31P spectroscopy in human calf muscle at 7 tesla using a balanced double-quadrature proton-phosphorus RF coil

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Introduction. Heteronuclear spectroscopy benefits from the increases in both sensitivity and spectral resolution at high fields. 31P experiments on calf muscle form one of the most common type of experiments to study energy metabolism in vivo. The aim of this work is to design a high sensitivity double-tuned 1H/31P coil for calf studies at 7T. The basic geometry is a double-quadrature double-tuned co-planar coil pair. Although the sensitivity of the proton channel could be sacrificed if only shimming and scout imaging are to be performed, the potential use of nOe enhancement and proton decoupling makes it desirable to have as high an efficiency on the proton channel as possible. In the co-planar overlapping quadrature surface coil design, counter-rotating currents lead to reduced proton sensitivity. Alecci [1] and Dabirzadeh [2] have shown that simple trap insertion into the heteronuclear coil can prevent these counter-currents. However, in a multi-segmented coil, insertion of a single trap-circuit reduces the coil symmetry significantly. Although multiple trap circuits could be introduced, a better solution is to incorporate a second-order lumped-element circuit which produces an open circuit at the proton frequency and a capacitance equivalent to the other series capacitors at the heteronuclear frequency. The design and performance of such a coil is shown here.

Methods. The quadrature proton portion of the coil, shown in Figure 1(a) consists of overlapping 15 cm square elements, with twelve capacitors in series with conductor lengths $<\lambda/20$ in length. The inner phosphorus quadrature pair consisted of two 12 cm squares, with four capacitive breaks of 18 pF capacitors. One or more of the 18 pF capacitors were replaced by the second-order trap circuits shown in Figure 1(b), which appears as an open-circuit at 298 MHz and an 18 pF capacitor at 121 MHz. The coils were constructed using copper tape on a thin teflon sheet, and then bent into the shape of a half-cylinder with outer diameter 16 cm, before final fine-tuning and matching with a human leg in position. All experiments were performed on a Philips Achieva 7T system (Philips Healthcare, Best, The Netherlands).

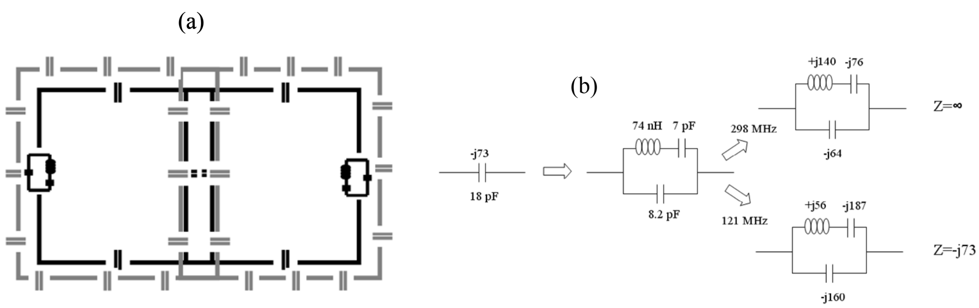

Figure 1. (a) Schematic layout of the proton (gray) and phosphorus (black) quadrature surface coils, with second-order trap circuits (b) inserted in one or more positions in the phosphorus coil.

Results and Discussion. Isolation between the two halves of the respective coils was >20 dB, with the trap-circuit eliminating any frequency shift on the proton channel when the phosphorus coils were added. Figure 2 shows a gradient-echo proton scout image, with the central 25 voxels (out of 64 total) of a 2D CSI spectral data set. The pulse angle was calibrated to maximize signal in the muscle. The S/N of the PCr resonance was measured to be > 50:1.

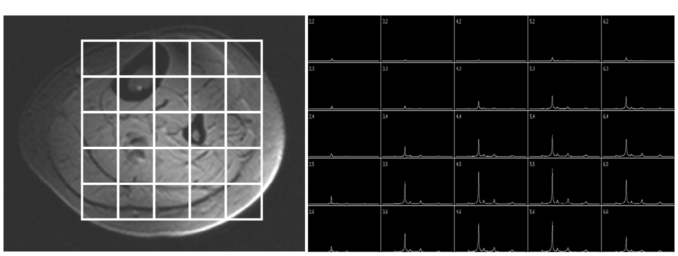

Figure 2. (left) Proton scout image with the central 5 x 5 voxel overlay shown. (right) Corresponding 31P localized spectra. TR=1680 ms, voxel size 20 x 20 mm, 8 x 8 matrix, 32 signal averages.

References. [1]. M.Alecci et al. J.Magn.Reson., 181, 203-211 2006. [2] A.Dabirzadeh, M.McDougall, Conc.Magn.Reson. 35B, 121, 2009.