# Chemical shift induced slab boundary artifacts reduction in Multi-Slab SPACE

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**Introduction** Multi-Slab SPACE (MS-SPACE) [1, 2] improves the time efficiency of 3D turbo spin echo imaging, especially in PD weighted contrast, but suffers from the slab boundary artifacts (SBA). Generally, SBA can be caused by these reasons: a) cross-talk from adjacent excitations; b) imperfect slab profile of the RF pulse from its design or the distortion caused by $B_0$ inhomogeneity etc; c) intrinsic chemical shift between fat and water signal in excitation. Cross-talk effect can be alleviated by interleaving acquisition. The minor SBA from the imperfect slab profile of the RF pulse can be reduced by postprocessing algorithm. Therefore the chemical shift in excitation becomes the main source of the SBA in MS-SPACE on high field system. In this work, it is shown that the chemical shift induced SBA can be significantly reduced by properly manipulating the frequency of the RF pulse and the polarity of the slab-selection gradients.

**Methods** The chemical shift between protons in water and fat is about 3.5 ppm (about 440 Hz on 3.0T system). This intrinsic frequency difference will cause a position deviation of the selected fat signal from water signal by

$$\Delta z = \frac{3.5 \cdot 10^{-6} \cdot \gamma \cdot B_0}{RFBW} \cdot TH = 3.5\Re$$

$\gamma$ represents the gyromagnetic ratio, $B_0$ is the strength of the static field, $RFBW$ represents the bandwidth of the RF pulses, $TH$ represents the selection thickness of the RF pulse, $\Re$ is calculated from the specific $B_0$, $RFBW$ and $TH$. Given a typical $RFBW$ of 1K Hz on 3.0T system, the chemical shift can be up to 44% of the slab thickness, which will cause serious boundary artifacts in slab selective acquisition. As shown in Fig1, $3.5\Re_1$ of the desired slab is invalid acquisition due to the original fat signal missing at the upper edge and a slice oversampling factor of $3.5\Re_1$ is needed to avoid the aliasing from the wrongly excited fat signal when the position of the nominal $FOV_z$ refers to the water signal. It is observed in Fig1 that the invalid part of the nominal $FOV_z$ can be eliminated by scaling up the excitation thickness *TH* of the RF pulse by $3.5\Re_1/(TH_1 - 3.5\Re_1)$ and positioning the nominal $FOV_z$ in the middle of the selected water signal and fat signal. However, more slice oversampling will be needed with the increased excitation thickness. To overcome the chemical shift problem with the minimum slice oversampling factor, a new excitation scheme is presented here: a) the desired $FOV_z$ is shifted into the middle of excited water signal and excited fat signal by adjusting the center frequency of the RF pulse by 1.75 *ppm* from water signal to fat signal; b) the opposite polarity of the selection gradients is used between signal excitation and refocusing; c) $FOV_z$ is defined as $TH - 3.5\Re$. As illustrated in Fig2, there is no shift between both excited and refocusing water signal and fat signal; therefore there is no need for additional slice oversampling to avoid the aliasing of wrongly excited signal in the new excitation scheme.

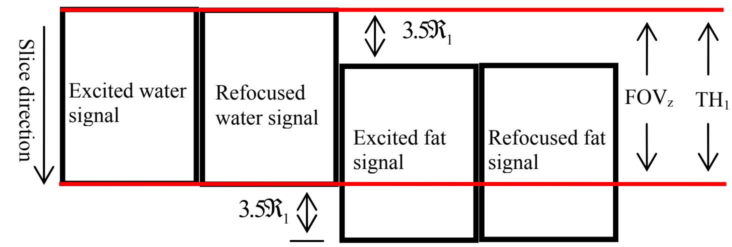



Fig1. Chemical shift phenomenon in normal excitation, where the center frequency of all RF pulses is located at the resonant frequency of water signal, and the polarity of all slab-selection gradients are the same. It can be observed that the fat signal is lost at the upper part of the $FOV_z$ due to chemical shift. In addition, slice oversampling factor should be increased by $3.5\Re_1$ to avoid the aliasing of the fat signal from the other side.

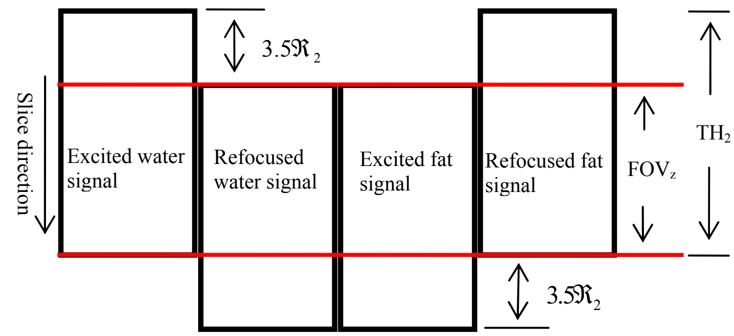
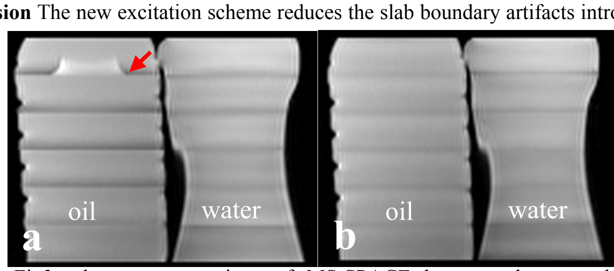



Fig2. New excitation scheme, where FOVz is kept the same as that in Fig1, but the selection thickness of the RF pulse is scaled up to $TH_2$. Because there is no shift between both excited and refocused water and fat signal and there is no signal in the region, which is only excited or only refocused, additional slice oversampling to avoid the aliasing of wrongly excited signal is not needed.

**Results** Phantom comparison between the normal excitation scheme and the new excitation scheme was done on a 3T MR scanner (MAGNETOM Verio, Siemens, Erlangen) with all other parameters the same (see Fig3 a, b). A comparison of volunteer images between Single-Slab SPACE and Multi-Slab SPACE with the new excitation scheme was then performed on a 1.5T MR scanner (MAGNETOM Avanto, Siemens, Erlangen) with the following parameters (see Fig3 c, d, e): In Single-Slab SPACE: 72 slices in a single slab, slice oversampling = 22%, concatenations =1, echo train length =63, averages = 1.5 to eliminate FID artifacts from non-selective refocusing pulses; In Multi-Slab SPACE: 6 slabs, 12 slices in each slab, slice oversampling factor = 66% to avoid aliasing of the excited signal in the transition band of the RF pulses, concatenations = 2, echo train length = 48, scaling factor of the selection thickness = 1.25, average number =1. Both two sequences shared these parameters: TR/TE = 1600ms/128ms, image matrix [SL x PE x RO] = [72 x 368 x 384], parallel acquisition factor =2; total acquisition time in Single-Slab SPACE = 8min26sec, total acquisition time in Multi-Slab SPACE = 3min58sec.

**Conclusion and Discussion** The new excitation scheme reduces the slab boundary artifacts introduced by chemical shift during excitation in MS-SPACE, which helps MS-SPACE to provide reliable image quality, especially on 1.5T system. The residual slab boundary artifacts can be further reduced by dedicated post-processing algorithm.



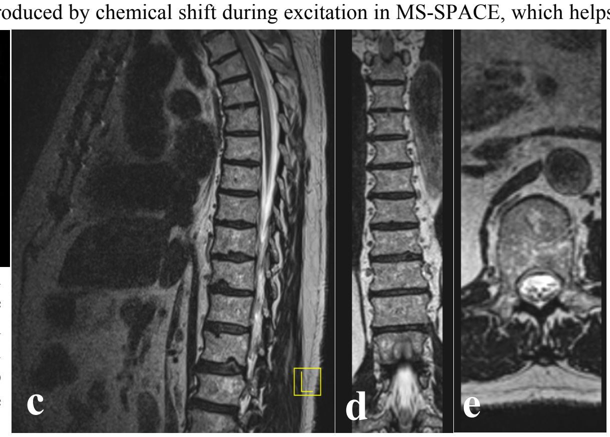




Fig3. phantom comparison of MS-SPACE between the normal excitation scheme (a) and the new excitation scheme (b); t-spine images acquired by MS-SPACE with new excitation scheme in sagittal orientation (c), and reformatted to coronal (d) and transversal orientation (e). In all the images, postprocessing for the residual slab boundary artifacts correction was not preformed to show the improvement.

**References**

[1] Mugler, ISMRM 2003, p203;
[2] Li GB, ISMRM 2010, p3037;