BEMS Abstract 2013

Title: Preliminary data on human central nervous system exposed to 50 and 60 Hz magnetic fields of up to 50 mT, magnetophosphene perception and associated neurophysiological responses

Due to limitation in the number of characters, title changed to:

Preliminary data on human central nervous system exposed to 50 and 60 Hz magnetic fields of up to 50 mT and magnetophosphenes

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Short Abstract (500 characters max): 486 characters (63 words)

OBJECTIVE: Establishing magnetic flux density thresholds for systematic neurophysiological responses at 50 and 60 Hz.
METHODS: Magnetophosphene perception, electroencephalography, tremor are tested between 0 and 50 mT.
RESULTS: Preliminary data including tremor recordings and repeated reports of magnetophosphenes with corresponding EEG activity will be presented.
CONCLUSIONS: Our protocol allows the detection of systematic effects related to 50 and 60 Hz exposures between 0 and 50 mT.

Long Abstract (10,000 characters max): 4969 characters (828 words)

INTRODUCTION

Both ICNIRP and IEEE recommendations/guidelines aim to protect individuals against adverse health effects (IEEE 2002, ICNIRP 2010) of electromagnetic field (EMF) exposure. In the Extremely Low Frequency (ELF) range, this is based on acute well-established effects on the human central nervous system, and more specifically on the threshold for retinal magnetophosphene perception. Magnetophosphenes are described as 'flickering-lights' perceived in a dark environment due to a time-varying magnetic field (MF) exposure. Although magnetophosphenes are the most robustly exposure-related established effect, the perception threshold at power frequencies (50 and 60 Hz) remains uncertain, since it is based on estimates extrapolated from non-replicated experimental data acquired at lower frequencies. The threshold for magnetophoshene perception is estimated to be the lowest at 20 Hz (between 5 and 10 mT - 50 to 100 V/m of induced E-field – 10 to 14 mA/m^2 of induced current density) and then to increase with frequency (Lovsund, Oberg et al. 1980, Silny 1986, IEEE 2002, Saunders and Jefferys 2007, ICNIRP 2010, Hirata, Takano et al. 2011).

MATERIAL AND METHODS

Our current project aims to: 1) establish the magnetophosphene perception threshold at 50 and 60 Hz in healthy volunteers; 2) simultaneously study the electroencephalographic (EEG) response in corresponding brain regions, 3) study the impact of the same stimulus on another highly sensitive neurophysiological indicator, such as physiological tremor. Two separate experimental protocols detail these objectives, both approved by Western University ethics board (HSREB #18882 and #103066).

Two exposure systems have been designed and developed for this project: a local head exposure system and a global head exposure system. Both systems are controlled using a LabView™ program driving a MTS™ Magnetic Resonance Imaging gradient amplifier capable of delivering up to 200 A (rms) at ± 345 V (MTS Automation 433 Caredean Dr. Horsham PA). First, the local exposure system (described in details in Keenliside et al. 2013) consists of a 176 turn coil (16 layers of 11 turns each – 6 cm inner diameter and 22 cm outer diameter) made of hollow square copper wire cooled by circulating water (Figure 1, right). This coil allows MF exposures between 0 and 100 Hz up to 50 mT at 3 cm from the side coil without any perceptible noise or vibration produced. Second, the global exposure system consists of a set of two 50 cm diameter 22-turn coils separated by 25 cm, positioned parallel to the ground at the head, centered level with the eyes, which allows homogeneous exposure at 50 and 60 Hz of up to 50 mT (± 5% across the human brain and eyes – Figure 1, left). The MTS constant-current amplifier drives the required current trough a transformer and a set of capacitors, pushing up to 650 A (rms) in the coils at full power. The global exposure system is developed in collaboration with the Research Institute of Hydro-Québec (Dr. Duc Nguyen – IREQ). Volunteers will wear earplugs to prevent them from earing the small "60 Hz buzz" produced by the coils. The distributions of the MF produced by both these coil systems, calculated using the 'Biot and Savart Law', are presented in Figure 1. Calculations have been confirmed by measurements made using a single axis MF Hall transducer (± 200 mT range with 0.1 % accuracy- Senis™ 0YA05F-C.2T2K5J probe, GMW Associates, San Carlos, USA).

Our protocol tests 2 groups of volunteers (n = 25 at 60 Hz, n = 5 at 50 Hz), each tested in 2 localized exposure conditions (eyeball and occipital cortex using a small coil) and 1 entire head exposure condition, each scanning 11 magnetic flux density conditions (0 to 50 mT, in 5 mT increments). Each flux density condition is repeated 5 times (in random order) and conditions are separated with five seconds between exposures. The volunteers are tested with eyes closed in a dark environment. They report magnetophosphene perception by button-press, while their occipital EEG activity is continuously recorded (MRI-compatible EEG system, caps, and cables allowing recordings of EEG and ECG during 50 mT exposure - Neuroscan-Compumedics Inc, Melbourne, Australia). Since we are using an MRI–compatible EEG system, the amplifiers do not saturate even in a strong time-varying MF environment. We hypothesize that magnetophosphene perception should be associated with an EEG alpha spectral power decrease (8-12 Hz).

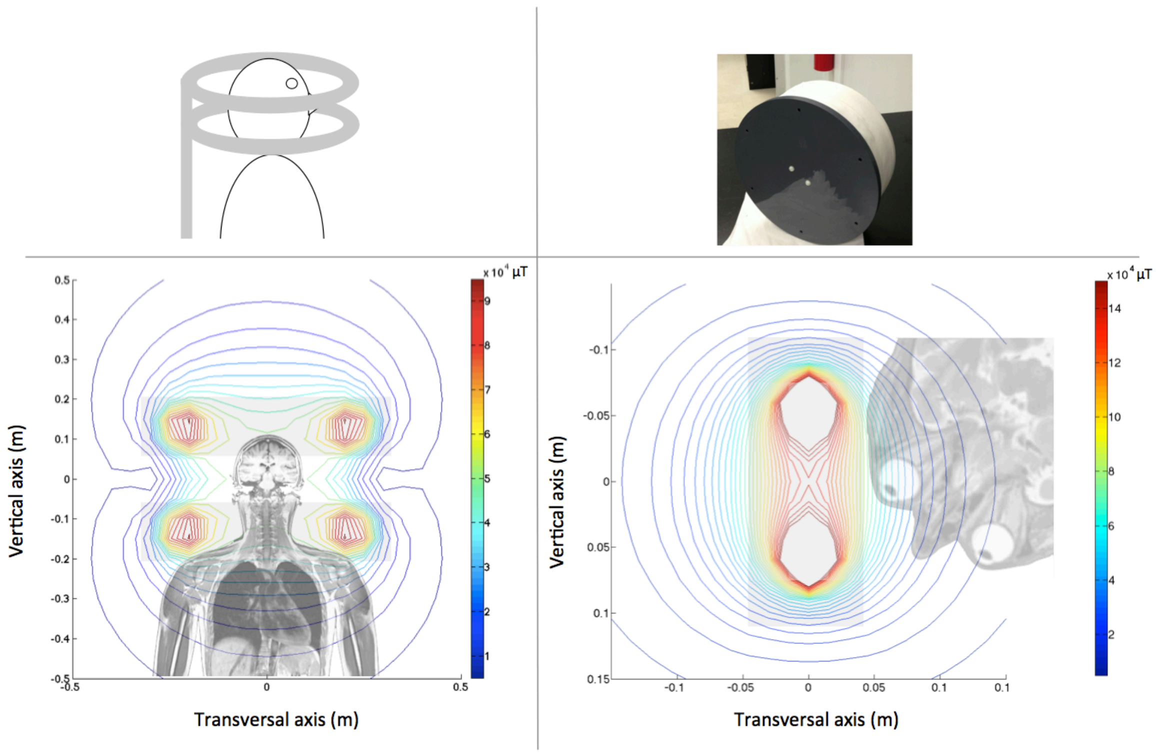

Figure 1: A graphic sketch of the global exposure system is presented in the upper left section. The lower left section represents a scaled coronal view of human anatomical image superimposed to the field distribution, as calculated using the 'Biot and Savart Law', produced by our global head exposure system (represented by the 2 horizontal transparent grey rectangles). The head of the subject is exposed to a homogeneous 50 mT MF (5 mT contour lines). Our local exposure coil is presented in the upper right section. A scaled representation of a transversal slice of human head is superimposed with the field distribution, as calculated using the 'Biot and Savart Law', is presented on the lower right corner. The vertical transparent grey rectangle represents the coil dimensions. The exposed eyeball is non-homogeneously exposed to 50 mT at 50 and 60 Hz.

The primary objective of our second protocol is to establish a magnetic flux density threshold at 60 Hz showing effects in human brain, muscle and/or physiological tremor activity. This pilot study consists of testing the physiological tremor recorded at the tip of the dominant index finger (Microlaser sensor LM10, series ARN11, Matsushita Electronic Work, Ltd., Osaka, Japan; 5 µm resolution), the associated electromyographic (EMG – of the *extensor carpi radialis)* and EEG activity (in the sensorimotor cortex), under the 0-50 mT flux density scanning protocol described above. In this protocol, the exposure is given to the contralateral sensorimotor cortex using our local exposure coil. We anticipate an increase of physiological tremor amplitude and associated electrophysiological signals (EEG, EMG) at the flux density corresponding to the magnetophosphene perception threshold.

RESULTS

Although the experiments have not started yet we have started testing volunteers acquiring pilot data to test our protocols. All the anecdotal volunteers we have pilot tested so far (n=9) have reported visual artefacts qualified as being magnetophosphene perception, both at 50 and 60 Hz, for flux densities reaching 50 mT. Tremor and EEG data have been acquired in both phantom and humans before, , during and after the exposure conditions in order to test for MF artefacts in the data (button-press has also been tested). The analyses confirm that all the data, including EEG data (which are the most prone to distortion due to electromagnetic noise/interference), are available even during MF exposure condition. Various Fourier and wavelet based filtering procedures have been tested and have been very effective in removing the 50 and 60 Hz artefacts (see Figure 2 for an illustration on EEG data during 60 Hz MF exposure).

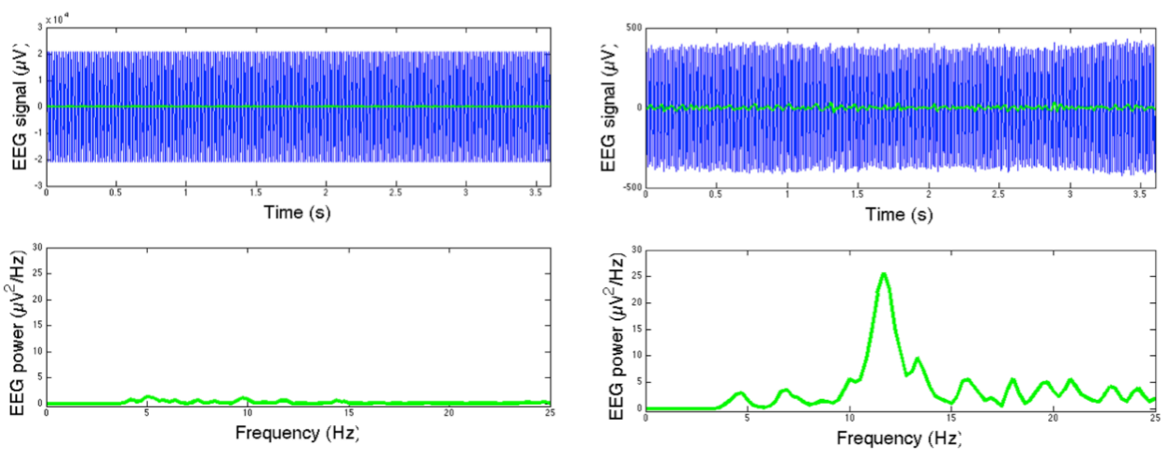

Figure 2: The upper left graph shows the EEG signal recorded in a phantom in the electrode C1 (on the sensorimotor cortex), while the 60 Hz exposure at 50 mT is centred on this electrode. The blue line represents the raw time series, with the strong 60 Hz artifact very well illustrated. The green line represents the same time

series after being Fourier band-pass filtered between 4 and 30 Hz. The lower left graph displays the corresponding power spectrum and shows that the signal is artefact free in the alpha (8-12 Hz) and low beta (13-25 Hz) EEG frequency bands. The upper right graph shows the raw (blue) and filtered (between 4 and 30 Hz - green) EEG signal recorded in the electrode O2 (occipital brain region) while the eyeball of a volunteer is exposed to a 25 mT MF at 60 Hz. The lower right power spectrum illustrates the absence of exposure artefact in the frequency range of interest (0-25 Hz) and shows the clear expected alpha EEG peak (eyes closed recording condition).

CONCLUSIONS

We have demonstrated the feasibility and started data collection in a protocol testing human central nervous system exposure to 50 and 60 Hz MF of up to 50 mT. To date, all the subjects who went through the protocol were able to describe MF exposure-induced magnetophosphene perception when the head at eyeball-level is exposed, in a dark environment, to flux densities approaching 50 mT. The perception is mostly described as a vibration of the visual flux (in various locations in the visual field) starting and stopping at the onset and the offset of the MF exposure. The feasibility of neurophysiological biomarkers recording during MF exposure, such as electroencephalography, is also demonstrated. Data and results will be presented at the conference.

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