The Coaxial Reentrant Cavity (ReCav) Coil for High Frequency Large Volume MRI/S

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<u>Introduction</u>
To achieve improved SNR and spectral resolution, MR systems continue a drive toward higher magnetic field strengths, and consequently higher resonant frequencies. Traditional rf coil design techniques used at lower field strengths begin to break down at higher frequencies as the coil dimensions approach significant portions of a wavelength. The coils can become far field radiators, compromising the near field performance, or they may become inhomogeneous due to significant phase shifts around the coil. New designs to reduce these problems involve the use of resonant cavities (1-6), with the TEM resonator (1) the most widely applied. In this work we explore the utility of the coaxial reentrant cavity as a simple and effective alternative high frequency volume rf coil.

<u>Theory</u>
Cavity resonators are used widely in microwave engineering where device dimensions and wavelengths are the same order of magnitude. One type of cavity resonator is the reentrant cavity, in which the walls of the cavity fold into, or reenter, the center of the cavity. The coaxial reentrant cavity (ReCav), displayed in fig.1, is one in which the electromagnetic fields can be MR compatible (1).

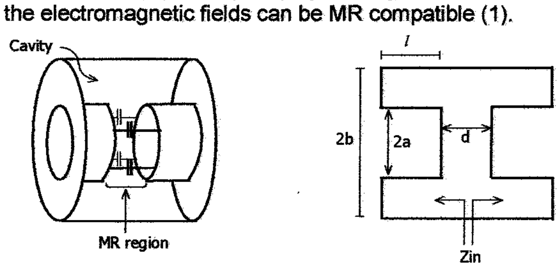

Fig 1. Schematic of the ReCav coil (left) with a cross-sectional equivalent (right)

The inductance and capacitance of the of the cavity are given by (7),

$$L = \frac{1}{\pi\omega}\sqrt{\frac{\mu}{\varepsilon}}\ln\frac{b}{a}\tan(\beta l) \qquad C = \frac{\varepsilon\pi a^2}{d}$$

where $\beta=2\pi/\lambda$. At resonance, $\omega L=1/\omega C$. Solution to this equation gives the resonant frequency of the ReCav coil. Note that the equation contains the tangent function, resulting in an infinite number of solutions. The secondary mode of propagation in the ReCav is the frequency of interest to MR.

<u>Methods</u>
A ReCav coil was made for use on a 4.7T Bruker Avance system. The ReCav was made from two coaxial cylinders, the outer cylinder of O.D. 7⅝", the inner cylinder of I.D. 3¾", total length of cavity 7¾", and length of MR useful region 2" (fig 1). The outer cylinder was covered with a thin copper sheet that was segmented to break up gradient induced eddy currents. The inner cylinder was covered with the same copper sheet, leaving a 2" gap in the center. The outer and inner cylinders were shorted at the ends with copper covered end plates. The capacitance of the cavity was controlled with four capacitors attached across the 2" center gap, spaced at azimuth angles 30°, 150°, 210°, and 330°. The ReCav was excited by inserting, from one end, a small loop between the inner and outer walls, oriented in the ZX plane. A shielded 8-element lowpass birdcage with equivalent dimensions as the ReCav coil was built for comparison. The birdcage was excited by capacitively coupling across one of the distributed capacitors in a leg. SNR comparisons were made on the 4.7T instrument with a cylindrical loading phantom filling 70% of the useable coil volume, and a rat brain *in vivo*. A standard spin echo imaging sequence was used for SNR measurement.

<u>.Results</u>
The loaded and unloaded Q measurements and SNR with the loading phantom are shown in the table below.

Coil	Q Empty	Q Loaded	Qe/Ql	SNR
ReCav	563	83	6.8	215/1.4=154
Birdcage	120	82	1.5	193/1.3=148

Q damping is much greater for the ReCav than the birdcage, however, loaded Q is equivalent. The SNR is similar for the coils on the loaded phantom. Animal images are shown in figure 2 and are virtually identical.

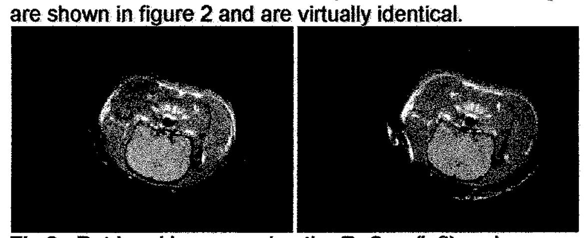

Fig 2. Rat head images using the ReCav (left) and birdcage (right) coils and identical imaging sequences.

<u>Discussion</u>
These results demonstrate a close performance equivalence of the ReCav coil and a birdcage coil at 200 MHz and 3 ¾ " internal diameter. In comparison to other designs in the literature, the ReCav coil is very simple to construct and control. The coil has just 6 capacitors, with tuning controlled by one of the capacitors across the 2" gap and matching controlled by a capacitor attached to the excitation loop. At higher frequencies, as the coil sizes approach significant portions of a wavelength, the ReCav efficiency may be better than the birdcage because of its ability to contain the electromagnetic fields. We are investigating larger ReCav coils at 500 MHz in expectation of delivery of a 11.7T/40cm Magnex/Bruker system.

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