Improved SNR/g using Small FOV Spatially Selective Pulses with Parallel Excitation

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Introduction

Recently, substantial effort in the area of transmit SENSE has focused on exciting uniform high flip angle profiles [1] and increasing the bandwidth of spatially selective excitations [2], with the aim of improving excitation homogeneity and making arbitrary shaped excitation for spectroscopic imaging feasible. Reduced FOV for cardiac imaging is an important application of spatially selective pulses, where zeroing the signals outside the excitation ROI is far more important than achieving a uniform profile. A main concern to this approach is SAR limitations, which relates to the transmit pulse length that is constrained when motion artifact plays a role in image quality. Transmit pulse lengths can be reduced by using a Tx array system [3], where complex 2D/3D pulse profiles can be achieved using a set of shorter pulses. Here, we use a 3T 8-channel transmit system for applying spatially selective RF pulses to reduce the imaging time required for a localized ROI without SNR drawbacks.

Methods

The focus of our spatially selective RF pulses was placed on zeroing the region within the sample, but outside the desired FOV. This is because after the reduced FOV is applied in the imaging sequence, it is no longer possible to unwrap the aliased signals. To minimize the artifact signal, we acquired accurate, complex experimental $B1^+$ sensitivity profiles by applying the all-but-one mapping technique [4], which required assuming a uniform phase distribution for the body coil. An 8-channel transmit-receive head coil was constructed, as shown in Fig. 1a). As shown to be optimal in [5], we used a variable density spiral trajectory of R = 5.6 (based on pulse length), such as Fig. 1b), to minimize outside signal excitation with a 20 spiral trajectory of length 11.8ms. To remove the high frequency ripples associated with sharp edges, a ramped transition was used at the side of our target square excitation, 1/3 the diameter of our 12cm phantom, prior to pulse calculation with our least squares pulse designer. With excitation artifact signal below the noise floor, an ideal (unity) g-factor map results for the designed reduction, being R = 3 in our case.

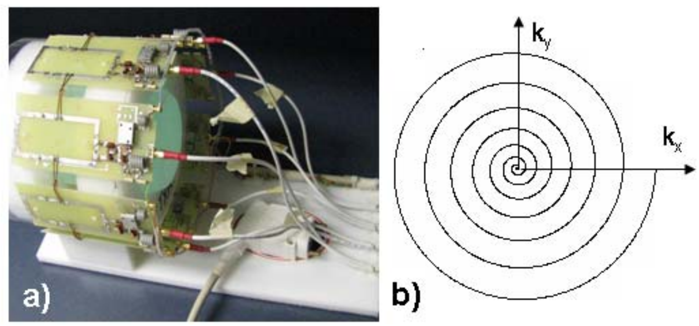

Fig. 1: a) 8-channel transmit-receive array constructed around a 20cm former with evenly distributed 4cm x 10cm azimuthal elements. b) Variable density spiral gradient trajectory with double the k-space sampling density at the center relative to the sampling density at the outer edge for efficient k-space coverage.

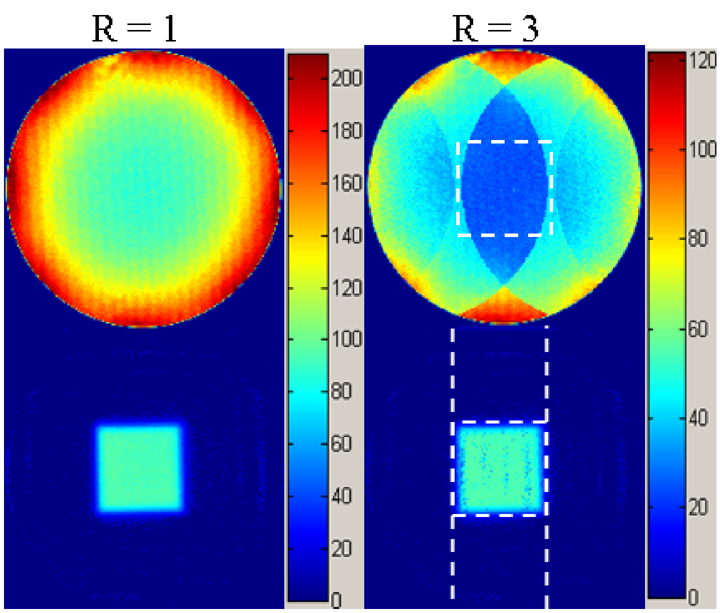

Fig. 2: Experimental SNR/g axial plots demonstrating SNR gain for R = 3 from a uniform excitation (top) and a spatially selective excitation (bottom) with a FOV 1/3 the size of the object. The SNR in the R = 3 images is scaled by a factor of $\sqrt{3}$ to accommodate the SNR dependence on $\sqrt{R}$.

Results

From the SNR plots in Fig 2, the improvement is clear for the designed R = 3 small FOV. The average g-factor in the dashed box of the top right image of Fig 2 is 2.08, which significantly degrades the image quality in that ROI. By treating the artifact signal as noise when reducing the FOV by the dashed lines in the bottom right image of Fig 2, the average SNR within the dashed squares is improved from 25.4 (top right) to 50.4, indicating a 98% gain in the small FOV case. For each specific application, a different spatially selective pulse must be generated for the exact ROI desired.

Conclusions

We investigated parallel imaging capabilities by using RF pulses to suppress sample signals outside the ROI. We showed that significant SNR gains can be realized with reduced FOV imaging by using spatially selective excitations on a transmit array system. For future improvements, more work can be done to optimize the RF pulse calculator, such as implementing a 3D optimal control approach [1] with a cost function to minimize artifact signals. Also, transmit coil array design should be optimized for minimizing SAR.

References

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