Coil Combination and Elimination for Improved Reconstruction Efficiency in Parallel Imaging

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Introduction: Recent parallel imaging applications have witnessed a steady increase in the number of coil elements and receiver channels. More channels enable higher acceleration factors but also allow more flexibility in the choice of field of view and/or scan planes. Often this redundancy results in an excessive data flow which burdens the reconstruction engine and slows down the exam without significant benefits as quantified by image signal-to-noise (SNR) ratio. We introduce and compare a class of algorithms to reduce the number of effective channels through linear combinations or elimination of coil data that do not contribute significantly in the region of interest (ROI).

Theory and Methods: The maximum image SNR achievable with a phased array is given by $\mathrm{SNR}(\boldsymbol{r})^2 = \Sigma\, C_j(\boldsymbol{r})^* \psi_{jk} C_k(\boldsymbol{r})$, where $C_j(\boldsymbol{r})$ is the sensitivity for coil j and $\psi_{jk} = \langle n_j(t)^* n_k(t)\rangle$ is the noise correlation matrix (1). If ψ were diagonal, it would be straightforward to select the coils that contribute maximally to the SNR at a specific location. For a generic ψ, this selection process is less trivial. We consider two alternative approaches: 1) diagonalize ψ and rewrite the SNR expression in the basis of eigenvectors of ψ. These linear combinations are uncorrelated and the selection problem is reduced to choosing the most relevant effective coils. 2) Alternatively, we can select which coils to eliminate neglecting off-diagonal elements of ψ and choosing the physical coils that contribute the largest signal at a specific ROI. Either approach is carried out between acquisition and reconstruction: ψ depends only on coil geometry and loading and not on field of view or scan planes. These methods can be extended to 2D-SENSE (2) accelerated imaging. Given an ROI, we choose the eigenvectors that maximize SNR in this region and use these same eigenvectors at the aliased pixel locations. Analogously in the coil elimination case, we keep the brightest coils at the ROI and use the data from these same coils at the aliased pixel locations for the SENSE reconstruction. We acquired noise data and sensitivity maps on a phantom with a 32-channel cardiac array (3) on a GE Signa scanner to validate the methods. In this work, we focus on an axial slice with a FOV of 40cm roughly through the center of the coil array. We studied two possible phase encode directions (A/P and R/L) and varied the number of linear combinations or physical coil data eliminated.

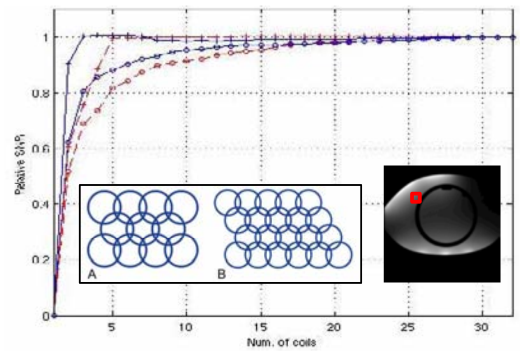

Fig 1. *Relative SNR dependence on number of eigenmodes or coils at ROI (red square in inset) for R=2. Blue solid curves represent eigenmode expansion, red curve coil elimination method. + symbols mark acceleration in L/R direction,* o *symbols A/P. Insets: Left: Coil geometry A:posterior panel, B: anterior. Right:Axial slice of phantom FOV=40cm.*

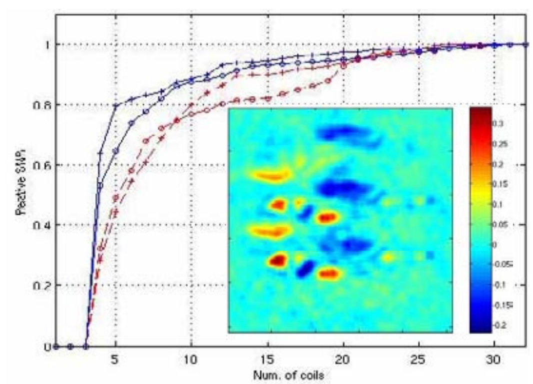

Fig 2. *Relative SNR for R=4. See Fig.1 for legend. Inset: Difference between relative SNR with N=16 eigenmodes or N=16 coils at R=4 with acceleration in the A/P direction.*

Results and Discussion: Figs. 1-2 show the relative SNR with acceleration R=2, 4, respectively for a ROI 15mm wide centered close to the position of the heart (see inset in Fig. 1). In this case, the eigenmode expansion proves to be a superior choice to coil elimination (see inset in Fig. 2 for a distribution of the difference between the two relative SNRs with N=16 linear combinations or coils in the R=4 case). We also note that the eigenmode expansion is especially successful relative to the coil elimination method when the acceleration is in the A/P direction. This can be understood realizing that eigenmodes are more delocalized over the whole coil than the individual coil sensitivities and therefore provide a more suitable basis for unwrapping the aliased images, especially when the acceleration factor is close to (or larger than) the number of coils in the direction of phase encoding (A/P in this case). The idea of using an eigenmode expansion was introduced in the context of non-accelerated imaging by King et al. (4) to take advantage of symmetric coil designs (like a head coil) to reduce the number of receivers. Our idea of selecting different eigenmodes at each location allows us to optimize SNR in an accelerated reconstruction in a computationally efficient way. In conclusion, we have demonstrated using a 32-channel cardiac array that it is possible to reduce the number of effective channels, either through an eigenmode expansion or coil elimination, with minimal impact on the image SNR at the ROI. In the best-case scenario, we observed that with a 5% loss in relative SNR, one could reduce the number of effective channels by as many as 16, or half of the total number of channels.

References:
1. PB Roemer, et al., Magn Reson Med 1990; 16:192-225.
2. KP Pruessmann, et al., Magn Reson Med 1999; 42:952-962.
3. CJ Hardy, et al., 13th ISMRM, 2005, p. 951.
4. SB King, et al., 11th ISMRM, 2003, p. 712.

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