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AREAL BIOIMPEDANCE EQUIPMENT

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Abstract: The contribution shows the principle and construction of the areal bioimpedance equipment, which enables the evaluation of the dynamic course of bioimpedance in different parts of the body. The principle of the areal bioimpedance equipment is based on the measuring of bioimpedance by a four-electrodes impedance (resistivity) measuring method. The two-dimensional dynamic picture of the bioimpedance is obtained by tracing the bioimpedance in a rectangular net. The construction of the areal bioimpedance equipment issues of the realised experiments and measurements. The equipment enables the extension of the application range of bioimpedance methods not only for tracing the haemodynamic of the heart and big arteries, but also of the tissues and organs.

Keywords: bioimpedance, haemodynamic; human functions measurement

1 INTRODUCTION

The contemporary medical practice prefers the non-invasive diagnostics, because these do not affect the patient by surgical interferences. The described method is based on changes of the electric impedance of the human body (tissue), caused by the changes of blood flow during the heart cycle and are used for examination of the cardiovascular system in the thorax area. With regard to the requirements of the clinical practice there was developed an experimental areal bioimpedance equipment, which enables to trace the blood saturation also in other parts of the body.

The basic principle of the areal bioimpedance equipment issues from the four-electrodes method of electroimpedance measurement. On the body surface, in the area above the part to be examined, are spaced the voltage and current electrodes and their perfect contact with the skin is ensured. The impedance is determined by the voltage difference of the voltage electrodes in a given moment. For the determination of the partial impedances there are always applied four electrodes, two external exciting current electrodes and two internal voltage electrodes for scanning. The choice of the partial impedance to be just evaluated is executed by switching the scanning electrodes.

The conductivity in the area defined by the measuring electrodes is proportional to the instantaneous quantity of blood inside the same. In consequence the magnitude of the bioimpedance and especially its change in the course of the heart cycle is inversely proportional to the blood saturation of the tissue and according to the magnitude of the observed changes of the bioimpedance this blood saturation may be evaluated. In the case of a dynamic measuring of the impedance the dynamic changes of blood saturation of the examined area in the course of the heart cycle may be traced.

With exciting by a constant current the voltage between the measuring electrodes is directly proportional to the traced impedance. The magnitude of this voltage is relatively small, with regard to the typical magnitudes of the measured impedances in the scope 20 to 70 Ω and the magnitude of the exciting current 1 mA, the indicated voltages vary between 20 and 70 mV. The changes of the impedance caused by the blood saturation of the tissue during the heart cycle in the areas with big arteries (thorax bioimpedance - aorta) achieve units per mille, the impedance changes in the periphery areas may be even an order lower. The measuring equipment must therefore enable to evaluate with a sufficient exactness voltage changes of the order of units of μV and the required sensitivity at the signal processing must be at least by an order better.

2 AREAL BIOIMPEDANCE EQUIPMENT

The basic principle of the measuring of bioimpedance is the determination of the voltage difference between the measuring electrodes, located in the current field of the exciting electrodes. This principle is used for one channel measuring of impedance, however, with small adaptations it has been used also for multichannel measuring of impedance of a definite area, through which flows a constant high frequency current.

To the measured tissue is applied a couple of feeding current electrodes fed from a constant measuring current source 1 mA. The high frequency measuring signal of 75 kHz is generated by a stable crystal controlled generator and amplified to the necessary level by a power amplifier. To the measuring circuit is the measuring signal fed through the transformer, which ensures the galvanic separation of the circuits and the safety of the equipment. At the multichannel measurement the choice of the exciting electrodes is enabled by an analogue multiplexer, controlled by the computer. The block diagram is shown at fig. 1.

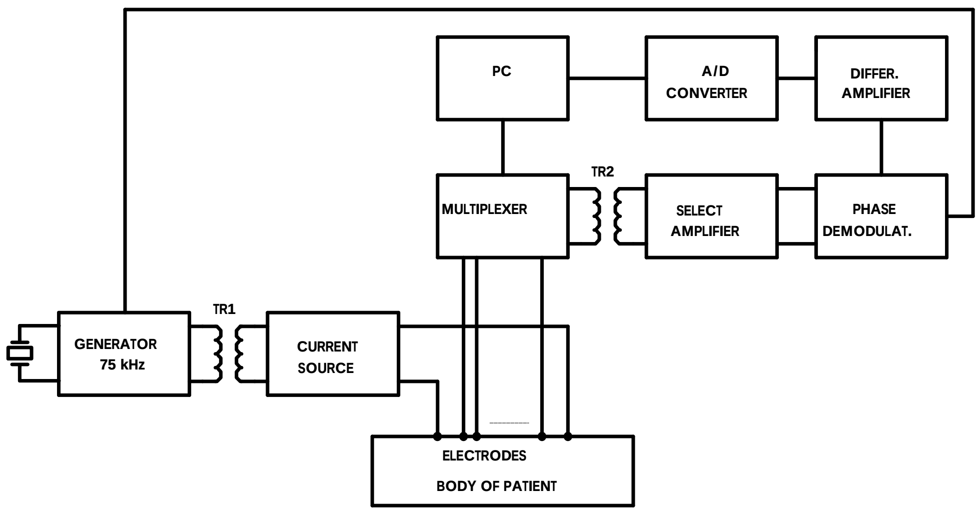


Fig. 1: The block diagram of the vector impedance tomograph.

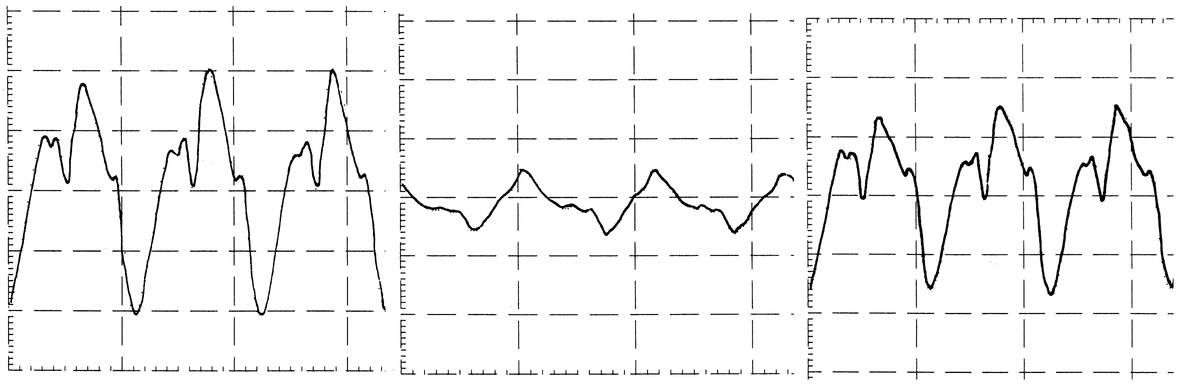
The evaluated voltage difference is measured always by a further couple of electrodes applied to the examined tissue section. The concrete measuring electrodes are chosen from the measuring matrix by means of another multiplexer, which again is addressed by the controlling computer. The voltage signal is through the separating transformer led to the input of the low noise small band amplifier. The amplified signal is rectified by two synchronous detectors, controlled by the signals from the 75 kHz generator. Between the controlling signals of both detectors there is a phase shift of 90 ^{0}, so that at the phase shift compensation in the measuring chain the output voltages of the detectors are proportional to the real and imaginary part of the measured impedance, which enables its vector evaluation. After the filtration and further amplifying the output signals of the detectors are led to the input of the A/D converter. The digital output signals are in the final phase evaluated by a special program by a computer.

3 EXPERIMENTAL RESULTS

The above described equipment has been realised and tested in laboratory conditions. There was used small dimension matrix sensor, enabling to determine the picture of impedances layout in 25 areas of a rectangular equidistant net. This small area is used for verification of the measuring method and of principal characters of the developed equipment. The measurement of the partial impedances was executed by a four-electrodes method, with arbitrary placing of measuring electrodes and switching of the voltage electrodes with constant position of the exciting current electrodes.

At first measurements there were determined the magnitudes of bioimpedance at different parts of the body: trunk, extremities, their dependence on the placing of electrodes, measuring frequency, current, etc. The experiments brought a basic information about the possible behaviour of the bioimpedance vector, confirmed the assumed, not too important dependence of the determined impedance on the placing of the exciting electrodes and the non-linearity of the bioimpedance, manifesting itself by a decrease at higher values of the measuring current.

Further measurements were carried out already with measuring equipment working in dynamic regime, enabling the evaluation of the differences of the components of the bioimpedance vector. A typical course of the time dependence of the differences of the components of the bioimpedance vector is depicted at fig. 2. The courses were determined by measuring the bioimpedance at the trunk, with measuring electrodes placed at the body symmetrical at a 7 cm distance below the thorax bone. The median of the absolute value of bioimpedance reached the value approximately 50 Ω, the phase angle approximately -20°. At fig. 2a) is depicted the time dependence of the difference of the real part, at fig. 2b) is depicted the time dependence of the difference of the imaginary part, at fig. 2c) is depicted the time dependence of the difference of the absolute value of the above bioimpedance. The changes of the values of the bioimpedance components during the heart cycle achieve magnitudes of hundreds mΩ, the course follows the heart action with an expressive decrease of the value during the systolis.



a) b) c)

Fig. 2: The time dependence of the difference of the bioimpedance: sensitivity 100 mΩ/d, time base 800 ms/d, a) real part, b) imaginary part, c) absolute value

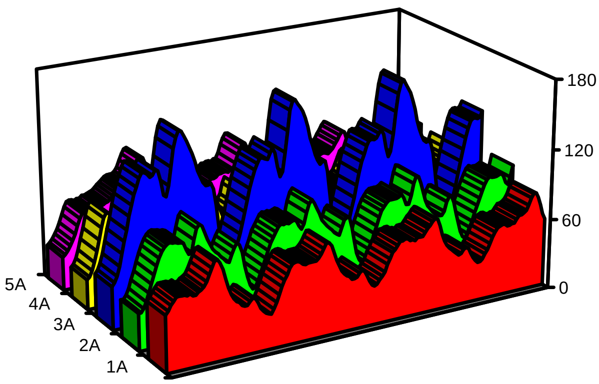


Fig. 3: The time dependence of the differences of the absolute value of bioimpedances Z_{iA} in line A, (i = 1, 2,....5) of the sensor matrix (see fig. 7)

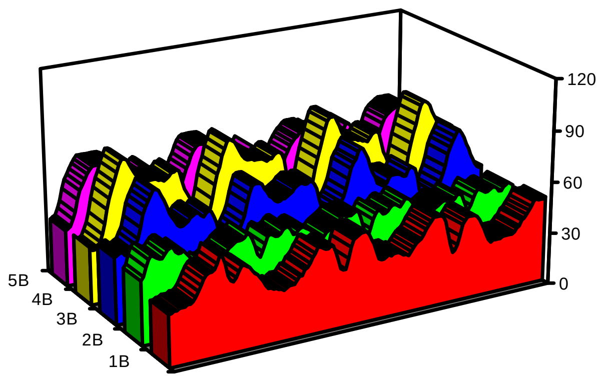


Fig. 4: The time dependence of the differences of the absolute value of bioimpedances Z_{iB} in line B, (i = 1, 2,....5) of the sensor matrix (see fig. 7)

The results of bioimpedance measurements with a matrix sensor are depicted at figs. 3, 4, 5 and 6. At figs. 3, 4, 5 are depicted the time dependences of the differences of the absolute value of bioimpedances Zxy in lines A, B, C of the sensor matrix (see fig. 7). From the courses of the individual impedances in the line there is evident a contemporary steep decrease of the bioimpedance in the whole area during the systolis and highest level of the differences in the centre of the examined area. At fig. 6 are in a three-dimensional graph depicted the magnitudes of oscillations of absolute values of bioimpedances in individual pixels of the matrix sensor. From the depicted graph there is possible to determine directly the area of greatest blood flow during the heart action.

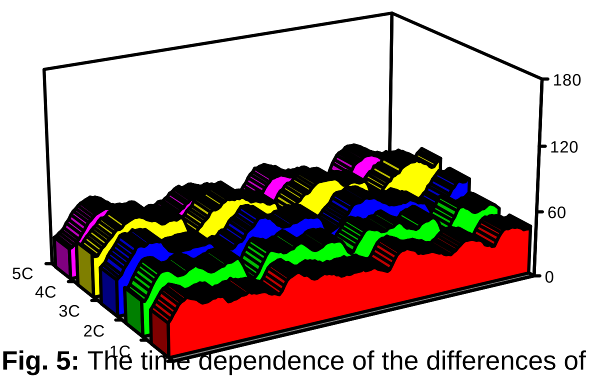


Fig. 5: The time dependence of the differences of the absolute value of bioimpedances Z_{iC} in line C, (i = 1, 2,....5) of the sensor matrix (see fig. 7)

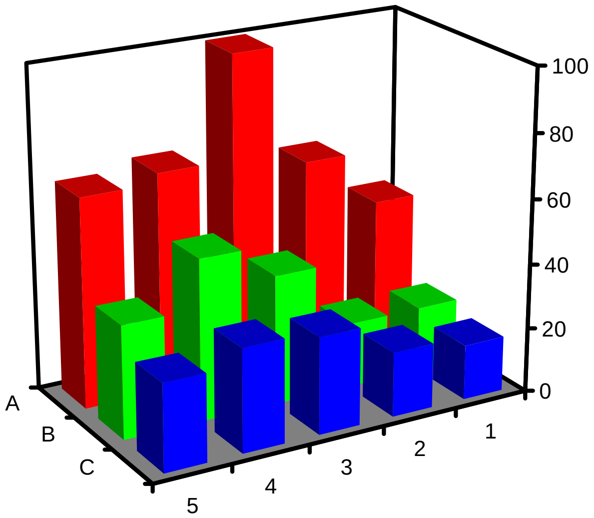


Fig. 6: The three-dimensional graph of the magnitudes of oscillations of absolute values of bioimpedances in individual pixels of the matrix sensor.

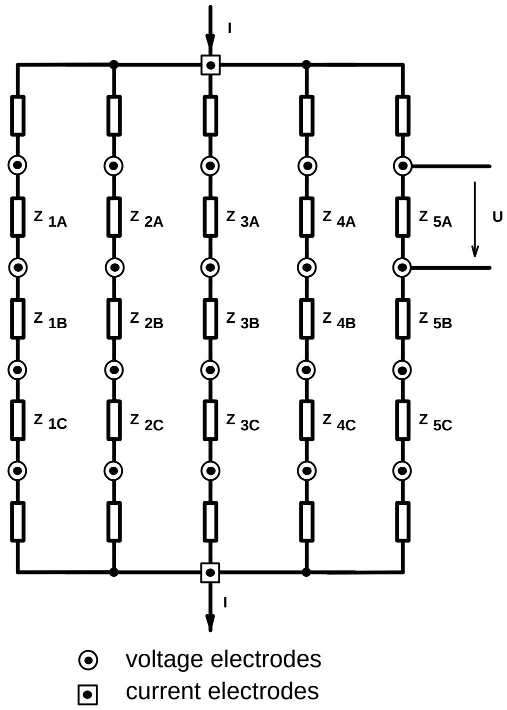


Fig. 7: Equivalent electrical schema of the measured impedance matrix.

4 CONCLUSION

The developed equipment shows higher sensibility than commercially produced devices for measuring of bioimpedances. The application of the matrix sensor enables, in comparison with advertised bioimpedance meters, to obtain information about the haemodynamic of tissues not only in the thorax area as a whole, but at the same time in many specially defined small areas of the body. This gives the presumptions for a considerable increase of the quality of the bioimpedance diagnostics.

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