In-vivo RF Receiver Sensitivity Measurement Using Phase-Based B1+ Mapping on a Reverse-Oriented Subject

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Introduction: Phase-based B_1^+ mapping allows determination of the amplitude of the transmit RF field in a human body independent of the proton density and relaxation effects. Extension of the benefit of a phase-based method to RF sensitivity mapping would allow complete isolation of RF propagation-related image shading in high-field MRI and will help determine intrinsic capability of an RF coil and potentially reduce image shading through post-processing. Through reciprocity the receiver sensitivity is directly proportional to the B_1^- field of the receiver coil. Such field can be determined by transmitting RF through the receiver coil and mapping the resulting B_1^+ field on a reverse-oriented subject (say in a feet-first instead of a head-first position). For a conventional, circularly polarized volume T/R coil, no repositioning of the coil itself is necessary. In this work we present multi-slice abdominal RF sensitivity mapping in a 3 T birdcage coil using subject reorientation and Bloch-Siegert shift-based B_1^+ mapping [1].

Theory: The basic principle was previously demonstrated with a surface coil on a phantom [2]. Here, we demonstrate the method in vivo with a circularly polarized body coil. We use the recently published off-resonance Bloch-Siegert B_1^+ mapping method for fast mapping that is unaffected by image contrast. In general, using B_1^+ mapping to determine the receiver sensitivity of a T/R coil relies on reversing the relative orientation of the static field and the entire RF propagation system, i.e., the coil plus the subject. The T/R coil then has to transmit in its receive mode. For a conventional birdcage coil, reversing the coil orientation and then transmitting in the receive mode are equivalent to keeping the coil in original position and transmitting as usual. Therefore a single B_1^+ mapping sequence, applied twice on a given physical slice of a subject in two different orientations in the magnet, can give a B_1^+ map and a receiver sensitivity map of the coil.

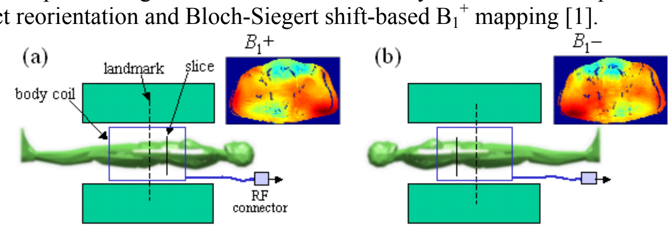

Figure 1. Subject orientation for receiver sensitivity mapping in a circularly polarized body T/R coil. (a) Imaging orientation in which usual B_1^+ maps are obtained. (b) Reverse orientation for B_1^- mapping

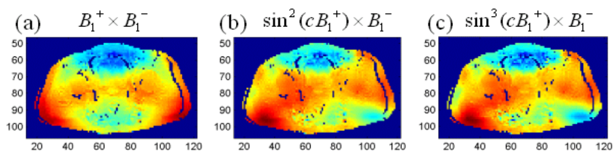

Figure 2. Predicted RF propagation contribution to image shading in a 3 T birdcage coil: (a)small-tip-angle GRE, (b)fast spin echo, (c) spin echo.

Method: A spin-echo based Bloch-Siegert B_1^+ mapping method was used to obtain multi-slice B_1^+ amplitude maps on the lower abdomen of a subject in a head-first supine position. The subject was subsequently taken out of the scanner, and was put in the magnet bore feet-first. The same B_1^+ mapping sequence was then applied to the same slices, guided by the optical landmark and the scanner's graphical prescription. Reasonable effort was made to avoid tilting the patient, which would cause alignment errors. Because B_1 field varies relatively smoothly in the body, a few mm offset in the patient position should not affect the measurement dramatically. Figure 1 summarizes the measurement procedure. Pixels representing air in either image are masked out using a common mask.

Results: Figure 2 shows intrinsic RF shading of the coil specific to the subject on one slice calculated by combining the measured B_1^+ and B_1^- maps (individually shown in Fig 1). For calculations on the spin echo images the multiplicative factor *c* in the titles of Fig 2 was chosen to make the average tip angle over the slice 90°. Figure 3 compares the transmit and receive sensitivity maps on five slices of the same subject and demonstrates their effect on GRE images. Approximate left-right flipping symmetry between the B_1^+ and B_1^- maps is seen on all slices. To validate the proposed sensitivity mapping method, we divided the raw images (top row) by $B_1^+ \times B_1^-$ to obtain significantly improved image homogeneity (bottom row). This is particularly noticeable in the relatively homogeneous and bright image intensity in the bladder liquid in the fourth and fifth columns.

Discussion: Despite significant improvement in image homogeneity shown here, post-processing-based shading correction using RF maps has two limitations: inconvenience of patient repositioning, and SNR loss. The proposed method, on the other hand, can characterize new and existing RF coils and guide their improvement [3] by singling out complete RF contributions to high field image shading in vivo. Accurate mapping of B_1^- field may also aid experimental determination of the electrical properties and RF power distribution in a human body [4].

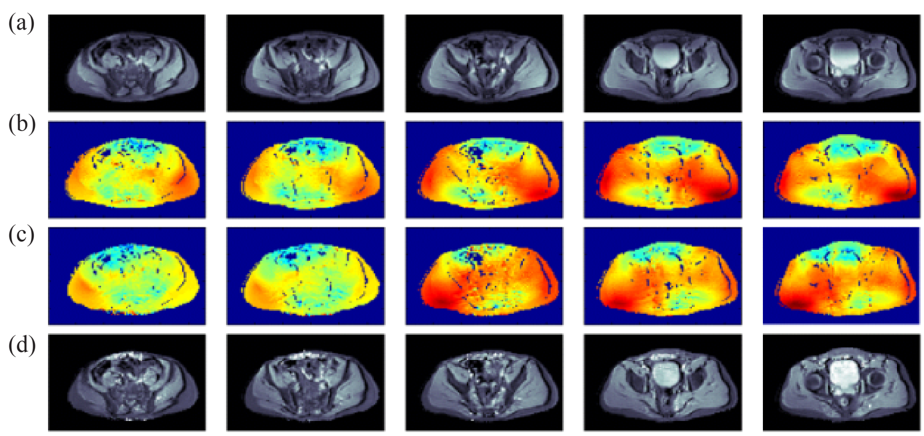

Figure 3. Transmit-and-receive RF shading effect in multi-slice abdominal GRE images at 3 T. (a) Raw images. TR/TE/slice thickness/slice number/tip = 2 s/4.5 ms/10 mm/10/10°. (b) Measured B_1^+ maps. (c) B_1^- maps obtained by the proposed method. Color scales are the same as in (b). (d) Raw images divided by $B_1^+ \times B_1^-$.

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References
[1] Sacolick L et al, Proc ISMRM (2010), 87 [2] Wang J et al., Proc ISMRM (2009), 4564 [3] Sacolick L et al, Proc ISMRM (2010), 3809 [4] Katscher U et al, IEEE Trans Med Imag 28 (2009), 1365