IMAGING IN A ROTATING FRAME: MRI WITHOUT B0 GRADIENTS

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PURPOSE: Spatial encoding with reduced reliance on B_o gradients has always been an interest for specialized applications. Examples include Hoult's rotating frame zeugmatography [1], and surface NMR devices relying on static B_0 gradients to perform depth profiling [2]. Parallel MRI partially replaces B_o gradient encoding and has proven immensely successful [3,4], but even before parallel MRI was demonstrated several investigators proposed entirely eliminating B_o gradients [5,6]. Lin and others have demonstrated entirely replacing gradient encoding in one direction [7,8]. Sharp has performed RF phase encoding with transmit arrays [9]. In another variation, Crozier's group has demonstrating rotating a receiver coil at very high rates to create a virtual array for RF spatial encoding [10]. Here we demonstrate early results from a novel planar imaging technique for MR imaging that uses no gradients at all, performing all spatial encoding by a combination of RF encoding and rotating the object. With some added complexity, the coil could be rotated instead. The specific interest here is the development of a simple, low-cost imaging system that is robust to magnetic field homogeneity.

METHODS: A sixty four element array of parallel, thin elements was used, combined with an in-house developed sixty four channel receiver and acquisition system [11]. A dish phantom was placed on top of the array, which was oriented in the coronal plane inside a 4.7T 40 cm scanner. The phantom was rotated and a single spin echo was simultaneously acquired from each element of the array at 4 degree increments of rotation. The center point of the spin echo from all 64 coils provides a 64 point projection of the magnetization along the axis perpendicular to the long axis of the array elements. Projection reconstruction was done in MATLAB. Uniform rotation was obtained by attaching an opaque wheel was attached to the rotor, with holes every four degrees. The wheel interrupted an optical beam, which generated a trigger for the scanner each time one of the holes passed during the rotation.

RESULTS: Figures 1a -1d compare Single Echo Acquisition images acquired with a frequency encoding gradient along the long axis of the element, at TE = 10 and 50 msec, to the no-gradient images obtained as described above. Some artifacts are caused by normalization of the signal from the different coils. Figure 2 demonstrates the robustness of the no-gradient approach to magnetic field homogeneity, comparing a conventional spin-echo image at low bandwidth (gradient strength) to the no-gradient image with a ferrous object distorting the magnetic field.

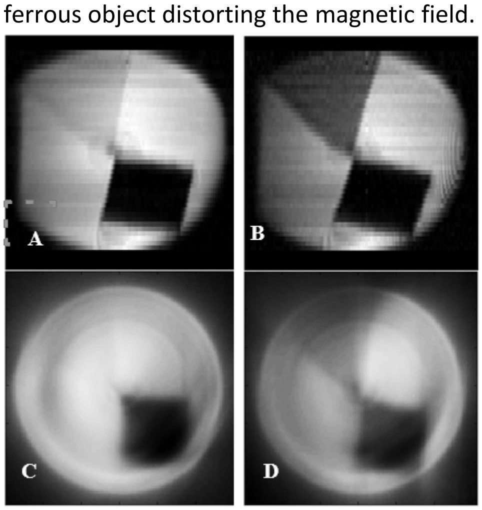

Figure 1. (Top) Frequency encoded images (no phase encode) using RF encoding in one direction. (Bottom) Corresponding images using no gradient encoding. TE = 10/50 left/right.

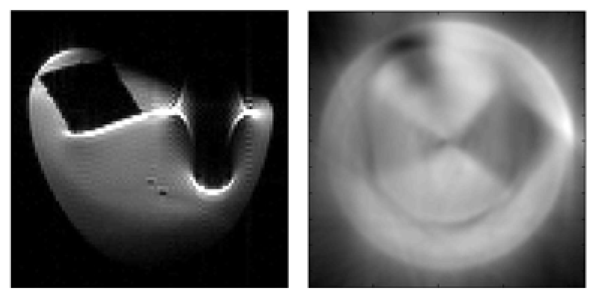

Figure 2. Left: Fully gradient encoded spin echo image on left, no-gradient image on right. Both images at TE = 35 msec, but the image on the left uses an 8 KHz spectral width, shims are off. An identical ferrous object, evident in both images was inserted onto the phantoms (chip resistor).

DISCUSSION AND CONCLUSION: 2D MR single point imaging using no B_o gradient encoding has been demonstrated using an array of long, parallel coils beneath a rotating phantom. SNR efficiency is high compared to mechanically probing the object as signal from the entire plane is obtained with each data point. As implemented here, only the magnitude of the echo peak is used, meaning that very simple data acquisition systems can be used. Additionally, the single point method is relatively insensitive to magnetic field inhomogeneity [2]. Thus, the method has the potential to enable very inexpensive MR imaging systems that may be used in applications where subsurface imaging is useful. Limited slice selection without gradients has been demonstrated previously by transmitting with the array and adjusting power [12].

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