1)

Sleep is not a uniform state of being. Instead, sleep is composed of several different stages that can be differentiated from one another by the patterns of brain wave activity that occur during each stage. These changes in brain wave activity can be visualized using EEG and are distinguished from one another by both the frequency and amplitude of brain waves. Sleep can be divided into two different general phases: REM sleep and non-REM (NREM) sleep. Rapid eye movement (REM) sleep is characterized by darting movements of the eyes under closed eyelids. Brain waves during REM sleep appear very similar to brain waves during wakefulness. In contrast, non-REM (NREM) sleep is subdivided into three stages distinguished from each other and from wakefulness by characteristic patterns of brain waves. The first three stages of sleep are NREM sleep, while the fourth and final stage of sleep is REM sleep. In this section, we will discuss each of these stages of sleep and their associated patterns of brain wave activity.

NREM Stages of Sleep

The first stage of NREM sleep is known as stage 1 sleep. Stage 1 sleep is a transitional phase that occurs between wakefulness and sleep, the period during which we drift off to sleep. During this time, there is a slowdown in both the rates of respiration and heartbeat. In addition, stage 1 sleep involves a marked decrease in both overall muscle tension and core body temperature.

In terms of brain wave activity, stage 1 sleep is associated with both alpha and theta waves. The early portion of stage 1 sleep produces alpha waves, which are relatively low frequency (8–13Hz), high amplitude patterns of electrical activity (waves) that become synchronized. This pattern of brain wave activity resembles that of someone who is very relaxed, yet awake. As an individual continues through stage 1 sleep, there is an increase in theta wave activity. Theta waves are even lower frequency (4–7 Hz), higher amplitude brain waves than alpha waves. It is relatively easy to wake someone from stage 1 sleep; in fact, people often report that they have not been asleep if they are awoken during stage 1 sleep.

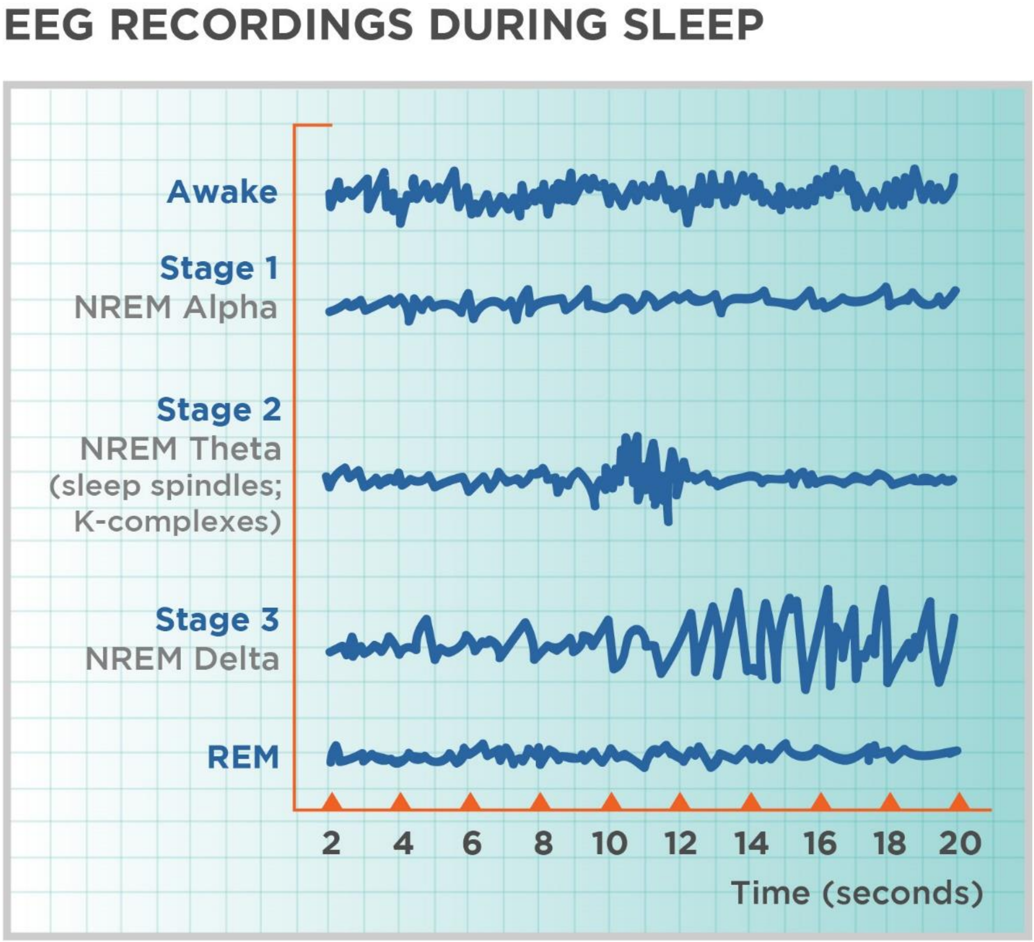


Figure 1. Brainwave activity changes dramatically across the different stages of sleep.

As we move into stage 2 sleep, the body goes into a state of deep relaxation. Theta waves still dominate the activity of the brain, but they are interrupted by brief bursts of activity known as sleep spindles (Figure 3). A sleep spindle is a rapid burst of higher frequency brain waves that may be important for learning and memory (Fogel & Smith, 2011; Poe, Walsh, & Bjorness, 2010). In addition, the appearance of K-complexes is often associated with stage 2 sleep. A K-complex is a very high amplitude pattern of brain activity that may in some cases occur in response to environmental stimuli. Thus, K-complexes might serve as a bridge to higher levels of arousal in response to what is going on in our environments (Halász, 1993; Steriade & Amzica, 1998).

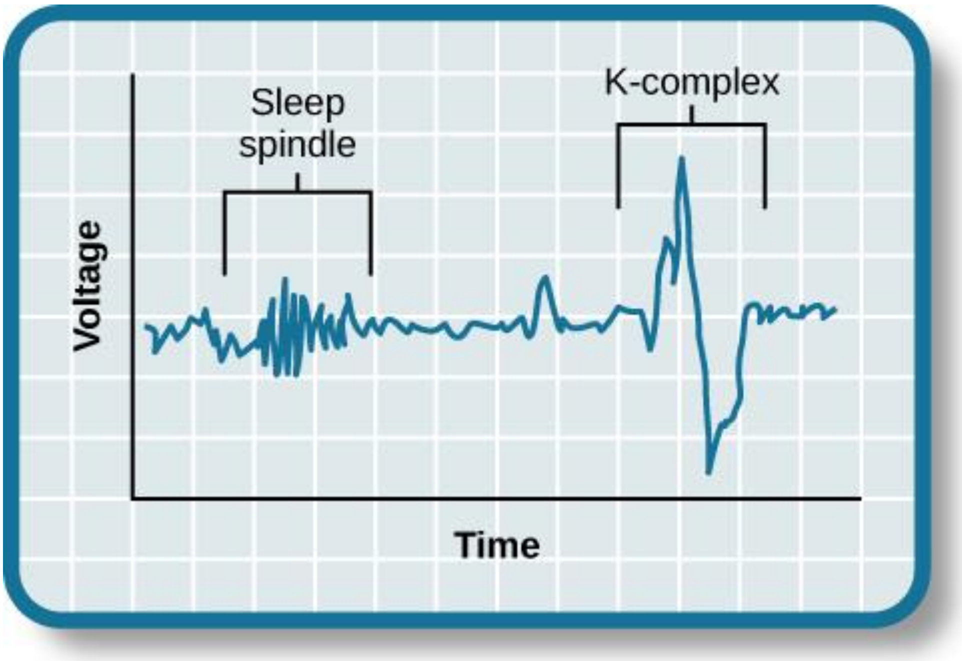


Figure 3. Stage 2 sleep is characterized by the appearance of both sleep spindles and K-complexes.

Stage 3 of sleep is often referred to as deep sleep or slow-wave sleep because these stages are characterized by low frequency (less than 3 Hz), high amplitude delta waves (Figure 4). During this time, an individual's heart rate and respiration slow dramatically. It is much more difficult to awaken someone from sleep during stage 3 than during earlier stages. Interestingly, individuals who have increased levels of alpha brain wave activity (more often associated with wakefulness and transition into stage 1 sleep) during stage 3 often report that they do not feel refreshed upon waking, regardless of how long they slept (Stone, Taylor, McCrae, Kalsekar, & Lichstein, 2008).

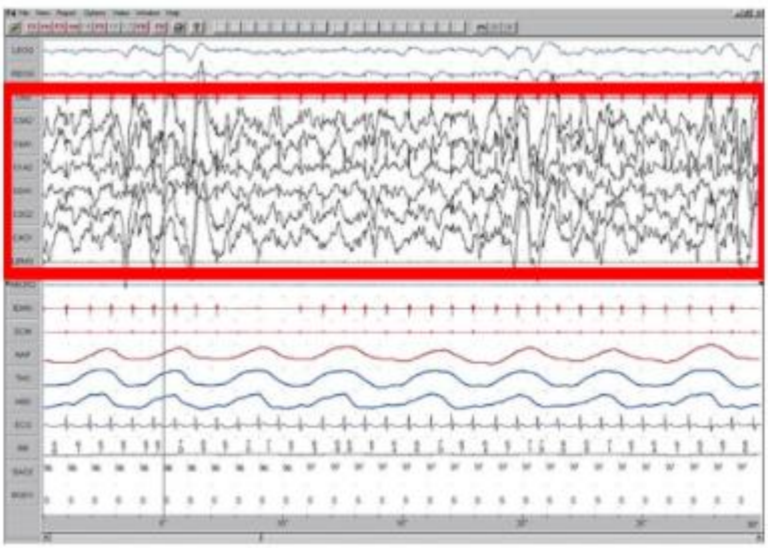


Figure 4. Delta waves, which are low frequency and high amplitude, characterize slow-wave stage 3 sleep.

REM Sleep

As mentioned earlier, REM sleep is marked by rapid movements of the eyes. The brain waves associated with this stage of sleep are very similar to those observed when a person is awake, as shown in Figure 5, and this is the period of sleep in which dreaming occurs. It is also associated with paralysis of muscle systems in the body with the exception of those that make circulation and respiration possible. Therefore, no movement of voluntary muscles occurs during REM sleep in a normal individual; REM sleep is often referred to as paradoxical sleep because of this combination of high brain activity and lack of muscle tone. Like NREM sleep, REM has been implicated in various aspects of learning and memory (Wagner, Gais, & Born, 2001), although there is disagreement within the scientific community about how important both NREM and REM sleep are for normal learning and memory (Siegel, 2001).

If people are deprived of REM sleep and then allowed to sleep without disturbance, they will spend more time in REM sleep in what would appear to be an effort to recoup the lost time in REM. This is known as the REM rebound, and it suggests that REM sleep is also homeostatically regulated. Aside from the role that REM sleep may play in processes related to learning and memory, REM sleep may also be involved in emotional processing and regulation. In such instances, REM rebound may actually represent an adaptive response to stress in nondepressed individuals by suppressing the emotional salience of aversive events that occurred in wakefulness (Suchecki, Tiba, & Machado, 2012). Sleep deprivation in general is associated with a number of negative consequences (Brown, 2012).

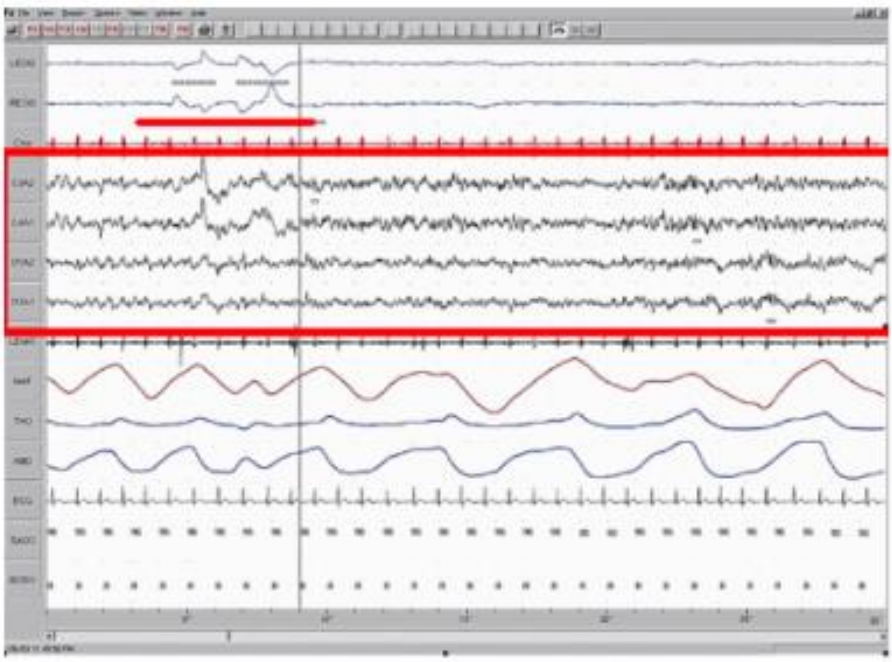


Figure 5. A period of rapid eye movement is marked by the short red line segment. The brain waves associated with REM sleep, outlined in the red box, look very similar to those seen during wakefulness.

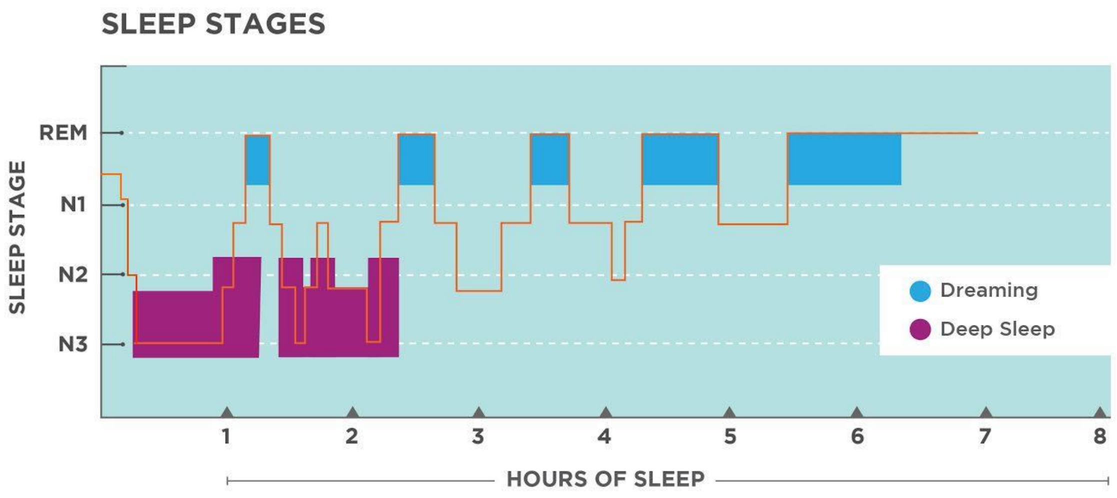
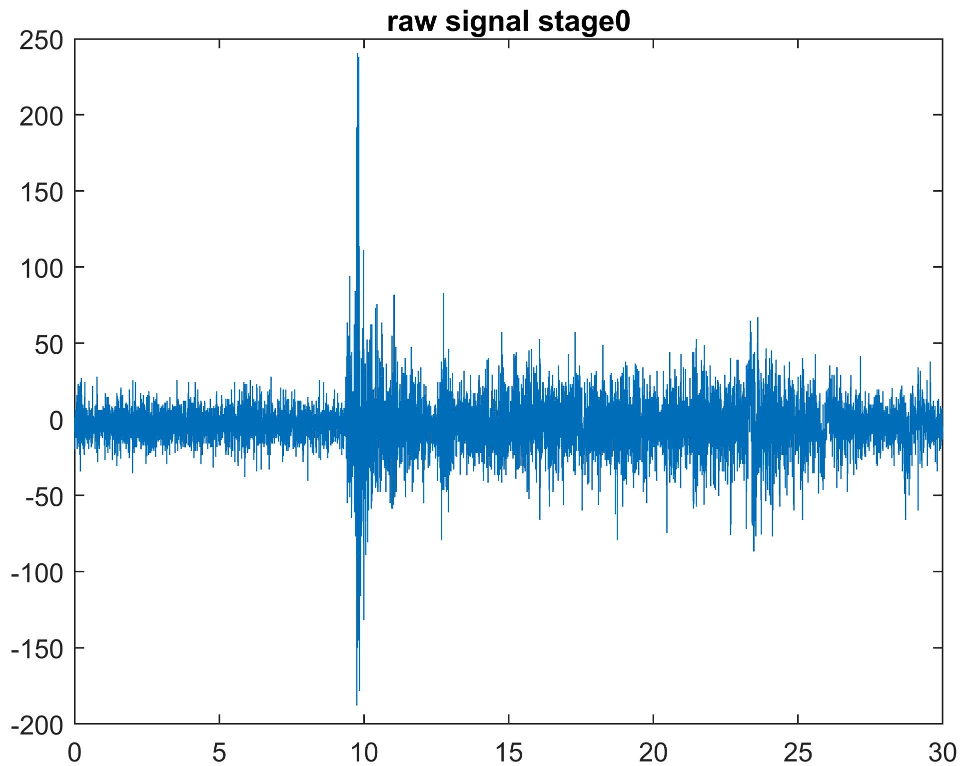


Figure 6. This hypnogram illustrates how an individual moves through the various stages of sleep. Deeper NREM sleep occurs early on in the night, while the duration of REM sleep increases as the night progresses.

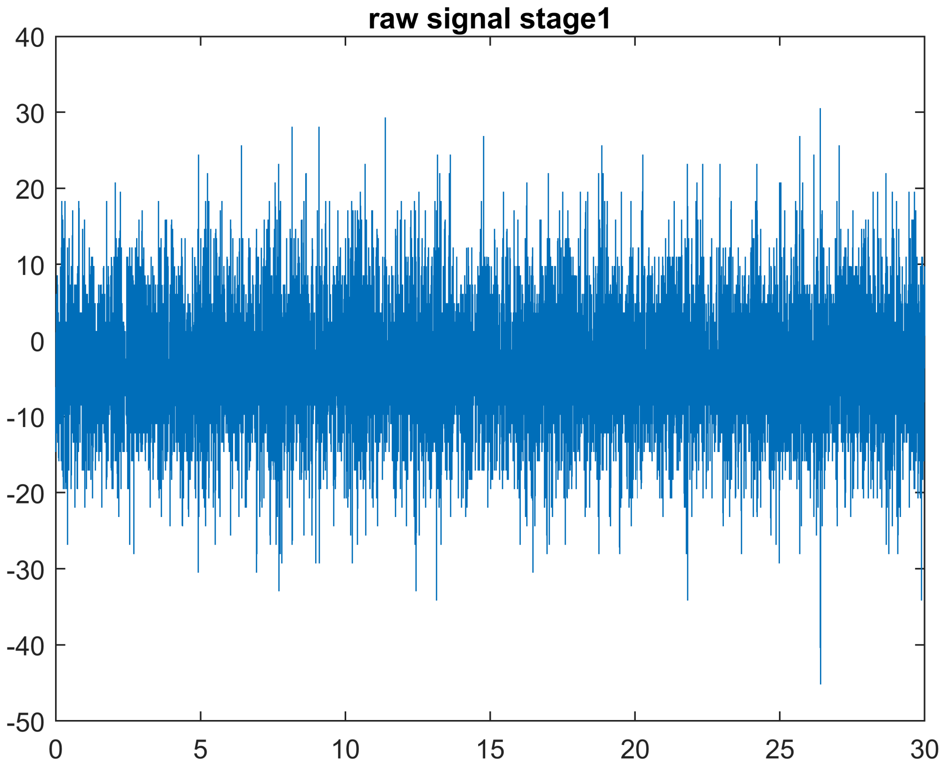
Source: https://courses.lumenlearning.com/waymaker-psychology/chapter/stages-of-sleep/

2)

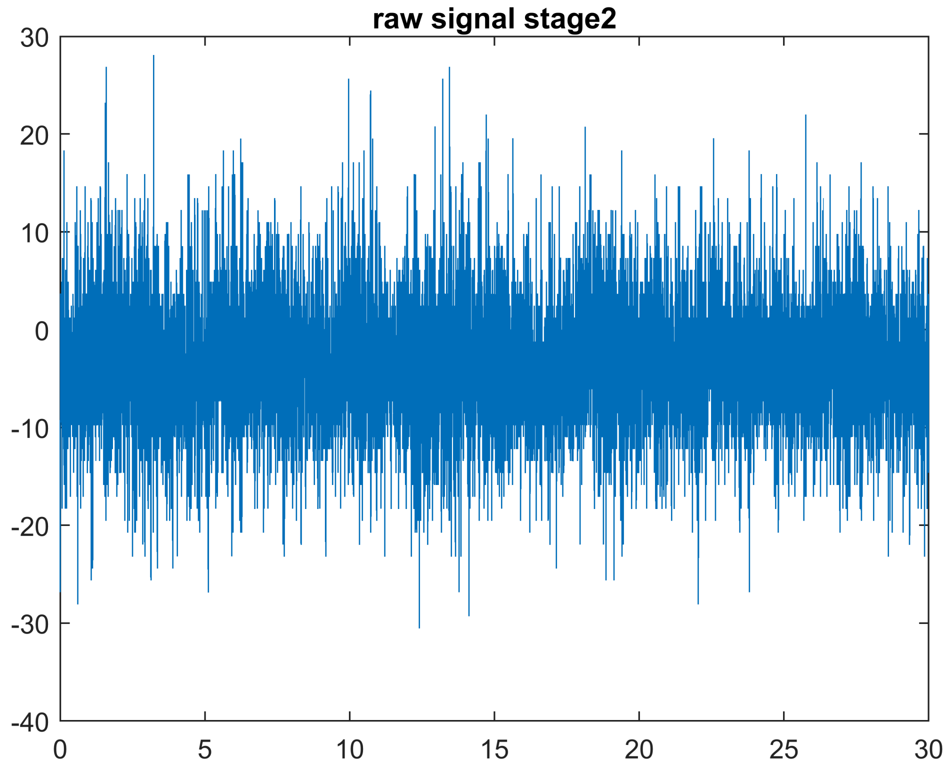
```
clear
clc
load matlab.mat
fs=stage0.Fs(3);
t=0:1/fs:(length(stage0.Data(:,3))-1)/fs;
plot(t,stage0.Data(:,3))
title('raw signal stage0')
```




```
t=0:1/fs:(length(stage1.Data(:,3))-1)/fs;
plot(t,stage1.Data(:,3))
title('raw signal stage1')
```

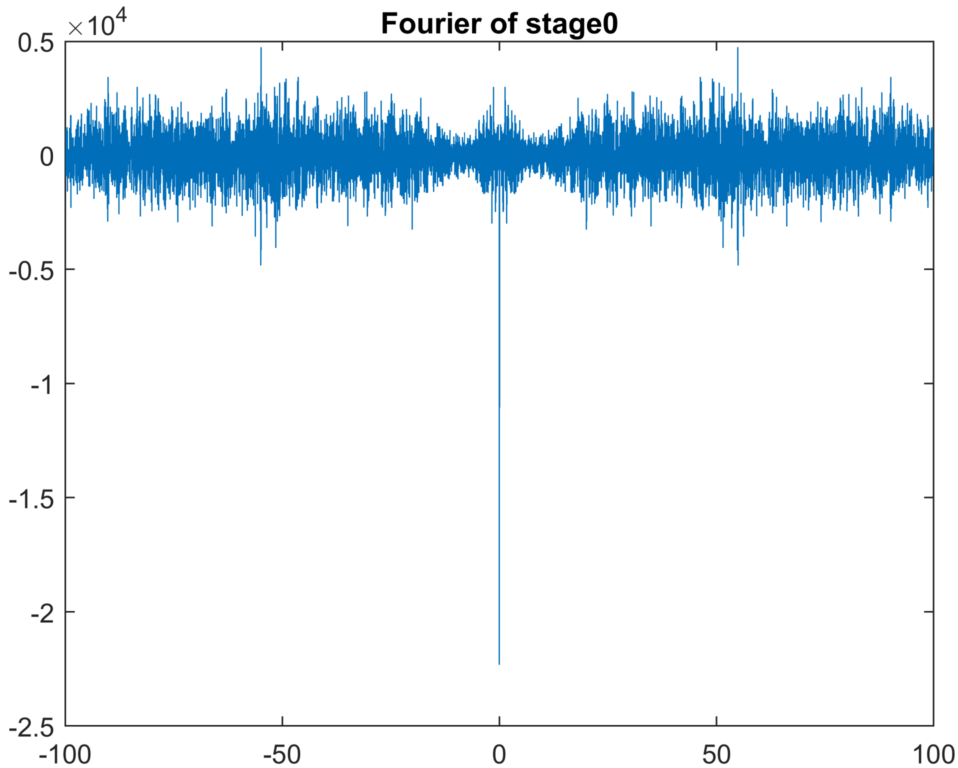



```
t=0:1/fs:(length(stage2.Data(:,3))-1)/fs;
plot(t,stage2.Data(:,3))
title('raw signal stage2')
```

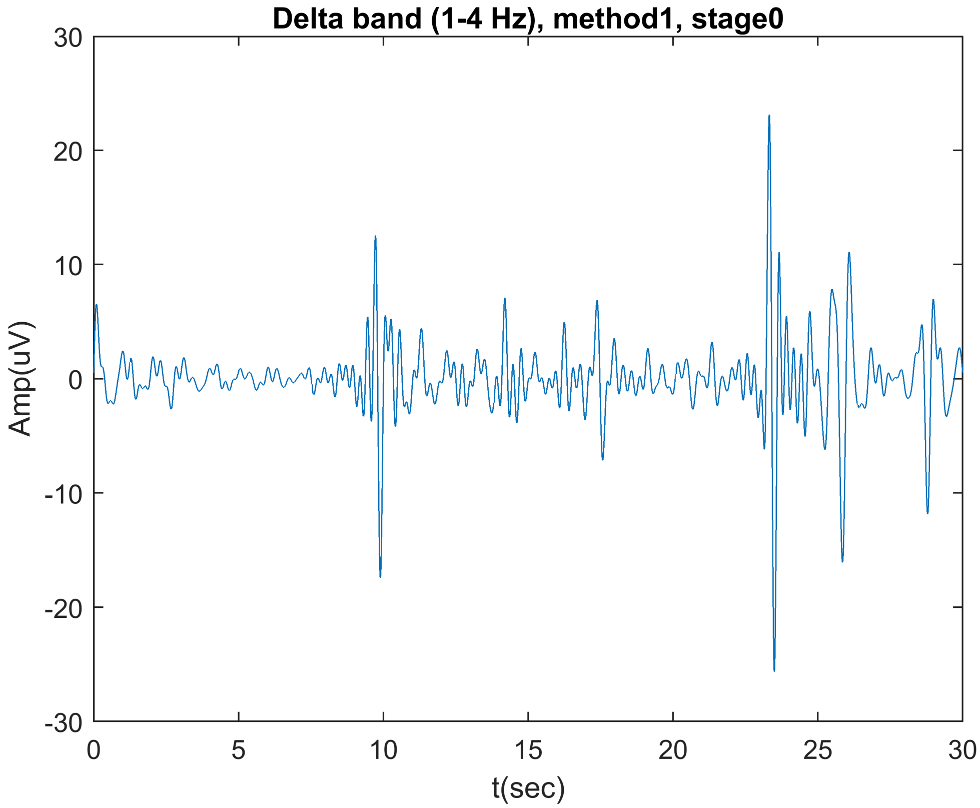


3) We take the Fourier transfom of channel 3 of the given signal and then filter it to decompose it to desired frequency bands.two methods are used for extracting Delta band which generate the same result(one is using bandpass filter and other one is manually filtering the frequencies of Fourier transform and taking inverse Fourier transform of it)

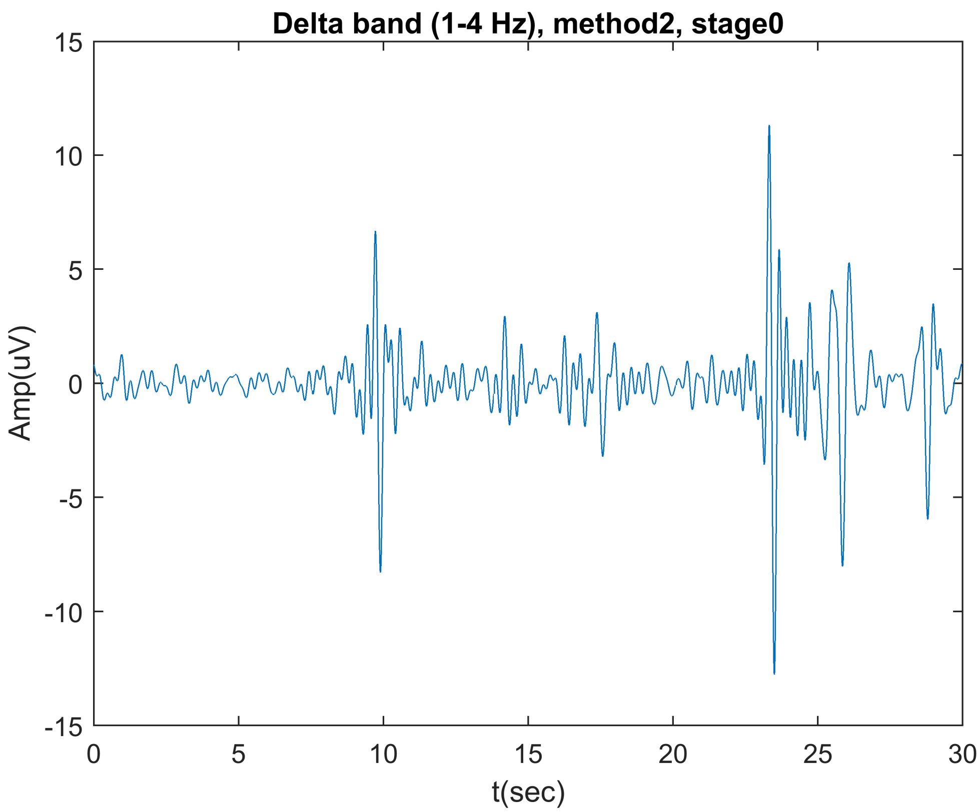
```
y=fft(stage0.Data(:,3));
y=fftshift(y);
fs=stage0.Fs(3);
oo=length(y);
L=(-oo/2:oo/2-1)*(fs/oo);
t=0:1/fs:(length(stage0.Data(:,3))-1)/fs;
plot(L,real(y))
title('Fourier of stage0')
```




```
%Delta extraction
delta1=bandpass(stage0.Data(:,3),[1 4],fs); %method1
plot(t,delta1)
title('Delta band (1-4 Hz), method1, stage0')
xlabel('t(sec)')
ylabel('Amp(uV)')
```

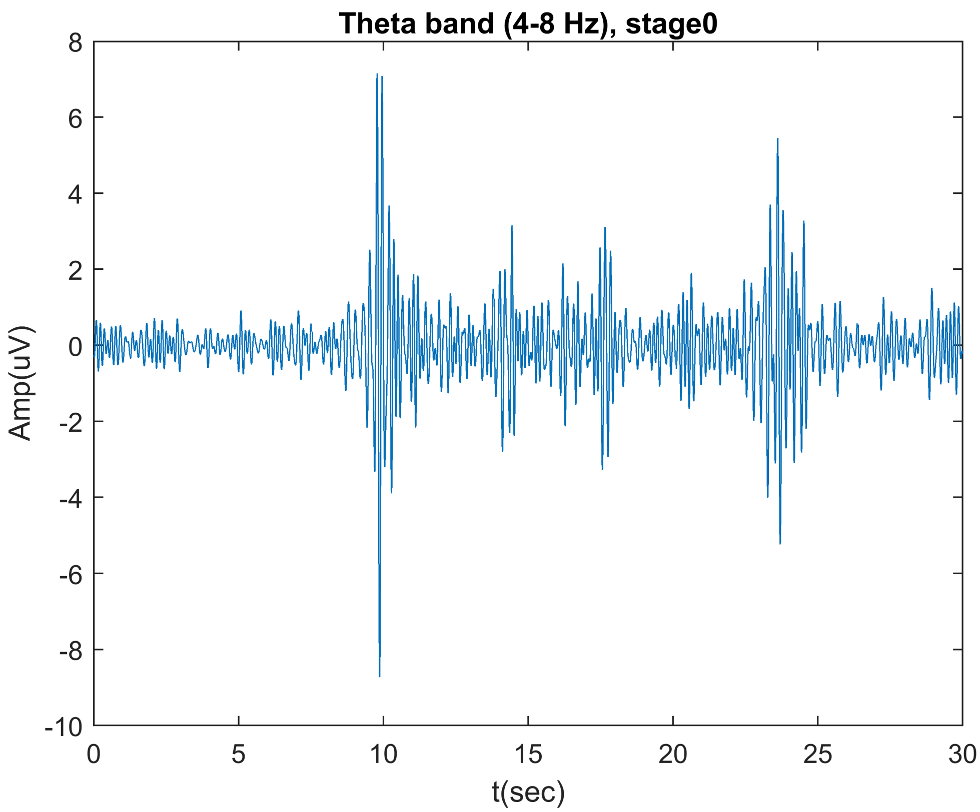



```
ydelta=y;
ydelta(~(-1<L & L<-4) & ~(L>1 & L<4))=0;    %method2
ydelta=ifftshift(ydelta);
delta=ifft(ydelta);
plot(t,real(delta))
title('Delta band (1-4 Hz), method2, stage0')
xlabel('t(sec)')
ylabel('Amp(uV)')
```



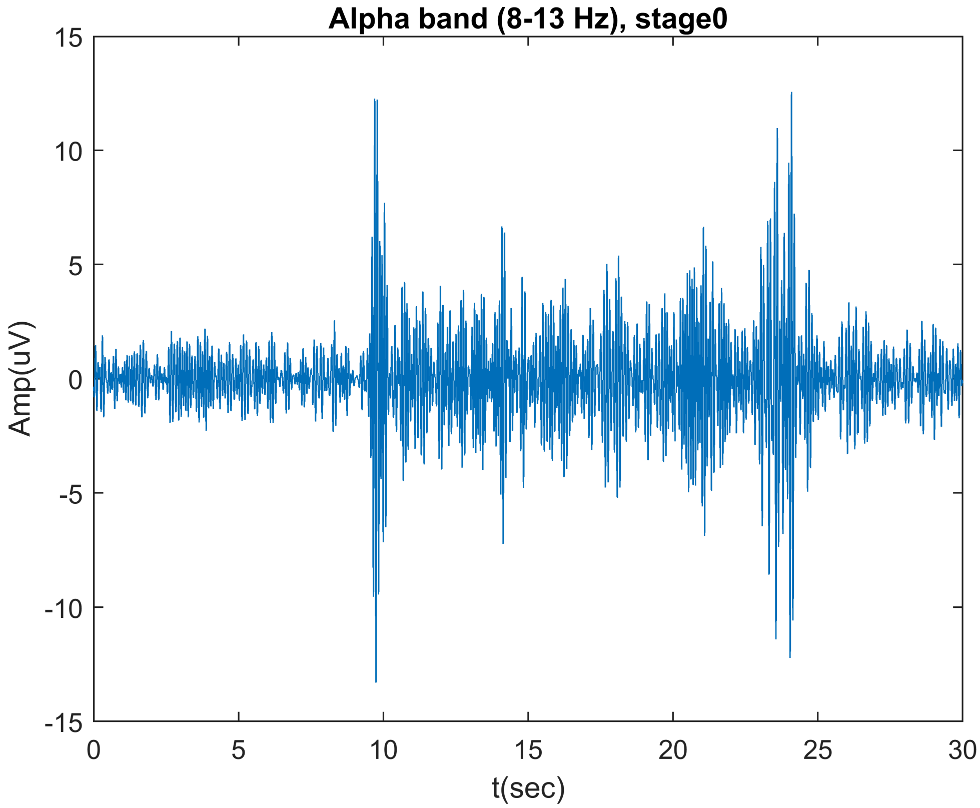

```
pdelta0=1/length(y)*sum(real(delta).^2);

%Theta extraction
ytheta=y;
ytheta(~(-4<L & L<-8) & ~(L>4 & L<8))=0;
ytheta=ifftshift(ytheta);
theta=ifft(ytheta);
plot(t,real(theta))
title('Theta band (4-8 Hz), stage0')
xlabel('t(sec)')
ylabel('Amp(uV)')
```



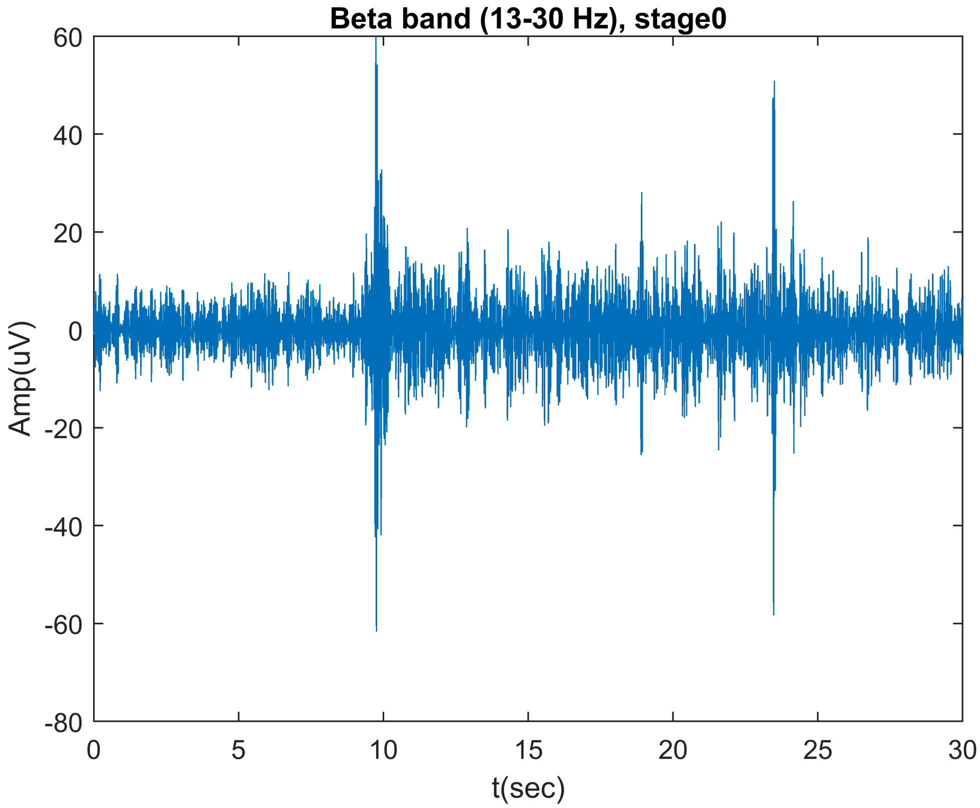

```
ptheta0=1/length(y)*sum(real(theta).^2);

%Alpha extraction
yalpha=y;
yalpha(~(-13<L & L<-8) & ~(L>8 & L<13))=0;
yalpha=ifftshift(yalpha);
alpha=ifft(yalpha);
plot(t,real(alpha))
title('Alpha band (8-13 Hz), stage0')
xlabel('t(sec)')
ylabel('Amp(uV)')
```



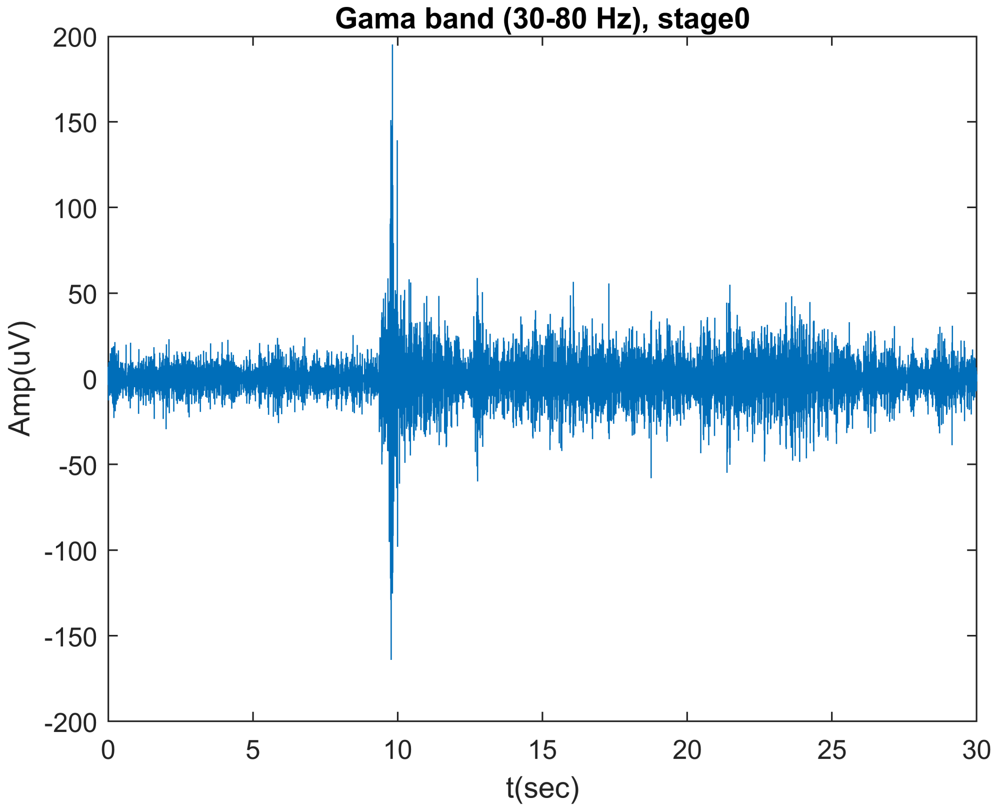

```
palpha0=1/length(y)*sum(real(alpha).^2);

%Beta extraction
ybeta=y;
ybeta(~(-30<L & L<-13) & ~(L>13 & L<30))=0;
ybeta=ifftshift(ybeta);
beta=ifft(ybeta);
plot(t,real(beta))
title('Beta band (13-30 Hz), stage0')
xlabel('t(sec)')
ylabel('Amp(uV)')
```



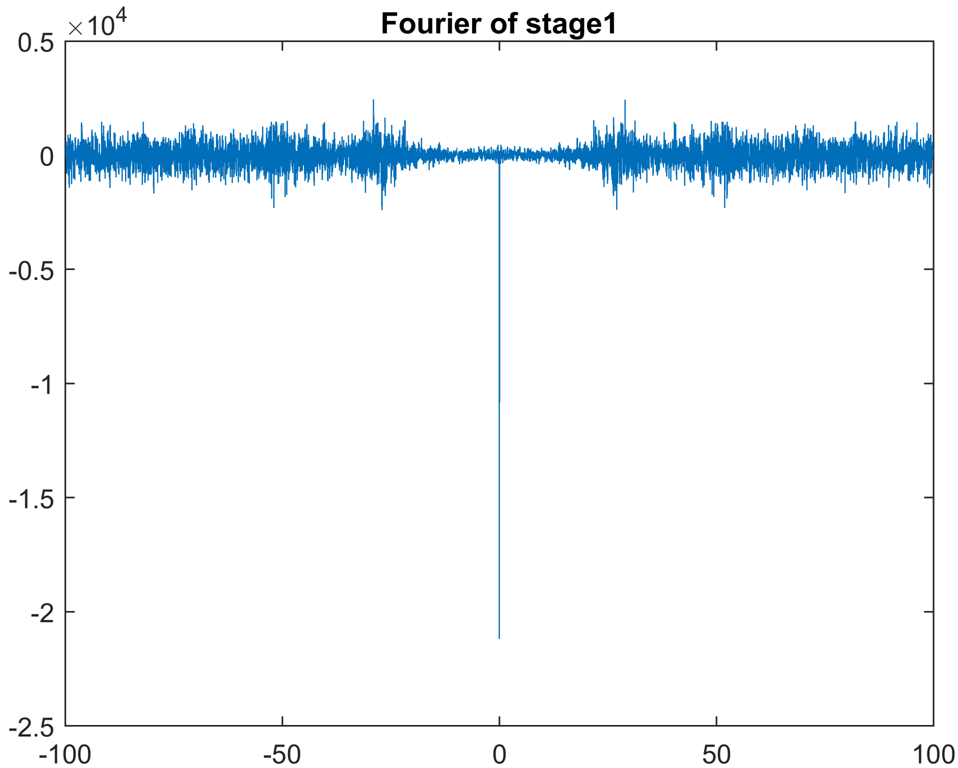

```
pbeta0=1/length(y)*sum(real(beta).^2);

%Gama extraction
ygama=y;
ygama(~(-80<L & L<-30) & ~(L>30 & L<80))=0;
ygama=ifftshift(ygama);
gama=ifft(ygama);
plot(t,real(gama))
title('Gama band (30-80 Hz), stage0')
xlabel('t(sec)')
ylabel('Amp(uV)')
```

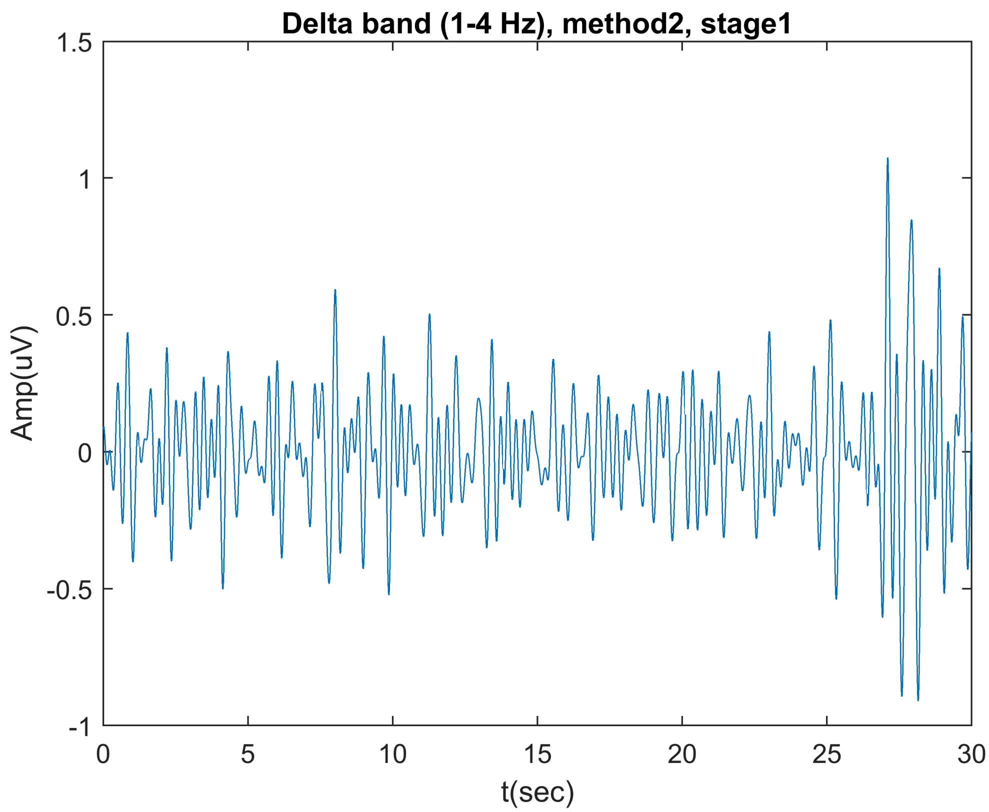



```
pgama0=1/length(y)*sum(real(gama).^2);

y=fft(stage1.Data(:,3));
y=fftshift(y);
fs=stage1.Fs(3);
oo=length(y);
L=(-oo/2:oo/2-1)*(fs/oo);
t=0:1/fs:(length(stage1.Data(:,3))-1)/fs;
plot(L,real(y))
title('Fourier of stage1')
```

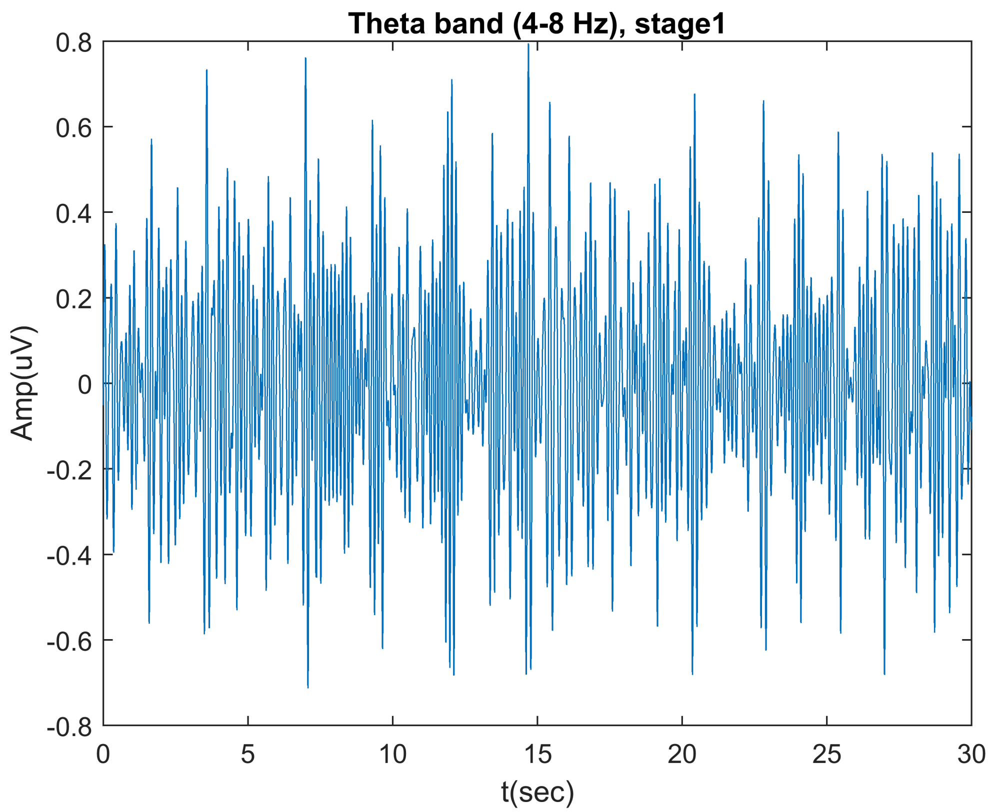



```
%Delta extraction
ydelta=y;
ydelta(~(-1<L & L<-4) & ~(L>1 & L<4))=0;    %method2
ydelta=ifftshift(ydelta);
delta=ifft(ydelta);
plot(t,real(delta))
title('Delta band (1-4 Hz), method2, stage1')
xlabel('t(sec)')
ylabel('Amp(uV)')
```



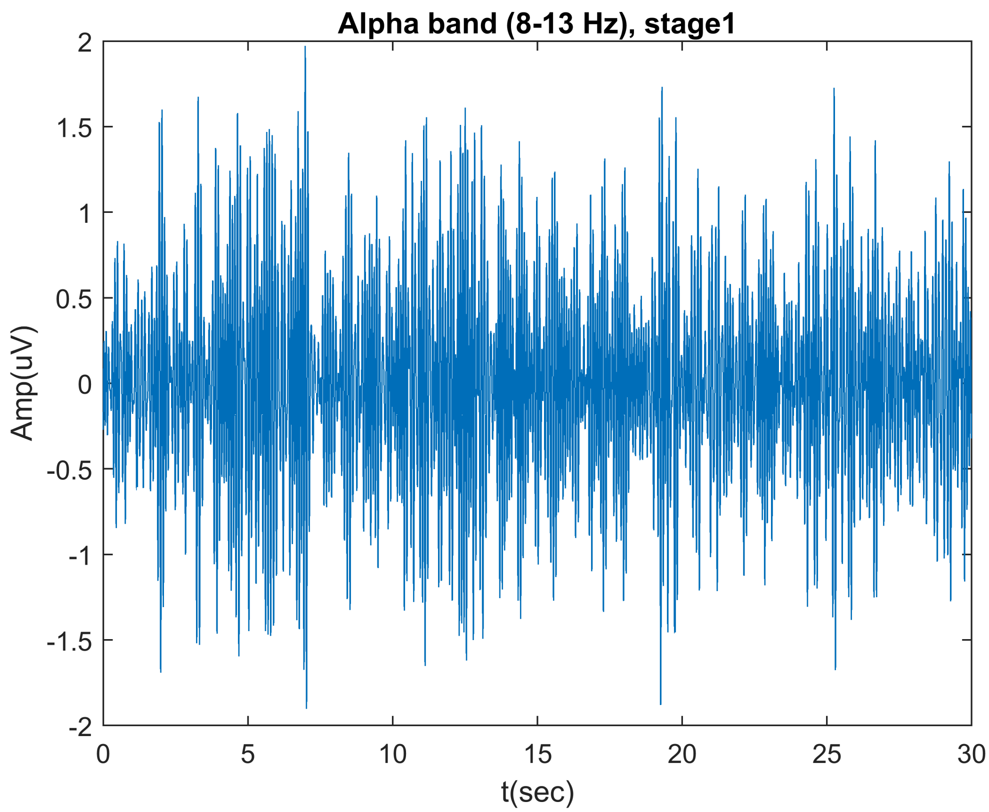

```
pdelta1=1/length(y)*sum(real(delta).^2);


%Theta extraction
ytheta=y;
ytheta(~(-4<L & L<-8) & ~(L>4 & L<8))=0;
ytheta=ifftshift(ytheta);
theta=ifft(ytheta);
plot(t,real(theta))
title('Theta band (4-8 Hz), stage1')
xlabel('t(sec)')
ylabel('Amp(uV)')
```



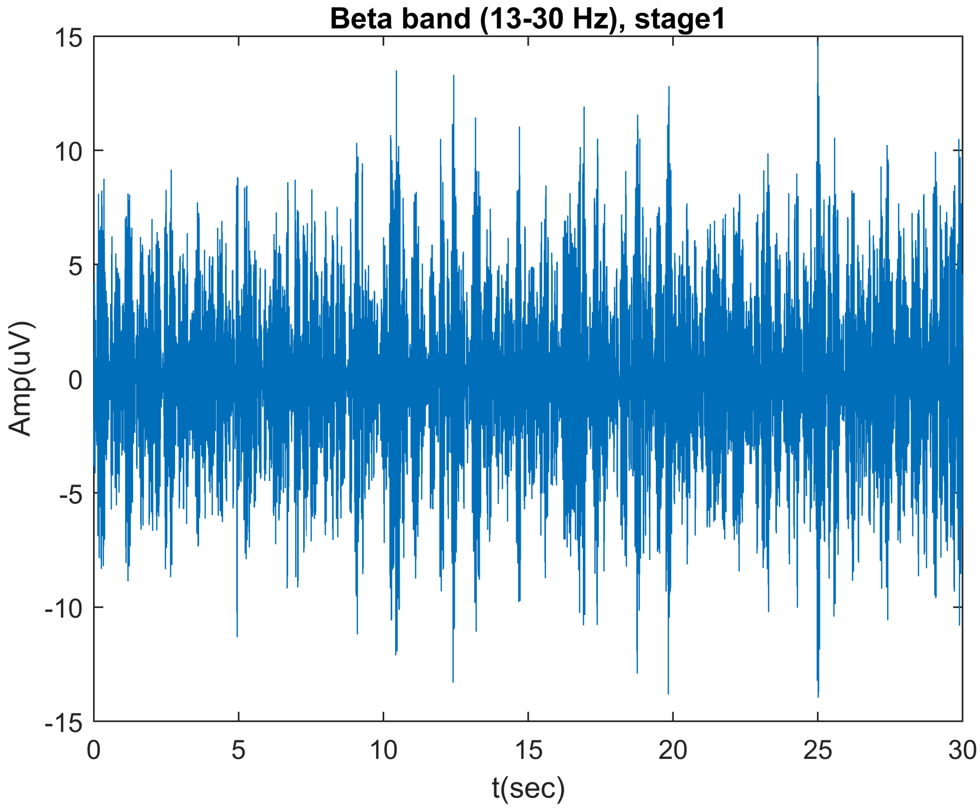

```
ptheta1=1/length(y)*sum(real(theta).^2);


%Alpha extraction
yalpha=y;
yalpha(~(-13<L & L<-8) & ~(L>8 & L<13))=0;
yalpha=ifftshift(yalpha);
alpha=ifft(yalpha);
plot(t,real(alpha))
title('Alpha band (8-13 Hz), stage1')
xlabel('t(sec)')
ylabel('Amp(uV)')
```



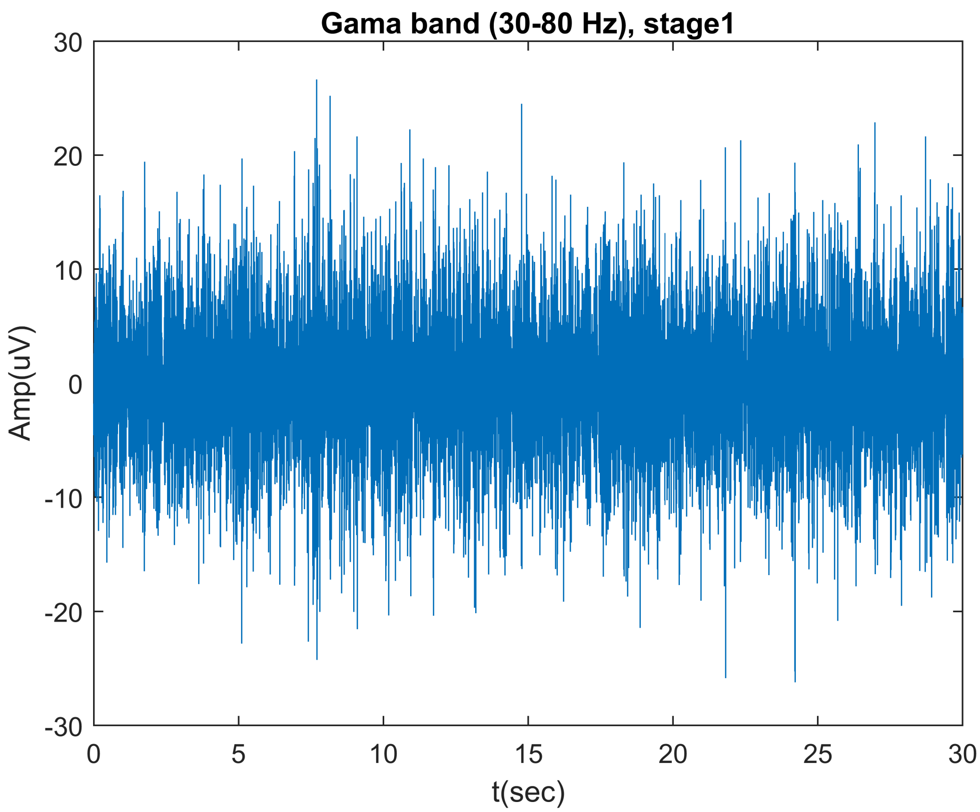

```
palpha1=1/length(y)*sum(real(alpha).^2);

%Beta extraction
ybeta=y;
ybeta(~(-30<L & L<-13) & ~(L>13 & L<30))=0;
ybeta=ifftshift(ybeta);
beta=ifft(ybeta);
plot(t,real(beta))
title('Beta band (13-30 Hz), stage1')
xlabel('t(sec)')
ylabel('Amp(uV)')
```



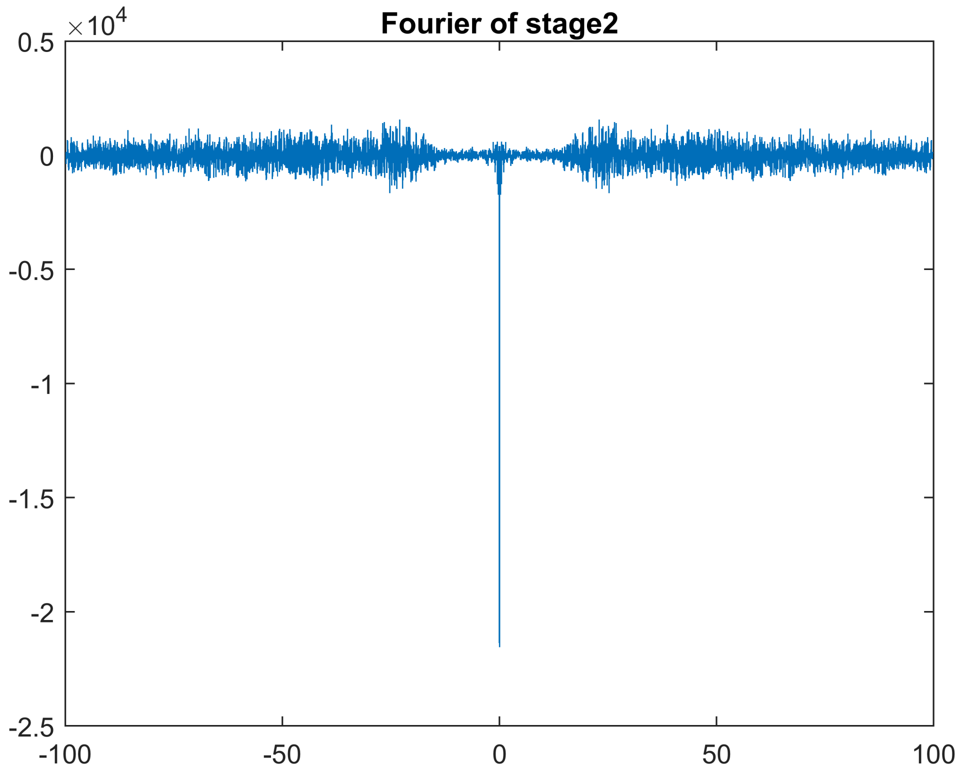

```
pbeta1=1/length(y)*sum(real(beta).^2);


%Gama extraction
ygama=y;
ygama(~(-80<L & L<-30) & ~(L>30 & L<80))=0;
ygama=ifftshift(ygama);
gama=ifft(ygama);
plot(t,real(gama))
title('Gama band (30-80 Hz), stage1')
xlabel('t(sec)')
ylabel('Amp(uV)')
```

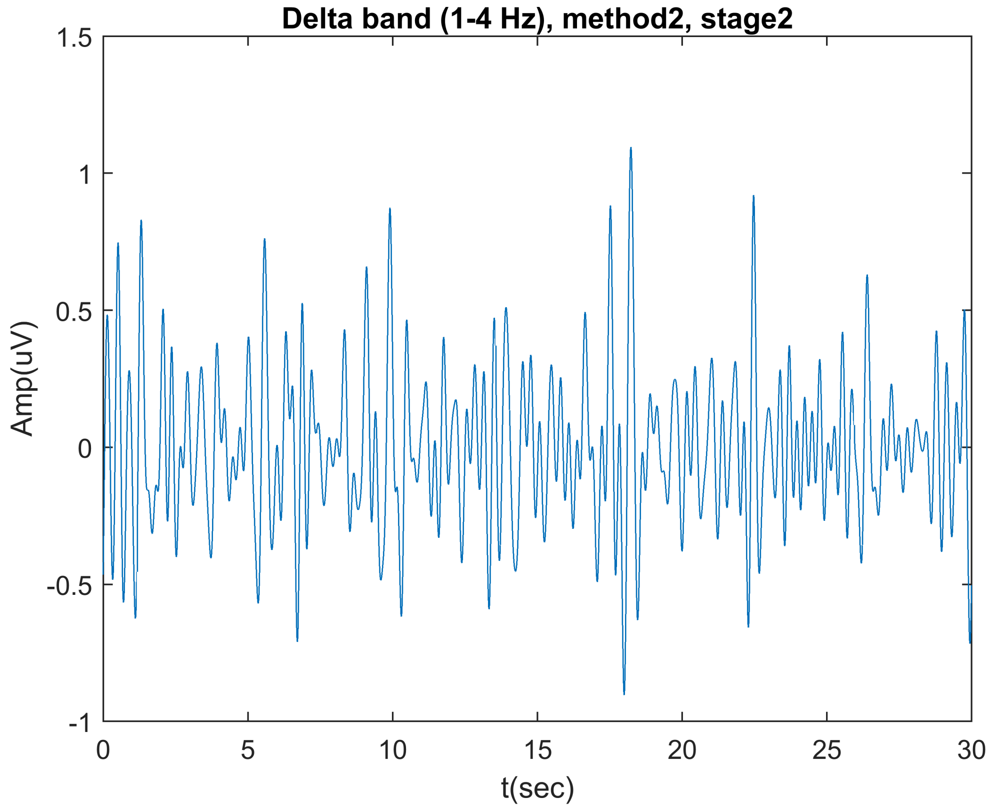



```
pgama1=1/length(y)*sum(real(gama).^2);


y=fft(stage2.Data(:,3));
y=fftshift(y);
fs=stage2.Fs(3);
oo=length(y);
L=(-oo/2:oo/2-1)*(fs/oo);
t=0:1/fs:(length(stage2.Data(:,3))-1)/fs;
plot(L,real(y))
title('Fourier of stage2')
```

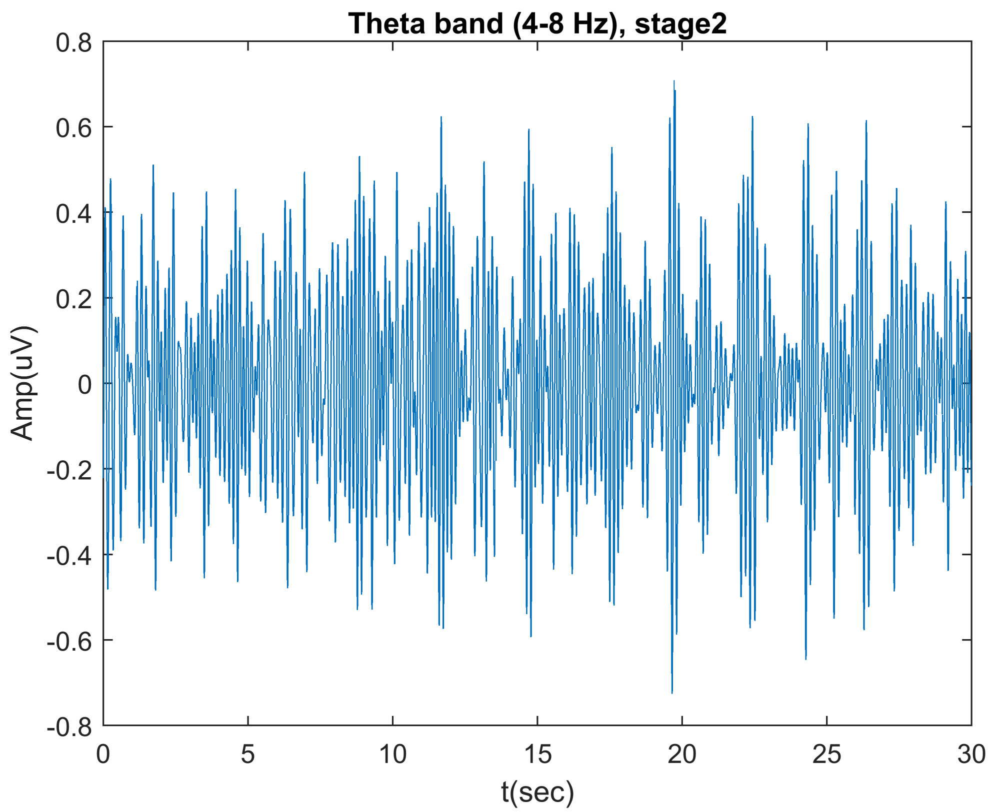



```
%Delta extraction
ydelta=y;
ydelta(~(-1<L & L<-4) & ~(L>1 & L<4))=0;    %method2
ydelta=ifftshift(ydelta);
delta=ifft(ydelta);
plot(t,real(delta))
title('Delta band (1-4 Hz), method2, stage2')
xlabel('t(sec)')
ylabel('Amp(uV)')
```



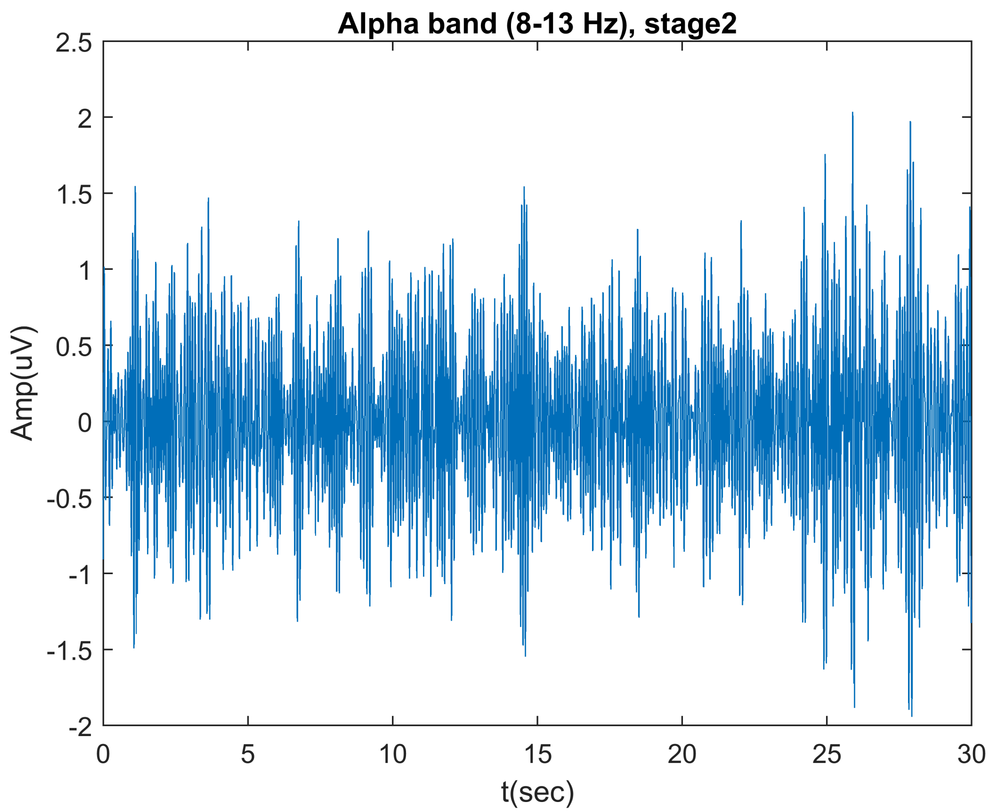

```
pdelta2=1/length(y)*sum(real(delta).^2);


%Theta extraction
ytheta=y;
ytheta(~(-4<L & L<-8) & ~(L>4 & L<8))=0;
ytheta=ifftshift(ytheta);
theta=ifft(ytheta);
plot(t,real(theta))
title('Theta band (4-8 Hz), stage2')
xlabel('t(sec)')
ylabel('Amp(uV)')
```



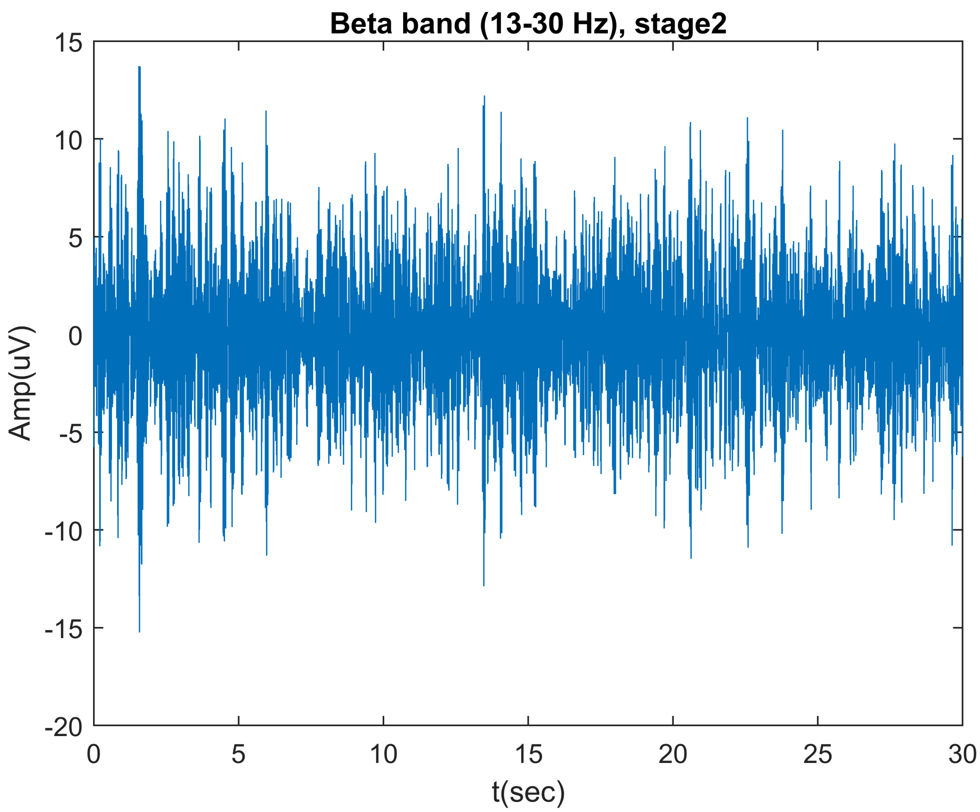

```
ptheta2=1/length(y)*sum(real(theta).^2);


%Alpha extraction
yalpha=y;
yalpha(~(-13<L & L<-8) & ~(L>8 & L<13))=0;
yalpha=ifftshift(yalpha);
alpha=ifft(yalpha);
plot(t,real(alpha))
title('Alpha band (8-13 Hz), stage2')
xlabel('t(sec)')
ylabel('Amp(uV)')
```



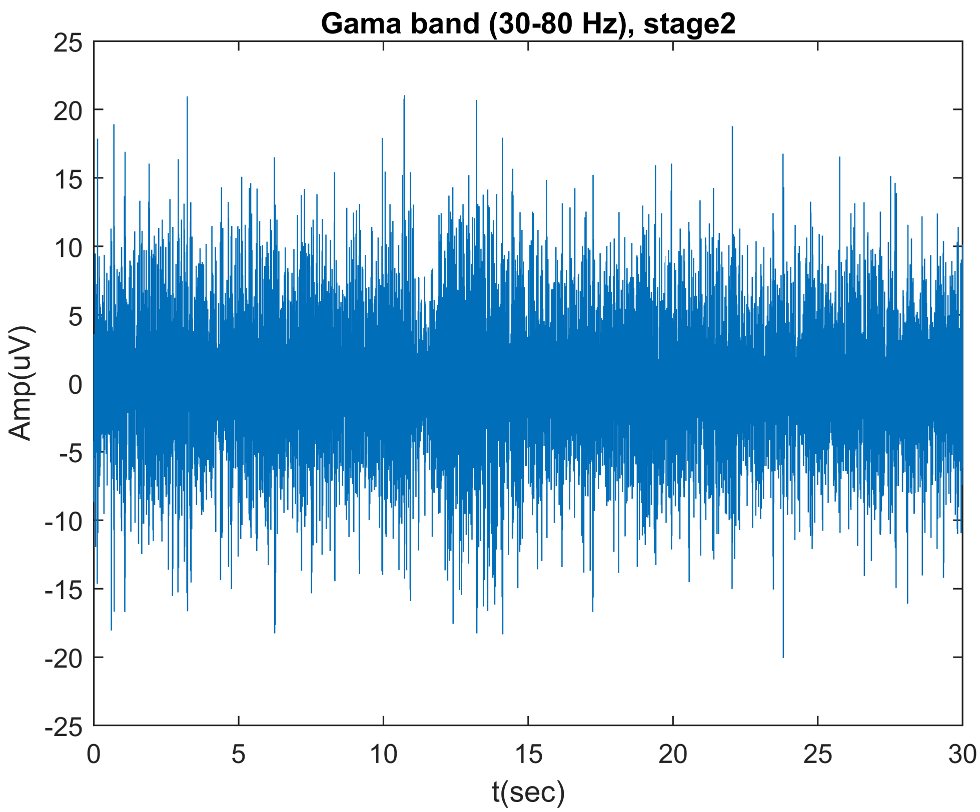

```
palpha2=1/length(y)*sum(real(alpha).^2);


%Beta extraction
ybeta=y;
ybeta(~(-30<L & L<-13) & ~(L>13 & L<30))=0;
ybeta=ifftshift(ybeta);
beta=ifft(ybeta);
plot(t,real(beta))
title('Beta band (13-30 Hz), stage2')
xlabel('t(sec)')
ylabel('Amp(uV)')
```




```
pbeta2=1/length(y)*sum(real(beta).^2);


%Gama extraction
ygama=y;
ygama(~(-80<L & L<-30) & ~(L>30 & L<80))=0;
ygama=ifftshift(ygama);
gama=ifft(ygama);
plot(t,real(gama))
title('Gama band (30-80 Hz), stage2')
xlabel('t(sec)')
ylabel('Amp(uV)')
```

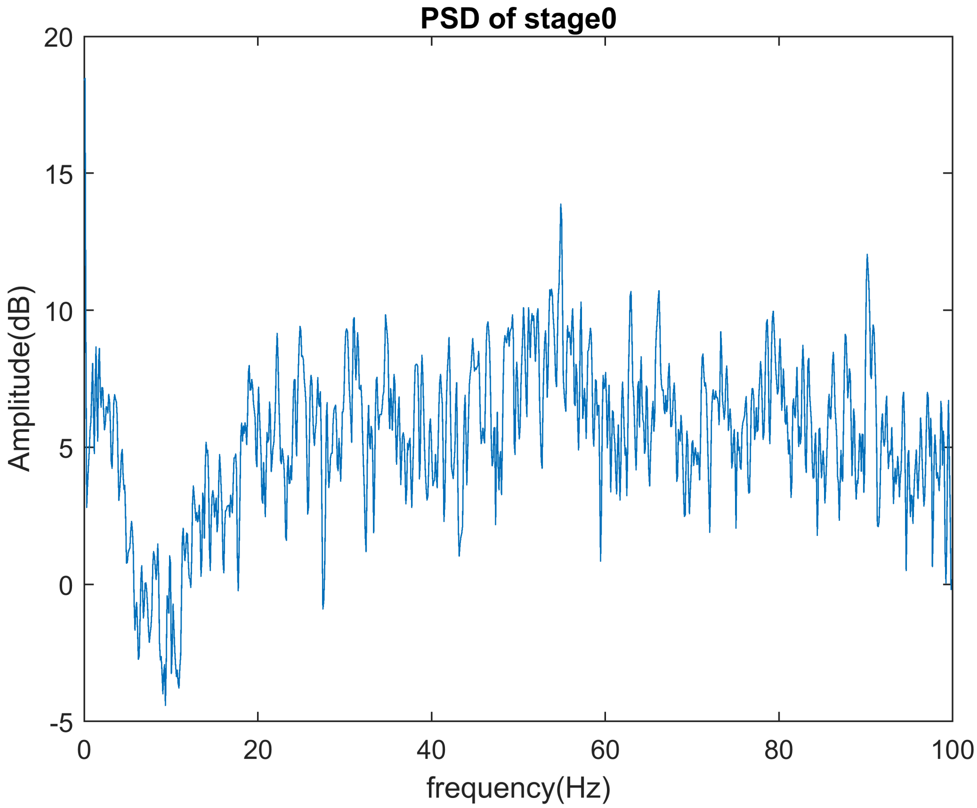



```
pgama2=1/length(y)*sum(real(gama).^2);
```

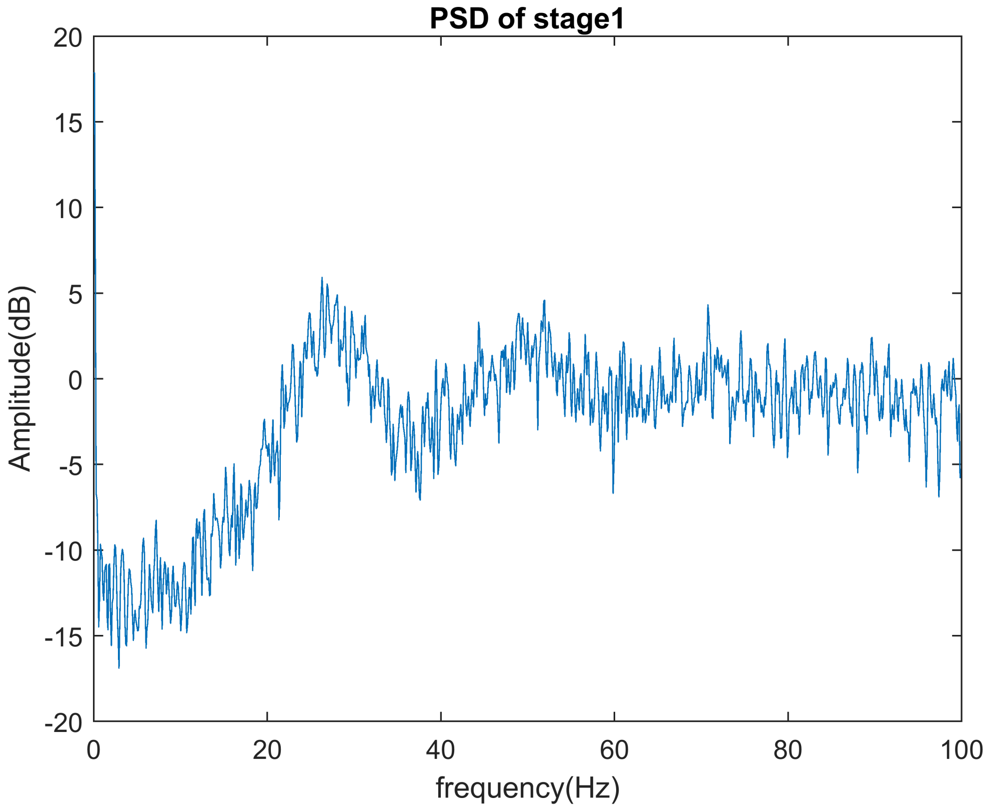
We can see that in stage0 the waves are not very periodic and synchronized but in stage 1 and stage 2 waves are more periodic and more synchronized and also have less amplitude than stage 0.

4)

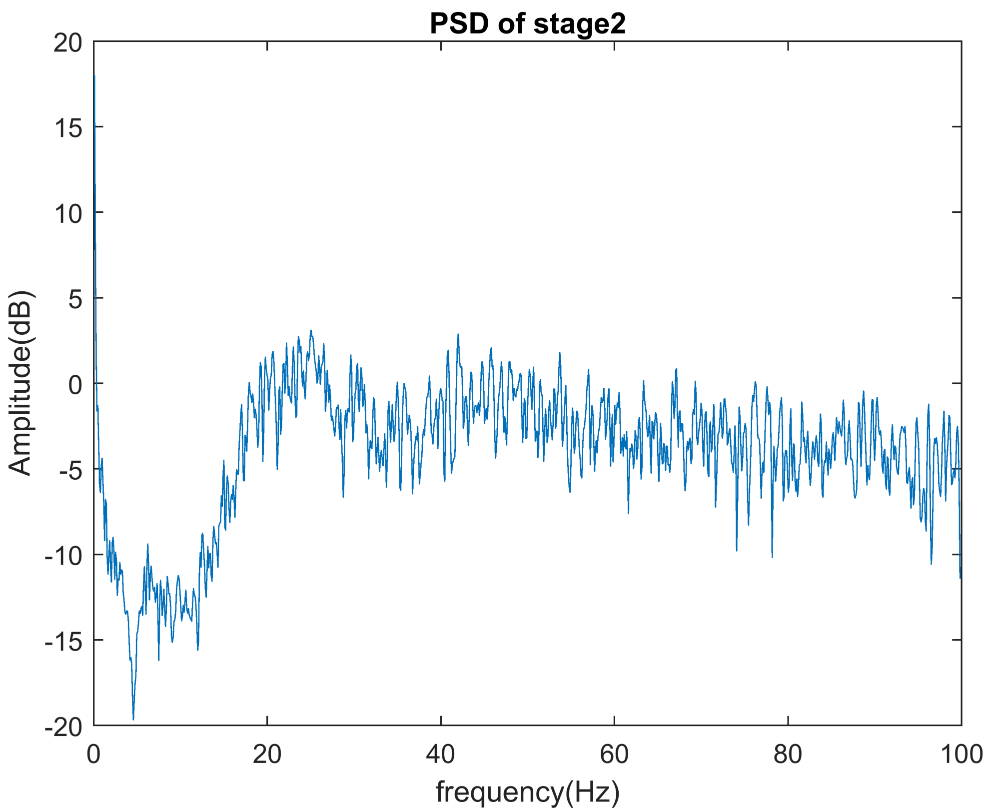
```
fs0=stage0.Fs(3);
[pxx0,f0]=pwelch(stage0.Data(:,3),[],[],[],fs0);
plot(f0,10*log10(pxx0))
title('PSD of stage0')
xlabel('frequency(Hz)')
ylabel('Amplitude(dB)')
```




```
fs1=stage1.Fs(3);
[pxx1,f1]=pwelch(stage1.Data(:,3),[],[],[],fs1);
plot(f1,10*log10(pxx1))
title('PSD of stage1')
xlabel('frequency(Hz)')
ylabel('Amplitude(dB)')
```




```
fs2=stage2.Fs(3);
[pxx2,f2]=pwelch(stage2.Data(:,3),[],[],[],fs2);
plot(f2,10*log10(pxx2))
y0=fft(stage0.Data(:,3));
title('PSD of stage2')
xlabel('frequency(Hz)')
ylabel('Amplitude(dB)')
```



We can see that overall amplitude of stage 0 is much larger than other stages and also amplitude in stage 1 is larger than stage2. in stage 0, Delta waves contribute more to PSD than in stage 1 and stage 2.

5)

```
pdelta0
```

```
pdelta0 = 2.7222
```

```
pdelta1
```

```
pdelta1 = 0.0484
```

```
pdelta2
```

```
pdelta2 = 0.0761
```

```
ptheta0
```

```
ptheta0 = 1.0351
```

```
ptheta1
```

```
ptheta1 = 0.0608
```

```
ptheta2
```

```
ptheta2 = 0.0489
```

```
palpha0
```

```
palpha0 = 4.2092
```

```
palpha1
```

```
palpha1 = 0.3622
```

```
palpha2
```

```
palpha2 = 0.3002
```

```
pbeta0
```

```
pbeta0 = 48.7218
```

```
pbeta1
```

```
pbeta1 = 15.2563
```

```
pbeta2
```

```
pbeta2 = 13.3368
```

```
pgama0
```

```
pgama0 = 216.7052
```

```
pgama1
```

```
pgama1 = 47.6224
```

```
pgama2
```

```
pgama2 = 30.8828
```

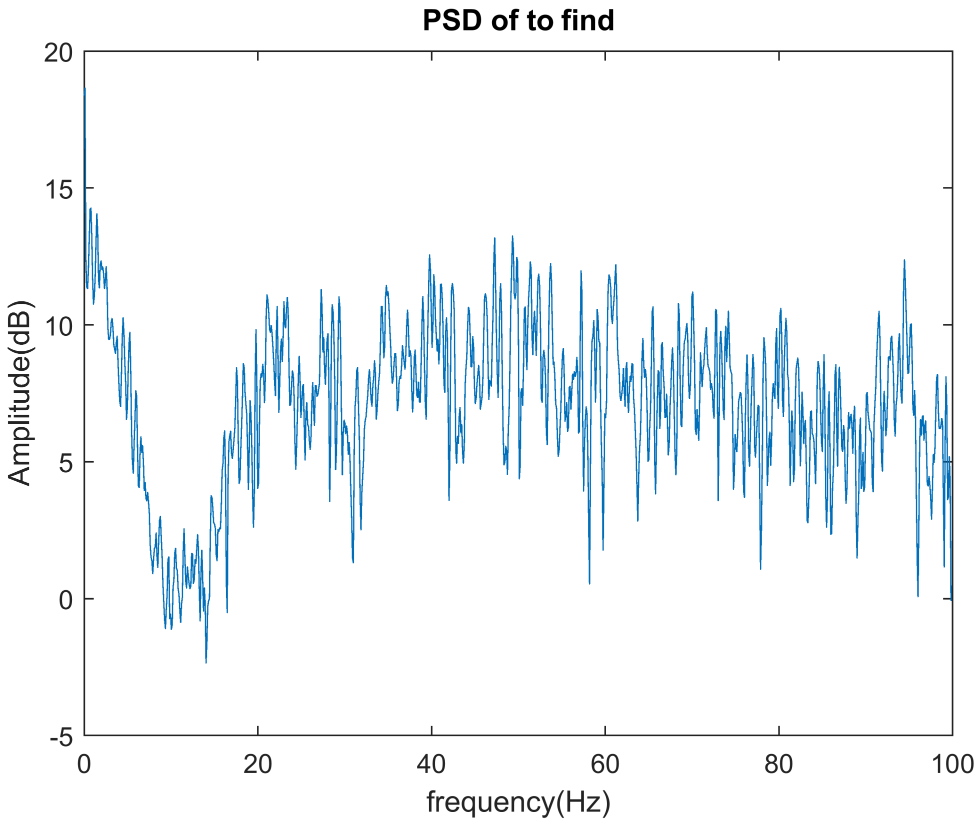
From power of each band in each state we can see that power of waves in stage 0 is greater than other two stages, and aslo power of bands in stage 1 is greater than power of stage2, but only power of Delta band in stage2 is greater than power of Delta band in stage 1, also beta and gama waves have higher powers and Delta and theta waves have lowest powers.

also from graphs in part 3, we can see that each band in stage0 has more amplitude than the other 2 and there is 2 peaks in stage 0 which is not is stages 1 and 2,

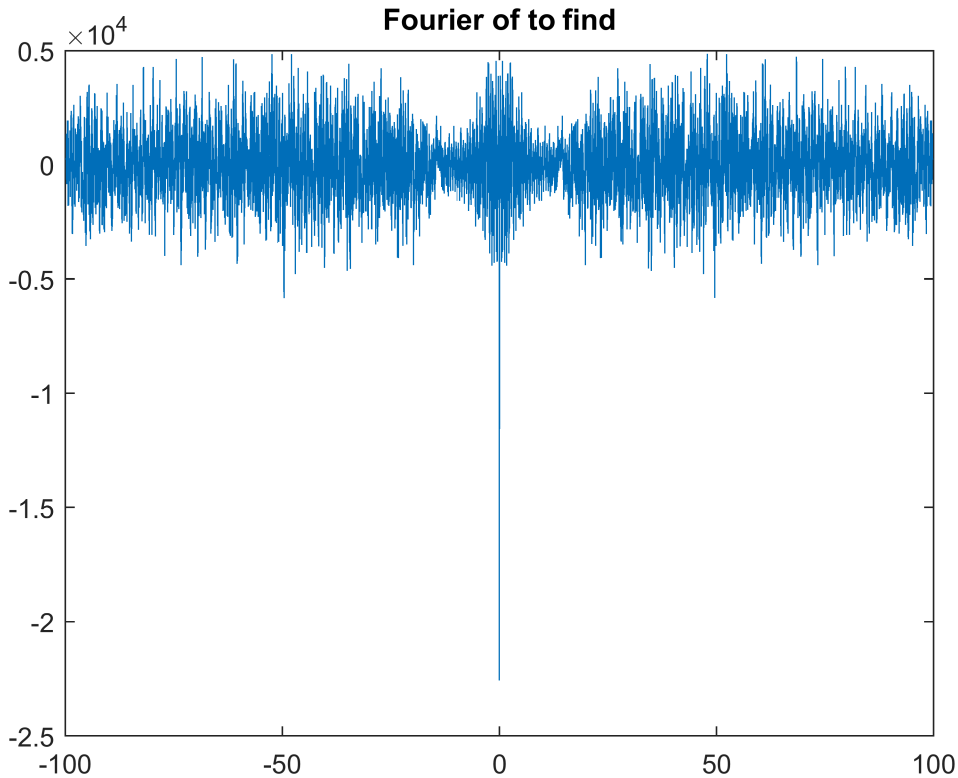
6)

```
fs3=to_find.Fs(3);
[pxx3,f3]=pwelch(to_find.Data(:,3),[],[],[],fs3);
```

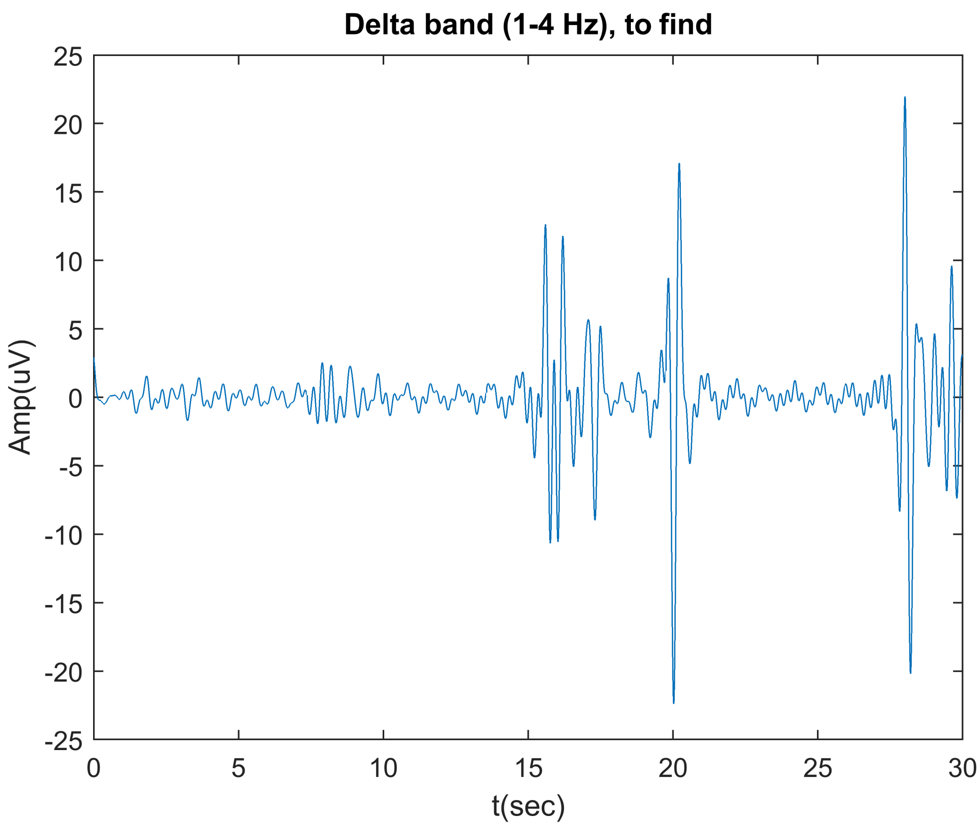
```
plot(f3,10*log10(pxx3))
title('PSD of to_ find')
xlabel('frequency(Hz)')
ylabel('Amplitude(dB)')
```




```
y3=fft(to_find.Data(:,3));
y3=fftshift(y3);
fs=to_find.Fs(3);
oo=length(y3);
L=(-oo/2:oo/2-1)*(fs/oo);
plot(L,real(y3))
title('Fourier of to_ find')
```



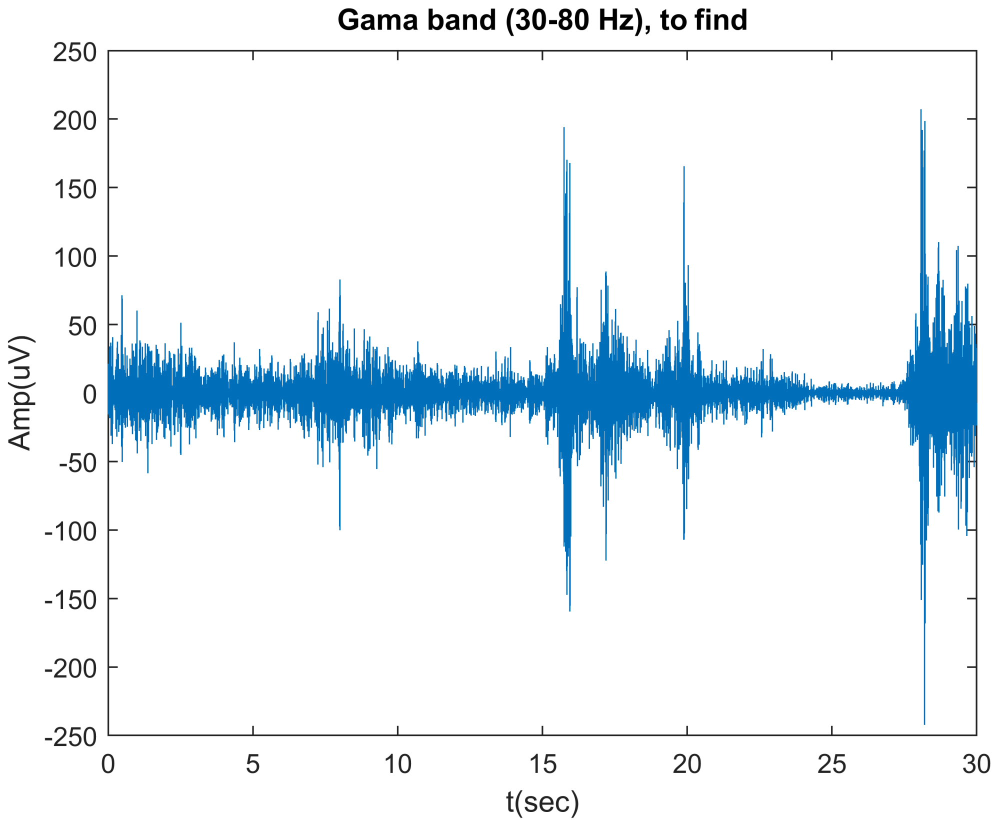

```
y=fft(to_find.Data(:,3));
y=fftshift(y);
fs=to_find.Fs(3);
oo=length(y);
L=(-oo/2:oo/2-1)*(fs/oo);
t=0:1/fs:(length(to_find.Data(:,3))-1)/fs;
ydelta=y;
ydelta(~(-1<L & L<-4) & ~(L>1 & L<4))=0;
ydelta=ifftshift(ydelta);
delta=ifft(ydelta);
plot(t,real(delta))
title('Delta band (1-4 Hz), to_ find')
xlabel('t(sec)')
ylabel('Amp(uV)')
```




```
pdelta4=1/length(y)*sum(real(delta).^2)
```

```
pdelta4 = 10.0994
```

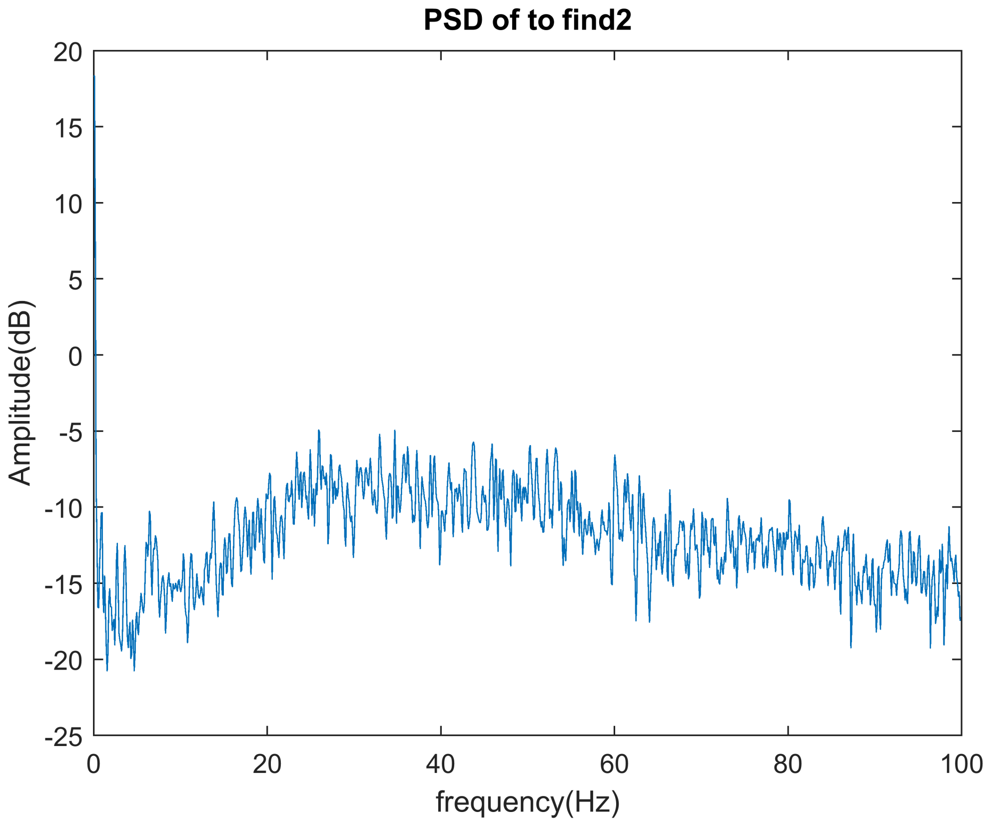
```
ygama=y;
ygama(~(-80<L & L<-30) & ~(L>30 & L<80))=0;
ygama=ifftshift(ygama);
gama=ifft(ygama);
plot(t,real(gama))
title('Gama band (30-80 Hz), to_ find')
xlabel('t(sec)')
ylabel('Amp(uV)')
```



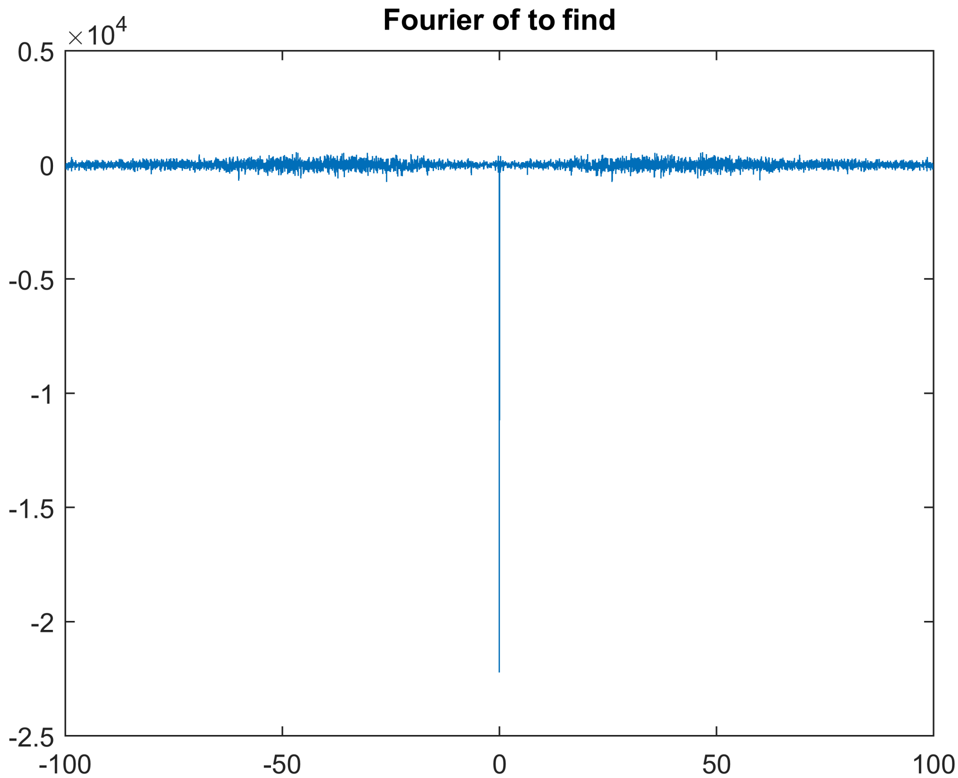

```
pgama4=1/length(y)*sum(real(gama).^2)
```

```
pgama4 = 444.0717
```

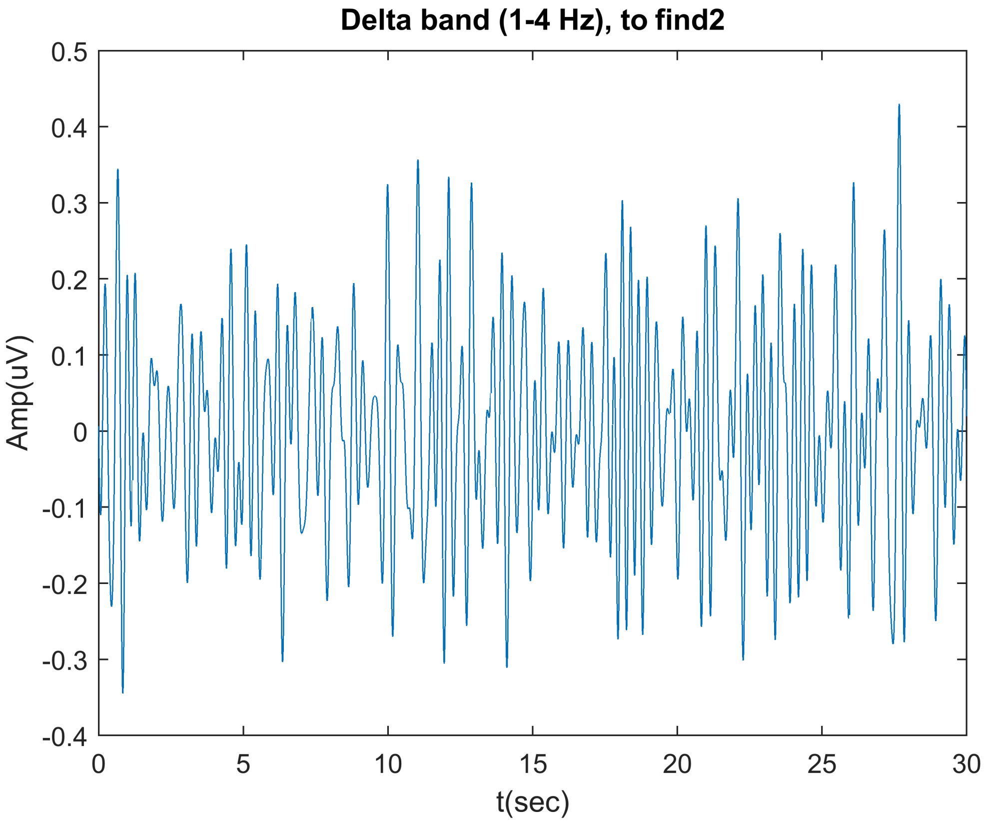
```
fs4=to_find2.Fs(3);
[pxx4,f4]=pwelch(to_find2.Data(:,3),[],[],[],fs4);
plot(f4,10*log10(pxx4))
title('PSD of to_ find2')
xlabel('frequency(Hz)')
ylabel('Amplitude(dB)')
```




```
y4=fft(to_find2.Data(:,3));
y4=fftshift(y4);
fs=to_find2.Fs(3);
oo=length(y4);
L=(-oo/2:oo/2-1)*(fs/oo);
plot(L,real(y4))
title('Fourier of to_ find')
```



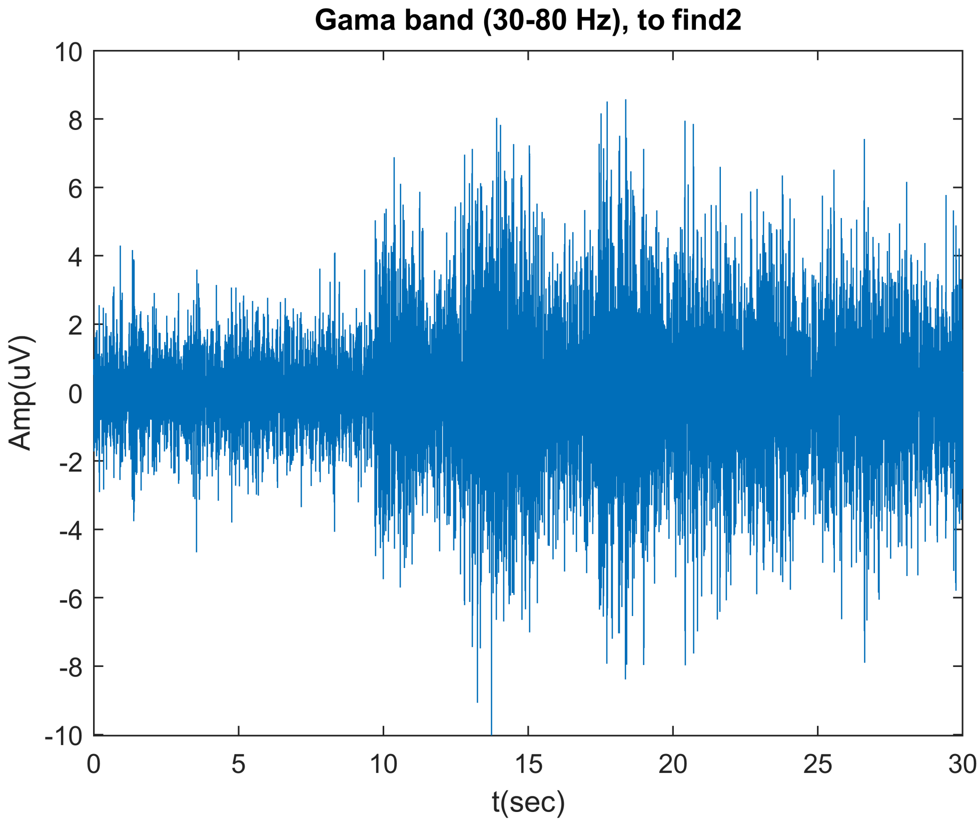

```
y=fft(to_find2.Data(:,3));
y=fftshift(y);
fs=to_find2.Fs(3);
oo=length(y);
L=(-oo/2:oo/2-1)*(fs/oo);
t=0:1/fs:(length(to_find2.Data(:,3))-1)/fs;
ydelta=y;
ydelta(~(-1<L & L<-4) & ~(L>1 & L<4))=0;     %method2
ydelta=ifftshift(ydelta);
delta=ifft(ydelta);
plot(t,real(delta))
title('Delta band (1-4 Hz), to_ find2')
xlabel('t(sec)')
ylabel('Amp(uV)')
```




```
pdelta5=1/length(y)*sum(real(delta).^2)
```

```
pdelta5 = 0.0170
```

```
ygama=y;
ygama(~(-80<L & L<-30) & ~(L>30 & L<80))=0;
ygama=ifftshift(ygama);
gama=ifft(ygama);
plot(t,real(gama))
title('Gama band (30-80 Hz), to_ find2')
xlabel('t(sec)')
ylabel('Amp(uV)')
```




```
pgama5=1/length(y)*sum(real(gama).^2)
```

```
pgama5 = 4.7255
```

From comparing psd, Delta and Gama waves, power of Delta and Gama bands and Fourier transform of to_find data with known data we can see that to_find is similar to stage 0, and to_find2 is more similar to stage 2