Calculating G-factor Maps from PROPELLER SENSE Reconstruction

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PURPOSE: In SENSE parallel imaging the spatially varying g-factor represents the loss in signal to noise ratio due to ill-conditioning of the matrix inversion during the reconstruction[1]. The g-factor depends on the acceleration factor, the number of coils, and the coil geometry. To the best of our knowledge, the g-factor of SENSE images acquired with the PROPELLER method[2,3] has never been studied. Calculation of g-factor with non-Cartesian sampling is a difficult task, since noise propagation is not easily calculated in arbitrary trajectories especially for iterative reconstruction[4]. Monte-Carlo based methods[5] provide a way to calculate g-factor maps for arbitrary k-space trajectories, but they are computationally demanding, rendering them infeasible in day-to-day practice. In this abstract, we propose a method to directly calculate the g-factor map for SENSE reconstruction with PROPELLER trajectories and compare it to a Monte-Carlo simulation. The method is applied both to phantom and human head images, and compared to Cartesian imaging.

METHODS: In PROPELLER MRI, each blade is acquired through the middle of k-space with Cartesian sampling and then rotated by an incremental angle $\Delta\alpha = \frac{\pi}{N}$, where N is the overall number of blades. When accelerating PROPELLER with SENSE, each blade is accelerated allowing a standard Cartesian SENSE reconstruction[1] for each blade. In order to reconstruct each blade, the sensitivity map is rotated by the incremental angle $\Delta\alpha$. Once all blades are SENSE reconstructed they undergo the standard PROPELLER reconstruction algorithm.

For Cartesian SENSE, the g-factor is defined as

$g(\rho) = \sqrt{[(\mathbf{S}^{\mathbf{H}}\boldsymbol{\Psi}^{-1}\mathbf{S})^{-1}]_{\rho,\rho}\,(\mathbf{S}^{\mathbf{H}}\boldsymbol{\Psi}^{-1}\mathbf{S})_{\rho,\rho}}$ at pixel ρ, where $\mathbf{S}$ is the sensitivity matrix, and $\boldsymbol{\Psi}$ is the receiver noise correlation matrix[1]. The proposed method has 5 steps: 1) Cartesian g-factor maps $\mathbf{g}_n$, n = 1, 2, … N, are calculated for each blade. 2) The square value $\mathbf{g}_n^2$ is calculated pixel by pixel. 3) $\mathbf{g}_n^2$ is sent into the standard PROPELLER reconstruction $f(\mathbf{g}_n^2)$. 4) For scaling, blades filled with real value 1 are reconstructed by PROPELLER to calculate the scaling factor $SF = f(\mathbf{1})$. 5) The final g-factor map is calculated as $\mathbf{g}_{\text{final}} = \frac{\sqrt{f(\mathbf{g}_n^2)}}{SF}$. The $\mathbf{g}_n^2$ values are proportional to noise variance. Step 3 reflects the fact that variances (and therefore $\mathbf{g}_n^2$) add rather than standard deviation (e.g. $\mathbf{g}_n$).

A set of axial phantom and head data were acquired on a Philips Ingenia 3T scanner (Philips, Best, The Netherlands) with a 13-channel head coil using a multi-slice turbo spin echo PROPELLER sequence (TR/TE = 4000/109ms, matrix size = 436 × 436, slice thickness = 5 mm, FOV = 25 cm^2). A reference sensitivity map is acquired, and then each blade is undersampled by acceleration factors R of 2, 3, and 4, respectively. To validate the proposed method, a Monte-Carlo simulation was performed with 9700 iterations producing pseudo multiple replica images to obtain a g-factor map[5] as the gold standard.

RESULTS AND DISCUSSION: The g-factor of the PROPELLER SENSE reconstruction with R=4 using the proposed method has similar spatial variation patterns as that of the g-factor map by the Monte-Carlo method (Fig 1). The mean g-factor values were 2.18 and 2.07 in the Monte-Carlo simulation and the proposed method, respectively. Increasing the number of iterations in the Monte-Carlo simulation may reduce its mean value. Fig. 2 shows the comparison of the g-factor maps between Cartesian SENSE and PROPELLER SENSE in a phantom. Noise amplification is rotated in PROPELLER SENSE in comparison to Cartesian SENSE, which may give its appearance a less obvious structure. Fig. 3 shows a reconstructed PROPELLER image and its g-factor map next to a Cartesian g-factor map of a human head.

CONCLUSION: A novel calculation of SENSE g-factor maps for PROPELLER MRI was validated with a Monte-Carlo simulation. The proposed approach provides a useful tool for identifying noise behavior in PROPELLER SENSE.

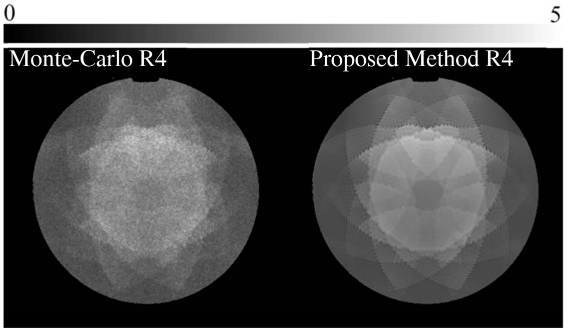

Fig 1: The proposed method was validated with the Monte-Carlo[5] method for a SENSE factor of 4.

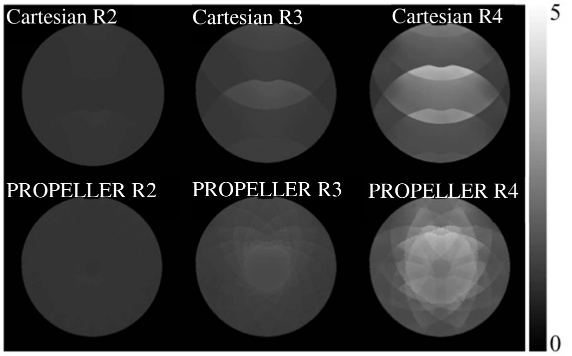

Fig 2: Comparison of g-factor maps in Cartesian and PROPELLER SENSE in a phantom.

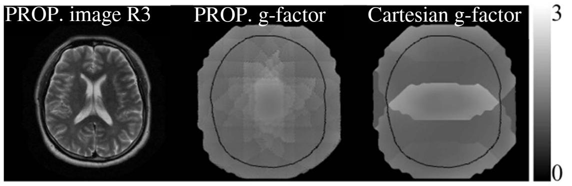

Fig 3: PROPELLER head image and its g-factor map next to a Cartesian g-factor map for a SENSE acceleration factor of 3. Black contours locate the head region in the g-factor maps that extend beyond the head due to sensitivity map extrapolation.

ACKNOWLEDGEMENT: This work was funded in part by Philips Healthcare.

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