Development of a very low field system for hyperpolarized noble gas MRI

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Introduction: One of the advantages of HP gas MRI is that the SNR does not decrease appreciably when the B_0 field is lowered, obviating the need for the expensive superconducting magnets used in conventional MRI systems. The authors have previously demonstrated *in vivo* very low field imaging of the lung gas-space in humans and in rats using hyperpolarized ^{3}He and ^{129}Xe [1] by ramping down a super-conducting magnet from 1.5T to 15mT. The design of a low field imaging system is significantly different from conventional MRI systems since a variety of system issues, such as noise sources, the earth field's effect and signal amplification, need to be re-assessed [2,3]. Building upon the knowledge and experience from previous experiments, we have redesigned our VLF MR system using a wire-wound solenoid magnet with many improvements for noise reduction and SNR optimization.

Methods: A 15mT human size very low field magnet system was built by Resonance Research with an optimized field homogeneity of 20 ppm over a 30 cm diameter spherical volume (DSV). The Bore size is 71 cm ID, sufficient for imaging large patients. The magnet is situated inside a RF enclosure made by ETS-Lindgren with the attenuation of electrical fields and plane waves down to 100 db at 10 KHz. The noise on the gradient coil was significantly reduced by using a set of custom-made gradient filters (ETS-Lindgren) which have the pass band only up to 20 KHz. 1.5 inch ID circular waveguides were installed for chiller water hoses to penetrate the shielded room in order to minimize the noise introduction into the room. A filtered connector panel was installed for all the signals in and out of the shielded room. A gradient system made by Resonance Research was installed with gradient amplifiers (Techron 8606) to produce a gradient field of 3 gauss/cm. The system was interfaced to a Resonance Instruments Ultra Maran console. ^{3}He gas was polarized to 10% via spin-exchange with rubidium, optically pumped using a 120W laser diode array (Optopower) and transported in the earth's magnetic field from another building to the magnet. The coil used in this study was a 100-turn solenoid coil tuned to 637 KHz for ^{1}H and 485 KHz for ^{3}He.

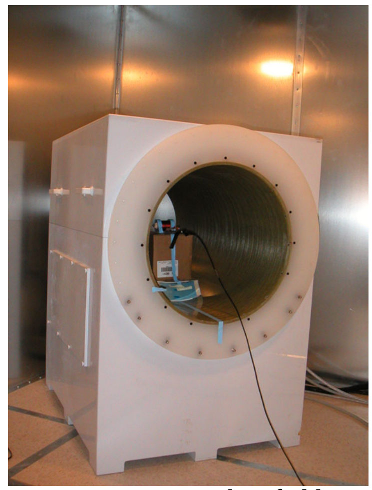

Fig.1. 15mT very low field solenoid magnet

Results: Figure 2 shows a ^{1}H image of a water filled syringe, acquired with a gradient echo Fourier imaging sequence, with size 64 x 64, averages 64 , FOV 47 cm x 18.5 cm , and flip angle of 90°, TR 2 s. Figure 3 shows an image of a hyperpolarized ^{3}He phantom acquired with the same sequence with a matrix of size of 64 x 64, single shot, FOV 34 cm x 13 cm, flip angle 20°.

Discussions: The preliminary results with phantoms demonstrate the successful operation of our new VLF MRI system. The noise reduction of this new system was achieved through the re-design of the filter systems. We envision that a VLF HP gas MRI system, if brought into clinical viability, could fast-track the early detection, diagnosis, and treatment of a range of pulmonary diseases especially for the people in rural areas of the US and developing nations.

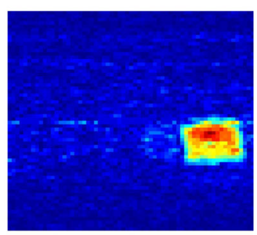

Fig.2. ^{1}H image of a water filled syringe.

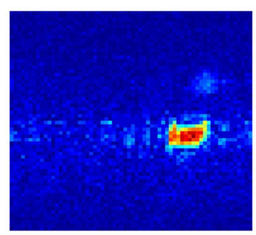

Fig.3. image of a hyperpolarized ^{3}He phantom.

References:

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