

Impact of Direct Virtual Coil Channel Combination on Reduced Field-of-View Artifacts

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Introduction Reduced field-of-view acquisitions occur when the extent of the imaging field-of-view in the phase-encode direction (or slice direction for 3-D imaging) is smaller than the extent of the excited signal. For Cartesian sampling, rFOV acquisitions result in signal aliasing, or wrapping, to the opposite side of the image. Combining parallel imaging with rFOV acquisitions is challenging since rFOV acquisitions violate underlying assumptions of many parallel imaging reconstruction methods. It has been shown that internally calibrated data-driven reconstruction methods such as GRAPPA work better than model driven approaches such as SENSE for rFOV acquisitions; whereas GRAPPA isolates the rFOV artifacts to the wrapped region, rFOV artifacts can propagate through the image when a SENSE reconstruction is used [1].

Direct Virtual Coil (DVC) parallel imaging is a data-driven technique that delivers similar image quality to coil-by-coil approaches, such as GRAPPA, while reducing memory and compute requirements by over 10X for high channel count coil arrays [2]. With respect to image quality, the fundamental difference between the DVC reconstruction method and coil-by-coil reconstruction methods is that the DVC method puts restrictions on how channel combination is performed. In this work, we evaluate the impact of DVC channel combination on rFOV acquisition image quality. Comparison of images reconstructed with DVC channel combination and sum-of-squares (SoS) channel combination were found to reveal interesting differences within the wrapped region. Like SoS channel combination, DVC channel combination was able to isolate the rFOV artifacts to the wrapped region; as such, clinically significant differences in image quality were not observed between the two channel combination strategies. However, subtle differences in the appearance of the aliasing artifacts were observed and are described in this work.

Theory Griswold et al. showed that rFOV imaging can be formulated in a similar manner to full FOV, but with ‘effective’ coil sensitivities that can have discontinuities [1]. To maximize SNR, channel combination should be performed by weighting each channel image by the conjugate of the coil sensitivity prior to accumulating across channels [3]. The DVC method requires that channel combination be performed using very low resolution channel combination weighting images, which are not able to track the discontinuities found in the effective coil sensitivities. This results in very different channel combination weighting images in the wrapped region for SoS and DVC (Fig. 1).

Methods Fourteen anonymized rFOV data sets were reconstructed using both a) coil-by-coil parallel imaging with sum-of-squares (SoS) channel combination and b) DVC integrated parallel imaging and channel combination. All reconstructions used ARC for unaliasing calibration and data synthesis [4] and were acquired with a 32-channel torso array, a spoiled gradient echo pulse sequence, internally calibrated parallel imaging with acceleration in both phase and slice directions and partial *k*-space in the readout direction. Data sets were a mix of pre and post contrast acquisitions. Reconstructions were examined to evaluate differences in rFOV artifacts and overall image quality by a blinded board certified radiologist.

Results Review of the reconstructed images by board certified radiologist found no clinically relevant image quality differences between the SoS and DVC reconstructed images. In the regions of wrapped signal, artifact differences were observed; typical examples are illustrated in Fig. 2. Specifically, the intensity of the wrapped signal varied between channel combination methods and in some cases the DVC-reconstructed images contained subtle “zebra” artifacts where the wrap artifact in the SoS-reconstructed images did not have the “zebra” appearance.

Discussion Our results indicate that the choice of channel combination strategy can impact rFOV artifacts; both SoS and DVC channel combination strategies resulted in visible artifact differences in the wrapped regions. We believe that the observed artifact differences can be attributed to the very low resolution channel combination weighting images used by the DVC method. We did not see evidence that the DVC calibration procedure was adversely impacted by rFOV data and the differences in artifact appearance were minimal and not clinically relevant. DVC is a promising method to dramatically reduce the memory and computation requirements for high-channel-count acquisitions.

References [1] Griswold et al. 2004, MRM 52:1118-26. [2] Beatty et al., ISMRM 2008, p8. [3] Roemer et al. 1990, MRM 16:192-225. [4] Beatty et al., ISMRM 2007, p1749.

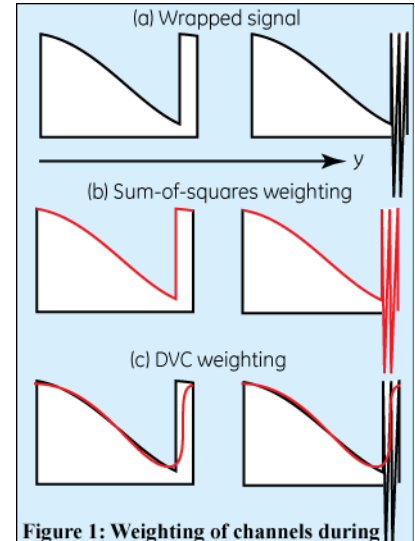


Figure 1: Weighting of channels during combination.

(a) Signal from a uniform phantom detected by a coil on the left during a reduced field-of-view (rFOV) acquisition, showing signal wrap to the right of the field-of-view. Right column shows wrap of oscillating phase signal, typically caused by B0 inhomogeneity toward the edge of the scanner bore.

During channel combination, each channel is multiplied by a weighting image and the results are then summed across channels.

(b) Weighting for SoS channel combination. (c) DVC channel combination weighting.

DVC enforces a very low-resolution weighting image that reduces the weighting of the signal wrap and can lessen its contribution to the final image. In addition, DVC channel combination does not re-phase regions of B0 inhomogeneity, leading to a “zebra” artifact appearance after channel combination.

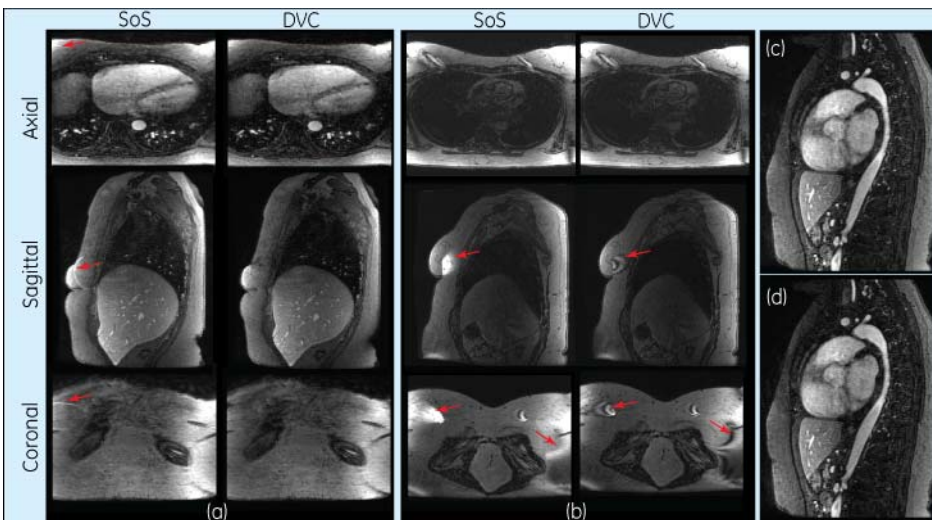


Figure 2: rFOV image quality and artifact comparison

(a), (b) Cross section images in wrapped region of reduced field-of-view (rFOV) acquisitions. Wrap is in the L/R direction.

(a) Sum-of-squares (SoS) images show wrap artifact that is not visible on DVC reconstructed images.

(b) Wrap artifact always adds constructively during channel combination with SoS combination; with the DVC, wrap can add destructively, leading to the “zebra” artifact when signal in a region of B0 inhomogeneity wraps into the FOV.

Artifact differences are caused by channel weighting differences during channel combination, as illustrated in Fig. 1.

(c) SoS and (d) DVC reconstructed images outside of wrapped region, were observed to have comparable image quality.