Digital Signal Processing
Term Project
"Filter Design and Implement"

In this project students will design digital filters using Pole-Zero placement method and implement these filters. The project is of two parts.

A) Design a Band-Pass Filter

Design a BPF with the center frequency of ω_0 and 3 dB cut off ω_c, i.e., it has the following specifications:

$$|H(\omega_0)| = 1, \qquad |H(\omega_c)| = 1/\sqrt{2}$$

Group No. versus frequencies:

Group_1: $\omega_0 = 0.2\pi$, $\omega_c = 0.23\pi$

Group_2: $\omega_0 = 0.25\pi$, $\omega_c = 0.22\pi$

Group_3: $\omega_0 = 0.42\pi$, $\omega_c = 0.37\pi$

Group_4: $\omega_0 = 0.33\pi$, $\omega_c = 0.35\pi$

Group_5: $\omega_0 = 0.19\pi$, $\omega_c = 0.23\pi$

Group_6: $\omega_0 = 0.28\pi$, $\omega_c = 0.25\pi$

Group_7: $\omega_0 = 0.32\pi$, $\omega_c = 0.28\pi$

Group_8: $\omega_0 = 0.35\pi$, $\omega_c = 0.31\pi$

Group_9: $\omega_0 = 0.41\pi$, $\omega_c = 0.45\pi$

Group_10: $\omega_0 = 0.26\pi$, $\omega_c = 0.29\pi$

Group_11: $\omega_0 = 0.45\pi$, $\omega_c = 0.41\pi$

Group_12: $\omega_0 = 0.28\pi$, $\omega_c = 0.32\pi$

Report: **You must provide the following:**

1) The difference equation of the filter.
2) Test the filter by implementing the filter as a difference equation and by giving the input signal cos(wn) and measuring the output amplitude and finding the gain (Vout/Vin) for ($\omega = 0 \rightarrow \pi$ *step*: 0.05π).
   Plot the resulting 20-point frequency response.
3) Comment on the curve.

B) De-scrambling of a spectrum folded scrambled voice signal

As you load the file {speech_scmb_1}
MATLAB loading Instruction: `load speech_scmb_1`

you will have a vector {x} which contains a scrambled voice signal sampled with a frequency of fs=44100 sample/second. {x} was obtained by folding the spectral components of a speech signal as shown in Fig.1 below:

De-scrambling operation:

1) Multiply the input x signal by $\cos(0.15\pi n)$ to refold the spectrum.
2) Pass the result in a 3-stage LPF. Each stage is a one-pole, (0.06π) 3 dB cut-off frequency.
3) Display the descrambled speech signal. For comparison, display the scrambled speech also.

What is required:

1) Provide the complete MATLAB program for descrambling and speech display.
2) Display the speech to show your work. You should here intelligible voice signal.

Hint:

The following MATLAB command will display speech found in a vector named {z} to speaker.

```
load speech_scmb_1
Fs=44100;
%%%%%  The following commands are for playing the speech with
suitable level  %%%%
%%%  The input vector is {x}


%%% The output is z   %%%%


gt=1.755*100000;
nm=(norm(z))^2;
gain=sqrt(gt/nm);
zz=z*gain;
player = audioplayer(zz, Fs);
play(player);
```

Speech Scrambling by Spectral Folding

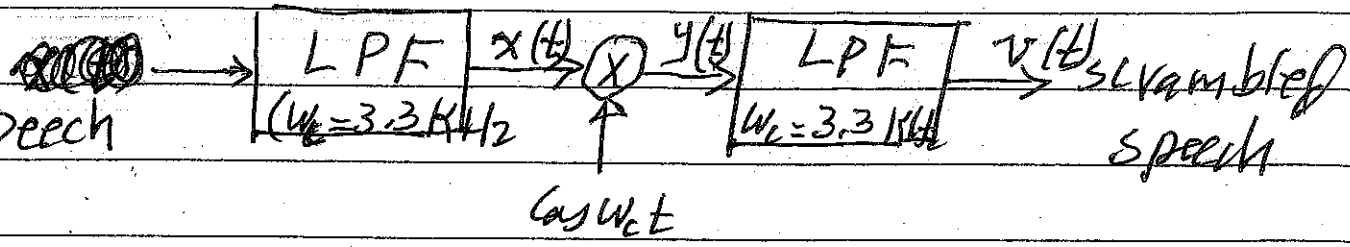
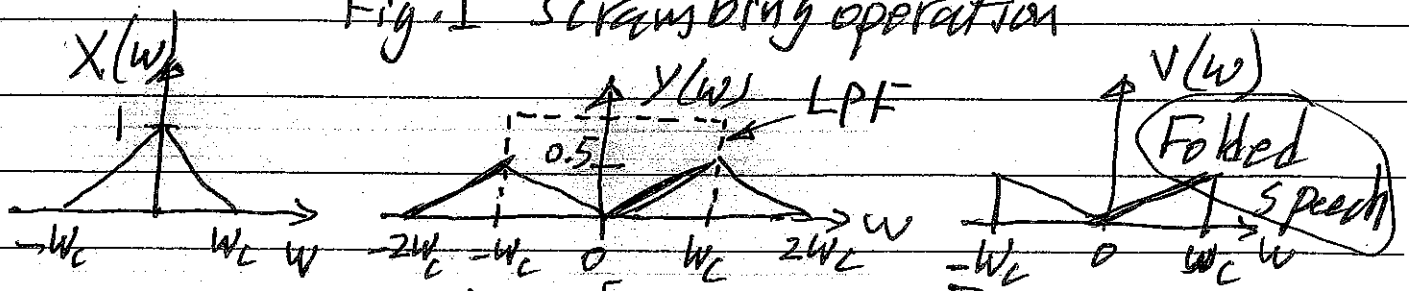


Fig. 1 scrambling operation



$$Y(w) = \frac{1}{2}[X(w-w_c) + X(w+w_c)]$$

De-Scrambling

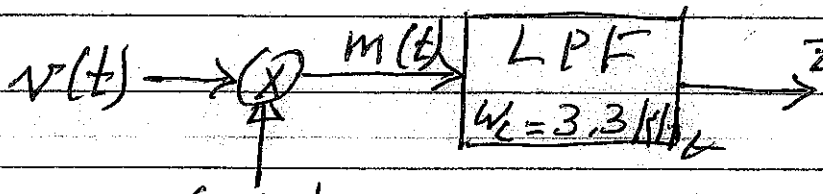
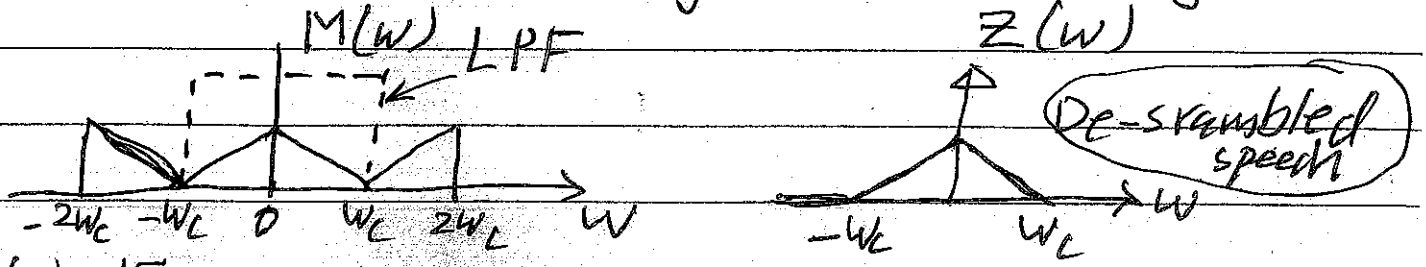
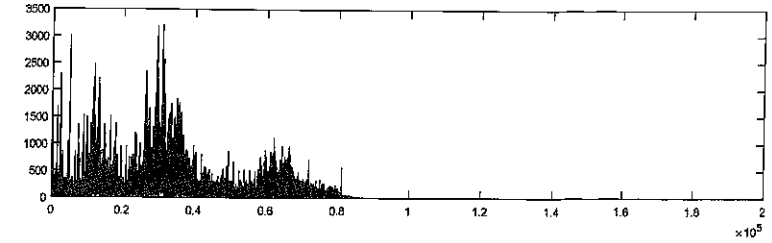


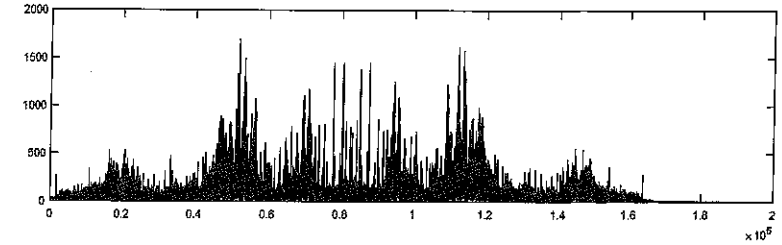
Fig. 2 De-scrambling



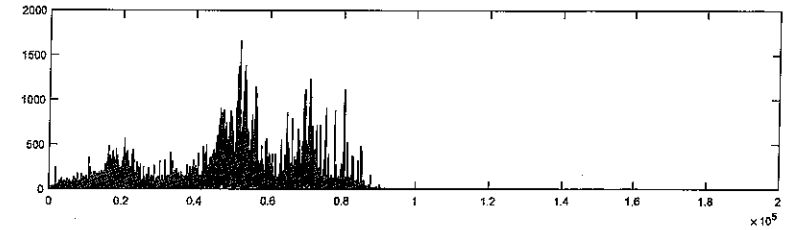
$$M(w) = \frac{1}{2}[V(w-w_c) + V(w+w_c)]$$


3500
3000
2500
2000
1500
1000
500
0
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
×10^5

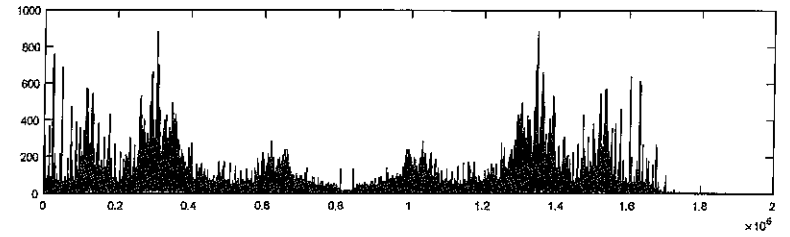
X(w)


2000
1500
1000
500
0
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
×10^5

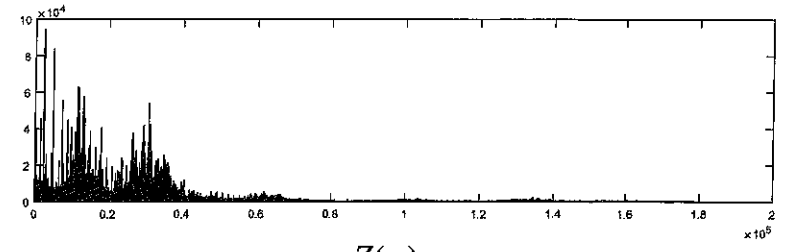
Y(w)


2000
1500
1000
500
0
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
×10^5

V(w)


1000
800
600
400
200
0
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
×10^6

M(w)


×10^4
10
8
6
4
2
0
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
×10^5

Z(w)