باسمه تعالی

گزارش تمرین کامپیوتری سری ۱

پردازش علائم بیولوژیک

دانشکده مهندسی برق

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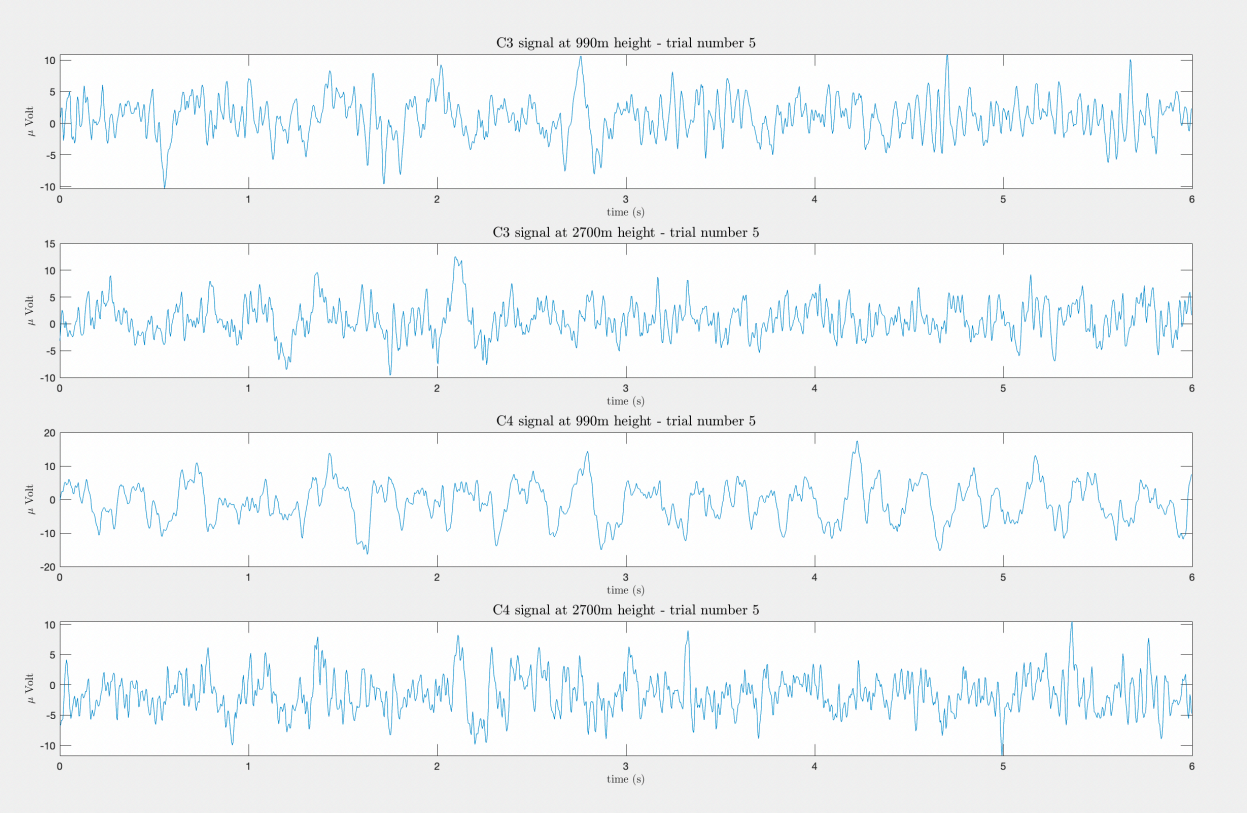
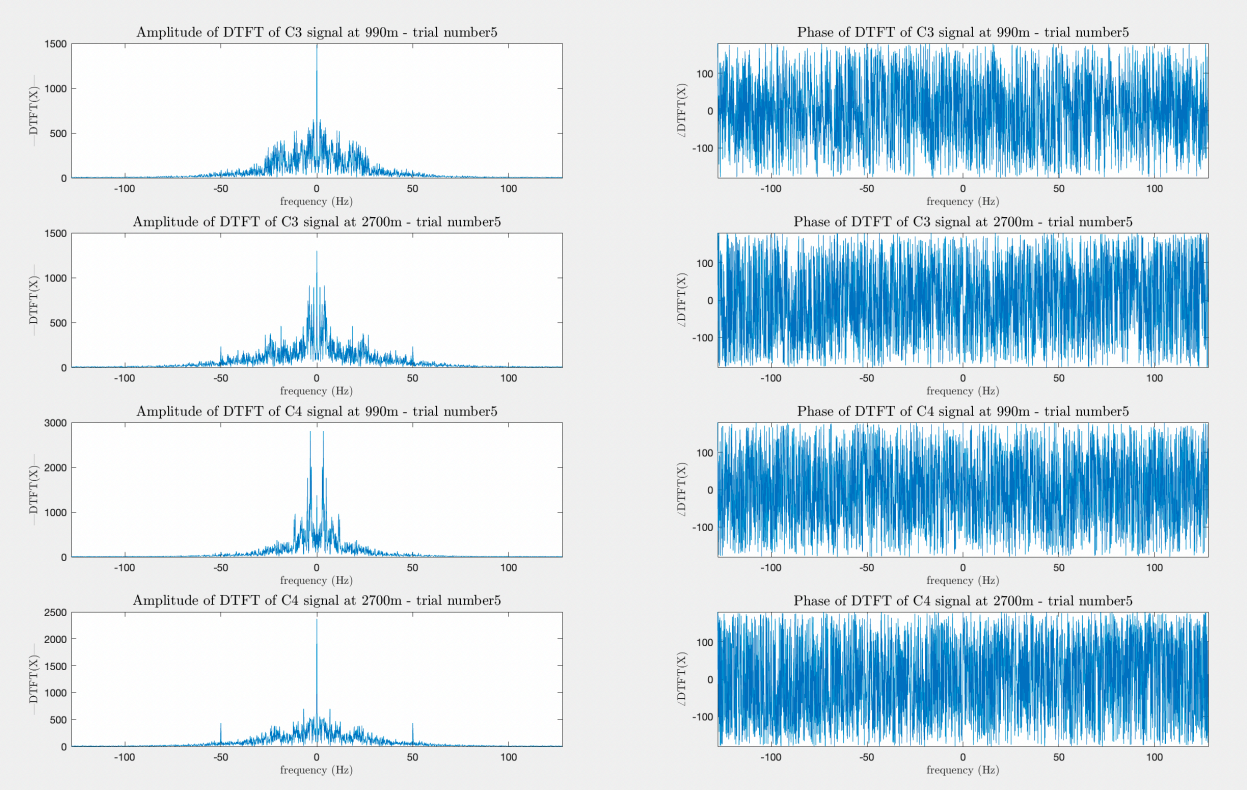
گردآورنده: رادین خیّام

سوال ۱:

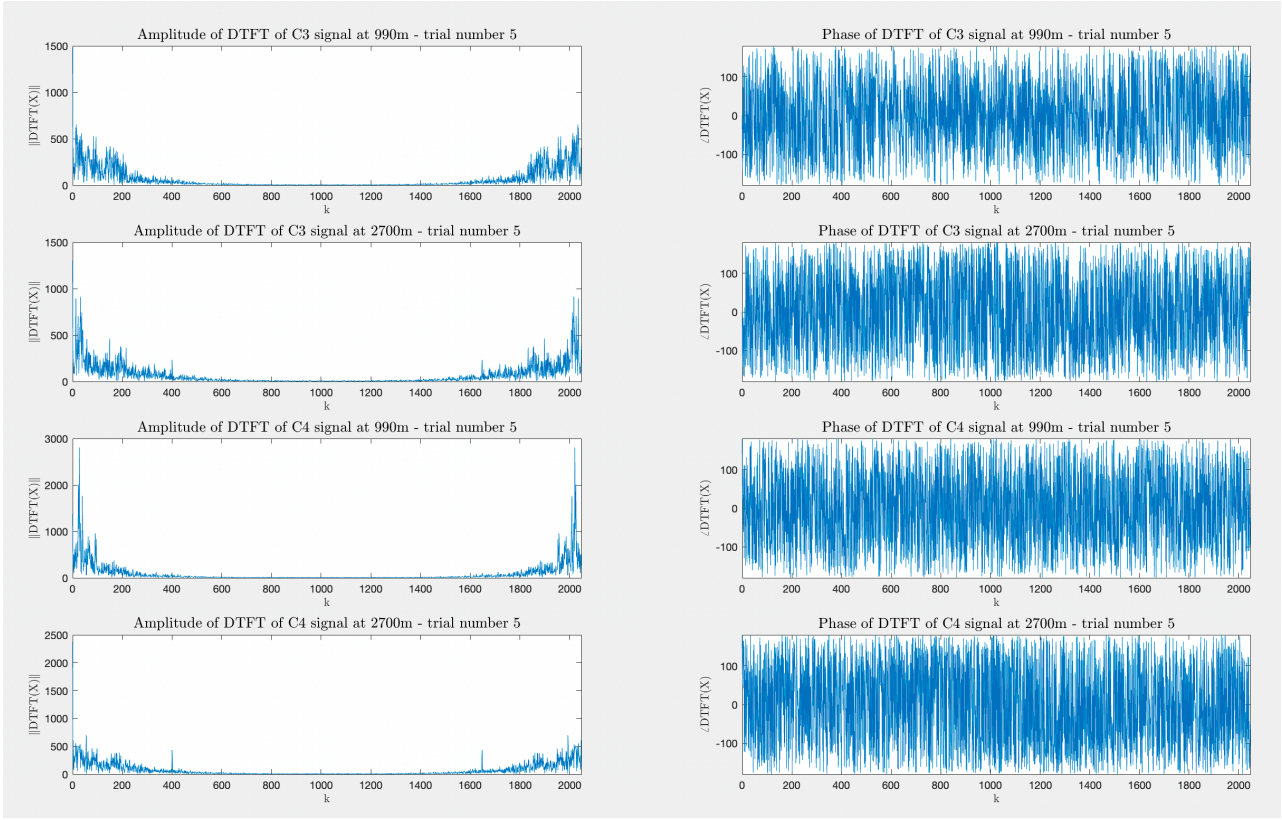
الف)


C3 signal at 990m height - trial number 5
C3 signal at 2700m height - trial number 5
C4 signal at 990m height - trial number 5
C4 signal at 2700m height - trial number 5
μ Volt
time (s)

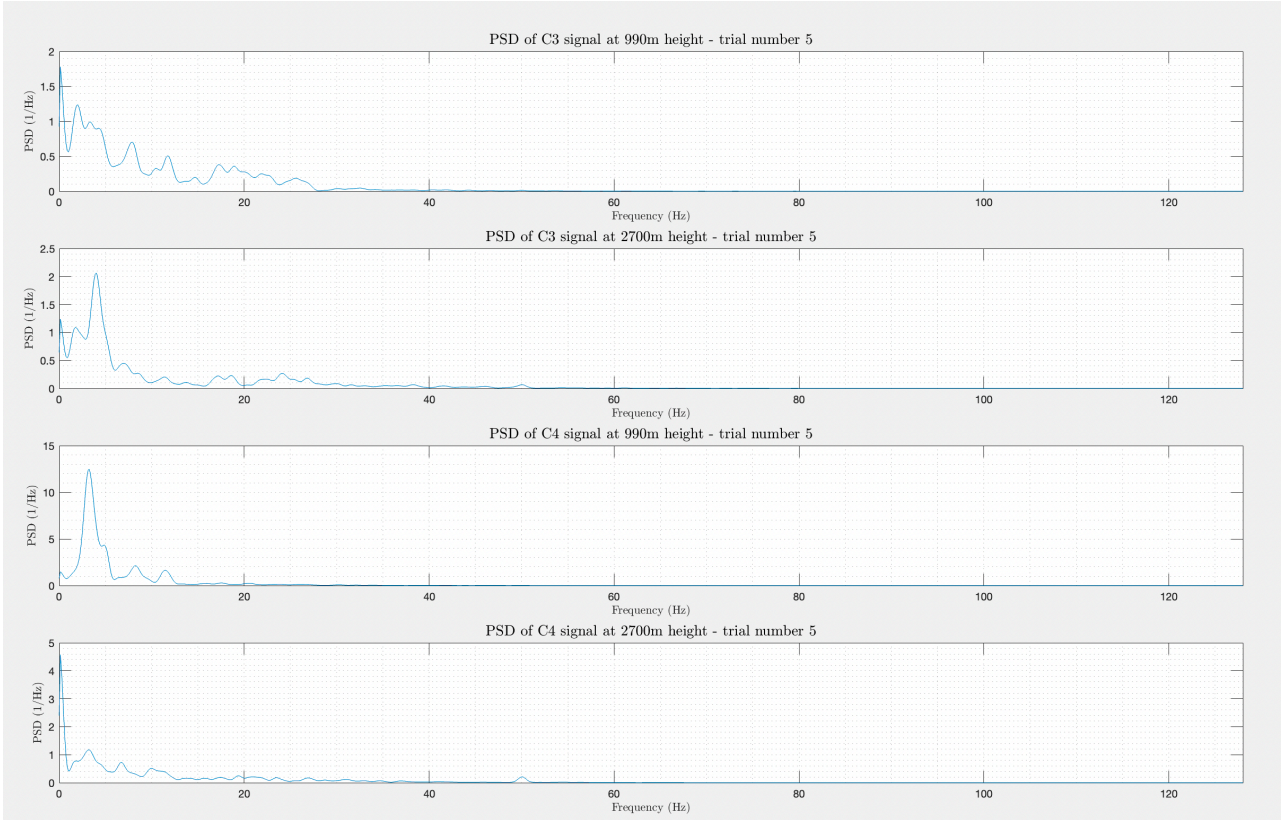
ب)


Amplitude of DTFT of C3 signal at 990m - trial number5
Phase of DTFT of C3 signal at 990m - trial number5
Amplitude of DTFT of C3 signal at 2700m - trial number5
Phase of DTFT of C3 signal at 2700m - trial number5
Amplitude of DTFT of C4 signal at 990m - trial number5
Phase of DTFT of C4 signal at 990m - trial number5
Amplitude of DTFT of C4 signal at 2700m - trial number5
Phase of DTFT of C4 signal at 2700m - trial number5
|DTFT(X)|
∠DTFT(X)
frequency (Hz)

پ)


Amplitude of DTFT of C3 signal at 990m - trial number 5
Phase of DTFT of C3 signal at 990m - trial number 5
Amplitude of DTFT of C3 signal at 2700m - trial number 5
Phase of DTFT of C3 signal at 2700m - trial number 5
Amplitude of DTFT of C4 signal at 990m - trial number 5
Phase of DTFT of C4 signal at 990m - trial number 5
Amplitude of DTFT of C4 signal at 2700m - trial number 5
Phase of DTFT of C4 signal at 2700m - trial number 5
||DTFT(X)||
∠DTFT(X)
k

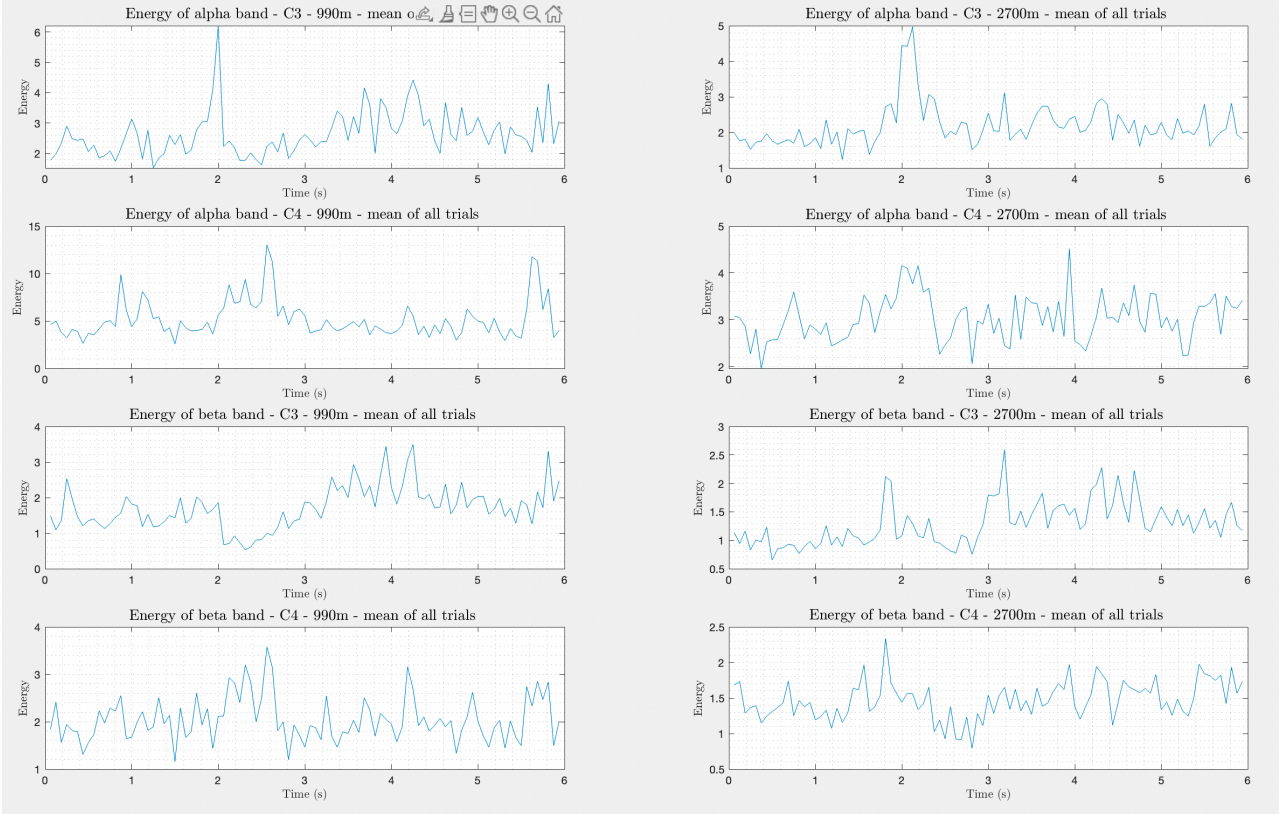
ت)


PSD of C3 signal at 990m height - trial number 5
PSD of C3 signal at 2700m height - trial number 5
PSD of C4 signal at 990m height - trial number 5
PSD of C4 signal at 2700m height - trial number 5
PSD (1/Hz)
Frequency (Hz)

ث و ج)


Energy of alpha band - C3 - 990m - trial number 5
Energy of alpha band - C3 - 2700m - trial number 5
Energy of alpha band - C4 - 990m - trial number 5
Energy of alpha band - C4 - 2700m - trial number 5
Energy of beta band - C3 - 990m - trial number 5
Energy of beta band - C3 - 2700m - trial number 5
Energy of beta band - C4 - 990m - trial number 5
Energy of beta band - C4 - 2700m - trial number 5
Energy
Time (s)

چ)


Energy of alpha band - C3 - 990m - mean o
Energy of alpha band - C3 - 2700m - mean of all trials
Energy of alpha band - C4 - 990m - mean of all trials
Energy of alpha band - C4 - 2700m - mean of all trials
Energy of beta band - C3 - 990m - mean of all trials
Energy of beta band - C3 - 2700m - mean of all trials
Energy of beta band - C4 - 990m - mean of all trials
Energy of beta band - C4 - 2700m - mean of all trials
Energy
Time (s)

خ)

ح)

در هر دو ارتفاع در باند آلفا و زمان ۲ ثانیه و الکترود C3 پیک مشهودی دیده می‌شود که احتمالا مربوط به زمان روشن شدن چراغ و فشردن دکمه توسط فرد است. همین پیک‌ها در زمان ۲ ثانیه در باند بتا و الکترود C4 نیز تا حدودی دیده می‌شوند. تا حدودی هم می‌شود گفت که وقتی ارتفاع زیاد شده است، تغییرات سیگنال نرم‌تر شده است.

کد:

```
%% Question 1

clc; clear; close all;

data_1 = load('EEG_990mS16.mat');

data_2 = load('EEG_2700mS16.mat');

fs = 256; % sampling frequency

%% Q1 - Part a

clc;

EEG_1_C3 = data_1.y(:,:,1);

EEG_1_C4 = data_1.y(:,:,2);

EEG_2_C3 = data_2.y(:,:,1);

EEG_2_C4 = data_2.y(:,:,2);
```

```
L = length(EEG_1_C3)/fs; % length of signal (s)
t = 0:1/fs:L-1/fs; % time axes
trial_slct = 5; % selected trial

figure;
subplot(4,1,1);
plot(t,EEG_1_C3(trial_slct, :));
title(['C3 signal at 990m height - trial number ',num2str(trial_slct)], 'Interpreter','latex','FontSize',14);
xlabel("time (s)",'Interpreter','latex');
ylabel("$\mu$ Volt","Interpreter",'latex');

subplot(4,1,2);
plot(t,EEG_2_C3(trial_slct, :));
title(['C3 signal at 2700m height - trial number ',num2str(trial_slct)], 'Interpreter','latex','FontSize',14);
xlabel("time (s)",'Interpreter','latex');
ylabel("$\mu$ Volt","Interpreter",'latex');

subplot(4,1,3);
plot(t,EEG_1_C4(trial_slct, :));
title(['C4 signal at 990m height - trial number ',num2str(trial_slct)], 'Interpreter','latex','FontSize',14);
xlabel("time (s)",'Interpreter','latex');
ylabel("$\mu$ Volt","Interpreter",'latex');

subplot(4,1,4);
plot(t,EEG_2_C4(trial_slct, :));
title(['C4 signal at 2700m height - trial number ',num2str(trial_slct)], 'Interpreter','latex','FontSize',14);
xlabel("time (s)",'Interpreter','latex');
ylabel("$\mu$ Volt","Interpreter",'latex');

%% Q1 - Part b
clc; close all;

NFFT = 2^nextpow2(length(EEG_2_C4(trial_slct,:)));
fft_1_C3 = fft(EEG_1_C3(trial_slct,:),NFFT);
```

```
fft_2_C3 = fft(EEG_2_C3(trial_slct,:),NFFT);

fft_1_C4 = fft(EEG_1_C4(trial_slct,:),NFFT);

fft_2_C4 = fft(EEG_2_C4(trial_slct,:),NFFT);


f = fs/NFFT*(-NFFT/2:NFFT/2-1); % frequency axes


figure;

subplot(4,2,1);

plot(f,abs(fftshift(fft_1_C3)));

title(['Amplitude of DTFT of C3 signal at 990m - trial
number',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("frequency (Hz)",'Interpreter','latex');

ylabel("|DTFT(X)|",'Interpreter','latex');

xlim([-fs/2,fs/2]);

subplot(4,2,2);

plot(f,180/pi*angle(fftshift(fft_1_C3)));

title(['Phase of DTFT of C3 signal at 990m - trial
number',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("frequency (Hz)",'Interpreter','latex');

ylabel("$\angle$DTFT(X)",'Interpreter','latex');

xlim([-fs/2,fs/2]);

ylim([-180,180]);


subplot(4,2,3);

plot(f,abs(fftshift(fft_2_C3)));

title(['Amplitude of DTFT of C3 signal at 2700m - trial
number',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("frequency (Hz)",'Interpreter','latex');

ylabel("|DTFT(X)|",'Interpreter','latex');

xlim([-fs/2,fs/2]);

subplot(4,2,4);

plot(f,180/pi*angle(fftshift(fft_2_C3)));

title(['Phase of DTFT of C3 signal at 2700m - trial
number',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("frequency (Hz)",'Interpreter','latex');

ylabel("$\angle$DTFT(X)",'Interpreter','latex');

xlim([-fs/2,fs/2]);

ylim([-180,180]);
```

```
subplot(4,2,5);

plot(f,abs(fftshift(fft_1_C4)));

title(['Amplitude of DTFT of C4 signal at 990m - trial
number',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("frequency (Hz)",'Interpreter','latex');

ylabel("|DTFT(X)|",'Interpreter','latex');

xlim([-fs/2,fs/2]);

subplot(4,2,6);

plot(f,180/pi*angle(fftshift(fft_1_C4)));

title(['Phase of DTFT of C4 signal at 990m - trial
number',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("frequency (Hz)",'Interpreter','latex');

ylabel("$\angle$DTFT(X)",'Interpreter','latex');

xlim([-fs/2,fs/2]);

ylim([-180,180]);


subplot(4,2,7);

plot(f,abs(fftshift(fft_2_C4)));

title(['Amplitude of DTFT of C4 signal at 2700m - trial
number',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("frequency (Hz)",'Interpreter','latex');

ylabel("|DTFT(X)|",'Interpreter','latex');

xlim([-fs/2,fs/2]);

subplot(4,2,8);

plot(f,180/pi*angle(fftshift(fft_2_C4)));

title(['Phase of DTFT of C4 signal at 2700m - trial
number',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("frequency (Hz)",'Interpreter','latex');

ylabel("$\angle$DTFT(X)",'Interpreter','latex');

xlim([-fs/2,fs/2]);

ylim([-180,180]);


%% Q1 - Part c

clc; close all;


NFFT = 2^nextpow2(length(EEG_2_C4(trial_slct,:)));

fft_1_C3 = fft(EEG_1_C3(trial_slct,:),NFFT);
```

```
fft_2_C3 = fft(EEG_2_C3(trial_slct,:),NFFT);

fft_1_C4 = fft(EEG_1_C4(trial_slct,:),NFFT);

fft_2_C4 = fft(EEG_2_C4(trial_slct,:),NFFT);


k = 0:1:NFFT-1;


figure;

subplot(4,2,1);

plot(k,abs(fft_1_C3));

title(['Amplitude of DTFT of C3 signal at 990m - trial number
',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("k",'Interpreter','latex');

ylabel("$\|$DTFT(X)$\|$",'Interpreter','latex');

xlim([0,NFFT-1]);

subplot(4,2,2);

plot(k,180/pi*angle(fft_1_C3));

title(['Phase of DTFT of C3 signal at 990m - trial number
',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("k",'Interpreter','latex');

ylabel("$\angle$DTFT(X)",'Interpreter','latex');

ylim([-180,180]);

xlim([0,NFFT-1]);


subplot(4,2,3);

plot(k,abs(fft_2_C3));

title(['Amplitude of DTFT of C3 signal at 2700m - trial number
',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("k",'Interpreter','latex');

ylabel("$\|$DTFT(X)$\|$",'Interpreter','latex');

xlim([0,NFFT-1]);

subplot(4,2,4);

plot(k,180/pi*angle(fft_2_C3));

title(['Phase of DTFT of C3 signal at 2700m - trial number
',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("k",'Interpreter','latex');

ylabel("$\angle$DTFT(X)",'Interpreter','latex');

ylim([-180,180]);

xlim([0,NFFT-1]);
```

```
subplot(4,2,5);

plot(k,abs(fft_1_C4));

title(['Amplitude of DTFT of C4 signal at 990m - trial number
',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("k",'Interpreter','latex');

ylabel("$\|$DTFT(X)$\|$",'Interpreter','latex');

xlim([0,NFFT-1]);

subplot(4,2,6);

plot(k,180/pi*angle(fft_1_C4));

title(['Phase of DTFT of C4 signal at 990m - trial number
',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("k",'Interpreter','latex');

ylabel("$\angle$DTFT(X)",'Interpreter','latex');

ylim([-180,180]);

xlim([0,NFFT-1]);


subplot(4,2,7);

plot(k,abs(fft_2_C4));

title(['Amplitude of DTFT of C4 signal at 2700m - trial number
',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("k",'Interpreter','latex');

ylabel("$\|$DTFT(X)$\|$",'Interpreter','latex');

xlim([0,NFFT-1]);

subplot(4,2,8);

plot(k,180/pi*angle(fft_2_C4));

title(['Phase of DTFT of C4 signal at 2700m - trial number
',num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel("k",'Interpreter','latex');

ylabel("$\angle$DTFT(X)",'Interpreter','latex');

ylim([-180,180]);

xlim([0,NFFT-1]);


%% Q1 - Part d

clc; close all;


[PSD_1_C3, ~] = pwelch(EEG_1_C3(trial_slct,:),[],[],NFFT,fs);

[PSD_2_C3, ~] = pwelch(EEG_2_C3(trial_slct,:),[],[],NFFT,fs);
```

```
[PSD_1_C4, ~] = pwelch(EEG_1_C4(trial_slct,:),[],[],NFFT,fs);

[PSD_2_C4, f] = pwelch(EEG_2_C4(trial_slct,:),[],[],NFFT,fs);


figure;

subplot(4,1,1);

plot(f,PSD_1_C3);

title(['PSD of C3 signal at 990m height - trial number ',
num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel('Frequency (Hz)','Interpreter','latex');

ylabel('PSD (1/Hz)','Interpreter','latex');

xlim([0,fs/2]);

grid minor;


subplot(4,1,2);

plot(f,PSD_2_C3);

title(['PSD of C3 signal at 2700m height - trial number ',
num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel('Frequency (Hz)','Interpreter','latex');

ylabel('PSD (1/Hz)','Interpreter','latex');

xlim([0,fs/2]);

grid minor;


subplot(4,1,3);

plot(f,PSD_1_C4);

title(['PSD of C4 signal at 990m height - trial number ',
num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel('Frequency (Hz)','Interpreter','latex');

ylabel('PSD (1/Hz)','Interpreter','latex');

xlim([0,fs/2]);

grid minor;


subplot(4,1,4);

plot(f,PSD_2_C4);

title(['PSD of C4 signal at 2700m height - trial number ',
num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel('Frequency (Hz)','Interpreter','latex');

ylabel('PSD (1/Hz)','Interpreter','latex');

xlim([0,fs/2]);
```

```
grid minor;


%% Part e and f

clc; close all;


[~ , ~, ~, ps_1_C3] = spectrogram(EEG_1_C3(trial_slct,:), hamming(32), 16, 256, fs, "psd");

[~ , ~, ~, ps_2_C3] = spectrogram(EEG_2_C3(trial_slct,:), hamming(32), 16, 256, fs, "psd");

[~ , ~, ~, ps_1_C4] = spectrogram(EEG_1_C4(trial_slct,:), hamming(32), 16, 256, fs, "psd");

[~ , f, t, ps_2_C4] = spectrogram(EEG_2_C4(trial_slct,:), hamming(32), 16, 256, fs, "psd");


E_alpha_1_C3 = sum(ps_1_C3(9:14, :));

E_alpha_2_C3 = sum(ps_2_C3(9:14, :));

E_alpha_1_C4 = sum(ps_1_C4(9:14, :));

E_alpha_2_C4 = sum(ps_2_C4(9:14, :));


E_beta_1_C3 = sum(ps_1_C3(15:19, :));

E_beta_2_C3 = sum(ps_2_C3(15:19, :));

E_beta_1_C4 = sum(ps_1_C4(15:19, :));

E_beta_2_C4 = sum(ps_2_C4(15:19, :));


figure;

subplot(4,2,1);

plot(t,E_alpha_1_C3);

title(['Energy of alpha band - C3 - 990m - trial number ',
num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Energy','Interpreter','latex');

xlim([0,6]);

grid minor;


subplot(4,2,2);

plot(t,E_alpha_2_C3);

title(['Energy of alpha band - C3 - 2700m - trial number ',
num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Energy','Interpreter','latex');

xlim([0,6]);
```

```
grid minor;


subplot(4,2,3);

plot(t,E_alpha_1_C4);

title(['Energy of alpha band - C4 - 990m - trial number ',
num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Energy','Interpreter','latex');

xlim([0,6]);

grid minor;


subplot(4,2,4);

plot(t,E_alpha_2_C4);

title(['Energy of alpha band - C4 - 2700m - trial number ',
num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Energy','Interpreter','latex');

xlim([0,6]);

grid minor;


subplot(4,2,5);

plot(t,E_beta_1_C3);

title(['Energy of beta band - C3 - 990m - trial number ',
num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Energy','Interpreter','latex');

xlim([0,6]);

grid minor;


subplot(4,2,6);

plot(t,E_beta_2_C3);

title(['Energy of beta band - C3 - 2700m - trial number ',
num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Energy','Interpreter','latex');

xlim([0,6]);

grid minor;
```

```
subplot(4,2,7);

plot(t,E_beta_1_C4);

title(['Energy of beta band - C4 - 990m - trial number ',
num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Energy','Interpreter','latex');

xlim([0,6]);

grid minor;


subplot(4,2,8);

plot(t,E_beta_2_C4);

title(['Energy of beta band - C4 - 2700m - trial number ',
num2str(trial_slct)],'Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Energy','Interpreter','latex');

xlim([0,6]);

grid minor;


%% Q1 - Part g

clc;

E_alpha_1_C3_mean = zeros(1,95);

E_alpha_2_C3_mean = zeros(1,95);

E_alpha_1_C4_mean = zeros(1,95);

E_alpha_2_C4_mean = zeros(1,95);


E_beta_1_C3_mean = zeros(1,95);

E_beta_2_C3_mean = zeros(1,95);

E_beta_1_C4_mean = zeros(1,95);

E_beta_2_C4_mean = zeros(1,95);


for i = 1:37

    [~ , ~, ~, ps_1_C3] = spectrogram(EEG_1_C3(i,:), hamming(32), 16, 256, fs, "psd");

    [~ , f, t, ps_1_C4] = spectrogram(EEG_1_C4(i,:), hamming(32), 16, 256, fs, "psd");


    E_alpha_1_C3_mean = E_alpha_1_C3_mean + sum(ps_1_C3(9:14, :));

    E_alpha_1_C4_mean = E_alpha_1_C4_mean + sum(ps_1_C4(9:14, :));

    E_beta_1_C3_mean = E_beta_1_C3_mean + sum(ps_1_C3(15:19, :));
```

```
    E_beta_1_C4_mean = E_beta_1_C4_mean + sum(ps_1_C4(15:19, :));
end

E_alpha_1_C3_mean = E_alpha_1_C3_mean / 37;
E_alpha_1_C4_mean = E_alpha_1_C4_mean / 37;
E_beta_1_C3_mean = E_beta_1_C3_mean / 37;
E_beta_1_C4_mean = E_beta_1_C4_mean / 37;



for i = 1:41
    [~ , ~, ~, ps_2_C3] = spectrogram(EEG_2_C3(i,:), hamming(32), 16, 256, fs, "psd");
    [~ , f, t, ps_2_C4] = spectrogram(EEG_2_C4(i,:), hamming(32), 16, 256, fs, "psd");

    E_alpha_2_C3_mean = E_alpha_2_C3_mean + sum(ps_2_C3(9:14, :));
    E_alpha_2_C4_mean = E_alpha_2_C4_mean + sum(ps_2_C4(9:14, :));
    E_beta_2_C3_mean = E_beta_2_C3_mean + sum(ps_2_C3(15:19, :));
    E_beta_2_C4_mean = E_beta_2_C4_mean + sum(ps_2_C4(15:19, :));
end

E_alpha_2_C3_mean = E_alpha_2_C3_mean / 41;
E_alpha_2_C4_mean = E_alpha_2_C4_mean / 41;
E_beta_2_C3_mean = E_beta_2_C3_mean / 41;
E_beta_2_C4_mean = E_beta_2_C4_mean / 41;

figure;
subplot(4,2,1);
plot(t,E_alpha_1_C3_mean);
title('Energy of alpha band - C3 - 990m - mean of all trials ','Interpreter','latex','FontSize',14);
xlabel('Time (s)','Interpreter','latex');
ylabel('Energy','Interpreter','latex');
xlim([0,6]);
grid minor;

subplot(4,2,2);
plot(t,E_alpha_2_C3_mean);
title('Energy of alpha band - C3 - 2700m - mean of all trials ','Interpreter','latex','FontSize',14);
```

```
xlabel('Time (s)','Interpreter','latex');
ylabel('Energy','Interpreter','latex');
xlim([0,6]);
grid minor;

subplot(4,2,3);
plot(t,E_alpha_1_C4_mean);
title('Energy of alpha band - C4 - 990m - mean of all trials ','Interpreter','latex','FontSize',14);
xlabel('Time (s)','Interpreter','latex');
ylabel('Energy','Interpreter','latex');
xlim([0,6]);
grid minor;

subplot(4,2,4);
plot(t,E_alpha_2_C4_mean);
title('Energy of alpha band - C4 - 2700m - mean of all trials ','Interpreter','latex','FontSize',14);
xlabel('Time (s)','Interpreter','latex');
ylabel('Energy','Interpreter','latex');
xlim([0,6]);
grid minor;

subplot(4,2,5);
plot(t,E_beta_1_C3_mean);
title('Energy of beta band - C3 - 990m - mean of all trials ','Interpreter','latex','FontSize',14);
xlabel('Time (s)','Interpreter','latex');
ylabel('Energy','Interpreter','latex');
xlim([0,6]);
grid minor;

subplot(4,2,6);
plot(t,E_beta_2_C3_mean);
title('Energy of beta band - C3 - 2700m - mean of all trials ','Interpreter','latex','FontSize',14);
xlabel('Time (s)','Interpreter','latex');
ylabel('Energy','Interpreter','latex');
xlim([0,6]);
grid minor;
```

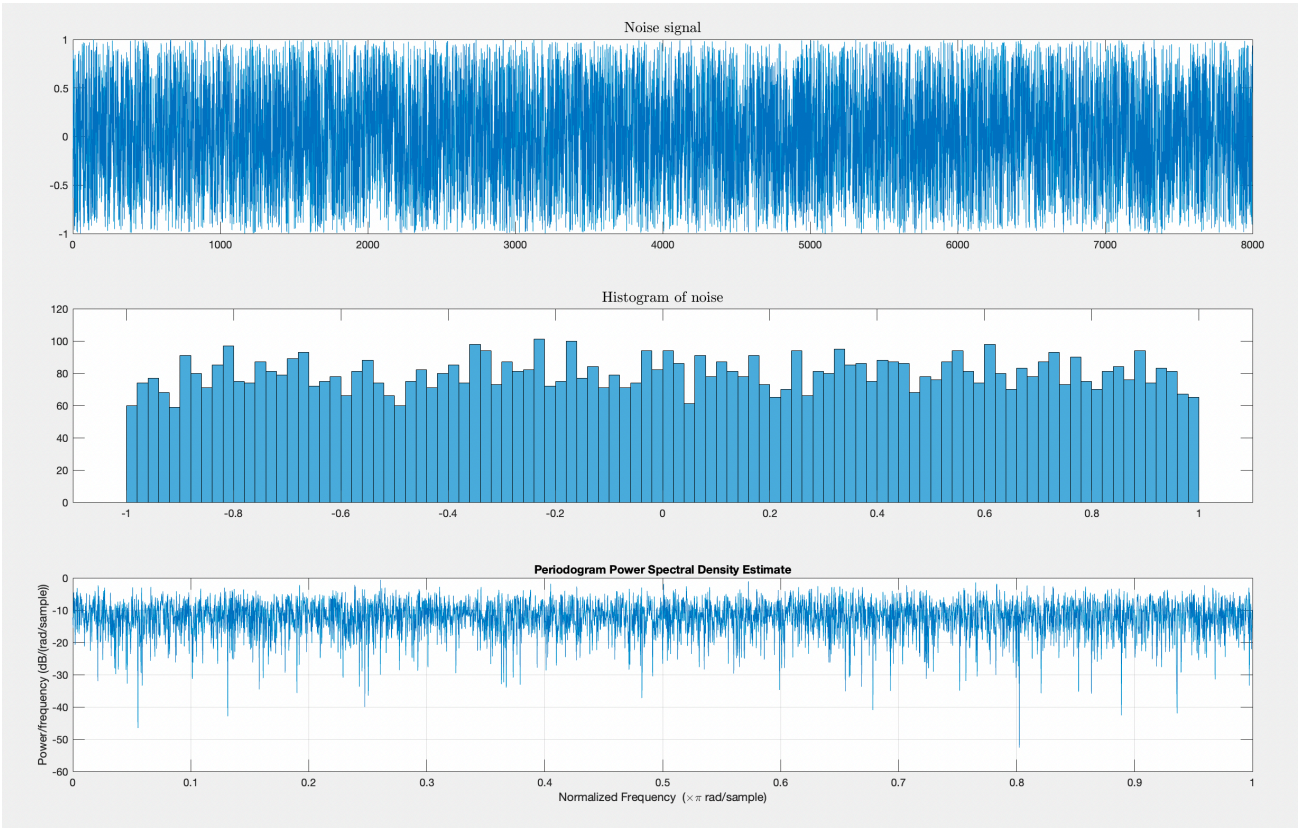
```
subplot(4,2,7);
plot(t,E_beta_1_C4_mean);
title('Energy of beta band - C4 - 990m - mean of all trials ','Interpreter','latex','FontSize',14);
xlabel('Time (s)','Interpreter','latex');
ylabel('Energy','Interpreter','latex');
xlim([0,6]);
grid minor;

subplot(4,2,8);
plot(t,E_beta_2_C4_mean);
title('Energy of beta band - C4 - 2700m - mean of all trials ','Interpreter','latex','FontSize',14);
xlabel('Time (s)','Interpreter','latex');
ylabel('Energy','Interpreter','latex');
xlim([0,6]);
grid minor;

%% Q1 - Part h
clc;

E_alpha_1_C3_ref = sum(E_alpha_1_C3_mean(8:24)) / 17;
E_alpha_1_C4_ref = sum(E_alpha_1_C4_mean(8:24)) / 17;
E_beta_1_C3_ref = sum(E_beta_1_C3_mean(8:24)) / 17;
E_beta_1_C4_ref = sum(E_beta_1_C4_mean(8:24)) / 17;
E_alpha_2_C3_ref = sum(E_alpha_2_C3_mean(8:24)) / 17;
E_alpha_2_C4_ref = sum(E_alpha_2_C4_mean(8:24)) / 17;
E_beta_2_C3_ref = sum(E_beta_2_C3_mean(8:24)) / 17;
E_beta_2_C4_ref = sum(E_beta_2_C4_mean(8:24)) / 17;

E_alpha_1_C3_diff = (E_alpha_1_C3_mean - E_alpha_1_C3_ref)/E_alpha_1_C3_ref * 100;
E_alpha_1_C4_diff = (E_alpha_1_C4_mean - E_alpha_1_C4_ref)/E_alpha_1_C4_ref * 100;
E_beta_1_C3_diff = (E_beta_1_C3_mean - E_beta_1_C3_ref)/E_beta_1_C3_ref * 100;
E_beta_1_C4_diff = (E_beta_1_C4_mean - E_beta_1_C4_ref)/E_beta_1_C4_ref * 100;
E_alpha_2_C3_diff = (E_alpha_2_C3_mean - E_alpha_2_C3_ref)/E_alpha_2_C3_ref * 100;
E_alpha_2_C4_diff = (E_alpha_2_C4_mean - E_alpha_2_C4_ref)/E_alpha_2_C4_ref * 100;
E_beta_2_C3_diff = (E_beta_2_C3_mean - E_beta_2_C3_ref)/E_beta_2_C3_ref * 100;
```

```
E_beta_2_C4_diff = (E_beta_2_C4_mean - E_beta_2_C4_ref)/E_beta_2_C4_ref * 100;


figure;

subplot(4,2,1);

plot(t,E_alpha_1_C3_diff);

title('Percentage of changes of alpha band energy - C3 - 990m - mean of all trials
','Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Percentage of changes','Interpreter','latex');

xlim([0,6]);

grid minor;


subplot(4,2,2);

plot(t,E_alpha_2_C3_diff);

title('Percentage of changes of alpha band energy - C3 - 2700m - mean of all trials
','Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Percentage of changes','Interpreter','latex');

xlim([0,6]);

grid minor;


subplot(4,2,3);

plot(t,E_alpha_1_C4_diff);

title('Percentage of changes of alpha band energy - C4 - 990m - mean of all trials
','Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Percentage of changes','Interpreter','latex');

xlim([0,6]);

grid minor;


subplot(4,2,4);

plot(t,E_alpha_2_C4_diff);

title('Percentage of changes of alpha band energy - C4 - 2700m - mean of all trials
','Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Percentage of changes','Interpreter','latex');

xlim([0,6]);

grid minor;
```

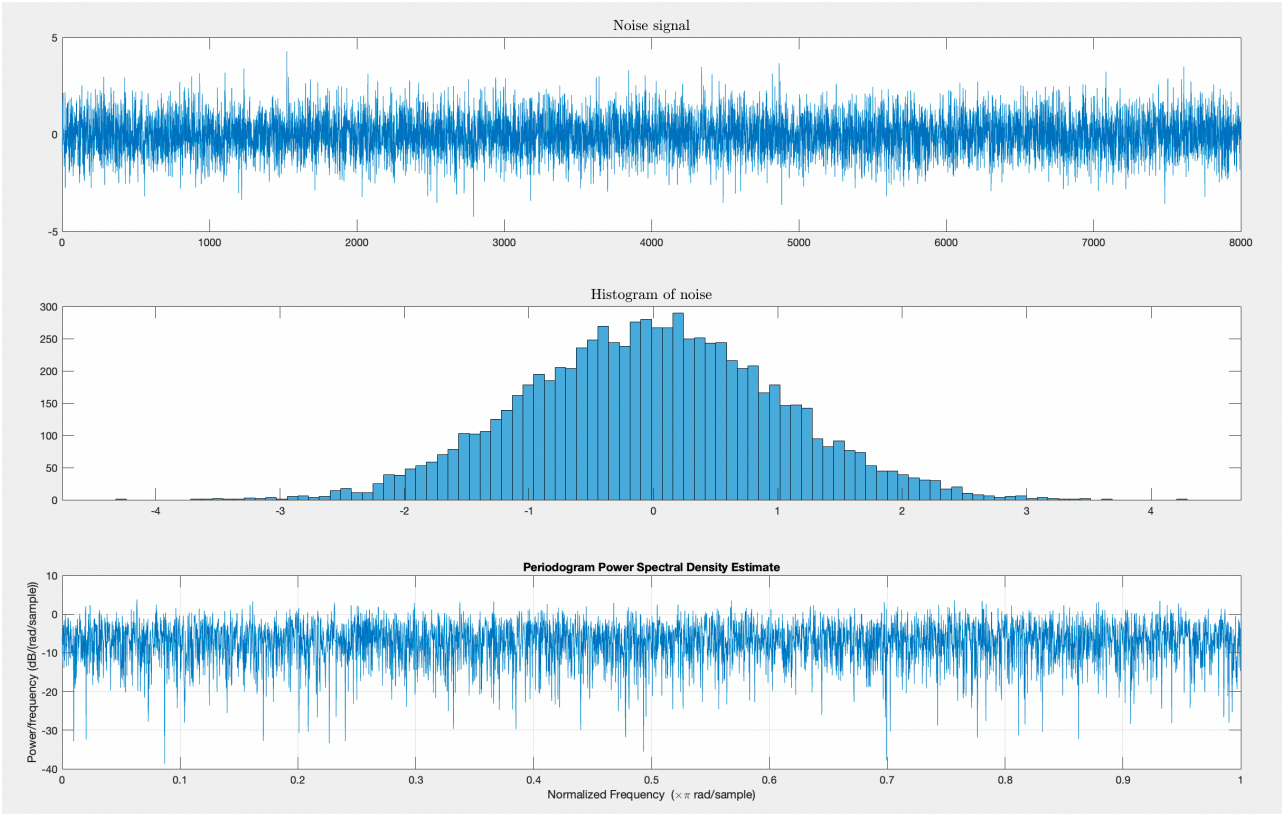
```
subplot(4,2,5);

plot(t,E_beta_1_C3_diff);

title('Percentage of changes of beta band energy - C3 - 990m - mean of all trials
','Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Percentage of changes','Interpreter','latex');

xlim([0,6]);

grid minor;


subplot(4,2,6);

plot(t,E_beta_2_C3_diff);

title('Percentage of changes of beta band energy - C3 - 2700m - mean of all trials
','Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Percentage of changes','Interpreter','latex');

xlim([0,6]);

grid minor;


subplot(4,2,7);

plot(t,E_beta_1_C4_diff);

title('Percentage of changes of beta band energy - C4 - 990m - mean of all trials
','Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Percentage of changes','Interpreter','latex');

xlim([0,6]);

grid minor;


subplot(4,2,8);

plot(t,E_beta_2_C4_diff);

title('Percentage of changes of beta band energy - C4 - 2700m - mean of all trials
','Interpreter','latex','FontSize',14);

xlabel('Time (s)','Interpreter','latex');

ylabel('Percentage of changes','Interpreter','latex');

xlim([0,6]);

grid minor;
```

سوال۲-

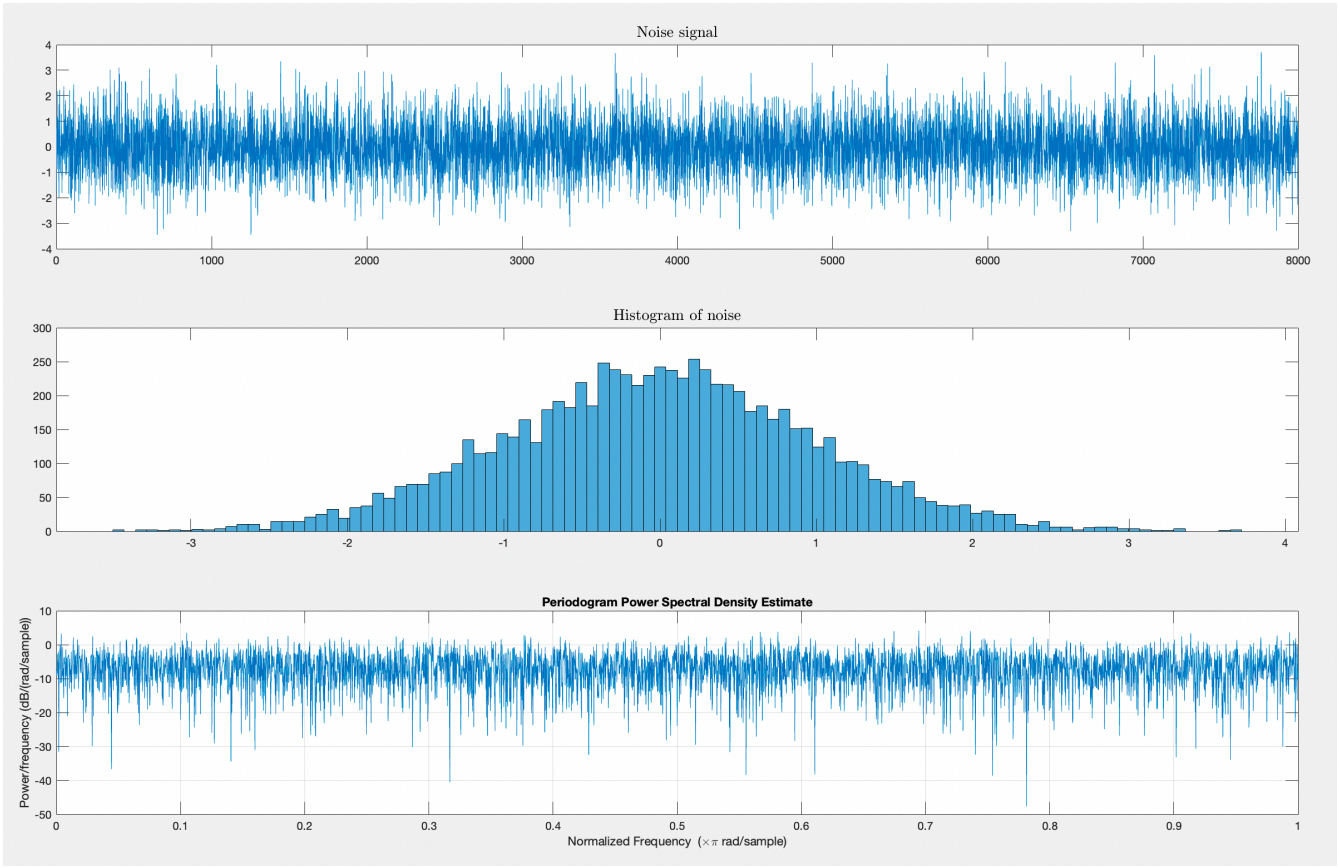
الف


Noise signal
Histogram of noise
Periodogram Power Spectral Density Estimate
Power/frequency (dB/(rad/sample))
Normalized Frequency (×π rad/sample)

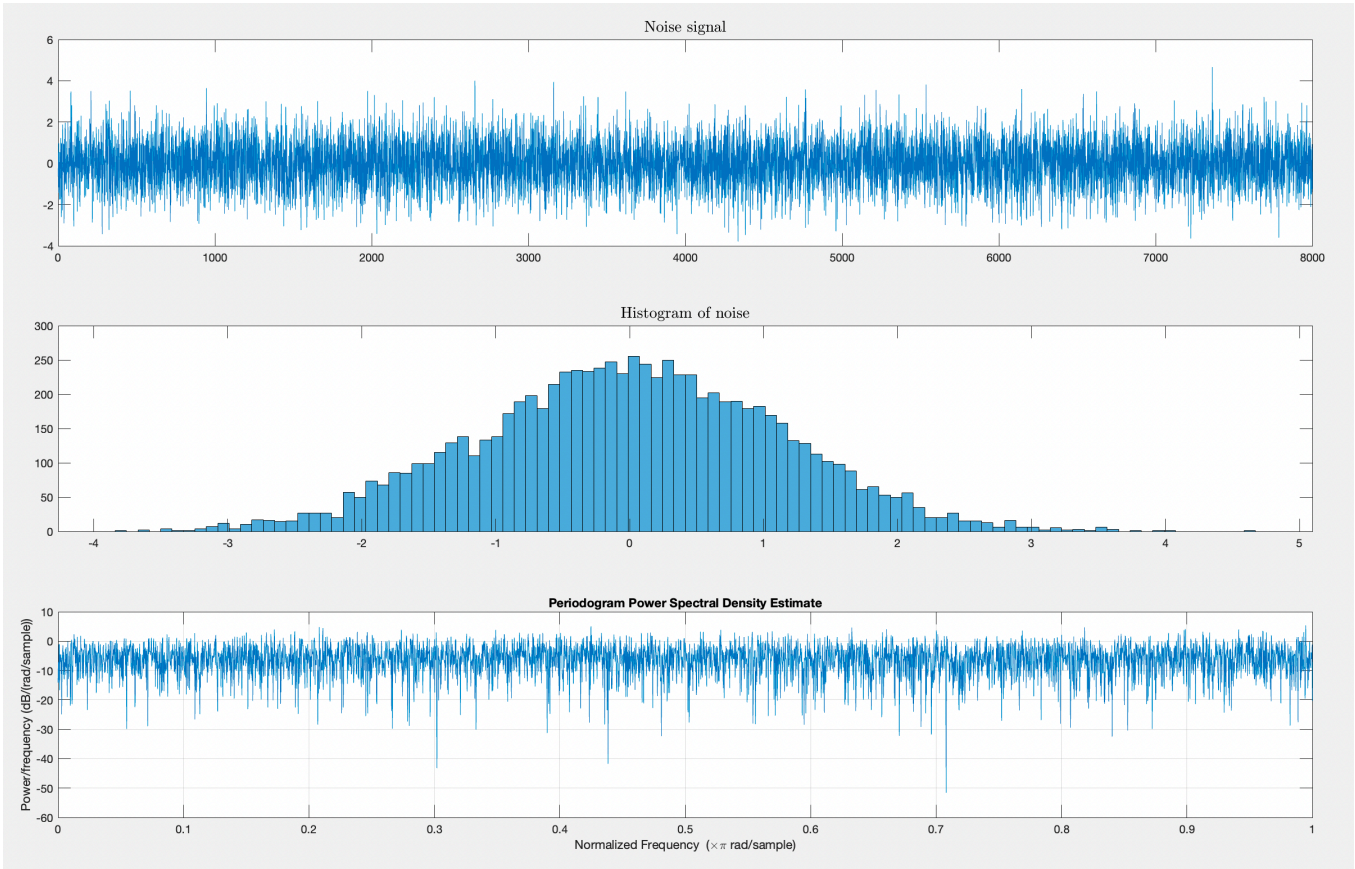
ب)


Noise signal
Histogram of noise
Periodogram Power Spectral Density Estimate
Power/frequency (dB/(rad/sample))
Normalized Frequency (×π rad/sample)

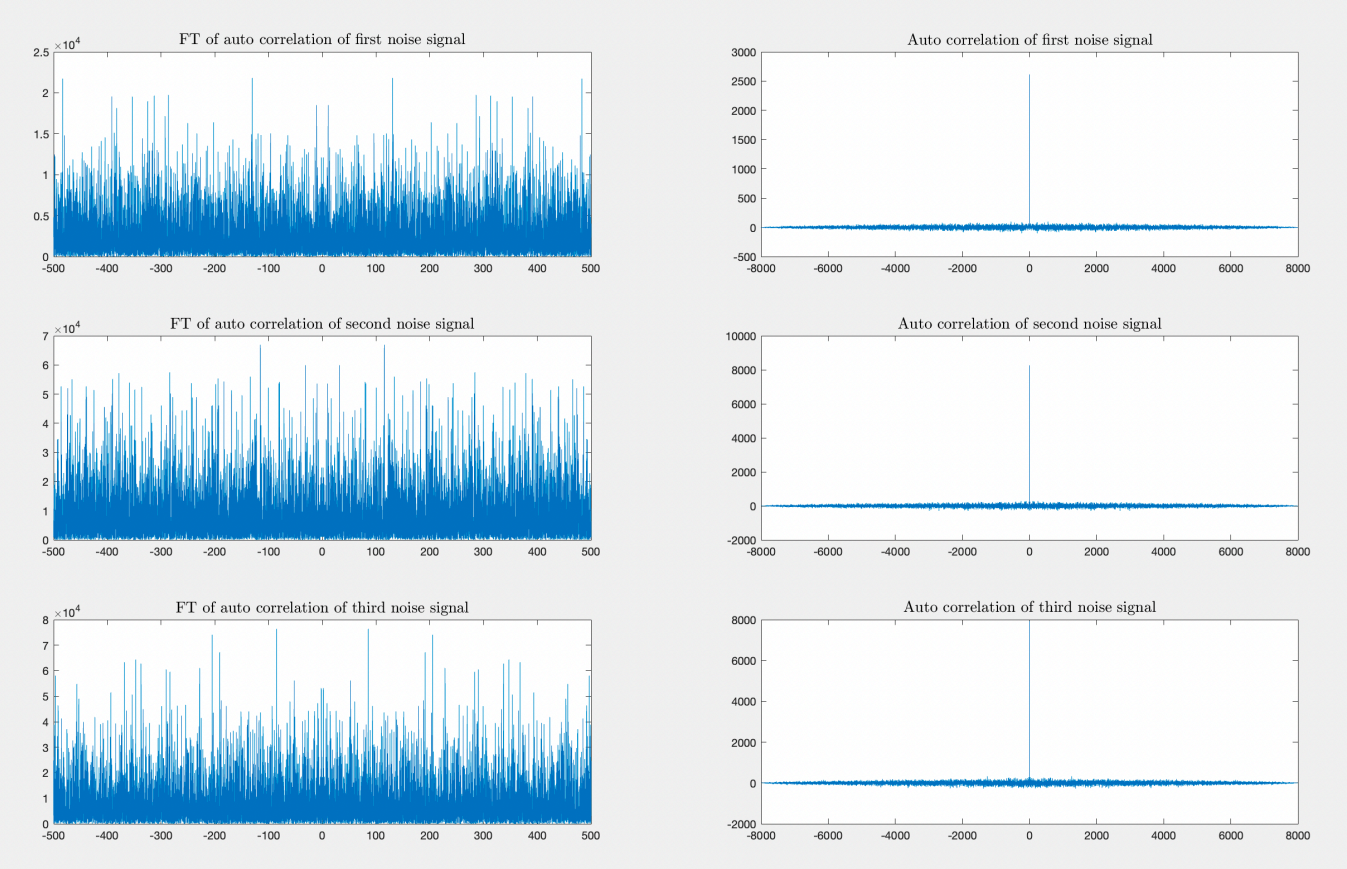
پ)


Noise signal
Histogram of noise
Periodogram Power Spectral Density Estimate
Power/frequency (dB/(rad/sample))
Normalized Frequency (×π rad/sample)

ت)


Noise signal
Histogram of noise
Periodogram Power Spectral Density Estimate
Power/frequency (dB/(rad/sample))
Normalized Frequency (×π rad/sample)

ث)



مشاهده می‌کنیم که فوریه تابع همبستگی مشابه با PSD رسم شده در قسمت‌های قبلی می‌باشد.

کد:

```
%% Question 2

clc; clear; close all;


%% Q2 - Part a

L = 8000; % Length of signal

noise_rand = -1 + 2*rand(1,L);


figure;

subplot(3,1,1);

plot(noise_rand);

title("Noise signal", 'Interpreter','latex','FontSize',14);

subplot(3,1,2);

histogram(noise_rand,100);
```

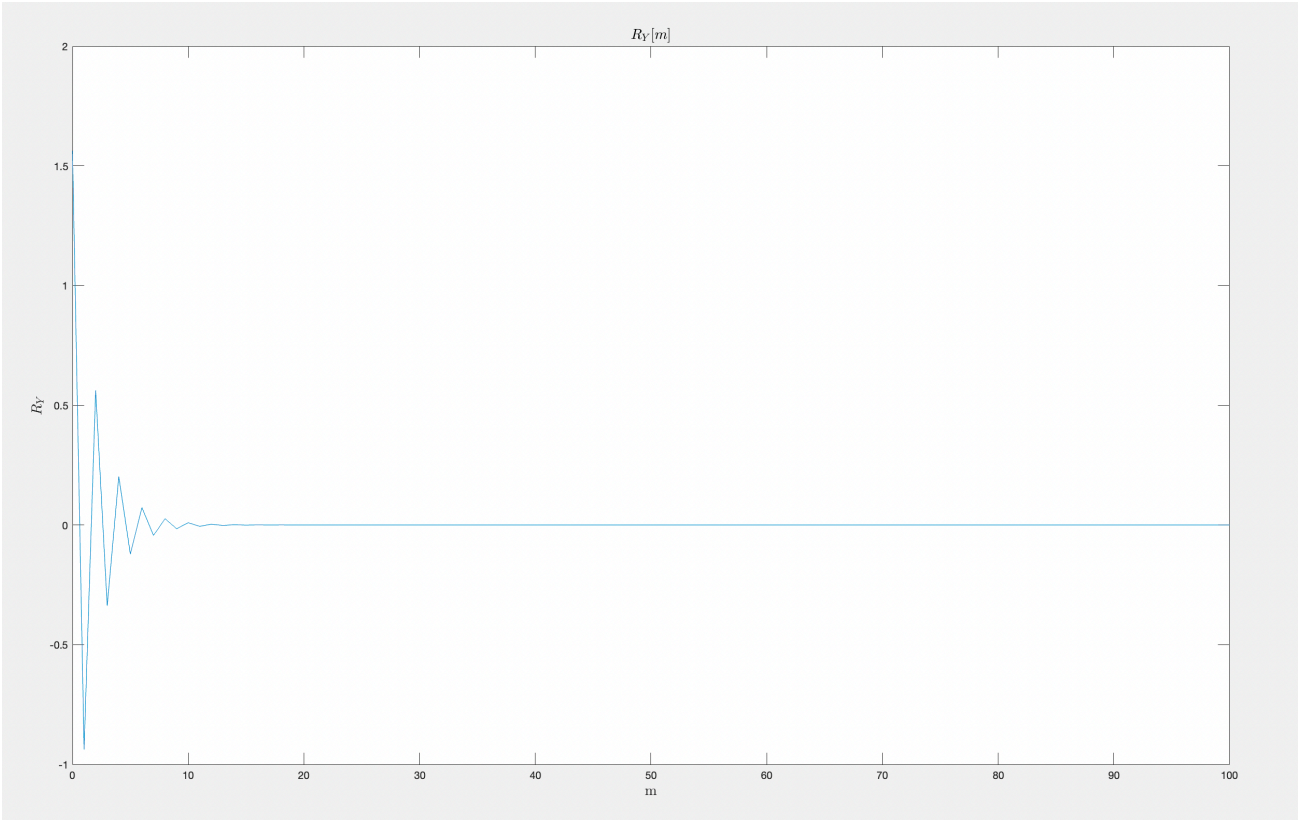
```
title("Histogram of noise", 'Interpreter','latex','FontSize',14);
subplot(3,1,3);
periodogram(noise_rand);

%% Q2 - Part b
clc; close all;
mu = 0; % Mean of signal
sigma = 1; % STD of signal
noise_randn = sigma*randn(1,L) + mu;

figure;
subplot(3,1,1);
plot(noise_randn);
title("Noise signal", 'Interpreter','latex','FontSize',14);
subplot(3,1,2);
histogram(noise_randn,100);
title("Histogram of noise", 'Interpreter','latex','FontSize',14);
subplot(3,1,3);
periodogram(noise_randn);

%% Q2 - Part c
clc; close all;

ab = rand(2,L);
mu = 0;
sigma = 1;
noise_x = sigma*cos(2*pi*ab(2,:)).*sqrt(-2*log(1-ab(1,:)))+mu;

figure;
subplot(3,1,1);
plot(noise_x);
title("Noise signal", 'Interpreter','latex','FontSize',14);
subplot(3,1,2);
histogram(noise_x,100);
title("Histogram of noise", 'Interpreter','latex','FontSize',14);
subplot(3,1,3);
```

```
periodogram(noise_x);
%% Q2 - Part d
clc; close all;

noise_wgn = wgn(1,L,1);

figure;
subplot(3,1,1);
plot(noise_wgn);
title("Noise signal", 'Interpreter','latex','FontSize',14);
subplot(3,1,2);
histogram(noise_wgn,100);
title("Histogram of noise", 'Interpreter','latex','FontSize',14);
subplot(3,1,3);
periodogram(noise_wgn);

%% Q2 - Part e
clc; close all;

[corr_noise_rand, ~] = xcorr(noise_rand);
[corr_noise_randn, ~] = xcorr(noise_randn);
[corr_noise_x, lags] = xcorr(noise_x);

NFFT = 2^nextpow2(length(corr_noise_rand));

fft_corr_rand = fft(corr_noise_rand,NFFT);
fft_corr_randn = fft(corr_noise_randn,NFFT);
fft_corr_x = fft(corr_noise_x,NFFT);

fs = 1000;
f = fs/NFFT*(-NFFT/2:NFFT/2-1); % frequency axes

figure;
subplot(3,2,1);
plot(f,abs(fftshift(fft_corr_rand)));
title("FT of auto correlation of first noise signal", 'Interpreter','latex','FontSize',14);
```

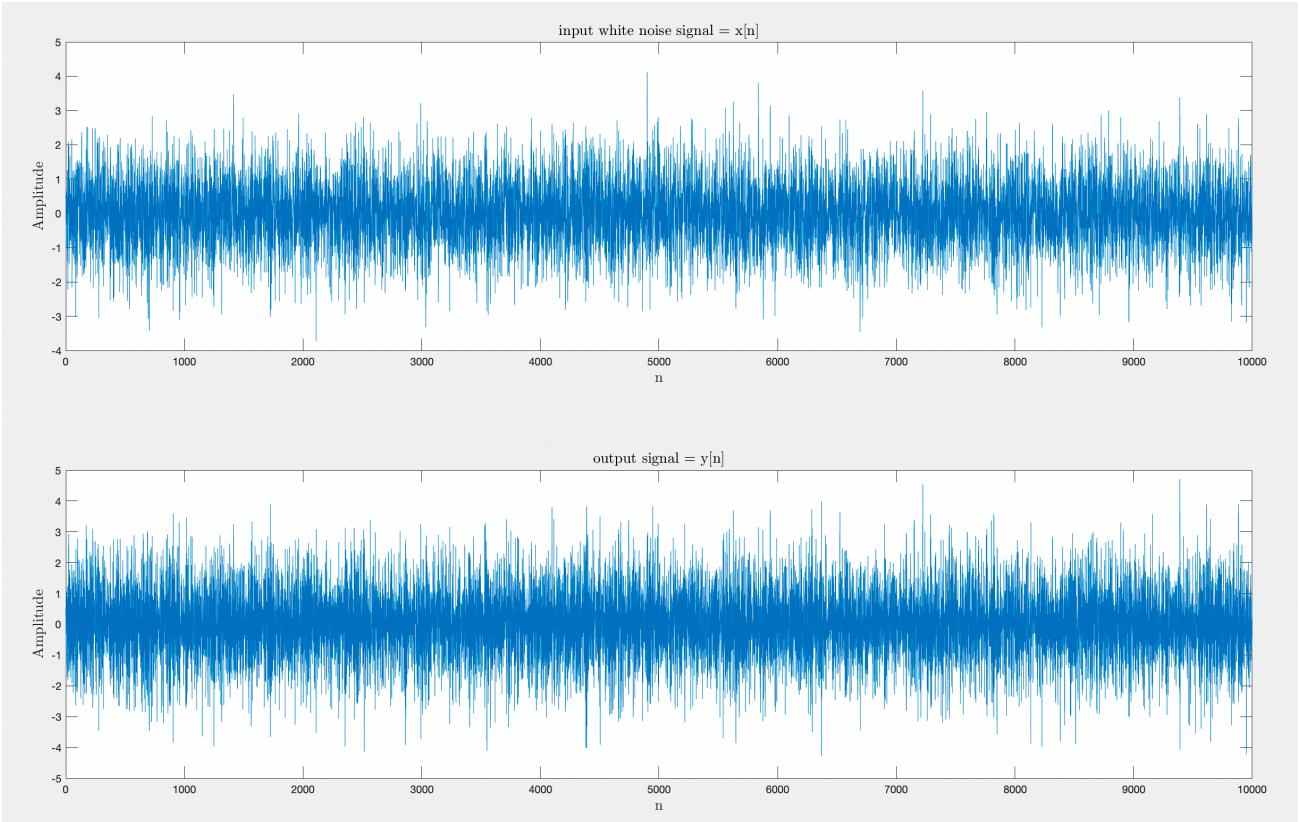
```
subplot(3,2,2);
plot(lags, corr_noise_rand);
title("Auto correlation of first noise signal","Interpreter","latex","Fontsize",14);


subplot(3,2,3);
plot(f,abs(fftshift(fft_corr_randn)));
title("FT of auto correlation of second noise signal", 'Interpreter','latex','FontSize',14);


subplot(3,2,4);
plot(lags, corr_noise_randn);
title("Auto correlation of second noise signal","Interpreter","latex","Fontsize",14);


subplot(3,2,5);
plot(f,abs(fftshift(fft_corr_x)));
title("FT of auto correlation of third noise signal", 'Interpreter','latex','FontSize',14);


subplot(3,2,6);
plot(lags, corr_noise_x);
title("Auto correlation of third noise signal","Interpreter","latex","Fontsize",14);
```

سوال ۳-

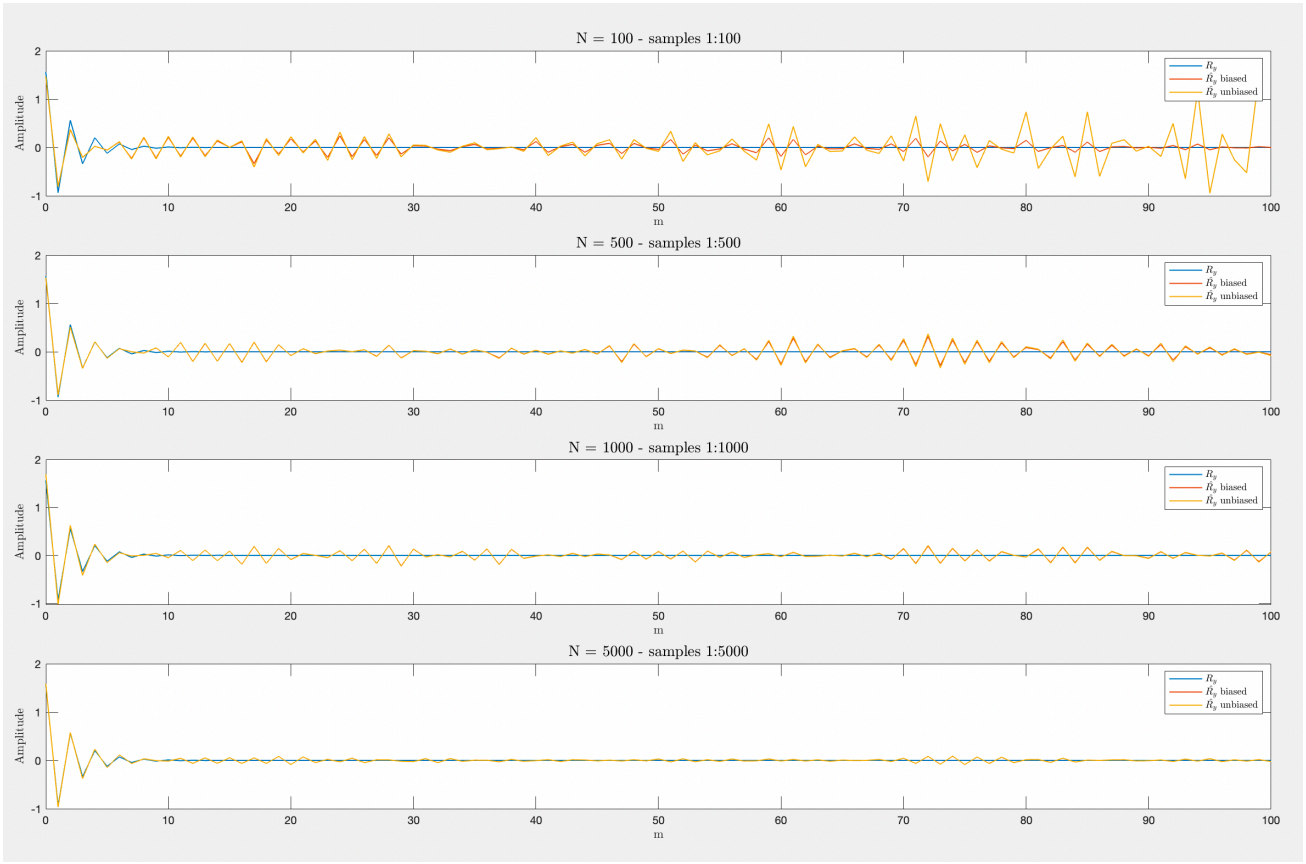
الف)

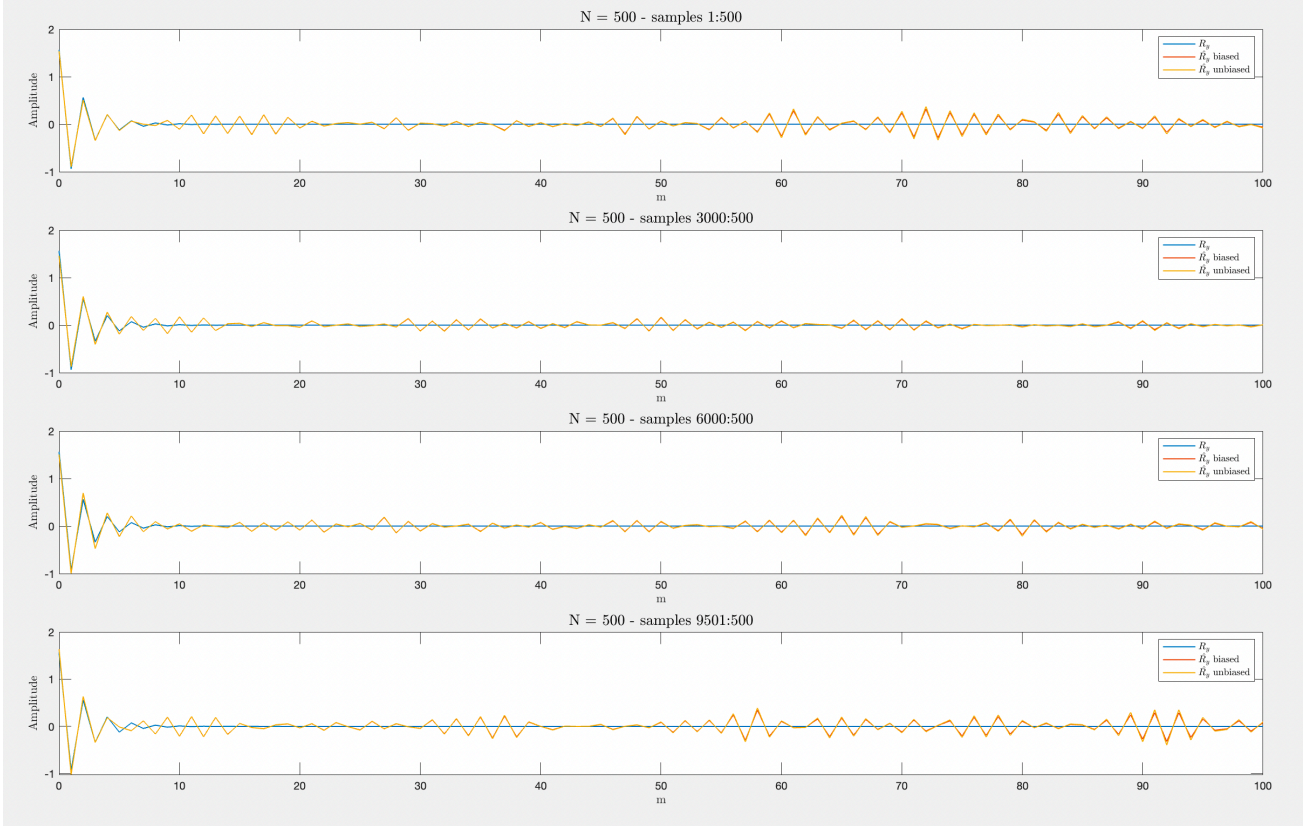

$R_Y[m]$
R_Y
m

ب)


input white noise signal = x[n]
Amplitude
n
output signal = y[n]
Amplitude
n

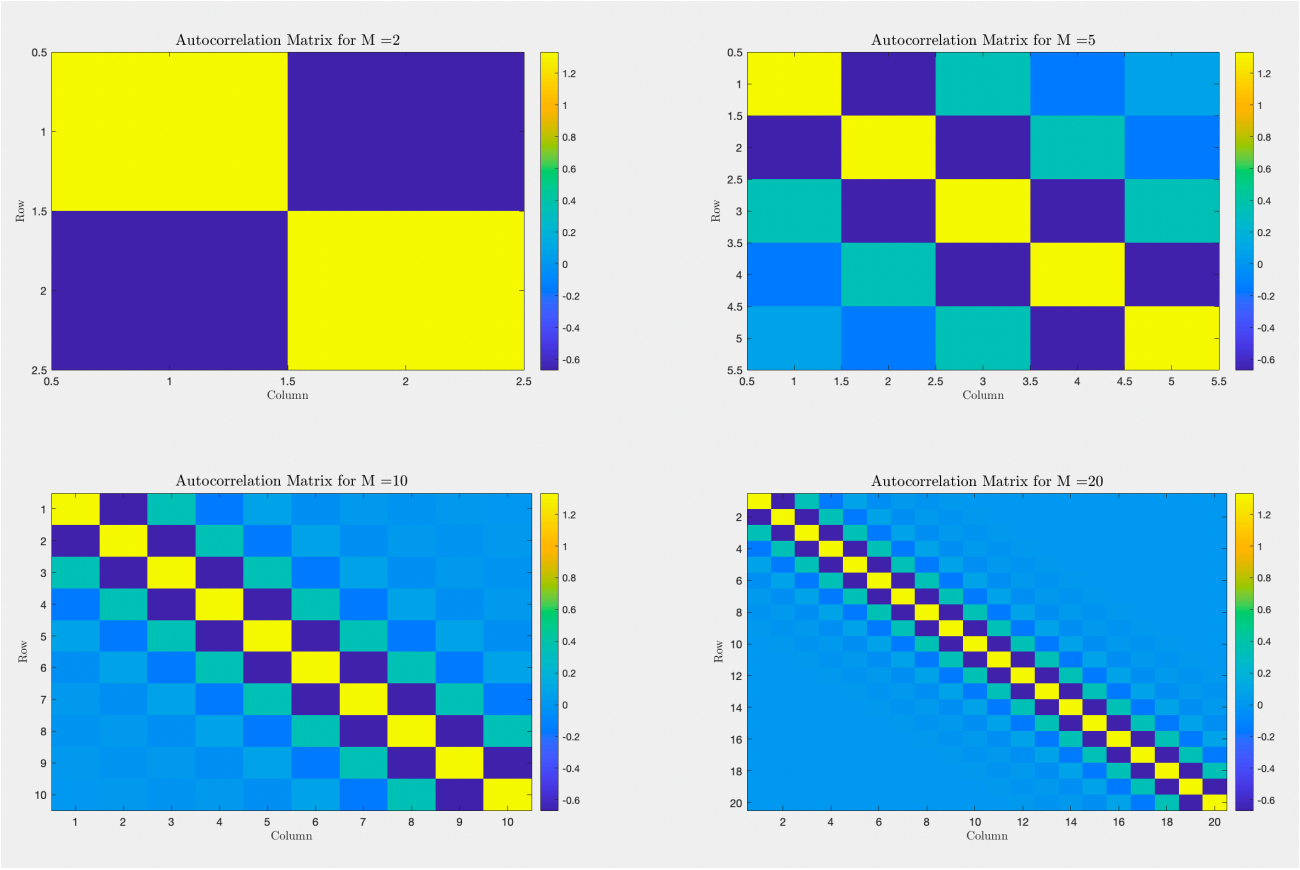
پ)


N = 100 - samples 1:100
N = 500 - samples 1:500
N = 1000 - samples 1:1000
N = 5000 - samples 1:5000
R_y
$\hat{R}_y$ biased
$\hat{R}_y$ unbiased
Amplitude
m


N = 500 - samples 1:500
N = 500 - samples 3000:500
N = 500 - samples 6000:500
N = 500 - samples 9501:500
R_y
$\hat{R}_y$ biased
$\hat{R}_y$ unbiased
Amplitude
m

مشاهده می‌کنیم که با افزایش N تخمین ما دقیق تر می‌شود و شباهت آن به تابع همبستگی اصلی بیشتر می‌شود. همچنین اگر تا m های بزرگ رسم می‌کردیم می‌دیدیم که حالت بدون بایاس به ازای m های خیلی بزرگ، مقدار زیادی پیدا می‌کرد ولی اینجا چون فقط 100 نمونه اول را رسم کردیم این تفاوت بین تخمینگر بدون بایاس و بایاس دار دیده نمی‌شود. زمانی هم که N نمونه را از قسمت‌های مختلف سیگنال بر می‌داریم، میبینیم که تخمین‌های ما یکسان نمی‌شود و تفاوت پیدا می‌کند، بر اساس نتایج حدس می‌توانیم بزنیم که وقتی N نمونه را از وسط سیگنال بر می‌داریم تخمین بهتری زده شده است.

ت)



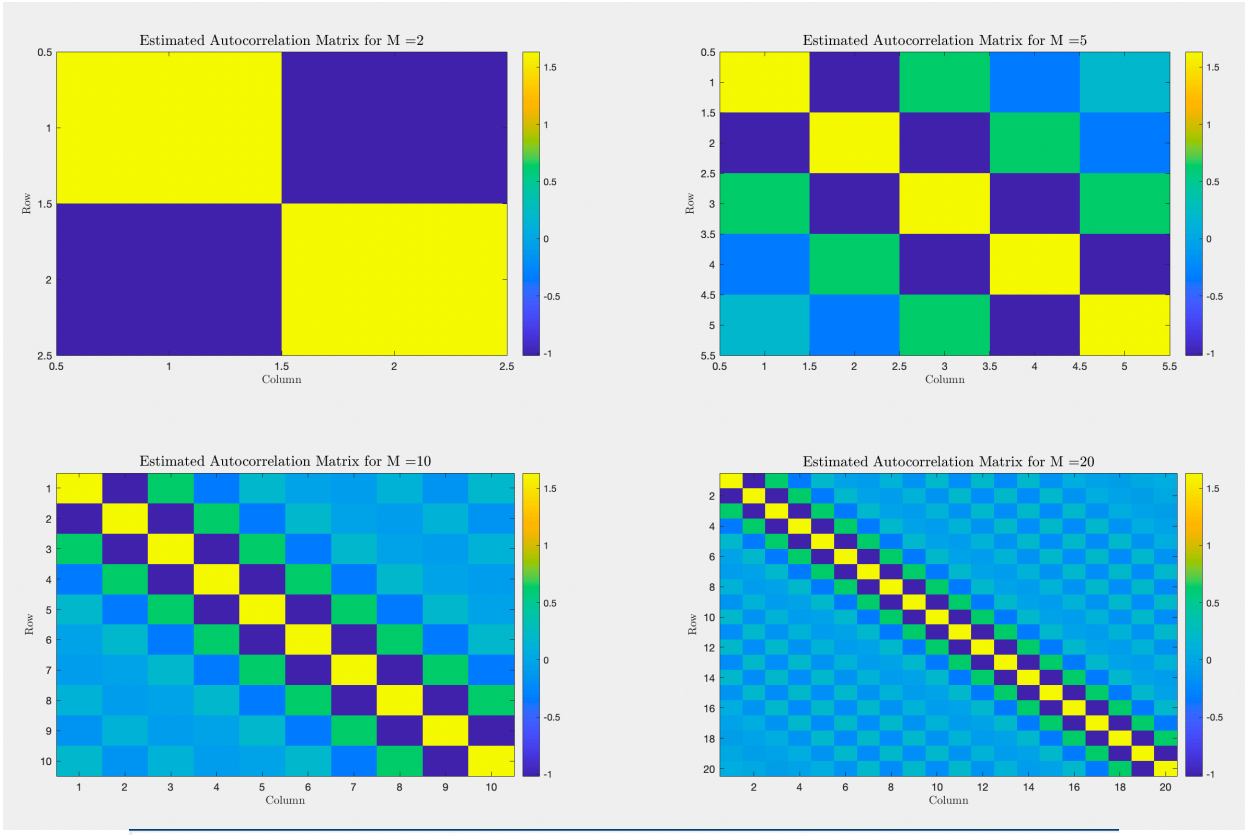

```
"==================== M = "    "2"    " ============================"

Auto Corrolation Matrix Is Symmetric
Determinant of Auto Correlation Matrix:
    1.3333

Eigenvalues of Auto Correlation Matrix:
    0.6667
    2.0000

Diagonal Elements of Auto Correlation Matrix:
    1.3333
    1.3333
```

```
  ======================================================
     "==================== M = "    "5"    " ========================="

  Auto Corrolation Matrix Is Symmetric
  Determinant of Auto Correlation Matrix:
      1.3333

  Eigenvalues of Auto Correlation Matrix:
      0.4803
      0.6096
      0.9205
      1.6404
      3.0159

  Diagonal Elements of Auto Correlation Matrix:
      1.3333
      1.3333
      1.3333
      1.3333
      1.3333
```

```
======================================================
    "==================== M = "    "10"    " ========================="

Auto Corrolation Matrix Is Symmetric
Determinant of Auto Correlation Matrix:
    1.3333

Eigenvalues of Auto Correlation Matrix:
    0.4537
    0.4828
    0.5366
    0.6243
    0.7629
    0.9824
    1.3333
    1.8880
    2.6921
    3.5771

Diagonal Elements of Auto Correlation Matrix:
    1.3333
    1.3333
    1.3333
    1.3333
    1.3333
    1.3333
    1.3333
    1.3333
    1.3333
    1.3333
```

```
======================================================
    "==================== M = "    "20"    " ========================="

Auto Corrolation Matrix Is Symmetric
Determinant of Auto Correlation Matrix:
    1.3333

Eigenvalues of Auto Correlation Matrix:
    0.4468
    0.4540
    0.4663
    0.4842
    0.5085
    0.5402
    0.5809
    0.6325
    0.6978
    0.7805
    0.8856
    1.0198
    1.1920
    1.4134
    1.6971
    2.0553
    2.4915
    2.9864
    3.4779
    3.8559

Diagonal Elements of Auto Correlation Matrix:
    1.3333
```

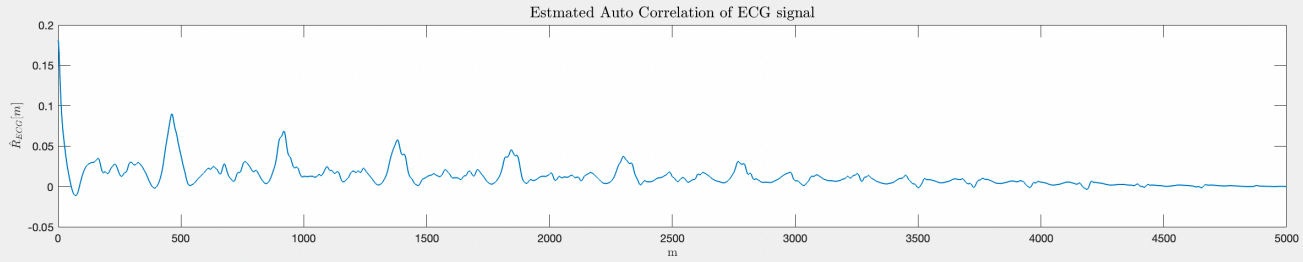
ث)

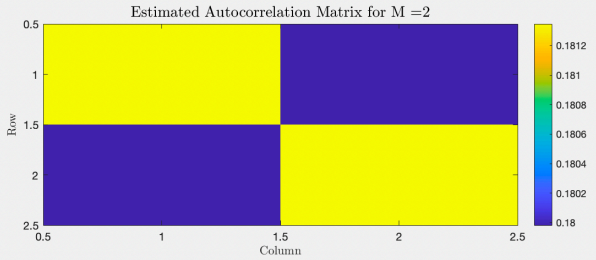


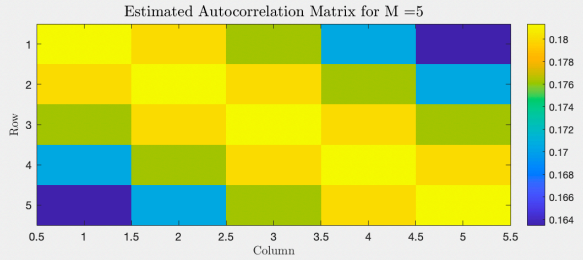

```
    "==================== M = "    "2"    " ========================="

Biased Estimated Auto Corrolation Matrix Is Symmetric
Determinant of Estimated Auto Correlation Matrix:
    1.0164

Eigenvalues of Estimated Auto Correlation Matrix:
    0.5491
    1.8510

Diagonal Elements of Estimated Auto Correlation Matrix:
    1.2001
    1.2001


=========================================================
    "==================== M = "    "5"    " ========================="

Biased Estimated Auto Corrolation Matrix Is Symmetric
Determinant of Estimated Auto Correlation Matrix:
    0.6034

Eigenvalues of Estimated Auto Correlation Matrix:
    0.4304
    0.5043
    0.6582
    1.4083
    2.9991

Diagonal Elements of Estimated Auto Correlation Matrix:
    1.2001
    1.2001
    1.2001
    1.2001
    1.2001
```

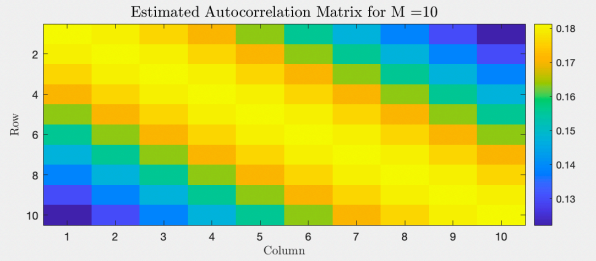
```
==================================================
    "=================== M = "    "10"    " ========================="

Biased Estimated Auto Corrolation Matrix Is Symmetric
Determinant of Estimated Auto Correlation Matrix:
    0.2386

Eigenvalues of Estimated Auto Correlation Matrix:
    0.3553
    0.4502
    0.4803
    0.4976
    0.5935
    0.6709
    0.9362
    1.7298
    2.6952
    3.5918

Diagonal Elements of Estimated Auto Correlation Matrix:
    1.2001
    1.2001
    1.2001
    1.2001
    1.2001
    1.2001
    1.2001
    1.2001
    1.2001
    1.2001
==================================================
    "=================== M = "    "20"    " ========================="

Biased Estimated Auto Corrolation Matrix Is Symmetric
Determinant of Estimated Auto Correlation Matrix:
    0.0313

Eigenvalues of Estimated Auto Correlation Matrix:
    0.3006
    0.3635
    0.3637
    0.3865
    0.4767
    0.4964
    0.5487
    0.5509
    0.5628
    0.6164
    0.6174
    0.7029
    0.7480
    0.8219
    1.4627
    2.1159
    2.3177
    3.2180
    3.3513
    3.9792

Diagonal Elements of Estimated Auto Correlation Matrix:
    1.2001
```

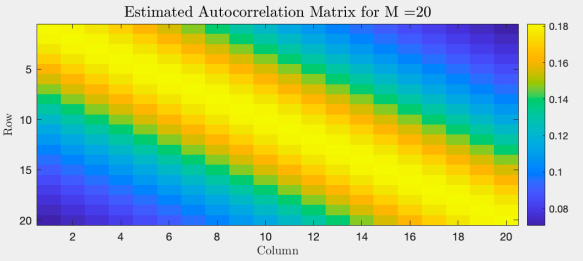
ج)


Estmated Auto Correlation of ECG signal
$\hat{R}_{ECG}[m]$
m

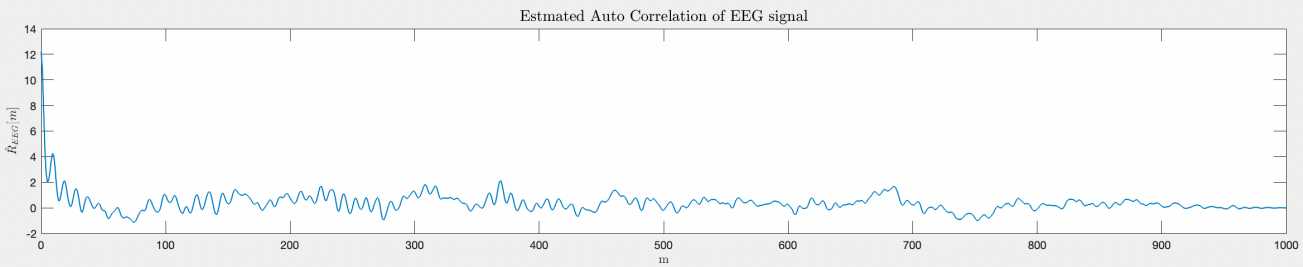

Estimated Autocorrelation Matrix for M =2
Row
Column

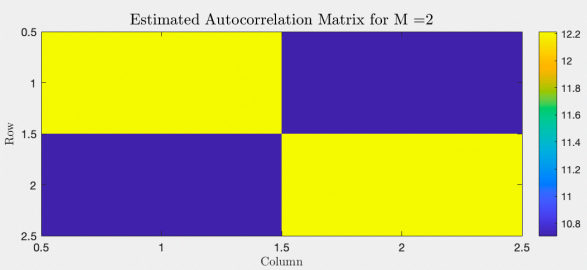

Estimated Autocorrelation Matrix for M =5
Row
Column

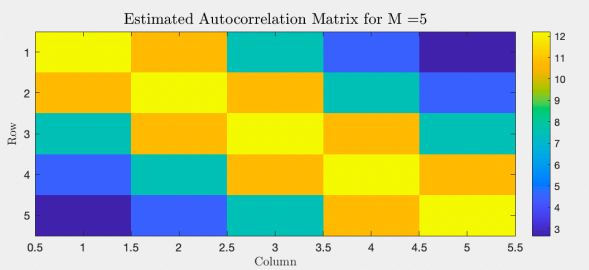

Estimated Autocorrelation Matrix for M =10
Row
Column

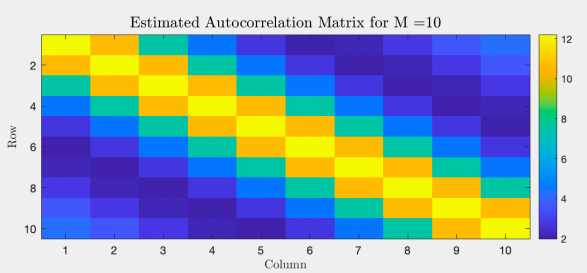

Estimated Autocorrelation Matrix for M =20
Row
Column

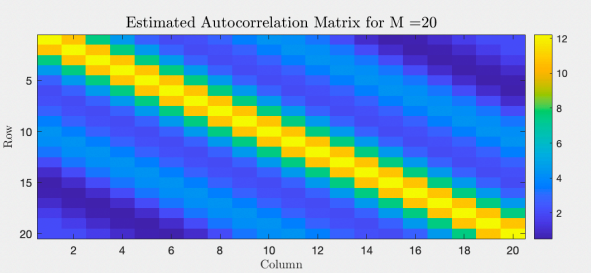
ج)


Estmated Auto Correlation of EEG signal
$\hat{R}_{EEG}[m]$
m


Estimated Autocorrelation Matrix for M =2
Row
Column


Estimated Autocorrelation Matrix for M =5
Row
Column


Estimated Autocorrelation Matrix for M =10
Row
Column


Estimated Autocorrelation Matrix for M =20
Row
Column

به دلیل ماهیت شبه تناوبی‌ای که سیگنال ECG دارد، می‌توان دید که تابع همبستگی هم تقریبا متناوب است و خیلی دیر به سمت صفر میل می‌کند، اما در سیگنال EEG به دلیل ماهیت تصادفی‌ای که وجود دارد، دیده می‌شود که همبستگی سریعا به سمت صفر میل می‌کند.

کد:

```
%% Question 3

%% Q3 - Part a

clc; clear;

sigma_x = 1;

a = 0.6;

m_period = 0:100;


Ry = sigma_x / (1-a^2) * (- a).^abs(m_period);


figure;

plot(m_period, Ry);

title("$$R_Y[m]$$","Interpreter","latex","FontSize",14);

xlabel("m","Interpreter","latex","FontSize",14);

ylabel("$$R_Y$$","Interpreter","latex","FontSize",14);


%% Q3 - Part b

clc;

x = randn(1,10000);

n = 0:10000-1;

y = filter(1, [1 a], x);


figure;

subplot(2,1,1);

plot(n,x);

title("input white noise signal = x[n]","Interpreter","latex","FontSize",14);

xlabel("n","Interpreter","latex","FontSize",14);

ylabel("Amplitude","Interpreter","latex","FontSize",14);


subplot(2,1,2);
```

```
plot(n,y);
title("output signal = y[n]","Interpreter","latex","FontSize",14);
xlabel("n","Interpreter","latex","FontSize",14);
ylabel("Amplitude","Interpreter","latex","FontSize",14);


%% Q3 - Part c
clc;


m_period = 0:100;
figure;
counter = 1;
for N = [100 500 1000 5000]
    N_sample = 1:N;
    [Ry ,Ry_biased, Ry_unbiased] = my_corr(y, N_sample, m_period);
    subplot(4,1,counter);
    plot(m_period,Ry,"LineWidth",1);
    hold on;
    plot(m_period,Ry_biased,"LineWidth",1);
    hold on;
    plot(m_period,Ry_unbiased,"LineWidth",1);
    title(['N = ',num2str(N),' - samples 1:',num2str(N)],"Interpreter","latex","FontSize",14);
    xlabel("m","Interpreter","latex");
    ylabel("Amplitude","Interpreter","latex");
    legend(["$$R_y$$","$$\hat{R_y}$$ biased","$$\hat{R_y}$$ unbiased"],'Interpreter','latex');
    counter = counter+1;
end


counter = 1;
figure;
for start_point = [1, 3000, 6000, 9501]
    N = 500;
    N_sample = start_point:start_point+N-1;
    [Ry ,Ry_biased, Ry_unbiased] = my_corr(y, N_sample, m_period);


    subplot(4,1,counter);
    plot(m_period,Ry,"LineWidth",1);
```

```
    hold on;
    plot(m_period,Ry_biased,"LineWidth",1);
    hold on;
    plot(m_period,Ry_unbiased,"LineWidth",1);
    title(['N = 500 - samples ',num2str(start_point),':500'],"Interpreter","latex","FontSize",14);
    xlabel("m","Interpreter","latex");
    ylabel("Amplitude","Interpreter","latex");
    legend(["$$R_y$$","$$\hat{R_y}$$ biased","$$\hat{R_y}$$ unbiased"],'Interpreter','latex');
    counter = counter+1;
end

%% Q3 - Part d
close all; clc;

figure;
counter = 1;
for M = [2 5 10 20]
    disp(["==================== M = ",num2str(M)," ========================="]);
    R = AC_matrix(M);
    if(isequal(R, R.'))
        disp("Auto Corrolation Matrix Is Symmetric")
    else
        disp("Auto Corrolation Matrix Isn't Symmetric")
    end
    disp("Determinant of Auto Correlation Matrix:");
    disp(det(R));
    disp("Eigenvalues of Auto Correlation Matrix:");
    disp(eig(R));
    disp("Diagonal Elements of Auto Correlation Matrix:")
    disp(diag(R));

    subplot(2,2,counter);
    imagesc(R);
    colorbar;
    xlabel("Column","Interpreter","latex");
    ylabel("Row","Interpreter","latex");
```

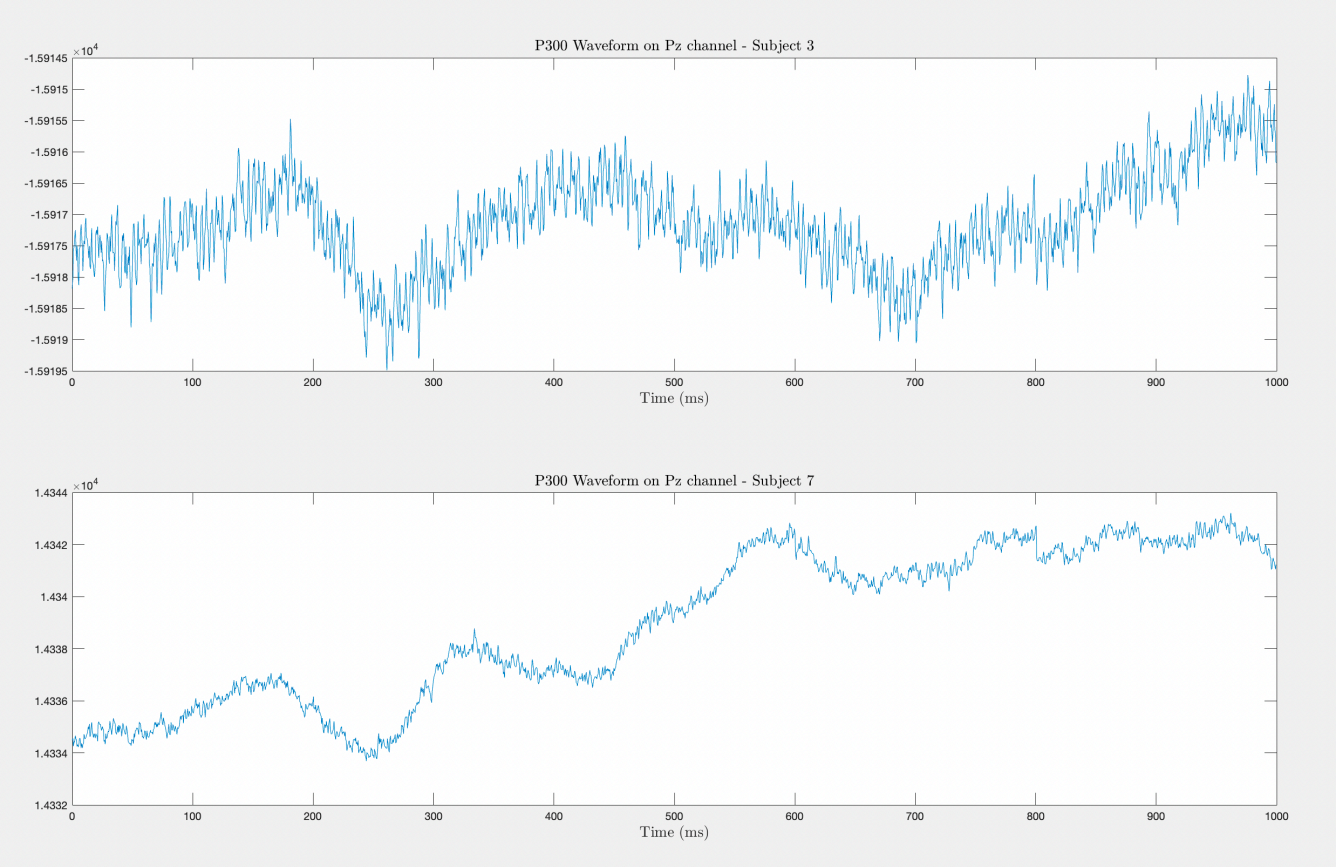
```
    title(['Autocorrelation Matrix for M =',num2str(M)],"Interpreter","latex","FontSize",14);
    disp("=====================================================");
    counter = counter+1;
end

%% Q3 - Part e
clc; close all;

figure;
counter = 1;
for M = [2 5 10 20]
    disp(["=================== M = ",num2str(M)," ========================="]);
    R_estimated = AC_matrix_est(M,y, N_sample, m_period);
    if(isequal(R_estimated, R_estimated.'))
        disp("Biased Estimated Auto Corrolation Matrix Is Symmetric")
    else
        disp("Biased Estimated Auto Corrolation Matrix Isn't Symmetric")
    end
    disp("Determinant of Estimated Auto Correlation Matrix:");
    disp(det(R_estimated));
    disp("Eigenvalues of Estimated Auto Correlation Matrix:");
    disp(eig(R_estimated));
    disp("Diagonal Elements of Estimated Auto Correlation Matrix:")
    disp(diag(R_estimated));

    subplot(2,2,counter);
    imagesc(R_estimated);
    colorbar;
    xlabel("Column","Interpreter","latex");
    ylabel("Row","Interpreter","latex");
    title(['Estimated Autocorrelation Matrix for M =',num2str(M)],"Interpreter","latex","FontSize",14);
    disp("=====================================================");
    counter = counter+1;
end

%% Q3 - Part f
```

```
clc; close all;

load mit200

m_period = 0:5000;
N_sample = 1:5000;
[~ ,Ry_biased, ~] = my_corr(ecgsig, N_sample, m_period);

figure;
subplot(3,2,[1,2]);
plot(m_period,Ry_biased,"LineWidth",1);
title("Estmated Auto Correlation of ECG signal","Interpreter","latex","FontSize",14);
xlabel("m","Interpreter","latex");
ylabel("$$\hat{R}_{ECG}[m]$$","Interpreter","latex");

counter = 3;
for M = [2 5 10 20]
    R_estimated = AC_matrix_est(M,ecgsig, N_sample, m_period);
    subplot(3,2,counter);
    imagesc(R_estimated);
    colorbar;
    xlabel("Column","Interpreter","latex");
    ylabel("Row","Interpreter","latex");
    title(['Estimated Autocorrelation Matrix for M =',num2str(M)],"Interpreter","latex","FontSize",14);
    counter = counter+1;
end
%% Q3 - Part g
clc; close all;
EEG = load('EEG_2700mS16.mat').y(1,:,1);

m_period = 0:1000;
N_sample = 1:1000;
[~ ,Ry_biased, ~] = my_corr(EEG, N_sample, m_period);

figure;
subplot(3,2,[1,2]);
```

```
plot(m_period,Ry_biased,"LineWidth",1);

title("Estmated Auto Correlation of EEG signal","Interpreter","latex","FontSize",14);

xlabel("m","Interpreter","latex");

ylabel("$$\hat{R}_{EEG}[m]$$","Interpreter","latex");


counter = 3;

for M = [2 5 10 20]

    R_estimated = AC_matrix_est(M,EEG, N_sample, m_period);

    subplot(3,2,counter);

    imagesc(R_estimated);

    colorbar;

    xlabel("Column","Interpreter","latex");

    ylabel("Row","Interpreter","latex");

    title(['Estimated Autocorrelation Matrix for M =',num2str(M)],"Interpreter","latex","FontSize",14);

    counter = counter+1;

end
```

سوال ۴-

متاسفانه نتیجه مطلوب گرفته نشده است.



کد:

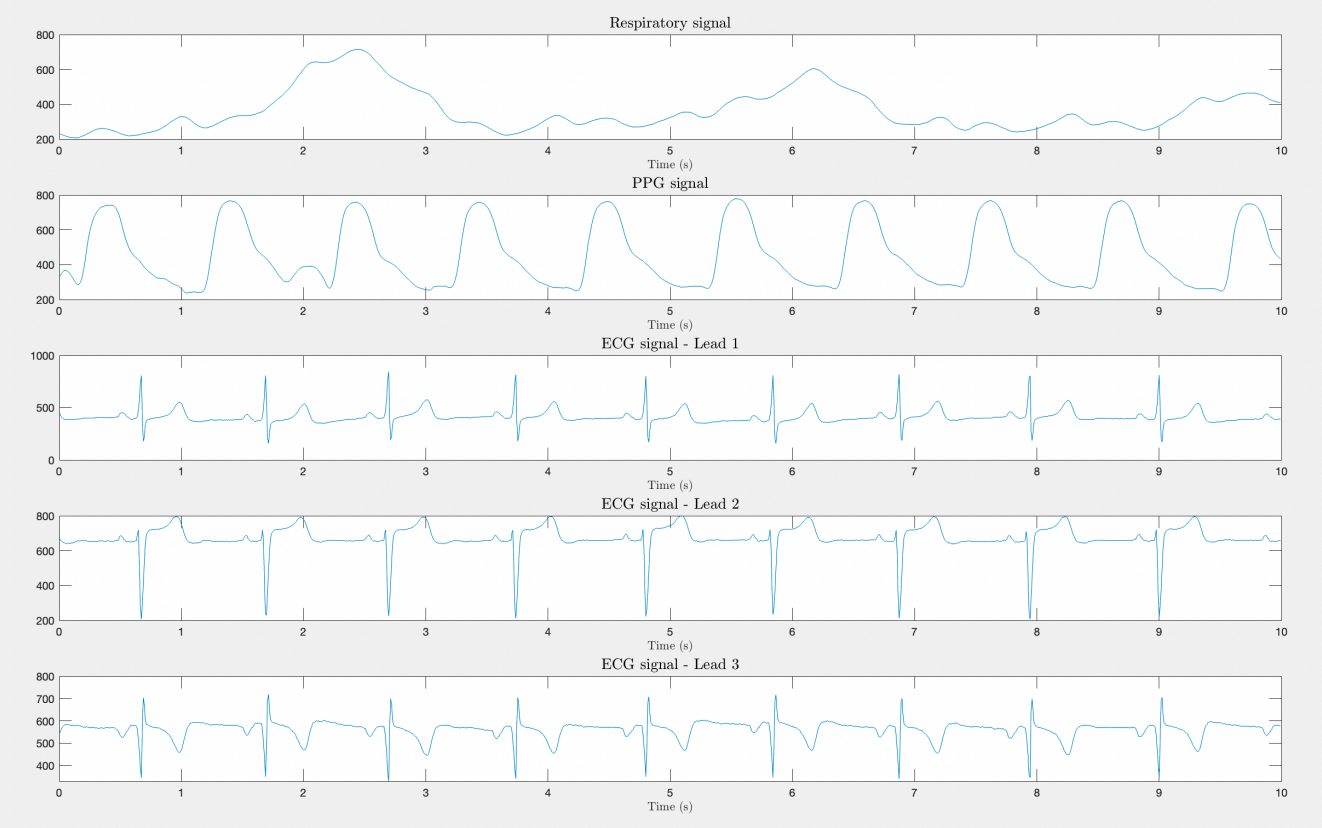
```
%% Question 4

clc; clear; close all;


fs = 2048;

window_size = 1; % 1 second

su3_trials = [];

su6_trials = [];


files = dir('subject3/*.mat');

for i=1:24

    data = load(['subject3/',files(i).name]);

    su3_trials = [su3_trials; seperate_trials(data, window_size, fs)];

end
```

```
files = dir('subject7/*.mat');
for i=1:24
    data = load(['subject7/',files(i).name]);
    su6_trials = [su6_trials; seperate_trials(data, window_size, fs)];
end

P300_su3 = mean(su3_trials,1);
P300_su6 = mean(su6_trials,1);

% fs = 32;
t = (0:1/fs:window_size - 1/fs)*1000;

figure;
subplot(2,1,1);
plot(t, P300_su3);
title('P300 Waveform on Pz channel - Subject 3','Interpreter','latex','FontSize',14);
xlabel("Time (ms)",'Interpreter','latex','FontSize',14);

subplot(2,1,2);
plot(t, P300_su6);
title('P300 Waveform on Pz channel - Subject 7','Interpreter','latex','FontSize',14);
xlabel("Time (ms)",'Interpreter','latex','FontSize',14);



function result = seperate_trials(data, window_size, fs)
    EEG = data.data(13, :);
%     [b,a] = butter(6,[0.5 12]/(fs/2));
%     EEG = filtfilt(b,a,EEG);
%     EEG = downsample(EEG, 64);
%     fs = 32;
    p = prctile(EEG,[10 90]);
    i1 = EEG < p(1);
    v1 = min(EEG(~i1));
    i2 = EEG > p(2);
    v2 = max(EEG(~i2));
    EEG(i1) = v1;
```

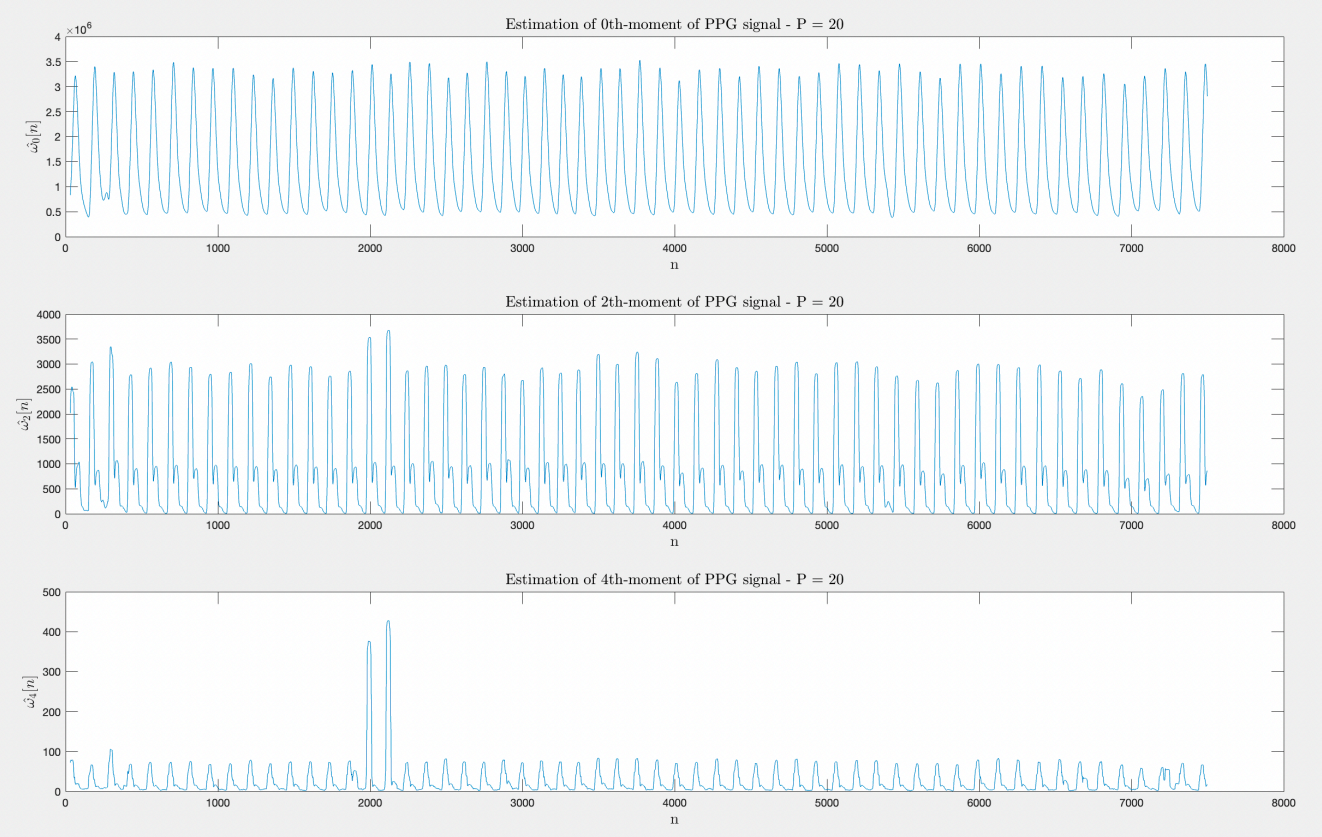
```
    EEG(i2) = v2;
    trials_num = size(data.stimuli,2);
    target = data.target;
    stim = data.stimuli;
    result = [];
    for i = 1:trials_num
        if (stim(i) == target)
            start_sample = floor(i*0.4*fs);
            end_sample = start_sample + floor(window_size*fs) - 1;
            result = [result; EEG(start_sample:end_sample)];
        end
    end
end
```

سوال ۵-

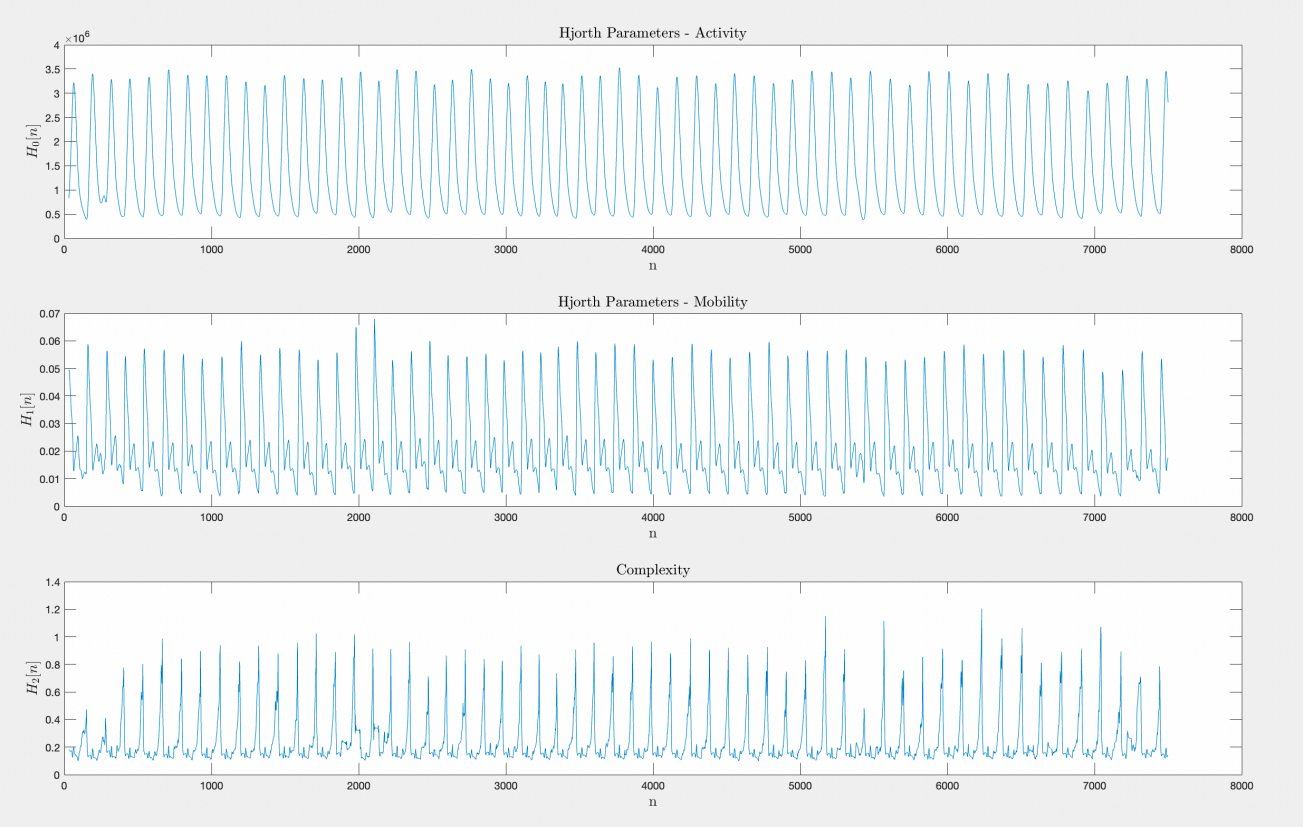
الف)


Respiratory signal
PPG signal
ECG signal - Lead 1
ECG signal - Lead 2
ECG signal - Lead 3
Time (s)

ب)


Estimation of 0th-moment of PPG signal - P = 20
Estimation of 2th-moment of PPG signal - P = 20
Estimation of 4th-moment of PPG signal - P = 20
n

پ)



ت)

پارامتر اکتیویتی نشان دهنده توان سیگنال یا به عبارتی واریانس تابع زمانی می‌باشد. درواقع نشان دهند انتگرال تابع چگالی توان است.

پارامتر موبیلیتی نشان دهنده میانگین فرکانس است که با انحراف معیار طیف توان متناسب است.

پارامتر کامپلکسیتی نشان دهنده تغییرات فرکانس است. این پارامتر شباهت سیگنال را با یک موج سینوسی خالص مقایسه می کند، به گونه‌ای که اگر سیگنال بیشتر شبیه باشد، مقدار به یک همگرا می شود.

ث)

در چکیده مقاله A Novel EEG Feature Extraction Method Using Hjorth Parameter آمد است که:

هنگام پردازش سیگنال های الکتروانسفالوگرافی (EEG) در مورد تصورحرکت، تجزیه و تحلیل آنها در هر دو حوزه زمان و فرکانس ضروری است. سیگنال EEG دارای خاصیت غیر ایستایی است و ویژگی‌های فرکانسی آن نیز از فردی به فرد دیگر متفاوت است. بنابراین، ما می‌توانیم استنباط کنیم که هر موضوع، زمان‌بندی و باند فرکانسی غالب خود را برای استخراج ویژگی‌های متمایز دارد. بر اساس این استنباط، پس از تجزیه و تحلیل سیگنال های EEG با

پارامتر Hjorth، باند فرکانسی اصلی و زمان بندی را با استفاده از نسبت فیشر پارامتر Hjorth انتخاب می کنیم. با انجام این کارها، عملکرد استخراج ویژگی در سیستم‌های BCI مبتنی بر EEG از نظر دقت طبقه‌بندی به طور متوسط 4.4 درصد بهبود یافته است.

کد:

```
%% Question 5

clc; clear; close all;


data = load("PPG_a44542m.mat");

fs = 125;

respiratory_signal = data.val(1,:);

PPG_signal = data.val(2,:);

ECG_lead_1 = data.val(3,:);

ECG_lead_2 = data.val(4,:);

ECG_lead_3 = data.val(5,:);


%% Q5 - Part a

t = 0:1/fs:10-1/fs;


figure;

subplot(5,1,1);

plot(t, respiratory_signal(1:fs*10));

title('Respiratory signal','Interpreter','latex','FontSize',14);

xlabel("Time (s)","Interpreter","latex");



subplot(5,1,2);

plot(t, PPG_signal(1:fs*10));

title('PPG signal','Interpreter','latex','FontSize',14);

xlabel("Time (s)","Interpreter","latex");


subplot(5,1,3);

plot(t, ECG_lead_1(1:fs*10));

title('ECG signal - Lead 1','Interpreter','latex','FontSize',14);

xlabel("Time (s)","Interpreter","latex");
```

```
subplot(5,1,4);
plot(t, ECG_lead_2(1:fs*10));
title('ECG signal - Lead 2','Interpreter','latex','FontSize',14);
xlabel("Time (s)","Interpreter","latex");

subplot(5,1,5);
plot(t, ECG_lead_3(1:fs*10));
title('ECG signal - Lead 3','Interpreter','latex','FontSize',14);
xlabel("Time (s)","Interpreter","latex");



%% Q5 - Part b
clc; close all;
P = 30;
L = length(PPG_signal);
omega_0 = zeros(1, L);
omega_2 = zeros(1, L);
omega_4 = zeros(1, L);
for n = P:L
    for k = (n-P+1):n
        omega_0(n) = omega_0(n) + (deriv(PPG_signal, k, 0))^2;
        omega_2(n) = omega_2(n) + (deriv(PPG_signal, k, 1))^2;
        omega_4(n) = omega_4(n) + (deriv(PPG_signal, k, 2))^2;
    end
    omega_0(n) = 2*pi/P * omega_0(n);
    omega_2(n) = 2*pi/P * omega_2(n);
    omega_4(n) = 2*pi/P * omega_4(n);
end

figure;
subplot(3,1,1);
plot(P+1:L-1,omega_0(1,P+1:end-1));
title("Estimation of 0th-moment of PPG signal - P = 20","Interpreter","latex","Fontsize",14);
ylabel("$$\hat{\omega_0}[n]$$","Interpreter","latex","Fontsize",14);
```

```
xlabel("n","Interpreter","latex","Fontsize",14);


subplot(3,1,2);
plot(P+1:L-1,omega_2(P+1:end-1));
title("Estimation of 2th-moment of PPG signal - P = 20","Interpreter","latex","Fontsize",14);
ylabel("$$\hat{\omega_2}[n]$$","Interpreter","latex","Fontsize",14);
xlabel("n","Interpreter","latex","Fontsize",14);


subplot(3,1,3);
plot(P+1:L-1,omega_4(P+1:end-1));
title("Estimation of 4th-moment of PPG signal - P = 20","Interpreter","latex","Fontsize",14);
ylabel("$$\hat{\omega_4}[n]$$","Interpreter","latex","Fontsize",14);
xlabel("n","Interpreter","latex","Fontsize",14);







%% Q5 - Part c
clc; close all;
H0 = omega_0;
H1 = sqrt(omega_2./omega_0);
H2 = sqrt(omega_4./omega_2 - omega_2./omega_0);


figure;
subplot(3,1,1);
plot(P+1:L-1,H0(1,P+1:end-1));
title("Hjorth Parameters - Activity","Interpreter","latex","Fontsize",14);
ylabel("$$H_0[n]$$","Interpreter","latex","Fontsize",14);
xlabel("n","Interpreter","latex","Fontsize",14);


subplot(3,1,2);
plot(P+1:L-1,H1(1,P+1:end-1));
title("Hjorth Parameters - Mobility","Interpreter","latex","Fontsize",14);
ylabel("$$H_1[n]$$","Interpreter","latex","Fontsize",14);
xlabel("n","Interpreter","latex","Fontsize",14);
subplot(3,1,3);
```

```
plot(P+1:L-1,H2(1,P+1:end-1));
title("Complexity","Interpreter","latex","Fontsize",14);
ylabel("$$H_2[n]$$","Interpreter","latex","Fontsize",14);
xlabel("n","Interpreter","latex","Fontsize",14);
```

فانکشن‌های استفاده شده در سوالات:

```
%% Functions
function result = seperate_trials(data, window_size, fs)
    EEG = data.data(13, :);
%     [b,a] = butter(6,[0.5 12]/(fs/2));
%     EEG = filtfilt(b,a,EEG);
%     EEG = downsample(EEG, 64);
%     fs = 32;
    p = prctile(EEG,[10 90]);
    i1 = EEG < p(1);
    v1 = min(EEG(~i1));
    i2 = EEG > p(2);
    v2 = max(EEG(~i2));
    EEG(i1) = v1;
    EEG(i2) = v2;
    trials_num = size(data.stimuli,2);
    target = data.target;
    stim = data.stimuli;
    result = [];
    for i = 1:trials_num
        if (stim(i) == target)
            start_sample = floor(i*0.4*fs);
            end_sample = start_sample + floor(window_size*fs) - 1;
            result = [result; EEG(start_sample:end_sample)];
        end
    end
end

function [corr_actual, corr_biased, corr_unbiased] = my_corr(signal, N_sample, m_period)
    N = length(N_sample);
    if (N <= length(signal))
        signal_sampled = signal(N_sample);
```

```
    else
        signal_sampled = signal;
    end

    corr_biased = zeros(1,length(m_period));
    corr_unbiased = zeros(1, length(m_period));

    for m = m_period
        for j = 1:N-m
            corr_biased(m+1) = corr_biased(m+1) + signal_sampled(j)*signal_sampled(j+m);
        end
        corr_unbiased(m+1) = corr_biased(m+1) / (N-m);
        corr_biased(m+1) = corr_biased(m+1) / N;
    end

    corr_actual = 1 / (1-0.6^2) * (- 0.6).^abs(m_period);

end

function matrix = AC_matrix(N)

    matrix = zeros(N);
    for i=1:N
        for j = 1:N
            matrix(i,j) =  4/3 * (-0.5).^abs(i-j);
        end
    end
end

function matrix_estimated = AC_matrix_est(N,signal, N_sample, m_period)
    [~, corr_biased, ~] = my_corr(signal, N_sample, m_period);
    matrix_estimated = zeros(N);
    for i=1:N
        for j = 1:N
            matrix_estimated(i,j) =  corr_biased(abs(i-j)+1);
        end
```

```
    end

end



function result = deriv(x, n, order)

    if(order == 0)
        result = x(n);
    elseif(order == 1 && n ~= 1)
        result = x(n) - x(n-1);
    elseif(order == 1 && n==1)
        result = x(n);
    elseif(order == 2 && n~= 1 && n~=length(x))
        result = (x(n+1) - x(n))-(x(n)-x(n-1));
    elseif(order == 2 && n==1)
        result = (x(n+1) - x(n)) - x(n);
    elseif(order == 2 && n==length(x))
        result = -x(n)-(x(n)-x(n-1));
    end
end
```