An Electric Field Test Using the MRI

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Abstract — The paper describes a test of an electric field on water molecules based on the present knowledge of the problem as discussed by references [6–11]. The basic configuration of the test was experimentally verified at the Institute of Scientific Instruments, Academy of Sciences of the Czech Republic. We also prepared other tests using a different type of substance to find the relation between the MRI and the macroscopic electric field intensity. As a matter of fact, it respects the classical Electrodynamics and Material Wave Theory (MWT). The experiments are intended for future applications in the field of health service.

1. INTRODUCTION

In recent years the research in this field has been focused on the search of different ways of treating various types of diseases like tumors, viruses, and other micro- and nanoscopic problems [1, 2]. The papers referred to in this study analyze the impact of an external electric field application on the development and persistence of tumor diseases. For example, paper [3] analyzes — depending on the effect of external influences, namely electromagnetic fields — the mechanisms of emergence of a cell and its uncontrolled development phase. The research carried out by the laboratory specialists of Norfolk University, USA [4, 5] features the analysis of the impact of impulse electromagnetic fields on tissue structure changes, genetic code changes, and the types of controlled variation in selected parts of an organism.

The basic experiments and studies of the impact of electric and electromagnetic fields on the development of tumor diseases have been presented by prof. Kikuchi [6]. The previous published studies [2], however, had not entirely respected the complex electro- magneto- hydro- dynamic (EMHD) principles of approach. According to the data available, the phases of a tumor disease development are classified into four stages as related to the status of a cell. The first two of these stages are reversible; within the remaining ones, however, distinctive changes in the cell metabolism are recorded and, given the standardly weak EMHD effects in the latter two stages, the principles of cell change become irreversible. The research conducted by Norfolk University is markedly oriented toward analyzing the latter two stages in the development of a cell within a tumor formation. In comparison with this research orientation, we have focused our research distinctly on the former two development stages.

The elementary approach to the problem consists in finding a suitable numerical model to analyze the impact of an electromagnetic field on the basic chemical structure elements. Within the process of numerical analysis, we perform the testing of the impact of an electric field on a small volume of purified homogeneous H\textsubscript{2}O water. In this respect, the interdependence is sought between the impacts of size, direction, and instantaneous course of the electric field intensity on the molecular properties of the material (water). Further, experiments are performed using the Nuclear Magnetic Resonance (NMR) and the Magnetic Resonance Imaging (MRI), and the shift and variation of the spectral line of the examined sample are monitored. In the process of the verification of laws resulting from the MWT and the available plus verifiable theories [7–13], the procedure of an electric field impact analysis will be directed toward more complex organic structures. The elementary findings of the sample status in the NMR testing are further completed with numerical analysis [13].

2. MRI EXPERIMENTS

In order to set the NMR method, both the impacts thereof on the resulting image and the material inhomogeneity impact on the processing of the NMR image were examined and numerically modelled [15]. Further, to support the analysis of the impact of an electric field depending on the
The instantaneous value and size of electric field $E$ intensity on the samples that can be located close to the operator, we developed special controlled voltage sources with output voltage regulation of $U_{out} = 1–100$ kV and current limitation (to the value of current manageable by a human organism) within the range of $I_{out} 0–1$ mA. Figs. 1 and 2 show the conception of the controlled, high-voltage source. This problem is analyzed in greater detail by the [14] reference study.

![Figure 1: A high voltage source compact conception.](image1)

![Figure 2: High voltage source component conception A), one module of the source.](image2)

This work deals with the design of an electronically controlled high-voltage power source used for special purposes. The source will be used to set up the intensity of an electric field on predefined shapes of material samples, from simple inorganic to complex organic materials. The design must fulfill the condition of a constant setting of the source’s output current. The regulation ranges should be: output voltage $U_o = 1–100$ kV, electric current $I_{max} = 10 \mu A–10$ mA, frequency $f = 0–1$ KHz. The device must satisfy safety requirements specified by Czech standards (ČN). Several designs have been prepared on the basis of available materials, and one was selected and realized: a circuit with an offline flyback regulator, regulated with pulse-width modulation frequency $f_m = 30$ KHz. The power source was realized and its specifications were experimentally verified. The electronic
control wiring diagram of the high-voltage source with current limitation is shown in Fig. 3. The numerical analysis results were experimentally verified using the 200 MHz/75 mm MR tomograph at the ISI, AS CR (Fig. 5). The tomograph elementary magnetic field $B_0 = 4.7000$ T is generated by a superconducting horizontal magnet produced by the Magnex Scientific company. The resonance frequency for the cores $^1$H is 200 MHz. From the measurements performed using the MRI we obtained the results of the electric field intensity $E$ impact on the cores of the $\text{H}_2\text{O}$ sample; an overview of these results is provided in Tab. 1. Further, experiments were carried out on the $\text{H}_2\text{O}$ sample using a device with a system of electrodes. There was a distance of 20 mm between the electrodes, which were fixed to a laboratory beaker containing the water sample. The fixation was realized in such a manner as to eliminate the displacement current effects on all the surfaces and dielectric volumes. Leakage current was secured, with the resulting assurance of operator safety. Then, the first measurement without the electric field intensity $E$ impact on the examined sample showed the centre on the frequency of $f_0 = 184$ Hz. After connecting voltage to the electrodes and producing the electric field intensity of 50 kV/m–4050 kV/m, we managed repeatedly to measure the resonance line shift of $\Delta f = 4$ Hz. Thus, the influence was experimentally proved of the electric field static intensity on the motion and behaviour of water molecule cores. According to the well-known relation between the change of frequency and the change of magnetic induction [15], the change of magnetic induction is

$$
\Delta B = \frac{2\pi \Delta f}{\gamma} = \frac{2\pi \Delta f}{2.67 \times 10^8}
$$

(1)

where $f$ [Hz] is the frequency, $\gamma [T^{-1} \cdot s^{-1}]$ is the gyromagnetic ratio of water, and $\Delta B [T]$ is the change of magnetic flux density module distribution in the sample. Then, the change of magnetic induction corresponds with $\Delta B = 94.1$ nT.

Figures 4 and 5 show the experimental MRI laboratory.

Table 1: The measured resonance frequency shifts.

<table>
<thead>
<tr>
<th>Electric Field Intensity $E_z$ [kV/m]</th>
<th>Resonance frequency offset [Hz]</th>
</tr>
</thead>
<tbody>
<tr>
<td>+4050</td>
<td>+4</td>
</tr>
<tr>
<td>+2025</td>
<td>+4</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>+2025</td>
<td>+3</td>
</tr>
<tr>
<td>-4050</td>
<td>+3</td>
</tr>
</tbody>
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3. CONCLUSION

The presented paper contains the results of experiments analyzing the impact of an electric (static) field on the behaviour of elementary compounds cores. The study represents a step forward in the analysis of the more complex chemical substances behaviour as related to the impact of an electric field. The results of EMHD theories were taken into account in studying the task, and an MWT-based model was used for the numerical support thereof.
ACKNOWLEDGMENT

The research described in the paper were financially supported by FRVŠ by research plan No. MSM 0021630516, ELCOM-No. MSM 0021630513, grant GAAV No. B208130603 and Prof. H. Kikuchi for the consultations and advises.

REFERENCES