# Reduced Heating of Implanted Electrical Conductors Using Parallel Radiofrequency Transmission

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## Introduction:

Implanted or transiently inserted medical devices can pose safety concerns when patients undergo MRI procedures. One example is Deep Brain Stimulation (DBS), where electrodes and leads are implanted to send therapeutic electrical impulses to deep brain nuclei. FDA-approved for movement disorders (eg. Parkinson's Disease) and with numerous other applications emerging[1], DBS requires MRI to determine precise electrode positioning, to evaluate post-operative effects and, in the future, functional MRI to assist in understanding the mechanism of therapeutic action. However, the long conductive leads and electrodes used in DBS cause local heating associated with the radiofrequency (RF) excitation during MRI. The electric field (E) created by the RF excitation couples with the leads, induces a current which amplifies E, and causes problematic resistive heating of nearby tissues. Recent studies[2,3] have used a birdcage coil operating in linear mode to minimize E near wires in a phantom, within a specific planar region. Here, numerical simulations are used to investigate whether parallel RF transmission[4] can be used to suppress heating effects flexibly in space by varying the amplitude and phase of each transmit element, while maintaining acceptable overall transmit magnetic field (H) homogeneity.

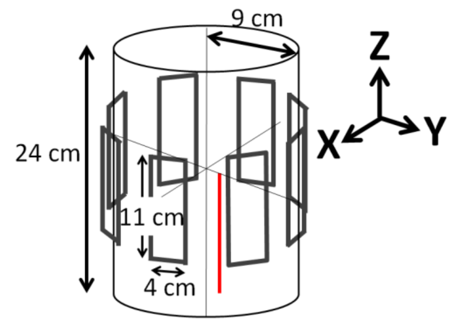


Figure 1

## Theory & Methods:

To demonstrate proof-of-concept, an 8-channel parallel transmit system was simulated surrounding a uniform cylindrical phantom (relative permittivity of 55, conductivity of 0.55 S/m) containing a perfectly conducting wire, providing a simple model pertinent to DBS (Fig. 1). The wire was positioned 2.5 cm from the center of the phantom in the longitudinal direction (red line) to produce average heating near the wire when compared with other wire positions in a birdcage coil and to approximate the placement of DBS leads. Using FEKO (EM analysis software, Stellenbosch, SA), the optimum amplitude and phase of each element was calculated to limit E in a 1 $cm^3$ target box surrounding the tip of the wire. A simplex optimization algorithm was used to determine the transmit amplitude and phase for each element according to a cost function with two evenly weighted goals: E < 3 V/m in the target box, and H homogeneity, $\|\vec{H}(\vec{r})\|/\max(\vec{H}) = 1$, in the XY plane at Z = 0 cm, the chosen imaging plane in this example (seen in Fig. 3).

The E field of the optimized parallel transmit system was compared with that of an 8-rung birdcage coil operating in linear mode. The input voltage of the birdcage coil was chosen to equalize the spatially averaged $B_1$ in the field of view for both transmit systems.

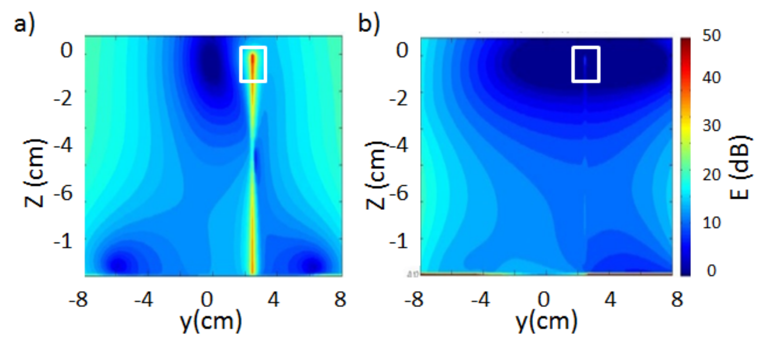


Figure 2

## Results:

Figure 2 shows E in dB in the ZY plane at X=0 (that includes the wire) for both systems. The target box boundary is shown in white, centred on the tip of the wire. The wire extends to the bottom of the plot. In the birdcage coil system (Fig. 2a), E is elevated along the entire wire with a maximum at the tip (approx. 140 V/m above background). In the parallel transmit system (Fig. 2b), E is suppressed in the target box. The E field is substantially reduced near the tip of the wire and surrounding regions, and exhibits low, slowly varying values throughout most of the field of view. Figure 3 shows the corresponding H field in dB in the XY plane at Z = 0 cm (where homogeneity was optimized). The location of the wire tip is marked by an "x" in white. The field is slightly less homogeneous than that of the birdcage coil, although the variation is < 10%.

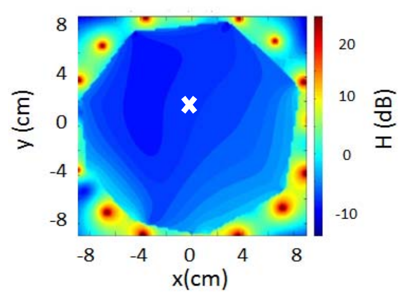


Figure 3

## Conclusion:

This work suggests that an 8-element parallel transmit array can reduce heating in a long wire implanted in a uniform phantom, without major impact on H homogeneity. Although the wire was arbitrarily placed in this example simulation, similar results are obtained for a variety of positions within the cylindrical phantom. The present results warrant investigations in more complex model systems and to confirm simulation results in actual MRI experiments, toward future applications involving DBS and other medical devices.

References: 1. Chen, X.L. et al, Intervent Neurol 1:200-212 (2012) 2. Eryaman, Y et al, Mag Res Med 65:1305-1313 (2011). 3. Eryaman, Y et al, Mag Res Med 69:845-852 (2013). 4. Katscher, U et al, Mag Res Med 49:144-150 (2003).