A Double-Resonant $^{19}F/^{1}H$ Transmit/Receive Solenoid Coil for MRI

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Introduction

^{19}F MR imaging has a high potential for the detection and direct quantification of fluorine-labeled tracers and drugs in the field of molecular imaging [1]. The combination with ^{1}H imaging provides associated anatomical information. So far, this application has been typically supported by separate ^{19}F and ^{1}H RF-coils [2,3]. The sensitivity profiles of the coils differ at these two frequencies, so that the measured ^{19}F data cannot be corrected using the obtained ^{1}H data. We demonstrate a new $^{19}F/^{1}H$ double resonant solenoid transmit/receive coil for 3T, which exhibits practically the same sensitivity profile for both frequencies. This allows the correction of B_1 inhomogeneities in the ^{19}F image via the ^{1}H sensitivity profile.

Materials and Methods

We based our design on a solenoid with an inner diameter of 70 mm. The coil is built from strip conductors wound around a fiberglass cylinder. The gap between the individual strip conductors is 8 mm (Fig. 1). The overall inductance of the solenoid is L_s=1024 µH at 124 MHz. For further calculations, this value is assumed to be constant over a bandwidth of 20 MHz. Equidistant splits with 15 capacitors (15*C_s) were introduced along the conductor to avoid current inhomogeneities by propagation effects. An additional split is used to include one parallel LC-circuit (C_p, C_h, L_h) in series with the coil conductor. The current of this parallel circuit does not influence the B_1-field profile of the solenoid. While the series circuit of L_s and C_s behaves like a capacitor (imag{Z}<0) for frequencies below the resonance frequency and like an inductance (imag{Z}>0) for higher frequencies, the parallel circuit behaves the opposite way. The solenoid can be tuned to resonate at the 3T Larmor-frequencies of ^{19}F (120.23 MHz) and ^{1}H (127.73 MHz) via selection of the circuit components. Fig. 2 shows a series of possible values for the capacitors and inductances achieving double resonance for $^{1}H/^{19}F$. The values for the capacitors and inductances were selected according to the simulation results (Fig. 3). Scans to verify the matching of the B_1 profile were performed on a 3T whole-body MR scanner (Achieva, Philips Medical Systems: FOV 70 mm, 128x128 matrix (0.54 mm pix), TR/TE = 17.4 ms/8.7 ms, 19 coronal slices à 2 mm, readout R/L, pixel BW 98.6 Hz).

Fig. 1: Solenoid RF-coil using strip conductors fixed on a fiberglass cylinder.

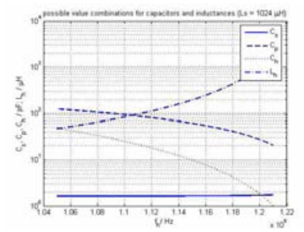

Fig. 2: Possible values for the double resonant coil (120.23 MHz, 127.73 MHz). Each value stack of a column gives a correct configuration.

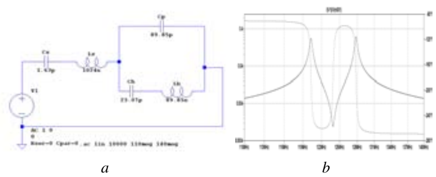

Fig. 3: Circuit diagram of the solenoid (L_s, C_s) and the implemented parallel circuit (C_p, C_h, L_h) (left). Simulated input impedance as function of frequency for a lumped element model (right).

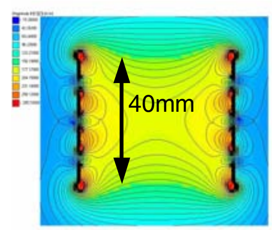

Fig. 4: Cross-section of the B_1-profile (^{1}H, ^{19}F) simulated with an EM-full-wave tool (FEKO).

Results and Discussion

The unloaded quality factor of the double tuned RF-coil was measured to be approximately Q=400 (Fig. 5b). Input impedance and transmission behavior was measured to be in good agreement with simulation (cf. Fig. 3b vs. Fig. 5c). Variable capacitors were used for fine-tuning. The measured input impedance after fine-tuning is shown in Fig. 5a. A good 50Ω matching could be achieved for both frequencies 120.23 MHz and 127.73 MHz. ^{19}F and ^{1}H images from a phantom are shown in Fig. 6. The inner cylinder contains ^{19}F in Perfluoro-Crown-Ether and is surrounded by water. Signal intensity profiles through the ^{19}F-fluid (green) and through water (red), normalized on the maximum, demonstrate the predicted agreement of both sensitivity profiles.

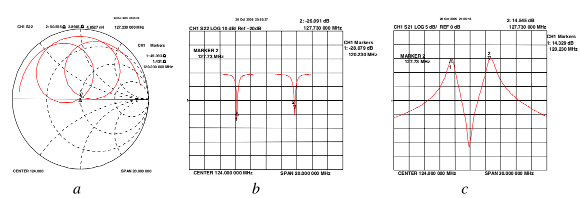

Fig. 5: Input impedance of the double resonant solenoid (left, mid) measured on a network analyzer. Transmission behavior (S21) displayed in a logarithmic scale (right). Matching to 50Ω is achieved for both frequencies, i.e. 120.23 MHz and 127.73MHz.

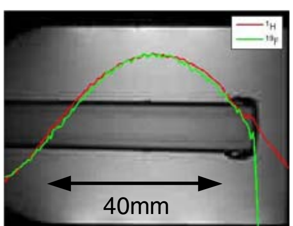

Fig. 6: Reconstructed $^{19}F/^{1}H$-image acquired with double resonant coil. No influence of parallel circuit can be seen

Conclusion

A new $^{19}F/^{1}H$ double resonant transmit/receive solenoid coil for MRI imaging was designed. The sensitivity profile for ^{19}F and ^{1}H is practically identical. The double-resonant coil allows small animal studies in contrast agent and drug research.

References

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[3] Krems B et al., Magn Reson B 108:155 (1995)