Active MR tracking using micro coils for both transmit and receive

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Introduction. Active MR tracking of devices exploits small receive coils with restricted spatial sensitivity [1]. When the Signal-to-Noise Ratio (SNR) of the detected MR signals is high, the accuracy and precision of tracking are well suited to a wide variety of applications. Non-idealities of the tracking device and the MR tracking environment, however, can restrict MR tracking rate and robustness.

Some of the challenges to signal quality in MR tracking arise from the construction of the catheters used for the electromagnetic simulation. As shown in Proc Intl Soc Mag Reson Med 19 (2011) 1034, artifacts that make identification of the device difficult in position determination. When the tracking coil used in the experiments was modeled to predict the received MR signals, the phase sensitivity profile of the small coil is virtually identical because the phase of the MR tracking coil is used for both transmitting and receiving, as evidenced in Figure 3B (e.g. approximately Gaussian). This makes peak detection more robust with a commensurate improvement in tracking accuracy. An additional benefit is the minimization of RF-induced catheter heating [3].

Exciting with the body coil results in a received signal with complex phase sensitivity profile in at least one direction for an arbitrarily oriented micro coil. This complex peak can be attributed to two phenomena: A) the coupling of unwanted MR signals into the MR tracking coil causing large rolling baseline artifacts, and B) employing the same phase sensitivity profile of the small coil is virtually identical because the phase of the MR tracking coil is used for both transmitting and receiving, as evidenced in Figure 3B (e.g. approximately Gaussian). This makes peak detection more robust with a commensurate improvement in tracking accuracy. An additional benefit is the minimization of RF-induced catheter heating [3].

Figure 1: System diagram

Methods. The systems diagram for the micro T/R circuit is shown in Figure 1. In this system the pulse sequence hardware controls a custom-built RF switch which allows the user to select either the micro coil(s) or body coil for excitation. A passive T/R switch employing a ¼ λ filter is used to protect the micro coil’s preamplifier.

A 90 cm 5 French catheter (Figure 2, Cordis Corp.) containing three tracking coils was suspended in a solution of copper sulfate (CuSO4). The coils were connected to the preamplifiers via the passive T/R switch. Tracking was performed using a gradient-echo based pulse sequence for MR tracking [1] at a rate of 22 frames per second. Tracking results were recorded for body coil transmit/micro coil receive and micro coil transmit/micro coil receive. Micro coil excitation was performed with less than 1W.

Figure 2: 5 French catheter with three integrated tracking coils.

Figure 3: MR tracking signals from micro coils acquired with an X magnetic field gradient. (A) Body coil transmit, (B) Micro coil transmit and receive.

Figure 4: Simulation results. (A) the solenoid model, (B) predicted MR signal using body coil excitation, and (C) predicted MR signal from micro coil excitation.

Results and Discussion. The experimental and simulation results agreed well and are presented in Figures 3 & 4. These figures highlight the difference between body coil transmit and micro coil transmit.

Figure 3: (A) Body coil transmit, (B) Micro coil transmit and receive.

Figure 4: Simulation results. (A) the solenoid model, (B) predicted MR signal using body coil excitation, and (C) predicted MR signal from micro coil excitation.

When the Signal-to-Noise Ratio decreases, the received MR signal can be used if a fully robust device tracking system is desired [2].

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Robust MR tracking under low SNR conditions is also made difficult by coupling of unwanted MR signals into the MR tracking coil. This coupling is usually insignificant in high SNR cases, but can result in large rolling baseline artifacts that make identification of the device difficult in position determination.

The magnetic field profile of a small solenoid coil is further complicated by: A) the orientation of the coil within the static magnetic field of the MR system, b) the orientation of the coil within the static magnetic field of the MR system, and c) the orientation of the coil with respect to the applied magnetic field gradients that are used in MR tracking pulse sequences. Unfortunately, no a-priori knowledge of the orientation of the coil can be used if a fully robust device tracking system is desired [2].

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The experimental results were well-predicted with the electromagnetic simulation. As shown in Figures 4B and 4C, we estimated the received MR signals using the B1 field inside and around the tracking coil. The peaks are much closer to ideal as expected, the received MR signal is closer to ideal because the phase of the excitation field matches that of the receive field.

Conclusions. Using micro coils for both excitation and reception during MR tracking provides significant improvements in the MR signal line shape and hence the accuracy of tracking. This improvement increases the peak height (and thus SNR) and can, in principle, permit tracking of even smaller coils.

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References.