2D-real-time MR imaging and simultaneous X-ray-like volume visualization of devices

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Objective: In X-ray-fluoroscopy-guided interventions, it is extremely helpful for the clinician that all devices in the FOV of the detector are always and entirely visible. This is a consequence of X-ray being a projection technique, but for the same reason, most tissue contrast is lost. In contrast, MR-guidance with one or few 2d-real-time imaging slices provides very good tissue contrast, but devices are only visible or detectable if contained in the measured slices. This applies not only to passive, but also to active device tracking and visualization methods using miniature receive coils on these devices. Thus, curved vasculature generally prohibits device visualization over the full FOV in MR. In practice, however, it would be highly desirable to visualize or track e.g. the tip section of a device, even if it is out of slice. It is the purpose of this work to present a technique that simultaneously provides both, high contrast real-time imaging of 2d-slices and visibility or active tracking of devices in the full volume of interest.

Materials and Methods: In order to achieve 3D volume-visibility of an active device during 2D slice selective real-time imaging, additional RF pulses with a wide bandwidth (hard pulses) were transmitted with the active device. This causes excitation of spins in the vicinity of the device even if it is not contained in the imaging slice. The hard pulses were derived from the imaging RF pulses transmitted by the body coil of the scanner (Achieva 1.5T, Philips Medical Systems). For this purpose, a pick-up coil (∅ 10cm) was positioned at the flare of the bore for inductive coupling with the body coil. The induced RF signal was spectrally widened by temporal gating and fed into the active device. The gating window was timed at the center of the imaging RF pulse using a monitor trigger of the scanner, and the window width was set to 20µs to achieve a bandwidth 20 times that of the imaging pulse. The hard pulse was transmitted by a 1m long RF-safe active device containing a transformer-based transmission cable [1] connected to a 5cm long single loop coil at the tip. The device was placed in a water-filled bowl and located on the chest of a volunteer (Fig. 1). An interactive balanced FFE sequence (TR 3.0, 160 k-lines, slice thickness 1cm) was performed acquiring signal with a 5-element cardiac coil and the active device on a separate receive channel. Coronal slices positioned 5-10cm posterior to the chest wall were acquired. Active device tracking was performed with a second device equipped with a transformer-based transmission cable now connected to a 3mm long solenoidal tip coil. The device was again placed in the bowl on the chest, and the in-plane co-ordinates of the tip coil were tracked while imaging the coronal slice below the chest.

Results and Discussion: Spin excitation was possible with the device positioned up to 10cm out of slice. The projection of the device on the imaging slice reconstructed from the device channel visualized the transformers and the tip coil clearly (Fig.2). When the pick-up coil was disconnected, the device signal almost vanished, which proves the effect of out-of slice excitation with the device. Real-time image quality was not affected by the additional hard pulse transmission (Fig. 3). This is a consequence of the local transmit sensitivity of the active device, which causes spin excitation only adjacent to the device and minimizes interference with the imaging steady-state. Images reconstructed from the device channel were used as overlay on the real-time images reconstructed from the cardiac coil signal (Fig. 3). Note that in-slice and out-of slice parts of the device can be distinguished by switching off the device transmission, which is clinically important.

Active in-plane tracking of the tip coil of the second device performed robustly with a distance of up to 15cm between the imaging slice and the device tip. Note that without transmission via the device, repeated non-selective pulses would be required to continuously track the in-plane position of a device that is out of slice [2]. Especially for balanced FFE sequences as often used for image guidance, the additional magnetization excited in the volume causes severe image artifacts, which motivated this work. For the proof-of-principle results presented here, the pick-up coil output in the range of 20V was not amplified. The use of an amplifier will enable shorter hard pulses and hence a wider spatial coverage. The pick-up coil technique has the advantage that it does not require any modifications of the scanner hardware, because transmit/receive switch, gating and amplification can all be implemented in the device interface. Alternatively, a separate transmit channel could be used. Here, the technique was demonstrated with balanced FFE imaging, but, in principle, it is compatible with most sequences. Full length visibility of the device in a volume may be achieved by combining the presented technique with a recently presented modified transformer cable [3].

Conclusion: Parts of devices that are far outside the real-time slice can be visualized without requiring any additional acquisition time, and their in-plane co-ordinates can be tracked by using the device in transmit/receive mode. Hard pulses transmitted with the device during imaging can be used to cover a volume centered at the imaging slice. The proposed method enhances MR device visualization, because it combines high contrast imaging of a thin slice with volume visibility of a device like in X-ray fluoroscopy.

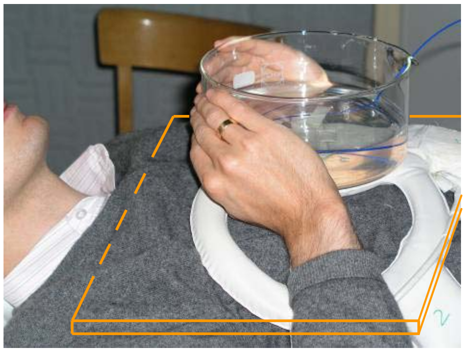

Fig. 1: Non-invasive test set-up: The blue active device in the bowl is about 10cm above the coronal imaging slice through the chest (orange).

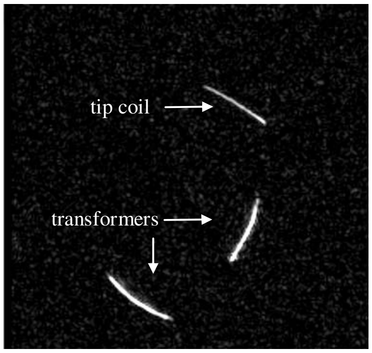

Fig. 2: Real-time bFFE image obtained from the receive channel of the active device, while the device was 10cm above the imaging slice.

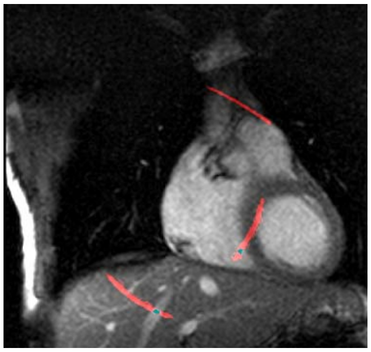

Fig. 3: Real-time bFFE image obtained with the cardiac coil with a red overlay of the signal from the device channel.

[1] Weiss S, et al. Transmission Line for Improved RF Safety of Interventional Devices. MRM 2005;54:182.
[2] Dumoulin, CL, et al. Real-time position monitoring of invasive devices using magnetic resonance. MRM 1993;29:411.
[3] Krueger S, et al. MR-visible and RF-safe low profile transmission line for active devices. ISMRM2007, p1105.