

# **Simulation of a Novel Radio Frequency Ablation Device within an MR Scanner**

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**Yik-Kiong Hue and Jerome L. Ackerman**

**Martinos Center, Department of Radiology**

**Massachusetts General Hospital**

**Charlestown, Massachusetts, USA**

**See also poster 1819**

**Novel Body Coil Driven Radio Frequency Ablation Device**

# Acknowledgements

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- **MIND Institute**

# Goals

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**Simulate electric and magnetic fields and SAR effects in MRI-mediated radiofrequency ablation**

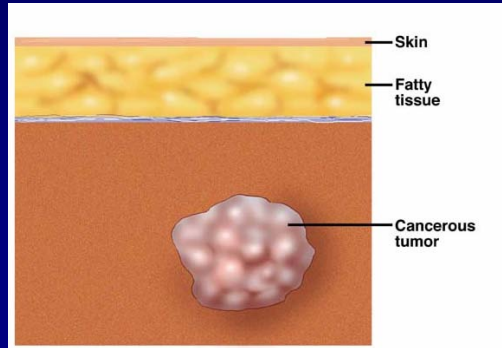
# Thermal Tissue Ablation

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- **Goal**  
Cell death by apoptosis and coagulation necrosis
- **Target temperature**  
55 – 60 °C
- **Heat sources**  
Laser, focused ultrasound, microwave, RF
- **Approach**  
Percutaneous, via body orifice

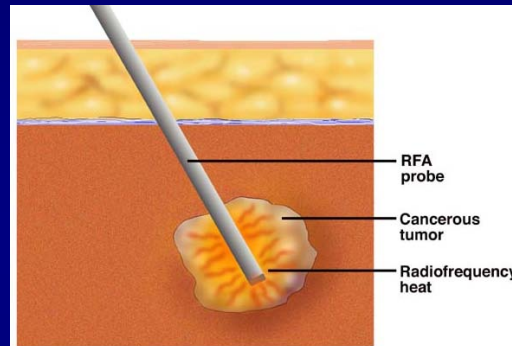
# Conventional Radiofrequency Ablation

## Solid tumor

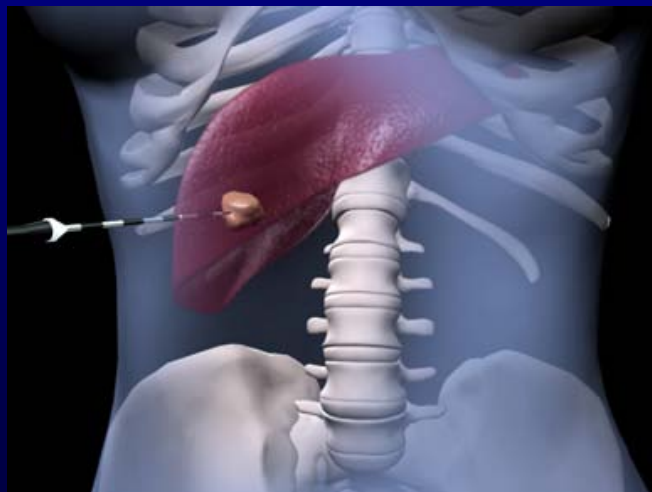
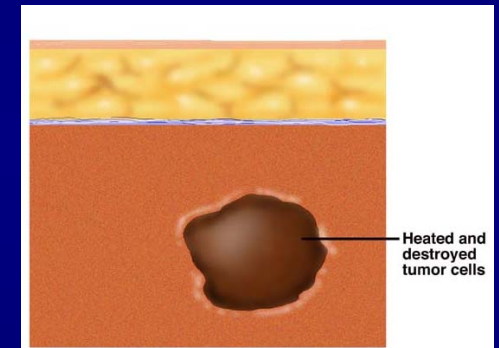


## Needle inserted

Tumor heated with electric current



## Dead tissue absorbed

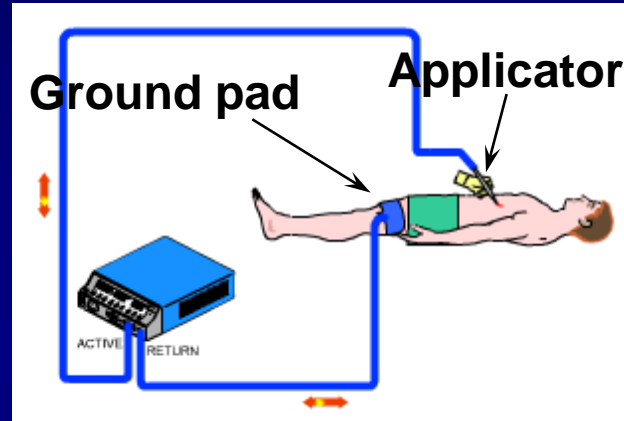


## Typical organs

- Liver
- Lung
- Breast

# Conventional RFA

## Generator (~500 kHz)



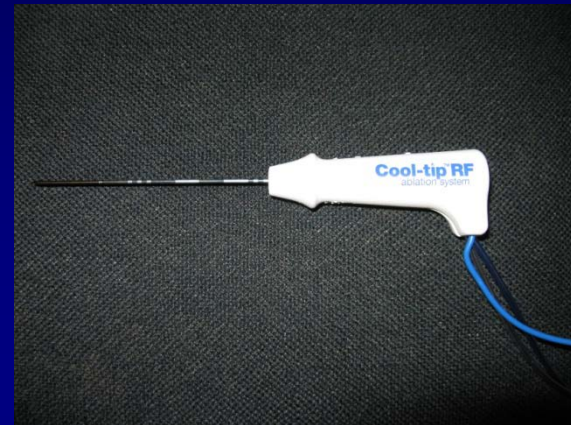
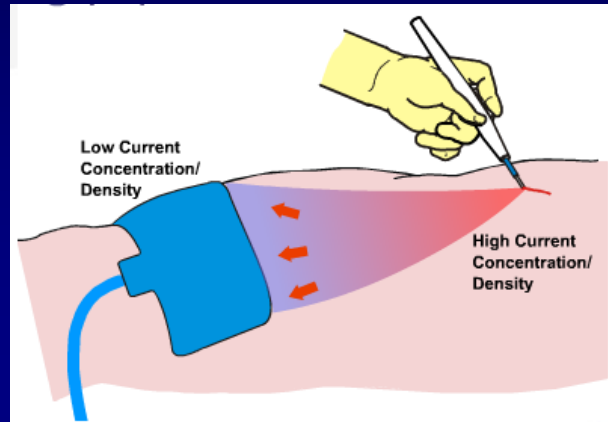
## Breast tumor RFA



RF applicator

Ultrasound guidance

# Conventional RFA



Valleylab commercial RF applicator



Contrast enhanced CT – pre-RFA



Six months – post-RFA

# MRI-Mediated RFA

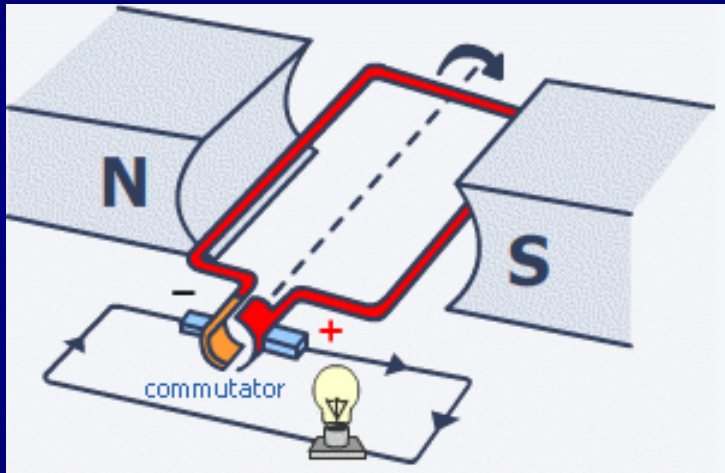
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- **Utilize scanner RF for tissue heating**
- **Harvest RF energy from body coil**  
Long wire or resonant loop antenna
- **Pulse sequence RF duty cycle controls heat deposition**
- **Utilize MRI for anatomy, guidance, temperature mapping, coagulation, perfusion, etc.**
- **Electrically floating, no generator or wiring to external devices**  
No ground pad or ground pad burns
- **Real time monitoring of tissue temperature should improve outcomes**  
Conventional RFA ~20% recurrence rate

# MRI-Mediated RFA Principles

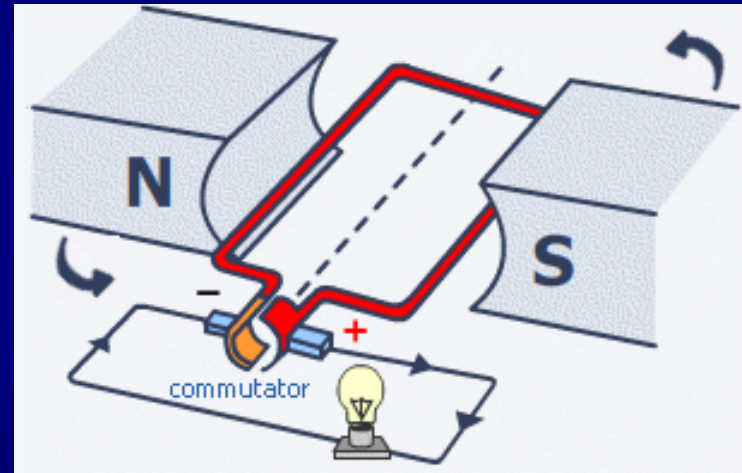
## Electric generator

Rotating coil in static magnetic field



## MRI ablation

Rotating RF field in MRI

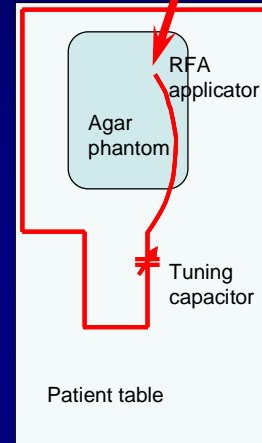
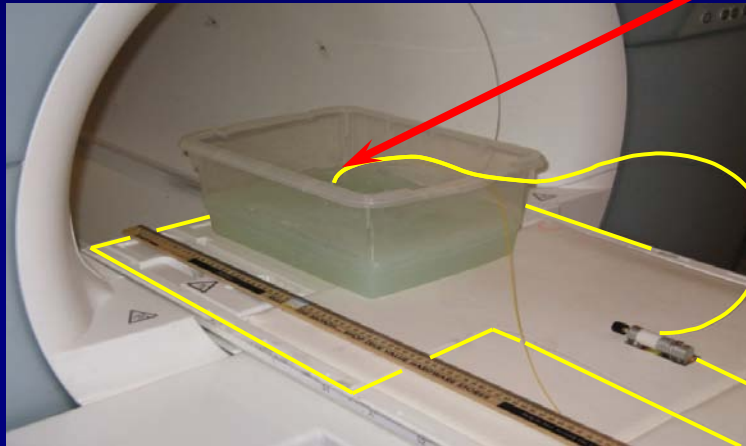


- **Body coil generates circularly polarized (rotating) RF field**
- **EMF induced in wire by Faraday induction**
- **At high frequency wire acts as a transmission line**

# MRI-Mediated RFA Implementation

Disposable wire antenna

RF applicator



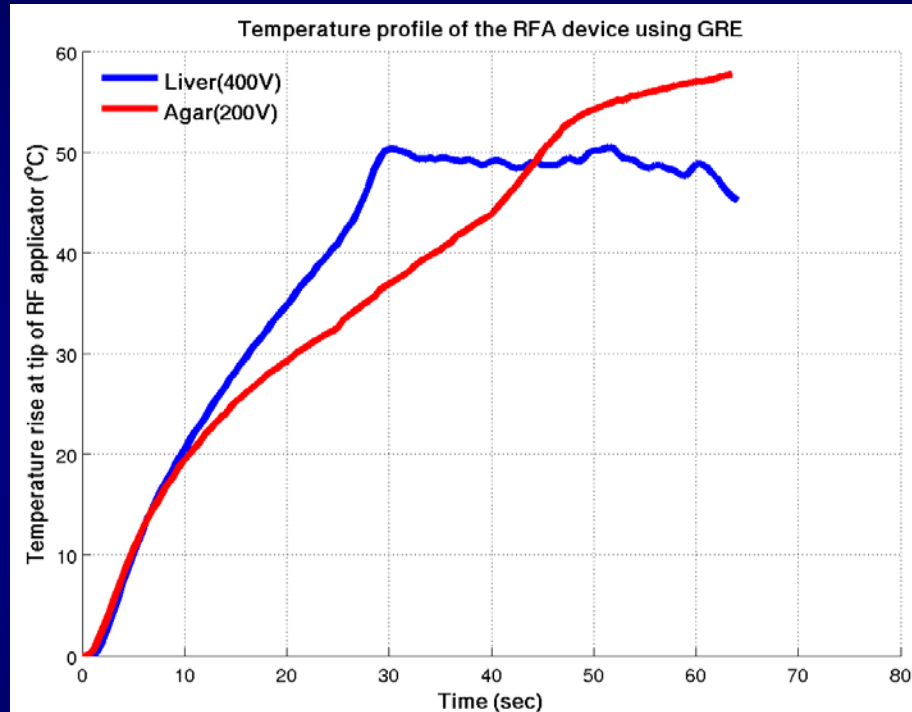
Capacitor adjusts electrical length of line

Disposable (?) loop antenna

Connection to RF applicator



# MRI-Mediated RFA Heating Rate



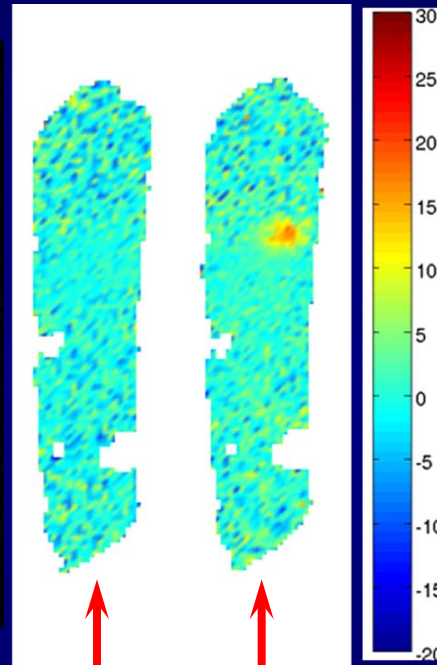
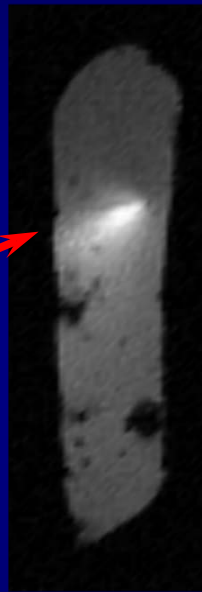
Tissue temperature monitored with fiber optic device

- Achieve target temperature in ~1-2 min  
Conventional RFA ~5-10 min
- Heating is primarily ohmic

# Temperature Imaging

## Beef liver specimen

**RF applicator**  
Self visualizing  
in the scan



**Before heating\*    After heating**

- Siemens Avanto 1.5 T, GRE, TE 10 ms, 3.4 s phase images before and after heating
- Unwrap phase images
- Temperature rise proportional to phase change
- Temperature map unaffected by presence of device

\*Device is present

## Simulation Details

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- **REMCOM XF7**

**Finite difference time domain (FDTD) model**

**Model space 70 x 70 x 150 cm<sup>3</sup>**

**Spatial step 1 cm**

**Gaussian pulse, cutoff 250 MHz**

- **Tuned Siemens 1.5 T (64 MHz) body coil with body loader**
- **Thin wire RFA device within body coil**

## Body Coil Model

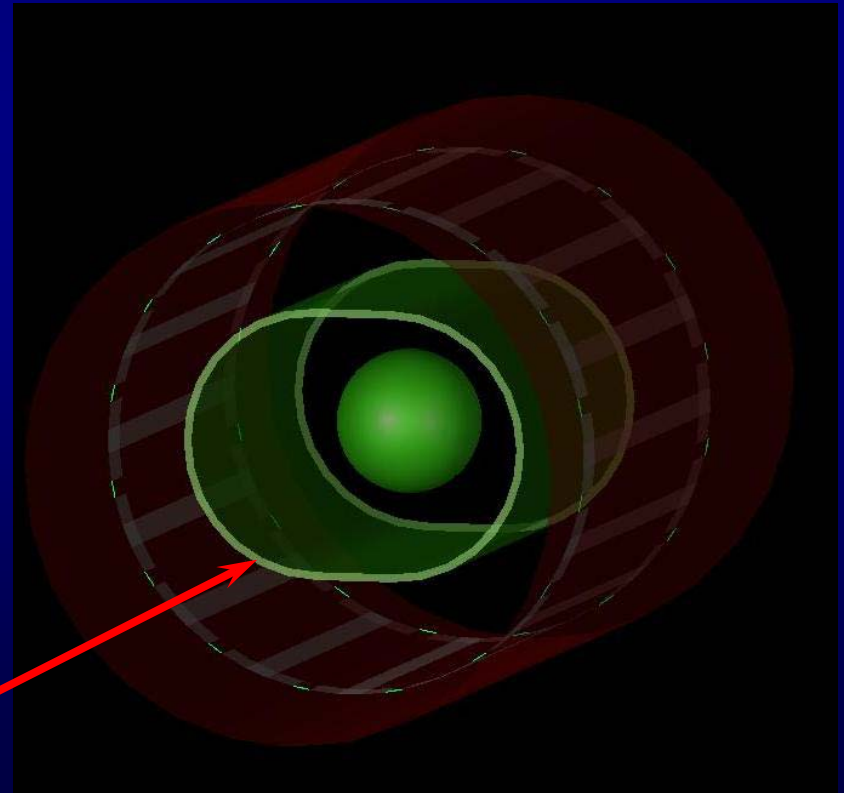
- High-pass 16 rung birdcage within RF shield
- Ports 1 and 2 at 4 and 7 o'clock respectively
- Rung capacitance 100 pF
- S-parameters at 64.1 MHz

$$S_{11} = -25 \text{ dB}$$

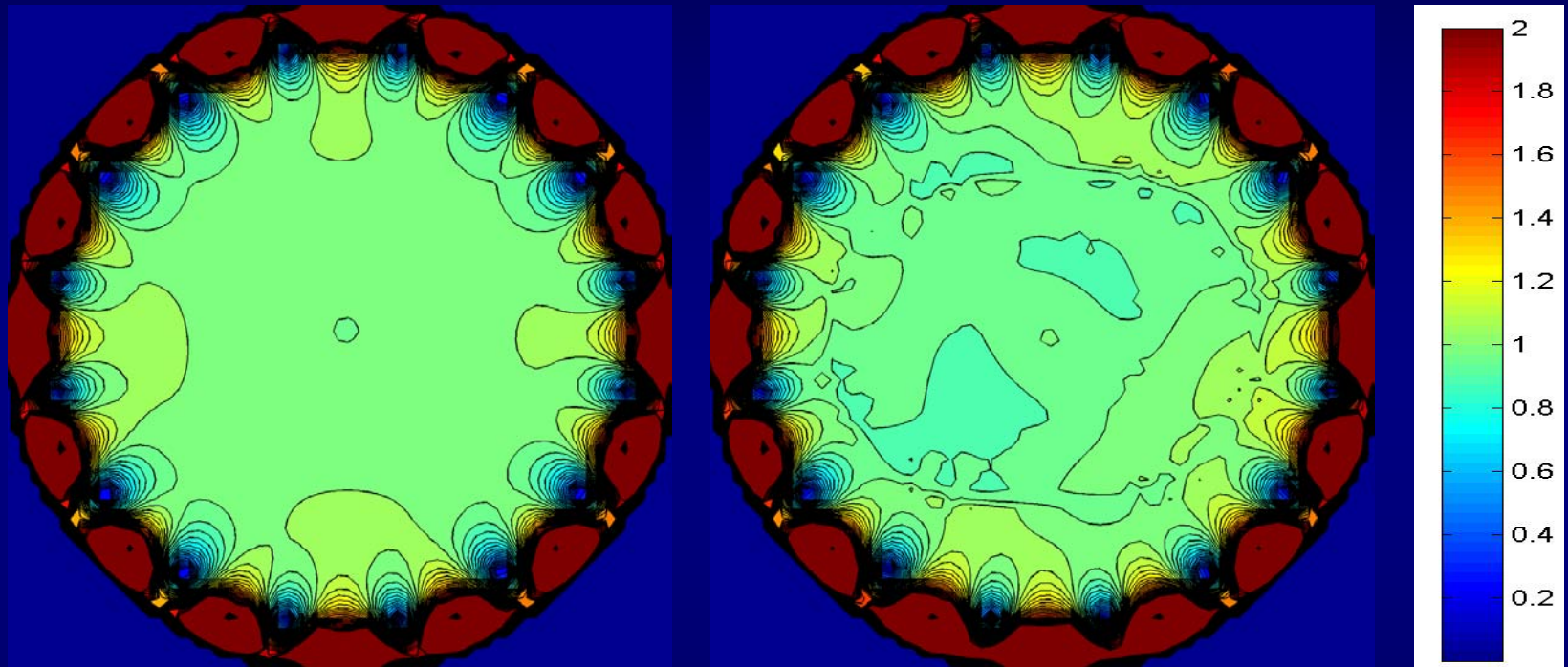
$$S_{22} = -23 \text{ dB}$$

$$S_{12} = -30 \text{ dB}$$

Loader



## $B_1^+$ of Central Axial Slice



**Unloaded**

**With body loader**

- Tuned with body loader
- Intensity of field at center normalized to 1
- Intensity  $> 2$  is clipped
- Contour interval 0.05

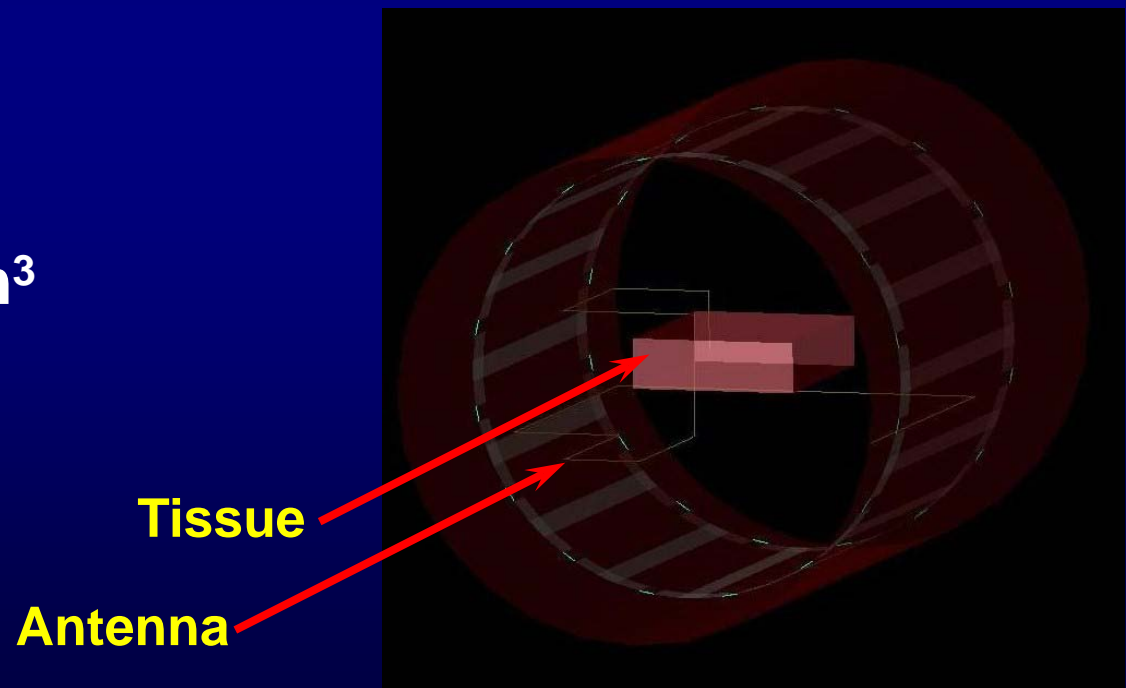
## RFA Device in Body Coil

- RFA antenna 26 cm wire loop around phantom
- RFA device immersed 4 cm in phantom
- Rectangular solid (box) tissue phantom

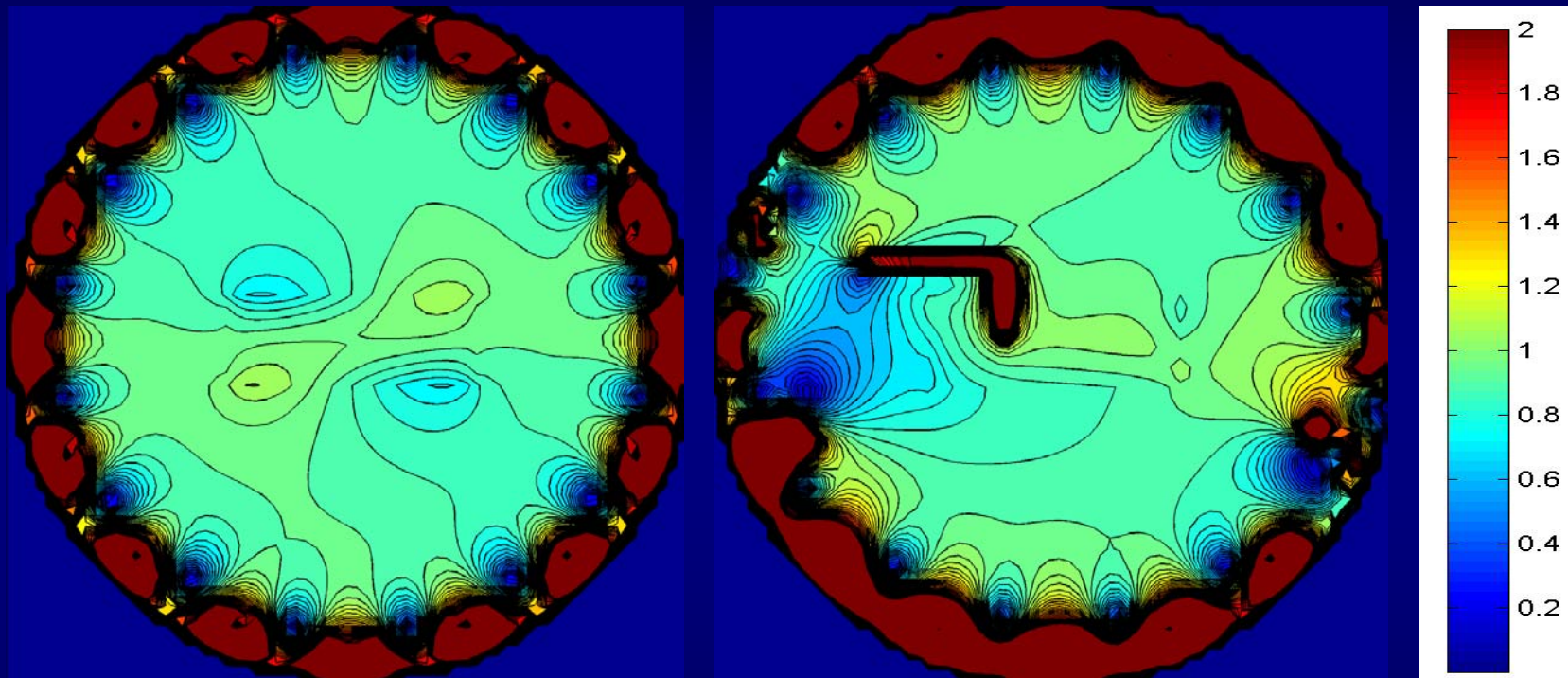
$$\epsilon = 71$$

$$\sigma = 0.55 \text{ S/m}$$

$$7 \times 31 \times 23 \text{ cm}^3$$



## $B_1^+$ of Central Axial Slice



**Without RFA device**

**With RFA device**

- Intensity of field at center normalized to 1
- Intensity  $> 2$  is clipped
- Contour interval 0.05

## Results - SAR Effects of RFA Device

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- SAR at device tip is **9.7x** maximum tissue surface SAR when device is not present
- Total power absorbed by phantom is **0.44x** power absorbed when device is not present
- Body coil performance is degraded somewhat when device is present

# Discussion and Conclusions

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- **RFA device has important local and global effects**
- **RFA device concentrates and directs RF power to tissue locally**
- **RFA device reduces global power absorption**
- **Future work**

**Simulate with human model**