Reducing Eddy Currents Artifacts for Self-Navigated Reconstruction in b-SSPF by Super-Segmented Acquisition

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Introduction: Recently, there has been great interest in cardiac and respiratory self-navigated sequences for cardiac imaging [1,2]. Such techniques could prove valuable for free breathing SSFP imaging of the heart. Common to these approaches is that the center profile in *k*-space (e.g. k_y=0 and k_z=0) has to be traversed at a pre-defined frequency that allows determination of respiratory and cardiac motions. However, the need for repeated acquisition of the center profile causes large jumps in *k*-space. These jumps, and the jumps in a regular segmented acquisition, introduce changes in eddy currents that disturb the steady state used in balanced SSFP sequences causing image artifacts [3]. We propose a new profile order scheme for 3D cine acquisition that avoids large jumps in *k*-space while enabling frequent sampling of the center of k-space. Experiments were carried out in a static phantom and the impact of eddy current artifacts in the images was qualitatively assessed.

Methods and Results: The new profile ordering scheme was implemented by modifying a segmented acquisition with N_S profiles per segment. The k_y-k_z space was divided into triangular areas (k_x is the readout direction), each defining a region that we will refer to as a Super Segment (SS). Each SS contains a number of profiles which are a multiple of N_S, i.e. each SS consists of a number of sub-segments. To order the profiles in each SS we defined two paths, one going from the center to the periphery and one in the opposite direction. The path of the profiles starting at the centre was directed such that the following two expressions were minimized: a) $\min(\text{dist}_o + \text{var}(\mathbf{d}_{out}))$ and b) $\min(\text{dist}_i + \text{var}(\mathbf{d}_{in}))$, where dist_o and dist_i are the distances for the next jumps in the two paths and the var function indicates the variance of all previous jumps in the two paths, $\mathbf{d}_{out}$ and $\mathbf{d}_{in}$. An example of the resulting profile order is shown in Fig. 1. In the standard segmented sequence, the same segment is acquired repeatedly for each cardiac phase, but in order to minimize *k*-space jumps, our sequence acquires a neighbouring sub-segment with each subsequent cardiac phase.

To test the method a bottle of doped water - which is highly sensitive to eddy currents - was scanned using a b-SSFP sequence. The imaging parameters were TE/TR = 1.5ms/3ms, flip angle = 50°, resolution 2.5x2.5x2.5 mm^3, matrix = 128x112, 40 slices, 17 cardiac phases, Ns =16 and 112 profiles per SS. The algorithm mentioned above was implemented on a Philips Achieva 1.5T scanner. Four scans were performed; (a) a segmented acquisition scan (Fig 2.a); (b), a segmented acquisition scan including the central line of k-space, acquired every 336ms (Fig 2.b); (c), a SS acquisition scan without the central line, (Fig 2.c), and (d), a SS acquisition acquiring the central line at the same frequency as for Fig 1.b (Fig 2.d). It is clear from visual inspection that eddy current artifacts are present in both Fig 2.a and 2.b (standard segmented acquisition), while the images obtained with the SS acquisition are relatively free of eddy current artifacts.

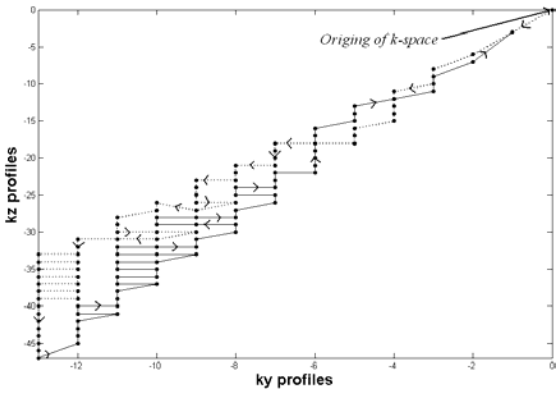

Figure 1. This is the path that defines in which order the profiles must be acquired. Dotted and bold lines represent the outward and inward paths from the center of k-space, respectively.

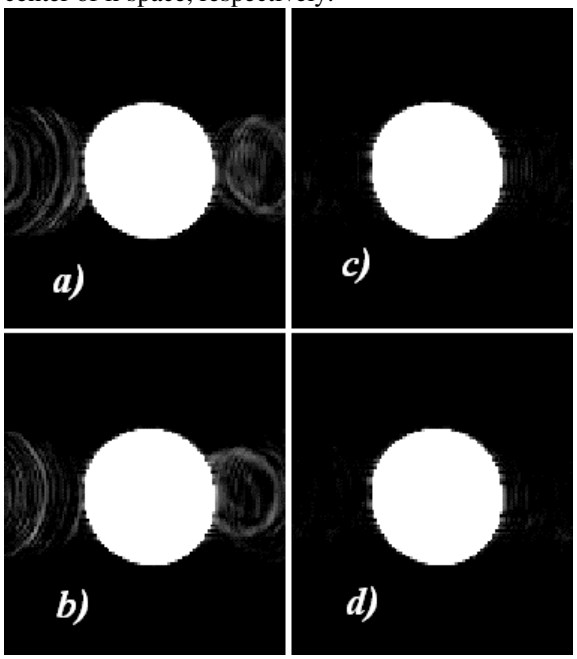

Figure 2. Comparison of eddy current artifacts a) standard segmented scan, b) segmented scan including the central profile, c) super segmented scan, d) super segmented scan including the central profile.

Conclusion: In this paper we designed a new profile order scheme for 3D cine cardiac MRI that allows us to sample the center of k_y-k_z space repeatedly without observable eddy current artifacts in the images. This is valuable for self-navigated sequences for cardiac imaging. Even without the sampling of the central profile, the standard segmented acquisition scheme results in eddy current artifacts, which are also substantially reduced with our proposed profile reordering.

References: [1] Larson et al, MRM. 53:159-68 (2005) [2] C. Stehning et al, MRM. 54:476-480 (2005). [3] O. Bieri et al, MRM. 54:129-137 (2005).