Efficient broadband set-up using travelling wave and strong loading for simultaneous fluorine and proton MRI at 7T

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Introduction: Fluorinated drugs are frequently used in chemotherapy, and can be monitored with Fluorine MRSI [1,2]. In contrast to PET imaging, drug metabolism can be observed in vivo enabling both prediction of treatment efficacy as well as toxicity assessment without contrast agents. However, since the concentration of these metabolites is low, clinical studies are restricted to inclusion of relatively large tumors well accessible with surface coils. In addition, sub-optimal measurement procedures had to be applied related to the small difference in frequency between 1H and 19F spins, thereby preventing the use of efficient double tuned coils. At 7T, a complete new RF concept may be applied. Since the tissue load of closely positioned RF coils increases with field strength (Q factor reduces), the bandwidth increases. Particularly when used as a receiver, the overall bandwidth may be sufficient to efficiently detect both 1H and 19F spins with the same single tuned RF coil because of the relatively large range in noise matched input impedances of preamplifiers. For both spins excitation, a travelling wave concept [3] with dielectric lining [4] can be applied as the Larmor frequency of fluorine spin is only 6% lower than proton one. Consequently, as the wavelength differs minimally, an array of broadband single tuned receivers combined with relatively uniform travelling wave excitation may be applied for quantitative 19F MR body imaging, using water as internal reference. Here we demonstrate the proof of principle that indeed the single tuned receiver enables SNR optimized detection of both 1H and 19F spins at 7T, and that travelling wave excitation can be obtained for both spins.

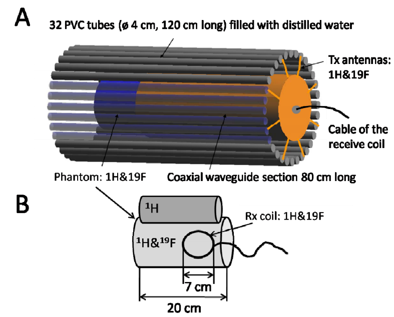

Figure 1. A: The multi-mode coaxial waveguide with a phantom in the cylindrical waveguide section. B: The phantom with the receive coil placed on its side.

Methods: The multi-mode coaxial waveguide [4] was used to perform excitation of both spins. FDTD simulations in a human model were obtained to verify field similarity between 280MHz and 298MHz excitations. To demonstrate proof of principle for broadband receive, so far only a single loop coil was tuned to 290 MHz (middle frequency between 280 and 298 MHz). SNR of the loaded coil at the three frequencies (280, 290 and 298 MHz) was compared, using a network analyzer and pick up probe to generate the signal, while noise was obtained with the network analyzer switched off. For MR experiments the multi-mode coaxial waveguide (Fig. 1A) and a water + water/fluorine (1M trifluoroethanol) phantom were placed in the bore of a 7T MR scanner. The proton and fluorine MRI were performed with the multi-mode coaxial waveguide to transmit and the local coil to receive (GRE, FA=5°, TE/TR=3/190 ms, acq. voxel: 2x2x5 mm^3).

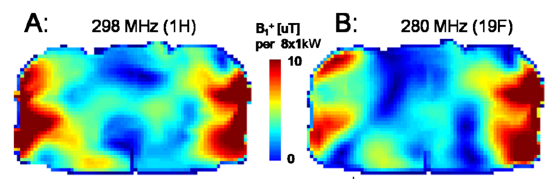

Figure 2. Combined transversal B_1^+ field distribution in human torso for 298 MHz (A) and 280 MHz (B) excitations with the multi-mode coaxial waveguide. Eight channels were combined with the quadrature phase settings.

Results and discussion: Simulations of the travelling wave fields demonstrated similar B_1^+ field patterns at both frequencies when loaded with the human body (Fig. 2). The S11 curve of the receive coil is plotted in Fig. 3A. The coil was tuned to 290 MHz and it had damping of only -3 dB at 280 (fluorine) and 298 (proton) MHz. However, calculated SNR showed that bandwidth of the preamplifier (Advanced Receiver Research, USA) was sufficient to detect these frequencies with only ~10 % SNR loss with respect to the center frequency (Fig. 3B). Figure 4 illustrates the transverse proton and fluorine GRE MRI images of the phantom received with the local coil. Scaling of Fig. 3C,D is 6 times higher to demonstrate the presences of the water bag in the proton images and its complete absence in the fluorine images (outlined with the dashed line).

Conclusions: It has been successfully demonstrated that SNR optimized proton and fluorine MRI could be performed within one set-up combining the multi-mode coaxial waveguide transmission and the wide banded local receive. The great advantage of this approach is shared transmit and receive field patterns that allow quantification of fluorine imaging.

References: [1] Klomp DWJ et al. MRM 2003; [2] Wolf W Adv Drug Deliv Rev 2000; [3] Brunner DO et al. Nature 457; [4] Andreychenko A et al. Proc. 19th ISMRM 2011.

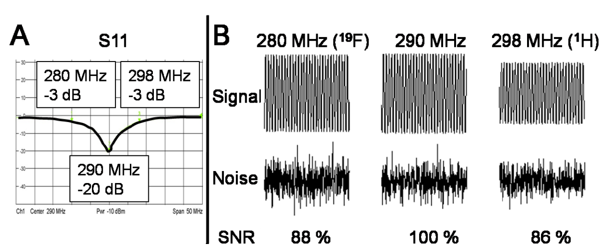

Figure 3. A: S11 curve of the receive coil placed on body. The coil was tuned to 290 MHz and had damping of - 3dB at 280 and 298 MHz. B: Signal and noise detected at the three frequencies and small (~10 %) SNR loss relative to the center frequency.

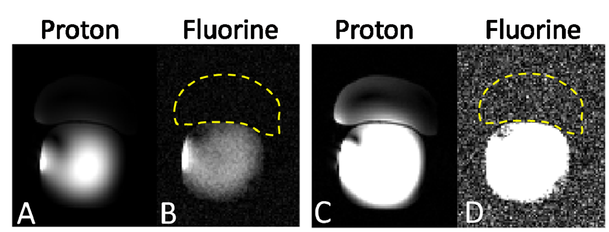

Figure 4. Transverse GRE images of proton (A,C) and fluorine (B,D). Dashed line indicates the water bag with no fluorine compounds inside. C and D images have 6 times lower scaling than A and B to emphasize signal from the water bag in proton MR image and only noise is present in the same region in fluorine MR image.