

Block Coil Compression for Virtual Body Coil without Phase Singularities

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INTRODUCTION: Combination of multi-channel data is a critical first step in imaging of phase and susceptibility contrast. This entails estimation of spatially varying phase offsets of each receive element, which are then subtracted from coil images for constructive coil combination. Incorrect estimation of receiver phase offsets leads to singularities and low SNR in the combined phase images. Roemer method [1,2] estimates these receiver sensitivities by normalizing the head array data by a body coil image, thus necessitating additional reference acquisitions. COMPOSER [3] employs a short TE reference scan for sensitivity estimation, and does not require a body coil acquisition. SVD technique [4] compresses the head array data into a virtual body coil (VBC), which is then used as a phase reference for ESPIRiT coil sensitivity estimation [5]. This technique obviates the need for reference acquisitions or a short TE scan, but fails to fully mitigate singularities at 7T. In this work, we introduce Block Coil Compression (BCC) for creating a VBC that eliminates phase singularities at ultra high field, without using any reference data. While BCC is applicable to all field strengths, it is particularly useful at ultra high field since these scanners may not be equipped with a body coil.

METHODS: Since the spatial variation in receiver phase increases at ultra high field, global (SVD [4]) or 1-dimensional (GCC: Geometric Coil Compression [6]) compression is not local enough to obtain a smooth VBC phase without singularities.

BCC: overcomes this by exploring

more ‘local’ SVD. As described in Fig1, head array data are divided into smaller blocks. Block size is flexible ($n_{read} \times n_{phase} \times n_{slice} = 1 \times 1 \times 60$ in Fig1), and larger blocks lead to similar results. In each block, a local SVD is computed to compress the data into a single channel. This yields an $n_c \times 1$ compression vector per block, where n_c is the number of channels. Since the phase of the compression vectors differs across blocks, phase alignment needs to be performed to guarantee smoothness [6]. The alignment computes the inner product between compression vectors of neighboring blocks, and ensures that the relative angle is zero. Phase aligned VBC is then used as a reference channel in ESPIRiT for sensitivity estimation. This way, phase of the VBC channel is subtracted from the array data, removing anatomical phase from sensitivities without introducing singularities.

GCC: compresses channels in 1-dimension by applying SVD and phase alignment per each slice along the readout direction [6].

SVD: applies a global SVD over entire volume to create a VBC [4].

Fig2: Three methods were tested on 3D-GRE data acquired at 7T with $1 \times 1 \times 2 \text{ mm}^3$ resolution, $224 \times 224 \times 60$ mtx, TR/TE = 27/10.9 ms. BCC block size was $1 \times 1 \times 60$, which required 224×224 local SVDs.

Fig3: To demonstrate application at high field, comparisons are provided on 3D-GRE data with 1 mm^3 voxels at 3T. Parameters were: $240 \times 192 \times 120$ mtx, TR/TE = 35/24.8 ms, BCC block size $1 \times 1 \times 120$. BET masking [7], Laplacian unwrapping [8] and LBV filtering [9] were used for phase processing.

RESULTS: Fig2: 7T) Tissue phase obtained with SVD-based VBC shows singularities in the difference images (arrows ending w/ square). While GCC mitigated singularities, it incurred intensity variation (arrows ending w/ circle) as the inhomogeneous VBC phase propagated to coil sensitivities. BCC eliminated singularities with similar homogeneity as the SVD approach. **Fig3: 3T)** All three methods yielded high quality tissue phase without singularities. As difference images reveal, results were very similar at 3T (4.2% difference in RMSE).

DISCUSSION: BCC compresses and phase-aligns smaller blocks for a more local representation in 3-dimensions. This eliminates singularities without incurring inhomogeneous contrast. Improved performance is demonstrated at 7T, while SVD and GCC are seen to be sufficient for brain imaging at 3T. For body imaging, phase singularities are expected to pose a challenge even at 3T, where BCC could mitigate this problem.

REFERENCES: 1. P Roemer MRM’90; 2. KP Pruessmann MRM’99; 3. SD Robinson MRM’15; 4. B Bilgic ISMRM ’16; 5. M Uecker MRM’14; 6. T Zhang MRM’13; 7. SM Smith HBM’02; 8. W Li NIMG’11; 9. D Zhou NMR in Biomed ’14.

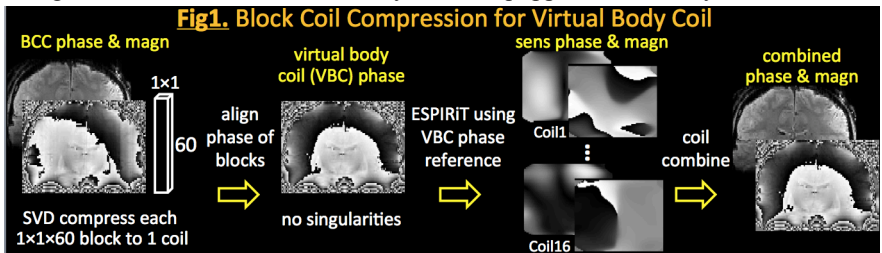


Fig2. Tissue phase @ 7T, $1 \times 1 \times 2 \text{ mm}^3$ voxels using SVD virtual body coil, GCC virtual body coil, proposed BCC virtual body coil

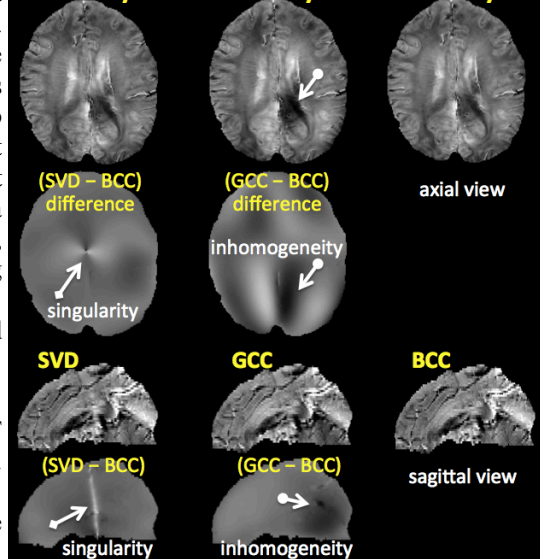


Fig3. Tissue Phase @ 3T, 1 mm^3 iso voxels proposed BCC virtual body coil, (SVD - BCC) difference, (GCC - BCC) difference

