Simultaneous Roadmap Imaging and Device Tracking with Parallel Excitation

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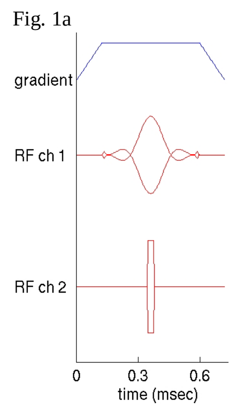
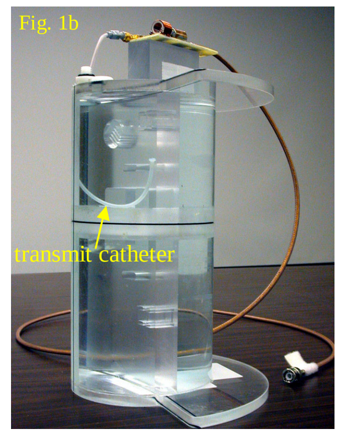
Introduction

A variety of MRI-based methods have been developed to monitor the placement of a catheter (or other invasive devices) during an interventional procedure. With one such method, small sensing coils are attached to the catheter at strategic sites and catheter location is inferred by collecting and processing MR signals picked up by the coils (1). With another example method, an MR catheter probe is employed for repeated transmit and receive, and the MR images thus produced reveal probe location (2). With either method, separate acquisition of roadmap images is performed every once in a while to provide anatomical information and/or to assist navigation. MRI-based device tracking exemplified by these may potentially replace x-ray fluoroscopy in some interventional procedures. At present however, MRI-based methods yet need to further improve in imaging speed/quality. For methods represented by the two above, which interleave roadmap scans with tracking scans, an increase in update rate with one type of scans typically implies a decrease in update rate with the other. The fact that catheter location information and roadmap images are obtained separately also implies potential registration errors due to the lapse of time between the scans, as well as an overhead associated with extra steps of spatial-information processing/integration. We propose a parallel excitation-based MRI method that enables simultaneous planar roadmap imaging and device tracking, and automatically produces images showing device location as a projection onto the roadmap frames. The method may be advantageously applied in cases where the tissue near the device undergoes motion/deformation and frequent roadmap-image update is necessary.

Methods and Results

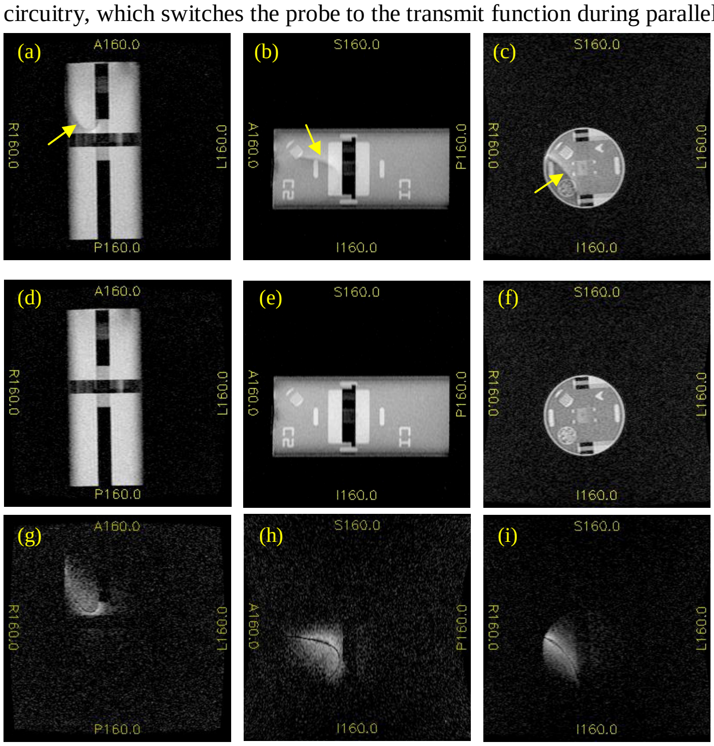
The new method is named SIMPLE, which stands for Simultaneous IMaging with ParalleL Excitation. For the present investigation, the method is tailored to achieve planar imaging of the subject at any prescribed scan plane and projection imaging of the device (and its surroundings) both at the same time. Key components of the method include integration of auxiliary transmit coils with the tracked device and control of the coils' RF transmission through additional channels that operate in parallel with a scanner's standard RF transmit channel.





In an example two-channel implementation, while the standard transmit channel drives a regular transmit coil to accomplish slice selection, the second channel may drive an auxiliary transmit coil with a non-selective or mildly-selective narrow pulse that is played-out at an time instant chosen for obtaining proper refocusing (Fig.1a). With this implementation, both in-slice spins, which are excited by the regular slice selective pulse, and off-slice spins surrounding the auxiliary transmit coil, which are excited by the narrow pulse, contribute to the MR signal. A regular planar acquisition sequence may readily project the 3D magnetization distribution, creating a 2D image that shows the selected slice as well as the surroundings of the auxiliary coil — superposition of device location information onto the roadmap planar image is automatically accomplished during image reconstruction.

Integration of auxiliary transmit coils with a catheter for example, can follow the approach of Dumoulin *et al.* (1) where small coils with or without water-filled vials are attached to the catheter at a set of selected locations, or the approach of Atalar *et al.* (2) which employs a custom made catheter probe. Fig.1b illustrates a catheter-probe built and tested in the present study. The probe body was constructed following a design similar to the loop-less catheter described in (2), which suits well the two-channel implementation described above. The probe was completed with a T/R switch circuitry, which switches the probe to the transmit function during parallel excitation while keeping it deactivated during receive.



Several implementations of simultaneous roadmap imaging and device tracking were evaluated with the support of an 8-channel parallel transmit MRI system (see a separate abstract) and an adapted gradient echo sequence that accommodates Fig.1a-type parallel excitation pulses. Fig.2 summarizes results of the two-channel catheter-probe implementation. Fig.2a-c show SIMPLE results corresponding to three different scan-plane prescriptions (2 long-axis and 1 short-axis views in this case). In all three views the shape and location of the tortuous catheter appears to be well captured despite its off-plane placement. As a comparison, Fig.2d-f show corresponding results obtained with zero input to the second channel (i.e., regular planar imaging), and Fig.2g-i show corresponding results obtained with zero input to the first channel (i.e., projection imaging of the catheter and its surroundings). In terms of pulse sequence timing, parallel transmission of a narrow pulse on the second channel adds no overhead. This implies fully retained freedom in optimizing the gradient echo sequence and good portability to other rapid planar imaging sequences of choice. An on-going investigation is evaluating the safety of the method's practical use, and the improvement of device-slice contrast by optimizing auxiliary coil(s) and RF output level(s).

1. C.L. Dumoulin, *et al.*, Real-time position monitoring of invasive devices using magnetic resonance, *MRM* 29:411-415,1993. 2. E. Atalar, *et al.*, Catheter-tracking FOV MR fluoroscopy, *MRM* 40:865-872,1998.