

Glasgow College, UESTC



# Digital Signal Processing

## Lab 1

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# LAB 1

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## INTRODUCTION

This report is the homework that should be finished on the MATLAB, there are four questions about Digital Signal Processing. Which is about generate the complex exponential functions, explore their properties, understand the sampling theory and understand the true meaning of the autocorrelation.

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## 1 PROBLEM 1

Writing a MATLAB program to compute 128-point DFT of the following sequence, you must firstly use DFT definition (directly computing DFT) to compute and use MATLAB function to test the result. Plot the two results in one figure.

$$g[n] = \sin(\pi n/4), \quad 0 \leq n \leq 31$$

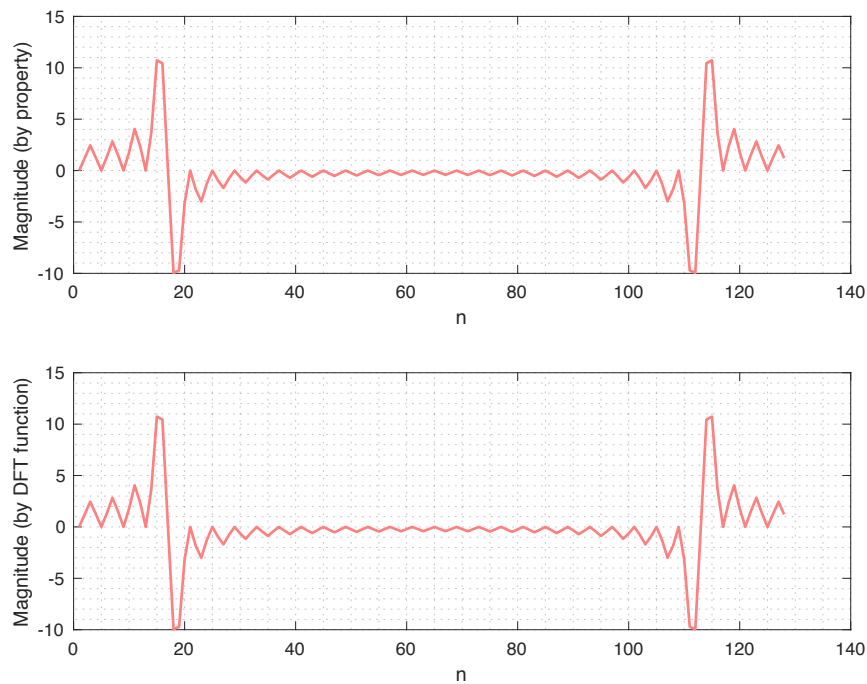


Figure 1: Using definition or MATLAB function to calculate the DFT

```

1 %% problem 1
2 clear
3 clc
4
5 % use the defination
6 n=0:31;
7 x=sin(pi*n/4);
8 y_defination=zeros(1,128);
9 for k=1:128
10     y=0;
11     for n=1:32
12         y=y+x(n)*exp(-1j*2*pi*(k-1)*(n-1)/128);
13     end
14     y_defination(k)=y;
15 end

```

```

16 k=1:128;
17
18 fig1 = figure;
19 subplot(2,1,1)
20 plot(k,y_defination,'LineWidth',1.5,'color',[1,0.5,0.5])
21 xlabel('n');
22 ylabel('Magnitude (by property)')
23 grid minor
24
25 % use the DFT function
26
27 n1=0:31;
28 x2=sin(pi*n1/4);
29 y_DFT=fft(x2,128);
30 subplot(2,1,2)
31 plot(k,y_DFT,'LineWidth',1.5,'color',[1,0.5,0.5])
32 xlabel('n');
33 ylabel('Magnitude (by DFT function)')
34 grid minor
35 saveas(fig1,['p1.pdf'],'pdf')

```

## 2 PROBLEM 2

**Write a MATLAB program to compute and plot the frequency response of a LTI discrete-time system with a transfer function given by the following equation in  $0 \leq \omega \leq \pi$**

$$X(e^{j\omega}) = \frac{0.15(1 - e^{-j2\omega})}{1 - 0.5e^{-j\omega} + 0.7e^{-j2\omega}}$$

```

1 %% problem 2
2 clear
3 clc
4
5 num=[0.15 0 -0.15];
6 den=[1 -0.5 0.7];
7 [h,w]=freqz(num,den);
8 fig2 = figure;
9 subplot(2,1,1);
10 plot(w/pi,abs(h),'LineWidth',1.5,'color',[1,0.5,0.5]);
11 xlabel('\omega/\pi');
12 ylabel('Magnitude of the function')
13 grid minor
14
15 n1=0:31;
16 x2=sin(pi*n1/4);
17 y2=fft(x2,128);
18 subplot(2,1,2)

```

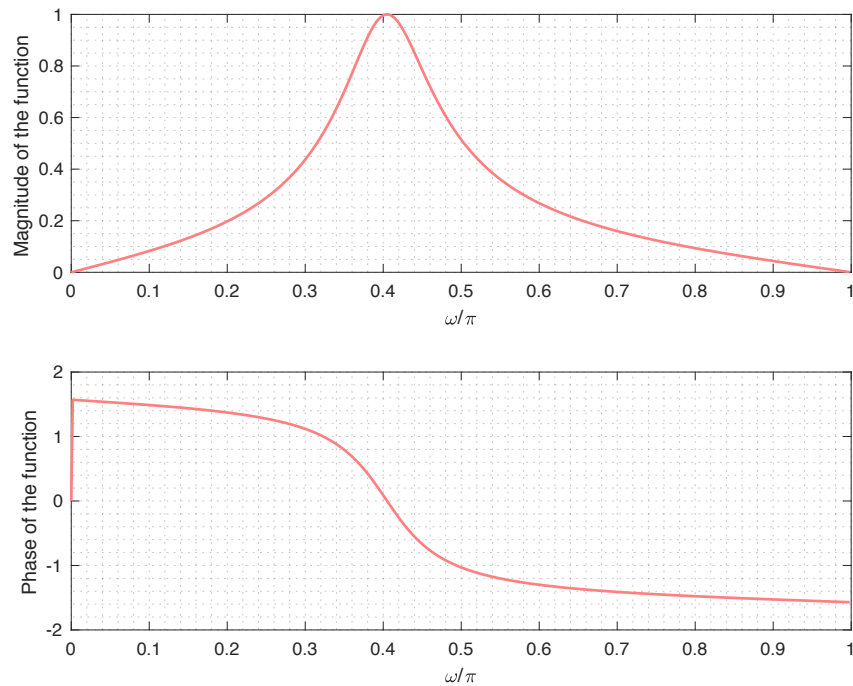


Figure 2: Magnitude and the phase of a transfer function

```

19 plot(w/pi,phase(h),'LineWidth',1.5,'color',[1,0.5,0.5])
20 xlabel('\omega/\pi');
21 ylabel('Phase of the function')
22 grid minor
23 saveas(fig2,['p2.pdf'],'pdf')

```

### 3 PROBLEM 3

**Writing a MATLAB program to compute the linear convolution of two length- $N$  sequences. Using this program to determine the following pair of sequences: and plot the result sequence.**

$$g[n] = \cos(0.2\pi n), \quad h[n] = 3^n, \quad 0 \leq n \leq 10$$

```

1 %% problem 3
2 clear
3 clc
4
5 n=0:10;
6 g=cos(0.2*pi*n);
7 h=3.^n;
8 y=conv(g,h);
9 n1=0:length(y)-1;

```

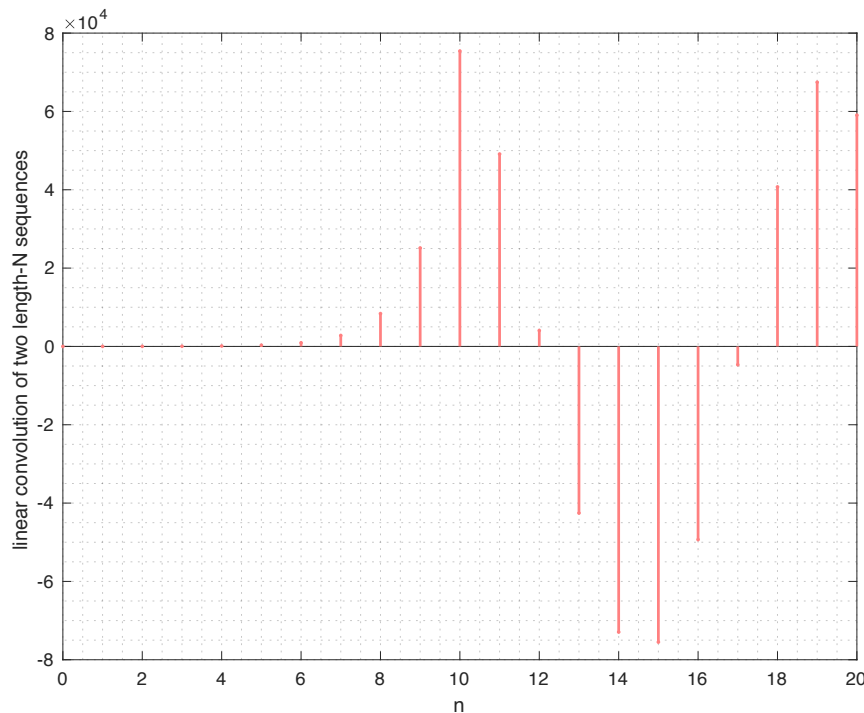


Figure 3: Linear convolution of two length-N sequences

```

10 fig3 = stem(n1,y, '.', 'LineWidth',1.5, 'color', [1,0.5,0.5]);
11 xlabel('n');
12 ylabel('linear convolution of two length-N sequences')
13 grid minor
14 saveas(fig3, ['p3.pdf'], 'pdf')

```

## 4 PROBLEM 4

Try to give a program to evaluate the following DTFT in the range:  $0 \leq \omega \leq \pi$ . Then run the program and compute the real and imaginary parts of the DTFT, and the magnitude and phase spectra. Is the DTFT a periodic function of  $\omega$ ? If it is, what is the period? Can you explain the jump in the phase spectrum? The jump can be removed using the MATLAB command "unwrap". Evaluate the phase spectrum with the jump removed.

$$X(e^{j\omega}) = \frac{1.35 + 4.95e^{-j\omega} + 8.55e^{-j2\omega} + 4.95e^{-j3\omega} + 1.8e^{-j4\omega}}{0.9 - 1.8e^{-j\omega} + 1.65e^{-j2\omega} - 0.75e^{-j3\omega} + 0.15e^{-j4\omega}}$$

The answer is: **DTFT is a periodic function with  $\omega = 2\pi$ .** The jump of the phase is due to the range of the phase is from 0 to  $2\pi$ , if phase is bigger than  $2\pi$ , the result will change to  $\text{phase} \% 2\pi$ , which would result in a gap.

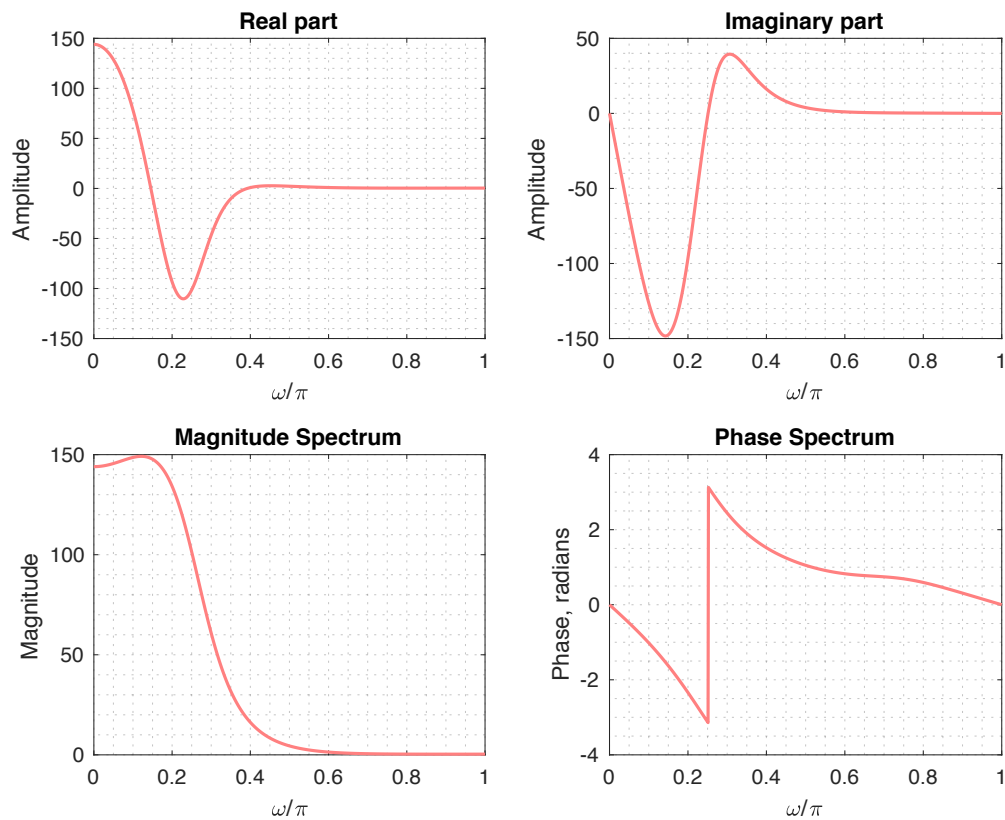


Figure 4: Real and imaginary parts of the DTFT

```

1 %% problem 4
2 clear
3 clc
4
5 % num = input('Numerator coefficients = ');
6 % den = input('Denominator coefficients = ');
7 k = 1000;
8 num = [1.35 4.95 8.55 4.95 1.8];
9 den = [0.9 -1.8 1.65 -0.75 0.15];
10
11 % Compute the frequency response
12 w = 0:pi/(k-1):pi;
13 h = freqz(num, den, w);
14 % Plot the frequency response
15 fig4 = figure;
16 subplot(2,2,1)
17 plot(w/pi,real(h),'LineWidth',1.5,'color',[1,0.5,0.5])
18 title('Real part')
19 xlabel('\omega/\pi');
20 ylabel('Amplitude')
21 grid minor
22
23 subplot(2,2,2)
24 plot(w/pi,imag(h),'LineWidth',1.5,'color',[1,0.5,0.5])
25 title('Imaginary part')

```

```

26 xlabel('\omega/\pi');
27 ylabel('Amplitude')
28 grid minor
29
30 subplot(2,2,3)
31 plot(w/pi,abs(h),'LineWidth',1.5,'color',[1,0.5,0.5])
32 title('Magnitude Spectrum')
33 xlabel('\omega/\pi');
34 ylabel('Magnitude')
35 grid minor
36
37 subplot(2,2,4)
38 plot(w/pi,angle(h),'LineWidth',1.5,'color',[1,0.5,0.5]) ...
    %unwrap(angle(h))
39 title('Phase Spectrum')
40 xlabel('\omega/\pi');
41 ylabel('Phase, radians')
42 grid minor
43 saveas(fig4,['p4.pdf'],'pdf')
44 %
45 %

```

I change the range of the calculation and the plot and the result is shown as follows. I know from the Figure that the DTFT is a periodic function and with period  $\omega = 2\pi$

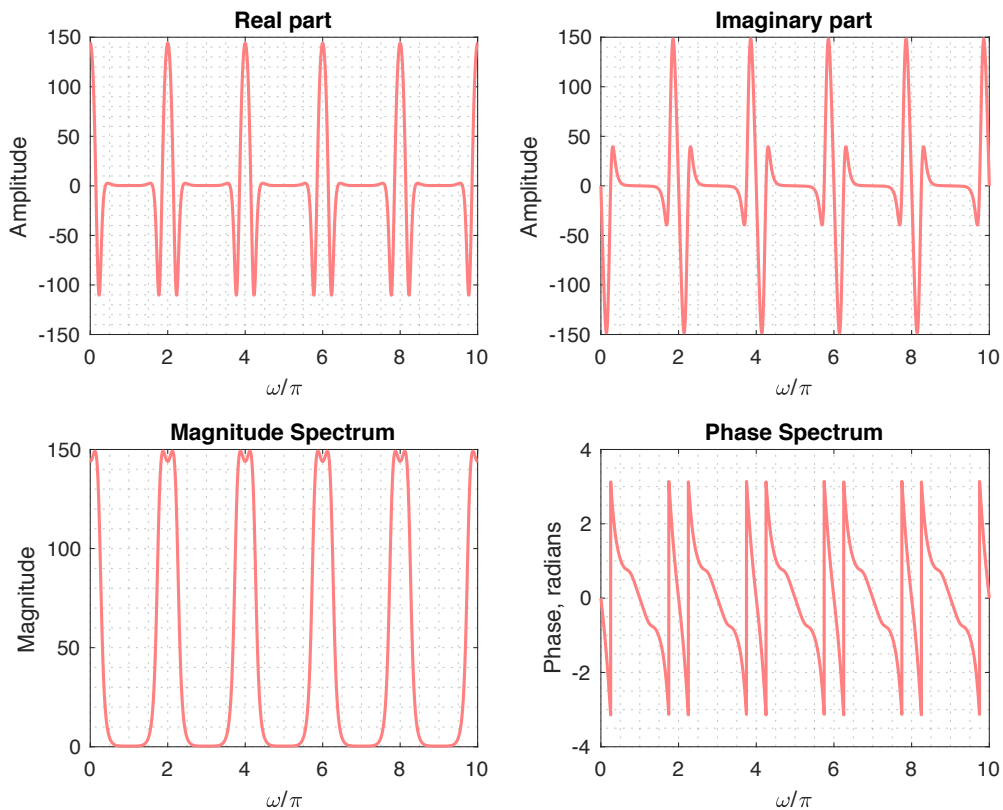


Figure 5: Real and imaginary parts of the DTFT for larger range



```

1 %% ===== problem 4 part two =====
2
3 clear
4 clc
5
6 % num = input('Numerator coefficients = ');
7 % den = input('Denominator coefficients = ');
8 k = 1000;
9 num = [1.35 4.95 8.55 4.95 1.8];
10 den = [0.9 -1.8 1.65 -0.75 0.15];
11
12 % Compute the frequency response
13 w = 0:pi/(k-1):10*pi;
14 h = freqz(num, den, w);
15 % Plot the frequency response
16 fig4_2 = figure;
17 subplot(2,2,1)
18 plot(w/pi,real(h), 'LineWidth',1.5, 'color', [1,0.5,0.5])
19 title('Real part')
20 xlabel('\omega/\pi');
21 ylabel('Amplitude')
22 grid minor
23
24 subplot(2,2,2)
25 plot(w/pi,imag(h), 'LineWidth',1.5, 'color', [1,0.5,0.5])
26 title('Imaginary part')
27 xlabel('\omega/\pi');
28 ylabel('Amplitude')
29 grid minor
30
31 subplot(2,2,3)
32 plot(w/pi,abs(h), 'LineWidth',1.5, 'color', [1,0.5,0.5])
33 title('Magnitude Spectrum')
34 xlabel('\omega/\pi');
35 ylabel('Magnitude')
36 grid minor
37
38 subplot(2,2,4)
39 plot(w/pi,angle(h), 'LineWidth',1.5, 'color', [1,0.5,0.5]) ...
    %unwrap(angle(h))
40 title('Phase Spectrum')
41 xlabel('\omega/\pi');
42 ylabel('Phase, radians')
43 grid minor
44 saveas(fig4_2, ['p4_2.pdf'], 'pdf')
45 %
46 %

```

When we use the unwrap function, we can remove the gap and get the following result.

```

1 fig4unwrap = figure;
2 plot(w/pi,unwrap(angle(h)), 'LineWidth',1.5, 'color', [1,0.5,0.5])

```

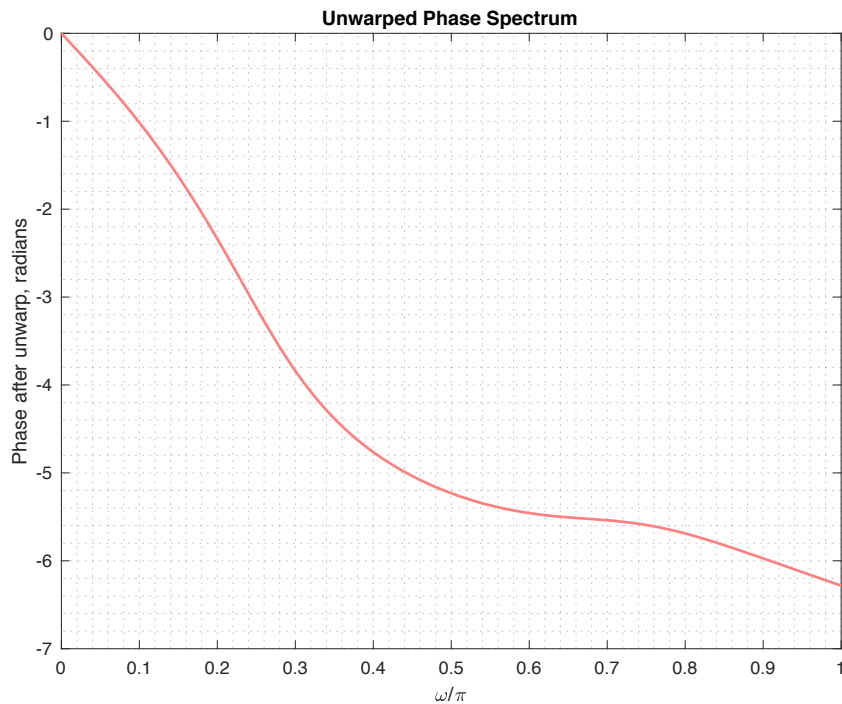


Figure 6: Phase after unwarp

```

3 title('Unwarped Phase Spectrum')
4 xlabel('\omega/\pi');
5 ylabel('Phase after unwarp, radians')
6 grid minor
7 saveas(fig4unwarp, ['p4unwarp.pdf'], 'pdf')

```

## 5 PROBLEM 5

Given a signal as follow and using a sampling frequency  $f_s = 20$  kHz, plot the magnitude and phase spectrum of the sampled sequence (given length 64)

$$x(t) = \sin(0.1\pi t) + 2\cos(0.3\pi t) + 3\sin(0.5\pi t)$$

```

1
2 %% problem 5
3 clear
4 clc
5
6 syms t;
7 x=sin(0.1*pi*t)+2*cos(0.3*pi*5*t)+3*sin(0.5*pi*t);
8 ft=20000;
9 n=1:64;

```

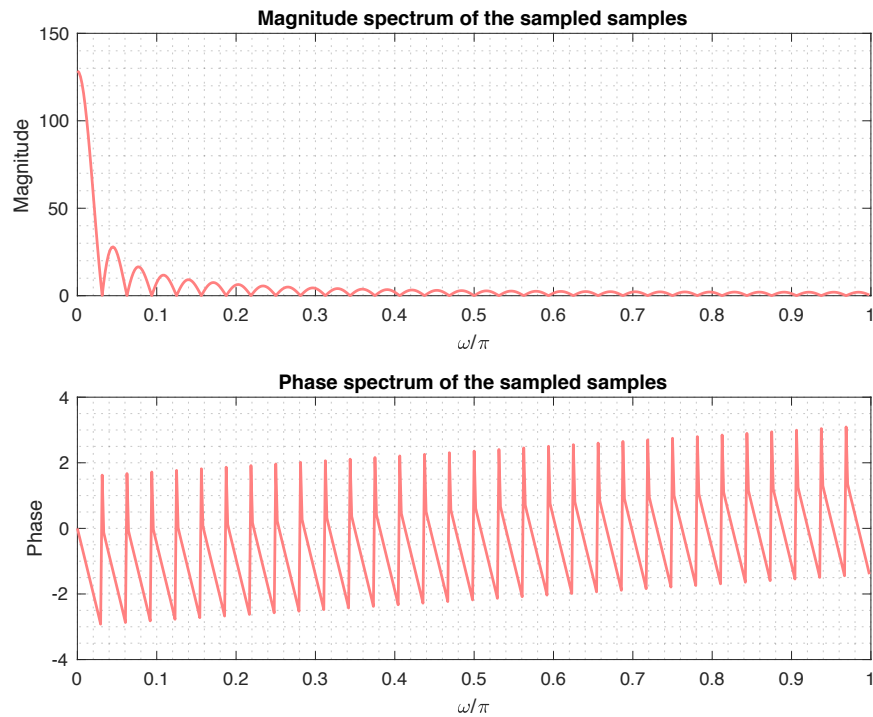


Figure 7: Magnitude and phase spectrum of the sampled sequence

```

10 y=subs(x,t,n/ft);
11
12 fig5 = figure;
13
14 subplot(2,1,1)
15 [h,w]=freqz(double(y),1);
16 plot(w/pi,abs(h),'LineWidth',1.5,'color',[1,0.5,0.5]);
17 title('Magnitude spectrum of the sampled samples')
18 xlabel('\omega/\pi');
19 ylabel('Magnitude')
20 grid minor
21
22 subplot(2,1,2)
23 plot(w/pi,angle(h),'LineWidth',1.5,'color',[1,0.5,0.5]);
24 title('Phase spectrum of the sampled samples')
25 xlabel('\omega/\pi');
26 ylabel('Phase')
27 grid minor
28 saveas(fig5,['p5.pdf'],'pdf')

```

## 6 SUMMARY

For this Homework, I understand more about Digital Signal Processing, as well as how to use the MATLAB to do the DFT, convolution and other operations. I

also know more about the sampling theorem and the autocorrelation between signals. I also know how to use the unwarp function to fix the phase gap.

## REFERENCES

- [1] Changgang-Zheng/Signals-and-Systems/report.<https://github.com/Changgang-Zheng/Signals-and-Systems>
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- [3] Digital Signal Processing: A Computer-Based Approach, 4th Edition. by S.K. Mitra, ISBN 0077320670.
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