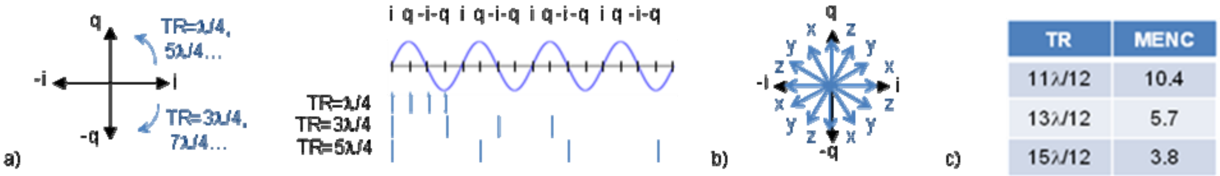
Matching Motion Sensitivity with TE and TR in Elastography for Faster Scans

Roger C Grimm[1], Jun Chen[1], Scott A Kruse[1], and Richard L Ehman[1]
[1]*Mayo Clinic, Rochester, MN, United States*

Purpose: Elastography acquisitions measure a propagating complex shear wave field at multiple phase points to estimate stiffness. In general there are 3 polarizations, x, y, z. Using the TR to advance the phase in a multi-frequency acquisition has been described in [1]. The purpose of this work is to examine timing options where the TR provides the phase advance in interleaved 3 polarization acquisitions. This eliminates misregistration of the wave fields images. When there is no gradient dead time, this results in discrete TE/TR and motion sensitivity values.

Methods: A single harmonic time series, with a time period λ, can be sampled with quadrature phase; that is, samples taken λ/4 apart. The static phase signal must be removed from the samples. A convenient way to remove this is to sample both positive and negative in-phase, *i*, and quadrature, *q*, terms. For the 3 polarizations this results in 12 samples. It has been previously shown [2] that 4 samples for each polarization is sufficient for inversion estimates. **Figure 1** illustrates the time advance for various TR values. Interleaving the 3 polarizations limit the valid number of slices due to incomplete sampling of all polarizations and complex plane positions. Odd slice numbers that are not multiples of 3 are valid; such as, 1, 5, 7, 11, 13, … The TR used depends on the needed motion sensitivity as seen in the table of **Figure 1c)**. A TR=15λ/12 uses a full 25ms motion encoding gradient and generates 2π phase for each 3.8μm of motion. Stepping back the motion encoding gradient results in lower TE and TR values with decreased sensitivity to motion.



TR	MENC
11λ/12	10.4
13λ/12	5.7
15λ/12	3.8

Figure 1a) TR values with odd multiples of λ/4 provide the appropriate timing to advance around the complex plane. **b)** For finer control, odd TR multiples of λ/12 provide phase advances of π/2 for each polarization. When using curl processing, the phase of the y and z polarizations need to be corrected by 11*2*π/12 and 22*2*π/12 respectively. **c)** The Motion ENCoding value (MENC) give motion in microns that will produce 2π phase. As the TR value decreases, the period of the encoding gradients decrease thus requiring more motion to produce 2π phase accumulation. Shown here are MENC values from a 3D acquisition with 40hz motion.

Results: Studies were performed with Institutional Review Board approved protocols. **Figure 3a)** shows results from a 2D GRE rectal wall exam with the following parameters; mechanical frequency=120Hz, flip=35, TE/TR=18.5/135.4, FOV=22cm, matrix=512x256x5, TR/slice=13λ/4, scan time=6:59. **Figure 3b)** shows results for a 3D GRE breast exam with the following parameters; mechanical frequency=40Hz, flip=15, TE/TR= inphase 18.2/22.96, FOV=30cm, matrix=96x96x36, TR=11λ/12, ARC reduction=2, scan time=7:15.

Conclusions: It is intuitive that large motion induced phase shifts should be acquired in less time. The proposed timing scheme allows adjustment of both TE/TR in 2λ/12 steps. Finer control of the TR should lead to less dead time and faster scans. MENC calculations of motion induced phase wraps can help to determine the tradeoffs of adjusting driver power and gradient sensitivity.

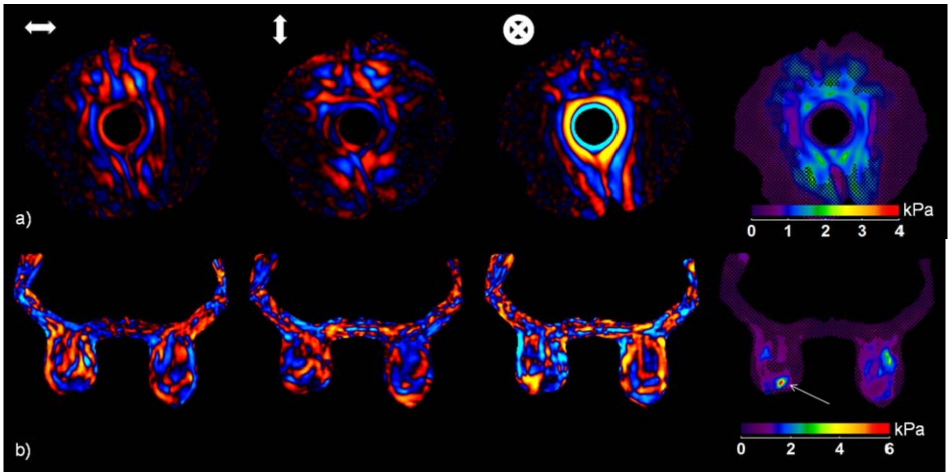


Figure 3a) Displayed are the 3 sampled wave polarizations and stiffness map for a 2D GRE rectal wall scan using a TR/slice=13λ/4. A 2D Direct Inversion (DI) was used to estimate stiffness. **b)** The 3D breast scan was acquired with a TR=11λ/12. A 3D DI inversion was performed with curl processing. The stiffness map identifies an invasive ductal carcinoma pointed to by an arrow. The hatched areas represent low R^2 values from a least squares fit of the wave data.

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Reference: **1**. Garteiser, ISMRM Proceedings 3423, 2012. **2**. Grimm ISMRM Proceedings 1051, 2010.