B1 Inhomogeneity Reduction with Transmit SENSE

V. Andrew Stenger[1,2], Suwit Saekho[2], Zhengui Zhang[2], Shuang Yu[1], and Fernando E. Boada[1,2]

[1]Department of Radiology, University of Pittsburgh, USA

[2]Department of Bioengineering, University of Pittsburgh, USA

INTRODUCTION:

Parallel imaging is an effective means of reducing acquisition *k*-space trajectories [1,2]. The same concepts have recently been demonstrated for reducing tailored RF pulse lengths using parallel transmitters [3,4]. Reduction of pulse lengths allows for practical implementations of multi-dimensional RF pulses. This paper presents 3D RF pulses for reducing B1 artifacts at 3T [5,6] and Bloch equation simulations of corresponding R=2 transmit SENSE pulses.

METHODS:

A slice $M(\mathbf{r})$ can be found for small tip angles using

$$M(\mathbf{r}) = \int C(\mathbf{r}) B_1(t) e^{-i\mathbf{k}(t)\cdot\mathbf{r}} d\mathbf{r}, \text{ where } \mathbf{k}(t) = -\gamma \int_t^T \mathbf{G}(s) ds.$$

$B_1(t)$ is the RF pulse, $\mathbf{G}$(t) are gradients that create *k*-space $\mathbf{k}(t)$, and $C(\mathbf{r})$ is the transmitter sensitivity. In matrix form, the pulse **b** can be determined by solving:

$$\mathbf{m} = \mathbf{Cb}.$$

The approximate **b** can be found from the "least squares" difference. Artifact reduction is accomplished by finding a $B_1(t)$ that excites an $M(\mathbf{r})$ tailored with a map or an approximate analytical function of the B1 inhomogeneity.

We designed two-shot (full *k*-space) and single-shot R=2 SENSE 3D RF pulses to reduce B1 inhomogeneity at 3T. The RF *k*-space was a spiral stack, slice thickness was 10 cm, pulse length 6.2 ms, and 45^0 flip angle. The full *k*-space pulses were demonstrated *in vivo* using measured B1 maps and a 128 phase-encode 3D acquisition.

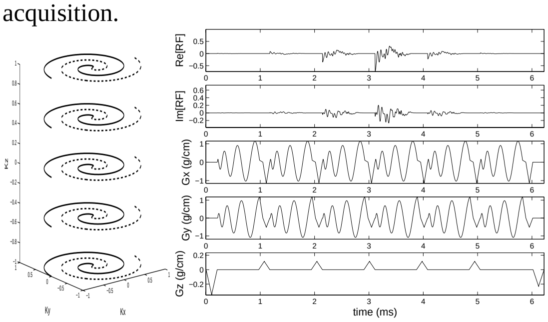

Figure 1: Stack of spirals *k*-space trajectory (left) and R=2 transmit SENSE 3D RF pulse (right). Each shot of the full *k*-space pulses looked similar.

The corresponding SENSE pulses were designed using sensitivity maps measured from a four-array receiver and the conjugate gradient least squares method (no regularization or conditioning). The pulses were simulated in the Bloch equations numerically. $M(\mathbf{r})$ was approximated as the difference between to Gaussians:

$$M(r) = \exp(-\pi r^2 / a^2) - \alpha \exp(-\pi r^2 / b^2).$$

Here *a* and *b* are the radii of the imaged object and the inhomogeneous region, respectively, and α parameterizes the degree of inhomogeneity.

RESULTS:

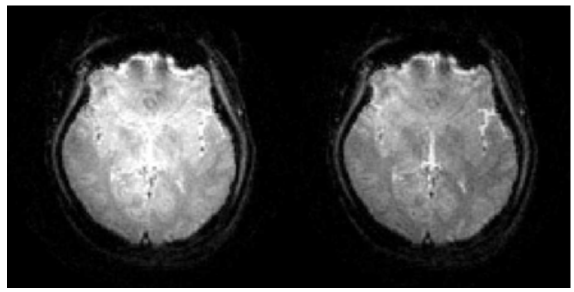

Figure 2: Head coil images at 3T using a standard RF pulse (left) and B1 inhomogeneity compensated full *k*-space two-shot RF pulse (right). Note the flatter profile in the right image.

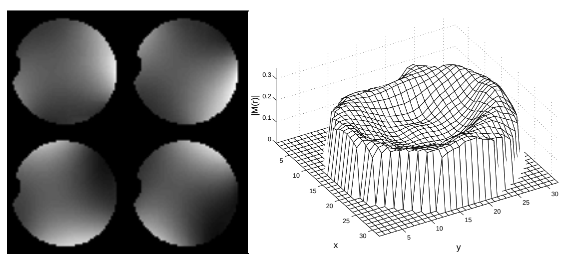

Figure 3: Sensitivity maps measured from array coil (left). Numerical simulation of inhomogeneity compensated $M(\mathbf{r})$ from R=2 SENSE pulse. Note the increased magnitude on the edges to compensate for the loss of signal.

DISCUSSION:

We propose transmit SENSE for reduced B1 inhomogeneity artifacts. A single pulse of 6.2 ms should be adequate in the brain over a 10 cm slab at 3T using a standard head coil. Implementation of transmit SENSE is being pursued but is hampered by lack of hardware.

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