# EMG Signals Case Study: A Time and Frequency Domain Analysis

M. Munteanu[1], C. Rusu[2], D. Moga[3], R. Moga[3], and G. Tont[4]

[1] Technical University of Cluj-Napoca, Faculty of Electrical Engineering, Cluj-Napoca, Romania
[2] Technical University of Cluj-Napoca, Faculty of Electronics, Telecommunications and Information Technology, Cluj-Napoca, Romania
[3] Technical University of Cluj-Napoca, Faculty of Automation and Computer Science, Cluj-Napoca, Romania
[4] University of Oradea, Faculty of Electrical Engineering and Information Technology, Oradea, Romania

*Abstract*— **The paper aims to analyze the time and frequency domains of EMG signals coming from healthy patients and from patients with muscular disorders (muscular myopathy and neuropathy). The study of these signals can reveal some features in time domain or in frequency domain, that can serve as a basis for diagnosis.**

*Keywords*— **EMG signals, time/frequency domain analysis, autocorrelation, STFT.**

## I. Introduction

The EMG signal records the electrical activity of muscles, being used to detect their abnormal electrical activity, which is a characteristic for certain diseases such as muscular dystrophy, inflammation of muscles, herniated disc or nerve problems of the limbs [1]. When a muscle is active, it will produce an electric current proportional with the level of activity (stimulus) that the muscle may have been subjected [1].

The EMG signal is often used, through its amplitude and frequency information, to determine the effort developed by a muscle or its degree of fatigue, during isotonic/isometric exercises [2].

The simplest way to record the signal that comes from the muscles of certain areas is the SEMG (Surface EMG), the electrodes being applied on the skin covering the muscle under investigation [1]; such a signal can be seen in Figure 1.

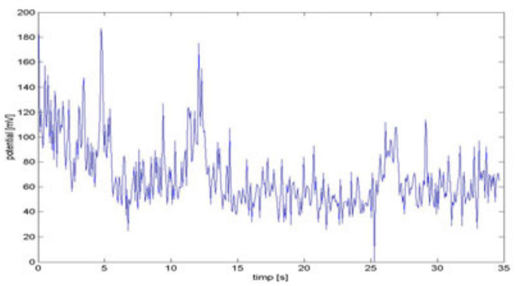


Fig. 1 SEMG signal recorded from a biceps subjected to a load of 2 kilograms [3]

However, the “classical” recording mode of this signal, which offers a high degree of accuracy, is the intra-muscular EMG, that involves placing a needle type electrode into the investigated muscle. Even though this measurement has a high degree of accuracy, it also has the disadvantage of the invasive nature (it causes discomfort and pain) [1].

A fundamental problem in biomedical signal analysis consists in finding information of interest: there are biological signals (ECG) for which this is codified in the form (morphology / amplitude of PQRST complex) and in its spectrum, but there are signals where the information of interest is “hidden” in the signal’s amplitude and spectrum [3]. In addition, for some medical signals, a certain periodicity or rhythmicity can be detected.

So, when analyzing the effort of the muscle, one is interested in its time response - namely, the electromyogram (EMG) amplitude for effort, but also in the spectrum of frequencies resulting from the stimulation. In addition, we will study the existence of a rhythmic nature within a signal obtained by invasive measuring from the leg muscles.

## II. Medical considerations

Neuropathy is a disease that affects the nervous system (a single nerve or several nerves simultaneously) and can lead to diseases of the motor fibers. Its diagnosis can be done using the EMG signal, in conjunction with nerve conduction velocity study [4].

Myopathy represents a disease that occurs in muscle fibers and which leads to a decrease of muscle tone in hands and legs (and in the abdomen or thorax). Also, in its case, the EMG investigation can help in diagnosing the disease and to estimate its evolution in time [4].

Given what was mentioned previously, this paper aims to investigate some EMG signals (obtained through invasive recordings, for a healthy patient and two subjects suffering of certain muscle diseases) with time and frequency analysis methods.

S. Vlad and R.V. Ciupa (Eds.): MEDITECH 2011, IFMBE Proceedings 36, pp. 202–205, 2011.
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## III. METHOD AND RESULTS

The analyzed EMG signals were taken from the database [5].

As mentioned in [5], the signals were acquired while the investigated subject executed flex motion of the leg, using concentric electrodes of 25 mm, which were placed into the "tibialis anterior" muscle of the patient (the electrode was repositioned until a satisfactory EMG record was obtained).

The acquired signals were collected from three adults (one without muscle problems and the other two with different diseases) [5] and their appearance in time domain is presented in Figure 2:

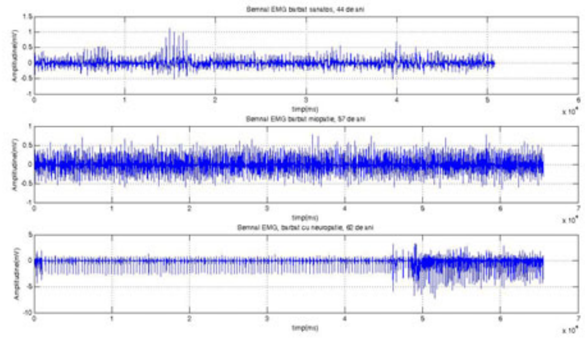

Fig. 2 The EMG signal taken from the three patients

### A. EMG Signal Analysis in Time Domain

The EMG recording offers the sampled version of a continuous signal, given by the potentials collected from the muscle under investigation. If that muscle will be subjected to regular exercise (in this case flexing the leg), normally every flex of the leg (so every maximum effort) will have an associated peak within the EMG signal. The regular sequence of these maximum potentials (given by the periodical flexing of the leg) could be considered as a periodicity (rhythmicity) characteristic inside the signal.

Three typical EMG signals were subjected to a time domain analysis, to detect the existence of a periodicity (rhythmicity). In order to perform this analysis, a constant section from the beginning of each signal was chosen, for which peak values were detected (depending on the chosen threshold) and their position on the time axis.

The results, obtained with techniques of Virtual Instrumentation - LabVIEW programming [6], [7], are presented in the following figures.

If the local maxima points seen between two absolute maxima are ignored, and considering that the peak pairs corresponding to the moments on the time axis (99.66 and 101.86, 798.98 and 802.08;) come, each one from a leg flexing, then a certain periodicity (rhythmicity) is noticed in the development of high value potentials, at the same time with the leg flexing: they occur on the time axis around values with indexes 100, 450, 800 and 1200. In fact, these highlight a period of about 400*(sampling interval), which is actually the period that the patient is flexing his leg (the maxima related around the samples with index 1000 on the time axis were not considered, as the form of the signal was indicating an artifact of low frequency, probably due to the movement of the patient body).


Fig. 3 The positioning and the amplitude of the signal's peak in the EMG taken from a healthy patient

This periodicity (rhythmicity) can also be highlighted by the vectorogram obtained using the Hilbert transform [8]

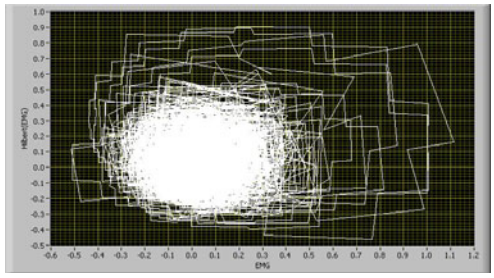

Fig. 4 The Vectorogram of the EMG signal taken from a healthy patient

It can be noticed that the trajectory is concentrating on a limit circle, except for some eccentricities, which can be explained taking into account the evolution of the EMG signal due to fatigue over time. This is also the reason why we selected only the first 1250 samples of signal, the muscular fatigue and the stress influencing both the amplitude of the maximum potentials and also the periodicity (rhythmicity) of their occurrence.

Analysis of signals from patients with muscle problems are presented in figures 5 and 6.

It is noticed that for these signals one can not identify any more the periodicity (rhythmicity) of the potential maxima' occurrence, that was highlighted for the signal taken from a healthy patient.

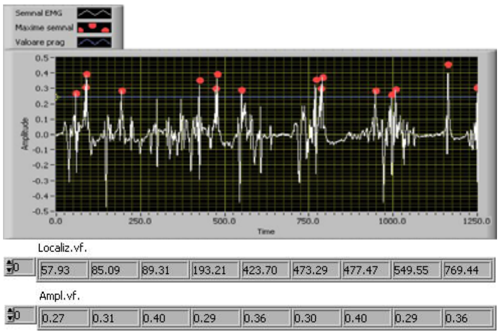


Fig. 5 The positioning and the amplitude of signal's peaks, of the EMG taken from a patient with myopathy

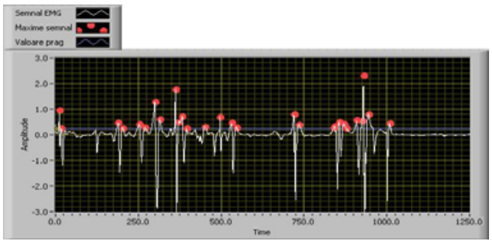


Fig. 6 The EMG signal taken from a patient with neuropathy

The periodicity (rhythmicity) of the occurrence of potential maxima was further investigated by performing the autocorrelation (in Matlab) for each of the studied sequences.

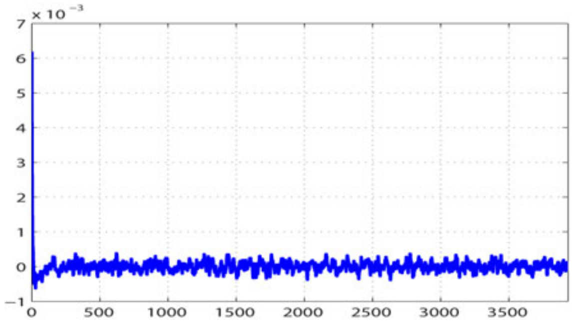

Fig. 7 Autocorrelation of the EMG sequence (miopathy case)

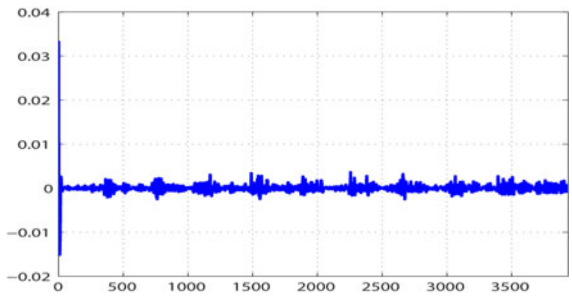

Fig. 8 Autocorrelation of the EMG sequence (neuropathy case)

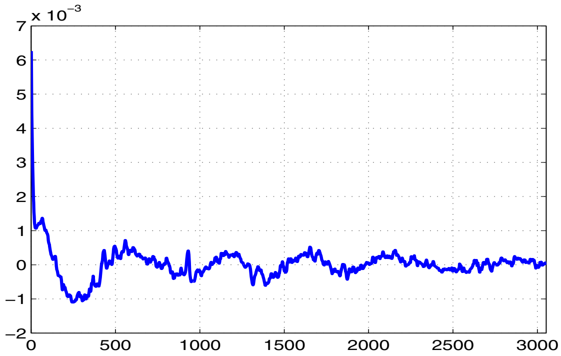

Fig. 9 Autocorrelation of the EMG sequence for a healthy patient

Therefore, healthy muscles subjected to a periodic effort, will provide an EMG signal that, at least for its early phase (where muscular fatigue and stress are not yet installed), presents some features of periodicity (rhythmicity) - demonstrated also by the results of the autocorrelation performed on the first third of the sequence of samples (see figure 9). This tendency is not valid any more for signals taken from patients with various muscle disorders (muscular myopathy, neuropathy – see figures 7 and 8), the peaks corresponding to the effort period (flexing the leg) being "drowned" in many different potentials of different values determined by the abnormal neural activity of muscles.

### B. *The Analysis of the EMG Signals in the Frequency Domain*

Besides the analysis in time-domain, these signals were further investigated through a more complex analysis, such as time-frequency type. This was performed in Matlab [9], using a Short Time Fourier Transform (STFT) in 1024 points and a Hamming Window in 256 points [8].

The results of this analysis are presented as follows:

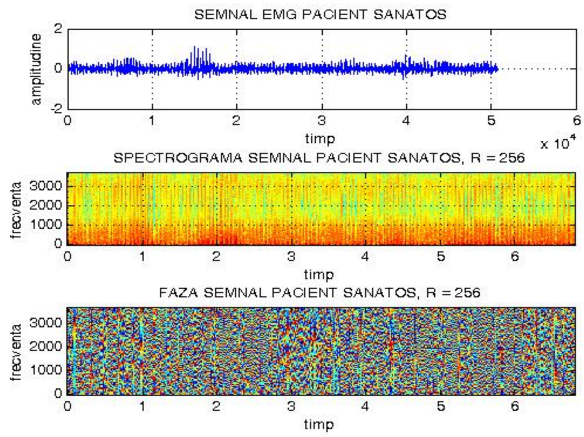


Fig. 10 The EMG signal/ Spectrogram/ Phase Diagram, healthy patient

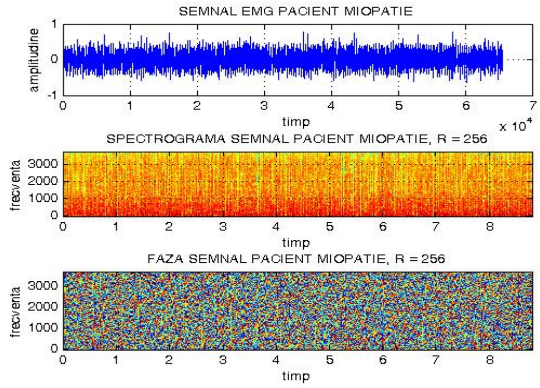


Fig. 11 The EMG signal/ Spectrogram/Phase Diagram, patient with myopathy

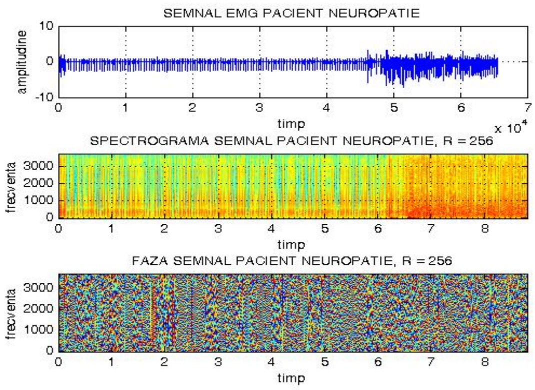


Fig. 12 The EMG signal/ Spectrogram/Phase Diagram, patient with neuropathy

## IV. COMMENTS AND FURTHER DEVELOPMENTS

The investigation in time domain of the three EMG signals revealed that for healthy muscles subjected to regular exercise, it can be highlighted the existence of a rhythmicity in the occurrence of maximum potentials, at least for the early part of the EMG signal, where muscular fatigue and stress hasn't been installed yet. For signals collected from patients with diseases (in this case muscular myopathy and neuropathy), this trend can no longer be observed, the maximum potentials (corresponding to the period of exercise - flexing the leg) being "drowned" in the multitude of potentials determined by the abnormal neural activity of muscles.

In frequency domain, the results are consistent with those of time domain, meaning that the periodicity is noticeable at the healthy patient.

For the signal acquired from the healthy patient, there are two frequency bands in which the components are significant; these frequency bands are not varying dramatically (very much) in time. We are talking about a low frequency band (up to 1 kHz) and then a higher frequency band (around 3 kHz).

In signals collected from patients with diseases, the high frequency band doesn't have anymore permanent significant components, sudden variations between the amplitude of the components being observed. The phase characteristics are not eloquent, due to the fact that the character of the EMG is closer to a noise type signal than to a harmonic signal.

A further validation of the results would involve the use of signals acquired from a greater number of patients (healthy, but also with muscular disorders) and the study of larger blocks of signals from time domain in order to detect the rhythmicity characteristics for healthy patients.

The validation of these results on larger groups of patients can promote and facilitate the diagnosis of some disorders for the investigated muscles, based on the absence of a certain rhythmicity in the early part of an EMG signal.

## ACKNOWLEDGMENT

The work presented in this paper was supported through the research project PN II IDEI – "Arhitectură complexă de monitorizare şi transfer a datelor medicale".

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Author: Mihai MUNTEANU
Institute: Technical University of Cluj-Napoca, Faculty of Electrical Engineering, Cluj-Napoca, Romania
Street: Memorandumului 28
City: Cluj-Napoca
Country: ROMANIA
Email: Mihai.Munteanu@et.utcluj.ro