Combining 2D RF excitation, parallel imaging and UNFOLD in Focused Ultrasound heating experiment

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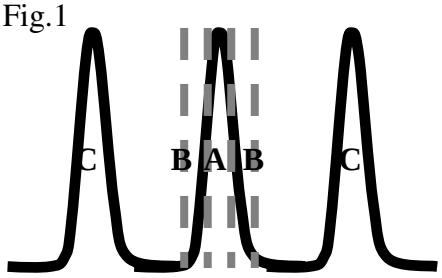
Introduction: In many clinical MRI-Guided Focused Ultrasound procedures, the focus is often much smaller than FOV. In addition, for acoustic wave to deliver to the ROI, there must be water in between the sonication source and the heated subject, resulting in even larger FOV and more scan time imaging unwanted region. To improve temporal resolution, we use technique that combines three different approaches at fast imaging: parallel imaging, UNFOLD and 2D RF excitation [3]. Results are shown in phase images where the FOV was fitted to a heated target, the FUS focus region, allowing temporal resolution to be increased by 8 fold.

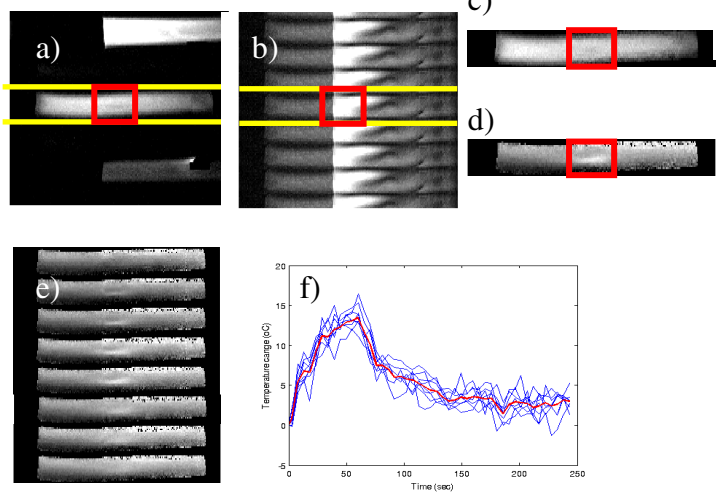
Theory and Method: To apply 2d RF excitation to zoom on a small ROI, a number of Gaussian-enveloped RF pulses are played out. The more RF pulses, the narrower the excitation profile along phase encoding direction. By setting up the distance (delta k) between RF pulses in excitation k space, and assigning phase values for each pulse, we can move and locate the excitation lobe to ROI. (Fig. 1) TE and TR limit the number of RF pulses we can play out. Since the Proton Resonance Frequency is exploited to monitor temperature changes, the band width is being set low (5 kHz), and TE is 18ms. For 40ms TR, the maximum number of RF pulses we can use is 11. (504us each, 6ms in total) The excitation profile along y is shown on Fig.1 for the 2d RF pulses used here. As we reduce FOV to only region A, region B and C will all overlap with desired FOV. Previous work has shown that region C can be removed with parallel imaging technique, while region B can be handled by UNFOLD.

Fig.1



All experiments were implemented at GE 1.5 T Signa MRI scanner. The transducer, which produces acoustic waves, was put in a box, filling with water, the size of which is designed to fit into a GE 8 channel head coil. A cylinder shape phantom gel was placed on top of the transducer. Axial images of the phantom were obtained from a single slice user-modified SPGR GRE sequence (TE = 20ms, TR = 40ms, 128 x 256, slice thickness = 5 mm, NEX = 1, flip angle = 15 degree). Before sonication, four calibration scans were preformed for sensitivity map. A 144 phases (time series of images), reduced fov with 2d RF excitation images were then acquired. A 60 sec, 20W sonication started after the first baseline image. A second dataset of 48 phases full fov images were acquired for comparison.

Fig.2



Results: Fig. 2a shows a full-fov magnitude image with a 2d RF excitation pulse, where the FUS heated region located in the rectangular ROI. The temporal resolution is 128TR = 5.1 s, scan duration of 250 s. With reduced FOV along y direction, only 1 k-space line every 8 was sampled. The temporal resolution is 16TR = 0.64 s, and scan duration remained unchanged. Fig. 2b is the magnitude image obtained from one of the eight receiver coils, and it features much aliasing artifacts. The region A is reconstructed with the present method (Fig. 2c), where no noticeable artifact is seen. To calculate the temperature change, phase images are necessary. Fig. 2d shows phase image of Fig. 2c. Dynamic phase images are shown in Fig. 2e, where images were picked up every 15 s (phase #1, #10, #18, #26, #34, #42, #50, #58, and #64 from top to bottom.). The temperature rise of ROI as a function of time for each individual coils (blue lines) and the average (red line) is ploted in Fig. 2f. The total temperature rise is about 14 ^{o}C. In a 250 s scan time, a conventional sequence can only provide a temporal resolution of 5.1 s, while the present approach provided 0.64 s, for a 8 fold improvement.

Discussion: For temporal resolution 0.64 s in scan time 250s, the number of phases is supposed to reach up to 320 or more. But in current user-modified sequence, the delay time in between scans doesn't reduce with single scan.

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References:

[1] B Madore et al, Proc.ISMRM.17 (2003).