Transmitted Power from a Tx/Rx Birdcage Coil to Nearby Conductors in Air and in Gel

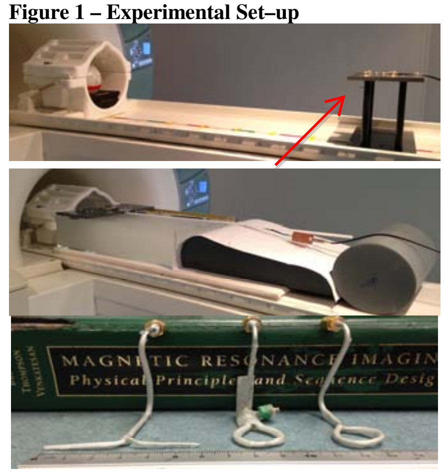
Zoltan Nagy[1,2], Aaron Oliver-Taylor[3], Andre Kuehne[4,5], and Nikolaus Weiskopf[1]

[1]Wellcome Trust Centre for Neuroimaging, University College London, London, United Kingdom, [2]Laboratory for Social and Neural Systems Research, University of Zürich, Zürich, Switzerland, [3]Institute for Women's Health, University College London, United Kingdom, [4]Center for Medical Physics and Biomedical Engineering, Medical University of Vienna, Austria, [5]MR Center of Excellence, Medical University of Vienna, Austria

Introduction:

Although many implants have been studied systematically[1], the sheer number of these devices means it is not possible to test every one. In addition, volunteers often do not know the specific implant they have, and even if they did, manufacturers reserve the right to change the composition without changing the part number. Thus the extent of heating around an implant, due to the radio–frequency (RF) field is difficult to predict. Often the transmit/receive (Tx/Rx) birdcage head coil is recommended for unknown implants which are *not–too–close* to the coil (e.g. abdominal implants) because it is assumed that the **E** and **B** fields of the Tx/Rx coil do not extend far beyond the physical dimension of the coil itself. This assumption however has not been systematically tested. While we accept that one cannot establish a worst–case scenario in a phantom, which would realistically represent a worst–case scenario in all human bodies[2], we investigated the transmitted power from the Tx/Rx coil to nearby conductors both in air and in an ASTM gel phantom[3,4]. We were interested in both the transmitted **E** and **B** fields at distances from the coil where abdominal implants would be found in adult human subjects. We performed experiments and simulations of the transmitted power and measured heating around a looped and a straight conductor.

Figure 1 – Experimental Set–up

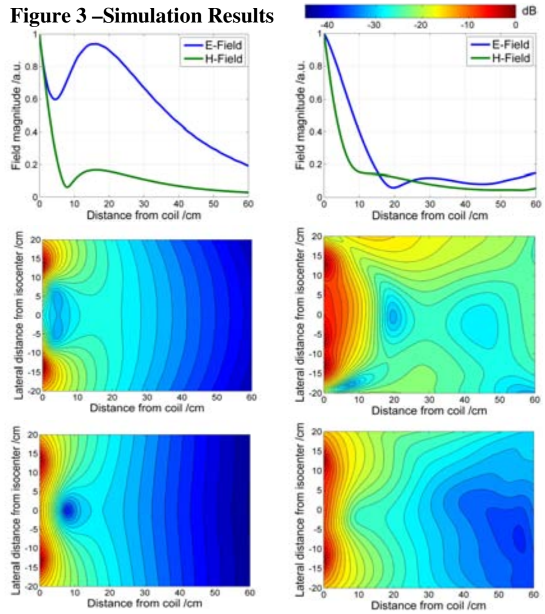


Measurement set–up for in air (top) and ASTM gel phantom (middle). For the in–air measurements spherical gel phantom was used to load coil. ***Red*** *arrow indicates of RF field probes (bottom).*

Methods:

All experiments were performed using a 3T Trio scanner (Siemens, Erlangen, Germany) using the Tx/Rx coil provided by the vendor. We performed three experiments and separately simulations for two of them. In Experiment 1 we investigated the power transmitted by the Tx/Rx coil through air. A modified MRI sequence was used to transmit a train of RF pulses but no gradients to avoid the confounding heating of the scanner gradient coils and subsequently the inside of the bore. Three RF probes (See Fig. 1 bottom for the non–resonant dipole (**E** field), resonant & non–resonant loops (**B** field)) were used to measure the transmitted power at distances up to 105 cm from the coil. The instantaneous pulse RMS voltage induced in each probe was measured with an oscilloscope (Wavelet 300A, Teledyne Lecroy, USA) set to either 50 Ω or 1 MΩ (not shown) input impedance. For each measurement at the different distances from the coil, we made both on centre (i.e. at the centre of the axial cross section of the coil) and off centre (starting at the edge of the coil nearest to the rungs) readings. The probes were connected to the scanner room filter plate via coaxial cables, fitted with 3 appropriate cable traps fitted (> 20 dB attenuation at 123.2 MHz 25 cm apart). In Experiment 2 similar measurements were made using the ASTM gel phantom[4]. Experiments 1-2 were approximated in simulation by calculating the electric and magnetic field distribution of an ideal "Birdcage" coil loaded with the two phantoms using a commercial finite-difference time domain (FDTD) solver (XFdtd, Remcom, State College, PA, USA). The 16-rung coil was driven in the CP1+ mode using current sources with appropriate phase shifts in the legs. In Experiment 3 we measured temperature changes around a looped (2 cm diameter) and a straight (15 cm) conductor, which were insulated except at the tips. The MRI pulse sequence from Experiment 1 was modified to provide 100% SAR and run for 15 minutes. The looped and straight conductors were positioned within the body of the ASTM phantom at different locations and orientations. Each time the sequence was run, the temperature was monitored using a 5–channel optical thermometer (Opsens, Quebec, Canada). Three channels were used to measure temperature around the tip of the conductors while one channel was left in the head and one in the body of the ASTM phantom as reference.

Figure 3 –Simulation Results

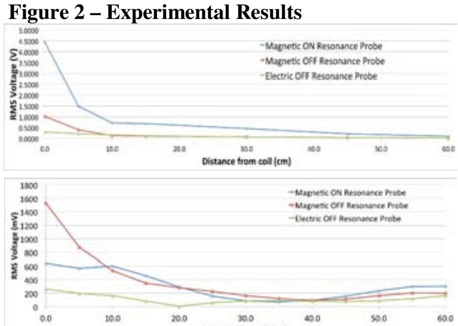


*In–air (left) and in–gel (right) results. Top displays the profile measured along a straight line down the middle of the field plots in the middle (**E**–field) and bottom (**B**–field) rows.*

Results:

Fig. 2 depicts the results of the experiments. As expected, Experiment 1 yielded monotonically decreasing RF power with increasing distance from the coil, but non–zero RF power could be measured up to 50 cm away from the physical dimensions of the coil. Measurements in gel in Experiment 2 produced more complex behaviour. Rather than monotonic decrease several local extrema could be observed and at the end of the ASTM gel–phantom (farthest from the Tx/Rx coil) a local maximum was apparent with all 3 probes. The simulations (Fig. 3) were in qualitative agreement with the experimental results. Subjecting either the looped or straight conductor to 15 min of 100% SAR resulted respectively in 1 °C and 3 °C temperature rise inside the head coil but did not yield any significant heating in any part of the ASTM phantom outside of the head coil.

Figure 2 – Experimental Results



On–axis measurements both in–air (top) and in–gel (bottom) using all 3 probes.

Discussion:

It is a commonly held opinion that the **E** and **B** fields of a Tx/Rx head coil die off rapidly beyond the physical dimensions of the coil itself. We showed here that significant power is transmitted to conductors that are well away from the Tx/Rx coil. These finding warrant further investigation into heating effects around conductors at a distance from the Tx/Rx head coil. In these measurements we could not observe any significant heating outside the Tx/Rx head coil (in particular in the abdominal area), but this as possibly related to the particular "test implants". Because a true worst–case–scenario is difficult (if not impossible)[2] to determine, further investigations are planned which include the properties of the "implant".

References: [1] Shellock (2013) ISBN 978-0974641065, [2] Kainz (2007) JMRI Vol 26(3) p450, [3] Amjad et al (2005) Magnetics IEEE Transations Vol41(10) p4185, [4] Standard F2182-02a, ASTM (www.astm.org)

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