

Unshielded and Asymmetric RF Transmit Coil for Hyperpolarized ^{129}Xe Human Lung Imaging at 3.0 T

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Introduction: Hyperpolarized ^3He gas provides unprecedented imaging of lung anatomy and function. However, ^3He is exceedingly rare and this is expected to limit its widespread clinical use. On the other hand, hyperpolarized ^{129}Xe gas is more plentiful and has been shown to provide similar image quality and diagnostic utility. Furthermore, ^{129}Xe has a high solubility in tissue and can reveal anomalies in pulmonary perfusion and gas exchange. Hyperpolarized gas imaging of human subjects is expected to benefit from parallel imaging approaches [1], requiring uniform transmit coils conforming to the human thorax. Asymmetric bird-cage resonators have previously been described for hyperpolarized ^3He lung imaging at 1.5 T, allowing uniform, quadrature B_1 transmission in the chest and room to accommodate multi-channel receive coil arrays [2]. In this work we describe a novel unshielded, asymmetric quadrature bird-cage transmit coil designed for hyperpolarized ^{129}Xe imaging of human lungs at 3.0 T while allowing proton imaging without having to move the subject. The coil performance is also compared to a conventional linear coil on the basis of SNR, B_1 homogeneity and patient comfort.

Methods: The geometrical design of the coil followed the method of conformal mapping and splits into two halves to allow easy access for the subject [2]. The coil is a high-pass design, and it was built to utilize the maximum space in the bore (Fig. 1.) of a 3.0 T MR imaging system (Discovery-MR750, GEHC). The transverse cross-section of the coil has a long axis of 54.0 cm and a short axis of 40.5 cm. The overall length (end-ring to end-ring) of the coil is 60.0 cm, including 16 rungs. End-ring capacitance values were evaluated based on analytical mesh inductance estimates [3] in order to provide tuning to the resonant frequency (35.34 MHz). The coil was derived by two ports at meshes number 5 (at the long axes) and 9 (at the short axes), which are connected to a quad-hybrid circuit through N-type connectors. The B_1 homogeneity of the coil was characterized using a 2 second (scan time) 3D acquisition sequence, and utilized the variable flip angle (VFA) approach [4], on a uniform gas phantom free of oxygen. The VFA scheme maintained constant transverse magnetization ignoring T_1 relaxation, and the flip angle was estimated on a pixel-by-pixel basis following 32 successive RF pulses. The phantom is a gas-tight, plastic cylinder made of acrylic (volume = 10.1 L) containing a mixture of 99% N_2 and 1% hyperpolarized ^{129}Xe provided by a commercial turn-key system (model XeBox-E10, Xemed LLC, NH, USA). The coil operated in transmit-receive mode and was employed for human studies using a 3D VFA fast gradient-echo pulse sequence ($\text{TE}=1.5\text{ms}$, $\text{TR}=6.7\text{ms}$; $\text{BW}=8\text{kHz}$) during an $\sim 14\text{s}$ breath-hold of hyperpolarized ^{129}Xe gas. ^1H imaging was also performed without re-positioning the subject, taking advantage of the unshielded design of the coil.



Fig. 1: Quadrature ^{129}Xe RF coil at 3.0T, showing unshielded-asymmetric design

Results: The measured isolation (S_{12}) of the coil was better than 20dB and with an 89.6° phase difference between the two driving ports. The ratio of loaded to unloaded Q was better than 2, with the coil loaded by a typical volunteer. The B_1 homogeneity was approximately 11% over the entire lung, and similar to that achieved with a linear coil. The SNR provided by the coil was more than 20, a factor of 1.6 improved with respect to the linear coil. Figure 2 shows a classic set of 3D static ventilation images obtained using the coil on a healthy volunteer who inhaled a mixture of 500mL/500mL $^{129}\text{Xe}/^4\text{He}$. The coil was able to accommodate all subjects in a comfortable manner.

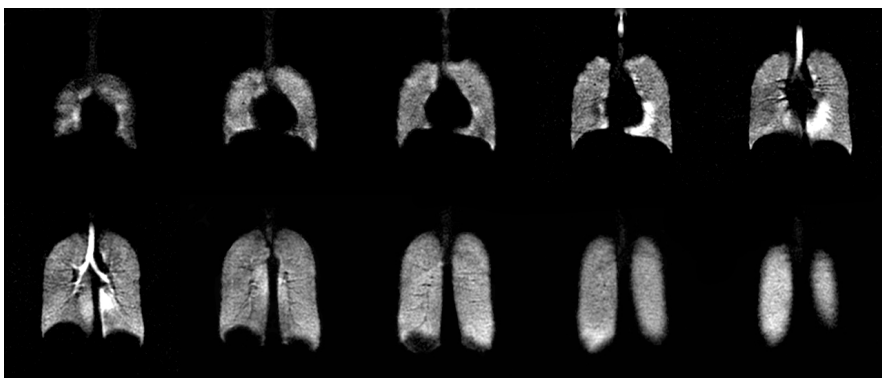


Fig. 2: Representative 3D ^{129}Xe images of a healthy volunteer taken for a matrix size=128x128; $\text{FOV}=40\text{X}40$; 16 slices with a thickness 15mm, $\text{SNR} > 20$)

Discussion: An unshielded, asymmetric quadrature birdcage RF coil has been developed and tested for hyperpolarized ^{129}Xe human lung imaging at 3.0 T. The larger volume (1.8 times the linear) and asymmetry of the coil allows comfortable positioning of human subjects compared to a smaller elliptical linear coil without loss in homogeneity (better than 10% over the entire lung volume) and with higher SNR. Such improvements can be explained by the good isolation between the two driving ports in the coil while an optimum current distribution permitted the achievement of high homogeneity. This homogeneity is expected to be particularly beneficial for hyperpolarized gas applications such as measurement of regional oxygen partial pressures, known to be sensitive to flip angle variations. The coil operated at double the power ($\sim 4\text{kW}$) of that used by the linear coil, however, this was not in particular a disadvantage as the trade off was better sensitivity, SNR and homogeneity. The unshielded design permits ^1H imaging without having to move the subject, nevertheless, noisy proton images was observed and tentatively explained by coupling between the upper meshes (being so close to the bore elements) and the bore elements. This coupling was surmounted by increasing the operating power during the proton scan. Although, the use of this coil described in this work is in a transmit/receive mode, it is straightforward to combine this with multiple receive coils for accelerated imaging applications.

References:

- [1] Lee et al, Magn Reson Med 55:1132–1141, 2006.
- [2] De Zanche et al, Magn Reson Med 60:431–438, 2008.
- [3] De Zanche N et al, Magn Reson Med 2005; 53:201–211.
- [4] Zhao, et al. J. Magn. Reson. B 1996; 113:179–183.