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Method of Adaptive Filtering of Pulse-Wave Low-Frequency Distortions

A. A. Fedotov* and S. A. Akulov**

Samara State Aerospace University, Samara, Russia
**e-mail: fedoaleks@yandex.ru*
***e-mail: sakulov1981@mail.ru*

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Abstract—Different methods of correcting the low-frequency distortions of pulse-wave signal have been considered. A correction method based on forming a reference signal of adaptive filter and using low-frequency filtering of initial biosignal is proposed. The efficiency of different methods of pulse-wave filtering is investigated under the conditions of exposure to interferences of different intensity. It has been found out that the proposed method of filtering low-frequency interferences makes it possible to obtain the lowest distortions in signal processing as compared to the model signals free from manifestation of distorting effects.

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1. INTRODUCTION

The registration and processing of pulse-wave signal find a widespread application in tooling systems of cardiac diagnostics for the monitoring of cardiac rate, arterial blood pressure, and determination of the arterial oxygen saturation [1, 2].

The pulse-wave registration using sphygmographic or plethysmographic sensors is accompanied by the presence of interferences of different nature. Interferences of the electrical nature occur due to the influence of external electromagnetic fields created mostly by the electric mains. Interferences of the physiological origin are determined by the patient breathing and the impact of neurohumoral factors of regulation and also by the presence of low-frequency motional artifacts. They result in distortion of the isoline and waveform of biosignal and emergence of the isoline drift representing quasiperiodic low-frequency distortions. The stochastic pattern of the isoline drift necessitates the creation of nontrivial digital processing methods of arterial pulsebeat signals.

In practice, the isoline drift correction nowadays involves the use of approximation methods that do not impose high requirements on the computational resources and feature fundamental limitations on the frequency range of the interference signal to be separated [3]. With the increasing frequency of isoline drift signal, the accuracy of separation of interference signal drops and when the interference frequency reaches the value equal to a half of the average heart rate representing the actual sampling frequency of the isoline drift signal, the recovery becomes impossible due to the breach of conditions of the Nyquist–Kotelnikov theorem.

With due regard for the fact that in certain cases the cardiac rhythm of man can reach 0.5 Hz (30 beats/min), while on average it is equal to 1 Hz (60 beats /min), the real frequency of interference signal, at which the elimination of isoline drift is possible using approximative methods, does not exceed 0.2–0.3 Hz.

The techniques of isoline drift correction based on the linear frequency filtration of pulse wave using the high-pass or low-pass filters are free from the specified drawbacks. In the first case a low-frequency additive interference of drift is filtered off from the useful signal, while in the second case the drift interference is separated from the additive mixture of signal and interference using a filter. Next it is subtracted. However, due to the inevitable overlapping of frequency spectra of pulse-wave and interference signal, in both cases the losses of the information part of biosignal spectrum during the digital processing are inevitable, as well as distortions during the separation of isoline drift.

Adaptive filtering of pulse-wave isoline drift does not find nowadays a widespread application due to the objective difficulties in registration of the reference signal correlated with interference signal that is a necessary condition for using the adaptive noise suppression method [4].