Dual echo based referenceless thermometry for MRgFUS applications

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Introduction: Thermal monitoring in Magnetic Resonance guided Focused UltraSound (MRgFUS) treatments is a crucial step where the phase images from MR images are used to get thermal maps. One of the widely used techniques is PRF shift technique that involves some form of image subtraction using a baseline pre-treatment image. Subject motion and tissue deformation due to coagulation can severely distort these techniques. Self-referenced methods [1] help to overcome this hurdle where the baseline phase in the region-of-interest (ROI) is estimated using the data available outside the hot zone (ROI) and subtracted with actual phase to get the thermal maps. In this work a new technique is described, where the baseline phases inside the ROI is estimated using the data acquired from two echos and their phase difference outside ROI. This method not only eliminates the need for baseline subtraction but also produces better results as the reference echo used in generating the model is acquired along same location.

Method: In this method first the baseline phase acquisition (φ_{o1} & φ_{o2}) was acquired using a 2D dual echo gradient echo pulse sequence on a phantom that has two layers of storage filled with water (figure 1.a) for the sake of comparison using GE Signa 3T MRI Scanner (GE Medical Systems, Milwaukee, WI, USA). The temperature of the water in the inner tank was then raised and stopped heating at one point.

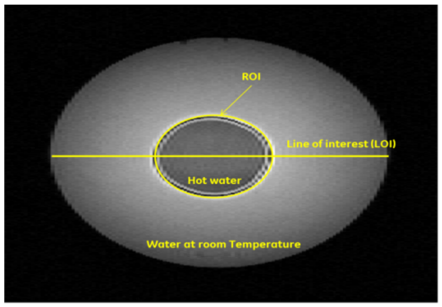

Figure 1.a. Phantom setup and LOI

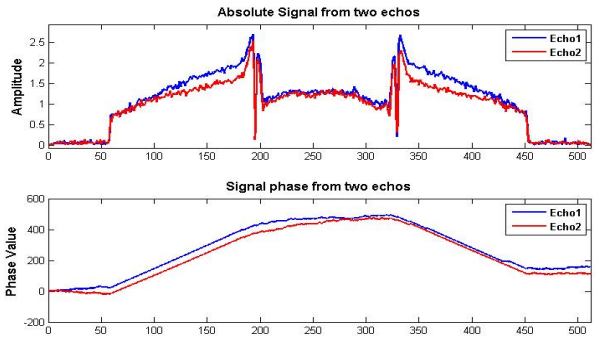

Figure 1.b- Profile along the LOI

Now again two echos were acquired using a 2D dual echo gradient echo pulse sequence whose phase are going to be φ_{11} & φ_{12} respectively (figure 1.b). From these, mark current phase in the ROI along line of interest (LOI) for the two echos as φ1cur and φ2cur. Difference between φ11 & φ12 outside the ROI along the LOI 'φdif' is modeled as first order fit where the intercept and the slope is a function of B0 eddy currents and gradient non linearity respectively. Later this was extrapolated in to the ROI. Either φ11 or φ12, outside the ROI along LOI on both sides were modeled as first order fit and extrapolated in to the ROI. Baseline phase in the ROI along the LOI is then estimated from these extrapolated φ11 or φ12 and φdif that would be 'φ1ref or φ2ref' based on the echo used. The difference between this estimated phase and the current phase (φ1cur- φ1ref or φ2cur- φ2ref) for either of the echo would indicate the temperature variations along LOI inside ROI

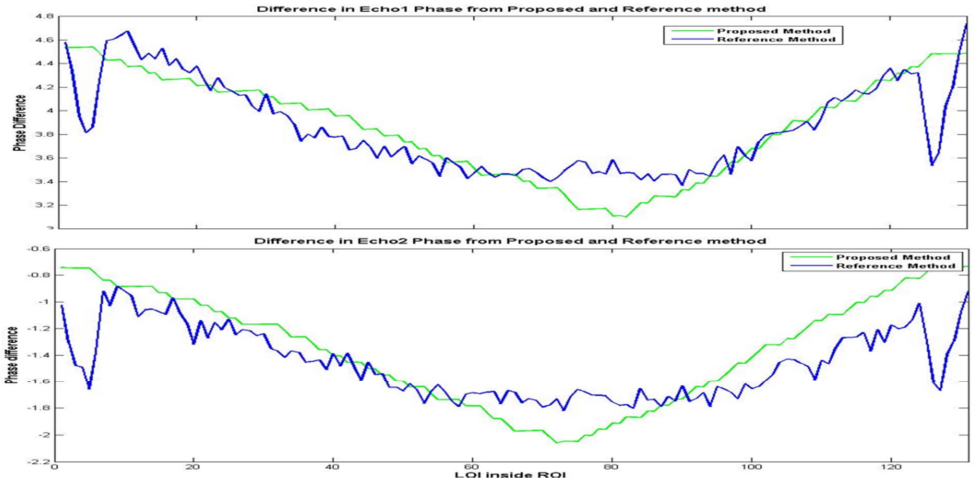

Figure2. Difference in phase due to temperature change obtained from reference(blue colour) and proposed referenceless *(*green colour*)* method using echo1 and echo2 respectively

Results: From the figure 2 it's evident that the difference in phase along LOI in ROI obtained from proposed method (φ_{1cur}- φ_{1ref} & φ_{2cur}- φ_{2ref}) and normal subtraction (φ_{1cur}- φ_{01} & φ_{2cur}- φ_{02}) method matches very well. This proves efficiency of the proposal in estimating the phase difference, in turn temperature. This method also gives option to use two use any/both of the echos available for getting the phase difference.

Conclusion: The proposed method eliminates the need for image subtraction and provides better results. In clinical scenario, temperature measurement at any location could be obtained without the baseline information by using the data from two echos. This new technique would be amenable for the MRgFUS treatments, in particular moving organs.

Reference: [1]] Rieke V, Butts Pauly K. JMRI 27: 376-390 (2008)