Compatibility of inner volume selection and VSS edge saturation with SENSE

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Introduction: Outer volume suppression techniques such as inner volume selection and edge saturation are often necessary in small FOV applications to eliminate signal aliasing in the phase encode direction. Such aliasing is detrimental to partially parallel imaging algorithms such as sensitivity encoding (SENSE) [1], and typically requires use of larger, unaliased FOV sizes to avoid artifacts that typically appear near the center of the image. This increases the matrix size necessary to achieve the desired resolution desired for small FOV applications, and counteracts the speed benefits of SENSE. Theoretically, the combined use of outer volume suppression with SENSE would produce a desirable multiplicative benefit in scan time reduction while eliminating such artifacts for 3D FSE sequences. However, inner volume selection produces poorly defined edges, while saturation pulses typically provide insufficient suppression for eliminating aliased signal. This study examines the combination of inner volume selection and very selective saturation (VSS) techniques [2,3], and tests their compatibility with SENSE in an effort to realize such gains.

Methods: All image acquisition was performed using a Signa EXCITE HD 3T system (General Electric Healthcare, Waukesha, WI) and an 8-channel head coil (MRI Devices Corp, Gainesville, FL). A conventional 3D Fast Recovery FSE sequence was modified to enable inner volume selective imaging by applying the slice selective gradients along the phase encoding direction for the excitation pulse. Also, standard spatial saturation pulses were replaced with VSS saturation pulses [3]. These SLR designed pulses are both frequency and amplitude modulated to produce narrower transition bands for a given peak B1 amplitude and pulse width. Two such saturation bands were applied perpendicular to the phase encoding direction, increasing minimum TR by 22 ms. An 18 cm diameter cylindrical water phantom was acquired using both the conventional and modified sequences with the following parameters: TE = 200 ms, TR = 1000 ms, ETL = 32, BW = +/- 31.25 kHz, FOV = 150x300x64mm, matrix = 128x256x16. These acquisitions were repeated with SENSE enabled over the same FOV, reducing the scan time by an acceleration factor of 2. The parallel imaging acquisition was repeated once again using the conventional sequence with twice the FOV and matrix size in the phase encoding direction to produce an unaliased image for comparison. Aliased signal in images acquired without SENSE was measured by taking the ratio of signal in the aliased area to the signal in the unaliased area. Artifacts in the center of images acquired with SENSE were visually compared.

Results: Images are shown in Fig 1. Inner volume selection provided near perfect reduction of aliased signal away from the edges but displayed wide transition edges of the excited slice. Some residual signal was still observed with VSS saturation, though suppression edges were sharp. In SENSE accelerated images, aliased signal appeared as artifacts at the center of the image when no outer volume suppression techniques were applied. Inner volume and edge saturation were similarly effective in reducing such artifacts. No aliased signal or artifacts were observed when both inner volume selection and edge saturation were applied. Ratios of aliased area to unaliased area signal was 1.93, 1.24, 1.46, and 1.25 for no suppression, inner volume selection, VSS, and combined inner volume with VSS techniques, respectively. Ratio of same locations in the unaliased image was 1.24. Some Gibbs ringing evident in the images in the images acquired without SENSE seem to align with the aliased signal artifacts in the SENSE images to produce a ghost-like appearance.

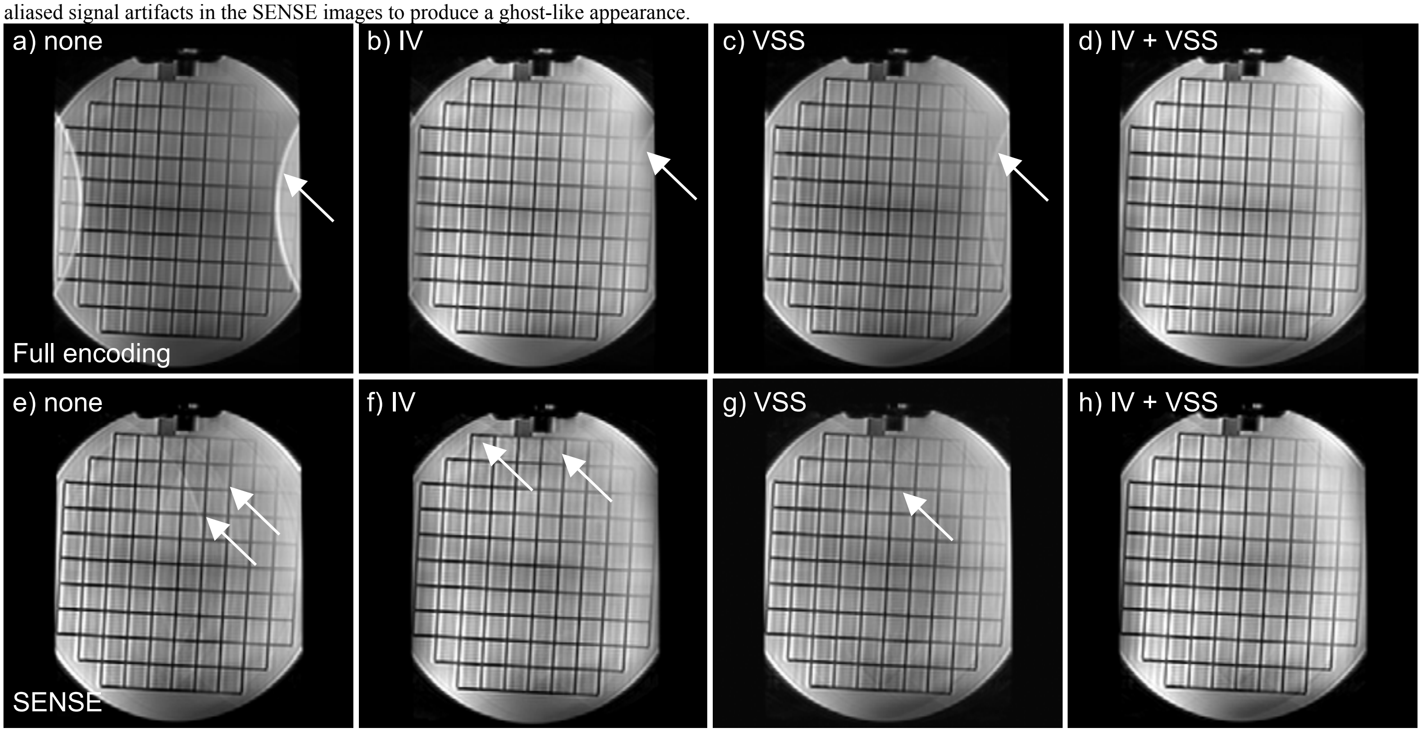

Figure 1. 18 cm diameter phantom images acquired over a 15 cm FOV with (a,e) no outer volume suppression, (b,f) inner volume selection, (c,g) VSS edge saturation, and (d,h) both inner volume selection and edge saturation. Top row (a-d) shows acquisitions were performed without SENSE and bottom row (e-h) with SENSE x2. White arrows indicate aliased signal and/or SENSE artifacts.

Discussion: Outer volume suppression was both distinct and adequately suppressive when inner volume selection and edge saturation techniques were combined. These characteristics lead to a less ambiguous unwrapping of aliased signal by the SENSE algorithm, which would erroneously place some aliased signal at the center of the image. The use of acceleration factors higher than 2 could potentially unwrap such signals but often introduces artifacts when coil geometry is not optimized for the acquisition. While a three-pulse scheme with VSS pulses can produce perfect outer volume suppression [3], we have shown that a single saturation pulse is just as effective in less time when combined with the inner volume selection technique.

Conclusion: The combination of inner volume selection and edge saturation by VSS pulses achieves outer volume suppression that is of sufficient quality for performing reduced FOV imaging with SENSE, resulting in shorter scan times.

References: 1. Pruessman KP et al, Magn. Reson. Med., 42:952-962, 1999. 2. Le Roux P, Proc 5th ISMRM, 1538, 1997. 3. Tran T-KC et al, MRM 43:23-33, 2000. 4. Le Roux P et al, JMRI, 8:1022-1032, 1998.