RF Pulse Design Tradeoffs Enabled by Parallel Imaging

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Overview

We describe a new method for limiting the size of a 3D excitation slab. We use parallel imaging (ASSET) to correct slab wrap arising from tradeoffs in RF profile design. By relaxing slab wrap constraints, we gain flexibility in RF pulse design. We apply this technique to SSFP scans, where short RF pulses are necessary to achieve repetition times short enough to minimize off-resonance artifacts.

Introduction

In RF pulse design, we make tradeoffs between pulse duration and excitation slab definition. For example, broadening a sinc pulse by adding zero crossings in the time domain produces a slab with a narrower transition band and lower sidelobes. However, if the pulse is truncated to shorten its duration in time, the result is increased ringing and signal from outside the desired slab. Choosing an RF pulse for a particular application involves a compromise between sequence time and slab definition. Shorter RF pulses can be used to reduce total scan time and increase temporal resolution. They can also be used to reduce artifacts by decreasing echo spacing in 3D fast spin echo sequences or by decreasing repetition time in steady state pulse sequences. These advantages come at the cost of decreased slab definition and artifacts related to slab wrap.

In traditional parallel imaging, we reduce scan acquisition time by undersampling in the phase and/or slice encode directions. This causes intentional aliasing which is unwrapped in reconstruction using multi-coil sensitivity (receiver weight) information (1). Parallel imaging reconstruction can also unwrap aliasing from other, unintentional, sources, including phase wrap from anatomy outside the field of view and slab wrap from excited slices in the falloff region of the RF excitation slab. In particular, we can use parallel imaging without scan time reduction (R=1) to correct slab wrap artifacts from tradeoffs in RF pulse design (2). In the tradition of alcohol-related parallel imaging acronyms (3), we call this an ASSET Limited Excitation (ALE).

Cartilage imaging using fat suppressed SSFP is a straightforward example of the ALE technique. As an SNR-limited application, this is not a good candidate for traditional parallel imaging techniques that reduce scan time. However, since SSFP off-resonance artifacts improve with shorter TR, shortening RF pulses can improve image quality when we use ASSET to correct for slab wrap.

Methods

We modified the acquisition and reconstruction software on a commercial 1.5T Signa TwinSpeed scanner (GE Medical Systems, Milwaukee, WI). We used a 3D SSFP pulse sequence modified to allow fat suppression with spectrally selective inversion recovery and a choice of six different product RF pulses ranging from 0.1ms to 1.6ms in duration. We used ASSET reconstruction software modified to allow R=1 slice ASSET processing with a slab wrap correction (2). We modified a cartilage imaging protocol (4) to give near isotropic resolution with a scan time under 2 minutes: minTE (1.5-1.6ms), minTR (5.6-7.0ms), target TI=85 (85-95ms), flip=25, BW=25kHz, 256x160, 16x14cm FOV, 64-0.8mm slices. Ranges given reflect values for different RF pulses. We scanned a healthy volunteer with a product three-channel transmit/receive knee coil (MRI Devices, Gainesville, FL) which has element separation S/I.

Results

We evaluated overall image quality including off-resonance and slab-wrap artifacts. Figure 1 shows off-resonance artifacts and minimal slab wrap with the 1.6ms (Fig. 1, left) and 0.8ms (Fig. 1, right) RF pulses. Figure 2 shows minimal off-resonance artifacts with the 0.1ms RF pulse. The image without ALE (Fig. 2, left) shows slab-wrap artifacts which are removed with ALE (Fig. 2, right). Figure 3 shows the slab wrap in a sagittal reformat of the 0.1ms RF data sets processed without (top) and with ALE (bottom).

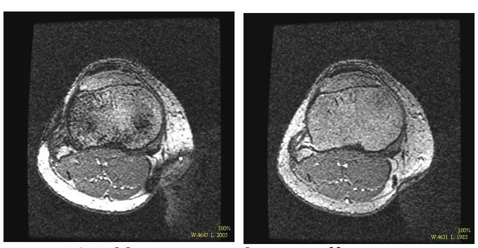

Fig. 1: Axial knee images showing off-resonance artifacts from 1.6ms (left) and 0.8ms (right) RF pulses.

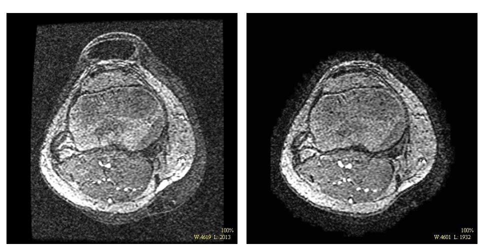

Fig. 2: Axial knee images using a 0.1ms RF pulse showing slab wrap artifacts uncorrected (left) and with ALE (right).

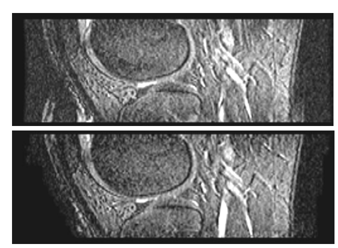

Fig. 3: Sagittal reformat (0.1ms RF), uncorrected (top) and ALE (bottom).

Conclusions

We have demonstrated the use of ASSET Limited Excitation (ALE) to enable shorter RF pulses without the cost of slab wrap artifacts. As a simple example, we used ALE with a short RF pulse to reduce TR, and therefore off-resonance artifacts, in SSFP cartilage scans. Parallel imaging (ASSET) processing was used for artifact (slab wrap) correction in an R=1 (no intentional aliasing) acquisition. ALE enables more flexibility in RF pulse design by relaxing traditional slab definition constraints.

References

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