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Acquisition and digital filtering for epithelial potential of breast via Matlab user interface

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***Abstract*— this article describes the development of a user interface for a reading device of potential differences in the epithelial surface of the female breast. This device consists of an array of 24 electrodes and signal acquisition card capable of taking a range of reading of 31.25[μV] to 1.024[V]. An analysis of the bioelectrical signal present in the breast of the woman took place and digital filtering thereof.**

***Index Terms*— biopotentials, user interface, bioelectrical signal filtering, epithelial potential difference, signal acquisition, electric potential.**

I. INTRODUCTION

The bioelectric signal is characteristic of biological systems. Its source is the trans-membrane potential, by certain conditions which may vary for generating a potential difference (action potential).

The cell membrane is composed of a lipid bilayer, by peripheral proteins in the inner and outer part and integral proteins spanning from end to end and the membrane and these are called channels, which ions pass [1]. These channels may be in different states, open or closed, making it possible not only communication between the inside and the outside, but also the generation of certain biological signals.

In measurements made to large cell groups, for example, surface electrodes are used as transducers. The bioelectrical signal is constituted by the action of many cells distributed in the vicinity of the electrodes generated by the electric field [2].

It has been observed in various studies that the membrane potential is different in cancer cells. One of the first was in 1986 by C. R. Weinstein Bingelli and exposing the membrane potential relationship with tumor cells [3].

In a study conducted in 1994 it found that the membrane potential breast biopsy tissue obtained from 9 women with infiltrating ductal carcinoma is significantly depolarized, compared with the measured values tissue from 8 women with benign breast disease. Depolarization was also observed in the transformed cells, compared to normal breast cells; transformed cells were particularly sensitive to the action of the channel blockers of K+. The results were consistent with previous observations of electro positivity in areas nearest the skin malignancies detected in the breast [4]. Studies have suggested that cells, that proliferate and transform quickly, have electrically depolarized cell membranes compared to normal cells [5], [6]. In addition, epithelial cells are electrically polarized due to a different apical and basolateral domain; also lose their transepithelial potential for carcinogenesis [7], [8].

To obtain the biopotential in epithelial tissue of the breast it is essential to analyze the bioelectric signal acquired in this region of the body to perform filtering and then the corresponding user interface.

II. MATERIALS AND METHODS

Starting from the epithelial potential difference in breast reading device represented in the block diagram shown in Figure 1, a user interface was developed using the mathematical software MATLAB® 2012a. This user interface is necessary to make the control of the reading of each of the channels having the device and to save data after a clinical trial, so it was decided to include two sections for the user interface of acquisition and analysis.

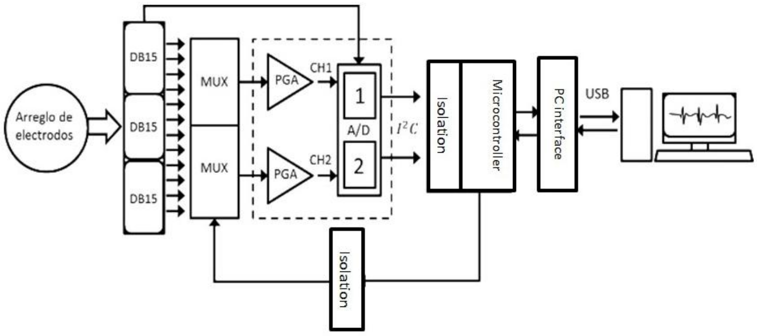

Fig. 1 Block diagram of the epithelial potential differences in breast reading device

A. Section of signal acquisition

To determine the required filter to acquire the potential of CD present in the epithelial tissue of the female breast a bioelectrical signal from the left breast of a person of 53 years was acquired, placing an electrode as shown in Figure 2.

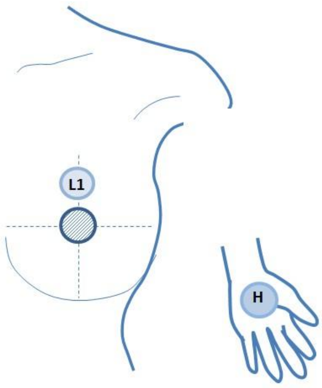

Fig. 2 Electrode L1 placements in left breast of a 53 year old woman

A sampling rate of 142[Hz] was used and the measurement time was 19.7[s], which equals 2800 samples vector. Figure 3 shows a section of the result of this measurement.

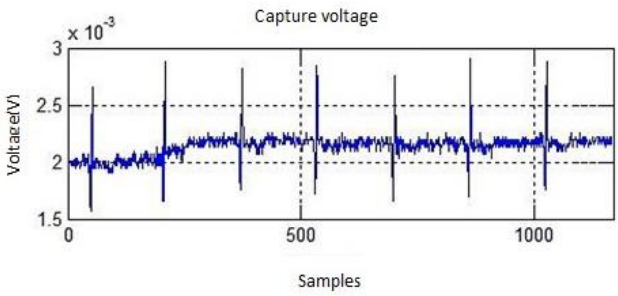

Fig. 3 Signal acquired through L1 electrode on the left breast of a 53 year old woman

The acquired signal at the frequency domain is illustrated in Figure 4. In this graph we can see that the frequency components that are above the -20[dB] range from 0.9[Hz] up to 0[Hz]. Considering that the fundamental frequency component of the signal from the muscle movement due to breathing is 0.5 to 1[Hz] for a person who is at rest the necessary digital low pass filter should have a cutoff frequency below the 0.4[Hz] to ensure that it does not interfere the breathing rate component.

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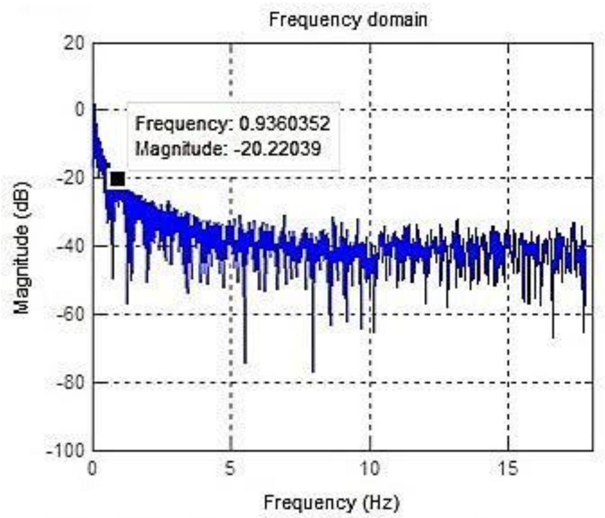

Fig. 4 Signal acquired at the frequency domain on the left breast of a 53 year old woman

At the stage of the graphic user interface it was necessary to design a digital IIR low pass filter to obtain the potential difference in the breast epithelial surface and remove frequency components that will not be useful in signal analysis.

Figure 5 shows the result of applying three low pass Butterworth IIR filters with different cutoff frequencies. For the cutoff frequency of 0.5[Hz] filter, it is observed a shorter response time than in the other two filters but you can still see fluctuations after 4[s]. Although the settling time is greater for the filter 0.25[Hz] can be seen less fluctuation of the output signal after 6 seconds compared to the filters of 0.12 and 0.5[Hz]. Although the settling time is greater for the 0.25Hz filter, it can be seen less fluctuation of the output signal after 6 seconds compared to the 0.12 and 0.5[Hz] filters.

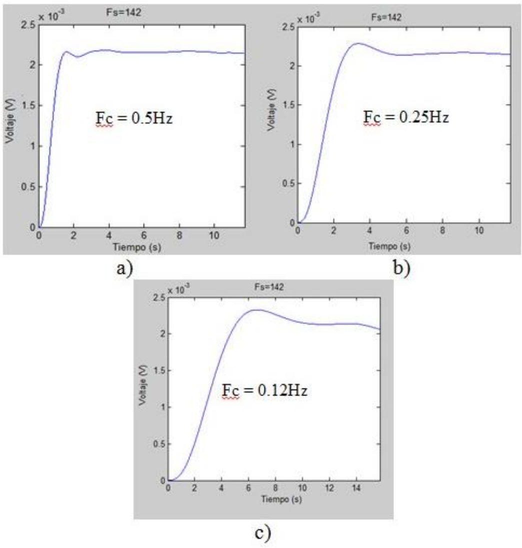

Fig. 5 Output signal after filtering with different cutoff frequency) 0.5[Hz] b) 0.25[Hz] c) 0.12[Hz]

You can see a better performance with low pass filters with a cutoff frequency between 0.25 and 0.5[Hz]. For the user interface it was decided to use a low pass Butterworth IIR filter with a cutoff frequency of 0.25[Hz] and order 3, Equation 1 corresponds to the function of the filter.

$$H(z) = \frac{2.5588x10^{-6}z^{-3}+7.6763z^{-1}+7.6763z^{-2}+2.5588x10^{-6}}{1-2.9335z^{-1}+2.8687z^{-2}-0.9352z^{-3}} \quad (1)$$

In Figure 6, the filter designed response is shown, you can observe the attenuation of -20[dB/decade] and unity gain for CD component, the phase shift is not important for the development of the device since the interest is in the magnitude of the measured signal.

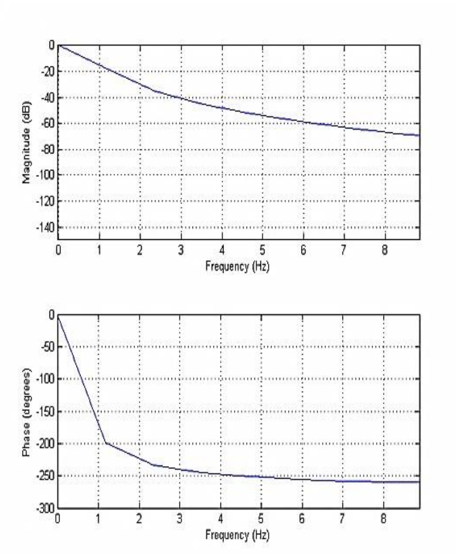

Fig. 6 Filter´s frequency response and phase response

The option of saving necessary data exists once a reading of two channels is done, content is performed within a folder of results and a filter is applied for the analysis. The data can be saved in .mat format using the following format as a suggestion L (No. Electrode)_(sample number).

B. Section of signal analysis

In this section the arithmetic mean of the signal is obtained, as has been done in previous studies [9] - [11]. A procedure used in the BDS device is also included [9]-[12], which consists in subtracting from the maximum average voltage acquired the minimum value (see Equation 4), this procedure is executed after filtering and it is useful for a diagnosis.

Depending on the number of samples performed by the user during the clinical trial is presented a table with the results obtained after the measurement on the different points where the electrodes were placed. At the same time a report is generated in a spreadsheet in the folder where the corresponding .mat files were stored.

The solution to avoid the error generated by the multiplexer settling time was taking the fraction of the signal after this time.

III. RESULTS

We decided to use a speed of 115200 bauds to establish serial communication between the microcontroller and the PC. In Figure 7 the windows of the application developed are illustrated. In one section the acquired signal and performs multiplexing control are displayed, and in the second section the read values are loaded and a report is generated with the values for each measured point, this in turn can be exported to a spreadsheet.

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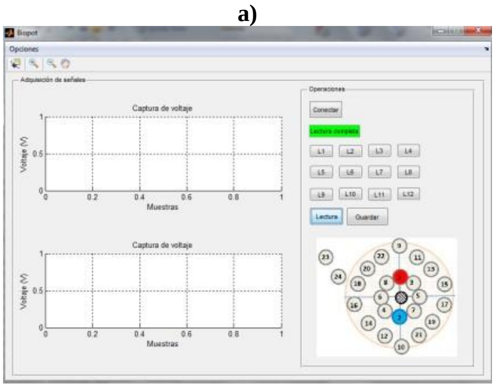
a)



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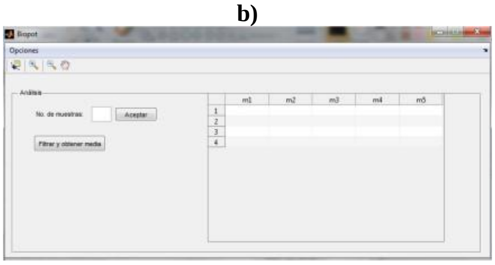

c)

Fig 7 Application for epithelial potential differences in breast reading developed in Matlab 2012a, a) Display Window b) reading window c) window analysis and reporting.

For testing two laptops were used, one of them with a microprocessor I3 to 1.20[GHz] and 4GB of RAM and the other with a microprocessor core 2 Duo to 2.53[GHz] with 2GB of RAM; both computers with a Windows 32-bit operating system and MATLAB 2012a installed. Figure 8 shows one of the computer equipment used and the device developed.

Fig. 8 Device for reading epithelial potential differences in breast 10-lead cables

IV. CONCLUSION

The time taken to perform 5 samples per electrode in a clinical trial was 1/2 hour, whereas the total number of electrodes over each breast is 24. This time could be reduced by performing hardware filtering and apply the arithmetic mean by software and consider using other software and computer equipment with a higher speed.

The software used for the graphical interface does not have a package or extension for handling databases, so the difficulty of handling the data would be directly proportional to the number of participants in a clinical trial. Therefore it is necessary to consider using another platform to develop graphical interface, speed up the handling and storage of the data.

The digital lowpass IIR 0.25[Hz] filter was appropriate to obtain the potential of CD which it is required for the mode of detection and diagnosis of breast tumors by potential differences, considering that the BDS uses a filter of the same type with a cut-off frequency around 1[Hz]. The filtrate was applied after the acquisition in order to analyze the bioelectric signals present in the breast and applying filters with a cutoff frequency.

The graphical interface developed will allow for further analysis of bioelectric signals acquired in the epithelial surface of the breast and for interfaces with a greater number of options that are more flexible or for any user.

Improvements that can be made to design the device is a mesh electrode facilitates the arrangement of the electrodes on the breast. Use of a greater number of multiplexers to perform a reading of a greater number of channels simultaneously and the placement of two grids on two breasts to reduce the reading time. The use of converters with higher resolution for higher sensitivity and a minor error. The development of a power supply that allows using the device in a fixed or portable. The development of an interface to generate reports with the data of the patient or user. Forming a database of healthy individuals for later use algorithms to determine whether a tumor is benign or malignant when detected by the device.

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