Coil Phase Compensation for Single Echo Acquisition (SEA) Imaging

M. P. McDougall[1], S. M. Wright[1]

[1]Electrical Engineering, Texas A&M University, College Station, TX, United States

Introduction

Using an array of 64 coils and a prototype 64 channel receiver [1,2] we have previously demonstrated the ability to obtain an entire image from a single echo acquisition [3,4]. In certain applications, single echo acquisition (SEA) imaging will enable MR imaging without phase encoding or other gradient based image encoding techniques. An interesting aspect of SEA imaging is the interaction between the array element phase patterns and resolution, and the need to compensate for this phase. This paper describes this interaction and how to correct for it with a fixed gradient pulse.

Methods

The fact that coil phase patterns can act as phase encode gradients was first observed by Jesmanowicz in 1984 [5]. This effect was later used in partially parallel imaging methods using array coils [6,7]. When the coil size is on the order of the voxel dimensions, the phase pattern of the coil becomes an important factor that must be taken into account. In order to calculate the necessary phase compensation gradient strength, a program was developed to model the phase across the planar pair element for a given coil size and imaging height above the array [see Figure 1]. Given the sequence parameters then, the compensation strength was translated to the k-space line that optimized SNR. The standard spin echo sequence on our GE Omega system was modified to allow the selection of a k-space line in order that imaging parameters could be freely changed, the echo strength observed, and the optimal line selected at the console without having to re-run the modeling program. 64 fully encoded (128x256) images of a 13 cm diameter resolution phantom were simultaneously acquired using the 64 channel receiver and the 64 channel array coil. 256 single echo images (128x64) were then reconstructed with progressing compensation gradient strengths – one from each phase encoding line – to compare the modeled and measured phenomena.

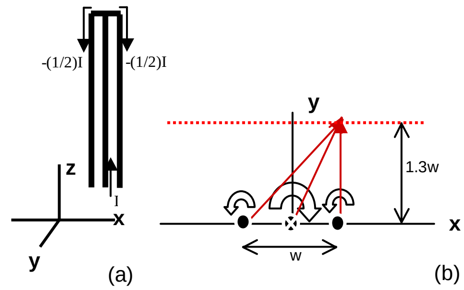

Figure 1: (a) Diagram of a planar pair element and (b) an “end-view” of the phase and a sample calculation line for the phase across the coil..

Results

Figure 2 shows the dependence of the optimal compensation strength on the imaging depth. A stronger compensating gradient is needed (i.e. red peak is at a higher k space line) to maximize the signal from a slice closer to the array where the phase across the coils is steeper. The figure also shows the close agreement between the calculated [relative] signal (blue) and the measured (black point data) versus k-space line. The calculated phase across the coil with and without various compensation gradient pulses and the corresponding SEA images are shown in Figure 3. As anticipated, the signal is lowered by the phase of the coil when no compensating gradient is applied, is maximized when the optimal compensation is applied, and emphasizes high frequency content when an overcompensating gradient is applied.

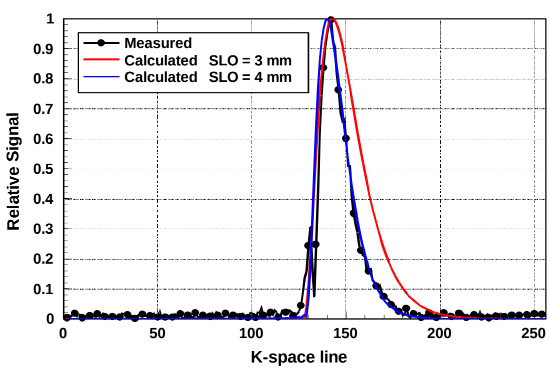

Figure 2: Relative signal strength vs. gradient compensation strength (translated to k-space line) showing 1. dependence of the optimal point on imaging depth (red and blue) and 2. close agreement between calculated and measured data (blue and black).

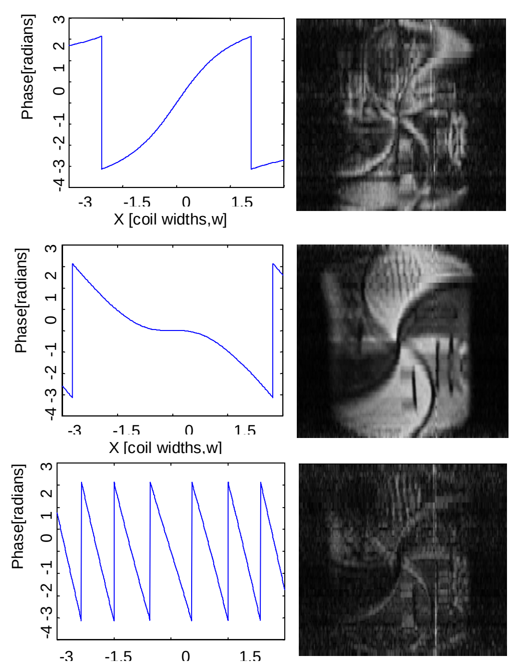

Figure 3: The phase across the coil and a SEA image (128x64) formed with k space line=0 (no compensation gradient)

Phase and SEA image with optimal compensation gradient applied

Phase and SEA image with over-compensating gradient applied, highlighting the high frequency components.

Conclusion

The phase pattern of the coil is a significant factor when a coil dimension is on the same order as the voxel size, as is the case in SEA imaging. The effect of this phase can be corrected by using a single compensation gradient pulse, in the place of the usual phase encoding gradient pulse. The amplitude of this pulse depends on the coil dimensions, imaging depth and pulse duration, and can be optimized for signal-to-noise or, alternatively, to accentuate particular spatial frequencies in the image.

References:

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