The research of the quality of ECG recording by capacitive electrodes in violation of the skin-electrode contact

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Abstract. This paper presents actual development in the field of personal telemedicine. For personal cardiographs most suitable dry electrodes that do not require a conductive gel. This article describes experiments with capacitive electrodes from Plessey Semiconductors. On the basis of the obtained experimental data, it is planned to create own capacitive electrodes with the possibility of detuning from the skin-electrode contact.

1. Introduction

Tele-electrocardiography (ECG) is one of the most important areas of preventive cardiology. Due to a number of advantages in personal cardiography devices, it is advisable to use capacitive electrodes. The use of this type of electrodes does not require the presence of a special conductive gel. Also, when using capacitive electrodes, it becomes possible to record ECG signals through a thin tissue. The disadvantage of such electrodes is lower noise immunity. Also, with an unstable force of pressing the electrode, a broadband interference of 10-20 Hz appears and the recorded signal is distorted. This obstacle always takes place due to the inconstancy of the force pressing the human hand [1].

The research team of the Tomsk Polytechnic University is developing an adaptive system based on capacitive electrodes that is capable of isolating and subtracting interference from an ECG signal based on ECG recording with bioimpedance, by that stabilizing it. Solving the problem of removing noise and stabilizing the signal will improve the quality of the signal and the practicality of the tele-ECG.

Before proceeding to the modeling of our own system based on capacitive sensors, almost all capacitive and dry electrodes available on the market were studied for choosing the most suitable as a reference model. Almost all the sensors considered have a significant disadvantage: the quality of the signal depends on electrical contact with the skin. Thus, the problem arises of creating a sensor with detuning from skin contact with the electrode. The basis for such a sensor can serve as a capacitive sensor, which uses the human body as a capacitor plate. Theoretically, such a sensor should not only provide an opportunity to take a better signal, but also allow it to be removed through clothing, which will increase the usability of cardiographs based on them. Before starting to create your own capacitive sensor, experiments were carried out based on capacitive sensors of Plessey Semiconductors – EPIC PS25255 [2].

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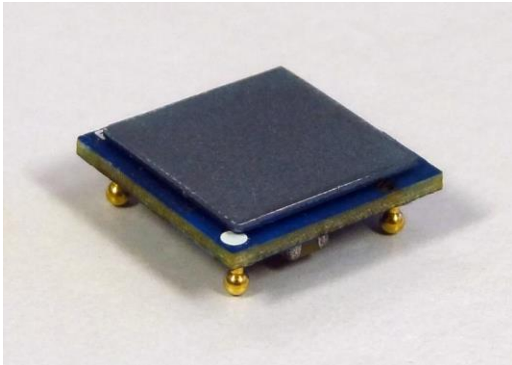
The purpose of this work is to conduct detailed studies of the effect of the quality of the skin-electrode contact to identify and justify the introduced distortions. The results will be the basis for developing a method of compensation for breach of contact.

2. Materials and methods

Experimental studies were carried out using the ECG-Express portable electrocardiograph (Figure 1,a). The portable ECG-Express cardiograph is undergoing preclinical testing at the Research Institute of Cardiology in Tomsk [3]. The ECG signals of various patients, obtained with the help of this cardiograph, are compared with the ECG signals of the same patients, taken with the help of certified and verified electrocardiographs and analyzed by cardiologists. Preliminary results of the use of the device by cardiologists indicate the reliability of the data obtained using it.

a



b

Figure 1. Electrocardiograph "EKG-Express" (a) and capacitive electrodes of Plessey Semiconductors (b).

In the course of the work, ECG signal processing algorithms were used, which were used in the EKG-Express portable electrocardiograph. The signal processing algorithms were implemented in the software package for solving the problems of technical calculations MATLAB. The algorithm works according to the following principle: it is automatically located in the QRS complex signal, since this type of segment is clearly visible on the ECG, it has clearly defined characteristics and can be detected even in a low-amplitude ECG. Next, the signal passes through a band-pass filter similar to the input filter constructed using the Pan-Tompkins algorithm. [4-6].

In the course of the experiments, ECG-express signals were obtained using the bipolar recording scheme with various changes in the capacity of the skin-electrode contact. The capacitance was changed by overlapping the contact between the body and the electrodes with various dielectrics (paper, cloth). The contact area was covered with a dielectric by 25%, 50%, 75% and 100%. All measurements were carried out for two positions of the neutral wire: on the arm and on the right hypochondrium. At the same time, potential electrodes were located on the left and right forearms. To reduce the effect of myographic interference, electrodes on the body were fixed with a medical patch. Also, as a control experiment were removed diagrams without a dielectric. The experiments were carried out in series (from 5 to 10 measurements). For the received ECG signals, spectral analysis was performed.

3. Results

Figure 2 shows the ECG signal and its spectral composition for the case when the electrodes have the best contact with the patient's skin and there is no additional dielectric. In the first series of measurements, the neutral electrode was located on the arm.

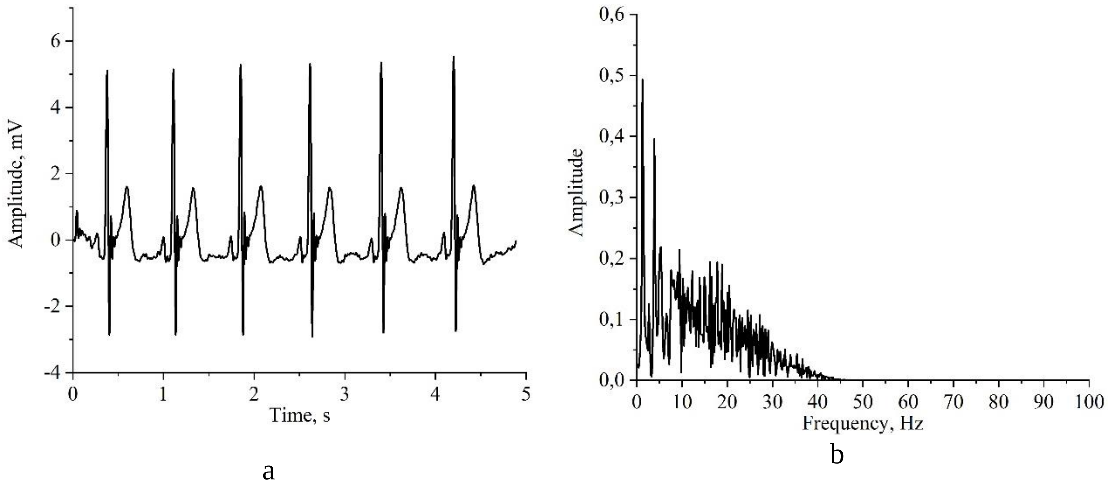


Figure 2. ECG signal (a) and its spectrum (b) taken without additional dielectric, the neutral electrode was located on the arm.

To assess the effect of the skin-electrode contact, we conducted a series of experiments on the overlapping of the electrodes with an additional dielectric. Thereby, various degrees of clamping of one and two electrodes were simulated. Figure 3 shows diagrams of ECG signals and their spectral composition with different overlap of the left electrode.

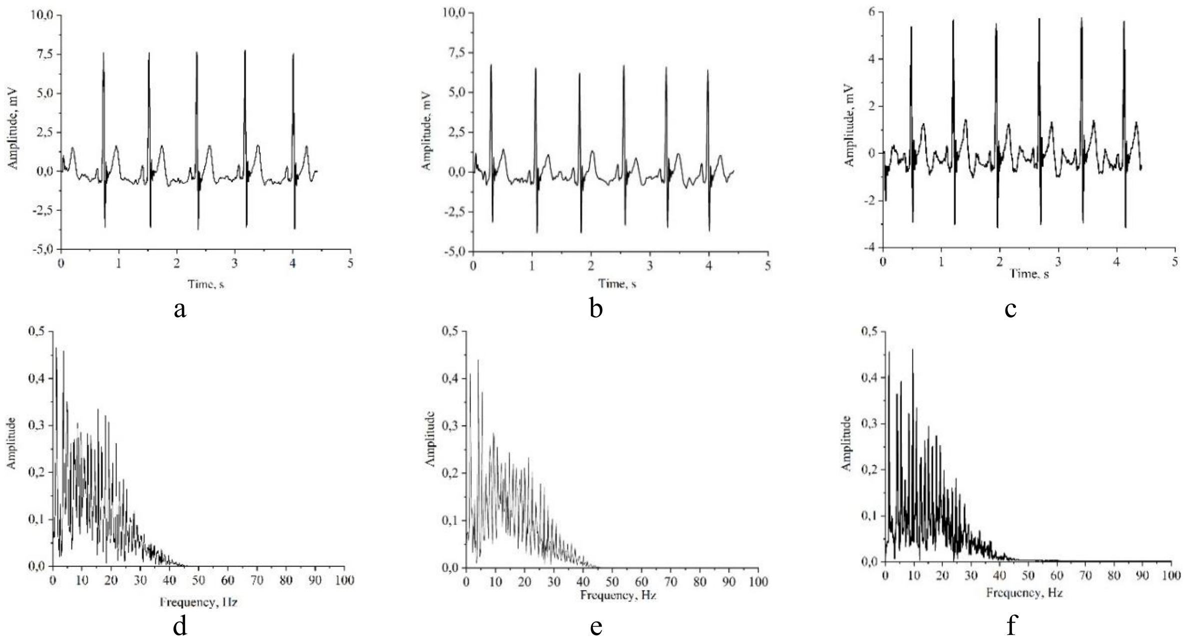


Figure 3. ECG signal (a,b,c) and its spectrum (d,e,f) taken when the left electrode overlaps on 25 % (a,d), 50% (b,e) and 100% (c,f), the neutral electrode was located on the arm.

Figure 4 shows diagrams of ECG signals and their spectral composition with different overlap of the right electrode.

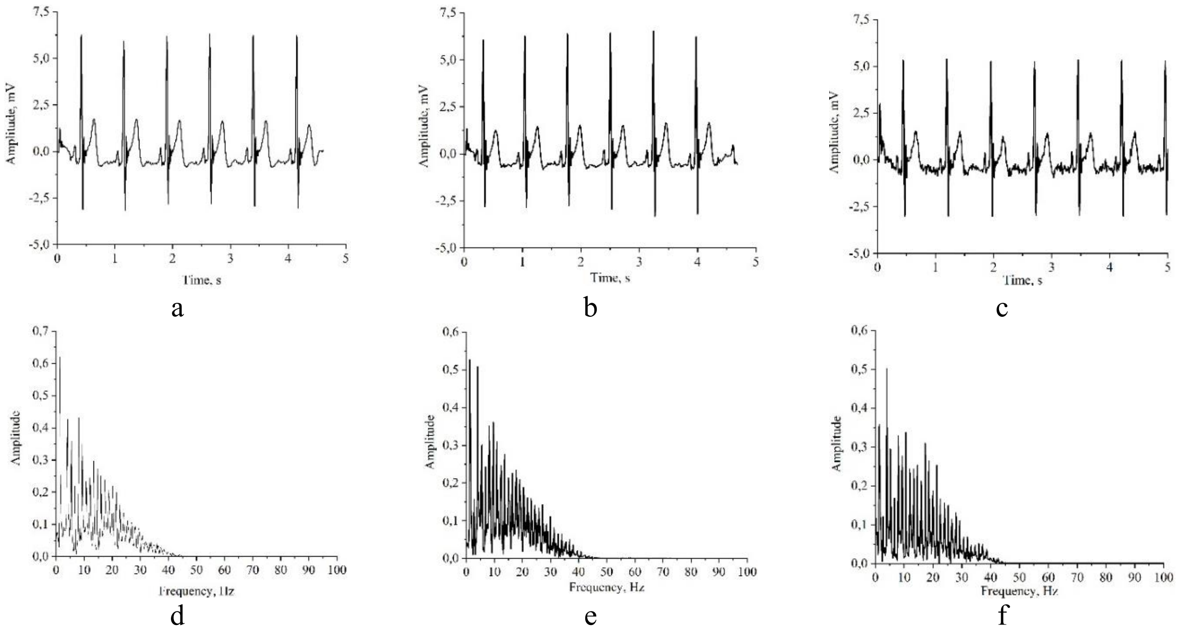


Figure 4. ECG signal (a,b,c) and its spectrum (d,e,f) taken when the right electrode overlaps on 25 % (a,d), 50% (b,e) and 100% (c,f), the neutral electrode was located on the arm.

Figures 3 and 4 show that with an increase in the degree of overlap (violation of the skin-electrode contact) of both the right and left electrodes, there is a slight increase in the contribution of high harmonics (over 10 Hz). Moreover, with an increase in the overlap area of the electrodes, a decrease in the first peak of the spectrum and a relative increase in subsequent harmonics. It should be noted that when the capacity of the right electrode changes, the signals become more noisy. Most likely, this effect is observed because the right electrode is farther from the heart. As a result, interference has a greater effect on the quality of the signal through the right electrode.

Figure 5 shows diagrams of ECG signals and their spectral composition with different overlap of both electrodes. In this experiment, both electrodes in equal parts overlapped with paper.

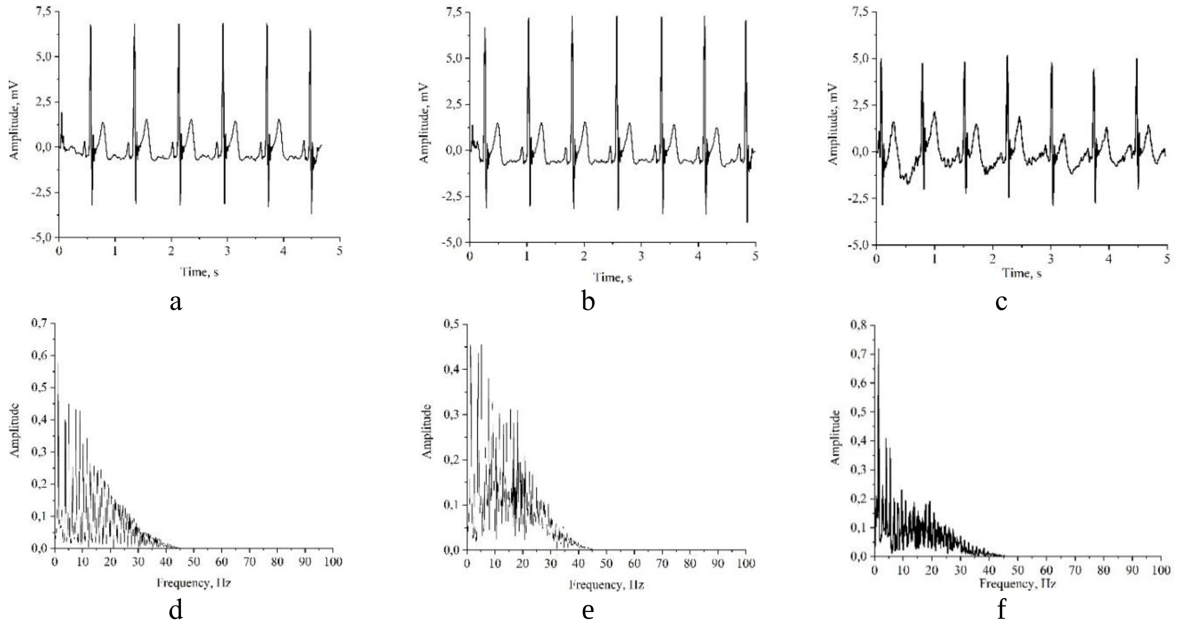


Figure 5. ECG signal (a,b,c) and its spectrum (d,e,f) taken when the both electrodes overlaps on 25 % (a,d), 50% (b,e) and 100% (c,f), the neutral electrode was located on the arm.

When registering ECG signals with a symmetric overlap of both electrodes, no distortion of the signal spectrum, as when overlapping one (left or right) electrode, was observed. This is due to the fact that the registration of the ECG is the removal of the differential signal. A series of similar experiments was also conducted with the neutral electrode on the right hypochondrium. During were obtained these experiments, similar results.

4. Conclusion

With an increase in the overlap area, the signal is somewhat distorted: the P and T teeth become more triangular. In addition, a negative surge follows the P and T prongs. The size of this emission is larger, the larger the dielectric area between the electrode and the skin. It is difficult to estimate the dependence of the absolute values on the dielectric capacitance in this situation, since in one series of experiments, the values could differ somewhat, which would be explained by human biorhythms, which are not the same at different points in time. The signal is “noisy” as the overlap area increases. Therefore, by tracking the degree of contact disturbance, by measuring the skin-electrode capacitance, it is possible to compensate using the means of mathematical signal processing, thereby improving the quality of the recorded ECG signal.

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