DOUBLE-RESONANT $^{13}\text{C} / ^{1}\text{H}$ COIL SYSTEM FOR $^{13}\text{C}$ IN VIVO NMR SPECTROSCOPY ON A 7-T WHOLE-BODY MR TOMOGRAPH

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INTRODUCTION: $^{13}\text{C}$ NMR spectroscopy ($^{13}\text{C}$ MRS) enables noninvasive quantification of various metabolites in vivo with or without enrichment of $^{13}\text{C}$. High field $^{13}\text{C}$ MRS in combination with $^{1}\text{H}$-decoupling provides a gain of information and signal in $^{13}\text{C}$ NMR spectra. The aim of this study was to design, implement and test a surface coil system for in vivo $^{1}$H-decoupled $^{13}$C NMR spectroscopy on an experimental 7-T whole-body MR tomograph. Hence a $^{13}\text{C}$/$^{1}\text{H}$ double-resonant transmit/receive coil system was developed. In order to reduce dielectric losses and capacitive detuning and to impose proper balancing a transmission line resonator (TLR) concept was used. Furthermore specific filters were implemented to decouple both channels properly.

METHODS: The TLR consists of a semi-rigid coaxial cable ($\Omega_{\text{cable}} = 5.5 \text{ mm}$) arranged to a loop ($\Omega_{\text{loop}} = 7.5 \text{ cm}$, fig. 1a+b). A small gap separates its outer conductor into two equal parts. The $^{13}\text{C}$ matching network is located on the left side and the $^{13}\text{C}$ short circuit at the right end of the loop, for $^{1}\text{H}$ the other way round. To achieve adequate electromagnetic decoupling for both channels ($^{13}\text{C}$, $^{1}\text{H}$) frequency selective filters are implemented. In particular the Chebyshev low pass filter in the $^{13}\text{C}$ channel is very important for the acquisition of $^{1}$H-decoupled $^{13}$C NMR spectra (fig. 1c+d).

RESULTS: The measured quality factors of the coil are $Q(1\text{H}) = 77$ and $Q(13\text{C}) = 91$. The forward transmission losses $S_{21}$ - low pass filter not included - amount to $S_{21}(13\text{C}, 2\text{H}, 74.73 \text{ MHz}) = -48 \text{ dB}$ and to $S_{21}(1\text{H}, 13\text{C}, 297.15 \text{ MHz}) = -24 \text{ dB}$. The low pass filter performs very well with $S_{21}(74.73 \text{ MHz}) = -0.15 \text{ dB}$ and $S_{21}(297.15 \text{ MHz}) \approx -100 \text{ dB}$. The complete coil design ensures a sufficient electromagnetic decoupling for both frequencies and allows its application in the decoupling mode ($^{1}\text{H}$ -$^{13}\text{C}$ MRS). Fig. 2 shows the methyl and methylene resonances of triacylglycerides (TAG) in the vegetable oil phantom without and with $^{1}$H-decoupling.

CONCLUSION: In this work a home-built $^{13}\text{C}$/ $^{1}\text{H}$ double-resonant surface coil for in vivo application was developed and implemented on a 7-T whole-body tomograph. Due to optimized frequency filter circuits an acquisition of $^{1}$H-decoupled $^{13}$C NMR spectra was possible with this coil design. High resolution $^{13}$C NMR spectra of a model solution with and without $^{1}$H-decoupling were acquired in about 2 minutes. $^{1}$H NMR spectra and images can also be obtained with this coil system.


![Fig. 1: (a) Circuit diagram and (b) implementation of $^{13}\text{C}$/ $^{1}\text{H}$ double-resonant surface coil with $f_{0}(^{13}\text{C}) = 74.73 \text{ MHz}$ and $f_{0}(^{1}\text{H}) = 297.15 \text{ MHz}$, (c) simulated, (d) constructed Chebyshev low pass filter with 4 chambers (bandwidth = 80 MHz, # poles = 7, passband ripple = 1.0 dB, $Z_{\text{in/out}} = 50 \Omega$)](image_url)

The double-resonant coil loaded with a vegetable oil phantom (280 ml) was tuned and matched. The quality factors of the loaded coil and the forward transmission losses $S_{21}$ from one channel to the other were determined with a network analyzer to evaluate the coil. Finally B0-shimmed $^{13}$C NMR spectra of the phantom were acquired without and with $^{1}$H-decoupling (WALTZ-4) on a MAGNETOM 7 T (Siemens Healthcare, Erlangen, Germany).

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![Fig. 2: B0-shimmed $^{13}$C NMR spectra with methyl and methylene resonances of TAG in the vegetable oil phantom ($^{13}$C FID sequence parameter: 32 avg., TR = 3.5 s, pulse length = 0.12 ms, $\Delta f = 4 \text{ kHz}$, 2048 data points, $U_{\text{pulse}} = 30 \text{ V}$) (a) without decoupling and (b) with $^{1}$H-decoupling (WALTZ-4: decoupling duration = 2 ms, DC total duration = 50 %, DC pause duration = 20 %, $U_{\text{WALTZ}} = 60 \text{ V}$)](image_url)

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