Table of Contents


```
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% Section: 28944
% TA: Noaki Sawahashi
```

QUESTION 1 COMMENTING

```
% DO NOT REMOVE THE LINE BELOW
% MAKE SURE 'eel3135_lab06_comment.m' IS IN THE SAME DIRECTORY AS THIS
 FILE
clear; close all; clc;
type('eel3135_lab06_comment.m')


%% USER-DEFINED VARIABLES
clear
close all
clc

%% DEFINE FILTER
N = 10;
h = (1/N)*ones(N,1);

% <-- Answer Question: What is the impulse response of this filter?
%     Use d in place of delta.
% 1/10(d[n] + d[n-1] + d[n-2] + d[n-3] + d[n-4] + d[n-5] + d[n-6] +
 d[n-7]
```

```
% + d[n-8] + d[n-9])

% COMPUTE THE DTFT
n = 0:(N-1);
w = -pi:pi/5000:pi;
H = DTFT(h,w);

% PLOT THE IMPULSE RESPONSE AND DTFT
figure
subplot(3,1,1)
stem(n,h)
xlim([-0.5 20.5])
title('Impulse Response of h')
xlabel('Time Index (n)')
ylabel('Amplitude')
subplot(3,1,2)
plot(w,abs(H))
grid on;
title('Magnitude Response of H')
ylabel('Magnitude [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
subplot(3,1,3)
plot(w,angle(H))
grid on;
title('Phase Response of H')
ylabel('Phase [rad]')
xlabel('Normalized Angular Frequency [rad/s]')


function H = DTFT(x,w)
%  ===> Computes the DTFT of the input <===

    H = zeros(length(w),1);
    for nn = 1:length(x)
        H = H + x(nn).*exp(-1j*w.'*(nn-1));
    end

end
```

QUESTION 2: DTFT OF COMMON FUNCTIONS

COMPUTE THE DTFT

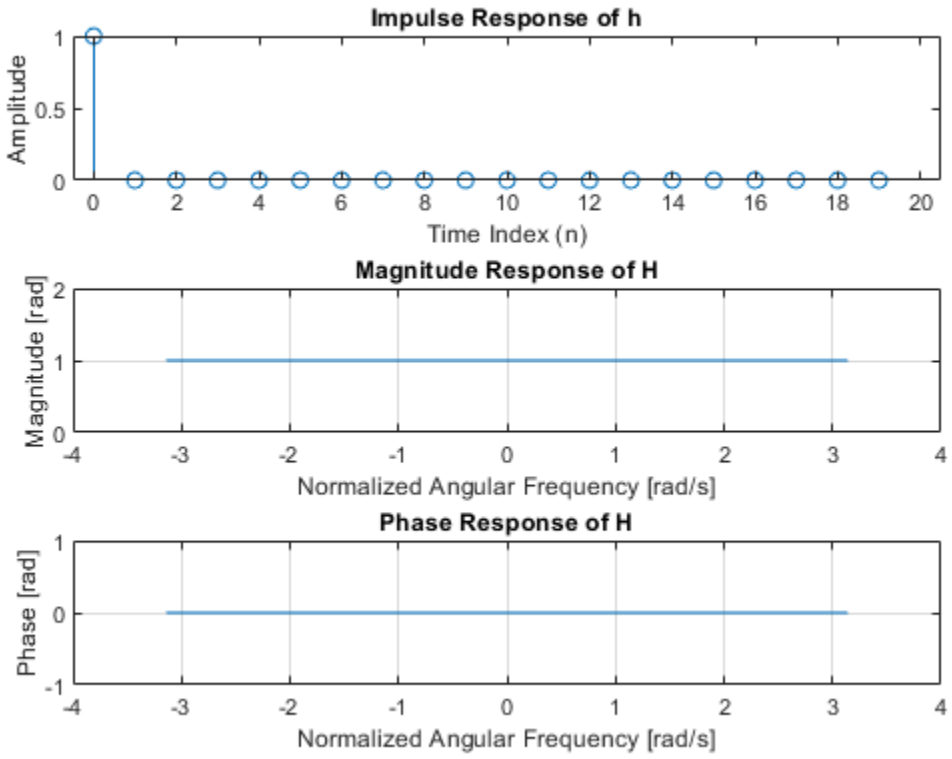
```
N = 20;
w = -pi:pi/5000:pi;
```

2 (a) PLOT DTFT

ALSO ANSWER: Is the data predominantly low frequency, high frequency, or neither? Neither predominantly high or low frequency

```
n = 0:(N-1);
h = [1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0];
```

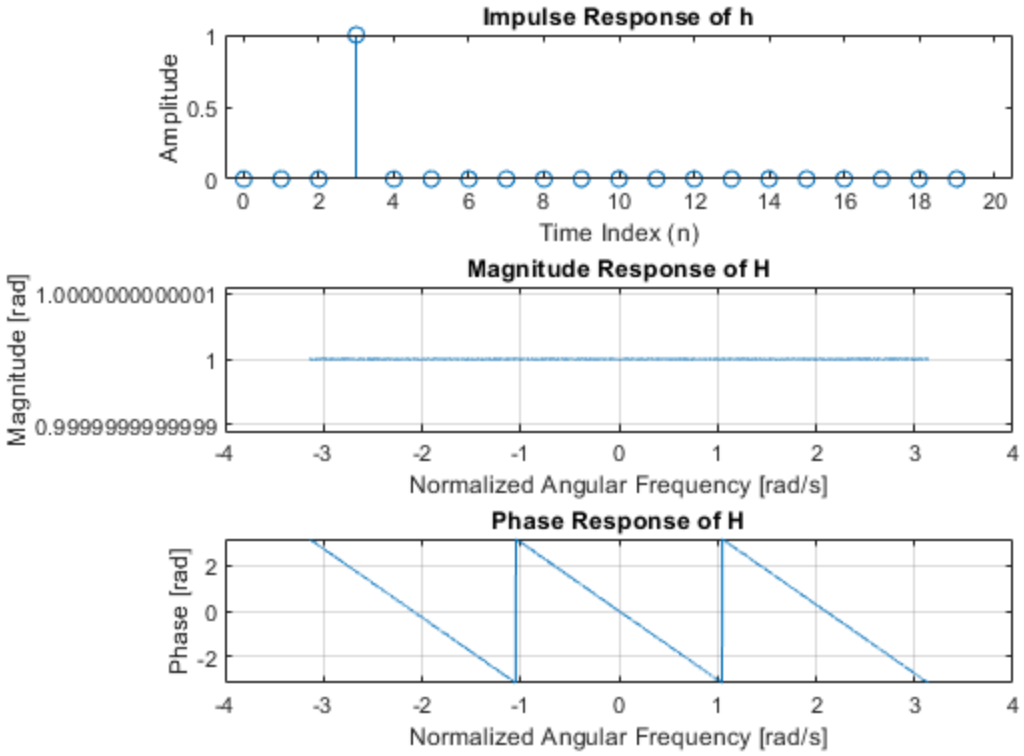
```
H = DTFT(h,w);

figure
subplot(3,1,1)
stem(n,h)
xlim([-0.5 20.5])
title('Impulse Response of h')
xlabel('Time Index (n)')
ylabel('Amplitude')
subplot(3,1,2)
plot(w,abs(H))
grid on;
title('Magnitude Response of H')
ylabel('Magnitude [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
subplot(3,1,3)
plot(w,angle(H))
grid on;
title('Phase Response of H')
ylabel('Phase [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
```



2 (b) PLOT DTFT

ALSO ANSWER: Is the data predominantly low frequency, high frequency, or neither? Neither predominantly high or low frequency

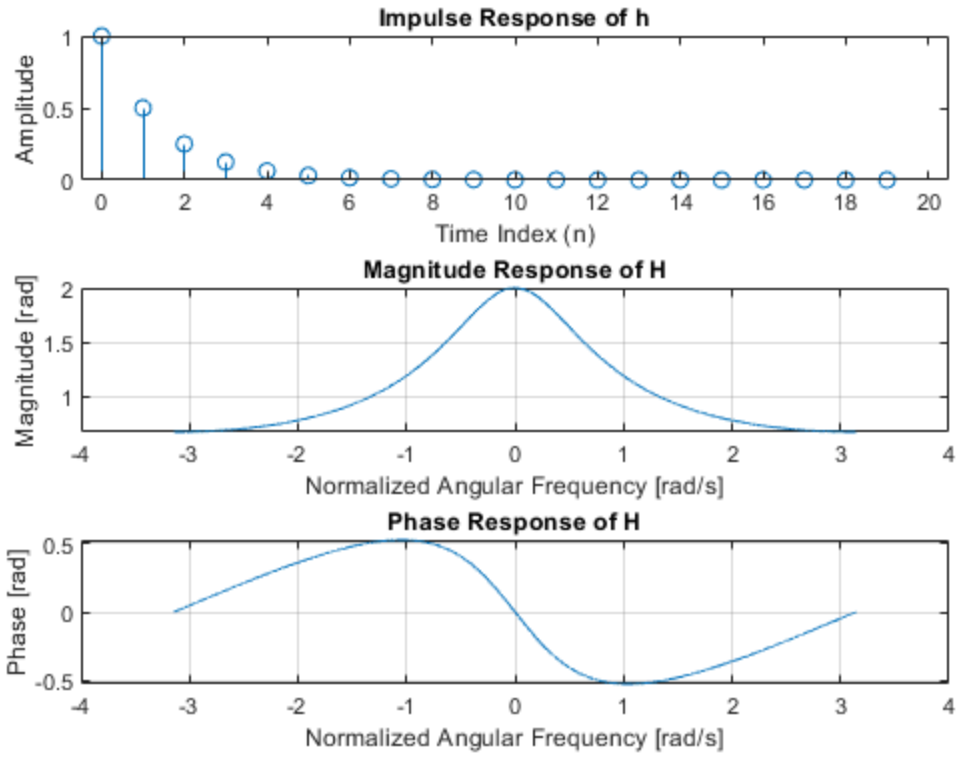
```
n = (0:(N-1));
h = [0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0];
H = DTFT(h,w);

figure
subplot(3,1,1)
stem(n,h)
xlim([-0.5 20.5])
title('Impulse Response of h')
xlabel('Time Index (n)')
ylabel('Amplitude')
subplot(3,1,2)
plot(w,abs(H))
grid on;
title('Magnitude Response of H')
ylabel('Magnitude [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
subplot(3,1,3)
plot(w,angle(H))
grid on;
title('Phase Response of H')
ylabel('Phase [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
```



2 (c) PLOT DTFT

ALSO ANSWER: Is the data predominantly low frequency, high frequency, or neither? Predominantly low frequency

```
n = (0:(N-1));
h = ((1/2).^n);
H = DTFT(h,w);

figure
subplot(3,1,1)
stem(n,h)
xlim([-0.5 20.5])
title('Impulse Response of h')
xlabel('Time Index (n)')
ylabel('Amplitude')
subplot(3,1,2)
plot(w,abs(H))
grid on;
title('Magnitude Response of H')
ylabel('Magnitude [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
subplot(3,1,3)
plot(w,angle(H))
grid on;
title('Phase Response of H')
ylabel('Phase [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
```

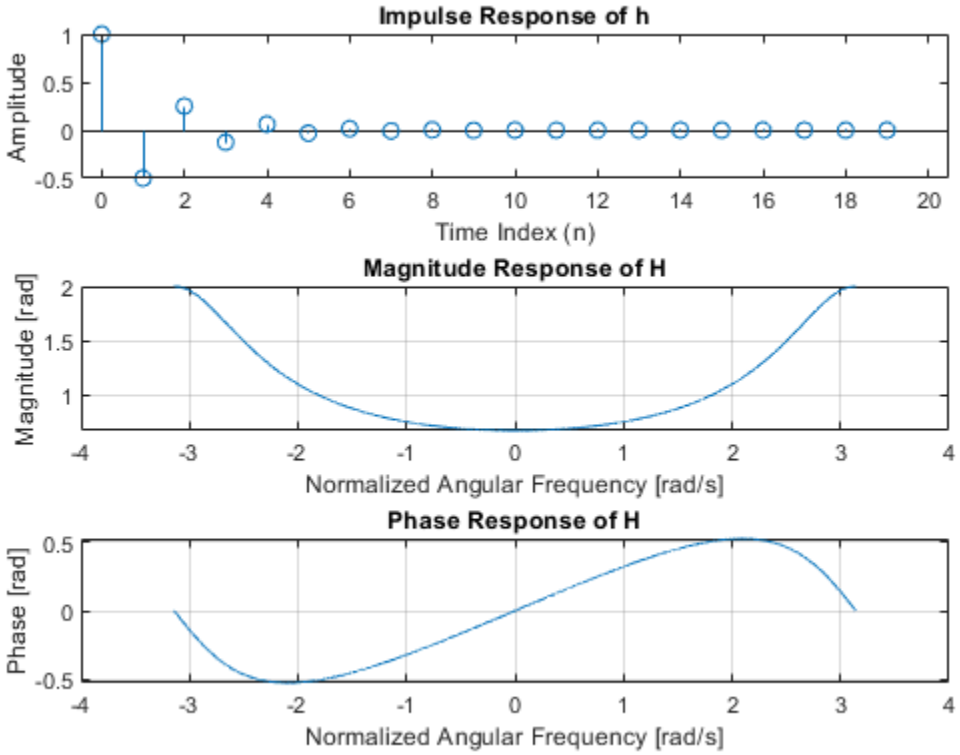


2 (d) PLOT DTFT

ALSO ANSWER: Is the data predominantly low frequency, high frequency, or neither? Predominantly high frequency

```
n = (0:(N-1));
h = (-1/2).^n;
H = DTFT(h,w);

figure
subplot(3,1,1)
stem(n,h)
xlim([-0.5 20.5])
title('Impulse Response of h')
xlabel('Time Index (n)')
ylabel('Amplitude')
subplot(3,1,2)
plot(w,abs(H))
grid on;
title('Magnitude Response of H')
ylabel('Magnitude [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
subplot(3,1,3)
plot(w,angle(H))
grid on;
title('Phase Response of H')
```

```
ylabel('Phase [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
```

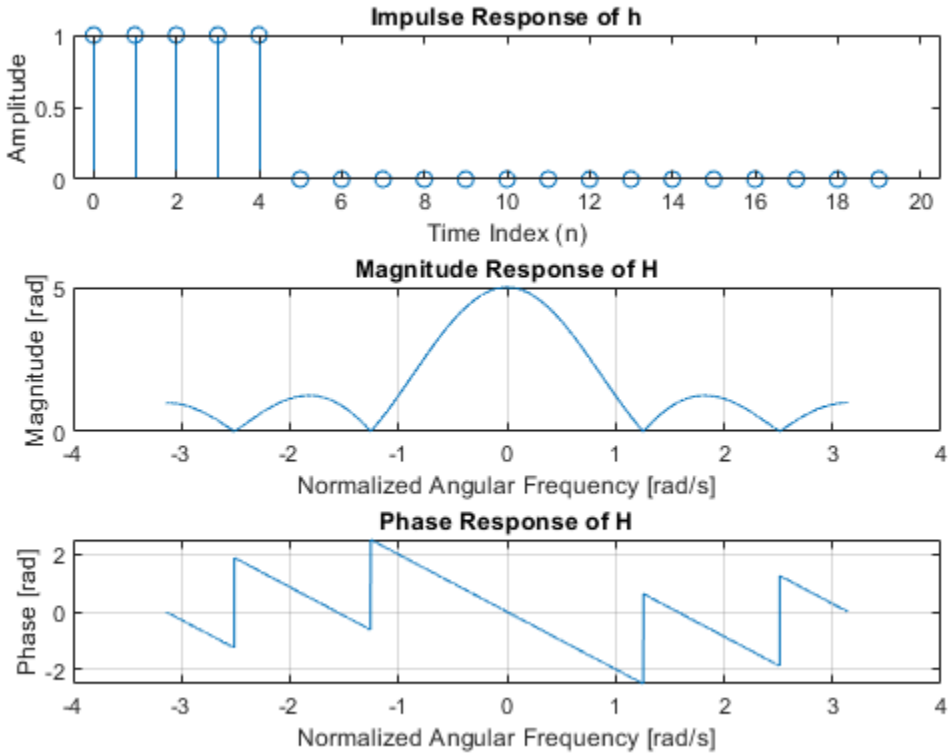


2 (e) PLOT DTFT

ALSO ANSWER: Is the data predominantly low frequency, high frequency, or neither? Predominantly low frequency with small bands over some high frequencies

```
n = (0:(N-1));
h = [1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0];
H = DTFT(h,w);

figure
subplot(3,1,1)
stem(n,h)
xlim([-0.5 20.5])
title('Impulse Response of h')
xlabel('Time Index (n)')
ylabel('Amplitude')
subplot(3,1,2)
plot(w,abs(H))
grid on;
title('Magnitude Response of H')
ylabel('Magnitude [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
subplot(3,1,3)
```

```
plot(w,angle(H))
grid on;
title('Phase Response of H')
ylabel('Phase [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
```

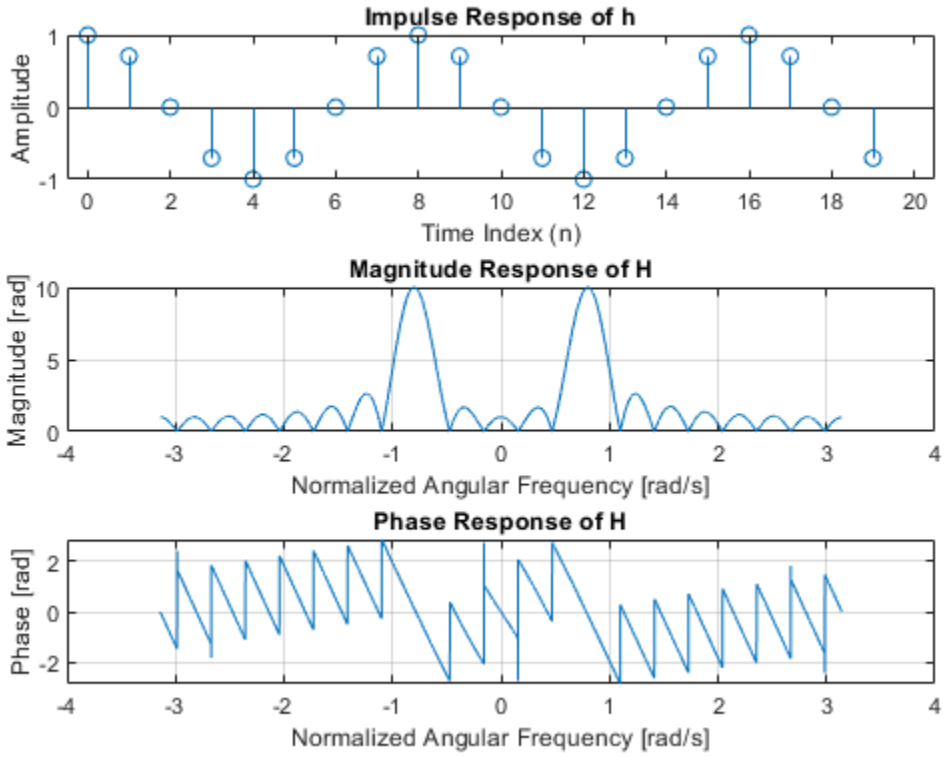


2 (f) PLOT DTFT

ALSO ANSWER: Is the data predominantly low frequency, high frequency, or neither? Predominantly low frequency with small bands over some high frequencies

```
n = (0:(N-1));
h = cos((pi/4).*n);
H = DTFT(h,w);

figure
subplot(3,1,1)
stem(n,h)
xlim([-0.5 20.5])
title('Impulse Response of h')
xlabel('Time Index (n)')
ylabel('Amplitude')
subplot(3,1,2)
plot(w,abs(H))
grid on;
title('Magnitude Response of H')
```

```
ylabel('Magnitude [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
subplot(3,1,3)
plot(w,angle(H))
grid on;
title('Phase Response of H')
ylabel('Phase [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
```



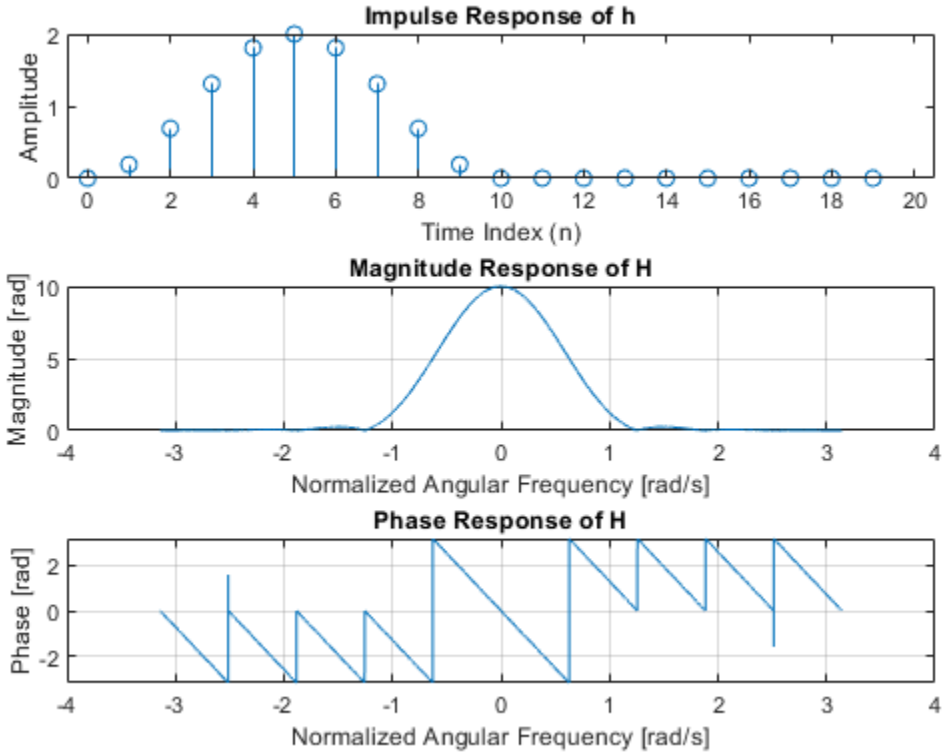
QUESTION 3: DTFT PROPERTIES

3(a) PLOT DTFT

ALSO ANSWER: describe how each system changes the frequency domain Is the original domain

```
n = (0:(N-1));
xn = (1 - cos((pi/5).*n)) .* [1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0
 0];
h = xn;
H = DTFT(h,w);

figure
subplot(3,1,1)
stem(n,h)
xlim([-0.5 20.5])
```

```
title('Impulse Response of h')
xlabel('Time Index (n)')
ylabel('Amplitude')
subplot(3,1,2)
plot(w,abs(H))
grid on;
title('Magnitude Response of H')
ylabel('Magnitude [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
subplot(3,1,3)
plot(w,angle(H))
grid on;
title('Phase Response of H')
ylabel('Phase [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
```



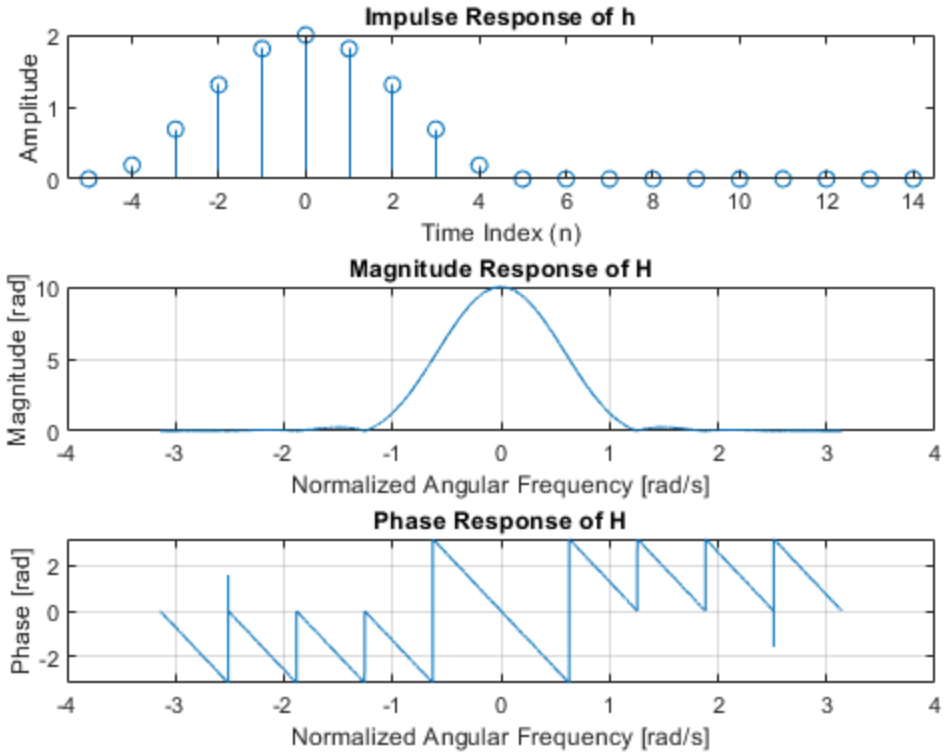
3(b) PLOT DTFT

ALSO ANSWER: describe how each system changes the frequency domain

Only the impusle response is shifted

```
n = (0:(N-1));
xn = (1 - cos((pi/5).*n)) .* [1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0
 0];
h = xn;
```

```
H = DTFT(h,w);

figure
subplot(3,1,1)
stem(n-5,h)
xlim([-5.5 14.5])
title('Impulse Response of h')
xlabel('Time Index (n)')
ylabel('Amplitude')
subplot(3,1,2)
plot(w,abs(H))
grid on;
title('Magnitude Response of H')
ylabel('Magnitude [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
subplot(3,1,3)
plot(w,angle(H))
grid on;
title('Phase Response of H')
ylabel('Phase [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
```

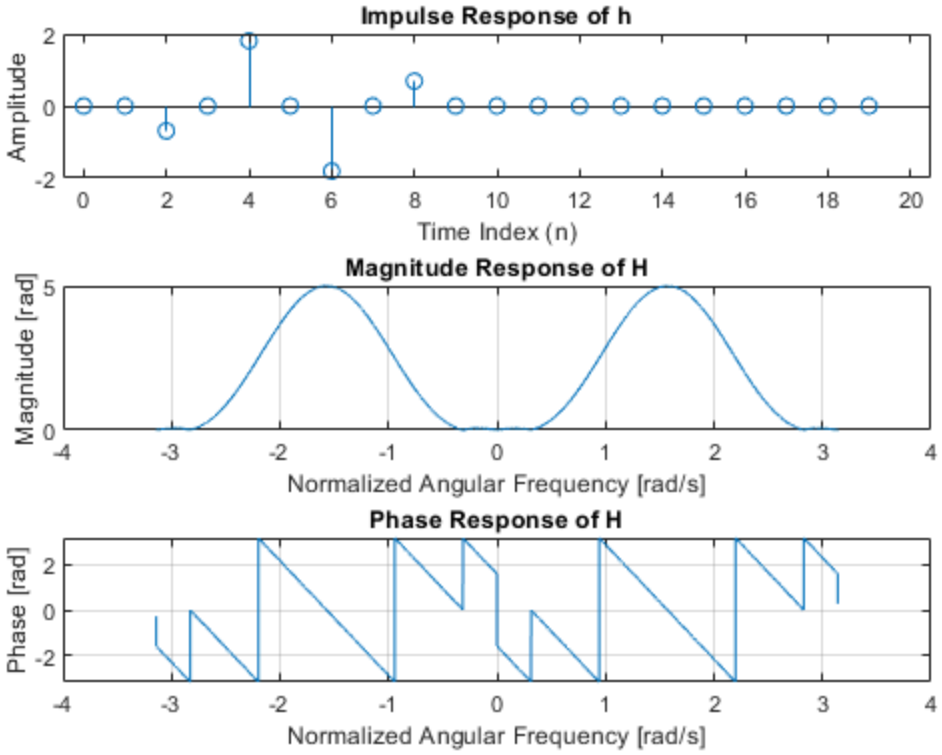


3(c) PLOT DTFT

ALSO ANSWER: describe how each system changes the frequency domain

There are bands over the frequency +-pi/2

```
n = (0:(N-1));
xn = (1 - cos((pi/5).*n)) .* [1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0
 0];
h = xn .*(cos((pi/2).*n));
H = DTFT(h,w);

figure
subplot(3,1,1)
stem(n,h)
xlim([-0.5 20.5])
title('Impulse Response of h')
xlabel('Time Index (n)')
ylabel('Amplitude')
subplot(3,1,2)
plot(w,abs(H))
grid on;
title('Magnitude Response of H')
ylabel('Magnitude [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
subplot(3,1,3)
plot(w,angle(H))
grid on;
title('Phase Response of H')
ylabel('Phase [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
```



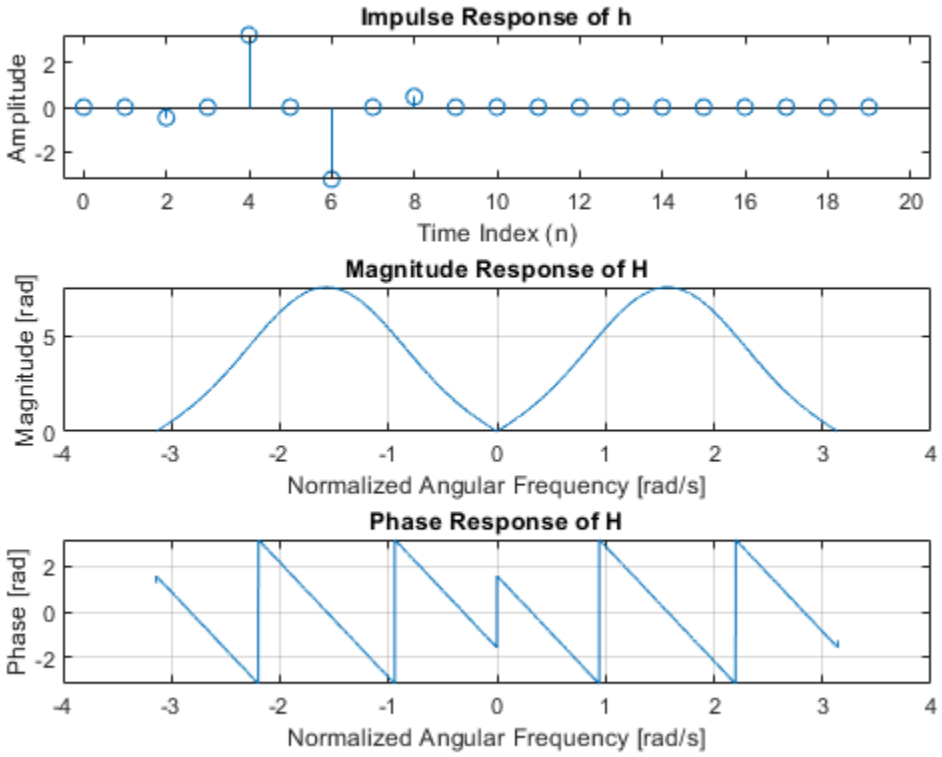
3(d) PLOT DTFT

ALSO ANSWER: describe how each system changes the frequency domain

There are evev larger bands over the frequency +-pi/2

```
n = (0:(N-1));
xn = (1 - cos((pi/5).*n)) .* [1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0
 0];
h = xn .* (xn.*(cos((pi/2).*n)));
H = DTFT(h,w);

figure
subplot(3,1,1)
stem(n,h)
xlim([-0.5 20.5])
title('Impulse Response of h')
xlabel('Time Index (n)')
ylabel('Amplitude')
subplot(3,1,2)
plot(w,abs(H))
grid on;
title('Magnitude Response of H')
ylabel('Magnitude [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
subplot(3,1,3)
```

```
plot(w,angle(H))
grid on;
title('Phase Response of H')
ylabel('Phase [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
```



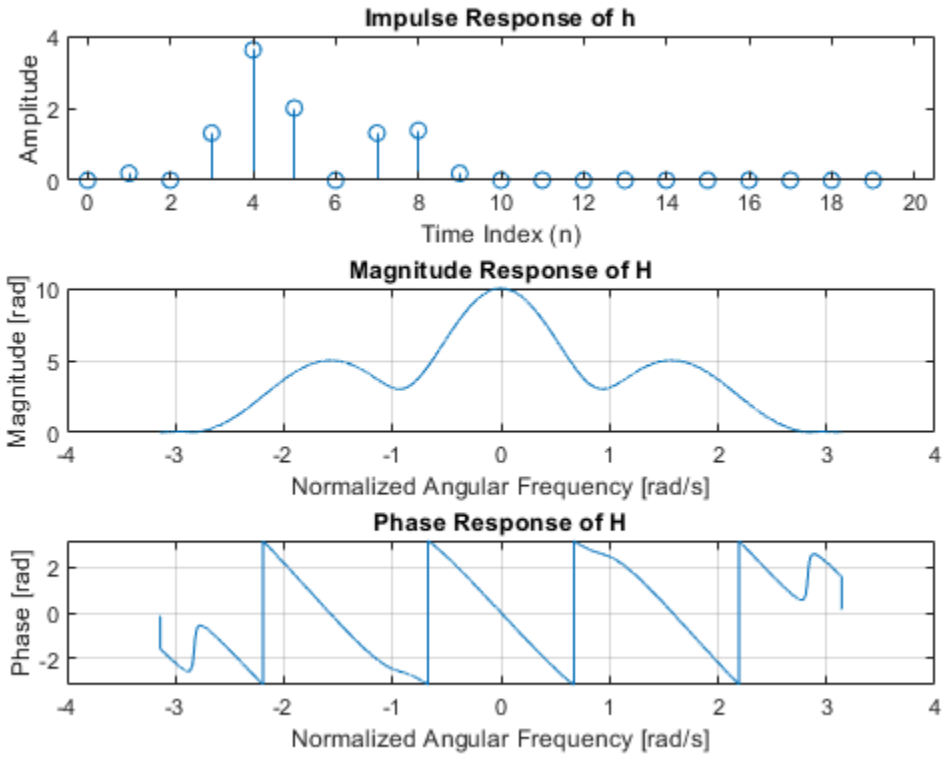
3(e) PLOT DTFT

ALSO ANSWER: describe how each system changes the frequency domain

The freqeuncy is centered around 0 with a decline towards +-pi with a small spike at +-pi/2

```
n = (0:(N-1));
xn = (1 - cos((pi/5).*n)) .* [1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0
 0];
h = xn + (xn.*(cos((pi/2).*n)));
H = DTFT(h,w);

figure
subplot(3,1,1)
stem(n,h)
xlim([-0.5 20.5])
title('Impulse Response of h')
xlabel('Time Index (n)')
ylabel('Amplitude')
subplot(3,1,2)
```

```
plot(w,abs(H))
grid on;
title('Magnitude Response of H')
ylabel('Magnitude [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
subplot(3,1,3)
plot(w,angle(H))
grid on;
title('Phase Response of H')
ylabel('Phase [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
```



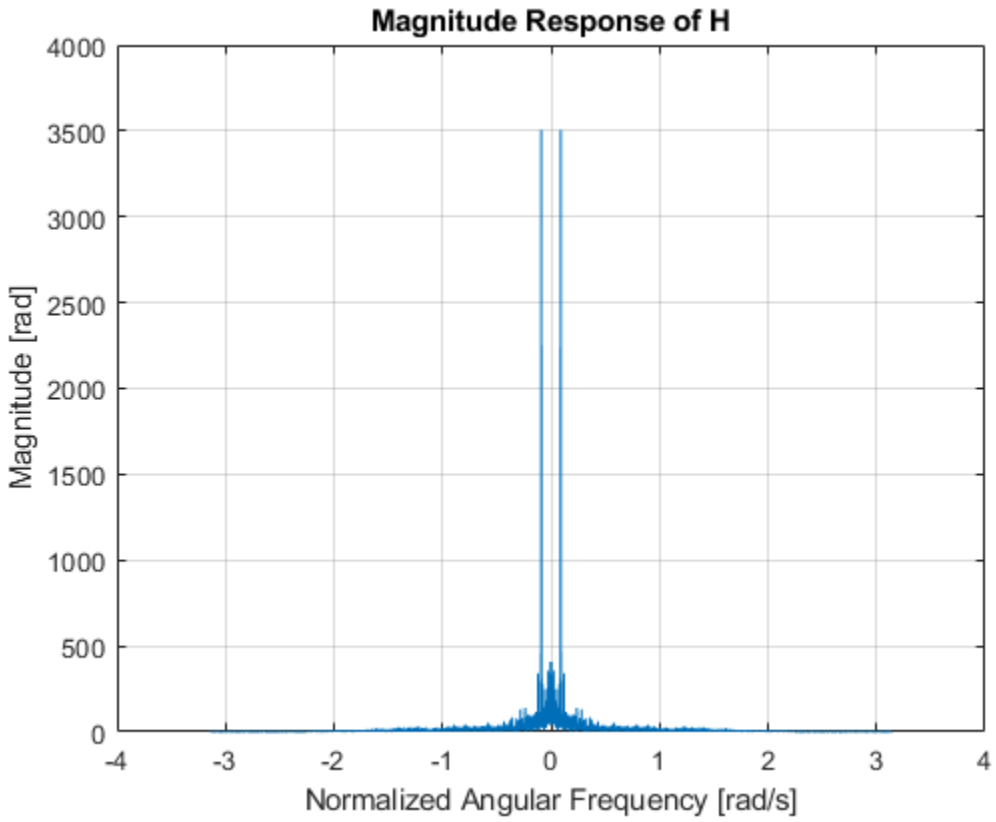
QUESTION 4: NULLING FILTER

```
% DO NOT REMOVE THE LINE BELOW
% MAKE SURE 'NoisyWannabe.wav' IS IN THE SAME DIRECTORY AS THIS FILE
[x, fs] = audioread('Noisy.wav');
```

4(a) EVALUATE DTFT OF INPUT SIGNAL

```
w = -pi:pi/5000:pi;
H = DTFT(x,w);

figure
plot(w, abs(H))
```

```
grid on
title('Magnitude Response of H')
ylabel('Magnitude [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
```



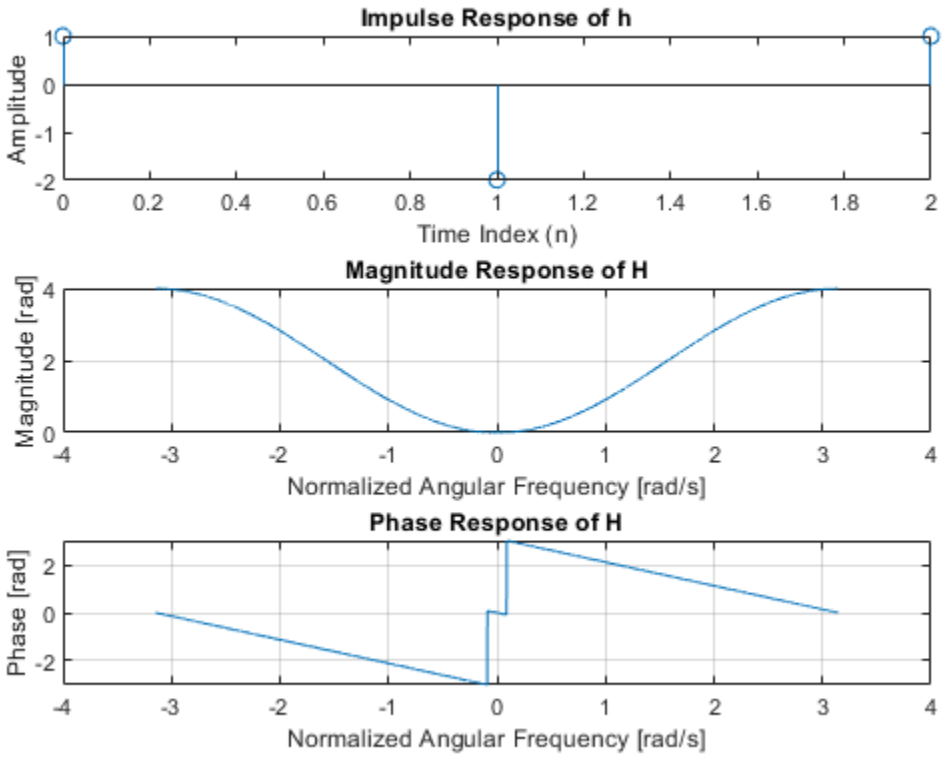
4(b) IDENTIFY FREQUENCY

```
% <== ANSWER TO QUESTION ==>
% The normalized angular noise freqeuncy is roughly 0.08922
% The continuous-time cyclic frequency is 626.2144

w1 = 0.08922;
freq1 = (w1*fs)/(2*pi);
```

4(c) DESIGN FILTER

```
h = [1, -2*cos(w1), 1];
N = length(h);
n = (0:(N-1));
H = DTFT(h,w);

figure
subplot(3,1,1)
stem(n,h)
title('Impulse Response of h')
```

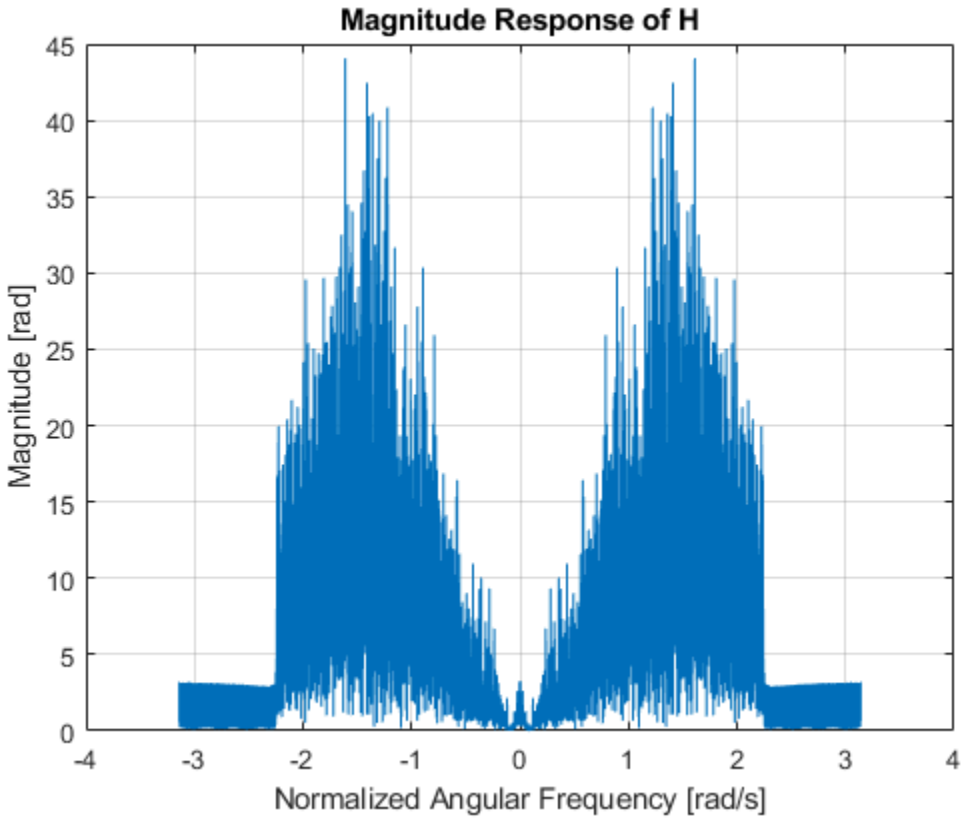
```
xlabel('Time Index (n)')
ylabel('Amplitude')
subplot(3,1,2)
plot(w,abs(H))
grid on;
title('Magnitude Response of H')
ylabel('Magnitude [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
subplot(3,1,3)
plot(w,angle(H))
grid on;
title('Phase Response of H')
ylabel('Phase [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
```



4(d) APPLY FILTER

```
% <== ANSWER TO QUESTION ==>
% There are no longer the massive peaks in magnitude in the filtered
 audio.
% The plot also follows the filter magnitude as if it were overlayed
 on top.

filter = conv(h,x);
H = DTFT(filter,w);
```

```
figure
plot(w,abs(H))
grid on;
title('Magnitude Response of H')
ylabel('Magnitude [rad]')
xlabel('Normalized Angular Frequency [rad/s]')
```



4(e) LISTEN TO AUDIO

```
soundsc(filter,fs);
filter_sc = filter/max(abs(filter));
audiowrite('lab6.wav', filter_sc, fs);
```

ALL FUNCTIONS SUPPORTING THIS CODE

```
function H = DTFT(x,w)
%  ===> Computes the DTFT of the input <===

    H = zeros(length(w),1);
    for nn = 1:length(x)
        H = H + x(nn).*exp(-1j*w.'*(nn-1));
    end

end
```

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