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

Tanja Platt[1], Andreas Korzowski[1], Reiner Umathum[1], and Peter Bachert[1]
[1]*Medical Physics in Radiology, German Cancer Research Center, Heidelberg, Baden-Württemberg, Germany*

INTRODUCTION: ^{13}C NMR spectroscopy (^{13}C MRS) enables noninvasive quantification of various metabolites in vivo with or without enrichment of ^{13}C. High field ^{13}C MRS in combination with ^{1}H-decoupling provides a gain of information and signal in ^{13}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 $^{13}C/^{1}H$ 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[1] (TLR) concept was used. Furthermore specific filters were implemented to decouple both channels properly.

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

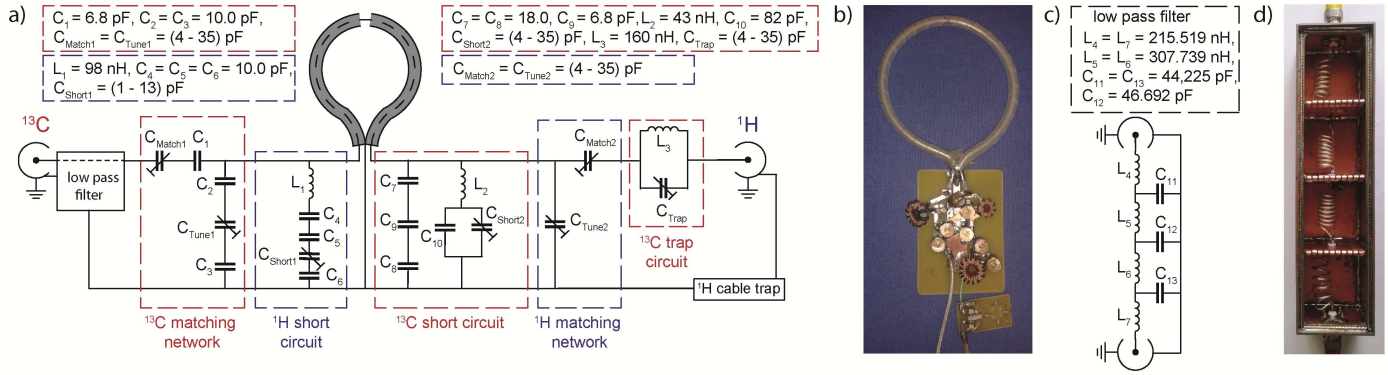

Fig. 1: (a) Circuit diagram and (b) implementation of $^{13}C/^{1}H$ double-resonant surface coil with $f_0(^{13}C)$ = 74.73 MHz and $f_0(^{1}H)$ = 297.15 MHz, (c) simulated, (d) constructed Chebyshev low pass filter with 4 chambers (bandwidth = 80 MHz, # poles = 7, passband ripple = 1.0 dB, $Z_{in/out}$ = 50 Ω)

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 B_0-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).

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

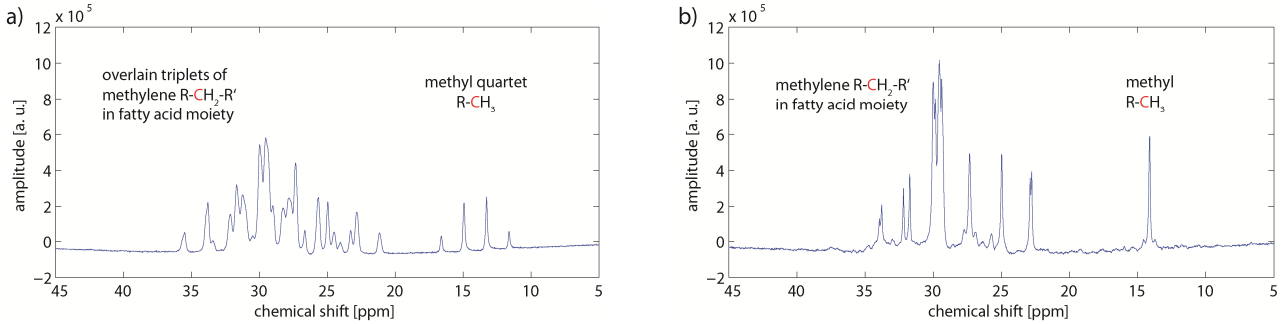

Fig. 2: B_0-shimmed ^{13}C NMR spectra with methyl and methylene resonances of TAG in the vegetable oil phantom (^{13}C FID sequence parameter: 32 avg., TR = 3.5 s, pulse length = 0.12 ms, Δf = 4 kHz, 2048 data points, U_{pulse} = 30 V) (a) without decoupling and (b) with ^{1}H-decoupling (WALTZ-4: decoupling duration = 2 ms, DC total duration = 50 %, DC pause duration = 20 %, U_{WALTZ} = 60 V)

CONCLUSION: In this work a home-built $^{13}C/^{1}H$ 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.

REFERENCES: 1. Zabel H-J, et al. High-Quality MR Imaging with Flexible Transmission Line Resonators. Radiology. 1987; 165:857-859