A novel B1-insensitive outer volume suppression pulse

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Introduction: Reduced field-of-view (rFOV) imaging reduces the Nyquist sampling criterion, thereby enabling acquisition acceleration [1] and reduced sensitivity to off resonance artifacts [2]. Because the data acquisition sampling requirements are determined by the prescribed field-of-view and spatial resolution, rFOV imaging also allows the prescription of finer image resolution without longer scan times. Outer volume suppression (OVS) preparations saturate spins outside the region of interest prior to excitation and acquisition, thereby functioning as a spatial anti-aliasing filter for rFOV prescriptions. A general purpose OVS preparation must be robust to B_1 variation, which at 3 Tesla can range from 0.4−1.2 just in the left ventricle [3]. We present a new B_1-insensitive OVS preparation pulse sequence design for rFOV imaging and demonstrate its performance at 3T.

Methods: Our design is similar to [2], which permits 2D multi-slice or 3D volumetric imaging, but to improve performance we use a B_1-insensitive adiabatic pulse followed by a −90º spiral pulse (Fig. 1a). The non-selective 90º BIR-4 [4] tip-down pulse rotates all spins into the transverse plane. Next, a spatially-selective 2-D −90º spiral tip-back pulse [5] re-establishes the longitudinal magnetization within a cylindrical volume. Compared to the +90º spiral pulse in [2], a −90º spiral pulse has lower aliasing sidelobes (Fig. 1b) which adds flexibility when optimizing its parameters. Our −90º spiral pulse design has a passband width of 45 mm, a transition width of 25 mm, and stopband width (un-aliased FOV) of 45 cm. For minimum passband attenuation, the spiral RF phase is tuned to match that of an on-resonance spin after the BIR-4 tip-down, as determined by simulation. Following the spiral pulse, a spoiler de-phases the residual transverse magnetization outside the cylinder. The total duration of the OVS preparation is 13.5 msec.

Phantom and *in vivo* data were acquired on a GE Signa Excite 3T scanner using gradient echo spiral acquisitions to demonstrate OVS performance. *In vivo* scans were cardiac-gated and the OVS sequence was played once per heartbeat immediately preceding data acquisition in diastole. Spectral-spatial RF [6] pulses were employed to avoid lipid excitation. A B_1 map was also measured with the phantom.

Results: Fig. 2 and Table 1 depict the OVS performance. Fig. 2c shows the OVS performance in a inhomogeneous B_1 field, and indicates a passband half-maximum width of about 30 mm, which is close to the designed value of 28.75 mm.

Discussion: The B_1 robustness of the BIR-4 pulse provided good stopband suppression despite the tissue heterogeneity in the chest cavity. Passband attenuation in the phantom was close to simulated values, and was about 16% when centered on the spine. When centered on the heart, however, passband attenuation was nearly 40%.

The high attenuation could have several causes. The tip-back performance of the spiral pulse will degrade in the presence of B_1 scaling factors less than unity. Measuring the mean scale factor and pre-compensating the spiral RF amplitude may mitigate this effect. Also, the phase of the transverse magnetization after the tip-down pulse may become decoupled from the phase of the tip-back pulse if significant off resonance, B_1 variation, or diffusion is present. This could be mitigated by commensurately tuning the spiral RF phase.

Future work will address the performance in cardiac scans and improve the spiral tip-back pulse design. Specifically, we will optimize the pulse's stopband width and determine the optimal field-of-view for a given passband size.

	Passband attenuation (percent)	Stopband attenuation (percent)
Simulation	3.1 ± 3.0	99.4 ± 0.6
Phantom	5.1 ± 1.8	86.9 ± 4.1
Spine	15.8 ± 7.4	92.5 ± 3.1
Cardiac	38.7 ± 9.8	84.8 ± 4.4

Table 1: OVS performance (mean ± std)

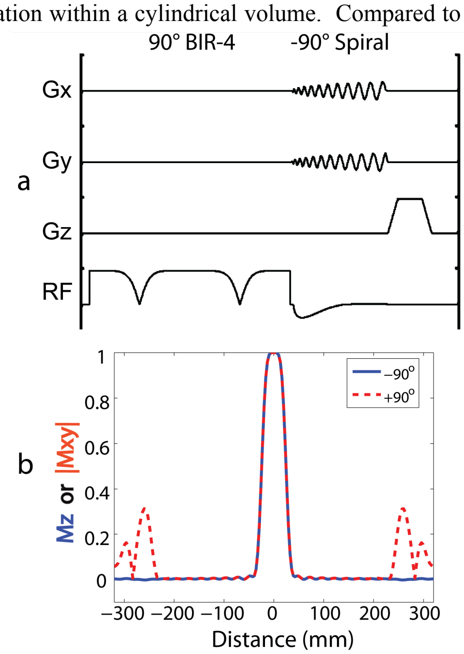

Fig. 1: (a) Pulse sequence diagram for the proposed OVS preparation. (b) Simulated response profiles for a +90º 2-D spiral (dashed red line showing the transverse mag.) and a −90º 2-D spiral (solid blue line showing the longitudinal mag.) indicate the beneficial sidelobe performance of the −90º pulse.

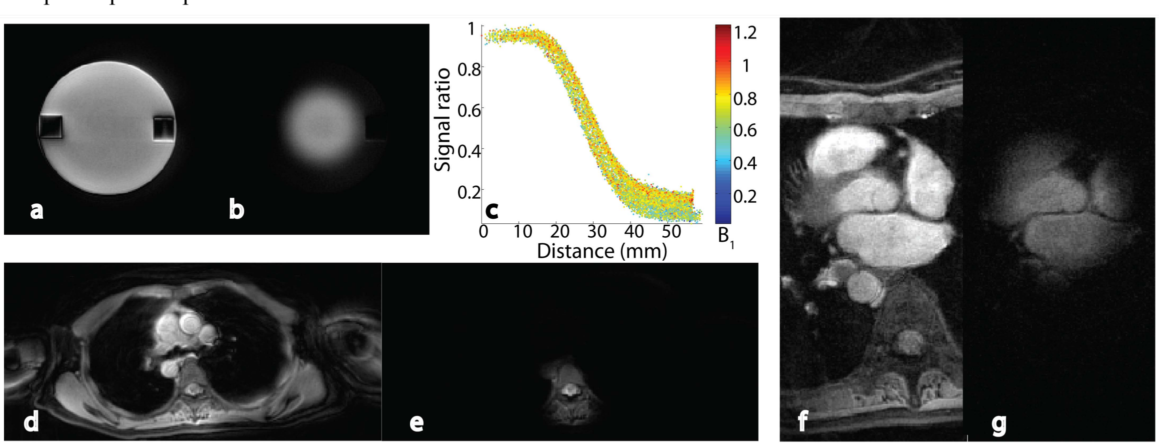

Fig. 2: Image pairs acquired without and with OVS are shown for phantom (a,b), spine (d,e), and cardiac (f,g) acquisitions, respectively. Each image pair has the same intensity scale. (c) The ratio of signals (with OVS ÷ without OVS) plotted against distance from the center of the passband with B_1 scale values depicted by color.

References:

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