SENSE Imaging Using a Transmission Line Volume Phased Array

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Purpose

In this work we demonstrate feasibility of extending the SENSE unaliasing algorithm to volume coil acquisitions. In this method an MR image is acquired from each individual element of a transmission line volume coil in which the interaction between the elements has been reduced to allow each resonant element to operate independently at 63.8 MHz.

Introduction

The time consuming operation in most MR imaging methods is the acquisition of the multiple phase encode steps. Rapid imaging techniques acquire multiple lines of k-space lines in a single acquisition at the expense of susceptibility induced image distortion and intra voxel dephasing (in EPI) or T2 decay (in RARE). Several strategies which un-alias a folded Fourier image have been proposed which allow a reduction of the number of phase encoding steps required.(1-5) These methods use the sensitivity profile of multiple receiver coils to provide the spatial information needed to unfold the reduced FOV image. The feasibility of these techniques has been reported for surface coil arrays using the k-space based SMASH reconstruction method(5) and the spatial domain based SENSE method.(3,4) Similar reconstruction techniques have utilized the spatial information available when both the uniform and gradient mode of a birdcage coil are simultaneously recorded.(2)

In this work, we demonstrate the feasibility of extending this method to a four leg volume-type coil in which the signal from each leg of the coil is recorded by a separate receiver. Coupling between elements is eliminated by the low impedance input of the preamplifier and inductive coupling is reduced by the close proximity of an RF shield. This renders the frequencies of the individual elements degenerate. The method is demonstrated with a 4 element, 4 receiver coil but offers the potential for extension to more uniform imaging by using a larger number of elements.

Methods

To demonstrate the volume-SENSE reconstruction, aliased gradient echo images were acquired using a 1.5T GE Signa scanner equipped with 4 phased array receivers. Phantom images with two-fold aliasing were acquired by reducing the FOV to 11 cm; half of what would normally spatially cover the object. Thus, the reduced FOV images required encoding half of the k-space lines. Magnitude images were saved from each of the 4 receivers and stored for off-line reconstruction. Full FOV phantom images from each individual receiver were also acquired as a map of the sensitivity of the individual receivers.

The pixel value of the aliased image at a given spatial coordinate (x,y) is described by the column vector **I**, where each of the 4 elements of the vector represent the measured magnitude intensity recorded by each of the 4 receivers. In the folded image acquired with half the number of k-space lines, the intensity at location x,y recorded by receiver *i* (I_i) is the linear combination of the signal intensity b_1 and b_2 from two spatial locations which are aliased onto one another. The linear combination is described by the 4 x 2 element sensitivity matrix **S**. Thus, the aliased pixel value is described by the over-determined linear equation,

$$\mathbf{I} = S\,\mathbf{b} + \mathbf{e}$$

where **e** is the error vector associated with each solution **b**. Least square fitting of the over-determined system was performed determine **b** while minimizing the error vector.

Results and Discussion

The methods were evaluated in a phantom imaging experiment using 4 receivers. Figure 1 shows the full FOV magnitude images acquired from the individual receivers and the combined image after application of the sum-of-squares algorithm. Figure 2 shows the half FOV aliased image acquired with half of the phase encode steps and the computed unfolded image. The spatial information contained SENSE reconstructed image allowed good reconstruction of the aliased data.

While the current coil implementation was limited by the number of phased array receivers available, this and other applications motivate the commercial development of increased receiver channels. The SENSE reconstruction may benefit from more coils by further overdetermining the linear equations and increasing the number of coil elements will potentially provide increased uniformity in the reconstructed image.

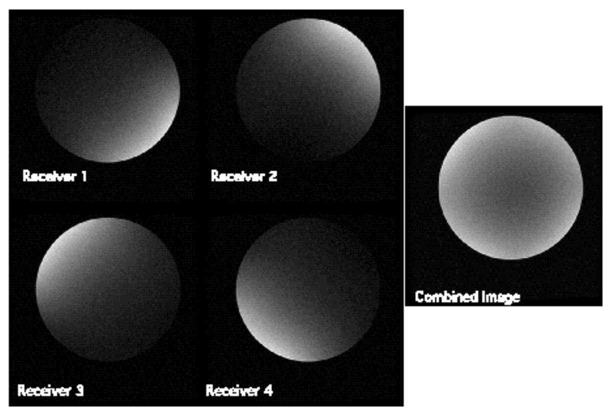

Figure 1. Phantom images from the individual receiver coils. Gradient echo images, FOV = 22cm, 256 x 256.

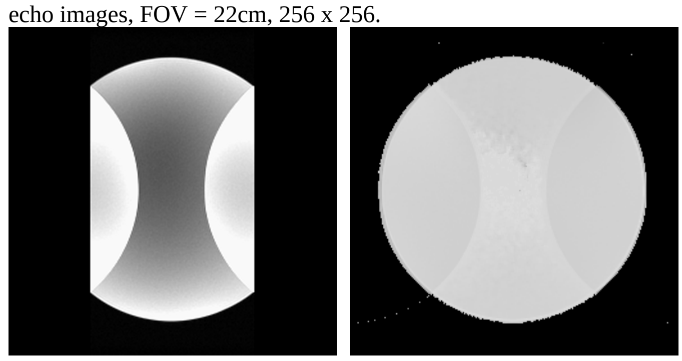

Figure 2. Aliased and SENSE reconstructed images from the individual receivers. The acquired image used the same parameters as Fig. 1 but an 11 cm FOV in the phase direction and 128 phase encode steps.

References

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