Improved Phase-Based Adiabatic B1 Mapping

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Introduction. Existing B1-mapping methods use either the intensity or the phase of the signal as the source of information. The phase-based approach (1,2) has the advantage of being independent on the relaxation properties of the object, and, as recently showed by Morrell, achieves a better sensitivity than in signal amplitude-based methods (3). Morrell's method uses two RF pulses: the first one producing a B1-dependent nutation about the x-axis, the second one rotating this state to the x-y plane and thus linking the nutation angle with the signal phase. The dynamic range of this method is limited by the ability of the second pulse to generate transverse magnetization: its effect is best at 90°, and vanishes at 180°. We propose a way of generating the B1-dependent signal phase with higher dynamic range using an adiabatic half passage excitation pulse.

Methods. It has been demonstrated (4) that an inverse adiabatic half passage pulse (IAHP), with the sweep starting on-resonance, also allows deriving B1 maps from the phase of the signal. This required simulation-based lookup tables and was prone to errors due to resonance offsets. The improved version presented here uses two IAHP's, each of them preceded by a short block section without the frequency sweep. The phase of this block pulse is identical with the starting phase of the IAHP in one experiment, and the opposite in the other. The phase difference of the images acquired in the two experiments is affected solely by the block section and allows a straightforward calculation of the RF field strength: $B1 = \Delta\phi/2\gamma\tau$, where τ is the block pulse duration. As a further, optional modification, each of the IAHP pulses can be preceded by a block rewinder pulse of the phase opposite to that of the IAHP. Its role is to compensate the phase accrual caused by the adiabatic pulse itself. Although this phase is subtracted upon the phase difference calculation, it may lead to intra-voxel dephasing (and signal loss) in regions of strong B1 gradients. The duration of the rewinder pulse was numerically optimized for the expected range of B1 and the given IAHP shape and sweep. As an alternative way of rephasing, an adiabatic full-passage (AFP) pulse with double duration, half amplitude and half sweep has been used to produce a spin echo. All excitation schemes have been combined with a standard 3DFT imaging gradient sequence. Bloch equations have been numerically solved for all sequences to verify the B1 vs. $\Delta\phi$ dependence and its sensitivity to Bo offsets.

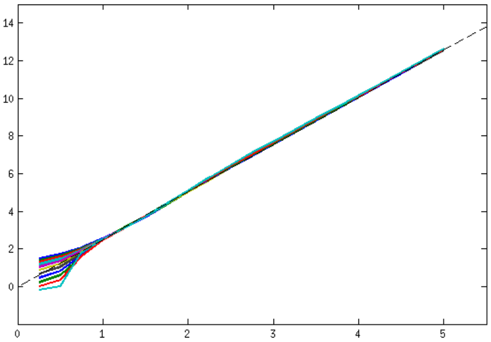

Fig.1. Simulated dependence of the phase difference (vertical, rad) as a function of B1 (kHz) for a range of B0 offsets (±500Hz).

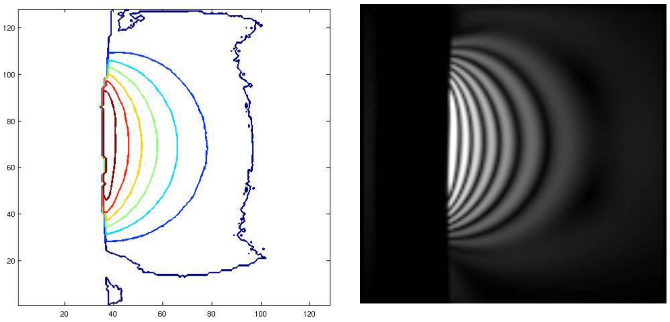

Fig.2. Measured 500 Hz contours of the B1 field cross-checked with a Nx180deg signal nulling for a 1ms block pulse.

Results. The result of the simulations (Fig. 1), for which a 5ms cos-sine IAHP pulse of 5kHz sweep was taken, show a good agreement of the phase difference with the theoretical value for an astonishingly high range of B1 values. The expected linear dependence is seen even at $\gamma B1/2\pi = 1$kHz, where the adiabadicity factor (nutation- to nutation-axis-velocity ratio) is of only 0.6. In the same range, the sensitivity to Bo offsets becomes marginal. All variants of the method were used to map the B1 field of a 3cm surface RF coil on a 7T Bruker BioSpec system. The phase difference was unwrapped and scaled to provide an image of B1 in frequency units. For a verification, another image was measured with a rectangular 1 ms pulse of the same peak amplitude as the IAHP. This pulse produces black bands where $\gamma B1/2\pi = n \times 500$ Hz, i.e., where the effective flip angle is a multiple of 180 degrees. An excellent agreement with measured B1 contours could be observed. (Fig. 2). A reduction of signal, and artifacts in the B1 map in a small region close to the RF coil circuit could be observed and disappeared when the rewinder pulse or the spin echo sequence was used.

Discussion/Conclusion. Compared to (1) our method replaces the second RF pulse by an adiabatic 90 degree plane rotation. This guarantees that the nutation angle caused by the initial pulse (block section) is perfectly transferred to the signal phase in a high range of B1 values. As a result, the B1 map can be reconstructed without lookup tables and in a higher dynamic range, making the method attractive for the evaluation of surface coils. The application of a rewinder RF pulse compensates the dephasing caused by the IHAP, similarly to the matched-AFP echo. The inherent 90-degree flip angle of this method has to be admitted as a drawback in the context of fast 3D acquisition.

References

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