Double Resonant $^1H/^{31}P$ Coil Configuration for ^{31}P MR Spectroscopy at a Whole Body 7 T MR Tomograph

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INTRODUCTION: Phosphorus-31 NMR spectroscopy (^{31}P MRS) takes advantage from high B_0 by enhanced signal-to-noise ratio (SNR) and spectral resolution. We built double-resonant coil systems for $B_0 = 7$ T with the goal to obtain high-quality B_0-shimmed ^{31}P NMR spectra. Usually the sensitivity of a double-resonant device either suffers from electromagnetic coupling into other resonant elements or from implemented filter circuits which are introduced to counteract the electromagnetic coupling [1].
The aim of this study was to find, implement, and test the optimum double-resonant configuration for two concentric planar surface coils (SFC) at $f_0(^{31}P) = 120.3$ MHz and $f_0(^1H) = 297.15$ MHz at an experimental 7-T whole-body MR tomograph.

METHODS: Coils. A set of four different 9-cm-diameter SFC was designed and built: Two ^1H coils with and without active detuning, and two ^{31}P coils with and without ^1H filter circuit (Fig. 1). The housing of the SFC permitted all possible combinations of the different single-resonant devices to form four double-resonant configurations.

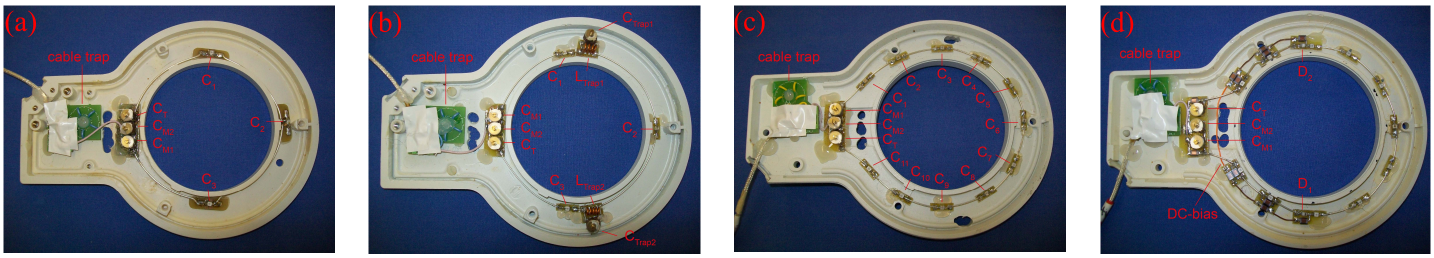

Fig. 1: Design of the single resonant surface coils. (a) ^{31}P, (b) ^{31}P with ^1H trap circuits ($^{31}P_{Trap}$), (c) ^1H, (d) ^1H with active detuning ($^1H_{Detune}$).

Evaluation. All setups were tuned, matched and characterized by measuring the quality factors loaded with a 275 ml 100 mM inorganic phosphate solution phantom in a bore simulator. ***^{31}P SNR:*** After a global flip angle calibration, a FID sequence (1-pulse-acquire, bandwidth 1000 Hz, 1024 data points, pulse duration 0.5 ms) was applied. SNR determination for the spectra was performed by dividing the integrated peak area in the spectrum (calculated by AMARES algorithm [2]) by the noise in time domain. ***^1H SNR:*** A local flip angle calibration was followed by spoiled gradient echo sequence (coronar slice in-plane of the SFC, TR/ TE/ α = 100 ms/ 10 ms/ 25°, FOV = 100 mm, 128 x 128 matrix, 5 mm slice). SNR maps were calculated using the bootstrapping method [3]. All measurements were performed on a MAGNETOM 7 T (Siemens Healthcare, Erlangen, Germany).

RESULTS & DISCUSSION: The results achieved at the workbench and the tomograph were in good agreement (Tables 1 and 2). A sufficient decoupling between both loops could be obtained by inserting ^1H trap circuits into the ^{31}P coil. However, the sensitivity for ^{31}P was then reduced by > 35%. Measurements showed no significant loss in quality factor and SNR when PIN diodes were used for active detuning in the single-resonant ^1H setup. Nevertheless, in the double resonant designs significant losses on both frequencies could be observed. Most likely the losses occur due to additional inductive coupling with the DC supply path. The combination of a $^{31}P_{Trap}$ and a ^1H surface coil turned out to be the best compromise in terms of sensitivity for both ^1H and ^{31}P sensitivity. A representative ^{31}P NMR spectrum from a model solution is shown in Fig. 2.

CONCLUSION: In this work we compared four home-built single-resonant coils and four double-resonant antenna systems for measuring the ^{31}P and ^1H NMR signal at a 7-T MR tomograph. In terms of sensitivity for both frequencies, a combination of a $^{31}P_{Trap}$ and a ^1H surface coil outperformed the other coil combinations in acquisition of high-quality ^{31}P NMR spectra.

REFERENCES:
[1] Alecci, M., et al., J. Magn. Reson. 181: 203 – 211 (2006).
[2] Vanhamme, L., et al., J. Magn. Reson. 129: 35 – 43 (1997).
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Table 1:

^{31}P characterization		Q_u/Q_l	SNR	SNR in % to reference
^{31}P	**single**	2.6	560.3	100
	with ^1H	2.7	530.4	95
	with $^1H_{Detune}$	2.1	368.8	66
$^{31}P_{Trap}$	**single**	2.2	364.0	65
	with ^1H	2.2	392.9	70
	with $^1H_{Detune}$	1.5	110.2	20

Table 2:

^1H characterization		Q_u/Q_l	SNR	SNR in % to reference
^1H	**single**	4.8	659.5	100
	with ^{31}P	1.8	535.1	81
	with $^{31}P_{Trap}$	2.9	646.1	97
$^1H_{Detune}$	**single**	3.3	654.1	99
	with ^{31}P	1.8	512.9	77
	with $^{31}P_{Trap}$	3.1	592.2	90

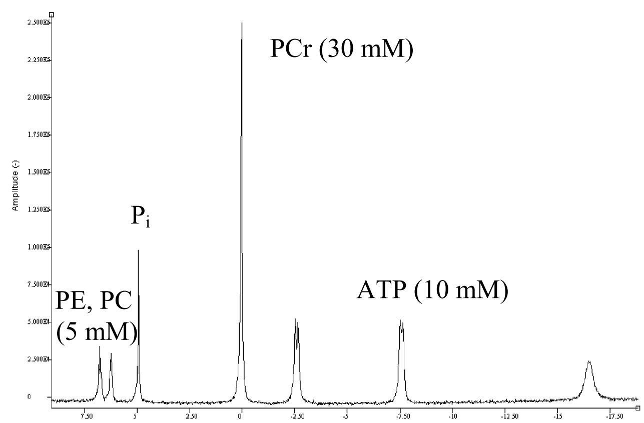

Fig. 2: 70.4-s ^{31}P NMR spectrum of a model solution with concentrations of ^{31}P metabolites like in human calf muscle. Shim: FWHM = 19,3 Hz; $T_2^* = 27$ ms. Sequence parameters: 128 excitations, TR = 550 ms, pulse length = 0,1 ms, Δf = 5000 Hz, 2048 data points, $U_{pulse} = 75$ V, $B_0 = 7$ T.