AUTOMATED SYSTEM FOR STUDYING MAN'S PHYSIOLOGICAL CONDITION AND ADAPTIVE CAPABILITIES UNDER NORMAL CONDITIONS AND UNDER PHYSICAL OVERLOAD

V.G.Kuzmin, I.Ya.Orlov, E.I.Shkelev, S.V.Kuznetsova, V.V.Lebedev

Nizhni Novgorod State University,
603600, 23 Gagarin Avenue, Nizhni Novgorod, Russia
e-mail: kuzmin@uic.nnov.ru

Abstract

Spectral analysis with high time-and-frequency resolution based on the Wigner-Will transform is applied for the diagnosis of the of the state of man's heart by means of studying acoustic noises and rhythms of the heart. The main characteristics of the heart's state can be obtained by analysing the time distribution of heart rhythm on the basis of electrocardiography and acoustic signals and acoustic signals. The signal can be characterised as impulses having a delicate structure. Heart beats are acoustic signals that have a number of modes with frequency modulation. By decoding the delicate structure of such signals one can get additional information about the state of the heart. A high time-and-frequency resolution is required to achieve it. Traditional spectral analysis methods could not offer this type of resolution.

1. INTRODUCTION

Objective evaluation of man's physiological condition under normal conditions or under physical overload requires a sufficiently large volume of versatile information. Usually, this kind of information can be obtained by measuring and analysing various signals.

The instrumentation of an automated system that allows measuring signals from man's body (electrocardiogram, ballistogram, acoustic noises and rhythms of heart, arterial blood pressure, pulse, humidity, frequency of breathing, temperature and other parameters) is discussed in this paper.

Simultaneously, the above system measures the signals from various devices used by man in his labour activities or physical exercises. Such electrical signals coming from the sensors attached to the devices serve to describe the parameters of various motions and the state of the devices. By measuring and analysing such signals simultaneously, one can obtain the information on man's condition and the dynamics of its change together with the information on physical efforts and their efficiency.

2. THEORY

The measuring complex considered here is designed for the application in the conditions of a sports hall. The system is built on the basis of an IBM PC computer with the controller of measuring instrumentation that can be used in a remotely controlled or an autonomous mode.

All measuring devices are connected by means of a modular parallel interface (MPI). In addition to its control function, the PC processes the results of measurements, systematises them and provides recommendations as to the dosage of loads and their influence on man's condition. The complex includes the devices for measuring and monitoring man's conditions (surface and depth temperature sensors, electrocardiograph sensors, acoustic noises and heart rhythm sensors) and the devices attached to gymnastic apparatus (elastic strain, shift, velocity and acceleration sensors).

Contact sensors built on the basis of chip transistors (for example, type 2T377A1 with sizes 1,5×0,3×0,3mm) are used for measuring the temperature of the human body on its surface. Such sensors do not introduce any significant changes in the temperature field being measured, they warm up rapidly (1…5 seconds), and their current depends linearly on the temperature in a wide temperature range. The measurement error is no greater than 0,1°C under ambient temperatures 20…30°C. Such sensors are connected to the system through a multiplexer to form a multi-channel circuit.

Depth temperature is controlled by means of contact sensors that receive thermal radiation from the deep layers of human body. Sensors [1] developed at the Nizhni Novgorod Radio Physics Research Institute are used. They have a good matching in a relatively broad frequency band (20%) with the standing-wave radio<1,5 and scattering ratio from the external object less than 0,2%. Contact antennas are executed in several versions: a system of symmetrical vibrators intersecting in the excitation region, a coaxial-strip 50-Ohm connector, and a magnetic vibrator. The signal-processing device is a modulation receiver that compares the brightness temperature with the temperature of the reference load. The wavelength used in the device is 10 cm, surface resolution is 1,5 cm, measuring time in one point is 5 seconds, fluctuation sensitivity threshold is 0.05 K, absolute measuring error is not worse than 0.2 K [2].

Acoustic noises of the heart are measured with a highly sensitive electret microphone located in the acoustic channel that has a contact membrane at the receiving end. A serial electrocardiograph is used to acquire electrocardiographic data and the information on heart rhythms. When measuring the rhythms of cardiac activity, temporal distribution of the cardiogram's main peaks (maxima) is analysed. The duration of time intervals between the neighbouring heart contractions is measured by two binary counters operating alternately. To synchronise them, a pulse train derived from the cardiograph signal is applied.

Elastic strain, shift, velocity and acceleration sensors are made on the basis of piezoelectrics, their design being appropriate to the object of investigation.

All physical sensors with analog output are connected to the inputs of a multichannel analog-to-digitial converter (ADC). The data in the digital form is carried through the buffer to the RAM of the controller. It is consequently transferred to the base memory of the computer.

Preliminary results of measurements and analysis of the acoustic noises and rhythms of the heart are given below. We applied spectral-temporal analysis based on Wigner - Will transform [3] ensuring maximum time-and-frequency resolution. The algorithm and techniques described in [4] as well as the formalism and software developed by Yu.P.Lebedev, one of the authors, were used in this work.

Figure1 shows a fragment of heart noises recording. Signal level is plotted as an ordinate, corresponding to the numerical value of the 10-digit ADC code, and time measured as a number of samples N with the sampling frequency of 2 kHz is plotted as an abscissa. Time interval t1…t4 corresponds to one cycle of heart contractions. Figure2 shows the time and frequency distribution of this signal. The noise power varies quasiperiodically over time, which is reflected by horizontal stripes of maximum intensity. These are the distribution regions marked by number 1-4. In these regions the instantaneous signal spectrum has a wide band.

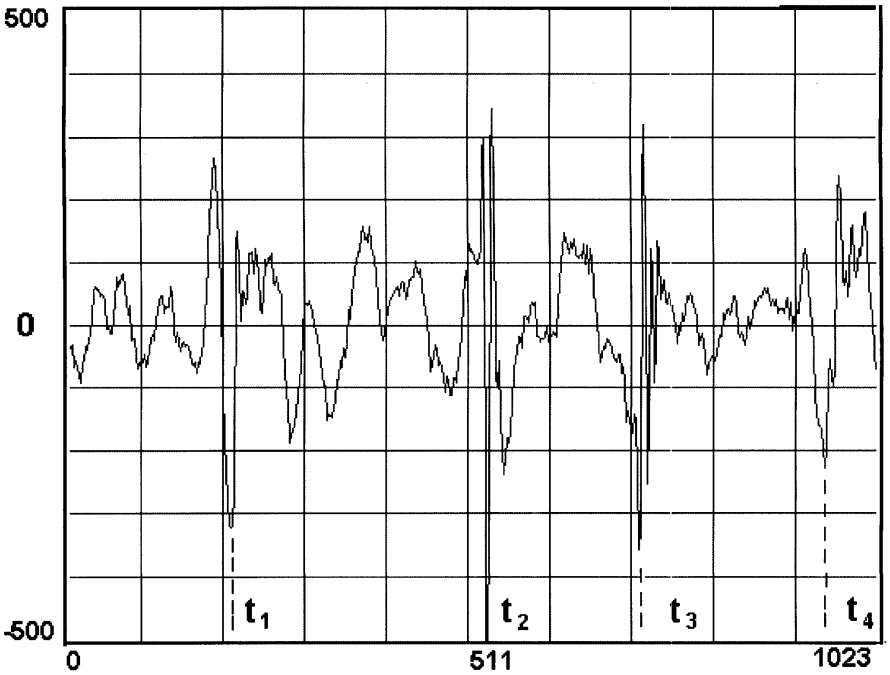

Figure 1.

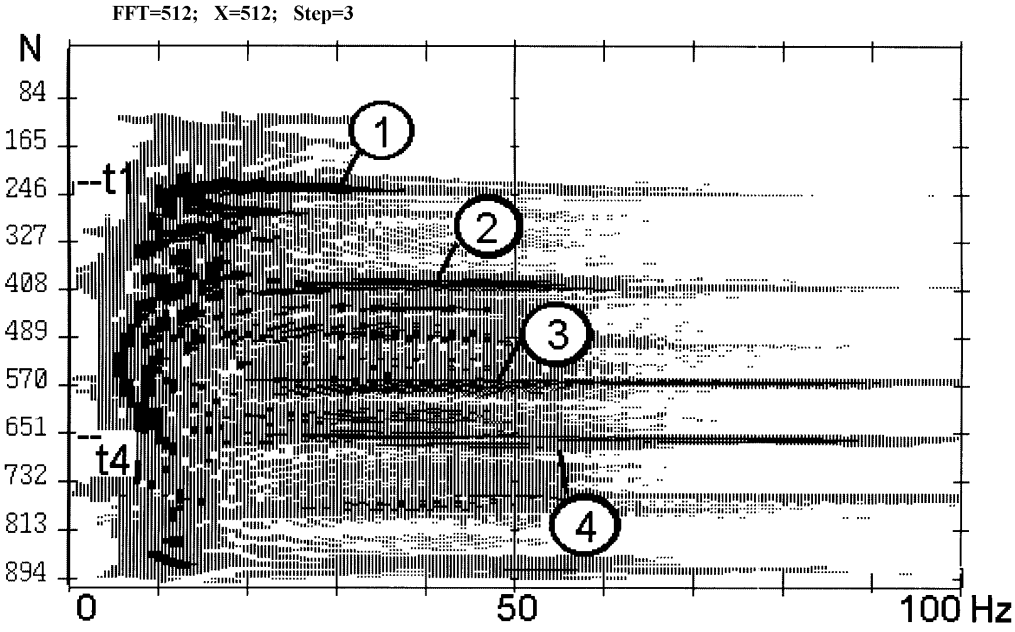

Figure 2.

At low frequencies of the order of 20 kHz wide spectral zones get relatively narrower, where the region of the energy frequency spectrum of the acoustic noise depends on time. This corresponds to the presence of various frequency-modulated modes in the heart noise. Fig.3 shows a similar distribution, but for a different cycle of heart contraction. It follows the same pattern as in Fig.2. Several series of measurements for different patients were carried out. We have noticed some general rules and some significant differences in the form of spectrum-and-time distributions of the noises measured.

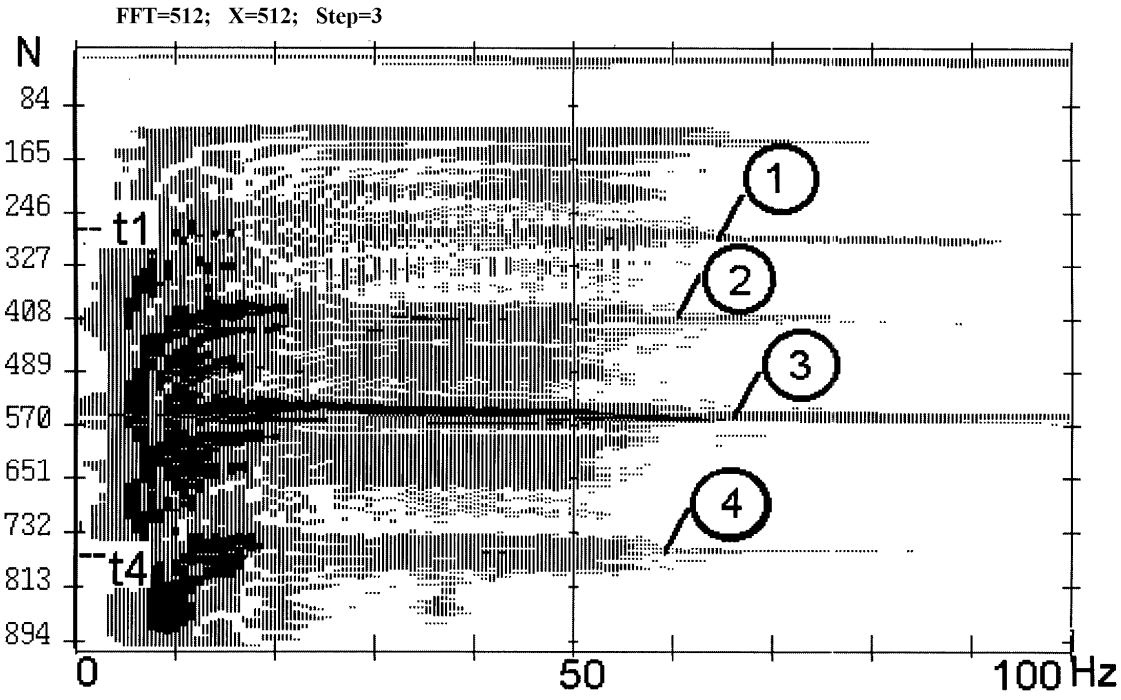

Figure 3.

Similar differences have been observed when we analysed the dependence of heart contractions on time. The results are given in Figs.4,5 where spectrum-and-time distributions of time intervals between pulse beats are shown. The number of beats counted for both measurements was 1024. Time measured as pulse beats is plotted as an ordinate in Fig.4,5, while frequency measured in the units equal to (1/1024) Hz is plotted as an abscissa.

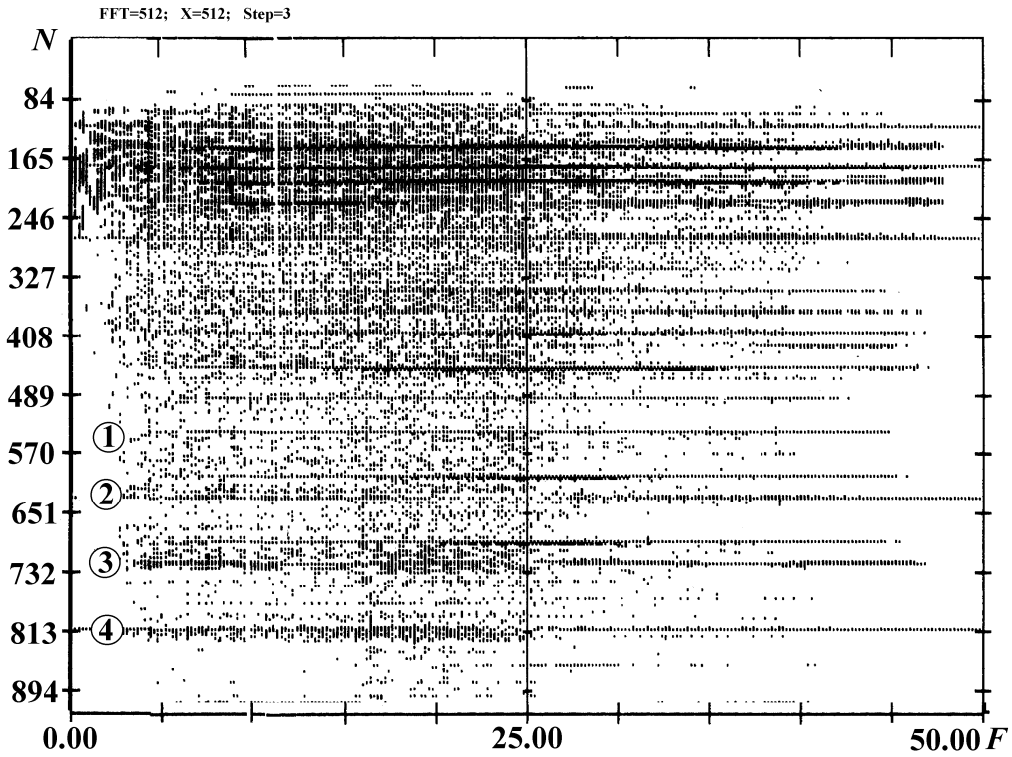

Figure 4.

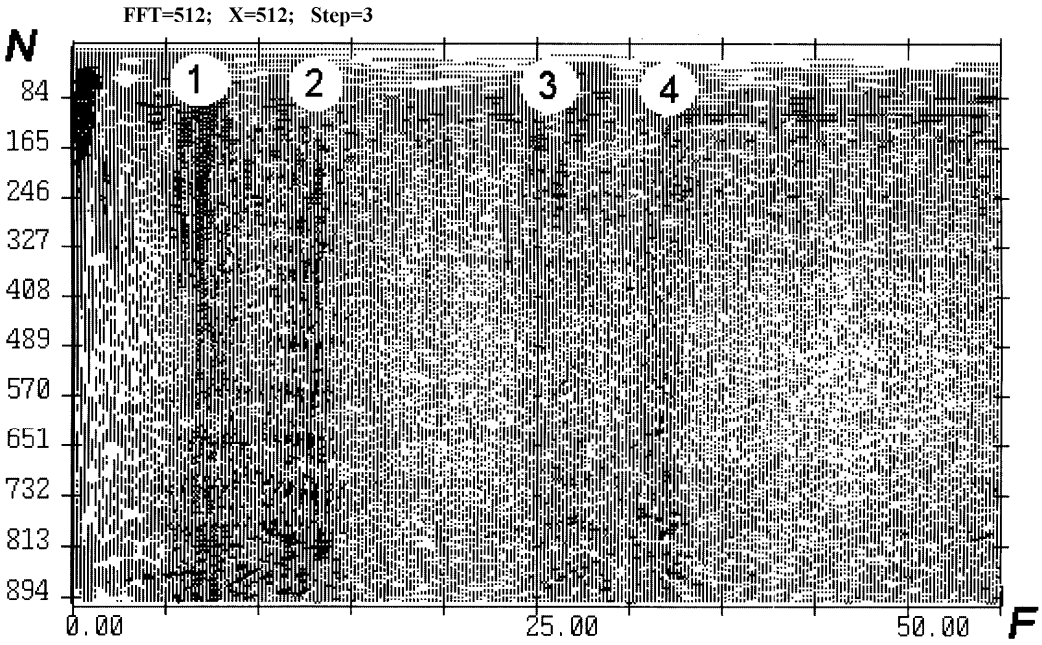

Figure 5.

Spectrum-and-time distribution in Fig.4 is in the form of horizontal irregularly alternating strips (strips like those marked by numbers1-4). In Fig.5, in the same distribution there are some regions of energy localisation mostly in the vertical zones 1-4. In the first case, one can observe significant irregularities in the time dependence of intervals between pulse beats. They are related to sharp deviations of the pulse frequency from the average value. In the second case, some periodicity can be seen in this dependency. It is of the order of 80-120 seconds with the average pulse period of 68 seconds.

3. CONCLUSION

These results and the results of the analysis of acoustic noises of the heart will have to be studied in more detail when there is enough statistical data. Only then the spectral and temporal analysis techniques that we propose can be used efficiently in medical diagnosis. We are planning to continue our work in this direction.

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