EXPERIMENTAL INVESTIGATION ON COMPUTER RESTORATION OF FREQUENCY SPECTRUM OF ECG – SIGNALS IN THE CASE OF INFLUENCE OF NOISE

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Abstract

Electrocardiographic signals are essential in medical diagnostic a wide range of pathologies in medicine. Therefore, there are stringent requirements for reliability in the transmission of these signals in any communications system. In this context, methods for improving the quality of transmitted medical information are up to date in the construction of modern communication system environments. Experimental studies on possibility for restoration of frequency spectrum of ECG signals using mathematical method of Eisenberg are described in the paper.

1. INTRODUCTION

As a result of the research was proposed theoretical expression (1), which serves as the basis for the construction of algorithms for computer restoration of frequency spectrum of ECG signals in the case of influence of noise using interpolation.

$$\dot{S}(\omega) = \lim_{m\to\infty} \sum_{k=1}^{m} \dot{S}(\omega_k) \frac{2i\sigma}{\omega - \omega_k + 2i\sigma} \text{ x}$$

$$\text{x} \prod_{j=1 \cap j\neq k}^{m} \frac{(\omega-\omega_j)(\omega_k-\omega_j+2i\sigma)}{(\omega-\omega_j+2i\sigma)(\omega_k-\omega_j)}, \qquad (1)$$

where:

$\{\omega_k\}$ is limited number of frequencies that are known spectral components of the signal; ω is an ongoing, random frequency value for which the calculated value of the spectral function $\dot{S}(\omega)$ inside the interval of recovery of the signal spectrum;

σ > 0 is a parameter which depends on the accuracy in the process of restoration of spectrum of the ECG signal;

m is the number of preliminary known spectral components of the signal;

j and k are integers (counters).

2. ALGORITHM FOR COMPUTER RECOVERY OF SPECTRUM OF ECG-SIGNALS IN THE CASE OF INFLUENCE OF NOISE BY INTERPOLATION

Figure 1 shows the proposed algorithm for computer recovery of spectrum of ECG-signals in the case of influence of noise by interpolation on the basis of equation (1). Compared to extrapolation, interpolation is more accurate and faster method of recovering signals. In this case, the optimal ratio between the number m of known components $\dot{S}(\omega_k)$ and coefficient σ, determining the accuracy of the calculations according to the equation (1) is not as important and time-consuming, since above certain values results differ after the fourth decimal place. The explanation for this stems from the fact that in mathematics task of interpolation is considered correct. In the case of interpolation interval Passed ECG signal has no major delays because the value of the coefficient σ is calculated once, then its value is used for all frequency components undergoing restoration.

3. EXPERIMENTAL INVESTIGATIONS

Experiments were conducted with real ECG signal representing the normal sinus rhythm of 40-year-old man without any apparent arrhythmia. Signal duration is about 18 hours, but for the purposes of this experiment, we used only small parts of this time interval. Was conducted utilizing a series of experiments using the algorithm (Fig.1) for t interpolation of the spectrum.

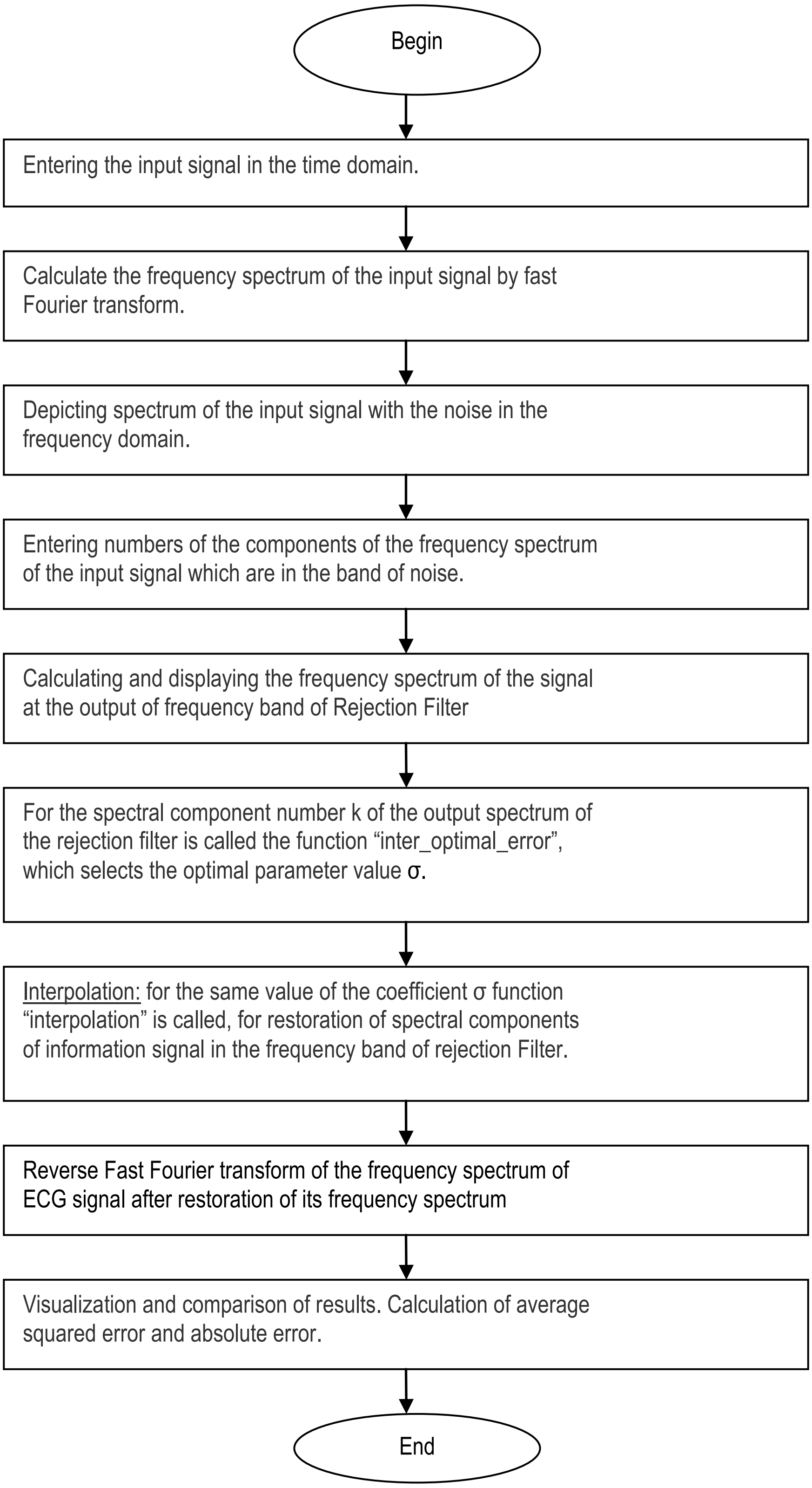

Fig. 1. Algorithm for restoration

Experiment 1. In Fig. 2 and Fig. 3 are shown the experimental results of fragment ECG signal with duration 1s (a total of 128 points, the discreet frequency is 128 Hz) and 10 components for recovery (from 20Hz to 29 Hz). The resulting average squared error is 0.0053 and the maximum absolute error is 1.6623. The coefficient σ was taken with a value 0.0144.

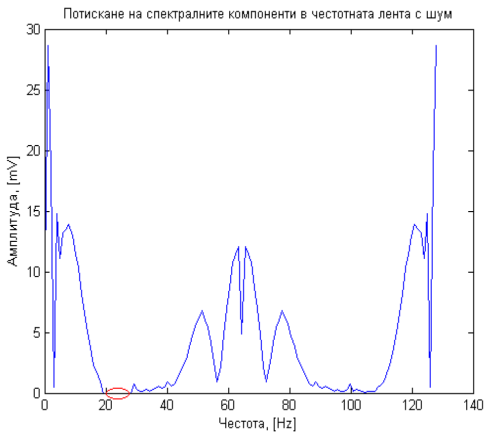

Fig. 2. Frequency spektrum $\dot{S}_R(\omega)$ of output signal of rejection filter

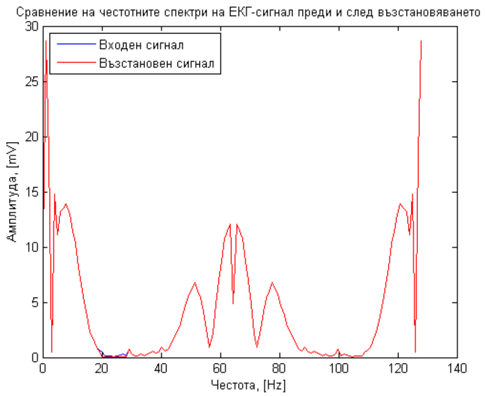

Fig. 3a. Spectral functions of input signal $\dot{S}_{in}(\omega)$ and output signal $\dot{S}_a(\omega)$

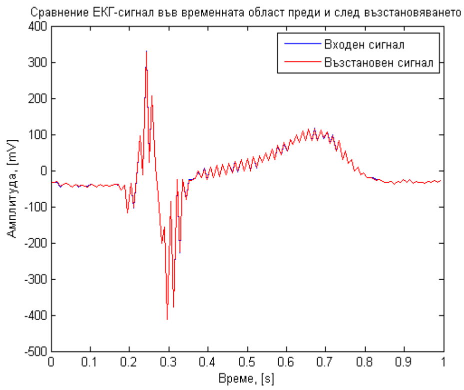

Fig. 3b Function of input signal $s_{in}(t)$ and output signal $s_a(t)$ in time

Experiment 2. In Fig. 4 and Fig. 5 are shown the results for the same length of EKG-signal (1s), but with an increased number of spectral component for recovery (from 21 Hz to 40 Hz). It is clear that average square error increases to 0.0138, expanding the frequency band of noise even other conditions would be the same. The maximum absolute error is also increased to 4.1949, but the results continue to be relatively good. Coefficient σ has a value of 0.0134.

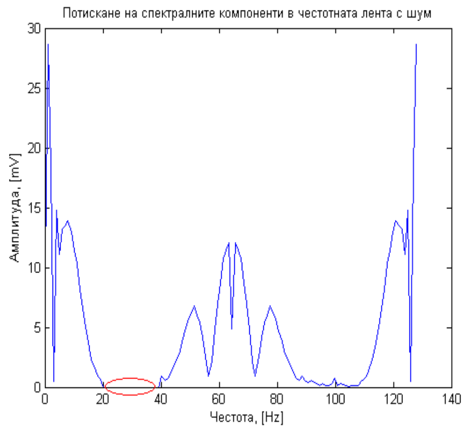

Fig. 4. Frequency spektrum $\dot{S}_R(\omega)$ of output signal of rejection filter

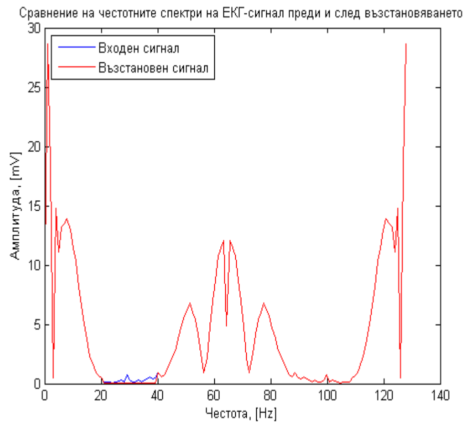

Fig. 5a. Spectral functions of input signal $\dot{S}_{in}(\omega)$ and output signal $\dot{S}_a(\omega)$

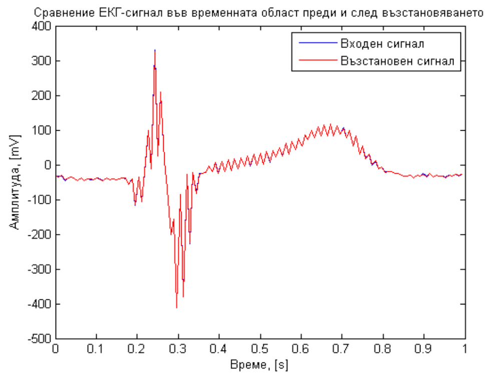

Fig. 5b. Function of input signal $s_{in}(t)$ and output signal $s_a(t)$ in time

Experiment 3. In this case, the length of the interval of the ECG signal is taken 10s, a noise band width is narrow (75 to 80 Hz). The results show that the computation time increases due to the increased number m of known frequency components, which is understandable given the expression (1). In this case, the amplitudes of the spectral components in the band of the Restoration are small and therefore the average squared error is small. It's 0.0767. For maximum absolute error should I obtain 29.2536. The calculations are made for parameter σ value 0.002.

Experimental results on amplitude-frequency spectrum of the ECG signal are shown in Fig. 6 and Fig.7.

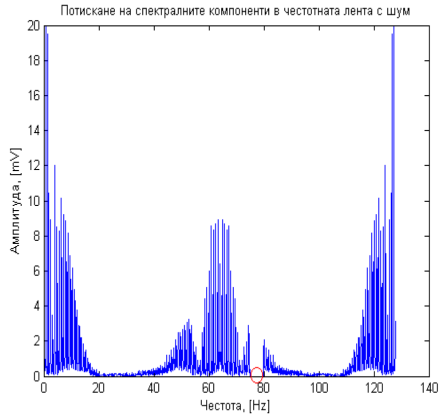

Fig. 6. Frequency spektrum $\dot{S}_R(\omega)$ of output signal of rejection filter

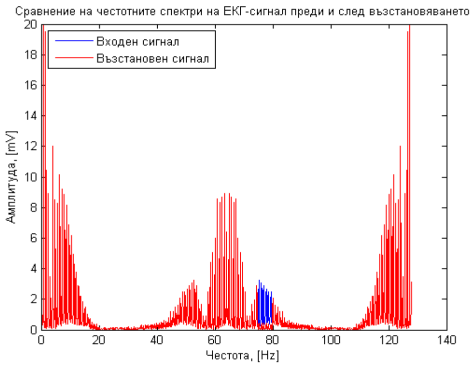

Fig. 7a. Spectral functions of input signal $\dot{S}_{in}(\omega)$ and output signal $\dot{S}_a(\omega)$

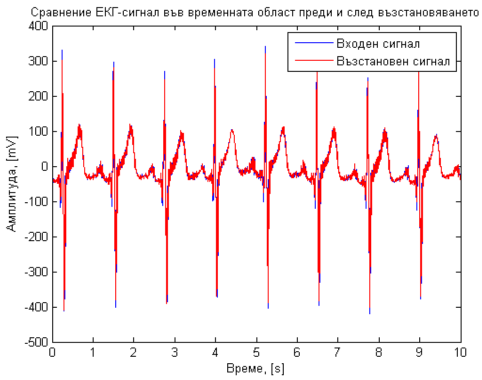

Fig. 7b. Function of input signal $s_{in}(t)$ and output signal $s_a(t)$ in time

4. CONCLUSIONS

1. Interpolation gives relatively good results on the recovered amplitude-frequency spectrum, even if not calculated the optimal value of the coefficient σ. This reduces the computation time according to the algorithm in Fig. 2, and increasing of the error is small. This is a very great potential to improve the performance of the digital filter, which works on the basis of the equation (1) and algorithm on fig. 2. For example, in the recovery of 10 spectral components of the finite ECG signal with duration of 1s and frequency band (from 100 Hz to 110 Hz), σ = 0.0001, the average square error is 0.0009 and the maximum absolute error is 4.2787.

2. In many cases, because of difference between amplitudes of the various components of the amplitude-frequency spectrum of the ECG-signal, a precise and accurate results can be obtained by pre-determining the optimal parameter σ value.

3. Theoretically the optimal parameter value σ should be calculated in advance for calculating each spectral component in the band interpolation according to the equation (1). Then the results would be very accurate and this would enhance significantly the quality of transmitted information at the output of digital filter, but the price for this would drastically reduce the performance of the said digital filter, especially when processing signals have a wide frequency band noise. Of course this is a typical problem of the digital filters. This problem did not stop digitization of communication systems through the use of ever faster microprocessors.

4. Theoretically, this estimation of the parameters is necessary. However, as seen from the above experiments, sometimes it's permissible to avoid pre-optimization of parameter σ in the process of interpolation. This is due to the fact that the task of interpolation is mathematically correct.

5. APPENDIX AND ACKNOWLEDGMENTS

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