An evaluation of the influence of a magnetic field on a human subject with the use of bio-impedance

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Abstract. The influence of a magnetic field on a living human organism was monitored using a bio-impedance evaluation of vasodilation effects. A quantitative evaluation of the influence of a magnetic field on a human being was implemented by means of a quantitative evaluation of changes in the bio-impedance of the tissue. The pulse of the magnetic field was controlled by a pseudo-random impulse signal using a power switch that controlled the current of the applicator coil. The peak magnetic field flux density was approximately 60 mT. The bio-impedance was measured by a four-electrode method by means of a radiofrequency narrow band vector bioimpedance meter. Experiments were performed on the magnetic exposure of the forearm of an exposed human subject. During exposure to a magnetic field, the bio-impedance change signal level increases above the normal level, and reaches the maximum level after about 10 minutes. The maximum value is approximately 50 % higher than the normal level.

1. Influence of a magnetic field on living tissue

Magnetic fields have been used in medicine for therapeutic purposes since ancient times. It is well known that a magnetic field leads to changes in inorganic and organic matter, and in some of its physical and chemical characteristics. These effects can also be observed on biological systems. The main effect of a pulse magnetic field is thus anticipated to be in the analgesic and vasodilation area. Our work provides a practical methodology for direct quantitative observation of the influence of a magnetic field on living tissue by means of bio-impedance evaluation of vasodilation effects.

Bio-impedance methods are based on the fact that the electric impedance of the tissue varies according to the amount of blood contained in a segment at a given instant. The values of theimpedance magnitude changes (dZ) are proportional to the amount of blood in the tissue and its flow during the heart cycle. This enables us to identify changes in tissue perfusion due to external influences in the course of regular measurements.

2. Description of the experimental a rrangement

The experiments consisted of measurements of the magnetic exposure of the forearm of a healthy human subject. The monitored segment was exposed to the effects of a magnetic field. Changes in the effective value (RMS) of the dZ signal were chosen as a measure of the magnetic field effects. The experiments were repeated several times in the same configuration. In order to eliminate the placebo effect, the subject was not informed whether a magnetic field was acting or not.

2.1. Magnetic field generator

A magnetic field was generated by a magneto-therapeutic instrument with a pulse random signal (RG)

or by a small magneto-therapeutic apparatus (MA), as described in [1]. To observe the bio-impedance we used a radiofrequency (RF) narrow-band vector bio-impedance meter, as described in [2].

The RG uses a generator of a Galois code to generate a digital random sequence of 16 bits. The frequency spectrum of the generated signal has a nearly constant level in the band from $f/(2^N - 1)$ to $f/2$, where N is the length of shift register (here N=16) and f is the clock frequency (here 100 Hz). The applicator is a couple of Helmholtz coils, with an inner diameter of 30 cm, distance 20 cm. It was possible to achieve a peak magnetic flux density value $B_{max} = 60$ mT between the coils with the use of a pulse random excitation current.

The MA generates a pulse magnetic field with a frequency of 25 Hz, 12,5 Hz, 6,25 Hz, 3,125 Hz and with a course corresponding to approximately half a sine wave of the electric network. The applicator consisted of a cylindrical multi-layer coil with outer diameter 52 mm and length 37 mm, with an open magnetic circuit made of ferromagnetic sheets formed by the core and the ferromagnetic casing. B_{max} in the surroundings of the applicator reached a level of 40 mT at a distance of 10 mm and a level of 20 mT at a distance of 20 mm from the frontal surface of the apparatus.

2.2. The bio-impedance meter

The bio-impedance meter was realized as a narrowband vector impedance meter (Z-meter) with four-electrode sensing. A narrow transmission bandwidth and coherent signal detection enabled higher sensitivity and noise immunity from the external disturbance in the surroundings of the pulse magnetic field generator.

A block diagram of the arrangement is illustrated in figure 1. 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 1 mA RF current with frequency 75 kHz.
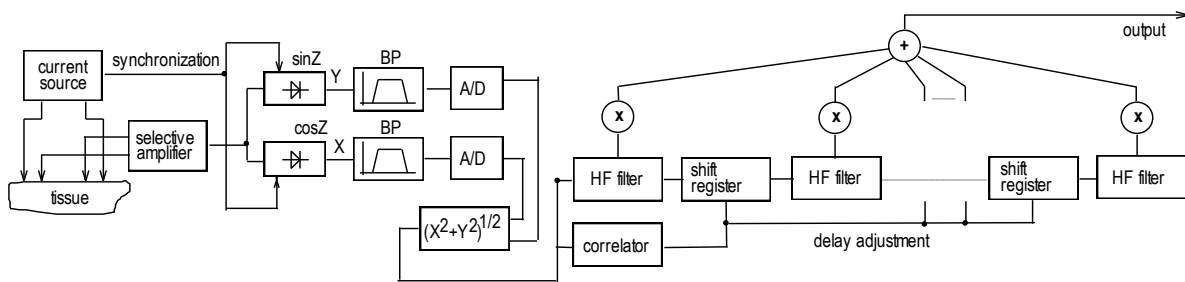

Figure 1 Block diagram of the bio-impedance meter

The evaluated voltage difference, which is proportional to the observed impedance, is measured by an internal couple of electrodes. The measuring amplifier is realized as a narrowband amplifier with high-quality selective resonant circuits and with high linearity. The amplified signal is rectified by two synchronous detectors, controlled by the signals from a 75 kHz generator. Between the controlling signals of the two 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 us to evaluate its vector.

2.3. Signal processing

The output signal of the synchronous detectors is first processed by amplifiers with an amplitude characteristic representative band pass (BP) with cut-off frequencies of approximately 0,5 and 20 Hz. After A/D conversion, digital dZ signal processing follows. The amplitude is determined for the vector signal of the bio-impedance, and this signal is processed in real time by the adaptive digital filter, using a signal processor and a computer. The amplitude characteristic of the filter corresponds approximately with the signal spectra of the bio-impedance, and practically enables maximal improvement of the signal-to-noise (S/N) ratio for the processed signal [3]. A typical amplitude characteristic of the filter is displayed in figure 2. The characteristic of the filter is approximately periodic, which corresponds to a comb filter with basic frequency f, and the envelope curve of the process corresponds to a low-pass filter with a multiple higher cut-off frequency up to about 7 to 10f (HF). The filter is designed as a filter with a finite impulse response. Its pulse response is created by

convolution of the pulse response of the comb filter and a low-pass HF filter. The filter is continuously adapted by setting the periodicity frequency f of the characteristics to a value which corresponds to the signal frequency rate. The tuning of the filter proceeds with a time delay adjustment of the shift registers in the filter. The signal frequency rate filter is based on analyses of the autocorrelation function of the signal. The typical time response of the bio-impedance signal, d*Z*, is shown in figure 3 before and after filtration.
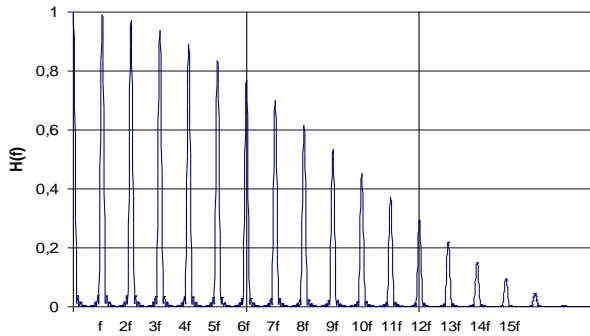
Figure 2 Typical frequency response of the digital filter
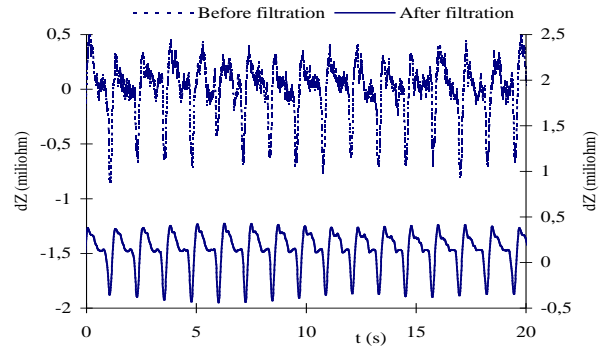
Figure 3 Typical time response of the bio-impedance signal, d*Z*

3. Experiment ordering

The schematic ordering of the tests is illustrated in figure 4. The electrodes for bio-impedance scanning were placed on the inside of the forearm. On the inside, the voltage electrodes were 10 cm apart, and the outer current electrodes were placed 5 cm from the voltage electrodes. There were disposable electrocardiograph wet gel electrodes. The area between the voltage electrodes was exposed to the magnetic field inside the Helmholtz coils, or MA was used. The actual layout with the Helmholtz coils applicator is displayed in figure 5.
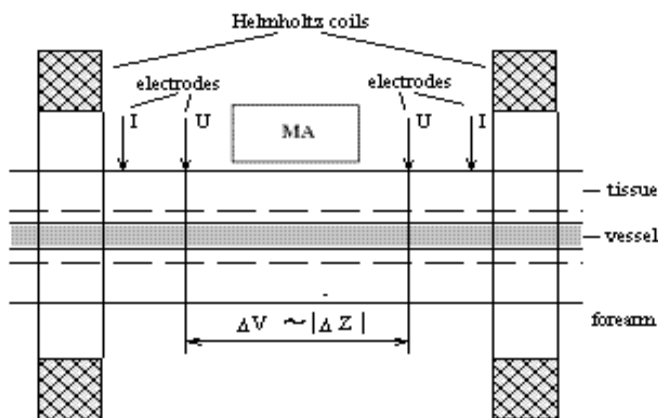

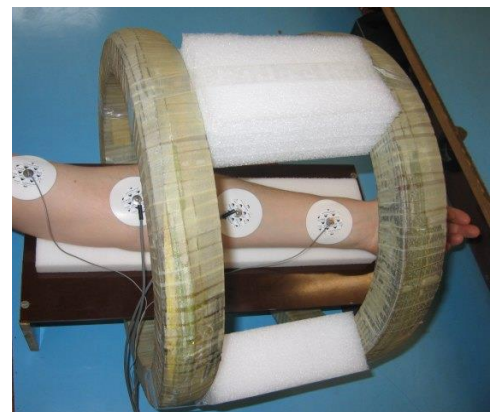Figure 4 Bio-impedance measurement with Helmholtz coils or with MA applicator

Figure 5 Bio-impedance measurement with a Helmholtz applicator

The experiments were carried out during 15-minute exposure to a field with the above-mentioned parameters. The relative deviations of the values of the RMS of d*Z* from the steady-state value before exposure to the magnetic field, measured with a magnetic field, are illustrated in the graphs.

In these graphs, forwards , we show the values of 4 experimental comparisons, which were measured without the present of a magnetic field. The values of 8 experiments with the presence of a magnetic field (marked with an abscissus above) are illustrated in these graphs, at the back .

Measurements with B_{max} = 60 or 20 mT and using MA were made in the same way. The average relative deviations of the RMS of the d*Z* values for all experiments are shown in figure 7. The results of our bio-impedance measurements were compared with an evaluation of the influence of the magnetic field when using plethysmographic measurements, see figure 8.
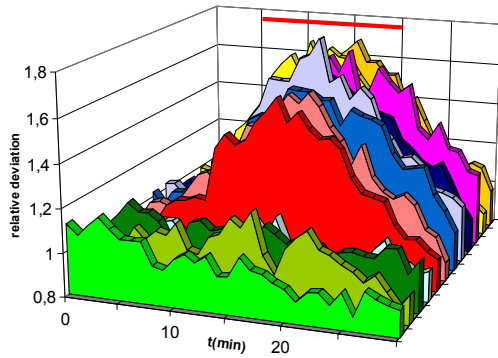
Figure 6 Bio-impedance time response of a random magnetic field with B_{max} 60 mT.
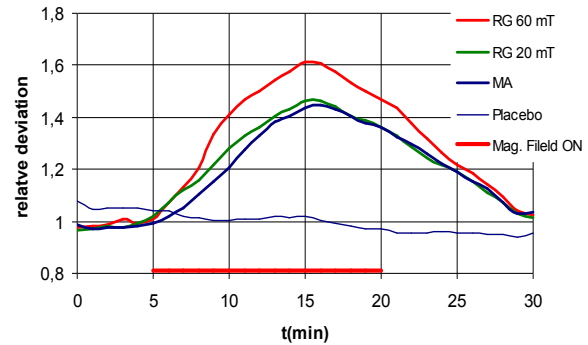

Figure 7 Average values of time responses of bio-impedance signals

The relative changes in volume during the heart cycle are presented in figure 9; in the case when random magnetic field B_{max}= 60 mT is applied (4 time behaviours, above) and in the case when no magnetic field is applied (1st time behaviour, below).
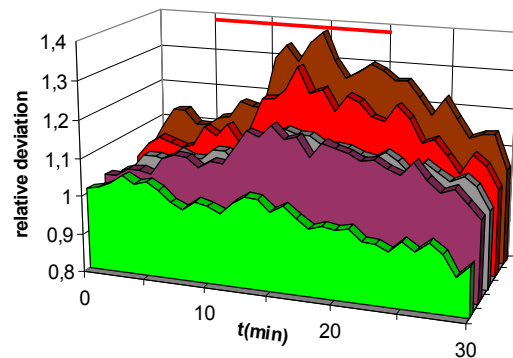

Figure 8 The plethysmograph in Helmholtz coils

Figure 9 Time responses of the plethysmographic signal

4. Conclusions

The signal level increases above the normal level when exposure begins (in the first 5 minutes of the experiment). The maximum is reached after about 10 minutes of exposure, and exceeds the normal level by approximately 60 % (see the curve in the 15th minute).

The bio-impedance responses and the plethysmographic signal responses are very similar.

The signal level begins to level out on longer exposure, and falls to an almost normal value after long exposure (approximately one hour). The influence of the signal with a random course is slightly greater. The influence of a field with higher intensity is also greater.

 References

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