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# ECG SIGNAL PROCESSING USING THE MATLAB SOFTWARE

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**Abstract.** *The aim of this article is to improve the process of the ECG signal using the Matlab software. In this case, we implemented some filters: Notch and Hanning ones. Also, we detected the R-R peaks, in order to determine the heart beat rate and developed an algorithm for the baseline wander, in order to detect the ST segment.*

**Keywords:** ECG signal, data acquisition, Hanning, Notch, Matlab, baseline wander

## 1. Introduction

The electrocardiogram (ECG) is one of the oldest and most important clinical investigations for diagnosing of heart diseases. This method is a noninvasive examination and the signal is obtained from the electrical currents which are present on the body surface. Each heartbeat is represented as a series of electrical waves characterized by peaks and valleys. An ECG gives two kinds of information: the duration of the electrical wave crossing the heart and the amount of electrical activity passing through the heart muscle. [1]

The recognition of the ECG signal is a very important part of the cardiac diagnosis process. That's why it is necessary to detect the QRS complex and the P, T and U waves. [2]

The frequency range of the electrocardiogram is between 0.05 and 100 Hz and the signal rage is at about 5 mV for an adult. This signal is characterized by 5 peaks and valleys: P, Q, R, S and T and in some cases another peak is present: U. Still, the performance of an ECG analysis depends mainly of the accurate detection of the QRS complex, which is the most important task in this signals analysis.

In figure 1 it is shown a representation of one normal ECG period.

While analyzing the ECG signal, a series of abnormalities can appear. Some of the most common are represent the in table 1.

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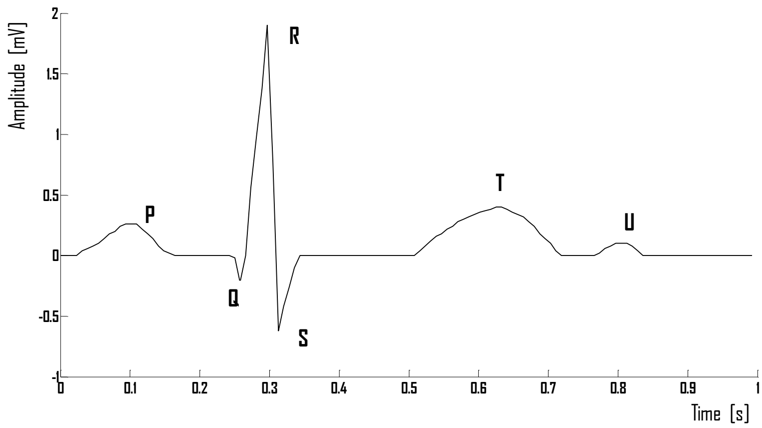


**Fig. 1.** ECG signal representation in Matlab.

**Table 1.** Abnormalities that can appear in an ECG signal [1]

| **Characteristics** | **Abnormality** |
|---|---|
| Inverse P-wave | Dextrocardia |
| R-R interval <0.6 s | Tachycardia |
| R-R interval >1 | Bradycardia |
| Tall T-wave and P-wave absent | Hyperkalemia |
| Inverse T-wave | Ischemia |
| QRS interval <0.1 s | Hypercalcaemia |

A bio-signal has a lot of frequency components. In order to process the ECG signal it is necessary to remove unwanted components or noise from the original signal. It is necessary to filter the ECG signal by analog or digital method.

The types of analog filters operate in continuous waveforms and are made from active and passive electronic components. The digital filters are implemented on sampling continuous waveforms and they can be designed by a digital computer program. [3]

Generally, the ECG signal is contaminated by power line interference, EMG noise (electrical activity of the muscle), baseline wander and moving artifacts, electrode-skin contact noise, instrumentation noise (electro-surgery).

These can be within the frequency band inside of ECG frequency domain or interference with them. In order to extract the useful information from the noisy ECG signal, it needs to be processed by filtering.

In this paper we have the following purposes:

a) Reading of an ECG signal from data acquisition file, txt type;

b) Obtaining a ECG signal contaminated with a 50 Hz frequency sine power line interference signal, obtained by Matlab simulation;

c) Filter the contaminated ECG signal, using a notch filter and reconstruct the original one;

d) Filter the ECG signal with the Hanning method, to reduce the artefacts;

e) Detect R-R interval, in order to determine the heart beat rate;

f) Implement an algorithm in order to detect the ST segment, in case of a baseline wander.

## 2. Methods

A normal ECG signal was generated by using the Matlab program, which is shown in figure 2(a). The amplitude of the ECG signal is approximately 1.75 mV and duration 5 s.

This normal ECG signal is contaminated with a sine power line noise, *s(t)*, which has an amplitude of 0.1 mV and a frequency of 50 Hz, like it is shown in figure 2(b).

$$s(t) = 0.1 \cdot \sin(2 \cdot \pi \cdot 50 \cdot t) \quad (1)$$

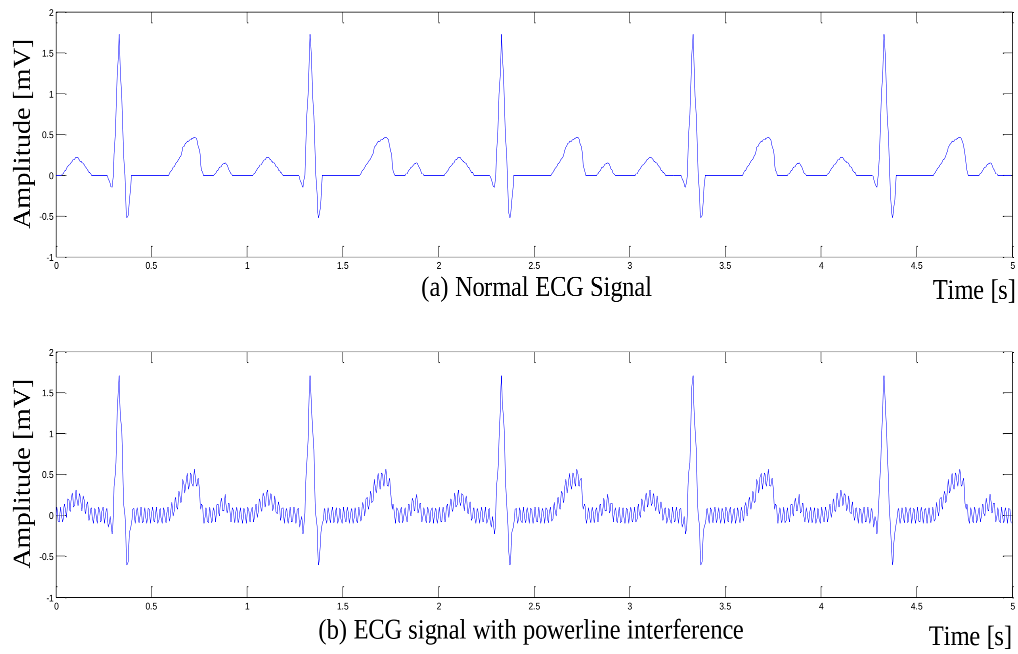


**Fig.2.** Matlab ECG signal simulation.

## 2.1. Notch filter

As we can see in the figure below, we have a representation of the ECG signal with a sine power line interference of 50 Hz. In order to remove this interference we used the Matlab program to implement a notch filter. This kind of filter is used when we want to remove the noise of a particular frequency or frequency range from a signal while passing higher or lower frequencies without attenuation. [3]

The filter command we used to implement this was *idealfilter,* which applies the ideal filter for the filter type 'notch', in a frequency interval of [49; 51] Hz for the time series object created, in our case the signal with the sine interference.

In figure 3, we have represented the ECG signal with the sine power interference and the reconstructed signal using this filter.

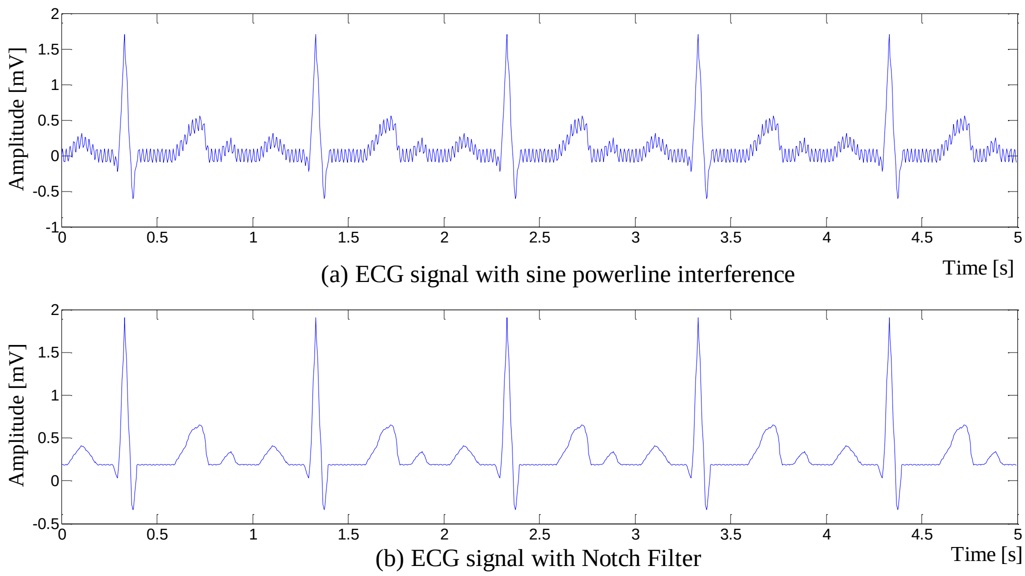


**Fig. 3.** Representation of the ECG signal with the power line interference and reconstruction using the Notch Filter

## 2.2. Hanning filter

The Hanning filter is a smoothing filter that computes a weighted moving average. To illustrate this filter, we used its difference equation and implemented in our Matlab program:

$$y(iT) = \frac{1}{4} * [x(iT) + 2x(iT - T) + x(iT - T)] \quad (2)$$

In figure 4 we have represented the results of this filtering. First, we introduce some artefacts in the signal, that can be seen in 4(a). In 4(b), by using the filter once, these artefacts were reduces, but they are still quite visible.

We used this algorithm 4 a few times, and as it is illustrated in figure 4(c), only then, these artefacts are almost eliminated. We also used a factor of 1.18 so we reconstruct the signal to its original amplitude.

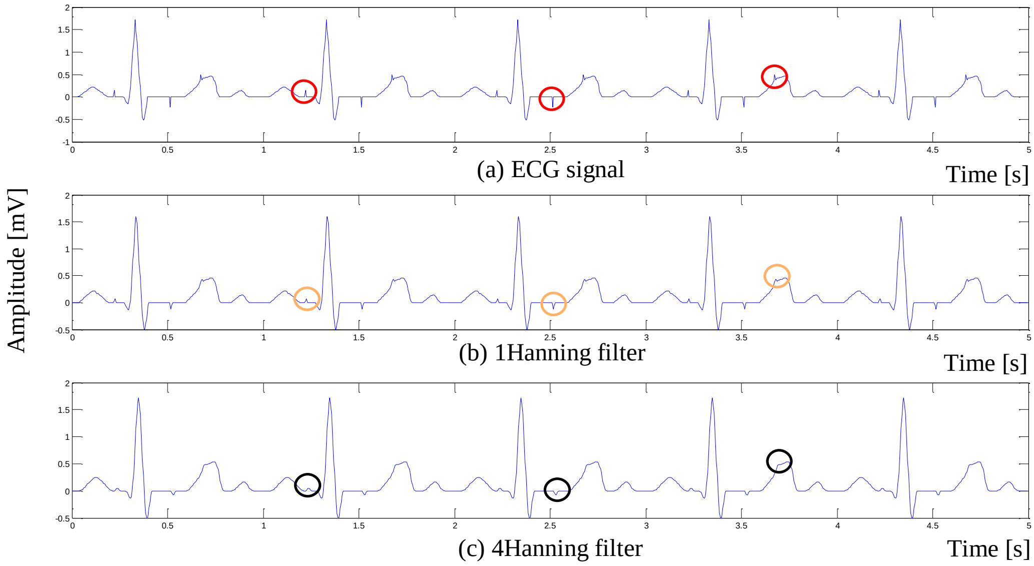


**Fig.4.** The use of the Hanning filter on the ECG signal.

## 2.3. Baseline wander

Analyzing the ST segment is very important for ischemia diagnosis, changes that can appear in during a stress test.

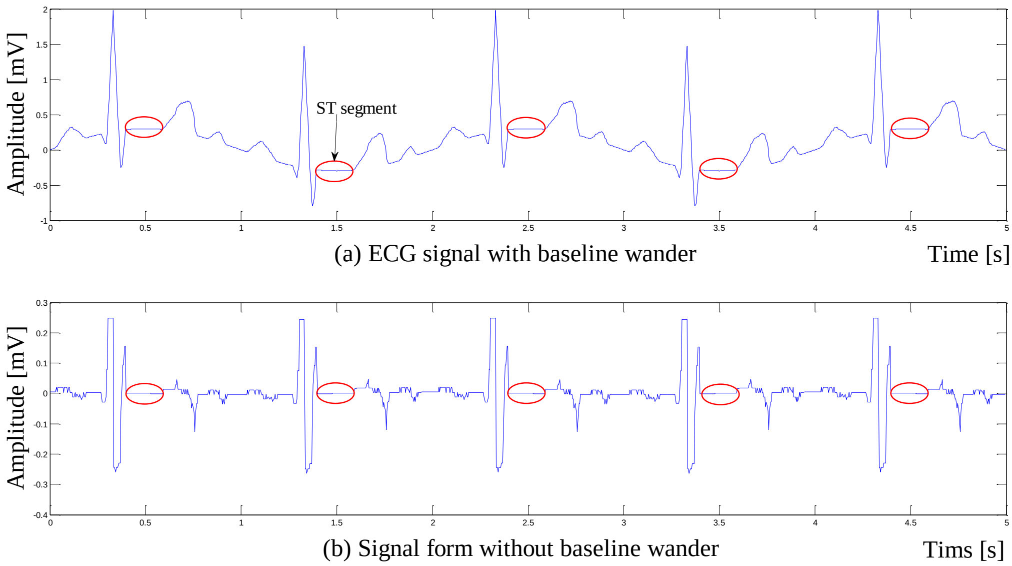


**Fig. 5.** An ECG signal with a baseline wonder and the detection of the ST segment of the signal form without the baseline wander.

If we have a baseline wander in the signal the analysis of the ECG signal gets difficult, especially the measuring of this segments deviation. Removing the baseline wander can cause distortion for some important diagnosis. [4]

In figure 5(a), we represented in Matlab the ECG signal with baseline wander and in figure 5(b), by using a code for the removal of the baseline wander, we were able to see the ST segment.

## 2.4. Heart beat rate measurement by using R detection

Detecting the QRS complex, particular the amplitude of the R wave, is done by detecting the maximum value from the range of values of an ECG period. Many times, the R wave amplitude varies, depending on some factors: patient disorders or noise introduces during the data acquisition. We have practically determined that the threshold value we consider we have a QRS complex is equal to 0.64* maximum value of the R wave. [5]

$$nR = \max(ECG) \tag{3}$$

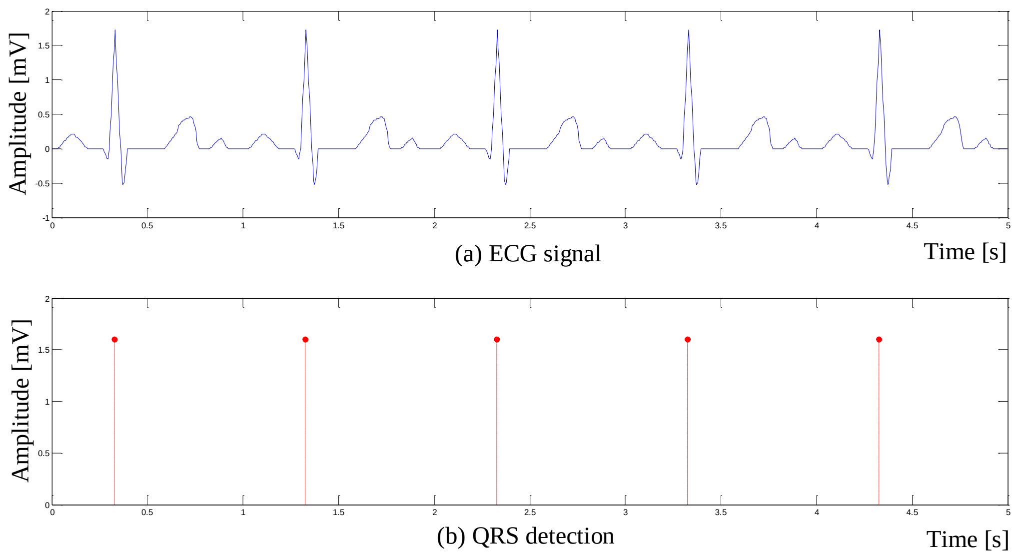


**Fig. 6.** The QRS detection of an ECG signal.

Applying this procedure, we have obtained the number of values for the R wave, as represented in figure 6(b).

The heart beat rate, *HBR*, is obtained with the equation:

$$HBR = \frac{60}{\Delta T}[bpm] \tag{4}$$

where $\Delta T$ is the time interval between 2 consecutive R waves.

## 3. Results and future work

Matlab is a very useful tool for performing any denoising technique over the Electrocardiogram. In this paper we saw how we can use a few filters and how they work in the process of filtering. This ECG signal was constructed using 1180 points. In the tables below, we have chosen 10 points from the considered ECG signal and we can see how that point looks in the reconstructed signal:

**Table 2.** Results of the original ECG signal and the reconstructed signal using the Notch Filter:

| Point in the ECG | Value original [mV] | Value reconstructed [mV] | Accuracy [%] |
|---|---|---|---|
| 1 | 0 | -0.0008388 | 99.92 |
| 23 | 0.1846 | 0.1795 | 99.50 |
| 211 | 0.1385 | 0.1357 | 99.72 |
| 345 | 0 | 0.000881 | 99.91 |
| 520 | 0 | 0.000129 | 99.98 |
| 521 | 0 | 0.002241 | 99.77 |
| 670 | 0.0154 | 0.01334 | 99.79 |
| 700 | 0 | -0.0002878 | 99.97 |
| 905 | 0.0154 | 0.01225 | 99.68 |
| 1100 | 0.2615 | 0.2619 | 99.96 |

**Table 3.** Results of the original ECG signal and the reconstructed signal using the Hanning Filter:

| Point in the ECG | Value original [mV] | Value reconstructed [mV] | Accuracy [%] |
|---|---|---|---|
| 1 | 0 | 0 | 100 |
| 23 | 0.1846 | 0.1659 | 98.13 |
| 211 | 0.1462 | 0.1516 | 99.46 |
| 345 | 0 | 0 | 100 |
| 520 | 0 | 0.0189 | 98.11 |
| 521 | 0 | 0.0093 | 99.07 |
| 670 | 0.0154 | 0.0033 | 98.79 |
| 700 | 0 | 0 | 100 |
| 905 | 0.0154 | 0.000070913 | 98.47 |
| 1100 | 0.2615 | 0.2179 | 95.65 |

In future work we want use the wavelet transform to see how it works with this signal and if it gives better reconstruction of the signal.

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