Single-input double-tuned birdcage coil with identical B1 field profile for 1H and 19F imaging

L. Hu[1], F. D. Hockett[1], J. Chen[1], G. M. Lanza[1], and S. A. Wickline[1]
[1]Washington University School of Medicine, St. Louis, MO, United States

Introduction: A double tuned birdcage coil was widely studied for its good field homogeneity and convenience in support of a heteronuclear MRI experiment. Since the birdcage coil is a multi-mode resonator with complicated electrical property, its double-tuned version is often designed to achieve the required frequency shift by geometrically rearranging coil legs, adding new tunable elements to specific legs, or varying shield size [1-3]. We proposed a novel design of double-tuned birdcage coil by inserting a secondary resonator in the feeding circuit without changing the structure of birdcage coil. The frequency response and magnetic field distribution of the coil were measured followed by in vivo demonstration. Furthermore, we experimentally showed that our coil is able to be integrated with active decoupling technique [4].

Materials and Methods: A high-pass 8-leg linear polarized birdcage coil was fabricated with quarter-inch adhesive copper tape on an acrylic tube of 50 mm in diameter and 128 mm in length. The whole coil was placed in a copper shield with a diameter of 135mm and then tuned to resonant at 200 MHz for 1H imaging at a Varian 4.7-Tesla ANOVA console. The secondary resonator (Fig. 1A) was built with a tunable capacitor (Cs, 1-20 pf) in parallel with a custom-made inductor (Ls, 32 nH) and the coupling between the main and secondary resonators was implemented with another tunable capacitor (Cc). The secondary LC loop was also tuned to 200 MHz. We then set the value of Cs (~7 pf) to over-couple these two resonators, giving rise to the second distinct frequency at 188 MHz which is the 19F resonant frequency. The feeding point for this coil (Fig. 1A) was located at the secondary resonator input and the whole circuit was matched to 50 Ω through matching capacitor (Cm). The return loss (S11) was measured on a network analyzer with a 50ml tube filled with saline as the load. The B1 field produced by the birdcage was measured with a 10 mm shielded loop. After that, in vivo experiment was carried out on a C57Bl/6 mouse anesthetized with a standard dose of ketamine/xylazine followed by intravenous injection of 20% v/v perfluoro-15crown-5-ether (CE) emulsion (4ml/kg). Multi-slice transverse 1H and 19F images of the mouse body were acquired. 19F MRI parameters are: pulse sequence, gradient echo; TR, 40ms; TE, 4ms; number of average, 1024; acquisition time, 21min; in plane resolution: 1.8mm * 1.8mm, slice thickness: 10 mm. To achieve the highest sensitivity for 19F MRI, we further placed an actively decoupled 19F surface coil inside the birdcage coil, perpendicular to the B1 field. In this setup, the doubled tuned birdcage served as transmitter/receiver for 1H MRI and transmitter for 19F MRI; the actively decoupled receiver coil served as receiver for 19F MRI. The sensitivity of 19F MRI with this two-coil setup was tested using a 1ml tube filled with 0.15% v/v CE emulsion.

Results: The measured S11 shows the double tuned birdcage coil is matched to 50 Ω at both 19F and 1H frequencies (Fig. 1B). The B1 field distribution along both z-axis (Fig. 1C) and y-axis (Fig. 1D) is homogeneous over 60% of the coil dimension. The B1 field homogeneity at both frequencies is essentially the same, a unique advantage of this design. In vivo 1H and 19F image shows intense 19F signal in the heart and liver (Fig. 2A-D), reflecting the 19F signal from blood-pool PFC NP and trapped NP in liver. Finally, we demonstrated more than 10 fold increase of 19F SNR could be achieved using the two coil setup by adding an actively decoupled 19F surface coil as receiver (Fig. 2E & F).

Discussion and Conclusion: Our design of a double-tuned birdcage coil preserved the standard birdcage structure. Thus, the B1 field distribution is inherently identical at 1H and 19F resonant frequencies. This unique feature minimizes the susceptibility effect on image co-registration, allowing automatic overlay of 19F and 1H images to localize delivered 19F agent. Finally, we demonstrated that this double-tuned birdcage can be integrated with an active decoupled receive coil to maximize 19F SNR.

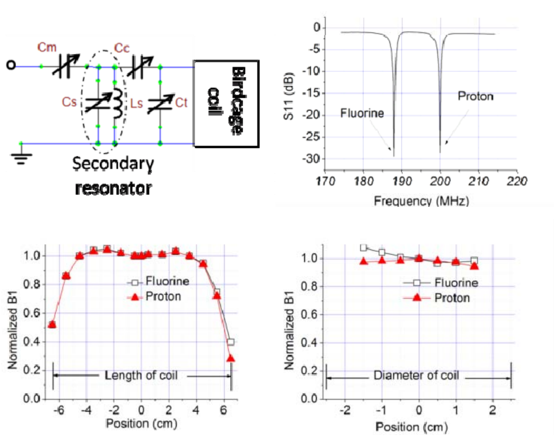

Figure 1. (A) Circuit. (B) The measured S11 shows the tuning and matching at 4.7T. The sensitivity profiles (or B1 field) along z-axis and y-axis are plotted in (C) and

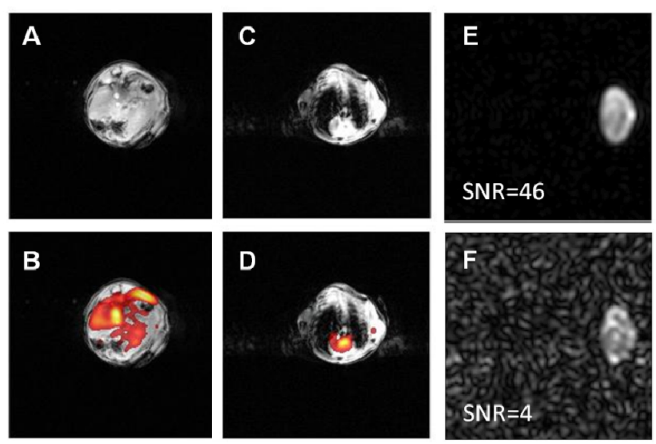

Figure 2. Two slices of 1H images (A & C) show the anatomy of abdomen and chest of a mouse. 19F images overlayed on the corresponding 1H images show high intensity of 19F signal in liver and heart (B & D). The 19F SNR acquired with an additional active decoupled receive coil (E) is over 10 times higher than that acquired by using the birdcage coil as transmitter/receiver (F).

References: [1] S. B. King, el al., Proc. ISMRM, p1559, 2004; [2] Alan R. Rath, J Magn Reson 86: 488-495, 1990; [3] Yunsuo Duan, et al., J Magn Reson 29: 12-22, 2009; [4] Joel R. Garbow, et al., Con Magn Reson B 33B(4) 252–259, 2008.