APPLICATION NOTES

Updated 1.5.2021

Application Note 118   EMG Frequency Signal Analysis

This Application Note will explain how to extract several measures derived from the power spectrum of an EMG signal. It is applicable to Acq*Knowledge* software 3.8.x to 5.x with MP160/150/36R hardware and BSL 3.7.x to 4.x software with MP36/35 hardware. The measures to be extracted are:

| Name	Abbrev.	Description	Units
Median Frequency	MedianF	Frequency at which 50% of the total power within the epoch is reached.	Hz
Mean Frequency	MeanF	Frequency at which the average power within the epoch is reached.	Hz
Peak Frequency	PeakF	Frequency at which the maximum power occurs during the epoch.	Hz
Mean Power	MeanP	The average power of the power spectrum within the epoch. (Units Note: V will be replaced with the voltage units in which the EMG was recorded)	$\dfrac{V^2}{Hz}$
Total Power	TotalP	The sum of the power at all frequencies of the power spectrum within the epoch. (Units Note: V will be replaced with the voltage units in which the EMG was recorded)	$\dfrac{V^2}{Hz}$

There are two ways to extract these measurements.

- **Automated Scoring**—Starting with Acq*Knowledge* 4.0 for Windows or 3.9.2 for Mac the software can extract the measurements in an automated fashion.

- **Manual Scoring**—If running older software or BSL, see the manual scoring instructions starting on page 4.

Part I. Automated Scoring (requires at least Acq*Knowledge* 4.0 for Windows or 3.9.2 for Mac)

Acq*Knowledge* includes a tool for automated EMG Frequency & Power Analysis (choose Analysis > Electromyography > EMG Frequency and power analysis). For a detailed description of the algorithm, consult the software manual (available from the Help menu)

The EMG Frequency and power analysis function will extract Median, Mean and Peak Frequency as well as Mean and Total Power but it will do so for fixed epochs of user-specified duration. That works fine if each EMG activation of interest occurs in perfectly spaced intervals (as would be the case if, for example, the participant was prompted to make a motor response every 2 seconds). A recording where the bursts of EMG activity are perfectly evenly spread out (there are exactly 2 sec between each EMG activation) will look like this:
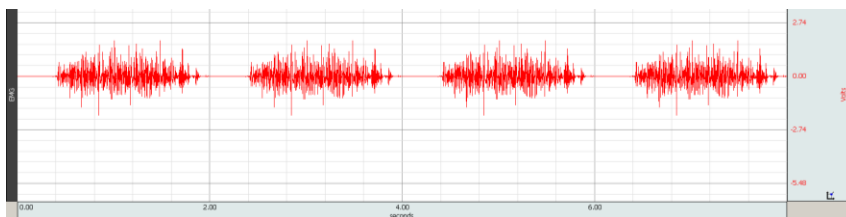

Using the EMG Frequency and power analysis function and setting the width of the epoch for 2 sec will result in measurements being reported for each contraction.

But depending on experiment design, the EMG data might contain only a single contraction of interest or multiple contractions that are spaced in uneven intervals (see the screenshot below). Additional steps are required in those cases.
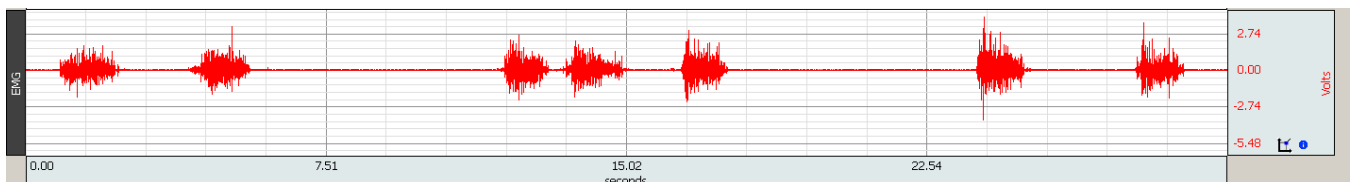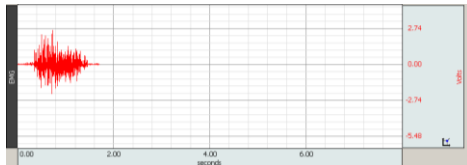
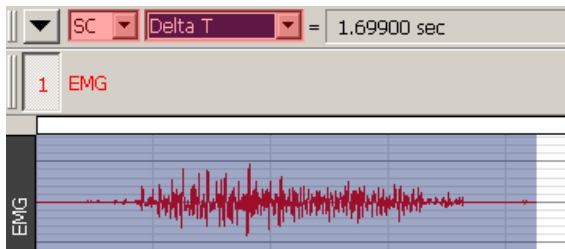### Case A: Extracting measurements from a single contraction

1. Highlight the muscle contraction of interest:
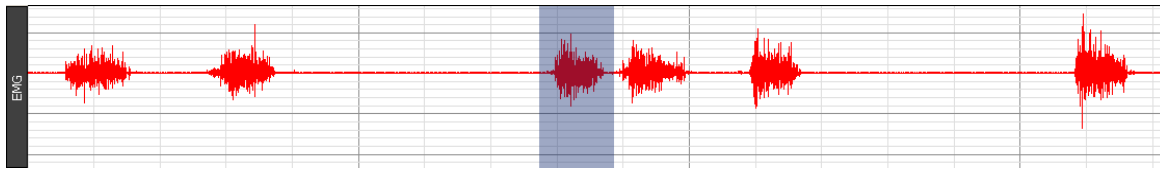
2. Choose Edit > Copy.

3. Choose File > New and create a new graph window.

4. Choose Edit > Paste. The file will contain just a single EMG contraction:

5. Choose Edit > Select All and set a measurement box to delta T. Write down the value in the box.

6. Run the EMG Frequency and power analysis function.

   a. Enter the value from the delta T box when prompted to enter the epoch width.

   b. The software will then extract a single set of measurements for the contraction because the file consists of 1 epoch that is of length identical to the duration of the file.

   c. Select the output type of the analysis via Analysis > Electromyography > Preferences.

   For this example, the Excel output of the analysis would look as follows:

Case B: Extracting measurements from multiple contractions

This is very similar to case A (above).

1. Decide on the epoch width—the time interval within which the EMG contraction of interest will be analyzed.

   • This will be the same for all EMG responses, so choose a width that will be at least as long as the duration of the longest EMG activation. This example assumes that an epoch width of 2 sec is chosen.

2. Highlight the first EMG contraction of interest so that the entire EMG contraction is highlighted and the delta T (the width of the highlighted section) is exactly 2 sec.

- For efficient selection, use the Selection palette (Display > Show > Selection palette):

    a.) Place the I-bar at the beginning of the EMG contraction.

    b.) Change the value for Right (this is the right edge of the selection) in the Selection Palette to 2 plus its current value.

    c.) Hit the Tab key on the keyboard.

    In this case, it would be changed from 0.79 to 2.79. This will result in the software highlighting exactly 2 seconds of data.
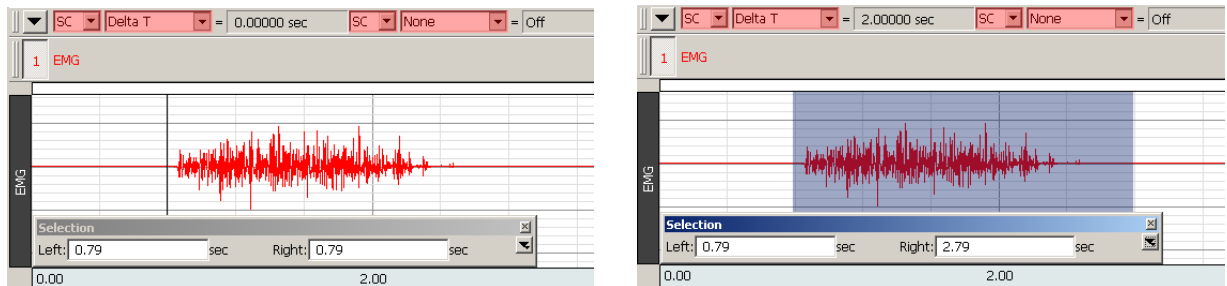
3. Choose Edit > Copy.

4. Choose File > New (New Graph option) to create a new File.

5. Choose Edit > Paste and the new file will contain the EMG contraction.

6. To create a file that is a concatenation of EMG contractions, each contained within a 2-sec window of data, repeat these steps (except that you will not need to create a new file in subsequent steps) to copy and paste more EMG contractions in the new file (see the figure below).
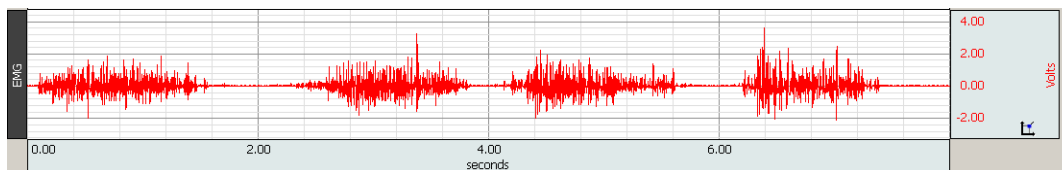

7. Run the EMG Frequency and power analysis function and set the epoch width to 2 sec.

- It will provide you with measurements for all of the contractions you have pasted into this new file. In this example 4 contractions are pasted in and the Excel output will look like this:

Microsoft Excel - TempSpreadsheet 2.xls

A1   *fx*   EMG Frequency and Power Analysis, CH 1, EMG

|	A	B	C	D	E	F	G
1	EMG Frequency and Power Analysis, CH 1, EMG						
2							
3	Epoch wid	2000	samples				
4							
5	Epoch	MedianF	MeanF	PeakF	MeanP	TotalP	
6	1	93.38521	143.9689	93.38521	2.96E-07	7.61E-05	
7	2	89.49416	142.0233	50.58366	3.59E-07	9.23E-05	
8	3	89.49416	138.1323	83.65759	3.62E-07	9.31E-05	
9	4	91.43969	140.0778	81.71206	4.36E-07	0.000112	
10							

Part II. Manual Scoring (Current BSL and older versions of Acq*Knowledge*)

When running Biopac Student Lab or older versions of Acq*Knowledge*, Median, Mean and Peak Frequency as well as Mean and Total Power for each EMG contraction are obtained with manual steps.

1. Highlight the EMG contraction.

2. Choose Transform > FFT and establish the following settings:
   Pad with zeros, magnitude, Linear, Windows: Hamming.

3. A new graph will be generated with Magnitude as a function of frequency.
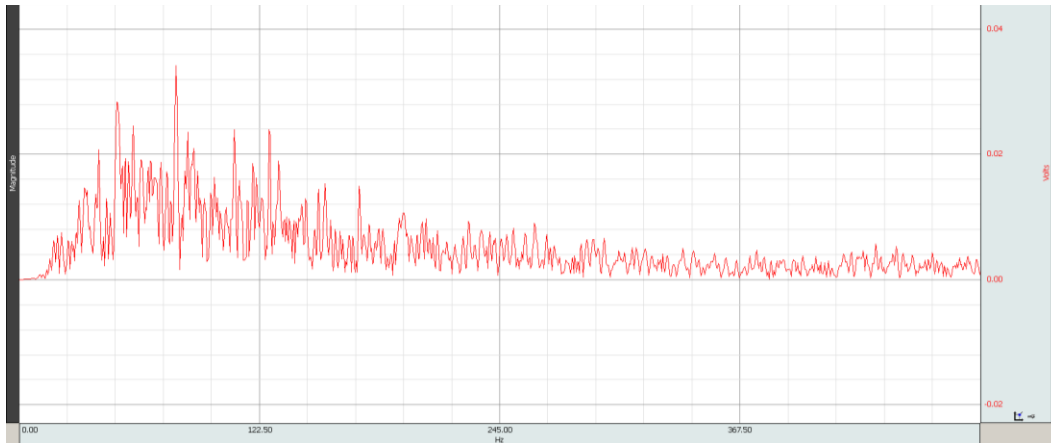
4. To obtain the graph of the squared FFT magnitude, choose Transform > Waveform Math, enter the following parameters (CH1 Magnitude * CH1 Magnitude => New), and click OK.

5. This should result in two channels in the graph window. The top channel represents the FFT magnitude and the bottom channel (labeled CH1*CH1) is the squared FFT magnitude.
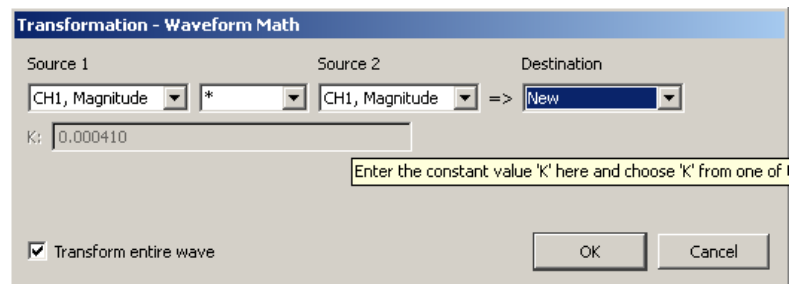
   - Choose Display > Autoscale Waveforms to autoscale the channels if necessary.

6. Create the integral of the squared FFT channel.

   a.) Select the bottom channel and choose Edit > Duplicate waveform.

   b.) Select the new channel that is generated (the graph window will have 3 channels and you need to select the bottom channel).

    c.) Choose Transform > Integral.
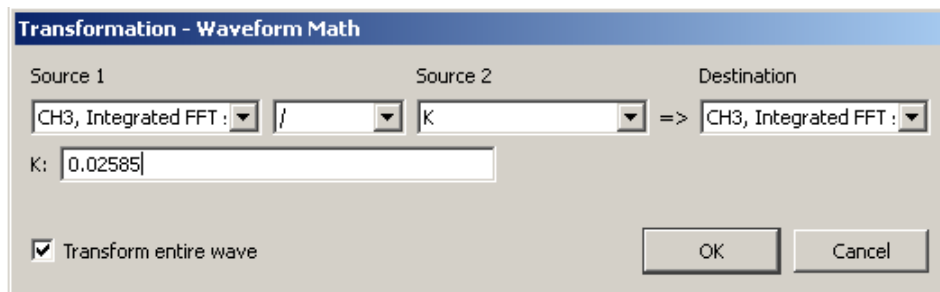
    d.) Choose Display > Autoscale Waveforms.
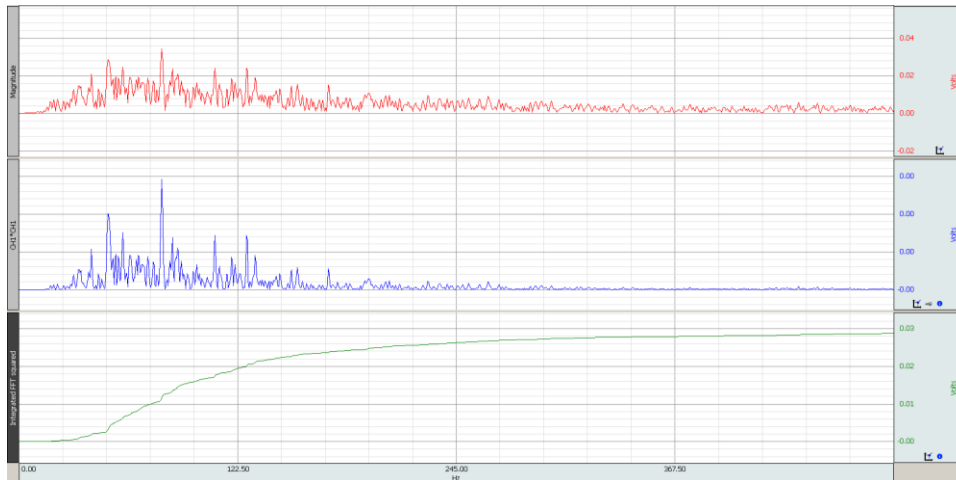
    e.) Change the channel label by double-clicking on its label (where it says CH1*CH1) and entering "Integrated FFT squared."

7. Normalize the Integrated FFT squared channel.

    a.) Select the Integrated FFT channel.
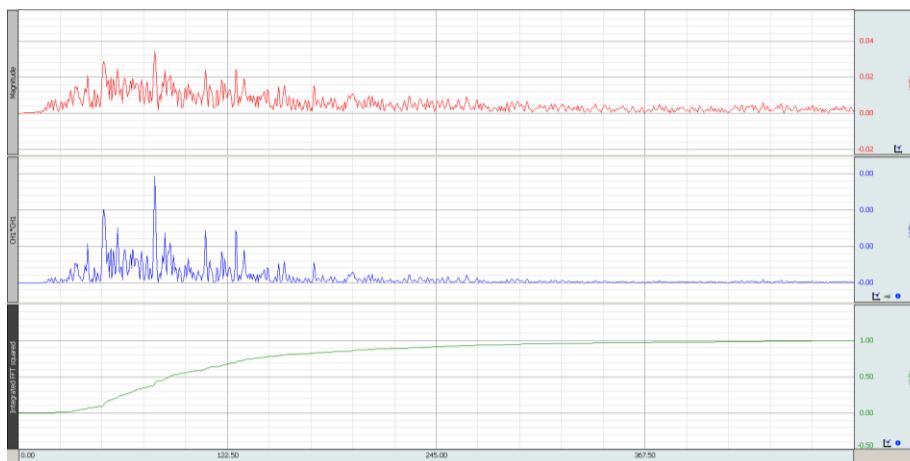
    b.) Choose Edit > Select All.

    c.) Set a measurement box to Max and write down the measurement. The result should resemble this:
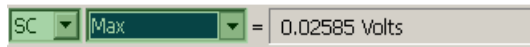
8. Choose Transform > Waveform Math, enter the following parameters (CH3 / K => CH3), enter K as the value from the Max measurement box, and click OK.

9. Choose Display > Autoscale Waveforms and the screen should resemble this:

10. Obtain the desired measurements.

- The following steps describe how to obtain each measurement (report measurement results in the units indicated in parentheses).

- **IMPORTANT**—If different instances of EMG activation are to be compared in terms of Mean Power and Total Power, keep the duration of each identical or, otherwise, perform normalization.

- Write measurement results down or paste them to the Journal via Edit > Journal > Paste Measurements.

Median Frequency (Hz)

Definition: Frequency at which 50% of the total power within the epoch is reached.

Set measurement boxes to CH3 and Value and SC and Freq (frequency). Place the cursor exactly where value is 0.5. The Freq measurement result is the Median Frequency.
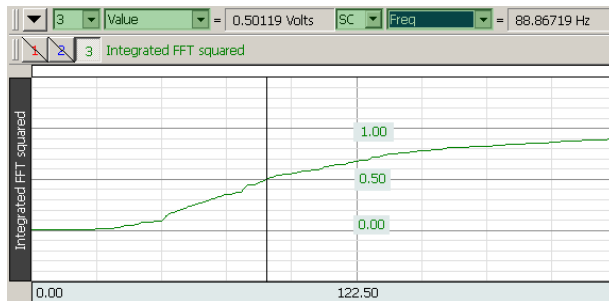
Mean Frequency (Hz)

Definition: Frequency at which the average power within the epoch is reached.

Set measurement boxes to CH3 and Mean and SC and Frequency. Choose Edit > Select All.
Write down the Mean measurement result—in our example, the result is 0.76293 volts:

Set another measurement box to CH3 and Value. Click with the I-bar on the Integrated FFT squared waveform (CH3) to place the I-bar exactly at 0.76293 volts (as indicated in the Mean measurement result). Use the keyboard arrow keys to move the I-bar left or right to place it precisely at the location where the Mean measurement result reads 0.76293. The Frequency measurement result is the Mean Frequency.

Peak Frequency (Hz)

Definition: Frequency at which the maximum power occurs during the epoch.

Set a measurement box to CH2 (the squared FFT channel) and Max F. Choose Edit > Select All.
The Max F measurement result is the Peak Frequency.

Mean Power (Volts^2/Hz)

Definition: The average power of the power spectrum within the epoch.
Units Note: V will be replaced with the voltage units in which the EMG was recorded.

Set a measurement box to CH2 (The squared FFT channel) and Mean. Choose Edit > Select All.
The Mean measurement result is the Mean Power.

Total Power (Volts squared/Hz)

Definition: The sum of the power at all frequencies of the power spectrum within the epoch.
Units Note: V will be replaced with the voltage units in which the EMG was recorded.

Set a measurement box to CH2 (the squared FFT channel) and Integral. Choose Edit > Select All.
The Integral measurement result is the Total Power.

Related Readings

Thongpanja, S. & Phinyomark, Angkoon & Limsakul, Chusak & Phukpattaranont, P.. (2015). Application of Mean and Median Frequency Methods for Identification of Human Joint Angles Using EMG Signal. Lecture Notes in Electrical Engineering. 339. 10.1007/978-3-662-46578-3_81.

Abstract: The analysis of surface electromyography (EMG) signals is generally based on three major issues, i.e., the detection of muscle force, muscle geometry, and muscle fatigue. Recently, there are not any techniques that can analyse all the issues. Mean frequency (MNF) and median frequency (MDF) have been successfully applied to be used as muscle force and fatigue indices in previous studies. However, there is the lack of consensus upon the effect of muscle geometry on the basis of varying joint angles. In this paper, the modification of MNF and MDF using a min-max normalization technique was proposed to provide a consistent relationship between feature value and joint angle across subjects…

Keywords: Feature extraction, Frequency analysis, Muscle fatigue, Spectral analysis, Surface electromyography signal

Phinyomark, Angkoon & Thongpanja, S. & Hu, Huosheng & Phukpattaranont, P. & Limsakul, Chusak. (2012). The Usefulness of Mean and Median Frequencies in Electromyography Analysis. 10.5772/50639.

Abstract: Mean frequency (MNF) and median frequency (MDF) are two useful and popular frequency-domain features for electromyography analysis both in clinical and engineering applications. MNF and MDF are frequently used as the gold standard tool to detect fatigue in the target muscles using EMG signals. The effectiveness of MNF and MDF under many experimental conditions is presented and confirmed in this chapter…

Keywords: electromyography, muscle force, muscle geometry, muscle fatigue, human-computer interaction (HCI), ergonomics, occupational therapy, sport science