A Double-Shielded Label Coil for Continuous Arterial Spin Labeling at 7 T

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Introduction. Recently, a shielded loop coil was proposed for continuous arterial spin labeling (CASL) at the human neck at 3 T [1]. At frequencies above approximately 150 MHz, this arrangement becomes impractical because capacitive tuning is no longer possible. As a solution to this problem, we introduce a double-shielded coil concept. Experimental maps of the magnetic radiofrequency (RF) transmit field, $B_1^{(+)}$, and the specific absorption rate (SAR) recorded at 7 T are compared to simulation results.

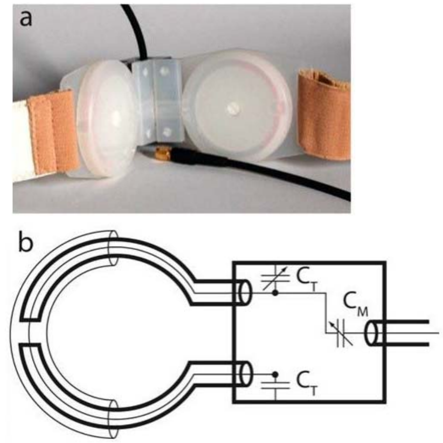

Figure 1. **(a)** 7T labeling coil with two perpendicular loops. **(b)** Sketch of a single loop and the matching network.

Methods. *Coil design:* The label coil consists of a perpendicular pair of shielded loops made of 50-Ω, 3.6-mm-diameter semi-rigid cable with a 1-mm gap opposite to the feed point. An additional floating shield ("secondary shield") covering the gap was made of heat-shrink tubing and copper foil on the outside (Fig. 1). The secondary shield acts as a capacitance, and shifts the impedance of the circuit towards inductive behavior. This, again, allows capacitive tuning at a frequency of 297.2 MHz as required for 7T MRI. Electric RF fields near the gap are shielded. The coil dimensions (6-cm loop diameter, 7-mm thick polypropylene insulation) were chosen with the goal of efficient labeling in the brain-feeding arteries (carotid and vertebral arteries) based on previous work at 3 T [1,2]. Tune and match capacitors of C_T = 14 pF and C_M = 3.5 pF were used for operation at 7 T. By adjusting the phase shift between both loops, different excitation modes can be obtained (e.g., 'Helmholtz mode' or 'Maxwell mode' with equal or opposite current directions in both loops, respectively). The coil is easily attached to the neck by a Velcro strip. For initial phantom experiments, the coil was equipped with a transmitter/receiver (Tx/Rx) switch. *Computer Simulations:* Numerical simulations of the tuned and matched coil were performed with HFSS 11 and Designer (Ansys, Inc., Canonsburg, PA) under consideration of the material properties, capacitors, excitation ports, and a cylindrical phantom with mean dielectric tissue parameters [1,3]. Attenuation between the amplifier output and the coil was ignored in the simulations. *7T MRI Experiments:* A MAGNETOM 7T scanner (Siemens, Erlangen, Germany) was employed for imaging. Flip angle distributions were measured with a gradient-recalled echo (GRE) based actual flip angle (AFI) sequence [4] in an agarose phantom. Temperature distributions inside the phantom were obtained from the phase shift recorded with a GRE sequence after 5min periods of heating by application of 14.6W RF power (measured at the amplifier output) [5]. Results were used to compute maps of $B_1^{(+)}$ and SAR.

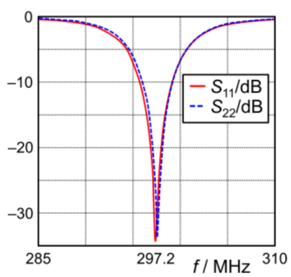

Figure 2. Measured reflection curves for both loops.

Results. Bench-top measurements indicated a low sensitivity to different loading conditions and excellent decoupling of both loops (Fig. 2). Computed $B_1^{(+)}$ and SAR maps are shown in Fig. 3. The $B_1^{(+)}$ distributions are slightly distorted (so-called 'dielectric resonance' effects) but indicate a sufficiently large amplitude at the expected positions of the carotid and vertebral arteries. Lowest SAR levels were achieved with the 'Maxwell mode', which was therefore used for 7T imaging [1]. Experimental $B_1^{(+)}$ maps obtained with 14.6W input power showed excellent agreement with the simulated profiles. The recorded temperature changes and SAR maps indicated safe operation within legal SAR limits.

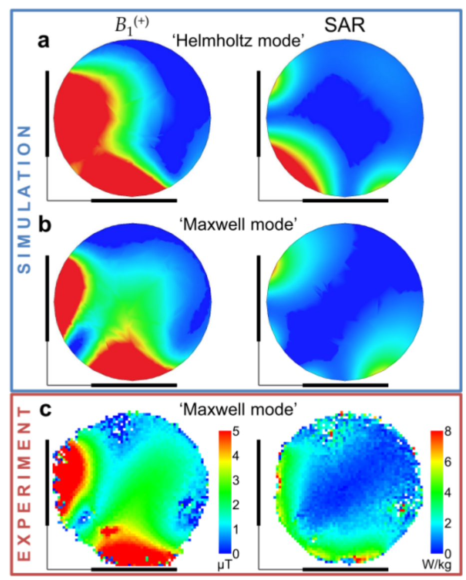

Figure 3. Simulation results for the **(a)** 'Helmholtz' and **(b)** 'Maxwell mode'. **(c)** Experimental results ('Maxwell mode'). Loops are indicated by thick black lines.

Discussion. The integration of a floating secondary shield allows adaptation of the shielded dual-loop coil to higher magnetic fields, where the standard design becomes impractical. Simulations and initial experiments suggest that the coil permits labeling at 7 T within legal SAR limits. For CASL experiments, the coil may be combined with a head coil [6]. Additional PIN diodes may be integrated to disconnect the coil during transmission with the head coil [1].

References: **[1]** S. Hetzer et al. *J. Magn. Reson. Imaging* 29: 1414-1424 (2009). **[2]** R. Trampel et al. *Magn. Reson. Med.* 51: 1187-1193 (2004). **[3]** W. Driesel et al. *Concepts Magn. Reson. Part B (Magn. Reson. Engineering)* 33B: 94-108 (2008). **[4]** V.L. Yarnykh. *Magn. Reson. Med.* 57: 192-200 (2007). **[5]** F. Seifert et. al. *J. Magn. Reson. Imaging* 26: 1315-1321 (2007). **[6]** T. Mildner et al. *NeuroImage* 27: 919-926 (2005).