Numerical safety assessment of magnetic-field-induced effects in a rotating head

Ilkka Laakso [1] **Sami Ilvonen** [1]

[1] ***Department of radio science and engineering***
Helsinki University of Technology, Otakaari 5 A, 02150 Espoo, Finland
Email: ilkka.laakso@tkk.fi

Movement in a strong static magnetic field induces electric fields in human tissues. These fields could potentially cause harmful effects. In this study, the fields induced by different rotational movements of a head in a strong homogeneous magnetic field are computed numerically. This topic is of particular interest for MRI procedures, during which medical staff may have to move in the strong stray field of the superconducting magnet.

The movement-induced electric field can be solved by using quasistatic approximation by dropping displacement current and self-induction. This leads to Poisson's equation for unknown scalar potential, which is solved using an efficient finite-element method (FEM) solver. In this study, the induced electric field is calculated in four different anatomically realistic head models for three rotational movement patterns: shaking, nodding and tilting motions.

The induced electric field may interact with the body by several mechanisms, which include magnetohydrodynamic forces, and sensory or nerve stimulation. The magnitudes of the induced currents are small, so the resistive heating can be omitted. Currently, there are no confirmed long-term biological hazards, and effects are limited to short-term reactions. These short-term sensory effects include magnetic field induced vertigo (MFIV), which is associated with head movement in a magnetic field. The mechanism behind the vertigo-like effects is likely to be the induced galvanic vestibular stimulation (iGVS) [4] by induced electric currents in the vestibular organs which are located in the inner ear.

Another short-term sensory effect of extremely low frequency magnetic field is phosphenes, i.e. seeing light flashes. It is likely to be caused by stimulation due to induced electric fields in the retina, and is considered to have the lowest threshold for direct sensory effects. The lowest threshold for phosphenes occurrence is at 20 Hz frequency, which is of course outside the range of frequencies involved in natural movements. Fortunately, due to the quasistatic approximation, the results for head movement are also valid for this frequency.

The goal of this study is to produce information for approximating the threshold electric field values of phosphenes and MFIV effects associated with movements of the head in a static magnetic field. Average field magnitudes near the retinas and inner ears are studied in order to gain insight into these effects. The results are compared with measurements available in the literature [4], [5], and are used for approximating the threshold electric field values for phosphenes and MFIV effects. Computed results are also compared to the basic restriction limits in [1], [2] and [3] in order to estimate the compliance of different rotational head movements in a strong static magnetic field, e.g. near MRI scanners. Based on these results, it seems that the basic restriction limits may be exceeded by natural movements near a MRI scanner.

References

[1] ICNIRP, "Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz)," *Health Phys.*, vol. 74, pp. 492–522, 1998.

[2] ICNIRP, "Guidance on determining compliance of exposure to pulsed fields and complex non-sinusoidal waveforms below 100 kHz with ICNIRP guidelines," *Health Phys.*, vol. 84, pp. 383–387, 2003.

[3] IEEE, *IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0-3 kHz, C95.6-2002*. New York: Institute of Electrical and Electronics Engineers, 2002.

[4] P. Glover, I. Cavin, W. Qian, R. Bowtell, and P. Gowland, "Magnetic-field-induced vertigo: A theoretical and experimental investigation," *Bioelectromagnetics*, vol. 28, no. 5, pp. 349 – 361, 2007.

[5] P. M. Glover and R. Bowtell, "Measurement of electric fields induced in a human subject due to natural movements in static magnetic fields or exposure to alternating magnetic field gradients," *Phys. Med. Biol.*, vol. 53, no. 2, pp. 361–373, 2008.