

# Safety Simulation-Based Assessment of RF-Induced Heating in MRI for Conductive Implants

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## INTRODUCTION

### Problem:

MRI is often needed in patients with deep brain stimulation (DBS), but radiofrequency (RF) fields can couple with conductive leads and cause localized heating.

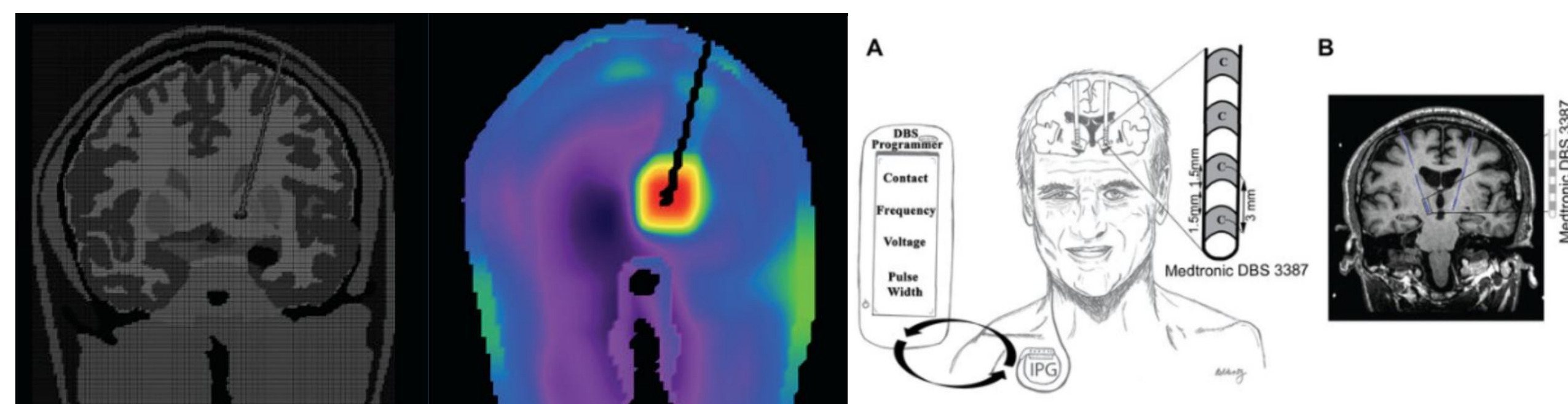


Figure 1: Local tissue hotspots quantified by Specific Absorption Rate (SAR) directly around DBS implant [2]

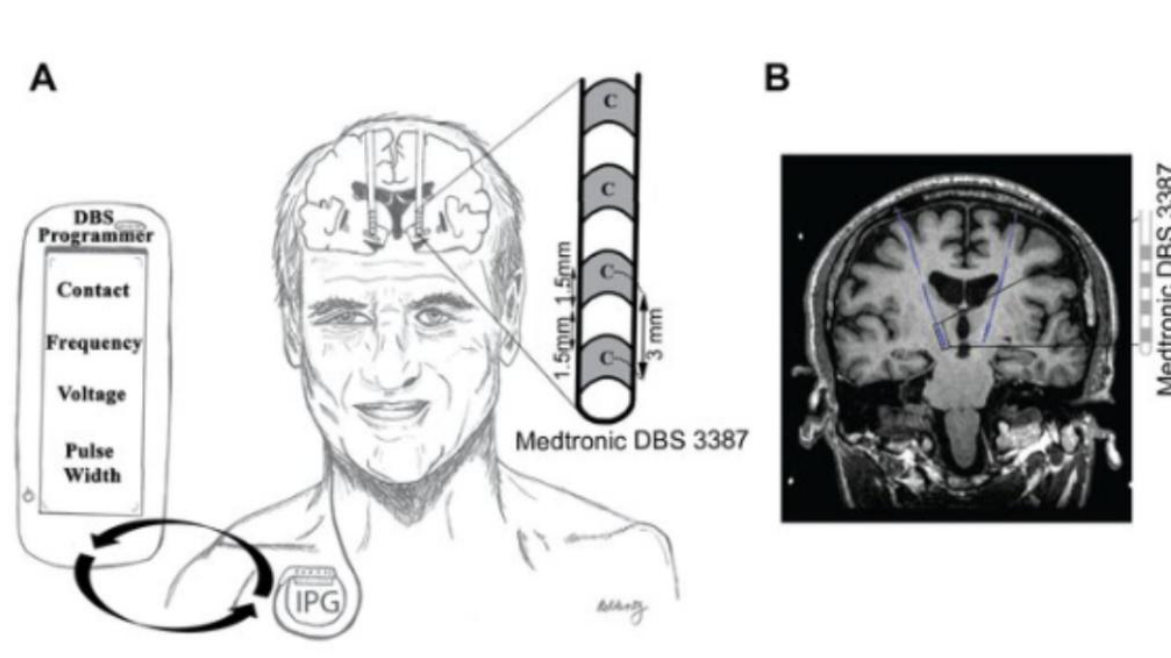


Figure 2: Experimental design of a Parkinson's (PD) patient implanted with bilateral DBS electrodes [3].

Prior studies show that DBS heating depends on lead trajectory and RF field orientation. It is less clear whether mitigation strategies that help single-lead systems remain effective in bilateral systems [4,5,6].

### Objective:

Evaluate how implant configuration, lead trajectory and RF excitation affect RF coupling and local SAR in DBS systems at 1.5 T MRI environment.

## METHODS

- Sim4Life full-wave simulations at 1.5 T (64 MHz)
- Homogeneous ellipsoidal phantom + simplified DBS lead model
- Systems: unilateral and bilateral
- Trajectories: baseline and compact loop
- RF excitation: standard and linearly polarized
- Outputs: incident E-field and localized SAR

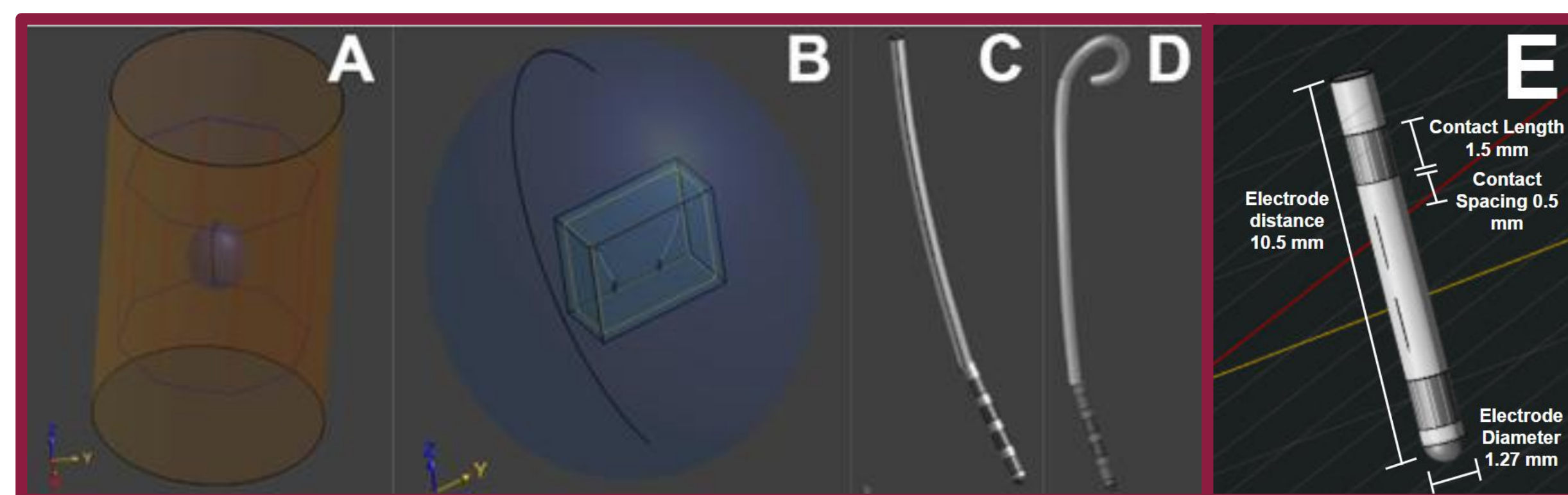


Figure 3: Simulation environment and DBS lead geometries (A) Generic 8-leg birdcage coil with homogeneous phantom positioned at isocenter. (B) Phantom with localized Huygens source region and DBS models. (C) Baseline DBS trajectory with a smooth non-looped extracranial path. (D) Compact cranial loop trajectory. (E) DBS electrode geometry.

## RESULTS

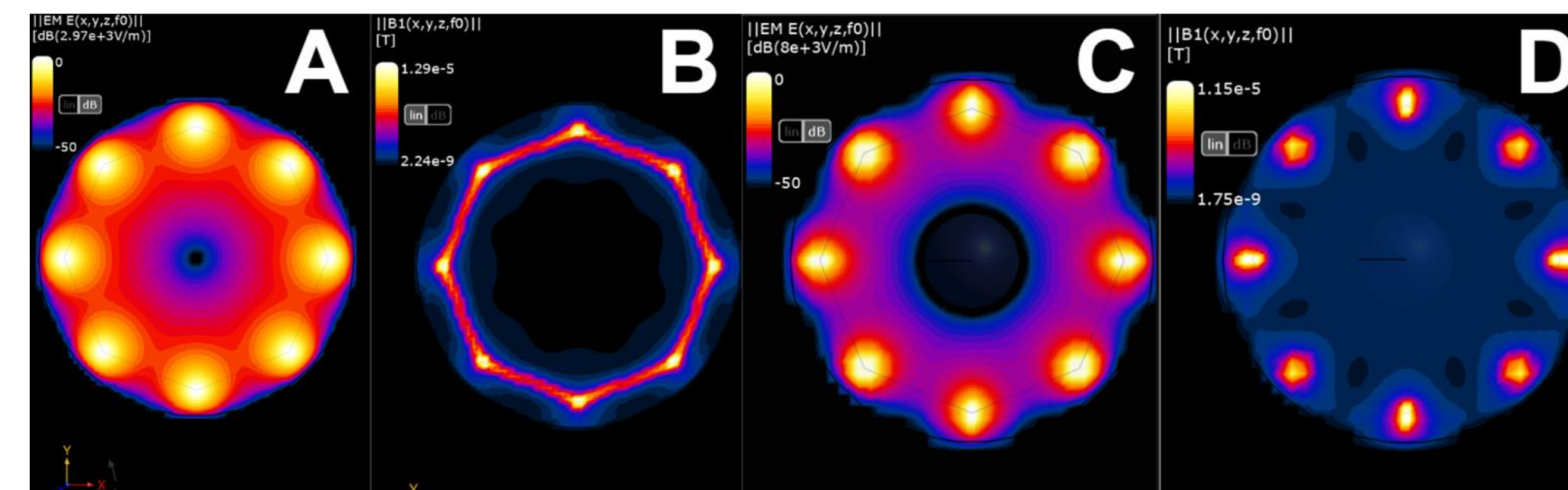


Figure 4: Baseline RF field distributions of the birdcage coil at 64 MHz. (A) Electric field magnitude in the unloaded coil. (B) Magnetic field in the unloaded coil. (C) Electric field magnitude in the phantom-loaded coil. (D) Magnetic field in the phantom-loaded coil. Phantom loaded coil simulations were used to generate Huygens source excitation for the following implant simulations.

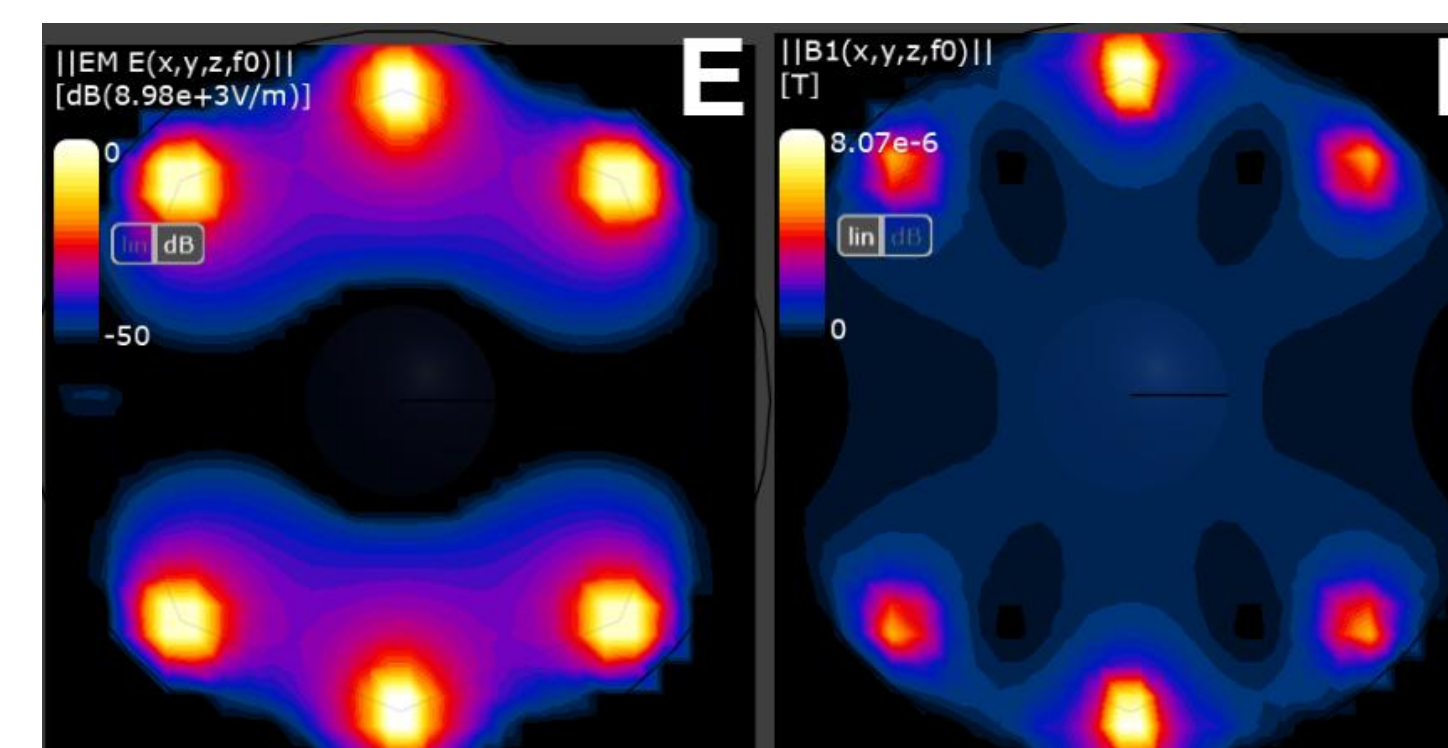


Figure 5: Linearly polarized RF field distributions of the birdcage coil at 64 MHz. (E) Electric field magnitude in the loaded coil. (F) Magnetic field in the loaded coil. Linear polarization creates a split lower electric field region that may reduce coupling to DBS leads.

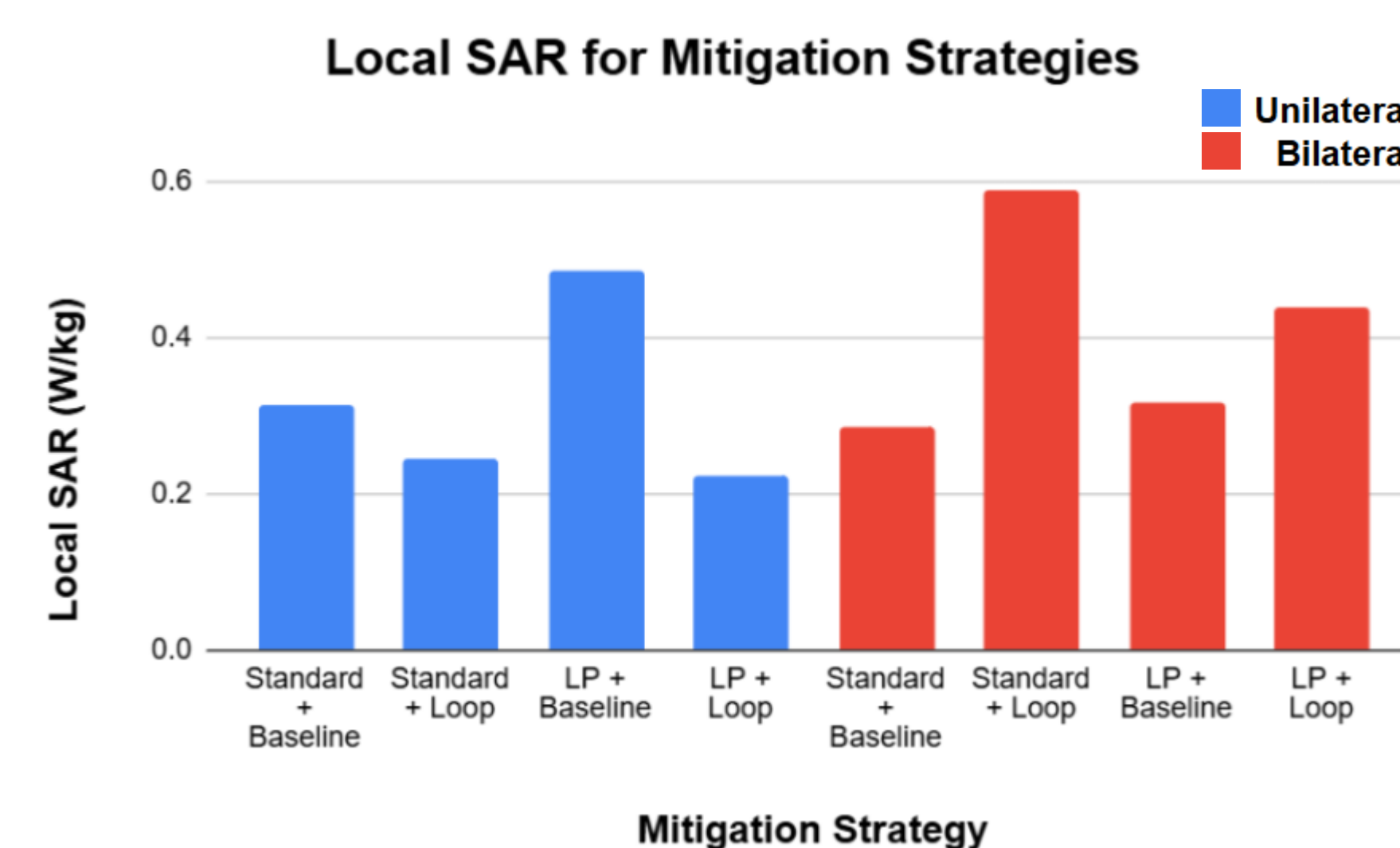


Figure 6: Localized SAR across unilateral and bilateral DBS configurations under standard and linearly polarized excitation for baseline and loop lead trajectories.

### Incident Electric Field Along DBS Lead Path:

Unilateral: 4.86-8.90 V/m → highest case: LP + loop

Bilateral: 6.09-6.84 V/m → highest case: LP + Baseline

## RESULTS

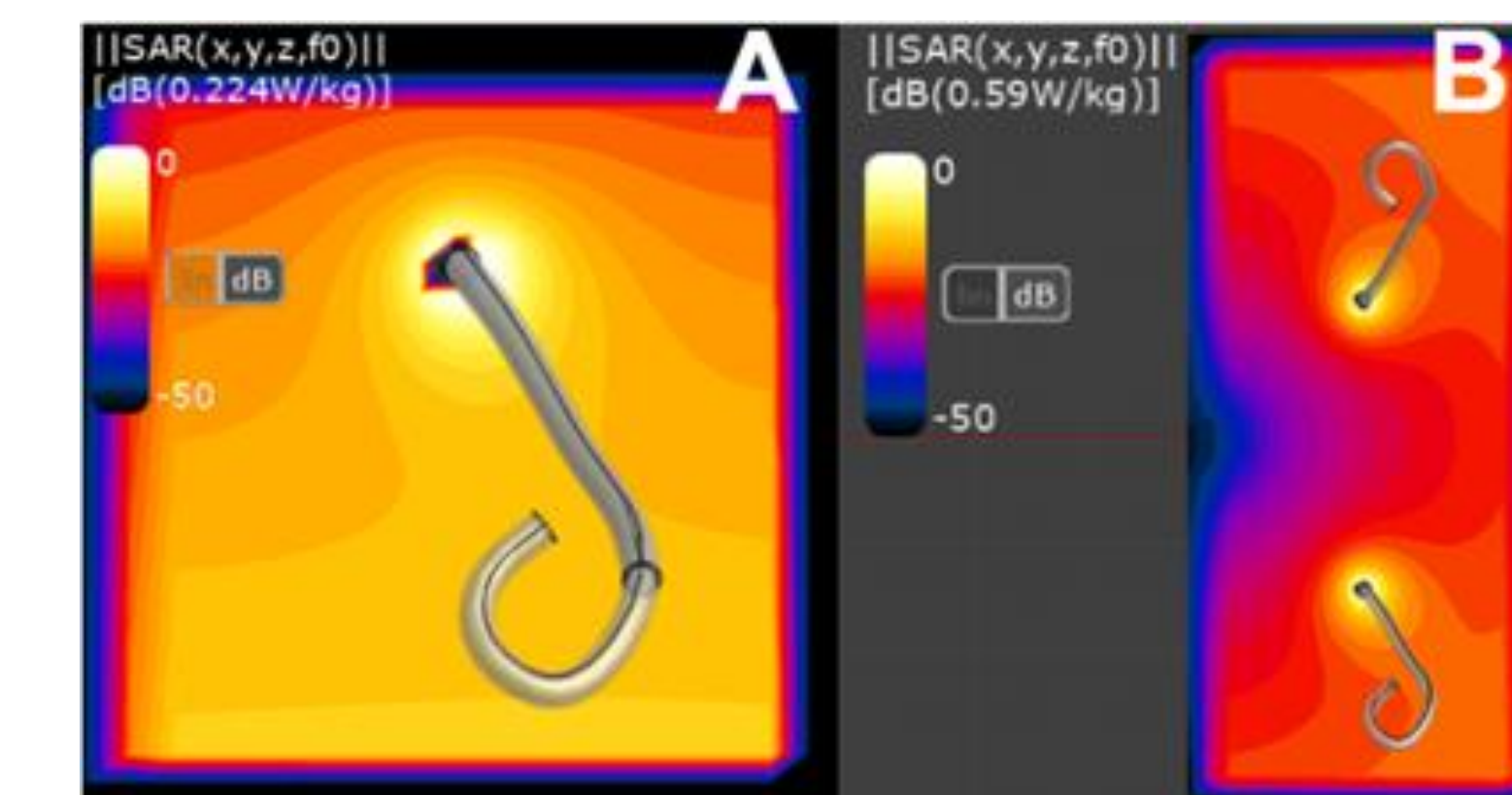


Figure 7: (A) Unilateral DBS system LP + loop has the lowest SAR (0.224 W/kg). (B) Bilateral DBS systems with standard + loop resulted in highest SAR (0.59 W/kg).

- Loop trajectory reduced SAR in unilateral DBS but increased SAR in bilateral DBS.
- This suggests bilateral lead coupling altered current distribution and local power deposition.
- Linearly polarized excitation did not uniformly reduce SAR.

## SUMMARY, CONCLUSIONS AND FUTURE DIRECTIONS

Loop trajectory reduced localized SAR in unilateral DBS but increased it in bilateral DBS. These results indicate that mitigation performance depended on implant configuration and lead coupling.

### Future work:

- Include full DBS systems with IPG and extensions
- Use anatomically realistic tissue models
- Evaluate regulatory-normalized MRI exposure conditions

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