The Cylindrical Meanderline RF Coil for Intravascular MRI of Atherosclerotic Plaque

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Introduction

The majority of all deaths in the United States result from cardiovascular disease. The rupture of an atherosclerotic plaque is often suspected to be the event precipitating a heart attack or stroke. MRI and MRS are playing an increasing role in the identification and characterization of potentially vulnerable plaque, but often exhibit marginal spatial resolution and signal to noise ratio (SNR) in this role. Conventional MR scanning employs RF coils positioned to cover the scanning region of interest, but always external to the body. Intravascular MR coils, which can be inserted into blood vessels and placed in close proximity to vessel walls, offer the promise of greatly improved SNR, but have not attained the desired performance characteristics to be clinically useful.

Problems and Potential Solutions

1. **Optimum sensitivity is obtained when the sensitive volume of the coil matches the scanning volume of interest (optimization of filling factor). External coils are too far from and much larger than plaques.**

   Use intravascular (iv) RF coils

2. **Previous iv coil designs have maximum sensitivity in the lumen of the artery and minimum sensitivity at the arterial wall. The receiver dynamic range is squandered by the intense blood signal.**

   Use a cylindrical meanderline coil, which has maximal sensitivity at the arterial wall and minimal sensitivity in the center of the lumen

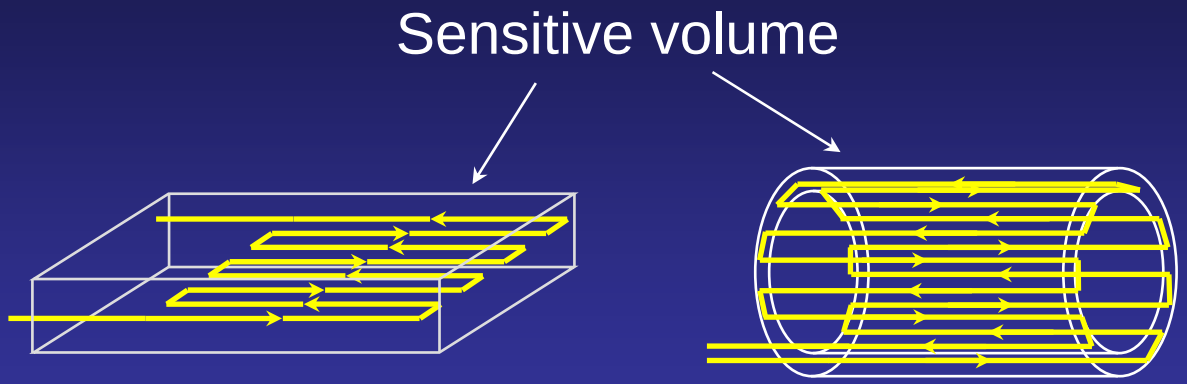
3. **Because of their small size and inaccessibility, intravascular coils, once positioned, cannot be tuned with variable mechanical capacitors**

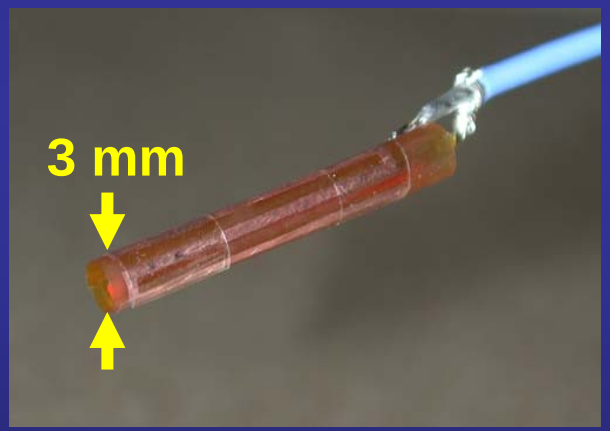
   Tune remotely with electrically variable capacitors

4. **The long, small diameter coaxial cable leads to significant signal loss**

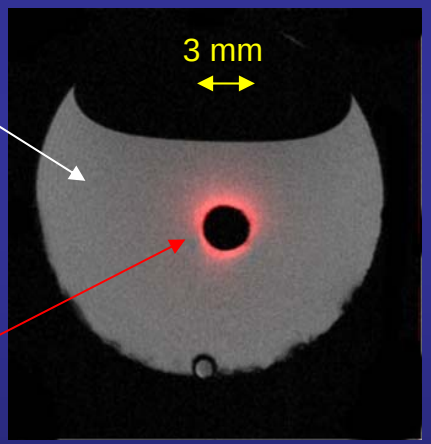
   Place a preamplifier inside the catheter near the coil

Cylindrical Meanderline Coil

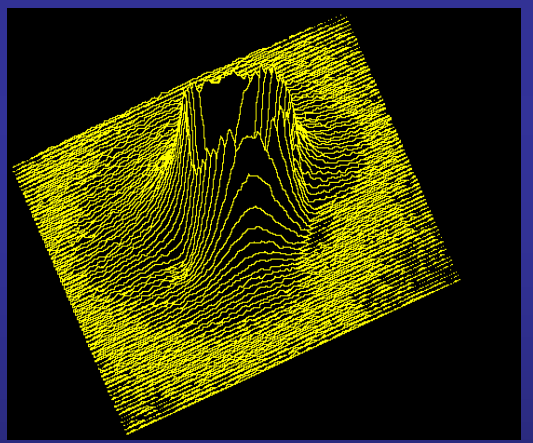




Prototype 3 mm o.d.
cylindrical meanderline coil



Volume Image



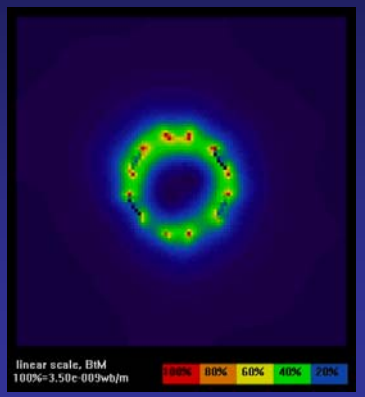
Sensitivity Profile

- Cylindrical shell sensitive volume well suited for imaging artery wall
- Coil depth of view determined by spacing between conductors
- Open coil interior allows for unimpeded blood flow during image acquisition

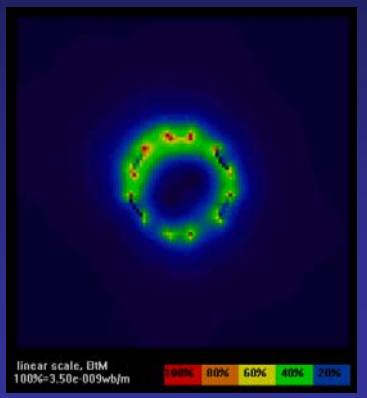
FDTD Simulations of the Magnetic Field

20 pF Tuning Capacitance

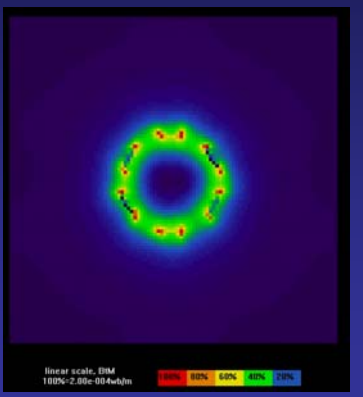
Finite Difference Time Domain (FDTD) Simulation



Saline Immersed (Exterior Only)

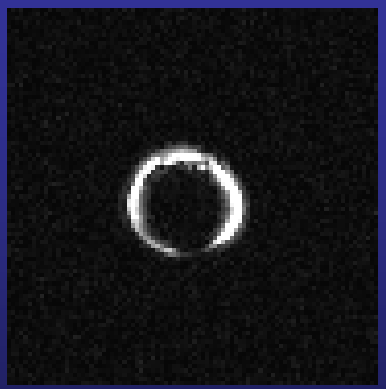


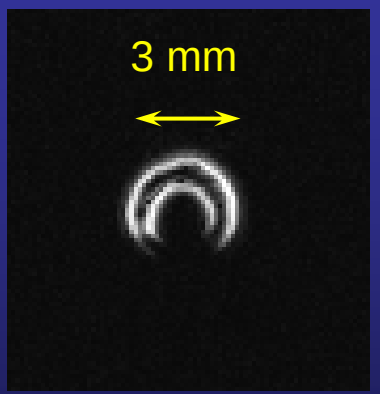
Saline Immersed (Interior & Exterior)

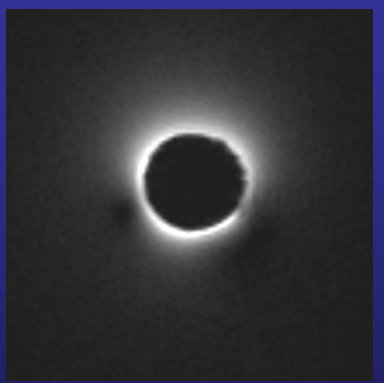


Saline Immersed (Exterior Only)

4.7 Tesla Experimental GE Images



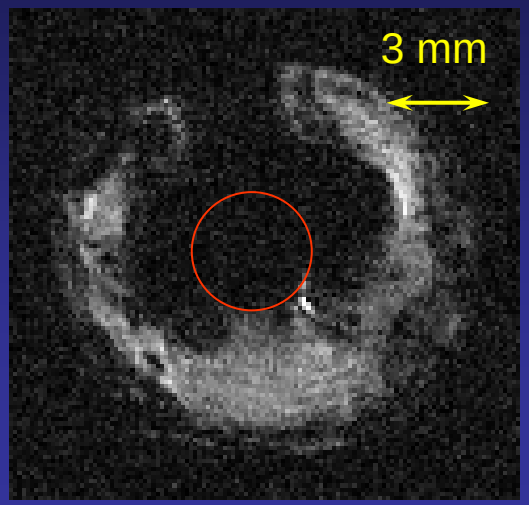


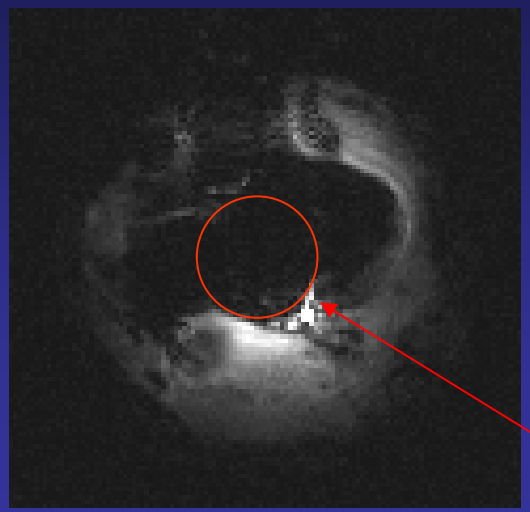


- Loading of cylindrical meanderline coil with saline distorts the field symmetry
- Incorporation of distributed tuning capacitance restores field symmetry and increases the signal-to-noise ratio (SNR)

MRI of Endarterectomy Specimen

Transmit/Receive Volume Coil





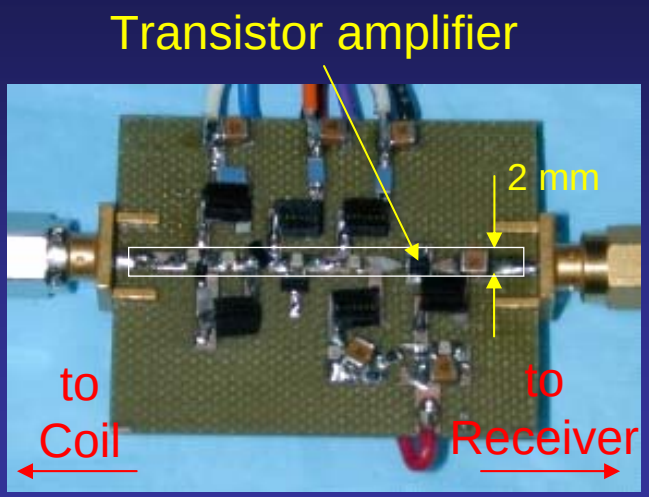
Cylindrical Meanderline Receive Coil

Position of meanderline coil

Cylindrical Meanderline Coil Advantages

1. The meanderline coil sensitive volume is limited to a cylindrical shell, allowing for the selective imaging of arterial walls with minimal or no signal from blood.
2. The meanderline coil can be made from shape-persistent materials allowing it to be deployed similarly to a stent, thereby stabilizing the coil against the blood vessel wall and minimizing imaging artifacts due to coil motion during pulsatile blood flow.
3. The center of the coil is open and allows for unimpeded blood flow during image acquisition.

Local Coil Tuning and Preamplification



Prototype Local Preamp

- Ultra low noise transistor amplifier with 20 dB gain.
- PIN diode to detune the RF coil and protect the transistor during RF pulses.
- Varactor diodes for automated tuning/matching of coil.
- Active (white box) components occupy 2 mm strip.
- Flexible, miniaturized circuit that will fit in a 7F catheter is currently being fabricated.

Automated Tuning and Matching Circuit