Evaluation of the Influence of the Magnetic Field on Human by Use of Bio-impedance

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Abstract **-** The influence of a magnetic field on human is monitored by the evaluation of bio-impedance changes of a tissue, which is exposed by a strong magnetic field. The pulse magnetic field in the form of a binary pseudo-random process or a pulse field with constant frequency of some few tens Hz was used. A couple of Helmholz coils or a small magneto-therapeutic apparatus were used as the applicator. The maximum value of the magnetic flux density reached 60 mT. A forearm of a person under test was exposed to a magnetic field and there was measured the bio-impedance. Bio-impedance was evaluated by a narrowband RF vector impedance meter by use of four-point method. A rising level of the bio-impedance signal at about 60 % was indicated during the 15 minutes exposure by a magnetic field. There was not found a significant difference between the stochastic and the deterministic field effect.

I. Influence of the magnetic field on a living tissue

The quantitative evaluation of magnetic field effects on human being is interesting from therapeutic and hygienical point of view. The use of a magnetic field for therapeutic purposes in medicine has been known since ancient times. It is well known already for many years that magnetic field effected the inorganic and organic matter changes some of its physical and chemical characteristics. This effect is possible to be observed on the biological systems too. Research interest in magnetic field effects namely on biological systems is significantly stimulated by the fact that magnetic field is possible to be used for the treatment of many health troubles. Already in the first half of twentieth century, many researches studied the general effects of magnetic field on biological systems and principal problems of its medical application. Studies of the influence of these methods in the treatment of various disorders have always been based on clinical studies.

The main effect of the pulse magnetic field is thus anticipated in the analgesic and vasodilatation area. Our work provides a practicable methodology for direct quantitative observation of the influence of a magnetic field on live tissue by means of bio-impedance evaluation of vasodilatation effects.

Bio-impedance methods exploit the fact, that the electric impedance of the tissue varies according to the amount of blood contained in a segment at a given moment. The impedance and especially its changes in the content of the tissue are proportional to the amount of blood in the tissue and its flow. This enables us to identify changes in the tissue perfusion due to external influences in the course of regular measurements.

II. Description of experimental arrangement

Experiments were performed by the influence of a magnetic field on the forearm of an exposed person. Monitored segment is exposed by effects of a magnetic field. Changes of the absolute value of the impedance during the heart cycle were chosen as a measure of a magnetic field effects. Experiments were repeated in the same configuration several times, whereas for placebo effect exclusion, the person under test did not know, if magnetic field acts or no.

A magnetic field was generated by a small magneto-therapeutic apparatus according to [1] or by magneto-therapeutic instrument with pulse random signal according to [2]. For observing the bio impedance we used the RF narrow-band vector bio-impedance meter according to [3].

The small magneto-therapeutic apparatus generate a pulse magnetic field with a frequency of 25 Hz, 12,5 Hz, 6,25 Hz, 3,125 Hz and with a course corresponding approximately to half a sine wave of electric network. Voltage and current time response in the coil applicator at the operation with the fundamental frequency 12,5 Hz is illustrated in Fig. 1.

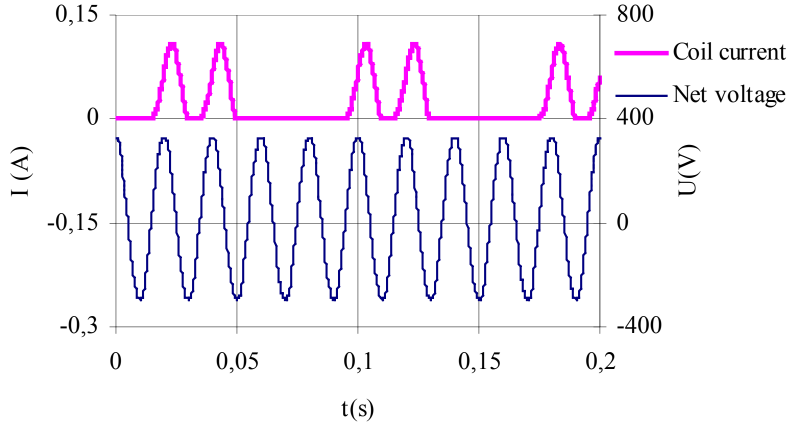

Fig. 1. Voltage and current time response in the coil applicator

The applicator coil has ohm resistance approximately 1200 Ω and winding inductance 11 H. It is solved for supplying by a simple frequency converter directly from the mains.
The applicator consists of a cylindrical multi-layer coil with opened magnetic circuit that is made from ferromagnetic sheets formed by the core and ferromagnetic case.
This opened magnetic circuit is designed to concentrate the magnetic field of the coil to the active area of apparatus and to limit the dispersion of field around the magnet. The magnetic field is emitted from apparatus in the direction of its axis and reaches therapeutically usable values in space roughly in shape of hemisphere over the active frontal area of case of apparatus (see Fig. 3).

Fig. 2. Small magneto-therapeutic apparatus

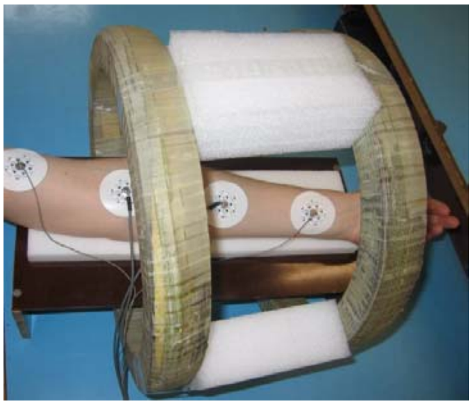

Fig. 4. Helmholtz coils applicator

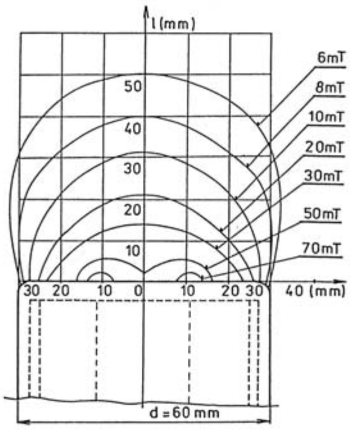

Fig. 3. Magnetic field values in front of the frontal plain of the apparatus

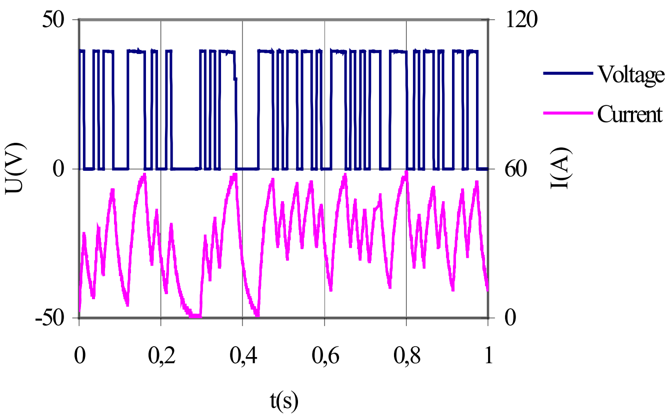

Fig. 5. Pulse random voltage and current time response

The peak value of magnetic flux density in the surroundings of the applicator achieve a level of 40 mT in the distance 10 mm and a level of 20 mT the distance 20 mm from the frontal surface of apparatus.
The magneto-therapeutic instrument with pulse random signal uses generator of a Galois code as a generator of digital 16-bits random sequence. Frequency spectrum of the generated signal has nearly a constant level in the band from $f/(2^N - 1)$ to f/2, where N is length of shift register (here 16) and f is clock frequency. The random signal frequency spectrum in this frequency band is conformable to frequency spectrum of the noise. The generator control a MOS-FET transistor power switch with maximal output current 60 A at voltage 40 V. An example of the voltage and current waves of the applicator with the basic clock frequency 100 Hz is shown in the Fig. 5.
The applicator consists of a couple of Helmholtz coils shown in the Fig. 4. Inner diameter is 30 cm, distance 20 cm, resistance and inductance of these two parallel-connected coils is 0,5 Ω and 17 mH. The course of standard value of magnetic flux density in the surroundings of the coils is displayed in Fig. 6. Approximately the constant magnetic field strength c. 60 mT was possible to achieve in this arrangement in a relatively big volume in the form of a cylinder with a diameter nearly 20 cm and length approximately 25 cm.

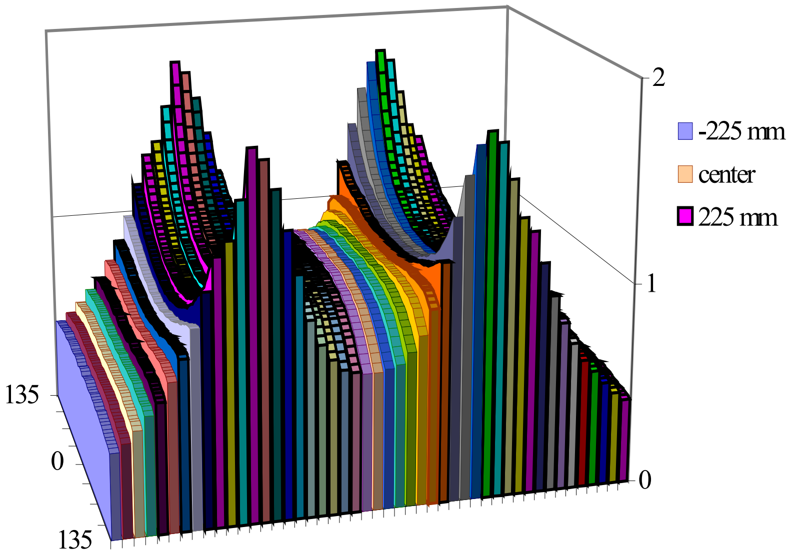

Fig. 6. Standard value of magnetic flux density in Helmholtz coils

Block diagram of the arrangement is illustrated in Fig. 7. The generator of the test signal, which is realized as the current source, supplies the two exciting outside electrodes of the four-electrode system with RF current 1 mA. A crystal oscillator and frequency divider generate the 75 kHz exiting signal and make control signals for coherent detectors. Output circuit of the test signal generator is galvanic separated by a transformer.

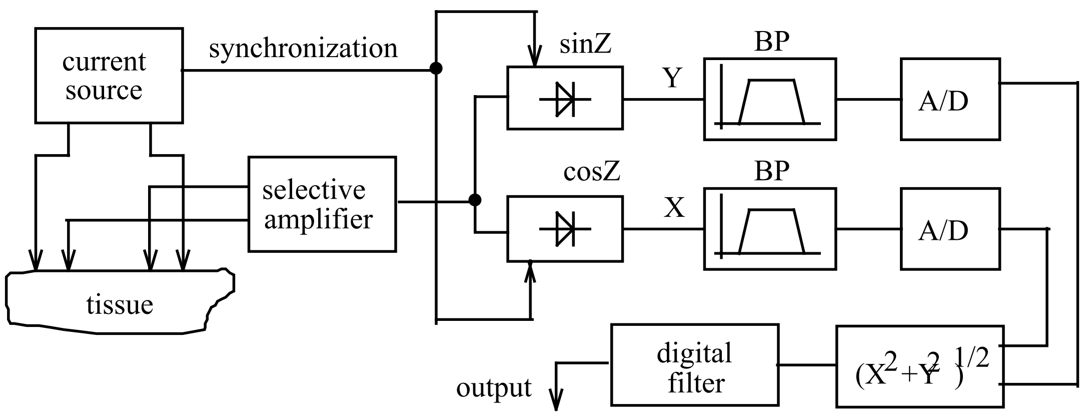

Fig. 7. Block diagram of the bio-impedance meter

The measuring amplifier is realized as a narrowband amplifier with high- quality selective LC circuits and with a high linearity. The amplifier has differential input which is designed as a differential transformer and with a selective filter. The amplified signal is rectified by two synchronous detectors, controlled by the signals from the generator of 75 kHz. Between the controlling signals of both detectors there is a phase shift of $\pi/2$, 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.
The output signal of synchronous detectors is at first processed by amplifiers with an amplitude characteristic representative band pass with the cut-off frequencies approximately 0,5 and 20 Hz. First analog filtering is succeeded before A/D conversion. Digital signal processing is realized by a computer.

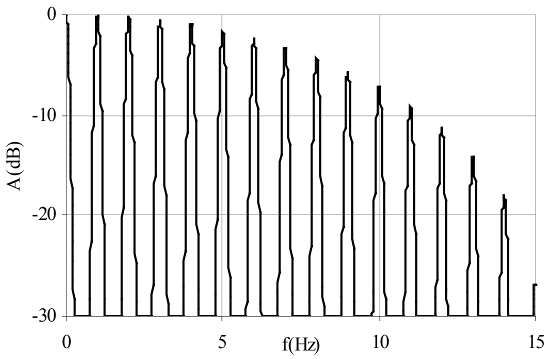

Fig. 8**.** Amplitude characteristic of the digital filter

There is used the no-recursive digital filter with a finite pulse response and with a length approximately 1200, which has the amplitude characteristic of comb filter. It is shown in Fig. 8. This characteristic approximately corresponds with the bio impedance signal spectra and allows practically the maximal improvement of the signal to noise S /N ratio for the processed signal at a holding of its in harmonic wave. The adaptive filter is fine-tuned in order that the period of its amplitude characteristic may correspond to the instantaneous signal frequency. Adaptation algorithm of the filter goes out of analyses of the autocorrelation function of the signal. The characteristic course of the impedance change signal d*Z* is shown in Fig. 9. Experiments ordering with a person under test are illustrated in Figs. 10 and 14.

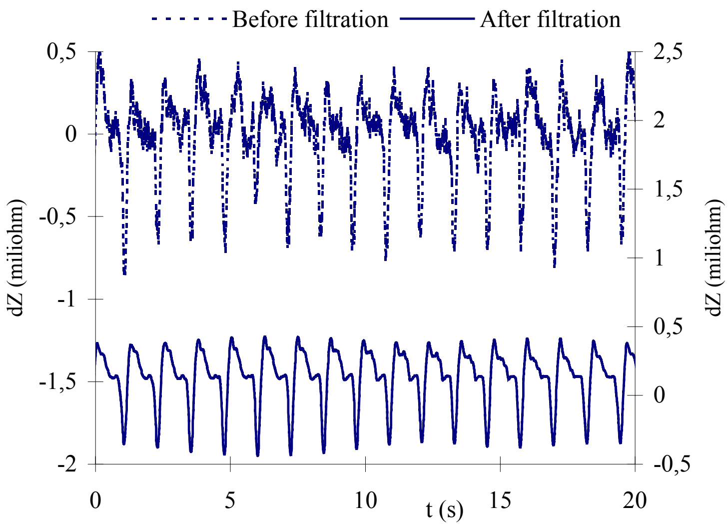

Fig. 9. Typical time response of the bio-impedance signal

Electrodes for bio-impedance scanning are placed on the inside of the forearm. Inner, voltage electrodes have the distance of 10 cm in between, outer current electrodes are placed 5 cm from voltage electrodes. There were disposable ECG wet gel electrodes. The area between voltage electrodes was exposed to magnetic field inside Helmholtz coils or by use of a small magneto-therapeutic apparatus.

III. Conclusions

Experiments have been provided during 30 minutes. The exposure took a time of 15 minutes (5^{th} – 20^{th} minute). Graphs in Figs 11, 12 and 13 illustrate relative deviations of the measured values of a RMS of bio-impedance signal from the steady-state value before the exposure by the magnetic field (vertical axis). Time is independent parameter in graphs. In the front of these graphs there are always illustrated values of 4 comparison experiments, which were measured without the present of the magnetic field. Values of 8 experiments with the present of the magnetic field are illustrated in these graphs behind.

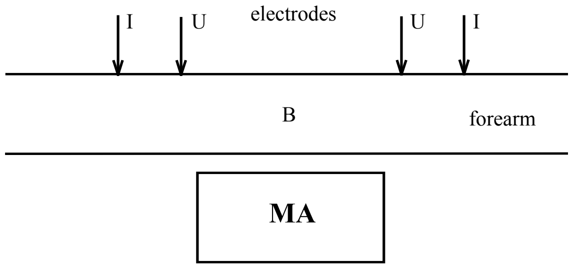

Fig. 10. Bio-impedance measurement by use of magneto-therapeutic apparatus (MA)

Graphs in Fig. 11 show the response of pulse magnetic field with the frequency 12,5 Hz from small magneto therapeutic apparatus. Fig. 12 shows the response of random magnetic field with the maximum flux density B_{max} 20 mT. Fig. 13 shows the response of random magnetic field with the maximum flux density B_{max} 60 mT.

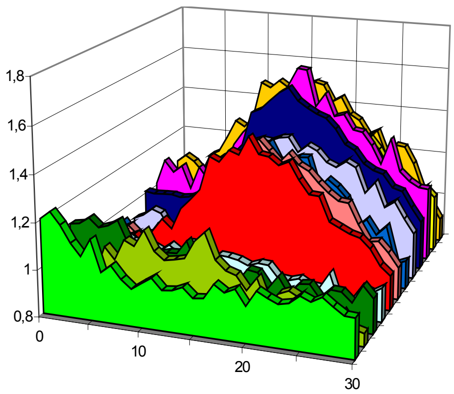

Fig. 11. Time responses of the bio-impedance signal by using of magneto-therapeutic apparatus.

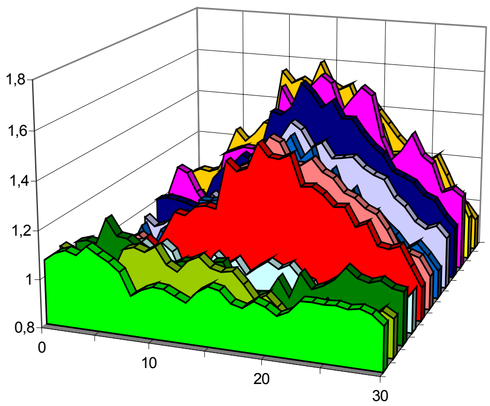

Fig. 12. Time responses of the bio-impedance signal by using of pseudo random magnetic field, B_{max} = 20 mT.

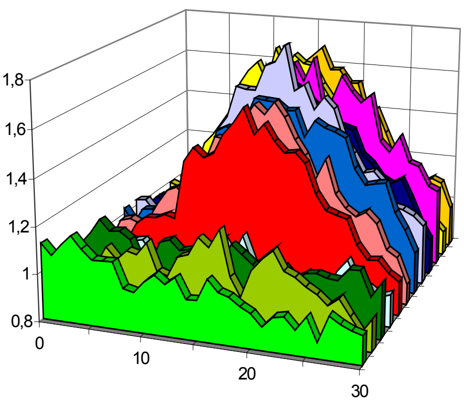

Fig. 13. Time responses of the bio-impedance signal by using of pseudo random magnetic field, Bmax = 60 mT.

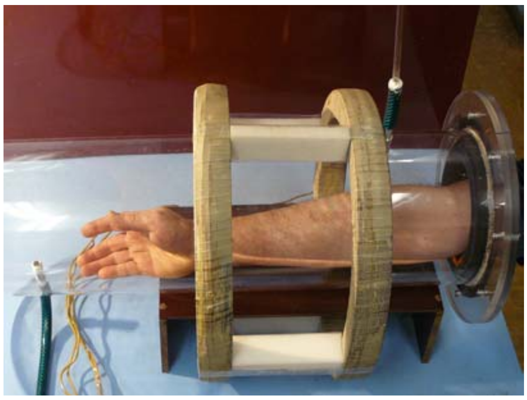

Fig. 14. The plethysmograph in Helmholtz coils

Results of our bio-impedance measurements were compared with evaluation of the influence of the magnetic field when in use plethysmographic measuring in plethysmograph according to the Fig. 14. Relative changes of the volume during the heart cycle are presented in Fig. 15; in the case, when magnetic field is applied and in the case, when magnetic field is not applied.

Average bio-impedance values of all experiments are visualized in Fig. 16. The signal level increases above the normal level when exposure begins (in the first 5 minutes of the experiment). The maximum arrives after about 10 minutes of the exposure and exceeds the normal level by approximately 60 % (see the curve in the 15th minute).

The signal level begins to level out on longer exposure, and falls almost to a normal value after a long exposure, after approximately one hour.

The influence of the signal with random course is a bit bigger. Influence of the field with higher intensity is also bigger.

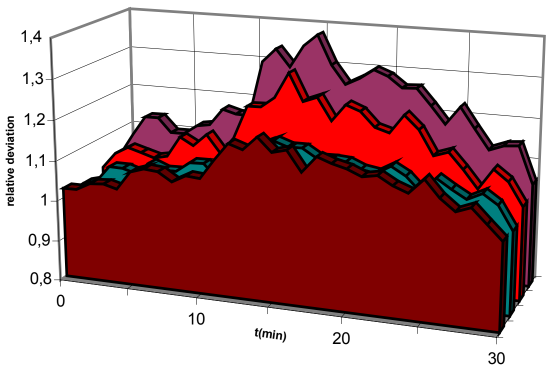

Fig. 15. Time responses of the pletysmographic signal by using of pseudo random magnetic field B_{max} = 60 mT.

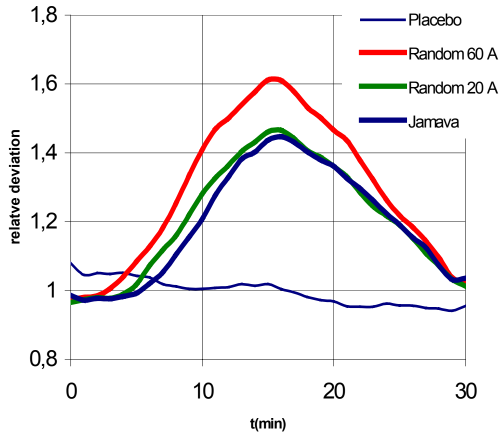

Fig. 16. Average values of time responses of bio-impedance signals

IV. Acknowledgment

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