Study of the Properties of Plessey's Electrocardiographic Capacitive Electrodes for Portable Systems

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Abstract. Cardiac diseases are still most widely spread in all regions of the world. And more and more devices are invented to satisfy increasing requirements of the patients. One of the perspective technologies in cardiac diagnostics is capacitive sensing ECG electrodes.
This article describes a study of the properties of electrocardiographic capacitive electrodes PS25255 from Plessey Semiconductors for portable systems as well as some undocumented parameters of these sensors. We developed special cardiograph using Plessey's electrodes and applied to the number of patients with ischemic heart disease. We paid our attention mostly to the correct transition of the ST segment as it has critical impact on the diagnostics of ischemic heart disease.

1.Introduction

The concept of capacitive electrodes for biopotentials sensing has known for a long time and at present many patents are registered. But the lively interest for them appeared only last few years thanks to modern miniature analog components, which made possible placing the necessary electronics in the electrode, thereby improving its performance.

Traditionally, Ag / AgCl electrodes with wet conductive gels are used for biopotential records. The standard Ag / AgCl electrode has been well described and studied for many decades [1–3]. Most of its properties are well studied [4], and there is sufficient number of empirical data describing its characteristics, such as low-frequency noise and drift [2]. By using these electrodes with appropriate preparation an excellent signal may be taken.

2.Theory

The main principles underlying the helium electrodes are also well known. Despite decades of research in the field of alternative technologies of biopotentials sensing [5–8] for ECG, standard wet Ag / AgCl electrode is still broadly used for clinical and research applications. Every year billions of clinical electrocardiograms are recorded with disposable glue electrodes, while dry electrodes are limited to a niche of not medical (scientific) application, for example for fitness monitoring and toys.

Thanks to recent developments, applied to the capacitive electrodes of the Plessey Semiconductors, it becomes possible to use dry electrodes for clinical tasks.

The connection between a capacitive electrodes and skin may be described as in the case with other types of electrode, the layered conductive and capacitive structure with combinations of a series of parallel RC elements. Figure 1 shows examples of these structures, with different values of conductivity and capacitance. For each of these types of electrodes, usually one of the sections of RC dominated and electrical connection can be provided in one piece with the conductivity gc and parallel capacitance Cc, or simplified relations method $Yc\ (j\omega) = gc + j\omega Cc$.

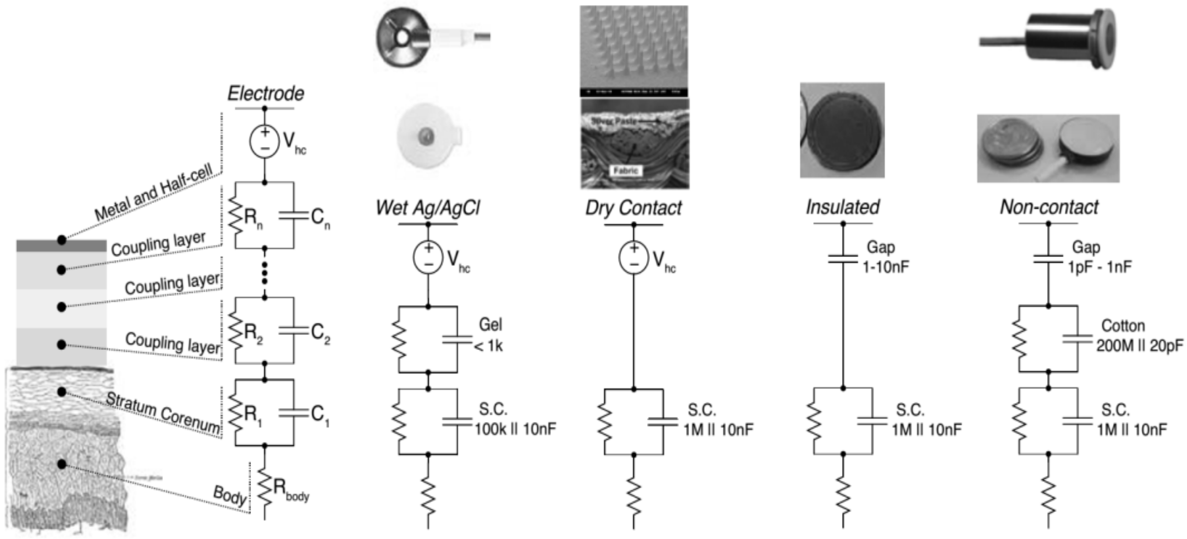

Figure 1. The electrical communication skin-electrode interface for different topologies of electrodes, including wet contact gel-based Ag/AgCl, with dry contact MEMS and the metal plate, a thin film of an insulated metal plate, the metal plate and wireless contact through clothes such as cotton. The insets shows examples of practical electrodes for each category [9].

All modern capacitor electrodes have the general the structure presented in figure 2. The structure of the electrode includes an amplifier with a high input resistance of about GOhms or even TOhms. The amplifier has active shield to protect input from interference from other sources, and includes a capacitive relation between the source and output of the amplifier.

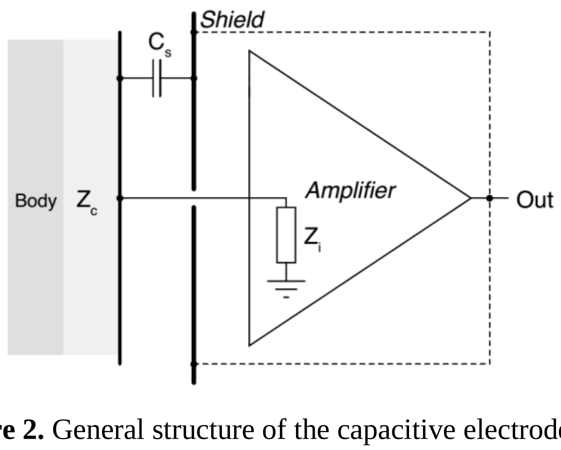

Figure 2. General structure of the capacitive electrode [9].

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3. Experiment

For study of properties and suitability of capacitive electrodes from Plessey in clinical practice we designed a testing device for ECG registration form the patient's chest. Registration is made at the same time with capacitive electrodes and standard self-adhesive AgCl electrodes for the further comparison and quality control. Research carried out in the Cardiological Clinic of Tomsk, Russia on patients with ischemic heart disease. Figures 3 and 4 shows examples of registered signals.

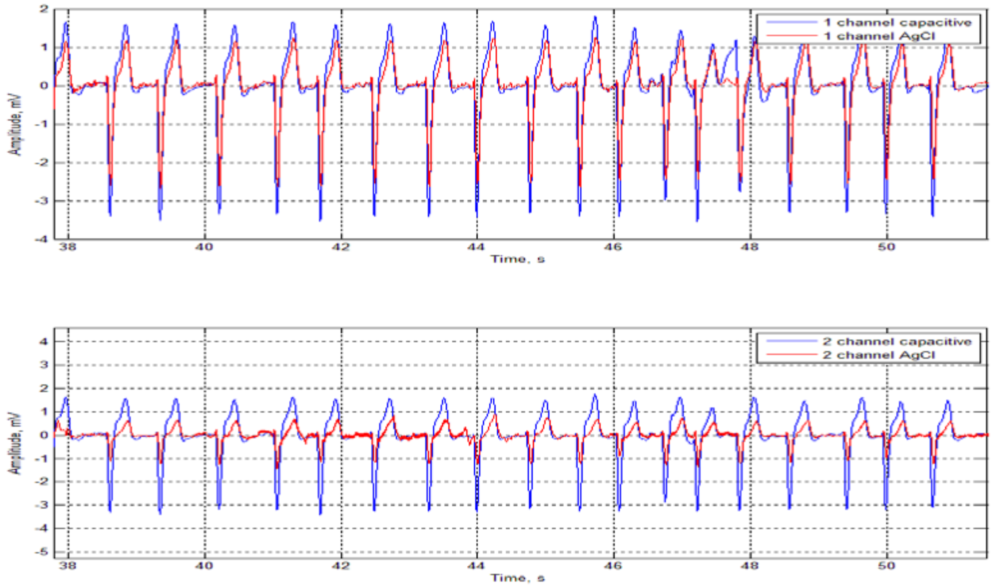

Figure 3. Example of a record from the patient in a fixed condition.

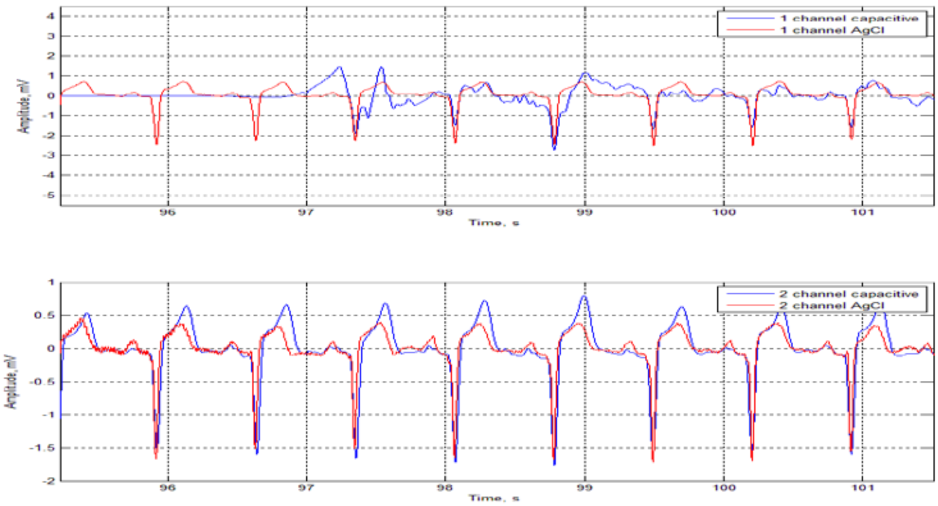

Figure 4. Example of a record from the patient during body rotation.

The experiment shows that capacitive electrodes sufficiently conduct the ECG signal with a comparable quality referring to the standard electrodes. However, the relative motion of the electrodes and the body, and friction of the electrodes with body surface leads to artifacts in the received signals (figure 4), which are a major barrier against adoption of dry electrodes in the mobile clinical practice.

During the research, at the capacitive electrodes were seen the transient processes about 1 second. This phenomenon was observed when the capacitive electrode is disconnected from the patient's skin for a moment and only after the transition process electrode remains to the normal condition. To confirm the presence of transient processes we carried out the experiment by using the square wave generator and an oscilloscope. Figure 5 presents the transient process of capacitive electrodes. It is worth noting, this characteristic was not presented in the standard technical documentation.

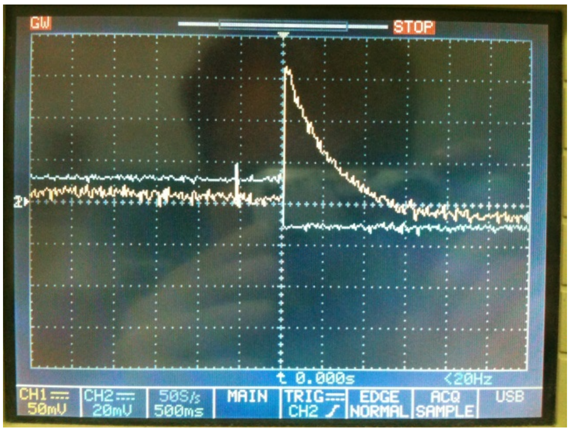

Figure 5. Transient process electrodes of the company Plessey.

Also, experiments were conducted to test the bandwidth. As a result, it was found that even outside of the documented bandwidth and up to 100 kHz electrodes' gain and phase shift is not changed.

4. Conclusion

Considering all of the above we can conclude that capacitive electrodes may be used in clinical practice, but they are needed to be improved to stabilize the signal from artifacts caused by patient motion. The reduction of patient's motion influence can be achieved by compensation of the relative movements of the electrode using an external mechanical structure, or by measuring the characteristics of the sensing circuit and following adaptive filtering.

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