Enhanced Parallel Imaging Acceleration with a B1 Accelerated Reconstruction Sequence (BARS)

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Introduction

Sensitivity encoding with multichannel receiver arrays has become commonplace, but the typical acceleration factor achieved, even with large arrays, has remained modest. A major factor limiting these acceleration factors is that surface coil profiles overlap with one another and are not usually arranged for optimal encoding along the phase encode direction. While many methods have been proposed to increase efficiency with alternative encoding functions,[1,2] we present an approach that applies the concepts of traditional accelerated imaging, such as EPI or RARE, in such a way as to maximize the acceleration factor gained by multichannel receiver encoding. The preliminary implementations of this sequence consists of excited bars in the field of view, earning it the acronym BAR (B1 Accelerated Reconstruction) imaging.

Methods

To improve the distinctness of the sensitivity profiles, we use RF excitation to shape the effective sensitivity profiles. In particular, we choose shapes that better resolve ambiguities arising from high degrees of undersampling along the phase encode direction. Unlike previous RF encoding techniques, the RF modulation in our sequence is chosen to break the image into a series of smaller images which are acquired in separate windows in an interleaved fashion at no time cost. Furthermore, each window has identical timing from the excitation, eliminating the relaxation induced distortions seen in traditional accelerated imaging sequences. (Figure 1)

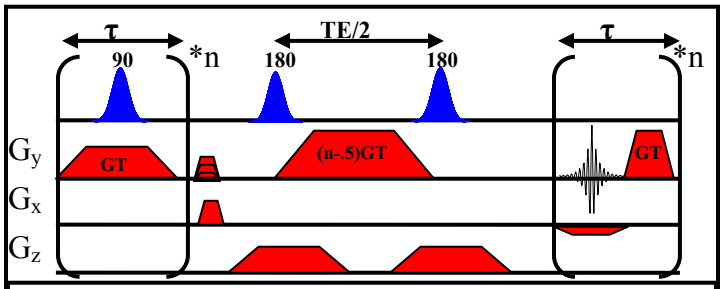

Figure 1: BAR Imaging Sequence. Each excitation pulse excites a particular shape within the field of view according to the pulse profile and the gradient strength. These n subdivisions of the image are then sequentially refocused in the same order they were excited so that each has identical T2 weighting.

In essence, the subdivision of the image is equivalent to weightings with spatially-varying hybrid sensitivities, similar to those produced by receiver arrays. Identical mathematics can be used to reconstruct the images, but there is far greater flexibility in sculpting the sensitivity profiles, which is a crucial advantage of this approach.

Results and Discussion

Both simulations and experimental data confirm that this sequence increases the upper bound on the achievable acceleration factor to (Number of coils)*(Number of Windows). (Figure 2) Furthermore, the choice of RF profile can be made to minimize the G-factor of the image; for example, the pulses can excite discontinuous profiles that are easily teased apart by the array sensitivity. (Figure 3) We present studies on G-factors and resultant images for sequences implementing different encoding shapes and divisions. With accurate knowledge of the surface coil and RF excitation profiles, SENSE produces robust reconstructions. However, we have also achieved successful reconstructions using GRAPPA, potentially obviating the need to measure the RF excitation profiles. We are presently investigating the combination of ACS lines and GRAPPA kernels best suited to BAR imaging.

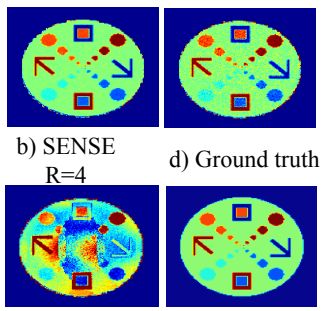

Figure 2: Simulated comparisons. With noise, an 8 channel array can typically only reach acceleration factors of 2-4 before the ambiguity is no longer completely resolved by the coils. (a-b) With the proposed sequence, we can break the image into ten windows chosen to maximize the disambiguation provided by the coils. Thus, the data can be undersampled by a factor of 20.

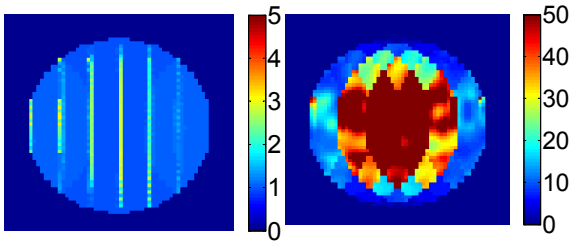

Figure 3: G-factor maps for 8 coils, R=8.
a) Experimental verification of BAR acquisition with 4 windows effectively creates 32 coils that can be shaped to minimize the G-factor.
b) Acquiring the same image in a single window, the G factors are an order of magnitude greater. In both cases, multicoil acquisition is simulated by multiplication with experimental coil profiles.

References

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