Very fast volumetric BI+ mapping at 7 Tesla using DREAM

Peter Börner1, Kay Nehrke1, Maarten Versluis2, and Andrew Webb3

1Philips Research Laboratories, Hamburg, Germany, 2C.J. Gorter Center for high field MRI, Leiden University Medical Center, Department of Radiology, Leiden, Netherlands

Introduction

The B1+ transmit field determines the spatial distribution of RF excitation, refocusing and/or magnetization preparation. With the move towards higher fields, RF homogeneity problems caused by wave propagations effects have become obvious, which can compromise clinical diagnosis. All approaches to counteract these effects, such as special RF pulses (1) and parallel transmit techniques (RF-shimming (2,3) and transmitSENSE (4,5)), require knowledge about the actual B1+ fields involved. Furthermore, measured B1+ maps can be used to estimate electric tissue parameters and E-field components (6), giving potential new diagnostic information and allowing prediction of the specific absorption rate (SAR) increasing patient safety for ultra high field imaging. However, currently available B1+ mapping techniques, either encoding the B1+ into signal phase or amplitude (7-12) are inefficient, because of the frequent repetition of the B1 encoding process and the need for at least two separate measurements for B1+ fitting. This is a serious issue especially in parallel transmit applications, where mapping time scales linearly with the number of transmit channels.

To overcome these limitations, in this work, a new, very fast, simple and safe B1+ mapping approach for ultra-high field imaging is introduced allowing volumetric B1+ brain mapping in less than 10s.

Methods

One ingredient of this new approach is to separate the B1+ sensitivity encoding process from its spatially resolved detection (9,10). Here a stimulated echo (STE), dual (α) RF pulse preparation scheme is chosen, storing the prepared magnetization in Mα exposed only to slow T1 relaxation (see Fig.1). After this preparation, two longitudinal states are available, the STE state: Mα2 = M0/2 sin2(α) and the untouched remaining one: Mα1 = M0 cos2(α). Using a repeated, efficient gradient echo block, the STE magnetization is imaged. The new idea is to sample not only the STE signal (~Mα2) via the STEAM (stimulated acquisition mode (13), but also the FID (~Mα1) generated by the β) RF pulse simultaneously (see Fig.1). Therefore, this dual echo sampling sequence is named DREAM (dual refocusing echo acquisition mode). Since, the tip angle of the gradient echo (β) influences both signals (I1, I2) in the same way: B1+ can be calculated from the arctan(I2/I1). Furthermore, the transmit phase can be estimated via arg(I1* I2)/2 if appropriate sequence timing (for Td, Te, T1/2, and ΔT) is chosen. This simple and very robust sequence allows for efficient, multislice (single-shot) B1+ mapping and is used here as a volumetric approach.

For confirmation, phantom and in-vivo experiments were performed using a 7T scanner (Achieva, Philips HealthCare, Cleveland) equipped with an integrated quadrature transmit and, 32-channel receive array head coil (Nova Medical). Mapping performance was tested using a FOV: 300×192×320mm³ using isotropic voxel resolutions of 5×5×5mm³ (Td/Te/ΔT: 9.5/1.97/1ms) resulting in a total scan time of 9.7s and 2.5×2.5×2.5mm³ (Td/Te/ΔT: 9/5.2/1.1ms), total scan time of 39s. 38 echo pairs were read-out using a TR between 4.3/5s each after preparation. For the two slice selective RF pulses (α, β) tip angles of roughly 60° and 10° and different thicknesses (thickness = 2 slice 0) were chosen, to improve mapping accuracy. The timing was optimized to ensure that both gradient echoes are sampled in a water/fat in-phase condition. In volunteer scans the influence of external dielectric material (BaTiO3 + deuterated water) for tailoring the spatial distribution of the electromagnetic field (14,15) was briefly investigated using the low resolution protocol.

Results

Figure 2 shows selected low resolution B1+ maps measured in a spherical phantom filled with water. Characteristic wave propagation effects are visible. Figure 3 shows selected high resolution in-vivo B1+ maps, illustrating the almost two-fold higher B1+ in the middle of the brain. Figure 4 shows selected low resolution B1+ maps measured without and with field shaping dielectric pads placed under the neck of the volunteer. Slight improvements of the RF field homogeneity and its extent are visible in areas such as the temporal lobe and base of the brain.

Conclusion

DREAM, as a very fast, robust and save B1+ mapping approach, can become a very valuable tool for ultra-high field MR supporting conventional high-field applications, electrical property imaging and parallel transmit MRI. Such a short volumetric 10s scan can support corresponding optimization with the patient in place. The sequence is safe in terms of SAR (only 17% of the legal limit), is not limited by gradient performance or available maximum B1+ and can easily be expanded to map more than one transmit channel or appropriate superposition. It is rather robust due to the simultaneous acquisition of the two echoes, which are not separated in time (reduced motion problem) and can easily be implemented.

References