Transmit volume coil-receive surface coil for proton operating at 14 Tesla

Masoumeh Dehghani M. [1], Arthur Magill W. [2], Yves Pilloud[1], Nicolas Kunz[2], and Rolf Gruetter[1,2]
[1]*Laboratory for Functional and Metabolic Imaging, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Vaud, Switzerland,* [2]*Centre d'Imagerie Biomédicale, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Vaud, Switzerland*

Target audience: RF-engineers and basic researchers who are interested in MR hardware for small animal imaging at UHF.

Introduction: Surface coils offer higher transmit efficiency and receive sensitivity than volume coils, but over a smaller sample volume. For imaging and spectroscopy sequences using 180° pulses, such as those using spin echoes, it is important to generate uniform excitation across the sample. In such cases, the use of a transmit volume coil combined with a surface receive coil (or array of receiver coils) is optimal. In this work we present a transmit birdcage coil combined with a surface receive loop for small animal imaging and spectroscopy at 600MHz (^{1}H at 14.1T). The receive loop is tuned using varactor diodes, eliminating the need for variable capacitors and detuning PIN diodes on the loop, saving considerable space in the probe design.

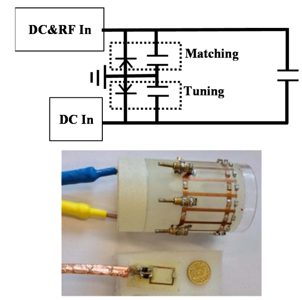

Fig 1. Circuit diagram of the surface coil, and photograph showing Birdcage and surface coil.

Methods: The transmit coil is a 16-rung high pass birdcage (50 mm diameter, 3 0mm long) made on PCB (12 µm Cu on 0.1 mm FR4), surrounded by a shield (100mm diameter, 90mm long), and driven in quadrature [1]. PIN diodes were added between every rung on one end ring to detune the resonator during reception. The resonator is active under reverse-bias. When forward biased (100 mA per diode), each PIN diode makes a short circuit across the endring capacitors. RF chokes (1µH) were placed between the diodes and driving voltage source to block RF current while passing DC current. The surface coil, also made from PCB (10mm×15mm, 0.1mm track width), includes the varactor diodes (GC1513, Microsemi) for tuning and matching (Fig 1). The capacitance of varactor diodes is controlled by the applied voltage, so they can be used for tuning and matching coils to different loads, and also for decoupling by down shifting the coil resonant frequency. A voltage control board was developed to generate signals for driving the PIN diodes on the volume coil (+100mA/-12V) and the varactor diodes on the surface coil (0-10V). Both coils were characterized at the bench using a network analyzer (E5017C, Agilent), while loaded with a saline phantom that simulated the loading of a mouse head. Imaging tests were performed in a 14.1T MR system with a 26cm horizontal bore (Agilent, Oxford, UK). A homemade Quad channel PIN diode driver [2], used for switching between transmit and receive coil and driving on voltage control board .To test the homogeneity of the transmit coil, the RF field was mapped using the double angle method [3]. Two images (matrix: 128×128, FOV: 25 ×30 mm, slice thickness: 2 mm, TE=3ms, TR = 8s) were acquired using the GEMS sequence, at flip angles of 60° and 120°, respectively. The performance of the transmit birdcage coil and receive surface coil was tested using an FSEMs sequence (matrix: 256×256, FOV: 20×20mm, TE = 2.5 ms, TR = 2s, average= 4). The sensitivity of the image was tested using a GEMs sequence (matrix: 128×128, FOV: 25×25mm, TE = 4.83 ms, TR = 2s, average= 1, Flip angle: 60° for signal and 0° for noise) and compared to results from a transmit-receive Birdcage coil.

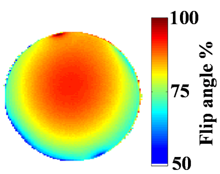

Fig 2. B1 mapping of transmit coil by double-angle method.

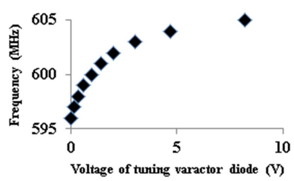

Fig 3. Frequency range of surface coil versus voltage applied on tuning varactor diode

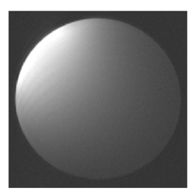

Fig 4. Axial slice of phantom image acquired using FSEMs sequence

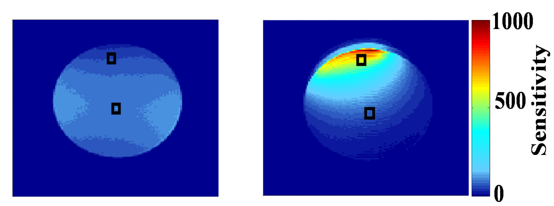

Fig 5. SNR map of transmit- receive Birdcage coil as receive and transmit (left), and transmit birdcage coil and receive surface coil (right).

Result and discussion: In the final configuration (Fig. 1), transmission and decoupling between the two modes of volume coil for the resonance frequency 600 MHz were below -25 dB and -17 dB, respectively. The quality factor of unloaded to loaded coil (Q) for two degenerate modes at the same frequency mode of birdcage coil were 170/116 and 189/121, respectively. B1 mapping results, processed using Matlab, confirm homogeneous excitation of birdcage coil (Fig. 2). The optimum match at 600 MHz for the surface coil was approximately -30 dB with Q factor of 1.5. The tuning frequency range of the surface coil is 10 MHz by changing the voltage applied to the tuning varactor diode, while fixing the voltage on matching varactor diode at maximum match for 600 MHz (Fig 3). The isolation between transmit and receive coils during reception and transmission was more than 15 dB. Imaging tests shown in Fig. 4 confirms the correct performance of PIN diodes and varactor diodes in isolating coils during transmission and receiving. SNR mapping of image acquired by transmit birdcage coil and receive surface coil shows ten times higher sensitivity at voxel placed close to surface coil (in Fig 5) in compare to transmit-receive Birdcage coil and also it has approximately same SNR as birdcage coil in voxel placed in center of phantom. This result shows substantial advantages including homogenous excitation and high SNR across a field of view at high magnetic field.

Conclusion: We show the feasibility of a volume coil for transmission and varactor-tuned surface coil for reception operating at 600MHz (14.1T). This system provides homogeneous excitation and high sensitivity for functional, anatomic, and other MRI/S studies. We now plan to extend the single-channel receive loop to a multichannel receive array, also utilizing varactor diodes for tuning and detuning.

Refernces: [1] Magill, et al., Proc. Intl. Soc. Mag. Res. Med 2012; 20. [2] Pilloud, et al., ESMRMB Congress 2013. [3]Cunningham et al., Mag. Res. Med 2006; 55:1326–1333.

Acknowledgements: Supported by Centre d'Imagerie BioMédicale (CIBM) of the UNIL, UNIGE, HUG, CHUV, EPFL, the Leenaards and Jeantet Foundations; SNF grant 131087.