2D compensating RF pulse with uniform image contrast in combination with an internal transceiver at 7T.

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Introduction

Ultra high field MRI provides high SNR that can be used to obtain images at high resolution. However, B_1 homogeneity becomes more challenging and also the B_1 strength is limited, particularly within the human body. New methods are being developed to increase the B_1 strength at the location of interest, while providing uniform B_1 and still remain within safety guidelines (SAR). Although local RF surface coils can provide the strongest B_1 per unit of SAR the field is very inhomogeneous, particularly orthogonal to the coil. Nonetheless, incorporating this most dominant non-uniformity in the design of the slab selective RF pulse, we have shown that a uniform and strong flip angle can still be obtained with an external surface coil[1]. However, most surface coils provide an inhomogeneous field in more than one dimension, particularly when used as an internal transceiver, like a radiating monopole[2]. In this work we demonstrate that the radial B_1 field pattern of an internal monopole antenna can still be used to provide a uniform flip angle at low SAR, thereby enabling high resolution MRI of tumors in the rectal wall.

Methods

The 2D compensating RF pulse (Fig.1) was designed[3] from the theoretical B_1 profile of the antenna (Fig.2a) while incorporating the limits in B_1 peak level, gradient strength and slewrate. Based on a maximum B_1 level of 50μT, the excitation pulse duration for a 41 degrees flip angle is 2.1ms (Fig.2b). The 2D RF pulse was implemented on a Philips 7T whole body system. In combination with the antenna transceiver[2], the 2D RF pulse was tested with the actual flip angle (AFI [4]) method and compared to a conventional RF pulse. To illustrate the benefit of using an internal transceiver with uniform flip angle distribution, we obtained 3D FFE images from the rectum of a healthy male volunteer at 7T using the 2D compensated and conventional RF pulse.

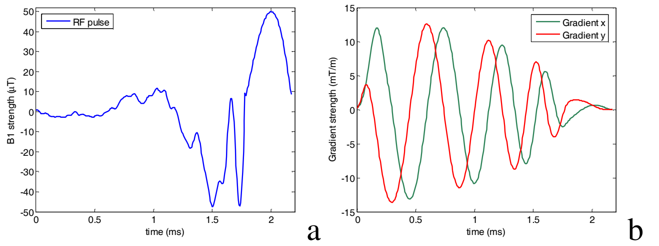

Fig.1. a) The RF pulse and b) the gradient shapes of the 2D compensating RF pulse.

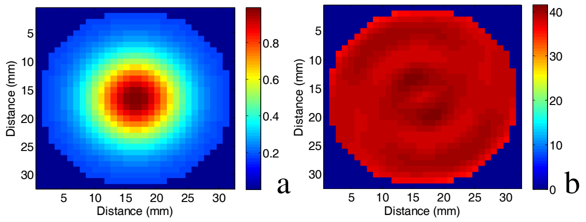

Fig. 2. B1 map of the antenna (a) combined with the 2D compensating RF pulse (Fig.1) results in a homogeneous flip angle distribution over space. The flip angle distribution was calculated by using the Bloch equation.

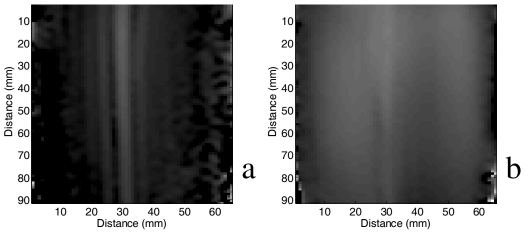

Fig. 3. B_1 maps (AFI) of a phantom with conventional RF pulses (a) and with the 2D compensating RF pulse (b). Note the significantly improved uniformity in flip angle distribution when applying the compensating RF pulse

Results

The actual flip angle map that was obtained with the 2D compensating pulse shows a uniform flip angle distribution when using the radiative antenna as a transceiver, particularly when compared to a conventional RF pulse (Fig.3). Consequently, in vivo images of a healthy volunteer (Fig.4) that were obtained with the compensating RF pulse shows not only improved contrast homogeneity, but also extended field of view even when compared to conventional RF pulse driven at stronger T_1 contrast (shorter T_R).

Conclusion and discussion

A thin antenna, applicable at 7T, enables high resolution imaging of internal structures that are accessible through cavities. When used as a transceiver, not only the high SNR of the local antenna can be used, but also the high duty cycle in flip angles provide strong contrasts. Due to the high efficiency (50μT with less than 1kW) sufficient bandwidth of the RF pulses can be maintained to enable accurate MRI in areas of strong susceptibility differences, like the rectum. Combining the antenna transceiver with a 2D compensating RF pulse restores contrast homogeneity and extends the field of view. Consequently, high resolution MRI of for instance rectal cancer would become feasible for clinical studies at 7T.

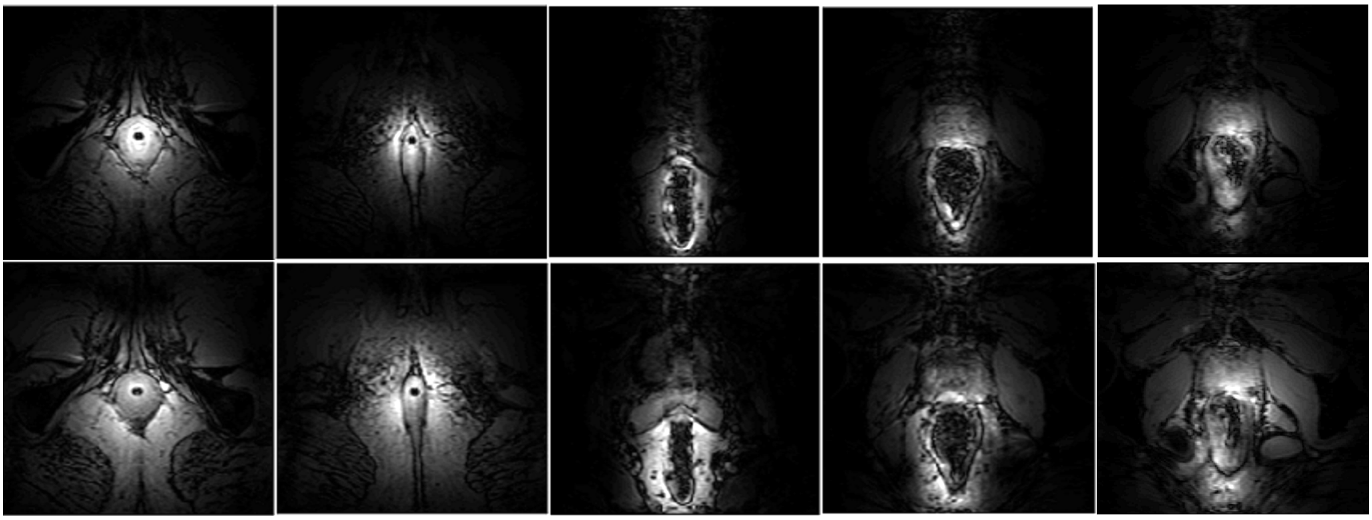

Fig. 4. In vivo 3D FFE images of the rectum of a healthy volunteer. A conventional pulse was used at the upper row, while the 2D compensating pulse was used at the lower row. Notice the increase in signal further away from the antenna and the restored homogeneity of the transmit field. FOV=180x250x180mm^3; voxelsize=0.7x1.0x1.0 mm^3; $T_{R\,\text{conventional pulse}}$=15ms; $T_{R\,\text{2D compensating pulse}}$=50ms.

References

[1] van Kalleveen et al. ISMRM 2012: 0641. [2] Kroeze et al. ISMRM 2012: 0539. Sbrizzi et al. MRM 2011 66:879-885. [4] Yarnykh MRM 2007 57:192-200.