Using RF to Create Nonlinear Virtual Coil Profiles

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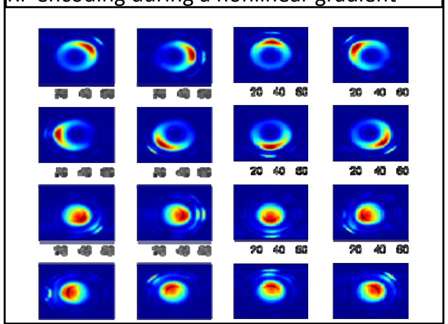
Introduction

We previously presented a sequence that used RF to create virtual coil sensitivity profiles (B1 Accelerated Reconstruction: BAR imaging), which effectively localize the signal to a particular region of the FOV. [1] In addition to increasing the effective number of coils, BAR imaging tailors coil profiles to efficiently compensate for the ambiguity introduced with undersampling. For example, that work showed that accelerated Cartesian data is complemented by rectangular bars chosen to excite patterns that minimally overlap when undersampled, allowing for much higher acceleration factors.

However, with the increasing availability of high powered nonlinear gradient sets, other shapes are possible that can better complement the azimuthal arrangement of multichannel coils. [2,3] Exploiting this flexibility, we present an implementation of ring-like RF profiles (BARings) and the acceleration enhancements they can bring to multichannel radial acquisitions.

Figure 1: Virtual coil profiles generated with RF encoding during a nonlinear gradient



Methods The sequence used to collect the BARing data is essentially identical to that used in the original BAR imaging method, except that the slice gradient and its rephaser are gradients of the shape ($2z^2-x^2-y^2$). Briefly, a series of slice selective RF pulses each excite a given shape in the sample, and gradient dephasing makes each of those excitations refocus sequentially with the same echo time.[1] Our preliminary implementations use a 3D encoding method to avoid complications from a nonuniform slice profile. Figure 1 presents the profiles generated on a 3T Siemens Trio using a liquid-cooled, actively-shielded z^2 gradient insert coil designed by Resonance Research, Inc. (Billerica, MA), which is able to generate up to 14,600 Hz/cm^2 . The figure shows data from a 2 ring sequence acquired with an 8 channel coil, resulting in 16 virtual coils available for spatial encoding.

Results and Discussion

Since surface coil profiles are not usually arranged for optimal encoding along the undersampled direction, we address this using RF encoding, not as a virtual gradient applying phase shifts to the entire sample, but rather as virtual coil profiles. The RF modulation is used to effectively break the image into a series of smaller images, and the signals from each of the smaller images are acquired in separate windows in an interleaved fashion at no time cost.

BAR encoding improves reconstruction of Cartesian undersampled data by localizing the sample along the single cardinal direction where all the undersampling occurs. This is in contrast with radial sampling, where the ambiguity occurs along many directions, namely the unsampled radial projections. Normally, the Fourier components of radial projections only provide information along those directions, with no localization perpendicular. However, when it is known that this signal is coming from a particular ring of the sample, it is actually localized in two directions, simply by virtue of the 2D geometry of the ring encoding function. Furthermore, the azimuthal geometry of the physical coil profiles further resolve this ambiguity by efficiently resolving the ambiguity within the ring, ultimately leading to better reconstructions at high acceleration factors.

Figure 2: Comparison of reconstructions with and without BARing encoding for various accelerations

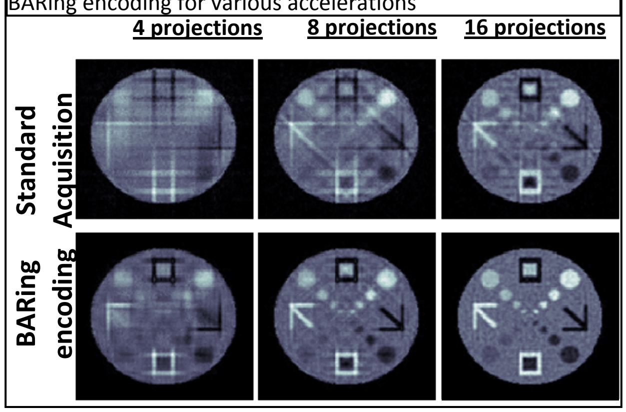


Figure 2 illustrates the improvements that can be attained with BARings profiles compared to regular coil encoding. Results are simulated for an 8 channel coil where the signal is either acquired with conventional parallel imaging or with a 4 ring BARings encoding, which provides 32 effective coils analogous to those shown in Figure 1. In both cases the data are reconstructed to a grid of 128^2 using a conjugate gradient algorithm. As can be seen , the additional encoding from the 32 virtual coils make an adequate reconstruction with as little as 8 projections. At 16 projections, though both images capture the broad features of the phantom, the BARings encoded data has significantly higher resolution, as can be seen by the better delineation of sharp edges within the phantom.

References: [1] G. Galiana et al, Proc. ISMRM 18, 4810. (2010). [2] J.P. Stockmann, P.A. Ciris, G. Galiana, L. Tam, and R.T. Constable, Magn. Reson. in Med., 64(2):447-456. (2010) [3] R. de Graaf et al, Proc ISMRM 15, 1350. (2007)

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