Joint B0 and B1 Mapping from Tagged Rapid 2D Acquisitions

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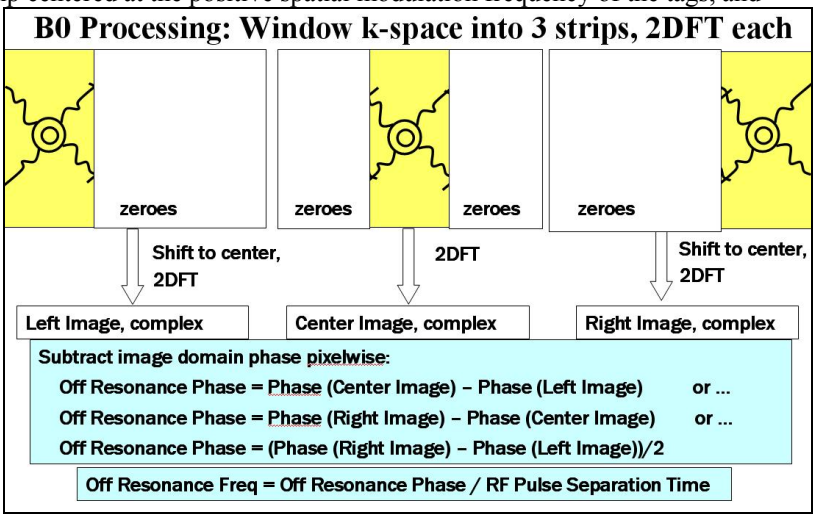
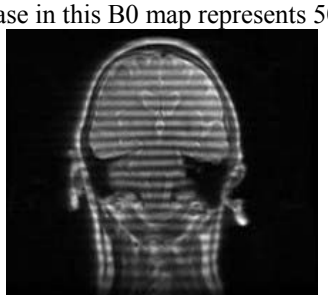
Introduction: A single acquisition with custom processing is presented which generates both B1 and B0 maps. It has previously been shown that RF spatial tagging in conjunction with k-space data processing yields a rapid method for 2D B1 mapping [1]. In this work it is shown that additional processing simultaneously yields 2D B0 maps. Off-resonance measurements can be useful in a variety of applications such as shimming, chemical shift methods, or temperature mapping. B1 transmit fields can be useful in areas such as high field imaging, parallel transmission design, and quantitative imaging.

Methods: Tagging prepulses can be applied immediately before excitation and readout, such as the simple SPAMM prepulse[2]: [(RFα) (GrModulate) (RFα) (GrSpoil)]. It is widely recognized that tagging is useful for tracking spatial displacements. It is less widely recognized that tags are also effective probes for measuring both transmit B1, and B0 or off-resonance. Where the (RFα) pulse does not exceed 45 degrees, local image regions exhibit sinusoidally modulated partial saturation. K-space is windowed into three strips: an unmodulated central strip, a frequency-shifted strip centered at the positive spatial modulation frequency of the tags, and another shifted strip centered at the negative spatial modulation frequency of the tags. The windowed strips are constructed independently. After the first RF pulse, tagged spins accrue phase $\Theta = \gamma(\vec{G} \cdot \vec{r} \cdot \delta + B0 \cdot \Delta)$, where (GrModulate) has amplitude $\vec{G}$ and duration δ, and the RF pulses are separated by Δ. After tag preparation, magnetization is $Mz = 1 - 2A(\cos(\Theta))$. The modulated portion of the signal appears at k-space locations $\pm\gamma \cdot \vec{G} \cdot \delta$ with phase terms $\pm\gamma \cdot B0 \cdot \Delta$. The k-space strips are shifted to remove the $\pm\gamma \cdot \vec{G} \cdot \delta$ terms, so the off-resonance effect $\pm\gamma \cdot B0 \cdot \Delta$ can be separated from other sources of phase by subtraction of the resulting phase maps. As previously demonstrated [1], an inverse cosine function of the ratio of the sums and differences of the magnitudes yields the B1 map.

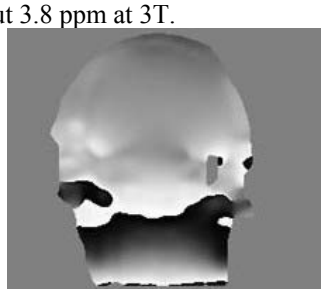


Results: Representative volunteers images (acquired under IRB approval on a 3T whole body research system) are shown for a raw tagged image (left), the B0 map (center), and the B1 map (right). The raw tag image used a multishot FSE readout and scan time 14 seconds. (The readout method can be chosen freely, as long as all of k-space is collected with the same tagging.) Areas of extremely low signal intensity are masked out, where the maps can become noisy. Phase wraps are not removed from this example B0 map, allowing the overall scale of the phase sensitivity to be perceived. Since the RF tagging pulses were separated by 2 msec, a complete cycle of phase in this B0 map represents 500Hz, or about 3.8 ppm at 3T.

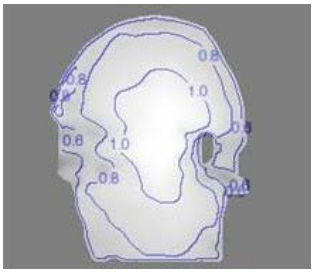
raw tags



B0 Map



B1 map



Discussion: The feasibility of extracting B1 and B0 maps simultaneously from rapid 2D slices has been shown. Other sources of spatial distortion should be considered in this technique, if they could be misinterpreted as B0 inhomogeneity. During the interval between tagging and acquisition, bulk translation (i.e. motion) can intervene. In the sequence above, for example, the time from tag generation to the readout of the center of k-space is 40 msec, and if tags have 6 mm spacing, then 1 cm/sec velocity yields tag displacement of 0.4 mm, or 0.066 tag cycles, similar to 0.25 ppm from B0 sources. If it is deemed important to distinguish possible motion from B0, then extensions of this technique are straightforward. Collecting two copies of the acquisition, each gated to capture the same motion but with opposite polarities of (GrModulate), yields two phase difference maps. Motion and B0 effects might then be separated by addition and subtraction of the two phase difference maps.

References: [1] Fast 2D B1 mapping by k-space processing of tagging patterns. W Dannels, A Wheaton. ISMRM 2010. Abstract #236. [2] MR Imaging of Motion with Spatial Modulation of Magnitude. L.Axel, L.Dougherty. Radiology 1989. 171: 841-845.