Hybrid Roemer Reconstruction for Multi-Element TX/RX Body Coil at 3T

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Introduction

For a TX/RX coil array, the transmit field inhomogeneity at higher field strengths (≥3T) is an important problem, which has been addressed by RF shimming [1,2]. However, as a result of the principle of reciprocity [3], the receive fields are affected by wave propagation effects at high fields as well. Hence, appropriate combination of the data from the individual receive channels has to be performed by image reconstruction to obtain homogeneous images. In this regard, the Roemer reconstruction [4] represents the optimum approach with respect to image homogeneity and SNR. Nevertheless, the complex coil sensitivities have to be known as a prerequisite, which, in general, requires an extra calibration scan. On the other hand, for an integrated, rigid coil array (e.g. multi-element body coil), a-priori knowledge on the coil sensitivities could be used to supersede the calibration scan. In the present work, a hybrid Roemer reconstruction based on pre-calibrated sensitivity data is proposed. It has been implemented, and its performance has been compared with simple data combination approaches based on sum-of-squares [4] or complex superposition.

Methods

Phantom and in-vivo experiments (five healthy volunteers) were performed on a 3T MRI system (Philips Medical Systems, Best, The Netherlands) equipped with an integrated 8-element TX/RX body coil [5]. The compatibility mode of the system was used [6], mimicking a standard quadrature body coil for both signal transmission and reception. Thus, the transmitted RF waveform was shifted by 45° between successive channels. Accordingly, for signal reception, the raw data were added prior to reconstruction, incorporating corresponding phase offsets (referred to as fast channel combination). For the present study, the raw data of the individual channels were additionally stored for subsequent analysis. Complex receive sensitivity maps were derived from phantom experiments (oil phantom with ∅=450 mm, standard gradient echo sequence, FOV =530² mm², scan matrix= 128²). For this purpose, complex images were reconstructed from the data of the individual channels and divided by the corresponding image derived from fast channel combination, which provided a homogeneous reference in case of the oil phantom. In-vivo, transversal stacks of different anatomical regions (thorax, abdomen, pelvis, legs) were acquired (Multi Slice FFE, FOV =530² mm², scan matrix =512², slice thickness=10 mm, number of slices=10, TR=100 ms, flip-angle =15°). Additionally, to check the transmit field homogeneity, in-vivo B_1 maps were measured using the AFI sequence [7] (FOV= 400×400×45 mm³, scan matrix =64×64×3, TR_1=20ms, TR_2=100 ms). For data combination, the following approaches were compared: a) fast channel combination, b) sum-of-squares, c) Roemer reconstruction using solely the phantom maps, d) modified Roemer reconstruction using the modulus of the phantom maps and the phases of the actual in-vivo scan. The results were compared qualitatively with respect to SNR and signal homogeneity.

Results

Fig.1 shows images of two different anatomical regions for the different data combination strategies considered. For the given scan protocol, the fast channel combination results in visible noise in the images (a). Moreover, significant image intensity variations (intensity holes) are noticeable. The sum-of-squares reconstruction yields improved SNR, but shows a systematic intensity drop in the image centre (b). The Roemer reconstruction based on phantom maps also improves SNR, however, fails to remove the intensity holes (c). In contrast, the modified Roemer reconstruction improves both SNR and homogeneity significantly (d), and hence, yields the best image quality while the phase of the image is preserved. Moreover, the corresponding B_1 transmit maps indicate that the remaining intensity holes in the images are mainly due to B_1 transmit field inhomogeneities (e).

Discussion

The lack of a homogenous reference coil represents a serious problem in high-field MRI, impeding applications such as e.g. SENSE [8]. The presented approach allows a body coil array to be used as homogenous reference. In addition, the SNR of the body coil array is boosted, thus facilitating simple imaging procedures omitting dedicated receive coils. Moreover, the approach comes essentially for free, since the receive maps have to be determined only once after system installation and calibration.

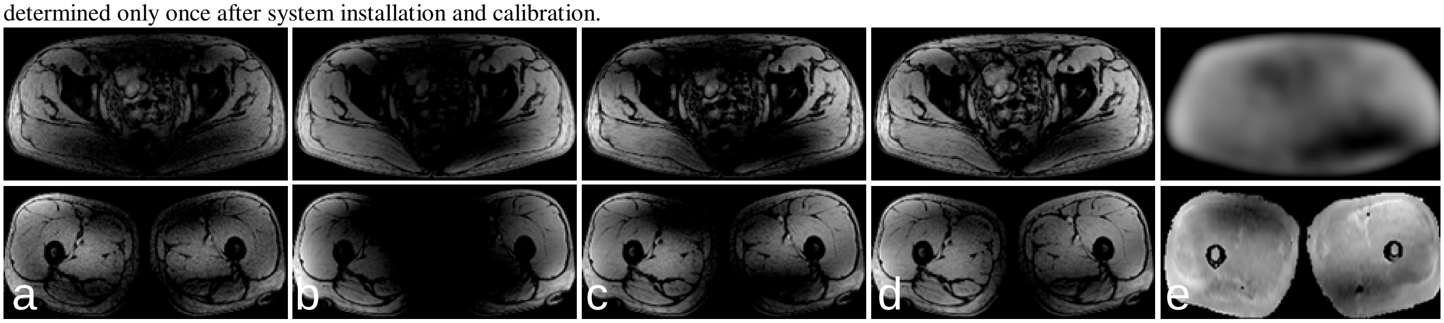

FIG. 1. Proton-density weighted gradient echo images of different anatomical regions (top: pelvis, bottom: thighs) for four different channel combination strategies (a: fast channel combination, b: sum-of-squares, c: Roemer reconstruction based on phantom maps, d: hybrid Roemer reconstruction). The images are leveled and windowed to emphasize intensity variations. In addition, corresponding transmit B_1 maps are shown (e). The B_1 transmit map of the pelvis was smoothed to suppress noise.

References

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