RYERSON UNIVERSITY

Faculty of Engineering, Architecture and Science

Department of Electrical and Computer Engineering

Course Number	ELE532
Course Title	Signals and Systems I
Semester/Year	Fall 2021

Instructor	Dr. Javad Alirezaie

ASSIGNMENT No.	**4**

Assignment Title	System Properties and Convolution

Submission Date	December 1, 2021
Due Date	December 6, 2021

Student Name	Reza Aablue
Student ID	500966944
Signature*	R.A.

Student Name	Rendel Abrasia
Student ID	500942743
Signature*	R.A.

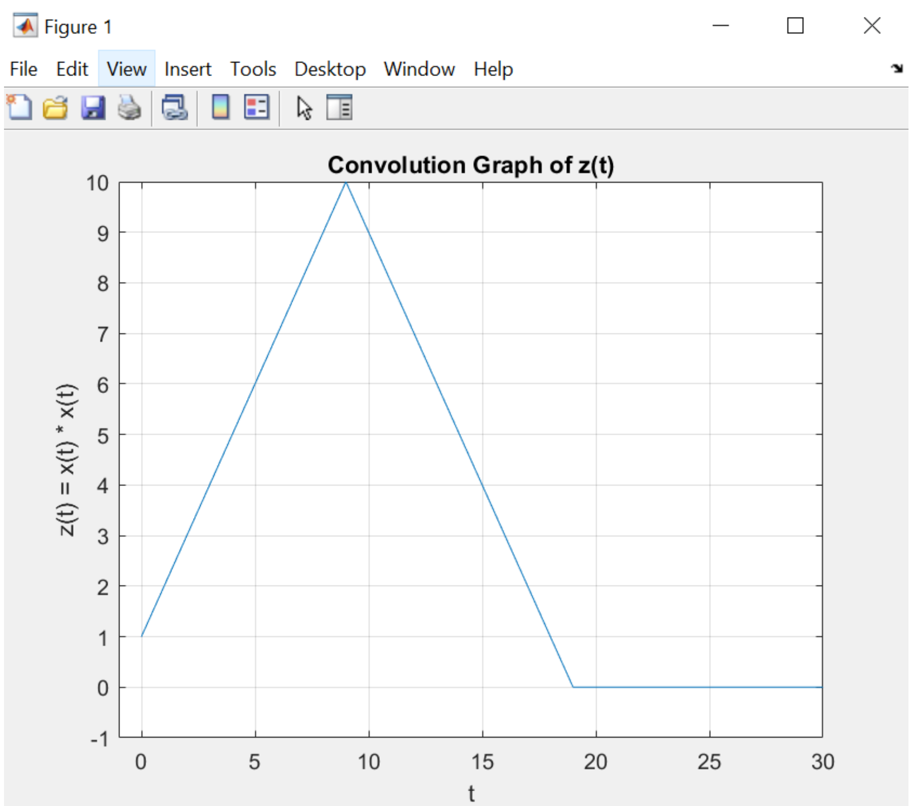
By signing above you attest that you have contributed to this written lab report and confirm that all work you have contributed to this lab report is your own work. Any suspicion of copying or plagiarism in this work* ***will result in an investigation of Academic Misconduct and may result in a "0" on the work,* *an "F" in the course, or possibly more severe penalties, as well as a Disciplinary Notice on your academic record under the Student Code of Academic Conduct, which can be found online at: www.ryerson.ca/senate/current/pol60.pdf.*

Problem A

Section A.1:

ProblemA.m | ProblemA5.m | ProblemA6.m | MagSpect.m | osc.m

```matlab
%Rendel Abrasia, Reza Aablue
%500942743, 500966944
%Section 4

% Problem A.1

N = 100;
PulseWidth = 10;
t = [0:1:(N-1)];

x = [ones(1,PulseWidth), zeros(1,N-PulseWidth)];

z = conv (x,x);

s = [0:1:2*(N-1)]

figure (1);
plot (s,z); grid on; axis ([-1 30 -1 10])
xlabel ('t'); ylabel ('z(t) = x(t) * x(t)');
title ('Convolution Graph of z(t)');
```

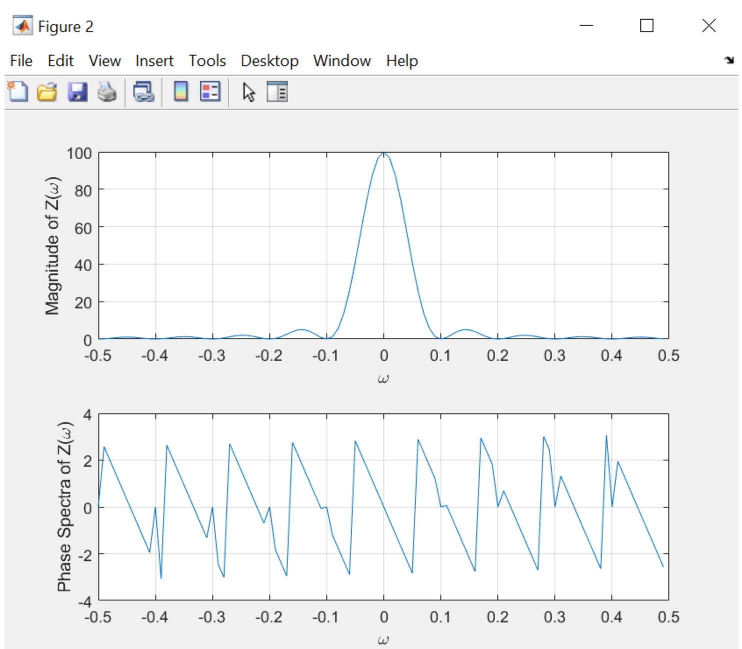


Section A.2:

```matlab
% Problem A.2

Xw=fft(x); % w = 2 x pi x f

f = [-(N/2):1:(N/2)-1]*(1/N);

Zw = Xw .* Xw;
```

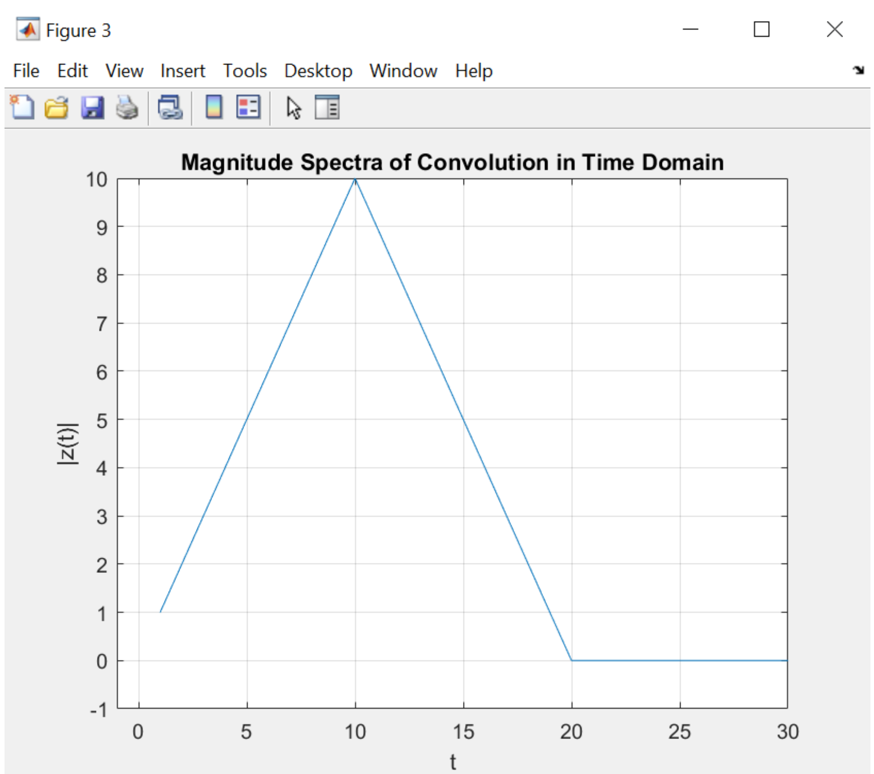
Section A.3:

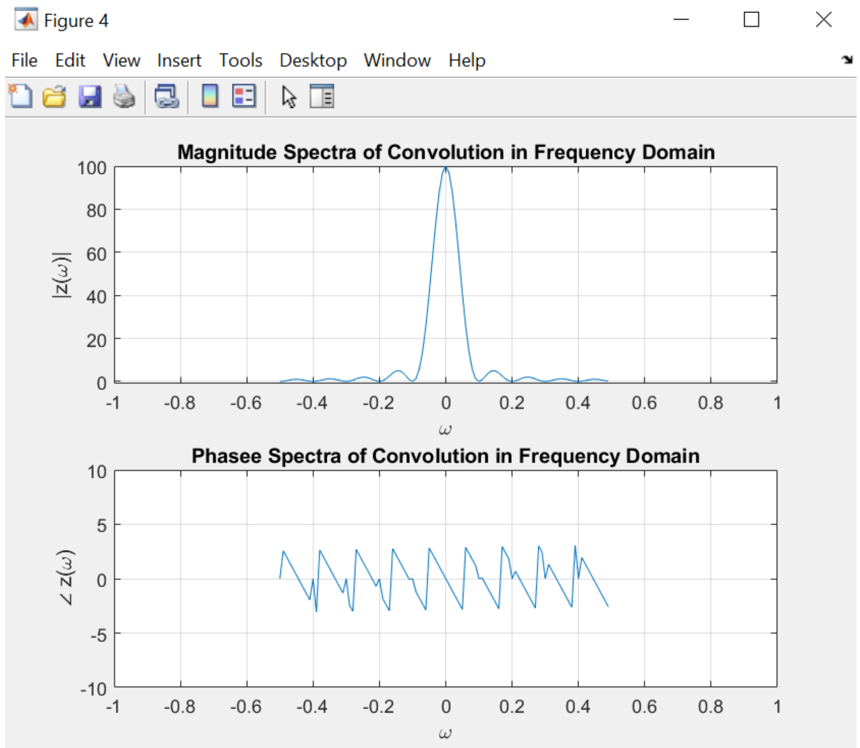
```matlab
% Problem A.3

figure (2);

subplot (2,1,1);
plot (f, fftshift(abs(Zw)));  grid on;
xlabel('\omega');
ylabel('Magnitude of Z(\omega)');

subplot (2,1,2);
plot (f, fftshift(angle(Zw)));  grid on;
xlabel('\omega');
ylabel('Phase Spectra of Z(\omega)');
```



Section A.4:

```
% Problem A.4
xFreqDom = fft(x);
zFreqDom = xFreqDom.*xFreqDom;

zTimeDom = ifft(zFreqDom);

figure (3);
plot (zTimeDom); grid on;
axis ([-1 30 -1 10])
title ('Magnitude Spectra of Convolution in Time Domain');
xlabel ('t'); ylabel ('|z(t)|');

figure (4);
subplot (2,1,1); plot (f, fftshift(abs(zFreqDom))); grid on;
axis ([-1 1 -1 100]);
title ('Magnitude Spectra of Convolution in Frequency Domain');
xlabel ('\omega'); ylabel ('|z(\omega)|');

subplot (2,1,2); plot (f, fftshift(angle(zFreqDom))); grid on;
axis ([-1 1 -10 10]);
title ('Phasee Spectra of Convolution in Frequency Domain');
xlabel ('\omega'); ylabel ('\angle z(\omega)');
```





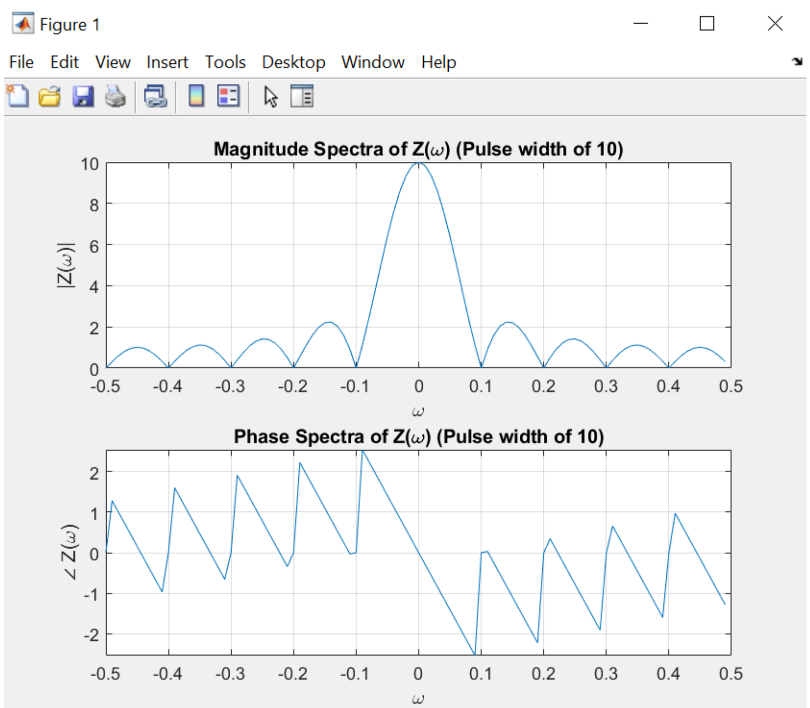
When comparing the magnitude and phase plots of sections A.1 and A.4, it is observed that the results are almost exactly the same. Through these two sections, the Fourier transform property of convolution is accurately demonstrated.

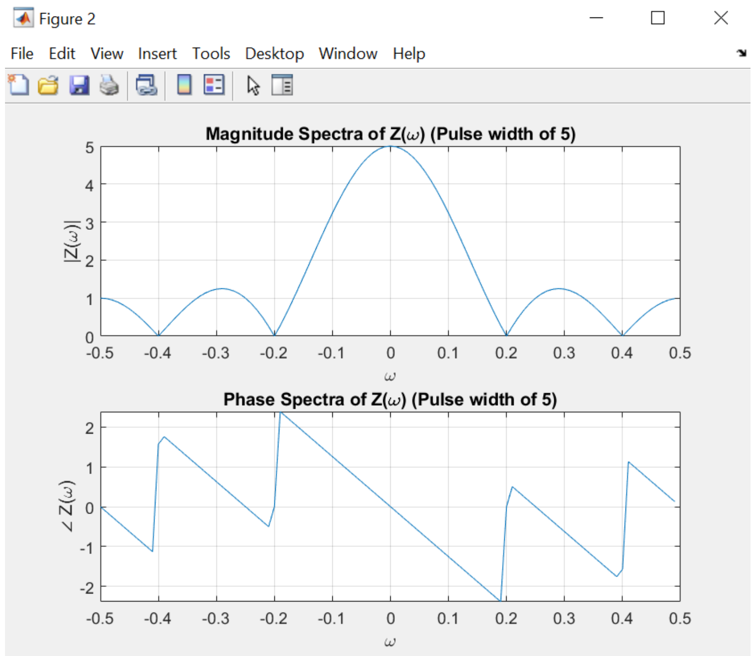
Section A.5:

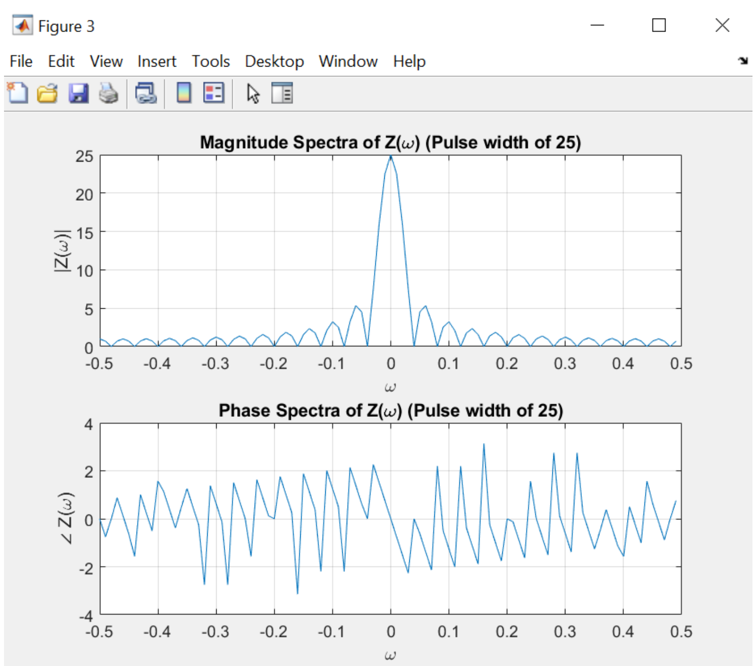
ProblemA.m | ProblemA5.m | ProblemA6.m | MagSpect.m | osc.m

```
%Rendel Abrasia, Reza Aablue
%500942743, 500966944
%Section 4

% Problem A.5
% Case 1: Pulse width of 10
N = 100; PulseWidth = 10;
t = [0:1:(N-1)]; x = [ones(1,PulseWidth), zeros(1, N-PulseWidth)];
xFT = fft(x); f = [-(N/2):1:(N/2)-1]*(1/N);

figure (1);
subplot (2,1,1); plot (f,fftshift(abs(xFT))); grid on;
xlabel('\omega'); ylabel ('|Z(\omega)|');
title ('Magnitude Spectra of Z(\omega) (Pulse width of 10)');

subplot (2,1,2); plot (f, fftshift(angle(xFT))); grid on;
xlabel('\omega'); ylabel ('\angle Z(\omega)');
title ('Phase Spectra of Z(\omega) (Pulse width of 10)');

% Case 2: Pulse width of 5
N = 100; PulseWidth = 5;
t = [0:1:(N-1)]; x = [ones(1,PulseWidth), zeros(1, N-PulseWidth)];
xFT2 = fft(x); f = [-(N/2):1:(N/2)-1]*(1/N);
```

```matlab

figure (2);
subplot (2,1,1); plot (f,fftshift(abs(xFT2))); grid on;
xlabel('\omega'); ylabel ('|Z(\omega)|');
title ('Magnitude Spectra of Z(\omega) (Pulse width of 5)');

subplot (2,1,2); plot (f, fftshift(angle(xFT2))); grid on;
xlabel('\omega'); ylabel ('\angle Z(\omega)');
title ('Phase Spectra of Z(\omega) (Pulse width of 5)');

% Case 3: Pulse width of 25
N = 100; PulseWidth = 25;
t = [0:1:(N-1)]; x = [ones(1,PulseWidth), zeros(1, N-PulseWidth)];
xFT3 = fft(x); f = [-(N/2):1:(N/2)-1]*(1/N);

figure (3);
subplot (2,1,1); plot (f,fftshift(abs(xFT3))); grid on;
xlabel('\omega'); ylabel ('|Z(\omega)|');
title ('Magnitude Spectra of Z(\omega) (Pulse width of 25)');

subplot (2,1,2); plot (f, fftshift(angle(xFT3))); grid on;
xlabel('\omega'); ylabel ('\angle Z(\omega)');
title ('Phase Spectra of Z(\omega) (Pulse width of 25)');
```







It is observed that all three frequency spectra graphs have the same shape in terms of curvature, with a difference of time stretch or compression between the three graphs. The magnitude spectra graphs differ in amplitude and time scaling. Therefore, the time scaling property is demonstrated in this section of the report.

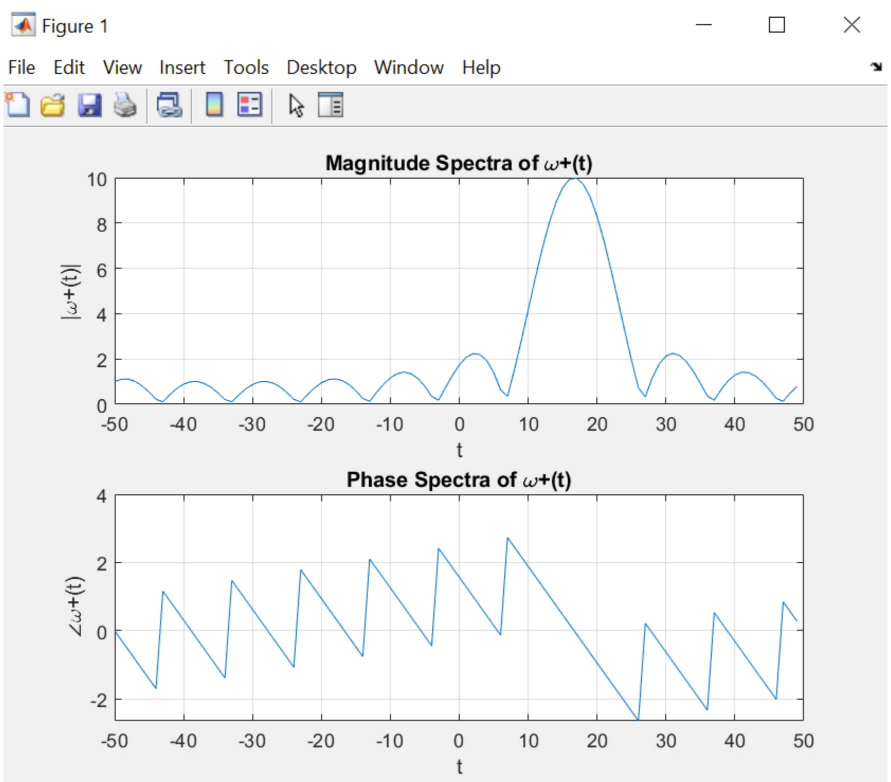
Section A.6:

ProblemA.m | ProblemA5.m | ProblemA6.m | MagSpect.m | osc.m

```
%Rendel Abrasia, Reza Aablue
%500942743, 500966944
%Section 4

% Problem A.6

% Magnitude and Phase Spectra for w+(t) function
N = 100; PulseWidth = 10;
t = [0:1:(N-1)];
x = [ones(1, PulseWidth), zeros(1, N-PulseWidth)];
wPLUSoft = x.* (exp(1i*(pi/3).*t));
wPLUSoftFT = fft(wPLUSoft);
f = [-(N/2):1:(N/2)-1];

figure (1);

subplot (2,1,1);
plot (f, fftshift(abs(wPLUSoftFT))); grid on;
xlabel ('t'); ylabel ('|\omega+(t)|');
title ('Magnitude Spectra of \omega+(t)');

subplot (2,1,2);
plot (f, fftshift(angle(wPLUSoftFT))); grid on;
```

```
xlabel ('t'); ylabel ('\angle\omega+(t)');
title ('Phase Spectra of \omega+(t)');

% Magnitude and Phase Spectra for w-(t) function
N = 100; PulseWidth = 10;
t = [0:1:(N-1)];
x = [ones(1, PulseWidth), zeros(1, N-PulseWidth)];
wMINUSoft = x.* (exp(-1i*(pi/3).*t));
wMINUSoftFT = fft(wMINUSoft);
f = [-(N/2):1:(N/2)-1];

figure (2);

subplot (2,1,1);
plot (f, fftshift(abs(wMINUSoftFT))); grid on;
xlabel ('t'); ylabel ('|\omega-(t)|');
title ('Magnitude Spectra of \omega-(t)');

subplot (2,1,2);
plot (f, fftshift(angle(wMINUSoftFT))); grid on;
xlabel ('t'); ylabel ('\angle\omega+(t)');
```

```
title ('Phase Spectra of \omega-(t)');

% Magnitude and Phase Spectra for wc(t) function
N = 100; PulseWidth = 10;
t = [0:1:(N-1)];
x = [ones(1, PulseWidth), zeros(1, N-PulseWidth)];
wcoft = x.*(cos((pi/3).*t));
wcoftFT = fft(wcoft);
f = [-(N/2):1:(N/2)-1];

figure (3);

subplot (2,1,1);
plot (f, fftshift(abs(wcoftFT))); grid on;
xlabel ('t'); ylabel ('|\omegac(t)|');
title ('Magnitude Spectra of \omegac(t)');

subplot (2,1,2);
plot (f, fftshift(angle(wcoftFT))); grid on;
xlabel ('t'); ylabel ('\angle\omegac(t)');
title ('Phase Spectra of \omegac(t)');
```



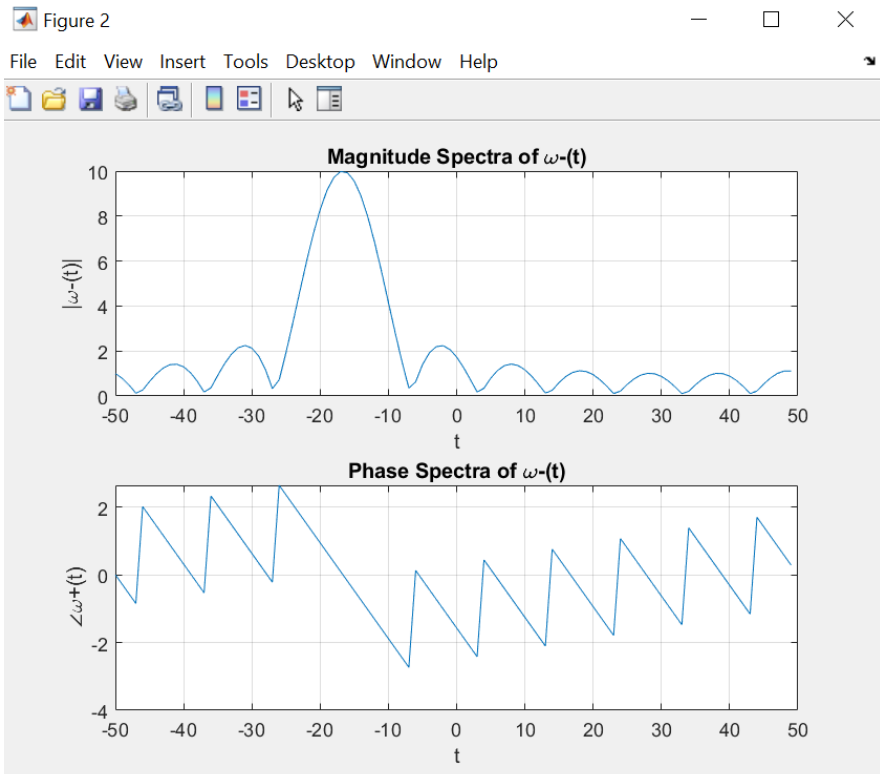


Figure 2
File Edit View Insert Tools Desktop Window Help
Magnitude Spectra of ω-(t)
|ω-(t)|
t
Phase Spectra of ω-(t)
∠ω+(t)
t

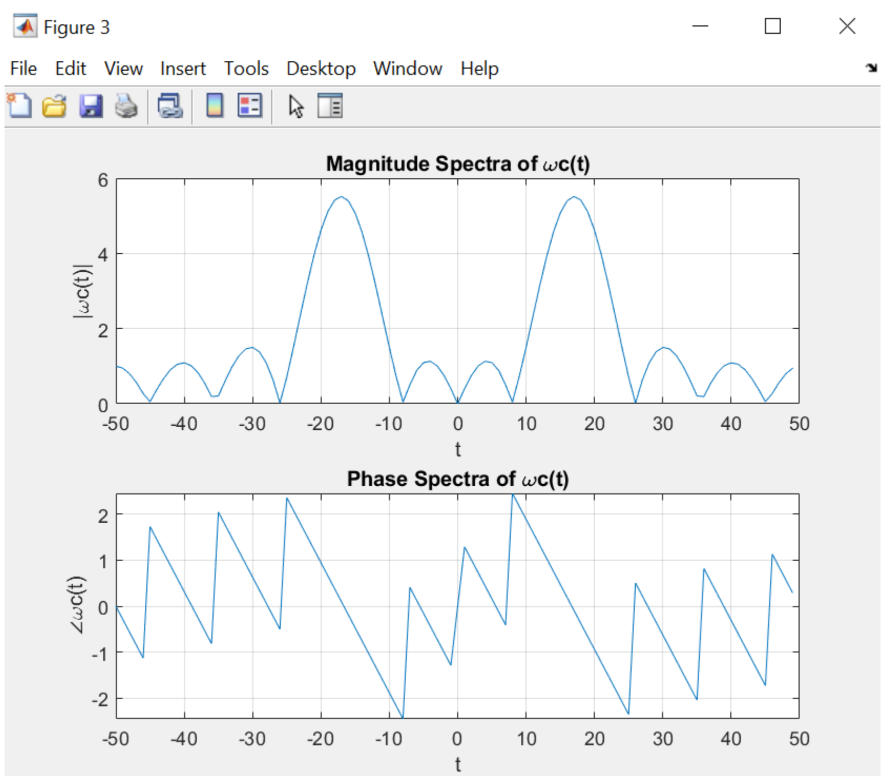


Figure 3
File Edit View Insert Tools Desktop Window Help
Magnitude Spectra of ωc(t)
|ωc(t)|
t
Phase Spectra of ωc(t)
∠ωc(t)
t

In this section of the report, the frequency shifting property of Fourier transforms is demonstrated. The results of section A.6 relative to A.3 has the same graph shapes for magnitude and phase spectra, with a slight difference in the frequency shift. It is observed that the final $\omega_c(t)$graph is the amplitude-modulated signal resulting from the combination of $\omega_+(t)$ and $\omega_-(t)$.

Problem B

Section B.1:

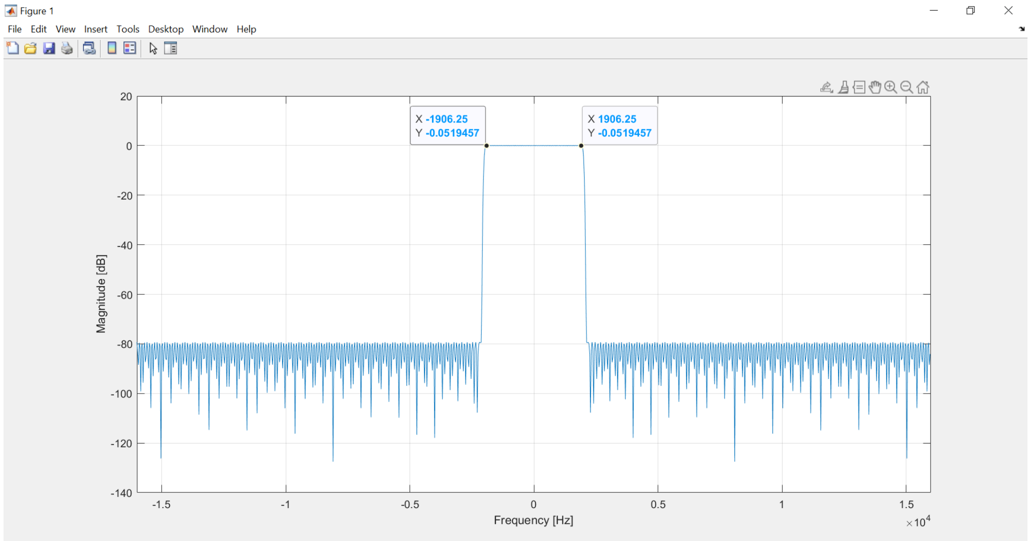
```
%Rendel Abrasia, Reza Aablue
%500942743, 500966944
%Section 4

% Problem B.1

data = load ("Lab4_Data.mat");

xspeech = data.xspeech;
hLPF2000 = data.hLPF2000; % 2000 Hz passband.
hLPF5000 = data.hLPF2500; % 2500 Hz passband.
hChannel = data.hChannel;

carrier_1 = osc (3500, 80000); % First carrier signal.
carrier_modulate = carrier_1 .* xspeech; % Modulated signal.
% Testing command: MagSpect (carrier_modulate)

convoluted_1 = conv (carrier_modulate, hChannel);
% Testing command: MagSpect (convoluted_1)

carrier_2 = osc (3500, 80810); % Second carrier signal
carrier_demodulate = carrier_2 .* convoluted_1; % Demodulated signal.
% Testing command: MagSpect (carrier_demodulate)
```

Using the MagSpect.m, osc.m, and the lab 4 data files, the behaviours of the low-pass filters hLPF2000 (2000 Hz cutoff) and hLPF2500 (2500 Hz cutoff) are examined in MATLAB. Another provided filter is the hChannel bandpass filter, where it has two bandpass cycles of 4000 Hz, representing the unit impulse response of a bandpass communications channel.

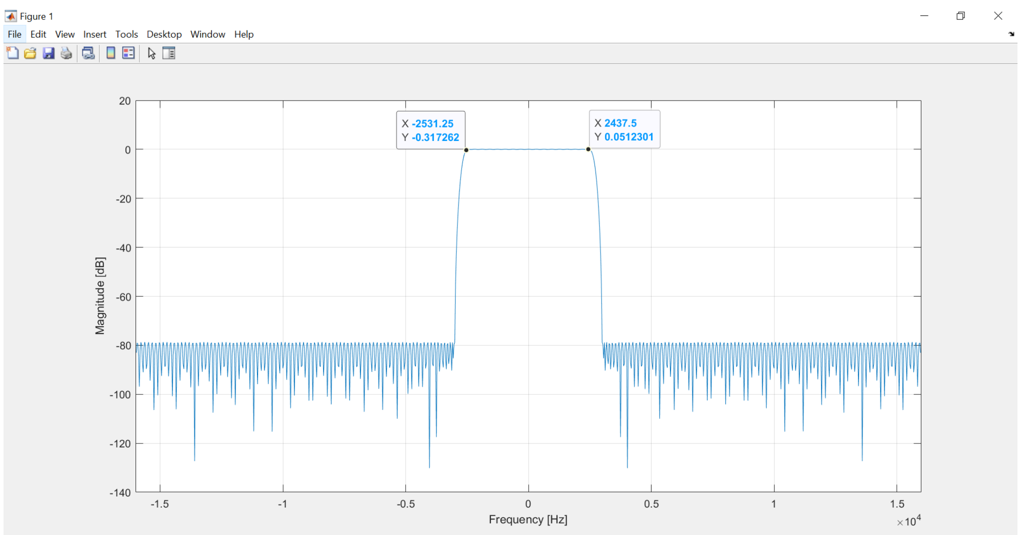
The first carrier signal, with bandwidth of 3.5 kHz and 80000 samples, is multiplied by the xspeech signal in time domain to be able to modulate the signal.

Next, by convoluting the carrier signal and hChannel in time domain, two “bumps” will be obtained in the graph, indicating that the modulated signal has been convoluted with the hChannel impulse response function.

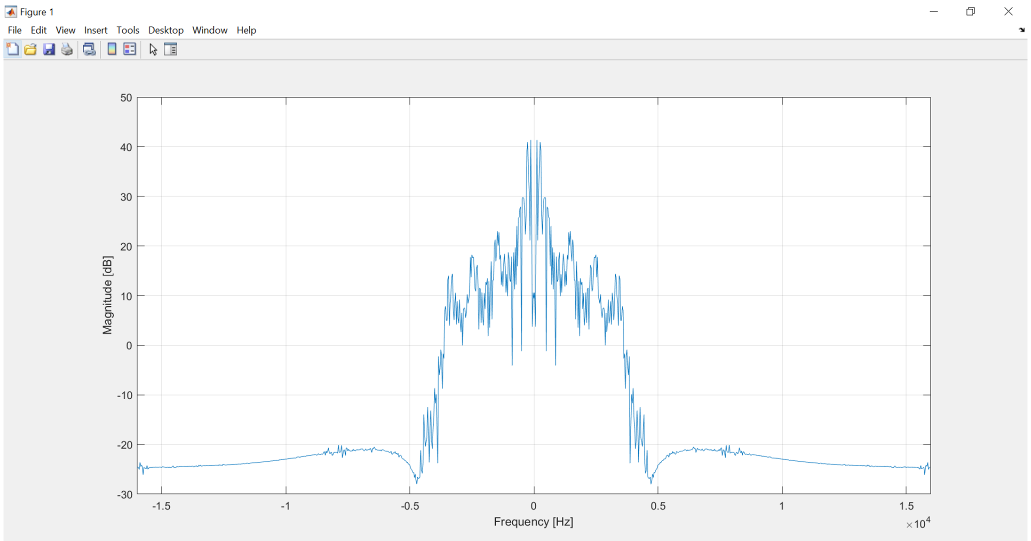
To demodulate the signal, a second carrier signal with bandwidth of 3.5 kHz and 80810 samples is multiplied by the signal from the previous step in the time domain. Finally, this signal is then convoluted with the lowpass filter of 2000 Hz cutoff frequency to be able to recover the original signal from the beginning.



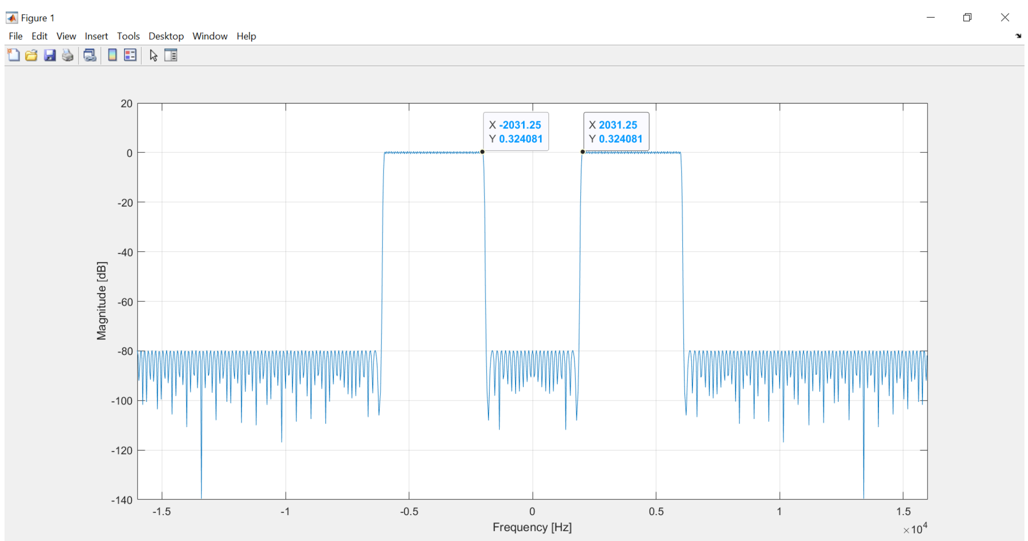
Lowpass filter hLPF2000 which cuts off at 2000 Hz.



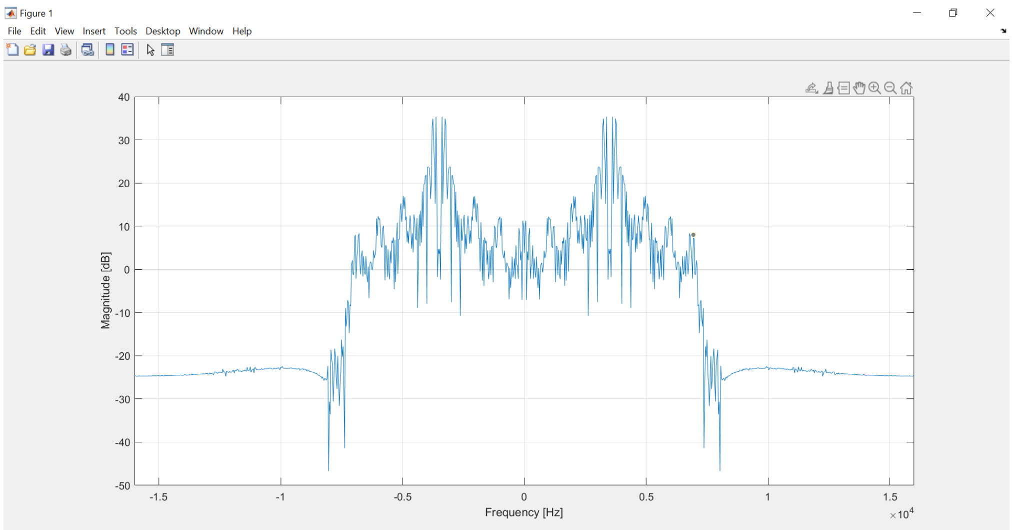
Lowpass filter hLPF2500 which cuts off at 2500 Hz.



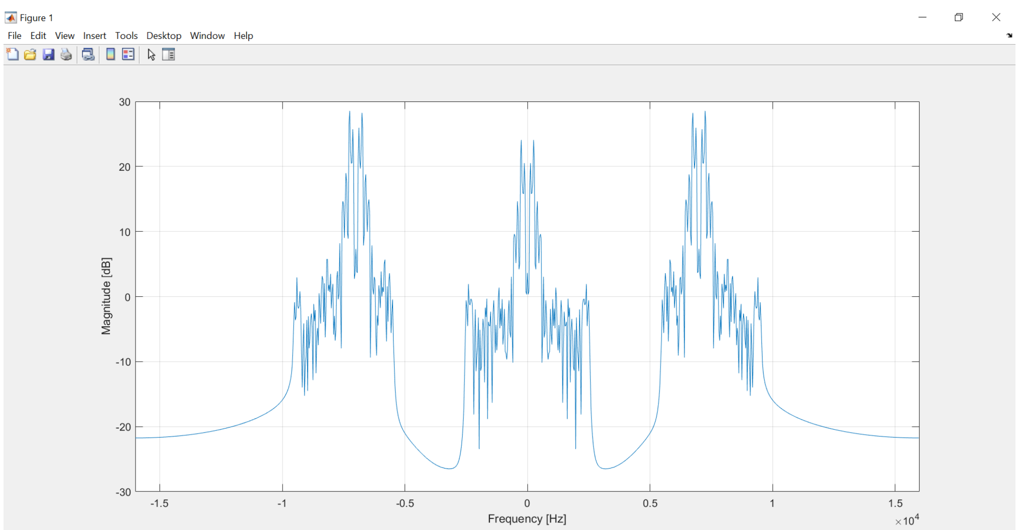
Data array xspeech, which has an 80,000 sample-long row vector representing 2.5 seconds of a speech signal from a radio broadcast sampled at 32 kHz.



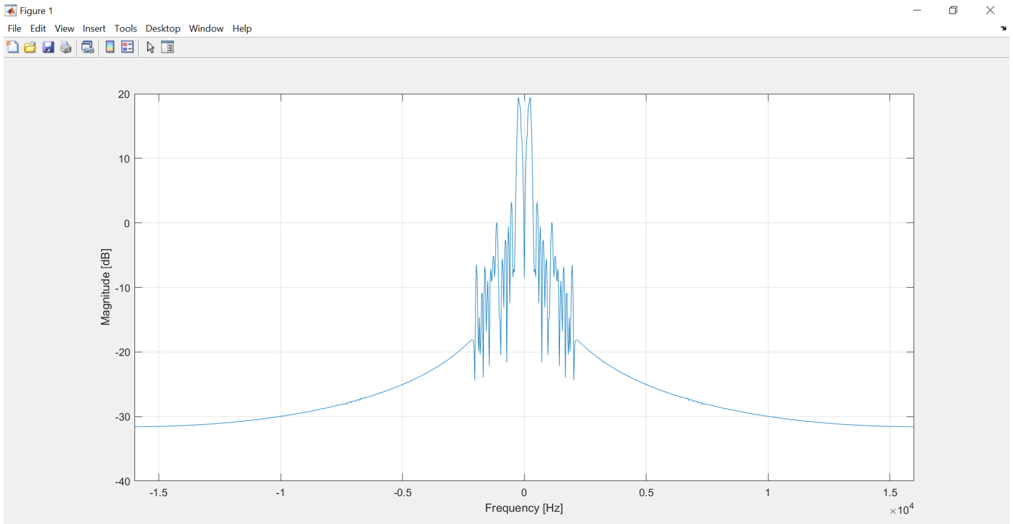
Bandpass filter hChannel with passband cycles of 4000 Hz.



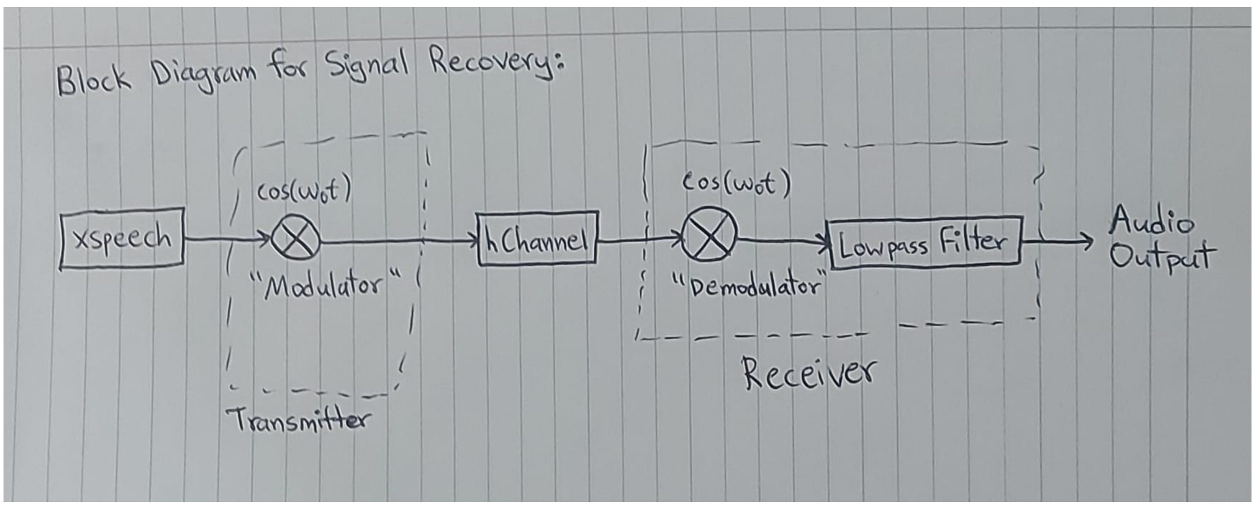
Modulated signal of the first carrier signal and xspeech data array.



The demodulated signal from the time-domain product of the second carrier signal and the modulated signal.



The original signal, recovered from modulating, demodulation and lowpass filter procedures.



Block diagram for the signal recovery process using modulation and demodulation, along with a lowpass filter.