Transmission Power from a Tx/Rx Birdcage Coil to Nearby Conductors in Air and in Gel
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Introduction:
Although many implants have been studied systematically1, 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 bodies2, we investigated the transmitted power from the Tx/Rx coil to nearby conductors both in air and in an ASTM gel phantom3. 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.

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 phantom4. 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 conductor. The 16-rung coil was driven in the CP1+ mode using current sources with appropriate phase shifts in the legs. In Experiment 2 similar measurements were made using the ASTM gel phantom5. 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 conductor.

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 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 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 1 – Experimental Set-up

Figure 2 – Experimental Results

Figure 3 – Simulation Results

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).

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 findings 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) to determine, further investigations are planned which include the properties of the “implant”.

References:

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