Simultaneous Visualization of Passive Marker and Anatomical Image with Rephasing Gradient Integrated Double Echo

K. Zhang[1], A-K. Homagk[1], W. Semmler[1], and M. Bock[1]
[1]Medical Physics in Radiology, German Cancer Research Center, Heidelberg, Germany

Introduction

In order to detect the position of devices in MR-guided interventions, different tracking techniques have been proposed. Active tracking methods with tracking coils provide a high SNR but are technically challenging, and RF-induced heating is still a problem. Passive tracking techniques often apply either positive or negative markers (e.g., para- or ferromagnetic material) to the vascular device. Recently, an MR-compatible guidewire with passive markers has been developed and demonstrated to be feasible in guided angioplasty and stenting of renal arteries [1].

Identification of these passive markers can be challenging in *in vivo* applications due to motion and flow artifacts. In this study we implemented a dual echo pulse sequence which acquires simultaneously a conventional MR image together with a dephased image to highlight the marker materials [2, 3]. After overlay of two images the maker can be easily detected in the anatomical images.

Materials and Methods

The local magnetic field inhomogeneities caused by a small cylindrical marker with susceptibility different from its surroundings creates a field pattern similar to a magnetic dipole field (Fig. 1a). The inhomogeineity of the static magnetic field B_{loc} leads to additional signal dephasing, which results in a faster apparent decay of the NMR signal (Fig. 1b). The additional accumulated phase φ, up to time t after RF excitation is $\varphi = -\gamma B_{loc} t$. The magnetic selective compensation method introduces a gradient $G_{rephase}$ to rephase the signal by $\varphi_{rephase} = \gamma G_{rephase} r t = -\varphi$. The signal in regions where the local gradients are of the right amplitude and orientation is thus compensated (white marker phenomenon). However, residual signal of the sample outside of these compensation regions becomes spoiled (Fig. 1d). To gain the information from both passive marker and background, this rephasing gradient was integrated into a double echo sequence. As presented in Fig. 1c, two echoes were acquired before and after a rephasing gradient in each TR of FLASH.

Phantom measurements were performed with a 0.035" polyetheretherketone (PEEK)-based MR-compatible guidewire (Vascular Intervention, Buelach, Switzerland). The 160cm-long guidewire has altogether 7 passive markers: 5 spaced at 20 mm and 2 separated by 40 mm as showed in Fig. 2a. The marker consists of paramagnetic iron oxide nanoparticles which is composed of alfa- Fe_3O_4 (90% wt/wt), with a mean size of 200 nm and a spherical shape [1]. The size of the markers were 0.03-mm thick and 1.5-mm broad.

All measurements were performed on a clinical 1.5 Tesla whole body MR system (Siemens Magnetom Symphony, Erlangen, Germany). The following imaging parameters were used to acquire two images with opposite contrasts simultaneously: TR = 7.8 ms, TE_1 = 2.12 ms, TE_2 = 5ms, α = 15°, FOV = 330×227 mm, matrix = 256×192, TA/series = 0.68s. The rephasing gradient in slice selection direction had a gradient amplitude of 5-14mT/m and was 1 ms long.

Results and Discussion

The two images acquired with rephasing gradient integrated double echo sequence are shown in Fig. 2. The first image with negative markers provides a normal FLASH contrast (Fig. 2b). The second echo shows the markers with a positive contrast (Fig. 2c) with signal (marker) to signal (background) ratio of 10. The shape of the single white marker is in good agreement with the simulation in Fig. 1d. Overlaying the marker signal in color onto the original image helps to identify the marker positions more easily.

The experiments showed that magnetic selective compensation can provide a positive contrast for the passive marker if the correct rephasing gradient and parameter were chosen. Following modified double echo after this technique, two images with opposite contrasts can provide information from markers and background both. Using such application visualization and tracking of devices in interventional MRI will become simple and fast. A further development will be to calculate the guidewire's position in 3D volume based on three 2D projected images and reorient the slice position.

References

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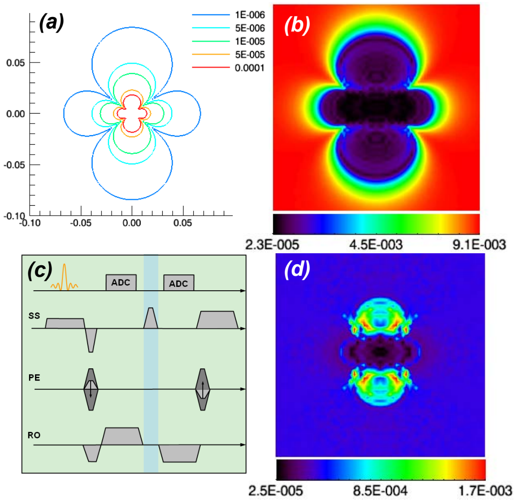

Fig 1. Simulation of the dipole field and magnetic conservation mechanism. (a) The colored contours indicate the corresponding isoline of distortional magnetic field caused by ferromagnetic tip, (b) The effect of dephasing caused by local inhomogeneous field on the signal intensity, the marker has a negative contrast (dark blue) to the bright background (red). After the rephasing gradient in the blue region of the sequence (c) signal from corresponding region (yellow green) is conserved, others(blue) is spoiled, the contrast is then converted (d).

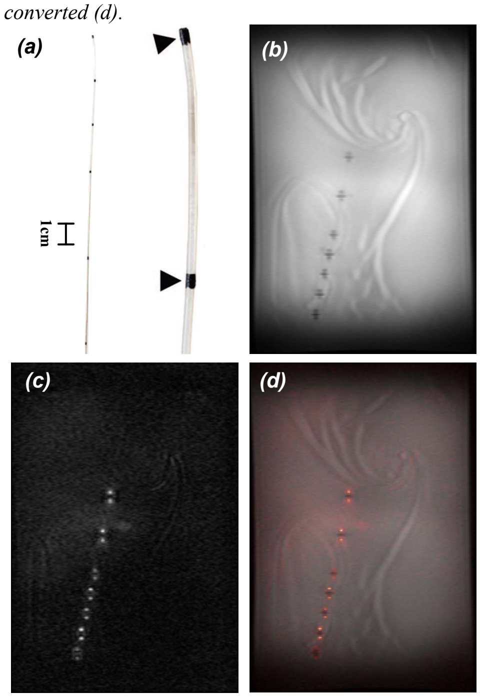

Fig 2. The PEEK-based guidewire (a) with 7 passive markers. With integrated rephasing double echo FLASH two images were generated. The first echo (b) shows the markers with a negative contrast. After overlay of the second image with positive (c) both markers and background can be easily identified(d).