Low Field RF Coil for Hyper-Polarized Noble Gas MRI

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Purpose: The purpose of this paper is to study on and to optimize the low-field (less than 0.1 Tesla) RF coil for hyper-polarized noble gas MRI.

Materials and Method: MRI can produce slice selective and 3-D images, and is non-invasive, but conventional ^1H_2O MRI has limitations for lung imaging because the gas space is water-free, and protons have an inconveniently short T_2^* in the lung tissue, owing to the inhomogeneous component of the magnetic susceptibility at the highly convoluted lung surface. In conventional MRI, the signal increases as the square of the magnetic field strength, B_0, hence it is greatly advantageous to use powerful magnets. The signal from hyper-polarized noble gas, however, increases just linearly with the magnetic field. Since the noise increases with frequency, which increases with B_0, the contrast between the two case is even more marked. At moderate field (B_0 = ~0.1T), the SNR with hyper-polarized noble gas is virtually independent of B_0. A substantial advantage of low-field MRI also arises from the proportional decrease of susceptibility artifact. This means that even more stress is put on the quality factor Q. Coils with high quality factor Q and high inductance are thus required at low fields. The Multi-loop RF coil with high inductances is studied with various coil parameters. The RF coil for hyper-polarized noble gas MRI has 35-cm-diameter multi-loop configuration. Coils are tuned to below 1 MHz. In addition, matching capacitors are used in order to propagate all signals without reflection of the signal. The following parameters are studied: (1) the unloaded and loaded coils, (2) the series and parallel connections, (3) the number of turns, (4) various wire thicknesses, and (5) the Litz and copper wire configuration.

Results: Signal intensities of unloaded and loaded coil are almost identical, which means that most noise is coming from the coil. At frequencies less than 1 MHz, the signal intensity from the coil with the series connection is 1.41 times larger than that with the parallel connection. In case of the unloaded coil, the more number of turns results in the better SNR. Thicker wire gives a better SNR. Litz wire gives about 2.6 dB (about 30 %) better SNR than the copper wire of a similar thickness for low frequencies (around 200kHz). At high frequency of about 1 MHz, however, the difference was only 0.5 dB (5 %).

Conclusion: Multi-loop RF coil for hyper-polarized noble gas imaging has been optimized based on the theory and experiments. The proposed coil with optimized parameters seems to be useful for low field MRI. In the future, we will develop new methods to decrease coil losses in low fields.