# Uniform Virtual Coil Reconstruction for Autocalibrating Parallel Imaging

**P. J. Beatty[1] and A. C. Brau[1]**

[1]Global Applied Science Lab, GE Healthcare, Menlo Park, CA, United States

Autocalibrating coil-by-coil parallel imaging reconstruction (1) has proven advantageous over previous single-coil autocalibrating approaches (2,3) in large part because of its greater robustness to phase-cancellation artifacts. In addition, autocalibrating coil-by-coil reconstruction has been shown to achieve good image quality, suppressing residual aliasing artifacts, even when coil sensitivity estimates are difficult to obtain (4). However, reconstructing each coil separately does have its drawbacks: 1) coil-by-coil reconstruction becomes computationally expensive when a large number of coils are used because the reconstruction time grows as the square of the number of coils; 2) the combined sum-of-squares image can exhibit sensitivity variation, which confounds reading and requires an additional post-processing step for correction; 3) the combined sum-of-squares image does not contain phase information, making combination with phase-sensitive applications challenging. In this work, we present an autocalibrating approach that synthesizes data for a *single* uniformly sensitive coil, the 'uniform virtual coil' (UVC). The method is robust to phase cancellation, does not exhibit sensitivity variation and reconstructs a single complex-valued image that can make the method easier to combine with phase-sensitive applications. The approach requires the additional acquisition of calibration data from the uniformly sensitive body coil; however, post-processing sensitivity variation correction can also require calibration data from the body coil (5). Since data for only one coil is synthesized, the computation scales favorably compared to coil-by-coil reconstruction as the number of coils is increased.

**Theory & Methods** Autocalibrating methods synthesize unacquired data on a 'target' coil using a linear combination of local acquired data from all coils. The linear combination coefficients (reconstruction weights) are found by fitting 'source' data on all coils to 'target' calibration data from the target coil. For coil-by-coil reconstructions, each coil is separately designated as the target coil. The proposed UVC reconstruction method is illustrated in Fig. 1. First, reconstruction weights are generated by fitting the calibration data from the multi-coil acquisition to the calibration data from the uniformly sensitive body coil acquisition. The reconstruction weights are then applied to the surface coil data, synthesizing a complete complex-valued data set for the uniform virtual coil (UVC). The UVC data set is then Fourier transformed to generate the reconstructed image.

Two volunteers were scanned with a 1.5T scanner (Signa® HDx, GE Healthcare, Waukesha, WI). For each multi-coil acquisition, an additional data set was acquired using the uniformly sensitive body coil and the phase-encodes in the calibration region of this scan were stored to calibrate the UVC reconstruction. First, a 3-D T1w spoiled gradient echo pelvis scan was acquired with an 8-channel pelvis array. 2-D variable-density acceleration (maximum acceleration of 2 in each phase-encode direction) was used with partial k-space acquisition in $k_z$ and a calibration region of 20x20 phase encodes. Imaging parameters were: 320x224, 36 slices, slice thickness=4.4 mm, BW=±62 kHz, TE/TR=2.2/4.6 ms, FOV=48x36 cm, scan time per data set=23 s. Next, an axial 2-D T2w FSE brain scan was acquired with an 8-channel head coil, 1-D acceleration (factor of 2) and a calibration region of 25 phase encodes. Imaging parameters were: 512x384, slice thickness=5 mm, BW=±31 kHz, TE/TR=98/6250 ms, FOV=24x18 cm, scan time per data set=81 s. Images were reconstructed using the UVC approach (Fig. 1). For comparison, the multi-coil acquisitions were also reconstructed using ARC (5), an efficient coil-by-coil autocalibrating method. The coil-by-coil images were combined using sum-of-squares. No separate coil intensity correction was applied to any reconstructed image.

**Results** The UVC reconstructions achieved good image quality, exhibiting no phase-cancellation artifacts and suppressing residual aliasing. Figure 2 shows images of an axial slice of the pelvis scan reconstructed with (a) standard coil-by-coil reconstruction and (b) UVC reconstruction. The images are identically window/leveled. The sensitivity variation visible in the coil-by-coil reconstruction is inherently corrected in the UVC reconstruction, as illustrated by the line profile in (c). Because UVC reconstructs only a single (virtual) coil, far fewer phase encodes need to be synthesized. For this 2D-accelerated volumetric scan, UVC synthesized 8350 phase encodes versus 37,440 phase encodes synthesized for the coil-by-coil reconstruction, a reduction of over 4X. Figure 3 shows brain images reconstructed with (a) coil-by-coil and (b) UVC, showing that the method is compatible with other coil arrangements, pulse sequences and acceleration schemes.

**Discussion** This work demonstrates the feasibility of UVC reconstruction, which achieves good image quality without phase cancellation artifacts or sensitivity variation. While integrating the acquisition of low-resolution body coil calibration data with the multi-coil acquisition could lead to a more efficient scan, the procedure used here was sufficient for testing the feasibility of the UVC method. For the 8-channel experiments in this work, far fewer phase-encodes needed to be synthesized for the UVC reconstruction, compared to coil-by-coil reconstruction. Because this disparity will increase as more coils are used, the UVC approach may present a viable method for achieving good image quality with efficient reconstruction when data is acquired using a larger number of coils.

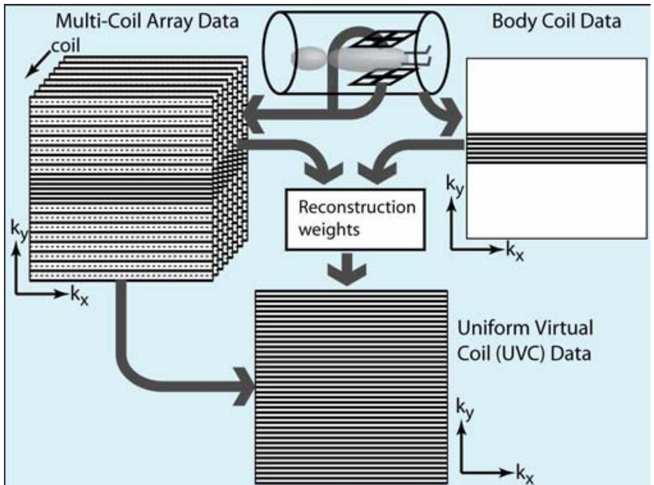


**Figure 1:** Schematic of UVC data synthesis. Calibration data from the multi-coil array and body coil are used to generate the reconstruction weights. The reconstruction weights are then applied to the multi-coil array data to synthesize the UVC data.

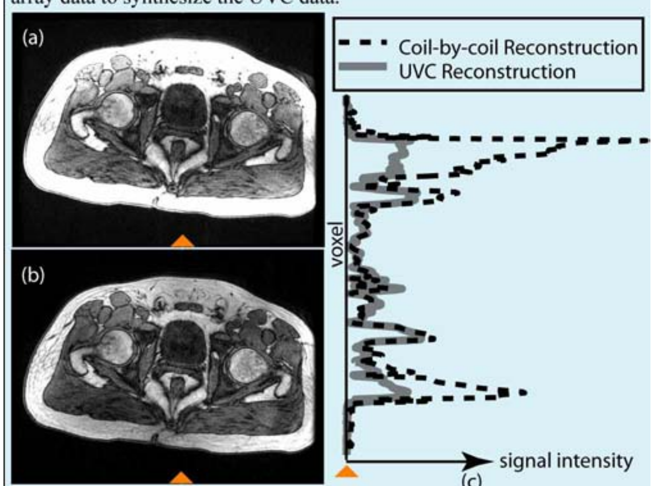


**Figure 2:** Axial slice of 2-D accelerated volumetric pelvis scan. Reconstruction with (a) standard coil-by-coil and (b) UVC. Sensitivity variation is removed by UVC as shown by (c) the A/P line profile (located at ▲). Coil-by-coil required the synthesis of 37,440 phase encodes while only 8350 encodes needed to be synthesized for UVC.

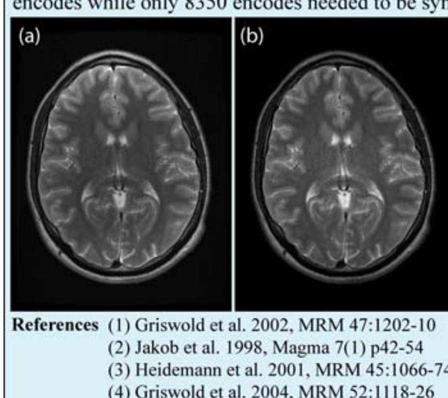


**Figure 3:** Axial T2w 1-D accelerated brain scan reconstructed with (a) standard coil-by-coil versus (b) UVC. UVC achieves good image quality with a uniform sensitivity profile.

**References** (1) Griswold et al. 2002, MRM 47:1202-10
(2) Jakob et al. 1998, Magma 7(1) p42-54
(3) Heidemann et al. 2001, MRM 45:1066-74
(4) Griswold et al. 2004, MRM 52:1118-26
(5) Brey and Narayana 1988, Med. Phys. 15(2):241-5
(6) Brau et al. ISMRM 2006, p2462