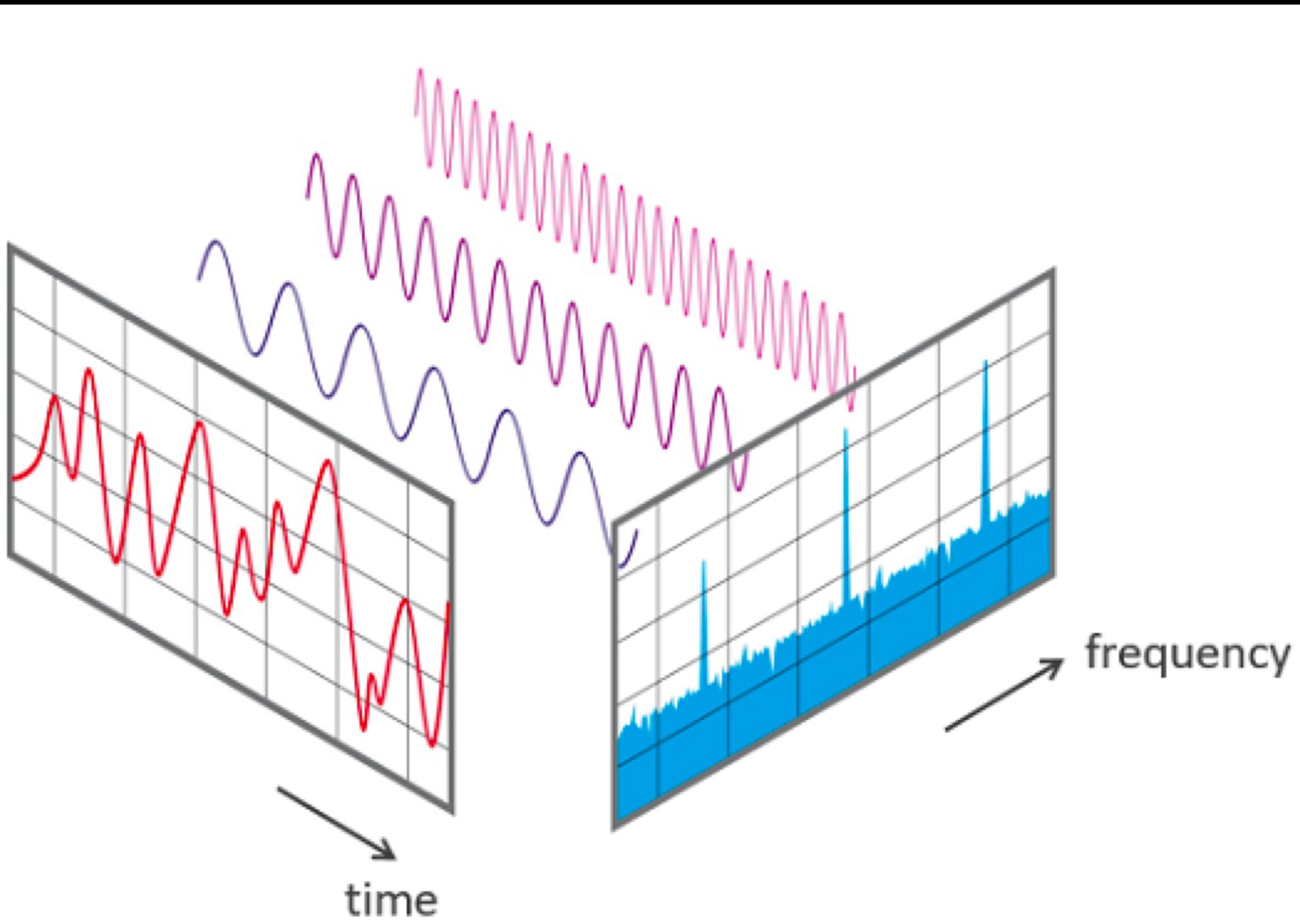
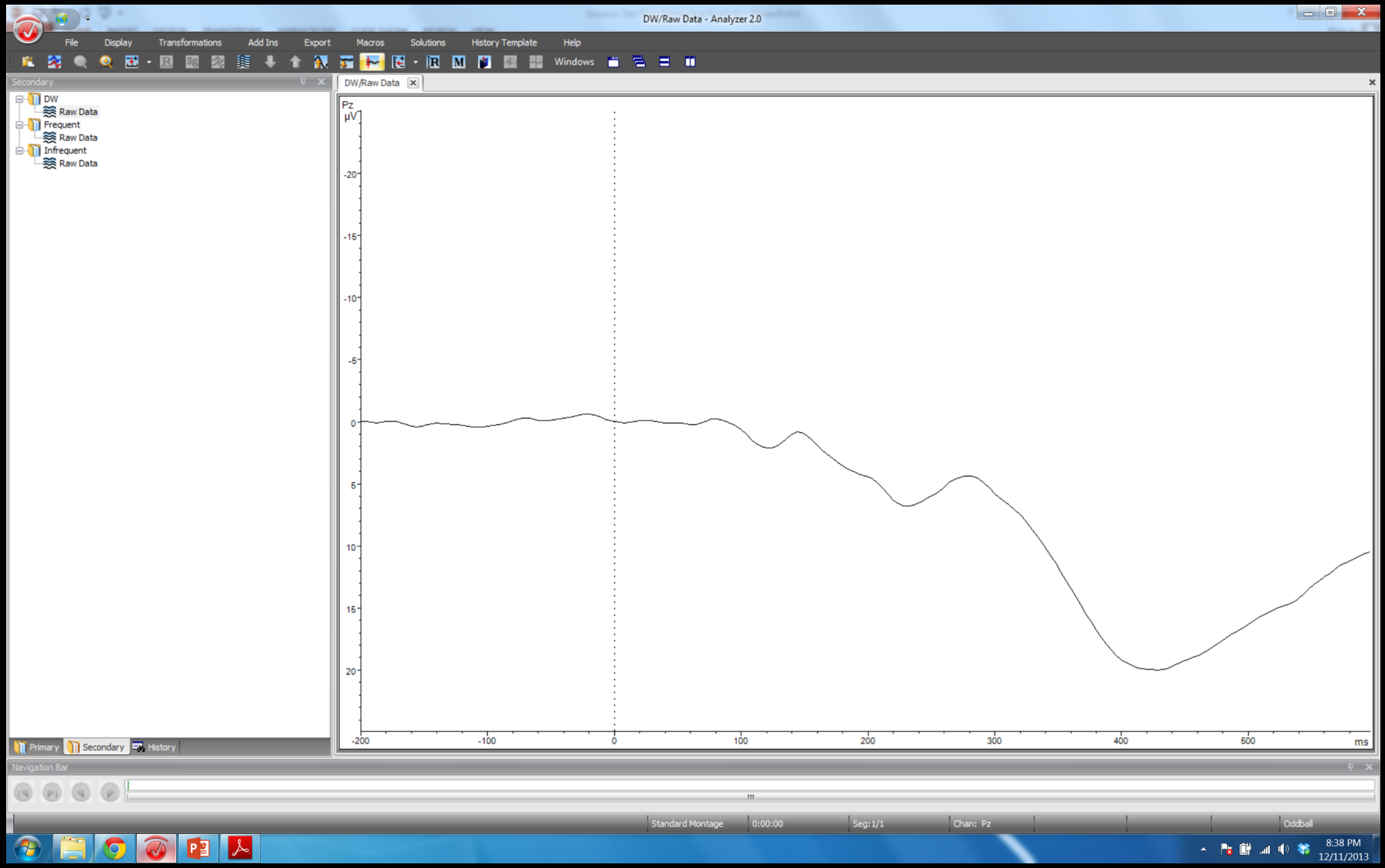
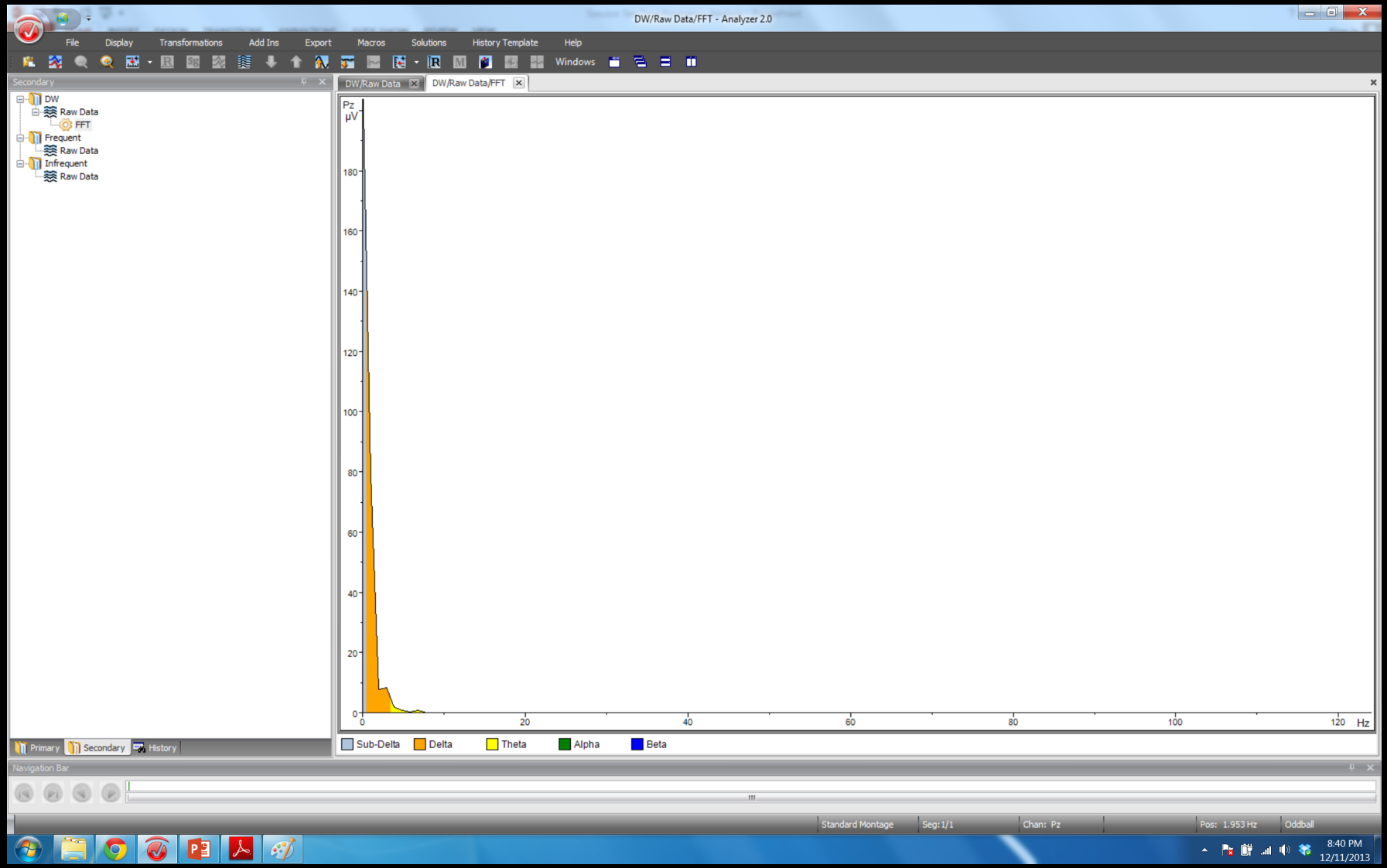
Time Frequency Analysis


frequency
time

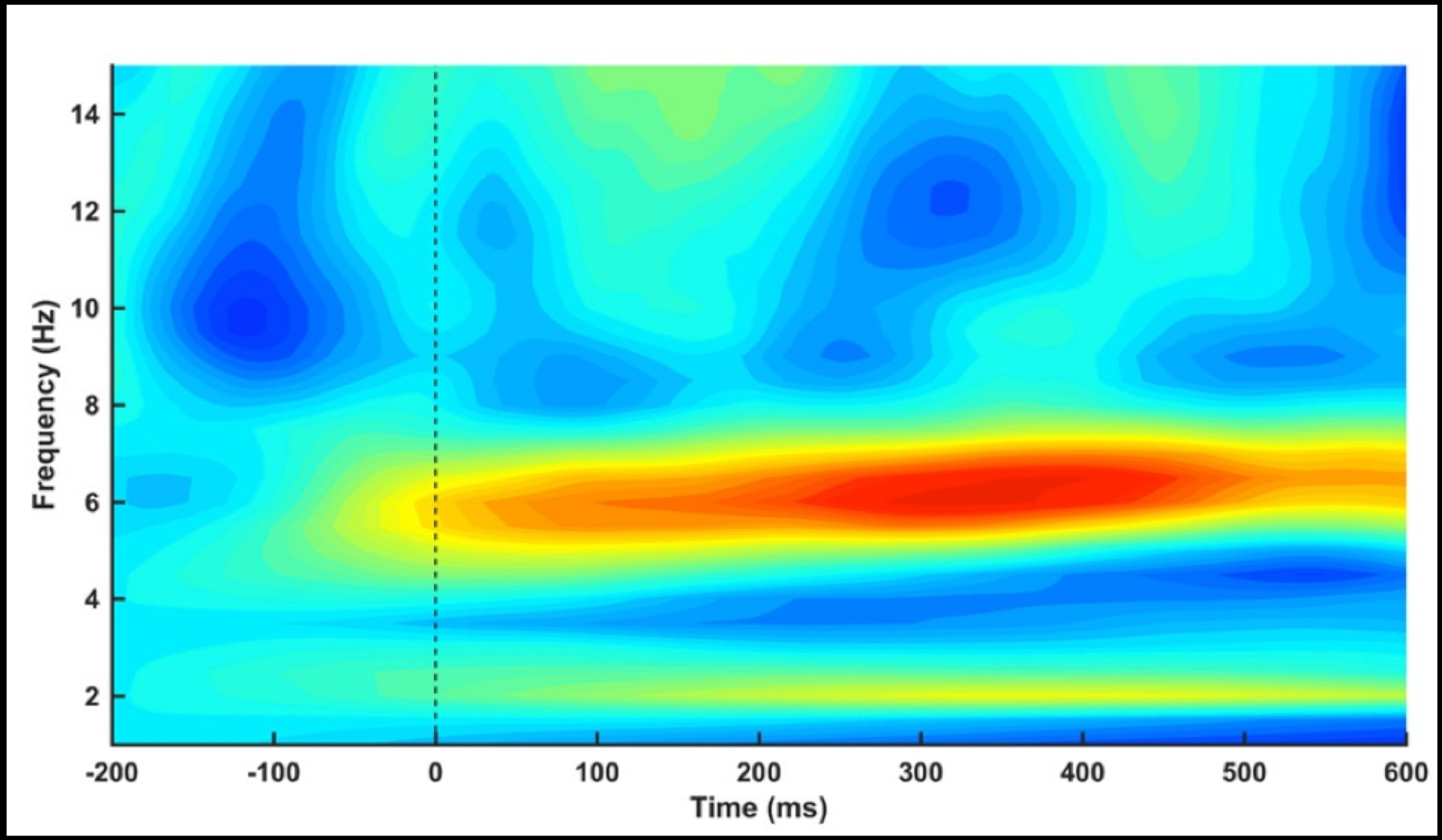
Time Domain

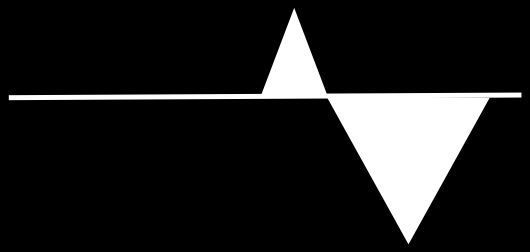

DW/Raw Data - Analyzer 2.0
File
Display
Transformations
Add Ins
Export
Macros
Solutions
History Template
Help
Windows
Secondary
DW
Raw Data
Frequent
Raw Data
Infrequent
Raw Data
Primary
Secondary
History
DW/Raw Data
Pz
µV
-20
-15
-10
-5
0
5
10
15
20
-200
-100
0
100
200
300
400
500
ms
Navigation Bar
Standard Montage
0:00:00
Seg: 1/1
Chan: Pz
Oddball
8:38 PM
12/11/2013

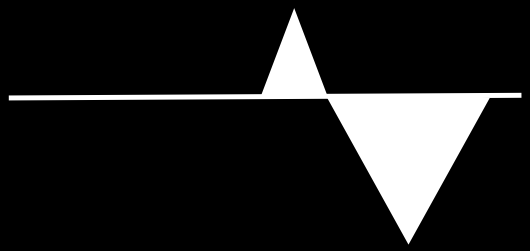
Frequency Domain

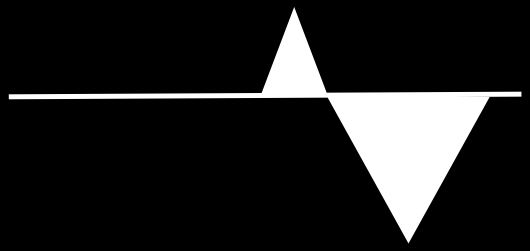


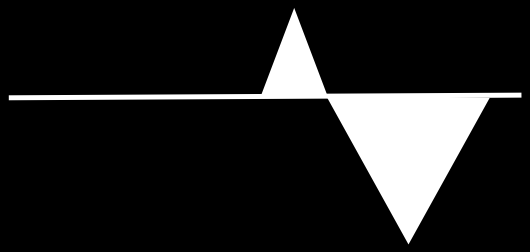
Time - Frequency Domain



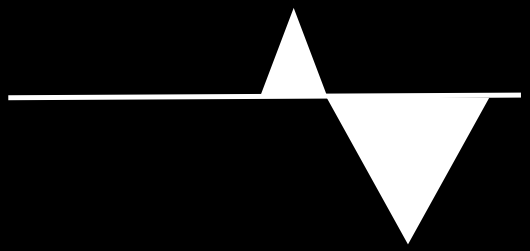




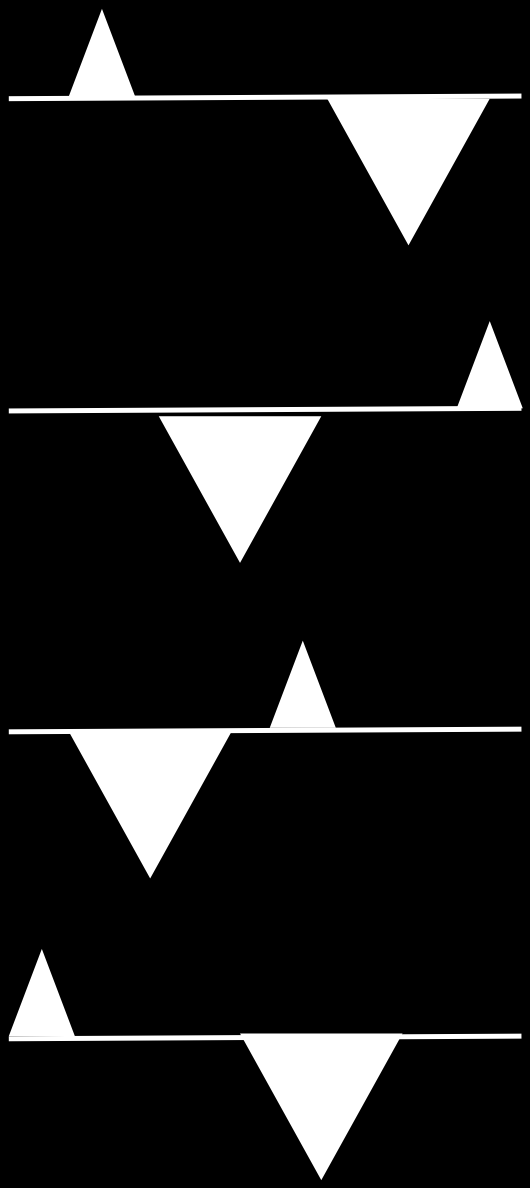




ERP



FFT



ERP

FFT

So...

In general, this is the point. Frequency analysis allows examination of asynchronous (induced) activity that is not visible in an ERP analysis.

Time-Frequency analysis in principle captures both, but can also be harder to interpret.

Segmented Data = Evoked + Induced

Average Data = Evoked

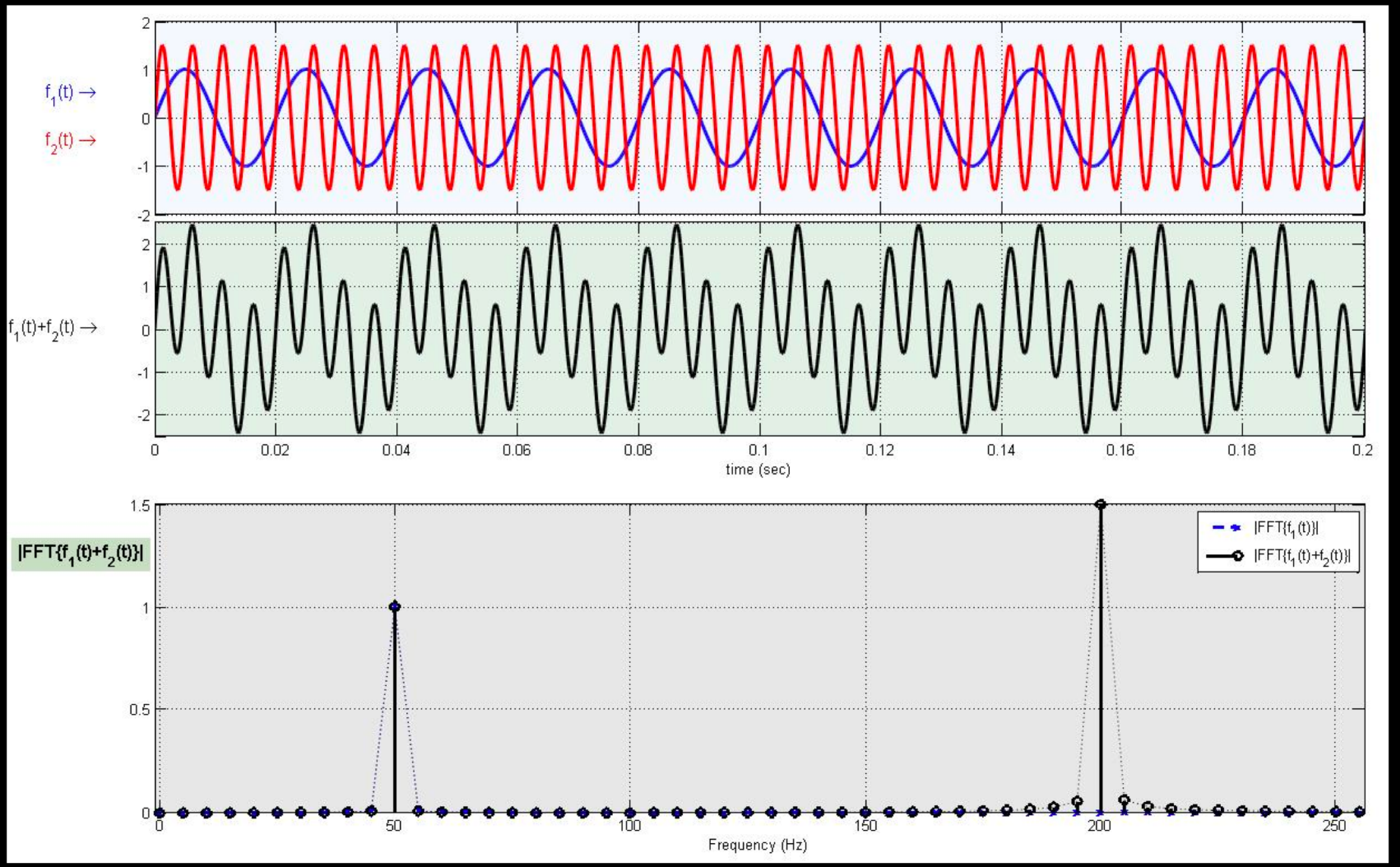
Segmented Data – Average Data = Induced

The Fourier Theorem

Recall…

Simply put, the Fourier theorem states that any waveform can be decomposed into a series of Sine waves.

As we noted previously, this is important in EEG research because it allows us to examine activity at different frequency bands.


f1(t) →
f2(t) →
f1(t)+f2(t) →
time (sec)
|FFT{f1(t)+f2(t)}|
|FFT{f1(t)}|
|FFT{f1(t)+f2(t)}|
Frequency (Hz)

Fast Fourier Transforms

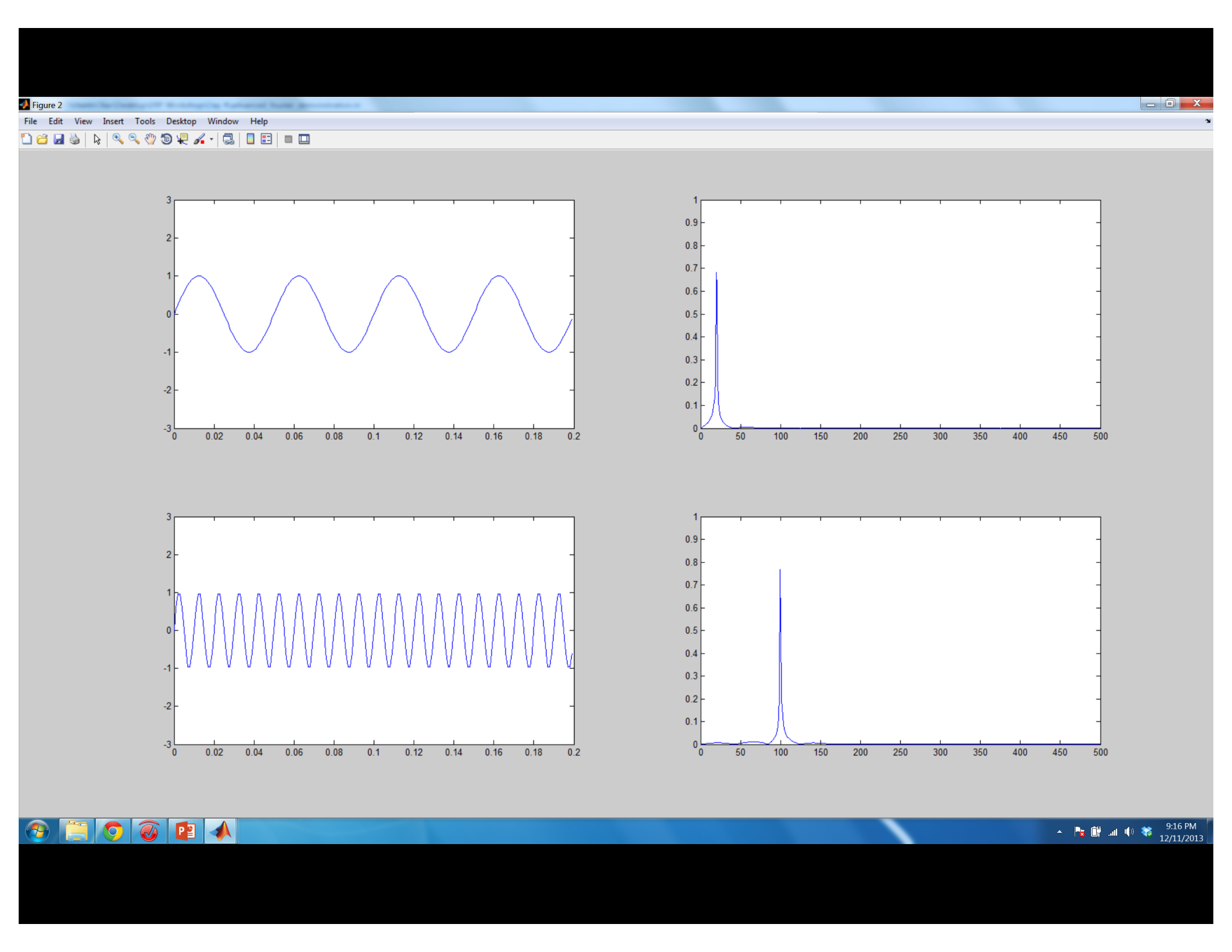
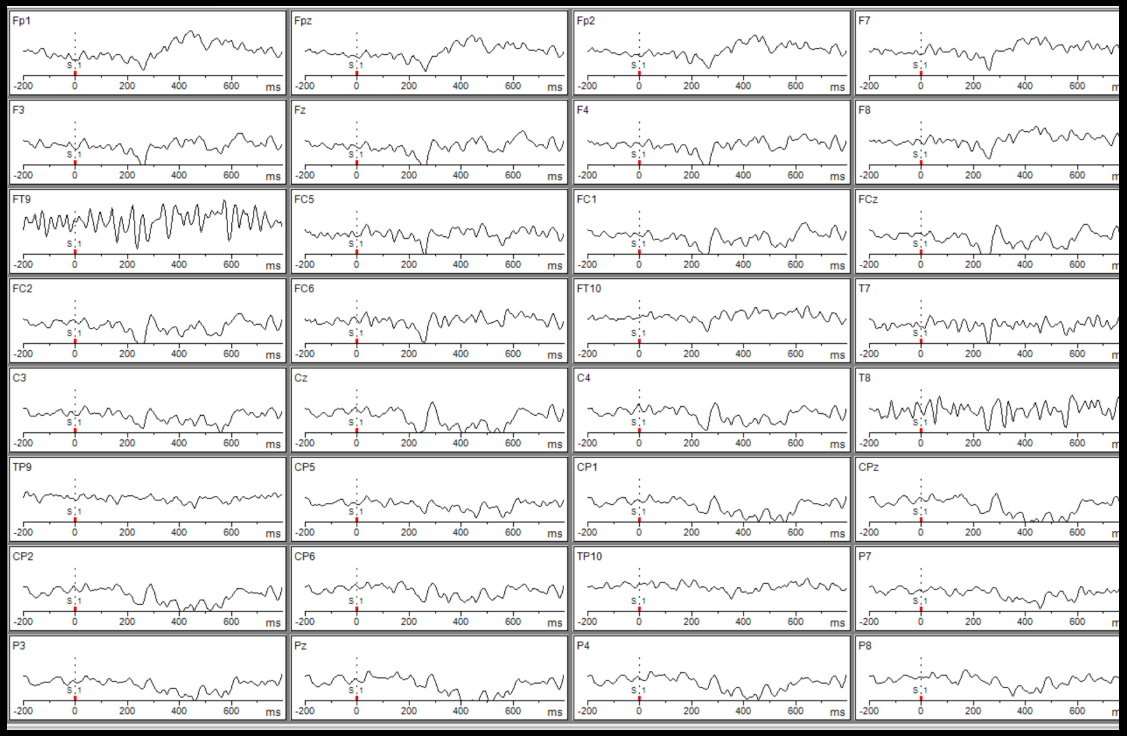
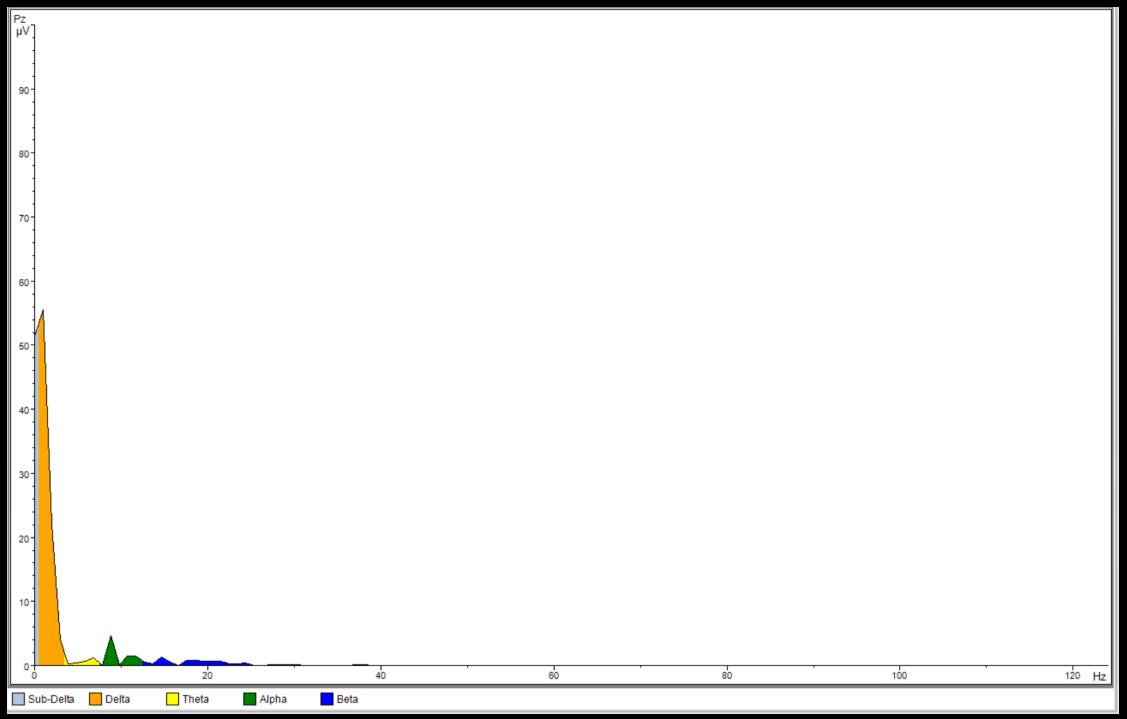


Figure 2
File Edit View Insert Tools Desktop Window Help
3 2 1 0 -1 -2 -3
0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 0.18 0.2
1 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0
0 50 100 150 200 250 300 350 400 450 500
3 2 1 0 -1 -2 -3
0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 0.18 0.2
1 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0
0 50 100 150 200 250 300 350 400 450 500
9:16 PM
12/11/2013

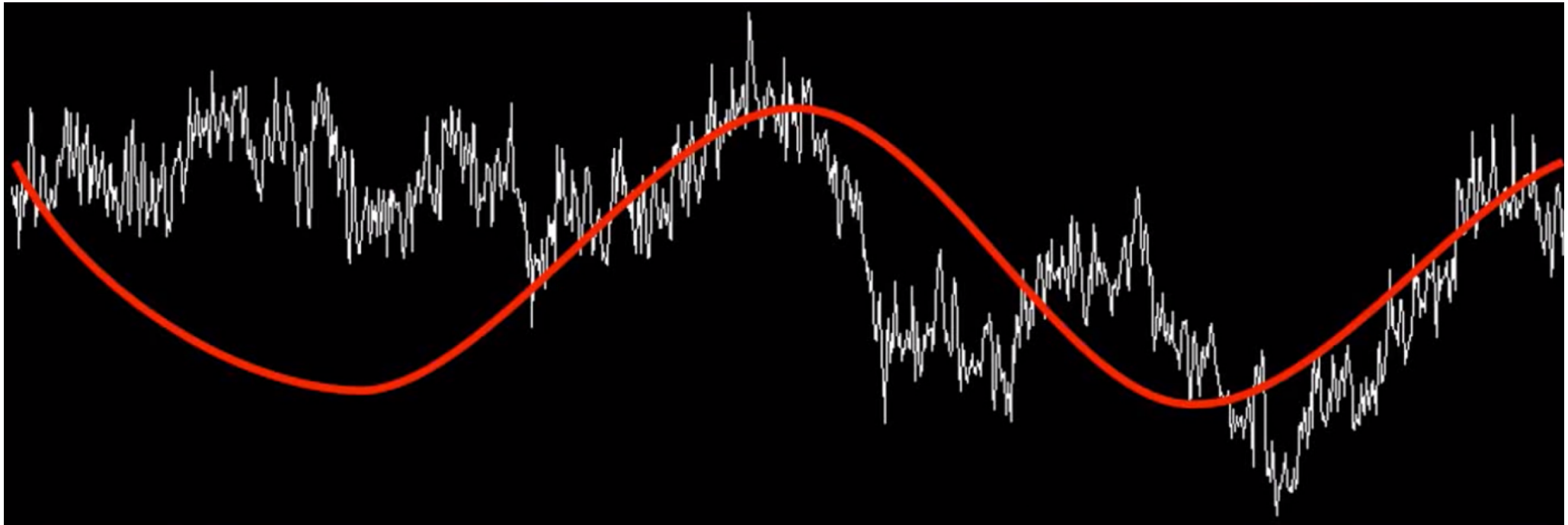

Fp1
Fpz
Fp2
F7
F3
Fz
F4
F8
FT9
FC5
FC1
FCz
FC2
FC6
FT10
T7
C3
Cz
C4
T8
TP9
CP5
CP1
CPz
CP2
CP6
TP10
P7
P3
Pz
P4
P8
-200
0
200
400
600
ms
S 1


Pz
µV
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Hz
Sub-Delta
Delta
Theta
Alpha
Beta

So…

Essentially for each subject you can get a number that quantifies the amount of power in a given frequency band for each channel. Then, statistics can be done accordingly.

How does it work?



signal .product sinewave = power

repeat for each sine wave frequency

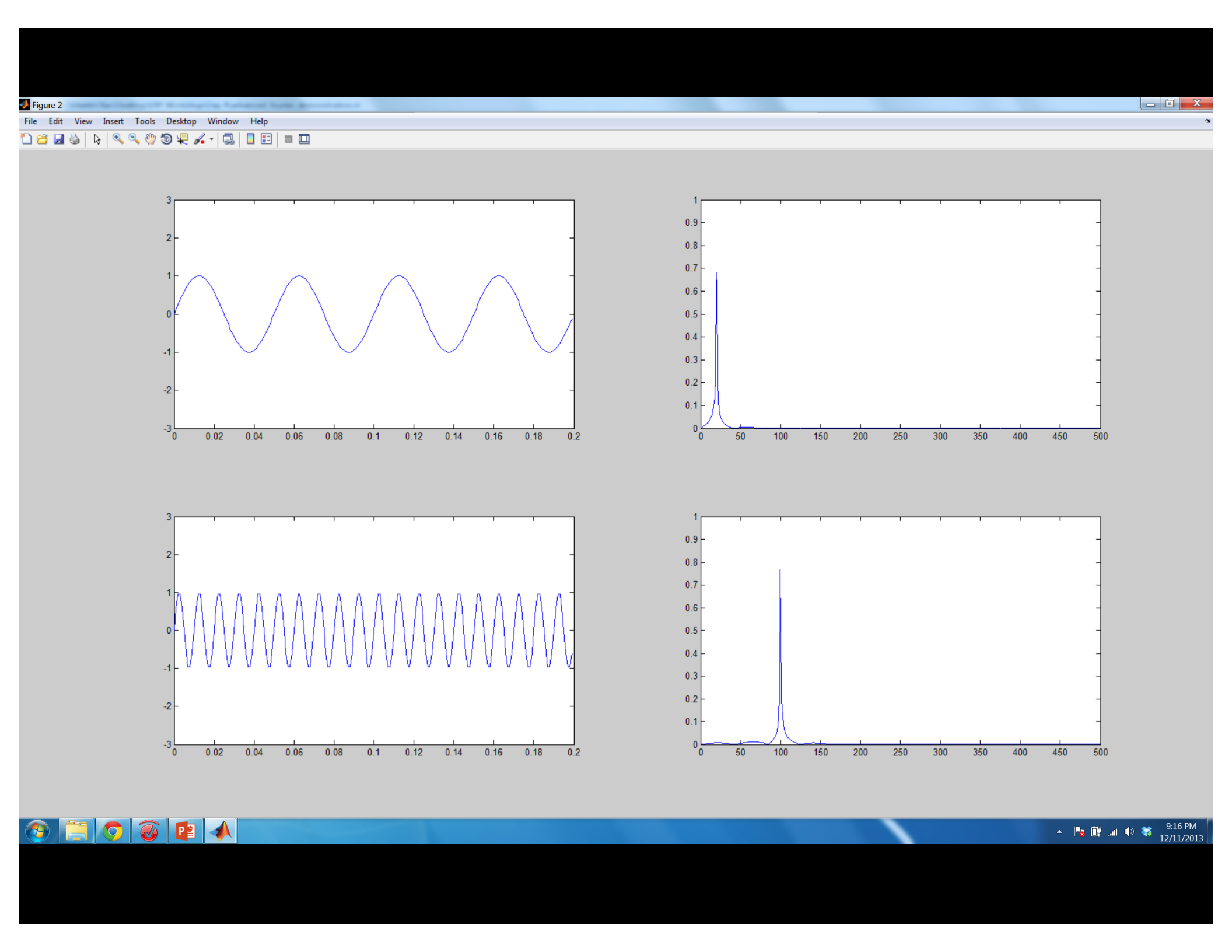


Figure 2
File Edit View Insert Tools Desktop Window Help
3 2 1 0 -1 -2 -3
0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 0.18 0.2
1 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0
0 50 100 150 200 250 300 350 400 450 500
3 2 1 0 -1 -2 -3
0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 0.18 0.2
1 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0
0 50 100 150 200 250 300 350 400 450 500
9:16 PM
12/11/2013

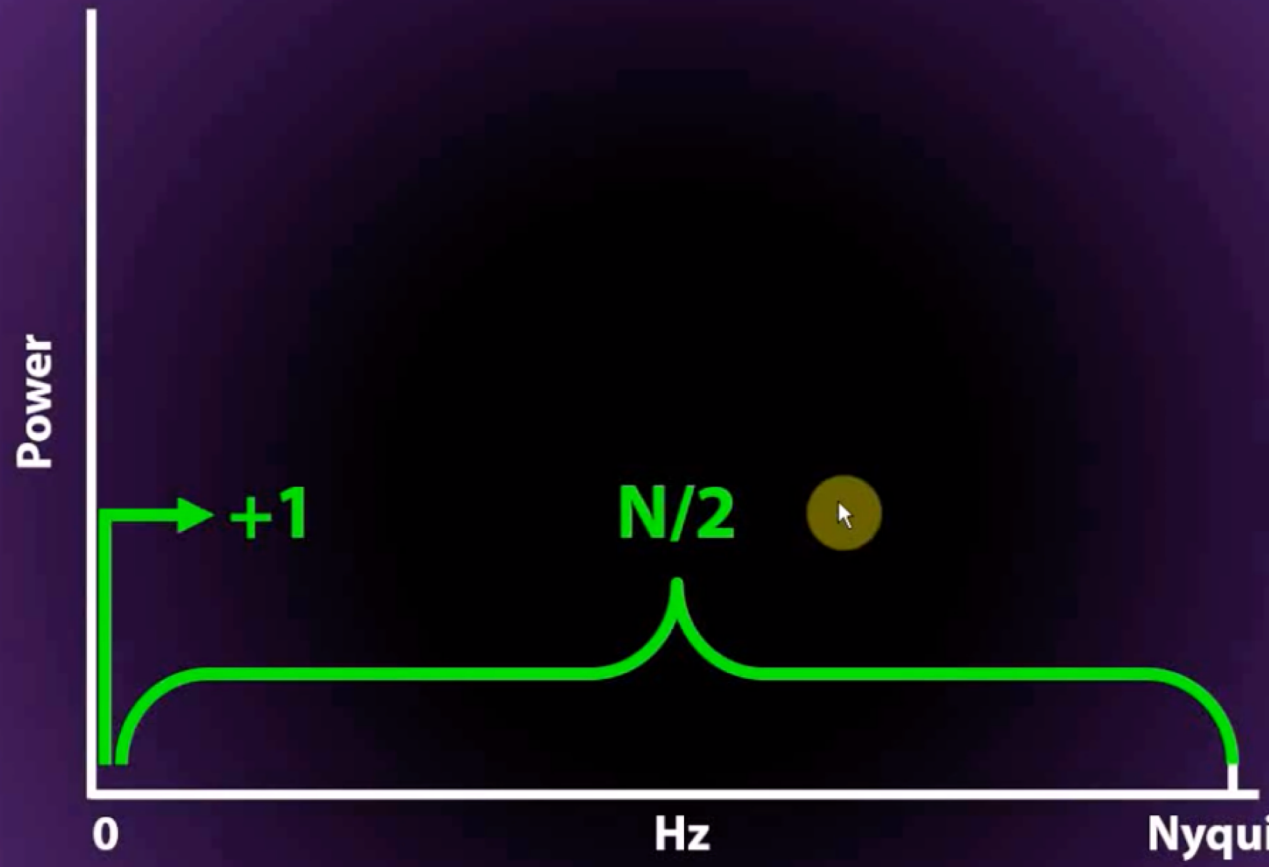
How many frequencies?

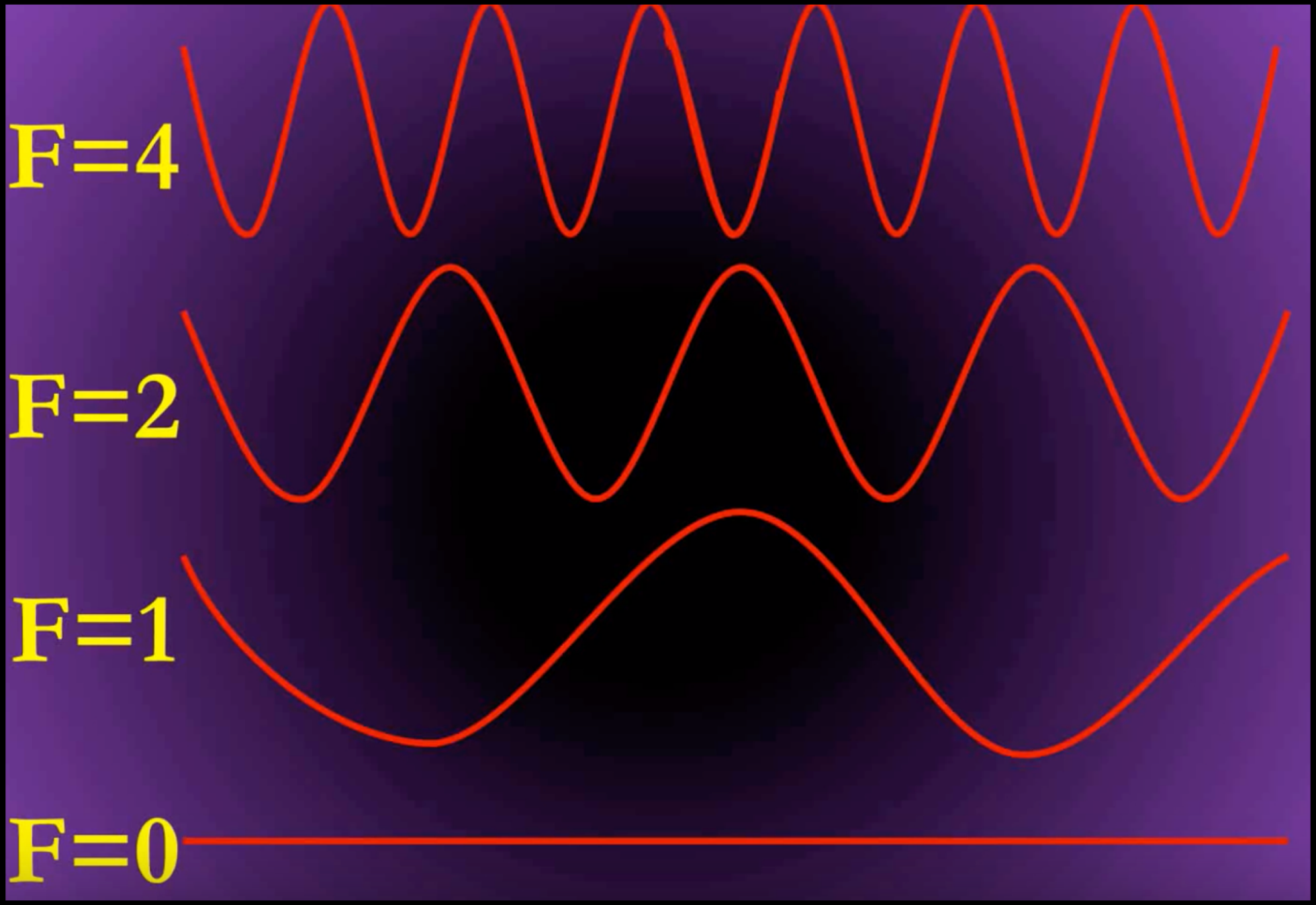
This is actually based on the data.

resolution = sampling rate / data points

To get 1 Hz resolution at 500 Hz you need 500 data points or 1000 ms of data.

Fourier and the number of frequencies

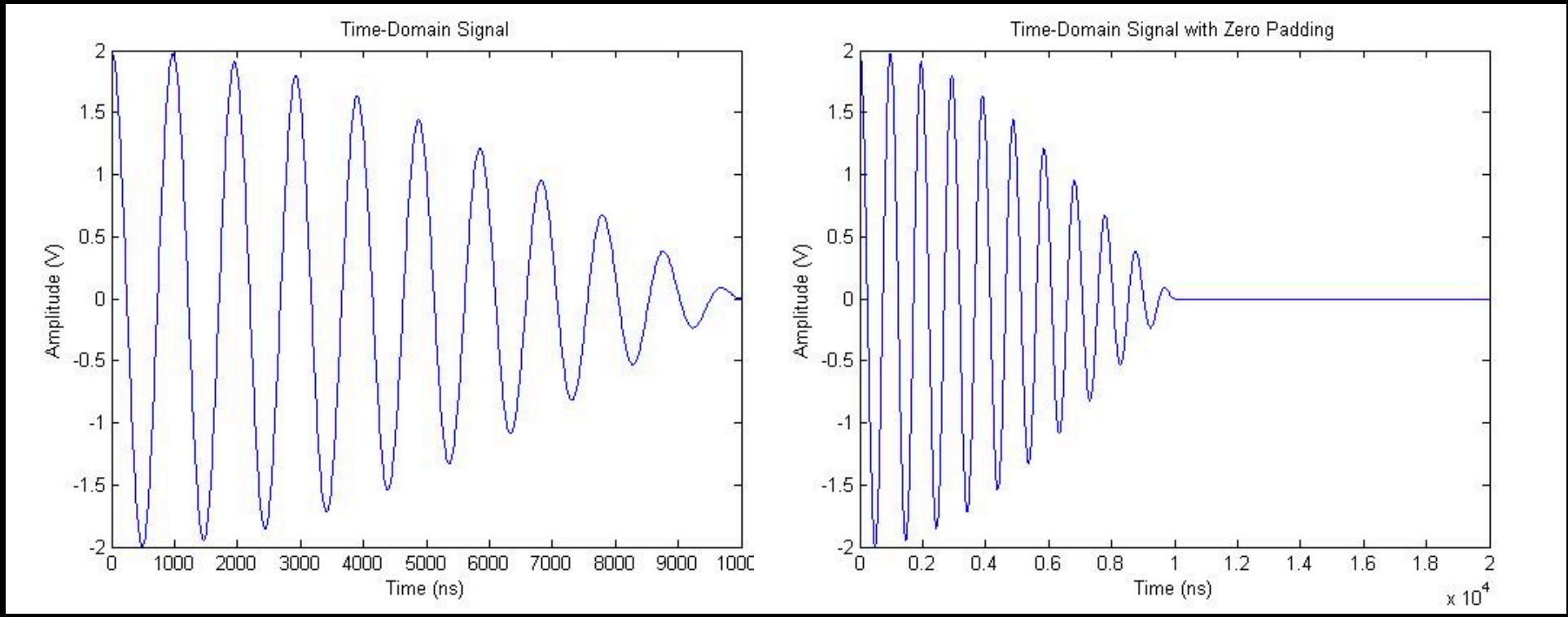


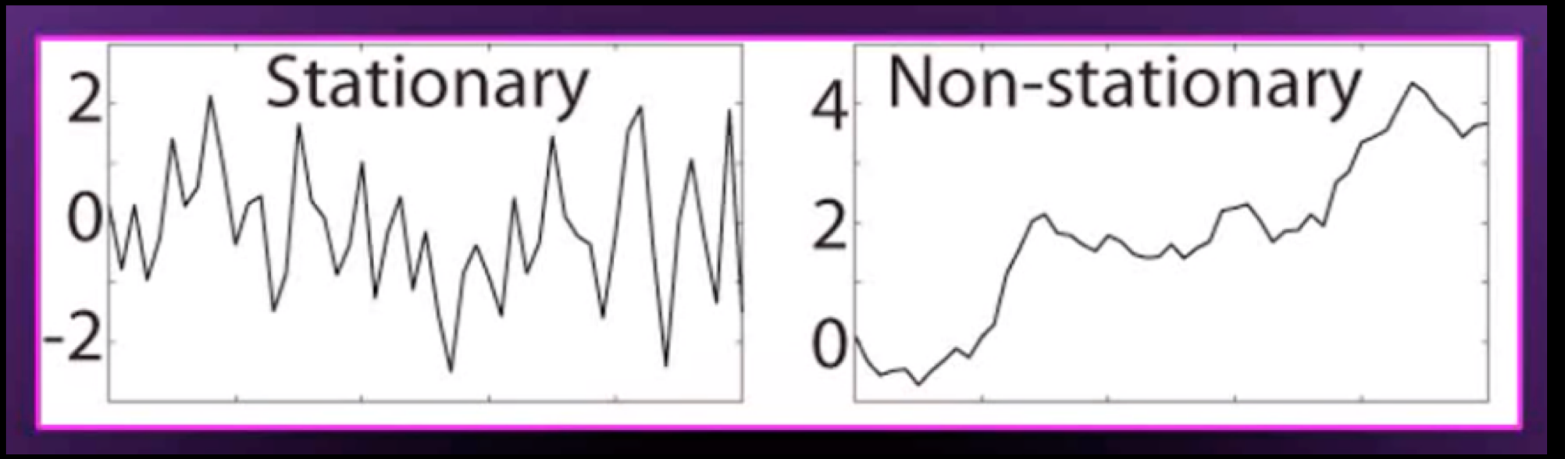

F=4
F=2
F=1
F=0

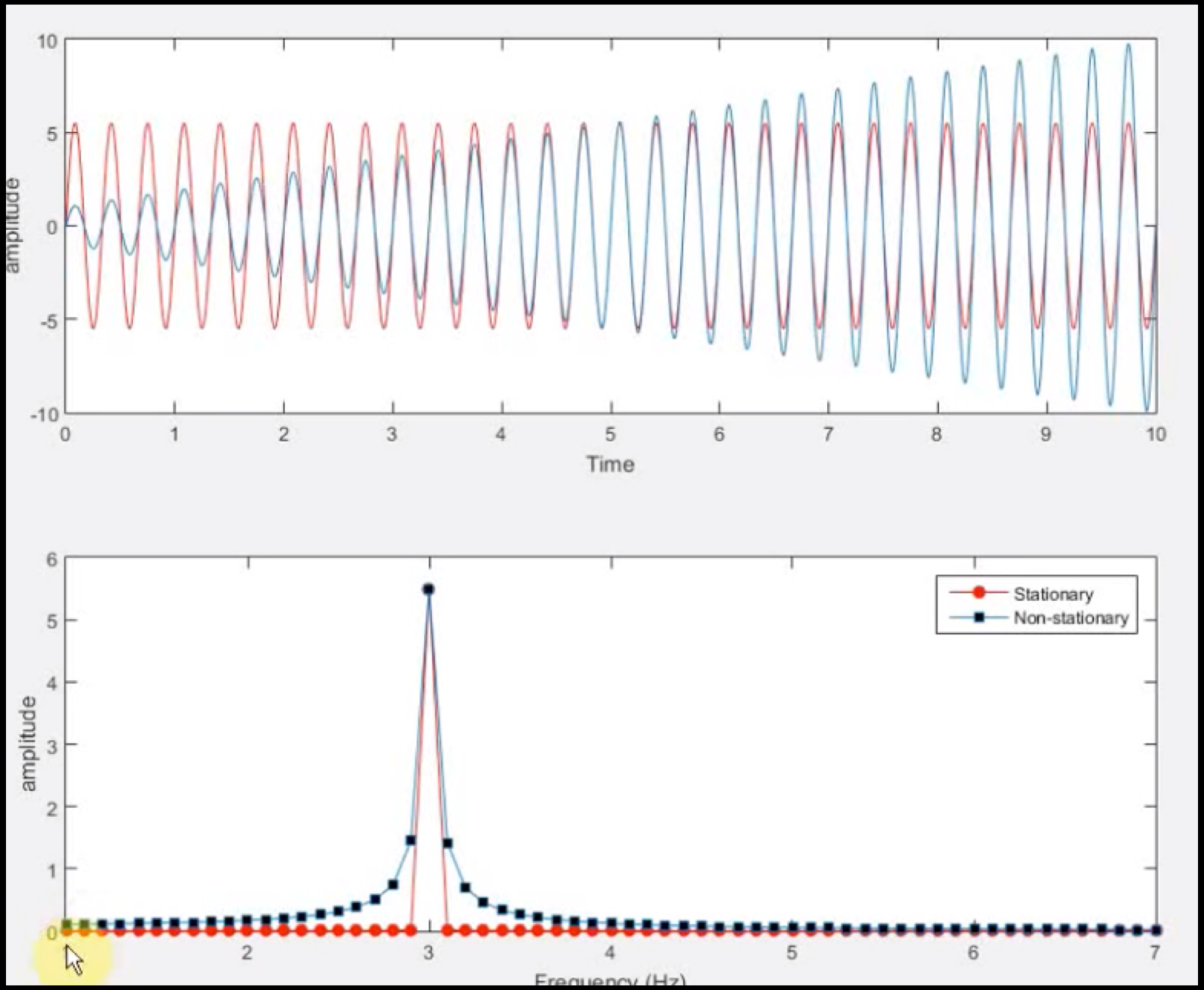
Zero Padding

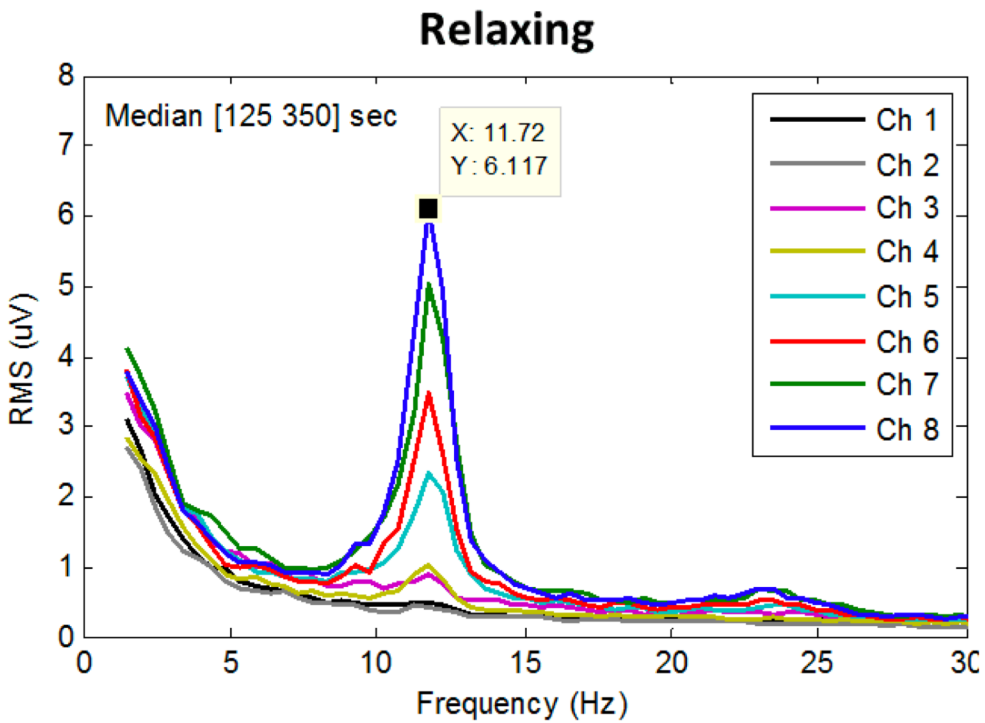
You can add zeros (literally zeros) to your time series data to increase the resolution as needed.

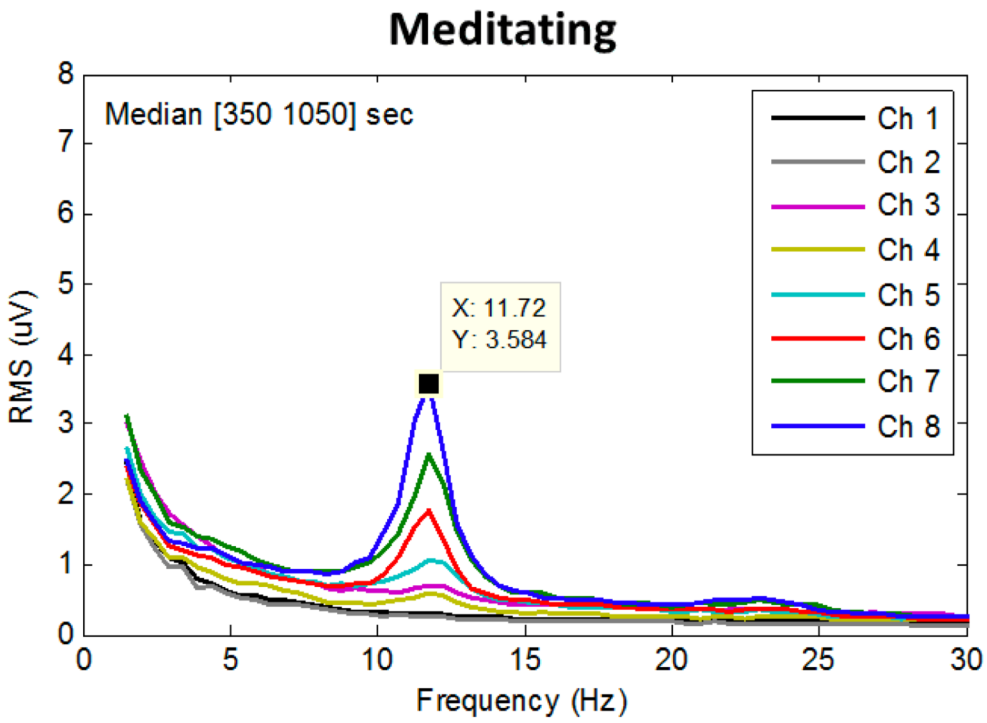
Imagine you have segments of EEG that are short, you can add zeroes to the end to increase the frequency resolution.


Time-Domain Signal
Amplitude (V)
Time (ns)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Time-Domain Signal with Zero Padding
Amplitude (V)
Time (ns)
x 10^4
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


Stationary
2
0
-2
Non-stationary
4
2
0


10
5
0
-5
-10
amplitude
0
1
2
3
4
5
6
7
8
9
10
Time
6
5
4
3
2
1
0
amplitude
Stationary
Non-stationary
2
3
4
5
6
7
Frequency (Hz)



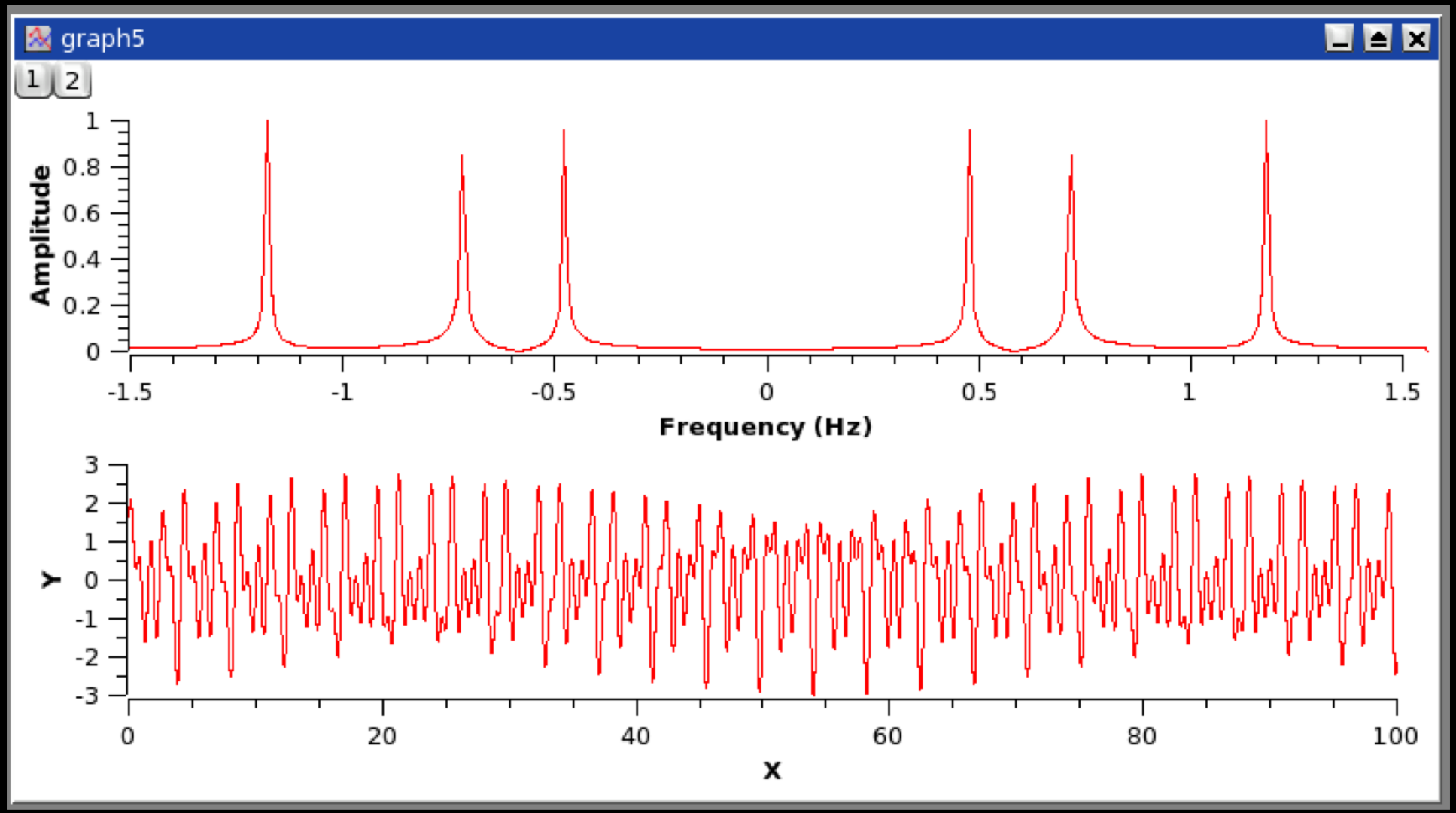


Note, the general decrease in the power spectra follows a power function as is to be expected.

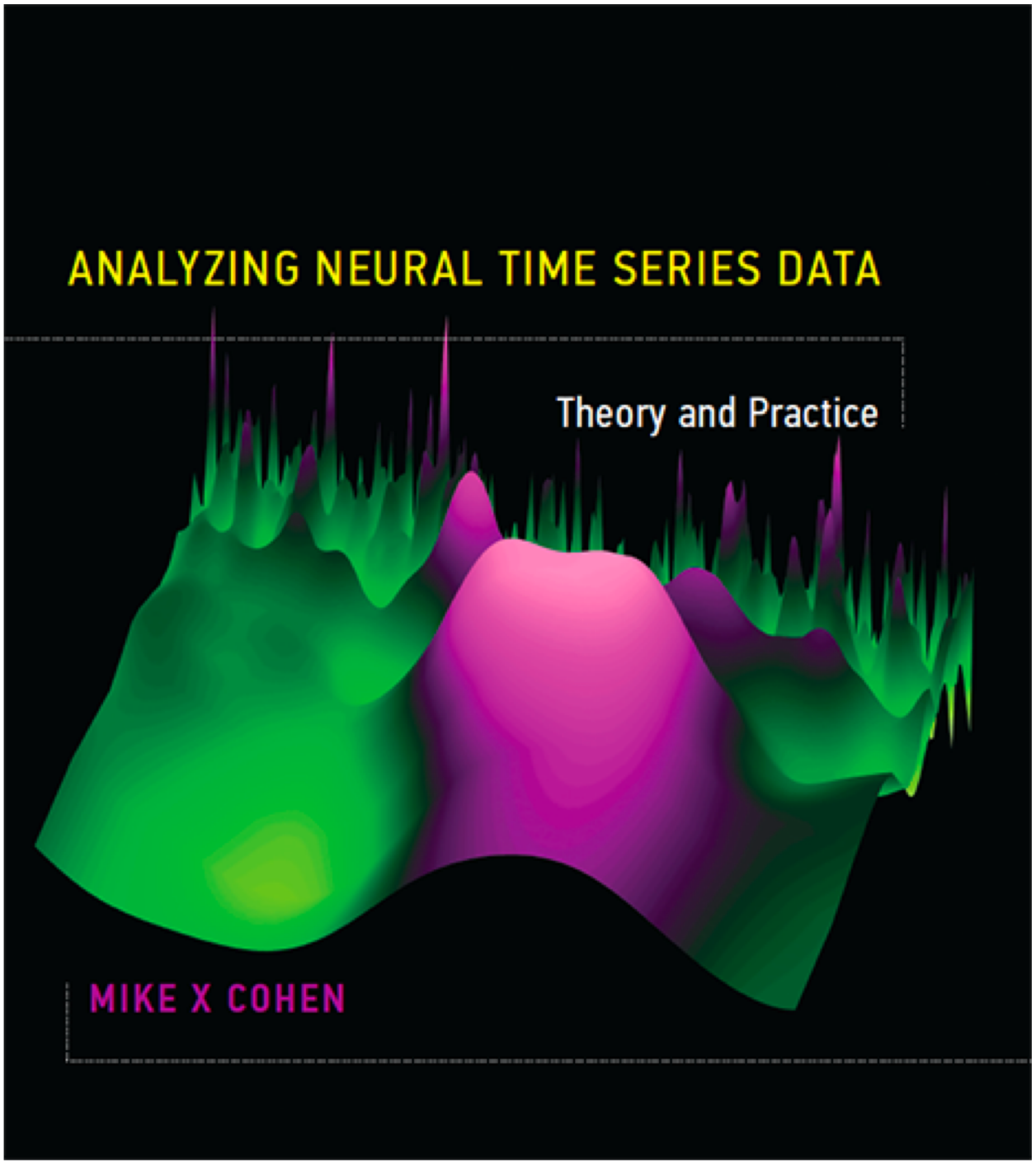
Important Point

The FFT decomposition is a PERFECT deconstruction of time series data into the frequency domain – no information is lost.

IFFT


graph5
1
2
Amplitude
1
0.8
0.6
0.4
0.2
0
-1.5
-1
-0.5
0
0.5
1
1.5
Frequency (Hz)
Y
3
2
1
0
-1
-2
-3
0
20
40
60
80
100
X

ANALYZING NEURAL TIME SERIES DATA



FFT Demo