# A 19F - 1H Linear Dual Tuned RF Birdcage Coil for Rat Lung Imaging at 3T

Gowtham Gajawada[1,2], Tao Li[1], Marcus J Couch[1,2], Matthew S Fox[3,4], and Mitchell Albert[1,2]
[1]*Thunder Bay Regional Research Institute, Thunder Bay, Ontario, Canada,* [2]*Lakehead University, Thunder Bay, Ontario, Canada,* [3]*Robarts Research Institute, London, Ontario, Canada,* [4]*Department of Medical Biophysics, Western University, London, Ontario, Canada*

**Introduction:** Inhaled inert fluorinated gas magnetic resonance imaging (MRI) is a promising technique for anatomical and functional lung imaging (1, 2). In order to better understand and develop this novel technique, a vast number of pre-clinical animal experiments are required for validation and optimization of radio frequency (RF) coils (3, 4). Before the advent of dual-tuned coils, multinuclear studies required more than one RF coil in order to capture all the desired information. Since the subject needs to be moved in order to switch the RF coils, image registration (co-alignment of separate images) may be required for correct image interpretation. The purpose of this study was to develop a $^{19}$F-$^{1}$H dual-tuned coil and to acquire inherently co-registered inert fluorinated gas ventilation images and their conventional proton image analogues *in vivo*.

**Theory:** A birdcage coil is a circular network of identical filter cells. When excited, a current is passed through and a standing wave is created. This gives a nearly ideal cosine current distribution along the coil surface, which theoretically generates a homogeneous magnetic field inside the coil. A birdcage coil inherently has two orthogonal channels that are electrically invisible to each other. Since proton ($^{1}$H) and fluorine ($^{19}$F) nuclei have close resonant frequencies at 3 T (127.74 MHz and 120.15 MHz, respectively), one can take advantage of these two channels and tune each of them to a different resonant frequency. This way the coil assures identical $B_1$ field profiles for the two nuclei, and also increases the filling factor especially for the $^{1}$H frequency, resulting in an improved SNR. A schematic of the proposed linear dual-tuned coil is shown in Figure 1.

**Methods:** The size of the coil was optimized for rodent imaging, and the coil was constructed on an 88.3 mm diameter acrylic tube. The $^{1}$H channel was at 0° and the $^{19}$F channel was at 90°. Figure 2 shows the S11 responses of the two channels, as well as the S21 responses between the two channels at both the $^{1}$H and $^{19}$F frequencies. An isolation of 17 dB was achieved at the $^{1}$H frequency, and 30 dB at the $^{19}$F frequency. The completed coil was interfaced with a Philips 3 T Achieva scanner via a dual frequency gateway (Clinical MR Solutions, LLC). In order to quantitatively study the field homogeneity for both nuclei, $^{1}$H $B_1$ field mapping was performed using dual-TR method and a 30 mL syringe of mineral oil and $^{19}$F $B_1$ field mapping was performed using dual angle method and a 30 mL syringe of sulfur hexafluoride ($SF_6$). 3D rat lung imaging was then performed on a healthy male Sprague-Dawley rat (348 g) using an animal care protocol approved by the local animal care committee. The rat was ventilated with a custom-built MR-compatible ventilator using a mixture of 80% $SF_6$ and 20% $O_2$ (5).

**Results:** Figure 3 shows the $B_1$ field mapping for both coil channels and the corresponding histograms. A 15 x 15 x 30 mm$^3$ field of view was considered for the $^{19}$F for $B_1$ map, and a 16 x 16 x 20 mm$^3$ field of view was considered for Proton for $B_1$ and histogram. The mean normalized B1 for the $^{1}$H and $^{19}$F frequencies (± standard deviation) were 0.8197 ± 0.1053 and 0.9477 ± 0.0199, respectively. Figure 4 shows *in vivo* rat lung images in the coronal and axial planes. The top row shows the $^{1}$H images acquired using a turbo spin echo sequence during free breathing (no gating). The second row shows the $^{19}$F images acquire using a 3D gradient echo sequence during free breathing (no gating).

**Discussion and Conclusions:** The completed coil has exhibited satisfactory electrical performances as well as good $B_1$ field homogeneity for both nuclei. A sufficient isolation was achieved between the two channels to minimize the coupling effects. This coil structure eliminates the need for active decoupling components and circuits, and greatly reduces the complexity of dual-tuned coil construction. The rat lung images demonstrate a sufficient signal to noise ratio for $^{19}$F MRI studies of animal models of pulmonary diseases.

**References:** [1] Couch et al. (2013) *Radiology* 269:903-909. [2] Halaweish et al. (2013) *Chest*, 144:1300-1310. [3] Schreiber et al. (2001) *Magn Reson Med* 45:605-613. [4] Ouriadov et al. (2014) Magn Reson Med doi:10.1002/mrm.25406. [5] Nouls et al. (2011) Concepts Magn Reson B 39B(2):78-88.

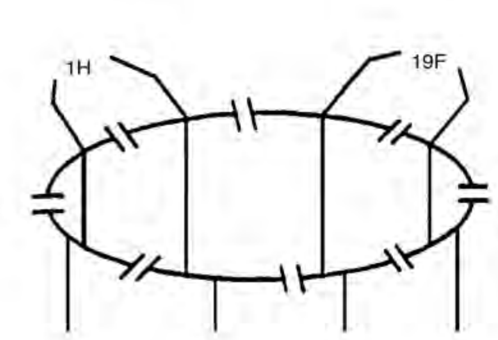


**Figure 1:** Structure of the linear dual tuned coil.

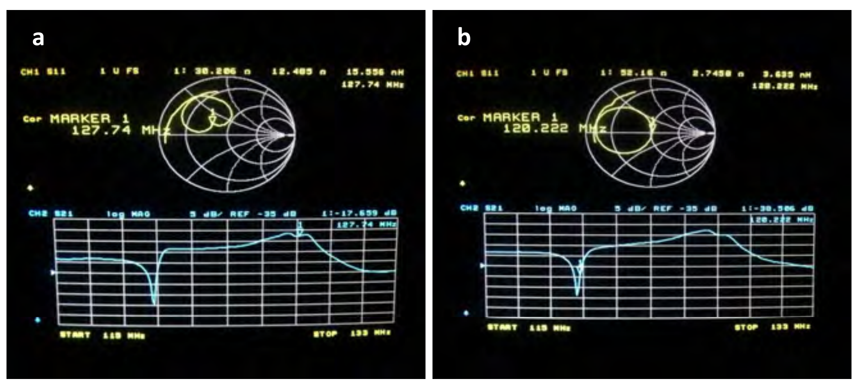


**Figure 2:** S11 response and S21 response for the (a) $^{1}$H frequency and (b) $^{19}$F frequency.

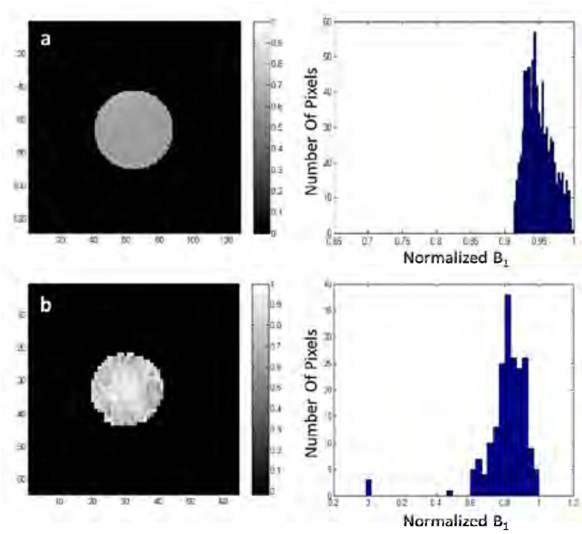


**Figure 3:** (a) A $B_1$ field map for the $^{1}$H channel and the corresponding histogram. (b) The $B_1$ field map for the $^{19}$F channel and its corresponding histogram.

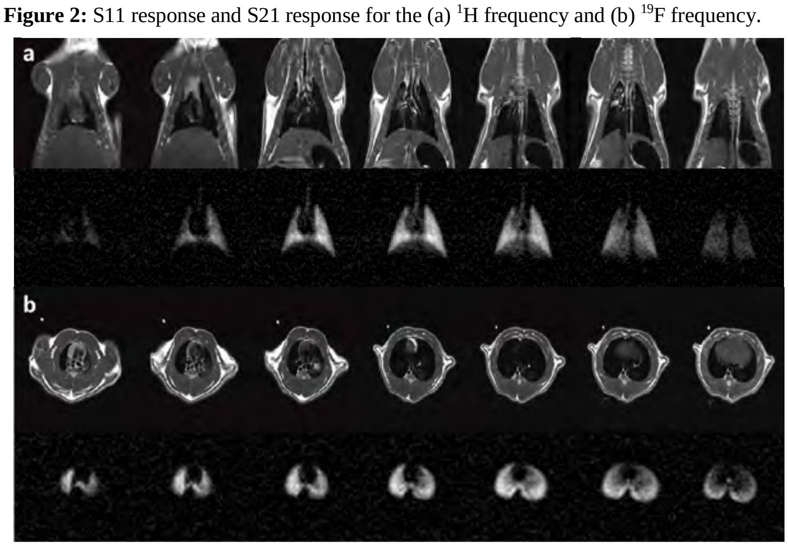


**Figure 4:** (a) Coronal and (b) axial views of the $^{1}$H and $^{19}$F MR lung images acquired in the lungs of a healthy rat.