Fast temperature measurement using a 2DRF pulse enables both reduced-FOV imaging and fat suppression

C-S. Mei[1,2], J. Yuan[1], N. J. McDannold[1], and L. P. Panych[1]

[1]Department of Radiology, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, United States, [2]Department of Physics, Boston College, Chestnut Hill, MA, United States

Introduction: Temperature measurement based on proton resonance frequency (PRF) method [1] can be corrupted by the presence of fat [2]. Therefore, it is necessary to include fat suppression for accurate temperature mapping during thermal therapies. In these treatments, the region of heating can be much smaller than the FOV, resulting in a waste of scan time to cover regions away from the heated zone. 2DRF with reduced-FOV (rFOV) along with parallel imaging and UNFOLD has been proposed for increasing the temporal resolution for MR temperature measurement [3]. Since the TE is generally long (comparable with T_2^*), relatively long 2DRF pulses can be employed to enable simultaneous fat suppression and reduced-FOV imaging [4,5], resulting in accurate temperature mapping in fatty tissue with reduced acquisition time compared to a conventional sequence.

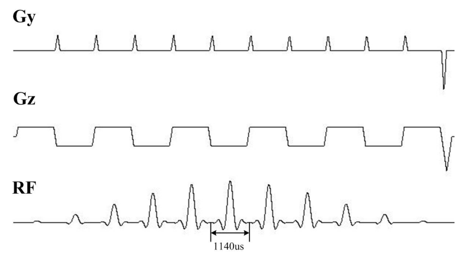

Fig.1: A 11*1140µs 2DRF pulse for fat suppression and rFOV imaging at 3T

Methods and Results: An optimized echo-planar 2DRF pulse was implemented using a 2DRF pulse library developed by National Center for Image-Guided Therapy (www.ncigt.org). This pulse was composed of 11 sub-pulses, each with pulse width 1140µs, along with a selected blip area (Fig.1). It enables both rFOV and fat suppression at 3T. Preliminary fat-water phantom experiments were performed on a GE Excite HD 3T scanner without heating. The excitation patterns are shown in Fig.2. When the Field of Excitation (FOE) is equal to the FOV (Fig.2d), the fat is completely suppressed without side excitation in water. The FOV can then be reduced and the scan shortened by a factor up to 2.5. In heating experiments, processed cheese containing a homogeneous mixture of fat and water (Original Velveeta, 21% fat, Kraft Foods Inc., Northfield, IL) was heated for 30 s with focused ultrasound (acoustic power: 6 W). The sonication began after an initial baseline scan, and a time-series of rFOV images were acquired during heating and cooling with a gradient-echo sequence modified to include the 2DRF pulse (imaging parameters: TR: 40 ms, flip angle: 30°, BW: 8.06 kHz, matrix: 128x256, FOV: 18 cm, and slice thickness: 5 mm). Three different TE's were tested: TE_1: 17.2 ms (water and fat in phase), TE_2: 18 ms, TE_3:= 19.8 ms (out of phase). Measurements with the fat suppressed rFOV sequence were compared to non-fat suppressed imaging using the product GE- fast gradient-echo sequence used clinically for temperature mapping.

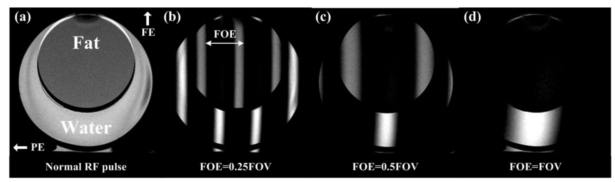

Fig.2: (a) Fat-water phantom imaged using a normal RF Pulse; (b-d) excitation patterns for an 11*1140µs 2DRF pulse with different FOEs. In (d), both fat suppression and rFOV are achieved. For all images; TR/TE: 30/17 ms, flip: 30°, matrix: 192x192, FOV: 10 cm, slice thickness: 5 mm, and bandwidth: 8.06 KHz.

The heating of the focal plane as a function of time for TE_1 is shown in Fig.3. No wrap-around is seen since both fat and water signal were not excited outside the reduced FOV. Temperature curves without fat suppression at the focal spot are shown in Fig.4a. Note that they are dependent on the TE values even for the identical sonication. The measurement accuracy is violated by the insensitivity of phase variation of fat to temperature. With fat suppression, however, the temperature curves as shown in Fig.4b are independent of TE. The red line shows the temperature change at the hottest spot for a rFOV experiment with a temporal resolution improvement of 2.3-fold.

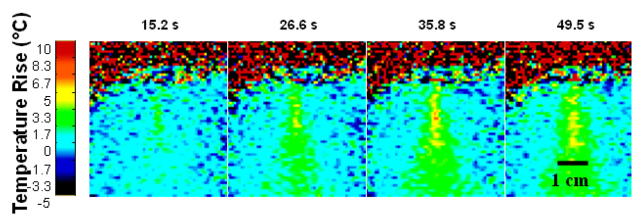

Fig.3: Dynamic set of rFOV temperature images in a cheese phantom in a FUS heating experiment. A total of 60 time frames were acquired in 137s (time frames 7, 12, 16, and 22 shown). The 2DRF waveform enabled fat suppression and rFOV imaging. No wrap-around is seen when the FOV is reduced by 60%.

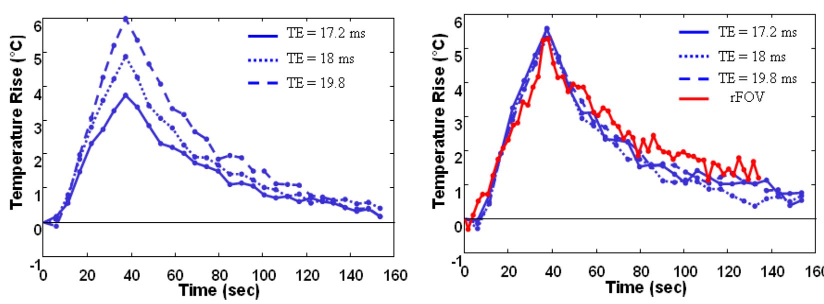

Fig.4: Temperature changes of a cheese phantom at the hottest voxel during FUS heating experiments. While measurements using GE fast gradient-echo sequence are echo time-dependent (a), the measurements using 2DRF pulse for fat suppression are very similar (b). With excitation pattern of Fig.2d, both fat suppression and 2D excitation were achieved, resulting in improvement in temporal resolution by 2.3 fold as shown in the red line.

Discussion: Higher reduction factor in FOV and hence higher temporal resolution could be achieved by manipulating the 2DRF parameters, such as sub-pulse numbers, sub-pulse duration and blip areas. A previously reported hybrid method of combining 2DRF, SENSE and UNFOLD [3] could be used to get rid of the possible wrap-around in the rFOV region. A 4-fold improvement in temporal resolution could be achieved.

Acknowledgement: This work was supported by NIH grants U41RR019703 and P01CA067165.

References: [1] Y Ishihara, et al. MRM 34:814-823 (1995). [2] JA de Zwart, et al. MRM 42:53-59 (1999). [3] CS Mei, et al, 16th ISMRM 1234 (2008). [4] J Yuan, et al, 16th ISMRM 1388 (2008). [5] K Sung, et al, 14th ISMRM 3010 (2006).