

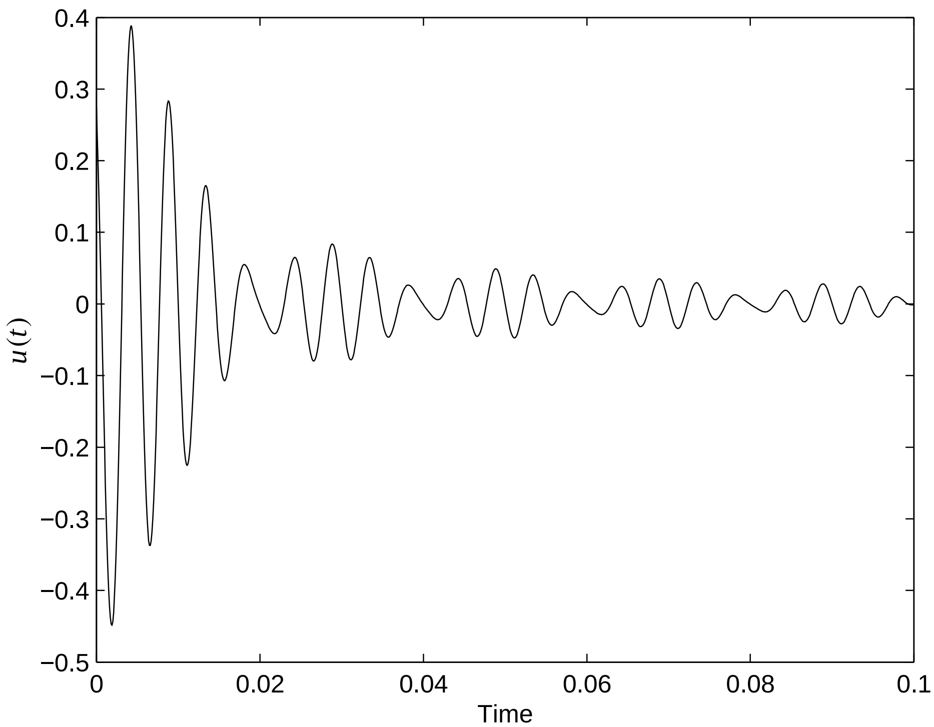

Figure 43: Modulated signal

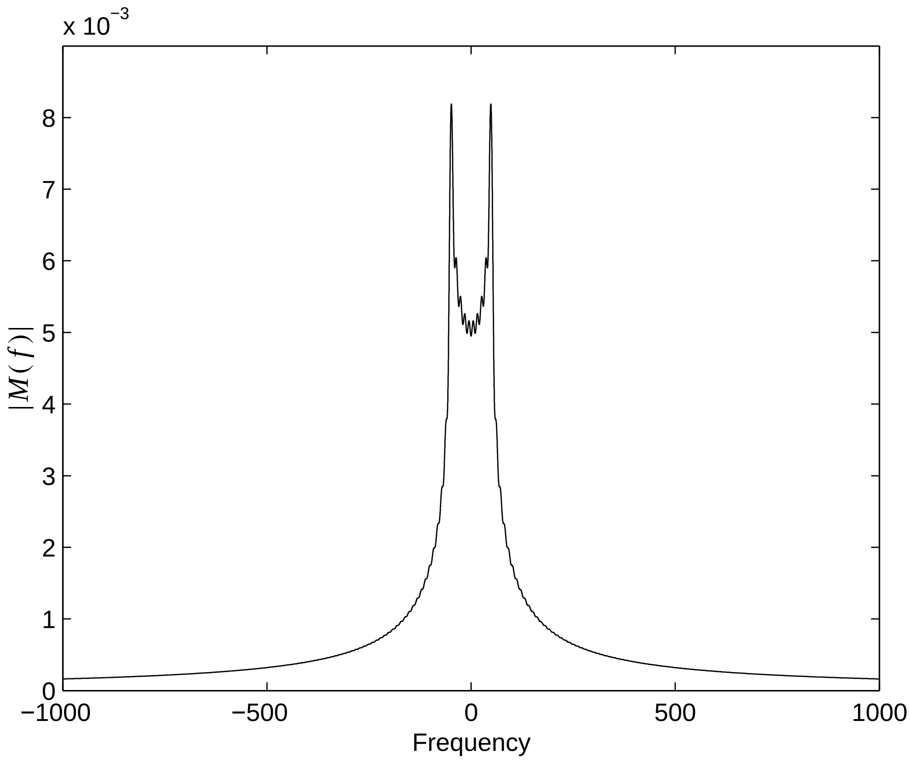

Figure 44: Spectrum of the message signal

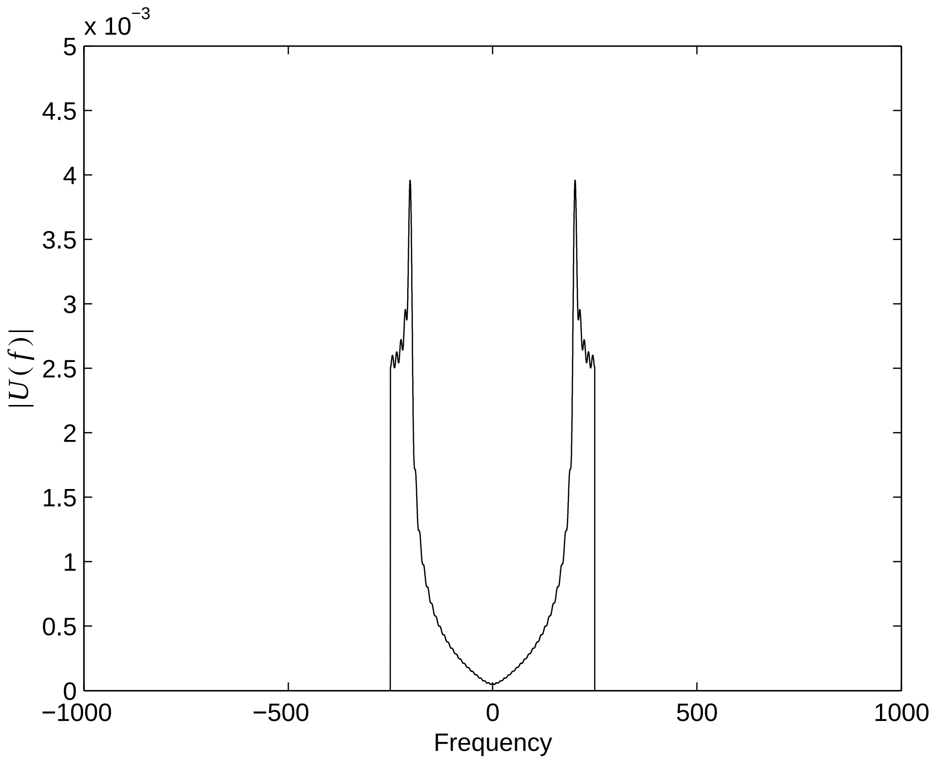

Figure 45: The spectrum of the modulated signal

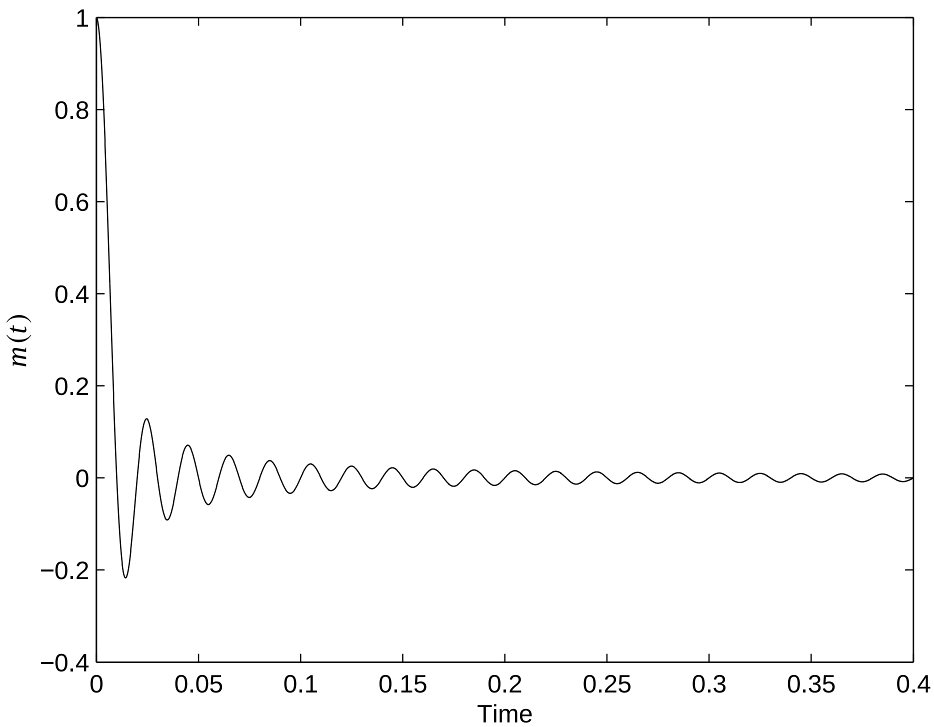

Figure 46: Message signal $m(t)$ for $t_0 = 0.4$

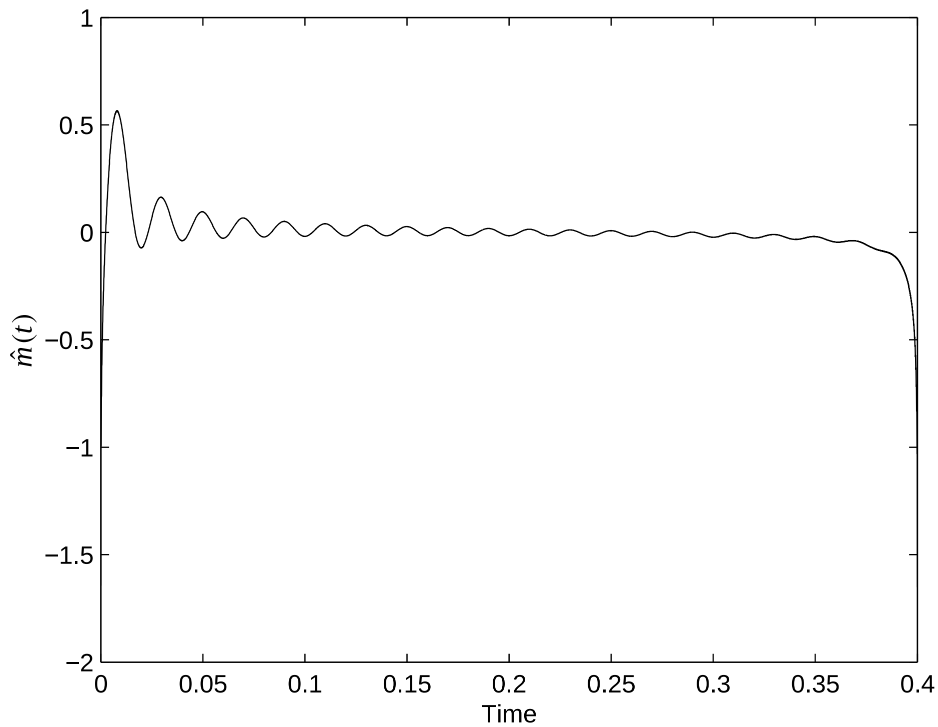

Figure 47: Hilbert transform of the message signal for $t_0 = 0.4$

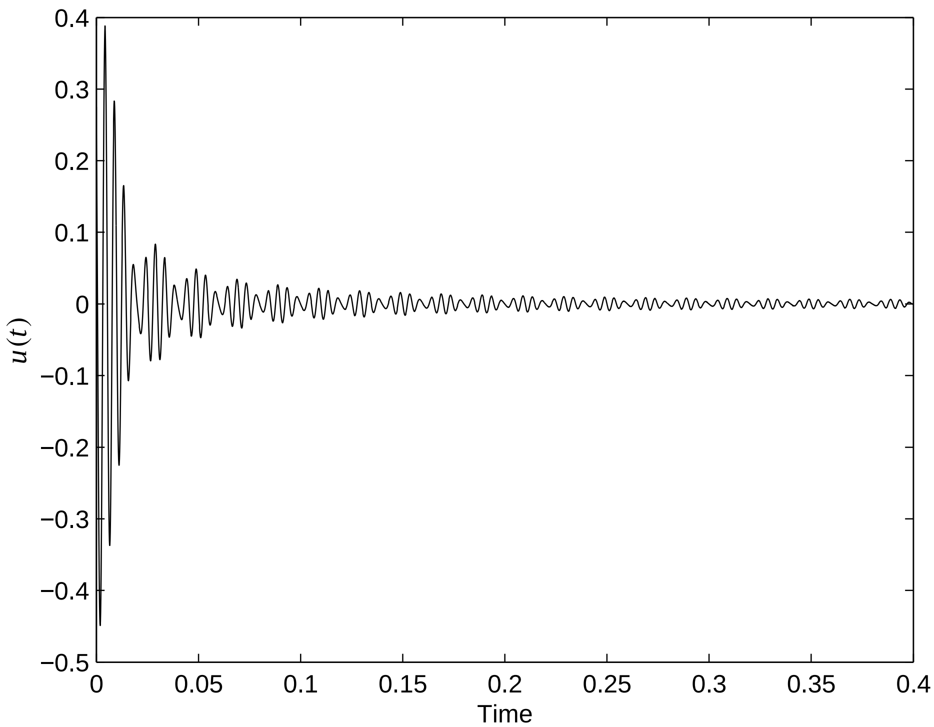

Figure 48: Modulated signal $u(t)$ for $t_0 = 0.4$

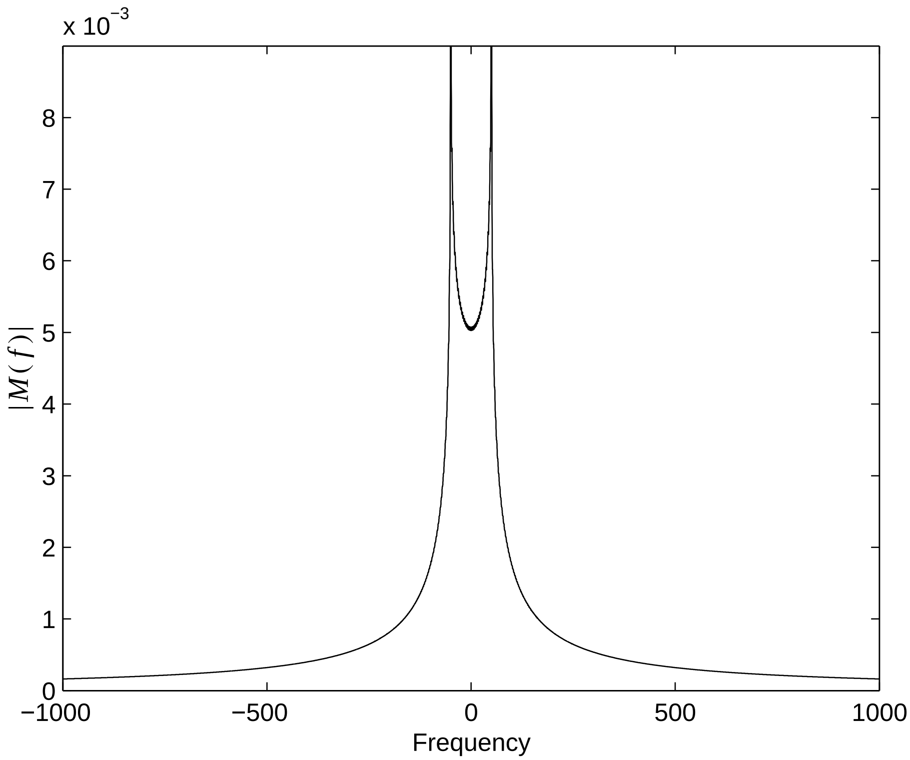

Figure 49: Spectrum of the message signal for $t_0 = 0.4$

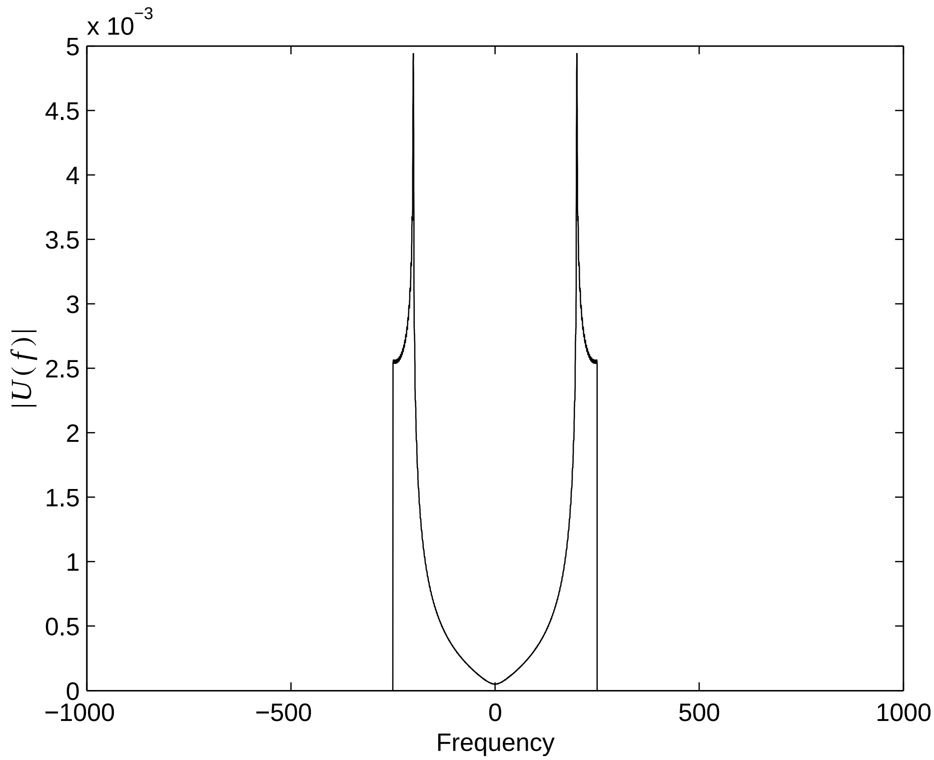

Figure 50: Spectrum of the modulated signal for $t_0 = 0.4$

```
xlabel('Time')
%Plot the Hilbert transform of the message signal
figure;
plot(t, imag(hilbert(m(1:length(t)))))
xlabel('Time');
%plot the LSSB-AM modulated signal
figure;
plot(t, u(1:length(t)))
xlabel('Time')
% Plot the spectrum of the message signal
figure;
plot(f,abs(fftshift(M)))
xlabel('Frequency')
axis([-1000 1000 0 0.009]);

% Plot the spectrum of the LSSB-AM modulated signal
figure;
plot(f,abs(fftshift(ULSSB)))
xlabel('Frequency')
axis([-1000 1000 0 0.005]);
```

Problem 3.4

1) The message signal $m(t)$ and the modulated signal $u(t)$ are presented in Figures 51 and 52, respectively.
2) The demodulation output is given in Figure 53 for $\phi = 0, \pi/8, \pi/4$, and $\pi/2$.
4) The demodulation output is given in Figure 54 for $\phi = 0, \pi/8, \pi/4$, and $\pi/2$.
The MATLAB script for this problem follows.

```
% MATLAB script for Computer Problem 3.4.
t0=.1;                        % signal duration
n=0:1000;
ts=0.001;                     % sampling interval
df=0.2;                       % frequency resolution
fs=1/ts;                      % sampling frequency
fc=250;                       % carrier frequency
t=[0:ts:t0];                  % time vector
m = sinc(100*t);              % message signal
c = cos(2*pi*fc.*t);
u=m.*c;                       % modulated signal
[M,m,df1]=fftseq(m,ts,df);    % Fourier transform
M=M/fs;                       % scaling
plot(t,m(1:length(t)))
xlabel('t')
figure;
plot(t,u(1:length(t)))
xlabel('t')

% design the filter
fs = 0.16;
fp = 0.0999;
```

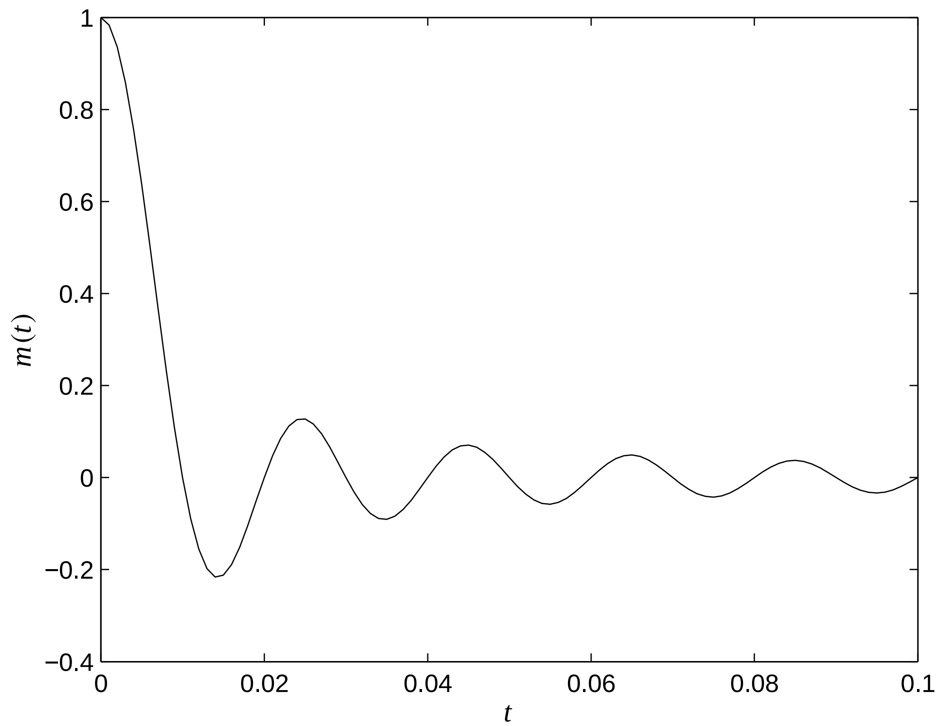

Figure 51: The message signal $m(t)$

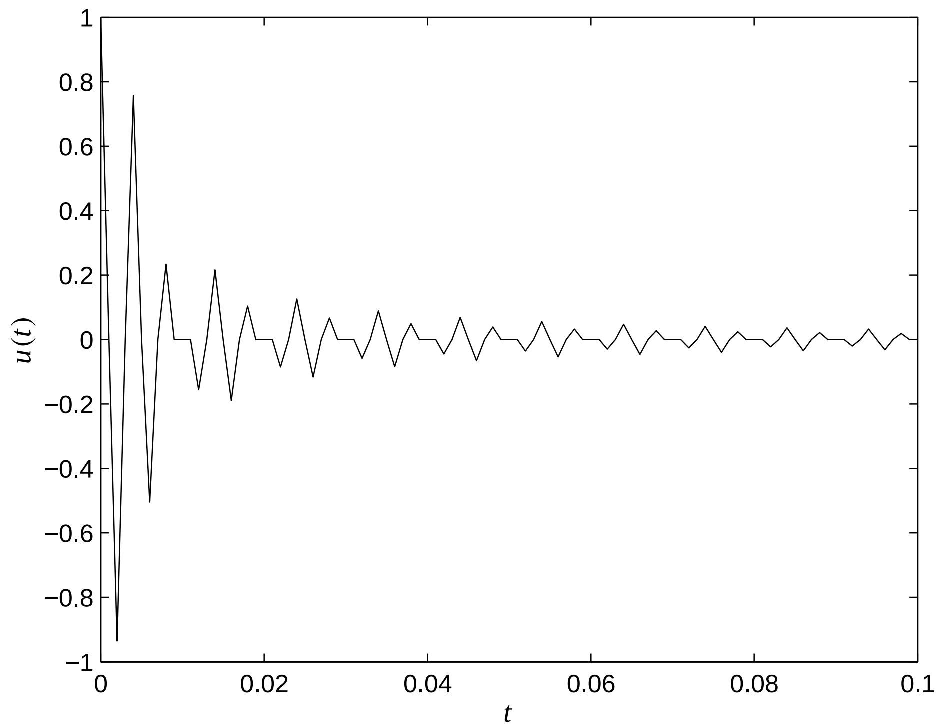

Figure 52: The modulated signal $u(t)$

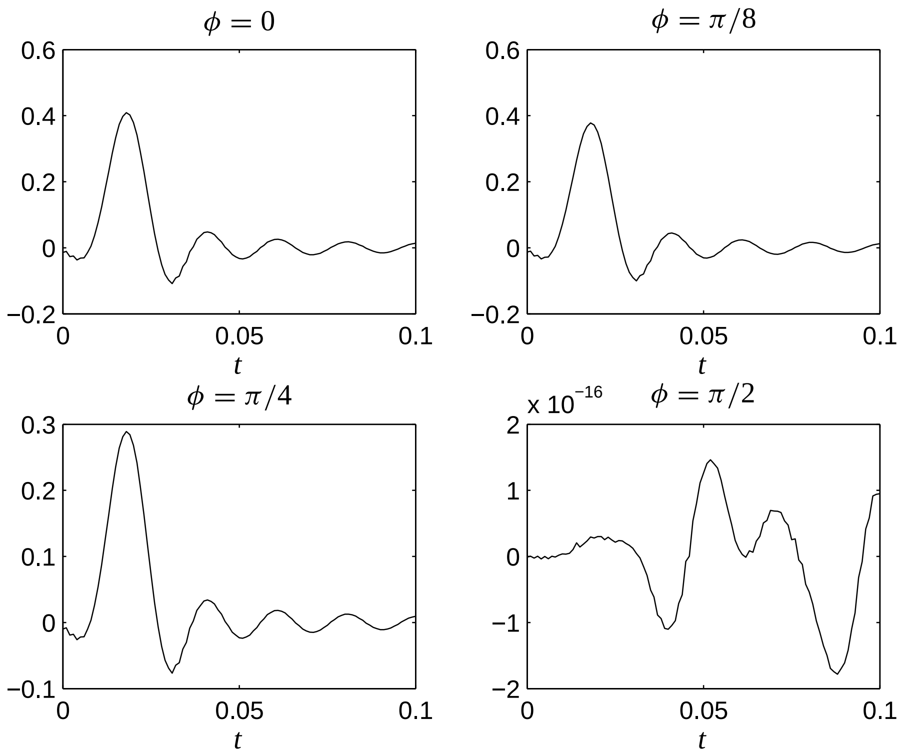

Figure 53: The demodulation output

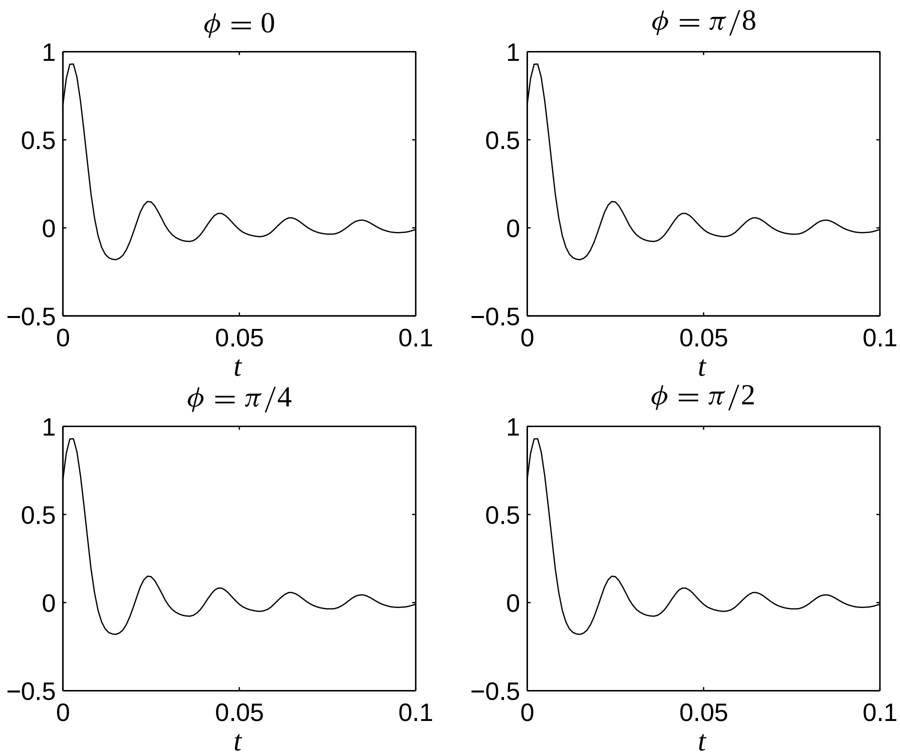

Figure 54: The demodulation output

```
f=[0 fp fs 1];
m=[1 1 0 0];
delta1 = 0.0875;
delta2 = 0.006;
df = fs - fp;
w=[delta2/delta1 1];
h=remez(31,f,m,w);

f_cutoff=100;
for i = 1:4
    fi = [0 pi/8 pi/4 pi/2];
    tit = ['a', 'b', 'c', 'd'];
    y=u.*cos(2*pi*fc.*t+fi(1));
    dem = filter(h, 1, y);
    figure(3);
    subplot(2,2,i);
    plot(t,dem(1:length(t)))
    xlabel('t')
    title('a');
    [Y,y,df1]=fftseq(y,ts,df);
    n_cutoff=floor(f_cutoff/df1);
    f=[0:df1:df1*(length(y)-1)]-fs/2;
    H=zeros(size(f));
    H(1:n_cutoff)=2*ones(1,n_cutoff);
    H(length(f)-n_cutoff+1:length(f))=2*ones(1,n_cutoff);
    Y=Y/fs;
    DEM=H.*Y;
    dem=real(ifft(DEM))*fs;
    figure(4);
    subplot(2,2,i);
    plot(t,dem(1:length(t)))
    xlabel('t');
    title(tit(i));
end
```

Problem 3.5

1) The message signal $m(t)$, the modulated signal $u(t)$ and the Hilbert transform of the message signal $\hat{m}(t)$ are presented in Figures 55, 56 and 57, respectively.
2) The demodulation output is given in Figure 58 for $\phi = 0, \pi/8, \pi/4$, and $\pi/2$.
4) The demodulation output is given in Figure 59 for $\phi = 0, \pi/8, \pi/4$, and $\pi/2$.
The MATLAB script for this problem follows.

```
% MATLAB script for Computer Problem 3.5.
t0=.1;                         % signal duration
ts=0.001;                      % sampling interval
df=0.1;                        % frequency resolution
fs=1/ts;                       % sampling frequency
fc=250;                        % carrier frequency
t=[0:ts:t0];                   % time vector
m = sinc(100*t);               % message signal
m_h = imag(hilbert(m));

u = m.*cos(2*pi*fc*t) + m_h .*sin(2*pi*fc*t);
```

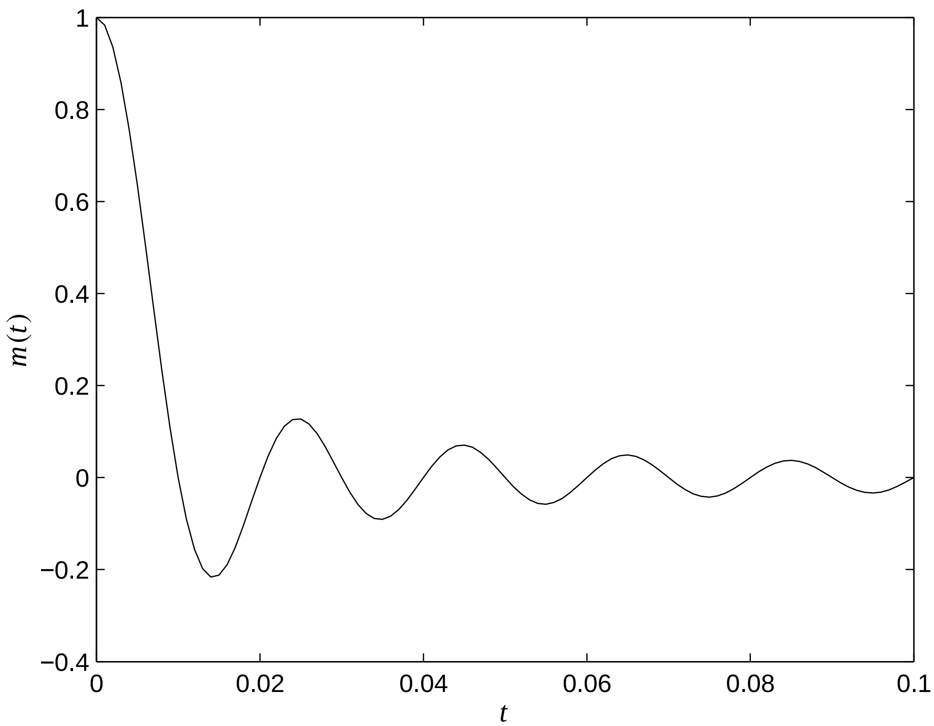

Figure 55: The message signal $m(t)$

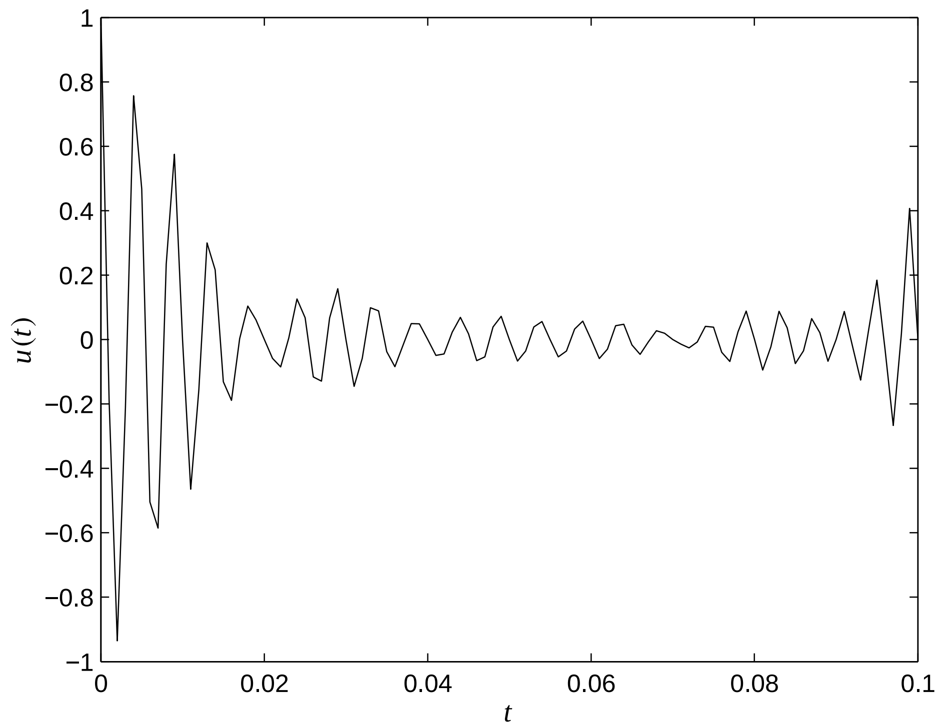

Figure 56: The modulated signal $u(t)$

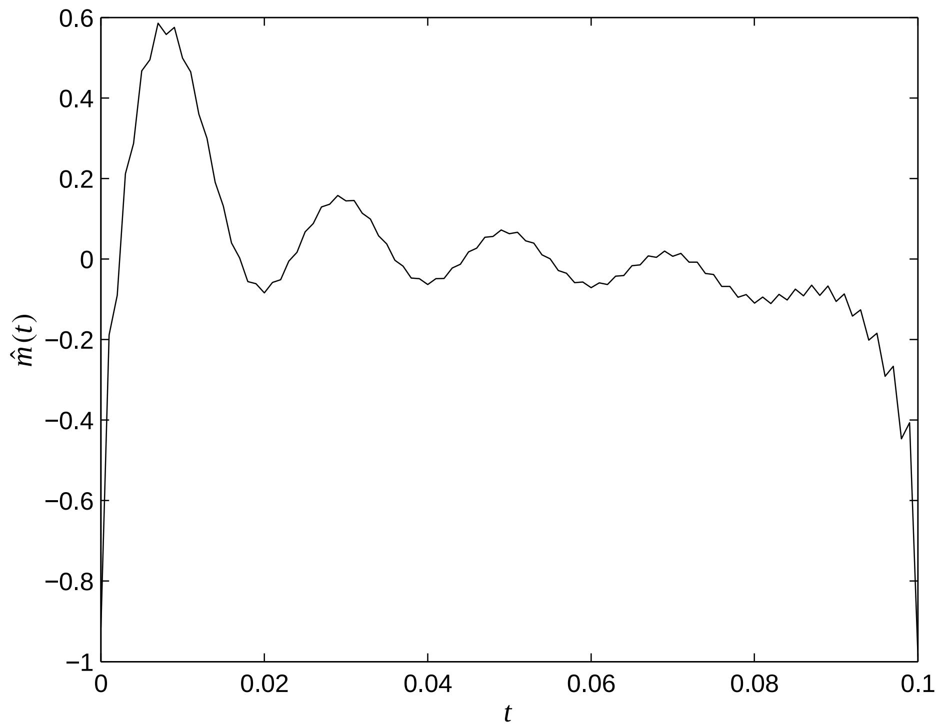

Figure 57: The Hilbert transform of the message signal

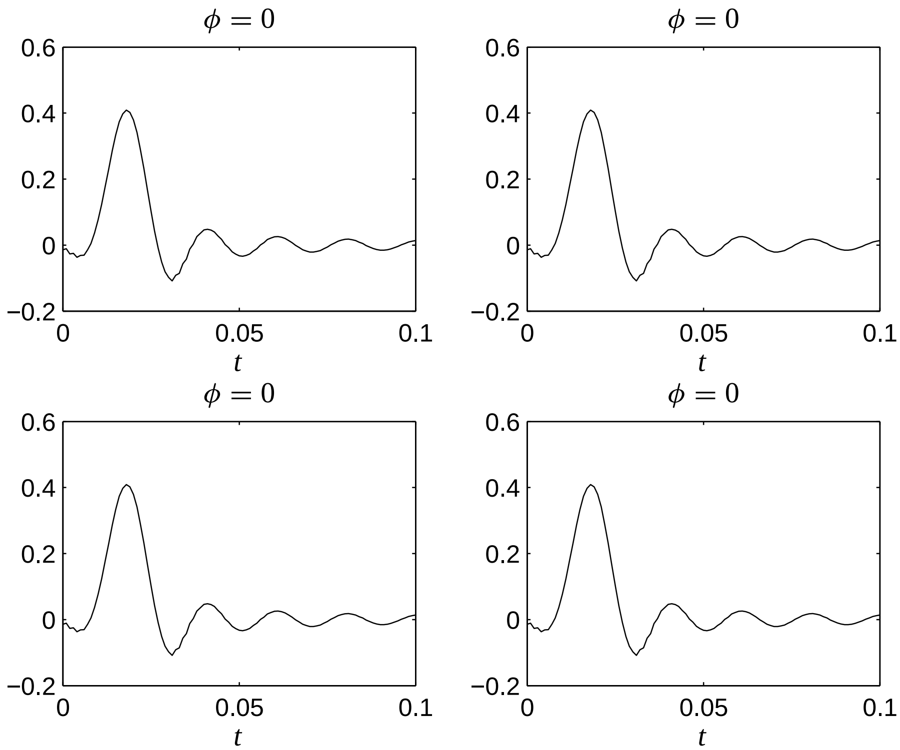

Figure 58: The demodulation output

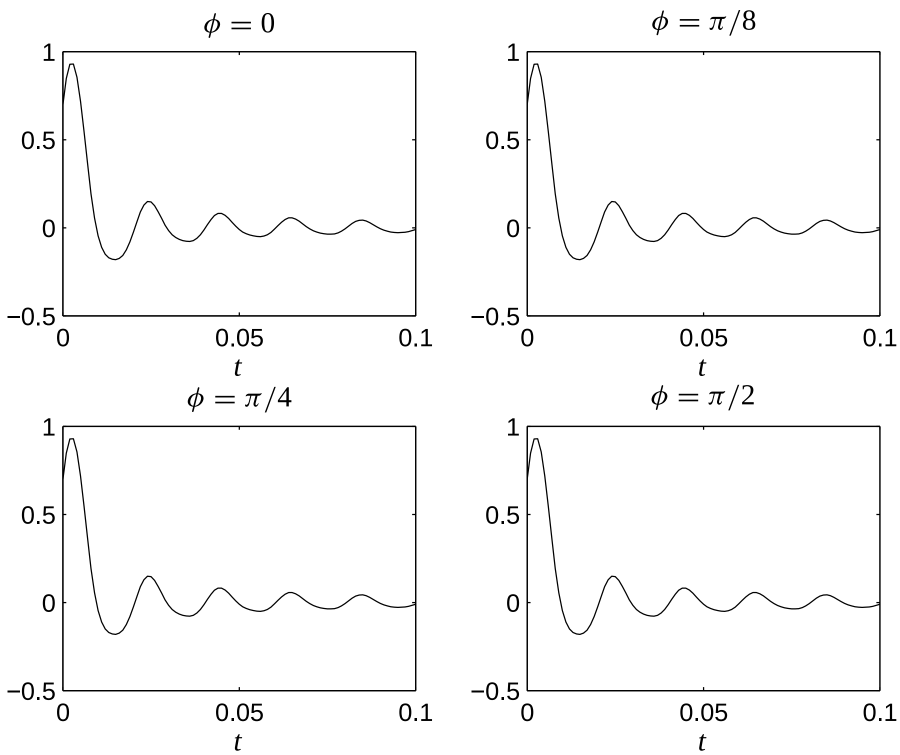

Figure 59: The demodulation output

```
plot(t,m(1:length(t)))
xlabel('t')
figure;
plot(t,m_h(1:length(t)))
xlabel('t')
figure;
plot(t,u(1:length(t)))
xlabel('t')
% design the filter
fs = 0.16;
fp = 0.0999;

f=[0 fp fs 1];
m=[1 1 0 0];
delta1 = 0.0875;
delta2 = 0.006;
df = fs - fp;
w=[delta2/delta1 1];
h=remez(31,f,m,w);

f_cutoff=100;
for i = 1:4
    fi = [0 pi/8 pi/4 pi/2];
    tit = ['a', 'b', 'c', 'd'];
    y=u.*cos(2*pi*fc.*t+fi(1));
    dem = filter(h, 1, y);
    figure(4);
    subplot(2,2,i);
    plot(t,dem(1:length(t)))
    xlabel('t')
    title('a');
    [Y,y,df1]=fftseq(y,ts,df);
    n_cutoff=floor(f_cutoff/df1);
    f=[0:df1:df1*(length(y)-1)]-fs/2;
    H=zeros(size(f));
    H(1:n_cutoff)=2*ones(1,n_cutoff);
    H(length(f)-n_cutoff+1:length(f))=2*ones(1,n_cutoff);
    Y=Y/fs;
    DEM=H.*Y;
    dem=real(ifft(DEM))*fs;
    figure(5);
    subplot(2,2,i);
    plot(t,dem(1:length(t)))
    xlabel('t');
    title(tit(i));
end
```

Problem 3.6

1) The message signal and modulated signal are presented in Figures 60 and 61

2) The demodulated received signal is presented in Figure 62

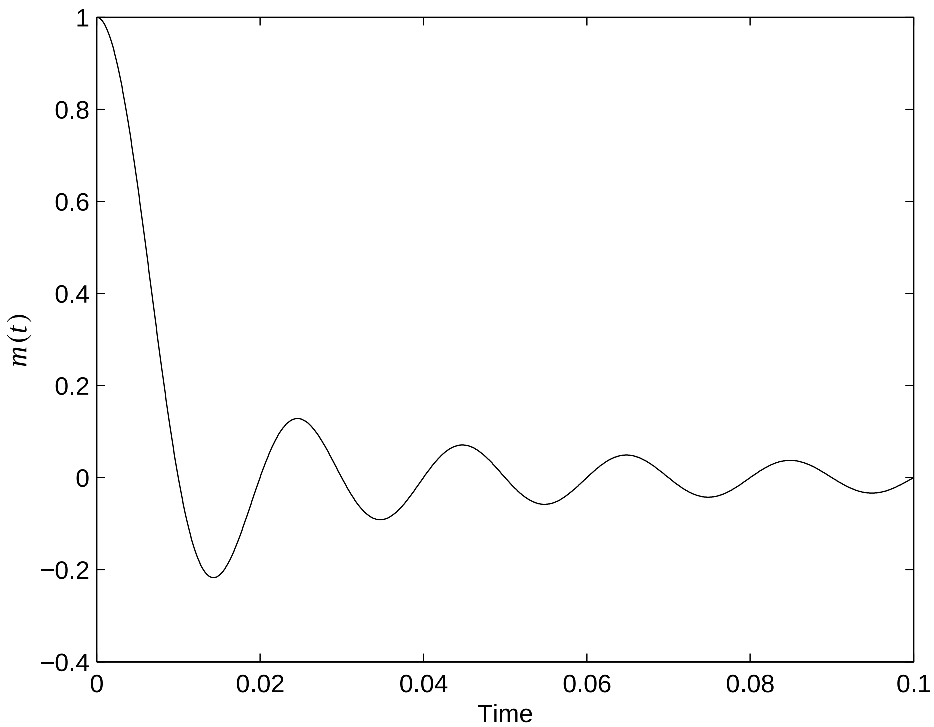

Figure 60: Message signal

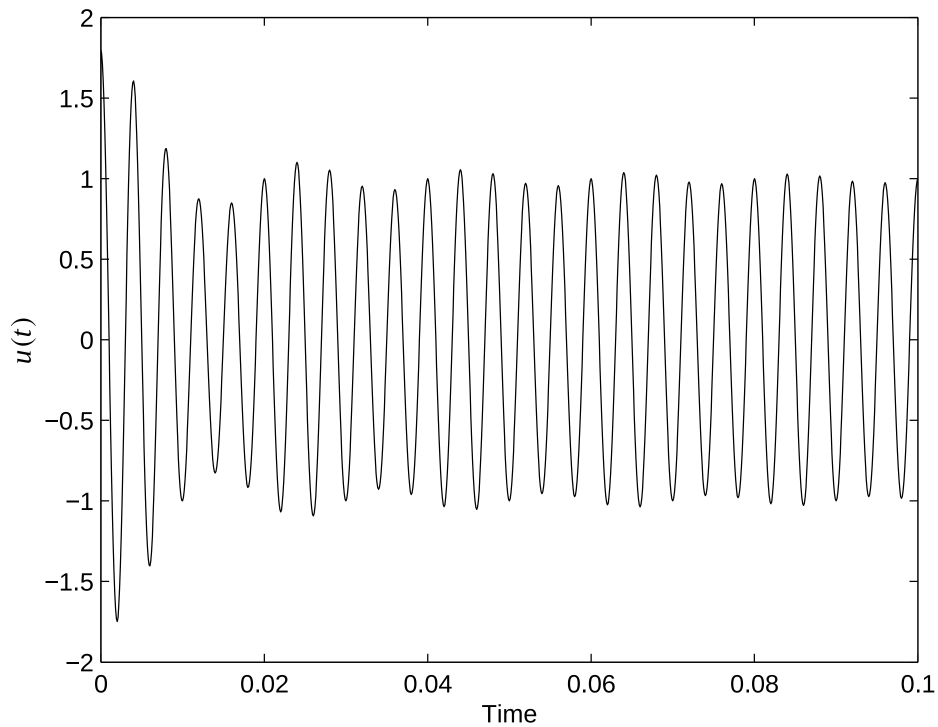

Figure 61: Modulated signal

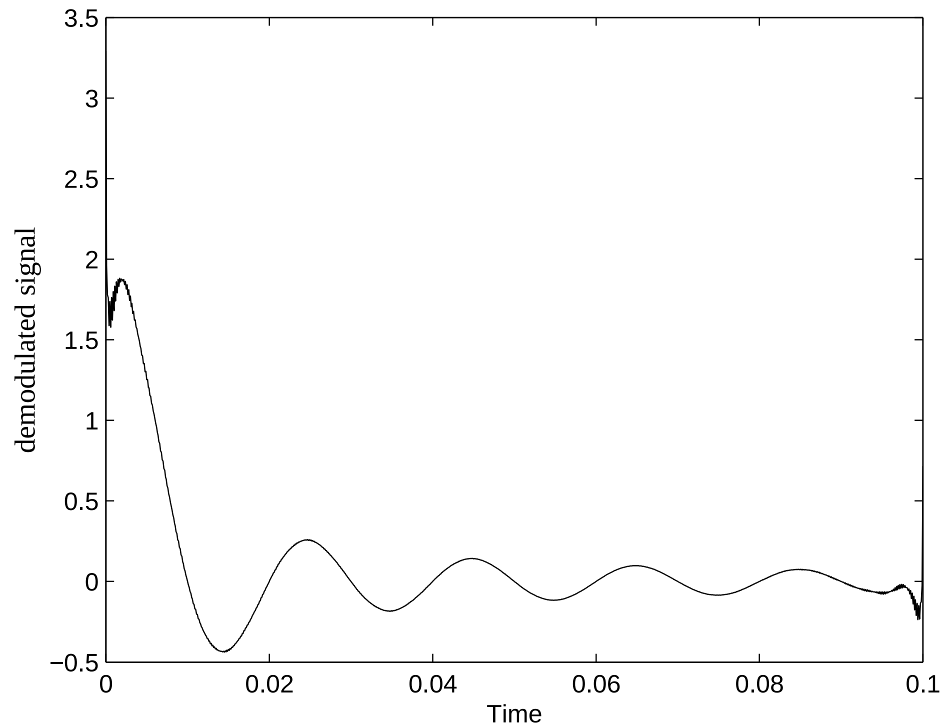

Figure 62: Demodulated signal

3) In the demodulation process above, we have neglected the effect of the noise-limiting filter, which is a bandpass filter in the first stage of any receiver. In practice, the received signal is passed through the noise-limiting filter and then supplied to the envelope detector. In this example, since the message bandwidth is not finite, passing the received signal through any bandpass filter will cause distortion on the demodulated message, but it will also decrease the amount of noise in the demodulator output.
The MATLAB script for this problem follows.

```
% MATLAB script for Computer Problem 3.6.
t0=.1;                             % signal duration
n=0:1000;
a = 0.8;
ts=0.0001;                         % sampling interval
df=0.2;                            % frequency resolution
fs=1/ts;                           % sampling frequency
fc=250;                            % carrier frequency
t=[0:ts:t0];                       % time vector
m = sinc(100*t);                   % message signal
c=cos(2*pi*fc.*t);                 % carrier signal
m_n=m/max(abs(m));                 % normalized message signal
[M,m,df1]=fftseq(m,ts,df);         % Fourier transform
f=[0:df1:df1*(length(m)-1)]-fs/2;  % frequency vector
u=(1+a*m_n).*c;                    % modulated signal
[U,u,df1]=fftseq(u,ts,df);         % Fourier transform
env=env_phas(u, a);                        % Find the envelope.
dem1=2*(env-1)/a;                  % Remove dc and rescale.

% plot the message signal
plot(t,m(1:length(t)))
xlabel('Time')

% plot the modulated signal
figure;
plot(t,u(1:length(t)))
xlabel('Time')

% plot the demodulated signal
figure;
plot(t,dem1(1:length(t)))
xlabel('Time')
```