Multi-slice Radio Frequency Current Density Imaging

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Introduction:

Radio frequency current density imaging (RF-CDI) is an imaging technique that measures electrical current density at the Larmor frequency, non-invasively, utilizing MRI. Previously implemented RF-CDI techniques [1] are only able to image a single slice transverse to the static magnetic field $\mathbf{B}_0$ (also the main direction of the RF current applied). In cases where the RF current density distribution in a plane parallel to the current flow direction or even in a 3D volume was of interest, the performance of RF-CDI was quite limited [2]. The goal of this work is to extend the ability of RF-CDI to image multi-slice RF current density.

Methods:

The Z projection sequence [1] was implemented on GE's Signa LX 1.5 Tesla MR imager to realize multi-slice RF-CDI. This sequence is essentially the rotating frame method as in the previous RF-CDI technique [3]. However, unlike single-slice RF-CDI, multi-slice RF-CDI stores components of magnetization in the z direction (parallel to $\mathbf{B}_0$) to utilize the T1 relaxation time. Because of T1 decay, the current density noise of each slice is dependent on T1 and the excitation order for the slice [4].

A cylindrical phantom with diameter 38 mm and height 110 mm was used for multi-slice RF-CDI experiments. Copper plate electrodes were placed on both ends, through which the Larmor frequency current was injected. The phantom was filled with CuSO4 doped saline. It was oriented with its cylindrical axis parallel to $\mathbf{B}_0$, so that the current was flowing mainly along $\mathbf{B}_0$. Rotating frame magnetic components were extracted from complex MR images. Current density was then computed by taking spatial derivatives of these components. Images without current applied were also acquired and processed to evaluate the RF current density noise.

Results:

The reconstructed RF current density magnitude (top) and phase (bottom) images for axial and sagittal slices are shown in Figure 1 and Figure 2, respectively. The current density images have overall uniform pattern. Figure 3 shows the results of
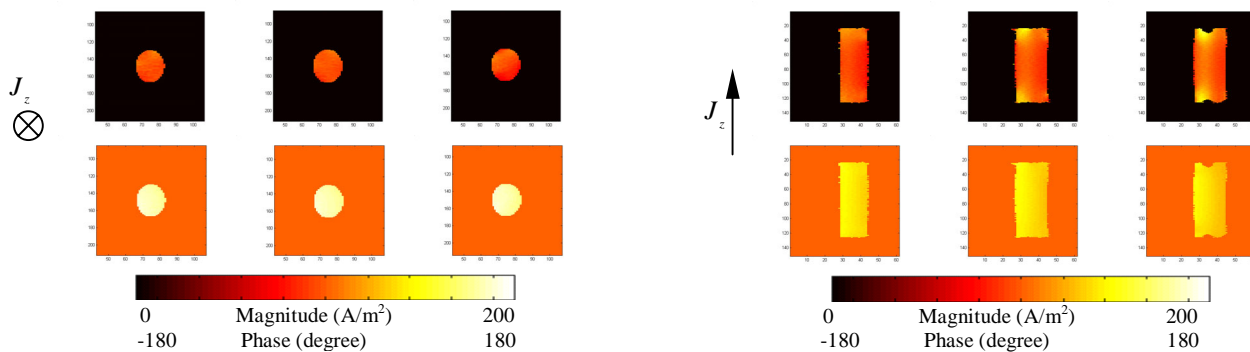

Figure 1 RF current density magnitude (top) and phase (bottom) images for three axial slices. The current direction is shown by $\otimes$

Figure 2 RF current density magnitude (top) and phase (bottom) images for three sagittal slices. The current direction is shown by the arrow.

measured and predicted [4] current density noise from seven slices for experiments with different imaging parameters. T1 was about 160 ms for these experiments. Current density noise increases exponentially with respect to the slice excitation order as predicted.

Discussion and Conclusions:

This is the first multi-slice RF-CDI sequence capable of imaging RF current density in multiple slices parallel or orthogonal to $\mathbf{B}_0$. The T1 relaxation rate of the material constrains the number of slices that can be imaged. For most biological applications, multi-slice RF-CDI will be able to image about 5 to 20 slices depending on the T1 values.
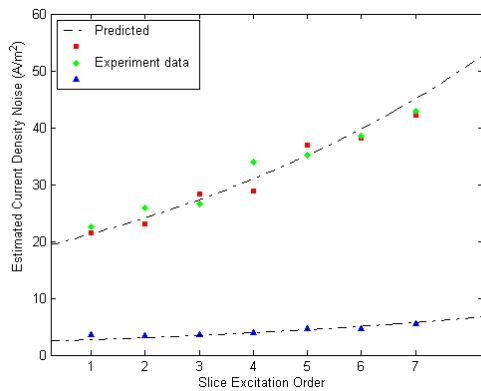

Figure3 Current noise evaluation with zero current

References

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