Bo anchored spatial excitation (BASE) for effective fat suppression under Bo inhomogeneity: implication for parallel transmission

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Introduction

MR spin excitation under an inhomogeneous magnetic field can experience marked off-resonance effects. For example, regions or slices adjacent to the target slice may be excited if a conventional excitation pulse and slice-selection gradient are used. In modern MRI experiments where complex excitation pulses (e.g. the spatial-spectral selective pulses) are becoming increasingly useful, they can be even more vulnerable to off-resonance excitations in the form of reduced signal intensity as the desired frequencies may be missed entirely. The goal of this study is to develop a method that can potentially achieve a uniform excitation under an inhomogeneous B_o field, especially in applications in vivo where there are large local field inhomogeneities (e.g. near air/tissue/bone interface) that cannot be effectively addressed by magnetic field shimming. We propose a new excitation strategy that can take advantage of the recent advances in parallel transmission to allow tunable frequencies in individual channels to match the B_o profile in space.

Methods

Recent advances in parallel transmission have provided new ways to achieve more efficient spin excitation. In particular, it can help reduce the excitation length of the complex RF pulses (1,2), or achieve more uniform B1 field (e.g. RF shimming) (3).

To remove the excitation vulnerability toward magnetic field inhomogeneity, we propose a new technique termed B_o anchored spatial excitation (BASE). This methodology is well suited to take advantage of the recent advances in parallel transmission to spatially match the resonance frequency, thereby removing the influence of field inhomogeneities. We carried out a preliminary investigation on its feasibility, using a simple proof-of-concept two-coil setup (Fig. 1) but with implications for parallel transmission of larger scale.

To demonstrate the effectiveness of the BASE technique, we performed our experiments using fat suppression as an example to illustrate the effect. All images were acquired in a gel phantom containing thoroughly mixed water and oil in equal parts. Under a homogeneous magnetic field, the water and fat resonance frequencies should be clearly distinguishable, allowing the fat suppression pulse to be readily centered on the fat resonance frequency and resulting in a complete fat suppression. However, under an inhomogeneous field which disperses the resonance frequencies of water and fat, a single coil setup will not allow the transmission frequency to spatially match the B_o profile. This will in turn lead to incomplete spin excitation and fat suppression.

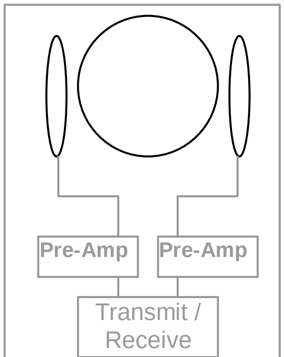

Fig. 1 A two-coil setup for BASE excitation.

Results

Images were acquired using a 16 cm FOV, 256×256 matrix, under four different conditions: First, image was acquired under a uniform magnetic field (< 20 Hz r.m.s. deviation); Second, image was acquired when the fat suppression module (with frequency offset to 590 Hz) was turned on, under the same uniform field condition; Third, the second experiment was repeated but under an inhomogeneous B_o field by deviating the x-shim gradient to introduce a 9Hz/mm frequency shift; And fourth, the third experiment was repeated by using a two-channel BASE excitation, under the same inhomogeneous B_o field.

As shown in Fig. 2 (left column)), when the B_o field is uniform, the selective excitation of water and suppression of fat signal are effective, as shown by the proportional signal reduction from panel A to B indicating a complete fat suppression. However, under an inhomogeneous B_o, the fat-specific excitation would be off-resonance in different regions, leading to an incomplete suppression in C. Using the space-frequency matched BASE excitation, fat-specific excitation remains on resonance at different locations, and suppression resumes its effectiveness, as shown in D. A schematic spectral illustration of the BASE technique is also shown in Fig. 2 (right column).

All experiments were conducted on a 4T whole-body MRI scanner (GE Healthcare, Waukesha, WI).

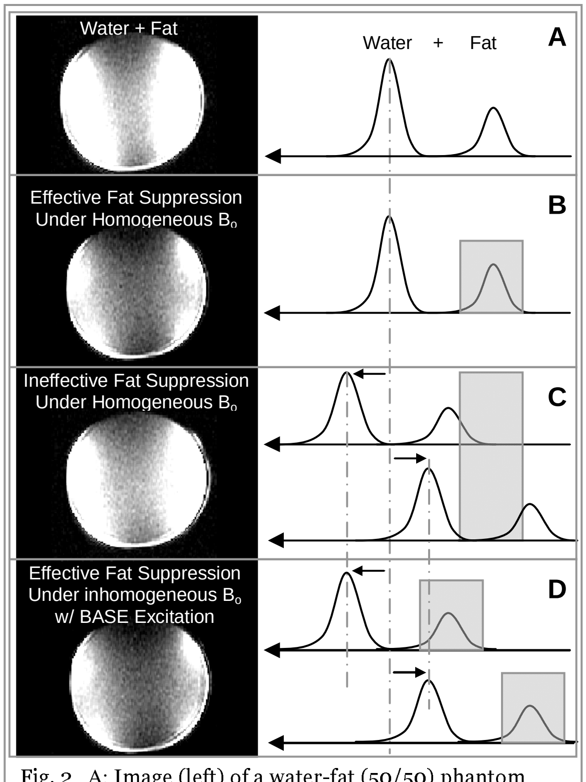

Fig. 2 A: Image (left) of a water-fat (50/50) phantom during normal excitation, and the corresponding spectral illustration (right). (B) Complete fat suppression under a homogeneous magnetic field, (C) incomplete fat suppression under a B_o inhomogeneity at 9 Hz/mm, and (D) complete fat suppression using BASE excitation under the same inhomogeneous field.

Discussions

As demonstrated in this initial effort, it is possible to achieve a uniform excitation in the presence of severe B_o inhomogeneities using BASE. With increasing availability and number of channels for parallel transmission, this strategy may prove to be highly useful for in vivo human applications in fMRI and spectroscopic imaging, where a uniform magnetic field may be difficult to achieve across the whole volume.

References:

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