Highly Efficient Inductively Coupled Double Resonant Surface Coil for Simultaneous $^{1}H/^{19}F$ PET-MRI

Christian Findeklee[1], Christoph Leussler[1], Daniel Wirtz[1], and Jochen Keupp[1]
[1]*Research Laboratories Hamburg, Philips Technologie GmbH, Hamburg, Germany*

Purpose

Multi-resonant RF-coils are used in several MRI applications. Next to a high SNR proton image, additional information of biological or clinical interest can be obtained by from other nuclei with a net nuclear spin. While ^{23}Na or ^{31}P are naturally abundant in the human body, also hyperpolarized gases and fluids (e.g. ^{129}Xe or ^{13}C), as well as liquid solutions of ^{19}F or ^{23}Na are used for identifying bio-molecular markers[1-3].

We built a $^{1}H/^{19}F$ multipurpose 3T surface coil which is also compatible with positron emission tomography (PET) for molecular imaging applications. For achieving highest possible SNR, the coil was designed to be adjustable at both resonance frequencies (127.7 and 120.3 MHz) for an arbitrary load. In order to allow RF power calibration (transmission) and homogeneity correction (reception) for non-proton MRI/MRS, the spatial B_1-profiles should be identical for both resonances.

Methods

Due to the proximity of PET-detectors, a local RF-shield is needed. In this configuration, the coil impedance is strongly variable from nearly unloaded to heavily loaded conditions. This requires a large tuning range, which can hardly be realized by the use of trimmer capacitors only. Moreover, an efficient trap on the coil cable is also essential for achieving common mode suppression. Both issues have been solved by applying an adjustable inductive feeding concept. The two loops, i.e. the field generating resonator and the feeding coil, were realized with dual-resonant circuits (Fig. 1), which has three advantages: (i) Both frequencies can be matched almost simultaneously by adjusting the inductive coupling only. (ii) The current ratio, and therefore also the spatial B_1 field profiles, are exactly the same at both resonances, and (iii) the tuning range is increased, as compared with non-resonant inductive feeding. Besides the adjustable inductive coupling, the coil has three additional degrees of freedom for fine tuning (trimmer capacitors C6, C7, C10 in the field generating loop, see Fig.1). The coil was equipped with a T/R switch and a low noise preamplifier to be connected to a clinical 3.0T MRI scanner (Achieva, Philips Healthcare, NL) for testing. A bottle phantom was used, containing seven small vials with Perfluoro-Crown-Ether ($C_{10}F_{20}O_5$) surrounded by water. 3D gradient-echo sequences on the proton and fluorine frequencies were used for imaging tests with a resolution of 0.5mm, FOV $(100mm)^2$, 15 slices of 6 mm, α=40°; 1H: TR/TE=13.7/6.7 ms, pixel bandwidth 96 Hz, acquisition time 52 s; 19F: TR/TE=14.5/7.1 ms, pixel bandwidth 90 Hz, acquisition time 55 s.

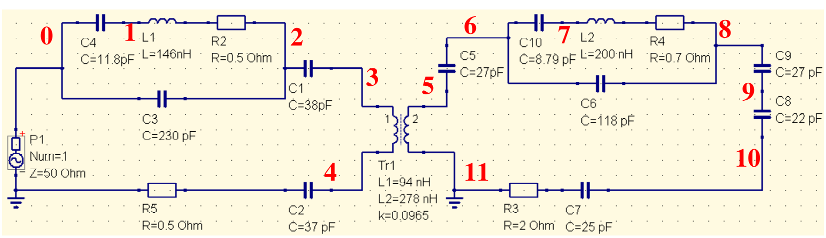

Fig. 1: Inductive feeding (left) and field generating loop (right)

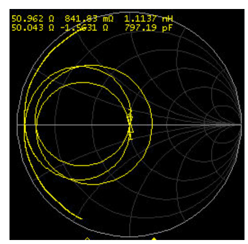

Fig. 2: Symmetric Smithchart

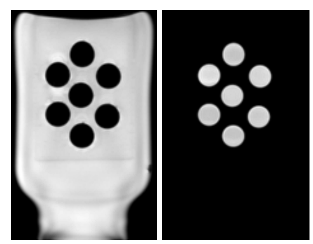

Fig. 3: ^{1}H and ^{19}F images

Results

The double resonant coil can be tuned and matched very easily at both resonances. In the adjusted state, the measured reflection curve plotted in a Smithchart becomes nicely symmetric as can be seen in Fig. 2. This further eases the tuning procedure. For small changes in loading (e.g. moving of a sample), the adjustment is dominated by updating the inductive coupling. High SNR could be achieved in less than one minute of acquisition time for both, Proton and Fluorine MR imaging as shown in Fig. 3.

Discussion/ Conclusion

The proposed concept of double resonant inductive feeding turned out to have many advantages. It integrates a cable trap, can be adjusted easily, produces absolutely identical field profiles and has a very large tuning range covering empty as well as heavy loaded situations. The proposed design enables high quality simultaneous $^{1}H/^{19}F$/PET imaging.

References

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