Inductively Coupled Coils for Local SNR-Enhancement during MR-guided Prostate Biopsy

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Introduction

It has been shown that both MRI and MRS can improve specificity in the detection of prostate cancer [1]. During MR-guided prostate biopsies suspect prostate areas can be identified on T2w MR images, and MRS metabolic information can further help to decide from which areas biopsy samples need to be harvested. Since the quality of MR data crucially depends on the local signal-to-noise ratio (SNR), typically local endorectal coils are utilized. To harvest the biopsy samples a commercial needle holder with a passive marker is available, which completely fills the available space in the rectum, and the integration of an endorectal coil becomes difficult. Inductively coupled rf coils with no direct connection to the MR system can be realized with significantly smaller space requirements, and usage of the coils is greatly simplified. We therefore examined two inductively coupled coil designs for possible integration into the commercial biopsy system to improve the local SNR at or near the biopsy sample area.

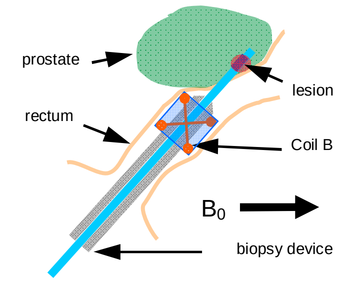

***Fig.1:** Biopsy device fitted with coil B*

Materials and Methods

The two inductively coupled coils designs were realized on cylindrical coil formers (Plexiglas®, Ø = 23 mm) that had a central hole to accommodate the passive marker of the biopsy system (InVivo, Schwerin, Germany). One rf coil (A) was a short solenoid coaxial with the needle axis (Ø = 22 mm), and the other (B) consisted of two orthogonal elliptic coils (long/short axis=31/22mm) at 45° angulation against needle axis (Fig. 2). The two coils in design B were geometrically [2] and capacitively decoupled from each other to prevent frequency splitting. Both coil configurations were tuned to the resonance frequency of the 1.5 T MR system (i.e., 63.69 MHz) by ceramic trimmer capacitors (type TZC3, muRata, Japan). During RF excitation the coils were passively detuned by crossed diodes (BA792, Philips, Netherlands). The coils were oriented so that the signal reception from the sample region 14 mm in front of the end of the marker was improved.

To characterize their angular sensitivities, both coils were placed on a phantom container (0.9% NaCl, 0.5% Gd-DTPA, T_1=95ms) for imaging in a clinical 1.5 T whole body MR system (Magnetom Symphony, Siemens, Erlangen, Germany). Local signal gain was assessed with a 2D-FLASH-acquisition (FOV = 180×180 mm², matrix: 256×256, TR = 9.3ms, TE = 4.5ms, SL = 5 mm, flip angle 5°). Inductive coupling to the receiving spine coil array was measured as a function of orientation with respect to B_0. Both coils' central axis was tilted from 0° to 90° in 10° steps. Coil B was measured in two orientations, coil wire crossings along (NS) and perpendicular (WE) to B_0. Residual B_1 amplification during rf transmission was measured with a 3D-FLASH acquisition (FOV = 280×175 mm², matrix: 192×120, TR = 7.7 ms, TE = 3.7 ms, 64 slices, SL = 2.2 mm, nominal flip angles 5° to 75°). From the flip angle series the B_1 amplification was calculated by comparison of the local nominal flip angle at maximum signal (i.e., the Ernst angle) with the Ernst angle far away from the coil.

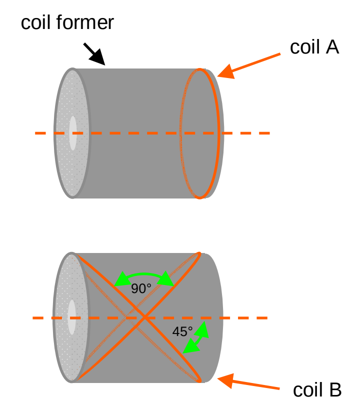

***Fig.2:** Inductively coupled solenoidal coil A (top), orthogonal configuration of elliptic coils B (bottom)*

Results and Discussion

Due to decoupling by crossed diodes both coils showed a small B_1 amplification only in the biopsy region; the single solenoid up to 10% due to its closeness to the target area (Fig. 3). The signal gain factor at the target point (distance to coil wire = 14mm) was 2.27/1.3 for design A/B. In the rotation experiments the solenoid coil provided the highest signal intensity at all rotation angles while the NS orientation of design B was found to be superior to the EW orientation (Fig 4.). In general, the signal showed the expected cos²-dependency. In all measurements solenoid design A was significantly superior to the orthogonal design B due to the proximity of the loop coil to the target. In [2], design B with active read-out of the two coils has been proposed as a forward-looking catheter coil design, however, the forward-looking characteristics demand an individual read-out of the two crossed loops, which cannot efficiently be realised for inductively coupled coils. We thus conclude that a simple loop design provides a good solution to increase the SNR during MR-guided prostate biopsies.

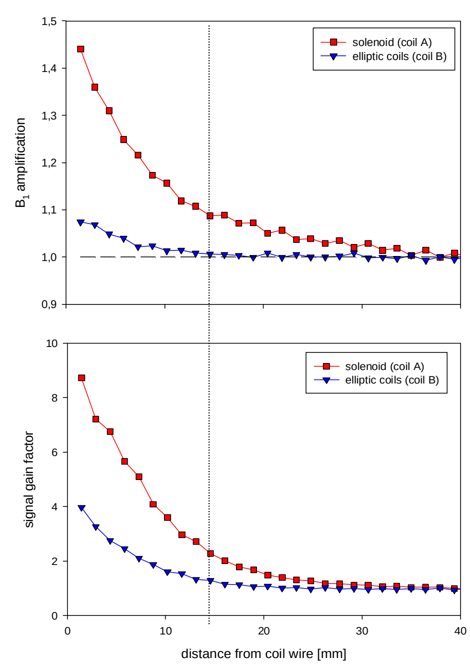

***Fig.3:** B_1 amplification and signal gain as a function of distance from the coil center. The target area of the biopsy needle is at 14 mm.*

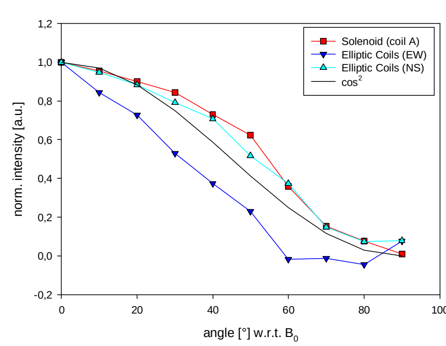

***Fig. 4**: Coil sensitivity vs. orientation w.r.t. B_0*

References

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