

Simultaneous Multi-Volume GRASE Imaging

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Introduction:

Simultaneous multi-slice imaging [1] has been utilized with EPI for faster TR and higher sensitivity in resting state connectivity studies [2-3]. The use of T₂ contrast in BOLD fMRI has been used at high field 7T with SE EPI and more recently with inner volume “zoomed” 3D GRASE [4-6]. The orthogonal intersecting 90° and 180° planes created an overlapping region where SE refocusing occurs. This has limited the experiment to usually a single volume to avoid overlapping excitation and refocusing planes. To overcome resulting spin saturations when rf slabs are applied sequentially in time, instead it is proposed here, to use multiband pulses to create multiple 3D image volumes simultaneously. In this initial implementation the volumes are positioned in rectilinear separated regions of the brain which would not be achievable when acquiring time-sequential image volumes.

Methods Simultaneous Multi-volume (SMV) inner volume GRASE pulse sequence (**Fig 1**) utilizes multibanded (MB) pulses to create a CPMG sequence with 3D phase encoding utilizing orthogonal orientations in slab selective axes of excitation and refocusing pulses.

The intersection of the multiple excitation planes (**Fig 2**) with the multiple refocusing planes creates multiple intersecting volumes of SE refocusing that are simultaneously readout in echo trains. The multiple “zoomed” inner volume images are recorded simultaneously. Holding the echo train length N constant, spatial resolution $R = FOV/N$ and reducing FOV effectively zooms resolution on image phase axes.

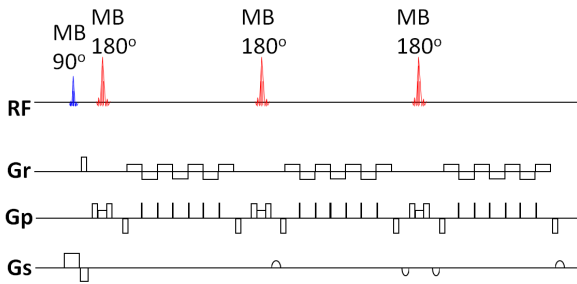


Figure 1. Simultaneous multi-slab inner volume GRASE sequence diagram.

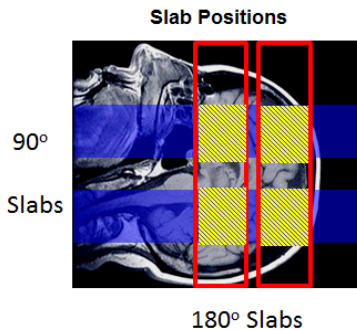


Figure 2. Illustration of multiple excited intersecting volumes of SMS inner volume GRASE. (color of slabs match pulses in Fig 1)

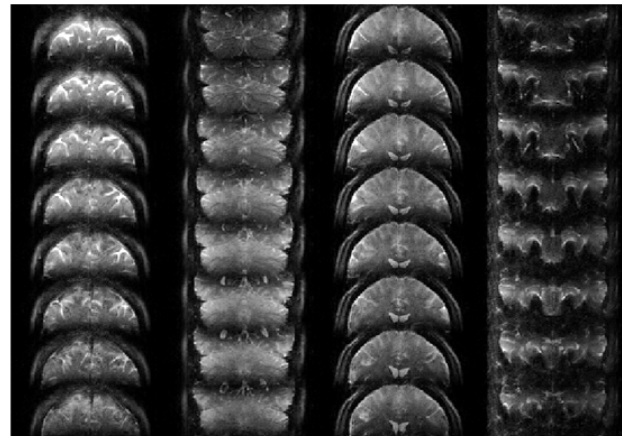
Experiments were performed at 3T Siemens Trio scanner with 32 channel head coil. Image parameters: TR = 4000-6000ms, TE = 38-47ms (centric order), matrix=120x42, slices/slab=8, 25% oversampling, slice thickness=3mm, gap 0-100%, FOV =180x63 mm², Echo Spacing=0.92ms. SMV=3 using MB=3 90° pulse (denoted as “MB3x1”), SMV=4 using MB=2 90° pulse and MB=2 180°(denoted as “MB2x2”).

Results:

Fig 3 shows representative multi-volume image acquisitions.



(a)



(b)

Figure 3. Human brain: (a) sagittal MB3x1 (b)coronal MB2x2

Simultaneous Multi-Volume (SMV) GRASE pulse sequence can be used to acquire very high resolution images from several regions at the same time. This newly introduced approach to imaging produces multiple adjacent zoomed 3D image volumes from a criss-crossing of rf planes to yield a larger number of image volumes than multi-volume imaging techniques.

References: [1] Larkman DJ et al. JMRI 2001 [2] Moeller S et al. MRM 2010 [3] Feinberg DA et al. Plos One 2010 [4] Feinberg et al. p. 2373 ISMRM 2009 [5] Zimmermann J et al. Plos One, 6(12): e28716, 2011 [6] Olman CA et al. PlosOne, 7(3): e32536, 2012