SIGNALS AND SYSTEMS

SEMESTER PROJECT

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SIGNALS AND SYSTEMS: LAB PROJECT

TASK 1:

NOTE: In the task 1, I Wrote my own programs to meet the requirement (i.e. to produce echo and to remove it) instead of defining impulse responses and convolving them with the signals. My solutions are same as per requirements. Impulse responses of my functions are shown in the solutions, which are true as they should be.

Function to produce echo:

```
function [ y ] = fun2( x, D, alpha )
y = zeros(size(x));
y(1:D)  = x(1:D);
for i = D+1:length(x)
    y(i) = x(i) + alpha*y(i-D);
end
end
```

Function to remove echo:

```
function [rec] = fun(y, D, alpha)
rec = zeros(1, length(y));
rec(1:D) = y(1:D);
for i = D+1:length(y)
    rec(i) = y(i) - alpha*y(i-D);
end
end
```

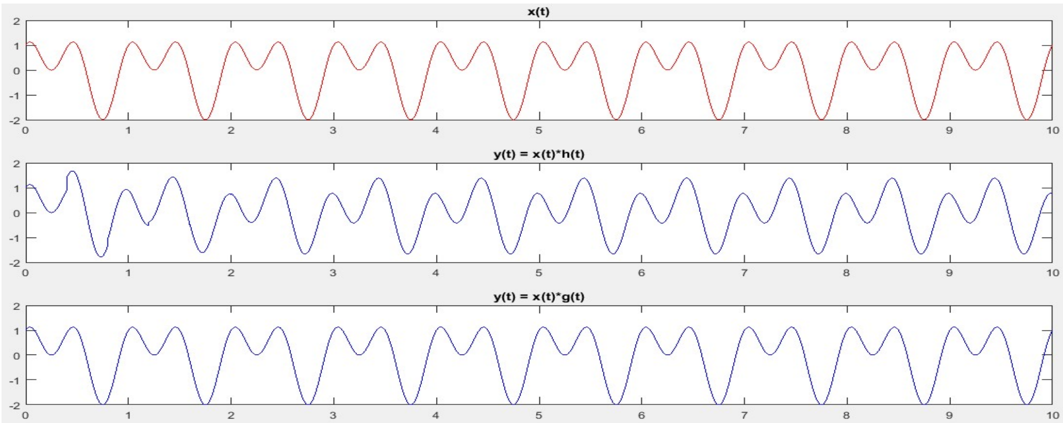
- In this Project these functions are used to produce and remove echo wherever required.

(A, B)

- First signal snapshot is for own defined function and the second one is for the audio read sound signal. This program was also tested on the audio signal.

```
% [x, Fs] = audioread('qwe.mp3');
% t = 1:length(x);
% sound(x, Fs);
Fs = 1000;
t = 0:1/Fs:10;
x = sin(2*pi*t)+cos(4*pi*t);
subplot(311), plot(t, x, 'r-')
title('x(t)');

T = 0.4;
alpha = 0.5;
D = T*Fs;

y = fun2(x, D, alpha)
```

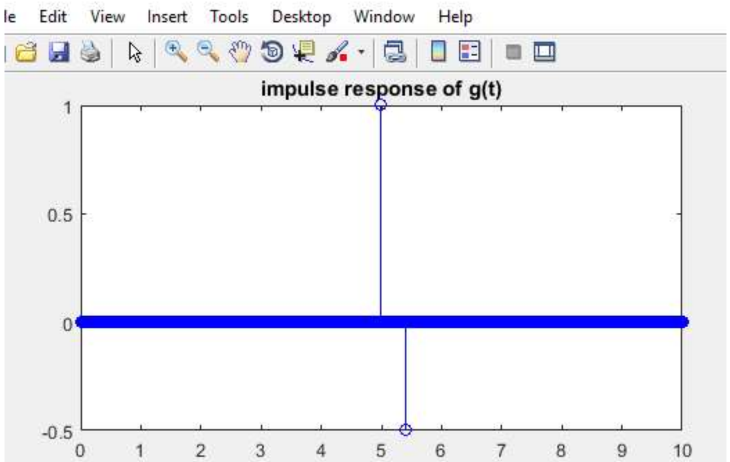
```
%sound(y, Fs); % echoed sound
subplot(312), plot(t, y, 'b-')
title('y(t) = x(t)*h(t)');

rec = fun(y, D, alpha)

subplot(313), plot(t, rec, 'b-')
title('y(t) = x(t)*g(t)');
```



(C)(1)

- Impulse response of echo removing Function.

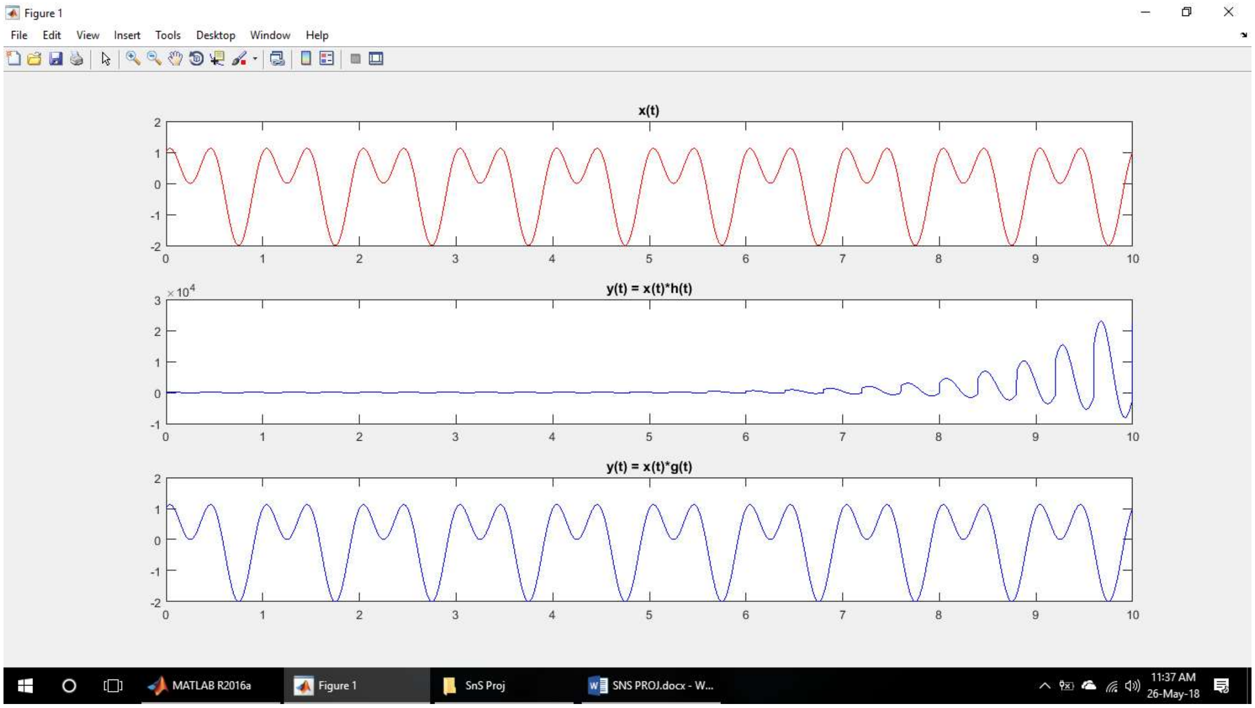
```
Fs = 1000;
t = 0:1/Fs:10;

T = 0.4;
alpha = 0.5;
D = T*Fs;
y = zeros(size(t));
y(5000) = 1;

rec = fun(y, D, alpha)

stem(t, rec, 'b-')
title('impulse response of g(t)');
```



(C)(2)

- When alpha becomes greater than one, system becomes unstable.

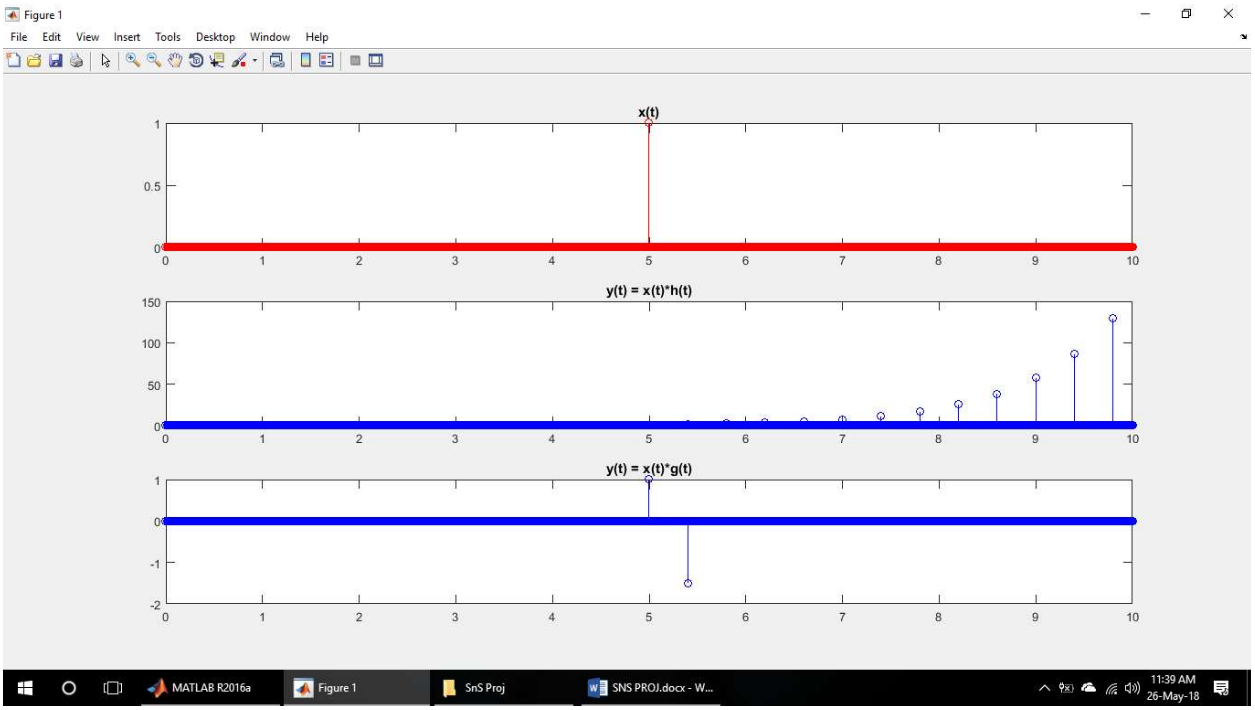
```
Fs = 1000;
t = 0:1/Fs:10;
x = sin(2*pi*t)+cos(4*pi*t);
subplot(311), plot(t, x, 'r-')
title('x(t)');

T = 0.4;
alpha = 1.5;     % alpha > 1
D = T*Fs;

y = fun2(x, D, alpha);

subplot(312), plot(t, y, 'b-')
title('y(t) = x(t)*h(t)');

rec = fun(y, D, alpha);

subplot(313), plot(t, rec, 'b-')
title('y(t) = x(t)*g(t)');
```



(C)(3)

- Impulse response when alpha is greater than one.

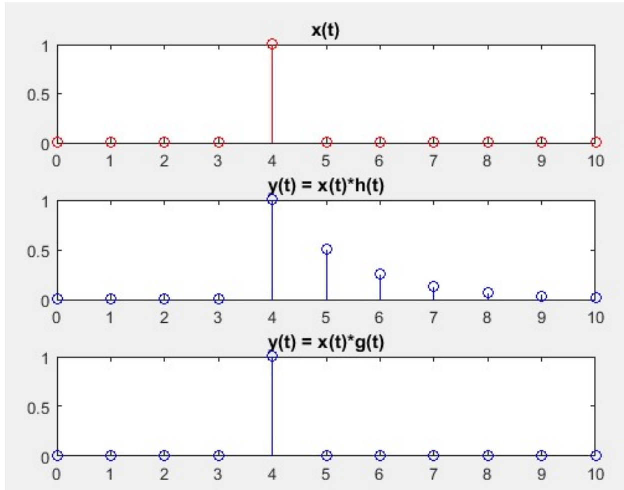
```
Fs = 1000;
t = 0:1/Fs:10;

x = zeros(1, length(t));
x(5000) = 1;

subplot(311), stem(t, x, 'r-')
title('x(t)');

T = 0.4;
alpha = 1.5;     % alpha > 1
D = T*Fs;

y = fun2(x, D, alpha);

subplot(312), stem(t, y, 'b-')
title('y(t) = x(t)*h(t)');

rec = fun(x, D, alpha)

subplot(313), stem(t, rec, 'b-')
title('y(t) = x(t)*g(t)');
```



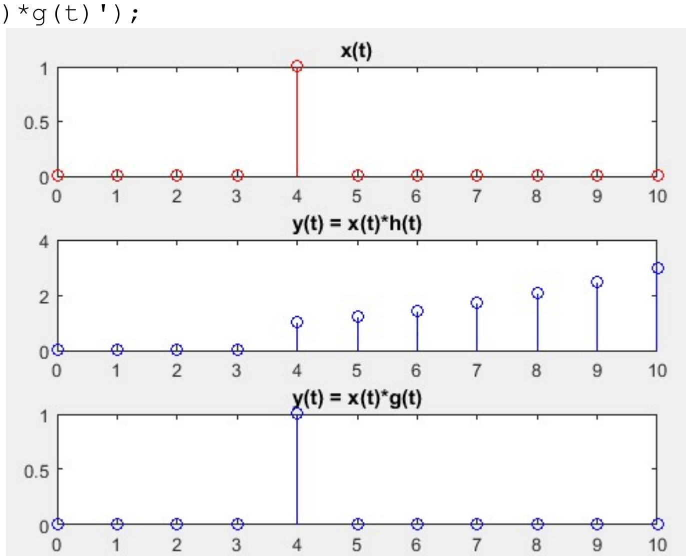
(D)

- The first implemented system in this part is invertible system. As the input impulse is very easily recovered from its impulse response. But the second one is non-invertible, because its impulse response is impulse train from –inf to +inf.

```
D = 1;
t = 0:10;
x = zeros(1, 11);
x(5) = 1;
subplot(311), stem(t, x, 'r-')
title('x(t)');

alpha = 0.5;

y = fun2(x, D, alpha);

subplot(312), stem(t, y, 'b-')
title('y(t) = x(t)*h(t)');

rec = fun(y, D, alpha);

subplot(313), stem(t, rec, 'b-')
title('y(t) = x(t)*g(t)');
```



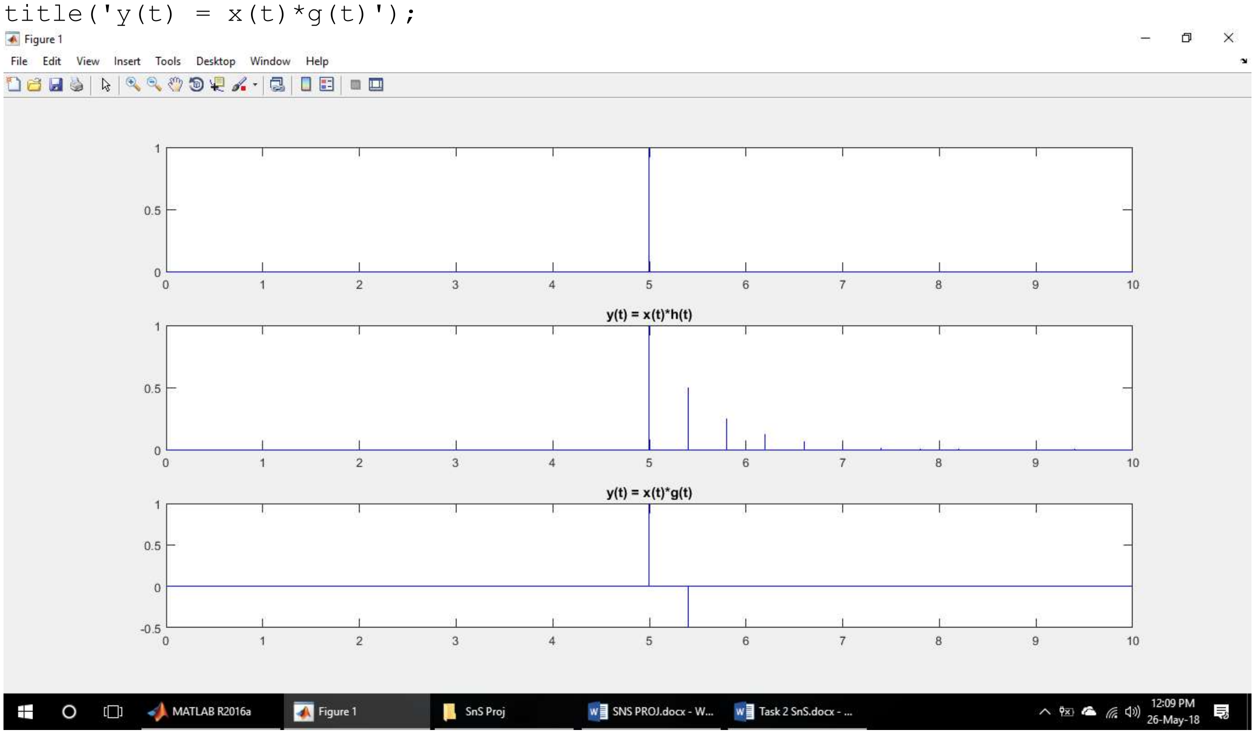

```
D = 1;
t = 0:10;
x = zeros(1, 11);
x(5) = 1;
subplot(311), stem(t, x, 'r-')
title('x(t)');

alpha = 1.2;

y = fun2(x, D, alpha);

subplot(312), stem(t, y, 'b-')
title('y(t) = x(t)*h(t)');

rec = fun(y, D, alpha);

subplot(313), stem(t, rec, 'b-')
title('y(t) = x(t)*g(t)');
```



TASK 2:

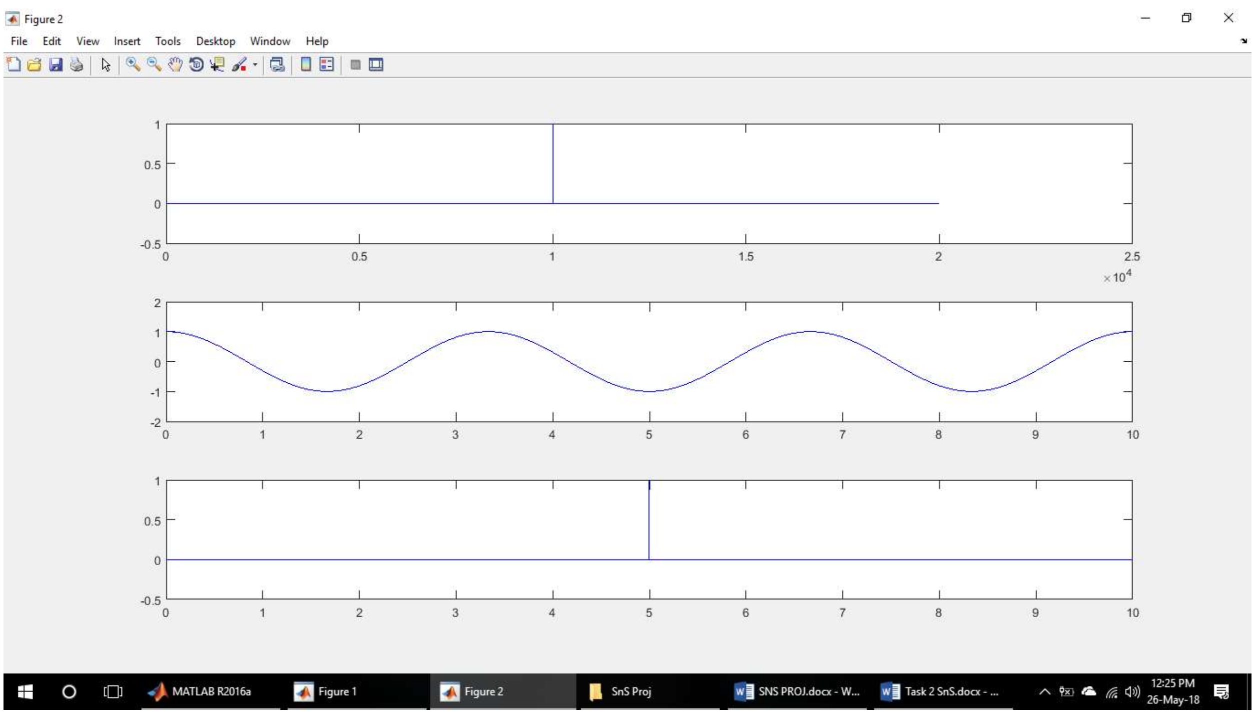
(A)

```
Fs = 1000;
t = 0:1/Fs:10;
x = zeros(size(t));
x(5000) = 1;
figure(1)
subplot(311), plot(t, x, 'b-')

T = 0.4;
alpha = 0.5;
D = T*Fs;

y = fun2(x, D, alpha);

subplot(312), plot(t, y, 'b-')
title('y(t) = x(t)*h(t)');

Y = zeros(size(t));
Y(5000) = 1;

rec = fun(Y, D, alpha);

subplot(313), plot(t, rec, 'b-')
title('y(t) = x(t)*g(t)');
```



- Impulse responses of both inverse systems.

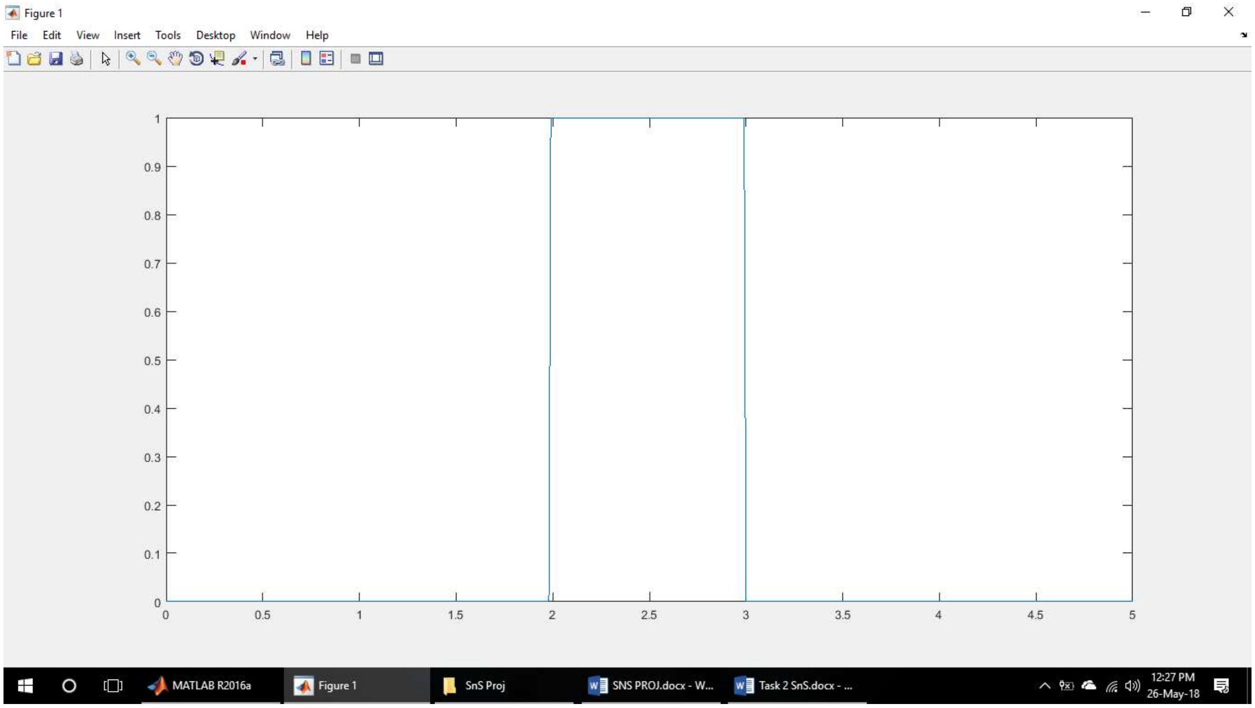
```
NEW = conv(rec, y); % conv of impulse responses of two systems in time domain
figure(2)
subplot(311), plot(NEW, 'b-')

% going into frequency domain, multiplying and taking ifft:
yw = fft(y);
recw = fft(rec);

NEW = yw.*recw;

subplot(312), plot(t, NEW, 'b-')

new = fftshift(ifft(NEW));
subplot(313), plot(t, new, 'b-')
```



- First one is the convolution of both system impulse responses, second one is multiplication in frequency domain of both signals. And the last one is the recovered signal.

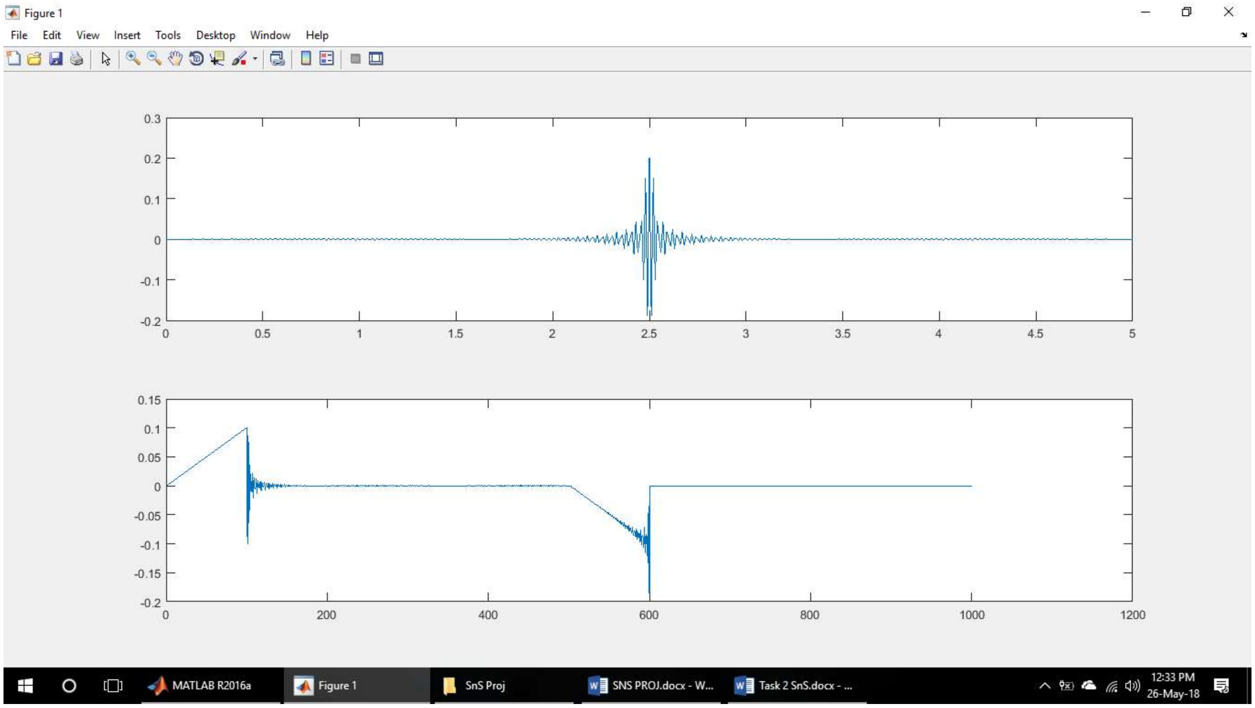
(B)(1)

```
w = 0:0.01:5;
Hjw = zeros(1, length(w));
Hjw(200:300) = 1;
length(Hjw)
plot(w, Hjw);
```



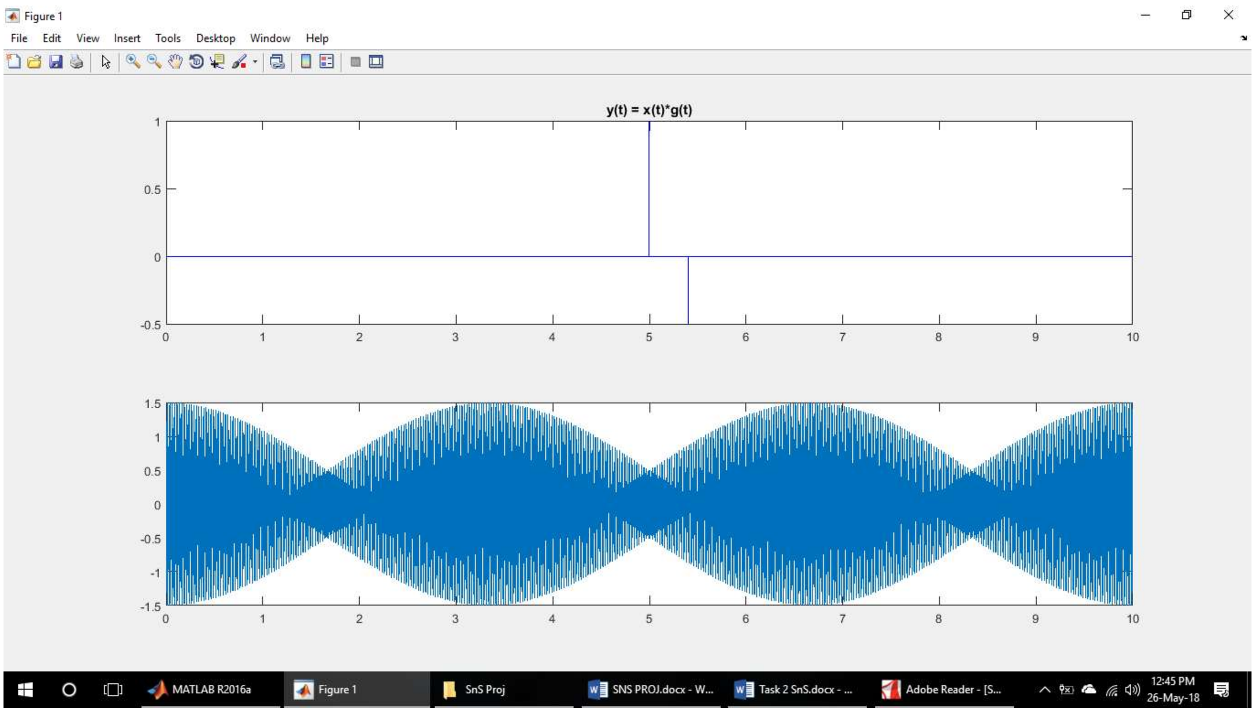
(b)(2)

```
w = 0:0.01:5;

H = zeros(1, length(w));
H(200:300) = 1;

t = 0:0.01:5;
y = t;
y(101:length(y)) = 0;

h = ifft(H);
subplot(211), plot(t, fftshift(h))

x = conv(h, y)
subplot(212), plot(1:length(x), x)
```



(C)

```
T = 0.4;
Fs = 1000;
alpha = 0.5;
D = T*Fs;

t = 0:1/Fs:10;
x = zeros(size(t));
x(5000) = 1;

g = fun(x, D, alpha);

subplot(211), plot(t, g, 'b-')
title('y(t) = x(t)*g(t)');

Gjw = fft(g);
subplot(212), plot(t, Gjw)

% FUNCTION fun IS THE INVERSE FUNCTION OF PRODUCING ECHO
% ITS IMPULSE RESPONSE IS AS FOLLOWS IN FREQ DOMAIN
```



- First one is the impulse response in time domain, and the second one is in frequency domain.

(D)

Q.2 d) $h(t) = 2\delta(t) + u(t)$

Taking Laplace Transform of both sides:

$$H(s) = 2 + \frac{1}{s} = \frac{2s+1}{s}$$

Let the inverse of $g(t)$ in time & $G(s)$ in freq. domain.

$$G(s) = \frac{1}{H(s)} = \frac{s}{2s+1} = \frac{1}{2} - \frac{1/2}{2s+1}$$

$$G(s) = \frac{1}{2} - \frac{1/2}{2s+1} = \frac{1}{2} - \frac{1/4}{s+1/2}$$

Taking Inverse Laplace transform:

$$g(t) = \frac{1}{2}\delta(t) - \frac{1}{4} e^{-0.5t} u(t)$$

(E)

Q.2 (e) LTI system described by the differential eq.

$$\frac{d^2}{dt^2}y(t) + 6\frac{d}{dt}y(t) + 9y(t) = \frac{d^2}{dt^2}x(t) + 3\frac{d}{dt}x(t) + 2(x(t))$$

Taking Laplace Transform of both sides:

$$s^2Y(s) + 6sY(s) + 9Y(s) = s^2X(s) + 3sX(s) + 2X(s)$$

$$(s^2 + 6s + 9)Y(s) = (s^2 + 3s + 2)X(s)$$

$$\frac{Y(s)}{X(s)} = \frac{s^2 + 3s + 2}{s^2 + 6s + 9} = H(s)$$

let $G(s)$ be the inverse LTI system i.e.

$$G(s) = \frac{X(s)}{Y(s)} = \frac{s^2 + 6s + 9}{s^2 + 3s + 2} = \frac{Y'(s)}{X'(s)}$$

$$(s^2 + 3s + 2)Y'(s) = (s^2 + 6s + 9)X'(s)$$

$$s^2Y'(s) + 3sY'(s) + 2Y'(s) = s^2X'(s) + 6sX'(s) + 9X'(s)$$

Taking Inverse Laplace Transform:

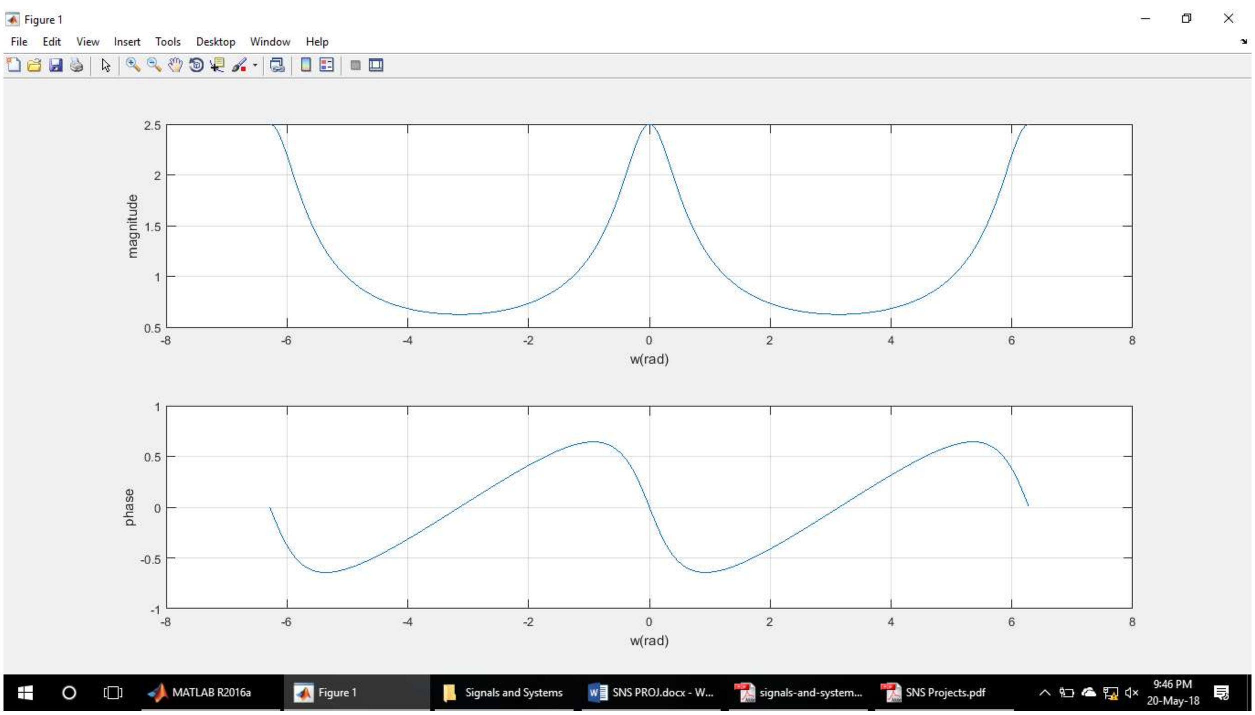
$$\frac{d^2}{dt^2}y(t) + 3\frac{d}{dt}y(t) + 2y(t) = \frac{d^2}{dt^2}x(t) + 6\frac{d}{dt}x(t) + 9(x(t))$$

TASK 3:

NOTE: All the Given figures were searched in the book and plotted in the matlab according to the given instructions.

(A)

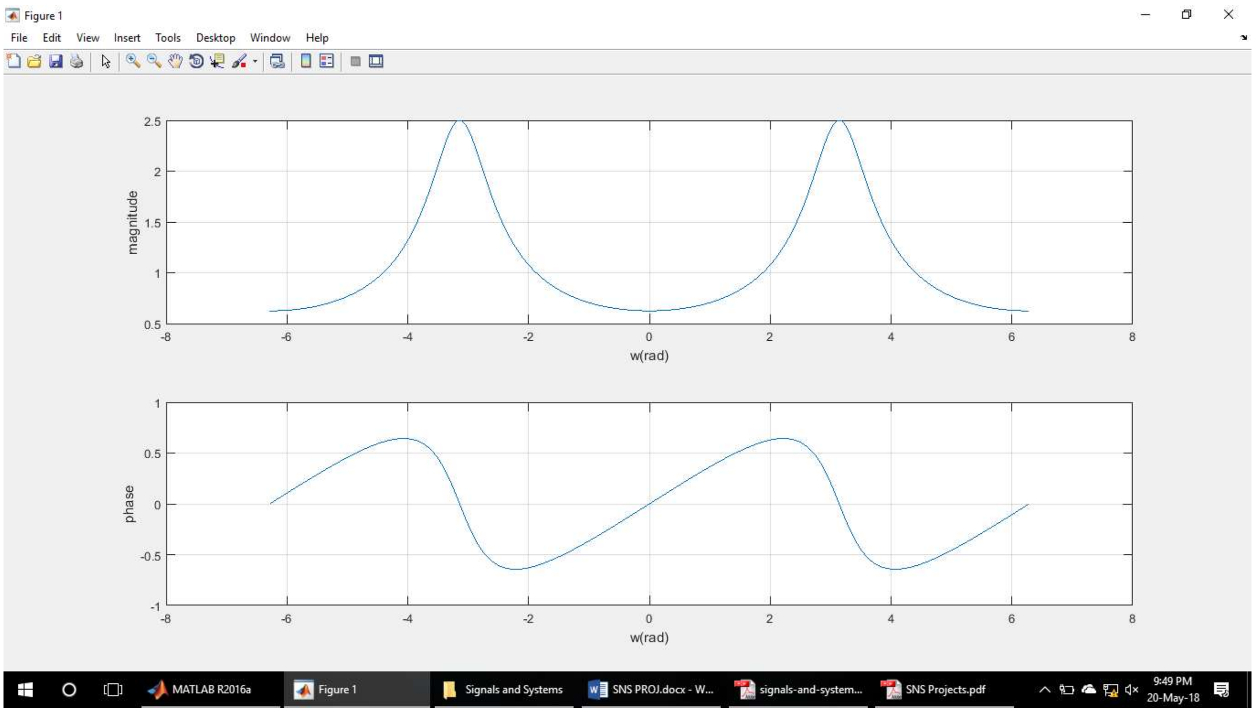
```
ws = 1000;
alpha = 0.6;
w = -2*pi:1/ws:2*pi;
H = 1./(1-(alpha).*exp(-j*w));

subplot(211), plot(w,abs(H)), grid on
ylabel('magnitude')
xlabel('w(rad)')

subplot(212), plot(w,angle(H)), grid on
ylabel('phase')
xlabel('w(rad)')
```



(B)

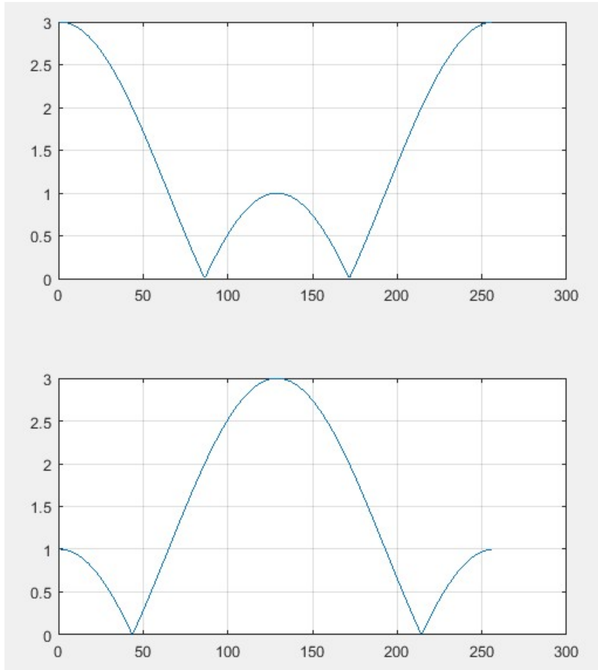
```
ws = 1000;
alpha = -0.6;
w = -2*pi:1/ws:2*pi;
H = 1./(1-(alpha).*exp(-j*w));
```

```
subplot(211), plot(w,abs(H)), grid on
ylabel('magnitude')
xlabel('w(rad)')

subplot(212), plot(w,angle(H)), grid on
ylabel('phase')
xlabel('w(rad)')
```



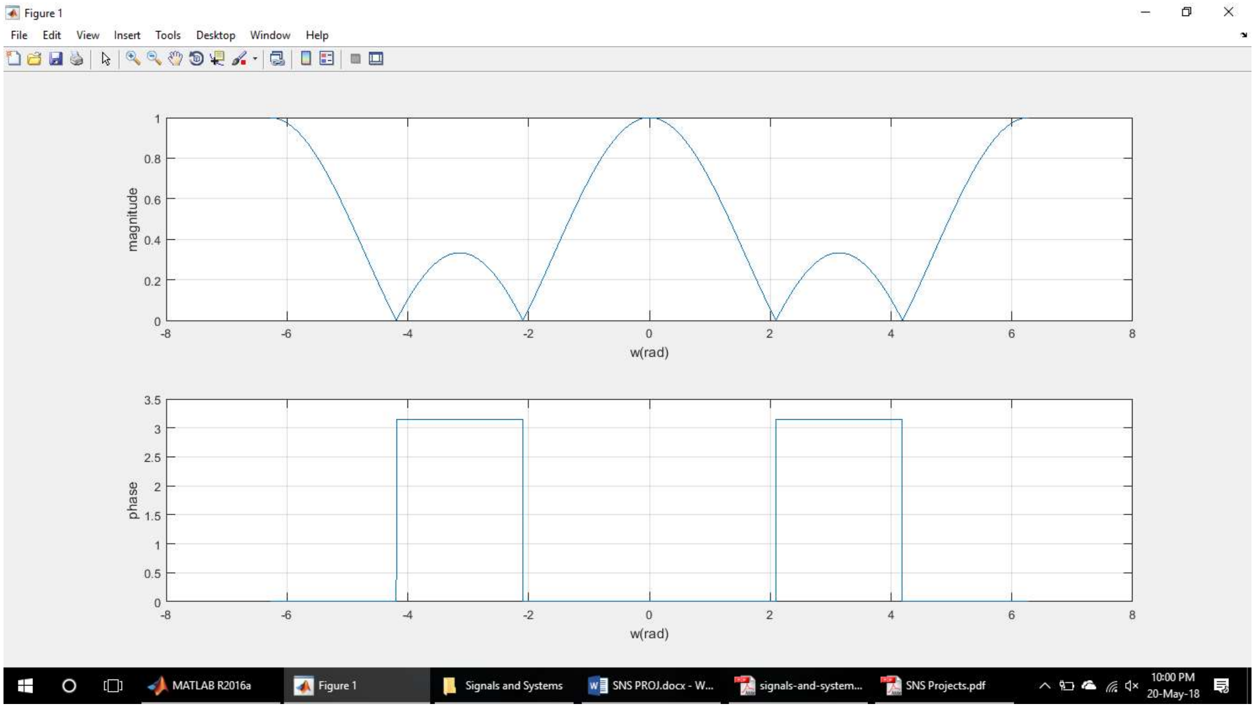
(C)

```
x = ones(1, 3);
n = 256;
X = fft(x, n);
subplot(211), plot(abs(X)), grid
subplot(212), plot(abs(fftshift(X))), grid
```



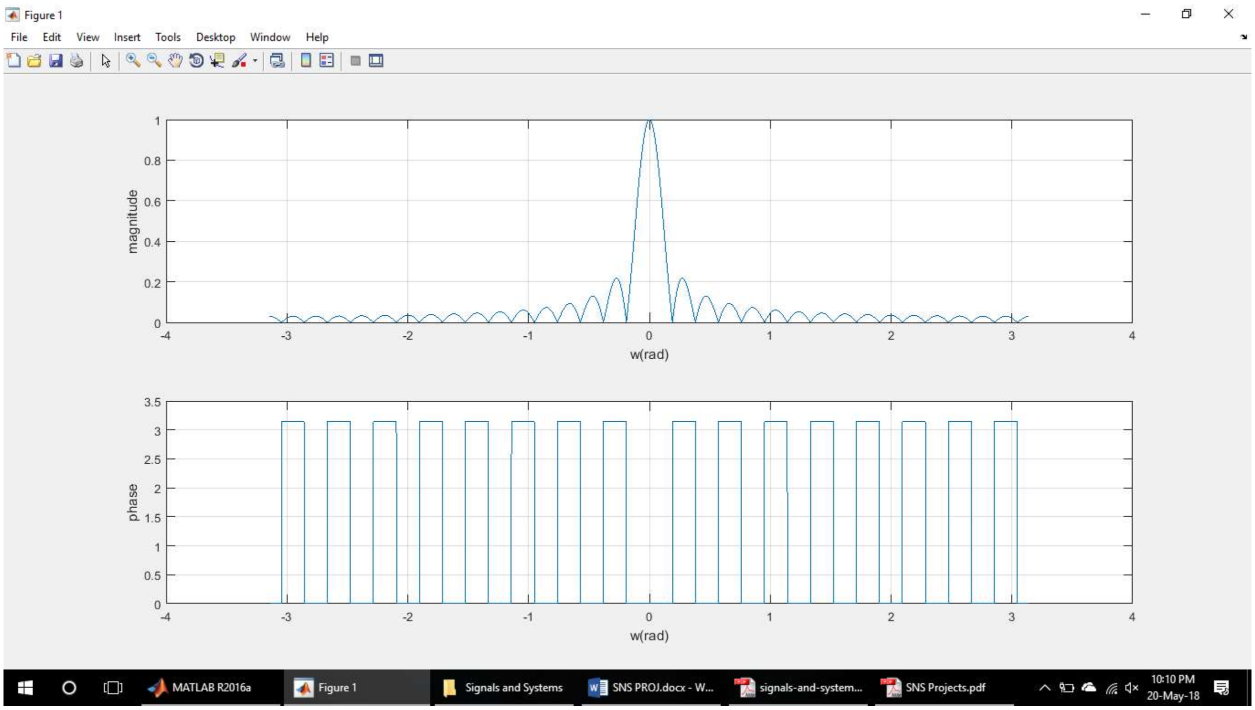
From the book calculated equations:

```
ws = 1000;
alpha = -0.6;
w = -2*pi:1/ws:2*pi;
H = 1/3*(1 + 2*cos(w));

subplot(211), plot(w,abs(H)), grid on
ylabel('magnitude')
xlabel('w(rad)')

subplot(212), plot(w,angle(H)), grid on
ylabel('phase')
xlabel('w(rad)')
```



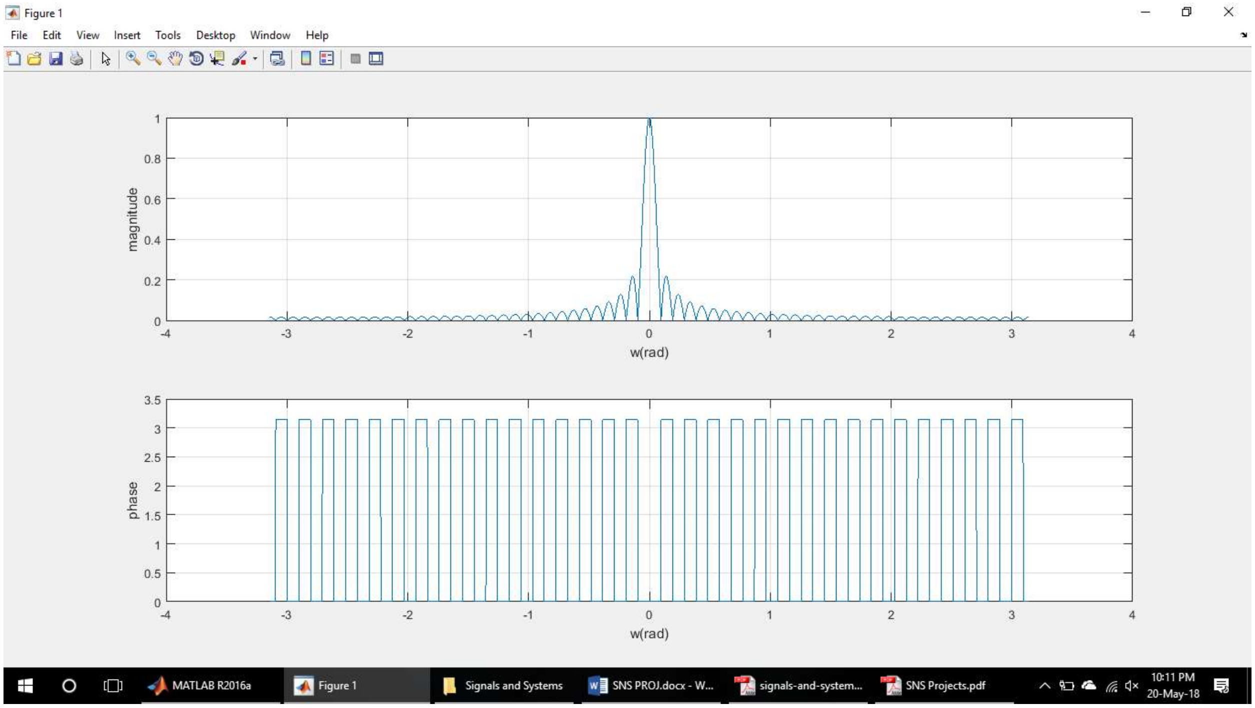
(D)(1)

```
M = 16;
N = 16;
ws = 1000;
w = -pi:1/ws:pi;
H = ((1/(M+N+1))./(sin(w/2))).*exp(j*w*(N-M)/2).*(sin(((M+N+1)/2)*w));

subplot(211), plot(w,abs(H)), grid on
ylabel('magnitude')
xlabel('w(rad)')

subplot(212), plot(w,angle(H)), grid on
ylabel('phase')
xlabel('w(rad)')
```



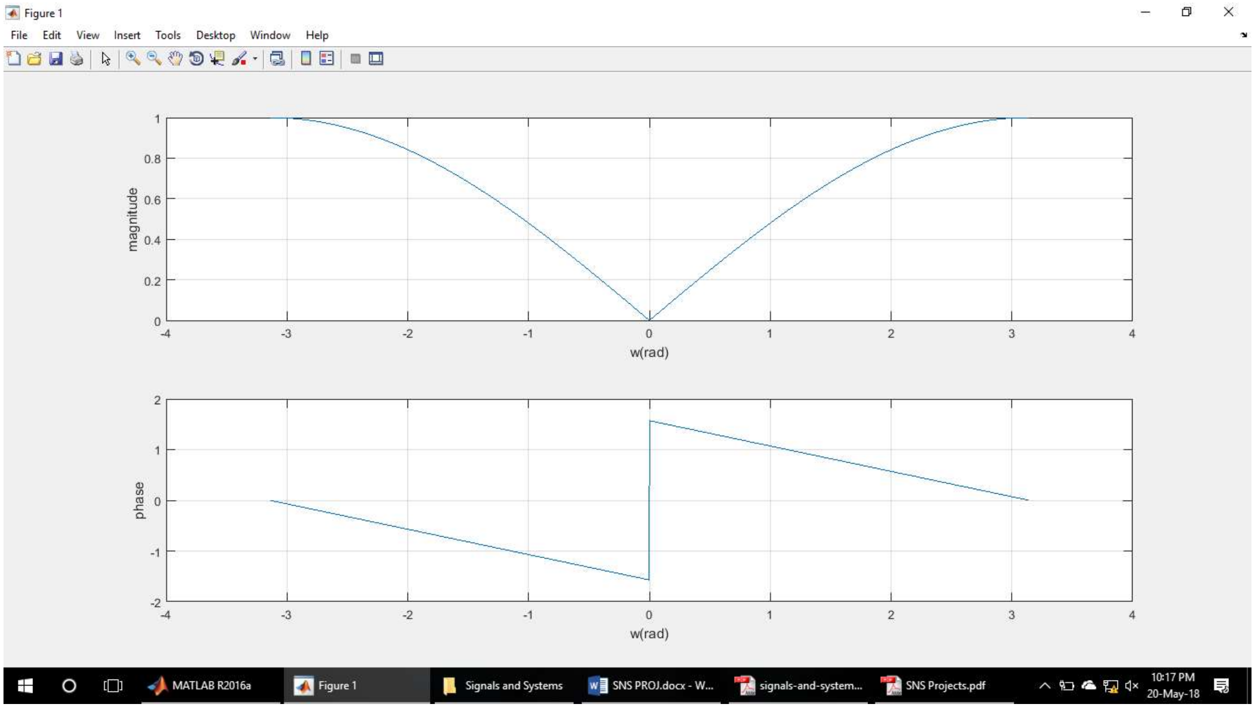
(D)(2)

```
M = 32;
N = 32;
ws = 1000;
w = -pi:1/ws:pi;
H = ((1/(M+N+1))./(sin(w/2))).*exp(j*w*(N-M)/2).*(sin(((M+N+1)/2)*w));

subplot(211), plot(w,abs(H)), grid on
ylabel('magnitude')
xlabel('w(rad)')

subplot(212), plot(w,angle(H)), grid on
ylabel('phase')
xlabel('w(rad)')
```



(D)

```
ws = 1000;
w = -pi:1/ws:pi;
H = 1/2*(1-exp(-j*w));

subplot(211), plot(w,abs(H)), grid on
ylabel('magnitude')
xlabel('w(rad)')

subplot(212), plot(w,angle(H)), grid on
ylabel('phase')
xlabel('w(rad)')
```



CONCLUSION:

The Purpose of this lab Project was to make us completely familiar with the different techniques of the MATLAB. I was supposed to work in the time domain (i.e. task 1) as well as the frequency domain (i.e. task 2). Moreover, in the last task, I was supposed to plot the different functions in the MATLAB. This project helped me in the Deep understanding of the software MATLAB.