Improving SNR and RF by Adding a Stripline to Endorectal Coil for the 7T

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Introduction and Objective:

Magnetic resonance spectroscopic imaging (MRSI) in patients with prostate cancer allows for the detection of choline, citrate and potentially other metabolites in de (sub) millimolar range. These biomarkers can be used to stage and monitor the tumor before and during treatment.

At high fields the use of radiofrequency (RF) pulses to excite and refocus the spins is limited due to a low penetration depth of RF in the human body, limited amount of available RF peak power and the appearance of hotspots that may lead to higher local specific absorption rates (SAR) which may exceed the approved limits of local RF power deposition in human tissue. It has been demonstrated that local endorectal RF coils can be used at 7T using the same loop coil for transmit and receive [1]. However the substantial non-uniformity in B_1^+ and B_1^- fields in such concept leads to local reduction in transmit efficiency and signal detection. In addition, the absence of a quadrature coil setup leads to a reduced potential efficiency and SNR. By adding different coil elements for transmission and reception of the signal in magnetic resonance imaging (MRI), it is possible to manipulate the distribution of these B_1^+ and B_1^- fields, obtaining a more homogeneous RF profile. In addition, if the coil geometries are chosen such that their field orientations are orthogonal in the area of the prostate, a substantial increase in the signal to noise ratio (SNR) is expected.

We have added a stripline coil of a 7T endorectal coil setup to investigate the effects of such second element inclusion in terms of RF gain. This device may be used for human studies at 7T.

Methods:

A stripline element of 6 cm length tuned to 298 MHz with two capacitors was positioned inside the inner balloon of a commercially available endorectal coil under the loop coil, tuned to 298 MHz (Figure 1). Two home built transmit receive switches were used to control transmit and receive fields independently. A double compartment phantom with 33.4 g/l NaCl and 1250 g/l sugar in both compartments to match the dielectric properties of the phantom to the average human constants of ε_r=55 and σ=0.64 S/m approximately for the 7T. Spin echo images were obtained at a fixed RF power setting using the coil either in quadrature or in anti-quadrature using a quadrature hybrid box. In all measurements, the signal was received with the two coils independently by the MR system. Finite difference time domain (FDTD) calculations were performed to simulate the B_1^+ field patterns for both elements operating in quadrature and anti-quadrature modes and the B_1^- field patterns of the individual coils.

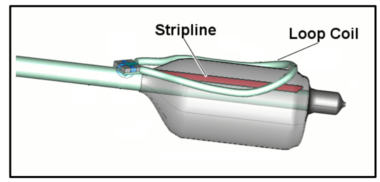

Figure 1: Schematic view of the coil system. In light green is the loop and in red the stripline. A transversal view of this geometry is used to present the MR and simulation results.

Results and discussion:

The black bands in the transversal spin echo (SE) images on figure 2 illustrate transition zones from excitations to inversions and vice versa. Comparing both setups, the quadrature setup (Fig. 2b) enables a 4-fold higher B_1^+ efficiency (4 more transition zones indicated by arrows), indicating that both coil elements have comparable contribution and its field lines are approximately orthogonal in this setup. FDTD simulations of the B_1^+ fields (Fig. 2 a,b upper right) correspond to the observed effect. B_1^- field maps are shown in figure 3 for a) the loop coil and b) the stripline. The asymmetry of these fields is clearly visible (indicated by the arrows) and it seems to be in reversed location from one to the other coil. Combining both images not only enhances SNR substantially, but also improves the homogeneity as shown in figure 4. These results also agree with the FDTD simulations (Fig. 3 a,b upper right). Results for SAR calculations revealed a local maximum SAR normalized to the minimum B_1^+ field in the area of the prostate to be 2.4 times lower for the combined setup compared to the loop coil alone.

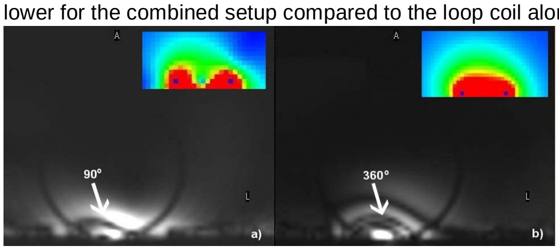

Figure 2: SE acquisitions showing transmit (B_1^+) field maps for a) anti-quadrature and b) quadrature configurations. The quadrature configuration in b) shows a more efficient transmit profile compared to the anti-quadrature setup, with 4-fold higher flip angle potential represented by the multiple number of high/low intensity rings in the image. The arrows pointed at the same distance from the coil setup. These images were obtained with the same RF power. Simulation profiles for the transmit fields are also shown in the upper right

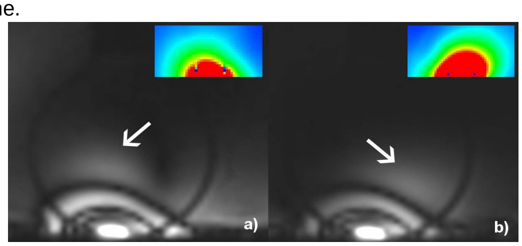

Figure 3: SE images reconstructed using either signal from a) the stripline coil and b) the loop coil. The higher intensities appear at different locations for the two coils indicated by the arrows. Due to the different natural in-homogeneity of the B_1^- fields from every element (see also FDTD results in upper right corners), there is an improvement in receive field homogeneity and therefore SNR on the combined system image.

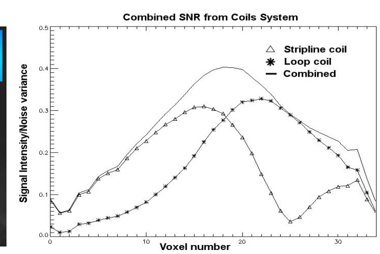

Figure 4: SNR profile of a line at 3 cm distance parallel to the coil setup from the SE images obtained either with the stripline coils, the loop coil or combining the images. The location of the line corresponds to the arrows in figure 3.

Conclusions:

Including a stripline to the endorectal RF coil for prostate imaging enables improved SNR and reduced RF power deposition at 7T. B_1^- fields of the individual elements showed RF hotspots in different regions which when combining the elements substantially improves the homogeneity of the reception profile of the setup. As the stripline is fully integrated in the mechanical housing of the endorectal probe, improved MR imaging of the prostate in-vivo should be feasible.

References:

[1] Klomp et al. NMR in Biomed in press.