An 8-channel dual-tuned 1H/19F flexible 7 Tesla body coil with meanders

Stephan Orzada1, Andreas K. Bitz1, Mark E. Ladd1, Kai Nassenstein2, and Stefan Maderwald1
1Erwin L. Hahn Institute for MRI, Essen, NRW, Germany, 2Department of Diagnostic and Interventional Radiology and Neuroradiology, University Hospital Essen, Essen, NRW, Germany

Introduction
Ultra-high field strengths of 7 T and above promise a high SNR which is useful especially when trying to image nuclei with only a small incidence such as 19F. A particular problem for high-resonance-frequency nuclei is introduced by the inhomogeneities due to the short wavelength which causes notable signal dropouts in body imaging. To cope with these problems, multi-channel methods such as RF shimming have been proposed. Since the resonance frequency of 19F (ca. 280 MHz @ 7 T) is very close to the resonance frequency of 1H (ca. 300 MHz @ 7 T), RF shimming or similar methods have to be applied for the detection of 19F, introducing the need for a 19F Tx array with multiple channels. A double-tuned array allows the use of the same B1 shim for both 1H and 19F, which should be sufficient due to the close proximity of the resonance frequencies. In this work we present a flexible 8ch Tx/Rx coil for human abdominal imaging of 1H and 19F at 7 T.

Material and Methods
The starting point of the development was an already successfully tested flexible 8-channel Tx/Rx micro strip line array with meanders [1]. To make the array double-tuned, the matching network was adapted. Figure 1 shows a schematic of the double-tuned element with meanders. The end capacitor C0 = 1.2 pF is used to adjust the current distribution on the micro strip line. The series capacitor Cs = 3.3 pF and the parallel capacitors C0 = 8 pF are the matching network for 1H. The element was matched to the higher resonance frequency of 1H with the capacitor C0. To match the single element to a lower resonance frequency, the capacitance of the parallel capacitor C0 has to be increased; therefore, parallel to this capacitor, another capacitor C1 was introduced in line with a shorted line with a length of \( \lambda/4 \). At the resonance frequency of 1H, this has no effect. At the resonance frequency of 19F the line has an inductance of ca. 212 nH. In line with a capacitor C1 = 1-1.2 pF, this leads to an effective capacitance C1 = 3.4-8 pF, adding to C0. The length of the \( \lambda/2 \) phasing line was chosen to be 180° at 290 MHz, right between the two resonance frequencies, so that only a small error is introduced at each frequency. The T/R-switches (Stark Contrast, Erlangen, Germany) with pre-amplifiers were located in a separate box at the head of the patient table. The imaging experiments were performed on a Siemens Magnetom 7 Tesla whole-body system (Siemens Healthcare Sector, Erlangen, Germany) equipped with a custom 8-channel RF shimming system [2]. First imaging experiments were performed in a horse’s liver within a plastic box. The volume of this phantom was ca. 36 x 26 x 12 cm³. The liver contained a vial filled with 3 ml emulsion of 10% Perfluoro-15-Crownether. A vial with 10 ml emulsion of 10% Perfluoro-15-Crownether was put on top as a reference. For acquisition of the 1H images a 3D VIBE sequence was used with an isotropic resolution of 0.6 mm acquired in 5:31 min. The 19F images were acquired with a 3D gradient echo sequence with an isotropic resolution of 4.8 mm. 48 averages were acquired at a total acquisition time of 5:12 min.

Results and Discussion
The vector modulators of the 8-channel shimming system were verified to modulate correctly within a frequency range of at least 100-500 MHz. The T/R-switches optimized for 1H were successfully tested for their suitability for 19F. Coupling between neighboring elements was below 20 dB for all channels at both frequencies. The reflection coefficient of all elements was around -10 dB and -7 dB for 19F and 1H, respectively, mainly due to tolerances in the length d (Fig. 1) and the compromise in choosing the value for C0.

Figure 2a) shows 1H VIBE images of the horse’s liver within the plastic box acquired with an isotropic resolution of 0.6 mm overlaid with 19F gradient echo images with an isotropic resolution of 4.8 mm using a hot metal color scale. Even though the pre-amplifiers are not optimized for 19F, the 1% emulsion could still be detected. Fig. 2b) shows the relative B1 maps of the eight elements. RF shimming was possible with the 8ch array. Compared to the single-tuned coil variant, the SNR of the 1H images was 55%. Since multi-tuned arrays always have a lower efficiency than single-tuned arrays, a dedicated receive array will be built in a future project, and the flexible body array will be used as a Tx/Rx array for 1H and a Tx-only array for 19F. This should enable the detection of even smaller concentrations of 19F.