An improved surface coil design for proton decoupled Carbon-13 Magnetic Resonance Spectroscopy

Eulalia Serés Roig[1], Guillaume Donati[1], Martin Meyerspeer[2], Lijing Xin[1,3], Rolf Gruetter[1,4], and Arthur W. Magill[1,3]

[1]*Laboratory of Functional and Metabolic Imaging, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Vaud, Switzerland,* [2]*Center for Medical Physics and Biomedical Engineering, Medical University of Vienna, Vienna, Vienna, Austria,* [3]*Department of Radiology, University of Lausanne, Lausanne, Vaud, Switzerland,* [4]*Department of Radiology, Universities of Lausanne and Geneva, Lausanne, Geneva, Switzerland*

Introduction Carbon-13 MRS is challenging because of its inherent low sensitivity, due to the low natural abundance and low gyromagnetic ratio of the ^{13}C-isotope. Detection is further complicated by ^{1}H-^{13}C hetero-nuclear *J*-coupling, which necessitates RF transmission at the ^{1}H frequency while receiving the ^{13}C signal, requiring strong decoupling between the ^{13}C and ^{1}H RF channels. Adding traps to the low-γ coils [1,2] makes it possible to construct a probe consisting of a quadrature X pair and a quadrature ^{1}H pair, with sufficient isolation between channels to allow simultaneous operation at both frequencies [3]. This can be used to improve the SNR at the X frequency by a factor of √2 without increasing power deposition at the ^{1}H frequency. In this abstract we compare the performance of the double-quadrature ^{13}C/^{1}H coil to a standard linear-^{13}C quadrature-^{1}H design [4], using glycogen measurements in the human calf at 7T.

Methods A ^{13}C-^{1}H surface coil was built, combining a quadrature ^{1}H pair with a quadrature ^{13}C pair (Fig. 1). Each coil pair was decoupled by overlapping [4], while isolation between the ^{1}H and the ^{13}C coils was achieved by adding a second-order trap to each ^{13}C loop [5]. In order to reduce common modes, bazooka baluns (for ^{1}H) and LC-traps (for ^{13}C) were placed on all coaxial cables [6]. A sphere (Ø 7mm) filled with 99% ^{13}C-enriched formic acid was placed in the centre of the ^{13}C coil as an external reference for in vivo measurements. Coil performance was evaluated on the bench by measuring the full coupling matrices and coil Q-factors (unloaded and loaded) with a network analyzer (E5071C, Agilent).

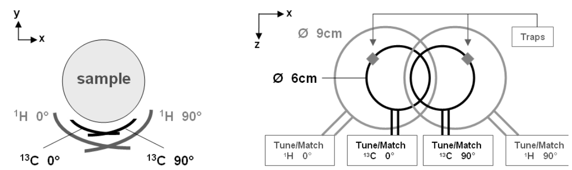

Figure 1: Layout of the double-quadrature ^{13}C-^{1}H coil, combining a quadrature ^{1}H coil and a quadrature ^{13}C coil.

MR experiments were performed on a 7 Tesla human scanner (Siemens Medical Solutions, Erlangen, Germany) to measure glycogen in the human calf. A pulse-acquire sequence was used with an adiabatic half passage excitation pulse; ^{1}H saturation was applied at 5.5ppm for the generation of NOE and WALTZ-16 decoupling. The NMR protocol was: TR=1s, 256 averages, vector size 2048, acquisition time 102ms, BW 20 kHz, WALTZ-16 decoupling duration 20ms, and NOE (10 pulses, 41ms pulse duration, 6ms pause between pulses). Measurements were performed in a healthy volunteer who gave informed consent according to the procedure approved by the local ethics committee. Quantification of the SNR was performed using Matlab.

S_{ij} /dB 297 MHz	^{1}H 0°	^{1}H 90°	^{13}C 0°	^{13}C 90°
^{1}H 0°	-40	-16	-31	-37
^{1}H 90°	-16	-37	-30	-32
^{13}C 0°	-31	-30	-	-
^{13}C 90°	-37	-32	-	-

S_{ij} /dB 75 MHz	^{1}H 0°	^{1}H 90°	^{13}C 0°	^{13}C 90°
^{1}H 0°	-	-	-30	-18
^{1}H 90°	-	-	-18	-32
^{13}C 0°	-30	-18	-58	-14
^{13}C 90°	-18	-32	-14	-43

Table 1: S-parameters (/dB) at the ^{1}H channel (297MHz, top) and at the ^{13}C channel (75MHz, bottom).

Results Isolation between the ^{1}H and the ^{13}C coil was better than -30dB (Table 1). The coil performance (Q_U/Q_L) was 1.6 and 2.1 for the ^{13}C loops, and 2.4 and 2.6 for the ^{1}H loops (Table 2). The glycogen peak was identified at 100.5ppm in measurements from both coils (Fig. 2). The double-quadrature coil provided a signal enhancement of glycogen (100.5ppm), as well as fatty acid (134ppm) and glycerol (63.1/72.8ppm). The SNR enhancement was 1.79 using the double-quadrature-coil relative to the linear coil.

Discussion A quadrature-^{13}C/quadrature-^{1}H surface coil was constructed, and an improvement in glycogen detection SNR was demonstrated, relative to the standard linear-^{13}C/quadrature-^{1}H probe design. Importantly, this is done without increasing the power deposition on the proton channel. The improvement is slightly above that theoretically predicted. This is thought to be due to uncertainty in the transmit power calibration: if the transmit power is set slightly high for ^{13}C excitation, a larger sample volume will fulfill the adiabatic condition and a larger volume will hence be excited. The increased detection sensitivity shown by this probe design is extremely useful for in-vivo ^{13}C MRS experiments.

Coil	Q_U	Q_L	Q_U/Q_L
^{1}H 0°	90	35	2.6
^{1}H 90°	82	34	2.4
^{13}C 0°	76	36	2.1
^{13}C 90°	62	38	1.6

Table 2: Measured quality factors.

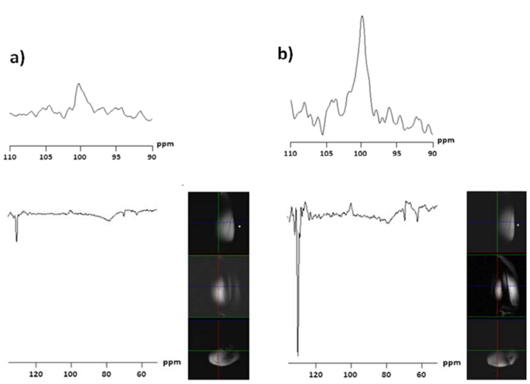

Figure 2: ^{13}C natural abundance Glycogen signal measured in a human calf using (a) the linear ^{13}C coil and (b) the double-quadrature ^{13}C coil.

References [1] M.Alecci et al, JMR 2006; [2] A.Dabirzadeh et al, concepts in MR 2009; [3] A.Webb et al, ISMRM 2010; [4] G. Adriany et al 1997; [5] M.Meyerspeer et al, ISMRM 2011; [6] BM.Schaller et al, ISMRM 2011; [7] E.Serés Roig et al, ISMRM 2012; [8] E.Serés Roig et al, ESMRMB 2012.

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