MR imaging capability of a field-cycled MRI/PET scanner

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Introduction: Field-cycled MRI employs two separately controlled electromagnets to a) polarize a sample and b) provide the magnetic field environment during image acquisition [1,2]. Advantages of field-cycled MRI are: reduced susceptibility artifacts, increased T_1 dispersion, reduced acoustic noise, and the ability to include a second imaging modality, such as PET [3]. A field-cycled MRI scanner was built by the authors (Fig. 1). A 9-cm gap was placed in the center of the scanner to allow for the insertion of a PET ring, at the expense of decreasing the homogeneity and achievable field strength of the MR scanner. Higher order shims were incorporated to increase B_0 homogeneity. A low-pass birdcage coil was used to increase the SNR of the coil-noise-dominated system. Three-dimensional MR images were acquired to demonstrate the MR imaging capabilities of the field-cycled MRI/PET scanner.

Methods and Results: The low-pass birdcage coil consisted of 20, 0.25"-wide, 0.021"-thick copper strips, spaced evenly apart (Fig. 2). The coil was 3.25" in diameter and 5.25" in length. The birdcage coil was driven in quadrature, with 23 dB of isolation between the 0° and -90° ports. The birdcage coil was tuned to 4.00 MHz, matched to 52 Ω, and had a Q of 75. The receive chain is shown in Fig. 3. A frequency synthesizer/mixer mixed down the transmit frequency of the console, and then mixed up the receive frequency. A Varian Unity Inova console drove the field-cycled MRI scanner.

Homogeneity of the scanner was improved by shimming with linear gradients and z^2, x^2-y^2, and xy shim coils. A 7-cm diameter spherical sample was shimmed to 28 Hz (7 ppm).

Proton-density-weighted 3d-FSE images were acquired of a rat and orange (BW: 20/18 kHz; FOV: 15x9x9 / 10x10x4 cm; matrix: 256x128x24 / 192x128x10; N_{avg}: 10/8; TR/TE: 2300/23, 3160/21 ms; T_{scan}: 150/67 min). To reduce field instability caused by the ramping down of the polarizing magnet, an 85 ms delay was inserted before the start of the CPMG sequence.

Discussion: The achieved homogeneity of 30 Hz is considerably less than a pixel bandwidth for the given imaging sequence, significantly reducing possible distortion and signal dropout due to B_0 inhomogeneity. Images in Fig. 4 show no apparent distortion artifacts due to B_0 inhomogeneity. By redesigning the birdcage coil and increasing its Q, the resulting √Q increase in SNR can applied towards reducing scan times.

Currently, the authors are integrating a PET system into the field-cycled MRI scanner. The added inhomogeneity, and resulting image artifacts, due to the insertion of a PET ring are expected to be negligible. The inclusion of a gap in the readout magnet for the insertion of a PET ring reduces homogeneity, yet the homogeneity of the readout field, with the use of higher order shimming, is still adequate to prevent artifacts in MR images. In the field-cycled MRI/PET scanner, the performance of the MR imaging modality is sacrificed to improve the performance of the PET system. However, high resolution images can be obtained using the current field-cycled MRI scanner. With the addition of a PET ring, the ability to overlay functional information on the anatomical MR images will increase the diagnostic potential of the images, and the scanner's overall SNR efficiency will increase greatly.

References:
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[2] Gilbert K M et al. 2006 *Phys. Med. Biol.* **51** 2825-2841
[3] Peng H et al. 2005 *Proc. 13th ISMRM* p 901

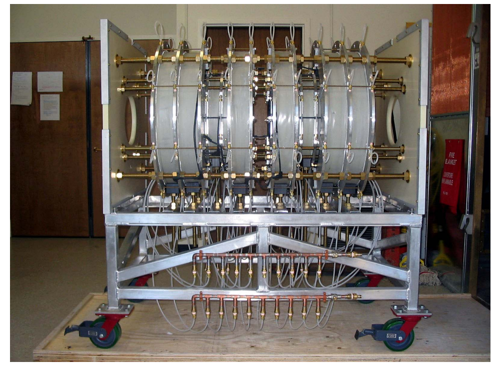

Fig. 1: Field-cycled MRI scanner.

Fig. 2: Low-pass birdcage coil.

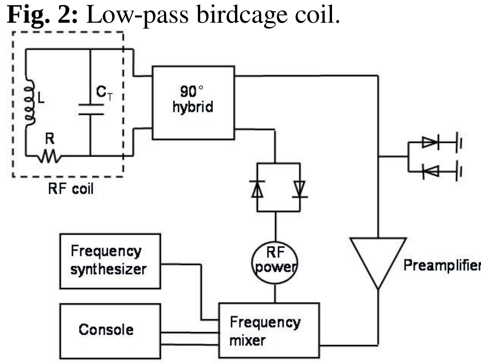

Fig. 3: The receive chain.

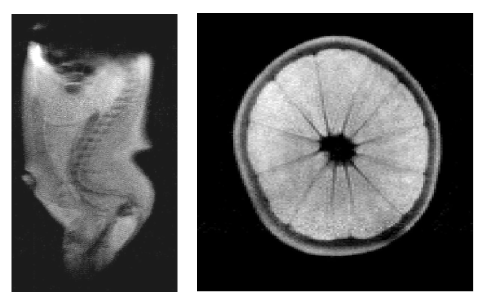

Fig. 4: 3d-FSE image slices of a rat (left) and orange (right). Two slices were averaged for each image.