A Portable MR Exposure Monitoring System for B_0 and dB/dt up to 7T.

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Targeted Audience: Basic Scientists in MR safety and MR engineering.

Purpose & Introduction: The EU directive 2004/40/EC is currently under review and will be replaced in 2013 [1]. The proposal for the new version limits electromagnetic exposure due to movement in strong static magnetic fields in the range of 5.17 T/s – 0.67 T/s for movements at 0.1 Hz – 1 Hz [2]. For magnetic field exposure monitoring probes have been developed. In this work a new portable and wireless probe is presented which can operate at field strengths of up to 7 Tesla, and can store measurement data over a time span of more than 48 hours.

Materials & Methods: A lightweight magnetic field probe with three orthogonal Hall sensors and three orthogonal induction coils was constructed to simultaneously measure the magnetic flux density B_0, the time varying magnetic flux density dB/dt_{trans} and the time varying magnetic density dB/d$t_{rot+trans}$ (according to ICNIRP [3]). Coils were wound on cubic acrylic glass formers (coil area: 5 mm², 500 windings). Each Hall sensor was attached to a circuit board which was fixed onto the cubic coil former. Both measurement systems were connected to separate voltage amplifiers with an integrated low pass filter with a cut-off frequency of 10 Hz to eliminate high frequency noise. Analog signals were converted with an open-source data logging circuitry based on the ATMEGA8-16PU (Atmel Corp., San José, California, USA) with a six channel ADC (10 bit). The digitized data was stored on a 2GB memory card. The electronic circuitry and rechargeable power supply is housed by a custom built casing (Fig. 1). The whole setup is built of nonmagnetic components. For calibration of both systems a 20 T-hall-probe (THM1176, Metrolab Instruments SA, Switzerland) was used.

To measure magnetic fields causing transient effects like magnetophosphenes or vertigo, the probe was attached to a cap close to the ear. Six measurements were performed during the work shift of technicians and scientists in the magnet room of a 7 T MR system (Siemens Healthcare, Erlangen, Germany). Three exposure parameters, B_0, dB/dt_{trans}, and the dB/d$t_{rot+trans}$ were recorded simultaneously.

Results & Discussion: During the six measurements maximum peak values of dB/dt_{trans}, B_0, and dB/d$t_{rot+trans}$ of 1.2 T/s, 0.7 T and 2.8 T/s were measured. Figure 2 shows exemplarily date of a procedure at 7 T.

The proposed limit values would only be exceeded during this procedure in a frequency range of 0.6-1.0 Hz and if the ICNIRP suggested definition of dB/dt (dB/d$t_{rot+trans}$) is used. Future refinements aim at further reducing the size of the circuitry to minimize the size of the setup.

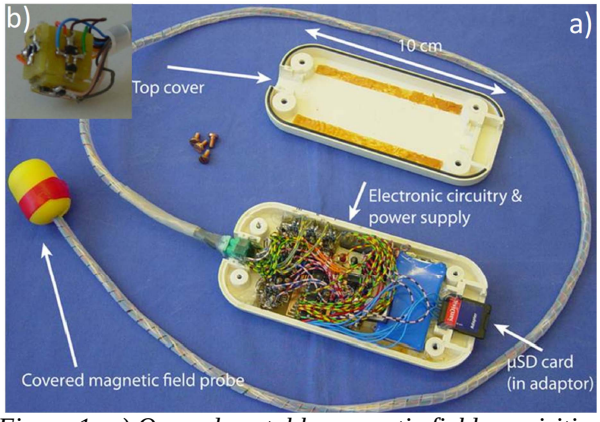

Figure 1: a) Opened portable magnetic field acquisition system. The magnetic field data is stored on a removable memory card for further analysis. b) Opened magnetic field probe showing 3 Hall sensors

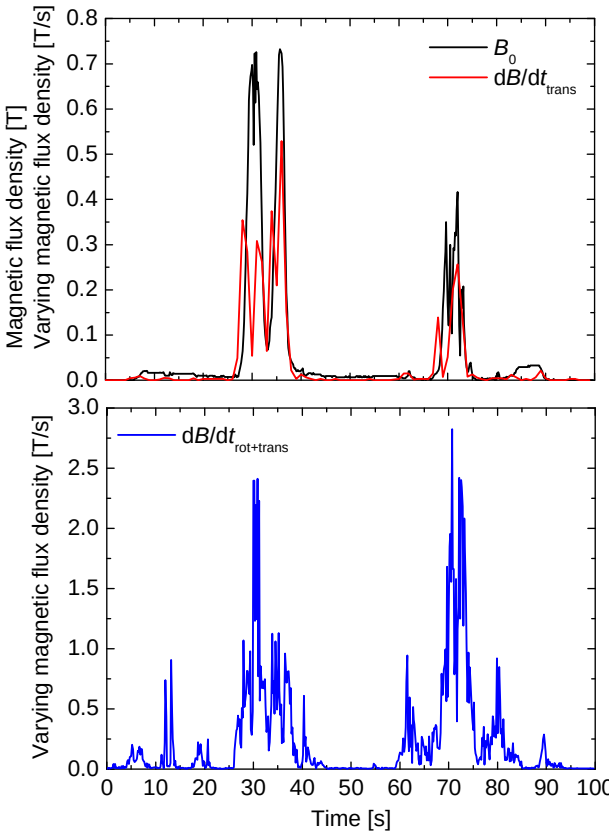

Figure 2: Exposure data from a coil plugging and phantom placement procedure at 7T.

References: [1] Directive 2012/11/EU, [2] COM (2011) 348, [3] ICNIRP Draft Feb. 2012