Glasgow College, UESTC

Digital Signal Processing

Lab 1

Author: Changgang Zheng
UoG ID: 2289258Z
UESTC ID: 2016200302027
E-mail: chnaggangzheng@std.uestc.edu.cn

LAB 1

CHANGGANG ZHENG[1]

April 17, 2019

CONTENTS

LIST OF FIGURES

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.

1*Glasgow College, University of Electronic Science and Technology of China, ChengDu, China*

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.

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

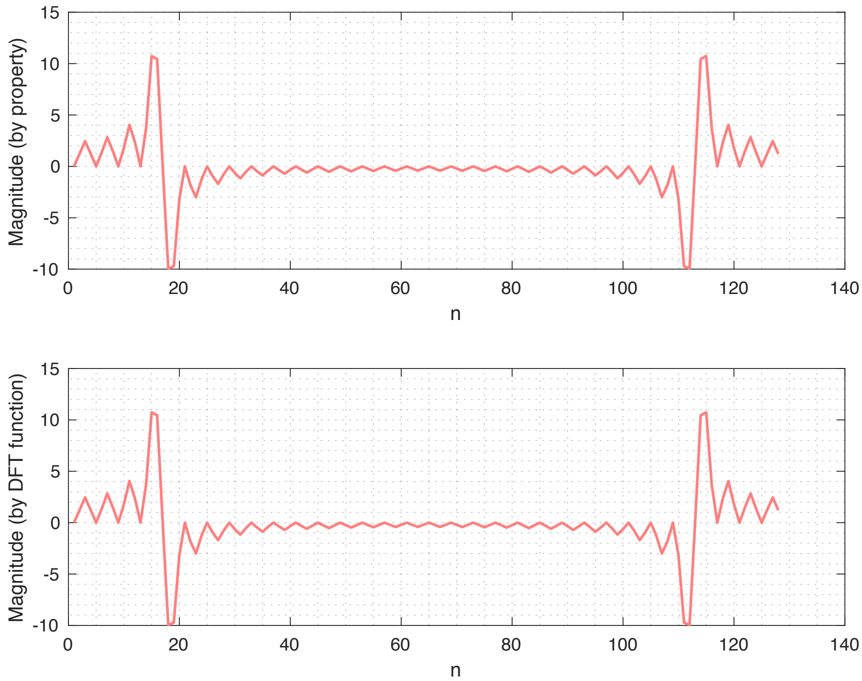

Figure 1: Using defination or MATLAB function to calculate the DFT

```
%% problem 1
clear
clc

% use the defination
n=0:31;
x=sin(pi*n/4);
y_defination=zeros(1,128);
for k=1:128
    y=0;
    for n=1:32
        y=y+x(n)*exp(-1j*2*pi*(k-1)*(n-1)/128);
    end
    y_defination(k)=y;
end
```

```
k=1:128;

fig1 = figure;
subplot(2,1,1)
plot(k,y_defination,'LineWidth',1.5,'color',[1,0.5,0.5])
xlabel('n');
ylabel('Magnitude (by property)')
grid minor

% use the DFT function

n1=0:31;
x2=sin(pi*n1/4);
y_DFT=fft(x2,128);
subplot(2,1,2)
plot(k,y_DFT,'LineWidth',1.5,'color',[1,0.5,0.5])
xlabel('n');
ylabel('Magnitude (by DFT function)')
grid minor
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 $0 \leqslant \omega \leqslant \pi$

$$X(e^{jw}) = \frac{0.15(1 - e^{-j2w})}{1 - 0.5e^{-jw} + 0.7e^{-j2w}}$$

```
%% problem 2
clear
clc

num=[0.15 0 -0.15];
den=[1 -0.5 0.7];
[h,w]=freqz(num,den);
fig2 = figure;
subplot(2,1,1);
plot(w/pi,abs(h),'LineWidth',1.5,'color',[1,0.5,0.5]);
xlabel('\omega/\pi');
ylabel('Magnitude of the function')
grid minor

n1=0:31;
x2=sin(pi*n1/4);
y2=fft(x2,128);
subplot(2,1,2)
```

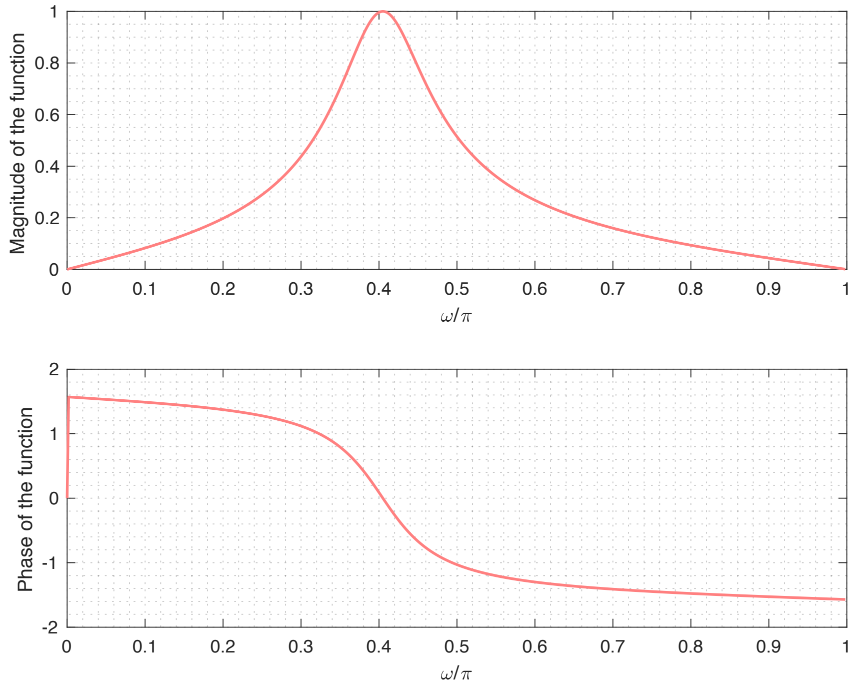

Figure 2: Magnitude and the phase of a transfer function

```
plot(w/pi,phase(h),'LineWidth',1.5,'color',[1,0.5,0.5])
xlabel('\omega/\pi');
ylabel('Phase of the function')
grid minor
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.

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

```
%% problem 3
clear
clc

n=0:10;
g=cos(0.2*pi*n);
h=3.^n;
y=conv(g,h);
n1=0:length(y)-1;
```

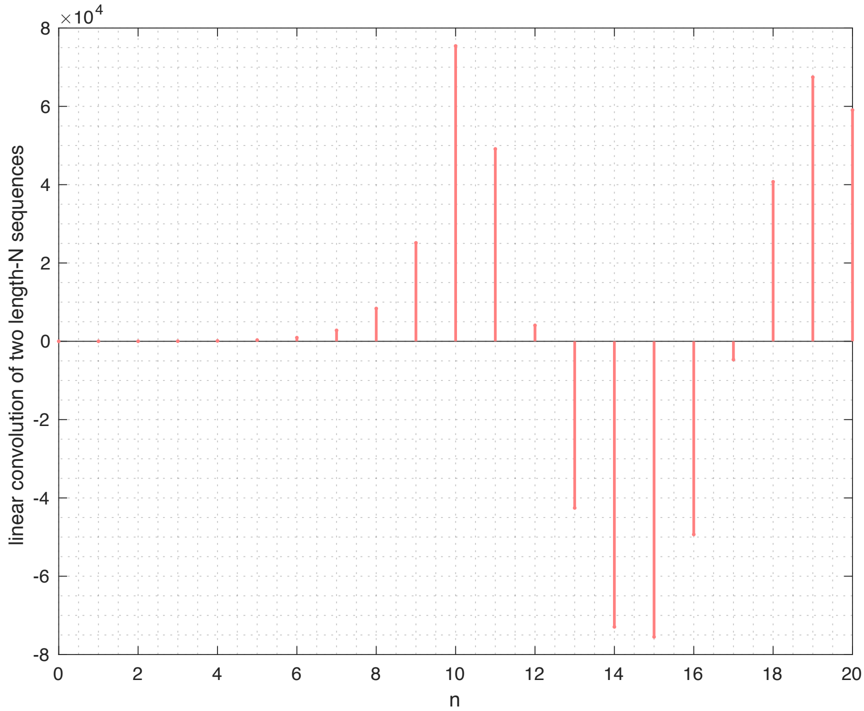

Figure 3: Linear convolution of two length-N sequences

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

4 PROBLEM 4

Try to give a program to evaluate the following DTFT in the range: $0 \leqslant \omega \leqslant \pi$. 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 ω? 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.

$$X(e^{jw}) = \frac{1.35 + 4.95e^{-jw} + 8.55e^{-j2w} + 4.95e^{-j3w} + 1.8e^{-j4w}}{0.9 - 1.8e^{-jw} + 1.65e^{-j2w} - 0.75e^{-j3w} + 0.15e^{-j4w}}$$

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 2π, if phase is bigger than 2π, the result will change to $phase\%2\pi$, which would result in a gap.

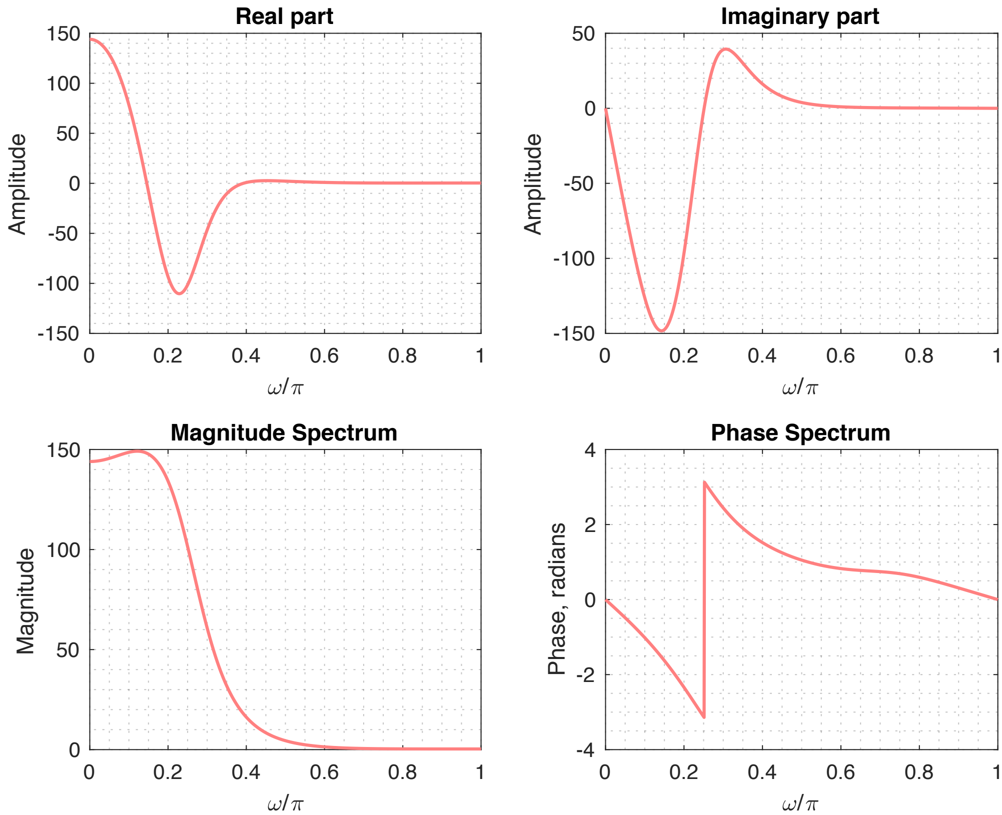

Figure 4: Real and imaginary parts of the DTFT

```
%% problem 4
clear
clc

% num = input('Numerator coefficients = ');
% den = input('Denominator coefficients = ');
k = 1000;
num = [1.35 4.95 8.55 4.95 1.8];
den = [0.9 -1.8 1.65 -0.75 0.15];

% Compute the frequency response
w = 0:pi/(k-1):pi;
h = freqz(num, den, w);
% Plot the frequency response
fig4 = figure;
subplot(2,2,1)
plot(w/pi,real(h),'LineWidth',1.5,'color',[1,0.5,0.5])
title('Real part')
xlabel('\omega/\pi');
ylabel('Amplitude')
grid minor

subplot(2,2,2)
plot(w/pi,imag(h),'LineWidth',1.5,'color',[1,0.5,0.5])
title('Imaginary part')
```

```
xlabel('\omega/\pi');
ylabel('Amplitude')
grid minor

subplot(2,2,3)
plot(w/pi,abs(h),'LineWidth',1.5,'color',[1,0.5,0.5])
title('Magnitude Spectrum')
xlabel('\omega/\pi');
ylabel('Magnitude')
grid minor

subplot(2,2,4)
plot(w/pi,angle(h),'LineWidth',1.5,'color',[1,0.5,0.5])  ...
    %unwrap(angle(h))
title('Phase Spectrum')
xlabel('\omega/\pi');
ylabel('Phase, radians')
grid minor
saveas(fig4,['p4.pdf'],'pdf')
%
%
```

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 $\omega = 2\pi$

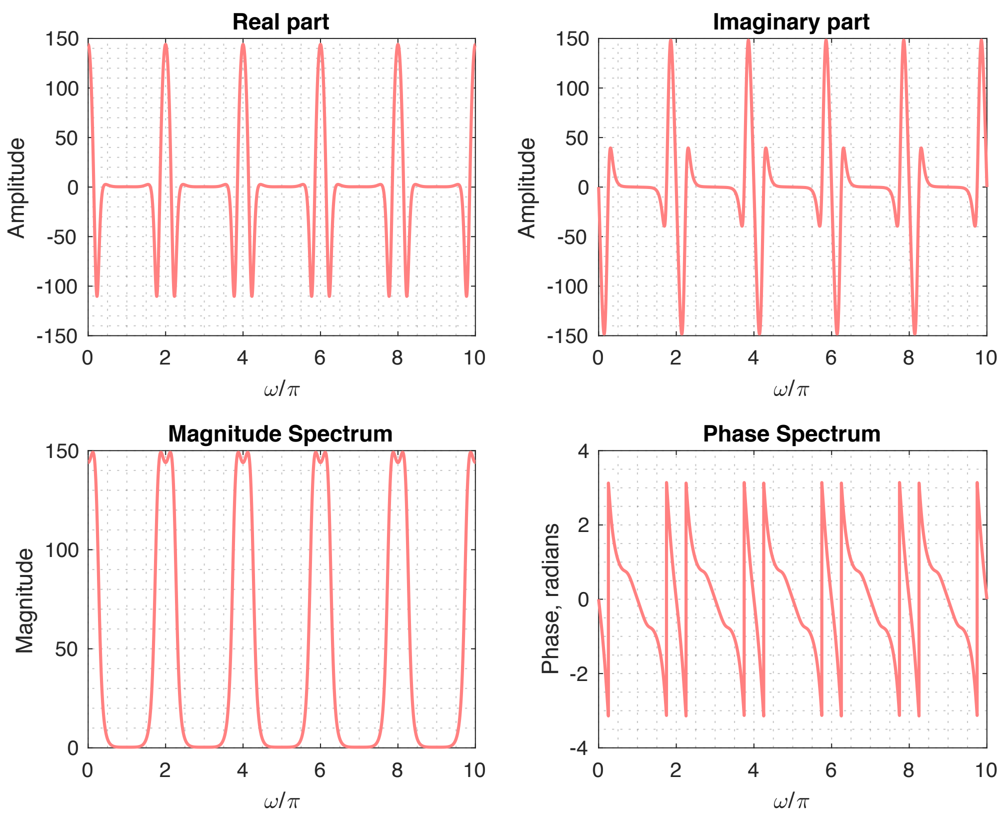

Figure 5: Real and imaginary parts of the DTFT for larger range

```
%% =========== problem 4 part two ===========

clear
clc

% num = input('Numerator coefficients = ');
% den = input('Denominator coefficients = ');
k = 1000;
num = [1.35 4.95 8.55 4.95 1.8];
den = [0.9 -1.8 1.65 -0.75 0.15];

% Compute the frequency response
w = 0:pi/(k-1):10*pi;
h = freqz(num, den, w);
% Plot the frequency response
fig4_2 = figure;
subplot(2,2,1)
plot(w/pi,real(h),'LineWidth',1.5,'color',[1,0.5,0.5])
title('Real part')
xlabel('\omega/\pi');
ylabel('Amplitude')
grid minor

subplot(2,2,2)
plot(w/pi,imag(h),'LineWidth',1.5,'color',[1,0.5,0.5])
title('Imaginary part')
xlabel('\omega/\pi');
ylabel('Amplitude')
grid minor

subplot(2,2,3)
plot(w/pi,abs(h),'LineWidth',1.5,'color',[1,0.5,0.5])
title('Magnitude Spectrum')
xlabel('\omega/\pi');
ylabel('Magnitude')
grid minor

subplot(2,2,4)
plot(w/pi,angle(h),'LineWidth',1.5,'color',[1,0.5,0.5])  ...
    %unwrap(angle(h))
title('Phase Spectrum')
xlabel('\omega/\pi');
ylabel('Phase, radians')
grid minor
saveas(fig4_2,['p4_2.pdf'],'pdf')
%
%
```

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

```
fig4unwarp = figure;
plot(w/pi,unwrap(angle(h)),'LineWidth',1.5,'color',[1,0.5,0.5])
```

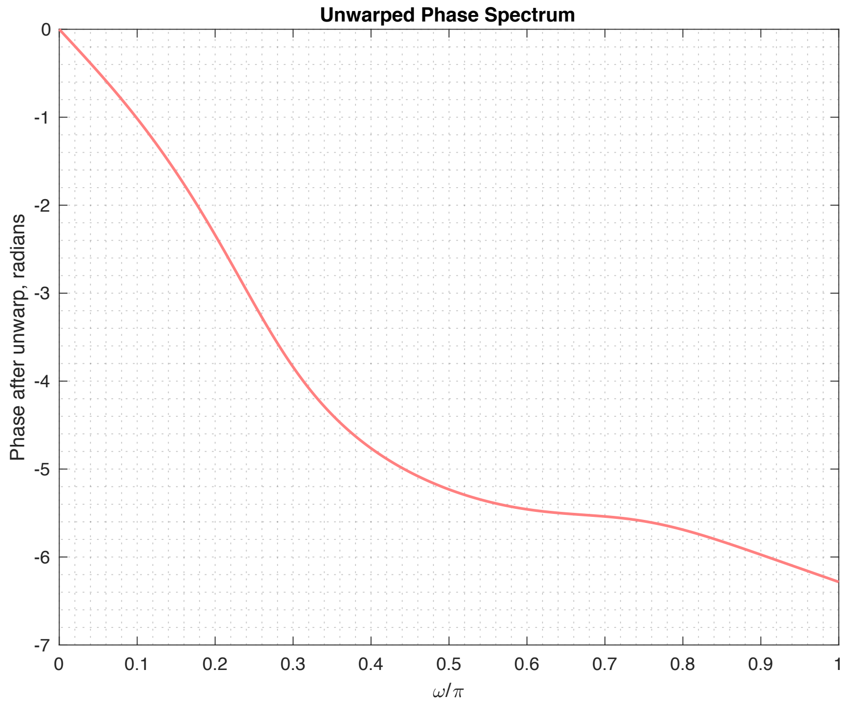

Figure 6: Phase after unwarp

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

5 PROBLEM 5

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

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

```

%% problem 5
clear
clc

syms t;
x=sin(0.1*pi*t)+2*cos(0.3*pi*5*t)+3*sin(0.5*pi*t);
ft=20000;
n=1:64;
```

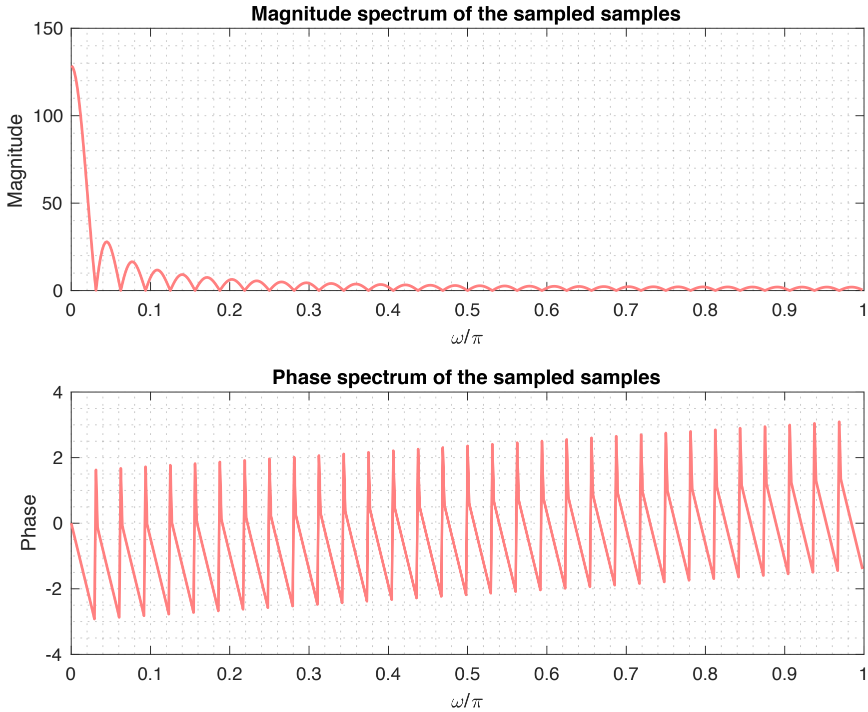

Figure 7: Magnitude and phase spectrum of the sampled sequence

```
y=subs(x,t,n/ft);

fig5 = figure;

subplot(2,1,1)
[h,w]=freqz(double(y),1);
plot(w/pi,abs(h),'LineWidth',1.5,'color',[1,0.5,0.5]);
title('Magnitude spectrum of the sampled samples')
xlabel('\omega/\pi');
ylabel('Magnitude')
grid minor

subplot(2,1,2)
plot(w/pi,angle(h),'LineWidth',1.5,'color',[1,0.5,0.5]);
title('Phase spectrum of the sampled samples')
xlabel('\omega/\pi');
ylabel('Phase')
grid minor
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

[2] Supplementary materials to the text book 'Digital Signal Processing: A Computer-Based Approach', 4th Edition. by S.K. Mitra, ISBN 0077320670. http://www.bb9.uestc.edu.cn/webapps/portal/frameset.jsp?tab_tab_group_id=_2_1&url=%2Fwebapps%2Fblackboard%2Fexecute%2Flauncher%3Ftype%3DCourse%26id%3D_13014_1%26url%3D

[3] Digital Signal Processing: A Computer-Based Approach, 4th Edition. by S.K. Mitra, ISBN 0077320670.

[4] Summary of DSP course in school of communication, University of Electronic Science and Technology of China https://wenku.baidu.com/view/b3b2f5b289eb172dec63b708.html