XVIII IMEKO WORLD CONGRESS
Metrology for a Sustainable Development
September, 17 – 22, 2006, Rio de Janeiro, Brazil

INFLUENCE OF A MAGNETIC FIELD ON LIVING TISSUE

Vaclav Papez [1], *Stanislava Papezova* [2]

[1] Faculty of Electrical Engineering, Czech Technical University in Prague, Czech Republic, papez@feld.cvut.cz
[2] Faculty of Mechanical Engineering, Czech Technical University in Prague, Czech Republic, stanislava.papezova@fs.cvut.cz

Abstract: This paper describes a system, which enables quantitative monitoring and evaluation of the influence of a pulse magnetic field on a live organism by using of bio-impedance measurement. There are presented results of performed experiments.

Keywords: magnetic field, bio-impedance, blood vessel flow.

1. INTRODUCTION

The use of a magnetic field for therapeutic purposes in medicine has been known since ancient times. It is a non-invasive therapy, with no risk of addiction. A therapy using a variable magnetic field with an influence different from that of a static field has been under development since the 1950s.

The main effect of the pulse magnetic field is thus anticipated in the analgesic and vasodilatation area.

Studies of the influence of these methods in the treatment of various disorders have always been based on clinical studies. Our work provides a practicable methodology for direct quantitative observation of the influence of a magnetic field on live tissue.

2. BIOIMPEDANCE METHOD

Evaluation of haemodynamics using the bio-impedance-method exploits the fact, that the electric impedance of tissue varies according to the amount of blood contained in a segment at a given instant. Because blood has greater conductivity than tissue, the presence of a slightly increased amount of blood decreases the impedance of the tissue. This impedance increases as the blood runs out of the segment of tissue (see Fig.1).

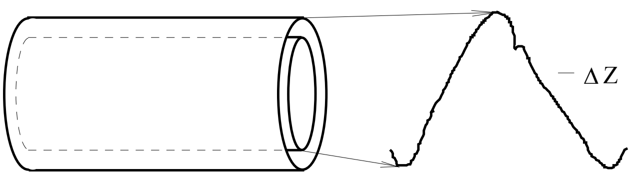

Fig. 1. Vessel and impedance changes during the heart cycle

The impedance change is therefore an ohmic representation of the blood vessel flow. This enables us to identify changes in the tissue perfusion due to external influences in the course of regular measurements.

3. EXPERIMENTAL WORK

Experiments were performed on the magnetic exposure of the forearm of a relatively healthy human.

Basic arrangement of this experiment is displayed in Fig. 2. Current field in a tissue is generated by external electrodes I, voltage on monitored segment is scanned by electrodes U. Monitored segment is exposed by effects of a magnetic field B. Impedance changes of the absolute value during the heart cycle was chosen as a measure of magnetic field effects. Experiments were repeated in the same configuration several times, whereas for placebo effect exclusion, person under test didn't know that, if magnetic field acts or no.

A magnetic field B was generated by a small magneto-therapeutic apparatus [1] (see Fig. 2) or by magneto-therapeutic instrument with pulse random signal. [2]

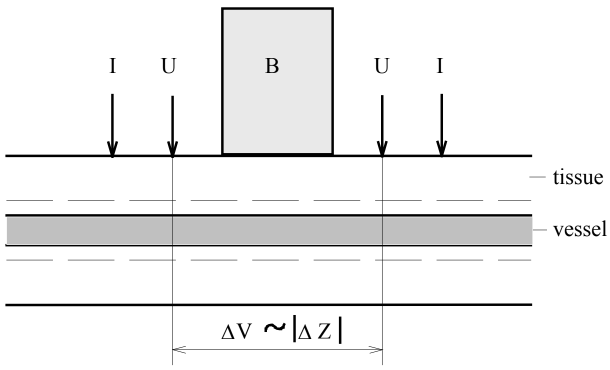

Fig. 2. Four-electrode method for measuring bio-impedance

For observing the bio impedance we used the RF narrow-band vector bio impedance meter [3].

In the first case a pulse magnetic field was used 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.

The applicator is consisted of a cylindrical multilayer coil with opened magnetic circuit 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 magnitudes in space roughly in shape of hemisphere over the active area of apparatus.

The peak value of magnetic induction in the surroundings of the applicator is displayed in Fig. 3 in the form of central section surfaces of constant magnetic induction.

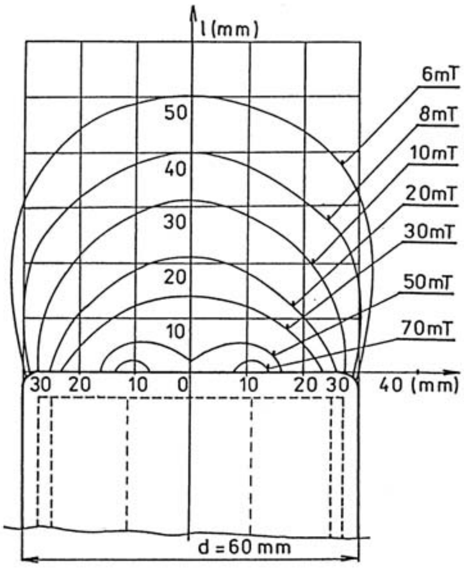

Fig. 3. Magnetic induction in the surroundings of the applicator

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. Block diagram of the apparatus is illustrated in Fig. 4.

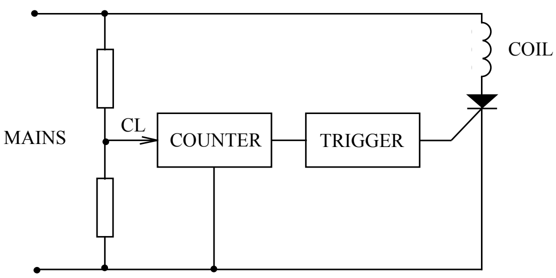

Fig. 4. Block diagram of the apparatus

Voltage and current time response in the coil applicator at the operation with the fundamental frequency 12,5 Hz is illustrated in Fig. 5.

The magneto therapeutic instrument with pulse random signal uses as the applicator a couple of Helmholtz coils. Inner diameter is 30 cm, distance 20 cm, resistance and inductance of these two parallel-connected coils is 0,5 Ω and 17 mH. Coils are supplied by maximal current 40 A at voltage 40 V.

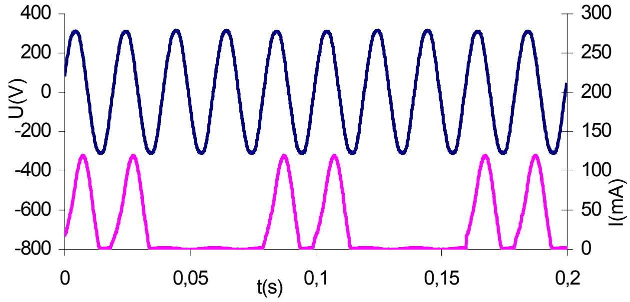

Fig. 5. Voltage and current time response in the coil applicator

Approximately the constant magnetic field strength c. 40 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.

Curves of constant value of the standardized magnetic field strength in the plain that crosscut axis of this coils is displayed in Fig.6.

Experiment ordering is illustrated in Fig 7

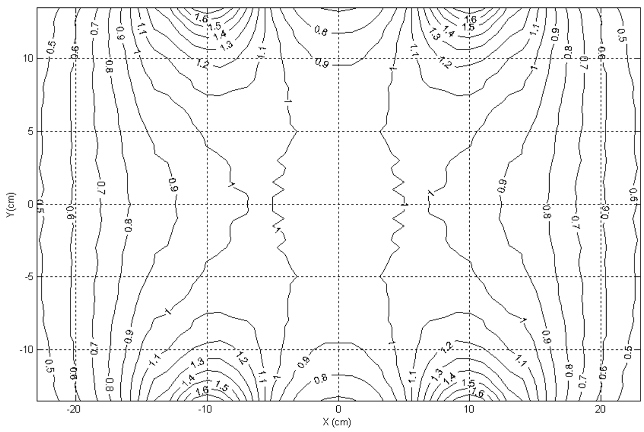

Fig. 6. Magnetic induction in the surroundings of the coils

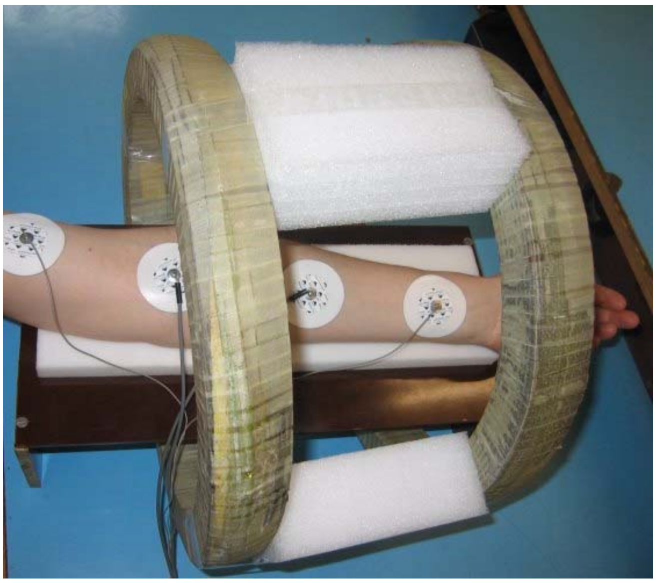

Fig. 7. Experiment ordering

The principal diagram of the generator operating with pulse random signal is shown in Fig. 8.

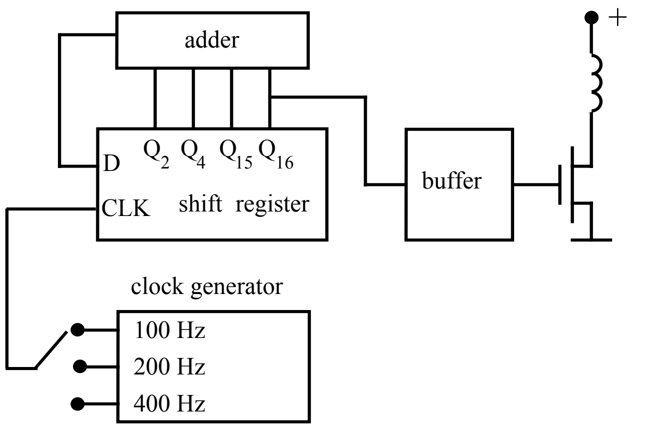

Fig. 8. Block diagram of the pseudo-random generator

This broad–spectrum enables covering so called biological frequency on which the interference of the field and biological system should be most effectual, without concrete information about the biological frequency.

The generator of digital random sequence was designed like 16-bits generator of a Galois code and realized as programmable logical array. That makes possible, with using of N-cell series shift register and relevant feedback with adder, generation of sequence of logical signals with maximal length of (2^N-1). Frequency spectrum of generated signal has practical constant level in the band from $f/(2^N-1)$ to $f/2$, where N is length of shift register and f is clock frequency. Frequency spectrum is getting very near to frequency spectrum of noise. A MOSFET transistor as power switch, exciter circuit for controlling of gate of transistor (buffer), clock generator with three selected frequencies (100, 200 and 400 Hz), making possible the shift of spectrum of generated signal, were used in this case. High inductivity of the coil of applicator affected as low pass filter.

An example of the voltage and current waves and frequency spectrum of the applicator with the basic clock frequency 100 Hz is shown in the Fig. 9.

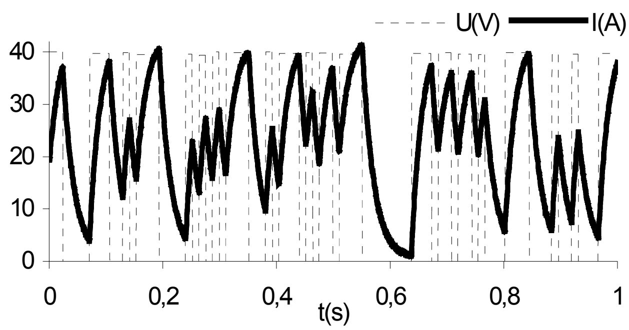

Fig. 9. a) Pulse random voltage and current time response in applicator coils for clock generator frequency 100 Hz

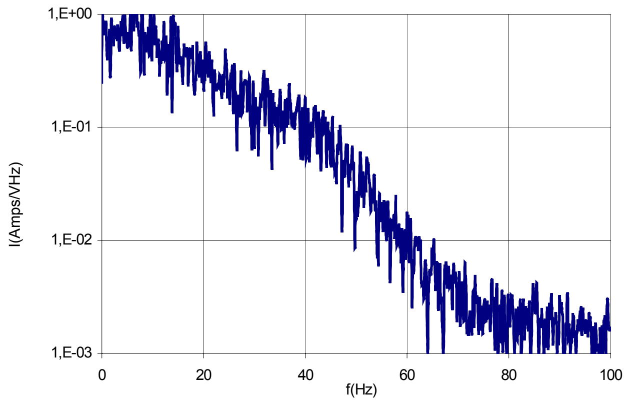

Fig. 9. b) Frequency spectrum of the current in applicator coil

The vector impedance meter is based on the four-electrode method of electro impedance measurement.

Block diagram of the arrangement is illustrated in Fig. 10.

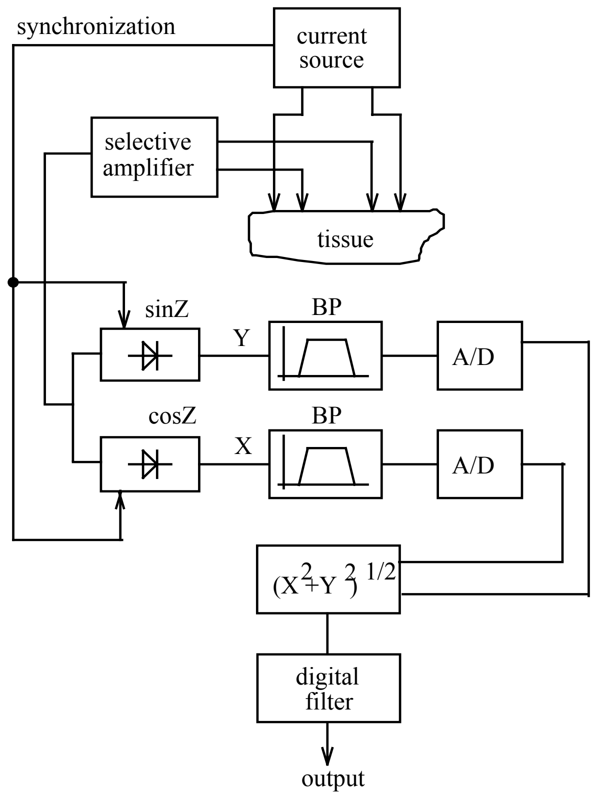

Fig. 10. Block diagram of the arrangement

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.

The evaluated voltage difference is measured always by a further couple of electrodes applied to the examined tissue section.

The voltage signal is 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 $\pi/2$, 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. 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.

The impedance changes were evaluated as a power signal *dZ*, which had been determined from the two components by digital processing of the sampled-data signals. The characteristic course of the signal *dZ* is shown in Fig. 11.

Courses A and B answer to the case without working of a magnetic field. Course C corresponds to the state on 15 minutes working of the field with B_{max} 40 mT inside Helmholtz coils.

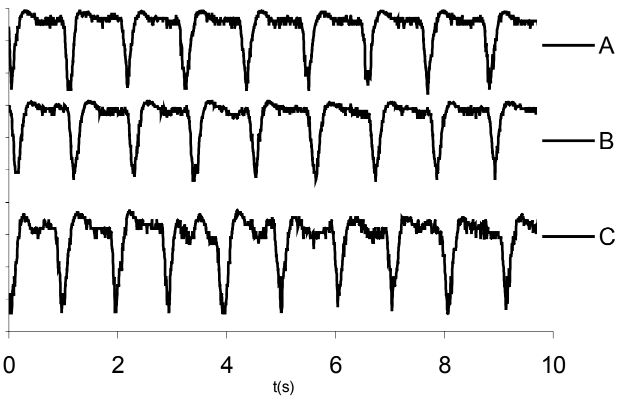

Fig. 11. Characteristic time response of signal *dZ*, vertical scale *dZ*: 1 mΩ/div

4. CONCLUSION

The typical exposure response of a bio-impedance signal with the use of the above-mentioned pulse magnetic field parameter for a period of 20 minutes is shown in Fig. 12, where curve 1 matches the exciter frequency 12,5 Hz, curve 2 random signal 20 A, curve 3 the high power random signal 40 A.

When exposure begins, the signal level increases above the normal level, represented by samples 1-2. The maximum arrives after about 10 minutes and exceeds the normal level by approximately 50 % see samples 6 and 7.

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

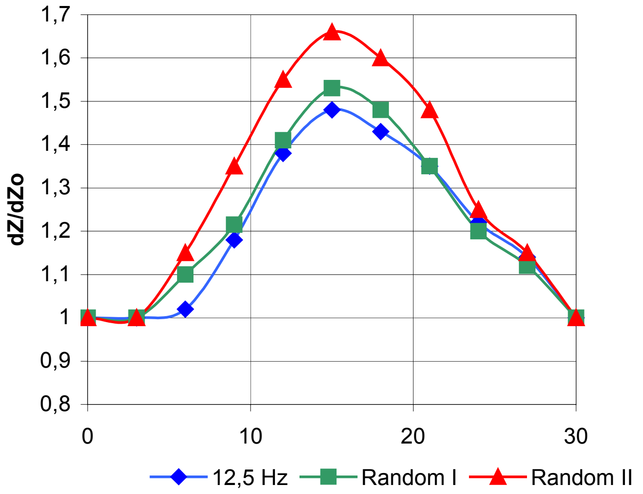

Fig.12. The typical exposure response of a bio-impedance signal with the use of the pulse magnetic field

ACKNOWLEDGEMENT

The research was supported by the research program No. MSM6840770015 "Research of Methods and Systems for Measurement of Physical Quantities and Measured Data Processing "of the CTU in Prague sponsored by the Ministry of Education, Youth and Sports of the Czech Republic.

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