SSFP banding artefact removal in large FOV images at 3T

S. I. Gonçalves[1], M. L. Ziech[1], J. Stoker[1], and A. J. Nederveen[1]
[1]Radiology, AMC, Amsterdam, Netherlands

Introduction

Balanced steady state free precession (b-SSFP) sequences with large flip angles (between 40º and 70º) are very attractive for abdominal imaging because they provide high signal, a "T2" like contrast and have short TR's (<10 ms) which are necessary to produce an entire scan within one breathhold. However, they are limited by banding artefacts which appear as bright and dark stripes in the images, and result from the dependence of the frequency response function (FRF) on the amount of dephasing experienced by the spins during each TR. At 3 T (and higher field strengths) the increased inhomogeneity of B0 enhances banding artefacts and make, until now, b-SSFP sequences practically useless for large field of view (FOV) abdominal images. Shortening the TR is the most straightforward way to minimize banding artefacts but at 3 T this is often problematic at such large flip angles because of specific absorption rate (SAR) constraints. In [1], a method based on combining scans with different phase cycling schemes is proposed to correct for banding artefacts. It is originally applied to images of the brain and spinal cord obtained with a 1 T scanner and its advantage, when considering higher field strengths, is that it does not impose constraints on TR. Here, its ability to obtain artefact free large FOV b-SSFP abdominal images at 3 T is shown.

Methods

The conventional b-SSFP sequence with phase alternation was modified to allow for different phase cycling schemes. A total number N of scans were acquired each of which having a phase increment of $2\pi j/N$, where j refers to the j^{th} scan. Data from each scan was subsequently combined, according to [1] to produce images of several of the echoes that compose the MR signal in b-SSFP [2]. Contrary to [1], data was combined in the image domain in order to simplify data handling and processing. Images from a phantom and from 3 patients with Crohn's disease were acquired on a 3.0 Tesla Philips Intera scanner using both conventional and modified balanced field echo (B-FFE) and a 16 channel SENSE-XL-Torso coil. The phantom consisted of a box containing water and 10 cylinders with T1 values ranging from 455 to 930 ms. Patient preparation consisted of fasting for 4 hours before the scan followed by drinking 1600 ml mannitol 2.5% in 1 hour before the scan. Scan parameters were: TR/TE=5.4/1.8 ms (1.9/0.8 ms), FA=40º (10º); 20 sagital slices; FOV=350×350 mm; voxel size=2.0×2.0×2.0 mm.

Results

Phantom images were obtained from combining N phase cycle schemes where N=4, 6, 8 and 10, for FA=40º and N=8, 10 and 14 for FA=10º (figs. 1 and 2). They show that combining scans obtained with 8 different phase cycling schemes is sufficient to remove the extensive banding artefacts that are present in the conventional B-FFE with FA=40º. When using a very low flip angle (fig. 2), images still clearly show artefacts, despite the much shorter TR. The FRF of low flip angles is inverted when compared to that of higher flip angles and that can be observed in figs. 1 and 2 where bands appear dark in one case and bright in the other. The low image intensity results therefore from the broad stop band that characterizes the FRF of low flip angles. However, even in this unfavourable situation, removal of the banding artefacts is obtained, though at the cost of the increase in the number of the necessary phase cycling scans. Figure 3 shows results obtained for 3 patients where sagittal abdominal images were acquired with both conventional and modified b-FFE, FA=40º. In all cases, good artefact removal was obtained. Namely, the extensive artefacts at the borders of the images were removed or greatly reduced and the same holds for those located more centrally in the FOV.

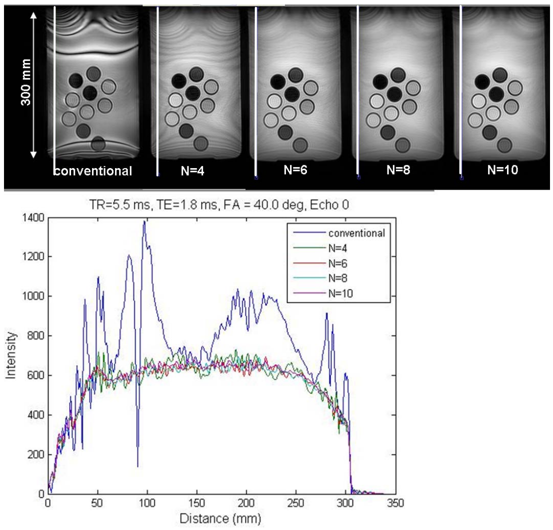

Figure 1: Phantom images and profiles along the given line for FA = 40º, Phase cycling images correspond to echo 0.

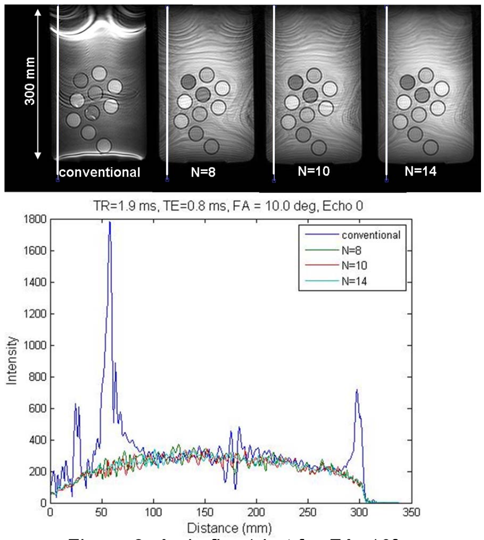

Figure 2: As in fig. 1 but for FA=10º.

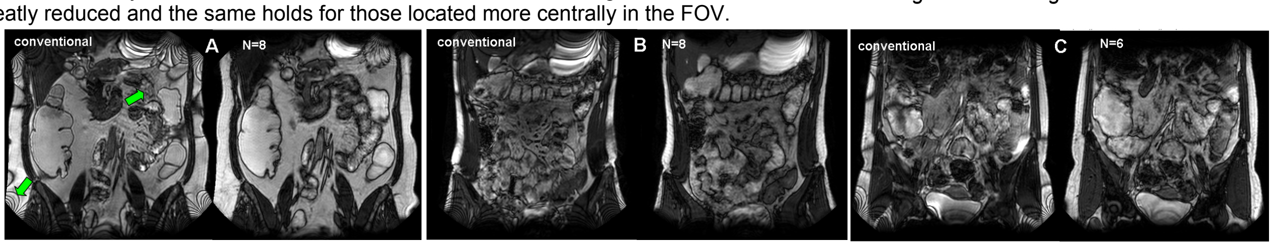

Figure 3: Patient images (A, B and C) obtained with both conventional and modified B-FFE, FA=40º. Typical examples of artefacts are indicated by the arrows.

Conclusions

Banding artefacts are a serious obstacle to the use of B-FFE sequences in large FOV images and (ultra-)high field strengths. It is more so because the shortening of TR to minimize this type of artefacts is often not possible because of SAR constraints. Furthermore, even with a TR as short as 1.9 ms, artefacts are still clearly present (fig. 2). It is shown that by combining scans with different phase cycling schemes one is able to correct for banding artefacts in large FOV abdominal images, with as few as 6 different phase cycling schemes. In phantom experiments, this holds also for low flip angles, though at the cost of increasing the number of phase cycling schemes. The latter point is of importance because low flip angles, though characterized by an unfavourable FRF, when together with dedicated shimming tools, might be one of the solutions to allow for the use of B-FFE sequences at ultra-high field strengths where SAR constraints and field inhomogeneities are even more problematic. Work in progress includes the combination of phase cycling with Alternating TR-bSSFP method [3] for fat suppression.

References

[1] Zur Y et al., Magn. Reson. Med. 1990; 16: 444-459; [2] Zur Y et a., Magn. Reson. Med. 1988; 6: 175-193; [3] Leupold J et al., Magn. Res. Med. 2006; 557-565