

Fast 2D B1 mapping by k-space processing of tagging patterns

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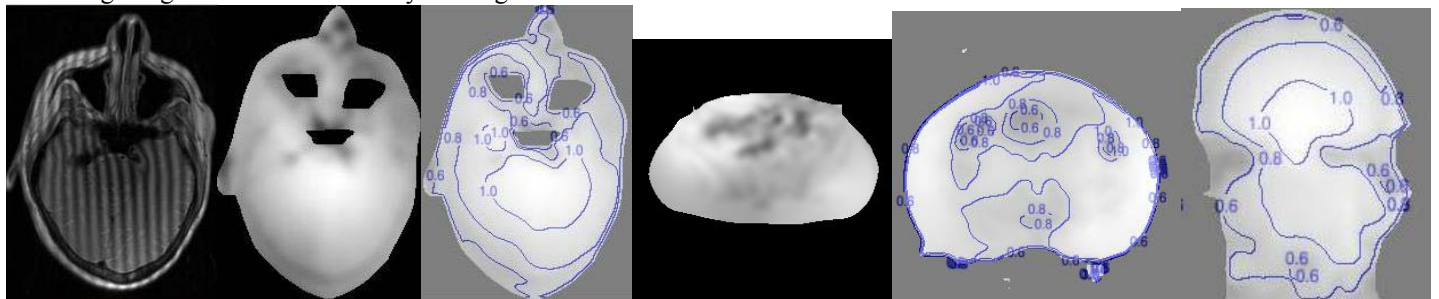
Introduction: Measuring B1 transmit fields in vivo has importance in areas such as high field imaging, parallel transmission design, and quantitative imaging. Numerous methods exist which exhibit tradeoffs between acquisition time, spatial resolution and coverage, accuracy, dynamic range, and robustness in the presence of motion. We present a new method of acquisition and data analysis for generating 2D B1 maps in vivo in as little as one TR. In this method saturation tag lines are applied before rapid imaging, tag lines are separated from the underlying image with k-space processing, and RF angles are computed from the tagging efficiency ratio.

Methods: 2D images are acquired with any imaging techniques used as readout, such as 1-shot or 2-shot FSE. A tagging prepulse [1] is applied immediately before excitation, consisting of $RF\alpha - GrSpoil1 - RF\alpha - GrSpoil2$. Where the $RF\alpha$ pulse does not exceed 45 degrees, tags result with a simple structure. The signal becomes partially suppressed with a sinusoidal pattern [2]. The amplitude envelopes of this modulated partial saturation are used to determine the RF pulse angle within the subject. If these envelopes are estimated directly in image space, difficulties arise from sampling the modulation peaks and valleys, and from spatial features in the unsuppressed image becoming confused with the modulation.

K-space processing reduces the problems in estimating the local tagging ratio. K-space is windowed into three strips: an unmodulated central strip, a modulated strip at the positive spatial frequency of the k-space tag spacing, and a modulated strip at the negative spatial frequency of the tags. The windowed k-space strips are reconstructed independently. Taking the magnitude of the complex modulated images removes the modulation frequency, leaving a pair of half-amplitude demodulated images. These are recombined into images of the amplitude modulation envelopes. A tagging ratio $R = (\text{SigSup} / \text{SigUnsup})$ is computed across the image, from the local maximally suppressed signal (SigSup) and the local unsuppressed signal (SigUnsup), i.e. the value at the "valleys" envelope divided by the value at the "peaks" envelope. R is converted to a flip angle with the relationship: $RF\alpha = 0.5 * \arcsin(1 - R)$. The spatial resolution in the final parametric image is set by the width of the window functions in k-space. This resolution is essentially the same as one spatial cycle of the tag line pattern. This acquisition yields a usable single-shot B1 map. Map quality can be improved by applying a 2-shot cycling and subtraction, alternating the polarity of one tagging $RF\alpha$ pulse relative to the polarity of the imaging excitation.

We implemented a rapid FSE sequence on a Toshiba 3T whole-body research system. We chose parameters so the sequence could be used across a wide range of anatomy, including: interecho spacing 6.5msec, TE 39, echo train length 53, and 192x256 matrix. Bias from T1 decay between tagging and excitation is typically about 1 percent, and can be ignored. Off-resonance effects are kept small by using short square pulses for the tagging RF pulses. B1 maps are generated of the B1 data, as are B1 isocontour overlays. Typical map resolution is about 1 cm across the tags.

Results: Representative volunteer images (acquired under IRB approval) are shown below. These used uncorrected body coil transmit with our B1 shimming hardware turned off, to demonstrate intrinsic subject-based field patterns. Below, the first tagged image is 1 of 2 phase cycles from an acquisition with 4 total shots. The second and third images show the resulting map from that acquisition, with and without isocontours. Of course, direct measurements are not possible inside signal voids such as the sinuses. The remaining images show other anatomy or image orientations.



Tagged Raw Image

B1 map

B1 Isocontours

Pelvis B1

Abdomen B1

Coronal Head B1

Discussion: This method has been used in our lab for investigational 3T imaging in all body parts. We routinely acquire midline sagittal, coronal and axial slices. In applications other than cardiac, a 4-shot version of the sequence currently is preferred, because of its good resolution and artifact suppression over a wide range body parts and FOV sizes. Two shots generate a higher resolution first tagged image, and further two-fold repetition provides the phase-cycled alternation improvement. Extensions to multislice volume require attention to preventing the tags from previous slices from affecting other slices acquired later.

References: [1] MR Imaging of Motion with Spatial Modulation of Magnitude. L.Axel, L.Dougherty. Radiology 1989. 171: 841-845
[2] Feasibility of rapid B1 mapping with RF prepulse tagging. X.Chen, X.Shou, W.Dannels. ISMRM 2008. Abstract #3045